To: Jessica Wieder[Wieder.Jessica@epa.gov]
Cc: Tony Nesky (nesky.tony@epa.gov)[nesky.tony@epa.gov]
From: DeCair, Sara
Sent: Wed 8/24/2016 2:05:31 PM
Subject: FW: Review of draft PAG Q&A document
PAGs Comm Tool QA 4-18-16+cover_EnDyna review 060216.docx

Here you go. We are sorry to have let the FRPCC briefing part go, but you know how we get overcome with day to day events!

From: Amy Doll [mailto:adoll@endyna.com]
Sent: Friday, June 24, 2016 8:27 AM
To: DeCair, Sara <DeCair.Sara@epa.gov>
Cc: siddhanti@endyna.com
Subject: FW: Review of draft PAG Q&A document

Hi Sara

I just wanted to confirm that you had everything you needed from EnDyna for the review of draft PAG Q&A document.

Hope the briefing goes well.

Thanks,

Amy

Amy Doll

Senior Associate

EnDyna, Inc.
7926 Jones Branch Drive, Suite 620
McLean, VA 22102

adoll@endyna.com
Tel: 703-848-8842 ext. 111

From: Amy Doll
Sent: Thursday, June 02, 2016 1:24 PM
To: DeCair, Sara (DeCair.Sara@epa.gov) (DeCair.Sara@epa.gov)
Cc: 'Smita Siddhanti (siddhanti@endyna.com)'
Subject: Review of draft PAG Q&A document

Hi Sara

As you requested, I've done a careful review of the draft PAG Q&A document. My comments/suggestions are either in Comment boxes or track changes, all embedded within the attached document.

When making language revisions, I've considered carefully the language used in the other federal agency Q&A documents that I checked this draft document against. I checked against the two FEMA documents, FDA's KI Q&A, CDC's dirty bombs Q&A, CDC's radiation emergencies Q&A, NRC's radiation protection Q&A, NRC's emergency preparedness and response Q&A.

Please don't hesitate to let me know if you have any questions, or need any other preparation before your June 28th briefing.

Thanks,

Amy

Amy Doll

Senior Associate

EnDyna, Inc.
7926 Jones Branch Drive, Suite 620
McLean, VA 22102

adoll@endyna.com
Tel: 703-848-8842 ext. 111

To: Hernandez-Quinones, Samuel[Hernandez.Samuel@epa.gov]
From: DeCair, Sara
Sent: Mon 8/15/2016 3:51:42 PM
Subject: Fw: Water PAG Docket List (with all comments classified)
Water PAG Docket List_081516.xlsx

Sam, do you have an updated comment spreadsheet with more Responses filled in? Amy just needs to make sure we maintain version control with the new (hopefully finished) set of comments that were posted as of this morning. Thanks for sending that today if possible, then you can definitely keep working on it once Amy has it updated.

Sara
cell 202-738-2871

From: Amy Doll <adoll@endyna.com>
Sent: Monday, August 15, 2016 11:29 AM
To: DeCair, Sara
Cc: Hernandez-Quinones, Samuel; Lee, Raymond; siddhanti@endyna.com
Subject: Water PAG Docket List (with all comments classified)

Hi Sara

Attached is the Water PAG docket list, which now has all comment classified.

The docket posted 58 more comments on 8/11 and posted 9 more comments on 8/12. I believe, based on what Raymond said, that those 9 comments posted on 8/12 are probably the last batch.

EnDyna has identified 18 more substantive comments – when you are ready, please send back the Water PAG Comment Matrix, and EnDyna will include those additional 18 substantive comments in the matrix. It seems EnDyna probably has enough hours/budget remaining to complete that.

Thanks,

Amy

Amy Doll

Senior Associate

EnDyna, Inc.
7926 Jones Branch Drive, Suite 620
McLean, VA 22102

adoll@endyna.com
Tel: 703-848-8842 ext. 111

From: Lee, Raymond [mailto:Lee.Raymond@epa.gov]
Sent: Thursday, August 11, 2016 10:50 AM
To: Amy Doll; DeCair, Sara
Cc: Hernandez-Quinones, Samuel; Smita Siddhanti
Subject: Re: Updated Water PAG Docket List (posted thru 8/11 930pm)

Hi all,

Good news! They are just about done - only 10 simple comments left to process and index.

Thanks,

Ray

From: Lee, Raymond
Sent: Thursday, August 11, 2016 10:26:26 AM
To: Amy Doll; DeCair, Sara
Cc: Hernandez-Quinones, Samuel; siddhanti@endyna.com
Subject: Re: Updated Water PAG Docket List (posted thru 8/11 930pm)

Already sent a note into the docket staff to check. Assem is on vacation but hopefully is back-up has an update for us; will let you know once I hear back!

From: Amy Doll <adoll@endyna.com>
Sent: Thursday, August 11, 2016 10:25:32 AM
To: DeCair, Sara
Cc: Hernandez-Quinones, Samuel; Lee, Raymond; siddhanti@endyna.com
Subject: RE: Updated Water PAG Docket List (posted thru 8/11 930pm)

That would be great! I just noticed that I meant 930am (not pm) for when I did last export

Amy Doll

Senior Associate

EnDyna, Inc.
7926 Jones Branch Drive, Suite 620
McLean, VA 22102

adoll@endyna.com
Tel: 703-848-8842 ext. 111

From: DeCair, Sara [mailto:DeCair.Sara@epa.gov]
Sent: Thursday, August 11, 2016 10:22 AM
To: Amy Doll
Cc: Hernandez-Quinones, Samuel; Lee, Raymond; Smita Siddhanti
Subject: Re: Updated Water PAG Docket List (posted thru 8/11 930pm)

Thank you, Amy. Ray will check with docket staff.

Sent from my iPhone

On Aug 11, 2016, at 10:11 AM, Amy Doll <adoll@endyna.com> wrote:

Hi Sara

Attached is a list of what is in your Water PAG docket, as posted through today 8/11 around 9:30pm.

This includes around 25 more comments posted by docket at end of day on 8/9.

No new comments were posed by docket on 8/10.

Maybe they are finished processing all of them? Please let me know if you find out whether they are done yet.

Thanks,

Amy

Amy Doll

Senior Associate

EnDyna, Inc.
7926 Jones Branch Drive, Suite 620
McLean, VA 22102

adoll@endyna.com
Tel: 703-848-8842 ext. 111

From: Amy Doll
Sent: Tuesday, August 09, 2016 4:39 PM
To: 'DeCair, Sara'
Cc: 'Hernandez-Quinones, Samuel'; 'Lee, Raymond'; 'Smita Siddhanti (siddhanti@endyna.com)'
Subject: RE: Updated Water PAG Docket List (posted thru 8/9 400pm)

Hi Sara

Attached is a list of what is in your Water PAG docket, as posted through today 8/9 around 4:00pm, which now includes even more comments than this morning!

Also this version has more of the comments categorized by EnDyna in the CATEGORY

column.

Thanks,

Amy

Amy Doll

Senior Associate

EnDyna, Inc.
7926 Jones Branch Drive, Suite 620
McLean, VA 22102

adoll@endyna.com
Tel: 703-848-8842 ext. 111

From: Amy Doll
Sent: Tuesday, August 09, 2016 8:52 AM
To: 'DeCair, Sara'
Cc: 'Hernandez-Quinones, Samuel'; 'Lee, Raymond'; 'Smita Siddhanti (siddhanti@endyna.com)'
Subject: RE: Updated Water PAG Docket List (posted thru 8/9 830am)

Hi Sara

Attached is a list of what is in your Water PAG docket, as posted through today 8/9 around 8:30am, which includes more comments!

Thanks,

Amy

Amy Doll

Senior Associate

EnDyna, Inc.
7926 Jones Branch Drive, Suite 620
McLean, VA 22102

adoll@endyna.com
Tel: 703-848-8842 ext. 111

From: Amy Doll
Sent: Monday, August 08, 2016 9:03 AM
To: 'DeCair, Sara'
Cc: 'Hernandez-Quinones, Samuel'; 'Lee, Raymond'; 'Smita Siddhanti (siddhanti@endyna.com)'
Subject: Updated Water PAG Docket List (posted thru 8/8 830am)

Hi Sara

Attached is a list of what is in your Water PAG docket, as posted through today 8/8 around 8:30am.

This latest batch posted by the docket includes at least one substantive comment.

Thanks,

Amy

Amy Doll

Senior Associate

EnDyna, Inc.

7926 Jones Branch Drive, Suite 620
McLean, VA 22102

adoll@endyna.com
Tel: 703-848-8842 ext. 111

From: Amy Doll
Sent: Thursday, August 04, 2016 9:26 AM
To: 'DeCair, Sara'
Cc: 'Hernandez-Quinones, Samuel'; 'Lee, Raymond'; 'Smita Siddhanti (siddhanti@endyna.com)'
Subject: Updated Water PAG Docket List (posted thru 8/4 830am)

Hi Sara

Attached is a list of what is in your Water PAG docket, as posted through 8/4 around 8:30am.

What number should I use to call you today? Also is there a good time this afternoon that we could schedule to talk?

It would be helpful if EPA could check with docket staff to find out whether they have completed processing and posting all the comments.

Thanks,

Amy

Amy Doll

Senior Associate

EnDyna, Inc.
7926 Jones Branch Drive, Suite 620
McLean, VA 22102

adoll@endyna.com
Tel: 703-848-8842 ext. 111

From: Amy Doll
Sent: Wednesday, August 03, 2016 4:11 PM
To: 'DeCair, Sara'
Cc: 'Hernandez-Quinones, Samuel'; 'Lee, Raymond'; 'Smita Siddhanti (siddhanti@endyna.com)'
Subject: Updated Water PAG Docket List (posted thru 8/3 1pm)

Hi Sara

Attached is a list of what is in your Water PAG docket, as posted through 8/3 around 1pm.

It would be helpful if EPA could check with docket staff to find out whether they have completed processing and posting all the comments.

EnDyna is still categorizing the comments, but you will see what we have identified as "substantive" category in our initial review.

Thanks,

Amy

Amy Doll

Senior Associate

EnDyna, Inc.
7926 Jones Branch Drive, Suite 620
McLean, VA 22102

adoll@endyna.com
Tel: 703-848-8842 ext. 111

From: Amy Doll
Sent: Wednesday, August 03, 2016 1:23 PM
To: 'DeCair, Sara'
Cc: 'Hernandez-Quinones, Samuel'; 'Lee, Raymond'; 'Smita Siddhanti (siddhanti@endyna.com)'
Subject: Updated Water PAG Docket List

Hi Sara

Attached is an updated Water PAG docket list, which now has more of the comments categorized.

The docket has posted more comments today, and I'll need to check whether they are late comments or not. Those new comments just posted today are not in this list yet.

Later today, I'll send another updated list.

Thanks,

Amy

Amy Doll

Senior Associate

EnDyna, Inc.
7926 Jones Branch Drive, Suite 620
McLean, VA 22102

adoll@endyna.com
Tel: 703-848-8842 ext. 111

From: Amy Doll
Sent: Tuesday, August 02, 2016 8:42 AM

To: 'DeCair, Sara'
Cc: 'Hernandez-Quinones, Samuel'; 'Lee, Raymond'; 'Smita Siddhanti (siddhanti@endyna.com)'
Subject: Water PAG Docket List (posted thru 8/2 8pm)

Hi Sara

Attached is a list of what is in your Water PAG docket, as posted through 8/2 around 8am.

It would be helpful if EPA could check with docket staff to find out whether they have completed processing and posting all the comments.

EnDyna is still categorizing the comments, but you will see what we have identified as "substantive" category in our initial review.

Thanks,

Amy

Amy Doll

Senior Associate

EnDyna, Inc.
7926 Jones Branch Drive, Suite 620
McLean, VA 22102

adoll@endyna.com
Tel: 703-848-8842 ext. 111

From: Amy Doll
Sent: Friday, July 29, 2016 4:23 PM
To: 'DeCair, Sara'
Cc: 'Hernandez-Quinones, Samuel'; 'Lee, Raymond'; 'Smita Siddhanti (siddhanti@endyna.com)'
Subject: Water PAG Docket List (posted thru 7/29 4pm)

Hi Sara

Attached is a list of what is in your Water PAG docket, as posted through 7/29 around 4pm.

The comments that are newly posted, as of 7/29 around 4pm, start with #0883.

NIRS organizational comment is posted now, and its #0910 – you probably want to take a look at that one! Their comment is representing 63 organizations.

Thanks,

Amy

Amy Doll

Senior Associate

EnDyna, Inc.
7926 Jones Branch Drive, Suite 620
McLean, VA 22102

adoll@endyna.com
Tel: 703-848-8842 ext. 111

From: Amy Doll
Sent: Friday, July 29, 2016 3:38 PM
To: 'DeCair, Sara'
Cc: Hernandez-Quinones, Samuel; Lee, Raymond
Subject: RE: Water PAG Docket List (posted thru 7/28)

Hi Sara

OK, I saw around mid-day that #0762 now has a document name of anonymous public comment (instead of the error this morning).

Also it seems that gradually throughout the day, the document names for the larger range (batch) #0542-#0741 have been gradually getting populated with document names. I hope they can get that done today!

I'll let you know if I see the CRCPD comment you were looking for.

Also, FYI, #0483 is Mary Olsen's personal comment, so that might be something for the docket to correct (the document name says she's commenting for NIRS). According to Mary's personal comment, NIRS submitted a separate organizational comment the same day but I have not seen an NIRS comment yet.

Thanks,

Amy

Amy Doll

Senior Associate

EnDyna, Inc.
7926 Jones Branch Drive, Suite 620
McLean, VA 22102

adoll@endyna.com
Tel: 703-848-8842 ext. 111

From: DeCair, Sara [mailto:DeCair.Sara@epa.gov]
Sent: Friday, July 29, 2016 3:28 PM
To: Amy Doll; Lee, Raymond
Cc: Hernandez-Quinones, Samuel
Subject: FW: Water PAG Docket List (posted thru 7/28)

Amy, see question and fix below. Thank you for replying to all if you have more on the question. Sara

From: Lee, Raymond
Sent: Friday, July 29, 2016 2:51 PM
To: Akram, Assem <Akram.Assem@epa.gov>
Cc: Castillo, Amparo <Castillo.Amparo@epa.gov>; DeCair, Sara <DeCair.Sara@epa.gov>
Subject: Re: Water PAG Docket List (posted thru 7/28)

Hi Sara,

Just FYI - can you let Amy at Endyna know? Also, Assem doesn't see an issue with 0762, is there more of an explanation or is it already fixed?

Thanks!

Ray

From: Akram, Assem
Sent: Friday, July 29, 2016 2:49:18 PM
To: Lee, Raymond
Cc: Castillo, Amparo
Subject: RE: Water PAG Docket List (posted thru 7/28)

Hi, Ray –

The big batch 0542-0741 was the result of a processing error on our part. These got posted before being processed. Our folks have already been working since thus morning to remedy that. We should be done with them before COB today.

As for 0762, I don't really see an issue with it: it's either fixed, or I am missing to see it.

Please let me know.

Many thanks!

Assem

>>>>>>>>>><<<<<<<<<<

Assem Akram

Docket Manager

USEPA Docket Center

Operated by ASRC Primus

(202) 566-0226

akram.assem@epa.gov

>>>>>>>>>><<<<<<<<<<

From: Lee, Raymond
Sent: Friday, July 29, 2016 2:38 PM
To: Akram, Assem <Akram.Assem@epa.gov>
Cc: Castillo, Amparo <Castillo.Amparo@epa.gov>
Subject: Fw: Water PAG Docket List (posted thru 7/28)

Hi Assem,

Please see the spreadsheet and the note from Amy Doll below. They are contractors that have been working on PAGs comments as well.

Thanks!

Ray

From: DeCair, Sara
Sent: Friday, July 29, 2016 10:22 AM
To: Lee, Raymond
Subject: Fwd: Water PAG Docket List (posted thru 7/28)

Ray can you ask the docket staff or can I write to that guy myself - name I can't recall ? Thx!

Sent from my iPhone

Begin forwarded message:

> **From:** Amy Doll <adoll@endyna.com>
> **Date:** July 29, 2016 at 8:56:23 AM EDT
> **To:** "DeCair, Sara (DeCair.Sara@epa.gov) (DeCair.Sara@epa.gov)" <DeCair.Sara@epa.gov>
> **Cc:** "Hernandez-Quinones, Samuel (Hernandez.Samuel@epa.gov)" <Hernandez.Samuel@epa.gov>, Smita Siddhanti <Siddhanti@endyna.com>, "Amber Brewer" <abrewer@endyna.com>
> **Subject: Water PAG Docket List (posted thru 7/28)**
>
> Hi Sara
>
> Attached is a list of what is in your Water PAG docket, as posted through 7/28.
>
> The comments that are newly posted, as of 7/28, start with #0496.
>
> Please ask the docket staff to fix the errors in the DOCUMENT NAME field for comments #542-741 and also #762 – apparently there was a problem with the batch upload or the documentation process.

If the docket staff could get those errors fixed today, that would be great.

Thanks,

Amy

Amy Doll

Senior Associate

EnDyna, Inc.
7926 Jones Branch Drive, Suite 620
McLean, VA 22102

adoll@endyna.com
Tel: 703-848-8842 ext. 111

<Water PAG Docket List_081116_in AM.xlsx>

To: Hernandez-Quinones, Samuel[Hernandez.Samuel@epa.gov]
From: DeCair, Sara
Sent: Thur 7/14/2016 7:35:47 PM
Subject: RE: Urgent: Letter signed by 60 orgs requesting cmt period extension?
PAGs Comment Period Extension FR 62413.doc

We didn't do a formal response to our request for extension in 2013, we just issued this FR on the last day of the comment period. That is when most of the comments come in, anyway!

See FR attached FYI.

From: Hernandez-Quinones, Samuel
Sent: Thursday, July 14, 2016 3:26 PM
To: DeCair, Sara <DeCair.Sara@epa.gov>
Subject: RE: Urgent: Letter signed by 60 orgs requesting cmt period extension?

Hi Sara,

Let me know if you have had requests like this one for the previous PAG proposal. If so let me know if you developed a formal response. I want to coordinate with you on our response to the 120 day extension request.

I will send you a draft version of the response tomorrow.

Thanks

Sam

==========

Samuel Hernández Quiñones, P.E.
Environmental Engineer
Office of Water

Environmental Protection Agency
1200 Pennsylvania Ave. NW
Washington, DC 20460
202-564-1735

"USEPA Protecting Human Health and the Environment"

From: DeCair, Sara
Sent: Thursday, July 14, 2016 11:51 AM
To: Hernandez-Quinones, Samuel <Hernandez.Samuel@epa.gov>
Subject: FW: Urgent: Letter signed by 60 orgs requesting cmt period extension?

Here it is, Sam.

From: Amy Doll [mailto:adoll@endyna.com]
Sent: Thursday, July 14, 2016 11:18 AM
To: DeCair, Sara <DeCair.Sara@epa.gov>
Subject: RE: Urgent: Letter signed by 60 orgs requesting cmt period extension?

Hi Sara

That's #0291 – it just got posted by docket yesterday (7/13/16). I've attached PDF and provided link: https://www.regulations.gov/document?D=EPA-HQ-OAR-2007-0268-0291

Thanks,

Amy

Amy Doll

Senior Associate

EnDyna, Inc.
7926 Jones Branch Drive, Suite 620
McLean, VA 22102

adoll@endyna.com
Tel: 703-848-8842 ext. 111

From: DeCair, Sara [mailto:DeCair.Sara@epa.gov]
Sent: Thursday, July 14, 2016 10:44 AM
To: Amy Doll
Subject: Urgent: Letter signed by 60 orgs requesting cmt period extension?

I guess Diane D'Arrigo called Office of Water and said a letter had been submitted in the comments that was signed by 60 organizations, requesting the comment period be extended. Have you seen that? I am also asking here, since some requests came in through our website's "Contact Us" button.

Thanks a ton, S.

Sara D. DeCair

http://www.epa.gov/radiation/rert/pags.html

202-343-9108

Room 1416 B in WJC West

To: Nesky, Anthony[Nesky.Tony@epa.gov]
From: DeCair, Sara
Sent: Thur 7/14/2016 6:06:20 PM
Subject: RE: Urgent: Letter signed by 60 orgs requesting cmt period extension?
Comment from 58 orgs.pdf

Yep, sure enough we found it – attached as an FYI. Water will decide whether to extend.

From: Nesky, Anthony
Sent: Thursday, July 14, 2016 1:56 PM
To: DeCair, Sara <DeCair.Sara@epa.gov>
Subject: RE: Urgent: Letter signed by 60 orgs requesting cmt period extension?

No. I checked the questions inbox and my own inbox and there was nothing there. I forwarded that one early email request from Tri-Valley to Lisa Christ, but there was no letter attached.

Is it possible that they submitted it directly to the Docket?

Tony Nesky

Center for Radiation Information and Outreach

Tel: 202-343-9597

nesky.tony@epa.gov

From: DeCair, Sara
Sent: Thursday, July 14, 2016 10:45 AM
To: Nesky, Anthony <Nesky.Tony@epa.gov>
Subject: FW: Urgent: Letter signed by 60 orgs requesting cmt period extension?

Tony have you seen the letter I describe below? I think you saw one such request come in early via our web page….

From: DeCair, Sara
Sent: Thursday, July 14, 2016 10:44 AM
To: Amy Doll <adoll@endyna.com>
Subject: Urgent: Letter signed by 60 orgs requesting cmt period extension?

I guess Diane D'Arrigo called Office of Water and said a letter had been submitted in the comments that was signed by 60 organizations, requesting the comment period be extended. Have you seen that? I am also asking here, since some requests came in through our website's "Contact Us" button.

Thanks a ton, S.

Sara D. DeCair

http://www.epa.gov/radiation/rert/pags.html

202-343-9108

Room 1416 B in WJC West

From: Mary Olson <maryo@nirs.org>
Sent: Friday, July 08, 2016 10:09 AM
To: A-AND-R-DOCKET
Subject: FW: Docket Number (EPA-HQ-OAR-2007-0268; FRL-9947-55 -OW)
Attachments: PAG H2O ext req2016.pdf

Same attached as PDF

To: Office of Ground Water and Drinking Water (draft Radioactive Water PAGs) Docket Number (EPA-HQ-OAR-2007-0268; FRL-9947-55-OW)

From: Fifty-Eight Organizations and two elected officials (undersigned) via Nuclear Information and Resource Service (NIRS) Contact: Mary Olson maryo@nirs.org 828-252-8409, Diane D'Arrigo (Primary Contact after July 13) dianed@nirs.org 301-270-6477
NOTE: the co-signers to this request have been compiled as a courtesy to the Agency. We have emails from each organization requesting they be signed on this request.

RE: Request for 120 day extension to comment on EPA's Draft Protective Action Guide (PAG) for Drinking Water After a Radiological Incident, EPA-HQ-OAR-2007-0268; FRL-9947-55-OW

Dear Lisa Christ, Office of Air and Radiation, and Office of Water:

We ask that EPA extend the public comment period on the Draft Protective Action Guide (PAG) for Drinking Water After a Radiological Incident (draft Radioactive Water PAGs) for 120 days beyond the July 25th deadline.

The changes proposed in the EPA draft Radioactive Water PAGs are extremely significant. They are complicated on their own and additionally by their proposed inclusion in the Draft PAGs (2013 PAG Manual at https://www.epa.gov/radiation/protective-action-guides-pags) on which many of us commented in 2013. Commenting must be done in conjunction with the existing PAG Manual since they would be combined in practice. Since radiation's effects are multiple, additive, cumulative and synergistic, we need to consider the impacts of proposed 100 to 500 millirems/year from water (Water PAG) in light of that from food, air, etc. (PAG) and bioaccumulation.

We appreciate EPA's acknowledgement in this draft of the reality that different life stages are differently impacted by radiation. The portion of the proposal recommending different levels of radioactive water contamination for different life stages adds complexity requiring more than technical analysis and discussion to comment meaningfully, especially when developing organizational positions and responses. Practical and philosophical issues must be considered as well. It appears that the life stage sensitivity is only being addressed in the Water PAG, not the whole PAG so this must be considered and assessed as well.

Excerpts to one of the supporting documents (NCRP-174) on which the proposed Water PAG is based have just been put up on the www.regulations.gov website (in July) but not the whole document in its entirety. The excerpts were not publically available for nearly half of the current comment period. We request this report and all other information used and supporting the Water PAGs be made publicly available, free of charge and that the comment period be extended to accommodate full review.

There are some confusing legal implications that need clarification before submitting comments. The length of time for which PAG guidance would apply is not expressly limited yet assumptions are made that it will be for limited periods only. Although the Federal Register says the PAG guidance levels don't supersede the Safe Drinking Water Act levels

(maximum concentration levels) does the PAG relieve the polluter from legal liability? Clarification of these questions would be helpful and certainly additional time is needed to provide meaningful comments.

We request a 120 day extension. We also respectfully ask that you decide and notify us of your decision by July 15th.

Thank you for consideration of this extension request.

Sincerely,

Timothy Judson, Executive Director
Nuclear Information and Resource Service
Takoma Park, MD

Barbara Gottlieb, Environment & Health Director
Physicians for Social Responsibility
Washington, DC

Lynn Thorp
Clean Water Action
Washington, DC

Catherine Lincoln
Committee to Bridge the Gap
Ben Lomond, CA

Ken Bossong
SUN DAY Campaign
Takoma Park, MD

Cindy Folkers
Beyond Nuclear
Takoma Park, MD

Deb Katz
Citizen Awareness Network
Rowe, MA

Dr. Gwen DuBois, President
Chesapeake Physicians for Social Responsibility
Baltimore, MD

Toni Iseeman, Mayor pro tem of Laguna Beach
Laguna Beach, CA

Pam Patterson, Mayor
San Juan Capistrano, CA

Elaine Holder, President
San Luis Obispo Mothers for Peace
San Luis Obispo, CA

Jane Williams, Executive Director
California Communities Against Toxics
Rosamond, CA

Marylia Kelley,
Tri-Valley Communities Against a Radioactive Environment
Livermore, CA

Joni Arends
Concerned Citizens for Nuclear Safety
Santa Fe, NM

Don Safer
Tennessee Environmental Coalition
Nashville, Tennessee

Becky D. Rafter, MPA, Executive Director
Georgia Women's Action for New Directions
Atlanta, GA

Dave Kraft
Nuclear Energy Information Service
Chicago, IL

Robert M. Gould, MD, President
San Francisco Bay Area Chapter
Physicians for Social Responsibility

Robert K. Musil, Ph.D., M.P.H.
President & CEO, Rachel Carson Council
Bethesda, MD

Ruth Thomas
Environmentalists Inc.
Columbus, NC

Sarah Fields
Uranium Watch

Louis A. Zeller
Blue Ridge Environmental Defense League

Moab, Utah

Jessica Azulay, Program Director
Alliance for a Green Economy
Syracuse, NY

Pamela Hughes
Sierra Club Niagara Group Chair
New York State, Atlantic Chapter

Iris Marie Bloom
Executive Director
Protecting Our Waters
NY, NJ, PA

Debra Borowiecki, Co-coordinator
LAWPA - Local Authority Western PA
Murrysville, PA

Paula Gotsch
Grandmothers, Mothers and More for Energy Safety
Normandy Beach, NJ

Barbara Warren
Citizens' Environmental Coalition
New York

Alice Hirt
Don't Waste Michigan
Holland, MI

Wes Raymond - Administrator
Citizens for Alternatives to Chemical Contamination
Lake, Michigan

Ed Oles, President
Citizens To Preserve Ligonier Valley
Ligonier, PA

Kristen Combs
Green Party of Pennsylvania
Philadelphia, PA

Gillian Graber
Protect PT
Trafford, PA

Susan Gordon, Coordinator
Multicultural Alliance for a Safe Environment

VA, NC, SC, TN, AL, GA

Connie Kline
Ohio CARE - Citizens Against a Radioactive Environment
Cleveland, OH

Bob Ciesielski, Energy Committee Chair
Sierra Club Atlantic Chapter
Albany, NY

Jenny Lisak, Co-director
Pennsylvania Alliance for Clean Water and Air
Punxsutawney, PA

Dr. Lewis Cuthbert
Alliance for a Clean Environment
Pottstown, PA. 19465

Priscilla Star
Coalition Against Nukes
Wainscott, NY

Michael J. Keegan
Coalition for a Nuclear Free Great Lakes
Monroe, MI

Regina Minniss
Crabshell Alliance
Baltimore, Maryland

Lynda Schneekloth, Advocacy Chair
Western New York Environmental Alliance
Buffalo, New York

Jan Milburn, President
Westmoreland Marcellus Citizens' Group
Westmoreland County , PA

Briget Shields
Marcellus Protest/Protect Our Parks Pittsburgh
Pittsburgh, PA

Ellen Connett
Fluoride Action Network
Canton, New York

Stephen Brittle
Don't Waste Arizona

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New Mexico

Greg Wingard, Executive Director
Waste Action Project
Covington, WA

Rita M Conn
Let Laguna Vote, and, Secure Nuclear Waste
Laguna Beach, California

Gary Headrick
San Clemente Green
San Clemente, CA

Faye More, Chair
Port Hope Community Health Concerns Committee
Port Hope, Ontario

Theresa A. McClenaghan
Executive Director and Counsel
Canadian Environmental Law Association
Toronto, ON

Tanya Keefe
Great Lakes Environmental Alliance
Port Huron, MI

Phoenix, Arizona

Mark Haim
Mid-Missouri Peaceworks/
Missourians for Safe Energy
Columbia, Missouri

Michael Welch
Redwood Alliance
Arcata, CA

Jessie Collins
Citizens' Resistance at Fermi Two (CRAFT)
MI

Ziggy Kleinau,
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ED_001057_00012091

To: Amy Doll[adoll@endyna.com]
From: DeCair, Sara
Sent: Wed 7/13/2016 6:48:06 PM
Subject: Full Manual ready for Refs section to be reviewed
PAG Manual OMB cmts in 7-12-2016.docx

Amy, I'm pretty sure that Appendix A, References, is in good shape, but you noted with green hilite that it was not yet reviewed/edited. I've been going through making this a track-changes version to show my bosses where tweaks were made based on feedback from OMB's interagency review. They are all very small! We expect more input from OMB, though, so the process is not finished.

I'd like to hold the version for now, but if you let me know if and where edits need to be made, we can do them in synch – I just may have to do edits on the fly for OMB if they call me over there. By the way, I checked all the "see Section ##" and made a couple tweaks based on the new section organization, also in track changes. So those can be un-highlighted. I also made all the sub-sub-section headings in Ch. 5 have three spaces after the section #, since I always have to search and replace two spaces after periods with one space, per my eagle-eyed Deputy Division Director…

Have a great afternoon and I'll talk to you soon!

Sara D. DeCair

http://www.epa.gov/radiation/rert/pags.html

202-343-9108

Room 1416 B in WJC West

To: White, Rick[White.Rick@epa.gov]; Tony Nesky (nesky.tony@epa.gov)[nesky.tony@epa.gov]
From: DeCair, Sara
Sent: Fri 6/24/2016 4:23:12 PM
Subject: FW: Review of draft PAG Q&A document
PAGs Comm Tool QA 4-18-16+cover_EnDyna review 060216.docx

Tony and Rick,

I'm going to be out on Monday when we have our next PAG Q&A meeting that Jessica encouraged us to keep having. Since we've been so busy, we've fallen off the routine of moving the Qs&As forward, but we did get this good review from my PAGs contractor.

Do you have a proposal for how we should proceed? The next FRPCC is on Tuesday and I can't attend, but perhaps we can get time on the agenda for the next one, which should be in September. Jess will be back then and we should be well positioned to ask the FRPCC for their review and then I suggest we publish it on the PAGs web page.

Thanks for your thoughts! See you Tuesday,

Sara

From: Amy Doll [mailto:adoll@endyna.com]
Sent: Friday, June 24, 2016 8:27 AM
To: DeCair, Sara <DeCair.Sara@epa.gov>
Cc: siddhanti@endyna.com
Subject: FW: Review of draft PAG Q&A document

Hi Sara

I just wanted to confirm that you had everything you needed from EnDyna for the review of draft PAG Q&A document.

Hope the briefing goes well.

Thanks,

Amy

Amy Doll

Senior Associate

EnDyna, Inc.
7926 Jones Branch Drive, Suite 620
McLean, VA 22102

adoll@endyna.com
Tel: 703-848-8842 ext. 111

From: Amy Doll
Sent: Thursday, June 02, 2016 1:24 PM
To: DeCair, Sara (DeCair.Sara@epa.gov) (DeCair.Sara@epa.gov)
Cc: 'Smita Siddhanti (siddhanti@endyna.com)'
Subject: Review of draft PAG Q&A document

Hi Sara

As you requested, I've done a careful review of the draft PAG Q&A document. My comments/suggestions are either in Comment boxes or track changes, all embedded within the attached document.

When making language revisions, I've considered carefully the language used in the other federal agency Q&A documents that I checked this draft document against. I checked against the two FEMA documents, FDA's KI Q&A, CDC's dirty bombs Q&A, CDC's radiation emergencies Q&A, NRC's radiation protection Q&A, NRC's emergency preparedness and

response Q&A.

Please don't hesitate to let me know if you have any questions, or need any other preparation before your June 28th briefing.

Thanks,

Amy

Amy Doll

Senior Associate

EnDyna, Inc.
7926 Jones Branch Drive, Suite 620
McLean, VA 22102

adoll@endyna.com
Tel: 703-848-8842 ext. 111

To: Nesky, Anthony[Nesky.Tony@epa.gov]
From: DeCair, Sara
Sent: Thur 6/2/2016 9:35:19 PM
Subject: Fwd: Review of draft PAG Q&A document
PAGs Comm Tool QA 4-18-16+cover_EnDyna review 060216.docx
ATT00001.htm

See below

Sent from my iPhone

Begin forwarded message:

From: "Amy Doll" <adoll@endyna.com>
To: "DeCair, Sara" <DeCair.Sara@epa.gov>
Cc: "siddhanti@endyna.com" <siddhanti@endyna.com>
Subject: Review of draft PAG Q&A document

Hi Sara

As you requested, I've done a careful review of the draft PAG Q&A document. My comments/suggestions are either in Comment boxes or track changes, all embedded within the attached document.

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Please don't hesitate to let me know if you have any questions, or need any other preparation before your June 28th briefing.

Thanks,

Amy

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To: Tony Nesky (nesky.tony@epa.gov)[nesky.tony@epa.gov]
From: DeCair, Sara
Sent: Thur 5/26/2016 8:23:02 PM
Subject: Q&A
Internal Q&A on Water PAG 9-28-2015.docx

Sara D. DeCair

http://www.epa.gov/radiation/rert/pags.html

202-343-9108

Room 1416 B in WJC West

To: Brozowski, George[brozowski.george@epa.gov]
From: DeCair, Sara
Sent: Wed 5/25/2016 5:02:50 PM
Subject: Re: Water PAGS

Some would contend it weakens water regs but I say it strengthens emergency preparedness.

Sent from my iPhone

On May 25, 2016, at 12:53 PM, Brozowski, George <brozowski.george@epa.gov> wrote:

Good late morning and why is this controversial?

OMB Advances Controversial EPA Guide for Radiological Emergencies (insideepa.com)

http://insideepa.com/daily-news/omb-advances-controversial-epa-guide-radiological-emergencies

The Obama administration appears to be moving forward with highly controversial drinking water amendments to EPA's protective action guides (PAGs) for radiological emergencies, despite attempts from a host of environmental groups to stop the amendments

George P. Brozowski

Regional Health Physicist/Radon Coordinator

US EPA – R6

1445 Ross Avenue

Mail Stop - 6MM-XU

Dallas, TX 75202

214-665-8541 o

214-755-1530 c

To: Tony Nesky (nesky.tony@epa.gov)[nesky.tony@epa.gov]
From: DeCair, Sara
Sent: Thur 5/19/2016 8:43:53 PM
Subject: FYI, OW may pull you in...

OMB cleared the drinking water PAG proposal for publication!!

In case OW's comms staff start changing the FR Package materials that we already reviewed and approved, Sam Hernandez will list your name as the point person from OAR to help ensure consistency with our larger PAGs materials. This all might be happening early next week (but you know how torturous those last few steps can be) – so let me know if you need anything!

Thanks,

S

Sara D. DeCair

http://www.epa.gov/radiation/rert/pags.html

202-343-9108

Room 1416 B in WJC West

To: Hallam, Christopher[Hallam.Christopher@epa.gov]
From: DeCair, Sara
Sent: Wed 4/13/2016 9:46:06 PM
Subject: Interesting article, some edits I started...
Basis lingo tweaks 4-13-2016.docx

See what you think, when you have time – this article is about decline of traffic deaths, and I've attached some edits I started. Thank you!

S.

http://www.alertdriving.com/home/fleet-alert-magazine/north-america/us-traffic-fatalities-fall-lowest-level-60-years

Sara D. DeCair

http://www.epa.gov/radiation/rert/pags.html

202-343-9108

Room 1416 B in WJC West

Early Phase Basis

For a full description of the risk-benefit analysis used to set the PAG levels, refer to the 1992 PAG Manual, Appendices B, C and E. The Manual is available online in a searchable format. Below is a short summary on the basis for the Early Phase evacuation/sheltering PAG of 1 to 5 rem over 4 days.

PAGs are intended to apply to all individuals in a population other than workers performing emergency services. However, there may be identifiable groups that have different average sensitivity to radiation or, because of their living situation, will receive higher or lower doses. In addition, some groups may be at greater risk from taking a given protective action. Special circumstances and age groups (e.g., fetal dose) were considered, when appropriate, in establishing values for the PAGs.

The following four principles provided the basis for establishing values for Protective Action Guides:

1. Acute effects on health (those that would be observable within a short period of time and which have a dose threshold below which they are not likely to occur) should be avoided.

2. The risk of delayed effects on health (primarily cancer and genetic effects, for which linear non-threshold relationships to dose are assumed) should not exceed upper bounds that are judged to be adequately protective of public health, under emergency conditions, and are reasonably achievable.

3. PAGs should not be higher than justified on the basis of optimization of cost and the collective risk of effects on health. That is, any reduction of risk to public health achievable at acceptable cost should be carried out.

4. Regardless of the above principles, the risk to health from a protective action should not itself exceed the risk to health from the dose that would be avoided.

EPA considered the acceptable range of costs for avoiding a statistical death from pollutants other than radiation and using a rounded value from the BEIR III risk of 0.0003 cancer deaths per person-rem. Further evaluation of thyroid, skin and fetal dose consequences was conducted as well.

Costs of evacuation:

Based on a prior published study ("An Analysis of Evacuation Options for Nuclear Accidents, EPA 520/1-87-023, 1987) evaluating evacuation options for several accident types, this analysis focused on the smallest category of fuel melt accident yielding effective dose equivalents during the first 4 days of exposure that are greater than 0.5 rem outside the assumed 2-mile evacuation circle for all stability classes. For this scenario, total and incremental costs were calculated for several different sized evacuation areas. Data on costs versus dose avoided for several meteorological stability classes and evacuation options (sizes) were summarized in tables in the 1992 PAG Manual, Appendix C.

For a risk of 0.0003 cancer deaths per person-rem, the range of evacuation costs can be compared to the marginal cost-effectiveness (dollars per person-rem) of evacuation over an angle of 90 degrees. The

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resulting ranges of upper bounds on dose are in tables in Appendix C, for three different accident scenarios. The maximum upper bounds (based on minimum costs for avoiding risk) range from 1 to 10 rem, with most values being approximately 5 rem. The minimum upper bounds (based on maximum costs for avoiding risk) range from 0.15 to 0.8 rem, with 0.5 rem dose incurred being representative of most situations.

From these data we conclude that, based on the cost of evacuation, a PAG larger than the range of values 0.5 to 5 rem would be incompatible with Principle 3.

Based on comparison of exposures from evacuation versus the presumed alternative of sheltering in various building types for several timeframes, the dose actually avoided by evacuation is one half of the projected dose.

Risk from evacuation:

Principle 4 requires that the risk of the protective action not exceed the risk associated with the dose that will be avoided. Risk from evacuation can come from several sources, including (1) transportation incidents for both pedestrians and vehicle passengers, (2) exposure to severe weather conditions or a competing disaster, and (3), in the case of immobile persons, anxiety, unusual activity, and separation from medical care or services. While all these factors must be considered, transportation incidents is the only category for which the risk has been quantified.

In a recent study of 230 mass evacuations in the U.S. ("Identification and Analysis of Factors Affecting Emergency Evacuations" NUREG/CR-6484, 2004) only six cases involved deaths from the hazard itself, and of these six, only one case involved deaths during the evacuation itself. Only two cases involved injuries during the evacuation. Traffic issues, such as traffic congestion, were reported in 28% of the evacuation cases studied. However, traffic accidents occurred in only 8% of the cases.

During the tsunami and nuclear disaster response in Japan in 2011, deaths occurred during evacuations, primarily among elderly hospital patients being moved from areas without power. Compounded disaster conditions including aftershocks, widespread power outages and radiation releases led to prolonged transit along routes extended to avoid hazards.

Conformance to Principle 1 (avoidance of acute health effects) is assured by the low risk required to satisfy Principle 2 (acceptable risk of delayed health effects), and thus requires no additional consideration. Based on Principle 2, evacuation of the general population is not justified below 0.5 rem. This represents a risk of about 0.0002 of fatal cancer. Maximum lifetime risk levels considered acceptable by EPA from <u>routine</u> operations of individual sources range from 0.000001 to 0.0001. Risk levels that are higher than this must be justified on the basis of the emergency nature of a situation. In this case, we judge that up to an order of magnitude higher combined risk from all phases of an incident may be justifiable. The choice of 0.5 rem avoided dose as an appropriate criterion for an acceptable level of risk during the early phase is a subjective judgment that includes consideration of possible contributions from exposure during other phases of the incident.

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Principle 4 (risk from the protective action must be less than that from the radiation risk avoided) supplies a lower bound of 0.03 rem on the dose at which evacuation of most members of the public is justified. The lower bound was derived from the risk of death from traffic accidents in emergency evacuations, using the factor of 0.0003 cancer deaths per person-rem. Finally, under Principle 3 (cost/risk considerations) evacuation is justified only at values equal to or greater than 0.5 rem. This will be limiting unless lower values are required for purely health-based reasons (Principle 2). But this is not the case. The single lower purely health-based value, 0.1 rem, is only valid as a health-based criterion for chronic exposure.

In summary, we have selected the value 0.5 rem as the avoided dose which justifies evacuation, because 1) it limits the risk of delayed effects on health to levels adequately protective of public health under emergency conditions, 2) the cost of implementation is justified, and 3) it satisfies the two bounding requirements to avoid acute radiation effects and to avoid increasing risk through the protective action itself.

The value of the PAG for evacuation of the general public is therefore chosen as one rem projected total effective dose from inhalation of radionuclides and exposure to external radiation.

Basis for Intermediate Phase PAGs:

For a full description of the risk-benefit analysis used to set the PAG levels, refer to the 1992 PAG Manual, Appendices B, C and E. The Manual is available online in a searchable format. Below is a short summary on the basis for the Intermediate Phase relocation PAGs.

In a prior section, for early phase (evacuation) PAGs, analysis was provided for the risks of health effects as a function of dose (Principles 1 and 2). Considerations for selection of PAGs for the intermediate phase of a nuclear incident differ from those for selection of PAGs for the early phase primarily with regard to implementation factors (i.e., Principles 3 and 4). Specifically, they differ with regard to cost of avoiding dose, the practicability of leaving infirm persons and prisoners in the restricted zone, and avoiding dose to fetuses. Although sheltering is not generally a suitable alternative to relocation, other alternatives (e.g., decontamination and shielding) are suitable.

For several assumed cumulative annual doses, the cost per day divided by the risk of fatality avoided by relocation was plotted for a radionuclide mixture from a hypothetical nuclear power plant accident. The cost per day of relocation is assumed to be constant, but with some nuclides decaying rapidly, the cost effectiveness of relocation diminishes over time. Drawing only general trends from this, the cost analysis supports relocation at doses as low as one rem for the first week and two rem for up to 25 days after an accident.

Based on the avoidance of acute effects alone (Principle 1) relocation of the general population and fetuses at 50 rem and 10 rem, respectively, is justified. However, on the basis of control of chronic risks (Principle 2) a lower upper bound is appropriate. Five rem is taken as an upper bound on acceptable risk

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for avoidable lifetime exposure to radiation, including avoidable exposure to deposited radioactive materials from a radiation incident.

Analyses based on Principle 3 (cost/risk) indicate that considering cost alone would not drive the PAG to values less than 5 rem. Analyses in support of Principle 4 (risk of the protective action itself) provide a lower bound for relocation PAGs of 0.15 rem. Based on the above, 2 rem projected committed effective dose equivalent from exposure in the first year is selected as the PAG for relocation. Implementation of relocation at this value will provide reasonable assurance that, for a reactor accident, a person relocated from the outer margin of the relocation zone will, by such action, avoid an exposure rate which, if continued over a period of one year, would result in a dose of about 1.2 rem. This assumes that 0.8 rem would not be incurred if a person was not relocated, due to normal partial occupancy of homes and other structures.

Contrary to the situation for evacuation during the early phase of an incident, it is generally not practical to leave a few persons behind when most members of the general population have been relocated from a specified area for extended periods of time. It will usually be practicable to reduce these risks by establishing a high priority for efforts other than relocation to reduce the dose in cases where pregnant women reside near the boundary of the restricted zone.

The implementation of simple dose reduction techniques will further reduce dose to persons who are not relocated from contaminated areas. Table E-6 summarizes the estimated maximum dose that would be received by these persons for various reactor accident categories with and without the application of simple dose reduction techniques. In the case of non-reactor accidents, decay and weathering effects differ, it may be necessary to base relocation decisions on the second and subsequent year dose projections.

Language on other detriments of evacuation, shelter

Planners should consider the unquantifiable detriments of evacuating or relocating community members in light of clear psychosocial and emotional impacts on communities moved for radiation protection. People impacted by radiation incidents in Goiania, Chernobyl and Fukushima have had long-lasting issues resulting from fears of radiation. Planners and decision makers should avoid imposing additional conservatism on protective action area decisions to impact as few people as possible when avoiding radiation doses at levels projected to exceed the PAGs.

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To: Jones, Terri[Terri.Jones@fda.hhs.gov]; ATeam-CLEVELAND, GORDON[GORDON.S.CLEVELAND@APHIS.USDA.GOV]
Cc: ATeam-DENNISON, KEVIN[KEVIN.M.DENNISON@APHIS.USDA.GOV]; Brooks, Michael5[Brooks.Michael5@epa.gov]; Sincek, Jeffrey[Jeffrey.Sincek@fda.hhs.gov]; Hallam, Christopher[Hallam.Christopher@epa.gov]; ATeam-JENSEN, JOHN[JOHN.JENSEN@DM.USDA.GOV]; Noska, Michael A[Michael.Noska@fda.hhs.gov]; Dixon, John E. (CDC/ONDIEH/NCEH)[gyf7@cdc.gov]
From: DeCair, Sara
Sent: Wed 3/30/2016 7:34:47 PM
Subject: Reentry info from PAG Manual & Op Guides
PAG Manual for Interim Use and Comment 4-2-2013.pdf
ogt_manual.pdf

This is a drill.

Please refer to Section 3.8 of the attached 2013 PAG Manual for a brief summary of Reentry guides, based on the Operational Guidelines which is also attached. Let us know if you need something more detailed, and those of us offsite will work on it. Thanks!

This is a drill.

Sara D. DeCair

http://www.epa.gov/radiation/rert/pags.html

202-343-9108

Room 1416 B in WJC West

4.1.3

2013

PAG Manual

Protective Action Guides And Planning Guidance For Radiological Incidents

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LIMITS ON SCOPE

This guidance does not address or impact site cleanups occurring under other statutory authorities such as the United States Environmental Protection Agency's (EPA) Superfund program, the Nuclear Regulatory Commission's (NRC) decommissioning program, or other federal or state cleanup programs.

As indicated by the use of non-mandatory language such as "may," "should" and "can," this Manual only provides recommendations and does not confer any legal rights or impose any legally binding requirements upon any member of the public, states, or any other federal agency.

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CHAPTER 1 – OVERVIEW

1.1. PLANNING GUIDANCE AND PROTECTIVE ACTION GUIDES

The U.S. Environmental Protection Agency (EPA) has developed this Manual to assist public officials in planning for emergency response to radiological incidents. For purposes of this document, a radiological incident is an event or a series of events, deliberate or accidental, leading to the release or potential release into the environment of radioactive materials in sufficient quantity to warrant consideration of protective actions. This Manual provides radiological protection criteria for application to all incidents that would require consideration of protective actions, with the exception of nuclear war.

During an incident with an uncontrolled source of radiation, protection of the public from unnecessary exposure to radiation may require some form of intervention that will disrupt normal living. Such intervention is termed a protective action. Examples of protective actions include:

- evacuating an area;
- sheltering-in-place within a building or protective structure;
- administering potassium iodide (KI) as a supplemental action;
- acquiring an alternate source of drinking water;
- interdiction of food/milk.

This Manual provides recommended numerical protective action guides (PAGs) for the principal protective actions available to public officials during a radiological incident. A PAG is defined for purposes of this document as the projected dose to an individual from a release of radioactive material at which a specific protective action to reduce or avoid that dose is recommended. PAGs are guides to help officials select protective actions under emergency conditions during which exposures would occur for relatively short time periods. They are not meant to be applied as strict numeric criteria, but rather as guidelines to be considered in the context of incident-specific factors. PAGs do not establish an acceptable level of risk for normal, nonemergency conditions, nor do they represent the boundary between safe and unsafe conditions. The PAGs are not legally binding regulations or standards and do not supersede any environmental laws. For information on roles, responsibilities and authorities during emergency response and recovery, please refer to the National Response Framework: http://www.fema.gov/national-response-framework and specifically for radiological incidents, the Nuclear Radiological Incident Annex: http://www.fema.gov/pdf/about/divisions/thd/IncidentNucRad.pdf (FEMA 2008a,b).

Some protective actions are not associated with a numerical PAG. For example, the control of access to areas is a protective action implemented in concert with other protective actions; it does not have its own PAG. Any reasonable action to reduce radiation dose is encouraged even if it is not associated with a PAG, such as recommending that individuals use ad hoc respiratory protection with a handkerchief or piece of folded cloth. Or in areas where PAGs are not exceeded, but airborne radioactivity is present, people might be asked to stay indoors to the extent practicable to reduce their exposures. To further develop radiological emergency plans, brief planning guides have been provided for reentry to relocation areas, the cleanup planning process and considerations for radioactive waste disposal.

1.2. APPLICABILITY

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Protective actions may be recommended for a wide range of incidents, but generally apply to incidents involving relatively significant releases of radionuclides. Radiological incidents with potential for significant releases include:

- a fire in a major facility such as a nuclear fuel manufacturing plant;
- an accident at a federal nuclear weapons complex facility;
- an accident at a commercial nuclear power plant (NPP);
- a transportation accident involving radioactive material;
- a terrorist act involving a radiological dispersal device (RDD) or yield-producing Improvised Nuclear Device (IND).

Each type of incident would pose a unique threat to public health and should be planned for and managed accordingly. Emergency response planning for a given facility or scenario should consider:

- the radionuclides involved;
- the dynamics of the release including size and magnitude;
- the feasibility of specific protective actions;
- the timing of notification, response and protective action implementation.

The decision to advise members of the public to take a protective action during a radiological incident involves a complex judgment in which the radiological risk must be weighed against the action's inherent risks. This decision may have to be made under emergency conditions, with limited information and little time to analyze options. Advance planning reduces the complexity of the decision-making process during an incident. The planning process can identify the viability of responses to various incidents, the courses of action that can be set in motion in advance and the decisions that can only be made during an actual emergency. While many aspects of protective actions can be considered well in advance of an emergency, the situations and conditions that exist at the time of emergency must be considered if the most effective action is to be selected.

The unpredictable locations of certain radiological incidents make advance planning challenging. For example, an RDD could detonate anywhere and spread radiological contaminants over a wide variety of surfaces and terrain. Emergency planners should be prepared to apply PAGs to a wide scope of facilities and circumstances.

1.3. BACKGROUND ON THE UP DATED PAGS

This Manual updates the "Manual of Protective Action Guides and Protective Actions for Nuclear Incidents" (EPA-400-R-92-001, May 1992), published by the U.S. EPA (EPA 1992b) (hereinafter referred to as the "1992 PAG Manual"). The guidance in this Manual was developed cooperatively with the Federal Radiological Preparedness Coordination Committee (FRPCC), with representation from the EPA; the Department of Energy (DOE); the Department of Defense (DoD); the DHS' Federal Emergency Management Agency (FEMA); the Nuclear Regulatory Commission (NRC); the Department of Health and Human Services (HHS), including the Centers for Disease Control and Prevention (CDC) and the Food and Drug Administration (FDA); the Department of Agriculture (USDA); and the Department of Labor (DOL).

1.3.1. Legal Basis

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The historical and legal basis of EPA's role in developing this guidance begins with Reorganization Plan No. 3 of 1970, in which the Administrator of EPA assumed all the functions of the Federal Radiation Council (FRC), including the charge to "…advise the President with respect to radiation matters, directly or indirectly affecting health, including guidance for all federal agencies in the formulation of radiation standards and in the establishment and execution of programs of cooperation with states" (Reorg. Plan No. 3 of 1970, sec. 2(a) (7), 6(a) (2); § 274.h of the Atomic Energy Act of 1954, as amended (AEA), codified at 42 U.S.C. § 2021(h)). Recognizing this role, FEMA directed EPA in their Radiological Emergency Planning and Preparedness Regulations to "establish Protective Action Guides (PAGs) for all aspects of radiological emergency planning in coordination with appropriate federal agencies" (44 Code of Federal Regulations (CFR) §351.22(a)). FEMA also tasked EPA with preparing "guidance for state and local governments on implementing PAGs, including recommendations on protective actions which can be taken to mitigate the potential radiation dose to the population" (44 CFR §351.22(b)). All of this information was to "be presented in the EPA Manual of Protective Action Guides and Protective Actions for Nuclear Incidents" (44 CFR §351.22(b)).

Additionally, section 2021(h) charged the Administrator with performing "such other functions as the President may assign to him [or her] by Executive Order." Executive Order 12656 states that the Administrator shall "[d]evelop, for national security emergencies, guidance on acceptable emergency levels of nuclear radiation…." (Executive Order No. 12656, sec.1601(2)). EPA's role in the development of PAGs was also recognized in the "Nuclear/Radiological Incident Annex of the National Response Framework" of June 2008.

1.3.2. Technical Basis

The FRC introduced the concept of a PAG in a series of recommendations issued in the 1960s. A key concept about PAGs is that the decision to implement protective actions should be based on the projected dose that would be avoided if the protective actions were implemented. Developers of the EPA PAGs considered the following three principles in establishing exposure levels for the PAGs—

1. Prevent acute effects.
2. Balance protection with other important factors and ensure that actions result in more benefit than harm.
3. Reduce risk of chronic effects.

These principles apply to the determination of any PAG. Principles 1 and 2 have been proposed for use by the international community as essential bases for decisions to intervene during an incident. Principle 3 has been recognized as an appropriate additional consideration (IAEA 1989). Although it is important during emergency planning to consider a range of source terms to assess the costs associated with their implementation, the PAGs are pre-determined for use in emergencies without regard to the magnitude or type of radiological release.

1.3.3. Changes in Scenarios since the Issuance of the 1992 PAG Manual

EPA's 1992 PAG Manual provided emergency management officials at the federal, state, tribal and local levels with the technical basis to plan responses to radiological emergencies. The 1992 PAG Manual was written to accommodate the worst release scenario deemed likely at the time – a major accident at a commercial NPP that would result in a significant off-site release of radioactive material. ("Site" and "off-site" in this Manual refer to locations where the radiological incident occurs and are not limited to facility-type incidents.) Certain characteristics typify NPPs, including: fixed locations at which an accident might occur; a known suite of radionuclides on site, the dose from which is dominated by short-lived radioisotopes; tight regulatory controls and requirements; skilled operational personnel who plan for

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and exercise emergency responses; state and local involvement in emergency planning; well-developed and zoned emergency evacuation plans and routes; and advance notice (generally hours to days) from deteriorating plant conditions prior to accidental release of radioactive material into the environment. Therefore, the 1992 PAG Manual provided decision-makers with radiation dose-based PAG values for various exposure pathways (such as whole body, skin dose and food ingestion) and associated protective actions that were adapted to the mix of radionuclides and operational environments associated with commercial NPPs.

In late 1991, EPA conducted a symposium titled "Implementing Protective Actions for Radiological Incidents at Other Than Nuclear Power Reactors," to evaluate PAGs for incidents other than accidents at NPPs and concluded that the PAGs could be applied to all radiological incidents (EPA 1992a). Since then, new radiological and nuclear scenarios involving terrorist use of radioactive materials have gained status in radiological emergency response planning.

In 2008, the Department of Homeland Security (DHS) published "Planning Guidance for Protection and Recovery Following Radiological Dispersal Device (RDD) and Improvised Nuclear Device (IND) Incidents" (DHS 2008). An RDD is a device or mechanism that is intended to spread radioactive material from the detonation of conventional explosives or other means. An IND is a crude, yield-producing nuclear weapon fabricated from diverted fissile material. Incidents like these may occur anywhere with little or no warning. The DHS guidance, developed cooperatively with EPA, DOE, DoD, DOL, HHS, Department of Commerce (DOC), and the NRC, affirms the applicability of existing 1992 EPA PAGs to terrorist acts, while acknowledging that the PAGs were inadequate for early response planning needs specific to an IND. To address this gap, "Planning Guidance for Response to a Nuclear Detonation" (NSS 2010) was subsequently published.

This Manual substantively incorporates late phase cleanup guidance provided in the 2008 DHS document and refers readers to additional planning resources.

1.3.4. Key Changes to PAGs in this Updated Manual

This updated Manual applies PAGs and protective actions to an expanded range of sources of potential radiological releases, including commercial nuclear power facilities, uranium fuel cycle facilities, nuclear weapons facilities, transportation accidents, radiopharmaceutical manufacturers and users, space vehicle launch and reentry, RDDs and INDs.

Dosimetry for all the PAGs was updated using the International Commission on Radiological Protection (ICRP) Publication 60 series (ICRP 1991). The PAGs in this Manual may be implemented using calculated, measurable values contained in the Federal Radiological Monitoring and Assessment Center (FRMAC) Assessment Manuals (DOE 2010a, b),[1] though using other incident-specific dose assessment methodologies is encouraged, where appropriate.

This Manual incorporates several related guidance documents published subsequent to the 1992 guidance, including FDA's 1998 update of the PAGs for interdiction of food. This Manual also incorporates FDA's 2001 decision to lower the PAG for administration of stable iodine to 5 rem (50 millisieverts (mSv)) projected child thyroid dose. Finally, this update removes the intermediate phase relocation PAG of 5 rem (50 mSv) over 50 years to avoid confusion with long-term cleanup. All other PAGs and corresponding protective actions from the 1992 PAG Manual remain unchanged.

[1] See FRMAC Assessment folder at http://www.nv.doe.gov/nationalsecurity/homelandsecurity/frmac/manuals.aspx.

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Recommended limits of exposure for emergency workers also remain unchanged from the 1992 PAG Manual. The emergency worker guides in this manual are consistent with federal and state regulations. Responsible officials should use judgment when doses may exceed regulatory limits and must advise workers of the risks Table 1-1 presents PAGs with their principal associated protective actions or planning guides.

To further develop radiological emergency plans, brief planning guides have been provided for reentry to relocation areas, a cleanup planning process and considerations for radioactive waste disposal. In this Manual, the term reentry is used for emergency workers and members of the public going into relocation areas temporarily, under controlled conditions.

1.4. RADIOLOGICAL INCIDENT PHASES AND APPLICABILITY OF PROTECTIVE ACTIONS

Emergency planners divide responses to radiological incidents into three phases of activity—

- **Early Phase** — The beginning of a radiological incident when immediate decisions for effective use of protective actions are required and must therefore be based primarily on the status of the radiological incident and the prognosis for worsening conditions. When available, predictions of radiological conditions in the environment based on the condition of the source or actual environmental measurements may be used. Protective actions based on the PAGs may be preceded by precautionary actions during the period. This phase may last from hours to days.
- **Intermediate Phase** — The period beginning after the source and releases have been brought under control (has not necessarily stopped but is no longer growing) and reliable environmental measurements are available for use as a basis for decisions on protective actions and extending until these additional protective actions are no longer needed. This phase may overlap the early phase and late phase and may last from weeks to months.
- **Late Phase** — The period beginning when recovery actions designed to reduce radiation levels in the environment to acceptable levels are commenced and ending when all recovery actions have been completed. This phase may extend from months to years. A PAG level, or dose to avoid, is not appropriate for long-term cleanup.

The phases cannot be represented by precise periods of time – and may even overlap – but to view them in terms of activities, rather than time spans, can provide a useful framework for emergency response planning.

In the early phase, sheltering-in-place and evacuation are the principal protective actions. These actions are meant to avoid inhalation of gases or particulates in an atmospheric plume and to minimize external radiation exposures. Administration of prophylactic drugs may be employed depending on the specific radionuclides released; in particular, KI, also called "stable iodine"—may be administered as a supplementary protective action in incidents involving the release of significant quantities of radioactive iodine, such as NPP incidents. Some protective actions may begin prior to the release of radioactive material when there is advance notice.

Planning considerations for reentry to relocation areas for specific tasks are suggested and basic planning guidance for late phase cleanup is provided in Chapters 3 and 4.

1.4.1. Implementation of Protective Action Guides and Protective Actions

Immediately upon becoming aware that an incident is about to occur or has occurred that may result in exposure of the population, responsible authorities should make a preliminary evaluation to determine the

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nature and potential magnitude of the incident. This evaluation should determine whether conditions indicate a significant possibility of a major release and, to the extent feasible, determine potential exposure pathways, populations at risk and projected doses. The incident evaluation and recommendations should then be presented to emergency response authorities for consideration and implementation.

During the early phase, the sequence of events includes—evaluation of conditions at the location of the incident, notification of responsible authorities, prediction or evaluation of potential consequences to the general public, recommendations for action and implementation of actions for the protection of the public.

In the intermediate phase, dose projections used to support decisions about protective actions may be based on measurements of environmental radioactivity and dose models. When conditions warrant relocation of populations, the collection of extensive radiological and cost-of-cleanup data will be necessary to form the decision basis for cleanup and recovery of the affected areas.

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Table 1-1. Planning Guidance and Protective Action Guides for Radiological Incidents

Phase	Protective Action Recommendation	Protective Action Guide or Planning Guide
Early (Chapter 2)	Sheltering-in-place or evacuation of the public[a]	1 to 5 rem (10 mSv to 50 mSv) projected dose/4 days[b]
	Administration of prophylactic drugs KI[c]	5 rem (50 mSv) projected child thyroid dose[d] from radioactive iodine
	Limit emergency worker exposure	5 rem (50 mSv)/year (or greater under exceptional circumstances)[e]
Intermediate (Chapter 3)	Relocation of the public	2 rem (20 mSv) projected dose first year[b] Subsequent years, 0.5 rem (5 mSv)/year projected dose
	Food interdiction[f]	0.5 rem (5 mSv)/year projected dose, or 5 rem (50 mSv)/year to any individual organ or tissue, whichever is limiting
	Limit emergency worker exposure	5 rem (50 mSv)/year[b]
	Reentry	Operational Guidelines[g] (Stay times and concentrations) for specific activities (see Section 3.7)
Late (Chapter 4)	Cleanup	Brief description of planning process
	Waste Disposal	Brief description of planning process

[a] Should begin at 1 rem (10 mSv); take whichever action (or combination of actions) that results in the lowest exposure for the majority of the population. Sheltering may begin at lower levels if advantageous.
[b] Projected dose- the sum of the effective dose from external radiation exposure (i.e., groundshine and cloudshine) and the committed effective dose from inhaled radioactive material.
[c] Provides thyroid protection from internal exposure to radioactive iodines only. For other information on radiological prophylactics and treatment, refer to http://www.fda.gov/Drugs/EmergencyPreparedness/BioterrorismandDrugPreparedness/ucm063807.htm http://www.bt.cdc.gov/radiation and www.orau.gov/reacts
[d] Thyroid equivalent dose. For more information, refer to http://www.fda.gov/Drugs/EmergencyPreparedness/BioterrorismandDrugPreparedness/ucm072265.htm.
[e] When radiation control options are not available, or, due to the magnitude of the incident, are not sufficient, doses to emergency workers above 5 rem (50 mSv) may be unavoidable and are generally approved by competent authority. For further discussion see Chapter 2, Section 2.6.
[f] For more information on food and animal feeds guidance, the complete FDA guidance may be found at http://www.fda.gov/downloads/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/UCM094513.pdf
[g] For extensive technical and practical implementation information please see "Preliminary Report on Operational Guidelines Developed for Use in Emergency Preparedness and Response to a Radiological Dispersal Device Incident" (DOE 2009)

Protective actions may already be designated in existing emergency response plans. Under NRC regulations, large commercial NPPs must maintain detailed radiological response plans for an emergency planning zone (EPZ) within a 10 mile (16.1 km) radius of the plant and for a separate ingestion pathway EPZ within a 50 mile (80.5 km) radius. Emergency responders should be prepared to select and implement appropriate protective actions when standing response plans are not available or applicable.

1.4.2. Early Phase Protective Action Guides and Protective Actions

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In the early phase, there may be little or no data on actual releases to the environment and responders may have to rely on crude estimates of airborne releases. Decision time frames are short and preparation is critical to make prudent decisions when data are lacking or insufficient.

The principal protective actions for the early phase are evacuation and sheltering-in-place. These protective actions would be taken if whole body doses are projected to exceed 1 to 5 rem (10 to 50 mSv) over four days. The decision to evacuate must weigh the anticipated radiation dose to individuals in the affected population against the feasibility of evacuating within a determined time frame and the risks associated with the evacuation itself. For example, evacuating a population of 50,000 carries with it a statistical risk of injury or death from transportation hazards or increased exposure. Evacuation also takes time. In the case of an accident at an NPP, there may be sufficient time for an orderly and relatively safe evacuation. In the case of a fire or explosion of an RDD in an urban area, evacuating a large group of people could leave them exposed to the plume and actually increase radiation dose. Sheltering-in-place may be warranted in situations where evacuation poses a greater risk of exposure or physical harm.

In addition, there are actions that are advisable, but not associated with a numerical PAG. For example, individuals should be instructed to cover airways (nose and mouth) with available filtering material when airborne radionuclides may be present. Decontamination is another protective action that may be utilized in the early phase and may include washing of contaminated individuals, removing contaminated clothing and decontaminating surfaces of critical areas and objects. Further, in areas where airborne radioactivity is present but PAGs are not exceeded, officials can consider asking people to stay indoors to the extent practicable. In such cases, individuals are not prevented from carrying out necessary tasks (e.g., seeking medical care, purchasing food). Similar to actions used in major cities on high pollution days, these measures can be effective to reduce radiation doses when prolonged releases occur, as was the case for the Fukushima accident in Japan.

In cases where significant quantities of radioiodine may have been released, administration of the radioprotectant KI should be considered as a supplementary protective action if the projected child thyroid dose exceeds 5 rem (50 mSv). This PAG is lower than the 1992 guidance. The lower dose, which FDA adopted in 2001, is for protection of children based on early studies of Chernobyl exposure data.

The choice of protective action will be based on the status of the incident site and the prognosis for worsening conditions. In the early phase, precautionary actions based on worst-case scenarios may be used before implementation of protective actions based on PAGs. For example, in the case of RDD detonation, governments may instruct affected populations to shelter in place as a precautionary action while radiation levels are being measured to determine appropriate PAG-based protective actions. Officials should plan for rapid broadcast and dissemination of protective action orders to the public.

When available, predictions of radiological conditions in the environment based on an estimate of the source or actual environmental measurements may be used. Nuclear facilities, for example, have continuous, real-time radioactive effluent monitoring capabilities to monitor radioactive material released to the environment and may have a network of off-site measurement stations.

1.4.3. Intermediate Phase Protective Action Guides and Protective Actions

Intermediate phase activities are intended to reduce or avoid dose to the public, to control worker exposures, to control the spread of radioactive contamination and to prepare for late phase cleanup operations.

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During the intermediate phase, relocation is the principal protective action against whole body external exposure from deposited material and internal exposure from inhalation of radioactive particulates. People may need to be relocated for weeks or months.

It is necessary to distinguish between evacuation and relocation. Evacuation is the urgent removal of people from an area to avoid or reduce high-level, short-term exposure from the plume or deposited activity. Relocation is the removal or continued exclusion of people (households) from contaminated areas to avoid chronic radiation exposure. Site-specific conditions may allow some groups evacuated in an emergency to return, while others may have to relocate. In other cases, some groups that were not previously evacuated may have to relocate (see Section 3.3.1 for more details).

Intermediate phase PAGs are based on doses projected in the first and a limited number of subsequent years. The PAG for relocation of the public is 2 rem (20 mSv) in the first year and 0.5 rem (5 mSv) in any subsequent year. (Note: Relocation PAGs are treated separately from food and water ingestion. That is, projection of intermediate phase doses should not include these ingestion pathways. In some instances, however, where withdrawal of food and/or water from use would, in itself, create a, health risk, relocation may be an appropriate alternative protective action. In this case, the ingestion dose should be considered along with the projected dose from deposited radionuclides via other pathways, for decisions on relocation.) When projected doses are less than the relocation PAG of 2 rem (20 mSv), focused environmental decontamination and cleanup may be able to reduce doses to populations that are not relocated. Decontamination and focused cleanup techniques can range from simple actions such as the scrubbing and flushing of surfaces to the removal and disposal of soil and contaminated debris.

Keeping projected doses below the 0.5 rem (5 mSv) PAG for out years – the second year and beyond – may be achieved through the decay of shorter half-life radioisotopes (as in the case of an accident at an NPP), through environmental decontamination and cleanup efforts or through other means of controlling public exposures, such as limiting access to certain areas. Information on food and animal feeds protective action guidance is contained in FDA's "Accidental Radioactive Contamination of Human Food and Animal Feeds: Recommendations for State and Local Agencies" (FDA 1998). Workers and members of the public may be allowed to re-enter relocation area for tasks related to critical infrastructure and key resources, to care for animals and to assess the condition of closed zones. Reoccupancy may be allowed under dose constraints acceptable to the community. In this Manual, the term reoccupancy refers to households and communities moving back into relocation areas where the cleanup process is still ongoing, based on radiation levels acceptable to those communities.

EPA is not proposing a specific drinking water PAG at this time. EPA has established enforceable drinking water standards for radionuclides under the Safe Drinking Water Act (SDWA). EPA recommends that, to the extent practicable, emergency measures for drinking water be based on the National Primary Drinking Water Regulations (NPDWR) for Radionuclides. The Radionuclides Rule provides states with flexibility when responding to radiological events. If a public water system exceeds the radionuclides standard it must work to get back into compliance as soon as feasible. States have the authority to determine if other corrective actions are needed (e.g. providing alternative water). Guidance on monitoring, notification and protective actions is provided in Chapter 3, along with several online resources for drinking water system operators.

However, in light the Fukushima nuclear power plant accident, in which some Japanese drinking water supplies were impacted, the Agency recognizes a short-term emergency drinking water guide may be useful for public health protection The Agency requests input on the appropriateness of, and possible values for, a drinking water PAG.

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While the NPDWR provide for a regulatory standard of 4 mrem/year (beta, photon emitters) based on life-time exposure, international organizations have developed technical approaches and methodologies that have produced a range of emergency guidelines related to drinking water (e.g., the World Health Organization[2], the International Atomic Energy Agency[3]), as have other federal agencies (e.g. the Department of Homeland Security[4], the Food and Drug Administration[5]) and non-federal organizations. EPA is seeking input on an approach and technical rationale for a drinking water PAG designed to help officials select protective actions under emergency conditions when exposures would occur over shorter time periods than those envisioned in the NPDWR.

During the intermediate phase, government officials may convene to discuss late phase cleanup and site restoration strategies. All actions taken during the early and intermediate phases should be considered with respect to the impact they may have on late phase remediation, such as avoiding the use of fixatives that could hinder surface decontamination at a later date.

1.4.4. Late Phase

The late phase, as used in this Manual, is the period beginning when cleanup and recovery actions have begun and ending when all recovery actions have been completed. This phase may extend from months to years.

The late phase cleanup process, as described in this guidance, begins sometime after the commencement of the intermediate phase and proceeds independently of intermediate phase protective action activities. The transition is characterized by a change in approach, from strategies predominantly driven by urgency, to strategies aimed at both reducing longer-term exposures and improving living conditions. The late phase involves the final cleanup of areas and property at which contamination directly attributable to the incident is present. It is in the late phase that final cleanup decisions are made and final recovery efforts following a radiological incident are implemented.

Unlike the early and intermediate phases of a radiological incident, decision makers will have more time and information during the late phase to allow for better data collection, stakeholder involvement and options analysis. Community members will influence decisions such as if and when to allow people to return home to contaminated areas. There will be populations, who were not relocated or evacuated, living in contaminated areas where efforts to reduce exposures will be ongoing. Implicit in these decisions is the ability to balance health protection with the desire of the community to resume normal life. Radiation protection considerations must be addressed in concert with health, environmental, economic, social, psychological, cultural, ethical, political and other considerations. Many federal, state, and local agencies have important roles to play. It is recognized that experience from existing programs, such as the U.S. EPA's Superfund program, the U.S. NRC's process for decommissioning and decontamination to terminate a nuclear facility license and other national recommendations may be useful for designing cleanup and recovery efforts that could apply to a radiological incident. The cleanup process described in Chapter 4, however, does not rely on and does not affect any authority, including the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), 42 U.S.C. 9601 et seq. and the National Contingency Plan (NCP), 40 CFR Part 300. For information on roles, responsibilities and authorities during emergency response and recovery please refer to the National Response Framework: http://www.fema.gov/national-response-framework and specifically for radiological incidents, the Nuclear Radiological Incident Annex: http://www.fema.gov/pdf/about/divisions/thd/IncidentNucRad.pdf (FEMA 2008a, b).

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[2] See: http://www.who.int/water_sanitation_health/dwq/gdwq3rev/en/ and http://www.who.int/hac/crises/jpn/faqs/en/index8.html
[3] See: http://www-pub.iaea.org/MTCD/publications/PDF/Pub1467_web.pdf.
[4] See: http://ogcms.energy.gov/73fr45029.pdf and the
[5] See: http://www.fda.gov/downloads/MedicalDevices/.../UCM094513.pdf.

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The late phase or cleanup process described in Chapter 4 consists of multiple steps, namely 1) characterization and stabilization, 2) development of goals and strategies and 3) implementation and reoccupancy; meaningful stakeholder involvement should be integrated *throughout* the process.

While radioactive waste handling and disposal will be an ongoing endeavor during the entire emergency response, brief planning guidance is provided in Chapter 4, the late phase. This guidance addresses both locations that may be identified by state and local officials and locations owned by the federal government, and lists criteria for evaluating their suitability for disposal, as well as actions that can be taken to facilitate their use. Legal and other considerations are also discussed. This guidance assumes that on-site disposal at a location affected by the incident, where appropriate, will be one of the locations of choice. Though recommended as the first consideration for discussion post-accident or attack, this guidance assumes that existing non-federal radioactive waste disposal capacity already available to impacted states and their regions is overwhelmed or otherwise eliminated from consideration, which drives the need to identify other disposal options or develop new disposal capacity.

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KEY POINTS IN CHAPTE R 1 – OVERVIEW

- A PAG is the projected dose to an individual from a release of radioactive material at which a specific protective action to reduce or avoid that dose is recommended. PAGs are guides to help officials select protective actions under emergency conditions when exposures would occur over relatively short time periods.
- EPA provides the PAG Manual to assist public officials with their radiological emergency response planning activities. The PAG Manual is a guidance document, not a legally binding regulation and does not affect or supersede any environmental laws. The PAG recommendations do not represent the boundary between safe and unsafe conditions.
- PAGs may be implemented to protect the public in a wide variety of radiological emergencies, including terrorist incidents and accidents involving nuclear power plants, transportation and the space program.
- PAGs are appropriate for implementation in the early and intermediate phases of radiological incidents. The early phase—lasting hours to days—is the period beginning at the projected (or actual) initiation of a release when immediate decisions for effective use of protective actions are required and must therefore be based primarily on the status of the release and the prognosis for worsening conditions. Little environmental data may be available in the early phase. The intermediate phase—lasting weeks to months—is the period beginning after the source and releases have been brought under control and environmental measurements are available for use as a basis for decisions on protective actions.
- Reentry and reoccupancy decisions will be made using incident-specific circumstances and the Operational Guidelines (DOE 2009).
- Cleanup and waste disposal decisions may be informed by planning guidance provided in Chapter 4.
- What's new in this updated Manual—
  - The PAGs in this Manual are implemented using the calculations and methods in the FRMAC Assessment Manual. Dosimetry in that Manual has been updated using the ICRP Publication 60 series (ICRP 1991).
  - EPA adopts the FDA guidance issued in 2001 that recommended lowering the projected thyroid dose at which the administration of KI is warranted as a supplementary protective action.
  - EPA adopts the 1998 FDA Food PAGs.
  - Planning guidance has been provided for reentry, late phase cleanup and waste disposal.

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CHAPTER 2 – EARLY PHASE PROTECTIVE ACTION GUIDES

2.1. INTRODUCTION

Decisions regarding protective actions for workers and the public during radiological incidents are risk management decisions and the recommendations in this Manual are provided in that context. Rapid action may be required to protect members of the public in the event of an incident involving a large release of radioactive materials into the environment. In all cases, all practical and reasonable means should be used to reduce or eliminate exposures.

This chapter presents PAGs for use in the early phase of a radiological incident. A PAG is the projected dose to an individual from a release of radioactive material at which a specific protective action should be taken to reduce or avoid that dose. The early phase begins at the actual or projected start of a release—most likely before ambient environmental and radiological data become available for quantitative risk-based actions. The exact duration of the early phase depends upon site conditions, but one should plan to project doses for four days.

Many radiological emergency scenarios would involve airborne releases, so this chapter provides guidance for estimating projected doses from exposure to an airborne plume of radioactive material and for implementing protective actions. Dose calculations for implementing the PAGs are made using the dose conversion factors (DCFs) and derived response level (DRL) methods referenced in the FRMAC Assessment Manuals (DOE 2010a, b).[6] Other calculation methods to implement PAGs may be appropriate.

2.2. EXPOSURE PATHWAYS DURING THE EARLY PHASE

During the early phase of an incident, there are three main exposure pathways from airborne releases—

- **Direct exposure** to radioactive materials in an atmospheric plume. The contents of such a plume will depend on the source of radiation involved and conditions of the incident. For example, in the case of an incident at an NPP, the plume may contain radioactive noble gases, radioiodines and radioactive particulate materials. Many of these materials emit gamma radiation that can expose people in the vicinity of the passing plume.
- **Inhalation** of radionuclides from immersion in a radioactive atmospheric plume and inhalation of ground-deposited radionuclides that are resuspended into a breathing zone. Inhaled radioactive particulates, depending on their solubility in body fluids, may remain in the lungs or move via the bloodstream to other organs, prior to elimination from the body. Some radionuclides become concentrated in a single body organ, with only small amounts going to other organs. For example, a significant fraction of inhaled radioiodines will move through the bloodstream to the thyroid gland.
- **Deposition** of radioiodine and particulates from a radioactive plume. Deposited materials can continue to emit beta and gamma radiation as "groundshine" after the plume has passed causing continued exposure to skin and internal body organs. Similarly, skin and clothes may become contaminated.

A plume may deposit materials on surfaces, posing a risk of longer-term exposures via ingestion, direct external exposure and inhalation pathways. If the release contains large quantities of radioactive iodines or particulates, the resulting long-term exposure to this "groundshine" can be more significant than

[6] See FRMAC Assessment folder at http://www.nv.doe.gov/nationalsecurity/homelandsecurity/frmac/manuals.aspx.

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external exposure from the passing plume if the exposure time to the ground contamination is long in comparison to the plume passage time. The early phase PAGs assume four days of exposure to ground contamination to address this possibility. Doses from groundshine can be readily measured by field monitoring teams dispatched at the onset of a significant radioactive release. Holding a detector probe horizontal and three feet above the contaminated surface provides a direct measurement of groundshine dose. Such assessments can confirm dose projections based upon effluent release data and the adequacy of protective actions in the early phase. More detailed analyses (e.g., isotopic) would be needed to support long-term dose projections in the intermediate phase. Doses for groundshine can be calculated during the intermediate phase (see Chapter 3). Exposure pathways that contribute less than ten percent to the total dose incurred need not be considered during the early phase.

2.2.1. The Establishment of Exposure Patterns

It is unlikely that sufficient environmental data will be available for accurate dose projections during and immediately following the early response to a radiological incident. Dose projections are needed to determine whether protective actions should be implemented in additional areas during the early phase.

For dose projections in the early phase there are two sources of data: current data from initial environmental measurements or estimates of the source term and estimated data using modeled or historical atmospheric transport data. Source term measurements, or exposure rates or concentrations measured in the plume at a few selected locations, may be used to estimate the extent of the exposed area in a variety of ways, depending on the types of data and computation methods available. The most accurate method of projecting doses is through the use of an atmospheric diffusion and transport model that has been verified for use at the site in question or for similar site conditions. A variety of computer software packages can be used to estimate dose in real time, or to extrapolate a series of previously-prepared isopleths for unit releases under various meteorological conditions. The latter can be adjusted for the estimated source magnitude or environmental measurements at a few locations during the incident. If the model projections have some semblance of consistency with environmental measurements, extrapolation to other distances and areas can be made with greater confidence. If projections using a sophisticated site-specific model are not available, a simple but crude method is to measure the plume centerline exposure rate[7] at ground level (measured at approximately 1 m height) at a known distance downwind from the release point and then to calculate exposure rates at other downwind locations by assuming that the plume centerline exposure rate is a known function of the distance from the release point.

The following relationship can be used for this calculation:

$$D_2 = D_1 (R_1/R_2)^y$$

where D_1 and D_2 are exposure rates at the centerline of the plume at distances R_1 and R_2 from the release, respectively and y is a constant that depends on atmospheric stability. For stability classes[8] A and B, y = 2; for stability classes C and D, y = 1.5; and for stability classes E and F, y = 1. Classes A and B (unstable) occur with light winds and strong sunlight and classes E and F (stable) with light winds at night. Classes C and D generally occur with winds stronger than about 10 mph. This method of extrapolation is risky because the measurements available at the reference distance may be unrepresentative, especially if the plume is aloft and has a looping behavior. In the case of an elevated

[7] The centerline exposure rate can be determined by traversing the plume at a point sufficiently far downwind that it has stabilized (usually more than one mile from the release point) while taking continuous exposure rate measurements.

[8] Pasquill stability classes categorize atmospheric turbulence into six stability classes named A, B, C, D, E and F, class A being the most unstable or most turbulence and class F the most stable or least turbulence. Pasquill, F. 1961. The Estimation of the Dispersion of Windborne Material. The Meteorological Magazine 90, No. 1063, 33-49.

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plume, the ground level concentration increases with distance from the source and then decreases, whereas any high-energy gamma radiation from the overhead cloud continuously decreases with distance. For these reasons, this method of extrapolation will perform best for surface releases or if the point of measurement for an elevated release is sufficiently distant (usually more than 1 mile) from the point of release for the plume to have expanded to ground level. The accuracy of this method will be improved by the use of measurements from many locations averaged over time.

2.3. THE PROTECTIVE ACTION GUIDES AND PROTECTIVE ACTIONS FOR THE EARLY PHASE: EVACUATION, SHELTERING-IN-PLACE AND ADMINISTRATION OF POTASSIUM IODIDE

The principal protective actions for the early phase are evacuation or sheltering-in-place. Evacuation is the urgent removal of people from an area to avoid or reduce high-level, short-term exposure from the plume or deposited activity. Sheltering-in-place is the action of staying or going indoors immediately. The administration of KI (stable iodine) to partially block the uptake of radioiodines by the thyroid is a supplemental protective action.

In addition, washing the body and changing clothing as soon as possible after significant exposure to a radioactive plume of any composition may be recommended protective actions. Changing of clothing is recommended primarily to provide protection from beta radiation from radioiodines and particulate materials deposited on the clothing.

The PAGs and corresponding protective actions for response during the early phase of an incident are summarized in Table 2-1. Evacuation or sheltering-in-place will be justified when the projected dose to an individual is 1 rem (10 mSv) projected over four days. This conclusion is based primarily on EPA's determination concerning acceptable levels of risk of health effects from radiation exposure in an emergency situation, while weighing costs and risks associated with any protective action. The basis for the PAGs for the early phase is given in Appendix C of the 1992 PAG Manual, available online as a historical reference at http://www.epa.gov/radiation/rert/pags.html.

Table 2-1. PAGs and Protective Actions for the Early Phase of a Radiological Incident

Protective Action Response	PAG (projected dose)	Comments
Sheltering-in-place or evacuation of the public[a]	1 to 5 rem (10 mSv to 50 mSv) over four days[b]	Evacuation (or, for some situations, sheltering-in-place) should be initiated when projected dose is 1 rem (10 mSv).
Supplementary administration of prophylactic drugs – KI[c]	5 rem (50 mSv) projected dose to child thyroid from exposure to iodine[d]	KI is most effective if taken prior to exposure. May require approval of state medical officials (or in accordance with established emergency plans).

[a]Should begin at 1 rem (10 mSv) except when practical or safety considerations warrant using 5 rem (50 mSv); take whichever action (or combination of actions) that results in the lowest exposure for the majority of the population. Sheltering may begin at lower levels if advantageous.
[b]Calculated dose is the projected sum of the effective dose from external radiation exposure (i.e., groundshine) and the committed effective dose from inhaled radioactive material.
[c]Provides thyroid protection from radioactive iodines only. For other information on radiological prophylactics and treatment, refer to http://www.fda.gov/Drugs/EmergencyPreparedness/BioterrorismandDrugPreparedness, http://www.emergency.cdc.gov/radiation or http://www.orau.gov/reacts.
[d]Thyroid equivalent dose (see Section 2.3.5).

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2.3.1. Evacuation vs. Sheltering-in-Place

Evacuation can be 100 percent effective in avoiding dose if completed before plume arrival. Evacuation is appropriate when its risks and secondary effects are less severe than the risk of the projected radiation dose.

Evacuation and sheltering-in-place provide different levels of dose reduction from the principal exposure pathways: direct gamma exposure and inhalation. Both sheltering and evacuation may be implemented during the same response in different areas or timeframes. Evacuation, if completed before plume arrival, can be 100 percent effective in avoiding radiation exposure. A decontamination station, with simple decontamination actions, may need to be colocated at shelters during the pre-evacuation period. This may reduce the spread of contamination and provide for greater protection during evacuation. Medical stations should also be collocated at shelters during the pre-evacuation period to ensure simple triage capabilities are met and to manage the distribution of prophylactic drugs. The effectiveness of evacuation will depend on many factors, such as how rapidly it can be implemented and the nature of the incident. For incidents where the principal source of dose is inhalation, evacuation could increase exposure if it is implemented during the passage of a short-term plume, since vehicles used to transport evacuees provide little protection against exposure (DOE 1990). Evacuation will seldom be justified at less than 1 rem (10 mSv) over the first four days.

Sheltering-in-place is a low-cost, low-risk protective action that can provide protection with an efficiency ranging from zero to almost 100 percent, depending on the type of release, the type of shelter available, the duration of the plume passage and climatic conditions. Because of these advantages, planners and decision makers may consider implementing sheltering-in-place when projected doses are below 1 rem (10 mSv) over the first four days. More guidance on the unique challenges posed by an IND can be found in the "Planning Guidance for Response to a Nuclear Detonation" (NSS 2010).[9]

Sheltering-in-place may be preferred for special populations (e.g., those who are not readily mobile) as a protective action at projected doses of up to 5 rem (50 mSv) over four days. When environmental, physical, or weather hazards impede evacuation, sheltering-in-place may be justified at projected doses up to 5 rem (50 mSv) for the general population (and up to 10 rem (100 mSv) for special populations). It is also comparatively easy to communicate with populations that have sheltered-in-place. Dose projections use a four-day exposure duration, but sheltering in place duration is intentionally not specified. Incident-specific decisions must be made to determine how long people should shelter in place.

Sheltering-in-place should be preferred to evacuation whenever it provides equal or greater protection.

Sheltering-in-place followed by informed evacuation may be most protective.

Selection of evacuation or sheltering-in-place is far from an exact science, particularly in light of time constraints that may prevent thorough analysis at the time of an incident. The selection process should be based on realistic or "best estimate" dose models and should take into account the unavoidable dose incurred during evacuation and potential failure scenarios for sheltering-in-place (e.g., a fire in the structure or leaking ventilation system).

Advance planning and exercises can facilitate the decision process. In a commercial NPP incident, early decisions should be based on information from the response plans for the EPZ and on actual conditions at the nuclear facility (see Section 2.3.5). For transportation accidents, RDDs, INDs and other incident

[9] See: http://www.epa.gov/rpdweb00/docs/er/planning-guidance-for-response-to-nuclear-detonation-2-edition-final.pdf

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scenarios for which EPZs are not practicable, best estimates of dose projections should be used for deciding on evacuation, sheltering-in-place or a combination thereof.

2.3.2. General Guidance for Evacuation and Sheltering-in-Place

The following is a summary of planning guidance for evacuation and sheltering-in-place—

- Evacuation may be the only effective protective action close to the plume source.
- Evacuation will be most effective if it is completed before arrival of the plume.
- Evacuation may increase exposure if carried out during the plume passage.
- Evacuation is also appropriate for protection from groundshine in areas with high exposure rates from deposited materials when suitable shelter is not available.
- Sheltering-in-place may be appropriate for areas not designated for immediate evacuation—
  - it may provide protection equal to or greater than evacuation for rapidly developing releases (e.g., RDDs) if followed by evacuation.
  - it positions the public to receive additional instructions.
  - Since it may be implemented rapidly, sheltering-in-place may be the protective action of choice (followed with evacuation when feasible) if rapid evacuation is impeded by:
    - severe environmental conditions, e.g., severe weather or floods;
    - uncertainty in contamination levels along routes;
    - health constraints, e.g., patients and workers in hospitals and nursing homes;
    - long mobilization times that may be associated with certain individuals, such as industrial and farm workers, or prisoners and guards;
    - physical constraints to evacuation, e.g., inadequate roads or blockage due to debris.
- If a major release of radioiodine or particulate materials occurs, inhalation dose may bea controlling criterion for protective actions—
  - Breathing air filtered through common household items (e.g., folded handkerchiefs or towels) may help reduce exposures.
  - After confirmation that the plume has passed, continued sheltering-in-place should be re-evaluated. Shelters should be opened to vent any airborne radioactivity trapped inside and people should remain sheltered until official notice about leaving high exposure areas as soon as possible to avoid exposure to deposited radioactive material.

2.3.3. Considerations for Evacuation and Sheltering In Place

Advance planning is essential to identify potential problems that may occur in an evacuation. An NRC case study cites the following aspects of planning as contributing to efficiency and effectiveness of evacuation (NRC 2005)—

- High level of cooperation among agencies.
- Use of multiple forms of emergency communications.
- Community familiarity with alerting methods, the nature of the hazard and evacuation procedures.
- Community communication.
- Well-trained emergency responders.

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The NRC 2005 study included an evaluation of 50 incidents of public evacuation involving 1,000 or more people. The evacuations studied were initiated in response to natural disasters, technological hazards and malevolent acts occurring between January 1, 1990 and June 30, 2003. The report indicated that public familiarity with alerting methods and door-to-door notification were statistically significant factors for the efficiency of evacuation. The report also indicated that many communities are making improvements to response capabilities by modernizing communication systems, improving traffic flow, local education awareness and developing interagency and cross-boundary coordination plans.

Regardless of size, large or small population groups can be evacuated effectively with minimal risk of injury or death. In the NRC report, only six of the 50 cases studied involved deaths from the hazard and of those six, only one involved death from the evacuation itself (NRC 2005).

However, in 2005, not long after this report was published, the gulf coast of the United States was hit by a series of hurricanes that resulted in the evacuation of approximately 5 million people. During the evacuation that accompanied Hurricane Rita in Houston, Texas, 106 people were reported to have died as a direct result of the evacuation. It is estimated that at least two-thirds of the evacuees did not need to evacuate but did so because of poor communication, fear and poor traffic management (NRC 2008).

The emergency planning process for radiological incidents should include effective traffic management plans and communications plans, including pre-scripted messages, provisions for evacuation of special needs populations, such as children in schools and child care facilities, people in institutions and people who have impaired mobility or lack personal transportation.

The degree of protection provided by structures is affected by factors such as attenuation of gamma radiation (shielding) by structural components (the mass of walls, ceilings, etc.) and outside/inside air exchange rates (see Figure 2-1). The use of large structures, such as shopping centers, schools, churches and commercial buildings, as collection points during evacuation mobilization will generally provide greater protection against gamma radiation than use of small structures. As with evacuation, delay in taking shelter during plume passage will result in higher exposure to radiation.

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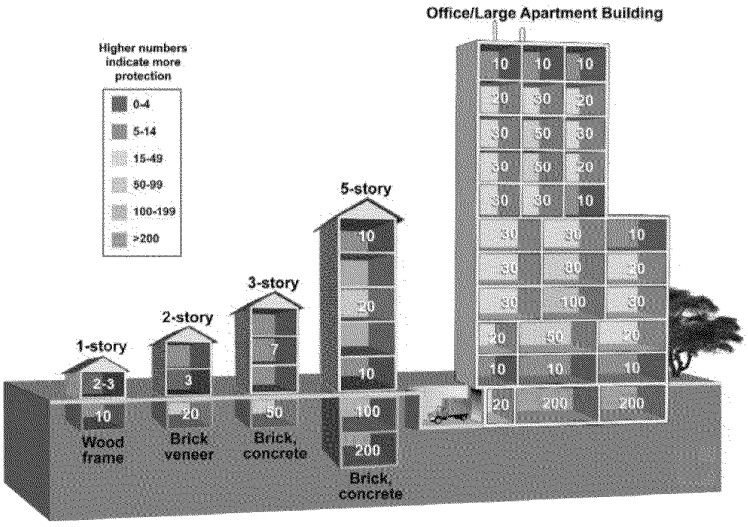
Figure 2-1: Exposure reduction from external radiation from nuclear fallout as a function of building type and location.



The numbers represent dose reduction factors. A dose reduction factor of 10 indicates that a person in that area would receive 1/10th of the dose of a person in the open. A dose reduction factor of 200 indicates that a person in that area would receive 1/200th of the dose of a person out in the open. Figure taken from *Planning Guidance for Response to a Nuclear Detonation*, *Second Edition*, National Security Staff Interagency Policy Coordination Subcommittee for Preparedness and Response to Radiological and Nuclear Threats, June 2010, courtesy of Lawrence Livermore National Laboratory. The protection factors in this figure are specific to nuclear detonation fallout, but the variations in factors throughout typical buildings may be informative for other airborne radiological releases.

2.3.4. Considerations for Potassium Iodide (KI)

FDA updated its guidance on the use of KI as a thyroid blocking agent during radiological emergencies in 2001 (FDA 2001 and FDA 2002). FDA based these dose recommendations on a review of the thyroid cancer data from the Chernobyl reactor accident of April 1986 and the experience of Poland in administering KI following the Chernobyl release (FDA 2001).

FDA recommends the following—

- Children 0-18 years of age: Administer KI when the projected radiation dose to the thyroid from exposure to radioiodine is 5 rem (50 mSv) or greater.
- Pregnant and lactating women: Administer KI when the projected radiation dose to the thyroid from exposure to radioiodine is 5 rem (50 mSv) or greater.
- Adults up to 40 years of age: Administer KI when the projected radiation dose to the thyroid from exposure to radioiodine is 10 rem (100 mSv) or greater.
- Adults over 40 years of age: Administer KI when the projected radiation dose to the thyroid from exposure to radioiodine is over 500 rem (5 Sv) in order to prevent hypothyroidism.

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However, FDA understands that a KI administration program that sets different projected thyroid radioactive exposure thresholds for treatment of different population groups may be logistically impractical to implement during a radiological emergency. In such cases, FDA recommends that KI be administered to both children and adults at the lowest intervention threshold (i.e., >5 rem (50 mSv) projected internal thyroid exposure in children) (FDA 2002).

Note that KI is effective only against uptake of radioiodine, and is best taken prior to or just after exposure. The protective effect of a single dose of KI lasts approximately 24 hours. It should be administered daily until the risk of significant exposure to radioiodine (either by inhalation or ingestion) no longer exists.

It should be noted that adults over 40 need to take KI only in the case of a projected large internal radiation dose to the thyroid (>500 rem (5 Sv)) to prevent hypothyroidism which could lead to lifelong dependence on thyroid hormone replacement therapy. Thyroid irradiation in adults over 40 years of age is associated with an extremely low incidence of cancer (FDA 2001).

Some people should not take KI. As a rule, individuals with known allergy to iodine or with pre-existing thyroid disease (e.g., Graves' disease, thyroid nodules, Hashimoto's thyroiditis) that might predispose them to adverse reactions should avoid KI.

Pregnant women should be given KI for their own protection and for that of the fetus, as iodine (whether stable or radioactive) readily crosses the placenta. However, because of the risk of blocking fetal thyroid function with excess stable iodine, repeat dosing with KI of pregnant women should be avoided. Lactating females should be administered KI for their own protection, as for other young adults, and potentially to reduce the radioiodine content of the breast milk, but not as a means to deliver KI to infants, who should get their KI directly. As for direct administration of KI, stable iodine as a component of breast milk may also pose a risk of hypothyroidism in nursing neonates. Therefore, repeat dosing with KI should be avoided in the lactating mother, except during continuing severe contamination. If repeat dosing of the mother is necessary, the nursing neonate should be monitored.

Once the plume has passed, protective actions such as evacuation and/or sheltering-in-place and food control measures to limit exposure to radioiodine should be implemented and the administration of KI should be suspended. Food control measures include providing the public with non-contaminated food supplies while awaiting the eventual radioactive decay of contaminated food. Consumption of contaminated food may be permitted on a case-by-case basis after surveying the foodstuffs and determining the level of contamination consistent with FDA food and animal feeds guidance. As a result of radioactive decay, grain products and canned milk and vegetables from sources affected by radioactive fallout will not present a risk from radioiodine if they have been stored for weeks to months after production.

An RDD is not likely to contain radioiodine, so administration of KI would not be necessary in such incidents. The administration of other prophylactic drugs should be evaluated on a case-by-case basis depending on the nature of the event and the radioisotopes involved. For more information on radiological prophylactics and treatments, see:
http://www.fda.gov/Drugs/EmergencyPreparedness/BioterrorismandDrugPreparedness.

2.3.5. PAGs and Nuclear Facilities Emergency Planning Zones (EPZ)

Under NRC regulations, before a nuclear power reactor may be issued a license, the NRC must find that licensee, state and local emergency plans are adequate and that they can be implemented. For nuclear power reactors, there is a plume exposure EPZ within a 10 mile (16.1 km) radius of the plant and for a

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separate ingestion pathway EPZ within a 50 mile (80.5 km) radius. The sizes of these EPZs were developed by the NRC/EPA Task Force Report on Emergency Planning, NUREG-0396/EPA 520/1-7-016 and are based, in part, on the numerical values of the PAGs for the plume exposure and ingestion pathway EPZ. The licensee develops and maintains a detailed emergency plan for its facility while state and local authorities within the EPZ develop and maintain detailed emergency response plans for their respective jurisdictions. Guidance to these licensees, states and local agencies for developing these emergency response plans, including guidance on arrangements for implementing immediate protective actions is primarily contained in NUREG-0654/FEMA-REP-1 (NRC 1980)[10] and supplemented with other guidance issued by NRC (for licensees) and FEMA (for off-site response organizations).

Planning for incidents at other types of nuclear facilities should be developed using similar considerations. Emergency preparedness requirements for non-power reactors (e.g., test and research facilities) are provided in 10 CFR Part 50 Appendix E with supporting guidance in NRC Regulatory Guide 2.6, "Emergency Planning for Research and Test Reactors." Emergency preparedness requirements for fuel cycle and materials facilities are provided in 10 CFR Parts 30, 40, and 70 with supporting guidance in NRC Regulatory Guide 3.67, "Standard Format and Content for Emergency Plans for Fuel Cycle and Materials Facilities." Because of the relatively limited number and diverse nature of these facilities, the size of the EPZs, is determined, if needed, on a case-by-case basis for reactors with an authorized power level less than 250 MW thermal.

Within an EPZ, an area should be pre-designated for immediate response based on specified plant conditions prior to a release, or, given a release, prior to the availability of information on quantities of radioactive materials released. The shape of this area will depend on local topography, as well as political and other boundaries. Additional areas of the EPZ, particularly in the downwind direction, may require evacuation or sheltering-in-place, as determined by dose projections. The size of these areas will be based on the potential magnitude of the release and on an angular spread determined by meteorological conditions and any other relevant factors.

The pre-designated areas for immediate protective action may be reserved for use only in the most severe incidents and in cases when the facility operator cannot provide a quick estimate of projected dose based on actual releases. For lesser incidents, or if the facility operator is able to provide prompt off-site dose projections, the area for immediate protective action may be specified at the time of the incident instead of using a pre-designated area. Regardless of the basis for the initial protective action, radiological assessments need to continue through the duration of the event and if warranted, the initial protective actions extended into additional geographical areas.

Such prompt off-site dose projections may be possible when the facility operator can estimate the potential off-site dose based on information at the facility, using relationships developed during planning that relate abnormal plant conditions and meteorological conditions to potential off-site doses. After the release starts and the release rate is measurable, or when plant conditions or measurements can be used to estimate the characteristics and rate of the release, then these factors, along with atmospheric stability, wind speed and wind direction, can be used to estimate integrated concentrations of radioactive materials as a function of location downwind. Although such projections are useful for initiating protective action,

[10] Immediate protective actions based on in-plant conditions and EPZs established by NUREG-0654/FEMA-REP-1 are not applicable to naval nuclear propulsion plants. The largest naval reactors are rated at less than one-fifth of a large U.S. commercial NPP. In addition, since reactor power is directly linked to propulsion requirements, naval nuclear propulsion plants typically operate at low power when the ship is close to shore where high speeds are not required and are normally shut down when in port. Therefore, less than about 1% of the radioactivity contained in a typical commercial NPP could be released from a naval nuclear propulsion plant, limiting the possible dose to the general public and the size of the area of potential concern. Therefore, there is no need for towns and cities to have special emergency response plans such as those required for cities near commercial NPPs.

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the accuracy of these methods for estimating projected dose will be uncertain prior to confirmatory field measurements because of unknown or uncertain factors affecting environmental pathways, inadequacies of computer modeling and uncertainty in the data for release terms.

The EPZs should be large enough to cover affected urban and rural areas and accommodate the various organizations needed for emergency response.[11] Although the size of the EPZ is based on the maximum distance at which a PAG might be exceeded, the actual boundary of an EPZ should be demarcated by features readily identifiable by people within that area. Such boundaries generally include major topographical features (e.g., rivers, roads, transmission line corridors, rail rights of way) and political boundaries. The EPZ should be further subdivided, using similarly identifiable features, to facilitate implementing protective actions when the entire EPZ is not affected. Maps, showing the boundaries of the EPZ and the sub-areas and evacuation routes should be provided to the public within the EPZ on a periodic basis in a format that will likely be available if the emergency occurs (e.g., inserted sectionsin local phone directories, wall calendars, etc.) EPZs are not necessary at those facilities where it is not possible for PAGs to be exceeded off-site.

2.4. DOSE PROJECTIONS

The PAGs in this chapter are specified in terms of the projected whole body dose. This projected dose is the sum of the effective dose from external exposure to the plume and the committed effective dose from inhaled radionuclides. Guidance is also provided on the thyroid equivalent dose. Further references to effective or organ dose equivalent refer to these two quantities, respectively. The FRMAC Assessment Manuals (DOE 2010a, b)[12] provide detailed methods for estimating projected dose. These methods require knowledge of, or assumptions for, the intensity and duration of exposure and makeuse of standard assumptions on the relation, for each radioisotope, between exposure and dose. Exposure and dose projections should be based on the best estimates available. The FRMAC methods and models may be modified as necessary for specific sites for improved accuracy. Emergency response organizations are encouraged to use the most current, applicable tools and methods for implementing PAGs.

2.4.1. Dose Projection during the Early Phase

PAGs are expressed in terms of projected dose. The calculation of projected doses should be based on realistic dose models, to the extent practicable. Unavoidable dose or doses incurred before the start of the protective action being considered generally should not be included in evaluating the need for protective action. Similarly, doses that may be incurred at later times than those affected by the specific protective action should not be included. As noted earlier, the projection of doses in the early phase needs to include only those exposure pathways that contribute a significant fraction (i.e., more than 10 percent) of the dose to an individual.

In the early phase of an incident, parameters other than projected dose may provide a more appropriate basis for decisions to implement protective actions. When a facility is operating outside its design basis and a substantial release to the environment has started, or is imminent but has not yet occurred, data adequate to directly estimate the projected dose may not be available. Emergency response plans should anticipate specific conditions at the source of a potential release and the possible consequences off-site. Emergency response plans for NPPs and facilities should make use of emergency action levels (EALs), based on in-plant conditions, to trigger notification and initial protective action recommendations to off-

[11] The development of EPZs for nuclear power facilities is discussed in the NUREG 0396.
[12] See FRMAC Assessment folder at http://www.nv.doe.gov/nationalsecurity/homelandsecurity/frmac/manuals.aspx.

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site officials.[13] Once the initial protective actions have been implemented, accident assessment should continue. Although initial assessments may be uncertain, the subsequent assessments will be less uncertain as additional information on facility condition and prognosis, effluent radiation monitor data and environmental data become available. The results of these continuing radiological assessments, including dose projections, should be used as the basis for refining the initial protective actions. In the case of transportation accidents, an RDD or IND, or other incidents that are not related to a facility, it may not be practicable to establish EALs.

Doses that may be incurred from ingestion of food and water, long-term radiation exposure (i.e., longer than four days), radiation exposure to deposited radioactive materials, or long-term inhalation of resuspended materials are chronic exposures for which neither emergency evacuation nor sheltering-in-place are appropriate protective actions. PAGs for the intermediate phase cover these exposure pathways (see Chapter 3).

2.4.2. Duration of Exposure

The projected dose for comparison to the early phase PAGs is calculated for exposure during the first four days following the anticipated (or actual) start of a release. The objective is to encompass the entire period of exposure to the plume and deposited material prior to implementation of any further, longer-term protective action such as relocation. For planning purposes, the four-day period is chosen as the duration of exposure during the early phase because it is a reasonable estimate of the time necessary to make measurements, reach decisions and prepare to implement further protective actions (such as relocation) if necessary. However, officials at the site at the time of the emergency may decide that a different time frame is more appropriate.

For example, doses incurred through ingestion pathways or long-term exposure to deposited radioactive materials take place over a longer time period. Protective actions for such exposures should be based on guidance addressed in Chapter 3.

The projected dose from each radionuclide in a plume is proportional to the time-integrated concentration of the radionuclide in the plume at each location. This concentration will depend on the rate and the duration of the release and meteorological conditions. Release rates will vary with time and this time-dependence cannot usually be predicted accurately. In the absence of more specific information, the release rate may be assumed to be constant.

Another factor affecting the estimation of projected dose is the duration of the plume at a particular location. For purposes of calculating projected dose from most pathways, exposure will start at a particular location when the plume arrives and will end when the plume is no longer present. Exposure from deposited materials will continue for an extended period as long as people are present. Other factors such as the aerodynamic diameter and solubility of particles, shape of the plume and terrain may also affect estimated dose and may be considered on a site- or source- specific basis.

Prediction of time frames for releases is difficult because of the wide range associated with the spectrum of potential incidents. Therefore, planners should consider the possible time periods between an initiating event and arrival of a plume and the duration of releases in relation to the time needed to implement competing protective actions (i.e., evacuation and sheltering-in-place). Analyses of commercial nuclear power reactors (NRC 1975) have shown that some incidents may take several days to develop to the point of a release while others may begin as early as a half hour after an initiating event. Furthermore, the

[13] Immediate protective actions based on in-plant conditions are not applicable to naval nuclear propulsion plants. See Footnote 7 for additional information. In addition, because of differences in design and operation, EALs based on in-plant conditions are not applicable to naval nuclear propulsion plants.

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duration of a release may range from less than 1 hour to several days, with the major portion of the release likely occurring within the first day.

Wind speed also influences radiological exposure rates from a plume. As a general rule, air concentration is inversely related to the wind speed at the point of release. Concentrations are also affected by the turbulence of the air, which tends to increase with wind speed and sunlight and by wandering of the plume, which is greater at the lower wind speeds. This results in higher concentrations generally being associated with low winds near the source and with moderate winds at larger distances. Higher wind speed also shortens the travel time of the plume. Planning information on time frames for releases from nuclear power facilities may be found in references NRC 1978 and EPA 1978. Time frames for releases from other facilities will depend on the characteristics of the facility.

2.4.3. Derived Response Levels and Dose Conversion Factors

A Derived Response Level (DRL) is a level of radioactivity in an environmental medium that would be expected to produce a dose equal to its corresponding PAG. A Dose Conversion Factor (DCF) is any factor used to change an environmental measurement to dose in the units of concern. Depending on the exposure pathway, other factors besides the DCF may be required to convert an environmental measurement into a dose.

The FRMAC Assessment Manuals (DOE 2010a, b)[14] provide guidance in calculating DRLs and DCFs based on the ICRP dosimetry models (ICRP 60 series). In addition, the FRPCC encourages the use of computational tools such as DOE's Turbo FRMAC and NRC's Radiological Assessment System for Consequence Analysis (RASCAL) as well as other appropriate or more current tools to implement the PAGs.

2.5. EMERGENCY WORKER PRO TECTION

These emergency worker guidelines were developed for a wide range of possible radiological scenarios, from a small transportation accident that may impact a single roadway to an IND that could potentially impact a large geographic region. Therefore, the 5, 10 and 25 rem (50, 100 and 250 mSv) guidelines (Table 2-2) should not be viewed as inflexible limits applicable to the range of early phase emergency actions covered by this guidance. Because of the range of impacts and case-specific information needed, it is impossible to develop a single turn-back dose level for all responders to use in all events, especially those that involve lifesaving operations. Indeed, with proper preparedness measures (training, personal protective equipment (PPE), etc.) most radiological emergencies addressed by this document, even lifesaving operations, may be manageable within the 5 rem (50 mSv) occupational limit. Moreover, Incident Commanders should make every effort to employ the ''as low as reasonably achievable'' (ALARA) principle after an incident. Still, in some incidents doses above the annual occupational 5 rem (50 mSv) dose limit may be unavoidable. For instance, in the case of a catastrophic incident, such as an IND, Incident Commanders may need to consider raising the lifesaving and valuable property (i.e., necessary for public welfare) emergency worker guidelines in order to prevent further loss of life and prevent the spread of massive destruction. It is essential that emergency workers have full knowledge of the associated risks prior to initiating emergency action and medical evaluation of emergency workers after such exposure.

Worker and public protection guidance and standards for normal operations are developed through risk management approaches and are implemented in federal and state regulations (e.g., 10 CFR Part 20; 10 CFR Part 835; 29 CFR Part 1910.1096). However, many factors or decision criteria in a radiological

[14] See FRMAC Assessment folder at http://www.nv.doe.gov/nationalsecurity/homelandsecurity/frmac/manuals.aspx.

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emergency differ from those in normal operations. Although there are times when implementation of standards or guidelines can cause or enhance other risks, these secondary risks can be controlled Standards for normal operations provide a margin of safety that is greater than that in guidelines for emergency response because that margin can be provided in a manner that ensures no significant increase in public health risk or detriment to the public welfare. Currently, the development of standards and guidelines for normal operations is done in a manner that provides reasonable assurance that implementation of the standards will not cause more risk than it averts.

Response organizations need to develop plans and protocols that address radiation protection during a radiological incident and that ensure appropriate training is provided to responders and decision makers. Detailed reports on radiation risk, risk management decision making, training and public communication should be consulted in the development of plans, protocols and training materials and may be obtained from organizations such as ICRP, the National Council on Radiation Protection and Measurements (NCRP), International Atomic Energy Agency (IAEA), the American Nuclear Society (ANS) and the Health Physics Society (HPS). Detailed information on the risks of radiological emergency response and worker protection procedures can be found in the FRMAC "Radiological Emergency Response Health and Safety Manual" (DOE 2001) and the NCRP's "Management of Terrorist Events Involving Radioactive Material, Report No. 138" (NCRP 2001) and "Responding to a Radiological or Nuclear Terrorism Incident: A Guide for Decision Makers, Report No. 165" (NCRP 2010).

2.6. CONTROLLING OCCUPATI ONAL EXPOSURE AND DO SES TO EMERGENCY RESPONDERS

This section provides guidance on occupational doses of radiation during an emergency response. In many radiological incidents, actual exposure of workers, including emergency responders, may be controlled to low doses when proper precautions are taken. During some emergencies, radiation exposures to responders may be unavoidable and may have the potential to exceed limits used for normal operations.

However, even in emergency conditions, every reasonable effort should be made to control doses to levels that are as low as practicable (consider NCRP 138[15] and NCRP 165[16] for recommendations that support ALARA).

2.6.1. Maintaining the ALARA Principle

To minimize the risks from exposure to ionizing radiation, employers of emergency responders should prepare emergency response plans and protocols in advance to keep worker exposures ALARA, an acronym for "as low as is reasonably achievable" means making every reasonable effort to maintain exposures to radiation as far below the dose limits in this part as is practical consistent with the purpose for which the activity is undertaken. Plans and protocols should include the following health physics and industrial hygiene practices to the maximum extent possible—

- Minimizing the time spent in the contaminated area.
- Maintaining the maximum distance from sources of radiation.
- Shielding of radiation sources.
- Tailoring of hazard controls to the work performed.
- Properly selecting and using respirators (see 29 CFR Part 1910.134) and other PPE.

[15] "Management of Terrorist Events Involving Radioactive Material, Report No. 138" (NCRP 2001).
[16] "Responding to a Radiological or Nuclear Terrorism Incident: A Guide for Decision Makers, Report No. 165" (NCRP 2010).

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- Using prophylactic medications, where medically appropriate, that either block the uptake or reduce the retention time of radioactive material in the body.

The incident commander's staff should be prepared to identify, to the extent possible, all hazardous conditions or substances and to perform appropriate site hazard analysis. Emergency management plans should include protocols to control worker exposures, establish exposure guidelines in advance and outline procedures for worker protection. Emergency procedures should include provisions for exposure monitoring, worker training commensurate with the hazards involved in response operations and ways to control them and medical monitoring.

2.6.2. Understanding Dose and Risk Relationships

Response worker guidelines are based on cumulative dose constraint levels. These are based on an assumption that doses acquired in response to a radiological incident would be ''once in a lifetime'' doses and that future radiological exposures would be substantially lower.

Recommendations in this document provide a guideline level of 5 rem (50 mSv) for worker protection and alternative response worker guidelines (see Table 2-2) for certain activities where exposures below 5 rem (50 mSv) cannot be maintained. For most radiological incidents, radiation control measures (e.g., minimizing time, maximizing distance, using shielding) will prevent doses from reaching the 5 rem (50 mSv) occupational exposure guide while performing typical emergency response activities such as transportation, firefighting and medical treatment of contaminated victims at hospitals. However, in those situations in which victims are injured or trapped in high radiation areas or can only be reached via high radiation areas, exposure control options may be unavailable or insufficient and doses above 5 rem (50 mSv) may be unavoidable.

Decisions to take response actions that could result in doses in excess of 5 rem (50 mSv) can only be made at the time of the incident, under consideration of the actual situation. In such situations, incident commanders and other responders need to understand the risk posed by such exposures in order to make informed decisions. The Response Worker Guidelines for life and property saving activities in Table 2-2 are provided to assist such decision-making. These guidelines apply to doses incurred over the duration of an emergency and are assumed to be once in a lifetime.

Emergency personnel may be exposed to increased radiation during the unique catastrophic event of an IND detonation resulting in firestorm and widespread destruction of structures. The emergency intervention needed to prevent further destruction and loss of life may result in increased exposure. Exceeding the Response Worker Guidelines in Table 2-2 may be unavoidable in responding to such events. Emergency responders undertaking a mission covered under the response worker guidelines should be informed when radiation control measures may not prevent doses from exceeding the 5 rem (50 mSv), general occupational exposure guideline and should be made fully aware of the sub-chronic and chronic risks involved, including numerical estimates of the risk of delayed health effects.

Table 2-2. Response Worker Guidelines

Guideline	Activity	Condition
5 rem (50 mSv)	All occupational exposures	All reasonably achievable actions have been taken to minimize dose.
10 rem (100 mSv)[a]	Protecting valuable property necessary for public welfare (e.g., a power plant).	Exceeding 5 rem (50 mSv) unavoidable and all appropriate actions taken to reduce dose. Monitoring available to project or

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		measure dose.
25 rem (250 mSv)[b]	Lifesaving or protection of large populations	Exceeding 5 rem (50 mSv) unavoidable and all appropriate actions taken to reduce dose. Monitoring available to project or measure dose.

[a] For potential doses >5 rem (50 mSv), medical monitoring programs should be considered.
[b] In the case of a very large incident, such as an IND, incident commanders may need to consider raising the property and lifesaving response worker guidelines to prevent further loss of life and massive spread of destruction.

The 25 rem (250 mSv) lifesaving response worker guidelines provide assurance that exposures will not result in detrimental deterministic health effects (i.e., prompt or acute effects). However, it could increase the risk of stochastic (chronic) effects, such as the risk of cancer. Response actions that could cause exposures in excess of the 25 rem (250 mSv) Response Worker Guideline should only be undertaken with an understanding of the potential acute effects of radiation to the exposed responder (see Table 2-3) and only when the benefits of the action clearly exceed the associated risks.

The estimated risk of fatal cancer[17] for workers exposed to 10 rem (100 mSv) is slightly less than the corresponding general population risk of 0.6 percent (6 cases per thousand exposed). Workers exposed to 25 rem (250 mSv) have an estimated risk of fatal cancer of 1.5 percent (15 cases perthousand exposed). Because of the latency period of cancer, younger workers face a larger risk of fatal cancer than older workers (for example, when exposed to 25 rem (250 mSv), 20 to 30-year-olds have a 9.1 per thousand risk of premature death, while 40 to 50-year-olds have a 5.3 per thousand risk of premature death).[18]

More specific risk determinations can be made when there is adequate information about the contaminants and the potential for human exposure. EPA's Federal Guidance Report #13 (EPA 1999) and Health Effects Assessment Summary Tables have risk factors for specific radionuclides.

Table 2-3. Acute Radiation Syndrome [a]

Feature or Illness	**Effects of Whole Body Absorbed Dose from external radiation or internal absorption, by dose range in rad**				
	0-100	100-200	200-600	600-800	>800
Nausea, Vomiting	None	5-50%	50-100%	75-100%	90-100%
Time of Onset		3-6 h	2-4 h	1-2 h	<1 h to minutes
Duration		<24 h	<24 h	<48 h	<48 h
Lymphocyte Count	Unaffected	Minimally Decreased	<1000 at 24 h	<500 at 24 h	Decreases within hours
Central Nervous	No	No Impairment	Cognitive	Cognitive	Rapid

[17] Risk per dose of a fatal cancer is assumed to be about $6x10^{-4}$ per rem ($6x10^{-5}$ per mSv). Cancer incidence is assumed to be about $8x10^{-4}$ per rem ($8x10^{-5}$ per mSv). (EPA 1999)

[18] The numerical estimate of cancer risk presented above (from Federal Guidance #13) was obtained by linear extrapolation using the nominal risk estimates based on data from human exposures at high doses and high dose rates. Other methods of extrapolation to the low-dose region could yield higher or lower numerical estimates of cancer deaths. Studies of human populations exposed at low doses are inadequate to demonstrate the actual magnitude of risk at low doses (about 0.1 Sv or 10 rem and below). There is scientific uncertainty about cancer risk in the low-dose region below the range of epidemiological observation and the possibility of no risk cannot be excluded. (EPA 1999)

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System Function	Impairment		impairment for 6-20 h	impairment for > 20 h	incapacitation
Mortality	None	Minimal	Low with aggressive therapy	High	Very High: Significant neurological symptoms indicate lethal dose

Source: Medical Management of Radiological Casualties, Second Edition, Armed Forces Radiobiology Research Institute. Bethesda, MD, April 2003.
[a] Percentage of people receiving whole-body doses within a few hours expected to experience acute health effects.

Prior to 5 rem (50 mSv) guideline being exceeded, workers should be provided the following—

- Site specific training, if no prior training was available, with respect to the risk associated with exposure to ionizing radiation (incident commanders and responders should consider having someone on each team with radiation safety experience).
- A thorough explanation of the latent risks associated with receiving exposures greater than 5 rem (50 mSv).

If the 5 rem (50 mSv) guideline is exceeded, workers should be provided with a medical follow-up and monitoring should be considered.

In addition, these guidelines represent dose constraint levels (e.g., when this level of dose is accumulated, the responder should not take part in the later stages of the response that may significantly increase their dose). Incident commanders and responders need a thorough understanding of the worker exposure guidelines for radiological emergency response, including the associated risks and specific worker protection procedures. The FRMAC "Radiological Emergency Response Health and Safety Manual" (FRMAC 2001) provides detailed information. Additional resources for advance planning are available on the Radiological Emergency Medical Management (REMM) web site: http://www.remm.nlm.gov/.

2.6.3. Occupational Safety Regulations for Radiological Emergency Response

The Occupational Safety and Health Act, requires employers to be responsible for the health and safety of their employees during routine and emergency operations. The primary occupational safety and health standard for emergency response is the Hazardous Waste Operations and Emergency Response (HAZWOPER) standard (29 CFR Part 1910.120).

Many U.S. states operate their own OSHA-approved state plans, which are required to be "at least as effective as" Federal OSHA standards and may impose additional or more stringent requirements.[19] Some states operate "complete" plans that cover both the private sector and state and local government employees, while others cover state and local government employees only. EPA's Worker Protection Standard (40 CFR 311) applies the HAZWOPER standard to state and local workers in states that do not have occupational health and safety plans.

In addition to the Occupational Safety and Health Act, several federal agencies (DOE, NRC and OSHA) and Agreement States issue occupational radiation safety standards (see Table 2-4). The occupational standards are not guidelines but instead are regulatory limits that cannot be exceeded except under certain

[19] For a list of state plans, see: http://www.osha.gov/dcsp/osp/index.html

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conditions. These occupational limits allow workers to receive radiation exposure during the course of performing their jobs.
Federal and state radiation safety standards recognize that it may be necessary to exceed dose limits to take critical lifesaving actions.

Table 2-4. Regulations for Worker Protection

Agency	Statutory Requirement	Title
Occupational Safety and Health Administration[1]	29 CFR 1910.120	Safety and Health-- HAZWOPER
	29 CFR 1910. 1096	Ionizing Radiation
Environmental Protection Agency[1]	40 CFR 311	Occupational Radiation Protection
Nuclear Regulatory Commission[2]	10 CFR 20	Standards for Protection Against Radiation
Department of Energy[3]	10 CFR 835	Radiation Protection Regulations

1. All states are either regulated by federal regulations or by respective state regulations. 40 CFR 311 applies the HAZWOPER standard in states that do not have their own occupational health and safety program.
2. NRC employees are covered by NRC Management Directive 10.131, ''Protection of NRC Employees Against Ionizing Radiation.'' Section VI, Guidance for Emergency Exposure Controls During Rescue and Recovery Activities, deals specifically with radiation exposure control during emergencies
3. These requirements apply to all DOE employees and contractors (except for Naval Nuclear Propulsion Program (NNPP)) who may be exposed to ionizing radiation as a result of their work for DOE, including work relating to emergency response activities. The NNPP has established requirements consistent with those contained in 10 CFR 835.

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2.7. CONTAMINATION LIMITS AND MONITORING OF THE ENVIRONMENT AND POPULATIONS

Areas under the plume can be expected to contain deposited radioactive materials if aerosols or particulate materials were released during the incident. In extreme cases, individuals and equipment may be highly contaminated and monitoring stations will be required for emergency monitoring, decontamination of individuals and medical evaluations. Equipment should be checked and decontaminated as necessary to avoid the spread of contamination to other locations. This monitoring service would be required for only a few days following plume passage until all such people have been evacuated or relocated.

People working in the parts of the restricted areas in which their dose from the residual radioactivity would exceed 2 mrem (20 µSv) in any hour or 100 mrem (1 mSv) in a year should operate under the controlled conditions established for occupational exposure.

Adults may reenter restricted areas under controlled conditions in accordance with occupational exposure standards. The need for monitoring stations should be evaluated along highways, which serve as the major evacuation or transportation routes, to control surface contamination at exits from the more highly contaminated areas. Decontamination and other measures should be implemented to maintain low-exposure rates at monitoring stations.

A contaminated item should not be released to an unrestricted area. Based on incident and locality specific considerations, it may be acceptable to release contaminated materials if the level of surface contamination is less than two times (2x) the existing background levels. As an alternative to decontamination, contaminated items (i.e., not people or animals) may be retained in the restricted area while the radiological contamination decays.

2.8. SURFACE CONTAMINATION CONTROL

Surface contamination must be controlled both before and after relocation protective actions are implemented. The principal exposure pathways for loose surface contamination on people, clothing and equipment are:

- internal doses from ingestion by direct transfer;
- internal doses from inhalation of resuspended materials;
- beta dose to skin from contaminated skin or clothing or from nearby surfaces;
- dose to the whole body from external gamma radiation;
- internal dose from absorption of contamination into wounds.

The contamination limit should be influenced by the potential for the contamination to be ingested, inhaled or transferred to other locations. Therefore, it is reasonable to establish lower limits for surfaces where contamination is loose than for surfaces where the contamination is fixed (except for skin). The expected period of exposure from fixed contamination on skin would be longer so a lower limit would be justified.

It is not practical to set contamination limits significantly lower than residual contamination levels in uncontrolled areas. Although the contamination levels recommended in this manual are accordingly set high, consideration should be given as the event progresses to using lower contamination control levels (and more sensitive monitoring instruments) once people are removed from areas causing high external doses. Such efforts will minimize cross-contamination of people located outside of the affected areas. For

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events involving fixed nuclear facilities, some evacuation reception centers or shelters will have walk-through portal monitors.

2.8.1. Priorities for Control of Contaminated Areas

The following priorities are recommended—

1. Do not delay urgent medical care for decontamination efforts or for time-consuming protection of attendants, such as donning of additional anti-contamination clothing.
2. In early phase scenarios where it might not be practical or would interfere with other life-saving and public health protection priorities, do not waste effort trying to contain contaminated wash water and be sure to notify sewage treatment plants.
3. Do not allow monitoring and decontamination to delay an ordered evacuation.
4. *When early screening is needed after a major incident*— After plume passage, it may be necessary to establish emergency contamination monitoring stations in areas not qualifying as low background areas. Gamma exposure rates in such areas should be less than 5 millirem (50 µSv) per hour. These monitoring stations should be used only during the early phase after major atmospheric releases to monitor people emerging from possible high exposure areas. The stations should be set up to provide simple (rapid) decontamination if needed and to evaluate whether affected people should undergo more extensive decontamination or other special care. Table 2-5 provides guidance on surface contamination levels for use if such centers are needed.
5. Establish monitoring and personnel decontamination (e.g., bathing) facilities at evacuation centers or other locations in low background areas (less than 0.1 millirem (1 µSv) per hour). *Encourage self-decontamination:* Encourage evacuated people who were exposed in areas where release of particulate materials would have warranted evacuation to change and bag the clothes they were wearing and store them in an area away from people and pets until authorities provide further instructions on their disposition, to wash other exposed surfaces such as cars and trucks and their contents and then report to these centers for monitoring. For more specific considerations on control of contaminated areas refer to "Population Monitoring in Radiation Emergencies: A Guide for State and Local Public Health Planners" (CDC 2007).[20] Table 2-6 provides surface contamination guidance. These screening levels are examples derived primarily on the basis of easily measurable radiation levels using portable instruments.
6. After the relocation area has been established, consider the need to set up monitoring and decontamination stations at exits from the more highly contaminated parts of the area. Low levels of contamination may be undetectable because of high background radiation levels at these locations. Monitoring should be done at lowest practical background levels. Nevertheless, these individuals should be advised to bathe and change clothes at their first opportunity—no later than within the next 24 hours. If, after decontamination, people still exceed the limits for the station, they should be sent for further decontamination or for medical or other special attention.

[20] See: http://emergency.cdc.gov/radiation/pdf/population-monitoring-guide.pdf

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Table 2-5. Recommended Surface Contamination Screening Levels for Emergency Screening of People and Objects at Monitoring Station in High Background Radiation Areas (0.1 mR/h to 1 mR/h Gamma Exposure Rate)[a]

Condition	Appropriate detection instrument reading	Recommended Action
Before Decontamination	<2x existing background	Unconditional release
	>2x existing background	Decontaminate. Equipment may be stored or disposed of as appropriate.
After Decontamination	<2x existing background	Unconditional release
	>2x existing background	Continue to decontaminate or refer to low background monitoring and decon station. Equipment may be stored for decay or disposed of as appropriate.

[b] Monitoring stations in such high exposure rate areas are for use only during the early phase of an incident involving major atmospheric releases of particulates. Otherwise use Table 2-6.

Table 2-6. Recommended Surface Contamination Screening Levels for People[a] and Objects at Monitoring Stations in Low Background Radiation Areas (<0.1 mR/h Gamma Exposure Rate)[b]

Condition	Appropriate detection instrument reading	Recommended Action
Before decontamination	<2x existing background	Unconditional release
	>2x existing background	Decontaminate
After simple[c] decontamination effort	<2x existing background	Unconditional release
	>2x existing background	Full decontamination
After full[d] decontamination effort	<2x existing background	Unconditional release
	>2x existing background	Continue to decontaminate people Release animals and equipment
After additional full decontamination effort	<2x existing background	Unconditional full release
	>2x existing background	Send people for special evaluation Release animals and equipment

[a] People reporting to monitoring stations in low background radiation areas have been previously instructed to change and bag clothes, wash other exposed surfaces such as cars and their contents and then report to these centers for monitoring.
[b] Levels higher than 2x existing background (not to exceed the meter reading corresponding to 0.1 mR/h) may be used to speed the monitoring of evacuees in very low background areas.
[c] Flushing with water and wiping is an example of a simple decontamination effort.
[d] Washing or gentle scrubbing with soap or other mild detergent followed by flushing is an example of a full decontamination effort.

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KEY POINTS IN CHAPTER 2 – EARLY PHASE

- The principal protective actions for the early phase are evacuation or sheltering-in-place. Evacuation is the urgent removal of people from an area to avoid or reduce high-level, short-term exposure from the plume or deposited activity. Sheltering-in-place refers to the use of a readily available structure that will provide protection from exposure to the plume.
- The PAG for evacuation or sheltering-in-place is a projected whole body dose of 1 to 5 rem (10 – 50 mSv) total effective dose (TED) over four days.
- Evacuation is appropriate when its risks and secondary effects are less severe than the risk of the projected radiation dose. Evacuation will be most effective in avoiding dose if completed before plume arrival.
- In general, sheltering-in-place should be preferred to evacuation whenever it provides equal or greater protection. After confirmation that the plume has passed, continued sheltering-in-place should be re-evaluated by public officials.
- The administration of KI to partially block the uptake of radioiodines by the thyroid is a supplemental protective action. The PAG for administration of KI is 5 rem (50 mSv) projected child thyroid dose. Other medical countermeasures are available, as well.
- Dose calculations for PAGs are made using the DCF and DRL calculation methods referenced in the FRMAC Assessment Manuals. Emergency response organizations are encouraged to use the most current, applicable tools and methods for implementing the PAGs.
- Response worker guidelines of 5, 10 or 25 rem (50, 100 or 250 mSv) are based on the urgency of activities and knowledge of the risks involved.

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CHAPTER 3 – INTERMEDIATE PHASE PROTECTIVE ACTION GUIDES

3.1. INTRODUCTION

This chapter presents PAGs for the intermediate phase and provides guidance for the implementation of corresponding protective actions. A PAG is the projected dose to an individual from the release of radioactive material at which a specific protective action should be taken to reduce or avoid that dose. The intermediate phase is defined as the period beginning after the source and releases have been brought under control and environmental measurements are available for use as a basis for decisions on protective actions and extending until these protective actions are terminated. The intermediate phase may last from weeks to months; but is assumed to last for one year for purposes of dose projection.

During the early phase, decisions must be made and implemented quickly by state and local officials before federal assistance is available. In contrast, many decisions and actions during the intermediate phase may be taken after federal resources are present, as described in the Nuclear/Radiological Incident Annex of the National Response Framework (FEMA 2008 a, b). Decisions will be made during the intermediate phase concerning whether particular areas or properties from which people have been evacuated will be decontaminated and reoccupied or the occupants relocated for an extended period.

This chapter provides the PAGs and corresponding protective actions for use by state and local officials in developing their radiological emergency response plans to protect the public from exposure to radiation from deposited radioactive materials. Due to the wide variety of types of radiological incidents and radionuclide releases that could occur, it is not practical to provide implementing guidance for every possible situation.

This chapter also provides guidance for translating radiological conditions in the environment into projected doses that serve as the basis for decisions to take appropriate protective actions and basic planning guidance on reentry as informed by the Operational Guidelines (DOE 2009).

3.2. EXPOSURE PATHWAYS DURING THE INTERMEDIATE PHASE

During the intermediate phase, the principal exposure pathways for the public occupying areas contaminated with deposited radioactive materials are:

- **exposure of the whole body** to external gamma radiation from deposited radioactive materials (groundshine). External gamma radiation is the expected dominant pathway for reactor accidents and incidents involving RDDs and INDs;
- **internal exposure** from the inhalation of resuspended materials;
- **internal exposure** from the ingestion of food and water.

Other potentially significant exposure pathways include exposure to beta radiation from surface contamination and direct ingestion of contaminated soil. These pathways are not expected to be controlling for NPP incidents (Aaberg 1989).

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3.3. THE PROTECTIVE ACTIO N GUIDES AND PROTECT IVE A CTIONS FOR THE INTERMEDIATE PHA SE: RELOCATION AND D OSE REDUCTION

The principal protective actions for reducing exposure of the public to deposited radioactive materials are:

- relocation;
- decontamination;
- shielding;
- time limits on exposure;
- control of the spread of surface contamination.

The most effective of these actions is relocation—the removal or continued exclusion of people (households) from contaminated areas to avoid chronic radiation exposure. Relocation is highly disruptive and therefore only implemented when the dose is sufficiently high to warrant it. The PAG for relocation is 2 rem (20 mSv) projected over the first year of exposure. After the first year, the PAG for relocation is 0.5 rem (5 mSv) per year.

The PAG level for relocation applies to doses that can be avoided by relocation; doses already incurred prior to relocation are not included in the calculations. PAGs for protection from deposited radioactivity during the intermediate phase are summarized in Table 3-1. The basis for these values is presented in detail in Chapters 4 and 7 and Appendix E of the 1992 PAG Manual, available online as a historical reference at http://www.epa.gov/radiation/rert/pags.html. The decision to relocate will be considered on a case-by-case basis. Efforts to decontaminate and remediate the contaminated area and the shielding offered by buildings and the residency factor attributable to the building, must be considered to see if the second year PAG (0.5 rem (5 mSv) in a year) will be exceeded.

Avoiding exceedance of the relocation PAGs may not be easy for the radionuclides most likely associated with RDDs because of their longer half-lives. If these radionuclides are released, it may be necessary to relocate people in the affected areas even if exposure is less than 2 rem (20 mSv) in the first yearprovided decontamination and remediation measures during the first year are unsuccessful.

In most scenarios, relocation decisions will be based on doses from whole-body and internal exposure from inhalation of resuspended contamination. Food and milk ingestion dose should be considered separately with decisions based on the FDA PAGs.[21]

Other protective actions, such as simple dose reduction techniques, can be applied in areas where levels of deposited radioactivity are not high enough to warrant relocation. Dose reduction actions can range from the simple—scrubbing or flushing surfaces, removal and disposal of small spots of highly contaminated soil (e.g., from settlement of water) and spending more time than usual in lower exposure rate areas (e.g., indoors)—to the difficult and time consuming processes of removal, disposal and replacement of contaminated surfaces. The simple processes would probably be most appropriate in contaminated areas outside the relocation area. Many of these can be carried out by the residents with support from officials for monitoring and guidance on appropriate actions and disposal. The more difficult processes will be appropriate for recovery of areas where contamination is fixed (not removable) and from which the population is relocated.

[21] Accidental Radioactive Contamination of Human Food and Animal Feeds: Recommendations for State and Local Agencies, FDA 1998, available online: http://www.fda.gov/downloads/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/UCM094513.pdf

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Large areas may have to be restricted under these PAGs. As the land area increases, protective actions become more difficult and costly to implement, especially when the affected area is densely populated. There may be situations where full implementation of early and intermediate phase protective actions is impracticable (e.g., a release in a large city). Informed judgment must be exercised to assure priority of protection for individuals in areas having the highest exposure rates.

Table 3-1. Protective Action Guides for Exposure to Deposited Radioactivity during the Intermediate Phase of a Radiological Incident

Protective Action Recommendation	PAG (Projected Dose)[a]	Comments
Relocate the general population[b]	≥ 2 rem (20 mSv) in the first year, 0.5 rem (5 mSv)/year in the second and subsequent years	Projected dose over one year
Apply simple dose reduction techniques[c]	< 2 rem (20 mSv)	These protective actions should be taken to reduce doses to as low as practicable levels

[a]Projected dose refers to the dose that would be received in the absence of shielding from structures or the application of dose reduction techniques. These PAGs may not provide adequate protection from some long-lived radionuclides (see Section 3.7).
[b]People previously evacuated from areas outside the relocation zone defined by this PAG may return to occupy their residences. Cases involving relocation of people at high risk from such action (e.g., patients under intensive care) may be evaluated individually.
[c]Simple dose reduction techniques include scrubbing or flushing hard surfaces, minor removal of soil from spots where radioactive materials have concentrated and spending more time than usual indoors or in other low exposure rate areas.

3.3.1. The Population Affected

The PAGs for relocation are intended for use in establishing the boundary of a relocation area within an area where radioactive materials have been deposited. The relocation PAGs have been established at a level that will provide adequate protection for the general population, including higher risk groups such as children and fetuses. People residing in contaminated areas outside the relocation area will be at some risk from radiation dose. Therefore, guidance on the reduction of dose during the first year to residents outside this zone is also provided. Monitoring and simple dose reduction efforts are recommended in these areas to reduce doses to the extent practical. Such actions are unlikely to be practical where the dosereduction achieved is less than 10 percent.

Affected populations may perceive that intermediate phase protective actions are not consistent with those taken in the early phase. Early-phase decisions on sheltering-in-place and evacuation may have been implemented prior to verification of the path of the plume. Therefore, some people may have been evacuated from areas where validated doses are much lower than were projected. Others who were in the path of the plume may have been sheltered or not protected at all. During the intermediate phase of the response, dose projections may be revised based on environmental measurements. People should be relocated from areas where the projected dose exceeds the PAG for relocation without regard to prior evacuation status.

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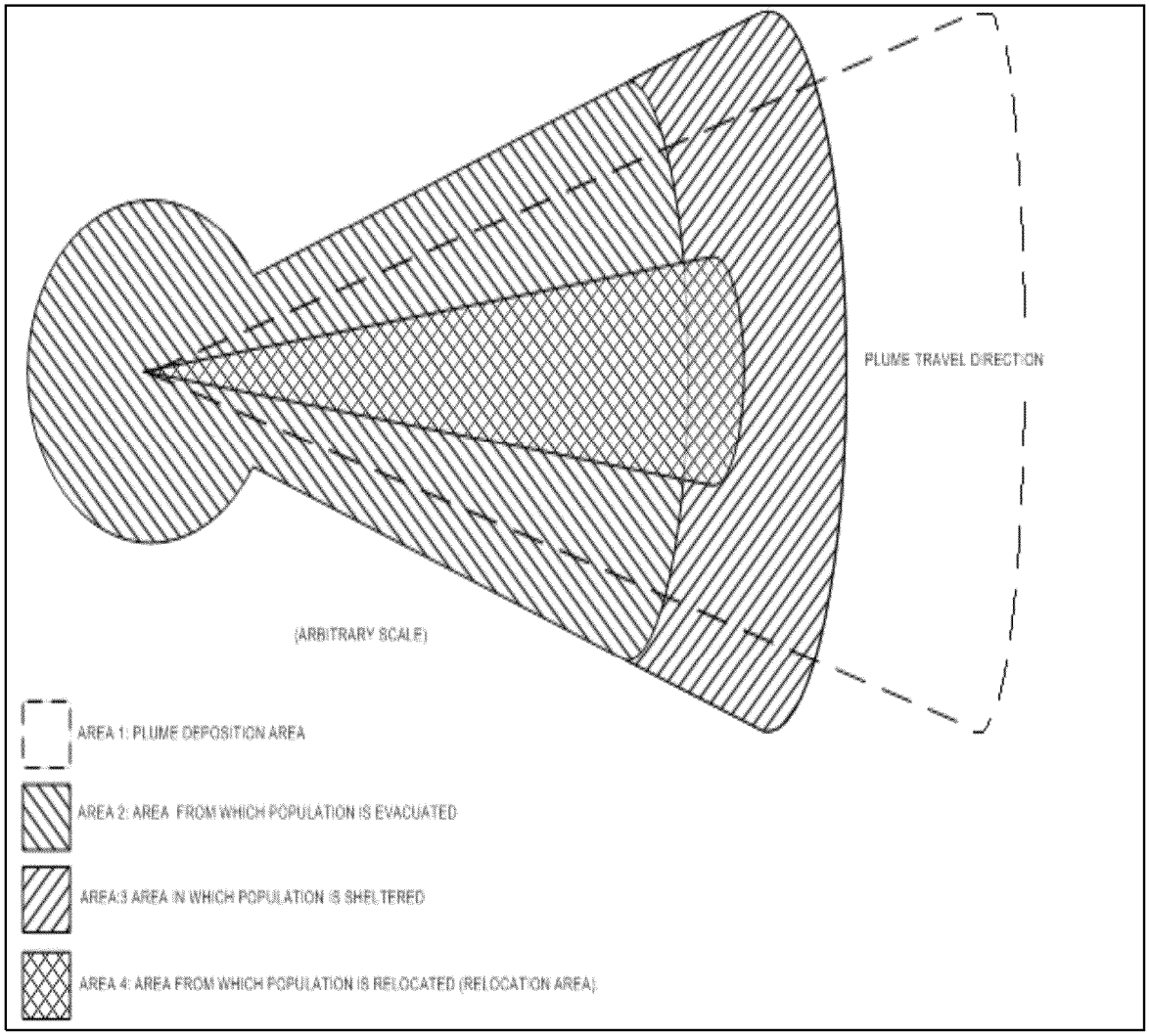

Figure 3-1. Generalized Protective Action Areas for NPP Incident

3.3.2. Areas Involved

Figure 3-1 provides a generalized example of the areas affected by different protective actions. Area 1 represents the plume deposition area. (In reality, variations in meteorological conditions would almost certainly produce a more complicated shape, but the same principles would apply.)

In situations such as an NPP accident, where early warning is given prior to a release of radioactive materials, people may already have been evacuated from Area 2 and sheltered in Area 3. People who have been evacuated from Area 2 or sheltered in Area 3 may go home if environmental monitoring verifies that their residences are outside the plume deposition area (Area 1).

Area 4 is the relocation area where projected doses are equal to or greater than the relocation PAG. People residing just outside the boundary of the relocation area may receive a dose approaching the PAG for relocation if decontamination or other dose reduction efforts are not implemented.

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Area 1, with the exception of the relocation area, represents the area of contamination that may continue to be occupied by the general public during the intermediate phase. Nevertheless, there will be contamination levels in this area that will require continued monitoring and dose reduction efforts other than relocation. Incident-specific levels below the PAGs may be used to control exposure to contamination. The relative positions of the boundaries shown in Figure 3-1 depend on areas evacuated and sheltered and the radiological and meteorological characteristics of the release. For example, Area 4 (the relocation area) could fall entirely inside Area 2 (area evacuated), so that the only people to be relocated would be those residing in Area 4 who were either missed in the evacuation process or who, because of mobility constraints for their evacuation, had remained sheltered during plume passage.

Establishing the boundary of a relocation area creates three groups of affected people—

- People who have already been evacuated from an area that is now designated as a relocation area and who now must be assigned relocation status.
- People who were not previously evacuated, but who reside inside the relocation area and should now relocate.
- People who were previously evacuated, but reside outside the relocation area and may now return home. A gradual return is recommended.

Small adjustments to the boundary of the relocation area established based on the PAG may be justified based on ease of implementation. For example, the use of a convenient natural boundary could be a logical reason for adjustment of the relocation area. However, such decisions should be supported by demonstration that exposure rates to people not relocated can be promptly reduced by methods otherthan relocation to meet the PAG, as well as the longer dose objectives addressed in Section 3.6.

The relocation PAG applies principally to personal residences but may impact other facilities as well. For example, it could impact work locations, hospitals and park lands as well as the use of highways and other transportation facilities. For each type of facility, the occupancy time of individuals should be taken into account to determine the criteria for using a facility or area. It might be necessary to avoid continuous use of homes in an area because radiation levels are too high. However, a factory or office building in the same area could be used because occupancy times are shorter. Similarly, a highway could be used at higher contamination levels because the exposure time of highway users would be considerably less than the time spent at home.

3.3.3. Priorities

In most cases, protective actions during the intermediate phase will be carried out over a relatively long period of time (e.g., months). Setting priorities will be important, especially when the affected area is so large that it is impractical to relocate members of the public from areas that barely exceed the relocation PAGs. The following priorities are appropriate—

- First, protect all people from doses that could cause acute health effects from all exposure pathways, including previous exposure to the plume.
- Conduct radiological surveys to verify or adjust estimates of radiological impacts.
- Recommend that affected people reduce their exposures by using simple decontamination techniques and remaining indoors.

3.4. SEQUENCE OF EVENTS

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The high-priority decisions on whether to relocate people from high exposure rate areas requires exposure rate measurements and dose analyses. Monitoring and dose assessment will be an ongoing process, with priority given to the areas with the highest exposure rates.

Following passage of the airborne plume, a number of tasks must be accomplished for the timely protection of the public. The general sequence of events is itemized below, but the time frames will overlap.

1. Determine the areas where the projected first-year dose will exceed the 2 rem (20 mSv) relocation PAG and relocate people from those areas, with priority given for people in the highest exposure rate areas.
2. Allow previously evacuated people to return as quickly as possible to areas where field gamma measurements indicate that exposure rates are near normal background levels. If there is a possibility that particles from high deposition areas could drift into the occupied areas, establish a buffer zone to restrict residential use until radiological measurements and assessments confirm that it is no longer necessary. Buffer zones are set with the understanding that conservatism is inherent in the PAGs.
3. Based on isodose-rate boundary (see Section 3.4.1), assign any evacuees who reside within the relocation area to be relocated. Evacuated people whose residence is in the area between the boundary of the plume deposition and the boundary to the relocation area may return gradually as dose projections allow.
4. Evaluate the dose reduction effectiveness of simple decontamination techniques and of sheltering-in-place in response to exposure from partial occupancy of residences and workplaces. Results of these evaluations may influence recommendations for reducing exposure rates for people who are not relocated from areas near, but outside, the relocation area.
5. Control access to and egress from the relocation area. This would be accomplished through control points at roadway accesses to the relocation area.
6. Establish monitoring and decontamination stations to support control of the relocation area.
7. Implement simple decontamination techniques in contaminated areas outside the relocation area, giving priority to areas with higher exposure rates.
8. Collect data needed to establish long-term radiation protection criteria for decontamination and dose reduction and data to determine the effectiveness of various decontamination or other dose reduction techniques.
9. Begin operations to clean up and recover contaminated property in the relocation area.
10. If not already done, evaluate whether food grown or produced within the plume deposition area need to be interdicted per the FDA PAGs and evaluate drinking water systems within the plume deposition area. Provide guidance on planting or harvesting specific agricultural products.

3.4.1. Establishment of Isodose-Rate Lines

As soon as federal or other assistance is available for aerial and ground monitoring, a concentrated effort should begin to establish isodose-rate lines on maps and identify boundaries of the relocation area. Standard maps should be developed on which all response organizations would record monitoring data. Records on monitoring and decontamination of the public and workers should also be collected.

Aerial monitoring can be used to collect data for establishing general patterns of radiation exposure rates and may form the primary basis for the development of dose lines out to the limit of aerial detectability.

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Initially during the early phase, detectability is limited to exposure rate changes of a few times natural background levels. Later during the intermediate phase, more sensitive measurements detect levels of radioactivity that are a small fraction of the natural background. Periodic air sample measurements will also be needed to verify the contribution to dose from inhalation of resuspended materials.

Gamma exposure rates measured at one meter (39 inches) will vary within a very small area because different surfaces have different deposition rates (e.g., smooth surfaces versus heavy vegetation). Rinsing or precipitation could also reduce levels in some areas and raise levels in others where runoff settles. In general, where exposure rates vary within designated areas, dose projections should be estimated using an appropriate average exposure rate.

3.4.2. Dose Projection

The FRMAC Assessment Manuals[22] provide detailed guidance for dose projection and calculating DRLs and DCFs (DOE 2010a, b). The FRMAC Assessment Manuals incorporate the ICRP dosimetry models (ICRP 60 series). In addition, the FRPCC encourages the use of computational tools such as DOE's Turbo FRMAC and NRC's RASCAL or other appropriate tools and methods to implement the PAGs.

The primary dose of interest in the intermediate phase is the sum of the effective dose from external exposure and the committed effective dose from inhalation. The exposure periods of interest are the first year and subsequent years after the incident. Other pathways should also be evaluated and their contributions considered, if significant. For example, anytime alpha-emitting radionuclides are involved, the inhalation of resuspended material must be considered. Although beta exposure will contribute to skin dose, its contribution to the overall risk of health effects from the radionuclides expected to be associated with reactor incidents should not be controlling in comparison to the whole body gamma dose (Aaberg 1989). However, the skin beta dose may be important for particulates deposited or transferred to the skin, as may be the case for an RDD that contains Strontium-90.

The dominant intermediate phase exposure pathway for incidents involving alpha-emitters (e.g. a weapons accident) is inhalation of resuspended material. For these incidents, dispersal of alpha-emitting material must be monitored carefully using proper measurement techniques. It is possible that there will be little or no associated gamma radiation or beta activity.

Calculation of the projected gamma dose from measurements will require knowledge of the principal radionuclides contributing to exposure and their relative abundances. Radiological characteristics can be compiled either through the use of portable gamma spectrometers or by radionuclide analysis of environmental samples. Several measurement locations may be required to determine whether any selective radionuclide deposition occurred as a function of meteorology, surface type, distance from the point of release, or other factors. In accordance with the Nuclear/Radiological Incident Annex to the National Response Framework, DOE, EPA and other federal agencies have the capability to assist state officials in performing environmental measurements, including determination of radiological characteristics of deposited materials (FEMA 2008 a, b).

The gamma exposure rate may decrease rapidly if deposited materials include a significant fraction of short-lived radionuclides. Therefore, the relationship between instantaneous exposure rate and projected first- and second-year annual doses will change as a function of time. These relationships must be established for the particular mix of deposited radioactive materials present at the time of the gamma exposure rate measurement. Over time, residual doses from gamma emitters will depend largely upon the

[22] See FRMAC Assessment folder at http://www.nv.doe.gov/nationalsecurity/homelandsecurity/frmac/manuals.aspx.

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half-lives of the radionuclides involved and could potentially remain significant over many years. It should be noted that natural attenuation as well as nuclear decay can affect long term dose assessments.

Projected dose considers exposure rate reduction from radioactive decay and, generally, weathering. When one also considers the anticipated effects of shielding from normal part time occupancy in homes and other structures, people who are not relocated should receive a dose substantially less than the projected dose. For commonly assumed reactor source-terms, it is estimated that 2 rem (20 mSv) projected dose in the first year will be reduced to about 1.2 rem (12 mSv) by this factor. The application of simple decontamination techniques shortly after the incident can be assumed to provide a further 30 percent or more reduction so that the maximum first year dose to people who are not relocated is expected to be less than 1 rem (10 mSv). Taking account of decay rates assumed to be associated with releases from NPP incidents (SNL 1982) and shielding from partial occupancy and weathering, a projected dose of 2 rem (20 mSv) in the first year is likely to amount to an actual dose of 0.5 rem (5 mSv) or less in the second year. The application of simple dose reduction techniques would reduce the dose further. Calculations supporting these projections are summarized in Table E-6 of the 1992 PAG Manual.[23]

Keeping below the 0.5 rem (5 mSv) PAG for "out-years"—the second year and beyond—may be achieved through natural decay of shorter half-life radioisotopes, through decontamination efforts, or through other means of controlling public exposures (such as limiting access to certain areas). In the case of an RDD, in which a longer half-life radioisotope would likely be utilized, reductions in dose may prove difficult to achieve without longer term measures (see Chapter 4).

Exposure from ingestion of food and water is considered independently of decisions for relocation and decontamination. In rare instances, however, where withdrawal of food or water from use would pose a health risk in itself, relocation may be an appropriate protective action against exposure via ingestion. In this case, the dose from ingestion should be considered along with the projected dose from other exposure pathways for decisions on relocation.

3.4.3. Projected External Gamma Dose

Projected whole body external gamma doses at 1 meter height at particular locations during the first year and second year after the incident are the parameters of interest (DOE 1988). Measurements made at 1 meter to project whole-body dose from gamma radiation should be made with instruments of the "closed window" type to avoid the detection of beta radiation. The environmental information available for calculating these doses is expected to be the current gamma exposure rate at 1 m height and the relative abundance of each radionuclide contributing significantly to that exposure rate. Calculation models are available for predicting future exposure rates as a function of time with consideration of radioactive decay and weathering.

Relocation decisions can generally be made on the basis of the first year projected dose. However, projected doses during the second year are needed for decisions on protective actions for people who are not relocated. DCFs are therefore needed to convert environmental measurements to projected dose during the first year and second year following the incident (See FRMAC Assessment Manuals). Of the many types of environmental measurements that can be made to project whole body external gamma dose, gamma exposure rate in air is the easiest to make and is the most directly linked to gamma dose rate. However, analyses of a few environmental samples (particularly, soil samples) must be coupled with the gamma exposure rate to properly project decreasing dose rates.

[23] The 1992 PAG Manual is available as a historical reference on line at: <http://www.epa.gov/radiation/rert/pags.html>

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In addition, measurements should be conducted to determine the dose reduction factors associated with simple, rapid, decontamination techniques so that these factors can be used in calculating dose to people who are not relocated. However, assumptions about these factors should not be included in calculating projected dose for decisions on relocation. Only dose reductions already accomplished can be considered.

3.4.4. Exposure Limits for People Reentering the Relocation Area

After the relocation area is established, people will need to reenter for a variety of reasons, including recovery activities, retrieval of property, security patrol, operation of vital services and, in some cases, care and feeding of farm and other animals. It may be possible to quickly decontaminate access ways to vital institutions and businesses in certain areas so that they can be occupied by adults either for living (i.e., institutions such as nursing homes and hospitals) or for employment. Clearance for occupancy of such areas will require dose reduction to meet exposure limits (EPA 1987). Dose projections should include both external exposure from deposited material and inhalation of resuspended deposited material for the duration of the planned exposure. People working in areas inside the emergency relocation area should operate under the controlled conditions established for occupational exposure (EPA 1987). The worker dose limitation does not need to include ongoing doses received from living in a contaminated area outside the relocation area. It is also not necessary to consider dose received previously from the plume or groundshine during the early phase of the radiological incident.

3.5. PROTECTIVE ACTION GUIDANCE FOR FOOD AND DRINKING WATER

Information on food and animal feeds protective action guidance is contained in FDA's "Accidental Radioactive Contamination of Human Food and Animal Feeds: Recommendations for State and Local Agencies" (FDA 1998).

EPA is not proposing a specific drinking water PAG at this time. EPA has established enforceable drinking water standards for radionuclides under the Safe Drinking Water Act (SDWA). EPA recommends that to the extent practicable, emergency measures for drinking water be based on the National Primary Drinking Water Regulations (NPDWR) for Radionuclides. The Radionuclides Rule provides states with flexibility when responding to radiological events. If a public water system exceeds the radionuclides standard it must work to get back into compliance as soon as feasible. States have the authority to determine if other corrective actions are needed (e.g. providing alternative water).

However, the Agency recognizes a short-term emergency drinking water guide may be useful for public health protection in light of the Fukushima nuclear power plant accident, which impacted some Japanese drinking water supplies. Input on the appropriateness of, and possible values for, an intermediate phase emergency drinking water PAG is being sought during the public review of this Manual.

While the NPDWR provide for a regulatory standard of 4 mrem/year (beta, photon emitters) based on life-time exposure, international organizations have developed technical approaches and methodologies that have produced a range of emergency guidelines related to drinking water (e.g., the World Health Organization[24], the International Atomic Energy Agency[25]) as have other federal agencies (e.g., the Department of Homeland Security[26], the Food and Drug Administration[27]) and non-federal organizations. EPA is seeking input on an approach and technical rationale for a drinking water PAG designed to help

[24] See: http://www.who.int/water_sanitation_health/dwq/gdwq3rev/en/ and http://www.who.int/hac/crises/jpn/faqs/en/index8.html.
[25] See: http://www-pub.iaea.org/MTCD/publications/PDF/Pub1467_web.pdf.
[26] See: http://ogcms.energy.gov/73fr45029.pdf
[27] See: http://www.fda.gov/downloads/MedicalDevices/.../UCM094513.pdf

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officials select protective actions under emergency conditions when exposures would occur over shorter time periods than those envisioned in the NPDWR.

3.5.1. Monitoring & Characterization of Contaminants

The Radionuclides Rule requires community water systems (CWS) to monitor at each entrypoint to the distribution system to ensure that every customer's water does not exceed the maximum contaminant levels (MCLs) for radionuclides. All CWS are required to monitor for gross alpha, radium-226/228 and uranium. In addition, CWS designated by the state as "vulnerable" or if they use waters contaminated by effluents from nuclear facilities must also conduct monitoring for beta particle and photon radioactivity.

In the event of a radiological event the state, at its own discretion, may exercise regulatory flexibility and require systems to collect samples for radionuclides, including beta particle and photon activity (40 CFR 141.26(c)). For more information about monitoring requirements for the Radionuclides Rule see the "Radionuclides Rule: A Quick Reference Guide" (EPA816-F-01-003, June 2001)[28] or "Implementation Guidance for Radionuclides" (EPA 816-F-00-002, March 2002).[29]

To determine if there is radiological contamination of drinking water sources and the extent to which such contamination is occurring, systems sampling for radionuclides must use approved EPA methods.[30]

3.5.2. Public Notification

If water sample monitoring indicates that contamination levels exceed the MCL for any radionuclide, water systems are required to issue a Tier 2 Public Notification (i.e., within 30 days).

States have the flexibility to elevate the notification if warranted to a Tier 1 Public Notification (i.e., within 24 hours) (40 CFR 141.201(a)(3) Special public notices: Occurrence of a waterborne disease outbreak or other waterborne emergency.

During a radiological event, water systems may be dealing with a number of requirements and operating procedures and may not be prepared to issue public notification. The state may issue public notification on behalf of the water system (40 CFR 141.210(a)). This would allow the state to develop and deliver a consistent message to all affected customers and also allows the system to concentrate its efforts on returning the system to operation and/or returning to compliance in the event of a radionuclides MCL violation. For more information see the Revised Public Notification Handbook (EPA 816-R-09-013, March 2010).[31]

3.5.3. Corrective Actions to Reduce Levels of Contamination

Water distribution systems all incorporate reserve and storage capacity. During the early phase of an incident it is unlikely that contamination could affect water which is directly available for consumption through distribution systems. It would take some time for radionuclides to be deposited from the plume into the supply system water source and then subsequently be distributed. During the early phase, recommendations to the public (i.e., about drinking tap water) should reflect these considerations. The public should be advised that the water is safe to drink unless otherwise informed by state officials. Some

[28] See: http://www.epa.gov/ogwdw/radionuclides/pdfs/qrg_radionuclides.pdf

[29] See: http://water.epa.gov/lawsregs/rulesregs/sdwa/radionuclides/upload/2009_04_16_radionuclides_guide_radionuclides_stateimplementation.pdf

[30] A list of EPA approved analytical methods for Radionuclides is available at: http://www.epa.gov/ogwdw/methods/pdfs/methods/methods_radionuclides.pdf

[31] See: http://water.epa.gov/lawsregs/rulesregs/sdwa/publicnotification/upload/PNrevisedPNHandbookMarch2010.pdf.

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useful and practical actions water systems can take during the intermediate phase to provide drinking water to customers are described below.

Wait for Flow-By
If radionuclides are deposited over a river, a section of the water can become contaminated and can be repeatedly contaminated as rain re-deposits radioactive particles. As this section flows down the river, this section of contaminated water is called a plume. This action calls for closing down any source intake valves along the path of the plume of contaminated water. While the intake valve is closed, no contaminated water can enter the water supply system; therefore the contaminated water is allowed to flow by the system. During this time, the system's existing storage capacity can be depended upon. If the stored water supplies could be depleted before the affected valves can be reopened, treatment of the contaminated water while using available stored water supplies should be considered. This assumes that the treatment technology will be in place or readily accessible. In the event of no other option, contaminated water could be temporarily replaced with large quantities of purchased uncontaminated water.

Treat Contaminated Water
Various treatment options exist for reducing or eliminating the contamination of drinking water by man-made radionuclides. Only a small percentage of all water systems treat specifically for radionuclides. However, typical technologies used to treat water for other contaminants can reduce the concentration of radioactivity. These technologies include coagulation/filtration, ion exchange, lime softening and reverse osmosis. Their actual removal efficiency depends on the radionuclide and the type of treatment.[32]

Activate Existing Connections to Neighboring Systems
If the water supply system is part of a larger, regional supply system, activation of existing connections to a neighboring area could be considered. Most large water systems can establish connections with other large systems for emergency purposes. As in many cases, this option may have already been considered during emergency planning. If this option is implemented, steps must be taken to ensure that the "clean" systems do not become contaminated from water backflow.

Smaller water supply systems (i.e., that serve between 10,000 and 75,000 people), or sparsely populated or rural areas, may not be connected to a neighboring system. In this case, regionalization may be a part of emergency planning to explore. This involves connecting smaller systems to larger systems, thus forming a regional water supply system. This is obviously a long-term proposition, but it does have the added advantage of reducing system vulnerability to water shortages or water quality problems other than those resulting from a radiological incident.

Establish Pipeline Connections to Closest Sources/Systems
Running a pipeline from a "clean" water supply system to various distribution centers located throughout the affected community is a routine means of providing clean water. For example, when water mains must be repaired or cleaned of debris, community water needs have been met through the assembly of temporary pipes and hoses. This is a relatively simple procedure, requiring very little construction and technical expertise. For medium- to long-term emergencies, the construction of a temporary pipeline could be cost-effective. PVC pipe, fire hoses and steel pipe have been used to provide emergency drinking water for periods of up to 2 months when service has been disrupted by earthquakes, drought, or bacterial contamination.

[32] Additional information about treatment options and compliance guidance is available at the following website: http://water.epa.gov/lawsregs/rulesregs/sdwa/radionuclides/compliancehelp.cfm.

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Import Water in Tanker Trucks
If an uncontaminated source of water is close to the affected area, it may be more efficient to arrange to transport water from that source by truck, rail, or barge to distribution centers located throughout the community. The most significant obstacle for the use of this option is the cleanliness and availability of transport vehicles. State and local laws may also affect this option.

Import Bottled Water
Importing bottled water into the affected community is another possible option. The water may come from a nearby water supply system or from a water bottling company. This option may be cost-effective during an emergency if water is needed quickly and if the length of the emergency does not merit long-term action, such as the construction of a temporary pipeline.

Ration Clean Water Supplies
Rationing uncontaminated water is also a possibility. This is particularly true if water reserves can provide each individual in the community with 1 L (0.264G, about 1 qt) of water per day until the contaminated plume has passed, the contaminated water is treated, or the water supply system has returned to normal operating conditions. If this option is chosen, it is important that efficient methods for rationing are in place. Rationing water might also be required if water treatment capabilities are limited. Consider a scheme to ration water as part of emergency planning efforts.

3.6. LONGER-TERM OBJECTIVES OF THE PROTECTIVE ACTION GUIDES FOR THE INTERMEDIATE PHASE

It is an objective of the PAGs to ensure that doses in any single year after the first will not exceed 0.5 rem (5 mSv). For source terms from NPP incidents, the PAG of 2 rem (20 mSv) projected dose in the first year is expected to meet this longer-term objective through radioactive decay, weathering and normal part-time occupancy in structures. If the release contains long-lived radionuclides, decontamination of areas outside the relocation area may be required during the first year to meet these objectives. For situations where it is impractical to meet these objectives through decontamination, relocation should be considered even if the projected first-year dose is lower than the relocation PAG.

Based on the relocation PAGs, reentry guidance can be found in the Reentry Matrix in Section 3.8, as well as in the Preliminary Report on Operational Guidelines Developed for Use in Emergency Preparedness and Response to a Radiological Dispersal Device Incident, Group C (DOE 2009). After the population has been protected in accordance with the PAGs for relocation, return for occupancy of the relocation areas should be governed on the basis of cleanup criteria and late phase cleanup activities should proceed.

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3.7. REENTRY DURING THE EARLY AND INTERMEDIATE PHASES

3.7.1. Assumptions and Definitions

The term reentry is used for emergency workers and members of the public going into radiologically contaminated areas temporarily under controlled conditions.

The incident response is divided into three activity planning phases. Early Phase begins with the incident and may last from hours to days. Intermediate Phase begins with control and characterization of the release; it may overlap early and late phase activity and last from weeks to months. Late Phase begins when recovery actions to reduce radiation in the environment begin and ends when all recovery actions are complete. The matrix below only addresses Early and Intermediate Phase activity.

3.7.2. Approach and Discussion

Interagency guidance informed this section, including—

- "Manual of Protective Action Guides and Protective Actions for Nuclear Incidents" (EPA, 1992)[33].
- "Preliminary Report on Operational Guidelines Developed for Use in Emergency Preparedness and Response to a Radiological Dispersal Device Incident" (DOE 2009)[34].
- FRMAC Assessment Manual (Sandia National Lab, 2010)[35].

The Operational Guidelines include detailed numeric guidance, developed by a multi-agency working group as a follow-up to the RDD/IND Planning Guidance. That work focused specifically on response and recovery for an RDD event; however, that work can be expanded to include isotopes from a variety of incident types.

The Operational Guidelines are informative for this guidance, specifically the discussions about applicable dose-based limits, timeframes and pathways of exposure related to reentry tasks. Food and agriculture guides use FRMAC assessment methods as well as the Operational Guidelines for implementation. These tools allow derivation of decontamination thresholds for the early and intermediate stages of a response.

As part of the U.S. response to the Japanese Fukushima accident, scientists performed dose calculations to ensure that passengers and workers on train trips through contaminated areas do not exceed doses typically received from cosmic radiation during an international flight. DOE's Argonne National Laboratory scientists utilized the RESRAD-RDD tool and hand calculations to approximate the NPP radionuclides.

[33] PAGs Manual online at http://www.epa.gov/rpdweb00/rert/pags.html.
[34] The Operational Guidelines were developed by federal agencies and published in draft form by DOE in February 2009 with DOE reference number DOE/HS-0001; ANL/EVS/TM/09-1, on-line at http://ogcms.energy.gov/review.html.
[35] FRMAC Assessment Manual, Overview and Methods online at: http://www.nv.doe.gov/nationalsecurity/homelandsecurity/frmac/manuals.aspx.

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3.8. REENTRY MATRIX FOLLOWING A RADIOLOGICAL INCIDENT OR ACCIDENT

PHASE	ACTIVITY	SUGGESTED LEVELS	CLEANUP ACTIONS
Early Phase (first 4 days)	**Sheltering or Evacuation for the Public** **Emergency Worker Protection**	**Public**: 1,000-5,000 mrem (10-50 mSv) projected over four days (See Ch. 2). A decision to evacuate weighs anticipated dose against feasibility of evacuating within a determined time frame, along with the risks associated with the evacuation itself. **Emergency Responders**: 5,000/10,000/25,000 mrem (50/100/250 mSv) incurred over the response duration. The higher limits are based on task (e.g., protecting large populations or critical infrastructure or lifesaving). Responder doses will be tracked with dosimeters. Emergency workers have knowledge of the risks associated with radiation exposure, training to protect themselves and dosimeters to track their doses.	It is too early for organized cleanup, due to chaos of the situation and higher priorities such as life-saving activities and clearly identifying shelter and evacuation zones. Any cleanup or decontamination information should focus on personal decontamination. It is doubtful any large-scale effort could change evacuation or shelter recommendations during this period (1st 4 days). Once evacuation is completed, there are simple actions cities can implement themselves: rinsing roofs and streets, street sweeping. The objective of these efforts is to move the bulk amounts of contamination away from occupied areas or areas where reoccupation is a priority. These actions should be based on measured amounts of contamination and priority of the location. Workers may face high dose levels and will need health physics support.
Intermediate Phase (first 30 days and up to a year)	**Relocation for the Public**	**Public**: 2,000 mrem (20 mSv) projected first year, 500 mrem (5 mSv) per year projected in subsequent years (See Ch. 3). In this phase, scientists run dose calculations with RESRAD RDD or Turbo FRMAC; the user can choose sensitive age groups, or enter lower guidelines, if desired. Additionally, local decision makers can adapt the guides with incident-specific considerations and implement variations as needed.	Early cleanup efforts should focus on the removable portion of the contamination: vacuuming, washing, vegetation removal. Vacuuming has the advantage of collecting removable contamination without water or surface impact, but is limited by equipment availability and can also expose the operators to high dose levels as the vacuums collect the contamination. Washing and rinsing are simple to implement, but only move the contamination to less-populated areas and may move contamination deeper into porous surfaces. For unpaved areas, vegetation removal can effectively reduce the amount of contamination present, but is labor intensive and can produce large amount of waste. Having addressed the removable part of the contamination, later efforts can focus on fixed contamination. Paved surface

Intermediate Phase (first 30 days and up to a year)	**Reentry For Use of Critical Infrastructure**	**Public**: 2,000 mrem (20 mSv) in first year (Preliminary Report on Operational Guidelines Developed for Use in Emergency Preparedness and Response to a Radiological Dispersal Device Incident, *Operational Guidelines Group C*). Dosimeters could be considered for the public.
	Radiation Worker Protection	**Radiation Worker Protection**: (dose not to exceed) 5,000 mrem (50 mSv) per year ((*Radiation Protection Guidance to Federal Agencies for Occupational Exposure*, EPA 1987). Radiation workers have knowledge of the risks associated with radiation exposure, training to protect themselves and dosimeters to track their doses. During an incident response, workers (police, waste handlers) needed in contaminated areas could be trained and given dosimeters. The guidance for Radiation Workers applies throughout the response.
	Reentry For Use of Roads and Walkways	**Public**: 2,000 mrem (20 mSv) first year, 500 mrem (5 mSv) per year in subsequent years (*Operational Guidelines, Group E*). While the dose values here are similar to those for Use of Critical Infrastructure above, the derived concentrations measured as triggers are different because the exposure conditions are different.
	Reentry For Access to the Relocation Zone	**Public**: 500 mrem (5 mSv) over one year for temporary access with stay times dependent on reentry tasks and site-specific conditions (*Operational Guidelines, Group D*). 'Stay time' is a term of art used in the radiation safety field. Stay times are the amount of time a person may access the contaminated area. These times vary based upon site-specific factors or incident characteristics such as indoor or outdoor work, sensitive populations and level of radioactivity. Section 7.1 of the Operational Guidelines, "Worker Access to Businesses for Essential Actions," provides tables and graphs of stay times at various limiting concentrations (see Figure 7.5 and Table 7.8). For example, if the maximum surface street removal is very effective, but requires specialized equipment and trained operators. Surface sealing is easier, but leaves the contamination in place, making it viable only in locations where the dose rates are low enough for occupation, or in low-occupancy areas. Repaving roads, lots and other paved surfaces is easy to implement, but can generate significant waste volumes. Unpaved areas can be further remediated by soil skimming (surface removal), deep plowing (turning the top foot or so of soil over) and appropriate chemical soil amendment methods like liming or chelating. As the Intermediate phase progresses, knowledge and experience increases and these methods can be re-applied, refined or customized for problem areas. Decisions about more difficult areas will benefit from professional judgment, additional analyses and application of more sophisticated technologies.

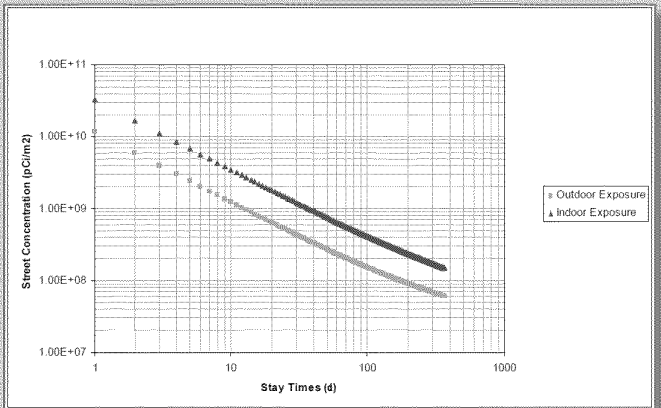

FIGURE 7.5 Limiting Concentrations of Cs-137 for Access to Business

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concentration of Cesium-137 is 3.00E+09 pCi/m^2 (1.11E+08 Bq/m^2), people limited to 500 mrem (5 mSv) should be in the contaminated area less than four 8-hour days if staying outdoors.

This may apply to individuals retrieving belongings from homes or to workers providing security patrols, or even to people reopening businesses in the area. As contamination levels are reduced during cleanup, stay times can be extended and total doses reduced.

Operational Guidelines provide stay times and concentrations for several different sets of assumptions about the exposure. Residents retrieving possessions may spend most of their time indoors, where stay times are longer than they are for outdoors tasks. Stay time recommendations can be used to guide decisions about allowing entry into the contaminated area for a limited time and dose reduction techniques like wearing dust masks, cleaning shoes and car tires upon exit and using time wisely keep radiation exposure 'ALARA' below the *Operational Guideline.*

Table 7.8 Scenario D2-2 Operational Guidelines for 0.5 rem Annual Dose: Residents Access to Houses (Indoor Exposure)

	Surface Street Concentration (pCi/m^2)		
Radionuclide	1 Day	4 Days	12 Days
Am-241	7.51E+07	2.86E+07	1.59E+07
Cf-252	3.50E+08	1.32E+08	7.13E+07
Cm-244	1.27E+08	4.82E+07	2.68E+07
Co-60	2.72E+09	6.87E+08	2.33E+08
Cs-137	1.14E+10	2.94E+09	1.01E+09
Ir-192	9.93E+09	2.54E+09	8.92E+08
Po-210	1.17E+09	3.86E+08	1.74E+08
Pu-238	6.56E+07	2.50E+07	1.39E+07
Pu-239	6.01E+07	2.29E+07	1.27E+07
Ra-226	6.08E+08	2.10E+08	9.97E+07
Sr-90	2.48E+10	7.70E+09	3.18E+09

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KEY POINTS IN CHAPTE R 3 – INTERMEDIATE PHASE

- The principal protective actions for reducing exposure of the public to deposited radioactive materials are relocation, decontamination and time limits on exposure. The PAG for relocation is 2 rem (20 mSv) over the first year of exposure. After the first year, the PAG for relocation is 0.5 rem (5 mSv) per year.
- Boundaries of relocation areas should be established based on the relocation PAG and site-specific geographical features such as rivers, mountains or roadways.
- Exposure limits must be set for people who must enter the relocation area to perform vital services.
- Other protective actions, such as focused decontamination and time limits on exposure, are applied to people in areas where levels of deposited radioactivity are not high enough to warrant relocation.
- Protective action guidance for food is contained in FDA's "Accidental Radioactive Contamination of Human Food and Animal Feeds: Recommendations for State and Local Agencies" (FDA 1998).
- EPA has established enforceable drinking water standards for radionuclides under the SDWA. EPA recommends that to the extent practicable, emergency measures for drinking water be based on the NPDWR for radionuclides. The Radionuclides Rule provides states with flexibility when responding to radiological events. Input on the appropriateness of, and possible values for, an intermediate phase emergency drinking water PAG is being sought during the public review of this Manual.
- To inform temporary reentry into relocation areas, use the Operational Guidelines (DOE 2009).

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CHAPTER 4 – GUIDANCE FOR THE LATE PHASE

4.1. CLEANUP PROCESS

This section describes the remediation cleanup process for the late phase of a nationally significant radiological incident, like a disaster at an NPP, an RDD or an IND. It should be noted that the extent and scope of contamination as a result of an NPP, RDD or IND incident may be at a much larger scale than a site or facility decommissioning or remedial cleanup. This process identifies the late phase remediation or cleanup process steps, including factors for decision makers to consider in determining final cleanup actions. For information on roles, responsibilities and authorities during emergency response and recovery please refer to the National Response Framework: http://www.fema.gov/national-response-framework and specifically for radiological incidents, the Nuclear Radiological Incident Annex: http://www.fema.gov/pdf/about/divisions/thd/IncidentNucRad.pdf (FEMA 2008a, b).

4.1.1. Transitioning from Intermediate to Late Phase Cleanup

The late phase cleanup process begins sometime after the commencement of the intermediate phase and proceeds independently of intermediate phase protective action activities. The transition is characterized by a change in approach, from strategies predominantly driven by urgency, to strategies aimed at both reducing longer-term exposures and improving living conditions. The late phase involves the final cleanup of areas and property at which contamination directly attributable to the incident is present. It is in the late phase that final cleanup decisions are made and final recovery efforts following a radiological incident are implemented.

Unlike the early and intermediate phases of a radiological incident, decision makers will have more time and information during the late phase to allow for better data collection, stakeholder involvement and options analysis. There will be opportunities to involve key stakeholders in providing sound, cost-effective cleanup recommendations. Generally, emergency phase decisions will be made directly by elected public officials, or their designees, with limited stakeholder involvement due to the need to act within a short timeframe. Longer-term decisions should be made with stakeholder involvement and can also include incident-specific technical working groups to provide expert advice to decision makers on impacts, costs and alternatives. Community members will influence decisions such as if and when to allow people to return home to contaminated areas. There will be people living in contaminated areas, outside the evacuation and relocation zones, where efforts to reduce exposures will be ongoing.

Because of the extremely broad range of potential impacts that may occur from NPP incidents, RDDs and INDs (e.g., light contamination of one building to widespread destruction of a major metropolitan area), a process should be used to determine acceptable cleanup criteria based on the societal objectives for expected land uses and the options and approaches available. Implicit in these decisions is the ability to balance health protection with the desire of the community to resume normal life. Radiation protection considerations must be addressed in concert with health, environmental, economic, social, psychological, cultural, ethical, political, and other considerations. It is recognized that experience from existing programs, such as the U.S. EPA's Superfund program, the U.S. NRC's process for decommissioning and decontamination to terminate a nuclear facility license and other national recommendations may be useful in planning cleanup and recovery efforts.

Consistent with the "Framework for Environmental Health Risk Management," mandated by the 1990 Clean Air Act Amendments and published by the Commission on Risk Assessment and Risk Management in 1997, the late phase cleanup process consists of multiple steps, including 1) characterization and stabilization, 2) development of goals and strategies and 3) implementation and

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reoccupancy. Stakeholder involvement should be integrated throughout the process. Characterization in this phase consists of delineation, in detail, of the nature and extent of contamination in areas impacted by the incident. Stabilization is intended to reduce the spread of contamination to clean areas, airborne inhalation hazards and the volume of radioactive waste generated. Establishment of cleanup goals and strategies should consider overall community health, along with a variety of factors described further below; they are based upon anticipated land use and a variety of selection criteria. Key to these steps is the involvement and acceptance of the impacted state and local community. These steps are discussed in more detail below.[36]

4.1.2. Characterization and Stabilization

The first step in the late phase remediation or cleanup process is characterization, or the comprehensive mapping and monitoring of the distribution and level of radioactive contamination. Characterization activities are necessary in the preparation for and verification of a successful remediation or cleanup effort. The late phase characterization work is designed to define, in detail, the nature and extent of the contamination and to provide information needed to develop and evaluate cleanup alternatives.

The characterization performed in support of the late phase will be much more detailed and comprehensive than the earlier characterization work to support PAG decisions made during the early and intermediate phases. It delineates the nature of any actual threat posed to human health or the environment and defines the extent of that threat.

Stabilization techniques are designed to immobilize radioactive contamination on soils, buildings, roads and equipment. This becomes paramount in a large-scale incident where the spread of contamination can occur from natural weathering effects to human and animal interactions with the environment. Stabilization reduces chronic low-level exposures to residual radiation, airborne hazards and volumes of secondary waste. These reductions can result in significant benefits to the long-term recovery in terms of time-to-normalcy and economic recovery.

4.1.3. Goals and Strategies

After late phase characterization and stabilization activities are accomplished, areas impacted by radioactive contamination are documented and defined to the best extent possible. At this point, decision makers must establish cleanup goals and strategies for moving forward. The development of goals and strategies marks the second step in the late phase remediation or final cleanup process. As part of an ongoing iterative process, cleanup goals are informed by the feasibility of cleanup strategies and specific cleanup strategies adjust as experience is gained. That is, risk management goals may be refined as decision makers and stakeholders gain appreciation for what is feasible, what the costs and benefits are and how the process of reducing exposures and risks can improve human and ecological health.

As actual levels for areas are determined, many factors come into play in decision making, such as balancing risk reduction with other factors, background levels of radioactivity and tolerance for voluntary versus involuntary risk. Determining these levels will require consideration of a number of factors—

- The types of contamination; the technical feasibility, cost, timeliness and effectiveness of decontamination measures; and the availability and cost of options for the disposal of wastes.

[36] This cleanup process does not rely on and does not affect any authority, including the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), 42 U.S.C. 9601 et seq. and the National Contingency Plan (NCP), 40 CFR Part 300. This document expresses no view as to the availability of legal authority to implement this process in any particular situation.

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- The size and character of the areas that are contaminated; past and projected future uses for these areas; and the preservation or destruction of places of historical, national, or regional significance.
- Site-specific natural and anthropogenic background levels of radioactivity.
- Estimates of the impacts of both contamination and options for decontamination, on human health, communities, the economy, ecosystems and ecosystem services.
- Public acceptability and intergenerational equity.

Community involvement and sentiment are vital to this process. The stress from both the incident itself as well as the longer term effects of separation from home will be important factors as overall community health is considered. In the United States, a range of one in a population of ten thousand (10^{-4}) to one in a population of one million (10^{-6}) excess cancer incidence outcomes is generally considered protective for both chemical and radioactive carcinogenic contaminant exposures. This range is the regulatory standard generally used in the context of EPA Superfund response actions. The NRC's decommissioning and decontamination process outcomes are usually in or near this range as well. A similar risk range may be an appropriate goal for radiological events that affect areas of comparable size. However, such risk ranges may not be practically achievable for major incidents that result in the contamination of very large areas. In making decisions about cleanup goals and strategies for a particular event, decision makers must balance the desired level of exposure reduction with the extent of the measures that would be necessary to achieve it, in order to maximize overall human welfare.

While it may take many years to achieve final cleanup levels, a timely return to normalcy, including reoccupancy and a viable community, will require a cleanup process that is flexible, iterative and inclusive. Decisions must be made on a site-specific basis and should reflect the interim risks that are reasonable and acceptable to the affected community as active remediation, radioactive decay and natural weathering move the site toward long-term cleanup goals.

Cleanup strategies are adopted as decision makers and stakeholders gain an understanding of all relevant factors. Tradeoffs between alternatives should be considered and balanced so that the best options are chosen. Local acceptance will be a key component of a fully transparent approach to long-term remediation and cleanup. Factors to consider in determining cleanup actions include evaluating:

- areas impacted (e.g., size, location relative to population);
- actions already taken during the early and intermediate phases;
- the ability of a remedy to maintain reliable protection of overall human health and the environment over time;
- assessing the relative performance of treatment technologies on the toxicity, mobility or volume of contaminants;
- the success or effectiveness of the cleanup or remediation as the cleanup progresses (contaminant removal);
- the adverse impacts on human health and the environment that may be posed in the time it takes to implement the remedy and achieve the community-based remediation goals;
- the impacts of alternative levels of clean up on the local and regional economy (e.g., job loss due to closed businesses, job creation due to decontamination and waste handling operations) and on residents' sense of place (e.g., continued limited access to one's home and community until clean up levels have been reached);
- preservation or destruction of places of historical, national, or regional significance;

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- the technical and administrative feasibility of the remedy, including the availability of materials and services needed to implement each component of the option in question;
- the cost of each alternative, including the estimated capital and operation and maintenance costs and net present value of capital and operation and maintenance costs;
- state concurrence with the remedy;
- community support for the remedy.

This may be an iterative process. As experience is gained, adjustments may be required to achieve long-term goals.

4.1.4. Implementation and Reoccupancy

To implement cleanup actions in each community, measurable quantities associated with cleanup goals should be derived taking into account exposures from all potential pathways and through all environmental media (e.g., soil, ground water, surface water, sediment, air, animals or plants). These values typically are derived considering reasonably anticipated future land use, dietary habits and commerce patterns. If meeting acceptable levels based upon the reasonably anticipated post-incident land use is not practicable and cost-effective, decision-makers can look to more restrictive land uses through institutional and engineering controls. This approach is based on the belief that early community involvement focusing on desired post-incident uses of the property will result in expedited, cost-effective and publicly-supported cleanups. Overall community health, including stress factors from the initial event and separation from home or family is a necessary consideration.

In some situations, a site or area may reasonably be anticipated to support a range of uses, so cleanup goals may be different for different subareas of the impacted area. Although it may take years to achieve the final cleanup goals for all land uses, reoccupancy of the affected area will be possible when interim cleanup can reduce short-term exposures to acceptable levels during the time it takes to achieve the long-term goals. There may be institutional or engineering controls placed on some portions of the site to prevent excessive exposures until further active remediation, radioactive decay, or natural weathering allow the site to meet cleanup goals. An example of an institutional control might be a restriction on planting vegetable gardens to avoid ingesting radionuclides that may be taken up by the plant roots from the soil. An example of an engineering control to limit exposures might be adding a layer of pavement or cement over gamma emitting radionuclides that have become fixed in place by sorbing onto the street and sidewalks.

In complex cases such as the situation represented by a wide-area NPP, RDD or IND event, cleanup and reoccupancy are likely to occur subarea by subarea in order of priority and community assessments. Critical infrastructure is likely to have been restored to some level of functionality and further remediation of the infrastructure should be evaluated against the cleanup goal. A community-based and transparent development of priorities would follow, resulting in sequential actions, whereby areas (e.g., residential, commercial) would be remediated and reoccupied utilizing temporary cleanup levels that would be considered acceptable for an interim period of time prior to final cleanup goals being achieved. Land use may need to be changed in a subarea where it is not feasible with a combination of remediation, engineering and institutional controls to support the pre-incident land use in a manner that protects human health. In all cases, an appropriate population health monitoring program should be implemented proportionate to the potential or estimated health risk.

4.1.5. Stakeholder Involvement

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Generally, early (or emergency) phase decisions will be made directly by elected public officials, or their designees, with limited stakeholder involvement due to the need to act within a short timeframe. With additional time and an increased understanding of the situation, there will be opportunities to involve key stakeholders in providing sound, cost-effective cleanup recommendations that are protective of human health and the environment.

Affected citizens should be involved in all phases of cleanup planning and long-term remediation of their communities. Early in the process, decision makers should bring together a broad group of stakeholders, e.g., residents, local business owners, local government officials and others interested in the processes that will be required to restore their communities. The credibility of a community group is a function of its inclusiveness. It must represent all stakeholder interests to ensure it is a voice for the entire community rather than a few interested parties. Empowering individuals to assist in the process is important and effective. The affected local community will need to be involved until the site remediation activities are complete and possibly beyond that if institutional and engineering controls are placed on some subareas of the site.

4.1.6. Cleanup Process Implementation and Organization: An Example

This example, reprinted from the Planning Guidance for Protection and Recovery Following Radiological Dispersal Device (RDD) and Improvised Nuclear Device (IND) Incidents (DHS 2008), describes a hypothetical organization to integrate federal cleanup support activities with state and local governments and the public. In particular, it addresses a scenario where the federal government is expected to be the primary funding entity for cleanup and recovery activities. For some radiological scenarios, states might take the primary leadership role in cleanup and contribute significant resources toward recovery of the site. This example does not address such a scenario, although states may choose to follow a similar process.

a) Cleanup Implementation

This approach describes how federal departments and agencies may coordinate during a response with state and local government counterparts and the public, consistent with the National Response Framework (NRF) (FEMA 2008a) and the National Disaster Recovery Framework (NDRF). The approach does not attempt to provide detailed descriptions of state and local roles and expertise. It is assumed those details will be provided in state and local level planning documents that address radiological/nuclear terrorism incidents.

During the intermediate phase, site cleanup planners should begin the process described below, under the direction of the on-site incident command or unified command (IC/UC) and in close coordination with federal, state and local officials. After early and intermediate phase activities have come to conclusion and only long-term cleanup activities are ongoing, the IC/UC structure may continue to support planning and decision-making for the long-term cleanup. The IC/UC may make personnel changes and structural adaptations to suit the needs of a lengthy, multifaceted and highly visible remediation process. For example, a less formal and structured command, more focused on technical analysis and stakeholder involvement, may be preferable for site extended site cleanup than what is required under emergency circumstances.

Radiological and nuclear incidents cover a broad range of potential scenarios and impacts. This example assumes that the incident is of sufficient size to trigger a state request for federal assistance and that the federal government is the primary funding agent for site cleanup. In particular, the process described for the late phase cleanup assumes an incident of relatively large size. For smaller incidents, all of the elements in this section may not be warranted. The process should be tailored to the circumstances of the particular incident. Decision makers should recognize that for some radiological/nuclear incidents, states

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will take the primary leadership role and contribute significant resources toward cleanup of the site. This section does not address such a scenario, but states may choose to use the process described here.

b) Cleanup Activities Overview

As described earlier in the document, radiological/nuclear emergency responses are often divided roughly into three phases: (1) the early phase, when the plume is active and field data are lacking or not reliable; (2) the intermediate phase, when the plume has passed and field data are available for assessment and analysis; and (3) the late phase, when long-term issues are addressed, such as cleanup of the site. For purposes of this example, the response to a radiological or nuclear incident is divided into two separate, but interrelated and overlapping, processes. The first is comprised of the early and intermediate phases of response, which consists of the immediate and near-term on-scene actions of state, local and federal emergency responders under the IC/UC. On-scene actions include incident stabilization, lifesaving activities, dose reduction actions for members of the public and emergency responders, access control and security, emergency decontamination of persons and property, "hot spot" removal actions and resumption of basic infrastructure functions.

The second process pertains to environmental cleanup, which is initiated soon after the incident (during the intermediate phase) and continues into the late phase. The process starts with convening stakeholders and technical subject matter experts to begin identifying and evaluating options for the cleanup of the site. The environmental cleanup process overlaps the intermediate phase activities described above and should be coordinated with those activities. This process is interrelated with the ongoing intermediate phase activities and the intermediate phase protective actions continue to apply through the late phase until cleanup is complete.

Cleanup planning and discussions should begin as soon as practicable after an incident to allow for selection of key stakeholders and subject matter experts, planning, analyses, contractual processes and cleanup activities. States may choose to pre-select stakeholders for major incident recovery coordination. These activities should proceed in parallel with ongoing intermediate phase activities and coordination between these activities should be maintained. Preliminary remediation activities during the intermediate phase—such as emergency removals, decontamination, resumption of basic infrastructure function and some return to normalcy in accordance with intermediate phase PAGs—should not be delayed for the final site remediation decisions.

A process for addressing environmental cleanup is presented below. This is a flexible process in which numerous factors are considered to achieve an end result that considers local needs and desires, health risks, costs, technical feasibility and other factors. The general process outlined below provides decision makers with input from both technical experts and stakeholder representatives and also provides an opportunity for public comment. The extent and complexity of the process for an actual incident should be tailored to the needs of the specific incident; for smaller incidents, the workgroups discussed below may not be necessary.

The goals of the process described below are: 1) transparency—the basis for cleanup decisions should be available to stakeholder representatives and to the public at large; 2) inclusiveness—representative stakeholders should be involved in decision-making activities; 3) effectiveness—technical subject matter experts should analyze remediation options, consider established dose and risk benchmarks and assess various technologies in order to assist in identifying a final solution that is optimal for the incident; and 4) shared accountability—the final decision to proceed will be made jointly by federal, state and local officials.

Under the NRF and NDRF, FEMA may issue mission assignments to the involved federal agencies, as appropriate, to participate in the overall recovery process. Additional funding may be provided to

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state/local governments to perform response or recovery activities through other mechanisms. The components of the process are as follows:

c) General Management Structure

Planning for the long-term cleanup should begin during the intermediate phase and at that time, a traditional National Incident Management System (NIMS) response structure should still be in place. However, NIMS was developed specifically for emergency management and may not be the most efficient response structure for long-term cleanup. If the cleanup will extend for years, the IC/UC may decide to transition at some point to a different long-term project management structure.

Under the NRF and NIMS, incidents are managed at the lowest possible jurisdictional level. In most cases, this will be at the level of the IC/UC. The IC/UC directs on-scene tactical operations. Responding local, state and federal agencies are represented in the IC/UC and Incident Command Post in accordance with NIMS principles regarding jurisdictional authorities, functional responsibilities and resources provided. For a wide-area radiological incident, multiple Incident Command Posts (ICPs) may be established to manage the incident with an Area Command or Unified Area Command supporting the ICPs and prioritizing resources and activities among them. If the incident happens on a federal facility or involves federal materials, the representatives in the UC may change appropriately and the response will be conducted according to the applicable federal procedures.

Issues that cannot be resolved at the IC/UC or Unified Area Command level may be raised with the Joint Field Office (JFO) and JFO Unified Coordination Group for resolution. The JFO coordinates and prioritizes federal resources and when applicable, issues mission assignments to federal agencies under the Stafford Act. Issues that cannot be resolved at the JFO level may be raised to the DHS National Operations Center senior-level interagency management groups and the White House Homeland Security Council and National Security Council.

Day-to-day tactical management, planning and operations for the cleanup process will be managed at the IC/UC level, but for large-scale cleanups involving significant federal resources, it is expected that the JFO Unified Coordination Group and national level federal officials will review proposed cleanup plans and provide strategic and policy direction. The federal agency(s) with primary responsibility for site cleanup should be represented in the JFO Unified Coordination Group. The IC/UC will need to establish appropriate briefing venues as the cleanup process proceeds, including the affected mayor(s) and governor(s).

The discussion below assumes a traditional NIMS IC/UC structure; if the IC/UC transitions later to a different management structure for a longer-term cleanup, the IC/UC would need to determine the appropriate way to incorporate the workgroups described below into that structure.

This process will be managed by the IC/UC, who ultimately determines the structure and organization of the Incident Command Post, but the discussion below provides one recommended approach for managing the cleanup process within a NIMS ICS response structure. The Incident Command Post Planning Section has the lead for response planning activities, working in conjunction with other sections and would have the lead for development of the cleanup options analysis, working closely with the Operations Section. The NIMS describes the units that make up the Planning Section and allows for additional units to be added depending on site-specific needs. NIMS states that for incidents involving the need to coordinate and manage large amounts of environmental sampling and analytical data from multiple sources, an Environmental Unit may be established within the Planning Section to facilitate interagency environmental data management, monitoring, sampling, analysis, assessment and site cleanup and waste disposal planning. Radiological incidents would involve the collection of not only large amounts of radiological data, but also data related to other environmental and health and safety hazards and therefore

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would likely warrant the establishment of an Environmental Unit in the Planning Section. Planning for FRMAC radiological sampling and monitoring activities will be integrated into the Planning Section and coordinated with other Situation and Environmental Unit data management activities.

The IC/UC may assign the Environmental Unit the responsibility for coordinating the development of the cleanup options analysis. For large incidents requiring more complicated tradeoffs or the evaluation of cleanup goals with broad implications, the IC/UC may choose to establish a separate unit in the Planning Section (for example, a Cleanup Planning Unit) to coordinate the development of the cleanup options analysis. The IC/UC may then convene a technical working group and a stakeholder working group, managed by the Environmental or Cleanup Planning Unit, to analyze cleanup options and develop recommendations. The Environmental or Cleanup Planning Unit would coordinate working group processes and interactions and report the results of the cleanup options analysis and workgroup efforts to the IC/UC through the Planning Section Chief.

The development and completion of the cleanup options analysis is expected to be an iterative process and for large incidents, the cleanup will likely proceed in phases, most likely from the "outside in" toward the most contaminated areas. The extent of the analysis and process used to develop it would be tailored to the needs of the specific incident, but the following working groups may be convened by the IC/UC to assist decision makers in the cleanup options process, particularly for large or complex cleanups.

d) Technical Working Group

A technical working group should be convened as soon as practicable, ideally within days or weeks of the incident. The technical working group would be managed by the Planning Section Unit that is assigned responsibility for the cleanup options analysis. The technical working group may or may not be physically located at the ICP. The group may review data and documents, provide input electronically and meet with incident management officials. The group may also be asked to participate in meetings with the JFO Unified Coordination Group if needed.

Function: The technical working group provides multi-agency, multi-disciplinary expert input on the cleanup options analysis, including advice on technical issues, analysis of relevant regulatory requirements and guidelines, risk analyses and development of cleanup options. The technical working group would provide expert technical input to the IC/UC; it would not be a decision-making body.

Makeup: The technical working group should include selected federal, state, local and private sector subject matter experts in such fields as environmental fate and transport modeling, risk analysis, technical remediation options analysis, cost, risk and benefit analysis, health physics and radiation protection, construction remediation practices and relevant regulatory requirements. The exact selection and balance of subject matter experts is incident-specific. The Advisory Team for Environment, Food and Health is comprised of federal radiological experts in various fields that may warrant representation on the technical working group, therefore, the Team or some of its members may be incorporated into this group as appropriate.

e) Stakeholder Working Group

The stakeholder working group should be convened as soon as practicable, ideally within days or weeks of the incident. The stakeholder working group would be managed by the Planning Section Unit that is assigned responsibility for the cleanup options analysis. The IC/UC may direct the Public Information Officer (PIO) (who would coordinate with the Joint Information Center (JIC)) to work with the group, including establishing a process for the group to report out its recommendations. How and where the stakeholder working group would meet to review information and provide its input would need to be determined in conjunction with the group members. The stakeholder working group may also be asked to participate in meetings with the JFO Unified Coordination Group if needed.

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Function: The function of the stakeholder working group is to provide input to the IC/UC concerning local needs and desires for site recovery, proposed cleanup options and other recommendations. The group should present local goals for the use of the site, prioritizing current and future potential land uses and functions, such as utilities and infrastructure, light industrial, downtown business and residential land uses. The stakeholder working group would not be a decision-making body.

Makeup: The stakeholder working group should include selected federal, state and local representatives, local non-governmental representatives as well as local and regional business stakeholders. The exact selection and balance of stakeholders is incident specific.

f) Activities: Cleanup Planning and Recommendations

The IC/UC directs the management of the cleanup options analysis through the Planning Section. Technical and stakeholder working groups assist in performing analyses and developing cleanup options and provide input to the IC/UC and may be asked to participate in meetings with the JFO Unified Coordination Group. The IC/UC reviews cleanup options analysis and selects a proposed approach for site cleanup in close coordination with federal, state and local officials. Again, depending on the incident size, it may be necessary to conduct the cleanup in phases. Thus, decisions on cleanup approaches may also be made in phases. As appropriate for the magnitude of the cleanup task, the IC/UC would brief relevant federal, state and local government officials on proposed cleanup plans for approval. This may involve the office of the affected mayor and governor. At the federal level, it may involve the JFO Unified Coordination Group and higher-level officials.

g) Public Review of Decision

The IC/UC should work with the PIO and JIC to publish a summary of the process, the options analyzed and the recommendations for public comments. Public meetings should also be convened at appropriate times. Public comments should be considered and incorporated as appropriate. A reconvening of the stakeholder or technical working group may be useful for resolving particular issues.

h) Execution of Cleanup and Peer Review

Assuming a Presidential declaration of a major disaster or emergency, FEMA may issue mission assignments to the federal departments and agencies that have the capability to perform the required cleanup, remediation, or debris removal activities. Cleanup activities should commence as quickly as practicable and allow for incremental reoccupation of areas as cleanup proceeds. For significant decontamination efforts, the IC/UC may choose to employ a technical peer review advisory committee to conduct a review of the effectiveness of the cleanup. The technical peer review committee would evaluate pre- and post-decontamination sampling data, the decontamination plan and any other information key to assessing the effectiveness of the cleanup.

4.2. DISPOSAL OF LARGE VOLUMES OF RADIOLOGICAL WASTE

If a large scale radiological incident were to occur in the United States, the complexity of radiological waste disposal would depend on the magnitude of the release and the decisions related to site cleanup, both of which will determine the amount and types of waste requiring disposal. Primary responsibility for waste management decisions falls to state and local officials. If there is a limited radiological incident with relatively small waste volumes, existing licensed radioactive waste capacity is available and may be sufficient to address waste disposal. However, in a situation involving a more significant release and certainly in an event such as the 2011 incident at the Fukushima nuclear facility, the waste resulting from such an incident would likely overwhelm current disposal capacity. When waste volumes exceed existing capacity, options available for consideration include supplements to existing commercial licensed

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radioactive waste disposal facilities, such as a combination of hazardous waste landfills, solid waste landfills, DOE facilities and construction of one or more new disposal facilities. New disposal capacity could be located at the site where the radionuclide release originated, elsewhere within the contaminated area, or away from the affected area altogether.

This section provides a short introduction to the issue, a summary of the types of available disposal options, a more detailed discussion of each disposal option, including disposal capabilities and discussion of roles and responsibilities. Although not addressed explicitly in this section, the need to prepare for and conduct safe and environmentally protective storage of waste generated during remediation will also present a significant challenge, as illustrated by the challenges that Japan faced in the aftermath of the Fukushima accident. Many of the considerations for siting disposal facilities will also be applicable to storage sites.

Planners and decision-makers need to view the long-term remediation and recovery as a comprehensive process in which waste management and disposal needs are considered from the earliest stages. For example, the selected decontamination and remediation approach should involve consideration of a number of viable alternatives with regard to potential treatment and disposal options. The precise mix of treatment and disposal options employed would depend on the nature of the specific incident (e.g., location, waste volumes). The suitability of using any individual facility would depend on a number of factors, including but not limited to the toxicity, mobility and volume of radioactively-contaminated wastes (these would be evaluated as part of the characterization process), possible treatment technologies (e.g., volume reduction technologies at the incident location; thermal treatment; neutralization), cost-effectiveness and existing federal and state (and possibly local) legal requirements governing waste disposal.

4.2.1. Potential Waste Volumes and Existing Waste Disposal Options

As noted above, the complexity of radiological waste disposal decisions would depend on a number of factors, including the magnitude of the release and the decisions related to site cleanup. Consideration of these factors will determine the amount and types of waste requiring disposal. While disposal in a licensed low-level radioactive waste (LLRW) disposal facility may be the preferable first choice, there are a limited number of such facilities and not all states have access to all licensed commercial disposal facilities. If there is a limited radiological incident with relatively small waste volumes, existing capacity is available and may be sufficient to address waste disposal. However, waste resulting from a large scale incident would likely overwhelm current disposal capacity. For large waste volumes, supplements to existing commercial radioactive waste disposal facilities would need to be considered, such as a combination of hazardous waste landfills, solid waste landfills, DOE disposal facilities and potentially, the construction of a new disposal facility. Organizational and administrative issues related to federal and state government coordination and preparation are also important.

a) Waste Volume

Discussions of waste disposal options often involve comparisons of estimated waste generation and available disposal capacity. The amount of waste generated is related to the cleanup approach, as the selected approach to decontamination and remediation, as well as the long-term cleanup goals, can affect the volume of waste actually requiring disposal. The projected amounts of wastes for a large scale radiological incident may range from tens to hundreds of million cubic feet (or several million metric tons). Some of the waste may contain high radioactivity, especially at the incident's origin; however, most of the waste is expected to be only slightly contaminated, though in large quantities. The volume of contaminated soil in Japan resulting from the Fukushima incident is estimated to exceed one billion cubic feet.

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As a point of comparison, roughly 28 million cubic feet of LLRW were disposed of at licensed commercial disposal facilities during the period 2002-2011. DOE disposed of approximately twice that volume in commercial facilities during the same period, in which it was involved in significant large-scale site cleanups.[37] Thus, over that ten-year period, an average annual volume of less than ten million cubic feet was disposed of in commercial facilities. Volumes from the non-governmental sector are not expected to increase significantly until the current fleet of NPPs is decommissioned. DOE generated additional waste volumes that were disposed of at DOE sites. For example, from 2000-2010, DOE disposed of approximately 20 million cubic feet of LLRW at the Nevada National Security Site (NNSS, formerly the Nevada Test Site). As it continues site cleanups, DOE projects generation of approximately 150 million cubic feet of LLRW for the period 2010-2015, most of which will be disposed at the site of origin or other designated DOE sites.

b) Capacity Issues

Managing the large volumes of waste resulting from a wide-scale radiological incident, such as with the Fukushima accident, would likely overwhelm existing capacity in the U.S. and thus require an overall strategy employing all available types of disposal facilities and integrating federal, state, local and private sector assets. For example, consider that:

- At the beginning of 2012, less than 100 million cubic feet of disposal capacity was licensed at commercial disposal facilities. An incident could consume all remaining licensed commercial LLRW disposal capacity, which would affect waste generators in the energy, industrial, research and medical sectors for whom the capacity was originally licensed. While there may be remaining property at the facilities that could be developed, there is no guarantee that additional capacity can be licensed or that states will allow all capacity to be consumed.
- Estimated waste volumes are comparable to projected generation from the entire DOE complex over the next several years, which include large-scale cleanups. While DOE is somewhat less constrained than non-DOE disposal sites in adding additional disposal capacity at its sites, displacement of projected DOE disposal with incident-related waste has the potential to interfere with ongoing cleanup activities, leading to extended on-site storage, slower cleanups and controversial efforts to expand disposal capacity at other DOE sites. Further, there is at present no mechanism to provide access to DOE disposal sites for disposal of incident-related waste.

4.2.2. Integrated Disposal Options

An effective response to a large-scale radiological incident will involve consideration of the entire range of potential disposal options. The precise mix of disposal options employed will depend on the nature of the specific incident (e.g., location, waste volumes). The process selected to plan and conductthe long-term decontamination and remediation should identify and make provisions for using the different available disposal options. In order to provide cleanup managers the use of all potential disposal capacity there are some issues that would need to be addressed, such as waste acceptance criteria for waste sites that have not been evaluated for radioactive material disposal. However, based on an understanding of the types of waste involved and the capabilities of existing disposal facilities, a generalized discussion of the attributes of the different disposal options, with qualifiers, can be developed and are discussed below.

- Licensed Commercial LLRW Disposal Facilities—
  - Can manage most anticipated waste types within license conditions.
  - Highest degree of public acceptance.
  - Significant bulk disposal volume possible.

[37] Information on disposal in commercial disposal facilities provided by the Manifest Information Management System (MIMS), operated by the DOE at http://mims.apps.em.doe.gov/.

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  - Access restrictions may require special approval for waste from certain states.
  - Management of mixed radioactive and hazardous waste will need to ensure proper disposal and long-term groundwater monitoring.
- Solid and Hazardous Waste Landfills—
  - May offer local disposal option for expected large volumes with limited contamination.
  - May offer a disposal option at hazardous waste landfills for mixed wastes (mixtures of hazardous and radiological wastes); hazardous waste landfills have specified construction and engineering requirements.
  - Need to consider the location of the units in proximity to large or sensitive populations, sensitive eco-systems, and sole source aquifers.
  - May require design modifications to ensure that the waste can be managed protectively over time.
  - Difficulty in obtaining public acceptance, although some hazardous waste landfills have accepted waste with limited radionuclide content with state approval.
  - Requires additional demonstration of suitability to ensure protectiveness for radiological material (e.g., groundwater monitoring, additional engineering controls); many solid waste landfills have not been evaluated for disposal of radioactive material and may not be suitable for radiological material.
  - May require longer-term/special monitoring, as well as institutional control.
- DOE Disposal Sites—
  - Could potentially handle higher-activity waste if insufficient commercial access/capacity.
  - May be suitable for some problematic waste types (e.g., whole vehicles).
  - DOE disposal facilities generally accept only DOE-owned or DOE-generated waste. Disposal of non-DOE waste requires additional review and agreements involving the host state, consistent with DOE's authorities particularly where existing agreements limit DOE's waste disposal activities.

Each of these potential disposal alternatives is discussed in more detail below. There may also be some remaining wastes that might require special consideration based on factors such as level ofcontamination, waste form, lack of access or capacity or presence of other hazardous or toxic contaminants. These wastes could include those containing both hazardous and toxic constituents (e.g., mercury and PCBs), animal carcasses or contaminated vehicles (where dismantling the vehicle may represent a greater potential for dispersal of contaminants and exposure of workers).

a) Commercially Licensed LLRW Disposal Facilities

Given that the bulk of the waste resulting from the release of radionuclides from a nuclear facility or a deliberate action will contain radionuclides commonly contained in LLRW, licensed commercial disposal facilities would be the most appropriate and publicly acceptable option for disposal if the volumes of waste from the incident were relatively small. It would be anticipated that the waste would be mostly at the lower end of radionuclide concentrations. Thus, these facilities will be capable of handling all but the most problematic waste types, if the amounts were limited. At present, all commercial LLRW disposal facilities are licensed by states (through agreements with NRC, referred to as "Agreement States").

As described earlier, available capacity and access are significant concerns in relying on commercial LLRW disposal facilities. Further, even if a facility would be generally available to all waste generators and it is found that all but a small portion of the waste would meet that facility's disposal criteria, it is

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possible that there may be objections to accepting all waste from an incident outside the state, even if the facility's capacity was sufficient.

Access to other facilities generally unavailable to the state(s) affected by the incident might be feasible in an emergency situation under NRC regulations, but it should not be expected that large volumes of waste will be accepted under these provisions. There is also the possibility that the affected state could construct a disposal facility to provide additional capacity. Several states conducted extensive studies of their geology in anticipation of constructing disposal facilities and these studies may be of use in such situations.

b) Solid and hazardous waste landfills

Most states are authorized by the EPA under the Resource Conservation and Recovery Act (RCRA) to operate their own hazardous waste management programs in lieu of the federal Subtitle C program.[38] Management of nonhazardous solid wastes is governed by RCRA Subtitle D, which is administered largely by the states. Compared to the number of licensed LLRW disposal facilities in the U.S., there are a greater number of commercial landfills operating under Subtitle C and many more operating under Subtitle D of RCRA for disposal of hazardous and solid wastes, respectively. It would not be expected that all of these facilities (particularly those operating under Subtitle D) would be appropriate disposal options. However, some of the hazardous waste landfills have accepted some radioactive material for disposal and a few have received the necessary state approvals to do so on a routine basis. Historically, most of the radiological waste streams accepted by hazardous waste landfills contain naturally-occurring radionuclides not regulated by NRC, such as wastes from the oil and gas or other resource extraction industries, as well as water treatment residuals. However, both NRC and DOE, in coordination with state regulators and facility operators have approved disposal of radioactive waste in RCRA landfills on a case-by-case basis. Thus, there is reason to believe that one or more hazardous waste landfills could contribute to the disposal capacity for incident-related waste. The use of any particular RCRA facility for the disposal of radioactive contaminants or mixed contamination would require that the unit is well designed and managed appropriately. The uniform design and engineering requirements applicable to hazardous waste landfills would facilitate such an evaluation; by contrast, not all solid waste landfills are constructed to the same specifications. Further, the evaluation would include consideration of the waste characteristics, site characteristics, waste acceptance criteria and other facility attributes.

RCRA hazardous and solid waste landfills may also offer the advantage of disposal capacity suitable for large volumes of lightly-contaminated material (e.g., soil)[39]. In addition, these facilities are more likely to be located near the incident location, which can facilitate their use if deemed appropriate by federal, state and local officials. However, use of these facilities for disposal of radionuclides typically found in low-level radioactive waste, even if it contains very low concentrations of those radionuclides, may generate public concern if the facilities have not been previously approved for this type of disposal. Therefore, additional effort by state and local officials would be necessary to ensure the facility can manage the waste in a protective manner, including technical modification, if appropriate.

c) DOE Disposal Sites

DOE facilities could potentially be a disposal alternative that may be most appropriate for limited volumes of waste for which there is no other disposal outlet (such as high-activity waste, certain mixed wastes, or other problematic waste streams). Waste disposed at DOE sites must meet the waste acceptance criteria for those sites. DOE does not generally accept non-DOE-owned or generated waste for

[38] Alaska, Iowa, Puerto Rico, the Virgin Islands, American Samoa and the Trust Territories and Northern Marianas Islands do not have authorized RCRA programs.

[39] EPA reports that about 132 million tons of municipal solid waste were landfilled in 2009, comparable to the rate over the past two decades. The 2009 figure represents about 54% of total generation. "Municipal Solid Waste in the United States: 2009 Facts and Figures," EPA530-R-10-012, December 2010.

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disposal at its sites. In addition, DOE has significant ongoing remediation at a number of sites that will generate large volumes of waste over the coming years. Diverting DOE disposal capacity to incident-related waste may interfere with those efforts. DOE has also utilized commercial low-level radioactive disposal, primarily for bulk waste streams from cleanups and this potential disposal alternative may also be affected by a wide-scale incident.

DOE's primary disposal site serving the DOE complex is the NNSS. DOE/NNSS continues to excavate additional disposal capacity as needed and estimates that significant additional capacity could be developed at NNSS.

DOE's other designated site for complex-wide disposal is Hanford, WA; however, DOE has an agreement with the State of Washington that it will not bring waste from other sites until certain remediation milestones have been met. Overall, DOE anticipates that most of its waste generated in the coming years will be disposed at the site of generation. Sites other than NNSS and Hanford are designated for disposal of waste generated at those sites, although exceptional situations may allow for disposal of waste generated off-site and development of some additional disposal capacity. Additional disposal capacity would likely be dependent upon agreement from the state in which the facility is located.

4.2.3. Planning and Coordination Among Federal and State Entities

A number of federal and state agencies may have important roles to play in making decisions on final disposal, depending on the extent of the waste. A framework for coordination with these various federal and state agencies should be an element of the process selected for long-term decontamination and remediation.

a) State Roles and Responsibilities

States must be intimately involved ahead of time in planning for a large-scale radiological incident and the resulting waste disposal.

- All existing commercial LLRW disposal facilities are licensed by Agreement States.
- Many, but not all, states have formed regional compacts (as authorized by Congress) to site and operate LLRW disposal facilities; compacts control access to these sites.
- Although statutorily required[40] to provide disposal capacity for low-level waste generated within the compact boundaries (with certain exceptions), states are under no obligation to accept waste from outside their compacts. States that are not members of compacts do not have the statutory protection to prohibit disposal of out-of-compact waste.
- All DOE disposal sites are located within states, many of which have agreements regarding the extent of long-term disposal or acceptance of off-site waste; States hosting DOE disposal sites should participate in planning for the potential disposal of incident-related off-site waste at DOE sites.
- States regulate hazardous waste (when authorized by EPA) and solid waste landfills that may be used for disposal of waste with very low concentrations of radioactivity; in planning for disposal of incident-related waste, states should take into account any restrictions placed on the disposal of radionuclides in these facilities.
- It is anticipated that on-site disposal at a location affected by the incident, where appropriate, will be one location of choice and that an affected state could approve construction of a new disposal facility for that purpose.

[40] Pursuant to the Low-Level Radioactive Waste Policy Act of 1980 (LLRWPA) and the 1985 LLRWP Amendments Act of 1985.

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b) Federal Agencies

Depending on the circumstances, coordination with numerous federal agencies would be necessary. Of particular note:

- EPA is the coordinating agency for long-term remediation and cleanup, as designated by the National Response Framework (FEMA 2008a) and has federal authority for hazardous waste disposal;
- DOE is "owner" of federal sites that might be used for waste disposal;
- NRC is the federal authority for commercial LLRW disposal;
- USDA provides technical assistance for agricultural materials contaminated by the release, including animal carcasses.

4.2.4. Other Potential Options and Considerations

a) Potential Federal Actions to Increase Preparedness

- Develop criteria under which access to DOE disposal sites is acceptable and identify issues to be resolved.
- Facilitate agreements among regional LLRW compacts and states to address situations in which access to compact sites can be assured for all states.
- Identify geographically strategic federal sites that can be used for staging and interim storage of large waste volumes.
- Identify federal sites that can be characterized in advance for construction of disposal capacity for incident-related waste, should the need arise.
- Clarify federal authorities that can be used in exceptional circumstances for acquisition of property for use as disposal or long-term storage capacity and indemnification of private sector service providers.
- Assist state and local officials in planning for and making decisions to use local disposal options (solid and hazardous waste landfills) for waste that contains relatively low concentrations of radionuclides, including:
  - developing criteria for case-by-case alternate disposal evaluations, such as those employed by NRC, EPA and DOE for limited volumes of waste;
  - establishing generally applicable criteria for disposal of radionuclides in solid and hazardous waste landfills;
  - supporting federal research into behavior of radionuclides and decontamination residuals in solid and hazardous waste landfills;
  - providing technical assistance and streamlined regulatory review (e.g., permitting) for states to evaluate existing sites and identify new sites for incident-related waste disposal capacity; and,
  - developing and disseminating tools to support planning and decision-making regarding incident-related waste management.

b) Detailed Guidance

It may be appropriate for the federal government to develop detailed guidance to address factors such as waste acceptance criteria needed for waste disposal at RCRA disposal facilities, safety evaluation of existing disposal facilities, or siting, development and regulatory approval of new disposal facilities.

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c) Adding Additional Disposal Capacity

Depending on the circumstances, it may be appropriate to create additional disposal capacity. This decision would most likely need to involve extensive discussion between the federal government and the affected state(s) where an incident occurred.

- On-site disposal. As a result of looking at the different choices, it may be advantageous to develop disposal capacity on-site (e.g., build a large disposal facility within the property boundaries where the facility causing the release is located) if the site is suitable.
- Off-site disposal. An additional option would be for a state or the federal government to build a disposal site on suitable public lands. The federal or state government could use the power of eminent domain to condemn property contaminated by a radiological incident and use it for waste disposal.

d) Site Selection Criteria

If it is determined that constructing a new disposal facility is the appropriate action, the proposed site(s) should be studied for suitability. Although the contemplated disposal actions would be taken in event of a national emergency, every effort should be made to ensure the protection of public health and the environment. Appropriate regulatory standards should be considered in developing a specific disposal plan. The disposal path and site suitability must take into account the radiological characteristics of the waste. As discussed above, some slightly radioactive materials are disposed in hazardous waste landfills if they are permitted for it. More radioactive materials are sent to sites licensed as LLRW disposal sites, though less contaminated materials are also sent to LLRW disposal sites. A small amount of waste from a radiological incident may have concentrated radioactivity, but most of the waste generated in a large scale radiological incident would likely be contaminated with low levels of radioactivity. The different radiological characteristics of the waste would have a bearing on the stringency of containment required of a waste disposal facility. All waste sites would need to have appropriate controls to protect public health and the environment for any level of radioactive contamination, but more highly radioactive materials would need more robust controls than slightly contaminated material.

e) Site Characteristics

The physical/geographic characteristics of the site and the availability of land will be important in determining the appropriateness of a potential disposal site. Sites with limited rainfall, high evapotranspiration, deep water tables and soil characteristics that limit migration of radionuclides have been found to be best suited to disposal of radioactive waste, although waste management and engineering can be applied to improve performance at sites with less favorable characteristics (e.g., controls on the waste form or level of allowable radioactivity, addition of liners, cover requirements or through construction of concrete bunkers or vaults). Other characteristics, such as location in a high risk area (e.g., flood plain or seismic zone) or sensitive ecologic area, should also be considered. A disposal cell for 1 million cubic feet of waste will occupy 1 acre or more of surface area, assuming disposal to a depth of about 30 feet. Large-scale disposal operations may also require extensive surface facilities.

f) Other Important Considerations

Additional considerations can also be applied to make finer distinctions among potentially suitable sites. These criteria include:

- proximity to the incident – it may be useful to consider sites in different regions of the country to limit transportation demands;
- proximity to residential areas or commercial districts – the potential for disposal activities to affect nearby populations or commercial activities, whether located within the site boundaries or on adjacent property, should be considered;

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- proximity to transportation – access to timely and direct transportation that can accommodate large shipments is desirable—
  - action to facilitate – construction of transportation infrastructure (e.g., direct rail lines);
- experience in waste disposal – waste disposal sites will have infrastructure, procedures and trained personnel that can make most efficient use of the site—
  - action to facilitate – development of infrastructure, training, construction of disposal cells and engineered containment (e.g., vaults or bunkers);
- level of existing contamination – areas that are unlikely to be remediated in the near future or unlikely to be released for public use may be more acceptable for disposal.

4.2.5. Potential Federal Actions to Develop New Disposal Capacity

In addition to criteria for siting new disposal facilities, the federal government has control of a large amount of land throughout the U.S. that could be repurposed, or could offer assistance to support state governments in developing new facilities.

a) DOE Sites

DOE has decades of experience in radioactive waste management. In considering the primary selection criteria described above, DOE sites in the western U.S. generally have more favorable characteristics and readily available property compared to those in the eastern U.S. However, DOE has successfully implemented disposal at the eastern sites, often with some engineering enhancements. DOE has several categories of sites for consideration, beginning with the most suitable—

- Active disposal or cleanup sites in the western U.S.
- Active disposal or cleanup sites in the eastern U.S.
- Closed sites with disposal areas.
- Closed uranium milling sites.
- Other long-term stewardship sites.

Considerations: Some DOE sites have agreements with states or other stakeholders regarding further disposal or cleanup activities. Current disposal sites have waste acceptance criteria by DOE policy or statute. Closed and long-term stewardship sites may not have large amounts of additional property available for disposal.

b) DoD Installations

DoD maintains some installations with large land areas, primarily in the western U.S. Many of these sites have been contaminated through extensive training or other activities. DoD likely has more sites in the eastern U.S. than does DOE. Categories of sites that could be considered suitable include:

- bombing and firing ranges;
- chemical weapons demilitarization and storage sites;
- ammunition plants and arsenals;
- surplus properties (e.g., base realignment and closure (BRAC), formerly used defense site (FUDS)).

Considerations: Section 2692 of title 10, United States Code, "Storage, Treatment and Disposal of NonDefense Toxic and Hazardous Materials," generally provides that the Secretary of Defense may not permit the use of an installation of the DoD for the storage, treatment, or disposal of any material that is a

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toxic or hazardous material and that is not owned either by the DoD or by a member of the armed forces (or by a dependent of the member) assigned to or provided military housing on the installation. Radiological waste resulting from either a nuclear accident or a terrorist attack may fall under this prohibition. The Secretary of Defense may grant exceptions to this restriction when "essential to protect the health and safety of the public from imminent danger." A determination whether or not radiological waste meets the "imminent danger" threshold would be required.

Additionally, some DoD properties, including ranges in the western U.S., are on "withdrawn" lands, which are part of the public domain supervised by the Bureau of Land Management (BLM). Withdrawn land statutes permit DoD to use the property for specific military mission needs. The use of withdrawn lands to manage radiological waste would violate those statutes.

c) Other Federal Properties

Agencies such as the Department of Interior (DOI) or USDA own large properties that could be considered suitable for disposal, many of which are in the western U.S. These properties may be administered by discrete entities within the cabinet-level departments, such as the National Park Service (NPS), BLM, or Forest Service. Some properties may be in proximity to DOE or DoD lands.

Considerations: Properties may be designated for protection or public use (e.g., wilderness areas or preserves). Many properties are also in rugged terrain with difficult access or border tribal lands.

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KEY POINTS IN CHAPTE R 4 –LATE PHASE

- PAGs will not be used to guide restoration and recovery of areas impacted by a radiological incident; rather, planning activities should include developing a process to involve stakeholders in setting priorities and determining actions. Such a process should be flexible enough to adapt to a variety of situations.
- Planning considerations for worst case scenarios are provided. Smaller radiological incidents may be well addressed by existing emergency response and environmental cleanup programs at local, state, tribal and federal levels.
- Reoccupying households and businesses should be considered in balance with progress made in reducing radiation risks through decontamination, radioactive decay and managing contaminated waste.
- Exposure limits in a range of one in a population of ten thousand (10^{-4}) to one in a population of one million (10^{-6}) excess lifetime cancer incidence outcomes are generally considered protective, though this may not be achievable after a large radiological incident. In making decisions about cleanup goals and strategies for a particular event, decision makers must balance the desired level of exposure reduction with the extent of the measures that would be necessary to achieve it, in order to maximize overall human welfare.
- Incidents that create large volumes of waste from a wide-scale radiological incident would likely overwhelm existing radioactive waste disposal capacity in the U.S.
- Following a nuclear accident, the states bear primary responsibility to identify and provide waste management options, including disposal capacity; in the event of a terrorist attack, the federal government can offer a range of assistance to state governments to identify and implement waste management options.
- Safely managing and disposing of radioactive waste will require pre-planning at all levels of government and careful coordination with stakeholders at all stages of the decision-making process.

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APPENDIX B – GLOSSARY

Acute health effects: health problems caused by high radiation doses received in a short period of time. Examples of acute effects include erythema (reddening of skin), blistering, epilation (hair loss) and vomiting.

ALARA: acronym for "as low as is reasonably achievable" means making every reasonable effort to maintain exposures to radiation as far below the dose limits in this part as is practical consistent with the purpose for which the activity is undertaken.

Alpha radiation: alpha radiation comes from the ejection of alpha particles from the nuclei of some unstable atoms. An alpha particle is identical to a helium nucleus and consists of two protons and two neutrons. Alpha particles are highly energetic, but can only travel a few centimeters in air. They have low penetrating power and can be stopped by a sheet of paper. Alpha particles generally cannot even penetrate the layer of dead cells on the skin, but can pose a health risk when inhaled or ingested.

Avoided dose: The radiation dose saved by implementing a protective action. (ICRP 1991b)

Beta radiation: beta radiation comes from the emission of beta particles during radioactive decay. Beta particles are highly energetic and fast-moving. They carry a positive or negative charge and can be stopped by a layer of clothing or few millimeters of a solid material. Beta particles can penetrate the skin and cause skin burns, but tissue damage is limited by their small size. Betaparticles are most hazardous when inhaled or ingested.

Committed effective dose: The sum of the committed equivalent doses following intake (inhalation or ingestion) of a radionuclide to each organ multiplied by a tissue weighting factor.

Contamination: Radionuclides on surface or in the environment as a result of an accidental release.

Concentration: Radionuclide activity per unit of mass.

Chronic effects: Health problems caused by radiation doses delivered over a long period. Examples of chronic effects include cancer and genetic mutations.

Derived Intervention Level (DIL): Concentration derived from the intervention level of dose at which introduction of protective measures should be considered. (FDA 1998)

Derived Response Level (DRL): A level of radioactivity in an environmental medium that would be expected to produce a dose equal to its corresponding Protective Action Guide.

Dose: The amount of radiation exposure a person has received, calculated considering the effectiveness of the radiation type (alpha, beta, gamma), the timeframe of the exposure and the sensitivity of the person or individual organs.

Dose conversion factor (DCF): Any factor that is used to change an environmental measurement to dose in the units of concern.

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Dose projection: A calculated future dose that an individual might receive; also the process of making these calculations

Dose reduction factor: A factor by which a decontamination technique or protective action reduces the radiation dose to a person.

Dosimetry: The system for assessing radiation doses from external radiation exposures and from intakes of radionuclides using biokinetic models and dosimetric quantities developed by the ICRP and the International Commission on Radiation Units and Measurements (ICRU).

Effective dose: The sum of organ equivalent doses weighted by ICRP organ weighting factors.

Emergency Planning Zone: A designated zone around a commercial nuclear power plant for which radiological response plans must be maintained under Nuclear Regulatory Commission regulations.

Evacuation: The urgent removal of people from an area to avoid or reduce high-level, short-term exposure, from the plume or from deposited activity. Evacuation may be a preemptive action taken in response to a facility condition rather than an actual release.

Gamma radiation: Gamma radiation comes from the emission of high-energy, weightless, chargeless photons during radioactive decay. Gamma photons are pure electromagnetic energy and highly penetrating--several inches of lead or a few feet of concrete may be required to attenuate them. External exposure to gamma rays poses a health threat to the entire body. Inhalation and ingestion of gamma emitters also poses a health threat.

Graves' disease: An autoimmune disorder that leads to the over activity of the thyroid.

Groundshine: Gamma radiation emitted from radioactive materials deposited on the ground.

Half-life: The time required for the half the atoms of a given radioisotope to transform by radioactive decay.

Hasimoto's thyroiditis: An autoimmune disorder that leads to underactive thyroid with bouts of over activity.

Isodose-rate line: A contour line that is used to connect points of equal radiation dose rates.

Latency period, cancer: The time elapsed between radiation exposure and the onset of cancer.

Microsievert: One ten-thousandth of a rem. See Rem.

Millirem: One thousandth of a rem. See Rem.

Millisievert: One thousandth of a Sievert. See Sievert.

Noble gases: A group of elemental gases that are tasteless, odorless and that do not undergo chemical reactions under natural conditions. The noble gases consist of Helium, Neon, Argon, Krypton, Xenon and Radon.

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Off-site: Areas outside the controlled border of a facility, such as a nuclear power plant. For an incident not involving a facility, this term may also be used to refer to areas impacted by contamination.

On-site: areas inside the controlled border of a facility, such as a nuclear power plant. For an incident not involving a facility, this term may refer to areas controlled during a response.

Potassium iodide: A salt of stable, nonradioactive iodine in medicine form. The administration of potassium iodine saturates the thyroid with non-radioactive iodine, so it does not absorb radioactive iodine released into the environment from a radiological incident.

Projected dose: The prediction of the dose that a population or individual could receive.

Protective actions: An activity conducted in response to an incident or potential incident to avoid or reduce radiation dose to members of the public.

Protective Action Guide (PAG): The projected dose to an individual, resulting from a radiological incident at which a specific protective action to reduce or avoid that dose is warranted.

Prophylactic: A treatment or medication designed to prevent exposure to radiation.

Rad (radiation absorbed dose): A basic unit of absorbed radiation dose. It is being replaced by the 'gray,' which is equivalent to 100 rad. One rad equals the dose delivered to an object of 100 ergs of energy, per gram of material.

Radioactive: Quality of a material that emits alpha particles, beta particles, gamma rays, or neutrons.

Radiological dispersion device (RDD): A device or mechanism that is intended to spread radioactive material from the detonation of conventional explosives or other means. An RDD is commonly known as a "dirty bomb."

Radiopharmaceutical: A radioactive chemical used for diagnosis cure, treatment, or prevention of diseases.

Recovery: The process of reducing radiation exposure rates and concentrations of radioactive material in the environment to levels acceptable for unconditional occupancy or use.

Reentry: Workers or members of the public going into relocation or radiological contaminated areas on a temporary basis under controlled conditions.

Release: Uncontrolled distribution of radioactive material to the environment.

Relocation: The removal or continued exclusion of people (households) from contaminated areas to avoid chronic radiation exposure. Not to be confused with *evacuation*.

Reoccupancy: The return of households and communities to relocation areas during the cleanup process, at radiation levels acceptable to the community.

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Rem (roentgen equivalent man): The product of the absorbed dose in rads and a weighting factor which accounts for the effectiveness of the radiation to cause biological damage; a conventional unit for equivalent dose. One rem equals 0.01 Sv.

Release rate: The measure of the amount of radioactive dispersed per unit of time.

Return: Permanent resettlement in evacuation or relocation areas with no restrictions, based on acceptable environmental and public health conditions.

Sievert (Sv): International unit of equivalent dose.

Source term: The amount of a contaminant available in a scenario or actually released to the environment.

Total Effective Dose (TED): The sum of the effective dose (for external exposures) and the committed effective dose; also referred to in this Manual as whole body dose. See Section 2.4.

Yield-producing improvised nuclear device: A crude weapon fabricated from diverted fissile material that produces a nuclear explosion.

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APPENDIX C – LIST OF ACRONYMS

ALARA	As Low as Reasonably Achievable
ANS	American Nuclear Society
BLM	Bureau of Land Management
BRAC	Base Realignment and Closure
CDC	Centers for Disease Control and Prevention
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
CWS	Community Water System
DCF	Dose Conversion Factor
DHS	Department of Homeland Security
DoD	Department of Defense
DOE	Department of Energy
DOI	Department of Interior
DOL	Department of Labor
DOT	Department of Transportation
DRL	Derived Response Level
EAL	Emergency Action Level
EPA	Environmental Protection Agency
EPZ	Emergency Planning Zone
FDA	Food and Drug Administration
FEMA	Federal Emergency Management Agency
FRC	Federal Radiation Council
FRMAC	Federal Radiological Monitoring and Assessment Center
FRPCC	Federal Radiological Preparedness Coordination Committee
FUDS	Formerly Used Defense Site
HAZWOPER	Hazardous Waste Operations and Emergency Response
HHS	Department of Health and Human Services
HPS	Health Physics Society
IAEA	International Atomic Energy Agency
ICP	Incident Command Post
ICRP	International Commission on Radiological Protection
IC/UC	Incident Command/Unified Command
IND	Improvised Nuclear Device

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JFO	Joint Field Office
JIC	Joint Information Center
KI	Potassium Iodide
LLRW	Low-level radioactive waste
LLRWPA	Low-Level Radioactive Waste Policy Act
MCL	Maximum Contaminant Level
NCP	National Contingency Plan
NCRP	National Council on Radiation Protection and Measurements
NIMS	National Incident Management System
NNPP	Naval Nuclear Propulsion Program
NNSS	Nevada National Security Site
NPDWR	National Primary Drinking Water Regulations
NPP	Nuclear Power Plant
NPS	National Park Service
NRC	Nuclear Regulatory Commission
NRF	National Response Framework
NDRF	National Disaster Recovery Framework
NSS	National Security Staff
OSHA	Occupational Safety and Health Administration
PAG	Protective Action Guide
PIO	Public Information Officer
PPE	Personal Protective Equipment
RASCAL	Radiological Assessment System for Consequence Analysis
RCRA	Resource Conservation and Recovery Act
RDD	Radiological Dispersal Device
SDWA	Safe Drinking Water Act
SNL	Sandia National Laboratories
TED	Total Effective Dose
USDA	United States Department of Agriculture

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To: Lee Veal[Veal.Lee@epa.gov]
From: DeCair, Sara
Sent: Thur 2/25/2016 3:10:22 PM
Subject: Your turn, please
Summary of changes from 2013 PAG Manual to Draft Final 2016 PAG manual.docx

I will think of other stuff to say from comments, too, and work on cutting that crazy yellow from the document! Thank you!

Sara D. DeCair

http://www.epa.gov/radiation/rert/pags.html

202-343-9108

Room 1416 B in WJC West

To: Perrin, Alan[Perrin.Alan@epa.gov]
From: DeCair, Sara
Sent: Thur 2/25/2016 1:37:28 PM
Subject: please print me
PAG Manual draft Final 2-25-2016.docx

Sure enough I don't trust this printer!

Sara D. DeCair

http://www.epa.gov/radiation/rert/pags.html

202-343-9108

Room 1416 B in WJC West

Publication XXXX.X-XXX
Month YYYY

PAG Manual: Protective Action Guides and Planning Guidance for Radiological Incidents

XXXX EDITION

KEY TO THIS MARKUP: gray = additions and ~~yellow = deletions~~

Office of Radiation and Indoor Air
Radiation Protection Division
U.S. Environmental Protection Agency
Washington, DC 20460

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LIMITS ON SCOPE

This guidance does not address or impact site cleanups occurring under other statutory authorities such as the United States Environmental Protection Agency's (EPA) Superfund program, the Nuclear Regulatory Commission's (NRC) decommissioning program, or other federal or state cleanup programs.

As indicated by the use of non-mandatory language such as "may," "should" and "can," this Manual only provides recommendations and does not confer any legal rights or impose any legally binding requirements upon any member of the public, state, tribe, locality, or any ~~other~~ federal agency.

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CHAPTER 1. OVERVIEW

1.1 PLANNING GUIDANCE AND PROTECTIVE ACTION GUIDES

The U.S. Environmental Protection Agency (EPA) has developed this Manual to assist public officials in planning for emergency response to radiological incidents. For purposes of this document, a radiological incident is an event or a series of events, deliberate or accidental, leading to the release or potential release into the environment of radioactive materials in sufficient quantity to warrant consideration of protective actions. This Manual provides radiological protection criteria for application to all incidents that would require consideration of protective actions, with the exception of nuclear war.

During an incident with an uncontrolled source of radiation, protection of the public from unnecessary exposure to radiation may require some form of intervention that will disrupt normal living. Such intervention is termed a protective action. Examples of protective actions include:

- Evacuating an area;
- Sheltering-in-place within a building or protective structure;
- Administering potassium iodide (KI) as a supplemental action;
- Relocation;
- Acquiring an alternate source of drinking water; and
- Interdiction of food/milk.

This Manual provides recommended numerical protective action guides (PAGs) for the principal protective actions available to public officials during a radiological incident. A PAG is defined for purposes of this document as the projected dose to an individual from a release of radioactive material at which a specific protective action to reduce or avoid that dose is recommended. PAGs are guides to help officials select protective actions under emergency conditions during which exposures would occur for relatively short time periods. They are not meant to be applied as strict numeric criteria, but rather as guidelines to be considered in the context of incident-specific factors. PAGs do not establish an acceptable level of risk for normal, nonemergency conditions, nor do they represent the boundary between safe and unsafe conditions. The PAGs are not legally binding regulations or standards and do not supersede any environmental laws. For information on roles, responsibilities and authorities during emergency response and recovery, please refer to the National Response Framework: http://www.fema.gov/national-response-framework and specifically for radiological incidents, the Nuclear Radiological Incident Annex: http://www.fema.gov/pdf/about/divisions/thd/IncidentNucRad.pdf (FEMA 2008a,b).

Some protective actions are not associated with a numerical PAG. For example, the control of access to areas is a protective action implemented in concert with other protective actions; it does not have its own PAG. Any reasonable action to reduce radiation dose is encouraged even if it is not associated with a PAG, such as recommending that individuals use ad hoc respiratory protection with a handkerchief or piece of folded cloth. Or in areas where PAGs are not exceeded, but airborne radioactivity is present, people might be asked to stay indoors to the extent practicable to reduce their exposures. To further develop radiological emergency plans, brief planning guides have been provided for reentry to relocation areas, the cleanup planning process and considerations for radioactive waste disposal.

1.2 APPLICABILITY

Protective actions may be recommended for a wide range of incidents, but generally apply to incidents involving relatively significant releases of radionuclides. Radiological incidents with potential for significant releases include:

- A fire in a major facility such as a nuclear fuel manufacturing plant;
- An accident at a federal nuclear weapons complex facility;
- An accident at a commercial nuclear power plant (NPP);
- A transportation accident involving radioactive material; and

- A terrorist act involving a radiological dispersal device (RDD) or yield-producing Improvised Nuclear Device (IND).

Each type of incident would pose a unique threat to public health and should be planned for and managed accordingly. Emergency response planning for a given facility or scenario should consider:

- The radionuclides involved;
- The dynamics of the release including size and magnitude;
- The feasibility of specific protective actions; and
- The timing of notification, response and protective action implementation.

The decision to advise members of the public to take a protective action during a radiological incident involves a complex judgment in which the radiological risk must be weighed against the action's inherent risks. This decision may have to be made under emergency conditions, with limited information and little time to analyze options. Advance planning reduces the complexity of the decision-making process during an incident. The planning process can identify the viability of responses to various incidents, the courses of action that can be set in motion in advance and the decisions that can only be made during an actual emergency. While many aspects of protective actions can be considered well in advance of an emergency, the situations and conditions that exist at the time of emergency must be considered if the most effective action is to be selected.

The unpredictable locations of certain radiological incidents make advance planning challenging. For example, an RDD could detonate anywhere and spread radiological contaminants over a wide variety of surfaces and terrain. Emergency planners should be prepared to apply PAGs to a wide scope of facilities and circumstances.

1.3 BACKGROUND ON THE UPDATED PAGS

This Manual updates the "Manual of Protective Action Guides and Protective Actions for Nuclear Incidents" (EPA-400-R-92-001, May 1992), published by ~~the U.S.~~ EPA (EPA 1992b) (hereinafter referred to as the "1992 PAG Manual"). The guidance in this Manual was developed cooperatively with the Federal Radiological Preparedness Coordination Committee (FRPCC), with representation from the EPA; the Department of Energy (DOE); the Department of Defense (DoD); the Department of Homeland Security (DHS) Federal Emergency Management Agency (FEMA); the Nuclear Regulatory Commission (NRC); the Department of Health and Human Services (HHS), including the Centers for Disease Control and Prevention (CDC) and the Food and Drug Administration (FDA); the U.S. Department of Agriculture (USDA); and the Department of Labor (DOL).

1.3.1 Legal Basis

The historical and legal basis of EPA's role in developing this guidance begins with Reorganization Plan No. 3 of 1970, in which the Administrator of EPA assumed all the functions of the Federal Radiation Council (FRC), including the charge to "…advise the President with respect to radiation matters, directly or indirectly affecting health, including guidance for all federal agencies in the formulation of radiation standards and in the establishment and execution of programs of cooperation with states" (Reorg. Plan No. 3 of 1970, sec. 2(a) (7), 6(a) (2); § 274.h of the Atomic Energy Act of 1954, as amended (AEA), codified at 42 U.S.C. § 2021(h)). Recognizing this role, FEMA, in its ~~their~~ Radiological Emergency Planning and Preparedness Regulations, directed EPA to "establish Protective Action Guides (PAGs) for all aspects of radiological emergency planning in coordination with appropriate federal agencies" (44 Code of Federal Regulations (CFR) §351.22(a)). FEMA also tasked EPA with preparing "guidance for state and local governments on implementing PAGs, including recommendations on protective actions which can be taken to mitigate the potential radiation dose to the population" (44 CFR §351.22(b)). All of this information was to "be presented in the EPA Manual of Protective Action Guides and Protective Actions for Nuclear Incidents" (44 CFR §351.22(b)).

Additionally, section 2021(h) charged the Administrator with performing "such other functions as the President may assign to him [or her] by Executive Order." Executive Order 12656 states that the Administrator shall "develop, for national security emergencies, guidance on acceptable emergency levels of nuclear

radiation…." (Executive Order No. 12656, sec. 1601(2)). EPA's role in the development of PAGs was also recognized in the "Nuclear/Radiological Incident Annex of the National Response Framework" of June 2008.

1.3.2 Interaction with Federal Radiation Council (FRC) Reports No. 5 and 7

In the 1960s, the Federal Radiation Council (FRC) defined PAGs and established limiting guides for ingestion of strontium-89, strontium-90, cesium-137, and iodine-131 (FRC 1964; FRC 1965). That guidance applied to restricting the use of food products that had become contaminated as the result of release of radioactivity to the stratosphere from weapons testing. During the period immediately following an incident at any domestic nuclear facility, when the critical source of exposure is expected to be a nearby airborne plume, the principal protective actions are evacuation or sheltering. The PAGs developed here thus do not supersede previous guidance, but provide additional guidance for prompt exposure pathways specific to a domestic nuclear incident.

1.3.3 Technical Basis

The FRC introduced the concept of a PAG in a series of recommendations issued in the 1960s. A key concept about PAGs is that the decision to implement protective actions should be based on the projected dose that would be avoided if the protective actions were implemented. Developers of the EPA PAGs considered the following three principles in establishing exposure levels for the PAGs—

1. Prevent acute effects.
2. Balance protection with other important factors and ensure that actions result in more benefit than harm.
3. Reduce risk of chronic effects.

These principles apply to the determination of any PAG. Principles 1 and 2 have been proposed for use by the international community as essential bases for decisions to intervene during an incident. Principle 3 has been recognized as an appropriate additional consideration (IAEA 2002). Although it is important during emergency planning to consider a range of source terms to assess the costs associated with their implementation, the PAGs are pre-determined for use in emergencies without regard to the magnitude or type of radiological release.

1.3.4 Changes in Scenarios since the Issuance of the 1992 PAG Manual

EPA's 1992 PAG Manual provided emergency management officials at the federal, state, tribal and local levels with the technical basis to plan responses to radiological emergencies. The 1992 PAG Manual was written to accommodate the worst release scenario deemed likely at the time – a major accident at a commercial NPP that would result in a significant off-site release of radioactive material. ("Site" and "off-site" in this Manual refer to locations where the radiological incident occurs and are not limited to facility-type incidents.) Certain characteristics typify NPPs, including: fixed locations at which an accident might occur; a known suite of radionuclides on site, the dose from which is dominated by short- lived radioisotopes; tight regulatory controls and requirements; skilled operational personnel who plan for and exercise emergency responses; state and local involvement in emergency planning; well-developed and zoned emergency evacuation plans and routes; and advance notice (generally hours to days) from deteriorating plant conditions prior to accidental release of radioactive material into the environment. Therefore, the 1992 PAG Manual provided decision-makers with radiation dose-based PAG values for various exposure pathways (such as whole body, skin dose and food ingestion) and associated protective actions that were adapted to the mix of radionuclides and operational environments associated with commercial NPPs.

In late 1991, EPA conducted a symposium titled "Implementing Protective Actions for Radiological Incidents at Other Than Nuclear Power Reactors," to evaluate PAGs for incidents other than accidents at NPPs and concluded that the PAGs could be applied to all radiological incidents (EPA 1992a). Since then, new radiological and nuclear scenarios involving terrorist use of radioactive materials have gained status in radiological emergency response planning.

In 2008, the Department of Homeland Security (DHS) published "Planning Guidance for Protection and Recovery Following Radiological Dispersal Device (RDD) and Improvised Nuclear Device (IND) Incidents" (DHS 2008). An RDD is a device or mechanism that is intended to spread radioactive material from the detonation of conventional explosives or other means. An IND is a crude, yield-producing nuclear weapon fabricated from diverted fissile material. Incidents like these may occur anywhere with little or no warning. The DHS guidance, developed cooperatively with EPA, DOE, DoD, DOL, HHS, Department of Commerce, and the NRC, affirms the applicability of existing 1992 EPA PAGs to terrorist acts, while acknowledging that the PAGs were inadequate for early response planning needs specific to an IND. To address this gap, "Planning Guidance for Response to a Nuclear Detonation" (NSS 2010) was subsequently published.

This Manual substantively incorporates late phase cleanup guidance provided in the 2008 DHS document and refers readers to additional planning resources.

1.3.5 Key Changes to PAGs in this Updated Manual

This updated Manual applies PAGs and protective actions to an expanded range of sources of potential radiological releases, including commercial nuclear power facilities, uranium fuel cycle facilities, nuclear weapons facilities, transportation accidents, radiopharmaceutical manufacturers and users, space vehicle launch and reentry, RDDs and INDs.

Dosimetry for all the PAGs was updated using the International Commission on Radiological Protection (ICRP) Publication 60 series (ICRP 1991). The PAGs in this Manual may be implemented using calculated, measurable values contained in the Federal Radiological Monitoring and Assessment Center (FRMAC) Assessment Manuals,[1] though using other incident-specific dose assessment methodologies is encouraged, where appropriate. EPA anticipates that radiological assessment methods will be periodically updated as improved models and methods become available. Therefore, readers are encouraged to review the FRMAC Assessment Manual to understand the most current, default radiological assessment methods. For simplicity, specific organ dose thresholds for evacuation and sheltering were removed.

This Manual incorporates several related guidance documents published subsequent to the 1992 guidance, including FDA's 1998 update of the PAGs for interdiction of food. This Manual also incorporates FDA's 2001 decision to lower the PAG for administration of stable iodine to 5 rem (50 millisieverts (mSv)) projected child thyroid dose. ~~Finally,~~ This update removes the intermediate phase relocation PAG of 5 rem (50 mSv) over 50 years to avoid confusion with long-term cleanup. ~~All other~~ Most of the PAGs and corresponding protective actions from the 1992 PAG Manual remain unchanged.

Recommended limits of exposure for emergency workers also remain unchanged from the 1992 PAG Manual. The emergency worker guides in this manual are consistent with federal and state regulations. Responsible officials should use judgment when doses may exceed regulatory limits and must advise workers of the risks. Table 1-1 presents PAGs with their principal associated protective actions or planning guides.

To further develop radiological emergency plans, brief planning guides have been provided for reentry to relocation areas, a cleanup planning process and considerations for radioactive waste disposal. In this Manual, the term reentry is used for emergency workers and members of the public going into relocation areas temporarily, under controlled conditions.

1.4 RADIOLOGICAL INCIDENT PHASES AND APPLICABILITY OF PROTECTIVE ACTIONS

Emergency planners divide responses to radiological incidents into three phases of activity—

[1] See FRMAC Assessment Manuals at http://www.nv.doe.gov/nationalsecurity/homelandsecurity/frmac/manuals.aspx.

- **Early Phase** — The beginning of a radiological incident ~~when~~ for which immediate decisions for effective use of protective actions are required and must therefore be based primarily on the status of the radiological incident and the prognosis for worsening conditions. When available, predictions of radiological conditions in the environment based on the condition of the source or actual environmental measurements may be used. Protective actions based on the PAGs may be preceded by precautionary actions during the period. This phase may last from hours to days.
- **Intermediate Phase** — The period beginning after the source and releases have been brought under control (has not necessarily stopped but is no longer growing) and reliable environmental measurements are available for use as a basis for decisions on protective actions and extending until these additional protective actions are no longer needed. This phase may overlap the early phase and late phase and may last from weeks to months.
- **Late Phase** — The period beginning when recovery actions designed to reduce radiation levels in the environment to acceptable levels are commenced and ending when all recovery actions have been completed. This phase may extend from months to years. A PAG level, or dose to avoid, is not appropriate for long-term cleanup.

The phases cannot be represented by precise periods of time—and may even overlap—but to view them in terms of activities, rather than time spans, can provide a useful framework for emergency response planning.

In the early phase, sheltering-in-place and evacuation are the principal protective actions. These actions are meant to avoid inhalation of gases or particulates in an atmospheric plume and to minimize external radiation exposures. Administration of prophylactic drugs may be employed depending on the specific radionuclides released; in particular, KI, also called "stable iodine," may be administered as a supplementary protective action in incidents involving the release of significant quantities of radioactive iodine, such as NPP incidents. Some protective actions may begin prior to the release of radioactive material when there is advance notice.

Planning considerations for reentry to relocation areas for specific tasks are suggested and basic planning guidance for late phase cleanup is provided in Chapters 3 and 4.

1.4.1 Implementation of Protective Action Guides and Protective Actions

Immediately upon becoming aware that an incident is about to occur or has occurred that may result in exposure of the population, responsible authorities should make a preliminary evaluation to determine the nature and potential magnitude of the incident. This evaluation should determine whether conditions indicate a significant possibility of a major release and, to the extent feasible, determine potential exposure pathways, populations at risk and projected doses. The incident evaluation and recommendations should then be presented to emergency response authorities for consideration and implementation.

During the early phase, the sequence of events includes—evaluation of conditions at the location of the incident, notification of responsible authorities, prediction or evaluation of potential consequences to the general public, recommendations for action and implementation of actions for the protection of the public.

In the intermediate phase, dose projections used to support decisions about protective actions may be based on measurements of environmental radioactivity and dose models. When conditions warrant relocation of populations, the collection of extensive radiological and cost-of-cleanup data will be necessary to form the decision basis for cleanup and recovery of the affected areas.

Table 1-1: Planning Guidance and Protective Action Guides for Radiological Incidents

Phase	Protective Action ~~Recommendation~~	Protective Action Guide or Planning Guide
Early[a] (Chapter 2)	Sheltering-in-place or evacuation of the public[b]	1 to 5 rem (10 mSv to 50 mSv) projected dose/4 days[c]
	Administration of prophylactic drugs KI[d]	5 rem (50 mSv) projected child thyroid dose[e] from radioactive iodine
	Limit emergency worker exposure	5 rem (50 mSv)/year (or greater under exceptional circumstances)[f]
Intermediate[a] (Chapter 3)	Relocation of the public	2 rem (20 mSv) projected dose first year[c] Subsequent years, 0.5 rem (5 mSv)/year projected dose
	Food interdiction[g]	0.5 rem (5 mSv)/year projected dose, or 5 rem (50 mSv)/year to any individual organ or tissue, whichever is limiting
	Limit emergency worker exposure	5 rem (50 mSv)/year[c]
	Reentry	Operational Guidelines[h] (Stay times and concentrations) for specific activities (see Section 3.7)
Late[i] (Chapter 4)	Cleanup	Brief description of planning process
	Waste Disposal	Brief description of planning process

a This guidance does not address or impact site cleanups occurring under other statutory authorities such as the United States Environmental Protection Agency's (EPA) Superfund program, the Nuclear Regulatory Commission's (NRC) decommissioning program, or other federal or state cleanup programs.

b Should begin at 1 rem (10 mSv); take whichever action (or combination of actions) that results in the lowest exposure for the majority of the population. Sheltering may begin at lower levels if advantageous.

c Projected dose- the sum of the effective dose from external radiation exposure (i.e., groundshine and cloudshine) and the committed effective dose from inhaled radioactive material.

d A supplemental protective action that provides thyroid protection from ~~internal exposure to~~ radioactive iodines only. The complete FDA guidance may be found at http://www.fda.gov/downloads/Drugs/GuidanceComplianceRegulatoryInformation/Guidances/ucm080542.pdf. Further information is also available: http://www.fda.gov/downloads/Drugs/GuidanceComplianceRegulatoryInformation/Guidances/ucm080546.pdf and http://www.fda.gov/Drugs/EmergencyPreparedness/BioterrorismandDrugPreparedness/ucm072265.htm.

e Thyroid equivalent dose. For information on other radiological prophylactics and treatment, refer to...http://www.fda.gov/Drugs/EmergencyPreparedness/BioterrorismandDrugPreparedness/ucm063807.htm http://www.bt.cdc.gov/radiation and www.orau.gov/reacts

f When radiation control options are not available, or, due to the magnitude of the incident, are not sufficient, doses to emergency workers above 5 rem (50 mSv) may be unavoidable and are generally approved by competent authority. For further discussion see Chapter 2, Section 2.6.

g For more information on food and animal feeds guidance, the complete FDA guidance may be found at http://www.fda.gov/downloads/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/UCM094513.pdf

h For extensive technical and practical implementation information please see "Preliminary Report on Operational Guidelines Developed for Use in Emergency Preparedness and Response to a Radiological Dispersal Device Incident" (DOE 2009)

I This cleanup process does not rely on and does not affect any authority, including the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), 42 U.S.C. 9601 et seq. and the National Contingency Plan (NCP), 40 CFR Part 300. This document expresses no view as to the availability of legal authority to implement this process in any particular situation.

Protective actions may already be designated in existing emergency response plans. Under NRC regulations, large commercial NPPs must maintain detailed radiological response plans for an emergency planning zone (EPZ) within a 10 mile (16.1 km) radius of the plant and for a separate ingestion pathway EPZ within a 50 mile (80.5 km) radius. ~~Emergency Responders~~ Emergency Workers should be prepared to select and implement appropriate protective actions when standing response plans are not available or applicable.

1.4.2 Conservatism built into the PAGs

Conservatism is built into the PAG levels themselves, as described in Sections 2.3.1 and 4.3.3 about the risk-benefit balancing process used to derive the PAGs. Additionally, assumptions made to generate default parameters and derived response levels in the FRMAC Assessment Manual, Volume 1, Appendix C, includes some conservative assumptions to ensure PAGs are appropriate emergency guides for all members of the public, including sensitive subpopulations such as young children. For example, Early Phase derived levels are based on the assumption that a person is outdoors twenty-four hours a day for four days being exposed to the plume. Intermediate Phase derived levels also conservatively do not account for shielding provided by being indoors part of each day of the projection year. People are assumed to remain in the contaminated area during the entire time (not going to work or school in an uncontaminated area, for instance.) Another example of conservatism is assuming that radionuclides are in the chemical and physical form that yields the highest dose, (e.g., the particle size is one micrometer mean aerodynamic diameter). These conservatisms allow dose assessors to project whole body doses (TED) to a reference person, for simplicity, and then decision makers can make protective action decisions that apply to entire communities including children, adults and the elderly.

Radiological assessors are encouraged to utilize realistic inputs when site- or source-specific information is available to limit the amount of conservatism built into the calculations. For example, if the radionuclide does not exist in a chemical or physical form or particle size that yields the highest dose, then assessors should use appropriate inputs to avoid overly conservative dose estimates that may lead to unnecessary protective actions.

Certain guidelines that lend themselves to different PAGs for different subpopulations are the PAGs for potassium iodide, food and water. These guidelines provide age-specific recommendations because of the radiosensitivity of the thyroid and young children with respect to ingestion and inhalation doses in particular.

Taking protective actions like use of KI, avoiding certain foods or using alternative sources of drinking water can be relatively simple to implement by the parents of younger children. Clear public messages can convey which age groups should take which action, unlike how an evacuation or relocation order should apply to entire households or neighborhoods.

An evaluation of dose consequences to several age groups across many radiological scenarios was done and, for the early phase including the plume, child whole body doses are typically no more than 15% higher than adult whole body doses. That margin is well within the conservatism discussed above, so that separate PAGs or projections need not be required. Therefore, basing evacuation, shelter in place and relocation dose projections on an adult is appropriate for all age groups. Sensitive age groups should be evaluated separately for KI, food and water decisions. Keeping calculations and decision making simple in the face of a disaster can enable timely actions to protect communities.

1.4.3 Early Phase Protective Action Guides and Protective Actions

In the early phase, there may be little or no data on actual releases to the environment and responders may have to rely on crude estimates of airborne releases. Decision time frames are short and preparation is critical to make prudent decisions when data are lacking or insufficient.

The principal protective actions for the early phase are evacuation and sheltering-in-place. These protective actions would be taken if whole body doses are projected to exceed 1 to 5 rem (10 to 50 mSv) over four days. The decision to evacuate must weigh the anticipated radiation dose to individuals in the affected population against the feasibility of evacuating within a determined time frame and the risks associated with the evacuation itself. For example, evacuating a population of 50,000 carries with it a statistical risk of injury or death from transportation hazards or increased exposure. Evacuation also takes time. In the case of an accident at an NPP, there ~~may~~ will likely be time for an orderly and relatively safe evacuation. In the case of a fire or explosion of an RDD in an urban area, evacuating a large group of people could leave them exposed to the plume and actually increase radiation dose. Sheltering-in-place may be warranted in situations where evacuation poses a greater risk of exposure or physical harm.

In addition, there are actions that are advisable, but not associated with a numerical PAG. For example, individuals should be instructed to cover airways (nose and mouth) with available filtering material when airborne radionuclides may be present. Decontamination is another protective action that may be utilized in the early phase and may include washing of contaminated individuals, removing contaminated clothing and decontaminating surfaces of critical areas and objects. Further, in areas where airborne radioactivity is present but PAGs are not exceeded, officials can consider asking people to stay indoors to the extent practicable. In such cases, individuals are not prevented from carrying out necessary tasks (e.g., seeking medical care, purchasing food). Similar to actions used in major cities on high pollution days, these measures can be effective to reduce radiation doses when prolonged releases occur, as was the case for the Fukushima accident in Japan.

In cases where significant quantities of radioiodine may have been released, administration of the radioprotectant KI should be considered as a supplementary protective action if the projected child thyroid dose exceeds 5 rem (50 mSv). This PAG is lower than the 1992 guidance. The lower dose, which FDA adopted in 2001, is for protection of children based on early studies of Chernobyl exposure data.

The choice of protective action will be based on the status of the incident site and the prognosis for worsening conditions. In the early phase, precautionary actions based on worst-case scenarios may be used before implementation of protective actions based on PAGs. For example, in the case of RDD detonation, governments may instruct affected populations to shelter in place as a precautionary action while radiation levels are being measured to determine appropriate PAG-based protective actions. Officials should plan for rapid broadcast and dissemination of protective action orders to the public.

When available, predictions of radiological conditions in the environment based on an estimate of the source or actual environmental measurements may be used. Nuclear facilities, for example, have continuous, real-time radioactive effluent monitoring capabilities to monitor radioactive material released to the environment and may have a network of off-site measurement stations.

1.4.4 Intermediate Phase Protective Action Guides and Protective Actions

Intermediate phase activities are intended to reduce or avoid dose to the public, to control worker exposures, to control the spread of radioactive contamination and to prepare for late phase cleanup operations.

During the intermediate phase, relocation is the principal protective action against whole body external exposure from deposited material and internal exposure from inhalation of radioactive particulates.

People may need to be relocated for weeks or months.

It is necessary to distinguish between evacuation and relocation. Evacuation is the urgent removal of people from an area to avoid or reduce high-level, short-term exposure from the plume or deposited activity. Relocation is the removal or continued exclusion of people (households) from contaminated areas to avoid chronic radiation exposure. Site-specific conditions may allow some groups evacuated in an emergency to return, while others may have to relocate. In other cases, some groups that were not previously evacuated may have to relocate (see Section 3.3.1 for more details).

Intermediate phase PAGs are based on doses projected in the first several years. The PAG for relocation of the public is 2 rem (20 mSv) in the first year and 0.5 rem (5 mSv) in any subsequent year. (Note: Relocation PAGs are treated separately from food and water ingestion. That is, projection of intermediate phase doses should not include these ingestion pathways. In some instances, however, where withdrawal of food and/or water from use would, in itself, create a~~,~~ health risk, relocation may be an appropriate alternative protective action. In this case, the ingestion dose should be considered along with the projected dose from deposited radionuclides via other pathways, for decisions on relocation.) When projected doses are less than the relocation PAG of 2 rem (20 mSv) in the first year, focused environmental decontamination and cleanup may be able to reduce doses to populations that are not relocated. Decontamination and focused cleanup techniques can range from simple actions such as the scrubbing and flushing of surfaces with uncontaminated water to the removal and disposal of soil and contaminated debris.

Keeping projected doses below the 0.5 rem (5 mSv) PAG ~~for out years –~~ in the second and subsequent years ~~and beyond~~ – may be achieved through the decay of shorter half-life radioisotopes (as in the case of an accident at an NPP), through environmental decontamination and cleanup efforts or through other means of controlling public exposures, such as limiting access to certain areas. Information on food and animal feeds protective action guidance is contained in FDA's "Accidental Radioactive Contamination of Human Food and Animal Feeds: Recommendations for State and Local Agencies" (FDA 1998). Workers and members of the public may be allowed to re-enter relocation area for tasks related to critical infrastructure and key resources, to care for animals and to assess the condition of closed zones. Reoccupancy may be allowed under dose constraints acceptable to the community. In this Manual, the term reoccupancy refers to households and communities moving back into relocation areas where the cleanup process is still ongoing, based on radiation levels acceptable to those communities.

~~EPA is not proposing a specific drinking water PAG at this time. EPA has established enforceable drinking water standards for radionuclides under the Safe Drinking Water Act (SDWA). EPA recommends that, to the extent practicable, emergency measures for drinking water be based on the National Primary Drinking Water Regulations (NPDWR) for Radionuclides. The Radionuclides Rule provides states with flexibility when responding to radiological events. If a public water system exceeds the radionuclides standard it must work to get back into compliance as soon as feasible. States have the authority to determine if other corrective actions are needed (e.g. providing alternative water). Guidance on monitoring, notification and protective actions is provided in Chapter 3, along with several online resources for drinking water system operators.~~

~~However, in light the Fukushima nuclear power plant accident, in which some Japanese drinking water supplies were impacted, the Agency recognizes a short-term emergency drinking water guide may be useful for public health protection The Agency requests input on the appropriateness of, and possible values for, a drinking water PAG.~~

~~While the NPDWR provide for a regulatory standard of 4 mrem/year (beta, photon emitters) based on life-time exposure, international organizations have developed technical approaches and methodologies that have produced a range of emergency guidelines related to drinking water (e.g., the World Health Organization[2], the International Atomic Energy Agency[3]), as have other federal agencies (e.g. the Department of Homeland Security[4], the Food and Drug Administration[5]) and non-federal organizations. EPA is seeking input on an approach and technical rationale for a drinking water PAG designed to help officials select protective actions under emergency conditions when exposures would occur over shorter time periods than those envisioned in the NPDWR.~~

{Placeholder for brief description of the final drinking water PAG}

During the intermediate phase, government officials may convene to discuss late phase cleanup and site restoration strategies. All actions taken during the early and intermediate phases should be considered with respect to the impact they may have on late phase remediation, such as avoiding the use of fixatives that could hinder surface decontamination at a later date.

1.4.5 Late Phase

The late phase, as used in this Manual, is the period beginning when cleanup and recovery actions have begun and ending when all recovery actions have been completed. This phase may extend from months to years.

The late phase cleanup process, as described in this guidance, begins sometime after the commencement of the intermediate phase and proceeds independently of intermediate phase protective action activities. The transition is characterized by a change in approach, from strategies predominantly driven by urgency, to strategies aimed at both reducing longer-term exposures and improving living conditions. The late phase involves the final cleanup of areas and property at which contamination directly attributable to the incident is present. It is in the late phase that final cleanup decisions are made and final recovery efforts following a radiological incident are implemented.

Unlike the early and intermediate phases of a radiological incident, decision makers will have more time and information during the late phase to allow for better data collection, stakeholder involvement and options analysis. Community members will influence decisions such as if and when to allow people to return home to contaminated areas. There will be populations, who were not relocated or evacuated, living in contaminated areas where efforts to reduce exposures will be ongoing. Implicit in these decisions is the ability to balance health protection with the desire of the community to resume normal life.

Radiation protection considerations must be addressed in concert with health, environmental, economic, social, psychological, cultural, ethical, political and other considerations. Many federal, state, and local agencies have important roles to play. It is recognized that experience from existing programs, such as the

U.S. EPA's Superfund program, the U.S. NRC's process for decommissioning and decontamination to terminate a nuclear facility license and other national recommendations may be useful for designing cleanup and recovery efforts that could apply to a radiological incident. The cleanup process described in Chapter 4, however, does not rely on and does not affect any authority, including the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), 42 U.S.C. 9601 et seq. and the National Contingency

~~[2] See http://www.who.int/water_sanitation_health/dwq/gdwq3rev/en/ and http://www.who.int/hac/crises/jpn/faqs/en/index8.html~~
~~[3] See http://www-pub.iaea.org/MTCD/publications/PDF/Pub1467_web.pdf~~
~~[4] See http://ogcms.energy.gov/73fr45029.pdf~~
~~[5] See http://www.fda.gov/downloads/MedicalDevices/.../UCM094513.pdf~~

Plan (NCP), 40 CFR Part 300. For information on roles, responsibilities and authorities during emergency response and recovery please refer to the National Response Framework: http://www.fema.gov/national-response-framework and specifically for radiological incidents, the Nuclear Radiological Incident Annex: http://www.fema.gov/pdf/about/divisions/thd/IncidentNucRad.pdf (FEMA 2008a, b).

The late phase or cleanup process described in Chapter 5 consists of multiple steps, namely 1) characterization and stabilization, 2) development of goals and strategies and 3) implementation and reoccupancy; meaningful stakeholder involvement should be integrated *throughout* the process.

While radioactive waste handling and disposal will be an ongoing endeavor during the entire emergency response, brief planning guidance is provided in Chapter 4, the late phase. This guidance addresses both locations that may be identified by state and local officials and locations owned by the federal government, and lists criteria for evaluating their suitability for disposal, as well as actions that can be taken to facilitate their use. Legal and other considerations are also discussed. This guidance assumes that on-site disposal at a location affected by the incident, where appropriate, will be one of the locations of choice. Though recommended as the first consideration for discussion post-accident or attack, this guidance assumes that existing non-federal radioactive waste disposal capacity already available to impacted states and their regions is overwhelmed or otherwise eliminated from consideration, which drives the need to identify other disposal options or develop new disposal capacity.

KEY POINTS IN CHAPTER 1 – OVERVIEW

- A PAG is the projected dose to an individual from a release of radioactive material at which a specific protective action to reduce or avoid that dose is recommended. PAGs are guides to help officials select protective actions under emergency conditions when exposures would occur over relatively short time periods.
- EPA provides the PAG Manual to assist public officials with their radiological emergency response planning activities. The PAG Manual is a guidance document, not a legally binding regulation and does not affect or supersede any environmental laws. The PAG recommendations do not represent the boundary between safe and unsafe conditions.
- PAGs may be implemented to protect the public in a wide variety of radiological emergencies, including terrorist incidents and accidents involving nuclear power plants, transportation and the space program.
- PAGs are appropriate for implementation in the early and intermediate phases of radiological incidents. The early phase—lasting hours to days—is the period beginning at the projected (or actual) initiation of a release when immediate decisions for effective use of protective actions are required and must therefore be based primarily on the status of the release and the prognosis for worsening conditions. Little environmental data may be available in the early phase. The intermediate phase— lasting weeks to months—is the period beginning after the source and releases have been brought under control and environmental measurements are available for use as a basis for decisions on protective actions.
- Reentry and reoccupancy decisions will be made using incident-specific circumstances and the Operational Guidelines (DOE 2009).
- Cleanup and waste disposal decisions may be informed by planning guidance provided in Chapter 5 .
- What's new in this updated Manual—
  - The PAGs in this Manual are implemented using the calculations and methods in the FRMAC Assessment Manual. Dosimetry in that Manual has been updated using the ICRP Publication 60 series (ICRP 1991).
  - EPA adopts the FDA guidance issued in 2001 that recommended lowering the projected thyroid dose at which the administration of KI is warranted as a supplementary protective action.
  - {Placeholder for mention of drinking water guidance }
  - EPA adopts the 1998 FDA Food PAGs.
  - Planning guidance has been provided for reentry, late phase cleanup and waste disposal.

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CHAPTER 2. EARLY PHASE PROTECTIVE ACTION GUIDES

1.5 INTRODUCTION

Decisions regarding protective actions for workers and the public during radiological incidents are risk management decisions and the recommendations in this Manual are provided in that context. Rapid action may be required to protect members of the public in the event of an incident involving a large release of radioactive materials into the environment. In all cases, all practical and reasonable means should be used to reduce or eliminate exposures.

This chapter presents PAGs for use in the early phase of a radiological incident. A PAG is the projected dose to an individual from a release of radioactive material at which a specific protective action should be taken to reduce or avoid that dose. The early phase begins at the actual or projected start of a release— most likely before ambient environmental and radiological data become available for quantitative risk- based actions. The exact duration of the early phase depends upon site conditions, but one should plan to project doses for four days.

Many radiological emergency scenarios would involve airborne releases, so this chapter provides guidance for estimating projected doses from exposure to an airborne plume of radioactive material and for implementing protective actions. Dose calculations for implementing the PAGs are made using the ~~dose conversion factors (DCFs)~~ dose parameter (DP) and derived response level (DRL) methods referenced in the FRMAC Assessment Manuals[6] Note that FRMAC refers to dose parameters in emergency response dose assessment methods to avoid confusion with dose coefficients and dose conversion factors published for radiation protection in general. Other calculation methods to implement PAGs may be appropriate.

1.6 EXPOSURE PATHWAYS DURING THE EARLY PHASE

During the early phase of an incident, there are three main exposure pathways from airborne releases—

- **Direct exposure** to radioactive materials in an atmospheric plume. The contents of such a plume will depend on the source of radiation involved and conditions of the incident. For example, in the case of an incident at an NPP, the plume may contain radioactive noble gases, radioiodines and radioactive particulate materials. Many of these materials emit gamma radiation that can expose people in the vicinity of the passing plume.
- **Inhalation** of radionuclides from immersion in a radioactive atmospheric plume and inhalation of ground-deposited radionuclides that are resuspended into a breathing zone. Inhaled radioactive particulates, depending on their solubility in body fluids, may remain in the lungs or move via the bloodstream to other organs, prior to elimination from the body. Some radionuclides become concentrated in a single body organ, with only small amounts going to other organs. For example, a significant fraction of inhaled radioiodines will move through the bloodstream to the thyroid gland.
- **Deposition** of radioiodine and particulates from a radioactive plume. Deposited materials can continue to emit "groundshine" (e.g., beta and gamma radiation) after the plume has passed causing continued exposure to skin and internal body organs. ~~Deposited materials can continue to emit beta and gamma radiation as "groundshine" after the plume has passed causing continued exposure to skin and internal body organs~~. ~~Similarly, skin and clothes may become contaminated.~~

A plume may deposit materials on surfaces, posing a risk of longer-term exposures via ingestion, direct external exposure and inhalation pathways. If the release contains large quantities of radioactive iodines or particulates, the resulting long-term exposure to this "groundshine" can be more significant than external

[6] See FRMAC Assessment Manuals at http://www.nv.doe.gov/nationalsecurity/homelandsecurity/frmac/manuals.aspx.

exposure from the passing plume if the exposure time to the ground contamination is long in comparison to the plume passage time. The early phase PAGs assume four days of exposure to ground contamination to address this possibility. Doses from groundshine can be readily measured by field monitoring teams dispatched at the onset of a significant radioactive release. Holding a detector probe horizontal and three feet (approximately one meter) above the contaminated surface provides a direct measurement of groundshine dose. Such assessments can confirm dose projections based upon effluent release data and the adequacy of protective actions in the early phase. More detailed analyses (e.g., isotopic) would be needed to support long-term dose projections in the intermediate phase. Doses for groundshine can be calculated during the intermediate phase (see Chapter 4). Exposure pathways that contribute less than ten percent to the total dose incurred need not be considered during the early phase.

1.6.1 The Establishment of Exposure Patterns

It is unlikely that sufficient environmental data will be available for accurate dose projections during and immediately following the early response to a radiological incident. Dose projections are needed to determine whether protective actions should be implemented in additional areas during the early phase.

For dose projections in the early phase there are two sources of data: current data from initial environmental measurements or estimates of the source term and estimated data using modeled or historical atmospheric transport data. Source term measurements, or exposure rates or concentrations measured in the plume at a few selected locations, may be used to estimate the extent of the exposed area in a variety of ways, depending on the types of data and computation methods available. The most accurate method of projecting doses is through the use of an atmospheric diffusion and transport model that has been verified for use at the site in question or for similar site conditions. A variety of computer software packages can be used to estimate dose in real time, or to extrapolate a series of previously-prepared isopleths for unit releases under various meteorological conditions. The latter can be adjusted for the estimated source magnitude or environmental measurements at a few locations during the incident. If the model projections have some semblance of consistency with environmental measurements, extrapolation to other distances and areas can be made with greater confidence. If projections using a sophisticated site-specific model are not available, a simple but crude method is to measure the plume centerline exposure rate[7] at ground level (measured at approximately 1 m height) at a known distance downwind from the release point and then to calculate exposure rates at other downwind locations by assuming that the plume centerline exposure rate is a known function of the distance from the release point.

The following relationship can be used for this calculation:

$$D_2 = D_1 (R_1/R_2)_y$$

where D_1 and D_2 are exposure rates at the centerline of the plume at distances R_1 and R_2 from the release, respectively and y is a constant that depends on atmospheric stability. For stability classes[8] A and B, y = 2; for stability classes C and D, y = 1.5; and for stability classes E and F, y = 1. Classes A and B (unstable) occur with light winds and strong sunlight and classes E and F (stable) with light winds at night. Classes C and D generally occur with winds stronger than about 10 mph. This method of extrapolation is risky because the measurements available at the reference distance may be unrepresentative, especially if the plume is aloft and has a looping behavior. In the case of an elevated plume, the ground level concentration increases with distance from the source and then decreases, whereas any high-energy gamma radiation from the overhead cloud continuously decreases with distance. For these reasons, this method of extrapolation will perform best for surface releases or if the point of measurement for an elevated release is sufficiently distant (usually more than

[7] The centerline exposure rate can be determined by traversing the plume at a point sufficiently far downwind that it has stabilized (usually more than one mile from the release point) while taking continuous exposure rate measurements.

[8] Pasquill stability classes categorize atmospheric turbulence into six stability classes named A, B, C, D, E and F, class A being the most unstable or most turbulence and class F the most stable or least turbulence. Pasquill, F. 1961. The Estimation of the Dispersion of Windborne Material. The Meteorological Magazine 90, No. 1063, 33-49.

1 mile) from the point of release for the plume to have expanded to ground level. The accuracy of this method will be improved by the use of measurements from many locations averaged over time.

1.7 THE PROTECTIVE ACTION GUIDES AND PROTECTIVE ACTIONS FOR THE EARLY PHASE: EVACUATION, SHELTERING-IN-PLACE AND ADMINISTRATION OF POTASSIUM IODIDE

The principal protective actions for the early phase are evacuation or sheltering-in-place. Evacuation is the urgent removal of people from an area to avoid or reduce high-level, short-term exposure from the plume or deposited activity. Sheltering-in-place is the action of staying or going indoors immediately. The administration of KI (stable iodine) to partially block the uptake of radioiodines by the thyroid is a supplemental protective action.

In addition, washing the body and changing clothing as soon as possible after significant exposure to a radioactive plume of any composition may be recommended protective actions. Changing of clothing is recommended primarily to provide protection from beta radiation from radioiodines and particulate materials deposited on the clothing.

The PAGs and corresponding protective actions for response during the early phase of an incident are summarized in Table 2-1. Evacuation or sheltering-in-place will be justified when the projected dose to an individual is 1 rem (10 mSv) projected over four days. This conclusion is based primarily on EPA's determination concerning acceptable levels of risk of health effects from radiation exposure in an emergency situation, while weighing costs and risks associated with any protective action. ~~The basis for the PAGs for the early phase is given in Appendix C of the 1992 PAG Manual, available online as a historical reference at http://www.epa.gov/radiation/rert/pags.html.~~

Table 2-1: PAGs and Protective Actions for the Early Phase of a Radiological Incident

Protective Action ~~Response~~	PAG (projected dose)	Comments
Sheltering-in-place or evacuation of the public[a]	1 to 5 rem (10 mSv to 50 mSv) over four days[b]	Evacuation (or, for some situations, sheltering-in-place) should be initiated when projected dose is 1 rem (10 mSv).
Supplementary administration of prophylactic drugs – KI[c]	5 rem (50 mSv) projected dose to child thyroid from exposure to iodine[d]	KI is most effective if taken prior to exposure. May require approval of state medical officials (or in accordance with established emergency plans).

[a]Should begin at 1 rem (10 mSv) if advantageous except when practical or safety considerations warrant using 5 rem (50 mSv); take whichever action (or combination of actions) that results in the lowest exposure for the majority of the population. Sheltering may begin at lower levels if advantageous.

[b]Calculated dose is the projected sum of the effective dose from external radiation exposure (i.e., groundshine and plume submersion) and the committed effective dose from inhaled radioactive material.

[c]A supplemental protective action that provides thyroid protection from radioactive iodines only. For other information on radiological prophylactics and treatment, refer to http://www.fda.gov/Drugs/EmergencyPreparedness/BioterrorismandDrugPreparedness, http://www.emergency.cdc.gov/radiation or http://www.orau.gov/reacts.

[d]~~Thyroid equivalent dose (see Section 2.3.5).~~ Thyroid dose (see Section 2.3.4)

This guidance does not address or impact site cleanups occurring under other statutory authorities such as the United States Environmental Protection Agency's (EPA) Superfund program, the Nuclear Regulatory Commission's (NRC) decommissioning program, or other federal or state cleanup programs.

1.7.1 Thyroid Based Evacuation

This revised PAG Manual does not include a footnote from the 1992 PAG Manual Early Phase PAG table, which noted that 'thyroid and skin may be 5 and 50 times larger, respectively.' That footnote effectively provided organ dose based evacuation thresholds in addition to the whole-body dose PAG range of 1 to 5 rem (10 to 50 mSv). Because of the factors described above, these organ dose based Early Phase PAGs are not necessary.

Regarding sensitive subpopulations, child thyroid doses typically are about twice as high as adult thyroid doses. The former range recommended for thyroid dose-based evacuation (5 to 25 rem adult thyroid dose) is well covered by projections of whole body dose, with evacuation recommended at 1 to 5 rem (10 to 50 mSv) adult TED. The conservatism built into the PAG levels when they were set results in an appropriate level of dose avoidance for the whole community, including all age groups, for an emergency. Planners should consider instituting public messaging templates in advance to address concerns the public may have about how protective the PAG recommendations are for all members of an impacted community.

The PAG Manual is guidance, and intentionally not prescriptive. This set of recommendations does not preclude an emergency manager from setting local or state protective action guidelines for actions based on specific organ or age group dose levels, as warranted by specific needs of that community.

1.7.2 Basis for Early Phase PAGs

For a full description of the risk-benefit analysis used to set the PAG levels, refer to the 1992 PAG Manual, Appendices B, C and E. The Manual is available online in a searchable format. Below is a short summary on the basis for the Early Phase evacuation/sheltering PAG of 1 to 5 rem (10 to 50 mSv) projected over 4 days.

PAGs are intended to apply to all individuals in a population other than workers performing emergency services. However, there may be identifiable groups that have different average sensitivity to radiation or, because of their living situation, will receive higher or lower doses. In addition, some groups may be at greater risk from taking a given protective action. Special circumstances and age groups (e.g., fetal dose) were considered, when appropriate, in establishing values for the PAGs.

The following four principles provided the basis for establishing values for Protective Action Guides:

a. Acute effects on health (those that would be observable within a short period of time and which have a dose threshold below which they are not likely to occur) should be avoided.

b. The risk of delayed effects on health (primarily cancer and genetic effects, for which linear non-threshold relationships to dose are assumed) should not exceed upper bounds that are judged to be adequately protective of public health, under emergency conditions, and are reasonably achievable.

c. PAGs should not be higher than justified on the basis of optimization of cost and the collective risk of effects on health. That is, any reduction of risk to public health achievable at acceptable cost should be carried out.

d. Regardless of the above principles, the risk to health from a protective action should not itself exceed the risk to health from the dose that would be avoided.

EPA considered the acceptable range of costs for avoiding a statistical death from pollutants other than radiation and using a rounded value from the BEIR III risk of 0.0003 cancer deaths per person-rem. Further evaluation of thyroid, skin and fetal dose consequences was conducted as well.

Costs of evacuation:

Based on a prior published study ("An Analysis of Evacuation Options for Nuclear Accidents, EPA 520/1-87-023, 1987) evaluating evacuation options for several accident types, this analysis focused on the smallest

ED_001057_00012426

category of fuel melt accident yielding effective dose equivalents during the first 4 days of exposure that are greater than 0.5 rem outside the assumed 2-mile evacuation circle for all stability classes. For this scenario, total and incremental costs were calculated for several different sized evacuation areas. Data on costs versus dose avoided for several meteorological stability classes and evacuation options (sizes) were summarized in tables in the 1992 PAG Manual, Appendix C.

For a risk of 0.0003 cancer deaths per person-rem, the range of evacuation costs can be compared to the marginal cost-effectiveness (dollars per person-rem) of evacuation over an angle of 90 degrees. The resulting ranges of upper bounds on dose are in tables in Appendix C, for three different accident scenarios. The maximum upper bounds (based on minimum costs for avoiding risk) range from 1 to 10 rem, with most values being approximately 5 rem. The minimum upper bounds (based on maximum costs for avoiding risk) range from 0.15 to 0.8 rem, with 0.5 rem dose incurred being representative of most situations.

From these data we conclude that, based on the cost of evacuation, a PAG larger than the range of values 0.5 to 5 rem would be incompatible with Principle 3.

Based on comparison of exposures from evacuation versus the presumed alternative of sheltering in various building types for several timeframes, the dose actually avoided by evacuation is one half of the projected dose.

Risk from evacuation:

Principle 4 requires that the risk of the protective action not exceed the risk associated with the dose that will be avoided. Risk from evacuation can come from several sources, including (1) transportation incidents for both pedestrians and vehicle passengers, (2) exposure to severe weather conditions or a competing disaster, and (3), in the case of immobile persons, anxiety, unusual activity, and separation from medical care or services. While all these factors must be considered, transportation incidents is the only category for which the risk has been quantified.

Conformance to Principle 1 (avoidance of acute health effects) is assured by the low risk required to satisfy Principle 2 (acceptable risk of delayed health effects), and thus requires no additional consideration. Based on Principle 2, evacuation of the general population is not justified below 0.5 rem. This represents a risk of about 0.0002 of fatal cancer. Maximum lifetime risk levels considered acceptable by EPA from routine operations of individual sources range from 0.000001 to 0.0001. Risk levels that are higher than this must be justified on the basis of the emergency nature of a situation. In this case, we judge that up to an order of magnitude higher combined risk from all phases of an incident may be justifiable. The choice of 0.5 rem avoided dose as an appropriate criterion for an acceptable level of risk during the early phase is a subjective judgment that includes consideration of possible contributions from exposure during other phases of the incident.

Principle 4 (risk from the protective action must be less than that from the radiation risk avoided) supplies a lower bound of 0.03 rem on the dose at which evacuation of most members of the public is justified. The lower bound was derived from the risk of death from traffic accidents in emergency evacuations, using the factor of 0.0003 cancer deaths per person-rem. Finally, under Principle 3 (cost/risk considerations) evacuation is justified only at values equal to or greater than 0.5 rem. This will be limiting unless lower values are required for purely health-based reasons (Principle 2). But this is not the case.

In summary, we have selected the value 0.5 rem as the avoided dose which justifies evacuation, because 1) it limits the risk of delayed effects on health to levels adequately protective of public health under emergency conditions, 2) the cost of implementation is justified, and 3) it satisfies the two bounding requirements to avoid acute radiation effects and to avoid increasing risk through the protective action itself.

The value of the PAG for evacuation of the general public is therefore chosen as one rem projected total effective dose from inhalation of radionuclides and exposure to external radiation.

1.7.3 Evacuation vs. Sheltering-in-Place

Evacuation and sheltering-in-place provide different levels of dose reduction from the principal exposure pathways: direct gamma exposure and inhalation. Both sheltering and evacuation may be implemented during the same response in different areas or timeframes. Evacuation, if completed before plume arrival, can be 100 percent effective in avoiding radiation exposure. A decontamination station, with simple decontamination actions, may need to be collocated at shelters during the pre-evacuation period. This may reduce the spread of contamination and provide for greater protection during evacuation. Medical stations should also be collocated at shelters during the pre-evacuation period to ensure simple triage capabilities are met and to manage the distribution of prophylactic drugs. The effectiveness of evacuation will depend on many factors, such as how rapidly it can be implemented and the nature of the incident. For incidents where the principal source of dose is inhalation, evacuation could increase exposure if it is implemented during the passage of a short-term plume, because the air inside a vehicle rapidly equalizes with the outside air even when all of the windows and vents are closed. ~~since vehicles used to transport evacuees provide little protection against exposure~~ (DOE 1990). Below 1 rem (10 mSv), evacuation is not recommended because of risks associated. ~~Evacuation will seldom be justified at less than 1 rem (10 mSv) over the first four days.~~

Sheltering-in-place is a low-cost, low-risk protective action that can provide protection with an efficiency ranging from zero to almost 100 percent, depending on the type of release, the type of shelter available, the duration of the plume passage and climatic conditions. Because of these advantages, planners and decision makers may consider implementing sheltering-in-place when projected doses are below 1 rem (10 mSv) over the first four days. More guidance on the unique challenges posed by an IND can be found in the "Planning Guidance for Response to a Nuclear Detonation" (NSS 2010).[9]

Sheltering-in-place may be preferred for special populations (e.g., those who are not readily mobile) as a protective action at projected doses of up to 5 rem (50 mSv) over four days. When environmental, physical, or weather hazards impede evacuation, sheltering-in-place may be justified at projected doses up to 5 rem (50 mSv) for the general population (and up to 10 rem (100 mSv) for special populations). It is also comparatively easy to communicate with populations that have sheltered-in-place. Dose projections use a four-day exposure duration, but sheltering in place duration is intentionally not specified. Incident- specific decisions must be made to determine how long people should shelter in place.

Selection of evacuation or sheltering-in-place is far from an exact science, particularly in light of time constraints that may prevent thorough analysis at the time of an incident. The selection process should be based on realistic or "best estimate" dose models and should take into account the unavoidable dose incurred during evacuation and potential failure scenarios for sheltering-in-place (e.g., leaking ventilation system).

Advance planning and exercises can facilitate the decision process. In a commercial NPP incident, early decisions should be based on information from the response plans for the EPZ and on actual conditions at the nuclear facility (see Section 2.3.5). For transportation accidents, RDDs, INDs and other incident scenarios for which EPZs are not practicable, best estimates of dose projections should be used for deciding on evacuation, sheltering-in-place or a combination thereof.

Sheltering-in-place should be preferred to evacuation whenever it provides equal or greater protection.
Sheltering-in-place followed by informed evacuation may be most protective.

1.7.4 ~~General Guidance for Evacuation and Sheltering-in-PlaceConsiderations for Evacuation~~

The following is a summary of planning guidance for evacuation and sheltering-in-place—Evacuation may be the only effective protective action close to the plume source.

- Evacuation will be most effective if it is completed before arrival of the plume.

[9] See http://www.epa.gov/rpdweb00/docs/er/planning-guidance-for-response-to-nuclear-detonation-2-edition-final.pdf

- Evacuation may increase exposure if carried out during the plume passage.
- Evacuation is also appropriate for protection from groundshine in areas with high exposure rates from deposited materials when suitable shelter is not available.
- Sheltering-in-place may be appropriate for areas not designated for immediate evacuation—
  - It may provide protection equal to or greater than evacuation for rapidly developing releases (e.g., RDDs) if followed by evacuation.
  - It positions the public to receive additional instructions.
  - Since it may be implemented rapidly, sheltering-in-place may be the protective action of choice (followed with evacuation when feasible) if rapid evacuation is impeded by:
    - severe environmental conditions (e.g., severe weather or floods);
    - uncertainty in contamination levels along routes;
    - health constraints (e.g., patients and workers in hospitals and nursing homes);
    - long mobilization times that may be associated with certain individuals, such as industrial and farm workers, or prisoners and guards;
    - physical constraints to evacuation (e.g., inadequate roads or blockage due to debris).
- If a major release of radioiodine or particulate materials occurs, inhalation dose may be a controlling criterion for protective actions—
  - Breathing air filtered through common household items (e.g., folded handkerchiefs or towels) may help reduce exposures.
  - After confirmation that the plume has passed, continued sheltering-in-place should be re-evaluated. Shelters may ~~should~~ be opened to vent any airborne radioactivity trapped inside and people should remain sheltered until official notice about leaving high exposure areas as soon as possible to avoid exposure to deposited radioactive material.

1.7.5 ~~Considerations for Evacuation and Sheltering-In-Place~~

Advance planning is essential to identify potential problems that may occur in an evacuation. An NRC case study cites the following aspects of planning as contributing to efficiency and effectiveness of evacuation (NRC 2005)—

- High level of cooperation among agencies.
- Use of multiple forms of emergency communications.
- Community familiarity with alerting methods, the nature of the hazard and evacuation procedures.
- Community communication.
- Well-trained ~~emergency responders~~ emergency workers.

The NRC 2005 study included an evaluation of 50 incidents of public evacuation involving 1,000 or more people. The evacuations studied were initiated in response to natural disasters, technological hazards and malevolent acts occurring between January 1, 1990 and June 30, 2003. The report indicated that public familiarity with alerting methods and door-to-door notification were statistically significant factors for the efficiency of evacuation. The report also indicated that many communities are making improvements to response capabilities by modernizing communication systems, improving traffic flow, local education awareness and developing interagency and cross-boundary coordination plans.

~~Regardless of size,~~ Large or small population groups can be evacuated effectively with minimal risk of injury or death. In the NRC report, only six of the 50 cases studied involved deaths from the hazard and of those six, only one involved death from the evacuation itself (NRC 2005).

However, in 2005, not long after this report was published, the gulf coast of the United States was hit by a series of hurricanes that resulted in the evacuation of approximately 5 million people. During the evacuation that accompanied Hurricane Rita in Houston, Texas, 106 people were reported to have died as a direct result of the evacuation. It is estimated that at least two-thirds of the evacuees did not need to evacuate but did so because of poor communication, fear and poor traffic management (NRC 2008).

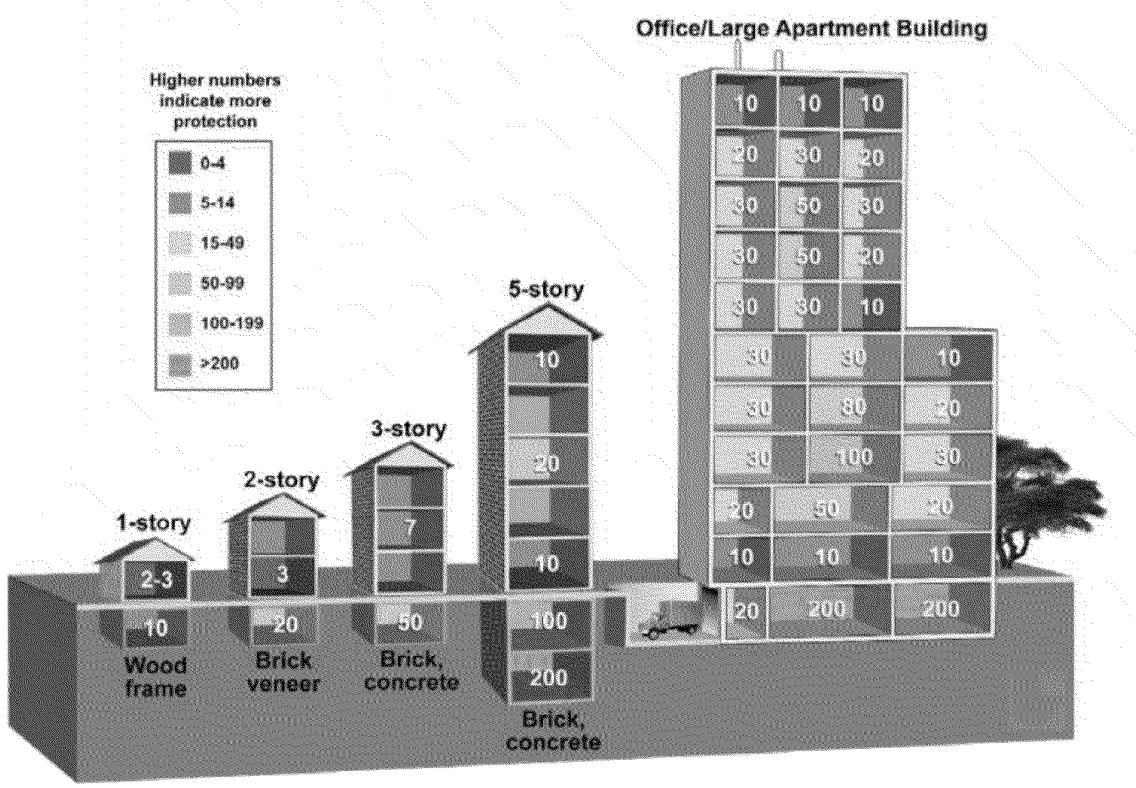
In a ~~recent~~ study of 230 mass evacuations in the U.S. ("Identification and Analysis of Factors Affecting Emergency Evacuations" NUREG/CR-6484, 2004) only six cases involved deaths from the hazard itself, and of these six, only one case involved deaths during the evacuation itself. Only two cases involved injuries during the evacuation. Traffic issues, such as traffic congestion, were reported in 28% of the evacuation cases studied. However, traffic accidents occurred in only 8% of the cases.

During the tsunami and nuclear disaster response in Japan in 2011, over 1,000 deaths occurred during evacuations, primarily among elderly hospital patients being moved from areas without power. Compounded disaster conditions including aftershocks, widespread power outages and radiation releases led to prolonged transit along routes extended to avoid hazards.

The emergency planning process for radiological incidents should include effective traffic management plans and communications plans, including pre-scripted messages, provisions for evacuation of special needs populations, such as children in schools and child care facilities, people in institutions and people who have impaired mobility or lack personal transportation.

The degree of protection provided by structures is affected by factors such as attenuation of gamma radiation (shielding) by structural components (the mass of walls, ceilings, etc.) and outside/inside air exchange rates (see Figure 2-2). The use of large structures, such as shopping centers, schools, churches and commercial buildings, as collection points during evacuation mobilization will generally provide greater protection against gamma radiation than use of small structures. As with evacuation, delay in taking shelter during plume passage will result in higher exposure to radiation.

Figure 2-1: Exposure reduction from external radiation from nuclear fallout as a function of building type and location.



The numbers represent dose reduction factors. A dose reduction factor of 10 indicates that a person in that area would receive 1/10th of the dose of a person in the open. A dose reduction factor of 200 indicates that a person in that area would receive 1/200th of the dose of a person out in the open.
Figure taken from Planning Guidance for Response to a Nuclear Detonation, Second Edition, National Security Staff

Interagency Policy Coordination Subcommittee for Preparedness and Response to Radiological and Nuclear Threats, June 2010, courtesy of Lawrence Livermore National Laboratory. The protection factors in this figure are specific to nuclear detonation fallout, but the variations in factors throughout typical buildings may be informative for other airborne radiological releases.

1.7.6 Considerations for Potassium Iodide (KI)

FDA updated its guidance on the use of KI as a thyroid blocking agent during radiological emergencies in 2001 (FDA 2001[10] and FDA 2002[11]). FDA based these dose recommendations on a review of the thyroid cancer data from the Chernobyl reactor accident of April 1986 and the experience of Poland in administering KI following the Chernobyl release (FDA 2001).

Table 2-2

Threshold Thyroid Radioactive Exposures and Recommended Doses of KI for Different Risk Groups

	Predicted Thyroid exposure (cGy)	KI dose (mg)	# of 130 mg tablets	# of 65 mg tablets
Adults over 40 yrs	≥500	130	1	2
Adults over 18 through 40 yrs	≥10			
Pregnant or lactating women	≥5			
Adults. Over 12 through 18 yrs*		65	1/2	1
Children over 3 through 12 yrs				
Over 1 month through 3 yrs		32	1/4	1/2
Birth through 1 month		16	1/8	1/4

However, FDA understands that a KI administration program that sets different projected thyroid radioactive exposure thresholds for treatment of different population groups may be logistically impractical to implement during a radiological emergency. In such cases, FDA recommends that KI be administered to both children and adults at the lowest intervention threshold (i.e., >5 rem (50 mSv) projected internal thyroid exposure in children)[12] (FDA 2002).

Regarding dosage of KI, FDA's guidance adheres to principles of minimum effective dose and therefore recommends graded dosing according to age (and thus, in effect, body size). There is ample evidence that the recommended doses, as well as higher doses (e.g., up to 130 mg), will effectively block thyroidal uptake of radioactive iodine if taken in advance of exposure. Furthermore, particularly among school-age children, higher milligram doses are extremely safe. However, FDA continues to emphasize attention to KI dosing in infants. Excess iodine intake can lead to transient iodine-induced hypothyroidism. Individuals who are intolerant of KI at protective doses, as well as neonates, pregnant, and lactating women, should be given priority with regard to other protective measures (i.e., sheltering, evacuation, and control of the food supply). In summary, if local emergency planners conclude that graded dosing is logistically impractical, FDA believes that for populations at risk for radioiodine exposure, the overall benefits of taking up to 130 mg of KI instead of the lower doses recommended for certain age groups far exceed the small risks of overdosing. However, where feasible, adherence to FDA guidance should be attempted when dosing infants. (FDA 2002).

[10] Food and Drug Administration [FDA]. Guidance Potassium Iodide as a Thyroid Blocking Agent in Radiation Emergencies. Federal Register, 66, 64045: 2001.

[11] Food and Drug Administration [FDA]. Guidance for Industry - KI in Radiation Emergencies -- Questions and Answers. Food and Drug Administration, Center for Drug Evaluation and Research. Procedural, Revision 1. Rockville, MD, (2002).

[12] Food and Drug Administration [FDA]. Guidance for Industry - KI in Radiation Emergencies -- Questions and Answers. Food and Drug Administration, Center for Drug Evaluation and Research. Procedural, Revision 1. Rockville, MD, (2002).

Note that KI is effective only against uptake of radioiodine, and is best taken prior to or just after exposure. The protective effect of a single dose of KI lasts approximately 24 hours. It should be administered daily until the risk of significant exposure to radioiodine (either by inhalation or ingestion) no longer exists, i.e., once the plume has passed. KI is a supplemental action, secondary to evacuation or sheltering. It should not be used as a substitute for evacuation or sheltering. Many communities do not use KI.

It should be noted that adults over 40 need to take KI only in the case of a projected large internal radiation dose to the thyroid (>500 rem (5 Sv) to prevent hypothyroidism which could lead to lifelong dependence on thyroid hormone replacement therapy. Thyroid irradiation in adults over 40 years of age is associated with an extremely low incidence of cancer (FDA 2001).

Some people should not take KI. As a rule, individuals with known allergy to iodine or with pre-existing thyroid disease (e.g., Graves' disease, thyroid nodules, Hashimoto's thyroiditis) that might predispose them to adverse reactions should avoid KI. Allergies to iodine and to shellfish are not related. People allergic to shellfish need not worry about cross reactions with stable iodine. More information is available at: http://www.foodallergy.org/allergens/shellfish-allergy and http://www.acaai.org/allergist/Resources/ask-allergist/Pages/Is_Shellfish_Allergy_Related_to_Iodine.aspx

Pregnant women should be given KI for their own protection and for that of the fetus, as iodine (whether stable or radioactive) readily crosses the placenta. However, because of the risk of blocking fetal thyroid function with excess stable iodine, repeat dosing with KI of pregnant women should be avoided.

Lactating females should be administered KI for their own protection, as for other young adults, and potentially to reduce the radioiodine content of the breast milk, but not as a means to deliver KI to infants, who should get their KI directly. As for direct administration of KI, stable iodine as a component of breast milk may also pose a risk of hypothyroidism in nursing neonates. Therefore, repeat dosing with KI should be avoided in the lactating mother, except during continuing severe contamination. If repeat dosing of the mother is necessary, the nursing neonate should be monitored.

Once the plume has passed, protective actions such as evacuation and/or sheltering-in-place and food control measures to limit exposure to radioiodine should be implemented and the administration of KI should be suspended. Food control measures include providing the public with non-contaminated food supplies while awaiting the eventual radioactive decay of contaminated food. Consumption of contaminated food may be permitted on a case-by-case basis after surveying the foodstuffs and determining the level of contamination consistent with FDA food and animal feeds guidance. As a result of radioactive decay, grain products and canned milk and vegetables from sources affected by radioactive fallout will not present a risk from radioiodine if they have been stored for weeks to months after production.

An RDD is not likely to contain radioiodine, so administration of KI would not be necessary in such incidents. The administration of other prophylactic drugs should be evaluated on a case-by-case basis depending on the nature of the event and the radioisotopes involved. For more information on radiological prophylactics and treatments, see: http://www.fda.gov/Drugs/EmergencyPreparedness/BioterrorismandDrugPreparedness.

1.7.7 PAGs and Nuclear Facilities Emergency Planning Zones (EPZ)

Under NRC regulations, before a nuclear power reactor may be issued a license, the NRC must find that licensee, state and local emergency plans are adequate and that they can be implemented. For nuclear power reactors, there is a plume exposure EPZ within a 10 mile (16.1 km) radius of the plant and for a separate ingestion pathway EPZ within a 50 mile (80.5 km) radius. The sizes of these EPZs were developed by the NRC/EPA Task Force Report on Emergency Planning, NUREG-0396/EPA 520/1-7-016 and are based, in part, on the numerical values of the PAGs for the plume exposure and ingestion pathway EPZ. The licensee develops and maintains a detailed emergency plan for its facility while state and local authorities within the EPZ develop and maintain detailed emergency response plans for their respective jurisdictions. Guidance to these licensees, states and local agencies for developing these emergency response plans, including guidance

on arrangements for implementing immediate protective actions is primarily contained in NUREG-0654/FEMA-REP-1 (NRC 1980)[13] and supplemented with other guidance issued by NRC (for licensees) and FEMA (for off-site response organizations).

Planning for incidents at other types of nuclear facilities should be developed using similar considerations. Emergency preparedness requirements for non-power reactors (e.g., test and research facilities) are provided in 10 CFR Part 50 Appendix E with supporting guidance in NRC Regulatory Guide 2.6, "Emergency Planning for Research and Test Reactors." Emergency preparedness requirements for fuel cycle and materials facilities are provided in 10 CFR Parts 30, 40, and 70 with supporting guidance in NRC Regulatory Guide 3.67, "Standard Format and Content for Emergency Plans for Fuel Cycle and Materials Facilities." Because of the relatively limited number and diverse nature of these facilities, the size of the EPZ, is determined, if needed, on a case-by-case basis for reactors with an authorized power level less than 250 MW thermal.

Within an EPZ, an area should be pre-designated for immediate response based on specified plant conditions prior to a release, or, given a release, prior to the availability of information on quantities of radioactive materials released. The shape of this area will depend on local topography, as well as political and other boundaries. Additional areas of the EPZ, particularly in the downwind direction, may require evacuation or sheltering-in-place, as determined by dose projections. The size of these areas will be based on the potential magnitude of the release and on an angular spread determined by meteorological conditions and any other relevant factors.

The pre-designated areas for immediate protective action may be reserved for use only in the most severe incidents and in cases when the facility operator cannot provide a quick estimate of projected dose based on actual releases. For lesser incidents, or if the facility operator is able to provide prompt off-site dose projections, the area for immediate protective action may be specified at the time of the incident instead of using a pre-designated area. Regardless of the basis for the initial protective action, radiological assessments need to continue through the duration of the event and if warranted, the initial protective actions extended into additional geographical areas.

Such prompt off-site dose projections may be possible when the facility operator can estimate the potential off-site dose based on information at the facility, using relationships developed during planning that relate abnormal plant conditions and meteorological conditions to potential off-site doses. After the release starts and the release rate is measurable, or when plant conditions or measurements can be used to estimate the characteristics and rate of the release, then these factors, along with atmospheric stability, the accuracy of these methods for estimating projected dose will be uncertain prior to confirmatory field measurements because of unknown or uncertain factors affecting environmental pathways, inadequacies of computer modeling and uncertainty in the data for release terms.

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[13] ~~Immediate protective actions based on in-plant conditions and EPZs established by NUREG-0654/FEMA-REP-1 are not applicable to naval nuclear propulsion plants. The largest naval reactors are rated at less than one-fifth of a large U.S. commercial NPP. In addition, since reactor power is directly linked to propulsion requirements, naval nuclear propulsion plants typically operate at low power when the ship is close to shore where high speeds are not required and are normally shut down when in port. Therefore, less than about 1% of the radioactivity contained in a typical commercial NPP could be released from a naval nuclear propulsion plant, limiting the possible dose to the general public and the size of the area of potential concern. Therefore, there is no need for towns and cities to have special emergency response plans such as those required for cities near commercial NPPs.~~ Immediate protective actions based on in-plant conditions and EPZs established by NUREG-0654/FEMA-REP-1 are not applicable to naval nuclear propulsion plants. The largest naval reactors are rated at less than one-fifth of a large U.S. commercial NPP. In addition, since reactor power is directly linked to propulsion requirements, naval nuclear propulsion plants typically operate at low power when the ship is close to shore where high speeds are not required and are normally shut down when in port. Therefore, less than about 1% of the radioactivity contained in a typical commercial NPP could be released from a naval nuclear propulsion plant, limiting the possible dose to the general public and the size of the area of potential concern. Therefore, existing all-hazards emergency response plans for responding to natural and industrial disasters are adequate to protect the public in areas around facilities where naval nuclear powered ships are located. However, the NNPP maintains close relationships with civil authorities to ensure that communications and emergency responses are coordinated, if required. Periodic exercises are conducted with all States and Guam where U.S. nuclear-powered warships are homeported and NNPP facilities are located.

The EPZs should be large enough to cover affected urban and rural areas and accommodate the various organizations needed for emergency response.[14]Although the size of the EPZ is based on the maximum distance at which a PAG might be exceeded, the actual boundary of an EPZ should be demarcated by features readily identifiable by people within that area. Such boundaries generally include major topographical features (e.g., rivers, roads, transmission line corridors, rail rights of way) and political boundaries. The EPZ should be further subdivided, using similarly identifiable features, to facilitate implementing protective actions when the entire EPZ is not affected. Maps, showing the boundaries of the EPZ and the sub-areas and evacuation routes should be provided to the public within the EPZ on a periodic basis in a format that will likely be available if the emergency occurs (e.g., inserted sections in local phone directories, wall calendars, etc.) EPZs are not necessary at those facilities where it is not possible for PAGs to be exceeded off-site.

1.8 DOSE PROJECTIONS

The PAGs in this chapter are specified in terms of the projected whole body dose. This projected dose is the sum of the effective dose from external exposure to the plume and the committed effective dose from inhaled radionuclides. Guidance is also provided on the thyroid equivalent dose. Further references to effective or organ dose equivalent refer to these two quantities, respectively. The FRMAC Assessment Manuals[15] provide detailed methods for estimating projected dose. These methods require knowledge of, or assumptions for, the intensity and duration of exposure and make use of standard assumptions on the relation, for each radioisotope, between exposure and dose. Exposure and dose projections should be based on the best estimates available. The FRMAC methods and models may be modified as necessary for specific sites for improved accuracy. Emergency response organizations are encouraged to use the most current, applicable tools and methods for implementing PAGs, understanding that differing approaches and assumptions will produce results with minor differences.

1.8.1 Dose Projection during the Early Phase

PAGs are expressed in terms of projected dose. The calculation of projected doses should be based on realistic dose models, to the extent practicable. Public protection decisions should be based upon the dose that can be avoided (i.e., avoidable dose) by taking some protective action (e.g., evacuation, sheltering). Unavoidable dose or doses incurred before the start of the protective action being considered generally should not be included in evaluating the need for protective action. Similarly, doses that may be incurred at later times than those affected by the specific protective action should not be included. As noted earlier, the projection of doses in the early phase needs to include only those exposure pathways that contribute a significant fraction (i.e., more than 10 percent) of the dose to an individual.

In the early phase of an incident, parameters other than projected dose may provide a more appropriate basis for decisions to implement protective actions. When a facility is operating outside its design basis and a substantial release to the environment has started, or is imminent but has not yet occurred, data adequate to directly estimate the projected dose may not be available. Emergency response plans should anticipate specific conditions at the source of a potential release and the possible consequences off-site. Emergency response plans for NPPs and facilities should make use of emergency action levels (EALs), based on in-plant conditions, to trigger notification and initial protective action recommendations to off-site officials.[16]Once the initial protective actions have been implemented, accident assessment should continue. Although initial assessments may be uncertain, the subsequent assessments will be less uncertain as additional information on facility condition and prognosis, effluent radiation monitoring data and environmental data become available. The results of these continuing radiological assessments, including dose projections, should be used as the basis for

[14] The development of EPZs for nuclear power facilities is discussed in the NUREG 0396 (NRC 1978).

[15] See FRMAC Assessment Manuals at http://www.nv.doe.gov/nationalsecurity/homelandsecurity/frmac/manuals.aspx.

[16] Immediate protective actions based on in-plant conditions are not applicable to naval nuclear propulsion plants. See Footnote 13 for additional information. In addition, because of differences in design and operation, EALs based on in-plant conditions are not applicable to naval nuclear propulsion plants.

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refining the initial protective actions. In the case of transportation accidents, an RDD or IND, or other incidents that are not related to a facility, it may not be practicable to establish EALs.

Doses that may be incurred from ingestion of food and water, long-term radiation exposure (i.e., longer than four days), radiation exposure to deposited radioactive materials, or long-term inhalation of resuspended materials are chronic exposures for which neither emergency evacuation nor sheltering-in- place are appropriate protective actions. PAGs for the intermediate phase cover these exposure pathways (see Chapter 4).

1.8.2 Duration of Exposure

The projected dose for comparison to the early phase PAGs is calculated for exposure during the first four days following the anticipated (or actual) start of a release. The objective is to encompass the entire period of exposure to the plume and deposited material prior to implementation of any further, longer- term protective action such as relocation. For planning purposes, the four-day period is chosen as the duration of exposure during the early phase because it is a reasonable estimate of the time necessary to make measurements, reach decisions and prepare to implement further protective actions (such as relocation) if necessary. However, officials at the site at the time of the emergency may decide that a different time frame is more appropriate.

For example, doses incurred through ingestion pathways or long-term exposure to deposited radioactive materials take place over a longer time period. Protective actions for such exposures should be based on guidance addressed in Chapter 4.

The projected dose from each radionuclide in a plume is proportional to the time-integrated concentration of the radionuclide in the plume at each location. This concentration will depend on the rate and the duration of the release and meteorological conditions. Release rates will vary with time and this time-dependence cannot usually be predicted accurately. In the absence of more specific information, the release rate may be assumed to be constant.

Another factor affecting the estimation of projected dose is the duration of the plume at a particular location. For purposes of calculating projected dose from most pathways, exposure will start at a particular location when the plume arrives and will end when the plume is no longer present. Exposure from deposited materials will continue for an extended period as long as people are present. Other factors such as the aerodynamic diameter and solubility of particles, shape of the plume and terrain may also affect estimated dose and may be considered on a site- or source- specific basis.

Prediction of time frames for releases is difficult because of the wide range associated with the spectrum of potential incidents. Therefore, planners should consider the possible time periods between an initiating event and arrival of a plume and the duration of releases in relation to the time needed to implement competing protective actions (i.e., evacuation and sheltering-in-place). Analyses of commercial nuclear power reactors (NRC 1975) have shown that some incidents may take several days to develop to the point of a release while others may begin as early as a half hour after an initiating event. Furthermore, the duration of a release may range from less than 1 hour to several days, with the major portion of the release likely occurring within the first day.

Wind speed also influences radiological exposure rates from a plume. As a general rule, air concentration is inversely related to the wind speed at the point of release. Concentrations are also affected by the turbulence of the air, which tends to increase with wind speed and sunlight and by wandering of the plume, which is greater at the lower wind speeds. This results in higher concentrations generally being associated with low winds near the source and with moderate winds at larger distances. Higher wind speed also shortens the travel time of the plume. Planning information on time frames for releases from nuclear power facilities may be found in references NRC 1978 and EPA 1978. Time frames for releases from other facilities will depend on the characteristics of the facility.

1.8.3 Derived Response Levels and Dose Parameters

A Derived Response Level (DRL) is a level of radioactivity in an environmental medium that would be expected to produce a dose equal to its corresponding PAG. Depending on the exposure pathway, many factors such as ground roughness, weathering and resuspension may be required to calculate the Dose Parameter (DP) that converts an environmental measurement into a projected dose over a given time period (e.g., Early Phase). ~~A Dose Conversion Factor (DCF) is any factor used to change an environmental measurement to dose in the units of concern. Depending on the exposure pathway, other factors besides the DCF may be required to convert an environmental measurement into a dose~~.

The FRMAC Assessment Manuals[17] provide guidance in calculating DRLs and DPs ~~DCFs~~ based on the ICRP dosimetry models (ICRP 60 series). In addition, the FRPCC encourages the use of computational tools such as DOE's Turbo FRMAC and NRC's Radiological Assessment System for Consequence Analysis (RASCAL) as well as other appropriate or more current tools to implement the PAGs.

1.8.4 Higher PAGs for Special Circumstances

Hazardous environmental conditions (e.g., severe weather or a competing disaster) could create transportation risks from evacuation that would be higher than normal. It is therefore appropriate to allow higher projected doses for evacuation decisions under these circumstances. In the absence of any definitive information on such higher risks from evacuation, one should assume that it would be appropriate to increase the recommended projected dose for evacuation of the general population under hazardous environmental conditions up to a factor of five higher than that used under normal environmental conditions.

It is also recognized that people who are not readily mobile are at higher risk from evacuation than are average members of the population. It would be appropriate to adopt higher PAGs for evacuation of individuals who would be at greater risk from evacuation itself than for the typically healthy members of the population, who are at low risk from evacuation. In the absence of definitive information on the higher risk associated with the evacuation of this group, one should assume that it is appropriate to adopt PAGs a factor of five higher for evacuation of high risk groups under normal environmental conditions. If both conditions exist, (high risk groups and hazardous environmental conditions) projected doses up to ten times higher than the PAGs for evacuation of the general population under normal conditions may be justified. These doses are expected to satisfy Principle 4 without violating Principles 1 and 3. Although they violate Principle 2, Principle 4 becomes, for such cases, the overriding consideration.

~~2.5 EMERGENCY WORKER PROTECTION~~

~~These emergency worker guidelines were developed for a wide range of possible radiological scenarios, from a small transportation accident that may impact a single roadway to an IND that could potentially impact a large geographic region. Therefore, the 5, 10 and 25 rem (50, 100 and 250 mSv) guidelines (Table 2-2) should not be viewed as inflexible limits applicable to the range of early phase emergency actions covered by this guidance. Because of the range of impacts and case-specific information needed, it is impossible to develop a single turn-back dose level for all responders to use in all events, especially those that involve lifesaving operations. Indeed, with proper preparedness measures (training, personal protective equipment (PPE), etc.) most radiological emergencies addressed by this document, even lifesaving operations, may be manageable within the 5 rem (50 mSv) occupational limit. Moreover, Incident Commanders should make every effort to employ the ''as low as reasonably achievable'' (ALARA) principle after an incident. Still, in some incidents doses above the annual occupational 5 rem (50 mSv) dose limit may be unavoidable. For instance, in the case of a catastrophic incident, such as an IND, Incident Commanders may need to consider raising the lifesaving and valuable property (i.e., necessary for public welfare) emergency worker guidelines in order to prevent further loss of life and prevent the spread of massive destruction. It is essential that emergency workers have full~~

[17] See FRMAC Assessment Manuals at http://www.nv.doe.gov/nationalsecurity/homelandsecurity/frmac/manuals.aspx.

~~knowledge of the associated risks prior to initiating emergency action and medical evaluation of emergency workers after such exposure.~~

~~Worker and public protection guidance and standards for normal operations are developed through risk management approaches and are implemented in federal and state regulations (e.g., 10 CFR Part 20; 10 CFR Part 835; 29 CFR Part 1910.1096). However, many factors or decision criteria in a radiological emergency differ from those in normal operations. Although there are times when implementation of standards or guidelines can cause or enhance other risks, these secondary risks can be controlled. Standards for normal operations provide a margin of safety that is greater than that in guidelines for emergency response because that margin can be provided in a manner that ensures no significant increase in public health risk or detriment to the public welfare. Currently, the development of standards and guidelines for normal operations is done in a manner that provides reasonable assurance that implementation of the standards will not cause more risk than it averts.~~

~~Response organizations need to develop plans and protocols that address radiation protection during a radiological incident and that ensure appropriate training is provided to responders and decision makers. Detailed reports on radiation risk, risk management decision making, training and public communication should be consulted in the development of plans, protocols and training materials and may be obtained from organizations such as ICRP, the National Council on Radiation Protection and Measurements (NCRP), International Atomic Energy Agency (IAEA), the American Nuclear Society (ANS) and the Health Physics Society (HPS). Detailed information on the risks of radiological emergency response and worker protection procedures can be found in the FRMAC "Radiological Emergency Response Health and Safety Manual" (DOE 2012) and the NCRP's "Management of Terrorist Events Involving Radioactive Material, Report No. 138" (NCRP 2001) and "Responding to a Radiological or Nuclear Terrorism Incident: A Guide for Decision Makers, Report No. 165" (NCRP 2010).~~

~~"Higher doses could be received by emergency responders emergency workers performing what NCRP Report No. 165, "Responding to a Radiological or Nuclear Terrorism Incident: A Guide for Decision Makers" calls "Time-Sensitive Mission-Critical" activities that could result in radiation doses higher than 25 rem. NCRP Report No. 165 expands the discussion on a Decision Dose of 50 rad. A Decision Dose can be used by the Incident Commander as a tool to address the need to and the consequences of exposing emergency responders emergency workers to higher doses to accomplish Mission Critical actions. This is especially important in an Improvised Nuclear Device (IND) incident."~~

~~2.6 CONTROLLING OCCUPATIONAL EXPOSURE AND DOSES TO emergency responders EMERGENCY WORKERS (~~This is now 3.2~~)~~

~~This section provides guidance on occupational doses of radiation during an emergency response. In many radiological incidents, actual exposure of workers, including emergency responders, may be controlled to low doses when proper precautions are taken. During some emergencies, radiation exposures to responders may be unavoidable and may have the potential to exceed limits used for normal operations.~~

~~However, even in emergency conditions, every reasonable effort should be made to control doses to levels that are as low as practicable (consider NCRP 138 and NCRP 165 for recommendations that support ALARA).~~

~~2.6.1 Maintaining the ALARA Principle (~~This is now 3.2.1~~)~~

~~To minimize the risks from exposure to ionizing radiation, employers of emergency responders emergency workers should prepare emergency response plans and protocols in advance to keep worker exposures ALARA, an acronym for "as low as is reasonably achievable" means making every reasonable effort to maintain exposures to radiation as far below the dose limits in this part as is practical consistent with the purpose for which the activity is undertaken. Plans and protocols should include the following health physics and industrial hygiene practices to the maximum extent possible—~~

- ~~Minimizing the time spent in the contaminated area.~~
- ~~Maintaining the maximum distance from sources of radiation.~~

- ~~Shielding of radiation sources.~~
- ~~Tailoring of hazard controls to the work performed.~~
- ~~Properly selecting and using respirators (see 29 CFR Part 1910.134) and other PPE.~~
- ~~Using prophylactic medications, where medically appropriate, that either block the uptake or reduce the retention time of radioactive material in the body.~~

~~The incident commander's staff should be prepared to identify, to the extent possible, all hazardous conditions or substances and to perform appropriate site hazard analysis. Emergency management plans should include protocols to control worker exposures, establish exposure guidelines in advance and outline procedures for worker protection. Emergency procedures should include provisions for exposure monitoring, worker training commensurate with the hazards involved in response operations and ways to control them and medical monitoring.~~

~~2.6.2 Understanding Dose and Risk Relationships (~~This is now 3.2.2~~)~~
~~response worker Emergency worker guidelines are based on cumulative dose constraint levels. These are based on an assumption that doses acquired in response to a radiological incident would be ''once in a lifetime'' doses and that future radiological exposures would be substantially lower.~~

~~Recommendations in this document provide a guideline level of 5 rem (50 mSv) for worker protection and alternative response worker emergency worker guidelines (see Table 2-2) for certain activities where exposures below 5 rem (50 mSv) cannot be maintained. For most radiological incidents, radiation control measures (e.g., minimizing time, maximizing distance, using shielding) will prevent doses from reaching the 5 rem (50 mSv) occupational exposure guide while performing typical emergency response activities such as transportation, firefighting and medical treatment of contaminated victims at hospitals. However, in those situations in which victims are injured or trapped in high radiation areas or can only be reached via high radiation areas, exposure control options may be unavailable or insufficient and doses above 5 rem (50 mSv) may be unavoidable.~~

~~Decisions to take response actions that could result in doses in excess of 5 rem (50 mSv) can only be made at the time of the incident, under consideration of the actual situation. In such situations, incident commanders and other responders need to understand the risk posed by such exposures in order to make informed decisions. The response worker emergency worker Guidelines for life and property saving activities in Table 2-2 are provided to assist such decision-making. These guidelines apply to doses incurred over the duration of an emergency and are assumed to be once in a lifetime.~~

~~Emergency personnel may be exposed to increased radiation during the unique catastrophic event of an IND detonation resulting in firestorm and widespread destruction of structures. The emergency intervention needed to prevent further destruction and loss of life may result in increased exposure.~~

~~Exceeding the response worker emergency worker Guidelines in Table 2-2 may be unavoidable in responding to such events. emergency responders Emergency workers undertaking a mission covered under the response worker emergency worker guidelines should be informed when radiation control measures may not prevent doses from exceeding the 5 rem (50 mSv), general occupational exposure guideline and should be made fully aware of the sub-chronic and chronic risks involved, including numerical estimates of the risk of delayed health effects.~~

~~Table 2-2.~~ ~~response worker Emergency Worker Guidelines~~

~~Guideline~~	~~Activity~~	~~Condition~~
~~5 rem (50 mSv)~~	~~All occupational exposures~~	~~All reasonably achievable actions have been taken to minimize~~

10 rem (100 mSv)[a]	Protecting valuable property necessary for public welfare (e.g., a power plant).	Exceeding 5 rem (50 mSv) unavoidable and all appropriate actions taken to reduce dose. Monitoring available to project or measure dose.
25 rem (250 mSv)[b]	Lifesaving or protection of large populations	Exceeding 5 rem (50 mSv) unavoidable and all appropriate actions taken to reduce dose. Monitoring available to project or measure dose.
>25 rem (250 mSv)	Lifesaving or protection of large populations	Only on a voluntary basis for people fully aware of the risks involved (See Tables 2-3 and 2-4)"
[a] For potential doses >5 rem (50 mSv), medical monitoring programs should be considered. [b] In the case of a very large incident, such as an IND, incident commanders may need to consider raising the property and lifesaving response worker emergency worker guidelines to prevent further loss of life and massive spread of destruction.		

The 25 rem (250 mSv) lifesaving response worker emergency worker guidelines provide assurance that exposures will not result in detrimental deterministic health effects (i.e., prompt or acute effects). However, it could increase the risk of stochastic (chronic) effects, such as the risk of cancer. Response actions that could cause exposures in excess of the 25 rem (250 mSv) response worker emergency worker Guideline should only be undertaken with an understanding of the potential acute effects of radiation to the exposed responder (see Table 2-3) and only when the benefits of the action clearly exceed the associated risks.

The estimated risk of fatal cancerfor workers exposed to 10 rem (100 mSv) is slightly less than the corresponding general population risk of 0.6 percent (6 cases per thousand exposed). Workers exposed to 25 rem (250 mSv) have an estimated risk of fatal cancer of 1.5 percent (15 cases per thousand exposed). Because of the latency period of cancer, younger workers face a larger risk of fatal cancer than older workers (for example, when exposed to 25 rem (250 mSv), 20 to 30-year-olds have a 9.1 per thousand risk of premature death, while 40 to 50-year-olds have a 5.3 per thousand risk of premature death).

More specific risk determinations can be made when there is adequate information about the contaminants and the potential for human exposure. EPA's Federal Guidance Report #13 (EPA 1999) and Health Effects Assessment Summary Tables have risk factors for specific radionuclides.

Table 2-3. Acute Radiation Syndrome [a]

Feature or Illness	**Effects of Whole Body Absorbed Dose from external radiation or internal absorption, by dose range in rad**				
	0-100 (0-1 Gy)	100-200 (1-2 Gy)	200-600 (2-61 Gy)	600-800 (6-8 Gy)	>800 (>8 Gy)
Nausea, Vomiting	None	5-50%	50-100%	75-100%	90-100%
Time of Onset		3-6 hr	2-4 hr	1-2 hr	<1r h to minutes
Duration		<24 hr	<24 hr	<48	<48 hr

Lymphocyte Count	Unaffected	Minimally Decreased	<1000 at 24 hr	<500 at 24 hr	Decreases within hours
Central Nervous System Function	No Impairment	No Impairment	Cognitive impairment for 6-20 hr	Cognitive impairment for >20 hr	Rapid incapacitation
Mortality	None	Minimal	Low with aggressive therapy	High	Very High: Significant neurological symptoms indicate lethal dose
Source: Medical Management of Radiological Casualties, Second Edition, Armed Forces Radiobiology Research Institute. Bethesda, MD, April 2003. a Percentage of people receiving whole-body doses within a few hours expected to experience acute health effects.					

Prior to 5 rem (50 mSv) guideline being exceeded, workers should be provided the following –

- Site specific training, if no prior training was available, with respect to the risk associated with exposure to ionizing radiation (incident commanders and responders should consider having someone on each team with radiation safety experience).
- A thorough explanation of the latent risks associated with receiving exposures greater than 5 rem (50 mSv).

If the 5 rem (50 mSv) guideline is exceeded, workers should be provided with a medical follow-up and monitoring should be considered.

In addition, these guidelines represent dose constraint levels (e.g., when this level of dose is accumulated, the responder should not take part in the later stages of the response that may significantly increase their dose). Incident commanders and responders need a thorough understanding of the worker exposure guidelines for radiological emergency response, including the associated risks and specific worker protection procedures. The FRMAC "Radiological Emergency Response Health and Safety Manual" (FRMAC 2001) provides detailed information. Additional resources for advance planning are available on the Radiological Emergency Medical Management (REMM) web site: http://www.remm.nlm.gov/.

2.6.3 Occupational Safety Regulations for Radiological Emergency Response (This is now 3.2.3)
The Occupational Safety and Health Act, requires employers to be responsible for the health and safety of their employees during routine and emergency operations. The primary occupational safety and health standard for emergency response is the Hazardous Waste Operations and Emergency Response (HAZWOPER) standard (29 CFR Part 1910.120).

Many U.S. states operate their own OSHA-approved state plans, which are required to be "at least as effective as" Federal OSHA standards and may impose additional or more stringent requirements. Some states operate "complete" plans that cover both the private sector and state and local government employees, while others cover state and local government employees only. EPA's Worker Protection Standard (40 CFR 311) applies the HAZWOPER standard to state and local workers in states that do not have occupational health and safety plans.

In addition to the Occupational Safety and Health Act, several federal agencies (DOE, NRC and OSHA) and Agreement States issue occupational radiation safety standards (see Table 2-4). The occupational standards are not guidelines but instead are regulatory limits that cannot be exceeded except under certain conditions. These occupational limits allow workers to receive radiation exposure during the course of performing their jobs.

Federal and state radiation safety standards recognize that it may be necessary to exceed dose limits to take critical lifesaving actions.

Table 2-4. Regulations for Worker Protection

Agency	Statutory Requirement	Title
Occupational Safety and Health Administration[a]	29 CFR 1910.120	Safety and Health – HAZWOPER
	29 CFR 1910. 1096	Ionizing Radiation
Environmental Protection Agency[a]	40 CFR 311	Occupational Radiation Protection
Nuclear Regulatory Commission[b]	10 CFR 20	Standards for Protection Against Radiation
Department of Energy[c]	10 CFR 835	Radiation Protection Regulations

a. All states are either regulated by federal regulations or by respective state regulations. 40 CFR 311 applies the HAZWOPER standard in states that do not have their own occupational health and safety program.
b. NRC employees are covered by NRC Management Directive 10.131, "Protection of NRC Employees Against Ionizing Radiation." Section VI, Guidance for Emergency Exposure Controls During Rescue and Recovery Activities, deals specifically with radiation exposure control during emergencies.
c. These requirements apply to all DOE employees and contractors (except for Naval Nuclear Propulsion Program (NNPP)) who may be exposed to ionizing radiation as a result of their work for DOE, including work relating to emergency response activities. The NNPP has established requirements consistent with those contained in 10 CFR 835.

2.4.5 {deleted Section 2.7, replacement below} CONTAMINATION LIMITS AND MONITORING OF THE ENVIRONMENT AND POPULATIONS

Areas under the plume can be expected to contain deposited radioactive materials if aerosols or particulate materials were released during the incident. In extreme cases, individuals and equipment may be highly contaminated and monitoring stations will be required for emergency monitoring, decontamination of individuals and medical evaluations. Equipment should be checked and decontaminated as necessary to avoid the spread of contamination to other locations. This monitoring service would be required for only a few days following plume passage until all such people have been evacuated or relocated.

People working in the parts of the restricted areas in which their dose from the residual radioactivity would exceed 2 mrem (20 µSv) in any hour or 100 mrem (1 mSv) in a year should operate under the controlled conditions established for occupational exposure.

Adults may reenter restricted areas under controlled conditions in accordance with occupational exposure standards. The need for monitoring stations should be evaluated along highways, which serve as the major evacuation or transportation routes, to control surface contamination at exits from the more highly contaminated areas. Decontamination and other measures should be implemented to maintain low exposure rates at monitoring stations.

A contaminated item should not be released to an unrestricted area. Based on incident and locality specific considerations, it may be acceptable to release contaminated materials if the level of surface contamination is less than two times (2x) the existing background levels. As an alternative to decontamination, contaminated items (i.e., not people or animals) may be retained in the restricted area while the radiological contamination decays.

A contaminated item should not be released to an unrestricted area. Based on incident and locality specific considerations, it may be acceptable to release contaminated materials if the level of surface contamination is below acceptable release criteria. As an alternative to decontamination, contaminated items (i.e., not people or animals) may be retained in the restricted area while the radiological contamination decays

~~In some extreme cases, decontamination may be impractical. Evacuating a large area requires resources, and decontamination may conflict with priority use of those resources. Screening and decontamination can slow egress, which could result in increased dose to the evacuees. Emergency managers should refer to CDC's "Population Monitoring in Radiation Emergencies: A guide for state and local public health planners" for more information. These simple initial screening guides are more general than FEMA REP-21 and REP-22 on use of handheld instruments and portal monitors for screening the public.~~

~~2.1 SURFACE CONTAMINATION CONTROL~~

~~Surface contamination must be controlled both before and after relocation protective actions are implemented. The principal exposure pathways for loose surface contamination on people, clothing and equipment are:~~

- ~~internal doses from ingestion by direct transfer;~~
- ~~internal doses from inhalation of resuspended materials;~~
- ~~beta dose to skin from contaminated skin or clothing or from nearby surfaces;~~
- ~~dose to the whole body from external gamma radiation;~~
- ~~internal dose from absorption of contamination into wounds.~~

~~The contamination limit should be influenced by the potential for the contamination to be ingested, inhaled or transferred to other locations. Therefore, it is reasonable to establish lower limits for surfaces where contamination is loose than for surfaces where the contamination is fixed (except for skin). The expected period of exposure from fixed contamination on skin would be longer so a lower limit would be justified.~~

~~It is not practical to set contamination limits significantly lower than residual contamination levels in uncontrolled areas. Although the contamination levels recommended in this manual are accordingly set high, consideration should be given as the event progresses to using lower contamination control levels (and more sensitive monitoring instruments) once people are removed from areas causing high external doses. Such efforts will minimize cross-contamination of people located outside of the affected areas. For events involving fixed nuclear facilities, some evacuation reception centers or shelters will have walk-through portal monitors.~~

> ~~"2x background is merely a simplified basis for responders to set their own instrument trigger levels based on practical circumstances at the time and location of each screening center. NCRP 161, "Population Monitoring and Radionuclide Decorporation Following a Radiological or Nuclear Incident (NCRP Report No. 166), National Council on Radiation Protection and Measurements, Bethesda, MD, 2011." and Koenig paper [cite properly] provide the basis for these simplified initial screening levels."~~

~~2.1.1 Priorities for Control of Contaminated Areas~~

~~The following priorities are recommended—~~

1. ~~Do not delay urgent medical care for decontamination efforts or for time-consuming protection of attendants, such as donning of additional anti-contamination clothing.~~
2. ~~In early phase scenarios where it might not be practical or would interfere with other life-saving and public health protection priorities, do not waste effort trying to contain contaminated wash water and be sure to notify sewage treatment plants.~~
3. ~~Do not allow monitoring and decontamination to delay an ordered evacuation.~~
4. ~~*When early screening is needed after a major incident*—After plume passage, it may be necessary to establish emergency contamination monitoring stations in areas not~~

qualifying as low background areas. Gamma exposure rates in such areas should be less than 5 millirem (50 µSv) per hour. These monitoring stations should be used only during the early phase after major atmospheric releases to monitor people emerging from possible high exposure areas. The stations should be set up to provide simple (rapid) decontamination if needed and to evaluate whether affected people should undergo more extensive decontamination or other special care. Table 2-5 provides guidance on surface contamination levels for use if such centers are needed.

5. Establish monitoring and personnel decontamination (e.g., bathing) facilities at evacuation centers or other locations in low background areas (less than 0.1 millirem (1 µSv) per hour). *Encourage self-decontamination:* Encourage evacuated people who were exposed in areas where release of particulate materials would have warranted evacuation to change and bag the clothes they were wearing and store them in an area away from people and pets until authorities provide further instructions on their disposition, to wash other exposed surfaces such as cars and trucks and their contents and then report to these centers for monitoring. For more specific considerations on control of contaminated areas refer to "Population Monitoring in Radiation Emergencies: A Guide for State and Local Public Health Planners" (CDC 20072014). Table 2-6 provides surface contamination guidance. These screening levels are examples derived primarily on the basis of easily measurable radiation levels using portable instruments.

6. After the relocation area has been established, consider the need to set up monitoring and decontamination stations at exits from the more highly contaminated parts of the area. Low levels of contamination may be undetectable because of high background radiation levels at these locations. Monitoring should be done at lowest practical background levels. Nevertheless, these individuals should be advised to bathe and change clothes at their first opportunity – no later than within the next 24 hours. If, after decontamination, people still exceed the limits for the station, they should be sent for further decontamination or for medical or other special attention.

Table 2-5. Recommended surface contamination screening levels for emergency screening of people and objects at monitoring station in high background radiation areas with elevated background area (0.1 mR/h to 1 mR/h or 1 to 10 µSv/h Gamma Exposure Rate)).

Condition	**Appropriate detection instrument reading**	**Recommended Action**
Before Decontamination	<2x existing background	Unconditional release Release for further screening outside affected area
	>2x existing background	Decontaminate. Equipment may be stored or disposed of as appropriate.
After Decontamination	<2x existing background	Unconditional release Release for further screening outside affected area

	>2x existing background	Continue to decontaminate or refer to low-background monitoring and decon station. Equipment may be stored for decay or disposed of as appropriate.
[b] Monitoring stations in such high exposure rate areas are for use only during the early phase of an incident involving major atmospheric releases of particulates. Otherwise use Table 2-6.		

Table 2-6. Recommended Surface Contamination Screening Levels for People[a] and Objects at Monitoring Stations in Low Background Radiation Areas (<0.1 mR/h Gamma Exposure Rate)[b]

Condition	**Appropriate detection instrument reading**	**Recommended Action**
Before decontamination	<2x existing background	Unconditional release
	>2x existing background	Decontaminate Partial Decontamination
After simple[c] decontamination effort	<2x existing background	Unconditional release
	>2x existing background	Full decontamination
After full[d] decontamination effort	<2x existing background	Unconditional release
	>2x existing background	Continue to decontaminate people Release animals and equipment
After additional full decontamination effort	<2x existing background	Unconditional full release
	>2x existing background	Send people for further evaluation Release animals and equipment

[a] People reporting to monitoring stations in low background radiation areas have been previously instructed to change and bag clothes, wash other exposed surfaces such as cars and their contents and then report to these centers for monitoring.
[b] Levels higher than 2x existing background (not to exceed the meter reading corresponding to 0.1 mR/h) may be used to speed the monitoring of evacuees in very low background areas.
[c] Washing hands and face and localized wiping are examples of a partial decontamination effort.
[d] Changing clothes and/or showering are examples of a full decontamination effort.

1.9 CONTAMINATION LEVELS AND MONITORING OF THE ENVIRONMENT AND POPULATIONS

Areas under the plume can be expected to contain deposited radioactive materials if aerosols or particulate materials were released during the incident. In extreme cases, individuals and equipment may be highly contaminated and monitoring stations will be required for emergency monitoring, decontamination of individuals and medical evaluations. Equipment should be checked and decontaminated as necessary to avoid the spread of contamination to other locations. This monitoring service would be required for only a few days following plume passage until all such people have been evacuated or relocated. Guidance on surface contamination levels for use at such monitoring stations is provided below.

Adults may reenter restricted areas under controlled conditions in accordance with occupational exposure standards. The need for monitoring stations should be evaluated along highways, which serve as the major evacuation or transportation routes, to control surface contamination at exits from the more highly contaminated areas. Decontamination and other measures should be implemented to maintain low- exposure rates at monitoring stations.

A contaminated item should not be released to an unrestricted area. Based on incident and locality specific considerations, it may be acceptable to release contaminated materials if the level of surface contamination is below acceptable release criteria. As an alternative to decontamination, contaminated items (i.e., not people or animals) may be retained in the restricted area while the radiological contamination decays.

In some extreme cases, decontamination may be impractical. Evacuating a large area requires resources, and decontamination may conflict with priority use of those resources. Screening and decontamination can slow egress, which could result in increased dose to the evacuees. Emergency managers should consult with their state radiation control authority to establish proposed radiation screening criteria. Refer to CDC's "Population Monitoring in Radiation Emergencies: A Guide for State and Local Public Health Planners" (CDC 2014)[18] for additional in-depth discussion in Appendix D on radiological screening criteria for external contamination. These simple initial screening guides from CDC are more general than FEMA REP-21 and REP-22 on use of handheld instruments and portal monitors for screening the public.

Surface Contamination Control

Surface contamination must be controlled both before and after evacuation protective actions are implemented. The contamination level for screening people, animals and objects for surface contamination at monitoring stations should be influenced by the potential for the contamination to be ingested, inhaled or transferred to other locations. The principal exposure pathways for loose surface contamination on people, clothing and equipment are:

- Internal doses from ingestion by direct transfer;
- Internal doses from inhalation of resuspended materials;
- Beta dose to skin from contaminated skin or clothing or from nearby surfaces;
- Dose to the whole body from external gamma radiation; and
- Internal doses from absorption of contamination into wounds.

It is not practical to set surface contamination screening levels significantly lower than residual contamination levels in uncontrolled areas. Although the contamination levels recommended in this manual are accordingly set high, consideration should be given as the incident event progresses to using lower contamination screening levels (and more sensitive monitoring instruments) once people are removed from areas causing high external doses. Such efforts will minimize cross-contamination of people located outside of the affected areas. For incidents involving fixed nuclear facilities, some evacuation reception centers or shelters will have walk-through portal monitors.

The recommended "2x existing background" level for screening for surface contamination at monitoring stations is merely a simplified basis for responders to set their own instrument trigger levels based on practical circumstances at the time and location of each screening center. Local and state officials may choose to establish a screening level expressed in measurements units (e.g., cpm, μR/h) that are compatible with radiation detection instruments being used and appropriate for local conditions, taking into account the number of people in need of screening and available resources.[19] The following guidance documents provide more detailed information about initial screening levels:

- "Population Monitoring and Radionuclide Decorporation Following a Radiological or Nuclear Incident," (NCRP Report No. 166), Bethesda, MD, 2011.
- "Responding to a Radiological or Nuclear Terrorism Incident: A Guide for Decision Makers," (NCRP Report No. 165), Bethesda, MD, 2010.
- "Management of Persons Contaminated with Radionuclides: Scientific and Technical Bases," (NCRP

[18] See: http://emergency.cdc.gov/radiation/pdf/population-monitoring-guide.pdf (CDC 2014)

Report No. 161, Vol. II), Bethesda, MD, 2010. Chapter 5: Performing Surveys and Controlling Personnel and Area Contamination.

- "Management of Persons Contaminated With Radionuclides: Handbook" (NCRP Report No. 161, Vol. I), Bethesda, MD, 2008.

Priorities for Control of Contaminated Areas

The following priorities are recommended—

- Do not delay urgent medical care for decontamination efforts or for time-consuming protection of attendants, such as donning of additional anti-contamination clothing.
- In early phase scenarios where it might not be practical or would interfere with other lifesaving and public health protection priorities, do not waste effort trying to contain contaminated wash water and be sure to notify sewage treatment plants.
- Do not allow monitoring and decontamination to delay an ordered evacuation.
- When early screening is needed after a major incident — After plume passage, it may be necessary to establish emergency contamination monitoring stations in areas not qualifying as low background areas. These monitoring stations should be used only during the early phase after major atmospheric releases to monitor people emerging from possible high exposure areas. The stations should be set up to provide simple (rapid) decontamination if needed and to evaluate whether affected people should undergo more extensive decontamination or other special care. Section 2.3.3 provides guidance on surface contamination levels for use if such emergency contamination monitoring stations centers are needed.
- Establish screening to control surface contamination — Establish monitoring and personnel decontamination (e.g., bathing) facilities at evacuation centers or other locations in low background areas (less than 0.1 millirem (1 μSv) per hour gamma exposure rate). Section 2.3.4 provides surface contamination guidance for monitoring stations in low background areas. These surface contamination screening levels are examples derived primarily on the basis of easily measurable radiation levels using portable instruments. The background may be elevated because of the incident, so these screening levels refer to a "2x existing background" level in a low radiation area.
- Encourage self-decontamination — Encourage evacuated people who were exposed in areas where release of particulate materials would have warranted evacuation to change and bag the clothes they were wearing and store them in an area away from people and pets until authorities provide further instructions on their disposition, to wash other exposed surfaces such as cars and trucks and their contents and then report to evacuation centers or other established locations for monitoring.
- After the evacuation area has been established, consider the need to set up monitoring and decontamination stations at exits from the more highly contaminated parts of the area. Low levels of contamination may be undetectable because of high background radiation levels at these locations. Monitoring should be done at lowest practical background levels. Nevertheless, these individuals should be advised to bathe and change clothes at their first opportunity—no later than within the next 24 hours. If, after decontamination, people still exceed the surface contamination screening levels for the station, they should be sent for further decontamination or for medical or other special attention.

Recommendations for Emergency Screening in Areas Not Qualifying as Low Background Areas

This section provides the recommended surface contamination screening levels for emergency screening of people and objects at monitoring stations in high background radiation areas in areas with elevated background radiation (exceeding 0.1 mR/h or 1 μSv/h gamma exposure rate). Monitoring stations in such high exposure rate areas are for use only during the early phase of an incident involving major atmospheric releases of particulates (otherwise see Section 2.3.4). For such emergency screening at monitoring stations, recommended actions for a detection instrument reading at either less than or greater than 2x existing background are outlined below.

- **Before Decontamination**:
  - If <2x existing background — Recommended action: Release for further screening outside affected area.
  - If >2x existing background — Recommended action: Perform gross decontamination (carefully remove outer layer of clothing) and/or simple decontamination (examples include washing hands and face, wiping of exposed skin, washing feet or soles of shoes). Equipment may be stored for decay, reuse or disposal in the same area, as appropriate.

- **After Decontamination**:
  - If <2x existing background — *Recommended action:* Release for further screening outside affected area.
  - If >2x existing background — *Recommended action:* Continue to decontaminate or refer to low background monitoring and decontamination station. Equipment may be stored for decay, reuse or disposal in the same area, as appropriate.

Recommendations for Screening in Low Background Areas

This section provides the recommended surface contamination screening levels for people and objects at monitoring stations in low background radiation areas (<0.1 mR/h or 1 μSv/h gamma exposure rate). People reporting to monitoring stations in low background radiation areas have been previously instructed to change and bag clothes, wash other exposed surfaces such as cars and their contents and then report to these centers for monitoring. Levels higher than 2x existing background (not to exceed the meter reading corresponding to 0.1 mR/h) may be used to speed the monitoring of evacuees in very low background areas. For screening at monitoring stations in low background areas, recommended actions for a detection instrument reading at either less than or greater than 2x existing background are outlined below.

- **Before Decontamination**:
  - If <2x existing background — Recommended action: Unconditional release.
  - If >2x existing background — Recommended action: Perform gross decontamination (carefully remove outer layer of clothing) and/or simple decontamination (examples include washing hands and face, wiping of exposed skin, washing feet or soles of shoes).

- **After Simple Decontamination Effort**:
  - If <2x existing background — Recommended action: Unconditional release.
  - If >2x existing background — Recommended action: Full decontamination.

- **After Full Decontamination Effort** (Changing clothes and/or showering are examples of a full decontamination effort. Washing or gentle scrubbing with soap or other mild detergent followed by flushing is another example of a full decontamination effort.):
  - If <2x existing background — Recommended action: Unconditional release.
  - If >2x existing background — Recommended action: Continue to decontaminate people.

- **After Additional Full Decontamination Effort**:
  - If <2x existing background — Recommended action: Unconditional full release.
  - If >2x existing background — Recommended action: Send people for further evaluation.

The recommended "2x existing background" level for screening for surface contamination at monitoring stations is merely a simplified basis for responders to set their own instrument trigger levels based on practical circumstances at the time and location of each screening center. Local and state officials may choose to establish a screening level expressed in measurements units (e.g., cpm, μR/h) that are compatible with radiation detection instruments being used and appropriate for local conditions, taking into account the number of people

in need of screening and available resources.

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KEY POINTS IN CHAPTER 2 – EARLY PHASE

- The principal protective actions for the early phase are evacuation or sheltering-in-place. Evacuation is the urgent removal of people from an area to avoid or reduce high-level, short-term exposure from the plume or deposited activity. Sheltering-in-place refers to the use of a readily available structure that will provide protection from exposure to the plume.
- The PAG for evacuation or sheltering-in-place is a projected whole body dose of 1 to 5 rem (10 – 50 mSv) total effective dose (TED) over four days.
- Evacuation is appropriate when its risks and secondary effects are less severe than the risk of the projected radiation dose. Evacuation will be most effective in avoiding dose if completed before plume arrival.
- In general, sheltering-in-place should be preferred to evacuation whenever it provides equal or greater protection. After confirmation that the plume has passed, continued sheltering-in-place should be re-evaluated by public officials.
- The administration of KI to partially block the uptake of radioiodines by the thyroid is a supplemental protective action. The PAG for administration of KI is 5 rem (50 mSv) projected child thyroid dose. Other medical countermeasures are available, as well.
- Dose calculations for PAGs are made using the dose parameter (DP) and derived response level (DRL) calculation methods referenced in the FRMAC Assessment Manuals. Emergency response organizations are encouraged to use the most current, applicable tools and methods for implementing the PAGs. ~~Dose calculations for PAGs are made using the DCF and DRL calculation methods referenced in the FRMAC Assessment Manuals. Emergency response organizations are encouraged to use the most current, applicable tools and methods for implementing the PAGs.~~

CHAPTER 3. EMERGENCY WORKER PROTECTION

1.10 INTRODUCTION

These emergency worker guidelines were developed for a wide range of possible radiological scenarios, from a small transportation accident that may impact a single roadway to an IND that could potentially impact a large geographic region. Therefore, the 5, 10 and 25 rem (50, 100 and 250 mSv) guidelines (Table 2-2) should not be viewed as inflexible limits applicable to the range of early phase emergency actions covered by this guidance. Because of the range of impacts and case-specific information needed, it is impossible to develop a single turn-back dose level for all responders to use in all events, especially those that involve lifesaving operations. Indeed, with proper preparedness measures (training, personal protective equipment (PPE), etc.) most radiological emergencies addressed by this document, even lifesaving operations, may be manageable within the 5 rem (50 mSv) occupational limit. Moreover, Incident Commanders should make every effort to employ the ''as low as reasonably achievable'' (ALARA) principle after an incident. Still, in some incidents doses above the annual occupational 5 rem (50 mSv) dose limit may be unavoidable. For instance, in the case of a catastrophic incident, such as an IND, Incident Commanders may need to consider raising the lifesaving and valuable property (i.e., necessary for public welfare) emergency worker guidelines in order to prevent further loss of life and prevent the spread of massive destruction. It is essential that emergency workers have full knowledge of the associated risks prior to initiating emergency action and medical evaluation of emergency workers after such exposure.

Worker and public protection guidance and standards for normal operations are developed through risk management approaches and are implemented in federal and state regulations (e.g., 10 CFR Part 20; 10 CFR Part 835; 29 CFR Part 1910.1096). However, many factors or decision criteria in a radiological emergency differ from those in normal operations. Although there are times when implementation of standards or guidelines can cause or enhance other risks, these secondary risks can be controlled. Standards for normal operations provide a margin of safety that is greater than that in guidelines for emergency response because that margin can be provided in a manner that ensures no significant increase in public health risk or detriment to the public welfare. Currently, the development of standards and guidelines for normal operations is done in a manner that provides reasonable assurance that implementation of the standards will not cause more risk than it averts.

Response organizations need to develop plans and protocols that address radiation protection during a radiological incident and that ensure appropriate training is provided to responders and decision makers. Detailed reports on radiation risk, risk management decision making, training and public communication should be consulted in the development of plans, protocols and training materials and may be obtained from organizations such as ICRP, the National Council on Radiation Protection and Measurements (NCRP), International Atomic Energy Agency (IAEA), the American Nuclear Society (ANS) and the Health Physics Society (HPS). Detailed information on the risks of radiological emergency response and worker protection procedures can be found in the FRMAC "Radiological Emergency Response Health and Safety Manual" (DOE 2012) and the NCRP's "Management of Terrorist Events Involving Radioactive Material, Report No. 138" (NCRP 2001) and "Responding to a Radiological or Nuclear Terrorism Incident: A Guide for Decision Makers, Report No. 165" (NCRP 2010).

"Higher doses could be received by ~~emergency responders~~ emergency workers performing what NCRP Report No. 165, "Responding to a Radiological or Nuclear Terrorism Incident: A Guide for Decision Makers" calls "Time-Sensitive Mission-Critical" activities that could result in radiation doses higher than 25 rem. NCRP Report No. 165 expands the discussion on a Decision Dose of 50 rad. A Decision Dose can be used by the Incident Commander as a tool to address the need to and the consequences of exposing ~~emergency responders~~ emergency workers to higher doses to accomplish Mission Critical actions. This is especially important in an Improvised Nuclear Device (IND) incident."

~~1.11~~ CONTROLLING OCCUPATIONAL EXPOSURE AND DOSES TO ~~emergency responders~~ EMERGENCY WORKERS

This section provides guidance on occupational doses of radiation during an emergency response. In many radiological incidents, actual exposure of workers, including emergency responders, may be controlled to low doses when proper precautions are taken. During some emergencies, radiation exposures to responders may be unavoidable and may have the potential to exceed limits used for normal operations.

However, even in emergency conditions, every reasonable effort should be made to control doses to levels that are as low as practicable (consider NCRP 138[20] and NCRP 165[21] for recommendations that support ALARA).

1.11.1 Maintaining the ALARA Principle

To minimize the risks from exposure to ionizing radiation, employers of ~~emergency responders~~ emergency workers should prepare emergency response plans and protocols in advance to keep worker exposures ALARA, an acronym for "as low as is reasonably achievable" means making every reasonable effort to maintain exposures to radiation as far below the dose limits in this part as is practical consistent with the purpose for which the activity is undertaken. Plans and protocols should include the following health physics and industrial hygiene practices to the maximum extent possible—

- Minimizing the time spent in the contaminated area.
- Maintaining the maximum distance from sources of radiation.
- Shielding of radiation sources.
- Tailoring of hazard controls to the work performed.
- Properly selecting and using respirators (see 29 CFR Part 1910.134) and other PPE.
- Using prophylactic medications, where medically appropriate, that either block the uptake or reduce the retention time of radioactive material in the body.

The incident commander's staff should be prepared to identify, to the extent possible, all hazardous conditions or substances and to perform appropriate site hazard analysis. Emergency management plans should include protocols to control worker exposures, establish exposure guidelines in advance and outline procedures for worker protection. Emergency procedures should include provisions for exposure monitoring, worker training commensurate with the hazards involved in response operations and ways to control them and medical monitoring.

1.11.2 Understanding Dose and Risk Relationships

~~response worker~~ Emergency worker guidelines are based on cumulative dose constraint levels. These are based on an assumption that doses acquired in response to a radiological incident would be ''once in a lifetime'' doses and that future radiological exposures would be substantially lower.

Recommendations in this document provide a guideline level of 5 rem (50 mSv) for worker protection and alternative ~~response worker~~ emergency worker guidelines (see Table 2-2) for certain activities where exposures below 5 rem (50 mSv) cannot be maintained. For most radiological incidents, radiation control measures (e.g., minimizing time, maximizing distance, using shielding) will prevent doses from reaching the 5 rem (50 mSv) occupational exposure guide while performing typical emergency response activities such as transportation, firefighting and medical treatment of contaminated victims at hospitals. However, in those situations in which victims are injured or trapped in high radiation areas or can only be reached via high radiation areas, exposure control options may be unavailable or insufficient and doses above 5 rem (50 mSv) may be unavoidable.

Decisions to take response actions that could result in doses in excess of 5 rem (50 mSv) can only be made at the time of the incident, under consideration of the actual situation. In such situations, incident commanders

[20] "Management of Terrorist Events Involving Radioactive Material, Report No. 138" (NCRP 2001).
[21] "Responding to a Radiological or Nuclear Terrorism Incident: A Guide for Decision Makers, Report No. 165" (NCRP 2010).

and other responders need to understand the risk posed by such exposures in order to make informed decisions. The ~~response worker~~ emergency worker Guidelines for life and property saving activities in Table 2-2 are provided to assist such decision-making. These guidelines apply to doses incurred over the duration of an emergency and are assumed to be once in a lifetime.

Emergency personnel may be exposed to increased radiation during the unique catastrophic event of an IND detonation resulting in firestorm and widespread destruction of structures. The emergency intervention needed to prevent further destruction and loss of life may result in increased exposure. Exceeding the ~~response worker~~ emergency worker Guidelines in Table 2-2 may be unavoidable in responding to such events. ~~emergency responders~~ Emergency workers undertaking a mission covered under the ~~response worker~~ emergency worker guidelines should be informed when radiation control measures may not prevent doses from exceeding the 5 rem (50 mSv), general occupational exposure guideline and should be made ~~fully~~ aware of ~~the sub-chronic and chronic~~ risks involved, including numerical estimates of the risk of delayed health effects.

Table 3-1. ~~response worker~~ Emergency Worker Guidelines

Guideline	Activity	Condition
5 rem (50 mSv)	All occupational exposures	All reasonably achievable actions have been taken to minimize
10 rem (100 mSv)[a]	Protecting valuable property necessary for public welfare (e.g., a power plant).	Exceeding 5 rem (50 mSv) unavoidable and all appropriate actions taken to reduce dose. Monitoring available to project or measure dose.
25 rem (250 mSv)[b]	Lifesaving or protection of large populations	Exceeding 5 rem (50 mSv) unavoidable and all appropriate actions taken to reduce dose. Monitoring available to project or measure dose.
>25 rem (250 mSv)	Lifesaving or protection of large populations	Only on a voluntary basis for people fully aware of the risks involved (See Tables 3-2 and 3-3)"

[a] For potential doses >5 rem (50 mSv), medical monitoring programs should be considered.

[b] In the case of a very large incident, such as an IND, incident commanders may need to consider raising the property and lifesaving ~~response worker~~ emergency worker guidelines to prevent further loss of life and massive spread of destruction.

This guidance does not address or impact site cleanups occurring under other statutory authorities such as the United States Environmental Protection Agency's (EPA) Superfund program, the Nuclear Regulatory Commission's (NRC) decommissioning program, or other federal or state cleanup programs.

The 25 rem (250 mSv) lifesaving ~~response worker~~ emergency worker guidelines provide assurance that exposures will not result in detrimental deterministic health effects (i.e., prompt or acute effects). However, it could increase the risk of stochastic (chronic) effects, such as the risk of cancer. Response actions that could cause exposures in excess of the 25 rem (250 mSv) ~~response worker~~ emergency worker Guideline should only be undertaken with an understanding of the potential acute effects of radiation to the exposed responder (see Table 3-2) and only when the benefits of the action clearly exceed the associated risks.

The estimated risk of fatal cancer[22] for workers exposed to 10 rem (100 mSv) is slightly less than the corresponding general population risk of 0.6 percent (6 cases per thousand exposed). Workers exposed to 25

[22] Risk per dose of a fatal cancer is assumed to be about 6×10^{-4} per rem (6×10^{-5} per mSv). Cancer incidence is

rem (250 mSv) have an estimated risk of fatal cancer of 1.5 percent (15 cases per thousand exposed). Because of the latency period of cancer, younger workers face a larger risk of fatal cancer than older workers (for example, when exposed to 25 rem (250 mSv), 20 to 30-year-olds have a 9.1 per thousand risk of premature death, while 40 to 50-year-olds have a 5.3 per thousand risk of premature death).[23]

More specific risk determinations can be made when there is adequate information about the contaminants and the potential for human exposure. EPA's Federal Guidance Report #13 (EPA 1999) and Health Effects Assessment Summary Tables have risk factors for specific radionuclides.

Table 3-2. Acute Radiation Syndrome [a]

Feature or Illness	Effects of Whole Body Absorbed Dose from external radiation or internal absorption, by dose range in rad (Gray)				
	0-100 (0-1 Gy)	100-200 (1-2 Gy)	200-600 (2-6 Gy)	600-800 (6-8 Gy)	>800 (>8 Gy)
Nausea, Vomiting	None	5-50%	50-100%	75-100%	90-100%
Time of Onset		3-6 hr	2-4 hr	1-2 hr	<1r h to minutes
Duration		<24 hr	<24 hr	<48	<48 hr
Lymphocyte Count	Unaffected	Minimally Decreased	<1000 at 24 hr	<500 at 24 hr	Decreases within hours
Central Nervous System Function	No Impairment	No Impairment	Cognitive impairment for 6-20 hr	Cognitive impairment for > 20 hr	Rapid incapacitation
Mortality	None	Minimal	Low with aggressive therapy	High	Very High: Significant neurological symptoms indicate lethal dose

Source: Medical Management of Radiological Casualties, Second Edition, Armed Forces Radiobiology Research Institute. Bethesda, MD, April 2003.

[a] Percentage of people receiving whole-body doses within a few hours expected to experience acute health effects.

Prior to 5 rem (50 mSv) guideline being exceeded, workers should be provided the following—

- Site specific training, if no prior training was available, with respect to the risk associated with exposure to ionizing radiation (incident commanders and responders should consider having someone on each team with radiation safety experience).

assumed to be about 8×10^{-4} per rem (8×10^{-5} per mSv). (EPA 1999)

[23] The numerical estimate of cancer risk presented above (from Federal Guidance #13) was obtained by linear extrapolation using the nominal risk estimates based on data from human exposures at high doses and high dose rates. Other methods of extrapolation to the low-dose region could yield higher or lower numerical estimates of cancer deaths. Studies of human populations exposed at low doses are inadequate to demonstrate the actual magnitude of risk at low doses (about 0.1 Sv or 10 rem and below). There is scientific uncertainty about cancer risk in the low-dose region below the range of epidemiological observation and the possibility of no risk cannot be excluded. (EPA 1999)

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- A thorough explanation of the latent risks associated with receiving exposures greater than 5 rem (50 mSv).

If the 5 rem (50 mSv) guideline is exceeded, workers should be provided with a medical follow-up and monitoring should be considered.

In addition, these guidelines represent dose constraint levels (e.g., when this level of dose is accumulated, the responder should not take part in the later stages of the response that may significantly increase their dose). Incident commanders and responders need a thorough understanding of the worker exposure guidelines for radiological emergency response, including the associated risks and specific worker protection procedures. The FRMAC "Radiological Emergency Response Health and Safety Manual" (FRMAC 2001) provides detailed information. Additional resources for advance planning are available on the Radiological Emergency Medical Management (REMM) web site: http://www.remm.nlm.gov/.

1.11.3 Occupational Safety Regulations for Radiological Emergency Response

The Occupational Safety and Health Act, requires employers to be responsible for the health and safety of their employees during routine and emergency operations. The primary occupational safety and health standard for emergency response is the Hazardous Waste Operations and Emergency Response (HAZWOPER) standard (29 CFR Part 1910.120).

Many U.S. states operate their own OSHA-approved state plans, which are required to be "at least as effective as" Federal OSHA standards and may impose additional or more stringent requirements.[24]Some states operate "complete" plans that cover both the private sector and state and local government employees, while others cover state and local government employees only. EPA's Worker Protection Standard (40 CFR 311) applies the HAZWOPER standard to state and local workers in states that do not have occupational health and safety plans.

In addition to the Occupational Safety and Health Act, several federal agencies (DOE, NRC and OSHA) and Agreement States issue occupational radiation safety standards (see Table 3-3). The occupational standards are not guidelines but instead are regulatory limits that cannot be exceeded except under certain conditions. These occupational limits allow workers to receive radiation exposure during the course of performing their jobs.

Federal and state radiation safety standards recognize that it may be necessary to exceed dose limits to take critical lifesaving actions.

[24] For a list of state plans, see: http://www.osha.gov/dcsp/osp/index.html

Table 3-3. Regulations for Worker Protection

Agency	Statutory Requirement	Title
Occupational Safety and Health Administration[a]	29 CFR Part 1910.120	Safety and Health-- HAZWOPER
	29 CFR Part 1910. 1096	Ionizing Radiation
Environmental Protection Agency[a]	40 CFR Part 311	Occupational Radiation Protection
Nuclear Regulatory Commission[b]	10 CFR Part 20	Standards for Protection Against Radiation
Department of Energy[c]	10 CFR Part 835	Radiation Protection Regulations

a. Worker safety and health is regulated in all states by federal OSHA or by respective state regulations under an OSHA-approved state plan. 40 CFR Part 311 applies the OSHA HAZWOPER standard (29 CFR 1910.120) to public-sector workers in states that do not operate their own occupational safety and health programs.

b. NRC employees are covered by NRC Management Directive 10.131, ''Protection of NRC Employees Against Ionizing Radiation.'' Section VI, Guidance for Emergency Exposure Controls During Rescue and Recovery Activities, deals specifically with radiation exposure control during emergencies.

c. These requirements apply to all DOE employees and contractors (except for Naval Nuclear Propulsion Program (NNPP)) who may be exposed to ionizing radiation as a result of their work for DOE, including work relating to emergency response activities. The NNPP has established requirements consistent with those contained in 10 CFR Part 835.

KEY POINTS IN CHAPTER 3 – EMERGENCY WORKER PROTECTION

- ~~response worker~~ Emergency worker guidelines of 5, 10 or 25 rem (50, 100 or 250 mSv) are based on the urgency of activities and knowledge of the risks involved.
- Worker safety is key to a successful emergency response.
- Incident commanders are responsible for balancing the individual risks and public benefits of each worker action.
- Emergency workers should be adequately informed of, and have an adequate understanding of, the risks they may experience during any missions they accept, including the risk of short-term and long-term health effects from exposure to ionizing radiation.
- Emergency workers should have relevant training, personal protective equipment, and monitoring instruments so they are able to protect themselves and others.
- Since there is assumed to be no threshold below which there is not an associated risk from radiation dose, workers who are reasonably expected to receive an occupational dose exceeding the established dose limit for members of the public, 0.1 rem (0.001 Sv), should be properly trained and monitored.
- Emergency workers should be trained, to the extent feasible, on actions to be taken. All reasonable steps have been taken to provide appropriate protection during the emergency activity.
- Worker protection statutes are listed in Table 3-3.

CHAPTER 4. INTERMEDIATE PHASE PROTECTIVE ACTION GUIDES

1.12 INTRODUCTION

This chapter presents PAGs for the intermediate phase and provides guidance for the implementation of corresponding protective actions. A PAG is the projected dose to an individual from the release of radioactive material at which a specific protective action should be taken to reduce or avoid that dose. The intermediate phase is defined as the period beginning after the source and releases have been brought under control and environmental measurements are available for use as a basis for decisions on protective actions and extending until these protective actions are terminated. The intermediate phase may last from weeks to months but is ~~assumed to last~~ projected for one year for calculation purposes ~~of dose projection~~.

During the early phase, decisions must be made and implemented quickly by state and local officials before federal assistance ~~is~~ may be available. In contrast, many decisions and actions during the intermediate phase may be taken after federal resources are present, as described in the Nuclear/Radiological Incident Annex of the National Response Framework (FEMA 2008 a, b). Decisions will be made during the intermediate phase concerning whether particular areas or properties from which people have been evacuated will be decontaminated and reoccupied or the occupants relocated for an extended period.

This chapter provides the PAGs and corresponding protective actions for use by state and local officials in developing their radiological emergency response plans to protect the public from exposure to radiation from deposited radioactive materials. Due to the wide variety of types of radiological incidents and radionuclide releases that could occur, it is not practical to provide implementing guidance for every possible situation.

This chapter also provides guidance for translating radiological conditions in the environment into projected doses that serve as the basis for decisions to take appropriate protective actions and basic planning guidance on reentry as informed by the Operational Guidelines (DOE 2009).

1.13 EXPOSURE PATHWAYS DURING THE INTERMEDIATE PHASE

During the intermediate phase, the following are the principal exposure pathways for the public occupying areas contaminated with deposited radioactive materials—

- **External exposure** ~~**of the whole body**~~ to external ~~gamma~~ radiation from deposited radioactive materials (groundshine). External gamma radiation is the expected dominant pathway for NPP incidents ~~reactor accidents~~ and incidents involving RDDs and INDs. Typically, the health risks from other pathways are expected to be minor in comparison to the risks due to external gamma radiation.
- **Internal exposure** from the inhalation of resuspended materials. Although normally expected to be of only minor importance for NPP incidents, the inhalation pathway would contribute additional doses to internal organs. Inhalation dose would, however, be an important exposure pathway for radiological incidents with significant fractions of pure beta emitters or alpha emitters.
- **Internal exposure** from the ingestion of food and water. In rare cases, where food or drinking water are contaminated to levels above the PAG for ingestion, and withdrawal of food and/or water from use would, in itself, create a health risk greater than that from the radiation dose, the committed effective dose from ingestion should be added to the dose from the above pathways.

Other potentially significant exposure pathways include exposure to beta radiation from surface contamination (e.g. beta dose to skin) and direct ingestion of contaminated soil. These pathways are not expected to be controlling for NPP incidents (Aaberg 1989).

1.14 THE PROTECTIVE ACTION GUIDES AND PROTECTIVE ACTIONS FOR THE INTERMEDIATE PHASE: RELOCATION AND DOSE REDUCTION

The principal protective actions for reducing exposure of the public to deposited radioactive materials are:

- Relocation;
- Decontamination;
- Shielding;
- Time limits on exposure; and
- Control of the spread of surface contamination.

The most effective of these actions is relocation—the removal or continued exclusion of people (households) from contaminated areas to avoid chronic radiation exposure. Relocation is highly disruptive and therefore only implemented when the dose is sufficiently high to warrant it. The PAG for relocation is 2 rem (20 mSv) projected over the first year of exposure. After the first year, the PAG for relocation is 0.5 rem (5 mSv) per year.

The PAG level for relocation applies to doses that can be avoided by relocation; doses already incurred prior to relocation are not included in the calculations. PAGs for protection from deposited radioactivity during the intermediate phase are summarized in Table 3-1. ~~The basis for these values is presented in detail in Chapters 4 and 7 and Appendix E of the 1992 PAG Manual, available online as a historical reference at http://www.epa.gov/radiation/rert/pags.html.~~ The decision to relocate will be considered on a case-by-case basis. Efforts to decontaminate and remediate the contaminated area and the shielding offered by buildings and the residency factor attributable to the building, must be considered to see if the second year PAG (0.5 rem (5 mSv) in a year) will be exceeded.

It may be difficult to avoid exceeding the relocation PAGs for the radionuclides most likely associated with RDDs because of their longer half-lives. If these radionuclides are released, it may be necessary to relocate people in the affected areas even if exposure is less than 2 rem (20 mSv) in the first year provided decontamination and remediation measures during the first year are unsuccessful.

In most scenarios, relocation decisions will be based on doses from external exposure to the whole body from deposited materials and internal exposure from inhalation of resuspended contamination.

Food and milk ingestion dose should be considered separately with decisions based on the FDA PAGs.[25]The FRMAC Assessment Manual provides guidance in calculating Ingestion Derived Response Levels that indicate the levels of deposited radioactive materials that may result in food exceeding the FDA PAGs

~~In most scenarios, relocation decisions will be based on doses from whole-body and internal exposure from inhalation of resuspended contamination. Food and milk ingestion dose should be considered separately with decisions based on the FDA PAGs.[21]~~

Other protective actions, such as simple dose reduction techniques, can be applied in areas where levels of deposited radioactivity are not high enough to warrant relocation. Dose reduction actions can range from the simple—scrubbing or flushing surfaces, removal and disposal of small spots of highly contaminated soil (e.g., from settlement of water) and spending more time than usual in lower exposure rate areas (e.g., indoors)—to the difficult and time consuming processes of removal, disposal and replacement of contaminated surfaces. The simple processes would probably be most appropriate in contaminated areas outside the relocation area. Many of these can be carried out by the residents with support from officials for monitoring and guidance on

[25] Accidental Radioactive Contamination of Human Food and Animal Feeds: Recommendations for State and Local Agencies, FDA 1998, available online: http://www.fda.gov/downloads/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/UCM094513.pdf

appropriate actions and disposal. The more difficult processes will be appropriate for recovery of areas where contamination is fixed (not removable) and from which the population is relocated.

Large areas may have to be restricted under these PAGs. As the land area increases, protective actions become more difficult and costly to implement, especially when the affected area is densely populated. There may be situations where full implementation of early and intermediate phase protective actions is impracticable (e.g., a release in a large city). Informed judgment must be exercised to assure priority of protection for individuals in areas having the highest exposure rates.

Table 4-1: Protective Action Guides for Exposure to Deposited Radioactivity during the Intermediate Phase of a Radiological Incident

Protective Action ~~Recommendation~~	PAG (Projected Dose)[a]	Comments
Relocate the general population[b]	≥ 2 rem (20 mSv) in the first year, 0.5 rem (5 mSv)/year in the second and subsequent years	Projected dose over one year
Apply simple dose reduction techniques[c]	~~< 2 rem (20 mSv)~~ < 2 rem (20 mSv) projected in the first year	These protective actions should be taken to reduce doses to as low as practicable levels

[a] Projected dose refers to the dose that would be received in the absence of shielding from structures or the application of dose reduction techniques. These PAGs may not provide adequate protection from some long-lived radionuclides (see Section 4.6).

[b] People previously evacuated from areas outside the relocation zone defined by this PAG may return to occupy their residences.

Cases involving relocation of people at high risk from such action (e.g., patients under intensive care) may be evaluated individually.

[c] Simple dose reduction techniques include scrubbing or flushing hard surfaces, minor removal of soil from spots where radioactive materials have concentrated and spending more time than usual indoors or in other low exposure rate areas.

This guidance does not address or impact site cleanups occurring under other statutory authorities such as the United States Environmental Protection Agency's (EPA) Superfund program, the Nuclear Regulatory Commission's (NRC)

1.14.1 Removal of the 50 Year Relocation PAG

For simplicity, the relocation PAG of 5 rem (50 mSv) over 50 years has been removed from this guidance. It is rarely, if ever, the driver for extending relocation area beyond that prompted by the first or second year relocation PAGs in scenarios that have been analyzed. Additionally, dose projections over 50 years after a radiological incident for various age groups showed no significant differences for individuals exposed at 3 months age versus adult. A response organization may wish to project 50-year doses to inform decision making, but should consider weathering, decay, credit for time spent indoors, and to the extent it can be predicted, dose reduction from mitigation activities. To keep emergency management decisions as simple as possible, however, the recommended relocation PAGs are 2 rem (20 mSv) projected over the first year, and 0.5 rem (5 mSv) projected over any subsequent year.

1.14.2 The Population Affected

The PAGs for relocation are intended for use in establishing the boundary of a relocation area within an area where radioactive materials have been deposited. The relocation PAGs have been established at a level that will provide adequate protection for the general population, including higher risk groups such as children and fetuses. People residing in contaminated areas outside the relocation area will be at some risk from radiation dose. Therefore, guidance on the reduction of dose during the first year to residents outside this zone is also

provided. Monitoring and simple dose reduction efforts are recommended in these areas to reduce doses to the extent practical. Such actions are unlikely to be practical where the dose reduction achieved is less than 10 percent.

Affected populations may perceive that intermediate phase protective actions are not consistent with those taken in the early phase. Early-phase decisions on sheltering-in-place and evacuation may have been implemented prior to verification of the path of the plume. Therefore, some people may have been evacuated from areas where validated doses are much lower than were projected. Others who were in the path of the plume may have been sheltered or not protected at all. During the intermediate phase of the response, dose projections may be revised based on environmental measurements. People should be relocated from areas where the projected dose exceeds the PAG for relocation without regard to prior evacuation status.

1.14.3 Basis for Intermediate Phase PAGs

For a full description of the risk-benefit analysis used to set the PAG levels, refer to the 1992 PAG Manual, Appendices B, C and E. The Manual is available online in a searchable format. Below is a short summary on the basis for the Intermediate Phase relocation PAGs.

In a prior section, for early phase (evacuation) PAGs, analysis was provided for the risks of health effects as a function of dose (Principles 1 and 2). Considerations for selection of PAGs for the intermediate phase of a radiological incident differ from those for selection of PAGs for the early phase primarily with regard to implementation factors (i.e., Principles 3 and 4). Specifically, they differ with regard to cost of avoiding dose, the practicability of leaving infirm people and prisoners in the restricted zone, and avoiding dose to fetuses. Although sheltering is not generally a suitable alternative to relocation, other alternatives (e.g., decontamination and shielding) are suitable.

For several assumed cumulative annual doses, the cost per day divided by the risk of fatality avoided by relocation was plotted for a radionuclide mixture from a hypothetical nuclear power plant accident. The cost per day of relocation is assumed to be constant, but with some nuclides decaying rapidly, the cost effectiveness of relocation diminishes over time. Drawing only general trends from this, the cost analysis supports relocation at doses as low as one rem (10 mSv) for the first week and two rem (20 mSv) for up to 25 days after an accident.

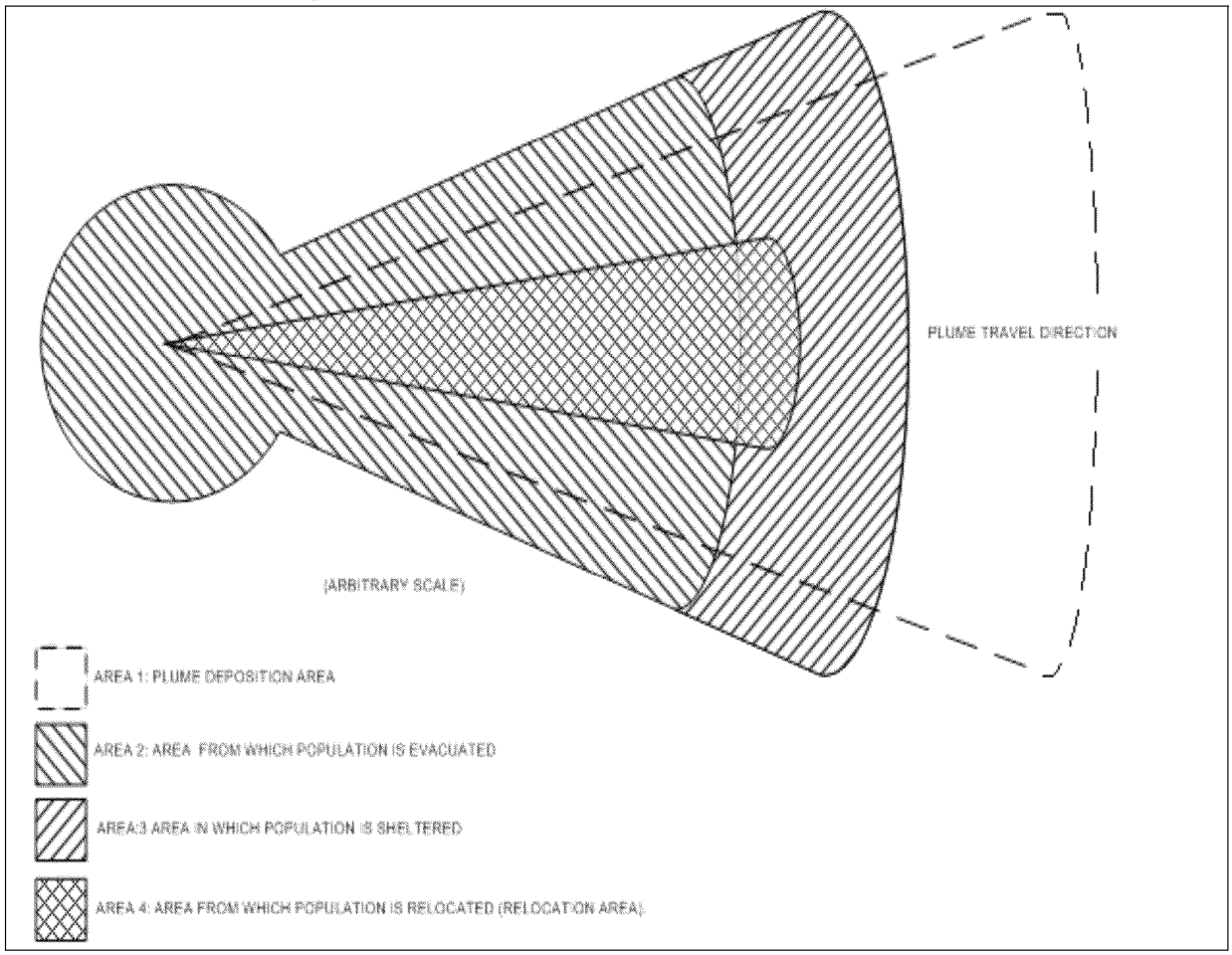
Based on the avoidance of acute effects alone (Principle 1) relocation of the general population and fetuses at 50 rem and 10 rem (500 and 100 mSv), respectively, is justified. However, on the basis of control of chronic risks (Principle 2) a lower upper bound is appropriate. Five rem is taken as an upper bound on acceptable risk for controllable lifetime exposure to radiation, including avoidable exposure to accidentally deposited radioactive materials.

Analyses based on Principle 3 (cost/risk) indicate that considering cost alone would not drive the PAG to values less than 5 rem (50 mSv). Analyses in support of Principle 4 (risk of the protective action itself) provide a lower bound for relocation PAGs of 0.15 rem (1.5 mSv). Based on the above, 2 rem (20 mSv) projected committed effective dose equivalent from exposure in the first year is selected as the PAG for relocation. Implementation of relocation at this value will provide reasonable assurance that, for a reactor accident, a person relocated from the outer margin of the relocation zone will, by such action, avoid an exposure rate which, if continued over a period of one year, would result in a dose of about 1.2 rem (12 mSv). This assumes that 0.8 rem (8 mSv) would be avoided without relocation through normal partial occupancy of homes and other structures.

Contrary to the situation for evacuation during the early phase of an incident, it is generally not practical to leave a few people behind when most members of the general population have been relocated from a specified area for extended periods of time. It will usually be practicable to reduce these risks by establishing a high priority for efforts other than relocation to reduce the dose in cases where pregnant women reside near the boundary of the restricted zone.

The implementation of simple dose reduction techniques will further reduce dose to people who are not relocated from contaminated areas. In the case of non-reactor accidents, decay and weathering effects differ, and it may be necessary to base relocation decisions on the second and subsequent year dose projections.

Figure 4-1: Generalized Protective Action Areas for NPP Incident



1.14.4 Areas Involved

Figure 4-1 provides a generalized example of the areas affected by different protective actions. Area 1 represents the plume deposition area. (In reality, variations in meteorological conditions would almost certainly produce a more complicated shape, but the same principles would apply.)

In situations such as an NPP accident, where early warning is given prior to a release of radioactive materials, people may already have been evacuated from Area 2 and sheltered in Area 3. People who have been evacuated from Area 2 or sheltered in Area 3 may go home if environmental monitoring verifies that their residences are outside the plume deposition area (Area 1).

Area 4 is the relocation area where projected doses are equal to or greater than the relocation PAG. People residing just outside the boundary of the relocation area may receive a dose approaching the PAG for relocation if decontamination or other dose reduction efforts are not implemented.

Area 1, with the exception of the relocation area, represents the area of contamination that may continue to be occupied by the general public during the intermediate phase. Nevertheless, there will be contamination levels in this area that will require continued monitoring and dose reduction efforts other than relocation. Incident-

specific levels below the PAGs may be used to control exposure to contamination. The relative positions of the boundaries shown in Figure 4-1 depend on areas evacuated and sheltered and the radiological and meteorological characteristics of the release. For example, Area 4 (the relocation area) could fall entirely inside Area 2 (area evacuated), so that the only people to be relocated would be those residing in Area 4 who were either missed in the evacuation process or who, because of mobility constraints for their evacuation, had remained sheltered during plume passage.

Establishing the boundary of a relocation area creates three groups of affected people—

- People who have already been evacuated from an area that is now designated as a relocation area and who now must be assigned relocation status.
- People who were not previously evacuated, but who reside inside the relocation area and should now relocate.
- People who were previously evacuated, but reside outside the relocation area and may now return home. A gradual return is recommended.

Small adjustments to the boundary of the relocation area established based on the PAG may be justified based on ease of implementation. For example, the use of a convenient natural boundary could be a logical reason for adjustment of the relocation area. However, such decisions should be supported by demonstration that exposure rates to people not relocated can be promptly reduced by methods other than relocation to meet the PAG, as well as the longer dose objectives addressed in Section 4.6.

The relocation PAG applies principally to personal residences but may impact other facilities as well. For example, it could impact work locations, hospitals and park lands as well as the use of highways and other transportation facilities. For each type of facility, the occupancy time of individuals should be taken into account to determine the criteria for using a facility or area. It might be necessary to avoid continuous use of homes in an area because radiation levels are too high. However, a factory or office building in the same area could be used because occupancy times are shorter. Similarly, a highway could be used at higher contamination levels because the exposure time of highway users would be considerably less than the time spent at home.

1.14.5 Priorities

In most cases, protective actions during the intermediate phase will be carried out over a relatively long period of time (e.g., months). Setting priorities will be important, especially when the affected area is so large that it is impractical to relocate members of the public from areas that barely exceed the relocation PAGs. The following priorities are appropriate—

- First, protect all people from doses that could cause acute health effects from all exposure pathways, including previous exposure to the plume.
- Conduct radiological surveys to verify or adjust estimates of radiological impacts.
- Recommend that affected people reduce their exposures by using simple decontamination techniques and remaining indoors.

1.15 SEQUENCE OF EVENTS

The high-priority decisions on whether to relocate people from high exposure rate areas requires exposure rate measurements and dose analyses. Monitoring and dose assessment will be an ongoing process, with priority given to the areas with the highest exposure rates.

Following passage of the airborne plume, a number of tasks must be accomplished for the timely protection of the public. The general sequence of events is itemized below, but the time frames will overlap.

1. Determine the areas where the projected first-year dose will exceed the 2 rem (20 mSv) relocation PAG and relocate people from those areas, with priority given for people in the highest exposure rate areas.

2. Allow previously evacuated people to return as quickly as possible to areas where field gamma measurements indicate that exposure rates are near normal background levels. If there is a possibility that particles from high deposition areas could drift into the occupied areas, establish a buffer zone to restrict residential use until radiological measurements and assessments confirm that it is no longer necessary. Buffer zones are set with the understanding that conservatism is inherent in the PAGs.
3. Based on isodose-rate boundary (see Section 4.4.1, below), assign any evacuees who reside within the relocation area to be relocated. Evacuated people whose residence is in the area between the boundary of the plume deposition and the boundary to the relocation area may return gradually as dose projections allow.
4. Evaluate the dose reduction effectiveness of simple decontamination techniques and of sheltering-in-place in response to exposure from partial occupancy of residences and workplaces. Results of these evaluations may influence recommendations for reducing exposure rates for people who are not relocated from areas near, but outside, the relocation area.
5. Control access to and egress from the relocation area. This would be accomplished through control points at roadway accesses to the relocation area.
6. Establish monitoring and decontamination stations to support control of the relocation area.
7. Implement simple decontamination techniques in contaminated areas outside the relocation area, giving priority to areas with higher exposure rates.
8. Collect data needed to establish long-term radiation protection criteria for decontamination and dose reduction and data to determine the effectiveness of various decontamination or other dose reduction techniques.
9. Begin operations to clean up and recover contaminated property in the relocation area.
10. If not already done, evaluate whether food grown or produced within the plume deposition area need to be interdicted per the FDA PAGs and evaluate drinking water systems within the plume deposition area. Provide guidance on planting or harvesting specific agricultural products.

1.15.1 Establishment of Isodose-Rate Lines

As soon as federal or other assistance is available for aerial and ground monitoring, a concentrated effort should begin to establish isodose-rate lines on maps and identify boundaries of the relocation area. Standard maps should be developed on which all response organizations would record monitoring data. Records on monitoring and decontamination of the public and workers should also be collected.

Aerial monitoring can be used to collect data for establishing general patterns of radiation exposure rates and may form the primary basis for the development of dose lines out to the limit of aerial detectability.

Initially during the early phase, detectability is limited to exposure rate changes of a few times natural background levels. Later during the intermediate phase, more sensitive measurements detect levels of radioactivity that are a small fraction of the natural background. Periodic air sample measurements will also be needed to verify the contribution to dose from inhalation of resuspended materials.

Gamma exposure rates measured at one meter (39 inches) will vary within a very small area because different surfaces have different deposition rates (e.g., smooth surfaces versus heavy vegetation). Rinsing or precipitation could also reduce levels in some areas and raise levels in others where runoff settles. In general, where exposure rates vary within designated areas, dose projections should be estimated using an appropriate average exposure rate.

1.15.2 Dose Projections

The FRMAC Assessment Manuals[26] provide detailed guidance for dose projection and calculating DRLs and DPs ~~DCFs~~ . The FRMAC Assessment Manuals incorporate the ICRP dosimetry models (ICRP 60 series). In

[26] See FRMAC Assessment Manuals at http://www.nv.doe.gov/nationalsecurity/homelandsecurity/frmac/manuals.aspx.

addition, the FRPCC encourages the use of computational tools such as DOE's Turbo FRMAC and NRC's RASCAL or other appropriate tools and methods to implement the PAGs.

The primary dose of interest in the intermediate phase is the sum of the effective dose from external exposure and the committed effective dose from inhalation. The exposure periods of interest are the first year and subsequent years after the incident. Other pathways should also be evaluated and their contributions considered, if significant. For example, anytime alpha-emitting radionuclides are involved, the inhalation of resuspended material must be considered. Although beta exposure will contribute to skin dose, its contribution to the overall risk of health effects from the radionuclides expected to be associated with reactor incidents should not be controlling in comparison to the whole body gamma dose (Aaberg 1989). However, the skin beta dose may be important for particulates deposited or transferred to the skin, as may be the case for an RDD that contains Strontium-90.

The dominant intermediate phase exposure pathway for incidents involving alpha-emitters (e.g. a weapons accident) is inhalation of resuspended material. For these incidents, dispersal of alpha-emitting material must be monitored carefully using proper measurement techniques. It is possible that there will be little or no associated gamma radiation or beta activity.

Calculation of the projected gamma dose from measurements will require knowledge of the principal radionuclides contributing to exposure and their relative abundances. Radiological characteristics can be compiled either through the use of portable gamma spectrometers or by radionuclide analysis of environmental samples. Several measurement locations may be required to determine whether any selective radionuclide deposition occurred as a function of meteorology, surface type, distance from the point of release, or other factors. In accordance with the Nuclear/Radiological Incident Annex to the National Response Framework, DOE, EPA and other federal agencies have the capability to assist state officials in performing environmental measurements, including determination of radiological characteristics of deposited materials (FEMA 2008 a, b).

The gamma exposure rate may decrease rapidly if deposited materials include a significant fraction of short-lived radionuclides. Therefore, the relationship between instantaneous exposure rate and projected first- and second-year annual doses will change as a function of time. These relationships must be established for the particular mix of deposited radioactive materials present at the time of the gamma exposure rate measurement. Over time, residual doses from gamma emitters will depend largely upon the half-lives of the radionuclides involved and could potentially remain significant over many years. It should be noted that natural attenuation as well as nuclear decay can affect long term dose assessments.

Because Intermediate Phase public protection decisions (e.g., relocation, re-entry) have less urgency than Early Phase decisions and the contamination is better characterized in the Intermediate Phase, it may be desired to improve the public protection decisions by modifying dose estimates with more realistic inputs. For example, the external dose reductions provided by building structures and dose reductions resulting from partial occupancy in the contaminated zone, which accounts for routine time spent outside the contaminated zone (e.g., work, school, shopping), may be included in the dose projections to make improved public protection decisions.

Projected dose considers exposure rate reduction from radioactive decay and, generally, weathering. When one also considers the anticipated effects of shielding from normal part time occupancy in homes and other structures, people who are not relocated should receive a dose substantially less than the projected dose. For commonly assumed reactor source-terms, it is estimated that 2 rem (20 mSv) projected dose in the first year will be reduced to about 1.2 rem (12 mSv) by this factor. The application of simple decontamination techniques shortly after the incident can be assumed to provide a further 30 percent or more reduction so that the maximum first year dose to people who are not relocated is expected to be less than 1 rem (10 mSv). Taking account of decay rates assumed to be associated with releases from NPP incidents (SNL 1982) and shielding from partial occupancy and weathering, a projected dose of 2 rem (20 mSv) in the first year is likely to amount

to an actual dose of 0.5 rem (5 mSv) or less in the second year. The application of simple dose reduction techniques would reduce the dose further.

Calculations supporting these projections are summarized in Table E-6 of the 1992 PAG Manual.[27]

Keeping below the 0.5 rem (5 mSv) PAG for ~~out~~ subsequent years—the second year and beyond—may be achieved through natural decay of shorter half-life radioisotopes, through decontamination efforts, or through other means of controlling public exposures (such as limiting access to certain areas). In the case of an RDD, in which a longer half-life radioisotope would likely be utilized, reductions in dose may prove difficult to achieve without longer term measures (see Chapter 5).

Exposure from ingestion of food and water is considered independently of decisions for relocation and decontamination. In rare instances, however, where withdrawal of food or water from use would pose a health risk in itself, relocation may be an appropriate protective action against exposure via ingestion. In this case, the dose from ingestion should be considered along with the projected dose from other exposure pathways for decisions on relocation.

1.15.3 Projected External Gamma Dose

Projected whole body external gamma doses at 1 meter height at particular locations during the first year and second year after the incident are the parameters of interest (DOE 1988). Measurements made at 1 meter to project whole-body dose from gamma radiation should be made with instruments of the "closed window" type to avoid the detection of beta radiation. The environmental information available for calculating these doses is expected to be the current gamma exposure rate at 1 m height and the relative abundance of each radionuclide contributing significantly to that exposure rate. Calculation models are available for predicting future exposure rates as a function of time with consideration of radioactive decay and weathering.

Relocation decisions can generally be made on the basis of the first year projected dose. However, projected doses during the second year are needed for decisions on protective actions for people who are not relocated. ~~DCFs~~ Conversion factors are therefore needed to convert environmental measurements to projected dose during the first year and second year following the incident (See FRMAC Assessment Manuals). Of the many types of environmental measurements that can be made to project whole body external gamma dose, gamma exposure rate in air is the easiest to make and is the most directly linked to gamma dose rate. However, analyses of a few environmental samples (particularly, soil samples) must be coupled with the gamma exposure rate to properly project decreasing dose rates.

In addition, measurements should be conducted to determine the dose reduction factors associated with simple, rapid, decontamination techniques so that these factors can be used in calculating dose to people who are not relocated. However, assumptions about these factors should not be included in calculating projected dose for decisions on relocation. Only dose reductions already accomplished can be considered.

1.15.4 Exposure Limits for People Reentering the Relocation Area

After the relocation area is established, people will need to reenter for a variety of reasons, including recovery activities, retrieval of property, security patrol, operation of vital services and, in some cases, care and feeding of farm and other animals. It may be possible to quickly decontaminate access ways to vital institutions and businesses in certain areas so that they can be occupied by adults either for living (i.e., institutions such as nursing homes and hospitals) or for employment. Clearance for occupancy of such areas will require dose reduction to meet exposure limits (EPA 1987). Dose projections should include both external exposure from deposited material and inhalation of resuspended deposited material for the duration of the planned exposure. People working in areas inside the ~~emergency~~ relocation area should operate under the controlled conditions established for occupational exposure (EPA 1987). The worker dose limitation does not need to include

[27] The 1992 PAG Manual is available as a historical reference online at: <http://www.epa.gov/radiation/rert/pags.html>

ongoing doses received from living in a contaminated area outside the relocation area. It is also not necessary to consider dose received previously from the plume or groundshine during the early phase of the radiological incident.

1.16 PROTECTIVE ACTION GUIDANCE FOR FOOD AND DRINKING WATER

Information on food and animal feeds protective action guidance is contained in FDA's "Accidental Radioactive Contamination of Human Food and Animal Feeds: Recommendations for State and Local Agencies" (FDA 1998).

{placeholder for drinking water PAG once final}

~~EPA is not proposing a specific drinking water PAG at this time. EPA has established enforceable drinking water standards for radionuclides under the Safe Drinking Water Act (SDWA). EPA recommends that to the extent practicable, emergency measures for drinking water be based on the National Primary Drinking Water Regulations (NPDWR) for Radionuclides. The Radionuclides Rule provides states with flexibility when responding to radiological events. If a public water system exceeds the radionuclides standard it must work to get back into compliance as soon as feasible. States have the authority to determine if other corrective actions are needed (e.g. providing alternative water).~~

~~However, the Agency recognizes a short-term emergency drinking water guide may be useful for public health protection in light of the Fukushima nuclear power plant accident, which impacted some Japanese drinking water supplies. Input on the appropriateness of, and possible values for, an intermediate phase emergency drinking water PAG is being sought during the public review of this Manual.~~

~~While the NPDWR provide for a regulatory standard of 4 mrem/year (beta, photon emitters) based on life-time exposure, international organizations have developed technical approaches and methodologies that have produced a range of emergency guidelines related to drinking water (e.g., the World Health Organization, the International Atomic Energy Agency) as have other federal agencies (e.g., the Department of Homeland Security, the Food and Drug Administration) and non-federal organizations. EPA is seeking input on an approach and technical rationale for a drinking water PAG designed to help officials select protective actions under emergency conditions when exposures would occur over shorter time periods than those envisioned in the NPDWR.~~

~~Monitoring & Characterization of Contaminants~~

~~The Radionuclides Rule requires community water systems (CWS) to monitor at each entry point to the distribution system to ensure that every customer's water does not exceed the maximum contaminant levels (MCLs) for radionuclides. All CWS are required to monitor for gross alpha, radium-226/228 and uranium. In addition, CWS designated by the state as "vulnerable" or if they use waters contaminated by effluents from nuclear facilities must also conduct monitoring for beta particle and photon radioactivity.~~

~~In the event of a radiological event incident, the state, at its own discretion, may exercise regulatory flexibility and require systems to collect samples for radionuclides, including beta particle and photon activity (40 CFR 141.26(e)). For more information about monitoring requirements for the Radionuclides Rule see the "Radionuclides Rule: A Quick Reference Guide" (EPA816-F-01-003, June 2001) or "Implementation Guidance for Radionuclides" (EPA 816-F-00-002, March 2002).~~

THESE FOOTNOTES WERE DELETED FROM THIS SECTION

~~See: http://www.who.int/water_sanitation_health/dwq/gdwq3rev/en/ and http://www.who.int/hac/crises/jpn/faqs/en/index8.html.~~

~~See: http://www-pub.iaea.org/MTCD/publications/PDF/Pub1467_web.pdf.~~

~~See: http://ogems.energy.gov/73fr45029.pdf~~

~~See: http://www.fda.gov/downloads/MedicalDevices/.../UCM094513.pdf~~

~~See: http://www.epa.gov/ogwdw/radionuclides/pdfs/qrg_radionuclides.pdf~~

~~See: http://water.epa.gov/lawsregs/rulesregs/sdwa/radionuclides/upload/2009_04_16_radionuclides_guide_radionuclides_stateimplementation.pdf~~

~~To determine if there is radiological contamination of drinking water sources and the extent to which such contamination is occurring, systems sampling for radionuclides must use approved EPA methods.~~

~~Public Notification~~

~~If water sample monitoring indicates that contamination levels exceed the MCL for any radionuclide, water systems are required to issue a Tier 2 Public Notification (i.e., within 30 days).~~

~~States have the flexibility to elevate the notification if warranted to a Tier 1 Public Notification (i.e., within 24 hours) (40 CFR 141.201(a)(3) Special public notices: Occurrence of a waterborne disease outbreak or other waterborne emergency.~~

~~During a radiological event, water systems may be dealing with a number of requirements and operating procedures and may not be prepared to issue public notification. The state may issue public notification on behalf of the water system (40 CFR 141.210(a)). This would allow the state to develop and deliver a consistent message to all affected customers and also allows the system to concentrate its efforts on returning the system [illegible] MCL violations. For more information see the Revised Public Notification Handbook (EPA 816-R-09-013, March 2010).~~

~~Corrective Actions to Reduce Levels of Contamination~~

~~Water distribution systems all incorporate reserve and storage capacity. During the early phase of an incident it is unlikely that contamination could affect water which is directly available for consumption through distribution systems. It would take some time for radionuclides to be deposited from the plume into the supply system water source and then subsequently be distributed. During the early phase, recommendations to the public (i.e., about drinking tap water) should reflect these considerations. The public should be advised that the water is safe to drink unless otherwise informed by state officials. Some useful and practical actions water systems can take during the intermediate phase to provide drinking water to customers are described below.~~

~~Wait for Flow-By~~

~~If radionuclides are deposited over a river, a section of the water can become contaminated and can be repeatedly contaminated as rain re-deposits radioactive particles. As this section flows down the river, this section of contaminated water is called a plume. This action calls for closing down any source intake valves along the path of the plume of contaminated water. While the intake valve is closed, no contaminated water can enter the water supply system; therefore the contaminated water is allowed to flow by the system. During this time, the system's existing storage capacity can be depended upon. If the stored water supplies could be depleted before the affected valves can be reopened, treatment of the contaminated water while using available stored water supplies should be considered. This assumes that the treatment technology will be in place or readily accessible. In the event of no other option, contaminated water could be temporarily replaced with large quantities of purchased uncontaminated water.~~

~~Treat Contaminated Water~~

~~Various treatment options exist for reducing or eliminating the contamination of drinking water by man-made radionuclides. Only a small percentage of all water systems treat specifically for radionuclides.~~

THESE FOOTNOTES WERE DELETED FROM THIS SECTION

- A list of EPA-approved analytical methods for Radionuclides is available at: http://www.epa.gov/ogwdw/methods/pdfs/methods/methods_radionuclides.pdf

- See: http://water.epa.gov/lawsregs/rulesregs/sdwa/publicnotification/upload/PNrevisedPNHandbookMarch2010.pdf.

However, typical technologies used to treat water for other contaminants can reduce the concentration of radioactivity. These technologies include coagulation/filtration, ion exchange, lime softening and reverse osmosis. Their actual removal efficiency depends on the radionuclide and the type of treatment.

Activate Existing Connections to Neighboring Systems

If the water supply system is part of a larger, regional supply system, activation of existing connections to a neighboring area could be considered. Most large water systems can establish connections with other large systems for emergency purposes. As in many cases, this option may have already been considered during emergency planning. If this option is implemented, steps must be taken to ensure that the "clean" systems do not become contaminated from water backflow.

Smaller water supply systems (i.e., that serve between 10,000 and 75,000 people), or sparsely populated or rural areas, may not be connected to a neighboring system. In this case, regionalization may be a part of emergency planning to explore. This involves connecting smaller systems to larger systems, thus forming a regional water supply system. This is obviously a long-term proposition, but it does have the added advantage of reducing system vulnerability to water shortages or water quality problems other than those resulting from a radiological incident.

Establish Pipeline Connections to Closest Sources/Systems

Running a pipeline from a "clean" water supply system to various distribution centers located throughout the affected community is a routine means of providing clean water. For example, when water mains must be repaired or cleaned of debris, community water needs have been met through the assembly of temporary pipes and hoses. This is a relatively simple procedure, requiring very little construction and technical expertise. For medium- to long-term emergencies, the construction of a temporary pipeline could be cost-effective. PVC pipe, fire hoses and steel pipe have been used to provide emergency drinking water for periods of up to 2 months when service has been disrupted by earthquakes, drought, or bacterial contamination.

Import Water in Tanker Trucks

If an uncontaminated source of water is close to the affected area, it may be more efficient to arrange to transport water from that source by truck, rail, or barge to distribution centers located throughout the community. The most significant obstacle for the use of this option is the cleanliness and availability of transport vehicles. State and local laws may also affect this option.

Import Bottled Water

Importing bottled water into the affected community is another possible option. The water may come from a nearby water supply system or from a water bottling company. This option may be cost-effective during an emergency if water is needed quickly and if the length of the emergency does not merit long- term action, such as the construction of a temporary pipeline.

Ration Clean Water Supplies

Rationing uncontaminated water is also a possibility. This is particularly true if water reserves can provide each individual in the community with 1 L (0.264G, about 1 qt) of water per day until the contaminated plume has passed, the contaminated water is treated, or the water supply system has returned to normal operating conditions. If this option is chosen, it is important that efficient methods for rationing are in place. Rationing water might also be required if water treatment capabilities are limited. Consider a scheme to ration water as part of emergency planning efforts.

THESE FOOTNOTES WERE DELETED FROM THIS SECTION

~~Additional information about treatment options and compliance guidance is available at the following website: http://water.epa.gov/lawsregs/rulesregs/sdwa/radionuclides/compliancehelp.cfm.~~

1.17 LONGER-TERM OBJECTIVES OF THE PROTECTIVE ACTION GUIDES FOR THE INTERMEDIATE PHASE

It is an objective of the PAGs to ensure that doses in any single year after the first will not exceed 0.5 rem (5 mSv). For source terms from NPP incidents, the PAG of 2 rem (20 mSv) projected dose in the first year is expected to meet this longer-term objective through radioactive decay, weathering and normal part-time occupancy in structures. If the release contains long-lived radionuclides, decontamination of areas outside the relocation area may be required during the first year to meet these objectives. For situations where it is impractical to meet these objectives through decontamination, relocation should be considered even if the projected first-year dose is lower than the relocation PAG.

Based on the relocation PAGs, reentry guidance can be found in the Reentry Matrix in Section 3.8, as well as in the Preliminary Report on Operational Guidelines Developed for Use in Emergency Preparedness and Response to a Radiological Dispersal Device Incident, Group C (DOE 2009). After the population has been protected in accordance with the PAGs for relocation, ~~return for~~ reoccupancy of the relocation areas should be governed on the basis of cleanup criteria and late phase cleanup activities should proceed. Refer to the Operational Guidelines manual for more information on how to implement the reentry guides in emergency plans.

1.18 REENTRY MATRIX FOLLOWING A RADIOLOGICAL INCIDENT OR ACCIDENT

~~**Assumptions and Definitions**~~

~~The term reentry is used for emergency workers and members of the public going into radiologically-contaminated areas temporarily under controlled conditions.~~

~~The incident response is divided into three activity planning phases. Early Phase begins with the incident and may last from hours to days. Intermediate Phase begins with control and characterization of the release; it may overlap early and late phase activity and last from weeks to months. , and is assumed to last for one year for purposes of dose projection only.~~

~~Late Phase begins when recovery actions to reduce radiation in the environment begin and ends when all recovery actions are complete. The matrix below only addresses Early and Intermediate Phase activity.~~

~~**Approach and Discussion**~~

~~Interagency guidance informed this section, including—~~

- ~~"Manual of Protective Action Guides and Protective Actions for Nuclear Incidents" (EPA, 1992).~~
- ~~"Preliminary Report on Operational Guidelines Developed for Use in Emergency Preparedness and Response to a Radiological Dispersal Device Incident" (DOE 2009).~~
- ~~FRMAC Assessment Manual (Sandia National Lab, 2010).~~

The "Preliminary Report on Operational Guidelines Developed for Use in Emergency Preparedness and Response to a Radiological Dispersal Device Incident" (DOE 2009), referred to as "Operational Guidelines" include detailed numeric guidance, developed by a multi-agency working group as a follow-up to the RDD/IND Planning Guidance. That work focused specifically on response and recovery for an RDD event;

however, that work can be expanded to include isotopes from a variety of incident types.

The Operational Guidelines are informative for this guidance, specifically the discussions about applicable dose-based limits, timeframes and pathways of exposure related to reentry tasks. The term reentry is used for emergency workers and members of the public going into radiologically contaminated areas, temporarily, under controlled conditions. Food and agriculture guides use FRMAC assessment methods as well as the Operational Guidelines for implementation. These tools allow derivation of decontamination thresholds for the early and intermediate stages of a response.

As part of the U.S. response to the Japanese Fukushima accident, scientists performed dose calculations to ensure that passengers and workers on train trips through contaminated areas do not exceed doses typically received from cosmic radiation during an international flight. DOE's Argonne National Laboratory scientists utilized the RESRAD-RDD tool and hand calculations to approximate doses from the NPP radionuclides.

THESE FOOTNOTES WERE DELETED FROM THIS SECTION

~~PAGs Manual online at http://www2.epa.gov/radiation/protective-action-guides-pags.~~

~~The Operational Guidelines were developed by federal agencies and published in draft form by DOE in February 2009 DOE/HS-0001; ANL/EVS/TM/09-1, on-line at http://web.ead.anl.gov/resrad/documents/ogt_manual_doe_hs_0001_2_24_2009c.pdf.~~

~~FRMAC Assessment Manual. Overview, and Methods online at: http://www.nv.doe.gov/nationalsecurity/homelandsecurity/frmac/manuals.aspx.~~

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Table 4.2: Reentry: Quick Reference to Operational Guidelines

PHASE	ACTIVITY	SUGGESTED LEVELS [a]	CLEANUP ACTIONS [b]
Early Phase ~~(first 4 days)~~	**Sheltering or Evacuation for the Public** **Emergency Worker Protection**	**Public**: 1-5 rem (10-50 mSv) projected over four days (See Ch. 2). A decision to evacuate weighs anticipated dose against feasibility of evacuating within a determined time frame, along with the risks associated with the evacuation itself. ~~response worker~~ Emergency Worker: 5/10/25 rem (50/100/250 mSv) incurred over the response duration. The higher limits are based on task (e.g., protecting large populations or critical infrastructure or lifesaving). Responder doses will be tracked with dosimeters. Emergency workers have knowledge of the risks associated with radiation exposure, training to protect themselves and dosimeters to track their doses.	It is too early for organized cleanup, due to chaos of the situation and higher priorities such as life-saving activities and clearly identifying shelter and evacuation zones. Any cleanup or decontamination information should focus on personal decontamination. It is doubtful any large-scale effort could change evacuation or shelter recommendations during this period (1st 4 days). Once evacuation is completed, there are simple actions cities can implement themselves: rinsing roofs and streets, street sweeping. The objective of these efforts is to move the bulk amounts of contamination away from occupied areas or areas where reoccupation is a priority. These actions should be based on measured amounts of contamination and priority of the location. Workers may face high dose levels and will need health physics
Intermediate Phase ~~(first 30 days and up to a year)~~	**Relocation for the Public**	**Public**: 2 rem (20 mSv) projected first year, 0.5 rem (5 mSv) per year projected in subsequent years (See Ch. 3). In this phase, scientists run dose calculations with RESRAD RDD or Turbo FRMAC; the user can choose sensitive age groups, or enter lower guidelines, if desired. Additionally, local decision makers can adapt the guides with incident-specific considerations and implement variations as needed.	Early cleanup efforts should focus on the removable portion of the contamination: vacuuming, washing, vegetation removal. Vacuuming has the advantage of collecting removable contamination without water or surface impact, but is limited by equipment availability and can also expose the operators to high dose levels as the vacuums collect the contamination. Washing and rinsing are simple to implement, but only move the contamination to less-populated areas and may move contamination deeper into porous surfaces. For unpaved areas, vegetation removal can effectively reduce the amount of contamination present, but is labor intensive and can produce large amount of waste. Having addressed the removable part of the contamination, later efforts can focus on fixed contamination. Paved surface
Intermediate Phase ~~(first 30 days and~~	**Reentry** **For Use of Critical**	**Public**: 2 rem (20 mSv) in first year (Preliminary Report on Operational Guidelines Developed for Use in Emergency Preparedness and Response to a Radiological Dispersal Device	removal is very effective, but requires specialized equipment and trained operators. Surface sealing is easier, but leaves the contamination in place, making it viable only in locations where the

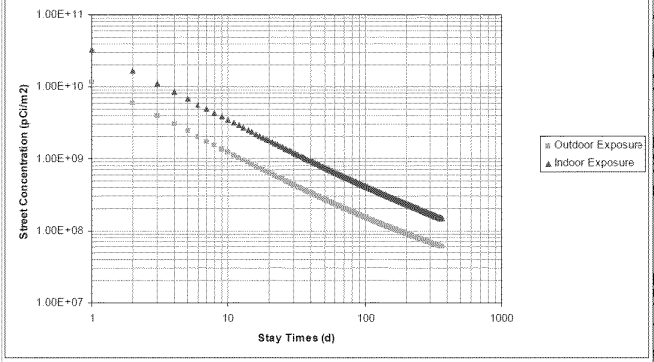

FIGURE 7.5 Limiting Concentrations of Cs-137 for Access to Business

ional Guidelines Group C). Dosimeters could be
mSv) first year, 0.5 rem (5 mSv) per year in
s (*Operational Guidelines, Group E*).
er Protection: (dose not to exceed) 5 rem (50
alues here are similar to those for Use of Critical
Radiation Protection Guidance to Federal
upational Exposure, EPA 1987).
rent because the exposure conditions are
rs have knowledge of the risks associated with
re, training to protect themselves and
5 mSv) over one year for temporary access with
ack their doses.
ndent on reentry tasks and site-specific
ational Guidelines, Group D).
n response workers (police, waste handlers)
minated areas could be trained and given
erm of art used in the radiation safety field. Stay
dosimeters. The guidance for Radiation Workers applies
throughout the response.

times are the amount of time a person may access the contaminated area. These times vary based upon site-specific factors or incident characteristics such as indoor or outdoor work, sensitive populations and level of radioactivity.

Section 7.1 of the Operational Guidelines, "Worker Access to Businesses for Essential Actions," provides tables and graphs of stay times at various limiting concentrations (see Figure 7.5 and Table 7.8). For example, if the maximum surface street

These graphics below are examples based on Operational Guidelines.

dose rates are low enough for occupation, or in low-occupancy areas. Repaving roads, lots and other paved surfaces is easy to implement, but can generate significant waste volumes. Unpaved areas can be further remediated by soil skimming (surface removal), deep plowing (turning the top foot or so of soil over) and appropriate chemical soil amendment methods like liming or chelating.

As the Intermediate phase progresses, knowledge and experience increases and these methods can be re-applied, refined or customized for problem areas. Decisions about more difficult areas will benefit from professional judgment, additional analyses and application of more sophisticated technologies.

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concentration of Cesium-137 is 3.00E+09 pCi/m2 (1.11E+08 Bq/m2), people limited to 0.5 rem (5 mSv) should be in the contaminated area less than four 8-hour days if staying outdoors.

This may apply to individuals retrieving belongings from homes or to workers providing security patrols, or even to people reopening businesses in the area. As contamination levels are reduced during cleanup, stay times can be extended and total doses reduced.

Operational Guidelines provide stay times and concentrations for several different sets of assumptions about the exposure. Residents retrieving possessions may spend most of their time indoors, where stay times are longer than they are for outdoors tasks. Stay time recommendations can be used to guide decisions about allowing entry into the contaminated area for a limited time and dose reduction techniques like wearing dust masks, cleaning shoes and car tires upon exit and using time wisely keep radiation exposure "ALARA" below the Operational Guideline.

Table 7.8 Scenario D2-2 Operational Guidelines for 0.5 rem Annual Dose: Residents Access to Houses (Indoor Exposure)

	Surface Street Concentration (pCi/m^2)		
Radionuclide	1 Day	4 Days	12 Days
Am-241	7.51E+07	2.86E+07	1.59E+07
Cf-252	3.50E+08	1.32E+08	7.13E+07
Cm-244	1.27E+08	4.82E+07	2.68E+07
Co-60	2.72E+09	6.87E+08	2.33E+08
Cs-137	1.14E+10	2.94E+09	1.01E+09
Ir-192	9.93E+09	2.54E+09	8.92E+08
Po-210	1.17E+09	3.86E+08	1.74E+08
Pu-238	6.56E+07	2.50E+07	1.39E+07
Pu-239	6.01E+07	2.29E+07	1.27E+07
Ra-226	6.08E+08	2.10E+08	9.97E+07
Sr-90	2.48E+10	7.70E+09	3.18E+09

[a] This guidance does not address or impact site cleanups occurring under other statutory authorities such as the United States Environmental Protection Agency's (EPA) Superfund program, the Nuclear Regulatory Commission's (NRC) decommissioning program, or other federal or state cleanup programs.

[b] This cleanup process does not rely on and does not affect any authority, including the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), 42 U.S.C. 9601 et seq. and the National Contingency Plan (NCP), 40 CFR Part 300. This document expresses no view as to the availability of legal authority to implement this process in any particular situation.

The Operational Guidelines were developed by federal agencies and published in draft form by DOE in February 2009 DOE/HS-0001; ANL/EVS/TM/09-1, on-line at http://web.ead.anl.gov/resrad/documents/ogt_manual_doe_hs_0001_2_24_2009c.pdf. (DOE 2009)

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KEY POINTS IN CHAPTER 4 – INTERMEDIATE PHASE

- The principal protective actions for reducing exposure of the public to deposited radioactive materials are relocation, decontamination and time limits on exposure. The PAG for relocation is 2 rem (20 mSv) over the first year of exposure. After the first year, the PAG for relocation is 0.5 rem (5 mSv) per year.
- Boundaries of relocation areas should be established based on the relocation PAG and site-specific geographical features such as rivers, mountains or roadways.
- Exposure limits must be set for people who must enter the relocation area to perform vital services.
- Other protective actions, such as focused decontamination and time limits on exposure, are applied to people in areas where levels of deposited radioactivity are not high enough to warrant relocation.
- Protective action guidance for food is contained in FDA's "Accidental Radioactive Contamination of Human Food and Animal Feeds: Recommendations for State and Local Agencies" (FDA 1998).
- EPA has established enforceable drinking water standards for radionuclides under the SDWA. EPA recommends that to the extent practicable, emergency measures for drinking water be based on the NPDWR for radionuclides. The Radionuclides Rule provides states with flexibility when responding to radiological events. Input on the appropriateness of, and possible values for, an intermediate phase emergency drinking water PAG is being sought during the public review of this Manual.
- {placeholder for drinking water}
- To inform temporary reentry into relocation areas, use the Operational Guidelines (DOE 2009).

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CHAPTER 5. PLANNING GUIDANCE FOR THE LATE PHASE

1.19 INTRODUCTION

This section describes the remediation cleanup process for the late phase of a nationally significant radiological incident, like a disaster at an NPP, an RDD or an IND. It should be noted that the extent and scope of contamination as a result of an NPP, RDD or IND incident may be at a much larger scale than a site or facility decommissioning or remedial cleanup. This process identifies the late phase remediation or cleanup process steps, including factors for decision makers to consider in determining final cleanup actions. For information on roles, responsibilities and authorities during emergency response and recovery please refer to the National Response Framework: http://www.fema.gov/national-response-framework and specifically for radiological incidents, the Nuclear Radiological Incident Annex:http://www.fema.gov/pdf/about/divisions/thd/IncidentNucRad.pdf (FEMA 2008a, b).

1.19.1 Transitioning from Intermediate to Late Phase Cleanup

The late phase cleanup process begins sometime after the commencement of the intermediate phase and proceeds independently of intermediate phase protective action activities. The transition is characterized by a change in approach, from strategies predominantly driven by urgency, to strategies aimed at both reducing longer-term exposures and improving living conditions. The late phase involves the final cleanup of areas and property at which contamination directly attributable to the incident is present. It is in the late phase that final cleanup decisions are made and final recovery efforts following a radiological incident are implemented.

Unlike the early and intermediate phases of a radiological incident, decision makers will have more time and information during the late phase to allow for better data collection, stakeholder involvement and options analysis. There will be opportunities to involve key stakeholders in providing sound, cost- effective cleanup recommendations. Generally, emergency phase decisions will be made directly by elected public officials, or their designees, with limited stakeholder involvement due to the need to act within a short timeframe. Longer-term decisions should be made with stakeholder involvement and can also include incident-specific technical working groups to provide expert advice to decision makers on impacts, costs and alternatives. Community members will influence decisions such as if and when to allow people to return home to contaminated areas. There will be people living in contaminated areas, outside the evacuation and relocation zones, where efforts to reduce exposures will be ongoing.

Because of the extremely broad range of potential impacts that may occur from NPP incidents, RDDs and INDs (e.g., light contamination of one building to widespread destruction of a major metropolitan area), a process should be used to determine acceptable cleanup criteria based on the societal objectives for expected land uses and the options and approaches available. Implicit in these decisions is the ability to balance health protection with the desire of the community to resume normal life. Radiation protection considerations ~~must~~ should be addressed in concert with health, environmental, economic, social, psychological, cultural, ethical, political, and other considerations. It is recognized that experience from existing programs, such as the U.S. EPA's Superfund program, the U.S. NRC's process for decommissioning and decontamination to terminate a nuclear facility license and other national recommendations may be useful in planning cleanup and recovery efforts.

Consistent with the "Framework for Environmental Health Risk Management," mandated by the 1990 Clean Air Act Amendments and published by the Commission on Risk Assessment and Risk Management in 1997, the late phase cleanup process consists of multiple steps, including 1) characterization and stabilization, 2) development of goals and strategies and 3) implementation and reoccupancy. Stakeholder involvement should be integrated throughout the process. Characterization in this phase consists of delineation, in detail, of the nature and extent of contamination in areas impacted by the incident. Stabilization is intended to reduce the

spread of contamination to clean areas, airborne inhalation hazards and the volume of radioactive waste generated. Establishment of cleanup goals and strategies should consider overall community health, along with a variety of factors described further below; they are based upon anticipated land use and a variety of selection criteria. Key to these steps is the involvement and acceptance of the impacted state and local community. These steps are discussed in more detail below.[28]

1.19.2 Characterization and Stabilization

The first step in the late phase remediation or cleanup process is characterization, or the comprehensive mapping and monitoring of the distribution and level of radioactive contamination. Characterization activities are necessary in the preparation for and verification of a successful remediation or cleanup effort. The late phase characterization work is designed to define, in detail, the nature and extent of the contamination and to provide information needed to develop and evaluate cleanup alternatives.

The characterization performed in support of the late phase will be much more detailed and comprehensive than the earlier characterization work to support PAG decisions made during the early and intermediate phases. It delineates the nature of any actual threat posed to human health or the environment and defines the extent of that threat.

Stabilization techniques are designed to immobilize radioactive contamination on soils, buildings, roads and equipment. This becomes paramount in a large-scale incident where the spread of contamination can occur from natural weathering effects to human and animal interactions with the environment. Stabilization reduces chronic low-level exposures to residual radiation, airborne hazards and volumes of secondary waste. These reductions can result in significant benefits to the long-term recovery in terms of time-to-normalcy and economic recovery.

1.19.3 Goals and Strategies

After late phase characterization and stabilization activities are accomplished, areas impacted by radioactive contamination are documented and defined to the best extent possible. At this point, decision makers ~~must~~ should establish cleanup goals and strategies for moving forward. The development of goals and strategies marks the second step in the late phase remediation or final cleanup process. As part of an ongoing iterative process, cleanup goals are informed by the feasibility of cleanup strategies and specific cleanup strategies adjust as experience is gained. That is, risk management goals may be refined as decision makers and stakeholders gain appreciation for what is feasible, what the costs and benefits are and how the process of reducing exposures and risks can improve human and ecological health.

As actual levels for areas are determined, many factors come into play in decision making, such as balancing risk reduction with other factors, background levels of radioactivity and tolerance for voluntary versus involuntary risk. Determining these levels will require consideration of a number of factors—

- The types of contamination; the technical feasibility, cost, timeliness and effectiveness of decontamination measures; and the availability and cost of options for the disposal of wastes.
- The size and character of the areas that are contaminated; past and projected future uses for these areas; and the preservation or destruction of places of historical, national, or regional significance.
- Site-specific natural and anthropogenic background levels of radioactivity.
- Estimates of the impacts of both contamination and options for decontamination, on human health, communities, the economy, ecosystems and ecosystem services.
- Public acceptability and intergenerational equity.

[28] This cleanup process does not rely on and does not affect any authority, including the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), 42 U.S.C. 9601 et seq. and the National Contingency Plan (NCP), 40 CFR Part 300. This document expresses no view as to the availability of legal authority to implement this process in any particular situation.

Community involvement and sentiment are vital to this process. The stress from both the incident itself as well as the longer term effects of separation from home will be important factors as overall community health is considered. In the United States, a range of one in a population of ten thousand (10^{-4}) to one in a population of one million (10^{-6}) excess cancer incidence outcomes is generally considered protective for both chemical and radioactive carcinogenic contaminant exposures. This range is the regulatory standard generally used in the context of EPA Superfund response actions. The NRC's decommissioning and decontamination process outcomes are usually in or near this range as well. A similar risk range may be an appropriate goal for radiological events that affect areas of comparable size. However, such risk ranges may not be practically achievable for major incidents that result in the contamination of very large areas. Every incident is unique. In making decisions about cleanup goals and strategies for a particular event, decision makers ~~must~~ should balance the desired level of exposure reduction with the extent of the measures that would be necessary to achieve it, in order to maximize overall human welfare.

While it may take many years to achieve final cleanup levels, a timely return to normalcy, including reoccupancy and a viable community, will require a cleanup process that is flexible, iterative and inclusive. Decisions ~~must~~ should be made on a site-specific basis and should reflect the interim risks that are reasonable and acceptable to the affected community as active remediation, radioactive decay and natural weathering move the site toward long-term cleanup goals.

Cleanup strategies are adopted as decision makers and stakeholders gain an understanding of all relevant factors. Tradeoffs between alternatives should be considered and balanced so that the best options are chosen. Local acceptance will be a key component of a fully transparent approach to long-term remediation and cleanup. Factors to consider in determining cleanup actions include evaluating:

- Areas impacted (e.g., size, location relative to population);
- Actions already taken during the early and intermediate phases;
- Ability of a remedy to maintain reliable protection of overall human health and the environment over time;
- Assessing the relative performance of treatment technologies on the toxicity, mobility or volume of contaminants;
- Success or effectiveness of the cleanup or remediation as the cleanup progresses (contaminant removal);
- Adverse impacts on human health and the environment that may be posed in the time it takes to implement the remedy and achieve the community-based remediation goals;
- Impacts of alternative levels of clean up on the local and regional economy (e.g., job loss due to closed businesses, job creation due to decontamination and waste handling operations) and on residents' sense of place (e.g., continued limited access to one's home and community until clean up levels have been reached);
- Preservation or destruction of places of historical, national or regional significance;
- Technical and administrative feasibility of the remedy, including the availability of materials and services needed to implement each component of the option in question;
- Cost of each alternative, including the estimated capital and operation and maintenance costs and net present value of capital and operation and maintenance costs;
- State concurrence with the remedy; and
- Community support for the remedy.

This may be an iterative process. As experience is gained, adjustments may be required to achieve long-term goals.

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1.19.4 Implementation and Reoccupancy

To implement cleanup actions in each community, measurable quantities associated with cleanup goals should be derived taking into account exposures from all potential pathways and through all environmental media (e.g., soil, ground water, surface water, sediment, air, animals or plants). These values typically are derived considering reasonably anticipated future land use, dietary habits and commerce patterns. If meeting acceptable levels based upon the reasonably anticipated post-incident land use is not practicable and cost-effective, decision-makers can look to more restrictive land uses through institutional and engineering controls. This approach is based on the belief that early community involvement focusing on desired post-incident uses of the property will result in expedited, cost-effective and publicly-supported cleanups. Overall community health, including stress factors from the initial event and separation from home or family is a necessary consideration.

In some situations, a site or area may reasonably be anticipated to support a range of uses, so cleanup goals may be different for different subareas of the impacted area. Although it may take years to achieve the final cleanup goals for all land uses, reoccupancy of the affected area will be possible when interim cleanup can reduce short-term exposures to acceptable levels during the time it takes to achieve the long- term goals. There may be institutional or engineering controls placed on some portions of the site to prevent excessive exposures until further active remediation, radioactive decay, or natural weathering allow the site to meet cleanup goals. An example of an institutional control might be a restriction on planting vegetable gardens to avoid ingesting radionuclides that may be taken up by the plant roots from the soil. An example of an engineering control to limit exposures might be adding a layer of pavement or cement over gamma emitting radionuclides that have become fixed in place by sorbing onto the street and sidewalks.

In complex cases such as the situation represented by a wide-area NPP, RDD or IND event, cleanup and reoccupancy are likely to occur subarea by subarea in order of priority and community assessments. Critical infrastructure is likely to have been restored to some level of functionality and further remediation of the infrastructure should be evaluated against the cleanup goal. A community-based and transparent development of priorities would follow, resulting in sequential actions, whereby areas (e.g., residential, commercial) would be remediated and reoccupied utilizing temporary cleanup levels that would be considered acceptable for an interim period of time prior to final cleanup goals being achieved. Land use may need to be changed in a subarea where it is not feasible with a combination of remediation, engineering and institutional controls to support the pre-incident land use in a manner that protects human health. In all cases, an appropriate population health monitoring program should be implemented proportionate to the potential or estimated health risk.

1.19.5 Stakeholder Involvement

Generally, early (or emergency) phase decisions will be made directly by elected public officials, or their designees, with limited stakeholder involvement due to the need to act within a short timeframe. With additional time and an increased understanding of the situation, there will be opportunities to involve key stakeholders in providing sound, cost-effective cleanup recommendations that are protective of human health and the environment.

Affected citizens should be involved in all phases of cleanup planning and long-term remediation of their communities. Early in the process, decision makers should bring together a broad group of stakeholders, e.g., residents, local business owners, local government officials and others interested in the processes that will be required to restore their communities. The credibility of a community group is a function of its inclusiveness. It ~~must~~ should represent all stakeholder interests to ensure it is a voice for the entire community rather than a few interested parties. Empowering individuals to assist in the process is important and effective. The affected local community will need to be involved until the site remediation activities are complete and possibly beyond that if institutional and engineering controls are placed on some subareas of the site.

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1.19.6 Cleanup Process Implementation and Organization: An Example

This example, reprinted from the Planning Guidance for Protection and Recovery Following Radiological Dispersal Device (RDD) and Improvised Nuclear Device (IND) Incidents (DHS 2008), describes a hypothetical organization to integrate federal cleanup support activities with state and local governments and the public. In particular, it addresses a scenario where the federal government is expected to be the primary funding entity for cleanup and recovery activities. For some radiological scenarios, states might take the primary leadership role in cleanup and contribute significant resources toward recovery of the site. This example does not address such a scenario, although states may choose to follow a similar process.

1.19.6.1 Cleanup Implementation

This approach describes how federal departments and agencies may coordinate during a response with state and local government counterparts and the public, consistent with the National Response Framework (NRF) (FEMA 2008a) and the National Disaster Recovery Framework (NDRF). The approach does not attempt to provide detailed descriptions of state and local roles and expertise. It is assumed those details will be provided in state and local level planning documents that address radiological/nuclear terrorism incidents.

During the intermediate phase, site cleanup planners should begin the process described below, under the direction of the on-site incident command or unified command (IC/UC) and in close coordination with federal, state and local officials. After early and intermediate phase activities have come to conclusion and only long-term cleanup activities are ongoing, the IC/UC structure may continue to support planning and decision-making for the long-term cleanup. The IC/UC may make personnel changes and structural adaptations to suit the needs of a lengthy, multifaceted and highly visible remediation process. For example, a less formal and structured command, more focused on technical analysis and stakeholder involvement, may be preferable for site extended site cleanup than what is required under emergency circumstances.

Radiological and nuclear incidents cover a broad range of potential scenarios and impacts. This example assumes that the incident is of sufficient size to trigger a state request for federal assistance and that the federal government is the primary funding agent for site cleanup. In particular, the process described for the late phase cleanup assumes an incident of relatively large size. For smaller incidents, all of the elements in this section may not be warranted. The process should be tailored to the circumstances of the particular incident. Decision makers should recognize that for some radiological/nuclear incidents, states will take the primary leadership role and contribute significant resources toward cleanup of the site. This section does not address such a scenario, but states may choose to use the process described here.

1.19.6.2 Cleanup Activities Overview

As described earlier in the document, radiological/nuclear emergency responses are often divided roughly into three phases: (1) the early phase, when the plume is active and field data are lacking or not reliable; (2) the intermediate phase, when the plume has passed and field data are available for assessment and analysis; and (3) the late phase, when long-term issues are addressed, such as cleanup of the site. For purposes of this example, the response to a radiological or nuclear incident is divided into two separate, but interrelated and overlapping, processes. The first is comprised of the early and intermediate phases of response, which consists of the immediate and near-term on-scene actions of state, local and federal ~~emergency responders~~ emergency workers under the IC/UC. On-scene actions include incident stabilization, lifesaving activities, dose reduction actions for members of the public and ~~emergency responders~~ emergency workers, access control and security, emergency decontamination of people and property, "hot spot" removal actions and resumption of basic infrastructure functions.

The second process pertains to environmental cleanup, which is initiated soon after the incident (during the intermediate phase) and continues into the late phase. The process starts with convening stakeholders and technical subject matter experts to begin identifying and evaluating options for the cleanup of the site. The

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environmental cleanup process overlaps the intermediate phase activities described above and should be coordinated with those activities. This process is interrelated with the ongoing intermediate phase activities and the intermediate phase protective actions may continue to apply through the late phase until cleanup is complete.

Cleanup planning and discussions should begin as soon as practicable after an incident to allow for selection of key stakeholders and subject matter experts, planning, analyses, contractual processes and cleanup activities. States may choose to pre-select stakeholders for major incident recovery coordination. These activities should proceed in parallel with ongoing intermediate phase activities and coordination between these activities should be maintained. Preliminary remediation activities during the intermediate phase—such as emergency removals, decontamination, resumption of basic infrastructure function and some return to normalcy in accordance with intermediate phase PAGs—should not be delayed for the final site remediation decisions.

A process for addressing environmental cleanup is presented below. This is a flexible process in which numerous factors are considered to achieve an end result that considers local needs and desires, health risks, costs, technical feasibility and other factors. The general process outlined below provides decision makers with input from both technical experts and stakeholder representatives and also provides an opportunity for public comment. The extent and complexity of the process for an actual incident should be tailored to the needs of the specific incident; for smaller incidents, the workgroups discussed below may not be necessary.

The goals of the process described below are: 1) transparency—the basis for cleanup decisions should be available to stakeholder representatives and to the public at large; 2) inclusiveness—representative stakeholders should be involved in decision-making activities; 3) effectiveness—technical subject matter experts should analyze remediation options, consider established dose and risk benchmarks and assess various technologies in order to assist in identifying a final solution that is optimal for the incident; and 4) shared accountability—the final decision to proceed will be made jointly by federal, state and local officials.

Under the NRF and NDRF, FEMA may issue mission assignments to the involved federal agencies, as appropriate, to participate in the overall recovery process. Additional funding may be provided to state/local governments to perform response or recovery activities through other mechanisms. The components of the process are as follows:

1.19.6.3 General Management Structure

Planning for the long-term cleanup should begin during the intermediate phase and at that time, a traditional National Incident Management System (NIMS) response structure should still be in place. However, NIMS was developed specifically for emergency management and may not be the most efficient response structure for long-term cleanup. If the cleanup will extend for years, the IC/UC may decide to transition at some point to a different long-term project management structure.

Under the NRF and NIMS, incidents are managed at the lowest possible jurisdictional level. In most cases, this will be at the level of the IC/UC. The IC/UC directs on-scene tactical operations. Responding local, state and federal agencies are represented in the IC/UC and Incident Command Post in accordance with NIMS principles regarding jurisdictional authorities, functional responsibilities and resources provided. For a wide-area radiological incident, multiple Incident Command Posts (ICPs) may be established to manage the incident with an Area Command or Unified Area Command supporting the ICPs and prioritizing resources and activities among them. If the incident happens on a federal facility or involves federal materials, the representatives in the UC may change appropriately and the response will be conducted according to the applicable federal procedures.

Issues that cannot be resolved at the IC/UC or Unified Area Command level may be raised with the Joint

Field Office (JFO) and JFO Unified Coordination Group for resolution. The JFO coordinates and prioritizes federal resources and when applicable, issues mission assignments to federal agencies under the Stafford Act. Issues that cannot be resolved at the JFO level may be raised to the DHS National Operations Center senior-level interagency management groups and the White House Homeland Security Council and National Security Council.

Day-to-day tactical management, planning and operations for the cleanup process will be managed at the IC/UC level, but for large-scale cleanups involving significant federal resources, it is expected that the JFO Unified Coordination Group and national level federal officials will review proposed cleanup plans and provide strategic and policy direction. The federal agency(s) with primary responsibility for site cleanup should be represented in the JFO Unified Coordination Group. The IC/UC will need to establish appropriate briefing venues as the cleanup process proceeds, including the affected mayor(s) and governor(s).

The discussion below assumes a traditional NIMS IC/UC structure; if the IC/UC transitions later to a different management structure for a longer-term cleanup, the IC/UC would need to determine the appropriate way to incorporate the workgroups described below into that structure.

This process will be managed by the IC/UC, who ultimately determines the structure and organization of the Incident Command Post, but the discussion below provides one recommended approach for managing the cleanup process within a NIMS ICS response structure. The Incident Command Post Planning Section has the lead for response planning activities, working in conjunction with other sections and would have the lead for development of the cleanup options analysis, working closely with the Operations Section. The NIMS describes the units that make up the Planning Section and allows for additional units to be added depending on site-specific needs. NIMS states that for incidents involving the need to coordinate and manage large amounts of environmental sampling and analytical data from multiple sources, an Environmental Unit may be established within the Planning Section to facilitate interagency environmental data management, monitoring, sampling, analysis, assessment and site cleanup and waste disposal planning. Radiological incidents would involve the collection of not only large amounts of radiological data, but also data related to other environmental and health and safety hazards and therefore would likely warrant the establishment of an Environmental Unit in the Planning Section. Planning for FRMAC radiological sampling and monitoring activities will be integrated into the Planning Section and coordinated with other Situation and Environmental Unit data management activities.

The IC/UC may assign the Environmental Unit the responsibility for coordinating the development of the cleanup options analysis. For large incidents requiring more complicated tradeoffs or the evaluation of cleanup goals with broad implications, the IC/UC may choose to establish a separate unit in the Planning Section (for example, a Cleanup Planning Unit) to coordinate the development of the cleanup options analysis. The IC/UC may then convene a technical working group and a stakeholder working group, managed by the Environmental or Cleanup Planning Unit, to analyze cleanup options and develop recommendations. The Environmental or Cleanup Planning Unit would coordinate working group processes and interactions and report the results of the cleanup options analysis and workgroup efforts to the IC/UC through the Planning Section Chief.

The development and completion of the cleanup options analysis is expected to be an iterative process and for large incidents, the cleanup will likely proceed in phases, most likely from the "outside in" toward the most contaminated areas. The extent of the analysis and process used to develop it would be tailored to the needs of the specific incident, but the following working groups may be convened by the IC/UC to assist decision makers in the cleanup options process, particularly for large or complex cleanups.

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1.19.6.4 Technical Working Group

A technical working group should be convened as soon as practicable, ideally within days or weeks of the incident. The technical working group would be managed by the Planning Section Unit that is assigned responsibility for the cleanup options analysis. The technical working group may or may not be physically located at the ICP. The group may review data and documents, provide input electronically and meet with incident management officials. The group may also be asked to participate in meetings with the JFO Unified Coordination Group if needed.

Function: The technical working group provides multi-agency, multi-disciplinary expert input on the cleanup options analysis, including advice on technical issues, analysis of relevant regulatory requirements and guidelines, risk analyses and development of cleanup options. The technical working group would provide expert technical input to the IC/UC; it would not be a decision-making body.

Makeup: The technical working group should include selected federal, state, local and private sector subject matter experts in such fields as environmental fate and transport modeling, risk analysis, technical remediation options analysis, cost, risk and benefit analysis, health physics and radiation protection, construction remediation practices and relevant regulatory requirements. The exact selection and balance of subject matter experts is incident-specific. The Advisory Team for Environment, Food and Health is comprised of federal radiological experts in various fields that may warrant representation on the technical working group, therefore, the Team or some of its members may be incorporated into this group as appropriate.

1.19.6.5 Stakeholder Working Group

The stakeholder working group should be convened as soon as practicable, ideally within days or weeks of the incident. The stakeholder working group would be managed by the Planning Section Unit that is assigned responsibility for the cleanup options analysis. The IC/UC may direct the Public Information Officer (PIO) (who would coordinate with the Joint Information Center (JIC)) to work with the group, including establishing a process for the group to report out its recommendations. How and where the stakeholder working group would meet to review information and provide its input would need to be determined in conjunction with the group members. The stakeholder working group may also be asked to participate in meetings with the JFO Unified Coordination Group if needed.

Function: The function of the stakeholder working group is to provide input to the IC/UC concerning local needs and desires for site recovery, proposed cleanup options and other recommendations. The group should present local goals for the use of the site, prioritizing current and future potential land uses and functions, such as utilities and infrastructure, light industrial, downtown business and residential land uses. The stakeholder working group would not be a decision-making body.

Makeup: The stakeholder working group should include selected federal, state and local representatives, local non-governmental representatives as well as local and regional business stakeholders. The exact selection and balance of stakeholders is incident specific.

1.19.6.6 Activities: Cleanup Planning and Recommendations

The IC/UC directs the management of the cleanup options analysis through the Planning Section. Technical and stakeholder working groups assist in performing analyses and developing cleanup options and provide input to the IC/UC and may be asked to participate in meetings with the JFO Unified Coordination Group. The IC/UC reviews cleanup options analysis and selects a proposed approach for site cleanup in close coordination with federal, state and local officials. Again, depending on the incident size, it may be necessary to conduct the cleanup in phases. Thus, decisions on cleanup approaches may also be made in phases. As appropriate for the magnitude of the cleanup task, the IC/UC would brief relevant federal, state and local government officials on proposed cleanup plans for approval. This may involve the office of the affected

mayor and governor. At the federal level, it may involve the JFO Unified Coordination Group and higher-level officials.

1.19.6.7 Public Review of Decision

The IC/UC should work with the PIO and JIC to publish a summary of the process, the options analyzed and the recommendations for public comments. Public meetings should also be convened at appropriate times. Public comments should be considered and incorporated as appropriate. A reconvening of the stakeholder or technical working group may be useful for resolving particular issues.

1.19.6.8 Execution of Cleanup and Peer Review

Assuming a Presidential declaration of a major disaster or emergency, FEMA may issue mission assignments to the federal departments and agencies that have the capability to perform the required cleanup, remediation, or debris removal activities. Cleanup activities should commence as quickly as practicable and allow for incremental reoccupation of areas as cleanup proceeds. For significant decontamination efforts, the IC/UC may choose to employ a technical peer review advisory committee to conduct a review of the effectiveness of the cleanup. The technical peer review committee would evaluate pre- and post-decontamination sampling data, the decontamination plan and any other information key to assessing the effectiveness of the cleanup.

1.20 DISPOSAL OF LARGE VOLUMES OF RADIOLOGICAL WASTE

If a large scale radiological incident were to occur in the United States, the complexity of radiological waste disposal would depend on the magnitude of the release and the decisions related to site cleanup, both of which will determine the amount and types of waste requiring disposal. Primary responsibility for waste management decisions falls to state and local officials. If there is a limited radiological incident with relatively small waste volumes, existing licensed radioactive waste capacity is available and may be sufficient to address waste disposal. However, in a situation involving a more significant release and certainly in an event such as the 2011 incident at the Fukushima nuclear facility, the waste resulting from such an incident would likely overwhelm current disposal capacity. When waste volumes exceed existing capacity, options available for consideration include supplements to existing commercial licensed radioactive waste disposal facilities, such as a combination of hazardous waste landfills, solid waste landfills, DOE facilities and construction of one or more new disposal facilities. New disposal capacity could be located at the site where the radionuclide release originated, elsewhere within the contaminated area, or away from the affected area altogether.

This section provides a short introduction to the issue, a summary of the types of available disposal options, a more detailed discussion of each disposal option, including disposal capabilities and discussion of roles and responsibilities. Although not addressed explicitly in this section, the need to prepare for and conduct safe and environmentally protective storage of waste generated during remediation will also present a significant challenge, as illustrated by the challenges that Japan faced in the aftermath of the Fukushima accident. Many of the considerations for siting disposal facilities will also be applicable to storage sites.

Planners and decision-makers need to view the long-term remediation and recovery as a comprehensive process in which waste management and disposal needs are considered from the earliest stages. For example, the selected decontamination and remediation approach should involve consideration of a number of viable alternatives with regard to potential treatment and disposal options. The precise mix of treatment and disposal options employed would depend on the nature of the specific incident (e.g., location, waste volumes). The suitability of using any individual facility would depend on a number of factors, including but not limited to the toxicity, mobility and volume of radioactively-contaminated wastes (these would be evaluated as part of the characterization process), possible treatment technologies (e.g., volume reduction technologies at the incident location; thermal treatment; neutralization), cost- effectiveness and existing federal and state (and possibly local) legal requirements governing waste disposal.

1.20.1 Potential Waste Volumes and Existing Waste Disposal Options

As noted above, the complexity of radiological waste disposal decisions would depend on a number of factors, including the magnitude of the release and the decisions related to site cleanup. Consideration of these factors will determine the amount and types of waste requiring disposal. While disposal in a licensed low-level radioactive waste (LLRW) disposal facility may be the preferable first choice, there are a limited number of such facilities and not all states have access to all licensed commercial disposal facilities. If there is a limited radiological incident with relatively small waste volumes, existing capacity is available and may be sufficient to address waste disposal. However, waste resulting from a large scale incident would likely overwhelm current disposal capacity. For large waste volumes, supplements to existing commercial radioactive waste disposal facilities would need to be considered, such as a combination of hazardous waste landfills, solid waste landfills, DOE disposal facilities and potentially, the construction of a new disposal facility. Organizational and administrative issues related to federal and state government coordination and preparation are also important.

Discussions of waste disposal options often involve comparisons of estimated waste generation and available disposal capacity. The amount of waste generated is related to the cleanup approach, as the selected approach to decontamination and remediation, as well as the long-term cleanup goals, can affect the volume of waste actually requiring disposal. The projected amounts of wastes for a large scale radiological incident may range from tens to hundreds of million cubic feet (or several million metric tons). Some of the waste may contain high radioactivity, especially at the incident's origin; however, most of the waste is expected to be only slightly contaminated, though in large quantities. The volume of contaminated soil in Japan resulting from the Fukushima incident is estimated to exceed one billion cubic feet.

As a point of comparison, roughly 28 million cubic feet of LLRW were disposed of at licensed commercial disposal facilities during the period 2002-2011. DOE disposed of approximately twice that volume in commercial facilities during the same period, in which it was involved in significant large-scale site cleanups.[29]Thus, over that ten-year period, an average annual volume of less than ten million cubic feet was disposed of in commercial facilities. Volumes from the non-governmental sector are not expected to increase significantly until the current fleet of NPPs is decommissioned. DOE generated additional waste volumes that were disposed of at DOE sites. For example, from 2000-2010, DOE disposed of approximately 20 million cubic feet of LLRW at the Nevada National Security Site (NNSS, formerly the Nevada Test Site). As it continues site cleanups, DOE projects generation of approximately 150 million cubic feet of LLRW for the period 2010-2015, most of which will be disposed at the site of origin or other designated DOE sites.

Managing the large volumes of waste resulting from a wide-scale radiological incident, such as with the Fukushima accident, would likely overwhelm existing capacity in the U.S. and thus require an overall strategy employing all available types of disposal facilities and integrating federal, state, local and private sector assets. For example, consider the following—

- At the beginning of 2016, more than 150 million cubic feet of capacity was licensed at commercial disposal facilities. An incident could consume all remaining licensed commercial LLRW disposal capacity, which would affect waste generators in the energy, industrial, research and medical sectors for whom the capacity was originally licensed. While there may be remaining property at the facilities that could be developed, there is no guarantee that additional capacity can be licensed or that states will allow all capacity to be consumed.
- Estimated waste volumes are comparable to projected generation from the entire DOE complex over the next several years, which include large-scale cleanups. While DOE is somewhat less constrained

[29] Information on disposal in commercial disposal facilities provided by the Manifest Information Management System (MIMS), operated by the DOE at http://mims.apps.em.doe.gov/.

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than non-DOE disposal sites in adding additional disposal capacity at its sites, displacement of projected DOE disposal with incident-related waste has the potential to interfere with ongoing cleanup activities, leading to extended on-site storage, slower cleanups and controversial efforts to expand disposal capacity at other DOE sites. Further, there is at present no mechanism to provide access to DOE disposal sites for disposal of incident-related waste.

1.20.2 Integrated Disposal Options

An effective response to a large-scale radiological incident will involve consideration of the entire range of potential disposal options. The precise mix of disposal options employed will depend on the nature of the specific incident (e.g., location, waste volumes). The process selected to plan and conduct the long-term decontamination and remediation should identify and make provisions for using the different available disposal options. In order to provide cleanup managers the use of all potential disposal capacity there are some issues that would need to be addressed, such as waste acceptance criteria for waste sites that have not been evaluated for radioactive material disposal. However, based on an understanding of the types of waste involved and the capabilities of existing disposal facilities, a generalized discussion of the attributes of the different disposal options, with qualifiers, can be developed and are discussed below.

- Licensed Commercial LLRW Disposal Facilities—
  - Can manage most anticipated waste types within license conditions.
  - Highest degree of public acceptance.
  - Significant bulk disposal volume possible.
  - Access restrictions may require special approval for waste from certain states.
  - Management of mixed radioactive and hazardous waste will need to ensure proper disposal and long-term groundwater monitoring.
- Solid and Hazardous Waste Landfills—
  - May offer local disposal option for expected large volumes with limited contamination.
  - May offer a disposal option at hazardous waste landfills for mixed wastes (mixtures of hazardous and radiological wastes); hazardous waste landfills have specified construction and engineering requirements.
  - Need to consider the location of the units in proximity to large or sensitive populations, sensitive ecosystems, and sole source aquifers.
  - May require design modifications to ensure that the waste can be managed protectively over time.
  - Difficulty in obtaining public acceptance, although some hazardous waste landfills have accepted waste with limited radionuclide content with state approval.
  - Requires additional demonstration of suitability to ensure protectiveness for radiological material (e.g., groundwater monitoring, additional engineering controls); many solid waste landfills have not been evaluated for disposal of radioactive material and may not be suitable for radiological material.
  - May require longer-term/special monitoring, as well as institutional controls.
- DOE Disposal Sites—
  - Could potentially handle higher-activity waste if insufficient commercial access/capacity.
  - May be suitable for some problematic waste types (e.g., whole vehicles).
  - DOE disposal facilities generally accept only DOE-owned or DOE-generated waste. Disposal of non-DOE waste requires additional review and agreements involving the host state, consistent with DOE's authorities particularly where existing agreements limit DOE's waste disposal activities.

Each of these potential disposal alternatives is discussed in more detail below. There may also be some remaining wastes that might require special consideration based on factors such as level of contamination, waste form, lack of access or capacity or presence of other hazardous or toxic contaminants. These wastes

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could include those containing both hazardous and toxic constituents (e.g., mercury and PCBs), animal carcasses or contaminated vehicles (where dismantling the vehicle may represent a greater potential for dispersal of contaminants and exposure of workers).

1.20.2.1 Commercially Licensed LLRW Disposal Facilities

Given that the bulk of the waste resulting from the release of radionuclides from a nuclear facility or a deliberate action will contain radionuclides commonly contained in LLRW, licensed commercial disposal facilities would be the most appropriate and publicly acceptable option for disposal if the volumes of waste from the incident were relatively small. It would be anticipated that the waste would be mostly at the lower end of radionuclide concentrations. Thus, these facilities will be capable of handling all but the most problematic waste types, if the amounts were limited. At present, all commercial LLRW disposal facilities are licensed by states (through agreements with NRC, referred to as "Agreement States").

As described earlier, available capacity and access are significant concerns in relying on commercial LLRW disposal facilities. Further, even if a facility would be generally available to all waste generators and it is found that all but a small portion of the waste would meet that facility's disposal criteria, it is possible that there may be objections to accepting all waste from an incident outside the state, even if the facility's capacity was sufficient.

Access to other facilities generally unavailable to the state(s) affected by the incident might be feasible in an emergency situation under NRC regulations, but it should not be expected that large volumes of waste will be accepted under these provisions. There is also the possibility that the affected state could construct a disposal facility to provide additional capacity. Several states conducted extensive studies of their geology in anticipation of constructing disposal facilities and these studies may be of use in such situations.

1.20.2.2 Solid and hazardous waste landfills

Most states are authorized by the EPA under the Resource Conservation and Recovery Act (RCRA) to operate their own hazardous waste management programs in lieu of the federal Subtitle C program.[30] Management of nonhazardous solid wastes is governed by RCRA Subtitle D, which is administered largely by the states. Compared to the number of licensed LLRW disposal facilities in the U.S., there are a greater number of commercial landfills operating under Subtitle C and many more operating under Subtitle D of RCRA for disposal of hazardous and solid wastes, respectively. It would not be expected that all of these facilities (particularly those operating under Subtitle D) would be appropriate disposal options. However, some of the hazardous waste landfills have accepted some radioactive material for disposal and a few have received the necessary state approvals to do so on a routine basis. Historically, most of the radiological waste streams accepted by hazardous waste landfills contain naturally-occurring radionuclides not regulated by NRC, such as wastes from the oil and gas or other resource extraction industries, as well as water treatment residuals. However, both NRC and DOE, in coordination with state regulators and facility operators have approved disposal of radioactive waste in RCRA landfills on a case-by-case basis. Thus, there is reason to believe that one or more hazardous waste landfills could contribute to the disposal capacity for incident-related waste. The use of any particular RCRA facility for the disposal of radioactive contaminants or mixed contamination would require that the unit is well designed and managed appropriately. The uniform design and engineering requirements applicable to hazardous waste landfills would facilitate such an evaluation; by contrast, not all solid waste landfills are constructed to the same specifications. Further, the evaluation would include consideration of the waste characteristics, site characteristics, waste acceptance criteria and other facility attributes.

RCRA hazardous and solid waste landfills may also offer the advantage of disposal capacity suitable for

[30] Alaska, Iowa, Puerto Rico, the Virgin Islands, American Samoa and the Trust Territories and Northern Marianas Islands do not have authorized RCRA programs.

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large volumes of lightly-contaminated material (e.g., soil)[31]. In addition, these facilities are more likely to be located near the incident location, which can facilitate their use if deemed appropriate by federal, state and local officials. However, use of these facilities for disposal of radionuclides typically found in low-level radioactive waste, even if it contains very low concentrations of those radionuclides, may generate public concern if the facilities have not been previously approved for this type of disposal. Therefore, additional effort by state and local officials would be necessary to ensure the facility can manage the waste in a protective manner, including technical modification, if appropriate.

1.20.2.3 DOE Disposal Sites

DOE facilities could potentially be a disposal alternative that may be most appropriate for limited volumes of waste for which there is no other disposal outlet (such as high-activity waste, certain mixed wastes, or other problematic waste streams). Waste disposed at DOE sites must meet the waste acceptance criteria for those sites. DOE does not generally accept non-DOE-owned or generated waste for disposal at its sites. In addition, ~~DOE has significant ongoing reme~~diation at a number of sites that will generate large volumes of waste over the coming years. Diverting DOE disposal capacity to incident-related waste may interfere with those efforts. DOE has also utilized commercial low-level radioactive disposal, primarily for bulk waste streams from cleanups and this potential disposal alternative may also be affected by a wide-scale incident.

DOE's primary disposal site serving the DOE complex is the NNSS. DOE/NNSS continues to excavate additional disposal capacity as needed and estimates that significant additional capacity could be developed at NNSS.

DOE's other designated site for complex-wide disposal is Hanford, WA; however, DOE has an agreement with the State of Washington that it will not bring waste from other sites until certain remediation milestones have been met. Overall, DOE anticipates that most of its waste generated in the coming years will be disposed at the site of generation. Sites other than NNSS and Hanford are designated for disposal of waste generated at those sites, although exceptional situations may allow for disposal of waste generated off-site and development of some additional disposal capacity. Additional disposal capacity would likely be dependent upon agreement from the state in which the facility is located.

1.20.3 Planning and Coordination among Federal and State Entities

A number of federal and state agencies may have important roles to play in making decisions on final disposal, depending on the extent of the waste. A framework for coordination with these various federal and state agencies should be an element of the process selected for long-term decontamination and remediation.

States ~~must~~ should be intimately involved ahead of time in planning for a large-scale radiological incident and the resulting waste disposal. The following roles and responsibilities may exist with states—

- All existing commercial LLRW disposal facilities are licensed by Agreement States.
- Many, but not all, states have formed regional compacts (as authorized by Congress) to site and operate LLRW disposal facilities; compacts control access to these sites.
- Although statutorily required[32] to provide disposal capacity for low-level waste generated within the compact boundaries (with certain exceptions), states are under no obligation to accept waste from outside their compacts. States that are not members of compacts do not have the statutory protection to

[31] EPA reports that about 132 million tons of municipal solid waste were landfilled in 2009, comparable to the rate over the past two decades. The 2009 figure represents about 54% of total generation. "Municipal Solid Waste in the United States: 2009 Facts and Figures," EPA530-R-10-012, December 2010.

[32] Pursuant to the Low-Level Radioactive Waste Policy Act of 1980 (LLRWPA) and the 1985 LLRWP Amendments Act of 1985.

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prohibit disposal of out-of-compact waste.

- All DOE disposal sites are located within states, many of which have agreements regarding the extent of long-term disposal or acceptance of off-site waste; states hosting DOE disposal sites should participate in planning for the potential disposal of incident-related off-site waste at DOE sites.
- States regulate hazardous waste (when authorized by EPA) and solid waste landfills that may be used for disposal of waste with very low concentrations of radioactivity; in planning for disposal of incident-related waste, states should take into account any restrictions placed on the disposal of radionuclides in these facilities.
- It is anticipated that on-site disposal at a location affected by the incident, where appropriate, will be one location of choice and that an affected state could approve construction of a new disposal facility for that purpose.

Depending on the circumstances, coordination with numerous federal agencies would be necessary. Of particular note:

- EPA is the coordinating agency for long-term remediation and cleanup, as designated by the National Response Framework (FEMA 2008a) and has federal authority for hazardous waste disposal;
- DOE is "owner" of federal sites that might be used for waste disposal;
- NRC is the federal authority for commercial LLRW disposal; and
- USDA provides technical assistance for agricultural materials contaminated by the release, including animal carcasses.

1.20.4 Other Potential Options and Considerations

Potential federal actions to increase preparedness include:

- Develop criteria under which access to DOE disposal sites is acceptable and identify issues to be resolved.
- Facilitate agreements among regional LLRW compacts and states to address situations in which access to compact sites can be assured for all states.
- Identify geographically strategic federal sites that can be used for staging and interim storage of large waste volumes.
- Identify federal sites that can be characterized in advance for construction of disposal capacity for incident-related waste, should the need arise.
- Clarify federal authorities that can be used in exceptional circumstances for acquisition of property for use as disposal or long-term storage capacity and indemnification of private sector service providers.
- Assist state and local officials in planning for and making decisions to use local disposal options (solid and hazardous waste landfills) for waste that contains relatively low concentrations of radionuclides, including:
  - developing criteria for case-by-case alternate disposal evaluations, such as those employed by NRC, EPA and DOE for limited volumes of waste;
  - establishing generally applicable criteria for disposal of radionuclides in solid and hazardous waste landfills;
  - supporting federal research into behavior of radionuclides and decontamination residuals in solid and hazardous waste landfills;
  - providing technical assistance and streamlined regulatory review (e.g., permitting) for states to evaluate existing sites and identify new sites for incident-related waste disposal capacity; and
  - developing and disseminating tools to support planning and decision-making regarding incident-related waste management.

It may be appropriate for the federal government to develop detailed guidance to address factors such as waste acceptance criteria needed for waste disposal at RCRA disposal facilities, safety evaluation of existing disposal facilities, or siting, development and regulatory approval of new disposal facilities.

Depending on the circumstances, it may be appropriate to create additional disposal capacity. This decision would most likely need to involve extensive discussion between the federal government and the affected state(s) where an incident occurred. Generally, there are two options for additional disposal capacity—

- **On-site disposal.** As a result of looking at the different choices, it may be advantageous to develop disposal capacity on-site (e.g., build a large disposal facility within the property boundaries where the facility causing the release is located), if the site is suitable.
- **Off-site disposal.** An additional option would be for a state or the federal government to build a disposal site on suitable public lands. The federal or state government could use the power of eminent domain to condemn property contaminated by a radiological incident and use it for waste disposal.

If it is determined that constructing a new disposal facility is the appropriate action, the proposed site(s) should be studied for suitability. Although the contemplated disposal actions would be taken in event of a national emergency, every effort should be made to ensure the protection of public health and the environment. Appropriate regulatory standards should be considered in developing a specific disposal plan. The disposal path and site suitability ~~must~~ should take into account the radiological characteristics of the waste. As discussed above, some slightly radioactive materials are disposed in hazardous waste landfills if they are permitted for it. More radioactive materials are sent to sites licensed as LLRW disposal sites, though less contaminated materials are also sent to LLRW disposal sites. A small amount of waste from a radiological incident may have concentrated radioactivity, but most of the waste generated in a large scale radiological incident would likely be contaminated with low levels of radioactivity. The different radiological characteristics of the waste would have a bearing on the stringency of containment required of a waste disposal facility. All waste sites would need to have appropriate controls to protect public health and the environment for any level of radioactive contamination, but more highly radioactive materials would need more robust controls than slightly contaminated material.

The physical/geographic characteristics of the site and the availability of land will be important in determining the appropriateness of a potential disposal site. Sites with limited rainfall, high evapotranspiration, deep water tables and soil characteristics that limit migration of radionuclides have been found to be best suited to disposal of radioactive waste, although waste management and engineering can be applied to improve performance at sites with less favorable characteristics (e.g., controls on the waste form or level of allowable radioactivity, addition of liners, cover requirements or through construction of concrete bunkers or vaults). Other characteristics, such as location in a high risk area (e.g., flood plain or seismic zone) or sensitive ecologic area, should also be considered. A disposal cell for 1 million cubic feet of waste will occupy 1 acre or more of surface area, assuming disposal to a depth of about 30 feet. Large-scale disposal operations may also require extensive surface facilities.

Additional considerations can also be applied to make finer distinctions among potentially suitable sites. These criteria include:

- Proximity to the incident: it may be useful to consider sites in different regions of the country to limit transportation demands;
- Proximity to residential areas or commercial districts: the potential for disposal activities to affect nearby populations or commercial activities, whether located within the site boundaries or on adjacent property, should be considered;
- Proximity to transportation: access to timely and direct transportation that can accommodate large shipments is desirable—action to facilitate: construction of transportation infrastructure (e.g., direct

rail lines);

- Experience in waste disposal: waste disposal sites will have infrastructure, procedures and trained personnel that can make most efficient use of the site—action to facilitate: development of infrastructure, training, construction of disposal cells and engineered containment (e.g., vaults or bunkers); and
- Level of existing contamination: areas that are unlikely to be remediated in the near future or unlikely to be released for public use may be more acceptable for disposal.

1.20.5 Potential Federal Actions to Develop New Disposal Capacity

In addition to criteria for siting new disposal facilities, the federal government has control of a large amount of land throughout the U.S. that could be repurposed, or could offer assistance to support state governments in developing new facilities.

1.20.5.1 DOE Sites

DOE has decades of experience in radioactive waste management. In considering the primary selection criteria described above, DOE sites in the western U.S. generally have more favorable characteristics and readily available property compared to those in the eastern U.S. However, DOE has successfully implemented disposal at the eastern sites, often with some engineering enhancements. DOE has several categories of sites for consideration, beginning with the most suitable—

- Active disposal or cleanup sites in the western U.S.
- Active disposal or cleanup sites in the eastern U.S.
- Closed sites with disposal areas.
- Closed uranium milling sites.
- Other long-term stewardship sites.

Considerations: Some DOE sites have agreements with states or other stakeholders regarding further disposal or cleanup activities. Current disposal sites have waste acceptance criteria by DOE policy or statute. Closed and long-term stewardship sites may not have large amounts of additional property available for disposal.

1.20.5.2 DoD Installations

DoD maintains some installations with large land areas, primarily in the western U.S. Many of these sites have been contaminated through extensive training or other activities. DoD likely has more sites in the eastern U.S. than does DOE. Categories of sites that could be considered suitable include:

- Bombing and firing ranges;
- Chemical weapons demilitarization and storage sites;
- Ammunition plants and arsenals; and
- Surplus properties (e.g., BRAC – base realignment and closure, FUDS – formerly used defense site).

Considerations: Section 2692 of title 10, United States Code, "Storage, Treatment and Disposal of NonDefense Toxic and Hazardous Materials," generally provides that the Secretary of Defense may not permit the use of an installation of the DoD for the storage, treatment, or disposal of any material that is a toxic or hazardous material and that is not owned either by the DoD or by a member of the armed forces (or by a dependent of the member) assigned to or provided military housing on the installation. Radiological waste resulting from either a nuclear accident or a terrorist attack may fall under this prohibition. The Secretary of Defense may grant exceptions to this restriction when "essential to protect the health and safety of the public from imminent danger." A determination whether or not radiological waste meets the "imminent danger" threshold would be required.

Additionally, some DoD properties, including ranges in the western U.S., are on "withdrawn" lands, which are part of the public domain supervised by the Bureau of Land Management (BLM). Withdrawn land statutes permit DoD to use the property for specific military mission needs. The use of withdrawn lands to manage radiological waste would violate those statutes.

1.20.5.3 Other Federal Properties

Agencies such as the Department of Interior or USDA own large properties that could be considered suitable for disposal, many of which are in the western U.S. These properties may be administered by discrete entities within the cabinet-level departments, such as the National Park Service (NPS), BLM, or Forest Service. Some properties may be in proximity to DOE or DoD lands.

Considerations: Properties may be designated for protection or public use (e.g., wilderness areas or preserves). Many properties are also in rugged terrain with difficult access or border tribal lands.

KEY POINTS IN CHAPTER 5 – LATE PHASE

- PAGs will not be used to guide restoration and recovery of areas impacted by a radiological incident; rather, planning activities should include developing a process to involve stakeholders in setting priorities and determining actions. Such a process should be flexible enough to adapt to a variety of situations.
- Planning considerations for worst case scenarios are provided. Smaller radiological incidents may be well addressed by existing emergency response and environmental cleanup programs at local, state, tribal and federal levels.
- Reoccupying households and businesses should be considered in balance with progress made in reducing radiation risks through decontamination, radioactive decay and managing contaminated waste.
- Exposure limits in a range of one in a population of ten thousand (10^{-4}) to one in a population of one million (10^{-6}) excess lifetime cancer incidence outcomes are generally considered protective, though this may not be achievable after a large radiological incident. In making decisions about cleanup goals and strategies for a particular event, decision makers must balance the desired level of exposure reduction with the extent of the measures that would be necessary to achieve it, in order to maximize overall human welfare.
- Incidents that create large volumes of waste from a wide-scale radiological incident would likely overwhelm existing radioactive waste disposal capacity in the U.S.
- Following a nuclear accident, the states bear primary responsibility to identify and provide waste management options, including disposal capacity; in the event of a terrorist attack, the federal government can offer a range of assistance to state governments to identify and implement waste management options.
- Safely managing and disposing of radioactive waste will require pre-planning at all levels of government and careful coordination with stakeholders at all stages of the decision-making process.

APPENDIX A – REFERENCES

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APPENDIX B – GLOSSARY

Acute health effects: health problems caused by high radiation doses received in a short period of time. Examples of acute effects include erythema (reddening of skin), blistering, epilation (hair loss) and vomiting.

ALARA: acronym for "as low as ~~is~~ reasonably achievable" means making every reasonable effort to maintain exposures to radiation as far below the dose limits in this part as is practical consistent with the purpose for which the activity is undertaken.

Alpha radiation: alpha radiation comes from the ejection of alpha particles from the nuclei of some unstable atoms. An alpha particle is identical to a helium nucleus and consists of two protons and two neutrons. Alpha particles are highly energetic, but can only travel a few centimeters in air. They have low penetrating power and can be stopped by a sheet of paper. Alpha particles generally cannot even penetrate the layer of dead cells on the skin, but can pose a health risk when inhaled or ingested.

Avoided dose: The radiation dose saved by implementing a protective action. (ICRP 1991b)

Beta radiation: beta radiation comes from the emission of beta particles during radioactive decay. Beta particles are highly energetic and fast-moving. They carry a positive or negative charge and can be stopped by a layer of clothing or few millimeters of a solid material. Beta particles can penetrate the skin and cause skin burns, but tissue damage is limited by their small size. Beta particles are most hazardous when inhaled or ingested.

Cloudshine: Gamma radiation emitted from an airborne plume overhead.

Committed effective dose: The sum of the committed equivalent doses following intake (inhalation or ingestion) of a radionuclide to each organ multiplied by a tissue weighting factor.

Contamination: Radionuclides on surface or in the environment as a result of an accidental release.

Concentration: Radionuclide activity per unit of mass.

cGy: Centigray (measurement unit)

Chronic effects: Health problems caused by radiation doses delivered over a long period. Examples of chronic effects include cancer and genetic mutations.

Derived Intervention Level (DIL): Concentration derived from the intervention level of dose at which introduction of protective measures should be considered. (FDA 1998)

Derived Response Level (DRL): A level of radioactivity in an environmental medium that would be expected to produce a dose equal to its corresponding Protective Action Guide.

Dose: The amount of radiation exposure a person has received, calculated considering the effectiveness of the radiation type (alpha, beta, gamma), the timeframe of the exposure and the sensitivity of the person or individual organs.

Dose ~~conversion factor~~ parameter ~~(DCF)~~ (DP): Any factor that is used to change an environmental measurement to dose in the units of concern.

Dose projection: A calculated future dose that an individual might receive; also the process of making these calculations.

Dose reduction factor: A factor by which a decontamination technique or protective action reduces the

radiation dose to a person.

Dosimetry: The system for assessing radiation doses from external radiation exposures and from intakes of radionuclides using biokinetic models and dosimetric quantities developed by the ICRP and the International Commission on Radiation Units and Measurements (ICRU).

Early phase: The beginning of a radiological incident for which immediate decisions for effective use of protective actions are required and must therefore be based primarily on the status of the radiological incident and the prognosis for worsening conditions. This phase may last from hours to days.

Effective dose: The sum of organ equivalent doses weighted by ICRP organ weighting factors.

Emergency Planning Zone: A designated zone around a commercial nuclear power plant for which radiological response plans must be maintained under Nuclear Regulatory Commission regulations.

Emergency Worker – Anyone with a role in responding to the incident whether a radiation worker previously or not, who should be protected from radiation exposure.

Evacuation: The urgent removal of people from an area to avoid or reduce high-level, short-term exposure, from the plume or from deposited activity. Evacuation may be a preemptive action taken in response to a facility condition rather than an actual release.

Gamma radiation: Gamma radiation comes from the emission of high-energy, weightless, chargeless photons during radioactive decay. Gamma photons are pure electromagnetic energy and highly penetrating--several inches of lead or a few feet of concrete may be required to attenuate them. External exposure to gamma rays poses a health threat to the entire body. Inhalation and ingestion of gamma emitters also poses a health threat.

Graves' disease: An autoimmune disorder that leads to the over activity of the thyroid.

Groundshine: Gamma radiation emitted from radioactive materials deposited on the ground.

Gy: Grey (measurement unit).

Half-life: The time required for the half the atoms of a given radioisotope to transform by radioactive decay.

Hashimoto's thyroiditis: An autoimmune disorder that leads to underactive thyroid with bouts of over activity.

Intermediate phase: The period beginning after the source and releases have been brought under control (has not necessarily stopped but is no longer growing) and reliable environmental measurements are available for use as a basis for decisions on protective actions and extending until these additional protective actions are no longer needed. This phase may overlap the early phase and late phase and may last from weeks to months.

Isodose-rate line: A contour line that is used to connect points of equal radiation dose rates.

Late phase: The period beginning when recovery actions designed to reduce radiation levels.

Latency period, cancer: The time elapsed between radiation exposure and the onset of cancer.

Microsievert: One ten-thousandth of a rem. See Rem.

Millirem: One thousandth of a rem. See Rem.

Millisievert: One thousandth of a Sievert. See Sievert.

Noble gases: A group of elemental gases that are tasteless, odorless and that do not undergo chemical reactions under natural conditions. The noble gases consist of Helium (He), Neon (Ne), Argon (Ar), Krypton (Kr), Xenon (Xe), and Radon (Rn).

Off-site: Areas outside the controlled border of a facility, such as a nuclear power plant. For an incident not involving a facility, this term may also be used to refer to areas impacted by contamination.

On-site: areas inside the controlled border of a facility, such as a nuclear power plant. For an incident not involving a facility, this term may refer to areas controlled during a response.

Potassium iodide: A salt of stable, nonradioactive iodine in medicine form. The administration of potassium iodine saturates the thyroid with non-radioactive iodine, so it does not absorb radioactive iodine released into the environment from a radiological incident.

Projected dose: The prediction of the dose that a population or individual could receive.

Protective actions: An activity conducted in response to an incident or potential incident to avoid or reduce radiation dose to members of the public.

Protective Action Guide (PAG): The projected dose to an individual, resulting from a radiological incident at which a specific protective action to reduce or avoid that dose is warranted.

Prophylactic: A treatment or medication designed to prevent exposure to radiation.

Rad (radiation absorbed dose): A basic unit of absorbed radiation dose. It is being replaced by the 'gray,' which is equivalent to 100 rad. One rad equals the dose delivered to an object of 100 ergs of energy, per gram of material.

Radioactive: Quality of a material that emits alpha particles, beta particles, gamma rays, or neutrons.

Radiological dispersion device (RDD): A device or mechanism that is intended to spread radioactive material from the detonation of conventional explosives or other means. An RDD is commonly known as a "dirty bomb."

Radiopharmaceutical: A radioactive chemical used for diagnosis, cure, treatment, or prevention of diseases.

Recovery: The phase after response when efforts focus on remediation, or the process of reducing radiation exposure rates and concentrations of radioactive material in the environment to levels acceptable for unconditional occupancy or use.

Reentry: Workers or members of the public going into relocation or radiological contaminated areas on a temporary basis under controlled conditions.

Release: Uncontrolled distribution of radioactive material to the environment.

Relocation: The removal or continued exclusion of people (households) from contaminated areas to avoid chronic radiation exposure. Not to be confused with *evacuation*.

Reoccupancy: The return of households and communities to relocation areas during the cleanup process, at radiation levels acceptable to the community.

Rem (roentgen equivalent man): The product of the absorbed dose in rads and a weighting factor which

accounts for the effectiveness of the radiation to cause biological damage; a conventional unit for equivalent dose. One rem equals 0.01 Sv.

Release rate: The measure of the amount of radioactive dispersed per unit of time.

Return: Permanent resettlement in evacuation or relocation areas with no restrictions, based on acceptable environmental and public health conditions.

Shelter in place: the action of staying or going indoors immediately.

Sievert (Sv): International unit of equivalent dose.

Source term: The amount of a contaminant available in a scenario or actually released to the environment.

Total Effective Dose (TED): The sum of the effective dose (for external exposures) and the committed effective dose; also referred to in this Manual as whole body dose. See Section 2.4.

Yield-producing improvised nuclear device: A crude weapon fabricated from diverted fissile material that produces a nuclear explosion.

APPENDIX C – LIST OF ACRONYMS

AEA	Atomic Energy Act
ALARA	As Low as Reasonably Achievable
BLM	Bureau of Land Management
CDC	Centers for Disease Control and Prevention
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
cGy	Centigray (measurement unit)
CWS	Community Water System
DC	Dose Coefficient
DHS	Department of Homeland Security
DIL	Derived Intervention Levels
DoD	Department of Defense
DOE	Department of Energy
DOL	Department of Labor
DP	Dose Parameter
DRL	Derived Response Level
EAL	Emergency Action Level
EPA	Environmental Protection Agency
EPZ	Emergency Planning Zone
FDA	Food and Drug Administration
FEMA	Federal Emergency Management Agency
FRC	Federal Radiation Council
FRMAC	Federal Radiological Monitoring and Assessment Center
FRPCC	Federal Radiological Preparedness Coordination Committee
FUDS	Formerly Used Defense Site
Gy	Gray (measurement unit)
HAZWOPER	Hazardous Waste Operations and Emergency Response
HHS	Department of Health and Human Services
HPS	Health Physics Society
IAEA	International Atomic Energy Agency
ICP	Incident Command Post
ICRP	International Commission on Radiological Protection
~~ICRU~~	~~Only used in glossary above~~
IC/UC	Incident Command/Unified Command
IND	Improvised Nuclear Device
~~JFO~~	~~Joint Field Office~~
JIC	Joint Information Center
KI	Potassium Iodide
LLRW	Low-level radioactive waste
LLRWPA	Low-Level Radioactive Waste Policy Act
MCL	Maximum Contaminant Level
mSv	Millisievert (measurement unit)
mrem	Millirem (measurement unit)
NCP	National Contingency Plan
NCRP	National Council on Radiation Protection and Measurements
NIMS	National Incident Management System
NNPP	Naval Nuclear Propulsion Program

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NNSS	Nevada National Security Site
NPDWR	National Primary Drinking Water Regulations
NPP	Nuclear Power Plant
NRC	Nuclear Regulatory Commission
NRF	National Response Framework
NDRF	National Disaster Recovery Framework
NSS	National Security Staff
NUREG	NRC technical report designation (Nuclear Regulatory Commission)
OSHA	Occupational Safety and Health Administration
PAG	Protective Action Guide
PIO	Public Information Officer
PPE	Personal Protective Equipment
RASCAL	Radiological Assessment System for Consequence Analysis
REMM	Radiation Emergency Medical Management
RESRAD	RESidual RADioactivity (computer code developed by Argonne National Laboratory)
RCRA	Resource Conservation and Recovery Act
RDD	Radiological Dispersal Device
SDWA	Safe Drinking Water Act
SNL	Sandia National Laboratories
TED	Total Effective Dose
USDA	United States Department of Agriculture

ED_001057_00012426

To: Perrin, Alan[Perrin.Alan@epa.gov]
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Sent: Wed 2/24/2016 9:26:09 PM
Subject: Please print me
PAG Manual draft Final 2-24-2016.docx

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http://www.epa.gov/radiation/rert/pags.html

202-343-9108

Room 1416 B in WJC West

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Subject: PAG Manual FR Notice with 'what we heard'
PAG Manual Finalized FR Notice 2-24-2016.docx

Here is an updated draft FR Notice, that includes edits from Alan and a version of "What We Heard" from the public comments – just FYI.

Sara D. DeCair

http://www.epa.gov/radiation/rert/pags.html

202-343-9108

Room 1416 B in WJC West

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ENVIRONMENTAL PROTECTION AGENCY

[EPA-HQ-OAR-2008-0268; FRL-9707-2]

Final revision to Protective Action Guides Manual: Protective Action Guides (PAGs) and Planning Guidance for Radiological Incidents

AGENCY: Environmental Protection Agency (EPA).

ACTION: Notice of document availability.

SUMMARY: As part of its mission to protect human health and the environment, the U.S. Environmental Protection Agency (EPA) publishes protective action guides to help federal, state, local and tribal emergency response officials make radiation protection decisions during emergencies. EPA, in coordination with a multi-agency working group within the Federal Radiological Preparedness Coordinating Committee (FRPCC), has finalized updates to the 1992 Manual of Protective Action Guides and Protective Actions for Nuclear Incidents, referred to as "The 1992 PAG Manual" (EPA 400-R-92-001, May 1992).

The updated guidance in this revised PAG Manual – Protective Action Guides and Planning Guidance for Radiological Incidents ("PAG Manual" hereafter) applies the PAGs to incidents other than just nuclear power plant accidents, updates the radiation dosimetry and dose calculations based on current science and incorporates late phase guidance. The final revisions incorporate input from public comments received in 2013 and include clarifications based on those comments. {{We have to talk about water here, whether it is in or not}} The final revision is available at www.regulations.gov.

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DATES: While the PAG Manual is only guidance, most organizations that use the PAGs in their emergency management plans will be expected to have incorporated this updated guidance within twelve months of this announcement.

FOR FURTHER INFORMATION CONTACT: Sara DeCair, Radiation Protection Division, Center for Radiological Emergency Management, Mail Code 6608T, U.S. Environmental Protection Agency, 1200 Pennsylvania Avenue NW, Washington, DC 20460; telephone number: (202) 343-9108 ; fax number: (202) 343-2304; E-mail: *decair.sara@epa.gov*.

SUPPLEMENTARY INFORMATION:

A. How can I get copies of the PAG Manual and supporting information?

Docket: All documents in the docket are listed in the www.regulations.gov index. Although listed in the index, some information is not publicly available, e.g., CBI or other information whose disclosure is restricted by statute. Certain other material, such as copyrighted material, will be publicly available only in hard copy. The EPA has established a docket for this action under Docket ID No. [EPA-HQ-OAR-2008-0268; FRL-9707-2]. Publicly available docket materials are available either electronically through www.regulations.gov or in hard copy at the Air and Radiation Docket in the EPA Docket Center, (EPA/DC) EPA West, Room 3334, 1301 Constitution Ave., NW, Washington, DC 20004. The EPA Docket Center Public Reading Room is open from 8:30 a.m. to 4:30 p.m., Monday through Friday, excluding legal holidays. The telephone number for the Public Reading Room is (202) 566-1744 and the telephone number for the Air and Radiation Docket is (202) 566-1742. In accordance with EPA's regulations at 40 CFR Part 2 and in accordance with normal EPA docket procedures, if copies of any docket materials are requested, a reasonable fee may be charged for photocopying.

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Electronic access: The PAG Manual in electronic form suitable for printing as well as related guidelines and further information can be found on the PAGs web page, at http://www.epa.gov/radiation/protective-action-guides-pags

B. What authority does the EPA have to provide Protective Action Guidance?

The historical and legal basis of EPA's role in the PAG Manual begins with Reorganization Plan No. 3 of 1970, in which the Administrator of the EPA assumed functions of the Federal Radiation Council (FRC), including the charge to "…advise the President with respect to radiation matters, directly or indirectly affecting health, including guidance for all federal agencies in the formulation of radiation standards and in the establishment and execution of programs of cooperation with states." (Reorg. Plan No. 3 of 1970, sec. 2(a) (7), 6(a) (2); § 274.h of the Atomic Energy Act of 1954, as amended (AEA), codified at 42 U.S.C. § 2021(h)). Recognizing this role, FEMA directed the EPA in their Radiological Emergency Planning and Preparedness Regulations to "establish Protective Action Guides (PAGs) for all aspects of radiological emergency planning in coordination with appropriate federal agencies." (44 CFR 351.22(a)). FEMA also tasked the EPA with preparing "guidance for state and local governments on implementing PAGs, including recommendations on protective actions which can be taken to mitigate the potential radiation dose to the population."(44 CFR 351.22(b)). All of this information was to "be presented in the Environmental Protection Agency (EPA) 'Manual of Protective Action Guides and Protective Actions for Nuclear Incidents.'"(44 CFR 351.22(b)).

Additionally, section 2021(h) charged the Administrator with performing "such other functions as the President may assign to him [or her] by Executive order." Executive Order 12656 states that the Administrator shall "[d]evelop, for national security emergencies, guidance

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on acceptable emergency levels of nuclear radiation…." (Executive Order No. 12656, sec.1601(2)). EPA's role in PAGs development was reaffirmed by the *National Response Framework, Nuclear/Radiological Incident Annex* of June 2008.

C. What is the PAG Manual: Protective Action Guides and Planning Guidance for Radiological Incidents?

The PAG Manual provides federal, state and local emergency management officials with guidance for responding to radiological emergencies. A protective action guide (PAG) is the projected dose to an individual from a release of radioactive material at which a specific protective action to reduce or avoid that dose is recommended. Emergency management officials use PAGs for making decisions regarding actions to protect the public from exposure to radiation during an emergency. Such actions include, but are not limited to, evacuation, shelter-in-place, temporary relocation, and food restrictions.

Development of the PAGs was based on the following essential principles, which also apply to the selection of any protective action during an incident—

- Prevent acute effects.
- Balance protection with other important factors and ensure that actions result in more benefit than harm.
- Reduce risk of chronic effects.

The PAG Manual is not a legally binding regulation or standard and does not supersede any environmental laws; PAGs are not intended to define "safe" or "unsafe" levels of exposure or contamination. This guidance does not address or impact site cleanups occurring under other

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statutory authorities such as the United States Environmental Protection Agency's (EPA) Superfund program, the Nuclear Regulatory Commission's (NRC) decommissioning program, or other federal or state cleanup programs. As indicated by the use of non-mandatory language such as "may," "should" and "can," the PAG Manual only provides recommendations and does not confer any legal rights or impose any legally binding requirements upon any member of the public, states, or any other federal agency. Rather, the PAG Manual recommends projected radiation doses at which specific actions may be warranted in order to reduce or avoid that dose. The PAG Manual is designed to provide flexibility to be more or less restrictive as deemed appropriate by decision makers based on the unique characteristics of the incident and the local situation.

D. What has changed since the 2013 draft revised PAG Manual?

The updates to the 1992 PAG Manual, published for public comment and interim use in 2013, were developed by a multi-agency Subcommittee of the Federal Radiological Preparedness Coordinating Committee (FRPCC) and are published by the EPA with concurrence from the Department of Energy (DOE); the Department of Defense (DoD); the Department of Homeland Security (DHS), including the Federal Emergency Management Agency (FEMA); the Nuclear Regulatory Commission; the Department of Health and Human Services (HHS), including both the Centers for Disease Control (CDC) and the Food and Drug Administration (FDA); the U.S. Department of Agriculture (USDA); and the Department of Labor (DOL).

We received 5,000 comments from members of the public, state and local emergency response and health organizations, industry associations, and from national and international radiation protection organizations. Based on questions raised in comments and issues identified

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about implementing the updated PAG Manual, significant changes we made include:

- Clarifying planning considerations related to the lower FDA KI (supplemental) PAG in combination with deleting the thyroid-based evacuation threshold
- Providing additional language on implementing the FRMAC tables of derived values
- Adding information from the appendices of the 1992 PAG Manual on how the PAG levels were set, in "Basis" sections
- {{placeholder for how we're addressing water}}
- Providing explanation about the removal of the Relocation PAG of 5 rem over 50 years to avoid confusion with long-term cleanup goals

E. What is being done to address concerns raised in the public comments?

The major themes we heard from commenters are grouped under these headings: (1) maintaining the strength of environmental regulations; (2) PAGs are higher than radiation protection standards; (3) concern about the need for PAGs; and (4) concern about the cleanup (remediation) process guidance.

Concern: *Many commenters expressed concern that the PAG Manual is a way to weaken environmental regulations.*

Environmental regulations or standards are legal limits designed to prevent health effects from everyday exposure to low levels of radiation over long periods. The PAG levels are emergency guidance and do not overturn or affect the stringency or enforcement of any standards or laws, or how they apply. The PAG levels are used only in an emergency when

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radiation levels have already exceeded environmental standards and could be high enough to cause health effects unless something is done. The PAG levels trigger public safety measures to minimize or avoid radiation exposure during an emergency.

Concern: The fact that the PAGs are higher than existing radiation protection regulations means that the EPA is allowing the public to get more radiation exposure.

• PAGs are guidance for use only in an emergency. Potential increased risk for cancer from radiation exposure at the PAG levels is approximately 0.12% or 12 additional cancers out of 10,000 people. If used early in an emergency, the PAG guidance could trigger safety actions to prevent the public from getting any additional exposure at all—they could be evacuated before the arrival of a radioactive plume. The PAG safety actions can be triggered by projected doses—officials do not have to wait for radiation measurements to order public safety measures if they have any reason to suspect that the radiation could approach the PAG levels. Actual exposures are likely to be much lower than projected doses, if protective actions are taken and especially if they're taken early. The whole point of protective actions is to avoid risks.

• The PAG Manual provides guidance for emergency situations only. No one is permitting a radiological accident or terrorist event. As long there are nuclear materials in the world, we have the responsibility to plan responses to protect the public from potential releases. The PAG Manual is emergency guidance, not a legal standard, and it does not set cleanup, or remediation, levels.

• The PAG Manual is a non-binding guidance document to help officials plan safety measures in the event of a radiological emergency. Standards are legally enforceable limits on radioactive emissions. The PAG Manual has no bearing on the interpretation, enforcement, or

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setting of standards. The PAG Manual was first issued in 1975, and has no effect on environmental regulations.

Concern: The PAG Manual is not necessary. You should just base your emergency responses on existing environmental standards instead of the higher PAG triggers.

• The PAGs are designed to prevent health effects by triggering public safety measures, such as evacuation. The PAG levels are higher than legal standards because they are based on the risk of health effects from radiation levels high enough to warrant having people evacuate or stay indoors for extended periods. The additional risk from a slight increase over legal limits is not worth the known risks of evacuation or sheltering in place, traffic accidents, trips and falls, anxiety from separation of family members, etc. The PAGs are set at a level where the health risk from radiation exposure outweighs the risk from the safety measures. Although higher than legal standards, the PAG levels are still highly protective, and the guidance in the PAG Manual is designed to minimize unnecessary exposure.

• Emergency preparedness starts with prevention, including radioactive materials regulation, nuclear facility siting and minimizing risks from industry. Preventing accidents by ensuring safety redundancies and by preparing local responders to take quick actions will save people from disasters. PAGs are focused on recommending the best prompt actions when bad things are happening.

Concern: The cleanup guidance in the PAG Manual allows too much radiation.

• The PAG Manual is non-binding guidance for emergency situations and does not set cleanup levels. Chapter 4 of the PAG Manual provides a list of considerations for planning and

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initiating a cleanup (remediation) process after the emergency is brought under control, but does not prescribe end goals. Remediation may take a long time and some safety measures may be necessary for years. For instance, some restrictions on use of certain areas may be in place for a long time.

• Where remediation doesn't achieve background levels, land use might have to be restricted. Superfund, for instance, balances reduced exposure with practical requirements of removing the contamination.

• Remediation levels will be decided by decision makers along with community members to balance the goals with their needs. Jobs, homes, social, practical and technical factors will inform the remediation goals. How long the remediation takes will directly impact people's ability to work and live in an area. This process can be sped up with additional funding, workers, equipment, technology and collaboration with local residents helping out.

F. What is the timeframe for implementation of this PAG Manual?

Emergency management and radiation protection organizations that use the PAGs in their emergency plans will be expected to have incorporated this updated guidance within twelve months of this announcement. During this time, training, plans, and procedures can be updated. By agreement with the Federal Emergency Management Agency, evaluation of offsite response organizations around nuclear power facilities based on the new PAG Manual will begin twelve months after the date of this Notice. Outreach and technical training will be conducted by the EPA, the FRMAC and interagency partners of the PAG Subcommittee.

For further information and related guidelines, see the PAGs web page: http://www.epa.gov/radiation/protective-action-guides-pags

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_____

Dated:

_____

Stan Meiburg,

Deputy Administrator.

To: Amy Doll[adoll@endyna.com]; Miguel Tuason[mtuason@endyna.com]
From: DeCair, Sara
Sent: Tue 2/23/2016 10:53:19 PM
Subject: Second set, very brief - PAG cmts
resolve PAG Manual draft Final 2-5-2016 MAJ VanHorne-Sealy comments.docx

These are even fewer and should be easy to incorporate. Thank you! I think that will be it for tonight, and I'll be back at it in the morning.

Sara D. DeCair

http://www.epa.gov/radiation/rert/pags.html

202-343-9108

Room 1416 B in WJC West

To: Lodwick, Jeffrey - OSHA[Lodwick.Jeffrey@dol.gov]; brown.christopher.k@dol.gov[brown.christopher.k@dol.gov]
Cc: Anderson, Jeri L. (CDC/NIOSH/DSHEFS)[jva2@cdc.gov]
From: DeCair, Sara
Sent: Tue 2/23/2016 10:47:21 PM
Subject: Quick turnaround: A set of worker Key Points for the PAG Manual
PAG Manual draft Final 2-5-2016.docx

We've decided to split the Worker sections out into its own chapter in the PAG Manual and we're gunning for an OMB review of the finalized Manual with public comments in very soon.

Each chapter has its own Key Points so I thought I'd try drafting some, but this is much more your area. Any chance you could make suggestions by tomorrow at 2 pm eastern? I'm getting the edits to my bosses then. I'm working on incorporating some other interagency editorial stuff now so don't mind the other parts of the Manual! Just for context….

KEY POINTS IN CHAPTER 3 – EMERGENCY WORKER PROTECTION

- Pending draft key points

KEY POINTS

•□□□□□□□□ Worker safety is key to a successful emergency response.

•□□□□□□□□ Worker protection statutes are listed in Table 3-3.

•□□□□□□□□ Balancing the individual risks and public benefits of each worker action is the responsibility of incident commanders.

•□□□□□□□□ Responders with training, personal protective equipment and monitoring instruments are able to protect themselves and others.

Sara D. DeCair

http://www.epa.gov/radiation/rert/pags.html

202-343-9108

Room 1416 B in WJC West

To: Miguel Tuason[mtuason@endyna.com]
Cc: Amy Doll[adoll@endyna.com]; siddhanti@endyna.com[siddhanti@endyna.com]
From: DeCair, Sara
Sent: Fri 2/5/2016 9:24:56 PM
Subject: RE: Yours for the afternoon: new PAG Manual version
PAG Manual draft Final 2-5-2016.docx

Thanks so much for checking, you never know if I something got stuck in the email pipeline!

I am done making final edits and am attaching what I have as of now. I have just a couple small requests from you in the next week or two:

- Format the Title and hyperlink for Table 4-2 which I named.
- Draft up some Key Points for Chapter 3 similar to ones we have for other chapters.
- Are the Chapter numbers duplicative of the 1.1, 2.1, and 3.1 at the top of each chapter?
- There are still too many small sections in 5.2, maybe make it a little more parallel with 5.1.

All we're doing Monday is sending it out, so there is no review call scheduled as yet, but when we do one, you'll definitely want to listen in! I've got Smita on the email distro so you all won't miss the invite if I space out.

Many thanks, and have a lovely weekend!

From: Miguel Tuason [mailto:mtuason@endyna.com]
Sent: Friday, February 05, 2016 4:17 PM
To: DeCair, Sara <DeCair.Sara@epa.gov>
Cc: Amy Doll <adoll@endyna.com>; siddhanti@endyna.com
Subject: RE: Yours for the afternoon: new PAG Manual version

Hi Sara –

We didn't hear from you this morning, so we're assuming you're all set for your next review.

Smita also reminded me to ask you if you'd like any of us on the review call on Monday.

We will make ourselves available, if so, so please let us know as soon as possible.

Either way, please also let us know when you'd like to have our next check-in call.

Thanks again and enjoy the weekend.

Best

Miguel

Miguel Tuason
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McLean, VA 22102
Tel: 703 848 8842 ext. 120
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Fax: 703 848 9001
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From: Miguel Tuason
Sent: Thursday, February 4, 2016 5:15 PM
To: 'DeCair, Sara' <DeCair.Sara@epa.gov>
Cc: Amy Doll <adoll@endyna.com>
Subject: RE: Yours for the afternoon: new PAG Manual version

Hi Sara –

We've gone ahead and addressed most of your notes below and attached the slightly revised version on this email.

Amy and I would like to have another quick call (any time after 10am Friday) to review these changes to make sure we are on the same page, correctly addressed your notes, and get you the most solid version for your Monday review.

Thanks again.

Best

Miguel

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From: DeCair, Sara [mailto:DeCair.Sara@epa.gov]
Sent: Thursday, February 4, 2016 3:28 PM
To: Miguel Tuason <mtuason@endyna.com>
Cc: Amy Doll <adoll@endyna.com>
Subject: Yours for the afternoon: new PAG Manual version

Miguel,

Thanks for turning around those changes for me! I have made my changes based in internal comments, and stuck with the Gray/Yellow them for word changes (not punctuation or capitalization).

I still want to check:

- FIXED Headers late in the doc, may not be same as earlier in doc

Will you check/fix:

- DONE Check format for my references that I added (FRC, 2 of them) – I used hard returns and guessed at how to cite them properly

- OKAY QA for wording changes that snuck back in:

o "major facility" had become "majority facility" in 1.2

o "nuclear fuel manufacturing" had become "nuclear manufacturing" in the same section

- DONE Basis for Early Phase should be its own section with a section #

- OKAY Let's make Ch. 5's Introduction that first paragraph that used to lead with Cleanup Process – does it look okay the way I did it?

- DONE – but should discuss if we should refrain from fourth-level (1.1.1.1) sections throughout the rest of the manual (for consistency) - We need fewer sections and section #s in the 5.2.4 area – those small outline and list parts can be larger and not so numbered

- DONE For this next review I'll be starting Monday, can you pull out most or all of the blue highlights for a clean version? (But I promise I'll look at them to give feedback during this next review. I'll just need reminders.)

- OKAY, FOR DISCUSSION I think in Ch. 3, the Key Points heading (we don't have any yet but I'd welcome your ideas for them) got mixed up in order with the last line of text and the table 3-3.

I'll be back at this about 9 am tomorrow, so let me know if any of this is indecipherable. Thank you!!

Sara

Sara D. DeCair

http://www.epa.gov/radiation/rert/pags.html

202-343-9108

Room 1416 B in WJC West

To: Miguel Tuason[mtuason@endyna.com]
Cc: Amy Doll[adoll@endyna.com]
From: DeCair, Sara
Sent: Thur 2/4/2016 8:28:24 PM
Subject: And... the attachment
PAG Manual Intra Agency Cmts In 2-4-2016.docx

Sigh.

Sara D. DeCair

http://www.epa.gov/radiation/rert/pags.html

202-343-9108

Room 1416 B in WJC West

To: Thornton, Marisa[Thornton.Marisa@epa.gov]
From: DeCair, Sara
Sent: Thur 1/21/2016 5:36:46 PM
Subject: PPT to PDF for web
PAG webinar slides updated Winter 2013.ppt

This was the file that was PDF'ed for the web site. Thank you!

Sara D. DeCair

http://www.epa.gov/radiation/rert/pags.html

202-343-9108

Room 1416 B in WJC West

2013 PAG Manual Revision

Overview with Questions & Answers

Sara DeCair, US EPA

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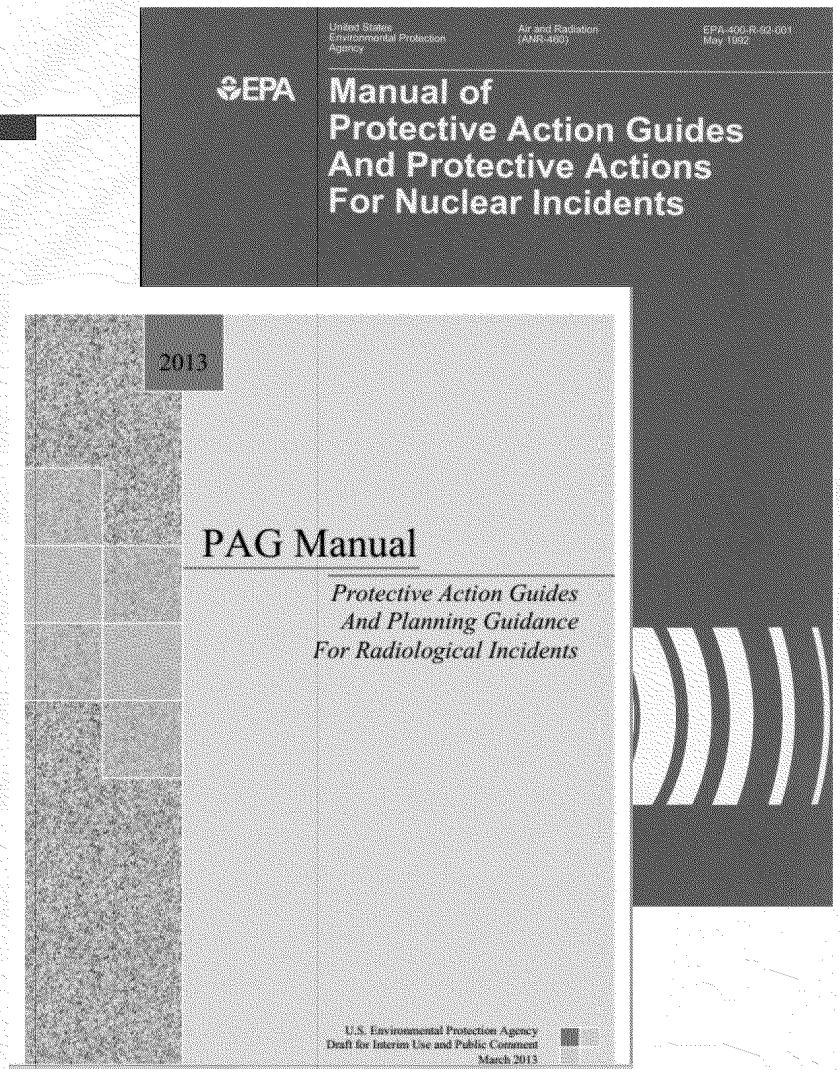
PAGs Manual

- Protective Action Guides (PAGs) Manual (1992)
- Early, Intermediate Phases only
- Promised Water and Late Phase (Recovery) PAGs



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2013 Draft PAG Manual

- Clarifies the use of PAGs for all radiological incidents, including terrorism
- Lowers projected thyroid dose for KI, via FDA
- Requests input on drinking water guidance
- Refers to 1998 FDA food guidance
- Includes guidance for long-term site restoration
- Updates dosimetry from ICRP 26 to ICRP 60, by referring to FRMAC methods

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When Do PAGs Apply?

- Not for radioactively contaminated sites
- Releases, incidents, or accidents
- Public protection is the focus
- Guidance, not regulatory
- This is not CERCLA or Superfund
- Avoided dose ≠ safe limit to allow

EPA

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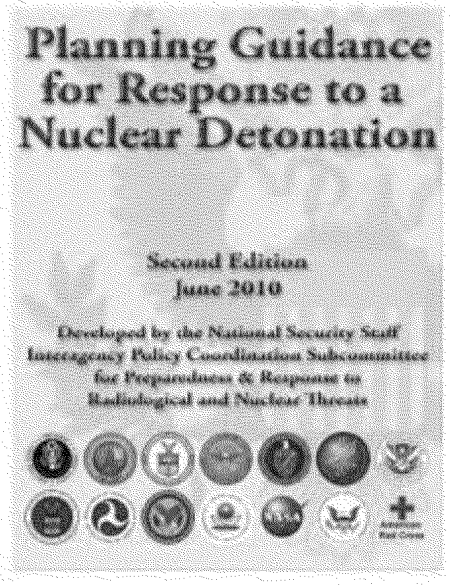
Relationship of EPA and DHS PAGs

- DHS vetted the Early and Intermediate PAGs for RDDs or INDs and provided needed guidance for Late Phase (recovery) guidance in 2008
  - ✓ EPA PAG Manual incorporates this late phase guidance
  - ✓ DHS document will 'sunset' when PAG Manual is finalized
- Planning Guidance for IND (2010)
  - ✓ PAGs don't apply well after an IND
  - ✓ Scope and scale
  - ✓ Priority on lifesaving and avoiding acute effects
  - ✓ Short response timeframe
  - ✓ Unique fallout decay curve
  - ✓ Referenced in PAG Manual



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Federal Register Questions

- Regarding the entire Manual:
  - ✓ Readers are referred to FRMAC Assessment Manuals for calculations using up-to-date dosimetry. Please comment on the usefulness of this approach and how to facilitate implementation of these methods.

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Early Phase

1992	2013
➢ Evacuation/Shelter 1-5 rem (10-50 mSv) ✓ thyroid/skin 5, 50 x higher	➢ Evacuation/Shelter 1-5 rem (10-50 mSv) ✓ (no organ dose specified)
➢ KI 25 rem (250 mSv) thyroid dose (adult)	➢ KI threshold 5 rem (50 mSv) thyroid dose (child)
➢ Worker 5, 10, 25+ rem (50, 100, 250+ mSv)	➢ Worker 5, 10, 25+ rem (50, 100, 250+ mSv)

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Potassium Iodide (KI) Actions

- FDA recommends a multi-pronged approach:

Threshold Thyroid Radioactive Exposures and Recommended Doses of KI for Different Risk Groups				
	Predicted Thyroid exposure(cGy)	KI dose (mg)	# of 130 mg tablets	# of 65 mg tablets
Adults over 40 yrs	≥500	130	1	2
Adults over 18 through 40 yrs	≥10			
Pregnant or lactating women	≥ 5			
Adoles. over 12 through 18 yrs*				
Children over 3 through 12 yrs		65	1/2	1
Over 1 month through 3 years		32	1/4	1/2
Birth through 1 month		16	1/8	1/4

- A simplified approach:
  - ✓ Provide KI to public if 5 rem (50 mSv) child thyroid dose projected
  - ✓ This is a supplemental action where evacuation is the primary protection

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Guidance for Emergency Workers

Dose (rem)	Activity	Condition
5	All	None
10	Protecting valuable property	Lower dose not practicable
25*	Lifesaving or protection of large populations	Lower dose not practicable

* Greater than 25 rem for lifesaving only to volunteers aware of the risks

EPA

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Federal Register Questions

Regarding the Early Phase:

- Please comment on the usefulness of the simplified KI implementation guidance
- Please comment specifically on the appropriateness of not retaining the skin and thyroid evacuation thresholds

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Intermediate Phase

1992	2013
➢ Relocate population ✓ ≥ 2 rem (20 mSv) first year (projected dose) ✓ 0.5 rem (5 mSv) any subsequent year ✓ 5 rem (50 mSv) over 50 yrs ➢ Apply dose reduction techniques ✓ < 2 rem (20 mSv)	➢ Relocate population ✓ ≥ 2 rem (20 mSv) first year (projected dose) ✓ 0.5 rem (5 mSv) any subsequent year ✓ (removed 50-year Relocation PAG) ➢ Apply dose reduction techniques ✓ < 2 rem (20 mSv)

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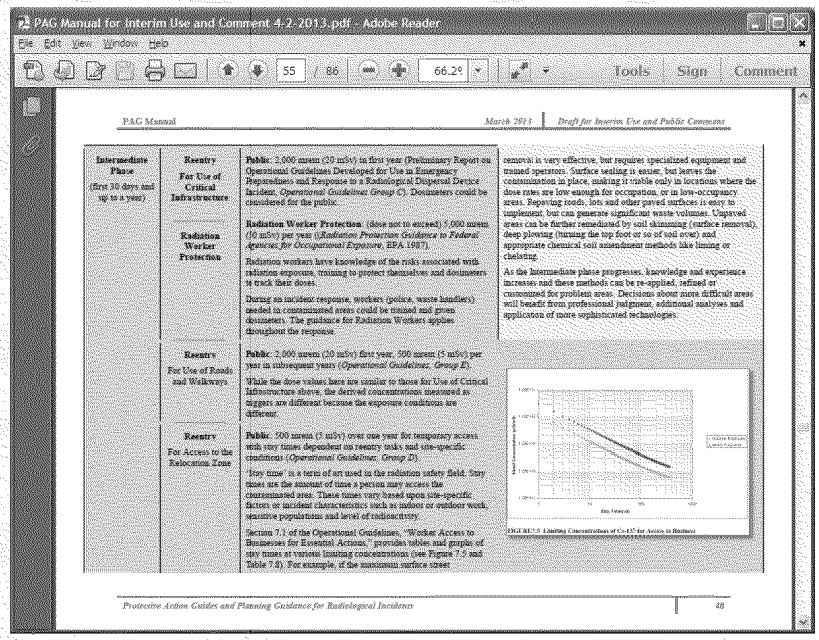
Re-entry Matrix

- New quick reference matrix
- Public, workers re-entering Relocation area to work during cleanup
- Basis: Relocation PAGs
- Assumptions: Detailed exposure scenarios in Operational Guidelines
- Do it yourself: RESRAD-RDD software


PAG Manual for Interim Use and Comment 4-2-2013.pdf - Adobe Reader

PAG Manual | March 2013 | Draft for Interim Use and Public Comment

Intermediate Phase (first 30 days and up to a year)	Reentry For Use of Critical Infrastructure	**Public**: 2,000 mrem (20 mSv) in first year (Preliminary Report on Operational Guidelines Developed for Use in Emergency Preparedness and Response to a Radiological Dispersal Device Incident, *Operational Guidelines, Group C*). Dosimeters could be considered for the public.	removal is very effective, but requires specialized equipment and trained operators. Surface sealing is easier, but leaves the contamination in place, making it viable only in locations where the dose rates are low enough for occupation, or in low-occupancy areas. Repaving roads, lots and other paved surfaces is easy to implement, but can generate significant waste volumes. Unpaved areas can be further remediated by soil skimming (surface removal), deep plowing (turning the top foot or so of soil over) and appropriate chemical soil amendment methods like liming or chelating.
	Radiation Worker Protection	**Radiation Worker Protection**: (dose not to exceed) 5,000 mrem (50 mSv) per year (*Radiation Protection Guidance to Federal Agencies for Occupational Exposure*, EPA 1987). Radiation workers have knowledge of the risks associated with radiation exposure, training to protect themselves and dosimeters to track their dose. During an incident response, workers (police, waste handlers) needed in contaminated areas could be trained and given dosimeters. The guidance for Radiation Workers applies throughout the response.	As the intermediate phase progresses, knowledge and experience increases and these methods can be re-applied, refined or customized for problem areas. Decisions about more difficult areas will benefit from professional judgment, additional analyses and application of more sophisticated technologies.
	Reentry For Use of Roads and Walkways	**Public**: 2,000 mrem (20 mSv) first year, 500 mrem (5 mSv) per year in subsequent years (*Operational Guidelines, Group E*). While the dose values here are similar to those for Use of Critical Infrastructure above, the derived concentrations measured as triggers are different because the exposure conditions are different.	
	Reentry For Access to the Relocation Zone	**Public**: 500 mrem (5 mSv) over one year for temporary access with stay times dependent on reentry tasks and site-specific conditions (*Operational Guidelines, Group D*). 'Stay time' is a term of art used in the radiation safety field. Stay times are the amount of time a person may access the contaminated area. These times vary based upon site-specific factors or incident characteristics such as indoor or outdoor work, sensitive populations and level of radioactivity. Section 7.1 of the Operational Guidelines, "Worker Access to Businesses for Essential Actions," provides tables and graphs of stay times at various limiting concentrations (see Figure 7.5 and Table 7.6). For example, if the maximum surface street	

FIGURE 7.5 Limiting Concentrations of Cs-137 for Access to Business

Protective Action Guides and Planning Guidance for Radiological Incidents | 48

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Federal Register Questions

Regarding the Intermediate Phase:

- Please comment on the appropriateness of removing the 5 rem over 50 years Relocation PAG
- Please comment on the format and utility of new Re-entry guidance
- Comment on whether it would be useful to develop a combined, all-pathways Intermediate Phase PAG

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Drinking Water PAG

1992	2013
➢ Promised	➢ National Primary Drinking Water Regulations provide emergency actions ✓ Increased monitoring ✓ Notifications ➢ Comments sought on whether, and what value, an emergency PAG for water should be considered

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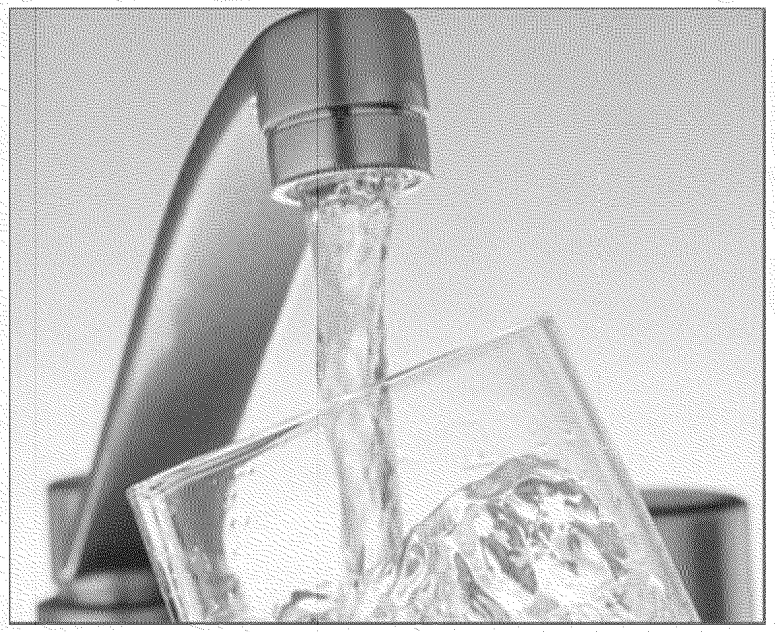
Drinking Water PAG

- Comments sought on whether, and what value, an emergency PAG for water should be considered
- Other related guides from WHO, IAEA, DHS, FDA may inform your input



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FDA Food PAGs

1992	2013
➢ 1982 FDA guidance ➢ NCRP 39 methodology ➢ Preventive PAG 0.5 rem (5 mSv) whole body and 1.5 rem (15 mSv) thyroid ➢ Emergency PAG 10 times higher, depends on impact ➢ Dose only, no activity levels provided	➢ 1998 FDA guide, by reference ➢ ICRP 56 & NRPB methods ➢ One set of PAGs ✓ 0.5 rem (5 mSv) whole body dose or ✓ 5 rem (50 mSv) to most exposed organ or tissue ➢ Dose and derived intervention levels (DILs) provided

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Federal Register Questions

Regarding Food and Water:

- Input on the appropriateness of, and possible values for, a drinking water PAG is being sought
- Since FDA's 1998 Food guidance is already final and published, comments are not requested on it

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Late Phase: Cleanup Goal

- Customer expectation of cleanup goal = background?
- Prescriptive or flexible
- Time, costs, risks, benefits
- What about your personal items?

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Step-wise Process

- Characterization and stabilization
- Establish cleanup goals based on options analysis
- Implementation and reoccupancy

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Decision-Making Organizations

- Focus on process for reaching consensus:
  - ✓ Decision Team – might be requesting funding
    - Senior local, state and federal officials
  - ✓ Recovery Management Team
    - Senior leadership in the field recovery effort
  - ✓ Stakeholder Working Group
    - Community leaders, local businesses, nongovernmental representatives, members of the public
  - ✓ Technical Working Group
    - Select subject matter experts, communicators

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Late Phase: Waste Management

- Document focuses on options for disposal
  - ✓ Licensed LLRW disposal facilities
  - ✓ RCRA solid and hazardous waste landfills
  - ✓ Federal facilities/sites
  - ✓ Newly developed disposal capacity
  - ✓ Appropriate for level of hazard
- States bear primary responsibility
  - ✓ Waste volumes will drive decision-making
    - Could overwhelm existing disposal capacity (see Japan)
    - Need to be considered in early planning

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EPA Waste Management Resources

- Waste Estimation Support Tool (WEST)
  - ✓ First-order estimates of waste types and volumes
  - ✓ Based on analysis of plume maps
- CBR Disposal Technology Workshop report
  - ✓ Technical issues in developing new capacity
  - ✓ http://www.epa.gov/nhsrc/pubs.html
- Minimization/Segregation Technology Guideline
  - ✓ Developed through the WARRP effort (available soon)
- Interactive, web-based waste management planning tool for incidents (early concept)

EPA

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Federal Register Questions

Regarding Late Phase:

- Please comment on the usefulness of the brief cleanup planning guidance, and how it might be implemented in state, tribal and local plans
- Please comment on the merging of the 2008 DHS RDD/IND cleanup guide with this Manual
- Please comment on the basic waste disposal planning guidance and how it should be implemented in plans at all levels of government

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The End

Comments or questions?

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To: Hallam, Christopher[Hallam.Christopher@epa.gov]
From: DeCair, Sara
Sent: Wed 1/13/2016 8:12:11 PM
Subject: Fun reading
pag-manual-interim-public-comment-4-2-2013.pdf

I'll bring by my trophy book of articles on this thing. It is my crown jewel but admittedly, it was written by Committee… cheers!

Sara D. DeCair

http://www.epa.gov/radiation/rert/pags.html

202-343-9108

Room 1416 B in WJC West

To: Amy Doll[adoll@endyna.com]; Smita Siddhanti[siddhanti@endyna.com]
From: DeCair, Sara
Sent: Wed 1/13/2016 4:35:14 PM
Subject: Mark up Manual, cmt spreadsheet
Redline PAG Manual 12-14-2015.docx
Cmt Resolution 12-14-2015.xlsx

Here are the versions I am working from. I do indeed have the cover examples from Miguel so I'll provide feedback on those this week. Thank you, and talk to you soon!

Sara

Sara D. DeCair

http://www.epa.gov/radiation/rert/pags.html

202-343-9108

Room 1416 B in WJC West

In 2013, the U.S. Environmental Protection Agency (EPA) proposed an update to the 1992 Protective Action Guides (PAG) Manual. The PAG Manual provides guidance to state and local officials planning for radiological emergencies. EPA requested public comment on the proposed revisions, while making them available for interim use by officials faced with an emergency situation. Developed with interagency partners, EPA's proposal incorporates newer dosimetric methods, identifies tools and guidelines developed since the current document was issued, and extends the scope of the PAGs to all significant radiological incidents, including radiological dispersal devices or improvised nuclear devices. EPA also requested input on potential protective action guides for drinking water. New in the PAG Manual is planning guidance for the late phase of an incident, after the situation is stabilized and efforts turn toward recovery. Because the late phase can take years to complete, decision makers are faced with managing public exposures in areas not fully remediated. The proposal includes quick reference operational guidelines to inform re-entry to the contaminated zone. Broad guidance on approaches to wide-area cleanup and developing cleanup goals is also provided. EPA adapted the cleanup process from the 2008 Department of Homeland Security (DHS) "Planning Guidance for Protection and Recovery Following Radiological Dispersal Device (RDD) and Improvised Nuclear Device (IND) Incidents" and the final PAG Manual will supersede that DHS guidance. Waste management guidance is also provided. Recognizing that an incident could result in radioactive waste volumes that severely strain or exceed available resources and capacity, officials may consider alternatives for disposal of waste that is relatively lightly contaminated. Waste management, which includes treatment, staging, and interim and long-term storage, must be an integral part of recovery.

2016

AG Manual

ective Action Guides and Planning Guidance for Radiological Incidents

U.S. Environmental Protection Agency
Final revision: Replaces 1992 and 2013 PAG Manuals
1/1/2016

Key to this markup:
Additions
Deletions

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LIMITS OF SCOPE

This guidance does not address or impact site cleanups occurring under other statutory authorities such as the United States Environmental Protection Agency's (EPA) Superfund program, the Nuclear Regulatory Commission's (NRC) decommissioning program, or other federal or state cleanup programs.

As indicated by the use of non-mandatory language such as "may," "should" and "can," this Manual only provides recommendations and does not confer any legal rights or impose any legally binding requirements upon any member of the public, states, or any other federal agency.

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CHAPTER 1 – OVERVIEW

1.1. PLANNING GUIDANCE AND PROTECTIVE ACTION GUIDES

The U.S. Environmental Protection Agency (EPA) has developed this Manual to assist public officials in planning for emergency response to radiological incidents. For purposes of this document, a radiological incident is an event or a series of events, deliberate or accidental, leading to the release or potential release into the environment of radioactive materials in sufficient quantity to warrant consideration of protective actions. This Manual provides radiological protection criteria for application to all incidents that would require consideration of protective actions, with the exception of nuclear war.

During an incident with an uncontrolled source of radiation, protection of the public from unnecessary exposure to radiation may require some form of intervention that will disrupt normal living. Such intervention is termed a protective action. Examples of protective actions include:

- Evacuating an area;
- Sheltering-in-place within a building or protective structure;
- Administering potassium iodide (KI) as a supplemental action;
- Relocation;
- Acquiring an alternate source of drinking water;
- Interdiction of food/milk.

This Manual provides recommended numerical protective action guides (PAGs) for the principal protective actions available to public officials during a radiological incident. A PAG is defined for purposes of this document as the projected dose to an individual from a release of radioactive material at which a specific protective action to reduce or avoid that dose is recommended. PAGs are guides to help officials select protective actions under emergency conditions during which exposures would occur for relatively short time periods. They are not meant to be applied as strict numeric criteria, but rather as guidelines to be considered in the context of incident-specific factors. PAGs do not establish an acceptable level of risk for normal, nonemergency conditions, nor do they represent the boundary between safe and unsafe conditions. The PAGs are not legally binding regulations or standards and do not supersede any environmental laws. For information on roles, responsibilities and authorities during emergency response and recovery, please refer to the National Response Framework: http://www.fema.gov/national-response-framework and specifically for radiological incidents, the Nuclear Radiological Incident Annex: http://www.fema.gov/pdf/about/divisions/thd/IncidentNucRad.pdf (FEMA 2008a,b).

Some protective actions are not associated with a numerical PAG. For example, the control of access to areas is a protective action implemented in concert with other protective actions; it does not have its own PAG. Any reasonable action to reduce radiation dose is encouraged even if it is not associated with a PAG, such as recommending that individuals use ad hoc respiratory protection with a handkerchief or piece of folded cloth. Or in areas where PAGs are not exceeded, but airborne radioactivity is present, people might be asked to stay indoors to the extent practicable to reduce their exposures. To further develop radiological emergency plans, brief planning guides have been provided for reentry to relocation areas, the cleanup planning process and considerations for radioactive waste disposal.

1.2. APPLICABILITY

Protective actions may be recommended for a wide range of incidents, but generally apply to incidents involving relatively significant releases of radionuclides. Radiological incidents with potential for significant releases include:

- A fire in a majority facility such as a nuclear manufacturing plant;
- An accident at a federal nuclear weapons complex facility;

- An accident at a commercial nuclear power plant (NPP);
- A transportation accident involving radioactive material;
- A terrorist act involving a radiological dispersal device (RDD) or yield-producing Improvised Nuclear Device (IND).

Each type of incident would pose a unique threat to public health and should be planned for and managed accordingly. Emergency response planning for a given facility or scenario should consider:

- The radionuclides involved;
- The dynamics of the release including size and magnitude;
- The feasibility of specific protective actions;
- The timing of notification, response and protective action implementation.

The decision to advise members of the public to take a protective action during a radiological incident involves a complex judgment in which the radiological risk must be weighed against the action's inherent risks. This decision may have to be made under emergency conditions, with limited information and little time to analyze options. Advance planning reduces the complexity of the decision-making process during an incident. The planning process can identify the viability of responses to various incidents, the courses of action that can be set in motion in advance and the decisions that can only be made during an actual emergency. While many aspects of protective actions can be considered well in advance of an emergency, the situations and conditions that exist at the time of emergency must be considered if the most effective action is to be selected.

The unpredictable locations of certain radiological incidents make advance planning challenging. For example, an RDD could detonate anywhere and spread radiological contaminants over a wide variety of surfaces and terrain. Emergency planners should be prepared to apply PAGs to a wide scope of facilities and circumstances.

1.3. BACKGROUND ON THE UPDATED PAGS

This Manual updates the "Manual of Protective Action Guides and Protective Actions for Nuclear Incidents" (EPA-400-R-92-001, May 1992), published by the U.S. EPA (EPA 1992b) (hereinafter referred to as the "1992 PAG Manual"). The guidance in this Manual was developed cooperatively with the Federal Radiological Preparedness Coordination Committee (FRPCC), with representation from the EPA; the Department of Energy (DOE); the Department of Defense (DoD); the DHS' Federal Emergency Management Agency (FEMA); the Nuclear Regulatory Commission (NRC); the Department of Health and Human Services (HHS), including the Centers for Disease Control and Prevention (CDC) and the Food and Drug Administration (FDA); the Department of Agriculture (USDA); and the Department of Labor (DOL).

1.3.1. Legal Basis

The historical and legal basis of EPA's role in developing this guidance begins with Reorganization Plan No. 3 of 1970, in which the Administrator of EPA assumed all the functions of the Federal Radiation Council (FRC), including the charge to "…advise the President with respect to radiation matters, directly or indirectly affecting health, including guidance for all federal agencies in the formulation of radiation standards and in the establishment and execution of programs of cooperation with states" (Reorg. Plan No. 3 of 1970, sec. 2(a) (7), 6(a) (2); § 274.h of the Atomic Energy Act of 1954, as amended (AEA), codified at 42 U.S.C. § 2021(h)). Recognizing this role, FEMA directed EPA in their Radiological Emergency Planning and Preparedness Regulations to "establish Protective Action Guides (PAGs) for all aspects of radiological emergency planning in coordination with appropriate federal agencies" (44 Code of Federal Regulations (CFR) §351.22(a)). FEMA also tasked EPA with preparing "guidance for state and local governments on

implementing PAGs, including recommendations on protective actions which can be taken to mitigate the potential radiation dose to the population" (44 CFR §351.22(b)). All of this information was to "be presented in the EPA Manual of Protective Action Guides and Protective Actions for Nuclear Incidents" (44 CFR §351.22(b)).

Additionally, section 2021(h) charged the Administrator with performing "such other functions as the President may assign to him [or her] by Executive Order." Executive Order 12656 states that the Administrator shall "develop, for national security emergencies, guidance on acceptable emergency levels of nuclear radiation…." (Executive Order No. 12656, sec. 1601(2)). EPA's role in the development of PAGs was also recognized in the "Nuclear/Radiological Incident Annex of the National Response Framework" of June 2008.

1.3.2. Interaction with Federal Radiation Council (FRC) Reports No. 5 and 7

In the 1960's, the Federal Radiation Council (FRC) defined PAGs and established limiting guides for ingestion of strontium-89, strontium-90, cesium-137, and iodine-131 (FR-64; FR-65). That guidance applied to restricting the use of food products that had become contaminated as the result of release of radioactivity to the stratosphere from weapons testing. During the period immediately following an incident at any domestic nuclear facility, when the critical source of exposure is expected to be a nearby airborne plume, the principal protective actions are evacuation or sheltering. The PAGs developed here thus do not supersede previous guidance, but provide additional guidance for prompt exposure pathways specific to a domestic nuclear incident.

1.3.3. Technical Basis

The FRC introduced the concept of a PAG in a series of recommendations issued in the 1960s. A key concept about PAGs is that the decision to implement protective actions should be based on the projected dose that would be avoided if the protective actions were implemented. Developers of the EPA PAGs considered the following three principles in establishing exposure levels for the PAGs—

1. Prevent acute effects.
2. Balance protection with other important factors and ensure that actions result in more benefit than harm.
3. Reduce risk of chronic effects.

These principles apply to the determination of any PAG. Principles 1 and 2 have been proposed for use by the international community as essential bases for decisions to intervene during an incident. Principle 3 has been recognized as an appropriate additional consideration (IAEA 1989). Although it is important during emergency planning to consider a range of source terms to assess the costs associated with their implementation, the PAGs are pre-determined for use in emergencies without regard to the magnitude or type of radiological release.

1.3.4. Changes in Scenarios since the Issuance of the 1992 PAG Manual

EPA's 1992 PAG Manual provided emergency management officials at the federal, state, tribal and local levels with the technical basis to plan responses to radiological emergencies. The 1992 PAG Manual was written to accommodate the worst release scenario deemed likely at the time – a major accident at a commercial NPP that would result in a significant off-site release of radioactive material. ("Site" and "off-site" in this Manual refer to locations where the radiological incident occurs and are not limited to facility-type incidents.) Certain characteristics typify NPPs, including: fixed locations at which an accident might occur; a known suite of radionuclides on site, the dose from which is dominated by short-lived radioisotopes; tight regulatory controls and requirements; skilled operational personnel who plan for and exercise emergency responses; state and local involvement in emergency planning; well-

developed and zoned emergency evacuation plans and routes; and advance notice (generally hours to days) from deteriorating plant conditions prior to accidental release of radioactive material into the environment. Therefore, the 1992 PAG Manual provided decision-makers with radiation dose-based PAG values for various exposure pathways (such as whole body, skin dose and food ingestion) and associated protective actions that were adapted to the mix of radionuclides and operational environments associated with commercial NPPs.

In late 1991, EPA conducted a symposium titled "Implementing Protective Actions for Radiological Incidents at Other Than Nuclear Power Reactors," to evaluate PAGs for incidents other than accidents at NPPs and concluded that the PAGs could be applied to all radiological incidents (EPA 1992a). Since then, new radiological and nuclear scenarios involving terrorist use of radioactive materials have gained status in radiological emergency response planning.

In 2008, the Department of Homeland Security (DHS) published "Planning Guidance for Protection and Recovery Following Radiological Dispersal Device (RDD) and Improvised Nuclear Device (IND) Incidents" (DHS 2008). An RDD is a device or mechanism that is intended to spread radioactive material from the detonation of conventional explosives or other means. An IND is a crude, yield-producing nuclear weapon fabricated from diverted fissile material. Incidents like these may occur anywhere with little or no warning. The DHS guidance, developed cooperatively with EPA, DOE, DoD, DOL, HHS, Department of Commerce (DOC), and the NRC, affirms the applicability of existing 1992 EPA PAGs to terrorist acts, while acknowledging that the PAGs were inadequate for early response planning needs specific to an IND. To address this gap, "Planning Guidance for Response to a Nuclear Detonation" (NSS 2010) was subsequently published.

This Manual substantively incorporates late phase cleanup guidance provided in the 2008 DHS document and refers readers to additional planning resources.

1.3.5. Key Changes to PAGs in this Updated Manual

This updated Manual applies PAGs and protective actions to an expanded range of sources of potential radiological releases, including commercial nuclear power facilities, uranium fuel cycle facilities, nuclear weapons facilities, transportation accidents, radiopharmaceutical manufacturers and users, space vehicle launch and reentry, RDDs and INDs.

Dosimetry for all the PAGs was updated using the International Commission on Radiological Protection (ICRP) Publication 60 series (ICRP 1991). The PAGs in this Manual may be implemented using calculated, measurable values contained in the Federal Radiological Monitoring and Assessment Center (FRMAC) Assessment Manuals (DOE 2010a, b),[1] though using other incident-specific dose assessment methodologies is encouraged, where appropriate. For simplicity, specific organ dose thresholds for evacuation and sheltering were removed.

This Manual incorporates several related guidance documents published subsequent to the 1992 guidance, including FDA's 1998 update of the PAGs for interdiction of food. This Manual also incorporates FDA's 2001 decision to lower the PAG for administration of stable iodine to 5 rem (50 millisieverts (mSv)) projected child thyroid dose. ~~Finally,~~ this update removes the intermediate phase relocation PAG of 5 rem (50 mSv) over 50 years to avoid confusion with long-term cleanup. ~~All other~~ Most of the PAGs and corresponding protective actions from the 1992 PAG Manual remain unchanged.

Recommended limits of exposure for emergency workers also remain unchanged from the 1992 PAG Manual. The emergency worker guides in this manual are consistent with federal and state regulations.

[1] See FRMAC Assessment folder at http://www.nv.doe.gov/nationalsecurity/homelandsecurity/frmac/manuals.aspx.

Responsible officials should use judgment when doses may exceed regulatory limits and must advise workers of the risks Table 1-1 presents PAGs with their principal associated protective actions or planning guides.

To further develop radiological emergency plans, brief planning guides have been provided for reentry to relocation areas, a cleanup planning process and considerations for radioactive waste disposal. In this Manual, the term reentry is used for emergency workers and members of the public going into relocation areas temporarily, under controlled conditions.

1.4. RADIOLOGICAL INCIDENT PHASES AND APPLICABILITY OF PROTECTIVE ACTIONS

Emergency planners divide responses to radiological incidents into three phases of activity—

- **Early Phase** — The beginning of a radiological incident ~~when~~ for which immediate decisions for effective use of protective actions are required and must therefore be based primarily on the status of the radiological incident and the prognosis for worsening conditions. When available, predictions of radiological conditions in the environment based on the condition of the source or actual environmental measurements may be used. Protective actions based on the PAGs may be preceded by precautionary actions during the period. This phase may last from hours to days.
- **Intermediate Phase** — The period beginning after the source and releases have been brought under control (has not necessarily stopped but is no longer growing) and reliable environmental measurements are available for use as a basis for decisions on protective actions and extending until these additional protective actions are no longer needed. This phase may overlap the early phase and late phase and may last from weeks to months.
- **Late Phase** — The period beginning when recovery actions designed to reduce radiation levels in the environment to acceptable levels are commenced and ending when all recovery actions have been completed. This phase may extend from months to years. A PAG level, or dose to avoid, is not appropriate for long-term cleanup.

The phases cannot be represented by precise periods of time – and may even overlap – but to view them in terms of activities, rather than time spans, can provide a useful framework for emergency response planning.

In the early phase, sheltering-in-place and evacuation are the principal protective actions. These actions are meant to avoid inhalation of gases or particulates in an atmospheric plume and to minimize external radiation exposures. Administration of prophylactic drugs may be employed depending on the specific radionuclides released; in particular, KI, also called “stable iodine”—may be administered as a supplementary protective action in incidents involving the release of significant quantities of radioactive iodine, such as NPP incidents. Some protective actions may begin prior to the release of radioactive material when there is advance notice.

Planning considerations for reentry to relocation areas for specific tasks are suggested and basic planning guidance for late phase cleanup is provided in Chapters 3 and 4.

1.4.1. Implementation of Protective Action Guides and Protective Actions

Immediately upon becoming aware that an incident is about to occur or has occurred that may result in exposure of the population, responsible authorities should make a preliminary evaluation to determine the nature and potential magnitude of the incident. This evaluation should determine whether conditions indicate a significant possibility of a major release and, to the extent feasible, determine potential exposure pathways, populations at risk and projected doses. The incident evaluation and recommendations should then be presented to emergency response authorities for consideration and implementation.

During the early phase, the sequence of events includes—evaluation of conditions at the location of the incident, notification of responsible authorities, prediction or evaluation of potential consequences to the general public, recommendations for action and implementation of actions for the protection of the public.

In the intermediate phase, dose projections used to support decisions about protective actions may be based on measurements of environmental radioactivity and dose models. When conditions warrant relocation of populations, the collection of extensive radiological and cost-of-cleanup data will be necessary to form the decision basis for cleanup and recovery of the affected areas.

Table 1-1. Planning Guidance and Protective Action Guides for Radiological Incidents

Phase	Protective Action Recommendation	Protective Action Guide or Planning Guide
Early (Chapter 2)	Sheltering-in-place or evacuation of the public[a]	1 to 5 rem (10 mSv to 50 mSv) projected dose/4 days[b]
	Administration of prophylactic drugs KI[c]	5 rem (50 mSv) projected child thyroid dose[d] from radioactive iodine
	Limit emergency worker exposure	5 rem (50 mSv)/year (or greater under exceptional circumstances)[e]
Intermediate (Chapter 3)	Relocation of the public	2 rem (20 mSv) projected dose first year[b] Subsequent years, 0.5 rem (5 mSv)/year projected dose
	Food interdiction[f]	0.5 rem (5 mSv)/year projected dose, or 5 rem (50 mSv)/year to any individual organ or tissue, whichever is limiting
	Limit emergency worker exposure	5 rem (50 mSv)/year[b]
	Reentry	Operational Guidelines[g] (Stay times and concentrations) for specific activities (see Section 3.7)
Late (Chapter 4)	Cleanup	Brief description of planning process
	Waste Disposal	Brief description of planning process

[a] Should begin at 1 rem (10 mSv); take whichever action (or combination of actions) that results in the lowest exposure for the majority of the population. Sheltering may begin at lower levels if advantageous.
[b] Projected dose- the sum of the effective dose from external radiation exposure (i.e., groundshine and cloudshine) and the committed effective dose from inhaled radioactive material.
[c] Provides thyroid protection from ~~internal exposure to~~ radioactive iodines only. The complete FDA guidance may be found at http://www.fda.gov/downloads/Drugs/GuidanceComplianceRegulatoryInformation/Guidances/ucm080542.pdf. Further information is also available: http://www.fda.gov/downloads/Drugs/GuidanceComplianceRegulatoryInformation/Guidances/ucm080546.pdf and http://www.fda.gov/Drugs/EmergencyPreparedness/BioterrorismandDrugPreparedness/ucm072265.htm.
[d] Thyroid equivalent dose. For information on other radiological prophylactics and treatment, refer to...http://www.fda.gov/Drugs/EmergencyPreparedness/BioterrorismandDrugPreparedness/ucm063807.htm http://www.bt.cdc.gov/radiation and www.orau.gov/reacts
[e] When radiation control options are not available, or, due to the magnitude of the incident, are not sufficient, doses to emergency workers above 5 rem (50 mSv) may be unavoidable and are generally approved by competent authority. For further discussion see Chapter 2, Section 2.6.
[f] For more information on food and animal feeds guidance, the complete FDA guidance may be found at http://www.fda.gov/downloads/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/UCM094513.pdf
[g] For extensive technical and practical implementation information please see "Preliminary Report on Operational Guidelines Developed for Use in Emergency Preparedness and Response to a Radiological Dispersal Device Incident" (DOE 2009)

Protective actions may already be designated in existing emergency response plans. Under NRC regulations, large commercial NPPs must maintain detailed radiological response plans for an emergency planning zone (EPZ) within a 10 mile (16.1 km) radius of the plant and for a separate ingestion pathway EPZ within a 50 mile (80.5 km) radius. ~~Emergency Responders~~ Emergency Workers should be prepared

to select and implement appropriate protective actions when standing response plans are not available or applicable.

1.4.2. Early Phase Protective Action Guides and Protective Actions

In the early phase, there may be little or no data on actual releases to the environment and responders may have to rely on crude estimates of airborne releases. Decision time frames are short and preparation is critical to make prudent decisions when data are lacking or insufficient.

The principal protective actions for the early phase are evacuation and sheltering-in-place. These protective actions would be taken if whole body doses are projected to exceed 1 to 5 rem (10 to 50 mSv) over four days. The decision to evacuate must weigh the anticipated radiation dose to individuals in the affected population against the feasibility of evacuating within a determined time frame and the risks associated with the evacuation itself. For example, evacuating a population of 50,000 carries with it a statistical risk of injury or death from transportation hazards or increased exposure. Evacuation also takes time. In the case of an accident at an NPP, there ~~may~~ will likely be time for an orderly and relatively safe evacuation. In the case of a fire or explosion of an RDD in an urban area, evacuating a large group of people could leave them exposed to the plume and actually increase radiation dose. Sheltering-in-place may be warranted in situations where evacuation poses a greater risk of exposure or physical harm.

In addition, there are actions that are advisable, but not associated with a numerical PAG. For example, individuals should be instructed to cover airways (nose and mouth) with available filtering material when airborne radionuclides may be present. Decontamination is another protective action that may be utilized in the early phase and may include washing of contaminated individuals, removing contaminated clothing and decontaminating surfaces of critical areas and objects. Further, in areas where airborne radioactivity is present but PAGs are not exceeded, officials can consider asking people to stay indoors to the extent practicable. In such cases, individuals are not prevented from carrying out necessary tasks (e.g., seeking medical care, purchasing food). Similar to actions used in major cities on high pollution days, these measures can be effective to reduce radiation doses when prolonged releases occur, as was the case for the Fukushima accident in Japan.

In cases where significant quantities of radioiodine may have been released, administration of the radioprotectant KI should be considered as a supplementary protective action if the projected child thyroid dose exceeds 5 rem (50 mSv). This PAG is lower than the 1992 guidance. The lower dose, which FDA adopted in 2001, is for protection of children based on early studies of Chernobyl exposure data.

The choice of protective action will be based on the status of the incident site and the prognosis for worsening conditions. In the early phase, precautionary actions based on worst-case scenarios may be used before implementation of protective actions based on PAGs. For example, in the case of RDD detonation, governments may instruct affected populations to shelter in place as a precautionary action while radiation levels are being measured to determine appropriate PAG-based protective actions. Officials should plan for rapid broadcast and dissemination of protective action orders to the public.

When available, predictions of radiological conditions in the environment based on an estimate of the source or actual environmental measurements may be used. Nuclear facilities, for example, have continuous, real-time radioactive effluent monitoring capabilities to monitor radioactive material released to the environment and may have a network of off-site measurement stations.

1.4.3. Conservatism built into the PAGs

Conservatism is built into the PAG levels themselves, as described in Sections __ and __ about the risk-benefit balancing process used to derive the PAGs. Additionally, assumptions made to generate default DPs and DRLs in FRMAC Assessment, Appendix C ensure protectiveness for all members of the public,

including sensitive subpopulations such as young children. For example, Early Phase derived levels are based on the assumption that a person is outdoors twenty-four hours a day for four days being exposed to the plume. Intermediate Phase derived levels also conservatively do not account for shielding provided by being indoors part of each day of the projection year. People are assumed to remain in the contaminated area during the entire time (not going to work or school in uncontaminated area, for instance.) Another example of conservatism is that it is assumed radionuclides are in the chemical and physical form that yields the highest dose, and that the particle size is one micrometer mean aerodynamic diameter. These conservatisms allow dose assessors to project whole body doses (TED) to a reference person, for simplicity, and then decision makers can make protective action decisions that apply to entire communities including children, adults and the elderly.

Certain guidelines that lend themselves to different PAGs for different subpopulations are the PAGs for potassium iodide, food and water. These guidelines provide age-specific recommendations because of the radiosensitivity of the thyroid and young children with respect to ingestion and inhalation doses in particular. Taking protective actions like use of KI, avoiding certain foods or using alternative sources of drinking water can be relatively simple to implement by the parents of younger children. Clear public messages can convey which age groups should take which action, unlike how an evacuation or relocation order should apply to entire households or neighborhoods.

An evaluation of dose consequences to several age groups across many radiological scenarios was done and, for the early phase including the plume, child whole body doses are typically no more than 15% higher than adult whole body doses. That margin is well within the conservatism discussed above, so that separate PAGs or projections need not be required. Therefore, basing evacuation, shelter in place and relocation dose projections on an adult is protective for all age groups. Sensitive age groups should be evaluated separately for KI, food and water decisions. Keeping calculations and decision making simple in the face of a disaster can enable timely actions to protect communities.

1.4.4. Intermediate Phase Protective Action Guides and Protective Actions

Intermediate phase activities are intended to reduce or avoid dose to the public, to control worker exposures, to control the spread of radioactive contamination and to prepare for late phase cleanup operations.

During the intermediate phase, relocation is the principal protective action against whole body external exposure from deposited material and internal exposure from inhalation of radioactive particulates. People may need to be relocated for weeks or months.

It is necessary to distinguish between evacuation and relocation. Evacuation is the urgent removal of people from an area to avoid or reduce high-level, short-term exposure from the plume or deposited activity. Relocation is the removal or continued exclusion of people (households) from contaminated areas to avoid chronic radiation exposure. Site-specific conditions may allow some groups evacuated in an emergency to return, while others may have to relocate. In other cases, some groups that were not previously evacuated may have to relocate (see Section 3.3.1 for more details).

Intermediate phase PAGs are based on doses projected in the first ~~and a limited number of~~ subsequent years. The PAG for relocation of the public is 2 rem (20 mSv) in the first year and 0.5 rem (5 mSv) in any subsequent year. (Note: Relocation PAGs are treated separately from food and water ingestion. That is, projection of intermediate phase doses should not include these ingestion pathways. In some instances, however, where withdrawal of food and/or water from use would, in itself, create a~~,~~ health risk~~,~~ relocation may be an appropriate alternative protective action. In this case, the ingestion dose should be considered along with the projected dose from deposited radionuclides via other pathways, for decisions on relocation.) When projected doses are less than the relocation PAG of 2 rem (20 mSv) in the first year, focused environmental decontamination and cleanup may be able to reduce doses to populations that are

not relocated. Decontamination and focused cleanup techniques can range from simple actions such as the scrubbing and flushing of surfaces with uncontaminated water to the removal and disposal of soil and contaminated debris.

Keeping projected subsequent doses below the 0.5 rem (5 mSv) PAG for out years – the second year and beyond – may be achieved through the decay of shorter half-life radioisotopes (as in the case of an accident at an NPP), through environmental decontamination and cleanup efforts or through other means of controlling public exposures, such as limiting access to certain areas. Information on food and animal feeds protective action guidance is contained in FDA's "Accidental Radioactive Contamination of Human Food and Animal Feeds: Recommendations for State and Local Agencies" (FDA 1998). Workers and members of the public may be allowed to re-enter relocation area for tasks related to critical infrastructure and key resources, to care for animals and to assess the condition of closed zones. Reoccupancy may be allowed under dose constraints acceptable to the community. In this Manual, the term reoccupancy refers to households and communities moving back into relocation areas where the cleanup process is still ongoing, based on radiation levels acceptable to those communities.

~~EPA is not proposing a specific drinking water PAG at this time. EPA has established enforceable drinking water standards for radionuclides under the Safe Drinking Water Act (SDWA). EPA recommends that, to the extent practicable, emergency measures for drinking water be based on the National Primary Drinking Water Regulations (NPDWR) for Radionuclides. The Radionuclides Rule provides states with flexibility when responding to radiological events. If a public water system exceeds the radionuclides standard it must work to get back into compliance as soon as feasible. States have the authority to determine if other corrective actions are needed (e.g. providing alternative water). Guidance on monitoring, notification and protective actions is provided in Chapter 3, along with several online resources for drinking water system operators.~~

~~However, in light the Fukushima nuclear power plant accident, in which some Japanese drinking water supplies were impacted, the Agency recognizes a short-term emergency drinking water guide may be useful for public health protection The Agency requests input on the appropriateness of, and possible values for, a drinking water PAG.~~

~~While the NPDWR provide for a regulatory standard of 4 mrem/year (beta, photon emitters) based on life-time exposure, international organizations have developed technical approaches and methodologies that have produced a range of emergency guidelines related to drinking water (e.g., the World Health Organization[2], the International Atomic Energy Agency[3]), as have other federal agencies (e.g. the Department of Homeland Security[4], the Food and Drug Administration[5]) and non-federal organizations. EPA is seeking input on an approach and technical rationale for a drinking water PAG designed to help officials select protective actions under emergency conditions when exposures would occur over shorter time periods than those envisioned in the NPDWR.~~

{Placeholder for brief description of the final drinking water PAG}

During the intermediate phase, government officials may convene to discuss late phase cleanup and site restoration strategies. All actions taken during the early and intermediate phases should be considered with respect to the impact they may have on late phase remediation, such as avoiding the use of fixatives that could hinder surface decontamination at a later date.

1.4.5. Late Phase

[2] See http://www.who.int/water_sanitation_health/dwq/gdwq3rev/en/ and http://www.who.int/hac/crises/jpn/faqs/en/index8.html
[3] See http://www-pub.iaea.org/MTCD/publications/PDF/Pub1467_web.pdf.
[4] See http://ogcms.energy.gov/73fr45029.pdf
[5] See http://www.fda.gov/downloads/MedicalDevices/.../UCM094513.pdf.

The late phase, as used in this Manual, is the period beginning when cleanup and recovery actions have begun and ending when all recovery actions have been completed. This phase may extend from months to years.

The late phase cleanup process, as described in this guidance, begins sometime after the commencement of the intermediate phase and proceeds independently of intermediate phase protective action activities. The transition is characterized by a change in approach, from strategies predominantly driven by urgency, to strategies aimed at both reducing longer-term exposures and improving living conditions. The late phase involves the final cleanup of areas and property at which contamination directly attributable to the incident is present. It is in the late phase that final cleanup decisions are made and final recovery efforts following a radiological incident are implemented.

Unlike the early and intermediate phases of a radiological incident, decision makers will have more time and information during the late phase to allow for better data collection, stakeholder involvement and options analysis. Community members will influence decisions such as if and when to allow people to return home to contaminated areas. There will be populations, who were not relocated or evacuated, living in contaminated areas where efforts to reduce exposures will be ongoing. Implicit in these decisions is the ability to balance health protection with the desire of the community to resume normal life.
Radiation protection considerations must be addressed in concert with health, environmental, economic, social, psychological, cultural, ethical, political and other considerations. Many federal, state, and local agencies have important roles to play. It is recognized that experience from existing programs, such as the U.S. EPA's Superfund program, the U.S. NRC's process for decommissioning and decontamination to terminate a nuclear facility license and other national recommendations may be useful for designing cleanup and recovery efforts that could apply to a radiological incident. The cleanup process described in Chapter 4, however, does not rely on and does not affect any authority, including the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), 42 U.S.C. 9601 et seq. and the National Contingency Plan (NCP), 40 CFR Part 300. For information on roles, responsibilities and authorities during emergency response and recovery please refer to the National Response Framework: http://www.fema.gov/national-response-framework and specifically for radiological incidents, the Nuclear Radiological Incident Annex: http://www.fema.gov/pdf/about/divisions/thd/IncidentNucRad.pdf (FEMA 2008a, b).

The late phase or cleanup process described in Chapter 4 consists of multiple steps, namely 1) characterization and stabilization, 2) development of goals and strategies and 3) implementation and reoccupancy; meaningful stakeholder involvement should be integrated *throughout* the process.

While radioactive waste handling and disposal will be an ongoing endeavor during the entire emergency response, brief planning guidance is provided in Chapter 4, the late phase. This guidance addresses both locations that may be identified by state and local officials and locations owned by the federal government, and lists criteria for evaluating their suitability for disposal, as well as actions that can be taken to facilitate their use. Legal and other considerations are also discussed. This guidance assumes that on-site disposal at a location affected by the incident, where appropriate, will be one of the locations of choice. Though recommended as the first consideration for discussion post-accident or attack, this guidance assumes that existing non-federal radioactive waste disposal capacity already available to impacted states and their regions is overwhelmed or otherwise eliminated from consideration, which drives the need to identify other disposal options or develop new disposal capacity.

KEY POINTS IN CHATER 1 – OVERVIEW

- A PAG is the projected dose to an individual from a release of radioactive material at which a specific protective action to reduce or avoid that dose is recommended. PAGs are guides to help officials select protective actions under emergency conditions when exposures would occur over relatively short time periods.
- EPA provides the PAG Manual to assist public officials with their radiological emergency response planning activities. The PAG Manual is a guidance document, not a legally binding regulation and does not affect or supersede any environmental laws. The PAG recommendations do not represent the boundary between safe and unsafe conditions.
- PAGs may be implemented to protect the public in a wide variety of radiological emergencies, including terrorist incidents and accidents involving nuclear power plants, transportation and the space program.
- PAGs are appropriate for implementation in the early and intermediate phases of radiological incidents. The early phase—lasting hours to days—is the period beginning at the projected (or actual) initiation of a release when immediate decisions for effective use of protective actions are required and must therefore be based primarily on the status of the release and the prognosis for worsening conditions. Little environmental data may be available in the early phase. The intermediate phase—lasting weeks to months—is the period beginning after the source and releases have been brought under control and environmental measurements are available for use as a basis for decisions on protective actions.
- Reentry and reoccupancy decisions will be made using incident-specific circumstances and the Operational Guidelines (DOE 2009).
- Cleanup and waste disposal decisions may be informed by planning guidance provided in Chapter 4.
- What's new in this updated Manual—
  - The PAGs in this Manual are implemented using the calculations and methods in the FRMAC Assessment Manual. Dosimetry in that Manual has been updated using the ICRP Publication 60 series (ICRP 1991).
  - EPA adopts the FDA guidance issued in 2001 that recommended lowering the projected thyroid dose at which the administration of KI is warranted as a supplementary protective action.
  - EPA provides a two- tier drinking water PAG and recommended water system remedies.
  - EPA adopts the 1998 FDA Food PAGs.
  - Planning guidance has been provided for reentry, late phase cleanup and waste disposal.

Chapter 2 – Early Phase Protective Action Guides

2.1. INTRODUCTION

Decisions regarding protective actions for workers and the public during radiological incidents are risk management decisions and the recommendations in this Manual are provided in that context. Rapid action may be required to protect members of the public in the event of an incident involving a large release of radioactive materials into the environment. In all cases, all practical and reasonable means should be used to reduce or eliminate exposures.

This chapter presents PAGs for use in the early phase of a radiological incident. A PAG is the projected dose to an individual from a release of radioactive material at which a specific protective action should be taken to reduce or avoid that dose. The early phase begins at the actual or projected start of a release—most likely before ambient environmental and radiological data become available for quantitative risk-based actions. The exact duration of the early phase depends upon site conditions, but one should plan to project doses for four days.

Many radiological emergency scenarios would involve airborne releases, so this chapter provides guidance for estimating projected doses from exposure to an airborne plume of radioactive material and for implementing protective actions. Dose calculations for implementing the PAGs are made using the dose ~~conversion factors (DCFs)~~ dose parameters (DPs) and derived response level (DRL) methods referenced in the FRMAC Assessment Manuals (DOE 2010a, b).[6] Note that FRMAC now refers to dose parameters in emergency response dose assessment methods to avoid confusion with dose conversion factors published for radiation protection in general. Other calculation methods to implement PAGs may be appropriate.

2.2. EXPOSURE PATHWAYS DURING THE EARLY PHASE

During the early phase of an incident, there are three main exposure pathways from airborne releases—

- **Direct exposure** to radioactive materials in an atmospheric plume. The contents of such a plume will depend on the source of radiation involved and conditions of the incident. For example, in the case of an incident at an NPP, the plume may contain radioactive noble gases, radioiodines and radioactive particulate materials. Many of these materials emit gamma radiation that can expose people in the vicinity of the passing plume.
- **Inhalation** of radionuclides from immersion in a radioactive atmospheric plume and inhalation of ground-deposited radionuclides that are resuspended into a breathing zone. Inhaled radioactive particulates, depending on their solubility in body fluids, may remain in the lungs or move via the bloodstream to other organs, prior to elimination from the body. Some radionuclides become concentrated in a single body organ, with only small amounts going to other organs. For example, a significant fraction of inhaled radioiodines will move through the bloodstream to the thyroid gland.
- **Deposition** of radioiodine and particulates from a radioactive plume. Deposited materials can continue to emit "groundshine" (e.g., beta and gamma radiation) after the plume has passed causing continued exposure to skin and internal body organs. ~~Deposited materials can continue to emit beta and gamma radiation as "groundshine" after the plume has passed causing continued exposure to skin and internal body organs~~. Similarly, skin and clothes may become contaminated.

A plume may deposit materials on surfaces, posing a risk of longer-term exposures via ingestion, direct external exposure and inhalation pathways. If the release contains large quantities of radioactive iodines

[6] See FRMAC Assessment folder at http://www.nv.doe.gov/nationalsecurity/homelandsecurity/frmac/manuals.aspx.

or particulates, the resulting long-term exposure to this "groundshine" can be more significant than external exposure from the passing plume if the exposure time to the ground contamination is long in comparison to the plume passage time. The early phase PAGs assume four days of exposure to ground contamination to address this possibility. Doses from groundshine can be readily measured by field monitoring teams dispatched at the onset of a significant radioactive release. Holding a detector probe horizontal and three feet above the contaminated surface provides a direct measurement of groundshine dose. Such assessments can confirm dose projections based upon effluent release data and the adequacy of protective actions in the early phase. More detailed analyses (e.g., isotopic) would be needed to support long-term dose projections in the intermediate phase. Doses for groundshine can be calculated during the intermediate phase (see Chapter 3). Exposure pathways that contribute less than ten percent to the total dose incurred need not be considered during the early phase.

2.2.1. The Establishment of Exposure Patterns

It is unlikely that sufficient environmental data will be available for accurate dose projections during and immediately following the early response to a radiological incident. Dose projections are needed to determine whether protective actions should be implemented in additional areas during the early phase.

For dose projections in the early phase there are two sources of data: current data from initial environmental measurements or estimates of the source term and estimated data using modeled or historical atmospheric transport data. Source term measurements, or exposure rates or concentrations measured in the plume at a few selected locations, may be used to estimate the extent of the exposed area in a variety of ways, depending on the types of data and computation methods available. The most accurate method of projecting doses is through the use of an atmospheric diffusion and transport model that has been verified for use at the site in question or for similar site conditions. A variety of computer software packages can be used to estimate dose in real time, or to extrapolate a series of previously-prepared isopleths for unit releases under various meteorological conditions. The latter can be adjusted for the estimated source magnitude or environmental measurements at a few locations during the incident. If the model projections have some semblance of consistency with environmental measurements, extrapolation to other distances and areas can be made with greater confidence. If projections using a sophisticated site-specific model are not available, a simple but crude method is to measure the plume centerline exposure rate[7] at ground level (measured at approximately 1 m height) at a known distance downwind from the release point and then to calculate exposure rates at other downwind locations by assuming that the plume centerline exposure rate is a known function of the distance from the release point.

The following relationship can be used for this calculation:

$$D_2 = D_1 (R_1/R_2)_y$$

where D_1 and D_2 are exposure rates at the centerline of the plume at distances R_1 and R_2 from the release, respectively and y is a constant that depends on atmospheric stability. For stability classes[8] A and B, y = 2; for stability classes C and D, y = 1.5; and for stability classes E and F, y = 1. Classes A and B (unstable) occur with light winds and strong sunlight and classes E and F (stable) with light winds at night. Classes C and D generally occur with winds stronger than about 10 mph. This method of extrapolation is risky because the measurements available at the reference distance may be unrepresentative, especially if the plume is aloft and has a looping behavior. In the case of an elevated plume, the ground level concentration increases with distance from the source and then decreases,

[7] The centerline exposure rate can be determined by traversing the plume at a point sufficiently far downwind that it has stabilized (usually more than one mile from the release point) while taking continuous exposure rate measurements.

[8] Pasquill stability classes categorize atmospheric turbulence into six stability classes named A, B, C, D, E and F, class A being the most unstable or most turbulence and class F the most stable or least turbulence. Pasquill, F. 1961. The Estimation of the Dispersion of Windborne Material. The Meteorological Magazine 90, No. 1063, 33-49.

whereas any high-energy gamma radiation from the overhead cloud continuously decreases with distance. For these reasons, this method of extrapolation will perform best for surface releases or if the point of measurement for an elevated release is sufficiently distant (usually more than 1 mile) from the point of release for the plume to have expanded to ground level. The accuracy of this method will be improved by the use of measurements from many locations averaged over time.

2.3. THE PROTECTIVE ACTION GUIDES AND PROTECTIVE ACTIONS FOR THE EARLY PHASE: EVACUATION, SHELTERING-IN-PLACE AND ADMINISTRATION OF POTASSIUM IODIDE

The principal protective actions for the early phase are evacuation or sheltering-in-place. Evacuation is the urgent removal of people from an area to avoid or reduce high-level, short-term exposure from the plume or deposited activity. Sheltering-in-place is the action of staying or going indoors immediately. The administration of KI (stable iodine) to partially block the uptake of radioiodines by the thyroid is a supplemental protective action.

In addition, washing the body and changing clothing as soon as possible after significant exposure to a radioactive plume of any composition may be recommended protective actions. Changing of clothing is recommended primarily to provide protection from beta radiation from radioiodines and particulate materials deposited on the clothing.

The PAGs and corresponding protective actions for response during the early phase of an incident are summarized in Table 2-1. Evacuation or sheltering-in-place will be justified when the projected dose to an individual is 1 rem (10 mSv) projected over four days. This conclusion is based primarily on EPA's determination concerning acceptable levels of risk of health effects from radiation exposure in an emergency situation, while weighing costs and risks associated with any protective action. ~~The basis for the PAGs for the early phase is given in Appendix C of the 1992 PAG Manual, available online as a historical reference at http://www.epa.gov/radiation/rert/pags.html.~~

Table 2-1. PAGs and Protective Actions for the Early Phase of a Radiological Incident

Protective Action Response	PAG (projected dose)	Comments
Sheltering-in-place or evacuation of the public[a]	1 to 5 rem (10 mSv to 50 mSv) over four days[b]	Evacuation (or, for some situations, sheltering-in-place) should be initiated when projected dose is 1 rem (10 mSv).
Supplementary administration of prophylactic drugs – KI[c]	5 rem (50 mSv) projected dose to child thyroid from exposure to iodine[d]	KI is most effective if taken prior to exposure. May require approval of state medical officials (or in accordance with established emergency plans).

[a]Should begin at 1 rem (10 mSv) if advantageous except when practical or safety considerations warrant using 5 rem (50 mSv); take whichever action (or combination of actions) that results in the lowest exposure for the majority of the population. Sheltering may begin at lower levels if advantageous.

[B]Calculated dose is the projected sum of the effective dose from external radiation exposure (i.e., groundshine and plume submersion) and the committed effective dose from inhaled radioactive material.

[c]Provides thyroid protection from radioactive iodines only. For other information on radiological prophylactics and treatment, refer to http://www.fda.gov/Drugs/EmergencyPreparedness/BioterrorismandDrugPreparedness, http://www.emergency.cdc.gov/radiation or http://www.orau.gov/reacts.

[d]~~Thyroid equivalent dose (see Section 2.3.5).~~ Thyroid dose (see Section 2.3.4)

2.3.1. Thyroid Based Evacuation

This revised PAG Manual does not include a footnote from the 1992 PAG Manual Early Phase PAG table, which noted that 'thyroid and skin may be 5 and 50 times larger, respectively.' That footnote effectively provided organ dose based evacuation thresholds in addition to the whole-body dose PAG range of 1 to 5 rem (10 to 50 mSv). Because of the factors described above, these organ dose based Early Phase PAGs are not necessary.

Regarding sensitive subpopulations, child thyroid doses typically are about twice as high as adult thyroid doses. The former range recommended for thyroid dose-based evacuation (5 to 25 rem adult thyroid dose) is well covered by projections of whole body dose, with evacuation recommended at 1 to 5 rem (10 to 50 mSv) adult TED. The conservatism built into the PAG levels when they were set ensures protection of the whole community when evacuation is based on these PAGs. Planners should consider instituting public messaging templates in advance to address concerns the public may have about how protective the PAG recommendations are for all members of an impacted community.

The PAG Manual is guidance, and intentionally not prescriptive. This set of recommendations does not preclude an emergency manager from setting local or state protective action guidelines for actions based on specific organ or age group dose levels, as warranted by specific needs of that community

2.1.1. Basis for Early Phase PAGs

For a full description of the risk-benefit analysis used to set the PAG levels, refer to the 1992 PAG Manual, Appendices B, C and E. The Manual is available online in a searchable format. Below is a short summary on the basis for the Early Phase evacuation/sheltering PAG of 1 to 5 rem (10 to 50 mSv) projected over 4 days.

PAGs are intended to apply to all individuals in a population other than workers performing emergency services. However, there may be identifiable groups that have different average sensitivity to radiation or, because of their living situation, will receive higher or lower doses. In addition, some groups may be at greater risk from taking a given protective action. Special circumstances and age groups (e.g., fetal dose) were considered, when appropriate, in establishing values for the PAGs.

The following four principles provided the basis for establishing values for Protective Action Guides:

1. Acute effects on health (those that would be observable within a short period of time and which have a dose threshold below which they are not likely to occur) should be avoided.
2. The risk of delayed effects on health (primarily cancer and genetic effects, for which linear non-threshold relationships to dose are assumed) should not exceed upper bounds that are judged to be adequately protective of public health, under emergency conditions, and are reasonably achievable.
3. PAGs should not be higher than justified on the basis of optimization of cost and the collective risk of effects on health. That is, any reduction of risk to public health achievable at acceptable cost should be carried out.
4. Regardless of the above principles, the risk to health from a protective action should not itself exceed the risk to health from the dose that would be avoided.

EPA considered the acceptable range of costs for avoiding a statistical death from pollutants other than radiation and using a rounded value from the BEIR III risk of 0.0003 cancer deaths per person-rem. Further evaluation of thyroid, skin and fetal dose consequences was conducted as well.

Costs of evacuation:

Based on a prior published study ("An Analysis of Evacuation Options for Nuclear Accidents, EPA 520/1-87-023, 1987) evaluating evacuation options for several accident types, this analysis focused on the smallest category of fuel melt accident yielding effective dose equivalents during the first 4 days of exposure that are greater than 0.5 rem outside the assumed 2-mile evacuation circle for all stability classes. For this scenario, total and incremental costs were calculated for several different sized evacuation areas. Data on costs versus dose avoided for several meteorological stability classes and evacuation options (sizes) were summarized in tables in the 1992 PAG Manual, Appendix C.

For a risk of 0.0003 cancer deaths per person-rem, the range of evacuation costs can be compared to the marginal cost-effectiveness (dollars per person-rem) of evacuation over an angle of 90 degrees. The resulting ranges of upper bounds on dose are in tables in Appendix C, for three different accident scenarios. The maximum upper bounds (based on minimum costs for avoiding risk) range from 1 to 10 rem, with most values being approximately 5 rem. The minimum upper bounds (based on maximum costs for avoiding risk) range from 0.15 to 0.8 rem, with 0.5 rem dose incurred being representative of most situations.

From these data we conclude that, based on the cost of evacuation, a PAG larger than the range of values 0.5 to 5 rem would be incompatible with Principle 3.

Based on comparison of exposures from evacuation versus the presumed alternative of sheltering in various building types for several timeframes, the dose actually avoided by evacuation is one half of the projected dose.

Risk from evacuation:

Principle 4 requires that the risk of the protective action not exceed the risk associated with the dose that will be avoided. Risk from evacuation can come from several sources, including (1) transportation incidents for both

pedestrians and vehicle passengers, (2) exposure to severe weather conditions or a competing disaster, and (3), in the case of immobile persons, anxiety, unusual activity, and separation from medical care or services. While all these factors must be considered, transportation incidents is the only category for which the risk has been quantified.

In a recent study of 230 mass evacuations in the U.S. ("Identification and Analysis of Factors Affecting Emergency Evacuations" NUREG/CR-6484, 2004) only six cases involved deaths from the hazard itself, and of these six, only one case involved deaths during the evacuation itself. Only two cases involved injuries during the evacuation. Traffic issues, such as traffic congestion, were reported in 28% of the evacuation cases studied. However, traffic accidents occurred in only 8% of the cases.
During the tsunami and nuclear disaster response in Japan in 2011, ## deaths occurred during evacuations, primarily among elderly hospital patients being moved from areas without power. Compounded disaster conditions including aftershocks, widespread power outages and radiation releases led to prolonged transit along routes extended to avoid hazards.

Conformance to Principle 1 (avoidance of acute health effects) is assured by the low risk required to satisfy Principle 2 (acceptable risk of delayed health effects), and thus requires no additional consideration. Based on Principle 2, evacuation of the general population is not justified below 0.5 rem. This represents a risk of about 0.0002 of fatal cancer. Maximum lifetime risk levels considered acceptable by EPA from routine operations of individual sources range from 0.000001 to 0.0001. Risk levels that are higher than this must be justified on the basis of the emergency nature of a situation. In this case, we judge that up to an order of magnitude higher combined risk from all phases of an incident may be justifiable. The choice of 0.5 rem avoided dose as an appropriate criterion for an acceptable level of risk during the early phase is a subjective judgment that includes consideration of possible contributions from exposure during other phases of the incident.

Principle 4 (risk from the protective action must be less than that from the radiation risk avoided) supplies a lower bound of 0.03 rem on the dose at which evacuation of most members of the public is justified. The lower bound was derived from the risk of death from traffic accidents in emergency evacuations, using the factor of 0.0003 cancer deaths per person-rem. Finally, under Principle 3 (cost/risk considerations) evacuation is justified only at values equal to or greater than 0.5 rem. This will be limiting unless lower values are required for purely health-based reasons (Principle 2). But this is not the case. The single lower purely health-based value, 0.1 rem, is only valid as a health-based criterion for chronic exposure.
In summary, we have selected the value 0.5 rem as the avoided dose which justifies evacuation, because 1) it limits the risk of delayed effects on health to levels adequately protective of public health under emergency conditions, 2) the cost of implementation is justified, and 3) it satisfies the two bounding requirements to avoid acute radiation effects and to avoid increasing risk through the protective action itself.
The value of the PAG for evacuation of the general public is therefore chosen as one rem projected total effective dose from inhalation of radionuclides and exposure to external radiation.

2.1.2. Evacuation vs. Sheltering-in-Place

Evacuation and sheltering-in-place provide different levels of dose reduction from the principal exposure pathways: direct gamma exposure and inhalation. Both sheltering and evacuation may be implemented during the same response in different areas or timeframes. Evacuation, if completed before plume arrival, can be 100 percent effective in avoiding radiation exposure. A decontamination station, with simple decontamination actions, may need to be collocated at shelters during the pre-evacuation period. This may reduce the spread of contamination and provide for greater protection during evacuation. Medical stations should also be collocated at shelters during the pre-evacuation period to ensure simple triage capabilities are met and to manage the distribution of prophylactic drugs. The effectiveness of evacuation will depend on many factors, such as how rapidly it can be implemented and the nature of the incident. For incidents where the principal source of dose is inhalation, evacuation could increase exposure if it is implemented during the passage of a short-term plume, because the air inside a vehicle rapidly equalizes with the outside air even when all of the windows and vents are closed. ~~since vehicles used to transport evacuees provide little protection against exposure~~ (DOE 1990).

Below 1 rem (10 mSv), evacuation is not recommended because of risks associated. ~~Evacuation will seldom be justified at less than 1 rem (10 mSv) over the first four days.~~

Sheltering-in-place is a low-cost, low-risk protective action that can provide protection with an efficiency ranging from zero to almost 100 percent, depending on the type of release, the type of shelter available, the duration of the plume passage and climatic conditions. Because of these advantages, planners and decision makers may consider implementing sheltering-in-place when projected doses are below 1 rem (10 mSv) over the first four days. More guidance on the unique challenges posed by an IND can be found in the "Planning Guidance for Response to a Nuclear Detonation" (NSS 2010).[9]

Sheltering-in-place may be preferred for special populations (e.g., those who are not readily mobile) as a protective action at projected doses of up to 5 rem (50 mSv) over four days. When environmental, physical, or weather hazards impede evacuation, sheltering-in-place may be justified at projected doses up to 5 rem (50 mSv) for the general population (and up to 10 rem (100 mSv) for special populations). It is also comparatively easy to communicate with populations that have sheltered-in-place. Dose projections use a four-day exposure duration, but sheltering in place duration is intentionally not specified. Incident-specific decisions must be made to determine how long people should shelter in place.

Selection of evacuation or sheltering-in-place is far from an exact science, particularly in light of time constraints that may prevent thorough analysis at the time of an incident. The selection process should be based on realistic or "best estimate" dose models and should take into account the unavoidable dose incurred during evacuation and potential failure scenarios for sheltering-in-place (e.g., leaking ventilation system).

Advance planning and exercises can facilitate the decision process. In a commercial NPP incident, early decisions should be based on information from the response plans for the EPZ and on actual conditions at the nuclear facility (see Section 2.3.5). For transportation accidents, RDDs, INDs and other incident scenarios for which EPZs are not practicable, best estimates of dose projections should be used for deciding on evacuation, sheltering-in-place or a combination thereof.

~~2.1.3. General Guidance for Evacuation and Sheltering-in-Place~~ Considerations for Evacuation

- The following is a summary of planning guidance for evacuation and sheltering-in-place—Evacuation may be the only effective protective action close to the plume source.
- Evacuation will be most effective if it is completed before arrival of the plume.
- Evacuation may increase exposure if carried out during the plume passage.
- Evacuation is also appropriate for protection from groundshine in areas with high exposure rates from deposited materials when suitable shelter is not available.
- Sheltering-in-place may be appropriate for areas not designated for immediate evacuation—
  - It may provide protection equal to or greater than evacuation for rapidly developing releases (e.g., RDDs) if followed by evacuation.
  - It positions the public to receive additional instructions.
  - Since it may be implemented rapidly, sheltering-in-place may be the protective action of choice (followed with evacuation when feasible) if rapid evacuation is impeded by:

Sheltering-in-place should be preferred to evacuation whenever it provides equal or greater protection.
Sheltering-in-place followed by informed evacuation may be most protective.

[9] See http://www.epa.gov/rpdweb00/docs/er/planning-guidance-for-response-to-nuclear-detonation-2-edition-final.pdf

- severe environmental conditions, e.g., severe weather or floods;
- uncertainty in contamination levels along routes;
- health constraints, e.g., patients and workers in hospitals and nursing homes;
- long mobilization times that may be associated with certain individuals, such as industrial and farm workers, or prisoners and guards;
- physical constraints to evacuation, e.g., inadequate roads or blockage due to debris.

- If a major release of radioiodine or particulate materials occurs, inhalation dose may be a controlling criterion for protective actions—
  - Breathing air filtered through common household items (e.g., folded handkerchiefs or towels) may help reduce exposures.
  - After confirmation that the plume has passed, continued sheltering-in-place should be re-evaluated. Shelters may ~~should~~ be opened to vent any airborne radioactivity trapped inside and people should remain sheltered until official notice about leaving high exposure areas as soon as possible to avoid exposure to deposited radioactive material.

2.1.4. Considerations for ~~Evacuation and~~ Sheltering In Place

Advance planning is essential to identify potential problems that may occur in an evacuation. An NRC case study cites the following aspects of planning as contributing to efficiency and effectiveness of evacuation (NRC 2005)—

- High level of cooperation among agencies.
- Use of multiple forms of emergency communications.
- Community familiarity with alerting methods, the nature of the hazard and evacuation procedures.
- Community communication.
- Well-trained ~~emergency responders~~ emergency workers.

The NRC 2005 study included an evaluation of 50 incidents of public evacuation involving 1,000 or more people. The evacuations studied were initiated in response to natural disasters, technological hazards and malevolent acts occurring between January 1, 1990 and June 30, 2003. The report indicated that public familiarity with alerting methods and door-to-door notification were statistically significant factors for the efficiency of evacuation. The report also indicated that many communities are making improvements to response capabilities by modernizing communication systems, improving traffic flow, local education awareness and developing interagency and cross-boundary coordination plans.

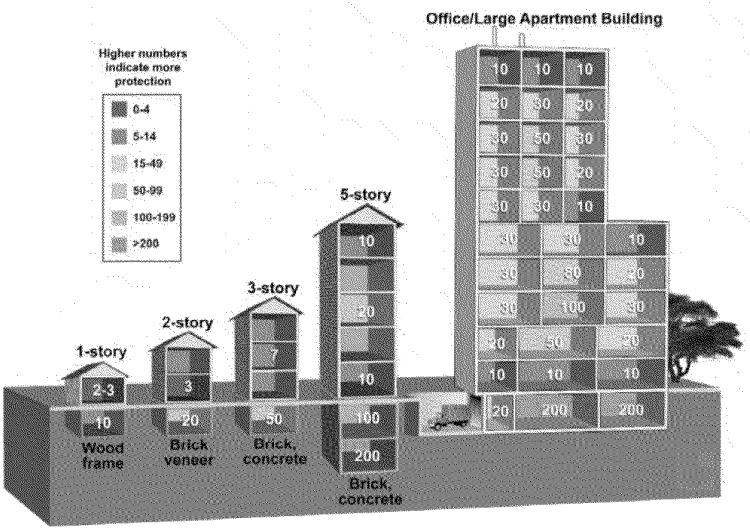
~~Regardless of size,~~ Large or small population groups can be evacuated effectively with minimal risk of injury or death. In the NRC report, only six of the 50 cases studied involved deaths from the hazard and of those six, only one involved death from the evacuation itself (NRC 2005).

However, in 2005, not long after this report was published, the gulf coast of the United States was hit by a series of hurricanes that resulted in the evacuation of approximately 5 million people. During the evacuation that accompanied Hurricane Rita in Houston, Texas, 106 people were reported to have died as a direct result of the evacuation. It is estimated that at least two-thirds of the evacuees did not need to evacuate but did so because of poor communication, fear and poor traffic management (NRC 2008).

The emergency planning process for radiological incidents should include effective traffic management plans and communications plans, including pre-scripted messages, provisions for evacuation of special needs populations, such as children in schools and child care facilities, people in institutions and people who have impaired mobility or lack personal transportation.

The degree of protection provided by structures is affected by factors such as attenuation of gamma radiation (shielding) by structural components (the mass of walls, ceilings, etc.) and outside/inside air exchange rates (see Figure 2-1). The use of large structures, such as shopping centers, schools, churches and commercial buildings, as collection points during evacuation mobilization will generally provide greater protection against gamma radiation than use of small structures. As with evacuation, delay in taking shelter during plume passage will result in higher exposure to radiation.

Figure 2-1: Exposure reduction from external radiation from nuclear fallout as a function of building type and location.



The numbers represent dose reduction factors. A dose reduction factor of 10 indicates that a person in that area would receive 1/10th of the dose of a person in the open. A dose reduction factor of 200 indicates that a person in that area would receive 1/200th of the dose of a person out in the open.
Figure taken from *Planning Guidance for Response to a Nuclear Detonation, Second Edition*, National Security Staff Interagency Policy Coordination Subcommittee for Preparedness and Response to Radiological and Nuclear Threats, June 2010, courtesy of Lawrence Livermore National Laboratory. The protection factors in this figure are specific to nuclear detonation fallout, but the variations in factors throughout typical buildings may be informative for other airborne radiological releases.

2.1.5. Consideration for Potassium Iodide (KI)

FDA updated its guidance on the use of KI as a thyroid blocking agent during radiological emergencies in 2001 (FDA 2001[10] and FDA 2002[11]). FDA based these dose recommendations on a review of the thyroid cancer data from the Chernobyl reactor accident of April 1986 and the experience of Poland in administering KI following the Chernobyl release (FDA 2001).

[10] Food and Drug Administration (US)[FDA]. Guidance Potassium Iodide as a Thyroid Blocking Agent in Radiation Emergencies. Federal Register, 66, 64045: 2001.
[11] Food and Drug Administration (US)[FDA]. Guidance for Industry - KI in Radiation Emergencies -- Questions and Answers. Food and Drug Administration, Center for Drug Evaluation and Research. Procedural, Revision 1. Rockville, MD, (2002).

Threshold Thyroid Radioactive Exposures and Recommended Doses of KI for Different Risk Groups				
	Predicted Thyroid exposure(cGy)	KI dose (mg)	# of 130 mg tablets	# of 65 mg tablets
Adults over 40 yrs	>500	130	1	2
Adults over 18 through 40 yrs	≥10			
Pregnant or lactating women	≥5			
Adoles. Over 12 through 18 yrs*		65	1/2	1
Children over 3 through 12 yrs				
Over 1 month through 3 yrs		32	1/4	1/2
Birth through 1 month		16	1/8	1/4

However, FDA understands that a KI administration program that sets different projected thyroid radioactive exposure thresholds for treatment of different population groups may be logistically impractical to implement during a radiological emergency. In such cases, FDA recommends that KI be administered to both children and adults at the lowest intervention threshold (i.e., >5 rem (50 mSv) projected internal thyroid exposure in children)[12] (FDA 2002).

Regarding dosage of KI, FDA's guidance adheres to principles of minimum effective dose and therefore recommends graded dosing according to age (and thus, in effect, body size). There is ample evidence that the recommended doses, as well as higher doses (e.g., up to 130 mg), will effectively block thyroidal uptake of radioactive iodine if taken in advance of exposure. Furthermore, particularly among school-age children, higher milligram doses are extremely safe. However, FDA continues to emphasize attention to KI dosing in infants. Excess iodine intake can lead to transient iodine-induced hypothyroidism. Individuals who are intolerant of KI at protective doses, as well as neonates, pregnant, and lactating women, should be given priority with regard to other protective measures (i.e., sheltering, evacuation, and control of the food supply). In summary, if local emergency planners conclude that graded dosing is logistically impractical, FDA believes that for populations at risk for radioiodine exposure, the overall benefits of taking up to 130 mg of KI instead of the lower doses recommended for certain age groups far exceed the small risks of overdosing. However, where feasible, adherence to FDA guidance should be attempted when dosing infants." (FDA 2002).

Note that KI is effective only against uptake of radioiodine, and is best taken prior to or just after exposure. The protective effect of a single dose of KI lasts approximately 24 hours. It should be administered daily until the risk of significant exposure to radioiodine (either by

[12] Food and Drug Administration (US)[FDA]. Guidance for Industry - KI in Radiation Emergencies -- Questions and Answers. Food and Drug Administration, Center for Drug Evaluation and Research. Procedural, Revision 1. Rockville, MD, (2002).

inhalation or ingestion) no longer exists, i.e., once the plume has passed. KI is a supplemental action, secondary to evacuation or sheltering. It should not be used as a substitute for evacuation or sheltering. Many communities do not use KI.

It should be noted that adults over 40 need to take KI only in the case of a projected large internal radiation dose to the thyroid (>500 rem (5 Sv) to prevent hypothyroidism which could lead to lifelong dependence on thyroid hormone replacement therapy. Thyroid irradiation in adults over 40 years of age is associated with an extremely low incidence of cancer (FDA 2001).

Some people should not take KI. As a rule, individuals with known allergy to iodine or with pre-existing thyroid disease (e.g., Graves' disease, thyroid nodules, Hashimoto's thyroiditis) that might predispose them to adverse reactions should avoid KI. Allergies to iodine and to shellfish are not related. People allergic to shellfish need not worry about cross reactions with stable iodine. More information is available at: http://www.foodallergy.org/allergens/shellfish-allergy and http://www.acaai.org/allergist/Resources/ask-allergist/Pages/Is_Shellfish_Allergy_Related_to_Iodine.aspx

Pregnant women should be given KI for their own protection and for that of the fetus, as iodine (whether stable or radioactive) readily crosses the placenta. However, because of the risk of blocking fetal thyroid function with excess stable iodine, repeat dosing with KI of pregnant women should be avoided.

Lactating females should be administered KI for their own protection, as for other young adults, and potentially to reduce the radioiodine content of the breast milk, but not as a means to deliver KI to infants, who should get their KI directly. As for direct administration of KI, stable iodine as a component of breast milk may also pose a risk of hypothyroidism in nursing neonates. Therefore, repeat dosing with KI should be avoided in the lactating mother, except during continuing severe contamination. If repeat dosing of the mother is necessary, the nursing neonate should be monitored.

Once the plume has passed, protective actions such as evacuation and/or sheltering-in-place and food control measures to limit exposure to radioiodine should be implemented and the administration of KI should be suspended. Food control measures include providing the public with non-contaminated food supplies while awaiting the eventual radioactive decay of contaminated food. Consumption of contaminated food may be permitted on a case-by-case basis after surveying the foodstuffs and determining the level of contamination consistent with FDA food and animal feeds guidance. As a result of radioactive decay, grain products and canned milk and vegetables from sources affected by radioactive fallout will not present a risk from radioiodine if they have been stored for weeks to months after production.

An RDD is not likely to contain radioiodine, so administration of KI would not be necessary in such incidents. The administration of other prophylactic drugs should be evaluated on a case-by-case basis depending on the nature of the event and the radioisotopes involved. For more information on radiological prophylactics and treatments, see: http://www.fda.gov/Drugs/EmergencyPreparedness/BioterrorismandDrugPreparedness.

2.1.6. PAGs and Nuclear Facilities Emergency Planning Zones (EPZ)

Under NRC regulations, before a nuclear power reactor may be issued a license, the NRC must find that licensee, state and local emergency plans are adequate and that they can be implemented. For nuclear power reactors, there is a plume exposure EPZ within a 10 mile (16.1 km) radius of the plant and for a separate ingestion pathway EPZ within a 50 mile (80.5 km) radius. The sizes of these EPZs were developed by the NRC/EPA Task Force Report on Emergency Planning, NUREG-0396/EPA 520/1-7-016 and are based, in part, on the numerical values of the PAGs for the plume exposure and ingestion pathway EPZ. The licensee develops and maintains a detailed emergency plan for its facility while state and local authorities within the EPZ develop and maintain detailed emergency response plans for their respective jurisdictions. Guidance to these licensees, states and local agencies for developing these emergency response plans, including guidance on arrangements for implementing immediate protective actions is primarily contained in NUREG-0654/FEMA-REP-1 (NRC 1980)[13] and supplemented with other guidance issued by NRC (for licensees) and FEMA (for off-site response organizations).

Planning for incidents at other types of nuclear facilities should be developed using similar considerations. Emergency preparedness requirements for non-power reactors (e.g., test and research facilities) are provided in 10 CFR Part 50 Appendix E with supporting guidance in NRC Regulatory Guide 2.6, "Emergency Planning for Research and Test Reactors." Emergency preparedness requirements for fuel cycle and materials facilities are provided in 10 CFR Parts 30, 40, and 70 with supporting guidance in NRC Regulatory Guide 3.67, "Standard Format and Content for Emergency Plans for Fuel Cycle and Materials Facilities." Because of the relatively limited number and diverse nature of these facilities, the size of the EPZs, is determined, if needed, on a case-by-case basis for reactors with an authorized power level less than 250 MW thermal.

Within an EPZ, an area should be pre-designated for immediate response based on specified plant conditions prior to a release, or, given a release, prior to the availability of information on quantities of radioactive materials released. The shape of this area will depend on local topography, as well as political and other boundaries. Additional areas of the EPZ, particularly in the downwind direction, may require evacuation or sheltering-in-place, as determined by dose projections. The size of these areas will be based on the potential magnitude of the release and on an angular spread determined by meteorological conditions and any other relevant factors.

The pre-designated areas for immediate protective action may be reserved for use only in the most severe incidents and in cases when the facility operator cannot provide a quick estimate of projected dose based on actual releases. For lesser incidents, or if the facility operator is able to provide prompt off-site dose projections, the area for immediate protective action may be specified at the time of the incident instead of using a pre-designated area. Regardless of the basis for the initial protective action, radiological assessments need to continue through the duration of the event and if warranted, the initial protective actions extended into additional geographical areas.

Such prompt off-site dose projections may be possible when the facility operator can estimate the potential off-site dose based on information at the facility, using relationships developed during planning that relate abnormal plant conditions and meteorological conditions to potential off-site doses. After the release starts and the release rate is measurable, or when plant conditions or measurements can be used to estimate the characteristics and rate of the release, then these factors, along with atmospheric stability, the accuracy of these methods for estimating projected dose will be uncertain prior to confirmatory field measurements because of unknown or uncertain factors affecting environmental pathways, inadequacies

[13] Immediate protective actions based on in-plant conditions and EPZs established by NUREG-0654/FEMA-REP-1 are not applicable to naval nuclear propulsion plants. The largest naval reactors are rated at less than one-fifth of a large U.S. commercial NPP. In addition, since reactor power is directly linked to propulsion requirements, naval nuclear propulsion plants typically operate at low power when the ship is close to shore where high speeds are not required and are normally shut down when in port. Therefore, less than about 1% of the radioactivity contained in a typical commercial NPP could be released from a naval nuclear propulsion plant, limiting the possible dose to the general public and the size of the area of potential concern. Therefore, there is no need for towns and cities to have special emergency response plans such as those required for cities near commercial NPPs.

of computer modeling and uncertainty in the data for release terms.

The EPZs should be large enough to cover affected urban and rural areas and accommodate the various organizations needed for emergency response.[14] Although the size of the EPZ is based on the maximum distance at which a PAG might be exceeded, the actual boundary of an EPZ should be demarcated by features readily identifiable by people within that area. Such boundaries generally include major topographical features (e.g., rivers, roads, transmission line corridors, rail rights of way) and political boundaries. The EPZ should be further subdivided, using similarly identifiable features, to facilitate implementing protective actions when the entire EPZ is not affected. Maps, showing the boundaries of the EPZ and the sub-areas and evacuation routes should be provided to the public within the EPZ on a periodic basis in a format that will likely be available if the emergency occurs (e.g., inserted sections in local phone directories, wall calendars, etc.) EPZs are not necessary at those facilities where it is not possible for PAGs to be exceeded off-site.

2.2. DOSE PROJECTIONS

The PAGs in this chapter are specified in terms of the projected whole body dose. This projected dose is the sum of the effective dose from external exposure to the plume and the committed effective dose from inhaled radionuclides. Guidance is also provided on the thyroid equivalent dose. Further references to effective or organ dose equivalent refer to these two quantities, respectively. The FRMAC Assessment Manuals (DOE 2010a, b)[15] provide detailed methods for estimating projected dose. These methods require knowledge of, or assumptions for, the intensity and duration of exposure and make use of standard assumptions on the relation, for each radioisotope, between exposure and dose. Exposure and dose projections should be based on the best estimates available. The FRMAC methods and models may be modified as necessary for specific sites for improved accuracy. Emergency response organizations are encouraged to use the most current, applicable tools and methods for implementing PAGs.

2.2.1. Dose Projection during the Early Phase

PAGs are expressed in terms of projected dose. The calculation of projected doses should be based on realistic dose models, to the extent practicable. Public protection decisions should be based upon the dose that can be avoided (i.e., avoidable dose) by taking some protective action (e.g., evacuation, sheltering). Unavoidable dose or doses incurred before the start of the protective action being considered generally should not be included in evaluating the need for protective action. Similarly, doses that may be incurred at later times than those affected by the specific protective action should not be included. As noted earlier, the projection of doses in the early phase needs to include only those exposure pathways that contribute a significant fraction (i.e., more than 10 percent) of the dose to an individual.

In the early phase of an incident, parameters other than projected dose may provide a more appropriate basis for decisions to implement protective actions. When a facility is operating outside its design basis and a substantial release to the environment has started, or is imminent but has not yet occurred, data adequate to directly estimate the projected dose may not be available. Emergency response plans should anticipate specific conditions at the source of a potential release and the possible consequences off-site. Emergency response plans for NPPs and facilities should make use of emergency action levels (EALs), based on in-plant conditions, to trigger notification and initial protective action recommendations to off-site officials.[16] Once the initial protective actions have been implemented, accident assessment should continue. Although initial assessments may be uncertain, the subsequent assessments will be less

[14] The development of EPZs for nuclear power facilities is discussed in the NUREG 0396.

[15] See FRMAC Assessment folder at http://www.nv.doe.gov/nationalsecurity/homelandsecurity/frmac/manuals.aspx.

[16] Immediate protective actions based on in-plant conditions are not applicable to naval nuclear propulsion plants. See Footnote 7 for additional information. In addition, because of differences in design and operation, EALs based on in-plant conditions are not applicable to naval nuclear propulsion plants.

uncertain as additional information on facility condition and prognosis, effluent radiation monitor data and environmental data become available. The results of these continuing radiological assessments, including dose projections, should be used as the basis for refining the initial protective actions. In the case of transportation accidents, an RDD or IND, or other incidents that are not related to a facility, it may not be practicable to establish EALs.

Doses that may be incurred from ingestion of food and water, long-term radiation exposure (i.e., longer than four days), radiation exposure to deposited radioactive materials, or long-term inhalation of resuspended materials are chronic exposures for which neither emergency evacuation nor sheltering-in-place are appropriate protective actions. PAGs for the intermediate phase cover these exposure pathways (see Chapter 3).

2.2.2. Duration of Exposure

The projected dose for comparison to the early phase PAGs is calculated for exposure during the first four days following the anticipated (or actual) start of a release. The objective is to encompass the entire period of exposure to the plume and deposited material prior to implementation of any further, longer-term protective action such as relocation. For planning purposes, the four-day period is chosen as the duration of exposure during the early phase because it is a reasonable estimate of the time necessary to make measurements, reach decisions and prepare to implement further protective actions (such as relocation) if necessary. However, officials at the site at the time of the emergency may decide that a different time frame is more appropriate.

For example, doses incurred through ingestion pathways or long-term exposure to deposited radioactive materials take place over a longer time period. Protective actions for such exposures should be based on guidance addressed in Chapter 3.

The projected dose from each radionuclide in a plume is proportional to the time-integrated concentration of the radionuclide in the plume at each location. This concentration will depend on the rate and the duration of the release and meteorological conditions. Release rates will vary with time and this time-dependence cannot usually be predicted accurately. In the absence of more specific information, the release rate may be assumed to be constant.

Another factor affecting the estimation of projected dose is the duration of the plume at a particular location. For purposes of calculating projected dose from most pathways, exposure will start at a particular location when the plume arrives and will end when the plume is no longer present. Exposure from deposited materials will continue for an extended period as long as people are present. Other factors such as the aerodynamic diameter and solubility of particles, shape of the plume and terrain may also affect estimated dose and may be considered on a site- or source- specific basis.

Prediction of time frames for releases is difficult because of the wide range associated with the spectrum of potential incidents. Therefore, planners should consider the possible time periods between an initiating event and arrival of a plume and the duration of releases in relation to the time needed to implement competing protective actions (i.e., evacuation and sheltering-in-place). Analyses of commercial nuclear power reactors (NRC 1975) have shown that some incidents may take several days to develop to the point of a release while others may begin as early as a half hour after an initiating event. Furthermore, the duration of a release may range from less than 1 hour to several days, with the major portion of the release likely occurring within the first day.

Wind speed also influences radiological exposure rates from a plume. As a general rule, air concentration is inversely related to the wind speed at the point of release. Concentrations are also affected by the turbulence of the air, which tends to increase with wind speed and sunlight and by wandering of the plume, which is greater at the lower wind speeds. This results in higher concentrations generally being

associated with low winds near the source and with moderate winds at larger distances. Higher wind speed also shortens the travel time of the plume. Planning information on time frames for releases from nuclear power facilities may be found in references NRC 1978 and EPA 1978. Time frames for releases from other facilities will depend on the characteristics of the facility.

2.2.3. Derived Response Levels and Dose Conversion Factors

A Derived Response Level (DRL) is a level of radioactivity in an environmental medium that would be expected to produce a dose equal to its corresponding PAG. Depending on the exposure pathway, many factors such as ground roughness, weathering and resuspension may be required to calculate the Dose Parameter (DP) that converts an environmental measurement into a projected dose over a given time period (e.g., Early Phase). ~~A Dose Conversion Factor (DCF) is any factor used to change an environmental measurement to dose in the units of concern. Depending on the exposure pathway, other factors besides the DCF may be required to convert an environmental measurement into a dose~~.

The FRMAC Assessment Manuals (DOE 2012)[17] provide guidance in calculating DRLs and DPs ~~DCFs~~ based on the ICRP dosimetry models (ICRP 60 series). In addition, the FRPCC encourages the use of computational tools such as DOE's Turbo FRMAC and NRC's Radiological Assessment System for Consequence Analysis (RASCAL) as well as other appropriate or more current tools to implement the PAGs.

2.2.4. Higher PAGs for Special Circumstances

Hazardous environmental conditions (e.g., severe weather or a competing disaster) could create transportation risks from evacuation that would be higher than normal. It is therefore appropriate to allow higher projected doses for evacuation decisions under these circumstances. In the absence of any definitive information on such higher risks from evacuation, we have arbitrarily assumed that it would be appropriate to increase the recommended projected dose for evacuation of the general population under hazardous environmental conditions up to a factor of five higher than that used under normal environmental conditions.

It is also recognized that people who are not readily mobile are at higher risk from evacuation than are average members of the population. It would be appropriate to adopt higher PAGs for evacuation of individuals who would be at greater risk from evacuation itself than for the typically healthy members of the population, who are at low risk from evacuation. In the absence of definitive information on the higher risk associated with the evacuation of this group, we have arbitrarily assumed that it is appropriate to adopt PAGs a factor of five higher for evacuation of high risk groups under normal environmental conditions. If both conditions exist, (high risk groups and hazardous environmental conditions) projected doses up to ten times higher than the PAGs for evacuation of the general population under normal conditions may be justified. These doses are expected to satisfy Principle 4 without violating Principles 1 and 3. Although they violate Principle 2, Principle 4 becomes, for such cases, the overriding consideration.

2.3. EMERGENCY WORKER PROTECTION

These emergency worker guidelines were developed for a wide range of possible radiological scenarios, from a small transportation accident that may impact a single roadway to an IND that could potentially impact a large geographic region. Therefore, the 5, 10 and 25 rem (50, 100 and 250 mSv) guidelines (Table 2-2) should not be viewed as inflexible limits applicable to the range of early phase emergency actions covered by this guidance. Because of the range of impacts and case-specific information needed, it is impossible to develop a single turn-back dose level for all responders to use in all events, especially those that involve lifesaving operations. Indeed, with proper preparedness measures (training, personal protective equipment (PPE), etc.) most radiological emergencies addressed by this document, even lifesaving operations, may be manageable within the 5 rem (50 mSv) occupational limit. Moreover,

[17] See FRMAC Assessment folder at http://www.nv.doe.gov/nationalsecurity/homelandsecurity/frmac/manuals.aspx.

Incident Commanders should make every effort to employ the ''as low as reasonably achievable'' (ALARA) principle after an incident. Still, in some incidents doses above the annual occupational 5 rem (50 mSv) dose limit may be unavoidable. For instance, in the case of a catastrophic incident, such as an IND, Incident Commanders may need to consider raising the lifesaving and valuable property (i.e., necessary for public welfare) emergency worker guidelines in order to prevent further loss of life and prevent the spread of massive destruction. It is essential that emergency workers have full knowledge of the associated risks prior to initiating emergency action and medical evaluation of emergency workers after such exposure.

Worker and public protection guidance and standards for normal operations are developed through risk management approaches and are implemented in federal and state regulations (e.g., 10 CFR Part 20; 10 CFR Part 835; 29 CFR Part 1910.1096). However, many factors or decision criteria in a radiological emergency differ from those in normal operations. Although there are times when implementation of standards or guidelines can cause or enhance other risks, these secondary risks can be controlled. Standards for normal operations provide a margin of safety that is greater than that in guidelines for emergency response because that margin can be provided in a manner that ensures no significant increase in public health risk or detriment to the public welfare. Currently, the development of standards and guidelines for normal operations is done in a manner that provides reasonable assurance that implementation of the standards will not cause more risk than it averts.

Response organizations need to develop plans and protocols that address radiation protection during a radiological incident and that ensure appropriate training is provided to responders and decision makers. Detailed reports on radiation risk, risk management decision making, training and public communication should be consulted in the development of plans, protocols and training materials and may be obtained from organizations such as ICRP, the National Council on Radiation Protection and Measurements (NCRP), International Atomic Energy Agency (IAEA), the American Nuclear Society (ANS) and the Health Physics Society (HPS). Detailed information on the risks of radiological emergency response and worker protection procedures can be found in the FRMAC "Radiological Emergency Response Health and Safety Manual" (DOE 2001) and the NCRP's "Management of Terrorist Events Involving Radioactive Material, Report No. 138" (NCRP 2001) and "Responding to a Radiological or Nuclear Terrorism Incident: A Guide for Decision Makers, Report No. 165" (NCRP 2010).

"Higher doses could be received by ~~emergency responders~~ emergency workers performing what NCRP Report No. 165, "Responding to a Radiological or Nuclear Terrorism Incident: A Guide for Decision Makers" calls "Time-Sensitive Mission-Critical" activities that could result in radiation doses higher than 25 rem. NCRP Report No. 165 expands the discussion on a Decision Dose of 50 rad. A Decision Dose can be used by the Incident Commander as a tool to address the need to and the consequences of exposing ~~emergency responders~~ emergency workers to higher doses to accomplish Mission Critical actions. This is especially important in an Improvised Nuclear Device (IND) incident."

2.4. CONTROLLING OCCUPATIONAL EXPOSURE AND DOSES TO ~~emergency responders~~ EMERGENCY WORKERS

This section provides guidance on occupational doses of radiation during an emergency response. In many radiological incidents, actual exposure of workers, including emergency responders, may be controlled to low doses when proper precautions are taken. During some emergencies, radiation exposures to responders may be unavoidable and may have the potential to exceed limits used for normal operations.

However, even in emergency conditions, every reasonable effort should be made to control doses to levels that are as low as practicable (consider NCRP 138[18] and NCRP 165[19] for recommendations that

[18] "Management of Terrorist Events Involving Radioactive Material, Report No. 138" (NCRP 2001).

[19] "Responding to a Radiological or Nuclear Terrorism Incident: A Guide for Decision Makers, Report No. 165" (NCRP 2010).

support ALARA).

2.4.1. Maintaining the ALARA Principle

To minimize the risks from exposure to ionizing radiation, employers of ~~emergency responders~~ emergency workers should prepare emergency response plans and protocols in advance to keep worker exposures ALARA, an acronym for "as low as is reasonably achievable" means making every reasonable effort to maintain exposures to radiation as far below the dose limits in this part as is practical consistent with the purpose for which the activity is undertaken. Plans and protocols should include the following health physics and industrial hygiene practices to the maximum extent possible—

- Minimizing the time spent in the contaminated area.
- Maintaining the maximum distance from sources of radiation.
- Shielding of radiation sources.
- Tailoring of hazard controls to the work performed.
- Properly selecting and using respirators (see 29 CFR Part 1910.134) and other PPE.
- Using prophylactic medications, where medically appropriate, that either block the uptake or reduce the retention time of radioactive material in the body.

The incident commander's staff should be prepared to identify, to the extent possible, all hazardous conditions or substances and to perform appropriate site hazard analysis. Emergency management plans should include protocols to control worker exposures, establish exposure guidelines in advance and outline procedures for worker protection. Emergency procedures should include provisions for exposure monitoring, worker training commensurate with the hazards involved in response operations and ways to control them and medical monitoring.

2.4.2. Understanding Dose and Risk Relationships

~~response worker~~ Emergency worker guidelines are based on cumulative dose constraint levels. These are based on an assumption that doses acquired in response to a radiological incident would be ''once in a lifetime'' doses and that future radiological exposures would be substantially lower.

Recommendations in this document provide a guideline level of 5 rem (50 mSv) for worker protection and alternative ~~response worker~~ emergency worker guidelines (see Table 2-2) for certain activities where exposures below 5 rem (50 mSv) cannot be maintained. For most radiological incidents, radiation control measures (e.g., minimizing time, maximizing distance, using shielding) will prevent doses from reaching the 5 rem (50 mSv) occupational exposure guide while performing typical emergency response activities such as transportation, firefighting and medical treatment of contaminated victims at hospitals. However, in those situations in which victims are injured or trapped in high radiation areas or can only be reached via high radiation areas, exposure control options may be unavailable or insufficient and doses above 5 rem (50 mSv) may be unavoidable.

Decisions to take response actions that could result in doses in excess of 5 rem (50 mSv) can only be made at the time of the incident, under consideration of the actual situation. In such situations, incident commanders and other responders need to understand the risk posed by such exposures in order to make informed decisions. The ~~response worker~~ emergency worker Guidelines for life and property saving activities in Table 2-2 are provided to assist such decision-making. These guidelines apply to doses incurred over the duration of an emergency and are assumed to be once in a lifetime.

Emergency personnel may be exposed to increased radiation during the unique catastrophic event of an IND detonation resulting in firestorm and widespread destruction of structures. The emergency intervention needed to prevent further destruction and loss of life may result in increased exposure. Exceeding the ~~response worker~~ emergency worker Guidelines in Table 2-2 may be unavoidable in responding to such events. ~~emergency responders~~ Emergency workers undertaking a mission covered

under the ~~response worker~~ emergency worker guidelines should be informed when radiation control measures may not prevent doses from exceeding the 5 rem (50 mSv), general occupational exposure guideline and should be made ~~fully~~ aware of ~~the sub-chronic and chronic~~ risks involved, including numerical estimates of the risk of delayed health effects.

Table 2-2. ~~response worker~~ Emergency Worker Guidelines

Guideline	Activity	Condition
5 rem (50 mSv)	All occupational exposures	All reasonably achievable actions have been taken to minimize
10 rem (100 mSv)[a]	Protecting valuable property necessary for public welfare (e.g., a power plant).	Exceeding 5 rem (50 mSv) unavoidable and all appropriate actions taken to reduce dose. Monitoring available to project or measure dose.
25 rem (250 mSv)[b]	Lifesaving or protection of large populations	Exceeding 5 rem (50 mSv) unavoidable and all appropriate actions taken to reduce dose. Monitoring available to project or measure dose.
>25 rem (250 mSv)	Lifesaving or protection of large populations	Only on a voluntary basis for people fully aware of the risks involved (See Tables 2-3 and 2-4)"

[a] For potential doses >5 rem (50 mSv), medical monitoring programs should be considered.
[b] In the case of a very large incident, such as an IND, incident commanders may need to consider raising the property and lifesaving ~~response worker~~ emergency worker guidelines to prevent further loss of life and massive spread of destruction.

The 25 rem (250 mSv) lifesaving ~~response worker~~ emergency worker guidelines provide assurance that exposures will not result in detrimental deterministic health effects (i.e., prompt or acute effects). However, it could increase the risk of stochastic (chronic) effects, such as the risk of cancer. Response actions that could cause exposures in excess of the 25 rem (250 mSv) ~~response worker~~ emergency worker Guideline should only be undertaken with an understanding of the potential acute effects of radiation to the exposed responder (see Table 2-3) and only when the benefits of the action clearly exceed the associated risks.

The estimated risk of fatal cancer[20] for workers exposed to 10 rem (100 mSv) is slightly less than the corresponding general population risk of 0.6 percent (6 cases per thousand exposed). Workers exposed to 25 rem (250 mSv) have an estimated risk of fatal cancer of 1.5 percent (15 cases per thousand exposed). Because of the latency period of cancer, younger workers face a larger risk of fatal cancer than older workers (for example, when exposed to 25 rem (250 mSv), 20 to 30-year-olds have a 9.1 per thousand risk of premature death, while 40 to 50-year-olds have a 5.3 per thousand risk of premature death).[21]

[20] Risk per dose of a fatal cancer is assumed to be about $6x10^{-4}$ per rem ($6x10^{-5}$ per mSv). Cancer incidence is assumed to be about $8x10^{-4}$ per rem ($8x10^{-5}$ per mSv). (EPA 1999)

[21] The numerical estimate of cancer risk presented above (from Federal Guidance #13) was obtained by linear extrapolation using the nominal risk estimates based on data from human exposures at high doses and high dose rates. Other methods of extrapolation to the low-dose region could yield higher or lower numerical estimates of cancer deaths. Studies of human populations exposed at low doses are inadequate to demonstrate the actual magnitude of risk at low doses (about 0.1 Sv or 10 rem and below). There is scientific uncertainty about cancer risk in the low-dose region below the range of epidemiological observation and the possibility of no risk cannot be excluded. (EPA 1999)

More specific risk determinations can be made when there is adequate information about the contaminants and the potential for human exposure. EPA's Federal Guidance Report #13 (EPA 1999) and Health Effects Assessment Summary Tables have risk factors for specific radionuclides.

Table 2-3. Acute Radiation Syndrome [a]

Feature or Illness	Effects of Whole Body Absorbed Dose from external radiation or internal absorption, by dose range in rad				
	0-100 (0-1 Gy)	100-200 (1-2 Gy)	200-600 (2-61 Gy)	600-800 (6-8 Gy)	>800 (>8 Gy)
Nausea, Vomiting	None	5-50%	50-100%	75-100%	90-100%
Time of Onset		3-6 h	2-4 h	1-2 h	<1 h to minutes
Duration		<24 h	<24 h	<48 h	<48 h
Lymphocyte Count	Unaffected	Minimally Decreased	<1000 at 24 h	<500 at 24 h	Decreases within hours
Central Nervous System Function	No Impairment	No Impairment	Cognitive impairment for 6-20 h	Cognitive impairment for > 20 h	Rapid incapacitation
Mortality	None	Minimal	Low with aggressive therapy	High	Very High: Significant neurological symptoms indicate lethal dose

Source: Medical Management of Radiological Casualties, Second Edition, Armed Forces Radiobiology Research Institute. Bethesda, MD, April 2003.

[a] Percentage of people receiving whole-body doses within a few hours expected to experience acute health effects.

Prior to 5 rem (50 mSv) guideline being exceeded, workers should be provided the following—

- Site specific training, if no prior training was available, with respect to the risk associated with exposure to ionizing radiation (incident commanders and responders should consider having someone on each team with radiation safety experience).
- A thorough explanation of the latent risks associated with receiving exposures greater than 5 rem (50 mSv).

If the 5 rem (50 mSv) guideline is exceeded, workers should be provided with a medical follow-up and monitoring should be considered.

In addition, these guidelines represent dose constraint levels (e.g., when this level of dose is accumulated, the responder should not take part in the later stages of the response that may significantly increase their dose). Incident commanders and responders need a thorough understanding of the worker exposure guidelines for radiological emergency response, including the associated risks and specific worker protection procedures. The FRMAC "Radiological Emergency Response Health and Safety Manual" (FRMAC 2001) provides detailed information. Additional resources for advance planning are available on the Radiological Emergency Medical Management (REMM) web site: http://www.remm.nlm.gov/.

2.4.3. Occupational Safety Regulations for Radiological Emergency Response

The Occupational Safety and Health Act, requires employers to be responsible for the health and safety of their employees during routine and emergency operations. The primary occupational safety and health standard for emergency response is the Hazardous Waste Operations and Emergency Response (HAZWOPER) standard (29 CFR Part 1910.120).

Many U.S. states operate their own OSHA-approved state plans, which are required to be "at least as effective as" Federal OSHA standards and may impose additional or more stringent requirements.[22]Some states operate "complete" plans that cover both the private sector and state and local government employees, while others cover state and local government employees only. EPA's Worker Protection Standard (40 CFR 311) applies the HAZWOPER standard to state and local workers in states that do not have occupational health and safety plans.

In addition to the Occupational Safety and Health Act, several federal agencies (DOE, NRC and OSHA) and Agreement States issue occupational radiation safety standards (see Table 2-4). The occupational standards are not guidelines but instead are regulatory limits that cannot be exceeded except under certain conditions. These occupational limits allow workers to receive radiation exposure during the course of performing their jobs.
Federal and state radiation safety standards recognize that it may be necessary to exceed dose limits to take critical lifesaving actions.

Table 2-4. Regulations for Worker Protection

Agency	Statutory Requirement	Title
Occupational Safety and Health Administration[1]	29 CFR 1910.120	Safety and Health-- HAZWOPER
	29 CFR 1910. 1096	Ionizing Radiation
Environmental Protection Agency[1]	40 CFR 311	Occupational Radiation Protection
Nuclear Regulatory Commission[2]	10 CFR 20	Standards for Protection Against Radiation
Department of Energy[3]	10 CFR 835	Radiation Protection Regulations

1. All states are either regulated by federal regulations or by respective state regulations. 40 CFR 311 applies the HAZWOPER standard in states that do not have their own occupational health and safety program.
2. NRC employees are covered by NRC Management Directive 10.131, ''Protection of NRC Employees Against Ionizing Radiation.'' Section VI, Guidance for Emergency Exposure Controls During Rescue and Recovery Activities, deals specifically with radiation exposure control during emergencies
3. These requirements apply to all DOE employees and contractors (except for Naval Nuclear Propulsion Program (NNPP)) who may be exposed to ionizing radiation as a result of their work for DOE, including work relating to emergency response activities. The NNPP has established requirements consistent with those contained in 10 CFR 835.

{deleted Section 2.7, replacement below} CONTAMINATION LIMITS AND MONITORING OF THE ENVIRONMENT AND POPULATIONS

Areas under the plume can be expected to contain deposited radioactive materials if aerosols or particulate materials were released during the incident. In extreme cases, individuals and equipment may be highly contaminated and monitoring stations will be required for emergency monitoring, decontamination of individuals and medical evaluations. Equipment should be checked and decontaminated as necessary to avoid the spread of contamination to other locations. This monitoring service would be required for only a few days following plume passage until all such people have been

[22] For a list of state plans, see: http://www.osha.gov/dcsp/osp/index.html

evacuated or relocated.

~~People working in the parts of the restricted areas in which their dose from the residual radioactivity would exceed 2 mrem (20 µSv) in any hour or 100 mrem (1 mSv) in a year should operate under the controlled conditions established for occupational exposure.~~

Adults may reenter restricted areas under controlled conditions in accordance with occupational exposure standards. The need for monitoring stations should be evaluated along highways, which serve as the major evacuation or transportation routes, to control surface contamination at exits from the more highly contaminated areas. Decontamination and other measures should be implemented to maintain low-exposure rates at monitoring stations.

~~A contaminated item should not be released to an unrestricted area. Based on incident and locality-specific considerations, it may be acceptable to release contaminated materials if the level of surface contamination is less than two times (2x) the existing background levels. As an alternative to decontamination, contaminated items (i.e., not people or animals) may be retained in the restricted area while the radiological contamination decays.~~

A contaminated item should not be released to an unrestricted area. Based on incident and locality specific considerations, it may be acceptable to release contaminated materials if the level of surface contamination is below acceptable release criteria. As an alternative to decontamination, contaminated items (i.e., not people or animals) may be retained in the restricted area while the radiological contamination decays

In some extreme cases, decontamination may be impractical. Evacuating a large area requires resources, and decontamination may conflict with priority use of those resources. Screening and decontamination can slow egress, which could result in increased dose to the evacuees. Emergency managers should refer to CDC's "Population Monitoring in Radiation Emergencies: A guide for state and local public health planners" for more information. These simple initial screening guides are more general than FEMA REP-21 and REP-22 on use of handheld instruments and portal monitors for screening the public.

2.5. SURFACE CONTAMINATION CONTROL

Surface contamination must be controlled both before and after relocation protective actions are implemented. The principal exposure pathways for loose surface contamination on people, clothing and equipment are:

- internal doses from ingestion by direct transfer;
- internal doses from inhalation of resuspended materials;
- beta dose to skin from contaminated skin or clothing or from nearby surfaces;
- dose to the whole body from external gamma radiation;
- internal dose from absorption of contamination into wounds.

The contamination limit should be influenced by the potential for the contamination to be ingested, inhaled or transferred to other locations. Therefore, it is reasonable to establish lower limits for surfaces where contamination is loose than for surfaces where the contamination is fixed (except for skin). The expected period of exposure from fixed contamination on skin would be longer so a lower limit would be justified.

It is not practical to set contamination limits significantly lower than residual contamination levels in uncontrolled areas. Although the contamination levels recommended in this manual are accordingly set high, consideration should be given as the event progresses to using lower contamination control levels (and more sensitive monitoring instruments) once people are removed from areas causing high external

doses. Such efforts will minimize cross-contamination of people located outside of the affected areas. For events involving fixed nuclear facilities, some evacuation reception centers or shelters will have walk-through portal monitors.

"2x background is merely a simplified basis for responders to set their own instrument trigger levels based on practical circumstances at the time and location of each screening center. NCRP 161, "Population Monitoring and Radionuclide Decorporation Following a Radiological or Nuclear Incident (NCRP Report No. 166), National Council on Radiation Protection and Measurements, Bethesda, MD, 2011." and Koenig paper [cite properly] provide the basis for these simplified initial screening levels."

2.5.1. Priorities for Control of Contaminated Areas

The following priorities are recommended—

1. Do not delay urgent medical care for decontamination efforts or for time-consuming protection of attendants, such as donning of additional anti-contamination clothing.
2. In early phase scenarios where it might not be practical or would interfere with other life-saving and public health protection priorities, do not waste effort trying to contain contaminated wash water and be sure to notify sewage treatment plants.
3. Do not allow monitoring and decontamination to delay an ordered evacuation.
4. *When early screening is needed after a major incident* — After plume passage, it may be necessary to establish emergency contamination monitoring stations in areas not qualifying as low background areas. Gamma exposure rates in such areas should be less than 5 millirem (50 µSv) per hour. These monitoring stations should be used only during the early phase after major atmospheric releases to monitor people emerging from possible high exposure areas. The stations should be set up to provide simple (rapid) decontamination if needed and to evaluate whether affected people should undergo more extensive decontamination or other special care. Table 2-5 provides guidance on surface contamination levels for use if such centers are needed.
5. Establish monitoring and personnel decontamination (e.g., bathing) facilities at evacuation centers or other locations in low background areas (less than 0.1 millirem (1 µSv) per hour). *Encourage self-decontamination:* Encourage evacuated people who were exposed in areas where release of particulate materials would have warranted evacuation to change and bag the clothes they were wearing and store them in an area away from people and pets until authorities provide further instructions on their disposition, to wash other exposed surfaces such as cars and trucks and their contents and then report to these centers for monitoring. For more specific considerations on control of contaminated areas refer to "Population Monitoring in Radiation Emergencies: A Guide for State and Local Public Health Planners" (CDC ~~2007~~2014).[23] Table 2-6 provides surface contamination guidance. These screening levels are examples derived primarily on the basis of easily measurable radiation levels using portable instruments.
6. After the relocation area has been established, consider the need to set up monitoring and decontamination stations at exits from the more highly contaminated parts of the area. Low levels of contamination may be undetectable because of high background radiation levels at these locations. Monitoring should be done at lowest practical background levels. Nevertheless, these individuals should be advised to bathe and change clothes at their first opportunity—no later than within the next 24 hours. If, after decontamination, people still exceed the limits for the station, they should be sent for further decontamination or for medical or other special attention.

[23] See: Population Monitoring and Radionuclide Decorporation Following a Radiological or Nuclear Incident (NCRP Report No. 166), National Council on Radiation Protection and Measurements, Bethesda, MD, 2011.

Table 2-5. Recommended surface contamination screening levels for emergency screening of people and objects at monitoring station ~~in high background radiation areas~~ with elevated background area (0.1 mR/h to 1 mR/h or 1 to 10 μSv/h Gamma Exposure Rate))[a]

Condition	Appropriate detection instrument reading	Recommended Action
Before Decontamination	<2x existing background	~~Unconditional release~~ Release for further screening outside affected area
	>2x existing background	Decontaminate. Equipment may be stored or disposed of as appropriate.
After Decontamination	<2x existing background	~~Unconditional release~~ Release for further screening outside affected area
	>2x existing background	Continue to decontaminate or refer to low background monitoring and decon station. Equipment may be stored for decay or disposed of as appropriate.

[b] Monitoring stations in such high exposure rate areas are for use only during the early phase of an incident involving major atmospheric releases of particulates. Otherwise use Table 2-6.

Table 2-6. Recommended Surface Contamination Screening Levels for People[a] and Objects at Monitoring Stations in ~~Low~~ Background Radiation Areas (<0.1 mR/h Gamma Exposure Rate)[b]

Condition	Appropriate detection instrument reading	Recommended Action
Before decontamination	<2x existing background	Unconditional release
	>2x existing background	~~Decontaminate~~ Partial Decontamination
After simple[c] decontamination effort	<2x existing background	Unconditional release
	>2x existing background	Full decontamination
After full[d] decontamination effort	<2x existing background	Unconditional release
	>2x existing background	Continue to decontaminate people Release animals and equipment
After additional full decontamination effort	<2x existing background	Unconditional full release
	>2x existing background	Send people for further evaluation ~~Release animals and equipment~~

[a] People reporting to monitoring stations in low background radiation areas have been previously instructed to change and bag clothes, wash other exposed surfaces such as cars and their contents and then report to these centers for monitoring.
[b] Levels higher than 2x existing background (not to exceed the meter reading corresponding to 0.1 mR/h) may be used to speed the monitoring of evacuees in very low background areas.
[c] Washing hands and face and localized wiping are examples of a partial decontamination effort.
[d] Changing clothes and/or showering are examples of a full decontamination effort.

2.7 CONTAMINATION LEVELS AND MONITORING OF THE ENVIRONMENT AND POPULATIONS

Areas under the plume can be expected to contain deposited radioactive materials if aerosols or particulate materials were released during the incident. In extreme cases, individuals and equipment may be highly contaminated and monitoring stations will be required for emergency monitoring, decontamination of individuals and medical evaluations. Equipment should be checked and decontaminated as necessary to avoid the spread of contamination to other locations. This monitoring service would be required for only a few days following plume passage until all such people have been evacuated or relocated. Guidance on surface contamination levels for use at such monitoring stations is provided below.

Adults may reenter restricted areas under controlled conditions in accordance with occupational exposure standards. The need for monitoring stations should be evaluated along highways, which serve as the major evacuation or transportation routes, to control surface contamination at exits from the more highly contaminated areas. Decontamination and other measures should be implemented to maintain low- exposure rates at monitoring stations.

A contaminated item should not be released to an unrestricted area. Based on incident and locality specific considerations, it may be acceptable to release contaminated materials if the level of surface contamination is below acceptable release criteria. As an alternative to decontamination, contaminated items (i.e., not people or animals) may be retained in the restricted area while the radiological contamination decays.

In some extreme cases, decontamination may be impractical. Evacuating a large area requires resources, and decontamination may conflict with priority use of those resources. Screening and decontamination can slow egress, which could result in increased dose to the evacuees. Emergency managers should consult with their state radiation control authority to establish proposed radiation screening criteria. Refer to CDC's "Population Monitoring in Radiation Emergencies: A Guide for State and Local Public Health Planners" (CDC 2014)[24] for additional in-depth discussion in Appendix D on radiological screening criteria for external contamination. These simple initial screening guides from CDC are more general than FEMA REP-21 and REP-22 on use of handheld instruments and portal monitors for screening the public.

2.5.2. Surface Contamination Control

Surface contamination must be controlled both before and after evacuation protective actions are implemented. The contamination level for screening people, animals and objects for surface contamination at monitoring stations should be influenced by the potential for the contamination to be ingested, inhaled or transferred to other locations. The principal exposure pathways for loose surface contamination on people, clothing and equipment are:

- Internal doses from ingestion by direct transfer;
- Internal doses from inhalation of resuspended materials;
- Beta dose to skin from contaminated skin or clothing or from nearby surfaces;
- Dose to the whole body from external gamma radiation; and
- Internal doses from absorption of contamination into wounds.

It is not practical to set surface contamination screening levels significantly lower than residual contamination levels in uncontrolled areas. Although the contamination levels recommended in this manual are accordingly set high, consideration should be given as the incident event progresses to using lower contamination screening levels (and more sensitive monitoring instruments) once people are removed from areas causing high external doses. Such efforts will minimize cross-contamination of people located outside of the affected areas. For incidents involving fixed nuclear facilities, some evacuation reception centers or shelters will have walk-through portal monitors.

The recommended "2x existing background" level for screening for surface contamination at monitoring stations is merely a simplified basis for responders to set their own instrument trigger levels based on practical circumstances at the time and location of each screening center. Local and state officials may choose to establish a screening level expressed in measurements units (e.g., cpm, µR/h) that are compatible with radiation

[24] See: http://emergency.cdc.gov/radiation/pdf/population-monitoring-guide.pdf (CDC 2014)

detection instruments being used and appropriate for local conditions, taking into account the number of people in need of screening and available resources.[25] The following guidance documents provide more detailed information about initial screening levels:

- "Population Monitoring and Radionuclide Decorporation Following a Radiological or Nuclear Incident," (NCRP Report No. 166), Bethesda, MD, 2011.
- "Responding to a Radiological or Nuclear Terrorism Incident: A Guide for Decision Makers," (NCRP Report No. 165), Bethesda, MD, 2010.
- "Management of Persons Contaminated with Radionuclides: Scientific and Technical Bases," (NCRP Report No. 161, Vol. II), Bethesda, MD, 2010. Chapter 5: Performing Surveys and Controlling Personnel and Area Contamination.
- "Management of Persons Contaminated With Radionuclides: Handbook" (NCRP Report No. 161, Vol. I), Bethesda, MD, 2008.

2.5.3. Priorities for Control of Contaminated Areas

The following priorities are recommended—

- Do not delay urgent medical care for decontamination efforts or for time-consuming protection of attendants, such as donning of additional anti-contamination clothing.
- In early phase scenarios where it might not be practical or would interfere with other lifesaving and public health protection priorities, do not waste effort trying to contain contaminated wash water and be sure to notify sewage treatment plants.
- Do not allow monitoring and decontamination to delay an ordered evacuation.
- *When early screening is needed after a major incident* — After plume passage, it may be necessary to establish emergency contamination monitoring stations in areas not qualifying as low background areas. These monitoring stations should be used only during the early phase after major atmospheric releases to monitor people emerging from possible high exposure areas. The stations should be set up to provide simple (rapid) decontamination if needed and to evaluate whether affected people should undergo more extensive decontamination or other special care. Section 2.3.3 provides guidance on surface contamination levels for use if such emergency contamination monitoring stations centers are needed.
- *Establish screening to control surface contamination* — Establish monitoring and personnel decontamination (e.g., bathing) facilities at evacuation centers or other locations in low background areas (less than 0.1 millirem (1 μSv) per hour gamma exposure rate). Section 2.3.4 provides surface contamination guidance for monitoring stations in low background areas. These surface contamination screening levels are examples derived primarily on the basis of easily measurable radiation levels using portable instruments. The background may be elevated because of the incident, so these screening levels refer to a "2x existing background" level in a low radiation area.
- *Encourage self-decontamination* — Encourage evacuated people who were exposed in areas where release of particulate materials would have warranted evacuation to change and bag the clothes they were wearing and store them in an area away from people and pets until authorities provide further instructions on their disposition, to wash other exposed surfaces such as cars and trucks and their contents and then report to evacuation centers or other established locations for monitoring.
- After the evacuation area has been established, consider the need to set up monitoring and decontamination stations at exits from the more highly contaminated parts of the area. Low levels of contamination may be undetectable because of high background radiation levels at these locations. Monitoring should be done at lowest practical background levels. Nevertheless, these individuals should be advised to bathe and change clothes at their first opportunity—no later than within the next 24 hours. If, after decontamination, people still exceed the surface contamination screening levels for the station, they should be sent for further decontamination or for medical or other special attention.

2.5.4. Recommendations for Emergency Screening in Areas Not Qualifying as Low Background Areas

This section provides the recommended surface contamination screening levels for emergency screening of people and objects at monitoring stations in high background radiation areas in areas with elevated background radiation (exceeding 0.1 mR/h or 1 μSv/h gamma exposure rate). Monitoring stations in such high exposure rate areas are for use only during the early phase of an incident involving major atmospheric releases of particulates (otherwise see Section 2.3.4). For such emergency screening at monitoring stations, recommended actions for a detection instrument reading at either less than or greater than 2x existing background are outlined below.

- **Before Decontamination:**
  - If <2x existing background — *Recommended action*: Release for further screening outside affected area.

- If >2x existing background — *Recommended action:* Perform gross decontamination (carefully remove outer layer of clothing) and/or simple decontamination (examples include washing hands and face, wiping of exposed skin, washing feet or soles of shoes). Equipment may be stored for decay, reuse or disposal in the same area, as appropriate.

- **After Decontamination:**
  - If <2x existing background — *Recommended action:* Release for further screening outside affected area.
  - If >2x existing background — *Recommended action:* Continue to decontaminate or refer to low background monitoring and decontamination station. Equipment may be stored for decay, reuse or disposal in the same area, as appropriate.

2.5.5. Recommendations for Screening in Low Background Areas

This section provides the recommended surface contamination screening levels for people and objects at monitoring stations in low background radiation areas (<0.1 mR/h or 1 µSv/h gamma exposure rate). People reporting to monitoring stations in low background radiation areas have been previously instructed to change and bag clothes, wash other exposed surfaces such as cars and their contents and then report to these centers for monitoring. Levels higher than 2x existing background (not to exceed the meter reading corresponding to 0.1 mR/h) may be used to speed the monitoring of evacuees in very low background areas. For screening at monitoring stations in low background areas, recommended actions for a detection instrument reading at either less than or greater than 2x existing background are outlined below.

- **Before Decontamination:**
  - If <2x existing background — *Recommended action*: Unconditional release.
  - If >2x existing background — *Recommended action:* Perform gross decontamination (carefully remove outer layer of clothing) and/or simple decontamination (examples include washing hands and face, wiping of exposed skin, washing feet or soles of shoes).
- **After Simple Decontamination Effort:**
  - If <2x existing background — *Recommended action:* Unconditional release.
  - If >2x existing background — *Recommended action:* Full decontamination.
- **After Full Decontamination Effort** (Changing clothes and/or showering are examples of a full decontamination effort. Washing or gentle scrubbing with soap or other mild detergent followed by flushing is another example of a full decontamination effort.):
  - If <2x existing background — *Recommended action:* Unconditional release.
  - If >2x existing background — *Recommended action:* Continue to decontaminate people.
- **After Additional Full Decontamination Effort:**
  - If <2x existing background — *Recommended action:* Unconditional full release.
  - If >2x existing background — *Recommended action:* Send people for further evaluation.

The recommended "2x existing background" level for screening for surface contamination at monitoring stations is merely a simplified basis for responders to set their own instrument trigger levels based on practical circumstances at the time and location of each screening center. Local and state officials may choose to establish a screening level expressed in measurements units (e.g., cpm, µR/h) that are compatible with radiation detection instruments being used and appropriate for local conditions, taking into account the number of people in need of screening and available resources.

KEY POINTS IN CHAPTER 2 – EARLY PHASE

- The principal protective actions for the early phase are evacuation or sheltering-in-place. Evacuation is the urgent removal of people from an area to avoid or reduce high-level, short-term exposure from the plume or deposited activity. Sheltering-in-place refers to the use of a readily available structure that will provide protection from exposure to the plume.
- The PAG for evacuation or sheltering-in-place is a projected whole body dose of 1 to 5 rem (10 – 50 mSv) total effective dose (TED) over four days.
- Evacuation is appropriate when its risks and secondary effects are less severe than the risk of the projected radiation dose. Evacuation will be most effective in avoiding dose if completed before plume arrival.
- In general, sheltering-in-place should be preferred to evacuation whenever it provides equal or greater protection. After confirmation that the plume has passed, continued sheltering-in-place should be re-evaluated by public officials.
- The administration of KI to partially block the uptake of radioiodines by the thyroid is a supplemental protective action. The PAG for administration of KI is 5 rem (50 mSv) projected child thyroid dose. Other medical countermeasures are available, as well.
- Dose calculations for PAGs are made using the dose parameter (DP) and derived response level (DRL) calculation methods referenced in the FRMAC Assessment Manuals. Emergency response organizations are encouraged to use the most current, applicable tools and methods for implementing the PAGs. ~~Dose calculations for PAGs are made using the DCF and DRL calculation~~ methods referenced in the FRMAC Assessment Manuals. Emergency response organizations are ~~encouraged to use the most current, applicable tools and methods for implementing the PAGs.~~
- ~~response worker~~ emergency worker guidelines of 5, 10 or 25 rem (50, 100 or 250 mSv) are based on the urgency of activities and knowledge of the risks involved.

CHAPTER 3 – INTERMEDIATE PHASE PROTECTIVE ACTION GUIDES

3.1. INTRODUCTION

This chapter presents PAGs for the intermediate phase and provides guidance for the implementation of corresponding protective actions. A PAG is the projected dose to an individual from the release of radioactive material at which a specific protective action should be taken to reduce or avoid that dose. The intermediate phase is defined as the period beginning after the source and releases have been brought under control and environmental measurements are available for use as a basis for decisions on protective actions and extending until these protective actions are terminated. The intermediate phase may last from weeks to months; but is assumed to last for one year for purposes of dose projection.

During the early phase, decisions must be made and implemented quickly by state and local officials before federal assistance is available. In contrast, many decisions and actions during the intermediate phase may be taken after federal resources are present, as described in the Nuclear/Radiological Incident Annex of the National Response Framework (FEMA 2008 a, b). Decisions will be made during the intermediate phase concerning whether particular areas or properties from which people have been evacuated will be decontaminated and reoccupied or the occupants relocated for an extended period.

This chapter provides the PAGs and corresponding protective actions for use by state and local officials in developing their radiological emergency response plans to protect the public from exposure to radiation from deposited radioactive materials. Due to the wide variety of types of radiological incidents and radionuclide releases that could occur, it is not practical to provide implementing guidance for every possible situation.

This chapter also provides guidance for translating radiological conditions in the environment into projected doses that serve as the basis for decisions to take appropriate protective actions and basic planning guidance on reentry as informed by the Operational Guidelines (DOE 2009).

3.2. EXPOSURE PATHWAYS DURING THE INTERMEDIATE PHASE

During the intermediate phase, the principal exposure pathways for the public occupying areas contaminated with deposited radioactive materials are:

- **Exposure of the whole body** to external gamma radiation from deposited radioactive materials (groundshine). External gamma radiation is the expected dominant pathway for reactor accidents and incidents involving RDDs and INDs;
- **Internal exposure** from the inhalation of resuspended materials;
- **Internal exposure** from the ingestion of food and water.

Other potentially significant exposure pathways include exposure to beta radiation from surface contamination and direct ingestion of contaminated soil. These pathways are not expected to be controlling for NPP incidents (Aaberg 1989).

3.3. THE PROTECTIVE ACTION GUIDES AND PROTECTIVE ACTIONS FOR THE INTERMEDIATE PHASE: RELOCATION AND DOSE REDUCTION

The principal protective actions for reducing exposure of the public to deposited radioactive materials are:

- Relocation;
- Decontamination;
- Shielding;
- Time limits on exposure;

- Control of the spread of surface contamination.

The most effective of these actions is relocation—the removal or continued exclusion of people (households) from contaminated areas to avoid chronic radiation exposure. Relocation is highly disruptive and therefore only implemented when the dose is sufficiently high to warrant it. The PAG for relocation is 2 rem (20 mSv) projected over the first year of exposure. After the first year, the PAG for relocation is 0.5 rem (5 mSv) per year.

The PAG level for relocation applies to doses that can be avoided by relocation; doses already incurred prior to relocation are not included in the calculations. PAGs for protection from deposited radioactivity during the intermediate phase are summarized in Table 3-1. ~~The basis for these values is presented in detail in Chapters 4 and 7 and Appendix E of the 1992 PAG Manual, available online as a historical reference at http://www.epa.gov/radiation/rert/pags.html.~~ The decision to relocate will be considered on a case-by-case basis. Efforts to decontaminate and remediate the contaminated area and the shielding offered by buildings and the residency factor attributable to the building, must be considered to see if the second year PAG (0.5 rem (5 mSv) in a year) will be exceeded.

Avoiding exceedance of the relocation PAGs may not be easy for the radionuclides most likely associated with RDDs because of their longer half-lives. If these radionuclides are released, it may be necessary to relocate people in the affected areas even if exposure is less than 2 rem (20 mSv) in the first year provided decontamination and remediation measures during the first year are unsuccessful.

In most scenarios, relocation decisions will be based on doses from external exposure to the whole body from deposited materials and internal exposure from inhalation of resuspended contamination.

~~In most scenarios, relocation decisions will be based on doses from whole-body and internal exposure from inhalation of resuspended contamination.~~ Food and milk ingestion dose should be considered separately with decisions based on the FDA PAGs.[26]The FRMAC Assessment Manual provides guidance in calculating Ingestion Derived Response Levels that indicate the levels of deposited radioactive materials that may result in food exceeding the FDA PAGs

~~In most scenarios, relocation decisions will be based on doses from whole-body and internal exposure from inhalation of resuspended contamination. Food and milk ingestion dose should be considered separately with decisions based on the FDA PAGs.[21]~~

Other protective actions, such as simple dose reduction techniques, can be applied in areas where levels of deposited radioactivity are not high enough to warrant relocation. Dose reduction actions can range from the simple—scrubbing or flushing surfaces, removal and disposal of small spots of highly contaminated soil (e.g., from settlement of water) and spending more time than usual in lower exposure rate areas (e.g., indoors)—to the difficult and time consuming processes of removal, disposal and replacement of contaminated surfaces. The simple processes would probably be most appropriate in contaminated areas outside the relocation area. Many of these can be carried out by the residents with support from officials for monitoring and guidance on appropriate actions and disposal. The more difficult processes will be appropriate for recovery of areas where contamination is fixed (not removable) and from which the population is relocated.

Large areas may have to be restricted under these PAGs. As the land area increases, protective actions

[26] Accidental Radioactive Contamination of Human Food and Animal Feeds: Recommendations for State and Local Agencies, FDA 1998, available online: http://www.fda.gov/downloads/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/UCM094513.pdf

become more difficult and costly to implement, especially when the affected area is densely populated. There may be situations where full implementation of early and intermediate phase protective actions is impracticable (e.g., a release in a large city). Informed judgment must be exercised to assure priority of protection for individuals in areas having the highest exposure rates.

Table 3-1. Protective Action Guides for Exposure to Deposited Radioactivity during the Intermediate Phase of a Radiological Incident

Protective Action Recommendation	PAG (Projected Dose)[a]	Comments
Relocate the general population[b]	≥ 2 rem (20 mSv) in the first year, 0.5 rem (5 mSv)/year in the second and subsequent years	Projected dose over one year
Apply simple dose reduction techniques[c]	~~< 2 rem (20 mSv)~~ < 2 rem (20 mSv) projected in the first year	These protective actions should be taken to reduce doses to as low as practicable levels

[a]Projected dose refers to the dose that would be received in the absence of shielding from structures or the application of dose reduction techniques. These PAGs may not provide adequate protection from some long-lived radionuclides (see Section 3.7).
[b]People previously evacuated from areas outside the relocation zone defined by this PAG may return to occupy their residences.
Cases involving relocation of people at high risk from such action (e.g., patients under intensive care) may be evaluated individually.
[c]Simple dose reduction techniques include scrubbing or flushing hard surfaces, minor removal of soil from spots where

3.3.1. Removal of the 50 year Relocation PAG

For simplicity, the Relocation PAG of 5 rem (50 mSv) over 50 years has been removed from this guidance. It is rarely, if ever, the driver for extending Relocation area beyond that prompted by the first or second year Relocation PAGs in scenarios that have been analyzed. Additionally, dose projections over fifty years after a radiological incident for various age groups showed no significant differences for individuals exposed at 3 months age versus adult. A response organization may wish to project fifty-year doses to inform decision making, but should consider weathering, decay, credit for time spent indoors, and to the extent it can be predicted, dose reduction from mitigation activities. To keep emergency management decisions as simple as possible, however, the recommended Relocation PAGs are 2 rem (20 mSv) projected over the first year, and 0.5 rem (5 mSv) projected over any subsequent year.

3.3.2. The Population Affected

The PAGs for relocation are intended for use in establishing the boundary of a relocation area within an area where radioactive materials have been deposited. The relocation PAGs have been established at a level that will provide adequate protection for the general population, including higher risk groups such as children and fetuses. People residing in contaminated areas outside the relocation area will be at some risk from radiation dose. Therefore, guidance on the reduction of dose during the first year to residents outside this zone is also provided. Monitoring and simple dose reduction efforts are recommended in these areas to reduce doses to the extent practical. Such actions are unlikely to be practical where the dose reduction achieved is less than 10 percent.

Affected populations may perceive that intermediate phase protective actions are not consistent with those

taken in the early phase. Early-phase decisions on sheltering-in-place and evacuation may have been implemented prior to verification of the path of the plume. Therefore, some people may have been evacuated from areas where validated doses are much lower than were projected. Others who were in the path of the plume may have been sheltered or not protected at all. During the intermediate phase of the response, dose projections may be revised based on environmental measurements. People should be relocated from areas where the projected dose exceeds the PAG for relocation without regard to prior evacuation status.

3.3.3. Basis for Intermediate Phase PAGs

For a full description of the risk-benefit analysis used to set the PAG levels, refer to the 1992 PAG Manual, Appendices B, C and E. The Manual is available online in a searchable format. Below is a short summary on the basis for the Intermediate Phase relocation PAGs.

In a prior section, for early phase (evacuation) PAGs, analysis was provided for the risks of health effects as a function of dose (Principles 1 and 2). Considerations for selection of PAGs for the intermediate phase of a nuclear incident differ from those for selection of PAGs for the early phase primarily with regard to implementation factors (i.e., Principles 3 and 4). Specifically, they differ with regard to cost of avoiding dose, the practicability of leaving infirm9399 people and prisoners in the restricted zone, and avoiding dose to fetuses. Although sheltering is not generally a suitable alternative to relocation, other alternatives (e.g., decontamination and shielding) are suitable.

For several assumed cumulative annual doses, the cost per day divided by the risk of fatality avoided by relocation was plotted for a radionuclide mixture from a hypothetical nuclear power plant accident. The cost per day of relocation is assumed to be constant, but with some nuclides decaying rapidly, the cost effectiveness of relocation diminishes over time. Drawing only general trends from this, the cost analysis supports relocation at doses as low as one rem (10 mSv) for the first week and two rem (20 mSv) for up to 25 days after an accident.

Based on the avoidance of acute effects alone (Principle 1) relocation of the general population and fetuses at 50 rem and 10 rem (500 and 100 mSv), respectively, is justified. However, on the basis of control of chronic risks (Principle 2) a lower upper bound is appropriate. Five rem is taken as an upper bound on acceptable risk for controllable lifetime exposure to radiation, including avoidable exposure to accidentally deposited radioactive materials.

Analyses based on Principle 3 (cost/risk) indicate that considering cost alone would not drive the PAG to values less than 5 rem (50 mSv). Analyses in support of Principle 4 (risk of the protective action itself) provide a lower bound for relocation PAGs of 0.15 rem (1.5 mSv). Based on the above, 2 rem (20 mSv) projected committed effective dose equivalent from exposure in the first year is selected as the PAG for relocation. Implementation of relocation at this value will provide reasonable assurance that, for a reactor accident, a person relocated from the outer margin of the relocation zone will, by such action, avoid an exposure rate which, if continued over a period of one year, would result in a dose of about 1.2 rem (12 mSv). This assumes that 0.8 rem (8 mSv) would be avoided without relocation through normal partial occupancy of homes and other structures.

Contrary to the situation for evacuation during the early phase of an incident, it is generally not practical to leave a few people behind when most members of the general population have been relocated from a specified area for extended periods of time. It will usually be practicable to reduce these risks by establishing a high priority for efforts other than relocation to reduce the dose in cases where pregnant women reside near the boundary of the restricted zone.

The implementation of simple dose reduction techniques will further reduce dose to people who are not relocated from contaminated areas. In the case of non-reactor accidents, decay and weathering effects differ,

and it may be necessary to base relocation decisions on the second and subsequent year dose projections.

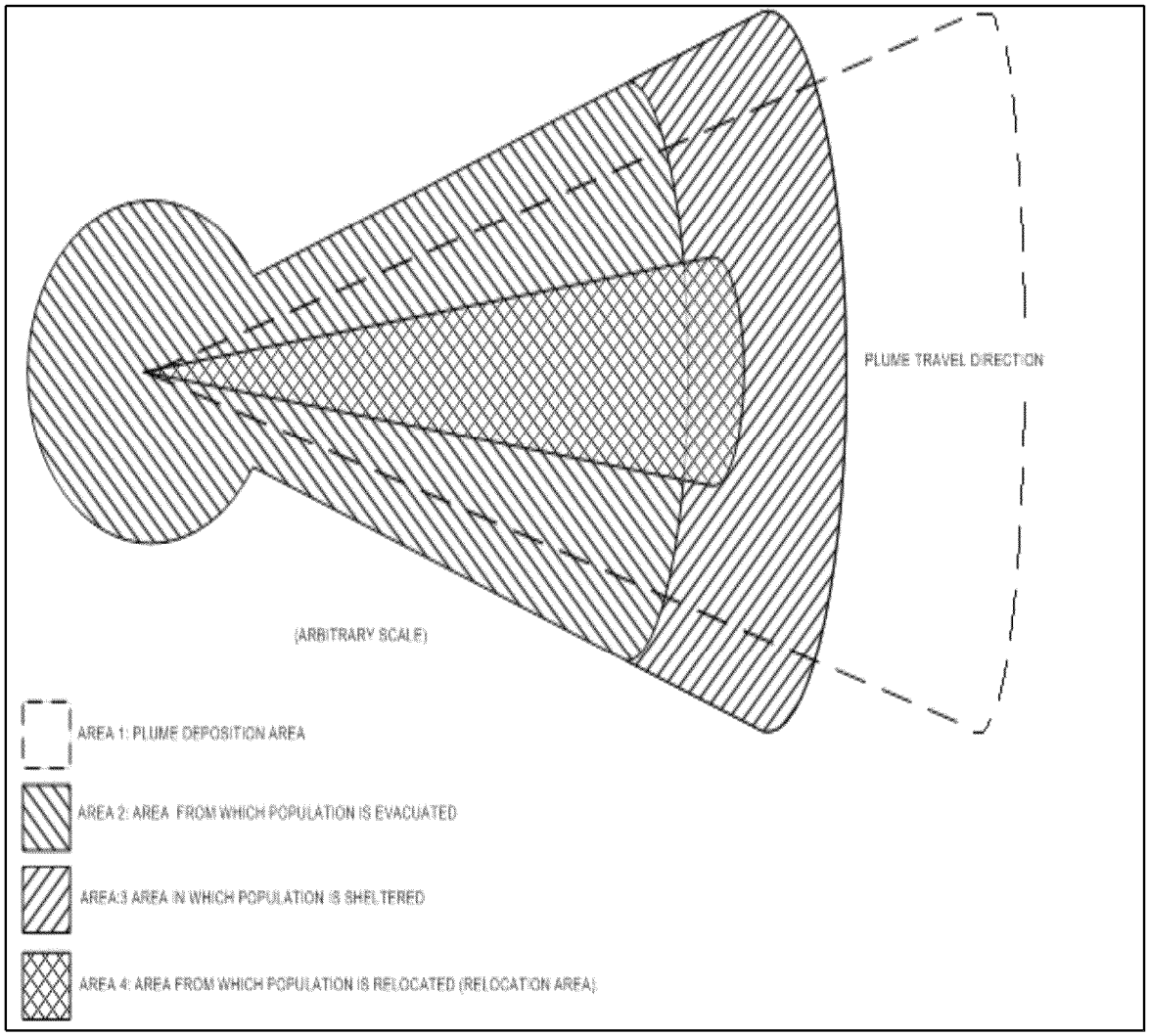


Figure 3-1. Generalized Protective Action Areas for NPP Incident

3.3.4. Areas Involved

Figure 3-1 provides a generalized example of the areas affected by different protective actions. Area 1 represents the plume deposition area. (In reality, variations in meteorological conditions would almost certainly produce a more complicated shape, but the same principles would apply.)

In situations such as an NPP accident, where early warning is given prior to a release of radioactive materials, people may already have been evacuated from Area 2 and sheltered in Area 3. People who have been evacuated from Area 2 or sheltered in Area 3 may go home if environmental monitoring verifies that their residences are outside the plume deposition area (Area 1).

Area 4 is the relocation area where projected doses are equal to or greater than the relocation PAG. People residing just outside the boundary of the relocation area may receive a dose approaching the PAG for relocation if decontamination or other dose reduction efforts are not implemented.

Area 1, with the exception of the relocation area, represents the area of contamination that may continue to be occupied by the general public during the intermediate phase. Nevertheless, there will be contamination levels in this area that will require continued monitoring and dose reduction efforts other than relocation. Incident-specific levels below the PAGs may be used to control exposure to contamination. The relative positions of the boundaries shown in Figure 3-1 depend on areas evacuated and sheltered and the radiological and meteorological characteristics of the release. For example, Area 4 (the relocation area) could fall entirely inside Area 2 (area evacuated), so that the only people to be relocated would be those residing in Area 4 who were either missed in the evacuation process or who, because of mobility constraints for their evacuation, had remained sheltered during plume passage.

Establishing the boundary of a relocation area creates three groups of affected people—

- People who have already been evacuated from an area that is now designated as a relocation area and who now must be assigned relocation status.
- People who were not previously evacuated, but who reside inside the relocation area and should now relocate.
- People who were previously evacuated, but reside outside the relocation area and may now return home. A gradual return is recommended.

Small adjustments to the boundary of the relocation area established based on the PAG may be justified based on ease of implementation. For example, the use of a convenient natural boundary could be a logical reason for adjustment of the relocation area. However, such decisions should be supported by demonstration that exposure rates to people not relocated can be promptly reduced by methods other than relocation to meet the PAG, as well as the longer dose objectives addressed in Section 3.6.

The relocation PAG applies principally to personal residences but may impact other facilities as well. For example, it could impact work locations, hospitals and park lands as well as the use of highways and other transportation facilities. For each type of facility, the occupancy time of individuals should be taken into account to determine the criteria for using a facility or area. It might be necessary to avoid continuous use of homes in an area because radiation levels are too high. However, a factory or office building in the same area could be used because occupancy times are shorter. Similarly, a highway could be used at higher contamination levels because the exposure time of highway users would be considerably less than the time spent at home.

3.3.5. Priorities

In most cases, protective actions during the intermediate phase will be carried out over a relatively long period of time (e.g., months). Setting priorities will be important, especially when the affected area is so large that it is impractical to relocate members of the public from areas that barely exceed the relocation PAGs. The following priorities are appropriate—

- First, protect all people from doses that could cause acute health effects from all exposure pathways, including previous exposure to the plume.
- Conduct radiological surveys to verify or adjust estimates of radiological impacts.
- Recommend that affected people reduce their exposures by using simple decontamination techniques and remaining indoors.

3.4. SEQUENCE OF EVENTS

The high-priority decisions on whether to relocate people from high exposure rate areas requires exposure rate measurements and dose analyses. Monitoring and dose assessment will be an ongoing process, with priority given to the areas with the highest exposure rates.

Following passage of the airborne plume, a number of tasks must be accomplished for the timely protection of the public. The general sequence of events is itemized below, but the time frames will overlap.

1. Determine the areas where the projected first-year dose will exceed the 2 rem (20 mSv) relocation PAG and relocate people from those areas, with priority given for people in the highest exposure rate areas.
2. Allow previously evacuated people to return as quickly as possible to areas where field gamma measurements indicate that exposure rates are near normal background levels. If there is a possibility that particles from high deposition areas could drift into the occupied areas, establish a buffer zone to restrict residential use until radiological measurements and assessments confirm that it is no longer necessary. Buffer zones are set with the understanding that conservatism is inherent in the PAGs.
3. Based on isodose-rate boundary (see Section 3.4.1), assign any evacuees who reside within the relocation area to be relocated. Evacuated people whose residence is in the area between the boundary of the plume deposition and the boundary to the relocation area may return gradually as dose projections allow.
4. Evaluate the dose reduction effectiveness of simple decontamination techniques and of sheltering-in-place in response to exposure from partial occupancy of residences and workplaces. Results of these evaluations may influence recommendations for reducing exposure rates for people who are not relocated from areas near, but outside, the relocation area.
5. Control access to and egress from the relocation area. This would be accomplished through control points at roadway accesses to the relocation area.
6. Establish monitoring and decontamination stations to support control of the relocation area.
7. Implement simple decontamination techniques in contaminated areas outside the relocation area, giving priority to areas with higher exposure rates.
8. Collect data needed to establish long-term radiation protection criteria for decontamination and dose reduction and data to determine the effectiveness of various decontamination or other dose reduction techniques.
9. Begin operations to clean up and recover contaminated property in the relocation area.
10. If not already done, evaluate whether food grown or produced within the plume deposition area need to be interdicted per the FDA PAGs and evaluate drinking water systems within the plume deposition area. Provide guidance on planting or harvesting specific agricultural products.

3.4.1. Establishment of Isodose-Rate Lines

As soon as federal or other assistance is available for aerial and ground monitoring, a concentrated effort should begin to establish isodose-rate lines on maps and identify boundaries of the relocation area. Standard maps should be developed on which all response organizations would record monitoring data. Records on monitoring and decontamination of the public and workers should also be collected.

Aerial monitoring can be used to collect data for establishing general patterns of radiation exposure rates and may form the primary basis for the development of dose lines out to the limit of aerial detectability.

Initially during the early phase, detectability is limited to exposure rate changes of a few times natural background levels. Later during the intermediate phase, more sensitive measurements detect levels of radioactivity that are a small fraction of the natural background. Periodic air sample measurements will also be needed to verify the contribution to dose from inhalation of resuspended materials.

Gamma exposure rates measured at one meter (39 inches) will vary within a very small area because different surfaces have different deposition rates (e.g., smooth surfaces versus heavy vegetation). Rinsing or precipitation could also reduce levels in some areas and raise levels in others where runoff settles. In general, where exposure rates vary within designated areas, dose projections should be estimated using an appropriate average exposure rate.

3.4.2. Dose Projection

The FRMAC Assessment Manuals[27] provide detailed guidance for dose projection and calculating DRLs and DPs ~~DCF~~s (DOE 2012). The FRMAC Assessment Manuals incorporate the ICRP dosimetry models (ICRP 60 series). In addition, the FRPCC encourages the use of computational tools such as DOE's Turbo FRMAC and NRC's RASCAL or other appropriate tools and methods to implement the PAGs.

The primary dose of interest in the intermediate phase is the sum of the effective dose from external exposure and the committed effective dose from inhalation. The exposure periods of interest are the first year and subsequent years after the incident. Other pathways should also be evaluated and their contributions considered, if significant. For example, anytime alpha-emitting radionuclides are involved, the inhalation of resuspended material must be considered. Although beta exposure will contribute to skin dose, its contribution to the overall risk of health effects from the radionuclides expected to be associated with reactor incidents should not be controlling in comparison to the whole body gamma dose (Aaberg 1989). However, the skin beta dose may be important for particulates deposited or transferred to the skin, as may be the case for an RDD that contains Strontium-90.

The dominant intermediate phase exposure pathway for incidents involving alpha-emitters (e.g. a weapons accident) is inhalation of resuspended material. For these incidents, dispersal of alpha-emitting material must be monitored carefully using proper measurement techniques. It is possible that there will be little or no associated gamma radiation or beta activity.

Calculation of the projected gamma dose from measurements will require knowledge of the principal radionuclides contributing to exposure and their relative abundances. Radiological characteristics can be compiled either through the use of portable gamma spectrometers or by radionuclide analysis of environmental samples. Several measurement locations may be required to determine whether any selective radionuclide deposition occurred as a function of meteorology, surface type, distance from the point of release, or other factors. In accordance with the Nuclear/Radiological Incident Annex to the National Response Framework, DOE, EPA and other federal agencies have the capability to assist state officials in performing environmental measurements, including determination of radiological characteristics of deposited materials (FEMA 2008 a, b).

The gamma exposure rate may decrease rapidly if deposited materials include a significant fraction of short-lived radionuclides. Therefore, the relationship between instantaneous exposure rate and projected first- and second-year annual doses will change as a function of time. These relationships must be established for the particular mix of deposited radioactive materials present at the time of the gamma exposure rate measurement. Over time, residual doses from gamma emitters will depend largely upon the half-lives of the radionuclides involved and could potentially remain significant over many years. It should be noted that natural attenuation as well as nuclear decay can affect long term dose assessments.

[27] See FRMAC Assessment folder at http://www.nv.doe.gov/nationalsecurity/homelandsecurity/frmac/manuals.aspx.

Projected dose considers exposure rate reduction from radioactive decay and, generally, weathering. When one also considers the anticipated effects of shielding from normal part time occupancy in homes and other structures, people who are not relocated should receive a dose substantially less than the projected dose. For commonly assumed reactor source-terms, it is estimated that 2 rem (20 mSv) projected dose in the first year will be reduced to about 1.2 rem (12 mSv) by this factor. The application of simple decontamination techniques shortly after the incident can be assumed to provide a further 30 percent or more reduction so that the maximum first year dose to people who are not relocated is expected to be less than 1 rem (10 mSv). Taking account of decay rates assumed to be associated with releases from NPP incidents (SNL 1982) and shielding from partial occupancy and weathering, a projected dose of 2 rem (20 mSv) in the first year is likely to amount to an actual dose of 0.5 rem (5 mSv) or less in the second year. The application of simple dose reduction techniques would reduce the dose further.
Calculations supporting these projections are summarized in Table E-6 of the 1992 PAG Manual.[28]

Keeping below the 0.5 rem (5 mSv) PAG for ~~out~~ subsequent years—the second year and beyond—may be achieved through natural decay of shorter half-life radioisotopes, through decontamination efforts, or through other means of controlling public exposures (such as limiting access to certain areas). In the case of an RDD, in which a longer half-life radioisotope would likely be utilized, reductions in dose may prove difficult to achieve without longer term measures (see Chapter 4).

Exposure from ingestion of food and water is considered independently of decisions for relocation and decontamination. In rare instances, however, where withdrawal of food or water from use would pose a health risk in itself, relocation may be an appropriate protective action against exposure via ingestion. In this case, the dose from ingestion should be considered along with the projected dose from other exposure pathways for decisions on relocation.

3.4.3. Projected External Gamma Dose

Projected whole body external gamma doses at 1 meter height at particular locations during the first year and second year after the incident are the parameters of interest (DOE 1988). Measurements made at 1 meter to project whole-body dose from gamma radiation should be made with instruments of the "closed window" type to avoid the detection of beta radiation. The environmental information available for calculating these doses is expected to be the current gamma exposure rate at 1 m height and the relative abundance of each radionuclide contributing significantly to that exposure rate. Calculation models are available for predicting future exposure rates as a function of time with consideration of radioactive decay and weathering.

Relocation decisions can generally be made on the basis of the first year projected dose. However, projected doses during the second year are needed for decisions on protective actions for people who are not relocated. ~~DCFs~~ Conversion factors are therefore needed to convert environmental measurements to projected dose during the first year and second year following the incident (See FRMAC Assessment Manuals). Of the many types of environmental measurements that can be made to project whole body external gamma dose, gamma exposure rate in air is the easiest to make and is the most directly linked to gamma dose rate. However, analyses of a few environmental samples (particularly, soil samples) must be coupled with the gamma exposure rate to properly project decreasing dose rates.

In addition, measurements should be conducted to determine the dose reduction factors associated with simple, rapid, decontamination techniques so that these factors can be used in calculating dose to people who are not relocated. However, assumptions about these factors should not be included in calculating projected dose for decisions on relocation. Only dose reductions already accomplished can be considered.

[28] The 1992 PAG Manual is available as a historical reference online at: <http://www.epa.gov/radiation/rert/pags.html>

3.4.4. Exposure Limits for People Reentering the Relocation Area

After the relocation area is established, people will need to reenter for a variety of reasons, including recovery activities, retrieval of property, security patrol, operation of vital services and, in some cases, care and feeding of farm and other animals. It may be possible to quickly decontaminate access ways to vital institutions and businesses in certain areas so that they can be occupied by adults either for living (i.e., institutions such as nursing homes and hospitals) or for employment. Clearance for occupancy of such areas will require dose reduction to meet exposure limits (EPA 1987). Dose projections should include both external exposure from deposited material and inhalation of resuspended deposited material for the duration of the planned exposure. People working in areas inside the emergency relocation area should operate under the controlled conditions established for occupational exposure (EPA 1987). The worker dose limitation does not need to include ongoing doses received from living in a contaminated area outside the relocation area. It is also not necessary to consider dose received previously from the plume or groundshine during the early phase of the radiological incident.

3.5. PROTECTIVE ACTION GUIDANCE FOR FOOD AND DRINKING WATER

Information on food and animal feeds protective action guidance is contained in FDA's "Accidental Radioactive Contamination of Human Food and Animal Feeds: Recommendations for State and Local Agencies" (FDA 1998).

{placeholder for drinking water PAG once final}

~~EPA is not proposing a specific drinking water PAG at this time. EPA has established enforceable drinking water standards for radionuclides under the Safe Drinking Water Act (SDWA). EPA recommends that to the extent practicable, emergency measures for drinking water be based on the National Primary Drinking Water Regulations (NPDWR) for Radionuclides. The Radionuclides Rule provides states with flexibility when responding to radiological events. If a public water system exceeds the radionuclides standard it must work to get back into compliance as soon as feasible. States have the authority to determine if other corrective actions are needed (e.g. providing alternative water).~~

~~However, the Agency recognizes a short-term emergency drinking water guide may be useful for public health protection in light of the Fukushima nuclear power plant accident, which impacted some Japanese drinking water supplies. Input on the appropriateness of, and possible values for, an intermediate phase emergency drinking water PAG is being sought during the public review of this Manual.~~

~~While the NPDWR provide for a regulatory standard of 4 mrem/year (beta, photon emitters) based on life-time exposure, international organizations have developed technical approaches and methodologies that have produced a range of emergency guidelines related to drinking water (e.g., the World Health Organization[29], the International Atomic Energy Agency[30]) as have other federal agencies (e.g., the Department of Homeland Security[31], the Food and Drug Administration[32]) and non-federal organizations. EPA is seeking input on an approach and technical rationale for a drinking water PAG designed to help officials select protective actions under emergency conditions when exposures would occur over shorter time periods than those envisioned in the NPDWR.~~

~~3.5.1. Monitoring & Characterization of Contaminants~~

~~The Radionuclides Rule requires community water systems (CWS) to monitor at each entry point to the distribution system to ensure that every customer's water does not exceed the maximum contaminant levels (MCLs) for radionuclides. All CWS are required to monitor for gross alpha, radium-226/228 and~~

[29] See: http://www.who.int/water_sanitation_health/dwq/gdwq3rev/en/ and http://www.who.int/hac/crises/jpn/faqs/en/index8.html.

[30] See: http://www-pub.iaea.org/MTCD/publications/PDF/Pub1467_web.pdf.

[31] See: http://ogcms.energy.gov/73fr45029.pdf

[32] See: http://www.fda.gov/downloads/MedicalDevices/.../UCM094513.pdf

~~uranium. In addition, CWS designated by the state as "vulnerable" or if they use waters contaminated by effluents from nuclear facilities must also conduct monitoring for beta particle and photon radioactivity.~~

~~In the event of a radiological event incident, the state, at its own discretion, may exercise regulatory flexibility and require systems to collect samples for radionuclides, including beta particle and photon activity (40 CFR 141.26(c)). For more information about monitoring requirements for the Radionuclides Rule see the "Radionuclides Rule: A Quick Reference Guide" (EPA816-F-01-003, June 2001)[33] or "Implementation Guidance for Radionuclides" (EPA 816-F-00-002, March 2002).[34]~~

~~To determine if there is radiological contamination of drinking water sources and the extent to which such contamination is occurring, systems sampling for radionuclides must use approved EPA methods.[35]~~

~~3.5.2. Public Notification~~

~~If water sample monitoring indicates that contamination levels exceed the MCL for any radionuclide, water systems are required to issue a Tier 2 Public Notification (i.e., within 30 days).~~

~~States have the flexibility to elevate the notification if warranted to a Tier 1 Public Notification (i.e., within 24 hours) (40 CFR 141.201(a)(3) Special public notices: Occurrence of a waterborne disease outbreak or other waterborne emergency.~~

~~During a radiological event, water systems may be dealing with a number of requirements and operating procedures and may not be prepared to issue public notification. The state may issue public notification on behalf of the water system (40 CFR 141.210(a)). This would allow the state to develop and deliver a consistent message to all affected customers and also allows the system to concentrate its efforts on returning the system to operation and/or returning to compliance in the event of a radionuclides MCL violation. For more information see the Revised Public Notification Handbook (EPA 816-R-09-013, March 2010).[36]~~

~~3.5.3. Corrective Actions to Reduce Levels of Contamination~~

~~Water distribution systems all incorporate reserve and storage capacity. During the early phase of an incident it is unlikely that contamination could affect water which is directly available for consumption through distribution systems. It would take some time for radionuclides to be deposited from the plume into the supply system water source and then subsequently be distributed. During the early phase, recommendations to the public (i.e., about drinking tap water) should reflect these considerations. The public should be advised that the water is safe to drink unless otherwise informed by state officials. Some useful and practical actions water systems can take during the intermediate phase to provide drinking water to customers are described below.~~

~~*Wait for Flow-By*~~

~~If radionuclides are deposited over a river, a section of the water can become contaminated and can be repeatedly contaminated as rain re-deposits radioactive particles. As this section flows down the river, this section of contaminated water is called a plume. This action calls for closing down any source intake valves along the path of the plume of contaminated water. While the intake valve is closed, no contaminated water can enter the water supply system; therefore the contaminated water is allowed to~~

[33] See: http://www.epa.gov/ogwdw/radionuclides/pdfs/qrg_radionuclides.pdf

[34] See: http://water.epa.gov/lawsregs/rulesregs/sdwa/radionuclides/upload/2009_04_16_radionuclides_guide_radionuclides_stateimplementation.pdf

[35] A list of EPA approved analytical methods for Radionuclides is available at: http://www.epa.gov/ogwdw/methods/pdfs/methods/methods_radionuclides.pdf

[36] See: http://water.epa.gov/lawsregs/rulesregs/sdwa/publicnotification/upload/PNrevisedPNHandbookMarch2010.pdf.

~~flow by the system. During this time, the system's existing storage capacity can be depended upon. If the stored water supplies could be depleted before the affected valves can be reopened, treatment of the contaminated water while using available stored water supplies should be considered. This assumes that the treatment technology will be in place or readily accessible. In the event of no other option, contaminated water could be temporarily replaced with large quantities of purchased uncontaminated water.~~

~~*Treat Contaminated Water*~~

~~Various treatment options exist for reducing or eliminating the contamination of drinking water by man-made radionuclides. Only a small percentage of all water systems treat specifically for radionuclides. However, typical technologies used to treat water for other contaminants can reduce the concentration of radioactivity. These technologies include coagulation/filtration, ion exchange, lime softening and reverse osmosis. Their actual removal efficiency depends on the radionuclide and the type of treatment.~~[37]

~~*Activate Existing Connections to Neighboring Systems*~~

~~If the water supply system is part of a larger, regional supply system, activation of existing connections to a neighboring area could be considered. Most large water systems can establish connections with other large systems for emergency purposes. As in many cases, this option may have already been considered during emergency planning. If this option is implemented, steps must be taken to ensure that the "clean" systems do not become contaminated from water backflow.~~

~~Smaller water supply systems (i.e., that serve between 10,000 and 75,000 people), or sparsely populated or rural areas, may not be connected to a neighboring system. In this case, regionalization may be a part of emergency planning to explore. This involves connecting smaller systems to larger systems, thus forming a regional water supply system. This is obviously a long-term proposition, but it does have the added advantage of reducing system vulnerability to water shortages or water quality problems other than those resulting from a radiological incident.~~

~~*Establish Pipeline Connections to Closest Sources/Systems*~~

~~Running a pipeline from a "clean" water supply system to various distribution centers located throughout the affected community is a routine means of providing clean water. For example, when water mains must be repaired or cleaned of debris, community water needs have been met through the assembly of temporary pipes and hoses. This is a relatively simple procedure, requiring very little construction and technical expertise. For medium- to long-term emergencies, the construction of a temporary pipeline could be cost-effective. PVC pipe, fire hoses and steel pipe have been used to provide emergency drinking water for periods of up to 2 months when service has been disrupted by earthquakes, drought, or bacterial contamination.~~

~~*Import Water in Tanker Trucks*~~

~~If an uncontaminated source of water is close to the affected area, it may be more efficient to arrange to transport water from that source by truck, rail, or barge to distribution centers located throughout the community. The most significant obstacle for the use of this option is the cleanliness and availability of transport vehicles. State and local laws may also affect this option.~~

~~*Import Bottled Water*~~

~~Importing bottled water into the affected community is another possible option. The water may come from a nearby water supply system or from a water bottling company. This option may be cost-effective during an emergency if water is needed quickly and if the length of the emergency does not merit long-term action, such as the construction of a temporary pipeline.~~

[37] Additional information about treatment options and compliance guidance is available at the following website: http://water.epa.gov/lawsregs/rulesregs/sdwa/radionuclides/compliancehelp.cfm.

~~*Ration Clean Water Supplies*~~

~~Rationing uncontaminated water is also a possibility. This is particularly true if water reserves can provide each individual in the community with 1 L (0.264G, about 1 qt) of water per day until the contaminated plume has passed, the contaminated water is treated, or the water supply system has returned to normal operating conditions. If this option is chosen, it is important that efficient methods for rationing are in place. Rationing water might also be required if water treatment capabilities are limited. Consider a scheme to ration water as part of emergency planning efforts.~~

3.6. LONGER-TERM OBJECTIVES OF THE PROTECTIVE ACTION GUIDES FOR THE INTERMEDIATE PHASE

It is an objective of the PAGs to ensure that doses in any single year after the first will not exceed 0.5 rem (5 mSv). For source terms from NPP incidents, the PAG of 2 rem (20 mSv) projected dose in the first year is expected to meet this longer-term objective through radioactive decay, weathering and normal part-time occupancy in structures. If the release contains long-lived radionuclides, decontamination of areas outside the relocation area may be required during the first year to meet these objectives. For situations where it is impractical to meet these objectives through decontamination, relocation should be considered even if the projected first-year dose is lower than the relocation PAG.

Based on the relocation PAGs, reentry guidance can be found in the Reentry Matrix in Section 3.8, as well as in the Preliminary Report on Operational Guidelines Developed for Use in Emergency Preparedness and Response to a Radiological Dispersal Device Incident, Group C (DOE 2009). After the population has been protected in accordance with the PAGs for relocation, return for occupancy of the relocation areas should be governed on the basis of cleanup criteria and late phase cleanup activities should proceed.

3.7. REENTRY MATRIX FOLLOWING A RADIOLOGICAL INCIDENT OR ACCIDENT

~~3.7.1. Assumptions and Definitions~~

~~The term reentry is used for emergency workers and members of the public going into radiologically contaminated areas temporarily under controlled conditions.~~

~~The incident response is divided into three activity planning phases. Early Phase begins with the incident and may last from hours to days. Intermediate Phase begins with control and characterization of the release; it may overlap early and late phase activity and last from weeks to months. , and is assumed to last for one year for purposes of dose projection only.~~

~~Late Phase begins when recovery actions to reduce radiation in the environment begin and ends when all recovery actions are complete. The matrix below only addresses Early and Intermediate Phase activity.~~

~~3.7.2. Approach and Discussion~~

~~Interagency guidance informed this section, including—~~

- ~~"Manual of Protective Action Guides and Protective Actions for Nuclear Incidents" (EPA, 1992)[38].~~
- ~~"Preliminary Report on Operational Guidelines Developed for Use in Emergency Preparedness and Response to a Radiological Dispersal Device Incident" (DOE 2009)[39].~~

[38] PAGs Manual online at http://www.epa.gov/rpdweb00/rert/pags.html.

[39] The Operational Guidelines were developed by federal agencies and published in draft form by DOE in February 2009 with DOE reference number DOE/HS-0001; ANL/EVS/TM/09-1, on-line at http://ogcms.energy.gov/review.html.

- ~~FRMAC Assessment Manual (Sandia National Lab, 2010)[40].~~

The "Preliminary Report on Operational Guidelines Developed for Use in Emergency Preparedness and Response to a Radiological Dispersal Device Incident" (DOE 2009), referred to as "Operational Guidelines" include detailed numeric guidance, developed by a multi-agency working group as a follow-up to the RDD/IND Planning Guidance. That work focused specifically on response and recovery for an RDD event; however, that work can be expanded to include isotopes from a variety of incident types.

The Operational Guidelines are informative for this guidance, specifically the discussions about applicable dose-based limits, timeframes and pathways of exposure related to reentry tasks. Food and agriculture guides use FRMAC assessment methods as well as the Operational Guidelines for implementation. These tools allow derivation of decontamination thresholds for the early and intermediate stages of a response.

As part of the U.S. response to the Japanese Fukushima accident, scientists performed dose calculations to ensure that passengers and workers on train trips through contaminated areas do not exceed doses typically received from cosmic radiation during an international flight. DOE's Argonne National Laboratory scientists utilized the RESRAD-RDD tool and hand calculations to approximate the NPP radionuclides.

[40] FRMAC Assessment Manual, Overview and Methods online at: http://www.nv.doe.gov/nationalsecurity/homelandsecurity/frmac/manuals.aspx.

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3.8. REENTRY MATRIX FOLLOWING A RADIOLOGICAL INCIDENT OR ACCIDENT

PHASE	ACTIVITY	SUGGESTED LEVELS	CLEANUP ACTIONS
Early Phase ~~(first 4 days)~~	**Sheltering or Evacuation for the Public**	**Public**: 1,000-5,000 rem (10-50 mSv) projected over four days (See Ch. 2). A decision to evacuate weighs anticipated dose against feasibility of evacuating within a determined time frame, along with the risks associated with the evacuation itself.	It is too early for organized cleanup, due to chaos of the situation and higher priorities such as life-saving activities and clearly identifying shelter and evacuation zones. Any cleanup or decontamination information should focus on personal decontamination. It is doubtful any large-scale effort could change evacuation or shelter recommendations during this period (1st 4 days).
	Emergency Worker Protection	~~response worker~~ Emergency Worker: 5,000/10,000/25,000 rem (50/100/ 250 mSv) incurred over the response duration. The higher limits are based on task (e.g., protecting large populations or critical infrastructure or lifesaving). Responder doses will be tracked with dosimeters. Emergency workers have knowledge of the risks associated with radiation exposure, training to protect themselves and dosimeters to track their doses.	Once evacuation is completed, there are simple actions cities can implement themselves: rinsing roofs and streets, street sweeping. The objective of these efforts is to move the bulk amounts of contamination away from occupied areas or areas where reoccupation is a priority. These actions should be based on measured amounts of contamination and priority of the location. Workers may face high dose levels and will need health physics
Intermediate Phase ~~(first 30 days and up to a year)~~	**Relocation for the Public**	**Public**: 2,000 rem (20 mSv) projected first year, 500 rem (5 mSv) per year projected in subsequent years (See Ch. 3). In this phase, scientists run dose calculations with RESRAD RDD or Turbo FRMAC; the user can choose sensitive age groups, or enter lower guidelines, if desired. Additionally, local decision makers can adapt the guides with incident-specific considerations and implement variations as needed.	Early cleanup efforts should focus on the removable portion of the contamination: vacuuming, washing, vegetation removal. Vacuuming has the advantage of collecting removable contamination without water or surface impact, but is limited by equipment availability and can also expose the operators to high dose levels as the vacuums collect the contamination. Washing and rinsing are simple to implement, but only move the contamination to less-populated areas and may move contamination deeper into porous surfaces. For unpaved areas, vegetation removal can effectively reduce the amount of contamination present, but is labor intensive and can produce large amount of waste. Having addressed the removable part of the contamination, later efforts can focus on fixed contamination. Paved surface

Intermediate Phase ~~(first 30 days and up to a year)~~	**Reentry** **For Use of Critical Infrastructure**	**Public**: 2,000 rem (20 mSv) in first year (Preliminary Report on Operational Guidelines Developed for Use in Emergency Preparedness and Response to a Radiological Dispersal Device Incident, *Operational Guidelines Group C*). Dosimeters could be considered for the public.	removal is very effective, but requires specialized equipment and trained operators. Surface sealing is easier, but leaves the contamination in place, making it viable only in locations where the dose rates are low enough for occupation, or in low-occupancy areas. Repaving roads, lots and other paved surfaces is easy to implement, but can generate significant waste volumes. Unpaved areas can be further remediated by soil skimming (surface removal), deep plowing (turning the top foot or so of soil over) and appropriate chemical soil amendment methods like liming or chelating. As the Intermediate phase progresses, knowledge and experience increases and these methods can be re-applied, refined or customized for problem areas. Decisions about more difficult areas will benefit from professional judgment, additional analyses and application of more sophisticated technologies.
	Radiation Worker Protection	**Radiation Worker Protection**: (dose not to exceed) 5,000 rem (50 mSv) per year ((*Radiation Protection Guidance to Federal Agencies for Occupational Exposure*, EPA 1987). Radiation workers have knowledge of the risks associated with radiation exposure, training to protect themselves and dosimeters to track their doses. During an incident response, workers (police, waste handlers) needed in contaminated areas could be trained and given dosimeters. The guidance for Radiation Workers applies	
	Reentry For Use of Roads and Walkways	**Public**: 2,000 rem (20 mSv) first year, 500 rem (5 mSv) per year in subsequent years (*Operational Guidelines, Group E*). While the dose values here are similar to those for Use of Critical Infrastructure above, the derived concentrations measured as triggers are different because the exposure conditions are different	
	Reentry For Access to the Relocation Zone	**Public**: 500 rem (5 mSv) over one year for temporary access with stay times dependent on reentry tasks and site-specific conditions (*Operational Guidelines, Group D*). 'Stay time' is a term of art used in the radiation safety field. Stay times are the amount of time a person may access the contaminated area. These times vary based upon site-specific factors or incident characteristics such as indoor or outdoor work, sensitive populations and level of radioactivity. Section 7.1 of the Operational Guidelines, "Worker Access to Businesses for Essential Actions," provides tables and graphs of stay times at various limiting concentrations (see Figure 7.5 and Table 7.8). For example, if the maximum surface street	

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concentration of Cesium-137 is 3.00E+09 pCi/m2 (1.11E+08 Bq/m2), people limited to 500 rem (5 mSv) should be in the contaminated area less than four 8-hour days if staying outdoors.

This may apply to individuals retrieving belongings from homes or to workers providing security patrols, or even to people reopening businesses in the area. As contamination levels are reduced during cleanup, stay times can be extended and total doses reduced.

Operational Guidelines provide stay times and concentrations for several different sets of assumptions about the exposure. Residents retrieving possessions may spend most of their time indoors, where stay times are longer than they are for outdoors tasks. Stay time recommendations can be used to guide decisions about allowing entry into the contaminated area for a limited time and dose reduction techniques like wearing dust masks, cleaning shoes and car tires upon exit and using time wisely keep radiation exposure 'ALARA' below the Operational Guideline.

Table 7.8 Scenario D2-2 Operational Guidelines for 0.5 rem Annual Dose: Residents Access to Houses (Indoor Exposure)

	Surface Street Concentration (pCi/m^2)		
Radionuclide	1 Day	4 Days	12 Days
Am-241	7.51E+07	2.86E+07	1.59E+07
Cf-252	3.50E+08	1.32E+08	7.13E+07
Cm-244	1.27E+08	4.82E+07	2.68E+07
Co-60	2.72E+09	6.87E+08	2.33E+08
Cs-137	1.14E+10	2.94E+09	1.01E+09
Ir-192	9.93E+09	2.54E+09	8.92E+08
Po-210	1.17E+09	3.86E+08	1.74E+08
Pu-238	6.56E+07	2.50E+07	1.39E+07
Pu-239	6.01E+07	2.29E+07	1.27E+07
Ra-226	6.08E+08	2.10E+08	9.97E+07
Sr-90	2.48E+10	7.70E+09	3.18E+09

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KEY POINTS IN CHAPTER 3 – INTERMEDIATE PHASE

- The principal protective actions for reducing exposure of the public to deposited radioactive materials are relocation, decontamination and time limits on exposure. The PAG for relocation is 2 rem (20 mSv) over the first year of exposure. After the first year, the PAG for relocation is 0.5 rem (5 mSv) per year.
- Boundaries of relocation areas should be established based on the relocation PAG and site-specific geographical features such as rivers, mountains or roadways.
- Exposure limits must be set for people who must enter the relocation area to perform vital services.
- Other protective actions, such as focused decontamination and time limits on exposure, are applied to people in areas where levels of deposited radioactivity are not high enough to warrant relocation.
- Protective action guidance for food is contained in FDA's "Accidental Radioactive Contamination of Human Food and Animal Feeds: Recommendations for State and Local Agencies" (FDA 1998).
- EPA has established enforceable drinking water standards for radionuclides under the SDWA. EPA recommends that to the extent practicable, emergency measures for drinking water be based on the NPDWR for radionuclides. The Radionuclides Rule provides states with flexibility when responding to radiological events. Input on the appropriateness of, and possible values for, an intermediate phase emergency drinking water PAG is being sought during the public review of this Manual.
- To inform temporary reentry into relocation areas, use the Operational Guidelines (DOE 2009).

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CHAPTER 4 – PLANNING GUIDANCE FOR THE LATE PHASE

4.1. CLEANUP PROCESS

This section describes the remediation cleanup process for the late phase of a nationally significant radiological incident, like a disaster at an NPP, an RDD or an IND. It should be noted that the extent and scope of contamination as a result of an NPP, RDD or IND incident may be at a much larger scale than a site or facility decommissioning or remedial cleanup. This process identifies the late phase remediation or cleanup process steps, including factors for decision makers to consider in determining final cleanup actions. For information on roles, responsibilities and authorities during emergency response and recovery please refer to the National Response Framework: http://www.fema.gov/national-response-framework and specifically for radiological incidents, the Nuclear Radiological Incident Annex: http://www.fema.gov/pdf/about/divisions/thd/IncidentNucRad.pdf (FEMA 2008a, b).

4.1.1. Transitioning from Intermediate to Late Phase Cleanup

The late phase cleanup process begins sometime after the commencement of the intermediate phase and proceeds independently of intermediate phase protective action activities. The transition is characterized by a change in approach, from strategies predominantly driven by urgency, to strategies aimed at both reducing longer-term exposures and improving living conditions. The late phase involves the final cleanup of areas and property at which contamination directly attributable to the incident is present. It is in the late phase that final cleanup decisions are made and final recovery efforts following a radiological incident are implemented.

Unlike the early and intermediate phases of a radiological incident, decision makers will have more time and information during the late phase to allow for better data collection, stakeholder involvement and options analysis. There will be opportunities to involve key stakeholders in providing sound, cost-effective cleanup recommendations. Generally, emergency phase decisions will be made directly by elected public officials, or their designees, with limited stakeholder involvement due to the need to act within a short timeframe. Longer-term decisions should be made with stakeholder involvement and can also include incident-specific technical working groups to provide expert advice to decision makers on impacts, costs and alternatives. Community members will influence decisions such as if and when to allow people to return home to contaminated areas. There will be people living in contaminated areas, outside the evacuation and relocation zones, where efforts to reduce exposures will be ongoing.

Because of the extremely broad range of potential impacts that may occur from NPP incidents, RDDs and INDs (e.g., light contamination of one building to widespread destruction of a major metropolitan area), a process should be used to determine acceptable cleanup criteria based on the societal objectives for expected land uses and the options and approaches available. Implicit in these decisions is the ability to balance health protection with the desire of the community to resume normal life. Radiation protection considerations must be addressed in concert with health, environmental, economic, social, psychological, cultural, ethical, political, and other considerations. It is recognized that experience from existing programs, such as the U.S. EPA's Superfund program, the U.S. NRC's process for decommissioning and decontamination to terminate a nuclear facility license and other national recommendations may be useful in planning cleanup and recovery efforts.

Consistent with the "Framework for Environmental Health Risk Management," mandated by the 1990 Clean Air Act Amendments and published by the Commission on Risk Assessment and Risk Management in 1997, the late phase cleanup process consists of multiple steps, including 1) characterization and stabilization, 2) development of goals and strategies and 3) implementation and

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reoccupancy. Stakeholder involvement should be integrated throughout the process. Characterization in this phase consists of delineation, in detail, of the nature and extent of contamination in areas impacted by the incident. Stabilization is intended to reduce the spread of contamination to clean areas, airborne inhalation hazards and the volume of radioactive waste generated. Establishment of cleanup goals and strategies should consider overall community health, along with a variety of factors described further below; they are based upon anticipated land use and a variety of selection criteria. Key to these steps is the involvement and acceptance of the impacted state and local community. These steps are discussed in more detail below.[41]

4.1.2. Characterization and Stabilization

The first step in the late phase remediation or cleanup process is characterization, or the comprehensive mapping and monitoring of the distribution and level of radioactive contamination. Characterization activities are necessary in the preparation for and verification of a successful remediation or cleanup effort. The late phase characterization work is designed to define, in detail, the nature and extent of the contamination and to provide information needed to develop and evaluate cleanup alternatives.

The characterization performed in support of the late phase will be much more detailed and comprehensive than the earlier characterization work to support PAG decisions made during the early and intermediate phases. It delineates the nature of any actual threat posed to human health or the environment and defines the extent of that threat.

Stabilization techniques are designed to immobilize radioactive contamination on soils, buildings, roads and equipment. This becomes paramount in a large-scale incident where the spread of contamination can occur from natural weathering effects to human and animal interactions with the environment. Stabilization reduces chronic low-level exposures to residual radiation, airborne hazards and volumes of secondary waste. These reductions can result in significant benefits to the long-term recovery in terms of time-to-normalcy and economic recovery.

4.1.3. Goals and Strategies

After late phase characterization and stabilization activities are accomplished, areas impacted by radioactive contamination are documented and defined to the best extent possible. At this point, decision makers must establish cleanup goals and strategies for moving forward. The development of goals and strategies marks the second step in the late phase remediation or final cleanup process. As part of an ongoing iterative process, cleanup goals are informed by the feasibility of cleanup strategies and specific cleanup strategies adjust as experience is gained. That is, risk management goals may be refined as decision makers and stakeholders gain appreciation for what is feasible, what the costs and benefits are and how the process of reducing exposures and risks can improve human and ecological health.

As actual levels for areas are determined, many factors come into play in decision making, such as balancing risk reduction with other factors, background levels of radioactivity and tolerance for voluntary versus involuntary risk. Determining these levels will require consideration of a number of factors—

- The types of contamination; the technical feasibility, cost, timeliness and effectiveness of decontamination measures; and the availability and cost of options for the disposal of wastes.
- The size and character of the areas that are contaminated; past and projected future uses for these areas; and the preservation or destruction of places of historical, national, or regional significance.
- Site-specific natural and anthropogenic background levels of radioactivity.
- Estimates of the impacts of both contamination and options for decontamination, on human health, communities, the economy, ecosystems and ecosystem services.

[41] This cleanup process does not rely on and does not affect any authority, including the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), 42 U.S.C. 9601 et seq. and the National Contingency Plan (NCP), 40 CFR Part 300. This document expresses no view as to the availability of legal authority to implement this process in any particular situation.

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- Public acceptability and intergenerational equity.

Community involvement and sentiment are vital to this process. The stress from both the incident itself as well as the longer term effects of separation from home will be important factors as overall community health is considered. In the United States, a range of one in a population of ten thousand (10^{-4}) to one in a population of one million (10^{-6}) excess cancer incidence outcomes is generally considered protective for both chemical and radioactive carcinogenic contaminant exposures. This range is the regulatory standard generally used in the context of EPA Superfund response actions. The NRC's decommissioning and decontamination process outcomes are usually in or near this range as well. A similar risk range may be an appropriate goal for radiological events that affect areas of comparable size. However, such risk ranges may not be practically achievable for major incidents that result in the contamination of very large areas. Every incident is unique. In making decisions about cleanup goals and strategies for a particular event, decision makers must balance the desired level of exposure reduction with the extent of the measures that would be necessary to achieve it, in order to maximize overall human welfare.

While it may take many years to achieve final cleanup levels, a timely return to normalcy, including reoccupancy and a viable community, will require a cleanup process that is flexible, iterative and inclusive. Decisions must be made on a site-specific basis and should reflect the interim risks that are reasonable and acceptable to the affected community as active remediation, radioactive decay and natural weathering move the site toward long-term cleanup goals.

Cleanup strategies are adopted as decision makers and stakeholders gain an understanding of all relevant factors. Tradeoffs between alternatives should be considered and balanced so that the best options are chosen. Local acceptance will be a key component of a fully transparent approach to long-term remediation and cleanup. Factors to consider in determining cleanup actions include evaluating:

- areas impacted (e.g., size, location relative to population);
- actions already taken during the early and intermediate phases;
- the ability of a remedy to maintain reliable protection of overall human health and the environment over time;
- assessing the relative performance of treatment technologies on the toxicity, mobility or volume of contaminants;
- the success or effectiveness of the cleanup or remediation as the cleanup progresses (contaminant removal);
- the adverse impacts on human health and the environment that may be posed in the time it takes to implement the remedy and achieve the community-based remediation goals;
- the impacts of alternative levels of clean up on the local and regional economy (e.g., job loss due to closed businesses, job creation due to decontamination and waste handling operations) and on residents' sense of place (e.g., continued limited access to one's home and community until clean up levels have been reached); preservation or destruction of places of historical, national, or regional significance;
- the technical and administrative feasibility of the remedy, including the availability of materials and services needed to implement each component of the option in question;
- the cost of each alternative, including the estimated capital and operation and maintenance costs and net present value of capital and operation and maintenance costs;
- state concurrence with the remedy;
- community support for the remedy.

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This may be an iterative process. As experience is gained, adjustments may be required to achieve long-term goals.

4.1.4. Implementation and Reoccupancy

To implement cleanup actions in each community, measurable quantities associated with cleanup goals should be derived taking into account exposures from all potential pathways and through all environmental media (e.g., soil, ground water, surface water, sediment, air, animals or plants). These values typically are derived considering reasonably anticipated future land use, dietary habits and commerce patterns. If meeting acceptable levels based upon the reasonably anticipated post-incident land use is not practicable and cost-effective, decision-makers can look to more restrictive land uses through institutional and engineering controls. This approach is based on the belief that early community involvement focusing on desired post-incident uses of the property will result in expedited, cost-effective and publicly-supported cleanups. Overall community health, including stress factors from the initial event and separation from home or family is a necessary consideration.

In some situations, a site or area may reasonably be anticipated to support a range of uses, so cleanup goals may be different for different subareas of the impacted area. Although it may take years to achieve the final cleanup goals for all land uses, reoccupancy of the affected area will be possible when interim cleanup can reduce short-term exposures to acceptable levels during the time it takes to achieve the long-term goals. There may be institutional or engineering controls placed on some portions of the site to prevent excessive exposures until further active remediation, radioactive decay, or natural weathering allow the site to meet cleanup goals. An example of an institutional control might be a restriction on planting vegetable gardens to avoid ingesting radionuclides that may be taken up by the plant roots from the soil. An example of an engineering control to limit exposures might be adding a layer of pavement or cement over gamma emitting radionuclides that have become fixed in place by sorbing onto the street and sidewalks.

In complex cases such as the situation represented by a wide-area NPP, RDD or IND event, cleanup and reoccupancy are likely to occur subarea by subarea in order of priority and community assessments. Critical infrastructure is likely to have been restored to some level of functionality and further remediation of the infrastructure should be evaluated against the cleanup goal. A community-based and transparent development of priorities would follow, resulting in sequential actions, whereby areas (e.g., residential, commercial) would be remediated and reoccupied utilizing temporary cleanup levels that would be considered acceptable for an interim period of time prior to final cleanup goals being achieved. Land use may need to be changed in a subarea where it is not feasible with a combination of remediation, engineering and institutional controls to support the pre-incident land use in a manner that protects human health. In all cases, an appropriate population health monitoring program should be implemented proportionate to the potential or estimated health risk.

4.1.5. Stakeholder Involvement

Generally, early (or emergency) phase decisions will be made directly by elected public officials, or their designees, with limited stakeholder involvement due to the need to act within a short timeframe. With additional time and an increased understanding of the situation, there will be opportunities to involve key stakeholders in providing sound, cost-effective cleanup recommendations that are protective of human health and the environment.

Affected citizens should be involved in all phases of cleanup planning and long-term remediation of their communities. Early in the process, decision makers should bring together a broad group of stakeholders, e.g., residents, local business owners, local government officials and others interested in the processes that will be required to restore their communities. The credibility of a community group is a function of its inclusiveness. It must represent all stakeholder interests to ensure it is a voice for the entire community

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rather than a few interested parties. Empowering individuals to assist in the process is important and effective. The affected local community will need to be involved until the site remediation activities are complete and possibly beyond that if institutional and engineering controls are placed on some subareas of the site.

4.1.6. Cleanup Process Implementation and Organization: An Example

This example, reprinted from the Planning Guidance for Protection and Recovery Following Radiological Dispersal Device (RDD) and Improvised Nuclear Device (IND) Incidents (DHS 2008), describes a hypothetical organization to integrate federal cleanup support activities with state and local governments and the public. In particular, it addresses a scenario where the federal government is expected to be the primary funding entity for cleanup and recovery activities. For some radiological scenarios, states might take the primary leadership role in cleanup and contribute significant resources toward recovery of the site. This example does not address such a scenario, although states may choose to follow a similar process.

a) Cleanup Implementation

This approach describes how federal departments and agencies may coordinate during a response with state and local government counterparts and the public, consistent with the National Response Framework (NRF) (FEMA 2008a) and the National Disaster Recovery Framework (NDRF). The approach does not attempt to provide detailed descriptions of state and local roles and expertise. It is assumed those details will be provided in state and local level planning documents that address radiological/nuclear terrorism incidents.

During the intermediate phase, site cleanup planners should begin the process described below, under the direction of the on-site incident command or unified command (IC/UC) and in close coordination with federal, state and local officials. After early and intermediate phase activities have come to conclusion and only long-term cleanup activities are ongoing, the IC/UC structure may continue to support planning and decision-making for the long-term cleanup. The IC/UC may make personnel changes and structural adaptations to suit the needs of a lengthy, multifaceted and highly visible remediation process. For example, a less formal and structured command, more focused on technical analysis and stakeholder involvement, may be preferable for site extended site cleanup than what is required under emergency circumstances.

Radiological and nuclear incidents cover a broad range of potential scenarios and impacts. This example assumes that the incident is of sufficient size to trigger a state request for federal assistance and that the federal government is the primary funding agent for site cleanup. In particular, the process described for the late phase cleanup assumes an incident of relatively large size. For smaller incidents, all of the elements in this section may not be warranted. The process should be tailored to the circumstances of the particular incident. Decision makers should recognize that for some radiological/nuclear incidents, states will take the primary leadership role and contribute significant resources toward cleanup of the site. This section does not address such a scenario, but states may choose to use the process described here.

b) Cleanup Activities Overview

As described earlier in the document, radiological/nuclear emergency responses are often divided roughly into three phases: (1) the early phase, when the plume is active and field data are lacking or not reliable; (2) the intermediate phase, when the plume has passed and field data are available for assessment and analysis; and (3) the late phase, when long-term issues are addressed, such as cleanup of the site. For purposes of this example, the response to a radiological or nuclear incident is divided into two separate, but interrelated and overlapping, processes. The first is comprised of the early and intermediate phases of response, which consists of the immediate and near-term on-scene actions of state, local and federal ~~emergency responders~~ emergency workers under the IC/UC. On-scene actions include incident stabilization, lifesaving activities, dose reduction actions for members of the public and ~~emergency responders~~ emergency workers, access control and security, emergency decontamination of people and

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property, "hot spot" removal actions and resumption of basic infrastructure functions.

The second process pertains to environmental cleanup, which is initiated soon after the incident (during the intermediate phase) and continues into the late phase. The process starts with convening stakeholders and technical subject matter experts to begin identifying and evaluating options for the cleanup of the site. The environmental cleanup process overlaps the intermediate phase activities described above and should be coordinated with those activities. This process is interrelated with the ongoing intermediate phase activities and the intermediate phase protective actions may continue to apply through the late phase until cleanup is complete.

Cleanup planning and discussions should begin as soon as practicable after an incident to allow for selection of key stakeholders and subject matter experts, planning, analyses, contractual processes and cleanup activities. States may choose to pre-select stakeholders for major incident recovery coordination. These activities should proceed in parallel with ongoing intermediate phase activities and coordination between these activities should be maintained. Preliminary remediation activities during the intermediate phase—such as emergency removals, decontamination, resumption of basic infrastructure function and some return to normalcy in accordance with intermediate phase PAGs—should not be delayed for the final site remediation decisions.

A process for addressing environmental cleanup is presented below. This is a flexible process in which numerous factors are considered to achieve an end result that considers local needs and desires, health risks, costs, technical feasibility and other factors. The general process outlined below provides decision makers with input from both technical experts and stakeholder representatives and also provides an opportunity for public comment. The extent and complexity of the process for an actual incident should be tailored to the needs of the specific incident; for smaller incidents, the workgroups discussed below may not be necessary.

The goals of the process described below are: 1) transparency—the basis for cleanup decisions should be available to stakeholder representatives and to the public at large; 2) inclusiveness—representative stakeholders should be involved in decision-making activities; 3) effectiveness—technical subject matter experts should analyze remediation options, consider established dose and risk benchmarks and assess various technologies in order to assist in identifying a final solution that is optimal for the incident; and 4) shared accountability—the final decision to proceed will be made jointly by federal, state and local officials.

Under the NRF and NDRF, FEMA may issue mission assignments to the involved federal agencies, as appropriate, to participate in the overall recovery process. Additional funding may be provided to state/local governments to perform response or recovery activities through other mechanisms. The components of the process are as follows:

c) General Management Structure

Planning for the long-term cleanup should begin during the intermediate phase and at that time, a traditional National Incident Management System (NIMS) response structure should still be in place. However, NIMS was developed specifically for emergency management and may not be the most efficient response structure for long-term cleanup. If the cleanup will extend for years, the IC/UC may decide to transition at some point to a different long-term project management structure.

Under the NRF and NIMS, incidents are managed at the lowest possible jurisdictional level. In most cases, this will be at the level of the IC/UC. The IC/UC directs on-scene tactical operations. Responding local, state and federal agencies are represented in the IC/UC and Incident Command Post in accordance with NIMS principles regarding jurisdictional authorities, functional responsibilities and resources provided. For a wide-area radiological incident, multiple Incident Command Posts (ICPs) may be established to manage the incident with an Area Command or Unified Area Command supporting the

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ICPs and prioritizing resources and activities among them. If the incident happens on a federal facility or involves federal materials, the representatives in the UC may change appropriately and the response will be conducted according to the applicable federal procedures.

Issues that cannot be resolved at the IC/UC or Unified Area Command level may be raised with the Joint Field Office (JFO) and JFO Unified Coordination Group for resolution. The JFO coordinates and prioritizes federal resources and when applicable, issues mission assignments to federal agencies under the Stafford Act. Issues that cannot be resolved at the JFO level may be raised to the DHS National Operations Center senior-level interagency management groups and the White House Homeland Security Council and National Security Council.

Day-to-day tactical management, planning and operations for the cleanup process will be managed at the IC/UC level, but for large-scale cleanups involving significant federal resources, it is expected that the JFO Unified Coordination Group and national level federal officials will review proposed cleanup plans and provide strategic and policy direction. The federal agency(s) with primary responsibility for site cleanup should be represented in the JFO Unified Coordination Group. The IC/UC will need to establish appropriate briefing venues as the cleanup process proceeds, including the affected mayor(s) and governor(s).

The discussion below assumes a traditional NIMS IC/UC structure; if the IC/UC transitions later to a different management structure for a longer-term cleanup, the IC/UC would need to determine the appropriate way to incorporate the workgroups described below into that structure.

This process will be managed by the IC/UC, who ultimately determines the structure and organization of the Incident Command Post, but the discussion below provides one recommended approach for managing the cleanup process within a NIMS ICS response structure. The Incident Command Post Planning Section has the lead for response planning activities, working in conjunction with other sections and would have the lead for development of the cleanup options analysis, working closely with the Operations Section. The NIMS describes the units that make up the Planning Section and allows for additional units to be added depending on site-specific needs. NIMS states that for incidents involving the need to coordinate and manage large amounts of environmental sampling and analytical data from multiple sources, an Environmental Unit may be established within the Planning Section to facilitate interagency environmental data management, monitoring, sampling, analysis, assessment and site cleanup and waste disposal planning. Radiological incidents would involve the collection of not only large amounts of radiological data, but also data related to other environmental and health and safety hazards and therefore would likely warrant the establishment of an Environmental Unit in the Planning Section. Planning for FRMAC radiological sampling and monitoring activities will be integrated into the Planning Section and coordinated with other Situation and Environmental Unit data management activities.

The IC/UC may assign the Environmental Unit the responsibility for coordinating the development of the cleanup options analysis. For large incidents requiring more complicated tradeoffs or the evaluation of cleanup goals with broad implications, the IC/UC may choose to establish a separate unit in the Planning Section (for example, a Cleanup Planning Unit) to coordinate the development of the cleanup options analysis. The IC/UC may then convene a technical working group and a stakeholder working group, managed by the Environmental or Cleanup Planning Unit, to analyze cleanup options and develop recommendations. The Environmental or Cleanup Planning Unit would coordinate working group processes and interactions and report the results of the cleanup options analysis and workgroup efforts to the IC/UC through the Planning Section Chief.

The development and completion of the cleanup options analysis is expected to be an iterative process and for large incidents, the cleanup will likely proceed in phases, most likely from the "outside in" toward the most contaminated areas. The extent of the analysis and process used to develop it would be tailored to the needs of the specific incident, but the following working groups may be convened by the IC/UC to assist

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decision makers in the cleanup options process, particularly for large or complex cleanups.

d) Technical Working Group
A technical working group should be convened as soon as practicable, ideally within days or weeks of the incident. The technical working group would be managed by the Planning Section Unit that is assigned responsibility for the cleanup options analysis. The technical working group may or may not be physically located at the ICP. The group may review data and documents, provide input electronically and meet with incident management officials. The group may also be asked to participate in meetings with the JFO Unified Coordination Group if needed.

Function: The technical working group provides multi-agency, multi-disciplinary expert input on the cleanup options analysis, including advice on technical issues, analysis of relevant regulatory requirements and guidelines, risk analyses and development of cleanup options. The technical working group would provide expert technical input to the IC/UC; it would not be a decision-making body.

Makeup: The technical working group should include selected federal, state, local and private sector subject matter experts in such fields as environmental fate and transport modeling, risk analysis, technical remediation options analysis, cost, risk and benefit analysis, health physics and radiation protection, construction remediation practices and relevant regulatory requirements. The exact selection and balance of subject matter experts is incident-specific. The Advisory Team for Environment, Food and Health is comprised of federal radiological experts in various fields that may warrant representation on the technical working group, therefore, the Team or some of its members may be incorporated into this group as appropriate.

e) Stakeholder Working Group
The stakeholder working group should be convened as soon as practicable, ideally within days or weeks of the incident. The stakeholder working group would be managed by the Planning Section Unit that is assigned responsibility for the cleanup options analysis. The IC/UC may direct the Public Information Officer (PIO) (who would coordinate with the Joint Information Center (JIC)) to work with the group, including establishing a process for the group to report out its recommendations. How and where the stakeholder working group would meet to review information and provide its input would need to be determined in conjunction with the group members. The stakeholder working group may also be asked to participate in meetings with the JFO Unified Coordination Group if needed.

Function: The function of the stakeholder working group is to provide input to the IC/UC concerning local needs and desires for site recovery, proposed cleanup options and other recommendations. The group should present local goals for the use of the site, prioritizing current and future potential land uses and functions, such as utilities and infrastructure, light industrial, downtown business and residential land uses. The stakeholder working group would not be a decision-making body.

Makeup: The stakeholder working group should include selected federal, state and local representatives, local non-governmental representatives as well as local and regional business stakeholders. The exact selection and balance of stakeholders is incident specific.

f) Activities: Cleanup Planning and Recommendations
The IC/UC directs the management of the cleanup options analysis through the Planning Section. Technical and stakeholder working groups assist in performing analyses and developing cleanup options and provide input to the IC/UC and may be asked to participate in meetings with the JFO Unified Coordination Group. The IC/UC reviews cleanup options analysis and selects a proposed approach for site cleanup in close coordination with federal, state and local officials. Again, depending on the incident size, it may be necessary to conduct the cleanup in phases. Thus, decisions on cleanup approaches may also be made in phases. As appropriate for the magnitude of the cleanup task, the IC/UC would brief relevant federal, state and local government officials on proposed cleanup plans for approval. This may

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involve the office of the affected mayor and governor. At the federal level, it may involve the JFO Unified Coordination Group and higher-level officials.

g) Public Review of Decision

The IC/UC should work with the PIO and JIC to publish a summary of the process, the options analyzed and the recommendations for public comments. Public meetings should also be convened at appropriate times. Public comments should be considered and incorporated as appropriate. A reconvening of the stakeholder or technical working group may be useful for resolving particular issues.

h) Execution of Cleanup and Peer Review

Assuming a Presidential declaration of a major disaster or emergency, FEMA may issue mission assignments to the federal departments and agencies that have the capability to perform the required cleanup, remediation, or debris removal activities. Cleanup activities should commence as quickly as practicable and allow for incremental reoccupation of areas as cleanup proceeds. For significant decontamination efforts, the IC/UC may choose to employ a technical peer review advisory committee to conduct a review of the effectiveness of the cleanup. The technical peer review committee would evaluate pre- and post-decontamination sampling data, the decontamination plan and any other information key to assessing the effectiveness of the cleanup.

4.2. DISPOSAL OF LARGE VOLUMES OF RADIOLOGICAL WASTE

If a large scale radiological incident were to occur in the United States, the complexity of radiological waste disposal would depend on the magnitude of the release and the decisions related to site cleanup, both of which will determine the amount and types of waste requiring disposal. Primary responsibility for waste management decisions falls to state and local officials. If there is a limited radiological incident with relatively small waste volumes, existing licensed radioactive waste capacity is available and may be sufficient to address waste disposal. However, in a situation involving a more significant release and certainly in an event such as the 2011 incident at the Fukushima nuclear facility, the waste resulting from such an incident would likely overwhelm current disposal capacity. When waste volumes exceed existing capacity, options available for consideration include supplements to existing commercial licensed radioactive waste disposal facilities, such as a combination of hazardous waste landfills, solid waste landfills, DOE facilities and construction of one or more new disposal facilities. New disposal capacity could be located at the site where the radionuclide release originated, elsewhere within the contaminated area, or away from the affected area altogether.

This section provides a short introduction to the issue, a summary of the types of available disposal options, a more detailed discussion of each disposal option, including disposal capabilities and discussion of roles and responsibilities. Although not addressed explicitly in this section, the need to prepare for and conduct safe and environmentally protective storage of waste generated during remediation will also present a significant challenge, as illustrated by the challenges that Japan faced in the aftermath of the Fukushima accident. Many of the considerations for siting disposal facilities will also be applicable to storage sites.

Planners and decision-makers need to view the long-term remediation and recovery as a comprehensive process in which waste management and disposal needs are considered from the earliest stages. For example, the selected decontamination and remediation approach should involve consideration of a number of viable alternatives with regard to potential treatment and disposal options. The precise mix of treatment and disposal options employed would depend on the nature of the specific incident (e.g., location, waste volumes). The suitability of using any individual facility would depend on a number of factors, including but not limited to the toxicity, mobility and volume of radioactively-contaminated wastes (these would be evaluated as part of the characterization process), possible treatment technologies (e.g., volume reduction technologies at the incident location; thermal treatment; neutralization), cost-effectiveness and existing federal and state (and possibly local) legal requirements governing waste disposal.

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4.2.1. Potential Waste Volumes and Existing Waste Disposal Options

As noted above, the complexity of radiological waste disposal decisions would depend on a number of factors, including the magnitude of the release and the decisions related to site cleanup. Consideration of these factors will determine the amount and types of waste requiring disposal. While disposal in a licensed low-level radioactive waste (LLRW) disposal facility may be the preferable first choice, there are a limited number of such facilities and not all states have access to all licensed commercial disposal facilities. If there is a limited radiological incident with relatively small waste volumes, existing capacity is available and may be sufficient to address waste disposal. However, waste resulting from a large scale incident would likely overwhelm current disposal capacity. For large waste volumes, supplements to existing commercial radioactive waste disposal facilities would need to be considered, such as a combination of hazardous waste landfills, solid waste landfills, DOE disposal facilities and potentially, the construction of a new disposal facility. Organizational and administrative issues related to federal and state government coordination and preparation are also important.

a) Waste Volume

Discussions of waste disposal options often involve comparisons of estimated waste generation and available disposal capacity. The amount of waste generated is related to the cleanup approach, as the selected approach to decontamination and remediation, as well as the long-term cleanup goals, can affect the volume of waste actually requiring disposal. The projected amounts of wastes for a large scale radiological incident may range from tens to hundreds of million cubic feet (or several million metric tons). Some of the waste may contain high radioactivity, especially at the incident's origin; however, most of the waste is expected to be only slightly contaminated, though in large quantities. The volume of contaminated soil in Japan resulting from the Fukushima incident is estimated to exceed one billion cubic feet.

As a point of comparison, roughly 28 million cubic feet of LLRW were disposed of at licensed commercial disposal facilities during the period 2002-2011. DOE disposed of approximately twice that volume in commercial facilities during the same period, in which it was involved in significant large-scale site cleanups.[42]Thus, over that ten-year period, an average annual volume of less than ten million cubic feet was disposed of in commercial facilities. Volumes from the non-governmental sector are not expected to increase significantly until the current fleet of NPPs is decommissioned. DOE generated additional waste volumes that were disposed of at DOE sites. For example, from 2000-2010, DOE disposed of approximately 20 million cubic feet of LLRW at the Nevada National Security Site (NNSS, formerly the Nevada Test Site). As it continues site cleanups, DOE projects generation of approximately 150 million cubic feet of LLRW for the period 2010-2015, most of which will be disposed at the site of origin or other designated DOE sites.

b) Capacity Issues

Managing the large volumes of waste resulting from a wide-scale radiological incident, such as with the Fukushima accident, would likely overwhelm existing capacity in the U.S. and thus require an overall strategy employing all available types of disposal facilities and integrating federal, state, local and private sector assets. For example, consider that:

- At the beginning of 2012, less than 100 million cubic feet of disposal capacity was licensed at commercial disposal facilities. An incident could consume all remaining licensed commercial LLRW disposal capacity, which would affect waste generators in the energy, industrial, research and medical sectors for whom the capacity was originally licensed. While there may be remaining property at the facilities that could be developed, there is no guarantee that additional

[42] Information on disposal in commercial disposal facilities provided by the Manifest Information Management System (MIMS), operated by the DOE at http://mims.apps.em.doe.gov/.

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capacity can be licensed or that states will allow all capacity to be consumed.

- Estimated waste volumes are comparable to projected generation from the entire DOE complex over the next several years, which include large-scale cleanups. While DOE is somewhat less constrained than non-DOE disposal sites in adding additional disposal capacity at its sites, displacement of projected DOE disposal with incident-related waste has the potential to interfere with ongoing cleanup activities, leading to extended on-site storage, slower cleanups and controversial efforts to expand disposal capacity at other DOE sites. Further, there is at present no mechanism to provide access to DOE disposal sites for disposal of incident-related waste.

4.2.2. Integrated Disposal Options

An effective response to a large-scale radiological incident will involve consideration of the entire range of potential disposal options. The precise mix of disposal options employed will depend on the nature of the specific incident (e.g., location, waste volumes). The process selected to plan and conduct the long-term decontamination and remediation should identify and make provisions for using the different available disposal options. In order to provide cleanup managers the use of all potential disposal capacity there are some issues that would need to be addressed, such as waste acceptance criteria for waste sites that have not been evaluated for radioactive material disposal. However, based on an understanding of the types of waste involved and the capabilities of existing disposal facilities, a generalized discussion of the attributes of the different disposal options, with qualifiers, can be developed and are discussed below.

- Licensed Commercial LLRW Disposal Facilities—
  - Can manage most anticipated waste types within license conditions.
  - Highest degree of public acceptance.
  - Significant bulk disposal volume possible.
  - Access restrictions may require special approval for waste from certain states.
  - Management of mixed radioactive and hazardous waste will need to ensure proper disposal and long-term groundwater monitoring.
- Solid and Hazardous Waste Landfills—
  - May offer local disposal option for expected large volumes with limited contamination.
  - May offer a disposal option at hazardous waste landfills for mixed wastes (mixtures of hazardous and radiological wastes); hazardous waste landfills have specified construction and engineering requirements.
  - Need to consider the location of the units in proximity to large or sensitive populations, sensitive eco-systems, and sole source aquifers.
  - May require design modifications to ensure that the waste can be managed protectively over time.
  - Difficulty in obtaining public acceptance, although some hazardous waste landfills have accepted waste with limited radionuclide content with state approval.
  - Requires additional demonstration of suitability to ensure protectiveness for radiological material (e.g., groundwater monitoring, additional engineering controls); many solid waste landfills have not been evaluated for disposal of radioactive material and may not be suitable for radiological material.
  - May require longer-term/special monitoring, as well as institutional control.
- DOE Disposal Sites—
  - Could potentially handle higher-activity waste if insufficient commercial access/capacity.
  - May be suitable for some problematic waste types (e.g., whole vehicles).
  - DOE disposal facilities generally accept only DOE-owned or DOE-generated waste. Disposal of

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non-DOE waste requires additional review and agreements involving the host state, consistent with DOE's authorities particularly where existing agreements limit DOE's waste disposal activities.

Each of these potential disposal alternatives is discussed in more detail below. There may also be some remaining wastes that might require special consideration based on factors such as level of contamination, waste form, lack of access or capacity or presence of other hazardous or toxic contaminants. These wastes could include those containing both hazardous and toxic constituents (e.g., mercury and PCBs), animal carcasses or contaminated vehicles (where dismantling the vehicle may represent a greater potential for dispersal of contaminants and exposure of workers).

a) Commercially Licensed LLRW Disposal Facilities

Given that the bulk of the waste resulting from the release of radionuclides from a nuclear facility or a deliberate action will contain radionuclides commonly contained in LLRW, licensed commercial disposal facilities would be the most appropriate and publicly acceptable option for disposal if the volumes of waste from the incident were relatively small. It would be anticipated that the waste would be mostly at the lower end of radionuclide concentrations. Thus, these facilities will be capable of handling all but the most problematic waste types, if the amounts were limited. At present, all commercial LLRW disposal facilities are licensed by states (through agreements with NRC, referred to as "Agreement States").

As described earlier, available capacity and access are significant concerns in relying on commercial LLRW disposal facilities. Further, even if a facility would be generally available to all waste generators and it is found that all but a small portion of the waste would meet that facility's disposal criteria, it is possible that there may be objections to accepting all waste from an incident outside the state, even if the facility's capacity was sufficient.

Access to other facilities generally unavailable to the state(s) affected by the incident might be feasible in an emergency situation under NRC regulations, but it should not be expected that large volumes of waste will be accepted under these provisions. There is also the possibility that the affected state could construct a disposal facility to provide additional capacity. Several states conducted extensive studies of their geology in anticipation of constructing disposal facilities and these studies may be of use in such situations.

b) Solid and hazardous waste landfills

Most states are authorized by the EPA under the Resource Conservation and Recovery Act (RCRA) to operate their own hazardous waste management programs in lieu of the federal Subtitle C program.[43] Management of nonhazardous solid wastes is governed by RCRA Subtitle D, which is administered largely by the states. Compared to the number of licensed LLRW disposal facilities in the U.S., there are a greater number of commercial landfills operating under Subtitle C and many more operating under Subtitle D of RCRA for disposal of hazardous and solid wastes, respectively. It would not be expected that all of these facilities (particularly those operating under Subtitle D) would be appropriate disposal options. However, some of the hazardous waste landfills have accepted some radioactive material for disposal and a few have received the necessary state approvals to do so on a routine basis. Historically, most of the radiological waste streams accepted by hazardous waste landfills contain naturally-occurring radionuclides not regulated by NRC, such as wastes from the oil and gas or other resource extraction industries, as well as water treatment residuals. However, both NRC and DOE, in coordination with state regulators and facility operators have approved disposal of radioactive waste in RCRA landfills on a case-by-case basis. Thus, there is reason to believe that one or more hazardous waste landfills could contribute to the disposal capacity for incident-related waste. The use of any particular RCRA facility for the disposal of radioactive contaminants or mixed contamination would require that the unit is well designed and managed appropriately. The uniform design and engineering requirements applicable to hazardous

[43] Alaska, Iowa, Puerto Rico, the Virgin Islands, American Samoa and the Trust Territories and Northern Marianas Islands do not have authorized RCRA programs

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waste landfills would facilitate such an evaluation. By contrast, not all solid waste landfills are constructed to the same specifications. Further, the evaluation would include consideration of the waste characteristics, site characteristics, waste acceptance criteria and other facility attributes.

RCRA hazardous and solid waste landfills may also offer the advantage of disposal capacity suitable for large volumes of lightly-contaminated material (e.g., soil)[44]. In addition, these facilities are more likely to be located near the incident location, which can facilitate their use if deemed appropriate by federal, state and local officials. However, use of these facilities for disposal of radionuclides typically found in low-level radioactive waste, even if it contains very low concentrations of those radionuclides, may generate public concern if the facilities have not been previously approved for this type of disposal. Therefore, additional effort by state and local officials would be necessary to ensure the facility can manage the waste in a protective manner, including technical modification, if appropriate.

c) DOE Disposal Sites

DOE facilities could potentially be a disposal alternative that may be most appropriate for limited volumes of waste for which there is no other disposal outlet (such as high-activity waste, certain mixed wastes, or other problematic waste streams). Waste disposed at DOE sites must meet the waste acceptance criteria for those sites. DOE does not generally accept non-DOE-owned or generated waste for disposal at its sites. ~~In addition, DOE has significant~~ ongoing remediation at a number of sites that will generate large volumes of waste over the coming years. Diverting DOE disposal capacity to incident- related waste may interfere with those efforts. DOE has also utilized commercial low-level radioactive disposal, primarily for bulk waste streams from cleanups and this potential disposal alternative may also be affected by a wide-scale incident.

DOE's primary disposal site serving the DOE complex is the NNSS. DOE/NNSS continues to excavate additional disposal capacity as needed and estimates that significant additional capacity could be developed at NNSS.

DOE's other designated site for complex-wide disposal is Hanford, WA; however, DOE has an agreement with the State of Washington that it will not bring waste from other sites until certain remediation milestones have been met. Overall, DOE anticipates that most of its waste generated in the coming years will be disposed at the site of generation. Sites other than NNSS and Hanford are designated for disposal of waste generated at those sites, although exceptional situations may allow for disposal of waste generated off-site and development of some additional disposal capacity. Additional disposal capacity would likely be dependent upon agreement from the state in which the facility is located.

4.2.3. Planning and Coordination among Federal and State Entities

A number of federal and state agencies may have important roles to play in making decisions on final disposal, depending on the extent of the waste. A framework for coordination with these various federal and state agencies should be an element of the process selected for long-term decontamination and remediation.

a) State Roles and Responsibilities

States must be intimately involved ahead of time in planning for a large-scale radiological incident and the resulting waste disposal.

- All existing commercial LLRW disposal facilities are licensed by Agreement States.
- Many, but not all, states have formed regional compacts (as authorized by Congress) to site and operate LLRW disposal facilities; compacts control access to these sites.

[44] EPA reports that about 132 million tons of municipal solid waste were landfilled in 2009, comparable to the rate over the past two decades. The 2009 figure represents about 54% of total generation. "Municipal Solid Waste in the United States: 2009 Facts and Figures," EPA530-R-10-012, December 2010.

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- Although statutorily required[45] to provide disposal capacity for low-level waste generated within the compact boundaries (with certain exceptions), states are under no obligation to accept waste from outside their compacts. States that are not members of compacts do not have the statutory protection to prohibit disposal of out-of-compact waste.
- All DOE disposal sites are located within states, many of which have agreements regarding the extent of long-term disposal or acceptance of off-site waste; States hosting DOE disposal sites should participate in planning for the potential disposal of incident-related off-site waste at DOE sites.
- States regulate hazardous waste (when authorized by EPA) and solid waste landfills that may be used for disposal of waste with very low concentrations of radioactivity; in planning for disposal of incident-related waste, states should take into account any restrictions placed on the disposal of radionuclides in these facilities.
- It is anticipated that on-site disposal at a location affected by the incident, where appropriate, will be one location of choice and that an affected state could approve construction of a new disposal facility for that purpose.

b) Federal Agencies

Depending on the circumstances, coordination with numerous federal agencies would be necessary. Of particular note:

- EPA is the coordinating agency for long-term remediation and cleanup, as designated by the National Response Framework (FEMA 2008a) and has federal authority for hazardous waste disposal;
- DOE is "owner" of federal sites that might be used for waste disposal;
- NRC is the federal authority for commercial LLRW disposal;
- USDA provides technical assistance for agricultural materials contaminated by the release, including animal carcasses.

4.2.4. Other Potential Options and Considerations

a) Potential Federal Actions to Increase Preparedness

- Develop criteria under which access to DOE disposal sites is acceptable and identify issues to be resolved.
- Facilitate agreements among regional LLRW compacts and states to address situations in which access to compact sites can be assured for all states.
- Identify geographically strategic federal sites that can be used for staging and interim storage of large waste volumes.
- Identify federal sites that can be characterized in advance for construction of disposal capacity for incident-related waste, should the need arise.
- Clarify federal authorities that can be used in exceptional circumstances for acquisition of property for use as disposal or long-term storage capacity and indemnification of private sector service providers.
- Assist state and local officials in planning for and making decisions to use local disposal options (solid and hazardous waste landfills) for waste that contains relatively low concentrations of

[45] Pursuant to the Low-Level Radioactive Waste Policy Act of 1980 (LLRWPA) and the 1985 LLRWP Amendments Act of 1985.

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radionuclides, including:

- developing criteria for case-by-case alternate disposal evaluations, such as those employed by NRC, EPA and DOE for limited volumes of waste;
- establishing generally applicable criteria for disposal of radionuclides in solid and hazardous waste landfills;
- supporting federal research into behavior of radionuclides and decontamination residuals in solid and hazardous waste landfills;
- providing technical assistance and streamlined regulatory review (e.g., permitting) for states to evaluate existing sites and identify new sites for incident-related waste disposal capacity; and,
- developing and disseminating tools to support planning and decision-making regarding incident-related waste management.

b) Detailed Guidance

It may be appropriate for the federal government to develop detailed guidance to address factors such as waste acceptance criteria needed for waste disposal at RCRA disposal facilities, safety evaluation of existing disposal facilities, or siting, development and regulatory approval of new disposal facilities.

c) Adding Additional Disposal Capacity

Depending on the circumstances, it may be appropriate to create additional disposal capacity. This decision would most likely need to involve extensive discussion between the federal government and the affected state(s) where an incident occurred.

- On-site disposal. As a result of looking at the different choices, it may be advantageous to develop disposal capacity on-site (e.g., build a large disposal facility within the property boundaries where the facility causing the release is located), if the site is suitable.
- Off-site disposal. An additional option would be for a state or the federal government to build a disposal site on suitable public lands. The federal or state government could use the power of eminent domain to condemn property contaminated by a radiological incident and use it for waste disposal.

d) Site Selection Criteria

If it is determined that constructing a new disposal facility is the appropriate action, the proposed site(s) should be studied for suitability. Although the contemplated disposal actions would be taken in event of a national emergency, every effort should be made to ensure the protection of public health and the environment. Appropriate regulatory standards should be considered in developing a specific disposal plan. The disposal path and site suitability must take into account the radiological characteristics of the waste. As discussed above, some slightly radioactive materials are disposed in hazardous waste landfills if they are permitted for it. More radioactive materials are sent to sites licensed as LLRW disposal sites, though less contaminated materials are also sent to LLRW disposal sites. A small amount of waste from a radiological incident may have concentrated radioactivity, but most of the waste generated in a large scale radiological incident would likely be contaminated with low levels of radioactivity. The different radiological characteristics of the waste would have a bearing on the stringency of containment required of a waste disposal facility. All waste sites would need to have appropriate controls to protect public health and the environment for any level of radioactive contamination, but more highly radioactive materials would need more robust controls than slightly contaminated material.

e) Site Characteristics

The physical/geographic characteristics of the site and the availability of land will be important in determining the appropriateness of a potential disposal site. Sites with limited rainfall, high evapotranspiration, deep water tables and soil characteristics that limit migration of radionuclides have been found to be best suited to disposal of radioactive waste, although waste management and engineering can be applied to improve performance at sites with less favorable characteristics (e.g.,

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controls on the waste form or level of allowable radioactivity, addition of liners, cover requirements or through construction of concrete bunkers or vaults). Other characteristics, such as location in a high risk area (e.g., flood plain or seismic zone) or sensitive ecologic area, should also be considered. A disposal cell for 1 million cubic feet of waste will occupy 1 acre or more of surface area, assuming disposal to a depth of about 30 feet. Large-scale disposal operations may also require extensive surface facilities.

f) Other Important Considerations

Additional considerations can also be applied to make finer distinctions among potentially suitable sites. These criteria include:

- proximity to the incident – it may be useful to consider sites in different regions of the country to limit transportation demands;
- proximity to residential areas or commercial districts – the potential for disposal activities to affect nearby populations or commercial activities, whether located within the site boundaries or on adjacent property, should be considered;
- proximity to transportation – access to timely and direct transportation that can accommodate large shipments is desirable—
  - action to facilitate – construction of transportation infrastructure (e.g., direct rail lines);
- experience in waste disposal – waste disposal sites will have infrastructure, procedures and trained personnel that can make most efficient use of the site—
  - action to facilitate – development of infrastructure, training, construction of disposal cells and engineered containment (e.g., vaults or bunkers);
- level of existing contamination – areas that are unlikely to be remediated in the near future or unlikely to be released for public use may be more acceptable for disposal.

4.2.5. Potential Federal Actions to Develop New Disposal Capacity

In addition to criteria for siting new disposal facilities, the federal government has control of a large amount of land throughout the U.S. that could be repurposed, or could offer assistance to support state governments in developing new facilities.

a) DOE Sites

DOE has decades of experience in radioactive waste management. In considering the primary selection criteria described above, DOE sites in the western U.S. generally have more favorable characteristics and readily available property compared to those in the eastern U.S. However, DOE has successfully implemented disposal at the eastern sites, often with some engineering enhancements. DOE has several categories of sites for consideration, beginning with the most suitable—

- Active disposal or cleanup sites in the western U.S.
- Active disposal or cleanup sites in the eastern U.S.
- Closed sites with disposal areas.
- Closed uranium milling sites.
- Other long-term stewardship sites.

Considerations: Some DOE sites have agreements with states or other stakeholders regarding further disposal or cleanup activities. Current disposal sites have waste acceptance criteria by DOE policy or statute. Closed and long-term stewardship sites may not have large amounts of additional property available for disposal.

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b) DoD Installations

DoD maintains some installations with large land areas, primarily in the western U.S. Many of these sites have been contaminated through extensive training or other activities. DoD likely has more sites in the eastern U.S. than does DOE. Categories of sites that could be considered suitable include:

- bombing and firing ranges;
- chemical weapons demilitarization and storage sites;
- ammunition plants and arsenals;
- surplus properties (e.g., base realignment and closure (BRAC), formerly used defense site (FUDS)).

Considerations: Section 2692 of title 10, United States Code, "Storage, Treatment and Disposal of NonDefense Toxic and Hazardous Materials," generally provides that the Secretary of Defense may not permit the use of an installation of the DoD for the storage, treatment, or disposal of any material that is a toxic or hazardous material and that is not owned either by the DoD or by a member of the armed forces (or by a dependent of the member) assigned to or provided military housing on the installation. Radiological waste resulting from either a nuclear accident or a terrorist attack may fall under this prohibition. The Secretary of Defense may grant exceptions to this restriction when "essential to protect the health and safety of the public from imminent danger." A determination whether or not radiological waste meets the "imminent danger" threshold would be required.

Additionally, some DoD properties, including ranges in the western U.S., are on "withdrawn" lands, which are part of the public domain supervised by the Bureau of Land Management (BLM). Withdrawn land statutes permit DoD to use the property for specific military mission needs. The use of withdrawn lands to manage radiological waste would violate those statutes.

c) Other Federal Properties

Agencies such as the Department of Interior (DOI) or USDA own large properties that could be considered suitable for disposal, many of which are in the western U.S. These properties may be administered by discrete entities within the cabinet-level departments, such as the National Park Service (NPS), BLM, or Forest Service. Some properties may be in proximity to DOE or DoD lands.

Considerations: Properties may be designated for protection or public use (e.g., wilderness areas or preserves). Many properties are also in rugged terrain with difficult access or border tribal lands.

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KEY POINTS IN CHAPTER 4 –LATE PHASE

- PAGs will not be used to guide restoration and recovery of areas impacted by a radiological incident; rather, planning activities should include developing a process to involve stakeholders in setting priorities and determining actions. Such a process should be flexible enough to adapt to a variety of situations.
- Planning considerations for worst case scenarios are provided. Smaller radiological incidents may be well addressed by existing emergency response and environmental cleanup programs at local, state, tribal and federal levels.
- Reoccupying households and businesses should be considered in balance with progress made in reducing radiation risks through decontamination, radioactive decay and managing contaminated waste.
- Exposure limits in a range of one in a population of ten thousand (10^{-4}) to one in a population of one million (10^{-6}) excess lifetime cancer incidence outcomes are generally considered protective, though this may not be achievable after a large radiological incident. In making decisions about cleanup goals and strategies for a particular event, decision makers must balance the desired level of exposure reduction with the extent of the measures that would be necessary to achieve it, in order to maximize overall human welfare.
- Incidents that create large volumes of waste from a wide-scale radiological incident would likely overwhelm existing radioactive waste disposal capacity in the U.S.
- Following a nuclear accident, the states bear primary responsibility to identify and provide waste management options, including disposal capacity; in the event of a terrorist attack, the federal government can offer a range of assistance to state governments to identify and implement waste management options.
- Safely managing and disposing of radioactive waste will require pre-planning at all levels of government and careful coordination with stakeholders at all stages of the decision-making process.

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APPENDIX B – GLOSSARY

Acute health effects: health problems caused by high radiation doses received in a short period of time. Examples of acute effects include erythema (reddening of skin), blistering, epilation (hair loss) and vomiting.

ALARA: acronym for "as low as is reasonably achievable" means making every reasonable effort to maintain exposures to radiation as far below the dose limits in this part as is practical consistent with the purpose for which the activity is undertaken.

Alpha radiation: alpha radiation comes from the ejection of alpha particles from the nuclei of some unstable atoms. An alpha particle is identical to a helium nucleus and consists of two protons and two neutrons. Alpha particles are highly energetic, but can only travel a few centimeters in air. They have low penetrating power and can be stopped by a sheet of paper. Alpha particles generally cannot even penetrate the layer of dead cells on the skin, but can pose a health risk when inhaled or ingested.

Avoided dose: The radiation dose saved by implementing a protective action. (ICRP 1991b)

Beta radiation: beta radiation comes from the emission of beta particles during radioactive decay. Beta particles are highly energetic and fast-moving. They carry a positive or negative charge and can be stopped by a layer of clothing or few millimeters of a solid material. Beta particles can penetrate the skin and cause skin burns, but tissue damage is limited by their small size. Beta particles are most hazardous when inhaled or ingested.

Committed effective dose: The sum of the committed equivalent doses following intake (inhalation or ingestion) of a radionuclide to each organ multiplied by a tissue weighting factor.

Contamination: Radionuclides on surface or in the environment as a result of an accidental release.

Concentration: Radionuclide activity per unit of mass.

Chronic effects: Health problems caused by radiation doses delivered over a long period. Examples of chronic effects include cancer and genetic mutations.

Derived Intervention Level (DIL): Concentration derived from the intervention level of dose at which introduction of protective measures should be considered. (FDA 1998)

Derived Response Level (DRL): A level of radioactivity in an environmental medium that would be expected to produce a dose equal to its corresponding Protective Action Guide.

Dose: The amount of radiation exposure a person has received, calculated considering the effectiveness of the radiation type (alpha, beta, gamma), the timeframe of the exposure and the sensitivity of the person or individual organs.

Dose ~~conversion factor~~ parameter ~~(DCF)~~ (DP): Any factor that is used to change an environmental measurement to dose in the units of concern.

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Dose projection: A calculated future dose that an individual might receive; also the process of making these calculations.

Dose reduction factor: A factor by which a decontamination technique or protective action reduces the radiation dose to a person.

Dosimetry: The system for assessing radiation doses from external radiation exposures and from intakes of radionuclides using biokinetic models and dosimetric quantities developed by the ICRP and the International Commission on Radiation Units and Measurements (ICRU).

Effective dose: The sum of organ equivalent doses weighted by ICRP organ weighting factors.

Emergency Planning Zone: A designated zone around a commercial nuclear power plant for which radiological response plans must be maintained under Nuclear Regulatory Commission regulations.

Emergency Worker – Anyone with a role in responding to the incident whether a radiation worker previously or not, who should be protected from radiation exposure.

Evacuation: The urgent removal of people from an area to avoid or reduce high-level, short-term exposure, from the plume or from deposited activity. Evacuation may be a preemptive action taken in response to a facility condition rather than an actual release.

Gamma radiation: Gamma radiation comes from the emission of high-energy, weightless, chargeless photons during radioactive decay. Gamma photons are pure electromagnetic energy and highly penetrating--several inches of lead or a few feet of concrete may be required to attenuate them. External exposure to gamma rays poses a health threat to the entire body. Inhalation and ingestion of gamma emitters also poses a health threat.

Graves' disease: An autoimmune disorder that leads to the over activity of the thyroid.

Groundshine: Gamma radiation emitted from radioactive materials deposited on the ground.

Half-life: The time required for the half the atoms of a given radioisotope to transform by radioactive decay.

Hashimoto's thyroiditis: An autoimmune disorder that leads to underactive thyroid with bouts of over activity.

Isodose-rate line: A contour line that is used to connect points of equal radiation dose rates.

Latency period, cancer: The time elapsed between radiation exposure and the onset of

cancer. **Microsievert:** One ten-thousandth of a rem. See Rem.

Millirem: One thousandth of a rem. See Rem.

Millisievert: One thousandth of a Sievert. See Sievert.

Noble gases: A group of elemental gases that are tasteless, odorless and that do not undergo chemical reactions under natural conditions. The noble gases consist of Helium, Neon, Argon, Krypton, Xenon and

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Radon

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Off-site: Areas outside the controlled border of a facility, such as a nuclear power plant. For an incident not involving a facility, this term may also be used to refer to areas impacted by contamination.

On-site: areas inside the controlled border of a facility, such as a nuclear power plant. For an incident not involving a facility, this term may refer to areas controlled during a response.

Potassium iodide: A salt of stable, nonradioactive iodine in medicine form. The administration of potassium iodine saturates the thyroid with non-radioactive iodine, so it does not absorb radioactive iodine released into the environment from a radiological incident.

Projected dose: The prediction of the dose that a population or individual could receive.

Protective actions: An activity conducted in response to an incident or potential incident to avoid or reduce radiation dose to members of the public.

Protective Action Guide (PAG): The projected dose to an individual, resulting from a radiological incident at which a specific protective action to reduce or avoid that dose is warranted.

Prophylactic: A treatment or medication designed to prevent exposure to radiation.

Rad (radiation absorbed dose): A basic unit of absorbed radiation dose. It is being replaced by the 'gray,' which is equivalent to 100 rad. One rad equals the dose delivered to an object of 100 ergs of energy, per gram of material.

Radioactive: Quality of a material that emits alpha particles, beta particles, gamma rays, or neutrons.

Radiological dispersion device (RDD): A device or mechanism that is intended to spread radioactive material from the detonation of conventional explosives or other means. An RDD is commonly known as a “dirty bomb.”

Radiopharmaceutical: A radioactive chemical used for diagnosis, cure, treatment, or prevention of diseases.

Recovery: The process of reducing radiation exposure rates and concentrations of radioactive material in the environment to levels acceptable for unconditional occupancy or use.

Reentry: Workers or members of the public going into relocation or radiological contaminated areas on a temporary basis under controlled conditions.

Release: Uncontrolled distribution of radioactive material to the environment.

Relocation: The removal or continued exclusion of people (households) from contaminated areas to avoid chronic radiation exposure. Not to be confused with *evacuation*.

Reoccupancy: The return of households and communities to relocation areas during the cleanup process, at radiation levels acceptable to the community.

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Rem (roentgen equivalent man): The product of the absorbed dose in rads and a weighting factor which accounts for the effectiveness of the radiation to cause biological damage; a conventional unit for equivalent dose. One rem equals 0.01 Sv.

Release rate: The measure of the amount of radioactive dispersed per unit of time.

Return: Permanent resettlement in evacuation or relocation areas with no restrictions, based on acceptable environmental and public health conditions.

Sievert (Sv): International unit of equivalent dose.

Source term: The amount of a contaminant available in a scenario or actually released to the environment.

Total Effective Dose (TED): The sum of the effective dose (for external exposures) and the committed effective dose; also referred to in this Manual as whole body dose. See Section 2.4.

Yield-producing improvised nuclear device: A crude weapon fabricated from diverted fissile material that produces a nuclear explosion.

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APPENDIX C – LIST OF ACRONYMS

AEA	Atomic Energy Act
ALARA	As Low as Reasonably Achievable
ANS	American Nuclear Society
BLM	Bureau of Land Management
BRAC	Base Realignment and Closure
CDC	Centers for Disease Control and Prevention
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
CWS	Community Water System
~~DCF~~	~~Dose Conversion Factor~~
DHS	Department of Homeland Security
DIL	Derived Intervention Levels
DoD	Department of Defense
DOE	Department of Energy
DOI	Department of Interior
DOL	Department of Labor
DOT	Department of Transportation
DP	Dose Parameter
DRL	Derived Response Level
EAL	Emergency Action Level
EPA	Environmental Protection Agency
EPZ	Emergency Planning Zone
FDA	Food and Drug Administration
FEMA	Federal Emergency Management Agency
FRC	Federal Radiation Council
FRMAC	Federal Radiological Monitoring and Assessment Center
FRPCC	Federal Radiological Preparedness Coordination Committee
FUDS	Formerly Used Defense Site
HAZWOPER	Hazardous Waste Operations and Emergency Response
HHS	Department of Health and Human Services
HPS	Health Physics Society
IAEA	International Atomic Energy Agency
ICP	Incident Command Post

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ICRP	International Commission on Radiological Protection
~~ICRU~~	~~only used once in Glossary above – deleting this~~
IC/UC	Incident Command/Unified Command
IND	Improvised Nuclear Device
JFO	Joint Field Office
JIC	Joint Information Center
KI	Potassium Iodide
LLRW	Low-level Radioactive Waste
LLRWPA	Low-Level Radioactive Waste Policy Act
MCL	Maximum Contaminant Level
NCP	National Contingency Plan
NCRP	National Council on Radiation Protection and Measurements
NIMS	National Incident Management System
NNPP	Naval Nuclear Propulsion Program
NNSS	Nevada National Security Site
NPDWR	National Primary Drinking Water Regulations
NPP	Nuclear Power Plant
NPS	National Park Service
NRC	Nuclear Regulatory Commission
NRF	National Response Framework
NDRF	National Disaster Recovery Framework
NSS	National Security Staff
OSHA	Occupational Safety and Health Administration
PAG	Protective Action Guide
PIO	Public Information Officer
PPE	Personal Protective Equipment
RASCAL	Radiological Assessment System for Consequence Analysis
REMM	Radiation Emergency Medical Management
RCRA	Resource Conservation and Recovery Act
RDD	Radiological Dispersal Device
SDWA	Safe Drinking Water Act
SNL	Sandia National Laboratories
TED	Total Effective Dose
USDA	United States Department of Agriculture

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To: Perrin, Alan[Perrin.Alan@epa.gov]
From: DeCair, Sara
Sent: Mon 11/16/2015 2:42:02 PM
Subject: Project plan update for Mike
Finalization proposal 11-16-2015.docx

Alan,

I think the note says the right thing and I added full Manual in November. I'll get that to you once I've skimmed for wonky formatting stuff.

Thanks for sending this up!

S.

Protective Action Guide (PAG) Manual Finalization

Federal Radiological Preparedness Coordinating Committee (FRPCC) PAGs Subcommittee members:

OGC: Sue Stahle	OW: Sam Hernandez	OEM: Paul Kudarauskas	ORIA: Sara DeCair
OSRTI: Mike Scozzofava	OP: Glynis Hill	OHS: Lisa Nanko	ORIA: Lee Veal
NRC: Trish Milligan	FDA: Mike Noska	CDC: Armin Ansari	FEMA: Mike Howe
DHS: John Mackinney	OSHA: Jeff Lodwick	USDA: John Jensen	DoD: Rick Reyes
Navy: Lee Nickel	NNSA: Terry Kraus	DOE: Ed Regnier	

Draft note to EPA partners:

ORIA has pulled together an internal-use only compilation of the public comments with proposed resolutions, as well as a proposed redline/strikeout edit of the 2013 PAG Manual. We suggest a facilitated review where intra-Agency and interagency partners can talk through the edits (mostly clarifications based on comments) and discuss the rationale for each comment resolution.

One logical progression would be to talk through PAG Manual sections in this order: Overview, Early Phase, Intermediate Phase, Food & Water, and then Late Phase. However, it may be of greatest interest to our EPA partners to focus first on Late Phase, where the Deputies papers make up the waste management and long term remediation guidance. There are no proposed changes in that section based on public comments, because these papers were finalized at a very senior level and any changes would have to clear a very high bar.

To step through the PAG Manual sections over the next few months, we'd send you advance copies of materials (the complete redline Manual first and relevant sections of the comment resolution) then host a webinar/in person meeting to listen to input from the full Subcommittee. Then we could circle with you to make comment resolution decisions, and hold a few OD-level check in meetings to enable finalizing the Manual in successive sections.

The schedule below is aggressive because in order to finish the full Manual concurrently with OMB review and public comment on the drinking water proposal, all before the change in Administration, we'd have to get the finalized Manual (with a drinking water placeholder) to OMB in early March.

Process map:
Send advance copy of Redline Manual, Cmt Resolutions to EPA partners for the current section
Conduct Subcmte webinar to solicit input on the resolutions for the section
Host EPA conf call to discuss comment resolutions and make comment resolution decisions

Nov. 16, 2015

Calendar:

<u>November</u> *Agree on process* *Send complete redline Manual to EPA partners*
<u>December</u> Dec. 1: Overview: Advance materials to EPA partners, Subcommittee webinar, EPA call Dec. 15: Early Phase: Advance materials to EPA partners, Subcommittee webinar, EPA call *Drinking water proposal over to OMB, when we'll ask if OMB will do concurrent reviews*
<u>January</u> Jan. 12: Intermediate Phase: Advance materials to EPA partners, Subcommittee webinar, EPA call Jan. 26: Food & Water: Advance materials to EPA partners, Subcommittee webinar, EPA call *Host an ODs meeting to approve finalization of the Overview & Early Phase sections*
<u>February</u> Feb. 9: Late Phase: Advance materials to EPA partners, Subcommittee webinar, EPA call *Host an ODs meeting to approve finalization of Intermediate, Food & Water and Late Phase sections* *Finalize FR package materials: FR Notice, Comms Plan, final PAG Manual, Internal Q&A, Desk Stmt*
<u>March</u> *Brief OAR AA and Deputy Administrator (who will sign the FR)* *Submit FR package to OP for OMB review*

Nov. 16, 2015

Update on the Proposed Protective Action Guide (PAG) Manual Revision

Background: On April 15, 2013, EPA proposed updates to the federal protective action guidelines for radiological incidents (PAG Manual) to reflect the best available radiation science and provide guidance to state and local emergency responders. The guide was last updated in 1992, and we issued this update for public review and interim use.

Comments adjudicated: We have finished adjudicating 5,000 comment sets submitted to the on-line docket, around 350 of which provided substantive suggestions, including:

- Lowering the KI (supplemental) PAG in combination with deleting the thyroid-based evacuation threshold may have unintended consequences, particularly in messaging. Further evaluation is underway.
- Referring users to FRMAC methods for DRLs and DCFs was seen as unhandy by some, but is necessary to keep the PAGs updated more than every 20 years.
- A water PAG is needed, and suggestions included DHS's 500 mrem/1st year (with a shorter timeframe, perhaps), the NPDWR 4 mrem/year or international guidelines. Note that 4 mrem ≠ 'do not drink' level. **We hope to have good news for you on a proposal, soon!**
- No substantive changes in the Reentry, Cleanup, Waste sections that came from the SOE/PLE process.

Implementing ICRP 60+: In March, we hosted an interagency group of experts on dose assessment for half day. Program experts from several agencies participated to discuss how they are looking at implementing International Commission on Radiation Protection (ICRP) 60 series recommendations and dosimetry factors, in particular age group-specific factors. The PAG Subcommittee worked on language for the Manual that can serve as recommended best practices for PAGs users to ensure new dosimetry is implemented in a practical way for emergencies. In short, some protective actions lend themselves to age-specificity (KI, food and water) and some do not (evacuation, sheltering and relocation) but all PAGs are protective of sensitive subpopulations with built-in conservatism.

Implementation timeframe: Once we're done producing a final revised Manual that we hope to issue in 2015, state, federal and local programs can take a year to update plans, procedures and training materials and start using the new Manual in 2016. Interim use allows states to use the new Manual sooner if needed, particularly if we have an incident before then.

You are a messenger:
To be responsive to the comments submitted, we're crafting a document about 'What We Heard' and how we address some of the big themes in general, and how we edited the Manual to improve it based on suggestions provided. Topics such as why PAGs are protective but why they differ from daily regulatory levels, how children are considered and why the levels are different for different pathways and phases may inform a web page section for future use. Your work in preparedness activities is an ideal forum for ensuring that state and local partners are clear on how they can best use the PAGs with flexibility for their needs. Let us know what questions you get!

Sept. 22, 2014

Fact Sheet
Revision of the "PAG Manual: Protective Action Guides and Planning Guidance for Radiological Incidents"

What are Protective Action Guides (PAGs)?

In the event of a radiological emergency, decision-makers can direct the members of the public to take protective actions to avoid exposure to unhealthy amounts of radiation. Protective Action Guides (PAGs) are radiation dose guidelines that trigger protective actions such as evacuation or staying indoors.

EPA developed a Manual of Protective Action Guides (the "PAG Manual") to help federal, state and local authorities decide how to protect the public during radiological emergencies. Emergency response organizations use the guidance in the PAG Manual in their emergency response planning.

PAGs are for use only in emergencies. PAGs are not legal radiation limits, and do not supersede any environmental laws or regulations. The PAG Manual provides emergency responders with flexible guidance on protective actions because every incident is different. State and local officials can take actions to protect the public based on incident-specific conditions.

Why has EPA updated the PAG Manual?

DRAFT

The last version of the PAG Manual was issued in 1992. Since then, there have been advancements in scientific understanding of radiation dose and risk to human health. EPA worked with multiple federal agencies including the Department of Homeland Security, Federal Emergency Management Agency, Department of Energy, Department of Health and Human Services, Nuclear Regulatory Commission, Occupational Safety and Health Administration and Department of Defense to develop the revised PAG Manual. EPA believes that guidance based on the best available science can help local authorities save lives and minimize the impact of a radiological emergency. Local authorities rely on EPA guidance to keep their emergency response plans up-to-date with the most current science.

2013 Draft PAG Manual for Interim Use—When will it be finalized?

EPA is assessing more than 5,000 public comments and plans to issue a final PAG Manual in 2015. A one-year training and adoption period will allow local authorities and other users to update their response plans.

The updated PAG Manual includes updated dose calculations based on the latest science. A number of other changes in the revised PAG Manual are based on lessons learned from actual radiological emergencies, including the Fukushima nuclear power plant accident. Significant changes in the new manual include—

- **Use of PAGs in Different Types of Radiological Emergencies:** The updated PAG Manual now applies to a broader range of radiological emergencies, including terrorist acts. The 1992 version, while it applied to all radiological emergencies, was heavily focused on nuclear power plant incidents.

- **Food Guidance:** Planners are referred to current guidance on radioactive contamination in food from the U.S. Food and Drug Administration (FDA). The previous version of the PAG Manual included an older FDA food guidance document that has been significantly updated since 1992.

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- **Administration of Potassium Iodide (KI):** In this update, EPA has adopted the latest guidance from FDA on administration of a potassium iodide (KI), a compound that inhibits the thyroid's uptake of radioactive iodine taken into the body. (Note: Administration of KI is an appropriate protective action only in emergencies that involve radioactive iodine; it does not provide protection against other radioactive substances.)

- **Guidance on Reentry**: The update contains brief planning guides on reentry to areas from which people have been removed because of a radiological incident.

- **Cleanup and Waste Disposal Considerations**: The proposed revision provides brief guidance for planning a cleanup process and considerations for planning the disposal of radioactive waste. Cleanup and waste disposal decisions will involve careful coordination with stakeholders throughout the process.

- **Update Dosimetry:** For projecting doses, the updated PAG Manual points refers users to the Federal Radiological Monitoring and Assessment Center (FRMAC) "Federal Manual for Assessing Environmental Data During a Radiological Emergency." The FRMAC Manual's dosimetry is based on the International Commission on Radiological Protection's Publication 60 (ICRP 60)

When would the PAG Manual be used?

DRAFT

The PAG Manual provides federal, state, and local emergency planners with guidance they can use in their emergency response plans. It provides information for each phase of a radiological incident—

- **Early or Emergency Phase:** This is the beginning of the incident, when immediate decisions must be made about actions to protect the public. This phase can last hours to days.

- **Intermediate Phase**: This period, lasting weeks to months, begins after the radiation releases have been brought under control, and reliable environmental measurements are available for use as a basis for decisions on protective actions.

- **Late or Recovery Phase:** This period, lasting months to years, is no longer a response to an emergency. Activities during this phase support site restoration and cleanup.

Where can I find more information?

Visit our web page to learn more and download the PAG Manual:

http://www.epa.gov/radiation/rert/pags.html

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6560-50-P

ENVIRONMENTAL PROTECTION AGENCY

[EPA-HQ-OAR-2008-0268; FRL-####-##]

Notice of Availability: Protective Action Guide (PAG) for Drinking Water after a Radiological Incident

AGENCY: Environmental Protection Agency (EPA).

ACTION: Notice of document availability for public comment.

SUMMARY: As part of its mission to protect human health and the environment, the Environmental Protection Agency (EPA) publishes protective action guides to help federal, state, local and tribal emergency response officials make radiation protection decisions during emergencies. EPA, in coordination with a multi-agency working group within the Federal Radiological Preparedness Coordinating Committee (FRPCC), is proposing an addition to the 2013 revised PAG Manual – Protective Action Guides and Planning Guidance for Radiological Incidents ("2013 revised PAG Manual" hereafter) to provide guidance on drinking water.

DATES: Comments must be received on or before [45 days after date of publication in the Federal Register].

ADDRESSES: Submit your comments, identified by Docket ID No. **EPA-HQ-OAR-2008-0268**, by one of the following methods—

- www.regulations.gov: Follow the on-line instructions for submitting comments.
- Email: to a-and-r-docket@epa.gov; Docket ID No. **EPA-HQ-OAR-2008-0268.**
- Fax: (202) 566-1741
- Mail: Air and Radiation Docket and Information Center, Environmental Protection Agency, Mail Code: 6102T, 1200 Pennsylvania Ave., NW, Washington, DC 20460

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Instructions: Direct your comments to Attn: Docket ID No. **EPA-HQ-OAR-2008-0268.** The Agency's policy is that all comments received will be included in the public docket without change and may be made available online at www.regulations.gov, including any personal information provided, unless the comment includes information claimed to be Confidential Business Information (CBI) or other information whose disclosure is restricted by statute. Do not submit information that you consider to be CBI or otherwise protected through www.regulations.gov or e-mail. The www.regulations.gov website is an "anonymous access" system, which means EPA will not know your identity or contact information unless you provide it in the body of your comment. If you send an e-mail comment directly to EPA without going through www.regulations.gov, your e-mail address will be automatically captured and included as part of the comment that is placed in the public docket and made available on the Internet. If you submit an electronic comment, EPA recommends that you include your name and other contact information in the body of your comment and with any disk or CD-ROM you submit. If EPA cannot read your comment due to technical difficulties and cannot contact you for clarification, EPA may not be able to consider your comment. Electronic files should avoid the use of special characters, any form of encryption and be free of any defects or viruses. For additional information about EPA's public docket, visit the EPA Docket Center homepage at http://www.epa.gov/epahome/dockets.htm.

Docket: All documents in the docket are listed in the www.regulations.gov index. Although listed in the index, some information is not publicly available, e.g., CBI or other information whose disclosure is restricted by statute. Certain other material, such as copyrighted material, will be publicly available only in hard copy. EPA has established a docket for this action under Docket ID No. **EPA-HQ-OAR-2008-0268**. Publicly available docket materials are available

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either electronically through www.regulations.gov or in hard copy at the Air and Radiation Docket in the EPA Docket Center, (EPA/DC) WJC West, Room 3334, 1301 Constitution Ave., NW, Washington, DC 20004. The EPA Docket Center Public Reading Room is open from 8:30 a.m. to 4:30 p.m., Monday through Friday, excluding legal holidays. The telephone number for the Public Reading Room is (202) 566-1744 and the telephone number for the Air and Radiation Docket is (202) 566-1742. In accordance with EPA's regulations at 40 CFR Part 2 and in accordance with normal EPA docket procedures, if copies of any docket materials are requested, a reasonable fee may be charged for photocopying.

FOR FURTHER INFORMATION CONTACT: Lisa M. Christ, Standards and Risk Management Division, Office of Ground Water and Drinking Water , Mail Code 4607M, U.S. Environmental Protection Agency, 1200 Pennsylvania Avenue NW, Washington, DC 20460; telephone number: (202) 564-8354; fax number: (202) 564-3758; E-mail: *christ.lisa@epa.gov*.

SUPPLEMENTARY INFORMATION:

1. General Information

A. Does this Action Apply to me?

This action does not impose any requirements on anyone. It notifies interested parties of EPA's proposed drinking water protective action guide (PAG) and request for public comment. The drinking water PAG will help federal, state, local, tribal officials and public water systems make decisions about use of water during radiological emergencies. The drinking water PAG is non-regulatory guidance.

B. What authority does EPA have to provide Protective Action Guidance?

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The historical and legal basis of EPA's role in the 2013 PAG Manual begins with Reorganization Plan No. 3 of 1970, in which the Administrator of EPA assumed all the functions of the Federal Radiation Council (FRC), including the charge to "…advise the President with respect to radiation matters, directly or indirectly affecting health, including guidance for all federal agencies in the formulation of radiation standards and in the establishment and execution of programs of cooperation with states." (Reorg. Plan No. 3 of 1970, sec. 2(a) (7), 6(a) (2); § 274.h of the Atomic Energy Act of 1954, as amended (AEA), codified at 42 U.S.C. § 2021(h)). Recognizing this role, FEMA directed EPA in their Radiological Emergency Planning and Preparedness Regulations to "establish Protective Action Guides (PAGs) for all aspects of radiological emergency planning in coordination with appropriate federal agencies." (44 CFR 351.22(a)). FEMA also tasked EPA with preparing "guidance for state and local governments on implementing PAGs, including recommendations on protective actions which can be taken to mitigate the potential radiation dose to the population."(44 CFR 351.22(b)). All of this information was to "be presented in the Environmental Protection Agency (EPA) 'Manual of Protective Action Guides and Protective Actions for Nuclear Incidents.'"(44 CFR 351.22(b)).

Additionally, section 2021(h) charged the Administrator with performing "such other functions as the President may assign to him [or her] by Executive order." Executive Order 12656 states that the Administrator shall "[d]evelop, for national security emergencies, guidance on acceptable emergency levels of nuclear radiation…." (Executive Order No. 12656, sec. 1601(2)). EPA's role in PAGs development was reaffirmed by the *National Response Framework, Nuclear/Radiological Incident Annex* of June 2008.

C. What is the PAG Manual: Protective Action Guides and Planning Guidance for Radiological Incidents?

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In 2013, EPA revised the PAG Manual that provides federal, state and local emergency management officials with guidance for responding to radiological emergencies (78 FR 22257, April 15, 2013). A protective action guide (PAG) is the projected dose to an individual from a release of radioactive material at which a specific protective action to reduce or avoid that dose is recommended. Emergency management officials use PAGs for making decisions regarding actions to protect the public from exposure to radiation during an emergency. Such actions include evacuation, shelter-in-place, temporary relocation, water and food restrictions.

The PAGs are based on the following essential principles, which also apply to the selection of any protective action during an incident:

- Prevent acute effects.
- Balance protection with other important factors and ensure that actions result in more benefit than harm.
- Reduce risk of chronic effects.

The PAG Manual is not a legally binding regulation or standard and does not supersede any environmental laws; PAGs are not intended to define "safe" or "unsafe" levels of exposure or contamination. As indicated by the use of non-mandatory language such as "may," "should" and "can," the Manual only provides recommendations and does not confer any legal rights or impose any legally binding requirements upon any member of the public, states or any federal agency. Rather, the PAG Manual provides projected radiation dose levels at which specific actions are recommended in order to reduce or avoid that dose. The 2013 revised PAG Manual is designed to provide flexibility to be more or less restrictive as deemed appropriate by decision makers based on the unique characteristics of the incident and the local situation.

D. What additional guidance is being proposed for the PAG Manual?

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Drinking water protective action guidance was developed by a multi-agency Subcommittee of the Federal Radiological Preparedness Coordinating Committee and is published by EPA with concurrence from the Department of Energy, the Department of Defense; the Department of Homeland Security, including the Federal Emergency Management Agency; the Nuclear Regulatory Commission; the Department of Health and Human Services, including both the Centers for Disease Control and Prevention as well as the Food and Drug Administration; the U.S. Department of Agriculture; and the Department of Labor.

A large scale radiation contamination incident could impact the US, driving the need for a pre-established drinking water PAG. EPA is proposing a two-tiered intermediate phase drinking water PAG of 100 mrem projected dose in the first year for infants, children and pregnant or nursing women and 500 mrem projected dose in the first year for the general population. The proposed PAG is consistent with the other Protective Actions Guides currently in place for other media in the intermediate phase (i.e., the Food and Drug Administration's 500 mrem PAG for ingestion of food) and provides an additional level of protection for the most sensitive life stages. Authorities have flexibility on how to apply the PAG. In some cases they may find it prudent to use the PAG of 100 mrem as a target for the whole population, while in other circumstances, authorities may find that it makes sense to use both targets simultaneously. For example, emergency managers can use a two-tiered approach to focus on protecting the most sensitive population with limited alternate water resources.

This proposed additional guidance recommends protective actions when drinking water may be impacted by a radiological or nuclear incident. The two-tier approach seeks to balance the goal of keeping radiation doses as low as possible with the practical and logistical challenges of providing alternative drinking water during the response to a disaster. In developing the drinking

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water PAG, the Agency considered potential cumulative exposure from a radiation incident. Ultimately, a PAG does not represent an "acceptable" routine exposure; a PAG is a dose to be avoided. Every PAG is developed with the same three principles: avoid acute effects, minimize cancer risk and ensure the actions taken are not more dangerous than the risk being avoided. Emergency management officials must consider all exposure routes when making protective action decisions in an emergency.

Under the Safe Drinking Water Act (SDWA), the Agency has established maximum contaminant levels (MCLs) for radiological contaminants in drinking water. The National Primary Drinking Water Regulations (NPDWR) for radionuclides are based on lifetime exposure criteria and assume 70 years of continued exposure to contaminants in drinking water. While the SDWA framework is appropriate for day-to-day normal operations, it does not provide the necessary tools to assist emergency responders with determining the need for an immediate protective action. EPA assumes that any drinking water system adversely impacted during a radiation incident will be able to achieve compliance with MCLs as soon as practicable.

E. When will the PAG Manual be finalized?

Once comments on this addition are adjudicated, drinking water guidance will be added to the full PAG Manual which will be issued in final form for incorporation into state, local, tribal and federal emergency response plans over a one-year implementation timeframe.

F. What Should I Consider as I Prepare My Comments for EPA?

1. *Submitting Confidential Business Information (CBI):*

Do not submit this information to EPA through www.regulations.gov or e-mail. Clearly mark all of the information that you claim to be CBI. For CBI information in a disk or CD ROM that you mail to EPA, mark the outside of the disk or CD ROM as CBI and then identify

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electronically within the disk or CD ROM the specific information that is claimed as CBI. In addition to one complete version of the comment that includes information claimed as CBI, a copy of the comment that does not contain the information claimed as CBI must be submitted for inclusion in the public docket. Information marked as CBI will not be disclosed except in accordance with procedures set forth in 40 CFR Part 2.

2. *Tips for Preparing Your Comments:*

When submitting comments, remember to:

- Identify the rulemaking by docket number, subject heading, ***Federal Register*** date and page number.
- Follow directions—EPA may ask you to respond to specific questions or organize comments by referencing the chapter number.
- Explain why you agree or disagree; suggest alternatives and substitute language for your requested changes.
- Describe any assumptions and provide technical information and data that you used.
- If you estimate potential costs or burdens, explain how you arrived at your estimate in sufficient detail to allow it to be reproduced.
- Illustrate your concerns with specific examples and suggest alternatives.
- Explain your views as clearly as possible, avoiding the use of profanity or personal threats.
- Make sure to submit your comments by the comment period deadline identified.

G. What Specific Comments are Being Sought?

While all comments regarding any aspect of the drinking water PAG guidance will be considered, please comment on the following issues specifically—

- Please comment on the appropriateness of the drinking water PAG, and the guidance for

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advance planning and challenges associated with the two-tier approach.

- Please suggest additional guidance that would aid pre-incident planning and implementation specific to your community's drinking water systems.
- Please comment on how this guidance should be implemented in emergency response and recovery plans at all levels of government, including considerations for public communications during an emergency.

In the future, calculations and derived response levels will be provided in the Federal Radiological Monitoring and Assessment Center (FRMAC) Assessment Manuals. Emergency planners are referred to FRMAC Monitoring and Sampling Methods to assess surface and drinking water impacts from a radiological emergency. See the Assessment and Monitoring & Sampling folders at http://www.nv.doe.gov/nationalsecurity/homelandsecurity/frmac/manuals.aspx. After considering public comments, EPA intends to issue a final PAG Manual which will supersede the 1992 PAG Manual and the 2013 revised PAG Manual.

_____

Dated: __ __, 2015

_____

Ken Kopocis,

Acting Assistant Administrator,

Office of Water.

ED_001057_00012671

To: Lee, Raymond[Lee.Raymond@epa.gov]; Gillam, Connie[Gillam.Connie@epa.gov]
From: DeCair, Sara
Sent: Wed 8/19/2015 2:23:49 PM
Subject: Review my Action Memo?
Water PAG draft Action Memo 8-19-2015.docx

Ray, Connie,

I wonder if you would both take a look at the attached Action Memo that will accompany our FR package for a drinking water PAG proposal up to OP in the next few weeks. Do you see any problems with format, organization or anything I've missed? I used the example from our 2013 PAG process… thank you very much for any input! If you could get back to me by Monday morning, that would be ideal.

Sara

Sara D. DeCair

http://www.epa.gov/radiation/rert/pags.html

202-343-9108

Room 1416 B in WJC West

MEMORANDUM

SUBJECT: Drinking Water Addition to Protective Action Guides Manual for Radiological Incidents; Notice
(Tier 4, SAN 5198) – **ACTION MEMORANDUM**

FROM: Peter Grevatt, OW-OGWDW
Director

Michael P. Flynn, OAR-ORIA
Director

TO: Ken Kopocis,
Acting Assistant Administrator, OW

Attached for your signature is the *Federal Register* notice announcing availability of a proposed drinking water guidance for radiological emergencies (hereinafter referred to as drinking water PAG), which is a key addition to the Agency's revision of the Protective Action Guides and Planning Guidance for Radiological Incidents ("PAG Manual"). The purpose of the PAG Manual is to help federal, state, and local authorities make decisions to protect the public during radiological emergencies. This *Federal Register* notice requests comments on the proposed drinking water PAG, which was a gap identified by commenters on the revised PAG Manual that we published for public comment and interim use in 2013.

BACKGROUND

The PAG Manual provides federal, state, and local emergency management officials with guidance for responding to radiological emergencies. A protective action guide (PAG) is the projected dose to an individual from a release of radioactive material at which a specific protective action to reduce or avoid that dose is recommended. Emergency management officials use PAGs for making decisions regarding actions to protect the public from exposure to radiation during an emergency. Such actions include, but are not limited to, evacuation, shelter-in-place, temporary relocation, access restrictions and food embargos. The PAGs are not legally binding regulations or standards and do not supersede any environmental laws or regulations. They are not intended to define "safe" or "unsafe" levels of exposure or contamination. They define the projected radiation doses at which specific actions may be warranted in order to reduce or avoid that dose. The PAG Manual provides flexibility to be more or less restrictive as deemed appropriate by decision makers based on the unique characteristics of the incident and the local situation.

Development of PAGs are based on the following essential principles, which also apply to the selection of any protective action during an incident—

- prevent acute effects
- balance protection with other important factors and ensure that actions result in more benefit than harm
- reduce risk of chronic effects.

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A drinking water PAG is the projected dose of radiation to an individual through consumption of drinking water at which a specific protective action—restrict use of drinking water—to reduce or avoid that dose is recommended.

- The primary pathway of concern for short-term exposure to water is drinking, not bathing or other uses.
- During emergencies, water systems could restrict the use of contaminated water for drinking purposes and provide alternative drinking water for the affected community.
- Options for providing alternate drinking water could include: bottled water, altering the source water (such as switching to ground water), interconnection between systems, or a combination of these actions.

The drinking water PAG consists of a two-tiered intermediate phase PAG of 100 mrem projected dose in the first year for children under 15 years old, nursing and pregnant women and 500 mrem projected dose in the first year for the general population. The protective action is to restrict the use of contaminated water for drinking purposes and to provide alternative drinking water for the affected community. Options for providing alternate drinking water could include: bottled water, altering the raw water source of a water system, interconnection between systems, or a combination of these.

Under the Safe Drinking Water Act (SDWA), the Agency has established MCLs for radiological contaminants in drinking water. The National Primary Drinking Water Regulations (NPDWR) for radionuclides established a dose-based limit of 4 mrem/yr for beta particle and photon radioactivity; based on lifetime exposure criteria, which assume 70 years of continued exposure to contaminants in drinking water. The Agency determined that it is not appropriate to base response measures during short-term emergency incidents on lifetime exposure criteria. While the SDWA framework is appropriate for normal operations, it does not provide the necessary tools to assist emergency responders with determining the need for an immediate protective action. Regardless of the cause of an incident, EPA expects that any drinking water system impacted during a radiation incident will take action to return to compliance with the NPDWR levels as soon as practical.

REGULATORY HISTORY

The Administrator of EPA assumed all the functions of the Federal Radiation Council in 1970, including the charge to "…advise the President with respect to radiation matters, directly or indirectly affecting health, including guidance for all federal agencies in the formulation of radiation standards and in the establishment and execution of programs of cooperation with States." EPA's role in PAGs development was reaffirmed by FEMA regulations and the Nuclear/Radiological Incident Annex of the National Response Framework in June 2008.

IMPACTS

The drinking water PAG is not regulatory; however, it does influence regulations of the Federal Emergency Management Agency and Nuclear Regulatory Commission regarding emergency preparedness near nuclear power plants and for homeland security. Specific statements in the document remind the users that the guidance is flexible, and that incident-specific conditions may warrant using judgment when taking protective actions. This proposed drinking water PAG does not modify existing Federal regulations or policies. The drinking water PAG relieves state, local, and tribal emergency preparedness entities of the need to independently derive radiation levels at which to take protective

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actions. The drinking water PAG provides a common platform from which emergency managers may make consistent decisions to protect public health; it raises no environmental justice issues because it applies to all members of the public equally.

The PAG Manual is for temporary measures in radiological emergencies and is not intended to impact site cleanups occurring under other statutory authorities such as EPA's Superfund program, the NRC's decommissioning program, or other federal or state cleanup programs.

This proposed addition of the drinking water PAG will make the revised PAG Manual more complete, covering all exposure pathways for impacts from a radiological emergency. Industry, state and professional organizations in radiation protection requested that this guidance be provided in comments on the 2013 PAG Manual revision and this proposal is responsive to their specific concerns.

STAKEHOLDER INVOLVEMENT

The primary users of the PAG Manual are state, local and tribal radiological preparedness organizations. A key audience for this proposed drinking water PAG is the drinking water industry. This proposal considers suggestions in comments received in 2013, and provides practical application strategies for emergency managers in state, local and tribal government organizations.

Document development and reviews have been conducted in close cooperation with the following departments and agencies on the PAGs Subcommittee of the Federal Radiological Preparedness Coordinating Committee (FRPCC): Department of Energy (DOE), the Department of Defense (DOD), the Department of Homeland Security (DHS) including the Federal Emergency Management Agency (FEMA), the Nuclear Regulatory Commission (NRC), the Department of Health and Human Services (HHS), including the Centers for Disease Control and Prevention (CDC) and the Food and Drug Administration (FDA), the Department of Agriculture (USDA), and the Department of Labor (DOL).

INTERNAL REVIEW

This is a Tier 4 action.

Within EPA, OSRTI (including the Environmental Response Team), OEM (including the Consequence Management Advisory Team), OW, OGC (ARLO and WLO) and OHS were briefed on this proposal and provided review. No major issues were identified and the reviewing offices agreed the document should be published for public review and comment.

OMB TRANSACTION

Because of interaction with other Department and Agency recommendations, OMB reviewed this proposal under EO 12866 & 13563. OMB clearance was received on _____.

PEER REVIEW

There were no major scientific or technical products supporting this action as defined by the Agency's Peer Review Handbook. We did not, therefore, submit any supporting documents for peer review.

PLAIN LANGUAGE

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The *Federal Register* notice is directed at interested members of the public, so it is written in plain language. However, due to the technical nature of the Manual itself, the proposed drinking water PAG is written in the same tone as the 2013 PAG Manual.

ANTICIPATED EXTERNAL REACTION

We are anticipating a similar reaction to this proposal as what the Agency received on the 2013 revised PAG Manual. In general, the intended users of the Manual (including state, local, and tribal entities) were positive about the 2013 PAG Manual and will provide helpful suggestions for incorporation during this round of review. The drinking water industry will provide feedback on further implementation guidance needed for their plans. There is a sentiment among some environmental groups that the radiation levels provided in the guidance are not safe, or will in some way undermine environmental regulations. Strategic messages have been included in our outreach materials as well as provided for the emergency managers who will implement the guidance in a real emergency.

STAFF CONTACT

The project lead is Sara DeCair, from the Office of Radiation and Indoor Air's Radiation Protection Division. She may be reached at (202) 343-9108.

RECOMMENDATION

Because of EPA's unique responsibility to provide PAGs and the need for consistent emergency preparedness across the United States in light of the Fukushima disaster, I recommend you sign the attached notice for publication.

Attachments

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To: Hyde, Courtney[Hyde.Courtney@epa.gov]
From: DeCair, Sara
Sent: Tue 8/18/2015 12:27:48 PM
Subject: Several steps later: Next Steps for EnDyna EP-G13H-00516 Capacity Issues
Endyna_May 29 2015 Water_IGCE.xls
5-29-2015 SOW for Water PAG & Manual finalization.doc
Lmtd Source Exercise Option III Early 5-29-2015.docx

From: DeCair, Sara
Sent: Friday, May 29, 2015 2:21 PM
To: Brown, Rayna
Cc: Miller, Beth
Subject: RE: Next Steps for EnDyna EP-G13H-00516 Capacity Issues

Rayna,

I hope what I've provided gets us most of the way there! The SOW and IGCE I attached delineate what work is needed over the next four months, with much urgency. You might not like that I included tasks in the SOW that I anticipate will not occur until after the new fiscal year starts (it was just so I could think through all the steps of the project). But I can cut those out and put them into a SOW for next year, easily.

The IGCE only reflects work needed over the next four months.

Then the memo 'Limited Source Justification' provides most, but not all of the items that you listed from the procurement regs. I highlighted the couple places where I need your help.

Beth will provide a requisition for the FY 15 funding, perhaps as soon as Monday (pretty please, Beth?) but definitely soon.

One last question – will we do a similar process in January when the next option can start, or might we need to do this again on Oct. 1, 2015?

I'm working from home on Monday only part of the day, since I have two dr. appts, but please do email me if you need to clarify or discuss anything. Then I'll be in the office the rest of the week. I will do anything needed to get this support in place!

Many thanks,

Sara

From: Brown, Rayna
Sent: Wednesday, May 27, 2015 1:43 PM
To: DeCair, Sara
Subject: Next Steps for EnDyna EP-G13H-00516 Capacity Issues

Hello Sara,

As discussed yesterday and in my previous email responses, we cannot exercise an option period early (in this case Option Period 3 – 01/08/2016 to 01/07/2017) in order to gain early access to the capacity (dollar ceiling) available under that option period. Thinking of option periods like mini contracts…they stand alone. Meaning, the pre-priced ceiling/value/capacity under Option Period 3 cannot be used until day 1 of the period which is 01/08/2016. It sounds like that would not meet your needs. The next options to explore is (1) pursuing a limited source justification (LSJ) if appropriate/justified or (2) re-procure the requirement early (if a LSJ is not appropriate) or (3) defer performance and activity until 01/08/2016 if all ceiling has been utilized under the current Option Period 2. If you would like to prepare a LSJ for a Contracting Officer's determination, please review and select a justification (only one is required) from 8.405-6(a)(1)(i)(A) thru (B) below. Then using the content requirements provided below, submit a LSJ, the IGCE (the additional effort/costs for the capacity required under the current option period 2 and any additional capacity modifications required for the remaining unexercised option periods), and description of services (statement of work (SOW)). I have to run as I am leaving out of town today and will return to the office on Friday but I wanted to give you something to digest and take action on during my absence. We can talk when I return. Thanks :o)

8.405-6 Limiting sources.

Orders placed or BPAs established under Federal Supply Schedules are exempt from the

requirements in part 6. However, an ordering activity must justify its action when restricting consideration in accordance with paragraphs (a) or (b) of this section-

(a) Orders or BPAs exceeding the micro-purchase threshold based on a limited sources justification.

(1) Circumstances justifying limiting the source.

(i) For a proposed order or BPA with an estimated value exceeding the micro-purchase threshold not placed or established in accordance with the procedures in 8.405-1, 8.405-2, or 8.405-3, the only circumstances that may justify the action are-

(A) An urgent and compelling need exists, and following the procedures would result in unacceptable delays;

(B) Only one source is capable of providing the supplies or services required at the level of quality required because the supplies or services are unique or highly specialized; or

(C) In the interest of economy and efficiency, the new work is a logical follow-on to an original Federal Supply Schedule order provided that the original order was placed in accordance with the applicable Federal Supply Schedule ordering procedures. The original order or BPA must not have been previously issued under sole-source or limited-sources procedures.

(ii) See 8.405-6(c) for the content of the justification for an order or BPA exceeding the simplified acquisition threshold.

Required content of the justification:

For a proposed order or BPA exceeding the simplified acquisition threshold, the requiring activity shall assist the ordering activity contracting officer in the preparation of the justification. The justification shall cite that the acquisition is conducted under the authority of the Multiple-Award Schedule Program (see 8.401).

(2) At a minimum, each justification shall include the following information:

(i) Identification of the agency and the contracting activity, and specific identification of the document as a "Limited-Sources Justification."

(ii) Nature and/or description of the action being approved.

(iii) A description of the supplies or services required to meet the agency's needs (including the estimated value).

(iv) The authority and supporting rationale (see 8.405-6(a)(1)(i) and (b)(1)) and, if applicable, a demonstration of the proposed contractor's unique qualifications to provide the required supply or service.

(v) A determination by the ordering activity contracting officer that the order represents the best value consistent with 8.404(d).

(vi) A description of the market research conducted among schedule holders and the results or a statement of the reason market research was not conducted.

(vii) Any other facts supporting the justification.

(viii) A statement of the actions, if any, the agency may take to remove or overcome any barriers that led to the restricted consideration before any subsequent acquisition for the supplies or services is made.

(ix) The ordering activity contracting officer's certification that the justification is accurate and complete to the best of the contracting officer's knowledge and belief.

(x) Evidence that any supporting data that is the responsibility of technical or requirements personnel (e.g., verifying the Government's minimum needs or requirements or other rationale for limited sources) and which form a basis for the justification have been certified as complete and accurate by the technical or requirements personnel.

(xi) For justifications under 8.405-6(a)(1), a written determination by the approving official identifying the circumstance that applies.

Kind regards,

Rayna D. Brown

Team Leader, Contracting Officer

U.S. Environmental Protection Agency (U.S. EPA)

OARM/OAM/HPOD/ACSC

(202) 564.6025 Office

To: Cunningham, William C[William.Cunningham@fda.hhs.gov]
From: DeCair, Sara
Sent: Mon 8/17/2015 1:29:35 PM
Subject: Re: Ok to add to water proposal?

Bill, these are currently being used for internal briefing purposes based on questions we've gotten from mgmt. the double-counting of water potential confusion is what I may want to address directly in the chapter. Do you have any time to talk tomorrow? I'll be in the office and able to show you more of what I'm working on, maybe webinar, my fave collaboration tool - let me know if you have open times if you would? Thx!

Sent from my iPhone

On Aug 17, 2015, at 9:04 AM, Cunningham, William C <William.Cunningham@fda.hhs.gov> wrote:

Sara,

Question 5 asks why do we need a water PAG when FDA already has one for food (which could logically include water)

Question 6 asks how FDA's and EPA's PAGs differ.

These are very different questions than the recurring "double-dosing" questions.

I need to know whether we need to draft answers to these questions or if these are suggestions on how to address the underlying double-dose dilemma.

Thanks,

Bill

From: DeCair, Sara [mailto:DeCair.Sara@epa.gov]

Sent: Thursday, August 13, 2015 8:38 AM
To: Cunningham, William C
Subject: Re: Ok to add to water proposal?

Super!

Sent from my iPhone

On Aug 13, 2015, at 6:34 AM, Cunningham, William C <William.Cunningham@fda.hhs.gov> wrote:

Sara,

I'll need to 'play' with it a little then bounce through Pat Hansen. I'll try to get back to you on Monday.

Bill

From: DeCair, Sara [mailto:DeCair.Sara@epa.gov]
Sent: Wednesday, August 12, 2015 4:07 PM
To: Cunningham, William C; Cunningham, William C
Cc: Noska, Michael A
Subject: Ok to add to water proposal?

Bill,

Here are some internal Q&As that we did to answer management questions during the water PAG process…. But it appears everyone asks the water in food question, so we might have to put one or more of these sentences in the proposed water chapter. Would you check if any of this needs editing, or if it is all true? Any input you have is appreciated, so I can get to OMB soon!

Question 5: FDA already has a PAG for food of 500 mrem. Why did EPA

just propose/publish a drinking water PAG of 500 mrem?

Answer: EPA's drinking water PAG is designed to limit risk due to radiological contamination of the drinking water supply. The FDA food PAG accounts for food ingestion and considers how water may be used in the preparation of some types of food products or how radionuclides transported through water might end up deposited in crops and ultimately enter the food supply (like milk or vegetables).

Because a radiological event may result in contamination of food, water, or both, a strict delineation between the two ingestion routes may not be straightforward. FDA and EPA PAGs and procedures are complementary and can be adapted to apply to the specifics of a given situation. Due to inherent differences in how the food and water supplies are protected, the intervention/response levels for food and water differ.

Question 6: What is the difference between the FDA Food PAG and EPA's Drinking Water PAG?

Answer: They both are implemented using "derived levels" called DILs and DRLs. There are two things to understand about the relationship between the FDA's Food PAG and EPA drinking water PAG; 1) They take water into account in different ways (food preparation vs. drinking water consumption) and 2) Decision makers can use both sets of guidance as appropriate for the specifics of the emergency at hand.

The FDA Food PAG was developed with a primary focus on responding to contamination events affecting the food supply. The EPA drinking water PAG was developed with a focus on responding to contamination events affecting the drinking water supply. The FDA DILs include a water component in the calculations (as part of the mass of the total diet) even though it is not regulated by FDA. Correspondingly, the EPA DRL calculations used survey data about tap water usage which includes drinking water intake as well as water added to beverages, and water added to foods during preparation, but not water intrinsic in food as purchased. This allows the DIL and DRL calculations to account for the possibility that exposure could come from both ingestion routes (food and water).

Sara D. DeCair

http://www.epa.gov/radiation/rert/pags.html

202-343-9108

Room 1416 B in WJC West

To: Cunningham, William C[William.Cunningham@fda.hhs.gov]
From: DeCair, Sara
Sent: Thur 8/13/2015 12:37:51 PM
Subject: Re: Ok to add to water proposal?

Super!

Sent from my iPhone

On Aug 13, 2015, at 6:34 AM, Cunningham, William C <William.Cunningham@fda.hhs.gov> wrote:

Sara,

I'll need to 'play' with it a little then bounce through Pat Hansen. I'll try to get back to you on Monday.

Bill

From: DeCair, Sara [mailto:DeCair.Sara@epa.gov]
Sent: Wednesday, August 12, 2015 4:07 PM
To: Cunningham, William C; Cunningham, William C
Cc: Noska, Michael A
Subject: Ok to add to water proposal?

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Sara D. DeCair

http://www.epa.gov/radiation/rert/pags.html

202-343-9108

Room 1416 B in WJC West

To: Veal, Lee[Veal.Lee@epa.gov]
From: DeCair, Sara
Sent: Mon 8/10/2015 1:30:57 PM
Subject: Re: I am back!

I haven't done the new schedule but I've talked about it with Alan... With new steps now with oswer many dates move. Can I do it at noon when I get in or do they have a 1 pm mtg?
And of course I have many old briefings...

Sent from my iPhone

> On Aug 10, 2015, at 9:22 AM, Veal, Lee <Veal.Lee@epa.gov> wrote:
>
> Hi Sara,
>
> Jon E left a voicemail for us about the PAGs. Mike is thinking about his next steps with Janet and would like a copy of the brief that was done some months ago (I think with Mike Shapiro) and the latest schedule. I had one that included dates in July, and given its now August, maybe there is something newer.
>
> Lee
>
> Lee Ann B. Veal
> Director, Center for Radiological Emergency Management
> Radiation Protection Division
> Office of Radiation and Indoor Air
> Office: 202-343-9448
> Cell: 202-617-4322
> www.epa.gov/radiation
>
> -----Original Message-----
> From: DeCair, Sara
> Sent: Sunday, August 09, 2015 11:30 PM
> To: Veal, Lee
> Subject: I am back!
>
> Back home and raring to go... And Monday morning I get to go to a new PT place for neck help, near our office. I should be in about noon and will look at water stuff first. I can't recall if I put in for SL but I will, if not.
> S.
>
> Sent from my iPhone

To: Pawel, David[Pawel.David@epa.gov]
From: DeCair, Sara
Sent: Wed 7/29/2015 7:44:36 PM
Subject: Water PAG risk report
Trigger Levels Report PAG for Drinking Water 4-2014.doc

David,

Thank you so much for agreeing to review the approach and the use of our published risk numbers for this project. I'll check with you in a couple weeks to see if you have questions or concerns.

Cheers!

Sara

Sara D. DeCair

http://www.epa.gov/radiation/rert/pags.html

202-343-9108

Room 1416 B in WJC West

TRIGGER LEVELS ASSOCIATED WITH ALTERNATIVE PROTECTIVE ACTION GUIDES FOR DRINKING WATER

Prepared by
John Mauro, PhD, CHP
Steve Marschke
SC&A, Inc.

Reviewed by
The Cadmus Group, Inc.

We would like to express our appreciation for the assistance provided by Dr. Joyce Lipsztein and Dr. Richard Leggett in the preparation of this report.

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KEY DEFINITIONS

Rad

A rad is the amount of absorbed radiation that delivers 100 ergs of energy per gram of absorbing medium.

For example, it is not unusual for a radionuclide to emit 1 MeV of photon or electron radiation each time it disintegrates. Since 1 MeV = 1.6E-6 ergs and the amount of energy required to break a chemical bond and create a free electron and a positively charged molecule (an ion pair) is typically about 30 to 40 eV, one rad will create about 2E12 ion pairs per gram of tissue exposed. These ion pairs are the cause of the damage associated with exposure to ionizing radiation, which at high whole body doses (>25 rad) can result in observable clinical damage, death at doses above about 400 rad, and a lifetime cancer risk of about between 0.0005 and 0.001 per rad delivered to the whole body.

rem and mrem

A rem is an expression of the amount of ionizing radiation absorbed by tissue multiplied by the a quality factor that takes into consideration the relative potential amount of damage the radiation might cause; a mrem (millirem) is 0.001 rem.

For example, for an internally deposited radionuclide, such as Cs-137, each time an atom of Cs-137 decays inside the body, it emits a certain amount of ionizing radiation in the form of beta particles (essentially electrons) and gamma rays (i.e., energetic photons). When this energy is deposited in tissue, the molecules that comprise living tissue are ionized, which results in an increased risk of cancer. The product of the absorbed dose to tissue (which is expressed in terms of rad) with the quality factor is referred to as the dose equivalent, expressed in units of rem or millirem. If 100 ergs per gram of any combination of beta particles ot photons is deposited into a gram of tissue, the absorbed dose to the exposed tissue is 1 rad and the dose equivalent to that tissue is 1 rem. If the energy deposited in tissue is in due to an alpha particle, the quality factor is 20 and the dose equivalent is 20 rem because the damage caused by the energy of an alpha particle in a gram of tissue is about 20 times greater than the same amount of energy of beta and photon radiation deposited in a gram of tissue is 20 times greater. If that energy is deposited uniformly in every gram of tissue in the body (whether alpha, beta or gamma), the exposure is defined as a whole body dose or effective dose.

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Sv	A sievert (Sv) is 100 rem. Sv is the International System of Units (SI) derived unit of ionizing radiation dose (the rem and mrem are older, non-SI units).
Effective dose	When ionizing radiation is deposited in tissue, it can be deposited in only a small part of the body or uniformly throughout the body. The potential for harm associated with 1 rem (100 ergs/g) deposited in only a portion of the body is less than the potential for harm if the entire body experiences 1 rem. In order to establish risk equivalency between a partial and a whole body dose when only a portion of the body is exposed, the dose equivalent to the tissue experiencing the exposure is multiplied by a tissue weighting factor which converts the tissue dose to an effective whole body dose, or simply referred to as the effective dose. For example, if a person ingests I-131, most of the internal dose will be delivered to the thyroid gland. The tissue weighting factor for the thyroid gland is 0.04. This means that the risk of cancer from the exposure of only the thyroid gland is about 0.04 of the risk of cancer if that same dose was delivered to the entire body. Hence, if one rem is delivered to the thyroid gland due to the ingestion of I-131, the effective whole body dose is 0.04 rem. If Cs-137 is ingested, it is distributed to the whole body so there is no need to apply a tissue weighting factor because the whole body is uniformly exposed.
Ci, pCi, and dps	A curie (Ci) is an expression of the amount of radioactivity that corresponds to that amount of radioactive material (atoms or grams) that has a decay rate of 3.7E10 disintegrations per second (dps). A picocurie (pCi) is one trillionth (i.e., 10^{-12}) of a Ci.
Bq	One becquerel (Bq) is the amount of a radioactive material (atoms or grams) that decays at a rate of 1 disintegration per second.
DCF	**Throughout this report, the terms dose and dose conversion factor (DCF) are used. If a person were to ingest a given radionuclide, the radionuclide might remain in his or her body for a long time. Hence, when we refer to a dose of 500 mrem delivered due to the ingestion of contaminated water for a one year period, the actual dose is the dose delivered to that person over his or her lifetime due to the radionuclides ingested in that year. Hence 500 mrem is actually 500 mrem lifetime dose commitment.** **Dose conversion factor, expressed in terms of Sv/Bq or mrem/Bq, actually is an expression of the lifetime dose**

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commitment due to the ingestion of one Bq of a given radionuclide. If the Bq is ingested in one day or one year, that dose rate is referred to as 1 Bq/day or per year, but the actual dose is delivered over a lifetime. For long lived radionuclides, like U-238, it could take an entire lifetime for uranium to be entire cleared from the body. For relatively short-lived radionuclides, such as I-131, the iodine is entirely cleared in a relative short period of time. It is still referred to as a lifetime dose commitment, but the dose is actually all delivered in a relatively short period of time because it decays away relatively quickly.

LET — **Linear Energy Transfer (LET) is an expression of the energy lost by a charged particle per unit distance traveled in a material (in KeV per micron traveled in an absorbing medium), such as living tissue. In general, for the same amount of energy deposited in a gram of tissue, the damage caused by high LET radiation, such as alpha particles and neutrons, is much greater than that same amount of energy deposited by beta and photon radiation. The reason for the difference in potential damage is the number of ions produced per unit path traveled by the high LET particle is much denser than that for low LET radiation, making it more difficult for the body to repair the damage caused by the radiation. For example, the carcinogenic risks associated with a rad of alpha particle exposure is estimated to be about 20 times greater than a rad of beta or photon exposure.**

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1.0 INTRODUCTION

During the early stages of a radiological emergency, such as following an accident at a nuclear power plant or other type of incident where drinking water supplies could become contaminated with a variety of radionuclides, it may become necessary for emergency response personnel to interdict drinking water resources for some time period until there is assurance that the concentration of radionuclides in the drinking water resources have declined to an acceptable level, either through natural attenuation or treatment. As part of the planning process for such incidents, a relationship needs to be established between the concentration of a given radionuclide in a drinking water resource and the radiation dose and health risk members of the population might experience as a result of drinking contaminated water. This report presents the results of investigations that will help the U.S. Environmental Protection Agency (EPA) make judgments regarding when intervention might be needed.

A number of factors must be taken into consideration when making judgments regarding interdiction decision making. Of particular importance are the types of radionuclides of concern, the duration that members of the public might be exposed to contaminated drinking water, and the radiation dose and health risk that different members of a population might experience as a result of drinking water contaminated with radionuclides. In this particular investigation, the EPA has selected six radionuclides that require investigation, including Sr-90, Cs-137, and I-131, which are of particular interest with respect to nuclear power plant accidents, and Ir-192, Po-210, and Co-60, which are of interest because of their potential to be used in a dirty bomb or other incidents where drinking water resources might be contaminated. However, it is important to note that Sr-90, Cs-137, and I-131 are also of interest as radionuclides that might be used by terrorists or involved in some other type of incident where drinking water resources might be contaminated.

The concentration of a given radionuclide in drinking water that requires interdiction depends primarily on the radiation dose and health risk that members of an exposed population might experience. In this particular investigation, we are interested in the concentration of the above six radionuclides that could result in radiation exposures of 4, 10, 15, 25, 100, 250, 300, 400, and 500 mrem/yr.[1] These exposures were selected because they bracket the range of radiation exposures that might be of public health concern. For example, 4 mrem/yr is associated with the current drinking water standards as set for in 40 CFR 141. If radionuclides in drinking water resources are below the concentration that can result in a whole body dose below 4 mrem/yr, the water is considered safe for drinking by EPA. At the other extreme, 500 mrem, has been selected by the Food and Drug Administration (FDA) as the radiation dose where it is appropriate to interdict food that might become contaminated with radionuclides. Hence, this range of doses represents potential interdiction levels, or Protective Action Guides (PAGs), that might warrant interdiction of contaminated water supplies. It is noted that under some circumstances higher interdiction levels might warrant consideration, including 1 rem, 5 rem, and perhaps as high as 25 rem.

[1] These values are actually the lifetime effective dose commitment associated with radionuclides ingested during the course of year or any of the other ingestion time periods addressed in this report.

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Interdiction decision making is complicated by the fact that, for the same quantity of a given radionuclide ingested in drinking water, different members of the public will experience different doses and health risks. For example, the dose and potential health risk that an adult might experience due to the ingestion of 1 Bq of a given radionuclide is different than the dose and health risk that a child might experience. In addition, since different members of the public consume different daily quantities of water, the amount of a given radionuclide that one member of the public might ingest in a day, such as an adult, will be different from the amount of that radionuclide that a child might ingest in a day for water containing the same concentration of a given radionuclide.

Ultimately, the radiation dose and health risk a given member of a population might experience from a given concentration of a radionuclide in drinking water will depend on the total amount of water consumed over the time period that the water resource is ingested. Hence, the radiation dose that a population might experience from drinking water contaminated with a given concentration of a radionuclide in water will be greater if the population is exposed for long periods of time, as opposed to short periods of time.

In light of these considerations, this report presents the concentrations of radionuclides in water and associated radiation health risks for the following array of circumstances and potential decision criteria (i.e., PAGs):

- Decision criteria or PAGs established at 4, 10, 15, 25, 100, 250, 300, 400, and 500 mrem/yr.
- Isotopes of interest: Sr-90, Cs-137, I-131, Ir-192, Po-210, Co-60.
- The dose and risk and conversion parameters contained in Federal Guidance Report 13 (FGR-13) (EPA 2002).
- Exposed subpopulations, including the embryo and fetus of pregnant women, infants, children, adults, elderly, and women of child bearing age. As discussed later in this report, dose conversion factors are not available separately for males or females or for pregnant women or the elderly in FGR-13 and International Commission on Radiological Protection (ICRP) publications . On the other hand, separate risk coefficients (RCs) are available for males and females and the elderly. With respect to the elderly, the dose commitment per unit intake of a given radionuclide is expected to be comparable to or less than the dose commitment per unit intake for other adults because of the shorter life expectancy of the elderly, which results in a shorter time period over which dose is delivered following intake. Hence, all other factors being equal regarding state of health and predisposition to cancer, if young adults are protected, so are the elderly. Rather than "children" generically, the sources support an evaluation of trigger levels and risks for 1 year olds, 5 year olds, 10 year olds, and 15 year olds.
- Consumption factors for exposure at different ages for each subpopulation as recommended in FGR 13. Since we were unable to make a distinction between males and females with respect to dose conversion factors, we had to make a choice regarding which drinking water values we should use: males, females, or the average for adults. In general, we chose to use the average for adults. However, in order to derive the doses to

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the developing fetus, we used the water ingestion rate for pregnant women as provided in the *EPA Exposure Factors Handbook* (EPA 2011).

- Exposure durations of 30, 60, 90, and 365 days for each age group considered. In the case of the child in utero the maximum duration of the ingestion period for the pregnant women is 270 days because that is (approximately) the duration of the gestation period.

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2.0 MODELS AND ASSUMPTIONS

The fundamental equations that are used to derive trigger levels in this report are as follows.

The first step in the process is to derive the quantity of radionuclide *i* ingested by age group *a* over a given time period, *T*.

$$I_{iaT} = C_i \times Ing_a \times T$$

Where:

I_{iaT} = The total intake of radionuclide *i* for age group *a* (pCi or Bq) over time period *T* (days)

C_i = The concentration of radionuclide *i* in drinking water (pCi/L or Bq/L). In this analysis, the concentration of the radionuclide is assumed to be constant over the time period *T* of interest. In the real world, the concentration of a given radionuclide in water will likely vary widely over a given time period of interest, especially over long time periods.

Ing_a = The daily ingestion rate of water for age group *a* as provided in FGR-13 (L/day).

T = The time period that the population is drinking contaminated water (days). In this analysis, the time periods of interest are 30, 60, 90, and 365 days.

The effective whole body dose (mrem or Sv) due to the ingestion of radionuclide *i* to age group *a* over time period *T* is derived as follows:

$$D_{iaT} = I_{iaT} \times DCF_{ia}$$

Where:

D_{iaT} = Effective whole body dose (mrem or Sv) due to the ingestion of radionuclide *i* to age group *a* over time period *T*

I_{iaT} = The total intake of radionuclide *i* for age group *a* (pCi or Bq) over time period *T*

DCF_{ia} = The effective dose coefficient (also referred to as the whole body dose conversion factor or DCF) for the ingestion of radionuclide *i* in drinking water and age group *a* (mrem/Bq or Sv/Bq) using the DCFs from FGR-13.

Risk, in this report, is expressed in terms of total cancer risk (morbidity) as opposed to fatal cancer risk (i.e., mortality). The lifetime risk of cancer due to the ingestion of radionuclide *i* by age group *a.*:

$$R_{iaT} = I_{iaT} \times RC_{ia}$$

Where:

R_{iaT} = The lifetime risk of cancer due to the ingestion of radionuclide *i* over time period *T* by age group *a* (life risk of cancer per Bq or per pCi ingested).

I_{iaT} = The total intake of radionuclide *i* for age group *a* (pCi or Bq) over time period *T*.

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RC_{ia} = The lifetime risk coefficient for the ingestion of radionuclide *i* in drinking water and age group *a* [lifetime risk per pCi (or per Bq) ingested in water] using the RCs from FGR-13.

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3.0 MODEL INPUT PARAMETERS

3.1 Effective Dose Coefficients (Sv/Bq Ingested)

Table 1 presents the effective whole body dose per Bq ingested of each radionuclide in water by each age group. The values apply to both males and females because DCFs are not provided separately for males and females. All the FGR 13 values are the average values for males and females.

Table 1. Dose Conversion Factors

Isotope	DCFs (Sv per Bq ingested at the age indicated) from FGR-13*					
	Infant (100 day old)	1 year old	5 year old	10 year old	15 year old	Adult
Sr-90	2.27E-07	7.24E-08	4.69E-08	5.97E-08	7.89E-08	2.77E-08
Y-90	3.13E-08	2.00E-08	9.97E-09	5.90E-09	3.34E-09	2.69E-09
Cs-137	2.11E-08	1.24E-08	9.69E-09	1.01E-08	1.34E-08	1.36E-08
I-131	1.84E-07	1.79E-07	1.04E-07	5.24E-08	3.42E-08	2.18E-08
Ir-192	1.34E-08	8.74E-09	4.59E-09	2.85E-09	1.71E-09	1.37E-09
Po-210	5.30E-06	1.79E-06	8.88E-07	5.25E-07	3.19E-07	2.45E-07
Co-60	5.43E-08	2.68E-08	1.69E-08	1.12E-08	7.94E-09	3.42E-09

* The values in this table were taken from the CD that accompanies FGR-13 (EPA 2002).

Doses on the order of 1E-5 to 1E-9 Sv/Bq imply that the ingestion of 1 Bq (i.e., the quantity of a radionuclide associated with 1 disintegration per second) is an extremely small quantity of radioactive material and is associated with a very small dose commitment.

For radionuclides like Po-210, which can be present in soluble or insoluble form in water, the DCFs for the soluble form are used because they have the higher DCFs and are more likely to reach receptors before they deposit or are filtered from the drinking water resource.

Although it is not among the six radionuclides of primary interest, Y-90 is also included in this table and other tables in this report because it is likely that Y-90, which is the progeny of Sr-90, will be present in equilibrium, or close to equilibrium, with Sr-90 in drinking water. If the Sr-90 is freshly separated, the Y-90 might not be initially present, because it has a 64-hour half-life, and it will take several weeks of growth before it achieves equilibrium with its parent, Sr-90. However, upon deposition in a drinking water resource, the Y-90 might already be present at levels close to equilibrium. The implications are that, when making use of these tables, a judgment will need to be made whether the DCFs and RCs for Sr-90 and Y-90 should be summed. However, since the DCFs and RCs for Y-90 are small compared to those for Sr-90, the additional dose or risk associated with Y-90 is small relative to that of Sr-90 and will not have a significant impact on interdiction decision making. The Y-90 values are provided here for completeness.

3.2 Effective Whole Body Dose (Sv/Bq) to Offspring Due to Ingestion of Radionuclides by the Mother between Conception and Birth

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Table 2 presents the Dose Conversion Factors corresponding to the effective whole body dose that will be experienced by the offspring while in utero and after birth due to the ingestion of the indicated radionuclides by the mother from conception to birth. More precisely, these values represent the doses (in Sv) that the offspring will experience in utero and from age 0 to 70 if the mother ingests 1 Bq of the indicated radionuclide during the course of the 9-month period from conception to birth of the child. The dose conversion factors apply to both male and female offspring. The results presented in Appendix 2 were calculated using the "in utero" dose conversion factors only, representing the dose incurred by the offspring before birth. Alternatively, the "in utero" and "after birth" values could be summed to enable calculation of a total lifetime dose.

Table 2. Dose Conversion Factors for Offspring Exposed in Utero

Isotope	DCFs (Sv per Bq ingested by mother during pregnancy) from ICRP 88*	
	In Utero	After Birth through the Age of 70
Sr-90	2.8E-08	1.5E-08
Y-90	Not available	Not available
Cs-137	5.2E-09	4.8E-10
I-131	2.1E-08	2.1E-09
Ir-192	Not available	Not available
Po-210	1.1E-07	2.0E-08
Co-60	1.5E-09	4.1E-10

Source: ICRP 2012

This rather unique subject has been discussed in two relatively recent reports:

- NCRP 2013. "Preconception and Prenatal Radiation Exposure: Health Effects and Protective Guidance," NCRP Report No. 174. National Council of Radiation Protection and Measurement.
- ICRP 2001. *Doses to Embryo and Fetus from Intakes of Radionuclides by the Mother*. ICRP Publication 88. Oxford, Pergamon Press.

A review of these documents helps to enrich our understanding of this important issue. It is quite conceivable that a woman might ingest radionuclides in water (or by inhalation or the ingestion or food) and accumulate a body burden before becoming pregnant. At the time of pregnancy, the radionuclides present in the woman's body can result in exposure of the developing embryo (conception to 8 weeks) and the developing fetus (from week 8 until birth) (ICRP 2001, Section 4.20.2, pg. 228). Of course, while the woman is pregnant, radionuclides ingested by the woman can expose the embryo and developing fetus to varying degrees. This report explicitly considers these exposure scenarios as part of investigations into alternative PAGs and trigger levels. Note, however, that the limiting exposure would occur if the woman ingests radionuclides while she is pregnant. Hence, this report is limited to that aspect of this exposure scenario.

3.3 Risk Coefficients (RCs)

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Table 3 presents, for different isotopes and different age groups, the lifetime risk of cancer (fatal plus nonfatal) per Bq ingested in water at that age. If the isotope could exist in organic vs. inorganic form, inorganic was assumed. The values presented here apply to both males and females. However, in the case of these RCs, separate values can be developed for males and females, if so desired. (Risk Tab Ver. 2.2.1, the source of the information in the table, presents risk conversion factors for both males and females and for both--i.e., the average of the two values. We used the average. We could develop a separate set of risk tables for males and females and also a separate set for morbidity and mortality.)

Table 3. Lifetime Morbidity Risk Conversion Factors (per Bq ingested in water at the indicated age)

Isotope	In utero	Infant	1 yr old	5 yr old	10 yr old	15 yr old	Adult (age 25-70)
Sr-90	not available	1.35E-08	8.59E-09	5.13E-09	3.21E-09	3.36E-09	1.10E-09
Y-90	not available	1.11E-08	8.08E-09	4.25E-09	2.54E-09	1.44E-09	1.13E-10
Cs-137	not available	3.40E-09	2.49E-09	1.97E-09	1.99E-09	2.44E-09	6.17E-10
I-131	not available	2.15E-08	1.99E-08	1.06E-08	5.04E-09	2.96E-09	4.58E-10
Ir-192	not available	4.12E-09	3.04E-09	1.65E-09	1.01E-09	5.94E-10	5.34E-11
Po-210	not available	1.77E-07	9.51E-08	5.15E-08	3.18E-08	1.95E-08	6.73E-09
Co-60	not available	7.52E-09	5.22E-09	3.30E-09	2.16E-09	1.42E-09	1.33E-10

These values were taken from Risk Tab Ver. 2.2.1 by K.F. Eckerman & N.S. Nelson (Nov. 8, 2012).

The term morbidity risk is an expression of the probability that the individual will contract a cancer during his or her lifetime. Risk conversion factors express the additional lifetime risk of cancer a person might experience as a result of ingesting one Bq of a radionuclide. As may be noted, the additional cancer risks associated with the ingestion of 1 Bq is extremely small relative to the lifetime risk of cancer due to other (often unknown) causes. Note that the lifetime risk of cancer per Bq ingested is higher for young people than for old people.

Risk conversion factors for the developing embryo and developing fetus are not available from Risk Tab Ver. 2.2.1 or any other source consulted. Therefore, although the risk for exposure in the womb may be non-zero, we are unable to quantify it.

3.4 Water Ingestion Rate

Two sources were used to derive ingestion rates, FGR-13 (EPA 2002) and the *EPA Exposure Factors Handbook: 2011 Edition* (EPA 2011).

Table 4 presents the mean values for tap water consumption taken from Table 3-1 of FGR-13 (EPA 2002). Values are provided for males and females in various age groups. Most of the ingestion values used in this report were taken from this table, which was designed to be used in conjunction with other data from FGR-13. Since the ingestion rates for males are higher (and therefore more conservative) than those for females, we elected to use the values for males to represent each age group. We could have used the average drinking water value for each age

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group, but then that would have underestimated the doses for males. If so desired, we can derive separates tables of risks for males and females.

Table 4. Drinking Water Ingestion Rates from FGR-13

Age (years)	Tap Water (L/day)*	
	Male	Female
0	0.191	0.188
1	0.223	0.216
5	0.542	0.499
10	0.725	0.649
15	0.900	0.712
20	1.137	0.754
50	1.643	1.119
75	1.564	1.179

*Values Extracted from EPA 2002, Table 3.1.

Table 5 presents the drinking water ingestion rates provided in "The Executive Summary" of the *EPA Exposure Factors Handbook: 2011 Edition* (EPA 2011). This table provides both mean and 95th percentile ingestion values for individuals (males and females aggregated) in various age groups, as well as in special cohorts such as pregnant and lactating women. The mean ingestion rate for pregnant women from this table (i.e., 0.819 L/day, which is slightly higher than for non-pregnant women) was used to calculate trigger levels for the developing fetus in Appendix 2 of this report.

Table 5. Per Capita Drinking Water Ingestion Rates from *EPA Exposure Factors Handbook* (2011)

Age	Mean mL/day	95th percentile mL/day
Children		
Birth to 1 month	184	839*
1 to<3 months	227*	896*
3 to <6 months	362*	1,056
6 months to <12 months	360	1,055
1 to <2 years	271	837
2 to <3 years	317	877
3 to <6 years	327	959
6 to <11 years	414	1,316
11 to <16 years	520	1,821
16 to <18 years	573	1,783
18 to <20 years	681	2,368
Adults		
>21 years	1,043	2,958
>65 years	1,046	2,730
Pregnant women	819*	2,503*
Lactating women	1,379*	3,434*

* Estimates are less statistically reliable, based on guidance published in NCHS 1993.

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An important judgment needs to be made whether the trigger levels and risks provided in this report are for use in protecting the average member of a given age group or the 95th percentile members of a given age group. We used the mean drinking water values, which means that some people will experience slightly higher doses and risks and some will experience slightly lower doses and risks. If the 95th percentile drinking water values from Table 5 were to be used, 95% of the population would be protected at the indicated levels. Finally, other values in the calculation, including the effective dose coefficients and risk conversion factors, have a degree of uncertainty and individual variability. The values used in this report are those recommended by the EPA in FGR-13 and represent a best estimate for a given population group. The uncertainty and individual variability in these values are described in the published literature.

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4.0 RESULTS – EXAMPLES

Using the models described in Section 2 and the input parameters in Section 3, we can derive the trigger levels and lifetime cancer risks associated with the ingestion of the six radionuclides in water (Sr-90, Cs-137, I-131, Ir-192, Po-210, and Co-60) for the different age groups, alternative PAGs (4, 10, 15, 25, 100, 250, 300, 400, and 500 mrem/yr), and the four different exposure time periods (30, 60, 90, and 365 days). These calculations are best performed using a spreadsheet. However, to aid the reader (and as part of the quality assurance check on the spreadsheet values), we will first perform selected calculations by hand for Cs-137. In these example calculations, the PAG is 500 mrem/yr and the time period of exposure is assumed to be 1 year.

4.1 Example 1: Cs-137 Dose and Risk to an Infant (100 day old)

Let us assume that a PAG is set at 500 mrem/yr (5 mSv or 0.005 Sv) and we are concerned with protecting an infant (100 day old) who might consume contaminated drinking water for 1 year. As described in Section 2, the basic equation used to perform this calculation is as follows:

$$D_{iaT} = C_i \times Ing_a \times T \times DCF_{ia}$$

Where:

D_{iaT} = Effective whole body dose (mrem or Sv) due to the ingestion of radionuclide *i* to age group *a* over time period *T*.

DCF_{ia} = The effective dose coefficient (or effective whole body DCF) for the ingestion of radionuclide *i* in drinking water and age group *a* (mrem/Bq or Sv/Bq) using the DCFs from FGR-13.

C_i = The concentration of radionuclide *i* in drinking water (pCi/L or Bq/L). In this analysis, the concentration of the radionuclide is assumed to be constant over the time period *T* of interest. In the real world, the concentration of a given radionuclide in water will likely vary widely over a given time period of interest, especially if long time periods are involved.

Ing_a = The daily ingestion rate of water for age group *a* as provided in FGR-13 (L/day).

T = The time period that the population is drinking contaminated water (days). In this analysis, the time periods of interest are 30, 60, 90, and 365 days.

The equation takes the following form when deriving the radionuclide concentrations:

$$C_i = D_{iaT} \div (Ing_a \times T \times DCF_{ia})$$

Where:

D_{iaT} = 0.005 Sv (or 500 mrem)

Ing_a = 0.191 L/day for a male 100 day old child

T = 365 days

DCF_{ia} = 2.11E-08 Sv/Bq ingested

C_i = 0.005 Sv ÷ (0.191 l/day × 365 × 2.11E-08 Sv/Bq) = 3,399 Bq/L = 91,773 pCi/L

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Hence, the trigger level would be 3,399 Bq/L, or 91,773 pCi/L, of Cs-137.

The lifetime risk of cancer to the child associated with this intake of Cs-137 in water is derived as follows:

$$R_{iaT} = I_{iaT} \times RC_{ia}$$

Where:

R_{iaT} = The lifetime risk of health detriment due to the ingestion of radionuclide *i* by age group *a* over time period *T*.

I_{iaT} = The total intake of radionuclide *i* for age group *a* (pCi or Bq) over time period *T*. (Calculated as the drinking water concentration, C_i in the previous equation, multiplied by the water ingestion rate, in this case for a newborn male from Table 4 above, multiplied by the time period, in this case 365 days.)

RC_{ia} = The lifetime risk coefficient for the ingestion of radionuclide *i* in drinking water and age group *a* [lifetime risk per pCi (or per Bq) ingested in water] using the RCs from FGR-13. Risk is expressed in terms of total cancer risk (morbidity), as opposed to fatal cancer risk (i.e., mortality).

R_{iaT} = 3,399 Bq/L × 0.191 L/day × 365 days × 3.40E-09/Bq = 8.06E-04 lifetime risk of cancer.

4.2 Example 2: Cs-137 Dose and Risk to an Adult

Performing the same exercise, we obtain the following results:

C_i = $D_{iaT} \div (Ing_a \times T \times DCF_{ia})$

C_i = 0.005 Sv ÷ 1.137 L/day × 365 days × 1.36E-08 Sv/Bq = 886 Bq/L = 23,922 pCi/L

R_{iaT} = 886 Bq/L × 1.137 L/day × 365 days × 6.02E-10/Bq = 2.2E-04 lifetime risk of cancer

Note that the concentration of Cs-137 in drinking water that is associated with a dose of 500 mrem for 1 year of exposure to a child is 3,399 Bq/L, while the concentration of Cs-137 in drinking water that results in 500 mrem to an adult from 1 year of exposure is 886 Bq/L. Hence, in order to achieve the same dose-based PAG, the concentration of Cs-137 in water must be about 3.8 times lower in order to protect an adult as opposed to a child (0–1 year old). This unexpected result is due to the fact that, even though the DCF for a child is about 1.6 times higher, adults ingest much larger quantities of water (1.137 versus 0.191 L/day). Therefore, the dose to the adult is limiting in this example.

4.3 Example 3: Cs-137 Dose In Utero

Performing the same exercise for in utero dose calculations, we obtain the following results:

C_i = $D_{iaT} \div (Ing_a \times T \times DCF_{ia})$

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C_i = 0.005 Sv ÷ (0.819 L/day × 270 days × 5.2E-09 Sv/Bq) = 4,348 Bq/L = 117,396 pCi//L

An estimate of risk to the developing fetus is not provided for the reasons described elsewhere in this report.

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5.0 RESULTS – COMPLETE SETS OF TABLES

In this section, we briefly describe and present the concentrations of radionuclides in water and associated lifetime risks of cancer for the following combination of alternative PAGs, isotopes, members of the exposed population, and time periods of exposure to contaminated water:

- PAGs established at 4, 10, 15, 25, 100, 250, 300, 400, and 500 mrem/yr.
- Isotopes of interest: Sr-90, Cs-137, I-131, Ir-192, Po-210, and Co-60.
- Exposed subpopulations: The data do not support analysis of all categories exactly as listed in the charge statement, but they support analysis that sheds at least some light on each category.
    - Embryo and fetus: Dose data are available for this population (with the exception of isotopes Y-90 and Ir-192); risk data are not. Ingestion rates for pregnant women are applied.
    - Infants: Dose data are available representing newborn infants (100 day old). Risk data representing both sexes in this age group are applied; drinking water ingestion rates for males in this age group are applied as more conservative than ingestion rates for females or the average.
    - Children: Dose data are available representing 1- 5-, 10-, and 15-year olds. Risk data representing both sexes in these age groups are applied; drinking water ingestion rates for males in these age groups are applied as more conservative than ingestion rates for females or the average.
    - Adults: Dose data are available for generic adults. Risk data representing both sexes in this age group are applied; drinking water ingestion rates for males in this age group are applied as more conservative than ingestion rates for females or the average.
    - Elderly: Dose data are not available specifically for the elderly population; general adult dose data may be consulted for the sake of comparison. The dose commitment per unit intake of a given radionuclide is expected to be comparable to or less than the dose commitment per unit intake for younger adults due to the shorter life expectancy after exposure and, therefore, the shorter time period over which dose is delivered following intake. Risk data and ingestion data for the elderly population are available (risk data for both sexes and ingestion rates for males would be applied, as in other population categories).
    - Women of child bearing age: Dose data are not available specifically for women of child-bearing age; general adult dose data may be consulted. Risk data and ingestion rates specific to this age and gender group are available and could be applied.
    - We also provide a set of tables with the results of the limiting age group for each radionuclide and each alternative PAG.

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- Exposure durations of 30, 60, 90, or 365 days. (In the case of in utero exposure, a duration of 270 days, approximating full-term pregnancy, is used.)

We have organized the information into separate appendices, as follows:

Appendix 1 – All Age Groups: This appendix presents the most restrictive concentrations of radionuclides in water for each radionuclide and each alternative PAG. These are the lowest concentrations in water, among the different age groups, for each candidate PAG. Specifically, we sorted on the values of trigger levels among each age group that are most limiting (lowest concentration) for each isotope, each alternative candidate PAG, and each exposure duration. This appendix allows the user of these tables to quickly determine the trigger level for each radionuclide that is most protective for each candidate PAG, and each time period of exposure, and which age group is the limiting.

Appendix 2 – Developing Embryo and Fetus: This appendix presents the radionuclide concentrations in drinking water associated with specified doses for developing embryos and fetuses whose mothers consume the indicated radionuclides in drinking water over the specified time periods during gestation. (The figures represent only the dose incurred during gestation, not the lifetime dose that results from exposure in utero.) The longest ingestion period considered in this appendix is 270 days, or the approximate length of a full-term pregnancy. Note that trigger levels could not be calculated for Y-90 or Ir-192, and lifetime risks could not be calculated for any isotope in utero.

Appendix 3 – Infant (100 day old): This appendix presents the radionuclide concentrations in drinking water and associated lifetime risks for an infant who consumes the indicated radionuclides in drinking water over the specified time periods.

Appendix 4 – 1 Year Old: This appendix presents the radionuclide concentrations in drinking water and associated lifetime risks for a 1 year old who consumes the indicated radionuclides in drinking water over the specified time periods at that age.

Appendix 5 – 5 Year Old: This appendix presents the radionuclide concentrations in drinking water and associated lifetime risks for a 5 year old who consumes the indicated radionuclides in drinking water over the specified time periods at that age.

Appendix 6 – 10 Year Old: This appendix presents the radionuclide concentrations in drinking water and associated lifetime risks for a 10 year old who consumes the indicated radionuclides in drinking water at that age.

Appendix 7 – 15 Year Old: This appendix presents the radionuclide concentrations in drinking water and associated lifetime risks for a 15 year old who consumes the indicated radionuclides in drinking water at that age.

Appendix 8 – Adult: This appendix presents the radionuclide concentrations in drinking water and associated lifetime risks for an adult who consumes the indicated radionuclides in drinking water over the specified time periods. The FGR 13 CD provides DCFs for adults and does not

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make a distinction among adults of different ages because the actual age when the adult ingests the drinking water has little effect on the trigger level or lifetime risk, until he or she is quite old; then the trigger levels decline due to declining DCFs because the time period over which the dose is delivered begins to decrease. Risks declines because of the latency period associated with cancer induction, which can extend beyond normal life expectancy.

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APPENDIX 1: ALL AGE GROUPS

Most Restrictive (i.e., Lowest)
Drinking Water Concentration (pCi/L) for Specified Dose (mrem) Over Specified Time

30 days

	4	10	15	25	100	250	300	400	500
Sr-90	5.07E+02	1.27E+03	1.90E+03	3.17E+03	1.27E+04	3.17E+04	3.81E+04	5.07E+04	6.34E+04
Y-90	6.03E+03	1.51E+04	2.26E+04	3.77E+04	1.51E+05	3.77E+05	4.52E+05	6.03E+05	7.53E+05
Cs-137	2.33E+03	5.83E+03	8.74E+03	1.46E+04	5.83E+04	1.46E+05	1.75E+05	2.33E+05	2.91E+05
I-131	6.39E+02	1.60E+03	2.40E+03	4.00E+03	1.60E+04	4.00E+04	4.79E+04	6.39E+04	7.99E+04
Ir-192	1.41E+04	3.52E+04	5.28E+04	8.80E+04	3.52E+05	8.80E+05	1.06E+06	1.41E+06	1.76E+06
Po-210	3.56E+01	8.90E+01	1.33E+02	2.22E+02	8.90E+02	2.22E+03	2.67E+03	3.56E+03	4.45E+03
Co-60	3.47E+03	8.69E+03	1.30E+04	2.17E+04	8.69E+04	2.17E+05	2.61E+05	3.47E+05	4.34E+05

60 days

	4	10	15	25	100	250	300	400	500
Sr-90	2.54E+02	6.34E+02	9.52E+02	1.59E+03	6.34E+03	1.59E+04	1.90E+04	2.54E+04	3.17E+04
Y-90	3.01E+03	7.53E+03	1.13E+04	1.88E+04	7.53E+04	1.88E+05	2.26E+05	3.01E+05	3.77E+05
Cs-137	1.17E+03	2.91E+03	4.37E+03	7.28E+03	2.91E+04	7.28E+04	8.74E+04	1.17E+05	1.46E+05
I-131	3.20E+02	7.99E+02	1.20E+03	2.00E+03	7.99E+03	2.00E+04	2.40E+04	3.20E+04	4.00E+04
Ir-192	7.04E+03	1.76E+04	2.64E+04	4.40E+04	1.76E+05	4.40E+05	5.28E+05	7.04E+05	8.80E+05
Po-210	1.78E+01	4.45E+01	6.67E+01	1.11E+02	4.45E+02	1.11E+03	1.33E+03	1.78E+03	2.22E+03
Co-60	1.74E+03	4.34E+03	6.51E+03	1.09E+04	4.34E+04	1.09E+05	1.30E+05	1.74E+05	2.17E+05

90 days

	4	10	15	25	100	250	300	400	500
Sr-90	1.69E+02	4.23E+02	6.34E+02	1.06E+03	4.23E+03	1.06E+04	1.27E+04	1.69E+04	2.11E+04
Y-90	2.01E+03	5.02E+03	7.53E+03	1.26E+04	5.02E+04	1.26E+05	1.51E+05	2.01E+05	2.51E+05
Cs-137	7.77E+02	1.94E+03	2.91E+03	4.86E+03	1.94E+04	4.86E+04	5.83E+04	7.77E+04	9.71E+04
I-131	2.13E+02	5.33E+02	7.99E+02	1.33E+03	5.33E+03	1.33E+04	1.60E+04	2.13E+04	2.66E+04
Ir-192	4.69E+03	1.17E+04	1.76E+04	2.93E+04	1.17E+05	2.93E+05	3.52E+05	4.69E+05	5.87E+05
Po-210	1.19E+01	2.97E+01	4.45E+01	7.42E+01	2.97E+02	7.42E+02	8.90E+02	1.19E+03	1.48E+03
Co-60	1.16E+03	2.90E+03	4.34E+03	7.24E+03	2.90E+04	7.24E+04	8.69E+04	1.16E+05	1.45E+05

365 days

	4	10	15	25	100	250	300	400	500
Sr-90	4.17E+01	1.04E+02	1.56E+02	2.61E+02	1.04E+03	2.61E+03	3.13E+03	4.17E+03	5.21E+03
Y-90	4.95E+02	1.24E+03	1.86E+03	3.10E+03	1.24E+04	3.10E+04	3.72E+04	4.95E+04	6.19E+04
Cs-137	1.92E+02	4.79E+02	7.18E+02	1.20E+03	4.79E+03	1.20E+04	1.44E+04	1.92E+04	2.39E+04
I-131	5.25E+01	1.31E+02	1.97E+02	3.28E+02	1.31E+03	3.28E+03	3.94E+03	5.25E+03	6.57E+03
Ir-192	1.16E+03	2.89E+03	4.34E+03	7.23E+03	2.89E+04	7.23E+04	8.68E+04	1.16E+05	1.45E+05
Po-210	2.93E+00	7.31E+00	1.10E+01	1.83E+01	7.31E+01	1.83E+02	2.19E+02	2.93E+02	3.66E+02
Co-60	2.86E+02	7.14E+02	1.07E+03	1.78E+03	7.14E+03	1.78E+04	2.14E+04	2.86E+04	3.57E+04

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Most Restrictive (i.e., Lowest)
Drinking Water Risk for Specified Dose (mrem) Over Specified Time

30 days

	4	10	15	25	100	250	300	400	500
Sr-90	1.59E-06	3.97E-06	5.96E-06	9.93E-06	3.97E-05	9.93E-05	1.19E-04	1.59E-04	1.99E-04
Y-90	1.68E-06	4.20E-06	6.30E-06	1.05E-05	4.20E-05	1.05E-04	1.26E-04	1.68E-04	2.10E-04
Cs-137	1.81E-06	4.54E-06	6.81E-06	1.13E-05	4.54E-05	1.13E-04	1.36E-04	1.81E-04	2.27E-04
I-131	8.40E-07	2.10E-06	3.15E-06	5.25E-06	2.10E-05	5.25E-05	6.30E-05	8.40E-05	1.05E-04
Ir-192	1.56E-06	3.90E-06	5.85E-06	9.74E-06	3.90E-05	9.74E-05	1.17E-04	1.56E-04	1.95E-04
Po-210	1.10E-06	2.75E-06	4.12E-06	6.87E-06	2.75E-05	6.87E-05	8.24E-05	1.10E-04	1.37E-04
Co-60	1.56E-06	3.89E-06	5.83E-06	9.72E-06	3.89E-05	9.72E-05	1.17E-04	1.56E-04	1.94E-04

60 days

	4	10	15	25	100	250	300	400	500
Sr-90	1.59E-06	3.97E-06	5.96E-06	9.93E-06	3.97E-05	9.93E-05	1.19E-04	1.59E-04	1.99E-04
Y-90	1.68E-06	4.20E-06	6.30E-06	1.05E-05	4.20E-05	1.05E-04	1.26E-04	1.68E-04	2.10E-04
Cs-137	1.81E-06	4.54E-06	6.81E-06	1.13E-05	4.54E-05	1.13E-04	1.36E-04	1.81E-04	2.27E-04
I-131	8.40E-07	2.10E-06	3.15E-06	5.25E-06	2.10E-05	5.25E-05	6.30E-05	8.40E-05	1.05E-04
Ir-192	1.56E-06	3.90E-06	5.85E-06	9.74E-06	3.90E-05	9.74E-05	1.17E-04	1.56E-04	1.95E-04
Po-210	1.10E-06	2.75E-06	4.12E-06	6.87E-06	2.75E-05	6.87E-05	8.24E-05	1.10E-04	1.37E-04
Co-60	1.56E-06	3.89E-06	5.83E-06	9.72E-06	3.89E-05	9.72E-05	1.17E-04	1.56E-04	1.94E-04

90 days

	4	10	15	25	100	250	300	400	500
Sr-90	1.59E-06	3.97E-06	5.96E-06	9.93E-06	3.97E-05	9.93E-05	1.19E-04	1.59E-04	1.99E-04
Y-90	1.68E-06	4.20E-06	6.30E-06	1.05E-05	4.20E-05	1.05E-04	1.26E-04	1.68E-04	2.10E-04
Cs-137	1.81E-06	4.54E-06	6.81E-06	1.13E-05	4.54E-05	1.13E-04	1.36E-04	1.81E-04	2.27E-04
I-131	8.40E-07	2.10E-06	3.15E-06	5.25E-06	2.10E-05	5.25E-05	6.30E-05	8.40E-05	1.05E-04
Ir-192	1.56E-06	3.90E-06	5.85E-06	9.74E-06	3.90E-05	9.74E-05	1.17E-04	1.56E-04	1.95E-04
Po-210	1.10E-06	2.75E-06	4.12E-06	6.87E-06	2.75E-05	6.87E-05	8.24E-05	1.10E-04	1.37E-04
Co-60	1.56E-06	3.89E-06	5.83E-06	9.72E-06	3.89E-05	9.72E-05	1.17E-04	1.56E-04	1.94E-04

365 days

	4	10	15	25	100	250	300	400	500
Sr-90	1.59E-06	3.97E-06	5.96E-06	9.93E-06	3.97E-05	9.93E-05	1.19E-04	1.59E-04	1.99E-04
Y-90	1.68E-06	4.20E-06	6.30E-06	1.05E-05	4.20E-05	1.05E-04	1.26E-04	1.68E-04	2.10E-04
Cs-137	1.81E-06	4.54E-06	6.81E-06	1.13E-05	4.54E-05	1.13E-04	1.36E-04	1.81E-04	2.27E-04
I-131	8.40E-07	2.10E-06	3.15E-06	5.25E-06	2.10E-05	5.25E-05	6.30E-05	8.40E-05	1.05E-04
Ir-192	1.56E-06	3.90E-06	5.85E-06	9.74E-06	3.90E-05	9.74E-05	1.17E-04	1.56E-04	1.95E-04
Po-210	1.10E-06	2.75E-06	4.12E-06	6.87E-06	2.75E-05	6.87E-05	8.24E-05	1.10E-04	1.37E-04
Co-60	1.56E-06	3.89E-06	5.83E-06	9.72E-06	3.89E-05	9.72E-05	1.17E-04	1.56E-04	1.94E-04

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Age Group With the Most Restrictive Drinking Water Concentration

30 days

	4	10	15	25	100	250	300	400	500
Sr-90	15 yr old	15 yr old	15 yr old	15 yr old	15 yr old	15 yr old	15 yr old	15 yr old	15 yr old
Y-90	Infant	Infant	Infant	Infant	Infant	Infant	Infant	Infant	Infant
Cs-137	Adult	Adult	Adult	Adult	Adult	Adult	Adult	Adult	Adult
I-131	5 yr old	5 yr old	5 yr old	5 yr old	5 yr old	5 yr old	5 yr old	5 yr old	5 yr old
Ir-192	Infant	Infant	Infant	Infant	Infant	Infant	Infant	Infant	Infant
Po-210	Infant	Infant	Infant	Infant	Infant	Infant	Infant	Infant	Infant
Co-60	Infant	Infant	Infant	Infant	Infant	Infant	Infant	Infant	Infant

60 days

	4	10	15	25	100	250	300	400	500
Sr-90	15 yr old	15 yr old	15 yr old	10 yr old	15 yr old	10 yr old	15 yr old	15 yr old	15 yr old
Y-90	Infant	Infant	Infant	Infant	Infant	Infant	Infant	Infant	Infant
Cs-137	Adult	Adult	Adult	Adult	Adult	Adult	Adult	Adult	Adult
I-131	5 yr old	5 yr old	5 yr old	5 yr old	5 yr old	5 yr old	5 yr old	5 yr old	5 yr old
Ir-192	Infant	Infant	Infant	Infant	Infant	Infant	Infant	Infant	Infant
Po-210	Infant	Infant	Infant	Infant	Infant	Infant	Infant	Infant	Infant
Co-60	Infant	Infant	Infant	Infant	Infant	Infant	Infant	Infant	Infant

90 days

	4	10	15	25	100	250	300	400	500
Sr-90	15 yr old	15 yr old	15 yr old	15 yr old	15 yr old	15 yr old	15 yr old	15 yr old	15 yr old
Y-90	Infant	Infant	Infant	Infant	Infant	Infant	Infant	Infant	Infant
Cs-137	Adult	Adult	Adult	Adult	Adult	Adult	Adult	Adult	Adult
I-131	5 yr old	5 yr old	5 yr old	5 yr old	5 yr old	5 yr old	5 yr old	5 yr old	5 yr old
Ir-192	Infant	Infant	Infant	Infant	Infant	Infant	Infant	Infant	Infant
Po-210	Infant	Infant	Infant	Infant	Infant	Infant	Infant	Infant	Infant
Co-60	Infant	Infant	Infant	Infant	Infant	Infant	Infant	Infant	Infant

365 days

	4	10	15	25	100	250	300	400	500
Sr-90	15 yr old	15 yr old	15 yr old	15 yr old	15 yr old	15 yr old	15 yr old	15 yr old	15 yr old
Y-90	Infant	Infant	Infant	Infant	Infant	Infant	Infant	Infant	Infant
Cs-137	Adult	Adult	Adult	Adult	Adult	Adult	Adult	Adult	Adult
I-131	5 yr old	5 yr old	5 yr old	5 yr old	5 yr old	5 yr old	5 yr old	5 yr old	5 yr old
Ir-192	Infant	Infant	Infant	Infant	Infant	Infant	Infant	Infant	Infant
Po-210	Infant	Infant	Infant	Infant	Infant	Infant	Infant	Infant	Infant
Co-60	Infant	Infant	Infant	Infant	Infant	Infant	Infant	Infant	Infant

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APPENDIX 2: DEVELOPING EMBRYO AND FETUS*

Drinking Water Concentration (pCi/L) for Specified Dose (mrem) Over Specified Time

30 days

	4	10	15	25	100	250	300	400	500
Sr-90	1.57E+03	3.93E+03	5.89E+03	9.82E+03	3.93E+04	9.82E+04	1.18E+05	1.57E+05	1.96E+05
Y-90*									
Cs-137	8.46E+03	2.12E+04	3.17E+04	5.29E+04	2.12E+05	5.29E+05	6.35E+05	8.46E+05	1.06E+06
I-131	2.10E+03	5.24E+03	7.86E+03	1.31E+04	5.24E+04	1.31E+05	1.57E+05	2.10E+05	2.62E+05
Ir-192*									
Po-210	4.00E+02	1.00E+03	1.50E+03	2.50E+03	1.00E+04	2.50E+04	3.00E+04	4.00E+04	5.00E+04
Co-60	2.93E+04	7.33E+04	1.10E+05	1.83E+05	7.33E+05	1.83E+06	2.20E+06	2.93E+06	3.67E+06

60 days

	4	10	15	25	100	250	300	400	500
Sr-90	7.86E+02	1.96E+03	2.95E+03	4.91E+03	1.96E+04	4.91E+04	5.89E+04	7.86E+04	9.82E+04
Y-90*									
Cs-137	4.23E+03	1.06E+04	1.59E+04	2.64E+04	1.06E+05	2.64E+05	3.17E+05	4.23E+05	5.29E+05
I-131	1.05E+03	2.62E+03	3.93E+03	6.55E+03	2.62E+04	6.55E+04	7.86E+04	1.05E+05	1.31E+05
Ir-192*									
Po-210	2.00E+02	5.00E+02	7.50E+02	1.25E+03	5.00E+03	1.25E+04	1.50E+04	2.00E+04	2.50E+04
Co-60	1.47E+04	3.67E+04	5.50E+04	9.17E+04	3.67E+05	9.17E+05	1.10E+06	1.47E+06	1.83E+06

90 days

	4	10	15	25	100	250	300	400	500
Sr-90	5.24E+02	1.31E+03	1.96E+03	3.27E+03	1.31E+04	3.27E+04	3.93E+04	5.24E+04	6.55E+04
Y-90*									
Cs-137	2.82E+03	7.05E+03	1.06E+04	1.76E+04	7.05E+04	1.76E+05	2.12E+05	2.82E+05	3.53E+05
I-131	6.98E+02	1.75E+03	2.62E+03	4.37E+03	1.75E+04	4.37E+04	5.24E+04	6.98E+04	8.73E+04
Ir-192*									
Po-210	1.33E+02	3.33E+02	5.00E+02	8.33E+02	3.33E+03	8.33E+03	1.00E+04	1.33E+04	1.67E+04
Co-60	9.78E+03	2.44E+04	3.67E+04	6.11E+04	2.44E+05	6.11E+05	7.33E+05	9.78E+05	1.22E+06

270 days

	4	10	15	25	100	250	300	400	500
Sr-90	1.75E+02	4.37E+02	6.55E+02	1.09E+03	4.37E+03	1.09E+04	1.31E+04	1.75E+04	2.18E+04
Y-90*									
Cs-137	9.40E+02	2.35E+03	3.53E+03	5.88E+03	2.35E+04	5.88E+04	7.05E+04	9.40E+04	1.18E+05
I-131	2.33E+02	5.82E+02	8.73E+02	1.46E+03	5.82E+03	1.46E+04	1.75E+04	2.33E+04	2.91E+04
Ir-192*									
Po-210	4.44E+01	1.11E+02	1.67E+02	2.78E+02	1.11E+03	2.78E+03	3.33E+03	4.44E+03	5.56E+03
Co-60	3.26E+03	8.15E+03	1.22E+04	2.04E+04	8.15E+04	2.04E+05	2.44E+05	3.26E+05	4.07E+05

* DCFs for Y-90 and Ir-192 for the developing fetus have not been developed. Hence these rows are left blank. This does not mean there are zero doses. We are not able to assign doses at this time.

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Risks Associated with Exposure in Utero

Risk conversion factors are not available for in utero exposure; therefore lifetime risks cannot be quantified.

Though we suspect that there might be some level of health risk to the developing fetus due to exposures resulting from the ingestion of contaminated water by the mother during gestation, Table 1-1 NCRP Report No. 17 titled, *Preconception and Prenatal Radiation Exposure: Health Effects and Protective Guidance* (2013) states that minimal non-stochastic health effects are anticipated at acute doses of low LET radiation below 15 rem during the most radiosensitive gestation time periods. Table 1-1 also states that "The lifetime risk of oncogenic effects following in utero irradiation appears to be lower than that following irradiation during childhood." Table 1-1 also states that "There is no data available that informs on which stages of pregnancy may be the most vulnerable to the oncogenic effects of radiation."

On this basis, we assume that exposures to other age groups are limiting or at least as radiosensitive with respect to health risk for chronic low levels of low LET radiation.

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APPENDIX 3: INFANT

Drinking Water Concentration (pCi/L) for Specified Dose (mrem) Over Specified Time

30 days

	4	10	15	25	100	250	300	400	500
Sr-90	8.31E+02	2.08E+03	3.12E+03	5.19E+03	2.08E+04	5.19E+04	6.23E+04	8.31E+04	1.04E+05
Y-90	6.03E+03	1.51E+04	2.26E+04	3.77E+04	1.51E+05	3.77E+05	4.52E+05	6.03E+05	7.53E+05
Cs-137	8.94E+03	2.24E+04	3.35E+04	5.59E+04	2.24E+05	5.59E+05	6.71E+05	8.94E+05	1.12E+06
I-131	1.03E+03	2.56E+03	3.85E+03	6.41E+03	2.56E+04	6.41E+04	7.69E+04	1.03E+05	1.28E+05
Ir-192	1.41E+04	3.52E+04	5.28E+04	8.80E+04	3.52E+05	8.80E+05	1.06E+06	1.41E+06	1.76E+06
Po-210	3.56E+01	8.90E+01	1.33E+02	2.22E+02	8.90E+02	2.22E+03	2.67E+03	3.56E+03	4.45E+03
Co-60	3.47E+03	8.69E+03	1.30E+04	2.17E+04	8.69E+04	2.17E+05	2.61E+05	3.47E+05	4.34E+05

60 days

	4	10	15	25	100	250	300	400	500
Sr-90	4.16E+02	1.04E+03	1.56E+03	2.60E+03	1.04E+04	2.60E+04	3.12E+04	4.16E+04	5.19E+04
Y-90	3.01E+03	7.53E+03	1.13E+04	1.88E+04	7.53E+04	1.88E+05	2.26E+05	3.01E+05	3.77E+05
Cs-137	4.47E+03	1.12E+04	1.68E+04	2.79E+04	1.12E+05	2.79E+05	3.35E+05	4.47E+05	5.59E+05
I-131	5.13E+02	1.28E+03	1.92E+03	3.20E+03	1.28E+04	3.20E+04	3.85E+04	5.13E+04	6.41E+04
Ir-192	7.04E+03	1.76E+04	2.64E+04	4.40E+04	1.76E+05	4.40E+05	5.28E+05	7.04E+05	8.80E+05
Po-210	1.78E+01	4.45E+01	6.67E+01	1.11E+02	4.45E+02	1.11E+03	1.33E+03	1.78E+03	2.22E+03
Co-60	1.74E+03	4.34E+03	6.51E+03	1.09E+04	4.34E+04	1.09E+05	1.30E+05	1.74E+05	2.17E+05

90 days

	4	10	15	25	100	250	300	400	500
Sr-90	2.77E+02	6.93E+02	1.04E+03	1.73E+03	6.93E+03	1.73E+04	2.08E+04	2.77E+04	3.46E+04
Y-90	2.01E+03	5.02E+03	7.53E+03	1.26E+04	5.02E+04	1.26E+05	1.51E+05	2.01E+05	2.51E+05
Cs-137	2.98E+03	7.45E+03	1.12E+04	1.86E+04	7.45E+04	1.86E+05	2.24E+05	2.98E+05	3.73E+05
I-131	3.42E+02	8.54E+02	1.28E+03	2.14E+03	8.54E+03	2.14E+04	2.56E+04	3.42E+04	4.27E+04
Ir-192	4.69E+03	1.17E+04	1.76E+04	2.93E+04	1.17E+05	2.93E+05	3.52E+05	4.69E+05	5.87E+05
Po-210	1.19E+01	2.97E+01	4.45E+01	7.42E+01	2.97E+02	7.42E+02	8.90E+02	1.19E+03	1.48E+03
Co-60	1.16E+03	2.90E+03	4.34E+03	7.24E+03	2.90E+04	7.24E+04	8.69E+04	1.16E+05	1.45E+05

365 days

	4	10	15	25	100	250	300	400	500
Sr-90	6.83E+01	1.71E+02	2.56E+02	4.27E+02	1.71E+03	4.27E+03	5.12E+03	6.83E+03	8.54E+03
Y-90	4.95E+02	1.24E+03	1.86E+03	3.10E+03	1.24E+04	3.10E+04	3.72E+04	4.95E+04	6.19E+04
Cs-137	7.35E+02	1.84E+03	2.76E+03	4.59E+03	1.84E+04	4.59E+04	5.51E+04	7.35E+04	9.19E+04
I-131	8.43E+01	2.11E+02	3.16E+02	5.27E+02	2.11E+03	5.27E+03	6.32E+03	8.43E+03	1.05E+04
Ir-192	1.16E+03	2.89E+03	4.34E+03	7.23E+03	2.89E+04	7.23E+04	8.68E+04	1.16E+05	1.45E+05
Po-210	2.93E+00	7.31E+00	1.10E+01	1.83E+01	7.31E+01	1.83E+02	2.19E+02	2.93E+02	3.66E+02
Co-60	2.86E+02	7.14E+02	1.07E+03	1.78E+03	7.14E+03	1.78E+04	2.14E+04	2.86E+04	3.57E+04

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Drinking Water Risk for Specified Dose (mrem) Over Specified Time

30 days

	4	10	15	25	100	250	300	400	500
Sr-90	2.38E-06	5.95E-06	8.92E-06	1.49E-05	5.95E-05	1.49E-04	1.78E-04	2.38E-04	2.97E-04
Y-90	1.42E-05	3.55E-05	5.32E-05	8.87E-05	3.55E-04	8.87E-04	1.06E-03	1.42E-03	1.77E-03
Cs-137	6.45E-06	1.61E-05	2.42E-05	4.03E-05	1.61E-04	4.03E-04	4.83E-04	6.45E-04	8.06E-04
I-131	4.67E-06	1.17E-05	1.75E-05	2.92E-05	1.17E-04	2.92E-04	3.51E-04	4.67E-04	5.84E-04
Ir-192	1.23E-05	3.07E-05	4.61E-05	7.69E-05	3.07E-04	7.69E-04	9.22E-04	1.23E-03	1.54E-03
Po-210	1.34E-06	3.34E-06	5.01E-06	8.35E-06	3.34E-05	8.35E-05	1.00E-04	1.34E-04	1.67E-04
Co-60	5.54E-06	1.38E-05	2.08E-05	3.46E-05	1.38E-04	3.46E-04	4.15E-04	5.54E-04	6.92E-04

60 days

	4	10	15	25	100	250	300	400	500
Sr-90	2.38E-06	5.95E-06	8.92E-06	1.49E-05	5.95E-05	1.49E-04	1.78E-04	2.38E-04	2.97E-04
Y-90	1.42E-05	3.55E-05	5.32E-05	8.87E-05	3.55E-04	8.87E-04	1.06E-03	1.42E-03	1.77E-03
Cs-137	6.45E-06	1.61E-05	2.42E-05	4.03E-05	1.61E-04	4.03E-04	4.83E-04	6.45E-04	8.06E-04
I-131	4.67E-06	1.17E-05	1.75E-05	2.92E-05	1.17E-04	2.92E-04	3.51E-04	4.67E-04	5.84E-04
Ir-192	1.23E-05	3.07E-05	4.61E-05	7.69E-05	3.07E-04	7.69E-04	9.22E-04	1.23E-03	1.54E-03
Po-210	1.34E-06	3.34E-06	5.01E-06	8.35E-06	3.34E-05	8.35E-05	1.00E-04	1.34E-04	1.67E-04
Co-60	5.54E-06	1.38E-05	2.08E-05	3.46E-05	1.38E-04	3.46E-04	4.15E-04	5.54E-04	6.92E-04

90 days

	4	10	15	25	100	250	300	400	500
Sr-90	2.38E-06	5.95E-06	8.92E-06	1.49E-05	5.95E-05	1.49E-04	1.78E-04	2.38E-04	2.97E-04
Y-90	1.42E-05	3.55E-05	5.32E-05	8.87E-05	3.55E-04	8.87E-04	1.06E-03	1.42E-03	1.77E-03
Cs-137	6.45E-06	1.61E-05	2.42E-05	4.03E-05	1.61E-04	4.03E-04	4.83E-04	6.45E-04	8.06E-04
I-131	4.67E-06	1.17E-05	1.75E-05	2.92E-05	1.17E-04	2.92E-04	3.51E-04	4.67E-04	5.84E-04
Ir-192	1.23E-05	3.07E-05	4.61E-05	7.69E-05	3.07E-04	7.69E-04	9.22E-04	1.23E-03	1.54E-03
Po-210	1.34E-06	3.34E-06	5.01E-06	8.35E-06	3.34E-05	8.35E-05	1.00E-04	1.34E-04	1.67E-04
Co-60	5.54E-06	1.38E-05	2.08E-05	3.46E-05	1.38E-04	3.46E-04	4.15E-04	5.54E-04	6.92E-04

365 days

	4	10	15	25	100	250	300	400	500
Sr-90	2.38E-06	5.95E-06	8.92E-06	1.49E-05	5.95E-05	1.49E-04	1.78E-04	2.38E-04	2.97E-04
Y-90	1.42E-05	3.55E-05	5.32E-05	8.87E-05	3.55E-04	8.87E-04	1.06E-03	1.42E-03	1.77E-03
Cs-137	6.45E-06	1.61E-05	2.42E-05	4.03E-05	1.61E-04	4.03E-04	4.83E-04	6.45E-04	8.06E-04
I-131	4.67E-06	1.17E-05	1.75E-05	2.92E-05	1.17E-04	2.92E-04	3.51E-04	4.67E-04	5.84E-04
Ir-192	1.23E-05	3.07E-05	4.61E-05	7.69E-05	3.07E-04	7.69E-04	9.22E-04	1.23E-03	1.54E-03
Po-210	1.34E-06	3.34E-06	5.01E-06	8.35E-06	3.34E-05	8.35E-05	1.00E-04	1.34E-04	1.67E-04
Co-60	5.54E-06	1.38E-05	2.08E-05	3.46E-05	1.38E-04	3.46E-04	4.15E-04	5.54E-04	6.92E-04

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APPENDIX 4: 1 YEAR OLD

Drinking Water Concentration (pCi/L) for Specified Dose (mrem) Over Specified Time

30 days

	4	10	15	25	100	250	300	400	500
Sr-90	2.23E+03	5.58E+03	8.37E+03	1.39E+04	5.58E+04	1.39E+05	1.67E+05	2.23E+05	2.79E+05
Y-90	8.08E+03	2.02E+04	3.03E+04	5.05E+04	2.02E+05	5.05E+05	6.06E+05	8.08E+05	1.01E+06
Cs-137	1.30E+04	3.26E+04	4.89E+04	8.14E+04	3.26E+05	8.14E+05	9.77E+05	1.30E+06	1.63E+06
I-131	9.03E+02	2.26E+03	3.39E+03	5.64E+03	2.26E+04	5.64E+04	6.77E+04	9.03E+04	1.13E+05
Ir-192	1.85E+04	4.62E+04	6.93E+04	1.16E+05	4.62E+05	1.16E+06	1.39E+06	1.85E+06	2.31E+06
Po-210	9.03E+01	2.26E+02	3.39E+02	5.64E+02	2.26E+03	5.64E+03	6.77E+03	9.03E+03	1.13E+04
Co-60	6.03E+03	1.51E+04	2.26E+04	3.77E+04	1.51E+05	3.77E+05	4.52E+05	6.03E+05	7.54E+05

60 days

	4	10	15	25	100	250	300	400	500
Sr-90	1.12E+03	2.79E+03	4.18E+03	6.97E+03	2.79E+04	6.97E+04	8.37E+04	1.12E+05	1.39E+05
Y-90	4.04E+03	1.01E+04	1.51E+04	2.52E+04	1.01E+05	2.52E+05	3.03E+05	4.04E+05	5.05E+05
Cs-137	6.52E+03	1.63E+04	2.44E+04	4.07E+04	1.63E+05	4.07E+05	4.89E+05	6.52E+05	8.14E+05
I-131	4.51E+02	1.13E+03	1.69E+03	2.82E+03	1.13E+04	2.82E+04	3.39E+04	4.51E+04	5.64E+04
Ir-192	9.24E+03	2.31E+04	3.47E+04	5.78E+04	2.31E+05	5.78E+05	6.93E+05	9.24E+05	1.16E+06
Po-210	4.51E+01	1.13E+02	1.69E+02	2.82E+02	1.13E+03	2.82E+03	3.39E+03	4.51E+03	5.64E+03
Co-60	3.01E+03	7.54E+03	1.13E+04	1.88E+04	7.54E+04	1.88E+05	2.26E+05	3.01E+05	3.77E+05

90 days

	4	10	15	25	100	250	300	400	500
Sr-90	7.44E+02	1.86E+03	2.79E+03	4.65E+03	1.86E+04	4.65E+04	5.58E+04	7.44E+04	9.30E+04
Y-90	2.69E+03	6.73E+03	1.01E+04	1.68E+04	6.73E+04	1.68E+05	2.02E+05	2.69E+05	3.37E+05
Cs-137	4.34E+03	1.09E+04	1.63E+04	2.71E+04	1.09E+05	2.71E+05	3.26E+05	4.34E+05	5.43E+05
I-131	3.01E+02	7.52E+02	1.13E+03	1.88E+03	7.52E+03	1.88E+04	2.26E+04	3.01E+04	3.76E+04
Ir-192	6.16E+03	1.54E+04	2.31E+04	3.85E+04	1.54E+05	3.85E+05	4.62E+05	6.16E+05	7.70E+05
Po-210	3.01E+01	7.52E+01	1.13E+02	1.88E+02	7.52E+02	1.88E+03	2.26E+03	3.01E+03	3.76E+03
Co-60	2.01E+03	5.02E+03	7.54E+03	1.26E+04	5.02E+04	1.26E+05	1.51E+05	2.01E+05	2.51E+05

365 days

	4	10	15	25	100	250	300	400	500
Sr-90	1.83E+02	4.59E+02	6.88E+02	1.15E+03	4.59E+03	1.15E+04	1.38E+04	1.83E+04	2.29E+04
Y-90	6.64E+02	1.66E+03	2.49E+03	4.15E+03	1.66E+04	4.15E+04	4.98E+04	6.64E+04	8.30E+04
Cs-137	1.07E+03	2.68E+03	4.02E+03	6.69E+03	2.68E+04	6.69E+04	8.03E+04	1.07E+05	1.34E+05
I-131	7.42E+01	1.86E+02	2.78E+02	4.64E+02	1.86E+03	4.64E+03	5.57E+03	7.42E+03	9.28E+03
Ir-192	1.52E+03	3.80E+03	5.70E+03	9.50E+03	3.80E+04	9.50E+04	1.14E+05	1.52E+05	1.90E+05
Po-210	7.42E+00	1.86E+01	2.78E+01	4.64E+01	1.86E+02	4.64E+02	5.57E+02	7.42E+02	9.28E+02
Co-60	4.96E+02	1.24E+03	1.86E+03	3.10E+03	1.24E+04	3.10E+04	3.72E+04	4.96E+04	6.19E+04

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Drinking Water Risk for Specified Dose (mrem) Over Specified Time

30 days

	4	10	15	25	100	250	300	400	500
Sr-90	4.75E-06	1.19E-05	1.78E-05	2.97E-05	1.19E-04	2.97E-04	3.56E-04	4.75E-04	5.93E-04
Y-90	1.62E-05	4.04E-05	6.06E-05	1.01E-04	4.04E-04	1.01E-03	1.21E-03	1.62E-03	2.02E-03
Cs-137	8.03E-06	2.01E-05	3.01E-05	5.02E-05	2.01E-04	5.02E-04	6.02E-04	8.03E-04	1.00E-03
I-131	4.45E-06	1.11E-05	1.67E-05	2.78E-05	1.11E-04	2.78E-04	3.34E-04	4.45E-04	5.56E-04
Ir-192	1.39E-05	3.48E-05	5.22E-05	8.70E-05	3.48E-04	8.70E-04	1.04E-03	1.39E-03	1.74E-03
Po-210	2.13E-06	5.31E-06	7.97E-06	1.33E-05	5.31E-05	1.33E-04	1.59E-04	2.13E-04	2.66E-04
Co-60	7.79E-06	1.95E-05	2.92E-05	4.87E-05	1.95E-04	4.87E-04	5.84E-04	7.79E-04	9.74E-04

60 days

	4	10	15	25	100	250	300	400	500
Sr-90	4.75E-06	1.19E-05	1.78E-05	2.97E-05	1.19E-04	2.97E-04	3.56E-04	4.75E-04	5.93E-04
Y-90	1.62E-05	4.04E-05	6.06E-05	1.01E-04	4.04E-04	1.01E-03	1.21E-03	1.62E-03	2.02E-03
Cs-137	8.03E-06	2.01E-05	3.01E-05	5.02E-05	2.01E-04	5.02E-04	6.02E-04	8.03E-04	1.00E-03
I-131	4.45E-06	1.11E-05	1.67E-05	2.78E-05	1.11E-04	2.78E-04	3.34E-04	4.45E-04	5.56E-04
Ir-192	1.39E-05	3.48E-05	5.22E-05	8.70E-05	3.48E-04	8.70E-04	1.04E-03	1.39E-03	1.74E-03
Po-210	2.13E-06	5.31E-06	7.97E-06	1.33E-05	5.31E-05	1.33E-04	1.59E-04	2.13E-04	2.66E-04
Co-60	7.79E-06	1.95E-05	2.92E-05	4.87E-05	1.95E-04	4.87E-04	5.84E-04	7.79E-04	9.74E-04

90 days

	4	10	15	25	100	250	300	400	500
Sr-90	4.75E-06	1.19E-05	1.78E-05	2.97E-05	1.19E-04	2.97E-04	3.56E-04	4.75E-04	5.93E-04
Y-90	1.62E-05	4.04E-05	6.06E-05	1.01E-04	4.04E-04	1.01E-03	1.21E-03	1.62E-03	2.02E-03
Cs-137	8.03E-06	2.01E-05	3.01E-05	5.02E-05	2.01E-04	5.02E-04	6.02E-04	8.03E-04	1.00E-03
I-131	4.45E-06	1.11E-05	1.67E-05	2.78E-05	1.11E-04	2.78E-04	3.34E-04	4.45E-04	5.56E-04
Ir-192	1.39E-05	3.48E-05	5.22E-05	8.70E-05	3.48E-04	8.70E-04	1.04E-03	1.39E-03	1.74E-03
Po-210	2.13E-06	5.31E-06	7.97E-06	1.33E-05	5.31E-05	1.33E-04	1.59E-04	2.13E-04	2.66E-04
Co-60	7.79E-06	1.95E-05	2.92E-05	4.87E-05	1.95E-04	4.87E-04	5.84E-04	7.79E-04	9.74E-04

365 days

	4	10	15	25	100	250	300	400	500
Sr-90	4.75E-06	1.19E-05	1.78E-05	2.97E-05	1.19E-04	2.97E-04	3.56E-04	4.75E-04	5.93E-04
Y-90	1.62E-05	4.04E-05	6.06E-05	1.01E-04	4.04E-04	1.01E-03	1.21E-03	1.62E-03	2.02E-03
Cs-137	8.03E-06	2.01E-05	3.01E-05	5.02E-05	2.01E-04	5.02E-04	6.02E-04	8.03E-04	1.00E-03
I-131	4.45E-06	1.11E-05	1.67E-05	2.78E-05	1.11E-04	2.78E-04	3.34E-04	4.45E-04	5.56E-04
Ir-192	1.39E-05	3.48E-05	5.22E-05	8.70E-05	3.48E-04	8.70E-04	1.04E-03	1.39E-03	1.74E-03
Po-210	2.13E-06	5.31E-06	7.97E-06	1.33E-05	5.31E-05	1.33E-04	1.59E-04	2.13E-04	2.66E-04
Co-60	7.79E-06	1.95E-05	2.92E-05	4.87E-05	1.95E-04	4.87E-04	5.84E-04	7.79E-04	9.74E-04

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APPENDIX 5: 5 YEAR OLD

Drinking Water Concentration (pCi/L) for Specified Dose (mrem) Over Specified Time

30 days

	4	10	15	25	100	250	300	400	500
Sr-90	1.42E+03	3.54E+03	5.32E+03	8.86E+03	3.54E+04	8.86E+04	1.06E+05	1.42E+05	1.77E+05
Y-90	6.67E+03	1.67E+04	2.50E+04	4.17E+04	1.67E+05	4.17E+05	5.00E+05	6.67E+05	8.34E+05
Cs-137	6.86E+03	1.72E+04	2.57E+04	4.29E+04	1.72E+05	4.29E+05	5.15E+05	6.86E+05	8.58E+05
I-131	6.39E+02	1.60E+03	2.40E+03	4.00E+03	1.60E+04	4.00E+04	4.79E+04	6.39E+04	7.99E+04
Ir-192	1.45E+04	3.62E+04	5.43E+04	9.05E+04	3.62E+05	9.05E+05	1.09E+06	1.45E+06	1.81E+06
Po-210	7.49E+01	1.87E+02	2.81E+02	4.68E+02	1.87E+03	4.68E+03	5.62E+03	7.49E+03	9.36E+03
Co-60	3.93E+03	9.84E+03	1.48E+04	2.46E+04	9.84E+04	2.46E+05	2.95E+05	3.93E+05	4.92E+05

60 days

	4	10	15	25	100	250	300	400	500
Sr-90	7.09E+02	1.77E+03	2.66E+03	4.43E+03	1.77E+04	4.43E+04	5.32E+04	7.09E+04	8.86E+04
Y-90	3.33E+03	8.34E+03	1.25E+04	2.08E+04	8.34E+04	2.08E+05	2.50E+05	3.33E+05	4.17E+05
Cs-137	3.43E+03	8.58E+03	1.29E+04	2.14E+04	8.58E+04	2.14E+05	2.57E+05	3.43E+05	4.29E+05
I-131	3.20E+02	7.99E+02	1.20E+03	2.00E+03	7.99E+03	2.00E+04	2.40E+04	3.20E+04	4.00E+04
Ir-192	7.24E+03	1.81E+04	2.72E+04	4.53E+04	1.81E+05	4.53E+05	5.43E+05	7.24E+05	9.05E+05
Po-210	3.74E+01	9.36E+01	1.40E+02	2.34E+02	9.36E+02	2.34E+03	2.81E+03	3.74E+03	4.68E+03
Co-60	1.97E+03	4.92E+03	7.38E+03	1.23E+04	4.92E+04	1.23E+05	1.48E+05	1.97E+05	2.46E+05

90 days

	4	10	15	25	100	250	300	400	500
Sr-90	4.73E+02	1.18E+03	1.77E+03	2.95E+03	1.18E+04	2.95E+04	3.54E+04	4.73E+04	5.91E+04
Y-90	2.22E+03	5.56E+03	8.34E+03	1.39E+04	5.56E+04	1.39E+05	1.67E+05	2.22E+05	2.78E+05
Cs-137	2.29E+03	5.72E+03	8.58E+03	1.43E+04	5.72E+04	1.43E+05	1.72E+05	2.29E+05	2.86E+05
I-131	2.13E+02	5.33E+02	7.99E+02	1.33E+03	5.33E+03	1.33E+04	1.60E+04	2.13E+04	2.66E+04
Ir-192	4.83E+03	1.21E+04	1.81E+04	3.02E+04	1.21E+05	3.02E+05	3.62E+05	4.83E+05	6.04E+05
Po-210	2.50E+01	6.24E+01	9.36E+01	1.56E+02	6.24E+02	1.56E+03	1.87E+03	2.50E+03	3.12E+03
Co-60	1.31E+03	3.28E+03	4.92E+03	8.20E+03	3.28E+04	8.20E+04	9.84E+04	1.31E+05	1.64E+05

365 days

	4	10	15	25	100	250	300	400	500
Sr-90	1.17E+02	2.91E+02	4.37E+02	7.28E+02	2.91E+03	7.28E+03	8.74E+03	1.17E+04	1.46E+04
Y-90	5.48E+02	1.37E+03	2.06E+03	3.43E+03	1.37E+04	3.43E+04	4.11E+04	5.48E+04	6.85E+04
Cs-137	5.64E+02	1.41E+03	2.11E+03	3.52E+03	1.41E+04	3.52E+04	4.23E+04	5.64E+04	7.05E+04
I-131	5.25E+01	1.31E+02	1.97E+02	3.28E+02	1.31E+03	3.28E+03	3.94E+03	5.25E+03	6.57E+03
Ir-192	1.19E+03	2.98E+03	4.46E+03	7.44E+03	2.98E+04	7.44E+04	8.93E+04	1.19E+05	1.49E+05
Po-210	6.15E+00	1.54E+01	2.31E+01	3.85E+01	1.54E+02	3.85E+02	4.62E+02	6.15E+02	7.69E+02
Co-60	3.23E+02	8.08E+02	1.21E+03	2.02E+03	8.08E+03	2.02E+04	2.43E+04	3.23E+04	4.04E+04

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Drinking Water Risk for Specified Dose (mrem) Over Specified Time

30 days

	4	10	15	25	100	250	300	400	500
Sr-90	4.38E-06	1.09E-05	1.64E-05	2.73E-05	1.09E-04	2.73E-04	3.28E-04	4.38E-04	5.47E-04
Y-90	1.71E-05	4.26E-05	6.39E-05	1.07E-04	4.26E-04	1.07E-03	1.28E-03	1.71E-03	2.13E-03
Cs-137	8.13E-06	2.03E-05	3.05E-05	5.08E-05	2.03E-04	5.08E-04	6.10E-04	8.13E-04	1.02E-03
I-131	4.08E-06	1.02E-05	1.53E-05	2.55E-05	1.02E-04	2.55E-04	3.06E-04	4.08E-04	5.10E-04
Ir-192	1.44E-05	3.59E-05	5.39E-05	8.99E-05	3.59E-04	8.99E-04	1.08E-03	1.44E-03	1.80E-03
Po-210	2.32E-06	5.80E-06	8.70E-06	1.45E-05	5.80E-05	1.45E-04	1.74E-04	2.32E-04	2.90E-04
Co-60	7.81E-06	1.95E-05	2.93E-05	4.88E-05	1.95E-04	4.88E-04	5.86E-04	7.81E-04	9.76E-04

60 days

	4	10	15	25	100	250	300	400	500
Sr-90	4.38E-06	1.09E-05	1.64E-05	2.73E-05	1.09E-04	2.73E-04	3.28E-04	4.38E-04	5.47E-04
Y-90	1.71E-05	4.26E-05	6.39E-05	1.07E-04	4.26E-04	1.07E-03	1.28E-03	1.71E-03	2.13E-03
Cs-137	8.13E-06	2.03E-05	3.05E-05	5.08E-05	2.03E-04	5.08E-04	6.10E-04	8.13E-04	1.02E-03
I-131	4.08E-06	1.02E-05	1.53E-05	2.55E-05	1.02E-04	2.55E-04	3.06E-04	4.08E-04	5.10E-04
Ir-192	1.44E-05	3.59E-05	5.39E-05	8.99E-05	3.59E-04	8.99E-04	1.08E-03	1.44E-03	1.80E-03
Po-210	2.32E-06	5.80E-06	8.70E-06	1.45E-05	5.80E-05	1.45E-04	1.74E-04	2.32E-04	2.90E-04
Co-60	7.81E-06	1.95E-05	2.93E-05	4.88E-05	1.95E-04	4.88E-04	5.86E-04	7.81E-04	9.76E-04

90 days

	4	10	15	25	100	250	300	400	500
Sr-90	4.38E-06	1.09E-05	1.64E-05	2.73E-05	1.09E-04	2.73E-04	3.28E-04	4.38E-04	5.47E-04
Y-90	1.71E-05	4.26E-05	6.39E-05	1.07E-04	4.26E-04	1.07E-03	1.28E-03	1.71E-03	2.13E-03
Cs-137	8.13E-06	2.03E-05	3.05E-05	5.08E-05	2.03E-04	5.08E-04	6.10E-04	8.13E-04	1.02E-03
I-131	4.08E-06	1.02E-05	1.53E-05	2.55E-05	1.02E-04	2.55E-04	3.06E-04	4.08E-04	5.10E-04
Ir-192	1.44E-05	3.59E-05	5.39E-05	8.99E-05	3.59E-04	8.99E-04	1.08E-03	1.44E-03	1.80E-03
Po-210	2.32E-06	5.80E-06	8.70E-06	1.45E-05	5.80E-05	1.45E-04	1.74E-04	2.32E-04	2.90E-04
Co-60	7.81E-06	1.95E-05	2.93E-05	4.88E-05	1.95E-04	4.88E-04	5.86E-04	7.81E-04	9.76E-04

365 days

	4	10	15	25	100	250	300	400	500
Sr-90	4.38E-06	1.09E-05	1.64E-05	2.73E-05	1.09E-04	2.73E-04	3.28E-04	4.38E-04	5.47E-04
Y-90	1.71E-05	4.26E-05	6.39E-05	1.07E-04	4.26E-04	1.07E-03	1.28E-03	1.71E-03	2.13E-03
Cs-137	8.13E-06	2.03E-05	3.05E-05	5.08E-05	2.03E-04	5.08E-04	6.10E-04	8.13E-04	1.02E-03
I-131	4.08E-06	1.02E-05	1.53E-05	2.55E-05	1.02E-04	2.55E-04	3.06E-04	4.08E-04	5.10E-04
Ir-192	1.44E-05	3.59E-05	5.39E-05	8.99E-05	3.59E-04	8.99E-04	1.08E-03	1.44E-03	1.80E-03
Po-210	2.32E-06	5.80E-06	8.70E-06	1.45E-05	5.80E-05	1.45E-04	1.74E-04	2.32E-04	2.90E-04
Co-60	7.81E-06	1.95E-05	2.93E-05	4.88E-05	1.95E-04	4.88E-04	5.86E-04	7.81E-04	9.76E-04

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APPENDIX 6: 10 YEAR OLD

Drinking Water Concentration (pCi/L) for Specified Dose (mrem) Over Specified Time

30 days

	4	10	15	25	100	250	300	400	500
Sr-90	8.33E+02	2.08E+03	3.12E+03	5.20E+03	2.08E+04	5.20E+04	6.24E+04	8.33E+04	1.04E+05
Y-90	8.42E+03	2.11E+04	3.16E+04	5.27E+04	2.11E+05	5.27E+05	6.32E+05	8.42E+05	1.05E+06
Cs-137	4.92E+03	1.23E+04	1.85E+04	3.08E+04	1.23E+05	3.08E+05	3.69E+05	4.92E+05	6.15E+05
I-131	9.49E+02	2.37E+03	3.56E+03	5.93E+03	2.37E+04	5.93E+04	7.11E+04	9.49E+04	1.19E+05
Ir-192	1.74E+04	4.36E+04	6.54E+04	1.09E+05	4.36E+05	1.09E+06	1.31E+06	1.74E+06	2.18E+06
Po-210	9.47E+01	2.37E+02	3.55E+02	5.92E+02	2.37E+03	5.92E+03	7.10E+03	9.47E+03	1.18E+04
Co-60	4.44E+03	1.11E+04	1.66E+04	2.77E+04	1.11E+05	2.77E+05	3.33E+05	4.44E+05	5.55E+05

60 days

	4	10	15	25	100	250	300	400	500
Sr-90	4.16E+02	1.04E+03	1.56E+03	2.60E+03	1.04E+04	2.60E+04	3.12E+04	4.16E+04	5.20E+04
Y-90	4.21E+03	1.05E+04	1.58E+04	2.63E+04	1.05E+05	2.63E+05	3.16E+05	4.21E+05	5.27E+05
Cs-137	2.46E+03	6.15E+03	9.23E+03	1.54E+04	6.15E+04	1.54E+05	1.85E+05	2.46E+05	3.08E+05
I-131	4.74E+02	1.19E+03	1.78E+03	2.96E+03	1.19E+04	2.96E+04	3.56E+04	4.74E+04	5.93E+04
Ir-192	8.72E+03	2.18E+04	3.27E+04	5.45E+04	2.18E+05	5.45E+05	6.54E+05	8.72E+05	1.09E+06
Po-210	4.73E+01	1.18E+02	1.78E+02	2.96E+02	1.18E+03	2.96E+03	3.55E+03	4.73E+03	5.92E+03
Co-60	2.22E+03	5.55E+03	8.32E+03	1.39E+04	5.55E+04	1.39E+05	1.66E+05	2.22E+05	2.77E+05

90 days

	4	10	15	25	100	250	300	400	500
Sr-90	2.78E+02	6.94E+02	1.04E+03	1.73E+03	6.94E+03	1.73E+04	2.08E+04	2.78E+04	3.47E+04
Y-90	2.81E+03	7.02E+03	1.05E+04	1.76E+04	7.02E+04	1.76E+05	2.11E+05	2.81E+05	3.51E+05
Cs-137	1.64E+03	4.10E+03	6.15E+03	1.03E+04	4.10E+04	1.03E+05	1.23E+05	1.64E+05	2.05E+05
I-131	3.16E+02	7.90E+02	1.19E+03	1.98E+03	7.90E+03	1.98E+04	2.37E+04	3.16E+04	3.95E+04
Ir-192	5.81E+03	1.45E+04	2.18E+04	3.63E+04	1.45E+05	3.63E+05	4.36E+05	5.81E+05	7.27E+05
Po-210	3.16E+01	7.89E+01	1.18E+02	1.97E+02	7.89E+02	1.97E+03	2.37E+03	3.16E+03	3.94E+03
Co-60	1.48E+03	3.70E+03	5.55E+03	9.25E+03	3.70E+04	9.25E+04	1.11E+05	1.48E+05	1.85E+05

365 days

	4	10	15	25	100	250	300	400	500
Sr-90	6.84E+01	1.71E+02	2.57E+02	4.28E+02	1.71E+03	4.28E+03	5.13E+03	6.84E+03	8.55E+03
Y-90	6.92E+02	1.73E+03	2.60E+03	4.33E+03	1.73E+04	4.33E+04	5.19E+04	6.92E+04	8.66E+04
Cs-137	4.04E+02	1.01E+03	1.52E+03	2.53E+03	1.01E+04	2.53E+04	3.03E+04	4.04E+04	5.06E+04
I-131	7.80E+01	1.95E+02	2.92E+02	4.87E+02	1.95E+03	4.87E+03	5.85E+03	7.80E+03	9.75E+03
Ir-192	1.43E+03	3.58E+03	5.38E+03	8.96E+03	3.58E+04	8.96E+04	1.08E+05	1.43E+05	1.79E+05
Po-210	7.78E+00	1.95E+01	2.92E+01	4.86E+01	1.95E+02	4.86E+02	5.84E+02	7.78E+02	9.73E+02
Co-60	3.65E+02	9.12E+02	1.37E+03	2.28E+03	9.12E+03	2.28E+04	2.74E+04	3.65E+04	4.56E+04

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Drinking Water Risk for Specified Dose (mrem) Over Specified Time

30 days

	4	10	15	25	100	250	300	400	500
Sr-90	2.15E-06	5.38E-06	8.07E-06	1.34E-05	5.38E-05	1.34E-04	1.61E-04	2.15E-04	2.69E-04
Y-90	1.72E-05	4.31E-05	6.46E-05	1.08E-04	4.31E-04	1.08E-03	1.29E-03	1.72E-03	2.15E-03
Cs-137	7.88E-06	1.97E-05	2.96E-05	4.93E-05	1.97E-04	4.93E-04	5.91E-04	7.88E-04	9.85E-04
I-131	3.85E-06	9.62E-06	1.44E-05	2.40E-05	9.62E-05	2.40E-04	2.89E-04	3.85E-04	4.81E-04
Ir-192	1.42E-05	3.54E-05	5.32E-05	8.86E-05	3.54E-04	8.86E-04	1.06E-03	1.42E-03	1.77E-03
Po-210	2.42E-06	6.06E-06	9.09E-06	1.51E-05	6.06E-05	1.51E-04	1.82E-04	2.42E-04	3.03E-04
Co-60	7.71E-06	1.93E-05	2.89E-05	4.82E-05	1.93E-04	4.82E-04	5.79E-04	7.71E-04	9.64E-04

60 days

	4	10	15	25	100	250	300	400	500
Sr-90	2.15E-06	5.38E-06	8.07E-06	1.34E-05	5.38E-05	1.34E-04	1.61E-04	2.15E-04	2.69E-04
Y-90	1.72E-05	4.31E-05	6.46E-05	1.08E-04	4.31E-04	1.08E-03	1.29E-03	1.72E-03	2.15E-03
Cs-137	7.88E-06	1.97E-05	2.96E-05	4.93E-05	1.97E-04	4.93E-04	5.91E-04	7.88E-04	9.85E-04
I-131	3.85E-06	9.62E-06	1.44E-05	2.40E-05	9.62E-05	2.40E-04	2.89E-04	3.85E-04	4.81E-04
Ir-192	1.42E-05	3.54E-05	5.32E-05	8.86E-05	3.54E-04	8.86E-04	1.06E-03	1.42E-03	1.77E-03
Po-210	2.42E-06	6.06E-06	9.09E-06	1.51E-05	6.06E-05	1.51E-04	1.82E-04	2.42E-04	3.03E-04
Co-60	7.71E-06	1.93E-05	2.89E-05	4.82E-05	1.93E-04	4.82E-04	5.79E-04	7.71E-04	9.64E-04

90 days

	4	10	15	25	100	250	300	400	500
Sr-90	2.15E-06	5.38E-06	8.07E-06	1.34E-05	5.38E-05	1.34E-04	1.61E-04	2.15E-04	2.69E-04
Y-90	1.72E-05	4.31E-05	6.46E-05	1.08E-04	4.31E-04	1.08E-03	1.29E-03	1.72E-03	2.15E-03
Cs-137	7.88E-06	1.97E-05	2.96E-05	4.93E-05	1.97E-04	4.93E-04	5.91E-04	7.88E-04	9.85E-04
I-131	3.85E-06	9.62E-06	1.44E-05	2.40E-05	9.62E-05	2.40E-04	2.89E-04	3.85E-04	4.81E-04
Ir-192	1.42E-05	3.54E-05	5.32E-05	8.86E-05	3.54E-04	8.86E-04	1.06E-03	1.42E-03	1.77E-03
Po-210	2.42E-06	6.06E-06	9.09E-06	1.51E-05	6.06E-05	1.51E-04	1.82E-04	2.42E-04	3.03E-04
Co-60	7.71E-06	1.93E-05	2.89E-05	4.82E-05	1.93E-04	4.82E-04	5.79E-04	7.71E-04	9.64E-04

365 days

	4	10	15	25	100	250	300	400	500
Sr-90	2.15E-06	5.38E-06	8.07E-06	1.34E-05	5.38E-05	1.34E-04	1.61E-04	2.15E-04	2.69E-04
Y-90	1.72E-05	4.31E-05	6.46E-05	1.08E-04	4.31E-04	1.08E-03	1.29E-03	1.72E-03	2.15E-03
Cs-137	7.88E-06	1.97E-05	2.96E-05	4.93E-05	1.97E-04	4.93E-04	5.91E-04	7.88E-04	9.85E-04
I-131	3.85E-06	9.62E-06	1.44E-05	2.40E-05	9.62E-05	2.40E-04	2.89E-04	3.85E-04	4.81E-04
Ir-192	1.42E-05	3.54E-05	5.32E-05	8.86E-05	3.54E-04	8.86E-04	1.06E-03	1.42E-03	1.77E-03
Po-210	2.42E-06	6.06E-06	9.09E-06	1.51E-05	6.06E-05	1.51E-04	1.82E-04	2.42E-04	3.03E-04
Co-60	7.71E-06	1.93E-05	2.89E-05	4.82E-05	1.93E-04	4.82E-04	5.79E-04	7.71E-04	9.64E-04

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APPENDIX 7: 15 YEAR OLD

Drinking Water Concentration (pCi/L) for Specified Dose (mrem) Over Specified Time

30 days

	4	10	15	25	100	250	300	400	500
Sr-90	5.07E+02	1.27E+03	1.90E+03	3.17E+03	1.27E+04	3.17E+04	3.81E+04	5.07E+04	6.34E+04
Y-90	1.20E+04	3.00E+04	4.50E+04	7.49E+04	3.00E+05	7.49E+05	8.99E+05	1.20E+06	1.50E+06
Cs-137	2.99E+03	7.47E+03	1.12E+04	1.87E+04	7.47E+04	1.87E+05	2.24E+05	2.99E+05	3.74E+05
I-131	1.17E+03	2.93E+03	4.39E+03	7.32E+03	2.93E+04	7.32E+04	8.78E+04	1.17E+05	1.46E+05
Ir-192	2.34E+04	5.85E+04	8.78E+04	1.46E+05	5.85E+05	1.46E+06	1.76E+06	2.34E+06	2.93E+06
Po-210	1.26E+02	3.14E+02	4.71E+02	7.84E+02	3.14E+03	7.84E+03	9.41E+03	1.26E+04	1.57E+04
Co-60	5.04E+03	1.26E+04	1.89E+04	3.15E+04	1.26E+05	3.15E+05	3.78E+05	5.04E+05	6.30E+05

60 days

	4	10	15	25	100	250	300	400	500
Sr-90	2.54E+02	6.34E+02	9.52E+02	1.59E+03	6.34E+03	1.59E+04	1.90E+04	2.54E+04	3.17E+04
Y-90	5.99E+03	1.50E+04	2.25E+04	3.75E+04	1.50E+05	3.75E+05	4.50E+05	5.99E+05	7.49E+05
Cs-137	1.49E+03	3.74E+03	5.60E+03	9.34E+03	3.74E+04	9.34E+04	1.12E+05	1.49E+05	1.87E+05
I-131	5.85E+02	1.46E+03	2.20E+03	3.66E+03	1.46E+04	3.66E+04	4.39E+04	5.85E+04	7.32E+04
Ir-192	1.17E+04	2.93E+04	4.39E+04	7.32E+04	2.93E+05	7.32E+05	8.78E+05	1.17E+06	1.46E+06
Po-210	6.28E+01	1.57E+02	2.35E+02	3.92E+02	1.57E+03	3.92E+03	4.71E+03	6.28E+03	7.84E+03
Co-60	2.52E+03	6.30E+03	9.46E+03	1.58E+04	6.30E+04	1.58E+05	1.89E+05	2.52E+05	3.15E+05

90 days

	4	10	15	25	100	250	300	400	500
Sr-90	1.69E+02	4.23E+02	6.34E+02	1.06E+03	4.23E+03	1.06E+04	1.27E+04	1.69E+04	2.11E+04
Y-90	4.00E+03	9.99E+03	1.50E+04	2.50E+04	9.99E+04	2.50E+05	3.00E+05	4.00E+05	5.00E+05
Cs-137	9.96E+02	2.49E+03	3.74E+03	6.23E+03	2.49E+04	6.23E+04	7.47E+04	9.96E+04	1.25E+05
I-131	3.90E+02	9.76E+02	1.46E+03	2.44E+03	9.76E+03	2.44E+04	2.93E+04	3.90E+04	4.88E+04
Ir-192	7.81E+03	1.95E+04	2.93E+04	4.88E+04	1.95E+05	4.88E+05	5.85E+05	7.81E+05	9.76E+05
Po-210	4.18E+01	1.05E+02	1.57E+02	2.61E+02	1.05E+03	2.61E+03	3.14E+03	4.18E+03	5.23E+03
Co-60	1.68E+03	4.20E+03	6.30E+03	1.05E+04	4.20E+04	1.05E+05	1.26E+05	1.68E+05	2.10E+05

365 days

	4	10	15	25	100	250	300	400	500
Sr-90	4.17E+01	1.04E+02	1.56E+02	2.61E+02	1.04E+03	2.61E+03	3.13E+03	4.17E+03	5.21E+03
Y-90	9.85E+02	2.46E+03	3.69E+03	6.16E+03	2.46E+04	6.16E+04	7.39E+04	9.85E+04	1.23E+05
Cs-137	2.46E+02	6.14E+02	9.21E+02	1.53E+03	6.14E+03	1.53E+04	1.84E+04	2.46E+04	3.07E+04
I-131	9.62E+01	2.41E+02	3.61E+02	6.01E+02	2.41E+03	6.01E+03	7.22E+03	9.62E+03	1.20E+04
Ir-192	1.92E+03	4.81E+03	7.22E+03	1.20E+04	4.81E+04	1.20E+05	1.44E+05	1.92E+05	2.41E+05
Po-210	1.03E+01	2.58E+01	3.87E+01	6.45E+01	2.58E+02	6.45E+02	7.74E+02	1.03E+03	1.29E+03
Co-60	4.14E+02	1.04E+03	1.55E+03	2.59E+03	1.04E+04	2.59E+04	3.11E+04	4.14E+04	5.18E+04

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Drinking Water Risk for Specified Dose (mrem) Over Specified Time

30 days

	4	10	15	25	100	250	300	400	500
Sr-90	1.70E-06	4.26E-06	6.39E-06	1.06E-05	4.26E-05	1.06E-04	1.28E-04	1.70E-04	2.13E-04
Y-90	1.72E-05	4.31E-05	6.47E-05	1.08E-04	4.31E-04	1.08E-03	1.29E-03	1.72E-03	2.16E-03
Cs-137	7.28E-06	1.82E-05	2.73E-05	4.55E-05	1.82E-04	4.55E-04	5.46E-04	7.28E-04	9.10E-04
I-131	3.46E-06	8.65E-06	1.30E-05	2.16E-05	8.65E-05	2.16E-04	2.60E-04	3.46E-04	4.33E-04
Ir-192	1.39E-05	3.47E-05	5.21E-05	8.68E-05	3.47E-04	8.68E-04	1.04E-03	1.39E-03	1.74E-03
Po-210	2.45E-06	6.11E-06	9.17E-06	1.53E-05	6.11E-05	1.53E-04	1.83E-04	2.45E-04	3.06E-04
Co-60	7.15E-06	1.79E-05	2.68E-05	4.47E-05	1.79E-04	4.47E-04	5.37E-04	7.15E-04	8.94E-04

60 days

	4	10	15	25	100	250	300	400	500
Sr-90	1.70E-06	4.26E-06	6.39E-06	1.06E-05	4.26E-05	1.06E-04	1.28E-04	1.70E-04	2.13E-04
Y-90	1.72E-05	4.31E-05	6.47E-05	1.08E-04	4.31E-04	1.08E-03	1.29E-03	1.72E-03	2.16E-03
Cs-137	7.28E-06	1.82E-05	2.73E-05	4.55E-05	1.82E-04	4.55E-04	5.46E-04	7.28E-04	9.10E-04
I-131	3.46E-06	8.65E-06	1.30E-05	2.16E-05	8.65E-05	2.16E-04	2.60E-04	3.46E-04	4.33E-04
Ir-192	1.39E-05	3.47E-05	5.21E-05	8.68E-05	3.47E-04	8.68E-04	1.04E-03	1.39E-03	1.74E-03
Po-210	2.45E-06	6.11E-06	9.17E-06	1.53E-05	6.11E-05	1.53E-04	1.83E-04	2.45E-04	3.06E-04
Co-60	7.15E-06	1.79E-05	2.68E-05	4.47E-05	1.79E-04	4.47E-04	5.37E-04	7.15E-04	8.94E-04

90 days

	4	10	15	25	100	250	300	400	500
Sr-90	1.70E-06	4.26E-06	6.39E-06	1.06E-05	4.26E-05	1.06E-04	1.28E-04	1.70E-04	2.13E-04
Y-90	1.72E-05	4.31E-05	6.47E-05	1.08E-04	4.31E-04	1.08E-03	1.29E-03	1.72E-03	2.16E-03
Cs-137	7.28E-06	1.82E-05	2.73E-05	4.55E-05	1.82E-04	4.55E-04	5.46E-04	7.28E-04	9.10E-04
I-131	3.46E-06	8.65E-06	1.30E-05	2.16E-05	8.65E-05	2.16E-04	2.60E-04	3.46E-04	4.33E-04
Ir-192	1.39E-05	3.47E-05	5.21E-05	8.68E-05	3.47E-04	8.68E-04	1.04E-03	1.39E-03	1.74E-03
Po-210	2.45E-06	6.11E-06	9.17E-06	1.53E-05	6.11E-05	1.53E-04	1.83E-04	2.45E-04	3.06E-04
Co-60	7.15E-06	1.79E-05	2.68E-05	4.47E-05	1.79E-04	4.47E-04	5.37E-04	7.15E-04	8.94E-04

365 days

	4	10	15	25	100	250	300	400	500
Sr-90	1.70E-06	4.26E-06	6.39E-06	1.06E-05	4.26E-05	1.06E-04	1.28E-04	1.70E-04	2.13E-04
Y-90	1.72E-05	4.31E-05	6.47E-05	1.08E-04	4.31E-04	1.08E-03	1.29E-03	1.72E-03	2.16E-03
Cs-137	7.28E-06	1.82E-05	2.73E-05	4.55E-05	1.82E-04	4.55E-04	5.46E-04	7.28E-04	9.10E-04
I-131	3.46E-06	8.65E-06	1.30E-05	2.16E-05	8.65E-05	2.16E-04	2.60E-04	3.46E-04	4.33E-04
Ir-192	1.39E-05	3.47E-05	5.21E-05	8.68E-05	3.47E-04	8.68E-04	1.04E-03	1.39E-03	1.74E-03
Po-210	2.45E-06	6.11E-06	9.17E-06	1.53E-05	6.11E-05	1.53E-04	1.83E-04	2.45E-04	3.06E-04
Co-60	7.15E-06	1.79E-05	2.68E-05	4.47E-05	1.79E-04	4.47E-04	5.37E-04	7.15E-04	8.94E-04

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APPENDIX 8: ADULT

Drinking Water Concentration (pCi/L) for Specified Dose (mrem) Over Specified Time

30 days

	4	10	15	25	100	250	300	400	500
Sr-90	1.14E+03	2.86E+03	4.29E+03	7.15E+03	2.86E+04	7.15E+04	8.58E+04	1.14E+05	1.43E+05
Y-90	1.18E+04	2.95E+04	4.42E+04	7.36E+04	2.95E+05	7.36E+05	8.84E+05	1.18E+06	1.47E+06
Cs-137	2.33E+03	5.83E+03	8.74E+03	1.46E+04	5.83E+04	1.46E+05	1.75E+05	2.33E+05	2.91E+05
I-131	1.45E+03	3.63E+03	5.45E+03	9.09E+03	3.63E+04	9.09E+04	1.09E+05	1.45E+05	1.82E+05
Ir-192	2.31E+04	5.78E+04	8.68E+04	1.45E+05	5.78E+05	1.45E+06	1.74E+06	2.31E+06	2.89E+06
Po-210	1.29E+02	3.23E+02	4.85E+02	8.09E+02	3.23E+03	8.09E+03	9.70E+03	1.29E+04	1.62E+04
Co-60	9.27E+03	2.32E+04	3.48E+04	5.79E+04	2.32E+05	5.79E+05	6.95E+05	9.27E+05	1.16E+06

60 days

	4	10	15	25	100	250	300	400	500
Sr-90	5.72E+02	1.43E+03	2.15E+03	3.58E+03	1.43E+04	3.58E+04	4.29E+04	5.72E+04	7.15E+04
Y-90	5.89E+03	1.47E+04	2.21E+04	3.68E+04	1.47E+05	3.68E+05	4.42E+05	5.89E+05	7.36E+05
Cs-137	1.17E+03	2.91E+03	4.37E+03	7.28E+03	2.91E+04	7.28E+04	8.74E+04	1.17E+05	1.46E+05
I-131	7.27E+02	1.82E+03	2.73E+03	4.54E+03	1.82E+04	4.54E+04	5.45E+04	7.27E+04	9.09E+04
Ir-192	1.16E+04	2.89E+04	4.34E+04	7.23E+04	2.89E+05	7.23E+05	8.68E+05	1.16E+06	1.45E+06
Po-210	6.47E+01	1.62E+02	2.43E+02	4.04E+02	1.62E+03	4.04E+03	4.85E+03	6.47E+03	8.09E+03
Co-60	4.63E+03	1.16E+04	1.74E+04	2.90E+04	1.16E+05	2.90E+05	3.48E+05	4.63E+05	5.79E+05

90 days

	4	10	15	25	100	250	300	400	500
Sr-90	3.81E+02	9.53E+02	1.43E+03	2.38E+03	9.53E+03	2.38E+04	2.86E+04	3.81E+04	4.77E+04
Y-90	3.93E+03	9.82E+03	1.47E+04	2.45E+04	9.82E+04	2.45E+05	2.95E+05	3.93E+05	4.91E+05
Cs-137	7.77E+02	1.94E+03	2.91E+03	4.86E+03	1.94E+04	4.86E+04	5.83E+04	7.77E+04	9.71E+04
I-131	4.85E+02	1.21E+03	1.82E+03	3.03E+03	1.21E+04	3.03E+04	3.63E+04	4.85E+04	6.06E+04
Ir-192	7.71E+03	1.93E+04	2.89E+04	4.82E+04	1.93E+05	4.82E+05	5.78E+05	7.71E+05	9.64E+05
Po-210	4.31E+01	1.08E+02	1.62E+02	2.70E+02	1.08E+03	2.70E+03	3.23E+03	4.31E+03	5.39E+03
Co-60	3.09E+03	7.72E+03	1.16E+04	1.93E+04	7.72E+04	1.93E+05	2.32E+05	3.09E+05	3.86E+05

365 days

	4	10	15	25	100	250	300	400	500
Sr-90	9.40E+01	2.35E+02	3.53E+02	5.88E+02	2.35E+03	5.88E+03	7.05E+03	9.40E+03	1.18E+04
Y-90	9.68E+02	2.42E+03	3.63E+03	6.05E+03	2.42E+04	6.05E+04	7.26E+04	9.68E+04	1.21E+05
Cs-137	1.92E+02	4.79E+02	7.18E+02	1.20E+03	4.79E+03	1.20E+04	1.44E+04	1.92E+04	2.39E+04
I-131	1.19E+02	2.99E+02	4.48E+02	7.47E+02	2.99E+03	7.47E+03	8.96E+03	1.19E+04	1.49E+04
Ir-192	1.90E+03	4.75E+03	7.13E+03	1.19E+04	4.75E+04	1.19E+05	1.43E+05	1.90E+05	2.38E+05
Po-210	1.06E+01	2.66E+01	3.99E+01	6.65E+01	2.66E+02	6.65E+02	7.97E+02	1.06E+03	1.33E+03
Co-60	7.62E+02	1.90E+03	2.86E+03	4.76E+03	1.90E+04	4.76E+04	5.71E+04	7.62E+04	9.52E+04

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Drinking Water Risk for Specified Dose (mrem) Over Specified Time

30 days

	4	10	15	25	100	250	300	400	500
Sr-90	1.59E-06	3.97E-06	5.96E-06	9.93E-06	3.97E-05	9.93E-05	1.19E-04	1.59E-04	1.99E-04
Y-90	1.68E-06	4.20E-06	6.30E-06	1.05E-05	4.20E-05	1.05E-04	1.26E-04	1.68E-04	2.10E-04
Cs-137	1.81E-06	4.54E-06	6.81E-06	1.13E-05	4.54E-05	1.13E-04	1.36E-04	1.81E-04	2.27E-04
I-131	8.40E-07	2.10E-06	3.15E-06	5.25E-06	2.10E-05	5.25E-05	6.30E-05	8.40E-05	1.05E-04
Ir-192	1.56E-06	3.90E-06	5.85E-06	9.74E-06	3.90E-05	9.74E-05	1.17E-04	1.56E-04	1.95E-04
Po-210	1.10E-06	2.75E-06	4.12E-06	6.87E-06	2.75E-05	6.87E-05	8.24E-05	1.10E-04	1.37E-04
Co-60	1.56E-06	3.89E-06	5.83E-06	9.72E-06	3.89E-05	9.72E-05	1.17E-04	1.56E-04	1.94E-04

60 days

	4	10	15	25	100	250	300	400	500
Sr-90	1.59E-06	3.97E-06	5.96E-06	9.93E-06	3.97E-05	9.93E-05	1.19E-04	1.59E-04	1.99E-04
Y-90	1.68E-06	4.20E-06	6.30E-06	1.05E-05	4.20E-05	1.05E-04	1.26E-04	1.68E-04	2.10E-04
Cs-137	1.81E-06	4.54E-06	6.81E-06	1.13E-05	4.54E-05	1.13E-04	1.36E-04	1.81E-04	2.27E-04
I-131	8.40E-07	2.10E-06	3.15E-06	5.25E-06	2.10E-05	5.25E-05	6.30E-05	8.40E-05	1.05E-04
Ir-192	1.56E-06	3.90E-06	5.85E-06	9.74E-06	3.90E-05	9.74E-05	1.17E-04	1.56E-04	1.95E-04
Po-210	1.10E-06	2.75E-06	4.12E-06	6.87E-06	2.75E-05	6.87E-05	8.24E-05	1.10E-04	1.37E-04
Co-60	1.56E-06	3.89E-06	5.83E-06	9.72E-06	3.89E-05	9.72E-05	1.17E-04	1.56E-04	1.94E-04

90 days

	4	10	15	25	100	250	300	400	500
Sr-90	1.59E-06	3.97E-06	5.96E-06	9.93E-06	3.97E-05	9.93E-05	1.19E-04	1.59E-04	1.99E-04
Y-90	1.68E-06	4.20E-06	6.30E-06	1.05E-05	4.20E-05	1.05E-04	1.26E-04	1.68E-04	2.10E-04
Cs-137	1.81E-06	4.54E-06	6.81E-06	1.13E-05	4.54E-05	1.13E-04	1.36E-04	1.81E-04	2.27E-04
I-131	8.40E-07	2.10E-06	3.15E-06	5.25E-06	2.10E-05	5.25E-05	6.30E-05	8.40E-05	1.05E-04
Ir-192	1.56E-06	3.90E-06	5.85E-06	9.74E-06	3.90E-05	9.74E-05	1.17E-04	1.56E-04	1.95E-04
Po-210	1.10E-06	2.75E-06	4.12E-06	6.87E-06	2.75E-05	6.87E-05	8.24E-05	1.10E-04	1.37E-04
Co-60	1.56E-06	3.89E-06	5.83E-06	9.72E-06	3.89E-05	9.72E-05	1.17E-04	1.56E-04	1.94E-04

365 days

	4	10	15	25	100	250	300	400	500
Sr-90	1.59E-06	3.97E-06	5.96E-06	9.93E-06	3.97E-05	9.93E-05	1.19E-04	1.59E-04	1.99E-04
Y-90	1.68E-06	4.20E-06	6.30E-06	1.05E-05	4.20E-05	1.05E-04	1.26E-04	1.68E-04	2.10E-04
Cs-137	1.81E-06	4.54E-06	6.81E-06	1.13E-05	4.54E-05	1.13E-04	1.36E-04	1.81E-04	2.27E-04
I-131	8.40E-07	2.10E-06	3.15E-06	5.25E-06	2.10E-05	5.25E-05	6.30E-05	8.40E-05	1.05E-04
Ir-192	1.56E-06	3.90E-06	5.85E-06	9.74E-06	3.90E-05	9.74E-05	1.17E-04	1.56E-04	1.95E-04
Po-210	1.10E-06	2.75E-06	4.12E-06	6.87E-06	2.75E-05	6.87E-05	8.24E-05	1.10E-04	1.37E-04
Co-60	1.56E-06	3.89E-06	5.83E-06	9.72E-06	3.89E-05	9.72E-05	1.17E-04	1.56E-04	1.94E-04

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To: Amy Doll[adoll@endyna.com]
From: DeCair, Sara
Sent: Fri 7/10/2015 3:35:07 PM
Subject: Possible way to get examples in
PAG_Surface Contam Control Section simple decon ideas.docx

I think it may be okay to mix simple and gross together, list them together, but I'd like to get away from partial throughout. I decided it's not bad for the examples of methods to come in this late since the rest of the sections before set the stage, and full decon doesn't really appear until that last section.

Thank you for your work on this and I look forward to the next version! Armin and Adela are always so helpful, too.

Have a great weekend,

Sara

EXCERPT WITH FORMER TABLE 2-5 and TABLE 2-6 NOW REVISED INTO TEXT:

- **Former Table 2-5 is now in the text and bullets for new sub-section 2.3.3 below**
- **Former Table 2-6 is now in the text and bullets for new sub-section 2.3.4 below**

ALSO SHOWS HOW FORMER SECTION 2.7 (Contamination limits and monitoring of the environment and populations) and FORMER SECTION 2.8 (Surface contamination control) WERE COMBINED (#4 in 1/20/15 Memo)

As reminder, Sara's decision was to use "level" instead of "limit"

2.3. CONTAMINATION LEVELS ~~LIMITS~~ AND MONITORING OF THE ENVIRONMENT AND POPULATIONS

Areas under the plume can be expected to contain deposited radioactive materials if aerosols or particulate materials were released during the incident. In extreme cases, individuals and equipment may be highly contaminated and monitoring stations will be required for emergency monitoring, grtamination of individuals and medical evaluations. Equipment should be checked and decontaminated as necessary to avoid the spread of contamination to other locations. This monitoring service would be required for only a few days following plume passage until all such people have been evacuated or relocated. Guidance on surface contamination levels for use at such monitoring stations is provided below.

~~People working in the parts of the restricted areas in which their dose from the residual radioactivity would exceed 2 mrem (20 µSv) in any hour or 100 mrem (1 mSv) in a year should operate under the controlled conditions established for occupational exposure.~~

Adults may reenter restricted areas under controlled conditions in accordance with occupational exposure standards. The need for monitoring stations should be evaluated along highways, which serve as the major evacuation or transportation routes, to control surface contamination at exits from the more highly contaminated areas. Decontamination and other measures should be implemented to maintain low-exposure rates at monitoring stations.

A contaminated item should not be released to an unrestricted area. Based on incident and locality specific considerations, it may be acceptable to release contaminated materials if the level of surface contamination is below acceptable release criteria ~~less than two times (2x) the existing background levels~~. As an alternative to decontamination, contaminated items (i.e., not people or animals) may be retained in the restricted area while the radiological contamination decays.

In some extreme cases, decontamination may be impractical. Evacuating a large area requires resources, and decontamination may conflict with priority use of those resources. Screening and decontamination can slow egress, which could result in increased dose to the evacuees. Emergency managers should refer to CDC's "Population Monitoring in Radiation Emergencies: A Guide for State and Local Public Health Planners" (CDC 2014)[1] for more information. These simple initial screening guides from CDC are more general than FEMA REP-21 and REP-22 on use of handheld instruments and portal monitors for screening the public.

2.3.1. Surface Contamination Control

Surface contamination must be controlled both before and after evacuation protective actions are implemented. The principal exposure pathways for loose surface contamination on people, clothing and equipment are:

- Internal doses from ingestion by direct transfer;
- Internal doses from inhalation of resuspended materials;

[1] ADD REFERENCE/LINK

- Beta dose to skin from contaminated skin or clothing or from nearby surfaces;
- Dose to the whole body from external gamma radiation; and
- Internal doses from absorption of contamination into wounds.

The contamination level ~~limit~~ for screening people, animals and objects for surface contamination at monitoring stations should be influenced by the potential for the contamination to be ingested, inhaled or transferred to other locations. Therefore, it is reasonable to establish lower levels ~~limits~~ for surfaces where contamination is loose than for surfaces where the contamination is fixed (except for skin). The expected period of exposure from fixed contamination on skin would be longer so a lower level ~~limit~~ would be justified.

It is not practical to set surface contamination screening levels ~~limits~~ significantly lower than residual contamination levels in uncontrolled areas. Although the contamination levels recommended in this manual are accordingly set high, consideration should be given as the incident ~~event~~ progresses to using lower contamination screening ~~control~~ levels (and more sensitive monitoring instruments) once people are removed from areas causing high external doses. Such efforts will minimize cross-contamination of people located outside of the affected areas. For incidents ~~events~~ involving fixed nuclear facilities, some evacuation reception centers or shelters will have walk-through portal monitors.

The recommended "2x background" level for screening for surface contamination at monitoring stations is merely a simplified basis for responders to set their own instrument trigger levels based on practical circumstances at the time and location of each screening center. NCRP 161, "Population Monitoring and Radionuclide Decorporation Following a Radiological or Nuclear Incident" (NCRP Report No. 166), National Council on Radiation Protection and Measurements, Bethesda, MD, 2011,[2] and Koenig paper [cite properly] provide the basis for these simplified initial screening levels.

2.3.2. Priorities for Control of Contaminated Areas

The following priorities are recommended—

- Do not delay urgent medical care for decontamination efforts or for time-consuming protection of attendants, such as donning of additional anti-contamination clothing.
- In early phase scenarios where it might not be practical or would interfere with other lifesaving and public health protection priorities, do not waste effort trying to contain contaminated wash water and be sure to notify sewage treatment plants.
- Do not allow monitoring and decontamination to delay an ordered evacuation.
- *When early screening is needed after a major incident* — After plume passage, it may be necessary to establish emergency contamination monitoring stations in areas not qualifying as low background areas. Gamma exposure rates in such areas should be less than 5 millirem (50 μSv) per hour. These monitoring stations should be used only during the early phase after major atmospheric releases to monitor people emerging from possible high exposure areas. The stations should be set up to provide simple (rapid) decontamination if needed and to evaluate whether affected people should undergo more extensive decontamination or other special care. Section 2.3.3 ~~Table 2-5~~ provides guidance on surface contamination levels for use if such emergency contamination monitoring stations ~~centers~~ are needed.
- *Establish screening to control surface contamination* — Establish monitoring and personnel decontamination (e.g., bathing) facilities at evacuation centers or other locations in low background areas (less than 0.1 millirem (1 μSv) per hour). Section 2.3.4 ~~Table 2-6~~ provides surface contamination guidance for monitoring stations in low background areas. These surface contamination screening levels are examples derived primarily on the basis of easily measurable

[2] See: Population Monitoring and Radionuclide Decorporation Following a Radiological or Nuclear Incident (NCRP Report No. 166), National Council on Radiation Protection and Measurements, Bethesda, MD, 2011.

radiation levels using portable instruments. For more specific considerations on control of contaminated areas refer to "Population Monitoring in Radiation Emergencies: A Guide for State and Local Public Health Planners" (CDC ~~2007~~2014).[3]

- *Encourage self-decontamination* — Encourage evacuated people who were exposed in areas where release of particulate materials would have warranted evacuation to change and bag the clothes they were wearing and store them in an area away from people and pets until authorities provide further instructions on their disposition, to wash other exposed surfaces such as cars and trucks and their contents and then report to ~~these~~ evacuation centers or other established locations for monitoring.
- After the evacuation area has been established, consider the need to set up monitoring and decontamination stations at exits from the more highly contaminated parts of the area. Low levels of contamination may be undetectable because of high background radiation levels at these locations. Monitoring should be done at lowest practical background levels. Nevertheless, these individuals should be advised to bathe and change clothes at their first opportunity—no later than within the next 24 hours. If, after decontamination, people still exceed the surface contamination screening levels ~~limits~~ for the station, they should be sent for further decontamination or for medical or other special attention.

2.3.3. Recommendations for Emergency Screening in Areas Not Qualifying as Low Background Areas

This section provides the recommended surface contamination screening levels for emergency screening of people and objects at monitoring stations ~~in high background radiation areas~~ in areas with elevated background radiation (0.1 mR/h to 1 mR/h or 1 to 10 µSv/h gamma exposure rate). Monitoring stations in such high exposure rate areas are for use only during the early phase of an incident involving major atmospheric releases of particulates (otherwise see Section 2.3.4 ~~Table 2-6~~). For such emergency screening at monitoring stations, recommended actions for a detection instrument reading at either less than or greater than 2x existing background are outlined below.

- **Before Decontamination:**
  - If <2x existing background — *Recommended action*: ~~Unconditional release~~ Release for further screening outside affected area.
  - If >2x existing background — *Recommended action:* Simple or gross Decontamination (examples may include wiping of exposed skin, shaking off outer clothing or washing of hands and soles of shoes.). Equipment may be stored or disposed of as appropriate.
- **After Decontamination:**
  - If <2x existing background — *Recommended action:* ~~Unconditional release~~ Release for further screening outside affected area.
  - If >2x existing background — *Recommended action:* Continue to decontaminate or refer to low background monitoring and decontamination station. Equipment may be stored for decay or disposed of as appropriate.

2.3.4. Recommendations for Screening in Low Background Areas

This section provides the recommended surface contamination screening levels for people and objects at monitoring stations in ~~low~~ background radiation areas (<0.1 mR/h gamma exposure rate). People reporting to monitoring stations in low background radiation areas have been previously instructed to change and bag clothes, wash other exposed surfaces such as cars and their contents and then report to these centers for monitoring. Levels higher than 2x existing background (not to exceed the meter reading corresponding

[3] ADD REFERENCE/LINK

to 0.1 mR/h) may be used to speed the monitoring of evacuees in very low background areas. For screening at monitoring stations in low background areas, recommended actions for a detection instrument reading at either less than or greater than 2x existing background are outlined below.

- **Before Decontamination:**
  - If <2x existing background — *Recommended action*: Unconditional release.
  - If >2x existing background — *Recommended action:* ~~Decontaminate.~~ Simple or gross decontamination.
- **After Simple Decontamination Effort**: ~~Flushing with water and wiping is an example of a simple decontamination effort.~~
  - If <2x existing background — *Recommended action:* Unconditional release.
  - If >2x existing background — *Recommended action:* Full decontamination.
- **After Full Decontamination Effort** (Changing clothes and/or showering are examples of a full decontamination effort. Washing or gentle scrubbing with soap or other mild detergent followed by flushing is another example of a full decontamination effort.):
  - If <2x existing background — *Recommended action:* Unconditional release.
  - If >2x existing background — *Recommended action:* Continue to decontaminate people. Release animals and equipment.
- **After Additional Full Decontamination Effort:**
  - If <2x existing background — *Recommended action:* Unconditional full release.
  - If >2x existing background — *Recommended action:* Send people for further ~~special~~ evaluation. ~~Release animals and equipment~~

To: Veal, Lee[Veal.Lee@epa.gov]
From: DeCair, Sara
Sent: Tue 7/7/2015 4:57:34 PM
Subject: RE: REVISED : Draft Drinking Water PAG for OSWER review

Good with me. Thank you again!! I am getting on a conf call with Endyna on another topic but I'm here if you need me. S.

From: Veal, Lee
Sent: Tuesday, July 07, 2015 12:55 PM
To: Edwards, Jonathan; DeCair, Sara; Perrin, Alan
Cc: Christ, Lisa; Wieder, Jessica; Boyd, Mike
Subject: REVISED : Draft Drinking Water PAG for OSWER review

All,

Please take a look at these changes.

Answers to Jim's Questions:

"Quick Q. In coming up with your proposed levels, it appears to me that the levels are based only on a drinking water or other exposures to water. (see page 2). Essentially, my question is what happens from a cumulative risk perspective? If 500 mrem/yr is the overall general population recommendation, should not the Agency state that is the cumulative "acceptable" level for exposures in this particular setting and that one needs to consider one's totality of exposures to max out at 500 mrem? I think that point is lost in what I read."

First, it is important to note that the NPDWR for radionuclides still applies to the drinking water utilities. Any exceedance of the maximum contaminant level, even in an emergency, is a violation and utilities must return to compliance with the NPDWR MCLs as soon as practical. In addition, the utility must notify customers that they are in violation. Those provisions are not

impacted by establishing a drinking water PAG.

In developing the drinking water PAG (500mrem/100mrem), EPA did consider cumulative exposure. The 500 mrem/year guidance for the general public that you mention, while outdated, is a non-emergency routine level, assuming exposures over a lifetime, and it is not appropriate for use during emergencies. PAGs do not represent "acceptable" routine exposures in the way that an environmental standard might. PAGs are projected levels that response authorities need for emergency decision making to avoid unnecessary radiation exposure. If one assumes that a person actually receives doses up to the various PAG levels that are recommended, their cumulative risk would still fall within a reasonable range considering the competing risks from a large radiation disaster. Here, I am using "reasonable" in the context of a large radiological emergency.

"Did anyone comment that that the Agency should go with more "CERCLA or MCL – type levels". Assuming some did, and if so, who in particular? Can we see those particular comments? Did any states comment and what were their comments?"

EPA received a broad range of comments on the drinking water PAG and I'm attaching a comment sheet for your reference. All of the comments are available on Regulations.Gov; however this sheet might help to highlight the drinking water comments more succinctly. Several States did comment (CA, OH, PA, MN, WA, IL, KS, NH), as well as two local boards (located in CA and OH) and multi-state organizations (Conference of Radiation Control Program Officers and Association of State and Territorial Solid Waste Management Officials). Two of the State/governmental board comments supported using the NPDWR 4 mrem/year standard and the remaining 10 State/governmental organization commenters supported establishing a separate drinking water PAG (various approaches). The two commenters who indicated a preference for using the NPDWR MCL were the CA Office of Emergency Services and the San Onofre Nuclear Generating Station Interjurisdictional Planning Committee.

Begin forwarded message:

> **From:** "Woolford, James" <Woolford.James@epa.gov>
> **Date:** July 6, 2015 at 5:56:11 PM EDT
> **To:** "Flynn, Mike" <Flynn.Mike@epa.gov>
> **Cc:** "Grevatt, Peter" <Grevatt.Peter@epa.gov>
> **Subject: RE: Draft Drinking Water PAG for OSWER review**

Was just reading this over. Sorry I missed the brief.

Quick Q. In coming up with your proposed levels, it appears to me that the levels are based only on a drinking water or other exposures to water. (see page 2). Essentially, my question is what happens from a cumulative risk perspective? If 500 mrem/yr is the overall general population recommendation, should not the Agency state that is the cumulative "acceptable" level for exposures in this particular setting and that one needs to consider one's totality of exposures to max out at 500 mrem? I think that point is lost in what I read.

Second, you all indicate that this chapter (on page 2) is based on the request for comments. Did anyone comment that that the Agency should go with more "CERCLA or MCL – type levels". Assuming some did, and if so, who in particular? Can we see those particular comments? Did any states comment and what were their comments?

Thanks

Jim Woolford, Director

Office of Superfund Remediation and Technology Innovation

Office of Solid Waste and Emergency Response

US Environmental Protection Agency

1200 Penn. Ave., NW

Washington, DC 20460

(Mail Code 5201-P)

Phone: (703) 603 8960– Main Office Line

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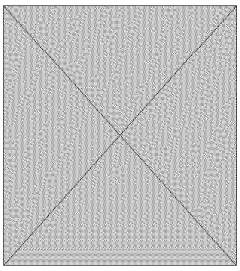
Arlington, VA 22202



From: Flynn, Mike
Sent: Wednesday, June 24, 2015 5:30 PM
To: Cheatham, Reggie; Woolford, James
Cc: Grevatt, Peter; Tulis, Dana; Gardner, Monica; Fitz-James, Schatzi; Kudarauskas, Paul; DeCair, Sara; Hernandez-Quinones, Samuel; Edwards, Jonathan; Burneson, Eric; Perrin, Alan; Christ, Lisa
Subject: Draft Drinking Water PAG for OSWER review
Importance: High

Reggie and Jim,

Peter and I appreciate your time and support on the drinking water PAG proposal and, as you know, we're anxious to get this to the Office of Policy soon. We hope yesterday's briefing and discussion with your staff will enable you to get feedback to us on this proposal by July 14. I've attached the draft PAG chapter for your review.

OW and OAR staff are available to discuss any of the proposal details as needed and when it's convenient for you. Please contact Sam Hernandez at (202) 564-1735 or Sara DeCair at (202) 343-9108 with any questions or to set up a meeting; please direct any comments or suggestions you have on the PAG chapter to them as well.

Again, thank you in advance for your support and input, and don't hesitate to call Peter or me if you have questions.

Thanks,

Mike

<image001.png>

To: Ex. 6 - Personal Privacy
From: DeCair, Sara
Sent: Wed 6/24/2015 4:55:09 PM
Subject: One Drive Doc
Internal Q&A 6-23-2015.docx

Sara D. DeCair

http://www.epa.gov/radiation/rert/pags.html

202-343-9108

Room 1416 B in WJC West

To: Amy Doll[adoll@endyna.com]
From: DeCair, Sara
Sent: Mon 6/22/2015 9:00:01 PM
Subject: Re: Acronym check for PAG Manual
Acronym Notes for Sara re PAG Manual_042815.docx

Thank you, Amy, this is very thorough. See my notes in red, and let me know if you need more from me on any of these items. By the way, I sent Armin a note with the new contam control section and his out of office response said he'll return on Monday.

Talk soon,

Sara

From: Amy Doll <adoll@endyna.com>
Sent: Tuesday, April 28, 2015 4:27 PM
To: DeCair, Sara
Cc: siddhanti@endyna.com
Subject: Acronym check for PAG Manual

Hi Sara

Attached are some notes from the acronym check of the PAG Manual, for your review.

•□□□□□□□□ The green highlights show my notes for your review, some of which we should discuss when you have a convenient time. We had already talked a bit about the KI and TED acronym issues that are summarized in these notes.

•□□□□□□□□ As before, yellow/strikeout means deletion (these two had already been deleted per your earlier discussions with Danielle, and I've checked that).

•□□□□□□□□ As before, grey means additions. The few lighter grey were already added per your earlier discussions with Danielle. The darker grey are my additions, based on my review of the document.

The acronym use within the document needs to be cleaned up, and I've got notes for myself on where to begin making those revisions.

•□□□□□□□□ Some acronyms are defined multiple times within the document text, and I'll correct that (unless I feel that you purposely defined it again for clarity, then I'll ask you first).

•□□□□□□□□ A few acronyms in the Appendix are not defined within the text, and I'll correct that.

•□□□□□□□□ A few acronyms are not defined in the right place (when first used), and I'll correct that.

Please let me know if you have any questions. If you want to make any comments in the attached notes document that would work, or we could schedule a time for a discussion to go through it.

Thanks,

Amy

Amy Doll

Senior Associate

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Tel: 703-848-8842 ext. 121

Fax: 703-848-9001

APPENDIX C – LIST OF ACRONYMS

[note from Amy: page numbers mentioned in my notes below refer to 2013 Manual]

AEA Atomic Energy Act [note from Amy: only used once on p. 2; could be deleted from text and acronym list] Keep it, since it's important in rad emergency response

ALARA As Low as Reasonably Achievable ANS American Nuclear Society Is this in there?

BEIR XXXXXXXX [note from Amy: only used once in new text for Basis for Early Phase PAGs ("… using a rounded value from the BEIR III risk of 0.0003 cancer deaths per person-rem") – it seems this refers to Committee on the Biological Effects of Ionizing Radiation of the National Academy of Sciences; may also need to add explanatory footnote in the text and a citation to that report in Appendix A] Yes, keep this one and make a complete reference to the Report No. 3. (We are up to BEIR 7 now…)

BLM Bureau of Land Management

BRAC Base Realignment and Closure [note from Amy: defined on p. 67, but never used elsewhere; could consider keeping because commonly used acronym and edit text accordingly] I'd cut this one since it has little to do with rad emergency response. Just define it in the text.

CDC Centers for Disease Control and Prevention

CERCLA Comprehensive Environmental Response, Compensation and Liability Act

CFR Code of Federal Regulations

cGy Centigray (measurement unit) [note from Amy: now included in new table, so will add to acronym list; should also add to Glossary – this new table is "Threshold Thyroid Radioactive Exposures and Recommended Doses of KI for Different Risk Groups" under new section on "Consideration for Potassium Iodide"] Yes add this to Glossary too.

CWS Community Water System

~~DCF Dose Conversion Factor [deleted this within text and in acronyms]~~ In its place do we need DC (dose coefficient?) – I think so.

DHS Department of Homeland Security

DIL Derived Intervention Levels [note from Amy: only used in glossary, never used within document]

DOC Department of Commerce [note from Amy: this is defined on p. 4, but never used elsewhere; could delete from p. 4 and then not include in acronym list] Agreed.

DoD Department of Defense

DOE Department of Energy

DOI Department of Interior [note from Amy: defined on p. 68, but never used elsewhere; could be deleted from text and acronym list] Agreed.

DOL Department of Labor

DOT Department of Transportation [note from Amy: only used in Appendix A for a reference that is not cited/used anywhere within document; should deleted here if reference deleted from Appendix A] Yes to both deletions.

DP Dose Parameter

DRL Derived Response Level

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EAL Emergency Action Level

EPA U.S. Environmental Protection Agency [note from Amy: three places within document have U.S. EPA, which I will replace with EPA to conform with EPA Style Guide] Great catch!

EPZ Emergency Planning Zone

FDA U.S. Food and Drug Administration [note from Amy: some footnotes have "(US) [FDA]" as well as some of the references; to avoid confusion this should be replaced with FDA] Agreed.

FEMA Federal Emergency Management Agency

FRC Federal Radiation Council

FRMAC Federal Radiological Monitoring and Assessment Center

FRPCC Federal Radiological Preparedness Coordination Committee

FUDS Formerly Used Defense Site [note from Amy: defined on p. 67, but never used elsewhere; could consider keeping because commonly used acronym and edit text accordingly]

Gy Gray (measurement unit) [note from Amy: now included in revisions to table from p. 27, so will add to acronym list; should also add to Glossary]

HAZWOPER Hazardous Waste Operations and Emergency Response

HHS Department of Health and Human Services

HPS Health Physics Society

IAEA International Atomic Energy Agency

ICP Incident Command Post

ICRP International Commission on Radiological Protection

~~ICRU only used once in Glossary above [deleted this in glossary and acronyms]~~

IC/UC Incident Command/Unified Command

IND Improvised Nuclear Device

JFO Joint Field Office

JIC Joint Information Center

KI Potassium Iodide [note from Amy: on p. 15 this acronym is defined as "stable iodine" and that term is also used within the text – but KI is first defined on p. 1 as "potassium iodide" — we should discuss how to be consistent with this terminology] I suggest deleting stable iodine since that term is a little old fashioned and potassium iodide is more specific.

LLRW Low-level radioactive waste

LLRWPA Low-Level Radioactive Waste Policy Act

MCL Maximum Contaminant Level

MIMS Manifest Information Management System Only used once in a citation so let's delete this one.

mSv Millisievert (measurement unit)

mrem Millirem (measurement unit)

NCP National Contingency Plan

NCRP National Council on Radiation Protection and Measurements

NIMS National Incident Management System

ED_001057_00012796

NNPP Naval Nuclear Propulsion Program

NNSS Nevada National Security Site

NPDWR National Primary Drinking Water Regulations

NPP Nuclear Power Plant

NPS National Park Service [note from Amy: defined on p. 68, but never used elsewhere; could be deleted from text and acronym list] Agreed.

NRC U.S. Nuclear Regulatory Commission [note from Amy: two places within document have U.S. NRC, which I will replace with NRC] Agreed.

NRF National Response Framework

NDRF National Disaster Recovery Framework

NSS National Security Staff

NUREG NRC technical report designation (Nuclear Regulatory Commission)

OSHA Occupational Safety and Health Administration

PAG Protective Action Guide

PCB Polychlorinated biphenyl Probably not used in PAG Manual, delete?

PIO Public Information Officer

PPE Personal Protective Equipment

RASCAL Radiological Assessment System for Consequence Analysis

REMM Radiation Emergency Medical Management Note this is a website

RESRAD RESidual RADioactivity (computer code developed by Argonne National Laboratory)

RCRA Resource Conservation and Recovery Act

RDD Radiological Dispersal Device

SDWA Safe Drinking Water Act

SNL Sandia National Laboratories

TED Total Effective Dose [note from Amy: TED is defined as "whole body doses" in new text inserted for "Conservatism built into the PAGs"; the new text for "Thyroid Based Evacuation" also implies that TED refers to "whole body dose" — we should discuss how to be consistent with this terminology] I think the Glossary covers this and the terms are used interchangeably by dose assessors – I'd like to keep both, but am open to suggestions on how to make it a little cleaner in the Manual.

USDA United States Department of Agriculture

ED_001057_00012796