WARZYN

Alternatives
Array Document
13076

Request For Applicable or Relevant And Appropriate Requirements (ARARs)
Wausau Water Supply NPL Site
Wausau, Wisconsin

Prepared for:

U.S. Environmental Protection Agency
Region V
Chicago, Illinois

Prepared by:

Warzyn Engineering Inc.
Madison, Wisconsin

July 1988

WARZYN

Engineers & Scientists
Environmental Services
Waste Management
Water Resources
Site Development
Special Structures
Geotechnical Analysis

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July 6, 1988
13076.96

Mr. Kevin Adler, RPM
Region V
U.S. EPA 5-HR-11
230 S. Dearborn Street
Chicago, IL 60604

Re: Phased Feasibility Study
Wausau Water Supply NPL Site

Dear Mr. Adler:

Enclosed are three copies of the Alternatives Array Document for the West Well Field ~~Phased Feasibility Study~~, Wausau Water Supply NPL Site. Please distribute the document for agency review and identification of applicable or relevant and appropriate requirements (ARARs) for this operable unit response. Considering the aggressive project schedule, an expeditious agency response would be most helpful. Copies of the document are being sent to the Wisconsin DNR.

Please call if you have questions.

Sincerely,

WARZYN ENGINEERING INC.

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Project Environmental Engineer

Dennis L. Iverson

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Request For Applicable or Relevant And Appropriate Requirements (ARARs) Wausau Water Supply NPL Site Wausau, Wisconsin

July 1988

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1.0 INTRODUCTION

1.1 Authorization

The Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA), has established a fund for the investigation and clean up associated with uncontrolled hazardous waste sites. CERCLA requires procedures be established to evaluate remedial activities, to determine the appropriate extent of the activities, and to ensure that remedial measures are cost effective. Such remedial measures must, to the extent practical, be in accordance with the National Oil and Hazardous Substances Pollution Contingency Plan (NCP).

The United States Environmental Protection Agency (U.S. EPA) has authority and responsibility for carrying out these provisions under CERCLA as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA). The provisions for enacting the requirements of CERCLA appear in the NCP (40 CFR 300) as Subpart F (40 CFR 300.61-300.71).

After discovery of a possible uncontrolled site, a preliminary determination is made as to whether the site presents or may present a threat to the public health or the environment. If additional action is determined to be warranted, the U.S. EPA places the site on the National Priorities List (NPL) of hazardous waste sites. For NPL sites, additional work is then undertaken to better define potential problems, to develop and evaluate possible solutions (remedies) and to select an action based on the study results. This process for selection of remedial measures consists of the following three major elements:

- Remedial Investigation (RI) - during the RI, data is collected to define site conditions, including the extent of releases from the site and the character of source materials. Data on releases are evaluated to assess the potential effects of releases on public health and the environment.
- Feasibility Study (FS) - In the FS, a number of potential remedial alternatives are developed, evaluated against a range of factors and compared against one another.
- Record of Decision (ROD) - The ROD documents the decision-making process used in selecting remedial measures to reduce or eliminate releases from the site and to reduce or eliminate waste sources.

Typically, an FS identifies solutions to address a full range of site problems. Exceptions can be made, however, in cases where a particular site problem requires an expedited response action, and the response is consistent with implementing the full site remedy. Section 300.68(c) of the NCP authorizes conducting response actions in operable units. An operable unit is a discrete part of the entire site response that decreases a release, threat of release or pathway of exposure. Because the expedited response action is necessarily consistent with the final site remedy, the study is often referred to as a Phased Feasibility Study (PFS).

The Wausau Water Supply NPL Site consists of the City of Wausau well fields located east and west of the Wisconsin River (see Figure 1). Contamination of the east and west well fields with volatile organic compounds (VOCs) was discovered in 1982. The City is currently making provisions for treating water from City Well CW6 for VOC removal, and plans to place the well back in service in Summer, 1988. Local hydrologic and hydrogeologic conditions are expected to change as a result of the well being placed back in service. Largely because of these changes, there is a need and an opportunity to begin a remedial response on the west side of the river. Therefore, a Phased Feasibility Study (PFS) was authorized to develop and evaluate alternatives for an operable unit response for the well field and contaminant source area located on the west side of the Wisconsin River.

This PFS is being conducted by Warzyn Engineering Inc. (Warzyn) of Madison, Wisconsin under an amended contract with the U.S. EPA to perform RI/FS activities for the Wausau Water Supply NPL Site. The study is being conducted to develop and evaluate alternatives for Phase I of remedial responses for the West Well Field area. The response actions described could be initiated prior to implementation of a full site remedy. These Phase I response actions would alleviate problems specifically associated with the West Well Field contamination and would be consistent with achieving a final site remedy.

CERCLA requires that remedial measures comply with Federal and more stringent State requirements. This document has been prepared to provide background information on the site and site problems, and to describe the development of remedial alternatives to familiarize agencies with the response actions under consideration. Concerned Federal and State agencies are requested to identify applicable or relevant and appropriate requirements (ARARs) for the operable unit and associated alternatives.

1.2 Report Organization

In this report, the site background and the nature and extent of the problem are discussed first. A qualitative assessment of risks associated with the West Well Field is presented, and objectives for the first phase remedial actions are identified. General responses actions to address problems associated with the West Well Field are presented. Remedial action technologies are then identified and screened. A limited number of alternatives are developed and described. Possible applicable or relevant and appropriate requirements are identified.

2.0 BACKGROUND INFORMATION

2.1 Site Location and Physiography

The City of Wausau is located along the Wisconsin River in north central Wisconsin in Marathon County. The City presently operates six groundwater production wells, which provide water for approximately 33,000 residents.

Five of the production wells are located on the north side of the City. Production Well CW8 is located adjacent to the Wausau Municipal Airport, on the south side of the City. The water from Production Well CW8 contains high iron concentrations and is used only during peak demand periods. Production Wells CW6, CW7 and CW9 are located west of the Wisconsin River and are collectively referred to as the West Well Field. The West Well Field is located in a predominantly residential area. However, Marathon Electric Inc., a manufacturing facility, currently occupies a large area south of the West Well Field. Production Wells CW3 and CW4 are located on the east side of the Wisconsin River and are referred to as the East Well Field. The East Well Field is located in a predominantly industrial section of the City. Area businesses include: Marathon Box Company, Marathon Press Company, Wausau Chemical Company, Wausau Energy Company and Wergin Construction Company. Refer to Figure 2 for the location of the northern municipal production wells and area businesses.

The six production wells are screened in an aquifer of glacial outwash and alluvial sand and gravel deposits adjacent to the Wisconsin River. This unconfined aquifer supplies nearly all potable, irrigation and industrial water to residents and industries located in Wausau and the surrounding areas. The aquifer formed when the ancestral Wisconsin River eroded a deep valley into the Precambrian aged igneous bedrock. The valley was widened by continental glaciation during the Pleistocene glacial epoch. When the glaciers retreated from north central Wisconsin, coarse outwash sand and gravel sediments were deposited within the valley. Continued erosion of the igneous bedrock upland areas resulted in the deposition of additional fluvial sediments. Within the study area (see Figure 2), the alluvial aquifer ranges from 0 to 160 feet thick, and has an irregular base and lateral boundaries.

2.2 Water Utility

2.2.1 Historical Summary of the Wausau Water Supply

The Wausau Water Works was established during the early 1880's for the purpose of providing a municipal water source for City residents. The Wausau Water Works was a predecessor company to the present City of Wausau Department of

Water and Sewerage. The utility was reportedly established in response to population expansion and increased fire hazard associated with low precipitation during the early 1880's (Kendy, 1986). The Wausau Water Works began supplying groundwater in 1885. The water was produced from a large diameter dug well located at the present site of the City filtration plant. This well was reportedly capable of supplying yields of 2100 gpm (Kendy, 1986).

In 1904 the water utility attempted to supplement the water supply by the addition of a surface water intake crib in the Wisconsin River. However, the usage of the surface water intake was reportedly short-lived due to problems with intake of silt and organic debris. The water utility installed two production wells shortly after 1910. Production Well CW1 was located in the vicinity of the City Water Filtration Plant. Production Well CW2 was reportedly located in the vicinity of the Wausau Chemical Company. Production Wells CW3 (former), CW4 (former) and CW5 were reportedly added to the supply system during the 1940's. The original Production Well CW3 was located immediately adjacent to its present location at the Wergin Construction Company property. Production Well CW4 was originally located near the intersection of Winton and Third Street. Production Well CW5 was installed near the intersection of West Street and 17th Ave, on the west side of the Wisconsin River. Available pumping history records do not indicate the use of Production Well CW5 for water supply.

The production well records indicate that Production Wells CW1 and CW2 were removed from service during the early 1950's, after installation of Production Wells CW6 and CW7 on the west side of the Wisconsin River. Following the shut down of Production Well CW1 and CW2, water demand was met by Production Wells CW3 (former) CW4 (former), CW6 and CW7. Production Well CW9 was added to the system in 1961 in order to meet increasing water demands. Production Wells CW3 and CW4 were replaced during the 1960's due to excessive wear of inferior materials used in well construction during World War II. The replacement well CW4 was relocated adjacent to the River at the City Filtration Plant. The City production system has remained relatively unchanged between 1966 and

1988, with respect to the installation of new water supply wells. However, Test Well CW10 was installed in early 1986, and was pump tested for more than a year but has not been used to augment the City water supply.

Groundwater production records have been kept by the Wausau Water Utility for approximately the past 40 years. The pumpage records indicate extreme seasonal fluctuations in the water demand over the 40 year period. The average water demand remained fairly constant at approximately 110 million gallons per month during the 1950's. Water demand increased throughout the 1960's and early 1970's. By the late 1970's, the average water demand had risen to approximately 140 million gallons per month. Water demand has increased slightly over the past 10 years and currently averages approximately 155 million gallons per month.

2.2.2 Water Supply System

The Wausau Water Utility provides potable water to the City of Wausau and some adjacent areas. There are currently six production wells and a test well available for use or potential use (see Table 1). The water treatment plant was originally designed for iron and manganese removal, disinfection and fluoridation. VOC removal capabilities for up to 3,500 gpm (4.9 MGD, design flow) are now provided by two packed tower VOC stripping towers located at the water treatment plant. The towers were placed in service in response to the VOC contamination problem under a U.S. EPA-sponsored technology demonstration program (Hand, et al., 1986). The total plant design flow is not known at this time, but there are four 3 MGD gravity sand filters, which would provide 9 MGD plant flow with one unit out of service. The plant has historically produced an average of approximately 5 MGD of potable water (Syftestad, 1985).

Both Production Wells CW3 and CW4 can be pumped to either stripper. Production Wells CW6, CW7 and CW9 can be pumped to a common pipe that crosses the river and conveys water from those wells to the treatment plant. Under the existing system, no VOC removal is possible for Production Well CW6 water; it can only be blended with water from Production Wells CW7 and CW9. Blending is unacceptable, because it is not possible to dilute water from Production

Well CW6 with water from uncontaminated wells to meet drinking water standards; further, the capacity of the water main crossing the river is limited. The City is currently using Production Well CW6 as a barrier well to stop the migration of contaminants toward Production Wells CW7 and CW9. The untreated purge water from Well CW6 is discharged to a storm sewer, which discharges into Bos Creek near the intersection with Burns Street.

The Water Utility currently uses Production Well CW4 as infrequently as possible. When Production Well CW4 is brought into service, the following problems are reported:

- Increased chlorine demand;
- Increased trihalomethane (THM) formation; and
- Decreased treatment efficiency in terms of iron and manganese removal.

Because of these problems, the City has indicated a desire to reduce their reliance on Production Well CW4 as a supply well, perhaps removing it from service altogether. This would make available adequate VOC removal capacity for Production Well CW6 water. The water from Production Well CW6 would need to be conveyed to the strippers without blending with water from Production Wells CW7 and CW9, because of the hydraulic limitations of the stripping towers. A new river crossing pipeline is being installed for this purpose. The pipeline would then be used to convey VOC-contaminated water to the two strippers. Production Well CW4 may ultimately be taken out of service, and a new Production Well CW10 would be constructed to replace the supply capacity lost due to abandonment of Well CW4. Water from Production Well CW10 would be pumped into the existing river crossing pipeline. Production Wells CW3, CW7, CW8 and CW9 would remain in service, using existing supply lines.

2.2.3 Distribution System Monitoring

VOC concentrations in the influent and effluent of the strippers were monitored during the period after startup for purposes of technology evaluation by Michigan Technological University. Recently the utility has collected stripping tower influent and effluent samples to monitor VOC removal efficiency, partly as a result of recent concern over possible VOC concentration increases at Production Well CW3. The water utility uses a five-week monitoring cycle for treated water sampling and analysis for tetrachloroethene, tricholorethene, dichloroethene and vinyl chloride. Four sampling locations are used: three in the distribution system and one at the water plant. The monitoring schedule being used in November 1987 was as follows:

Week	Day	Location
1	Friday	Plant effluent
2	Wednesday	Green Bay Packaging
3	Monday	Airport
4	Thursday	Plant effluent
5	Tuesday	Holiday Inn

2.3 Hydrogeology

The City production wells are located within glacial outwash and alluvial sediments adjacent to the Wisconsin River. The aquifer is located within a bedrock valley which is underlain and laterally bounded by relatively impermeable igneous bedrock. The shape of the aquifer and its water yielding properties are strongly controlled by pre-glacial topography on the bedrock surface. In general, the maximum groundwater yields are obtained from areas where the aquifer width has been extended by outwash filled tributary valleys merging with the main valley (i.e., the West Well Field). However, sizeable production well yields are also obtained from municipal wells located closer to the Wisconsin River. These wells induce recharge of surface water into the aquifer, resulting in higher aquifer yields. The groundwater flow in the vicinity of the City well fields is strongly influenced by the following factors:

- Production well pumpage rate and duration;
- Bedrock topography;
- Soil heterogeneities;
- Fluctuations of river and stream elevations;
- Hydraulic resistance of stream and river beds; and
- Rate and distribution of rainfall percolation recharging the aquifer.

A detailed description of the role that each of these factors plays in groundwater flow and contaminant migration is beyond the scope of this document.

Groundwater flow within the unconfined glacial aquifer has been drastically changed by the installation of City production wells. Under non-pumping conditions, groundwater flows toward the Wisconsin River and its tributaries (Bos Creek). Groundwater naturally discharges at the surface water bodies, however, under pumpage conditions, the groundwater flows toward the production wells. The natural groundwater flow directions are frequently reversed and induced recharge of surface water into the aquifer is common. If production well pumpage is sustained at a sufficient rate, the zone of influence may extend beneath the Wisconsin River and influence flow from the opposite side.

The horizontal flow in the vicinity of the well field is indicated by the potentiometric contours shown in Figure 3. The potentiometric map indicates pronounced cones of depression around the five active City production wells. The combined cone of depression of the West Well Field extends asymmetrically away from the pumping wells. Based on water levels recorded during January 1988, the southern extent of the cone of depression at the water table appears to be limited by Bos Creek, which acts as a recharge boundary. The effectiveness of this recharge boundary is evident in potentiometric Cross Section BB' (see Figure 4). The potentiometric section shows the divide extends through the fine coarse sand and into the underlying fine sand. This section indicates there may be continuity of flow from south of Bos Creek to Production Well CW6 within the basal gravel deposit. The recharge boundary effect at Bos Creek may be more pronounced since early 1986, when Well CW6 began regularly discharging to the creek, substantially increasing the flow. Prior to 1986, the groundwater divide may have been located further south of its present location due to higher pumpage at Production Well CW6 and lack of discharge into Bos Creek.

The potentiometric surface map also indicates that the cone of depression from the East Well Field appears to affect groundwater flow below and to the west of the Wisconsin River. This is shown by the continuity in gradient from the west to the east side monitoring wells. The effect of the East Well Field production well pumpage is shown by potentiometric Cross Section AA' (see Figure 5). The potentiometric contours on Section AA' indicate a relatively strong component of vertical flow (recharge) adjacent to the bedrock valley slopes, especially on the west end of Section AA'. This recharge may be the result of inflow of groundwater from bedrock fractures, but more likely is caused by infiltration of surface water runoff from the bedrock uplands. The potentiometric contours become increasingly vertical toward the east, indicating a higher component of horizontal groundwater flow. Monitoring Well Nests located at Marathon Electric, indicate very slight downward gradients adjacent to the Wisconsin River. Below the Wisconsin River, the East Well Field production well pumpage has induced surface water recharge of the aquifer, causing flow downward through the river bed and toward Production Well CW3. Deep groundwater flow remains predominantly eastward (horizontal) as indicated by the almost vertical equipotential lines. Potentiometric contours of the aquifer below the East Well Field indicate groundwater flow converging at Production Well CW3. Groundwater flowing at the base of the aquifer flows upward into the pumping well and shallow groundwater flows downward to reach the screened section of the production well.

Aquifer hydraulic conductivity tests performed during the Phase I investigation indicate hydraulic conductivity values ranging from 1.7 x 10^{-4} cm/sec at Monitoring Well C4D to 8.1 x 10^{-2} cm/sec at Monitoring Well E22. The overall average hydraulic conductivity of the outwash aquifer is approximately 2.2 x 10^{-2} cm/sec. In general, the bedrock valley underlying the present Wisconsin River tends to widen toward the south. This bedrock valley widening may have resulted in decreased flow velocities during deposition, resulting in finer sediments being deposited in the southern portion of the well field and coarser sediments being deposited in the northern portion of the well field. This depositional scheme may result in reduced hydraulic conductivity toward the south. However, hydraulic conductivity tests results do not confirm such a relationship.

3.0 NATURE AND EXTENT OF THE PROBLEM

3.1 Groundwater Quality

Groundwater quality sampling conducted during the Phase I investigation has identified a vertical and lateral distribution of Total Chlorinated Ethenes which suggest that a minimum of three sources are affecting the City Well fields. The estimated areal distribution of Total Chlorinated Ethenes is shown on Figure 6. The distribution is based on a combination of data obtained from contract laboratory VOC analyses of Round 1 groundwater samples (October 1987) and field GC analyses of groundwater samples collected during drilling (October and November 1987).

Monitoring Wells W52, W54, W55, C4D, R2D and R4D appear to delineate a deep (greater than 100 foot) north-south trending TCE plume. Based on the vertical distribution of TCE throughout the aquifer in the vicinity of Monitoring Wells W53 and W54 and the presence of TCE in unsaturated zone soils at Boring W54, a source appears to be located within the northern portion of the former City of Wausau Landfill. The plume appears to have migrated northward, under the influence of pumpage from city production Well CW6. The highest TCE concentration (4200 ug/L) within this plume was detected at Monitoring Well W55, which is located approximately 550 feet south of Production Well CW6. The magnitude of the TCE concentrations detected at Well W55 and the distance from the suspected source area suggest that the contaminant release rate was previously much greater. TCE concentrations in the vicinity of the suspected source are currently generally less than 3000 ug/L.

TCE concentrations within the deep aquifer plume appear to abruptly decrease in the vicinity of Bos Creek as indicated by the relatively low concentrations at R3D. Refer to isoconcentration profile BB', presented in Figure 7. TCE concentrations at Monitoring Wells R2D and W52, indicate substantial decreases. TCE levels at Monitoring Well R2D have decreased from 1020 ug/L in October 1986, to approximately 400 ug/L in December 1986. The TCE concentrations at Monitoring Well W52 decreased from approximately 650 ug/L to 180 ug/L over a similar time period. The decreasing concentrations in this area appear to be a relatively recent phenomenon resulting from the development of a recharge boundary in the vicinity of Bos Creek. The recharge boundary appears to have become more pronounced as a result of Production Well CW6 pumpage rate being decreased with the well discharge pumped to waste into Bos Creek creating additional head within the creek. Production Well CW6 has been pumped to waste since February 1986.

TCE was observed in the shallow aquifer at Monitoring Wells R3S, R2S, W55A, W56A and MW4B. This plume is shown on Figure 6 by the lightly screened contours between Bos Creek and Production Well CW6. The shallow aquifer TCE contamination appears to result from the induced infiltration of surface water from Bos Creek, which has been contaminated by the discharge of Production Well CW6. The induced surface water recharge of the aquifer is evident from the downward vertical gradients at Monitoring Well Nests R2 and R3. The TCE levels within the creek have exhibited wide fluctuation. Based on contract lab analysis of samples collected during October 1987, TCE concentrations adjacent to the CW6 discharge were above 100 ug/L. TCE concentrations at the ponded area northwest of Randolph Street were approximately 70 ug/L. Surface water samples collected from the ponded area during December 1987 indicate TCE concentrations of approximately 36 ug/L. However, the lower TCE concentrations observed during the December 1987 sampling are probably the result of substantial dilution resulting from precipitation during the sampling period. TCE was not detected in surface water samples collected upstream of the CW6 discharge.

The distribution of TCE in Monitoring Wells E21, E27, E30, E31, W53, W54, C4D and Production Well CW3 suggests eastward migration of a deep TCE plume below the Wisconsin River from the vicinity of the former City Landfill (refer to Figure 6). TCE appears to be vertically distributed throughout the aquifer in the vicinity of Monitoring Wells W53 and W54, indicating close proximity to the source area. Slight vertical downward gradients were observed in the area surrounding these wells. The highest concentrations of TCE were detected at a depth of approximately 115 feet (1105 feet MSL). After sinking deep into the aquifer, a portion of the plume appears to migrate eastward under the influence of pumpage from Production Well CW3 (refer to Figure 3). As previously stated, a part of the plume has also been captured by the pumpage from Production CW6 and appears to migrate northward under the influence of this well. Due to the strong induced recharge from the Wisconsin River, the eastern portion of the plume is forced to flow along the base of the aquifer where it is detected by Monitoring Wells E27, E21, E30, and E31. As the plume approaches Production Well CW3, the groundwater flow converges, causing the contaminated groundwater to ascend to the screened interval.

The resulting TCE concentrations in Production Wells CW3 an CW6 are significantly less than the highest observed TCE concentrations in the surrounding aquifer due to dilution across the screened interval. The TCE-contaminated portion of the aquifer appears to be less than 20 feet thick and is laterally restricted to a relatively narrow flow path into the well. Production Well CW6 produces water nearly equally from all sides of the 50 foot screened interval, resulting in a dilution factor that appears to range from 15 to 25.

Elevated concentrations of volatile halogenated hydrocarbons (VHH), predominantly tetrachloroethene (PCE), have also been identified within the shallow aquifer in the vicinity of the East Well Field (CW3 and CW4). However, this impact appears to be the result of a separate VHH source and therefore is not addressed under the current operable unit FS.

3.2 Source Conditions

The predominant source of TCE contamination to Production Wells CW6 and CW3 appears to be the Marathon Electric/Former City Landfill area. Elevated concentrations of TCE were detected in groundwater, soil and soil gas samples obtained from the northern portion of the landfill. Soil gas concentrations within the landfill range from below minimum detection limits (1.0 ug/L) to approximately 82 ug/L. Soil samples obtained from Boring W54 indicate TCE concentrations of approximately 200 ug/kg. Groundwater samples obtained from the water table in the vicinity of the landfill (300 feet) indicate TCE concentrations ranging from 16 ug/L at C7S (December 1987) to approximately

1900 ug/L at C2S (December 1987). Also detected in the vicinity of the landfill were 1,1,1-trichloroethane (TCA), 1,2-dichloroethene (1,2-DCE), chloroform and carbon tetrachloride at concentrations generally below 100 ug/L. Potential sources within the landfill will be investigated in greater detail during the Phase II RI.

The former City Landfill occupies a sand and gravel pit located on the west bank of the Wisconsin River. The landfill covered approximately 4.5 acres, underlying the southeastern portion of Marathon Electric property. The landfill operated from approximately 1948 to 1955 and was reportedly the only landfill operating within the City at that time. During its period of operation, almost all commercial, industrial and residential waste generated within the City was disposed at the site. Prior to landfilling, the waste was generally burned in order to reduce volume. Ash and cinders are reportedly disposed throughout the landfill. Former landfill employees indicated that waste burning often could not keep pace with the amount of waste received in a day. In such instances, waste was generally filled directly into the western part of the former sand and gravel pit at the landfill site. The former employees also indicated that bulk liquids contained in 55-gallon drums were frequently emptied directly into the landfill.

The majority of the landfill site is presently covered by a bituminous pavement for a parking lot. However, the southern portion of the site is grass covered. An electric utility substation also covers the south central portion of the landfill. The Marathon Electric Company reportedly encountered drummed waste materials during foundation excavations beneath the east side of the plant foundry.

3.3 Water Supply Contamination

In early 1982, the City discovered that Production Wells CW3, CW4 and CW6 were contaminated by two-carbon volatile halogenated hydrocarbon compounds (VHH). Toluene, ethylbenzene and xylenes were also detected at Production Well CW4 (Hand, et al., 1986). Trihalomethanes (THMs) were detected in the distribution system, but were attributed to chlorination in the water treatment process. TCE is the predominant volatile organic compound detected at Production Well CW6, although below method detection limit (BMDL) concentrations of PCE and DCE have also been previously reported (Weston, 1975). Since the contamination was first detected in early 1982, TCE concentrations from Production Well CW6 have ranged from 70 ug/L to 260 ug/L. The most recent sampling (March 1988) indicates TCE concentrations of approximately 160 ug/L. Sample results from the East Well Field (Production Wells CW3 and CW4) have indicated considerable PCE, TCE and DCE impact at both wells. Production Well CW4 has generally indicated steadily decreasing concentrations of the three constituents since February 1984. Production Well CW3 has indicated decreasing PCE and DCE concentration since the problem was discovered in early 1982. However, TCE concentrations at Production Well CW3 have remained relatively constant at concentrations ranging between 80 ug/L and 210 ug/L.

To reduce VHH concentrations, the City originally instituted a program where uncontaminated water from Production Wells CW9 and CW7 was blended with water from Production Wells CW3, CW4 and CW6 to dilute the VHH concentrations.

In 1983, the U.S. EPA awarded the City of Wausau a Federal grant to help fund the design and installation of a packed tower VOC stripper in order to provide sufficient water of acceptable quality to City residents. As an interim measure in May 1984, the U.S. EPA installed a granular activated carbon (GAC) treatment system on Production Well CW6. VOC stripping towers were installed in the Summer and Fall of 1984 at the City water treatment plant to treat water from CW3 and CW4. Subsequently, the GAC system was removed from service in October 1984. The City has been blending treated water with well water from uncontaminated supply sources (Production Wells CW7 and CW9) to reduce VHH concentrations in the water supply distribution system.

Data indicate that prior to treatment (pre-July 1984), the water supply consistently contained TCE with concentrations ranging from detectable levels (> 1 ug/L) to 80 ug/L. Lower levels of PCE and DCE were identified shortly after discovery of the contamination, probably before blending had reduced the levels of VHHs.

Following installation of the packed tower VOC strippers, the water supply distribution system has had relatively low levels of VHHs (generally below detection limits of 0.5 to 1.0 ug/L). These levels are dependent on continued effective operation of the treatment system for Production Wells CW3 and CW4, the influent VHH concentration for each well, and continued use of the two uncontaminated wells (Production Wells CW7 and CW9).

As indicated in Section 2.2.2, the City intends to bring Production Well CW6 back on line as a supply well. This involves conveying water from Production Well CW6 across the Wisconsin River via a dedicated pipeline to the water treatment plant. Bringing this well back on line will cause a change in source water quality relative to current conditions, because water produced by Production Well CW6 is contaminated with TCE. Because of this change, and because uncertainties exist regarding possible increases in contaminant concentrations, an analysis of VOC stripping tower performance was completed to determine whether the existing towers would be capable of reducing VOC concentrations to acceptable levels under a range of water flow rate and raw water TCE concentration assumptions. The analysis is described in Appendix A. Under the new conditions, the two stripping towers could potentially be used to treat water from three wells. Various combinations of wells and pumping rates could potentially be used. The following flow rates were used in the analysis and are considered to represent a reasonable range of operating conditions for the two towers:

Water Flow	8 ft. tower	600 to 2100 gpm
	9 ft. tower	900 to 2400 gpm
Air Flow	8 ft. tower	6000 to 12000 cfm
	9 ft. tower	8000 to 16000 cfm

Results of the analysis for TCE and PCE (the major contaminants at Wells CW3, CW4 and CW6) are presented in Table 2. Predicted contaminant removal efficiencies are given for each tower under various combinations of air and water flow rates. Also shown are the corresponding estimated maximum raw water contaminant concentrations that could be treated, while still meeting drinking water standards in the stripper effluent. The values for TCE were calculated using the federal maximum contaminant level (MCL) of 5 ug/L as the effluent goal. The values for PCE were calculated using 5 ug/L (reportedly under consideration as a Federal MCL) and 10 ug/L (currently used by the WDNR as an advisory level for PCE in public water supplies). The analysis indicates that drinking water standards can be met over a range of operating conditions using the existing stripping towers.

It should be recognized that water from the strippers is normally blended with water from uncontaminated Production Wells CW7 and CW9. Thus, the contaminant concentrations in the distribution system have been lower than drinking water standards and generally less than analytical method detection limits of 0.5 ug/L or 1.0 ug/L, depending on the compound and laboratory conducting the analysis. Results of distribution system monitoring data submitted to the WDNR by the City are summarized in Table 3.

3.4 Preliminary Assessment of Current Health Risks

Determination of the health risk due to an environmental contaminant involves identification of contaminating substances, routes of contaminant migration and populations exposed to the contaminant. This information is integrated to determine total contaminant exposure levels for a given population, which, in turn, can be compared to toxicological information to arrive at an estimation of health risk.

3.4.1 Contaminant Identification

The predominant contaminant identified in City groundwater is TCE. PCE and DCE have also been detected but to a much lesser extent. The characteristics of the contamination with respect to the magnitude, extent, potential sources and mitigating practices are described in Section 3.3.

3.4.2 Exposure Pathways

The City water distribution system supplies potable water, derived exclusively from a groundwater source, to approximately 33,000 residents. Possible routes of VOC exposure to the residents through contaminated groundwater include ingestion via drinking and cooking, as well as inhalation and dermal exposure while bathing. During the period of 1982 through mid 1984, prior to pumping Production Well CW6 to waste and the installation of the VOC strippers, levels of TCE sampled at various points throughout the water distribution system ranged from approximately 10 to 100 ug/L. PCE and DCE were periodically detected, but usually below minimum detectable limits (Weston, 1985). Recently, the City has been monitoring levels of TCE, PCE and DCE weekly at selected points in the distribution system (Table 3). Results of these analyses show undetectable levels of these VOCs (TCE detection limit, 0.5 ug/L). Thus, exposure to these compounds via the groundwater is below measurable limits under the existing water distribution practices.

As described above, contaminated water from Production Well CW6 is currently being discharged into Bos Creek, which is located in a primarily residential area. Field GC analysis of VOCs from Bos Creek surface water sampled in October, 1987 showed TCE concentrations ranging from 160 ug/L at Production Well CW6 discharge to 108 ug/L at a ponded area located several hundred yards downstream from the discharge. A population theoretically at risk of exposure would be residents in the immediately vicinity of the creek via inhalation of volatile ethylenes. This exposure pathway is not thought to pose an appreciable risk, because the concentration of TCE in Bos Creek is low and volatilized TCE would be expected to be diluted to insignificant levels a short distance from the creek. An additional population potentially at risk may be children who swim or play in the creek. These individuals would be exposed to VOCs via inhalation of vapors, as well as through dermal absorption of contaminants from the surface water. Information about the magnitude of this group is not known and the frequency of exposure via this pathway would be expected to be low and intermittent. Thus, this exposure scenario is not considered to be of an appreciable importance in the assessment of health risk.

A third potential exposure point may be the City landfill area. Currently, the landfill is covered with asphalt and serves as a parking lot for the Marathon Electric Company. Soil gas analyses conducted in October and December 1987 have identified a potential source of contamination located near the boundary of the former landfill, approximately 100 ft from a Marathon Electric assembly building and shipping area. TCE was the major contaminant identified, with other VOCs, including PCE, DCE, toluene, benzene and 1,1,1-trichloroethane present, generally below method detection limits. The asphalt parking lot surface serves as a physical barrier, minimizing the potential for volatilization and release of TCE into the air. Therefore, volatilization with subsequent inhalation of TCE by those present in the area (Marathon Electric employees) is currently thought to be present a significant exposure pathway. Excavation at this site, which may involve removal of a concentrated VOC source may be a potentially important point of exposure for excavation crews and Marathon Electric employees via inhalation of volatiles.

3.4.3 Toxicology

Among the VOCs detected, TCE occurs most frequently and at the highest concentrations. For this reason, its toxic effects are summarized:

Acute Exposure Effects -- Short-term inhalation of TCE at concentrations commonly found in the workplace can result in depression of the central nervous system and is characterized by headache, fatigue and dulling of the senses, as well as nausea, vomiting and burning eyes. TCE is also a mild skin irritant and sensitizer; it can cause rash and blistering, if present on the skin for a substantial length of time.

Subchronic Exposure Effects -- Effects in workers exposed to TCE vapors for 1-5 years included headache, dizziness, sleepiness, nausea, vomiting and conjunctivitis. TCE exposure has not been linked with increased mortality in humans.

Cancer Potential -- A significant excess of cancer of the urogenital tract was observed in a cohort of Swedish workers. An increase in hematolyophatic malignancies also was detected. There is evidence that TCE causes liver cancer in some strains of mice, induces adenoma of the lung in mice, and causes renal tubule cancer in rats.

Other -- TCE readily crosses the placental barrier in humans and has been found in fetal blood in women given TCE as an anesthetic. Prenatally-exposed rats showed delayed ossification of the sternum, indicating environmental impairment. Postnatal weight gain was also reduced. No major malformations, embryotoxicity or maternal toxicity were reported. In studies with yeast, the authors concluded that TCE induced both mutations and base substitutions in the DNA.

3.4.4 Risk Evaluation

Based on undetectable levels of VOC present in the treated water within the City water distribution system, the immediate risk to health associated with VOC contamination appears negligible under current water usage practices. The U.S. EPA has set a Maximum Contaminant Level (MCL) of 5 ug TCE/L of drinking water. MCLs are enforceable standards promulgated under the Safe Drinking Water Act which indicate the level of a given contaminant not expected to cause adverse health effects over a lifetime exposure. Because TCE is carcinogenic and is not considered to be without hazard below a given threshold, the U.S. EPA has set a non-enforceable Maximum Contaminant Level Goal of zero for TCE in drinking water. Because it is not possible to measure accurately levels of TCE below the minimum detectable limit, a future health hazard may exist to individuals consuming water over a prolonged period of time in which TCE is present, but below detectable limits.

3.5 Need for Expedited Remedial Action

The major issues concerning the West Well Field can be summarized as follows:

- Contaminants are being drawn toward the West Well Field from an apparent source area located to the south on or near Marathon Electric Co. property.
- Trichloroethene (TCE) is the major contaminant observed in the West Well Field contaminant plume.
- Production Well CW6 is currently being pumped to waste, with a discharge to Bos Creek.
- Production Well CW6 acts as an interceptor well, capturing contaminants that would migrate further north to clean wells CW7 and CW9, if CW6 was not being pumped.

- The discharge of Production Well CW6 to Bos Creek has resulted in a groundwater mound between the source area and CW6. The influence of the groundwater mound may not fully penetrate the glacial outwash aquifer, but recent data suggest the mound may have served to effectively divide the West Well Field contaminant plume into northern and southern portions, indicating that contaminant migration from the source area may have been slowed. However, discharging untreated water from Production Well CW6 into Bos Creek has apparently caused induced recharge of contaminated surface water from Bos Creek to the upper portions of the aquifer, resulting in a northward-moving, shallow, low-concentration TCE plume.

- The City plans to place Production Well CW6 back in service during early summer of 1988. Therefore, the pumping rate of CW6 will probably be increased substantially, and the discharge to Bos Creek will be discontinued. These two factors will both tend to increase the rate of migration from the source area toward CW6. The probable source of the shallow aquifer contaminants will be removed, however.

- Water from Production Well CW6 will be treated for VOC removal using one of the existing stripping towers at the water utility. Based on stripping tower operating experience, water meeting drinking water standards for TCE can be produced using CW6 as a source well.

- If no further action is taken, Production Well CW6 will continue to serve as an interceptor well, providing the sole protection for the remaining wells in the West Well Field. Contaminant migration from the apparent source area would likely resume, and TCE concentrations at CW6 may not decline as rapidly as would be anticipated, if additional controls were implemented.

Ultimately, the solution to protecting the West Well Field will involve additional controls to prevent contaminants from migrating to the north. An opportunity exists now to take advantage of apparently slowed contaminant migration to the north away from the source area. By taking action soon to provide additional protection of the West Well Field, it may be possible to prevent or limit the extent of renewed contaminant movement to the north. If this can be accomplished, then it should be possible to limit the time during which Production CW6 draws in contaminants, thereby also limiting the period during which water consumers are exposed to trace levels of contaminants.

An expedited action is desirable from a public health stand point. Taking action as soon as possible will shorten the time required to achieve long-term protection of the water supply. Expedited remedial action in this operable unit is therefore considered to be consistent with achieving a final site remedy.

4.0 DEVELOPMENT OF REMEDIAL ACTION ALTERNATIVES

4.1 Remedial Action Objectives

Considering the long term goals of protecting public health and the environment, and the site-specific goals of protecting the West Well Field, a number of specific remedial action objectives were developed for this operable unit response. The major objectives are:

- Reduce the period during which water consumers are exposed to trace concentrations of TCE by reducing or minimizing the mass of contaminants allowed to migrate to Production Well CW6.
- Provide back-up controls for clean west side wells, to protect the well field if Production Well CW6 had to be removed from service for an extended period.
- Provide continued cleanup of the aquifer north of Bos Creek.
- Remove as much VOC mass as possible while meeting other response objectives.
- Develop remedial actions which are consistent with a final site remedy.

If these objectives can be met, it would be desirable to attain additional objectives. These secondary objectives are:

- Limit the potential for an increase in contaminant concentrations at Production Well CW6.
- Avoid adverse hydraulic effects on Production Well CW6.
- Reduce or minimize potential contaminant migration from the apparent West Well Field source area to the east toward Production Well CW3.
- Obtain information that may be used in evaluation, design or implementation of additional remedial measures for the full site remedy.

4.2 General Constraints on the Development of Alternatives

Alternatives must be formulated to address the specific circumstances of the West Well Field and the operable unit response objectives. Considering physical site conditions and public health, environmental and administrative needs, constraints that affect configuration of the operable unit alternatives have been identified. The major constraints are:

- Operable unit remedies should employ technologies that enable rapid implementation of response actions.
- Treatment for the removal or destruction of contaminants must be considered. Response actions must primarily address problems associated with the West Well Field source areas.
- Removal or treatment of the West Well Field source(s) is not considered viable for the operable unit response, because the source(s) has not been adequately characterized, the existence and/or extent of continued contaminant releases is not known, and source control actions would not achieve the response objectives within the desired time.
- Disruption of the City Water Utility's operation should be avoided or minimized.

4.3 General Response Actions

It is apparent that controlling contaminant migration using groundwater controls will most effectively and expeditiously accomplish the response objectives. Because most groundwater controls involve groundwater extraction, environmentally acceptable methods of treating and discharging contaminated water and other processes residuals must also be considered. In-situ treatment methods were considered as alternatives to conventional above-ground water treatment.

General response actions and associated technology groups identified for consideration are:

Response Actions	Technology Group
Groundwater Controls	Barriers Injection Extraction Extraction/Injection
Groundwater Treatment (above-ground and in-situ)	Physical Chemical Biological
Discharge	Groundwater Surface Water

4.4 Identification and Screening of Technologies

In the following sections, specific technologies corresponding to the general response actions and technology groups presented in Section 4.3 are identified and discussed. A decision is made whether to retain a given technology for use in developing alternatives or to eliminate it from further consideration. The purpose of the screening is to select a limited number of promising technologies for consideration in developing alternative remedial actions.

The general criteria used in screening technologies are effectiveness, implementability and cost. Effectiveness is evaluated considering end results; i.e., whether the technology can be used to attain a desired cleanup or other effects within the desired time frame. Implementability is evaluated considering a range of factors relevant to obtaining, installing and using particular technologies. Some remedial technologies are proven and readily available, while others are in research and development stages. Insufficiently developed technologies are generally screened out. Site conditions must be compatible with the feasible range of a given technologies capability, considering, for example, aquifer characteristics, depth to bedrock, depth to groundwater, space requirements, contaminant types and concentrations. In this case, the existence of commercial and residential development in the area of concern favors the use of technologies whose construction and operation is relatively non-disruptive. Certain institutional issues may also be addressed, as appropriate. For example, technologies requiring extended testing, review, approval or permitting processes would not be appropriate where an expedited response is required. Once the technologies have been screened for basic application at the site, relative cost may be used for further screening. Both capital and annual operation and maintenance (O&M) costs are considered, as appropriate.

4.4.1 Groundwater Controls

Groundwater control methods fall into two categories: physical barriers and hydraulic gradient control. Physical barriers can be effective in controlling the movement of groundwater and its associated contaminants by placement of low permeability barriers to reduce flow from one area to another. Hydraulic gradient control is used to modify local groundwater flow patterns. This is accomplished using water injection, groundwater extraction, or a combination of the two. The screening of groundwater control technologies is summarized in Table 4.

Barriers

Physical barriers could be effective in preventing contaminant migration. However, implementability limitations are sufficient to eliminate them from further consideration. A major limitation to using barriers as part of the first phase response is that the source area has not yet been adequately characterized. A partial barrier could potentially be placed to limit the migration of contaminants to the West Well Field. This would involve constructing a barrier north of the apparent source area. Under a containment scenario for the final remedy, a full barrier around the source may be required, to prevent contaminant migration in other directions. It may not be feasible to construct such a barrier, because of the buildings located near the apparent source area. The feasibility of a full barrier cannot be determined until the source area extent is better known. A partial barrier may be effective in the short term, but it cannot be determined at this time whether this action would be consistent with the final remedy. Individual barrier technologies are discussed below.

Slurry wall barriers are constructed by excavating a trench to the desired depth and backfilling with impermeable material. Backfill materials are typically either clay/sand soil mixes or cement. During construction, trench sidewall collapse is prevented by filling the trench with a dense bentonite slurry. The slurry exerts a pressure against the sidewalls, preventing collapse until the backfill is placed. In this application, dragline or clamshell bucket excavating equipment would be required for trenching at depths up to approximately 200 ft. This deep excavation would be required, because contaminants are apparently migrating at depth near the bedrock. The wall would therefore have to be keyed into bedrock. A wall would be placed from the Wisconsin River along Bos Creek, extending either north along Randolph St. or northeast along Bos Creek. Adequate space for large equipment, slurry preparation, trench spoils staging and backfill preparation is not considered to be available in this developed area. Slurry walls are eliminated from consideration for the phased FS.

Other barrier construction methods are available. Interlocking steel sheet piles could be driven to bedrock, requiring less area for staging during construction, compared to that for a slurry trench wall. This would be a noisy operation, and this type of wall would be relatively less effective than slurry trench walls due to leakage at gaps between steel sheet piles. There is anticipated little cost advantage of a steel sheet pile wall over a slurry wall. This technology is screened out, based on noise considerations and relatively limited effectiveness.

A grout wall is typically constructed by injecting grout under pressure into closely-spaced boreholes. The grout moves into the porous formation and forms a low permeability barrier after setting up. This technology has not been well demonstrated, is relatively costly, and is therefore screened out.

A synthetic membrane wall can be constructed by sliding sheets of synthetic material into a slurry trench. The barrier can be effective, but for a deep application like the one contemplated for this site, installing the membrane would be difficult. This technology is therefore screened out.

<u>Injection</u>
Water could be injected into the aquifer using wells, trenches or seepage basins. Seepage basins would require too large an area for this site. Trenches may not have a hydraulic influence that fully penetrates the aquifer. Injection wells would be the most promising technology for this action. Three potential sources of water for injection are:

City Water - Injection would be a waste of an already limited supply of potable water.

River Water - Pretreatment would be necessary, and THM production at the water plant would likely increase.

Groundwater - Direct use of clean groundwater as a potable water source would be more efficient.

Injection alone is not considered viable, because no adequate source of injection water is available, and injection wells are generally not allowed by the WDNR.

Extraction

Groundwater extraction is the most promising method of controlling groundwater movement, while removing contaminants. Wells and trenches are most commonly used to collect groundwater. In this application, wells would be favored over trenches, because they are relatively more effective and flexible in obtaining desired water table depression, and can more reliably effect a hydraulic influence deep in the aquifer. Extraction wells are retained for consideration in developing alternatives.

Extraction/Injection

A combination of groundwater extraction and injection would be used to control local hydraulic gradients. The vertical influence of trenches may be limited. Wells are favored over trenches in this application for reasons similar to those discussed for groundwater extraction. Extraction and reinjection are judged to be technically feasible, but a surface water discharge would be less costly. Based on preliminary groundwater flow modeling, the desired gradient control can be accomplished with pumping wells, with no reinjection of water. Injection wells are not allowed by the WDNR, and it is doubtful that a waiver from this requirement would be granted when there are other viable options. Considering effectiveness, costs and State requirements, extraction/reinjection is screened out in favor of extraction with surface water discharge.

4.4.2 Groundwater Treatment

Groundwater treatment may be used prior to discharge to a surface water body. Preliminary indications are that treatment would likely not be required from a discharge permitting standpoint. However, Bos Creek remains as a viable discharge option. If untreated water were discharged to Bos Creek to create a groundwater mound between the source area and Production Well CW6, then shallow contaminants would migrate in the upper aquifer from the creek toward CW6 as is the case under current conditions. If treated water were discharged, the mound could be created while substantially reducing the potential for contaminant discharge to the upper aquifer. Treatment methods can be divided into three categories: physical, chemical, and biological.

Physical Methods

Conventional physical treatment methods such as screening, filtration or settling would not treat VOCs and are therefore screened out. Ion exchange is applicable only for removal of charged ions or complexes in solution, and is therefore inappropriate for removal of uncharged dissolved VOCs such as TCE. Potentially applicable physical treatment technologies include stripping, adsorption and reverse osmosis (hyperfiltration).

VOCs are conventionally stripped from water using air or steam in a packed column. Water is pumped to the top of a tower packed with a high surface area, high void volume inert material. Water trickles over the packing and is discharged at the bottom of the tower. The stripping gas is introduced at the bottom of the tower, flows upward through the packing void spaces and is discharged at the top of the tower. Volatile contaminants are transferred from the water to the stripping gas. For a solute as volatile and readily strippable as TCE at the concentrations anticipated ($<$ 1 mg/L), ambient temperature stripping with air is generally used. Air pollution controls may be required. The capabilities of this technology have been well demonstrated at the water utility and at numerous other sites, and the technology is therefore retained.

Activated carbon adsorption is also commonly used to remove VOCs, including TCE. Most frequently, granular activated carbon beds are used. Contaminated water flows through the carbon bed and contaminants are adsorbed to the carbon. The process is capable of reducing contaminants to less than detectable levels. When the capacity of the carbon is exhausted, the bed is taken out of service. The spent carbon is usually either regenerated, disposed in a landfill or incinerated. The choice of carbon handling methods depends largely on the contaminants, concentrations and economics of regeneration versus disposal or destruction. The effectiveness of this technology for TCE removal has been demonstrated at several sites, and the technology is retained.

Reverse osmosis (hyperfiltration) is potentially applicable for the removal of TCE. A semi-permeable membrane used to effect a separation of solvent (water in this case) and solute (TCE in this case). The pore size in the membrane is such that water passes through more readily than the contaminant. Contaminated water is pumped under high pressure to membrane-holding cartridges. Water with low contaminant levels passes through the membrane (permeate stream) and a concentrated aqueous TCE solution (concentrate stream) remains on the pressurized side of the membrane. A concentrated reject stream must therefore be managed. The relative proportions of permeate and concentrate depend on solute properties, membrane, properties, flow rates, operating pressures and the configuration and number of units used in the process. No reports of full scale use of membrane separation for TCE removal have been identified. Laboratory and pilot scale testing to determine feasibility and design parameters would likely cause a substantial delay in implementation. A rapid response is required for the operable unit, therefore it is inappropriate to retain this insufficiently demonstrated treatment technology.

<u>Chemical Methods</u>

Conventional chemical treatment methods such as coagulation or precipitation would not be effective in TCE removal. Chemical oxidation may be applicable, providing contaminant destruction. The most promising technology is oxidation using ozone and/or hydrogen peroxide.

In this process, ozone and hydrogen peroxide are contacted with contaminated water in a reactor. Ozone is fed to the reactor using fine bubble diffusers and hydrogen peroxide is fed as a concentrated liquid solution. Ozone decomposes in water to form hydroxyl radicals which react with chlorinated ethenes. The addition of hydrogen peroxide accelerates the process, because a hydrogen peroxide decomposition product (hydroperoxide ion) accelerates the decomposition of ozone (Glaze and Kang, 1988). Chemical doses and overall reaction rates must be determined experimentally for a particular water because of competing oxidation and free radical reactions. This technology is retained.

Biological Methods

Aerobic biological degradation does not appear to be applicable to TCE removal, because microbially-mediated TCE degradation has not been generally observed under aerobic conditions (e.g., Bouwer, et al., 1981), although conflicting results are reported (Wilson and Wilson, 1985). Microbially-mediated TCE degradation under anaerobic or anoxic conditions has been reported (Bouwer and McCarty, 1983; Kloepfer, et al., 1985; Vogel and McCarty, 1985). Based on information available, it does not appear that TCE can be used as the sole carbon and energy source, so an external carbon source and suitable nutrients would need to be added to maintain a biological population. Groundwater would be pumped to an anaerobic biological reactor for treatment. Laboratory and pilot scale studies would have to be conducted to determine TCE removal rates, biological growth kinetics and nutrient requirements. Conducting these studies with slow-growing anaerobes can be time-consuming, and would likely result in substantial delays in implementing an interim remedy. Although this technology holds some promise, it has not been demonstrated, even at the pilot scale. It is not considered to be adequately developed for use in the interim remedy, and is therefore eliminated from consideration.

4.4.4. In-Situ Treatment Methods

In-place treatment of contaminants is potentially viable for TCE contamination problems. As with above-ground processes, the technologies can be categorized as physical, chemical or biological methods.

Physical In-Situ Methods

The only viable in-situ treatment method is a vertical permeable treatment bed. In this system, a trench is excavated to a depth sufficient to enable capture of the contaminant plume, and is backfilled with an adsorbent material, such as granular activated carbon. Slurry trench construction methods would be used, and the implementation problems associated with deep trench construction in this area would apply to this technology. The trench width would be limited to perhaps three feet. In principle, groundwater would flow through the trench and contaminants would be removed by adsorption to the carbon. A major problem with this system is that there is no provision for replacing the adsorbent, and TCE would break through when the bed capacity is exhausted. This technology would ultimately only slow, not prevent, migration of TCE toward Production Well CW6. This technology is eliminated from further consideration because of its limited effectiveness.

Chemical In-Situ Methods

The most promising in-situ chemical method is oxidation. As discussed earlier, ozone and hydrogen peroxide can be used to chemically destroy TCE in water in a reactor vessel. In principle, these chemicals could be injected into the aquifer to effect TCE destruction. Because the desired reactions would take place in the porous medium of the aquifer instead of in a tank, many other competing reactions could be anticipated. The system would involve feeding chemicals in aqueous solution into water from groundwater extraction wells, and reinjecting the water into the aquifer. Materials of construction (pumps, piping, wells, etc.) must be resistant to the oxidants used. No reports of chemical oxidation of TCE in an aquifer have been identified, so this technology would require extensive testing. Obtaining approvals for injection into the aquifer would likely be time-consuming, at the very least. This technology is not considered appropriate for rapid implementation for this operable unit, and is therefore eliminated from consideration.

Biological In-Situ Methods

According to most available information, the biological degradation of TCE occurs anaerobically. Physically, the system would be similar to the extraction and injection system discussed above for in-situ chemical treatment. Nutrients, an organic substrate, and possibly a chemical reducing agent would be fed into the reinjection stream instead of chemical oxidants. The goal of this system would be to maintain suitable environmental conditions throughout the aquifer section of interest to support the growth of desired anaerobic and/or facultative bacteria responsible for TCE degradation. The major difficulties associated with this treatment is that neither the organisms responsible for TCE degradation nor optimum growth conditions have been identified. Therefore, the ability to maintain suitable conditions is difficult to assess. Again, obtaining approval for a system incorporating injection of chemicals into an aquifer near a public water source may be difficult. The technology is not considered to be adequately developed for implementation in the operable unit, and is therefore eliminated from consideration.

4.4.3 Discharge Options

Groundwater

As discussed above under injection and extraction/injection, a groundwater discharge is not considered feasible in this case.

Surface Water

Three options are available for discharge of groundwater to surface water:

1) Conventional pipeline and outfall,

2) Cascade discharge, and

3) Publically-owned treatment works (POTW).

A conventional discharge to surface water is appropriate for consideration and is retained. A cascade-type discharge would involve constructing a structure that would create turbulence in the water prior to discharge into the receiving stream. This would provide a partial removal of volatile organics, and may be desirable if some limited VOC removal is required. This option is retained. Discharge to the POTW would result in an increase in hydraulic loading on the order of 0.7-2 MGD. Volatilization would be the major fate of VOCs at the POTW, and substantial removal efficiencies would likely be obtained, even though the plant was not specifically designed for VOC removal. Preliminary indications are that groundwater treatment may not be required in this case, prior to a surface water discharge. POTW performance could be adversely affected due to increased hydraulic loading. There does not appear to be a substantial benefit in discharging to the POTW, because treatment may not be required. This discharge option is therefore screened out.

4.5 Technologies retained for Alternatives Development

Considering the site and contaminant characteristics, operable unit response objectives and identified constraints on the Phase I response, the following technologies were retained for use in developing alternatives.

Response Action	Technology
Groundwater Controls	Extraction Wells
Groundwater Treatment	Ambient Temperature Stripping Carbon Adsorption Oxidation
Discharge	Pipeline or Cascade Discharge to Surface Water

5.0 DEVELOPMENT OF ALTERNATIVES

A limited number of remediation alternatives were developed for the West Well Field operable unit responses. Both the range of viable responses and the number of technologies are limited, therefore a preliminary analysis and screening of alternatives was not considered useful. The No Action alternative is included to provide an assessment of the consequences of taking no response at this time. Each of the remaining alternatives includes groundwater pumping, optional groundwater treatment and a surface water discharge. The preliminary location of wells and range of flow rates discussed below were determined using the USGS modular groundwater flow model, referred to as MODFLOW (McDonald and Harbaugh, 1984). MODFLOW is being used to simulate the response of a two-dimensional aquifer to the conditions imposed. The model was developed to accommodate both areally and vertically variable parameters. The model can account for variable saturated thicknesses, uneven bedrock surfaces, and both seepage from and groundwater discharge to surface streams. Model selection, development and calibration is described in the Phase I RI Technical Memorandum (Warzyn, 1988).

5.1 Alternative 1: No Action

Under the No Action alternative, Production Well CW6 would be brought on line as a water supply well according to the City's plan. The discharge to Bos Creek would be halted. Production Well CW6 would be pumped nearly continuously at a rate of approximately 1600 gpm during the high-demand summer months, based on communications with water utility representatives. Contaminants would be drawn to the north under the influence of Production Well CW6 pumpage. Water from Production Well CW6 would be treated at the water utility for VOC removal using existing stripping towers. If Production Well CW6 ceased pumping, contaminants would be expected to migrate further north under the influence of Production Wells CW7 and CW9 pumpage. There would be no provision for protecting uncontaminated Production Wells CW7 and CW9 in the event of a Production Well CW6 failure that results in substantial down time.

5.2 Alternative 2: Extraction Well North of Bos Creek

Alternative 2 involves installation of a groundwater extraction well north of Bos Creek and south of Production Well CW6. Groundwater would be treated, if required, and discharged either to the Wisconsin River or to Bos Creek.

The extraction well would be located in the vicinity of Schofield Park near the intersection of Randolph and Burek Streets (See Figure 6). Placement of the well near the center of the contaminant plume would likely be the most effective location. The well would serve to remove contaminants from the northern portion of the TCE plume, and would draw in and intercept contaminants from the south. Based on information gathered to date, the plume is estimated to be approximately 500 feet wide and 20 feet thick in that area, and it appears to be within approximately 50 feet of the bedrock base of the aquifer. A deep well would therefore be used. A groundwater divide would be created between the extraction well and Production Well CW6. Preliminary groundwater flow model results indicate the divide would be located approximately 600 to 800 ft south of Production Well CW6 with an extraction well pumping rate of 500 gpm, and with Production Wells CW6, CW7 and CW9 pumping in the West Well field.

Extracted groundwater would be treated, if required, prior to discharge. Two factors will determine whether treatment is used: 1) discharge permit limitations, and 2) the potential for contaminant migration back into the aquifer. TCE concentrations in extracted groundwater are anticipated to be on the range of 200-500 ug/L. Based on initial regulatory agency contacts, it does not appear that treatment would be required prior to surface water discharge. There may be a benefit in discharging to Bos Creek, to maintain recharge to the aquifer from the creek. This may slow the movement of contaminants from the south to the north side of Bos Creek. Because a portion of the water discharged to the creek would be recharged to the aquifer, the water would be treated prior to discharge.

The most likely treatment method for VOC removal would be packed tower stripping. Compared to the other available technologies, it is relatively low cost, and has greater operational flexibility. Assuming a TCE concentration of 500 ug/L, 100% removal efficiency and a 500 gpm flow rate, tower off-gas VOC emissions would be approximately 3 lb/day. Based on current State regulations, the air discharge would not need to be permitted or controlled.

Two options were formulated for Alternative 2 as follows:

- Option A includes groundwater extraction and discharge to the Wisconsin River without treatment.
- Option B includes groundwater extraction, treatment for VOC removal and discharge to Bos Creek.

5.3 Alternative 3: Extraction Well South of Bos Creek

Under Alternative 3, a groundwater extraction well would be constructed south of Bos creek. Water would be treated, if required, and discharged to surface water.

The extraction well would be located near the center of the southern portion of the plume and north of the apparent TCE source area. A location near the southeast corner of the eastern most Marathon Electric Co. building near Monitoring Wells C2S and R4D would be suitable, based on available information (See Figure 6). The plume appears to be fairly wide in this area, and contamination has been observed throughout the 130 ft saturated thickness of the aquifer (See Figure 7). A deep well would likely be used. This well would remove contaminants from the southern portion of the plume, and could potentially draw some contaminants back to the south, away from Production Well CW6. Preliminary groundwater flow model results indicate the divide would be located roughly 800 to 1000 ft. south of Production Well CW6 for an extraction rate of 1000 gpm, with Production Wells CW6, CW7 and CW9 pumping in the West Well Field.

Considerations regarding groundwater treatment and discharge are similar to those discussed for Alternative 2. If similar TCE concentrations are obtained in extracted groundwater, then air emissions from a stripping tower would be 6 lb TCE/day. It does not appear that a permit or emission controls would be required for the air discharge.

Two options are incorporated into Alternative 3:

- Option A includes groundwater extraction using a well located south of Bos Creek, with discharge to the Wisconsin River without treatment.
- Option B includes groundwater extraction, treatment for VOC removal and discharge to Bos Creek.

5.4 Alternative 4: Extraction Wells located North and South of Bos Creek

Alternative 4 is essentially a combination of Alternatives 2 and 3. Two extraction wells would be used: one north and one south of Bos Creek. This system should result in the most rapid removal of contaminants from the aquifer.

Groundwater divides would be created between the new extraction wells and between the northern extraction well and Production Well CW6. Discharging extracted groundwater to Bos Creek would likely affect the location of the groundwater divides. Whether this would be detrimental or beneficial to the remedial action will be determined based on additional groundwater flow modeling. At this time, an option for groundwater treatment and discharge to Bos Creek is incorporated into Alternative 4.

Assuming the pumping rates and TCE concentrations for the two extraction wells to be similar to those discussed under Alternatives 2 and 3, untreated discharge water would contain approximately 200-500 ug TCE/L, and TCE emissions from a stripper off-gases would be 3.6 to 9 lb TCE/day. It does not appear that water treatment, an air discharge permit, or VOC emission controls would be required.

(TCE) Acute Toxic % work place guideline Pounded Limits for exemptions Air Toxic's Rule pending

The two options for Alternative 4 are as follows:

- Option A includes two groundwater extraction wells (one located north of Bos Creek and one located south of Bos Creek) with discharge of untreated groundwater to the Wisconsin River. 22½ lb/hour
- Option B includes two groundwater extraction wells (one located north of Bos Creek and one located south of Bos Creek) with groundwater treatment and discharge to Bos Creek. Supply info for permit.

6.0 REQUEST FOR APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARS)

This document has been prepared as a formal request to State and Federal agencies to elicit the identification of ARARs for the site and associated remedial actions under consideration. ARARs can be placed in three categories: chemical-specific, location-specific and action-specific. These categories of ARARs are discussed in the following sections along with a preliminary identification of some possible ARARs.

6.1 Chemical-Specific ARARs

TCE is the major contaminant detected at Production Well CW6, and at most other west side wells. Other contaminants detected include 1,2-dichloroethene, 1,1,1-trichloroethane, 1,1,2-trichloroethane, tetrachloroethene and toluene. These compounds were detected less frequently than TCE, and at much lower concentrations. The other compounds were observed more frequently at locations closer to the apparent source area. Possible chemical-specific ARARs for the operable unit include Clean Water Act Ambient Water Quality Criteria (AWQC) and Wisconsin Groundwater Quality Standards (Chapter NR140, Wisconsin Administrative Code [WAC]). Federal AWQC may be used in setting surface water discharge limits, and State Chapter NR140 Standards may be used in establishing numerical goals for groundwater quality at a point of standards application.

6.2 Location-Specific ARARs

Location-specific ARARs are requirements related to the physical setting of the site and features located in or near the study area. No RCRA waste management is proposed. No historically or archaeologically significant sites have been identified. No endangered species or critical habitat has been found in the study area. The Wisconsin River is not a designated wild or scenic river in the area. No potentially affected wetlands have been identified. In short, no location-specific ARARs have been identified for the operable unit. Flood plain Info.

6.3 Action-Specific ARARs

Action-specific ARARs are those requirements associated with the response actions under consideration for the operable unit. Specific response actions being considered include the following:

- Groundwater extraction well siting and construction (one or two wells),
- Groundwater withdrawal at rates ranging from approximately 500 gpm to 1500 gpm,
- Treatment of extracted groundwater using packed tower VOC stripping, with no off-gas treatment, and

- Discharge line and outfall construction, and discharge of treated or untreated water to the Wisconsin River, or discharge of treated water to Bos Creek.

Extraction well siting, construction and groundwater withdrawal rates would be subject to Chapter NR 112, WAC requirements. The precise regulatory requirements that apply to treatment and discharge in connection with groundwater cleanup are uncertain, because this type of activity has little historical precedent. The WDNR is authorized to administer provisions of the Federal Clean Water Act, and could potentially establish surface water discharge limits under authority of Chapter NR 102, WAC (based on AWQC), or under Chapter NR 217, WAC (uncategorized point sources) based on technology capabilities. Air emissions from VOC strippers could potentially be regulated under Chapter NR 424, WAC, which establishes limits for emissions from process lines. VOC emissions less than 3 lb/hr or 15 lb/day are exempt from review, permit and emissions from control requirements under this chapter. VOC emissions could also be regulated under the general authority of Chapter NR 445, WAC.

7.0 SUMMARY

Under the authority of CERCLA, as amended, the U.S. EPA has authorized Warzyn to conduct a Phased Feasibility Study to identify and evaluate alternative response actions that would address groundwater contamination in the West Well Field operable unit of the Wausau Water Supply NPL Site. Section 121 of CERCLA requires that remedial actions comply with Federal and more stringent State requirements, although certain requirements may be waived for interim remedies. Accordingly, Federal and State agencies are requested to identify ARARs for the contaminants identified and the groundwater extraction, treatment and discharge actions under consideration, and to notify the U.S. EPA of these requirements.

RLM/sss/DWH
[sss-600-23]

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[sss-600-23]

TABLE 1
SUMMARY OF CITY WELL LOCATION AND USE
WAUSAU WATER SUPPLY NPL SITE
WAUSAU, WISCONSIN

Well	Approximate Location	Approx.* Capacity	Comments
CW3	East Study Area between Third St., RR Tracks, E. Wausau Ave. and Devoe St.	1600 gpm	Contaminated with VOCs; water pumped to stripping tower.
CW4	East Study Area, S. of water treatment plant	1400 gpm	Contaminated with VOCs; high Fe, Mn, H_2S odor; THM production up when #4 is on line; water pumped to stripping tower.
CW6	West Study Area, E. side of Pearson St., just S. of Crocker St.	1050 gpm	Reportedly reliable in terms in terms of volume and inorganic water quality; low Fe, Mn; Contaminated with VOCs; currently pumped to waste; water normally would feed into line that crosses river to treatment plant.
CW7	West Study Area, E. side of Marten St., between Crocker St. and Bugbee Ave.	1000 gpm	Not contaminated with VOCs; water pumped into line that crosses river to treatment plant.
CW8	South of study areas, near airport	gpm	Reportedly not contaminated with VOCs; high Fe, Mn; used infrequently; pumped directly into distribution system; addition of disinfectant and iron sequestering agents.
CW9	West Study Area, N. side of Bugbee Ave., near Pearson St. intersection.	800 gpm	Reportedly not contaminated with VOCs; heavily used; water pumped into line that crosses river to treatment plant.
CW10	West Study Area, N.E. corner of Bugbee Ave. and Tierney Rd. intersection	150 gpm	Reportedly not contaminated with VOCs; small test well, not a production well; pumped to waste.

* Typical pumping rates, based on recent pumping records.

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TABLE 2
ESTIMATED VOC STRIPPER PERFORMANCE AND MAXIMUM INFLUENT
CONCENTRATIONS FOR MEETING PERFORMANCE LEVELS
WAUSAU WATER SUPPLY NPL SITE
WAUSAU, WISCONSIN

			8 ft Tower Trichloroethene		8 ft Tower Tetrachloroethene			9 ft Tower Trichloroethene		9 ft Tower Tetrachloroethene		
Water Flow gpm	Air Flow cfm	A:W Ratio v/v	Pred. Removal Eff. %	Max. Infl. Conc. for Effl. of 5 ug/L	Pred. Removal Eff. %	Maximum Influent Concentration for Effluent of: 5 ug/L	Maximum Influent Concentration for Effluent of: 10 ug/L	Pred. Removal Eff. %	Max. Infl. Conc. for Effl. of 5 ug/L	Pred. Removal Eff. %	Maximum to Effluent 5 ug/L	Influent meet of: 10 ug/L
600	6000	74.8	99.29	705	99.25	666	1332	*	*	*	*	*
900	6000	49.9	98.63	364	98.63	365	730	*	*	*	*	*
1200	6000	37.4	97.83	230	97.93	241	483	*	*	*	*	*
1500	6000	29.9	96.93	163	97.17	176	353	*	*	*	*	*
1800	6000	24.9	95.94	123	96.36	137	274	*	*	*	*	*
2100	6000	21.4	94.89	98	95.51	111	223	*	*	*	*	*
600	8000	99.7	99.39	820	99.33	741	1483	*	*	*	*	*
900	8000	66.5	98.84	432	98.79	413	827	99.33	743	99.30	713	1426
1200	8000	49.9	98.20	278	98.20	277	554	98.90	454	98.90	455	911
1500	8000	39.9	97.49	199	97.56	205	410	98.40	312	98.46	324	649
1800	8000	33.2	96.72	153	96.89	161	322	97.83	230	97.97	247	494
2100	8000	28.5	95.91	122	96.20	131	263	97.21	179	97.46	197	393
2400	8000	24.9	*	*	*	*	*	96.54	144	96.91	162	324
600	10000	124.7	99.45	903	99.37	795	1589	*	*	*	*	*
900	10000	83.1	98.97	484	98.88	448	896	99.41	847	99.36	783	1566
1200	10000	62.3	98.41	315	98.35	303	606	99.05	524	99.01	506	1011
1500	10000	49.9	97.81	228	97.78	226	451	98.63	364	98.62	363	726
1800	10000	41.6	97.15	176	97.19	178	356	98.16	272	98.20	279	557
2100	10000	35.6	96.47	141	96.59	146	293	97.65	213	97.76	223	447
2400	10000	31.2	*	*	*	*	*	97.11	173	97.30	185	370
600	12000	149.6	99.48	968	99.40	834	1668	*	*	*	*	*
900	12000	99.7	99.05	524	98.95	474	948	99.46	930	99.40	837	1673
1200	12000	74.8	98.55	344	98.45	323	645	99.14	581	99.08	544	1088
1500	12000	59.8	98.00	251	97.93	242	483	98.77	407	98.73	393	787
1800	12000	49.9	97.43	194	97.39	192	383	98.36	306	98.35	303	607
2100	12000	42.7	96.82	157	96.84	158	316	97.92	241	97.95	244	489
2400	12000	37.4	*	*	*	*	*	97.45	196	97.54	203	407
900	14000	116.4	*	*	*	*	*	99.50	997	99.43	879	1758
1200	14000	87.3	*	*	*	*	*	99.20	627	99.13	575	1150
1500	14000	69.8	*	*	*	*	*	98.87	442	98.80	417	835
1800	14000	58.2	*	*	*	*	*	98.50	334	98.45	323	647
2100	14000	49.9	*	*	*	*	*	98.11	264	98.09	262	523
2400	14000	43.6	*	*	*	*	*	97.69	217	97.71	218	436
900	16000	133.0	*	*	*	*	*	99.52	1052	99.45	913	1826
1200	16000	99.7	*	*	*	*	*	99.25	666	99.17	600	1200
1500	16000	79.8	*	*	*	*	*	98.94	472	98.86	437	875
1800	16000	66.5	*	*	*	*	*	98.60	358	98.53	340	680
2100	16000	57.0	*	*	*	*	*	98.24	285	98.19	276	551
2400	16000	49.9	*	*	*	*	*	97.86	234	97.83	231	461

* Not evaluated for the flow rates indicated.

TABLE 3
SUMMARY OF WAUSAU WATER
DISTRIBUTION SYSTEM AND WELL CW3 (UNTREATED)
MONITORING RESULTS*
WAUSAU WATER SUPPLY NPL SITE
WAUSAU, WISCONSIN

SAMPLE LOCATION	DATE	VC*	DCE*	TCE*	PCE*
		ug/L			
Holiday Inn	1/15/88	<2.0	<1.0	<0.5	<0.5
Water Plant	2/05/88	<2.0	<1.0	<0.5	<0.5
Green Bay Packaging	2/10/88	<2.0	<1.0	<0.5	<0.5
Wausau Airport	2/17/88	<2.0	<1.0	<0.5	<0.5
Water Plant	2/24/88	<2.0	<1.0	<0.5	<0.5
Water Plant	3/09/88	<2.0	<1.0	<0.5	<0.5
Holiday Inn	3/13/88	<2.0	<1.0	<0.5	<0.5
Water Plant	3/24/88	<2.0	<1.0	<0.5	<0.5
Green Bay Packaging	3/30/88	<2.0	<1.0	<0.5	<0.5
Wausau Airport	4/06/88	<2.0	<1.0	<0.5	<0.5
Water Plant	4/21/88	<2.0	<1.0	<0.5	<0.5
Holiday Inn	4/28/88	<2.0	<1.0	<0.5	<0.5
Green Bay Packaging	5/06/88	<2.0	<1.0	<0.5	<0.5
Wausau Airport	2/17/88	<2.0	<1.0	<0.5	<0.5
Well CW3	2/17/88	<2.0	8.9	74.2	14.1
Well CW3	2/24/88	<2.0	8.0	69.5	13.0
Well CW3	3/02/88	<2.0	9.8	73.8	14.9
Stripper #2 Effluent	3/02/88	<2.0	<1.0	0.5	<0.5
Well CW3	3/09/88	<2.0	8.4	69.5	13.1
Well CW3	3/15/88	<2.0	9.7	69.9	12.2
Well CW3	3/24/88	<2.0	4.2	71.3	10.4
Well CW3	3/30/88	<2.0	9.0	76.3	14.0
Well CW3	4/06/88	<2.0	8.5	67.1	11.0
Well CW3	4/21/88	<2.0	18.3	115	11.5
Well CW3	4/28/88	<2.0	17.2	115	9.8
Well CW3	5/06/88	<2.0	16.8	102	8.6
Well CW3	5/11/88	<2.0	17.8	101	10.2

* Monitoring Data Reported by the Wausau Water and Sewerage Utilities to the WDNR on May 12, 1988 and June 16, 1988. Samples were analyzed for: Vinyl Chloride (VC), 1,2-Dichloroethenes (DCE), Trichloroethene (TCE) and Tetrachloroethene (PCE).

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TABLE 4
SUMMARY OF TECHNOLOGY SCREENING
GROUNDWATER CONTROLS
PHASED FEASIBILITY STUDY
WAUSAU WATER SUPPLY NPL SITE
WAUSAU, WISCONSIN

Technology Group	Technology	Retain	Comment
Barriers	Soil-Bentonite Slurry Wall Cement-Bentonite Slurry Wall Steel Sheet-Pile Wall Grout Curtain Wall Synthetic Membrane Wall Vibrating Beam Slurry Wall	No No No No No No	Deep bariers would be required. Depth to bedrock is over 100 ft. over much of the area, and bedrock surface is irregular, making an effective key into bedrock difficult. Trenching, driving beams, injecting grout, and placing a membrane are not practical at this site. Construction would cause substantial disruption of area residents and businesses.
Injection	Wells	No	Acceptable for disposal of water suitable as potable water supply, to maintain a potentially fully penetrating hydraulic barrier. Possible sources include: City Water — This would be a waste of potable water. River Water — Pretreatment would be necessary, and THM production at the water plant would likely increase. Groundwater — From a well located in an uncontaminated area. This water could be acceptably clean, but clean water would be more efficiently used as a water source, not to protect the source. This action would have to continue indefinitely, until the threat of well field contamination is removed.
	Trenches	No	Vertical influence of shallow trenches would be limited. Deep trench construction in this developed area is not considered feasible.
	Basins	No	Vertical influence of basins may be limited. Land required for basins would be too large for this area.
Extraction	Wells	Yes	Demonstrated effectiveness in achieving fairly extensive areas of influence locally in the aquifer. Compared to other extraction methods, well construction would be the least disruptive of area residents and businesses.
	Trenches	No	Shallow trenches would not achieve the desired influence throughout the depth of the aquifer. Construction of deep trenches that would achieve the desired effect is not considered feasible in this area.

TABLE 4 (cont)
SUMMARY OF TECHNOLOGY SCREENING
GROUNDWATER CONTROLS
PHASED FEASIBILITY STUDY
WAUSAU WATER SUPPLY NPL SITE
WAUSAU, WISCONSIN

Technology Group	Technology	Retain	Comment
Extraction/ Injection	Wells	No	Wells would be the most appropriate from a technical standpoint, but this option is less favored than a surface water discharge for two major reasons: (1) energy costs for reinjection would be higher than costs for a local surface water discharge, and (2)approval for groundwater injection would be difficult to obtain in Wisconsin
	Wells/Trenches	No	The limitations discussed above would also apply to trenches used either for extraction or reinjection. Water recharged to the aquifer would have to meet NR 140 Groundwater Quality standards.

[sss-600-23c]

TABLE 5
SUMMARY OF TECHNOLOGY SCREENING
GROUNDWATER TREATMENT
PHASED FEASIBILITY STUDY
WAUSAU WATER SUPPLY NPL SITE
WAUSAU, WISCONSIN

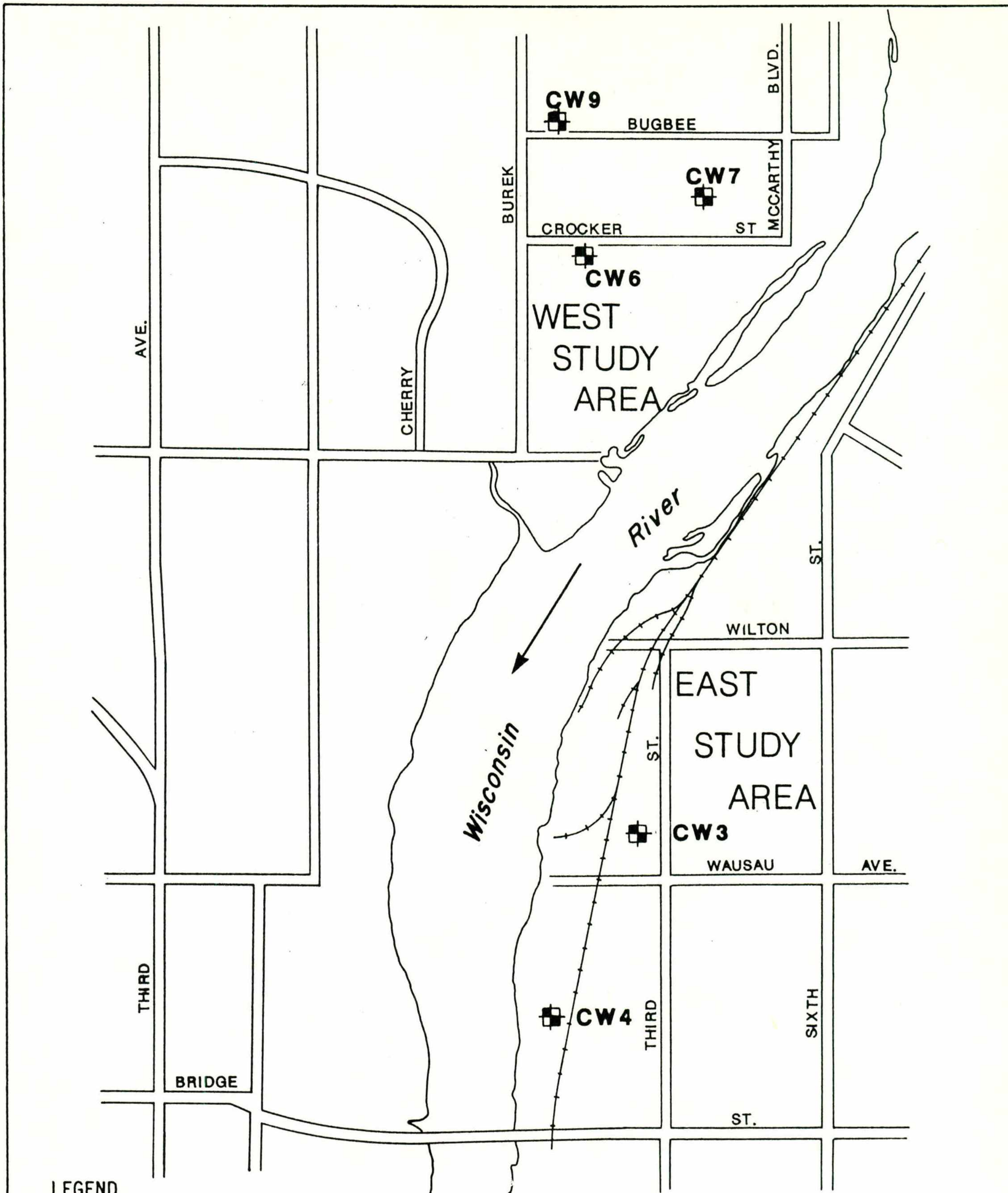
Technology Group	Technology	Retain	Comment
Physical	Filtration	No	Water quality does not warrant use.
	Settling	No	Water quality does not warrant use.
	Stripping	Yes	Demonstrated effectiveness in VOC removal.
	Adsorption	Yes	Demonstrated effectiveness in VOC removal.
	Ion Exchange	No	Water quality does not warrant use.
	Reverse Osmosis	No	Promising for removal of low concentrations of VOCs.
Chemical	Neutralization	No	Water quality does not warrant use.
	Coagulation/Precipitation	No	Water quality does not warrant use.
	Oxidation	Yes	VOC removal may be required. Contaminant destruction.
	Reduction	No	Not demonstrated for contaminants of concern.
Biological	Aerobic Processes	No	The primary reported removal mechanism of chlorinated VOCs in aerobic systems is volatilization. Effective contaminant degradation has not been consistently reported.
	Anaerobic Processes	No	Anaerobic degradation of chlorinated VOCs has been reported, but maintaining a population of slow-growing anaerobes would likely be difficult, considering the concentrations of chlorinated VOCs and other organics in the groundwater.
In-Situ Physical	Fixation	No	Plume area is too large. Source area extent is not adequately defined.
	Adsorbent Trenches	No	Difficulties with trench construction as mentioned previously. Contaminants would not be permanently immobilized.
In-Situ Chemical	Oxidation	No	Technology is not adequately demonstrated in this type of application. Long lead time required for studies would not be consistent with the need for expedited response.
	Reduction	No	Technology is not adequately demonstrated in this type of application. Long lead time required for studies would not be consistent with the need for expedited response.
In-Situ Biological	Anaerobic	No	Technology is not adequately demonstrated in this type of application. Long lead time required for studies would not be consistent with the need for expedited response.

[sss-600-23c]

TABLE 6
SUMMARY OF TECHNOLOGY SCREENING
DISCHARGE OPTIONS
PHASED FEASIBILITY STUDY
WAUSAU WATER SUPPLY NPL SITE
WAUSAU, WISCONSIN

Technology Group	Technology	Retain	Comment
Groundwater	Wells Trenches Basins	No No No	Wells would be the only viable technology in this situation. A discharge to grounwater is not desirable in comparison to a surface water discharge because: (1) treatment to levels acceptable for discharge to groundwater would be the most expensive option, and (2) operation and maintenance would likely be more expensive for injection wells than for a surface water discharge structure.
Surface Water	Pipeline Cascade Discharge	Yes Yes	A conventional pipeline would probably be at least partially submerged for part of the year. A cascade-type structure would provide the additional benefit of partial VOC removal. This may be acceptable as the sole treatment if discharge limits on VOCs are not very stringent.
	Publically-Owned Treatment Works (POTW)	No	Flow rates required for groundwater will be too high to make discharge to the POTW a viable option.

[sss-600-23c]



LEGEND

CW6 CITY SUPPLY WELL

north

SCALE: 1" = 1000'

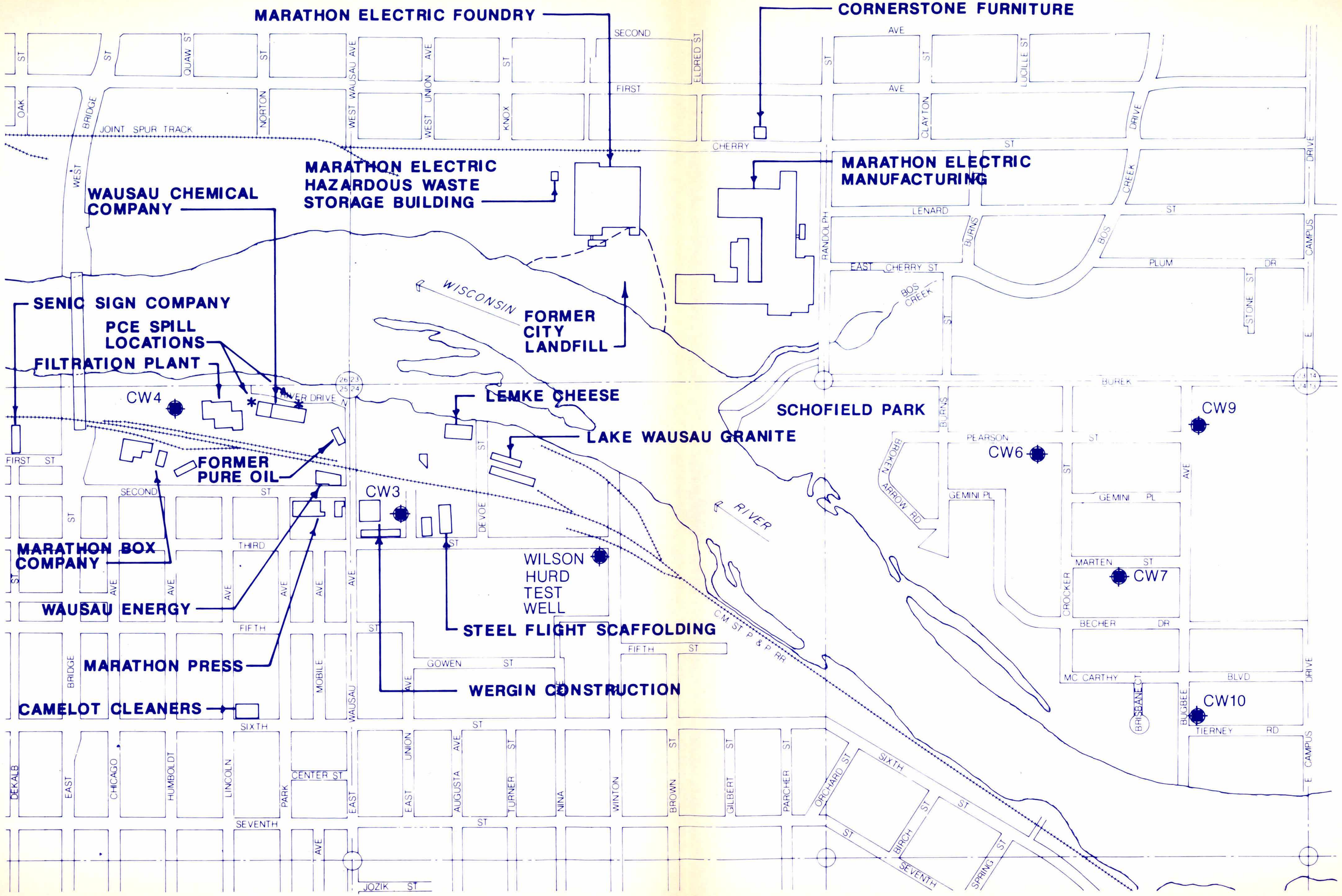
NOTE:

BASE MAP DEVELOPED FROM U.S.G.S. 15 MIN. QUADRANGLE MAPS WAUSAU EAST & WAUSAU WEST DATED 1963, PHOTOREVISED 1978.

FIGURE 1

WARZYN ENGINEERING INC	SITE LOCATION MAP WAUSAU WATER SUPPLY NPL SITE WAUSAU, WISCONSIN	

DWN SJP	APP'D RLM	DATE 7/6/88	13076-A23



north

LEGEND

- EXISTING STRUCTURE
- CW9 PUMPING MUNICIPAL WELL
- SECTION CORNER AND NUMBERS
- QUARTER SECTION MARKER
- EDGE OF WATER
- CREEK/INTERMITTENT STREAM
- RAILROAD TRACKS

NOTES

1. THE BASE MAP WAS DEVELOPED FROM THE CITY OF WAUSAU PLAT MAP, REPORTED SCALE: 1" = 1000', DATED MARCH, 1987.
2. REVIEW OF AERO-METRIC ORTHOPHOTOGRAPHIC MAPS DATED APRIL 26, 1974 INDICATE THAT THE CITY OF WAUSAU PLAT MAP EXHIBITS SCALE INCONSISTANCIES.
3. BUILDING LOCATIONS TRANSFERRED FROM AERIAL PHOTOGRAPHS DATED APRIL 23, 1986.
4. TETRACHLOROETHENE (PCE) SPILL LOCATIONS AT WAUSAU CHEMICAL CO. BASED ON INFORMATION OBTAINED DURING THE INDUSTRIAL SURVEY.
5. APPROXIMATE EXTENT OF FORMER CITY LANDFILL BASED ON INTERVIEW OF FORMER CITY EMPLOYEES.

OFFICE COPY

LOCATION OF MUNICIPAL WELLS & INDUSTRIAL SURVEYED BUSINESSES

FEASIBILITY STUDY

WAUSAU WATER SUPPLY NPL SITE

WAUSAU, WISCONSIN

WARZYN

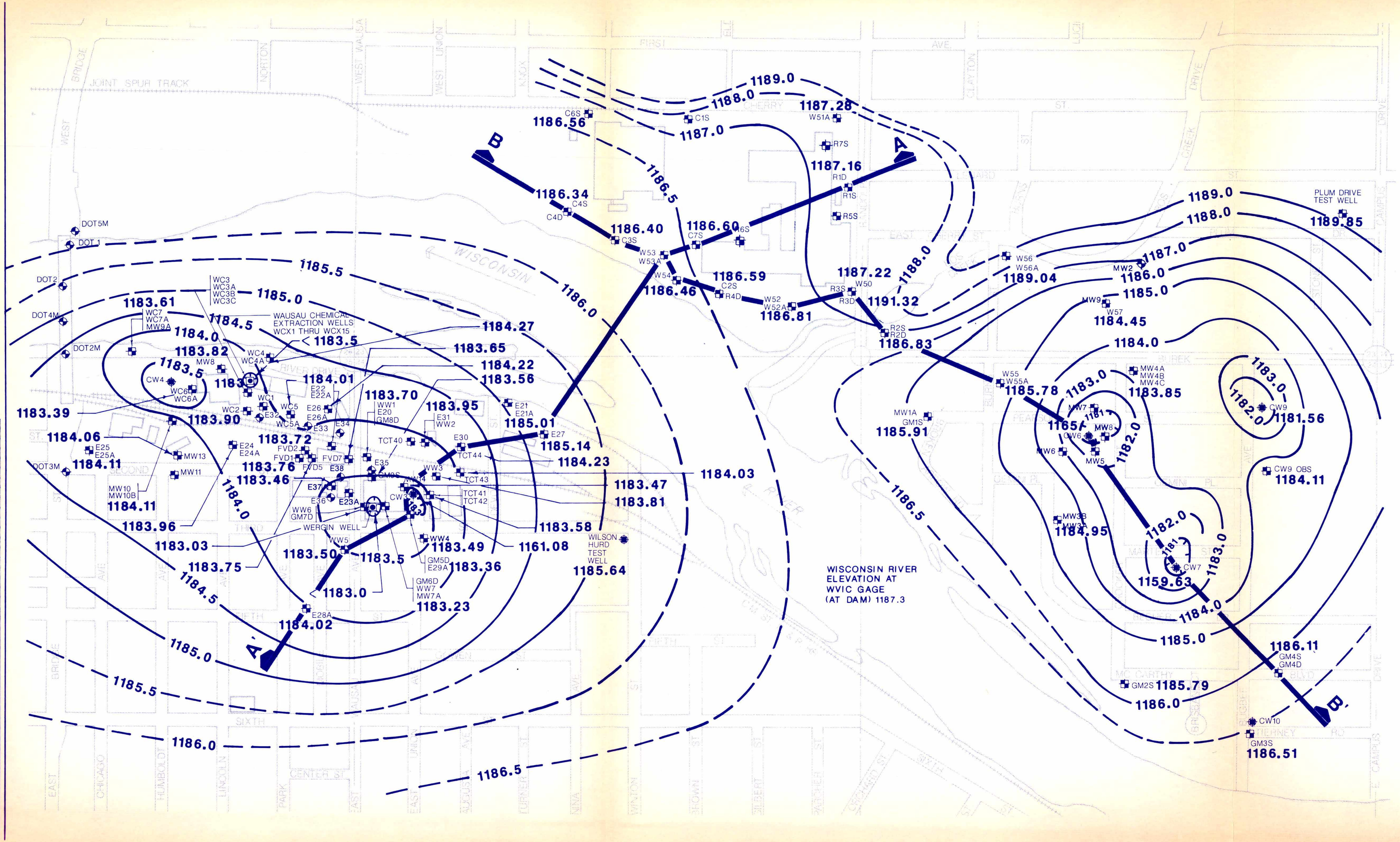
Scale 1" = 500' (APPROXIMATE)

Checked By DLI Date 7/6/88

Project Number 13076 B37

WARZYN

FIGURE 2



LEGEND

W6	MONITORING WELL LOCATION AND NUMBER
1181.56	WATER TABLE ELEVATION
CW7	PUMPING MUNICIPAL WELL LOCATION AND NUMBER
— 1183.0 —	UPPER AQUIFER POTENTIOMETRIC CONTOUR (DASHED WHERE INFERRED)
SG1	STAFF GAGE LOCATION AND NUMBER
A	GEOLOGIC CROSS SECTION AND NUMBER

NOTES

1. REFER TO DRAWING 13076-B37 (FIGURE 2) FOR NOTES AND LEGEND.
2. GROUNDWATER ELEVATIONS NOTED ARE BASED ON MEASUREMENTS TAKEN BY WARZYN ENGINEERING INC. ON JANUARY 7 AND 8, 1988.
3. REFER TO APPENDIX H PHASE I REMEDIAL INVESTIGATION TECHNICAL MEMORANDUM (WARZYN, APRIL 1988), FOR SUMMARY OF MONITORING WELL CONSTUCTION DETAILS AND OBSERVED GROUNDWATER ELEVATIONS.

JUL 11 1988

POTENTIOMETRIC SURFACE (1/7-8/88) AND CROSS SECTION LOCATION MAP
FEASIBILITY STUDY
WAUSAU WATER SUPPLY NPL SITE
WAUSAU, WISCONSIN

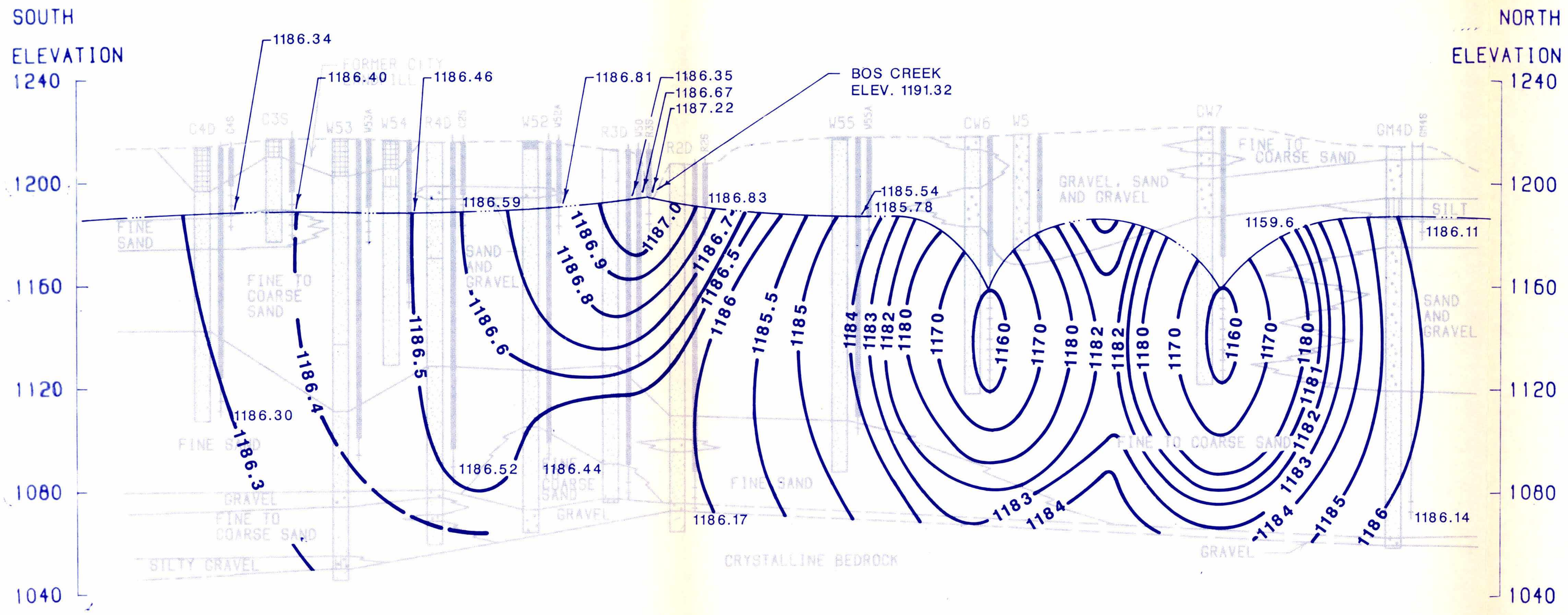
Revisions
Date · By · App'd

WARZYN
WARZYN ENGINEERING INC
Madison · Milwaukee
Minneapolis · Chicago
Detroit

Designed By
Drawn By JC
Checked By DLI
Approved By Robert L Mumford
Date 7/6/88
Scale 1" = 400' (APPROXIMATE)
Reference

Project Number 13076 B38
WARZYN

FIGURE 3



SECTION B-B'

HORIZONTAL SCALE: 1" = 400' (APPROXIMATE)
VERTICAL SCALE: 1" = 40'

NOTES

1. THE STRATUM LINES ARE BASED ON INTERPOLATION BETWEEN BORINGS AND MAY NOT REPRESENT ACTUAL SUBSURFACE CONDITIONS.
2. CROSS SECTION LOCATIONS ARE SHOWN ON DRAWING 13076-B38 (FIGURE 3)
3. FOR THE PURPOSE OF ILLUSTRATING SUBSOIL CONDITIONS ON THE CROSS SECTIONS, SOME OF THE BORING LOGS HAVE BEEN SIMPLIFIED. FOR A DETAILED DESCRIPTION OF SUBSURFACE CONDITIONS AT INDIVIDUAL BORINGS, REFER TO SOIL BORING LOGS, APPENDIX B OF RI TECHNICAL MEMORANDUM (WARZYN, 1988).
4. FOR COMPLETE MONITORING WELL INSTALLATION DETAILS, REFER TO APPENDIX C OF RI TECHNICAL MEMORANDUM (WARZYN,1988).
5. CROSS SECTIONS HAVE BEEN EXAGGERATED TEN (10) TIMES.
6. HORIZONTAL DISTANCES ARE MEASURED WITH RESPECT TO THE CENTER OF EACH SOIL BORING LOCATION.
7. ELEVATIONS ARE SHOWN IN U.S.G.S. DATUM.
8. DASHED GEOLOGIC CONTACT LINES ARE INFERRED.
9. GROUNDWATER EQUIPOTENTIAL CONTOURS BASED ON GROUNDWATER LEVELS MEASURED BY WARZYN ENGINEERING INC., JANUARY 7 AND 8, 1988.
10. REFER TO APPENDIX H PHASE I REMEDIAL INVESTIGATION TECHNICAL MEMORANDUM (WARZYN, APRIL 1988), FOR SUMMARY OF MONITORING WELL CONSTRUCTION DETAILS AND OBSERVED GROUNDWATER ELEVATIONS.

JUL 1 1 1988

POTENTIOMETRIC SECTION BB'
FEASIBILITY STUDY
WAUSAU WATER SUPPLY NPL SITE
WAUSAU, WISCONSIN

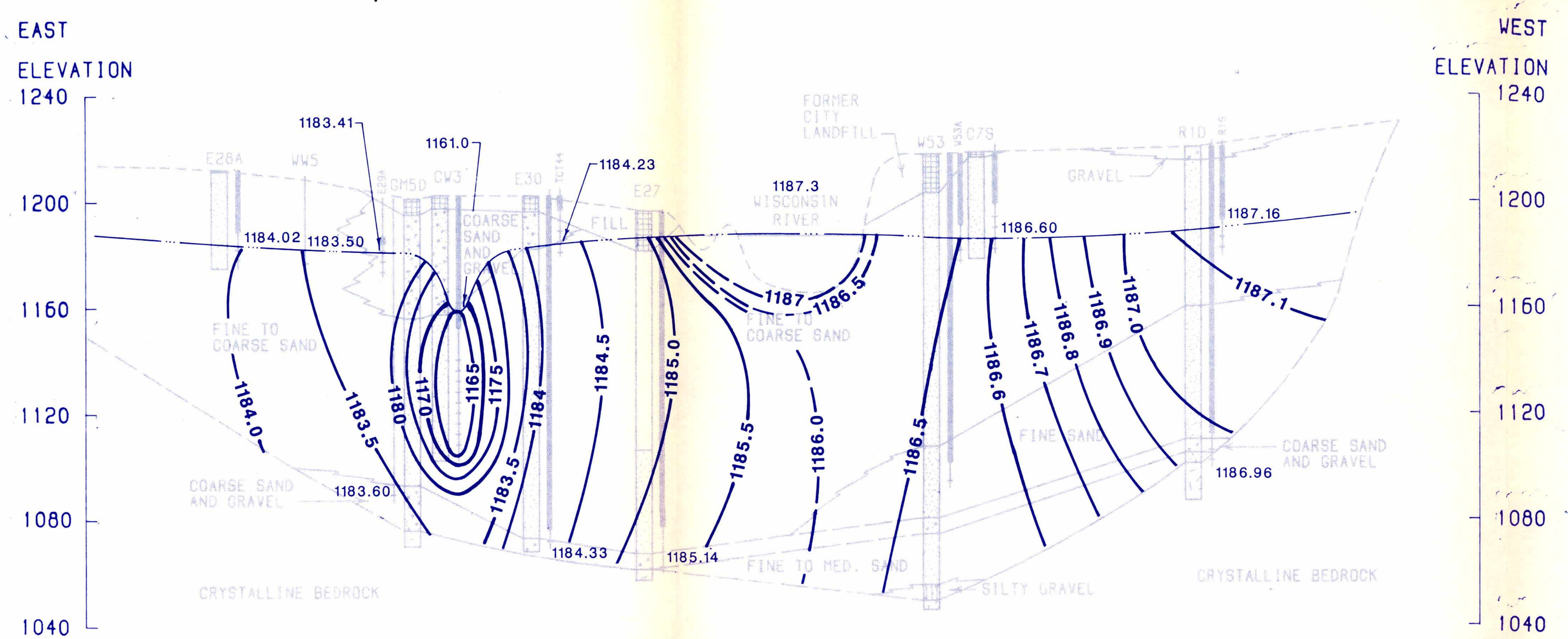
WARZYN

Drawn By JL
Approved By Robert L Mumford
Checked By DLI
Date 7/6/88
Scale AS SHOWN

13076 B39

WARZYN

FIGURE 4



SECTION A-A'

HORIZONTAL SCALE: 1" = 400' (APPROXIMATE)
VERTICAL SCALE: 1" = 40'

NOTES

1. REFER TO DRAWING NO. 13076-B39 (FIGURE 4) AND LEGEND.
2. GROUNDWATER EQUIPOTENTIAL CONTOURS BASED ON GROUNDWATER LEVELS MEASURED BY WARZYN ENGINEERING INC., JANUARY 7 AND 8, 1988.
3. REFER TO APPENDIX H PHASE I REMEDIAL INVESTIGATION TECHNICAL MEMORANDUM (WARZYN, APRIL 1988), FOR SUMMARY OF MONITORING WELL CONSTUCTION DETAILS AND OBSERVED GROUNDWATER ELEVATIONS.
4. REFER TO DRAWING 13076-B38 FOR CROSS SECTION LOCATION.

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POTENTIOMETRIC SECTION AA'
FEASIBILITY STUDY
WAUSAU WATER SUPPLY NPL SITE
WAUSAU, WISCONSIN

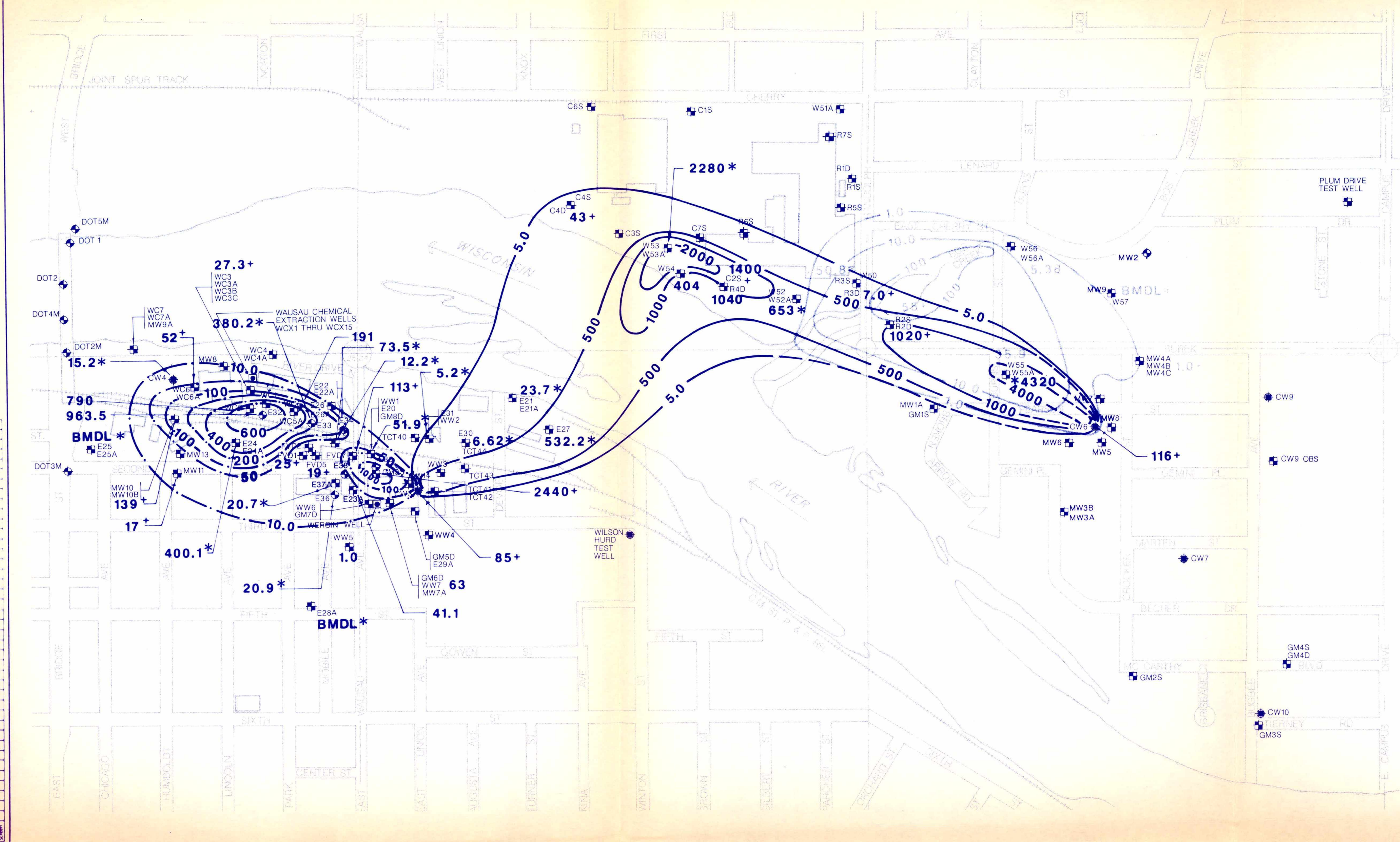
WARZYN

Drawn By: JL
Approved By: Robert L. Mumford
Checked By: DLI
Date: 7/6/88
Scale: AS SHOWN

Project Number 13076 B40

WARZYN

FIGURE 5



north

JUL 11 1988

LEGEND

E27	MONITORING WELL LOCATION AND NUMBER
CW4	PUMPING MUNICIPAL WELL LOCATION AND NUMBER
E34	SOIL BORING LOCATION AND NUMBER
532.2	TOTAL CHLORINATED ETHENES CONCENTRATION (ug/L)
BMDL	TOTAL CHLORINATED ETHENES DETECTED BUT BELOW MINIMUM REPORTABLE LIMITS
10.0	CONTOUR OF EQUAL CONCENTRATION OF TOTAL CHLORINATED ETHENES (PREDOMINANTLY TCE) AT GROUNDWATER SURFACE
500	CONTOUR OF EQUAL CONCENTRATION OF TOTAL CHLORINATED ETHENES (PREDOMINANTLY TCE) NEAR BASE OF AQUIFER
50	CONTOUR OF EQUAL CONCENTRATION OF TOTAL CHLORINATED ETHENES (PREDOMINANTLY PCE) AT GROUNDWATER SURFACE
*	TOTAL CHLORINATED ETHENES CONCENTRATION DETERMINED FROM ON SITE ANALYSIS OF GROUNDWATER SAMPLES COLLECTED DURING DRILLING
+	TOTAL CHLORINATED ETHENES CONCENTRATION DETERMINED FROM ROUND 1 SAMPLING OF PRE-EXISTING WELLS

NOTES

1. REFER TO DRAWING 13076-B37 (FIGURE 2) FOR BASE MAP LEGEND AND NOTES.
2. PRE-EXISTING MONITORING WELLS WERE SAMPLED BY WARZYN ENGINEERING INC., SEPTEMBER 29 TO OCTOBER 7, 1987.
3. GROUNDWATER SAMPLES WERE COLLECTED AND ANALYZED BY WARZYN ENGINEERING INC. USING AN ON-SITE GAS CHROMATOGRAPH (GC), OCTOBER 12 TO DECEMBER 12, 1987.
4. REFER TO APPENDICES F AND G OF RI TECHNICAL MEMORANDUM (WARZYN, 1988). GROUNDWATER ANALYSIS AND RESULTS OF GROUNDWATER SAMPLING WHILE DRILLING, RESPECTIVELY.

PRELIMINARY ESTIMATE OF TOTAL CHLORINATED ETHENES OCCURENCE AQUIFER

FEASIBILITY STUDY

WAUSAU WATER SUPPLY NPL SITE

WAUSAU, WISCONSIN

Revisions | Date · By · App'd

WARZYN
WARZYN ENGINEERING INC.
Madison · Milwaukee
Minneapolis · Chicago
Detroit

Designed By | Drawn By JC | Checked By DLI

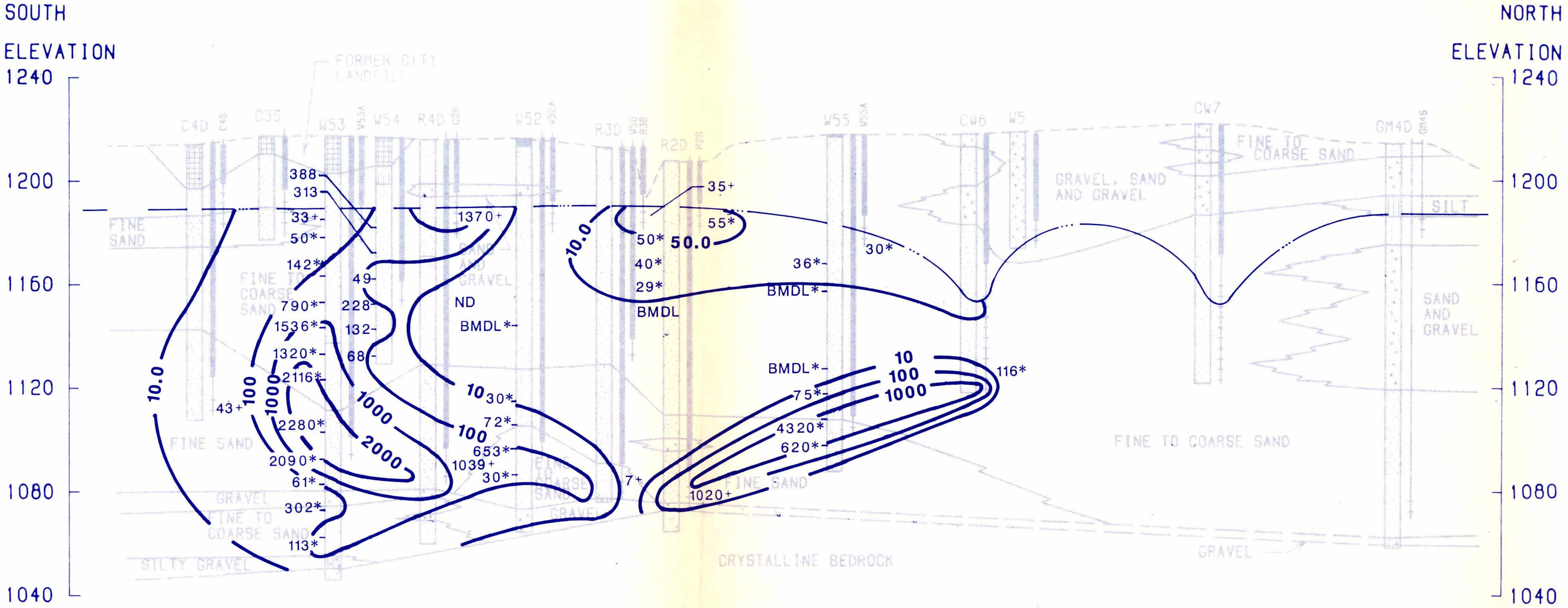
Approved By Robert I. Mumford | Date 7/6/88

Scale 1" = 400' (APPROXIMATE) | Reference

Project Number 13076 B41

WARZYN

FIGURE 6



SECTION B-B'

HORIZONTAL SCALE: 1" = 400' (APPROXIMATE)
VERTICAL SCALE: 1" = 40'

LEGEND

72* 653* 30*	TOTAL CHLORINATED ETHENES CONCENTRATIONS IN ug/L DETERMINED FROM GC ANALYSIS OF GROUNDWATER SAMPLE OBTAINED DURING DRILLING (OCTOBER 12, 1987 TO DECEMBER 12, 1987).
43+	TOTAL CHLORINATED ETHENES CONCENTRATIONS IN ug/L DETERMINED FROM CONTRACT LABORATORY ANALYSIS OF ROUND 1 SAMPLES OBTAINED FROM SEPTEMBER 29, 1987 TO OCTOBER 6, 1987.
BMDL	TOTAL CHLORINATED ETHENES AT CONCENTRATIONS BELOW MINIMUM REPORTABLE DETECTION LIMITS.
ND	TOTAL CHLORINATED ETHENES NOT DETECTED.
—— 100 ——	CONTOUR OF EQUAL TOTAL CHLORINATED ETHENES CONCENTRATION, DASHED WHERE INFERRED.

NOTES

1. REFER TO DRAWINGS 13076-B39 (FIGURE 4) FOR ADDITIONAL NOTES AND LEGENDS.
2. REFER TO DRAWING 13076-B41 (FIGURE 6) FOR AREAL VIEW OF TOTAL CHLORINATED ETHENES DISTRIBUTION IN THE AQUIFER.
3. REFER TO APPENDICES F AND G RI TECHNICAL MEMORANDUM (WARZYN, 1988). FOR SUMMARY OF ANALYTICAL DATA AND DETECTION LIMITS.
4. CROSS SECTION VERTICAL EXAGERATION IS 10 X.
5. REFER TO DRAWING 13076-B38 (FIGURE 3) FOR CROSS SECTION LOCATION

JUL 11 1988

ISOCONCENTRATION SECTION BB'
FEASIBILITY STUDY
WAUSAU WATER SUPPLY NPL SITE
WAUSAU, WISCONSIN

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Approved By Robert L Mumford | Date 7/6/88
Scale AS SHOWN | Reference

Project Number 13076 **B42**

WARZYN

FIGURE 7

APPENDIX A

STRIPPING TOWER ANALYSIS

WARZYN

APPENDIX A

STRIPPING TOWER ANALYSIS

In late 1984, the Wausau Water Utility began operation of two VOC stripping towers installed to allow continued use of Production Wells CW-3 and CW-4 to produce potable water. During the first four months of operation, the Production Well CW4 (8 ft) tower was studied extensively. Results of the process analyses and design, and of tower operation were reported by Hand, et al. (1986)

The transfer unit model (Colburn, 1935), based on the two-resistance theory of gas-liquid mass transfer (Lewis and Whitman, 1924), has long been used in analysis and design of countercurrent flow strippers and absorbers for chemical engineering applications (Treybal, 1980; Perry, 1984). More recently, these concepts have been applied to dilute aqueous solutions of volatile synthetic organic compounds (Kavanaugh and Trussell, 1980).

Cummins (1982) demonstrated the feasibility of VOC removal at Wausau using a pilot scale packed tower stripper to treat water from Production Well CW3. Hand, et al. (1986) reported on the design and performance of one of the Wausau stripping towers designed using the transfer-unit concept. Mass transfer coefficients were estimated using correlations developed by Onda et al. (1968). Henry's Law constants were measured using contaminated Production Well CW4 water. Other solute, packing and fluid properties were obtained from the literature.

The 8-ft diameter tower was designed for a 1500 gpm water flow rate with a design air:water volumetric ratio of 30:1. The tower size was optimized based on a target performance level of 95% removal of trichloroethene. A 9-ft diameter tower was also designed to treat water from Production Well CW3. A summary of design parameters for the two towers is presented in Table A-1.

Performance data for the towers are summarized in Table A-2. The available data indicate performance of the strippers has met or exceeded design target levels.

Data for the 8-ft diameter tower was collected by Hand, et al. (1986), during the first few months of tower operation. The water flow rate was varied from approximately 1170 to 1500 gpm, and the air flow rate was varied from approximately 8200 to 9650 cfm. Resulting air:water ratios were 41, 53 and 62 for the three operating conditions reported. Trichloroethene influent concentrations ranged from 66 to 72 ug/L, and effluent concentrations ranged from 1.0 to 1.8 ug/L (97.3 to 98.5 percent removal).

Data for the 9-ft diameter tower was reported by the Wausau Water Utility, based on influent and effluent samples collected on March 2, 1988. The influent and effluent TCE concentrations were 73.8 ug/L and 0.5 ug/L respectively (99.3% removal). No water and air flow rates were reported.

An analysis of stripper performance was conducted with two goals in mind: (1) to compare predicted removal efficiencies with reported performance, and (2) to predict tower performance under a range of water and air flow rates corresponding to the range of viable operating conditions. The transfer unit model was used in the analysis. Predicted removal efficiencies for the 8-ft and 9-ft diameter towers are shown in Table A-3, along with the removal efficiencies calculated from operating data. Predicted removal efficiencies exceeded measured removal efficiencies for 1,2-dichloroethene. Predicted removal efficiencies for trichloroethene and tetrachloroethene were not consistently either higher or lower than measured values. In general, the measured and predicted values are relatively close. Therefore, the model used for predictions should provide reasonable estimates of tower performance.

A range of water and air flow rates were used in the analysis of stripping tower performance. It was assumed that either stripper might be used to treat water from a single well, or that flow from a single well could be split to the two strippers. During high demand periods, individual wells may be pumped at a high rate, resulting in high loadings to strippers. The highest water flow rates used correspond to hydraulic loadings of approximately 40 gpm/ft^2 of tower cross sectional area. Low loadings would be anticipated in cases where flow from a single well was split between the two strippers. The lowest water flow rates used correspond to hydraulic loadings of approximately 14 gpm/ft^2. Air flow rates were varied from design loadings up to near maximum blower capacity. In summary, the following flow rates were used in the analysis:

Water Flow	8 ft tower	600 to 2100 gpm
	9 ft tower	900 to 2400 gpm
Air Flow	8 ft tower	6000 to 12000 cfm
	9 ft tower	8000 to 16000 cfm

Packing depths of 23 ft (8-ft tower, due to reported settling) and 24.5 ft (9-ft tower, design value) were used. The operating temperature was held constant at 10°C. Packing properties of 3-in. Intalox saddles were used. The compounds reported as detected in CW4 water by Hand, et al. (1986) were used in the analysis. Solute properties are summarized in Table A-4. Air and water properties were obtained from handbooks (Weast, 1984; Perry, 1984).

Results of the analysis are summarized in Table A-5 for the 8-ft tower, and in Table A-6 for the 9-ft tower. It is apparent that for the major contaminants of concern at present (TCE and PCE), high removal efficiencies can be anticipated under the range of air and water flow rates used in the analysis. For a given air flow rate, removal efficiency decreases as the water flow rate increases. The best performance is predicted at low water flow and high air flow, although the performance is less sensitive to air flow rates at low water flow rates. The analysis indicates that both towers could treat water containing higher concentrations of TCE and PCE than have been observed at Production Wells CW3 or CW6 under a range of air and water flow rates.

Based on the available information and on the analysis conducted, the following conclusions can be drawn regarding the VOC stripping towers at the water utility:

- The 8-ft and 9-ft diameter towers were designed to treat 1500 gpm and 2000 gpm, respectively, and to obtain 95% removal of TCE.

- Performance data indicates the towers are capable of meeting or exceeding design requirements.
- There is adequate flexibility in the systems to allow varying water and air flow rates to obtain contaminant removal efficiencies in excess of design levels.
- Predictions of tower performance indicate that target effluent concentrations can be achieved even with substantial increases in raw water contaminant concentrations.

RLM/sss/MSR/DWH
[sss-600-61a]

TABLE A-1

SUMMARY OF DESIGN
PARAMETERS FOR WAUSAU
WATER UTILITY PACKED TOWER STRIPPERS
WAUSAU WATER SUPPLY NPL SITE
WAUSAU, WISCONSIN

Parameter	Production Well CW4 Tower (1)	Production Well CW3 Tower
Air: Water Ratio (v:v)	30	30
Packing Pressure Drop	0.06 in w.c./ft	0.06 in w.c./ft
VOC Removal (TCE)	95%	95%
Henry's Law Constant (TCE)	0.116	0.116
Temperature	10°C	10°C
Packing Type	3-inch plastic saddles	3-inch plastic saddles
Tower Diameter	8 ft	9 ft
Packing Depth	24.5 ft	24.5 ft
Water Flow Rate	1500 gpm	2000 gpm
Air Flow Rate	6000 cfm	8000 cfm

(1) Hand, et al., 1986

13076.15
RLM/sss/MSR/DWH
[sss-600-23f]

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TABLE A-2

SUMMARY OF STRIPPING
TOWER PERFORMANCE
WAUSAU WATER SUPPLY NPL SITE
WAUSAU, WISCONSIN

	Production Well CW4 Stripper (1)			Production Well CW3 Stripper (2)		
Compound	Influent	Effluent	Removal	Influent (3)	Effluent	Removal
Cis-1,2-Dichloroethene	82.3	2.6	96.8	9.8	ND	>90.0
Trichloroethene	72.0	1.4	98.0	73.8	0.5	99.3
Tetrachloroethene	59.6	0.96	98.4	14.9	ND	96.6
Toluene	30.9	0.94	96.9	NA	--	--
Ethylbenzene	5.1	<0.3	>94.0	NA	--	--
Xylenes	16.6	0.60	96.4	NA	--	--
Vinyl Chloride	8.8	<0.3	>96.5	NA	--	--

(1) Average during first four months of operation (Hand, et al., 1986).

(2) Samples collected March 2, 1988.

(3) Sample collected at the CW3 well head.

ND Not Detected

NA Not Analyzed

13076.15
RLM/sss/MSR/DWH
[sss-600-23g]

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TABLE A-3
MEASURED AND PREDICTED TOWER
PERFORMANCE EFFICIENCY
WAUSAU WATER UTILITY
WAUSAU WATER SUPPLY NPL SITE
WAUSAU WISCONSIN

Compound	Water Flow (gpm)	Air Flow (cfm)	Removal Efficiency Measured (%)	Removal Efficiency Predicted (%)
8 ft Tower				
1,2-Dichloroethene	1199.6	8496	95.9	98.8
1,2-Dichloroethene	1499.1	8196	93.9	98.3
1,2-Dichloroethene	1169.5	9648	97.4	98.9
Trichloroethene	1199.6	8496	98.5	98.5
Trichloroethene	1499.1	8196	97.3	97.8
Trichloroethene	1169.5	9648	98.4	98.6
Tetrachloroethene	1199.6	8496	98.6	98.5
Tetrachloroethene	1499.1	8196	98.8	97.9
Tetrachloroethene	1169.5	9648	98.5	98.6
9 ft Tower				
1,2-Dichloroethene	1600*	10000*	ND	98.8
Trichloroethene	1600*	10000*	99.3	98.5
Tetrachloroethene	1600*	10000*	ND	98.5

* - Assumed Flow Rates
ND - Not detected in effluent

[sss-600-23e]

WARZYN

TABLE A-4
SUMMARY OF SELECTED VOC PROPERTIES
WAUSAU WATER SUPPLY NPL SITE
WAUSAU, WISCONSIN

Compound	Henry's Law Constant (1) -	Mol. Weight g/gmol	Lebas Molar Volume (2) cm3/mol	Diff. in Water (3) m2/s	Diff. in Air (4) m2/s
Vinyl Chloride	0.533	62.5	65.3	8.3e-10	1.0e-05
1,2-Dichloroethene	0.207	96.94	86.2	7.1e-10	8.6e-06
Trichloroethene	0.207	131.39	107.1	6.2e-10	7.6e-06
Tetrachloroethene	0.289	165.83	128.0	5.6e-10	6.9e-06
1,1,1-Trichloroethane	0.417	133.41	114.5	6.0e-10	7.4e-06
Toluene	0.134	92.14	118.2	5.9e-10	7.6e-06
Ethylbenzene	0.143	106.17	140.4	5.3e-10	6.9e-06
Xylene (as o-Xylene)	0.0861	106.17	140.4	5.3e-10	6.9e-06

(1) Ratio of molar concentration in each phase at 10 C. Vinyl chloride est. from data of Hayduk and Laudie (1974), tetrachloroethene est. from data of Gossett and Lincoff (1981), and all others est. from data of Mumford (1987)
(2) Calculated using additive volume increments from Lyman, et al. (1982)
(3) Estimated at 10 C using method of Hayduk and Laudie (Lyman, et al., 1982)
(4) Estimated at 10 C using method of Fuller, Schettler and Giddings (Lyman, et al., 1982)

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TABLE A-5
SUMMARY OF ESTIMATED VOC STRIPPER PERFORMANCE: 8 FT TOWER
WAUSAU WATER SUPPLY NPL SITE
WAUSAU, WISCONSIN

Water Flow gpm	Air Flow cfm	A:W Ratio v/v	VC Removal Eff. %	1,2-DCE Removal Eff. %	TCE Removal Eff. %	PCE Removal Eff. %	1,1,1-TCA Removal Eff. %	TOL Removal Eff. %	EBZ Removal Eff. %	XYL Removal Eff. %
600	6000	74.8	99.81	99.49	99.29	99.25	99.46	98.85	98.65	97.74
900	6000	49.9	99.62	98.97	98.63	98.63	99.02	97.74	97.44	95.55
1200	6000	37.4	99.39	98.31	97.83	97.93	98.52	96.39	96.03	92.97
1500	6000	29.9	99.13	97.55	96.93	97.17	97.99	94.85	94.46	90.12
1800	6000	24.9	98.85	96.70	95.94	96.36	97.42	93.17	92.78	87.11
2100	6000	21.4	98.54	95.77	94.89	95.51	96.83	91.38	91.01	84.04
600	8000	99.7	99.82	99.57	99.39	99.33	99.50	99.06	98.88	98.25
900	8000	66.5	99.65	99.14	98.84	98.79	99.11	98.20	97.92	96.64
1200	8000	49.9	99.45	98.62	98.20	98.20	98.67	97.17	96.82	94.74
1500	8000	39.9	99.22	98.03	97.49	97.56	98.21	96.02	95.61	92.65
1800	8000	33.2	98.98	97.38	96.72	96.89	97.72	94.76	94.33	90.42
2100	8000	28.5	98.71	96.67	95.91	96.20	97.22	93.43	92.98	88.10
600	10000	124.7	99.83	99.61	99.45	99.37	99.53	99.18	99.00	98.53
900	10000	83.1	99.67	99.24	98.97	98.88	99.16	98.45	98.18	97.23
1200	10000	62.3	99.48	98.80	98.41	98.35	98.76	97.60	97.26	95.70
1500	10000	49.9	99.28	98.30	97.81	97.78	98.33	96.65	96.25	94.03
1800	10000	41.6	99.05	97.75	97.15	97.19	97.89	95.63	95.18	92.24
2100	10000	35.6	98.81	97.16	96.47	96.59	97.44	94.55	94.07	90.38
600	12000	149.6	99.84	99.64	99.48	99.40	99.54	99.26	99.08	98.71
900	12000	99.7	99.69	99.30	99.05	98.95	99.19	98.61	98.35	97.59
1200	12000	74.8	99.51	98.90	98.55	98.45	98.81	97.87	97.53	96.30
1500	12000	59.8	99.31	98.46	98.00	97.93	98.42	97.05	96.65	94.88
1800	12000	49.9	99.10	97.98	97.43	97.39	98.01	96.17	95.72	93.38
2100	12000	42.7	98.88	97.47	96.82	96.84	97.59	95.24	94.76	91.81

Temperature: 10 C
Packing Height: 23 ft
Packing Size: 3 in
Packing Type: Intalox Saddles
Tower Diameter: 8 ft

Abbreviations - VC: Vinyl Chloride; 1,2-DCE: 1,2-Dichloroethenes; TCE: Trichloroethene; PCE: Tetrachloroethene; 1,1,1-TCA: 1,1,1-Trichloroethane; TOL: Toluene; EBZ: Ethylbenzene; XYL: Xylenes

WARZYN

TABLE A-6
SUMMARY OF ESTIMATED VOC STRIPPER PERFORMANCE: 9 FT TOWER
WAUSAU WATER SUPPLY NPL SITE
WAUSAU, WISCONSIN

Water Flow gpm	Air Flow cfm	A:W Ratio v/v	VC Removal Eff. %	1,2-DCE Removal Eff. %	TCE Removal Eff. %	PCE Removal Eff. %	1,1,1-TCA Removal Eff. %	TOL Removal Eff. %	EBZ Removal Eff. %	XYL Removal Eff. %
900	8000	66.5	99.83	99.52	99.33	99.30	99.51	98.88	98.68	97.70
1200	8000	49.9	99.72	99.18	98.90	98.90	99.23	98.14	97.88	96.20
1500	8000	39.9	99.58	98.78	98.40	98.46	98.92	97.26	96.95	94.44
1800	8000	33.2	99.43	98.31	97.83	97.97	98.59	96.26	95.93	92.50
2100	8000	28.5	99.26	97.79	97.21	97.46	98.23	95.17	94.82	90.42
2400	8000	24.9	99.08	97.22	96.54	96.91	97.86	93.99	93.63	88.23
900	10000	83.1	99.84	99.58	99.41	99.36	99.54	99.06	98.88	98.16
1200	10000	62.3	99.74	99.30	99.05	99.01	99.29	98.46	98.22	96.99
1500	10000	49.9	99.61	98.97	98.63	98.62	99.01	97.76	97.46	95.64
1800	10000	41.6	99.48	98.59	98.16	98.20	98.71	96.97	96.64	94.13
2100	10000	35.6	99.33	98.16	97.65	97.76	98.40	96.11	95.74	92.51
2400	10000	31.2	99.17	97.70	97.11	97.30	98.07	95.19	94.80	90.81
900	12000	99.7	99.85	99.62	99.46	99.40	99.56	99.17	99.00	98.44
1200	12000	74.8	99.75	99.37	99.14	99.08	99.32	98.66	98.42	97.47
1500	12000	59.8	99.64	99.08	98.77	98.73	99.07	98.07	97.78	96.36
1800	12000	49.9	99.51	98.75	98.36	98.35	98.79	97.41	97.07	95.12
2100	12000	42.7	99.37	98.39	97.92	97.95	98.50	96.69	96.32	93.80
2400	12000	37.4	99.22	98.00	97.45	97.54	98.20	95.92	95.52	92.39
900	14000	116.4	99.85	99.65	99.50	99.43	99.58	99.25	99.08	98.62
1200	14000	87.3	99.76	99.42	99.20	99.13	99.35	98.79	98.57	97.79
1500	14000	69.8	99.65	99.16	98.87	98.80	99.11	98.27	97.99	96.83
1800	14000	58.2	99.53	98.87	98.50	98.45	98.85	97.69	97.37	95.78
2100	14000	49.9	99.40	98.55	98.11	98.09	98.58	97.07	96.70	94.65
2400	14000	43.6	99.26	98.20	97.69	97.71	98.30	96.40	96.00	93.45
900	16000	133.0	99.86	99.67	99.52	99.45	99.59	99.30	99.14	98.75
1200	16000	99.7	99.77	99.46	99.25	99.17	99.37	98.89	98.67	98.01
1500	16000	79.8	99.66	99.22	98.94	98.86	99.14	98.42	98.14	97.17
1800	16000	66.5	99.55	98.95	98.60	98.53	98.89	97.90	97.58	96.24
2100	16000	57.0	99.42	98.66	98.24	98.19	98.63	97.34	96.98	95.25
2400	16000	49.9	99.29	98.34	97.86	97.83	98.37	96.74	96.35	94.20

Temperature: 10 C
Packing Height: 24.5 ft
Packing Size: 3 in
Packing Type: Intalox Saddles
Tower Diameter: 9 ft

Abbreviations - VC: Vinyl Chloride; 1,2-DCE: 1,2-Dichloroethenes; TCE: Trichloroethene; PCE: Tetrachloroethene; 1,1,1-TCA: 1,1,1-Trichloroethane; TOL: Toluene; EBZ: Ethylbenzene; XYL: Xylenes

WARZYN