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Recommended Plan for a Comprehensive Solution of the Polynuclear Aromatic Hydrocarbon Contamination Problem in the St. Louis Park Area

Volume I
Technical Report

ERT
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FOREWORD

INTRODUCTION

This Foreword presents a background discussion that places the St. Louis Park "problem" in perspective. It explains how the problem came to exist and seeks to explain clearly what the problem is -- and what it is not. Explanation of the technical conclusions discussed in this Foreword is provided in the report and its technical appendices. This Foreword also is designed as an overview for lay audiences, since the Technical Summary which follows and the report itself are written by, and principally for, technical experts.

The Report was written by Environmental Research & Technology, Inc. (ERT). It was commissioned by Reilly Tar & Chemical Corporation (Reilly) in response to an invitation by the United States, Minnesota, and St. Louis Park governments to prepare a comprehensive solution report for the St. Louis Park problem. The comprehensive nature of the report is significant itself; no other study to date has viewed the situation in such a fully integrated manner.

The prime objective of the comprehensive approach has been to define the nature and scope of both the problem and appropriate remedies. An important result of this approach for public policy-makers is that the need for further study largely has been eliminated. Efforts and funds can now be applied to remedies and solutions.

To understand fully the nature of and remedy for the St. Louis Park problem, it is as important to know what that problem is <u>not</u> as to know what it is.

The situation in St. Louis Park has often been characterized as a hazardous waste dump site. However, it was an industrial plant site, not a dump. As this Foreword will indicate, the substances involved are the residue of a common industry that has been in existence for over a century. Indeed, portions of the site are now developed for a variety of residental and commercial uses.

The situation has been referred to as a water resource problem, but it does not involve threats to recreational uses of water such as swimming, fishing, or boating, since the only water involved is ground water (that is, subsurface water), not lakes or rivers.

And, it has been perceived as a health problem, particularly, one of cancer. It is true that trace amounts of substances known as polynuclear aromatic hydrocarbons (PAH) have been found in some municipal drinking water supply wells. However, these amounts in finished drinking water do not exceed Environmental Protection Agency (EPA) criteria for carcinogenic (cancer-causing) PAH in ambient water. In fact, the only major issue related to health deals with establishing acceptable concentrations of noncarcinogenic PAH.

Thus, the St. Louis Park problem is not a crisis for human health or the environment. What, then, is it?

It is a result of our industrialized society, which has led to the need to manage resources carefully and prudently. That this can be done is an important finding of this report.

The St. Louis Park problem is one of water supply: how to obtain adequate supplies of water for residents in the community, given the fact that several municipal supply wells have been closed in recent years. It is also a problem of public health policy, in particular, agreeing to and adopting a criterion for the noncarcinogenic members of the class of compounds known as PAH. There is no dispute about the appropriate criterion for those PAH that are animal carcinogens and are treated as though they are human carcinogens.

The primary recommendations of this report are as follows:

(1) That St. Louis Park and the State of Minnesota promptly decide upon PAH criteria to be applied to finished drinking water, based upon available literature that demonstrates the safety of a criterion for carcinogenic PAH of 28 nanograms per liter (28 parts per trillion), and a criterion for noncarcinogenic PAH of from 4 to 400 micrograms per liter (4 to 400 parts per billion).

(2) That, depending upon the criteria adopted (a) the closed St. Louis Park wells be reopened, or (b) the deep Mt. Simon-Hinckley aquifer be used as an alternate water supply, or (c) existing water treatment be improved to remove PAH to acceptable concentrations.

(3) That wells in the St. Louis Park area be monitored to ensure that finished water exceeding the PAH criteria is not used for drinking water.

(4) That the City of St. Louis Park and the Minnesota Department of Health prohibit any use of contaminated areas of shallow aquifers for drinking water or related uses. The affected areas of these aquifers are not presently used as a source of public water supply.

(5) That work which is already underway to explore and ultimately seal certain multi-aquifer wells be completed, and in some respects expanded.

These five major recommendations appear as eleven specific recommendations in the technical summary, the main report, and technical appendices. The detailed studies that provide the basis for these recommendations are also found in that summary, the report, and its appendices.

BACKGROUND

Site History

Reilly Tar & Chemical Corporation (Reilly) is a family-owned business, founded in 1896, with its general offices in Indianapolis, Indiana. While a major part of its business activities today consist of the development, manufacture, and sale of synthetic chemical products for a variety of uses, it also operates four coal tar refineries. From 1917 to 1972 it operated such a refinery and a wood treating plant in St. Louis Park, Minnesota in an industrial zone near the intersection of Highway 7 and Lake Street.

A coal tar refinery uses coal tar as a raw material to make several useful products. Most coal tar comes from coking operations conducted by steel mills. The Reilly plant at St. Louis Park purchased most of its requirements from the United States Steel plant in Duluth, Minnesota, which, like Reilly's St. Louis Park plant, closed in the early 1970's.

Coal tar is refined by heating it in a still. As it is heated, various grades of oils are boiled off, then cooled and condensed back to liquid products. Some of these liquids are blended and made into various grades of creosote oil. Depending upon how much oil is removed, the residue left in the still is used as road tar, or as coal tar pitch, or coke. Eventually all of the raw material used in a coal tar refinery is converted into useful products. There are no major waste materials produced.

The raw materials used and products made at the Reilly plant are all derived from natural materials. No synthetic chemicals were produced at the plant.

Road tar was used extensively in St. Louis Park and elsewhere in Minnesota for surfacing streets and highways prior to use of bituminous asphalt and concrete in recent decades. Coal tar is also used for the manufacture of coal tar enamel, which is widely used for external and internal protection in pipes and tanks for a variety of uses, including drinking water distribution systems. Coal tar is also used in certain medicinal applications.

Creosote oil is used for preserving wood against decay. It is applied to railroad ties, utility poles and pilings. Thus, it serves to conserve the country's forests, which would otherwise be more quickly depleted in an attempt to supply the demand for timber. These uses of creosote oil have involved the widespread placement of treated lumber on or into the ground, apparently without adverse environmental or public health consequences.

Over the fifty-five years during which Reilly's St. Louis Park plant operated, residues of coal tar and creosote oil were deposited on the ground because of leaks from pipes, pumps, and other mechanical devices necessary to the plant's operation and probably from other spills. In addition, since the City of St. Louis Park did not have a public sewer system in 1917, a swamp, or bog, immediately south of the plant became the ultimate resting place for the plant's wastewater, which contained small quantities of coal tar, creosote oil, and related chemicals. This waste was generated from several plant sources, including water present in the coal tar, which was distilled in the coal-tar refining process, and then cooled by passing it around cooling coils, allowed to settle in a tank in order to recover most of the light oil still in this water, and then discharged. In 1940, the plant's wastewater treatment was improved by the addition of an oil/water separator downstream from the settling tank. The separator, like the settling tank, operated on the principle of gravity separation; that is, oils heavier than water settle to the bottom and oils lighter than water float to the top, where they are removed by wooden baffles. Wastewater also was treated in this separator from other plant operations, such as boiler blowdown and wood treating cylinder waste.

Further improvements were made in 1941, when a phenol extraction system was installed, and in 1951, when a straw filter was added downstream of the settling basin. In 1968, another straw filter was added in the plant's drainage ditch at the point where the wastewater left the property. These improvements were installed in order to improve the efficiency of the removal of oils and phenols.

Plant records document the fact that Reilly negotiated with the City of St. Louis Park in the 1960's concerning possible discharge of its waste into the city sewer. However, such connections were never made. Plant records and photographs also document, although imperfectly, that waste releases from the plant property and into the bog may have been increased because runoff water from nearby city streets was apparently channeled through culverts and onto plant property.

The bog into which Reilly's wastewater was discharged was located in the midst of St. Louis Park's heaviest industrial area. It is a low point in an area which has been occupied by other chemical plants, rubber companies, plywood companies, and other industries. Prior to 1905, the Reilly plant site was occupied by the Minnesota Beet Sugar Manufacturing Company. The sugar beet refinery discharged wastewater into the bog.

The Chemicals Involved

Polynuclear aromatic hydrocarbons (PAH) are a class of substances which is widespread in the environment. They consist of carbon and hydrogen in the form of two or more fused aromatic molecular rings. A further definition may be found in the Definition of Terms section in the body of this report. They are created by both slow and rapid combustion and pyrolysis. They occur throughout the environment because of both natural and human activities. They are found in coal, coal tar, creosote oil, and petroleum, because coal and oil are formed over millions of years as decayed animal and vegetable matter undergoes compaction and thermal processes. Accordingly, PAH are found in peat and other organic soils, as well as in many types of vegetation. PAH are found in treated and untreated public drinking water supplies of many communities in the United States and throughout the world.

PAH have been studied intensively by the scientific community because some of them were among the first compounds to be associated with the development of cancerous tumors in animals. Only a small percentage of the many hundreds of PAH compounds has been evaluated for carcinogenic activity. However, there are data concerning many of the PAH commonly found in drinking water. These data show that only certain specific PAH are considered carcinogenic.* PAH that are carcinogenic are high molecular weight compounds containing four or

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*It is important to note that in this report a carcinogenic PAH is considered to be one which results in a significant elevation in tumor incidence when administered by any route to any species of animal. Such compounds are thus treated, for regulatory or public policy purposes, as though they are human carcinogens, even though the only evidence may be from animal tests.

more molecular rings. Among those that are, the carcinogenic potency varies widely. Many other PAH have been demonstrated to be noncarcinogenic. These also exhibit low acute and chronic toxicity, which means that significant quantities must be consumed before illness will result.

High molecular weight PAH containing many aromatic rings are less mobile in the environment than those of lower molecular weight. For example, high molecular weight PAH percolating into the ground would tend to cling strongly to organic soils. Low molecular weight PAH would be more likely to stay with the ground water. Available data indicate that all PAH, however, are retarded in their migration relative to the ground water.

The words "phenol," "phenols" or "phenolics" are not considered as synonymous under modern scientific usage. However, in Reilly, City, and State documents reviewed for the purposes of this report it appears that these terms are often used interchangeably. This report uses the term "phenolics" to describe the set of phenols measured by specific types of tests. These terms, too, are defined in the body of the report. Phenols and phenolics are not carcinogenic; they can be toxic in sufficiently large doses. However, the principal drinking water concern is that phenolics can impart a discernable taste to water at very low (part per billion) levels if the drinking water is chlorinated. Like PAH, they are found in coal, coal tar, peat, organic soils, and many types of vegetation.

Over a large part of the plant's history (since 1932) a dispute existed between Reilly and the City (then Village) of St. Louis Park and the State of Minnesota concerning whether a phenolic or swampy taste attributed to an old city well south of the plant should be blamed on Reilly or on other sources, such as the peat which is common in the area. This dispute and other complaints resulted in a lawsuit begun in 1970 by the City and the Minnesota Pollution Control Agency. The lawsuit appears to have been settled, at least between Reilly and the City, in 1972 and 1973 by virtue of the sale of the property by Reilly to the City. However, the State of Minnesota declined to deliver a dismissal of the litigation when requested to do so by St. Louis Park in 1973.

Previous Technical Studies

The dispute between Reilly, the City, and the State resulted in technical studies of Reilly's activities and of phenolic concentrations in nearby ground water through each decade since the 1930's. In the late 1960's, ground-water quality and Reilly's operations were studied in detail by consultants to the City and by the Minnesota Pollution Control Agency (MPCA). In the early 1970's, the ground-water problem continued to be studied by the City and the MPCA and by other governmental bodies and private consultants. In all, over fifty different studys by many different agencies or consultants (in addition to ERT and its consultants) have reviewed the St. Louis Park ground-water problem and soil contamination at the Reilly plant site, as shown by the table attached to this Foreword. These studies have produced abundant data concerning the site and the surrounding area. The State of Minnesota indicates that it has spent $500,000 in studying this site to date, and the City indicates that it has spent $1 million. A grant of $400,000 in Federal "Superfund" money has also been spent. A grant of $2.0 million in Superfund monies was made recently, primarily for additional studies. However, few actions have been taken to date to remedy the problem, nor has there been any previous comprehensive or integrated approach to a solution. This situation recently led the City to describe these government-sponsored studies of the Reilly site as "an endless search."

In 1978, the ongoing studies of the ground water in the vicinity of the site showed that the water contained PAH. Because of uncertainties at that time concerning acceptable concentrations of PAH in drinking water, four wells in St. Louis Park were ordered closed. At the present time, six wells in St. Louis Park and one in Hopkins have been closed.

Approach

ERT's study has made use of the large amount of data that have already been produced by the many consultants who have studied the St. Louis Park problem. ERT has evaluated this information and used that

which appears to make a valuable contribution to the overall solution. The independent contributions of this report, not found in previous reports, are chiefly as follows:

(1) it includes comprehensive ground-water modeling, which describes the movement of ground water and helps to explain PAH and phenolic contamination in the St. Louis Park area;

(2) it addresses the subject of the value of ground water as a natural resource;

(3) it adds to the existing understanding of the effects of iron removal treatment (which is commonly applied at municipal supply wells in the St. Louis Park area), in removing PAH;

(4) it provides a compilation of all available ground-water sampling and analysis data for PAH and related compounds in a computerized data base;

(5) it offers techniques to determine the present value cost of remedial actions that may be undertaken in the future or last for many years;

(6) it identifies and evaluates remedial action alternatives for contamination at the site, for multi-aquifer wells (both on-site and off-site), for managing the migration of ground-water contaminants, for drinking water treatment technologies, and for alternative drinking water supplies; and

(7) it recommends the establishment of specific numerical criteria and monitoring protocols for PAH in finished drinking water that will protect the public health, based upon conservative health risk assessments.

PRINCIPAL FINDINGS OF THIS REPORT

The Ground Water

There are five major aquifers underlying the St. Louis Park area: the Drift-Platteville (0 to 90 feet deep), the St. Peter (90 to 200 feet deep), the Prairie du Chien-Jordan (260 to 500 feet deep), the Ironton-Galesville (700 to 750 feet deep), and the Mt. Simon-Hinckley (830 to 1100 feet deep). These aquifers and the intervening confining beds are shown in the figure attached to this Foreword.

Because the effective water level (piezometric head) in each aquifer decreases with increasing depth, any flow between the aquifers will be in a downward direction. However, the aquifers are separated by confining beds made up of rock types which are relatively impermeable to vertical ground-water flow. Although confining beds are not water-tight, water flows through them very slowly. For example, it requires many millions of years for water to travel through the Eau Clair confining bed that separates the Ironton-Galesville and Mt. Simon-Hinckley aquifers. An exception to this general impermeability is those local areas where the Glenwood Shale formation, the confining bed which separates the Drift-Platteville aquifer from the St. Peter aquifer, is absent.

Within all of these aquifers water flows generally west to east, although the flow pattern is altered by the pumping of private and muncipal supply wells. The aggregate impact of pumping these wells and of the natural flow is to create a ground-water divide in the Prairie du Chien-Jordan aquifer to the south and east of St. Louis Park. The divide acts as a hydraulic barrier, effectively isolating the Prairie du Chien-Jordan aquifer beneath St. Louis Park from areas to the east (Minneapolis and the Mississsippi River) and south (southern parts of Edina and Hopkins, and Bloomington). The contaminated portions of the aquifer are well within this divide.

Transport of PAH is much slower in some aquifers than in others. All of the bedrock aquifers listed above are sandstone formations except the Platteville and Prairie du Chien, which are limestone and dolomite formations, respectively. The Drift aquifer is composed of galcial sediment. PAH adsorb more readily to sediments in the glacial drift and to bedrock material in sandstone aquifers, such as the Mt. Simon-Hinckley, than in the Prairie du Chien-Jordan. Such adsorption significantly slows the movement of PAH relative to the movement of ground water.

The aquifers of greatest concern are the Prairie du Chien-Jordan and Mt. Simon-Hinckley, since other aquifers do not provide an adequate, high quality source of potable water, irrespective of contamination by PAH and related compounds.

The Contamination

Portions of the plant site and adjacent bog contain soil that is contaminated to various degrees and depths by coal-tar-related chemicals (primarily phenolics, PAH, and PAH-related compounds), based on comparison with estimated background concentrations of these materials in the site area. This contamination is attributable in part to former operations at the plant. Other natural and man-made sources in the site area were also likely contributors of these contaminants.

The surficial ground water (in the Drift-Platteville aquifer) beneath and to at least 1400 feet to the east of and contiguous with the site is variably contaminated by PAH and related compounds that have in part emanated from the site. The surficial ground water has become contaminated by precipitation percolating down through contaminated soil, thus leaching PAH and related compounds. Also, ground water flowing under the site flows through zones of contaminated soil and ground fluid. In doing so, it picks up PAH and related compounds and transports them downgradient from the site.

A local accumulation of organic fluid consisting of water and creosote-like oil exists in the ground water under the bog. There is insufficient information to define the precise size of this ground fluid body, but nearby wells and borings indicate that its maximum possible size is about 16,000 cubic feet. Its actual size may be very much smaller. There is no evidence of additional ground fluid bodies under the site and, based on the density of wells and borings at the site, it is unlikely that other such bodies exist. This ground fluid body appear to be largely immobile under present conditions.

The deep well on the site used by Reilly (well W23) was explored by contractors to the State of Minnesota in the summer of 1982. Coal-tar-like solid materials, sand, gravel, and a brownish liquid were found in a portion of the well below a depth of about 600 feet, but stopping above the Mt. Simon-Hinckley aquifer. These materials were removed from the well at that time. It is unknown when or how the material entered the well. Coal-tar-like material also covered

much of the surface of the well bore and casing. Well W23 is now filled with bentonite up to the bottom of the Jordan aquifer and exploration work is still in progress.

Criteria for PAH

There are no legally established limits for PAH in drinking water. The Environmental Protection Agency (EPA) has published quality criteria for carcinogenic PAH in ambient water based upon a conservative health risk assessment. These criteria have no legal effect. The EPA assessment is based upon an assumed relationship between dose and effect sometimes referred to as the "no-threshold assumption." Health scientists who utilize this assumption do so because of the belief that it is prudent, for planning purposes, to assume that any exposure, however small, could produce some effect, if the size of the hypothetically exposed population is large enough.

Other health scientists believe that the no-threshold assumption is not supported by human experience with exposure to carcinogens. Persons are exposed to a measurable burden of carcinogens in their daily diet and through other activities in normal everyday life. These scientists recognize that the human body has well-developed natural defense mechanisms that provide for effective detoxification of foreign chemicals, including carcinogens.

The EPA criteria document, based upon the conservative no-threshold theory, postulates that drinking two liters of water per day containing 28 nanograms per liter (28 parts per trillion) of benzo(a)pyrene (a carcinogenic PAH) will create a risk no greater than one additional cancer in a population of 100,000 persons, all of whom have consumed this quality water daily, for their entire lifetime. While benzo(a)pyrene is one of the most potent carcinogenic PAH commonly found in drinking water, the EPA recommends a further conservative assumption that all carcinogenic PAH be treated as if they are as potent as benzo(a)pyrene. The only published health-based criterion for noncarcinogenic PAH is the EPA ambient water quality criterion for fluoranthene of 42 micrograms per liter (42,000 parts per trillion), which includes consumption of contaminated fish and shellfish.

PRINCIPAL RECOMMENDATIONS OF THIS REPORT

Adoption of PAH Criteria

This report recommends that the EPA criterion of 28 parts per trillion for carcinogenic PAH be utilized for finished water in St. Louis Park. This criterion is met by finished water from all of the municipal supply wells in St. Louis Park and Hopkins that are currently shut down, based on recent analyses by a number of different laboratories. In fact, the total concentration of carcinogenic PAH in finished water that would result from reopening these wells is comparable to concentrations in finished drinking water supplied in most communities in the United States.

Since there are no published criteria for noncarcinogenic PAH as a class, this report incorporates the recommendations of Dr. Joseph Santodonato (Syracuse Research Corporation, author of the EPA Ambient Water Quality Criteria documents for PAH and fluoranthene) and Dr. Julian Andelman (Graduate School of Public Health, University of Pittsburgh), who jointly authored Appendix I, which develops proposed criteria for PAH in potable waters.

The adoption of a standard for noncarcinogenic PAH is a task that cannot be implemented solely by health scientists. Rather, there are public-policy issues involved that are not unlike the issues which communities frequently resolve when they decide whether to treat their public water in order to remove iron or in order to remove hardness. It is clear that so long as the total concentration of noncarcinogenic PAH in finished water is kept below from 100 to 400 micrograms per liter (100 to 400 parts per billion) no observable adverse health effects are expected. This recommended range reflects uncertainty in the a health risk assessment for noncarcinogenic PAH. There is also uncertainty as to possible taste and odor effects which could occur at concentrations as low as 4 micrograms per liter. If no objectionable tastes or odors result, the 100 to 400 microgram per liter criterion will protect against observable adverse health effects.

If the St. Louis Park community desires to re-start the presently closed municipal wells immediately, that could be done, since finished water from the wells does not exceed the criteria of 28 parts per trillion for carcinogenic PAH and 100 to 400 parts per billion for noncarcinogenic PAH. PAH of high molecular weight are strongly adsorbed by the soil and bedrock materials and carcinogenic PAH are all of high molecular weight. Therefore, carcinogenic PAH are not likely to appear in the future in significantly higher concentrations than presently seen in drinking water wells. If a criterion as low as 4 parts per billion for noncarcinogenic PAH is required to prevent taste and odor problems, then it becomes necessary to consider other options to satisfy water supply shortfalls that will result from closure of wells exceeding this criterion. The two options determined by this study to be reliable and cost-effective are additional treatment at existing iron removal plants, or using new wells in the Mt. Simon-Hinckley aquifer.

The costs of these alternatives are closely comparable. Additional treatment would consist of injecting ozone or powdered activated carbon. These treatment options are much less expensive than activated carbon treatment, and testing has shown that they are capable of meeting the recommended criteria. These options should be technically feasible, but this remains to be demonstrated. On the other hand, utilizing the uncontaminated Mt. Simon-Hinckley aquifer is clearly effective and may be immediately implemented. Indeed, the City is presently drilling one new Mt. Simon-Hinckley well. In any event, the decision to be made by the community is not whether to accept or reject a health risk posed by noncarcinogenic PAH, for none of the options suggested by this report requires acceptance of any such health risk. Rather, the question is: what standard does the community want for substances that are admittedly noncarcinogenic?

Recommended Actions for Shallow Aquifers

Tests of the water in contaminated areas of the Drift and Platteville aquifers indicate that this water would not meet the recommended criteria for PAH in drinking water. However, municipal

wells do not make substantial use of these aquifers.* The major use of this aquifer is through private commercial and residential wells. All of the private residences in St. Louis Park are already connected to the public water supply, as required for many years by City ordinance, in part because of contamination of shallow aquifers by septic tank discharges, infiltration of urban runoff, and other sources. Many private residential wells still exist because they are used for lawn and garden sprinkling. The report recommends that the City of St. Louis Park and the Minnesota Department of Health prohibit human consumption of water from these shallow wells.

Although there is very little evidence for determining whether the St. Peter aquifer is presently contaminated by PAH, the St. Peter is vulnerable to contamination because of fractures in the Glenwood Shale above it and because of multi-aquifer well flow from the Drift-Platteville. It is not necessary that St. Louis Park discontinue use of well SLP3, the only municipal well utilizing St. Peter water, because that well is not contaminated and is not predicted to become contaminated. It should be monitored, as subsequently explained. However, it would be inordinately expensive and difficult to monitor all private wells in the St. Peter. Accordingly, human consumption of water from the St. Peter aquifer should be prohibited in any areas where PAH concentrations exceed or are predicted to exceed the recommended criteria.

Recommended Actions for Multi-Aquifer Wells

Multi-aquifer wells that are not cased properly may provide a pathway for downward migration of PAH. Work on two such wells on the plant site has already been commenced. Well W23, the old deep well

*Only well SLP3, which draws both from the Platteville and the St. Peter, taps this shallow aquifer. It is not contaminted.

used by Reilly, has already been explored and partially filled with bentonite to prevent downward migration into the Mt. Simon-Hinckley. Similar work that is planned by the State of Minnesota for well W105, the old well used by the sugar beet refinery, should be completed. An inventory of other multi-aquifer wells currently underway should be completed and expanded if necessary. Only those wells which provide possible pathways for contamination to reach the Mt. Simon-Hinckley aquifer should be rebuilt or replaced.

Recommended Monitoring

The ground-water modeling previously mentioned, which is described in detail in Appendix E of the report, demonstrates that PAH contamination of the Prairie du Chien-Jordan is not expected to spread to adjacent communities, although there is a possibility that it could spread to Edina wells that are closest to St. Louis Park after several decades. This conclusion follows even if the closed St. Louis Park wells are kept closed. If they are reopened and used (either with or without treatment) then they would act as gradient control wells, which would further protect against southerly migration. This report recommends a comprehensive monitoring program to protect against unforeseen contaminant migration. It also recommends contingency measures that would only be taken in the event of such migration. The contingency action would be to restart the closed St. Louis Park wells and use them as gradient control wells, or drill new gradient control wells, if necessary.

Estimated Costs and Remedial Measures Rejected

The estimated present value cost of the recommendations contained in this report is between $1.9 and $4.7 million, if a noncarcinogen criterion is established at 4 parts per billion. A noncarcinogen criterion within the recommended range but greater than about 10 parts per billion reduces the estimated present value cost by at least $1.0 million. The estimated present value cost of the contingency measures is between $0.2 million and $0.3 million, if such measures are required in fifty years.

This report has considered, and rejected, a wide variety of source and end-use controls, such as excavation of contaminated soils at the site, treatment or excavation of the ground fluid body, and granular activated carbon treatment of ground water to remove PAH. For reasons stated in the body of the report, source controls are neither practical nor necessary. Granular activated carbon treatment of municipal supply wells is not cost-effective in view of the comparative ease with which the community could turn to alternate supplies in the Mt. Simon-Hinckley aquifer and in view of the belief that the establishment of a reasonable criterion for noncarcinogenic PAH would allow for treatment methods which involve relatively simple additions to those already in place, such as injecting ozone or powdered activated carbon.

Proposed Superfund Studies

The results of this study indicate that many of the studies and activities planned for the $2.0 million in Superfund monies recently allocated to the Minnesota Pollution Control Agency for the St. Louis Park problem are unnecessary or not cost-effective. Modeling and testing of gradient control well systems are not required because this study has shown that such systems are not cost-effective at the present time. Further evaluation of drinking water treatment alternatives is also not necessary at the present time. However, should St. Louis Park decide that it would prefer to treat its drinking water rather than seek alternate supplies, limited additional investigation would be necessary to select the appropriate modifications in treatment.

Conclusion

The measures recommended in this report are straight-forward. Part of their value lies in their simplicity in achieving the objectives of (1) providing the City of St. Louis Park and neighboring communities with a safe and adequate supply of drinking water,

(2) allowing for use of ground-water resources in a reliable manner, and (3) allowing for reasonable and beneficial use of the site. These measures can and should be implemented promptly.

Dorsey & Whitney
Environmental Research & Technology, Inc.
Reilly Tar & Chemical Corporation

April 1983

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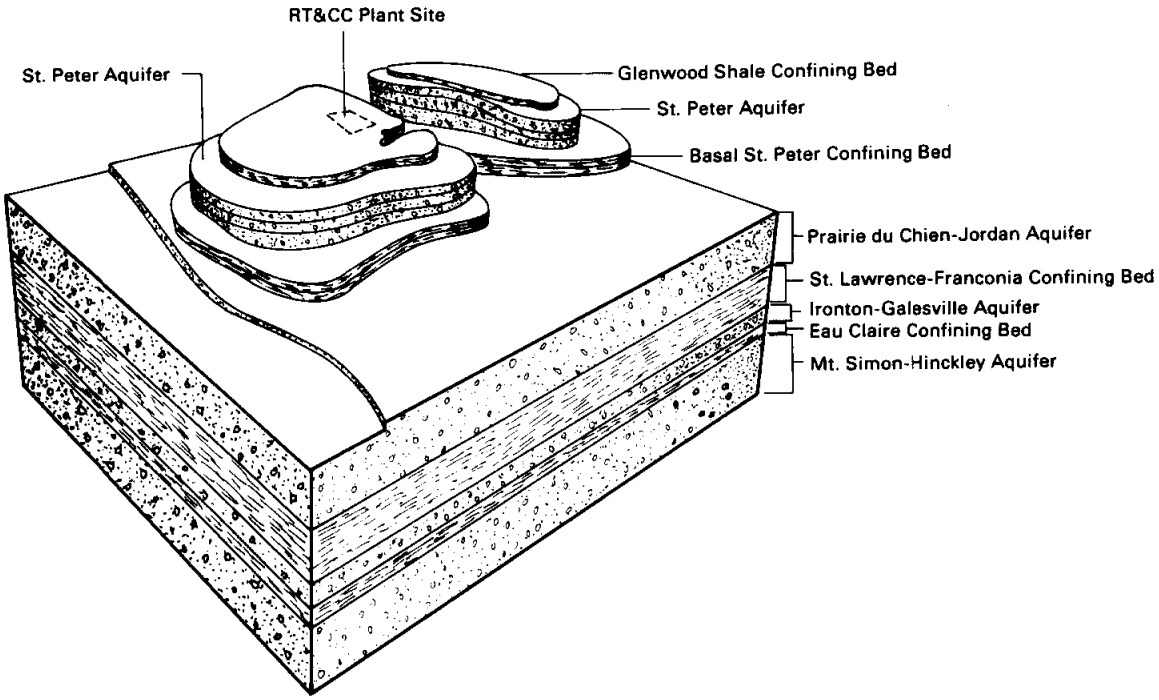

Geology Beneath Drift-Platteville Aquifer

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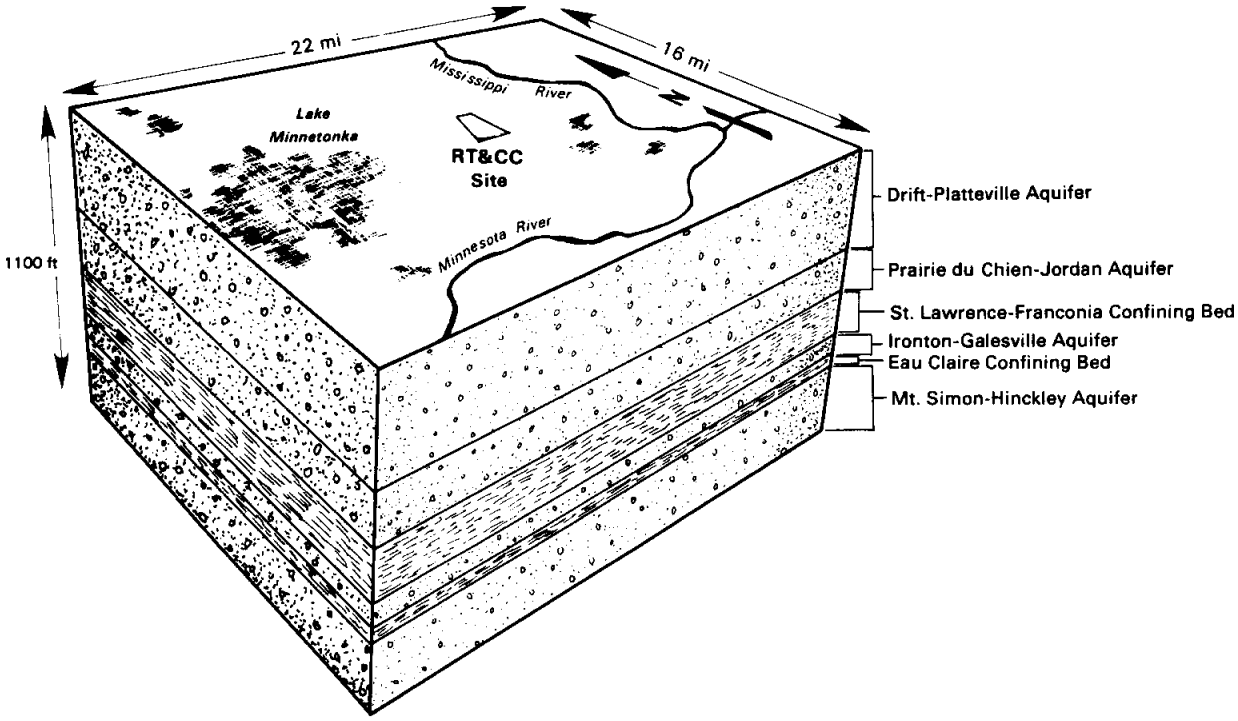

Surface Features and Drift-Platteville Aquifer

Schematic View of Twin Cities Basin Geology

CHRONOLOGICAL LISTING OF
STUDIES RELEVANT TO THE ST. LOUIS PARK PROBLEM

Date	Study	Author
9-0-69	Ground Water Investigation Program at St. Louis Park, MN (Progress Report 1)	Eugene A. Hickok & Associates, Inc.
10-13-69	Preliminary Soils Investigation, 80 Acre Site W. of 2nd St. NW and Republic Ave.; St. Louis Park, Republic Creosoting Co.	Soil Engineering Services, Inc.
4-22-70	Memorandum of Waste Disposal at Republic Creosote Co. and Reilly Tar & Chemical Co.	Minnesota Pollution Control Agency (MPCA)
11-2-70	Mellon-Rice Phenolics Data on Well Samples	Carnegie-Mellon University & C. W. Rice Division, NUS
1971,1973	Analyses of soil samples	Tri City Public Health Lab (St. Louis Park)
8-1-72	An Assemblage of Analytical Data Regarding the Reilly Tar & Chemical Property, St. Louis Park, MN	St. Louis Park Health Dept.
1-11-73	Status Report on Creosote Site and Texa-Tonka Area	(St. Louis Park) Planning Dept.
4-23-73	Surface & Subsurface Ground Reclamation; Republic Creosote Site, City of St. Louis Park	OSM Consulting Engineers

Date	Study	Author
4-23-73	Surface and Subsurface Ground Reclamation; Republic Creosote Site, City of St. Louis Park.	OSM Consulting Engineers
8-6-73	Storm Water Study; Public Improvement #72-43 (Republic Creosote Area)	OSM Consulting Engineers
1973-1981	Intermittant Analyses for phenolics in area wells	Minnesota Department of Health (MDH)
0-0-74	Investigation of the Phenol Problem in Private and Municipal Wells in St. Louis Park	Minnesota Department of Health (MDH)
3-0-74	Geology of the St. Louis Park Area - A Review by the MN Geological Survey; Report on Investigation of Municipal Water Supply, St. Louis Park.	Minnesota Department of Health (MDH)
5-16-74	Soil Investigation; Proposed Storm Sewer and Holding Ponds Near Hwy. 7 and Louisiana Ave., St. Louis Park	Soil Exploration Co.
7-0-74	Hydrogeologic Study of the Republic Creosote Site	Gerald Sunde, Consulting Engineer
11-15-74	Data re: The History and Development of a Storm Sewer System for the City in the Area of the Former Republic Creosote Prop.	City of St. Louis Park
11-19-74	Memorandum on Ground Water Contamination, St. Louis Park, MN	Minnesota Pollution Control Association (MPCA)
1974,1981-1982	Soil and water analyses	Twin Cities Testing and Engineering Laboratory, Inc.
11-14-75	St. Louis Park Creosote Contamination Study	Minnesota Department of Health (MDH)
1975	Soil & water analyses	Sanitary Engineering Laboratories, Inc.(SERCO)

Date	Study	Author
5-0-76	Soil and Ground Water Investigation Coal Tar Distillation and Wood Preserving Site, St. Louis Park (Barr Engineering - Phase I Report)	Barr Engineering Co.
6-0-76	Stability Study of Para-Benzo Quinone for the City of St. Louis Park	SERCO
9-17-76	Soil Boring & Chemical Analysis of the Northern Portion of Oak Park Village	National Biocentric, Inc.
12-2-76	Development Plan, Northern Portion, Oak Park Village	St. Louis Park
12-28-76	Memorandum: Review of Recent Studies of Soil Contamination at the Former Republic Creosote Site - Recommendations to City's Proposed Development Plan.	Minnesota Pollution Control Agency (MPCA)
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10-0-77	Assessment of Possible Human Health Effects Resulting from Contamination of the Former Republic Creosote Site.	Minnesota Department of Health (MDH)
1977,1981	Water analyses for PAH	United States Environmental Protection Agency
1-5-78	Soil Report; Proposed Oak Park Village, St. Louis Park, MN	Soil Testing Services of MN, Inc.
1-11-78	Recommendations for Plugging or Modification of Abandoned Wells in the Area of the Former Republic Creosote Plant.	St. Louis Park

Date	Study	Author
3-0-78	Soil Borings for Louisiana Avenue Extension	Soil Exploration Co.
3-0-78	Results of Laboratory Analysis, St. Louis Park Soil Borings	SERCO
6&7-78	Report of Well Water Survey St. Louis Park, MN	SERCO
7-1-78	Report on the Existing Creosote Problem in St. Louis Park, MN	James Bailey, Agricultural Engineer, U. of M.
10-0-78	Soil Borings for Building Locations on Site	Soil Exploration Co.
10&11-78	Report of Soil Sampling, City of St. Louis Park	SERCO
1978-1983	PAH analyses in area well	Minnesota Department of Health (MDH)
11-0-78	Health Implications of Polynuclear Aromatic Hydrocarbons in St. Louis Park Drinking Water	Minnesota Department of Health (MDH)
11-14-78	Status Report to the MPCA: Proposed Development, Oak Park Village.	City of St. Louis
12-15-78	Water Quality Development in Oak Park Village	St. Louis Park
1978-1979	Water analyses	Pace Laboratories, Inc.
1978-1982	Contaminant transport experiments	University of Minnesota
2-6-79	Report Tabulating Information on Four Existing Wells in St. Louis Park (Not Titled)	United States Geological Survey, Water Resources Division (USGS)
3-27-79	Status Report: St. Louis Park Development	Minnesota Pollution Control Agency (MPCA)

Date	Study	Author
4-13-79	Progress Report: Investigation of Coal Tar Derivatives in Ground Water-St. Louis Park	USGS
1979,1982	Soil Investigations	Braun Engineering Co.
1-11-80	Summary Report on the City of St. Louis Park Activated Carbon Pilot Plant Study-July & October, 1979	SERCO
1-0-81	Preliminary Evaluation of Ground Water Contamination by Coal Tar Derivatives, St. Louis Park Area, MN	USGS in cooperation with MDH
4-0-81	Report on Drinking Water Treatment and Remedy Evaluation for St. Louis Park, MN	Eugene A. Hickok and Associates, Inc.
10-7-81	Results of Analysis of Water Samples, & Soil Samples for Polycyclic Aromatic Compounds (Hydrocarbons, Azagrenes, Phenols)	Midwest Research Institute
11-0-81	Study of Ground Water Contamination in St. Louis Park, MN	Eugene A. Hickok & Associates, Inc., Geraghty & Miller, Inc. and Hennigson, Durham & Richardson, Inc.
1981-1982	Water analyses for PAH	Capsule Laboratories
1-11-82	Terminating an Endless Search: An Action Approach to Solving the Water Problem	St. Louis Park
11&12-0-82	Degradation of Phenolic Contaminants in Ground Water by Anaerobic Bacteria: St. Louis Park, MN	Ehrlich, Goerlitz, Godsy & Hult

Date	Study	Author
1982-1983	Evaluation of Ground Water Treatment Alternative	CH2M Hill
1982-1983	Well W23 Invesitgations	E.H. Renner & Sons, Inc. E.A. Hickok & Associates, Inc. and MPCA

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DEFINITION OF TERMS

Bog	The land immediately south and adjacent to the plant site that received runoff and waste water from the plant site. The bog is bounded by Walker Street to the north, on the east by the route of Louisiana Avenue, on the south by Lake Street and on the west by former railroad embankments. The bog is shown in Figure 2-1.
Benzene Extractable Hydrocarbons	The weight of organic material, per unit volume or mass, obtained on extracting a water or soil sample with benzene. Hydrocarbon in this definition is not meant to be restrictive to material containing carbon and hydrogen, but rather is meant to include all organic material so extracted.
Contaminants	PAH and related compounds that are present in soil or ground water at levels that are clearly above expected background levels for an urban area in the affected media.
Contaminated	Soil or ground water that contains concentrations of PAH and related compounds which are clearly above expected background levels of these compounds for an urban area in the affected media.
Heterocyclic PAH	PAH chemicals with one or more aromatic carbon atoms replaced by nitrogen, oxygen, or sulfur atoms. Unless otherwise stated, alkyl substituted heterocylic PAH are also included by this term.
Hetero-Substituted PAH	PAH chemicals with one or more heteroatomic functional substituted groups attached to the aromatic rings. For the purposes of this term, such functional groups include amines, cyanides, mercaptans, thiols, ketones, ethers, carboxylic acids, alkyl groups, etc. but specifically exclude hydroxyl groups (i.e., phenols).

Modeling Area	An area of 22 miles east-west and 16 miles north-south which is approximately centered on the site area and was modeled for ground-water flow hydraulics as part of this study. The modeling area is defined by the border of the upper map in Figure 2-1.
PAH and Related Compounds	PAH (as defined above) plus related aromatic chemicals that are often associated with PAH in coal tar, soot, petroleum distillates and similar materials. These related aromatic chemicals are by definition limited to heterocyclic PAH, heterosubstituted PAH and phenols (defined elsewhere).
Phenolics	Chemicals measured by standard colorimetric tests for phenols, the current standard test being the 4-aminoantipyrene method. Colorimetric tests typically measure one-ring phenols (phenol and ortho-and meta-substituted phenols and possibly certain para-substituted phenols), and possibly two ring or larger phenols.
Phenols	Chemicals consisting of one or more fused aromatic rings containing carbon and hydrogen with one or more hydroxyl (-OH) groups attached to the ring. Unless otherwise stated, alkyl substituted phenolics are also included by this term.
Plant Site	The land that was formerly the site of the Reilly Tar & Chemical Corporation's creosote wood preserving and coal tar refinery plant. The plant site is bounded on the north by West 32nd street, on the east by Gorham Avenue, Second Street Northwest and Republic Avenue, on the south by Walker Street, and on the West by Pennsylvania Avenue and Oak Hill Park. The plant site is shown in Figure 2-1.

Polynuclear Aromatic Hydrocarbons (PAH)	Chemicals consisting of carbon and hydrogen and containing two or more fused aromatic rings, with each ring consisting of five or six carbon atoms. Unless otherwise stated, alkyl-substituted PAH are also included by this term.
Site	The plant site and bog area together.
Site Area	An area extending approximately 8500 feet east-west and 6000 feet north-south in which the site occupies the northwest corner. The site area is defined by the border of the lower map appearing in Figure 2-1.
St. Louis Park Area	Areas of St. Louis Park and neighboring communities that have been affected by ground water contamination by PAH and related compounds.
St. Louis Park Problem	The overall problems in the St. Louis Park Area related to the contamination of soil and ground water by PAH and related compounds, including in particular the presence of contaminated soil and ground water in the former RT&CC plant site and adjacent bog, the presence of contamination in confined bedrock aquifers underlying the St. Louis Park area, and the present water supply shortage faced by the Cities of St. Louis Park and Hopkins as a result of municipal supply well closures.

DEFINITION OF TRACE CONCENTRATION UNITS

This report makes frequent use of units for expressing trace concentrations. The units used in this report are defined in the table below. In order to avoid misunderstandings over real or suspected typographic errors, an effort has been made to write out all of the units used in this report. Abbreviations are therefore presented below for comparison with other data and reports.

Dimensionless Concentration	Concentration in Water	Concentration in Soil or Other Solid
Parts per million (ppm)	Milligrams per liter (mg/1)	Milligrams per kilogram (mg/kg)
Parts per billion (ppb)	Micrograms per liter ug/1	Micrograms per kilogram (ug/kg)
Parts per trillion (ppt)	Nanograms per liter ng/1	Nanograms per kilogram (ng/kg)

In order to provide a better understanding for the magnitude of these trace concentration units, the following table presents equivalent quantities in more familiar measures of volume, length and time.

Fractional Expression	Volume Equivalent	Length Equivalent	Time Equivalent
1 part per million	1 drop in 26.4 gallons	1 inch in 15.8 miles	1 second in 11.6 days
1 part per billion	1 drop in 26,400 gallons (volume of a typical railroad tank car)	1 inch in 15,800 miles (almost two-thirds of the distance around the earth)	1 second in 31.7 years
1 part per trillon	1 drop in 26.4 million gallons (volume of a 10 acre lake that is 8 feet deep)	1 inch in 15.8 million miles (66 times the distance from the earth to the moon)	1 second in 317 centuries (3 times more distant than the last Ice Age)

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TECHNICAL SUMMARY

BACKGROUND

Reilly Tar & Chemical Corporation (RT&CC) operated a creosote wood-preserving plant and coal-tar refinery in St. Louis Park, Minnesota from 1917 to 1972. In 1972 the site was sold to the City of St. Louis Park. The plant was removed, and the site was converted to non-industrial uses. Soil and ground-water contamination by a variety of coal-tar-related chemicals has been observed in the immediate vicinity of the former plant site. In addition, polynuclear aromatic hydrocarbons (PAH), which are constituents of creosote and coal tar, as well as being associated with many other natural and man-made sources, have been measured in some of the deep bedrock aquifers in the St. Louis Park area. The use of seven municipal drinking-water supply wells (six in St. Louis Park and one in Hopkins) has been discontinued because of the presence of PAH in untreated water from these wells. The wells were closed out of concern over possible adverse health effects from ingesting PAH. Possible carcinogenic effects associated with certain PAH have been a particular concern. The soil and ground-water contamination problems in St. Louis Park have resulted in many technical studies since the late 1960's, but relatively few actions have been taken to date to remedy the problem.

This report presents a specific plan for a comprehensive solution to the PAH contamination problems in the St. Louis Park area. It reflects the results of an intensive six-month study by Environmental Research & Technology, Inc. (ERT). The purpose of this study is to describe the scope and effects of the contamination problems in St. Louis Park, define a specific set of objectives for comprehensively addressing these problems, and develop a specific plan of action to achieve the stated objectives. The study evaluated the various engineering, hydrogeologic, economic, and toxicologic factors required to develop a plan to solve the contamination problems in the St. Louis Park area.

This technical summary provides a concise description of the conclusions and recommendations from ERT's study. The supporting

documentation for these conclusions is presented in the main text of ERT's report and the twelve supporting technical appendices.

OBJECTIVES

This report establishes three primary objectives for a comprehensive solution to the St. Louis Park contamination problem.

1) Provide the City of St. Louis Park and neighboring communities with a safe and adequate supply of potable water at present, and for the reasonably foreseeable future, in a cost-effective and reliable manner.
2) Allow for present and reasonably foreseeable future use of ground-water resources in the St. Louis Park area in a cost-effective and reliable manner.
3) Allow for safe, reasonable, and beneficial use of the former Reilly Tar & Chemical Corp. plant site and adjacent bog for the reasonably foreseeable future, in a cost-effective and reliable manner.

For the purposes of this study, the term "reasonably foreseeable future" means the next 100 years. Establishing such a finite time-frame is necessary to arrive at a finite and effective solution to the PAH contamination problems in the St. Louis Park area. A finite time-frame does not mean that any problems occurring beyond the next 100 years are ignored. Rather, it reflects the difficulty in planning actions now that account for conditions in the distant future, which may differ greatly, but unpredictably, from current and reasonably foreseeable conditions. The particular technical and physical characteristics of the St. Louis Park problem make it difficult to predict reliably, beyond about a century, the behavior of many physical systems that affect the definition and remedy of the problem. Furthermore, technological advances very likely will occur beyond, and probably within, the next 100 years, which will change significantly the definition and remedy of future problems. Finally, expenditures made more than 100 years from now are discounted so greatly, when expressed as present value costs, that they become negligible in evaluating solutions. All of these factors together

indicate that a finite time-frame of the next 100 years is both reasonable and necessary to evaluate solutions to the PAH contamination problems in the St. Louis Park area.

APPROACH

This study evaluates many alternatives for achieving the three stated objectives. The two basic types of alternatives considered are source controls and end-use controls, alone or in combination. Source controls include actions taken to prevent well W23 (the former plant supply well on the site) or contaminated soil and ground water at the site from acting as sources of ground-water contamination. Actions taken to manage or control the migration of contaminants are also classified, for the purposes of this study, as source controls. End-use controls remedy ground-water contamination problems at the point of use, either by treating the water for acceptable use or by providing alternate sources of drinking water. Source controls alone cannot meet all three objectives, since source controls have no immediate effect on providing safe and adequate drinking-water supplies. This is because of the long time required for ground-water contamination to respond to source controls. On the other hand, end-use controls alone can be the most cost-effective approach to achieve all three objectives, since source controls are shown in this report to be unnecessary to allow for safe, reasonable, and beneficial future use of the site.

This study largely relies on currently available data to characterize the problems at St. Louis Park and to define and evaluate remedial action alternatives. This is important because many studies have already been performed, and $2.0 million in Superfund expenditures are planned, mostly for still more studies. Currently available data can be used to define reliably the most cost-effective solution to the St. Louis Park problem or a limited set of possible solutions. Thus, the scope and focus of any further studies clearly can be limited and targeted, resulting in savings of Superfund monies.

This study has not had access to all of the available data that are pertinent to the St. Louis Park problems. ERT requested additional existing data from the United States Geological Survey

(USGS), Minnesota Department of Health (MDH), and Minnesota Pollution Control Agency (MPCA), but was unable to obtain much of the requested data before the publication of this report. It is unlikely, however, that these additional data would change substantially the conclusions of this study, based on ERT's understanding of the nature of these data.

An important approach used in this study is the evaluation and comparison of alternative remedial actions for source and end-use control. These evaluations are based upon effectiveness, reliability, and cost--a set of factors described in this report under the general term "cost-effectiveness". This approach is consistent with objectives set out by the U.S. Environmental Protection Agency in the National Contingency Plan for responding to hazardous waste sites under the authority of the Comprehensive Environmental Response, Compensation and Liability Act of 1980 ("Superfund"). The purpose of evaluation based on cost-effectiveness is to determine remedial actions that are the most effective and reliable, relative to the costs of the actions. To compare costs on an equal basis, the initial capital expenditure and lifetime operating expenses for each remedial action are expressed as a single present value cost. Present value costs are computed using an effective net (without inflation) interest rate of 5 percent per annum, assuming a maximum life of 100 years for all actions.

Many individual technical elements are involved in this study's evaluation of alternative solutions to the St. Louis Park problem. These include the following:

1) assessment of former RT&CC plant operations on the introduction of PAH and related compounds to soil and ground water at the site;
2) identification and evaluation of remedial action alternatives for the site;
3) computer modeling of ground-water flow in the St. Louis Park area;
4) compilation of all available ground-water sampling and analysis data for PAH and related compounds in a computerized data base;

5) identification and evaluation of remedial action alternatives for multi-aquifer wells, both on-site (wells W23 and W105) and off-site;
6) identification and evaluation of alternatives to manage the migration of ground-water contaminants, including alternative methods to dispose of water discharged by gradient control wells;
7) recommendation of criteria for acceptable PAH concentrations in finished potable water, including means for monitoring compliance with these criteria;
8) evaluation of alternative drinking water treatment technologies to produce finished water that meets the recommended PAH criteria;
9) evaluation of alternative supply sources for municipal drinking water supplies; and
10) evaluation of techniques to determine the present value cost of remedial actions that last for many years or may be required in the future.

These individual technical elements provide tools and data to analyze the St. Louis Park problem and potential remedies for this problem in an overall context. In general, the techniques used in each area are as straightforward as possible to provide the necessary answers in a reliable manner. In addition, the accuracy and sensitivity of the results obtained have been checked to ensure the overall reliability of the conclusions reached. Detailed descriptions of the approach and results for each of these technical areas are provided in the technical appendices to this report.

CONCLUSIONS

Hydrogeologic Background

There are five major aquifers underlying the St. Louis Park area. Their names and approximate depth are as follows:

Drift-Platteville	0 - 90 feet
St. Peter	90 - 200 feet

Prairie du Chien-Jordan	260 - 500 feet
Ironton-Galesville	700 - 750 feet
Mt. Simon-Hinckley	830 - 1100 feet

Potentiometric head in each aquifer decreases with increasing depth. Thus, flow between the aquifers is in a downward direction. However, the aquifers are separated by confining beds made up of rock types that are relatively impermeable to ground-water flow. Confining beds are not water-tight; water flows through them very slowly. For example, thousands of years are required for water to travel through the Eau Claire confining bed that separates the Ironton-Galesville and Mt. Simon-Hinckley aquifers. Generally, the confining beds of the St. Louis Park area hydrogeologic system prevent significant flow of either ground water or contaminants between aquifers. The exceptions are those local areas where the Glenwood Shale formation is absent. The Glenwood Shale is the confining bed that separates the Drift-Platteville from the St. Peter aquifer.

All of the bedrock aquifers listed above are sandstone formations, except the Platteville and Prairie du Chien, which are dolomitic limestone and dolomite formations. The Drift aquifer is composed of unconsolidated glacial sediments. This distinction is important because attentuation due to adsorption is greater in the sandstone and unconsolidated aquifers.

The Prairie du Chien-Jordan is the major source of municipal water supply in the St. Louis Park area, and is also a source of commercial and industrial supply. The Mt. Simon-Hinckley aquifer is also used for municipal water supply, although to a lesser extent. The Drift-Platteville and St. Peter aquifers are predominantly used for private, commercial, and industrial water supply. The Ironton-Galesville aquifer is not used in the St. Louis Park area. Ground-water flow patterns in these various aquifers are described further below.

Sources of Contamination

Portions of the plant site and adjacent bog contain soil that is contaminated to various degrees and depths by coal-tar-related

chemicals, primarily phenolics, PAH, and PAH-related compounds, based on comparison with estimated background concentrations of these materials in the site area. This contamination is attributable, in part, to former operations at the RT&CC plant. Other man-made and natural sources in the site area are also likely contributors to total concentrations of these contaminants. Below the original surface of contaminated portions of the plant site and adjacent bog, soil contamination occurs in discrete zones that are often associated with lenses or strata of fine-grained sediments. These sediments appear to play a major role in controlling the rate and direction of contaminant migration.

The surficial ground water in the Drift-Platteville aquifer beneath, and to 1400 feet to the east of and contiguous with the site, is variably contaminated by PAH and related compounds that have, in part, emanated from the site. The surficial ground water has become contaminated by precipitation percolating down through contaminated soil, thus leaching PAH and related compounds. Also, surficial ground water under the site flows through zones of contaminated soil and ground fluid. In doing so, it picks up PAH and related compounds and transports them downgradient from the site.

All soil types and surficial ground water in the site area contain varying levels of PAH and related compounds. These compounds are introduced by many human activities and by natural sources, such as peat deposits. In the site area, especially to the south and east of the former RT&CC plant site, suburban development and commercial and industrial activities are sources of PAH and related compounds. For example, sources of PAH and related compounds include combustion products of fossil fuels, spills of fossil fuels, and run-off from bituminous concrete pavement. The manufacture, use, and disposal of various common commercial products result in accumulation and migration of PAH and related compounds in and through soil and ground water.

There is a local accumulation of an organic fluid consisting of water and creosote-like oil, in the ground water under the bog. There is insufficient information to define the size of this ground fluid

body, but nearby wells and borings indicate that its maximum possible size is about 16,000 cubic feet. Its actual size may be much smaller. There is no evidence of additional ground fluid bodies under the site, and, based on the density of wells and borings in the site, it is unlikely that other such bodies exist. Current evidence suggests that the ground fluid body is relatively immobile.

The former RT&CC plant water supply well (W23) has served as a direct source of contamination of some deeper aquifers underlying the site. A plug of coal-tar-like material was found in a portion of well W23, from below the Prairie du Chien-Jordan to above the Mt. Simon-Hinckley. This plug was removed from the well in the summer of 1982 by the MPCA. It is unknown when or how the material entered the well.

Coal-tar-like material covered portions of the surface of the well bore and casing above the plug in well W23. These deposits were largely removed by the MPCA during remedial action work in the fall of 1982, from the bottom of the well up through the bottom of the Jordan sandstone. Well W23 is now filled with bentonite from the bottom of the well up to the bottom of the Jordan. Additional exploration work at the well is still in progress.

Well W23 is defined as a multi-aquifer well because it is open to more than one aquifer. The coal-tar-like materials in well W23 acted as a source of contamination for the Ironton-Galesville and Prairie du Chien-Jordan aquifers, and perhaps to the St. Peter and Drift-Platteville aquifers. Ground-water flow in contact with contaminated casing and/or well bore surfaces leached contaminants into the aquifers. Down-hole flow in the well into the Prairie du Chien-Jordan appears to have played an important role in introducing contaminants into this aquifer. The magnitude and extent of contamination in the various aquifers caused by well W23 are poorly known. There are no water quality data showing that the Mt. Simon-Hinckley was affected by contaminants in well W23.

Transport of Contaminants

Well W23 and other multi-aquifer wells in the vicinity of the site have acted to transport contaminants from upper aquifers to lower aquifers. A multi-aquifer well creates a hydraulic connection between aquifers, and thus may provide a pathway for contaminated ground water to travel from shallow to deeper aquifers.

The number and location of such multi-aquifer wells, and their relative contribution in transporting contamination to deeper aquifers, are poorly documented. There are many multi-aquifer wells connecting the Drift-Platteville and St. Peter aquifers, fewer connecting either of these aquifers to the Prairie du Chien-Jordan, and very few reaching as far as the Mt. Simon-Hinckley. Some of these multi-aquifer wells have been sealed by the MDH and MPCA over the last few years to prevent interaquifer flow.

Transport of contaminants in the aquifers underlying the St. Louis Park area is controlled by the flow of ground water and by physical and chemical processes that remove contaminants or reduce the rate at which they migrate. Contaminant transport in ground water is of most concern, since soil contaminants at the site are relatively immobile, and to the extent that they migrate, such migration is largely controlled by ground-water flow in the Drift aquifer.

Predictions of contaminant transport formulated in this study are generally based upon the assumption that contaminants will travel at the same velocity as ground-water, that is, at the hydraulic transport rate. This is a conservative assumption because it neglects chemical and physical processes that slow the speed at which contaminants travel. As a result of chemical and physical retardation, contaminants travel many times more slowly than the hydraulic transport rate. For example, it is estimated from laboratory studies at the University of Minnesota that low molecular weight contaminants (two-ring PAH) will travel about 20 times more slowly than ground water in the Drift and St. Peter formations. Higher molecular weight contaminants (four-ring PAH) will travel more than one hundred times

slower than ground water. Similar attenuation is reasonably assumed in other sandstone formations (Jordan, Ironton-Galesville, and Mt. Simon-Hinckley).

Ground-water flow in the Drift-Platteville aquifer is dominated by the regional west to east water table gradient. Contaminants in this aquifer in the site area have been and will continue to be carried to the east and southeast by this ground-water flow pattern. A portion of the Drift-Platteville ground-water flow is diverted into a buried tributary bedrock valley approximately 3000 feet southeast of the site. Water flowing from the site reaches the tributary bedrock valley in one to two decades, according to the computer model. Roughly 30 percent of the water passing directly over the valley is predicted to flow down into the valley and into the St. Peter aquifer. The buried tributary bedrock valley is thus a potential conduit for spreading contamination from surficial sources at the site to the St. Peter aquifer. Water from the site must travel at least 60 years to reach a major bedrock valley connecting the Drift-Platteville to the Prairie du Chien-Jordan. The major bedrock valley is located to the east of the tributary bedrock valley, farther away from the site. Accounting for retardation effects, the predicted travel time of contaminants from the site to the major bedrock valley exceeds 1000 years.

Ground-water flow in the St. Peter aquifer is also dominated by a regional west to east flow pattern. A potentiometric high occurs in the St. Peter at the buried tributary bedrock valley, where water enters the aquifer from the Drift-Platteville. This high causes ground water traveling from the site to be deflected either north or south of the buried valley. Sustained operation of St. Louis Park municipal well SLP3 at full capacity may induce flow from the St. Peter beneath the site into the well, with predicted hydraulic travel times on the order of many decades. The few water quality data available show no PAH contamination in the St. Peter in the vicinity of the site. If any contaminants are present, travel times to well SLP3 would be over a thousand years, accounting for retardation effects. No contamination of St. Louis Park Well SLP3, which is the only municipal supply well in this aquifer, has been observed.

Ground-water and contaminant flow patterns in the Prairie du Chien-Jordan are very complex because of the many high-capacity wells withdrawing water from the aquifer. Regional flow is directed from west to east by potentiometric gradients of roughly ten feet per mile. This regional flow is significantly influenced by the concentration of large municipal pumping wells in St. Louis Park, Hopkins, and Edina. The aggregate impact of these wells creates a potentiometric low bounded by a ground-water divide to the south and east of St. Louis Park. The divide acts as a hydraulic barrier, effectively isolating the enclosed aquifer area from areas to the east (Minneapolis and Mississippi River) and south (southern parts of Edina and Hopkins, and Bloomington). Significantly, the contaminated portions of the aquifer are well within this divide.

The extent of contaminant attenuation in the Prairie du Chien-Jordan is not well known. This study has assumed that substantial attenuation is unlikely to occur. This is because solution channels in the Prairie du Chien limestone do not provide a high surface area to pore volume ratio. A high ratio, as is present in sandstone aquifers, appears necessary to cause appreciable adsorption.

Little is known about ground-water flow in the Ironton-Galesville aquifer in the St. Louis Park area because the aquifer is not used in the area. Contaminants have been introduced to this aquifer by well W23 and perhaps by other multi-aquifer wells. Because the aquifer is not used, nor is expected to be used in the foreseeable future, the limited and ill-defined contamination in the Ironton-Galesville is not a problem.

Ground-water flow patterns in the Mt. Simon-Hinckley aquifer are dominated by the potentiometric lows created by a few high-capacity municipal supply wells in St. Louis Park and Edina. Regional flow travels from all directions to the well centers. Within the aquifer, three, and possibly more, abandoned industrial wells had the potential to act as pathways to introduce PAH contaminants: well W23 (former Reilly Tar & Chemical Corp.), well W38 (Milwaukee Railroad), and well W105 (former sugar beet refinery). However, there is no evidence of

contamination in the Mt. Simon-Hinckley. If inter-aquifer flow reached the Mt. Simon-Hinckley via these wells, it would most likely flow to St. Louis Park well SLP11 and certainly no farther than the potentiometric low created by St. Louis Park wells SLP11 and SLP12 and Edina well E12, as long as they continue to operate. Many decades would be required for water to travel to the municipal wells from the site. Contaminant travel times would be much longer, due to significant retardation effects.

Effects of Contaminants

Physical and Toxicological Properties of PAH

The class of chemicals known as polynuclear aromatic hydrocarbons (PAH) is ubiquitous in the environment, as a result of both natural and anthropogenic sources. Human populations are exposed continually to PAH in their food, air, and drinking water, with estimated typical exposures via these media differing by roughly a factor of ten. Typical food exposure is about ten times greater than the typical air exposure, which in turn is about ten times greater than the typical drinking water exposure.

The primary concern with human exposure to PAH is that certain compounds in the class are carcinogenic; however, this is only true for certain specific compounds and not for all compounds in this class. In this report, a PAH is considered to be carcinogenic if it causes a significant elevation in tumor incidence when administered by any route to any species of animal. Such compounds are treated as though they are human carcinogens, even though the only evidence may be from animal tests. Carcinogenic PAH tend to be higher molecular weight compounds, containing four or more fused aromatic rings. Carcinogenic PAH as a class are probably the most extensively studied carcinogens, in part because they include some very potent carcinogens and because they are widespread. The potencies of carcinogenic PAH as a class vary widely, however. Noncarcinogenic PAH exhibit low acute and chronic toxicity. There are many individual compounds in

environmental mixtures of PAH, and the noncarcinogenic fraction is generally much greater than the carcinogenic fraction in these mixtures.

The behavior of PAH in the environment is largely controlled by their low vapor pressure, low aqueous solubility, and high adsorption tendencies. These properties are a strong function of molecular weight, with higher molecular weight PAH being much less mobile in the environment.

Drinking Water Criteria for PAH

The major resource value of ground water affected adversely by trace (part per billion) levels of PAH contamination is its value as a high-quality source of drinking water. Other uses of ground water involving direct human ingestion, such as watering certain vegetables or direct use in food processing plants, may also be affected adversely. Use of ground water for other irrigation, cooling, or industrial purposes is not affected adversely. The role and value of ground water as a source of recharge for surface water likewise is not affected adversely.

It is necessary to establish criteria for acceptable concentrations of PAH and related compounds in finished drinking water in order to solve the St. Louis Park problem. This study recommends separate criteria for carcinogenic and noncarcinogenic compounds because of their distinctly different toxicologic properties. The recommended criteria are limited to PAH and heterocyclic PAH because these are the only classes of PAH-related compounds that have been detected in untreated municipal supply wells in the St. Louis Park area.

The recommended criterion for total carcinogenic PAH and carcinogenic heterocyclic PAH in finished drinking water is 28 nanograms per liter (parts per trillion). This criterion corresponds to an increased life-time cancer risk of one incidence per 100,000 people exposed, based on a very conservative risk assessment approach. This criterion is derived from the U.S. EPA ambient water

quality criterion for PAH, and has been applied by the MDH in evaluating untreated municipal well water supplies in the St. Louis Park area. This criterion is met by finished water from all of the municipal supply wells in St. Louis Park and Hopkins that are currently shut down, based on recent analyses by a number of different laboratories. In fact, the total concentration of carcinogenic PAH in finished water that would result from reopening these wells is comparable to concentrations in finished drinking water supplies in most communities in the United States.

A criterion for noncarcinogenic PAH and noncarcinogenic heterocyclic PAH is central to solving the ground-water contamination problems in St. Louis Park, because the criterion for carcinogenic PAH and carcinogenic heterocyclic PAH is currently satisfied by finished water from municipal supply wells. However, recommending a specific criterion for noncarcinogenic PAH and noncarcinogenic heterocyclic PAH is difficult because of the limited data on the chronic toxicity of these compounds. This study concludes that a criterion in the range of from 108 to 400 micrograms per liter (parts per billion) for total noncarcinogenic PAH and noncarcinogenic heterocyclic PAH in finished drinking water will prevent observable adverse health effects. A criterion may need to be set as low as 4 micrograms per liter, however, to prevent objectionable tastes or odors, although this should be confirmed by testing because of the limited available data on the organoleptic effects of PAH and related compounds. The calculation of a criterion for noncarcinogenic PAH and noncarcinogenic heterocyclic PAH is derived by applying a safety factor of 100 to the no observable adverse effect doses measured in animal tests.

The criteria recommended by this study apply to finished drinking water. However, these criteria are important in assessing ground-water contamination because testing to date indicates that conventional drinking water treatment in the St. Louis Park area (chlorination, fluoridation, and/or iron removal) does not remove significant amounts of noncarcinogenic PAH and related compounds, although iron removal does remove some carcinogenic PAH. This means that a ground water supply that does not meet the recommended criteria

is likely to result in finished water that does not meet the recommended criteria, unless specific types of advanced or modified treatment are employed.

The criteria recommended by this study apply to finished water at the point of addition to the distribution system, even though actual exposures occur from use of water at the tap, and the National Contingency Plan specifies that health effects concerns should be addressed at the tap. The application of criteria to finished water is recommended for ease in monitoring compliance and because tap water quality should be no worse than finished water quality with respect to PAH and related compounds. Any exceptions to this assumption would result from factors in the distribution system, such as cross-connections or coal tar or asphalt linings in pipes and tanks, that are in no way related to ground-water contamination problems.

Effects of Ground-Water Contamination

Areas of the Drift-Platteville aquifer downgradient from and contiguous with the site contain PAH contaminants at levels exceeding background levels and both of the recommended criteria for finished drinking water. However, there are many potential sources of PAH in the Drift-Platteville aquifer downgradient and along the gradient from the site. In addition, this aquifer has been degraded by residential, commercial, and industrial development. For example, there has been influx of various contaminants from road de-icing chemicals, low level sewer leakage, industrial activities, and, in the past, from septic tanks and leaching fields. There are a number of industrial, commercial, and private wells in the Drift-Platteville aquifer in the vicinity of the site, but only the use of private wells for drinking water supply, gardening, or food processing is affected by PAH concentrations that exceed the proposed criteria.

Areas of the St. Peter aquifer in the vicinity of the site may be contaminated by PAH, although the few available data do not indicate contamination. This aquifer contains a number of industrial, commercial, and private wells, but only the use of private wells for drinking water supply, gardening, or food processing should be

affected if contaminants are present at concentrations exceeding either of the recommended criteria. The only municipal supply well in this aquifer is SLP3, which shows no evidence of contamination, and will not be affected for hundreds of years if contaminants are present in the St. Peter in the vicinity of the site.

PAH contamination is observed in a number of municipal, industrial, and commercial wells spanning an area of several square miles in the Prairie du Chien-Jordan aquifer. Seven municipal supply wells have been taken out of service by the MDH as a result of PAH contamination. These include six wells in St. Louis Park (wells SLP4, SLP5, SLP7, SLP9, SLP10 and SLP15) and one in Hopkins (well H3). Monitoring data from recent years, when more reliable analytical techniques were used, show that 1) finished water from none of the municipal wells exceeds the carcinogen criterion of 28 parts per trillion, 2) only finished water from two St. Louis Park wells (SLP5 and SLP15) exceeds the lower bound of the recommended noncarcinogen criterion range (4 parts per billion), and 3) none of the municipal wells has ever approached the upper bound of the recommended noncarcinogen criterion range (400 parts per billion).

PAH concentrations exceeding both of the recommended criteria are present in the Ironton-Galesville aquifer in the immediate vicinity of well W23 and perhaps a few other multi-aquifer wells. The areal extent of this contamination is unknown, but likely to be small. This limited contamination does not pose adverse effects to the Ironton-Galesville aquifer because the aquifer is not used for municipal water supply in the St. Louis Park area, and there are no known future plans to do so.

PAH contamination has not been observed in the Mt. Simon-Hinckley aquifer. During exploration of well W23 in the summer of 1982, efforts were made to isolate the aquifer and test its water. However, these tests were inconclusive. The plug of coal tar-like material in W23 did not extend to the Mt. Simon-Hinckley and, in fact, acted for an unknown period to prevent effectively multi-aquifer flow into the Mt. Simon-Hinckley in W23. The recent installation of the bentonite seal will continue to prevent such flow. Any recent contamination in

the immediate vicinity of well W23 in the Mt. Simon-Hinckley will not affect existing municipal supply wells for hundreds of years, if ever, because of long contaminant migration times and dilution and dispersion of the limited amount of contamination present.

Effects of Soil Contamination

Contamination of soil at the plant site and adjacent bog by PAH and related compounds does not pose a substantial threat to human health or the environment under normal and reasonable use of these areas. The overwhelming majority of contamination is located below the surface and will not affect surface uses of the site. Future construction at the site will not be adversely affected by contamination or pose a threat to human health if ordinary care is exercised in construction practices.

RECOMMENDATIONS

This study recommends a set of specific actions and limited further investigations to solve the PAH contamination problems in the St. Louis Park area. These recommendations represent the most cost-effective and reliable means for achieving the three objectives established by this study. A total of eleven specific actions are recommended for implementation now; three additional recommended actions are contingent on the results of limited further investigations or on the results of future ground-water monitoring.

Site Area

The plant site and adjacent bog can be used safely and beneficially for reasonable purposes without undertaking extensive remedial actions to remove or contain soil contaminants. Ground-water contamination in surficial aquifers in the site area should be monitored, but actions to remove or contain ground-water contaminants are not necessary or cost-effective in achieving the stated objectives of this study.

Specific recommendations for the site are as follows:

Recommendation 1 - Prohibit use of the Drift-Platteville and St. Peter aquifers for private and municipal drinking water supply or direct use in food processing in areas where PAH concentrations exceed the recommended criteria, or are predicted to do so within the next few decades, and warn against use of water in these areas for gardening.

Recommendation 2 - Construction of the Louisiana Avenue/Highway 7 interchange can proceed, as can appropriate and beneficial development of the site. Construction practices during any development should recognize the past use of and current contamination patterns at the site.

Recommendation 3 - Monitor migration of contaminants in the Drift-Platteville and St. Peter aquifers in the site area, for as long as contaminants continue to migrate or for as long as this migration is viewed as a potential problem.

The estimated present value cost of implementing recommendations 1, 2 and 3 ranges from $0.22 million to $0.45 million, depending primarily on the required frequency of monitoring.

Multi-Aquifer Wells

Both on-site and off-site multi-aquifer wells require further evaluation before specific recommendations can be made regarding which wells should be abandoned or reconstructed, with the exception of well W23 and of any other multi-aquifer wells that can allow transport of contaminants into the Mt. Simon-Hinckley. Further evaluation is required because 1) results of a multi-aquifer well inventory recently completed by E.A. Hickok and Associates were not available for this report and 2) Hickok's recent inventory effort may need to be extended in certain areas. Further evaluation should be limited to determining whether sealing or reconstructing multi-aquifer wells is a cost-effective addition to the recommendations of this study.

Specific recommendations regarding multi-aquifer wells are as follows.

Recommendation 4 - Seal well W23 to the surface with grout or bentonite once remaining exploration work is completed.

Recommendation 5 - Explore well W105 to determine its significance as a source of contamination to deep bedrock aquifers, particularly the Mt. Simon-Hinckley. When exploration work is completed, evaluate remedial action for well W105 in a manner similar to the evaluation of well W23 by this study. At this time, it appears that the likely remedial action will be to seal well W105, rather than to use it as a pump-out control well.

Recommendation 6 - Seal or reconstruct all identified multi-aquifer wells that extend to the Mt. Simon-Hinckley aquifer to prevent interaquifer flow into this aquifer, and ensure that the inventory of multi-aquifer wells leading to the Mt. Simon-Hinckley covers all areas of present and foreseen contamination in above-lying aquifers. Continue this as necessary as contaminants in overlying aquifers continue to migrate.

Recommendation 7 - Evaluate the results of Hickok's recent multi-aquifer well inventory in the specific context of this study's conclusions, and expand available information as needed to evaluate the cost-effectiveness of sealing or reconstructing multi-aquifer wells. The particular concern is evaluating the cost effectiveness of sealing or reconstructing multi-aquifer wells that connect the Drift-Platteville, St. Peter, and/or Prairie du Chien-Jordan aquifers.

The estimated present value cost of these recommendations ranges from $0.2 million to $1.1 million, depending primarily on the number of multi-aquifer wells extending to the Mt. Simon-Hinckley that will require sealing or reconstruction.

Municipal Water Supplies

Contamination of aquifers below the St. Peter in the St. Louis Park area only affects the use of ground water from the Prairie du

Chien-Jordan aquifer for municipal water supply. There are two alternatives for meeting PAH criteria for finished water if the untreated water supply exceeds the criteria: providing alternative water supplies and treating contaminated supply water to meet the criteria. The most cost-effective choice between these alternatives, and among options within these alternatives, depends primarily on the criterion established for noncarcinogenic PAH and noncarcinogenic heterocyclic PAH.

If the criterion for noncarcinogenic PAH and noncarcinogenic heterocyclic PAH is established in the high end of the recommended range (about 10 to 400 micrograms per liter), then the cost-effective solution to contamination of municipal supply wells is to reopen all of the municipal supply wells that are currently closed. This conclusion results from the fact that finished water from none of the municipal supply wells that are currently closed exceeds 28 nanograms per liter for total carcinogenic PAH and carcinogenic heterocyclic PAH or about 10 micrograms per liter for total noncarcinogenic PAH and noncarcinogenic heterocyclic PAH. If reopened municipal supply wells subsequently exceed the recommended criteria, then the cost-effectiveness of alternative drinking water supplies versus drinking water treatment will need to be evaluated.

If the criterion for noncarcinogenic PAH and noncarcinogenic heterocyclic PAH is established in the low end of the recommended range (from 4 to about 10 micrograms per liter), then the most cost-effective solution is either to provide alternate drinking water supplies by drilling new Mt. Simon-Hinckley wells or to treat contaminated supply water by injecting powdered activated carbon or ozone upstream of existing iron removal treatment plants. Injection of either powdered activated carbon or ozone appears to be feasible and cost-effective, but sufficient design data are not available to show this conclusively. In the event that powdered activated carbon or ozone injection are found to be infeasible, or much more expensive than predicted, then new Mt. Simon-Hinckley wells will be required, because granular activated carbon treatment is clearly not cost-effective compared to this alternative.

Independent of cost considerations, the alternative of drilling new Mt. Simon-Hinckley wells has the advantages of being implemented immediately without major additional study and of providing a water supply unaffected by PAH contamination, which is consistent with the basic precept in drinking water supply of using the best available source of water. However, this alternative constitutes abandonment of a limited area of the Prairie du Chien-Jordan for its value as a high-quality drinking water supply. The treatment alternative has the advantage of providing a de facto gradient control well system to limit the further migration of contaminants in the Prairie du Chien-Jordan aquifer.

The available toxicologic data indicate that no significant reduction in health effects risks would be achieved by a criterion below 100 micrograms per liter for total noncarcinogenic PAH and noncarcinogenic heterocyclic PAH. However a criterion as low as 4 micrograms per liter may be required to prevent taste and odor effects. If a noncarcinogenic criterion less than 4 micrograms per liter were established, based on the philosophy that communities should be provided with finished water that is comparable to finished water in other areas, then the solution to municipal supply well contamination will be driven towards the use of new Mt. Simon-Hinckley supply wells. This is true since powdered activated carbon or ozone injection become more expensive as the criterion is reduced, and may ultimately become infeasible, if the criterion is reduced to tenths of micrograms per liter. The only feasible treatment alternative for meeting a very low criterion for noncarcinogenic PAH and noncarcinogenic heterocyclic PAH is granular activated carbon, which is much more expensive than using new Mt. Simon-Hinckley wells.

Given the above considerations of the cost and effectiveness implications of a criterion for noncarcinogenic PAH and noncarcinogenic heterocyclic PAH, this study makes the following recommendations.

Recommendation 8 - Establish criteria for concentrations of PAH and related compounds in finished drinking water that are adequate to protect the public health, and monitor and enforce

these criteria in an open, consistent, and equitable fashion. Recommended criteria are that 1) the total concentration of a specific list of carcinogenic PAH and carcinogenic heterocyclic PAH not exceed 28 nanograms per liter (parts per trillion) and 2) the total concentration of a specific list of noncarcinogenic PAH and noncarcinogenic heterocyclic PAH not exceed a value established in the range of 4 to 400 micrograms per liter (parts per billion). The relative cost and effectiveness associated with meeting a noncarcinogenic criterion are important considerations in establishing such a criterion.

Recommendation 9 - If a criterion for noncarcinogenic PAH and noncarcinogenic heterocyclic PAH is established in the higher end of the recommended range (greater than about 10 micrograms per liter), then reopen and use all municipal supply wells that are currently closed as a result of PAH contamination. If finished water from these wells subsequently exceeds the criteria, then evaluate and implement the most cost-effective alternative that satisfies the supply shortfall. If a criterion for noncarcinogenic PAH and noncarcinogenic heterocyclic PAH is established in the lower end of the recommended range (less than about 10 micrograms per liter), then evaluate and implement the more cost-effective alternative between using new Mt. Simon-Hinckley wells and providing additional treatment at existing iron removal plants. This evaluation must focus on the optimal management of municipal water supply among multiple wells and the feasibility, design, and cost of adding powdered activated carbon or ozone injection at existing iron removal treatment plants.

The estimated present value cost of implementing recommendations 8 and 9 is from $0.9 million to $2.3 million if new Mt. Simon-Hinckley wells are used and from $0.6 million to $1.9 million if powdered activated carbon or ozone injection at existing iron removal treatment plants is implemented (including costs required to evaluate such treatment). The ranges in these estimated costs reflect uncertainties in the design and costing of these alternatives, and are based on a criterion for noncarcinogenic PAH and noncarcinogenic heterocyclic PAH

in the lower end of the recommended range. The present value cost of meeting a noncarcinogenic criteria in the higher end of the recommended range is uncertain because of uncertainties in predicting when municipal supply wells would exceed such a criterion, if ever. At worst, the cost would be no more than the costs associated with a lower criterion. At best, municipal supply wells would never exceed the criteria.

Any solution for achieving the objective of safe and adequate municipal water supplies in the St. Louis Park area will require regular monitoring of municipal supply wells to ensure compliance with the recommended criteria for PAH and heterocyclic PAH. Such monitoring will also provide data for tracking the migration of contaminants in deep aquifers. Specific monitoring recommendations are as follows.

Recommendation 10 - Monitor municipal supply wells in St. Louis Park, Hopkins, and Edina for compliance with the recommended PAH criteria at specified frequencies, depending on existing and predicted future levels of PAH contaminants in these wells.

Recommendation 11 - Establish and implement procedures for maintaining records of all ground-water monitoring data (including data from the Drift-Platteville and St. Peter aquifers per Recommendation 3) and reviewing, evaluating, and publicly reporting monitoring results.

The estimated present value cost of these monitoring actions ranges from $0.6 million to $1.2 million, depending on the frequency of compliance monitoring and the criterion established for noncarcinogenic PAH and heterocyclic PAH. Compliance monitoring costs associated with new Mt. Simon-Hinckley wells are $0.2 million to $0.3 million less than those associated with drinking water treatment, if one of these actions is required.

The total estimated present value cost of all recommended action is from $1.9 million to $4.5 million if a noncarcinogen criterion is established in the low end of the recommended range (below about 10

micrograms per liter). A criterion at the high end will probably reduce total costs by at least $1.0 million.

Contingency Actions

This study recommends three specific contingency actions to be evaluated for reliability and cost-effectiveness in response to specific circumstances, particularly if contaminant migration is found in the future to occur at significantly faster rates and in substantially different directions than predicted by this study. These recommendations are as follows.

Contingency Action 1 - If further evaluation of the significance of contaminant transport by multi-aquifer wells connecting the Drift-Platteville, St. Peter, and/or Prairie du Chien-Jordan indicate that it is cost-effective to prevent such transport, then such wells should be sealed or reconstructed.

Contingency Action 2 - If future ground-water monitoring data indicate that PAH contaminants in the Prairie du Chien-Jordan are migrating substantially faster or in different directions than predicted by this study, then the cost-effectiveness of installing gradient control wells in the Prairie du Chien-Jordan should be re-evaluated. This contingency is of more concern if new Mt. Simon-Hinckley wells are used to satisfy municipal water supply shortages, because treatment of contaminated municipal wells will limit the migration of contaminants in the Prairie du Chien-Jordan.

Contingency Action 3 - If future ground-water monitoring data indicate that contaminants in the Drift-Platteville are migrating substantially faster or in different directions than predicted by this study, then a gradient control well scheme and/or removal of the ground fluid body should be implemented if this is shown to be cost-effective.

The present value cost of implementing all of these contingency actions is from $1.9 million to $3.6 million. This range largely

reflects uncertainties in the design of a gradient control well system and in the number of multi-aquifer wells requiring sealing or reconstruction. In order to arrive at a current present value cost, the future cost of any contingency action must be discounted by the number of years into the future that any such action will be required. As an example, actions taken in 20 years are discounted by 62 percent and actions in 50 years are discounted by 91 percent.

Superfund Studies

The results of this study indicate that many of the studies and activities planned for the $2.0 million in Superfund monies recently allocated to the Minnesota Pollution Control Agency for the St. Louis Park problem are unnecessary or not cost-effective. In particular, further studies of remedial actions for treating, removing, or containing contaminants at the site are unnecessary because these alternatives have already been evaluated in detail by this study. Modeling and testing of gradient control well systems are not required because this study has shown that such systems are not cost-effective at the present time. Further evaluation of drinking water treatment is unnecessary, unless powdered activated carbon or ozone injection is selected as the desired means to achieve a low criterion for noncarcinogenic PAH and heterocyclic PAH. The results of this study indicate that at least $1.0 million - and perhaps close to the full $2.0 million - of the planned Superfund expenditures could be used for implementing the recommendations made this study.

1.0 PURPOSE

Reilly Tar & Chemical Corporation (RT&CC) operated a creosote wood preserving plant and coal tar refinery in St. Louis Park, Minnesota from 1917 to 1972. In 1972 the plant site was sold to the City of St. Louis Park, and the plant was removed. The 80 acre site was subsequently converted to a variety of productive uses, including an apartment complex, some commercial buildings, a new roadway, a storm sewer system, and a large open park-like area. Contamination, by creosote and coal tar-like materials, of soil, shallow ground water, and a deep bedrock well have occurred at the site. Also, certain coal tar-like chemicals have been found in portions of deep bedrock aquifers in the St. Louis Park area. The discovery of these chemicals in some municipal drinking water supply wells has caused well use to be discontinued. The soil and ground-water contamination problems have prompted many technical studies since the late 1960's, but few actions have been taken to date to remedy the problem.

Environmental Research & Technology, Inc. (ERT) has been retained by the law firm of Dorsey & Whitney to provide technical support to RT&CC in litigation that has arisen from the contamination problems related to RT&CC's former operations in St. Louis Park. In addition, ERT has been asked to produce a report that describes the scope of the contamination problems in St. Louis Park, defines a specific set of objectives to be met in addressing these problems, and proposes a specific plan of action to provide a comprehensive solution to these problems. This report is intended to serve that purpose, based on the conclusion that there has been sufficient study of the problem, by a number of investigators, to be able to propose a set of specific actions and to propose focused additional studies that will satisfy a specific and carefully-defined set of objectives. This report reflects information available to ERT as of April 4, 1983.

2.0 BACKGROUND

The ground-water and soil contamination problem in St. Louis Park has been linked to operations of the former RT&CC coal-tar refinery and creosote wood-preserving plant. It has been shown by several investigators that coal-tar-like material is present in the ground water and soil in the vicinity of the plant site. Futhermore, ground-water contamination by PAH in deep aquifers in the St. Louis Park area has resulted in the forced closing of several public water supply wells. To better understand the complexity of this problem and its solution, it is important to have a general understanding of the background to the contamination problem, including a historical perspective of the use of the land that is believed to be the source of contamination.

This background chapter includes brief reviews of the historical uses of the site; of coal tar refining and wood preserving operations at the former RT&CC St. Louis Park plant; of the ground-water resources, uses, and contamination problem in St. Louis Park; and of past studies and investigations that have been performed to aid in solving the problem at St. Louis Park.

Several terms are used throughout this report and the appendices to designate specific areas within the St. Louis Park vicinity. The areas and general boundries are defined below (see Definition of Terms for a more complete definition) and are illustrated in Figure 2-1.

- Plant Site - The land that was formally the site of the RT&CC creosote wood preserving and coal tar refinery plant.

- Bog - The land immediately south and adjacent to the plant site which received runoff and plant waste discharges.

- Site - The plant site and bog together.

- Site Area - An area around the site as shown in Figure 2-1.

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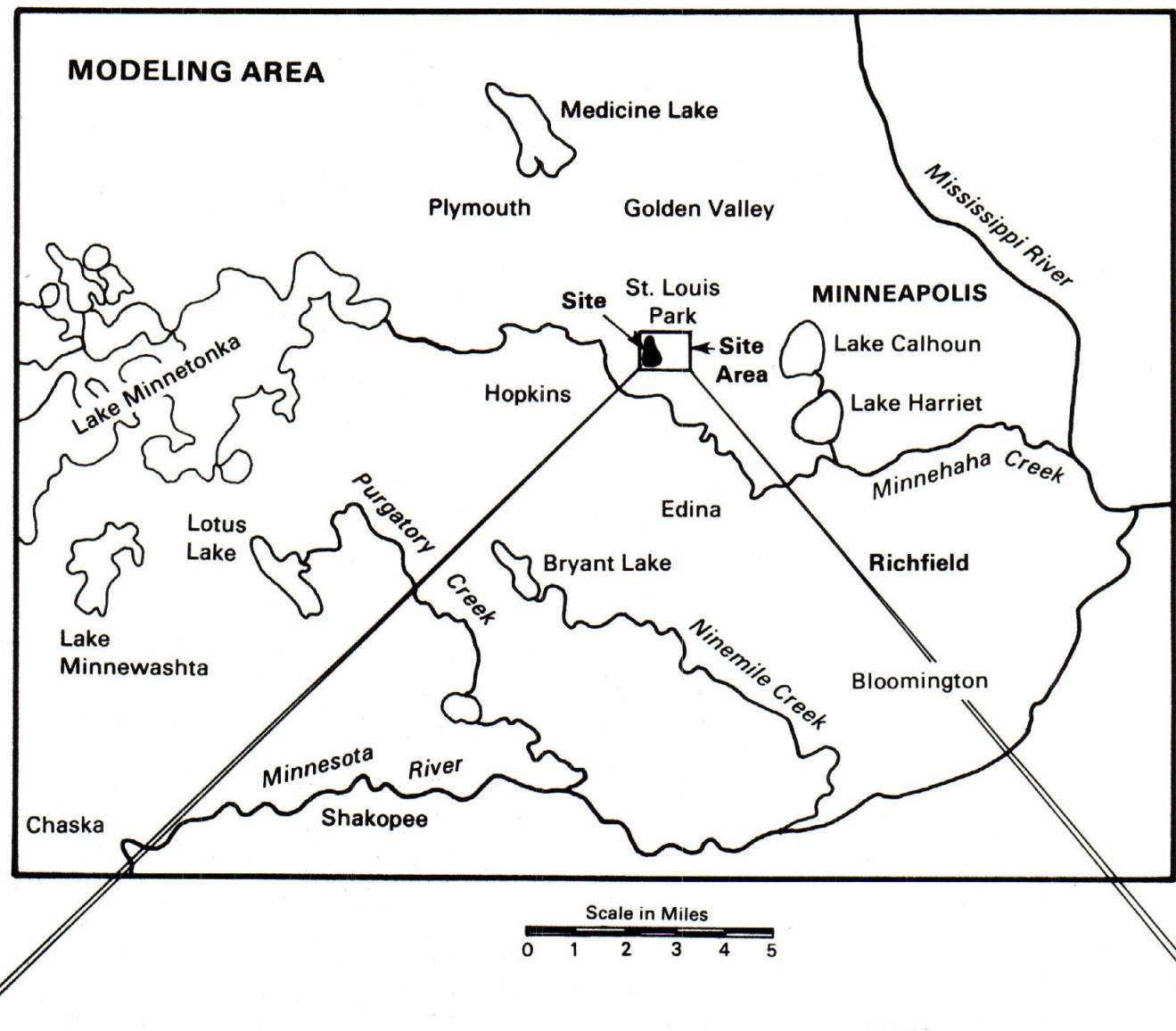


HT177

NON-RESPONSIVE

[redacted]

Figure 2-1 Definition of Subdivisions Within the Overall Area of Investigation

- Modeling Area - The area that was modeled in this study to describe ground-water flow hydraulics. The area is approximately centered on the site. It is an area of 22 miles east to west, and 16 miles north to south.

2.1 Historical Use of the RT&CC Plant Site

The following discussion of plant site use is divided into two time periods, 1) prior to 1905 when a sugar beet refinery was located on the plant site, and 2) from 1917 to 1972 when RT&CC owned and operated a creosote wood preserving plant and coal tar refinery. The use of the plant site following the closing and razing of the RT&CC plant is discussed in section 2.2. A more detailed description of the history of the plant site and RT&CC's plant operations is provided in Appendix A.

2.1.1 Plant Site Use Prior to 1905

A sugar beet refinery was first built on the plant site in 1897 by the Minnesota Beet Sugar Manufacturing Company (Thomas undated). The sugar beet plant consisted of six large brick buildings on approximately 36 acres and employed about 400 men.

In 1899, the Minnesota Beet Sugar Manufacturing Company was accused of polluting Minnehaha Creek (Washburn vs. Minnesota Beet Sugar Manufacturing Company 1899). The magnitude of this pollution is not known; however, it is known that roughly 2000 gallons per minute of ground water was used by the sugar beet plant, and a large percentage of this water was probably discharged from the plant after use in various sugar beet refining operations. The quality of this wastewater is unknown, but based on current industry data, these wastewaters may have contained substantial quantities of phenolics, total organic carbon, and biochemical oxygen demand (Brenton and Fischer 1970). It is probable that some of this wastewater percolated down through the soil of the plant site drainage ditch and contaminated the ground water and soil.

In 1905, the Minnesota Beet Sugar Manufacturing Company closed the St. Louis Park plant, and from 1905 to 1917 the plant site remained unused.

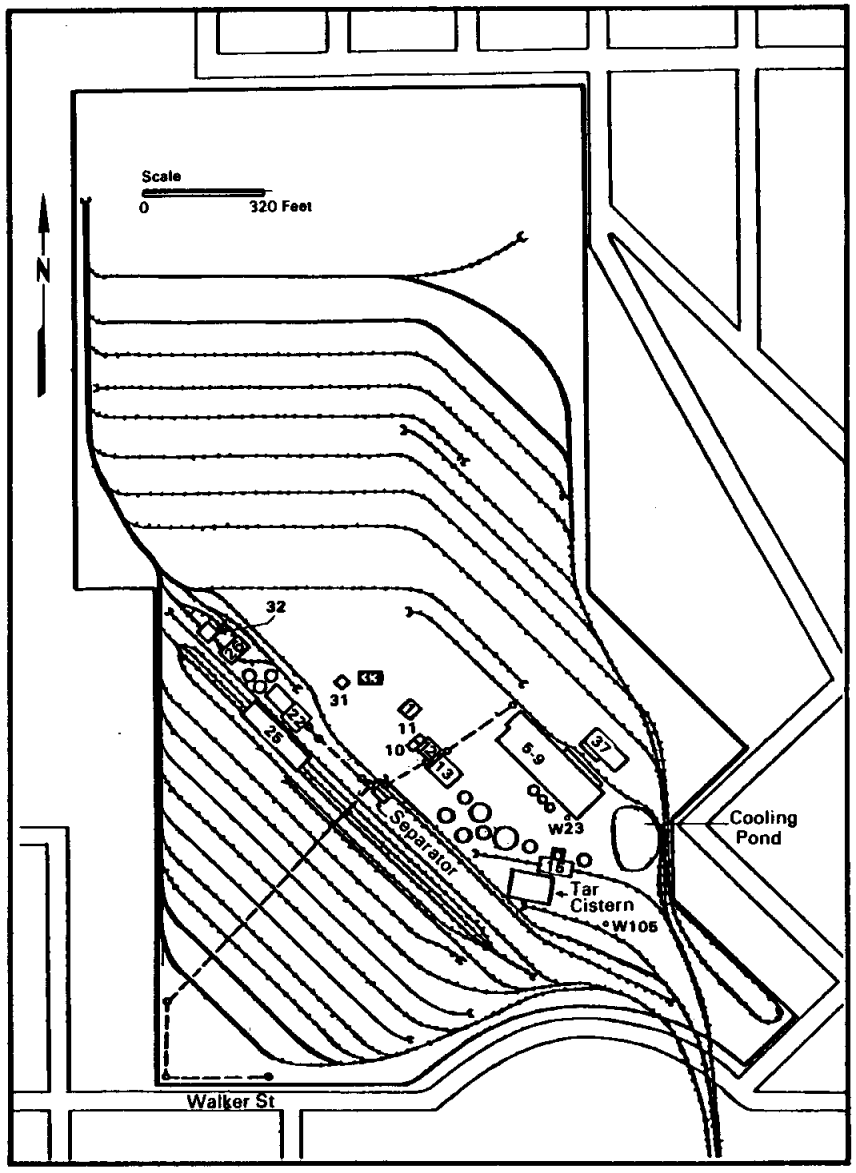
2.1.2 Plant Site Use From 1917 to 1972

From 1917 to 1972, RT&CC owned and operated a coal tar refinery and wood preserving plant on the plant site. Creosote, coke, refined tars, pitches, and other coal tar refinery by-products were produced at the refinery. Railroad ties, timber, poles, pilings, and various types of posts, blocks, etc. were preserved using the creosote produced from the coal tar refinery. The magnitude of these operations is shown in Figure 2-2, an aerial photograph of the plant site taken in the 1950's. The road in the foreground is Walker Street, and the large warehouse in the lower right hand corner was originally part of the sugar beet plant. As can be seen in the photograph, much of the site was used to stockpile untreated and treated wood products. Figure 2-3 is a sketch of the plant site based on a 1944 blueprint.

Coal tar was refined by batch distillation. The distillate cuts collected were called wet cut, light oil, middle oil, and heavy oil. The wet cut, consisting of water present in the coal tar, was vaporized or discharged to the plant site drainage ditch during the early years of plant operation. Later, the wet cut was treated before being discharged from the plant. The light oil cut was used as feedstock for the by-products plant. The middle and heavy cuts were blended with acid-free light oil from the by-products plant to produce creosote.

About 1950, the by-products plant was closed. The primary refinery products after 1950 were soft pitch, anode pitch, refined tars, and creosote oil. During the 1960's, the light oil cut was blended with the middle and heavy cuts to produce creosote.

Figure 2-2 RT&CC Plant, 1950's



RT&CC PLANT SITE BUILDING IDENTIFICATION

Description	Building No.
Office and Laboratory	1
Refinery	5-9
Blacksmith Shop	10
Locker and Change Room	11
Garage	12
By-Products Building	13
Tar Shed	15
Tank House	21
Boiler House	22
Treating Building	25
Adzing and Boring Mill	26
Garage	31
Wash Room	33
Tool House	37

EXPLANATION

- Narrow Gauge RR Track
- Standard Gauge RR Track
- Standard/Narrow Gauge RR Track
- Sewer Lines

Figure 2-3 Plant Site Drawing From 1944 Blueprint

In the by-products plant, the light oil cut was washed with caustic and a solution of sodium carbonate to produce acid-free light oil. The spent sodium carbonate solution was treated with sulfuric acid to liberate acids, and the resultant sodium sulfate solution was washed with naphtha or light oil to remove emulsified oils and discharged from the plant. In 1941, a phenol extraction unit was added to plant operations to reduce phenolic levels in the waste stream.

Raw wood products were readied for creosote treatment using a variety of pretreatment methods including seasoning, incizing, adzing, boring and water removal. Creosote preserving of raw wood products took place in three treatment cylinders using the Rueping or Lowery processes. Both processes use pressure treating methods to preserve wood products. After treatment, the wood products were stored in the yard or shipped to customers.

Waste discharges from the RT&CC refinery and wood preserving operations have been documented in various plant records (Appendix A). The following is a summary of waste streams that were discharged from the plant at various times during the life of the plant:

- waters from benzol separation tanks, tar acid distillation, tar cistern, laboratory sinks;
- sulfate water from springing operations;
- cooling water;
- boiler blowdown;
- tank farm trench water;
- treating cylinder waste; and
- storm water runoff.

The majority of waste discharges from the plant were intermittent flows originating from batch operations. Long-term flow records are unavailable, although plant records for 1938 to 1940 indicate that a total of 1,000 gallons per month of tar distillation water and about 6,000 to 12,000 gallons per month of sulfate water were discharged from the plant. Discharges occurred several times per month. The wet cut was discharged from the plant on a more continuous basis (12 times per week) and totalled about 4,800 gallons per month.

The quality of wastewater discharged from the plant is not well documented, but data are available to characterize the quality of the wastewater in the drainage ditch leaving the plant site boundary (Table 2-1). These analytical data were collected by the Minnesota Department of Health in 1938 and by the State and City of St. Louis Park in the late 1960's. At best, the results characterize the discharge from the RT&CC plant qualitatively because of the sample locations and the variety of analytical procedures employed. Regardless, the results show that phenolics and oil and grease were present in the RT&CC plant discharge. Similar to the sugar beet plant discharge, it is probable that some of this wastewater percolated down through the soil of the drainage ditch and contaminated the ground water and soil.

From 1917 to 1939, all plant wastewaters from the refinery, by-products, and wood preserving plant were discharged untreated via the drainage ditch into the bog south of the plant site. The water from the bog discharged into Minnehaha Creek via a culvert under Lake Street until about 1930, when the culvert collasped, thus restricting the flow into Minnehaha Creek.

Major wastewater treatment units were installed at the RT&CC plant in 1940 and 1941. A phenol extractor and waste separator were installed to treat various wastewaters from the refinery. An oil/water separator was installed at the wood preserving operation. Tar acid distillation water was no longer discharged but reused in the plant. In 1950, the phenol extraction unit was presumably closed down when the by-products plant was closed. Straw filters were added to the separator outlet in 1951 and were also installed in the Walker Street drainage ditch in 1968. These measures undoubtedly reduced the contaminant load discharged from the plant. The sampling and analytical results presented in Table 2-1 show improved water quality in the late 1960's and early 1970's compared to 1938 and 1940.

In summary, waste discharges from the RT&CC coal tar refinery and creosote wood preserving plant were discharged from the plant via a drainage ditch which led to the bog south of the plant and eventually

TABLE 2-1

QUALITY OF DRAINAGE DITCH WATER LEAVING
RT&CC PLANT SITE

Date Sampled or Reported	Laboratory/Agency (a)	Concentration Milligrams per liter	
		Phenolics	Oil & Grease
5/19/38	MDH	50	-(b)
7/38	UNKNOWN(c)	62.5	-
8/27/38	RT&CC(c,d)	109	158
11/7/38	RT&CC(d)	-	106
11/9/38	RT&CC(d)	-	436
11/7 - 9/38 Composite	RT&CC(c,d)	112	130
11/18/38	RT&CC(c,d,e)		
11:20 am		213	784
1:30 pm		1180	2260
2:30 pm		1640	1580
3:30 pm		1050	1360
5/10/40	SLP(c)	127	-
	RT&CC(c)	146	-
6/6/40	SLP(c)	30	-
	RTC(c)	82	-
5/9/68	TCT	20	207
6/13/68	MPCA	130	-
6/24/68	TCT	13	25
8/1/68	MPCA	140	-
11/15/68	TCT	1.4	3
1/20/69	TCT	0.5	1
12/21/69	TCT	0.56	1.6
4/14/70	MPCA	150	-
4/18/70	UNKNOWN	1110	-
9/3/70	TCT	3.5	-
10/29/70	CWR	9.8	-
10/29/70	MI	13.0	-
12/9/71	MPCA	140	140
7/21/72	MSB	7.5/11.5	41/41

a) The following laboratories or government agencies conducted or reported results:

MDH - Minnesota Department of Health
RT&CC - Reilly Tar & Chemical Corporation
SLP - St. Louis Park
TCT - Twin Cities Testing
MPCA - Minnesota Pollution Control Agency
CWR - C. W. Rice Company
MI - Mellon Institute
MSB - Metropolitan Sewer Board

b) A dash means parameter not analyzed.
c) Phenolics determined by Chapin method.
d) Oil & Grease determined by extraction with ether.
e) Samples collected while hot sulfate water was being discharged from plant.

into Minnehaha Creek. Samples of drainage ditch water collected from 1938 to 1972 show the presence of phenolics and oil and grease. Phenolics were probably also present in the discharge from the sugar beet refinery which operated prior to the RT&CC plant. Wastewater treatment was installed at the RT&CC plant in the early 1940's, and from all indications, this treatment reduced the levels of phenolics and oil and grease discharged from the plant. In 1972 the RT&CC plant was closed and removed.

2.2 Current Characteristics of the Site

In 1972, the RT&CC plant buildings and other structures were demolished, below-grade structures were removed, voids filled, the plant site leveled, and the land sold to the City of St. Louis Park. Since 1972 the site has been involved in four major non-industrial construction projects. In 1973, a storm water runoff collection system was installed, which included the construction of a lined holding pond in the southern portion of the plant site. In 1976, construction of condominiums on the northern portion of the plant site began. In 1977, plans to extend Louisiana Avenue through the site were proposed and construction initiated. The extension is complete but the intersection with Highway 7 is not because of suspected complications associated with its construction near the bog. In 1980, a bowling alley was built on the eastern edge of the plant site. These current features of the plant site are shown in Figure 2-4, an aerial photograph of the site taken in November 1982.

The condominium complex located in the northern portion of the plant site is called Oak Park Village. The complex is surrounded with paved parking areas and grassy fields. The lined surface runoff pond is located to the south and west of Oak Park Village and is used as a storm water runoff collection pond. The pond discharge is routed to the south and empties into another collection pond before being discharged into Minnehaha Creek. Louisiana Avenue runs approximately north and south along the eastern edge of the plant site and is a four lane divided road. The Park Tavern, a combination bowling alley and lounge/restaurant, was constructed along Louisiana Avenue and just across from well W23. In the southwestern corner of the plant site

Figure 2-4 Aerial Photograph of Site, November 26, 1982

and just west of the pond is a stockpile of soil excavated from construction projects on the plant site. This stockpile of soil is presumed to be contaminated; however, the magnitude of this contamination and the contaminants present are unknown.

2.3 Ground-Water Resources and Use in the St. Louis Park Area

The ground water in the St. Louis Park area is a valuable resource used extensively by local communities as a source of drinking water. Ground water is also used for a variety of industrial purposes, and there are numerous industrial wells in the area. In addition, there are numerous shallow residential wells used for drinking water and other household uses.

There are five major aquifers underlying the St. Louis Park area. Their names and approximate depth beneath St. Louis Park are as follows:

		Approximate Depth (feet)
1)	Mt. Simon-Hinckley	830 - 1100
2)	Ironton-Galesville	700 - 750
3)	Prairie du Chien-Jordan	260 - 500
4)	St. Peter	90 - 200
5)	Drift-Platteville	0 - 90

Table 2-2 presents the average annual pumpage of major public and private industrial wells for each aquifer in the St. Louis Park area, based on pumpage during the 1970's. The pumpage reported in this table is for those wells considered for this study's analysis of ground-water flow hydraulics and ground-water model development (see Appendix E for details).

The Prairie du Chien-Jordan aquifer is the most heavily used aquifer, with a total of 51 major wells in the study area. The communities of St. Louis Park, Hopkins, Edina, Bloomington, Minnetonka, Plymouth, Eden Prairie, Richfield, and Robbinsdale have drinking water supply wells in this aquifer. Ten of St. Louis Park's fourteen municipal wells are located in this aquifer, accounting for

TABLE 2-2

SUMMARY OF MAJOR GROUND-WATER PUMPAGE IN THE MODELING AREA

Aquifer	Number of Wells		Approximate Annual Pumpage Millions of Gallons [a]		Percent of Grand Total Annual Pumpage
	Municipal	Private	Municipal	Private	
Mt. Simon-Hinckley	6[b]	0	1900	0	16.6
Ironton-Galesville	0	0	0	0	0
Prairie du Chien-Jordan	36	15[c]	7400	2000	80.4
St. Peter	1[d]	0	60	0	0.5
Drift-Platteville	3	0	290	0	2.5
Totals	46[b]	15	9650	2000	100

a) Data are for selected years in the period of 1971 through 1979. Pumpage based on Hult and Schoenburg (1981) for 1976, Minnesota Department of Natural Resources (1981) for 1978 and 1979, and Guswa et al. (1982) for 1971 through 1977.

b) This does not include an unknown number of additional wells whose pumpage is given by Guswa et al. (1982) with no indication of whether the wells are private or municipal.

c) Includes three wells (W45, W46, and W62) which are also open to the St. Peter.

d) This well (SLP3) is also open to the Platteville.

approximately 75 percent of the City's supply. Three of these wells are large capacity wells that provide nearly half of St. Louis Park's total supply: SLP6, SLP8, and SLP16 pumped a total of approximately 1200 million gallons out of 2500 million gallons pumped by St. Louis Park in 1976. Fifteen of the 51 Prairie du Chien-Jordan wells are used for industrial purposes. The total pumpage of the Prairie du Chien-Jordan in the modeling area in 1976 was approximately 9400 million gallons.

The Mt. Simon-Hinckley aquifer is the second-most used aquifer and contains thirteen major wells in the modeling area. The St. Peter and Drift-Platteville aquifers contain four major wells in the modeling area. No major wells are located in the Ironton-Galesville Aquifer in the modeling area.

2.4 Ground-Water Contamination in the St. Louis Park Area

Problems with ground-water contamination were first brought to public attention in 1932 when St. Louis Park drilled its first drinking water supply well. This well (W112), drilled in the Prairie du Chien-Jordan, was closed two weeks after being opened because of taste and odor problems. During the 1930's and 1940's, several residents living near the plant site complained of taste and odor problems in their private, Drift-Platteville wells; however, the Minnesota Department of Health (MDH) said the water was safe to drink. The MDH continued routine monitoring of well water, but it was not until 1970 that the MDH began testing for phenolics. Most of the well samples analyzed for phenolics showed levels below the analytical detection limit of 2 micrograms per liter (parts per billion); however, some wells showed levels in the tens of micrograms per liter range, and some wells drilled in the bog, south of the plant site, showed phenolic levels in the milligram per liter (parts per million) range.

Six of the fourteen St. Louis Park wells are currently closed because of observed or expected PAH contamination. The St. Louis Park wells closed and their date of closure are as follows:

Well	Closure Date
SLP7	November 1978
SLP9	November 1978
SLP10	November 1978
SLP15	November 1978
SLP4	December 1979
SLP5	August 1981

St. Louis Park wells SLP7, SLP9, SLP10, and SLP15 were closed in November 1978 by the Minnesota Department of Health, after elevated levels of PAH were found in untreated well water from SLP10 and SLP15. Wells SLP7 and SLP9 were closed out of concern they would also become contaminated (Englund 1982). In December 1979, well SLP4 was also closed because of elevated PAH concentrations. In August 1981, well SLP5 was closed because well water exceeded the 280 nanograms per liter (parts per trillion) total non carcinogenic PAH guideline, which was unofficially established by the Minnesota Department of Health. Hopkins well H3 was also closed in March 1981 for the same reason as well SLP5. The above six well closures accounted for roughly 20 percent of St. Louis Park's total water supply in the 1970's. The city of St. Louis Park has increased pumping rates at existing wells, instituted use restrictions during the summer, and made interconnections with the City of Plymouth to increase their water supply. A new well is currently under construction and is being drilled in the Mt. Simon-Hinckley aquifer (SLP17).

2.5 Efforts to Solve the St. Louis Park Area Problem

The St. Louis Park problems has recieved a great deal of attention and study, particularly since the late 1960's, but few actions have been taken to remedy the problem. Table 2-3 provides a chronological listing of pertinent reports since 1969. Early efforts to solve the St. Louis Park problem involved field studies to determine the extent of contaminated soil and ground water at the site. As outlined in Appendix B, several soil boring projects were performed at the site during the early to middle 1970's that included collecting soil

TABLE 2-3

CHRONOLOGICAL LISTING OF
STUDIES RELEVANT TO THE ST. LOUIS PARK PROBLEM

Date	Study	Author
9-0-69	Ground Water Investigation Program at St. Louis Park, MN (Progress Report 1)	Eugene A. Hickok & Associates, Inc.
10-13-69	Preliminary Soils Investigation, 80 Acre Site W. of 2nd St. NW and Republic Ave.; St. Louis Park, Republic Creosoting Co.	Soil Engineering Services, Inc.
4-22-70	Memorandum of Waste Disposal at Republic Creosote Co. and Reilly Tar & Chemical Co.	Minnesota Pollution Control Agency (MPCA)
11-2-70	Mellon-Rice Phenolics Data on Well Samples	Carnegie-Mellon University & C. W. Rice Division, NUS
1971,1973	Analyses of soil samples	Tri City Public Health Lab (St. Louis Park)
8-1-72	An Assemblage of Analytical Data Regarding the Reilly Tar & Chemical Property, St. Louis Park, MN	St. Louis Park Health Dept.
1-11-73	Status Report on Creosote Site and Texa-Tonka Area	(St. Louis Park) Planning Dept.
4-23-73	Surface & Subsurface Ground Reclamation; Republic Creosote Site, City of St. Louis Park	OSM Consulting Engineers

TABLE 2-3 (continued)

Date	Study	Author
4-23-73	Surface and Subsurface Ground Reclamation; Republic Creosote Site, City of St. Louis Park.	OSM Consulting Engineers
8-6-73	Storm Water Study; Public Improvement #72-43 (Republic Creosote Area)	OSM Consulting Engineers
1973-1981	Intermittant Analyses for phenolics in area wells	Minnesota Department of Health (MDH)
0-0-74	Investigation of the Phenol Problem in Private and Municipal Wells in St. Louis Park	Minnesota Department of Health (MDH)
3-0-74	Geology of the St. Louis Park Area - A Review by the MN Geological Survey; Report on Investigation of Municipal Water Supply, St. Louis Park.	Minnesota Department of Health (MDH)
5-16-74	Soil Investigation; Proposed Storm Sewer and Holding Ponds Near Hwy. 7 and Louisiana Ave., St. Louis Park	Soil Exploration Co.
7-0-74	Hydrogeologic Study of the Republic Creosote Site	Gerald Sunde, Consulting Engineer
11-15-74	Data re: The History and Development of a Storm Sewer System for the City in the Area of the Former Republic Creosote Prop.	City of St. Louis Park
11-19-74	Memorandum on Ground Water Contamination, St. Louis Park, MN	Minnesota Pollution Control Association (MPCA)
1974,1981-1982	Soil and water analyses	Twin Cities Testing and Engineering Laboratory, Inc.
11-14-75	St. Louis Park Creosote Contamination Study	Minnesota Department of Health (MDH)
1975	Soil & water analyses	Sanitary Engineering Laboratories, Inc.(SERCO)

TABLE 2-3(continued)

Date	Study	Author
5-0-76	Soil and Ground Water Investigation Coal Tar Distillation and Wood Preserving Site, St. Louis Park (Barr Engineering - Phase I Report)	Barr Engineering Co.
6-0-76	Stability Study of Para-Benzo Quinone for the City of St. Louis Park	SERCO
9-17-76	Soil Boring & Chemical Analysis of the Northern Portion of Oak Park Village	National Biocentric, Inc.
12-2-76	Development Plan, Northern Portion, Oak Park Village	St. Louis Park
12-28-76	Memorandum: Review of Recent Studies of Soil Contamination at the Former Republic Creosote Site - Recommendations to City's Proposed Development Plan.	Minnesota Pollution Control Agency (MPCA)
6-0-77	Soil & Ground Water Investigation, Coal Tar Distillation and Wood Preserving Site, St. Louis Park (Barr Engineering - Phase II Report)	Barr Engineering Co.
10-0-77	Assessment of Possible Human Health Effects Resulting from Contamination of the Former Republic Creosote Site.	Minnesota Department of Health (MDH)
1977,1981	Water analyses for PAH	United States Environmental Protection Agency
1-5-78	Soil Report; Proposed Oak Park Village, St. Louis Park, MN	Soil Testing Services of MN, Inc.
1-11-78	Recommendations for Plugging or Modification of Abandoned Wells in the Area of the Former Republic Creosote Plant.	St. Louis Park

TABLE 2-3(continued)

Date	Study	Author
3-0-78	Soil Borings for Louisiana Avenue Extension	Soil Exploration Co.
3-0-78	Results of Laboratory Analysis, St. Louis Park Soil Borings	SERCO
6&7-78	Report of Well Water Survey St. Louis Park, MN	SERCO
7-1-78	Report on the Existing Creosote Problem in St. Louis Park, MN	James Bailey, Agricultural Engineer, U. of M.
10-0-78	Soil Borings for Building Locations on Site	Soil Exploration Co.
10&11-78	Report of Soil Sampling, City of St. Louis Park	SERCO
1978-1983	PAH analyses in area well	Minnesota Department of Health (MDH)
11-0-78	Health Implications of Polynuclear Aromatic Hydrocarbons in St. Louis Park Drinking Water	Minnesota Department of Health (MDH)
11-14-78	Status Report to the MPCA: Proposed Development, Oak Park Village.	City of St. Louis
12-15-78	Water Quality Development in Oak Park Village	St. Louis Park
1978-1979	Water analyses	Pace Laboratories, Inc.
1978-1982	Contaminant transport experiments	University of Minnesota
2-6-79	Report Tabulating Information on Four Existing Wells in St. Louis Park (Not Titled)	United States Geological Survey, Water Resources Division (USGS)
3-27-79	Status Report: St. Louis Park Development	Minnesota Pollution Control Agency (MPCA)

TABLE 2-3 (continued)

Date	Study	Author
4-13-79	Progress Report: Investigation of Coal Tar Derivatives in Ground Water-St. Louis Park	USGS
1979,1982	Soil Investigations	Braun Engineering Co.
1-11-80	Summary Report on the City of St. Louis Park Activated Carbon Pilot Plant Study-July & October, 1979	SERCO
1-0-81	Preliminary Evaluation of Ground Water Contamination by Coal Tar Derivatives, St. Louis Park Area, MN	USGS in cooperation with MDH
4-0-81	Report on Drinking Water Treatment and Remedy Evaluation for St. Louis Park, MN	Eugene A. Hickok and Associates, Inc.
10-7-81	Results of Analysis of Water Samples, & Soil Samples for Polycyclic Aromatic Compounds (Hydrocarbons, Azagrenes, Phenols)	Midwest Research Institute
11-0-81	Study of Ground Water Contamination in St. Louis Park, MN	Eugene A. Hickok & Associates, Inc., Geraghty & Miller, Inc. and Hennigson, Durham & Richardson, Inc.
1981-1982	Water analyses for PAH	Capsule Laboratories
1-11-82	Terminating an Endless Search: An Action Approach to Solving the Water Problem	St. Louis Park
11&12-0-82	Degradation of Phenolic Contaminants in Ground Water by Anaerobic Bacteria: St. Louis Park, MN	Ehrlich, Goerlitz, Godsy & Hult

TABLE 2-3 (continued)

Date	Study	Author
1982-1983	Evaluation of Ground Water Treatment Alternative	CH2M Hill
1982-1983	Well W23 Invesitgations	E.H. Renner & Sons, Inc. E.A. Hickok & Associates, Inc. and MPCA

samples for subsequent chemical analysis (see Appendix B, Table B2-1). Many of these projects also investigated soil conditions for various construction activities at the site (see Appendix A). For example, in February 1974 Soil Exploration Company performed seventeen soil borings for the City of St. Louis Park to evaluate soil and ground water conditions for the construction of the storm sewer system on the site. Seven samples were taken for analysis of oil, grease, and paraffin. In two projects in June and August of 1976, National Biocentric, Inc. made twenty-two soil borings for the City of St. Louis Park to determine the extent of contamination in the northern portion of the site where construction of Oak Park Village was planned. Nine samples were collected for ethanol extractables as part of this work.

Because the soil boring programs in the early to mid-1970's were limited to specific areas of the site relating to construction projects that were being planned, the results of these programs could not readily be used to define the overall extent of soil contamination of the site. Also, the fact that separate programs used different chemical analyses to define contamination makes it difficult to compare results.

The first study, which evaluated contaminated ground water in the bedrock aquifer system, was made in 1974 by Gerald M. Sunde, a consulting engineer hired by the City of St. Louis Park. Sunde analyzed MDH water quality data and the pumping records for St. Louis Park municipal wells in an attempt to define the problem and provide recommendations. Sunde concluded that the city wells were not detrimentally contaminated with phenolics and that some measured phenolic concentrations could not be attributed to the site. In addition, Sunde concluded that as long as the city wells continued pumping, contaminants would not spread any farther. Sunde recommended that multi-aquifer wells be plugged, that the site be developed to decrease infiltration of surface runoff, and that further study of the area begin with the placement of monitoring wells.

Since the Sunde report, there have been four major studies of the contamination problems in St. Louis Park. All these reports are available to the public:

1) Barr Engineering Company Phase I Report - 1976,
2) Barr Engineering Company Phase II Report - 1977,
3) U.S. Geological Survey Report by Hult and Schoenberg - 1981, and
4) E. A. Hickok & Associates Report - 1981

The 1976 Barr Phase I studies were conducted to begin defining: "1) the vertical and horizontal extent of coal-tar waste in the soils overlying bedrock, 2) the general quality of ground water in the glacial drift, and 3) the interactions between the glacial drift and bedrock aquifers" (Barr 1977). Barr's report concludes by making recommendations for additional studies to define remedial actions.

The Phase II studies conducted by Barr were an extension of Phase I studies and findings. The Phase II report findings were used by Barr to recommend remedial actions. As part of the Phase II studies, Barr placed borings and installed monitoring wells, from which soil and ground-water samples were collected and analyzed. Ground-water and soil samples were analyzed primarily for phenolics and benzene extractable hydrocarbons, although some samples were analyzed for PAH. The Barr Phase II report concludes with the following basic recommendations: 1) grout and abandon multi-aquifer wells and uncased wells near the plant site, 2) install a ground-water gradient control well system for the glacial drift aquifer, 3) install monitoring wells in the St. Peter aquifer beneath the ground fluid body, and 4) conduct further studies to better define the hydrogeology of the St. Louis Park area and to define the potential public health effects of trace levels of phenolics and PAH. The ground fluid body refers to an accumulation of two phase fluid (water and hydrocarbon) in the center of the bog (Chapter 5 and Appendix B).

In 1978, the U.S. Geological Survey (USGS) began a study to better define the ground-water flow system and the transport of organic contaminants in the St. Louis Park area. This study continues. The

single major report published to date as a result of USGS studies (Hult and Schoenberg 1981) discusses possible avenues of contamination from the plant site, ground-water movement in the various aquifers underlying the site, and contaminant movement in relationship to ground-water flow patterns. This report also discusses the possible role that multi-aquifer wells play in transporting contaminants between the aquifers, and emphasizes the role of well W23, the plant supply well, in this respect.

In November 1981, Eugene A. Hickok and Associates prepared a report for the Minnesota Department of Health. This report presents remedial actions for the ground-water and soil contamination problems in St. Louis Park. The report also presents preliminary designs and cost estimates for remedial actions. The Hickok report makes the following recommendations: 1) install a gradient control well system for all aquifers from the Drift-Platteville through the Mt. Simon-Hinckley, inclusive, 2) remove the ground fluid body from the bog, and 3) excavate surficial peat and associated fluid south of the plant site. As an interim measure prior to excavation, Hickok recommends capping the surficial peat.

In March 1982, Hickok contracted with the Minnesota Pollution Control Agency (MPCA) to perform an investigation of well W23 and to perform a survey of other multi-aquifer wells in the St. Louis Park area. The well W23 investigation was designed to determine how the well contributed to the migration of contaminants from the plant site in the past and how best to prevent any future contaminant migration. This work started in June 1982 and has yet to be completed. Hickok's multi-aquifer well survey included a door-to-door search, a file search, and the development of abandonment specifications for wells that were found. This work has been completed, although the results have not been made available for inclusion in this study's analysis.

There have also been a number of studies performed to evaluate treatment methods to reduce PAH contaminants in the raw well water. In 1979, Serco Laboratories conducted studies at St. Louis Park well SLP15 to assess the effect of adding powdered activated carbon at the

well head. In 1980 and 1981, Hickok Associates conducted pilot and bench scale tests to determine the effect of injecting powdered activated carbon at SLP15 and the use of granular activated carbon columns. Four tests were conducted with both forms of carbon. A single test was also conducted to assess the possible use of hydrogen peroxide as a method to reduce PAH levels. In September 1982, CH2M Hill began studies to assess a variety of drinking water treatment methods, including activated carbon, hydrogen peroxide, ozone, macroreticular resins, and the existing iron removal plant at SLP15. Based on results of bench-scale tests, CH2M Hill is recommending pilot-scale testing of granular activated carbon. In December 1982, Environmental Research and Technology Inc. (ERT) began field investigations at SLP15 to assess the effect of the existing iron removal treatment plant to reduce PAH levels. Appendix G presents a summary of the drinking water treatment studies performed to date, including the complete results from ERT's studies.

In February 1981, the MPCA was granted $400,000 under the Superfund program, a program established by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The purpose of the Superfund grant was to help finance the work being done by Hickok as outined above. This money was for 1) investigating and abandoning well W23 and well W105, the sugar beet well on site, 2) the multi-aquifer well survey and abandonment program, and 3) developing a water treatment system for SLP15. This initial grant proved to be insufficient to complete all of the studies for which it was intended. However, on or about January 1, 1983 additional Superfund monies totalling $2.0 million were awarded to the MPCA to continue well abandonment work and to do new studies of source materials on the plant site and in the bog south of the plant site. This work largely remains to be done.

None of the studies mentioned above have yet resulted in a solution to the contamination problems in the St. Louis Park area. This report presents the results of an in-depth study aimed at developing a specific set of recommendations to address all of the various aspects of the St. Louis Park problem. A critical aspect of

this study is the analysis of the cost-effectiveness of various alternatves for solving the contamination problems in the St. Louis Park area. The following chapter discusses the overall approach used in this study to develop a comprehensive solution plan for the contamination problems in the St. Louis Park area.

3.0 APPROACH

The goal of this report is to define the problems at St. Louis Park, define specific objectives and priorities in addressing the problems, identify and evaluate alternative actions to meet the objectives, and recommend the most cost-effective actions from among the alternatives available. The first section of this chapter defines the specific objectives and priorities that have been used in this study as the basis to define the problems at St. Louis Park and to evaluate and select remedies to solve the problems. These objectives are stated at the outset, so that subsequent sections of this chapter and the balance of this report can be understood within a specific and focused context.

The second section in this chapter describes the overall approach taken in this study to define and evaluate alternative solutions to the problems at St. Louis Park. A final section then follows, which generally describes the individual technical elements involved in this study. Since the study addresses a wide variety of technical issues and problems, using a variety of techniques and approaches, the last two sections in this chapter provide an overview of the technical approach and study framework. Summary descriptions of the technical approaches for individual study elements are provided in subsequent chapters, with more detailed descriptions supplied in the technical appendices included with this report.

3.1 Objectives and Priorities

For overall objectives to be useful, they must be precisely defined. With carefully defined objectives, practical and operational definitions can be derived to judge how best to achieve the overall objectives and to determine when they have been achieved. Thus, the first step required, in addressing the problems at St. Louis Park, is to define a clear and specific set of objectives. This step is intimately related to the definition of the problem, since the scope of any problem and the value of any action taken in response depend on the objectives under which facts and actions are evaluated.

This basic step, of clearly defining objectives, appears to have been lacking in many earlier studies of the St. Louis Park problem. This report begins, therefore, with a carefully defined set of objectives, so that the success and effectiveness in achieving them can be explicitly measured.

There are three distinct objectives that must be achieved to provide a comprehensive solution to the St. Louis Park problem:

1) provide the City of St. Louis Park and neighboring communities with a safe and adequate supply of potable water at present, and for the reasonably foreseeable future, in a cost-effective and reliable manner;

2) allow for present and reasonably foreseeable future use of ground-water resources in the St. Louis Park area in a cost-effective and reliable manner; and

3) allow for safe, reasonable, and beneficial use of the site for the reasonably foreseeable future, in a cost-effective and reliable manner.

Further explanation of each of these three objectives is provided below, after some common terms in the objectives are described.

Each of the three objectives above includes the phrase "cost-effective and reliable". This terminology is meant to provide the basis to choose among alternative actions aimed at satisfying these objectives. In other words, the three key components used to compare alternatives are the reliability, effectiveness, and cost of the actions being considered. These three evaluation criteria are consistent with objectives set out by the U. S. Environmental Protection Agency's National Contingency Plan for responding to hazardous waste sites under the authority of the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (47 FR 31180, July 16, 1982). The operational definitions of these terms are further discussed in section 3.2.2.

The term "foreseeable future" is also used in each of the three objectives. Because of the nature of the problems at St. Louis Park, many of the solutions considered in this report and by previous investigators may involve very long time periods (on the order of many decades) beyond anyone's ability to predict future changes in waste and drinking water treatment and remedial action technologies, medical science, demographics, social values and attitudes, analytical techniques, the economy, and a wide variety of other factors that will have a direct bearing on future perceptions of the reliability, effectiveness, and cost of any remedial actions undertaken in the next few years. This inability to predict events in the distant future, which will affect the value of actions taken in the near term, requires that a limit be placed on how far one looks into the future to evaluate the reliability, effectiveness, and costs of actions taken now.

In this study, costs and effects have nominally been examined over the next 100 years, although it seems certain that important technological and social changes will occur during this period that will have a direct bearing on the long-term remedy of the St. Louis Park problems. The operational definition of "foreseeable" for the purposes of this study, then, involves two parts. First, an attempt has been made to project physical phenonomena 100 years into the future. Second, social and technological phenomena, such as demographics, progress in medical and analytical sciences, and advances in potentially applicable remedial action technologies, are not projected per se. With only a few exceptions, these projections are treated as though the status quo will continue. If one reasonably expects that the future will bring improvements and advancements, then these projections represent a conservative analysis.

Finally, protection of the ecology of the St. Louis Park area was considered for inclusion in the objectives. But, because there are no significant or substantial natural ecosystems in the area, the protection of aquatic and terrestrial ecology was not defined as a major objective. The area does have valuable urban parks and common urban and suburban flora and fauna, but there is no evidence of harm to the flora and fauna from contamination; nor is harm likely to occur.

3.1.1 Safe and Adequate Potable Water Supplies

To better define the objective to provide St. Louis Park and neighboring communities with safe and adequate supplies of potable water first requires further operational definitions of certain terms. In particular, the term "safe" means that the quality of finished drinking water should meet all applicable health-based Federal and State regulatory requirements and standards. Since there are no such standards or requirements for polynuclear aromatic hydrocarbons in drinking water, this report proposes criteria for PAH in finished potable water, that provide an adequate margin of safety to protect public health. These criteria can be used as a basis to promulgate explicit regulations with provisions for compliance monitoring and enforcement. The proposed criteria and their bases are presented and described in Chapter 4.

The term "adequate" refers both to the quantity and quality of finished water supplies. In the former case, "adequate" means that a sufficient quantity of safe, finished water is available to meet present and reasonably foreseeable future demands. In the latter case, the term means that the quality of finished water should meet non-health-based requirements for practical and effective use. For example, water quality characteristics such as hardness and iron content are viewed as quality-related measures of adequacy.

The term "neighboring communities" refers to those communities adjacent to and near St. Louis Park, which are now or could foreseeably be affected by the ground-water contamination problem.

3.1.2 Use of Ground-water Resources

The objective to allow for present and foreseeable future use of ground-water resources is closely related to, but nevertheless distinct from, the objective to provide safe and adequate potable water supplies. These objectives are related because ground water is a major source of drinking water in the St. Louis Park area. They are

distinct, however, in that safe and adequate drinking water supplies can be obtained from surface water sources or a variety of ground-water sources (e.g., one aquifer can be unacceptable as a drinking water supply without major treatment to remove contaminants, while another aquifer may not be contaminated).

It is important to define the common resource value of ground water in order to address the need to protect ground water in the St. Louis Park area for present and foreseeable future uses. Ground water is valuable as a resource for consumptive uses and for recharge to surface waters in the hydrologic cycle. Contamination of ground water in and of itself does not pose a threat to human health or the environment because it is not in direct contact with human, aquatic, or terrestrial populations.* Such threats only arise when the ground water is withdrawn for use or when it discharges to surface water.

The four basic resource values of ground water are 1) a source of recharge for surface water, 2) use for irrigation, 3) use for cooling or industrial purposes and 4) use for potable water supply. Appendix H discusses the impacts of trace PAH contamination of various ground water uses, particularly items 2 and 3 above.

Contamination of ground water by low part per billion levels of PAH does not adversely affect its use for cooling or industrial purposes from the standpoint of effects on equipment. Such PAH concentrations are tens of times lower than naturally occurring levels of organics in St. Louis Park area ground water (as evidenced by total organic carbon contents in the range of a few parts per million). Such levels are also too low to increase PAH emissions to air (cooling tower use) or surface water (industrial process use) significantly when compared to present levels of PAH emissions to these media. Use

*This statement does not consider the effect of contamination on microorganisms living in ground water. Such an effect may exist, but this is not viewed as a significant environmental impact. This statement also ignores possible effects of contaminated surface aquifers which may be in contact with plant root systems, although this may be viewed as a case of effectively discharging to surface waters.

of PAH-contaminated ground water in direct contact air conditioning systems is not a concern because the resulting inhaled quantities of PAH are far below acceptable levels, except perhaps in instances of highly contaminated ground water (part per million concentrations). Use of contaminated ground water in direct contact applications in the food processing industries should be avoided if the water is not usable for potable supply, although there may be exceptions where more highly contaminated water could be used safely.

The discharge of ground water containing low part per billion levels of PAH into nearby surface water (streams, rivers, and lakes) does not pose significant adverse human health or environmental impacts, given the high dilution ratios typically observed when ground water is discharged into surface water and given the background trace levels of PAH in most surface water as a result of natural and man-made sources.

Most irrigation uses of ground water containing trace quantities of PAH do not pose a significant human health or environmental problem, since the resulting mass fluxes of PAH added to plants and soil during irrigation are minor compared to existing mass fluxes and the assimilative capacity of plants and soil for PAH. However, watering of certain vegetable crops with large surface areas (such as lettuce) may result in unusually high, and perhaps unsafe, human intake of PAH if highly contaminated water is used (low part per million levels).

The use of ground water as a source of potable water is, therefore, the only major resource value of ground water adversely impacted by the presence of trace quantities of PAH. Other uses may be adversely affected, such as gardening and food processing uses, but such impacts are minor given the high concentrations required to produce adverse effects and/or the limited extent of such uses in the St. Louis Park area (see Appendix H).

3.1.3 Safe Future Use of the Site Area

In order to allow for safe, beneficial, and reasonable future uses of the plant site and adjacent bog area, three important qualifiers for evaluating cost-effective achievement of the objective ought to be considered. The term "reasonable uses" means uses of the site that are compatible with present and future foreseeable land use in the immediate vicinity. For example, building private homes in the bog area does not appear to be a reasonable use of the land, given its poor foundation and drainage characteristics and its location in the middle of a developed zone of light industry next to a major highway. The term "beneficial" means some productive use of the land. As an extreme example, covering the entire site and bog area with a cap of concrete or asphalt to prevent surface water infiltration or contact with contaminated soil would result in a costly and unproductive use of the land. The term "safe" covers normal human use of the site area. For example, construction activities at the site should proceed with appropriate caution if extensive excavation is carried out, while normal surface use of the same area would not result in potential adverse health effects. In this example, normal use of the site would be considered safe, while subsurface construction activities might require some measures to protect the workers' health.

3.1.4 Priorities

After establishing objectives, priorities among these objectives and among alternatives for accomplishing them must be established. This is important because actions taken to achieve different objectives may conflict, or available means and resources may be insufficient to achieve all objectives. For present purposes, this report assumes that the three stated objectives (safe and adequate drinking water supplies, protection of ground-water resources, and safe future use of the site) are all of high priority and should all be accomplished if possible. In the event that conflicts or constraints arise in meeting these three primary objectives, the over-riding concern should be the protection of human health.

3.2 Overall Approach

The overall approach taken in this study was to evaluate a variety of alternative schemes for satisfying the three objectives discussed above. The alternatives studied included various combinations of source control and end-use control actions. These alternatives were then compared on the basis of reliability, effectiveness, and cost to arrive at a reduced set of alternatives, which are clearly cost-effective in meeting the stated objectives. Given the present state of knowledge on certain aspects of the St. Louis Park problem, it was not always possible to arrive at a single recommended action, but rather a limited set of potentially cost-effective actions. Where this was the case, this report has attempted to define very clearly what additional studies are required and how their results should be used to arrive at a final choice among alternatives. This overall approach is consistent with the requirements of the National Contingency Plan (40 CFR Part 300, Subpart F). Further discussion of the key issues involved in this overall approach is provided below.

3.2.1 Source Versus End-Use Actions

There are two basic types of actions that can be taken alone or in combination to achieve the three stated objectives for solving the St. Louis Park problem. One type of action is based on controlling the source or sources of continued contaminant addition to ground-water resources. The second type is based on remedying ground-water contamination at the point of use by treatment or by providing another source of supply. Table 3-1 summarizes the possible effectiveness of each of these basic types of source and end-use controls in meeting the three primary objectives stated for the study. Further discussion of the points raised by Table 3-1 is provided below.

PAH compounds are measurable in some ground water aquifers over a wide area in St. Louis Park and vicinity; thus, source controls alone cannot satisfy the objective of providing St. Louis Park and neighboring communities with a safe and adequate supply of potable

TABLE 3-1

POSSIBLE EFFECTIVENESS OF REMEDIAL ACTION TYPES
IN MEETING THE THREE PRIMARY OBJECTIVES

Type of Remedial Action	OBJECTIVE 1 Provide Safe and Adequate Drinking Water Supplies to the St. Louis Park Area	OBJECTIVE 2 Allow for Present and Reasonably Foreseeable Future Uses of Ground Water Resources in the St. Louis Park Area	OBJECTIVE 3 Allow for Safe, Reasonable and Beneficial Use of the Site
SOURCE CONTROLS ALONE			
Site Controls	Ineffective at present	May be effective over the long-term	May not be necessary
Well W23 Controls	Ineffective at present	May be effective over the long-term	May not be necessary
Multi-aquifer Well Controls	Ineffective at present	May be effective over the long-term	Not applicable
Gradient Control Wells	Ineffective at present	May be effective over long-term	Not applicable
END-USE CONTROLS ALONE			
Drinking Water Treatment	Effective	May be effective	Not applicable
Alternative Water Supplies	Effective	May be effective	Not applicable
Ground-water Quality Monitoring	May be effective	May be effective	Not applicable
Water Use Restrictions	Effective	May be effective	Not applicable

water. Complete control of all contamination sources now will not show effects for many years, perhaps centuries, in the quality of finished water at existing municipal wells that have been closed due to contamination. Therefore, some end-use controls will be required to satisfy the objective of a safe and adequate water supply, even if such controls only involve providing an alternate supply.

Because source controls can only be effective, given current technology, over a long time, it is unlikely that they can be used to meet present needs; however, it is possible that end-use controls alone can satisfy all three stated objectives in a timely and cost-effective manner. This conclusion results from the analytic approach used in this study to value expenditures made at different times in the future, (see section 3.2.2 below). This requires that the costs of actions taken now, which will show effects at some time far in the future, must be compared with the present value cost of waiting to take action until some future time when it is required.

In addition, management of the migration and movement of contaminated ground water via multi-aquifer well control and gradient control well systems were considered as source control alternatives. These alternatives can be viewed as source controls or as end-use controls, depending on the perspective taken. Contaminated ground water can migrate and cause the contamination of currently uncontaminated ground water, in which case the contaminated ground water can be viewed as a source, albeit a secondary source removed from the primary source or sources that originally caused the contamination. On the other hand, contaminated ground water can be viewed as a result of past events rather than as a source in and of itself. This study has taken the former viewpoint, although the technical issues associated with the management of contaminated ground water (e.g., ground-water hydraulics and transport modeling) are closely related to two other types of end-use controls. For example, treating contaminated ground water to yield acceptable finished water for potable use also effects management of contaminated ground water, since the wells being pumped will act as gradient control wells. Similarly, provision of alternate supplies of drinking water will

effect de facto management of contaminated ground water, since leaving wells unused or pumping new wells in different locations will affect the movement of contaminated ground water. This view of managing contaminated ground water as a form of end-use control also applies to source control studies for the site area, in that contaminated surficial ground water that has migrated from the site area can be viewed not as a source, but rather as a resulting characteristic of the affected ground water, which must be considered in its long-term management and use.

The sources evaluated for source control actions in this report are the multi-aquifer wells on and off the plant site and the contaminated soil and surficial ground water at the plant site and adjacent bog. A wide variety of source controls was considered in this study. A summary of the results of these studies is provided in Chapter 5. More detailed results and approach descriptions are provided in Appendices C (plant site and bog controls), D (on-site and off-site multi-aquifer well controls), E (gradient control well schemes), and F (disposal of contaminated ground water from gradient control wells).

Two basic types of end-use controls were evaluated in this study: 1) treatment of contaminated ground water to yield finished water that meets the proposed criteria for PAH in potable water, 2) provision of alternate supplies of drinking water. A number of distinct technical areas were examined in this study as inputs to the evaluation of end-use controls. Ground-water modeling was performed to study the effects of well use and pumping on the movement of contaminated ground water in the various aquifers affected by PAH contamination in the St. Louis Park area (see Appendix E for details). Technologies for treating contaminated ground water to provide finished water that meets the proposed criteria for PAH in potable water were evaluated (see Appendix G for details). Alternative sources of municipal water supply were identified and evaluated (see Appendix H for details). The effects of source control actions on further contamination and movement of contaminated ground water were also studied. Chapter 6 summarizes the results of these end-use control studies.

More detailed descriptions of the technical approach and results for each of these areas are presented in the technical appendices included with this report.

3.2.2 Choosing Among Alternative Actions

The source control and end-use control remedial action alternatives considered in this study are evaluated and compared on the basis of reliability, effectiveness, and cost. In order to make these comparisons on a consistent basis, an attempt has been made to compare alternatives that have the same general effectiveness in meeting specific objectives, and by assessing the potential impact of unreliable alternatives by recommending and costing contingency actions. When possible, alternative actions are projected to produce the same basic effects, so that their costs can be directly compared. When this is not possible, qualitative and subjective judgments are required to compare the alternatives.

Issues of reliability are addressed, when possible, by assessing the potential cost if an action turns out to be unreliable. The cost of contingency actions to correct problems not reliably solved the first time may be taken as a measure of the cost of an action failing to meet its stated objective. While this technique still involves subjective judgments, it is valuable in forcing the issue of reliability to be addressed consistently.

The remedial action alternatives considered in this study involve various capital and operating expenditures over different periods of time. In order to choose the most cost-effective action from a set of alternatives involving different expenditures over different time periods, the costs of all alternatives have been expressed as a single present value cost. This approach is the same as determining how much money would be required 1) to pay for any present capital expenditures, 2) to invest at a given interest rate to yield sufficient funds at some future date to pay for a capital expenditure at that date, and 3) to invest at a given interest rate to yield sufficient funds (both earnings on principal and gradual withdrawal of principal) to pay for the operating expenses over the lifetime of an alternative action or set of actions.

This approach can be used to establish a present value cost of alternative actions that last for a few years or last effectively "forever" (hundreds of years or more). Costs of alternatives that last "forever" can be expressed as a finite present cost because the analytical expressions for converting future costs into present value costs asymptotically approach finite limits as the time involved becomes very long. At moderate interest rates, these asymptotic values are closely approached within 100 years, which means that actions of this duration or longer effectively become actions of infinite duration as far as the time value of money is concerned.

The present value cost calculations in this report are based on an effective net interest rate of 5 percent per annum. This interest rate has been selected as a reasonable prediction of the net value (or cost) of money over a long future period based on historical returns on investments. The term "net" is used to describe this interest rate because it is intended to reflect the value of money after the effects of inflation are taken into account. While analytical expressions are available to examine rigorously the effects of separate rates of return and inflation rates, the results of these equations are closely approximated by the simpler equations based on a single "net" interest rate when long time periods are involved. Appendix L provides further discussion on the selection of a 5 percent net interest rate and on the rigorous treatment of inflation compared to the simplified approach used in this study.

3.2.3 Arriving at Conclusions and Recommendations

The present state of knowledge in the many different technical areas involved in providing a solution to the St. Louis Park problem is such that it is not possible, at this time, to define a single set of actions that can be taken now to satisfy each of the three objectives set out in section 3.1. However, it is possible to arrive at a limited set of possible actions, among which one set will ultimately prove to be the most cost-effective and reliable solution. This definition of a limited set of alternatives should be valuable in focusing future studies of the St. Louis Park problem. In areas where

future studies will be required to evaluate and choose among this limit set of alternatives, this report attempts to clearly define the nature, scope, and objectives of such future studies. Such a careful definition of future studies is required to insure that time and money are spent most effectively in solving the St. Louis Park problem. Such definition is particularly important in light of the $2.0 million in planned additional studies funded with Superfund monies. Chapter 7 of this report, therefore, includes conclusions and recommendations on the appropriateness of planned Superfund studies of the St. Louis Park problem, in view of the results obtained from this study.

3.3 Technical Approach

This section summarizes the major common characteristics of the technical approach and the individual technical elements of this study. In particular, the issues of data sources, appropriateness of the techniques used, and sensitivity and accuracy are each discussed below. Summary descriptions of the data and analysis tools and techniques used in the individual elements of this study are provided in subsequent chapters, with more detailed descriptions provided in the technical appendices.

3.3.1 Data Sources

As a systematic approach to define the problems in St. Louis Park and identify and evaluate possible solutions, relevant data generated by previous studies, together with new data in selected areas generated by ERT and other consultants to Dorsey & Whitney have been analyzed. These data have been supplemented by relevant information available from the open literature and from government agencies and authorities. Every effort has been made to clearly reference the origin of such data and information as they are used in this report. ERT independently analyzed and processed this information and data to define the problem and to evaluate possible solutions. In many instances, ERT has relied on the analysis of previous investigators to perform its own analysis, although in all cases the conclusions and interpretations presented in this report are ERT's own, unless specifically stated otherwise.

The reliance on the results of previous investigations is intentional and important because many of the data from previous investigations of the St. Louis Park problem are valuable in defining and solving the problem. As will be seen later in this report, sufficient data and information are presently available to define a distinct and limited set of reliable, cost-effective solutions to the St. Louis Park problem and to focus and limit significantly the scope of additional studies required to choose among and implement ultimate remedies. This focusing of the problem and its resolution is critical because of the planned expenditure of $2.0 million in Superfund monies largely to undertake further studies of the problem without actually funding ultimate remedial actions. As discussed in Chapter 7, many of the planned Superfund studies are unnecessary or redundant given the analysis, conclusions, and recommendations presented in this report. Instead, many of these Superfund monies should be devoted to funding actual remedies.

3.3.2 Appropriateness of Techniques

The technical and data analysis tools and techniques used in this study reflect certain basic philosophies. Foremost among these is the belief that the technical analysis tools used should be commensurate with the nature of the specific problem being addressed. In general, this means that the simplest techniques possible should be used to analyze a problem both reliably and effectively. Applying techniques that are overly simplified can lead to unreliable or inaccurate conclusions. Conversely, applying overly sophisticated and elaborate techniques is often ineffective in solving a problem because the extra time and effort spent do not produce results that are comparably more accurate or useful.

Selection of appropriate analytical techniques is often dictated by the accuracy of the results required. While there are many aspects of the St. Louis Park problem that are complex and difficult to address, given the present state of knowledge, some of these aspects can be simplified by assumptions or approximations, which give sufficiently accurate and conservative results to choose among

alternative courses to action. This study has attempted to use the simplest and most effective techniques to produce results that are suitable for sorting among alternative solutions to the St. Louis Park problem. As an example, the ground-water modeling performed for this study used established techniques to study hydraulic transport issues in the ground-water aquifers. While transport of chemical contaminants in ground water may be different than the movement of the water itself (hydraulic transport) due to absorption, reaction, or other attenuation mechanisms, the fact that chemical contaminants cannot move in substantially different directions or at faster rates than the ground water means that transport modeling can be used to bound a problem, (i.e., to predict the shortest time that contaminants could move from one place to another). Such bounding results, in some cases, can be sufficient to choose among alternatives.

3.3.3 Accuracy and Sensitivity

A second basic technical philosophy underlying this study is that the importance of the accuracy, or inaccuracy, of results used to choose among alternative actions should be made explicit, especially when simplified techniques are used. In other words, it is important to know how much inaccuracy can be tolerated in a result without the final outcome being changed. For example, if costs are estimated to within thirty percent accuracy, then there is a distinct possibility that choosing a $500,000 solution over a $700,000 solution will not actually yield the least expensive solution. In contrast, the choice of a $500,000 solution over a $2,000,000 solution should result in the least expensive solution, although it may actually end up costing significantly more or less than $500,000.

An issue related to accuracy is sensitivity, which is a measure of how predicted results respond to inaccuracies in assumptions or input data. As an example, many functional relationships between variables are not directly proportional, so that a given percentage error in an input variable may lead to a much smaller or much larger percentage error in the result. Where such input/output error relationships are

not readily apparent (i.e. in instances where multiple complex equations and variables are involved), it is important to check the sensitivity of results to possible errors in the starting data or assumptions.

An attempt has been made throughout this report to explicitly address the accuracy and sensitivity of the results presented. This is done primarily in the context of ensuring that choices among alternative actions are correct in spite of uncertainties or inaccuracies in the data and assumptions used.

4.0 RECOMMENDED CRITERIA FOR PAH IN FINISHED POTABLE WATER

One of the most important steps in solving the St. Louis Park problem is to establish criteria for allowable levels of PAH and related compounds in finished drinking water. Such criteria are necessary in order to meet two of the stated objectives of this study, namely: 1) to provide a safe and adequate drinking water supply for St. Louis Park and neighboring communities and, 2) to protect present and reasonably foreseeable uses of ground-water resources in the St. Louis Park area.

In the early years of the St. Louis Park problem (beginning with the closure of St. Louis Park wells 7, 9, 10, and 15 in November, 1978), there was no explicit public standard for allowable levels of PAH in potable waters. In recent years, however, (apparently beginning in 1981) the Minnesota Department of Health (MDH) has been applying specific guidelines for acceptable levels of PAH in potable water. These guidelines are as follows (Englund 1982):

1) the sum of the concentrations of carcinogenic PAH should be below 28 nanograms per liter (parts per trillion) and

2) the sum of the concentration of all noncarcinogenic PAH should be below 280 nanograms per liter (parts per trillon).

Both guidelines need to be satisfied; water that exceeds either or both of the guidelines is regarded as unsafe for potable use. According to the latest information available, the term "carcinogenic PAH" has been defined as a specific list of twelve PAH compounds classified as carcinogenic by the U.S. EPA Carcinogen Assessment Group (CH2M Hill 1982; Hickok 1981), namely:

benz(a)anthracene
benzo(b)fluoranthene
benzo(j)fluoranthene
benzo(a)pyrene
chrysene

dibenz(a,h)anthracene
dibenzo(a,e)pyrene
dibenzo(a,h)pyrene
dibenzo(a,i)pyrene
7,12-dimethylbenz(a)anthracene
indeno(1,2,3-cd)pyrene
3-methylcholanthrene

The term "noncarcinogenic PAH" has not been explicitly defined by the MDH, but apparently has been limited to non-alkylated PAH and does not include heterocyclic or heterosubstituted PAH (see Definitions of Terms).

It is important to establish criteria and standards for PAH in finished potable water. The term "criteria" is used in this report to refer to a set of specific concentrations for various categories of PAH, which are established so that potable use of water containing PAH at concentrations up to these criteria levels will protect public health. The term "standards" is used in this report to refer to a set of specific rules and guidelines for determining compliance with the criteria and for deciding on a course of action when the criteria are exceeded. Both criteria and standards should address the variety of PAH and related compounds measured in contaminated ground water in the St. Louis Park area. This is an area where there has been some uncertainty to date. Any criteria should recognize and account for the present scientific knowledge on the toxicological properities of PAH and related compounds. This present toxicological understanding indicates that the wide variety of PAH and related compounds exhibit widely varying toxicologic effects, ranging from carcinogenesis to very mild acute or chronic toxicity. It is ERT's opinion that the guidelines presently used by the MDH do not properly recognize the toxicologic properties of noncarcinogenic PAH.

Given these concerns with present MDH guidelines, and the overall importance of PAH criteria in evaluating reliable and cost-effective solutions to the St. Louis Park problem, this report begins by recommending criteria for PAH in finished potable water. This chapter

presents the recommended criteria, summarizes their derivation and discusses issues related to their monitoring and enforcement (i.e., related standards). The final section of this chapter compares the measured quality of municipal wells in the St. Louis Park area with the recommended criteria.

4.1 Recommended Criteria

The following recommended criteria for PAH and heterocyclic PAH in finished water will provide an adequate margin of safety to protect the public health:

1) The sum of the concentrations of carcinogenic PAH and carcinogenic heterocyclic PAH* should be less than or equal to 28 nanograms per liter (parts per trillion), where carcinogenic PAH are defined to be those compounds listed in Tables 4-1 and 4-2.

2) The sum of the concentrations of noncarcinogenic PAH and noncarcinogenic heterocyclic PAH should be less than or equal to a value between 4 and 400 micrograms per liter (parts per billion), where noncarcinogenic PAH are defined to be any non-substituted or alkyl-substituted PAH or heterocyclic PAH not listed in Tables 4-1 and 4-2.

Both of these criteria must be simultaneously satisfied.

The criterion for noncarcinogenic PAH and heterocyclic PAH is expressed as a range of acceptable values based on available data on chronic toxicity and organoleptic effects of noncarcinogenic PAH. A

*The criteria recommended by this study apply both to PAH and heterocyclic PAH. In many instances, the phrases "carcinogenic PAH and heterocyclic PAH" and "noncarcinocenic PAH and heterocyclic PAH" are used to describe the criteria. In such instances, it should be noted that the adjectives "carcinogenic" or "noncarcinogenic" are intended to modify the entire phrase "PAH and heterocyclic PAH."

TABLE 4-1

LIST OF UNSUBSTITUTED CARCINOGENIC PAH AND HETEROCYCLIC PAH BASED ON ANIMAL TESTING RESULTS

(See Appendix I for basis and references)

Unsubstituted PAH	Unsubstituted Heterocyclic PAH
Benz(a)anthracene	10-Azabenzo(a)pyrene
Benzo(c)chrysene	Benz(a)acridine
Benzo(g)chrysene	Benz(c)acridine
Benzo(b)fluoranthene	Benzo(f)benzo(2,3)thieno(3,2-b)quinoline
Benzo(j)fluoranthene	Benzo(h)benzo(2,3)thieno(3,2-b)quinoline
Benzo(ghi)perylene	11H-Benzo(a)carbazole
Benzo(c)phenanthrene	7H-Benzo(g)- -carboline
Benzo(a)pyrene	Benzo(h)naphtho(1,2-f)quinoline
Chrysene	7H-Benzo(a)pyrido(3,2-g)carbazole
Dibenz(a,c)anthracene	13H-Benzo(a)pyrido(3,2-i)carbazole
Dibenz(a,h)anthracene	7H-Benzo(c)pyrido(3,2-g)carbazole
Dibenz(a,j)anthracene	7H-Benzo(g)pyrido(3,2-a)carbazole
Dibenzo(a,e)pyrene	4,11-Diazabenzo(b,def)chrysene
Dibenzo(a,h)pyrene	1,12-Diazabenzo(rst)pentaphene
Dibenzo(a,i)pyrene	Dibenz(a,h)acridine
Dibenzo(a,l)pyrene	Dibenz(a,j)acridine
Indeno(1,2,3-cd)pyrene	Dibenz(c,h)acridine
Naphtha(2,3-b)pyrene	7H-Dibenzo(a,g)carbazole
Tribenzo(a,e,i)pyrene	Dibenzo(a,h)carbozole
	13H-Dibenzo(a,i)carbazole
	7H-Dibenzo(c,g)carbazole
	Fluoreno(9,9a,1-gh)quinoline
	Phenanthro(2,1-d)thiazole
	Pyrido(2,3-a)thieno(2,3-i)carbazole
	Quinoline
	Tricycloquinazoline

TABLE 4-2

LIST OF ALKYL-SUBSTITUTED CARCINOGENIC PAH AND HETEROCYCLIC PAH BASED ON ANIMAL TESTING RESULTS

Certain specific methyl, dimethyl, trimethyl, tetramethyl, ethyl, diethyl, or methylethyl alkyl-substituted isomers of the compounds listed below have been found to be carcinogenic in animal bioassays. See Appendix I for a list of the specific isomers that have been tested.

PAH	Heterocyclic PAH
Anthracene	Benz(a)acridine
Benz(a)anthracene	Benz(c)acridine
Benzo(c)phenanthrene	
Benzo(a)pyrene	
Cholanthrene	
Chrysene	
Fluoranthene	
Phenanthrene	

policy decision will be required to establish a criterion within this range. As discussed in Chapter 6, establishing a criterion within this range has major effects on the selection and cost of a solution to the St. Louis Park problem. The scientific basis for recommending this range is described below.

The criteria above are intended to be applied to finished drinking water at the point at which it is added to the distribution system. However, exposure to any PAH in drinking water actually occurs at the tap, which is the point of concern according to the EPA's National Contingency Plan. This report recommends that criteria be applied to finished water at the point of addition to the supply system for ease and practicality in monitoring compliance and because tap water concentrations should not be greater than finished water concentrations. The only exception to this would arise from factors in the distribution system that are unrelated to ground-water contamination (e.g., cross-connections or the use of pipes or storage tanks lined with asphalt or coal tar pitch or enamel). It is also possible, and likely, that tap concentrations will generally be much lower than finished water concentrations, as a result of dilution in the supply system and the effect of water treatment devices used in many homes, such as softeners and faucet filters. The application of criteria to finished water is therefore felt to be a conservative approach. It is also consistent with current practice in regulating drinking water supplies.

The recommended criteria apply to PAH and heterocyclic PAH, with or without alkyl substitutions, but do not apply to other PAH-related compounds (see the Definition of Terms). Other PAH-related compounds (such as hetero-substituted PAH) are not addressed because they have not been detected in untreated water from contaminated municipal supply wells in the St. Louis Park area, even though some efforts have been made to analyze for such compounds (e.g., amino-substituted PAH analyses by CH2M Hill 1982). Furthermore, hetero-substituted PAH are not expected to be present in contaminated municipal supply wells at detectable concentrations, given their much lower concentrations compared to PAH and heterocyclic PAH in possible coal-tar-related

and/or petroleum fuel-related source materials. Phenols are not addressed by the criteria because water quality criteria for various one-ring phenols have already been established by the EPA, based largely on preventing undesirable tastes or odors associated with chlorinated phenols that can result from chlorinating water containing phenols. Further discussion of limiting the recommended criteria to PAH and heterocyclic PAH is provided in Appendix I.

The criteria recommended by this study were developed by Dr. Julian B. Andelman and Dr. Joseph Santodonato, who are recognized experts in drinking water and PAH health effects and issues. Their report, which discusses the scientific basis for the recommended criteria, is included as Appendix I of this report. ERT developed recommended sampling and analysis procedures for monitoring compliance with the recommended criteria. These procedures are summarized in section 4.3 and presented in more detail in Appendix J.

4.2 Basis For Recommended Criteria

Before discussing the basis for the recommended criteria, two important facts should be recognized. First, PAH are ubiquitous in the environment from both man-made and natural sources, so that the public is regularly and repeatedly exposed to PAH via air inhalation and food and water ingestion. Table 4-3 summarizes reported estimates of average daily exposures to PAH via these media. Food intake is the predominant exposure source, while estimated typical drinking water exposures are about one hundred times lower. Second, PAH should not be considered synonymous with carcinogenesis. Present knowledge indicates that most PAH are not carcinogenic and are relatively non-toxic. PAH that have carcinogenic properties are relatively few and, in most cases, represent unique molecular structures with fairly high molecular weights (generally four to six fused rings).

Throughout this report, a carcinogenic PAH is considered to be any PAH for which a significant increase in tumor incidence was observed after the administration of the compound by any route to any species of animal. Such compounds are treated for regulatory or

TABLE 4-3

ESTIMATE OF TOTAL DAILY HUMAN EXPOSURE TO PAH FROM VARIOUS MEDIA[a]

Source	Estimated Exposure, micrograms/day		
	Benzo[a] Pyrene	Carcinogenic PAH[b]	Total PAH
Food	0.16-1.6	-	1.6-16
Food	-	-	8-11[c]
Air[d]	0.01-0.04	0.04	0.2
Water	0.001	0.004	0.03
TOTAL	0.16-1.6	-	2-16
One Pack of Cigarettes per Day	0.4	-	-

(a) From Santodonato, et al, 1981, except as noted.
(b) Total of benzo(a)pyrene, benzo(j)fluoranthene, and indeno(1,2,3-ed)pyrene.
(c) From Borneff, 1977.
(d) Based on air quality data in urban areas.

public policy purposes as though they are human carcinogens, even though the only evidence may be from animal tests. This definition of carcinogenicity is more conservative than definitions used by some other scientific authorities. For example, the International Agency for Research on Cancer considers the evidence for carcinogenicity to be sufficient only if a substance results in increased tumor incidence in multiple animal species or strains, or in multiple experiments.

4.2.1 Carcinogenic PAH Criterion

The recommended criterion of 28 nanograms per liter for carcinogenic PAH and heterocyclic PAH is based on limiting the incremental increased life-time risk of cancer to one chance in 100,000 (10^{-5} risk level). This criterion was derived by the U.S. EPA, as a suggested ambient water quality criteria, but has not been promulgated nor is intended to be promulgated as a federal drinking water standard (U.S. EPA 1980). This criterion is based on consuming 2 liters per day of water and 6.5 grams per day of fish and shellfish obtained from ambient water containing PAH at the criterion concentration. If consumption of contaminated fish is excluded, which is appropriate for a criterion applied to ground water, then the criterion increases slightly to 35 nanograms per liter. This study still recommends that the 28 nanograms per liter criterion be used, even though 35 nanograms per liter is strictly more correct for a ground water application. This is because the 28 nanograms per liter criterion has been used widely, the difference between the two is very minor compared to the uncertainties in their derivation, and the 28 number is somewhat more conservative.

The EPA's risk estimate for carcinogenic PAH is derived by extrapolating test data developed from feeding benzo(a)pyrene to mice. A linear regression technique was used to extrapolate from the test doses (0.1 to 6 milligrams per kilogram per day) to the predicted effects on humans at doses about one million times lower (28 nanograms per liter corresponds to a dose of 1×10^{-6} milligrams per kilogram per day based on a 70 kilogram person consuming 2 liters of water and 6.5 grams of fish and shellfish per day).

There are many scientific uncertainties involved in establishing a drinking water criterion for carcinogenic PAH. For example, it is difficult to extrapolate the results of high doses of a carcinogen in test animals to effects in man at greatly lower doses. Thus, the linearized multistage model used by the EPA is a conservative extrapolation technique, since the model assumes no threshold concentration for carcinogens. That is, any exposure to a carcinogen, however low, is assumed to create an increased risk of cancer. The risk estimate developed by the EPA is also conservative in that the upper 95 percent confidence level of the extrapolated dose-response curve is used to establish the criterion. This means there is only 1 chance in 20 that exposure to 28 parts per trillion of benzo(a)pyrene will produce an excess lifetime cancer risk greater than 10^{-5}; however, there are 19 chances in 20 that the actual risk would be less than 10^{-5}.

Another major uncertainty in developing a drinking water criterion for carcinogenic PAH is the problem of risk estimations for a mixture of PAH. The recommended criterion of 28 parts per trillion is conservative in that it is based on benzo(a)pyrene, which is one of the most potent carcinogenic PAH, and assumes that any other carcinogenic PAH are as potent as benzo(a)pyrene.

The recommended criterion for carcinogenic PAH comprehensively categorizes individual PAH and heterocyclic PAH compounds with carcinogenic properties. The list of PAH and heterocyclic PAH to be covered by this criterion (Tables 4-1 and 4-2) is considerably longer than the EPA Carcinogen Assessment Group list used by the MDH. The list in Tables 4-1 and 4-2 was developed based on reported tests showing a significant elevation of tumor incidence resulting from administration by any route and to any species of animal. This criterion for determining which PAH are carcinogenic is more conservative than criteria used by some other expert scientific bodies (e.g., the International Agency for Research on Cancer).

In summary, the recommended criterion of 28 nanograms per liter for carcinogenic PAH and heterocyclic PAH represents a very conservative approach to ensure that the excess lifetime cancer risk

from consuming water containing this concentration of carcinogenic PAH and heterocyclic PAH will be less than one chance in 100,000.

4.2.2 Noncarcinogenic PAH Criterion

The recommended criterion of from 4 to 400 micrograms per liter for noncarcinogenic PAH is intended to provide an adequate margin of safety from acute or chronic toxic effects of the compounds and to prevent undesirable tastes or odors. As described in Appendix I, noncarcinogenic PAH generally are not very toxic. Furthermore, studies have shown that these compounds are not accumulated in the body, but are instead readily metabolized and excreted.

The recommended criterion for noncarcinogenic PAH and heterocyclic PAH is based on the chronic threshold exposure level below which no significant adverse effects are produced in healthy populations. Threshold exposure levels are typically derived from "no observable adverse effect levels (NOAEL) inferred from animal bioassays. A NOAEL based on animal bioassay data is then transformed into an acceptable daily intake (ADI) using an appropriate safety factor of 10, 100, or 1000, according to guidelines established by the National Academy of Sciences (NAS 1977). The data base for chronic toxicity for noncarcinogenic PAH is small, largely because testing has focused on carcinogenic PAH. The approach used in this study was to calculate ADI valves for noncarcinogenic PAH by analogy with more well-studied carcinogenic PAH, which are the only PAH for which long-term oral exposure studies have been conducted. This approach assumes that the chronic toxicity of noncarcinogenic PAH is the same (or similar) as for carcinogenic PAH, with the exception of tumor formation. This assumption appears to be reasonable, based on long-term skin painting studies and the known acute toxicities of both carcinogenic and noncarcinogenic PAH. In fact, the acute toxicity of carcinogenic PAH appears to be greater than for noncarcinogenic PAH.

Based on NOAELs obtained from chronic oral testing of benzo(a)pyrene and 3-methylcholanthrene, the calculated ADI for noncarcinogenic PAH is from 240 to 750 micrograms per day for a 70 kilogram adult. These ADI values are based on a safety (or uncertainty) factor of 100, per recommended guidelines established by

the NAS (1977). Available data indicate that the typical intake of noncarcinogenic PAH from food and air is on the order of 1 to 10 micrograms per day, so that almost the entire ADI could be safely consumed via drinking water, which results in a criterion of 120 to 375 micrograms per liter. This range compares very favorably with the EPA's development of an ambient water quality criterion for fluoranthene, which is a noncarcinogenic PAH (U.S. EPA 1980b). The EPA criterion for fluoranthene is 42 micrograms per liter, allowing for consumption of contaminated fish and shellfish. If consumption of contaminated fish is excluded, which is appropriate for a ground-water criterion, then the fluoranthene criterion increases to 200 micrograms per liter.

There are few reported data on the organoleptic effects of PAH in drinking water. Reported values range from 4 micrograms per liter for detecting the odor of coal tar in water, to well over 1 milligram per liter for detecting certain individual PAH compounds by taste or odor. These data indicate that a criterion for noncarcinogenic PAH as low as 4 micrograms per liter may be necessary to prevent detectable tastes or odors. The EPA has developed an ambient water quality criterion for acenaphthene, a noncarcinogenic PAH, of 20 micrograms per liter, based on controlling undesirable taste and odor (U.S. EPA 1980c). A criterion in the 100 to 400 micrograms per liter range may also be adequate in preventing taste or odor problems, but this should be confirmed by organoleptic testing of contaminated water from the St. Louis Park area.

The classification of PAH and heterocyclic PAH compounds as noncarcinogenic for the purposes of the recommended criterion is based on 1) compounds that have been found to be noncarcinogenic as a result of adequate animal tests and 2) compounds that have not been tested for carcinogenicity but are not expected to have carcinogenic properties based on their chemical structures. Table 4-4 lists PAH and heterocyclic PAH that are classified as noncarcinogenic based on animal testing. The compounds listed in Table 4-4 are only a subset of the PAH and heterocyclic PAH compounds considered to be noncarcinogenic for purposes of the recommended criteria. This is

TABLE 4-4

LIST OF NONCARCINOGENIC PAH AND HETEROCYCLIC PAH BASED ON RESULTS OF ANIMAL TESTING[a]

Unsubstituted PAH(b)	Unsubstituted Heterocyclic PAH(b)
Acenaphthylene	Acridine
Anthanthrene	Benzoquinoline
Anthracene	Carbazole
Benzo(b)chrysene	
Benzo(g)chrysene	
Benzo(k)fluoranthene	
Benzo(ghi)fluoranthene	
Benzo(a)fluorene	
Benzo(b)fluorene	
Benzo(c)fluorene	
Benzo(a)naphthacene	
Benzo(e)pyrene	
Benzo(a)tetracene	
Coronene	
Dibenzo(b,k)chrysene	
Dibenzo(de,qr)naphthacene	
Dibenzo(a,j)naphthacene	
Dibenzo(a,g)phenanthrene	
Dibenzo(b,g)phenanthrene	
Dibenzo(e,l)pyrene	
Fluoranthene	
Fluorene	
Hexacene	
Naphthacene	
Naphthalene	
Pentacene	
Pentaphene	

TABLE 4-4 (continued)

Unsubstituted PAH(b)	Unsubstituted Heterocyclic PAH(b)
Perylene	
Phenanthrene	
Picene	
Pyrene	
Tetracene	
Tripheylene	

Notes:

(a) - See Appendix I for the basis for this list.

(b) - Many alkyl-substituted PAH and heterocyclic PAH are also noncarcinogenic (see Appendix I).

because there are many hundreds of alkylated and nonsubstituted isomers not listed in Tables 4-1, 4-2 or 4-4 which have not been tested for their carcinogenic properties. In the absence of test data or chemical structures to the contrary, the recommended criteria assume that such compounds are noncarcinogenic.

4.2.3 Synergistic Effects

In establishing criteria for carcinogenic and noncarcinogenic PAH and heterocyclic PAH, synergistic effects between carcinogenic and noncarcinogenic PAH must be considered. A synergistic effect occurs if the potency of a carcinogen increases when it is mixed with a noncarcinogenic compound. It is important to note that true synergism is a rare biological phenomenon, and its relevance to PAH carcinogenesis in man is questionable.

Synergistic effects are difficult to predict in complex environmental mixtures of carcinogenic and noncarcinogenic PAH, because very few studies have been conducted on well-defined, complex mixtures. The well-documented studies that are available for complex mixtures indicate that the tumorigenic activity of carcinogenic PAH is either unaffected, or else is inhibited by the presence of specific mixtures of noncarcinogenic PAH (see Appendix I for details). It therefore appears reasonable to evaluate the carcinogenic risk of a complex PAH mixture based on the sum of its carcinogenic constituents. This is the approach taken in deriving the criteria recommended by this study.

4.2.4 Other Possible Criteria

Establishing any criteria for carcinogenic and noncarcinogenic PAH requires that public policy judgements be made concerning trade-offs among risks, costs, and benefits. The criteria recommended by this study are based on a scientific assessment of health effects risks,with a minimum number of policy judgements, which are explicitly identified when made. It is possible, however, to make different policy judgements and arrive at different criteria than those recommended by this study. In order to clearly indicate the

trade-offs involved with such policy judgements, a brief discussion of other possible bases for establishing PAH criteria is provided here.

The criterion for carcinogenic PAH and heterocyclic PAH recommended by this study is based on a maximum allowable increased lifetime cancer risk of one chance in 100,000. This criterion and corresponding risk level have already been applied by the MDH to the St. Louis Park problem. This risk level has also been used by the EPA in developing ambient water quality criteria. However, it could be argued that a lower risk level should be achieved. Zero risk is unattainable, however, if the assumption of no threshold level for carcinogenic effects is maintained, because PAH are ubiquitous in the environment and have been detected, with sufficiently sensitive analytical techniques, in all water supplies studied to date (see Appendices G and I). In fact, finished water in some U.S cities has been found to contain over 10 nanograms per liter of carcinogenic PAH (see Appendices G and I). It is possible, therefore, that establishing a criterion for carcinogenic PAH at a risk level much below 10^{-5} would indicate that many finished water supplies elsewhere in Minnesota are unacceptable.

The criterion for noncarcinogenic PAH and heterocyclic PAH recommended by this study is based on ensuring no observable adverse health effects. As such, it represents a scientific judgement based on the best available data of a concentration that presents no risk of adverse health effects. As shown in Appendix I, however, the recommended criterion range for noncarcinogenic PAH and heterocyclic PAH is greater than concentrations of noncarcinogenic PAH that have been measured in finished water supplies in selected cities in the U.S. and Canada. Furthermore, the recommended criterion range is greater than concentrations of noncarcinogenic PAH measured in untreated water supplies in other communities near St. Louis Park (see Appendix K). It could be argued that a criterion for noncarcinogenic PAH should be based on achieving concentrations typical of those in other communities' drinking water. Such an approach would lead to a criterion below the range recommended by this study, perhaps by as much as an order of magnitude. It should be stressed, however, that such a lower criterion would not result in reduced risks of adverse

health effects, based on the available data on chronic threshold effects levels for noncarcinogenic PAH. The implications of a noncarcinogenic PAH criterion well below the range recommended by this study are discussed in section 6.6.

4.3 Compliance Monitoring for Proposed Criteria

Any criteria developed to determine the acceptability of a finished water for potable use should be publicly stated and include defined standards for monitoring and enforcing compliance. Public notification is needed to allow public comment and to ensure that standards are equitably applied and enforced. Defined standards are required to ensure that compliance is consistently determined and documented and to ensure efficient and equitable enforcement of the criteria.

The term "compliance monitoring" refers to a set of explicit procedures and protocols for determining if finished water from a municipal supply well complies with the recommended PAH criteria. This is distinct from surveillance monitoring, which refers to procedures for tracking PAH contaminants in an aquifer, or from control monitoring, which refers to procedures for measuring and controlling, on a regular basis, the performance of a drinking water treatment technology for removing PAH. This section discusses recommended procedures for compliance monitoring. Surveillance monitoring is discussed in section 6.5 and control monitoring is discussed in Appendix G.

4.3.1 Objectives

In order to determine if source water is safe for human consumption or if possible treatment processes are working efficiently, a compliance monitoring standard needs to be developed. Such a standard is necessary for the following reasons:

- defined monitoring procedures ensure that compliance is consistently determined and documented;

- defined monitoring procedures ensure efficient and equitable enforcement;
- defined sampling and analytical procedures ensure continuity and reproducibility of analytical data; and
- defined scope and frequency of monitoring allow flexibility and continued protection if situations change.

Given the importance of defined compliance procedures, one aspect of this study has been to evaluate the monitoring issues associated with compliance enforcement and ground water surveillance. This section summarizes recommendations for a compliance monitoring standard for the recommended PAH criteria. More detailed discussion of compliance monitoring issues is provided in Section 6.5 and Appendix J.

4.3.2 Selection of Monitoring Pollutants

In order to assess compliance with the recommended PAH criteria, it is necessary to select a list of specific compounds that will be monitored to determine compliance. The recommended criteria include both carcinogenic and noncarcinogenic PAH and heterocyclic PAH. This study recommends that specific compounds within each category be selected to form a primary list for compliance monitoring. This primary list will be used for calculations of total carcinogenic and noncarcinogenic PAH and heterocyclic PAH, and will include compounds likely to contribute, based on past analyses, to the total concentrations in these two categories (Table 4-5). This primary list needs to be established because 1) the list of noncarcinogenic PAH andheterocyclic PAH compounds is very long (many hundreds of compounds) when all the various alkylated isomers are considered, 2) the list of carcinogenic PAH and heterocyclic PAH defined by the criteria, while of finite length, includes many compounds that have not been detected in contaminated ground water in the St. Louis Park area and are not expected to be detected in the foreseeable future, and 3) the list ofcarcinogenic PAH and heterocyclic PAH includes many alkylated compounds whose separate isomers can only be analyzed at very great expense (see Table I2-2 and I2-4 in Appendix I).

TABLE 4-5

COMPLIANCE MONITORING STANDARD, PRIMARY COMPOUND LIST

Carcinogens	Non-Carcinogens
Benz(a)anthracene	Indene
Dibenz(a,h)anthracene	2,3-dihydroindene
Benzo(b)fluoranthene	Naphthalene
Benzo(a)pyrene	2-methyl naphthalene
Quinoline	1-methyl naphthalene
Indeno(1,2,3,cd)pyrene	Biphenyl
Chrysene	Acanaphthylene
Benzo(g,h,i)perylene	Dihydroacanaphthylene
	Fluorene
	Phenanthrene
	Anthracene
	Fluoranthene
	Pyrene
	Benzo(k)fluoranthene
	Benzo(a)pyrene
	Perylene
	Acridine
	Carbazole
	2,3-benzofuran
	Dibenzofuran
	Benzo(b)thiophene
	Dibenzothiophene
	Indole

A secondary list of PAH compounds is also recommended for monitoring as a check against the continued validity of the primary list. Wells should be sampled and analyzed for the secondary list on a regular basis, but less frequently than for the primary list. The secondary list includes any carcinogenic PAH and heterocyclic PAH listed in Tables 4-1 and 4-2 that are not on the primary list, plus any additional noncarcinogenic PAH and heterocyclic PAH that can be detected by wide-scan gas chromatography/mass spectroscopy. Because of the difficulty and expense in analyzing individual isomers of alkylated PAH and heterocyclic PAH, analysis to separate isomers will not be part of the secondary list unless significant concentrations of such compounds as a class (e.g. methylated chrysenes) are detected. Depending on the results of secondary list analyses, compounds may be added to or deleted from the primary monitoring list. Further recommendations for primary and secondary monitoring are provided in Appendix J.

4.3.3 Monitoring Designations and Frequencies

A compliance monitoring standard must define what is to be monitored and when it is to be monitored. This study recommends that municipal supply wells be categorized in one of three groups for determining required monitoring frequency (Table 4-6). The distinction between the groups is based on the current or expected levels of PAH contamination and the use of the well. Group 1 wells are considered priority monitoring wells. A priority monitoring well is defined as a well whose PAH concentrations exceed either of the following trigger values but do not exceed the criteria:

- Carcinogenic PAH: Total greater than 5.0 nanograms per liter
- Noncarcinogenic PAH: Total greater than 10 percent of the criterion

Group 1 also includes any wells that exceed the recommended criteria in the untreated water but are treated for PAH removal to produce an acceptable finished water. Group 2 wells are located in the path of possible future contaminant migration during approximately the next

TABLE 4-6

RECOMMENDED MUNICIPAL SUPPLY WELL GROUPS
FOR A COMPLIANCE MONITORING STANDARD

GROUP 1 - QUARTERLY MONITORING

Group 1A

wells with drinking water treatment for PAH removal with PAH concentrations in the untreated water that exceed the recommended criteria.

Group 1B

wells with PAH concentrations above the compliance monitoring trigger level but below the PAH criteria level. The trigger level is defined as 10 per cent of the noncarcinogenic PAH criterion and 5.0 nanograms per liter for carginogenic PAH.

GROUP 2 - ANNUAL MONITORING

Group 2A

wells with PAH concentrations exceeding the recommended criteria that are taken out of service.

Group 2B

wells with PAH concentrations below the trigger level but which are in the possible path of future contaminant migration over approximately the next decade.

GROUP 3 - MONITORING EVERY 5 YEARS

Group 3

wells with PAH concentrations below the trigger level but which may be in the path of future contaminant migration over the next century.

decade, based on modeling predictions discussed in Appendix E. Group 2 wells also include wells that exceed the proposed PAH criteria levels. Group 3 wells are located outside the predicted zone of influence, present or future, of PAH contamination for about the next 100 years. Depending upon the data gathered from compliance monitoring, wells be may moved from one group to another. Grouping considerations and recommendations are discussed in Appendix J.

The group within which a well is placed determines the frequency of sampling, as shown in Table 4-6. The frequency of monitoring is related to the seriousness of present or future contamination. Therefore, Group 1 wells are sampled most frequently (quarterly) and Group 3 wells least frequently (every five years). As data are generated, certain wells will show definite patterns of PAH concentrations. Therefore, the monitoring frequency should be allowed to change as the data for a particular well dictate. The considerations and guidelines for changing sampling frequencies are discussed in Appendix J.

4.3.4 Sampling and Preservation Procedures

Specific sample collection, handling, and preservation procedures need to be specified in order to ensure that consistent and representative samples are obtained. Such procedures have already been recommended by the U.S. EPA for aqueous sampling for priority pollutants, which include certain PAH compounds. These procedures represent adequate state-of-the-art techniques for collecting, handling, and preserving samples to monitor compliance with the proposed PAH criteria. Appendix J outlines some specific recommendations in this area. The major recommendations are as follows: 1) thorough chain-of-custody procedures should be used, including record maintenance; 2) samples should be stored at $4^{o}C$, with a maximum of 7 days storage prior to extraction and 40 days storage prior to analysis; 3) samples of finished water should be collected at the point immediately before the water enters the distribution system; and 4) wells should be pumped for at least 12 hours prior to sampling to ensure that a representative sample is obtained.

4.3.5 Analytical Procedures

Gas chromatography/mass spectroscopy (GC/MS), in a selected ion monitoring (SIM) mode, represents the best available analysis method for monitoring compliance with the recommended PAH criteria. This method has already been used by a number of laboratories to analyze ground-water samples from the St. Louis Park area. Results indicate good repeatability within a single laboratory and good comparability of results on samples split between different laboratories. This method is also appropriate because of its flexibility in analyzing a wide variety of PAH and related compounds, its general ability to distinguish many closely related PAH isomers, and its ability to achieve low detection limits (generally from 1 to 10 parts per trillion for any given compound). Appendix J discusses a recommended analytical procedure in detail.

4.3.6 Enforcement

Figure 4-1 shows a recommended decision tree to be followed for wells whose routine compliance monitoring data indicate exceedance of the PAH criteria. Appendix J discusses in detail the rationale behind the decision tree's structure. The decision tree is based on the need to verify that observed exceedances are real and not a result of sampling or analytical errors or variations. The decision tree shows that a single exceedance measurement should be confirmed by resampling and analysis in duplicate. If the resampling shows no exceedance, then one more sampling and analysis round is required to confirm that the initial exceedance result was erroneous. If a second sampling and analysis round shows an exceedance, then this confirms that the well exceeds the criteria.

The recommended decision tree indicates that a municipal supply well should be taken out of service when it is confirmed that the finished water added to the distribution system exceeds the proposed PAH criteria. If the finished water is produced from a drinking water treatment technology aimed at removing PAH, the well can be returned to service once the problem in the treatment plant's performance is identified and its correction is documented. If the well has no

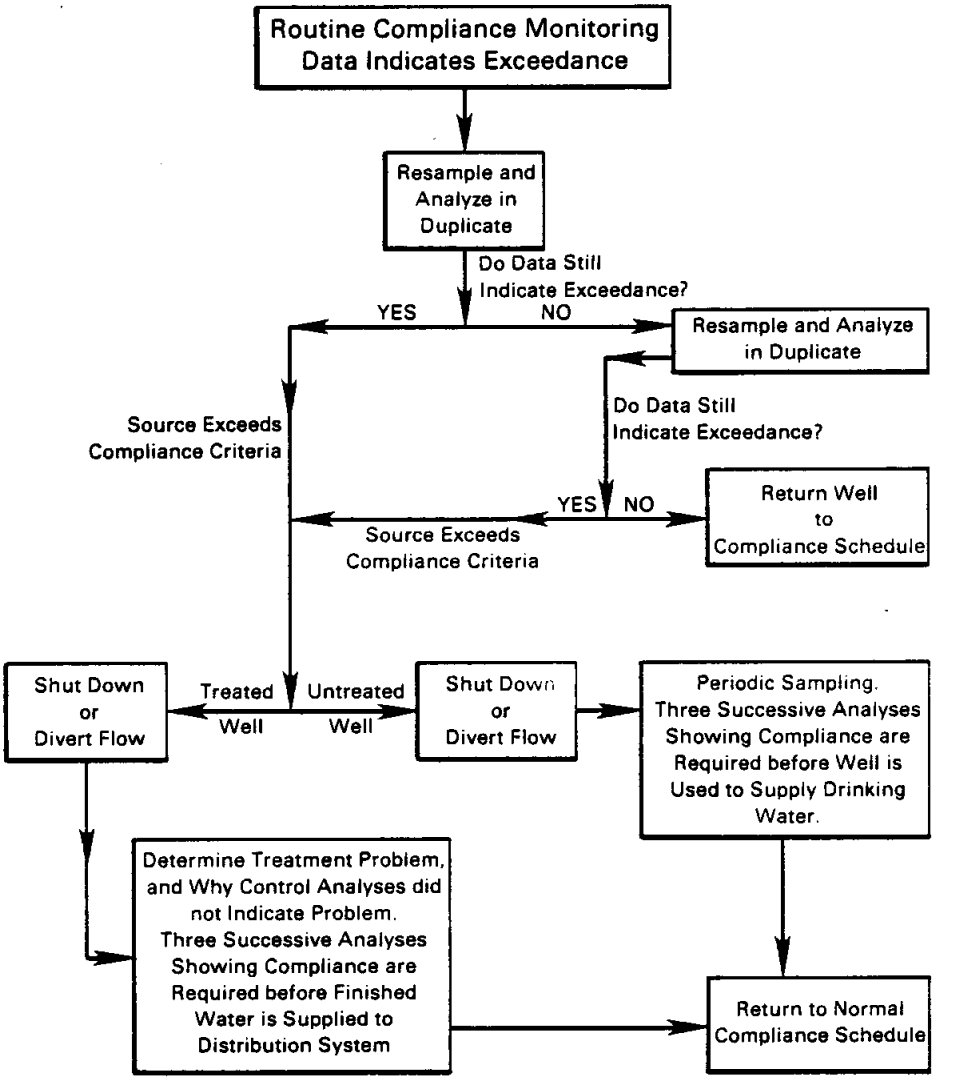


Figure 4-1 Enforcement Decision Tree

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associated PAH-removal drinking water treatment technology, then the well must remain out of service, unless appropriate drinking water treatment is added or until the finished water again meets the criteria.

4.4 Evaluation of St. Louis Park Area Wells by the Recommended Criteria

In order to evaluate the effects of the recommended PAH criteria for finished water on the continued use of drinking water supply wells in the St. Louis Park area, ERT has compiled a computerized data base of all of the available PAH analysis data for wells in the St. Louis Park area. These data represent analyses by a number of laboratories, primarily the Minnesota Department of Health, Serco Laboratories, CH2M Hill, Midwest Research Institute, Capsule Labs, and Monsanto Research Corporation. These data include all water quality information presently available to ERT, but it is believed that some additional data were unavailable when preparing this report. Appendix K provides more detail on the data included and the data sources used.

Figures 4-2 through 4-8 present chronological plots of total noncarcinogenic and carcinogenic PAH and heterocyclic PAH concentrations in St. Louis Park wells SLP4, SLP5, SLP7, SLP9, SLP10, and SLP15 and Hopkins well H3. These are all of the municipal supply wells in the St. Louis Park area that have been taken out of service by the MDH due to PAH contamination. The basis by which the MDH closed these wells is described in Chapter 2. Note that all of the data shown are for samples of untreated wellhead water, not finished water sent to the distribution system. This is important because all of the wells have chlorine and fluoride treatment, and St. Louis Parkwells SLP10 and SLP15 and Hopkins well H3 have iron removal treatment plants. As discussed in section 6.3, and in detail in Appendix G, iron removal treatment achieves significant removal of high molecular weight carcinogenic PAH, in which case finished water would have had lower concentrations of carcinogenic PAH than those shown in Figures 4-6, 7, and 8. In addition, St. Louis Park wells

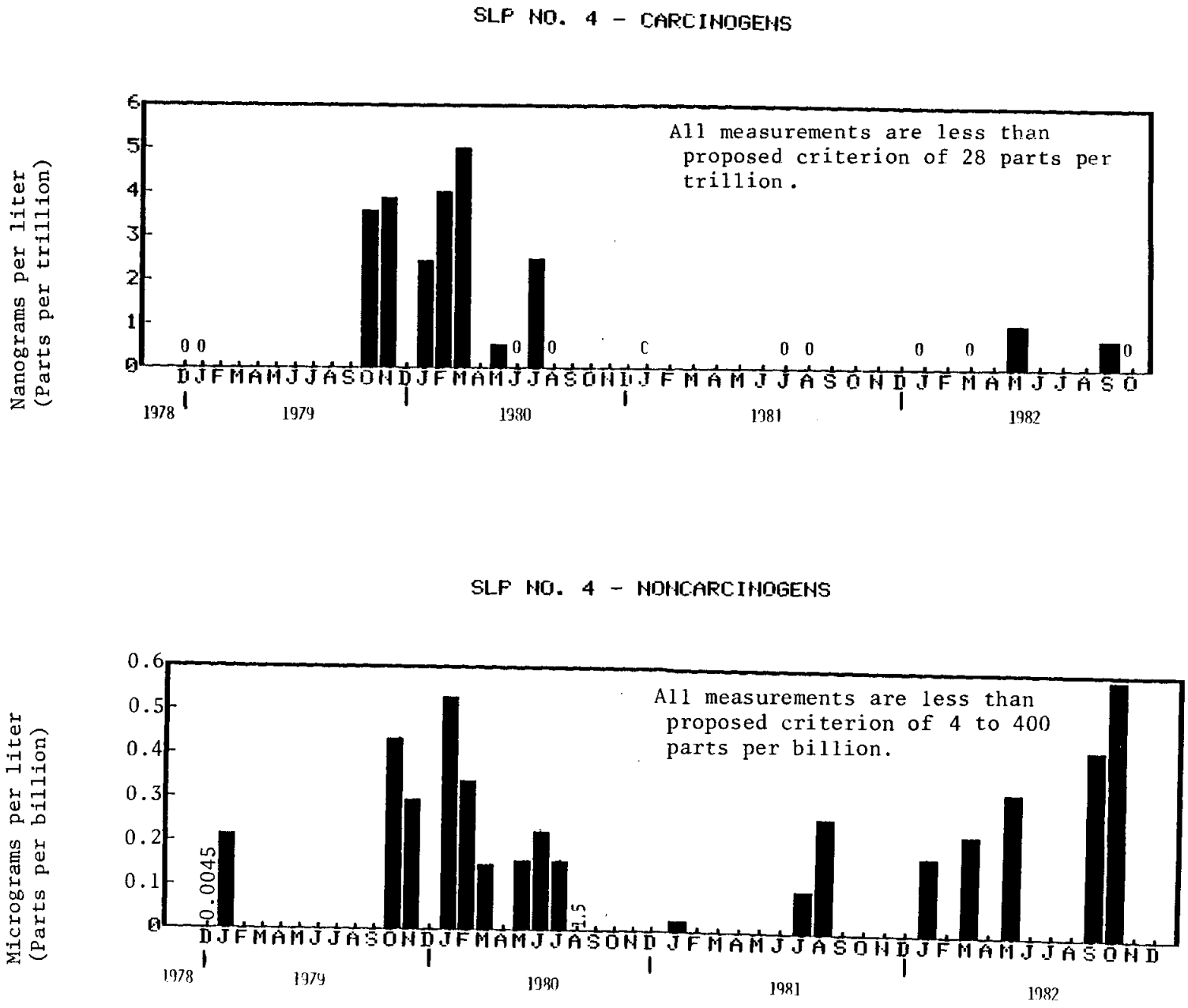
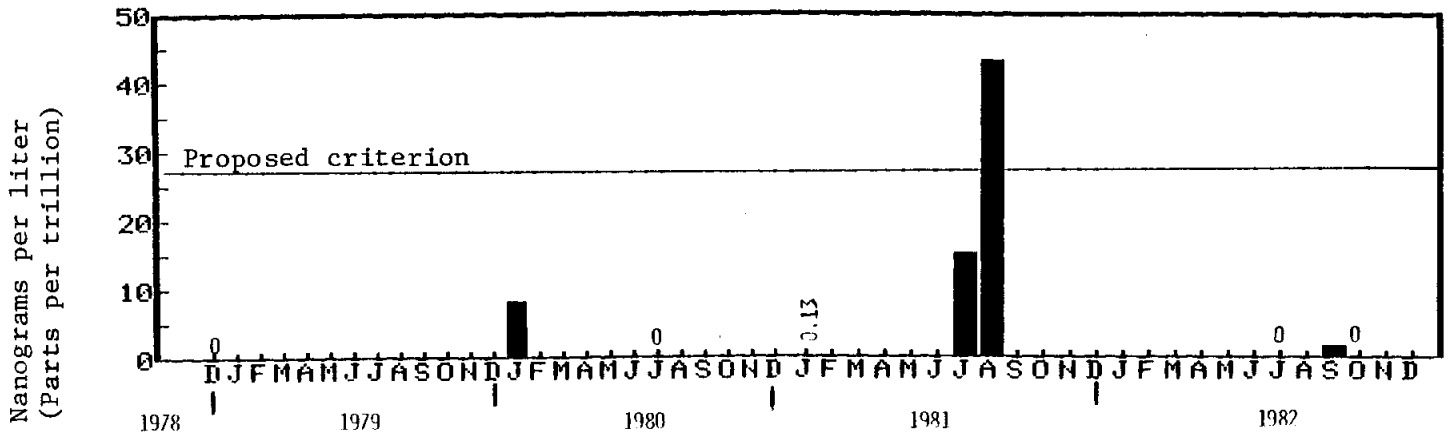


Figure 4-2. Chronological Summary of Total Carcinogenic and Noncarcinogenic PAH Concentrations Measured at St. Louis Park Well SLP4.

SLP NO. 5 - CARCINOGENS



SLP NO. 5 - NONCARCINOGENS

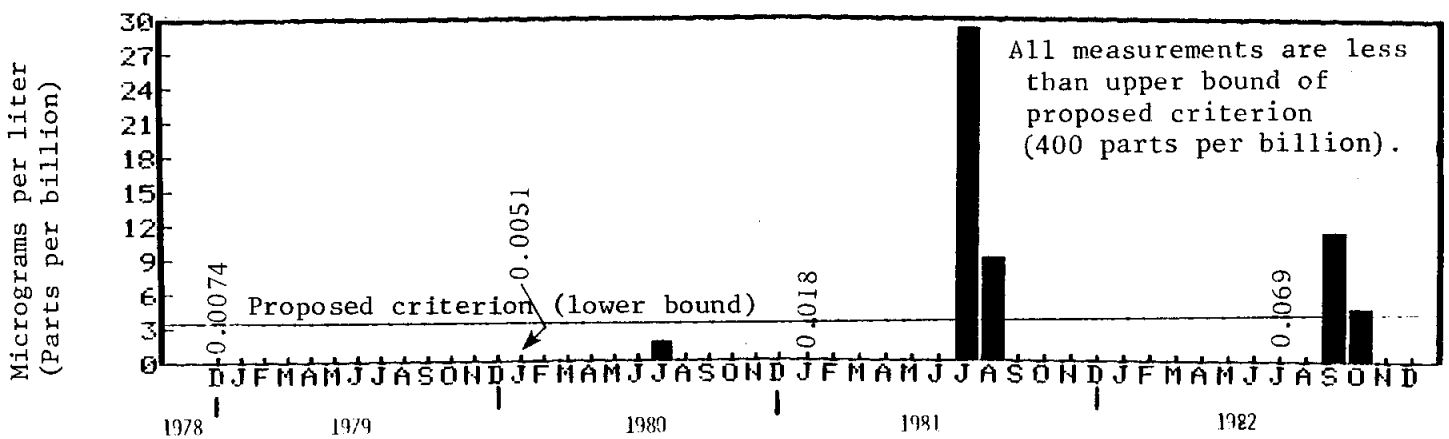


Figure 4-3. Chronological Summary of Total Carcinogenic and Noncarcinogenic PAH Concentrations Measured at St. Louis Park Well SLP5.

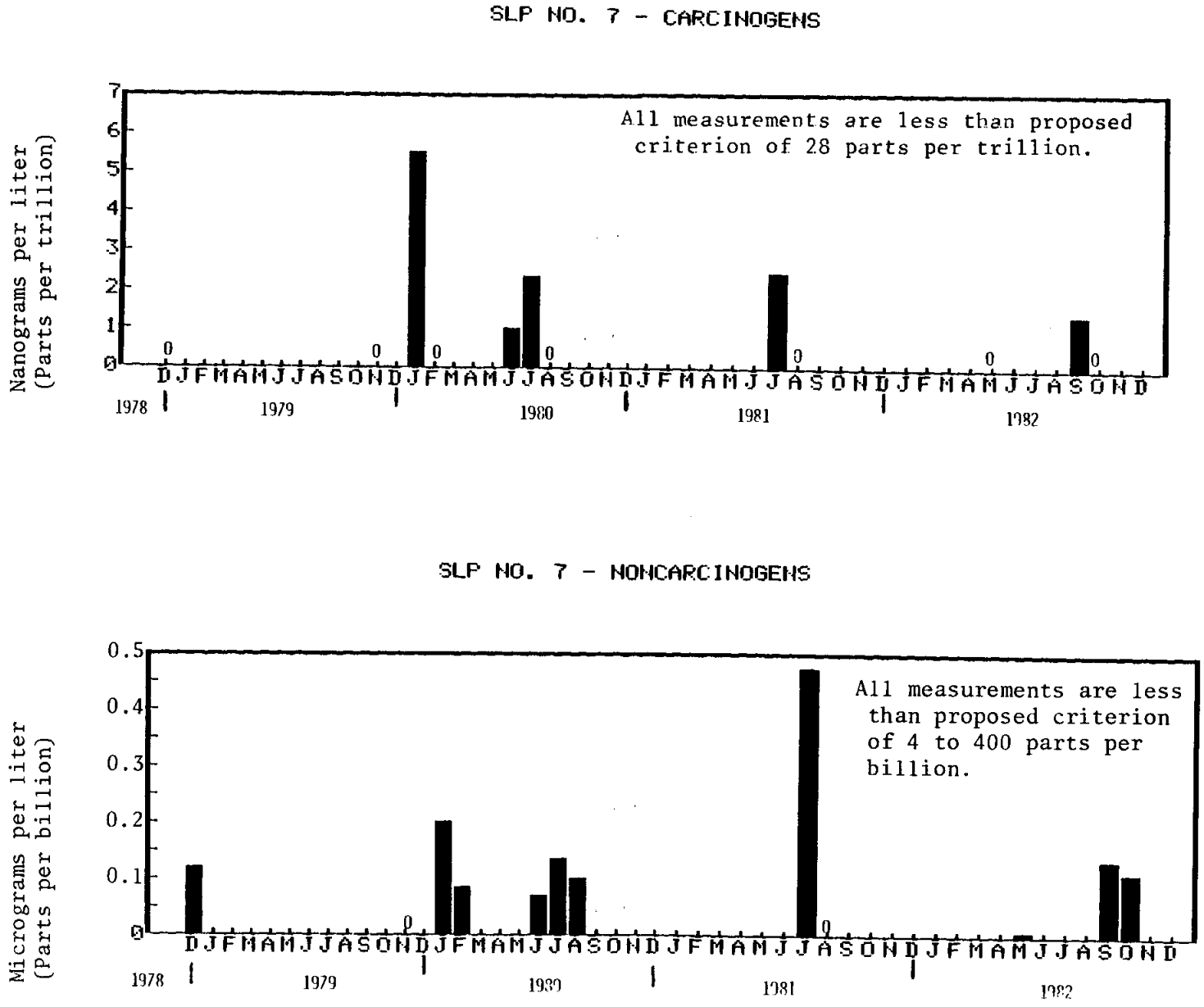
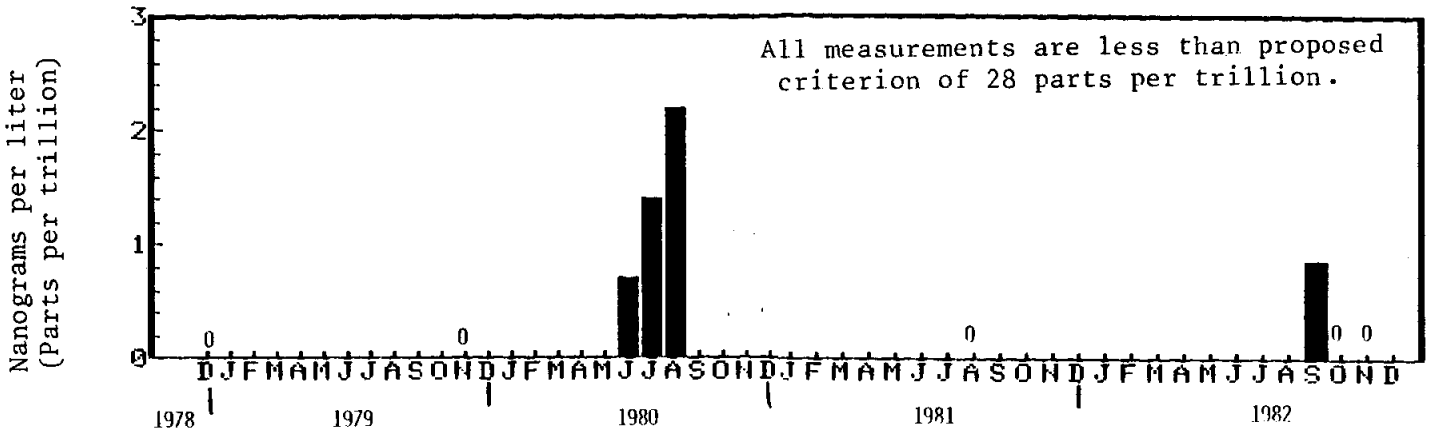


Figure 4-4. Chronological Summary of Total Carcinogenic and Noncarcinogenic PAH Concentrations Measured at St. Louis Park Well SLP7.

SLP NO. 9 - CARCINOGENS



SLP NO. 9 - NONCARCINOGENS

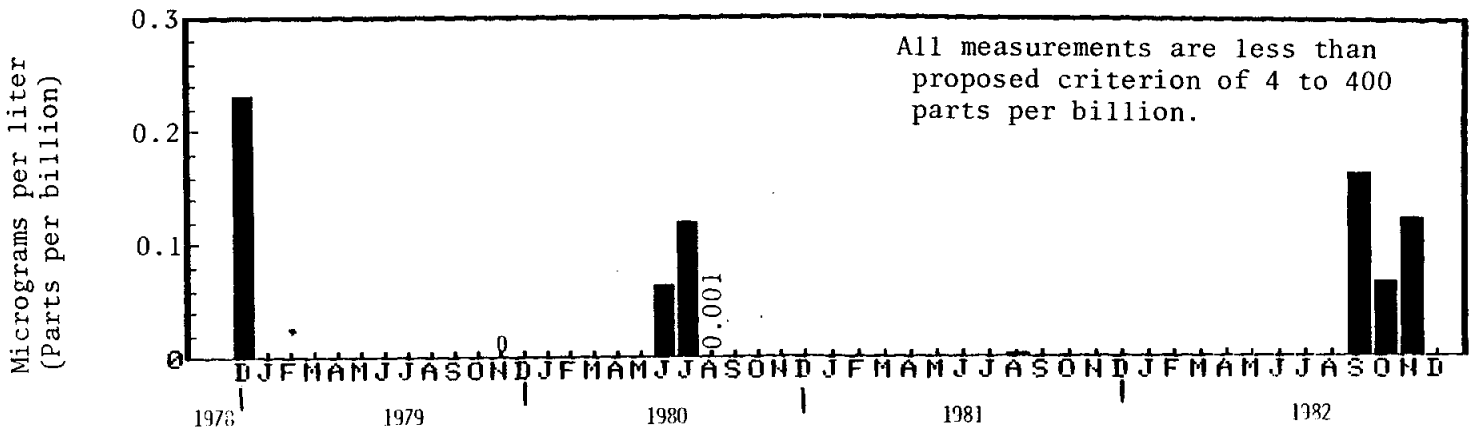
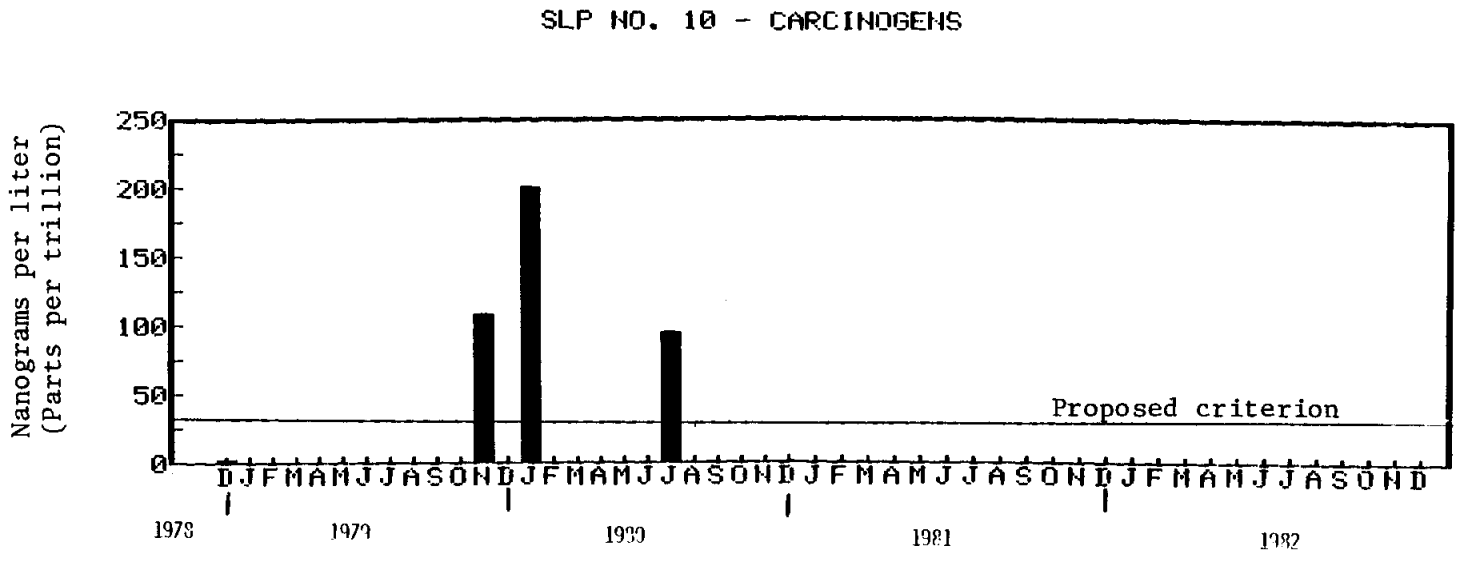


Figure 4-5. Chronological Summary of Total Carcinogenic & Noncarcinogenic PAH Concentrations Measured at St. Louis Park Well SLP9.



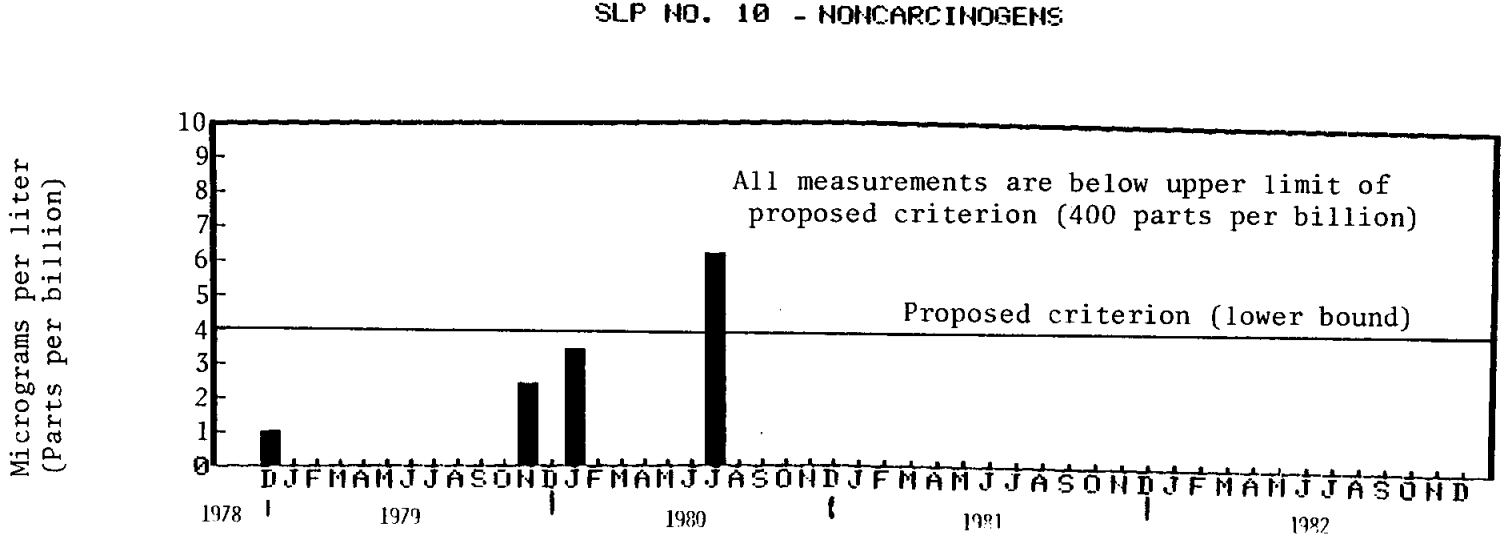


Figure 4-6. Chronological Summary of Total Carcinogenic and Noncarcinogenic PAH Concentrations Measured at St. Louis Park Well SLP10.

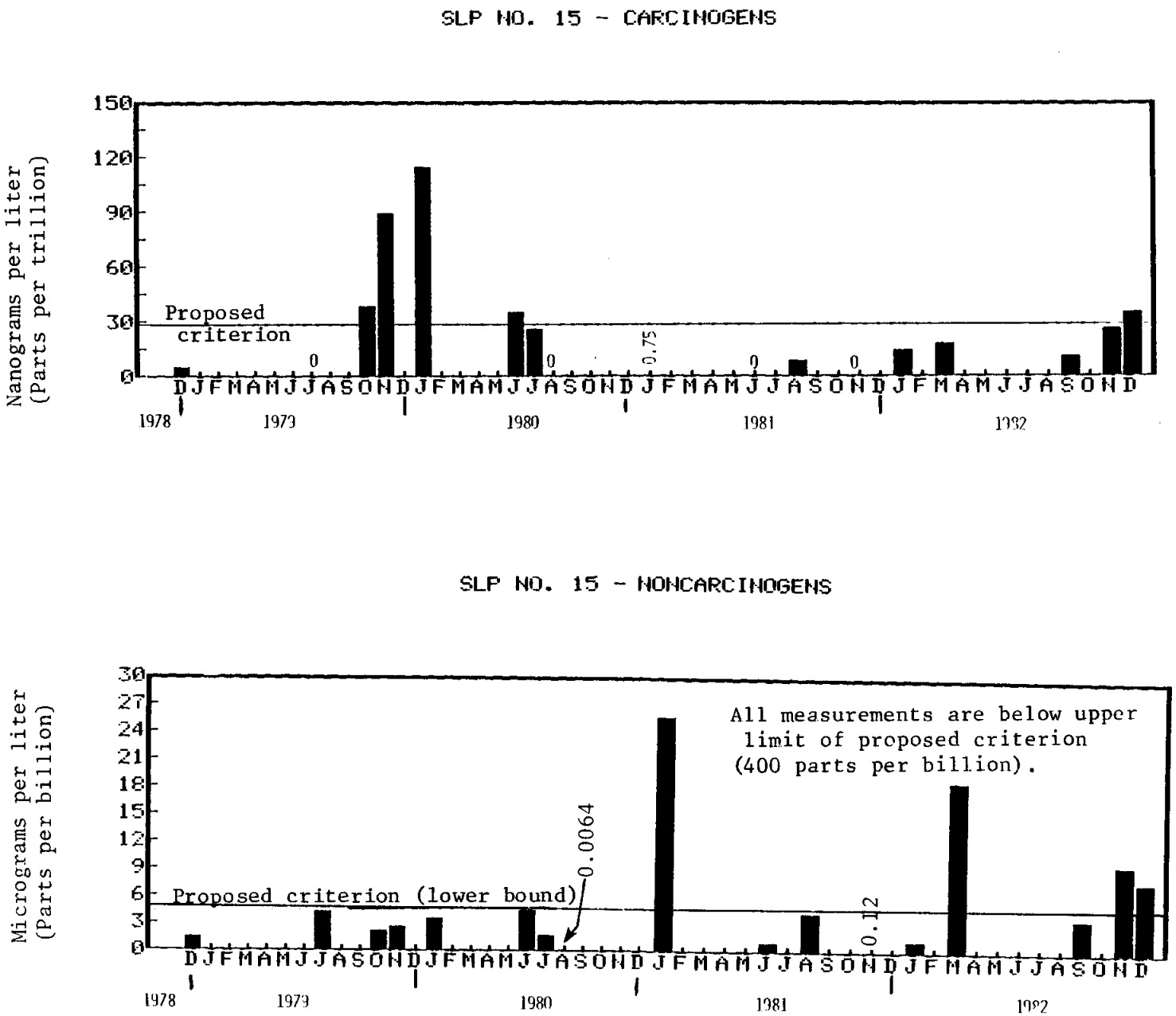
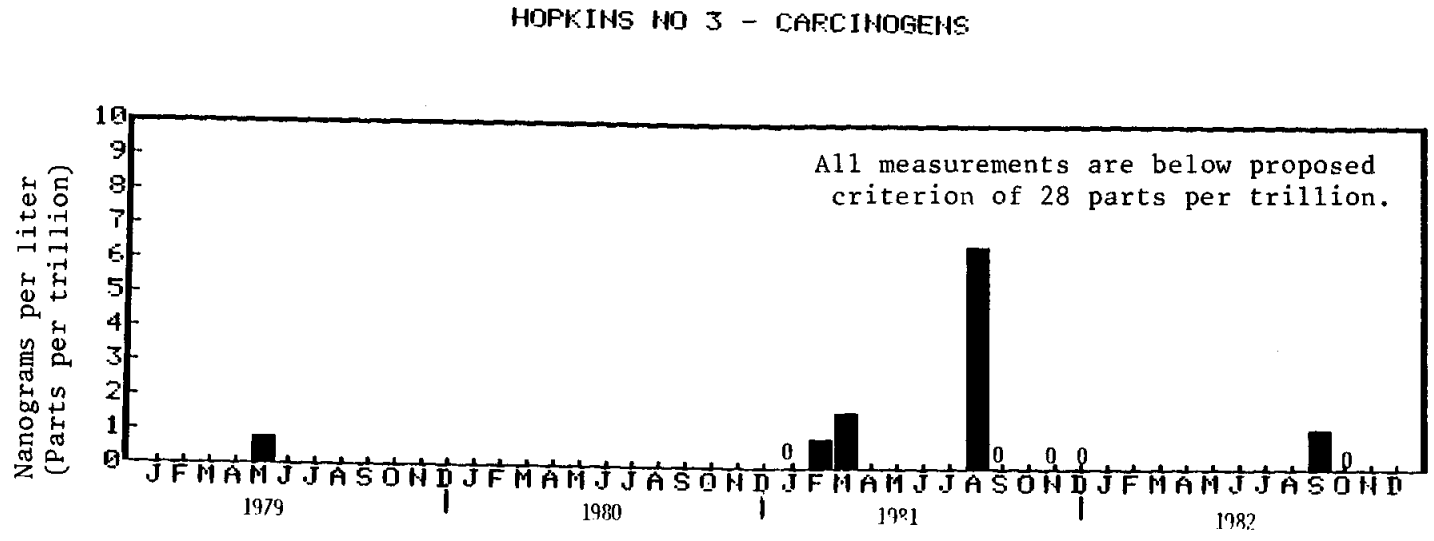


Figure 4-7. Chronological Summary of Total Carcinogenic and Noncarcinogenic PAH Concentrations Measured at St. Louis Park Well SLP15.



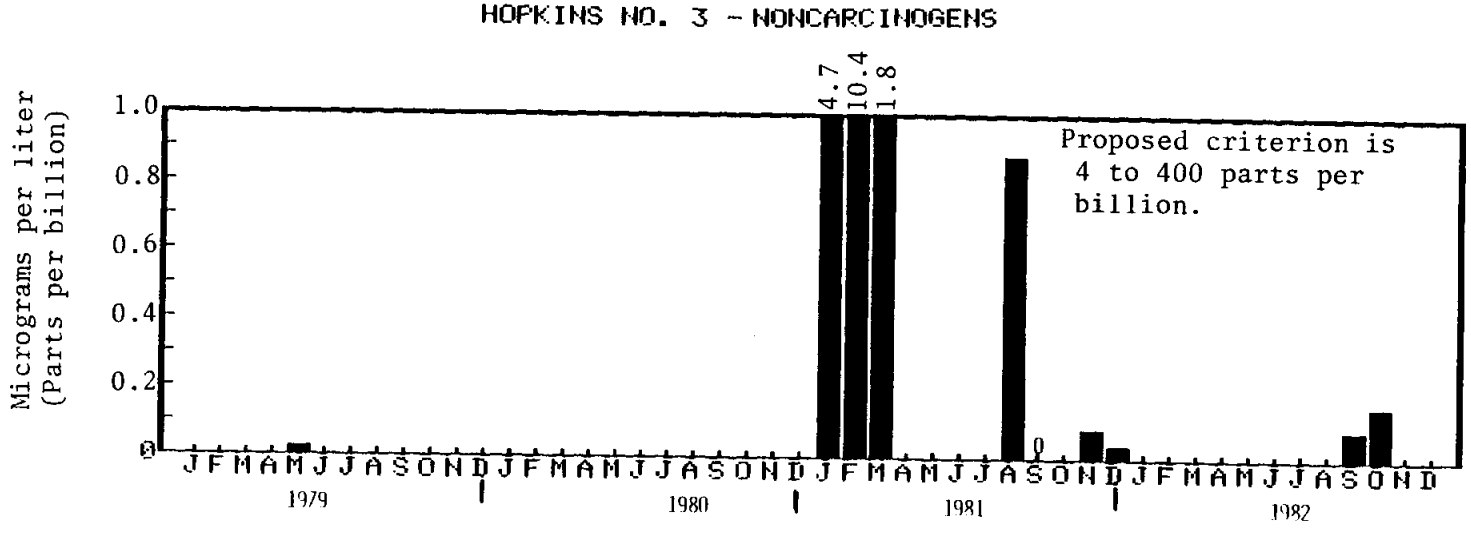


Figure 4-8. Chronological Summary of Total Carcinogenic and Noncarcinogenic PAH Concentrations Measured at Hopkins Well 3.

SLP10 and SLP15 are located at a treatment station with two other wells that are not contaminated by PAH (SLP3 and SLP11). The finished water from this station represents combined water from all four wells.

It is apparent from Figures 4-2, 4-4, and 4-5 that St. Louis Park wells SLP4, SLP7, and SLP9 have never exceeded or even closely approached the proposed PAH criteria. Total carcinogenic PAH concentrations in these three wells have never exceeded 6 nanograms per liter, and total noncarcinogenic PAH concentrations have never exceeded 0.6 micrograms per liter. Hopkins well H3 exceeded the lower bound of the recommended noncarcinogenic PAH criterion range (4 micrograms per liter) in three samples collected in February and March 1981, but all samples collected since then have been well below the criterion (Figure 4-8). These results indicate that all four of these municipal supply wells (SLP4, SLP7, and SLP9 and H3) could be placed back in service and meet the proposed PAH criteria, at least in the near term. The issue of whether these wells would become more contaminated in the future, to the point of exceeding the proposed criteria, is addressed in Chapter 6.

Figure 4-3 shows that SLP5 exceeded the lower bound of the recommended noncarcinogenic criterion range on a number of occasions in 1981 and 1982 and slightly exceeded the carcinogenic PAH criterion in 1981, although analyses in 1982 show that the carcinogenic criterion is readily satisfied. Figure 4-7 shows that water from the wellhead of SLP15 has exceeded both the carcinogenic criterion and the lower bound of the noncarcinogenic criterion at various times since 1979. However, SLP15 significantly exceeded the carcinogenic PAH criterion only for samples analyzed by high performance liquid chromatography (HPLC) by the MDH in 1979 and 1980. Results from 1981 and 1982, when more accurate GC/MS techniques were used, indicate that the carcinogenic PAH criterion was not exceeded or was only slightlyexceeded in recent analyses from November and December 1982. Figure 4-6 shows that PAH concentrations for SLP10 are, as expected, similar to those for SLP15, which is only a few hundred feet away. No analyses are available for SLP10 in recent years because the well has become sandlocked. Finished water from the treatment station containing wells SLP10 and SLP15 would not exceed the carcinogen

criterion if all four wells were operated at capacity because finished water concentrations would be reduced by about half as a result of dilution by uncontaminated water from wells SLP3 and SLP11 and because the iron removal plant at the well station achieves significant removal of carcinogenic PAH (see Chapter 6). Dilution by wells SLP3 and SLP11 could also reduce concentrations in combined finished water to below the lower bound of the noncarcinogen criterion range, depending on the relative pumping rates, and especially if SLP10 was not operated (since it is currently sandlocked).

In summary, Figures 4-2 through 4-8 show that none of the municipal supply wells in St. Louis Park or Hopkins that are currently out of service, as a result of PAH contamination, exceeds the recommended criterion of 28 nanograms per liter for carcinogenic PAH and heterocyclic PAH. Well SLP15, and presumably SLP10, slightly exceed the carcinogenic PAH criterion at the wellhead, but finished water from the treatment station would meet the criterion, given the effects of the iron removal plant and operation of wells SLP3 and SLP11. None of the currently closed wells even approach the upper bound of the recommended criterion for noncarcinogenic PAH and heterocyclic PAH (400 micrograms per liter). In fact, the highest concentrations of noncarcinogenic PAH and heterocyclic PAH ever observed are over ten times lower than the upper bound of the recommended criterion. Only wells SLP5, SLP10 and SLP15 currently exceed the lower bound of the recommended noncarcinogen criterion (4 micrograms per liter). As for carcinogenic PAH, finished water from wells SLP10 and SLP15 could meet the lower bound noncarcinogen criterion if wells SLP3 and SLP11 are also operated. Untreated water supplies from municipal wells in the St. Louis Park area that are still in operation are orders of magnitude below the recommended criteria (see Appendix K). It should also be noted that no measurements have ever been made to detect the presence of PAH in tap samples while contaminated wells were operating. Thus, none of the data obtained to date gives a direct measure of actual PAH exposures resulting from contaminated municipal supply wells.

The conclusion from comparing PAH data for municipal supply wells in the St. Louis Park area with the criteria recommended by this study

is that noncarcinogenic PAH are the primary problem in contaminated wells, not carcinogenic PAH. This is important in solving the St. Louis Park problem, both in light of public attitudes and in developing technical solutions.

5.0 EVALUATION OF SOURCE CONTROL ALTERNATIVES

Alternatives to control the sources of ground-water contamination by PAH and related compounds in the St. Louis Park area were evaluated for two distinct sources: 1) contaminated soil and surficial ground water at the site, and 2) multi-aquifer wells located on the plant site. Control of off-site multiaquifer wells and gradient control well schemes for containing contaminated ground water were also evaluated. A summary description of the technical approach used to identify and evaluate each of these types of controls is provided in this chapter, with more detailed descriptions provided in the technical appendices included with this report.

As discussed in Section 3.2.1, source controls alone cannot achieve all three stated objectives of this study. However, they may be used in combination with end-use controls to provide the most cost-effective overall solution to achieve the stated objectives. This chapter discusses the effects of source controls when applied alone. The effects of source controls used in conjunction with end-use controls are discussed in Chapters 6 and 7.

5.1 Site Controls

Source controls were evaluated for contaminated soil and ground water at the plant site and the bog immediately south of and adjacent to the plant site. The objectives, approach, and results of evaluating source controls for these areas are summarized below.

5.1.1 Objectives

Source controls were evaluated on their ability to help satisfy the three basic objectives set out in Section 3.1. As noted in Section 3.2.1, however, source controls alone cannot satisfy the objective of providing St. Louis Park and neighboring communities with a safe and adequate supply of potable water, nor is it clear that source controls alone can meet the objective of allowing for present and reasonably foreseeable future uses of ground-water resources in the St. Louis Park area. The direct objective addressed by source

controls for the site area is, therefore, to allow for safe, reasonable, and beneficial use of the site area. Source controls for the site area are also evaluated, however, on their effectiveness to indirectly help achieve the objectives of safe and adequate potable water supplies and protection of ground-water resource uses. Since source controls must be coupled with end-use controls to meet these latter objectives, the integration of source control results with end-use controls is reserved for later discussion in Chapters 6 and 7.

5.1.2 Approach

Sources and their effects were characterized by compiling and evaluating useful and reliable data available from previous studies. These data were used to define the spatial extent and levels of soil and ground-water contamination by PAH and related compounds in the site area, to explain the likely causes of the distribution of contaminants, and to predict the future behavior of these contaminants, if they are left in place.

Once the present extent and likely future behavior of contaminants at the site were characterized, an exhaustive list of remedial action alternatives was developed. Alternatives were included which, at least in theory, could be used to remove the contaminants or to contain or control their future movement. This list of alternatives was screened on the basis of effectiveness, reliability, and cost to rate each alternative as suitable or unsuitable in meeting the stated objectives for site area controls. The more favorable alternatives were then described in greater detail on a site specific basis and evaluated on the basis of effectiveness, reliability, feasibility, and cost.

5.1.3 Site Characterization

The site and ground water in the vicinity of the site have been locally contaminated with PAH and related compounds. To the extent that this contamination came from the plant, it resulted from spillage of process materials, drippings from leaky piping, precipitation washoff from stockpiled creosoted lumber, and wastewater discharge.

Contamination of surface soil underlying the plant site and discharge of wastewater to the bog have resulted in contamination of the surficial ground water (in the Drift-Platteville aquifer) beneath and within 1400 feet to the east (downgradient) of well W13. Well W13 is located in the middle of the bog.

Description and delineation of the nature and extent of the soil and surficial ground-water contamination are based on data compiled by other investigators and public agencies. No new data were gathered. These past investigations are discussed in Appendix B.

Measures of Contamination

This study has chosen benzene extractable hydrocarbons and phenolics as indicators of soil contamination. The largest set of analytical soil data included results for these parameters. This, in turn, allowed the greatest areal and vertical extent of the site area to be characterized by a single set of consistent data. While no direct relationship has been established between contamination by benzene extractable hydrocarbons and contamination by PAH and related compounds, it is implicitly assumed that such a relationship holds, to at least an approximate degree, in the site areas.

A sample of soil is considered contaminated if it contains concentrations of phenolics and benzene extracable hydrocarbons that exceed estimated background concentrations typical for the type of soil from which the sample was taken. All soil types in the site area contain some background level of phenolics and benzene extractable hydrocarbons. These background levels originate from anthropogenic (resulting from human activity) as well as natural sources. The anthropogenic sources result from off-site activities that were not in any manner specific to coal tar refining operations. For example, anthropogenic sources of benzene extractable hydrocarbon included in background concentrations can result from combustion of fossil fuels, spills of fossil fuels, and bituminous asphalt pavement. The steady manufacture, use, and disposal of various common commercial products, especially in industrial/commercial areas, result in at least low

level accumulations of contaminants that exceed naturally occurring background concentrations. This increase represents the anthropogenic contribution to background levels.

Benzene extractable hydrocarbon analyses have been performed on only two soil samples indicative of background levels in the St. Louis Park area. The samples were taken at locations roughly two miles from the plant site. With only these two samples available, background concentrations had to be estimated by comparing measurements of phenolics and benzene extractable hydrocarbons to qualitative descriptions of contamination in the soil samples. These background estimates were further refined by identifying an appropriate background estimate with each soil type (Table 5-1). For example, a benzene extractable hydrocarbon concentration of 20,000 milligrams per kilogram is a typical background concentration for the bog deposits underlying the site, but that same level would indicate contamination of the glacio-lacustrine clay, which has a background benzene extractable hydrocarbon concentration of about 1,000 milligrams per kilogram.

These background concentrations are used as standards to which the concentrations of phenolics and benzene extractable hydrocarbons in the soil samples are compared. If these estimated background concentrations are exceeded, the samples are considered to be contaminated.

Contamination of surficial ground water was also discerned by comparing indicator parameter concentrations to background concentrations. PAH and phenolics were chosen as indicators of surficial ground-water contamination. Background concentrations were selected from wells screened (open to the formation) in the Drift or Platteville Limestone that are upgradient from the site, or are laterally removed across the hydraulic gradient southwest of the site. Selection of wells that are located across the hydraulic gradient allows for inclusion of the anthropogenic contribution to the background concentrations. According to the gradient mapped by Hult and Schoenberg (1981) and verified by Ehrlich et al. (1982) these wells could not have received water-borne contaminants from the site,

TABLE 5-1

ESTIMATED BACKGROUND CONCENTRATIONS OF PHENOLICS AND BENZENE EXTRACTABLE HYDROCARBONS

Soil Type	Background Level Milligrams per Kilogram		Comments	
	Phenolics	Benzene Extractable Hydrocarbons	Phenolics	Benzene Extractables Hydrocarbons
Fill	1	500 - 1,000	7 of 8 samples ≥1 milligram per kilogram described as visibly contaminated.	1 of 4 samples <1000 milligrams per kilogram described as contaminated. All 6 samples >1000 milligrams per kilogram described as contaminated.
Peat and Organic Silt (Bog Deposits)	10	10,000 - 25,000	2 of 9 samples <10 milligrams per kilogram described as contaminated. 9 of 12 samples >10 milligrams per kilogram described as contaminated.	2 of 8 samples <10,000 milligrams per kilogram described as contaminated. All six samples >25,000 milligrams per kilogram contaminated. One background sample at 22,300 milligrams per kilogram.
Clay & Silt (Glacio-Lacustrine Deposits)	5	1,000	2 of 13 samples <5 milligrams per kilogram said to be contaminated. 5 of 6 samples >5 milligrams per kilogram said to be contaminated.	1 of 7 samples less than 1,000 milligrams per kilogram described as contaminated. 7 of 10 samples >1,000 milligrams per kilogram said to be contaminated.
Sand & Gravel (Glacio-Fluvial Deposits)	1 - 2	1,000	1 of 44 samples <1 milligram per kilogram described as contaminated. 7 of 13 samples >2 milligrams per kilogram described as contaminated.	2 of 52 samples ≤1,000 milligrams per kilogram said to be contaminated. 7 of 11 samples >1,000 milligrams per kilogram described as contaminated.
Clay, Silt, Sand & Gravel (Undifferentiated Till and Glacio-Fluvial Deposits)	1	500	None called contaminated. 39 of 46 samples were ≤1.0 milligram per kilogram Maximum value was 7.8 milligrams per kilogram.	None called contaminated. 52 of 57 samples were ≤500 milligrams per kilogram Maximum value was 1,900 milligrams per kilogram.

but can receive contaminants from other upgradient sources. Analytical data from these wells are representative of the quality of the site area ground water that has not been affected by contaminants migrating from the site. Downgradient wells that yield samples containing concentrations of indicator parameters greater than the concentrations in the background wells are considered contaminated.

Soil Contamination

The site has been divided into three areas based on the nature and the relative level of contamination (Figure 2-1). These areas are the northern half of the plant site, the southern half of the plant site, and the bog to the south of the plant site.

A pattern of discrete zones of contamination is typical of sites at which contaminants have been applied to the surface unevenly. Contaminant inflow to the surficial sediments was concentrated in areas such as the coal-tar refinery, wood-treating area, the surface-water drainage path, and the deeper surface-water flow zones of the bog. The uneven pattern of application, together with the heterogeneous and anisotropic properties of the sediments, create uneven and difficult-to-predict patterns of contamination and migration of PAH and related compounds. This uneven accumulation is further augmented by the physical properties of the contaminants. They are variably denser than water and have relatively low solubilities. In some areas contaminants are present in the saturated sediments in concentrations above their solubilities. This indicates that they are migrating in a phase separate from the ground water and in response to their own properties.

The northern half of the plant site was used to stockpile raw and treated lumber. It is slightly contaminated, the contamination being found within ten feet of the surface. However, most of the soil within this depth contains benzene extractable hydrocarbons and phenolics at levels below background concentrations. No contaminated soil is exposed at the surface. In addition, a large amount ofsurface soil was removed from the condominium development and stockpiled in the southern half of the plant site. These findings indicate that the

northern half of the plant site is probably not a source of contaminants that can enter the surficial ground water and migrate off site.

The southern half of the plant site, which contained the coal-tar refinery, tank farm, and wood-treating equipment, is generally contaminated from the original surface to a depth of about ten feet. Contamination appears to be greatest in the former wood-treating areas and in the area of the coal-tar refinery. In addition, discrete bodies of contamination in the Middle and Lower Drift sediments indicate that PAH and related compounds have migrated laterally and downward from where they were deposited at the surface.

The bog is generally contaminated from its original surface through a depth of ten feet. The bog has been extensively filled with soil of undetermined quality. Below ten feet there are discrete zones of contamination that are associated with lenses or strata of fine-grained sediments. Contamination is discernable above, within, and immediately below these lenses of fine-grained sediments. These lenses or strata predominantly control the rate and direction of contaminant movement.

There is regular occurrence of discrete bodies of contaminated soil throughout the surficial deposits underlying the site below and separate from the overlying areas that received the initial contaminant inflow. This strongly implies that the deposits of fine-grained sediments (i.e., the glacio-lacustrine deposits and the till deposits) are not homogeneously persistent across the site. That is, they are thin or absent in areas, and they vary in grain-size distribution and permeability to ground-water flow and contaminant migration.

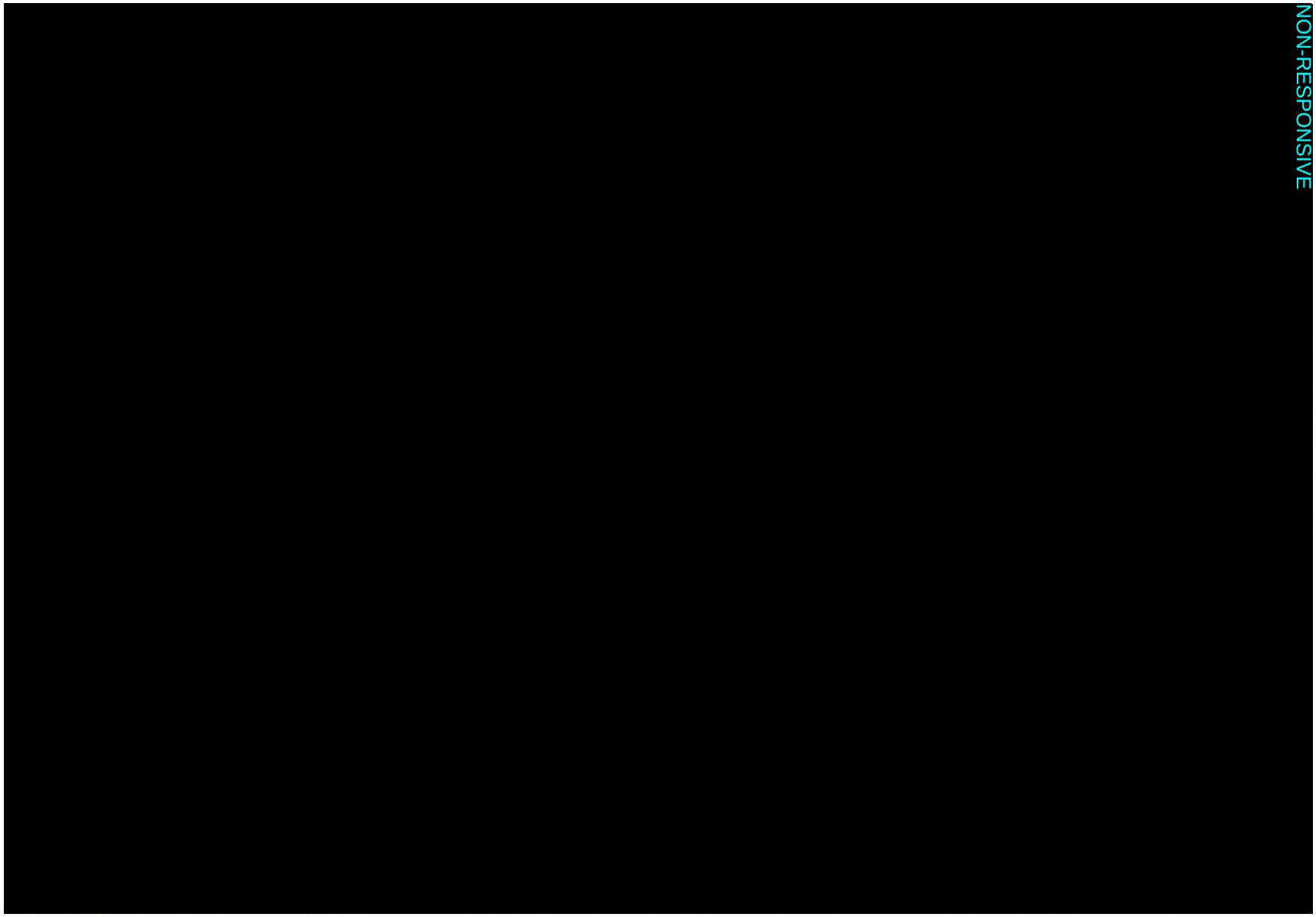
The occurrence and nature of surface contamination of the site has been greatly modified since the plant was removed in 1972. The east side of the northern half of the plant site supports a condominium development. A full array of subsurface utilities has beeninstalled. An indeterminate amount of soil was excavated from the condominium area and stockpiled in the southwest corner of the plant

site. The western portion of the northern half of the plant site currently supports a dense growth of grass, weeds, and several large trees. There is no visible evidence of contaminated soil at the surface, nor is there any indication of vegetation stress. The southern half of the plant site has been converted into a park-like area. No evidence of contamination is visible at the surface. The area is covered with dense sod, and there are no signs of vegetation stress, odors, or other manifestations of potential surface contamination. A 98,000 cubic yard stockpile of soil occupies the west side of the southern half of the plant site. It is composed of spoil from the runoff collection pond and spoil from nearby excavations. The quality of the stockpiled soil and its effect on ground-water and subsurface soil quality are unknown. Most of the bog has been filled with soil of unknown quality, and much of the bog has been developed. There is no visible evidence of contaminated soil.

Ground-Water Contamination

The ground water beneath and to 1,400 feet to the east (down the hydraulic gradient) from the bog is variably contaminated by PAH and related compounds primarily attributable to manufacturing and wood-treating at the plant site. The areal extent of surficial ground-water contamination contiguous with the site is illustrated in Figure 5-1. The ground water has become contaminated by precipitation percolating down through contaminated surface soil, thus leaching contaminants. Also, ground water flowing under the site from upgradient flows through zones of contaminated soil and ground fluid. In doing so, it picks up contaminants and transports them downgradient to the east.

At Well W13, which is located in the center of the bog (Figure 5-1), there is a local accumulation of two-phase ground fluid. This ground fluid is composed of an aqueous phase containing about 29,000 micrograms per liter of phenolics and 22,000 micrograms per liter of PAH. An oily phase is enriched in PAH. The ground fluid (both phases) contains about 0.1 weight percent PAH (Ehrlich et al. 1982). This ground fluid probably exists as a small lens in the pore space of the Middle Drift deposits on top of the fine grained upper till unit.



Base: USGS 7.5 min Topographic Series
Hopkins and Minneapolis South Minnesota

Figure 5-1 Map of the Areal Extent of Soil and Drift-Platteville Ground-Water Contamination

Its maximum dimensions are estimated to correspond to a right circular cone five feet in height and 100 feet in radius. Assuming a porosity of 30 percent, it would occupy a maximum fluid volume of 16,000 cubic feet. However, the ground fluid could also be much smaller than this, as data to accurately determine its size are currently unavailable.

The contaminated soil underlying the site and the accumulation of hydrocarbons in the ground-water saturated sediments at Well W13 continue to act as sources of surficial ground-water contamination (i.e., in the Drift-Platteville aquifer) below and downgradient from the site.

Contaminants have been detected in two wells down gradient from the site that were open to the Platteville and St. Peter aquifers. These wells are Terry Excavating well (W27) and Midco well (W33). Samples from these wells contain concentrations of phenolics ranging from 52 to 1400 micrograms per liter (Minnesota Department of Health 1980a and Barr 1977). However, these samples contained water from both the Drift-Platteville and St. Peter aquifers; thus, they are not good indicators of the water quality in either individual aquifer. Some indication of this came in 1979 when W33 was reconstructed as a well to only the St. Peter aquifer. After reconstruction, the St. Peter aquifer was found to be uncontaminated, based on measurements of PAH (Minnesota Department of Health 1980a). In any event, reconstruction of W33 eliminated it as a possible conduit of future contaminant flow to the St. Peter. The Terry Excavating well (W27) was grouted through the St. Peter at the same time and is no longer a multi-aquifer well either. The Hartmann well (W41) is open to the Platteville and St. Peter, and could act as a conduit to the St. Peter Sandstone if contaminants migrate that far. It is not known if there are other wells near to and downgradient from the site, that could act as conduits of flow of contaminated Drift-Platteville ground water into the St. Peter. On-site, deep, multi-aquifer wells (W23 and W105) potentially provide conduits for migration of contaminants from the soil, and surficial ground water immediately underlying the site, to deep bedrock aquifers. These wells, and mechanisms of contaminant migration through them, are discussed in section 5.2.

The ground-water quality data reviewed for this interpretation do not depict any trend in ground-water quality indicative of a pattern of change in the near future. Phenolics, however, are known to degrade at the site in ground water by the action of anaerobic bacteria (Erhlich et al. 1982). The pattern of phenolic degradation indicates that effective removal of these contaminants occurs within 1,400 feet of the site. Phenolic concentrations in the surficial ground water have been shown to decrease from 29,000 micrograms per liter to less than 90 micrograms per liter within 1400 feet downgradient from Well W13 (Erhlich et al. 1982). Other potential contributions of phenolics within this distance downgradient from the site have not been assessed, although they likely exist.

It is reasonable to assume that the rate of off-site migration of PAH and related compounds will not increase. These contaminants have been available for migration for at least the 65 years since the plant started operating in 1917. The quality of wastewater discharged from the plant improved over the last 30 years of plant operation, as wastewater treatment was steadily upgraded (Appendix A). The rate of contaminant input to surficial ground water has probably declined over the years since the plant closed in 1972. The overall potential for contaminants to migrate offsite is decreasing because there is no longer a continuous input of wastewater, and because physical, chemical, and biological mechanisms are steadily attenuating the contaminants in the sediments and ground water. The flux of PAH and related compounds vertically through the bog deposits into the Drift-Platteville aquifer was greatest during plant operation, when the steady influx of wastewater exceeded surface flow out of the bog and evapotranspiration. This created a ground-water mound and increased the vertical gradient (Hult and Schoenberg 1981). Since 1971, this vertical gradient has been reduced by cessation of wastewater input, and in 1975 by construction of lined runoff retention ponds and culverts. The flux of contaminants vertically through the bog deposits is now lower than it was during the last years of plant wastewater discharge to the bog. Short term variations in the rate of contaminant migration could result from fluctuations in precipitation, changes in ground-water pumping, and shifting of the ground fluid near Well W13.

In summary, the available data indicate that the site is and has been a source of contamination in the surficial ground water, and the nature and extent of the contamination will not increase for the near future. Ground-water borne contaminants will continue to flow in an easterly and downward direction from the site. Their downward migration will be retarded by the Glenwood Shale, and their lateral migration will be limited by physical, chemical, and biological interactions.

5.1.4 Site Area Control Alternatives

A detailed evaluation of potential remedial actions, which could be implemented as source controls, is presented in Appendix C. All remedial actions were initially screened to identify technically feasible alternatives. No effort was made in the initial screening to determine if these remedial actions could meet study objectives.

A limited number of the potential site remedial actions was found feasible. These site control options were subsequently evaluated in depth to assess their reliability, effectiveness, and cost in meeting the stated objectives of the study. As discussed in Section 5.5.1, site source controls alone cannot meet the objectives of providing safe and adequate potable water supplies or allowing for present and reasonably foreseeable future uses of ground-water resources in the area. Site controls were also evaluated for their effectiveness to reduce contaminant transport from the site to deep bedrock aquifers, as a means of indirectly helping to achieve the above stated objectives. However, there is no evidence to indicate that the site is, or has been in the past, a significant source of contamination to deep bedrock aquifers.

Table 5-2 presents the remedial actions evaluated in this study, as well as those evaluated in previous studies (Barr 1977, Hickok 1981). The screening effort showed that the following remedial actions are technically feasible for the plant site and bog:

- excavation,
- ground fluid pumping,

TABLE 5-2

IDENTIFICATION OF SITE REMEDIAL ACTIONS PREVIOUSLY AND CURRENTLY UNDER CONSIDERATION

Remedial Action Method	Consultant's Report & Date		
	Barr 1977	Hickok 1981	This Study
Ground Water Pumping	X		X
Excavation	X	X	X
Well Closures	X		X
Additional Municipal Water Treatment	X		X
Surface Sealing		X	X
Barrier-Slurry Walls		X	X
Barrier-Grout Curtains	X		X
Incineration (w/Excavation)		X	X
Encapsulation		X	X
In-Situ Treatment (Chemical Injection)		X	X
Solidification		X	X
No Action		X	
Ground Fluid Removal	X	X	X
Barrier-Sheet Piling			X
Bottom Liners			X
Gradient Control Wells	X	X	X
Bioreclamation			X
Site Security & Monitoring			X

- gradient control wells,
- bioreclamation, and
- monitoring and site use controls.

Excavation of contaminated soils is technically feasible. However, the effectiveness of excavation to reduce contaminant transport is considered poor. Significant amounts of contaminated drift deposits would remain in place, due to limitations associated with the depth of excavation and the presence of buildings and roads, which would hinder complete removal. The contaminated deposits remaining in place after excavation would still be a potential source of contamination to the ground water. Removing contaminated soil will not allow for the safe future use of the site without implementing a site use control plan. If a site-use-control plan were implemented, however, there would be no significant benefit from excavation per se.

In addition to these problems with the effectiveness of excavation, this alternative is also extremely expensive. It is estimated that it would cost over $25 million simply to excavate contaminated soil throughout the plant site and bog. Comparable or greater costs would be incurred in disposing the excavated soil. Even partial excavation of the bog alone would be very expensive, with an estimated cost of $5 to $10 million, excluding disposal costs. Appendix C provides further details on these cost estimates.

Removing the ground fluid body is technically feasible, although some residual fluid would remain as a contaminant source to the Drift-Platteville aquifer. Removing the ground fluid would increase the surface area of the source/ground water interface, and therefore change present equilibrium conditions between the soil, the ground fluid, and local ground water. Removing the ground fluid, thus, could temporarily result in an increase in ground water concentrations of PAH and related compounds. This study concludes that removal of the ground fluid should only be considered in conjunction with the installation of a gradient control well system. Installation of a gradient control well system is not recommended by this study. Therefore, there are no apparent benefits achieved by removing the ground fluid.

The technical feasiblity of implementing bioreclamation is questionable. Limited experience is available with this technique, and it has never been used at sites contaminated by coal tar materials or implemented in organic soils. Futhermore, available data concerning microbial degradation of oily wastes by land treatment indicate that PAH removal would not be complete. The effectiveness of this technique for meeting any study objective is considered poor.

Gradient control wells are technically feasible. However, the effectiveness of a gradient control well system to reduce contaminant transport is considered moderate due to leakage effects. Installation of a gradient control well system would not result in any significant benefits in allowing for the safe future use of the site. Gradient control wells would be moderately effective in preventing further contamination of the surficial aquifers and ultimately of deeper bedrock aquifers via multi-aquifer wells or via the buried bedrock valley downgradient of the bog. However, as discussed in Chapters 6 and 7, gradient controls at the site are not cost-effective from an overall view of meeting the stated objectives of this study due to their higher operation costs.

Monitoring and site use controls can be easily implemented and are the most effective option to allow for the safe future use of the site. Also, these controls are highly effective in determining the potential impacts of uncontrolled contaminant migration although they do not control contaminant transport per se. If monitoring results indicate that contaminant migration is occurring at significantly different rates or directions than predicted by this study, then cost-effective responses can be reevaluated.

Table 5-3 presents the estimated present value costs for the five site remedial actions evaluated. For this evaluation, the study objective to allow for present and reasonably foreseeable future uses of ground-water resources in the St. Louis Park area has been substituted with a more appropriate objective: to reduce contaminant transport to deeper bedrock aquifers. This substitution has been made because source controls at the site area do not directly achieve the stated objectives for deep bedrock aquifers, but instead do so

TABLE 5-3

COST OF SITE REMEDIAL ACTIONS

Remedial Action s)	Present Value Costs $ Millions
Excavationion	200
Ground Fluid Recovery	0.85
Gradient Control Wells	0.86 - 1.23
Bioreclamation	0.77 - 3.56
Monitoring	0.19 - 0.26

indirectly. This substitution has also been made because the effects of the site area on present and reasonably foreseeable future uses of surficial ground-water resources are most effectively addressed by use restrictions (see section 5.1.5 below).

5.1.5 Recommended Site Area Controls

The majority of the site area has been covered, supports normal types of vegetation, and is being used for community and private purposes. The only known impediment to reasonable, foreseeable future use of the site concerns the construction of the Louisiana Avenue extension. The site contamination itself does not affect the construction of this road. It is suspected that uncertainties related to the possible implementation of source controls such as excavation have halted completion of this project. This study has evaluated possible remedial actions to allow for the safe continued use of the site and finds no evidence to indicate that construction of the Louisiana Avenue extension can not proceed as planned.

Each of the above five source control options was evaluated in detail and found to vary significantly in terms of effectiveness (as defined by the ability of the remedial action to meet study objectives), technical feasibility (as defined by the previous application of the technology to similar site and contamination characteristics), and cost (as defined by present worth).

The most cost-effective option to ensure safe future use of the site is to institute a monitoring and site control program. The program would provide a documentation of site contamination, which could be included as part of the public records that would beavailable to future purchasers or developers of the property. Prior to preparing such a description, the USGS data that are not reported in Hult and Schoenberg (1981) and Ehrlich et al. (1982) should be integrated.

A monitoring program coupled with additional studies is the most cost-effective option (and only applicable site source control action) to ensure a safe adequate drinking water supply for St. Louis Park.

Based on the monitoring program and study results, an area in the Drift-Platteville in which drinking water withdrawal is prohibited should be delineated. The additional studies needed to properly delineate this area include a detailed evaluation of 1) the ongoing well survey in the vicinity of the site area by Hickok and 2) additional USGS data not presented in Hult and Schoenberg (1981) and Ehrlich et al. (1982). Specific recommendations concerning the private use of the Drift-Platteville aquifer downgradient from the site will be developed after the data are made available. These recommendations will include a general ban on the use of aquifers for drinking water downgradient from the site, over a discrete area and time period, and monitoring of these aquifers downgradient from the site. The adverse impact of this action is minimal, since all potentially affected residences are on a public water supply system.

The following additional studies would be necessary to develop a monitoring and site use control program:

- integration of any available data on the hydraulic characteristics and water quality of the Drift-Platteville aquifer that have not been published or made available to this study;
- evaluation of data from the private well survey currently underway to identify the location of multiaquifer wells and potentially affected private water supply wells.

These studies are directly related to developing a monitoring and site use control program. The recommended studies should not change the conclusions presented in this section. The studies, however, will generate the data necessary to design a final solution for the site.

5.2 Plant Site Multi-Aquifer Well Controls

This section evaluates the control of the two deep multi-aquifer wells located on the plant site. These wells are W23, the plant supply well, and W105, the old sugar beet refinery well.

5.2.1 Objectives

The purpose of evaluating source controls at wells W23 and W105 is to determine if such controls are a reliable and cost-effective aid in achieving the objectives of 1) a safe and adequate public water supply for St. Louis Park and neighboring communities and 2) protecting ground-water resource uses. Source controls at wells W23 and W105 cannot achieve either of these objectives singly, but in combination with end-use controls, they may increase the reliability and cost-effectiveness of controls aimed at achieving these objectives. With respect to allowing for the safe, reasonable and future use of the site area, source controls at wells W23 and W105 would have no effect because any contaminants in these wells are far below ground level.

5.2.2 Approach

Source controls at the on-site multi-aquifer wells were evaluated by first characterizing the present distribution of contaminants in the well and its immediate vicinity. These characteristics were then used to assess the potential for this well to act as a continuing source of ground-water contamination, if left unremedied, and to define remedial actions that would significantly change these source characteristics. The remedial action alternatives were then evaluated for their reliability, feasibility, and cost-effectiveness. Details of the characterization, remedy evaluation approach, and results are presented in Appendix D.

Of the two known plant site multi-aquifer wells, well W23 has been the object of considerable investigation in recent years, whereas well W105 has not. W105 has only recently been located at the site. Little is known about present conditions in well W105, in part because the well was abandoned in 1933. Well W105 is included in this discussion because it has an unknown potential to be a major contributor to the migration of contaminants from the site.

5.2.3 Well W23 Characteristics

This section characterizes the present distribution of contaminants in and around well W23 for each aquifer penetrated by the well. This characterization is based on the history of the well during plant operations, and the results of recent investigations of the well since the plant closed, as described in Appendix D.

As a source of contamination, well W23 is unique because coal-tar-like material has been found in the well in direct contact with aquifers deep underground. The term coal-tar-like material is used because the physical properties of the material in well W23 are indicative of a coal-tar-related material, but no measurements have been made to show that it is coal tar per se. It includes material that has coated portions of the casings and rock surfaces in the well and the material referred to as the plug. The plug was discovered in 1979 by the US Geological Survey during their investigation of W23. The top of the plug was 595 feet below the ground surface, and in 1982 the bottom of the plug was found at a depth of 740 feet. The origin of this plug of material and when it came into existence are currently unknown.

A general description of current conditions in well W23 is shown in Figure 5-2. The depth of the well is now 545 feet, the bottom having been filled with bentonite after being cleaned to 866 feet. An eight-inch diameter pipe has been installed to a depth of 253 feet, where a packer prevents the flow of water from the St. Peter to the Prairie du Chien. Another packer at about 85 feet prevents the flow of water from the Platteville to the St. Peter. The following discusses the potential impact of well W23 on each of the aquifers that it penetrates.

<u>Mt. Simon-Hinckley Aquifer</u>

Historical PAH water quality data for municipal supply wells completed in the Mt. Simon-Hinckley aquifer do not indicate any contamination in this aquifer. As discussed in Appendix D, the work performed on W23 in 1982 by the MPCA resulted in an accumulation of

St. Peter

A great many wells in the St. Louis Park area are open to both the Drift-Platteville and St. Peter aquifers. Location of all potential multi-aquifer wells in this category would be very difficult because of the large number of wells involved. This is indicated by the report that Hickok's recent multi-aquifer well survey identified about 1,000 wells in a 4 square mile area bounded by West 28th Street to the north, Virginia Avenue to the west, France Avenue to the east, and Excelsior Boulevard and West 40th Street to the south (Hansel 1983). About half of these had not been identified before. Most of these 1,000 wells are shallow, although a significant number are reported to extend as far as the St. Peter (Hansel 1983). Tables 5-4 and 5-5 indicate about 25 wells connecting the Drift-Platteville and St. Peter aquifers based on data prior to the Hickok survey.

The USGS (Hult and Schoenberg 1981) has indicated that shallow multi-aquifer wells do not necessarily show flow from the Platteville to the St. Peter. They postulate that skin effects in the Platteville prevent flow. In any event, the possibility that such wells do not allow multi-aquifer flow and the large number of such wells imply that further investigation would be prudent before embarking on an expensive program to seal all such wells. Selective reconstruction of a number of wells as St. Peter monitoring wells is a cost-effective means to determine the extent of contamination without the expense of drilling new monitoring wells. This program is necessary prior to a major, and perhaps needlessly expensive, well sealing program.

5.3.4 Remedial Action Alternatives for Off-Site Multi-Aquifer Wells

The remedial action alternatives considered by this study for off-site multi-aquifer wells are

- no action,
- permanent abandonment or replacement,
- further inventorying.

Each of these alternatives is discussed below.

No Action Option

Remedial action may be unneccessary or ineffective for some or all off-site multi-aquifer wells. This would certainly be the case where multi-aquifer wells are found not to be contaminant pathways, where multi-aquifer wells do not penetrate deeper aquifers used for drinking water supply, or where the wells do not originate in areas where the surficial aquifers are contaminated by PAH and related compounds. It may even be that remedying multi-aquifer wells that do fit one of these categories would still not be cost-effective, when the cost of sealing is compared to the savings (drinking water treatment or new supply wells) assocated with continued contamination.

Permanent Abandonment/Replacement Option

The purpose of this section is to outline procedures for permanent well reconstruction or abandonment and replacement if necessary. Additional procedural details are supplied in Appendix D.

Within areas where there is known contamination of surficial aquifers, it serves little purpose to log multi-aquifer wells prior to permanent abandonment, since, under this option, all multi-aquifer wells in areas of known contamination would be permanently sealed. Furthermore, flow meter logs cannot prove conclusively that low velocity interaquifer flow does not exist within the well bore. In addition, a flow meter cannot measure interaquifer flow that occurs in the annular space between the casing and the well bore.

As part of this option, multi-aquifer wells can be abandoned following these general guidelines. After any obstructions in the well are removed, the well can be sealed with cement grout. If solution cavities or extensive fracture systems exist, casing may be required to seal them. Finally, soil will be excavated around the well head at the surface to allow a thick cement seal to be installed around the casing.

Any multi-aquifer wells that remain in good condition can be considered for reconstruction under this option. Multi-aquifer wells can be reconstructed into single aquifer wells by sealing off portions of the well bore in all but one aquifer. Reconstructed wells can be used for monitoring purposes, or for water supply.

If wells that require permanent sealing or reconstruction are currently used, a replacement supply is necessary. Low demand wells may be cost-effectively replaced by connection to the municipal water system. For larger wells, replacement wells must be drilled and connected prior to the start of remedial work on the old well. Replacement wells should be single aquifer wells drilled to the shallowest aquifer with acceptable quality for the type of use (i.e. process or potable).

Table 5-6 presents cost estimates developed for permanent abandonment of multi-aquifer wells and for drilling replacement wells. These estimates are relatively conservative in that they assume that a drill rig will be required to clean out the well and install the grout seal. In cases where the well to be sealed is in good condition, grout can be installed by a two person crew at substantially less than the assumed drill rig cost of $95.00 per hour for rig and crew. However, in most cases, some clean out work (e.g. removing pump) will require drill rig assistance. Estimated grout costs reflect the large volumes of grout that may be required to fill small cavities in the St. Peter formation and small solution channels in the Prairie du Chien formation. Large voids would necessitate grouting around casing installed to the appropriate depth.

Additional Logging and Inventory

Preparations to assess and, if necessary, control multi-aquifer wells that could be affected by possible future migration of contaminants in the Drift-Platteville, St. Peter and Prairie du Chien-Jordan aquifers should be initiated in advance of the actual appearance of contaminants. The multi-aquifer well inventory recently completed by Hickok should be adequate for this purpose for multi-aquifer wells that connect the Drift-Platteville and/or St.

TABLE 5-6

ESTIMATED COSTS FOR

MULTI-AQUIFER WELL

ABANDONMENT AND RECONSTRUCTION

(Costs do not include well replacement.)

Case	Permanent Abandonment	Reconstruction of Monitoring Well
Deep Well (1000 feet deep, 6-10 inch diameter)	$15,000 - $30,000	$10,000 - $25,000
Shallow Well (250 feet deep, 6-10 inch diameter)	$ 5,000 - $10,000	$ 3,000 - $ 7,000

Notes:

See Appendix D for description of cost bases.

Peter to lower aquifers, based on the current extent of contamination and the predicted contaminant migration rates in these aquifers. However, the boundaries of a multi-aquifer well survey for wells connecting the Prairie du Chien-Jordan and Mt. Simon-Hinckley aquifers must be extended. Additional multi-aquifer well surveys covering further areas for both shallow aquifers (wells that connect the Drift-Platteville and/or St. Peter to lower aquifers) and the Prairie du Chien-Jordan (wells that connect this aquifer to the Mt. Simon-Hinckley) may be required during the next 100 years, if contaminants migrate in these aquifers.

On the basis of a review of the well inventory recently completed by Hickok, it may be determined that further study of existing wells in the inventory area is warranted. These studies would augment the Hickok inventory by filling information gaps. Wells of unknown depth should be sounded to determine total depth. If sounding results are inconclusive, geophysical, down hole television, and/or flow meter (spinner), logging should be conducted in order to identify multi-aquifer wells that allow interaquifer flow. Accurate location and elevation measurements should be surveyed for all wells. The estimated cost of these additional studies is from $25,000 to $50,000.

Future multi-aquifer well inventories for expanded areas of the Drift-Platteville and St. Peter should be conducted in the following manner. First, a study area should be defined that includes areas likely to be impacted by contaminant migration in the Drift-Platteville and St. Peter over the following few decades. Second, a file search of U. S. Geological Survey, Minnesota Geological Survey, Minnesota Department of Health, municipal water boards, and driller's records should be conducted. Third, a door-to-door survey of additional wells in the study area should be completed. Finally, a priority list of known or suspected multi-aquifer wells should be assembled for further study. These studies might include water quality analysis, geophysical logging, downhole television logging, or downhole flow meter logging. The estimated cost to conduct an additional survey as described above is from $25,000 to $100,000 depending on the area covered and the number of multi-aquifer wells discovered.

An inventory of multi-aquifer wells that connect the Prairie du Chien-Jordan with the Mt. Simon-Hinckley should generally follow the procedures outlined above. However, door-to-door surveys should be limited to industrial or commercial well owners, since it is highly unlikely that private homes will have wells extending as deep as the Mt. Simon-Hinckley. The costs of such a survey is estimated to be $20,000 to $50,000. This range is somewhat lower than that for shallow well surveys, since fewer wells should be involved.

5.3.5 Recommended Remedial Actions for Off-Site Multi-Aquifer Wells

Table 5-7 summarizes the recommendations for controlling off-site multi-aquifer wells and the estimated costs of the various actions. Wide ranges are presented for many of the costs because of considerable uncertainty in the number of multi-aquifer wells that will require control. Five specific actions are recommended, with a sixth action being dependent on the results of further study. Each of these recommended actions is discussed below.

Multi-Aquifer Well Inventory and Logging

Three specific recommendations are related to further inventory and logging of multi-aquifer wells. First, information gaps on the characteristics of multi-aquifer wells identified by Hickok's recent survey should be addressed. Once this is done, the results of this study should provide an adequate inventory of shallow multi-aquifer wells (those which extend down from the Drift-Platteville and/or St. Peter) for the next 25 to 50 years, based on predicted migration rates of contaminants in these aquifers (see Chapter 6 and Appendix E). This inventory of shallow multi-aquifer wells should be expanded to wider areas, if contaminants migrate. This should be done every 25 to 50 years, depending on how fast contaminants migrate. This constitutes the second multi-aquifer well inventory recommendation. The third recommendation is that the inventory of multi-aquifer wells that connect the Prairie du Chien-Jordan and Mt. Simon-Hinckley should

TABLE 5-7

ESTIMATED COSTS OF RECOMMENDED

REMEDIAL ACTIONS FOR OFF-SITE MULTI-AQUIFER WELLS

Recommended Remedial Action	Current Expenditures	Fixed Expenditures (made every 25 to 50 years)	
1. Fill Information Gaps in Hickok's Recent Multi-aquifer Well Survey	$25,000 - $50,000	Not Applicable	
2. Repeat Multi-aquifer Well Inventory for Shallow Aquifer as Contaminants Migrate	Not Applicable	$25,000 - $100,000	
3. Expand Inventory of Multi-aquifer Wells Connecting the Prairie du Chien-Jordan to the Mt. Simon-Hinckley	$20,000 - $50,000	$20,000 - $50,000	
4. Seal or Reconstruct Multi-aquifer Wells which Connect:			
• Shallow Aquifers to the Mt. Simon-Hinckley	$0 - $300,000[a]	$0 - $300,000[a]	
• Prairie du Chien-Jordan to the Mt. Simon-Hinckley	$0 - $150,000[b]	$0 - $150,000[b]	
5. Assess the Significance of Multi-aquifer Wells Identified in Item 6	$25,000[e]	$25,000[e]	
6. If Shown to be Cost-Effective as a Result of Item 5 - Seal or Reconstruct Multi-aquifer Wells which Connect:			
• Drift-Platteville to the St. Peter	$0 - $200,000[c]	$0 - $200,000[c]	
• Drift-Platteville and/or St. Peter to the Prairie du Chien-Jordan	$0 - $300,000[d]	$0 - $300,000[d]	
Total Present Value Cost		Every 25 Years	Every 50 Years
• Without Item 6	$70,000 - $575,000	$30,000 - $260,000	$6,000 - $60,000
• With Item 6	$70,000 - $1,075,000	$30,000 - $470,000	$6,000 - $105,000

Notes

(a) Based on zero to ten wells being sealed at a cost of $15,000 to $30,000 per well (see Table 5-6).
(b) Based on zero to five wells being sealed at a cost of $15,000 to $30,000 per well (see Table 5-6).
(c) Based on zero to twenty wells being sealed at a cost of $5,000 to $10,000 per well (see Table 5-6).
(d) Based on zero to ten wells sealed at a cost of $15,000 to $30,000 per well (see Table 5-6).
(e) Study costs for evaluating ground-water monitoring data and for performing simplified ground-water modeling.

be extended now to cover a wider area, and should be extended farther as needed on a regular basis (every 25 to 50 years) if contaminants in the Prairie du Chien-Jordan migrate.

Multi-Aquifer Well Reconstruction or Sealing

Because the Mt. Simon-Hinckley may serve as alternate source of public water supply, it is important that multi-aquifer wells that could transmit contaminants into this aquifer be either reconstructed or sealed. However, there is some margin for error in this effort, since transport times in the Mt. Simon-Hinckley are long, and significant dilution, dispersion, and alteration of any undetected contaminants that enter the aquifer should be substantial.

It is also recommended that further limited study be performed to better assess the significance of multi-aquifer wells that connect the Drift-Platteville, St. Peter and/or Prairie du Chien-Jordan aquifers. It is not apparent from the results of this study that sealing or reconstructing these multi-aquifer wells would be cost-effective in removing or controlling contamination in the Prairie du Chien-Jordan or St. Peter aquifers. A limited study aimed at predicting contaminant migration is required to better resolve this cost-effectiveness question. This study would incorporate the results of Hickok's multi-aquifer well survey with ground-water modeling studies. If the results of this study indicate that it is indeed cost-effective to seal or reconstruct multi-aquifer wells that connect the Drift-Platteville, St. Peter and/or Prairie du Chien-Jordan, then this should be done. Table 5-7 includes estimated costs to seal or reconstruct these types of multi-aquifer wells.

Estimated Costs

Table 5-7 shows that the present value cost of the five recommended remedial actions for off-site multi-aquifer wells ranges from $70,000 to $575,000. This wide range is largely due to uncertainties in the number of multi-aquifer wells that will require sealing or reconstruction. It also reflects uncertainty in the frequency of future multi-aquifer well inventories. The actual cost

is likely to be less than $500,000, since the number of Mt. Simon-Hinckley multi-aquifer wells requiring remedy is likely to be less than the worst-case projection of 15 wells every 25 years. Few such wells have been identified to date, and finding a great many more is unlikely. This is particularly so in light of the intensive study of the industrial/commercial area near the site and the fact Mt. Simon-Hinckley wells are expected to occur only in such areas.

Table 5-7 shows that the estimated present value cost to remedy multi-aquifer wells connecting the Drift-Platteville, St. Peter or Prairie du Chien-Jordan could be as high as $700,000 in a worst-case projection (30 wells requiring remedy every 25 years). Again, if it is shown that it is cost-effective to remedy such wells, the actual cost is likely to be less than $500,000..

The cost estimates given in Table 5-7 do not include the cost of new wells to replace multi-aquifer wells that are sealed. This reflects the assumption that every reasonable effort would be made to avoid this additional expense by reconstructing multi-aquifer wells that are in use or to minimize this additional expense by reconstructing multi-aquifer wells that are in use or by drilling shallow (Drift-Platteville or St. Peter) wells for industrial supply purposes.

5.4 Gradient Control Well Systems

5.4.1 Objectives

The purpose of a gradient control well system is to aid in achieving the stated objectives of 1) supplying St. Louis Park and neighboring communities with a safe and adequate drinking water supply and 2) allowing for present and reasonably foreseeable future uses of ground-water resources in the St. Louis Park area. Gradient control wells can assist in achieving these objectives by limiting the spread of contamination and by pumping contaminants out of the affected aquifer.

5.4.2. Approach

The cost-effectiveness of gradient control well schemes was evaluated in this study in the context of protecting ground-water resources now used or likely to be used in the foreseeable future as a source of municipal water supply. This context is the only one consistent with the stated objectives of this study because the major resource value of ground-water, which is affected by trace levels of PAH contaminants, is its value as a high quality source of drinking water (see section 3.1). The reliability and cost-effectiveness of various gradient control well schemes was evaluated using the results of ground-water flow modeling, which predicts the rate and direction of contaminant migration under different pumping patterns (Appendix E). Alternative schemes to dispose of gradient control well discharge water were evaluated and their costs estimated (see Appendices C and F). The costs and effects of gradient control wells were then assessed in light of the recommended actions for end-use controls and other source controls.

Early in this study, it became apparent that gradient control schemes alone would not be cost-effective in meeting the stated objectives of this study. An early finding of this study came with ground-water modeling results, which showed that the existing pumping patterns for municipal supply wells in the St. Louis Park area produce an effective gradient control scheme (see Chapter 6 and Appendix E). This section, therefore, focuses on gradient control wells in the context of ground-water modeling results and as possible contingency actions to manage the spread of ground-water contamination.

5.4.3. Applicability of Gradient Control Well Schemes

The theory behind a gradient control well is that a pumping well will intercept flow coming from upgradient of the well. Thus, placement of a well downgradient of a contaminant source can act to capture the flow from the source and limit the spread of contamination. A gradient control well can thus act as a preventative measure. It can also act as a corrective action over long time

periods by slowly removing contaminant from an area. Gradient control wells are much less cost-effective in the latter mode, due to the greater pumping volumes required.

The applicability of gradient control wells in each of the aquifers beneath St. Louis Park is discussed below. This discussion is based on the results of computer modeling of ground-water flow in the aquifers underlying the St. Louis Park area. These modeling results are summarized in section 6.1 and presented in detail in Appendix E.

Mt. Simon-Hinckley

Ground-water flow in the Mt. Simon-Hinckley aquifer is dominated by the potentiometric low in the vicinity of St. Louis Park wells SLP11, SLP12, SLP13 and Edina wells E9, E10, and E12. The plant site lies immediately adjacent to this low. These wells currently act as a de facto gradient control well system in that wells SLP11, SLP12, and E12 are the likely eventual recipients of any contaminants introduced beneath the site (see Appendix E).

The present situation provides adequate control over contaminant movement in the Mt. Simon-Hinckley and additional gradient control provisions are unnecessary. The amount of PAH contamination, if any, in the Mt. Simon-Hinckley is unknown. As shown in Appendix K, PAH concentrations measured in water from wells E10, E12, SLP11, SLP12, and SLP13 are insignificant (data are not available for E9). Any contaminants introduced to the Mt. Simon-Hinckley will travel very slowly, due to the low ground-water flow rates in this aquifer and the expectation that adsorption, dilution, and dispersion will significantly attenuate the movement of contaminants.

Given that there are no observed contamination problems in the Mt. Simon-Hinckley, municipal supply wells in this aquifer should continue to operate. Whatever contamination may be in the aquifer will ultimately be contained by pumping these wells. A regular program of monitoring (as proposed in section 4.3) will insure that the water withdrawn is safe for drinking water purposes. Until PAH

compounds ever appear in unsafe concentrations in these wells, which is not expected to occur, the water can be used with regular testing. In the remote event that contamination ever requires the wells to be closed as drinking water sources, the wells should continue to operate for gradient control purposes, disposing the pumped water in storm sewers or surface water, as described in Appendix F, or treating the water for use as drinking water, as described in Chapter 6 and Appendix G.

Ironton-Galesville Aquifer

The Ironton-Galesville aquifer is not used in the St. Louis Park area as a source of drinking water. With no wells tapping the aquifer, little is known of its water quality or potentiometric elevation. Without potentiometric surface data, a gradient control well scheme cannot be designed. Moreover, if the aquifer is not used as a ground-water resource, the investment to install gradient control wells is unjustified on a cost-effectiveness basis. Therefore, it is, recommended that remedial actions for the Ironton-Galesville not be considered further unless adverse water quality is discovered and can be shown to have an impact upon present or reasonably foreseeable future use of the aquifer.

Prairie du Chien-Jordan Aquifer

Analysis of ground-water flow in the Prarie du Chien-Jordan in Appendix E indicates that existing patterns of pumping from the aquifer create a de facto gradient control system. If further well closures are necessitated by PAH contamination, the gradient control created by these wells will be lost. St. Louis Park well SLP6, Edina wells E2, E6, and E11, and Hopkins well H1, which are pumped heavily and regularly, are particularly important in this respect. Therefore, as wells close it becomes important to monitor for contaminant migration and evalute the need to inaugurate a gradient control well system. Such a gradient control system will require that the municipal wells continue to be pumped with the water disposed in sanitary sewers or surface water, as described in Appendix F, or treated for drinking water, as described in Appendix G.

Control of contaminant migration in the Prairie du Chien-Jordan can also be effected by pumping municipal wells that are currently contaminated by PAH. These wells include St. Louis Park wells SLP5, SLP10, and SLP15, which exceed the proposed PAH criteria, and SLP4, SLP7, SLP9, and Hopkins well H3, which do not exceed the proposed criteria (see section 4.4). Pumping these wells will withdraw contaminants from the Prairie du Chien-Jordan and also limit their spread. Nonpotable water pumped from these wells could be discharged to storm sewers or surface water or treated for use as drinking water.

St. Peter Aquifer

Gradient control wells in the St. Peter are of uncertain value, since the aquifer is in relatively minor use as a drinking water supply and since there are few data to indicate the degree and areal extent of PAH contamination in the aquifer. Alternative remedial actions to gradient control wells in the St. Peter include the imposition of use restrictions for private drinking water wells and implementation of a ground-water quality monitoring program. These alternatives are considerably more cost-effective than a gradient control well system. Adequate definition of PAH contamination in the St. Peter is a prerequisite to the design of remedial actions for the aquifer.

Drift-Platteville Aquifer

A gradient control well scheme for the Drift aquifer in the vicinity of the plant site and bog is discussed in section 5.1 and Appendix C. Such a system is intended to control the migration of contaminants from the designated source areas in the Drift aquifer. As with the St. Peter, a gradient control well system for the Drift-Platteville is unlikely to be cost-effective in light of the Drift-Platteville's minor role as a drinking water source. Far less costly, but equally effective, is the imposition of use restrictions for private drinking water wells in contaminated areas of the Drift-Platteville. A ground-water monitoring program is also likely to be cost-effective. These alternatives are discussed in greater detail in section 6.4 of this report.

5.4.4. Costs of Gradient Control Well Schemes

The cost of potential gradient control well schemes was evaluated for the Prairie du Chien-Jordan and Drift-Platteville aquifers only. Costs for a Drift-Platteville gradient control well system are discussed in section 5.1 and Appendix C. Gradient control wells were not evaluated for the St. Peter or Ironton-Galesville because they would clearly not be cost-effective for these aquifers. Gradient control wells were also not evaluated for the Mt. Simon-Hinckley because it is unlikely that significant PAH contamination in municipal supply wells in this aquifer will be observed within the next 100 year, if ever.

The gradient control well schemes considered by this study for the Prairie du Chien-Jordan are largely based on the use of existing municipal supply wells in this aquifer. Drilling of new wells for the sole purpose of gradient control was not considered for current gradient control well schemes because such new wells should not be necessary. Water discharged by municipal supply wells acting as gradient control wells can be handled in two basic ways. First, the water can be treated to meet the proposed PAH criteria and continue to be used for drinking water supply. Or, the water can be discharged to storm sewers or surface water bodies. Alternative technologies and costs for drinking water treatment are summarized in Chapter 6 and presented in detail in Appendix G. Alternative discharge schemes and their costs are summarized here, with further details presented in Appendices F.

The least expensive alternative for disposing of discharge water from municipal supply wells is to discharge the water to nearby storm sewers. Storm sewers in central and eastern areas of St. Louis Park discharge to the Minneapolis Chain of Lakes located just east of St. Louis Park. Storm sewers in western and southern areas of St. Louis Park, northern areas of Edina, and the northeast section of Hopkins discharge to Minnehaha Creek. The Chain of Lakes should be able to assimilate the flow and quality of gradient control well discharge water. There may be some concern in discharging gradient control well water to Minnehaha Creek, however, since it has a low stream flow of

zero, in which case the water in the creek would consist entirely of gradient control well discharge water. It is unknown at present if this would pose undesirable human health or ecological impacts. Pending further study of this issue, if warranted, this study has only considered discharging gradient control wells to storm sewers that discharge to the Chain of Lakes.

The estimated capital cost to connect St. Louis Park wells SLP4, SLP5, SLP7, SLP9, and SLP15 to nearby storm sewers that discharge into the chain of lakes is from $90,000 to $120,000. Well SLP6 could also be connected for a minimal addition to this total cost. The operating and maintenance cost for each gradient control well depends primarily on the rate at which it is pumped. The estimated pumping cost per well is from $5,000 per year, based on a total pumping head of 200 feet and a pumping rate of from 100 to 300 million gallons per year (190 to 570 gallons per minute on a continuous basis). The present value cost of pumping a single well at this rate for 100 years is from $100,000 to $300,000, at an effective interest rate of 5 percent per annum.

5.4.5 Recommended Gradient Control Well Schemes

The use of gradient control wells is not recommended for the Drift-Platteville, St. Peter, Ironton-Galesville, or Mt. Simon-Hinckley aquifers. Gradient control well systems in any of these aquifers would not be cost-effective in meeting the stated objectives of this study. There is currently no evidence of PAH contamination in the Ironton-Galesville or Mt. Simon-Hinckley that will affect present and reasonably foreseeable future uses of these aquifers. While PAH contamination does exist in certain areas of the Drift-Platteville, and possibly the St. Peter, such contamination is most cost-effectively addressed by use restrictions on private drinking water wells, since these aquifers are not now, nor foreseen to be, significantly used for municipal water supply.

Immediate implementation of a gradient control well system in the Prairie du Chien-Jordan is not required to meet the stated objectives of this study in a cost-effective manner. As discussed in Chapter 6

and 7, this study recommends continued use of most Prairie du Chien-Jordan wells, with monitoring to track the migration of contaminants and use of Mt. Simon-Hinckley wells or drinking water treatment to replace or restore contaminant municipal supply wells in the Prairie du Chien-Jordan. Given this recommendation, gradient control wells in the Prairie du Chien-Jordan would not be cost-effective at present in helping to meet the objectives established by this study. However, as contaminant migration in the Prairie du Chien-Jordan is monitored, it is possible that gradient control wells in the Prairie du Chien-Jordan would become cost-effective.

The three possibilities that could lead to the use of gradient control wells in the Prairie du Chien-Jordan are as follows. First, if contaminants in the Prairie du Chien-Jordan migrate toward municipal supply wells in Edina at significantly faster rates than predicted by this study, it may be cost-effective to implement a gradient control well system that would halt or retard the migration of contaminants. A gradient control well system in this case would be cost-effective if the present value cost of the system was less than the present value cost of replacing municipal supply wells in Edina that would have to be taken out of service as a result of PAH contamination if no gradient control was implemented. Second, if contaminants in the Prairie du Chien-Jordan migrate to the east and southeast at rates significantly higher than those predicted by this study, and if the City of Minneapolis is using or plans to use Prairie du Chien-Jordan wells near or east of the Chain of Lakes to supply drinking water, it could be cost-effective to implement a gradient control well scheme to halt or retard the migration of contaminants in this direction. The decision on cost-effectiveness would be similar to that described above for Edina wells. Finally, if contaminants in the Prairie du Chien-Jordan migrate toward municipal supply wells in Hopkins to the southwest at rates significantly higher than those predicted by this study, then a gradient control well system to halt or retard this migration could be cost-effective, when judged as described above for the case of Edina wells.

Detailed cost estimates for gradient control well systems in the Prairie du Chien-Jordan under these three scenarios were not prepared in this study. This is because it is unlikely that they will occur and because of uncertainties in predicting when and how they would occur, and hence, in designing gradient control well systems that would address the problems. As a rough indication of possible costs, it is estimated that connecting an existing municipal supply well to a nearby storm sewer would cost from $15,000 to $30,000 (see Appendix F); installing a new gradient control would cost from $100,000 to $200,000; and pumping and maintaining a gradient control well (new or existing) at a rate of 100 to 300 million gallons per year would cost from $5,000 to $15,000 a year. It is assumed that there would be no constraints in discharging a gradient control well to the nearest storm sewer, regardless of where the storm sewer discharged. Assuming that three gradient control wells would be sufficient for any of the three scenarios described above, the present value cost of a gradient control well system operating for 100 years would range from $0.34 million to $1.0 million, if only existing wells were used, or from $0.64 million to $1.6 million, if all new wells were required. The ranges in each case represent individual well pumping rates of 100 to 300 million gallons per year (190 to 570 gallons per minute).

The present value costs derived above are for a future expenditure and therefore must be discounted to arrive at a present value cost. Since the time when a Prairie du Chien-Jordan gradient control well system might be required is unknown, the current present value costs for a range of assumed implementation times are presented below, based on three wells (new or existing each pumping at 300 million gallons per year.

Year Required	Present Value Cost
1983	$1.0 to 1.6 million
1993	$0.6 to 1.0 million
2003	$0.4 to 0.6 million
2013	$0.2 to 0.4 million
2023	$0.1 to 0.2 million

This table indicates that the present value cost of a Prairie du Chien-Jordan gradient control well system decreases rapidly as the time at which it is required is extended further into the future. This result, when evaluated in the context of the end-use controls discussed in Chapter 6, makes it clear that gradient control wells in the Prairie du Chien-Jordan should not be implemented now, but should be considered as a contingency action in the future, if necessary.

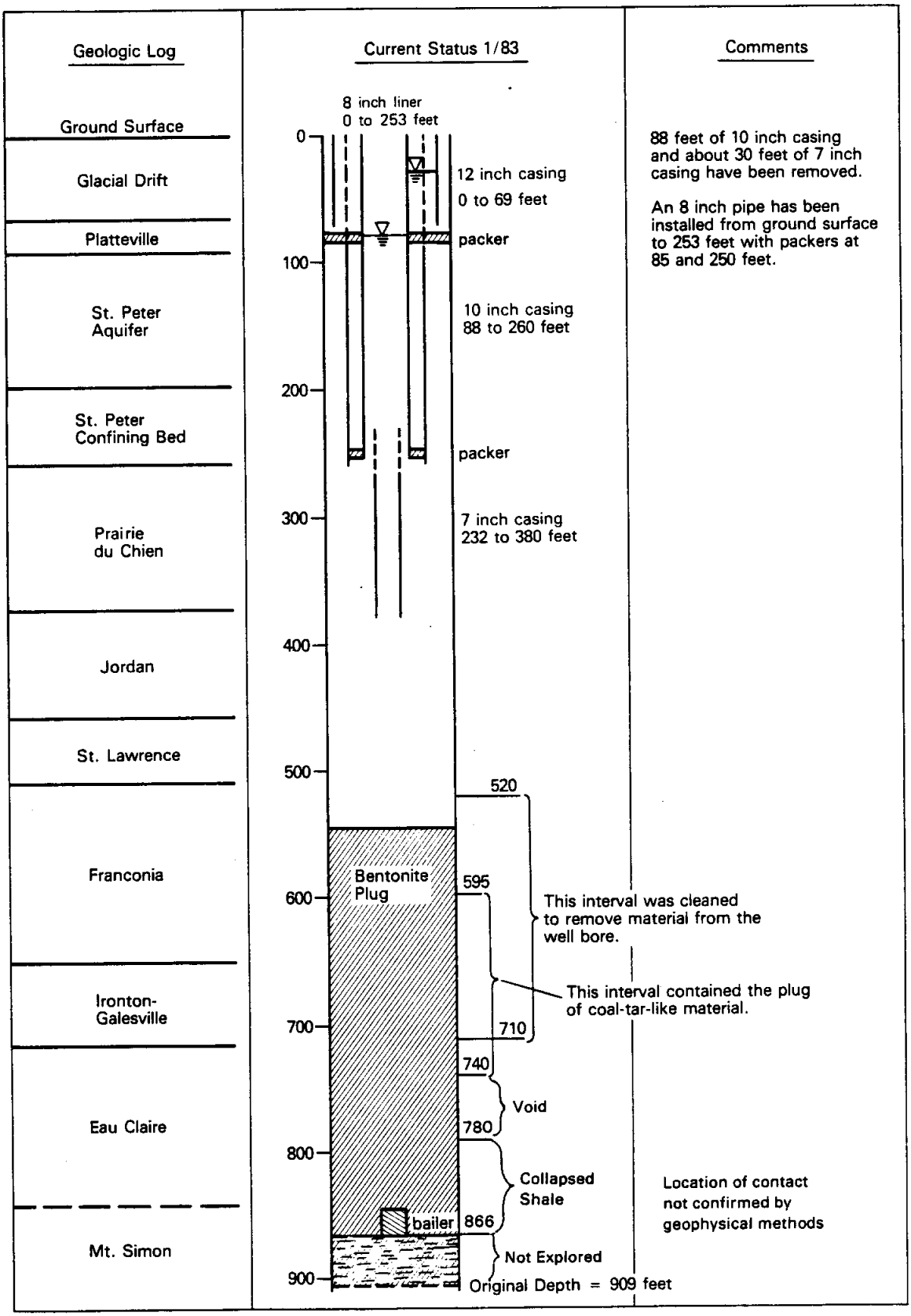


Figure 5-2 Current Sketch of Well W23

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black water in the bottom of the well (to a depth of 866 feet) for a period of 82 days. The effect of this presumably contaminated water on the Mt. Simon-Hinckley is unknown. As shown in Figure 5-2, the contact between the Eau Claire and the Mt. Simon is in question. The contact is assumed to be at 840 feet below the ground surface based on the original well log; however, because of difficulties encountered when redrilling W23, this contact was not verified by geophysical methods, as were each of the other contacts shown in Figure 5-2. Therefore, it is not known if this black water was actually in contact with the Mt. Simon-Hinckley aquifer. There is no evidence of historical contamination of the Mt. Simon-Hinckley by PAH and related compounds. Multi-aquifer well flow in W23 was effectively kept from the Mt. Simon-Hinckley over an unknown period of time by the material plugging the well. The installation of the bentonite plug in the bottom of the well prevents future multi-aquifer well flow to the Mt. Simon-Hinckley. Ground-water modeling has indicated that flow in the Mt. Simon-Hinckley aquifer in the vicinity of well W23 is predominantly induced by pumping St. Louis Park municipal well SLP11 and that ground-water flow velocities to SLP11 are on the order of 0.1 to 0.2 feet per day. Therefore, it would take at least 40 to 90 years for water to move from well W23 to well SLP11 in the Mt. Simon-Hinckley aquifer (a distance of 0.6 miles). Because of attenuation, transport of any contaminants from well W23 to well SLP11 is expected to take significantly longer.

Ironton-Galesville Aquifer

Well W23 has been a source of contamination to the Ironton-Galesville aquifer. Mechanisms for contamination are that 1) well W23 originally provided a conduit for contaminants to reach the aquifer, and 2) the plug of coal-tar-like material eventually filled the bore hole adjacent to the aquifer. The magnitude of this contamination is currently unknown, due to the lack of appropriate data for the Ironton-Galesville aquifer. Currently there are parts per million total PAH in the ground water within about ten feet of well W23 in the Ironton-Galesville (See Appendix D). Much of this contamination is believed to be due to the recent work done on well W23. Because virtually nothing is known about the head distribution

in the Ironton-Galesville, it is not possible to conclude where a plume of contaminated water around well W23 might go. A concern might be that contaminated water would leak via multi-aquifer wells into the Mt. Simon-Hinckley aquifer. The nearest known well that might leak is well W105 located about 200 feet south of W23. If contaminants were carried into the Mt. Simon-Hinckley through W105, they would be directed towards well SLP11 as previously discussed.

Prairie du Chien-Jordan Aquifer

Contamination of the Prairie du Chien-Jordan aquifer has occurred over the lifetime of well W23 by at least two recognizable methods. The first method involves the flow of contaminated water from a hole in the casing adjacent to the St. Peter to a hole in the casing adjacent to the Prairie du Chien aquifer. The USGS measured this flow and determined it to be about 150 gallons per minute (Hult and Schoenburg 1981). This is likely the primary method by which well W23 historically contributed contamination to other aquifers, because of the ability of the relatively high flow rate to introduce significant amounts of contaminants directly to the aquifer.

The second recognizable method by which well W23 contributed contaminants to the Prairie du Chien-Jordan aquifer is the direct introduction of coal-tar-like material to the aquifer. TV logs of well W23 have shown what appears to be coal-tar-like material coating the well bore adjacent to the Jordan Sandstone. This material probably represents residues from the coal-tar-like material that formed the plug in well W23 from 595 to 740 feet. The contamination due to this source is believed to be minor compared to the contamination due to interaquifer flow because the Prairie du Chien formation was at least partially protected from this source of contamination by the seven-inch casing.

The plug of coal-tar-like material from 595 to 740 feet was not itself a contaminant source to the Prairie du Chien-Jordan aquifer. Also, there is no evidence to indicate what role, if any, the material coating the solution channels of the Prairie du Chien may have in contributing contaminants.

Future contamination of the Prairie du Chien-Jordan aquifer due to well W23 may be limited to a minor release of contaminants from coal-tar-like material coating the rock surfaces, and from an assumed halo of contaminated water and aquifer materials around the well. Contamination due to interaquifer flow of water was halted in 1979 when the City of St. Louis Park installed a packer in the well. The measured contamination at several of the area's municipal supply wells can be expected to eventually decrease in response to the stoppage of this flow. Well closings since the packer was installed have probably been the result of changing the distribution of contaminants, rather than an increase in the amount of contaminants, in the Praire du Chien-Jordan aquifer.

St. Peter Aquifer

The role that well W23 has played as a source of contamination to the St. Peter aquifer is presently unknown. There are no data to indicate that well W23 is a source of contamination, although it is probable that some contaminants have been added to the St. Peter aquifer from well W23. Leakage in the annular space between the casing and the well bore is the likely mechanism by which well W23 has contributed contaminants to the St. Peter aquifer. The degree to which this leakage has contaminated the St. Peter aquifer is unknown.

Drift-Platteville

The Drift-Platteville aquifer has been the subject of considerable investigation in the site area. The role that well W23 may have had in contributing to the contamination of the Drift-Platteville is masked by the other major contaminant sources to the Drift-Platteville (see Section 5.1.3). The location of well W23, next to the refinery building, made it readily susceptible to high contaminant loadings. The relationship between well W23 and the Drift-Platteville aquifer system is important, not because of added contamination of the aquifer from the well, but because of the conduit well W23 provided for contamination to deeper bedrock aquifers in the past.

5.2.4 Well W23 Control Alternatives

The purpose of source controls at well W23 is to increase the reliability and cost-effectiveness of end-use controls aimed at achieving the stated overall objectives of this study, as presented in Section 3.1. This purpose can only be met if source controls at well W23 prevent significant amounts (as defined by current PAH concentrations) of contaminants from reaching the potable water supply or the area's ground-water resources. As discussed in the previous section, it is not currently known if significant amounts of contaminants continue to migrate from in and around well W23, since the flow of water between aquifers has been stopped. Therefore, the issue of reliability involves the ability to determine the significance of current contaminant migration from well W23 as well as the ability to measure the effectiveness of source controls in the future. In this context, the issue of reliability is discussed further in Chapters 6 and 7.

Appendix D discusses source control alternatives for well W23 on an aquifer-by-aquifer basis. Control alternatives are basically the same for each aquifer, namely: 1) to physically remove contaminants from the well bore (or casing), 2) to contain the contaminants by sealing the well bore with grout, and 3) to control the spread of contaminants (and ultimately remove them) by pumping the well.

The first source control alternative evaluated for well W23 is the physical removal of contaminants from the well bore. In the past, removal has been achieved by air cleaning the well bore, removing casing sections that were partially coated with coal-tar-like material, and by removing the plug of coal-tar-like material that existed in the hole. Air cleaning does not appear to be a reliable method to remove contaminants from the well because of uncertainties regarding the fate of the contaminants, and the necessary disruption of the packers that isolate sections of the hole. Also, air cleaning does not remove contaminants outside the well and is, therefore, incompletely effective. The method is relatively easy to implement

and is fairly quick. The estimated cost of this work is $10,000 (see Appendix D for a detailed explanation of the basis of this cost estimate).

Casing removal has been done in the past for exploratory purposes. Where the casing has a coating of contaminants, removal serves as a remedial action also. Strictly as a remedial action, casing removal is a reliable method to reduce the amount of contaminants in the well, but it does not address contamination outside the well bore. Thus, it is not completely effective technique.

The second control alternative is to seal the well with grout. Grouting would effectively reduce contaminant transport within the well bore, but would not address contamination outside the well, except for some degree of control in the solution channels of the Prairie du Chien-Jordan. The cost of this alternative is about the same as for air cleaning; however, it is dependent on the uncertain time and material required to grout the solution channels in the Prairie du Chien-Jordan.

The third alternative is to pump water at or near well W23 in order to draw contaminants toward the pumping well. It is assumed that pumping would be required for a very long time, which, as discussed in Chapter 3, is considered in this study to be a period of 100 years. At low pumping rates (50 to 100 gallons per minute) contaminants in the well and in a local zone around the well would effectively be prevented from migrating through the aquifer(s). A large pumping rate, e.g., 400 gallons per minute, would control contaminants dispersed in the ground water over a much larger area, about a quarter of a mile in all directions around well W23. It is expected that this technique would reliably and effectively eliminate well W23 as a contaminant source. The cost of this option is largely dependent on the method of disposing the pumped water. The present value cost of disposal to the sanitary sewer for pumping at 50 gallons per minute is about $375,000, and for 400 gallons per minute is about $3.0 million (Appendix F). The other costs for this alternative, including equipment, power, and even drilling a new well, are small compared to the disposal costs. For high pumping rates, treatment and

disposal to the storm sewer would be less expensive than sanitary sewer disposal. For example, at 400 gallons per minute pumpage, treatment and disposal would cost from $0.7 million to $1.3 million.

5.2.5 Recommended W23 Controls

This section presents a discussion of recommended controls for well W23. The recommended controls are based on the current status of work on well W23; however, it is recognized that further exploratory work is planned for well W23, and that a new well, W300, may be installed nearby. This additional exploratory work is discussed in terms of what is required to choose among alternatives or to design and implement a control plan.

Mt. Simon-Hinckley

The predicted hydraulic transport travel time for ground water in the Mt. Simon-Hinckley aquifer from well W23 to SLP11 is from 40 to 90 years. Any contaminants from W23 will be attenuated by retardation effects, which will significantly delay their arrival at well SLP11 compared to ground water flow. Therefore, there is no cost-effective basis to spend on the order of $400,000 of more to control a source that should have no effect within the next century. The addition of more Mt. Simon-Hinckley wells at other SLP well field locations (e.g., SLP17 at the SLP5 well field) will not affect this recommendation because these other locations are farther from well W23 than well SLP11.

Ironton-Galesville Aquifer

No source controls at well W23 in the Ironton-Galesville aquifer are recommended because this aquifer is not used for municipal water supply in the St. Louis Park Area, and it is unlikely to be used in this manner in the reasonably foreseeable future. Therefore, there is no cost-effective basis for spending on the order of at least $400,000 to control well W23 as a source in this aquifer.

Prairie du Chien-Jordan Aquifer

The cost-effectiveness of source control alternatives for this aquifer is dependent on the end-use control alternative selected and the affect that remaining contamination inside and outside well W23 will have on that end-use control. As discussed in Chapter 7, the end-use control alternative, recommended by this study, with respect to the Prairie du Chien-Jordan aquifer is to install drinking water treatment for PAH removal or to replace contaminated* municipal supply wells with new Mt. Simon-Hinckley wells and to monitor the continued migration of contaminants in the Prairie du Chien-Jordan. The recommendation includes a contingency option of using out-of-service municipal supply wells as gradient control wells if contaminants in the Prairie du Chien-Jordan migrate at significantly different rates and directions than predicted by this study. Within the context of this end-use control recommendation, the most cost-effective source control alternative for the Prairie du Chien-Jordan aquifer at well W23 is to grout the well.

Grouting well W23 is the only cost-effective solution because the costs associated with pumping alternatives are not commensurate with their effects in the overall context of managing ground-water contamination in the Prairie du Chien-Jordan. Pumping W23 as a source control action has a present value cost of $0.4 million to 1.3 million to dispose of the discharge, depending on the pumping rate and disposal option selected (see Appendix F). At best, pumping well W23 would result in fewer Prairie du Chien-Jordan wells being closed due to additional contaminant migration in the future, or in currently contaminated municipal supply wells becoming uncontaminated (i.e., PAH concentrations being reduced below the proposed criteria levels) sooner than if well W23 was not pumped. However, pumping well W23 is unlikely to produce these improvements in the quality of municipal supply wells in the Prairie du Chien-Jordan for at least a few decades. The potential cost savings from fewer municipal supply well closures or more rapid purging of currently contaminated municipal supply wells, therefore, should be discounted by the time-value of money saved in a few decades. The present value cost of drilling and operating a new Mt. Simon-Hinckley well 20 years from now is about

$300,000 (see Section 6.4), and 50 years from now is only about $75,000. These costs are well below the $0.4 to $1.3 million present value cost of pumping well W23 in the Prairie du Chien-Jordan. Similarly, the present value of savings from pumping a Prairie du Chien-Jordan municipal supply well as opposed to a Mt. Simon-Hinckley well is about $200,000 when discounted by 20 years and only about $50,000 when discounted by 50 years (see Section 6.4). The present value of savings from being able to stop treating a typical drinking water supply well in 20 years is less than $200,000, based on the most cost-effective treatment (ozone or powdered activated carbon injection see Appendix G). These potential savings indicate that pumping well W23 in the Prairie du Chien-Jordan is not cost-effective, but that grouting the well in this formation (at a cost of about $10,000) could be.

St. Peter Aquifer

The recommended control alternative for the St. Peter aquifer is to grout this interval of the well. The basis for this recommendation is the lack of evidence that well W23 is a significant source of contamination to the St. Peter. Further investigations of the possibility that W23 is a source are not believed to be warranted because the aquifer is not currently, and is not anticipated to be, an important drinking water resource. As discussed in Chapter 6, SLP3 will require occasional monitoring as a precautionary measure.

Drift-Platteville Aquifer

No source control options are recommended for this aquifer at well W23, because the well is not thought to contribute any contamination to the aquifer (although the reverse is probably true), and the thrust of the Drift-Platteville source controls are focused toward the bog south of the site. It is recommended, however, that the grout seal should extend to the surface in order to seal the hole reliably. This extra amount of grouting should only cost a few thousand dollars.

Given that these are plans to explore the nearby sugar beet well (W105) and given that the reliability of the data and the credibility of the results of pumping tests greatly improve when the drawdown and recovery in nearby observation wells can be measured, it is recommended that the packers and liner remain in W23 unchanged, until the W105 work has been accomplished. The added benefits of waiting for W105 work to be completed do not affect the cost of the alternatives presented for W23 because the W105 work is scheduled to take place anyway.

It is recommended that exploration well W300 to the Prairie du Chien-Jordan near well W23 not be done as currently planned.

5.2.6 W105 Recommendations

As stated in section 5.2.2, the present distribution of contaminants, if any, in well W105 cannot be characterized because little is known about conditions in the well. While it is likely that interaquifer flow occurred in well W105 for at least a portion of the well's history, it is not known if well W105 was ever a source of contamination. Therefore, in the context of overall source controls for plant site multi-aquifer wells, it would be premature to install source controls at well W23 until the role of well W105 as a source has been evaluated. In addition, the cost-effectiveness of the overall remedial action alternative may be affected by the results of an investigation of W105.

5.3 Off-Site Multi-Aquifer Well Controls

5.3.1. Objectives

The purpose of evaluating controls for off-site multi-aquifer wells is to determine if such controls provide a cost-effective aid in achieving the objectives of 1) providing St. Louis Park and neighboring communities with a safe and adequate supply of drinking water and 2) allowing for present and reasonably foreseeable future use of ground-water resources in the St. Louis Park area. Controlling off-site multi-aquifers wells cannot achieve either of these

objectives as a stand-alone action, but may improve the cost-effectiveness and reliability of end-use controls.

5.3.2 Approach

Controls for off-site multi-aquifer wells were evaluated by 1) summarizing the available data on the distribution and characteristics of multi-aquifer wells, 2) evaluating the role of multi-aquifer wells in transporting contaminants in light of the ground-water modeling results obtained by this study, 3) estimating the costs of plugging, reconstructing, abandoning or replacing multi-aquifer wells, and 4) evaluating the effects of multi-aquifer well controls on the cost, effectiveness, and reliability of end-use control alternatives. This section summarizes the results of these efforts, with further details provided in Appendix D.

Complete and up-to-date information on the distribution and significance of multi-aquifer wells in the St. Louis Park area was not available for this study. The results of a recent multi-aquifer well survey by Hickok and of survey results by the USGS other than those reported by Hult (1979) and Hult and Schoenberg (1981) were not available for this study. Based on preliminary information on the nature of these data, it is not expected that these results will significantly alter the conclusions reached by this study. However, these additional results should be incorporated into the design of a final remedial action plan for off-site multi-aquifer wells.

5.3.3 Off-Site Multi-Aquifer Well Characteristics

The extent and significance of multi-aquifer flow and its contribution to the contamination problem have not been completely established by the studies to date. While certain multi-aquifer wells are likely to be significant, such as the on-site wells addressed in Section 5.2, the remaining wells are likely to be less significant. This section presents background data and cost estimates for multi-aquifer wells excluding W23 and W105.

The summary source of data for off-site multi-aquifer wells has been the USGS inventory (Hult and Schoenberg 1981) which encompasses a two-square-mile area surrounding the site. Tables 5-4 and 5-5 list multi-aquifer wells identified by the U.S. Geological Survey and the Minnesota Pollution Control Agency.

The patterns of interaquifer flow through multi-aquifer wells are important, since contaminated ground water may follow these pathways. Factors that influence the rate and direction of interaquifer flow include: well design and construction, present well condition, formation permeability (including local effects of plugging or encrustation) differences in water level between aquifers and effects of nearby pumping wells. Certain conditions favor relatively rapid movement of contaminated ground water in multi-aquifer wells. These conditions include uncased wells, severely deteriorated casing, and high formation permeability (such as the presence of solution cavities) in the portion of the aquifer open to interaquifer flow.

The following discussion addresses likely multi-aquifer well effects in each aquifer.

Mt. Simon-Hinckley

Due to its great depth, few wells penetrate the Mt. Simon-Hinckley. Three multi-aquifer wells to the Mt. Simon-Hinckley have been identified within the study area: W23 and W105 on the Plant Site and W38, the abandoned Milwaukee Railroad well. Wells W23 and W105 are discussed in Section 5.2 of this report. Well W38 has been reconstructed as a monitoring well and no longer acts as a multi-aquifer flow path. Because of the aquifer's great depth, additional multi-aquifer wells to the Mt. Simon-Hinckley are unlikely. Additional deeps wells are probably restricted to commercial and industrial areas since residential wells would not be drilled to the depth of the Mt. Simon-Hinckley. Therefore, additional multi-aquifer wells connecting the Mt. Simon-Hinckley are likely to be very limited in number. The depth of deep industrial and commercial

TABLE 5-4

MULTI-AQUIFER WELLS IDENTIFIED BY USGS, MDH AND MPCA

Well Number	Well Name	Aquifers Open to Well[a]: Drift-Platteville	St. Peter	Prairie du Chien-Jordan	Ironton-Galesville	Mt. Simon-Hinckley	Status[b]	Source[c]	Remarks
Deep Wells									
W29	Flame Industries	X?	X?	X?			P	H,M,U	1976 in minor use
W32	Texatonka Shopping Ctr.			X			L	H,U	
W34	Crib Diaper Service			S			SM,G	H,U	
W35	Burdick Grain Co.	X?	X?	X			MW;P	M,H,U,MPCA	
W38	Milwaukee RR Well	S	S	S	X	S	MW	H,U,UE	
W40	Minnesota Rubber			X			P	H,M,U	1976 in active use
W45	S&K Products, Inc.		X	X			P	H,M,U	
W46	S&K Products, Inc.		X	X			P	H,M,U	1976 in minor use
W47	Belco; Burdick Grain	S		S			S;G	U,H	
W49	Strom Block Co.		X	X			-	H,M,U	
W50	Prestolite		S	S	S		SM;G	U	
W62	McGourtney Plastics		X	X			P	H,M,U	
W66	Black Top Service	X?	X?	X?			RF	H,U	deep well
W69	Hedberg-Friedheim	S	S	S			SM;G	H,U	Wolfe Lake
W70	Park Theatre			X			P	H,U	
W74	Landers Gravel	X?	X?	X			RS	S,U	
W105	Minn. Sugar Beet	X	X	X		X?	-	H,U	under study by Hickok, 1983
W107	Interior Elev.	X?	X	X	X		-	H,U	
W112	Old SLP #1			X			MW;G	H,U	Old St. Louis Park Well SLP #1
W114	Hedberg-Friedheim	S	S				SM	U	

TABLE 5-4 (Continued)

Well Number	Well Name	Aquifers Open to Well[a]: Drift-Platteville	St. Peter	Prairie du Chien-Jordan	Ironton-Galesville	Mt. Simon-Hinckley	Status[b]	Source[c]	Remarks
Shallow Wells									
W27	Terry Excavating	X	S				MW;G	H,U	11 Oct 79 St. Peter sealed
W30	3636 Quebec	S	S				SM	H,U	
W33	Strand Mfg.	S	X				P; MW; G	H,U	11 Oct 79 Platteville sealed
W37	Dayton Rogers #2	X	X				MW;G	H,U	
W41	Hartman #1	X	X				O	M	
W44	Kings Inn	X	X				P	H,U	
W52	Merit Gauge	S	S				SM; G	H,U	
W60	3645 Rhode Island	S	S				SM	H,U	
W61	W.V. Terry						-	H,U	No Data
W65	Ace Mfg.	X	X				L	H,U	
W67	Black Top Service	X?	X				-	H,U	Shallow Well
W75	Park Pet Hospital	X	X				P	H,U	
W76	Professional Instru.	X?	X				P	H,U	
W106	Hedberg-Friedheim	X?	X				-	H,U	
W113	SLP #3	X	X				P	H,U	St. Louis Park Well SLP #3

(a) Aquifer Legend
X, aquifer presently open to well; X?, aquifer probably open to well; S, aquifer no longer open to well.

(b) Status Legend
D, destroyed; O, obstructed; L, located; P, located with pump; S, sealed; RS, reportedly sealed; SM, sealed by MDH; MW, reconstructed as monitoring well; RF, reportedly filled; G, geophysically logged.

(c) Source Legend
H, Hult (1979); U, Hult and Schoenberg (1981); M, Minnesota Department of Health (1979-1981); UE, USGS-ERT meeting of April 1980; MPCA, Minnesota Pollution Control Agency (1982).

TABLE 5-5

OTHER POSSIBLE MULTI-AQUIFER WELLS

Well Number	Well Name	Aquifers Open to Well: Drift-Platteville	St. Peter	Prairie du Chien-Jordan	Ironton-Galesville	Mt. Simon-Hinckley	Status[a]	Source[b]	Remarks
W39	3612 Alabama		X				D	U	
W48	Methodist Hospital		X	X			P; G	U	also screened in St. Lawrence Form. 285' deep
W63	National Foods			X			P	U	
W72	Harder Res.		X				-	U	
W73	Jasperson Dairy	X	X				-	U	
W80	Red Owl			X			-	U	
W82	Weldwood Nursing	X?	X?	X?			-	U	
W86	Prudential #1			X			-	U	also screened in St. Lawrence Form.
W104	Rice Sand & Gravel			X?			-	U	
W109	Max Renner's Shop	X?	X				-	U	
W111	6030 Oxford		X				L; G	U	
W118	Golf Course			X			RS	U	also screened in St. Lawrence Form.
W119	Golf Course			X			-	U	also screened in St. Lawrence Form.

[a] Status Legend
D, destroyed; O, obstructed; L, located; P, located with pump; S, sealed; RS, reportedly sealed; SM, sealed by MDH; MW, reconstructed as monitoring well; TS, temporarily sealed; RF, reportedly filled; G, geophysically logged.

[b] Source Legend
H, Hult (1979); U, Hult and Schoenberg (1981); M, Minnesota Department of Health (1979-1981); UE, USGS-ERT meeting of April 1980.

wells found in the recent Hickok survey should be measured to determine which, if any, of these wells may be leaking into the Mt. Simon-Hinckley.

Prairie du Chien-Jordan

Multi-aquifer wells to the Prairie du Chien-Jordan occur more frequently than do those to the Mt. Simon-Hinckley. Tables 5-4 and 5-5 indicate that there are about fifteen multi-aquifer wells known to this study that lead to the Prairie du Chien-Jordan. Although most of the wells afford more pathways for contamination, only wells that connect areas of contamination on the surface or in upper aquifers will transmit contamination to the Prairie du Chien-Jordan. This limits the wells of current concern to those in the immediate vicinity of the site. The area of concern would, of course, expand if contaminants migrate further in the Drift-Platteville and St. Peter aquifers.

Travel of contaminant from the St. Peter aquifer to the Prairie du Chien-Jordan is of unknown significance. Wells that monitor only the St. Peter, and do not also connect to the Platteville or Drift, are few. Thus, the extent of contamination in the St. Peter is poorly defined. Better definition of possible contamination in the St. Peter is a necessary step to determine the role of St. Peter to Prairie du Chien-Jordan interaquifer flow as a pathway for contamination.

Multi-aquifer wells may also convey flow from the Drift-Platteville to the Prairie du Chien-Jordan. This is of greatest concern in those areas where the upper aquifer is known to be contaminated, as mapped in Figure 5-1. Known wells in this area which connect to the Prairie du Chien-Jordan aquifer, are W23, W50, and W105. Of these, W23 is temporarily sealed pending further exploratory work; W105 will be explored shortly; and W50 has been sealed. Given the intensity of past investigation of this area, it is unlikely there are many additional wells that have not yet been discovered.

6.0 EVALUATION OF END-USE CONTROL ALTERNATIVES

The source control remedial actions evaluated in the preceding chapter do not fulfill the objective of providing a safe and adequate supply of drinking water for St. Louis Park and surrounding communties. End-use controls are therefore necessary to meet this objective. Two types of end-use controls are considered in this chapter: 1) treatment of contaminated well water to produce potable water that meets the criteria for PAH recommended in Chapter 4 and 2) replacement of contaminated well water by alternate drinking water supplies.

In order to select an end-use control strategy and design an end-use control system, the important influence of the ground-water flow system must be taken into account. Demands on the end-use control system will depend upon the extent of contamination in the future. However, as will be shown, the kinds of controls that are implemented will significantly influence the future migration of contaminants. In order to evaluate end-use controls in the proper perspective, this chapter begins with a discussion of the ground-water flow system and the behavior of contaminated ground water in the St. Louis Park area. The discussion is based upon the ground-water modeling study conducted as a part of this investigation; Appendix E presents the modeling study in greater detail.

Once ground-water flow patterns are established, the next important area to understand in evaluating end-use controls is the operation of municipal water supply systems that are now, or could become, affected by PAH contamination. Section 6.2 of this chapter describes the operation of the municipal water supply systems in St. Louis Park, Hopkins and Edina, with particular emphasis on the St. Louis Park system. With this necessary background in hand, the remainder of this chapter discusses drinking water treatment alternatives, alternate drinking water supplies and monitoring of ground-water contamination. The last topic is included because it is directly related to implementing end-use controls.

6.1 Management of Ground-Water Flow in the St. Louis Park Area

6.1.1 Ground-Water Modeling Results

The behavior of contaminated ground water was evaluated in this study by computer simulation of ground-water flow in the five aquifers beneath the St. Louis Park area. The primary modeling tool was a version of the U.S. Geological Survey three-dimensional flow model by Trescott (1975) and Trescott and Larson (1976). The model was modified by ERT for the purposes of this study to print and plot information on flow direction and velocity and the time of travel associated with flow. Results from the flow model were used to predict the hydraulic transport of contaminants, that is, the motion of contaminants carried along with the flow of ground water. This is a conservative approach in that it over-predicts the rate at which contaminants will move. Contaminant transport is slowed by dispersion, which tends to dilute the contaminants, and by chemical reactions and adsorption, which remove contaminants or retard their flow. The net effect is substantially slower transport of contaminants than predicted for hydraulic transport alone. Some effort was made to bound the expected retardation of contaminant flow relative to hydraulic flow, but this is difficult to do with any certainty given the current knowledge in this area.

As described in Appendix E, adsorption column studies at the University of Minnesota indicate that naphthalene will travel about 20 times slower than ground water in the Drift and St. Peter aquifers. No data for other PAH compounds or other aquifer materials are available. It is reasonable to assume, however, that adsorption in other sandstone aquifers (namely the Jordan, Ironton-Galesville and Mt. Simon-Hinckley) will be comparable to that measured for the St. Peter. As for other PAH compounds, reported adsorption column studies for various river and lake sediments indicates that adsorption coefficients for higher molecular weight PAH increase by roughly an order of magnitude for each additional ring. This implies that migration of 3-ring PAH would be retarded by about two orders of magnitude and 4-ring PAH by about three orders of magnitude compared to ground-water flow in sandstone aquifers. In the absence of usable

field data or literature values for dolomite and limestone aquifers, it is assumed that there will be no alteration of contaminants in the Platteville or Prairie du Chien as a result of adsorption. This is a reasonable assumption because the presence of solution channels in these aquifers precludes the high ratio of aquifer matrix surface area to void volume in sandstone aquifers, which is presumably important in adsorption.

The USGS model was employed in this study using a minimum finite difference grid size of one-half mile. This limited the model's ability to resolve flow patterns at scales of less than one mile. Although this is adequate for many of the purposes of this study, it presents limitations in the analysis of flow dynamics within the dense well network in the Prairie du Chien-Jordan aquifer. To supplement the USGS model in addressing local phenomena in this aquifer, an additional model was developed. The additional model was based upon analytical solutions to the equation for steady-state drawdown about a well in a leaky confined aquifer. The influence of multiple pumping wells and a linear regional potentiometric gradient were included in the model.

The USGS model approach was to first specify parameter values based on published data, and to then calibrate the model by varying the parameter values within reasonable ranges, in order to achieve an adequate match between the computer predictions and observed behavior under a specified set of conditions. Sensitivity testing was used to evaluate changes in the model results as a result of changes in the values of the parameters. Results of this process are reported in Appendix E. Good model calibration was achieved with minimal parameter adjustments, and the model sensitivity was low to moderate. The same parameter values employed in the USGS model were also used in the analytical model of the Prairie du Chien-Jordan.

The ground-water models were employed to simulate past and present conditions in an effort to understand how the ground-water system behaves and is likely to behave in the future. The various investigations are discussed fully in Appendix E. Salient features emerging from the study are summarized below for each aquifer.

Drift-Platteville Aquifer

Flow in the Drift-Plattevile aquifer is dominated by the regional west to east water table gradient. This gradient is weakly affected by pumping at St. Louis Park well SLP3, which is open to the Platteville. Very slow migration of ground water from the site towards SLP3 is predicted by the computer model when SLP3 pumps at full capacity. The migration is very slow, and poses only a remote chance of contamination of SLP3. A portion of the regional Drift-Platteville ground-water flow is diverted into a buried tributary bedrock valley southeast of the site. Water flowing from the site reaches the tributary bedrock valley in one to two decades according to the computer model, and roughly 30 percent of the water passing directly over the valley is predicted to flow down into the valley and into the St. Peter aquifer. The buried tributary bedrock valley is thus a conduit for spreading contamination from surficial sources at the site to the St. Peter aquifer. Water from the site must travel at least 60 years to reach a major bedrock valley connecting the Drift-Platteville to the Prairie du Chien-Jordan, which is located farther east of the tributary bedrock valley. Accounting for retardation effects, the predicted travel time to the major bedrock valley is over 1000 years.

St. Peter Aquifer

The St. Peter aquifer is not a major source of municipal ground-water supply. Flow in the aquifer is predominately from west to east, driven by a regional potentiometric gradient of approximately 10 feet per mile. Computer simulations indicate that a potentiometric high is likely to occur at the buried tributary bedrock valley where water flows from the Drift-Platteville to the St. Peter. Locally, this high deflects ground-water flow, so that water traveling from the site is directed roughly due east on the north side of the buried valley. Computer simulations indicate that sustained operation of well SLP3 at full capacity may lead to very slow induced flow from the St. Peter beneath the site area to the south of well SLP3. Thus, there is the

remote possibility that well SLP3 may experience contamination in the future, if the St. Peter is contaminated beneath the site. Contamination of SLP3 has not been observed to date.

Prairie du Chien-Jordan Aquifer

Simulation of the Prairie du Chien-Jordan reveals a complex ground-water flow system that is highly influenced by many wells withdrawing water from the aquifer. Regional flow is directed from west to east by potentiometric gradients of roughly 10 feet per mile. This regional flow is significantly influenced by the concentration of large municipal pumping wells in St. Louis Park, Hopkins, and Edina. The aggregate impact of these wells creates a potentiometric low defined by a ground-water divide to the south and east of St. Louis Park. The divide acts as a hydraulic barrier, effectively isolating the enclosed aquifer area from areas to the east (Minneapolis and the Mississippi River) and south (southern parts of Edina and Hopkins, and Bloomington). Significantly, the contaminated portions of the aquifer are entirely within this divide. Figure 6-1 presents a computer generated plot of flow in the Prairie du Chien-Jordan. The ground-water divide is delineated in the figure, as well as selected major geographical features.

Within the confines of the divide, smaller scale effects occur. Prior to 1979, well W23, and possibly another deep well on the plant site (W105), acted as sources of contamination to the Prairie du Chien-Jordan. Flow is likely to have occured via a multi-aquifer well connecting the St. Peter and other upper aquifers to the Prairie du Chien-Jordan. A concentration of additional multi-aquifer wells is located to the south and east of the site, creating a local potentiometric high.

Contamination of wells to the north, west, and south of the site was investigated with the ground-water flow models. The analysis indicates that when a nearby municipal supply well is pumped at full capacity, the aquifer responds quickly. The potentiometric low created by the pumping well induces flow from the surrounding area,

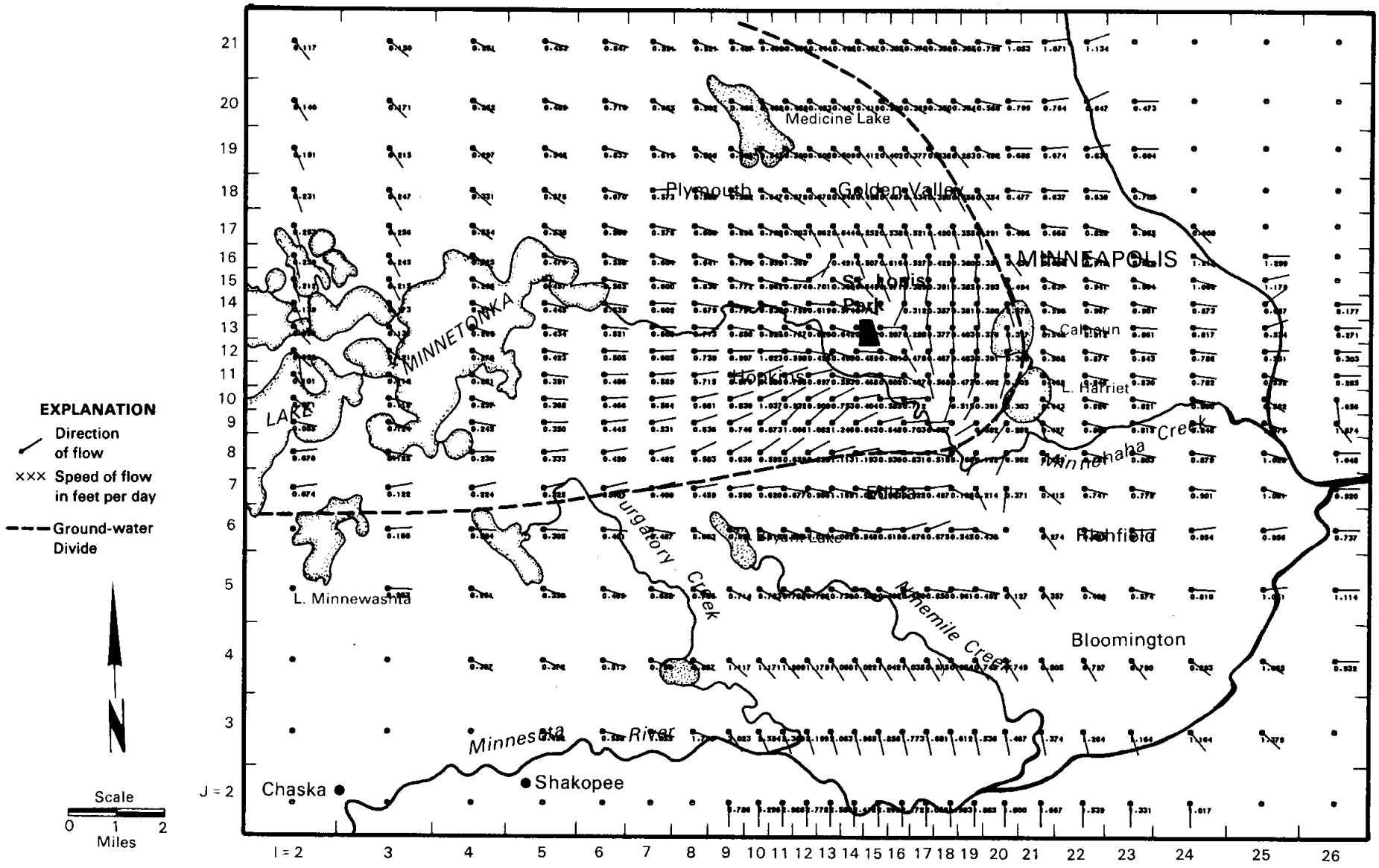

Figure 6-1 Pattern of Ground-Water Flow in the Prairie du Chien-Jordan Aquifer Predicted by Computer Model

including the potentiometric high at the multi-aquifer wells. This flow carries contaminant from the site in the direction of, and eventually into, the municipal wells. Such flow patterns may explain the contamination of St. Louis Park wells SLP5, SLP10, and SLP15 and Hopkins well H3. No set of pumping conditions was found likely to induce flow from well W23 to St. Louis Park wells SLP7 and SLP9.

The investigation of historical flow patterns described above leads to the conclusion that there is unlikely to be a well-defined plume of contaminants carried downgradient from the site by the prevailing regional flow. Rather, transient pumping in all directions about the site has dispersed the plume over a wide area around source multi-aquifer wells. The contaminated ground water within this area is not free to migrate indefinitely. The water is contained by the ground-water divide discussed above. Eventually, all of the contaminated ground water will be withdrawn by wells within the confines of the divide, although this could take many centuries to occur.

Mt. Simon-Hinckley Aquifer

The deep Mt. Simon-Hinckley aquifer is penetrated by a few large-capacity municipal wells in St. Louis Park and Edina. The flow patterns in the aquifer are determined by the potentiometric low created by these wells. Regional flow travels from all directions to the well centers. Within the aquifer, three and possibly more abandoned industrial wells have the potential to act as pathways for PAH contaminants: well W23 (old Reilly Tar & Chemical Corp.), well W38 (Milwaukee Railroad), and well W105 (old sugar beet refinery). Computer simulations indicate that interaquifer flow from these wells will most likely flow to St. Louis Park well SLP11 and certainly no farther than the potentiometric low created by St. Louis Park wells SLP11 and SLP12 and Edina well E12, as long as they continue to operate. Many decades would be required for water to travel to the municipal wells from the site. Many centuries would be required for contaminant migration in the same path, given expected attenuation effects. No contamination of any municipal supply well in the Mt. Simon-Hinckley has been observed to date.

6.1.2 Contaminant Migration in the Prairie du Chien-Jordan

As the major water supply aquifer of the area, the Prairie du Chien-Jordan was the object of particular attention in the modeling study. This section discusses the findings for the Prairie du Chien-Jordan. Understanding of contaminant migration in the Prairie du Chien-Jordan requires a grasp of two seemingly conflicting propositions pertaining to two flow regimes that govern flow in the aquifer, with each flow regime pertinent to different scales of length and time.

First, the flow regime pertinent to long-term flow over long distances must be considered. Over a long period of time, the patterns of flow determined by regional gradients and long-term average pumping rates will prevail. The USGS model simulations are based upon these conditions, and results from these simulations show that water in the Prairie du Chien-Jordan below the site will probably flow to the southeast, eventually to be withdrawn by St. Louis Park wells SLP6 and SLP4 (if operating) and Edina wells E2 and E3. The time for contaminants to travel to these wells is from 60 to 100 years; this estimate neglects retardation effects.

The long-term trends are modified over short times and within local areas by the second flow regime. This regime is described in Appendix E with the confined aquifer analytical model. The results from this model indicate that periodic pumping of St. Louis Park wells SLP5, SLP10, and SLP15 or Hopkins well H3 exerts a strong local influence that causes contaminants in the Prairie du Chien-Jordan below the site to be drawn into the supply well. Pumping at full or nearly full capacity need not continue for long periods to produce this effect because flow in the aquifer responds to transient pumping periods within days. Similar short-term effects will be felt wherever contaminants move. For example, contaminants reaching the area of St. Louis Park wells SLP4 and SLP6 will be alternately pulled in the direction of one well and then another, depending upon which well is pumping at any given time.

The overall picture is thus one of a dispersed and erratic plume of contamination.

- Near the site, contaminant has been dispersed by the alternate "pulling" by SLP5, SLP10, SLP15, and H3.

- Over time, contaminants will migrate from their dispersed source area in a generally southeasterly direction, eventually to reach SLP4, SLP6, E2, and E3.

- In the course of migration, contaminants will stray from their long-term course and be dispersed and withdrawn by the periodic operation of nearby pumping wells.

- Contaminants will be contained within the regional potentiometric low and will be withdrawn by a pumping well. Significant quantities of contaminants are unlikely to cross the ground-water divide bordering this low and travel farther to wells in southern Edina and Bloomington, so long as enough of the major pumping wells which create the divide continue to pump.

These conclusions are based upon the results of computer simulations as reported in Appendix E. They are consistent with the observed pattern of contamination in the Prairie du Chien-Jordan.

With this understanding of ground water and contaminant flow behavior in the Prairie du Chien-Jordan as a basis, the following conclusions are drawn concerning future actions.

- If restarted as water supply wells, St. Louis Park wells SLP5, SLP10, and SLP15 and Hopkins well H3 will entrain contaminants from beneath the site. Thus, drinking water treatment could be required to return these wells to active status, depending on the criteria applied for PAH and heterocyclic PAH.

- St. Louis Park wells SLP7 and SLP9 are not in jeopardy of direct entrainment of contaminants from beneath the site. Thus, these wells may be restarted. Some residual contamination from the area of St. Louis Park wells SLP10 and SLP15 may be withdrawn by wells SLP7 and SLP9; however, the concentrations will be lowered by dilution and eventual purging of contaminants.

- Over time, wells downgradient of the site may experience contamination; wells SLP4, SLP6, E2, E3, and perhaps E4 and E6. Hydraulic travel times to these wells from the site are on the order of 65 years to SLP4 and SLP6, 100 years to E2, 120 years to E3, and somewhat longer to E4 and E6. Use of these wells for drinking water supply may eventually require treatment, depending upon the criteria established for PAH and heterocyclic PAH. However, there is considerable uncertainty over when, and even if, these wells may become contaminated. The times given above are based on conservative assumptions and are considered to be worst-case possibilities.

- Contaminant migration control schemes, such as the gradient control wells proposed by Hickok (1981), are unlikely to be effective in the Prairie du Chien-Jordan, in light of the conflicting and transient influences of existing municipal and other wells. Hickok's design and analysis of the gradient control well scheme failed to consider these influences.

In the following section, the implications of these findings are explored within the context of the two alternatives for end-use controls:

1) restoration of drinking water supply wells by treatment to remove PAH contaminants and to produce finished water that meets the recommended criteria for PAH in potable water; and

2) abandonment of wells that are or become contaminated and replacement of these supplies with alternate supplies.

6.1.3 Ground-water Management Implications of End-use Controls

The selection of either drinking water treatment or replacement of contaminated wells by alternate supplies carries implications for the future fate of contaminated ground water. Each end-use control option creates an implicit level of ground-water management, which must be appreciated to properly evaluate the options. This subsection explores the ground-water management implications of these end-use control options.

Installation of drinking water treatment will provide the greatest degree of ground-water management. Installation of treatment to restore existing wells will recreate the ground-water flow configuration present prior to 1978. As discussed in Appendix E, under those conditions a well-defined ground-water divide in the Prairie du Chien-Jordan isolates the area of contaminated ground water from noncontaminated areas to the south and east. The divide and accompanying patterns of flow are created by the concentration of large municipal supply wells in St. Louis Park, Hopkins, and northern Edina. These wells thus act as a de facto gradient control well system, intercepting and withdrawing contaminated ground-water and preventing its further migration to the south and east. If pumping patterns prior to 1978 are restored and continued, the ground water divide will prevent migration of contaminants farther south than Edina wells E2, E3, E4 and E6, and most probably not even beyond well E2.

Replacement of contaminated wells by alternative water supplies is also a means to satisfy muncipal supply needs if contaminants migrate to additional wells. This scenario is examined in Appendix E using the results of ground-water model simulations. However, as long as municipal wells in the Prairie du Chien-Jordan continue to pump, as assumed in the preceding option, migration of contaminants will be contained by the resulting ground-water divide. Moreover, if newly-contaminated wells are closed and replaced by alternative

drinking water supplies, there will be less control on contaminant migration. As wells are closed, the containing effects of the ground-water divide will diminish, and contaminants will be able to travel farther. In theory, contaminants could travel indefinitely, albeit slowly, until finally reaching the Mississippi or Minnesota Rivers. In fact, adsorption to the aquifer solid matrix and dilution by dispersion is likely to limit effectively the distance of transport to some distance short of the rivers. This distance cannot be predicted with confidence, however. The potential risks are that Edina wells E5, E11, E17, and E18 could eventually become contaminated, although this is not a likely possibility within 100 years. If, on the other hand, present pumping patterns are continued, future contaminant migration is unlikely to travel beyond wells SLP6 and E2.

In summary, results from the ground-water flow model have shown that, with the installation of drinking water treatment, the continuance of existing pumping patterns acts as a de facto ground-water management scheme. The effect of that management scheme is to create gradient controls that limit future contaminant migration to the northernmost wells in Edina. The other option, abandonment of wells that become contaminated and replacement of the wells with alternative drinking water supplies, places fewer controls on long-term future contaminant migration. The contaminant is thus able to travel to wells farther to the south. The impacts of such mirgation would not, however, be manifested for 100 years or more.

6.2 Municipal Water Supply Systems in the St. Louis Park Area

There are two basic aspects of the operation of municipal water supply systems in the St. Louis Park area that are important in evaluating end-use controls: the location and capacity of wells and associated treatment plants, and management of well pumpage to meet water demand. These factors are important in determining supply shortfalls resulting from well closures caused by PAH contamination and in designing treatment or alternate water supply schemes to meet supply shortfalls. These two areas are discussed below, with further details provided in Appendix G.

6.2.1 Supply System Characteristics

Figure 6-2 and Table 6-1 summarize the main features of the St. Louis Park drinking water supply system. Throughout the 1970's, prior to the closure of a number of supply wells due to PAH contamination, the city supplied about 2300 million gallons of water per year from fourteen wells. The system serves a population of about 50,000 people through roughly 14,000 service connections. Ten of the supply wells draw from the Prairie du Chien-Jordan aquifer, with one well drawing from the Platteville and St. Peter aquifers (SLP3) and three wells drawing from the Mount Simon-Hinckley aquifer (SLP11, SLP12 and SLP13).

Most of the raw supply water in St. Louis Park is treated for iron removal. As shown in Table 6-1, there are five iron removal plants in the city, which treated over 90 percent of the total water supplied during 1970's. Pressure sand filters are used to remove iron. In simple terms, iron removal is accomplished by aerating the water to oxidize soluble ferrous iron (Fe^{+2}) to give an insoluble ferric iron (Fe^{+3}) precipitate, which is then filtered out by the sand beds. Iron levels in the raw well water are generally in the range of 0.5 to 1.0 milligrams per liter and can be reduced to less than 0.05 milligrams per liter using pressure sand filters. In addition, all raw water in St. Louis Park is treated with chlorine and fluoride before distribution, with or without iron removal treatment.

The six supply wells that have been closed in St. Louis Park accounted for about 20 percent of the water system's total supply (Table 6-1) and about 40 percent of the system's nominal well pumpage capacity during the 1970's (see Appendix G). The city has taken a number of measures in response to this reduced water-supply capacity. First, the city has increased the pumping rate at many of the wells that remain in service. Second, the city sponsored work by Serco Laboratories in 1979 and by Eugene A. Hickok and Associates in 1980 to study possible treatment of contaminated supply water by activated carbon to remove PAH, although no treatment was installed. Third, the city instituted water use restrictions in the summer of 1980, primarily to control lawn sprinkling and other non-essential uses.

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KEY

▲ = Well field location.

= Iron removal treatm

= Wells which are cu
due to PAH contam
numbers for these

NOTE: All wells are Pr
wells except for

SLP3	Platteville
SLP11	Mount Sin
SLP12	Mount Sin
SLP-13	Hinckley

Scale in Feet

0 1000 2000 3000

NON-RESPONSIVE

TABLE 6-1

SUMMARY DATA FOR THE ST. LOUIS PARK

MUNICIPAL WELL SYSTEM

Well Station	Iron Removal Plant(e)	Well Numbers	Aquifer	Average Annual Production(a) 1972 - 1977 Millions of Gallons per Year	Operating Rate, Percent of Capacity(d)	Well Status
1	Yes	3	Platteville-St. Peter	57	9.0	
		10	Prairie du Chien-Jordan	46	8.8	Closed 11/78.
		11	Mt. Simon-Hinckley	305	48.4	
		15	Prairie du Chien-Jordan	242	38.4	Closed 11/78.
4	No	4	Jordan	41	6.5	Closed 12/79.
5	No	5	Prairie du Chien-Jordan	91	14.4	Closed 8/81.
		17	Mt. Simon-Hinckley	NA		Construction begun 10/81.
6	Yes	6	Jordan	273	43.3	
		12	Mt. Simon-Hinckley	171	21.7	
7	No	7	Prairie du Chien-Jordan	26	4.1	Closed 11/78.
		9	Prairie du Chien-Jordan	26	4.1	Closed 11/78.
8	Yes	8	Prairie du Chien-Jordan	321	58.2	
10	Yes	13	Hinckley	243	30.8	
		14	Jordan	94	22.4	Closed 9/81. Reopened 12/81.
16	Yes	16	Jordan	225 (b)	69.9	
			TOTAL	2161 (c)		
Total for wells which are presently closed			472 (22%)	Total for wells with iron removal plants		1977 (91%)

Notes:

(a) Averages calculated from data in Table G2-2.
(b) Average pumpage for well 16 is from 1972 to 1977 even though this well was started up in late 1974.
(c) Total is of individual well averages shown. The actual average total pumpage from 1972 to 1977 was 2166 million gallons per year.
(d) Average annual production for 1972-1977 divided by design capacity given in Table G2-2.
(e) All wells have chlorination and fluorination treatment, with or without iron removal treatment.

Fourth, the city began drilling a new Mt. Simon-Hinckley well (SLP17) in October 1981. Drilling is near completion. Finally, the city started obtaining water through a supply interconnection with the City of Plymouth in July 1982 to supply the far northwest corner of St. Louis Park, which has reduced the overall water demand on St. Louis Park supply wells by about ten percent.

The St. Louis Park water supply system appears to be operated satisfactorily and has been given consistently high Sanitation Safety Ratings by the Minnesota Department of Health (MDH) throughout the 1970's and 1980's, with scores generally of 96 and above out of a possible score of 100.

Table 6-2 and Figure 6-3 summarize the major features of other municipal water supply systems in the St. Louis Park area. The supply systems in Hopkins, Edina, Richfield, and Bloomington are of particular interest, since they are located downgradient from St. Louis Park and in the path of regional ground-water flow from the contaminated wells (see Appendix E). All four of these supply systems obtain most of their water via wells from the Prairie du Chien-Jordan aquifers. All of the raw water supply in Hopkins, Richfield, and Bloomington is treated for iron removal in pressure or gravity sand filtration plants. The major base demand supply wells in Edina are also treated for iron removal using pressure sand filters. None of the supply wells in these communities has been closed by PAH contamination, except for Hopkins well H3, which was closed in March 1981.

Municipal water supply in St. Louis Park and neighboring communities is affected by daily and seasonal variations in demand. Many municipal supply wells are only pumped during a few months of the year to help meet peak summer demand. Total monthly pumpage in the summer can be two or three times higher than winter pumpage. Demand variations also exist within single days, with higher demand in the afternoon and evening hours. Peak hourly demands during a single day are primarily satisfied from stored water produced during off-peak hours, so that well closures do not directly impact supply of hourly demand variations. However, well closures do affect the ability to

TABLE 6-2

SUMMARY DATA FOR THE EDINA AND HOPKINS

MUNICIPAL WATER SUPPLY SYSTEMS

Well Number	Aquifer[a]	Iron Removal Treatment[b]	1976 (1982) Production,[a,c] Millions of Gallons per Year	
EDINA WELLS				
2	Jordan	Plant No. 1	426.5	(417.0)
3	Prairie du Chien-Jordan		39.1	(21.9)
4	Prairie du Chien-Jordan	Plant No. 2	167.7	(29.1)
5	Prairie du Chien-Jordan		86.8	(56.8)
6	Prairie du Chien-Jordan	Plant No. 2	348.2	(413.4)
7	Prairie du Chien-Jordan		72.6	(72.7)
8	Jordan		64.2	(64.9)
9	Mount Simon-Hinckley		74.0	(45.3)
10	Mount Simon-Hinckley	Plant No. 3	256.5	(220.4)
11	Jordan	Plant No. 3	397.3	(356.4)
12	Hinckley	Plant No. 4	57.6	(387.5)
13	Jordan	Plant No. 4	385.6	(40.8)
14	Prairie du Chien-Jordan		46.4	(30.6)
15	Prairie du Chien		169.4	(51.4)
16	Prairie du Chien-Jordan		306.4	(265.2)
17	Jordan		117.5	(56.9)
18	Jordan		49.8	(18.8)
			3066	(2549.1)
HOPKINS WELLS				
1	Prairie du Chien-Jordan	Plant No. 1	269.0	
3	Prairie du Chien-Jordan	Plant No. 3	71.3	
4	Prairie du Chien-Jordan	Plant No. 4		
5	Prairie du Chien-Jordan	Plant No. 4	573.9	
6	Prairie du Chien-Jordan	Plant No. 4	0	
			914	

Notes:

(a) Aquifer and pumpage data from Hult and Schoenberg (1981).
(b) Treatment plant location data from Libby (1983) and Strojan (1983).
(c) 1982 pumpage data from Libby (1983).

NON-RESPONSIVE

[redacted]

EXPLANATION

Treatment:

- ○ Municipal supply well without iron removal treatment
- ● Municipal supply well with iron removal treatment

Supply Aquifer:

- △ Platteville-St. Peter
- ○ Prairie du Chien-Jordan
- ▽ Mt. Simon-Hinkley

Well numbers shown are the municipal well numbers

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Figure 6-3 Location of Municipal Supply Wells and Iron Removal Treatment Plants in St. Louis Park and Surrounding Communities

meet peak daily demands, which vary seasonally. For example, peak daily demand in St. Louis Park in 1975 was 18 million gallons, with daily demand exceeding 10 million gallons on 18 different days, while annual average daily demand was 5.6 million gallons. St. Louis Park had a peak supply capacity of just under 20 million gallons per day prior to the closure of wells by the MDH. These well closures have reduced current peak supply capacity to about 12 million gallons per day, which has prevented the city from meeting peak demand, during the summer months. Further details on daily and seasonal demand variations in St. Louis Park and Edina are provided in Appendix G.

6.2.2 Supply Shortfalls

Municipal supply shortfalls due to well closure have been experienced since 1978. Six St. Louis Park wells and one Hopkins well are closed at present. These losses have limited the ability of St. Louis Park to meet the city's water demand. In 1982, St. Louis Park purchased over 25 million gallons of potable water from Plymouth to meet its supply needs (Tollefsrud 1983).

The wells that have been closed to date and their average production rates prior to closure are presented in Tables 6-1 and 6-2. The closed wells supplied an average total of 543 million gallons per year (472 million gallons per year for St. Louis Park and 71 million gallons per year for Hopkins) before they were shut down. No allowance is made in these calculated shortfalls for the fact that some of the currently closed wells (SLP4, SLP7, SLP9 and H3) do not exceed the PAH criteria recommended by this study (see section 4.4).

Based on the ground-water flow modeling presented in Appendix E, St. Louis Park, Hopkins, and Edina are the only communities that may be influenced during the next 100 years by contaminantion migration. Future growth in these areas is expected to be limited, and projections through the year 2000 predict declining or stable populations and water usage for St. Louis Park, Hopkins, and Edina (see Tables 6-3 and 6-4). These trends are predicted to hold true for the reasonably foreseeable future. This leads to the conclusion that

TABLE 6-3

POPULATION PROJECTIONS

Community	1970	1980	1990	2000	2010	2020
St. Louis Park[a]*	48,883	42,931	(40,000)[c]	(38,000)		
Edina[a]*	44,046	46,073	(45,000)	(40,000)		
Hopkins[a]*	13,428	15,336	(14,000-15,000)	(NA)[e]		
Crystal[a]*	30,925	25,543	(24,000)	(23,000)		
Golden Valley[a]*	24,246	22,775	(23,500)	(23,000)		
Minnetonka[a]	35,776	38,683	(40,500)	(42,000)		
New Hope[a]*	23,180	23,087	(21,500)	(21,500)		
Plymouth	18,077	31,615	(43,500)	(54,000)		
Totals	238,561	246,043	(252,000-253,000)	(255,000-256,000)		
Hennepin County[b]	960,080	941,411	950,762	952,521	926,388	890,988

Notes:

(a) Metropolitan Council of the Twin Cities Area 1978.
(b) Hennepin County Demographers Office 1983.
(c) ( )Indicates preliminary projections from Metropolitan Council of the Twin Cities Area 1983, Operts 1983a.
(d) *Indicates areas which are physically full.
(e) NA Not available

TABLE 6-4

HISTORICAL AND PROJECTED WATER USAGE

(Billions of Gallons Per Year)

Year	St. Louis Park(a,b,e)	Edina(c,e)	Hopkins(d,e)
1972	2.02	1.85	
1973	2.21	2.20	
1974	2.17	2.29	
1975	2.04	2.18	0.91
1976	2.53	2.93	0.91 (d)
1977	2.02	2.30	0.80 (d)
1978	2.09	2.36	
1979	1.95	2.28	
1980	2.17	2.63	
1981	2.07	2.47	
1982	1.83	2.71	
(1990)	(1.95)	(2.57)	(0.80)
(2000)	(1.91)	(2.63)	(0.80)

Notes:

(a) 1972-1975 pumping data from Orr, Schelen, Mayeren 1976.
(b) 1976-1982 pumping data, Tollefsrud 1982.
(c) Historical pumping records, Libby 1983.
(d) Metropolitan Council of the Twin Cities Area 1979.
(e) ( )Projections from Metropolitan Council of the Twin Cities Area 1979, Operts 1983b.

there will beno growth in water demand and that supply shortfalls will originate only from well closures in Edina, Hopkins and St. Louis Park over the next 100 years.

Ground-water flow modeling was used to predict future municipal well closures resulting from contaminant migration in the Prairie du Chien-Jordan aquifer (see Appendix E). Table 6-5 summarizes the predicted timing of future well closures for the two end-use control cases considered: 1) taking contaminated municipal supply wells out-of-service and providing alternate supplies and 2) treating selected contaminated municipal supply wells in order to meet the recommended PAH criteria in the finished water. The resulting supply shortfalls, based on the historic pumping rates shown in Tables 6-1 and 6-2, are also indicated in Table 6-5.

The timing of predicted well closures in Table 6-5 are rough estimates derived from a series of computer model runs made to simulate successive well closures. The estimates are only approximate because hydraulic travel times were developed from the USGS model using long-term average historic pumping rates, while actual contaminant migration is stongly influenced by short-term fluctuations in pumping patterns, which alternately pull contaminants in different directions along a general path, (Appendix E). The estimates are based on no appreciable attenuation of contaminants occurring in the Prairie du Chien-Jordan. The reported ranges for Edina wells E2 and E3 represent an accuracy of plus or minus 10 to 15 years for the hydraulic travel times predicted by computer modeling for ground-water flow from well SLP6 to these wells. The predicted closures for St. Louis Park wells SLP4, SLP6, SLP7, and SLP9 are based on re-starting and using these wells, since they do not currently exceed the recommended PAH criteria. The ranges in predicted closure times for these wells reflects uncertainty in how long it will take for PAH concentrations to exceed the recommended criteria. This question cannot be directly addressed by the modeling done in this study, so the reported ranges reflect judgements based on observed contaminant migration to date and results of computer model simulations of general ground-water flow behavior in the Prairie du Chien-Jordan.

TABLE 6-5

PREDICTED MUNICIPAL WELL CLOSURES

AND RESULTING SUPPLY SHORTFALLS

	Contaminated Wells Remain Closed (See Section 6.4)		Selected Contaminated Wells are Treated (see Section 6.3)	
Well	Predicted Closure Timing[a]	Supply Shortfall, Millions of Gallons per Year[b]	Predicted Closure Timing[a]	Supply Shortfall Millions of Gallons per Year[b]
SLP 4	0-5 years	40	0-5 years	40
SLP 5	Now	90	Now	90
SLP 6	0-10 years	270	0-10 years	270
SLP 7	Not predicted	0	Not predicted	0
SLP 9	Not predicted	0	Not predicted	0
SLP 10	Now	50	Now	50
SLP 15	Now	240	Now	240
Subtotals		690		690
E2	20-50 years	420	30-70 years	420
E3	40-80 years	30	50-100 years	30
E4	50-80 years	130	100 years, if ever	0
E6	50-90 years	380	100 years, if ever	0
Subtotals		960		450
Totals		1650		1140

Notes:

(a) Based on a criterion for noncarcinogenic PAH and heterocyclic PAH at the low end of the recommended range (4 micrograms per liter).

(b) Based on historic average pumping rates shown in Tables 6-1 and 6-2.

The predicted well closure timings in Table 6-5 are based on a criterion for noncarcinogenic PAH and heterocyclic PAH at the low end of the recommended range (4 micrograms per liter). If the noncarcinogen criterion is established at the high end of the recommended range (400 micrograms per liter), it is uncertain if any municipal supply wells would ever exceed the recommended criteria. This uncertainty arises from the fact that there are no long-term monitoring data to show the effect of continued pumping of a contaminanted well on PAH concentrations. It is judged to be very unlikely that any municipal supply wells outside of St. Louis Park would exceed the recommended criteria within the next 100 years - if ever - if the noncarcinogen criterion is set at 400 micrograms per liter. It is possible, but again seems very unlikely, that municipal supply wells in St. Louis Park could exceed 400 micrograms per liter of noncarcinogenic PAH and heterocyclic PAH if they were restarted, particularly wells SLP5, SLP10, and SLP15. Exceeding a criterion of 400 microgram per liter is judged to be unlikely because no contaminated wells in the Prairie du Chien-Jordan have ever approached this concentration (see Chapter 4 and Appendix K).

The predicted well closures in Table 6-5 are also based on the assumption that Hopkins well H3 will remain closed for the reasonably foreseeable future. It is recommended that this well remain closed in order to avoid drawing contaminants to the southwest, across or against the potentiometric gradients that would otherwise exist in this area of the Prairie du Chien-Jordan. Pulling contaminants in this direction is undesirable, because they might then migrate to areas further south or west, under the influence of municipal supply wells in Edina (well E13 and E15), which would otherwise not be affected by PAH contamination. No adverse effects on Hopkins' municipal water supply should occur if well H3 remains closed. Well H3 supplied a small portion of Hopkins' total supply before it was closed (see Table 6-2), and this resulting slight shortfall has been, and should continue to be, replaced by greater pumpage of the other municipal supply wells in Hopkins.

The bases for the predicted closure timings for each of the wells in Table 6-5 are summarized below, all based on a criterion of 4 micrograms per liter for noncarcinogenic PAH and heterocyclic PAH.

- SLP5, SLP10, and SLP15 - currently exceed the recommended criteria.

- SLP6 - based on hydraulic travel time from SLP4 or W48 (Methodist Hospital well).

- SLP7 and SLP9 - not predicted to exceed the recommended criteria because they are upgradient of contaminated wells and are only pumped during the summer, although they might entrain some traces of contamination from the area around wells SLP10 and SLP15.

- E2 and E3 - based on hydraulic travel time from SLP6, assuming that SLP6 becomes contaminated in 0 to 10 years.

- E4 and E6 - based on hydraulic travel times from well SLP6 or well E2. Predicted closure times for wells E2 and E3 are estimated to be at least 10 years longer if SLP6 is pumped and treated once it becomes contaminated, compared to the case of closing SLP6. This is a worst-case estimate, which reflects the fact that contaminants may not be completely captured by pumping well SLP6 as a result of short-term fluctuations in pumping patterns. It is also possible that pumping well SLP6 would effectively prevent further migration of contaminants to the south, in which case no Edina wells would become contaminated. Predicted closure times for wells E4 and E6 were similarly increased for the case of continuing to pump wells SLP6 and E2 once they become contaminated.

6.3 Drinking Water Treatment

6.3.1 Objectives

This section examines the feasibility of using drinking water treatment technologies to remove PAH from contaminated ground water in order to meet the recommended criteria for PAH and heterocyclic PAH. Water treatment must also satisfy other quality concerns and take into account bacteria, trace metals, iron, hardness, and other use characteristics or contaminants. However, these other potable water supply concerns have not posed unusual problems in the past and are not directly related to the PAH contamination problems in St. Louis Park. They are, therefore, assumed to be achievable in the future, although the effects of any PAH-related treatment alternatives on these supply characteristics must be considered.

As discussed in Chapter 4, the criteria recommended by this study for PAH and related compounds in potable-water supplies are as follows:

- the total concentrations of a specific list of carcinogenic PAH and heterocyclic PAH should be less than 28 nanograms per liter;
- the total concentrations of a specific list of noncarcinogenic PAH and heterocyclic PAH should be less than from 4.0 to 400 micrograms per liter.

Both of these criteria must be achieved simultaneously. Recommended procedures to determine compliance with these criteria are discussed in Chapter 4 and Appendix J.

Reopening of closed wells and subsequent treatment of contaminated ground water will address the objective of allowing for present and foreseeable future uses of ground-water resources in the St. Louis Park area because pumping contaminated ground water (i.e., ground water that requires treatment to meet the recommended PAH criteria for potable use) will create a de facto gradient control well system, which will prevent further migration of contaminants. This section,

however, only addresses the technical issues associated with the treatment of contaminated ground water that does not meet the proposed PAH criteria for potable use.

6.3.2 Approach

A number of studies have been performed, or are in progress, concerning the removal of PAH and related compounds from contaminated St. Louis Park ground water. In particular, these studies have focused on the treatment of water from St. Louis Park well SLP15 and have included independent field studies by ERT. In addition, many studies on the treatment of PAH in waste and drinking water have been reported in the scientific literature. The approach used in this study was to review and summarize the results of these studies, particularly those at SLP15, and to determine which drinking water treatment technologies have been shown to be or are likely to be effective in meeting the recommended criteria for PAH and heterocyclic PAH in potable waters. Public literature and private and government data sources were used to estimate the cost of applying these technologies to potable water supply wells in the St. Louis Park area. In order to estimate costs it was necessary to assume certain design conditions, because studies to date do not provide a firm design basis. Ranges of likely design conditions were used in order to evaluate the sensitivity of cost estimates. The selection of wells requiring treatment was based on ground-water modeling results and supply shortfall calculations, as presented in the first two sections of this chapter. A more detailed description of the approach and results obtained in these efforts is provided in Appendix G.

6.3.3 Drinking Water Treatment Alternatives

The fact that PAH are ubiquitous in the environment, as a result of both natural and anthropogenic sources, means that PAH are expected to be present, at least in trace concentrations, in any drinking water supply. A number of scientific studies have indeed shown that trace levels of PAH are present in all surface and ground-water supply sources that have been analyzed with sufficiently powerful

techniques. Total PAH concentrations in these instances have ranged from low part per trillion (nanogram per liter) levels to low part per billion (microgram per liter) levels. As discussed in Appendices G and I, these trace concentrations of PAH have not been shown to be linked to adverse public health effects.

Considerable data have been developed on the behavior of PAH in drinking water treatment systems during the course of scientific studies on the distribution and occurrence of PAH in aquatic environments (see Appendix G). These data indicate that a number of conventional drinking water treatment technologies (e.g., chlorination, coagulation, and filtration) are effective in removing PAH, as well as some more advanced technologies (e.g., granular activated carbon treatment, ozonation). In all of these drinking water treatment applications, PAH removal has been a side-effect of the primary treatment effect desired.

ERT is unaware of any drinking water treatment system that has been specifically designed for the purpose of removing trace quantities of PAH. This makes the drinking water treatment problem at St. Louis Park unique and, unfortunately, means that most of the data on the behavior of PAH in conventional and advanced drinking water treatment are not directly applicable to the St. Louis Park problem. This is because available data on PAH removal by various drinking water treatment technologies are applicable to surface water, to higher PAH concentrations, or to entire treatment systems, not individual treatment operations. However, data on PAH removal in existing drinking water treatment systems indicate technologies that may be applicable to the St. Louis Park problem. Appendix G contains a brief review of the scientific literature covering the behavior of PAH in drinking water treatment systems.

Summary of SLP15 Test Results

Because of the unique nature of the drinking water treatment problem at St. Louis Park, a number of studies have been performed to examine possible treatment technologies for the specific raw water characteristics in St. Louis Park. All of these studies have used

water from well SLP15. These studies are briefly summarized below, with more detailed review presented in Appendix G.

1) Serco Laboratories, 1979 - Three tests were conducted to evaluate the effects of adding powdered activated carbon (PAC) slurries at the wellhead of SLP15. PAH analyses were performed by Serco and the MDH using High Performance Liquid Chromatography (HPLC).

2) E. A. Hickok and Associates, 1980-81 - Pilot and bench tests were conducted to evaluate PAC injection and granulated activated carbon (GAC) columns on PAH removal at SLP15. Four tests each of PAC and GAC were performed. PAH analyses were performed by Serco Laboratories using HPLC. A single test was also conducted to evaluate the effect of hydrogen peroxide with ultraviolet light at short residence time.

3) CH2M Hill, 1982-present - Performed a literature review of potentially applicable PAH removal technologies; tested effects of the existing iron removal plant at SLP15 (September 1982); performed bench-scale testing of activated carbon adsorption, addition of ozone and hydrogen peroxide - both with and without UV light, chlorination, aeration and filtration, and macroreticular resins. Based on results of bench-scale testing and an economic screening evaluation of GAC versus ozone/UV versus hydrogen peroxide/UV, pilot-scale testing of GAC is currently in progress at SLP15. All PAH analyses have been performed by CH2M Hill using Gas Chromatography/Mass Spectroscopy (GC/MS) techniques.

4) ERT, 1982-present - Performed two field tests of the effects of the existing iron removal plant at SLP15 (December 1982 and February 1983). All PAH analyses were performed by Monsanto Research Corporation using GC/MS.

A simplified summary of the results of these various studies is presented in Table 6-6. More detailed discussion of the results is presented in Appendix G. The major conclusions from these various

TABLE 6-6

SUMMARY OF KEY RESULTS FROM PAH REMOVAL STUDIES

AT ST. LOUIS PARK WELL SLP15[a]

(Concentrations in nanograms per liter)

Description of Treatment Studied	Untreated Water		Treated Water		Comments
	Noncarcinogenic PAH	Carcinogenic PAH	Noncarcinogenic PAH	Carcinogenic PAH	
SERCO TESTS (July 1979)					
• PAC injection at 1 to 2 milligrams per liter	4,300	ND[b]	1,700	ND	
• PAC injection at 9 to 12 milligrams per liter	4,300	ND	35	ND	
HICKOK TESTS (September and October 1980)					
• PAC injection at 5.5 milligrams per liter	400	60	2	ND	PAC treatment was applied to combined water from wells SLP11 and SLP15.
• GAC column at 7.5 minutes contact time	850	26	3	ND	
CH2M HILL TESTS					
• Existing Iron Removal Plant at Well SLP15					Both tests were affected by iron precipitate deposits on the filter beds. Quinoline was the only carcinogen detected in treated samples.
- September 1982 Test	9,300	ND	2,100	11	
- December 1982 Test	8,700	30	8,300	8	

TABLE 6-6 (Continued)

Description of Treatment Studied	Untreated Water		Treated Water		Comments
	Noncarcinogenic PAH	Carcinogenic PAH	Noncarcinogenic PAH	Carcinogenic PAH	
• Ozone bench-scale testing at 1 milligram per liter dose					
- without UV light	11,000	44	2,800	2	
- with UV light	11,000	44	160	ND	
• PAC Bench-Scale Testing					Results from adsorption isotherm testing with pulverized activated carbon.
- 1 milligram per liter PAC	11,000	24	6,700	ND	
- 10 milligrams per liter PAC	11,000	24	380	ND	
• GAC Bench Testing	11,000	44	34	1	
ERT TESTS					
• Existing Iron Removal Plant at Well SLP15					First two tests were affected by iron precipitate deposits on the filter beds.
- September 1982 Test	4,300	15	610	ND	
- December 1982 Test	5,300	39	4,800	ND	
- February 1983 Test	5,300	59	4,800	17	

Notes:

(a) See Appendix G, Section G4.6 for details on the derivation of this summary table.
(b) ND indicates none detected.

studies, as indicated by Table 6-6, are summarized below. All of the following conclusions are based on a criterion for noncarcinogenic PAH and heterocyclic PAH at the low end of the recommended range (4 micrograms per liter), since untreated water from SLP15 meets the high end of the recommended range (400 micrograms per liter).

The existing pressure sand filter iron removal plant at SLP15 does not, on its own, appear to be capable of sufficient PAH removal to meet a low criterion, for noncarcinogenic PAH and heterocyclic PAH, but could meet the carcinogen criterion. Test results in September 1982 and December 1982 were affected by deposits of iron precipitate and iron bacteria slime on the surface of the filter beds. These deposits are undesirable in operating an iron removal plant, and steps were subsequently taken by St. Louis Park Water Department personnel to remove them and prevent their reoccurrence. These deposits appear to have resulted in the substantial PAH removals observed during the September 1982 test and to have sufficiently upset flow patterns in the filter units to have resulted in the poorer PAH removals observed during the December 1982 test (see Table 6-6). Retesting of the iron removal plant by ERT in February 1983, after the deposits had been removed, indicated little overall removal of PAH, although some PAH, particularly higher molecular weight carcinogenic PAH, were adsorbed by the sand filter beds.

Both granular and powdered activated carbon have been shown to be effective in achieving substantial PAH removal. Tests by Serco, Hickok and CH2M Hill are all in agreement on this conclusion, which fits with expectations from the scientific literature. Sufficient test data to design a granular activated carbon treatment unit are currently unavailable, although pilot testing by CH2M Hill at SLP15 is in progress and should provide the necessary data.

Either ozone or hydrogen peroxide treatment in the presence of ultraviolet light is capable of achieving the proposed PAH criteria. In the absence of UV light, only ozone appears to be capable of achieving the proposed PAH criteria. The need or lack of need for UV light is important because of the substantial costs associated with its use.

Candidate Treatment Technologies

Based on the test results described above, there appear to be two basic approaches to drinking water treatment that could achieve the recommended PAH criteria: 1) simple additions to existing treatment plants at iron removal treatment and 2) granular activated carbon treatment. Simple additions to iron removal treatment refers to a variety of treatment alternatives that could capitalize on the presence of existing iron removal treatment plants. Such simple additions may have little to do with iron removal per se, but they do make use of existing equipment to minimize the cost and complexity of additional treatment. Granular actived carbon treatment involves building a new, stand-alone treatment plant, which can be operated with or without an associated iron removal plant. Each of these two basic approaches are described below.

Test results indicate that pressure sand filter iron removal treatment alone is not sufficient to achieve the proposed PAH criteria for potable water. However, relatively simple modifications or additions to existing iron removal plants may be able meet the recommended PAH criteria. Three possible modifications are indicated by test results to date and are discussed below.

One possible modification is the addition of powdered activated carbon (PAC) upstream of the sand filters This modification makes use of the existing sand filter beds to remove PAC from the treated water. Injection of PAC has been shown to be effective in removing PAH, although potentially adverse impacts on the operation of the iron removal plant need to be investigated.

A second possible modification is the injection of ozone upstream of the sand filters. CH2M Hill's bench-test results indicate that ozone injection alone (without UV light) can meet the recommended PAH criteria, although partially degraded oxidized PAH byproducts may be formed. Given the uncertain health effects of such byproducts and their distinctly different physical/chemical properties compared to the parent PAH compounds, it may be desirable and possible to remove these byproducts in the iron removal plant downstream, with perhaps

some modification in the operation of the iron-removal system. Additional study would be required to evaluate this alternative.

A third possible modification of iron-removal treatment is the adjustment of operating conditions or the addition of chemicals to improve the filtering performance of the systems. This proposal is entirely speculative, however, pending further study on the mechansims for PAH removal which could be exploited in an iron removal plant.

Test results indicate that granular activated carbon (GAC) can be effective in reducing PAH levels well below the recommended PAH criteria. However, insufficient data are now available to design a GAC treatment system. Information on the major design variables of contact time and breakthrough time are currently lacking. Short-term bench tests indicate that relatively brief contact times (on the order of 15 minutes or less) should be effective and that GAC has a high equilibrium adsorption capacity for PAH, but actual breakthrough capacities are currently unknown. The pilot-scale GAC column tests currently underway at SLP15 by CH2M Hill should yield the necessary design information on contact and breakthrough times.

Unit Costs of Alternative Treatment Technologies

Based on the results of PAH drinking water treatment studies at St. Louis Park, ERT has estimated the costs of alternative technologies. Since definitive design-basis data are unavailable for any of these technologies, the cost estimates are developed on the basis of reasonable design and performance assumptions. This has been done to indicate which technologies warrant further investigation, not to make a final selection. While the available data are insufficient to make a final selection, they are sufficient to screen alternate technologies to determine which deserve further study.

Drinking water treatment cost estimates were developed using a parametric approach to evaluate the cost impacts of different design conditions. This was done for two reasons. First, this approach

indicates the sensitivity of treatment costs to variations in basic design conditions (e.g., contact times, reactant dosages). This is important because sufficient information is currently unavailable to establish design conditions with certainty. Second, this approach indiates how treatment costs vary with plant capacity and flow rate. This is important because the municipal supply wells in the St. Louis Park area that could require treatment to remove PAH have different capacities and operate at different flow rates. ERT's approach was to develop cost curves for capital and operating and maintenance costs as a function of capacity and operating flow rate so that any set of conditions could be readily evaluated. The distinction between plant capacity and operating rate is important because municipal supply wells in the St. Louis Park area generally operate at or near full capacity when they are operated, but are not operated full-time.

Drinking water treatment cost estimates were largely developed from cost data available in the public literature, with the exception of iron removal plant costs, which were developed from data specific to the five iron removal plants in St. Louis Park. All costs employ a December 1982 cost basis. Capital cost estimates represent installed cost, that is, the cost of all necessary equipment and instrumentation, construction, engineering, legal and administrative fees, and contractor's overhead and profit. Operating costs include the cost of monitoring plant performance on a regular basis (weekly for modified iron removal techniques and every other week for GAC treatment - this distinction reflecting the better ability of GAC to absorb shock loadings or operating upsets). Performance monitoring costs were estimated by assuming the development of a reliable technique to monitor indicator or surrogate parameters, which would be much less expensive and time-consuming than standard GC/MS analyses. Costs to develop such a technique were also estimated and included. Appendix G provides further details on cost and design bases.

Table 6-7 summarizes the results of drinking water treatment cost estimates for two basic cases of alternative treatment technologies for a typical municipal supply well in the St. Louis Park area. The two treatment technology cases considered are:

1) treatment that capitalizes on the use of pressure sand

TABLE 6-7

ESTIMATED COSTS OF DRINKING WATER TREATMENT ALTERNATIVES FOR A 1200 GALLON PER MINUTE CAPACITY WELL OPERATED AT 300 MILLION GALLONS PER YEAR[a]

Case Description	Well with Existing Iron Removal Plant: Capital Cost $ Thousands	Operating and Maintenance Costs, $ Thousands per	Present[g] Value Costs, $ Thousands	Well Without Existing Iron Removal Plant[f]: Capital Cost, $ Thousands	Operating and Maintenance Costs, $ Thousands per Year	Present[g] Value Cost, $ Thousands
Simple additions to iron removal plants:						
• Ozone injection[b]	120-190	16-18	450-560	600-670	27-29	1190-1300
• PAC injection[c]	13-15	11-25	230-510	493-495	22-36	970-1250
Granular activated carbon treatment:						
• equilibrium breakthrough time[d,e]	340-880	31	980-1570	520-1070	31	1180-1780
• 1-year breakthrough time[d]	340-880	50-117	1360-3280	520-1070	50-117	1560-3480

Notes:

(a) See Appendix G for cost bases and derivation.
(b) Range reflects ozone injection dose of from 1 to 2 milligrams per liter.
(c) Range reflects PAC injection dose of from 2 to 10 milligrams per liter.
(d) Range reflects empty-bed contact time of from 7.5 to 30 minutes.
(e) Maximum breakthrough time allowed is 10 years.
(f) Additional costs included for building and operating a new iron removal treatment plant for the case of ozone or PAC injection, or for operating a GAC column in part as an iron precipitate filter.
(g) Present value costs based on 100 years operation at an effective annual interest rate of 5 percent, with allowance for replacing equipment after 50 years.

filter iron removal plants by the addition of ozone or PAC upstream of the sand filters, with ozone injection at from 1 to 2 milligrams per liter and PAC injection at from 2 to 10 milligrams per liter; and

2) granular activated carbon treatment with breakthrough times of 10 years (optimistic) or 1 year (likely to be more realistic) and contact times of 30 minutes (pessimistic) to 7.5 minutes (likely to be more realistic).

Table 6-7 shows capital, annual operating and maintenance, and present value costs for these various design cases for a 1200 gallon per minute capacity well operated at 300 million gallons per year. The present value costs are based on 100 years operation with an effective annual interest rate of 5 percent. Costs for monitoring plant performance are included in the annual operating cost estimates. More detailed descriptions of the cost derivations and design bases and assumption are presented in Appendix G.

The cost estimates in Table 6-7 show that simple additions to iron removal treatment is clearly the least expensive alternative, if such additions are feasible. The only exception is the case where a new iron removal plant would be required for PAC or ozone treatment, in which case the present value cost is comparable to that for the most optimistic GAC treatment case (7.5 minutes contact time and equilibrium breakthrough time). Injection of powdered activated carbon is less expensive than ozone injection under optimistic design conditions, but under pessimistic design conditions for PAC the estimated present value costs ranges for these two cases overlap. That is, ozone injection at 1 to 2 milligrams per liter is comparable in cost with PAC injection at high doses (10 milligrams per liter). Cost curves presented in Appendix G for different size treatment plants indicate that PAC injection is less expensive than ozone injection at PAC injection rates less than about 5 milligrams per liter for any size well up to 500 million gallons per year.

Granular activated carbon treatment, which is capable of achieving the recommended PAH criteria, is shown in Table 6-7 to have

a present value cost on the order of from $1.0 to $3.5 million for a single well. These costs are significantly affected by the design contact time, which primarily affects capital costs, as indicated by the ranges shown for each case (7.5 minutes at the low end and 30 minutes at the high end). Operating costs of GAC treatment are significantly affected by the breakthrough time, which indicates the importance of studies to determine actual breakthrough times. Based on other experiences with GAC treatment, however, it appears that the 1-year breakthrough time is more realistic. Granular activated carbon treatment requires some additional expense at a well without an iron removal plant compared to one already having such treatment. This is based on the assumption that a GAC column operated on untreated well water would also operate as an iron removal filter (to prevent plugging due to growth of iron bacteria), with associated costs for additional backwashing facilities.

6.3.4 Drinking Water Treatment System Costs

This section presents estimated costs to restart and treat contaminated wells in the St. Louis Park area and to treat wells that may become contaminated in the future. Based upon the population and water use forecasts presented in section 6.2, no growth in water demand was assumed in the development of future expenditures. Present and future treatment needs are based on satisfying the supply shortfalls resulting from municipal well contamination predicted by ground-water flow modeling (see Section 6.2 and Appendix E). Table 6-8 shows predicted municipal water supply shortfalls in St. Louis Park and Edina for the case of treating and using selected contaminated wells. This table is derived from the shortfall predictions presented in Table 6-5. The supply shortfall in Hopkins resulting from permanently abandoning well H3 is not considered, because this relatively small shortfall can be made up by increased pumping of the other municipal supply wells in Hopkins. The cost estimates for drinking water treatment are based on a noncarcinogen criterion at the low end of the recommended range (4 micrograms per liter), because no wells are likely to ever exceed a noncarcinogen criterion at the high end of the recommended range (400 micrograms per liter). A higher noncarcinogen criteria would therefore likely

TABLE 6-8

PREDICTED MUNICIPAL WATER SUPPLY SHORTFALLS IN ST. LOUIS PARK AND EDINA TO BE MET BY TREATING CONTAMINATED WELLS

(Millions of Gallons per Year)

	Best Case Prediction		Worst Case Prediction	
Year	St. Louis Park	Edina	St. Louis Park	Edina
1983	380	0	690	0
1988	420	0	690	0
1993	690	0	690	0
2013	690	0	690	420
2033	690	0	690	450
2053	690	420	690	450
2083	690	450	690	450

eliminate the need for drinking water treatment, since no wells currently exceed the recommended criterion of 28 nanograms per liter for carcinogenic PAH and heterocyclic PAH in finished water. In the event that the carcinogenic criterion above is exceeded, simple modifications of exciting iron removal and treatment plants aimed at improving their filtering or adsorption efficiency for PAH might provide sufficient removal of carcinogenic PAH and heterocydic PAH, based on the fact that removal of higher molecular weight PAH was observed during ERT's tests at the iron removal plant at well SLP15 (see Appendix G).

The minimum cost for drinking water treatment to make up the supply shortfall resulting from contaminated municipal supply wells is achieved by only treating wells with existing iron removal plants that are operated at high rates (see Appendix G). Treating all contaminated wells is unnecessary to meet supply shortfalls and requires considerable additional expenditures for treatment. The minimum cost for drinking water treatment is based on abandoning wells SLP4, SLP5, and E3 and treating wells SLP6, SLP10, SLP15, and E2 when they exceed the recommended PAH criteria. Untreated water from some of these wells (SLP5, SLP10, and SLP15) already exceeds the recommended criteria, based on a criterion for noncarcinogenic PAH and heterocyelic PAH at the low end of the recommended ranged (4 micrograms per liter). Wells SLP4 and E3 are assumed to be abandoned because they do not have existing iron removal plants and historically have operated at relatively low rates (see Tables 6-1 and 6-2). Well SLP5 is abandoned because it does not have an existing non removal plant and is being replaced by a new, adjacent Mt. Simon-Hinckley well (SLP17) and using this new well is more cost-effective than treating well SLP5 (see Appendix G). Wells SLP6, SLP10, SLP15, and E2 all have existing iron removal plants and historically have operated at relatively high rates, with the exception of SLP10 (see Tables 6-1 and 6-2). Well SLP10 has become sand-locked in recent years, so it is assumed that this well would be cleaned out, at an estimated cost of $50,00 to $100,000. This represents an effective expenditure to bring a contaminated well in service because SLP10 and SLP15 are located at the same treatment station, thereby allowing for significant economies of scale in treatment.

Table 6-9 presents estimated costs for drinking water treatment at wells SLP6, SLP10, SLP15, and E2 for best-case and worst-case predictions of contaminant migration and resulting timings of well contamination. Costs are presented as ranges for different design bases for granular activated carbon treatment and for injection of powdered activated carbon or ozone. Costs are based on operating flow rates sufficient to meet the shortfalls indicated in Table 6-8, provided that well SLP17 is operated at a rate of 100 million gallons per year. This is an assumed minimal operating rate for this new well, based on the assumption that its use would be desirable to provide a balanced supply in the distribution system and to help meet peak demands. Operating well SLP17 at high rates would not be cost-effective, if drinking water treatment is installed at contaminated wells, because it is less expense to treat an incremental amount of contaminated water, once a treatment plant is built, than it is to pump the same incremental amount from the Mt. Simon-Hinckley. For example, pumping an additional 100 million gallons per year from SLP17 has a present value cost of from $130,000 to $230,000 (see section 6.4), compared to a present value cost of from $10,000 to $150,000 to incrementally treat this much more water (see Appendix G).

Estimated costs of additional studies required to implement drinking water treatment for PAH removal are also included in Table 6-9. Estimated study costs for PAC or ozone injection are significantly higher than for GAC treatment, based on the additional work required to test and design a PAC or ozone injection system. Estimated study costs include developing an inexpensive and reliable technique for monitoring PAH removal performance. Further details on study costs are presented in Appendix G.

The cost estimates in Table 6-9 indicate that the most optimistic present value cost for drinking water treatment is $0.6 million, based on best-case contaminant migration and the least expensive treatment option (injecting 2 milligrams per liter of PAC). The most expensive treatment option based on additions to existing iron removal plants (injecting 2 milligrams per liter of ozone) has an estimated present value cost of $1.5 million. The present value cost of adding treatment to existing iron removal plants (PAC or ozone injection)

TABLE 6-9

ESTIMATED COSTS FOR DRINKING WATER TREATMENT AS AN END-USE CONTROL

WORST-CASE CONTAMINANT MIGRATION:

Well	Year Required	Capacity, Gallons per Minute[a]	Flow Rate, Millions of Gallon per Year[a]	Existing Iron Removal Plant	Present Value Cost, $ Millions: Powdered Activated Carbon Or Ozone Injection[b]	Present Value Cost, $ Millions: Granular Activated Carbon Treatment[c]
SLP10 & SLP15[f]	1983	2200	300	Yes	0.28-0.76[d]	1.2-5.3[d]
SLP6	1983	1200	300	Yes	0.23-0.56	1.0-3.3
E2	2013	800	400	Yes	0.06-0.12	0.26-0.58
				Study Costs[e]	0.2-0.4	0.1-0.2
				Totals	0.8-1.8	2.6-9.4

BEST-CASE CONTAMINANT MIGRATION:

Well	Year Required	Capacity, Gallons per Minute	Flow Rate, Millions of Gallon per Year	Existing Iron Removal Plant	Present Value Cost, $ Millions: Powdered Activated Carbon Or Ozone Injection	Present Value Cost, $ Millions: Granular Activated Carbon Treatment
SLP10 & SLP15[f]	1983	2200	300	Yes	0.28-0.76	1.2-5.3[d]
SLP6	1993	1200	300	Yes	0.14-0.34	0.60-2.0
E2	2053	800	400	Yes	0.01-0.02	0.04-0.08
				Study Costs[e]	0.2-0.4	0.1-0.2
				Totals	0.6-1.5	1.9-7.6

Notes:

(a) From Appendix G section G.2.
(b) Lower bound represents PAC injection at 2 milligrams per liter.
Upper bound represents ozone injection at 2 milligrams per liter.
(c) Lower bound represents 7.5 minute contact time and equilibrium breakthrough time, upper bound represents 30 minute contact time and 1-year breakthrough time.
(d) Includes cost of $50,000 to $100,000 to clean out well SLP10, which is currently sand-locked.
(e) Includes $0.1 million to develop a reliable and inexpensive performance monitoring technique, plus costs of additional studies required to investigate the design of treatment alternatives. (See Appendix G for details).
(f) Pumping of SLP17 at 100 million gallons per year is assumed to help meet supply shortfalls.

increases by $0.2 million to $0.3 million if worst-case contaminant migration is assumed. In the event that PAC or ozone injection are not technically feasible, then granular activated carbon treatment would be required. Table 6-9 shows that GAC treatment is much more expensive, with a present value cost of from $1.9 million to $7.6 million under best-case contaminant migration. This wide range reflects uncertainty in the required design parameters for contact and breakthrough times. The higher costs of GAC treatment clearly indicate a great incentive to further investigate PAC or ozone injection treatment, if drinking water treatment is the end-use control selected.

6.4 Alternative Drinking Water Supplies

An alternative to treating contaminated ground water is to develop other water sources or to purchase water from other municipalities. Either alternative would provide safe and adequate potable water supplies to communities presently or expected to be affected by PAH contamination. The projection of possible well losses and future water supply requirements presented in section 6.2 are used to determine the water supply requirements.

6.4.1 Approach

Three alternate sources have been considered for the communities which are affected by PAH contamination or may become affected:

- develop new wells in the Mt. Simon-Hinckley aquifer;
- purchase water from municipalities with existing wells pumping from the Prairie du Chien-Jordan aquifer far upgradient from observed or predicted areas of PAH contamination; or
- purchase water from the Minneapolis water system (which uses water from the Mississippi River).

Each water supply source is compared with respect to availability, feasibility, and costs.

Table 6-10 summarizes the water supply shortfalls that currently exist or are predicted to occur as a result of PAH concentrations in untreated municipal supply wells exceeding the recommended criteria. These shortfalls are based on the ground-water flow and contaminant migration predictions discussed in section 6.2. These shortfalls are also based on a criterion for noncarcinogenic PAH and heterocyclic PAH at the low end of the recommended range (4 micrograms per liter), since no municipal supply wells are ever expected to exceed a noncarcinogenic PAH criterion at the high end of the recommended range (400 micrograms per liter). Supply shortfalls are only shown for St. Louis Park and Edina because the relatively small shortfall resulting from abandoning Hopkins well H3 can be satisfied by increased pumping of other municipal supply wells in Hopkins. Table 6-10 shows that the total projected supply shortfall for St. Louis Park is 690 million gallons per year, which will occur in from zero to ten years. The total projected supply short fall for Edina is 960 million gallons per year, which will occur in from 50 to 90 years.

6.4.2. Costs of Additional Mt. Simon-Hinckley Wells

One of the the alternate sources of drinking water is to develop additional wells in the Mt. Simon-Hinckley aquifer. St. Louis Park has begun to install a new Mt. Simon-Hinckley well near well SLP5. This well (SLP17) will have a pumping capacity of 800 gallons per minute. It is expected that annual production from this well could be as high as 300 to 400 million gallons per year. Pumping this new well at such a rate will alleviate approximately half of the supply shortfall for St. Louis Park. An additional well at 300 to 400 million gallons per year would be required to satisfy the rest of the supply shortfall. The capacities of the existing wells and their historic annual production rates are presented in Appendix G.

If Edina were to lose up to four wells during the next 100 years (potential loss of 960 million gallons per year), this deficit would require up to three Mt. Simon-Hinckley wells at an average annual production of from 300 to 400 million gallons per year each. However, there is also a projected decline in population from 45,000 to 40,000 by the year 2000 (see Appendix H). This reduction may result in a

TABLE 6-10

PREDICTED MUNICIPAL WATER SUPPLY SHORTFALLS IN ST. LOUIS PARK AND EDINA TO BE MET BY PROVIDING ALTERNATIVE WATER SUPPLY SOURCES

(Millions of Gallons per Year)

	Best Case Prediction		Worst Case Prediction	
Year	St. Louis Park	Edina	St. Louis Park	Edina
1983	380	0	690	0
1988	420	0	690	0
1993	690	0	690	0
2003	690	0	690	420
2023	690	0	690	450
2033	690	420	690	960
2043	690	420	690	960
2063	690	450	690	960
2073	690	960	690	960

simultaneous water demand reduction of about 300 million gallons per year (based on 1980 per capita water use rates). It is also possible that two high capacity Mt. Simon-Hinckley wells used at high rates (400 million gallons per year each) could meet enough of the predicted supply shortfall to allow the balance to be satisfied by increased pumping rates at other municipal supply wells in Edina. It is therefore not clear that a third well would be required to meet the total (960 million gallons per year) demand if four Edina wells are closed. Ground-water flow modeling indicates that the Mt. Simon-Hinckley has sufficient yield in the St. Louis Park area to support additional withdrawals of up to 2500 million gallons per year (see Appendix E).

For the purpose of estimating costs for new Mt. Simon-Hinckley wells, it is assumed the additional St. Louis Park well would be installed near wells SLP10 and SLP15 or well SLP6. Neither of these locations would require substantial changes in the St. Louis Park water distribution system, and chlorination, fluorination, and iron removal treatment could be accomplished with existing systems at the abandoned Prairie du Chien-Jordan wells. The installation costs for a new Mt. Simon-Hinckley well are based on well SLP17 costs. The original contract cost for well SLP17 was $300,000, but difficulties encountered during drilling are expected to yield a final installed cost of $400,000 (Tollefsrud 1983). These two costs were used as a range for installing new Mt. Simon-Hinckley wells. It is assumed, of course, that a new Mt. Simon-Hinckley well would be properly cased and grouted to prevent inter aquifer flow from above-lying aquifers.

Operation and maintenance costs for a new Mt. Simon-Hinckley well are based on incremental costs compared to a similar size Prairie du Chien-Jordan well. This incremental cost is the proper basis for assessing costs because Prairie du Chien-Jordan wells would be pumpedif they were not closed down due to PAH contamination. Incremental operating costs are primarily the result of the higher pumping head in the Mt. Simon-Hinckley compared to the Prairie du Chien-Jordan. An annual incremental cost of from $25,000 to $45,000 is estimated for pumping 400 million gallons per year, based on 300 feet of head difference between the Prairie du Chien-Jordan and Mt.

Simon-Hinckley, power costs at 5¢ per kilowatt-hour, and a combinedpump/motor efficiency of 70 percent. Operating and maintenance costs are proportional to flow rate.

Although it is feasible to redrill the existing Prairie du Chien wells to reach the Mt. Simon-Hinckley aquifer, there are practical considerations in drilling that may significantly reduce the well size which would limit a well's productivity. There may also be difficulty in drilling through the existing well base or effectively grouting the well. The costs for this alternative have not been included in this analysis, but could be less expensive than drilling new Mt. Simon-Hinckley wells.

Table 6-11 presents estimated present value costs to drill and operate new Mt. Simon-Hinckley wells in order to satisfy supply short falls resulting from contamination of Prairie du Chien-Jordan wells. Costs are presented for both best case and worst case predictions of contaminant migration. The costs shown for the first St. Louis Park well (SLP17) are based on the incremental cost of pumping an additional 300 million gallons per year from this well beyond the 100 million gallons per year assumed in the drinking water treatment case (see section 6.3.4). Total present value costs for the best case of contaminant migration is $0.9 million to $1.5 million, which increases to from $1.4 million to $2.3 million for the worst case. The ranges in these cost estimates largely reflect uncertainties in the pumping head for the wells.

6.4.3 Costs of Municipal Supply Interconnections

The costs to purchase water from Minneapolis or an adjoining upgradient community range from 73 to 42 cents per thousand gallons, respectively. The Minneapolis rate is based on water rates effective January 1980 for direct customers within the city limits (Elwell 1980). This represents an optimistic fee. The 42 cents rate is based on charges to St. Louis Park for water supplied by Plymouth in 1982 (Tollefsrud 1983). The present value costs to purchase sufficient

TABLE 6-11

PRESENT VALUE COSTS FOR NEW MT. SIMON-HINCKLEY WELLS

Well	Discount Period, Years[a] Worst Case	Discount Period, Years[a] Best Case	Operating Rate, Millions of Gallons per Year	Present Value Cost, $ Millions[b] Worst Case	Present Value Cost, $ Millions[b] Best Case
St. Louis Park					
• First New Well (SLP17)[c]	0	0	400	0.37-0.67	0.37-0.67
• Second New Well	0	10	300	0.67-1.07	0.41-0.66
Edina					
• First New Well	20	50	400	0.30-0.49	0.07-0.11
• Second New Well	50	90	400	0.07-0.11	0.01-0.03
Totals			1500	1.4 - 2.3	0.9 -1.5

Notes:

(a) Derived from Table 6-10.
(b) Present value cost for 100 years operation at 5 percent effective annual interest rate based on capital cost of $300,000 to $400,000 and incremental operating and maintenance costs of $25,000 to $45,000 per year for pumping 400 million gallons per year.
(c) Costs for SLP17 are operating costs only, since this well is already built. Incremental operating costs are for an additional 300 million gallons per year pumpage compared to the drinking water treatment case.

water at these charges to meet the best case supply shortfalls shown in Table 6-10 are:

St. Louis Park	$ 4.8 to $8.4 million
Edina	$ 0.3 to $0.5 million

The present value costs for Edina are low because costs are discounted by 50 years, which is the predicted time for the first well closure best case migration. Present value costs would be much greater for worst case migration. If this alternative is chosen, significant changes in the distribution system are expected to be needed to provide water to those areas in St. Louis Park and Edina served by wells that may be closed (e.g. southeastern St. Louis Park and northern Edina). Since the present value costs are much larger than for the new Mt. Simon-Hinckley well alternative, based on water charges alone, the additional capital costs for distribution system changes have not been estimated.

6.5 Ground-Water Monitoring

Previous sections discussing source and end-use controls have presented specific conclusions and recommendations concerning present or future needs for the closure or treatment of specific municipal wells. In addition, the recommended source control options include provisions for controlling the use of private, untreated drinking water wells in contaminated portions of the Drift-Platteville and, if necessary, the St. Peter aquifer. A ground-water monitoring requirement is implied in each of these recommendations to verify the study conclusions and meet the study objectives. This section discusses a comprehensive ground-water monitoring plan for the affected aquifers.

6.5.1 Drift-Platteville and St. Peter

The Drift-Platteville aquifer has been affected by the contaminants migrating from the site, although the full extent of aquifer contamination is unknown. It is unclear if the St. Peter is contaminated, since available data are sparse and do not yet show

contamination. A recently completed survey of private wells, which was not available to ERT in preparing this report, indicates that there are over 1,000 private wells in the St. Louis Park area, most of which are screened in these shallow aquifers (Hansel 1983). Since the entire area is connected to a municipal water supply, many of these wells have been abandoned, although some are still serviceable and may continue to be used for non-potable purposes. The presence of these wells suggest that contaminant transport in these aquifers is a potential concern, if the contamination, which may be present in private wells, is not a matter of public record. Furthermore, St. Louis Park well SLP3 is open to the Platteville and St. Peter. This well is not presently contaminated; however, modeling indicates that the well may be affected in the future by contaminant transport in the St. Peter aquifer.

Appendix B describes the extent of contamination in the Drift-Platteville and St. Peter aquifers. Limited data indicate that the Drift-Platteville contamination extends at least 1,400 feet due east from the site and that the area of contamination is as wide as the contaminated soil area (see Figure 5-1). Far fewer data are available for the St. Peter. Any contamination in this aquifier is assumed to be discontinuous and associated with multi-aquifer wells that connect the Drift-Platteville to the St. Peter. Water quality in one of these wells (Midco well W33) significantly improved after the well was reconstructed to prevent Drift-Platefille water from entering the well. Figure 6-4 shows the extent of contamination that has been mapped in the Drift-Platteville and the extent of the recent well survey study area.

This study recommends that the extent of contamination in these aquifers should be clearly identified and that the use of these aquifers for private drinking water supply or food processing should be prohibited and gardening use should be warned against in the area of known contamination. Water quality downgradient from these areas should be monitored to identify if and at what rate contaminants are

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NON-RESPONSIVE

Figure 6-4 Map of St.Louis Park Showing Area of 1982 Well Survey and the Extent of Contamination in the Drift-Platteville

moving downgradient. Specific ground-water control recommendations for this area should be developed after evaluating

- all currently existing data on ground-water quality in the Drift-Platteville and St. Peter;

- any available unpublished USGS data on hydrology and water quality in the Drift-Platteville and St. Peter; and

- results of the recent well survey by E.A. Hickok and Associates.

The USGS data should be used to identify the extent of contamination in these aquifers more accurately. The well survey data should then be used to 1) identify wells within the contaminated area which should be abandoned or closed and 2) identify an appropriate area in which the use of these aquifers for private drinking water supply and other uses resulting in human ingestion of PAH is prohibited.

A comprehensive ground-water monitoring plan should be developed based on the extent of ground-water contamination. The monitoring plan should include the sampling of new and existing wells which are within the contamination area and downgradient of the area. In addition, this study recommends that two multi-level monitoring wells be installed in the Drift-Platteville and St. Peter between the northeast corner of the site and well SLP3.

The comprehensive monitoring plan should identify appropriate monitoring frequencies and parameters and a statistical basis for determining if contaminant transport is occurring. A contingency plan should be incorporated in the comprehensive monitoring plan to identify appropriate responses to statistically significant increases or decreases in water quality parameters. These contingency responses could include decreasing or increasing the area over which a drinking water use ban is in force and recommendations concerning the future need to abandon or treat well SLP3.

For preliminary planning purposes, it is proposed that the comprehensive monitoring plan include the installation, sampling and analysis of ten new multi-level monitoring wells and the sampling and analysis of ten existing wells. The wells should be analyzed for parameters such as phenolics, total organic carbon (TOC), sodium, total dissolved solids (TDS), and selected PAH. An annual sampling frequency is proposed, with 3 samples collected from each well (i.e., nested wells) for a total of 60 samples per year. However, it is likely that contanimant migration rates will be slow enough to allow bi-annual sampling, with half of the wells sampled one year and the other half sampled the next.

6.5.2 Municipal Water Supply Aquifers

Contaminant migration in the Prairie du Chien-Jordan and Mt. Simon-Hinckley must be monitored to ensure that finished water meets the recommended PAH criteria, to verify ground-water modeling conclusions, and to identify future impacts on municipal water supply wells to develop appropriate contingency responses. A detailed compliance and surveillance plan is presented in Appendix J to monitor drinking water quality in 27 municipal wells in the St. Louis Park area. These wells include all of the municipal supply wells in St. Louis Park and Hopkins, plus selected wells in Edina.

The monitoring parameters recommended for surveillance and compliance monitoring are carcinogenic and noncarcinogenic PAH. In addition, it is recommended that phenolics and TOC also be included as ground-water quality monitoring parameters. These samples should be collected and analyzed per the recommendations in Section 4.3 and Appendix J.

Collection of ground-water monitoring data implies that the data will be reviewed periodically and specific conclusions and recommendations concerning the results will be developed. Qualified personnel will be required to review the data and provide specific recommendations. Possible recommendations may include decreasing or increasing monitoring points, parameters and/or frequencies, extending or decreasing the area over which limitations on the use of private

wells for drinking water supply are implemented, and identifying future requirements and time frames for the closure of municipal wells, development of alternative production wells, and development of gradient control well systems, if needed.

6.5.3 Costs of Ground-Water Monitoring

Estimated costs for implementing a ground water monitoring program are presented in Table 6-12. The costs for sampling and analyzing ground water in the Drift-Platteville and St. Peter assume that 60 individual sampling points will be sampled and analyzed annually or biannually at a cost of $200 per sample. An allowance of 20 percent for replicate and blank samples is also included (10 percent extra samples for each). Capital costs are based on the installation of 10 new multi-level sampling wells. Costs for sampling and analyzing municipal supply wells are based on the well sampling frequencies presented in Appendix J, based on estimated costs from $500 to $600 per sample for analyzing the primary list of PAH and $1000 to $1500 per sample for the secondary list of PAH. Every fourth sample from each well is assumed to be analyzed for the secondary list of PAH and an additional 20 percent is included for duplicate and blank samples. The cost of a qualified individual to compile, review, and report on the monitoring data is estimated to be $10,000 per year. Sample collection is estimated at $5,000 per year. The cost of preparing a detailed monitoring plan for the Drift-Platteville is estimated at $20,000 to $40,000.

Ground-water monitoring costs in Table 6-12 are presented for best and work case predictions of contaminant migration (see section 6-2) and for three different combinations of criteria for noncarcinogenic PAH and heterocyclic PAH:

- a noncarcinogen criterion of 400 micrograms per liter, in which case no end-use controls should be required;

- a noncarcinogen criterion of 4 micrograms per liter, with drinking water treatment as the end-use control; and

TABLE 6-12

ESTIMATED PRESENT VALUE COST

OF GROUND-WATER MONITORING

Type of Monitoring	Present Value Costs[a] in $Millions for Different Noncarcinogen Criteria and End-use Controls		
	400 Micrograms per Liter	4 Micrograms per Liter with Drinking Water Treatment	4 Micrograms per Liter with New Mt. Simon-Hinckley Wells
BEST CASE MIGRATION			
• Drift-Plateville and St. Peter Wells[b]	0.18-0.37	0.18-0.37	0.18-0.37
• Municipal SupplyWells [c]	0.28-0.35	0.56-0.72	0.38-0.48
• Data Review and Reporting[d]	0.30	0.30	0.30
• Total	0.76-1.02	1.04-1.39	0.86-1.15
WORST CASE MIGRATION			
• Drift-Platteville and St. Peter Wells[b]	0.18-0.37	0.18-0.37	0.18-0.37
• Municipal Supply Wells[c]	0.32-0.40	0.67-0.86	0.40-0.51
• Data Review and Reporting[d]	0.30	0.30	0.30
• Total	0.80-1.07	1.15-1.53	0.88-1.18

Notes:

(a) Based on 100 years operation at 5 percent annual effective interest rate.
(b) Based on $20,000 to $50,000 capital cost for installing 10 new multi-level sampling wells and sampling and analysis of 60 sampling points at $200 per sample once a year or once every other year, plus 20 percent for duplicates and blanks. Also includes cost of $20,000 to $40,000 to develop a detailed monitoring plan.
(c) Costs derived in Appendix J.
(d) Based on $15,000 per year for sample collection and data compilation, review and reporting.

- a noncarcinogen criterion of 4 micrograms per liter with new Mt. Simon-Hinckley wells as the end-use action.

As shown in Appendix J, these cases result in different compliance monitoring frequencies and therefore different costs. Table 6-12 shows that monitoring costs for the drinking water treatment case are from $200,000 to $300,000 higher than for the case of using new Mt. Simon-Hinckley wells. This added cost reflects the need to monitor contaminated wells that are treated more frequently than other wells. The costs of Drift-Platteville and St. Peter monitoring and of data review and reporting should not be significantly affected by the noncarcinogen criterion established on the end-use control selected.

6.6 Recommended End-Use Controls

The three factors considered in selecting end-use controls to achieve the stated objectives of this study are effectiveness, reliability, and cost. Particular concerns are 1) reliability in ensuring safe finished municipal supply water (i.e., water that meets the recommended criteria for PAH and heterocyclic PAH); 2) effectiveness in ensuring adequate water supplies, both for base and peak demand; and 3) reliability in controlling the further migration of contaminants in the Prairie du Chien-Jordon. These concerns, together with costs, are greatly affected by the criterion established for noncarcinogenic PAH and heterocyclic PAH. This section discusses recommended end-use controls based on effectiveness, reliability, and costs for various cases of noncarcinogen criteria.

6.6.1 Costs of End-Use Controls

Table 6-13 shows ranges of estimated present values costs for capital and operating and maintenance costs for various end-use control cases, plus associated compliance monitoring costs. The table shows that costs are closely comparable for two end-use control options, alternate supplies via new Mt. Simon-Hinckley wells and treatment of contaminated wells by injecting ozone or powdered activated carbon (PAC). Treatment of contaminated wells with granular activated carbon (GAC) is more expensive than either of these options,

TABLE 6-13

PRESENT VALUE COST OF END-USE CONTROL OPTIONS, INCLUDING COMPLIANCE MONITORING COSTS[d]

Cost Item	Present Value Cost, $ Millions[a]		
	New Mt. Simon-Hinckley Wells	Treatment With PAC or Ozone	Treatment With GAC
BEST CASE CONTAMINANT MIGRATION			
Capitol and Operating costs[b]	0.9-1.5	0.6-1.5	1.9-7.6
Compliance Monitoring Costs[c]	0.9-1.2	1.0-1.4	1.0-1.4
Total Cost	1.8-2.7	1.6-2.9	2.9-9.0
WORST CASE			
Capitol and Operating Costs[b]	1.4-2.3	0.8-1.8	2.6-9.4
Compliance Monitoring Costs[c]	0.9-1.2	1.2-1.5	1.2-1.5
Total Cost	2.3-3.5	2.0-3.3	3.8-10.9

Notes:

(a) Based on 100 years at 5 percent effective annual interest rate.
(b) From Tables 6-9 and 6-11.
(c) From Table 6-12.
(d) All costs based on a criterion for noncarcinogenic PAH and heterocyclic PAH at the low end of the recommended range (4 micrograms per liter).

particularly if the optimistic design bases (7.5 minutes contact time and equilibrium breakthrough time) used to develop the lower bound estimates for GAC treatment are not achievable. The costs shown onTable 6-13 correspond to a criterion for noncarcinogenic PAH and heterocylic PAH at the low end of the recommended range.

There are many technical assumptions underlying the cost ranges given in Table 6-13. These assumptions were made to account for uncertainties in designing end-use controls, resulting from a current lack of necessary data or from uncertanties in predicting future events. The primary assumptions and their significance in interpreting the cost ranges in Table 6-13 are summarized below.

- The lower bound cost for treatment by PAC or ozone injection represents an optimistic projection of a design basis for PAC injection, namely, an injection dose of 2 milligrams per liter. Drinking water treatment costs increase significantly if this design basis is not feasible. For example, a required PAC dose of 5 milligrams per liter will increase present value costs by about $200,000. If PAC is not feasible at all (as a result, for example, of operating problems in sand filters downstream) and ozone injection must be used, present value costs would increase by $400,000 to $500,000 for an ozone dose of 1 milligram per liter. The upper bound cost is based on ozone injection at a dose of 2 milligrams per liter. Note that the feasibility of ozone injection is also not certain, primarily due to concerns over oxidized PAH by-products in the treated water.

- All drinking water treatment costs are based on the assumption that a reliable technique can be developed for monitoring and controlling the performance of a treatment plant at a cost of $100 per sample. Such a technique does not currently exist. Drinking water treatment costs will increase significantly, to the extent that such a technique can not be developed or will require a higher cost per sample. The cost of a standard SIM GC/MS analysis, which represents the worst case for plant performance monitoring,

is from $500 to $600 per sample. Each incremental cost of $100 per sample adds about $200,000 to the present value cost of drinking water treatment (based on weekly sampling and analysis).

- The lower bound cost for GAC treatment is based on an optimistic design basis of 7.5 minutes contact time and equilibrium breakthrough capacity. While the assumed contact time may be achievable, a more relistic breakthrough time is probably on the order of one year. The present value cost of GAC treatment is increased by about $1.0 million with a one-year breakthrough time and a 7.5 minute contact time.

These factors indicate that the lower bound costs of drinking water treatment may be optimistically low by roughly $0.5 million for PAC or ozone injection and by $1.0 million or more for GAC treatment. In addition, it must be noted that the feasibility of PAC or ozone injection treatment has not been demonstrated, although there is good reason to assume that such treatment is indeed feasible (see Appendix G for further details).

The present value cost ranges shown in Table 6-13 for new Mt. Simon-Hinckley wells largely reflect two different assumed pumping head differences between the Prairie de Chien-Jordan and Mt. Simon-Hinckley, namely, 300 and 500 feet. The average head difference between St. Louis Park municipal supply wells in these two aquifer was about 220 feet from 1975 to 1981 (MDH 1975, 1977, 1980b, 1981). The range of 300 to 500 feet in head difference is inferred from computer ground-water flow modeling. The 500 feet head difference is felt to be conservative, expecially for the decades when only two new wells in the Mt. Simon-Hinckley would be required in St. Louis Park. Therefore, the present value cost of new Mt. Simon-Hinckley wells is likely to be closer to the lower bound of the reported range than to the upper bound.

Table 6-14 shows the sensitivity of present value costs for various end-use control options to different effective interest rates,

TABLE 6-14

SENSITIVITY OF PRESENT VALUE COSTS FOR DRINKING WATER TREATMENT AND NEW MT. SIMON-HINCKLEY WELLS TO DIFFERENT EFFECTIVE INTEREST RATES[a]

Case	Total Present Value Cost[b] at Various Effective Annual Interest Rates, $ Millions		
	3 Percent	5 Percent	7 Percent
BEST CASE CONTAMINANT MIGRATION			
Drinking Water Treatment			
• GAC Treatment	3.0-10.1	1.9-7.6	1.5-4.4
• PAC or Ozone Injection	0.9-2.2	0.6-1.5	0.5-1.3
New Mt. Simon-Hinckley Wells	1.6-2.7	0.9-1.5	0.6-1.0
WEST CASE CONTAMINANT MIGRATION			
Drinking Water Treatment			
• GAC Treatment	3.8-12.1	2.6-9.4	2.0-5.6
• PAC or Ozone Injection	1.1-2.6	0.8-1.8	0.6-1.6
New Mt. Simon-Hinckley Wells	2.3-4.0	1.4-2.3	1.0-1.7

Notes:

(a) Excluding compliance monitoring costs, but including study costs for drinking water treatment.
(b) Based on 100 years operation.

excluding costs for compliance monitoring. This check on sensitivity was made because of the importance of end-use controls in solving the St. Louis Park problem, and because costs for new Mt. Simon-Hinckley wells and treatment by PAC or ozone injection are so similar. The results in Table 6-14 show that the relative costs of the three end-use control options are similar at effective annual interest rates of 3 and 7 percent, as well as at the rate of 5 percent used as the bases in this study. This indicates that the conclusions obtained with a 5 percent annual effective interest rate would also hold true for other, similar interest rates.

In summary, the estimated present value cost for new Mt. Simon-Hinckley wells and for drinking water treatment by PAC or ozone injection span closely comparable ranges. The present value cost of drinking water treatment by GAC is clearly greater than either of these options, however. In addition, it appears that the present value cost of PAC or ozone drinking water treatment is likely to be nearer the middle of the reported range, while the cost of new Mt. Simon-Hinckley wells is likely to be nearer the low end of the reported range. These represent judgements, however, that cannot be clearly documented because of uncertainties in the data and analysis techniques used.

6.6.2 Adequacy of Drinking Water Supplies

The two end-use control cases considered by this study were evaluated on the basis of meeting equivalent projected annual average supply shortfalls. For St. Louis Park, the shortfall is 690 million gallons per year. For Edina, the shortfall ranges from 450 to 960 million gallons per year, depending on the predicted rate of contaminant migration in the Prairie du Chien-Jordan. Costs for new Mt. Simon-Hinckley wells and drinking water treatment were estimated on the basis of meeting these annual average supply shortfalls. However, the effects of the two options on meeting peak demand are also important, and are discussed below.

Prior to the closure of wells SLP4, SLP5, SLP7, SLP9, SLP10, and SLP15 by the MDH, the St. Louis Park municipal water supply system had

a peak demand capacity of 19.7 million gallons per day (Orr, Schelen, Mayeron 1976). This peak demand capacity was adequate to meet daily usage throughout 1975, but was predicted to be inadequate to meet projected ultimate daily usage for about 4 days per year. Closing the six wells in St. Louis Park reduced the peak demand capacity to 11.8 million gallons per day, resulting in a significant number of days when peak demand can not be met.

Table 6-15 shows the peak demand capacity in St. Louis Park at present, before well closures, and after implementing drinking water treatment or new Mt. Simon-Hinckley wells as end-use controls. The table shows that either end-use control option will significantly improve the current peak demand capacity shortfall in St. Louis Park, although not to the point of restoring all of the peak demand capacity that existed prior to well closures. Based on the results shown in Table 6-15, either of the end-use control options should be adequate to meet peak demand requirements. This judgement reflects the facts that 1) population and water demand are projected to decrease in St. Louis Park over the next few decades (see Table 6-1 and 6-2) and 2) the peak demand capacity of the St. Louis Park system can be readily and inexpensively increased, if necessary, by improving pumping equipment (Orr, Schelen, Mayeron 1976). Peak demand requirements and capacity were not evaluated for Edina because of the larger number of wells in the Edina system and because only a few (from 2 to 4), if any, of these wells are predicted to be affected by future contamination.

6.6.3 Reliability and Effectiveness Considerations

Drinking water treatment and new Mt. Simon-Hinckley wells each have their own distinct strengths and weaknesses with respect to reliability and effectiveness. These strengths and weaknesses are summarized below.

Using new Mt. Simon-Hinckley wells has a significant advantage in that it can be implemented immediately without significant additional study. Drinking water treatment by PAC or ozone injection, in contrast, will require major additional study to verify that such

TABLE 6-15

SUMMARY OF PEAK DEMAND CAPACITY

IN THE ST. LOUIS PARK WATER SUPPLY SYSTEM

WITH AND WITHOUT END-USE CONTROLS

Case	Number of Wells in Service	Peak Daily Capacity, Millions of Gallons per Day(a)	Number of Days per Year That Peak Daily Capacity Is Exceeded[b]	
			In 1975	Projected Ultimate Demand
Prior to Well Closures	14	19.7	0	4
After Well Closures[c]	8	11.8	13	21
With Drinking Water Treatment[d,f]	13	17.7	1	7
With New Mt. Simon-Hinckley Wells[e,f]	11	15.8	3	10

Notes:

(a) Based on peak demand pumping rates on June 8, 1976 as reported by Orn, Schelen, Mayeron (1976) assuming a peak demand pumping rate of 800 gallons per minute for the new well SLP17 and 1000 gallons per minute for a second new Mt. Simon-Hinckley well (SLP18).
(b) Derived from the daily demand frequency curve presented in Appendix G, Figure G2-11.
(c) Wells closed are SLP4, SLP5, SLP7, SLP9, SLP10 and SLP15.
(d) Based on abandoning wells SLP4 and SLP5, and using Wells SLP6, SLP7, SLP9, SLP10, SLP15 and SLP17.
(e) Based on abandoning wells SLP4, SLP5, SLP6, SLP10 and SLP15, and using wells SLP7, SLP9, SLP17 and SLP18.
(f) Based on a criterion for noncarcinogenic PAH and heterocyclic PAH at the low end of the recommended range (4 micrograms per liter).

treatment is feasible, to design such treatment, and to develop a reliable and inexpensive technique for monitoring treatment plant performance. The estimated cost of these studies is from $200,000 to $400,000 (included in the total cost of this option), and they would probably require about 6 months to complete. In addition, it is possible that these studies will show that treatment by PAC or ozone injection is not feasible or cost-effective.

The option of new Mt. Simon-Hinckley wells has the advantage of using a source that is unaffected by PAH contamination and will not be affected in the reasonably foreseeable future, if ever. This is consistent with the basic precept in drinking water supply of using the best available source. This would also minimize any public concerns over using contaminated water, even if treated. It also will provide St. Louis Park with water that is comparable to the water supplied in neighboring communities.

Treating contaminated wells for use as drinking water supply wells has the advantage of maintaining the ground-water flow divide in the Prairie du Chien-Jordan. This divide acts to limit or slow further migration of contaminants in this aquifer. Using new Mt. Simon-Hinckley wells, on the other hand, involves abandoning contaminated Prairie du Chien-Jordan wells, which will reduce the effectiveness of the ground-water divide. While the estimated costs for new Mt. Simon-Hinckley wells account for the reduced effectiveness of the ground-water divide, the ground-water flow modeling results in this case may be somewhat less reliable in predicting the rate and direction of contaminant migration. A rough indication of the potential cost of the ground-water modeling predictions being wrong is given by the cost of implementing a gradient control well system in the Prairie du Chien-Jordan some time in the future. As discussed in section 5.4, the present value cost of a gradient control system implemented in 30 years is from $0.2 million to $0.4 million.

6.6.4 Effects of Recommended Criteria

All of the discussion above is based on a criterion for noncarcinogenic PAH and heterocyclic PAH at the low end of the

recommended range (4 micrograms per liter). Establishing a substantially different criterion for noncarcinogens will greatly affect the selection of end-use controls, however. There are three basic cases in which the noncarcinogen criterion dictates the most cost-effective end-use control. These cases are briefly described below.

Chapter 4 recommends that the criterion for noncarcinogenic PAH and heterocyclic PAH should be in the range of from 4 to 400 micrograms per liter (parts per billion). Establishing a criterion in the low end of this range will require a choice between new Mt. Simon-Hinckley wells or drinking water treatment by injecting PAC or ozone. Based on historical PAH data for municipal supply wells, any noncarcinogen criterion below about 10 micrograms per liter within the recommended range will lead to this result. In fact, a criterion below the recommended lower bound criterion of 4 micrograms per liter will produce the same result, down to a limit of about 1 microgram per liter. A criterion much below 1 microgram per liter will probably make PAC or ozone injection treatment infeasible, in which case new Mt. Simon-Hinckley wells would be the most cost-effective option. As noted in Chapter 4, it is possible to argue for a noncarcinogen criterion below 4 micrograms per liter, based on the principle that finished water in St. Louis Park should be comparable to that in neighboring communities. However, present scientific knowledge indicates that a noncarcinogen criterion below 100 micrograms per liter would not reduce the risk of observable adverse health effects and that a criterion as low as 4 micrograms per liter may only be necessary to prevent taste or odor problems.

Establishing a criterion for noncarcinogenic PAH and heterocyclic PAH in the upper end of the recommended range, from about 10 to 20 micrograms per liter up to 400 micrograms per liter, will mean that the municipal supply wells in St. Louis Park and Hopkins that are currently closed can be reopened and used, since finished water from none of these wells exceeds the recommended carcinogen criterion or a noncarcinogen criterion above about 10 micrograms per liter (except for well SLP5). It is uncertain when, if ever, these wells would exceed either the carcinogen or noncarcinogen criteria if a higher

noncarcinogen criterion is established. In the event that this does happen, the options would then be new Mt. Simon-Hinckley wells or treatment with PAC or ozone, as described above.

In the cases discussed above, the choice of end-use control options is only between new Mt. Simon-Hinckley wells and drinking water treatment by PAC or ozone injection. Drinking water treatment with granular activated carbon is not a recommended option, because it is significantly more expensive than either of these two alternatives.

6.6.5 Recommendations

In light of the above discussion, it is clear that two policy decisions are required in order to solve the water supply problem in St. Louis Park and neighboring communities. First, a criterion must be established for noncarcinogenic PAH and noncarcinogenic heterocyclic PAH. Second, depending on the criterion established, a decision will be required concerning the public policy implications of meeting municipal water supply shortfalls with new Mt. Simon-Hinckley wells or by drinking water treatment using PAC or ozone injection. Technical recommendations that result from possible decisions regarding a noncarcinogen criterion are as follows.

- If a noncarcinogen criterion is established in the range of about 10 to 400 micrograms per liter, then closed municipal supply wells in St. Louis Park should be reopened and used until such time, if ever, that they exceed the carcinogen or noncarcinogen criteria. At such time, the affected well(s) should be closed and the cost-effectiveness of drinking water treatment versus new Mt. Simon-Hinckley wells should be re-evaluated.

- If a noncarcinogen criterion is established in the range of about 1 to about 10 micrograms per liter, a policy decision will be required to choose between using Mt. Simon-Hinckley wells or treating contaminated wells to meet municipal supply shortfalls. If the treatment option is selected, then studies will be required to investigate the feasibility

and to design PAC or ozone injection treatment plants. If such treatment techniques are found to be infeasible or much more expensive than new Mt. Simon-Hinckley wells, then new Mt. Simon-Hinckley wells should be drilled and used.

- If a noncarcinogen criterion is established below about 1 microgram per liter, then new Mt. Simon-Hinckley wells should be used to meet municipal water supply shortfalls resulting from abandoning contaminated Prairie du Chien-Jordan supply wells.

Regular monitoring of municipal supply wells will be required in any of the three cases, and should be implemented according to the recommendations in Chapter 4 and Appendix J.

7.0 CONCLUSIONS AND RECOMMENDATIONS

This study puts forth specific conclusions and recommendations that address the sources, transport, effects, and remedy of soil and ground-water contamination by PAH and related compounds in the St. Louis Park area. These conclusions and recommendations are summarized in this chapter. They are discussed in detail in earlier chapters of this report and in the technical appendices. This chapter concludes with a brief review and comment on the planned expenditure of $2.0 million in Superfund monies, in light of the conclusions and recommendations reached by this study.

7.1 Conclusions

The conclusions of this study are grouped under four main topics: sources of contamination, transport of contaminants, effects of contamination, and remedy of adverse effects. Specific recommendations resulting from these conclusions are presented in the following sections.

7.1.1 Sources of Contamination

Portions of the former RT&CC plant site and adjacent bog area contain soil that is contaminated to various degrees and depths by coal tar-related chemicals, primarily phenolics, PAH, and PAH related compounds. This contamination resulted in part from the operations of the former RT&CC wood preserving plant and coal tar refinery, with associated spills and leaks of process materials, run-off from the plant site, and discharge of plant wastewater to the adjacent bog area to the south. Some of these contaminants were also likely contributed by other man-made sources in the area. For the purpose of this study, contamination is defined as concentrations of a material that are above background concentrations specific to the site area. This is necessary because phenolics and PAH are a natural part of the environment and are also widely produced and dispersed by human activities in urban areas.

Soil contamination at the plant site and bog area occurs in discrete zones. Contamination near the surface is generally greatest near former processing areas and along the path of the wastewater drainage flow. Contamination at greater depths occurs in uneven patterns that are difficult to predict and reflect the complex subsurface migration behavior of contaminants. Discrete zones of contamination are often associated with lenses or strata of fine-grained sediments, which appear to play a major role in controlling the rate and direction of contaminant migration.

Surficial ground-water in the Drift-Platteville aquifer under the southern portion of the plant site, the bog area, and up to 1400 feet east (downgradient) of the bog area is contaminated by phenolics, PAH, and PAH related compounds. This contamination resulted from leaching of soil contaminants by precipitation infiltration, ground-water flow through zones of contaminated soil, and the influx of plant wastewater. Again, these contaminants likely resulted from other man-made sources in addition to the RT&CC plant. As for soil contamination, ground-water contamination has been defined by comparison with background concentrations specific to the site area.

There is a local accumulation of an organic fluid, consisting of water and creosote-like oil, in the ground water under the bog. There is insufficient information to define the size of this ground fluid body, but nearby wells and borings indicate that its maximum possible size is about 16,000 cubic feet. Its actual size may be much smaller. There is no evidence of additional ground fluid bodies under the site, and, based on the density of wells and borings in the site, it is unlikely that other such bodies exist. Current evidence suggests that the ground fluid body is relatively immobile.

The former RT&CC plant water supply well (W23) has served as a direct source of contamination of some deeper aquifers underlying the site. A plug of coal-tar-like material filled portions of the well passing through the lower half of the Franconia, the Ironton-Galesville, and upper portion of the Eau-Claire formations. A bridge of collapsed shale, together with sand and gravel within the

coal-tar-like material, kept the plug from extending to the bottom of the well in the Mt. Simon formation. This plug was removed from the well in the summer of 1982 by the MPCA. It is unknown when or how the material entered the well. The contents of the plug are referred to as coal-tar-like material because the physical properties of the material are indicative of a coal-tar-related material, but no measurements have been made to show that it is coal tar per se. Above the plug in well W23, much of the well bore and casing is, or was, covered with deposits of coal-tar-like material. During remedial action work in the fall of 1982, the MPCA removed these deposits from the bottom of the well up to the top of the Jordan aquifer.

Well W23 is defined as a multi-aquifer well because it is open to more than one aquifer. The coal-tar-like materials in well W23 acted as a source of contamination for the Ironton-Galesville and Prairie du Chien-Jordan aquifers, and perhaps to the St. Peter and Drift-Platteville aquifers. Ground-water flow in contact with contaminated casing and/or well bore surfaces leached contaminants into the aquifers. Down-hole flow in the well into the Prairie du Chien-Jordan appears to have played an important role in introducing contaminants into this aquifer. The magnitude and extent of contamination in the various aquifers caused by well W23 are poorly known.

There are no water quality data showing that the Mt. Simon-Hinckley was affected by contaminants in well W23. During exploration of W23 by the MPCA in the summer of 1982, efforts were made to isolate the aquifer and test its water. However, these tests were inconclusive. The plug of coal-tar-like material did not extend to the Mt. Simon-Hinckley and, in fact, acted for an unknown period to effectively prevent multi-aquifer flow into the Mt. Simon-Hinckley in W23.

7.1.2 Transport of Contaminants

Transport of contaminants in the aquifers underlying the St. Louis Park area is controlled by the flow of groundwater. The primary factors that control contaminant transport via ground-water flow are

regional potentiometric gradients, well pumping patterns, multi-aquifer well connections between aquifers, and attenuation of contaminants by dispersion, reaction, and adsorption. Each of these factors are discussed below for the aquifers that have been or could be affected by contamination.

Transport Mechanisms

Well W23 and other multi-aquifer wells in the vicinity of the site have acted to transport contaminants from upper aquifers to lower aquifers. A multi-aquifer well creates a hydraulic connection between aquifers, and thus may provide a pathway for contaminated ground water to travel from shallow to deeper aquifers.

The number and location of such multi-aquifer wells, and their relative contribution in transporting contamination to deeper aquifers, are poorly documented. There are many relatively multi-aquifer wells connecting the Drift-Plateville and St. Peter aquifers, fewer connecting either of these aquifers to the Prairie du Chien-Jordan, and very few reaching as far as the Mt. Simon-Hinckley. Some of these multi-aquifer wells have been sealed by the MDH and MPCA over the last few years to prevent interaquifer flow.

Transport of contaminants in the aquifers underlying the St. Louis Park area is controlled by the flow of ground water and by physical and chemical processes that remove contaminants or reduce the rate at which they migrate. Contaminant transport in ground water is of most concern, since soil contaminants at the site are relatively immobile, and to the extent that they migrate, such migration is largely controlled by ground-water flow in the Drift aquifer.

Predictions of contaminant transport formulated in this study are generally based upon the assumption that contaminants will travel at the same velocity as ground-water, that is, at the hydraulic transport rate. This is a conservative assumption because it neglects chemical and physical processes that slow the speed at which contaminants travel. As a result of chemical and physical retardation,

contaminants travel many times slower than the hydraulic transport rate. For example, it is estimated from laboratory studies at the University of Minnesota that low molecular weight contaminants (two-ring PAH) will travel about 20 times slower than ground water in the Drift and St. Peter formations. Higher molecular weight contaminants (four-ring PAH) will travel more than one hundred times slower than ground water. Similar attenuation is reasonably assumed in other sandstone formations (Jordan, Ironton-Galesville, and Mt. Simon-Hinckley).

Drift-Platteville Aquifer

Ground-water flow in the Drift-Platteville aquifer is dominated by the regional west to east water table gradient. Contaminants in this aquifer in the site area have been and will continue to be carried to the east and southeast by this ground-water flow pattern. A portion of the Drift-Platteville ground-water flow is diverted into a buried tributary bedrock valley approximately 3000 feet southeast of the site. Water flowing from the site reaches the tributary bedrock valley in one to two decades, according to the computer model, and roughly 30 percent of the water passing directly over the valley is predicted to flow down into the valley and into the St. Peter aquifer. The buried tributary bedrock valley is thus a potential conduit for spreading contamination from surficial sources at the site to the St. Peter aquifer. Water from the site must travel at least 60 years to reach a major bedrock valley connecting the Drift-Platteville to the Prairie du Chien-Jordan. The major bedrock valley is located to the east of the tributary bedrock valley, farther away from the site. Accounting for retardation effects, the predicted travel time of contaminants from the site to the major bedrock valley exceeds 1000 years. In addition, the USGS has shown that phenolic contaminants are being biodegraded in the Drift-Platteville in the site area (Ehrlich et al. 1982).

Contaminants in the Drift-Platteville can also be transported to underlying aquifers via multi-aquifer leaking wells. There are a number of such wells that connect the Drift-Platteville and St. Peter

aquifers in the vicinity of the site. There are also a few multi-aquifer wells that connect the Drift-Platteville with the Prairie du Chien-Jordan and/or Mt. Simon-Hinckley.

St. Peter Aquifer

Ground-water flow in the St. Peter aquifer is also dominated by a regional west to east flow pattern. A potentiometric high at the buried tributary bedrock valley where water enters the aquifer from the Drift-Platteville causes ground water traveling from the site to be deflected either north or south of the buried valley. Sustained operation of St. Louis Park municipal well SLP3 at full capacity may induce flow from the St. Peter beneath the site into the well, with predicted hydraulic travel times on the order of many decades. The few water quality data available show no PAH contamination in the St. Peter in the vicinity of the site. If any contaminants are present, travel times to well SLP3 would be over a thousand years, accounting for retardation effects. No contamination of St.Louis Park well SLP3, which is the only municipal supply well in this aquifer, has been observed.

Transport of contaminants into the St. Peter from the Drift-Plattsville and out of the St. Peter into underlying aquifers is controlled by the distribution and characteristics of multi-aquifer wells. The number and significance of such wells is not well known, based on the data available for this study, nor is the distribution of contaminants in the St. Peter aquifer well known.

Prairie du Chien-Jordan Aquifer

Ground-water and contaminant flow patterns in the Prairie du Chien-Jordan are very complex because of the many high-capacity wells withdrawing water from the aquifer. Regional flow is directed from west to east by potentiometric gradients of roughly ten feet per mile. This regional flow is significantly influenced by the concentration of large municipal pumping wells in St. Louis Park, Hopkins, and Edina. The aggregate impact of these wells creates a

potentiometric low defined by a ground-water divide to the south and east of St. Louis Park. The divide acts as a hydraulic barrier, effectively isolating the enclosed aquifer area from areas to the east (Minneapolis and Mississippi River) and south (southern parts of Edina and Hopkins, and Bloomington). Significantly, the contaminated portions of the aquifer are well within this divide.

Contaminants have entered the Prairie du Chien-Jordan aquifer via at least one multi-aquifer well (W23), and possibly many others. Transient pumping by major wells in all directions about the site has dispersed contaminants over a wide area. Thus, it is unlikely that there is a well-defined plume of contamination. Dispersed contaminants in the Prairie du Chien-Jordan are not free to migrate indefinitely. Eventually, they will be withdrawn by wells within the confines of the ground-water divide discussed above, although this could take centuries to occur.

The extent of contaminant attenuation in the Prairie du Chien-Jordan is not well known. This study has assumed that substantial attenuation is unlikely to occur. This is because solution channels in the Prarie du Chien limestone do not provide the high surface area to pore volume ratios in the aquifer matrix that appear to be required to effect appreciable adsorption, as are present in sandstone aquifers.

Ironton-Galesville Aquifer

Little is known about ground-water flow in the Ironton-Galesville aquifer in the St. Louis Park area, as the aquifer is not used in the area. Contaminants have been introduced to this aquifer by well W23 and perhaps by other multi-aquifer wells. Because the aquifer is not used, nor is expected to be used in the foreseeable future, the limited and ill-defined contamination in the Ironton-Galesville is not a problem. Furthermore, contaminant migration should be very slow as a result of adsorption.

Mt. Simon-Hinckley Aquifer

Ground-water flow patterns in the Mt. Simon-Hinckley aquifer are dominated by the potentiometric lows created by a few high-capacity municipal supply wells in St. Louis Park and Edina. Regional flow travels from all directions to the well centers. Within the aquifer, three, and possibly more, abandoned industrial wells had the potential to act as pathways to introduce PAH contaminants: well W23 (former Reilly Tar & Chemical Corp.), well W38 (Milwaukee Railroad), and well W105 (former sugar beet refinery). However, there is no evidence of contamination in the Mt. Simon-Hinckley. If inter-aquifer flow reached the Mt. Simon-Hinckley via these wells, it would most likely flow to St. Louis Park well SLP11 and certainly no farther than the potentiometric low created by St. Louis Park wells SLP11 and SLP12 and Edina well E12, as long as they continue to operate. Many decades would be required for water to travel to the municipal wells from the site. Contaminant travel times would be orders of magnitude longer, due to significant retardation effects.

7.1.3 Effects of Contamination

The class of chemicals known as polynuclear aromatic hydrocarbons (PAH) is ubiquitous in the enviroment, as a result of both natural and anthropogenic sources. Human populations are exposed continually to PAH in their food, air, and drinking water, with estimated typical exposures via these media differing by roughly a factor of ten. Typical food exposure is about ten times the typical air exposure, which in turn is about ten times the typical drinking water exposure.

The primary concern with human exposure to PAH is that certain compounds in the class are carcinogenic; however, this is only true for certain specific compounds and not for all compounds in this class. In this report, a PAH is considered to be carcinogenic if it causes a significant elevation in tumor incidence when administered by any route to any species of animal. Such compounds are treated as though they are human carcinogens, even though the only evidence may be from animal tests. Carcinogenic PAH tend to be higher molecular

weight compounds, containing four or more fused aromatic rings. Carcinogenic PAH as a class are probably the most extensively studied carcinogens, in part because they include some very potent carcinogens and because they are widespread. The potencies of carcinogenic PAH as a class vary widely, however. Noncarcinogenic PAH exhibit low acute and chronic toxicity. There are many individual compounds in environmental mixtures of PAH, and the noncarcinogenic fraction is generally much greater than the carcinogenic fraction in these mixtures.

The behavior of PAH in the environment is largely controlled by their low vapor pressure, low aqueous solubility, and high adsorption tendencies. These properties are a strong function of molecular weight, with higher molecular weight PAH being much less mobile in the environment. There is evidence that PAH are naturally degraded in the environment by oxidation and by biological processes.

Given this perspective on the human health impacts and environmental behavior of PAH, the following conclusions have been reached regarding the significance of observed levels and distribution of PAH contamination the St. Louis Park area.

Soil Contamination

Contamination of soil at the plant site and adjacent bog by PAH and related compounds does not pose a substantial threat to human health or the environment under normal and reasonable use of these areas. The overwhelming majority of contamination is located below the surface and will not affect surface uses of the site. Future construction will not be adversely affected by contamination or pose a threat to human health if ordinary care is exercised in construction practices.

Ground-Water Contamination

The major resource value of groundwater that is affected adversely by trace (part per billion) levels of PAH contamination is its value as a high-quality source of drinking water. Other uses of

ground water involving direct human ingestion, such as watering certain vegetables or direct use in food processing plants, may also be adversely affected. Use of ground water for other irrigation, cooling, or industrial purposes is not affected adversely. The role and value of ground water as a source of recharge for surface water likewise is not affected adversely.

Drinking Water Criteria for PAH

It is necessary to establish specific criteria for acceptable concentrations of PAH and related compounds in finished drinking water in order to solve the St. Louis Park problem. This study recommends separate criteria for carcinogenic and noncarcinogenic compounds because of their distinctly different toxicologic properties. The recommended criteria are limited to PAH and heterocyclic PAH because these are the only classes of PAH-related compounds that have been detected in untreated municipal supply wells in the St. Louis Park area.

The recommended criterion for total carcinogenic PAH and carcinogenic heterocyclic PAH in finished drinking water is 28 nanograms per liter (parts per trillion). This criterion corresponds to an increased life-time cancer risk of one incidence per 100,000 people exposed, based on a very conservative risk assessment approach. This criterion is derived from the U.S. EPA ambient water quality criterion for PAH, and has been applied by the MDH in evaluating untreated municipal well water supplies in the St. Louis Park area.

A criterion for noncarcinogenic PAH and noncarcinogenic heterocyclic PAH is central to solving the ground-water contamination problem in St. Louis Park, because the criterion for carcinogenic PAH and carcinogenic heterocyclic PAH is currently satisfied by finished water from municipal supply wells. However, recommending a specific criterion for noncarcinogenic PAH and noncarcinogenic heterocyclic PAH is difficult because of the limited data on the chronic toxicity of these compounds. This study concludes that a criterion in the range

of from 100 to 400 micrograms per liter (parts per billion) for total noncarcinogenic PAH and noncarcinogenic heterocyclic PAH in finished drinking water will prevent observable adverse health effects. A criterion may need to be set as low as 4 micrograms per liter, however, to prevent objectionable tastes or odors, although this should be confirmed by testing because of the limited available data on the organoleptic effects of PAH and related compounds. The calculation of a criterion for noncarcinogenic PAH and noncarcinogenic heterocyclic PAH is derived by applying a safety factor of 100 to the no observable adverse effect doses measured in animal tests. The recommended criteria are based on the fact that typical food and air exposures only contribute a small portion of the acceptable daily intake of noncarcinogenic PAH.

The criteria recommended by this study apply to finished drinking water. However, these criteria are important in assessing ground-water contamination because testing to date indicates that conventional drinking water treatment in the St. Louis Park area (chlorination, flouridation, and/or iron removal) does not remove significant amounts of noncarcinogenic PAH and related compounds, although iron removal treatment does remove some carcinogenic PAH. This means that a ground water supply that does not meet the recommended criteria is likely to result in finished water that does not meet the recommended criteria, unless specific types of advanced or modified treatment are employed.

The criteria recommended by this study apply to finished water at the point of addition to the distribution system, even though actual exposures occur from use of water at the tap, and the National Contingency Plan specifies that health effects concerns should be addressed at the tap. The application of criteria to finished water is recommended for ease in monitoring compliance and because tap water quality should be no worse than finished water quality with respect to PAH and related compounds. Any exceptions to this assumption would result from factors in the distribution system, such as cross-connections or coal tar or asphalt linings in pipes and tanks, that are in no way related to ground-water contamination problems.

Drift-Platteville Aquifer

Areas of the Drift-Platteville aquifer downgradient from and contiguous with the site contain PAH contaminants at levels exceeding background levels and the recommended criteria for finished drinking water. However, there are many potential sources of PAH in the Drift-Platteville aquifer downgradient and along the gradient from the site. In addition, this aquifer has been degraded by residential, commercial, and industrial development. For example, there has been an influx of various contaminants from road de-icing chemicals, low level sewer leakage, and industrial activities. There are a number of industrial, commercial, and private wells in the Drift-Platteville aquifer in the vicinity of the site, but only the use of private wells for drinking water supply, gardening, or food processing is affected by PAH concentrations that exceed the proposed crieria.

St. Peter Aquifer

Areas of the St. Peter aquifer in the vicinity of the site may be contaminated by PAH, although the few available data do not indicate contamination. This aquifer contains a number of industrial, commercial, and private wells, but only the use of private wells for drinking water supply, gardening, or food processing should be affected if contaminants are present at concentrations exceeding the recommended criteria. The only municipal supply well in this aquifer is SLP3, which shows no evidence of contamination, and will not be affected for hundreds of years if contaminants are present in the St. Peter in the vicinity of the site.

Prairie du Chien-Jordan Aquifer

PAH contamination is observed in a number of municipal, industrial and commercial wells spanning an area of several square miles in the Prairie du Chien-Jordan aquifer. Seven municipal supply wells have been taken out of service as a precaution in light of PAH contamination. These include six wells in St. Louis Park (wells SLP4, SLP5, SLP7, SLP9, SLP10 and SLP15) and one in Hopkins (well H3).

However, only four of these wells (SLP5, SLP10, SLP15 and H3) have ever exceeded the criteria recommended by this study based on the lower bound of the recommended noncarcinogen criterion range (4 parts per billion), and Hopkins well H3 currently contains PAH concentrations that are about a factor of ten below the proposed criteria. No municipal supply well in the St. Louis Park area has ever approached the upper bound of the recommended noncarcinogen criterion range (400 parts per billion). Finished water from all of the closed wells currently meets the carcinogen criterion of 28 parts per trillion.

Ironton-Galesville Aquifer

PAH concentrations exceeding the proposed criteria are present in the immediate vicinity of well W23 and perhaps a few other multi-aquifer wells. The areal extent of this contamination is unknown, but likely to be small. This limited contamination does not pose adverse effects because the aquifer is not used for municipal water supply in the St. Louis Park area and there are no known or foreseen plans to do so in the future.

Mt. Simon-Hinckley Aquifer

No PAH contamination is observed in the Mt. Simon-Hinckley aquifer, although discrete, limited areas of contamination may exist around a few multi-aquifer wells, such as well W23. Any such limited areas of contamination do not pose a problem because of substantial dilution effects and very long (centuries) contaminant migration rates before contaminants would reach existing municipal supply wells, if ever.

7.1.4 Remedy of Contamination

This section presents the conclusions of this study based on an evaluation of a wide variety of remedial action alternatives for soil and ground-water contamination. These evaluations were made with the goal of achieving three specific objectives, which are presented

below. This is followed by a summary of the conclusions from evaluating the following types of remedial actions: 1) removal or containment of soil and ground-water contaminants at the site, 2) control of on-site multi-aquifer wells, 3) control of off-site multi-aquifer wells, 4) control of ground-water contaminant migration with gradient control wells, 5) treatment of drinking water to produce finished water that meets the proposed PAH criteria, 6) provision of alternate drinking water supplies, 7) monitoring of ground-water contaminants, and 8) ground-water use restrictions. Specific recommendations resulting from the conclusions in these areas are summarized in section 7.2.

Objectives

This study established three specific objectives as the goals of any remedial action.

1) Provide St. Louis Park and neighboring communities with a safe and adequate supply of potable water at present, and for the reasonably foreseeable future, in a cost-effective and reliable manner.

2) Allow for present and reasonably foreseeable future use of ground-water resources in the St. Louis Park area in a cost-effective and reliable manner.

3) Allow for safe, reasonable, and beneficial use of the former RT&CC plant site and adjacent bog area, for the reasonably foreseeable future, in a cost-effective and reliable manner.

Each objective includes the phrase "cost-effective and reliable," which describes the basis for choosing among alternative actions. This approach is consistent with the objectives established by the U.S. EPA's National Contingency Plan for responding to hazardous waste sites.

For the purposes of this study, the term "reasonably foreseeable future" means the next 100 years. Establishing such a finite time frame is necessary to arrive at a finite and effective solution to the PAH contamination problems in the St. Louis Park area. A finite time frame does not mean that any problems occurring beyond the next 100 years are ignored. Rather it, reflects the difficulty in planning actions now that account for conditions in the distant future, which may differ greatly, and unpredictably, from current and reasonably foreseeable conditions. The particular technical and physical characteristics of the St. Louis Park problem make it difficult to predict reliably, beyond about a century, the behavior of many physical systems that affect the definition and remedy of the problem. Furthermore, technological advances very likely will occur beyond, and probably within, the next 100 years, which will change significantly the definition and remedy of future problems. Finally, expenditures made more than 100 years from now are discounted so greatly, when expressed as present value costs, that they become negligible in evaluating solutions. All of these factors together indicate that a finite time frame of the next 100 years is both reasonable and necessary to evaluate solutions to the PAH contamination problem in the St. Louis Park area.

Site Remedy

A wide variety of alternatives was evaluated for removing or containing contaminated soil and ground water at the site, with particular attention focused on excavation, ground fluid removal, bioreclamation, gradient control wells, monitoring, and site use controls. This evaluation concluded that excavation, ground fluid removal, bioreclamation, gradient control wells, or other likely measures to remove or contain contaminants are not cost-effective in meeting the stated objectives of this study. The cost-effective actions are continued monitoring of ground-water contaminant migration, limited controls on site use, and limited restrictions on the use of contaminated groundwater. Any removal or containment actions are not cost-effective because the impact of soil and ground-water contamination at the site is only indirectly related to

the first two objectives, and such actions are not required to meet the third objective. The estimated present value cost to monitor ground-water contamination in the site area for the next 100 years is from $180,000 to $370,000, depending on the required frequency. This includes the cost of developing a detailed monitoring plan.

On-Site Multi-Aquifer Wells

Remedial actions to remove contaminants from well W23 or to prevent their further migration into ground water were evaluated for each of the aquifers affected by well W23. The two basic alternatives considered were grouting the well or pumping it. The cost to dispose of water discharged from pumping well W23 are too high relative to the effects of this well for pumping alternatives to be cost-effective. It is therefore concluded that well W23 should be grouted after remaining exploratory work is completed. The estimated cost of this action is from $10,000 to $20,000. This compares with a minimum cost of about $400,000 to pump the well for 100 years.

The characteristics of well W105 (the old sugar beet refinery well) and its role in transporting contaminants are presently unknown. Exploration work is required to address this issue. Once this work is completed, remedial action alternatives for the well should be evaluated in a similar manner to the evaluation performed for well W23. Assuming that no contamination substantially greater than that in W23 is discovered, the cost-effective remedy for well W105 is also likely to be grouting.

Off-Site Multi-Aquifer Wells

Sealing or reconstructing all off-site multi-aquifer wells is not a necessary or cost-effective action. Sealing or reconstructing selected wells may be cost-effective, but additional information is required to make this evaluation.

Multi-aquifer wells that can allow transport of contaminants into the Mt. Simon-Hinckley should be identified and sealed or reconstructed to prevent this aquifer from becoming contaminated.

Only three such wells are known to date (W23, W38, and W105) and two of these have already been sealed. It is expected that there are few additional multi-aquifer wells connected to the Mt. Simon-Hinckley because of its great depth and limited use. The estimated present value cost to identify and remedy Mt. Simon-Hinckley multi-aquifer wells is from $30,000 (if no additional multi-aquifer wells are discovered) to $710,000 (worst case estimate based on 15 wells requiring remedy after well inventories made every 25 years).

It is unclear at present if sealing or reconstructing multi-aquifer wells that connect the Drift-Platteville, St. Peter and/or Prairie du Chien-Jordan aquifer is a cost-effective action in achieving the stated objectives of this study. Additional studies to make this evaluation and updating such studies every 25 years have an estimated present value cost of from $70,000 to $125,000. If such studies indicate that shallower multi-aquifer wells should be sealed or reconstructed, the present value cost of this work could exceed $0.5 million.

Gradient Control Wells

Gradient control wells in the Drift-Platteville, St. Peter, Ironton-Galesville, and Mt. Simon-Hinckley aquifers would not be cost-effective in achieving the stated objectives of this study. There is no evidence of PAH contamination in the latter two aquifers that will affect their present or reasonably foreseeable future use, so gradient control wells in these aquifers are unnecessary. Contamination does exist in limited areas of the Drift-Platteville aquifer and may exist in the St. Peter aquifer, but gradient control wells in these aquifers would not be cost-effective.

Gradient control wells in the Prairie du Chien-Jordan aquifer are not required at present to meet the stated objectives of this study, nor is it expected that they will be required in the next 100 years. This conclusion is based on ground-water flow modeling results indicating that contaminants will migrate slowly to the southeast. However, gradient control wells in the Prairie du Chien-Jordan were

evaluated as a contingency action to be implemented at some time in the future if contaminant migration is found to occur at substantially faster rates and different directions than predicted. Gradient control wells would be implemented if they would then be cost-effective. The estimated future present value cost of a three-well gradient control well system in the Prairie du Chien-Jordan is from $1.0 to $1.5 million, depending on how many, if any, new wells would be required. This future cost reduces to a current present value cost of $0.4 to $0.6 million if discounted by 20 years, and to $0.1 to $0.2 million if discounted by 50 years. This cost is based on discharging gradient control well water to the nearest storm sewer. It is possible, however, that it would be less expensive to treat the water for potable use instead.

Drinking Water Treatment

Drinking water treatment costs were evaluated on the basis of satisfying current and predicted municipal water supply shortages resulting from closure of wells exceeding the recommended PAH criteria. Drinking water treatment costs are based on a criterion for noncarcinogenic PAH and noncarcinogenic heterocyclic PAH at the low end of the recommended range (4 parts per billion). A noncarcinogen criterion at the high end of the recommended range (400 parts per billion), or at any value above about 10 parts per billion, would allow most municipal supply wells that are currently closed to be placed back in service. The 10 parts per billion cut-off is based on the expected quality of finished water at St. Louis Park well station no. 1 with all four wells (SLP3, SLP10, SLP11 and SLP15) operating.

Drinking water treatment at wells SLP10 and SLP15 (currently closed) and SLP6 (predicted to become contaminated within the next decade) will provide an adequate water supply for St. Louis Park for the reasonably foreseeable future. This is based on wells SLP7 and SLP9 being reopened (they do not exceed the recommended criteria), wells SLP4 and SLP5 remaining closed, and the new Mt. Simon-Hinckley well now under construction (SLP17) being used. Hopkins well H3 should remain closed to prevent drawing contaminants towards the other

Hopkins municipal supply wells. The closure of well H3 will not adversely impact the supply capabilities of the Hopkins water supply system. Edina wells E2 and E3 may become sufficiently contaminated to exceed the recommended criteria at some time within the next 100 years. Only well E2 would need to be treated to maintain adequate supply capacity, since E3 is a small well used for peak demand periods and can be abandoned without adversely affecting supply capabilities in the Edina municipal water supply system. In summary, drinking water treatment costs were evaluated for St. Louis Park wells SLP6, SLP10 and SLP15 and Edina well E2. All of these wells have existing iron removal treatment plants.

Granular activated carbon treatment is capable of reducing PAH concentrations in contaminated Prairie du Chien-Jordan municipal supply wells to well below the proposed PAH criteria. However, additional information is required to design a granular activated carbon treatment plant. Key information needs are required contact time and system breakthrough time.

Pressure sand filter iron removal plants are commonly used to treat water from municipal supply wells throughout the St. Louis Park area. Such treatment removes slight quantities of PAH contaminants, particularly higher molecular weight PAH. When operated in a normal manner, iron removal treatment does not remove sufficient PAH to achieve the lower bound of the recommended noncarcinogen criterion (4 parts per billion), but is capable of meeting the carcinogen criterion. It is likely that adding treatment to the existing iron removal treatment plants, by injecting ozone or powdered activated carbon upstream of the sand filter beds, can achieve sufficient PAH removal to meet a 4 microgram per liter criterion for noncarcinogenic PAH. Considerable additional study would be required to confirm the feasibility of these approaches and to design such systems, however.

The estimated present value cost of installing granular activated carbon treatment plants at selected municipal supply wells that now exceed the proposed PAH criteria, or are predicted to do so in the

next 100 years, is from $2.6 to $9.4 million. This range of cost reflects uncertainty in the breakthrough time for PAH in granular activated carbon columns. The lower bound corresponds to a 10-year breakthrough time, which is very optimistic, and the upper bound corresponds to a 1-year breakthrough time, which is much more realistic. This present value cost range reduces to $1.9 to $7.6 million if some attenuation of contaminant migration is assumed in the Prairie du Chien-Jordan.

The estimated present value cost of adding powdered activated carbon or ozone injection at existing iron removal plants at selected municipal wells, that are now affected, or are predicted to be affected by PAH contamination in the next 100 years, is from $0.8 to $1.8 million. The lower bound cost corresponds to the most optimistic treatment design (injecting 2 milligrams per liter of powdered activated carbon) and the upper bound corresponds to the most pessimistic design (injecting 2 milligrams per liter of ozone). This present value cost range reduces to $0.6 to $1.5 million if some attenuation of contaminant migration is assumed in the Prairie du Chien-Jordan. Cost estimates for granular activated carbon and iron removal treatment both include the cost of additional studies required to implement these alternatives.

Alternate Drinking Water Supplies

Three different options for providing alternate drinking water supplies were evaluated: 1) drilling new Mt. Simon-Hinckley wells, 2) supply interconnections with Minneapolis, and 3) supply interconnections with nearby communities whose water is derived from Prairie du Chien-Jordan wells located far up-gradient of currently contaminated areas. The least expensive alternative was found clearly to be drilling new Mt. Simon-Hinckley wells. The estimated present value cost of drilling and operating three new high-capacity (300 million gallons per year) Mt. Simon-Hinckley wells, which should be adequate to replace supply shortage caused by present and predicted well closures in the Prairie du Chien-Jordan, is from $0.9 to $1.5

million for best-case predicted migration and $1.4 to $2.3 million for worst-case predicted migration. These wells can be installed near abandoned Prairie du Chien-Jordan wells so that existing chlorination and fluoridation equipment and iron removal plants (if applicable) can be used.

Ground-water modeling results indicate that the Mt. Simon-Hinckley has sufficient yield to support these three new wells. Ground-water monitoring data indicate that this aquifer is currently not affected by PAH contamination. A few possible exceptions are small, discrete areas near a few multi-aquifer wells. These areas are not predicted to appreciably affect the quality of present or future municipal supply water withdrawn from the Mt. Simon-Hinckley.

Ground-Water Monitoring

Two types of ground-water monitoring were evalauted by this study, compliance monitoring and surveillance monitoring. The purpose of compliance monitoring is to ensure that municipal supply wells meet the proposed PAH criteria. Surveillance monitoring is intended to monitor the migration of ground-water contaminants.

Specific sampling and analysis frequencies and procedures for compliance monitoring are required to ensure that enforcement of the PAH criteria is consistent and accurate. This study makes specific recommendations for these protocols. Municipal supply wells are separated into three main groups based on the current and projected potential PAH contamination. Group 1 wells are those that exceed specified trigger levels but are below the criteria. Group 1 wells may also include wells in which PAH levels exceed the criteria in raw water, which is then treated for drinking water use. These wells are recommended for quarterly monitoring. Group 2 wells include out-of-service wells that exceed the criteria, and in-service wells that contain no PAH above specified trigger levels, but are in the possible path of contaminant migration over the next decade. Group 2 wells are recommended for annual monitoring. Group 3 wells contain no

PAH above specified trigger levels, but may be in the path of future contaminant migration over the next century. These wells are recommended for monitoring every 5 years. All samples are recommended to be analyzed by GC/MS for a specific list of individual PAH compounds.

The estimated present value cost of monitoring selected municipal supply wells in St. Louis Park, Hopkins, and Edina for the next 100 years under this scheme is from $0.6 to $1.2 million. The range reflects the effects of different criteria for noncarcenogenic PAH and heterocyclic PAH and of different means of satisfying any municipal water supply shortfalls. Monitoring costs associated with drinking water treatment are $0.2 to $0.3 million higher than those for monitoring if new Mt. Simon Hinckley wells are used.

Surveillance monitoring of contaminated groundwater in the Drift-Platteville and St. Peter aquifers is based on a network of 20 multi-level monitoring wells. The estimated present value cost of monitoring these wells for the next 100 years on an annual basis is $180,000 to $370,000, including the cost of installing 10 new monitoring wells and designing a detailed monitoring plan. This cost would be halved if monitoring could be reduced to a biannual frequency. It is likely that future monitoring results will indicate that a reduced monitoring frequency is acceptable, based on the slow contaminant migration rates expected in the Drift-Platteville and St. Peter aquifers.

Ground-Water Use Restrictions

This study concludes that restricting the use of selected areas of the Drift-Platteville and possibly of the St. Peter aquifers for private or public drinking water supply is a cost-effective solution to the ground-water contamination problem in these aquifers. Such restrictions could take the form of a ban or warning against such uses in specified areas. Further study of available data is required to precisely define these areas. In particular, considerably more

information is required to determine the water quality of the St. Peter aquifer. The impacts of this restriction will be minimal, because all residences, industries, and commercial establishments in the area are currently connected to municipal potable water supplies. Ground-water use for other purposes that can result in direct ingestion of PAH contaminants may also need to be restricted, such as watering gardens or use in food processing plants.

7.2 Recommendations

Tables 7-1 and 7-2 summarize the remedial actions recommended by this study and the estimated present value costs of these actions. Table 7-1 summarizes remedial actions that can and should be undertaken now. Table 7-2 summarizes contingency remedial actions. These contingenty actions should only be undertaken if ground-water contaminant migration occurs at significantly greater rates and in substantially different directions than predicted by this study and if evaluations performed at such a time indicate that remedial actions would be cost-effective. The possibility of this occuring is felt to be very remote.

7.2.1 Current Remedial Action Recommendations

Site Area

The plant site and adjacent bog can be used safely and beneficially for reasonable purposes without undertaking extensive remedial actions to remove or contain soil contaminants. Ground-water contamination in surficial aquifers in the site area should be monitored, but actions to remove or contain ground-water contaminants are not necessary or cost-effective in achieving the stated objectives of this study. Specific recommendations for the site are as follows.

Recommendation 1 - Prohibit use of the Drift-Platteville and St. Peter and aquifers for private and municipal drinking water supply or direct use in food processing in areas where PAH concentrations exceed

TABLE 7-1

SUMMARY OF RECOMMENDED REMEDIAL ACTIONS

	Recommended Action	Estimated Present Value Cost ($Millions)	Cost Basis
PLANT SITE AND BOG AREA (See Section 5.1)			
R1.	Prohibit the use of the Drift-Platteville and St. Peter aquifers for private and municipal drinking water supply and direct use in food processing, warn residents against use for gardening.	0.02-0.04	Define prohibited use areas; legal and administrative expenses.
R2.	Construct Louisiana Avenue/Highway 7 interchange as planned.	0.02-0.04	Worker education regarding site-specific safety practices during any construction activities.
R3.	Monitor ground-water contamination in the Drift-Platteville and St. Peter.	0.18-0.37	Range depends on sampling frequency (annual to biannual).
ON-SITE MULTI-AQUIFER WELLS (See Section 5.2)			
R4.	Grout well W23 up to the surface.	0.01-0.02	
R5.	Explore well W105, evaluate remedial actions, and implement any necessary remedial actions.	0.1-0.2	Assumes that W105 will be no worse than W23 as a source and will eventually be sealed.
OFF-SITE MULTI-AQUIFER WELLS (See Section 5.3)			
R6.	Seal or reconstruct multi-aquifer wells that extend to the Mt. Simon-Hinckley and ensure that the inventory of such wells is complete and regularly updated every 25 to 50 years.	0.03-0.71	Lower bound is cost of completing and updating an inventory of Mt. Simon-Hinckley multi-aquifer wells. Upper bound includes unlikely worst-case cost of remedying 15 wells every 25 years.
R7.	Evaluate the results of Hickok's recent multi-aquifer well survey expand the results as necessary, and update the inventory every 25 to 50 years.	0.07-0.13	
GRADIENT CONTROL WELLS (See Section 5.4)			

(Contingency actions only -- see Table 7-2)

TABLE 7-1

SUMMARY OF RECOMMENDED REMEDIAL ACTIONS (continued)

Recommended Action	Estimated Present Value Cost ($Millions)	Cost Basis
MUNICIPAL WATER SUPPLY WELLS (See Sections 4.1, 6.3, 6.4 and 6.6)		
R8. Establish criteria and enforcement procedures for PAH and heterocyclic PAH in finished drinking water of 28 nanograms per liter for carcinogens and 4 to 400 micrograms per liter for noncarcinogens.	0.03-0.06	Finalize monitoring and enforcement procedures; legal and administrative expenses.
R9.a) If a noncarcinogen criterion is established in the higher end of the recommended range (greater than about 10 micrograms per liter), then restart municipal supply wells that are currently closed.	a) 0-0.9	Upper bound is a worst-case estimate based on criteria for carcinogens or noncarcinogens being exceeded 20 years later than predicted for a 4 microgram per liter noncarcinogen criterion. Lower bound reflects criteria not being exceeded in the next 100 years.
If a noncarcinogenic criterion is established near the low end of the recommended range (less than about 10 micrograms per liter), then either b) drill new Mt. Simon-Hinckley wells or c) provide powdered activated carbon or ozone injection treatment at selected contaminated wells in order to satisfy water supply requirements.	b) 0.9-2.3	Estimated cost for new Mt. Simon-Hinckley wells. Range reflects uncertainties in contaminant migration rates and well drawdowns.
	c) 0.6-1.8	Estimated cost for drinking water treatment. Range reflects uncertainties in treatment design and in contaminant migration rates.
GROUND-WATER MONITORING (See Sections 4.3 and 6.5 and recommendation R3)		
R10. Monitor municipal supply wells in St. Louis Park, Hopkins, and Edina for compliance with the recommended PAH criteria.	a) 0.28-0.40 b) 0.38-0.51 c) 0.56-0.86	Range depends on frequency of of monitoring. Various cases are a) noncarcinogen criterion of 400 micrograms per liter, b) noncarcinogen criterion of 4 micrograms per liter with Mt. Simon-Hinckley wells, and c) noncarcinogen criterion of 4 micrograms per liter with drinking water treatment.
R11. Establish and implement procedures for reviewing, evaluating and reporting ground-water monitoring data.	0.30	
TOTAL ESTIMATED PRESENT VALUE COST		
• With 400 microgram per liter criterion for noncarcinogenic PAH and noncarcinogenic heterocyclic PAH.	$1.0-3.2 million	
• With 4 micrograms per liter noncarcinogen criterion with drinking water treatment.	$2.0-4.7 million	
• With 4 micrograms per liter noncarcinogen criterion with new Mt. Simon-Hinckley wells.	$1.9-4.5 million	

TABLE 7-2

SUMMARY OF RECOMMENDED CONTINGENCY ACTIONS
(All action are contingent upon contaminants migrating at significantly different rates and directions than predicted by this study and subsequent analyses to determine if any additional action would then be cost effective)

Recommended Action	Estimated Present Value Cost ($Millions)	Cost Basis
OFF-SITE MULTI-AQUIFER WELLS (See Section 5.3)		
C1. Seal or reconstruct multiaquiver wells that connect the Drift-Platteville, St. Peter and/or Prairie du Chien-Jordan aquifer.	0-0.7	Upper bound represents unlikely worst-case of remedying 30 wells every 25 years.
GRADIENT CONTROL WELLS (See Section 5.4)		
C2. Implement a three-well gradient control well system in the Prairie-du Chien-Jordan to halt or retard migration of contaminants.	1.0-1.6	Range based on number of new wells required, as opposed to nearest storm sewer.
PLANT SITE AND BOG AREA (See Section 5.1)		
C3. Implement a gradient control well system in the Drift-Platteville and/or remove the ground fluid body.	0.9-1.3	
TOTAL ESTIMATED PRESENT VALUE COST	$1.9-$3.6 million	
• Discounted by 20 years	$0.7-$1.4 million	
• Discounted by 50 years	$0.2-$0.3 million	

the recommended criteria, or are predicted to do so within the next few decades, and warn against use of water in these areas for gardening.

Recommendation 2 - Construction of the Louisiana Avenue/Highway 7 interchange can proceed, as can appropriate and beneficial development of the site. Construction practices during any development should recognize the past use of and current contamination patterns of the site.

Recommendation 3 - Monitor migration of ground-water contaminants in the Drift-Platteville and St. Peter aquifers in the site area on a regular basis, as long as contaminants continue to migrate or their migration is viewed as a potential problem.

The estimated present value cost of implementing recommendations 1, 2 and 3 ranges from $0.22 million to $0.45 million, depending primarily on the required frequency of monitoring.

Multi-Aquifer Wells

Both on-site and off-site multi-aquifer wells require further evaluation before specific recommendations can be made regarding which wells should be abandoned or reconstructed, with the exception of well W23 and of any other multi-aquifer wells that can allow transport of contaminants into the Mt. Simon-Hinckley. Further evaluation is required because 1) results of a multi-aquifer well inventory recently completed by E.A. Hickok and Associates were not available for this report and 2) Hickok's recent inventory effort may need to be extended in certain areas. Further evaluation should be limited to determining whether sealing or reconstructing multi-aquifer wells is a cost-effective addition to the recommendations of this study. Specific recommendations regarding multi-aquifer wells are as follows.

Recommendation 4 - Fill well W23 to the surface with cement grout or bentonite once the on-going exploration studies at the well are completed.

Recommendation 5 - Explore well W105 to determine its possible role and significance as a source of contamination to deep bedrock aquifer, particularly the Mt. Simon-Hinckley. When this work is completed, remedial actions for well W105 should be evaluated in a similar manner to the evaluation of well W23 by this study, and the most cost-effective remedial action should then be implemented. At this time, it appears that the likely remedial action will be to seal well W105, rather than to use it as a pump-out control well.

Recommendation 6 - Seal or reconstruct all identified multi-aquifer wells that extend to the Mt. Simon-Hinckley aquifer to prevent interaquifer flow into this aquifer, and ensure that the inventory of multi-aquifer wells leading to the Mt. Simon-Hinckley covers all areas of present and foreseen contamination in above-lying aquifers. Continue this as necessary as contaminants in overlying aquifers continue to migrate.

Recommendation 7 - Evaluate the results of Hickok's recent multi-aquifer well inventory in the specific context of this study's conclusions, and expand available information as needed to evaluate the cost-effectiveness of sealing or reconstructing multi-aquifer wells. The particular concern is evaluating the cost effectiveness of sealing or reconstructing multi-aquifer wells that connect the Drift-Platteville, St. Peter, and/or Prairie du Chien-Jordan aquifers.

The estimated present value cost of recommendations 4 through 7 ranges from $0.2 million to $1.1 million, depending primarily on the number of multi-aquifer wells extending to the Mt. Simon-Hinckley that will require sealing or reconstruction.

Municipal Water Supplies

Contamination of aquifers below the St. Peter in the St. Louis Park area only affects the use of ground water from the Prairie du Chien-Jordan aquifer for municipal water supply. Criteria must be established for PAH and heterocyclic PAH in finished drinking water in

order to evaluate the need for and implement remedial actions for contaminated muncipal supply wells. A criterion for noncarcinogenic PAH and heterocyclic PAH is most critical in evaluating remedies, since finished water from currently contaminated municipal supply wells meets the recommended carcinogen criterion of 28 nanograms per liter. Finished water from most contaminated municipal supply wells will meet a noncarcinogen criterion established in all but the low end of the recommended range (from about 10 micrograms per liter up to 400 mirograms per liter). A noncarcinogen criterion near the low end of the recommended range (from 4 to about 10 micrograms per liter) will prevent some contaminated municipal supply wells from being used. The resulting water supply shortfall could be satisfied by 1) providing alternative water supplies or 2) treating contaminated wells to meet the criteria.

Given these implications of establishing criteria for PAH and heterocyclic PAH, this study makes the following recommendations.

Recommendation 8 - Establish criteria for concentrations of PAH and related compounds in finished drinking water that are adequate to protect the public health, and monitor and enforce these criteria in an open, consistent, and equitable fashion. Recommended criteria are that 1) the total concentration of a specific list of carcinogenic PAH and carcinogenic heterocyclic PAH not exceed 28 nanograms per liter (parts per trillion) and 2) the total concentration of a specific list of noncarcinogenic PAH and noncarcinogenic heterocyclic PAH not exceed a value established in the range of 4 to 400 micrograms per liter (parts per billion). The relative cost and effectiveness associated with meeting a noncarcinogenic criterion are important considerations in establishing such a criterion.

Recommendation 9 - If a criterion for noncarcinogenic PAH and noncarcinogenic heterocyclic PAH is established in the higher end of the recommended range, (greater than about 10 micrograms per liter), then reopen and use all municipal supply wells that are currently closed as a result of PAH contamination. If finished water from these

wells subsequently exceeds the criteria, then evaluate and implement the most cost-effective alternative that satisfies the supply shortfall.

If a criterion for noncarcinogenic PAH and noncarcinogenic heterocyclic PAH is established in the lower end of the recommended range (less than about 10 micrograms per liter), then evaluate and implement the more cost-effective alternative between using new Mt. Simon-Hinckley wells and providing additional treatment at existing iron removal plants. This evaluation must focus on the optimal management of municipal water supply among multiple wells and the feasibility, design, and cost of adding powdered activated carbon or ozone injection at existing iron removal treatment plants.

The estimated present value cost of recommendations 8 and 9 is from $0.9 million to $2.4 million if new Mt. Simon-Hinckley wells are used and from $0.6 million to $1.9 million if powdered activated carbon or ozone injection at existing iron removal treatment plants is implemented (including costs required to evaluate such treatment). The ranges in these estimated costs reflect uncertainties in the design and costing of these alternatives, and are based on a criterion for noncarcinogenic PAH and noncarcinogenic heterocyclic PAH in the lower end of the recommended range. The present value cost of meeting a noncarcinogenic criteria in the higher end of the recommended range is uncertain because of uncertainties in predicting when municipal supply wells would exceed such a criterion, if ever. At worst, the cost would be comparable to the costs associated with a lower criterion, only discounted by some unknown time period. For example, a twenty-year discount period would give a present value cost of $0.2 million to $0.9 million. At best, municipal supply wells would never exceed the criteria.

Ground-Water Monitoring

Any solution for achieving the objective of safe and adequate municipal water supplies in the St. Louis Park area will require regular monitoring of municipal supply wells to ensure compliance with

the recommended criteria for PAH and heterocyclic PAH. Such monitoring will also provide data for tracking the migration of contaminants in deep aquifers. Specific monitoring recommendations are as follows.

Recommendation 10 - Monitor municipal supply wells in St. Louis Park, Hopkins, and Edina for compliance with the recommended PAH criteria at specified frequencies, depending on existing and predicted future levels of PAH contaminants in these wells.

Recommendation 11 - Establish and implement procedures for maintaining records of all ground-water monitoring data (including data from the Drift-Platteville and St. Peter aquifers per Recommendation 3) and reviewing, evaluating, and publicly reporting monitoring results.

The estimated present value cost of these monitoring actions ranges from $0.6 million to $1.2 million, depending primarily on the frequency of compliance monitoring, as determined by the criterion established for noncarcinogenic PAH and the means used to satisfy municipal water supply shortfalls.

The total estimated present value cost of all recommended action is from $1.0 million to $4.7 million. The range depends in part on the criterion established for noncarcinogenic PAH and heterocyclic PAH, as shown in Table 7-1. A noncarcinogen criterion near the lower bound of the recommend range will result in additional costs of at least $1.0 million compared to a higher criterion.

7.2.2 Contingency Actions Recommendations

This study recommends three specific contingency actions to be evaluated for reliability and cost-effectiveness in response to specific circumstances, particularly if contaminant migration is found in the future to occur at significantly different rates and in substantially different directions than predicted by this study. These recommendations are as follows.

Contingency Action 1 - If further evaluation of the significance of contaminant transport by multi-aquifer wells connecting the Drift-Platteville, St. Peter, and/or Prairie du Chien-Jordan indicate that it is cost-effective to prevent such transport, then such wells should be sealed or reconstructed.

Contingency Action 2 - If future ground-water monitoring data indicate that PAH contaminants in the Prairie du Chien-Jordan are migrating substantially faster or in different directions than predicted by this study, then the cost-effectiveness of installing gradient control wells in the Prairie du Chien-jordan should be re-evaluated. This contingency is of more concern if new Mt. Simon-Hinckley wells are used to satisfy municipal water supply shortages, because treatment of contaminated municipal wells will limit the migration of contaminants in the Prairie du Chien-Jordan.

Contingency Action 3 - If future ground-water monitoring data indicate that contaminants in the Drift-Platteville are migrating substantially faster or in different directions than predicted by this study, then a gradient control well scheme and/or removal of the ground fluid body should be implemented if this is shown to be cost-effective.

The present value cost of implementing all of these contingency actions if from $1.9 million to $3.6 million. This range largely reflects uncertainties in the design of a gradient control well system and in the number of multi-aquifer wells requiring sealing or reconstruction. In order to arrive at a curent present value cost, the future cost of any contingency action must be discounted by the number of years into the future that any such action will be required. As an example, actions taken in 20 years are discounted by 62 percent and actions in 50 years are discounted by 91 percent.

7.3 Comments on Proposed Superfund Studies

The Minnesota Pollution Control Agency was awarded $2.0 million in Superfund monies on December 21, 1982 to undertake selected remedial

actions and additional remedial action studies for the soil and ground-water PAH contamination problems in the St. Louis Park area. It is appropriate to comment on the planned Superfund activities in light of the conclusions and recommendations developed by this study. Table 7-3 summarizes planned Superfund activities and their proposed costs, based on the work statement (Attachment A) for the State of Minnesota's application for Superfund monies (Hird 1983). Summaries of ERT's comments concerning each activity are indicated. These comments are further discussed below.

Planned Superfund activities call for spending $900,000 to study and then abandon, reconstruct and/or replace from 30 to 40 multi-aquifer wells in the vicinity of the site (Tasks 1d, to 1g). The nine high priority wells that have been identified all connect the Platteville, St. Peter, and/or Prairie du Chien-Jordan aquifers. This study concludes that insufficient information is available -- at least to ERT -- to conclude that abandoning or reconstructing multi-aquifer wells is cost-effective. This study recommends that this question be studied further within the specific context of the cost-effective remedial actions recommended in this report. Until such a study is completed, no money should be spent to abandon or reconstruct multi-aquifer wells in aquifers lying above the Mt. Simon-Hinckley. However, this report does recommend that any multi-aquifer wells that penetrate the Mt. Simon-Hinckley should be located and abandoned or reconstructed.

Planned Superfund studies call for spending $25,000 to compile existing ground-water analysis data (Table 2c). This is a worthwhile effort in light of the ground-water monitoring recommendations made by this report. However, ERT has already developed a computerized data base that contains all PAH and phenolics ground-water quality data currently available to ERT (see Appendix K). This data base should be used as a starting point for updating efforts in order to minimize costs.

TABLE 7-3

SUMMARY OF COMMENTS ON

PROPOSED $2.0 MILLION SUPERFUND ACTIVITIES[a]

Superfund Task	Source	Amount	Comment
1. Abandon multi-aquifer wells			
1a. well W23	In Progress[b]	NA[g]	Well W23 exploration should be completed and the well grouted.
1b. well W105	In Progress[b]	NA	Well W105 should be explored and then remedied, probably by grouting.
1c. well survey	Completed[b]	NA	NA
1d. feasibility study on providing alternative water sources for abandoned wells	New Superfund Monies		Unnecessary at present, other than any multi-aquifer wells leading to the Mt. Simon-Hinckley. Further evaluation of the cost-effectiveness of remedying multi-aquifer wells above the Mt. Simon-Hinckley is required using the results of Hickok's recently completed well survey (Table 1c.) and the analysis approach outlined by this study.
1e. abandon top 10 priority wells	New Superfund Monies	$900,000	
1f. cost-effective analysis of well abandonment program	New Superfund Monies		
1g. abandonment of other wells	New Superfund Monies		
2. Install gradient control system			
2a. facility planning	Completed[c]	NA	NA
2b. review by USGS	In Progress[d]	NA	NA
2c. compile existing ground-water analysis data	New Superfund Monies	$ 25,000	Many of the data have already been compiled for this study's computerized data base. Additional work to include data unavailable for this study is recommended
2d. modeling and testing of gradient control well system	New Superfund Monies	$250,000	Unnecessary. Ground water modeling was performed in this study.
2e. cost-effectiveness evaluation	New Superfund Monies		Gradient controls were evaluated by this study and found not to be cost-effective.
2f. plans and specifications	Future Work	NA	
2g. construction	Future Work	NA	
3. Gradient control well water treatment and disposal			
3a. evaluate various water treatment and disposal alternatives	In Progress[e]	NA	Further study is unnecessary because gradient control wells are not cost-effective.
3b. plans and specifications	Future Work	NA	
3c. construction	Future Work	NA	

TABLE 7-3 (continued)

Superfund Task	Funding Source	Amount	Comment
4. Provide drinking water for St. Louis Park and Hopkins			
4a. St. Louis Park connection with Plymouth	Completed[f]	NA	
4b. St. Louis Park drills new Mt. Simon-Hinckley well (SLP17)	In Progress[f]	NA	Further study and testing of drinking water supply alternatives is unnecessary, unless powdered activated carbon or ozone injection is selected as the desired means to achieve a low criterion for noncarcinogenic PAH and heterocyclic PAH.
4c. St. Louis Park negotiates connections with Minnetonka and Minneapolis	In Progress[f]	NA	
4d. water treatment study (same as Task 3a)	In Progress	NA	
4e. plans and specifications	Future Work	NA	
4f. construction	Future Work	NA	
5. Treat/contain/remove source material			
5a. compile soil logs and analyze existing cores	New Superfund Work	$ 46,000	Unnecessary, except to complete this study's compilation with data unavailable to this study. Further analysis of soil borings is unnecessary in evaluating remedial actions for the site.
5b. drill borings to define site contamination	In Progress[d]	NA	
5c. evaluate remedial action alternatives	New Superfund Work	$450,000	Unnecessary. This study has evaluated remedial actions for the site and made specific recommendations to be implemented.
5d. plans and specifications	Future Work	NA	
5e. construction	Future Work	NA	
6. Program Management and community relations	New Superfund Work	$322,300	Cost can be reduced as unnecessary studies are eliminated.
TOTAL COST OF NEW SUPERFUND ACTIVITIES		$1,993,300	

NOTES:

(a) Task descriptions and funding based on Attachment A to the State of Minnesota's Superfund Cooperative Agreement proposal (Hird 1983). Status per August 8, 1982 filing date, updated as known by ERT.

(b) Funding from reprogramming previous RCRA funds. Work being performed by Eugene A. Hickok and Associates.

(c) Completed as a result of Hickok's 1981 study and report.

(d) Funding provided by the U.S. EPA.

(e) Funding from reprogramming previous RCRA funds. Work in progress by CH2M Hill.

(f) Funding provided by St. Louis Park.

(g) Not applicable or not available.

Planned Superfund activities involve spending $250,000 to model and test the gradient control well system proposed by Hickok in 1981 (Tasks 2d and 2c). Such studies are unnecessary given the results of this study, which has developed and successfully applied ground-water flow models, shown that the gradient control well system proposed by Hickok is fundamentally flawed in its design, and concluded that gradient control wells are not a cost-effective remedial action. ERT, therefore, recommends that no Superfund studies of any kind be devoted to gradient control well schemes (this also applies to treatment and disposal of water discharged by gradient control wells (Task 3a).

Planned Superfund activities include evaluating remedial action alternatives at the site (Task 5c) and, in a related effort, compiling existing soil boring logs and analyzing existing soil boring cores (Task 5a). This report has evaluated remedial actions at the site in great detail and concludes that there are no feasible remedial actions that are cost-effective. Therefore, no further study of remedial actions at the site is necessary. As part of this study, all existing soil boring logs available to ERT were compiled and analyzed. Updating this compilation with any additional soil boring logs would be useful in better documenting the distribution of contaminants at the site. Analyzing selected additional soil boring samples might be useful in checking this study's approach at defining areas of contamination; however, major work in this area is not necessary.

Planned Superfund activities include the completion of on-going granulated activated carbon pilot testing studies and subsequent design of a granular activated carbon treatment plant (Task 4d). Pilot testing of granular activated carbon treatment at well SLP15 was recently completed (April 1, 1983). No additional studies on drinking water treatment should be performed, unless criteria are established and policy descisions are made that require further testing of powdered activated carbon and/or ozone injection (see recommendations 8 and 9).

Planned Superfund activities include completing exploratory and remedial action work at well W23 (Task 1a), performing similar work at well W105 (Task 1b), and drilling a new deep well (W300) in the vicinity of these two wells as part of the exploratory work. The results of this study indicate that exploratory work at wells W23 and W105 is necessary, but that the new deep well (W300) would not serve a useful purpose (Shanahan and Gregg 1983). Remedial actions for these two wells should follow the recommendations made by this study (R4 and R5).

It is noteworthy that only about ($900,000) half of the planned Superfund expenditures is for undertaking actual remedial action work, namely, abandoning multi-aquifer wells. The other half ($1,093,300) is for additional studies, program management, and community relations. With few exceptions, the additional Superfund studies planned are unnecessary, given the studies performed and conclusions reached by this report. Furthermore, it is unclear if any of the planned multi-aquifer well abandonment work planned is necessary or cost-effective. Therefore, it appears that at least $1.0 million - and perhaps close to the full $2.0 million - of the planned Superfund expenditures could be used for implementing the recommendations made by this study.

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