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No 0000009

FINAL REPORT
FEASIBILITY STUDY

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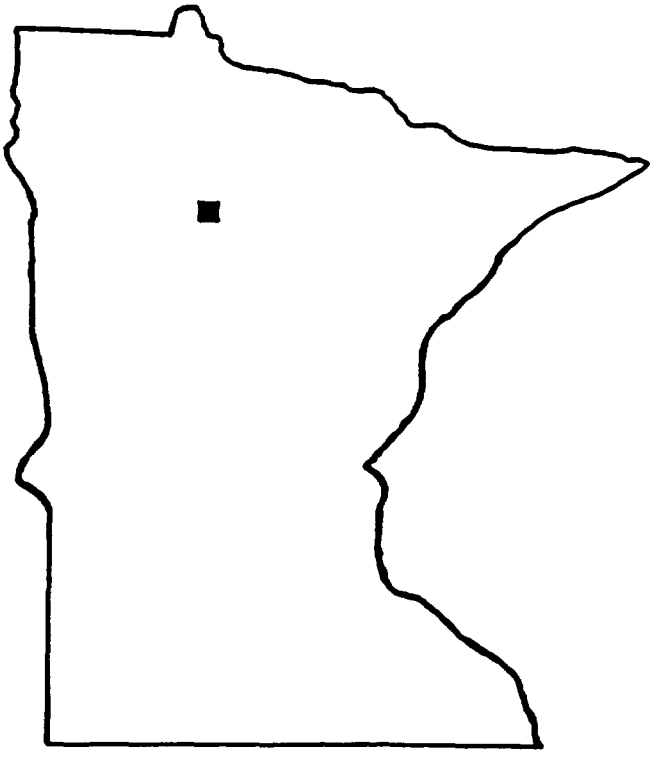
MPCA, Ground Water
& Solid Waste Div.

FOR

GROUND WATER OPERABLE UNIT
KUMMER SANITARY LANDFILL



Northern Township
Beltrami County, Minnesota

Minnesota Pollution Control Agency

JULY, 1990
PROJECT: 0871-03-9M89

MALCOLM PIRNIE

MALCOLM PIRNIE, INC.
ENVIRONMENTAL ENGINEERS, SCIENTISTS & PLANNERS

July 19, 1990

Ms. Miriam Horneff
Project Manager
Solid Waste Section
Ground Water & Solid Waste Division
Minnesota Pollution Control Agency
520 Lafayette Road North
St. Paul, MN 55155

Re: Kummer Sanitary Landfill Final Ground Water Feasibility Study Report

Dear Miriam:

We are pleased to submit three bound and one unbound copies of the ground water operable unit final feasibility study. This report addresses MPCA and USEPA comments on the draft report.

We appreciate the efforts of you and your staff, including Ingrid Verhagen, in assisting us with the feasibility study. We have enjoyed working with you on the Kummer project. If you or other members of your staff have any questions or comments on this report, please don't hesitate to contact us.

Very truly yours,

MALCOLM PIRNIE, INC.

Charles R. Michael, P.E.
Senior Associate

mr

c: D. K. Cohen
W. P. Dee
J. P. Sparks

0871-03-9M89

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EXECUTIVE SUMMARY

This report presents the results of the evaluation of alternative remedial action technologies for contaminated ground water at the Kummer Sanitary Landfill site. The Kummer site is located in Northern Township, Beltrami County, Minnesota approximately one mile west of Lake Bemidji. A shallow aquifer utilized for potable drinking water supply has been contaminated due to operations at the landfill. Ongoing remedial actions at the site include extension of the City of Bemidji municipal water supply into the affected area, institutional controls on ground water use, and closure of the landfill site by a cover system utilizing a clay barrier. The Minnesota Department of Health (MDH) is also expected to issue a drilling advisory on the affected aquifer. This report considers ground water adjacent to and downgradient from the Kummer landfill.

The landfill accepted wastes from about 1971 until about 1984. Volatile organic compounds were found by the MPCA in on-site monitoring wells in 1982 and 1983, and in shallow downgradient drinking water supply wells during 1984. A full-scale remedial investigation (RI) was conducted from 1986 to 1989. The results of the RI are published as a separate report entitled "Final Report Remedial Investigation for Kummer Sanitary Landfill" and dated January 1990.

Key conclusions from the RI report are:

- Ground water adjacent to and downgradient from the landfill has been contaminated by volatile organic compounds (VOCs) including vinyl chloride, trans-1,2 dichloroethene, tetrachloroethene (PCE), 1,1,2-trichloroethene (TCE), and benzene.

- Concentrations of certain inorganic compounds are significantly higher in downgradient monitoring wells than in upgradient wells. Inorganic compounds which have regulatory significance include aluminum, arsenic, barium, iron, manganese, nickel, and nitrate. Barium concentrations exceeded present drinking water supply standards at four wells (2A, 2B, 3A, and 7A) near the landfill.

Contaminant transport in the aquifer was modeled in early 1990 using the Pricket-Lonnquist Aquifer Simulation Model with random walk. The objective of the modeling was to predict contaminant distribution in the aquifer after installation of the landfill cover system, and to simulate an active pumping alternative. Results of the modeling are presented in Appendix B to this Feasibility Study. Conclusions from the modeling are:

- The plume of detectable contamination by VOCs has not yet reached Lake Bemidji.

- If the cover system prevents future introduction of contaminants to the aquifer, it will take about 34 years for the VOC plume to reach Lake Bemidji. Even after 80 years, total VOC concentration at the ground water discharge to Lake Bemidji is near compound detection limits.

- Much of the present plume can be recovered in about 4 years using a 5 well pumping network with total flow rate of about 85 gallons per minute.

This feasibility study builds on the results of the RI and the ground water modeling to identify and evaluate alternative technologies for ground water hydraulic controls, treatment, and effluent management. The report is divided into 4 sections. Section 1 presents a history of the site and the contamination problems found. Remedial action objectives and clean-up criteria are developed in Section 2. The general area of response is established, and technologies are screened based on effectiveness, implementability, and cost. Promising technologies are developed and screened further in Section 3. Section 4 evaluates remedial action alternatives based on the nine criteria the USEPA uses for selection of a Superfund remedy.

The objectives for remedial action are presented on Table I. The objectives for ground water remediation are two-fold. The first objective is to provide a safe drinking water supply for residents downgradient of the landfill. The criteria for this objective is that residents receive water compliant with Safe Drinking Water Act Maximum Contaminant Levels. The alternate water supply provided under an on-going remedial action effectively achieves this objective.

A second objective is to prevent significant impacts on surface water quality at Lake Bemidji. The criteria are proposed surface water quality standards developed by the MPCA Water Quality Division for Lake Bemidji. A memorandum discussing these criteria is included as Appendix C to this report. Objectives are also presented for surface water and air. These objectives are utilized to define performance requirements for ground water treatment technologies.

The response boundaries include up to 300 million gallons of contaminated ground water located beneath and to the east of the landfill. Contamination appears limited to the upper 50 feet of the aquifer, except at the southeastern corner of the landfill where it is deeper. The area of ground water contamination basically corresponds to monitoring well locations where vinyl chloride was detected at concentrations which exceed drinking water quality standards. Ground water flow is generally to the east, with a velocity of about 10 to 100 feet per

TABLE I
KUMMER SANITARY LANDFILL, MINNESOTA

OBJECTIVES FOR REMEDIAL ACTION

Pathway	Objectives	Criteria
Ground Water	Provide a safe drinking water supply for down-gradient residents.	Residents receive water compliant with Safe Drinking Water Act Maximum Contaminant Levels (MCLs).
	Prevent significant impacts on surface water quality.	MPCA Surface Water Quality Criteria for Lake Bemidji and the Mississippi River.
Surface Water	Prevent adverse impact on human health due to use of surface water as a drinking supply or ingestion of fish. Prevent degradation of downstream water quality. Applies to non-point or point source discharges during implementation of ground water remedial technologies.	Clean Water Act best available technology economically achievable (BAT). MPCA Surface Water Quality Criteria for Lake Bemidji and the Mississippi River. Discharge cannot be greater than 1% above baseline quality.
Air	Prevent chronic adverse impact on human health during implementation of ground water material technologies.	Annual average ground level concentrations of volatile organics corresponding to incremental cancer risk of 10^{-6}.
	Prevent acute and subchronic adverse impact on human health during implementation of ground water remedial technologies.	Maximum volatile organic concentrations no greater than Threshold Limit Value (TLV) time-weighted average for work place.

year.

Hydraulic control technologies judged applicable to the Kummer site include:

- no further action
- passive hydraulic controls (drains)
- active upgradient pumping, and
- active downgradient pumping.

Applicable on-site treatment technologies for organics removal are air stripping, combined stripping/carbon adsorption, and advanced oxidation processes (AOPs). Coagulation/flocculation and lime-soda softening are applicable technologies for inorganics removal. Bioremediation is another treatment technology which may warrant future consideration.

Disposal of treated ground water requires special consideration at the Kummer site. Treatment effluent management technologies include discharge to a publicly-owned treatment works (POTW), infiltration ponds, and discharge to surface waters.

The applicable technologies are developed and screened according to effectiveness, technical feasibility and implementability, environmental effects, and cost criteria. The passive hydraulic control alternative consists of a 700-foot trench along the eastern perimeter of the landfill. The trench depth ranges from 50 to 80 feet, and is designed to intercept ground water as it leaves the landfill property. Active upgradient controls include up to 18 pumping wells located on the western perimeter of the landfill. The wells are intended to divert clean ground water around the landfill. Active downgradient pumping includes about 5 extraction wells patterned after the ground water modeling results.

No further action is retained because modeling results indicate that the technology can meet surface water quality objectives for a period of up to 80 years. Passive downgradient controls are screened out based on implementability, effectiveness, and cost. The upgradient pumping network is eliminated based on effectiveness and possible adverse environmental impacts. The downgradient pumping network is retained.

Organic compound treatment alternatives developed in Section 3 include air stripping, advanced oxidation processes, discharge to POTW, and bioremediation. Air stripping and AOP are retained. Discharge to the POTW is eliminated based on implementability and effectiveness. The high volume of dilute flow may upset the removal of conventional pollutants, and inorganics may pass through in concentrations greater than current discharge limitations. Bioremediation is

retained, but only if new approaches are discovered which demonstrate the effectiveness of the process in treating Kummer site ground water contaminants. Inorganic compound treatment alternatives are precipitation, lime-soda softening, and discharge to a POTW. Discharge to the POTW is eliminated. Treatment alternatives retained for further evaluation are:

- precipitation and air stripping
- lime-soda softening and AOP.

The discharge to surface water effluent management alternative includes non-point and point source discharges. Non-point discharge consists of allowing the ground water plume to seep into Lake Bemidji. Two possible points are considered for point source discharge: Lake Bemidji about one mile east of the site, and an existing storm sewer located about one mile south of the site. Discharge to a POTW requires construction of a 4-inch sewer line of length about 1100 feet. The on-site infiltration pond consists of a 200-foot by 500-foot area about 10 feet deep. The high permeability of site soils makes it likely that detention time in the pond will be less than one hour. Discharge to surface water and the on-site infiltration pond are retained effluent management technologies. Discharge to the POTW is again eliminated based on implementability and cost.

Based on screening results, the following alternatives are developed for ground water remediation:

- Alternative I - No further action or limited action with non-point source discharge to Lake Bemidji.

- Alternative II - Active downgradient pumping, on-site treatment by AOP and lime-soda softening, and point source discharge to Lake Bemidji.

- Alternative III - Active downgradient pumping, on-site treatment by AOP, possible on-site treatment by lime-soda softening, and on-site disposal in an infiltration pond. Bioremediation may also be considered if the technology is sufficiently demonstrated prior to remedial action implementation.

A summary of the nine criteria evaluation is presented in Table II.

No further action has the lowest capital costs of all the alternatives. No further action includes long-term tracking of movement of ground water contaminants. It may be protective of public health and the environment in the long-term due to the cover system and alternative water supply. No action is not protective of the environment in the short-term because contaminants will continue to migrate to downgradient ground water. It may be protective in the long-term because the cover system may provide adequate controls at the

TABLE II
KUMMER LANDFILL, MINNESOTA

COMPARATIVE ANALYSIS AMONG ALTERNATIVES

Evaluation Criteria	I - No Further Action	II - Active Downgradient - Surface Water Discharge	III - Active Downgradient - Infiltration Pond Discharge
Overall protective of Human Health and the Environment	Likely protective	Maximum protection	Protective
Compliance with ARARs	May be inconsistent with performance standards for ground water quality at new and operating landfills. However, actions are being implemented to address the problem.	Complies with air and surface water criteria; also consistent with landfill per-performance standards and drinking water quality regulations.	Complies with air and surface water criteria; also consistent with landfill performance standards and drinking water quality regulations.
Long-term Effectiveness	Probably effective. Short-term continued migration of contaminants down-gradient, but eventual impacts on surface water quality may be insignificant.	Effective. Downgradient ground water and surface waters are protected. Organics are destroyed. Long-term effectiveness of land disposal of inorganic treatment sludge is unknown.	Effective. Downgradient ground water and surface water protected. Organics are destroyed.
Reduction of Toxicity, Mobility, Volume	Not applicable. May increase toxicity if vinyl chloride results from anaerobic degradation of ground water contaminants.	Reduction of volume of ground water contaminants at the site. Reduction of toxicity an mobility of organic contaminants. Partial reduction of toxicity and mobility of inorganics.	No reduction of volume of inorganic ground water contaminants, unless treatment provided. Reduction of toxicity and mobility of organic contaminants.

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TABLE II (cont'd)
KUMMER LANDFILL, MINNESOTA

COMPARATIVE ANALYSIS AMONG ALTERNATIVES

Evaluation Criteria	I - No Further Action	II - Active Downgradient - Surface Water Discharge	III - Active Downgradient - Infiltration Pond Discharge
Short-term Effectiveness	Probably effective, but continued migration of contaminants downgradient.	Minimal risk to public. Workers require protection during well development and water treatment.	Minimal risk to public. Workers require protection during well development, water treatment, and excavation of pond area.
Implementability	May be difficult to enforce institutional controls.	Discharge to surface water technically feasible. Administratively feasible.	Technically feasible. May require a MDH permit to recharge treated ground water.
Cost			
Capital $	73,000	1,300,000	1,000,000 to 1,400,000
Annual O&M $	24,000	510,000	240,000 to 510,000
4 or 30 years Present Worth $	300,000	3,000,000 to 6,200,000	3,000,000 - 6,200,000** 1,800,000 - 3,300,000*
Support Agency Acceptance	To be determined	To be determined	To be determined
Community Acceptance	May be unacceptable	Likely acceptable	Likely acceptable

* Cost range organic treatment only
** Cost range organic and inorganic treatment

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contamination source. Modeling results indicate contaminant concentrations will gradually decrease with time, and probably will never exceed current surface water quality standards at Lake Bemidji.

The advantage of Alternative II is that it provides direct indication that remedial action objectives are achieved. The alternative provides for destruction of organic compounds, and maximum protection of public health and the environment. Alternative II complies with all ARARs. The disadvantages are that additional land must be procured for the pumping system and associated piping. Unknown physical and administrative barriers may exist for a point source discharge to Lake Bemidji. Inorganics treatment results in a sludge which must be landfilled, possibly as a hazardous waste. Estimated present worth costs are higher than for Alternative I, and potentially higher than Alternative III depending on the inorganics treatment requirements for effluent discharge.

Alternative III also provides direct indication that remedial action alternatives are achieved. In comparison to Alternative II, the on-site recharge pond may be administratively easier to implement than a new point source discharge to Lake Bemidji. On-site recharge may allow deletion of inorganics treatment, if pumped ground waters comply with drinking water standards for inorganics. Deletion of inorganics treatment results in considerable cost savings.

1.0 INTRODUCTION

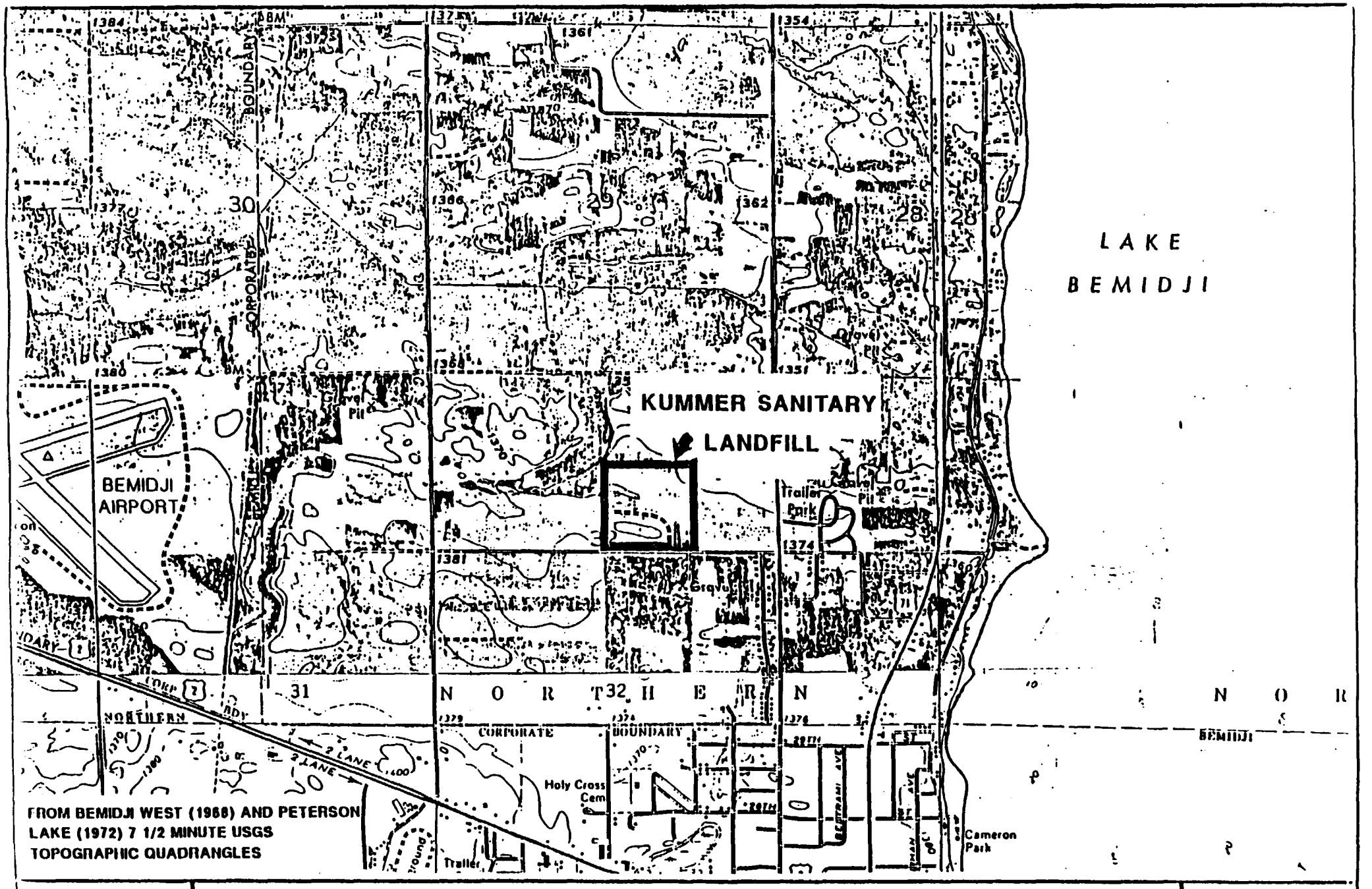
The Kummer Sanitary Landfill is located in Northern Township, Beltrami County, Minnesota approximately one mile west of Lake Bemidji. The site is located along the north side of Anne Street, N.W., and midway between U.S. 71 and County State-Aid Highway 15. The northern corporate limits of the City of Bemidji are one-half mile south of the site (Figure 1-1).

The Minnesota Pollution Control Agency (MPCA) issued Permit No. SW-31 to construct and operate the Kummer Sanitary Landfill to Mr. Charles Kummer on April 26, 1971. From its opening in 1971 to November of 1984, the landfill accepted material described only as mixed-municipal waste. During 1982 and 1983 the MPCA sampled ground water from on-site monitoring wells. Nineteen volatile organic compounds (VOC's) were detected in the down-gradient wells while the upgradient wells were uncontaminated, indicating ground water contamination as a result of the landfill operation. The site was included on the National Priorities List in May 1986. In January 1990, Malcolm Pirnie, Inc. (Malcolm Pirnie) completed the report entitled "Final Report Remedial Investigation for Kummer Sanitary Landfill" which detailed the extent of ground water contamination at the landfill based on monitoring performed during the remedial investigation (RI).

1.1 PURPOSES AND ORGANIZATION

Based on the results of the RI, a shallow aquifer utilized for potable water supply has become contaminated due to operations at the landfill. Both ground water beneath the landfill and down-gradient from the landfill have been impacted. This report is a Feasibility Study (FS) for the ground water both adjacent to and down-gradient from the Kummer landfill. The purpose of this report is to identify, evaluate, and select hydraulic and treatment technologies to remediate the contaminated ground water. This FS is conducted under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) as amended by the Superfund Amendments Reauthorization Act (SARA), Minnesota Environmental Response and Liability Act (MERLA) and the National Contingency Plan (NCP).

The remainder of Chapter 1 presents a summary of the information contained in the RI, concentrating on site description, site history, nature and extent of contamination, contaminant fate and transport, and baseline risk assessment.



MALCOLM PIRNIE

KUMMER LANDFILL FEASIBILITY STUDY

SITE LOCATION

MALCOLM PIRNIE, INC.

FIGURE 1-1

Chapter 2 presents objectives of the remedial action and the general response actions applicable for hydraulic controls, ground water treatment and effluent management. Chapter 2 also identifies feasible technologies for each response action identified and provides a preliminary screening based on implementability at the Kummer site. Chapter 3 combines and develops the technologies identified in Chapter 2 into a number of feasible alternatives. The alternatives are screened based on effectiveness, implementability, and cost. The final chapter of this report provides a detailed analysis of those alternatives which have passed the initial screenings and compares them based on nine criteria that USEPA uses for selection of a CERCLA remedy.

1.2 BACKGROUND INFORMATION

The site information presented in this section regarding site description and history, nature and extent of contamination, contaminant fate and transport, and baseline risk assessment has been summarized from the January 1990 RI report.

1.2.1 Site Description

The Kummer Sanitary Landfill is located in Northern Township one-half mile north of the City of Bemidji. Northern Township has a population of 4,095 (1986 data) and is generally sparsely populated. Approximately 1500 of the 4,095 are affected by the contaminant plume and are hooked up to the alternative water supply of Northern Township. The township is largely undeveloped with large tracts of forests, open land, and wetlands. Most of the township's residents live in the southeastern section of the township near the City of Bemidji and along the western shore of Lake Bemidji. To the north and west of the landfill site, the land is sparsely developed with farm residences and other isolated buildings. The residential building closest to the landfill is the Kummer residence located on-site in the extreme southeast corner of the property. A large residential community lies approximately 1,500 feet further to the east and southeast. This area includes Hillcrest Manor Trailer Park, Anne Street, Cedar Lane, Irvine Avenue, Minnesota Avenue, Tamarack Avenue, Bemidji Avenue, and several smaller streets. No buildings are located within 3,000 feet directly south of the landfill. North Country Hospital is located directly southwest of the site at the corner of Pine Ridge Avenue and Anne Street. The Sandy Hills Acres subdivision borders the western edge of the landfill property. Greenleaf

Avenue in this subdivision lies within 500 feet of the landfill. Presently several homes have been built in Sandy Hills Acres.

The landfill property is over 40 acres in size with approximately 30 to 35 acres of the site filled. The landfill has relatively steep outslopes, a gentle sloping to flat upper surface and is poorly to moderately well vegetated. The landfill cover material was obtained from the extreme northern portion of the site from on-site sand and gravel deposits, thereby potentially making the cover permeable. The site physiography, surface hydrology and hydrogeology, and climatology are described in the paragraphs below.

1.2.1.1 Site Physiography

The region is characterized by flat to gently rolling terrain to the north and gently rolling terrain to the south. Surface elevations range from approximately 1,050 to 1,550 feet above mean sea level (MSL). The area contains numerous wetlands and lakes. Prior to agricultural drainage, one-half of Beltrami County was comprised of wetland. Mineral resources of the county consist primarily of aggregate sand/gravel, and peat.

The terrain in the immediate vicinity of the site is very gently rolling. The site is bounded on the east and west by pasture and/or grain croplands, on the north by woodlands and a bog, and on the south by planted woods and a gravel pit. Surface elevation at the site ranges from about 1,360 to 1,380 feet above MSL. Local surface drainage is generally northward. Approximately one-half mile to the north, a modified stream channel or ditch carries runoff to Lake Bemidji. Drainage from the site does not enter this channel.

1.2.1.2 Surface Hydrology and Hydrogeology

The Kummer Sanitary Landfill is located in the Mississippi River Headwaters Watershed. Water resources in the area are considered abundant, with lakes and streams occupying about eight percent of the regional surface area. Stream flow is fairly regular because of storage in lakes, swamps, and glacial deposits. The Mississippi River, its tributaries, headwaters, reservoirs, and numerous lakes provide water suitable in quantity and quality for most industrial, municipal, agricultural, and recreational uses. Average annual runoff from the watershed is about 5.34 inches (Oakes, E. L. and L. E. Bidwell, 1968, Water Resources of the Mississippi Watershed, North-Central Minnesota, U.S. Geol. Survey Hydrogeologic Investigations Atlas, HA-278).

The ground water reservoir contains the largest quantity of water available in the area. Ground water discharge provides part of the base flow of streams and uniform lake stages. Glacial outwash deposits underlying the present surface water courses are highly productive and are the best source of ground water supply for many municipal, industrial and agricultural needs. Additional ground water supply is also available from buried valleys filled with glacial deposits and from Precambrian sedimentary rock. (Oakes and Bidwell, 1968).

The landfill site is underlain primarily by permeable glacial outwash sands deposited by meltwater streams flowing away from the front edge of a continental glacier. The sands encountered over most of the site are well-sorted, with individual grains being subangular to rounded. These characteristics are typical of material that has been transported by flowing waters. Glacial outwash sands extend approximately 100 feet below the average site elevation. Sand and gravel lenses less than six feet thick and clay and/or silt lenses generally less than five feet thick are interbedded with the outwash sands at some locations and appear to be discontinuous. A body of low permeability glacial till underlies much of the area immediately east of the landfill. Till is a heterogeneous material deposited by a retreating glacier, consisting of unsorted and unstratified gravels, sands, silts and clay. The thickness of this till varies from five feet to almost sixty feet. In some areas it was not encountered during drilling and may be discontinuous or present at greater depths (Final RI Report for the Kummer Sanitary Landfill, 1990).

Ground water in the glacial outwash sands flows generally to the east, where it eventually discharges into Lake Bemidji. An approximate ground water velocity of 0.075 to 7.2 ft/day is calculated from an estimated hydraulic conductivity of 10 to 120 ft/day and a porosity of 0.2 to 0.4 for the outwash sands of the aquifer. The hydraulic gradient of the water table ranges from 0.003 to 0.012 ft/ft (Final RI Report for the Kummer Sanitary Landfill, 1990). Ground water use in the Bemidji area is limited to the unconsolidated deposits above bedrock. The City of Bemidji primary water supply wells are located upgradient of the landfill approximately one and one-quarter miles west of the site and are completed in a confined glacial drift aquifer about 160 feet deep (Oakes and Bidwell, 1968). Based on a study by Barr Engineering, these city wells are not impacted by the landfill (Hydrogeological Analysis, City of Bemidji Well Field, February 1989).

1.2.1.3 Climatology

Climate in this region is temperate. The National Oceanic and Atmospheric Administration compiled climatic data from the Bemidji Airport (one and one-half miles west of the site) for the period 1941 to 1970 which indicate an annual average temperature range of -16°C (+3.2°F) in January to 20°C (68°F) in July. Precipitation is moderate, 22.25 inches annually with 10.5 inches of this amount occurring as rain in June, July, and August. During the period November through March, an equivalent to 3.2 inches of rain falls as snow. Most of this moisture is held in storage as snow until the spring thaw which allows recharge of the ground water table as well as runoff to surface water bodies.

1.2.2 Site History

The landfill accepted waste identified only as mixed municipal waste from 1971 until 1984. In 1974 a demolition debris disposal area was opened and received large quantities of fly ash and saw dust.

Three monitoring wells were installed by Mr. Kummer on the landfill property in the summer of 1971. Information in the files of MPCA indicates the wells were not properly maintained. In the fall of 1986, twenty-two monitoring wells were installed at nine locations as part of the RI. Ten additional wells were installed in January and February of 1988. A well was installed through filled wastes in June 1989. Six other down-gradient wells were also installed at four off-site locations in June 1989. Supplemental trenching in the landfill was completed in May 1990.

Based on the results of a focused feasibility study prior to the RI, Operable Unit 1 (OU1) was created to supply an alternative drinking water source. Three other operable units were created based on the conclusions of the Remedial Investigation. MPCA (with the concurrence of EPA/Region V) created Operable Units OU2, OU3 and OU4 to expedite response actions at the site. The site operable units are:

- OU1: Alternative Water Supply
- OU2: Landfill Cover System
- OU3: Ground Water Beneath the Landfill
- OU4: Down-gradient Ground Water

Operable units OU3 and OU4 were recombined in August 1989, into a new OU3 which includes all site ground water. The following paragraphs describe the operable units and site history in more detail.

1.2.2.1 Operable Units

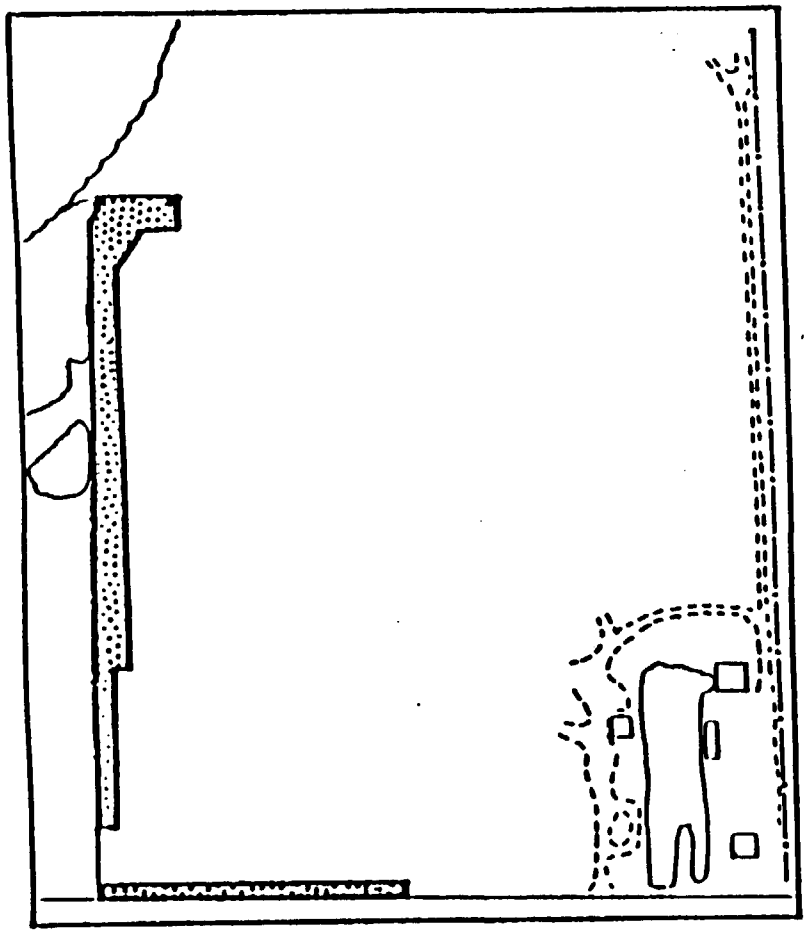
The work for the Kummer Sanitary Landfill site has been divided into three operable units to expedite response actions at the site. Operable Unit #1 involves extending City water supply lines into the area of ground water contamination and drilling a new municipal well. This work was completed in 1990. The second operable unit (OU2) consists of appropriate closure of the landfill. The OU2 Record of Decision (ROD) selected a cover system consistent with Minnesota Rules closure requirements for mixed municipal solid waste landfill facilities as appropriate for the Kummer site. The remedial design (RD) of the cover system is underway and expected to be complete in 1990. This report considers all site ground water beneath the landfill and down-gradient from the landfill as OU3.

1.2.2.2 Waste Disposal Activities

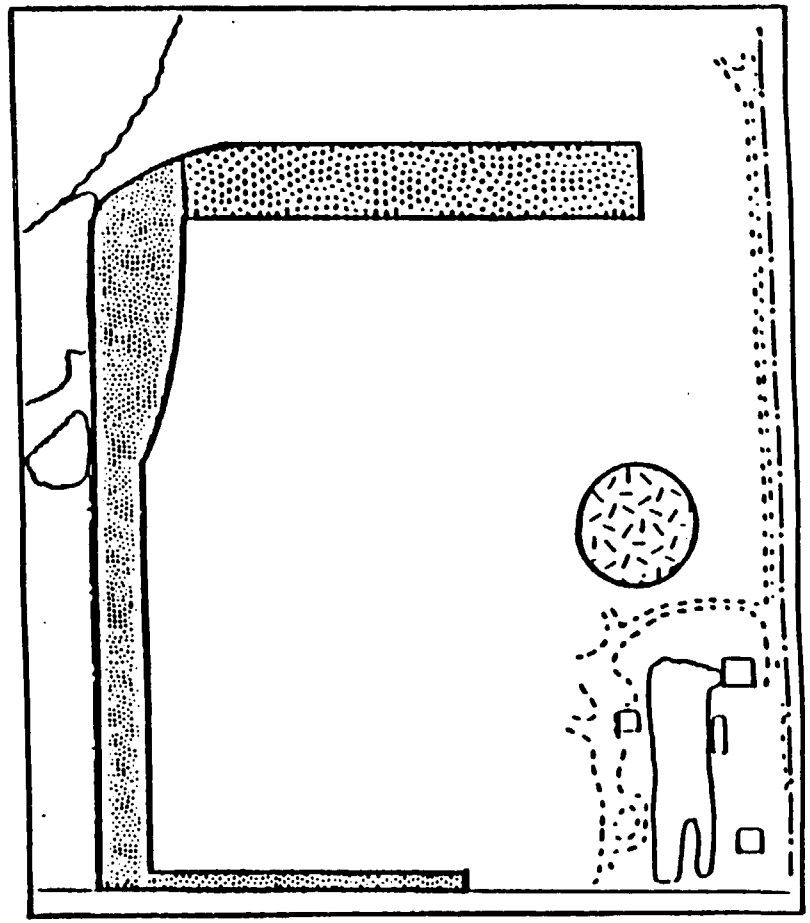
The landfill was opened in 1971 with a permit (No. SW-31) from the Minnesota Pollution Control Agency (MPCA). Until 1984, the landfill accepted material described only as mixed municipal waste. The waste was deposited in the landfill using a trench and fill technique. It is highly probable, based on an MPCA inspection report, that the trenches were excavated down to the water table and some refuse was placed in contact with the ground water. Mr. Larry Olson, MPCA solid waste inspector, noted that near the end of landfill operations, at least one trench was dug down to the ground water table. This may have been the large final trench located near the center of the landfill property.

Results from the RI indicate that waste is in contact with ground water in at least one location (monitoring well MW-16) near the center of the landfill. Earlier trenches were located along the southern, western, and northern borders of the property. Cover material was excavated from borrow areas on the landfill site. These borrow areas later became active landfill sites. The extent of landfill usage, based on historic aerial photographs, is illustrated in Figures 1-2, 1-3 and 1-4. The landfill area occupied a major portion of the property by 1984. The demolition debris disposal area near the eastern edge of the site was opened in 1974 and contains fly ash and saw dust.

The landfill operator was cited several times by MPCA for violations and non-compliance with permit requirements. Ground water samples were collected from the landfill's monitoring wells by MPCA staff in 1982 and 1983. Nineteen volatile organic compounds (VOCs), including trichlorofluoromethane, 1,1,2,2-tetrachloroethene (PCE), benzene, 1,2-dichloroethane and 1,1,2-trichloroethene



KUMMER LANDFILL BEMIDJI, MINNESOTA
MAY 1972



KUMMER LANDFILL BEMIDJI, MINNESOTA
1974

CURRENTLY ACTIVE FILL AREA

PREVIOUSLY FILLED AREA

DEMOLITION AREA

NOT TO SCALE

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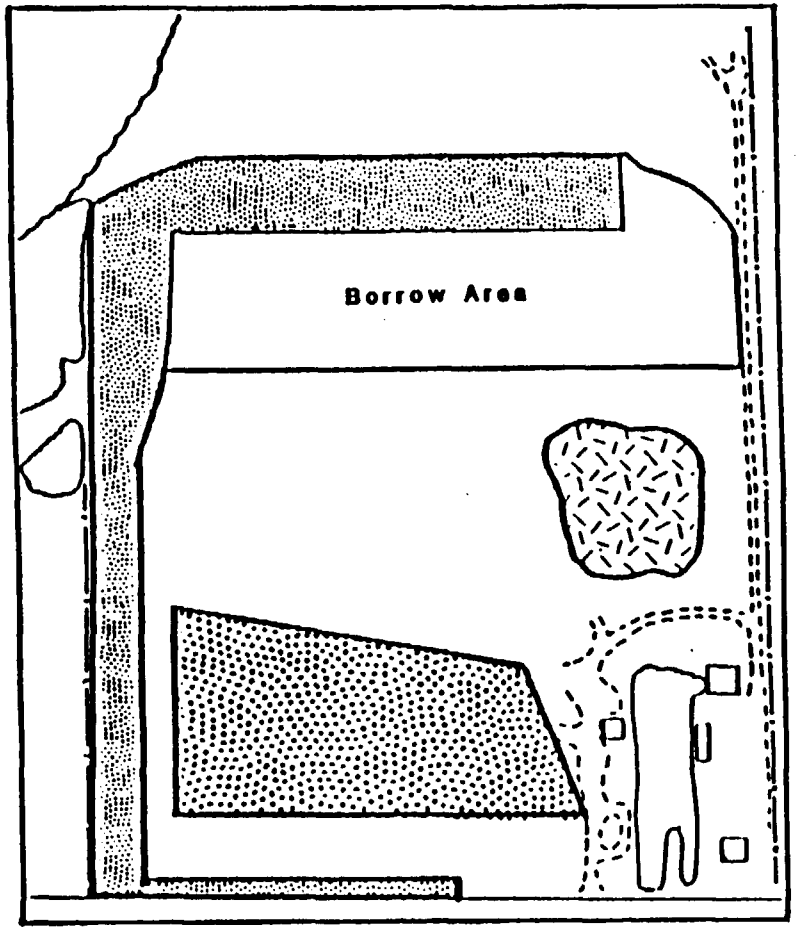
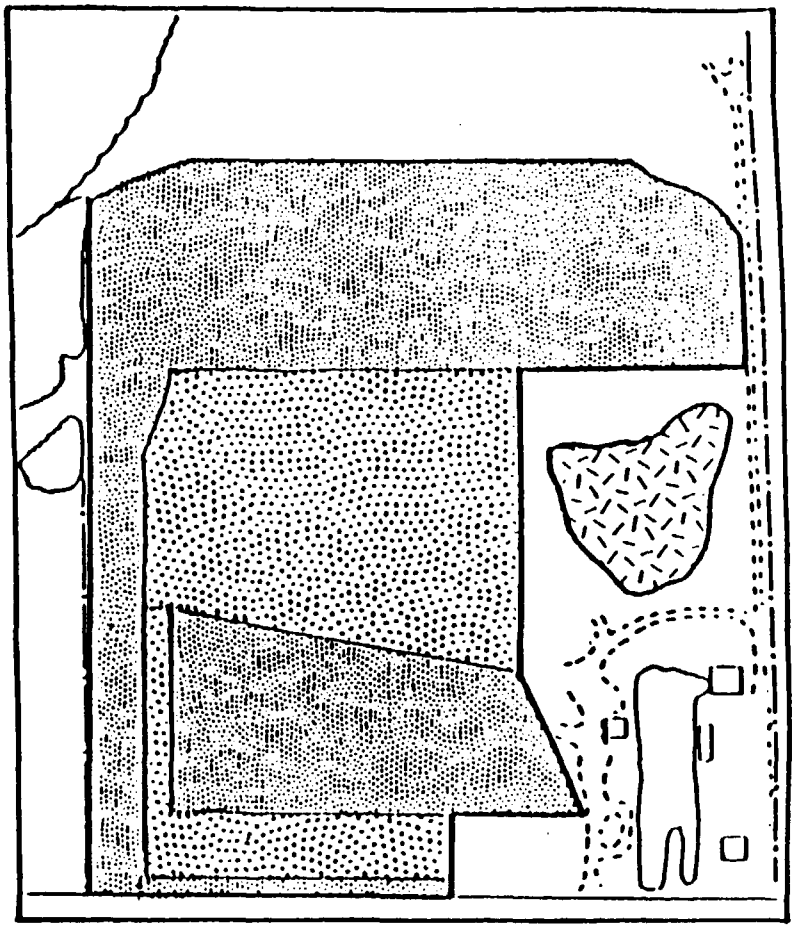
KUMMER LANDFILL
FEASIBILITY STUDY
HISTORY OF SITE OPERATIONS

MALCOLM PIRNIE, INC.

FIGURE 1-2



KUMMER LANDFILL BEMIDJI, MINNESOTA
AUGUST 1976



KUMMER LANDFILL BEMIDJI, MINNESOTA
MAY 1979

CURRENTLY ACTIVE FILL AREA

PREVIOUSLY FILLED AREA

DEMOLITION AREA

NOT TO SCALE

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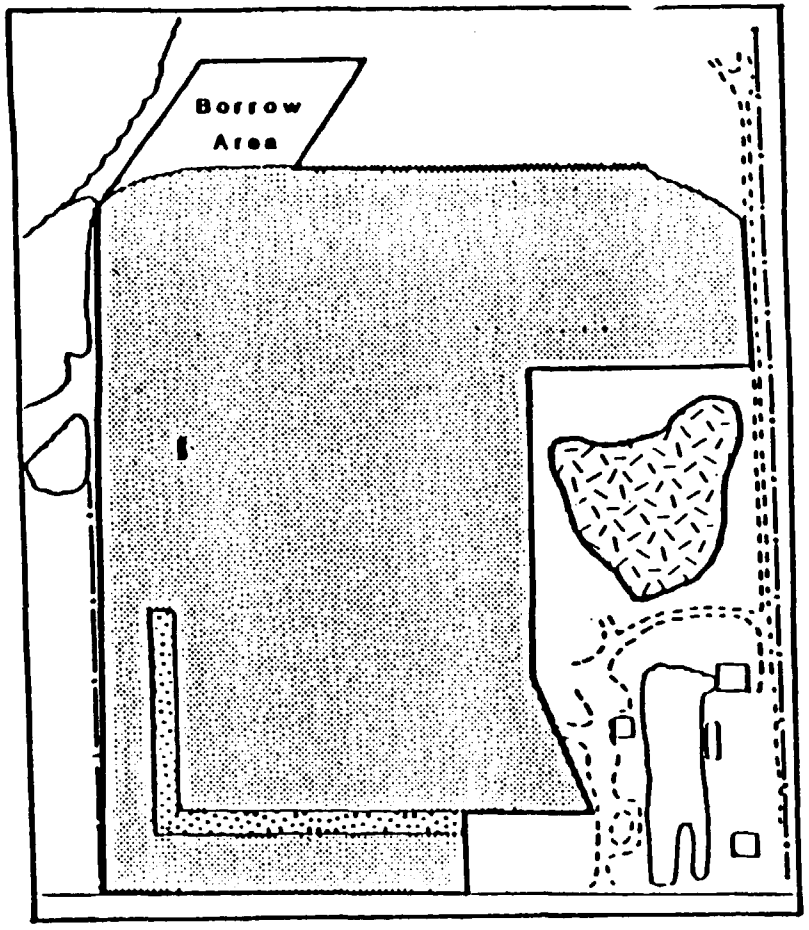
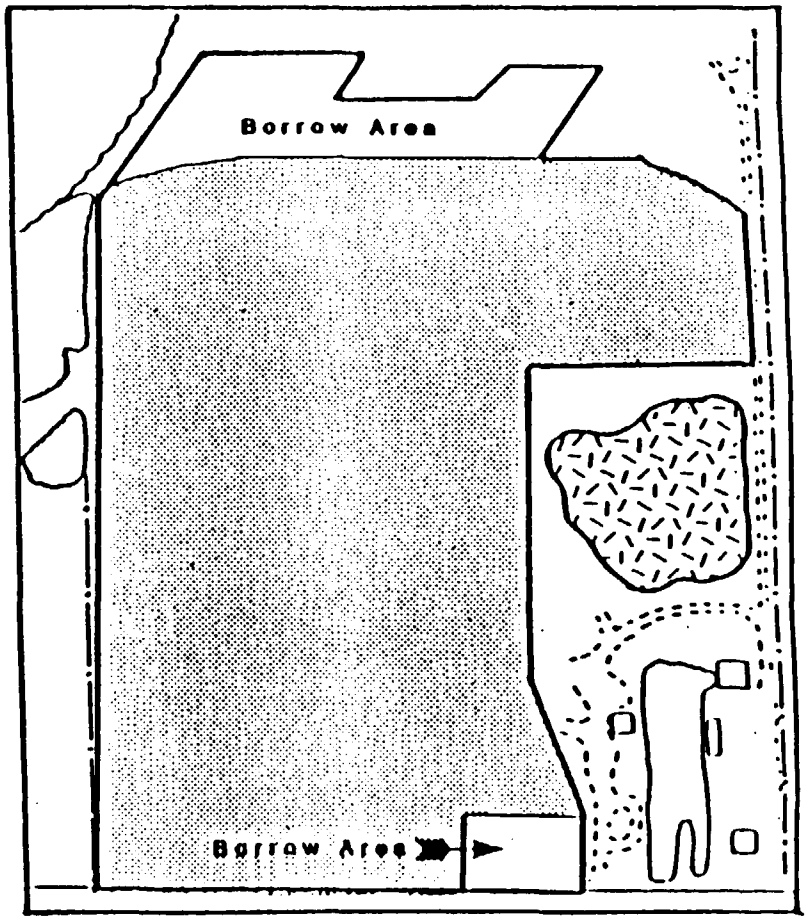
FEASIBILITY STUDY
HISTORY OF SITE OPERATIONS

MALCOLM PIRNIE, INC.

FIGURE 1-3



KUMMER LANDFILL BEMIDJI, MINNESOTA
1981



KUMMER LANDFILL BEMIDJI, MINNESOTA
JULY 1983

CURRENTLY ACTIVE FILL AREA

PREVIOUSLY FILLED AREA

DEMOLITION AREA

NOT TO SCALE

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KUMMER LANDFILL
FEASIBILITY STUDY
HISTORY OF SITE OPERATIONS

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FIGURE 1-4

(TCE), were found in water samples from the down-gradient wells. Numerous VOCs were also detected in samples from shallow potable wells down-gradient of the landfill during sampling by MPCA in 1984.

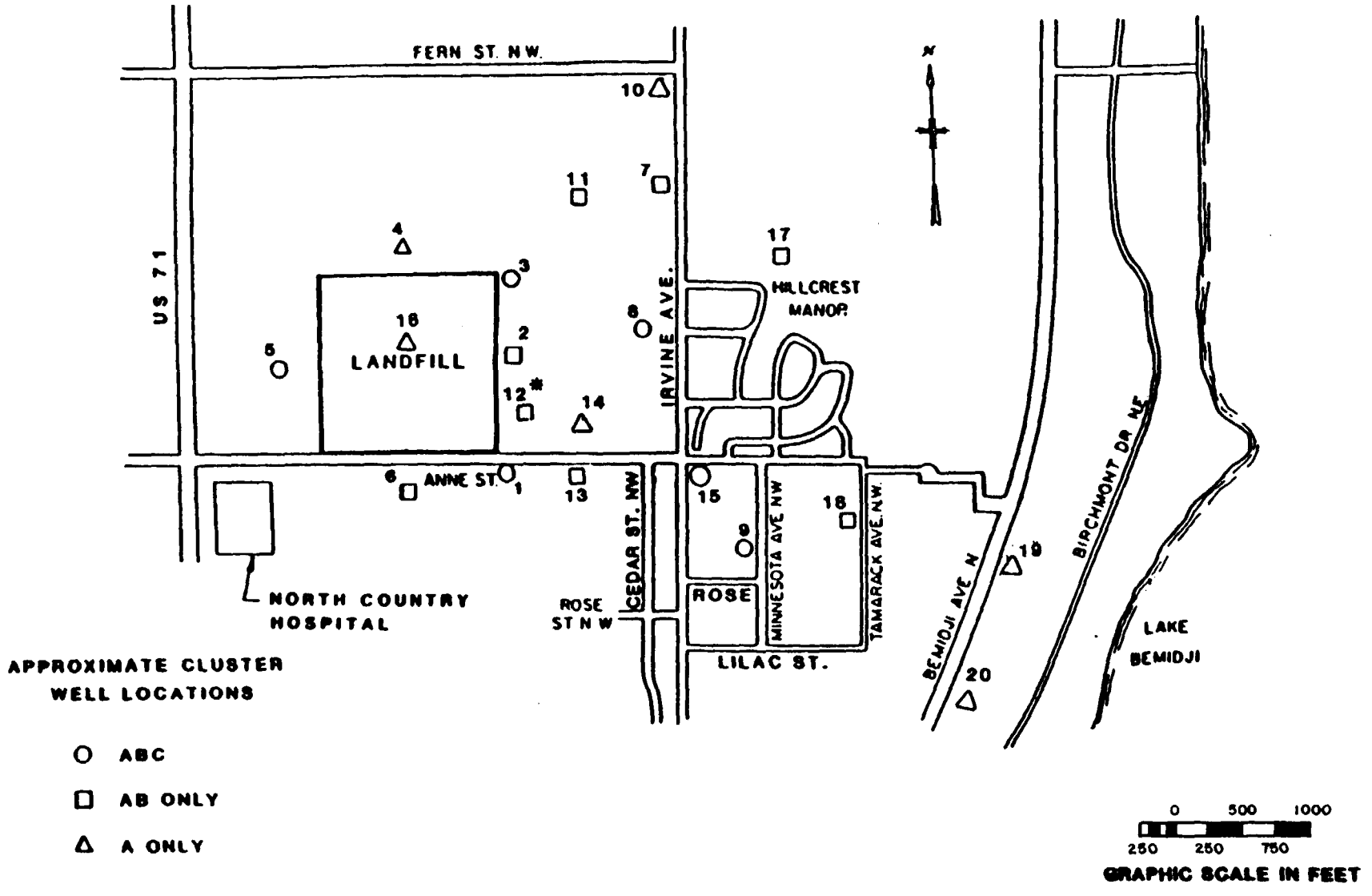
Repeated efforts by MPCA to require the landfill operator to comply with Minnesota rules and regulations and to close the landfill finally culminated in a temporary restraining order on April 4, 1985. The MPCA then issued an Administrative Order on June 25, 1985 closing the landfill, revoking permit SW-31 and requiring the operator to monitor ground water at the site.

1.2.2.3 Remedial Investigations

The Remedial Investigation (RI) began in October 1986. Nine well sites were selected with depths planned to reach 108 feet at the locations shown on Figure 1-5. Twenty-two monitoring wells were installed at those nine sites in clusters of one to three wells of various depths. Sampling of the twenty-two monitoring wells and fourteen selected residential wells was conducted over three sampling rounds.

A supplemental Remedial Investigation program was begun in January 1988. A total of ten new wells and two piezometers were installed down-gradient of the landfill at locations selected to complement data from the original monitoring well network. The ten wells are located at six sites, 10 through 15, and are shown on Figure 1-5. Three additional rounds of samples were collected from selected monitoring wells and analyzed for the volatile fraction of the hazardous substance list (HSL). The results of sampling suggest that VOCs are being introduced into the shallow ground water from the Kummer Sanitary Landfill. These organics include vinyl chloride, trans-1,2 dichloroethene, PCE, TCE, benzene, ethyl benzene, and xylene. Analyses for inorganic constituents show that contaminants typically found in landfill leachate are present in concentrations significantly higher in down-gradient monitoring wells than in the upgradient wells. These constituents include aluminum, arsenic, barium, calcium, iron, magnesium, manganese, nickel, nitrates, potassium and sodium. Significant differences in specific conductance and pH were also detected between upgradient and down-gradient wells.

Seven additional monitoring wells were installed at five locations (wells 16 through 20 shown on Figure 1-5) during supplemental RI work conducted in June, 1989. A total of sixteen soil borings were also installed. Ten of those borings and one monitoring well were completed in the landfill; the remainder were down-



* 12 IS A SINGLE WELL SCREENED THROUGH BOTH A AND B ZONES

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KUMMER LANDFILL FEASIBILITY STUDY

APPROXIMATE CLUSTER WELL LOCATIONS

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FIGURE 1-5

gradient from the landfill. A sampling round which includes all of the old and new monitoring wells was completed in June 1989.

Supplemental trenching activities were completed within the landfill area in May 1990. The purpose of the trenching was to verify the areal extent of fill. The trenching results, presented in Appendix A, largely support the history of fill operations depicted in Figure 1-2 through 1-4.

Ground water contamination appears to be limited to water which has moved beneath the fill in the upper 30 to 50 feet of the aquifer. Ground water samples from the shallow wells indicate a contamination plume extending east-northeast to MW-7. Another component of the plume extends to greater depth and trends east-southeast from the Kummer landfill site.

Soil samples collected around the landfill during the RI did not show measurable contamination. Some common laboratory contaminants were present at concentrations lower than detection limits.

1.2.3 Nature and Extent of Contamination

Ground water at the Kummer Sanitary Landfill site is contaminated predominantly with volatile organic compounds (VOCs) and some inorganic constituents. The contamination is most likely the result of precipitation infiltrating through the permeable landfill cover and coming in contact with the waste, or of the waste being in direct contact with ground water. Specific contaminants may also result from anaerobic degradation of VOCs. The exact nature and state of materials within the landfill is not known.

1.2.3.1 Water

Surface water was not present on-site during sampling surveys conducted during the RI. The closest occasional surface water to the landfill area are a pond located in a former borrow area immediately north of the fill area and two ditches along the south and west perimeter of the fill area. Given the nature of site problems, it is unlikely that surface water, when present, is adversely affected.

Based on historic data and results from the RI, ground water contamination is of primary concern at this site. Wells upgradient of the landfill have shown no contamination, while twenty five halogenated and nonhalogenated organic compounds were detected in down-gradient monitoring wells and private wells. The range of concentrations of these organics in monitoring and residential wells prior to 1986 are shown in Table 1-1. Concentrations of these organic compounds

TABLE 1-1
KUMMER SANITARY LANDFILL, MINNESOTA

VOLATILES FOUND IN GROUND WATER PRIOR TO 1986

	Lowest	Highest
Methylene Chloride	1.0	46.0
1,1-Dichloroethane	0.3	5.4
1-2-Dichloroethylene (total)	0.2	27.0
1,1,2-Trichloroethane	0.2	2.7
Trichlorofluoromethane	0.2	5.6
1,1-Dichloroethylene	0.2	1.7
1-2,Dichloropropane	0.2	1.7
Vinyl Chloride	*	*
Chloromethane	*	*
Dichlorofluoromethane	*	*
Bromomethane	*	*
1,2-Dichloroethane	0.1	4.2
1,1,1-Trichloroethylene	0.2	8.8
Dichlorodifluoromethane	*	*
Acetone	16.0	100.0
Ethyl Ether	0.1	60.0
Benzene	0.3	3.1
Toluene	0.5	6.8
Total Xylenes	0.6	8.2
Tetrahydrofuran	0.5	130.0
Ethyl Benzene	0.5	8.0
1,1,2,2-Tetrachloroethylene	2.0	16.0
Chloroform	0.2	2.4
Chloroethane	*	*
1,1,2,2,-Tetrachlorethane	2.0	4.6
1,2-Dibromomethane	0.4	0.7
Bromodichloromethane	0.2	0.7
1,2-Dibromoethane	0.4	0.7
Trichloroethylene	0.2	2.8
Methyl Isobutyl Ketone	5.0	6.0
1,1-Dichloro-1-Propane	0.2	1.8

All values in micrograms/liter.

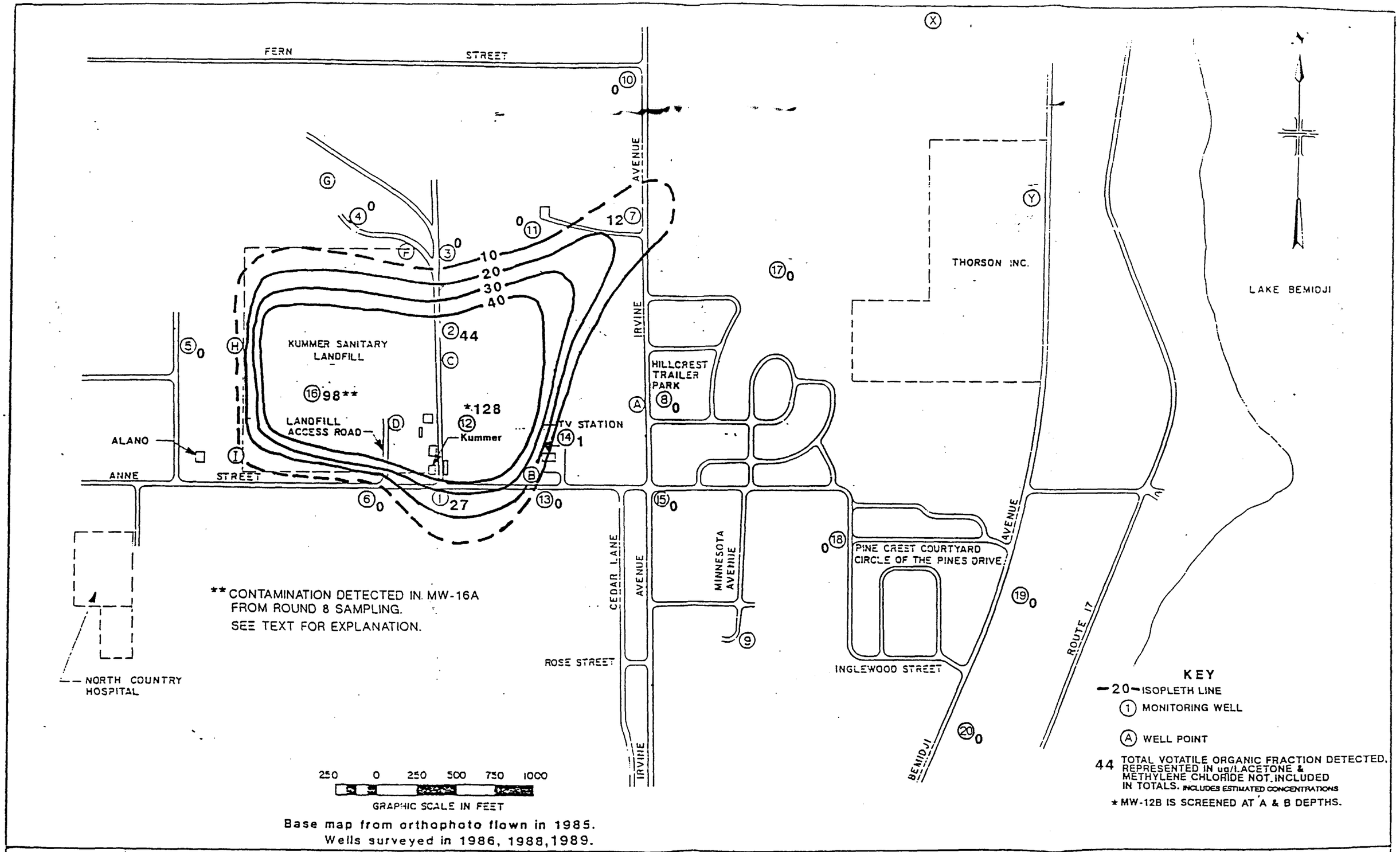
* If no Lowest-Highest value is given, the volatile organic compound was detected as a peak below the detection level.

in the down-gradient wells ranged from barely detectable to upwards of 130 ug/L (tetrahydrofuran). The highest concentration of an organic compound found in a residential well was 46 ug/L (methylene chloride). Otherwise, most of the organic compounds were found at concentrations below 10 ug/L. The data obtained prior to 1986 indicate an area of ground water contamination southeast of the landfill.

Sampling of additional monitoring wells installed in October 1986, and selected residential wells, confirmed earlier findings that the VOCs are being introduced into the ground water from the Kummer Landfill. This is also evident from significantly higher concentrations of inorganic compounds in down-gradient wells as compared to upgradient wells. Total VOC concentration isopleths, based on 1989 sampling results, are shown in Figures 1-6, 1-7, and 1-8. Figure 1-6 corresponds to A depth wells, generally screened in the upper 10 feet of the aquifer. Contamination in B depth wells, below the A zone and separated by a layer of clay and silt, is shown on Figure 1-7. Contamination in the deepest C zone, located above bedrock, is limited to one location as shown on Figure 1-8. In both private and monitoring down-gradient wells, based on data collected through 1989, the range of concentrations of VOCs which have been identified as contaminants of concern are:

	Range Detected in Ground water (ug/L)
- Tetrachloroethene (PCE)	1.0 - 12
- Trichloroethene (TCE)	1.0 - 6.8
- Trans-1,2-Dichloroethene (tDCE)	1.3 - 35
- Vinyl Chloride	3.0 - 94
- Benzene	1.0 - 6

The contamination appears to be limited to water which has moved beneath the fill in the upper 30 to 50 feet of the aquifer. An upward vertical hydraulic gradient exists east of the landfill which retards the movement of contaminants into deeper portions of the aquifer in this area. Based on results of ground water modeling contained in Appendix B, the extent of ground water contamination is believed to be limited to a zone east and slightly north and south of the landfill, perhaps extending to the east of Irvine Avenue. The spatial distribution of the plumes is likely due to variations in hydraulic conductivity and porosity within the fill material. The isopleths are averaged and do not indicate variations in concentration with time, although it is possible that contaminants are released as pulses corresponding with rainfall events.



Base map from orthophoto flown in 1985.
Wells surveyed in 1986, 1988, 1989.

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MINNESOTA POLLUTION CONTROL AGENCY

CONTAMINANT ISOPLETH MAP
A - DEPTH WELLS - ROUND 7

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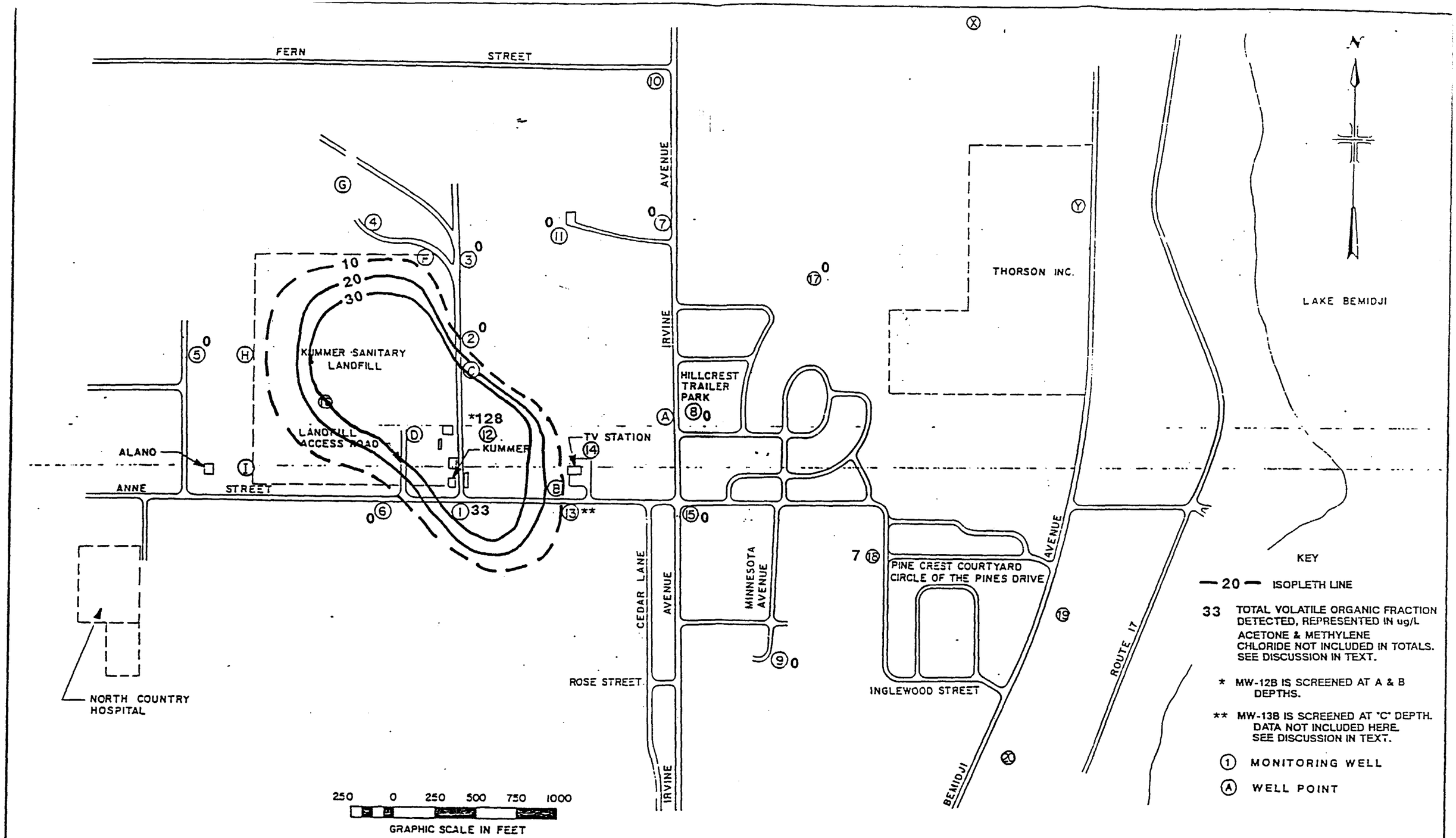
FIGURE 1-6



Base map from orthophoto flown in 1985.
Wells surveyed in 1986, 1988, 1989.

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MINNESOTA POLLUTION CONTROL AGENCY

CONTAMINANT ISOPLETH MAP
B-DEPTH WELLS - ROUND 7

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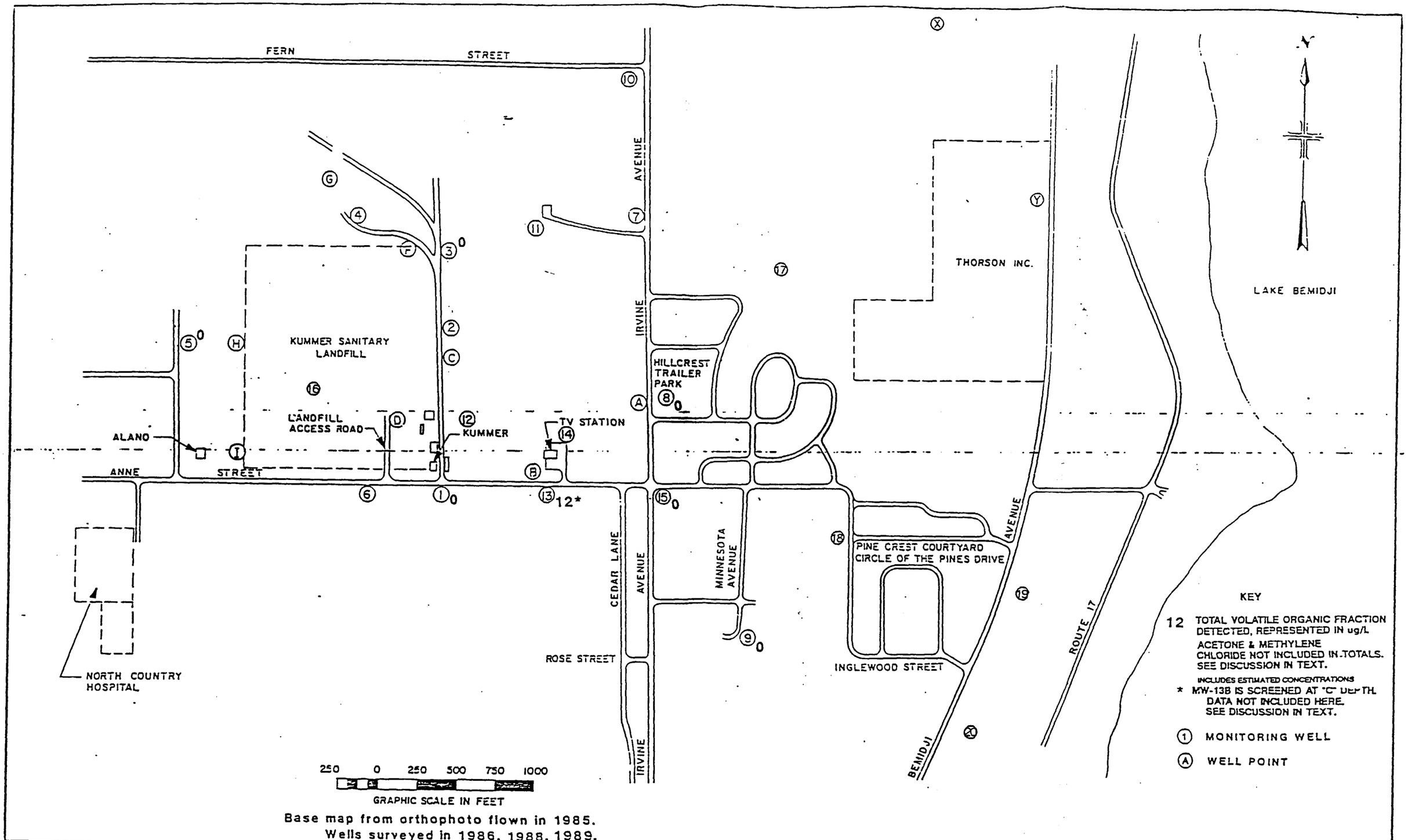
FIGURE 1-7



Base map from orthophoto flown in 1985.
Wells surveyed in 1986, 1988, 1989.

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KUMMER LANDFILL FEASIBILITY STUDY
MINNESOTA POLLUTION CONTROL AGENCY

CONTAMINANT OCCURRENCES
C-DEPTH WELLS - ROUND 7

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FIGURE 1-8

The area of ground water contamination was modeled in early 1990. The purpose of the modeling was to estimate the impact of the plume as it migrated toward Lake Bemidji, and to investigate the impact of remedial action alternatives on contaminant distribution within the aquifer. Ground water modeling results are presented in Appendix B.

Additional information on ground water contamination and ABC depth profiles is given in the RI report.

1.2.3.2 Air

The contaminants of primary importance described in Section 1.2.3.1 may be present in the landfill in either bulk quantities or distributed throughout the landfill in small amounts. In addition, vinyl chloride is probably present as a result of degradation of those same contaminants. Air impacts from gas emissions from the landfill were not quantified, although some releases are likely because of probable presence of these volatiles in the landfill, their lack of containment (as evidenced by their presence in ground water samples obtained from off-site locations), and the lack of an impermeable landfill cover.

The air investigation conducted during the Kummer RI was limited to real-time ambient monitoring during drilling activities. The monitoring was performed as an on-going health and safety requirement and to assist in the selection of subsurface soil samples. Air monitoring using an HNu photoionization instrument was conducted in the immediate work area. No positive HNu readings were recorded during drilling activities. Two hits were recorded during supplemental trenching. It is recognized, however, that a photoionization detector does not provide compound specific readings, and the minimum detection limit of this instrument for VOCs is far higher than the concentrations of concern. Therefore based on the investigative activities conducted, it is not presently possible to determine what constituents, and their concentrations, may be found in landfill gas emissions.

Air emissions are being considered under the OU2 cover system. The OU2 design includes the installation of gas vents and gas monitoring wells. As part of required maintenance and monitoring activities, VOC monitoring can be added to methane monitoring.

1.2.3.3 Soil

Three soil sediment samples were collected from the pond located in a borrow area adjacent to the north side of the landfill area, and two ditches immediately

adjacent to the south and west perimeters of the landfill area. The samples were submitted for quantitative HSL analysis. Analyses of these three samples did not indicate contamination except for common laboratory contaminants. It has been assumed that the source of contamination detected in ground water is mixed municipal refuse located in the Kummer Sanitary Landfill. Since this material cannot readily impact surrounding surface soils, it can be reasonably concluded that surface soils from areas surrounding the landfill are not contaminated.

Wetland areas to the north and northeast of the landfill have not been studied for the presence of site contaminants. It is unlikely that fluctuations in contaminated ground water levels can significantly impact soil quality.

1.2.4 Contaminant Fate and Transport

It appears that the main pathways of contaminant migration are by the leaching of waste in the landfill from infiltrating precipitation and by the direct contact of waste with ground water. Movement of ground water under the landfill from west to east conveys contaminants off-site. Even though the landfill has been closed for several years, this process apparently is still on-going as evidenced by contaminants still found immediately down-gradient of the landfill. Ground water modeling results suggest contaminants will persist in the area immediately downgradient of the landfill because of a clay layer which slows plume movement. The slow movement of ground water also contributes to contaminant concentrations within the monitoring network that have been relatively constant over the 8 rounds of ground water sampling. The following paragraphs describe the fate and transport of the contaminants of concern as identified in Section 1.2.3.1.

The RI identified a number of indicator parameters for the subject site. The indicator selection is designed to identify the "highest risk" contaminants at the site so that the public health evaluation and subsequent remediation is focused on the chemicals of greatest concern. The indicator contaminants are chosen based on their toxicity, mobility and quantity and are listed below:

Chlorinated ethene-based chemicals

- Tetrachloroethene (PCE)
- Trichloroethene (TCE)
- Trans-1,2-dichloroethene (tDCE)
- Vinyl chloride

BTX based chemicals

- Benzene

The following paragraphs characterize the above chemicals in terms of environmental fate and biological processes including toxicity.

Chlorinated Ethene-Based Chemicals

PCE and TCE are suspected carcinogens which, in terms of relevant potency, rank in the lowest quartile among 55 suspected or known carcinogens evaluated by the USEPA Carcinogen Assessment Group (USEPA 600/8/84/026F). Vinyl chloride and benzene are known carcinogens, while tDCE has not been identified as a carcinogenic compound. Important physical properties of these five compounds are shown in Table 1-2. Degradative transformation of PCE through TCE and through one or more dichloroethene intermediates such as tDCE occurs through both chemical and biological processes. (Science Appl. Inter. Corp. 1985. Summary of available information related to the occurrence of vinyl chloride in ground water as a transformation product of other volatile organic chemicals. Prepared for the U.S. EPA SAIC, McLena, VA.) Biological degradation is being increasingly studied, and there are many recent reports in the literature. Many factors, such as temperature, pH, type and number of microorganisms present, availability of oxygen, and the chemical concentration of contaminants may affect the transformation or rate of transformation.

In soils, especially in soils of low organic content, the chlorinated ethenes will be transported into ground water. PCE and TCE adsorb to soils with high levels of organic content. Sorption is probably an insignificant fate for tDCE and vinyl chloride. It is uncertain if PCE and TCE bounded to organic material can be easily biodegraded. The most important transport and fate process for the chlorinated ethenes in the upper layer of soil and surface water is probably volatilization into the atmosphere. The chlorinated ethenes can be bioaccumulated to some degree and there is some evidence that they can be metabolized by higher organisms. Bioaccumulation and biodegradation are not important environmental fate processes for vinyl chloride.

Benzene

Sorption, leaching and biodegradation are environmental fate processes for benzene introduced to soils. The octanol/water partition coefficient for benzene indicates that it will adsorb to sedimentary organic material and sorption processes are likely removal mechanisms in both ground water and surface waters.

TABLE 1-2
KUMMER SANITARY LANDFILL, MINNESOTA

PHYSICAL CHARACTERISTICS OF CONTAMINANTS OF CONCERN

Contaminant	Molecular[1] Weight	Specific[1] Gravity	Solubility[1] In Water (mg/L)	Henry's Law[2] Constant	Vapor[1] Pressure (mm Hg)
Tetrachloroethene (PCE)	165.83	1.6227	175	0.295	17.8
Trichloroethene (TCE)	131.29	1.4642	1,000	0.116	75
Trans-1,2-Dichloroethene (tDCE)	97.0	1.270	6,300	0.093*	200
Vinyl Chloride	62.50	0.9195	9,150	265	2660
Benzene	78.11	0.879	1,780	0.106	100

[1] Table B-1 Chemical/Physical Properties. EPA 560/4-88-002

[2] Unitless. Crittenden, J. A. et.al. Using GAC to Remove VOCs from Air Stripper Off-Gas. J. AWWA. 80:73, (1988).

* Estimated from the published value for cis-1,2-dichloroethene

Benzene has a relatively high water solubility and a low soil-water distribution coefficient; therefore, benzene is expected to leach from soils of low organic content. Benzene may be utilized as a source of carbon by some bacteria. Gradual biodegradation by a variety of microorganisms probably occurs, the rate of which may be enhanced by the presence of other hydrocarbons.

Volatilization is the primary transport process for benzene introduced to surface water. Environmental conditions, such as water turbulence, affect the rate of volatilization. Bioaccumulation in aquatic organisms is low at these observed environmental concentrations. Once introduced to the atmosphere, benzene may be rapidly photooxidized. Photolysis is an unlikely fate process.

1.2.5 Public Health Assessment

The principal pathway of migration of the contaminants of concern and subsequent human exposure is through the ground water. Use of ground water for drinking or cooking results in ingestion exposure. However, the alternative water system is thought to have virtually eliminated current human exposure through ingestion. The release of VOCs from bath or shower water can result in inhalation exposure, although at the concentrations observed in the monitoring and residential wells at the site, it is unlikely to pose any significant risk of inhalation exposure. Skin adsorption during bathing and routine washing activities does not appear to be a significant exposure pathway due to the high volatility of the contaminants. The alternative water system also eliminates inhalation and adsorption exposure from shower and washing. Exposure due to inhalation or ingestion of contaminated soils is not discussed in this section because it is an unlikely source of exposure.

The maximum concentrations of the chemicals of concern in ground water from private supply wells and monitoring wells, determined during the RI, are presented in Table 1-3. This table also compares these concentrations to the USEPA drinking water maximum contaminant levels (MCLs) developed under the Safe Drinking Water Act, the Minnesota Department of Health (MDH) Recommended Allowable Limits (RALs, 1988), and to other criteria as required by USEPA (USEPA, 1986).

MCLs are maximum permissible levels of contaminants that can be present in water delivered to the user of a public water supply. They represent allowable lifetime exposure levels for a 70 kg adult ingesting 2 liters of water per day. Other daily sources are considered in the development of MCLs and a margin of safety is added to protect the more sensitive members of the population. The

TABLE 1-3
KUMMER SANITARY LANDFILL, MINNESOTA

Comparison of Contaminant Concentrations in
Ground Water to Applicable Criteria
(X denotes exceedance; all units in ug/L)

Contaminant	Well Type	Maximum Contaminant Concentration	MCLS	Other Criteria				
				MCLGs	PMCLs	PMCLGs	RALs	AWQC
Tetrachloroethene (PCE)					5	0	6.6	0.88
	Private	7.5			X	X	X	X
	Monitoring	12			X	X	X	X
Trichloroethene (TCE)			5	0			31.0	2.7
	Private	6.8	X	X				X
	Monitoring	4.0		X				X
trans-1,2-Dichloroethene (tDCE)					100	100	70	NA
	Private	35						
	Monitoring	7.6						
Vinyl chloride			2	0			0.15	2.0
	Private	41	X	X			X	X
	Monitoring	94	X	X			X	X
Benzene			5	0			7	0.67
	Private	LT 1.3		X				
	Monitoring	6.0	X	X				X

Notes:

SWQ - Surface Water Quality Criteria for Lake Bemidji
MCLs and MCLGs - USEPA Maximum Contaminant Levels and Maximum Contaminant Level Goals (MCLs for PCE and tDCE are proposed)
PMCLs and PMCLGs - USEPA Proposed Maximum Contaminant Levels and Proposed Maximum Contaminant Level Goals
RALS - Minnesota Department of Health Recommended Allowable Limits
NA - Not available
LT - Less than

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MCLs incorporate technological and economic criteria in addition to health factors. MCLs have been promulgated for some of the contaminants of concern at the Kummer site. The maximum TCE and vinyl chloride concentrations detected in the private supply wells exceed the MCLs. The maximum vinyl chloride and benzene concentrations detected in the monitoring wells exceed the MCLs.

The other criteria presented in Table 1-3 are USEPA maximum contaminant level goals (MCLGs), proposed MCLs and proposed MCLGs developed under the Safe Drinking Water Act, Minnesota Department of Health (MDH) Recommended Allowable Limits (RALs, 1988), and USEPA ambient water quality criteria (AWQC) for the protection of human health. MCLGs, entirely health-based, are developed by USEPA as part of the process for setting MCLs. They represent the maximum concentrations of contaminants in drinking water at which no known or anticipated adverse effect on the health of persons occur, and they include a margin of safety. While MDH indicates that the RALs apply only to private water supply, they are compared to all the data presented in Table 1-3. The RALs for systemic toxicants, in this case tDCE, are based on the application of safety factors to accepted allowable daily intakes; for compounds classified as known or probable carcinogens, RALs have been calculated at a 10^{-5} (one in one hundred thousand) lifetime incremental risk level. Federal AWQC are estimates of ambient surface water concentrations that will not result in adverse human health effects.

MCLGs of zero have been established for the carcinogens vinyl chloride and benzene. The maximum concentrations of these contaminants in ground water from the monitoring wells exceed the goals. The RALs for PCE and vinyl chloride are also exceeded, indicating lifetime incremental cancer risks greater than one in one hundred thousand (10^{-5}). PCE, TCE, vinyl chloride and benzene levels in ground water exceed the AWQC.

Although not presented in Table 1-3, an inorganic constituent was also found to exceed established Federal MCLs. At two monitoring well locations barium exceeds the current Safe Drinking Water Act (SDWA) MCL of 1000 ug/L. The RCRA MCL for barium is 100 mg/L, and is not exceeded in the monitoring network. Other inorganic compounds are below RCRA limits. However, an increase in the barium SDWA MCL to 5000 ug/L is proposed. Barium concentrations are below this proposed higher MCL.

2.0 IDENTIFICATION AND SCREENING OF TECHNOLOGIES

In this chapter general remedial technologies are screened based on applicability to environmental problems and remedial actions at the Kummer landfill site. Remedial action objectives are defined, and clean-up criteria are developed from applicable or relevant and appropriate environmental requirements (ARARs) and guidelines. The general area of response is also established.

2.1 REMEDIAL ACTION OBJECTIVES

The objectives for remedial action at a CERCLA site are traditionally expressed as goals for control of further contaminant migration through pathways such as ground water, surface water, air, or soils. Ground water is the quantified pathway for contaminant migration at the Kummer Sanitary Landfill site. Surface water and air are not currently pathways of exposure at the site. However, these pathways may be impacted by ground water technologies employed during remedial action. Therefore, remedial action objectives are presented on Table 2-1 for ground water, surface water, and air pathways.

Ground Water

The objectives for ground water remediation are two-fold. The first objective is to provide a safe drinking water supply for residents down-gradient of the landfill. The criteria for this objective is that residents receive water compliant with the Safe Drinking Water Act Maximum Contaminant Levels (MCLs). The alternate water supply provided by the OU1 remedial action effectively achieves this objective.

A second objective is to prevent significant impacts on surface water quality at Lake Bemidji. The criteria are proposed surface water quality standards developed by the MPCA Water Quality Division for Lake Bemidji. A memorandum discussing these criteria is included in Appendix C. Also considered is Minnesota Rule 7050.0180 and 7050.0185 on nondegradation of Lake Bemidji and the Mississippi River. The corresponding surface water quality criteria for organic and inorganic compounds are listed in Tables 2-2 and 2-3, respectively. These criteria are used to assure that remedial actions at the Kummer site provide long-term protection of public health.

TABLE 2-1
KUMMER SANITARY LANDFILL, MINNESOTA

OBJECTIVES FOR REMEDIAL ACTION

Pathway	Objectives	Criteria
Ground Water	Provide a safe drinking water supply for down-gradient residents.	Residents receive water compliant with Safe Drinking Water Act Maximum Contaminant Levels (MCLs).
	Prevent significant impacts on surface water quality.	MPCa Surface Water Quality Criteria for Lake Bemidji and the Mississippi River.
Surface Water	Prevent adverse impact on human health due to use of surface water as a drinking supply or ingestion of fish. Prevent degradation of downstream water quality. Applies to non-point or point source discharges during implementation of ground water remedial technologies.	Clean Water Act best available technology economically achievable (BAT). MPCA Surface Water Quality Criteria for Lake Bemidji and the Mississippi River. Discharge cannot be greater than 1% above baseline quality.
Air	Prevent chronic adverse impact on human health during implementation of ground water material technologies.	Annual average ground level concentrations of volatile organics corresponding to incremental cancer risk of 10^{-5}.
	Prevent acute and subchronic adverse impact on human health during implementation of ground water remedial technologies.	Maximum volatile organic concentrations no greater than Threshold Limit Value (TLV) time-weighted average for work place.

TABLE 2-2
KUMMER SANITARY LANDFILL, MINNESOTA

COMPARISON OF ARARs AND OTHER CRITERIA TO BE CONSIDERED FOR ORGANIC CONTAMINANTS

Pathway	ARARs	Contaminant	ARAR Concentration	Units	Other Criteria to be Considered			
Ground Water	SWQC			ug/L	RALs	ILs	MCLs	10^{-5} CA Risk
		1,1,2,2-tetrachloroethylene (PCE)	8.9		6.6	1.7	5	8
		1,1,2-trichloroethylene (TCE)	120		31.0	7.8	5	27
		trans - 1,2-dichloroethylene (tDCE)	50		70	17	100	NA
		vinyl chloride	7.6		0.15	0.037	2	20
		benzene	38		7	3	5	6.6
Surface Water	NPDES SWQC			ug/L	AWQC	HSWA		
		1,1,2,2-tetrachloroethylene (PCE)	8.9		0.8	See Note		
		1,1,2-trichloroethylene (TCE)	120		2.7			
		trans - 1,2-dichloroethylene (tDCE)	50		NA			
		vinyl chloride	7.6		2.0			
		benzene	38		0.66			
Air	NAAQS			ug/m^3	1% TLV	10^{-5}CA Risk	10^{-6}CA Risk	
		1,1,2,2-tetrachloroethylene (PCE)	NA		3350	4.1	0.41	
		1,1,2-trichloroethylene (TCE)	NA		2700	1.5	0.15	
		trans - 1,2-dichloroethylene (tDCE)	NA		NA	NA	NA	
		vinyl chloride	NA		100	0.28	0.028	
		benzene	NA		300	0.27	0.027	

Notes:

NA	=	Not Available
SWQC	=	MPCA proposed Surface Water Quality standards for Lake Bemidji and the Mississippi River
MCLs	=	Safe Drinking Water Act Maximum Contaminant Levels. Values for PCE and tDCE are proposed.
RALs	=	Minnesota Department of Health Recommended Allowable Limits (1988)
ILs	=	Minnesota Rules mixed municipal solid waste landfill ground water performance Intervention Limits (7035.2815 Subpart 4).
Background	=	Observed contaminant concentrations in up-gradient monitoring wells
10^{-5},10^{-6} CA Risk	=	Concentration corresponding to a lifetime incremental cancer risk of 10^{-5} or 10^{-6} (ground water numbers from EPA 440/5-86-001, USEPA Quality Criteria for Water 1986)
NPDES	=	National Pollutant Discharge Elimination System (also Minnesota Rules Chapter 7001 and Minnesota Statutes Chapters 115 and 116)
AWQC	=	USEPA Ambient Water Quality Criteria - drinking water and fish consumption (10^{-6} incremental cancer risk)
TLV	=	Threshold Limit Value work-shift time-weighted average
NAAQS	=	National Ambient Air Quality Standard
<	=	Compound present at less than detection limit
HSWA	=	Land ban on disposal of untreated and certain liquid wastes in land-based waste management units.

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TABLE 2-3
KUMMER SANITARY LANDFILL, MINNESOTA

COMPARISON OF ARARs AND OTHER CRITERIA TO BE CONSIDERED FOR INORGANIC CONTAMINANTS

Pathway	ARARs	Contaminant	ARAR Concentration	Units	Other Criteria to be Considered			
Ground Water	SWQC			ug/L	RALs	ILs	MCLs	10^{-5} CA Risk
		Aluminum	125				50(s)[1](p)[2]	N/A
		Arsenic	30		50	12.5	50	0.022
		Barium	N/A		1,500	375	1,000[3]	N/A
		Iron	1000		NA		300(s)[1]	N/A
		Manganese	1000		NA		50(s)[1]	N/A
		Nickel	213		150	38		N/A
		Nitrate-N	N/A		10,000	2,500	10,000	
Surface Water	NPDES SWQC			ug/L	AWQC	HSWA		
		Aluminum	125		N/A	See Note		
		Arsenic	30		.0022			
		Barium	N/A		1,000			
		Cobolt	10					
		Copper	13.6					
		Iron	1000		300			
		Manganese	1000		50			
		Mercury	0.0069					
		Nickel	213		13.4			
		Nitrate-N	N/A		10,000			
		Silver	1					
		Zinc	155					

Notes:

N/A = Not Available
SWQC = MPCA proposed Surface Water Quality standards for Lake Bemidji and the Mississippi River.
RALs = Minnesota Department of Health Recommended Allowable Limits
ILs = Minnesota Rules mixed municipal solid waste landfill ground water performance Intervention Limits (7035.2815 Subpart 4)
Background = Observed contaminant concentrations in up-gradient monitoring wells
10^{-5},10^{-6} CA Risk = Concentration corresponding to a lifetime incremental cancer risk of 10^{-5} or 10^{-6} (ground water numbers from EPA 440/5-86-001, USEPA Quality Criteria for Water 1986)
NPDES = National Pollutant Discharge Elimination System (also Minnesota Rules Chapter 7001 and Minnesota Statutes Chapters 115 and 116)
AWQC = USEPA Ambient Water Quality Criteria - drinking water and fish consumption (10^{-6} incremental cancer risk)
< = Compound present at less than detection limit
HSWA = Land ban on disposal of untreated and certain liquid wastes in land-based waste management units.
1) These are secondary standards
2) These are proposed standards
3) Proposed MCL for barium is 5000 ug/L

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Other criteria to be considered include:

- Minnesota Department of Health (MDH) Recommended Allowable Limits (RALs)
- Minnesota Rules Section 7035.2815 performance standards for ground water quality at the compliance boundary of a mixed municipal solid waste landfill disposal facility (Intervention Limits)
- Background ground water quality
- Contaminant concentrations corresponding to 10^{-5} increased cancer risk.

These criteria are discussed in Section 2.1.2 of this report.

Surface Water

The remedial action objectives for the surface water pathway are to prevent acute and chronic adverse impacts on human health due to use of surface water as a drinking supply or from ingestion of fish, and to prevent significant degradation of downstream water quality. These objectives are applied to any remedial action alternative which includes ground water discharge and possible treatment. Also applicable from the Clean Water Act are the substantive requirements of the National Pollutant Discharge Elimination System (NPDES) discharge limits with respect to treatment technology. Best available technology economically achievable (BAT) is required for toxic and nonconventional pollutants such as those present in the ground water, in accordance with 40 CFR 122.44(a). The criteria for discharge quality are the proposed surface water quality standards for Lake Bemidji presented on Tables 2-2 and 2-3.

The RCRA Hazardous and Solid Waste Amendments of 1984 (HSWA) provide criteria to be considered if treated ground water is discharged to landfills, surface impoundments, or similar facilities. HSWA disallows any disposal of untreated liquid hazardous waste in land-based management units after 1992. Land disposal of certain waste streams, including chlorinated solvents and certain metals, was banned as of July 1987. All injection well disposal was banned as of August 1988 unless specific locations are approved by USEPA as safe disposal sites. Wastes with less than one percent of certain organic solvents (such as those present in the Kummer site ground water) were granted a two-year variance from the ban.

Air

Air quality may also be impacted in remedial alternatives which include ground water withdrawal and treatment. The air pathway remedial action objective is to prevent acute or chronic adverse impact on human health via inhalation of

volatile organic ground water contaminants. Short-term air quality criteria presented on Table 2-2 are based on a generalized MPCA air quality guideline for the approval of a new facility. This guideline is one percent of the threshold limit value (TLV) for toxic compounds. One percent of the time-weighted average (TWA) for 40-hour workweek exposure to ground water contaminants is an appropriate criteria for total emissions which is protective of on-site worker health. Also considered is the Office of Solid Waste and Emergency Response (OSWER) Directive 9355.0-28 on Control of Air Emissions from Superfund Air Strippers. This directive is discussed further in section 3.4.1.1 of this report.

Benzene and vinyl chloride are listed hazardous air pollutants under Section 112 of the Clean Air Act. Emission standards have been proposed for waste management units that contain 10% by weight of benzene and for manufacturing units of vinyl chloride. These standards will probably not be applicable to remediation technologies at the Kummer site, but are to be considered. Section III(b) of the Clean Air Act also sets performance standards for new sources of air emissions.

Chronic effects air quality criteria are based on the 10^{-5} and 10^{-6} increased cancer risk for volatile organic contaminants present in ground water. The 10^{-5} requirement is based upon MPCA air quality permits issued pursuant to Minnesota Statute Section 116.07, Subdivision 4.a. These numbers are calculated based upon the following assumptions:

- 70 kg adult
- air inhalation of 20 m^3/day
- 70 year lifetime exposure
- complete absorption of the inhaled materials to body tissue.

The air quality criteria are fenceline values which are measured at a controlled distance from the source point (such as an air stripping column). A dispersion factor is required to account for average meteorological conditions and expected ambient concentrations for populations at risk. The dispersion modified air quality criteria is conservative for long-term health risks because ground water remediation may require a much shorter time period than the 70 years of exposure used in the criteria calculation.

2.1.1 Contaminants of Concern

The predominant contaminants present in the ground water are volatile organic compounds (VOCs). The following five VOCs were identified as contaminants of concern during the RI because of human health impacts:

- tetrachloroethene (PCE)
- 1,1,2-trichloroethene (TCE)
- trans-1,2-dichloroethene (tDCE)
- vinyl chloride
- benzene

These compounds were selected due to their mobility, frequency of detection in ground water samples, and (with the exception of tDCE) their status as known or suspected human carcinogens.

Inorganic compounds present in the ground water also have regulatory significance. These compounds are:

- aluminum
- arsenic
- barium
- iron
- manganese
- nickel
- nitrate

These inorganics will also be considered in the development of clean-up criteria and remedial action alternatives for the Kummer site ground water.

2.1.2 Ground Water Quality Criteria

Ground water quality clean-up criteria for organic and inorganic compounds are listed in Tables 2-2 and 2-3, respectively. The listed criteria are consistent with the ground water objective to prevent significant impacts on surface water quality. The criteria are used to assure that remedial actions at the Kummer site provide long-term protection of human health and the environment. Possible criteria are discussed below:

Surface Water Quality Criteria - These values have been developed by the MPCA Water Quality Division based on the designation of the Mississippi River as an outstanding Resource Value Water (ORVW). Although Lake Bemidji is within an exempted area, Minnesota Rules 7050.0180 subpart 9 requires that any new or expanded discharge be controlled so as to assure no deterioration of the downstream ORVW. No dilution factor is allowed at the discharge point. A memorandum discussing the surface water quality criteria is presented in Appendix C.

Recommended Allowable Limits - RALs are water quality guidelines provided by the MDH for private water supplies and public water systems. RALs are not promulgated.

Intervention Limits - Intervention limits (ILs) are pollutant concentrations which must not be exceeded at mixed municipal solid waste landfill ground water compliance boundaries. The ILs are contained within solid waste rules promulgated by the State of Minnesota and are calculated as one-fourth of the Minnesota Department of Health (MDH) Recommended Allowable Limits (RALs) for drinking water supply. ILs apply to new and existing landfills, and are criteria to be considered for the inactive Kummer site. In addition the RALs may become the ILs after completion of the RI/FS because of a provision in the rules for alternative standards (Minn. Rules pt 7035.2815 subpt 4 item H.2).

Maximum Contaminant Levels - MCL's are maximum permissible levels of contaminants in water delivered to the user of a public water supply. They are promulgated under the Safe Drinking Water Act, and are applicable when an aquifer is used as a potable water supply.

10^{-5} Increased Cancer Risk - Contaminant concentrations corresponding to 1 in 100,000 incremental cancer risk are also shown in Table 2-2, and where applicable, in Table 2-3. The concentrations are adopted from EPA/440-5-86-001, USEPA Quality Criteria for Water, 1986 (also known as the Gold Book).

The criteria selected for the ground water adjacent and down-gradient from the Kummer landfill are surface water quality criteria. These standards allow any discharge of the ground water plume to Lake Bemidji to achieve the objective of prevention of significant impacts on surface water quality. MCLs are not selected for the aquifer because the alternative drinking water supply provided under OU1 remedial action already achieves these criteria. Adoption of the surface water quality criteria may require a waiver of the State municipal landfill ground water performance criteria, since the proposed criterion for vinyl chloride is greater than the IL or RAL. However, the waiver is acceptable because additional protection of public health and the environment is provided by the alternate water supply in the down-gradient area.

2.1.3 Location and Action Specific ARARs

Other environmental regulations and guidelines to be considered in development of remedial action alternatives include the following:

USEPA and State of Minnesota Ground Water Protection Strategy - The USEPA GWPS discourages further or continued degradation of quality in an aquifer which

serves as an existing or potential source of drinking water. The GWPS is a non-promulgated guideline to be considered. State of Minnesota GWPS guidelines are in draft release. Initiative I (to protect ground water quality now and for the future; to ensure safe drinking water supplies and to prevent ground water contamination by effectively regulating sources of pollution) is applicable. It proposes a nondegradation goal to prevent future impacts. Where ground waters are presently impacted, the first priority is source control. Further clean-up actions are to be considered on a site by site basis.

Discharge to a Publicly-Owned Treatment Works - If remedial action includes discharge of waste or treated effluent to a POTW, the waste stream must be in compliance with local pretreatment regulations. Consideration should be made of the POTW history of compliance with its NPDES discharge permit. The waste stream discharged to the POTW cannot pass-through untreated, interfere with ongoing treatment, contaminate sludge, endanger worker health, cause fire or corrosion, obstruct flow, or cause a significant temperature increase.

Reinjection - The Federal Underground Injection Control program regulations are applicable to possible reinjection of clean or treated ground water. The UIC allows treated ground water to be reinjected into the same formation from which it is withdrawn, provided that reinjection quality is consistent with MCLs.

The MPCA and Minnesota Department of Health (MDH) regulate injection or introduction of substances to ground water. Waiver of several rules is required to reinject ground waters using wells. Fewer regulations govern infiltration ponds.

2.2 GENERAL RESPONSE ACTIONS

The following sections identify the site area where ground water remedial actions might be applied. General response boundaries are defined while taking into account the cover system alternative planned under operable unit 2. The volume and flow of ground water are estimated based on hydrogeological data from the remedial investigation. Representative ground water quality is estimated for comparison to remedial action objectives, screening of remedial technologies, and development of remedial alternatives.

2.2.1 Response Boundaries

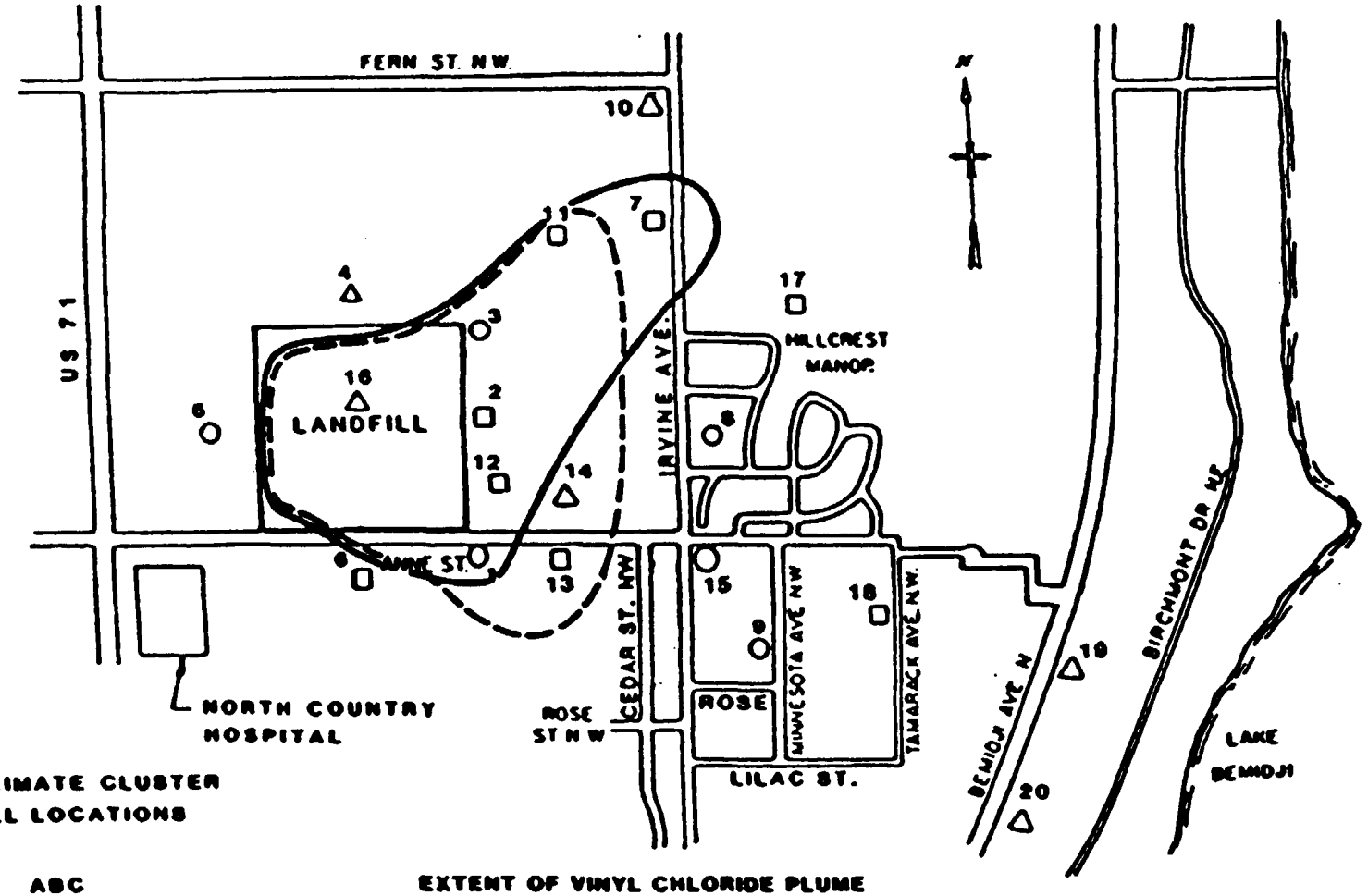
Approximate response boundaries are defined in Figure 2-1. These response boundaries are based on monitoring well locations where contaminant concentration exceeded an MCL. Except for well locations immediately adjacent to the landfill, vinyl chloride is the contaminant which defines the probable boundaries for ground water remedial action. Based on results from monitoring well 16A, located near the center of the landfill, it is expected that all ground water beneath the landfill should be included within the compliance boundary.

2.2.2 Ground Water Volume and Flow

Ground water is flowing beneath the Kummer Landfill in a general west to east direction. A generalized north-south cross-section through the eastern boundary is shown on Figure 2-2. As ground water leaves the eastern perimeter of the landfill boundary, it flows through three saturated facies within the glacial outwash deposits of sand, clay, and gravel. These saturated facies were encountered in wells MW-1, MW-2, MW-3 and MW-12 and are identified as zones A, B, and C, corresponding typically to the well depth nomenclature adopted during the Remedial Investigation. During the RI, the shallow "A" wells were placed to bridge the water table, the intermediate depth "B" wells were placed below any possibly confining clay layers and above any occurrence of till, and the deeper "C" wells were screened below the till.

The upper interval ("A" zone) is located along the top of the water table and has an average saturated thickness of about 10 feet. The second interval ("B" zone) is separated from the "A" zone by a layer of clay and silt, is discontinuous along the eastern boundary, and has an average saturated thickness of about 12 feet. The third interval ("C" zone) extends to the bedrock and has an average saturated thickness of at least 50 feet. Although these zones are fairly well defined along the eastern perimeter of the landfill (see Figure 2-2), they are likely to be hydraulically connected to saturated horizons in other areas of the contaminant plume (See Figure 2-1) and are not considered to be hydraulically distinct.

An aquifer pumping test of the A and B zones was conducted as part of the RI and suggests that the glacial deposits in the area of the contaminant plume have a bulk hydraulic conductivity of about 10 ft/day. Slug tests conducted on well 16A, located in the landfill, indicate a hydraulic conductivity for the shallow A zone of about 10 ft/day. Additional slug tests, conducted on wells in the contaminant plume and screened in the B zone, yielded average values from



APPROXIMATE CLUSTER WELL LOCATIONS

- ○ ABC
- □ AB ONLY
- △ A ONLY

EXTENT OF VINYL CHLORIDE PLUME

- —— A ZONE
- —— B ZONE

0 500 1000
250 250 750
GRAPHIC SCALE IN FEET

THE C ZONE IS ALSO INCLUDED AT WELL LOCATION 1

VINYL CHLORIDE, DCE, AND PCE WERE ALSO DETECTED IN SAMPLING ROUND 8 AT WELL LOCATION 18 B

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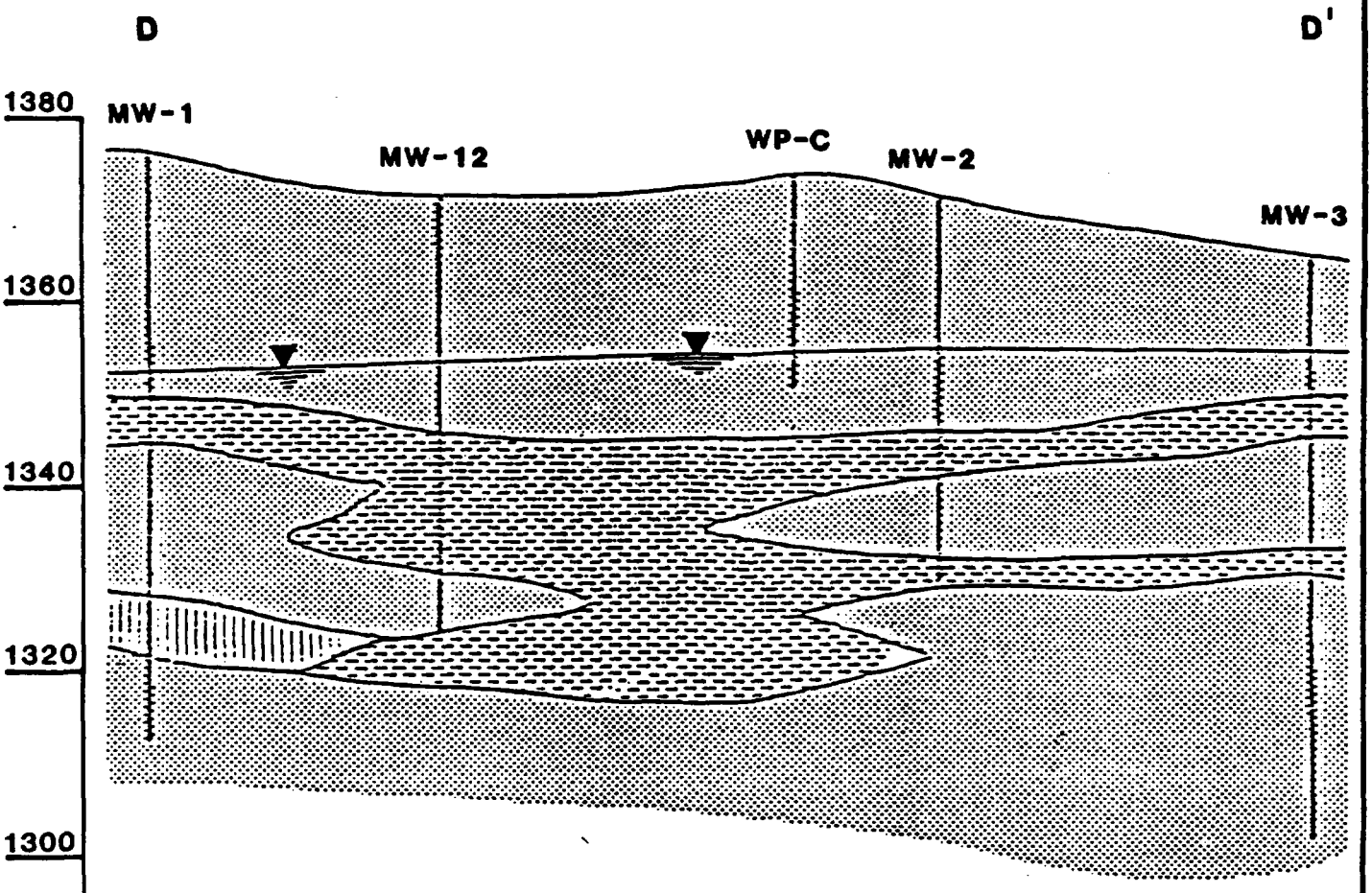
KUMMER LANDFILL GROUND WATER FEASIBILITY STUDY

RESPONSE BOUNDARIES

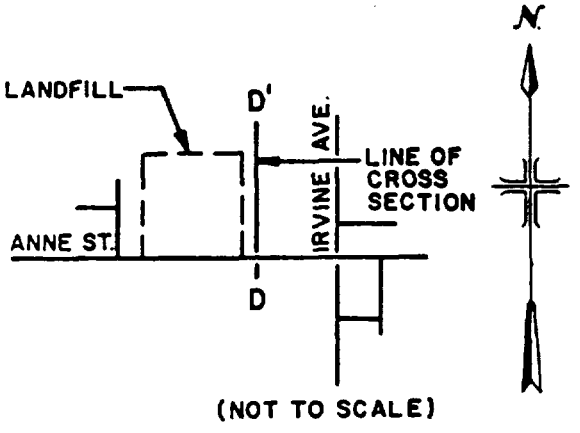
MALCOLM PIRNIE, INC.

FIGURE 2-1

141101



VERTICAL SCALE: 1"=20'
HORIZONTAL SCALE: 1"=250'
VERTICAL EXAGGERATION=12.5 X



KEY

	SAND
	CLAY AND/OR SILT
	TILL (SAND, CLAY, GRAVEL)
▼	WATER TABLE ELEVATION
MW-1	MONITORING WELL NO.
WP-A	WELL POINT

LOCATION MAP

MALCOLM PIRNIE

KUMMER LANDFILL GROUND WATER FEASIBILITY STUDY
REPRESENTATIVE GEOLOGIC CROSS-SECTION

MALCOLM PIRNIE, INC.

FIGURE 2-2

about 20 to 45 ft/day. These values suggest a wide range of hydraulic conductivities due to lithologic variation across the site. Further down-gradient of the plume hydraulic conductivity of the A and B zones appears to be even higher. A slug test was conducted on the C zone at a location just down-gradient of the plume and indicated an average hydraulic conductivity value of 13 ft/day. Based on the pumping test, slug tests, and field observations, representative hydraulic conductivities of the A; B, and C horizons in the contaminant plume are about 10, 20, and 15 ft/day, respectively.

Ground water gradients within the response boundary range from 0.001 to 0.003 ft/ft, with the A zone averaging 0.0027 ft/ft, the B zone averaging 0.002 ft/ft, and the C zone averaging 0.0015 ft/ft. Ground water discharge volumes are calculated for the ground water flowing through a typical cross section of the contaminant plume, the landfill's eastern boundary, by using the formula Q = KIA and converting cubic feet to gallons, where:

Q = Discharge (gal/day)
K = Hydraulic Conductivity (ft/day)
I = Hydraulic gradient (ft/ft)
A = Cross-sectional area of saturated interval (ft^2)

An estimated average of 3,500 gallons per day flows through the A zone, which extends continuously 1,750 feet along the eastern boundary. An average of 6,000 gallons per day is estimated to flow through the B zone.

The C zone is not fully penetrated by any of the monitoring wells, and only the upper 9 feet of saturated thickness is assumed to be impacted by the landfill (wells MW-1C and MW-3C are screened across approximately 9 feet of the C zone). This upper portion of the C zone extends continuously across the eastern landfill boundary and has an estimated discharge volume of 2,500 gallons per day. By combining these three discharge volumes, a total average discharge of up to 12,000 gallons per day is estimated to flow across the contaminant plume cross section.

The contaminant plume includes a large volume of ground water. By multiplying the approximate contaminant plume area (3,600,000 ft^2), the saturated thicknesses of zones A, B, and C (31 feet, which includes all of zone A, all of zone B, and the upper 9 feet of zone C), and the porosity of typical glacial deposits (assuming a range from .20 to .40) a total ground water volume ranging from 167 million to 334 million gallons is estimated.

Ground water velocities beneath the Kummer landfill can be calculated by using the formula V=KI/p, where:

V = Velocity (ft/day)
K = Hydraulic Conductivity (ft/day)
I = Hydraulic gradient (ft/ft)
p = Porosity (assumed to range from .20 to .40)

The ground water velocities of zones A, B, and C are estimated to be 22 to 55 ft/yr, 18 to 109 ft/yr, and 14 to 55 ft/yr, respectively. These velocities were obtained by assuming representative hydraulic conductivities, estimated from a pumping test and slug tests in the contaminant plume area. Higher hydraulic conductivities (up to 45 ft/day) were estimated from slug tests, and indicate that some velocities may approach 250 ft/yr in some small areas. Aquifer hydraulic parameters and physical characteristics are summarized in Table 2-4.

2.2.3 Ground Water Quality

Ground water quality is composited from eight sampling events. Ground water quality beneath the landfill is defined at a single well (MW-16) installed through a trench near the center of the active site fill activity. Samples were collected as follows:

Initial Sampling Program	Dates
Round 1	December 16 and 17, 1986
Round 2	February 18 and 19, 1987
Round 3	April 29 and 30, 1987
Second Sampling Program	
Round 4	February 16, 17 and 18, 1988
Round 5	March 22, 23 and 24 1988
Round 6	September 26 and 27, 1988
Third Sampling Program	
Round 7	June 28 and 29, 1989
Round 8	August 15, 1989

Table 2-5 contains a summary of the organic results found in wells within the approximate response boundary. Values reported are the highest concentration detected in any sampling event. Compounds reported are those which were detected at more than one well location. Low levels of methylene chloride were found in the blanks as well as the samples, and may be due to laboratory contamination. Trace amounts of phthalates were frequently detected, and may have been

TABLE 2-4
KUMMER SANITARY LANDFILL, MINNESOTA

GENERAL AQUIFER HYDRAULIC PARAMETERS - CONTAMINANT PLUME AREA

Parameters	Units	Saturated Interval A	B	C	Combined
Saturated Thickness	ft	10	12	9[5]	31
Hydraulic conductivity[1]	ft/day	10	22-44	13	N/A
Hydraulic conductivity[2]	ft/day	10	10	N/A	10
Representative value	ft/day	10	20	15	N/A
Hydraulic gradient	ft/ft	0.0024-0.0030	0.001-.003	0.001-0.002	N/A
Representative value	ft/ft	0.0027	0.002	0.0015	N/A
Discharge[3]	gal/day	3,100-3,900	3,100-9,400	1,800-3,600	8,000-16,800
Representative value	gal/day	3,500	6,000	2,500	12,000
Volume of ground water	MG[6]	54-108	65-130	48-96	167-334
Representative value	MG[6]	75	90	75[5]	240
Velocity[4]	ft/year	22-55	18-109	14-55	14-109
Representative value	ft/year	40	64	35	45

Notes:

1 From slug tests

2 Bulk value for A and B horizons combined, derived from pumping tests

3 Calculated as Q=KIA

4 Calculated as V=KI/p (p=0.20 to 0.40)

5 Includes only the upper 9 feet of zone C

6 Million gallons

N/A = Not applicable

TABLE 2-5
KUMMER SANITARY LANDFILL, MINNESOTA

SUMMARY OF GROUND WATER QUALITY IN THE RESPONSE AREA

Interval and Compound	Organic Contaminant Concentrations (ug/L) Well Nos. 1	2	3	7	11	12	13	16	AVG
A:									
VOLATILE									
Vinyl Chloride	15	41	16	13	3	94		34	31
Chloroethane		10		3		5		5	6
Methylene Chloride	3.8	5		3.3		3		1	3
t-1,2-Dichloroethene	6.8	3.7	1.4	5.2					4
1,2-Dichloroethene (total)		1		3	1	4			2
Benzene	3	5	2			5		6	4
Tetrachloroethene	1.8			2.2					2
Toluene		3.3				4		4	4
Ethyl Benzene		5.9	1					3	3
Total Xylenes		4.4	2			3		15	6
Total TICS	44	15	9	8		20		20	19
SEMI-VOLATILE									
bis (2-ethylhexyl) Phthalate	12	37	43					4	24
4 Methyl Phenol		10						4	7

Highest concentration of compounds found during 8 sampling rounds.

Average concentration is used for conceptual design of treatment alternatives.

TICs = Tentatively Identified Compounds

Blank space = not detected in any sampling round.

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introduced during sampling and analysis. Table 2-6 contains a summary of the inorganic results from wells within the approximate response boundary.

Well cluster locations as shown in Figure 1-5 are:

- 1: southeast corner of the landfill
- 2: east of and adjacent to landfill
- 3: northeast corner of the landfill
- 4: single well, north of the landfill
- 5: west of the landfill
- 6: south of the landfill
- 7: 1500 feet northeast of the landfill
- 8: 1500 feet east of the landfill
- 9: 2000 feet southeast of landfill
- 10: single well, 2000 feet northeast of the landfill
- 11: 500 feet northeast of the landfill
- 12: single well, east of and adjacent to the landfill
- 13: 500 feet southeast of the landfill
- 14: single well, east of the landfill, north of the TV Station
- 15: intersection of Anne Street and Irvine Avenue
- 16: single well, in the center of the landfill
- 17: 2000 feet east of the landfill
- 18: 2250 feet southeast of the landfill
- 19: single well, 3500 feet southeast of the landfill
- 20: single well, 3500 feet southeast of the landfill.

Conclusions from ground water data are used for establishing response boundaries, screening of remedial technologies, and development of remedial alternatives. Conclusions relative to the response boundaries are:

- The general response area is defined by monitoring well clusters 1, 2, 3, 7, 11, 12, 13, and 16.

- Vinyl chloride is present in the A zone in an area beneath the landfill, adjacent to the landfill along the eastern perimeter, and downgradient to the northeast of the landfill, extending just beyond Irvine Avenue. Ground water quality within the A zone plume is defined by wells 1A, 2A, 3A, 7A, 11A, 12A/B, and 16A.

- Vinyl chloride is present in the B zone in an area adjacent to the eastern landfill perimeter. The eastern extent of the B plume is less than for the A plume. However, the B plume also includes ground water southeast of the landfill not contained in the A plume. B plume ground water quality is defined by results at wells 1B, 2B, 3B, 11B, 12A/B, and 13B. It is assumed the B zone is also impacted beneath the landfill.

- Ground water quality data from well 3C indicates that contamination of the C zone may be limited to the area near well location 1C.

Ground water contaminant concentrations in the probable response boundary are shown on Tables 2-5 and 2-6. The concentrations shown are the highest value detected in an individual monitoring well. An average of all detected values within a zone is also shown. The average values are conservative estimates of

TABLE 2-6
KUMMER SANITARY LANDFILL, MINNESOTA

SUMMARY OF GROUND WATER QUALITY IN THE RESPONSE AREA

Interval	Inorganic Contaminant Concentrations (ug/L)														
	A							B					C		
	Well Nos.							Well Nos.					Well Nos.		
	1	2	3	7	16		Avg	1	2	3	7	Avg	1	3	Avg
Compound															
Aluminum	65	59	65		31.2	B	55	50	28		25	34	137	64	101
Arsenic		20		15	22.2	BWN	19	15		5.4	11	10			
Barium	81	2,290	1,180	1,070	342	EN	993	107	1,810	145	36	498	102	59	81
Calcium	96,200	75,500	111,000	95,900	103,000	E	96,320	84,200	140,000	96,800	42,200	90,800	75,700	53,000	64,350
Cobalt		7.9 B	14 B												
Copper	43	14	14		14.5	B	21	14	22	14	3.2	13	14	14 E	14
Iron	23	19,500	16,100	287	6,730	E*	8,528	43	8,840	2,580	6.4	11,469	509	37	273
Magnesium	25,200	54,900	33,800	29,200	125,000	E	53,620	27,800	60,800	33,400	10,900	33,225	23,500	15,500	19,500
Manganese	21	486	778	1,100	1,890	EN	855	823	630	474	39	492	447	288	368
Mercury		0.3						0.4	0.3	0.3			0.4	0.3	
Nickel		47	40		149		79	35				35			
Potassium	2,090	44,600	22,200		132,000	E	50,223	2,350	11,800	2,430	1,060	4,410	2,420	1,730	2,075
Silver			5.1												
Sodium	17,600	121,000	46,800	31,000	286,000	E	100,480	48,200	121,000	21,600	9,530	50,083	29,500	5,570	17,535
Zinc	74 E	128 E	32 E	354	26.5		123	822 E	614 E	136 E	56	407	78 E	36 E	57

Notes:
B = Compound present at less than CRDL but greater than IDL
E = Estimated because of interference
N = The spiked sample recovery was not within control limits
W = The post-digestion spike for furnace AA analysis is outside of the 85-115% control limits, while sample absorbance in less than 50% of the spike absorbance
* = Duplicate analyses are not within control limits.
Average concentration is used for conceptual design of treatment alternatives.

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probable ground water quality during pumping actions, and are used in screening ground water treatment technologies and developing remedial alternatives which include ground water treatment.

2.3 IDENTIFICATION OF APPLICABLE REMEDIAL TECHNOLOGIES

Table 2-7 presents possible general response actions for the Kummer Landfill ground water. A technology is eliminated in screening based on one or more of the following:

- does not or cannot achieve remedial objectives
- inconsistent with the contaminants detected
- physical or regulatory constraints block implementation
- estimated cost is at least an order of magnitude greater than another favorable technology.

Considerations for the elimination of a specific remedial technology are given below.

Containment: Ground water containment technologies such as slurry walls are not technically feasible due to shallow, discontinuous till formations which may not provide an impermeable base. Trenches and/or drains are not implementable due to the depth to the bottom of the contaminated aquifer. Trench safety considerations would require a massive dewatering program approaching the scale of an extraction network, or a width at ground surface of 300 feet of more. However, a downgradient drain is retained because the lesser quantity of ground water to be treated may offset the high capital costs of trench construction.

Diversion is not implementable due to hydraulic characteristics of the aquifer and regulatory constraints on reinjection. Upgradient pumping may reduce the hydraulic gradient at the landfill, and reverse the present pattern of contaminant migration. Any waters pumped upgradient of the landfill would require discharge to surface water or an infiltration pond.

Pumping: Reinjection wells may be difficult to implement because of MPCA and MDH regulations governing discharges to an aquifer used for potable supply. However, reinjection is allowed if justified and given variance by the MPCA Board and MDH Commissioner.

TABLE 2-7
KUMMER SANITARY LANDFILL, MINNESOTA

ESTIMATED GROUND WATER QUALITY IN THE RESPONSE AREA
A INTERVAL

	Beneath Landfill	Eastern	North Eastern
Volatiles			
Vinyl Chloride	34	94	13
Chloroethane	5	10	3
Methylene Chloride	1	5	3.3
t-1,2 Dichloroethene		6.8	5.2
1,2-Dichlorothene (total)		4	3
Benzene	6	5	
Tetrachloroethene		1.8	2.2
Toluene	4	4	
Ethylbenzene	3	5.9	
Total Xylenes	15	4.4	
Total TICS	32	44	8
Semi Volatiles			
bis (2 Ethylhexyl) Phthalate	4	43	
4-Methylphenol	4	10	
Inorganics			
Aluminum	31.2 B	65	
Arsenic	22.2 BWN	20	15
Barium	342 EN	2,290	1,070
Calcium	103,000 E	111,000	95,900
Copper	14.5 B	43	
Iron	6,730 E*	19,500	287
Magnesium	125,000 E	54,900	29,200
Manganese	1,890 EN	778	1,100
Nickel	149	47	
Potassium	132,000 E	44,600	
Sodium	286,000 E	121,000	31,000
Zinc	26.5	128 E	354

Note: B = Compound present at less than CRDL but greater than IDL
E = Estimated because of interference
N = The spiked sample recovery was not within control limits
W = The post-digestion spike for furnace AA analysis is outside of the 85-115% control limits, while sample absorbance is less than 50% of the spike absorbance.
* = Duplicate analyses are not within control limits.

On-Site Treatment: Biological treatment is not proven at the clean-up levels proposed for vinyl chloride. Granular activated carbon adsorption is not appropriate as a primary treatment technology because vinyl chloride does not adsorb readily onto carbon. Bioremediation has not been demonstrated at the clean-up criteria for the Kummer site. However, it is retained as a possible treatment step or addition to extraction technology. Thermal treatment is not cost-effective at low organic compound concentrations. Ion exchange is compound specific and may be ineffective in removing inorganic species of concern in the ground water. Also, regeneration of ion exchange resins will produce a liquid waste stream which may be hazardous. Reverse osmosis will also create a liquid waste stream which would require further treatment or disposal.

Off-Site Treatment: Off-site ground water treatment at a RCRA compliant facility is not cost-competitive with on-site treatment options due to the quantity of contaminated ground water requiring disposal and transportation. The transport of the ground water to a treatment/disposal facility creates additional potential for human exposure due to spills or accidents. Off-site ground water treatment at a municipal waste water treatment plant is retained as a less costly alternative which provides similar protection of public health and the environment.

On-Site Disposal: Land application will only be implementable during warm weather months. The spray may release contaminants to the air as aerosols.

Off-Site Disposal: Available off-site ground water disposal options such as deep well injection are not cost-competitive with on-site treatment options due to the large quantity of contaminated ground water requiring disposal and transportation. Deep well injection may not be implementable over the life of the remedial action due to pending land ban regulations under HSWA. Injection facilities are banned in Minnesota by the MDH. The sludges produced by lime-soda softening will have to be disposed of off-site.

2.4 SELECTION OF REMEDIAL TECHNOLOGIES

Table 2-8 identifies technologies which passed initial screening. Hydraulic controls include no further action, drains, and down-gradient pumping. Applicable on-site treatment technologies for organics removal are air stripping;

TABLE 2-8
KUMMER SANITARY LANDFILL, MINNESOTA

APPLICABLE TECHNOLOGIES

General Response Action	Media	Remedial Technology
No Action	Ground water	Monitoring and analysis
Pumping	Ground water	Extraction Wells, Trenches
On-Site Treatment	Ground water	Organic Compounds: Air stripping Combined carbon adsorption /stripping Advanced oxidation processes Inorganic Compounds: Coagulation/flocculation Lime-soda softening
Off-Site Treatment	Ground water	Discharge to POTW
On-Site Disposal	Ground water	Infiltration ponds
Off-Site Disposal	Ground water	Surface water discharge Discharge to POTW
Off-Site Disposal	Sludge	Landfill

combined stripping/carbon adsorption; and advanced oxidation processes. Bioremediation may be applicable for certain organic contaminants in combination with other treatment and hydraulic control technologies. Coagulation/flocculation and lime-soda softening are applicable on-site technologies for inorganics removal.

Applicable effluent management technologies include discharge to POTW, infiltration ponds, and surface water discharge. Off-site discharge of ground water to a POTW may be an available treatment option, although improvements to the existing facility may be required for some Kummer site waste streams. Treatment effluent may also be managed on-site by discharge to an infiltration pond. Off-site disposal of treated ground water includes discharge to surface water. Discharge can be a point source from a ground water treatment system, or non-point source due to areal discharge of the affected plume of ground water. These remaining applicable technologies will be incorporated into remedial action alternatives in the following section.

3.0 DEVELOPMENT AND SCREENING OF REMEDIAL ALTERNATIVES

In this chapter the technologies identified in the initial screening are developed into remedial action alternatives. Technologies are presented in accordance with three response categories: hydraulic controls, ground water treatment and effluent management. These technologies are screened according to effectiveness, technical feasibility and implementability, environmental effects and cost criteria. The most promising technologies are then combined into alternatives for ground water remedial action. Detailed analysis of alternatives is presented in Chapter 4.0 of this report.

3.1 DEVELOPMENT OF ALTERNATIVES

Remedial alternatives are developed based on the following response categories:

- hydraulic controls
- ground water treatment
- effluent management.

The hydraulic controls represent a range of alternatives for preventing significant migration of landfill contaminants to down-gradient ground water. This objective is reached by one or more of the following actions:

- diverting ground water flow around the landfill
- artificially lowering the ground water table beneath the landfill so that ground water no longer contacts waste material.
- recovering potentially contaminated ground water at the eastern and southeastern boundary of the response area.

Some hydraulic control alternatives may require treatment of pumped ground waters prior to surface water discharge or on-site disposal to an infiltration pond. Treatment may include removal of organic and/or inorganic contaminants. Treatment alternatives are developed based on the objectives for the pathways which may be impacted by the implementation of ground water treatment technologies:

- <u>Ground water pathway</u> - Hydraulic controls are appropriate if continued migration of ground water contaminants may cause significant water quality impacts at Lake Bemidji. If on-site disposal of treated ground water is the effluent management technology, treated ground water recharged to the aquifer must not significantly impact water quality at Lake Bemidji. Treatment for removal of organic compounds is likely required as the vinyl chloride concentration exceeds the proposed water quality standard for Lake

Bemidji. Removal of inorganic compounds may not be required, depending on actual inorganic concentration in pumped ground water.

- Surface water pathway - For point source discharge of treated ground waters to surface water, effluent contaminant concentrations must be less than proposed surface water quality standards for Lake Bemidji through the use of BAT or equivalent. For non-point source discharge of ground water, residual contaminant concentrations must be below proposed surface water quality standards at the interface to Lake Bemidji.

- Air pathway - Air discharges during ground water treatment cannot exceed annual average concentrations which correspond to an incremental cancer risk of 10^{-5}. This performance criterion is applicable to air stripping treatment technology. Vapor phase control technologies will also be considered for air stripping technology, consistent with OSWER Directive 9355.0-28 for control of Air Emissions from Superfund Air Strippers at Superfund Ground Water Sites. Vapor phase controls are included in the air stripper conceptual design.

All treatment technologies are developed for the surface water quality standards for Lake Bemidji. This allows treatment effluent to be managed in any of the following ways:

- discharge to surface water
- on-site disposal to infiltration pond
- discharge to POTW.

Each of the hydraulic control alternatives requires provisions for effluent management of treated and/or pumped ground waters.

3.2 ALTERNATIVE SCREENING CRITERIA

The screening process includes evaluation of alternatives with respect to:

- effectiveness
- technical feasibility and implementability
- adverse effect on the environment
- cost

Screening criteria are detailed below. Screening results are described in Sections 3.3, 3.4, and 3.5.

3.2.1 Effectiveness

Alternatives that do not satisfy the response action objectives and do not provide adequate protection of public health, welfare or the environment are rejected. On-site alternatives must achieve adequate control of contaminants in terms of abating or minimizing the release or threatened release. Off-site

alternatives must minimize or mitigate the threat of harm to public health, welfare, or the environment, or they will be excluded from further consideration.

3.2.2 Technical Feasibility and Implementability

Alternatives that may prove extremely difficult to implement, or that rely on totally unproven technologies will generally be excluded from further consideration.

- Implementability is assessed in terms of technical feasibility (experience with the contaminants under similar conditions, difficulties and unknowns, reliability, ease of undertaking additional action, and effectiveness of monitoring); administrative feasibility (ability to obtain required approvals and permits); and availability of services and materials.

- Reliability is assessed in terms of past experiences under similar conditions, vendor information and maintenance records.

3.2.3 Adverse Effects on the Environment

Alternatives that do not adequately protect human health and the environment will be eliminated.

- Technologies must not create additional significant long-term negative impacts upon air, surface water, ground water, or soil quality.

- Technologies must not have significant long-term adverse impact on environmentally sensitive areas.

- Technologies must meet applicable environmental standards for air, surface water, ground water, or soils quality unless a site-specific circumstance warrants a waiver.

3.2.4 Costs

Alternatives whose estimated costs far exceed those of other alternatives in relation to the benefits which the alternatives will produce will be eliminated. The cost estimate includes both capital costs and operating and maintenance costs. Since remedial action design is conceptual and generalized, broad categories of costs are considered. The categories include the following:

- Direct Capital Costs

    - construction
    - equipment
    - land and site development
    - disposal and off-site transportation
    - buildings and services
    - engineering costs

- contingency allowances
- operation and maintenance costs
- labor
- maintenance, materials and labor
- utilities and energy costs
- purchased services
- residuals management
- administrative costs
- insurance, taxes, and license
- maintenance reserve and contingency

Typically, engineering and design costs have been estimated as about 20 percent of total capital costs. Annual legal, permit, and licensing fees are estimated at about 5 percent of initial capital costs. Equipment installation, contractor overhead and profit, piping, and electrical/instrumentation costs are also estimated as a percent of equipment and capital costs. A discount rate of 10 percent is used for present worth analyses of long-term operating, maintenance, and monitoring costs. The design period for present worth cost varies depending on the hydraulic control technology. An overall contingency of 25 percent is used to cover unforeseen work items and additional quantities discovered during site remediation. The contingency was selected to be within the cost accuracy specified for detailed analysis in the FS Guidance Document (Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, October 1988).

Competing alternatives with similar effectiveness, technical feasibility, and environmental impacts are compared with respect to cost. Containment or off-site alternatives with estimated costs an order of magnitude greater than other technologies under consideration, but without additional environmental or public health benefits, are eliminated. A treatment technology is eliminated only if its estimated cost is at least an order of magnitude greater than the cost of an alternative treatment technology. Costs alone are not used to eliminate a treatment technology in comparison to a containment or off-site methodology.

3.3 SCREENING OF HYDRAULIC CONTROL REMEDIAL ALTERNATIVES

This section describes the hydraulic control remedial action alternatives developed from the applicable technologies identified in Section 2.0. Cost and non-cost features of each alternative are discussed, and the key elements of each alternative are summarized.

Hydraulic control alternatives are:

- No further action

- Passive hydraulic controls
- Active upgradient hydraulic controls
- Active downgradient hydraulic controls

3.3.1 No Further Action

As mandated by the National Contingency Plan (NCP) and the Superfund Amendments and Reauthorization Act (SARA), a no action remedial alternative must be evaluated for each Superfund site.

The no further action alternative consists of leaving the site conditions as they currently exist. The intent of the no action alternative is to provide a basis of comparison for analysis of other remedial action alternatives, and to justify the need for any remedial action.

The no further action alternative is developed on the assumption that the OU1 alternative water supply and OU2 landfill cover system are implemented in accordance with their respective RODs. Future organic compound distribution is based on the ground water modeling results presented in Appendix B. These results indicate that organic compounds do not reach Lake Bemidji in detectable concentrations for about 36 years after cover system completion. After about 40 years of elapsed time, total organic compound concentration likely remains below the proposed surface water quality standard for vinyl chloride.

Based on modeling results, the no action alternative appears to achieve the ground water remedial action objective of preventing significant contaminant migration to shallow ground water downgradient from the Kummer landfill. Long-term effectiveness of the no further action alternative will depend on the adequacy of the cover system in preventing future migration of landfill contaminants to ground water. Further degradation of chlorinated ethenes to vinyl chloride may increase ground water toxicity. The no action alternative may be inconsistent with the USEPA ground water protection strategy because contaminants currently present at the eastern perimeter and beneath the landfill will continue to migrate to the downgradient aquifer system. However, natural processes in the aquifer may attenuate the plume with time.

No action is likely consistent with Minnesota Rules mixed municipal solid waste landfill disposal facilities ground water performance standards. Although intervention limits are exceeded at the eastern landfill perimeter, ground water corrective action has taken place in the form of the alternative water supply provided to affected residents. Additional institutional controls may also be required to prevent adverse impacts on public health due to future use of the aquifer for drinking water supply.

No further action will require the following:

- removal of off-site monitoring wells installed during the remedial investigation (if required by property owners)

- ground water quality monitoring for a period of 30 years or more in order to track the plume, and institutional controls.

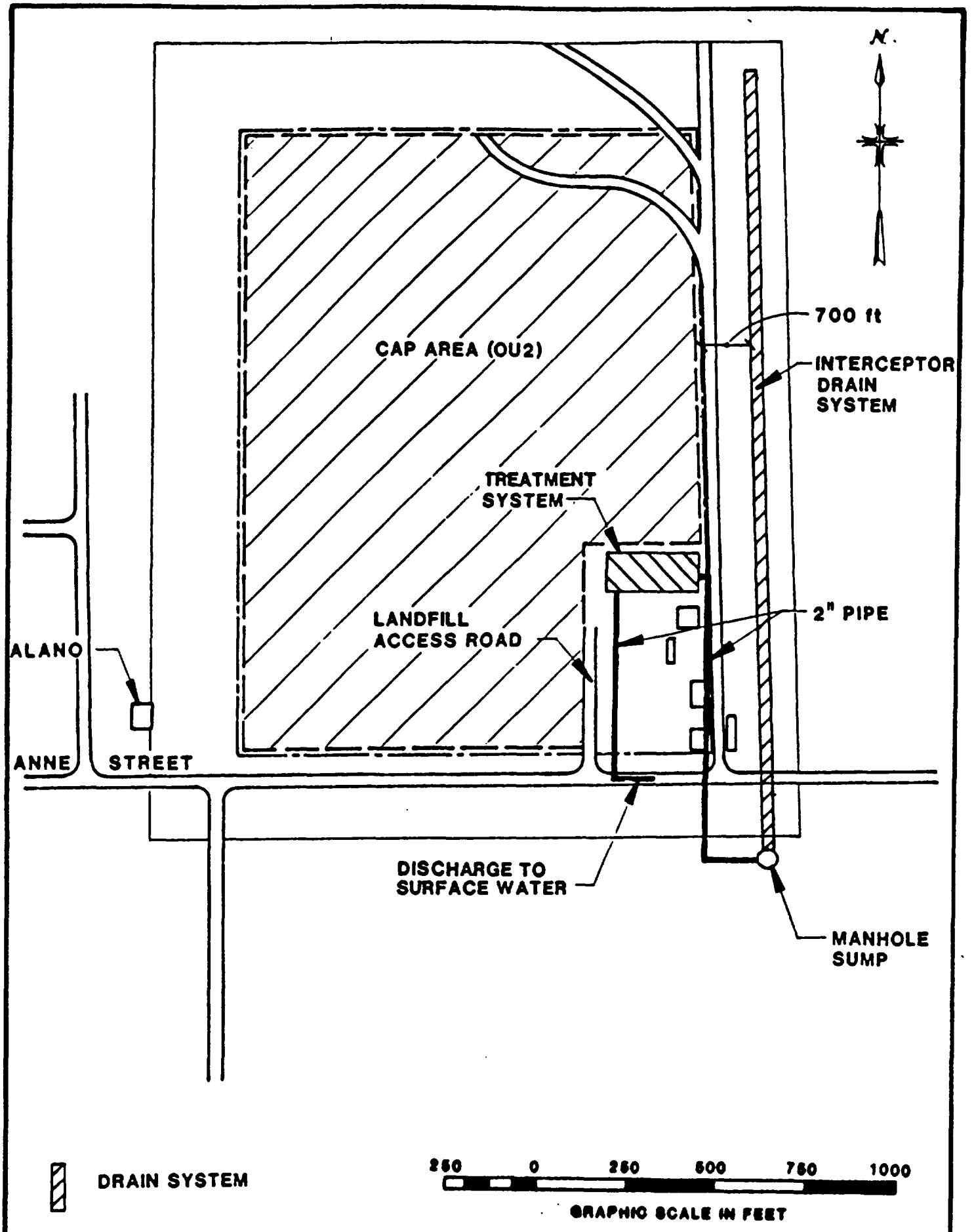
3.3.2 Passive Hydraulic Controls

To effectively reduce the mixing of ground water with the landfilled wastes, a dewatering program must be implemented whereby the ground water table is lowered to a level below the wastes or the ground water flow is significantly restricted. One approach for accomplishing this goal is the use of a passive ground water collection system to intercept the flow of ground water as it enters or leaves the landfill boundary.

The intent of this alternative is to induce a ground water "sink" at either the western (upgradient) or eastern (downgradient) boundary, thereby controlling the inflow or outflow of ground water and preventing the continued migration of landfill contaminants to downgradient ground water. Since the system will be "passive", the ground water flowing into the collection system will utilize the existing gradients and ground water velocities, reducing the daily removal rates to volumes much less than those recovered by pumping systems. Costs for ground water treatment may therefore be reduced.

A downgradient interceptor drain system is selected as the passive hydraulic control technology most applicable to the Kummer site. This system would intercept the flow of ground water leaving the landfill and would restrict the further migration of contaminants to the downgradient aquifer. An upgradient passive system would prevent shallow ground water from entering the landfill's western boundary, but would not prevent contaminants currently beneath the landfill from continuing their eastern migration. Capital costs for the upgradient and downgradient systems would be nearly equal. Since the downgradient system provides greater protection of public health and the environment at no additional cost, it is selected for development and evaluation.

Ground water leaving the eastern perimeter of the Kummer landfill would be collected by an interceptor drain. This drain will be located approximately 700 feet east of the landfill and will be oriented in a north-south direction. It will be approximately 1800 feet long and 200-300 feet wide at ground surface. (See Figure 3-1). A collector pipe will be situated along the bottom of the trench, allowing the ground water to flow under the existing gradients and



MALCOLM PIRNIE

KUMMER LANDFILL GROUND WATER FS
PASSIVE DOWNGRADIENT HYDRAULIC CONTROLS PLAN

MALCOLM PIRNIE, INC.

FIGURE 3-1
JULY 1990

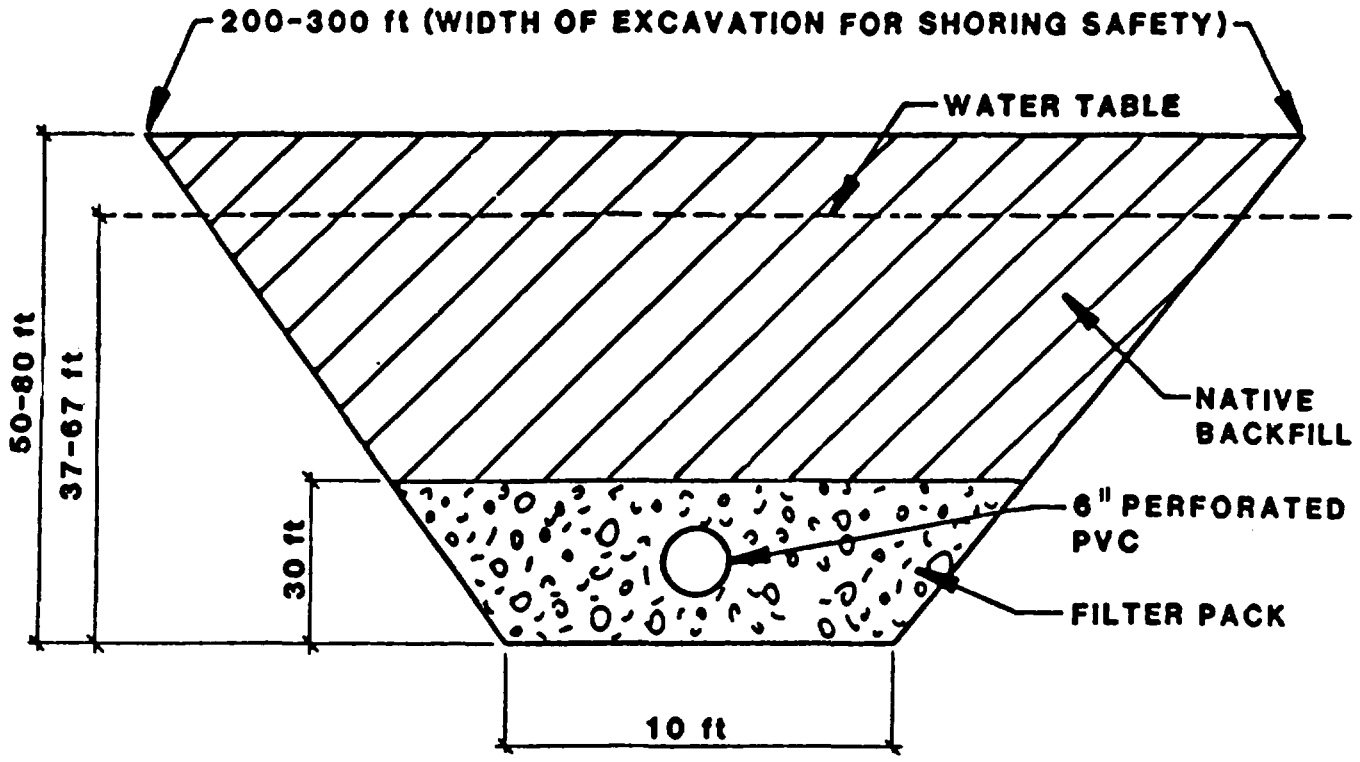
velocities into the system (See Figure 3-2). The bottom of the trench will correspond to the "C" aquifer zone, and will slope southward from a 50-foot initial depth to 80-feet at the southern end. A manhole structure and sump pump will be located at the southern end to remove the accumulated ground water. It is expected that the pumpage rate from the interceptor drain will be approximately 20 gpm. Table 3-1 lists the conceptual design parameters for this alternative. The ground water removed by the sump pump will contain organic and inorganic contaminants which require treatment, but will be discharged at a volume which may be manageable by a POTW.

During the installation of the interceptor drain, however, larger volumes of contaminated ground water (up to 300 gpm) will be pumped to dewater the excavation area. This water will require treatment and or disposal during a construction period of up to 1 year.

The period of performance of this alternative may be infinite because any interruption in ground water collection and removal will re-establish the existing ground water gradient and may allow wastes to again contact ground water. Continuous removal is also necessary to prevent the spread of contaminants presently beneath the landfill to the downgradient shallow aquifer and surface waters.

The passive downgradient hydraulic control alternative is technically feasible but not implementable at the Kummer landfill. The geologic stratigraphy beneath the eastern perimeter was sufficiently described during the RI and, when penetrated by the interceptor drain, will allow the shallow aquifer (zones A, B, and C) to dewater under existing gradients and prevent the further spread of contaminants. The excavation process, however, will involve very large volumes of soil (up to 0.8 million cubic yards) and will necessitate the active pumping of approximately 400,000 gallons of contaminated ground water per day to effectively dewater the area for excavation work. The trench will be approximately 300 feet wide in some areas and 80 feet deep at its maximum, extending 37-67 feet into the water table. This scope of dewatering and excavation is economically unattractive utilizing conventional construction techniques.

The passive downgradient hydraulic control system may not be effective. At the current hydraulic gradient of the aquifer, the passive drain system is expected to yield 20 to 50 gpm, which would not lower the water table out of the filled material across the landfill within five years. The drain may not prevent flow out of the downgradient side of the system because upward gradients from



INTERCEPTOR DRAIN

NOT TO SCALE

MALCOLM PIRNIE	KUMMER LANDFILL GROUND WATER FS TYPICAL PASSIVE SYSTEM DETAIL	MALCOLM PIRNIE, INC. FIGURE 3-2 JULY 1990

TABLE 3-1
KUMMER LANDFILL, MINNESOTA

PASSIVE HYDRAULIC CONTROLS CONCEPTUAL DESIGN PARAMETERS

Type drain pipe	Perforated PVC
Piping - diameter	Six inches
Spacing	Horizontally continuous
Trench Depth	50-85 feet
Trench Width	10 feet (at bottom)
Inflow schedule	Continuously
Flow rate	20 gpm
Backfill	Selected for permeability
Length	1,800 feet
Horsepower Requirement	1
Capital Cost	$16,000,000
Annual O&M Cost	$59,000
Period of Performance[1]	Up to 30 years or more
Present Worth Cost	$17,000,000

Notes: [1] For cost estimates a design life of 30 years is assumed. A detailed capital cost estimate is provided in Appendix Table D-1a. O&M costs are listed in Appendix Table D-2.

lower strata may prevent any drawdown. In this case, the drain may worsen conditions by allowing contaminated shallow ground waters to mix with cleaner deep ground waters. The drain is expected to collect contaminated water for a long, if not infinite, period of time.

By operating the interceptor drain system for an infinite time period, this alternative will satisfy the ground water remediation objective of preventing significant contaminant migration to shallow ground water downgradient from the Kummer landfill. Regardless of the source (continued vertical leachate migration or horizontal migration due to waste contact with ground water), contaminants will be continuously intercepted by the passive controls system and will no longer migrate to areas beyond the eastern boundary of the landfill.

This alternative will provide for the protection of human health and the environment by controlling the migration of contaminants from the landfill, thereby virtually "removing" the source of contaminants and allowing for the long-term restoration of downgradient shallow ground water quality. Ground water contaminant concentrations will likely be diluted to values below the proposed surface water quality standards for Lake Bemidji.

The estimated capital and operations and maintenance costs and key features are summarized on Table 3-1. Implementation of this alternative requires purchase of additional land to the east of the landfill.

3.3.3 Active Upgradient Hydraulic Controls

Ground water extraction along the western perimeter of the landfill is selected as the active upgradient hydraulic control technology most applicable to the Kummer site. The intent of this alternative is to intercept the flow of uncontaminated ground water entering the landfill by inducing a ground water "sink" along the western perimeter. Pumped ground water can be reintroduced to the aquifer downgradient of the landfill or discharged to surface water. As a result of active upgradient hydraulic controls, flow of ground water beneath the landfill will be reduced. Migration of contaminants due to contact between wastes and ground water will be controlled by artificially lowering the ground water table. Altered hydraulic gradients may slow or prevent the migration of existing contaminants to the downgradient aquifer.

The period of performance for this alternative may be infinite because:

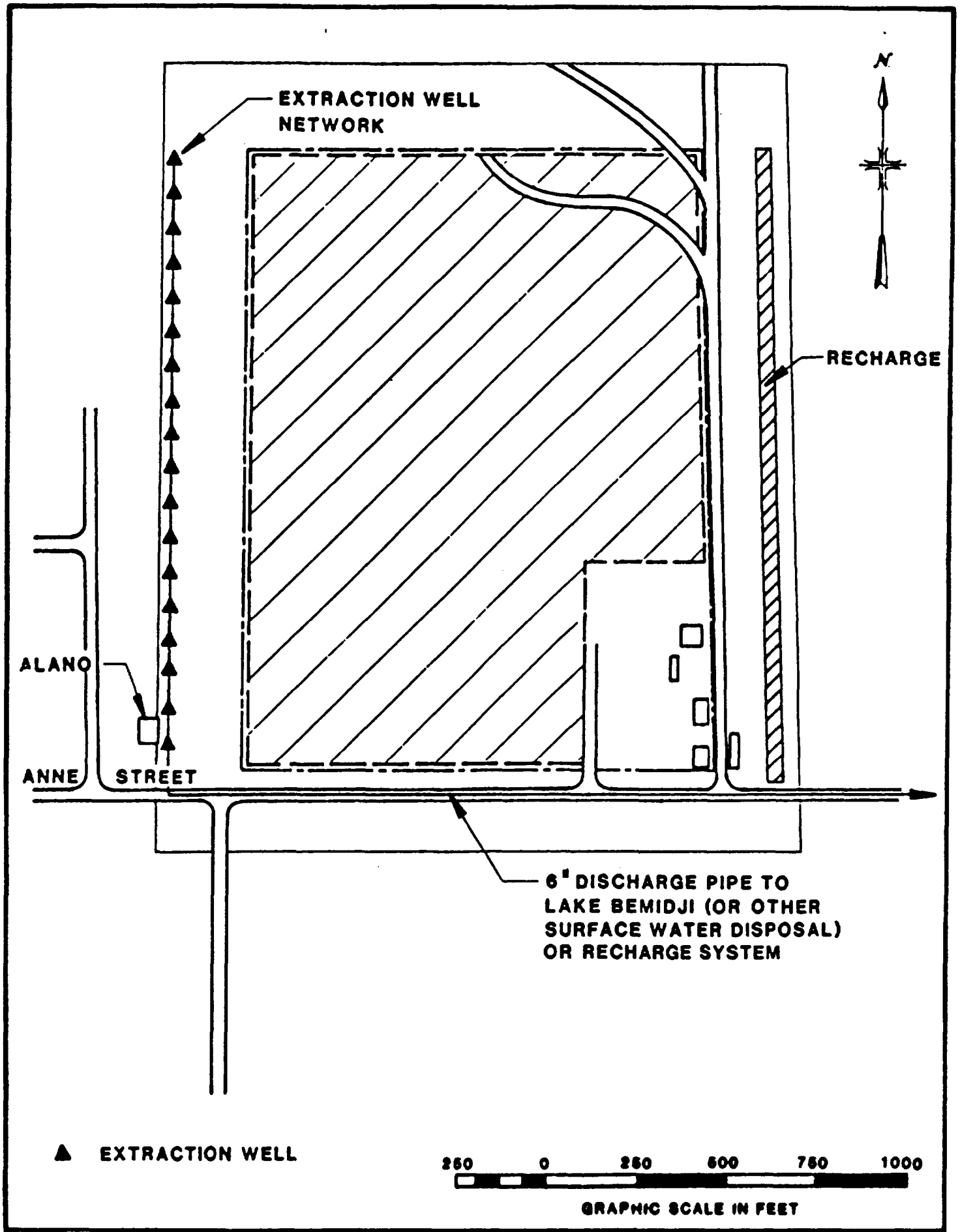
- any interruption in pumping will re-establish existing ground water elevations and may allow wastes to again contact the aquifer

- cessation of pumping will re-establish hydraulic gradients and allow contaminant migration to downgradient ground water.

The ground water "sink" will be formed by installing and operating up to eighteen (18) extraction wells along the western perimeter of the landfill, inducing a trough of depression to intercept the inflowing shallow ground water. A large number of wells is required to depress the ground water table beneath the landfill. Fewer wells may be adequate to intercept water flowing beneath the landfill. These wells will be positioned at approximate 100-foot intervals in a north-south line, from the northwest corner of the landfill to the southwest corner (see Figure 3-3). The array of wells will be located up to 200-feet west of the landfill. Each well will be approximately 40 feet deep and equipped with screens along the 10-to-40 foot interval. Figure 3-4 shows construction details for the extraction wells. Submersible pumps will be installed in each well and pumping rates will be from 10 to 15 gallons per minute (gpm) per well. Table 3-2 lists the conceptual design parameters for this alternative.

The ground water removed by the pumping wells may initially be free of contaminants, since no adverse water quality was noted in these areas during the RI. However, the zone of influence of the pumping wells will extend beneath the landfill, to a distance of up to 1400 feet. Contaminated water beneath the landfill may be pulled toward the upgradient wells. If pumped waters are recharged to the aquifer to the east of the landfill, the resulting ground water mound may locally reverse the hydraulic gradient beneath the landfill. Gradient reversal may provide some abatement of downgradient contaminant migration through dilution, but may contribute to migration of contaminants to ground waters north and south of the landfill, previously not impacted by waste disposal activities.

The upgradient hydraulic control alternative is technically feasible and implementable along the western perimeter of the landfill, since the geologic materials in the area consist of saturated sands with very little silt or clay. However, the alternative only marginally satisfies the ground water remediation objective of preventing significant contaminant migration to surface water at Lake Bemidji. Active upgradient controls will not prevent continued migration of contaminants which have already moved beyond the landfill boundaries. The alternative does not directly address possibly continued impact to on-site ground water quality due to vertical infiltration of precipitation prior to completed construction of the cover system. Contaminants beneath the landfill may be pulled to upgradient wells and then recharged downgradient of the site.

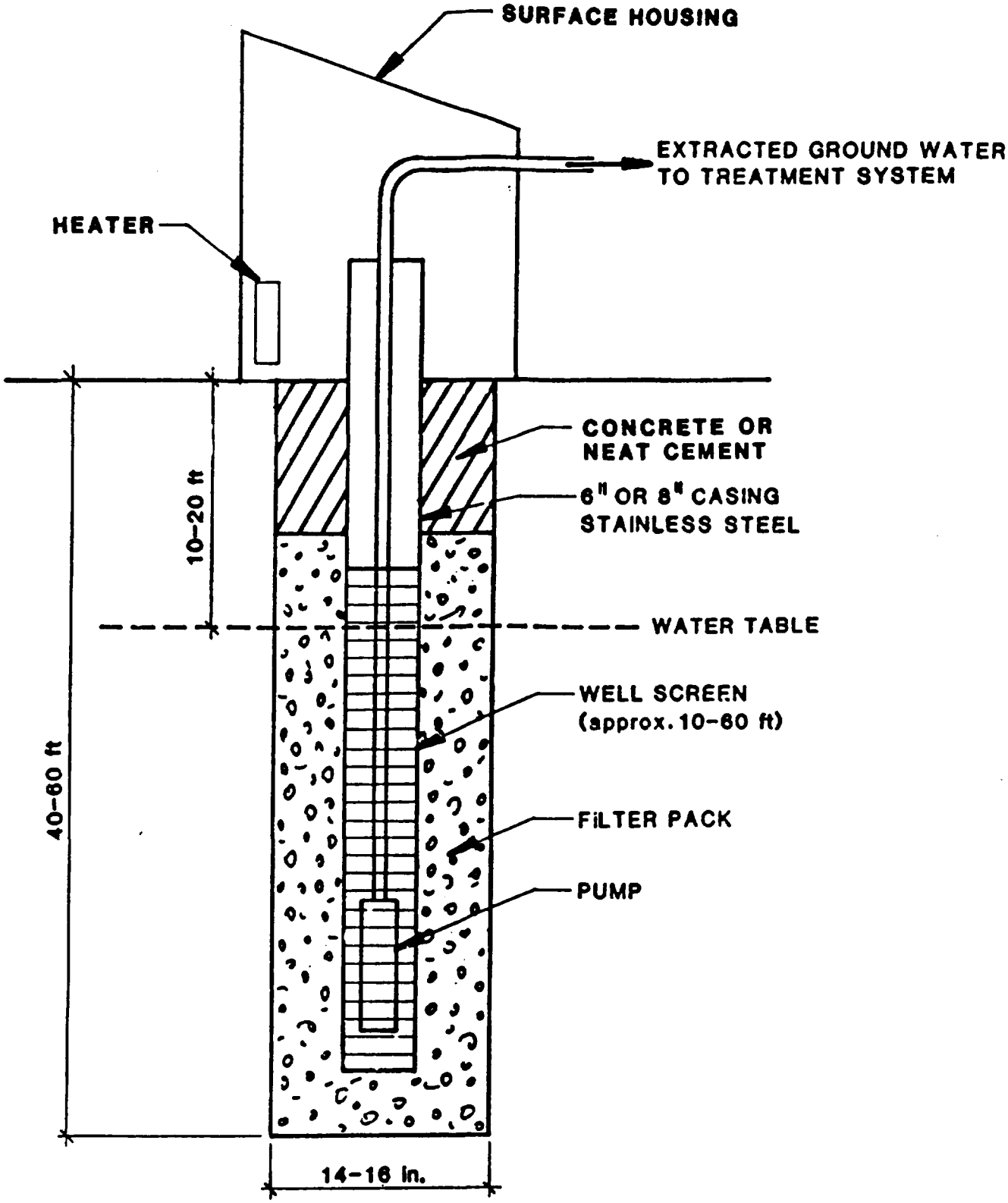


MALCOLM PIRNIE

KUMMER LANDFILL GROUND WATER FS
ACTIVE UPGRADIENT HYDRAULIC CONTROLS PLAN

MALCOLM PIRNIE, INC.

FIGURE 3-3
JULY 1990



MALCOLM PIRNIE

KUMMER LANDFILL GROUND WATER FS
TYPICAL PUMPING WELL DETAIL

MALCOLM PIRNIE, INC.

FIGURE 3-4
JULY 1990

TABLE 3-2
KUMMER LANDFILL, MINNESOTA

ACTIVE UPGRADIENT HYDRAULIC CONTROLS CONCEPTUAL DESIGN PARAMETERS

Note: All extraction wells will be drilled, constructed, and operated in identical fashion.

Number of Wells	18
Spacing	100 feet
Type Casing	Stainless steel
Casing Diameter	Six-inches
Depth	40 feet
Screened Interval	10-40 feet
Pumping Rate	10-15 gpm
Pumping Schedule	Continuously
Total Pumping Rate	180-270 gpm
Horsepower Requirement	9 hp
Capital Cost	$420,000
Annual O&M Cost	$58,000
Period of Performance[1]	Indefinite
Present Worth Cost	$970,000

Notes: [1] For cost estimates a design life of 30 years is assumed.

A detailed capital cost estimate is provided in Appendix Table D-1. O&M costs are listed in Appendix Table D-2.

Downgradient reintroduction of pumped waters to the aquifer may cause adverse environmental effects if it results in reversal of the hydraulic gradient beneath the landfill. Contaminants may migrate to upgradient ground waters not previously impacted by waste disposal in the Kummer landfill.

Capital and operations and maintenance costs are shown in Table 3-2.

3.3.4 Active Downgradient Hydraulic Controls

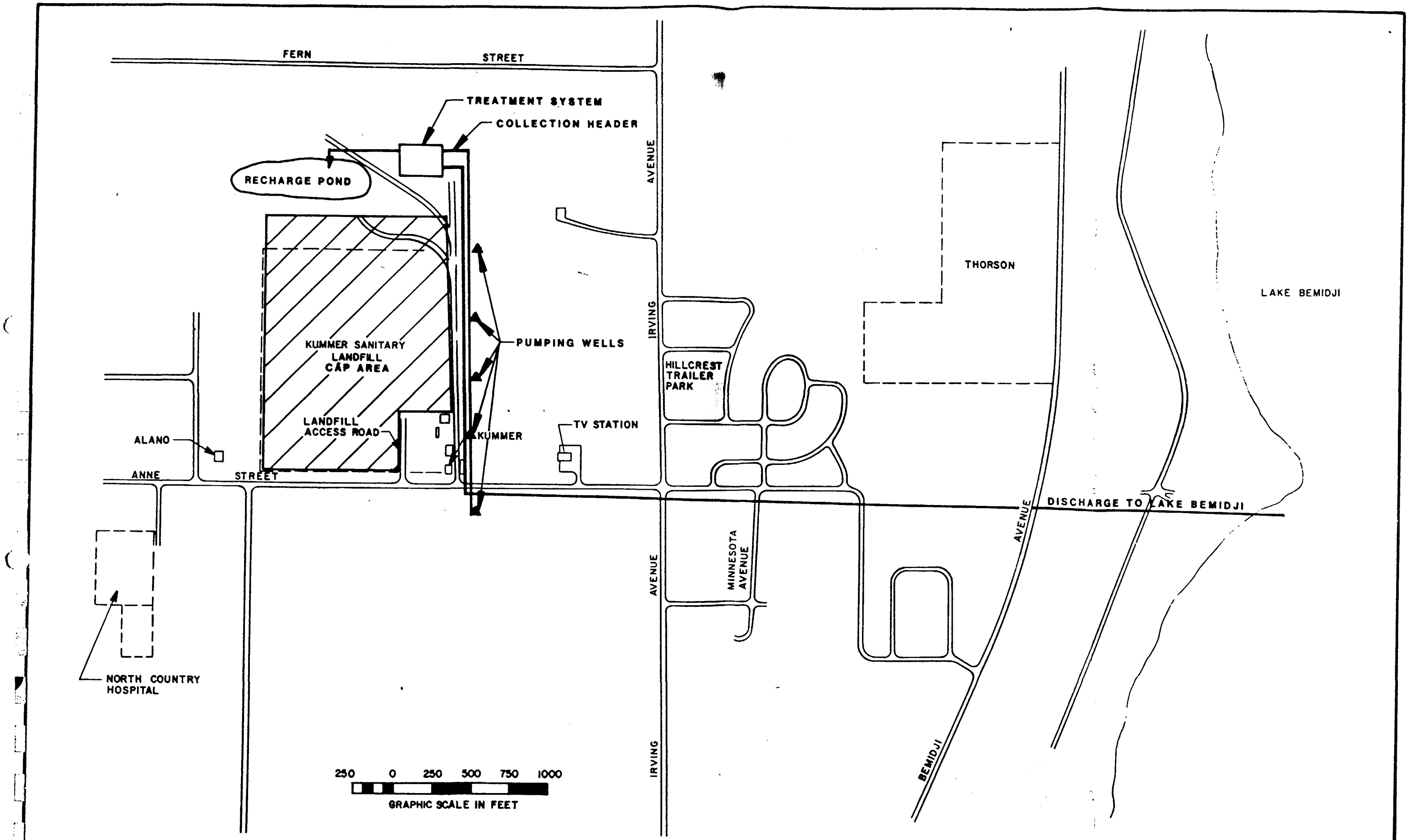
Ground water extraction within the volatile organic compound (VOC) plume is selected as the active downgradient hydraulic control technology most applicable to the Kummer site. The intent of this alternative is to extract the VOC plume and intercept the flow of any additional contaminated ground water leaving the landfill. Pumped ground water will require treatment to remove the contaminants. Effluent management alternatives are discussed in section 3.5 of this FS.

The ground water "sink" will be formed by installing and operating a series of about five extraction wells near the eastern perimeter of the landfill. Conceptual design of the withdrawal network is based on the pump-out system modeling described in Appendix B. Figure 3-5 depicts the wells, the location of the treatment system, and the possible recharge system or discharge to surface water.

Construction details for the extraction wells are shown on Figure 3-4. Wells will be up to 60 feet deep and equipped with screens along the 10-to-60-foot interval. Most wells will extract water from the "A" and "B" zones, shown to be contaminated in the vicinities of wells MW-12, MW-2, and MW-3. Wells located at the southern end of the array will extract water from the "A", "B", and "C" zones in the general vicinity of MW-1, the only monitoring well showing contamination at the "C" depth. These wells will be screened to 60 feet.

Submersible pumps will be installed in each well and pumping rates will be from 10 to 20 gpm per well. Table 3-3 lists the conceptual design parameters and costs for the pump-out network. The ground water extracted by the pumping wells will contain organic and inorganic contaminants, and must be treated. Appropriate treatment systems are described in Section 3.4.

The period of performance is unknown. The time period may be about 4 years, corresponding to the time required to recover ground water presently contaminated by VOCs plus other water pulled in by the pumping network. This period of performance is based on modeling results presented in Appendix B. However, the period of performance may be up to 30 years if wastes in contact



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KUMMER LANDFILL GROUND WATER FS

ACTIVE DOWNGRADIENT HYDRAULIC CONTROLS PLAN

MALCOLM PIRNIE, INC.

FIGURE 3-5
JULY 1990

TABLE 3-3
KUMMER LANDFILL, MINNESOTA

ACTIVE DOWNGRADIENT HYDRAULIC CONTROLS CONCEPTUAL DESIGN PARAMETERS

Parameters	Deep Wells	Total
Number	5	5
Spacing	See Figure	
Type Casing	Stainless steel	
Casing Diameter	Eight inches	
Depth	60 feet	
Screened Interval	10-60 feet	
Pumping Rate	10-20 gpm each	
Pumping Schedule	Continously	
Total Pumping Rate		100 gpm
Horsepower Requirement		5 hp
Capital Cost		$300,000
Annual O&M Cost		$ 43,000
2 year Present Worth Cost		$370,000
30 year Present Worth Cost		$710,000

Notes: A detailed capital cost estimate is provided in Appendix Table D-1. O&M costs are listed in Appendix Table D-2.

with ground water cause future introduction of landfill contaminants to the ground water system even after cover system completion. Pumping will alter the hydraulic gradient beneath the landfill and may decrease the time period required for horizontal movement of ground water from west to east beneath the landfill. The cover system and/or downgradient pumping may lower the ground water table so that wastes are no longer in contact with ground water. However, if pumping stops, ground water levels may reestablish existing patterns and bring wastes back into contact with the aquifer.

The downgradient hydraulic control alternative is technically feasible and implementable. Downgradient pumping well installation will require procurement of additional land or negotiation of long-term lease arrangements to access wells. The geologic stratigraphy beneath the eastern landfill perimeter was sufficiently defined during the RI, and showed that three distinct saturated intervals exist. Pumping wells can be easily installed in these intervals and continuously operated to effectively dewater the shallow zone, and capture the flow of contaminated ground water.

This alternative satisfies the ground water remediation objective of preventing significant contaminant migration to downgradient surface water. It also accomplishes the objectives of the USEPA ground water protection strategy. The withdrawal and treatment of contaminated ground water will minimize further migration of contaminants from the landfill. Regardless of the source (continued vertical leachate migration or horizontal migration due to waste contact with ground water) contaminants will be intercepted by the downgradient line of pumping wells and will no longer migrate to areas beyond the eastern perimeter of the landfill.

This alternative will provide for the protection of human health and the environment by controlling the migration of contaminants from the landfill, and allowing for the long-term restoration of downgradient shallow ground water quality.

The estimated capital and operations and maintenance costs and key features are summarized on Table 3-3.

3.3.5 Summary of Hydraulic Control Technology Screening

The results of evaluation of hydraulic control alternatives is presented on Table 3-4. No further action is retained. Modeling results indicate no further action may meet surface water quality objectives for a period of up to

TABLE 3-4
KUMMER LANDFILL, MINNESOTA

SUMMARY OF HYDRAULIC CONTROL ALTERNATIVES SCREENING

Alternative	Effectiveness	Feasibility/Implementability	Environmental Effects	Present Worth Cost
No Action	Meets surface water quality objectives; inconsistent with landfill and drinking water regulatory standards.	Not applicable	In short-term, contaminants migrate to downgradient aquifer. Long-term effectiveness depends on results of the cover system. Surface water quality impacts not significant if cover system minimizes future contaminant loading to the aquifer.	$ 200,000
Passive Downgradient	Effective. Recovers site contaminants at the eastern landfill boundary and prevents downgradient contaminant migration.	Not implementable with conventional construction techniques	Requires pumping to prevent continued contaminant migration	$17,000,000
Active Upgradient	Marginal. May reverse hydraulic gradients	Requires considerable monitoring	Alters contaminant migration via ground water pathway	$ 1,900,000 - $ 2,300,000
Active Downgradient	Effective. Provides direct indication of achievement of response objectives.	Feasible and easily implemented.	Effective. Contaminants are intercepted and removed for treatment.	$ 370,000 - $ 710,000

80 years. It also has the lowest present worth cost of all hydraulic control technologies.

Passive down-gradient hydraulic controls are eliminated. The trench is not implementable with conventional construction methods due to the depth to ground water. Estimated present worth cost for the alternative is an order of magnitude greater than the down-gradient pump-out network, without additional protection of public health and the environment.

Active upgradient hydraulic controls are also eliminated. The effectiveness of upgradient controls is unknown, and may actually increase the extent of ground water contamination by reversing present hydraulic gradients beneath the landfill. A large volume of pumped ground water will require disposal by infiltration pond or discharge to surface water. Estimated present worth cost for this alternative is also greater than the down-gradient pump-out network, without additional protection of public health and the environment.

Active down-gradient hydraulic controls are retained. Downgradient pumping will be effective in controlling present and future migration of site contaminants via the ground water pathway. The pumping network will provide direct indication that remedial action objectives are achieved.

3.4 SCREENING OF GROUND WATER TREATMENT ALTERNATIVES

This section describes the ground water treatment alternatives developed from the applicable technologies identified in Section 2.0. Cost and non-cost features of each alternative are discussed, and the key elements of each alternative are summarized.

Treatment technologies are:

- Air stripping
- Advanced oxidation processes
- Granular activated carbon (for polishing)
- Bioremediation (with pump-out systems)
- Precipitation
- Lime-soda softening
- Discharge to publicly-owned treatment works (POTW).

Treatment technologies are described below. Treatment alternatives are assembled and evaluated in Section 3.4.3.

3.4.1 Organics Treatment Alternatives

Organic compounds present in on-site ground water include:

- benzene
- chloroethane
- trans-1,2-dichloroethene (tDCE)
- ethylbenzene
- vinyl chloride
- total xylenes
- naphthalene

In addition, the following site contaminants have been detected in downgradient monitoring wells, and may appear in extraction wells during pumping:

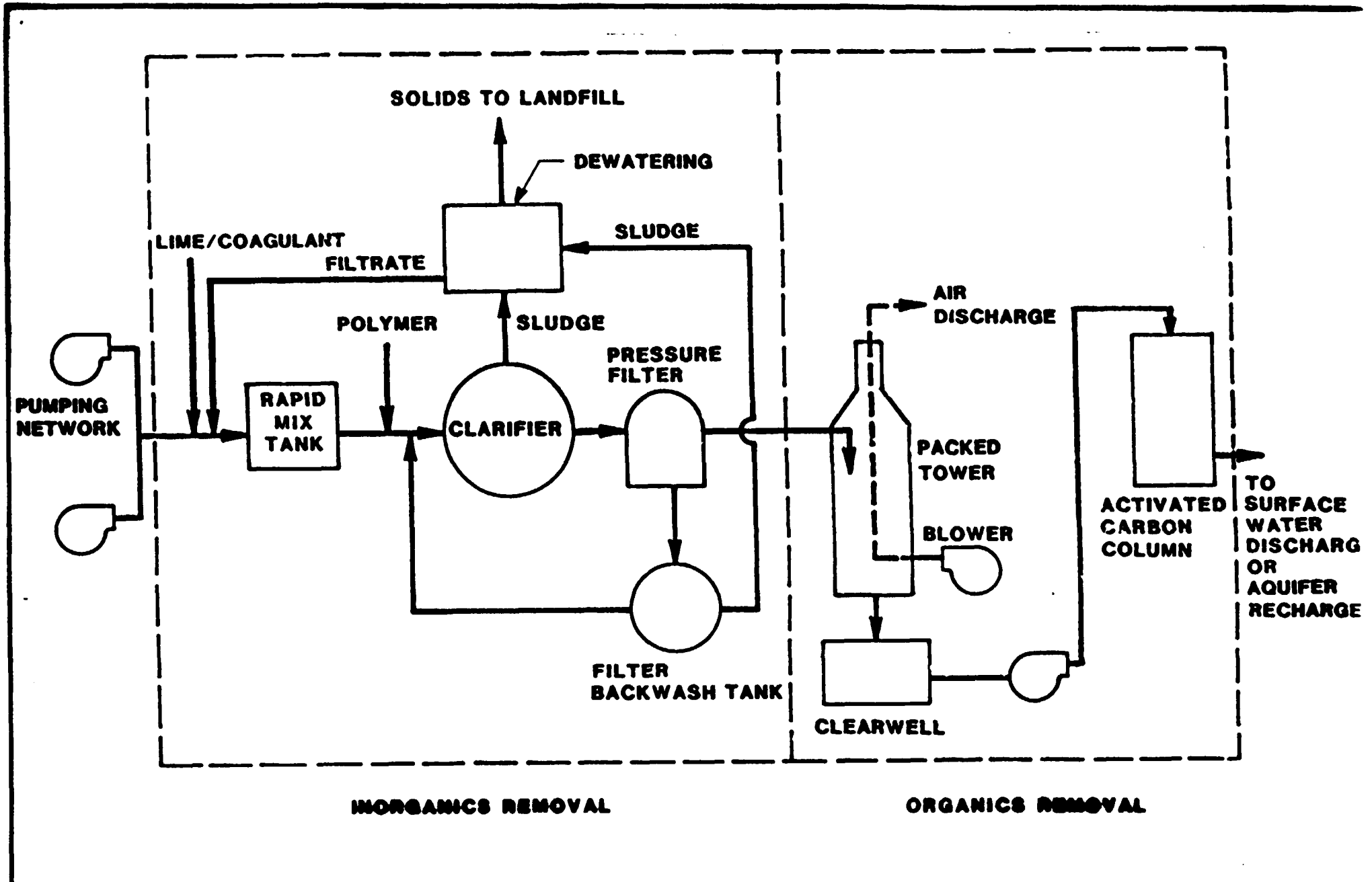
- trichloroethene (TCE)
- tetrachloroethene (PCE)

Although vinyl chloride is the compound that defines hydraulic control networks, organics treatment alternatives are developed for the removal of all above compounds from pumped ground water. This includes the health-based indicator compounds identified in Section 2.1.

3.4.1.1 Air Stripping

The organics identified in ground water sampling, except for naphthalene, are volatile compounds. Therefore, the removal of these compounds from the water can be accomplished by transferring them to air with an air stripper. Air stripping is a physical treatment process in which the volatile contaminants in water are transferred to the gas phase. Several equipment configurations have been demonstrated based upon forced-air technologies. The air stripping design at the Kummer site is based on forced air, packed column technology with granular activated carbon (GAC) vapor phase controls. Diffused air and induced draft technologies warrant additional consideration during preliminary engineering at the remedial design project stage. The packed column technology will achieve effluent quality consistent with surface water standards and provide for flexibility in removing additional volatile contaminants which may appear in extraction wells.

A schematic of the air stripping process appears in Figure 3-6. Some pretreatment is desirable to remove inorganic compounds which may precipitate within the column and impact volatile organics removal efficiencies. Inorganic removal is described in Section 3.4.2 of this report. Treatment for organics takes place in a fiber-reinforced plastic or stainless steel tower. Contaminated water is introduced through spray nozzles at the top of the tower, and air is



MALCOLM PIRNIE	KUMMER LANDFILL GROUND WATER FS	ON-SITE GROUND WATER TREATMENT PRECIPITATION/STRIPPING	MALCOLM PIRNIE, INC FIGURE 3-6 JULY 1990

forced into the bottom of the tower. Removal takes place across a packed bed designed for maximum contact area between the water and air phases.

The packed tower conceptual design is based on the following input parameters:

- water flow rate
- influent VOC concentrations
- effluent VOC concentrations
- Henry's Law constants for VOCs
- mass transfer coefficients for VOCs
- design air to water ratio

The design ground water flow rate and estimated influent VOC concentrations are listed in Table 3-5. Effluent VOC concentrations are the surface water quality standards presented in Table 2-2. These standards allow for discharge of the air stripper effluent to Lake Bemidji.

The Henry's Law constants and mass transfer coefficients describe properties of each compound to be removed. Mass transfer coefficients are a function of temperature, liquid loading rates, and the type of packing used in the column. Typical values for Henry's Law constants used in the Kummer conceptual design are shown in Table 1-2. The mass transfer coefficients utilized in conceptual design range from 50 to 83 $hour^{-1}$.

An air to water (A:W) ratio of 30:1 is used in the Kummer packed column design. A column designed at a higher A:W ratio will somewhat reduce the column height required for a given percent removal of contaminant. However, operating costs for the blower will be higher. The design packed tower height is based on removal of vinyl chloride. At the vinyl chloride design criteria all other compounds are removed to levels equal to or lower than surface water quality standards. Conceptual design parameters for the air stripper are given in Table 3-6. Treatment to surface water quality standards requires a stripping tower with about 2 foot diameter and about 8 feet of packing.

The conceptual design includes vapor phase carbon controls consistent with the OSWER directive for controls of air emissions from Superfund air strippers at Superfund ground water sites. The conceptual design is based on dehumidifiers, preheaters, and GAC contactors placed at the stripper exhaust point. However, treatment of stripper air emissions may not be required for compliance with air pathway performance criteria or the OSWER directive. Estimated point emissions at the stack for compounds of concern are:

- vinyl chloride: 400 ug/m^3
- tDCE: 70 ug/m^3
- benzene: 40 ug/m^3

TABLE 3-5
KUMMER LANDFILL, MINNESOTA

RECOVERY WELL FLOWRATE AND INFLUENT CONTAMINANT CONCENTRATION

Parameter	Downgradient Active Wells
Flowrate (gpm)	100
Benzene (ug/l)	4
t-1,2-dichloroethene (ug/l)	5
vinyl chloride (ug/l)	33
Arsenic (ug/l)	14
Barium (ug/l)	81
Iron (ug/l)	273
Manganese (ug/l)	368
Nickel (ug/l)	70

Influent concentration values for downgradient active hydraulic control wells are estimated from average values presented on Table 2-5 and 2-6.

TABLE 3-6
KUMMER LANDFILL, MINNESOTA

PRECIPITATION/STRIPPING/ACTIVATED CARBON TREATMENT FACILITY
CONCEPTUAL DESIGN CRITERIA

Inorganics Removal:Polymer	
Hydraulic Capacity (gpm)	100
Chemical Dosage (mg/L), (lb/day)	10, 15
Clarifier Overflow Rate (gal/sf/day)	1000
Sludge Production @ 3% Solids (gal/day)	800
Dewatered Sludge @ 50% Solids (cy/day)	0.25
Multi-media Pressure Filter (gpm/sf), (psi)	3-5,100-150
Horsepower Requirement	30
Capital Cost	$320,000
Annual O&M Cost	$200,000
Period of Performance	4 to 30 years
Present Worth Cost	$950,000 to $2,200,000

Organics Removal:Packed Column Aeration	
Hydraulic Capacity (gpm)	100
Hydraulic Loading Rate (gpm/sf)	30
Column Surface Area (sf)	3.5
Column Diameter (ft)	2
Air:Water Ratio	30:1
Air Flowrate (cfm)	400
Packing Height (ft)	8
Horsepower Requirement	1

Organics Removal:Activated Carbon Polishing	
Hydraulic Capacity (gpm)	100
Carbon Contact Time (minutes)	20
Carbon Contractor Volume (cf)	270
No. of Carbon Contactors	1
Size of Carbon Contactors (ft)	7 x 7
Carbon Use Rate (lb/year)	600
Horsepower Requirement	1

Total Cost of Organics Removal	
Capital Cost	$530,000
Annual O&M Cost	$130,000
Period of Performance	4 to 30 years
Present Worth Cost	$940,000 to $1,800,000

Notes: A detailed capital cost estimate is provided in Appendix Table A-5. O&M costs are listed in Appendix Table A-6.

The concentrations for tDCE and benzene are well below performance criteria given in Table 2-2. However, vinyl chloride is above the performance criteria. If stack height is increased to about 30 feet, dispersion effects will reduce the concentration of vinyl chloride in air to levels which are protective of human health prior to any exposure points. Additional air modeling is required for lesser stack heights. Order of magnitude dispersion effects were estimated using an annual average temperature of 38 degrees Fahrenheit and average annual windspeed of 11 mph (National Oceanic and Atmospheric Administration annual averages for Duluth, Minnesota, published 1986). When dispersion is considered, annual average ambient vinyl chloride concentrations at ground level are below air criteria. Reevaluation of air treatment would be required during full-scale design of stripping technology.

A carbon contactor is included in the conceptual design to provide for effluent polishing. Carbon cannot be used for primary treatment because it is ineffective in removing vinyl chloride. Carbon is not required to achieve performance criteria based on present ground water quality data. However, the types of wastes present in the landfill are unknown. It is possible that less mobile semi-volatile organics may appear in perimeter extraction wells during implementation of remedial action. These organics were detected as tentatively-identified compounds in the landfill monitoring well, MW-16. Carbon contactors provide a low-cost contingency for treatment of a possible variable suite of organic contaminants.

Granular activated carbon (GAC) is a proven technology capable of removing a wide variety of organic compounds. Compounds are removed from water by adsorption to the carbon surface. The carbon is replaced when the available surface area is exhausted and compounds are no longer adsorped. Contaminants are eventually destroyed during regeneration of the spent carbon at elevated temperatures.

Carbon contactors are sized to allow the contaminated water to contact the GAC for a minimum of 15 minutes. Water is pumped once to the top of the contactor, and flows under pressure through the treatment unit to discharge. Carbon contactors may be operated in series or parallel configurations. Series operation offers maintenance flexibility and maximum protection against system failure. In series operation, treatment proceeds until the first carbon unit is exhausted. Treatment can be allowed to continue in the second contactor while new carbon is placed in the first, or be temporarily interrupted. The

series design safeguards against the pass through of contaminants, and allows the most efficient use of carbon.

Initial estimates of the frequency of carbon regeneration are based on previous experience with GAC for effluent polishing. Carbon usage may be in the range of 0.05 to 0.1 pounds of GAC per 1,000 gallons of water treated. A bench scale investigation may be necessary to determine the exact carbon usage rate. A summary of the carbon adsorption treatment design is provided in Table 3-6.

3.4.1.2 Advanced Oxidation Processes

Advanced oxidation processes (AOPs) are chemical treatment technologies which involve the addition of one or more of the following to contaminated ground water:

- ozone
- hydrogen peroxide
- ultraviolet light (UV)

AOPs are most effective in treating unsaturated organic straight-chain and ringed compounds such as those present in ground water at the Kummer site. The principal attraction of AOPs is their ability to destroy the organics of concern rather than transfer them to another pathway, such as air or carbon.

Two reaction pathways are responsible for compound degradation. In the first, ozone directly attacks the organic compound and is responsible for degradation. This direct reaction pathway is highly selective, but requires high contact times to account for slow rates of reaction. The second pathway, indirect reaction, is more significant. In the indirect reaction, ozone or hydrogen peroxide is first broken down to free hydroxide radicals. The hydroxide radical then oxidizes all organic and inorganic materials present in the ground water. The indirect reaction pathway is non-selective and allows for low contact times due to high rates of reaction.

The transformation to hydroxide radical, necessary for high rates of reaction, is catalyzed by the addition of UV or hydrogen peroxide. A combined ozone/hydrogen peroxide system is therefore selected as a treatment system which will successfully treat Kummer site organics. Alternative systems which utilize UV light and hydrogen peroxide will likely also be effective in oxidizing organic contaminants. Scaling of UV lights by inorganic precipitates has been a problem in these systems. However, at least one vendor now offers a system where the UV light tubes are continuously scoured to prevent build-up of scale. Bench scale testing will be required to confirm the treatment combination most effective in removing site contaminants, and verify conceptual design parameters.

A schematic of AOP treatment appears in Figure 3-7. Pretreatment is desirable with AOP to remove alkalinity and other inorganic compounds which scavenge the hydroxide free radical and contribute to high ozone dosages and treatment costs. Inorganic removal technologies are described in Section 3.4.2 of this report. Lime-soda softening pretreatment is consistent with AOP treatment, and removes carbonate and bicarbonate alkalinity from AOP process influent.

Treatment for organics takes place in a fiber-reinforced plastic or stainless steel reaction vessel. Contaminated water and hydrogen peroxide are fed through the vessel, and ozone is continuously supplied. The vessel is vented through an ozone destruct unit for low temperature thermal treatment of the exhaust air.

The AOP conceptual design is based on the following input parameters:

- water flow rate
- influent VOC concentrations
- effluent VOC concentrations
- ozone contact time
- ozone dosage
- ozone/hydrogen peroxide dose ratio (by weight)

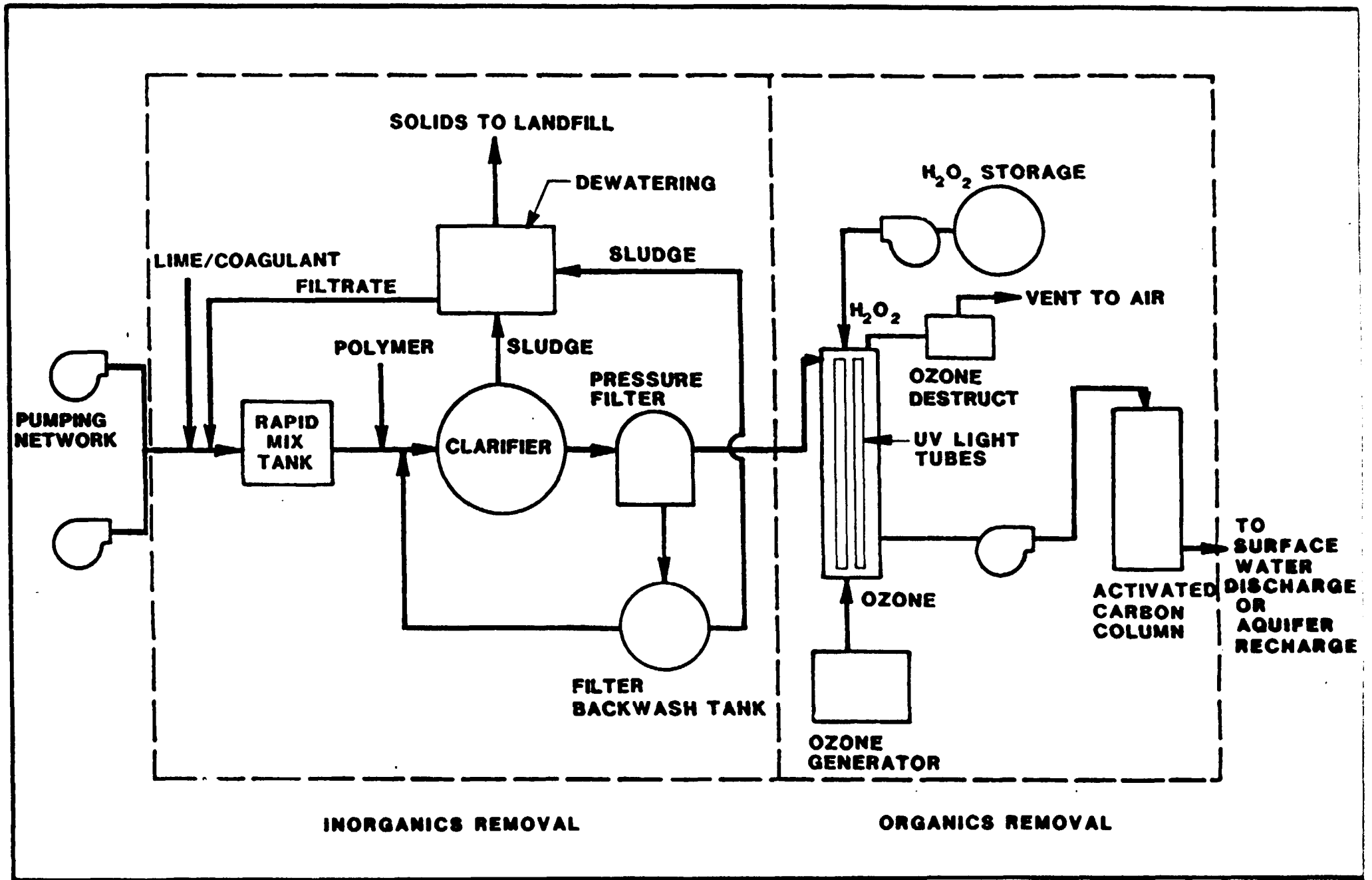
The design ground water flow rate and influent VOC concentrations are listed in Table 3-5. Effluent VOC concentrations are the surface water quality standards presented in Table 2-2. These standards allow for discharge of effluent to Lake Bemidji.

An ozone dosage of 5 to 30 mg/L will likely be required to oxidize volatile organics present in the Kummer ground water. The hydrogen peroxide to ozone ratio (by weight) selected for conceptual design is 0.5. Other conceptual design parameters are presented in Table 3-7.

Effluent polishing by activated carbon is also included in the conceptual design for AOP. Carbon is not required to achieve performance criteria based on present ground water quality data. Carbon is included, however, for the following reasons:

- Incomplete oxidation can result in organic intermediates which also may be toxic. Carbon will likely remove organic compounds which result from incomplete oxidation. Bench-scale testing will be required prior to implementation.

- The types of wastes present in the landfill are unknown. Carbon contactors provide a low-cost contingency for treatment of a possibly variable suite of organic compounds which may not be destroyed by AOP.



MALCOLM PIRNIE	KUMMER LANDFILL GROUND WATER FS	ON-SITE GROUND WATER TREATMENT PRECIPITATION/OZONE & H_2O_2	MALCOLM PIRNIE, INC. FIGURE 3-7 JULY 1990

141801

TABLE 3-7
KUMMER LANDFILL, MINNESOTA

SOFTENING/AOP/ACTIVATED CARBON TREATMENT FACILITY
CONCEPTUAL DESIGN CRITERIA

Inorganics Removal:Lime Softening

Hydraulic Capacity	100
Lime Dosage (mg/L), (lb/day)	400, 600
Clarifier Overflow Rate (gal/sf/day)	1000
Dry Weight Lime Sludge Production (lb/day)	900
Lime Sludge Production @ 10% Solids (gal/day)	1000
Dewatered Lime Sludge @ 50% Solids (cy/day)	1
Multi-media Pressure Filter (gpm/sf), (psi)	3-5, 100-150
Horsepower Requirement	35
Capital Cost	$400,000
Annual O&M Cost	$270,000
Period of Performance	4 to 30 years
Present Worth Cost	$1,300,000 to $2,900,000

Organics Removal:Ozone/Hydrogen Peroxide

Hydraulic Capacity (gpm)	100
Ozone Dosage (mg/L, (lb/day)	5-30, 6-36
Ozone Generator (lb/day)	30
Hydrogen Peroxide/Ozone Dose Ratio by Weight	0.50
Hydrogen Peroxide Dosage (mg/L), (lb/day)	2.5-15, 7-43
Ozone Contact Time (minutes)	5
Ozone Contactor Volume (gallons)	500
Ozone Contactor Diameter (ft)	2.5
Ozone Contactor Height (ft)	15
Horsepower Requirement	1

Organics Removal:Activated Carbon Polishing

Hydraulic Capacity (gpm)	100
Carbon Contact Time (minutes)	20
Carbon Contractor Volume (cf)	270
No. of Carbon Contactors	1
Size of Carbon Contactors (ft)	7 x 7
Carbon Use Rate (lb/year)	600
Horsepower Requirement	1

Total Cost of Organics Removal

Capital Cost	$440,000
Annual O&M Cost	$170,000
Period of Performance	4 to 30 years
Present Worth Cost	$1,000,000 to $2,000,000

Note: A detailed capital cost estimate is provided in Appendix Table A-7. O&M costs are listed in appendix Table A-8.

Conceptual design parameters for carbon adsorption polishing are presented on Table 3-8. Physical treatment units are similar to those described in Section 3.4.1.1 for polishing of air stripper effluent.

Estimated carbon usage rates for polishing AOP effluent are similar to those estimated for polishing air stripper effluent. Rates are expected to be somewhat higher for AOP due to possible oxidation by-products. However, AOP will also be effective in removing most semi-volatile organics, such as naphthalene. Because of this trade-off, carbon usage rates for AOP polishing are estimated to be equal to rates for air stripping polishing. It is possible that AOP bench tests will show the effectiveness of the treatment process in removing all site organic compounds, so that carbon polishing is unnecessary in final design.

3.4.1.3 Discharge to Publicly Owned Treatment Works

Under this alternative, pumped ground water is discharged into the collection system for the Town of Bemidji POTW. There is precedent for treating landfill leachate in POTWs (Key, H.G., "Pilot Testing for Combined Treatment of Leachate from a Domestic Waste Landfill Site, Journal Water Pollution Control Federation, 59(5): 254-261 [May 1987]). Treatment is accomplished by air stripping and biological degradation in aeration units.

The Town of Bemidji operates a POTW with hydraulic capacity of 2 MGD. Current average daily flow is about 1.2 MGD. Flow from the Kummer landfill may add an additional .13 MGD. There are pretreatment standards for metals which might prevent the discharge of the recovered ground water into the treatment plant collection system. The effluent discharges into Lake Bemidji and strict controls on toxics are enforced. The MPCA does not believe the POTW can accept the Kummer ground water flow and still meet effluent quality permits (personal communication with Jim Klang). The POTW recently rejected a 6,000 gallons per week waste stream with inorganic quality similar to the Kummer ground water. Pumping alternatives under consideration for on-site ground water generate flows of up to one million gallons per week. The passive downgradient hydraulic controls result in a ground water flow of about 200,000 gallons per week.

Implementation of this treatment alternative will require construction of a sewer line to connect the site to the City of Bemidji sanitary sewer system. A 9-inch concrete line about 1100 feet long would be constructed at approximate capital cost of $100,000. The current cost of treatment at the plant is $2.95/1000 gallons. Annual treatment costs would therefore range from about

TABLE 3-8
KUMMER LANDFILL, MINNESOTA

SUMMARY OF TREATMENT ALTERNATIVES SCREENING

Alternative	Effectiveness	Feasibility/Implementability	Environmental Effects	Present Worth Cost
Coagulation/Flocculation Air Stripping	Effective for organics, probably effective for inorganics.	Feasible and easily implemented.	Inorganic contaminants transferred to land disposal. Vapor phase controls required to prevent release of organic contaminants to air.	$1,900,000 to $4,000,000
Lime-Soda Softening Advanced Oxidation Processes	Effective. Flexibility to treat for unknown organics and inorganics which may appear during pumping	Feasible with several available technologies. AOP requires bench testing.	Inorganic contaminants transferred to land disposal. Organic contaminants destroyed.	$2,300,000 to $4,900,000
Discharge to POTW(1)	Probably effective. If contaminants are not removed, dilution will occur.	High flow rates not acceptable at POTW due to strict effluent limitations on inorganics quality.	Probable transfer of contaminants to air, surface water, and land disposal.	$ 580,000 to $1,900,000

Notes: (1) Applicable to Alternative 2 only. Based on $2.95/1000 gallons discharged.

$30,000 for passive downgradient controls to about $150,000 for the pump-out network presented above in section 3.3.4.

3.4.1.4 Bioremediation

Bioremediation involves the introduction of nutrients, especially oxygen, into the aquifer to enhance naturally-present biodegradation processes. Bioremediation at present is most effective for hydrocarbon plumes. Reduction of vinyl chloride concentrations to surface water quality standards is not proven. However, as the technology is developed further, new approaches to bioremediation may be discovered which reduce the concentrations of vinyl chloride and other organic compounds. Oxygenating the aquifer may also prevent further formation of vinyl chloride by anaerobic degradation of the chlorinated ethenes.

The bioremediation process presently developed for the Kummer site is based on active down-gradient controls, and an on-site infiltration pond. Nutrients, including dissolved oxygen, nitrogen, and phosphorous, may need to be added ahead of the infiltration pond. Biotreatment occurs in the vadose zone beneath the infiltration pond and in the aquifer. The pond must be carefully located to maximize site hydraulics and distribute nutrients throughout the plume of contamination. The cost of nutrient addition is less than 10 cents per 1000 gallons, resulting in an annual treatment cost for a 100 gpm flow rate of about $5,000.

At present, bioremediation will likely not be effective in reducing vinyl chloride to surface water quality standards. The process will have little or no impact on inorganic contaminants. Implementation is difficult, as the most beneficial location for recharge is the landfill itself and cannot be utilized. Implementation may also require a variance from MDH and MPCA regulations which govern discharges to aquifers. Recharge near the landfill may cause a mound that brings ground water into contact with landfilled wastes. Destruction of organic compounds may be realized, however, with minimal impact on the environment.

Bioremediation may warrant further consideration at a future date if technical developments and study results offer new approaches to implementation.

3.4.2 Inorganics Treatment Alternatives

Significant inorganic compounds present in on-site ground waters include:

- arsenic
- barium
- iron

- manganese
- nickel

Inorganic treatment alternatives are developed for the removal of these compounds, and other inorganics which may impact removal efficiency in organics treatment units, from pumped ground water. Conceptual designs are primarily based on barium as this compound is present at concentrations that sometimes exceed current drinking water standards.

3.4.2.1 Precipitation

Coagulation and flocculation are physical treatment processes which involve destabilization of charged colloidal particles, then aggregation and precipitation. Destabilization is typically accomplished by addition of iron or aluminum salts, or inert organic polymers. Some solubilized ions (including barium, nickel, and arsenic) may be partially removed by adsorption on the floc. However, proprietary technology used in the semi-conductor industry reportedly removes ions at a pH of 7.5 to 8.5.

A schematic of the coagulation/flocculation process is shown in Figure 3-8. The conceptual design is based on the following input parameters:

- water flow rate
- influent inorganic concentrations
- effluent inorganic concentrations
- influent alkalinity and pH

The design flow rate and influent inorganic concentrations are listed in Table 3-4. Effluent inorganic concentrations are the surface water quality standards presented in Table 2-3.

Polymer is added with a pump and mixed with the ground water. Sludges are removed in a clarifier. Clarifier overflow is filtered prior to treatment for organics. Underflow is dewatered using a filter press. Filtrate is recycled to the head end of the treatment process. Dewatered sludges require landfill disposal. If RCRA characteristics are exceeded, sludges will require disposal as a hazardous waste. It is likely that because sludges originated on a CERCLA site, they may also require disposal as a hazardous waste. Any landfill disposal increases future liability due to potential pollutant release. Conceptual design parameters for the coagulation/flocculation process are given in Table 3-5.

3.4.2.2 Lime-Soda Softening

Lime-soda softening is a chemical treatment process. It involves converting bicarbonate alkalinity to carbonate alkalinity, then removing divalent

ions as precipitates of carbonate and/or hydroxides. During the process pH is raised to above 10, causing the precipitation of arsenic, nickel, and barium. Other ionic compounds may also be removed by adsorption to the carbonate and/or hydroxide precipitates.

A schematic of the lime-soda softening process is shown in Figure 3-9. The conceptual design is similar to that for coagulation/flocculation, except lime is added in the place of polymer. Conceptual design parameters for the lime-soda softening process are given in Table 3-6.

In comparison to coagulation/flocculation, the advantages of lime-soda softening are:

- chemical additions are less costly.
- alkalinity is removed, which improves the effectiveness of organics removal by AOP treatment.

The disadvantage of softening is that a much higher volume of sludge is produced, increasing costs for handling and disposal. The sludge is the result of precipitation of divalent cations to compounds such as calcium carbonate. The system may also require a sophisticated controls, as the pH ranges are narrow for optimal removal of arsenic, nickel, and barium. Arsenic removal is complicated further by several possible valence states.

3.4.2.3 Discharge to Publicly Owned Treatment Works

Discharge to the City of Bemidji POTW will also remove inorganic by adsorption, chemical/biological reaction, and dilution processes. Requirements for discharge to the town of Bemidji POTW are discussed above in Section 3.4.1.3.

3.4.3 Development and Evaluation of Treatment Alternatives

Three treatment alternatives are selected as follows:

- inorganic removal by coagulation/flocculation followed by organics removal by air stripping
- inorganic removal by lime-soda softening followed by organics removal by AOP treatment
- discharge to the Town of Bemidji POTW

Organics removal technologies include alternatives for on-site treatment by non-destructive (air stripping) and destructive (AOP) techniques, and off-site treatment. Inorganic treatment technologies are assigned based on compatibility with organics technologies. Removal of alkalinity as provided by lime-soda softening process is desirable for AOP treatment. Coagulation/flocculation, with

estimated lower capital cost and sludge production, is adequate pretreatment for air stripping.

The treatment alternatives are evaluated in the following sections. Results of the evaluation are summarized on Table 3-8.

3.4.3.1 Alternative A - Precipitation and Air Stripping

These technologies are technically implementable at the Kummer site. However, both may result in transfer of contaminants from one medium to another without treatment. Inorganics are accumulated in sludge which requires land disposal. Unless vapor phase controls are provided, organic compounds (except naphthalene) are released to the air. The air discharge has been estimated to be protective of public health with respect to incremental risk of cancer. The air discharge, however, will impact all persons in the site area.

Estimated capital and operations and maintenance costs for this alternative are presented on Table 3-6. Annual operating costs are high due to the expense of coagulants required to remove inorganics at the neutral pH of pumped ground water.

3.4.3.2 Alternative B - Lime-Soda Softening and AOP

These technologies are also technically implementable at the Kummer site. Both technologies remove a wide range of inorganic and organic compounds, offering process flexibility in the event that the suite of contaminants changes over time. However, operations may be difficult as the pH range must be carefully controlled. Inorganics are accumulated in a lime sludge which requires land disposal. It is likely that this sludge will require landfill disposal as a hazardous waste. Organic compounds, however, are destroyed with no potential release to the environment.

Estimated capital and operation and maintenance costs for this alternative are presented on Table 3-7. Estimated capital and operating costs for AOP are slightly lower than for air stripping, due to the added cost of vapor phase controls for the stripper. Lime-soda softening operating costs are similar to costs for coagulation/precipitation. This treatment alternative is preferred over Alternative A based on destruction of organic compounds at similar present worth cost.

3.4.3.3 Alternative C - Discharge to POTW

Discharge to the City of Bemidji POTW is technically feasible. However, the alternative may not be implementable due to the strict effluent limits for metals. Environmental effectiveness is unknown. Contaminants may not be destroyed in the process, but rather diluted and discharged to the air (during aeration), water (in dilute effluent), or land (in waste sludge). Annual costs for treatment in the POTW are lower than for on-site treatment systems. However, it is likely not implementable at the 100 gpm flow rate developed by the downgradient pumping network.

3.4.3.4 Bioremediation

Bioremediation is not feasible at present, but is an attractive innovative technology which may warrant future consideration. Bioremediation might minimize further anaerobic degradation of chlorinated ethenes to vinyl chloride. Bioremediation requires precise location of an on-site recharge pond to maximize site hydraulics. A location north of the landfill is not optimal because it doesn't introduce nutrients to the present plume. It may not be possible to locate this pond very near the landfill without creating a mound which may bring ground water into contact with landfilled wastes. Location further downgradient of the landfill would require procurement of additional land for implementation of the pond.

3.5 SCREENING OF EFFLUENT MANAGEMENT ALTERNATIVES

This section describes the effluent management alternatives developed from the applicable technologies identified in section 2.0. Cost and non-cost features of each alternative are discussed, and the key elements of each alternative are summarized.

Effluent management alternatives are:

- Discharge to surface water
- Discharge to POTW
- On-site discharge to infiltration pond.

3.5.1 Discharge to Surface Water

There are two possible points for surface water discharge: Lake Bemidji, located about one mile east of the landfill; and an existing storm sewer, located about one mile south of the landfill. Non-point source discharge is also possible if the no further action alternative is selected for hydraulic control.

The storm sewer discharges to the Mississippi River to the west of Lake Bemidji. County-maintained open trenches used near the site for drainage are not acceptable for discharge because of freezing during cold weather.

Conceptual design parameters for either discharge point are presented on Table 3-9. Either discharge point is effective provided that effluent is treated to surface water quality standards for Lake Bemidji and the Mississippi River. These standards would likely require removal of inorganic contaminants as well as organic prior to discharge. Connection to the existing storm sewer may require coordination with the City of Bemidji to assure that existing lines have adequate hydraulic capacity for all expected flows. Either point source location will need to meet the permit requirements of the MPCA Water Quality Division. Permit requirements may also be applicable to an expanded non-point discharge. Ground water modeling results presented in Appendix B suggest the non-point discharge resulting from the no further action alternative complies with applicable surface water quality standards for Lake Bemidji.

3.5.2 Discharge to POTW

Discharge to the City of Bemidji sanitary sewer system is a second effluent management alternative. Implementation requires construction of a 4-inch sewer line of length about 1,100 feet. The current discharge fee for the City of Bemidji POTW is about $2.95/1,000 gallons. Conceptual design parameters and the present worth cost estimate for this alternative is presented on Table 3-9.

Discharge to the POTW requires pretreatment to surface water quality standards due to the effluent quality standards for the plant. Because of the current discharge fee and flow rate, this effluent management alternative has a high present worth cost. The large quantity of dilute influent will also likely interfere with the efficiency of the POTW in removing conventional organic pollutants.

3.5.3 On-Site Discharge to Infiltration Pond

An on-site management alternative is discharge to an infiltration pond. Conceptual design parameters for the pond are presented on Table 3-10. Design is based on permeability data for the unsaturated zone, and hydraulic conductivity data presented on Table 2-7. For design of a full-scale system, additional field tests including infiltration capacity would be required during preliminary engineering.

TABLE 3-9
KUMMER LANDFILL, MINNESOTA

DISCHARGE NETWORK CONCEPTUAL DESIGN PARAMETERS

DISCHARGE NETWORK:

Parameters	Discharge to Surface Water	Discharge to POTW
Piping:		
Type	concrete	HDPE
Diameter	4"	4"
Length	1 mile	1100 feet
Depth	6 feet	6 feet
Capital Cost	$200,000	$ 42,000
Annual O&M Cost	$ 18,000	$ 200,000
4 year Present Worth Cost	$260,000	$ 680,000
30 year Present Worth Cost	$370,000	$1,900,000

Notes: A detailed capital cost estimate is provided in Appendix Table A-3. O&M costs are listed in Appendix Table A-4.

TABLE 3-10
KUMMER LANDFILL, MINNESOTA

RECHARGE POND CONCEPTUAL DESIGN PARAMETERS

RECHARGE NETWORK:

PARAMETERS	Infiltration Pond
Basin Depth	10 feet
Basin Width	200 feet
Basin Length	500 feet
Backfill	Native Soil
Vegetation (Recommended for erosion prevention)	100,000 ft^2
Inflow schedule	Continuously
Impact stilling basin	6 ft x 6 ft x 3 ft
Piping:	
Type	PVC
Diameter	4 inch
Length	2500 feet
Depth	6 feet
*Capital Cost	$230,000
Annual O&M Cost	$ 29,000
4 year Present Worth Cost	$320,000
30 year Present Worth Cost	$500,000

*Includes cost of excavation, vegetation and pumping

Existing data indicate the strata are extremely permeable so that pond size is minimal. On-site space is available to the north of the landfill area, although this location may not be ideal for maximizing performance of the pumping network. Depth is set at 10 feet to allow for continued operation during extended sub-freezing temperatures characteristic of the Bemidji winters. Costs are based on construction of a new facility from grade, but savings can be realized if the existing borrow area is used for the pond or pond construction is combined with placement of the cover system.

Based on average annual conditions, detention time in the pond is expected to be less than one hour. During rainy seasons detention time will be greater, in dry periods the pond may hold little or no water. Pond design is based on a water balance calculation which includes:

- discharge rate of water into the pond
- evapotranspiration
- runoff
- infiltration
- percolation
- interlayer drainage

The capital cost estimate for the pond includes berms to prevent landfill cover system runoff from entering the pond. An alternate design is to increase pond size to account for landfill runoff volumes. Costs are also provided for annual dredging or reworking of the pond bottom, with landfill disposal of dredge materials.

Implementation of this alternative will require treatment for organics removal prior to recharge. Inorganic treatment may or may not be required depending on remedial action objectives for the aquifer and the distribution of inorganic compounds at the completion of pumping. Removal of the VOC plume is expected to redistribute inorganic compounds so that concentrations are below drinking water guidelines. Inorganic compound concentrations may also be below surface water quality standards at the completion of pumping.

3.5.4 Summary of Effluent Management Technology Screening

Evaluation of effluent management technologies is summarized on Table 3-11. Both point source and non-point source discharges to surface water are evaluated.

As discussed in section 3.3.1 and Appendix B, the no further action with non-point discharge to Lake Bemidji apparently meets surface water quality criteria. A discharge does not occur if organic compound concentrations at monitoring well locations near Lake Bemidji are below surface water quality limits. Ground water modeling results suggest this is the case for over 30

TABLE 3-11
KUMMER LANDFILL, MINNESOTA

SUMMARY OF EFFLUENT MANAGEMENT ALTERNATIVES SCREENING

Alternative	Effectiveness	Feasibility/Implementability	Environmental Effects	4 or 30 year Present Worth
Non-point discharge to Lake Bemidji	Apparently meets surface water quality criteria.	Not applicable	Some deterioration of surface water quality near the discharge, but the impacts are likely not detectable for organic compounds.	$200,000
Point source discharge to Lake Bemidji	Large volume of water can be effectively handled by discharge to open waters.	Several treatment methods may be required to meet strict effluent discharge limits.	Minimal effects because of strict discharge quality criteria.	$260,000 to $370,000
Discharge to POTW	Effective, but probably requires on-site treatment for removal of organic and inorganic compounds prior to discharge.	High flow rates may not be acceptable at POTW due to impacts on present operations.	Minimal effects because of on-site pretreatment, unless the discharge causes process upsets at the POTW and release of conventional polutants.	$680,000 to $1,900,000
Infiltration Pond	Effective. Groundwater can be recharged at a high rate. Freezing problems during cold weather operations must be managed.	Implementable. Feasible in northern site area previously used for borrow area.	Must limit public access to open pond. May deflect direction of flow of shallow groundwater.	$320,000 to $500,000

years. Non-point discharge to Lake Bemidji is therefore retained as an effluent management technology to accompany no further action for hydraulic controls.

Point source discharge is an effective management technology for large volumes of effluent. For any point source discharge to meet current NPDES permit requirements, treatment for removal of organic and inorganic compounds is required. Present worth cost of the point source discharge is similar to the present worth cost of an on-site infiltration pond.

Discharge to the POTW has high estimated cost in comparison to point source discharge and the on-site infiltration pond. The alternative is eliminated based on costs.

The infiltration pond is effective and possibly implementable within an existing site borrow area. Implementation is easier than for a point source discharge because fewer regulations exist. The present worth cost estimate is similar to the cost for a point source discharge. The technology is retained for pumping alternatives.

3.6 SUMMARY OF REMEDIAL ACTION ALTERNATIVES

Based on screening results presented above, the following alternatives are carried forth for detailed evaluation in section 4.0:

- Alternative I - No further action or limited action with non-point source discharge to Lake Bemidji
- Alternative II - Active downgradient controls, on-site treatment by AOP and lime soda softening, and point source discharge to Lake Bemidji
- Alternative III - Active downgradient controls, on-site treatment by AOP, possible on-site treatment by lime soda softening, and on-site disposal in an infiltration pond.

4.0 ANALYSIS OF REMEDIAL ACTION ALTERNATIVES

This chapter presents the detailed analyses of the ground water remediation alternatives. Each alternative is analyzed on nine evaluation criteria. The alternatives are then compared, and the key tradeoffs among alternatives identified. The analyses summarize the relevant information needed to select an appropriate site remedy.

4.1 INTRODUCTION

Nine evaluation criteria have been developed by the USEPA to address the requirements and considerations for appropriate remedial action at a CERCLA site. The nine criteria address the following concerns:

- Long-Term Effectiveness - This criterion evaluates the long-term protection of human health and the environment at the completion of remedial action. It is assessed in the magnitude of residual risks, adequacy of controls in achieving clean-up criteria, reliability of controls against possible failure, and potential to provide continued protection.

- Reduction of Toxicity, Mobility, and Volume - This criterion evaluates the anticipated performance of treatment alternatives.

- Short-Term Effectiveness - The effectiveness of alternatives in protecting human health and the environment during implementation of remedial action is evaluated by this criterion. Short-term effectiveness is assessed by protection of the community, protection of workers, environmental impacts, and time until protection is achieved.

- Implementability - This assessment evaluates the technical and administrative feasibility of alternatives and the availability of services and materials.

- Cost - The estimated capital, annual maintenance and monitoring, and present worth value costs are evaluated by this criterion. Present worth costs are calculated using a 10 percent discount rate over the expected period of operation. Cost estimate summaries of alternative control and treatment are given in Appendix D.

- Overall Protection of Human Health and the Environment - This is a summary assessment which draws on the results of the above evaluations to describe whether, and how, each alternative provides protection of human health and the environment.

- Compliance with ARARs - This summary assessment describes how the alternative complies with ARARs, or if a waiver is required and why it is justified.

- Support Agency Acceptance - This assessment evaluates the technical and administrative concerns the Support Agency may have regarding each of the alternatives. The Support Agency for the State-lead Kummer site is the USEPA. This criterion will be discussed in the Record of Decision once comments on the proposed plan have been received.

- Community Acceptance - This criterion evaluates the community's apparent preferences or concerns about alternatives. Prior to community meetings, the community acceptance is anticipated. This evaluation criteria is updated as public comments are received.

4.2 ALTERNATIVE ANALYSIS

This section presents the assessment and summary of each alternative against the nine evaluation criteria. The discussion includes summary tables highlighting the assessment of each alternative.

4.2.1 Alternative I - No Further Action

4.2.1.1 Description

The no action alternative consists of allowing contaminated ground water to eventually discharge to Lake Bemidji. Off-site monitoring wells no longer required for long-term tracking of the plume may be removed, and ground water quality will be monitored annually for 30 years. Some new monitoring wells may also be installed near Lake Bemidji. Capital costs are estimated based on removing all but 10 existing monitoring wells, and adding two new wells. Additional costs are possible if wells require future replacement. Annual monitoring costs include semi-annual sampling of the remaining wells and analysis for volatile organic compounds, conventional water quality parameters, and priority pollutant metals.

A limited action alternative adds institutional controls such as a drilling advisory in the area of ground water contamination. Additionally, it is possible to abandon existing private drinking water supply wells if requested by the affected public.

4.2.1.2 Assessment

A summary of the nine criteria evaluation for the no action alternative is presented on Table 4-1. A discussion of the evaluation follows.

Overall Protection of Human Health and the Environment - Based on ground water modeling results contained in Appendix B, no further action may be protective of the environment. Volatile organic compounds do not reach Lake Bemidji for over 30 years, and at concentrations that are likely below surface water quality standards. However, contaminants remain in ground water down-gradient of the landfill. No action is protective of human health as long as an alternative water supply is available. It may provide long-term effectiveness if the cover system prevents significant additional contaminant migration from the landfill. A long-term drilling advisory will also be implemented and enforced by MDH to prevent downgradient aquifers from being used in the future for drinking water supply.

Compliance with ARARs - No action may comply with MPCA municipal waste facility ground water standards because corrective action has been implemented in the form of the alternative drinking water supply. The drinking water MCL for vinyl chloride is exceeded at the eastern landfill boundary. No action is inconsistent with the USEPA ground water protection strategy.

Long-Term Effectiveness - No action may be effective in preventing significant future contaminant migration to surface water if the cover system reduces the load of contaminants introduced to ground water at landfill. However, increased health risks will result from future use of downgradient aquifers for drinking water supplies.

Reduction of Toxicity, Mobility, or Volume - This criterion is not applicable because no treatment technologies are proposed. Toxicity may increase if anaerobic degradation of chlorinated ethenes causes vinyl chloride concentrations to increase in the aquifer.

TABLE 4-1
KUMMER LANDFILL, MINNESOTA

ALTERNATIVE I ANALYSIS

ALTERNATIVE I - NO FURTHER ACTION

Description: The No Action Alternative consists of no further action with long-term monitoring of ground water quality at the landfill and near Lake Bemidji. Limited action may also be taken to include institutional controls.

Assessment:

Overall Protection of Human Health and the Environment

- Based on modeling results, and surface water quality standards, likely protective of the environment. Contaminants will continue to migrate to the downgradient aquifer system. However, the risk of ingestion exposure is minimized by the alternate water supply.
- May be protective of human health in combination with the alternate water supply. However, public health may be adversely affected by use of the aquifer for a drinking water supply.

Compliance with ARARs:

- May not comply with Minnesota Standards for ground water quality at the compliance boundary of mixed municipal solid waste landfills. Probably complies with Surface Water Quality Criteria for Lake Bemidji. Drinking water MCLs are achieved by the alternate water supply. Inconsistent with USEPA ground water protection strategy.

Long-Term Effectiveness:

- Effective because alternate water supply system virtually eliminates human ingestion exposure pathway.

Reduction of Toxicity, Mobility, or Volume:

- Not met because no treatment or controls are involved.
- May increase toxicity if anaerobic degradation mechanisms cause vinyl chloride concentrations to increase.

Short-Term Effectiveness:

- Probably ineffective because there will be continued migration of contaminants to downgradient ground waters.

Implementability:

- Technical feasibility is not applicable as no treatment or controls are involved.
- Availability of services is not applicable as no treatment or controls are involved.
- May be difficult to enforce institutional controls or require private owners to abandon existing drinking water supply wells.

TABLE 4-1 (cont'd)

Cost:

- Capital Cost: $73,000
- Annual Maintenance and Monitoring Cost: $24,000
- Estimated Present Worth: $300,000

Support Agency Acceptance:

- To be evaluated after development of the proposed plan.

Community Acceptance:

- Resistance possible.

Short-Term Effectiveness - No action is effective in the short-term because the risk of human ingestion of contaminants is virtually eliminated by the alternative water supply system. The cover system may also reduce the rate of contaminant migration from the landfill to ground water.

Implementability - Technical feasibility is not applicable as no treatment or controls are planned. The no action alternative may increase the scope of, or accelerate the need for, future downgradient ground water remedial action if significant contaminant concentrations remain in ground water beneath the landfill. Institutional controls may be difficult to enforce.

Cost - The estimated capital, maintenance and monitoring, and present worth costs for no action are presented on Table 4-1. These costs do not include any future response actions required if the cover system does not prevent future migration of contaminants from landfilled wastes to ground water.

Support Agency Acceptance - This criterion will be evaluated after development of the proposed plan.

Community Acceptance - The community may not favor the no action alternative. Contaminant discharges to Lake Bemidji will be questioned.

4.2.2 Alternative II - Active Downgradient Hydraulic Controls and Surface Water Discharge

4.2.2.1 Description

Ground water will be collected in a series of pumping wells located within the present plume of VOC contamination. An on-site treatment facility is constructed with removal of inorganic compounds by lime-soda softening and filtration, and removal of organic compounds by advanced oxidation processes. Inorganics treatment sludges are landfilled off-site, but may be placed on-site. Treated ground water is discharged to Lake Bemidji via a dedicated discharge line and below water discharge structure. Treatment operations may continue from 4 to 30 years,

depending on long-term effectiveness of the cover system in blocking future contaminant migration to ground water at the landfill.

4.2.2.2 Assessment

Table 4-2 presents a summary of the nine criteria evaluation for Alternative II. A discussion of the evaluation follows.

Overall Protection of Human Health and the Environment - This alternative provides protection of human health because ground water contaminants are removed and treated to surface water quality standards. The environment is also protected by improving ground water quality down-gradient of the landfill and preventing future contaminant migration to down-gradient ground water and surface water.

Compliance with ARARs - Alternative II is consistent with all site ARARs, including Minnesota Rules for landfill performance, USEPA and MDH drinking water quality regulations and guidelines, and surface water quality standards. The alternative is consistent with USEPA and State of Minnesota ground water protection strategies.

Long-Term Effectiveness - This alternative provides direct indication that long-term surface water quality objectives are achieved. Organic compounds are removed from the aquifer and destroyed. Inorganic compounds will be transferred to a treatment sludge for landfill disposal. The long-term effectiveness of landfill disposal is unknown.

Reduction of Toxicity, Mobility, or Volume - Ground water pumping will reduce the volume of contaminated media at the site. Destruction of organic compounds in the treatment process will reduce toxicity of site contaminants. The toxicity of some of the inorganic contaminants may also be reduced by the formation of metal salts during treatment.

Short-Term Effectiveness - There is minimal risk to workers and the general public during remedial action construction and operations. Some VOC emissions are possible from the AOP treatment process, rapid mix, and clarification. Treatment plant workers will be required to handle chemicals and sludges which may be caustic or toxic.

Implementability - Well construction, treatment plant construction, and effluent discharge to surface water are technically feasible. Additional ground water modeling will be required to optimize the pumping network. Pump tests will be required during remedial construction to verify modeling results. Treatability tests will be required to determine treatment system design parameters, and to verify that AOP and lime-soda softening processes can achieve surface water quality standards.

Unknown barriers may exist for construction of a pipeline to discharge to surface water. Requirements for an NPDES point source discharge permit can be met, but administrative requirements may delay remedial action implementation. Inorganics treatment sludges may be landfilled as hazardous wastes at increased cost over municipal facilities. Land purchases or long-term lease agreements are required for downgradient pumping well locations and pipeline routes.

Cost - Estimated capital, maintenance and monitoring, and present worth costs for Alternative II are presented in Table 4-2. Costs for inorganics treatment and disposal are sensitive to the concentration of inorganic compounds in pumped ground water and the disposal requirements for dewatered sludges. The range of estimated present worth costs corresponds to an operations period of from 4 to 30 years. Actual time of operations depends on the long-term effectiveness of the cover system.

Support Agency Acceptance - This criterion will be evaluated after development of the proposed plan.

Community Acceptance - The community will likely favor active ground water remediation.

4.2.3 Alternative III - Active Downgradient Hydraulic Controls and Infiltration Pond Discharge

4.2.3.1 Description

Ground water will be collected in a series of pumping wells located within the present plume of VOC contamination. An on-site treatment facility will be constructed for removal of organic compounds by advanced oxidation processes. Inorganics treatment may be provided if average

TABLE 4-2
KUMMER LANDFILL, MINNESOTA

ALTERNATIVE II ANALYSIS

ALTERNATIVE II - ACTIVE DOWNGRADIENT HYDRAULIC CONTROLS - SURFACE WATER DISCHARGE

Description: Ground water will be extracted along the eastern perimeter of the landfill, treated on-site to remove organic and inorganic contaminants of concern and discharged to surface water. Inorganic removal will involve lime softening, precipitation and filtration. Organic removal will include ozone treatment followed by GAC polishing.

Assessment:

Overall Protection of Human Health and the Environment:

- Will be protective of human health and the environment as contaminated groundwater is removed and treated to surface water quality standards for Lake Bemidji.

Compliance with ARARs:

- Complies with Minnesota standards for ground water quality at the compliance boundary of mixed municipal solid waste landfills.
- Complies with air and surface water objectives and criteria.
- Can meet drinking water MCLs for the aquifer.
- Consistent with USEPA ground water protection strategy.
- Likely requires inorganics removal for effluent compliance with NPDES requirements.

Long-Term Effectiveness:

- Pumping wells will effectively capture the flow of contaminated ground water.
- Downgradient ground water will be protected from future contamination.
- Organic contaminants of concern will be destroyed by ozone and intermediate compounds will be removed with GAC.
- Inorganic contaminants of concern will be removed from the ground water but transferred to sludge.
- It is unknown if the disposal of sludge in a landfill provides long-term effectiveness.
- Caustic and reactive compounds will be used in the treatment of contaminated ground water; workers will wear protective equipment and be trained to handle spills and upsets.

Reduction of Toxicity, Mobility, or Volume:

- The proposed treatment scheme for organic and inorganic removal will reduce the toxicity of the contaminated ground water.
- Ozone treatment will destroy the organics of concern.
- Inorganic treatment will result in a sludge which will require landfill disposal. Sludge may require disposal as a hazardous waste.

TABLE 4-2 (cont'd)

Short-Term Effectiveness:

- Minimal risk to the community during well development and treatment of contaminated ground water.
- Possible risk to workers during well development and ground water treatment due to VOC emissions. Requires air monitoring and possible respiratory protection.
- Treatment plant personnel will be working with caustic and reactive products. Requires protective equipment and spill response training.

Implementability:

- Technically feasible. Well construction will use proven techniques and organic and inorganic treatment methodologies have proved effective in similar conditions. Effectiveness can be easily determined by monitoring.
- Ozone treatment may require bench studies to determine full-scale design parameters.
- Construction of a pipeline to discharge to surface water may be difficult to implement due to unknown physical barriers. Probably administratively feasible.
- Must meet NPDES permit requirements to discharge into surface water.
- Construction of a discharge pipeline may require additional city and county permits.
- Services and materials are available.
- Treatment sludges may be disposed of in Kummer landfill if non-hazardous.
- May require purchase of downgradient land for pumping well locations.

Cost:

- Capital Cost: $1,300,000
- Annual Maintenance and Monitoring Cost: $510,000
- Estimated Present Worth: $3,000,000 - $6,200,000

Support Agency Acceptance:

- To be evaluated after development of the proposed plan.

Community Acceptance:

- Community will likely favor active ground water remediation.

contaminant concentrations exceed drinking water quality guidelines. If required, lime-soda softening will be provided for inorganics removal. Treated ground water is placed in an on-site pond for recharge to the aquifer. Treatment operations may continue from 4 to 30 years, depending on long-term effectiveness of the cover system in blocking future contaminant migration to ground water beneath the landfill.

4.2.3.2 Assessment

Table 4-3 presents a summary of the nine criteria evaluation for Alternative III. A discussion of the evaluation follows.

Overall Protection of Human Health and the Environment - Alternative III is protective of human health and the environment because contaminated ground water is removed, treated to drinking water quality standards, and discharged to ground water. Ground water quality is improved, and future organic contaminant migration to down-gradient ground water and surface water is prevented.

Compliance with ARARs - Complies with the Minnesota standards for ground water quality at the compliance boundary of mixed municipal solid waste landfills and with air and surface water criteria. Alternative III utilizes Best Available Technology or equivalent for treatment of organic and possibly inorganic contaminants. The alternative is consistent with USEPA and State of Minnesota ground water protection strategies.

Long-Term Effectiveness - Active downgradient controls provide direct indication that long-term surface water quality objectives are achieved. Organic contaminants will be destroyed by AOP treatment. Inorganic contaminants may be removed from the ground water and transferred to a treatment sludge for landfill disposal. The long-term effectiveness of land disposal is unknown.

Reduction of Toxicity, Mobility or Volume - Ground water pumping will reduce the volume of contaminated media at the site. Destruction of organic compounds in the treatment process will reduce toxicity of site contaminants. The toxicity of some of the inorganic contaminants may also be reduced by the formation of metal salts during treatment. The long-

TABLE 4-3
KUMMER LANDFILL, MINNESOTA

ALTERNATIVE III ANALYSIS

ALTERNATIVE III - ACTIVE DOWNGRADIENT HYDRAULIC CONTROLS - INFILTRATION POND DISCHARGE

Description: Ground water will be extracted along the eastern perimeter of the landfill, treated on-site to remove organic contaminants, possibly treated on-site to remove inorganic contaminants, and discharged to an on-site infiltration pond.

Assessment:

Overall Protection of Human Health and the Environment:

- Will be protective of human health and the environment as contaminated ground water is removed and treated.

Compliance with ARARs:

- Complies with Minnesota standards for ground water quality at the compliance boundary of mixed municipal solid waste landfills.
- Meets surface water criteria for Lake Bemidji.
- Can meet drinking water MCLs for the aquifer.
- Consistent with USEPA ground water protection strategy.

Long-Term Effectiveness:

- Active downgradient hydraulic controls will minimize the migration of landfill contaminants to down-gradient ground water and surface water.
- Organic contaminants of concern will be destroyed by ozone and intermediate compounds will be removed by GAC.
- Inorganic contaminants of concern will be removed from the ground water but transferred to sludge.
- It is unknown if the disposal of sludge in a landfill provides long-term effectiveness.
- Caustic and reactive compounds will be used in the treatment of contaminated ground water; workers will wear protective equipment and be trained to handle spills and upsets.
- Discharge to an infiltration pond will prevent downstream degradation of surface water quality.
- An on-site pond may alter present ground water hydraulics.
- Volatilization of compounds from the pond will require monitoring.

Reduction of Toxicity, Mobility, or Volume:

- The proposed treatment scheme for organic and inorganic removal will reduce the toxicity of the contaminated ground water.
- Ozone treatment will destroy the organics of concern.
- Inorganic treatment will result in a sludge which will require landfill disposal. Sludge may require disposal as a hazardous waste.

TABLE 4-3 (cont'd)

- Mobility of contaminants of concern will be reduced by treatment methods.

Short-Term Effectiveness:
- Minimal risk to the community due to pond construction.
- May effect shallow groundwater flow.
- Possible risk to workers during well development and ground water treatment due by VOC emissions. Requires air monitoring and possible respirator protection.
- Treatment plant personnel will be working with caustic and reactive products. Requires protective equipment and spill response training.

Implementability:
- Well construction is technically feasible. Treatment methodologies may require bench studies to determine full-scale design parameters.
- Services and material are available.
- May require purchase of downgradient land for pumping well locations.

Costs:
- Capital Cost: $1,000,000 to 1,400,000
- Annual Maintenance and Monitoring Cost: $240,000 to $510,000
- Estimated 4 year Present Worth: $1,800,000 to $3,000,000
- Estimated 30 year Present Worth: $3,300,000 to 6,200,000

Support Agency Acceptance:
- To be evaluated after development of the proposed plan.

Community Acceptance:
- Community will likely favor active ground remediation.

term effectiveness of land disposal in reducing inorganic contaminant mobility is unknown.

Short-Term Effectiveness - There is minimal risk to workers and the general public during well development and treatment of ground water. Some VOC emissions are possible from the AOP treatment process, rapid mix, and clarification. Treatment plant workers will be required to handle chemicals and possibly sludges which may be caustic or toxic. Exposure to inorganic compounds is possible at the recharge pond. The pond may alter ground water hydraulics.

Implementability - Well, treatment plant, and recharge pond construction are technically feasibly. The ground water extraction network involves proven techniques. Additional ground water modeling will be required to optimize the pumping network. Pump tests will be required during remedial construction to verify modeling results. Bench tests will be required to determine full-scale treatment system design parameters. The contaminants of concern will be monitored to assure that treatment goals are achieved.

Land purchases or long-term lease agreements are required for downgradient pumping well locations and pipeline routes.

This alternative is administratively feasible. MDH will have to approve any recharge system. City and county permits may be required for pipeline construction. If treatment sludges are hazardous, an appropriate facility must be located. Periodic dredging of the recharge pond may also generate sludges which must be handled as hazardous wastes.

Cost - Estimated capital, maintenance and monitoring, and present worth costs are presented in Table 4-3. Low end ranges of estimated present worth costs do not include inorganics treatment; upper end costs include lime-soda softening and sludge disposal.

Support Agency Acceptance - This criterion will be evaluated after development of the proposed plan.

Community Acceptance - The community will likely favor active ground water remediation.

4.3 COMPARISON AMONG ALTERNATIVES

This section presents a comparison among alternatives with respect to the nine evaluation criteria. The highlights of the comparison among alternatives are presented on Table 4-4.

4.3.1 Overall Protection of Human Health and the Environment - No action is likely protective of human health based on modeling projections of ground water quality at Lake Bemidji. Alternatives II and III are protective. Alternative II is the more protective as both organic and inorganic contaminants are removed.

4.3.2 Compliance with ARARs - Alternative I is inconsistent with the Safe Drinking Water Act MCLs. No further action is also inconsistent with the USEPA ground water protection strategy. Alternative II requires both organics and inorganics treatment to comply with all state and federal ARARs. Alternative III requires only organic compound removal to comply with drinking water standards. Recharge of treated ground water may require a permit from MDH.

4.3.3 Long-Term Effectiveness - It is likely that Alternative I will be protective of downgradient surface water quality in the long-term. Contaminants will remain in down-gradient ground water for 50 years or more. Alternatives II and III will be effective in the long-term. However, both alternatives may produce treatment sludges which will require land disposal. The long-term effectiveness of land disposal is unknown.

4.3.4 Reduction of Toxicity, Mobility, and Volume - This criterion is not applicable to no action. Toxicity may actually increase if anaerobic degradation of chlorinated ethenes results in the increased formation of vinyl chloride. Alternatives II and III reduce the volume of organic contaminants on-site. Inorganic compounds are transferred to another medium for land disposal. Alternatives II and III reduce the toxicity and mobility of organic contamination, and partially reduce these characteristics for inorganics.

TABLE 4-4
KUMMER LANDFILL, MINNESOTA

COMPARATIVE ANALYSIS AMONG ALTERNATIVES

Evaluation Criteria	I - No Further Action	II - Active Downgradient - Surface Water Discharge	III - Active Downgradient - Infiltration Pond Discharge
Overall protective of Human Health and the Environment	Likely protective	Maximum protection	Protective
Compliance with ARARs	May be inconsistent with performance standards for ground water quality at new and operating landfills. However, actions are being implemented to address the problem.	Complies with air and surface water criteria; also consistent with landfill per-performance standards and drinking water quality regulations.	Complies with air and surface water criteria; also consistent with landfill performance standards and drinking water quality regulations.
Long-term Effectiveness	Probably effective. Short-term continued migration of contaminants down-gradient, but eventual impacts on surface water quality may be insignificant.	Effective. Downgradient ground water and surface waters are protected. Organics are destroyed. Long-term effectiveness of land disposal of inorganic treatment sludge is unknown.	Effective. Downgradient ground water and surface water protected. Organics are destroyed.
Reduction of Toxicity, Mobility, Volume	Not applicable. May increase toxicity if vinyl chloride results from anaerobic degradation of ground water contaminants.	Reduction of volume of ground water contaminants at the site. Reduction of toxicity an mobility of organic contaminants. Partial reduction of toxicity and mobility of inorganics.	No reduction of volume of inorganic ground water contaminants, unless treatment provided. Reduction of toxicity and mobility of organic contaminants.

TABLE 4-4 (cont'd)
KUMMER LANDFILL, MINNESOTA

COMPARATIVE ANALYSIS AMONG ALTERNATIVES

Evaluation Criteria	I - No Further Action	II - Active Downgradient - Surface Water Discharge	III - Active Downgradient - Infiltration Pond Discharge
Short-term Effectiveness	Probably effective, but continued migration of contaminants downgradient.	Minimal risk to public. Workers require protection during well development and water treatment.	Minimal risk to public. Workers require protection during well development, water treatment, and excavation of pond area.
Implementability	May be difficult to enforce institutional controls.	Discharge to surface water technically feasible. Administratively feasible.	Technically feasible. May require a MDH permit to recharge treated ground water.
Cost			
Capital $	73,000	1,300,000	1,000,000 to 1,400,000
Annual O&M $	24,000	510,000	240,000 to 510,000
4 or 30 years Present Worth $	300,000	3,000,000 to 6,200,000	3,000,000 - 6,200,000** 1,800,000 - 3,300,000*
Support Agency Acceptance	To be determined	To be determined	To be determined
Community Acceptance	May be unacceptable	Likely acceptable	Likely acceptable

* Cost range organic treatment only
** Cost range organic and inorganic treatment

4.3.5 Short-Term Effectiveness - Alternative I is probably effective in the short-term, but contaminants continue to migrate to downgradient aquifers. Both Alternatives II and III pose minimal risk to on-site workers and the public. The recharge pond in Alternative III may alter ground water hydraulics and cause a shift in plume location.

4.3.6 Implementability - Institutional controls under Alternative I may be difficult to enforce. Alternatives II and III are technically feasible. Purchase of additional land or long-term lease agreements are likely required for installation of pumping wells and associated piping. It is likely easier to install a recharge pond than construct a point source discharge to Lake Bemidji.

4.3.7 Cost

The estimated present worth cost of each remedial alternative is listed in Table 4-4. No further action is the lowest estimated cost remedial alternative. Active downgradient hydraulic controls and surface water discharge has lower estimated present worth cost than infiltration pond discharge, unless pond discharge allows inorganics treatments to be eliminated.

4.3.8 Support Agency Acceptance - This criterion will be evaluated after development of the proposed plan.

4.3.9 Community Acceptance - The community is likely to favor active ground water remediation.

4.4 SUMMARY OF DETAILED ANALYSIS

The key tradeoffs among alternatives are discussed below.

4.4.1 Alternative I - No further action has the lowest capital costs of all the alternatives. It may be protective of public health and the environment in the long-term due to the cover system and alternative water supply. No action is not protective of the environment in the short-term because contaminants will continue to migrate to downgradient ground water, but may be protective in the long-term because modeling results

indicate contaminant concentrations will not exceed surface water quality standards at Lake Bemidji. This alternative is not likely to be favored by the community.

4.4.2 Alternative II - The advantage of Alternative II is that it provides direct indication that remedial action objectives are achieved. The alternative provides for destruction of organic compounds, and maximum protection of public health and the environment. Alternative II complies with all ARARs. The disadvantages are that additional land needs to be procured for the pumping system and associated piping. Unknown physical and administrative barriers may exist for a point source discharge to Lake Bemidji. Inorganics treatment results in a sludge which must be landfilled. Estimated present worth costs are higher than for Alternative I.

4.4.3 Alternative III - Alternative III also provides direct indication that remedial action objectives are achieved. In comparison to Alternative II, the on-site recharge pond may be administratively easier to implement than a new point source discharge to Lake Bemidji. On-site recharge may allow deletion of inorganics treatment, if pumped ground waters comply with drinking water standards for inorganics. Deletion of inorganics treatment results in considerable cost savings.

APPENDIX A

LANDFILL TRENCHING RESULTS

MALCOLM PIRNIE

MALCOLM PIRNIE, INC.
ENVIRONMENTAL ENGINEERS, SCIENTISTS & PLANNERS

May 23, 1990

Ms. Miriam Horneff
Solid Waste Section
Ground Water & Solid Waste Division
Minnesota Pollution Control Agency
520 Lafayette Road North
St. Paul, MN 55155

Re: Trenching Investigation
Kummer SLF

Dear Ms. Horneff:

Starting May 7 and ending on May 10, 1990 Malcolm Pirnie, Inc. conducted a Solid Waste Investigation at the Kummer Sanitary Landfill in Bemidji, Minnesota. The investigation was authorized by the Minnesota Pollution Control Agency in Amendment No. 1 to Work Order MP-KU-RD-1, dated April 23, 1990. The objective of the investigation was to determine the areas and relative extent of clean fill material, thus helping to locate areas which will not require capping.

The site is located north of Bemidji in Northern Township between Anne and Fern Streets. The landfill incorporates the southern 40 acres at the 80 acre Kummer property as shown in Figure 1.

In order to establish a grid as an aid during the exploratory trenching, Malcolm Pirnie contracted with Stewart & Walker surveyors to lay out a 250 ft. by 250 ft. grid, tied to the State coordinate system. This grid system helped identify field trenching locations on project drawings. Also under contract with Malcolm Pirnie, Stevens Well Drilling Co. supplied a backhoe and an OSHA-trained operator to execute the trenches. The grid system and trenching locations are shown on Figure 2.

Site personnel included Peter Cangialosi and Victor Vasas of Malcolm Pirnie, Inc., Kathryn Gerland and Pamela Farr of the Minnesota Pollution Control Agency, and Bob Kruck of Stevens Drilling.

5001 W. 80TH ST., SUITE 770 MINNEAPOLIS, MN 55437 612-835-2504 TELEX 137384

Findings and Evaluation

1. The investigation began at the northeast corner of the site at grid point F6. We discovered waste at this coordinate, indicating that the edge of the landfill cap in this area should be extended about 70 feet east.

2. Generally, over the entire landfill, the waste unearthed was mixed household waste with some commercial waste such as lumber, textile and metallic materials often observed. The waste had a characteristic septic odor, however no HNu readings were detected at the majority of trenches opened. Average thickness of earth cover above waste was between 12" - 18".

3. Along the northern edge of the landfill waste was found at all the trench locations.

4. HNu readings were detected at two locations: 5.0 ppm at coordinate F3, and 1.5 ppm at coordinate E3.

5. At grid point E2, a disposed gas cylinder was discovered. The cylinder had a diameter of 8" and a length of 3 feet. It did not appear to be crushed and no label could be seen. We could not investigate the cylinder for punctures and for safety reasons we did not approach it closer than 5 feet. The cylinder was left in the trench and the trench was backfilled.

6. Along the western edge of the landfill waste was discovered 60-70 feet east of the line 1 and about 20-30 feet east of the barbed wire fence apparently representing the property line.

7. Small amounts of waste were found closer to the property line in the trenches. We suspect that this is windblown material deposited before the daily cover could be placed over the waste.

8. The landfill north of line D generally has a more uniform and managed look than the area south of line D. South of line D the fill is irregular and mixed with more scrap iron and demolition debris. The waste layer south of line D is thin and mixed with sand. The waste surrounds an apparently clean area of sand that may be useful as a borrow area, and may not need capping. This clean area is generally south of line C, north of line B, and east of line 2.

9. Along the southern border of the property the limit of household waste occurs at line A. In the center of the landfill (more precisely between C3 and C4, east of grid points C4 and D4, and in the close proximity of grid points D5 and D6), the surface varies considerably in deep cuts and steep

slopes. These features make the prediction of the limits of waste disposal unreliable.

10. The demolition debris disposal area in the vicinity of D5 and D6 consists of piles of dirt mixed with concrete blocks, bricks, timber, wood products and other building and construction material.

Based on the conditions observed during this investigation, a more precise extent of the waste can be determined. The redefined limits of waste are shown on Figure 2. This figure also illustrates the approximate limits of demolition debris and the approximate locations of the exploratory trenches.

This information will now be used to develop a refined extent of the planned landfill cover. If you have any questions or require additional assistance, please contact us.

Very truly yours,

MALCOLM PIRNIE, INC.

Charles R. Michael, P.E.
Senior Associate

rb

Enclosures

c: R. Cox, w/encl
W. Dee, w/encl

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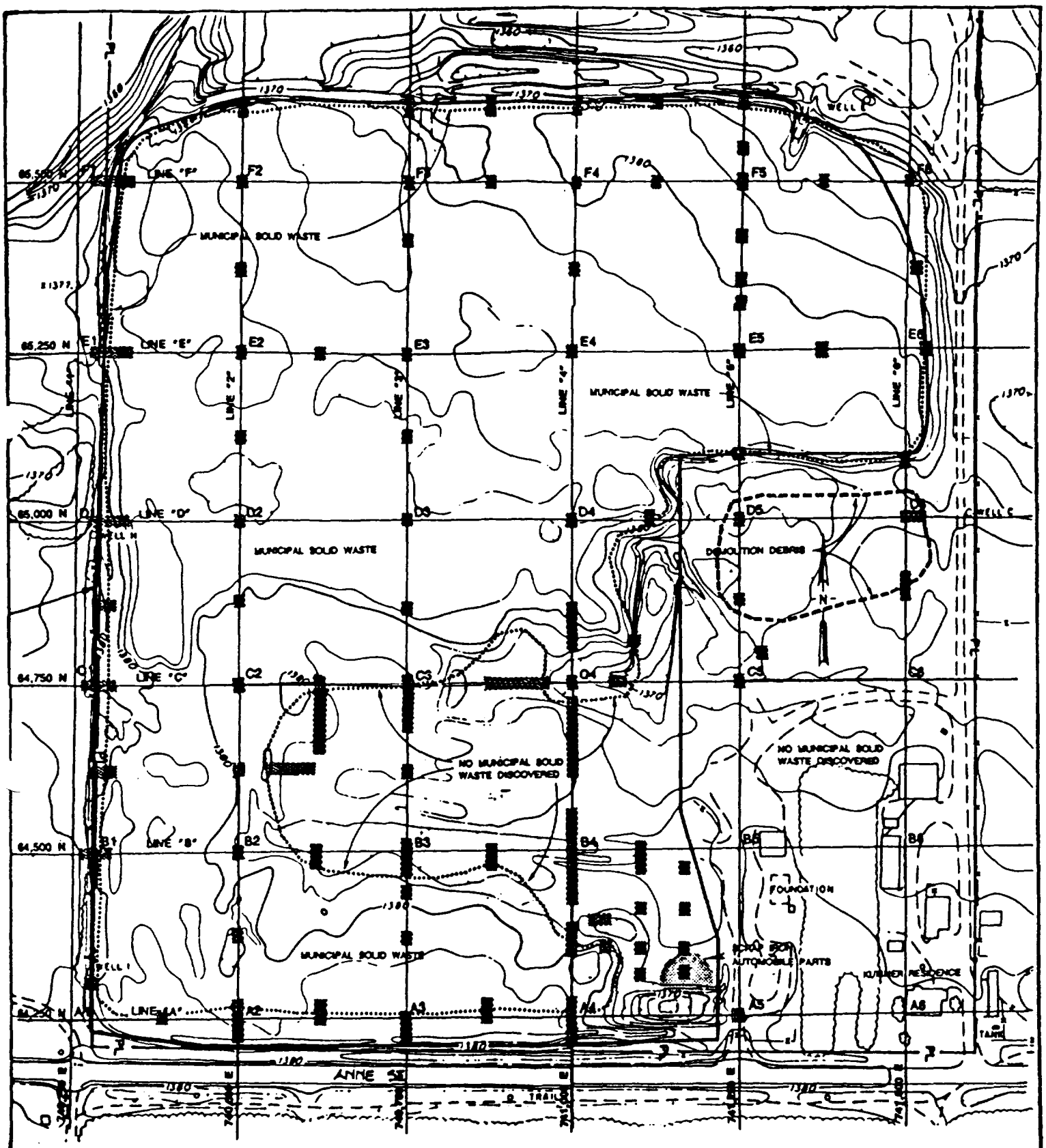


LEGEND:

- APPROXIMATE LANDFILL LIMIT
- LIMITS OF HOUSEHOLD WASTE
- LIMITS OF DEMOLITION DEBRIS
- LIMIT OF EXPLORATORY TRENCHES

MALCOLM PIRNIE

KUMMER SANITARY LANDFILL WASTE INVESTIGATION

FIGURE 2

APPENDIX B

RESULTS OF GROUND WATER MODELING

B.1 INTRODUCTION

The purpose of ground water modeling was to evaluate the most feasible remedial action alternatives. The model needed to address the questions of time of travel and concentration of the total VOC plume when it reaches Lake Bemidji. The prime concern is whether the total VOC concentrations will exceed water quality standards set for Lake Bemidji. A 2-dimensional combined ground water flow/solute transport model was used to simulate two remediation scenarios: 1) a capped landfill with no action taken to capture the plume; and 2) a capped landfill with a ground water collection system to capture the plume.

The Pricket-Lonnquist Aquifer Simulation Model (PLASM) was used to simulate ground water flow and RANDOM WALK was used to simulate solute transport in the two scenarios. The PLASM ground water model was used to simulate steady state flow through the shallow water-bearing zone in an area extending from west of the Kummer Sanitary Landfill to Lake Bemidji. Results from PLASM were directly applied to the RANDOM WALK mass transport model to predict the movement and concentration of a total Volatile Organic Compound (VOC) plume in the shallow ground water.

Data presented in the Final Report of the Remedial Investigation (RI) (January 1990) were used in the model. The geologic cross sections found on Plates 2 and 3 of the RI report were used to define the site geology within the model grid. Geologic variables such as aquifer bottom elevation and thickness were determined from these cross-sections and from geologic logs. Water levels measured in round 7# (August 1989) were considered representative of "static" levels and were used to calibrate the flow model. Ground water quality as characterized in sample rounds 4# and 7# were considered representative of the total VOC plume configuration and concentrations and were used in RANDOM WALK to calibrate the

plume. A detailed description of the complete data sets used in the models are explained in the following sections.

Results of the no action simulation indicate that it will take approximately 34 years for the plume to reach Lake Bemidji and the concentration once it arrives does not exceed 5 ppb of total VOC. The simulation was run out to 80 years and the concentration still did not exceed 5 ppb. Results of the ground water collection simulation indicate that the plume can be captured to prevent further off-site migration of contaminants using a series of 5 recovery wells pumping at a combined rate of 85 gpm. The model results also indicate that this configuration will also capture a portion of the plume already down gradient from the site. However, a portion of the plume will escape the capture zone created by these wells and will enter the lake at a total VOC concentration of 2 ppb, although this concentration was never exceeded over the 40 year simulation. It should be noted that the no action scenario results indicate that the total VOC concentrations at Lake Bemidji will remain below the required water quality standards for the lake, and that ground water collection may not be necessary.

B.2 GROUND WATER FLOW MODEL (PLASM)

B.2.1 Model Description

The Prickett-Lonnquist Aquifer Simulation Model (PLASM) (Prickett and Lonnquist, 1971) is the numerical computer model used in this study. The model simulates two-dimensional ground water flow under a variety of conditions including steady state or transient flow in a homogeneous or non-homogeneous aquifer under confined or unconfined conditions. The model computes changes in aquifer head distribution across an area through time.

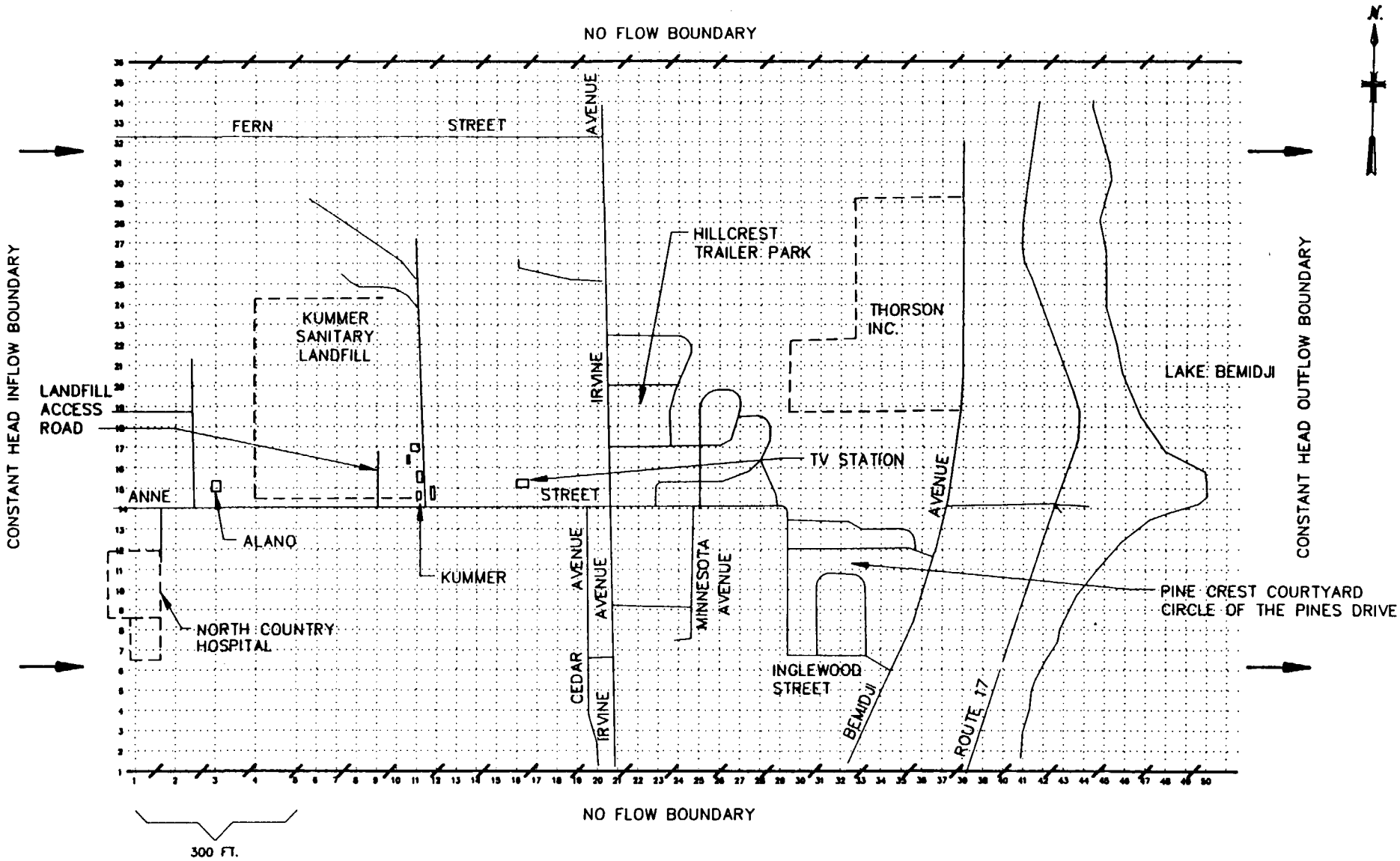
The numerical solutions to the ground water flow equations in the model are solved iteratively through a finite difference approach with the aid of a desk top computer. The model output includes numerical values for the aquifer head elevation distribution and a summary water balance calculation comprised of total water inflow and outflow volume plus or minus changes in storage at the end of each iterative step. Model steady state conditions are reached when ground water inflow approximately equals ground water outflow and the volumetric change in ground water storage approaches zero. The model also calculates ground water flow velocities and node-specific discharge volumes.

Assumptions inherent to the model are that:

- Darcy's Law is valid and hydraulic head gradients are the only significant driving mechanism for fluid flow;
- porosity and hydraulic conductivity are constant with time; and
- temperature and viscosity do not affect the velocity distribution.

B.2.2 Model Specification

A two dimensional (2-D) flow and solute transport model has been used to simulate a one layer aquifer while accounting for interactions of surface and ground waters and leakage from semi-confining units. This 2-D model was sufficient to address the objectives needed for final development of the FS in light of the available data. The model was constructed by superimposing a variably spaced finite-difference grid consisting of 50 columns by 36 rows spaced 150 feet apart over the study area, although 5 columns near the edge of the grid are spaced 300 feet apart as shown on Figure B-1. The finite-difference grid was oriented with the rows parallel to the general direction of shallow ground water flow. Constant-head boundary conditions were assigned to the first and last



BASE MAP FROM ORTHOPHOTO FLOWN IN 1985.

WELLS SURVEYED IN 1986, 1988, 1989.

250 0 250 500 750 1000
SCALE IN FEET

GRID NODE 150 FEET
GRID NODE 300 FEET

MALCOLM PIRNIE

KUMMER LANDFILL GROUND WATER MODELING STUDY

MINNESOTA POLLUTION CONTROL AGENCY

FINITE - DIFFERENCE GRID

VARIABLE SPACED

MALCOLM PIRNIE, INC.

FIGURE B-1

CKENNA : 0871038M98\FIGB-1 SCALE: 1:12000: 06/06, 1990 at 15:19

columns of the model grid and no flow boundaries were assigned to the first and last row of model grid.

Input parameters assigned at each of the 1,800 grid nodes include: initial water level elevation; aquifer bottom elevation; hydraulic conductivity; storativity; aquifer recharge; and leakance values. The till layer as defined by cross-sections found in the RI report was used as the bottom elevation of the aquifer. Water levels from August 1989 (round 7) were used to represent "static" levels. The saturated thickness was represented as the difference between the bottom elevation of the aquifer and the water table.

Annual recharge rates from 2 to 6 inches/year to the shallow aquifer are typical in the Kummer Sanitary Landfill area, although the recharge rates were adjusted to calibrate the flow model. Previous to the modeling study at Kummer, Barr Engineering modeled the City of Bemidji Well Field one mile west of Kummer Sanitary Landfill. The rates of recharge used in their study are consistent with those used in ground water modeling at Kummer. In the area of the landfill, the addition of a clay cap would significantly reduce recharge to the water table aquifer. Therefore the Hydraulic Evaluation Landfill Performance (HELP) model was also used to determine the amount of annual recharge through a clay cap at the landfill.

The RI data indicate the existence of slight vertical gradients in the eastern and western areas of the site. A slight downward gradient exits on the west central part of the modeled area. However, as ground water flows easterly and approaches Lake Bemidji the gradient tends to reverse upward typical of a ground water discharge zone. The effect of these vertical gradients has been incorporated into the model by assigning varying leakance values to individual nodes over the grid area.

Initial values for the input parameters were derived from field data presented in the RI and from published data as follows:

- Initial ground water levels were selected from synoptic water level data collected in August 1989. Ground water elevations range from 1360 to 1340 feet mean sea level (MSL) with an hydraulic gradient average of 0.0027 ft/ft.

- Hydraulic conductivity (K) values for specific locations within the aquifer were estimated from in-situ hydraulic conductivity testing and from a 24 hour pumping test completed in the shallow water-bearing zone. In areas between test locations, the thickness of each identifiable stratigraphic unit was measured from geologic logs. These units were assigned representative hydraulic conductivities from published literature based on their soil type, and an average for hydraulic conductivity was assigned. These values had a wide range, as expected from outwash deposits, from 5 gpd/sq ft to 924 gpd/sq ft with an average hydraulic conductivity of 335 gpd/sq ft; standard deviation of 247.

- A storage coefficient of 0.1 was chosen from published literature (Freeze & Cherry 1979), based on the average size and sorting of the unconsolidated material typical of a water table aquifer.

- Values for annual precipitation and recharge were taken from the data provided in the RI/FS. The assigned values ranged from 2-6 inches/year or .003 - .01 gpd/sq ft. (person. comm. MPCA; Barr Engineering's report) used over the grid area.

- Leakance is defined as the rate of leakage into or out of the aquifer at individual nodes. Leakance into or out of aquifer was dependent upon the relationship between the source bed head and water table elevation. Values range from .003 to .406 gpd/cu ft.

- The bottom boundary of the aquifer (the modeled layer) was established from geologic logs and cross sections presented in the RI report. The bottom elevation ranges from 1312 to 1342 MSL, marked by a glacial till layer at the bottom of the shallow aquifer. The saturated thickness varies from 10 to 40 feet, thinning toward Lake Bemidji.

- Transmissivity was calculated internally by PLASM. The values range from 130 gpd/ft to 20,277 gpd/ft.

Parameter estimation between actual data points within the model grid was determined statistically using Geostat System International's IN-SITE SYSTEM geostatistical software and Golden Graphics program Surfer. These programs allowed for stochastic modeling to optimize parameter estimation within the input data file. These tools allowed quick quantification of auto-correlation, kriged estimations, and error mapping of regionalized variables within the model grid. Variogram analysis helped determined that hydraulic conductivity is anisotropic in the aquifer. Some minor input parameter revisions were necessary to achieve calibration.

B.2.3 Flow Model Calibration/Validation

Flow model calibration involved matching of computer generated head data at steady state conditions with observed measurements in the field. Calibration, or history matching, is the process in which the model is run with the initial set of input data and the results are compared to known conditions. If the match is not within acceptable limits, the input data are adjusted through a realistic range until the simulated heads fall within those limits. This calibration is required as the model must be able to reproduce historic and present conditions accurately before it is used to predict future water level changes.

The model calibration procedure involved adjusting estimated parameters, boundary conditions and grid spacing until the model - generated head data were similar to those recorded in the field. The model was then "fine-tuned" by adjusting model-sensitive parameters through a hydrogeologically realistic range of values for the site. Model sensitive parameters included changes in hydraulic conductivity and recharge.

Final steady state calibration was considered achieved when the average difference between actual water levels at monitoring locations and simulated water levels were within 0.5 feet. Table B-1 compares simulated water levels to water levels measured in the field during June, 1988 and August, 1989. The mean difference in June, 1988 is shown as a positive residual of 0.19 feet probably the a result of the wet season where actual water level are on average higher than simulated values. The mean difference in August, 1989 show a residual of -0.36 feet. The August 1989 water level data was used for final calibration in the flow model. Figures B-2 and B-3 compare the contour configuration of simulated steady state flow after 10 years to the August, 1989 water levels. The achievement of small deviations of simulated versus actual water level values as well as similar contour orientations confirm model validation.

The early drawdown data from the 24 hour pumping test is not believed to be representative of the aquifer parameters. These pump test results reflect the effect of casing storage and low well efficiency rather than true aquifer parameters. The computer model can not take these storage affects into account and therefore, the pumping test drawdown data was not used during final calibration.

B.2.5 Ground Water Flow Simulations

Two ground water flow simulations were conducted to evaluate remedial alternatives for ground water at the landfill as follows:

- (1) No action - a capped landfill, no recovery system;
- (2) Capped landfill with recovery wells down gradient and water treated and disposed offsite.

An infiltration rate of 1.46 per year inches was indicated by the HELP model with a simulated clay cap on the landfill.

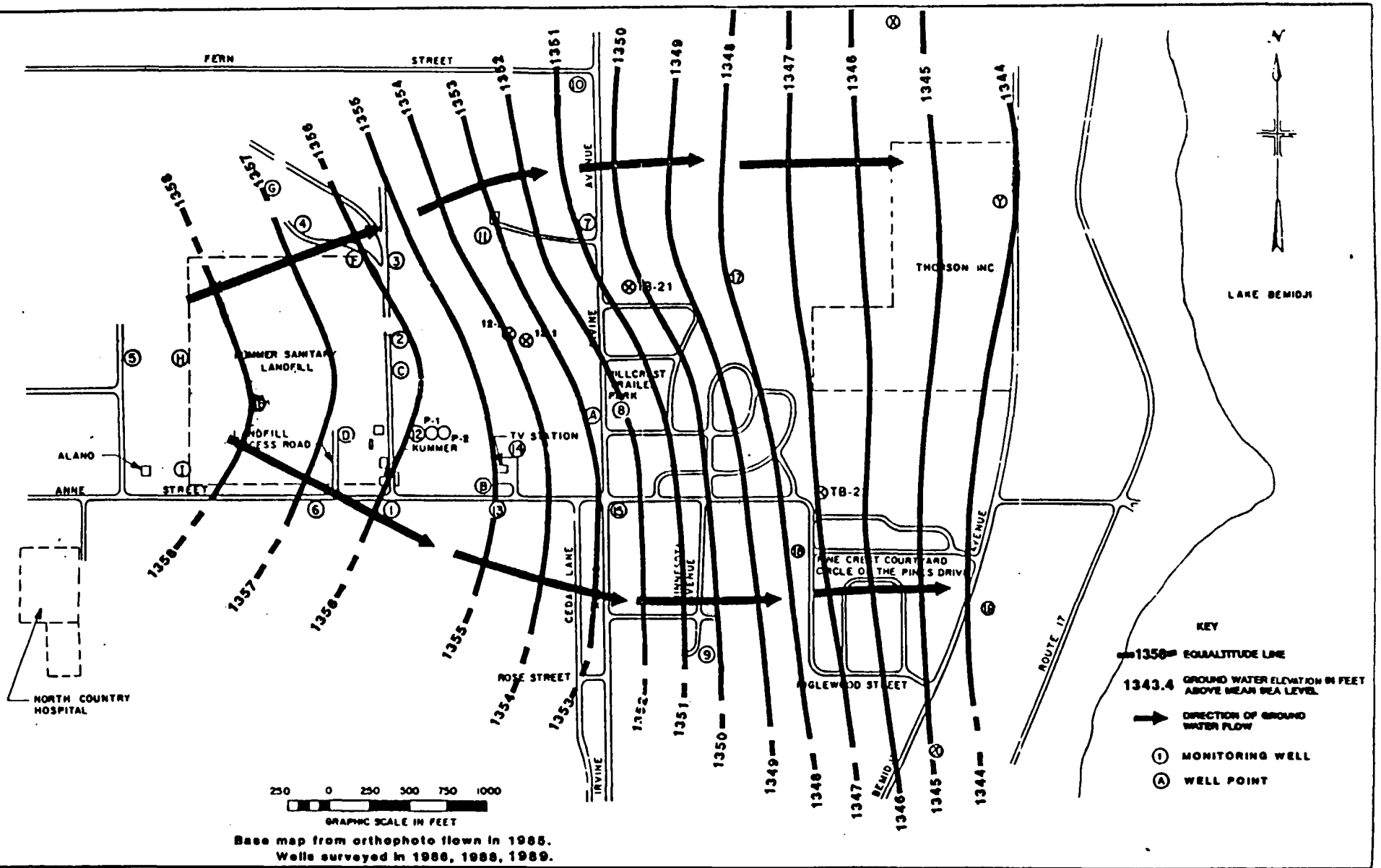
TABLE B-1

SIMULATED VERSUS ACTUAL WATER LEVELS USED FOR FLOW CALIBRATION

WELLS	SIMULATED WATER LEVELS STEADY STATE	SAMPLE ROUND 4# *(JUNE 1989)*	RESIDUAL WATER LEVELS *(JUNE 1989)*	SAMPLE ROUND 7# *(AUG 1989)*	RESIDUAL WATER LEVELS *(AUG 1989)*
WP-X	1346.92	=	=	1345.4	-1.52
MW-10	1351.8	1352.6	0.8	1350.6	-1.2
USGS-7	1344.82	1345	0.18	1344.2	-0.62
MW-7	1352.23	1351.9	-0.33	1350.6	-1.63
MW-11	1354.18	1354.6	0.42	1353.5	-0.68
MW-4	1356.23	1357.6	1.37	1356.8	0.57
WP-F	1356.31	=	=	1356.2	-0.11
MW-17	1349.32	1348.4	-0.92	1347.8	-1.52
MW-3	1355.76	1356.7	0.94	1355.3	-0.46
MW-2	1356.24	1356.8	0.56	1356.2	-0.04
MW-5	1359.04	1359.6	0.56	1359.1	0.06
WP-H	1358.51	=	=	1358.6	0.09
WP-C	1356.26	=	=	1356.4	0.14
MW-8	1352.95	1352.5	-0.45	1352.2	-0.75
MW-16A	1357.66	1358.3	0.64	1358	0.34
MW-12	1356.17	=	=	1356.3	0.13
MW-A	1353.09	=	=	1352.9	-0.19
MW-14	1354.58	1354.9	0.32	1354.8	0.22
WP-I	1358.39	=	=	1358.5	0.11
MW-1	1355.94	1356	0.06	1355.8	-0.14
MW-13	1354.96	1355.4	0.44	1355	0.04
MW-15	1353.2	1352.6	-0.6	1352.6	-0.6
MW-6	1356.96	=	=	1356.7	-0.26
MW-18	1348	1348	0	1347.8	-0.2
MW-19	1343.77	1344	0.23	1343.4	-0.37
MW-9	1351.56	1350.8	-0.76	1350.4	-1.16
MW-20	1345.1	1345.4	0.3	1345	-0.1

AVERAGE (FT)	0.19	-0.36
MININUM (FT)	-0.92	-1.63
MAXIUMUM (FT)	1.37	0.57
STANDARD DEVIATION	0.60	0.59

NOTE: FLOW MODEL WAS CALIBRATED TO AUGUST 1989 DATA



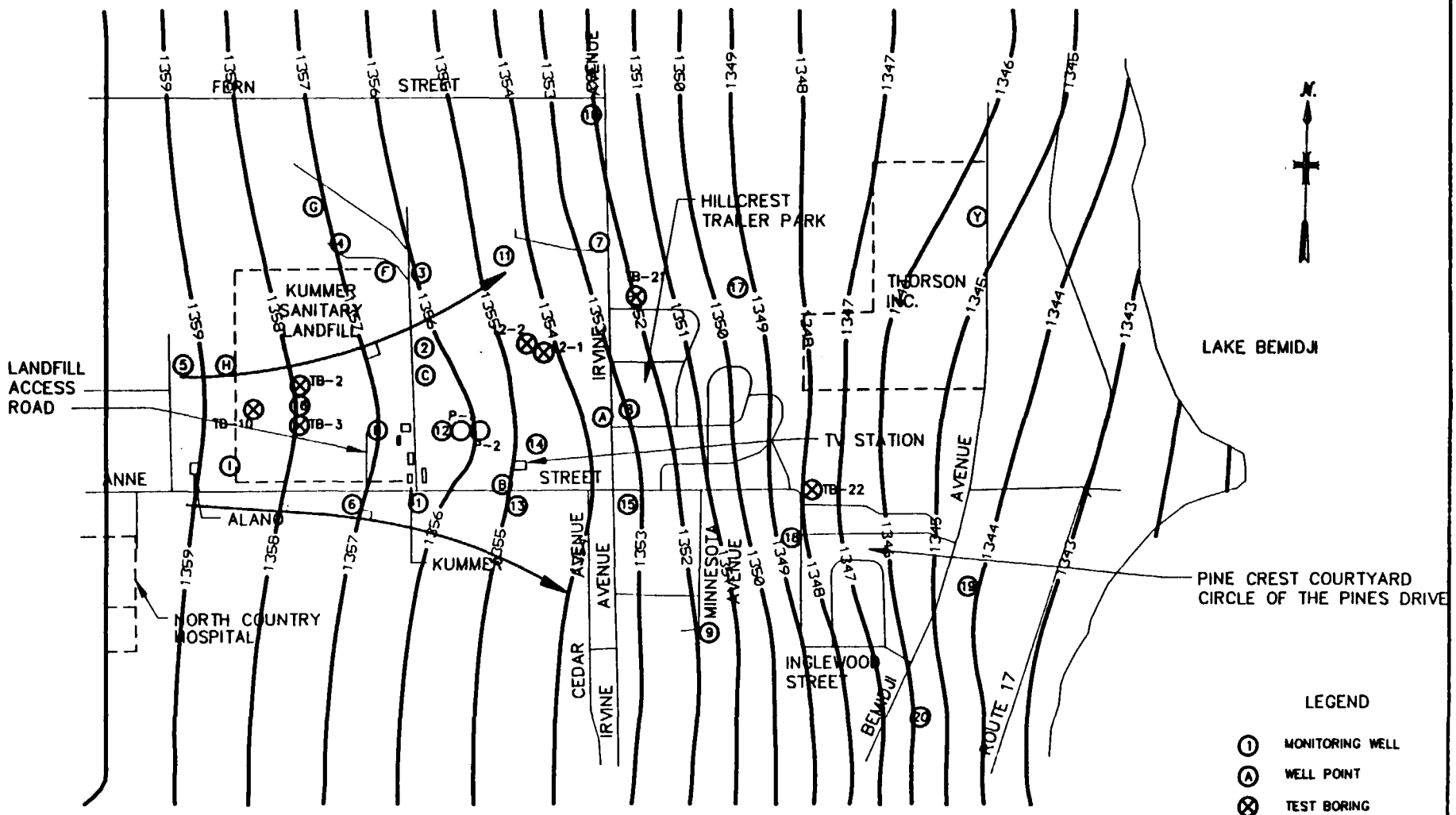
MALCOLM PIRNIE

KUMMER LANDFILL REMEDIAL INVESTIGATION
MINNESOTA POLLUTION CONTROL AGENCY

WATER TABLE CONTOUR MAP
AUGUST 14-15, 1989

MALCOLM PIRNIE, INC.

FIG B-2



BASE MAP FROM ORTHOPHOTO FLOWN IN 1985.

WELLS SURVEYED IN 1986, 1988, 1989.

MALCOLM PIRNIE	KUMMER LANDFILL GROUND WATER MODELING STUDY MINNESOTA POLLUTION CONTROL AGENCY	WATER TABLE CONTOUR MAP SIMULATED TO STEADY STATE (10 YRS)	MALCOLM PIRNIE, INC. FIGURE B-3

CKENNA : 0871038M98\FIGB-3 SCALE: 1:12000; 06/13, 1990 at 10:37

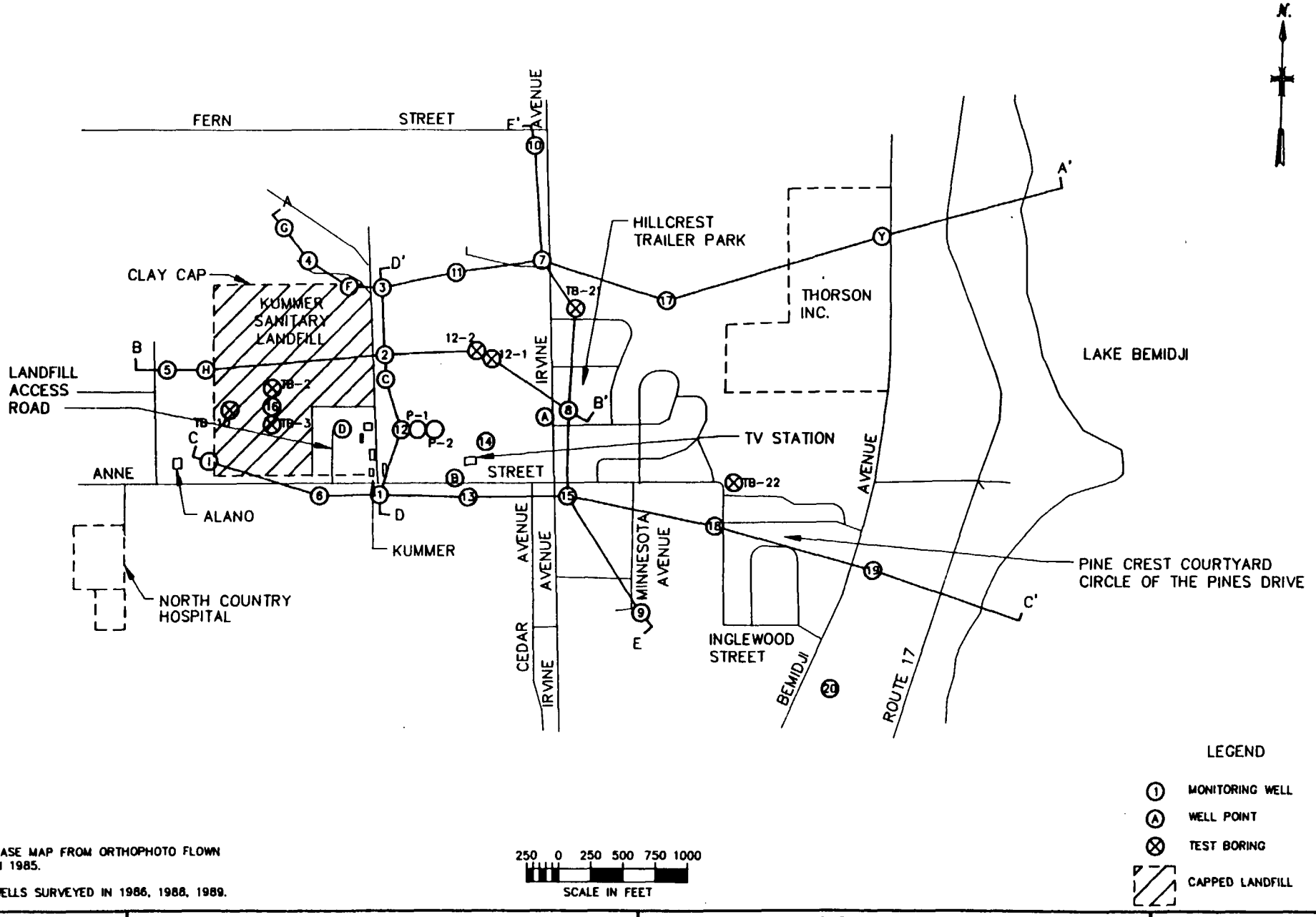
Figure B-4 depicts the extent of the clay cap taken into account using the PLASM flow model. To simulate the presence of the clay cap, recharge to the water table was reduced by 75 percent. Both scenarios simulated a clay cap to evaluate the effect of reduced recharge to the water table.

A third scenario, although not simulated was considered to evaluate a capped landfill and recovery wells down gradient, with treated water disposed on-site to a recharge basin. The recharge basin which was proposed to be located north of the site would not enhance remediation of the plume since it would not be located upgradient of the landfill. Neither dilution or an increased hydraulic gradient would be created by the recharge basin that would affect the portion of the plume which escapes the capture radius of the recovery wells. This location for the recharge basin would not increase the time needed to capture the plume and decrease its concentration. Therefore, the scenario was not to simulated.

B.2.5.1 Scenario #1 - No Action Flow Simulation

The purpose of this simulation was to reproduce ground water flow with reduced recharge to the water table aquifer beneath the landfill. With the exception of infiltration beneath the landfill, model input values remained constant to simulate the effect of the cap. Simulated water levels in the area covered by the cap indicate minor decline in water levels of approximately 0.5 to 0.9 feet after 10 years. In the general vicinity of the landfill the flow patterns show slightly less divergent flow than under uncapped conditions as shown in Figure B-5.

Ground water flow velocity increases down gradient of the landfill. Velocities range from as low as .007 to as much as 1 foot per day. Ground water flow patterns diverge east of the landfill due to the presence of large areas of clay. Cross-section B-B' and D-D' in the RI report depict the clay and its probable extent. The pattern of ground water flow

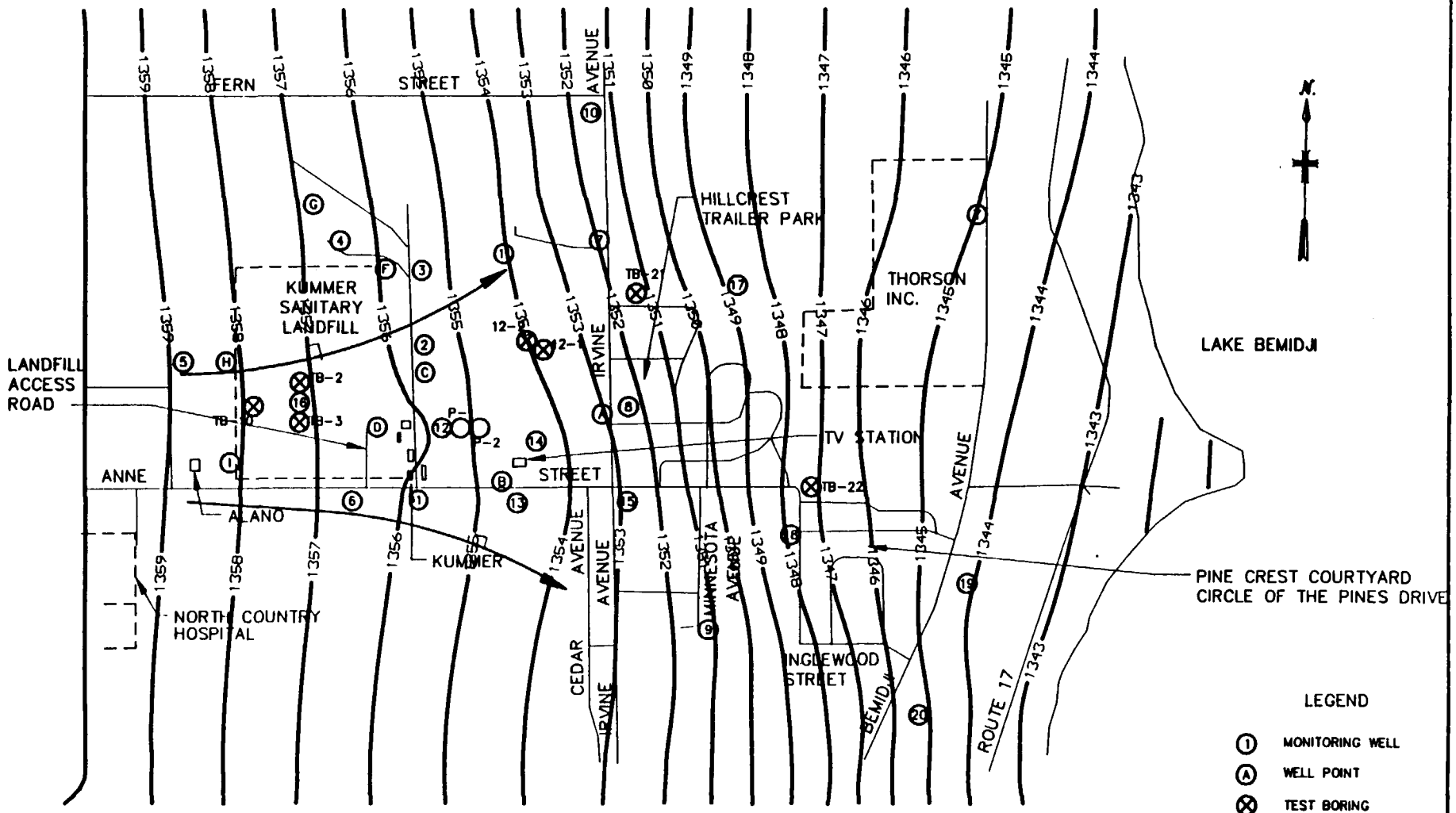


BASE MAP FROM ORTHOPHOTO FLOWN IN 1985.

WELLS SURVEYED IN 1986, 1988, 1989.

MALCOLM PIRNIE	KUMMER LANDFILL GROUND WATER MODELING STUDY MINNESOTA POLLUTION CONTROL AGENCY	CLAY CAP DISTRIBUTION INFILTRATION RATE 1.46 IN/YR (DETERMINED BY HELP MODEL)	MALCOLM PIRNIE, INC. FIGURE B-4

:CKENNA : 0871038M98\FIGB-4 SCALE: 1:12000i 06/06, 1990 at 15:47



BASE MAP FROM ORTHOPHOTO FLOWN IN 1985.

WELLS SURVEYED IN 1986, 1988, 1989.

MALCOLM PIRNIE	KUMMER LANDFILL GROUND WATER MODELING STUDY MINNESOTA POLLUTION CONTROL AGENCY	WATER TABLE CONTOUR MAP SCENARIO #1 - SIMULATED FLOW MODEL TO STEADY STATE (10 yrs)	MALCOLM PIRNIE, INC. FIGURE B-5

MCKENNA : 0871038M98\FIGB-5 SCALE: 1:12000: 06/06, 1990 at 16:07

around the clay is governed primarily by the directional hydraulic conductivity. These conditions are typical of glacial deposits where sand and clay lenses dictate preferential ground water flow direction.

B.2.5.2 Scenario 2 - Recovery Wells Flow Simulation

The purpose of this simulation was to produce a sufficient cone of depression using a series of recovery wells adjacent the landfill to capture contaminants on- and off-site. Ground water collection in the shallow water bearing zone down gradient of the landfill has been evaluated by using PLASM to simulate a variably spaced line of interceptor wells. A primary objective of the flow simulation was to minimize the number of wells and their total pumping rate while optimizing the cone of influence which will capture the VOC plume migrating from the landfill. The information generated from this flow model would aid in developing a cost-effective design for a ground water collection system. The withdrawal of water from five wells hydrodynamically produced a line sink resulting in a barrier to the migration of ground water from the landfill. The hydraulic influence increased for two years as the depressed water table level expanded outward from the collection system. After two years steady state was reached as water levels did not significantly change around the pumping wells.

Various numbers and configurations of wells were evaluated at 10 to 20 gpm each until steady state was reached. Eight wells or more produced an elongated linear cone sufficient to capture flow not only from the landfill, but from a large portion of the surrounding area as well. Fewer than five wells did not produce a sufficient capture zone. Variations in the amount of drawdown were observed north-south along the simulated cone of depression due to changes in the local stratigraphy. By simulating various combinations of pumping wells at different rates the optimal scenario was achieved.

The optimal configuration consisted of five interceptor wells spaced between 300 and 450 feet apart, pumping at a combined rate of 85 gpm to steady state. These five wells produced a combined cone of depression sufficient to capture all ground water flowing from the landfill as flow lines indicate in Figure B-6, without also capturing an excessive amount of regional flow. Drawdowns along the cone of depression range from 3 to 9 feet and are greatest in the area of lowest hydraulic conductivities (e.g., 5 to 10 gpd/ sq ft near MW-12B). The approximate simulated individual capture radii appear to vary from 150 feet to 450 feet along the cone influenced by the line of pumping wells.

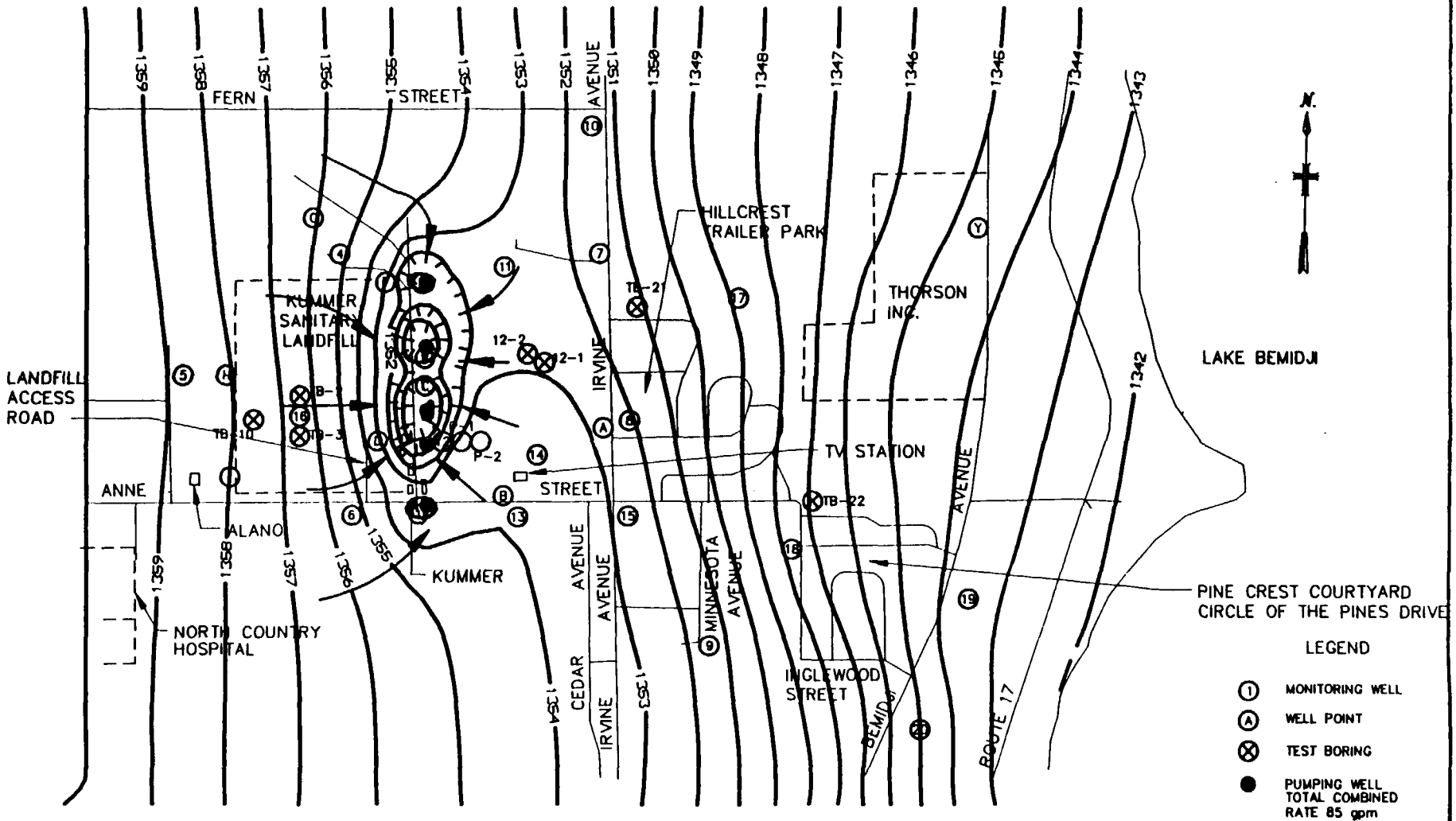
B.3 SOLUTE TRANSPORT MODEL (RANDOM WALK)

The RANDOM WALK mass transport model was used to simulate contaminant transport in the shallow water-bearing zone and to predict changes in ground water concentrations within the plume over time. The solute transport model is primarily dependent on the flow velocities produced by the PLASM flow model, but takes into account all of the hydrogeologic conditions specified in PLASM.

A single contaminant source was assumed to be the Kummer Landfill. The concentrations in the landfill have been assigned based on actual and estimated data. A discussion of the actual contaminant and loading in the landfill is found in section B.3.2 Model Application.

Specific RANDOM WALK model simulations were conducted to:

- evaluate migration of the existing plume under the no action scenario to assess the time necessary for the plume to reach Lake Bemidji, its change in shape and concentration over time, and the eventual contaminant loading to Lake Bemidji.
- evaluate the effect of pumping wells on the plume in the recovery scenario, and to further assess the



BASE MAP FROM ORTHOPHOTO FLOWN IN 1985.

WELLS SURVEYED IN 1986, 1988, 1989.

MALCOLM PIRNIE	KUMMER LANDFILL GROUND WATER MODELING STUDY MINNESOTA POLLUTION CONTROL AGENCY	WATER TABLE CONTOUR MAP SCENARIO #2 - SIMULATED FLOW MODEL TO STEADY STATE (10 yrs)	MALCOLM PIRNIE, INC. FIGURE B-6

'CKENNA : 0871038M98\FIGB-6 SCALE: 1:12000i 06/06, 1990 at 16:21

potential impact of any uncaptured portion of the plume on Lake Bemidji.

B.2.1 Model Description

The RANDOM WALK Mass Transport Model (Prickett, et al., 1981) is a two-dimensional solute transport model which is compatible with the PLASM ground water flow model. RANDOM WALK is capable of simulating horizontal movement of a contaminant plume under a variety of conditions, including those suggested as potential remedial alternatives at Kummer. For this reason, the model is well-suited for application at sites where contaminant movement and the effectiveness of various pumping alternatives are of interest.

Using the PLASM 50 x 36 finite-difference grid, RANDOM WALK simulates the movement of a contaminant plume by computing changes in concentration due to advective transport, and hydrodynamic dispersion, and accounts for contaminant retardation under site specific conditions. The contaminant concentration at each grid node is represented by a specific number of particles of a pre-determined unit mass. The particles are transported to different positions on the finite-difference grid for a specified time using a "random-walk" technique consistent with advective transport. Movement of a particle representing a mass of a specific chemical constituent contained in a defined volume of water is simulated by the combination of advective flow (along flow lines determined by the PLASM model), and by random motion governed by scaled probability curves based on the length of the flow path, hydrogeologic conditions, any retardation factors and longitudinal and transverse dispersion. Thus, the mass transport model is essentially a particle tracking model, with contaminant concentration represented by the distribution of a finite number of discrete particles.

In the model, solute concentrations at individual nodes are calculated at the end of each time increment. The number of particles at each node is converted into solute concentrations by equations presented in Bulletin 65 of the Illinois

State Water Survey (Prickett et al., 1981). Like PLASM, the mass transport model is also two-dimensional, and solute concentration at a given node represents a vertical average over the saturated aquifer thickness.

The solute concentrations in the ground water may be dependant upon chemical or physical reactions between the dissolved constituents and the porous media. The net effect of chemical reactions is to retard the movement of contaminants relative to ground water velocity. This is factored into the model by applying a contaminant specific retardation factor.

The shape of the area over which particle source loading occurs can be simulated as a rectangular, linear or circular source. Particles are distributed randomly over the source area as either a slug, where particles are added to the model only at the beginning of the first time increment, or a continuously source, where particles are added to the model continuously within each time increment.

The mass of each particle represents a fraction of the total contaminant mass involved and is obtained by dividing the total contaminant mass by the total number of particles chosen for the simulation. The solute concentration at a node is therefore directly proportional to the particle mass. The total number of particles chosen for the simulation is dependent on both the resolution desired and the execution time of the model. Generally the greater the number of particles the greater the resolution, but also the longer the execution time for each simulation. It is therefore desireable to achieve optimum resolution based on the available data and run time length for the simulation.

The various input parameters used in the model include:

- The ground water flow file generated for the PLASM model which contains ground water velocities and pumpage rates;
- effective porosity;

- longitudinal and transverse dispersivity;
- retardation factor; and
- particle mass.

Additional input for each time increment includes: simulation length, frequency of particle movement calculations, number of particles to be added, and the continuing shape of the source area (e.g., rectangle, line, circle).

Assumptions inherent to the RANDOM WALK model include:

- those previously specified for the flow PLASM model;
- that the change in solute concentrations in ground water are limited to dispersion, dilution and mixing; and
- that dispersion in porous media is a random process that is normally distributed.

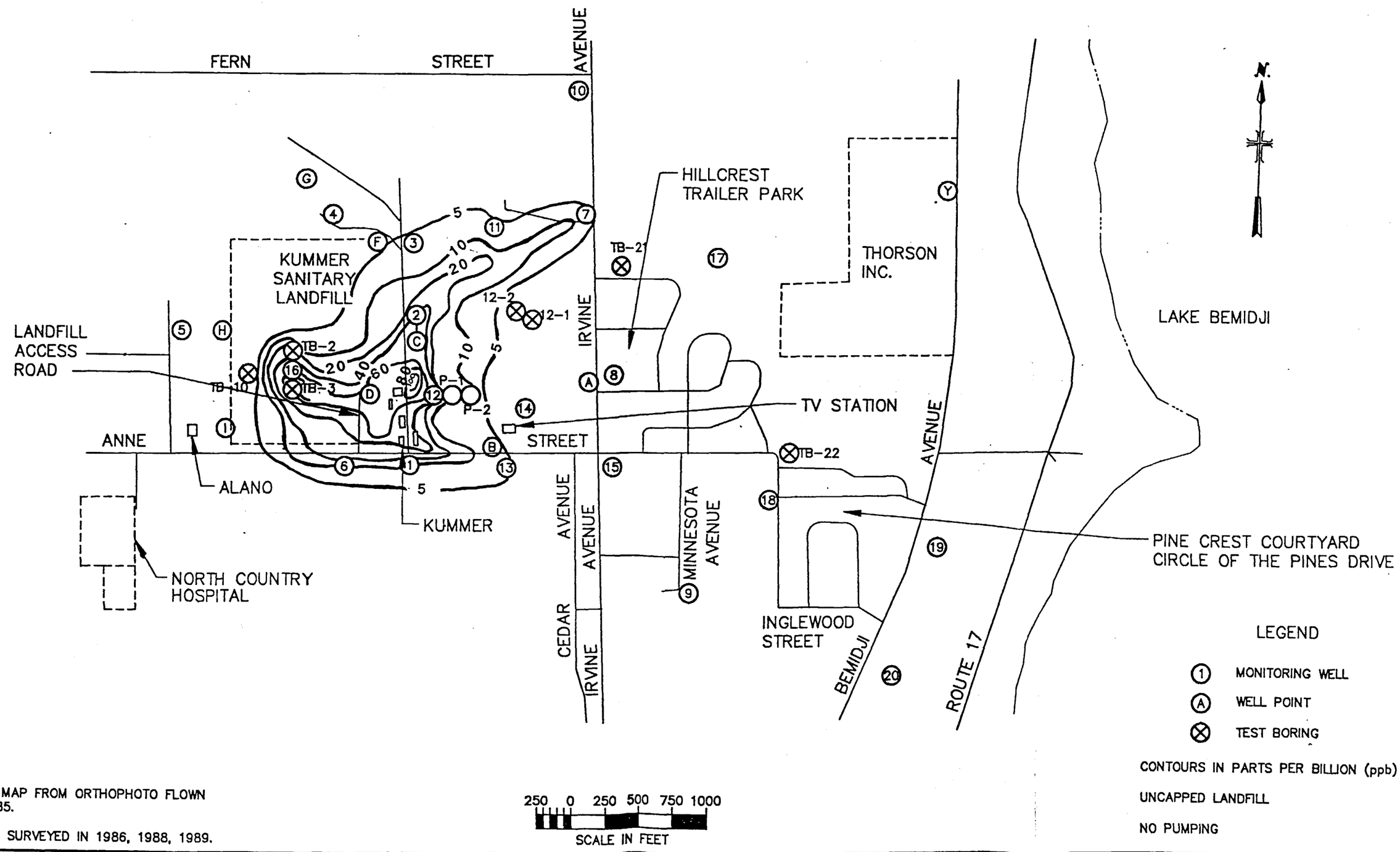
B.2.2 Model Application

The principal mechanism for contaminant loading to ground water is precipitation-induced percolation through landfill waste. Ground water sampling and chemical analyses during sample rounds 4 (June 1988) and 7 (August 1989) have documented the presence of volatile organic contamination in the ground water. As presented in the Final RI report volatile organic contaminants of concern were Tetrachloroethylene (PCE) at concentration ranging from 1 to 12 ppb, Trichloroethylene (TCE) at concentration ranging from 1.0 to 6.8 ppb, Trans-1,2-Dichloroethylene (tDCE) at concentration ranging from 1.2 to 35 ppb, Vinyl Chloride at concentrations ranging from 3.0 to 94 ppb, and Benzene at concentrations ranging from 1.0 to 6.0 ppb. The contaminant of primary concern is Vinyl Chloride, particularly its concentration when the plume reaches Lake Bemidji. It should be noted that Vinyl Chloride was not consistently detected in ground water analyses. Therefore, total VOCs were modeled, instead of Vinyl Chloride alone to maintain conservatism and account for the inconsistent

detection of Vinyl Chloride. Additionally, it was necessary to merge the total VOCs found in the A and B plumes, as identified in the RI report, to better delineate the areal extent of contamination in the 2-dimensional model. Incorporating this representative field data, the RANDOM WALK model was used to simulate the migration of the VOC plume in the shallow ground water zone following calibration.

B.3.3 Plume Calibration

Since the landfill has been in operation for approximately 18 years, there is some uncertainty as to the precise location and contaminant loading rates over time as the landfill was being developed. However, current ground water quality and plume configuration were assessed using total VOC data in the shallow water-bearing zones using actual analytical data from sample rounds 4 and 7. The solute transport model was calibrated to reproduce the existing plume configuration, based on historic data, before it was used to simulate future conditions. Figures B-7 shows the model calibrated plume derived from the distribution of averaged total VOCs in ground water samples. During RANDOM WALK plume calibration, initial conditions were established by assigning continuous contaminant loadings at specific grid nodes beneath the landfill based on the distribution of known or approximated concentration values. Contaminant loading was held continuous for 18 years and the loading rate adjusted until a best fit was obtained between actual and simulated plume extent and concentration. Table B-2 shows total VOC concentrations for sample rounds 4 and 7. Notice that plume was calibrated to the maximum combined average of both sampling rounds. These concentration are believed to be the most representative with some degree of conservatism. The configuration and concentration of the calibrated plume at monitoring wells represents a close match to the maximum combined average found in ground



BASE MAP FROM ORTHOPHOTO FLOWN IN 1985.

WELLS SURVEYED IN 1986, 1988, 1989.

MALCOLM PIRNIE	KUMMER LANDFILL GROUND WATER MODELING STUDY MINNESOTA POLLUTION CONTROL AGENCY	CALIBRATION ISOCONCENTRATION CONTOUR MAP TOTAL VOC PLUME AT PRESENT CONCENTRATION	MALCOLM PIRNIE, INC. FIGURE B-7

TABLE B-2

TOTAL VOLITILE ORGANIC CONTAMINANTS (VOCs) DATA USED IN PLUME CALIBRATION

SAMPLE ROUND 7 (AUGUST 1989)

WELLS	Zone A	Zone B	MAXIMUM (value)
MW-7	12	0	12
MW-11	0	0	0
MW-3	0	0	0
MW-2	44	0	44
MW-12	128	128	128
MW-1	27	33	33
MW-13	0	12	12
MW-16	98	=	98
MW-4	0	=	0
MW-14	1	=	1
MW-6	0	0	0
MW-5	0	0	0
MW-8	0	0	0
MW-15	0	0	0
MW-10	0	=	0
MW-9	=	0	0
MW-17	0	0	0
MW-18	0	7	7
MW-19	0	=	0
MW-20	0	=	0

SAMPLE ROUND 4 (JUNE 1988)

WELLS	Zone A	Zone B	MAXIMUM (value)
MW-7	15	0	15
MW-11	0	5	5
MW-3	21	8	21
MW-2	41	34	41
MW-12	91	91	91
MW-1	19	15	19
MW-13	0	98	98
ABSENT	=	=	=
MW-4	0	=	0
MW-14	0	=	0
MW-6	0	0	0
MW-5	0	0	0
MW-8	0	0	0
MW-15	0	0	0
MW-10	0	=	0
MW-9	0	0	0

MAXIMUM COMBINED AVERAGE (ROUNDED)
14
3
11
43
110
26
55
98
0
1

NOTE: CONCENTRATION MEASUREMENTS ARE (PPB)
MW-13 IN ROUND 4# 98 PPB IS NOT BELIEVED REPRESENTATIVE
MW-18 IN ROUND 7# CANNOT BE CORRELATED TO THE LANDFILL
= SAMPLES NOT TAKEN, ROUND 4# MW-17 TO MW-20 ABSENT

water samples (round 4 and 7) as shown on Figure B-8 in the following bar graph.

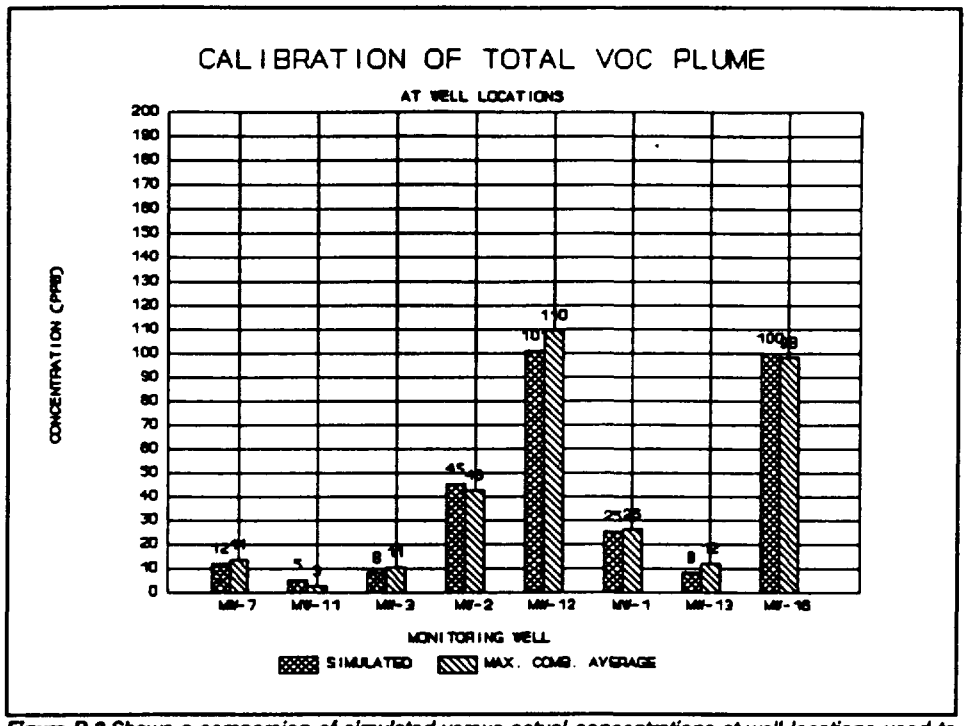


Figure B-8 Shows a comparsion of simulated versus actual concentrations at well locations used to calibrate the model.

B.3.4 <u>Plume Migration Simulations</u>

Two ground water flow simulations were used to evaluate the no action and ground water collection scenarios. These scenarios include:

- o (1) No action - a capped landfill, no recovery system;
- o (2) Capped landfill with recovery wells down gradient and water treated and disposed off-site;

In addition to the flow model output values, input parameters used in both simulations for the solute transport model are described as follows:

- o Ground Water Velocity - the driving mechanism for particle movement is based on the velocity values contained in the PLASM flow model output file;

- Effective porosity - a porosity value of 0.23 was assumed for all simulations (as cited in NWWA, 1988 publication), based on the presence of predominantly fine and medium sand;

- Dispersivity - a transverse dispersivity value of 22 feet, longitudinal dispersivity value of 7 feet and dispersion ratio of 0.314 were used. These values were developed during the model calibration to simulate an accurate match to the existing plume over the 18 year existence of the landfill.

- Retardation Factor - could not be calculated directly because the dry bulk density of stratum (pb) was never measured and lack of data to accurately calculate a soil/water partition coefficient (kp). Representative values for (pb) and (kp) were used to estimate the retardation factor. A final value of 1.2 was used for retardation in the model based on the calibration results and is regarded as a conservative estimate for total VOCs.

$$RF = 1.0 + (pb/n \times Kp)$$

where:

pb - dry bulk density of the stratum

n - effective porosity

Kp - soil/water partition coefficient

for organic compounds, the partition coefficient is calculated as:

$$Kp = Koc \times foc$$

where:

Koc - organic carbon/water partition coefficient

foc - organic carbon content of the stratum

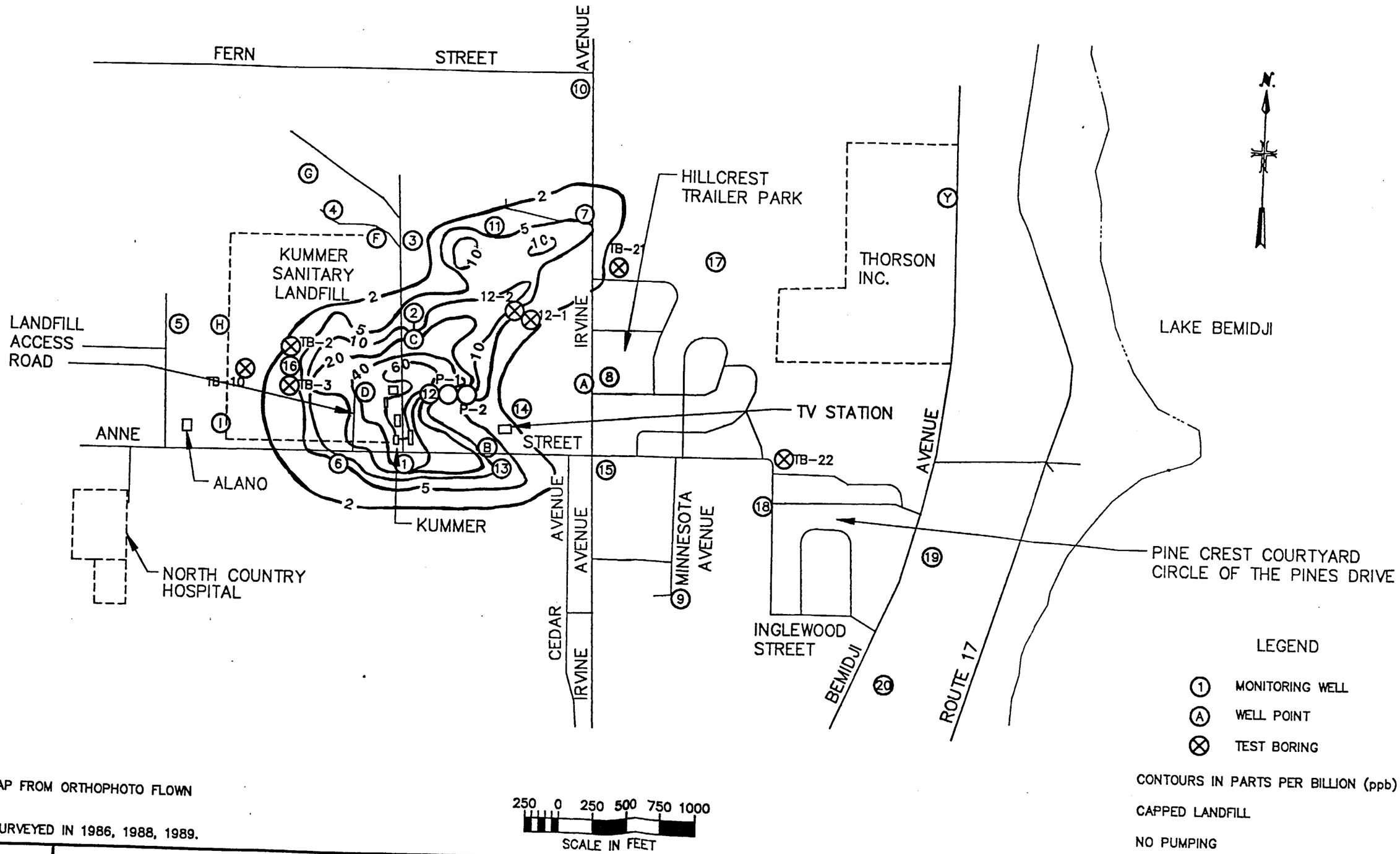
- Particle Mass - the particle mass used for Total VOCs was 0.0266 with a total of 872 particles. These values represent the maximum contaminant mass loading rates that could occur under existing conditions.

- Simulation Length - The no action transport scenario was simulated under steady-state conditions in two year time increments for a total length of 80 years. The recovery well scenario was simulated for 10 time increments during the first two years of pumping. After the first two years, two year time increments were simulated under steady state conditions for total length of 40 years.

- DMAX - the frequency at which particle summations are made during mathematical particle movement (dispersion) is determined by a finer grid spacing of (30 feet) as defined by a DMAX value of 1/5 of one grid spacing. This factor also aids in optimizing the model resolution.

B.3.4.1 Scenario 1# - No Action Plume Simulation

As a result of capping the landfill, the no action scenario would inhibit precipitation-induced percolation through landfill waste, decrease leachate generation and therefore reduce ground water contaminant loading. The effect of the cap was simulated by assuming a 25% reduction in contaminant loading every two years for the first six year following placement of the cap. After six years, contaminant loading remained constant at a decreased rate to the aquifer. This is considered a conservative value since the cap will likely reduce leachate generation by even more than the 75% reduction used here. Results of this simulation indicate that contaminants will migrate away from the landfill toward the lake as an open U-shaped plume. The divergent nature of contaminant movement appears to be a function of the anisotropic nature of hydraulic conductivities immediately east of the landfill. After 10 years, as shown on Figure B-9, the plume has moved only a small distance indicative of the low hydraulic conductivities and ground water velocity near the landfill. Figure B-10 shows the concentration of the total VOCs plume when it first reaches the lake after 34 years. The northern arm of the plume appears to migrate faster, typical of the higher hydraulic conductivities near the lake. A concentration of 5 ppb total VOCs enter the lake at this time which is below individual VOC water quality standards at Lake



BASE MAP FROM ORTHOPHOTO FLOWN IN 1985.

WELLS SURVEYED IN 1986, 1988, 1989.

MALCOLM PIRNIE

KUMMER LANDFILL GROUND WATER MODELING STUDY

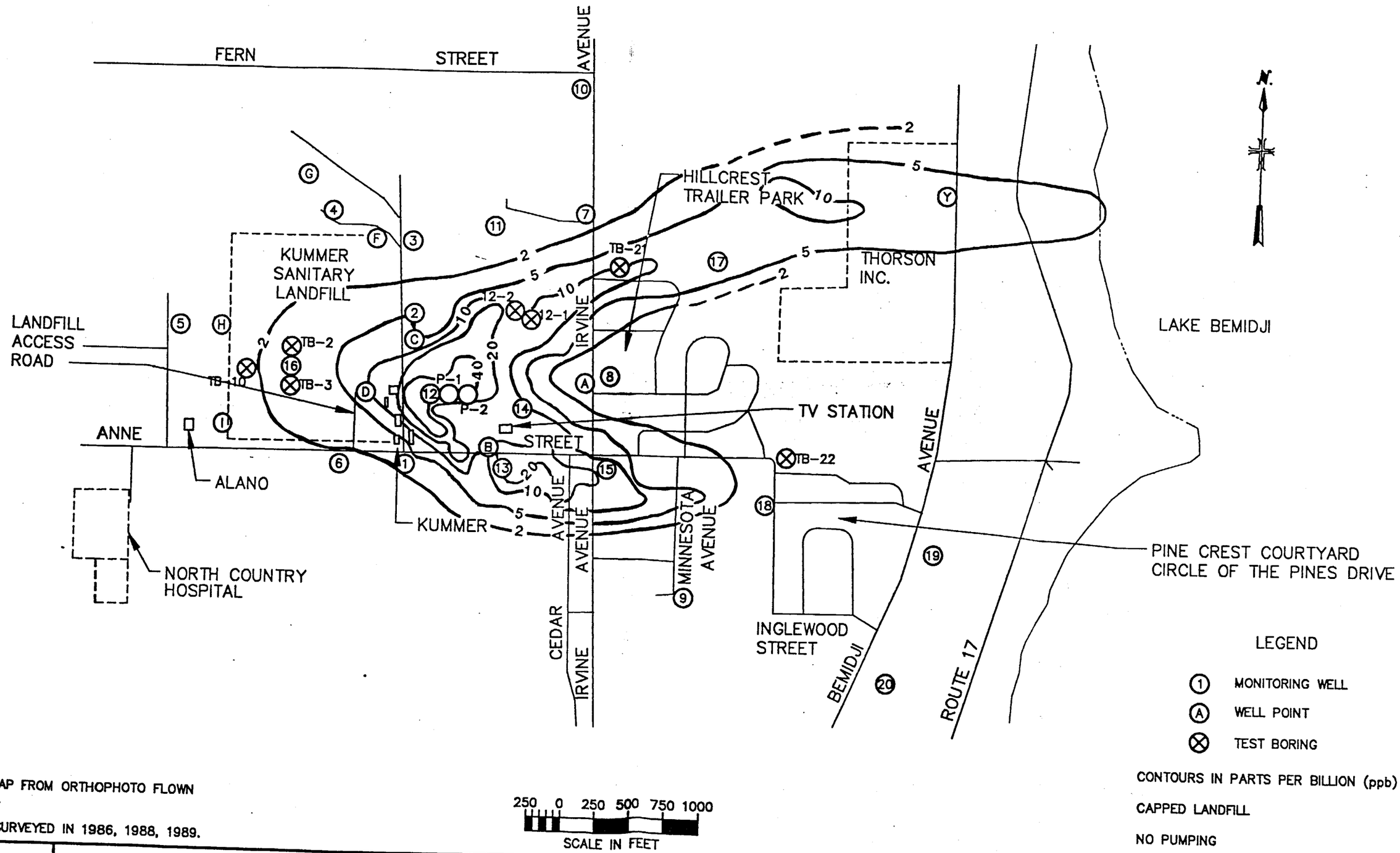
MINNESOTA POLLUTION CONTROL AGENCY

SCENARIO 1 # NO ACTION ISOCONCENTRATION CONTOUR MAP

TOTAL VOC PLUME AFTER 10 YEARS

MALCOLM PIRNIE, INC.

FIGURE B-9



BASE MAP FROM ORTHOPHOTO FLOWN IN 1985.

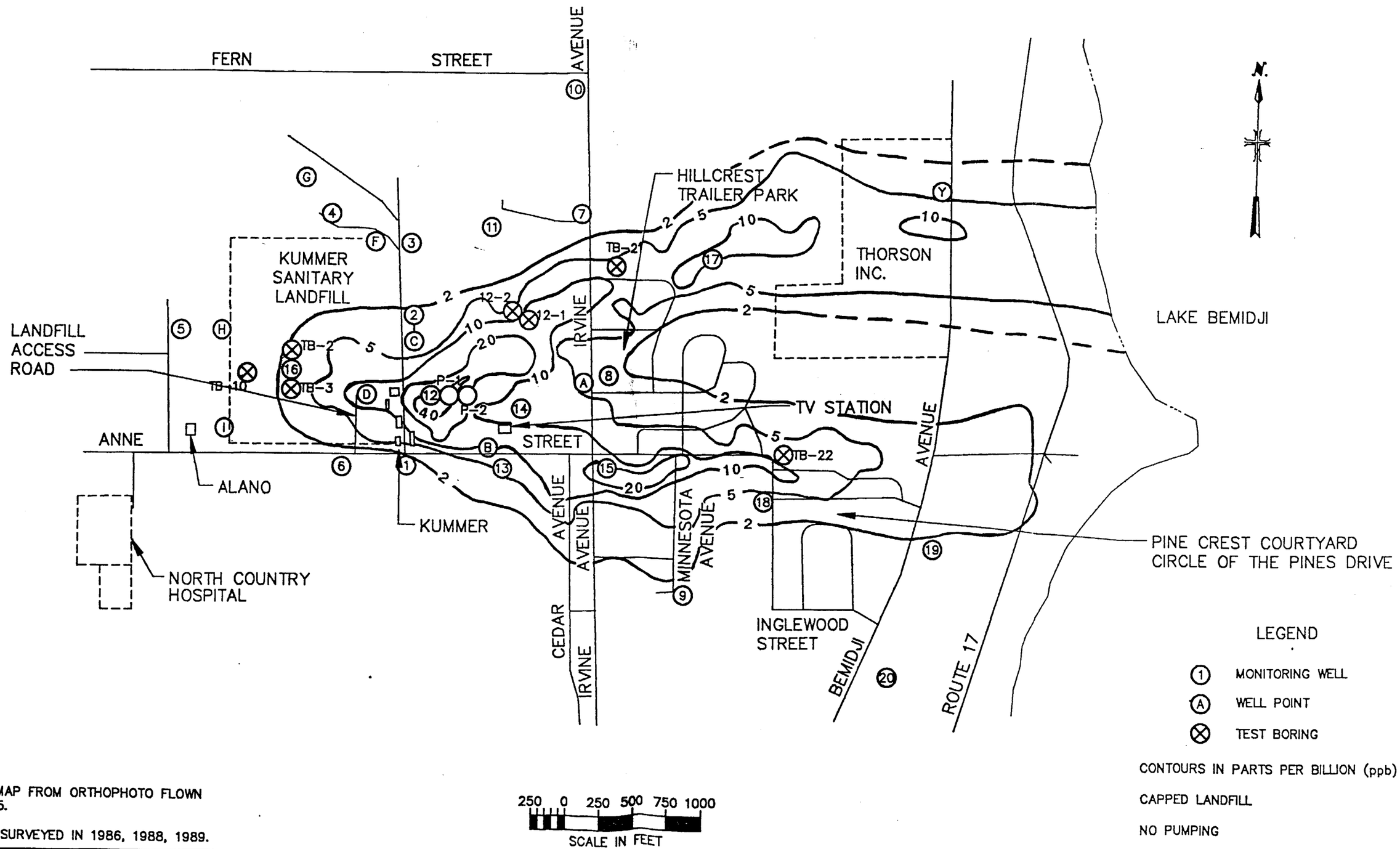
WELLS SURVEYED IN 1986, 1988, 1989.

MALCOLM PIRNIE	KUMMER LANDFILL GROUND WATER MODELING STUDY MINNESOTA POLLUTION CONTROL AGENCY	SCENARIO 1 # NO ACTION ISOCONCENTRATION CONTOUR MAP TOTAL VOC PLUME AFTER 34 YEARS	MALCOLM PIRNIE, INC. FIGURE B-10

Bemidji's interface. Figure B-11 illustrates the plume after 50 years, and shows a significant dispersal of total VOCs. The size of the plume has enlarged, but concentrations remain below Lake Bemidji water quality standards. Although model predictions have much less confidence with long time periods, an 80 year simulation as shown on Figure B-12 portrays the effect of longitudinal and transverse dispersion when the plume has achieved its greatest regional extent, and total VOC concentrations average 5 ppb or less.

B.3.4.2 Scenario 2 - Ground Water Collection Network Plume Simulation

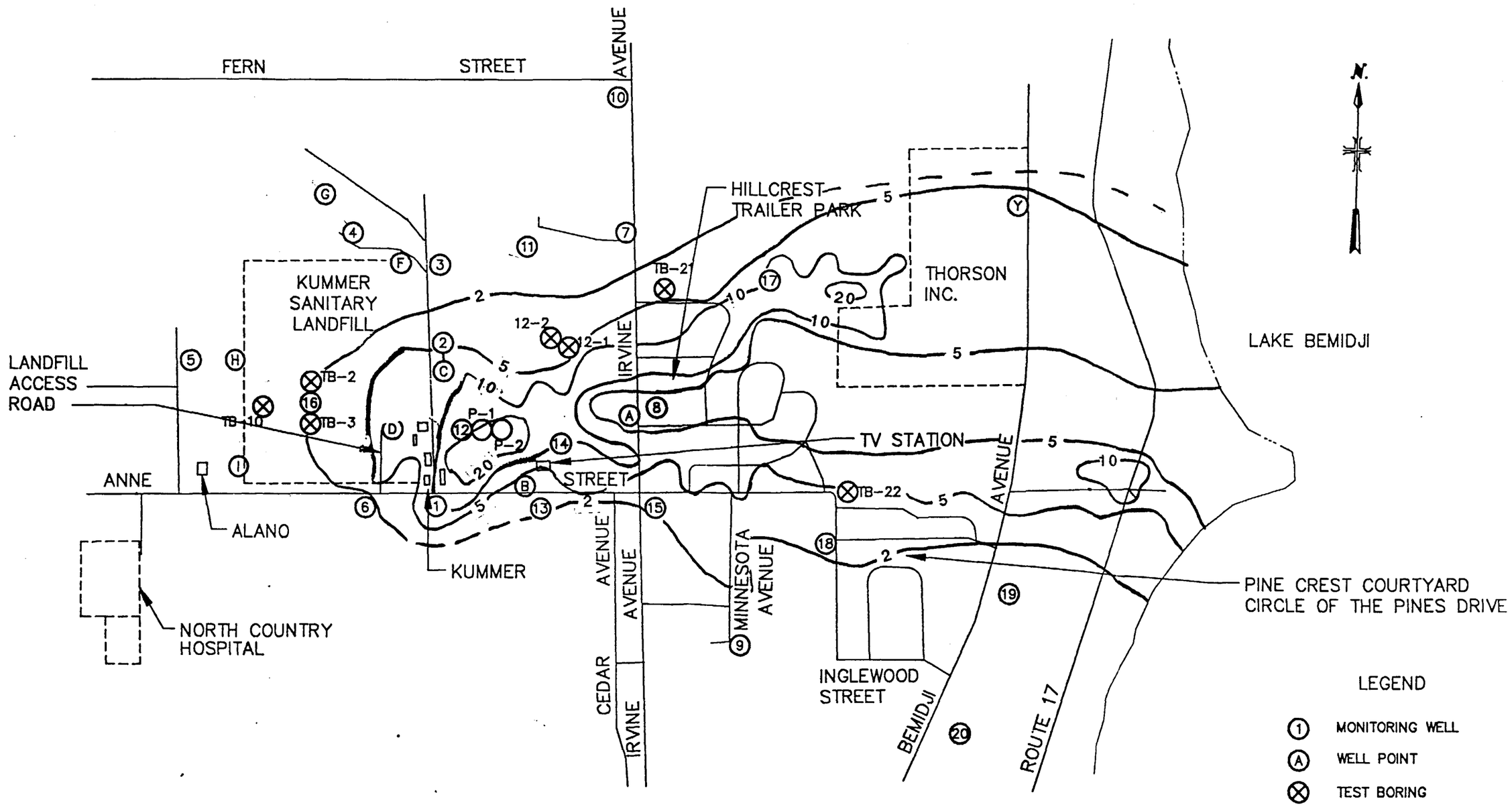
In simulating the effect of a ground water collection system on plume movement, the effect of capping the landfill was simulated identically as described above. However, smaller time increments were required to simulate changes in plume concentrations at the beginning of the pumping scenario. During the first two years of simulated pumping, total VOCs were added over 10 time increments to assure greater accuracy as the aquifer approached steady state pumping conditions. Beginning in year three of simulated pumping, total VOCs were added in two year increments for a total of 40 years. After six years of simulated pumping contaminant loading was held constant. Model results indicate that approximately 21% of the plume will be captured by the pumping wells after 209 days of operation as shown on Figure B-13. After 3.5 years approximately 60% of total VOC's will be captured by the five pumping wells. Total VOC concentrations in the landfill will decrease to approximately 20 ppb (Figure B-14), while concentrations remain high near the low permeability zone in the vicinity of MW-12B. The model further indicates that after 10 years the plume will move by only 400 to 700 feet eastward toward the lake and the total VOC concentrations remain below 5 ppb, except near the low permeable unit south-east of the landfill as shown in Figure B-15. After 20 years, it appears



BASE MAP FROM ORTHOPHOTO FLOWN IN 1985.

WELLS SURVEYED IN 1986, 1988, 1989.

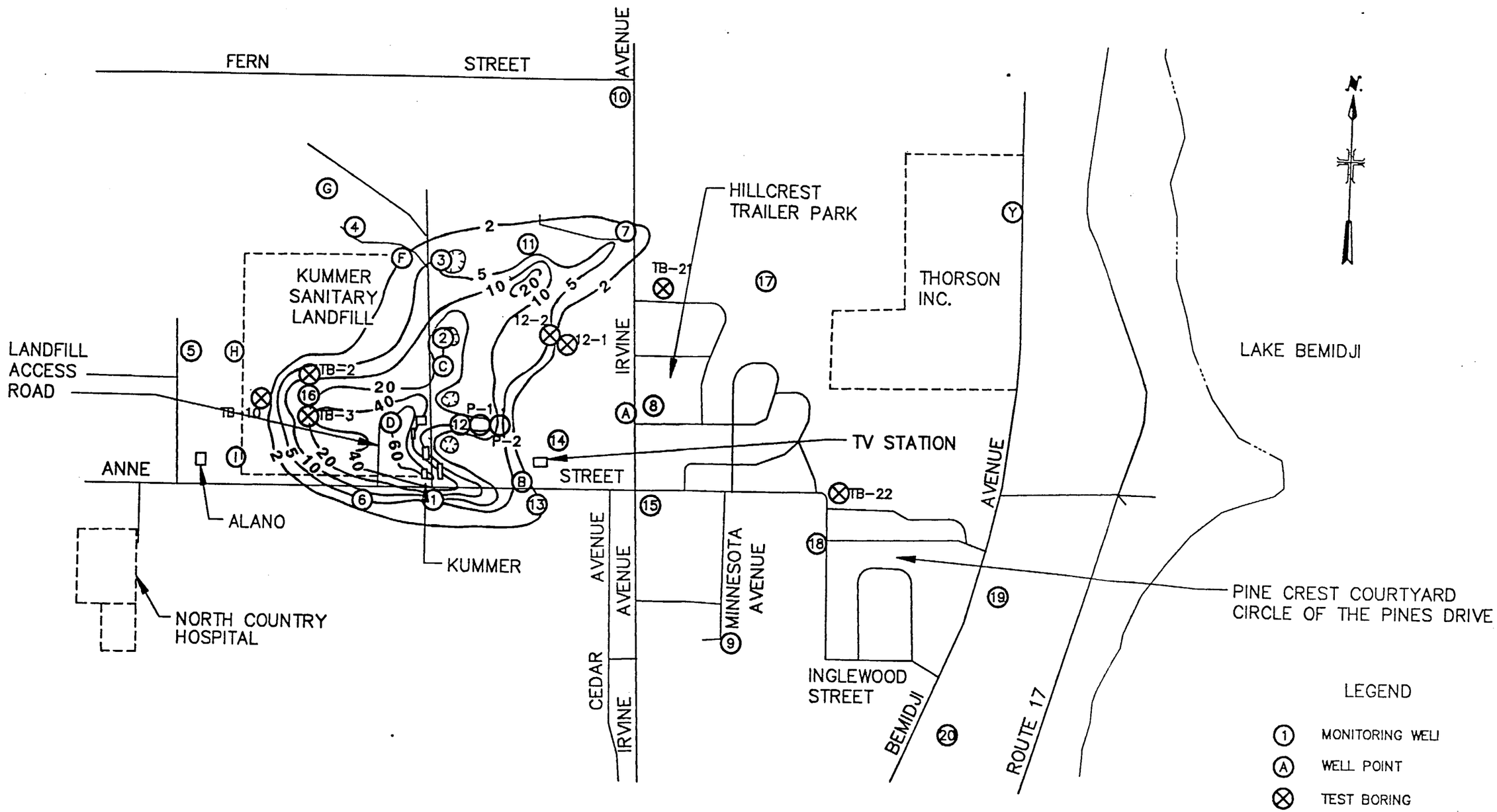
MALCOLM PIRNIE	KUMMER LANDFILL GROUND WATER MODELING STUDY MINNESOTA POLLUTION CONTROL AGENCY	SCENARIO 1 # NO ACTION ISOCONCENTRATION CONTOUR MAP TOTAL VOC PLUME AFTER 50 YEARS	MALCOLM PIRNIE, INC. FIGURE B-11



BASE MAP FROM ORTHOPHOTO FLOWN IN 1985.

WELLS SURVEYED IN 1986, 1988, 1989.

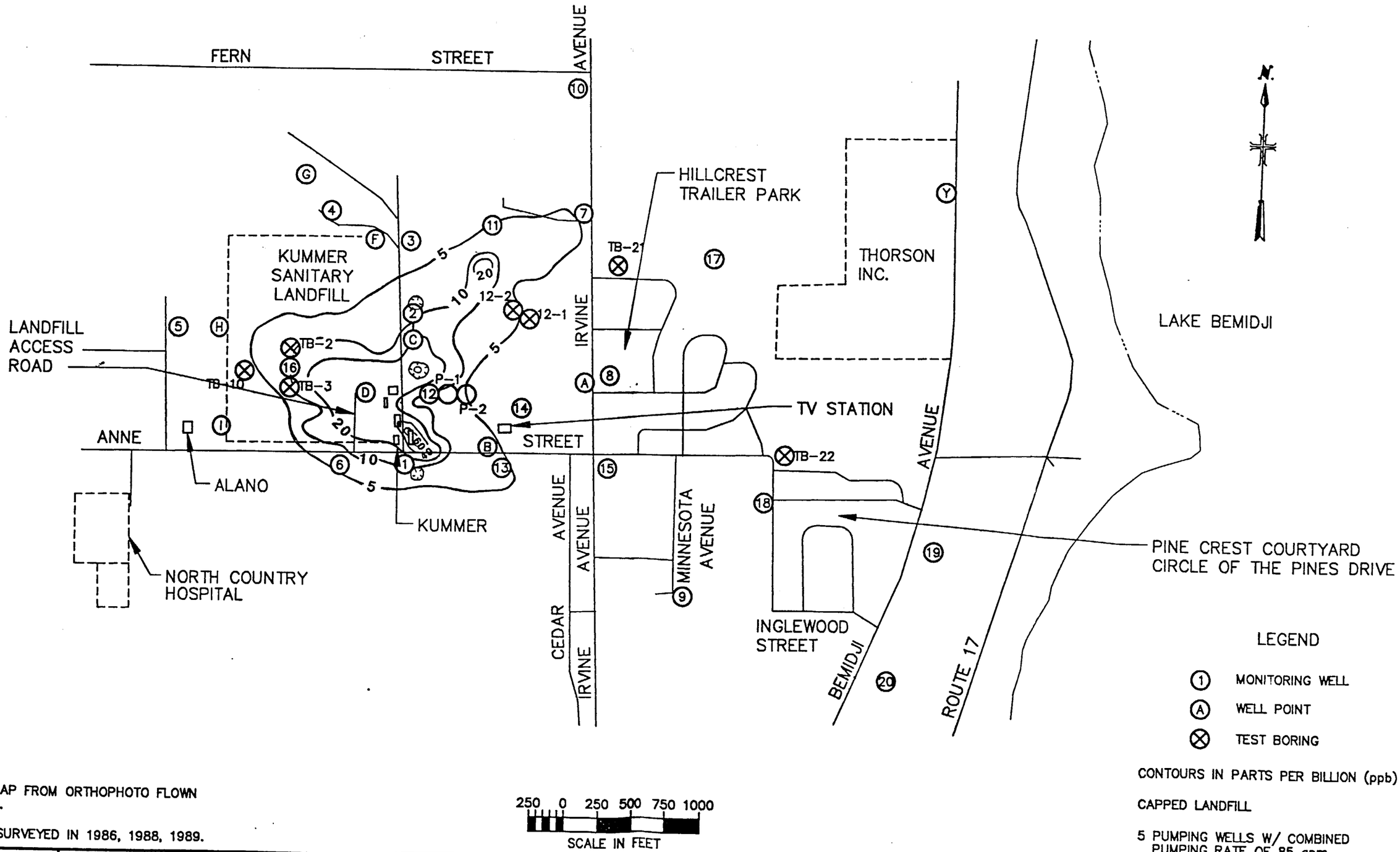
MALCOLM PIRNIE	KUMMER LANDFILL GROUND WATER MODELING STUDY MINNESOTA POLLUTION CONTROL AGENCY	SCENARIO 1 # NO ACTION ISOCONCENTRATION CONTOUR MAP TOTAL VOC PLUME AFTER 80 YEARS	MALCOLM PIRNIE, INC. FIGURE B-12



BASE MAP FROM ORTHOPHOTO FLOWN IN 1985.

WELLS SURVEYED IN 1986, 1988, 1989.

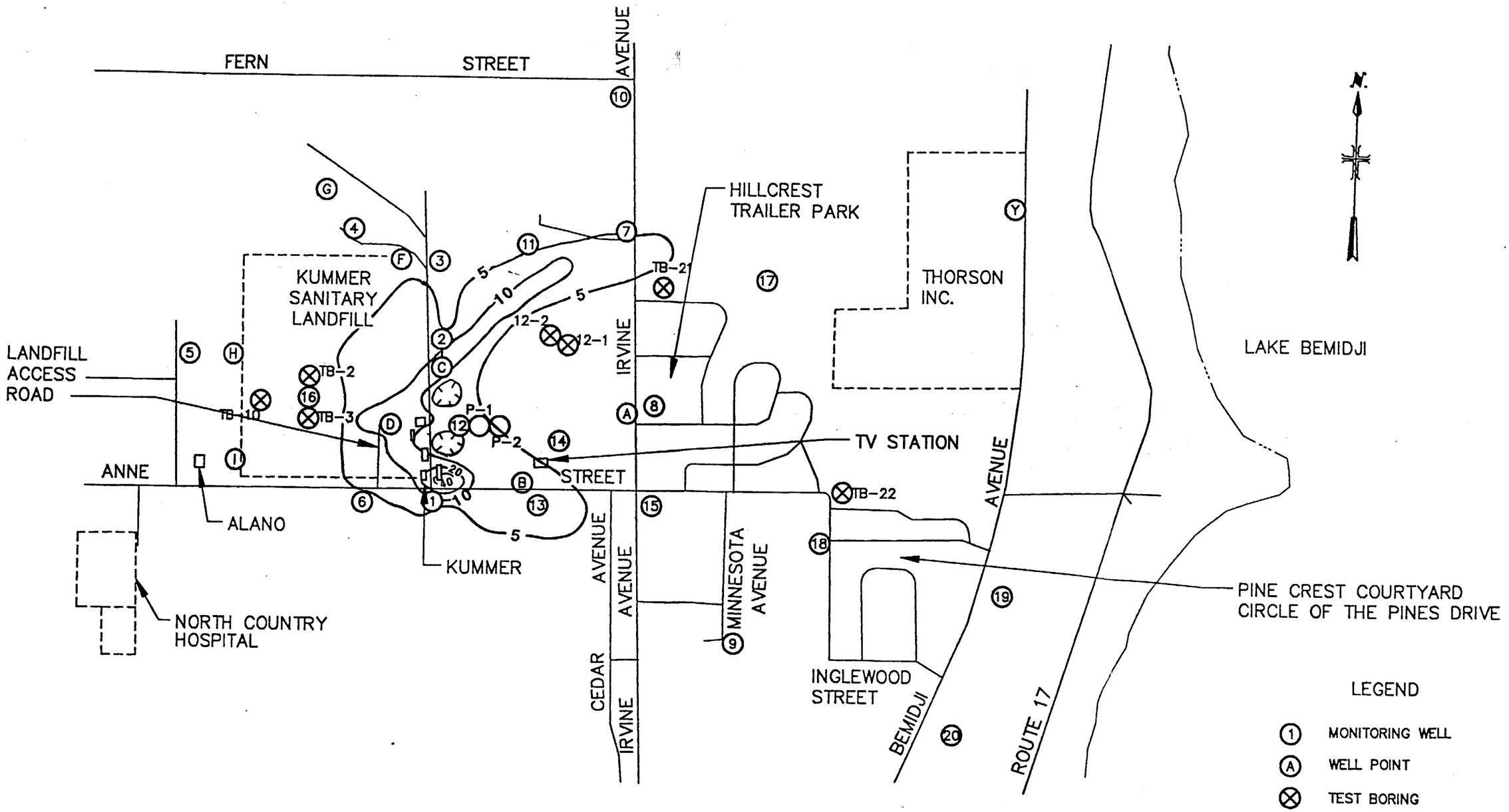
MALCOLM PIRNIE	KUMMER LANDFILL GROUND WATER MODELING STUDY MINNESOTA POLLUTION CONTROL AGENCY	SCENARIO 2 # RECOVERY WELL SIMULATION ISOCONCENTRATION CONTOUR MAP TOTAL VOC PLUME AFTER 209 DAYS	MALCOLM PIRNIE, INC. FIGURE B-13



BASE MAP FROM ORTHOPHOTO FLOWN IN 1985.

WELLS SURVEYED IN 1986, 1988, 1989.

MALCOLM PIRNIE	KUMMER LANDFILL GROUND WATER MODELING STUDY MINNESOTA POLLUTION CONTROL AGENCY	SCENARIO 2 # RECOVERY WELL SIMULATION ISOCONCENTRATION CONTOUR MAP TOTAL VOC PLUME AFTER 3.5 YEARS	MALCOLM PIRNIE, INC. FIGURE B-14



BASE MAP FROM ORTHOPHOTO FLOWN IN 1985.

WELLS SURVEYED IN 1986, 1988, 1989.

MALCOLM PIRNIE	KUMMER LANDFILL GROUND WATER MODELING STUDY MINNESOTA POLLUTION CONTROL AGENCY	SCENARIO 2 # RECOVERY WELL SIMULATION ISOCONCENTRATION CONTOUR MAP TOTAL VOC PLUME AFTER 10 YEARS	MALCOLM PIRNIE, INC. FIGURE B-15

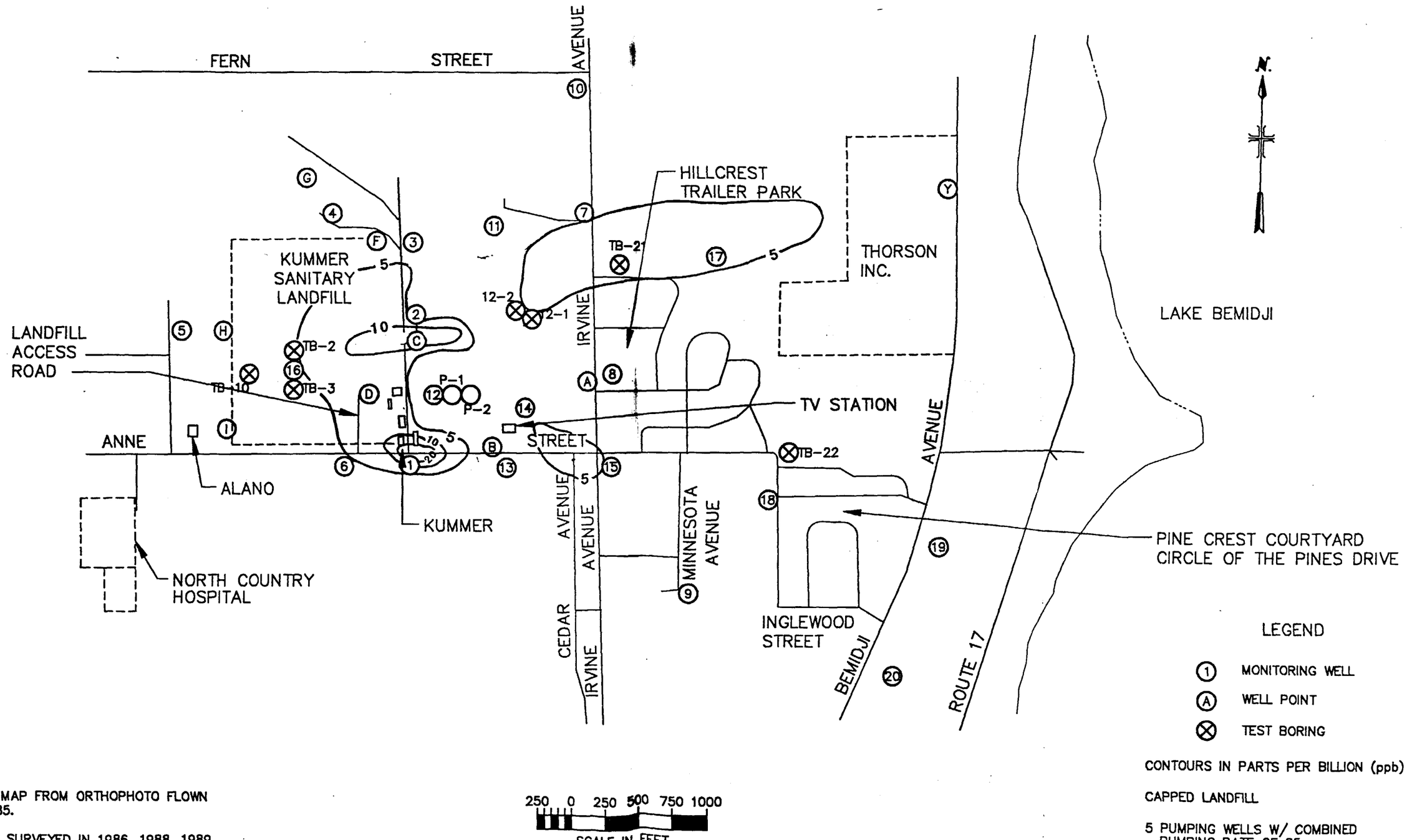
that some of the plume has escaped the capture zone created by the pumping wells. Figure B-16 shows the plume moving to within 1800 feet of the lake with average concentration of 2 to 5 ppb. The model indicates that the plume will reach the lake after 36 years at a concentration of 2 ppb as shown on Figure B-17. Again, the total VOC concentration are below Lake Bemidji water quality standards.

B.5 MODEL SENSITIVITY

The modeling conducted for this project did include a sensitivity analysis of hydrogeologic variables. Hydraulic conductivity and recharge were seen to be the most sensitive variables used in PLASM, and the retardation factor was seen as the most sensitive variable in RANDOM WALK. Retardation values other than 1.2 could not reproduce the plume configuration or concentration during calibration. Sensitivity analysis with no retardation show the plume extending well beyond the location indicated by actual data. Retardation higher than 1.2 were not consistent with estimated retardation factors for total VOCs contaminants and showed the plume barely moving. The modeling results represent the best predictions attained by applying the available RI data to flow/solute transport modeling.

B.6 CONCLUSIONS

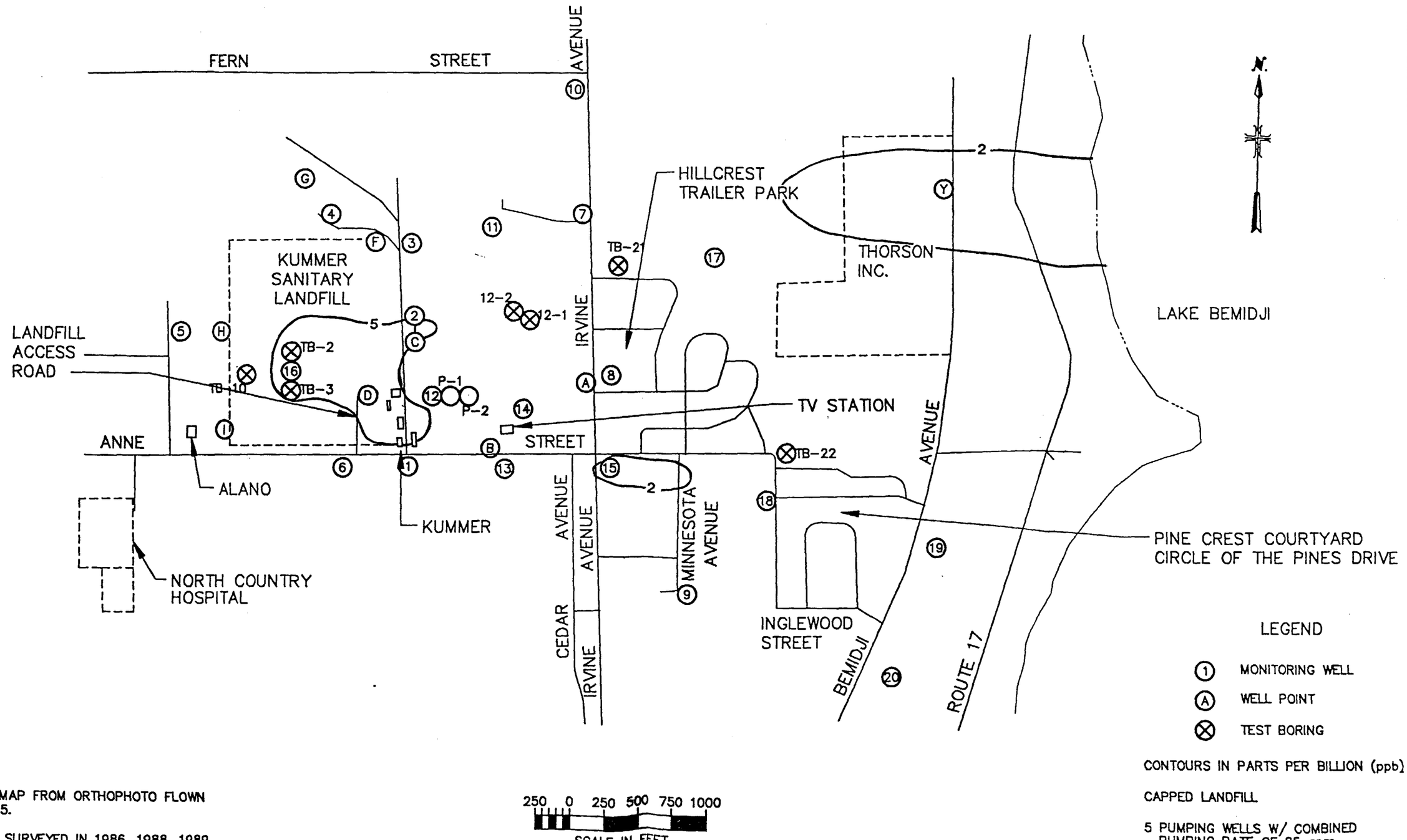
The 2-dimensional model was sufficient to evaluate the remedial alternatives which included: 1) a capped landfill with no action taken to capture the plume; and 2) a capped landfill with a ground water collection system to capture the plume. These alternatives were simulated to assess the efficiency of the alternatives for remediation of the ground water contamination at the Kummer Sanitary Landfill. The results of the no action scenario indicate that the total VOC



BASE MAP FROM ORTHOPHOTO FLOWN IN 1985.

WELLS SURVEYED IN 1986, 1988, 1989.

MALCOLM PIRNIE	KUMMER LANDFILL GROUND WATER MODELING STUDY MINNESOTA POLLUTION CONTROL AGENCY	SCENARIO 2 # RECOVERY WELL SIMULATION ISOCONCENTRATION CONTOUR MAP TOTAL VOC PLUME AFTER 20 YEARS	MALCOLM PIRNIE, INC. FIGURE B-16



BASE MAP FROM ORTHOPHOTO FLOWN IN 1985.

WELLS SURVEYED IN 1986, 1988, 1989.

MALCOLM PIRNIE	KUMMER LANDFILL GROUND WATER MODELING STUDY MINNESOTA POLLUTION CONTROL AGENCY	SCENARIO 2 # RECOVERY WELL SIMULATION ISOCONCENTRATION CONTOUR MAP TOTAL VOC PLUME AFTER 36 YEARS	MALCOLM PIRNIE, INC. FIGURE B-17

plume will reach Lake Bemidji in 34 years at a maximum concentration of 5 ppb. The model simulated plume movement over a total period of 80 years, during which the total VOC concentration never exceeded levels above 5 ppb at the lake interface. The ground water collection scenario simulated five pumping wells at a combined rate of 85 gpm over a total of 40 years. Results of this simulation indicate that the majority of plume will be captured within 10 years. A small portion of the plume will escape the capture zone generated by the five pumping wells, and will reach the lake after 36 years with total VOC concentrations of 2 ppb. Total VOC concentrations entering the lake in both scenarios are predicted to be below the surface water standards for Lake Bemidji.

Long-term ground water monitoring is expected to confirm modeling results. It should be noted that past chemical analyses of ground water samples have shown high variations in total VOC distribution and concentrations at monitoring locations due to the very low concentrations present. It is expected that future sampling may also show these variations before a statistically representative baseline can be established. However, concentrations of total VOCs reaching the lake are expected to be within one order of magnitude of the predicted values based on the variability of total VOC concentrations during past sampling events.

A ground water monitoring program should be developed to confirm the accuracy of plume movement and total VOC concentrations as characterized during solute transport modeling. Results of the ground water model can be used as a guide to assist placement of monitoring wells along paths of predicted plume migration. A network of monitoring wells within the plume and near the lake interface should be sampled at consistent specified times. The ground water monitoring should also be used to confirm and, where necessary, update modeling results.

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APPENDIX C

SURFACE WATER QUALITY CRITERIA FOR LAKE BEMIDJI

420d

DEPARTMENT : Minnesota Pollution Control Agency

STATE OF MINNESOTA
Office Memorandum

PHONE : 296-9134

DATE : April 9, 1990 DRAFT

TO : Art Dunn
Chief, Solid Waste Section
Division of Water Quality

FROM : Gene Soderbeck
Supervisor, Program Development Section
Water Quality Division

SUBJECT : Surface Water Quality Criteria for Lake Bemidji

Thank you for requesting surface water quality criteria for Lake Bemidji. The lake is classified as a 2B,3B,4A,4B,5 and 6 class water. The Mississippi River, which runs through the lake, is an Outstanding Resource Value Water (ORVW) from Lake Itasca to the southern border of Morrison County. This designation is in accordance with the Mississippi Headwaters Board; the river is protected by the board's comprehensive management plan rather than a federal wild and scenic river designation. The counties in the board have set aside several areas in the corridor which are not covered by the plan and therefore are not ORVWs. Lake Bemidji is in one of these exempted areas. However, according to Minn. Rules 7050.0180, subp. 9, any new or expanded discharge must be controlled so as to assure no deterioration in the quality of the downstream ORVW.

If the heart of the contaminated ground water plume has not reached the lake, then the discharge will be considered expanded. The water that reaches the lake must not only meet the surface water quality criteria, it must also be controlled so that there is no change in the quality of the Mississippi River at County Road 19 on the east side of the lake where the ORVW corridor begins again.

Since the discharge is to a lake, there will not be a dilution factor allowed for the contaminated ground water discharge. The ground water must meet the surface water criteria at the interface. The appropriate criteria are included in Table 1. Note that the table includes the chronic and acute criteria for the existing rule and the revision that is presently going through the rule-making process. It should be effective sometime this summer. Numbers for some of the chemicals could change.

Please note that there are some special requirements for monitoring for surface waters. The metals should be analyzed as total, rather than dissolved, and the lab should use graphite furnace, rather than flame, atomic absorption. Also, because this discharge is to a lake the ground water must be monitored for nutrients. Required parameters are total phosphorus, ortho phosphorus, total Kjeldahl nitrogen, total alkalinity, chloride, pH, temperature and ammonia. If levels are excessive, the discharge may receive a phosphorus limit. Note that the flow rate of the plume in cubic feet per second will also be needed.

If you have further questions or comments, please call Carri Lohse-Hanson of my staff at 296-9134.

Table 1. Surface water quality criteria for Lake Bemidji.

PARAMETER	UNITS	CHRONIC CRITERIA	PROPOSED WQSTANDARD	ACUTE CRITERIA	PROPOSED FAV	OTHER
Inorganic						
Ammonia, unionized as N	ug/l	40	40	1000	-	
Chloride	mg/l	230	230	1720	1720	100
Cyanide, free	ug/l	5	5.2	45	45	
Dissolved oxygen	mg/l	-	-	-	-	5
Oil	ug/l	500	500	-	10000	
pH	low	-	-	-	-	6.5
	high	-	-	-	-	8.5
Specific conductance	umhos/cm	-	-	-	-	1000
Metals and Elements						
Aluminum	ug/l	255	125	3292	2145	
Antimony	ug/l	631		3850		
Arsenic	ug/l	30	70	696	720	
Barium	ug/l					
Beryllium	ug/l	5		647		
Boron	ug/l					500
Cadmium*	ug/l	1.18	1.72	111.5	121.7	
Chromium, +3*	ug/l	54	320	4570	5357	
Chromium, +6	ug/l	10	11	28	32	
Cobalt	ug/l	10		854		
Copper*	ug/l	13.6	13.7	60.3	58.5	
Iron	ug/l	1000		4200		
Lead*	ug/l	8.7	6.3	291	322	
Manganese	ug/l	1000		3850		
Mercury	ug/l	0.012	0.0069	3.9	4.9	
Nickel*	ug/l	213	213	4443	4443	
Selenium	ug/l	5	5	40	40	
Silver	ug/l	1	1	8.5	10.1	
Thallium	ug/l	11		350		
Zinc*	ug/l	155	166	624	367	
Organics						
Acenapthene	ug/l	20	12		81	
Acetone	ug/l	11700		3800000		
Acrolein	ug/l	7		17		
Acrylonitrile (C)	ug/l	0.9	0.89	1888	2281	
Alachlor	ug/l	16.3		733		
Aldrin	ug/l	0.003		3.4		
Anthracene	ug/l		0.029		1.6	
Benzene (C)	ug/l	38	114	2792	8974	
Bromoform	ug/l		558		5800	
Carbon tetrachloride (C)	ug/l	6	5.9	8800	3500	
Chlordane (C)	ug/l	0.001	0.00829	1.2	2.4	
Chlorobenzene	ug/l	109	10	4884	846	
Chloroform (C)	ug/l	257	224	11560	4471	
Chlorpyrifos	ug/l	0.04	0.041	0.15	0.17	
DDT (C)	ug/l	0.00026	0.0017	1	1.1	
1,2-Dichlorobenzene	ug/l	14		632		
1,3-Dichlorobenzene	ug/l	28		1255		
1,4-Dichlorobenzene	ug/l	10		448		
1,2-Dichloroethane (C)	ug/l	128	190	29500	90100	
1,1-Dichloroethylene	ug/l	50		7568		
1,2-Dichloroethylene (c+t)	ug/l	449				
2,4-Dichlorophenol	ug/l	0.3		505		
1,1-Dichloropropane	ug/l	128		5750		

Table continued

1,2-Dichloropropane	ug/l	54.2		1312	
1,3-Dichloropropene (c+t)	ug/l	41.7		32750	
Dieldrin (C)	ug/l	0.0003	0.000026	6.18	2.5
Di-2-ethylhexyl phthalate (C)	ug/l	1	2.1	5550	
Diethyl phthalate	ug/l	290		13025	
2,4-Dimethyl phenol	ug/l	12		530	
Dinitrotoluene	ug/l	12		7750	
1,2-Diphenylhydrazine	ug/l	1.2			
Di-n-Octyl phthalate	ug/l		30		1650
Endosulfan	ug/l	0.15	0.15	0.6	0.56
Endrin	ug/l	0.016	0.016	0.39	0.18
Ethylbenzene	ug/l	175	68	7867	3717
Fluoranthene	ug/l		4.6		398
Heptachlor (C)	ug/l	0.00026	0.00039	0.3	0.52
Heptachlor epoxide (C)	ug/l		0.00048		0.53
Hexachlorobenzene (C)	ug/l	0.0006	0.00022		
Hexachlorobutadiene	ug/l	0.3		12.8	
Hexachlorocyclohexane, alpha	ug/l	0.015			
Hexachlorocyclohexane, beta	ug/l	0.1			
Hexachlorocyclohexane, gamma see Lindane					
Hexachloroethane	ug/l	0.84			
Isophorone	ug/l	650		29250	
Lindane (C)	ug/l	0.04	0.036	10	8.8
Methyl ethyl ketone	ug/l	2880		468000	
Methyl isobutyl ketone	ug/l	2828		127250	
Methylene chloride (C)	ug/l	1072	1561	48250	19200
Naphthalene	ug/l	20.4		920	
N-nitrosodiphenylamine	ug/l	22		1462	
PAHs, total carcinogenic	ug/l	0.07			
PAHs, total noncarcinogenic	ug/l	17			
Parathion	ug/l	0.05	0.013	0.5	0.13
Pentachlorophenol**	ug/l	13.7	15.6	42.9	50
Phenanthrene	ug/l	1	2.1		58
Phenol	ug/l	212	123	9547	4428
Polychlorinated biphenyls (C)	ug/l	0.00008	0.000029		2
Styrene	ug/l	0.2		5750	
2,3,7,8-Tetrachlorodibenzo-p-dioxin (C)	pg/l	0.002	0.0018		
1,1,2,2-Tetrachloroethane (C)	ug/l	14.6	13	2330	2253
1,1,2,2-Tetrachloroethylene (C)	ug/l	9	8.9	2110	857
Tetrahydrofuran	ug/l	6500		292500	
Toluene	ug/l	68	253	3044	2703
Toxaphene (C)	ug/l	0.00057	0.0013	1.7	11.5
1,1,1-Trichloroethane	ug/l	138	263	6222	5256
1,1,2-Trichloroethane	ug/l	123		9032	
1,1,2-Trichloroethylene (C)	ug/l	123	120	10175	13976
2,4,5-Trichlorophenol	ug/l	1			
2,4,6-Trichlorophenol	ug/l	2	2		203
Vinyl chloride (C)	ug/l	3.3	7.6		
Xylenes, total	ug/l	42	166	1894	2814

* Based on a hardness of 170 at MN-1292 and MN-1365 (total of 214 observations).
** Based on a pH of 8.0 in Lake Bemidji (14 observations).

(C) carcinogenic chemical
(c+t) cis and trans

APPENDIX D

COST ESTIMATES

DESCRIPTION OF APPENDIX D TABLES

Table	Description
D-1	Capital Cost Estimate for Groundwater Collection Component of Hydraulic Control Alternatives
D-1a	Capital Cost Estimate for Groundwater Collection Trench for Passive Downgradient Hydraulic Controls
D-2	Annual Operation and Maintenance Cost Estimate for Groundwater Collection Component of Hydraulic Control Alternatives
D-3	Capital Cost Estimate for Onsite Groundwater Treatment By Precipitation/Stripping/Granular Activated Carbon
D-4	Annual Operation and Maintenance Cost Estimate for Onsite Groundwater Treatment By Precipitation/Stripping/ Granular Activated Carbon
D-5	Capital Cost Estimate for Onsite Groundwater Treatment By Lime Softening/AOP/Granular Activated Carbon
D-6	Annual Operation and Maintenance Cost Estimate for Onsite Groundwater Treatment By Lime Softening/AOP/Granular Activated Carbon
D-7	Total Capital and O&M Cost Estimates for Alternatives I, II and III.

TABLE D-1
KUMMER LANDFILL, MINNESOTA

CAPITAL COST ESTIMATE FOR GROUNDWATER COLLECTION COMPONENT
OF HYDRAULIC CONTROL ALTERNATIVES (1)

	ALTERNATIVE 1 NO ACTION	ALTERNATIVE 3 ACTIVE UPGRADIENT HYDRAULIC CONTROLS	ALTERNATIVE 4 ACTIVE DOWNGRADIENT HYDRAULIC CONTROLS
GROUNDWATER COLLECTION			
Well Construction & Testing	$5,000	$135,000	$70,000
Well Pump Equipment	$0	$30,000	$10,000
Groundwater Collection Pipeline	$0	$55,000	$36,000
Groundwater Collection Trench	$0	$0	$0
MISCELLANEOUS			
Remove Monitoring Wells	$45,000	$50,000	$50,000
Land Acquistion (2)	$0	$20,000	$40,000
SUBTOTAL CAPITAL COSTS	$50,000	$290,000	$206,000
CONTINGENCY @ 25%	$12,500	$72,500	$51,500
ENGINEERING @ 20%	$10,000	$58,000	$41,200
TOTAL CAPITAL COST	$73,000	$420,000	$300,000

NOTES: (1) Capital cost estimate for Alternative 2 is included in Table D-1a.
(2) Based on $2000/acre.
Columns may not add due to rounding.

TABLE D-1a
KUMMER LANDFILL, MINNESOTA

CAPITAL COST ESTIMATE FOR GROUNDWATER COLLECTION COMPONENT
OF HYDRAULIC CONTROL ALTERNATIVE 2:PASSIVE DOWNGRADIENT CONTROLS

PASSIVE TRENCH CONSTRUCTION	UNITS	QUANTITY	UNIT COST	TOTAL COST
Dewatering Wells	EA	15	$14,000	$210,000
Excavation	CY	1,080,000	$2	$2,160,000
Filter Rock Backfill, Material	CY	334,000	$18	$6,012,000
Filter Rock Backfill, Placement	CY	334,000	$3	$1,002,000
Soil Backfill, Placement	CY	746,000	$1	$746,000
Collection Pipe	FT	1,800	$50	$90,000
Manhole	FT	80	LS	$25,000
Water Disposal From Dewatering	GAL	158,000,000	$0.003	$474,000
Grading & Revegetation	ACRE	40	$1,500	$60,000
Remove Monitoring Wells	EA	25	$2,000	$50,000
Land Acquistion	ACRE	40	$2,000	$80,000
SUBTOTAL CAPITAL COSTS				$10,909,000
CONTINGENCY @ 50%				$5,454,500
ENGINEERING @ 20%				$2,181,800
LESS CREDIT FOR EXCESS SOIL BACKFILL				(2,300,000)
TOTAL CAPITAL COST				$16,000,000

NOTES: Columns may not add due to rounding.

TABLE D-2
KUMMER LANDFILL, MINNESOTA

O&M COST ESTIMATE FOR GROUNDWATER COLLECTION COMPONENT
OF HYDRAULIC CONTROL ALTERNATIVES

ANNUAL COST ITEM	ALTERNATIVE 1 NO ACTION	ALTERNATIVE 2 PASSIVE DOWNGRADIENT HYDRAULIC CONTROLS	ALTERNATIVE 3 ACTIVE UPGRADIENT HYDRAULIC CONTROLS	ALTERNATIVE 4 ACTIVE DOWNGRADIENT HYDRAULIC CONTROLS
MAINTENANCE MATERIALS & LABOR				
15% of Equipment Capital Cost	$0	$800	$5,000	$1,500
AUXILIARY MATERIALS & LABOR				
Electricity (1) Groundwater Pumping	$0	$400	$5,200	$2,500
PURCHASED SERVICES				
Well Water Analyses (2)	$15,000	$15,000	$15,000	$15,000
INSURANCE, TAXES, & LICENSES				
5% of Capital Cost (3)	$4,000	$31,000	$21,000	$15,000
SUBTOTAL ANNUAL O&M COST	$19,000	$47,200	$46,200	$34,000
CONTINGENCY @ 25% OF ANNUAL O&M COST	$5,000	$11,800	$11,550	$8,500
TOTAL ANNUAL O&M COST	$24,000	$59,000	$58,000	$43,000
PRESENT WORTH OF O&M COST (4)	$230,000	$560,000	$550,000	$410,000

NOTES: (1) Based on $0.08/kwhr.
(2) Based on annual groundwater sampling for HSL volatiles,metals,conventional parameters for Alternative #1 and semi-annual testing for Alternatives #2, #3, and #4.
(3) Insurance,taxes and license costs for Alternative 2 are assumed approximately equal to costs for Alternative 4.
(4) Present worth cost based on 30 year project life and 10% discount rate.

Columns may not add due to rounding.

TABLE D-3
KUMMER LANDFILL , MINNESOTA

PRECIPITAION/STRIPPING/ACTIVATED CARBON TREATMENT
CAPITAL COST ESTIMATE

CAPITAL COSTS:INORGANICS REMOVAL		TOTAL COST	SOURCE/COMMENTS
Coagulant Feed/Mixing System		$10,000	
Chemical Storage Tank			
Metering Feed Pump			
Solids Handling Equipment			
Clarifier & Internals		$50,000	Gary Huebner,WAMCON
Centrifuge		$75,000	Ken Lindgren,Bird Machine Company
Polymer Feed System		$10,000	
Mixing Tank			
Metering Feed Pump			
Filtration System			
Multi-Media Pressure Sand Filter		$8,000	Jeff Hughes, Bob J. Johnson & Assoc.
Backwash Tank		$5,000	
Pumps			
Pressure Filter (2)		$8,000	
Filter Backwash (1)		$4,000	
Sludge Pump (2)		$8,000	
Centrifuge Filtrate (1)		$2,000	
Filter Backwash Tank (1)		$2,000	
Piping & Valves @ 10%		$18,000	
Electrical & Instrumentation @ 10%		$18,000	
SUBTOTAL CONSTRUCTION COST		$218,000	
CONTINGENCY @ 20%		$43,600	
CONTRACTOR OVERHEAD & PROFIT @ 10%		$21,800	
ENGINEERING @ 15%		$32,700	
TOTAL CAPITAL COST		$320,000	

CAPITAL COSTS:ORGANICS REMOVAL		Total Cost	Source
Packed Column, Air Filter, Blower		$75,000	
Vapor Phase Control Equipment		$60,000	
Carbon Contactor		$50,000	
Initial Carbon (20,000 lb)		$10,000	
Piping & Valves @ 10%		$19,000	
Electrical & Instrumentation @ 10%		$19,000	
Sitework		$3,000	
Foundation & Clearwell		$35,000	
Building		$90,000	
Land Acquisition		$3,000	
SUBTOTAL CONSTRUCTION COST		$364,000	
CONTINGENCY @ 20%		$72,800	
CONTRACTOR OVERHEAD & PROFIT @ 10%		$36,400	
ENGINEERING @ 15%		$54,600	
TOTAL CAPITAL COST		$530,000	

NOTES: Columns may not add due to rounding.

TABLE D-4
KUMMER LANDFILL, MINNESOTA

PRECIPITATION/STRIPPING/ACTIVATED CARBON TREATMENT
ANNUAL O&M COST ESTIMATE

OPERATING COSTS:INORGANICS REMOVAL	UNITS	QUANTITY	UNIT COST	TOTAL COST
Power	KWHR		$0.08	$8,000
Labor	HOURS	2,000	$25	$50,000
Maintenance Materials @ 5%				$9,000
Coagulant	LBS	14,000	$1.75	$25,000
Polymer	LBS	1,000	$2.50	$3,000
Solids Disposal	CY	100	$200	$20,000
Monitoring			LS	$30,000
Insurance, Taxes, & Licenses @ 5%				$16,000
SUBTOTAL ANNUAL O&M COST				$161,000
CONTINGENCY @ 25%				$40,000
TOTAL ANNUAL O&M				$200,000
PRESENT WORTH O&M (1)				$1,900,000

OPERATING COSTS:ORGANICS REMOVAL	UNITS	QUANTITY	UNIT COST	TOTAL COST
Power	KWHR		$0.08	$4,000
Labor	HOURS	2000	$25	$50,000
Natural Gas				
Liquid Phase GAC (0.05 lb/1000 gal)	LBS	6000	$1.00	$6,000
Maintenance Materials @ 5%				$9,500
Monitoring			LS	$30,000
Insurance, Taxes, & Licenses @ 5%				$3,000
SUBTOTAL ANNUAL O&M COST				$103,000
CONTINGENCY @ 25%				$26,000
TOTAL ANNUAL O&M				$130,000
PRESENT WORTH O&M (1)				$1,200,000

NOTES: (1) Present worth cost based on 30 year project life and 10% discount rate.

Columns may not add due to rounding.

TABLE D-5
KUMMER LANDFILL, MINNESOTA

SOFTENING/AOP/ACTIVATED CARBON TREATMENT
CAPITAL COST ESTIMATE

CAPITAL COSTS:INORGANICS REMOVAL		TOTAL COST	SOURCE/COMMENTS
Lime Feed/Mixing System		$50,000	Gary Huebner,WAWCON
Lime Storage Tank			
Metering Feed Pump			
Rapid Mix Tanks			
Mechanical Mixer			
Solids Handling Equipment			
Clarifier & Internals		$50,000	Gary Huebner,WAWCON
Centrifuge		$75,000	Ken Lindgren,Bird Machine Company
CO2 pH Adjustment System		$10,000	
Sparger			
pH Probe			
Polymer Feed System		$10,000	
Mixing Tank			
Metering Feed Pump			
Filtration System			
Multi-Media Pressure Sand Filter		$8,000	Jeff Hughes, Bob J. Johnson & Assoc.
Backwash Tank		$5,000	
Pumps			
Pressure Filter (2)		$8,000	
Filter Backwash (1)		$4,000	
Sludge Pump (2)		$8,000	
Centrifuge Filtrate (1)		$2,000	
Filter Backwash Tank (1)		$2,000	
Piping & Valves @ 10%		$23,000	
Electrical & Instrumentation @ 10%		$23,000	
SUBTOTAL CONSTRUCTION COST		$278,000	
CONTINGENCY @ 20%		$55,600	
CONTRACTOR OVERHEAD & PROFIT @ 10%		$27,800	
ENGINEERING @ 15%		$41,700	
TOTAL CAPITAL COST		$400,000	

CAPITAL COSTS:ORGANICS REMOVAL		Total Cost	Source
Ozone Generator System		$90,000	Jerry Gruber, Griffin Technics,Inc.
Air Dryers/Filters			
Diffuser			
Power Supply			
Ozone Leak Monitor			
Packed Column Ozone Decomposer			
Start-up and Training			
Hydrogen Peroxide System		$10,000	PulsaFeeder
Hydrogen Peroxide Storage Tank			
Metering Feed Pump			
Diffuser			
Ozone Contactor		$10,000	
Carbon Contactor		$50,000	
Initial Carbon (20,000 lb)		$10,000	
Piping & Valves @ 10%		$16,000	
Electrical & Instrumentation @ 10%		$16,000	
Sitework		$3,000	
Foundation		$10,000	
Building		$90,000	
SUBTOTAL CONSTRUCTION COST		$305,000	
CONTINGENCY @ 20%		$61,000	
CONTRACTOR OVERHEAD & PROFIT @ 10%		$30,500	
ENGINEERING @ 15%		$45,750	
TOTAL CAPITAL COST		$440,000	

NOTES: Columns may not add due to rounding.

TABLE D-6
KUMMER LANDFILL, MINNESOTA

SOFTENING/AOP/ACTIVATED CARBON TREATMENT
ANNUAL O&M COST ESTIMATE

OPERATING COSTS:INORGANICS REMOVAL	UNITS	QUANTITY	UNIT COST	TOTAL COST
Power	KWHR		$0.08	$10,000
Labor	HOURS	2000	$25	$50,000
Maintenance Materials @ 5%				$11,500
Lime	LBS	220,000	$0.05	$11,000
Carbon Dioxide	LBS	7,000	$0.40	$2,800
Polymer	LBS	1,000	$2.50	$3,000
Solids Disposal	CY	400	$200	$80,000
Monitoring			LS	$30,000
Insurance, Taxes, & Licenses @ 5%				$20,000
SUBTOTAL ANNUAL O&M COST				$218,000
CONTINGENCY @ 25%				$55,000
TOTAL ANNUAL O&M				$270,000
PRESENT WORTH O&M (1)				$2,500,000

OPERATING COSTS:ORGANICS REMOVAL	UNITS	QUANTITY	UNIT COST	TOTAL COST
Power	KWHR		$0.08	$13,000
Labor	HOURS	2,000	$25	$50,000
Maintenance Materials @ 5%				$8,000
Liquid Phase GAC (0.10 lb/1000 gal)	LBS	6,000	$1.00	$6,000
Hydrogen Peroxide	LBS	16,000	$0.50	$8,000
Monitoring			LS	$30,000
Insurance, Taxes, & Licenses @ 5%				$22,000
SUBTOTAL ANNUAL O&M COST				$137,000
CONTINGENCY @ 25%				$34,000
TOTAL ANNUAL O&M				$170,000
PRESENT WORTH O&M (1)				$1,600,000

NOTES: (1) Present worth cost based on 30 year project life and 10% discount rate.

Columns may not add due to rounding.

TABLE D-7
KUMMER LANDFILL, MINNESOTA

SUMMARY OF COST COST ESTIMATES FOR HYDRAULIC CONTROL ALTERNATIVES
AND ONSITE TREATMENT ALTERNATIVES

CONTROL STRATEGIES	ALTERNATIVE I	ALTERNATIVE II	ALTERNATIVE III
HYDRAULIC CONTROL	NO ACTION	ACTIVE DOWNGRADIENT HYDRAULIC CONTROLS	ACTIVE DOWNGRADIENT HYDRAULIC CONTROLS
TREATMENT CONTROL	NO ACTION	LIME SOFTENING/AOP & GAC POLISHING	LIME SOFTENING/AOP & GAC POLISHING
DISCHARGE	NO ACTION	DISCHARGE TO SURFACE WATER	DISCHARGE TO INFILTRATION POND
TOTAL CAPITAL COSTS			
Groundwater Collection/Miscellaneous	$73,000	$300,000	$300,000
Groundwater Discharge System	$0	$200,000	$230,000
Inorganics Removal	$0	$400,000	$400,000
Organics Removal	$0	$440,000	$440,000
TOTAL ANNUAL O&M COSTS			
Groundwater Collection/Miscellaneous	$24,000	$43,000	$43,000
Groundwater Discharge	$0	$18,000	$29,000
Inorganics Removal	$0	$270,000	$270,000
Organics Removal	$0	$170,000	$170,000
PRESENT WORTH TOTAL O&M COSTS			
Groundwater Collection/Miscellaneous	$230,000	$410,000	$410,000
Groundwater Discharge	$0	$170,000	$300,000
Inorganics Removal	$0	$2,500,000	$2,500,000
Organics Removal	$0	$1,600,000	$1,600,000
TOTAL PROJECT COSTS			
Total Capital Cost	$73,000	$1,300,000	$1,400,000
Total Annual O&M Cost	$24,000	$500,000	$510,000
Present Worth Annual O&M	$230,000	$4,700,000	$4,800,000
TOTAL PROJECT COST	$300,000	$6,000,000	$6,200,000

NOTE: Columns may not add due to rounding.