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PROJECT: ARCS II EPA Contract No. 68-W9-0024
Work Assignment No.: 053-2L3U

DOCUMENT NO.: 7720-053-EP-CTBG

SUBJECT: Groundwater Feasibility Study
Forest Glen Site
Niagara Falls, New York
Document No.: 7720-053-FS-CTBH

Dear Mr. Austin and Ms. Sosa:

CDM Federal Programs Corporation (CDM Federal) is pleased to submit the enclosed Groundwater Feasibility Study, Forest Glen Site, Niagara Falls, New York.

If you have any questions or comments regarding this submittal, please do not hesitate to call me or Jeanne Litwin at (212) 785-9123.

Sincerely,

CDM FEDERAL PROGRAM S CORPORATION

Robert D. Goltz, P.E.
ARCS II Program Manager

Enclosure

cc: J. Litwin, CDM Federal
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Document Control

US EPA Contract No. 68-W9-0024

ARCS II

GROUNDWATER FEASIBILITY STUDY
FOREST GLEN SITE
NIAGARA FALLS, NEW YORK

REMEDIAL PLANNING ACTIVITIES AT SELECTED UNCONTROLLED HAZARDOUS SUBSTANCE DISPOSAL SITES WITHIN EPA REGION II
(NY, NJ, PR, VI)

CDM Federal Programs Corporation

GROUNDWATER FEASIBILITY STUDY
FOREST GLEN SITE
NIAGARA FALLS, NEW YORK

PREPARED FOR:
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EPA Work Assignment No.	:053-2L3U
EPA Region	:II
Contract No.	:68-W9-0024
CDM Federal Programs Corporation Document No.	:7720-053-FS-CTBH
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Date Prepared	:March 8, 1999

GROUNDWATER FEASIBILITY STUDY
FOREST GLEN SITE
NIAGARA FALLS, NEW YORK

PREPARED FOR:
U.S. Environmental Protection Agency
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New York, New York 10007-1866

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1.0 INTRODUCTION

This Groundwater Feasibility Study (FS) Report for Operable Unit III of the Forest Glen Superfund Site (Forest Glen) in Niagara Falls, Niagara County, New York, has been prepared by CDM Federal Programs Corporation (CDM Federal) for the U. S. Environmental Protection Agency (EPA) Region II as authorized under the ARCS II Contract No. 68-W9-0024 Work Assignment 053-2L3U. This report is based on:

- Information gathered during the comprehensive field investigations conducted by CDM Federal from November 1994 through December 1995 and summarized in the Final Remedial Investigation Report dated December 16, 1996 and the Final Risk Assessment Report dated November 1, 1996.

- Results of the Supplemental Groundwater Investigation conducted by Roy F. Weston and CDM Federal from July through September of 1997.

1.1 PURPOSE, ORGANIZATION AND EVALUATION CRITERIA

1.1.1 PURPOSE

The purpose of this FS Report is to document the basis and procedures used in identifying, developing, screening, and evaluating a range of remedial alternatives which address groundwater contamination at the Forest Glen site. The primary objective of this report is to provide EPA and the New York State Department of Environmental Conservation (NYSDEC) with sufficient data to select feasible and cost-effective remedial alternatives that protect public health and the environment from the potential risks posed by groundwater contamination.

1.1.2 REPORT ORGANIZATION

This FS report is comprised of five sections as described below.

Section 1.0 - Introduction, includes a statement of the primary objective of this report and defines the evaluation criteria used. Section 1.0 provides a summary of site background information including the description, history, and physical characteristics of the study area; describes the nature and extent of the contamination; presents the results of the baseline risk assessment; and states the basis for conducting the FS.

Section 2.0 - Identification and Screening of Remedial Technologies, presents the potential site-specific applicable or relevant and appropriate requirements (ARARs) and to be considered requirements (TBCs). Section 2.0 states the remedial action objectives and provides area and volume estimates of the contaminated groundwater; identifies and screens remedial technologies and process options for each category of general response actions; and presents the evaluation and selection of representative technologies and process options.

Section 3.0 - Development and Screening of Remedial Alternatives, presents the remedial alternatives developed by combining feasible technologies. Alternatives are described in Section 3.0 and an evaluation of each alternative based on the screening criteria of effectiveness, implementability, and cost is provided.

Section 4.0 - Detailed Analysis of Alternatives, presents a detailed evaluation of each alternative that passed the initial screening with respect to the following nine criteria: overall protection of human health and the environment; compliance with ARARs; long-term effectiveness and permanence; reduction of toxicity, mobility, or volume through treatment; short-term effectiveness; implementability; cost; state acceptance; and community acceptance.

Section 5.0 - Comparative Analysis, provides an overall comparison among the various remedial alternatives examined in Section 4.0.

1.1.3 EVALUATION CRITERIA

This FS follows the basic methodology outlined in the National Contingency Plan (NCP) with consideration of the requirements outlined in Section 121 of the Superfund Amendments and Reauthorization Act (SARA). The EPA has issued additional RI/FS guidance that includes nine criteria, noted above, for evaluating remedial alternatives (OSWER Directive Number 9355.3-01 - Interim Final Guidance for Conducting RI/FS Under Comprehensive Environmental Response, Compensation, and Liability Act [CERCLA], October 1988).

The FS process under SARA retains the basic approach for the remedial alternatives screening and evaluation outlined in the EPA FS Guidance Document (EPA, June 1985). SARA Section 121 and OSWER Directive 9355.3-01 have modified the FS process and provide nine key criteria that should be considered when evaluating and comparing remedial alternatives. The nine criteria, noted above, are classified as follows:

- Threshold Criteria
  - Overall Protection of Human Health and the Environment
  - Compliance with ARARs
- Balancing Criteria
  - Long-term Effectiveness and Permanence
  - Reduction of Toxicity, Mobility or Volume through Treatment
  - Short-term Effectiveness
  - Implementability
  - Cost
- Modifying Criteria
  - State Acceptance
  - Community Acceptance

Brief discussions for each of the above criteria are presented in the sections below.

1.1.3.1 Overall Protection of Human Health and the Environment

This evaluation criterion provides a final check to assess whether each alternative provides adequate protection of human health and the environment. The overall assessment of protection draws on the assessments conducted under other evaluation criteria, especially long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs. The evaluation focuses on whether a specific alternative achieves adequate protection.

1.1.3.2 Compliance With ARARS

Alternatives are assessed as to whether they attain legally applicable or relevant and appropriate requirements of other Federal and State environmental and public health laws, including, as appropriate:

- Chemical-specific ARARs (e.g., Maximum Contaminant Levels [MCLs], National Ambient Air Quality Standards [NAAQS]).
- Location-specific ARARs (e.g., restrictions on actions at historic sites).
- Action-specific ARARs (e.g., Department of Transportation [DOT] regulations for transport of hazardous materials)
- Compliance with other criteria, advisories, and guidelines.

SARA provides for waivers under six situations where all ARARs cannot be met in Section 121(d)(4). These waivers are discussed in Section 2.2 of this report.

1.1.3.3 Long-Term Effectiveness and Permanence

Alternatives are also assessed for the long-term effectiveness and permanence they afford along with the degree of certainty that the remedy will prove successful. Factors which might be considered, according to OSWER Directive 9355.3-01, are as follows:

- Magnitude of residual risks in terms of amounts and concentrations of wastes remaining following implementation of a remedial action, considering the persistence, toxicity, mobility and propensity to bioaccumulate, of such hazardous substances and their constituents.
- Long-term reliability and adequacy of the engineering and institutional controls, including uncertainties associated with land disposal of untreated wastes and residuals.

1.1.3.4 Reduction of Toxicity, Mobility or Volume Through Treatment

The degree to which alternatives employ treatment that reduces toxicity, mobility, or volume are also to be assessed. According to OSWER Directive 9355.3-01, factors that might be relevant include:

- The treatment processes that the remedies employ and the materials they will treat.
- The amount of hazardous materials that will be destroyed or treated.
- The degree of expected reduction in toxicity, mobility, or volume.
- The degree to which the treatment is irreversible.
- The type and quantity of residuals that will remain following treatment, considering the persistence, toxicity, mobility and propensity to bioaccumulate of such hazardous substances and their constituents.
- Whether the alternative would satisfy the statutory preference for treatment as a principal element.

1.1.3.5 Short-Term Effectiveness

The short-term effectiveness of alternatives needs to be assessed considering appropriate factors among the following:

- Protection of the community during remedial actions.
- Protection of the workers during remedial actions.
- Time until remedial response objectives are achieved.

1.1.3.6 Implementability

The guidance also specifies that the ease or difficulty of implementing the alternatives should be assessed by considering the following types of factors:

- Technical Feasibility
  - Degree of difficulty associated with constructing and operating the technology.
  - Expected operational reliability of the technologies.
  - Ease of undertaking additional remedial actions, if necessary.

- Ability to monitor the effectiveness of the remedy.

- Administrative Feasibility

  - Need to coordinate with and obtain necessary approvals and permits (e.g., New York State Pollution Discharge Elimination Permit or SPDES, Dredge and Fill permits for off-site actions) from other agencies and offices.

- Availability of Services and Materials

  - Availability of necessary equipment and specialists.
  - Availability of adequate capacity and location of needed treatment, storage and disposal services.
  - Availability of prospective technologies.
  - Availability of services and materials, plus the potential for obtaining competitive bids.

1.1.3.7 Cost

The types of costs that need to be assessed during the FS include the following:

- Capital costs

- Annual operation and maintenance costs

- Present worth analysis

The typical cost estimate made during the FS is expected to provide an accuracy of +50 percent to -30 percent. Also, when necessary, a sensitivity analysis may be performed. A sensitivity analysis (presented in Section 5.0) assesses the effect that specific assumptions associated with an alternative can have on the estimated cost.

1.1.3.8 State (Support Agency) Acceptance

This assessment evaluates the technical and administrative issues and concerns which the State (or support agency in the case of State-lead sites) may have regarding each of the alternatives.

1.1.3.9 Community Acceptance

This assessment evaluates the issues and concerns the public may have regarding each of the alternatives. This criterion will be addressed in the ROD once comments on the Groundwater FS report and Proposed Plan have been received.

1.2 SITE BACKGROUND INFORMATION

1.2.1 SITE DESCRIPTION

The Forest Glen site is in Niagara Falls, Niagara County, New York (Figure 1-1). It is located in an area zoned for mixed residential, commercial, and industrial use. The majority of the site is located in the City of Niagara Falls, however the two permanent homes on Edgewood Drive are considered part of the Town of Niagara. Shopping malls, fast food restaurants, and commercial businesses are to the southeast and southwest of the site along Porter and Packard Roads. The 120-unit Expressway Village mobile home park, located 500 feet south of Forest Glen's southern boundary, is approximately 19 acres in size. The site is also bounded to the north by property owned by the Power Authority of the State of New York (PASNY), to the east by Interstate Highway 190 and Service Road, and to the west by the Conrail Foote Railroad yard. Two other sites containing hazardous wastes are also in the vicinity: CECOS, a regulated hazardous waste landfill, south of the Forest Glen site, and the New Road Landfill, once investigated by the New York State Department of Environmental Conservation (NYSDEC), to the west of the Conrail Foote Railroad yard.

The 39-acre site is divided by East Gill Creek into two separate parcels of land (Figure 1-2). South of East Gill Creek is the 21-acre Forest Glen Subdivision, which consists of 51 mobile homes and two permanent homes. The majority of the Subdivision's acreage is characterized by residential development including paved roads and driveways, sod lawns, and ornamental trees and shrubs. The only undeveloped areas within the Subdivision are the wooded lots located north and south of Edgewood Drive. Historical reports indicate that these forested areas, which had originally been targeted for residential development, were filled with construction and industrial waste. Access to the site is from Service Road, which is off Porter Road.

To the north of East Gill Creek is the site's Northern Aspect, which is an 18-acre, undeveloped, open field. An eleven foot high 1,300 foot-long berm, constructed of fill and natural materials, runs along most of the Northern Aspect's western boundary. Another significant feature within the Northern Aspect is the wooded wetland area, a low-lying depression of approximately of 1.5 acres, located in the southeastern corner of the Northern Aspect. City tax maps and historical records indicate that residential development of the Northern Aspect had been planned.

Public water services in the vicinity of the site include the City of Niagara Falls and the Town of Niagara. The water departments of these municipalities were contacted for information on the possible existence of water supply wells in the vicinity of the site and CDM Federal conducted a groundwater well search for a 3-mile radius surround the site. No public water supply wells were reported to exist within a 3-mile radius of the site.

The Niagara County Department of Health (NCDH) was contacted for information regarding the possible existence of private water supply wells in the area of the site. No private water supply wells are believed to exist within a two-mile radius of the site. A few non-potable use wells may exist in the farmland to the east of the two-mile radius.

1.2.2 SITE HISTORY

Historical records and aerial photographs indicate that the Forest Glen site was originally a forested wetland. During the late 1950s and the early 1960s, the area surrounding the site was impacted by several major construction projects including construction of the Niagara Expressway (Interstate 190), expansion of the railroad yard adjacent to the west side of the site, and construction of Power Authority conduits located to the west of the site. Maps and aerial photographs indicate a Subdivision or trailer park, thought to be temporary housing for Power Authority workers, was located in the Northern Aspect. It is suspected the housing area was removed to allow for construction of Interstate 190.

The Subdivision remained wooded until the mid 1960s. A 1966 aerial photograph shows the Subdivision cleared of trees. The photograph also indicates a length of East Gill Creek that previously ran through the Subdivision was rerouted 400 feet to the north to its current location.

Anecdotal reports from area residents state that illegal landfilling of industrial wastes occurred during the early 1970s in portions of the Northern Aspect. Drums and chemical wastes were also reportedly dumped in adjacent areas north and east of the area currently occupied by the Subdivision. A 1972 aerial photograph reveals that the cleared, low-lying areas of the site and portions of the former East Gill Creek bed had been filled. Anecdotal reports from local firemen describe the site during those years as a popular scavenger dumping area. Records from the Niagara Falls Fire Department report that a "dump" fire occurred at the site in 1972.

Before 1973, portions of the area were owned by Michigan-Mayne Realty, PASNY, and three individuals, Ernest Booth, James Strong, and Sandford Brownler. In 1973, the land that is now the Subdivision was purchased by Thomas Sottile. Mr. Sottile and his wife formed the Niagara Falls USA Campsite Corporation in that same year. The Subdivision plans were approved by the Niagara Falls City Engineer in October, 1975. Shortly after, the property was leveled and divided into mobile home lots. It is thought that waste materials landfilled in low-lying areas were redistributed throughout the northern portion of the Subdivision during development of the Forest Glen Subdivision. A fire reportedly has destroyed all City file information regarding the development of the Subdivision.

Installation of Subdivision roads and utilities began in the mid-1970s. During these installation activities, ash, packets of white solid material, and small pieces of black plastic were noted in the utility excavations by construction workers. In 1979, the Niagara Falls USA Campsite Corporation began the sale of individual lots for mobile homes. Fifty-three families were living in the Subdivision by the mid-1980s.

According to the Niagara County Health Department (NCHD), in June, 1980 a resident of 31 Lisa Lane, located in the southeastern portion of the Subdivision, reported the presence of a yellow resin-like substance and 55-gallon drum tops in the surface soil surrounding her home. NCHD

subsequently collected soil and water samples from the Lisa Lane property. The solid waste material was analyzed and determined to be a phenolic material.

In August, 1981, local gas company personnel encountered 55-gallon steel drums and a white solid material during excavation activities along Carrie Drive. The substance was later identified as non-hazardous polyvinyl chloride.

In December, 1982, a resident reported a resin-like substance in the surface soil at 43 Lisa Lane. A sample of the substance was collected and analyzed by NCHD. Infra-red spectral analysis, often considered inconclusive, identified the material as carbon methyl cellulose. At that time approximately ten truckloads of this material were reportedly excavated by the owners of the Niagara Falls USA Campsite Corporation and disposed of at the CECOS landfill.

Resident complaints of waste material migrating to the Subdivision surface soil were commonly noted after periods of heavy rain or during construction activities. Drums also were discovered by residents at the ground surface east of Carrie Drive in an area where "odorous and sticky brown" deposits had been noted.

In 1987, EPA Region II was contacted by NCHD and NYSDEC in regard to the Forest Glen site. In August, 1987, the EPA Region II Field Investigation Team (FIT) contractor, NUS, collected four soil samples in the northern portion of the Subdivision during an initial site inspection. The four soil samples were submitted to a Contract Laboratory Program (CLP) laboratory for Hazardous Substance List (HSL) parameters. Analytical results of the samples indicated the presence of volatile organics and semivolatile organic polyaromatic hydrocarbons (PAHs) and heavy metals at varying concentrations in the soil. Several tentatively identified compounds (TICs) were also found at elevated concentrations in the soil.

Based on the 1987 analytical results, EPA determined that additional investigatory activities were necessary at the site. At EPA's direction, FIT conducted a series of follow-up sampling programs from September, 1988 to April of 1989 to determine the extent of soil contamination. All samples were submitted to CLP laboratories for Target Compound List/Target Analyte List (TCL/TAL) parameters. Analytical results from the FIT sampling events indicated that the areas of highest contamination were located in the northern portion of the Subdivision. Soil samples collected from the northern portion of the Subdivision and from the wooded lots north and south of Edgewood Drive, and sediment samples collected from East Gill Creek contained elevated concentrations of semivolatile PAHs, semivolatile TICs, and inorganics. Solid waste material, present in the shallow subsurface soil, was also found to contain elevated levels of the semivolatile TICs. Figure 1-3 indicates the extent of contamination as delineated by the FIT investigations.

In March, 1989, the Agency for Toxic Substances and Disease Registry (ATSDR), after reviewing the FIT sampling data, issued a Health Consultation for the Forest Glen site indicating that site conditions posed a potential health risk to residents. The ATSDR also recommended that the TICs in the soil be positively identified so potential health effects could be determined.

On March 25, 1989, EPA issued an Administrative Order, pursuant to Section 106 (a) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), requiring that the potentially responsible parties (PRPs) carry out actions to reduce the immediate threat posed by site conditions. EPA, at the time of the Administrative Order, identified three PRPs, including the Niagara Falls USA Campsite Corporation, Thomas Sottile, and Ernest Booth, who were determined to be viable and responsible for the contamination in the Subdivision. EPA ordered the three PRPs to secure leaking or potentially leaking drums and containers, and to submit a Work Plan that would detail (1) construction of cover to seal off contaminated soil, (2) offsite disposal of drums, and (3) fencing of undeveloped areas east of the Subdivision on either side of Edgewood Drive. The three PRPs did not comply with the Administrative Order.

In April, 1989, FIT, upon ATSDR's recommendation and at EPA's request, resampled 14 Subdivision locations that previously exhibited high concentrations of TIC contamination. These samples were reanalyzed to confirm the presence of those compounds that previously had only been tentatively identified. Reanalysis positively identified the presence of aniline, benzothiazole, 2(3H)benzothiazole, 2(3H)benzothiazolethione, molecular sulfur, phenothiazine, and perylene in the Subdivision soils. These compounds then became known as site-specific targeted organic compounds.

In the spring of 1989, EPA ultimately conducted interim measures to stabilize site conditions and to protect Subdivision residents. Interim actions included collection, sampling, and offsite disposal of 100 drums, drum remnants, and small hazardous waste containers found in the areas north and east of the Subdivision, installation of temporary fencing around the undeveloped areas of Edgewood Drive, and placement of geotextile covers over "hot spots" where solid waste material was visually observed in Subdivision surface soils.

In July, 1989, ATSDR issued a Preliminary Health Assessment for the Forest Glen site. The assessment, which was based on the April, 1989 confirmatory sampling results, concluded that a significant health risk could occur from direct ingestion of and dermal contact with site soils and wastes contaminated with aniline, benzothiazole, mercaptobenzothiazole, and semivolatile PAHs. Potential health effects included allergic contact dermatitis, phototoxic skin reactions and cancer. ATSDR recommended that individuals be removed from the site due to this significant health risk. On July 31, 1989, ATSDR issued a Public Health Advisory in which it recommended relocating the residents of the Subdivision. Based upon the ATSDR Public Health Assessment and Public Health Advisory, the USEPA, through its removal program and in conjunction with the Federal Emergency Management Agency (FEMA), implemented a temporary relocation program for the Forest Glen residents. Temporary Relocation activities began immediately after the Public Health Advisory was issued.

On November 15, 1989, the Forest Glen site was placed on the Superfund National Priority List (NPL). Once the site was listed on the NPL, EPA released a Focused Feasibility Study (FFS) for the Forest Glen Subdivision that evaluated the effectiveness of the available alternatives in

responding to the potential onsite health threat. EPA then released a Proposed Remedial Action Plan (PRAP) stating that permanent resident relocation was the preferred remedial alternative.

A Record of Decision (ROD) issued in December, 1989 mandated permanent resident relocation as the remedial action for the Forest Glen site. FEMA, on behalf of EPA, implemented all site-related remedial activities, which included the permanent relocation of all residents and the purchase of personal property. The resident relocation program was designated by the ROD as the first operable unit. The ROD also mandated that a Remedial Investigation/Feasibility Study (RI/FS) be conducted for the site as the second operable unit.

In December, 1992, the last family was relocated, leaving the Subdivision deserted. The mobile homes have yet to be removed from the site and are currently boarded up. In 1994, a fence was installed around the Subdivision's perimeter to limit potential access to the site.

CDM Federal initiated RI field activities for the second operable unit in November, 1994. It was noted at the time that the Subdivision mobile homes were in poor condition as a result of vandalism and lack of maintenance. Flooding in the central portion of the Subdivision, caused by leaking water pipes, was also observed. Segments of the site perimeter fence in both the Subdivision and Northern Aspect had been removed, and the pedestrian gate in the Northern Aspect had been dislodged from its hinges.

CDM Federal completed RI field activities in November of 1995. In July of 1997, Roy F. Weston initiated the site Supplemental Groundwater Investigation to address data gaps that were identified in CDM Federal's RI report. CDM Federal completed Supplemental Groundwater Investigation field activities in September of 1997.

1.2.3 CDM FEDERAL'S REMEDIAL INVESTIGATION FIELD ACTIVITY

CDM Federal conducted a two-phase field investigation at the Forest Glen site to acquire data for the RI. The first phase was the initial site characterization, the second was the field data collection activities. The RI for Operable Unit II was conducted in accordance with the Final Work Plan dated December 14, 1993 developed by EPA (as modified by CDM Federal).

Based on the sampling results of previous EPA investigations and discussions with EPA technical staff, CDM Federal developed an analytical list of site-specific compounds that are not included on the TCL/TAL list. These site-specific compounds are collectively referred to as the targeted organic compounds. The targeted organic compound list consists of the following compounds: benzothiazole; 2-mercaptobenzothiazole; anilinobenzothiazole; diphenylamine; N,N'-diphenyl-1,4-benzenediamine; phenyl isothiocyanate; aniline; phenothiazine; and perylene. All samples collected during the RI field investigation were analyzed for the Forest Glen targeted organic compounds.

Initial site characterization, conducted in November and December, 1994, was designed to screen geologic, hydrogeologic, and hydrologic conditions at the site and to refine the soil sampling

locations and monitoring well network proposed in the Final Work Plan. The following activities were conducted during the initial site characterization: a topographic survey, a geophysical survey, a drive-point soil boring program, and a Phase I ecological assessment.

Based on the conclusions of the initial site characterization study, CDM Federal reevaluated and redesigned the subsequent field data collection phase to more clearly define site conditions and to investigate newly identified potential areas of concern. Field data collection activities, conducted from June to November, 1995, included test pit trenching, surface and subsurface soil sampling, wetland sediment sampling, two rounds of surface water and sediment sampling in East Gill Creek, monitoring well installation, continuous and synoptic water level measurements, and two rounds of groundwater sampling.

Table 1-1 summarizes the field activities conducted during CDM Federal's RI. A complete description of the CDM Federal field investigation can be found in Final Forest Glen Remedial Investigation Report (December 1996) and the Forest Glen Feasibility Study (August 1997). This report will only present information on the groundwater investigation conducted as part of CDM Federal's RI field activities.

1.2.3.1 Contaminant Source Investigations

CDM Federal reviewed historical information from Federal, State, and local agencies regarding the Forest Glen site and other sites in the area regulated under CERCLA and the Resource Conservation and Recovery Act (RCRA). This historical information, along with aerial photographs and anecdotal reports from local residents, depicts the past disposal practices at the site and identifies potential contaminant source areas. Based on this information and CDM Federal's field investigation, six areas of concern (AOCs) were designated as discrete units because of their unique physical characteristics, waste disposal practices, and/or presence of visual contamination. These areas of concern are shown on Figure 1-4 and are described below.

1.2.3.1.1 Berm (AOC 1)

The berm is located in the Northern Aspect (AOC 2). Approximately 1,300 feet long, 50 feet wide, and 11 feet high, it is bordered on the west and north by the Conrail Foote Railroad yard and to the east and south by the Northern Aspect. The berm, constructed of fill material and native soil excavated from the ground surface of the Northern Aspect, was reportedly built to act as a sound barrier for the residential area that had been planned. CDM Federal's geophysical survey identified a series of anomalies associated with the berm. Soil boring activities later confirmed the presence of waste and fill materials within the central portion of the berm.

1.2.3.1.2 Northern Aspect (AOC 2)

This area consists of the 18-acre open field located north of the Subdivision. The area is bounded to the south by East Gill Creek and the Service Road, to the north by the Conrail Foote Railroad

yard, and to the east by Interstate 190. Anecdotal reports from area residents also suggest that illegal landfilling occurred in the Northern Aspect throughout the years. These reports were later confirmed when drums containing chemical wastes were discovered and removed from the area during EPA removal actions in 1989. CDM Federal's field investigation also later confirmed these reports. Test pits, later excavated during field data collection activities to confirm the anomalies, unearthed isolated pockets of buried trash, construction debris, and scrap metal.

1.2.3.1.3 Wooded Wetland (AOC 3)

This is a 1.5-acre low-lying wooded wetland area located in the southeastern part of the Northern Aspect. The area is characterized as a palustrine forest broad leaved deciduous wetland. It is bounded on the north and west by the Northern Aspect, on the south by East Gill Creek, and on the east by Service Road.

1.2.3.1.4 East Gill Creek (AOC 4)

East Gill Creek is a narrow, shallow, low flowing creek that serves as the Subdivision's northern boundary. Subdivision runoff is directed into the creek via two outfalls. Aerial photographs indicate that a section of the creek was rerouted from its original location, the area now between Lisa Lane and Carrie Drive, 400 feet north to its current location sometime in the late 1960s. The creek flows onto the site from the east, after being directed under Interstate-190 by a series of culverts. It then flows westward across the northern portion of the Subdivision and is directed off the site through a culvert under the Conrail Foote Railroad yard. The creek emerges through another culvert located west of the railroad yard, before it is directed underground through another westward-flowing culvert.

1.2.3.1.5 Edgewood Drive Wooded Lots (AOC 5)

This area of concern consists of the two wooded, undeveloped lots located to the north and south of Edgewood Drive. The lots are bisected by Edgewood Drive and are both bounded by T Mark drive to the west and the Service Road to the east. The north lot is approximately 3 acres in size and is bounded to the north by East Gill Creek. The south lot is approximately 3.3 acres in size and extends approximately 250 feet to the south of Edgewood Drive. Aerial photographs and anecdotal reports from residents suggest illegal landfilling occurred in the wooded areas over the years. CDM Federal's field investigation appeared to confirm the historical reports and analytical results.

1.2.3.1.6 Forest Glen Subdivision (AOC 6)

This area includes the abandoned residential Subdivision located in the southwest corner of the site; it consists of 51 mobile homes situated on 10 acres. The Subdivision is bounded by T Mark Drive to the east, the Conrail Foote Railroad yard to the west, Lisa Lane to the south, and East Gill Creek to the north, and is accessed via Edgewood Drive. CDM Federal's field investigation, which included collection of subsurface soil samples from throughout the Subdivision and a concentration

of surface soil samples in the Subdivision's northern end, confirmed EPA's earlier investigations. Black-stained fill and elevated contaminant concentrations were detected in numerous samples collected from the northern end of the Subdivision.

1.2.3.2 Groundwater Investigation

Because groundwater quality was not characterized during the previous EPA investigations at the site, the CDM Federal groundwater sampling program sought to define the nature and extent of site-related contamination in the two local aquifer zones. Two rounds of groundwater samples were collected from nine newly installed well clusters. All well clusters consist of two wells, one in the shallow zone and one in the deep, except cluster MW-3. Overburden and perched wells were installed at location MW-3, along with the shallow and deep bedrock monitoring wells.

1.2.3.2.1 Monitoring Well Installation

The monitoring well program focused on the groundwater which may have been impacted by the Subdivision source areas identified in the previous studies. CDM Federal initially proposed that seven monitoring well clusters be installed to evaluate the potential horizontal and vertical extent of groundwater contamination beneath the Subdivision. Each cluster was to consist of an overburden (zero to 20 feet BGS), a shallow bedrock (20 to 35 feet BGS), and a deep bedrock monitoring well (greater than 35 feet BGS).

Upon completion of the drive point soil borings during the initial site characterization, CDM Federal noted the site lithology generally consisted of 10 to 12 feet of thick, dry, and stiff red-brown clay overlying 2 to 3 feet of a moist, red-brown clay till, overlying weathered gray Lockport dolomite. With the exception of limited areas of perched groundwater located in Subdivision fill areas, groundwater was encountered only in the thin clay till layer and in the fractured bedrock. Additionally, no subsurface fill or visual contamination was encountered in the Northern Aspect during the initial site characterization soil boring activities. Based on the information obtained during the initial site characterization, a total of nine monitoring well clusters were installed with respect to the west trending regional groundwater flow. The locations of the nine monitoring well clusters are shown on Figure 1-5.

CDM Federal's rationale for each monitoring well cluster is as follows:

- Monitoring well cluster MW-1(S/D) is located on the east side of the Service Road across from the intersection with Edgewood Drive. This cluster provides data on upgradient, background groundwater quality.

- Monitoring well clusters MW-9(S/D) and MW-2(S/D) are source area wells located in the wooded lot north and south of Edgewood Drive, respectively.

- Monitoring well cluster MW-3 is a source area well located in the fill area, west of T Mark Drive, that was delineated during drive-point sampling activities. Perched water (PW), located in the fill, was also encountered during these activities. Therefore, perched water and overburden (OB) monitoring wells were installed in addition to the shallow and deep bedrock wells for a total of four wells at cluster MW-3.

- Monitoring well clusters MW-4(S/D), MW-5(S/D), and MW-6(S/D), are located along the site's western fence line. These wells are downgradient of the delineated fill area and serve to intercept the groundwater flow from the potential source areas.

- Monitoring well clusters MW-7(S/D) and MW-8(S/D) are located off site and downgradient of the delineated fill area. These wells intercept offsite flow from the site's potential source areas.

CDM Federal has defined the groundwater zones monitored by the well network as follows:

Perched Water. The perched water zone at MW-3 was defined as the water encountered locally in the fill material that was encountered above the clay layer .

Overburden Groundwater. The overburden groundwater zone at MW-3 was defined as the groundwater encountered locally in the fill present above the bedrock.

Shallow Groundwater. Shallow groundwater was defined as the first groundwater encountered in a zone of highly fractured and broken bedrock, as determined from coring and water loss during coring operations.

Deep Groundwater. Deep groundwater was defined as the second highly fractured and broken bedrock zone encountered, as determined from coring and water loss during coring operations.

1.2.3.2.2 Groundwater Sampling

The first round of groundwater sampling was conducted from September 11 through September 14, 1992, approximately one month after well installation and development. A confirmatory sampling round was conducted from November 13 through November 17, 1995. Table 1-2 summarizes the well data for the sampling rounds.

Groundwater samples were analyzed for TCL organics, TAL inorganics, targeted organic compounds, TOC, nitrate-nitrite, chemical oxygen demand (COD), total Kjeldahl nitrogen (TKN), ammonia, biochemical oxygen demand (BOD), and TDS.

1.2.3.2.3 Water Level Measurements

Prior to the first groundwater sampling event, continuous water level measurements were collected from three well clusters to monitor for cyclical head fluctuations in the perched water, overburden water, shallow bedrock, and deep bedrock aquifer zones. A total of three well clusters were monitored.

Before each of the two groundwater sampling rounds, synoptic water level measurements were collected from each site monitoring well. Four additional rounds of synoptic water level measurements were collected during the morning and afternoon on November 16 and December 28, 1995. These data were collected in an effort to identify any regional fluctuations in water levels that might occur throughout the day. Table 1-3 summarizes the water level elevation data.

1.2.4 SUPPLEMENTAL GROUNDWATER INVESTIGATION

CDM Federal concluded in the Final Forest Glen RI report that several data gaps, related to the site groundwater flow direction and groundwater quality, existed. These data gaps and CDM Federal's recommendations to address them are presented below.

- It was recommended that one additional shallow and deep bedrock well be installed recommended in the Subdivision, south of MW6, to verify the groundwater flow direction and quality in the southern section of the site.

- Although there were anecdotal reports regarding contamination in the Northern Aspect, this area was not considered a source area during the RI/FS project planning. Additionally, the RI drive-point soil boring investigation performed during the initial site characterization did not reveal areas of fill. Therefore, the RI did not include a groundwater investigation in the Northern Aspect. Since high levels of organic and inorganic contamination were found in the fill material in the berm and the adjacent test pits during field data collection activities, this area was subsequently determined to be a potential source area. During the leveling of the ground surface in the Northern Aspect and the construction of the berm, the clay layer may have been breached, potentially allowing contaminants to migrate into the groundwater. It was recommended that several monitoring well clusters be installed in the Northern Aspect to characterize groundwater quality in the area.

- Volatile organic compound concentrations were noted to increase in some instances by an order of magnitude between the two rounds of sampling. Inorganic detections were noted to decrease in the second round. Therefore, it was recommended that additional groundwater sampling be conducted.

Based on CDM Federal's recommendations, EPA directed Roy F. Weston (Weston), under its Response Engineering Analytical Contract (REAC) to conduct a Supplemental Groundwater

Investigation at the Forest Glen site. As part of the supplemental investigation, Weston installed monitoring wells, collected a round synoptic water level measurements, and collected a round of groundwater samples (Round Three) from the both the existing and newly installed monitoring wells.

As per EPA direction, CDM Federal, as part of the Supplemental Groundwater Investigation, conducted an aquifer test, collected a round synoptic water level measurements, and collected a round of groundwater samples (Round Four) from the both the existing and newly installed monitoring wells.

1.2.4.1 Monitoring Well Installation

The Supplemental Groundwater Investigation monitoring well network focused on the characterization of the characterization of groundwater quality and flow direction in the southern section of the Subdivision and the characterization of groundwater quality in the northern aspect. Based on the information obtained during the CDM Federal RI field activities, a total of six monitoring well clusters were installed with respect to the west trending regional groundwater flow. The locations of the six new monitoring well clusters are shown on Figure 1-5.

CDM Federal's rationale for each monitoring well cluster is as follows:

- Monitoring well cluster MW-10(S/D) is located on the west side of Lisa Lane in the southern portion of the Subdivision. This cluster provides data on groundwater quality and flow direction the southern portion of the subdivision.

- Monitoring well cluster MW-11(S/D) is located along the eastern boundary of the Northern Aspect. This cluster provides data on upgradient, background groundwater quality. A significant water bearing interval was encountered in the overburden at this location. Therefore, an overburden (V) monitoring well was installed in addition to the shallow and deep bedrock wells for a total of three wells at cluster MW-11.

- Monitoring well clusters MW-12(S/D), MW-13(S/D), and MW-14(S/D), are located along the western boundary of the berm. These wells serve to intercept the groundwater flow from this potential source areas. A significant water bearing interval was encountered in the overburden at MW-12. Therefore, an overburden (V) monitoring well was installed in addition to the shallow and deep bedrock wells for a total of three wells at cluster MW-12.

- Monitoring well cluster MW-15 (S/D) is located in the center of the Northern Aspect in a potential source area that was delineated during the CDM Federal RI field investigation.

The following groundwater zones monitored by the Supplemental Groundwater Investigation well network:

Overburden Groundwater. The overburden or vadose groundwater zone was defined as the groundwater locally encountered in the overburden at MW-11 and MW-12.

Shallow Groundwater. Shallow groundwater was defined as the first groundwater encountered in a zone of highly fractured and broken bedrock, as determined from coring and water loss during coring operations.

Deep Groundwater. Deep groundwater was defined as the second highly fractured and broken bedrock zone encountered, as determined from coring and water loss during coring operations.

1.2.4.2 Aquifer Testing

CDM Federal, in an attempt to estimate the hydraulic properties (transmissivity in particular) of the bedrock aquifer at the Forest Glen Site, conducted an aquifer performance test (APT) in the upper 50 feet of the Lockport Dolomite aquifer. The 10-hour aquifer test was conducted on September 11, 1997.

Prior to initiating the test, background water level measurements were continuously collected from all the test wells for a period of approximately seven days to monitor for cyclical changes, pumping center impacts, barometric pressure effects and rainfall effects.

A step drawdown test was performed on September 9, 1997 to determine the optimum pumping rate for MW-5S (production well) for the aquifer test. MW-5S was chosen to act as the production well since it had the highest concentrations of groundwater contaminants of all the site monitoring wells. The step drawdown test consisted of pumping MW-5S at three different discharge rates. The first and third step lasting approximately one hour and the middle step, 15 minutes. During the step drawdown MW-5S was pumped at successive rates of 2.4 gallons per minute (gpm), 5 gpm, and 10 gpm. No recovery was allowed between steps. The pump rate of 10 gpm was the maximum for the type of pump used (Grundfos Rediflo2) and drawdown was approximately 0.5 foot. It was evident, however, at the first step, that a greater capacity pump would be needed to stress the aquifer at MW-5S.

It was determined prior to the aquifer test that monitoring wells MW-3S, MW-4S, MW-4D, MW-5D, MW-6S, MW-6D, MW-9S, MW-10S, MW-14S, MW-14D, and MW-15S would be used as observation wells.

During the test, the pump operated for a period of 10.5 hours. Flow was measured approximately every hour by using a stopwatch to record the time needed to fill a beaker with a known volume.

The average flow rate for the test was estimated to be 22 gallons per minute (gpm). All water pumped from the production well was discharged to a temporary holding tank during the test.

Drawdown was measured in each of the test wells during the 10.5-hour pumping period and for a recovery period of approximately 9 hours at predetermined time increments. These measurements were collected using pressure transducers and the HERMIT 2000 Environmental Datalogger.

A detailed description of the procedures used and analysis of the aquifer test results are presented in CDM Federal's Aquifer Performance Test Report that is presented in Appendix A of this report.

1.2.4.3 Groundwater Sampling

Round Three groundwater sampling was conducted by Weston from July 22 to August 1, 1997. A confirmatory sampling round (Round Four) was conducted by CDM Federal from September 15 through September 18, 1997. All newly installed and existing site monitoring wells were sampled during both rounds. Groundwater samples were analyzed for low detection level volatile organics, TCL organics, TAL inorganics, and targeted organic compounds. A discussion of the procedures used by Weston and the data for the Round Three investigation was presented to EPA in a trip report dated September 19, 1997. A technical memorandum that detailed the Round Four data collection and analytical results was submitted to EPA by CDM Federal on July 24,1998. Table 1-2 summarizes the well data for both sampling rounds.

1.3 PHYSICAL FEATURES OF THE FOREST GLEN SITE

A complete description of the site's physical features can be found in Final Forest Glen Remedial Investigation Report (December 1996) and the Forest Glen Feasibility Study (August 1997). is report will only present information on the site's physical features that impact groundwater flow as well as groundwater quality.

1.3.1 SURFACE FEATURES

The Forest Glen site is generally flat with the ground elevation increasing toward to the north. Local variations in topography occur along East Gill Creek, the northern aspect berm, surface drainage features, and several soil mounds. Surface elevations range from 591 feet above mean sea level (amsl) in the subdivision to 608 feet amsl in the northern aspect (including the approximately 11-foot-high berm).

The subdivision's two homes and 51 mobile homes have been badly vandalized but all remain standing. The two houses and the mobile homes are situated on the four paved roads: Edgewood Drive, T Mark Drive, Lisa Lane, and Carrie Drive. The entire subdivision is surrounded by a 15-foot-high chain link fence that is equipped with a vehicle gate, on Edgewood Drive, and three pedestrian gates, located throughout the subdivision. The integrity of the pedestrian gates and a portion of the fenceline along T Mark Drive have been compromised.

The entire site, excluding the paved subdivision and northern aspect berm, is classified as wetland. Ponded water is seasonally present throughout the undeveloped areas of the site. East Gill Creek flows onto the site from the east and flows westward across the northern portion of the subdivision forming its northern boundary.

1.3.2 METEOROLOGY

The City of Niagara Falls is located on the shores of the Niagara River, which flows northward from Lake Erie to Lake Ontario. The average annual daily temperature is 48° F, with the average summer temperature of 68° F and the average winter temperature of 27° F (NOAA, 1992). The prevailing wind direction is from the west and north with an average wind speed of 9 miles per hour (AWS, 1987). Summer is characterized by cool breezes originating from the Great Lakes. Gale force winds with snow occur in winter.

Because of the close proximity of the Great Lakes, the area receives an average of 35 inches of rain annually that is distributed at a fairly consistent rate of approximately 3 inches per month. In the winter months, precipitation comes in the form of snow, averaging 67 inches per year (AWS, 1987). Table 1-4 presents a summary of climatic data in the vicinity of the site.

1.3.3 SURFACE WATER HYDROLOGY

The site, excluding the berm in the northern aspect, is fairly flat with a gentle southern declination in the northern aspect. Local variations in topography occur along East Gill Creek and several drainage ditches on and adjacent to the site.

There is one low flowing creek and two surface water pools onsite. In addition to these, minor depressions and drainageways exist on a microscale throughout the site. Figure 1-6 depicts the surface waterways and water bodies located at the site. East Gill Creek (AOC4) a shallow and slow-flowing creek, runs east to west and is located between the northern aspect and Edgewood and Carrie Drives. It enters the site approximately 10 feet to the west of the Service Road through three adjacent culverts. At this point, the creek is an undistinguished drainage channel, approximately 8 feet wide and variable in depth to one foot, with small vegetated islands of mounded sediment. As the creek flows westerly adjacent to the subdivision, it is approximately 6 feet wide and 9 inches in depth. Farther west, at the northwest corner of the subdivision, the creek makes a turn and flows southerly. Here, the creek is approximately 4 feet wide and 10 inches deep. At this point and for approximately 30 feet, the creek narrows to approximately 12 to 18 inches wide, the streambed slopes at 5 to 10 percent, and the flow becomes more rapid. Approximately 300 feet downstream, where the creek exits the site through a culvert underneath the railroad yard at the eastern boundary of the site, small riffles exist due to the presence of cobbles. The water depth at this location varies from 3 to 10 inches and the creek forms a 10- by 5-foot pool.

East Gill Creek originates approximately one mile upstream of the site, draining residential and commercial areas before entering the site. Upon leaving the site, the creek flows through a culvert

under the Conrail Foote Railroad yard to the west of the site. The creek reemerges adjacent to the western edge of the railroad yard, where it continues to flow approximately 20 feet to the west and into another culvert. East Gill Creek ultimately flows into Hyde Park Lake, joining the main channel of Gill Creek, at a location immediately south of New York State Route 182 (approximately 1 mile southwest of the site). East Gill Creek, as a tributary to Gill Creek, is classified by NYSDEC as a Class C fresh surface water (Beech, 1996). Class C fresh surface waters are suitable for fish propagation and survival as well as for primary and secondary contact recreation (including swimming and boating), although other factors may limit recreational use.

The onsite portion of East Gill Creek appears to be a permanent stream (i.e., with continual water presence) with no measurable flow, as observed during the November, 1995 sampling activities. The streambed material appears to be of a fine texture (clay with silt).

The pH of the water is basic and varies from its most acidic as it enters the site to its most basic, pH greater than 8, as it leaves the site. The dissolved oxygen content of the onsite portion of the creek was demonstrated to vary widely between summer and late fall. The dissolved oxygen content of the creek during the August, 1994 field activities was so low that it did not comply with the water quality standard (less than 4.0 mg/l) for minimum daily average dissolved oxygen.

Two other surface water bodies exist at the site. One, a shallow body of water located in a depression within the wooded wetland (AOC 3) has the appearance of a historical, winding streambed. It is estimated to be one-third acre in size. The surface water from this location drains into the East Gill Creek. The other notable surface water body is 20 feet south of Edgewood Drive and 15 feet west of the permanent residence south of Edgewood Drive. This shallow pool was observed to be approximately one tenth acre in size during the May, 1995 field activities; however, is likely to vary seasonally.

As observed during the May and November, 1995 ecological field activities, other areas on site have pockets of smaller, amorphous pools of standing water. One such area is in the woods between East Gill Creek and Edgewood Drive (north lot of AOC 5). Another is in the woods south of the permanent residence to the south of Edgewood Drive (south lot of AOC 5). All of these pools are shallow and may exist seasonally. Some pools, such as several in the woods to the southeast of the site, are vegetated with wetland plants.

Much of the site surface water runoff is discharged into East Gill Creek. Figure 1-6 shows the location and flow direction of the onsite storm sewers. In the northern aspect, surface water runoff generally flows southward along minor drainage depressions into the wooded wetland (AOC3) and ultimately drains into East Gill Creek. The surface water runoff from the wooded lot north of Edgewood Drive drains into East Gill Creek and into the storm sewer at the corner of T Mark and Carrie Drives. Surface water runoff from the wooded lot south of Edgewood Drive flows either into the drainage ditch along Edgewood Drive and into the storm sewer inlet at T Mark Drive, or to the west, directly into the storm sewer inlets along T Mark Drive.

Surface water runoff from the subdivision flows into the storm sewer inlets along Carrie and T Mark Drives and along Lisa Lane. Runoff that enters those storm sewer inlets located along Carrie and T Mark Drives and along the eastern-most portion of Lisa Lane is discharged to East Gill Creek via an outfall located approximately 75 feet north of where the creek exits the site. Runoff that enters storm sewer inlets located along the remainder of Lisa Lane is discharged to East Gill Creek via an outfall located approximately 45 feet north of where the creek exits the site.

1.3.4 REGIONAL AND SITE GEOLOGY

1.3.4.1 Regional Geology

The city of Niagara Falls is located within the Erie-Ontario Lowlands Physiographic Province. The geomorphology of this area is the product of the advance and subsequent retreat of the Laurentide continental glacier between 20,000 and 30,000 years ago. One of the most significant topographic features in the region is the east-northeast trending Niagara Escarpment. This feature is interpreted to be the result of post-glacial uplift related to unloading caused by the removal of the ice sheets (Tepper, et.al., 1990). Relief along the north face of this escarpment is on the order of 200 feet. Post-glacial uplift is also thought to be the cause of the other main topographic feature in the area: the Niagara River Gorge. As the terrain rebounded following the retreat of the continental glacier, the Niagara River cut back into the escarpment, creating a gorge approximately 160 feet deep.

The area to the south of the escarpment and to the east of the Niagara River Gorge was shaped primarily by the action of the advancing and retreating glacier. As the ice sheet advanced, the underlying rock units were scoured and eroded. Much of the material picked up by the glacier was deposited as terminal moraine material. The remainder was deposited as ground moraine along the base of the glacier. This material, commonly known as lodgment till, is compact and generally very impermeable. The resulting topography is generally flat due to the scouring effect of the glacier, and poorly drained due to the impermeability of the glacial lacustrine clay and glacial till.

The region surrounding the site exhibits glacial geomorphology, although evidence of manmade modification is apparent. The open areas to the northeast and southwest of the site display a slightly hummocky terrain. The land surface slopes gently to the south and the total local relief is on the order of about 10 to 15 feet. The regional overburden thickens to the southeast and thins to the west toward the Niagara Gorge and to the north toward the Niagara Escarpment (NUS, 1989).

The underlying bedrock consists of approximately 150 feet of upper Silurian Lockport Dolomite overlying approximately 120 feet of middle Silurian limestones and shales (Clinton Group) including the impermeable Rochester Shale (Johnston, 1964). Below the Clinton Group is approximately 130 feet of lower Silurian interbedded limestone and sandstone. Underlying the interbedded limestone and sandstone is the upper Ordovician Queenstone Shale (Johnston, 1964)

(Figure 1-7). This stratigraphic sequence is well exposed at Niagara Falls where the Lockport dolomite forms the lip of the Falls (Figure 1-8). The bedrock beneath the site and throughout the region dips gently to the south at 29 feet per mile (Zenger, 1962).

1.3.4.2 Site Geology

Stained Fill Material - Fill was encountered in borings and test pits in the northwest section of the Northern Aspect, in all berm samples, in some of the borings north and south of Edgewood Drive, and in the northern and central section of the Subdivision. The locations of the CDM Federal RI soil borings are shown on Figure 1-9.

The fill was thickest in the northwest section of the Northern Aspect and in the berm (Figure 1-10). The geophysical anomalies, investigated during test pit investigations, were correlated to a fill composed of clay, wet burnt cardboard, metal pipe, and some black-stained material. Similar fill material was also observed beneath the berm. The berm, however, also contained white and yellow powder granules and more black stained material than was what encountered in the test pits.

The fill north and south of Edgewood Drive consisted of a black-stained silt and fine sand that contained black, coal-like material and white and yellow powder granules. North of Edgewood Drive the fill was 2 to 4 feet thick, while south of Edgewood Drive it was 6 to 7.5 feet thick. Table 1-5 shows the grain size distributions for fill samples.

The fill below the Subdivision was similar to that found in the vicinity of Edgewood Drive. The fill was encountered from the ground surface to depths of 9.3 feet. The greatest thickness of fill was observed in borings DP-013 and DP-017, with thicknesses of 9.3 feet and 7.5 feet, respectively. The fill encountered in these two borings (DP-013, DP-017) appeared to have been artificially placed over the native clay layer. In all other borings, where fill was encountered, it appears to be mixed with the native clay. Two to three feet of black-stained silty clay was observed beneath the fill in several of these borings.

Clay

The clay layer, overlain by approximately 6 inches of topsoil, was found in every boring. The clay consists of a 2-foot yellow-brown to brown silty clay layer underlain by a 4 to 8-foot red-brown to brown clay layer. The clay is laminated, dry, and stiff, with numerous breaks along silt partings. Moist seams of less than 1-centimeter width, usually associated with very fine sand partings, were noted in some split-spoon samples collected from the bottom of the clay layer. These seams are too thin to produce any noticeable amounts of groundwater. No groundwater was encountered in the overburden clay layer.

The thickness of the clay ranged from 0.5 feet in boring SB-01 to 13.0 feet in boring DP-006. The thickness of the clay is generally between 6 and 10 feet beneath most sections of the

Subdivision and the Northern Aspect. The clay is thin in the northwest section of the Subdivision and thicker in the south central portion of the Subdivision, and in the southern section of the Northern Aspect (Figure 1-11). It is possible that during illegal landfilling activities that the clay layer was breached which would have allowed fill material to come in contact with the more permeable clay till.

Shelby tube samples of clay taken from the Subdivision and the Northern Aspect indicate the samples are composed of 60 percent clay, 35 percent silt and 5 percent fine sand. The coefficient of permeability for the two samples was approximately 1.0×10^{-8} cm/sec. The plasticity indices and liquid limits of both samples reveal clay of moderate plasticity with a moisture content of 26 percent. Grain size analyses of 34 split-spoon samples of clay collected during soil boring activities showed similar grain size distributions when clay and colloid sizes were combined (Table 1-6).

Clay Till - The transition downward from the clay layer into clay till is indicated by the presence of soft silty clay mixed with pebbles, gravel, and sand, (Table 1-7) and by moist to wet conditions. This poorly sorted material is typical of glacial sediments found in the site vicinity (Maslia and Johnston, 1982). The clay till is encountered throughout the site and at approximately 8 to 10 feet BGS. The clay till directly overlies the Lockport Group bedrock at the site. The full thickness of the clay till was observed in eight borings: DP-001, DP-002, DP-004, DP-005, DP-006, DP-008, SB-07, and DP-031. These borings were drilled in order to characterize the thickness of the clay till and the depth to bedrock. The thickness of the clay till ranged from 1.1 feet in boring DP-006 to 7.1 feet in DP-002 and averaged 2 to 3 feet thick.

Lockport Dolomite - Dark gray dolomite fragments, indicating the top of bedrock, were encountered in seven borings and two test pits advanced to bedrock contact. The top of bedrock (Lockport Dolomite) was determined by auger or split-spoon refusal and by visual inspection of the sample. The bedrock elevation map in the vicinity of the monitoring wells reveals areas of differential erosion. A bedrock surface elevation high is located at MW-7, while a bedrock surface elevation low is present at MW-5 (Figure 1-12). Bedrock is unusually shallow (5 feet BGS) in the area between the Subdivision (near MW-4) and the Northern Aspect, (near test pits TP-09 and TP-10). This area also coincided with a large negative electromagnetic anomaly (blue region) that was noted near north grid nodal points 0.0, 2.0 and 0.0 1.5. Shallow bedrock may be indicated by a negative electromagnetic anomaly since less highly conductive clay and more low conductive dolomite is encountered by the electromagnetic field generated by the survey instrument.

During the CDM Federal RI, nine monitoring well locations were cored into the bedrock beneath the site. The Lockport dolomite encountered is similar among the cores. The first 10 to 15 feet of rock is moderately fractured and highly vuggy. Most fractures are horizontal, paralleling bedding, with some vertical fractures present. The vugs are sometimes filled with recrystallized gypsum. The next 7 to 10 feet consist of fine grained, fairly competent dolomite, with few, if any, vugs. This competent zone is considered to define the division between the shallow and

deep bedrock zones beneath the site. The competent zone is then followed by an increase in vugginess and horizontal fractures. A few vertical fractures were noticed in this zone. This zone was approximately 25 feet thick and was terminated as the open hole monitoring interval of the deep bedrock zone well (Figures 1-13 through 1-15).

1.3.5 REGIONAL AND SITE HYDROGEOLOGY

1.3.5.1 Regional Hydrogeology

Overburden - The overburden consists of the glacial lacustrine clay deposits, fill, where encountered, and the the basal clay till and extends approximately from zero to 20 feet BGS. The overburden is generally a very low permeability formation; hydraulic conductivity values ranging from 1×10^{-4} to 1×10^{-6} cm/sec have been estimated by Woodward-Clyde (1988). The low permeability of these deposits commonly results in either perched water conditions below surface or standing water conditions at the surface. The static water table is often found in the sand lenses directly above the clay till. These sand lenses are not considered to be a significant aquifer in the area and were not encountered during the RI field activities. According to Johnston (1964), well yields from the overburden zone in the Niagara Falls area are on the order of 1 to 3 gallons per minute (gpm).

Lockport Dolomite - The Lockport Dolomite is the major water-producing formation of the area. Bedding plane fractures that parallel the formation bedding are believed to transmit the majority of the groundwater flow (Johnston, 1964; Miller and Kappel, 1987; Yaeger and Kappel, 1987). High angle to vertical joints related to regional stress patterns are common in the Lockport Dolomite and also contribute groundwater production from this formation. These joints are best developed in the upper part of the Lockport Dolomite, where a relatively high degree of weathering has occurred (Johnston, 1964). Where dissolution has occurred, these joints may serve as conduits for vertical and horizontal movement of groundwater between bedding plane fractures. The prominent sets of vertical joints in the Niagara Falls area are oriented N65°E and N30°W (Johnston, 1964). Near the bedrock surface, joints tend to be open and well developed; however, they become relatively tight and poorly developed at depth (Miller and Kappel, 1987).

Johnston (1964), Yaegar and Kappel (1987) and Tepper, et al. (1990) all provide evidence for a regional structural lineament (fracture zone) that passes southeast of the site and may have a dramatic influence on the regional groundwater flow pattern. The original evidence for this feature was provided by Johnston (1964), who made direct observations of fractures at the intersection of the Falls Street Tunnel and the buried conduits. Johnston correlated these fractures to an alignment of highly productive wells. A dewatering well installed along this alignment was pumped at 950 gallons per minute for one month before the surrounding bedrock was dewatered. Although structural, seismic, and hydrogeologic evidence support the existence of this feature (Tepper, et al., 1990), the details of its shape, size, and subcrop pattern are not well defined. Information provided in Tepper, et al., (1990) was used to plot the approximate location

of the lineament (Figure 1-16). The lineament appears to pass approximately 4,000 feet southeast of the site.

Johnston (1964) reported that a significant amount of groundwater flow occurs through horizontal water-bearing bedding plane fracture zones in the bedrock underlying the site, based on observations of the exposed walls of the buried conduits which cut through the Lockport Dolomite west of the site area. Johnston (1964) identified seven water-bearing zones, each consisting of either a single open bedding plane or an interval of rock layers containing several open bedding planes. These water bearing zones are isolated from each other by impermeable bedrock, and are therefore considered to be semiconfined aquifers.

Power Authority of the State of New York (PASNY) Hydroelectric Power Projects on Hydrogeology - The regional topography makes the Niagara Falls area well suited for the development of hydroelectric power. Figure 1-16 shows the main features of the PASNY hydroelectric power operations in the Niagara Falls vicinity. The Niagara River Gorge provides for a head differential of approximately 160 feet between two large manmade reservoirs located on either side of the gorge and the river base. The Niagara River above the falls is a groundwater recharge boundary. At the falls, the surface water elevation drops below the surrounding groundwater level and the river forms a regional groundwater discharge boundary. The numerous seeps found in the walls of the gorge provide ample evidence of this relationship.

The Forebay Canal is a discharge boundary and Robert Moses Power Plant Reservoir is a recharge area. A groundwater convergence lies along the buried conduits. According to Miller and Kappel (1987), the convergence is related to a subsurface drainage system that serves the buried conduits. Daily head fluctuations in the Forebay Canal are on the order of 15 feet. This head fluctuation is carried along the buried conduits' drainage system and has been detected as far south as the CECOS Landfill (Yaeger, personal communication) just south of the site, and affects groundwater levels within 0.5 mile of the buried conduits (Miller and Kappel, 1987). Groundwater flowed to the southwest in the vicinity of the site before the PASNY construction (Figure 1-17) but changed to the west, toward the buried conduits, after construction (Figure 1-18).

1.3.5.2 Site Hydrogeology

At Forest Glen, site hydrogeology is defined by three hydrostratigraphic zones: perched overburden water, shallow bedrock, and deep bedrock.

Overburden Zone - The overburden consists of the glacial lacustrine clay deposits, fill, where encountered, and the basal clay till and extends approximately from zero to 20 feet BGS. Due to the low permeability of the overburden materials, perched groundwater conditions were encountered in two drive-point soil borings (DP-013 and DP-017), and within the fill material in the berm and the test pits. Since perched conditions were not aerially extensive, CDM Federal's investigation focused on the shallow and deep bedrock groundwater zones. A significant water

bearing interval in the overburden was also encountered by Weston in the Northern Aspect (MW-11V and MW-12V).

Shallow Bedrock Zone - This zone is encountered at depths from 16 to 28 feet BGS and is the first zone of highly fractured Lockport Dolomite bedrock where significant core drilling water loss occurred. Groundwater in this zone flows both vertically and horizontally through an interconnecting system of closely spaced joints and bedding plane fractures. Over large areas where the density of the vertical joints is high, this zone has been modeled as a confined heterogenous aquifer. However, given the relatively small size of the site, this aquifer should be considered a discretely, fractured, heterogenous, anisotropic aquifer. The Weston monitoring well installation program confirmed CDM Federal's definition of this groundwater zone.

Deep Bedrock Zone - Below the shallow zone, the vugginess and fractures decrease and a 5 to 10-foot section of fine-grained structurally competent dolomite is encountered. Below this competent zone, the deep bedrock is characterized by an increase in vugginess and fractures.

This zone is encountered at depths of 40 to 45 feet BGS. Although literature states that each fracture can be treated as a discrete, confined, homogeneous anisotropic aquifer at this depth, some vertically oriented closed and open fractures containing mineralization were observed while coring this zone. It is probable that hydraulic communication occurs between the shallow and deep bedrock zones beneath the site. The Weston monitoring well installation program confirmed CDM Federal's definition of this groundwater zone.

1.3.5.2.1 Groundwater Flow

Shallow Bedrock Zone - Synoptic water level measurements collected during the RI indicated that the groundwater flow in this zone closely mimicked the top of bedrock elevation contours toward a bedrock surface low beneath the MW-5 cluster. Groundwater elevations in wells adjacent to MW-5S were between 0.5 to 1 foot higher than in MW-5S.

The groundwater elevation of MW-7S was anomalously high (on the order of five feet) compared to surrounding wells. This groundwater high results in a local flow to the east and south that deviates from the expected regional flow to the west.

Synoptic water level measurements collected during the Supplemental Groundwater Investigation confirmed CDM Federal's earlier findings. Groundwater contour elevations for the shallow bedrock aquifer generally mimicked the bedrock surface with flow generally to the south-southwest. Flow was again noted to converge in the vicinity of MW-5S as well as MW-14S and MW-4S. An anomalous groundwater elevation high was again noted at MW-7S. This high directs flow from this area east toward the subdivision. The groundwater high may be due to the bedrock high in this area and also may be due to leakage from East Gill Creek which is just south of this well. (Figures 1-19 and 1-20)

Deep Bedrock Zone - Synoptic water level measurements collected during the RI indicated that groundwater in this zone generally flows to the west/southwest. Groundwater elevations at MW-2D were slightly lower than expected and MW-3D groundwater elevations slightly higher in relation to the regional flow to the west. These anomalies may be due to slight variations in fracture permeabilities. These permeability variations may affect the reaction time to changes that affect groundwater levels, like barometric pressure, when compared to water levels in adjacent monitoring wells. Generally, deep bedrock zone groundwater flow followed a more expected pattern with MW-7D and MW-8D being downgradient of the site and MW-1D upgradient of the site.

The synoptic water level measurements collected during the Supplemental Groundwater Investigation (August and September 1997) revealed that groundwater flow direction in the deep bedrock zone was generally toward the south/southwest through the northern aspect with a flattening of the hydraulic head gradients in the subdivision. Groundwater flow across the subdivison was in a southwest direction. Groundwater flow direction was fairly consistent during both rounds of synoptic water level measurements (Figures 1-21 and 1-22). The groundwater levels collected in August and September 1997 indicated that MW-11D is upgradient of the site and that MW-6D, MW-7D, MW-8D, and MW-10D are downgradient of the site.

Vertical Gradients - Vertical gradients each monitoring well cluster were downward as evidenced by the higher groundwater elevations of the shallow versus those of the deep wells, indicating that the site is located in a groundwater recharge area. The downward vertical gradient evident in the site wells were confirmed by measurements collected during the Supplemental Groundwater Investigation. It should be noted that slight upward gradient (0.06 foot) was observed in the August 1997 water level measurement collected at the MW-4 cluster. This upward gradient was not confirmed by the September 1997 water levels.

Groundwater Fluctuation - According to Miller and Kappel (1987) groundwater, within 0.5 mile from the buried conduits, is affected by water level fluctuations in the conduits that are induced by level changes in the Forebay Canal. They also state that groundwater levels up to 3.5 miles south of the Forebay Canal are affected by water level fluctuations in the canal. The Forest Glen site is approximately 0.5 miles east of the buried conduits and 2.4 miles southeast of the Forebay Canal.

Continuous water level measurements were performed over a 7-day period in August, 1995 in MW-5S, MW-5D, MW-2S, MW-2D, MW-3S, MW-3D, and MW-3P and over a 24-hour period in December 1995 in MW-7S, MW-7D, MW-8S and MW-8D to monitor any significant water level changes in the wells.

Groundwater levels in MW-5S, MW-2S, MW-2D, MW-3S, MW-3D, and MW-3P from the August event indicated only slight variations, on the order of 0.1 foot. The groundwater levels in MW-7S, MW-7D, and MW-8D from the December event show a drop of 0.3 feet in water levels during this period. These slight changes are likely due to barometric pressure fluctuations.

Groundwater levels in MW-5D exhibited daily groundwater fluctuations on the order of 1 foot and may be affected by NYPA water use for the production of hydroelectric power to the north and west.

During the August, 1995 7-day continuous water level monitoring of well clusters MW-5, MW-3, and MW-2, only MW-5D appeared to be impacted by the NYPA daily fluctuations. This may be because MW-5D is closest to the buried conduits and intersects the same fracture system that is in contact with both the conduits and the Forebay Canal.

MW-7D and MW-8D monitored in December, 1995, are closer to the buried conduits but did not experience the same daily fluctuation as MW-5D. These wells may not intersect the connecting fracture system. Additionally, these wells may have been monitored in period when water level fluctuations caused the Forebay Canal are small. The Forebay Canal water level fluctuates as much as 25 feet during the summer and fall as little as 5 feet in the spring (Miller and Kappel, 1987).

The measurements for MW-8S, taken during the December event, show an erratic pattern of sharp water level drops probably caused by data logger malfunction rather than natural or manmade impacts on the water levels.

During the Supplemental Groundwater Investigation continuous water level measurements were collected from 12 monitoring wells using pressure transducers and Hermit Data Loggers. Monitoring wells MW-3S, MW-5S, MW-5D, MW-6S, MW-6D, MW-9S, and MW-10S were monitored from September 2, 1997 (18:38 hours) to September 9, 1997 on Hermit Data Logger Unit 1 while MW-4S, MW-4D, MW-14S, MW-15S, and MW-15D were monitored from September 3, 1997 (15:38 hours) to September 9, 1997 on Hermit Data Logger Unit 2. Barometric pressure was also recorded.

Based on the collected data, it was apparent that groundwater levels at the site respond rapidly to rainfall, but in significantly varying degrees depending on the location. In addition to rainfall and barometric pressure impacts, no cyclical changes or pumping well impacts were noticed in the long-term groundwater level data.

1.3.5.2.2 Aquifer Properties

The aquifer test pumping phase analysis results indicate that the transmissivity of the bedrock aquifer at the site varies from approximately 400 to 2000 feet^2/day and averages approximately 1100 feet^2/day. The pumping phase analysis results also indicate that the storage coefficient varies from approximately 0.000082 to 0.084 and averages 0.0007, while the specific yield may range from approximately 0.00039 to 0.44 and average 0.003. Note, however, that because the aquifer test was only 10.5 hours long, the estimates for specific yield should not be considered reliable as the test may not have been run long enough to measure the full impacts of delayed gravity drainage. However, as indicated above, the primary purpose of the test was to estimate

the transmissivity of the bedrock aquifer. Therefore, the APT was designed and run accordingly. Note also that all average values of aquifer properties presented above and below were calculated using a geometric mean, as recommended by Schilfgaarde (1974).

The aquifer test recovery phase analysis results indicate the transmissivity of the bedrock aquifer may vary from approximately 800 to 2200 feet^2/day.

To help estimate the area of influence of the APT, periodic water level measurements were also collected manually, both prior to and during the APT, from all the remaining monitor wells that were not used as observation wells. The drawdown data indicate that while groundwater levels at monitor wells MW-2S, MW-2D, MW-3D, MW-7D, MW-8D, MW-9D, and MW-10D were affected by the APT (inside the area of influence), water levels at monitor wells MW-1S, MW-1D, MW-7S, MW-8S, MW-11S, MW-11D, MW-12S, MW-12D, MW-13S, MW-13D, and MW-15D were not significantly affected by the APT (outside the area of influence).

The drawdowns at the end of the pumping phase of the APT were calculated for each monitor well. Using these drawdown data, drawdown contour maps for both the shallow and deep portions of the bedrock aquifer were prepared and are presented in Figures 1-23 and 1-24. These drawdown contour maps indicate that the radius of influence of the APT was approximately 600 feet. It should be noted, however, that because water levels were still falling at the end of the pumping phase of the APT, it is likely the final radius of influence, if pumping at monitor well MW-5S were allowed to continue until steady state water levels were achieved, would be significantly greater than 600 feet. Thus, it is apparent that pumping from one extraction well can impact water levels over a large area at the Forest Glen Site.

A detailed discussion of the aquifer test results is presented in CDM Federal's Aquifer Performance Test Report that is presented in Appendix A of this report.

1.4 NATURE AND EXTENT OF CONTAMINATION

1.4.1 SOURCES OF CONTAMINATION

Historical records and aerial photographs indicate that the site was originally a forested wetland. Reports also indicate that the illegal landfilling of industrial fill material in many areas of the site occurred during the 1970s.

Analytical data collected during this RI, combined with historical data, suggest that the primary source of contamination is the fill material. Fill material was encountered in discrete areas of the northwest section of the Northern Aspect, the berm, the western edge of the Edgewood Drive lots, and the northern and central sections of the Subdivision.

CDM Federal focused the characterization of the groundwater contamination on those constituents that were identified as contaminants of concern (COCs). COCs were determined by

the following criteria: 1) exceedance of regulatory screening criteria or naturally occurring background levels; 2) frequency of exceedance; and 3) magnitude of exceedance.

1.4.2 GROUNDWATER

1.4.2.1 Chemical Screening Values for Groundwater

Forest Glen groundwater analytical results were screened against the National Primary Drinking Water Standards. The Safe Drinking Water Act (SWDA) requires EPA to assess and regulate all contaminants in the drinking water supply that could have an adverse effect on public health. The National Drinking Water Standards identify maximum contaminant levels (MCLs). MCLs represent the maximum permissible level that a contaminant can be detected in the drinking water supply. The MCLs are developed based upon health risks, detection limits, treatability, and treatability costs associated with the best available treatment technology. Maximum contaminant level goals (MCLGs), which represent concentrations that present no adverse health effect, have also been established for groundwater contaminants. National Secondary Drinking Water Standards have also been established for contaminants that do not present adverse health effects. These secondary MCLs are based upon aesthetic considerations such as taste, color, odor, and appearance and are non-enforceable standards.

These Federal standards are implemented by the primary agency, which in New York State is the New York State Department of Health. Part 5 of the New York State Sanitary Code establishes MCLs for the same contaminants regulated under EPA's SDWA. State MCLs must be at least as stringent as the Federal standards. Both the Federal and State drinking water standards are ARARs.

Forest Glen groundwater analytical results were also screened against NYSDEC Groundwater Quality Standards as provided in NYCRR Title 6, Chapter X, Part 703. These standards have been promulgated by the statutory authority of Environmental Conservation Law (Sections 3-0301 [2][m], 15-0313, 17-0301, 17-0303, 17-0809). These State standards are ARARs. Tables 1-8 and 1-9 list the ARARs for the contaminants detected in the groundwater samples.

While the critical evaluation criteria for groundwater contamination are regulatory standards, not background concentrations, upgradient groundwater quality was evaluated to determine at what point contaminants may be entering the aquifer system.

1.4.2.2 Groundwater Contamination at the Site

Groundwater Flow

Groundwater at the site flows both vertically and horizontally through an interconnected system of closely spaced joints and bedding plant fractures. Groundwater flow, as indicated by elevation contours, in the shallow bedrock zone closely follows the top of bedrock toward a bedrock

surface depression beneath the MW-5 cluster. The groundwater high at MW-7S results in localized flow to the east, toward MW-5S, and south toward MW-8S. This causes the local flow in this area to deviate from the expected regional flow to the west. Groundwater in the deep bedrock zone generally flows to the south/southwest across the northern aspect and northern subdivision and bends to a west southwest direction across the remainder of the subdivision. MW-11D is upgradient of the site and MW-6D, MW-7D, MW-8D and MW-10D are downgradient.

The vertical hydraulic gradient at each monitoring well cluster was downward, as evidenced by the higher groundwater elevations of the shallow wells versus those of the deep wells. This indicates that the site is located in a groundwater recharge area.

Groundwater Contamination

Site soil contamination has appeared to have migrated vertically to the underlying groundwater. This suggests the overburden clay layer, found throughout the site, may have been breached during illegal landfilling activities.

In all four sampling rounds, volatile organic compounds, including vinyl chloride, 1,2-DCE, 1,1-DCA, and TCE were consistently detected in the wells downgradient of the fill areas. While volatile organic compounds were not commonly detected in soil samples collected during the RI field investigation, their presence in the site soils and fill materials was documented during previous site investigations. Generally, the highest volatile organic compounds detections were noted in well MW-5S. As discussed above, shallow groundwater flows from all directions toward a slight bedrock depression in the vicinity of MW-5S. This flows regime could be responsible for transporting groundwater contamination from throughout the site to the MW-5S area, explaining the elevated levels of volatile organic compounds detected in the well. Additionally, volatile organic concentrations increased in Round 2, when groundwater elevations were three to four feet higher than in Round 1. Volatile organic concentrations in Rounds 3 and 4 confirmed the Round 2 detections and contaminant levels.

In Rounds 1 and 2, semivolatile organic compounds detections and standard exceedances in the groundwater were generally limited to two wells, MW-6D and MW3-PW. Pentachlorophenol and hexachlorobutadiene, at concentrations above State or Federal MCLs, were noted in well MW-6D which is downgradient of the Edgewood Drive and Subdivision fill areas. Semivolatile PAHs, and one standard exceedance of benzo(a)pyrene, were generally noted in MW-3PW the perched water well. The MW-3 well cluster was installed in a fill area that was delineated during drive point boring activities. In Rounds 3 and 4, semivolatile organic detections were limited to singular detections of di-n-butylphthlate, diethylphthlate, and benzo(a)pyrene. Pentachlorophenol was detected in both sampling rounds in monitoring well MW-12V.

Inorganic analytes were widely detected in all four rounds of groundwater sampling. Chromium, nickel, lead, iron, manganese, however, were the only analytes with concentrations that exceeded

State and Federal drinking water standards. All five of the analytes were widely detected in the site surface and subsurface soils, with the highest analytes concentrations noted in the fill material. Accordingly, the highest inorganic concentrations were generally detected in samples collected from source area wells, MW-3OB and MW-3S, and wells downgradient of the Subdivision and Edgewood Drive fill area, MW-4S, MW-4D, and MW-5D. The presence of these analytes, commonly detected in the subsurface fill material, in the deep monitoring wells suggests that inorganic contamination has migrated vertically. It should be noted that chromium, nickel, and lead were less frequently detected, at concentrations above action levels, in Rounds 2, 3, and 4.

Volatile organic compounds and inorganic analytes were noted in the offsite wells MW-7D, MW-8S, and MW-8D at concentrations that exceeded State and drinking water standards. Since the same contaminants were detected in onsite wells at higher concentrations, it appears that contamination is migrating offsite.

The following figures summarize the analytical results for the four rounds of groundwater sampling conducted during the investigation. Figure 1-25 - Round 1 detected targeted organic compounds and TCL organic exceedances, Figure 1-26 - Round 2 TCL organic exceedances, Figure 1-27 - Round 3 detected targeted organic compounds and TCL organic exceedances, Figure 1-28 - Round 4 TCL organic exceedances, Figure 1-29 - Round 1 inorganic exceedances, and Figure 1-30 - Round 2 inorganic exceedances. Figure 1-31 - Round 4 inorganic exceedances, and Figure 1-32 - Round 4 inorganic exceedances.

1.4.2.3 Relationship Between Soil and Groundwater Contamination

Contaminants identified in the groundwater are very similar to those identified in the site soils, especially the more soluble volatile organics. The primary VOCs in the groundwater include vinyl chloride, 1,2-dichloroethene, 1,1-dichloroethane, trichloroethene, and xylene. The same compounds were identified in sampling by NUS in 1987 and 1988.

A similar comparison of groundwater and soil sampling results for semivolatile compounds in the Subdivision and Edgewood Drive wooded lots indicate that these compounds do not migrate as readily from soils to the groundwater. Only a few semivolatile compounds were detected in the groundwater, while many were detected in soils. The semivolatile compounds are generally significantly less soluble than VOCs and are not expected to migrate into the groundwater.

Numerous inorganic analytes have been detected in Subdivision soils and fill material. These same inorganics have also been detected in the groundwater, with chromium, nickel, and lead exceeding State and Federal drinking water standards.

1.5 CONTAMINANT FATE AND TRANSPORT

Please refer to the Final Forest Glen Remedial Investigation Report for complete discussion on contaminant fate and transport. Fate and transport properties are important for contaminants that exceed ARARs, and contaminants identified as COCs for the human health or ecological risk assessment. COCs for the risk assessments are determined based on their toxicity characteristics, frequency, and the maximum concentration at which they were detected at the site in surface water, sediment, soil or groundwater. Due to the extensive list of COCs, only risk-related contaminants and those that occur at higher frequencies are discussed in this section.

Table 1-10 summarizes the chemical classes of COCs in site media by AOC and chemical groups. These COCs may have been physically introduced to the site by illegal landfilling activities, as reported by area residents.

1.5.1 PROPERTIES OF SITE MEDIA INFLUENCING CONTAMINANT TRANSPORT

The physical characteristics that affect the transport of contaminants are briefly described below.

1.5.1.1 Topography

The site is fairly flat except for a slight southern decline in the Northern Aspect and the elevated berm in the Northern Aspect. East Gill Creek, two surface water pools (one in the wooded wetland and the other to the south of Edgewood Drive), other seasonal water bodies, surface drainages, and several soil mounds provide conduits for potential surficial contaminant transport. The surface water pools ultimately drain into East Gill Creek on and off the site. Contaminants carried in surface water runoff will adsorb to suspended sediments in the water and eventually accumulate where the sediments are deposited.

1.5.1.2 Surficial Geology

The composition of the surficial geologic units exert a major control on the mobility of contaminants in the unsaturated zone. In undisturbed areas of the site, the overburden lithology, from ground surface to the Lockport Dolomite, is characterized by an 8 to 10-foot thick clay layer overlying a 2-feet clay till. In portions of the Subdivision, north and south of Edgewood Drive, the Northern Aspect, and the berm, disturbed soils (fill) were encountered above the clay layer. Soil borings revealed that the fill is separated from the clay till and the Lockport Dolomite by at least 3 feet of clay. This fill material is permeable when compared to the underlying clay layer and can produce perched water zones during wet periods. Areas of perched water were encountered in the central Subdivision and in the berm.

1.5.1.3 Groundwater Flow

Site-specific hydrogeologic properties determine contaminant transport rates and direction. In the overburden, rainwater or spills in contact with surface fill will be either absorbed by the fill material or may flow vertically down to the clay layer. Standing water pools are created in areas where surface clay material exists.

Groundwater flows, both vertically and horizontally, through an interconnected system of closely spaced joints and bedding plane fractures. Groundwater flow in the shallow bedrock zone closely mimics the top of bedrock elevation contours toward a bedrock surface depression beneath the MW-5 cluster.

The groundwater high at MW-7S results in localized flow to the east, toward MW-5S, and south toward MW-8S, deviating from the expected regional flow to the west. Groundwater in the deep bedrock zone generally flows to the west/southwest with MW-1D being upgradient of the site and MW-7D and 8D being downgradient.

Vertical groundwater flow at each monitoring well cluster is downward, as evidenced by the higher groundwater elevations of the shallow versus those of the deep wells. This indicates that the site is located in a groundwater recharge area. An exception to this is the lack of any gradient at the MW-1 cluster during the November, 1995 water level round. In addition, a slight upward gradient (0.06 foot) was observed in the August 1997 water level measurement collected at the MW-4 cluster. This upward gradient was not confirmed by the September 1997 water levels.

1.5.1.4 Soil Chemistry

The soil properties most affecting contaminant persistence and mobility include:

- redox potential (Eh);
- pH; and
- total organic carbon (TOC) content.

Redox potential of the subsurface affects the speciation of contaminants, and hence their mobility or persistence in the environment. Microbial activity and organic contaminants may create reducing conditions. The pH of soils and groundwater affects hydrolysis rates, equilibrium partitioning conditions, and contaminant solubility. The soil pH at the site varies between 6.2 and 8.9. High total organic carbon content in the site soil increases contaminant absorption and hinders the movement of contaminants through the soil. The TOC of the soil at the Forest Glen site is relatively high ranging from 14,000 mg/kg for the surface soils in the Northern Aspect to 90,000 mg/kg in the sediments of the wooded wetland. The natural soil type at the site is the Odessa silty clay loam, which is a poorly drained, moderately fine textured soil in which clay dominates. This corresponds to the relatively high TOC content of the soil samples and the existence of surface water bodies in depressed areas.

1.5.2 POTENTIAL CONTAMINANT TRANSPORT PATHWAYS

There are several potential contaminant transport pathways for contaminants identified at the site, including:

- Surface runoff to sediments in surface water bodies, through drainage channels and ultimately to East Gill Creek;
- The migration of chemical contaminants present in soil via surface runoff and windblown dusts;
- The volatilization of chemical contaminants present in surface soil into the ambient air;
- Discharge of contaminated groundwater to downgradient water bodies or vertically through soil/rock fractures
- Uptake of contaminants in soil by biota.

1.5.3 CHEMICAL AND PHYSICAL PROPERTIES OF CONTAMINANTS

To predict the persistence and potential migration of contaminants in soils and groundwater, it is necessary to identify which contaminants are likely to leach, degrade (biotically or abiotically), or volatilize. This depends on a given chemical's physical and chemical properties and the properties of the media through which it migrates. Table 1-11 presents the chemical and physical properties of the contaminants. The following sections describe the persistence and mobility of the identified contaminant groups, focusing on such properties as degradation, dissolution/precipitation, volatilization, biotransformation, adsorption, and bioaccumulation or bioconcentration.

1.5.3.1 Contaminant Persistance (Fate)

Contaminant persistence describes the length of time that a contaminant will remain in its original chemical state in the environment. The chemicals that will persist in a given medium are those that form insoluble precipitates, or resist biodegradation, hydrolysis, and volatilization.

The major processes affecting the fate, or persistence, of each class of COCs in soils and groundwater are shown on the following table.

Contaminant Group	Fate Process
Pesticides/PCBs	Very, very slow biodegradation
PAHs, Targeted Organics	Very slow biodegradation
Phenols	Rapid biodegradation, dissolution/precipitation,
Metals	Dissolution/precipitation - pH dependent
Chlorinated VOCs	Biodegradation/biotransformation, hydrolysis

COC Persistence

The chemical, physical, and biological factors that affect the persistence of each chemical group of contaminants are described in this section.

VOCs. The detected chlorinated solvents (i.e., TCA, TCE, DCA and DCE) are moderately persistent in the environment. They are resistant to chemical degradation, but moderately susceptible to biodegradation under anaerobic conditions. For example, TCE undergoes anaerobic degradation to produce DCE and other chlorinated species, like vinyl chloride, with significant toxicological concerns. One of the end products, vinyl chloride, is not readily degraded and tends to accumulate. However, due to the high volatilization and mobility of vinyl chloride, it will not persist in the soil environment but will tend to leach to groundwater or volatilize. The concentration of VOCs in the soil is expected to decrease gradually. The presence of vinyl chloride in the groundwater (ranging from 3 to 16 ug/l in Round 1 and from 3.1 to 240 ug/l in Round 4) confirms this.

PAHs. These compounds are relatively persistent in the environment. The degree of persistence generally increases with the molecular size of the compound. The relatively high octanol/water coefficients of PAHs indicate that they will be primarily detected in the suspended particulate fraction (unfiltered samples) in water. The larger PAHs such as benzo(a)anthracene (maximum concentration - 7700 mg/kg, and benzo(b)fluoranthene (maximum concentration 12,000 mg/kg)) found in the Northern Aspect, and some of the targeted organics such as N,N-diphenyl-1,4-benezenediamine and 2-anilinobenzothiazole are not volatile therefore, loss to the atmosphere is not expected to be significant. Biodegradation and biotransformation are the ultimate fate mechanisms affecting most PAHs. The smaller PAHs are readily biodegraded, with half-lives in soil measured in hours to weeks. The larger PAHs, such as the COCs, take significantly longer to biodegrade, with half-lives measured in weeks to months. The PAHs were detected at high concentrations as shown in the following AOCs: berm - benzo(a)pyrene (maximum concentration 3,800 ug/kg), Northern Aspect - benzo(b)fluoranthene (150 - 12,000 ug/kg), wooded wetlands - benzo(b)fluoranthene (ranging from 570 to 1400 ug/kg), Edgewood Drive - fluoranthene (56 to 130,000 ug/kg), and the Subdivision-benzo(a)anthracene (ranging from 130

to 250,000 ug/kg). Based on the high concentrations present at the site and the persistence of PAHs they will remain sorbed to the organic matter in the soils.

Pesticides. Alpha-BHC, for example, which was detected in site soils, has a moderate solubility in water, low vapor pressure, low subsurface mobility, and little tendency to biodegrade. This pesticide, when released to surface water, will strongly adsorb to sediments. It may, however, volatilize very slowly. Alpha-BHC was found in all the sediment samples of the wooded wetland (ranging from 0.5 to 5.5 ug/kg) and at even lower concentrations in the surface water of East Gill Creek (ranging from 0.06 to 0.11 ug/l). Pesticide concentrations are therefore expected to decrease slowly over time. This could take place via adsorption to particulate material in surface runoff to surface waters of the creek which flows off site.

Phenols. These compounds show low to moderate adsorption to clay-type soils. Their adsorption indicates moderate soil mobility with possible leaching to groundwater through any available conduits. As noted previously, phenols have a high tendency to biodegrade. Thus, phenols are not expected to persist except where iron oxide and pH levels are high (Artola - Fortuny et al 1982).

PCBs. PCBs are highly immobile in the soil/groundwater environment because of their high affinity for sorption to soils and their very low solubility. The tendency of PCBs for adsorption increases with the degree of chlorination and with the organic content of the soil. These compounds also have a tendency to bioaccumulate.

Metals. The COC metals at the site are relatively soluble in water, except lead and mercury, and show high tendencies to dissolve into the water phase and move along with the water flow instead of sorbing to soil or organic matter in soil or suspended in aqueous media. Leaching of metal from areas of deposition into aqueous media will occur. The persistence will depend on the rates of leaching, amount of rainfall and individual metal properties. The persistence of metals is complicated by processes such as precipitation and dissolution which are dependent upon pH, the presence of certain ions or complexing agents and concentrations of the metals in solution. These factors are discussed further under mobility.

1.5.3.2 Contaminant Mobility (Transport)

The major processes affecting the transport, or mobility, of each chemical type in soils and groundwater shown in the following table.

Contaminant Group	Transport Process
Chlorinated VOCs	Volatilization
Pesticides/PCBs	Sorption, bioaccumulation/bioconcentration
PAHs, Targeted Organics	Sorption, sedimentation
Phenols	Adsorption, volatilization, precipitation
Metals	Sorption, bioaccumulation, volatilization (Hg)

Mobility of Organic Compounds

Chlorinated VOCs. Chlorinated VOCs are generally highly mobile in the environment. They are highly volatile, do not adsorb readily to soils, and have low retardation factors in groundwater, with their flow rates equal to approximately that of groundwater. Previous investigations found these compounds at higher levels in soils than were detected during the RI.

Past practices of illegal landfilling at the site may account for their presence in the soils in the northern portion of Subdivision. A large fraction of the VOCs, when originally released, would have rapidly evaporated from the surface soil due to their high vapor pressure. Then, since these chlorinated solvents are moderately to highly soluble in water, and do not sorb to soils, the fraction remaining in the soil would readily infiltrate through the unsaturated zone by partitioning between the liquid phase (soil moisture) and the vapor phase and leaching into the groundwater. The contaminant transport pathway for VOC from the surface soils is therefore direct discharge to soils, leaching to groundwater, and migration with groundwater flow with only slight retardation.

Metals

A variety of factors affect the mobility of metals in soil/water systems, including:

- the presence of water (soil moisture content);
- the presence of other complexing chemicals in solution
- the pH and oxidation/reduction potential, which affect the speciation of all metals and complexing agents;
- the temperature; and

- soil properties, such as cation exchange, the presence of hydrous oxides of iron and magnesium, and the presence of organic matter.

Because of the wide range of soil conditions in the environment and the resulting high variability of certain physical parameters, it is difficult to predict the mobility of metals. Soil sorption constants may vary over several orders of magnitude for a given metal in different soils and/or under different environmental conditions. Thus, there is no single sorption constant describing the binding of metals in solution to soils and no one mobility prediction holds for all environmental conditions.

In a study of metals retention in soils, the relative mobility of 11 metals in various soil types was assessed (EPA, 1978). The study concluded that chromium, mercury, and nickel are among the most mobile, while lead and copper are the least mobile. For the other metals studied, the mobility varied with the conditions, although the order of mobility was generally:

Most Mobile--As>V>Se>Cd>Zn>Be--Least Mobile

For this investigation, estimates of overall mobility were made for each metal COC, based on the anticipated speciation of the chemicals in fresh water, general solubility patterns, and general soil sorption patterns. General guidelines used to assign metals to a mobility group (high, medium, or low) were:

- metals whose predominant species in freshwater are anions (i.e., arsenic, and vanadium) which are only minimally retarded in soils, are among the most mobile;
- metals known to be fairly strongly sorbed to most soils under normal environmental conditions (i.e., pH 6 to 8 near neutral redox potential) are among the least mobile; and
- metals whose predominant freshwater species are cations, especially divalent heavy metals (i.e., copper, lead) which are subject to sorption via cation exchange, are among the least mobile.

The relative mobilities assigned to the metal contaminants are shown in Table 1-12 and described below.

Chromium. The mobility of chromium in soils depends on its oxidation state. It is most often found in the oxidation state Cr(III) and, to a lesser extent, Cr(VI). Chromium can be adsorbed or complexed to soil particles, metal oxides, or organic matter and is therefore rather immobile. Most of the Cr(III) found in soils is mixed Cr(III) and Fe(III) oxides or in the lattice of minerals, although Cr(III) complexed with organic ligands may stay in solution for over a year. Cr(III) is mobilized only in very acidic soil media. Cr(VI), by contrast, is easily mobilized, independent of the soil pH. The

absorption of chromium onto clays is pH dependent: Cr(III) adsorption increases as pH increases, whereas Cr(VI) adsorption decreases as pH increases.

Mobility of Site Contaminants in Groundwater

To characterize the behavior of contaminants along the predicted flow path (through soils or in the water), their physical and chemical properties were used to establish a scheme of relative mobilities. A "retardation factor" was approximated for each chemical considered to be a COC at the site. These factors serve as estimates, within an order of magnitude, of the relative mobilities of each compound. This approach ignores the possible contribution of "facilitated transport", wherein the contaminant is transported along with mobile colloidal particles to which it is attached.

Retardation factors are based on four parameters: the bulk density of the subsurface material (1.57 kg/l); the fraction of organic matter in the subsurface material (f_{oc} = .0494); the effective porosity of the subsurface material (0.3); and an adsorption coefficient for each compound. The equation for calculating the retardation factor is:

$R_f = 1 + p\,K_d/n$
$= 1 + p\,K_{oc}f_{oc}/n$

R_f = retardation factor (dimensionless)
p = soil bulk density (kg/l)
k_d = sorption constant (l/kg)
k_{oc} = organic carbon normalized sorption constant (l/kg)
f_{oc} = weight fraction organic carbon in soil ($0 \leq f_{oc} \leq 1$) (dimensionless)
n = soil porosity ($0 \leq n \leq 1$) (dimensionless)

Estimates of the first three parameters were made based on saturated soil conditions. The fraction of organic carbon was estimated by averaging TOC concentrations over the entire saturated zone. The average TOC was calculated at 49,373 mg/kg, expressed as a fraction of 1 (i.e., 0.0494).

The fourth parameter, K_d is independent of position in the subsurface soils and is, instead, particular to each chemical. The adsorption coefficient reflects a compounds tendency to distribute itself as a solute dissolved in ground water or adsorbed to soil.

Using this equation, a retardation factor (Rf) was estimated for each compound in the saturated zone (Table 1-10). The range of retardation factors spans several orders of magnitude, indicating that different compounds move at different rates through the groundwater.

Due to the low soil permeability and relatively high organic content of the soils, organic compounds would not be expected to be found in the groundwater, except for the moderate (lighter weight SVOCs) and highly mobile organics (VOCs). Groundwater sampling has confirmed that this is the case. VOCs such as, vinyl chloride and 1,2 DCE total were detected in the groundwater as well as

TCE, DCA and xylenes (total). It is suspected that the pathway for these VOCs is volatilization to the air from surface soils and vertical transport through breached areas of the clay. The moderately mobile organics (low molecular weight SVOCs) were also detected above screening criteria in the groundwater e.g. pentachlorophenol and hexachlorobutadiene.

Even though they are highly mobile, phenols were only detected in two groundwater samples (MW-6S, MW-6D) at concentrations that slightly exceeded drinking water standards. As explained previously, adsorption is enhanced by reduced degradation activity and hydrogen bonding. Any phenol transported through the subsurface and to the groundwater quickly attenuates. Phenol degradation is sufficiently rapid such that most groundwater is sufficiently free of this pollutant (Delfino, 1976).

The extensive clay layer beneath the surface causes the retention of water above the water table (perched water) in some areas of the site (Subdivision and Northern Aspect). The highly mobile organics are therefore retained. However, illegal landfilling activities may have breached the clay layer which would have allowed contaminants to migrate into the underlying bedrock aquifers. Additionally, VOCs were detected in the groundwater in areas where the clay depth is thinnest (MW5S). The highly retarded organics have remained in the soil.

1.5.4 SUMMARY OF CONTAMINANT FATE AND TRANSPORT

The majority of the chemicals of concern detected in the surface water, sediment, soils, and groundwater of the site can be grouped into three general categories that describe their persistence and mobility in the environment:

Group 1 — Persistent, non-volatile, and very slowly degradable organic chemicals such as PCBs, Pesticides, PAHs and many of the targeted organics. These chemicals strongly sorb to soils and are relatively immobile. Concentrations present in soils will persist into the future, with very slow degradation of the organics. This group represents the majority of chemical contamination detected in soils and sediments during the remedial investigation. The PAHs and targeted organics will remain in the soil for years.

Group 2 — Volatile, soluble, degradable contaminants such as volatile organic compounds. These chemicals do not sorb strongly to soils and are relatively mobile in groundwater. Their persistence will be determined by their rates of biodegradation, and their mobility by their retardation coefficients (Kd) and the velocity of groundwater. These chemicals, VOCs, are the constituents of concern in the groundwater. Although they reached the water table through releases to soils, very few traces of the VOCs remain in site soils that were sampled.

Group 3 — Low volatility, soluble, degradable such as the phenols. These chemicals show low soil adsorption and are relatively mobile in soils. Phenols biodegrade quite rapidly in water and in soil. The high concentration of phenols (ranging to 9,700 ug/kg in the berm) still remaining in the subsurface soils suggest that microbial populations in the soil have been destroyed by high concentration spills. This has reduced or prevented the normally rapid degradation in soils. At the site, phenol has displayed abnormally moderate to high adsorption to the soils. It is expected however, that the phenols have and will continue to leach to groundwater due to their high solubilities (e.g. 2-methylphenol - 25,000 mg/l in water). They will not be detected in the groundwater in high concentrations since they degrade rapidly (hours to days). However, the concentrations in the soils are expected to decrease.

1.6 ENDANGERMENT ASSESSMENT

1.6.1 BASELINE HUMAN HEALTH RISK ASSESSMENT

In general, the USEPA recommends target values or ranges (i.e., risk of 10^{-4} to 10^{-6} or hazard index of one) as threshold values for potential human health impacts (USEPA, 1989). These target values aid in determining the objectives of the baseline human health risk assessment which include determining whether additional response action is necessary at the site, by providing a basis for determining residual chemical levels that are adequately protective of human health, by providing a basis for comparing potential health impacts of various remedial alternatives, and to help support selection of the "no action" remedial alternative, where appropriate.

In the baseline human health risk assessment, groundwater was quantitatively evaluated for potential health threats to human receptors via the ingestion, dermal contact, and inhalation routes of exposure. Receptors including trespassers (area residents), residents (adults and children), and construction workers were evaluated under present and potential future land use conditions, as appropriate.

Chemicals of potential concern were selected for each matrix based on criteria outlined in RAGS (USEPA, 1989a). The chemicals of potential concern included VOCs (1,2-dichlorethene (total), vinyl chloride), SVOCs (benzo(a)pyrene, hexachlorobutadiene, n-nitroso-di-n-propylamine), and inorganics (arsenic, chromiumVI, manganese, and nickel). The essential nutrients (i.e., calcium, magnesium, potassium, and sodium) were not quantitatively addressed as their potential toxicity is significantly lower than other inorganics at the site, and most existing toxicological data pertain to dietary intake.

1.6.1.1 Human Health Risks and Hazards Identified

The following discussion presents by receptor group carcinogenic risks and noncarcinogenic hazard index values in exceedance of the USEPA's target levels for the matrices evaluated in this risk

assessment. Brief mention of those risks and hazards not exceeding any target levels are also included for completeness.

Residents:

Groundwater: Potential future site residents were quantitatively evaluated for on-site groundwater exposure via the ingestion and inhalation of VOCs (during and after showering) routes. For adults, only the ingestion route of exposure showed a carcinogenic risk in exceedance of the USEPA's target risk range. The adult ingestion risk of 6.8E-04 was due largely to vinyl chloride and n-nitroso-di-n-propylamine, although individually neither risk exceeded the target risk range.

The ingestion of groundwater by adults and children showed hazard index value in exceedance of 1. The adult hazard index of 1.3E+01 was due largely to 1,2-dichloroethene (total) and manganese. The child hazard index of 3.0E+01 was due largely to 1,2-dichloroethene (total), hexachlorobutadiene, arsenic, and manganese.

In summary, a review of the overall carcinogenic risks for the various matrices and receptor populations showed that potential future residential exposure to groundwater via ingestion (adults only) were in exceedance of the USEPA's target risk range of 10^{-4} to 10^{-6}. A review of the noncarcinogenic hazard index values for the site matrices and receptors showed that potential future child exposures to groundwater via ingestion exceeded the USEPA's target level of 1. For potential future adult resident exposure to groundwater via ingestion, the noncarcinogenic hazard index value exceeded the USEPA's target level of 1.

In accordance with standard risk assessment practice, central tendency calculations were performed as a quantitative measure of uncertainty in the risk assessment. The 50th percentile parameters used in these calculations were assumed to be representative of the general population. These central tendency calculations, however, have the potential to underestimate true risks/hazard indices for sensitive receptors.

1.7 BASIS FOR CONDUCTING THE FEASIBILITY STUDY

Samples collected during the RI from each of the four environmental media (surface water, sediment, groundwater, and soil) were analyzed by CDM Federal's laboratory subcontractor or through EPA's Contract Laboratory Program. Samples were validated by CDM Federal or EPA using EPA Region II procedures. All analytical results, summary tables, and text summaries and conclusions are based upon the validated analytical data. In some instances, the analytical data was used in conjunction with other RI data, such as water level contours, to develop conceptual models that illustrated contaminant distribution within the site groundwater. Since such illustrations involve interpretation and subsurface environments are constantly changing, delineated boundaries and contour intervals should not be considered fixed points.

A review of the overall carcinogenic risks for the various matrices and receptor populations showed that potential future residential exposures to groundwater via ingestion (adults only) were in exceedance of the USEPA's target risk range of 10^{-4} to 10^{-6}. A review of the noncarcinogenic hazard index values for the site groundwater and receptors showed that potential future child exposures via ingestion exceeded the USEPA's target level of 1. For potential future adult resident exposure to groundwater via ingestion, the noncarcinogenic hazard index value exceeded the USEPA's target level of 1.

The groundwater within the bedrock aquifer is contaminated with volatile organic and inorganic compounds in excess of Federal and State MCLs, as determined through four rounds of groundwater sampling. Hence, this FS addresses groundwater alternatives for the Lockport Dolomite aquifer.

This FS is based on the following goals and assumptions:

- The soil remedy for Operable Unit II (i.e. source control) will be implemented prior to the groundwater remedy so that the overburden soil within the Edgewood Drive Lots (AOC 5) and the Subdivision (AOC 6) does not continue to serve as a potential source of groundwater contamination.

- Prevent human exposure to contaminated groundwater.

- Prevent/minimize offsite migration of groundwater contamination in the fractured bedrock aquifer. Fully contain the contaminated groundwater (that which is above Federal and State MCLs) from all depth zones and reduce the mass of contaminants to the maximum extent possible. The goal of EPA's Superfund approach is to return usable groundwaters to their beneficial uses.

TABLE 1-1
FOREST GLEN GROUNDWATER FEASIBILITY STUDY
SUMMARY OF RI FIELD ACTIVITIES

ACTIVITY	DATES
INITIAL SITE CHARACTERIZATION	
Phase I Topographic Survey	June 1-6, 1994
Geophysical Survey	June 6-22, 1994 Nov. 14-18, 1995
Drive-Point Soil Boring Sampling	Nov. 14 - Dec. 2, 1994
Phase I Ecological Survey	Nov. 21-23, 1994
FIELD DATA COLLECTION	
Wetland Delineation	April 24-25, 1995
Surface Soil Sampling	June 8, 1995
Test Pit Sampling	June 12-15, 1995
Soil Boring Sampling	June 19-25, 1995
Wooded Wetland Sediment Sampling	June 20-21, 1995
Monitoring Well Installation	July 10 - Aug. 16, 1995
Continuous Water Level Measurements	Aug. 24 - Sept. 1, 1995
Round One Surface Water/Sediment Sampling	Aug. 24-25, 1995
Phase Two Survey Activities	Aug. 23-25, 1995
Round One Synoptic Water Level Measurements	Sept. 11, 1995
Round One Groundwater Sampling	Sept. 11-14, 1995
Round Two Surface Water/Sediment Sampling	Nov. 9-10, 1995
Round Two Synoptic Water Level Measurements	Nov. 13, 1995
Round Two Groundwater Sampling	Nov. 13-16, 1995
Round Three Synoptic Water Level Measurements	Nov. 16, 1995
Round Two Continuous Water Level Measurements	Dec. 27-28, 1995
Round Four Synoptic Water Level Measurements	Dec. 28, 1995

TABLE 1-2
FOREST GLEN GOUNDWATER FEASIBILITY STUDY
GROUNDWATER PURGE DATA
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LOCATION	MW1S R1	MW1S R2	MW1S R3	MW1S R4	MW1D R1	MW1D R2	MW1D R3	MW1D R4	MW2S R1	MW2S R2	MW2S R3	MW2S R4
pH	6.72	NA	6.92	7.34	7.02	NA	6.88	7.28	6.59	7.16	6.96	6.93
Conductivity**	3,200	1,600	3.03	4.05	1,400	1,200	2.03	1.75	1,000	970	1.68	1.32
Temperature °C	11	13.5	12.8	13.2	11.5	12	13.5	12.6	10.5	970	10.8	10.7

Notes:

NA Readings not available due to instrument failure.
NS Monitoring well was not sampled.
** Conductivity readings presented in umhos/cm in R1 and R2 and in mmhos/cm in R3 and R4

Table presents the final water quality measurements collected at the completion of the well purging activity.

TABLE 1-2
FOREST GLEN GOUNDWATER FEASIBILITY STUDY
GROUNDWATER PURGE DATA
PAGE 2 OF 12

LOCATION	MW2D R1	MW2D R2	MW2D R3	MW2D R4	MW3S R1	MW3S R2	MW3S R3	MW3S R4	MW3D R1	MW3D R2	MW3D R3	MW3D R4
pH	6.30	6.95	7.03	6.45	5.70	7.30	6.88	6.88	5.70	7.02	7.41	7.02
Conductivity**	1,250	1,000	1.50	1.48	1,150	610	1.38	1.28	1,100	700	1.32	1.20
Temperature °C	10.5	8.8	12.5	10.9	12.75	9.9	10.7	11.8	12.0	10.2	11.8	12.2

Notes:

NA Readings not available due to instrument failure.
NS Monitoring well was not sampled.
** Conductivity readings presented in umhos/cm in R1 and R2 and in mmhos/cm in R3 and R4

Table presents the final water quality measurements collected at the completion of the well purging activity.

TABLE 1-2
FOREST GLEN GOUNDWATER FEASIBILITY STUDY
GROUNDWATER PURGE DATA
PAGE 3 OF 12

LOCATION	MW3O R1	MW3O R2	MW3O R3	MW3O R4	MW3P R1	MW3P R2	MW3P R3	MW3P R4	MW4S R1	MW4S R2	MW4S R3	MW4S R4
pH	8.43	NA	7.00	6.68	7.97	NA	6.87	6.49	7.27	6.82	7.10	6.98
Conductivity**	2,420	NA	3.39	3.43	1,450	NA	1.21	1.36	1,210	1,500	1.57	1.84
Temperature °C	14.5	NA	10.9	12.4	15.8	NA	13.3	13.5	11.8	10.3	13.7	12.6

Notes:

NA Readings not available due to instrument failure.
NS Monitoring well was not sampled.
** Conductivity readings presented in umhos/cm in R1 and R2 and in mmhos/cm in R3 and R4

Table presents the final water quality measurements collected at the completion of the well purging activity.

TABLE 1-2
FOREST GLEN GOUNDWATER FEASIBILITY STUDY
GROUNDWATER PURGE DATA
PAGE 4 OF 12

LOCATION	MW4D R1	MW4D R2	MW4D R3	MW4D R4	MW5S R1	MW5S R2	MW5S R3	MW5S R4	MW5D R1	MW5D R2	MW5D R3	MW5D R4
pH	6.54	6.78	7.16	6.96	7.19	6.51	6.60	6.93	8.87	6.62	6.83	7.02
Conductivity**	1,100	990	1.36	1.42	1,180	820	1.32	1.42	1,220	940	1.36	1.46
Temperature °C	12	9.5	11.8	12.1	12.8	10.4	11.3	13.3	11.8	10.2	11.1	10.0

Notes:

NA Readings not available due to instrument failure.
NS Monitoring well was not sampled.
** Conductivity readings presented in umhos/cm in R1 and R2 and in mmhos/cm in R3 and R4

Table presents the final water quality measurements collected at the completion of the well purging activity.

TABLE 1-2
FOREST GLEN GOUNDWATER FEASIBILITY STUDY
GROUNDWATER PURGE DATA

LOCATION	MW6S R1	MW6S R2	MW6S R3	MW6S R4	MW6D R1	MW6D R2	MW6D R3	MW6D R4	MW7S R1	MW7S R2	MW7S R3	MW7S R4
pH	9.76	7.10	7.15	7.16	8.96	6.7	6.64	7.17	6.32	NA	6.63	7.00
Conductivity**	600	500	1.40	1.22	1,100	870	1.40	1.37	650	300	0.76	0.62
Temperature °C	11.7	9.9	10.9	11.9	11.9	9.8	11.4	11.6	14	13	11.7	14.9

Notes:

NA Readings not available due to instrument failure.
NS Monitoring well was not sampled.
** Conductivity readings presented in umhos/cm in R1 and R2 and in mmhos/cm in R3 and R4

Table presents the final water quality measurements collected at the completion of the well purging activity.

TABLE 1-2
FOREST GLEN GOUNDWATER FEASIBILITY STUDY
GROUNDWATER PURGE DATA

LOCATION	MW7D R1	MW7D R2	MW7D R3	MW7D R4	MW8S R1	MW8S R2	MW8S R3	MW8S R4	MW8D R1	MW8D R2	MW8D R3	MW8D R4
pH	6.61	NA	6.64	6.74	5.95	8.05	6.85	7.15	5.56	7.87	6.98	6.82
Conductivity**	1,200	NA	1.52	1.57	550	450	0.72	0.64	1,200	1,050	1.84	1.48
Temperature °C	12	NA	12.5	13.2	12.5	11.1	13.8	13.1	12	11.0	12.1	13.2

Notes:

NA Readings not available due to instrument failure.
NS Monitoring well was not sampled.
** Conductivity readings presented in umhos/cm in R1 and R2 and in mmhos/cm in R3 and R4

Table presents the final water quality measurements collected at the completion of the well purging activity.

TABLE 1-2
FOREST GLEN GOUNDWATER FEASIBILITY STUDY
GROUNDWATER PURGE DATA
PAGE 7 OF 12

LOCATION	MW9S R1	MW9S R2	MW9S R3	MW9S R4	MW9D R1	MW9D R2	MW9D R3	MW9D R4	MW10S R1	MW10S R2	MW10S R3	MW10S R4
pH	6.34	6.43	6.70	6.91	7.80	6.43	7.13	7.08	NS	NS	7.44	7.00
Conductivity**	800	800	1.13	0.94	1,150	820	1.36	1.39	NS	NS	1.18	0.75
Temperature °C	11.5	9.0	11.1	12.8	10.0	11.0	13.0	12.7	NS	NS	111.5	11.1

TABLE 1-2
FOREST GLEN GOUNDWATER FEASIBILITY STUDY
GROUNDWATER PURGE DATA

LOCATION	MW10D R1	MW10D R2	MW10D R3	MW10D R4	MW11S R1	MW11S R2	MW11S R3	MW11S R4	MW11D R1	MW11D R2	MW11D R3	MW11D R4
pH	NS	NS	6.83	7.30	NS	NS	7.27	6.99	NS	NS	7.63	7.11
Conductivity **	NS	NS	1.5	1.47	NS	NS	1.43	1.43	NS	NS	1.3	1.54
Temperature °C	NS	NS	12.0	12.9	NS	NS	11.7	12.8	NS	NS	14.0	12.7

Notes:

NA Readings not available due to instrument failure.
NS Monitoring well was not sampled.
** Conductivity readings presented in umhos/cm in R1 and R2 and in mmhos/cm in R3 and R4

Table presents the final water quality measurements collected at the completion of the well purging activity.

TABLE 1-2
FOREST GLEN GOUNDWATER FEASIBILITY STUDY
GROUNDWATER PURGE DATA

LOCATION	MW11V R1	MW11V R2	MW11V R3	MW11V R4	MW12S R1	MW12S R2	MW12S R3	MW12S R4	MW12D R1	MW12D R2	MW12D R3	MW12D R4
pH	NS	NS	7.82	7.36	NS	NS	7.27	7.15	NS	NS	6.56	7.41
Conductivity **	NS	NS	1.13	1.12	NS	NS	1.65	1.66	NS	NS	1.35	1.46
Temperature °C	NS	NS	12.3	15.6	NS	NS	12.1	12.4	NS	NS	12.1	12.9

Notes:

NA Readings not available due to instrument failure.
NS Monitoring well was not sampled.
** Conductivity readings presented in umhos/cm in R1 and R2 and in mmhos/cm in R3 and R4

Table presents the final water quality measurements collected at the completion of the well purging activity.

TABLE 1-2
FOREST GLEN GOUNDWATER FEASIBILITY STUDY
GROUNDWATER PURGE DATA

LOCATION	MW12V R1	MW12V R2	MW12V R3	MW12V R4	MW13S R1	MW13S R2	MW13S R3	MW13S R4	MW13D R1	MW13D R2	MW13D R3	MW13D R4
pH	NS	NS	6.78		NS	NS	7.06	6.85	NS	NS	6.87	6.70
Conductivity **	NS	NS	1.45		NS	NS	1.45	1.6	NS	NS	1.37	1.5
Temperature °C	NS	NS	16.4		NS	NS	11.8	12.0	NS	NS	12.8	11.7

Notes:

NA Readings not available due to instrument failure.
NS Monitoring well was not sampled.
** Conductivity readings presented in umhos/cm in R1 and R2 and in mmhos/cm in R3 and R4

Table presents the final water quality measurements collected at the completion of the well purging activity.

TABLE 1-2
FOREST GLEN GOUNDWATER FEASIBILITY STUDY
GROUNDWATER PURGE DATA

LOCATION	MW14S R1	MW14S R2	MW14S R3	MW14S R4	MW14D R1	MW14D R2	MW14D R3	MW14D R4	MW15S R1	MW15S R2	MW15S R3	MW15S R4
pH	NS	NS	6.16	6.75	NS	NS	6.89	6.97	NS	NS	6.95	7.00
Conductivity **	NS	NS	1.32	1.30	NS	NS	1.40	1.41	NS	NS	1.36	1.32
Temperature °C	NS	NS	12.1	12.4	NS	NS	12.5	12.2	NS	NS	11.9	12.3

Notes:

NA Readings not available due to instrument failure.
NS Monitoring well was not sampled.
** Conductivity readings presented in umhos/cm in R1 and R2 and in mmhos/cm in R3 and R4

Table presents the final water quality measurements collected at the completion of the well purging activity.

TABLE 1-2
FOREST GLEN GOUNDWATER FEASIBILITY STUDY
GROUNDWATER PURGE DATA

LOCATION	MW15D R1	MW15D R2	MW15D R3	MW15D R4
pH	NS	NS	7.34	7.03
Conductivity **	NS	NS	1.28	1.31
Temperature °C	NS	NS	12.8	12.6

Notes:

NA Readings not available due to instrument failure.
NS Monitoring well was not sampled.
** Conductivity readings presented in umhos/cm in R1 and R2 and in mmhos/cm in R3 and R4

Table presents the final water quality measurements collected at the completion of the well purging activity.

TABLE 1-3
FOREST GLEN GROUNDWATER FEASIBILITY STUDY
SYNOPTIC WATER LEVELS
PAGE 1 OF 2

MONITORING WELL	Top of Casing Elevation(TOC) (ft MSL)	Depth to Groundwater 09/11/95 (ft BGS)	Elevation of Groundwater 09/11/95 (ft MSL)	Depth to Groundwater 11/13 AM (ft BGS)	Elevation of Groundwater 11/13 AM (ft MSL)	Depth to Groundwater 11/16 AM (ft BGS)	Elevation of Groundwater 11/16 AM (ft MSL)	Depth to Groundwater 11/16 PM (ft BGS)	Elevation of Groundwater 11/16 PM (ft MSL)	Depth to Groundwater 12/28 AM (ft BGS)	Elevation of Groundwater 12/28 AM (ft MSL)	Depth to Groundwater 12/28 PM (ft BGS)	Elevation of Groundwater 12/28 PM (ft MSL)
MW-1D	597.05	19.15	577.90	13.20	583.85	12.80	584.25	13.00	584.05	16.92	580.13	16.95	580 10
MW-2D	595.98	19.00	576.98	13.25	582.73	13.10	582.88	13.00	582.98	16.75	579.23	16.73	579 25
MW-3D	596.10	18.95	577.15	13.12	582.98	12.83	583.27	13.00	583.10	16.39	579.71	16 38	579 72
MW-4D	594.44	17.45	576.99	11.90	582.54	11.70	582.74	11.40	583.04	15.17	579.27	15.07	579 37
MW-5D	593.34	16.43	576.91	10.79	582.55	10.70	582.64	10.50	582.84	14.15	579.19	14.13	579.21
MW-6D	595.73	18.81	576.92	13.15	582.58	13.00	582.73	12.90	582.83	16.50	579.23	16.48	579 25
MW-7D	595.28	18.50	576.78	12.60	582.68	13.40	581.88	12.60	582.68	16.18	579.10	16.15	579 13
MW-8D	595.86	18.30	577.56	14.50	581.36	14.50	581.36	14.80	581.06	18.46	577.40	18.45	577.41
MW-9D	594.31	17.08	577.23	10.80	583.51	11.20	583.11	11.20	583.11	14.70	579.61	14.63	579 68
MW-1S	597.15	19.20	577.95	17.20	579.95	12.90	584.25	13.20	583.95	16.85	580.30	16.82	580 33
MW-2S	595.95	18.55	577.40	12.78	583.17	12.80	583.15	12.90	583.05	16.00	579.95	16.00	579 95
MW-3S	596.43	19.00	577.43	13.20	583.23	12.95	583.48	13.10	583.33	16.50	579.93	16.50	579 93
MW-30	595.91	16.75	579.16	10.02	585.89	*15.92	579.16	10.40	568.76	NR	NR	14.15	581 76
MW-3P	595.99	7.95	588.04	7.00	588.99	8.81	579.23	7.30	580.74	7.53	588.46	7.50	588 49
MW-4S	594.34	16.63	577.71	11.20	583.14	10.90	583.44	10.90	583.44	13.92	569.22	14.03	580 31
MW-5S	593.25	16.13	577.12	10.40	582.85	10.20	583.05	10.30	582.95	13.85	579.40	13 82	579 43
MW-6S	596.11	18.75	577.36	12.17	583.94	12.10	584.01	12.00	584.11	15.63	580.48	15 55	580 56
MW-7S	595.28	12.30	582.98	6.70	588.58	7.40	587.88	7.40	587.88	9.70	585.58	9 80	585 48
MW-8S	595.67	15.70	579.97	12.20	583.47	12.80	582.87	12.90	582.77	15.48	580.19	15.50	580 17
MW-9S	594.22	10.25	583.97	10.60	583.62	10.80	583.42	10.70	583.52	14.05	580.17	13.95	580.27

*Potential measuring error
NR No reading due to problems with water level indicators
MSL Mean Sea Level
BGS Below Ground Surface

TABLE 1-3
FOREST GLEN GROUNDWATER FEASIBILITY STUDY
SYNOPTIC WATER LEVELS
PAGE 2 OF 2

MONITORING WELL	Top of Casing Elevation(TOC) (ft MSL)	Depth to Groundwater 08/01/97 (ft BGS)	Elevation of Groundwater 08/01/97 (ft MSL)	Depth to Groundwater 09/15/97 (ft BGS)	Elevation of Groundwater 09/15/97 (ft MSL)	MONITORING WELL	Top of Casing Elevation (TOC) (ft MSL)	Depth to Groundwater 08/01/97 (ft BGS)	Elevation of Groundwater 08/01/97 (ft MSL)	Depth to Groundwater 09/15/97 (ft BGS)	Elevation of Groundwater 09/15/97 (ft MSL)
MW-1S	598.15	16.59	579.21	15.42	580.38	MW-9S	595.22	14.04	579.16	12.43	580.77
MW-1D	598.05	16.81	579.09	15.63	580.27	MW-9D	595.31	14.71	578.79	13.44	580.06
MW-2S	596.95	16.61	578.94	14.48	580.62	MW-10S	595.52	16.15	577.55	14.95	578.75
MW-2D	596.98	16.43	578.57	15.16	579.84	MW-10D	594.96	15.88	577.52	14.68	578.72
MW-3S	597.43	16.40	578.90	14.62	580.68	MW-11S	600.54	12.99	585.41	12.23	586.17
MW-3D	597.10	16.27	578.83	14.78	580.32	MW-11D	600.20	10.88	587.72	9.94	588.66
MW-3O	596.91	14.80	580.00	13.95	580.85	MW-11V	600.40	10.23	588.17	8.62	589.78
MW-3P	596.99	16.34	578.86	6.11	589.09	MW-12S	600.24	15.38	582.32	14.26	583.44
MW-4S	595.34	14.12	579.48	12.68	580.92	MW-12D	600.36	15.41	582.29	14.29	583.41
MW-4D	595.44	14.86	578.54	13.39	580.01	MW-12V	599.90	5.66	592.44	5.53	592.57
MW-5S	594.25	13.55	578.65	12.15	580.05	MW-13S	597.75	13.94	581.86	13.05	582.75
MW-5D	594.34	13.89	578.51	12.57	579.83	MW-13D	597.87	14.33	581.77	13.37	582.73
MW-6S	597.11	16.13	579.07	14.13	581.07	MW-14S	597.18	16.52	578.58	15.20	579.90
MW-6D	596.73	16.24	578.56	14.87	579.93	MW-14D	596.38	16.18	578.52	14.80	579 90
MW-7S	596.28	10.12	584.18	6.00	588.30	MW-15S	599.70	14.74	582.66	13.68	583.72
MW-7D	596.28	15.81	578.39	14.51	579.69	MW-15D	598.37	14.65	582.35	13.58	583.42
MW-8S	596.67	13.81	580.99	12.05	582.75						
MW-8D	596.86	17.76	577.04	16.51	578.29						

*Potential measuring error
NR - No reading due to problems with water level indicators
MSL - Mean Sea Level
BGS - Below Ground Level

TABLE 1-4
FOREST GLEN GROUNDWATER FEASIBILITY STUDY
CLIMATIC DATA FOR THE VICINITY OF THE SITE

	Mean Temperature[1] (F°)	Mean Wind Speed (Kts) and Mean Wind Direction[2]	Mean Precipitation[2] (Inches)	Mean Snowfall[2] (Inches)
January	23.5	11 W	2.5	18
February	24.9	10 WSW	2.3	14
March	34.1	10 SW	2.8	9
April	45.7	9 SW	2.9	3
May	57.0	8 SW	2.9	<0.05
June	65.9	8 SW	2.8	0
July	70.9	8 SW	2.6	0
August	68.9	7 SW	3.6	0
September	61.8	8 SW	3.1	<0.05
October	51.2	8 W	2.8	<0.05
November	40.4	10 W	3.2	6
December	29.0	10 W	3.2	17
Annual Mean	47.8	9 SW	-	-
Annual Total	-	-	34.7	67

1 Values from the Lockport 2NE Station (4311N Latitude, 07839W Longitude). Source of data: National Oceanic and Atmospheric Administration (NOAA). 1992. Monthly Station Normals of Temperature, Precipitation, and Heating and Cooling Degree Days, 1961-90, New York. NOAA, National Climatic Data Center, Asheville, NC. January 1992.

2 Values fro the Niagara Falls International Airport Station (4306N latitude, 97857W longitude). Source of data: Air Weather Service. 1987. Climatic Brief for the Niagara Falls, New York International Airport Station.

TABLE 1-5
FOREST GLEN GROUNDWATER FEASIBILITY STUDY
GRAIN SIZE ANALYSES OF FILL SAMPLES

SAMPLE NO.	DEPTHS (ft bgs)	GRAVEL[1] % WEIGHT	SAND (A) COARSE[2] % WEIGHT	SAND (B) MEDIUM[2] % WEIGHT	SAND (C) FINE[2] % WEIGHT	SAND (D) FINE[2] % WEIGHT	SILT (A)[3] % WEIGHT	SILT (B)[3] % WEIGHT	CLAY* % WEIGHT	COLLOIDS* % WEIGHT	AOC LOCATION
Berm -2A	4.0 - 6.0	6.40	8.30	3.60	9.30	2.50	12.70	12.40	3.10	41.80	1
Berm -2	8.0 - 10.0	14.00	10.10	5.00	11.80	3.00	19.10	14.80	11.00	11.10	1
Berm- 3A	10.0 - 12.0	12.60	22.20	11.60	13.80	1.10	0.00	5.90	8.10	24.70	1
SB-10SS	0.0 - 2.0	16.20	7.60	10.40	32.40	5.70	18.30	9.50	0.00	0.00	5
SB-13SS	0.0 - 2.0	37.40	7.50	10.80	28.00	6.20	0.30	9.80	0.00	0.00	5
SB-14SS	0.0 - 2.0	10.80	4.80	8.30	19.70	4.10	3.70	18.40	11.50	18.80	5
SB-CENTER SS	0.0 - 2.0	12.30	6.10	8.10	22.30	4.50	0.00	17.10	9.00	22.00	5
SB-CENTER	4.0 - 6.0	4.80	3.10	5.60	15.10	2.40	2.40	13.90	15.50	37.20	5
DP-013B	2.0 - 4.0	17.60	11.60	12.00	18.00	3.60	18.20	14.40	2.00	0.70	2
DP-017B	2.0 - 4.0	12.20	15.90	6.00	21.00	4.60	25.50	13.50	0.00	1.20	2
DP-018B	2.0 - 4.0	9.50	11.80	4.50	12.10	2.50	18.90	12.60	9.40	15.30	2
DP-033SS	0.0 - 2.0	3.10	3.60	2.00	5.40	2.10	23.20	14.70	17.40	27.60	2
DP-034SS	0.0 - 2.0	11.40	6.30	2.40	6.50	2.00	19.30	8.70	13.30	28.40	2
AVERAGE		**12.95**	**9.15**	**6.95**	**16.57**	**3.41**	**12.43**	**12.75**	**7.72**	**17.60**	

(1) Gravel, (Passing 3 in. & retained on No. 4 sieve)

(2) Sand
- (a) Coarse Sand (Passing No. 4 sieve & retained on No. 20 sieve)
- (a) Medium Sand (Passing No. 20 sieve & retained on No. 40 sieve)
- (b) Fine Sand (Passing No. 40 sieve & retained on No. 140 sieve)
- (c) Fine Sand (Passing No. 140 sieve & retained on No. 200 sieve)

(3) Silt Size (,0.075 to-0.005 mm)
- (a) Silt (0.075 to 0.033 mm)
- (b) Silt (0.033 to 0.007 mm)

* Clay Size (0.007 to 0.001 mm)

Colloids (smaller than 0.001 mm)

NA Not available

TABLE 1-6
FOREST GLEN GROUNDWATER FEASIBILITY STUDY
GRAIN SIZE ANALYSES OF CLAY SAMPLES

SAMPLE NO.	DEPTHS (ft.bgs)	GRAVEL[1] % WEIGHT	SAND (A) COARSE[2] % WEIGHT	SAND (B) MEDIUM[2] % WEIGHT	SAND (C) FINE[2] % WEIGHT	SAND (D) FINE[2] % WEIGHT	SILT (A)[3] % WEIGHT	SILT (B)[3] % WEIGHT	CLAY* % WEIGHT	COLLOIDS* % WEIGHT	AOC LOCATION
Berm -1	14.0 - 16.0	0	0.3	0.4	1.40	0.60	20.60	12.8	20.8	43.2	1
Berm-5	6.0 - 8.0	0	1.4	0.8	2.9	1.1	19.6	22	21.4	30.8	1
SB-01SS	0 - 2.0	0	2.3	0.6	2.8	0.8	19.8	19.9	14.4	39.4	2
SB-02SS	0 - 2.0	0.7	2.2	1.1	3.7	1.5	22.6	17.5	20.9	29.8	2
SB-04SS	0 - 2.0	1.9	2.3	1.6	4.8	1.4	16.9	17.4	22.2	31.7	5
SB-05SS	0 - 2.0	0	0.1	0.4	0.9	0.4	0	8.29	22	75.4	5
SB-06SS	0 - 2.0	0	0.3	1.1	3.3	1	18.4	16.4	22.7	36.9	5
SB-08SS	0 - 2.0	0	1	2.2	4	0.8	18.3	23.2	27.4	23.1	5
SB-09SS	0 - 2.0	1	0.2	0.6	2.4	0.8	12	18.9	21.6	42.5	5
SB-10	6.0 - 8.0	0.4	0.4	0.8	4	1	0	8.5	24.3	67.2	5
SB-11SS	0 - 2.0	1.1	0.4	0.9	3.2	1	0	1.4	26.2	65.8	5
SB-12SS	0 - 2.0	0	1.7	1.9	9	2.5	22.5	14.8	16.2	31.4	5
SB-13	NA	0.2	0.5	1.9	7.2	1.8	21	14.5	18.1	34.9	5
SB-15SS	0 - 2.0	0	0.3	0.8	4.7	1.5	6.1	22.4	21.2	43	5
SB-16SS	0.0 - 2.0	0	0.8	1.3	3.9	1.1	19.9	19.6	20	33.5	5
SB-17SS	0.0 - 12.0	0	0.1	0.1	0.9	0.3	0	15.4	25.2	59.4	5
DP-004	10 - 12.0	0	0.9	0.5	2.6	1.6	10.1	23.5	25.8	34.8	6
DP-013	11 - 13.0	0.2	0.4	0.2	0.5	0.4	6.9	19.4	30.6	40.4	6
DP-017	9 - 11.0	0	0.1	0.1	0.7	0	5.2	12.5	28.7	52.4	6
DP-018	10.0 - 12.0	0.9	0.9	0.5	2.1	1	9.4	18.7	27.6	37.8	6
DP-021SS	0 - 2.0	0	0.2	0.2	0.8	0.2	21	13.5	22	42.1	2
DP-022SS	0 - 2.0	0.7	0.6	0.5	2.5	0.6	28.3	18.4	17.5	30.9	2
DP-023SS	0 - 2.0	0	0.1	0.1	0.8	0.5	6	15.2	25.5	51.8	2
DP-025SS	0 - 2.0	0	0.6	0.7	2.5	1.1	30.1	15.1	16.4	32.4	2
DP-026SS	0 - 2.0	0	0.3	0.5	1.1	0.4	2.9	13.1	27.9	53.8	2
DP-027SS	0 - 2.0	0	0.1	0.2	0.9	0.3	24	13.7	21.3	39.4	2
DP-028SS	0 - 2.0	0	0.9	0.9	2.9	1.5	5.7	20.1	19.2	47.9	2
DP-030SS	0 - 2.0	0	0.5	0.3	2.5	1	10.9	20	20.3	43.9	2
DP-031SS	0 - 2.0	0	0.3	0.6	1.7	0.7	7.7	17.8	26.8	44.4	2
DP-032SS	0 - 2.0	0.5	0.5	0.3	2	0.9	12.1	18.2	22.8	42.7	2
Average		**0.25**	**0.69**	**0.74**	**2.71**	**0.91**	**12.58**	**16.41**	**22.57**	**42.76**	

(1) Gravel, (Passing 3 in & retained on No 4 sieve)

(2) Sand
- (a) Coarse Sand (Passing No 4 sieve & retained on No. 20 sieve)
- (a) Medium Sand (Passing No 20 sieve & retained on No. 40 sieve)
- (b) Fine Sand (Passing No 40 sieve & retained on No. 140 sieve)
- (c) Fine Sand (Passing No 140 sieve & retained on No 200 sieve)

(3) Silt Size (.0.075 to-0.005 mm)
- (a) Silt (0.075 to 0.033 mm)
- (b) Silt (0.033 to 0.007 mm)

* Clay Size (0 007 to 0.001 mm)

Colloids (smaller than 0.001 mm)

NA Not available

TABLE 1-7
FOREST GLEN GROUNDWATER FEASIBILITY STUDY
GRAIN SIZE ANALYSES OF CLAY TILL SAMPLES

SAMPLE NO.	DEPTHS (ft. bgs)	GRAVEL[1] % WEIGHT	SAND (A) COARSE[2] % WEIGHT	SAND (B) MEDIUM[2] % WEIGHT	SAND (C) FINE[2] % WEIGHT	SAND (D) FINE[2] % WEIGHT	SILT (A)[3] % WEIGHT	SILT (B)[3] % WEIGHT	CLAY* % WEIGHT	COLLOIDS* % WEIGHT	AOC LOCATION
SB-01	8.0 - 10.0	13.10	10.00	3.20	9.80	4.80	34.60	21.40	3.10	0.00	2
SB-06	8.0 - 10.0	9.50	9.50	3.50	10.70	4.60	20.40	17.10	8.60	16.20	5
SB-09	8.0 - 10.0	20.70	4.50	4.20	12.10	4.70	29.70	13.60	7.20	3.30	5
SB-12	6.0 - 7.0	9.90	1.40	1.40	4.70	2.70	25.80	19.50	17.20	17.50	5
SB-16	8.0 - 10.0	6.40	2.60	3.00	9.60	3.20	26.40	21.20	16.80	10.70	5
SB-18	12.0 - 14.0	10.00	12.70	4.30	14.40	5.40	28.20	18.70	6.20	0.00	2
DP-019	10.0 - 12.0	12.90	9.60	3.70	10.10	5.40	37.50	15.00	2.40	0.00	6
DP-022	8.0 - 10.0	12.70	9.40	3.30	11.60	2.10	35.10	15.60	3.90	4.50	2
DP-023	10.0 - 12.0	7.50	2.70	1.30	4.10	1.60	17.10	11.90	17.40	36.10	2
DP-025	6.0 - 8.0	9.60	11.20	4.00	14.20	6.40	29.00	14.50	5.20	4.40	2
DP-031	10.0 - 12.0	4.90	8.10	3.30	10.60	5.50	25.80	18.80	8.80	12.60	2
Average		**10.65**	**7.43**	**3.20**	**10.17**	**4.22**	**28.15**	**17.03**	**8.80**	**9.57**	

(1) Gravel, (Passing 3 in. & retained on No. 4 sieve)

(2) Sand
- (a) Coarse Sand (Passing No. 4 sieve & retained on No. 20 sieve)
- (a) Medium Sand (Passing No. 20 sieve & retained on No. 40 sieve)
- (b) Fine Sand (Passing No. 40 sieve & retained on No. 140 sieve)
- (c) Fine Sand (Passing No. 140 sieve & retained on No. 200 sieve)

(3) Silt Size (,0.075 to-0.005 mm)
- (a) Silt (0.075 to 0.033 mm)
- (b) Silt (0.033 to 0.007 mm)

* Clay Size (0.007 to 0.001 mm)

Colloids (smaller than 0.001 mm)

NA Not available

TABLE 1-8
FOREST GLEN GROUNDWATER FEASIBILITY STUDY
GROUNDWATER MCLs FOR DETECTED INORGANIC CONTAMINANTS OF CONCERN
ALL VALUES UG/L

Analyte	National Primary Drinking Water Standards	New York State Department of Health Drinking Water Standards	NYSDEC Groundwater Quality Standards	Maximum Concentration Detected
Chromium	100.00	100.00	50.00	749.00J
Iron	50*	300*	300	32,500
Lead	15	50	25	105.00
Manganese	300*	300*	300	6,790J
Nickel	100	N/A	N/A	725.00J

Notes:
MCLS - Maximum Contaminant Level
N/A - Not Available
J - Reported value is estimated
* Indicates value is a secondary standard

Sources:
National Primary Drinking Water Standards, 40 CFR Part 141.
New York State Department of Health, Drinking Water Standards.
New York State Department of Environmental Conservation, Groundwater Quality Standards 6 NYCRR Chapter X, Part 703.

TABLE 1-9
FOREST GLEN GROUNDWATER FEASIBILITY STUDY
GROUNDWATER MCLs
FOR DETECTED ORGANIC CONTAMINANTS OF CONCERN
ALL VALUES UG/L

Compound	National Primary Drinking Water Standards	New York State Department of Health Drinking Water Standards	NYSDEC Groundwater Quality Standards	Maximum Concentration Detected
Volatile Organic				
Vinyl Chloride	2.00	2.00	2.00	240
1,1-Dichloroethane	NA	5.00	5.00	92
1,1,1-Trichloroethane	200	5.00	5.00	88
Trichloroethene	5.00	5.00	5.00	230
1,2-Dichloroethene (Total)	70 - 100.00	5.00	5.00	1709
Xylenes	10,000	5.00	5.00	8.00J
Benzene	5.00	5.00	0.7	2.00J
Semivolatile Organic Compounds				
Benzo(a)pyrene	0.20	NA	5.00	0.70J
Pentachlorophenol	1.00	1.00	1.00	32
Hexachlorobutadiene	NA	5.00	5.00	10.00J
Phenol	NA	NA	1.00	8.00J
2-Chlorophenol	NA	NA	5.00	10.00J
4-Chloro-3-Methylphenol	NA	NA	5.00	10.00J
4-Nitrophenol	NA	NA	5.00	10.00J
Pyrene	NA	NA	5.00	6.00J
Di-N-Octylphlate	NA	NA	5.00	10.00

Notes:
MCLs- Maximum Contaminant Levels
J - Reported value is estimated
NA - Not Available

Sources:
National Primary Drinking Water Standards, 40 CFR Part 141.
New York State Department of Health, Drinking Water Standards.
New York State Department of Environmental Conservation, Groundwater Quality Standards 6 NYCRR, Chapter X, Part 703.

The concentrations presented on this table represent the highest reported analyte detections over four sampling rounds.

TABLE 1-10
FOREST GLEN GROUNDWATER FEASIBILITY STUDY
SUMMARY OF CHEMICAL CLASSES OF COCS IN SITE MEDIA

MEDIA	AREA OF CONCERN	CONTAMINANT OF CONCERN GROUP
Surface water	4 - East Gill Creek	Pesticide and metals
Sediment	3 - Wooded wetland	Pesticide/PCB, PAH, Targeted organic and metals
	4 - East Gill Creek	Targeted organic and metals
Surface soil	2 - Northern Aspect	Targeted organic, PAH, and metals
	5 - Edgewood Drive	Targeted organic, PAH, and metals
	6 - Subdivision	Targeted organic, PAH, and metals
Subsurface soil	1 - Berm	Targeted organic, phenol, PAH, and metals
	2 - Northern Aspect	Targeted organic, phenol, PAH, and metals
	5 - Edgewood Drive	Targeted organic, PAH, and metals
	6 - Subdivision	Targeted organic, PAH, and metals
Groundwater	Sitewide	VOC and metals

TABLE 1-11
FOREST GLEN GROUNDWATER FEASIBILITY STUDY
FATE AND TRANSPORT PROPERTIES FOR FOREST GLEN SITE CONTAMINANTS

CONTAMINANT	Molec. Weight (g/mole)	Specific Density @20-25 C	Water Solubility @20-25 C (mg/l)*	Vapor Pressure @20-25 C (mm HG)	Henry's Law Constant @20-25 C (atm-m ^3/mol)	Koc (cc/gm)	log Kow	Kd (cc/gm)	Rf	Adsorption	Volatilization from Water	Mobility
TCL Volatile Organics												
Vinyl chloride	63	0.91	2.7E+03	2.7E+03	8.2E-02	2.5E+00	0.6	1.3E-01	4.9E+00	Low	High	High
Trichloroethene	131	1.46	1.1E+03	5.8E+02	9.1E-03	1.3E+02	2.5	6.3E+00	2.0E+02	High	High	Moderate
1,1,1-Trichloroethane	133	1.34	1.5E+03	1.2E+02	1.4E-02	1.5E+02	2.5	7.5E+00	2.4E+02	High	High	Moderate
1,1-Dichloroethane	99	1.18	5.5E+03	1.8E+02	4.3E-03	3.0E+01	1.8	1.5E+00	4.8E+01	Moderate	High	Moderate
1,2-Dichloroethene (cis)	97	1.27	3.5E+03	2.1E+02	7.6E-03	1.4E+02	1.9	7.0E+00	2.2E+02	High	High	Moderate
1,2-Dichloroethene (trans)	97	1.27	6.3E+03	3.2E+02	6.6E-03	1.8E+02	2.1	9.0E+00	2.8E+02	High	High	Moderate
Xylenes (Total)	106	0.88	2.0E+02	1.0E+01	7.0E-03	1.3E+02	3.2	6.5E+00	2.1E+02	High	High	Moderate
TCL Semi-Volatile Organics - 1												
Phenol	94	1.06	9E+04	2.0E-01	2.7E-07	2.7E+01	1.5	1.4E+00	4.3E+01	Moderate	Low	Moderate
2-Methylphenol	108	1.05	2.5E+04	2.4E-01	1.2E-06	2.2E+01	1.9	1.1E+00	3.6E+01	Moderate	Moderate	Moderate
4-Methylphenol	108	1.02	2.3E+04	1.3E-01	7.9E-07	4.9E+01	1.7	2.5E+00	7.8E+01	High	Moderate	Moderate
Pentachlorophenol	266	1.98	2.0E+01	1.7E-04	3.4E-06	8.9E+02	5.01	4.5E+01	1.4E+03	High	Moderate	Low
Hexachlorobutadiene	261	1.55	2.55	1.5E-01	1.3E-02	4.7E+03	4.9	2.3E+02	7.3E+03	High	High	Low
TCL Semi-Volatile Organics - 2 (PAH)												
Anthracene	178	1.28	1.3E+00	2.0E-04	6.5E-05	1.9E+04	4.3	9.5E+02	3.0E+04	High	Moderate	Low
Benzo(a)anthracene	228	1.27	9.0E-03	1.1E-07	8.0E-06	1.4E+06	5.9	7.0E+04	2.2E+06	High	Moderate	Low
Benzo(b)fluoranthene	252	ND	1.4E-02	5.0E-07	1.2E-05	5.5E+05	6.6	2.8E+04	8.6E+05	High	Moderate	Low
Benzo(a)pyrene	252	1.35	1.2E-03	5.6E-09	1.6E-06	4.0E+05	6.0	2.0E+04	6.3E+05	High	Moderate	Low
Benzo(g,h,i)perylene	276	ND	2.6E-04	1.0E-10	1.4E-07	7.8E+06	7.1	3.9E+05	1.2E+07	High	Moderate	Low
Benzo(k)fluoranthene	252	ND	5.5E-04	9.6E-11	1.0E-03	4.4E+06	6.9	2.2E+05	6.9E+06	High	Moderate	Low
Chrysene	228	1.27	6.0E-03	6.3E-09	7.3E-20	2.5E+05	5.6	1.2E+04	3.8E+05	High	Low	Low
Dibenz(a,h)anthracene	278	1.28	5.0E-04	1.0E-09	7.3E-09	1.7E+06	6.4	8.5E+04	2.7E+06	High	Low	Low
Dibenzofuran	168	1.09	1.0E+01	ND	ND	8.1E+03	4.2	4.1E+02	1.3E+04	High	-	Low
Fluoranthene	202	1.25	2.6E-01	1.0E-02	1.7E-02	4.2E+04	5.2	2.1E+03	6.6E+04	High	High	Low
Indeno(1,2,3-cd)pyrene	276	ND	6.2E-02	1.0E-09	3.0E-20	3.1E+07	6.0	1.6E+06	4.9E+07	High	Low	Low
Napthalene	128	1.16	3.1E+01	2.3E-01	4.6E-04	5.5E+02	3.4	2.8E+01	8.6E+02	High	Moderate	Moderate
Phenanthrene	178	1.18	8.2E-01	6.8E-04	3.9E-05	5.2E+03	4.6	2.6E+02	8.2E+03	High	Moderate	Low
Pyrene	202	1.27	1.6E-01	6.9E-07	1.1E-05	4.6E+04	4.9	2.3E+03	7.2E+04	High	Moderate	Low
Targeted Organics												
Aniline	93	1.00	3.6E+04	4.5E-01	1.9E-06	5.4E+01	0.9	2.7E+00	8.6E+01	High	Moderate	Moderate
2-Anilinobenzothiazole	226	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzothiazole	135	1.25	Slight	3.4E+01	NA	NA	NA	NA	NA	NA	NA	NA
Diphenylamine	169	1.20	5.8E+01	3.8E-05	1.5E-07	4.7E-07	3.6	2.4E-08	1.0E+00	Low	Moderate	High
N,N-diphenyl-1,4-benzenediamine	260	1.20	Slight	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Mercaptobenzothiazole	167	1.40	2.5E+03	NA	NA	NA	NA	NA	NA	NA	NA	NA
Perylene	252	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Phenothiazine	199	NA	Insoluble	NA	NA	NA	NA	NA	NA	NA	NA	NA
Phenylisothiocyanate	135	1.13	Insoluble	NA	NA	NA	NA	NA	NA	NA	NA	NA
TCL Pesticides/PCBs												
Aroclor 1254	327	1.51	1.2E-02	7.7E-05	2.7E-03	4.1E+05	6.5	2.1E+04	6.4E+05	High	High	Low
alpha-BHC	291	1.87	2.0E+00	2.5E-05	5.3E-06	1.9E+03	3.8	9.5E+01	3.0E+03	High	Moderate	Low

TABLE 1-11
FOREST GLEN GROUNDWATER FEASIBILITY STUDY
FATE AND TRANSPORT PROPERTIES FOR FOREST GLEN SITE CONTAMINANTS

CONTAMINANT	Molec. Weight (g/mole)	Specific Density @20-25 C	Water Solubility @20-25 C (mg/l)*	Vapor Pressure @20-25 C (mm HG)	Henry's Law Constant @20-25 C (atm-m ^3/mol)	Koc (cc/gm)	log Kow	Kd (cc/gm)	Rf	Adsorption	Volatilization from Water	Mobility
TAL Inorganics												
Aluminium	27	2.70	Insoluble						1.0E+00			
Arsenic (+3)	75	4.70	Insoluble	-	NA	NA	NA	3.0E+01	9.4E+02	High	NA	Moderate
Chromium (+6)	52	7.10	Insoluble	-	NA	NA	NA	1.5E+01	4.7E+02	High	NA	Moderate
Cobalt	59	8.90	Insoluble						1.0E+00			
Lead	207	11.34	Insoluble						1.0E+00			
Mercury	201	13.55	Insoluble	2.0E-03	NA	322	NA	1.8E+02	5.7E+03	High	NA	Low
Nickel	59	8.90	Insoluble	0.0E+00	NA	NA	NA	7.9E+01	2.5E+03	High	NA	Low

VARIABLES

Fraction Organic Carbon, foc =	5.0%	
Soil Bulk Density, Rho_b =	1.57	gm/cc
Effective Porosity, Eta_e =	5%	

Adsorption is	"Low"	if Kd <	0.5
	"High"	if Kd >	2
	"Moderate"	if Kd is in-between	
	"Immobile"	if Kd >10	
Volatilization from Water is	"Low"	if H <	1.0E-07
	"High"	if H >	1.0E-03
	"Moderate"	if H is in-between	
Mobility is	"High"	if Rf <	1.0E+01
	"Low"	if Rf >	1.0E+03
	"Moderate"	if Rf is in-between	

NOTATION

Koc = Soil Organic Carbon/Water Partition Coefficient, cc/gm
Kow = n-Octanol/Water Partition Coefficient, dimensionless
Kd = Soil/Water Partition Coefficient [= Koc X foc for organics], cc/gm
Rf = Retardation Factor = 1 + (Rho_b X Kd / Eta_e), dimensionless
NA= Data is not available

NOTES

The Kd values for inorganics are based information provided in the EPA Soil Screening Guidance Document (EPA, 1994).
The Kd values for mercury, and nickel were developed by EPA using an equilibrium
geochemical speciation model (MINTEQ2), assuming a certain pore-water chemistry.
The values for arsenic, and chromium (6+), were based on empirical, pH-dependent relationships
developed by EPA. The Kd values used here were adjusted for a site specific pH of 7.6.
However, for these values to be more site-specific, site-specific modeling would be required because, unlike
for organics, Kd values for inorganics are significantly affected by a variety of soil conditions.
* For inorganics, solubility is based on "per 100 parts," i.e., units are [mg/(1.0E-04 l)].

Sources: 1 - Fate and Exposure Data by Howard, Philip H., Lewis Publishers
2 - Groundwater Chemicals Desk Reference by John H. Montgomery and Linda M. Welko, Lewis Publishers
3 - Merck index, 11th Edition, Merck & Co. Inc., Rahway, N.J., 1989.
4 - Dangerous Properties of Industrial Materials
5 - USEPA Superfund Public Health Evaluation Manual, OSWER Directive 9285.4-1; October, 1986
6 - Koc value for Aniline, Soil Science Journal, 1986, Citation 141:26; Bouchard, D; Mattice,J.; Lavy, T.L.
7 - Solubility of 2-Mercaptobenzothiazole, EPA-560/2-76-006. Washington D.C: U.S. EPA. PP160, 1976. Investigation of selected potential environmental contaminants: Mercaptobenzothiazoles. Santodonato, J.; Davis,L.N.;Howard,P.H.;Saxena,J.
8 - Henry's Law value for Aniline: Syracuse Research Corporation, 1988
9 - Batelle, 1989

TABLE 1-12
FOREST GLEN GROUNDWATER FEASIBILITY STUDY
RELATIVE MOBILITIES OF INORGANIC COCS

HIGH	MEDIUM	LOW
Nickel	Aluminum	Cobalt
Vanadium	Arsenic	Zinc
	Cadmium	Vanadium
		Mercury

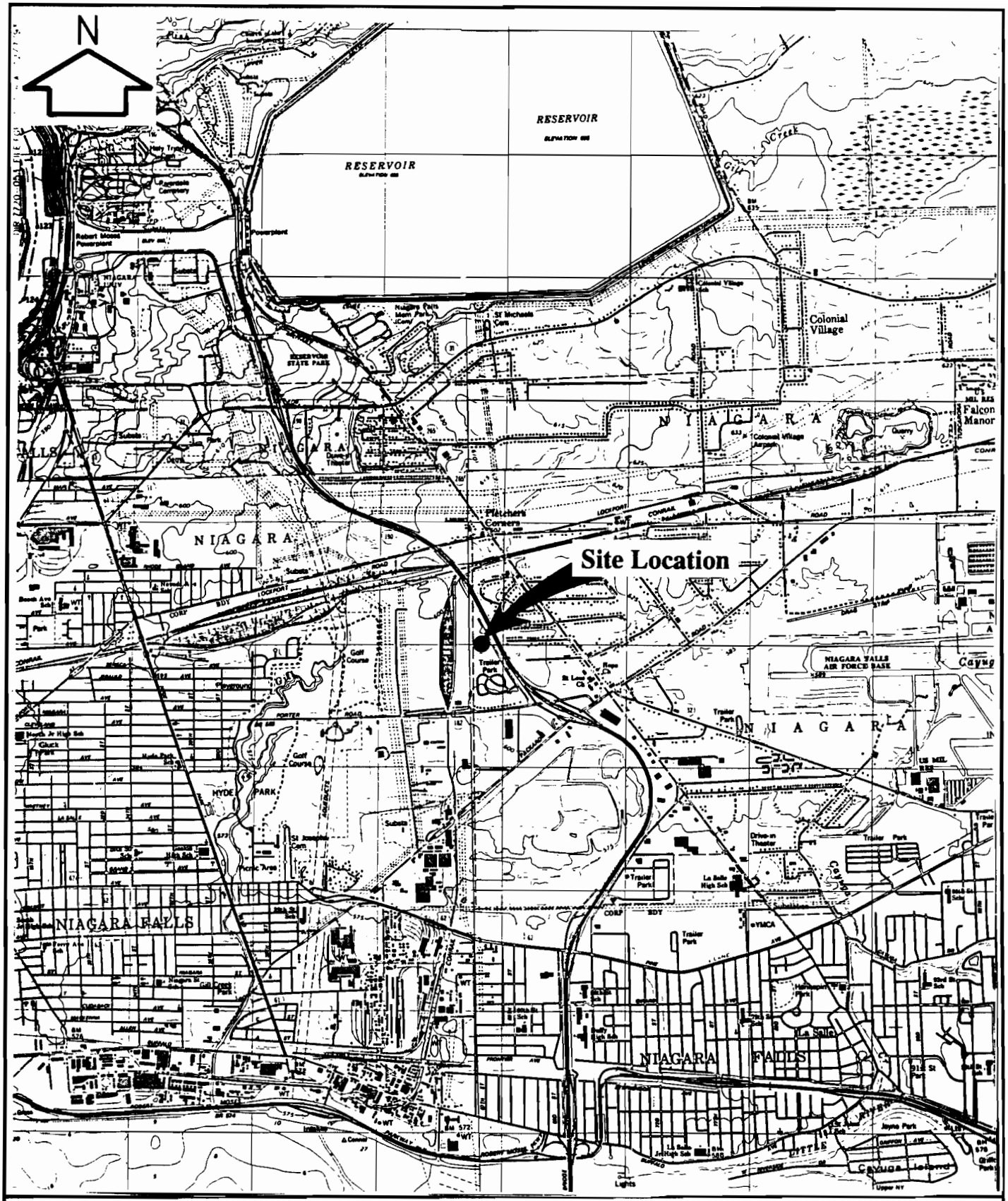
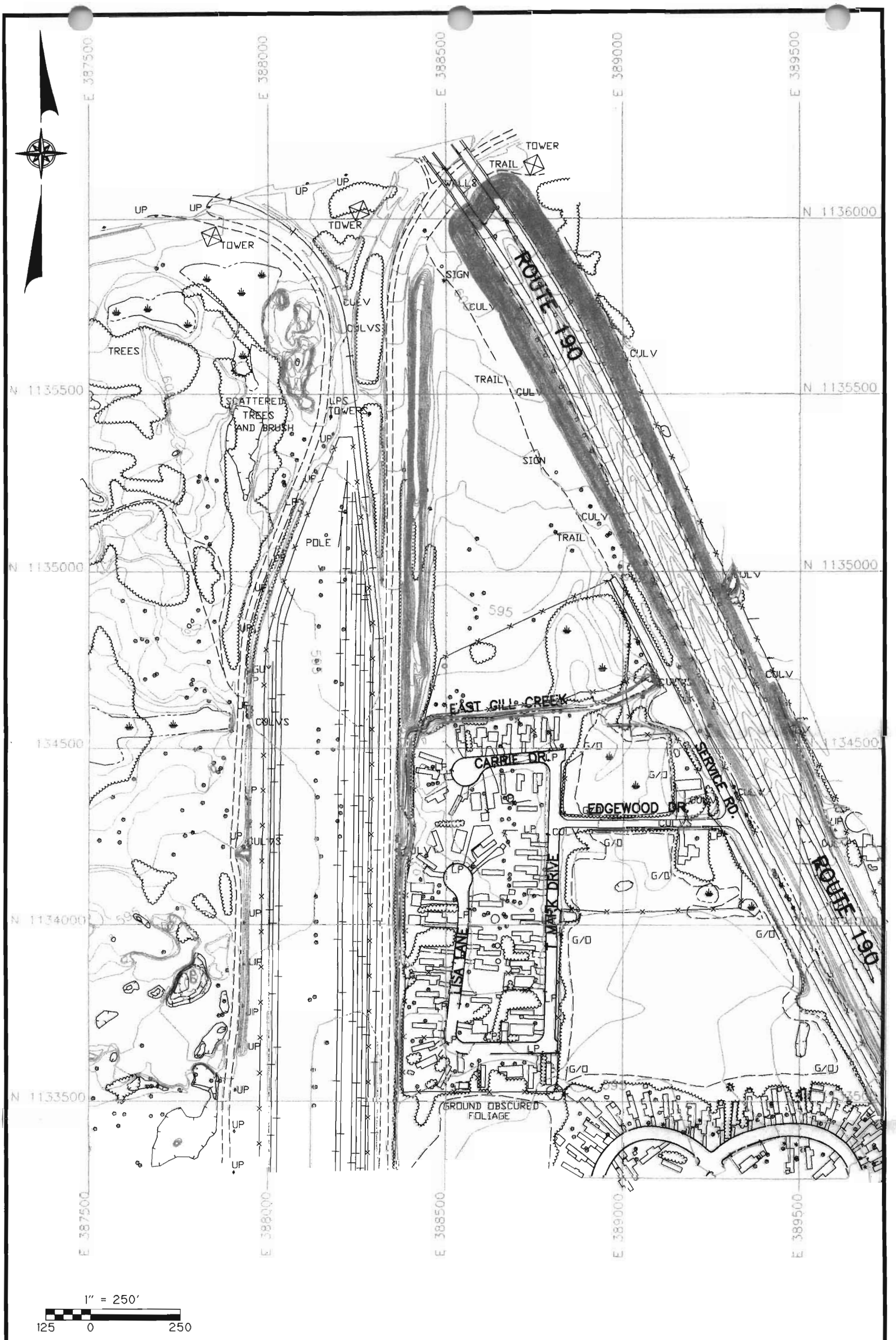


Figure 1-1
SITE LOCATION MAP

FOREST GLEN SITE
NIAGARA FALLS, NEW YORK
WORK ASSIGNMENT 053-2L3U

Source: USGS Topographic Maps

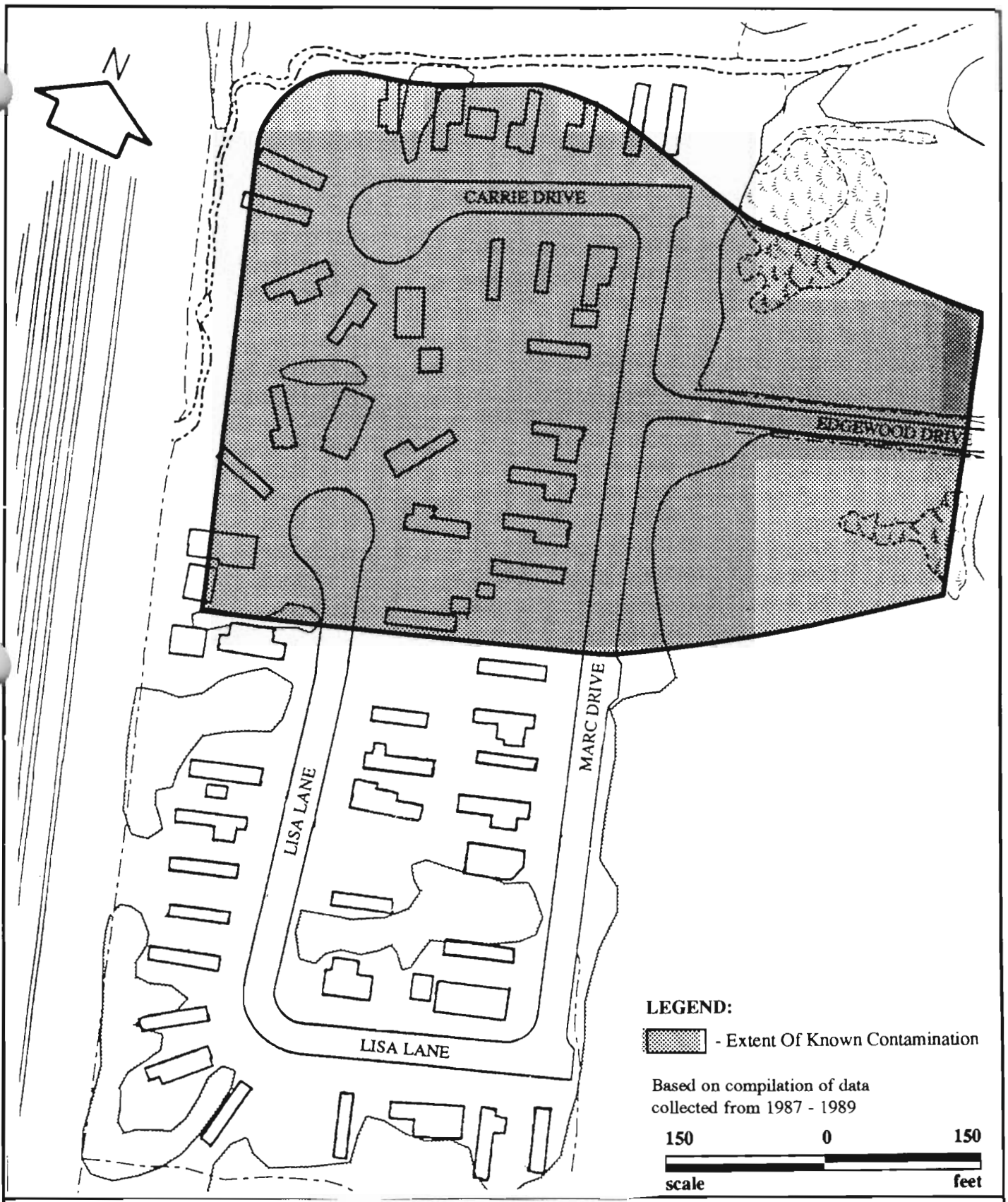
[redacted]
CDM FEDERAL PROGRAMS CORPORATION
a subsidiary of Camp Dresser & McKee Inc.



CDM FEDERAL PROGRAMS CORPORATION
a subsidiary of Camp Dresser & McKee Inc.

FOREST GLEN SITE
NIAGARA FALLS, NEW YORK
WORK ASSIGNMENT 053-2L3U

FIGURE 1-2
SITE MAP



FOREST GLEN SITE
NIAGARA FALLS, NEW YORK
WORK ASSIGNMENT 053-2L3U
Source: NUS Corporation

CDM FEDERAL PROGRAMS CORPORATION
a subsidiary of Camp Dresser & McKee Inc.

Figure 1-3
EXTENT OF CONTAMINATION DELINATED BY PREVIOUS EPA INVESTIGATIONS (THROUGH 1989)

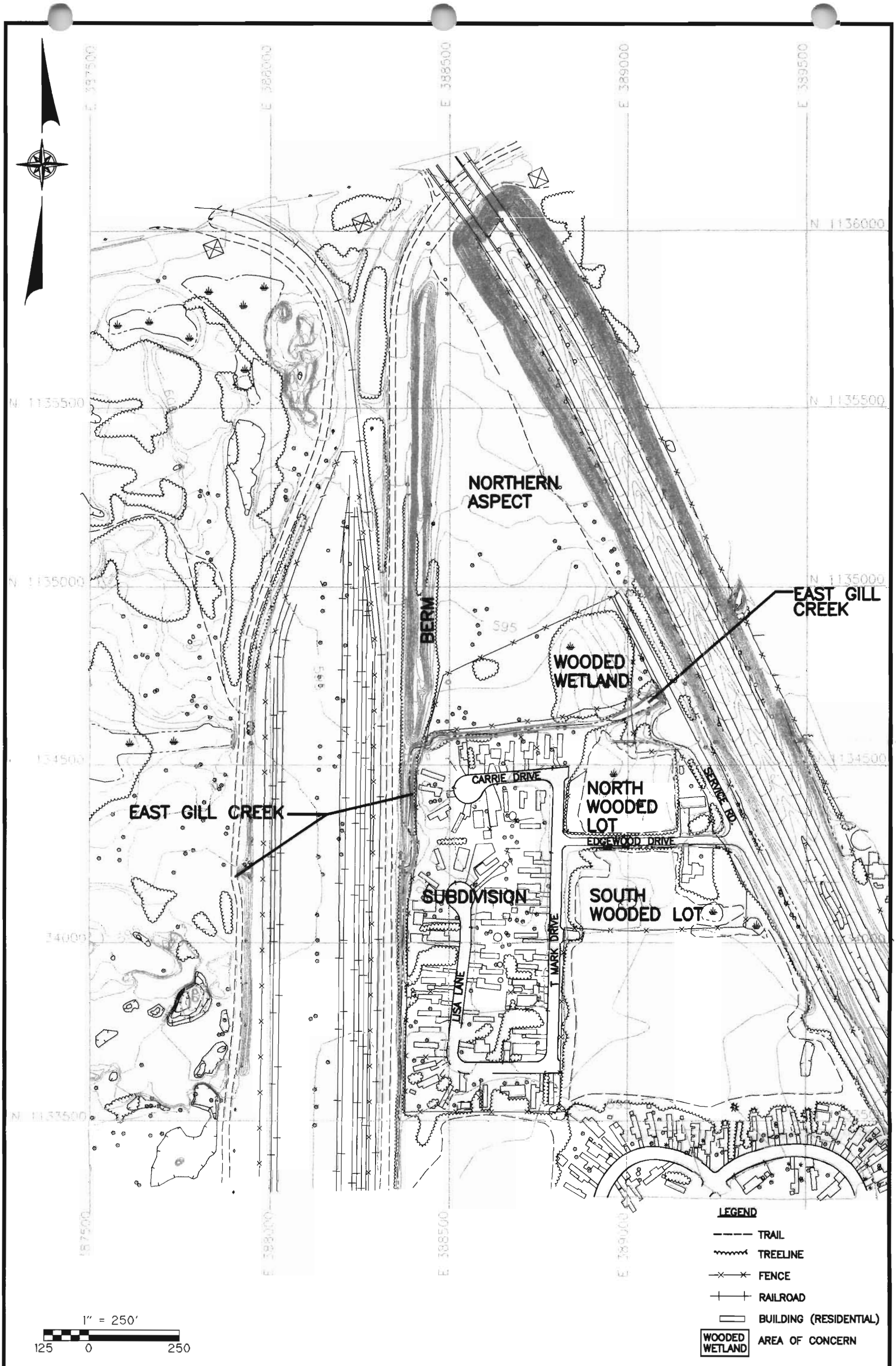


FIGURE 1–4

AREAS OF CONCERN MAP

WORK ASSIGNMENT 053–2L3U
Forest Glen Site, Niagara Falls, New York

CDM FEDERAL PROGRAMS CORPORATION
a subsidiary of Camp Dresser & McKee Inc.

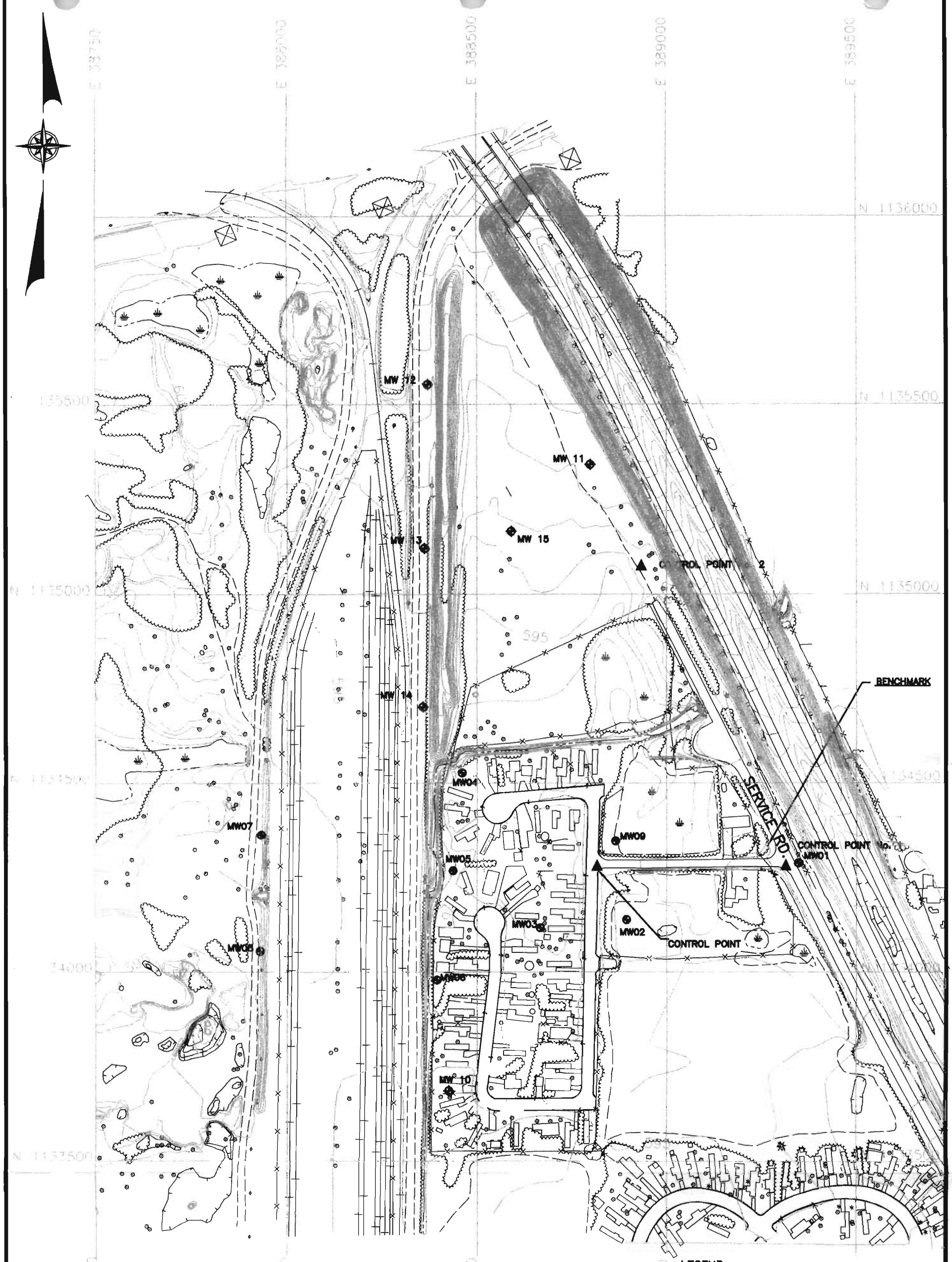


FIGURE 1–5

MONITORING WELL CLUSTER LOCATIONS

CDM FEDERAL PROGRAMS CORPORATION
a subsidiary of Camp Dresser & McKee Inc.

WORK ASSIGNMENT 053–2L3U
Forest Glen Site, Niagara Falls, New York

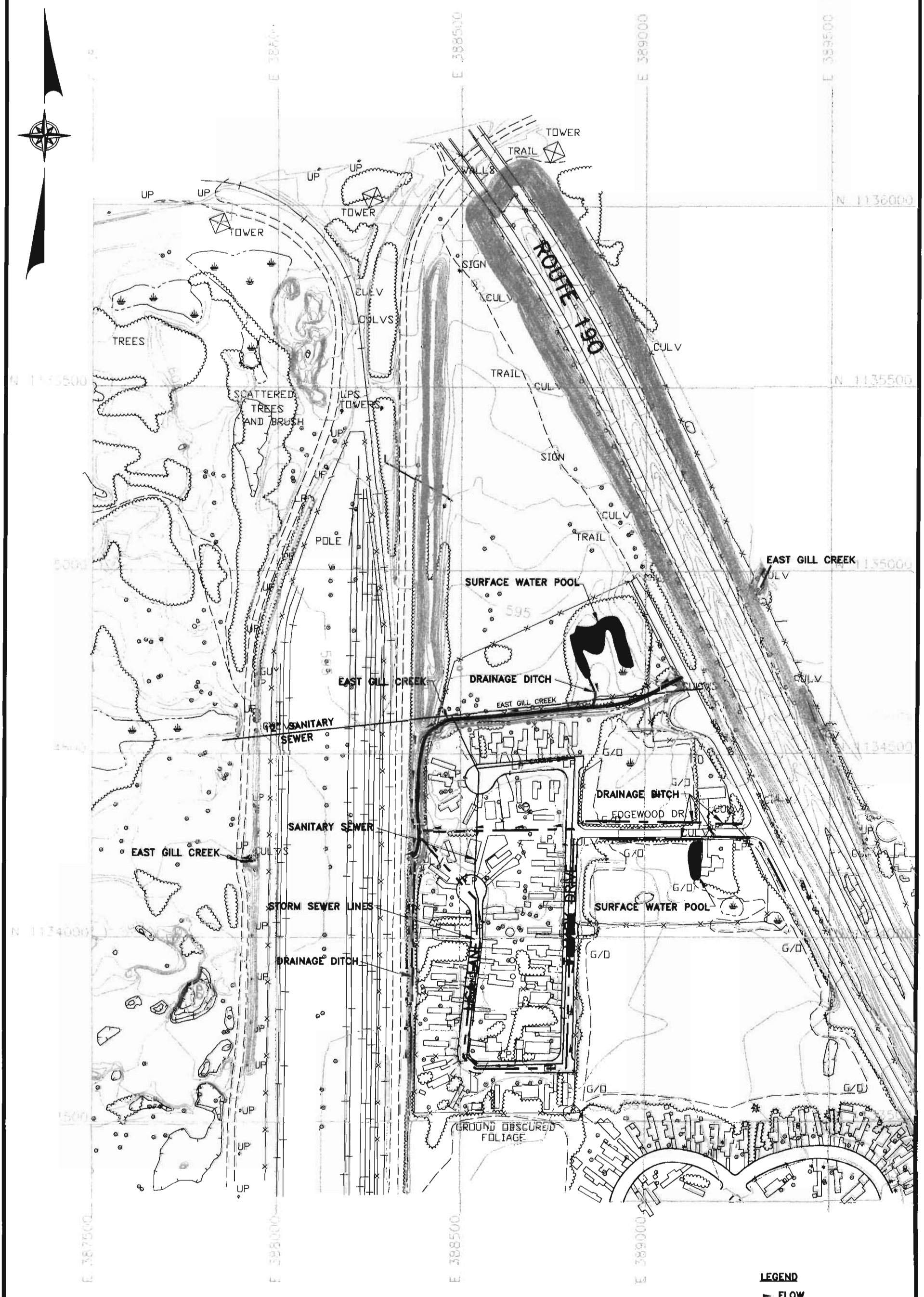


FIGURE 1-6

SURFACE WATER DRAINAGE AND WATER BODIES

WORK ASSIGNMENT 053-2L3U
Forest Glen Site, Niagara Falls, New York

CDM FEDERAL PROGRAMS CORPORATION
a subsidiary of Camp Dresser & McKee Inc.

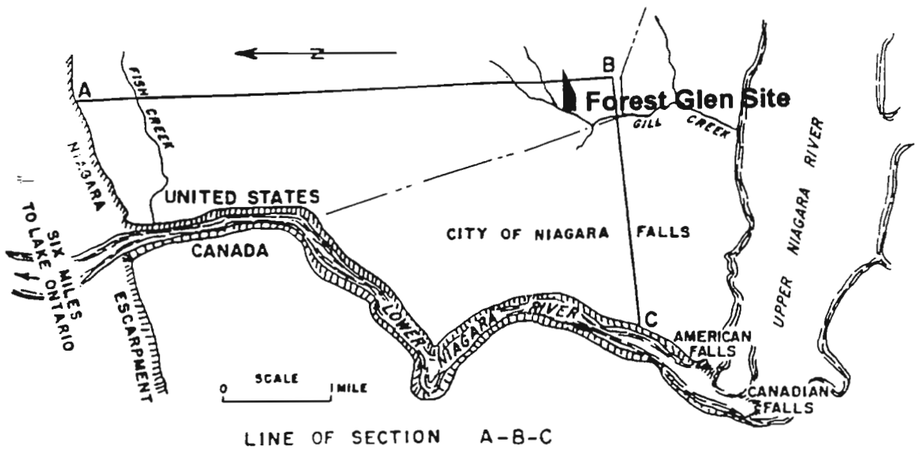
System and series		Group	Formation	Thickness (feet)	Description
Silurian	Middle	Lockport	Lockport Dolomite	158	Dark-gray to brown, massive to thin-bedded dolomite locally containing algal reefs and small, irregularly shaped masses of gypsum. Near the base are light-gray coarse-grained limestone (Gasport Limestone Member, dark-gray shaley dolomite)
		Clinton	Rochester Shale	60	Dark-gray calcareous shale weathering light-gray to olive.
			Irondequoit Limestone	12	Light-gray to pinkish-white coarse-grained limestone.
			Reynales Limestone	10	White to yellowish-gray shaly limestone and dolomite.
			Neahga Shale	5	Greenish-gray soft fissile shale.
	Lower	Medina	Thorold Sandstone	8	Greenish-gray shaly sandstone.
			Grimsby Sandstone	45	Reddish-brown to greenish-gray cross-bedded sandstone interbedded with red to greenish-gray shale.
			Power Glen Shale	40	Gray to greenish-gray shale interbedded with light-gray sandstone.
			Whirlpool Sandstone	20	White, quartzitic sandstone
Ordovician	Upper	Richmond	Queenston Shale	1,200	Brick-red sandy to argillaceous shale.

FIGURE 1-7
STRATIGRAPHY OF THE NIAGARA FALLS AREA

FOREST GLEN SITE
NIAGARA FALLS, NEW YORK
WORK ASSIGNMENT 053-2L3U

Source: Miller and Kappel, 1987

[redacted]
CDM FEDERAL PROGRAMS CORPORATION
a subsidiary of Camp Dresser & McKee Inc.



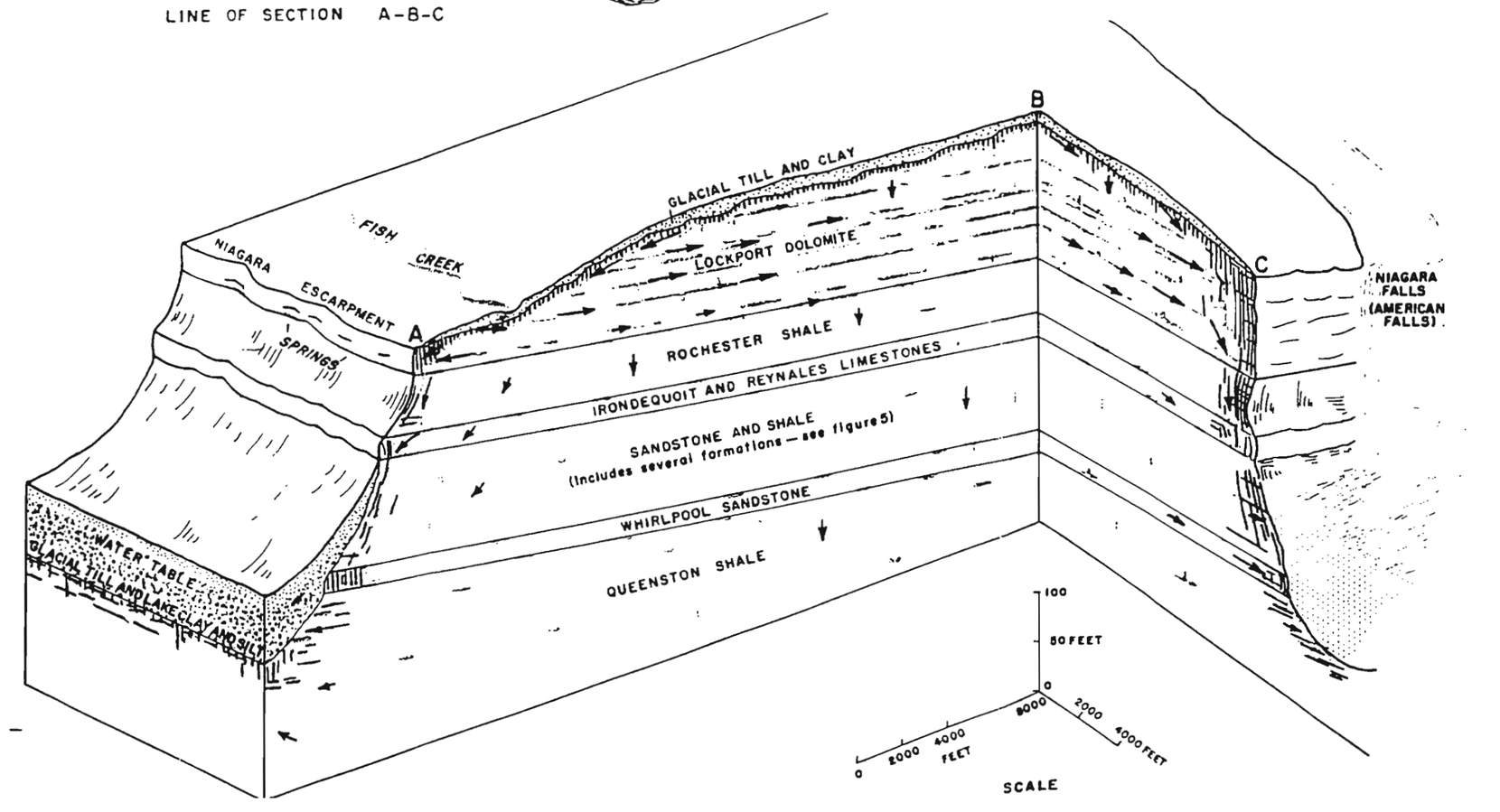
LINE OF SECTION A-B-C

EXPLANATION

WATER-BEARING ZONES AND OPENINGS IN BEDROCK

ZONE OF SATURATION IN THE UNCONSOLIDATED DEPOSITS

DIRECTION OF GROUND-WATER MOVEMENT IN PLANE OF SECTION

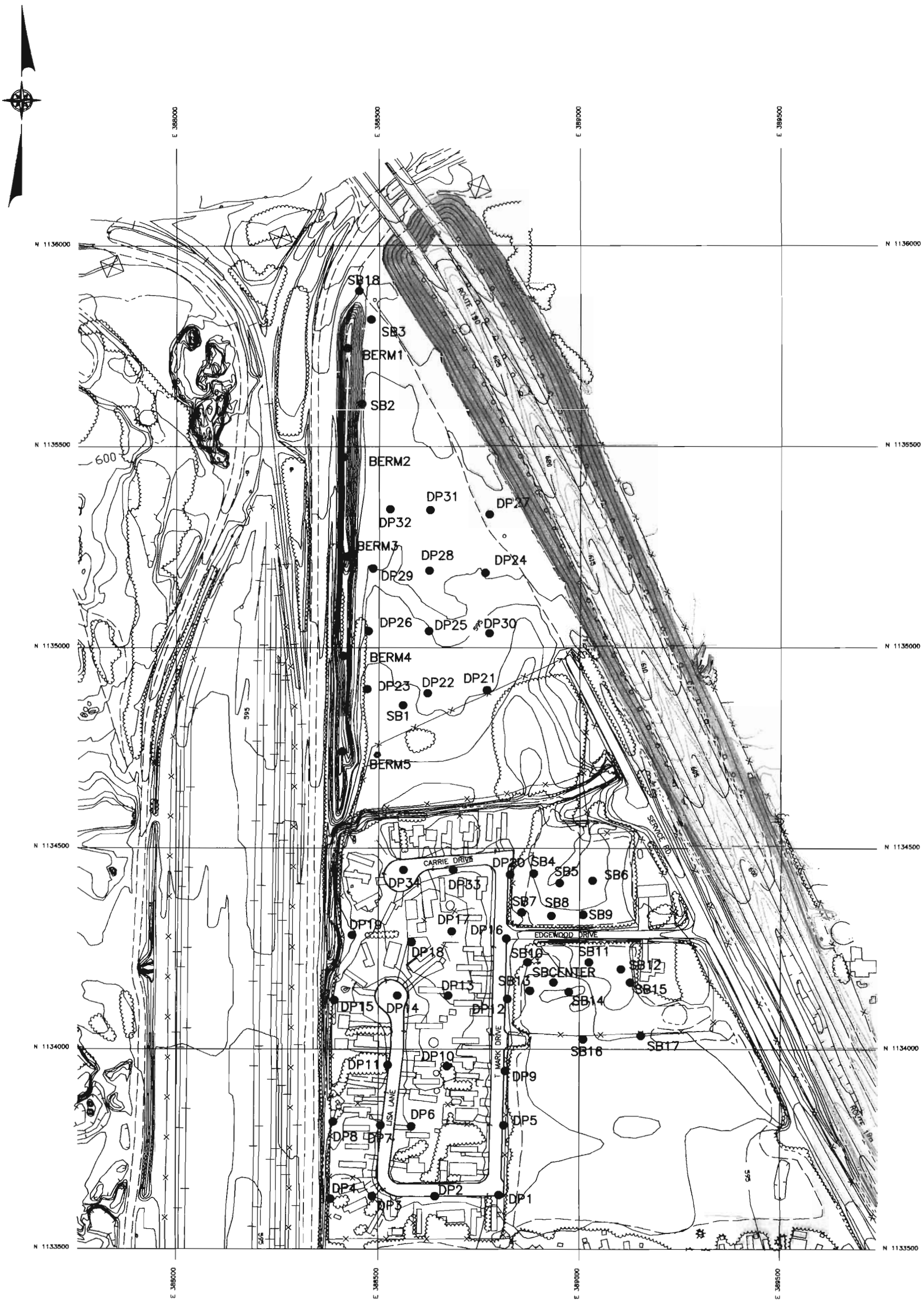


CDM FEDERAL PROGRAMS CORPORATION
a subsidiary of Camp Dresser & McKee Inc.

FOREST GLEN SITE
NIAGARA FALLS, NEW YORK
WORK ASSIGNMENT 053-2L3U

Source: Johnston, 1964

FIGURE 1-8
GEOLOGIC CROSS SECTION OF THE NIAGARA FALLS AREA



125' 0 250'

SCALE:

LEGEND

- TRAIL
- TREELINE
- FENCE
- RAILROAD
- BUILDING (RESIDENTIAL)
- SUBSURFACE SAMPLE LOCATION

FIGURE 1–9

SOIL BORING LOCATIONS

WORK ASSIGNMENT 053–2L3U
Forest Glen Site, Niagara Falls, New York

CDM FEDERAL PROGRAMS CORPORATION
a subsidiary of Camp Dresser & McKee Inc.

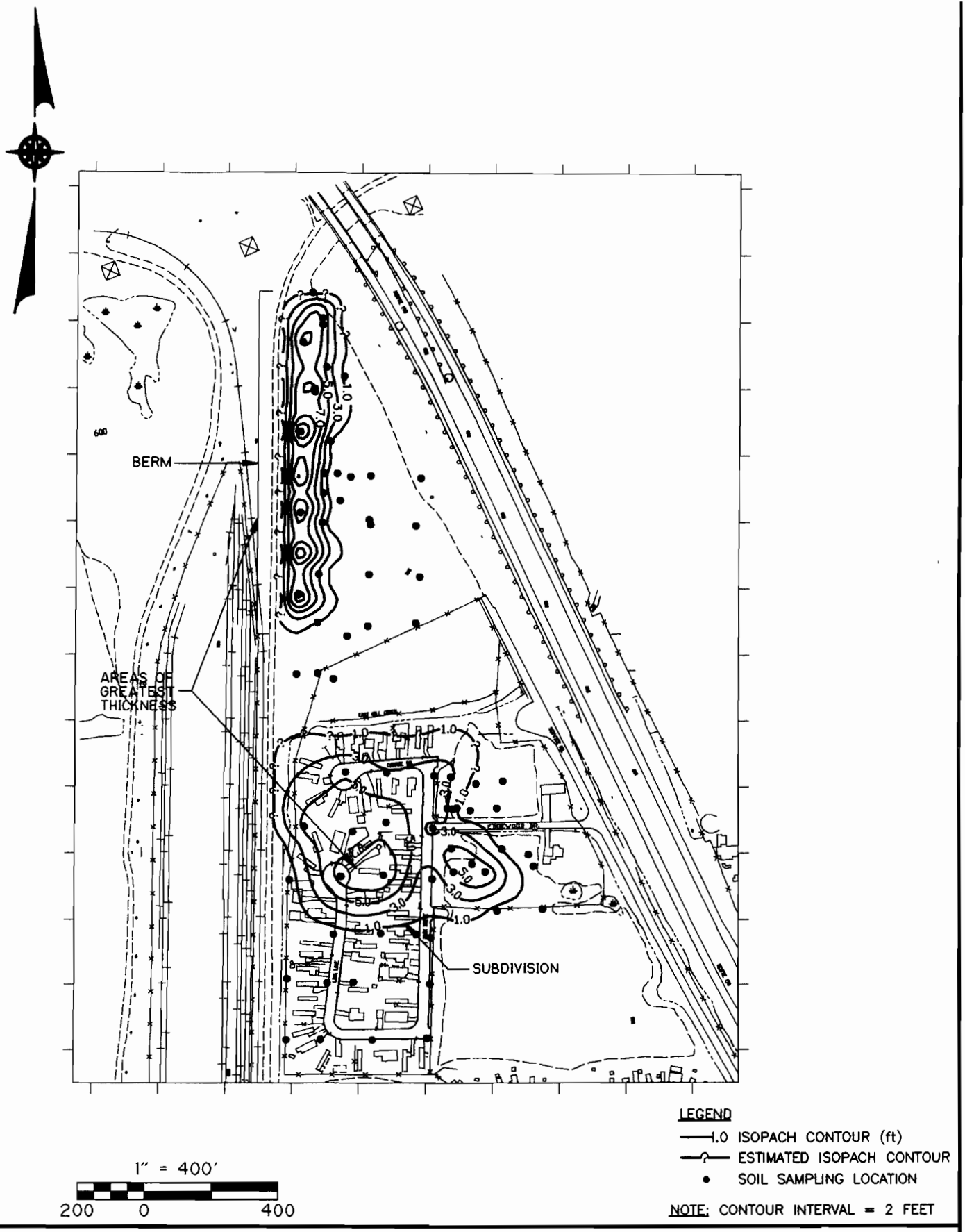
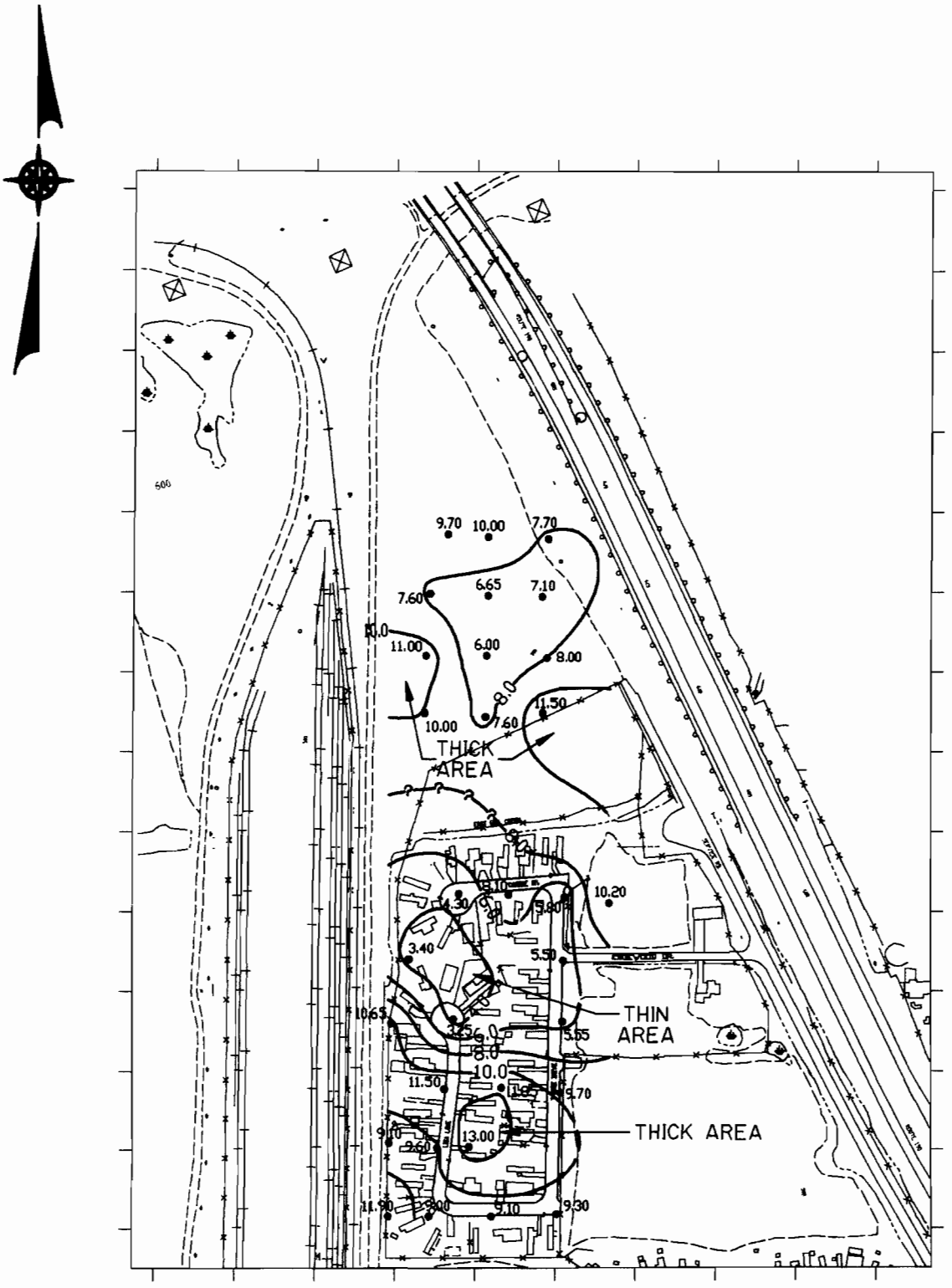


FIGURE 1–10

LOCATION OF FILL AREAS EXCEEDING 1FT. IN THICKNESS

WORK ASSIGNMENT 053–2L3U
Forest Glen Site, Niagara Falls, New York

CDM FEDERAL PROGRAMS CORPORATION
a subsidiary of Camp Dresser & McKee Inc.



LEGEND

—1.0 ISOPACH CONTOUR (ft)

—?— ESTIMATED ISOPACH CONTOUR

• SOIL SAMPLING LOCATION

NOTE: CONTOUR INTERVAL = 2 FEET

1" = 400'

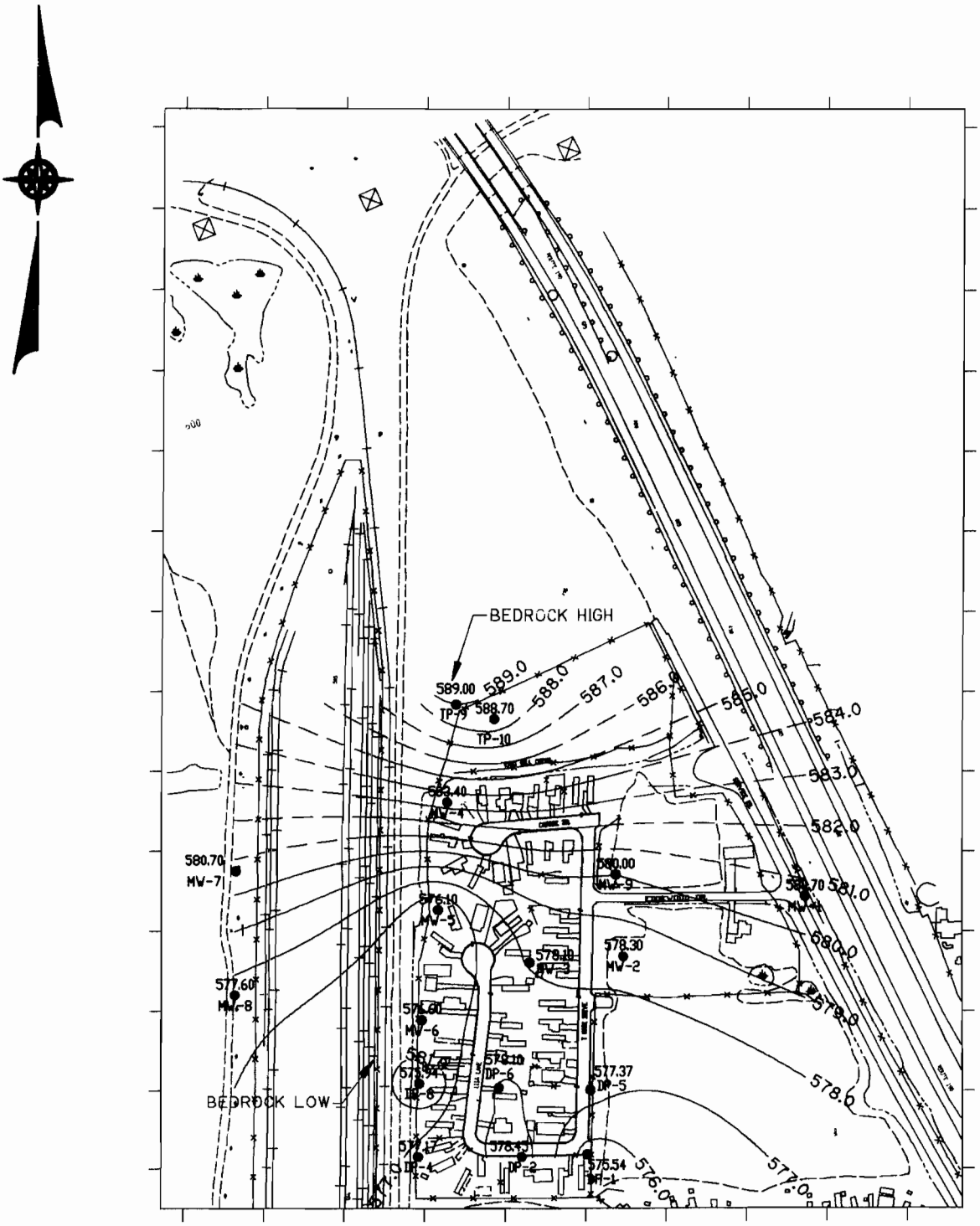
200 0 400

FIGURE 1-11

ISOPACH MAP OF CLAY LAYER

CDM FEDERAL PROGRAMS CORPORATION
a subsidiary of Camp Dresser & McKee Inc.

WORK ASSIGNMENT 053-2L3U
Forest Glen Site, Niagara Falls, New York



LEGEND

——577	BEDROCK SURFACE ELEVATION CONTOUR (ft MSL)
— —	ESTIMATED CONTOUR
580.70	BEDROCK SURFACE ELEVATION (MSL)
MW-7 ●	SAMPLING LOCATION

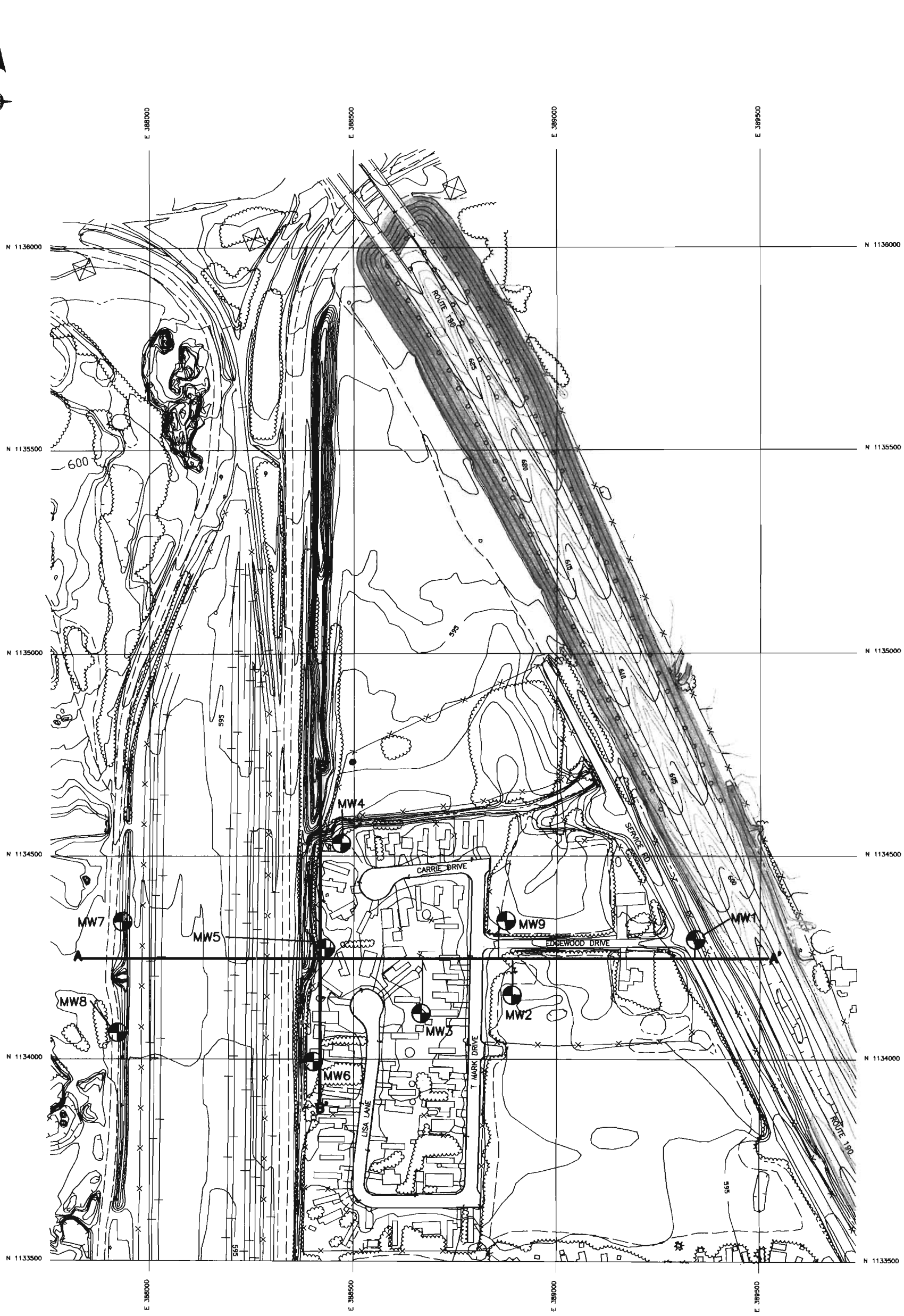
NOTE: CONTOUR INTERVAL = 1 FOOT

FIGURE 1-12

BEDROCK SURFACE ELEVATION

WORK ASSIGNMENT 053-2L3U
Forest Glen Site, Niagara Falls, New York

CDM FEDERAL PROGRAMS CORPORATION
a subsidiary of Camp Dresser & McKee Inc.



CDM FEDERAL PROGRAMS CORPORATION
a subsidiary of Camp Dresser & McKee Inc.

FIGURE 1–13

LOCATION OF UPPER LOCKPORT DOLOMITE CROSS SECTIONS

WORK ASSIGNMENT 053–2L3U
Forest Glen Site, Niagara Falls, New York

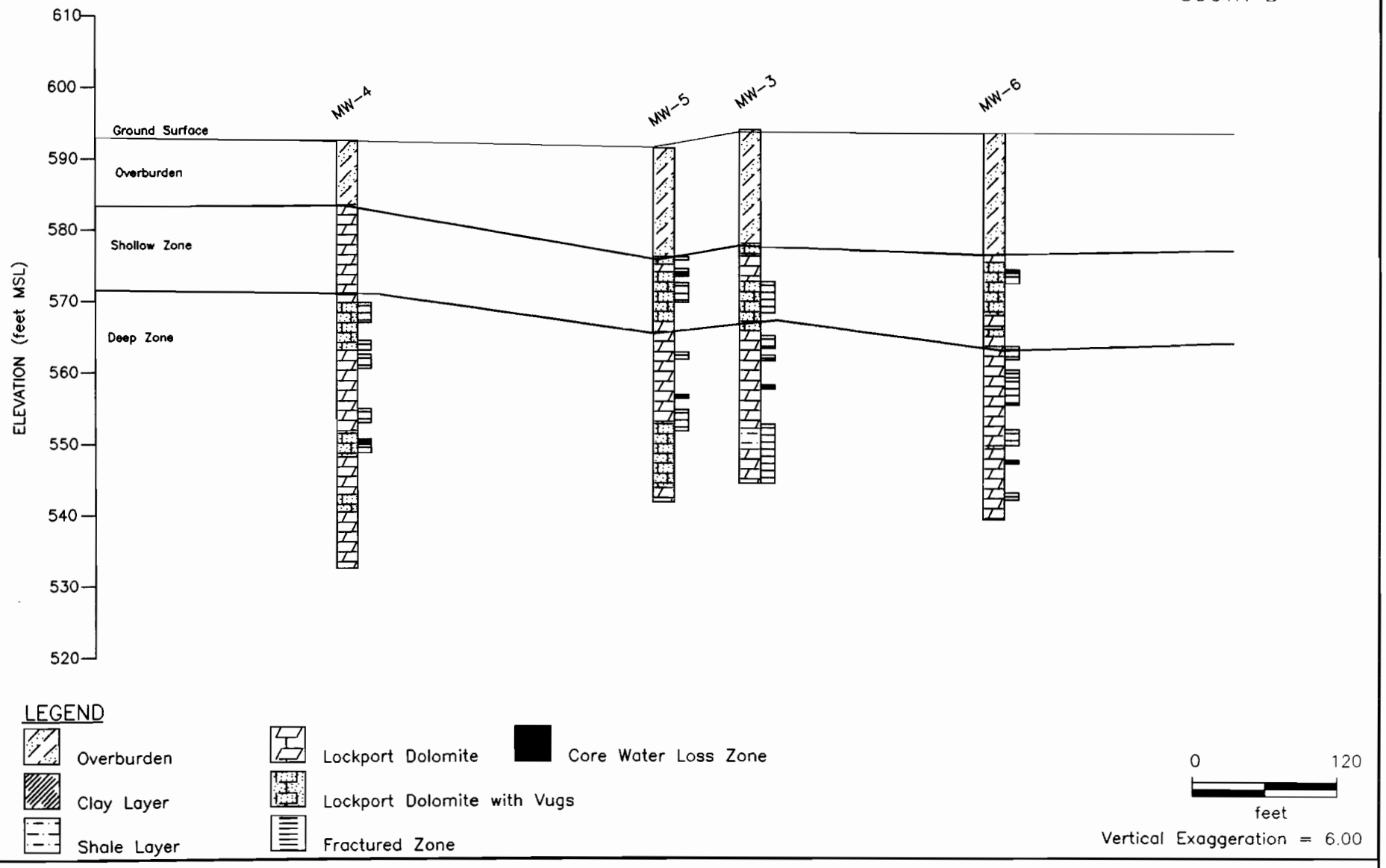
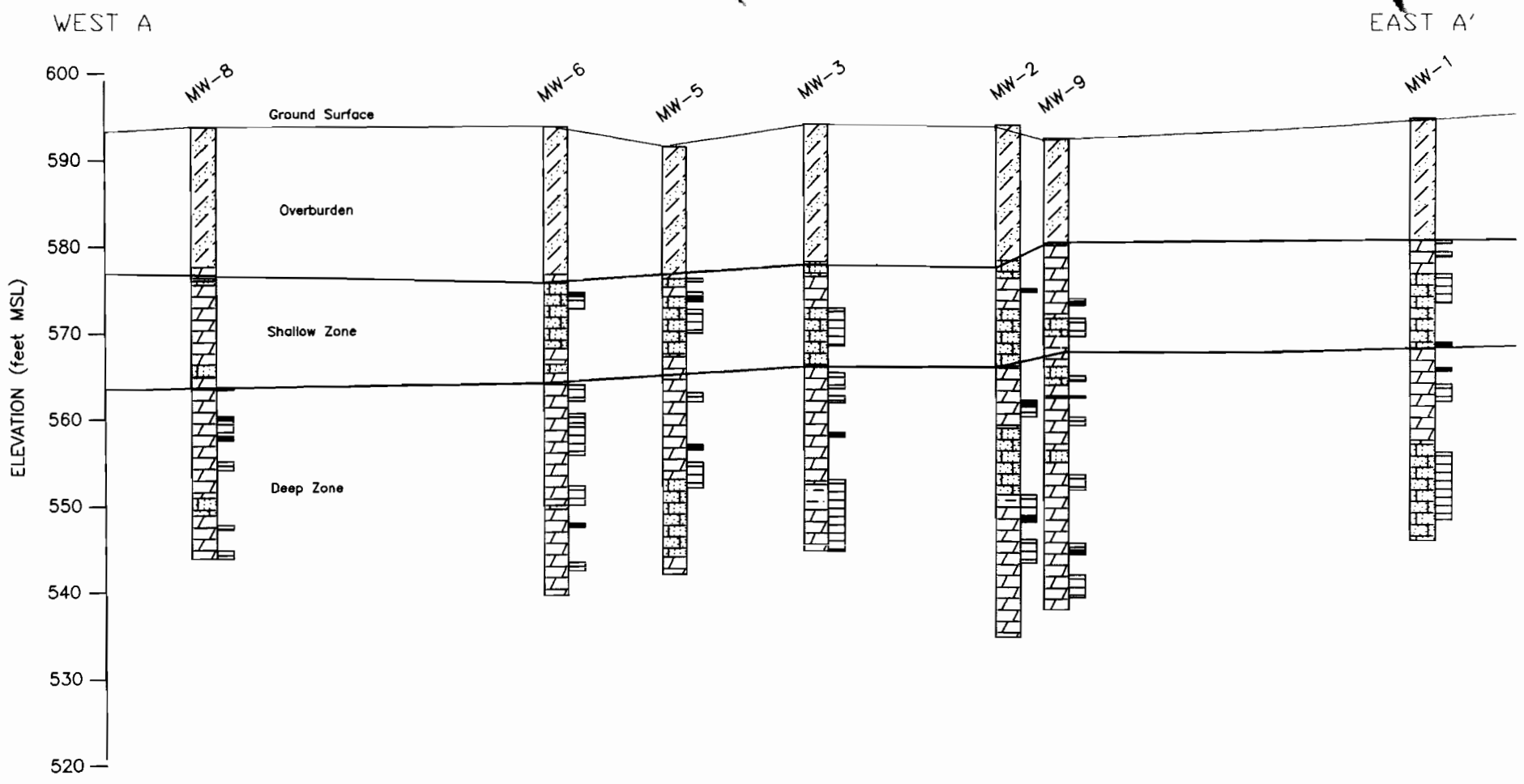


FIGURE 1-14

NORTH-SOUTH CROSS SECTION OF UPPER LOCKPORT DOLOMITE CORED AT THE FOREST GLEN SITE

CDM FEDERAL PROGRAMS CORPORATION
a subsidiary of Camp Dresser & McKee Inc.

WORK ASSIGNMENT 053-2L3U
Forest Glen Site, Niagara Falls, New York



LEGEND

- Overburden
- Clay Layer
- Shale Layer
- Lockport Dolomite
- Lockport Dolomite with Vugs
- Fractured Zone
- Core Water Loss Zone

0 190

feet

Vertical Exaggeration = 10.00

FIGURE 1-15

EAST-WEST CROSS SECTION OF UPPER LOCKPORT DOLOMITE CORED AT THE FOREST GLEN SITE

CDM FEDERAL PROGRAMS CORPORATION
a subsidiary of Camp Dresser & McKee Inc.

WORK ASSIGNMENT 053-2L3U
Forest Glen Site, Niagara Falls, New York

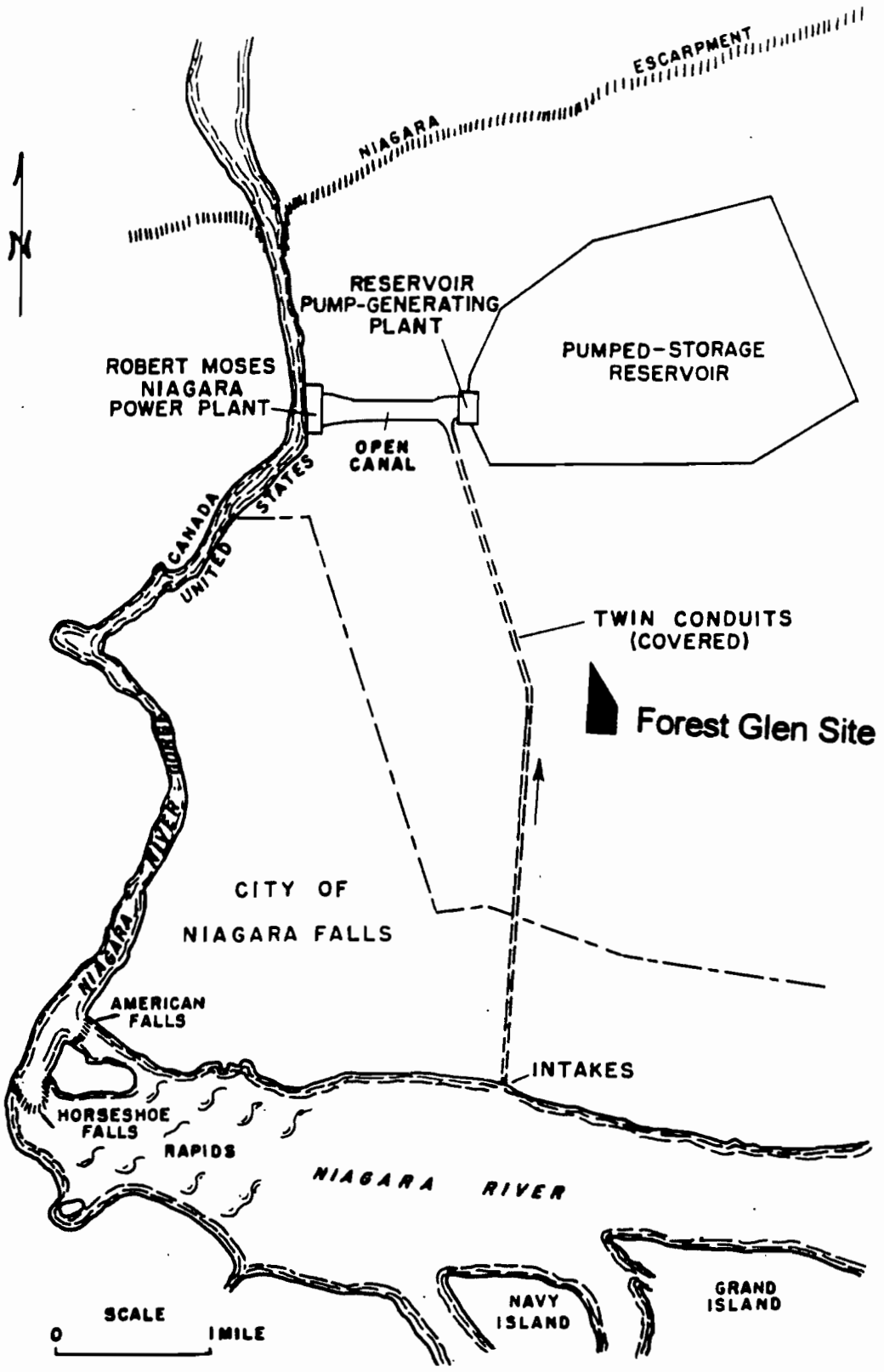


FIGURE 1-16

FEATURES OF PASNY HYDROELECTRIC POWER SYSTEM

FOREST GLEN SITE
NIAGARA FALLS, NEW YORK
WORK ASSIGNMENT 053-2L3U

Source: Johston, 1964.

CDM FEDERAL PROGRAMS CORPORATION
a subsidiary of Camp Dresser & McKee Inc.

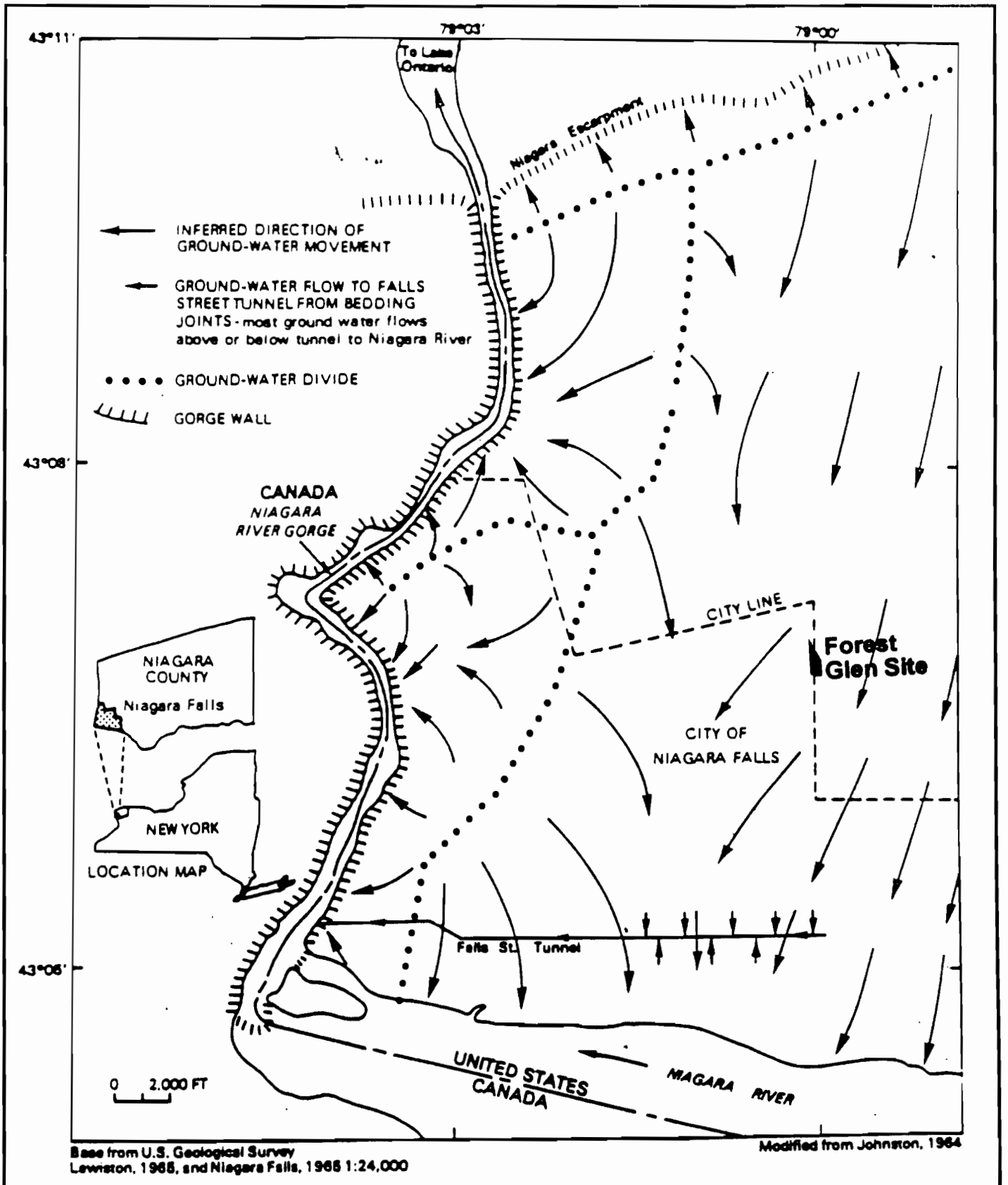


FIGURE 1-17
GROUNDWATER FLOW
BEFORE PASNY
CONSTRUCTION

FOREST GLEN SITE
NIAGARA FALLS, NEW YORK
WORK ASSIGNMENT 053-2L3U

Source: Miller and Kappel, 1967

CDM FEDERAL PROGRAMS CORPORATION
a subsidiary of Camp Dresser & McKee Inc.

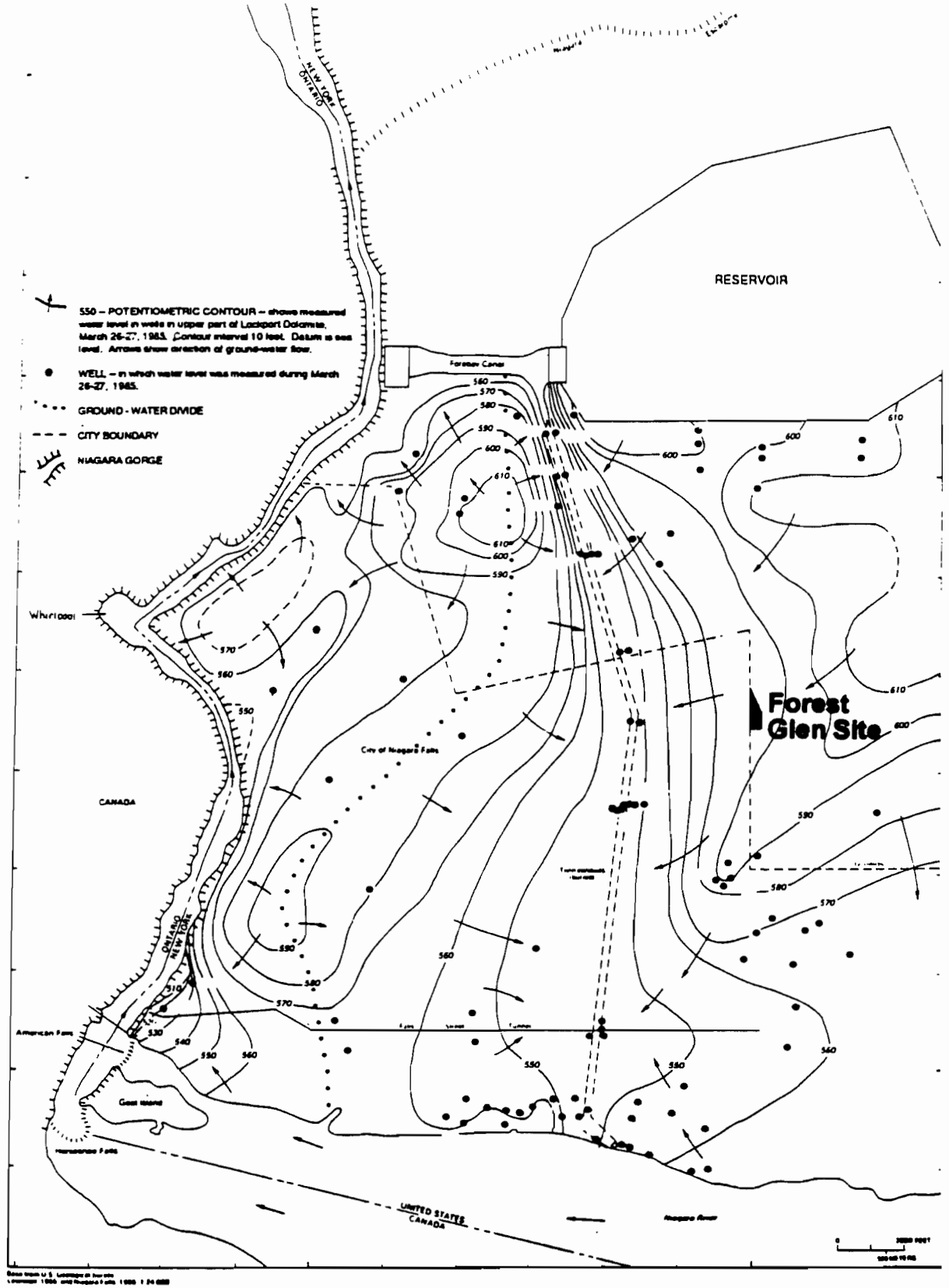


FIGURE 1-18
GROUNDWATER FLOW
AFTER PASNY
CONSTRUCTION

FOREST GLEN SITE
NIAGARA FALLS, NEW YORK
WORK ASSIGNMENT 053-2L3U

Source: Yager and Kappel, 1987

CDM FEDERAL PROGRAMS CORPORATION
a subsidiary of Camp Dresser & McKee Inc.

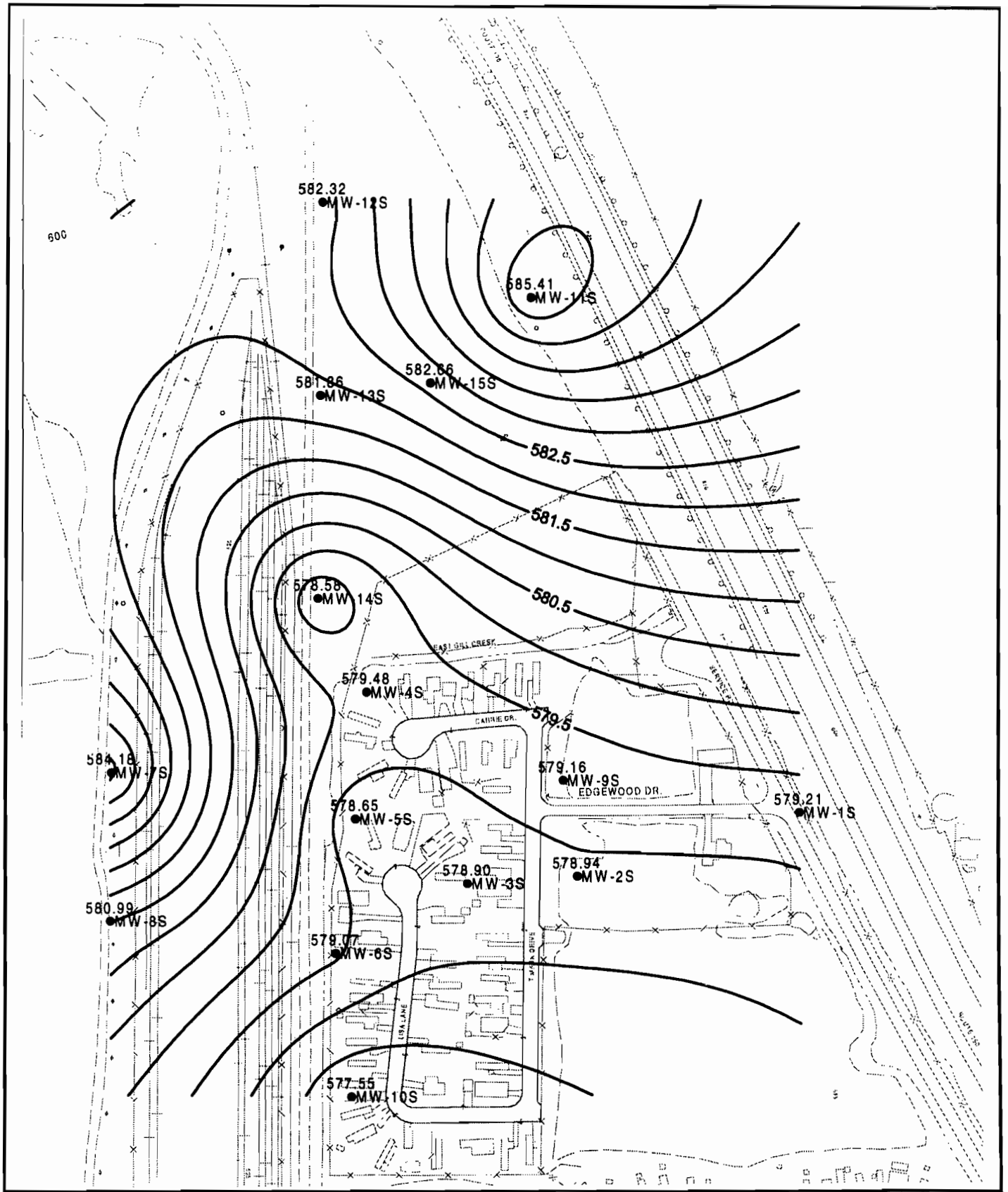
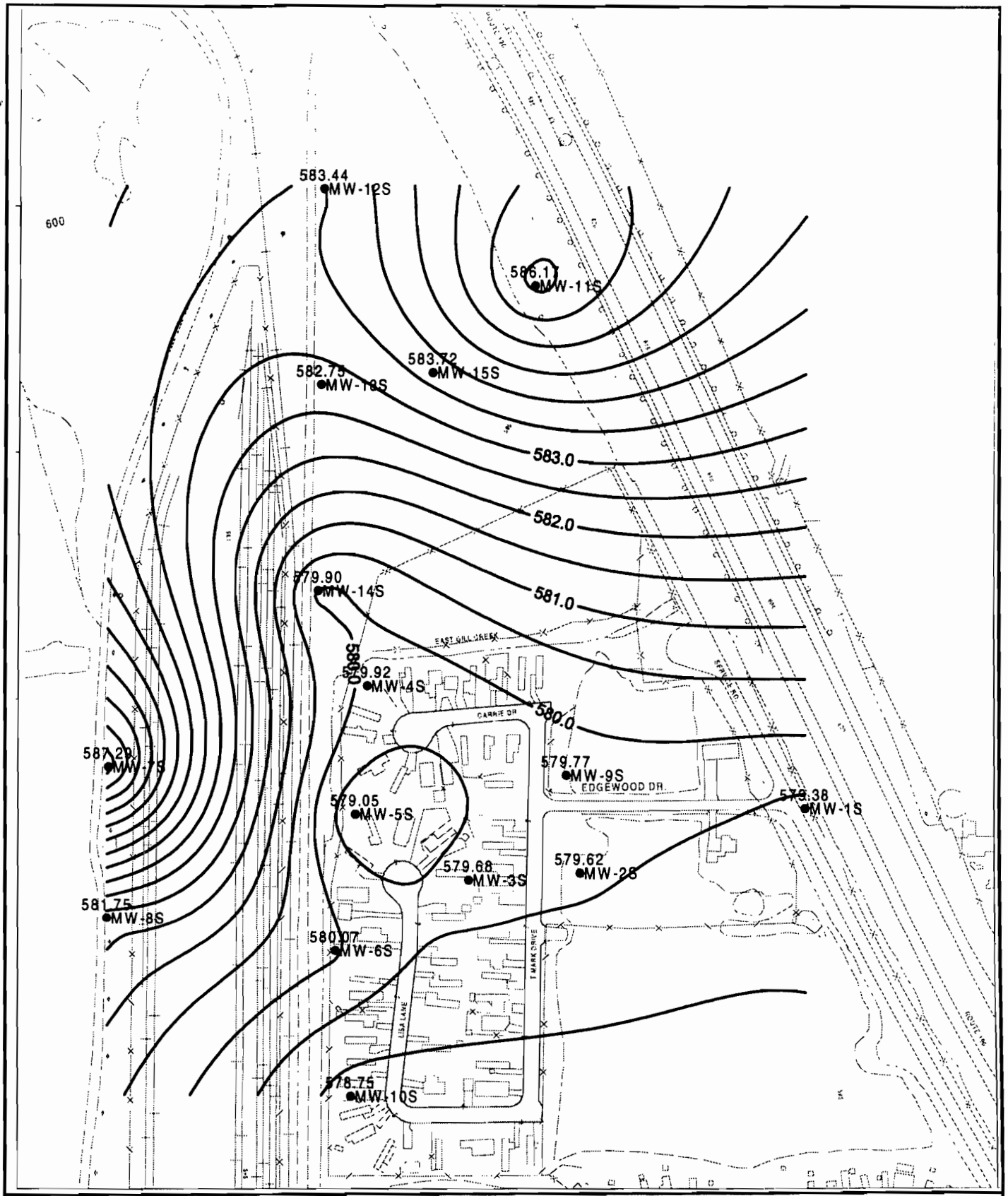


FIGURE 1-19
POTENTIOMETRIC SURFACE - SHALLOW BEDROCK WELLS - AUGUST 1997

FOREST GLEN SITE
NIAGARA FALLS, NEW YORK
WORK ASSIGNMENT 053-2L3U

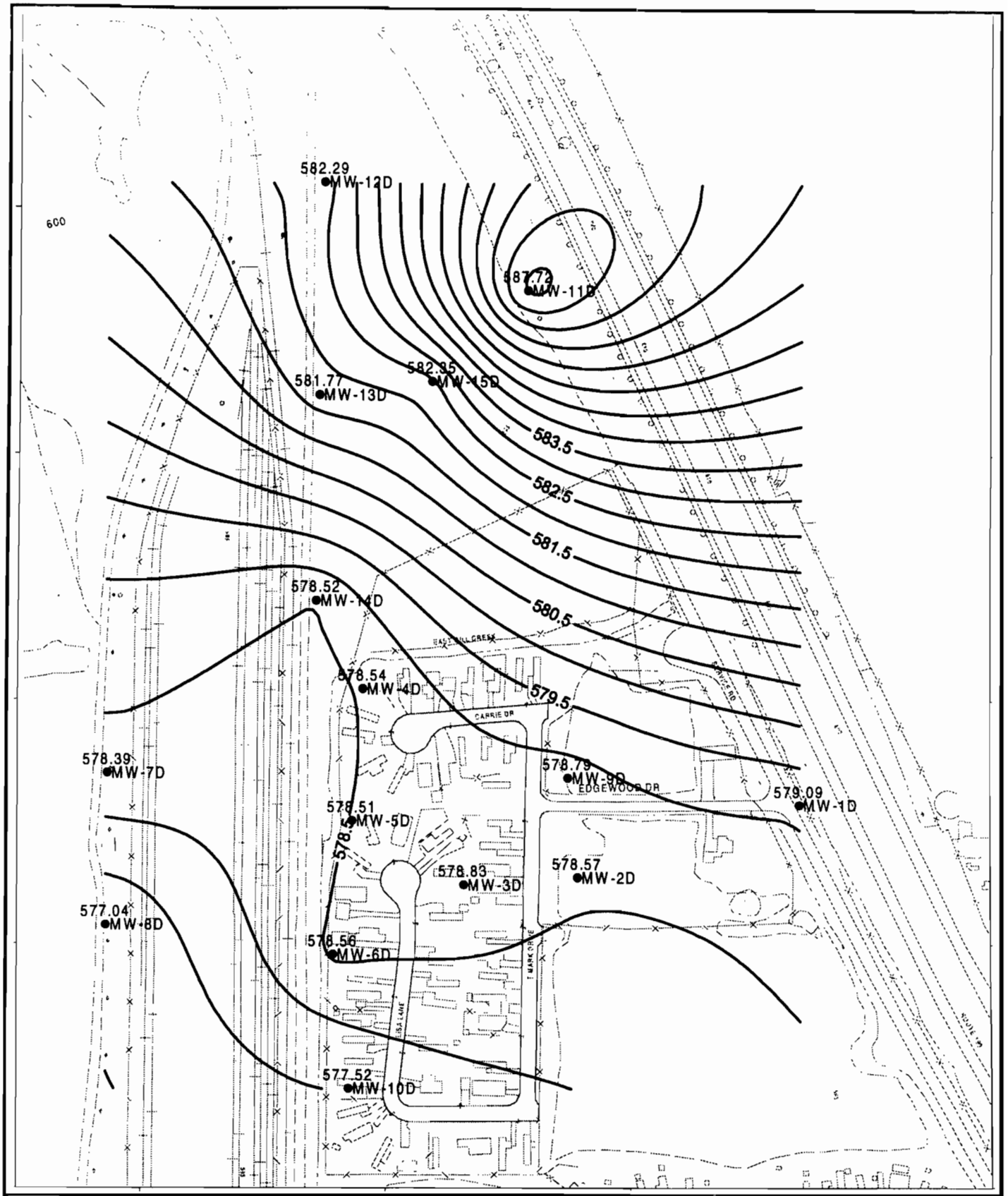
CDM FEDERAL PROGRAMS CORPORATION
a subsidiary of Camp Dresser & McKee Inc.



CDM FEDERAL PROGRAMS CORPORATION
a subsidiary of Camp Dresser & McKee Inc.

FOREST GLEN SITE
NIAGARA FALLS, NEW YORK
WORK ASSIGNMENT 053-2L3U

FIGURE 1-20
POTENTIOMETRIC SURFACE - SHALLOW BEDROCK WELLS - SEPTEMBER 1997



CDM FEDERAL PROGRAMS CORPORATION
a subsidiary of Camp Dresser & McKee Inc.

FOREST GLEN SITE
NIAGARA FALLS, NEW YORK
WORK ASSIGNMENT 053-2L3U

FIGURE 1-21
POTENTIOMETRIC SURFACE - DEEP BEDROCK WELLS - AUGUST 1997

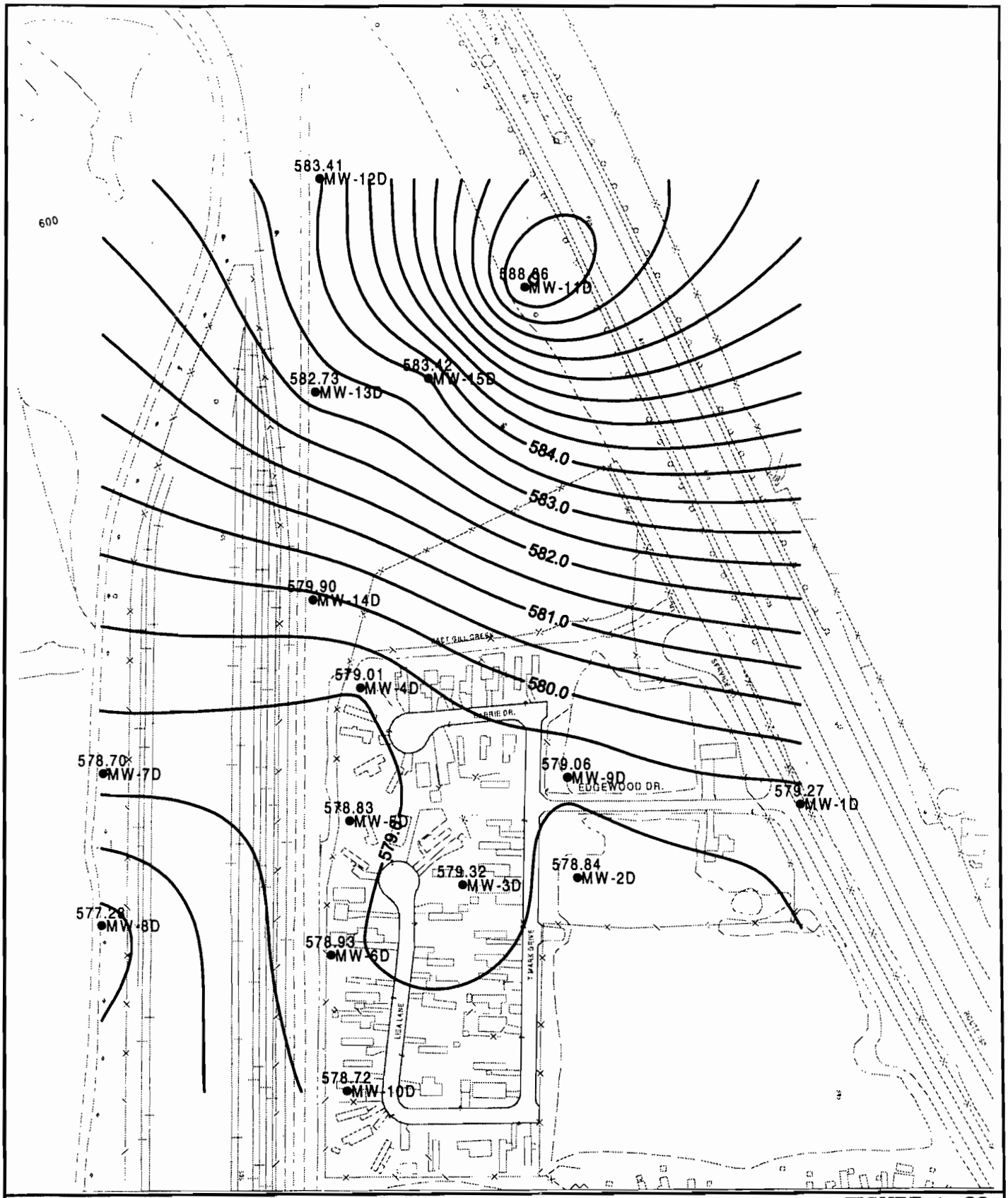
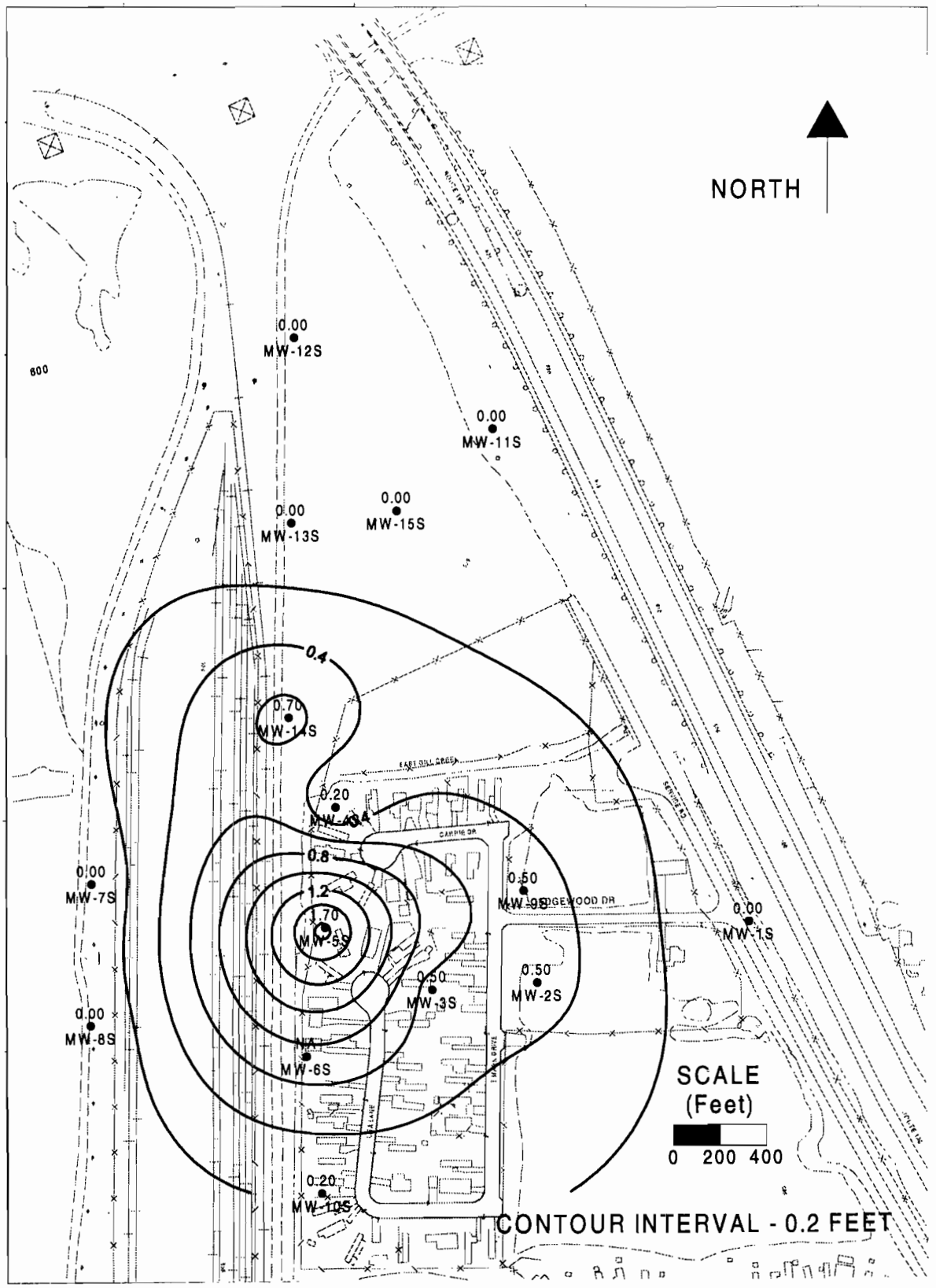


FIGURE 1-22

FOREST GLEN SITE
NIAGARA FALLS, NEW YORK
WORK ASSIGNMENT 053-2L3U

POTENTIOMETRIC SURFACE - DEEP BEDROCK WELLS - SEPTEMBER 1997

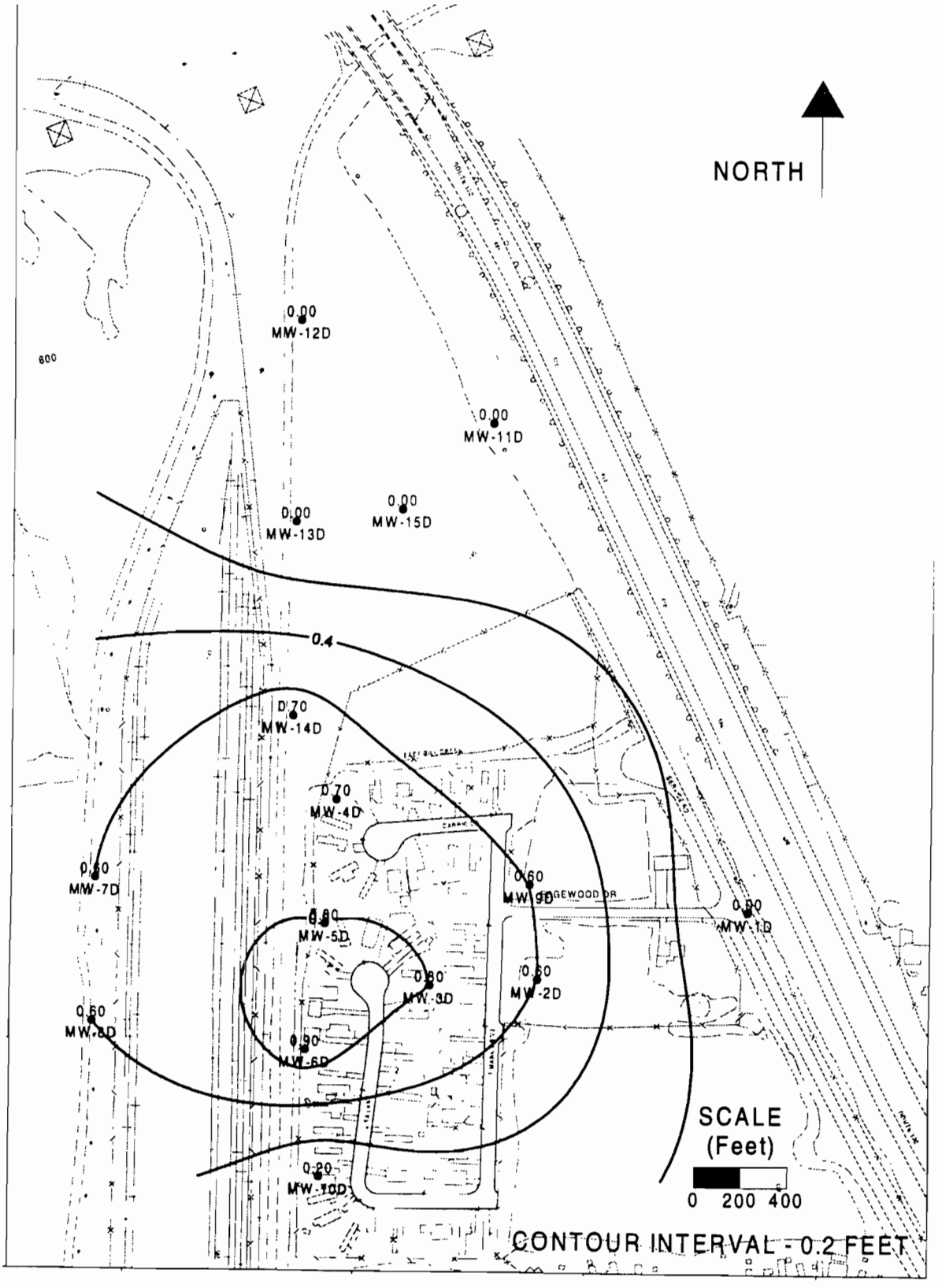
CDM FEDERAL PROGRAMS CORPORATION
a subsidiary of Camp Dresser & McKee Inc.



CDM FEDERAL PROGRAMS CORPORATION
a subsidiary of Camp Dresser & McKee Inc.

FOREST GLEN SITE
NIAGARA FALLS, NEW YORK
WORK ASSIGNMENT 053-2L3U

FIGURE 1-23
AQUIFER TEST
DRAWNDOWN -
SHALLOW BEDROCK



FOREST GLEN SITE
NIAGARA FALLS, NEW YORK
WORK ASSIGNMENT 053-2L3U

FIGURE 1-24
AQUIFER TEST
DRAWNDOWN -
DEEP BEDROCK

CDM FEDERAL PROGRAMS CORPORATION
a subsidiary of Camp Dresser & McKee Inc.

NATIONAL PRIMARY DRINKING WATER STANDARDS (MCLs) (a)	
VINYL CHLORIDE	2.00
1,1-DICHLORDETHANE	NO STANDARD
1,2-DICHLORDETHENE (total)	70.00 - 100.00
TRICHLORDETHENE	5.00
XYLENES (total)	10,000.00
BENZENE	5.00
PHENOL	NO STANDARD
2-CHLORDPHENOL	NO STANDARD
HEXACHLORDBUTADIENE	NO STANDARD
4-CHLORD-3-METHYLPHENOL	NO STANDARD
4-NITROPHENOL	NO STANDARD
PENTACHLORDPHENOL	1.00
PYRENE	NO STANDARD

NYS DEPARTMENT OF HEALTH DRINKING WATER STANDARDS (b)	
VINYL CHLORIDE	2.00
1,1-DICHLORDETHANE	5.00
1,2-DICHLORDETHENE (total)	5.00
TRICHLORDETHENE	5.00
XYLENES (total)	5.00
BENZENE	5.00
PHENOL	NO STANDARD
2-CHLORDPHENOL	NO STANDARD
HEXACHLORDBUTADIENE	5.00
4-CHLORD-3-METHYLPHENOL	NO STANDARD
4-NITROPHENOL	NO STANDARD
PENTACHLORDPHENOL	1.00
PYRENE	NO STANDARD

NYS DEPARTMENT OF ENVIRONMENTAL GROUNDWATER STANDARDS (c)	
VINYL CHLORIDE	2.00
1,1-DICHLORDETHANE	5.00
1,2-DICHLORDETHENE (total)	5.00
TRICHLORDETHENE	5.00
XYLENES (total)	5.00
BENZENE	0.70
PHENOL	1.00*
2-CHLORDPHENOL	5.00
HEXACHLORDBUTADIENE	5.00
4-CHLORD-3-METHYLPHENOL	5.00
4-NITROPHENOL	5.00
PENTACHLORDPHENOL	1.00*
PYRENE	5.00

* STANDARD IS FOR PHENOLIC COMPOUNDS (TOTAL PHENOLS).

MW4D
Round 1
BENZOTHIAZOLE 1.00 J

MW5D
Round 1
VINYL CHLORIDE 15.00 abc
1,1-DICHLORDETHANE 8.00 Jbc
1,2-DICHLORDETHENE (total) 21.00 bc

MW5S
Round 1
VINYL CHLORIDE 16.00 abc
1,2-DICHLORDETHENE (total) 130.00 abc
TRICHLORDETHENE 8.00 Jabc

MW7D
Round 1
BENZENE 1.00 Jc

MW8S
Round 1
VINYL CHLORIDE 3.00 Jabc
1,2-DICHLORDETHENE (total) 13.00 bc

MW8D
Round 1
BENZENE 1.00 Jc

MW6D
Round 1
1,2-DICHLORDETHENE (total) 6.00 Jbc

MW10S (DUP)
Round 1
1,2-DICHLORDETHENE (total) 6.00 Jbc

MW6D
Round 1
PHENOL 8.00 Jc
2-CHLORDPHENOL 10.00 Jc
HEXACHLORDBUTADIENE 10.00 Jbc
4-CHLORD-3-METHYLPHENOL 10.00 Jc
4-NITROPHENOL 10.00 Jc
PENTACHLORDPHENOL 6.00 Jbc
PYRENE 6.00 Jc

MW6S
Round 1
PHENOL 4.00 Jc

MW9D
Round 1
XYLENES (total) 8.00 Jbc
BENZENE 2.00 Jc

MW9D
Round 1
BENZOTHIAZOLE 1.00 J

MW3D
Round 1
XYLENES (total) 7.00 Jbc
BENZENE 2.00 Jc

MW4 MW5 MW7 MW3 MW6 MW9 MW1 MW2

CARRIE DRIVE
EDGEWOOD DRIVE
LISA LANE
T MARK DRIVE
ROUTE 19A

E 388000 E 388500 E 389000 E 389500
N 1136000 N 1135500 N 1135000 N 1134500 N 1134000 N 1133500

LEGEND:

MONITORING WELL CLUSTER LOCATIONS

REFER TO FIGURE 1-8A FOR EXPLANATION OF ADDITIONAL MAP SYMBOLS

SAMPLE NUMBER ROUND	
COMPOUND	CONCENTRATION (ug/l)

125' 0 250'

SCALE:

FIGURE 1-25

MONITORING WELL CLUSTER LOCATIONS DETECTED TARGETED ORGANIC COMPOUNDS AND TCL ORGANIC EXCEEDANCES IN ROUND 1 GROUNDWATER SAMPLES

NATIONAL PRIMARY DRINKING WATER STANDARDS (MCLs) (a)	
VINYL CHLORIDE	2.00
1,1-DICHLORDETHANE	NO STANDARD
1,2-DICHLORDETHENE (total)	70.00 - 100.00
1,1,1-TRICHLORDETHANE	200.00
TRICHLORDETHENE	5.00
DI-N-DCTYLPHTHALATE	NO STANDARD
BENZO(A)PYRENE	0.20

NYS DEPARTMENT OF HEALTH DRINKING WATER STANDARDS (b)	
VINYL CHLORIDE	2.00
1,1-DICHLORDETHANE	5.00
1,2-DICHLORDETHENE (total)	5.00
1,1,1-TRICHLORDETHANE	5.00
TRICHLORDETHENE	5.00
DI-N-DCTYLPHTHALATE	NO STANDARD
BENZO(A)PYRENE	NO STANDARD

NYS DEPARTMENT OF ENVIRONMENTAL CONSERVATION GROUNDWATER STANDARDS (c)	
VINYL CHLORIDE	2.00
1,1-DICHLORDETHANE	5.00
1,2-DICHLORDETHENE (total)	5.00
1,1,1-TRICHLORDETHANE	5.00
TRICHLORDETHENE	5.00
DI-N-DCTYLPHTHALATE	5.00
BENZO(A)PYRENE	5.00

MW05D Round 2

VINYL CHLORIDE	44.00 Jabc
1,1-DICHLORDETHANE	13.00 bc
1,2-DICHLORDETHENE (total)	68.00 bc
1,1,1-TRICHLORDETHANE	12.00 bc

MW05S Round 2

VINYL CHLORIDE	220.00 Jabc
1,1-DICHLORDETHANE	70.00 Jbc
1,2-DICHLORDETHENE (total)	1,300.00 abc
1,1,1-TRICHLORDETHANE	65.00 Jbc
TRICHLORDETHENE	76.00 Jabc
DI-N-DCTYLPHTHALATE	10.00 c

MW08S Round 2

1,2-DICHLORDETHENE (total)	11.00 bc

MW03PV Round 2

BENZO(A)PYRENE	0.70 Ja

MW06D Round 2

VINYL CHLORIDE	51.00 Jabc
1,2-DICHLORDETHENE (total)	17.00 bc

MW1 MW2 MW3 MW4 MW5 MW6 MW7 MW8 MW9

CARRIE DRIVE
EDGEWOOD DRIVE
T MARK DRIVE
LISA LANE
SERVICE RD.
ROUTE 190

LEGEND:

MONITORING WELL CLUSTER LOCATIONS

REFER TO FIGURE 1-9A FOR EXPLANATION OF ADDITIONAL MAP SYMBOLS

SAMPLE NUMBER ROUND	
COMPOUND	CONCENTRATION (ug/l)

125' 0 250'

SCALE:

FIGURE 1-26

MONITORING WELL CLUSTER LOCATIONS TCL ORGANIC EXCEEDANCES IN ROUND 2 GROUNDWATER SAMPLES

WORK ASSIGNMENT 053-2L3U

Forest Glen Site, Niagara Falls, New York

CDM FEDERAL PROGRAMS CORPORATION
a subsidiary of Camp Dresser & McKee Inc.

NATIONAL PRIMARY DRINKING WATER STANDARDS (MCLs) (a)	
VINYL CHLORIDE	2.00
1,1-DICHLOROETHENE	7.00
1,1-DICHLOROETHANE	NO STANDARD
1,2-DICHLOROETHENE (total)	70.00 - 100.00
1,1,1-TRICHLOROETHANE	200.00
TRICHLOROETHENE	5.00
BENZENE	5.00
TETRACHLOROTHENE	5.00
PENTACHLOROPHENOL	1.00
DI-N-BUTYLPHTHALATE	NO STANDARD
BIS(2-ETHYLHEXYL)PHTHALATE	NO STANDARD

NYS DEPARTMENT OF HEALTH DRINKING WATER STANDARDS (b)	
VINYL CHLORIDE	2.00
1,1-DICHLOROETHENE	5.00
1,1-DICHLOROETHANE	5.00
1,2-DICHLOROETHENE (total)	5.00
1,1,1-TRICHLOROETHANE	5.00
TRICHLOROETHENE	5.00
BENZENE	5.00
TETRACHLOROTHENE	5.00
PENTACHLOROPHENOL	1.00
DI-N-BUTYLPHTHALATE	NO STANDARD
BIS(2-ETHYLHEXYL)PHTHALATE	NO STANDARD

NYS DEPARTMENT OF ENVIRONMENTAL GROUNDWATER STANDARDS (c)	
VINYL CHLORIDE	2.00
1,1-DICHLOROETHENE	5.00
1,1-DICHLOROETHANE	5.00
1,2-DICHLOROETHENE (total)	5.00
1,1,1-TRICHLOROETHANE	5.00
TRICHLOROETHENE	5.00
BENZENE	0.70
TETRACHLOROTHENE	5.00
PENTACHLOROPHENOL	1.00*
DI-N-BUTYLPHTHALATE	50.00
BIS(2-ETHYLHEXYL)PHTHALATE	50.00

* STANDARD IS FOR PHENOLIC COMPOUNDS (TOTAL PHENOLS).

MW12V-R3 Round 3
PENTACHLOROPHENOL 16.00 abc

MW11V-R3 Round 3
BENZENE 1.70 c

MW05D-R3 Round 3

VINYL CHLORIDE	57.00 abc
1,1-DICHLOROETHANE	26.00 bc
1,2-DICHLOROETHENE (total)	63.20 bc
1,1,1-TRICHLOROETHANE	17.00 bc

MW05S-R3 Round 3

VINYL CHLORIDE	170.00 abc
1,1-DICHLOROETHENE	16.00 abc
1,1-DICHLOROETHANE	92.00
1,2-DICHLOROETHENE (total)	1,709.30 abc
1,1,1-TRICHLOROETHANE	110.00 bc
TRICHLOROETHENE	350.00 abc

MW07D-R3 Round 3

VINYL CHLORIDE	26.00 abc
1,1-DICHLOROETHANE	8.00 bc
1,2-DICHLOROETHENE (total)	69.00 bc
1,1,1-TRICHLOROETHANE	5.70 bc

MW09D-R3 Round 3
VINYL CHLORIDE 9.10 abc

MW08S-R3 Round 3

VINYL CHLORIDE	2.30 abc
1,2-DICHLOROETHENE (total)	8.70 bc

MW08S-R3 (DUP) Round 3

VINYL CHLORIDE	2.50 abc
1,2-DICHLOROETHENE (total)	8.90 bc

MW06D-R3 Round 3

VINYL CHLORIDE	22.00 abc
1,1-DICHLOROETHANE	5.80 bc
1,2-DICHLOROETHENE (total)	14.00 bc

MW04D-R3 Round 3
VINYL CHLORIDE 2.40 abc

MW04D-R3 (DUP) Round 3
VINYL CHLORIDE 2.60 abc

MW03D-R3 Round 3

VINYL CHLORIDE	3.20 abc
1,2-DICHLOROETHENE (total)	8.90 bc

MW03S-R3 Round 3

VINYL CHLORIDE	33.00 abc
1,2-DICHLOROETHENE (total)	150.00 abc
TETRACHLOROETHENE	35.00 abc

MW03D-R3 Round 3
BENZOTHIAZOLE 1.80 J

MW02S-R3 Round 3

DI-N-BUTYLPHTHALATE	270.00 c
BIS(2-ETHYLHEXYL)PHTHALATE	65.00 c

MW12V MW12D MW12S
MW11V MW11D MW11S
MW13S MW13D
MW15S MW15D
MW14S MW14D
MW07S MW07D
MW08S MW08D
MW06S MW06D
MW04S MW04D
MW05S MW05D
MW09S MW09D
MW01S MW01D
MW03S MW03P MW03D MW03C
MW02S MW02D
MW10D MW10S

CONTROL POINT 2
CONTROL POINT 1
CONTROL POINT
BENCHMARK
SERVICE RD.

LEGEND:

MONITORING WELL CLUSTER LOCATIONS

REFER TO FIGURE 1-2A FOR EXPLANATION OF ADDITIONAL MAP SYMBOLS

SAMPLE NUMBER
ROUND

COMPOUND CONCENTRATION (ug/l)

1" = 250'
125 0 250

CDM FEDERAL PROGRAMS CORPORATION
a subsidiary of Camp Dresser & McKee Inc.

FIGURE 1-27

MONITORING WELL CLUSTER LOCATIONS DETECTED TARGETED ORGANIC COMPOUNDS AND TCL ORGANIC EXCEEDANCES IN ROUND 3 GROUNDWATER SAMPLES

WORK ASSIGNMENT 053-2L3U
Forest Glen Site, Niagara Falls, New York

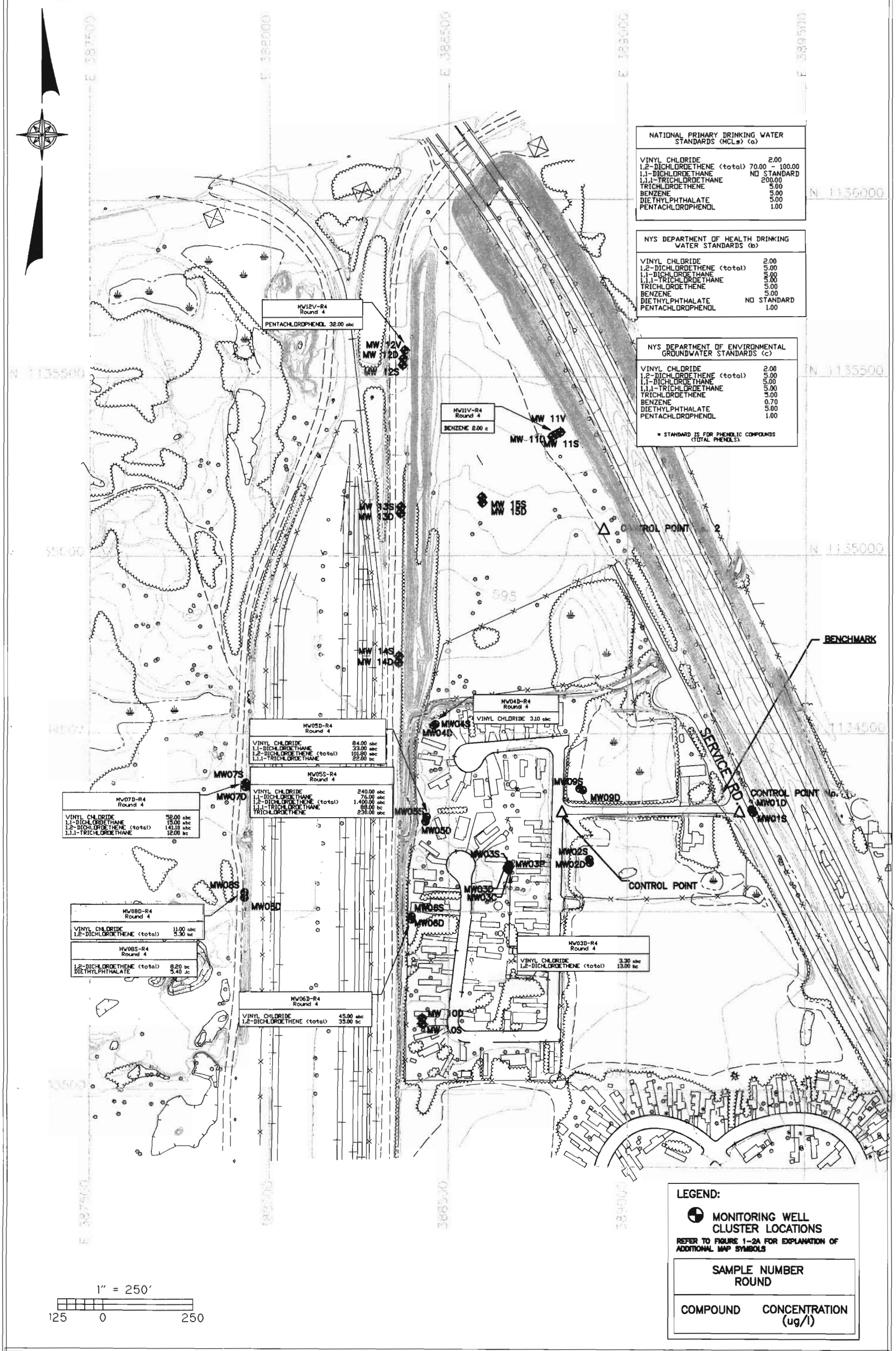


FIGURE 1-28

MONITORING WELL CLUSTER LOCATIONS TCL ORGANIC EXCEEDANCES IN ROUND 4 GROUNDWATER SAMPLES

WORK ASSIGNMENT 053-2L3U

Forest Glen Site, Niagara Falls, New York

CDM FEDERAL PROGRAMS CORPORATION

a subsidiary of Camp Dresser & McKee Inc.

NATIONAL PRIMARY DRINKING WATER STANDARDS (MCLs) (a)		
CHROMIUM	100.00	
IRON	300.00	*
LEAD	15.00	
MANGANESE	50.00	*
NICKEL	100.00	

NYS DEPARTMENT OF HEALTH DRINKING WATER STANDARDS (b)		
CHROMIUM	100.00	
IRON	300.00	*
LEAD	50.00	
MANGANESE	300.00	*
NICKEL	NO STANDARD	

NYS DEPARTMENT OF ENVIRONMENTAL CONSERVATION GROUNDWATER STANDARDS (c)	
CHROMIUM	50.00
IRON	300.00
LEAD	25.00
MANGANESE	300.00
NICKEL	NO STANDARD

MW5D Round 1

CHROMIUM	541.00 Jabc
IRON	15,100.00 Jabc
NICKEL	346.00 Ja

MW5S Round 1

IRON	5,050.00 Jabc
MANGANESE	393.00 Jabc

MW4S Round 1

IRON	32,500.00abc
LEAD	105.00abc
MANGANESE	1,780.00abc

MW4D Round 1

IRON	937.00 c
NICKEL	124.00 a

MW7D Round 1

IRON	2,550.00 abc

MW7S Round 1

IRON	879.00 abc
MANGANESE	469.00 abc

MW9D Round 1

IRON	1,320.00Jabc

MW9S Round 1

IRON	3,950.00 Jabc
MANGANESE	685.00 Jabc

MW2S Round 1

IRON	1,140.00Jabc

MW2D Round 1

IRON	417.00 abc

MW8S Round 1

CHROMIUM	162.00 ab
IRON	2,210.00 abc
NICKEL	104.00 a

MW8D Round 1

CHROMIUM	63.50 Jc
IRON	6,290.00 Jabc
LEAD	83.50 Jabc

MW6D Round 1

CHROMIUM	97.90 c
IRON	5,450.00 abc

MW10S (DUP OF MW6D) Round 1

CHROMIUM	78.90 Jc
IRON	4,590.00 Jabc

MW6S Round 1

IRON	785.00 abc

MW30B Round 1

CHROMIUM	749.00 Jabc
IRON	11,000.00 Jabc
MANGANESE	677.00 Jabc
NICKEL	725.00 Ja

MW3D Round 1

CHROMIUM	64.20 Jc
IRON	5,730.00 Jabc

MW3S Round 1

CHROMIUM	207.00 Jabc
IRON	3,550.00 Jabc
MANGANESE	352.00 Jabc
NICKEL	152.00 Ja

MW3PW Round 1

IRON	6,040.00 Jabc
MANGANESE	6,790.00 Jabc

MW1 MW2 MW3 MW4 MW5 MW6 MW7 MW8 MW9

LEGEND:

MONITORING WELL CLUSTER LOCATIONS

REFER TO FIGURE 1-8A FOR EXPLANATION OF ADDITIONAL MAP SYMBOLS

SAMPLE NUMBER
DEPTH (FT)

ANALYTE CONCENTRATION (ug/l)

* INDICATES SECONDARY STANDARD

125' 0 250'

SCALE:

FIGURE 1-29

MONITORING WELL CLUSTER LOCATIONS
INORGANIC EXCEEDANCES IN ROUND 1 GROUNDWATER SAMPLES

WORK ASSIGNMENT 053-2L3U
Forest Glen Site, Niagara Falls, New York

CDM FEDERAL PROGRAMS CORPORATION
a subsidiary of Camp Dresser & McKee Inc.

NATIONAL PRIMARY DRINKING WATER STANDARDS (MCLs) (a)	
CHROMIUM	100.00
IRON	300.00 *
LEAD	15.00
MANGANESE	50.00 *
NICKEL	100.00
ZINC	NO STANDARD

NYS DEPARTMENT OF HEALTH DRINKING WATER STANDARDS (b)	
CHROMIUM	100.00
IRON	300.00 *
LEAD	50.00
MANGANESE	300.00 *
NICKEL	NO STANDARD
ZINC	NO STANDARD

NYS DEPARTMENT OF ENVIRONMENTAL CONSERVATION GROUNDWATER STANDARDS (c)	
CHROMIUM	50.00
IRON	300.00
LEAD	25.00
MANGANESE	300.00
NICKEL	NO STANDARD
ZINC	300.00

MW04D Round 2	
IRON	2,060.00 abc
NICKEL	125.00 a

MW04S Round 2	
CHROMIUM	488.00 abc
IRON	19,300.00 abc
LEAD	37.50 ac
MANGANESE	893.00 abc
ZINC	328.00 c

MW05D Round 2	
IRON	2,620.00 abc

MW05S Round 2	
IRON	1,930.00 abc

MW07D Round 2	
IRON	1,250.00 abc

MW07S Round 2	
IRON	503.00 abc

MW08D Round 2	
IRON	1,530.00 abc

MW08S Round 2	
IRON	905.00 abc

MW06S Round 2	
IRON	2,560.00 abc

MW03D Round 2	
IRON	1,530.00 abc

MW03S Round 2	
CHROMIUM	52.00 abc
IRON	339.00 abc

MW03DB Round 2	
IRON	407.00 abc

MW03PW Round 2	
IRON	606.00 abc
MANGANESE	1,330.00 abc

MW09D Round 2	
IRON	565.00 abc

MW09S Round 2	
IRON	3,490.00 abc
MANGANESE	588.00 abc

MW10S (DUP OF MW03S) Round 2	
IRON	352.00 abc

MW01D Round 2	
IRON	1,510.00 abc

MW01S Round 2	
IRON	491.00 abc

MW02D Round 2	
IRON	437.00 abc

MW02S Round 2	
IRON	1,740.00 abc

MW1 MW2 MW3 MW4 MW5 MW6 MW7 MW8 MW9

CARRIE DRIVE

EDGEWOOD DRIVE

MARK DRIVE

ROUTE 130

125' 0 250'

SCALE:

LEGEND:

MONITORING WELL CLUSTER LOCATIONS

REFER TO FIGURE 1-2A FOR EXPLANATION OF ADDITIONAL MAP SYMBOLS

SAMPLE NUMBER ROUND	
ANALYTE	CONCENTRATION (ug/l)

* - EXCEEDS SECONDARY STANDARD

FIGURE 1-30

MONITORING WELL CLUSTER LOCATIONS
INORGANIC EXCEEDANCES IN ROUND 2 GROUNDWATER SAMPLES

WORK ASSIGNMENT 053-2L3U
Forest Glen Site, Niagara Falls, New York

CDM FEDERAL PROGRAMS CORPORATION
a subsidiary of Camp Dresser & McKee Inc.

NATIONAL PRIMARY DRINKING WATER STANDARDS (MCLs) (a)	
CHROMIUM	100.00
IRON	300.00 *
LEAD	15.00
MANGANESE	50.00 *
ZINC	NO STANDARD

NYS DEPARTMENT OF HEALTH DRINKING WATER STANDARDS (b)	
CHROMIUM	100.00
IRON	300.00 *
LEAD	50.00
MANGANESE	300.00 *
ZINC	NO STANDARD

NYS DEPARTMENT OF ENVIRONMENTAL CONSERVATION GROUNDWATER STANDARDS (c)	
CHROMIUM	50.00
IRON	300.00
LEAD	25.00
MANGANESE	300.00
ZINC	300.00

MW12V-R3 Round 3: IRON 3,000.00 abc; MANGANESE 460.00 abc

MW13D-R3 Round 3: IRON 2,300.00 abc

MW13S-R3 Round 3: IRON 960.00 abc

MW11D-R3 Round 3: IRON 390.00 abc

MW11S-R3 Round 3: IRON 790.00 abc

MW11V-R3 Round 3: IRON 3,300.00 abc; MANGANESE 410.00 abc

MW15D-R3 Round 3: IRON 480.00 abc; LEAD 17.00 a

MW15D-R3 (DUP) Round 3: IRON 470.00 abc; LEAD 16.00 a

MW15S-R3 Round 3: IRON 1,600.00 abc

MW14D-R3 Round 3: IRON 820.00 abc

MW14S-R3 Round 3: IRON 1,100.00 abc

MW04D-R3 Round 3: IRON 800.00 abc

MW04D-R3 (DUP) Round 3: IRON 730.00 abc

MW04S-R3 Round 3: CHROMIUM 380.00 abc; IRON 20,000.00 abc; LEAD 26.00 ac; MANGANESE 1,200.00 abc; ZINC 450.00 c

MW09D-R3 Round 3: IRON 420.00 abc

MW09S-R3 Round 3: IRON 3,600.00 abc; MANGANESE 480.00 abc

MW07D-R3 Round 3: IRON 2,400.00 abc

MW07S-R3 Round 3: MANGANESE 520.00 abc

MW05D-R3 Round 3: IRON 2,300.00 abc

MW05S-R3 Round 3: IRON 2,700.00 abc; MANGANESE 330.00 abc

MW01D-R3 Round 3: IRON 440.00 abc

MW01S-R3 Round 3: CHROMIUM 130.00 abc; IRON 680.00 abc

MW08D-R3 Round 3: IRON 480.00 abc

MW08S-R3 Round 3: IRON 1,200.00 abc

MW08S-R3 (DUP) Round 3: IRON 1,100.00 abc

MW06D-R3 Round 3: IRON 3,500.00 abc; LEAD 26.00 ac

MW06S-R3 Round 3: IRON 1,400.00 abc

MW03D-R3 Round 3: IRON 910.00 abc; MANGANESE 310.00 abc

MW02D-R3 Round 3: IRON 360.00 abc

MW03S-R3 Round 3: CHROMIUM 280.00 abc; IRON 5,990.00 abc; MANGANESE 670.00 abc

MW02S-R3 Round 3: IRON 1,200.00 abc

MW03P-R3 Round 3: IRON 4,600.00 abc; MANGANESE 5,500.00 abc

MW03D-R3 Round 3: IRON 3,200.00 abc; MANGANESE 580.00 abc

MW10D-R3 Round 3: IRON 640.00 abc

MW10S-R3 Round 3: IRON 1,000.00 abc

MW 12V, MW 12D, MW 12S; MW 11V, MW 11D, MW 11S; MW 13S, MW 13D; MW 15S, MW 15D; MW 14S, MW 14D; MW04S, MW04D; MW07S, MW07D; MW05S, MW05D; MW08S, MW08D; MW06S, MW06D; MW03S, MW03P, MW03D; MW02S, MW02D; MW09S, MW09D; MW01S, MW01D; MW10S, MW10D

CONTROL POINT No. 2

CONTROL POINT No. 1

CONTROL POINT

BENCHMARK

SERVICE RD.

E 387500 E 388000 E 388500 E 389000 E 389500

N 1136000 N 1135500 N 1135000 N 1134500 N 1134000

595

LEGEND:

MONITORING WELL CLUSTER LOCATIONS

REFER TO FIGURE 1-2A FOR EXPLANATION OF ADDITIONAL MAP SYMBOLS

SAMPLE NUMBER
ROUND

ANALYTE | CONCENTRATION (ug/l)

* - INDICATES SECONDARY STANDARD

1" = 250'

125 0 250

FIGURE 1-31

MONITORING WELL CLUSTER LOCATIONS
INORGANIC EXCEEDANCES IN ROUND 3 GROUNDWATER SAMPLES

WORK ASSIGNMENT 053-2L3U
Forest Glen Site, Niagara Falls, New York

CDM FEDERAL PROGRAMS CORPORATION
a subsidiary of Camp Dresser & McKee Inc.

NATIONAL PRIMARY DRINKING WATER STANDARDS (MCLs) (a)	
IRON	300.00 *
MANGANESE	50.00 *

NYS DEPARTMENT OF HEALTH DRINKING WATER STANDARDS (b)	
IRON	300.00 *
MANGANESE	300.00 *

NYS DEPARTMENT OF ENVIRONMENTAL CONSERVATION GROUNDWATER STANDARDS (c)	
IRON	300.00
MANGANESE	300.00

E 387500 E 388000 E 388500 E 389000 E 389500

N 1136000 N 1135500 N 1135000 N 1134500 N 1134000 N 1133500

MW12V-R4 Round 4: IRON 1,800.00 abc; MANGANESE 350.00 abc

MW13D-R4 Round 4: IRON 1,000.00 abc

MW13S-R4 Round 4: IRON 2,200.00 abc

MW11D-R4 Round 4: IRON 780.00 abc

MW11S-R4 Round 4: IRON 860.00 abc

MW11V-R4 Round 4: IRON 7,900.00 abc; MANGANESE 550.00 abc

MW15D-R4 Round 4: IRON 1,000.00 abc

MW15S-R4 Round 4: IRON 1,200.00 abc

MW14D-R4 Round 4: IRON 1,500.00 abc

MW14S-R4 Round 4: IRON 1,900.00 abc

MW04D-R4 Round 4: IRON 530.00 abc

MW04S-R4 Round 4: IRON 4,200.00 abc

MW04S-R4 (DUP) Round 4: IRON 2,700.00 abc

MW09S-R4 Round 4: IRON 3,600.00 abc; MANGANESE 490.00 abc

MW07D-R4 Round 4: IRON 2,500.00 abc

MW05D-R4 Round 4: IRON 1,100.00 abc

MW05S-R4 Round 4: IRON 2,700.00 abc; MANGANESE 350.00 abc

MW08D-R4 Round 4: IRON 510.00 abc

MW08S-R4 Round 4: IRON 620.00 abc

MW06D-R4 Round 4: IRON 1,000.00 abc

MW06S-R4 Round 4: IRON 1,100.00 abc

MW06S-R4 (DUP) Round 4: IRON 1,100.00 abc

MW03D-R4 Round 4: IRON 620.00 abc; MANGANESE 440.00 abc

MW03P-R4 Round 4: IRON 6,400.00 abc; MANGANESE 5,500.00 abc

MW02S-R4 Round 4: IRON 1,200.00 abc

MW01D-R4 Round 4: IRON 450.00 abc

MW01S-R4 Round 4: MANGANESE 360.00 abc

MW10S-R4 Round 4: IRON 1,500.00 abc

MW12D
MW12S
MW11V
MW11D
MW11S
MW13S
MW13D
MW15S
MW15D
MW14S
MW14D
MW04S
MW04D
MW09S
MW09D
MW07S
MW07D
MW05S
MW05D
MW03S
MW03P
MW03D
MW03C
MW02S
MW02D
MW08S
MW08D
MW06S
MW06D
MW10D
MW10S
MW01D
MW01S

CONTROL POINT
CONTROL POINT
CONTROL POINT
BENCHMARK
SERVICE RD.

595

1" = 250'
125 0 250

LEGEND:

MONITORING WELL CLUSTER LOCATIONS

REFER TO FIGURE 1-2A FOR EXPLANATION OF ADDITIONAL MAP SYMBOLS

SAMPLE NUMBER ROUND	
ANALYTE	CONCENTRATION (ug/l)

* - INDICATES SECONDARY STANDARD

FIGURE 1-32

MONITORING WELL CLUSTER LOCATIONS INORGANIC EXCEEDANCES IN ROUND 4 GROUNDWATER SAMPLES

WORK ASSIGNMENT 053-2L3U
Forest Glen Site, Niagara Falls, New York

CDM FEDERAL PROGRAMS CORPORATION
a subsidiary of Camp Dresser & McKee Inc.

2.0 IDENTIFICATION AND SCREENING OF REMEDIAL TECHNOLOGIES

2.1 INTRODUCTION

The purpose of this section is to present the development of remedial action objectives and to identify, screen, and select the most appropriate technologies to address the groundwater contamination at the Forest Glen site. The most representative technology types and process options are combined in Section 3.0 into remedial alternatives for the contaminated groundwater plume.

The identification and screening of remedial technologies is carried out in a step-wise manner. First, site-specific ARARs and TBCs are identified (Section 2.2). Then, remedial action objectives are developed in Section 2.3 based on the characterization of contaminants, the risk assessment, and compliance with ARARs. The area of contamination within the Forest Glen site, and the volume of the contaminated groundwater to which general response actions may be applied are quantified in Section 2.4. General response actions, which address the groundwater contamination problems and meet the cleanup goals and objectives are identified in Section 2.5. Potential technologies associated with each response action are identified in Section 2.6, and screened to eliminate those that are inappropriate for the conditions at Forest Glen. Finally, representative process options are evaluated and selected in Section 2.7 for each technology type retained for consideration. Although specific processes are selected for development and evaluation of remedial alternatives, these processes are intended to represent the broader range of process options within a general technology type. Utilization of process options provides greater flexibility in the final design, while simplifying the FS process.

2.2 SITE-SPECIFIC APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) AND TO BE CONSIDERED (TBCs) REQUIREMENTS

The primary concern during the development of remedial action objectives for hazardous waste sites under CERCLA or "Superfund", is the degree of protection afforded by a given remedy to human health and the environment. Section 121(d) of SARA and the NCP (40 CFR 300; March 8, 1990) require that primary consideration be given to remedial alternatives that attain or exceed ARARs. The purpose of this requirement is to make response actions executed under CERCLA comply with all pertinent Federal and (New York) State environmental requirements. State requirements must also be attained under Section 121 (d)(2)(c) of SARA, if they are legally enforceable and consistently applied statewide. EPA has indicated that ARARs must be identified for each site on the NPL.

This section provides a preliminary determination of the regulations that are applicable or relevant and appropriate to the remediation of the Forest Glen Operable Unit I RI/FS. Both Federal and State environmental regulations and public health requirements are considered. In addition, this section presents an identification of Federal and State criteria, advisories, and guidance that could be used for evaluating remedial alternatives.

2.2.1 DEFINITION AND TYPES OF ARARs AND TBCs

Applicable, or relevant and appropriate requirements, are referred to as ARARs. The Environmental Protection Agency (EPA) defines **Applicable Requirements** as "those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under Federal environmental or State environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site". Applicable requirements must directly and fully address the situation at the site. Further, Applicable Requirements are those requirements promulgated under Federal or State laws that would be legally applicable to the response action if that action were not taken pursuant to Sections 104 or 106 of CERCLA.

The EPA defines **Relevant and Appropriate Requirements** as "those clean-up standards, standards of control, or other substantive requirements, criteria, or limitations promulgated under Federal environmental or State environmental or facility siting laws that, while not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at CERCLA sites that their use is well suited to the particular site". Relevant and appropriate requirements are intended to have the same weight as applicable requirements.

Actions must comply with State ARARs that are more stringent than Federal ARARs. State ARARs are also used in the absence of a Federal ARAR, or where a State ARAR is broader in scope than the Federal ARAR. In order to qualify as an ARAR, State requirements must be promulgated and identified in a timely manner. Furthermore, for a State requirement to be a potential ARAR it must be applicable to all remedial situations described in the requirement, not just at CERCLA sites.

ARARs are not currently available for every chemical, location, or action that may be encountered. For example, there are currently no ARARs which specify clean-up levels for soils (other than the NY Technical and Administartive Guidance Memorandum (TAGM) and the proposed corrective action standards in Appendices A, B and C of the Subpart S requirements of 40 CFR 264 under RCRA [55 FR 30865, July 27, 1990]). When ARARs are not available, remediation goals may be based upon other Federal or State criteria, advisories and guidance, or local ordinances. In the development of remedial action alternatives, the information derived from these sources is termed **To Be Considered** and the resulting requirements are referred to as TBCs. EPA guidance allows cleanup goals to be based upon non-promulgated criteria and advisories such as reference doses when ARARs do not exist, or when an ARAR alone would not be sufficiently protective in the given circumstance.

Section 121 of SARA requires that the remedy chosen for a CERCLA site must attain all ARARs unless one of the six conditions (under which compliance with ARARs may be waived) is satisfied. These are:

(1) the selected remedial action is an interim remedy or a portion of a total remedy which will attain the standard upon completion;

(2) compliance with such requirements could result in greater risk to human health and the environment than alternate options;

(3) compliance with such requirements is technically impracticable from an engineering perspective;

(4) the selected remedial action will attain an equivalent standard of performance;

(5) the requirement has been promulgated by the State, but has not been consistently applied in similar circumstances; or,

(6) compliance with the ARAR will not provide a balance between protecting the public health and the environment at this site with the availability of funds for response at other sites.

ARARs are used as a guide to establish the appropriate extent of site cleanup; to aid in scoping, formulating and selecting proposed treatment technologies; and to govern the implementation and operation of the selected remedial alternative. Primary consideration should be given to remedial alternatives that attain or exceed the requirements of the identified ARARs. Throughout the RI/FS, ARARs are identified and utilized by taking into account the following:

Contaminants suspected or identified to be at the site

Chemical analyses performed, or scheduled to be performed

Types of media (air, soil, ground and surface water)

Geology and other site characteristics

Present/future use of site resources and media

Potential contaminant transport mechanisms

Purpose and application of potential ARARs

Remedial alternatives considered for site clean-up

ARARs and TBCs are both used during the FS process to evaluate the remedial alternatives.

ARARs and TBCs fall into three broad categories, based on the manner in which they are applied at a site. These categories are as follows:

- Contaminant-specific - These ARARs and TBCs define acceptable exposure levels for a specific chemical in an environmental medium and are used in establishing

preliminary remediation goals. They may be actual concentration based cleanup levels, or they may provide the basis for calculating such levels. Examples of contaminant-specific ARARs are MCLs for drinking water or ambient air quality standards.

- Location-specific - These ARARs and TBCs set restrictions on remedial activities at a site due to its proximity to specific natural or man-made features. Examples of natural site features include floodplains or wetlands. Examples of man-made features are local historic buildings and structures.

- Action-specific - These ARARs and TBCs set controls or restrictions for particular treatment and disposal activities related to the management of hazardous substances. Examples of action-specific ARARs are effluent discharge limits and hazardous waste manifesting requirements.

2.2.2 CONTAMINANT SPECIFIC ARARs AND TBCs

A partial listing of potential Federal and State contaminant-specific ARARs and TBCs that apply to Forest Glen, is presented in Table 2-1. All of the ARARs and TBCs listed provide some specific guidance on "acceptable" or "permissible" concentrations of contaminants in air, drinking water, treatment residues, etc., at the site. It should be noted that such a list is not totally inclusive and must be reviewed for completeness periodically, to evaluate if additions to or deletions from the list are required. A brief discussion of some of the contaminant-specific ARARs and TBCs is presented below.

The Clean Air Act of 1976 (42 USC 7401) governs air emissions resulting from remedial actions. National Ambient Air Quality Standards (NAAQS) were promulgated under the Clean Air Act. NAAQS are available for six chemicals or groups of chemicals and for airborne particulates. The sources of the contaminant and the route of exposure were considered in the formulation of the standards, but the costs of achievement and the feasibility of implementing them were not considered. The NAAQS allow for a margin of safety to account for unidentified hazards and effects. During the soil remediation which is expected to precede the groundwater remediation, it will be necessary to keep particulate emissions to a minimum.

Section 112 of the Clean Air Act defines the National Emissions Standards for Hazardous Air Pollutants (NESHAPs). NESHAPs are available for several compounds found at the site. A number of other pollutants are recognized as hazardous, but no emissions standards have been developed for them. In these cases, other guidelines such as reference doses or carcinogenic potency factors may be useful.

Reference Doses (RfDs) refer to the amount of a toxicant (in mg/day for a 70 kg adult) that is not expected to result in adverse health effects after chronic exposure of the general population. They are used to evaluate the potential for noncarcinogenic effects associated with exposure to site-related contaminants.

Carcinogenic Slope Factors (CSFs) represent the upper 95 percent confidence limit of the carcinogenic potency of a compound. The CSF is expressed as the lifetime cancer risk per mg of contaminant per kg of body weight per day (kg-day/mg). An upper bound estimate of cancer risk can be determined by converting the estimated dose of a compound to an incremental lifetime cancer risk. CSFs for the site contaminants were presented in the RI report.

The Safe Drinking Water Act (SDWA) promulgated National Primary Drinking Water Standard MCLs (40 CFR 141). MCLs are enforceable standards for contaminants in public drinking water supply systems. They are based on health risks, as well as the economic and technical feasibility of removing a contaminant from a water supply system. EPA has recently also proposed Maximum Contaminant Level Goals (MCLGs) for several organic and inorganic compounds in drinking water. MCLGs are nonenforceable guidelines that do not consider the technical feasibility of contaminant removal. Secondary MCLs (40 CFR 143) are not enforceable, but are intended as guidelines to protect the public welfare. Contaminants covered are those that may adversely affect the aesthetic quality of drinking water, such as taste, odor, color, and appearance, and may deter public acceptance of drinking water provided by public water systems. SDWA requirements are applicable to groundwater treatment alternatives.

EPA Health Advisories are nonenforceable guidelines, developed by the EPA Office of Drinking Water, for chemicals that may be intermittently encountered in public water supply systems. Health advisories are available for short-term, long-term, and lifetime exposures for a 10 kg child and/or a 70 kg adult. Health advisories may be applicable for remedial actions involving groundwater treatment, especially for contaminants that are not regulated under the SDWA.

EPA Ambient Water Quality Criteria (AWQC) were developed for 64 pollutants in 1980, pursuant to Section 304(a)(1) of the Clean Water Act. In 1984, EPA revised nine criteria previously published in 1976 (Quality Criteria for Water) and in the 1980 documents. AWQC are not legally enforceable, but have been used by many states to develop enforceable water quality standards. AWQC are available for the protection of human health from exposure to contaminants in drinking water and from the ingestion of aquatic biota and for the protection of freshwater and saltwater aquatic life. AWQC may be applicable to those remedial actions which involve groundwater treatment and/or discharges to surface water.

2.2.3 LOCATION SPECIFIC ARARs AND TBCs

A partial listing of potential Federal and State location-specific ARARs and TBCs is presented in Table 2-2. It should be noted that such a list is not totally inclusive and must be reviewed for completeness periodically, to evaluate if additions to or deletions from the list are required. At a minimum this review would take place every five years. A brief discussion of some of the location-specific ARARs and TBCs is presented below.

Executive Order 11990 (Wetlands Protection) requires Federal agencies to take action to minimize the destruction, loss, or degradation of wetlands and to preserve and enhance the natural and beneficial values of wetlands. The order emphasizes the importance of avoiding undertaking new construction located in wetlands (unless there is no practical alternative to that construction),

minimizing the harm to wetlands, and providing early and adequate opportunities for public review of plans involving new construction in wetlands.

The Wetlands Construction and Management Procedures (40 CFR 6, Appendix A) will need to be considered if the wetlands at the site will be impacted by any of the remedial alternatives. It is expected that some of the groundwater extraction and treatment alternatives may affect the wetlands, (e.g. construction of the buried extraction system pipe network). It is difficult to predict the degree and extent of this potential impact at this stage of the FS process.

In order to evaluate the requirements of the Endangered Species Act, the Fish and Wildlife Improvement Act of 1978, the Fish and Wildlife Conservation Act of 1980, and the Fish and Wildlife Coordination Act, the National Heritage Database was consulted. The report that was generated provides information on managed areas, rare plants and animals, and their status. This information is summarized in the RI Report.

Executive Order 11988 (Floodplain Management) requires Federal agencies to evaluate potential effects of the planned actions in a floodplain environment to reduce the risk of flood losses and to restore and preserve the natural and beneficial values of the floodplain. The Flood Disaster Protection Act and the National Flood Insurance Act and their implementation regulations (24 CFR 1909) require the purchase of flood insurance before Federal funds are spent for projects in a special flood hazard area in a community participating in the National Flood Insurance Program. Coverage must continue throughout the useful life of the project. The drainage areas of the East Gill Creek may be considered to be a flood hazard area.

The National Historic Preservation Act of 1966 requires Federal agencies to identify all affected properties on or eligible for the National Register of Historic Places in the vicinity of the site when considering remedial actions.

2.2.4 ACTION-SPECIFIC ARARs AND TBCs

A partial listing of potential Federal and State action-specific ARARs and TBCs is presented in Table 2-3. It should be noted that such a list is not totally inclusive and must be reviewed for completeness periodically, to evaluate if additions to or deletions from the list are required. At a minimum, this review would take place every five years. A brief discussion of some of the action-specific ARARs and TBCs is presented below. These ARARs govern activities undertaken as part of site remediation.

The Resource Conservation and Recovery Act (RCRA), as amended, governs the generation, transportation, storage, and the disposal of hazardous wastes. RCRA (40 CFR 264) standards apply to remedial actions that include on-site treatment and storage and off-site hauling and disposal of hazardous wastes, which may be considered for this site.

OSHA requirements provide for the protection of the health and safety of workers engaged in on-site remedial activities. Threshold Limit Values (TLVs) refer to airborne concentrations of substances and represent conditions under which repeated exposures are not expected to result in adverse

effects. These ARARs are within the jurisdiction of the on-site health and safety officer. Except for the No Further Action alternative, OSHA requirements apply to all other remedial alternatives.

DOT regulations govern the off-site transport of hazardous materials for disposal and/or treatment. Waste handlers involved in site remediation activities must have all proper permits and certifications. These regulations will be applicable to all remedial alternatives involving treatment or disposal of contaminated media or residues at Forest Glen.

SARA requires that Federal agencies pursue permanent solutions. Implementation of alternatives that provide permanent solutions has been evaluated in this report.

The Hazardous and Solid Waste Amendments and the RCRA Land Disposal Restrictions regulate land disposal of hazardous wastes. These must be considered when evaluating disposal options for the Forest Glen site.

40 CFR 264 and 265, Subparts Z, AA and BB address new regulations developed to provide standards for controlling hazardous volatile organic compound emissions. These would be considered during groundwater treatment.

2.3 REMEDIAL ACTION OBJECTIVES

Remedial action objectives are established for the protection of human health and the environment. These remedial action objectives are to:

- Restore the presently vacant and abandoned site to beneficial use based on its current zoning as a residential property (except for portions of the site that are used for groundwater extraction, treatment and discharge). It is assumed that the soil remedy for Operable Unit II (i.e. source control) will be implemented prior to the groundwater remedy so that the overburden soil within the Edgewood Drive Lots (AOC 5) and the Subdivision (AOC 6) does not continue to serve as a potential source of groundwater contamination.

- Prevent/minimize offsite migration of groundwater contamination in the fractured bedrock aquifer. Fully contain the contaminated groundwater (that which is above Federal and State MCLs) from all depth zones and reduce the mass of contaminants to the maximum extent possible. The goal of EPA's Superfund approach is to return usable groundwaters to their beneficial uses.

- Prevent human exposure to contaminated groundwater.

The maximum concentrations for all the contaminants of concern and the Federal and State cleanup standards for groundwater were presented in Section 1.4.

2.4 AREA AND VOLUME ESTIMATES

As stated in Section 1.7, this FS is based on the following assumptions concerning the volume of the contaminated groundwater:

- The horizontal extent of the contaminated groundwater plumes (primarily VOCs and metals like iron and manganese) at Forest Glen are as shown on Figures 1-25 through 1-32. Although in many instances the secondary MCLs for iron and manganese have been exceeded, the contamination is primarily due to chlorinated volatile organics. For purposes of calculation in this FS, the horizontal extent of contamination is assumed to lie within an oval shaped plume as presented in Figure 2-1. It is recognized that offsite contamination exists beyond the site boundaries and has not been fully determined.

- The vertical extent of contamination in groundwater is conservatively assumed to be to an average depth of 70 feet below ground surface which is approximately 100 feet above the depth of the bottom boundary (top of the Rochester Shale) used in CDM Federal's preliminary groundwater model. (See Appendix B)

Based on these boundaries, the assumed contaminated groundwater plume for Forest Glen has an areal extent of 808,234 square feet. The saturated zone depth of the aquifer that corresponds to the conservatively assumed depth of contamination is 55 feet. Using an effective porosity of 3.6 percent, the corresponding estimated volume for Forest Glen plume is 11.970 million gallons.

This volume is representative of the equivalent of one pore volume for the fractured bedrock aquifer. Based on the soil (rock)/water distribution coefficients of organic compounds present in the groundwater, it is estimated that several pore volumes (approximately 22) will need to be treated before cleanup goals (Federal and State MCLs or background levels, as appropriate) can ever be expected to be achieved. The goal of EPA's Superfund approach is to return usable groundwaters to their beneficial uses.

2.5 GENERAL RESPONSE ACTIONS

General response actions are broad categories of remediation capable of addressing the contamination problem at the site. Some response actions may be sufficiently broad to be able to satisfy all the remedial action objectives and cleanup goals for the site by themselves. Other response actions must be combined in order to achieve the site remedial goals and cleanup objectives.

Based on the existing knowledge of the site, general response actions identified for groundwater remediation at Forest Glen include: no action, limited action, collection, on-site and off-site treatment, on-site and off-site disposal. Containment actions were not included because of site-specific conditions, such as the proposed soil remedy for Operable Unit II and the depth of contamination in the fractured bedrock aquifer. Containment actions include technologies that involve little or no treatment, but provide protection of human health and the environment by

reducing the mobility of contaminants and risks of exposure. Containment actions consist of controlling groundwater movement through the use of technologies like capping, and horizontal and vertical barriers. Again, the objective of this FS is to develop mitigation/management of migration alternatives involving treatment to reduce the mass(volume) of contaminants, their mobility and toxicity, and therefore, options involving solely containment through hydraulic control have not been developed.

Remedial technologies and process options associated with each category of response action are shown in Figure 2-2. A brief description of each response action is stated below:

No Action: The NCP and SARA require the evaluation of a No Action alternative as a basis for comparison with other remedial alternatives. Under this category of response, existing monitoring wells at the site would be used to conduct a groundwater monitoring program for a five year period. For the Forest Glen site, a five-year review would be conducted to determine whether or not the contamination has spread. If necessary, appropriate action would be considered at that time.

Limited Action: For this category of response action, no active remedial measures would be conducted. However, existing and new monitoring wells at the site would be used to conduct a long-term groundwater monitoring program for a thirty year period.This response action category includes natural processes which are often described by the term "monitored natural attenuation" or MNA. MNA includes in-situ processes like biodegradation, dispersion, dilution through advection and recharge, adsorption, and volatilization. Typically, MNA is used in conjunction with active remediation measures. Additional institutional controls (such as declaring an as yet undefined area around the site as a well restriction area) would also be imposed.

Collection: In the case of groundwater, collection actions refer to extraction techniques. They typically involve extraction of the plume using interceptor trenches (barrier drains) and/or extraction wells. Based on the remedial investigation, it has been determined that interceptor trenches are not suitable for Forest Glen site conditions. Collection reduces the mobility of the contaminants through physical removal and by changing the hydraulic gradient in the surrounding area. However, by themselves, collection actions do not reduce either the toxicity or the volume of hazardous substances at the site. They are generally used in combination with treatment technologies.

Treatment: This category of response action is preferred under SARA and can occur either on-site or off-site. Treatment technologies include physical, chemical and biological processes. Thermal processes are a special class of treatment technologies that involve both physical and chemical phenomena. Treatment technologies are preferred because they generally reduce the toxicity, mobility or volume of hazardous substances present at the site. Treatment technologies generally afford a higher degree of protection to public health and the environment.

Disposal: This category of response action can occur on-site or off-site. Disposal actions like collection, reduce the mobility of the contaminants through physical deposition and may be used separately or in conjunction with treatment technologies. However, by themselves, disposal actions do not reduce the toxicity or the volume of hazardous substances at the site. In the case of groundwater, disposal technologies typically include reinjection, discharge to surface waters,

discharge to a public water supply (after treatment), and discharge to a publicly owned treatment works (POTW).

2.6 IDENTIFICATION AND INITIAL SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS

The remedial technologies associated with each of the general response actions typically considered for the cleanup of contaminated groundwater were developed from: the Interim Final Guidance for Conducting RI/FS under CERCLA (October 1988); the Guidance on Remedial Actions for Contaminated Groundwater at Superfund Sites (December 1988); the revised Handbook for Remedial Action at Waste Disposal Sites (1985); experience on other hazardous waste projects; knowledge of new technologies; and the best professional judgement of engineers and scientists performing feasibility studies.

A summary of the initial screening performed on potentially applicable groundwater remediation technologies and process options for the Forest Glen site is presented in Figure 2-3. The initial screening process was used to eliminate technologies that are not appropriate for implementation at the Forest Glen site. The screening process considered site-specific conditions, contaminant types and concentrations, and the area and volume to be remediated. The three main column headings presented in Figure 2-3 are General Response Actions, Technologies, and Process Options. General Response Actions are discussed in Section 2.5. The Technology category refers to a general group of technologies which can be used to address a required remedial response action. The Process Option category contains specific processes which are examples of a technology group. The two remaining columns in Figure 2-3 are Description and Screening Comments. The description column briefly describes the individual process options. The screening comments indicate if a particular process option is removed from further consideration or retained for further evaluation during the FS. Process options are only removed at this time if they are technically infeasible or they cannot be effectively implemented.

The initial screening process was used to eliminate technologies that are not appropriate for implementation at the Forest Glen site. The screening process considered specific conditions for individual source areas, contaminant types and concentrations, and the areas and volumes to be remedied. Two containment technologies that were eliminated are vertical and horizontal barriers.

Vertical barriers refer to a variety of methods whereby low permeability cut-off walls are installed below ground to contain, capture, or redirect groundwater flow in the vicinity of the source areas. They are generally keyed in to an aquitard such as a clay layer. They separate the contaminated zone from the clean zone in order to isolate the waste and to prevent contaminant migration. At source areas where the depth of contamination is below the water table, vertical barriers reduce the groundwater flow toward the source area and redirect the contaminated groundwater away from the source areas. Materials used for barriers generally have very low permeability. Slurry walls and sheet piling are two process options generally considered for implementation as vertical barriers. Vertical barriers are not implementable at the Forest Glen site because the groundwater within the fractured bedrock is already contaminated. Therefore, the use of vertical barriers is not relevant.

Liners and Grout Injection are examples of horizontal barriers. Placement of liners below source areas requires excavation and the creation of landfills. The Grout Injection process option is mainly used to inject grout materials in order to form an impermeable or low permeability layer. It will not reduce the toxicity or volume of waste but it can prevent vadose zone contaminants from migrating into groundwater. It is not implementable at the Forest Glen site because the groundwater within the fractured bedrock is already contaminated. Hence, horizontal barriers were eliminated from further consideration.

The initial screening process was also used to eliminate two ex-situ treatment technologies - aerobic biological treatment and carbon adsorption. Aerobic biological treatment is not very effective for chlorinated aliphatic hydrocarbons (CAHs) such as cis-1,2-dichloroethene (cis-1,2-DCE) and carbon adsorption is not well suited for CAHs like vinyl chloride.

2.7 EVALUATION AND SELECTION OF REPRESENTATIVE TECHNOLOGY TYPES AND PROCESS OPTIONS

In this section, technologies considered implementable after the initial screening are described and evaluated. The evaluation process utilizes three criteria: effectiveness, implementability, and relative cost. The guidance recommends that this evaluation focus on the effectiveness criterion, with less emphasis directed at the implementability and relative cost criteria. Process options that are reliable, but only partially treat the contaminants present in the groundwater and soils will be retained for further consideration if they can be effectively combined with other reliable process options to fully remediate the site.

Brief definitions of effectiveness, implementability, and relative cost, as they apply to the screening process are as follows:

Effectiveness - This evaluation focuses on the potential effectiveness of process options in handling the estimated volume of media and meeting the remediation goals; the potential impacts to human health and the environment during construction and implementation; and how proven and reliable the process is with respect to the contaminants and conditions at the site.

Implementability - This evaluation encompasses both the technical and administrative feasibility of the technology or process option. It includes an evaluation of pretreatment requirements, residuals management, the relative ease or difficulty in obtaining the required permits, the availability of equipment and materials, and operating and maintenance requirements. Process options that are clearly ineffective or unworkable at the site are eliminated.

Relative Cost - Cost plays a limited role in the screening process. Both capital as well as operating and maintenance costs are considered. The cost analysis is based on engineering judgement, and each process is evaluated as to whether costs are high, low or moderate relative to the other options within the same technology type.

At least one representative process option is selected, if possible, for each technology type to simplify the subsequent development and evaluation of remedial alternatives without limiting flexibility during remedial design.

2.7.1 No Action

Description: The NCP and SARA require the evaluation of a No Action alternative as a basis for comparison with other remedial alternatives. Under this category of response, existing monitoring wells at the site would be used to conduct a groundwater monitoring program for a five year period. For the Forest Glen site, a five-year review would be conducted to determine whether or not the contamination has spread. If necessary, appropriate action would be considered at that time.

Effectiveness: The contaminated groundwater will continue to migrate downgradient towards the PASNY conduits. No Action is ineffective in meeting any of the remediation objectives.

Implementability: No Action is readily implemented. Regular monitoring of water quality in existing monitoring wells and a five-year review are the only activities that must be conducted.

Cost: The relative cost of this response action will be the least of all considered remedial measures.

Conclusion: No Action does not reduce the toxicity, mobility, or volume of the contamination. The dominant risk is likely to be posed by the potential future use of the groundwater at the site for drinking and showering. Almost all downgradient offsite residents and commercial establishments do have an alternate water supply source for drinking and showering at present. No Action will be retained for further consideration, as required by SARA, to serve as a basis for comparison with other remedial alternatives.

2.7.2 Limited Action

Description: Under the Limited Action alternative no active remedial measures would be conducted. However, existing and new monitoring wells at the site would be used to conduct a long-term groundwater monitoring program for a thirty year period. This technology category includes natural processes which are often described by the term "monitored natural attenuation" or MNA. MNA includes in-situ processes like biodegradation, dispersion, dilution through advection and recharge, adsorption, and volatilization. Typically, MNA is used in conjunction with active remediation measures. The feasibility of MNA at Forest Glen has been evaluated in Appendix D. Additional institutional controls (such as declaring an as yet undefined area around the site as a well restriction area) would also be imposed.

Effectiveness: The contaminated groundwater will continue to move downgradient toward the PASNY conduits. As stated in Appendix D, further site-specific studies are necessary to better determine the effectiveness of MNA for the Forest Glen site. Preliminary modeling has shown that although significant reduction of contaminant concentrations are possible, the contaminant plume would extend offsite to the PASNY conduits at

levels above Federal and State MCLs. MNA may be effective in conjunction with other active remediation measures. Limited action does not reduce the mobility, toxicity or volume of the hazardous substances. However, it would be somewhat effective in protecting public health through the monitoring of contamination and the potential for providing a warning against the use of contaminated groundwater.

Implementability: This category of response action can be easily implemented. Periodic sampling and analysis of groundwater would be easily performed. Further site-specific investigations as described in Appendix D could easily be performed. The declaration of a well restriction area would require additional investigation to determine the boundaries of this area.

Cost: The relative costs for this category of response actions are very low compared to most of the remedial actions.

Conclusion: Limited Action as described above would provide only minimally more protection than No Action through the monitoring of contamination and the potential for providing a warning against the use of contaminated groundwater. However, migration of the plume would continue and the water quality of the fractured bedrock aquifer would not be restored to action levels for a very long time (more than thirty years). Limited Action (specifically MNA) will be retained for further consideration in alternative development because it can be used in conjunction with other active remediation measures and to preserve a range of response actions.

2.7.3 Collection Technologies

Collection technologies involve the active manipulation (extraction) and management of groundwater prior to subsequent treatment and/or disposal. Collection technologies are utilized to remove the contaminated groundwater from the aquifer and to physically prevent or reduce contaminant plume migration. The selection of an appropriate groundwater collection system depends upon the objectives of the remedial action, the depth of contamination, and the geologic and hydrogeologic characteristics of the aquifer.

2.7.3.1 Barrier Drain Systems

Description: The barrier drain system uses trench drains, tile drains or dual media drains to collect and extract the groundwater downgradient of the contamination plume. This system is most useful in formations with low transmissivity and when the flow of contaminated groundwater must be controlled over a large area. It creates a continuous zone of influence in which groundwater flow is directed toward the drain. The major activities associated with construction of subsurface drains are trench excavation, trench stabilization, and installation of a perforated drain pipe and associated filter materials.

Effectiveness: The barrier drain system would not directly reduce the volume or toxicity of contaminants, but would be used to collect groundwater prior to treatment. Additionally, installing drains may reduce the mobility of the contaminants by changing the hydraulic gradient in the surrounding region, causing contaminants to flow toward the drain. Based on the remedial

investigation at the Forest Glen site, which showed that the uppermost water bearing zone is not within the overburden and is actually within the weathered bedrock, the barrier drain extraction system has been determined to be ineffective for site conditions.

Implementability: Drains installed within a weathered bedrock zone are difficult to construct and generally do not perform well. Barrier drains involve long-term operations and do not treat the groundwater; but act only as a preliminary collection step.

Cost: The cost to install barrier drains is relatively low to moderate.

Conclusion: Barrier drains will not be considered further at the Forest Glen site because they have been determined to be ineffective for existing site conditions.

2.7.3.2 Extraction Wells

Description: Extraction well systems consist of a series of wells installed into a stratum to remove contaminated groundwater. These systems are most useful in formations with high transmissivity. They can be installed and screened at any desired depth and location. The zone of influence and amount of water that can be extracted from these wells depends primarily on the aquifer characteristics.

Effectiveness: As with the barrier drain system, the extraction wells do not directly reduce the volume or toxicity of the contaminated water but are used rather as a support process prior to implementing a treatment technology. Additionally, the wells can be used for gradient control to reduce the rate of contaminant migration. A scheme of varying the flow rates can be used to optimize the removal from a specific zone of contamination. The extraction well system is well demonstrated and highly reliable at hazardous waste sites.

Implementability: This technology uses simple and readily available equipment. Application of this technology would require long-term operations.

Cost: The cost of extraction well systems depends on the number of wells, their depths, and the rate of extraction. The relative costs for this technology are moderate.

Conclusion: Extraction wells are a necessary component of any groundwater extraction and treatment scheme that will be considered at the Forest Glen site, and will be retained for further consideration.

2.7.4 Treatment Technologies

Treatment technologies can be located on-site using mobile units or more permanent treatment plants contained within buildings, or located off-site at a treatment plant facility. Although the same remedial technologies are applicable for on-site or off-site treatment of contaminated groundwater, on-site treatment should be considered first to minimize transportation and handling costs. The applicability of complete or partial on-site treatment depends primarily on the availability of land

for the treatment facilities. It is expected that the groundwater treatment system would require a relatively large capacity and, therefore, off-site treatment would not be technically practical and cost-effective. However, the only exception would be using a local POTW because the contaminated groundwater could be conveyed to the POTW through existing sewers or via a new pipeline. Therefore, the only off-site treatment considered in this FS will be at a local POTW. This option is currently being further investigated and a permit application has been submitted to the City of Niagara Falls POTW with plans for utilizing the existing onsite sanitary sewer system. Transportation to a licensed RCRA facility is not feasible due to the distance from the site. The available technologies for treating groundwater include biological, physical and chemical processes.

2.7.4.1 Biological Treatment

General Description: Biodegradation is a treatment process whereby hazardous chemical substances (primarily organic chemicals) may be transformed to non-toxic or less toxic metabolites through the enzymatic action of microorganisms. Under optimum conditions, and through the use of appropriate organisms, such degradation mechanisms may result in the complete mineralization of organic chemicals to carbon dioxide, water or methane, and biomass. Biodegradation of selected organic chemicals can be conducted through the use of chemical-specific aerobic or anaerobic microorganisms. Such organisms may be indigenous species that have been isolated and developed through various enrichment techniques or exogenous bacteria which were isolated from other sites or waste streams and developed for commercial use, or they may be cultures that have been genetically engineered to degrade various persistent synthetic compounds.

Biological treatment systems are dependent upon the ability of the microorganisms to biodegrade various organic substrates. Studies have shown that the availability of oxygen (for aerobic systems), and micronutrients like phosphorus and nitrogen, the proper pH, and temperature, are important parameters to be considered for biological treatment systems to function properly. Additional factors that may also be necessary to biodegrade various organics include trace inorganic elements, cosubstrates such as glucose or other readily degraded organics, or possible analog enrichment (the use of a similarly structured biodegradable compound to promote enzyme production to biodegrade the compound of interest). Several factors may have a negative influence on biological systems such as the presence of toxins or the formation of toxic metabolites, preferred substrates and contaminant concentrations that are high enough to be toxic or inhibitory. In addition, it is possible that in some cases the groundwater contaminant concentrations are below the threshold concentration where enzymes are produced and thus result in no degradation. Often more than one species of microflora may be required to accomplish the complete degradation of a given substrate. One species may be able to transform the parent compound, but may be unable to further degrade the metabolic byproducts, and additional species are required to complete the biodegradation process. Numerous studies have been conducted to determine the effectiveness of specific classes, genera, or species for the degradation of specific compounds or classes of compounds. Although, these studies are very informative, they are often not representative of actual environmental conditions or biological systems. Many types of microorganisms are typically required to completely mineralize organic compounds or organic waste streams. In general, mixed microbial cultures have a greater biodegradative capacity and provide a better probability to reduce organic compounds to carbon dioxide and water.

Biological treatment could be applied to groundwater in-situ, or in a bioreactor system after collection/extraction. The processes can be classified as aerobic or anaerobic, depending on whether the microorganisms used thrive in the presence or absence of oxygen, respectively. Aerobic biodegradation is achieved in the presence of oxygen and is the most widely used biological process. Aerobic process options include activated sludge, trickling filters, and rotating biological contractors. Anaerobic biodegradation is performed by microorganisms that do not require oxygen. The most common anaerobic process, anaerobic digestion, produces methane and carbon dioxide as byproducts of the degradation process. New biotechnologies are considered to be those which use genetically engineered and mutated microorganisms. Theoretically, these organisms can be developed to feed on only the major site contaminants. These organisms are then released into the groundwater. After all the organic contaminants are destroyed, the microorganisms die from lack of food. This treatment method is still in the experimental stages.

In situ treatment is generally applicable to more permeable media like sand and gravel. Transport processes in fractured bedrock are considerably more difficult and complex. Conditions within the fractured bedrock are likely to be anaerobic. Biofouling of the fractures is very likely. Enhanced in-situ bioremediation has been recently developed by EPA and USAF as an innovative technology and has been implemented at relatively few sites.

The destructive process by which microorganisms transform an organic contaminant into forms useful for cell energy requires facilitating the transfer of electrons from donors (BTEX, or other organic carbon compound), to acceptors (oxygen, nitrate, ferric iron, sulfate, and carbon dioxide) and conserving energy in the transfer. For biodegradable compounds, this results in the oxidation of the organic contaminant to carbon dioxide and water, and a reduction of the electron acceptor. For thermodynamic reasons, microorganisms preferentially utilize those electron acceptors that provide the greatest amount of free energy during respiration (in order: oxygen, nitrate, ferric iron, sulfate, then carbon dioxide). During biodegradation, microorganisms will facilitate only those redox reactions that yield energy (exothermic reaction) by providing the necessary activation energy through their enzymatic systems. As each of the electron acceptors is used in turn, the local environment becomes more reducing (lower redox potential).

The VOCs detected at the Forest Glen site are commonly referred to as chlorinated aliphatic hydrocarbons (CAHs). Many CAHs are not used as food and energy sources (electron donor) for microbial populations; therefore, these microorganisms do not posess the enzymes necessary to directly catalyze the breakdown of these compounds. The most common means by which the chlorinated solvents at the Forest Glen site biodegrade (or biotransform) is through a process known as anaerobic dechlorination. In this reaction, the CAHs act as an electron acceptor, under highly reducing (low redox potential) conditions, and sequentially lose a chlorine atom on the molecule.

The extent to which chlorinated alkenes can be anaerobically biotransformed to less chlorinated alkenes is highly dependent upon site-specific conditions. The following briefly explains the complexities of anaerobic reductive dechlorination of chlorinated alkenes.

The anaerobic biotransformation of PCE and TCE occurs through a microbially-mediated, sequential dechlorination process:

PCE--> TCE--> cis-1,2-dichloroethene(cis-DCE)--> vinyl chloride (VC) --> ethene/ethane

The degree to which this sequence proceeds depends on four factors:

The oxidation/reduction (redox) potential: The environment must be progressively more reducing (lower redox potential) to remove each successive chlorine atom. For example, cis-DCE cannot be used as an electron acceptor in the redox environment characterized by sulfate reduction (McCarty 1996), and thus the dehalogenation sequence stops at cis-DCE. Complete dechlorination to ethene/ethane can only occur when redox conditions are such that carbon dioxide is used as an electron acceptor and methane is produced, methanogenesis.

The presence of competing electron acceptors: Those electron acceptors offering the greatest release of energy will preferably be used and those organisms will predominate. Although PCE and TCE can act as an electron acceptor under highly reduced conditions, sulfate reduction releases more energy than dehalogenation of either compound; therefore, the bacteria preferentially reduce sulfate. For example, Pon (1996) suggested that sulfate concentrations greater than 100 mg/L are more favorable to the sulfate-reducing bacteria which then metabolically out-compete the dehalogenation reactions. Furthermore, Pon (1996) concluded that dehalogenation of TCE does not even begin until sulfate concentrations are reduced to less than 200 mg/L.

The presence of suitable electron donors: If a suitable electron donor (organic carbon) is not available, neither dechlorination nor any other type of energy metabolism will occur.

The presence of dechlorinating microorganisms: Microorganisms that dechlorinate hydrocarbons incidentally are ubiquitous. Direct dechlorinators that transform PCE to cis-DCE (but do not obtain energy from the process) appear to be relatively widespread. However, direct dechlorinators capable of transforming PCE and other chlorinated ethenes past cis-DCE seem to be much less common (Gossett and Zinder 1996).

Aerobic biodegradation of some CAHs also occurs. The most familar mechanism involves the cometabolic biodegradation of CAHs when the microorganism is growing on methane or some aromatic hydrocarbon such as phenol or toluene. However, this mechanism is not likely to be widespread in the environment. Anaerobic plumes that are moving into aerobic groundwaters can sometimes carry sufficient methane to induce this reaction. However, for the most part if biodegradable organic compounds are present in groundwaters, dissolved oxygen will be limiting for aerobic metabolism. Recent evidence has shown that cis-DCE and vinyl chloride are potentially aerobically biodegradable as primary substrates. Therefore, plume areas possessing sufficient oxygen may stimulate the biodegradation of these CAHs (Bradley and Chappelle, 1997; Bradley and Chappelle, 1998).

Effectiveness: The groundwater at Forest Glen is contaminated mainly with CAHs like vinyl chloride, 1,1-dichloroethane, 1,1-dichloroethene, 1,2-dichloroethene, 1,1,1-trichloroethane, and trichloroethene, and with inorganics like iron and manganese. These chlorinated organics are difficult to degrade via aerobic biological treatment. Anaerobic treatment can handle chlorinated

organics but requires longer residence times. It is very likely, however, that there are insufficient nutrients like phosphorus present in the groundwater to support biological growth. Naturally occurring bioremediation has been evaluated in Appendix D. In situ biodegradation is not likely to be very effective unless an adequate supply of proper nutrients and growth conditions thoughout the fractured bedrock aquifer is maintained as described in Appendix D.

Implementability: Application of this technology would also require long-term operations to develop and maintain the necessary bacterial population including regular analysis of the microbial community to ensure that proper conditions are being maintained. Microorganisms are sensitive to temperature and the surrounding environment, therefore, biological systems to treat groundwater require careful operator control to maintain a healthy microbial community. Additionally, bioreactors generate sludge, a semi-solid for which disposal will have to be arranged. An NYSPDES permit equivalent must also be obtained. In situ biodegradation is considerably more complex to implement and monitor in fractured bedrock and may not easily permitted based on the existing knowledge of Forest Glen site conditions.

Cost: The relative costs of an ex-situ anaerobic biological treatment system for the Forest Glen site would range from medium to high because of site-specific conditions. Costs of an enhanced in-situ anaerobic bioremediation system would be relatively lower based on recent studies by EPA and USAF.

Conclusion: Enhanced In-Situ Anaerobic biological treatment will be retained for further consideration in alternatives development because it is an innovative technology that could potentially be effective with lower costs and to preserve a range of remedial response actions. It should be further investigated before or during remedial design as described in Appendix D. However, as required by SARA, a contingency remedy would have to be selected if it is later determined that the results are not as promising as originally predicted.

2.7.4.2 Physical Treatment

Physical treatment processes utilize the differences in physical properties of the contaminants to separate them from the water. The water may then be discharged or treated further by other methods. Potentially applicable physical treatment technologies include sedimentation, filtration, air and steam stripping, carbon adsorption, and reverse osmosis.

2.7.4.2.1 Sedimentation/Clarification

Description: Sedimentation or clarification is a process used to remove settleable suspended particles from water. The equipment used produces quiescent hydraulic conditions so that gravitational forces are able to settle out the unstable solids. The typical designs of sedimentation tanks involve a sloping bottom to collect the settled solids and an overflow weir for the supernatent (clear) liquid. Once the particles reach the bottom, they are generally removed as an underflow, and their movement is assisted by a series of slowly moving paddles, rakes or arms. This technology can be used alone or in conjunction with precipitation.

Effectiveness: By itself, sedimentation may not significantly remove all of the suspended particles present in the groundwater. However, in conjunction with chemical precipitation it can be very effective in removing inorganic contaminants from the groundwater. Organic contaminants will generally not be affected by this process.

Implementability: This technology is readily available and can be easily implemented at the Forest Glen site. A discharge permit might be necessary.

Cost: The relative costs of this support technology are low.

Conclusion: Sedimentation/Clarification will be retained for further consideration because it is potentially applicable for removal of inorganics like iron and manganese to prevent subsequent fouling of organics treatment equipment.

2.7.4.2.2 Filtration

Description: Filtration is a process in which suspended and colloidal particles which are not readily settleable are removed from the water by physical entrapment on a given media. Fluid flow through the filter medium may be accomplished by gravity or it may be pressure induced. Beds of granular material like sand and anthracite are commonly used filters in water treatment. Other types of filters include vacuum filters, plate and frame filters, and belt filters. These are often used to dewater sludges produced by processes like sedimentation and chemical precipitation. Packed beds of granular material are usually backwashed to remove the filter cake. The collected solids will require disposal and their costs will depend on whether the material is considered hazardous or non-hazardous.

Effectiveness: Pretreatment by filtration is a well-established technology and is routinely used in water treatment. Both granular media beds and the other types of filters described above are typically part of a treatment process train. They serve to reduce the mobility and volume of hazardous substances and provide a significant degree of protection.

Implementability: Filtration is readily implemented because the materials, equipment and skills for operation are available through many vendors. Additional handling of the solids is necessary, but is readily accomplished.

Cost: Costs for filtration are generally low. Costs of disposing of the removed solids will depend on whether they are classified as hazardous or non-hazardous.

Conclusion: Filtration will be retained as a support technology in the formulation of remedial alternatives.

2.7.4.2.3 Air and Steam Stripping

Description: Air stripping is a mass transfer process in which volatile contaminants in water are transferred to the gaseous phase. This process works best on contaminants with high volatility and

low solubility. Generally, organic compounds with a Henry's Law constant greater than or equal to 3.0 liter-atm/mole can be readily removed from groundwater by air-stripping. Several contacting systems can be used, such as mechanical surface aerators, diffused aeration, spray or tray towers, open channel cascades, spray fountains, and counter-current packed towers. Surface aeration and counter-current packed towers are considered to be the most energy efficient systems. Air-stripping might require consideration of techniques to mitigate atmospheric discharge of contaminants in the exhaust gas. Packed tower systems are more amenable to air pollution controls. Generally, vapor phase carbon adsorption beds, flare burner systems, and, catalytic incineration are used for capture and/or destruction of the volatilized contaminants. In the counter-current packed tower configuration, water is distributed over the top of the packing material, while air is forced upward from the bottom of the tower. Primary factors which govern the efficiency of the process include the air-to-water ratio, pressure drop, tower height, surface area of the packing material, contact time, and temperature of the influent. Pretreatment of suspended solids and inorganics like iron and manganese, may be necessary to avoid deposition on and subsequent clogging of the packing material.

Steam-stripping uses steam to remove organics from aqueous waste in much the same way that air-stripping works, but because of the heat involved in the process, is sometimes more effective on some contaminants than air stripping alone. It is generally used for removal of organic compounds which are relatively less volatile and more soluble, and can handle a wider concentration range of contaminants in the influent stream. The towers used for steam stripping are generally smaller than those used for air stripping because the higher temperatures used provide a greater driving force for removal. However, the energy costs are generally much higher. Steam stripping is generally not used unless the contaminants include compounds like methyl-ethyl ketone, isophorone, etc.

Effectiveness: Air stripping is preferred over steam stripping for the volatile organics present in the groundwater at the Forest Glen site. Depending on the operating conditions used, removal efficiencies of 95-99 percent are generally possible for this technology. It is a well-established and proven technology and provides a significant level of protection.

Implementability: Counter-current packed tower systems are readily available from many vendors. Air pollution controls may be required for off-gas treatment and pretreatment for removal of inorganics is sometimes necessary. Permits for control of air emissions may also be required.

Cost: The relative costs of this process range from low to moderate.

Conclusion: Air stripping will be retained for further consideration in formulating remedial alternatives because it is a well established and proven technology that provides an adequate level of protection at a relatively low to moderate cost.

2.7.4.2.4 Carbon Adsorption

Description: Carbon adsorption removes organics from aqueous wastes via surface attachment between the organic solutes and the large internal pore structure of the activated carbon. This attachment within the pores is due to a force of attraction known as Van der Waals force. The major parameters which influence the effectiveness of the adsorption include the solubility of the organic

compound, the pH and temperature of the influent, empty bed contact time, and the surface area/volume ratio of the adsorbent. Typical activated carbon adsorption treatment systems include gravity flow or pressure flow columns in series and/or parallel configurations with backwashing capability. Granular activated carbon is generally used with loading rates of 0.5 to 5.0 gpm/sq.ft. This technology can treat single-phase waste streams with high molecular weights, high boiling points, low solubility and polarity, and relatively non-polar chlorinated hydrocarbons and aromatics. Concentrations of up to 10,000 ppm can be effectively treated using carbon adsorption; however, the process works best for aqueous streams with suspended solids' concentration less than 100 ppm and concentration of dissolved inorganics, oil, and grease of less than 10 ppm. For these reasons, some pretreatment of the aqueous waste stream may be necessary. The spent carbon must be either regenerated at an appropriate facility, or disposed of as a hazardous material.

Effectiveness: Activated carbon adsorption is a well-established water treatment process where removal efficiencies of up to 99 percent are possible. These systems have been used as a primary removal mechanism or as a polishing step. This process provides a high degree of protection because it significantly reduces the mobility and volume of hazardous substances in the groundwater. It is a very reliable process. However, carbon adsorption is not suitable for vinyl chloride because this compound tends to break through very rapidly thereby requiring frequent regeneration and increasing costs.

Implementability: Although pretreatment to remove inorganics and suspended solids is often necessary to lower the usage of activated carbon, and regeneration or disposal of the spent carbon is required, this process is very readily implemented. There are a large number of vendors providing the necessary materials, equipment and manpower required for this process.

Cost: The relative cost for this process is moderate to high and depends on whether the process is used as the primary removal or the polishing step. It also increases with higher flow rates.

Conclusion: This technology will not be retained for further consideration in development of suitable remedial alternatives because it is not effective for removal of vinyl chloride.

2.7.4.2.5 Reverse Osmosis

Description: Osmosis is a process which occurs whenever two solutions of different solute concentration levels reach an equilibrium across a semi-permeable membrane. The solvent (water in this case) will naturally flow from the less concentrated solution into the more concentrated solution. To reverse this process, the solution with the high concentrations must be pressurized to a level higher than the osmotic pressure. At sufficiently high pressures, usually 200-800 pounds per square inch (psi), the water will flow out of the more concentrated solution, leaving the contaminants trapped on the other side of the semi-permeable membrane. The volume of the concentrated waste is generally 10 to 20 percent of the feed volume. This concentrated waste will require additional treatment which is usually expensive. Reverse osmosis has been demonstrated to be effective for treatment of brackish waters, aqueous metal wastes, and radionuclides, and recent findings indicate that it is useful in removing some specific organics from solution. The effectiveness of this process

is highly dependent on the chemical composition of the waste solution to be treated and the characteristics of the membrane.

Effectiveness: This process is highly effective for inorganics, and may be suitable for chlorinated organic contaminants of the type found at the Forest Glen site. Pilot-scale treatability studies may be needed to determine the removal efficiencies of the various contaminants at the site. Concentrations in the treated water are generally in the 10 to 50 ppb range, which may or may not meet ARARs.

Implementability: Operation of the unit requires skilled personnel and pretreatment requirements must be addressed and closely monitored to ensure that the system runs optimally. Disposal of the concentrated waste stream (generally on the order of 15 to 25 percent of the influent volume) is also required and may be expensive. Due to the higher pressures involved, additional consideration must be given to process safety requirements.

Cost: Capital and operational costs of the system are high and increase with increased flow rate.

Conclusion: This technology should be eliminated from further consideration, because it does not provide a higher degree of protection than the other alternative technologies in spite of higher costs.

2.7.4.3 Chemical Treatment

Chemical treatment processes generally involve destruction of hazardous substances by reaction with other chemical species to convert them into nonhazardous gases, liquids or solids. Potentially applicable process options include ion exchange, chemical precipitation, oxidation/reduction, and ultra-violet (UV) radiation induced photolysis. Chemical oxidation with ozone or hydrogen peroxide enhanced by UV photolysis is often a very effective combination and is discussed below.

2.7.4.3.1 Ion Exchange

Description: Ion exchange is a process in which toxic ions are removed from solution by being exchanged with relatively harmless ions held by the ion exchange material. Both organics and inorganics can be removed by this process. However, removal of inorganics is more common. Ion exchange resins are also effective in removing radionuclides. Ion exchange resins are manufactured for removal of a wide variety of organic and inorganic ions and radionuclides. A practical upper concentration limit for ion exchange is about 2500 to 4000 ppm. Contaminant concentrations in the groundwater at the Forest Glen site are well below these levels. Due to the large variety of ions present in the water, removal to levels below ARARs may be difficult. Generally, a train of resin beds in series containing different resins for organics, cation and anion removal are typically used. The beds have to be monitored for breakthrough and must be regenerated using a wide variety of regeneration chemicals which may themselves be hazardous. Ion exchange can be used both as a pretreatment and as a polishing step.

Effectiveness: Ion exchange would require treatability studies to select the types of resins for use at the site and to determine their removal efficiencies. The use of ion exchange for removal of

inorganics is fairly well established. This technology can provide a significant removal of hazardous materials from the contaminated medium and thus provide adequate protection.

Implementability: There are many vendors who can provide the necessary equipment, materials and skills to implement this technology. However regeneration and disposal of spent regeneration chemical streams could result in significant disposal costs.

Cost: The relative cost of this technology is high.

Conclusion: Ion exchange should be removed from further consideration because the higher costs cannot justify the degree of protection afforded by the technology.

2.7.4.3.2 Chemical Precipitation

Description: Precipitation is a physical and chemical technique that can be used to remove metals from an aqueous stream. The metals can be precipitated out of solution by changing the chemical equilibrium of the solution. It is generally achieved by adding a chemical that reacts directly with the metal to form an insoluble product. When used prior to other treatment technologies, this process eliminates the probability of reduced efficiency due to dissolved metals precipitation during later phases of treatment. The pH of the waste stream can be adjusted to optimize the precipitation process. Usually, the pH varies between 8 and 12. Metals can be precipitated as hydroxides, carbonates, and sulfides. Typical precipitating agents include calcium oxide, caustic soda, sodium sulfide, ferrous sulfide, and hydrogen sulfide gas.

Effectiveness: Precipitation is a well-established process for removal of inorganic contaminants. It affords a high degree of protection. It is generally used in conjunction with support technologies like sedimentation/clarification.

Implementability: Chemical precipitation can be readily implemented. It is simple to operate. Handling and disposal of the sludge produced would be an important consideration.

Cost: The relative cost of this technology is moderate. The cost of the precipitation agent is a continuing operation cost along with disposal costs for the sludge.

Conclusion: This technology will be retained for further consideration in the development of remedial alternatives because it is quite effective for inorganics removal prior to treatment of volatile organics.

2.7.4.3.3 Chemical Oxidation Enhanced by UV Photolysis

Description: Chemical oxidation enhanced by UV photolysis is an emerging technology for cleanup and destruction of organics in groundwater. Commercial applications using hydrogen peroxide and ozone as the oxidant have been developed. UV light reacts with hydrogen peroxide and/or ozone molecules to form hydroxyl radicals. These very powerful chemical oxidants then react with the organic contaminants in the water. In addition, many organic contaminants absorb UV light and

become more reactive to chemical oxidants. If carried to completion, the end products of the oxidation process are carbon dioxide and water. Both hydrogen peroxide and ozone form hydroxyl radicals under UV light catalysis.

The UV/oxidation treatment technology may be used to oxidize a variety of chlorinated hydrocarbons, including PCE and TCE. UV/oxidation will not eliminate inorganic contaminants; however, they could be removed by precipitation prior to allowing the feed stream to enter the UV/oxidation unit. The system has no filtering or adsorption media to dispose of or regenerate, and treats groundwater contaminated with VOCs without air emissions or generation of hazardous wastes. There is no secondary waste management necessary.

Design of a UV/oxidation treatment system is dependent upon many variables including the type and concentration of organic contamination, the light transmittance of the water, and the type and concentration of dissolved solids. Pretreatment of the contaminated groundwater may be necessary to reduce the suspended solids content, since excessive suspended solids can occlude the UV light, thus decreasing the effectiveness of the system. Additionally, precipitation of metals may be necessary to reduce scaling and fouling of the unit.

Effectiveness: Pilot testing and full scale applications have substantiated the effectiveness of innovative UV systems to treat VOCs and other organic chemicals in contaminated groundwater. Recent tests have established that the use of UV light in conjunction with a strong oxidizing agent such as ozone or hydrogen peroxide can significantly enhance chemical degradation rates for organic compounds such as tetrachloroethylene, and trichloroethylene. This technology can provide adequate protection because it is capable of achieving significant reductions in the toxicity, mobility and volume of hazardous organic compounds.

Implementability: This technology can be readily implemented because it is commercially available even though it is relatively new. Pretreatment for removal of inorganics and suspended matter is necessary.

Cost: The relative cost of this technology is medium to high.

Conclusion: This technology will be retained for further consideration in the development of remedial alternatives, because it destroys the hazardous organic compounds associated with the contaminated groundwater and does not transfer them to another medium.

2.7.4.4 In Situ Treatment

In situ treatment technologies treat the hazardous contaminants within the medium they are located without requiring physical removal. Typical process options for in situ groundwater treatment that are commonly considered include biodegradation and passive treatment walls. Biodegradation was already discussed in Section 2.7.4.1 and passive treatment walls are described below.

2.7.4.4.1 Passive Treatment Walls

Description: Passive treatment walls (also referred to as funnel and gate system or trench and gate system) is an in situ technology for treatment of groundwater. The technique involves the construction of a cut-off trench excavated though the aquifer to shallow relatively impermeable bedrock or it may be installed as a hanging wall if it can be anchored in a suitably impermeable material. Generally two such trenches are constructed at an angle to each other and hydraulically downgradient of the contamination. The downgradient side, the top, and the base of the trench are sealed with a synthetic liner, and the trench is backfilled with a layered highly permeable aggregate. The aggregate is required to encourage drainage and prevent mounding along the walls of the trench. Slotted PVC pipe is added to the trench to act as a drainage tile and to reduce fluid potential losses dur to friction and tortuosity. At the intersection of the trenches, natural gradients channel contaminated groundwater through a permeable wall or treatment gate. In the gate, air is sparged which promotes natural biodegradation. Infrastructure for the delivery of other nutrients, remediation fluids, other reactive treatment media, or solutions to prevent biofouling is also installed during construction. Air sparging is a technique in which air is injected into water saturated zones for the purpose of removing organic contaminants by a combination of volatilization and aerobic biodegradation processes. It is typically used in conjunction with soil vapor extraction to eliminate off-site migration of vapors. Passive treatment walls have broad appeal because in general, like soil vapor extraction, the technology is relatively simple to implement and capital costs are modest (for many sites in sand and gravel aquifers with shallow depths of contamination). However, like most subsurface remediation techniques, it relies on the interactions between complex physical, chemical and biological processes, many of which are not properly understood. This technology is still in its infancy and has not been subject to adequate research, nor have adequate monitoring methods been employed or even developed. Treatability studies/pilot testing will be necessary before designing systems for a specific application. Consequently, most in situ applications are designed, operated, and monitored based upon the experience of individual practioners.

Effectiveness: The usefulness of passive treatment walls as a treatment technology for the Forest Glen site is questionable at best because of the depth of contamination in the fractured bedrock aquifer. As stated under barrier drains, construction of trenches within the rock is very difficult and expensive. Also, the large areal extent of contamination further compounds the problem. A very long series of trenches would be required to provide adequate coverage of this relatively large area. The physics of air movement in saturated fractured porous media is not widely understood. Nearly all published reports incorrectly show air movement occurring as bubbles. This will rarely be the case since air flow will almost always occur as small continuous air channels. Small variations in permeability may control the air pathways within the medium. Therefore large portions of the targeted remediation zone may be bypassed by the sparge air.

Implementability: The process is not likely to be easily implemented (based on the typical application of this new technology) for the site conditions at Forest Glen. Although the other materials and equipment needed are readily available, construction of trenches is generally limited to shallower depths and unconsolidated media.

Cost: The relative costs for an in situ passive wall treatment system are likely to be moderate to very high even if it was technically possible to construct such a system at such depths.

Conclusion: The passive treatment walls technology will not be retained for further consideration because its effectiveness and implementability is questionable for the Forest Glen groundwater plume.

2.7.5 On-Site/Off-Site Disposal Technologies

If one or more of the collection/treatment technologies in Section 2.7.3 are incorporated into potential alternatives, the disposal of extracted groundwater must also be addressed. The requirements for disposal can be divided into two categories depending on whether the groundwater is disposed of off-site, or disposed of on-site. This disposal would occur after the groundwater had undergone complete, limited or no treatment depending on the situation as described below.

2.7.5.1 Off-Site Disposal

In this category the contaminated groundwater may or may not undergo complete treatment depending on whether it is disposed of by discharging to a nearby surface water body (e. g. Hyde Park Lake) or to a local POTW following some or no pretreatment.

2.7.5.1.1 Off-site Discharge to Surface Water

Description: Under this disposal option, groundwater would be treated to meet EPA/NYSDEC surface water standards and then conveyed via a pipeline to a surface water such as Hyde Park Lake. It is probably capable of handling the projected volumes and flowrates. Hyde Park Lake is used for recreation purposes. The need for additional flood control measures may have to be investigated before design plans are prepared and implemented.

Effectiveness: This discharge option would have no impact on any portion of the site study area.

Implementability: This discharge option may not be readily implemented because the area near the lake is heavily populated and there may be major institutional barriers.

Cost: The relative costs of this disposal option are moderate to high.

Conclusion: This disposal option will be eliminated for further evaluation in formulation of remedial alternatives because the treated groundwater would have to be piped over a relatively large distance.

2.7.5.1.2 Discharge to Publicly Owned Treatment Works

Description: Under this disposal option, the extracted groundwater would be directed to a local publicly owned treatment works (POTW) for treatment and discharge. At present, a hookup to a local POTW (City of Niagara Falls POTW does exist via the onsite sanitary sewer system. A relatively short new piping system would have to be constructed to transport the wastewater to the sewer system manhole on Carrie Drive. The POTW does not require some pretreatment before accepting the

contaminated groundwater. At present, the POTW does appear to have the available capacity and adequate treatment processes to handle the quantity of wastewater expected to be generated by the groundwater extraction system for this FS.

Effectiveness: Off-site disposal in this manner would be effective.

Implementability: The POTW has indicated that in general they would be willing to accept contaminated water from a CERCLA site. Further, an application for a permit to discharge the Forest Glen groundwater has been submitted recently.

Cost: The relative cost of this option is low to moderate under the circumstances.

Conclusion: This disposal option will be retained for further consideration because it is has many advantages.

2.7.5.2 On-Site Disposal

Under this category the extracted groundwater treated on-site would either be reinjected on site, or discharged into East Gill Creek.

2.7.5.2.1 Reinjection of Groundwater (Injection/Infiltration):

Description: Under this option, the groundwater would be treated to meet Federal and State (NYSDEC) drinking water standards, as appropriate, before being reintroduced into the aquifer system. Injection systems are frequently used in combination with extraction wells in order to facilitate groundwater restoration. Injection systems often are used to direct contaminants to the extraction wells and to accelerate groundwater restoration. Injection of groundwater is carried out by installing wells at different depths and locations within the aquifer. Sometimes, the treated water may also be introduced into the aquifer by constructing infiltration galleries. In order to allow for flexibility in design it will be assumed that both techniques are applicable to the site and can be used independently or in combination.

Effectiveness: Reinjection of treated groundwater can help meet remediation goals and is often used at Superfund sites. The effectiveness will depend on the design of the extraction/ reinjection system. Also, reinjection of treated water can help flush contaminants from the vadose zone soils and the dewatered portion of the fractured bedrock into the saturated zone and may speed up the overall remedy. Reinjection into fractured bedrock may also however, have the unintended consequence of pushing contaminants into previously uncontaminated fractures. In that respect its effectiveness is clearly unknown.

If the groundwater treatment plant does not include metals removal (iron and manganese), iron fouling may be a problem. The problem of iron deposition on the well screens generally occurs when the iron is not removed from the extracted groundwater before reinjection.

Implementability: Reinjection of groundwater is readily implementable because the necessary equipment and materials can be easily obtained and installed. Administratively, a NYSDEC permit equivalent would have to be obtained.

Cost: The relative costs for this discharge option are moderate.

Conclusion: Reinjection of treated groundwater into the aquifer will not be retained for further consideration in the development of remedial alternatives because it may have the unintended consequence of allowing contaminants to enter previously uncontaminated fractures within the bedrock.

2.7.5.2.2 On-site Surface Water Discharge

Description: In this disposal option, groundwater would be treated to meet EPA/NYSDEC surface water standards and then discharged to East Gill Creek. Proper soil erosion and sediment control measures would have to be implemented. The drainage basin of East Gill Creek is considered to lie within a 100-year floodplain. The need for additional flood control measures may have to be investigated before design plans are prepared and implemented. The impact on the wetlands of the site may also have to be investigated further. Current knowledge based on the remedial investigation, indicates that the projected flow rates would not be a problem as long as the water is treated to meet ARARs.

Effectiveness: On-site surface water discharge of treated groundwater can help meet remediation goals and is often used at Superfund sites. The effectiveness of this discharge option will depend on the remedial design and actual experience in operating the selected treatment system.

Implementability: The ability of the drainage basin of East Gill Creek to accept the projected volumes and flowrates (upto 40 gpm for the remedy as conceptually designed) has already been determined. Hence, this option could be readily implemented provided there are no major institutional restrictions regarding the projected ability to satisy all of the NYSPDES permit conditions.

Cost: The relative costs of this discharge option (not including treatment) range from low to moderate.

Conclusion: This option will be retained for further evaluation because it is potentially part of a remedy involving onsite groundwater treatment.

2.8 SUMMARY OF RETAINED TECHNOLOGIES AND PROCESS OPTIONS

The screening process eliminated: collection technologies like subsurface drains; containment technologies such as capping, vertical and horizontal barriers; ex-situ treatment technologies such as aerobic and anaerobic biological treatment, carbon adsorption, reverse osmosis, and ion exchange;

in-situ treatment technologies such as passive treatment treatment walls; and, off-site treatment at a RCRA facility.

A list of the technology types and the process options retained for combination into remedial alternatives for further evaluation are shown in Figure 2-3. In addition, Table 2-4 presents a summary of the treatment technologies that were retained and the types of chemical compounds to which they are most applicable. These technologies and options will be used to develop and screen remedial alternatives. As discussed earlier, it should be noted that treatment can be performed on-site or off-site. The selection of a single representative treatment process for groundwater remediation is somewhat limited. Due to the stringent remediation goals (i.e., cleanup levels) and the types of contaminants present at the site, several treatment technology process options must be linked together to achieve required treatment levels.

TABLE 2-1
FOREST GLEN FEASIBILITY STUDY
POTENTIAL CONTAMINANT SPECIFIC ARARs/TBCs

Standard, Requirement, Criteria Or Limitation	Citation or Reference	Description	Status	Comments
Federal				
Soil: Toxic Substance Control Act	15 USC 2605	Applicable to storage and disposal of PCB and pesticide contaminated material.	Not Applicable	Establishes requirements for soil containing >50 ppm PCBs.
Air: Clean Air Act	42 USC 7401 Section 112	Establishes limits on parameter emissions to atmosphere.	Potentially Applicable	Pollutants deemed hazardous or non-hazardous based on public health.
National Primary and Secondary Ambient Air Quality Standards (NAAQS)	40 CFR 50	Establishes primary and secondary NAAQS under Section 109 of the Clean Air Act.	Potentially Applicable	Primary NAAQS define levels of air quality necessary to protect public health. Secondary NAAQS define levels of air quality necessary to protect the public welfare from any known or anticipated adverse effect of a pollutant. Applicable to remedial action alternative (s) that may emit pollutants to the atmosphere.
Proposed Federal Air Standards for Volatile Organic Control Equipment	52 Federal Register 3748	Establishes standards for treatment process emissions.	Potentially Applicable	Applicable if remedial action system generates air emissions.

TABLE 2-1
FOREST GLEN FEASIBILITY STUDY
POTENTIAL CONTAMINANT SPECIFIC ARARs/TBCs

Standard, Requirement, Criteria Or Limitation	Citation or Reference	Description	Status	Comments
Federal (continued)				
Groundwater: Safe Drinking Water Act (SWDA)	40 CFR 141.11-16	Sets limits to the maximum contaminant levels (MCLs) and maximum contaminant level goals (MCLGs).	Applicable	Aquifer beneath the site is designated for drinking water use.
National Primary Drinking Water Standards	40 CFR Part 141	Applicable to the use of public water systems; Establishes maximum contaminant levels, monitoring requirements, and treatment techniques.	Applicable	Primary MCLs are legally enforceable.
National Secondary Drinking Water Standards	40 CFR Part 143	Applicable to the use of public water systems; Controls contaminants in drinking water that primarily effect the aesthetic qualities relating to public acceptance of drinking water.	Applicable	Secondary MCLs pertain to aesthetic characteristics and are not legally enforceable.
SDWA MCL Goals	40 CFR 141.50	Established drinking water quality goals, set at levels of anticipated adverse health effect with an adequate margin of safety.	Applicable	May be applicable to groundwater cleanup.

TABLE 2-1
FOREST GLEN FEASIBILITY STUDY
POTENTIAL CONTAMINANT SPECIFIC ARARs/TBCs

Standard, Requirement, Criteria Or Limitation	Citation or Reference	Description	Status	Comments
Federal (continued)				
USEPA Office of Drinking Water Health Advisories		Standards issued by the USEPA Office of Drinking Water.	TBC	May be applicable to groundwater cleanup.
USEPA Health Effects Assessments		Chemical profiles and toxicology studies released by the USEPA.	TBC	May be applicable to groundwater cleanup.
Surface Water: Clean Water Act	33 USC 1251 et. seq.	Established criteria for surface water quality for water and fish ingestion and fish consumption for human health.	Potentially Applicable	Applicable for remedial alternative (s) with point discharges to surface water.
RCRA: Resource Conservation and Recover Act (RCRA) - Identification and Listing of Hazardous Waste.	40 CFR Part 264.1	Defines those solid wastes which are subject to regulations as hazardous wastes under 40 CFR parts 262-265 and Parts 124, 270, 271.	Potentially Applicable	May be considered an ARAR for the disposal of site soils and for solids produced by groundwater treatment alternatives.

TABLE 2-1
FOREST GLEN FEASIBILITY STUDY
POTENTIAL CONTAMINANT SPECIFIC ARARs/TBCs

Standard, Requirement, Criteria Or Limitation	Citation or Reference	Description	Status	Comments
Federal (continued)				
Other: Pretreatment Standards	40 CFR 403	Establishes pretreatment standards to control pollutants that pass through or interferers with POTW treatment processes or may contaminate sewage sludge.	Potentially Applicable	Applicable to remedial action alternative(s) that include discharge t POTW or a sewer system that is connected to a POTW.
New York State				
Soil/Sediment: NYSDEC Soil Cleanup Objectives and Cleanup Levels	NYSDEC TAGM HWR-92-4046 November 16, 1992	Recommended cleanup goals based on human health criteria, groundwater protection, background levels, and laboratory quantification levels. Provides basis and procedure to develop soil cleanup objectives and determine soil cleanup levels.	TBC	Applicable to the cleanup of contaminated soils.
NYSDEC Technical Guidance for Screening Contaminated Sediments	NYSDEC, July, 1994	Establishes sediment screening criteria based on contaminant toxicity to marine and aquatic ecosystems.	TBC	Applicable to the cleanup of contaminated sediments.

TABLE 2-1
FOREST GLEN FEASIBILITY STUDY
POTENTIAL CONTAMINANT SPECIFIC ARARs/TBCs

Standard, Requirement, Criteria Or Limitation	Citation or Reference	Description	Status	Comments
New York State (continued)				
Air: NYSDEC Division of Air Guidelines for the Control of Toxic Ambient Air Contaminants	Air Guide 1	Establishes air quality guidelines and standards.	Potentially Applicable	May be applicable if the remedial alternative(s) include discharge to air.
New York Ambient Air Quality Standards	6 NYCRR 256 and 257	Establishes air quality standards.	Potentially Applicable	May be applicable if the remedial alternative(s) include discharge to air.
Groundwater and Surface Water: NYSDEC " Derivation and Use of Standards &Guidance Values"	6 NYCRR Part 702	Provides basis for derivation and use of water quality standards.	Applicable	Applicable to groundwater cleanup levels.
New York Water Classifications and Quality Standards	6 NYCRR Parts 609; 700-704	Describes classification system for surface water and groundwater. Establishes standards of Quality and Purity.	Potentially applicable	May be applicable if remedial alternative includes discharge to surface water.
NYSDEC Standards Raw Water Quality	10 NYCRR 170.4	Provides water quality standards.	Potentially Applicable	May be applicable to groundwater cleanup levels.
NYSDOH State Sanitary Code Drinking Water Supplies (MCLs)	10 NYCRR Part 5, Subpart 5-1	Establishes water quality standards for potable water.	Potentially Applicable	May be applicable to groundwater cleanup levels.

TABLE 2-1
FOREST GLEN FEASIBILITY STUDY
POTENTIAL CONTAMINANT SPECIFIC ARARs/TBCs

Standard, Requirement, Criteria Or Limitation	Citation or Reference	Description	Status	Comments
New York State (continued)				
New York Regulations on State Pollution Discharge Elimination System (SPDES)	6 NYCRR Parts 750-758	Describes the requirements and provisions of SPDES permits to specific effluent limits.	Potentially Applicable	May be applicable if remedial alternative includes discharge to surface water.
Hazardous Waste: New York Identification and Listing of Hazardous Waste Regulations	6 NYCRR Part 371: Identification and Listing of Hazardous Waste	Identifies "characteristic" hazardous wastes and "listed" hazardous wastes.	Potentially Applicable	May be applicable if hazardous wastes are generated, treated, or disposed during remedial activities.
NYSDEC Land Disposal Restrictions	6 NYCRR Part 376	Identifies hazardous wastes that are subject to land disposal restrictions.	Potentially Applicable	May be applicable if site remedial alternative (s) include disposal.

TABLE 2-2
FOREST GLEN FEASIBILITY STUDY
POTENTIAL LOCATION SPECIFIC ARARs/TBCs

Standard, Requirement, Criteria, Or Limitation	Citation or Reference	Description	Status	Comments
Federal				
Groundwater and Surface Water: Clean Water Act	40 CFR 149	Prohibits discharge of dredged or fill material into wetlands without a permit. Enhances and preserves wetlands.	Potentially Applicable	Requires a permit for any remedial activity that proposes to discharge dredged or fill material into wetlands.
Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities	40 CFR, Part 264.18	Establishes location standards including seismic considerations and floodplain requirements.	Potentially Applicable	May be applicable to remedial activities affected by seismic considerations or remedial activities conducted in floodplain areas.
Fish and Wildlife: Fish and Wildlife Coordination Act	16 USC 661	Provides procedures for consultation between regulatory agencies to consider wildlife conservation during water resource-related projects.	Not Applicable	May be applicable to remedial activities that may affect fish and wildlife resources.

TABLE 2-2
FOREST GLEN FEASIBILITY STUDY
POTENTIAL LOCATION SPECIFIC ARARs/TBCs

Standard, Requirement, Criteria, Or Limitation	Citation or Reference	Description	Status	Comments
Federal (continued)				
Endangered Species Act	16 USC 1531	Requires Federal agencies to ensure that actions they authorize, fund, or carry out are not likely to jeopardize the continued existence of endangered/threatened species or adversely modify the critical habitats of such species.	Not Applicable	Applicable to remedial activities that may affect endangered or threatened species that may exist in the areas affected by the remedial activities.
Floodplain, Wetland, Coastal Zone: Executive Order on Floodplain Management	Executive Order No. 11988 40 CFRs 6.302(b) and Appendix A	Requires Federal agencies to evaluate the potential effects of actions that may take place in a floodplain to avoid the adverse impacts associated with direct and indirect development of a floodplain.	Applicable	Applicable to remedial actions that affect wetland areas.
Wetland Executive Order	Executive Order No. 11990	Details requirements for the preservation of wetlands.	Applicable	Applicable to remedial actions that affect wetland areas.

TABLE 2-2
FOREST GLEN FEASIBILITY STUDY
POTENTIAL LOCATION SPECIFIC ARARs/TBCs

Standard, Requirement, Criteria, Or Limitation	Citation or Reference	Description	Status	Comments
Federal (continued)				
Other: National Historic Preservation Act (NHPA)	7 CFR ss.650	Establishes regulations for determining a site's eligibility for listing in the National Historic Places.	Applicable	Requires consideration of remedial activity impact upon any property included in or eligible for inclusion in The National Registry of Historic Places.
New York State				
Fish and Wildlife: Endangered and Threatened Species of Fish and Wildlife	6 NYCRR Part 182	Designates endangered and threatened species for protection.	Not Applicable	Applicable to remedial activities that may affect endangered or threatened species.
New York State (continued)				
Floodplain, Wetlands, Costal Zone: Floodplain Management Regulations - Development Permits	6 NYCRR 500 ECL Article 36	Establishes standards for development activities conducted within floodplain areas.	Potentially Applicable	Applicable to remedial activities conducted within floodplain areas.

TABLE 2-2
FOREST GLEN FEASIBILITY STUDY
POTENTIAL LOCATION SPECIFIC ARARs/TBCs

Standard, Requirement, Criteria, Or Limitation	Citation or Reference	Description	Status	Comments
New York State (continued)				
New York Wetland Laws	6 NYCRR Articles 24, 25	Establishes requirements for the protection of New York State waters.	Applicable	May be applicable if remedial activities affect wetland areas.
New York Freshwater Wetlands Permit Requirements and Classification	6 NYCRR Articles 663 and 664	Establishes permit requirements and wetland classifications.	Applicable	May be applicable if remedial activities affect wetland areas.

TABLE 2-3
FOREST GLEN FEASIBILITY STUDY
POTENTIAL ACTION SPECIFIC ARARs/TBCs

Standard, Requirement, Criteria Or Limitation	Citation or Reference	Description	Status	Comments
Federal				
Air: Clean Air Act	42 USC 7401	Establishes limits on parameter emissions to atmosphere.	Potentially Applicable	Applicable to alternatives that may impact ambient air quality (e.g., LTTD).
National Ambient Air Quality Standards(NAAQS)	40 CFR Part 50	Establishes primary and secondary NAAQs under Section 109 of the Clean Air Act.	Potentially Applicable	Applicable to alternatives that may emit pollutants to the air; establishes standards to protect public health and welfare.
Standards of Performance for New Stationary Sources	40 CFR Part 60	Establishes standards for new or modified stationary sources that will emit pollutants to the air.	Potentially Applicable	May be applicable if remedial alternative system generates air emissions.
Threshold Limit Values, American Conference of Governmental Industrial Hygienists	ACGIH ISBN: 0-936713-92-9	Threshold Limit Values (TLVs) and Biological Exposure Indices (BEIs) are listed as guidelines to assist in the control of health hazards.	TBC	TLVs and BEIs were not developed for use as legal standards but may be used as a basis for a health and safety program during site remedial activities.

TABLE 2-3
FOREST GLEN FEASIBILITY STUDY
POTENTIAL ACTION SPECIFIC ARARs/TBCs
Page 2 of 14

Standard, Requirement, Criteria Or Limitation	Citation or Reference	Description	Status	Comments
Federal (continued)				
National Emission Standards for Hazardous Air Pollutants (NESHAPS)	40 CFR 261	Establishes emission standards for hazardous air pollutants.	Potentially Applicable	Applicable to alternatives that may emit pollutants to the air; establishes standards to protect public health and welfare.
Groundwater and Surface Water: Clean Water Act	33 CFR 1251 et seq	Sets standards for the restoration and maintenance of chemical, physical, and biological integrity of the nation's water.	Applicable	Applicable to groundwater cleanup.
Effluent Limitations	Section 301	Technology-based discharge limitations for point sources of conventional, nonconventional, and toxic pollutants.	Potentially Applicable	Applicable for treatment options that discharge to either surface water bodies or POTWs.
Water Quality Standards And Effluent Limitations	Section 302	Protection of intended uses of receiving water (e.g., Public water supply, recreational uses).	Potentially Applicable	Applicable for treatment options that discharge to either surface water bodies or POTWs.

TABLE 2-3
FOREST GLEN FEASIBILITY STUDY
POTENTIAL ACTION SPECIFIC ARARs/TBCs

Standard, Requirement, Criteria Or Limitation	Citation or Reference	Description	Status	Comments
Federal (continued)				
Water Quality Standards And Implementation Plans	Section 303	Requires State to develop water quality criteria.	Potentially Applicable	Applicable for treatment options that discharge to either surface water bodies or POTWs.
Toxic And Pretreatment Effluent Standards	Section 307	Establishes list of toxic pollutants and promulgate pretreatment standards for POTW's discharge.	Potentially Applicable	Applicable for treatment options that discharge to either surface water bodies or POTWs.
National Pollutant Discharge Elimination System (NPDES) Permit Regulations	40 CFR 122-125	Establishes permitting requirements for effluent discharge.	Potentially Applicable	Applicable for treatment options that discharge to either surface water bodies or POTWs.
NPDES Regulations	40 CFR 125	Establishes criteria and standards for technology-based treatment requirements under the Clean Water Act.	Potentially Applicable	May be applicable for treatment options that discharge either to surface water bodies or POTWs.
Regulations on Test Procedures for the Analysis of Pollutants	40 CFR 136	Establishes test procedures for pollutant analysis in water.	Potentially Applicable	May be applicable for treatment options that discharge either to surface water bodies or POTWs.

TABLE 2-3
FOREST GLEN FEASIBILITY STUDY
POTENTIAL ACTION SPECIFIC ARARs/TBCs

Standard, Requirement, Criteria Or Limitation	Citation or Reference	Description	Status	Comments
Federal (continued)				
Guidance on Remedial Actions for Contaminated Groundwater at Superfund Sites, USEPA Office of Emergency and Remedial Response	EPA/540/G-88/003 OSWER Directive 9283.1-2	Provides guidance for developing, evaluating, and selecting groundwater remedial actions at Superfund sites.	TBC	Guidance for selecting remedial alternative. Includes action related considerations, such as overall protection of human health and the environment, and implementability.
RCRA: RCRA Subtitle C- Hazardous Waste	40 CFR Part 264	Applicable to the treatment, storage, transportation, and disposal of hazardous waste and wastes listed under 40 CFR Part 261.	Potentially Applicable	May be required for waste/soil disposal or treatment options.
RCRA Subtitle D - Non-Hazardous Waste Management Standards	40 CFR Part 257	Applicable to the management and disposal of non-hazardous waste.	Applicable	Specifies minimum technical standards for solid waste disposal facilities.

TABLE 2-3
FOREST GLEN FEASIBILITY STUDY
POTENTIAL ACTION SPECIFIC ARARs/TBCs

Standard, Requirement, Criteria Or Limitation	Citation or Reference	Description	Status	Comments
Federal (continued)				
Hazardous Waste Permit Program	40 CFR 270	EPA administered hazardous waste permit program.	Applicable	Covers the basis permitting, application, monitoring, and reporting requirements for offsite hazardous waste management facilities.
RCRA - Part 264 Standards for Owners and Operators	40 CFR Part 264	Standards for owners and operators of hazardous waste facilities.	Potentially Applicable	Includes design requirements for capping, treatment, and post closure care.
RCRA -Part 262- Standards for generators Part 263- Standards for transporters	40 CFR Parts 262 and 263	Standards for generators and transporters of hazardous waste.	Potentially Applicable	Applicable to the offsite disposal or treatment of hazardous material.

TABLE 2-3
FOREST GLEN FEASIBILITY STUDY
POTENTIAL ACTION SPECIFIC ARARs/TBCs

Standard, Requirement, Criteria Or Limitation	Citation or Reference	Description	Status	Comments
Federal (continued)				
RCRA - Land disposal restrictions	40 CFR Part 268	Applicable to alternatives that involve the land disposal of hazardous waste, and that require treatment to diminish a waste's toxicity and/or minimize contaminant migration.	Potentially Applicable	May be required for waste/ soil disposal or treatment options.
Transportation of Hazardous Wastes	49 CFR 107, 171.1-171.500	Federal Highway Administration, Department of Transportation, and National Highway Traffic Safety Administration regulations are codified in Title 23 (Highways) of the Code of the Federal Regulations (23 CFR Parts 1-1399) Additional Transportation regulations are codified in title 49 (Transportation) of the code of Federal Regulations (49 CFR Parts 1-1399).	Potentially Applicable	Applicable to remediation alternatives that involve the offsite transportation of hazardous waste.

TABLE 2-3
FOREST GLEN FEASIBILITY STUDY
POTENTIAL ACTION SPECIFIC ARARs/TBCs

Standard, Requirement, Criteria Or Limitation	Citation or Reference	Description	Status	Comments
Federal (continued)				
Wetlands: Wetland Permits	Section 404	Provides standards for remedial actions in and around wetlands.	Applicable	Applicable to treatment options involving excavation or dredging in and around wetlands.
Fish and Wildlife: Fish and Wildlife Coordination Act	16 USC 661	Provides procedures for consultations between agencies to consider wildlife conservation during water resource related projects.	Not Applicable	May be applicable to remedial actions that affect wildlife resources.
Other: National Historic Preservation Act (NHPA)	7 CFR 650	Regulations for determining a site's eligibility for listing in the National Register of Historic Places.	Applicable	A federal agency must take into account the effect of a project on any property included in or eligible for inclusion in the National Register of Historic Places.

TABLE 2-3
FOREST GLEN FEASIBILITY STUDY
POTENTIAL ACTION SPECIFIC ARARs/TBCs

Standard, Requirement, Criteria Or Limitation	Citation or Reference	Description	Status	Comments
New York State				
Air: Air Permits and Certificates	6 NYCRR Part 201	Describes requirements and procedures for obtaining air permits and certificates.	Potentially Applicable	Applicable to remedial alternatives that result in emissions to the air.
General Process Air Emission Requirements	6 NYCRR Parts 200-212	Establishes allowable emissions for general process sources.	Potentially Applicable	Applicable to remedial alternatives that result in emissions to the air.
Incinerators	6 NYCRR Part 219	Establishes particulate emission limits for incinerators.	Not Applicable	Applicable to remedial alternatives that involve incineration.
General Prohibitions	6 NYCRR Part 211	Describes requirements and procedures for obtaining Air Permits and Certificates.	Potentially Applicable	Applicable to remedial alternatives that result in fugitive dust emissions, such as the excavation and transport of soil.
New York Environmental Conservation Law	New York Consolidated Laws Service: Conservation Law, Articles 1,3,5,7-8,19,38,70-72	Establishes requirements for the protection of air quality.	Potentially Applicable	May be applicable to remedial activities that discharge to the air.

TABLE 2-3
FOREST GLEN FEASIBILITY STUDY
POTENTIAL ACTION SPECIFIC ARARs/TBCs

Standard, Requirement, Criteria Or Limitation	Citation or Reference	Description	Status	Comments
New York State (continued)				
New York Air Pollution Control Regulations	6 NYCRR Parts 200-221	Provides provisions for the prevention and control of air contamination and air pollution.	Potentially Applicable	May be applicable to remedial activities that discharge to the air.
Air Quality Standards	6 NYCRR Part 257	Establishes air quality standards.	Potentially Applicable	Applicable to remedial alternatives that result in emissions to the air.
Groundwater and Surface Water: New York Regulations on State Pollution Discharge Elimination System (SPDES)	6 NYCRR Parts 750-757	Permit requirements, applications, standards, compliance schedule, duration, reissuance, monitoring, recording, and reporting of SPDES permitting process.	Potentially Applicable	Remedial action alternatives must comply with substantive provision of the SPDES permitting requirements. May be applicable if remedial activities require SPDES permit.
New York Water Pollution Control Regulations	6 NYCRR Parts 608, 610-614	Establishes regulations for the use and protection of waters.	Potentially Applicable	May be applicable if remedial alternative includes discharge to groundwater or surface water.

TABLE 2-3
FOREST GLEN FEASIBILITY STUDY
POTENTIAL ACTION SPECIFIC ARARs/TBCs

Standard, Requirement, Criteria Or Limitation	Citation or Reference	Description	Status	Comments
New York State (continued)				
Ambient Water Quality Guidance Values, Technical Operating Guidance	April 1987	Establishes technical operating guideline for activities that affect ambient water quality.	TBC	To be considered in conjunction with remedial activities that affect ambient water quality.
Organic Chemical Action Steps for Drinking Water	NYSDOH PWS 69	Establishes action guidelines for organic chemicals once not covered under State MCLs.	TBC	To be considered in evaluating concerns regarding organic chemical contamination of public water systems.
New York Rules on SPDES Program Fees	6 NYCRR Part 485	Specifies SPDES program fees.	Potentially Applicable	May be applicable if remedial activities require SPDES permit.
Hazardous Waste: New York Identification and Listing of Hazardous Waste Regulations	6 NYCRR Part 371	Describes methods for identifying hazardous wastes and lists known hazardous wastes.	Potentially Applicable	Applicable to the identification of hazardous wastes that are generated , treated, stored, or disposed during remedial activities.
New York Hazardous Waste Treatment, Storage and Disposal Facility Permitting Requirements	6 NYCRR Part 373-1	Establishes permit requirements and construction and operations standards.	Potentially Applicable	May be applicable if remedial activities include the treatment, storage, and/or disposal of hazardous waste.

TABLE 2-3
FOREST GLEN FEASIBILITY STUDY
POTENTIAL ACTION SPECIFIC ARARs/TBCs
Page 11 of 14

Standard, Requirement, Criteria Or Limitation	Citation or Reference	Description	Status	Comments
New York State (continued)				
New York Final Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities	6 NYCRR Part 373-2	Establishes minimum State standards that define the acceptable management of hazardous waste.	Potentially Applicable	May be applicable if remedial activities include the treatment, storage, and/or disposal of hazardous waste.
New York Interim Status Standards for Owners and Operators of Hazardous Waste Facilities.	6 NYCRR Part 373-3	Establishes minimum State standards that define the acceptable management of hazardous waste during the period of interim status and until final closure of post-closure certification.	Potentially Applicable	May be applicable if remedial activities include the treatment, storage, and/or disposal of hazardous waste.
New York Rules on Releases, Registration, and Listing of Hazardous Substances	6 NYCRR Parts 595-597	Establishes requirements for the reporting of releases, emergency response, investigation of releases, and corrective action.	Potentially Applicable	May be applicable if remedial activities include the storage of hazardous waste.

TABLE 2-3
FOREST GLEN FEASIBILITY STUDY
POTENTIAL ACTION SPECIFIC ARARs/TBCs

Standard, Requirement, Criteria Or Limitation	Citation or Reference	Description	Status	Comments
New York State (continued)				
New York General Hazardous Waste Management System Regulations	6 NYCRR Part 370	Provides definition of terms and general standards applicable to hazardous waste management system regulations.	Potentially Applicable	May be applicable if remedial action alternative includes the management of hazardous waste.
New York Rules on Hazardous Waste Program Fees	6 NYCRR Part 483	Establishes Regulatory program fees.	Potentially Applicable	May be applicable if remedial action alternative includes the management of hazardous waste.
New York Hazardous Waste Manifest System Regulations	6 NYCRR Part 372	Establishes record keeping requirements and standards related to the manifest system for hazardous wastes.	Potentially Applicable	May be applicable if site remedial action alternative requires the transportation of hazardous waste.
New York Rules on Collection and Transport of Industrial Wastes	6 NYCRR Part 364	Regulates transportation of hazardous waste.	Potentially Applicable	May be applicable if the remedial action results in the offsite transport of hazardous materials.

TABLE 2-3
FOREST GLEN FEASIBILITY STUDY
POTENTIAL ACTION SPECIFIC ARARs/TBCs

Standard, Requirement, Criteria Or Limitation	Citation or Reference	Description	Status	Comments
New York State (continued)				
New York State Solid Waste Management Requirements and Siting Restrictions	6 NYCRR Parts 360 -361	Establishes standards applicable to the operation of solid waste management facilities. Describes design criteria, monitoring and closure requirements for solid waste management facilities such as landfills.	Not Applicable	May be applicable if the site remedial action includes the disposal of soils at an onsite landfill.
Fish and Wildlife: Endangered and Threatened Species of Fish and Wildlife; Species of Special Concern	6 NYCRR Part 182	Identifies endangered and threatened species and species of special concern.	Not Applicable	May be applicable if any such species are know to habituate the area that will be impacted by the remedial activity.
Wetlands: New York Wetlands Laws	NYCRR Articles 24, 25	Establishes requirements for the protection of freshwater and tidal wetlands.	Potentially Applicable	May be applicable if treated waters are discharged to wetland areas.

TABLE 2-3
FOREST GLEN FEASIBILITY STUDY
POTENTIAL ACTION SPECIFIC ARARs/TBCs

Standard, Requirement, Criteria Or Limitation	Citation or Reference	Description	Status	Comments
New York State (continued)				
Environmental Conservation Law	New York Law Consolidated Laws Service: Environmental Conservation Law: Articles 17, 37, 71, 72	Establishes requirements for the protection of New York state waters.	Potentially Applicable	May be applicable if remedial activities include discharge to groundwater or surface water.
Use and Protection of Waters.	6 NYCRR Part 608	Establishes standards for use and protection of waters.	Applicable	Applicable to remedial activities that affect waters.
Other: New York Uniform Procedures Regulations	6 NYCRR Part 621	Governs the administration of environmental permits.	Potentially Applicable	May be applicable if remedial activities require permitting.

TABLE 2-4

APPLICABILITY OF GROUNDWATER TREATMENT TECHNOLOGIES
RETAINED FOR ALTERNATIVES DEVELOPMENT

Technology/Process Option	Nature of Contaminants
Sedimentation	Inorganics
Precipitation	Inorganics
Air Stripping	Volatile Organics
Enhanced UV Photolysis	Volatile Organics
In-situ bioremediation	Volatile Organics
Filtration	Suspended solids
POTW	Volatile Organics

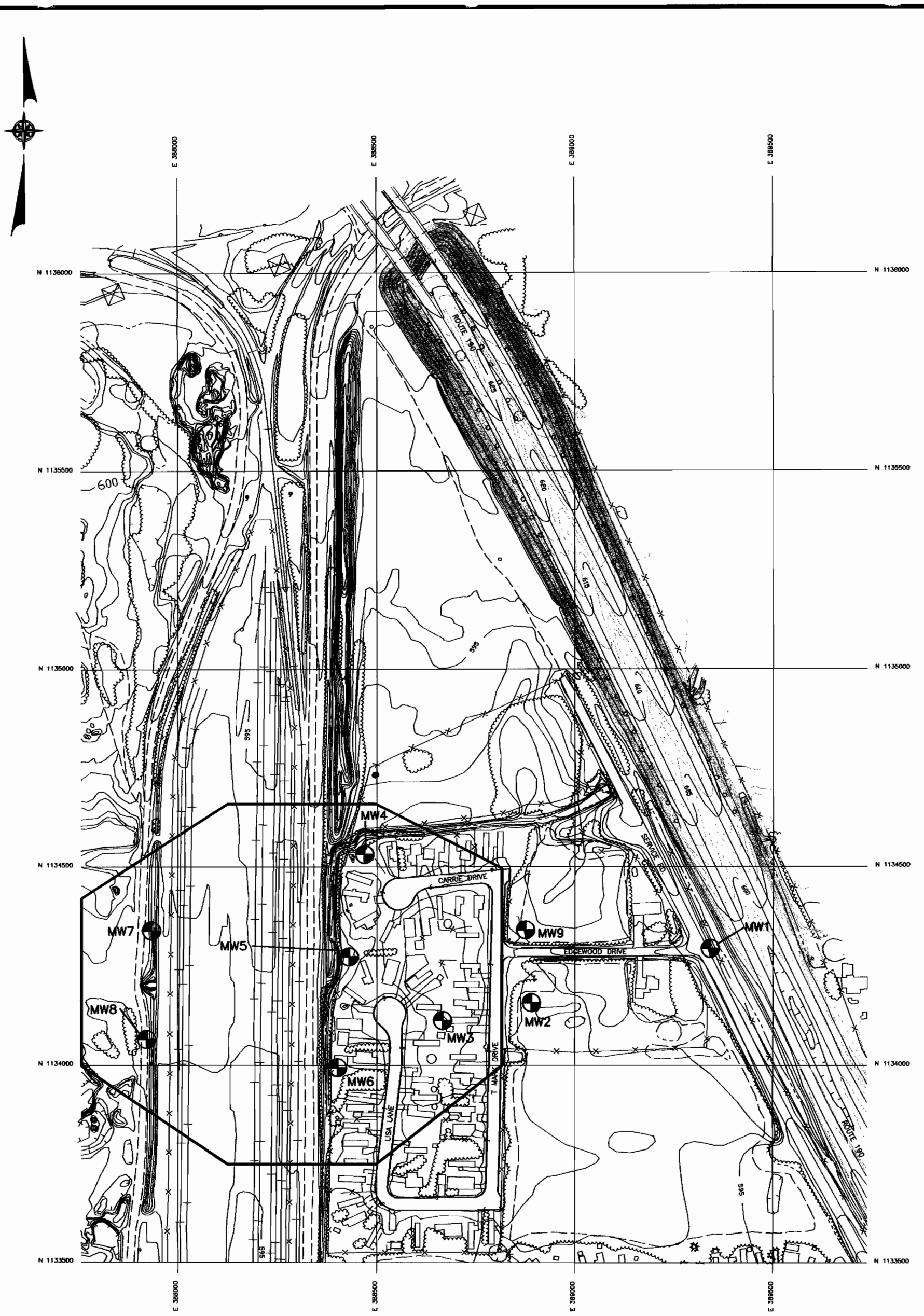


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FIGURE 2-1

AREA OF GROUNDWATER PLUME

WORK ASSIGNMENT 053-2L3U
Forest Glen Site, Niagara Falls, New York

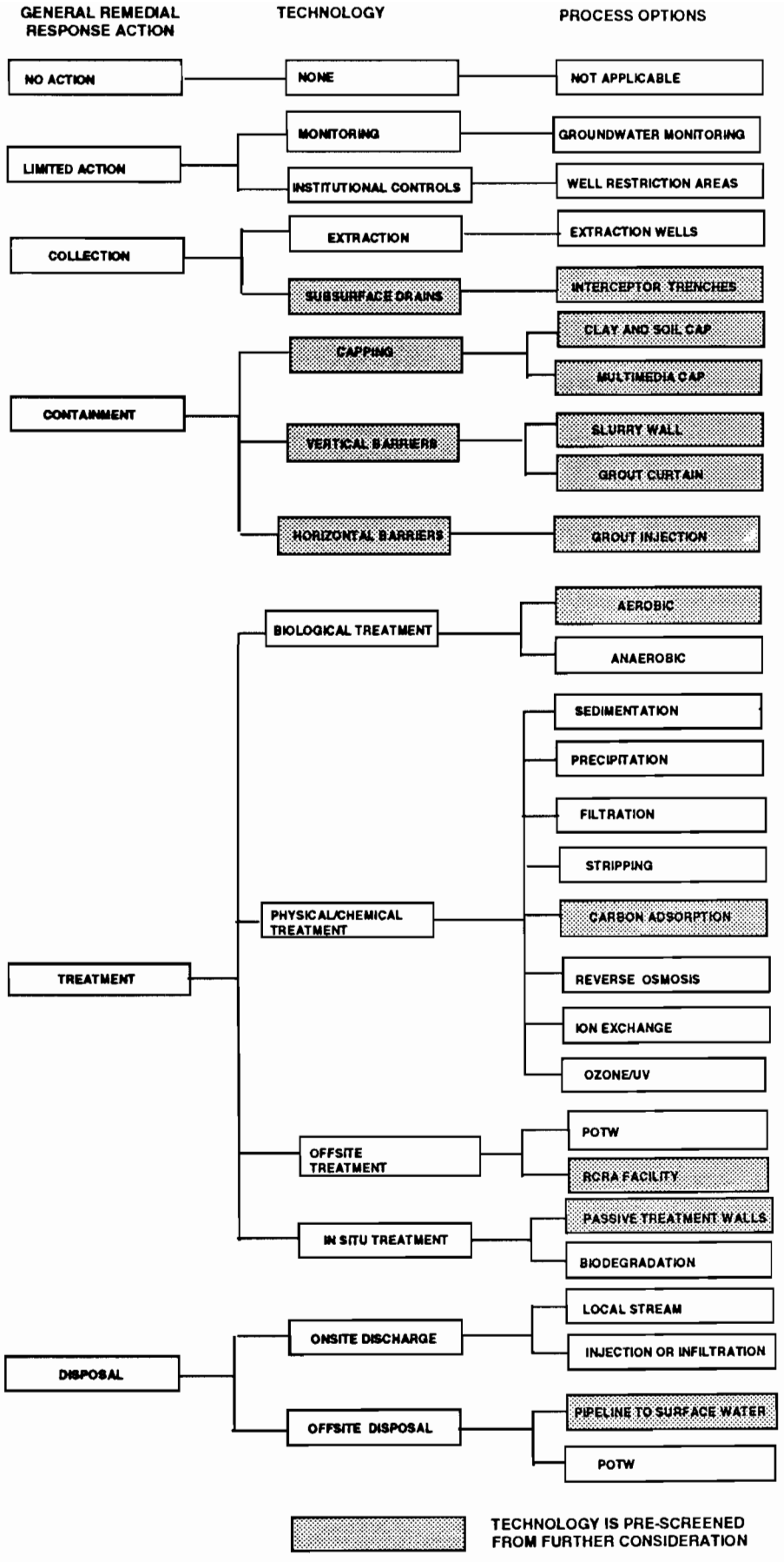

FIGURE 2-2
GENERAL RESPONSE ACTIONS, TECHNOLOGIES AND PROCESS OPTIONS FOR GROUNDWATER REMEDIATION

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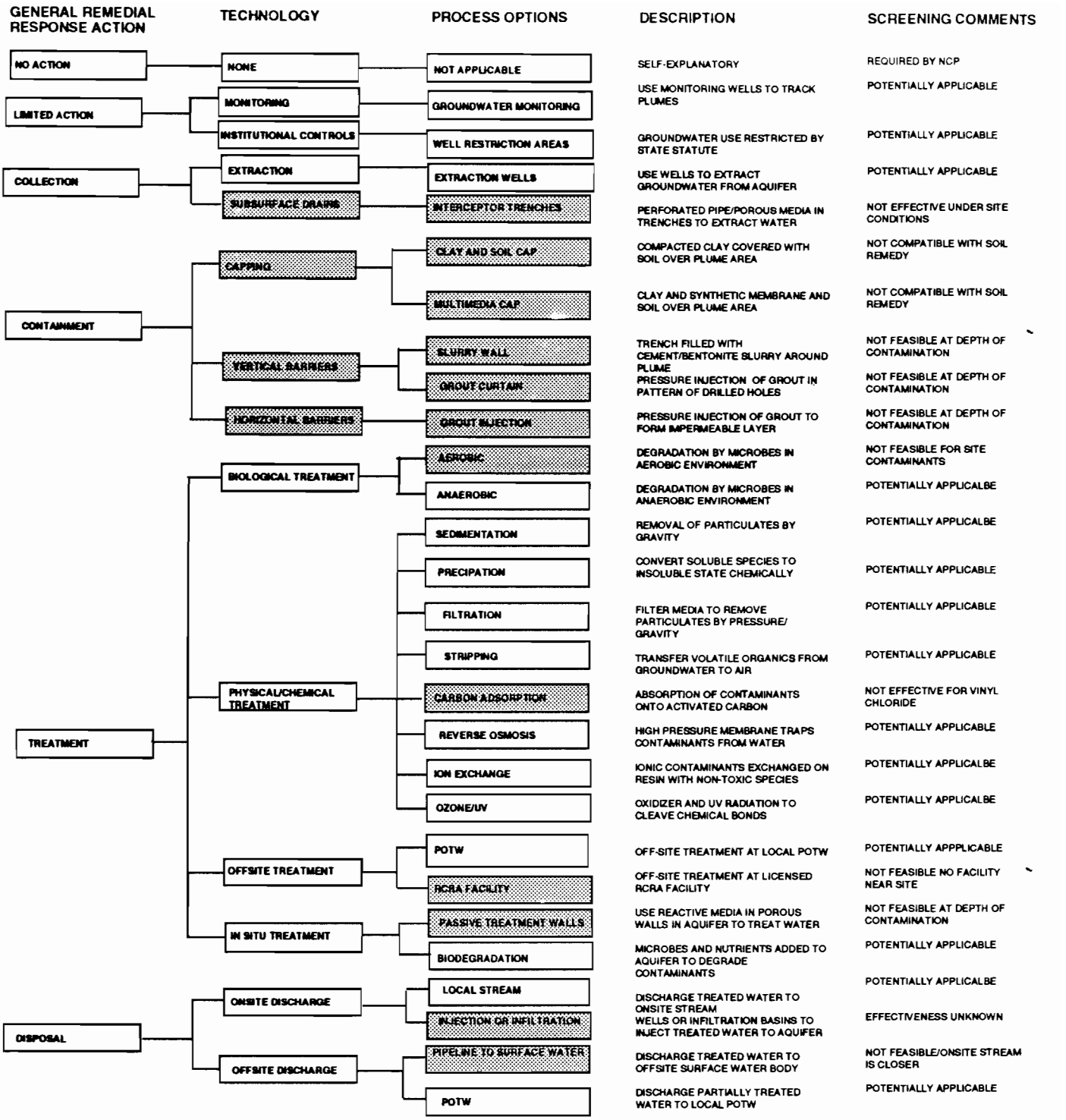

FIGURE 2-3
INITIAL SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS FOR GROUNDWATER REMEDIATION

CDM FEDERAL PROGRAMS CORPORATION
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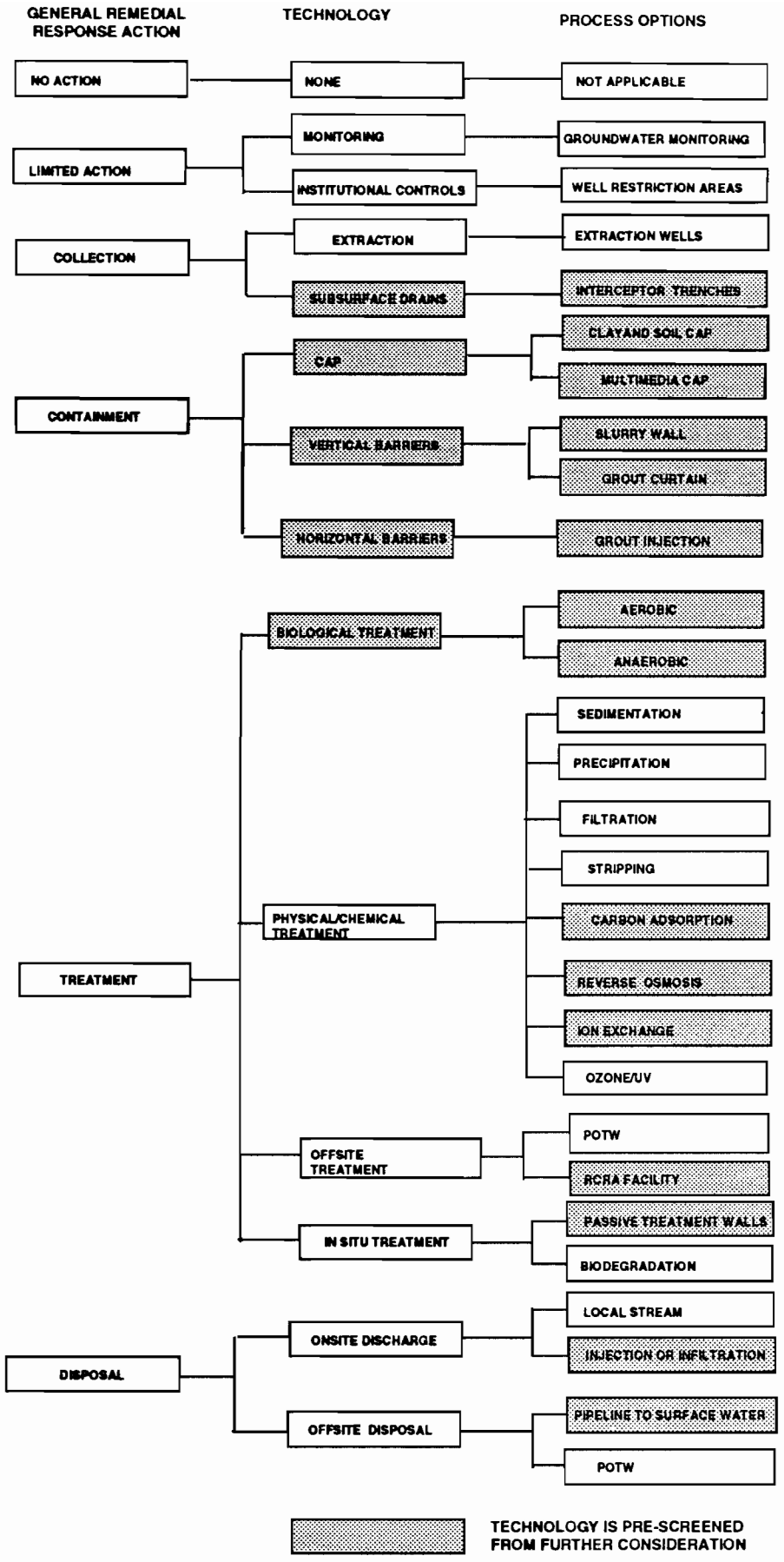

FIGURE 2-4
TECHNOLOGIES AND PROCESS OPTIONS FOR GROUNDWATER REMEDIATION RETAINED FOR ALTERNATIVES DEVELOPMENT

3.0 DEVELOPMENT AND SCREENING OF REMEDIAL ALTERNATIVES

In this section, potential remedial alternatives for the Forest Glen site are developed by grouping the potential remedial technologies identified in Section 2.8. In this section, the alternatives have been screened on the basis of effectiveness, implementability, and cost considerations. This screening step was performed to narrow the field of potential alternatives while preserving an adequate range of options. The alternatives that remained following this screening are further evaluated via the detailed analysis presented in Section 4.0.

As stated in Section 2.0, the primary focus of this FS is: to restore the presently vacant and abandoned site to beneficial use; prevent human exposure to groundwater contaminated with chlorinated aliphatic hydrocarbons and inorganics above cleanup goals; and, to prevent/minimize offsite migration of groundwater contamination in the fractured bedrock aquifer and (through the process of containment) reduce the mass of contaminants to the maximum extent possible. In order to meet these objectives, this FS considers various groundwater extraction / treatment / discharge schemes and an innovative in-situ technology for remediation of contaminated groundwater. The primary contaminants in the groundwater are volatile chlorinated aliphatic hydrocarbons and inorganics like iron and manganese.

This FS considers those alternatives which can be typically categorized as Management of Migration alternatives. Source control alternatives were described in the FS for Operable Unit II. Management of migration alternatives generally prevent or minimize risks due to the migration of the hazardous substances away from the source. This section also restates the response objectives to be achieved by the remedial alternatives. Management of migration alternatives are developed in Section 3.1, and described and screened in Section 3.2. Alternative development criteria and applicable guidelines are also presented in Section 3.1.

It must be stressed that the alternatives developed and screened herein are conceptual. Any characteristics of these alternatives (such as remediation locations, depths, and extraction rates) should be considered to be approximate. These details will have to be further developed through additional field tests during remedial design.

3.1 REMEDIAL ALTERNATIVE DEVELOPMENT

3.1.1 ALTERNATIVE DEVELOPMENT CRITERIA

Alternative development must conform to the requirements of CERCLA, as amended by SARA, and to the extent possible, the NCP. Section 300.68 of the NCP specifically refers to ARARs in the development of alternatives. CERCLA Section 121(d) requires that Superfund remedial actions attain ARARs or other Federal statutes. Superfund remedial actions must also attain State requirements that are more stringent than Federal requirements to the extent that they are also applicable or relevant and appropriate and are identified by NYSDEC to USEPA in a timely manner.

CERCLA, Section 121(b) identifies the following statutory preferences that must be considered when developing and evaluating remedial alternatives:

- Remedial actions that involve treatment that permanently and significantly reduces the

volume, toxicity, or mobility of the hazardous substances are preferred over remedial actions not involving such treatment.

- Off-site transport and disposal of hazardous substances or contaminated materials without treatment is considered the least favorable remedial alternative when practical treatment technologies are available.

- Remedial actions using permanent solutions, alternative treatment technologies, or resource recovery technologies shall be assessed.

Based on these statutory preferences and the response objectives developed in Section 2.3, remedial alternatives were developed to meet the following criteria:

- The remedial alternative is protective of human health and the environment.

- The remedial alternative attains chemical-specific ARARs and can be implemented in a manner consistent with location-specific and action-specific ARARs.

- The remedial alternative uses permanent solutions and alternative treatment technologies to the maximum extent possible.

- The alternatives developed are capable of achieving the remedy in a cost-effective manner.

EPA OSWER Directive Number 9355.0-19, dated December 24, 1986, provides guidance regarding implementation of CERCLA amendments during the remedy selection process. This directive states that the treatment alternatives should range from an alternative that, to the degree possible, would eliminate the need for long-term management (including monitoring) at the site to alternatives involving treatment that would reduce toxicity, mobility, or volume. This directive also indicates that the containment option (involving little or no treatment) and a no action alternative should be developed.

At the Forest Glen site, remedial alternatives can be categorized as Management of Migration actions since a contaminated groundwater plume has been identified as extending beyond the physical boundaries of the site and at depths monitored by the deepest monitoring wells.

3.1.2 CONSIDERATION OF REMEDIAL ACTION OBJECTIVES IN ALTERNATIVE DEVELOPMENT

Based on the information presented in the RI, the risk assessment determined that the contamination present in the groundwater at the Forest Glen site currently has no definable impacts on the environment (ecological receptors) that warrant active measures. Therefore, the remedial action objectives were developed only for the protection of public health. As discussed in Section 2.0, the following remedial action objectives have been established for cleanup activities at the site. These objectives are to:

- Restore the presently vacant and abandoned site to beneficial use based on its current zoning

as a residential property (except for portions of the site that are used for groundwater extraction, treatment and discharge).

- Prevent/minimize offsite migration of groundwater contamination in the fractured bedrock aquifer. Fully contain the contaminated groundwater (that which is above Federal and State MCLs) from all depth zones and, in so doing, reduce the mass of contaminants to the maximum extent possible. Aquifer restoration is highly unlikely in this fractured bedrock and is not practical.

- Prevent human exposure to contaminated groundwater.

These objectives have been considered in developing and evaluating the various remedial alternatives.

3.1.3 COMBINATION OF POTENTIALLY APPLICABLE REMEDIAL TECHNOLOGIES INTO REMEDIAL ALTERNATIVES

The potentially applicable technologies remaining after the initial screening in Section 2.0 have been combined into a number of remedial alternatives, as follows:

Alternative GW-1:	No Action
Alternative GW-2:	Monitored Natural Attenuation
Alternative GW-3:	Enhanced Anaerobic In-Situ Bioremediation
Alternative GW-4:	Extraction of Groundwater and Discharge to POTW
Alternative GW-5:	Extraction of Groundwater, Treatment with Chemical Precipitation followed by Air Stripping / Chemical Oxidation Enhanced with UV Photolysis and Discharge to Surface Water
Alternative GW-6:	Extraction of Groundwater, Treatment with Chemical Precipitation followed by Air Stripping / Chemical Oxidation Enhanced with UV Photolysis and Discharge to POTW

Alternatives GW-1 and GW-2 do not include any extraction or treatment of contaminated groundwater and Alternative GW-3 includes innovative in-situ treatment of contaminated groundwater. The treatment alternatives GW-4, GW-5, and GW-6 consist of groundwater extraction from the onsite and/or the offsite plume (please see the two selected scenarios in Appendix B), onsite or offsite treatment and discharge to surface water or the POTW.For alternatives GW-4, GW-5, and GW-6, Option A consists of groundwater extraction from the onsite plume using two extraction wells and monitored natural attenuation of the offsite plume. For alternatives GW-4, GW-5, and GW-6, Option B consists of groundwater extraction from the onsite and offsite plume using four extraction wells. For Alternative GW-4, treatment is performed at the City of Niagara Falls POTW whereas for Alternatives GW-5 and GW-6, treatment is performed onsite. Alternatives GW-5 and GW-6 both include a treatment train which consists of chemical precipitation to remove inorganics like iron and manganese followed by either air stripping (sub-option 1) or chemical oxidation enhanced with UV photolysis (sub-option 2) to remove the volatile chlorinated aliphatic hydrocarbons. The only difference between Alternatives GW-5 and GW-6 is in how the treated water is discharged. For Alternative GW-5, the contaminated groundwater must be treated to Federal and State surface water standards. For Alternative GW-6, the contaminated groundwater

must be treated to Federal and State drinking water MCLs.

3.1.4 EVALUATION CRITERIA AND APPROACH

The screening criteria discussed herein conform with the remedy selection requirements set forth in CERCLA, as amended, Section 121, and in the NCP (40 CFR 300.68(g)) and OSWER Directive 9355.3-01. The three criteria used for the initial screening of alternatives at the Forest Glen site are described below.

Effectiveness:

Effectiveness criteria are based on the outline presented in CERCLA, as amended, Section 121(b). The primary criterion in screening the effectiveness of a remedial alternative is its ability to protect human health and the environment. Other factors to be considered are:

- The ability of a remedial alternative to reduce the toxicity, mobility, or volume of contamination.
- The capability of an alternative to attain the potential ARARs presented in Section 2.2.
- The goals, objectives, and requirements of the Solid Waste Disposal Act.
- The persistence, toxicity, and mobility of the hazardous substances, and their propensity to bioaccumulate.
- Short-term and long-term potential for adverse health effects from human exposure.
- The potential for future remedial action costs if the remedial alternative in question were to fail.

Implementability:

Implementability is considered in the screening process as a measure of the technical and administrative feasibility of constructing, operating, and maintaining a remedial action. Factors considered in this evaluation include:

- The ability to construct and operate alternative technologies within site-specific and technology-specific regulations and constraints. Technical aspects to be considered include operation, maintenance, monitoring, and post-implementation support.
- The extent of administrative coordination required to substantively comply with permit requirements and the coordination required with other government agencies.
- The availability of key alternative components and the time required for installation and attainment of the desired results.

Cost:

The intent of the cost screening is to make order-of-magnitude comparisons to screen out alternatives which have much higher costs than other alternatives without providing a comparative increase in protection. Costs were identified as advantageous (low) or disadvantageous (high) to aid in choosing among alternatives of the same type. Both capital, and operation and maintenance costs were considered. Alternatives that have excessive costs (at least an order of magnitude higher than a comparable alternative), and do not provide an increase in protection, have been eliminated from further consideration. Costs were used to screen between on-site versus off-site treatment technologies. Costs were not used to screen between treatment and non-treatment alternatives. Cost details are presented in the detailed analysis of alternatives, Section 4.0.

3.2 DESCRIPTION AND SCREENING OF REMEDIAL ALTERNATIVES

Three out of six alternatives developed for the Forest Glen site (with the exception of Alternatives GW-1, GW-2 , and GW-3) consist of contaminated groundwater extraction from the onsite and/or offsite plumes, onsite or offsite groundwater treatment, and treated or untreated water discharge. A three dimensional, finite element groundwater flow model (DYNFLOW) was used to develop a preliminary conceptual groundwater model of the Forest Glen study area (see Appendix B). This model was used to develop two suitable groundwater extraction scenarios for the Forest Glen groundwater contamination plume. A principal strategy used during the modeling effort was to extract groundwater at relatively low flow rates from onsite locations that have been identified during the RI as being contaminated above Federal and State MCLs. This approach allows removal and treatment of a large mass of contaminants from the aquifer without unnecessary dilution by groundwater from clean zones. The net average groundwater extraction rates (based on conservative assumptions) were determined to be 30 to 40 gallons per minute (gpm). These rates of 30 to 40 gpm were used as the nominal design rates for cost estimation purposes. In order to estimate the duration of treatment operations, the "Batch Flush" model described in Appendix C was used. The duration of the treatment operations for the two groundwater extraction scenarios was determined to be 7 years (onsite plume) and 13 years (onsite and offsite plume), respectively. It is assumed that source control for Operable Unit II (soil remediation) will be implemented before groundwater remediation. Monitoring of the plume will be a component for all of the remedial alternatives for groundwater at Forest Glen.

3.2.1 Alternative GW-1: No Action

Description:

This alternative includes a single sampling event and a review of site conditions at the end of five years to determine whether or not the contamination has spread. Under this alternative, groundwater samples would be collected from eight existing shallow bedrock and eight existing deep bedrock monitoring wells. All samples would be analyzed for TCL organics and TAL inorganics. A review of site conditions would occur at the end of five years to determine whether or not the contamination

has spread. If necessary, appropriate action would be considered at that time.

Evaluation:

- Effectiveness:This alternative relies on natural attenuation and flushing processes to achieve reduction in toxicity of contaminants and is ineffective in meeting the remediation goals. The contaminated groundwater will continue to move downgradient towards the PASNY conduits. Emergency measures may have to be undertaken in the event a future risk arises, because this alternative does not reduce long-term risks.

- Implementability: No Action is readily implemented. Only the activities described above must be conducted.

- Cost: There is no capital cost associated with this alternative. The annual operation and maintenance costs for this alternative are estimated at $35,000 (one-time cost at the end of 5 years). The present worth, calculated at a discount rate of 5%, is $35,000.

Conclusion:

The No Action alternative does not reduce the toxicity, mobility, or volume of the contamination. The dominant risk is posed by the potential future use of the groundwater for drinking and showering. Almost all current downgradient users have an alternate water supply source for drinking and showering at present. No Action has been retained for detailed analysis, in accordance with CERCLA and the NCP, to serve as a basis for comparison with other remedial alternatives.

3.2.2 Alternative GW-2: Monitored Natural Attenuation

Description:

The major features of this remedial alternative include:performance of a baseline investigation and groundwater modeling study to determine and evaluate intrinsic biodegradation and other natural attenuation processes as described in section D.1.7 of Appendix D; quarterly groundwater sampling from new and existing monitoring wells for at least a thirty year period; and a performance monitoring program to evaluate historical contaminant time-trends.

After initial baseline conditions are established, existing and new monitoring wells at the site would be used to conduct a long-term groundwater monitoring program which would track contaminant migration in the Lockport Dolomite bedrock aquifer for at least 30 years. All samples would be analyzed on a quarterly basis for TCL organics, TAL inorganics, BOD, COD, TDS, TSS, dissolved organic carbon, oxygen, and carbon dioxide, redox potential, methane, ethane, ethene, ferrous iron, nitrate and sulfate. The natural attenuation and migration of the contamination plume would be assessed annually utilizing the data collected during the monitoring activities. This is expected to continue for at least several decades or until the contaminant mass is reduced such that contaminant concentrations show no significant change. If necessary, appropriate action would be considered at

that time. As part of the performance monitoring program, the data would be compared to action levels defined by the Federal and State MCLs for public drinking water supplies or natural background, as appropriate. In cases where MCLs or groundwater quality standards have not been promulgated, the cleanup level would be defined as the upper contaminant limit for which the average lifetime risk is within the range of 10^{-4} to 10^{-6} (for carcinogens) or for which the cumulative hazard index is less than one (for non-carcinogens). An alternate water supply source for drinking and showering already exists at the site, so developing a new one is not necessary.

Evaluation:

- Effectiveness: Since the baseline investigation has not been performed at this time, the effectiveness of this alternative (based on present knowledge) is uncertain. Based on the conclusions drawn from the preliminary evaluation of the feasibility of monitored natural attenuation (see Appendix D), the water quality in the fractured bedrock aquifer is not expected to be restored to below MCLs or background levels for at least several decades (possibly more than thirty years). It is estimated that many of the remediation goals could perhaps be attained over a long period of time. This alternative relies on natural attenuation and flushing processes to achieve reduction in toxicity of contaminants and is not very effective in meeting the remediation goals (in the short-term). The contaminated groundwater will continue to move downgradient towards the PASNY conduits. However, it does reduce the dominant risk through the periodic monitoring program and the potential for providing a warning against the use of contaminated groundwater. Emergency measures may have to be undertaken in the event a future risk arises, because this alternative does not reduce long-term risks.

- Implementability: Monitoring and review activities are included in this alternative. Monitored Natural Attenuation can be readily implemented onsite and immediately west of the site near the Conrail Foote Railroad property. Further west there are other potential contaminant sources such as the New Road Landfill that could potentially make it difficult to monitor the groundwater plume emanating from the Forest Glen site. Provision of an alternate water supply already exists at the site.

- Cost: The capital and annual operation and maintenance costs for this alternative are estimated at $392,200 and $3,173,800 (for 30 years), respectively. The present worth, calculated at a discount rate of 5%, is $3,566,000.

Conclusion:

Monitored Natural Attenuation as described above is only a somewhat effective method of preventing unnecessary exposure to contaminants present in the groundwater. This is especially true since the dominant risk is due to certain types of future exposure scenarios only and an alternate water supply already exists at the Forest Glen site. However, migration of the plume would continue all the way to the PASNY conduits approximately 3,000 feet west of the site and the water quality of the aquifer would not be actively restored to action levels for a very long period of time (possibly more than thirty years). This alternative will not be retained for detailed analysis because it does not

prevent plume migration in any depth zone. Based on present knowledge, compared to other remedial alternatives, the effectiveness of MNA is uncertain.

3.2.3 Alternative GW-3: Enhanced Anaerobic In-Situ Bioremediation

Description:

The major features of this remedial alternative include: performance of a baseline investigation and groundwater modeling study to determine and evaluate intrinsic biodegradation and other natural attenuation processes as described in section D.1.7 of Appendix D; performance of laboratory microcosm studies to determine the optimum level of electron donors to reduce the contaminant concentration to methanogenic conditions and the approximate rate of dechlorination activity as well as the extent of biodegradation as described in section D.2.1 of Appendix D; performance of a field-scale pilot study to verify the findings of the microcosm study and to ensure proper scale-up procedures and operation prior to the full-scale implementation of enhanced anaerobic bioremediation (EAB) as described in section D.2.2 of Appendix D; installation of an onsite groundwater treatment system to mix and inject suitable reagents; quarterly groundwater sampling from new and existing monitoring wells for an estimated eighteen year period; and a performance monitoring program to evaluate historical contaminant time-trends.

EAB is an innovative technology which has been implemented at relatively few sites. EAB relies on the addition of sufficient organic compounds to contaminated groundwater to induce highly reducing methanogenic conditions necessary to achieve complete reductive dechlorination of chlorinated solvents. Inherent in the technically and economically feasible implementation of EAB is that site groundwaters have only low levels of alternative electron acceptors, such that only a minimal addition of organic compounds is necessary to achieve and sustain a highly reduced groundwater environment.

After initial baseline conditions are established, laboratory microcosm studies are shown to be favorable, and a field-scale pilot study has been completed, a groundwater treatment system to store and mix suitable reagents (electron donors) for injection throughout the groundwater plume. Existing and new monitoring wells at the site would be used to conduct a long-term groundwater monitoring program which would track contaminant migration in the Lockport Dolomite bedrock aquifer for at least 18 years (five years beyond estimated remediation time of 13 years). The estimated duration of the in-situ remedy is based on comparable calculations performed using the batch flush model in Appendix C for groundwater extraction remedies described in Alternatives GW-4, GW-5 and GW-6. All samples would be analyzed monthly for the first year and subsequently on a quarterly basis for TCL organics, TAL inorganics, BOD, COD, TDS, TSS, dissolved organic carbon, oxygen, and carbon dioxide, redox potential, methane, ethane, ethene, ferrous iron, nitrate and sulfate. The in-situ biodegradation and migration of the contamination plume would be assessed annually utilizing the data collected during the monitoring activities. This is expected to continue for an estimated 18 years or until the contaminant mass is reduced such that contaminant concentrations show no significant change. As part of the performance monitoring program, the data would be compared to action levels defined by the Federal and State MCLs for

public drinking water supplies or natural background, as appropriate. In cases where MCLs or groundwater quality standards have not been promulgated, the cleanup level would be defined as the upper contaminant limit for which the average lifetime risk is within the range of 10^{-4} to 10^{-6} (for carcinogens) or for which the cumulative hazard index is less than one (for non-carcinogens). An alternate water supply source for drinking and showering already exists at the site, so developing a new one is not necessary.

Evaluation:

- Effectiveness: The feasibility of this remedial alternative is currently unknown and will rely largely on results from electron acceptor analyses of the site groundwaters (performed as part of a natural attenuation evaluation), results from microcosm studies, and a field pilot study. Since the baseline investigation has not been performed at this time, the effectiveness of this alternative (based on present knowledge) is uncertain. Based on the conclusions drawn from the preliminary evaluation of the feasibility of enhanced anaerobic in-situ bioremediation (see Appendix D), it appears that no definitive conclusions can be drawn at this time about the water quality in the fractured bedrock aquifer. Although EAB has shown promising results for petroleum hydrocarbons in sand and gravel aquifers, the results with chlorinated aliphatic hydrocarbons in fractured bedrock are unknown. This alternative relies on the addition of electron donors to augment natural attenuation and flushing processes to achieve reduction in toxicity of contaminants and is likely to be significantly more effective than Alternative GW-2 in meeting the remediation goals (in the short-term). Since there is no active measure to capture the plume, the contaminated groundwater will continue to move downgradient towards the PASNY conduits. This alternative does reduce the dominant risk through the periodic monitoring program and the potential for providing a warning against the use of contaminated groundwater. Further studies and pilot testing at Forest Glen would have to be performed during the preliminary design stage of this remediation project in an attempt to demonstrate that Alternative GW-3 which is based on an innovative technology will sufficiently improve the water quality of the Lockport Dolomite Aquifer for beneficial use.

- Implementability: The additional studies described above can be easily perofrmed. Monitoring and review activities are included in this alternative. EAB can be readily implemented onsite and immediately west of the site near the Conrail Foote Railroad property. Further west there are other potential contaminant sources such as the New Road Landfill that could potentially make it difficult to monitor the groundwater plume emanating from the Forest Glen site. Provision of an alternate water supply already exists at the site.

- Cost: The capital and annual operation and maintenance costs for this alternative are estimated at $695,700 and $2,906,900 (for 18 years - five years beyond estimated remediation time of 13 years), respectively. The present worth, calculated at a discount rate of 5%, is $3,602,600.

Conclusion:

EAB as described above is likely a more effective method of preventing unnecessary exposure to contaminants present in the groundwater as compared to MNA. This is especially true since the dominant risk is due to certain types of future exposure scenarios only and an alternate water supply already exists at the Forest Glen site. However, migration of the plume would potentially continue all the way to the PASNY conduits approximately 3,000 feet west of the site. This alternative will not be retained for detailed analysis because it does not prevent plume migration in any depth zone (it does not meet the remedial action objectives). Based on present knowledge (since the additional studies and modeling suggested in Appendix D have not been performed), compared to other remedial alternatives, the effectiveness of EAB is uncertain.

3.2.4 Alternative GW-4: Extraction of Groundwater and Discharge to POTW

Description:

The major features of this remedial alternative include: groundwater extraction (pumping and collection) from the Forest Glen plume as depicted in Figures 10, 10A and 11 of Appendix B; discharge of the treated water to the City of Niagara Falls POTW; and a performance monitoring program.

For alternative GW-4, Option A consists of groundwater extraction from the onsite plume using two extraction wells and monitored natural attenuation of the offsite plume. Option B consists of groundwater extraction from the onsite and offsite plume using four extraction wells. Table 3-1 presents the average concentration of the groundwater contaminants in the entire (onsite and offsite) oval shaped plume as shown in Figure 2-1. Table 3-2 presents the average concentration of the groundwater contaminants in the offsite plume (west of the Subdivision beneath the Conrail Foote Railroad yard).

Under Option A, groundwater would be extracted at an average rate of 30 gpm from the onsite plume using extraction wells 5D and PROP1. As stated in Appendix B, well 5D and well PROP1 would be pumped at 15 gpm each, and groundwater would be extracted from the onsite shallow and deep portions of the Lockport Dolomite fractured bedrock aquifer. It has been estimated that this groundwater extraction would continue for a seven year period (see Appendix C). The offsite portion of the plume (which has much lower concentrations as shown in Table 3-2) would not be captured and it would be allowed to naturally attenuate. For this option, a baseline investigation and groundwater modeling to determine and evaluate intrinsic biodegradation and other natural attenuation processes would be performed as described in section D.1.7 of Appendix D. Since the offsite portion of the plume has much lower contaminant concentrations, it has been estimated that approximately 12 years would be required to attain Federal and State MCLs through MNA for the offsite groundwater. After initial baseline conditions are established, existing and new monitoring wells offsite would be used to conduct a long-term groundwater monitoring program which would track contaminant migration in the Lockport Dolomite bedrock aquifer for an estimated 12 year period. All samples would be analyzed on a quarterly basis for TCL organics, TAL inorganics,

BOD, COD, TDS, TSS, dissolved organic carbon, oxygen, and carbon dioxide, redox potential, methane, ethane, ethene, ferrous iron, nitrate and sulfate. The natural attenuation and migration of the offsite contamination plume would be assessed annually utilizing the data collected during the monitoring activities. As part of the performance monitoring program, the data would be compared to action levels defined by the Federal and State MCLs for public drinking water supplies or natural background, as appropriate. In cases where MCLs or groundwater quality standards have not been promulgated, the cleanup level would be defined as the upper contaminant limit for which the average lifetime risk is within the range of 10^{-4} to 10^{-6} (for carcinogens) or for which the cumulative hazard index is less than one (for non-carcinogens).

Under Option B, groundwater would be extracted at an average rate of 40 gpm from the onsite and offsite plume using extraction wells 5D, PROP1, PROPRR1 and PROPRR2. As stated in Appendix B, wells 5D, PROP1, PROPRR1 and well PROPRR2 would be pumped at 10 gpm each, and groundwater would be extracted from both the onsite and offsite shallow and deep portions of the Lockport Dolomite fractured bedrock aquifer. The addition of wells PROPRR1 and PROPRR2 to the extraction system would allow capture of contaminated groundwater from offsite areas west of the Subdivision beneath the Conrail Foote Railroad yard. It has been estimated that this groundwater extraction would continue for a thirteen year period (see Appendix C).

For both Options A and B, the extracted groundwater would be collected in an onsite storage tank. The collected groundwater would be discharged to the City of Niagara Falls POTW via a proposed connection to an existing sanitary sewer manhole in the cul-de-sac on Carrie Drive. The locations of the proposed storage tank and extraction wells are shown in Figure 3-1. At the City of Niagara Falls POTW contaminated groundwater would be treated to action levels defined by the Federal and State MCLs for public drinking water supplies or natural background, or Federal and State Surface Water Quality Standards, as appropriate. In cases where MCLs or surface water quality standards have not been promulgated, the cleanup level would be defined as the upper contaminant limit for which the average lifetime risk is within the range of 10^{-4} to 10^{-6} (for carcinogens) or for which the cumulative hazard index is less than one (for non-carcinogens).

Sixteen existing monitoring wells at the site would be used to conduct an annual long-term groundwater monitoring program which would track contaminant migration/plume containment in the aquifer for at least 5 years beyond the estimated duration of groundwater extraction . All samples would be analyzed for TCL organics and TAL inorganics. An alternate water supply source for drinking and showering already exists at the site, so developing a new one is not necessary.

Evaluation:

- Effectiveness: This alternative would be effective in reducing the toxicity, mobility and volume of contaminants because the groundwater extracted from the onsite and offsite portion of the plume would be treated to meet Federal and State ARARs at the City of Niagara Falls POTW. It is estimated that the remediation goals would be attained over a period of 7 years for Option A and over a period of 13 years for Option B. Under Option

A, for the offsite portion of the plume that has much lower contaminant concentrations than the onsite plume, it has been estimated that approximately 12 years would be required to attain Federal and State MCLs through MNA. Since the baseline investigation for MNA of the offsite portion of the plume (under Option A) has not been performed at this time, the effectiveness of this aspect of alternative (based on present knowledge) is relatively uncertain. This aspect of this alternative (for Option A) relies on natural attenuation and flushing processes to achieve reduction in toxicity of contaminants and is not as effective in meeting the remediation goals (in the short-term). The contaminated groundwater that is not captured by the extraction wells under Option A will continue to move downgradient towards the PASNY conduits. However, it does reduce the dominant risk through the periodic monitoring program and the potential for providing a warning against the use of contaminated groundwater. Under Option B, all of the contaminated groundwater would be captured by the four extraction wells. Hence Option B is clearly more effective. However, as stated earlier, the water quality in the fractured bedrock aquifer is not expected to be restored to below MCLs or background levels for at least 13 years.

The preliminary groundwater modeling performed by CDM Federal shows that extraction wells 5D and PROP1 appear to capture all of the contaminated groundwater from the onsite plume and that extraction wells PROPRR1 and PROPRR2 appear to capture all of the contaminated groundwater from the offsite plume. These projected capture zones will have to be investigated further during the remedial design stage.

- Implementability: Groundwater extraction and carbon adsorption (the technology used at the City of Niagara Falls POTW) are well established technologies. It has been estimated that all of the vinyl chloride present in the groundwater would likely volatilize in the sanitary sewer before the groundwater reaches the POTW. Further, the amount of activated carbon used at the POTW is very large (approximately 5 million pounds). Hence any vinyl chloride that does reach the POTW would be effectively removed. The 40 gpm groundwater extraction rate is well within the reserve capacity of the POTW as designed and is available at present. The proposed groundwater extraction system (for both options A and B) would have to be installed in trenches dug after completion of the source control (soil) remedy. The future installation of a buried influent pipe can be expected to require a modest amount of administrative effort in obtaining the necessary approvals and coordination with EPA, NYSDEC and local engineering and public works departments. For Option B, an additional access agreement would have to be obtained from Conrail to install well PROPRR2. A portion of this buried pipeline may potentially have to cross areas designated as scrub-shrub wetlands.

- Cost: The capital cost of this alternative is estimated to be $683,300 (for Option A) and $453,200 (for Option B). The estimated annual operation and maintenance costs of the options range from $3,431,900 (Option A for 12 years) to $4,753,400 (Option B for 18 years -five years beyond estimated remediation time of 13 years). The present worth of these options, calculated at a discount rate of 5%, is $4,115,200 (Option A) and $5,206,600 (Option B), respectively. These costs are summarized in Tables 3-3 and 3-4.

Conclusion:

This alternative (both options) will be retained for detailed analysis because it is capable of meeting the remediation goals for the Forest Glen site. Clearly, Option B is more expensive, but it is also more reliable and more effective.

3.2.5 Alternative GW-5: Extraction of Groundwater, Treatment with Chemical Precipitation followed by Air Stripping / Chemical Oxidation Enhanced with UV Photolysis and Discharge to Surface Water

Description:

The major features of this remedial alternative include: groundwater extraction (pumping and collection) from the Forest Glen plume as depicted in Figures 10, 10A and 11 of Appendix B; groundwater treatment to MCLs or natural background, or surface water quality standards, as appropriate; discharge of the treated water; and a performance monitoring program.

For alternative GW-5, Option A consists of groundwater extraction from the onsite plume using two extraction wells and monitored natural attenuation of the offsite plume. Option B consists of groundwater extraction from the onsite and offsite plume using four extraction wells. Table 3-1 presents the average concentration of the groundwater contaminants in the entire (onsite and offsite) oval shaped plume as shown in Figure 2-1. Table 3-2 presents the average concentration of the groundwater contaminants in the offsite plume (west of the Subdivision beneath the Conrail Foote Railroad yard).

Under Option A, groundwater would be extracted at an average rate of 30 gpm from the onsite plume using extraction wells 5D and PROP1. As stated in Appendix B, well 5D and well PROP1 would be pumped at 15 gpm each, and groundwater would be extracted from the onsite shallow and deep portions of the Lockport Dolomite fractured bedrock aquifer. It has been estimated that this groundwater extraction would continue for a seven year period (see Appendix C). The offsite portion of the plume (which has much lower concentrations as shown in Table 3-2) would not be captured and it would be allowed to naturally attenuate. For this option, a baseline investigation and groundwater modeling to determine and evaluate intrinsic biodegradation and other natural attenuation processes would be performed as described in section D.1.7 of Appendix D. Since the offsite portion of the plume has much lower contaminant concentrations, it has been estimated that approximately 12 years would be required to attain Federal and State MCLs through MNA for the offsite groundwater. After initial baseline conditions are established, existing and new monitoring wells offsite would be used to conduct a long-term groundwater monitoring program which would track contaminant migration in the Lockport Dolomite bedrock aquifer for an estimated 12 year period. All samples would be analyzed on a quarterly basis for TCL organics, TAL inorganics, BOD, COD, TDS, TSS, dissolved organic carbon, oxygen, and carbon dioxide, redox potential, methane, ethane, ethene, ferrous iron, nitrate and sulfate. The natural attenuation and migration of the offsite contamination plume would be assessed annually utilizing the data collected during the monitoring activities. As part of the performance monitoring program, the data would be compared

to action levels defined by the Federal and State MCLs for public drinking water supplies or natural background, as appropriate. In cases where MCLs or groundwater quality standards have not been promulgated, the cleanup level would be defined as the upper contaminant limit for which the average lifetime risk is within the range of 10^{-4} to 10^{-6} (for carcinogens) or for which the cumulative hazard index is less than one (for non-carcinogens).

Under Option B, groundwater would be extracted at an average rate of 40 gpm from the onsite and offsite plume using extraction wells 5D, PROP1, PROPRR1 and PROPRR2. As stated in Appendix B, wells 5D, PROP1, PROPRR1 and well PROPRR2 would be pumped at 10 gpm each, and groundwater would be extracted from both the onsite and offsite shallow and deep portions of the Lockport Dolomite fractured bedrock aquifer. The addition of wells PROPRR1 and PROPRR2 to the extraction system would allow capture of contaminated groundwater from offsite areas west of the Subdivision beneath the Conrail Foote Railroad yard. It has been estimated that this groundwater extraction would continue for a thirteen year period (see Appendix C).

For both Options A and B, the extracted groundwater would be collected in an onsite storage tank. Treatment of the extracted groundwater would consist of chemical precipitation to remove inorganics like iron and manganese. It would then be followed by either air stripping (sub-option 1) or chemical oxidation enhanced with ultra-violet (UV) photolysis (sub-option 2) to remove volatile chlorinated aliphatic hydrocarbons from the contaminated groundwater. The treated groundwater would be discharged to East Gill Creek via a proposed outfall located south west of the cul-de-sac on Carrie Drive. The locations of the proposed treatment plant and extraction wells are shown in Figure 3-1. At the onsite treatment plant contaminated groundwater would be treated to action levels defined by the Federal and State MCLs for public drinking water supplies or natural background, or Federal and State Surface Water Quality Standards, as appropriate. In cases where MCLs or surface water quality standards have not been promulgated, the cleanup level would be defined as the upper contaminant limit for which the average lifetime risk is within the range of 10^{-4} to 10^{-6} (for carcinogens) or for which the cumulative hazard index is less than one (for non-carcinogens).

Sixteen existing monitoring wells at the site would be used to conduct an annual long-term groundwater monitoring program which would track contaminant migration/plume containment in the aquifer for at least 5 years beyond the estimated duration of groundwater extraction . All samples would be analyzed for TCL organics and TAL inorganics. In addition, for Alternative GW-5, two samples would be collected from East Gill Creek (one upstream and one downstream of the proposed outfall) every quarter. The stream samples would be analyzed for TCL organics, TAL inorganics, and conventional water parameters (such as BOD, COD, TDS, TSS, etc.). An alternate water supply source for drinking and showering already exists at the site, so developing a new one is not necessary.

Evaluation:

- Effectiveness: This alternative would be effective in reducing the toxicity, mobility and volume of contaminants because the groundwater extracted from the onsite and offsite portion of the plume would be treated to meet Federal and State ARARs at the onsite treatment plant. It is estimated that the remediation goals would be attained over a period of 7 years for Option A and over a period of 13 years for Option B. Under Option A, for

the offsite portion of the plume that has much lower contaminant concentrations than the onsite plume, it has been estimated that approximately 12 years would be required to attain Federal and State MCLs through MNA. Since the baseline investigation for MNA of the offsite portion of the plume (under Option A) has not been performed at this time, the effectiveness of this aspect of alternative (based on present knowledge) is relatively uncertain. This aspect of this alternative (for Option A) relies on natural attenuation and flushing processes to achieve reduction in toxicity of contaminants and is not as effective in meeting the remediation goals (in the short-term). The contaminated groundwater that is not captured by the extraction wells under Option A will continue to move downgradient towards the PASNY conduits. However, it does reduce the dominant risk through the periodic monitoring program and the potential for providing a warning against the use of contaminated groundwater. Under Option B, all of the contaminated groundwater would be captured by the four extraction wells. Hence Option B is clearly more effective. However, as stated earlier, the water quality in the fractured bedrock aquifer is not expected to be restored to below MCLs or background levels for at least 13 years.

The preliminary groundwater modeling performed by CDM Federal shows that extraction wells 5D and PROP1 appear to capture all of the contaminated groundwater from the onsite plume and that extraction wells PROPRR1 and PROPRR2 appear to capture all of the contaminated groundwater from the offsite plume. These projected capture zones will have to be investigated further during the remedial design stage.

Sludge from the chemical precipitation will require off-site disposal as a non-hazardous waste. For Sub-option 1, volatile organic compounds that would be emitted from the air stripper are estimated to be at levels below allowable discharge rates without any air pollution controls. For Sub-Option 2, chemical oxidation enhanced with UV photolysis, treatability studies may be required to establish operating parameters for site-specific conditions. All of the treatment technologies considered are reliable technologies. The discharge of the treated water to East Gill Creek is not expected to affect the wetlands or cause localized flooding. These impacts will have to be further investigated during remedial design.

- Implementability: Groundwater extraction, air stripping, and chemical oxidation enhaced with UV photolysis are well established reliable technologies. All of them are readily available commercially. Sufficient land is available onsite to build the treatment plant. A NYSPDES permit equivalent from NYSDEC and /or local authorities would have to be obtained for the proposed outfall. The proposed groundwater extraction system (for both options A and B) would have to be installed in trenches dug after completion of the source control (soil) remedy. The future installation of a buried influent pipe can be expected to require a modest amount of administrative effort in obtaining the necessary approvals and coordination with EPA, NYSDEC and local engineering and public works departments. For Option B, an additional access agreement would have to be obtained from Conrail to install well PROPRR2. A portion of this buried pipeline may potentially have to cross areas designated as scrub-shrub wetlands.

- Cost: The capital cost of this alternative is estimated to be $1,328,800 (for Option A Sub-option 1), $1,432,600 (for Option A Sub-option 2), $1,139,600 (for Option B Sub-option 1), and $1,258,600 (for Option B Sub-option2). The estimated annual operation and maintenance costs of the options range from $4,183,200 (for Option A Sub-option 1) to $4,615,600 (for Option A Sub-option 2) for a period of 12 years. The estimated annual operation and maintenance costs of the options range from $6,179,300 (for Option B Sub-option 1) to $6,920,200 (for Option B Sub-option 2) for a period of 18 years. The present worth of these options, calculated at a discount rate of 5%, is, $5,512,000 (for Option A Sub-option 1), $6,048,200 (for Option A Sub-option 2), $7,318,900 (for Option B Sub-option 1), and $8,178,800 (for Option B Sub-option2) respectively. These costs are summarized in Tables 3-3 and 3-4.

Conclusion:

Alternative GW-5 (all options) will be retained for detailed analysis because it is capable of meeting the remediation goals for the Forest Glen site. Clearly, Option B is more expensive, but it is also more reliable and more effective. Also, costs for the air stripping sub-option are estimated to be lower than those for chemical oxidation enhanced with UV photolysis.

3.2.6 Alternative GW-6: Extraction of Groundwater, Treatment with Chemical Precipitation followed by Air Stripping / Chemical Oxidation Enhanced with UV Photolysis and Discharge to POTW

Description:

The major features of this remedial alternative include: groundwater extraction (pumping and collection) from the Forest Glen plume as depicted in Figures 10, 10A and 11 of Appendix B; groundwater treatment to MCLs or natural background, as appropriate; discharge of the treated water to the City of Niagara Falls POTW; and a performance monitoring program.

For alternative GW-6, Option A consists of groundwater extraction from the onsite plume using two extraction wells and monitored natural attenuation of the offsite plume. Option B consists of groundwater extraction from the onsite and offsite plume using four extraction wells. Table 3-1 presents the average concentration of the groundwater contaminants in the entire (onsite and offsite) oval shaped plume as shown in Figure 2-1. Table 3-2 presents the average concentration of the groundwater contaminants in the offsite plume (west of the Subdivision beneath the Conrail Foote Railroad yard).

Under Option A, groundwater would be extracted at an average rate of 30 gpm from the onsite plume using extraction wells 5D and PROP1. As stated in Appendix B, well 5D and well PROP1 would be pumped at 15 gpm each, and groundwater would be extracted from the onsite shallow and deep portions of the Lockport Dolomite fractured bedrock aquifer. It has been estimated that this groundwater extraction would continue for a seven year period (see Appendix C). The offsite portion of the plume (which has much lower concentrations as shown in Table 3-2) would not be captured and it would be allowed to naturally attenuate. For this option, a baseline investigation and

groundwater modeling to determine and evaluate intrinsic biodegradation and other natural attenuation processes would be performed as described in section D.1.7 of Appendix D. Since the offsite portion of the plume has much lower contaminant concentrations, it has been estimated that approximately 12 years would be required to attain Federal and State MCLs through MNA for the offsite groundwater. After initial baseline conditions are established, existing and new monitoring wells offsite would be used to conduct a long-term groundwater monitoring program which would track contaminant migration in the Lockport Dolomite bedrock aquifer for an estimated 12 year period. All samples would be analyzed on a quarterly basis for TCL organics, TAL inorganics, BOD, COD, TDS, TSS, dissolved organic carbon, oxygen, and carbon dioxide, redox potential, methane, ethane, ethene, ferrous iron, nitrate and sulfate. The natural attenuation and migration of the offsite contamination plume would be assessed annually utilizing the data collected during the monitoring activities. As part of the performance monitoring program, the data would be compared to action levels defined by the Federal and State MCLs for public drinking water supplies or natural background, as appropriate. In cases where MCLs or groundwater quality standards have not been promulgated, the cleanup level would be defined as the upper contaminant limit for which the average lifetime risk is within the range of 10^{-4} to 10^{-6} (for carcinogens) or for which the cumulative hazard index is less than one (for non-carcinogens).

Under Option B, groundwater would be extracted at an average rate of 40 gpm from the onsite and offsite plume using extraction wells 5D, PROP1, PROPRR1 and PROPRR2. As stated in Appendix B, wells 5D, PROP1, PROPRR1 and well PROPRR2 would be pumped at 10 gpm each, and groundwater would be extracted from both the onsite and offsite shallow and deep portions of the Lockport Dolomite fractured bedrock aquifer. The addition of wells PROPRR1 and PROPRR2 to the extraction system would allow capture of contaminated groundwater from offsite areas west of the Subdivision beneath the Conrail Foote Railroad yard. It has been estimated that this groundwater extraction would continue for a thirteen year period (see Appendix C).

For both Options A and B, the extracted groundwater would be collected in an onsite storage tank. Treatment of the extracted groundwater would consist of chemical precipitation to remove inorganics like iron and manganese. It would then be followed by either air stripping (sub-option 1) or chemical oxidation enhanced with ultra-violet (UV) photolysis (sub-option 2) to remove volatile chlorinated aliphatic hydrocarbons from the contaminated groundwater. The treated groundwater would be discharged to the City of Niagara Falls POTW via a proposed connection to an existing sanitary sewer manhole in the cul-de-sac on Carrie Drive. The locations of the proposed storage tank and extraction wells are shown in Figure 3-1. At the onsite treatment plant contaminated groundwater would be treated to action levels defined by the Federal and State MCLs for public drinking water supplies or natural background, as appropriate. In cases where MCLs or groundwater quality standards have not been promulgated, the cleanup level would be defined as the upper contaminant limit for which the average lifetime risk is within the range of 10^{-4} to 10^{-6} (for carcinogens) or for which the cumulative hazard index is less than one (for non-carcinogens).

Sixteen existing monitoring wells at the site would be used to conduct an annual long-term groundwater monitoring program which would track contaminant migration/plume containment in the aquifer for at least 5 years beyond the estimated duration of groundwater extraction . All samples would be analyzed for TCL organics and TAL inorganics. An alternate water supply source for drinking and showering already exists at the site, so developing a new one is not necessary.

Evaluation:

- Effectiveness: This alternative would be effective in reducing the toxicity, mobility and volume of contaminants because the groundwater extracted from the onsite and offsite portion of the plume would be treated to meet Federal and State ARARs at the City of Niagara Falls POTW. It is estimated that the remediation goals would be attained over a period of 7 years for Option A and over a period of 13 years for Option B. Under Option A, for the offsite portion of the plume that has much lower contaminant concentrations than the onsite plume, it has been estimated that approximately 12 years would be required to attain Federal and State MCLs through MNA. Since the baseline investigation for MNA of the offsite portion of the plume (under Option A) has not been performed at this time, the effectiveness of this aspect of alternative (based on present knowledge) is relatively uncertain. This aspect of this alternative (for Option A) relies on natural attenuation and flushing processes to achieve reduction in toxicity of contaminants and is not as effective in meeting the remediation goals (in the short-term). The contaminated groundwater that is not captured by the extraction wells under Option A will continue to move downgradient towards the PASNY conduits. However, it does reduce the dominant risk through the periodic monitoring program and the potential for providing a warning against the use of contaminated groundwater. Under Option B, all of the contaminated groundwater would be captured by the four extraction wells. Hence Option B is clearly more effective. However, as stated earlier, the water quality in the fractured bedrock aquifer is not expected to be restored to below MCLs or background levels for at least 13 years.

  The preliminary groundwater modeling performed by CDM Federal shows that extraction wells 5D and PROP1 appear to capture all of the contaminated groundwater from the onsite plume and that extraction wells PROPRR1 and PROPRR2 appear to capture all of the contaminated groundwater from the offsite plume. These projected capture zones will have to be investigated further during the remedial design stage.

  Sludge from the chemical precipitation will require off-site disposal as a non-hazardous waste. For Sub-option 1, volatile organic compounds that would be emitted from the air stripper are estimated to be at levels below allowable discharge rates without any air pollution controls. For Sub-Option 2, chemical oxidation enhanced with UV photolysis, treatability studies may be required to establish operating parameters for site-specific conditions. All of the treatment technologies considered are reliable technologies. The discharge of the treated water to East Gill Creek is not expected to affect the wetlands or cause localized flooding. These impacts will have to be further investigated during remedial design.

- Implementability: Groundwater extraction, air stripping, and chemical oxidation enhaced with UV photolysis are well established reliable technologies. All of them are readily available commercially. Sufficient land is available onsite to build the treatment plant. A permit equivalent from the City of Niagara Falls POTW, NYSDEC and /or local authorities would have to be obtained for the proposed sanitary sewer connection. The 40 gpm

groundwater extraction rate is well within the reserve capacity of the POTW as designed and is available at present. The proposed groundwater extraction system (for both options A and B) would have to be installed in trenches dug after completion of the source control (soil) remedy. The future installation of a buried influent pipe can be expected to require a modest amount of administrative effort in obtaining the necessary approvals and coordination with EPA, NYSDEC and local engineering and public works departments. For Option B, an additional access agreement would have to be obtained from Conrail to install well PROPRR2. A portion of this buried pipeline may potentially have to cross areas designated as scrub-shrub wetlands.

- Cost: The capital cost of this alternative is estimated to be $1,388,400 (for Option A Sub-option 1), $1,492,100 (for Option A Sub-option 2), $1,208,800 (for Option B Sub-option 1), and $1,327,900 (for Option B Sub-option2). The estimated annual operation and maintenance costs of the options range from $4,465,000 (for Option A Sub-option 1) to $4,896,700 (for Option A Sub-option 2) for a period of 12 years. The estimated annual operation and maintenance costs of the options range from $6,735,400 (for Option B Sub-option 1) to $7,477,500 (for Option B Sub-option 2) for a period of 18 years. The present worth of these options, calculated at a discount rate of 5%, is, $5,853,400 (for Option A Sub-option 1), $6,388,800 (for Option A Sub-option 2), $7,944,200 (for Option B Sub-option 1), and $8,805,400 (for Option B Sub-option2) respectively. These costs are summarized in Tables 3-3 and 3-4.

Conclusion:

Alternative GW-6 (all options) will not be retained for detailed analysis, because even though it is capable of meeting the remediation goals for the Forest Glen site, it is more expensive than alternative GW-4 and does not provide any added level of protection of human health and the environment.

3.3 SUMMARY AND DISCUSSION OF RETAINED REMEDIAL ALTERNATIVES

Based on the screening evaluation of effectiveness, implementability, and cost, Alternatives GW-2, GW-3 and GW-6 have been eliminated from further consideration in the detailed analysis presented in Section 4.0. Options A and B for remedial alternatives GW-4 and GW-5 and the No Action alternative (GW-1) will be retained. It should be noted that treatment alternatives GW-4 and GW-5 are designed to capture some or all of the contaminated groundwater beneath the Forest Glen property and are not expected to restore the water quality of the fractured bedrock aquifer. They are however expected to provide a significant reduction in the mass of contaminants that are present in the aquifer to levels below Federal and State MCLs.

TABLE 3-1

AVERAGE CONCENTRATIONS FOR ENTIRE PLUME

ANALYTE	CONC. (ug/L)
Vinyl chloride	69
1,1-Dichloroethene	7
1,1-Dichloroethane	28
1,2-Dichloroethene (total)	336
1,1,1-Trichloroethane	29
Trichloroethene	43
Total Organic Carbon	4,800
Iron	10,984
Manganese	2,186
Calcium	199,143
Magnesium	88,257

Procedures for estimating the Average Concentrations:
Data from monitoring wells MW-3, -4, -5, -6, -7 and -8 collected in four rounds of sampling were used to calculate average concentrations.
At each well in the plume, for a given detected contaminant, the highest concentration from all rounds of sampling is retained for calculating the average concentrations. For a given contaminant, the arithmetic mean of the retained concentrations from the wells is reported as the average concentration. The detection limit is used for concentrations below the detection limit.

TABLE 3-2

AVERAGE CONCENTRATIONS FOR OFF-SITE PLUME

ANALYTE	CONC. (ug/L)
Vinyl chloride	22
1,1-Dichloroethene	5
1,1-Dichloroethane	8
1,2-Dichloroethene (total)	53
1,1,1-Trichloroethane	7
Trichloroethene	5

Procedures for estimating the Average Concentrations:
Data from monitoring wells MW-7 and -8 collected in four rounds of sampling were used to calculate average concentrations.
At each well in the plume, for a given detected contaminant, the highest concentration from all rounds of sampling is retained for calculating the average concentrations. For a given contaminant, the arithmetic mean of the retained concentrations from the wells is reported as the average concentration. The detection limit is used for concentrations below the detection limit.

TABLE 3-3

FOREST GLEN GROUNDWATER REMEDIATION
SUMMARY OF COST ESTIMATES FOR ON-SITE PLUME REMEDIATION ALTERNATIVES*

Alternative Number	Alternative	Capital Cost	O & M COSTS Net Present Worth	TOTAL COST
GW-1	No Action	$0	$35,000	$35,000
GW-2	Monitored Natural Attenuation	$392,200	$3,173,800	$3,566,000
GW-3	Enhanced Anaerobic In-Situ Bioremediation**	$695,700	$2,906,900	$3,602,600
GW-4	Groundwater Extraction and POTW Discharge (Off-Site Natural Attenuation)	$683,300	$3,431,900	$4,115,200
GW-5	Groundwater Extraction, Treatment and Surface Water Discharge (Off-Site Natural Attenuation)			
5.1	Chemical Precipitation and Air Stripping	$1,328,800	$4,183,200	$5,512,000
5.2	Chemical Precipitation and Chemical Oxidation Enhanced with UV Photolysis	$1,432,600	$4,615,600	$6,048,200
GW-6	Groundwater Extraction, Treatment and POTW Discharge (Off-Site Natural Attenuation)			
6.1	Chemical Precipitation and Air Stripping	$1,388,400	$4,465,000	$5,853,400
6.2	Chemical Precipitation and Chemical Oxidation Enhanced with UV Photolysis	$1,492,100	$4,896,700	$6,388,800

* On-Site pump and treat options also include off-site natural attenuation
** Enhanced Anaerobic In-Situ Bioremediation is for both on-site and off-site plumes

TABLE 3-4

FOREST GLEN GROUNDWATER REMEDIATION
SUMMARY OF COST ESTIMATES FOR ON-SITE AND OFF-SITE PLUME REMEDIATION ALTERNATIVES

Alternative Number	Alternative	Capital Cost	O & M COSTS Net Present Worth	TOTAL COST
GW-1	No Action	$0	$35,000	$35,000
GW-2	Monitored Natural Attenuation	$392,200	$3,173,800	$3,566,000
GW-3	Enhanced Anaerobic In-Situ Bioremediation	$695,700	$2,906,900	$3,602,600
GW-4	Groundwater Extraction and POTW Discharge	$453,200	$4,753,400	$5,206,600
GW-5	Groundwater Extraction, Treatment and Surface Water Discharge			
5.1	Chemical Precipitation and Air Stripping	$1,139,600	$6,179,300	$7,318,900
5.2	Chemical Precipitation and Chemical Oxidation Enhanced with UV Photolysis	$1,258,600	$6,920,200	$8,178,800
GW-6	Groundwater Extraction, Treatment and POTW Discharge			
6.1	Chemical Precipitation and Air Stripping	$1,208,800	$6,735,400	$7,944,200
6.2	Chemical Precipitation and Chemical Oxidation Enhanced with UV Photolysis	$1,327,900	$7,477,500	$8,805,400

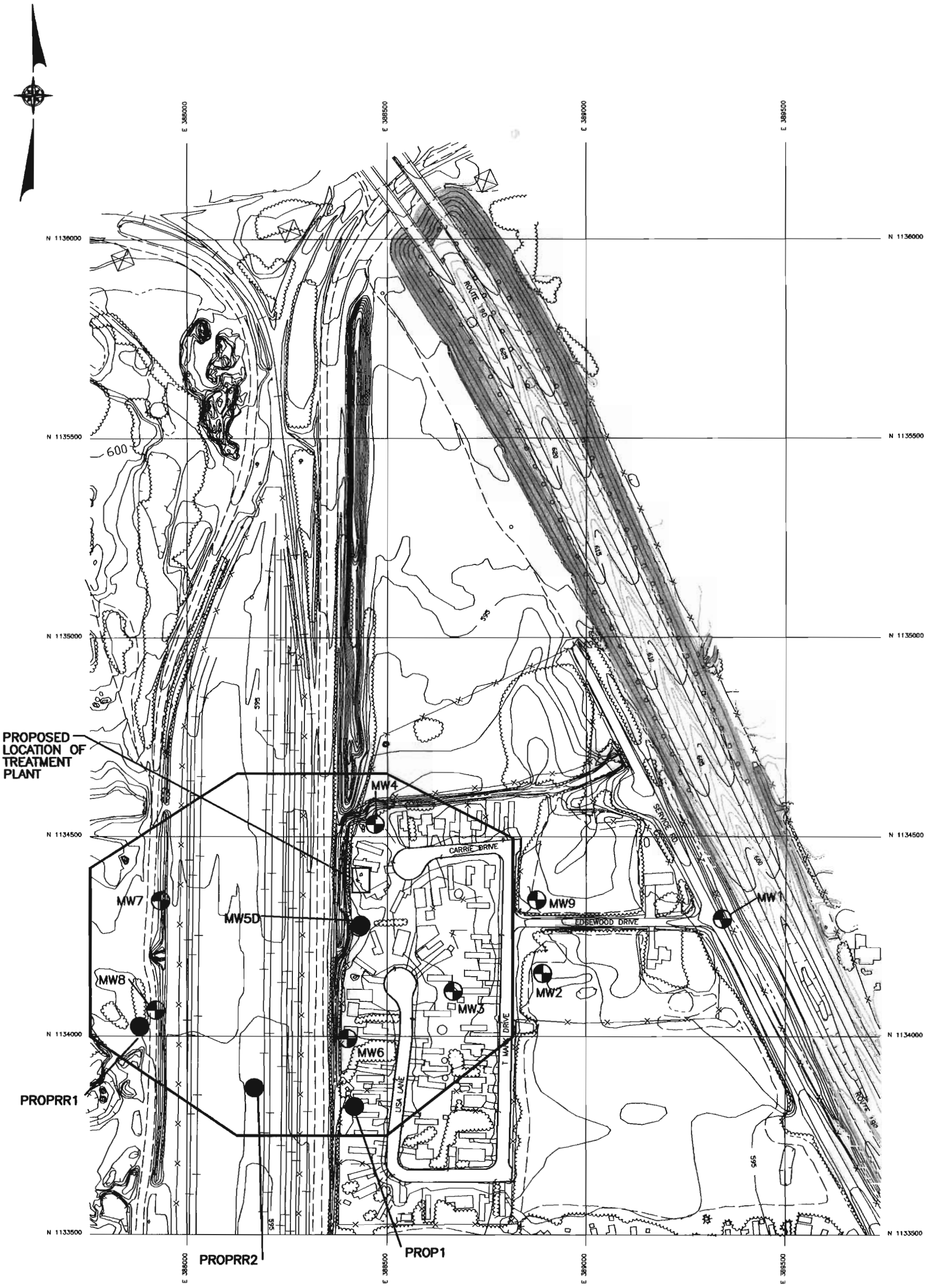

FIGURE 3-1

LOCATION OF PROPOSED TREATMENT SYSTEM AND EXTRACTION WELLS

WORK ASSIGNMENT 053-2L3U

Forest Glen Site, Niagara Falls, New York

CDM FEDERAL PROGRAMS CORPORATION

a subsidiary of Camp Dresser & McKee Inc.

4.0 DETAILED ANALYSIS OF ALTERNATIVES

This section presents a detailed description and analysis of each remedial alternative that passed the initial screening evaluation in Section 3.0. Section 4.1 provides a list of these alternatives that are subject to detailed analysis. Section 4.2 briefly describes the evaluation process and the nine criteria (defined in Section 1.1.3) used to analyze each remedial alternative. Section 4.3 addresses the alternatives for groundwater contaminated primarily with volatile chlorinated aliphatic hydrocarbons and inorganics like iron and manganese.

4.1 INTRODUCTION

This section analyzes the assembled alternatives in order to provide a basis for the selection of a remedy for the Forest Glen site. The extent to which alternatives are analyzed during the detailed evaluation is determined, to a large degree, by the available data and the use of best engineering judgement.

The alternatives to be evaluated include the following:

Alternative GW-1:	No Action
Alternative GW-4(A and B):	Extraction of Groundwater and Discharge to POTW
Alternative GW-5(A and B):	Extraction of Groundwater, Treatment with Chemical Precipitation followed by Air Stripping / Chemical Oxidation Enhanced with UV Photolysis and Discharge to Surface Water

Please note that the evaluation of the groundwater alternatives have assumed that the soils (i.e. source areas) have been remediated.

4.2 EVALUATION PROCESS

The detailed description of the remedial alternatives includes the following:

- A description of the alternative, including the technologies comprising the alternative;
- A description of engineering, safety, environmental, public health, or other considerations that affect the feasibility of the alternative;
- The aspects of the groundwater contamination problem that the alternative will or will not control; and
- A preliminary conceptual engineering design including necessary facilities, equipment, and construction items. A breakdown of the quantities, dimensions, and sizing of major components of the conceptual design are provided as a basis for cost estimation. The level of detail in the preliminary design is focused on providing cost estimates with an accuracy in the range of -30 percent to +50 percent

Each alternative is evaluated against specific criteria on the basis of the statutory requirements of CERCLA Section 121, program initiatives promulgated in the National Contingency Plan, and site-specific experience gained in the Superfund program. A total of nine criteria are used in the

alternative evaluation. The first two criteria are threshold criteria which must be met by each alternative. The next five criteria are the primary balancing criteria upon which the analysis is based. The final two criteria are referred to as modifying criteria and are applied, following the public comment period, to evaluate state and community acceptance.

The two threshold criteria are:

- Overall Protection of Human Health and the Environment; and
- Compliance with ARARs.

The five primary balancing criteria upon which the analysis is based, are:

- Long-term Effectiveness and Permanence;
- Reduction of Toxicity, Mobility or Volume through Treatment;
- Short-term Effectiveness;
- Implementability; and
- Cost.

The two modifying criteria will be evaluated following comments on the Proposed Plan, and will be described in the ROD for the site. These criteria are:

- State Acceptance; and
- Community Acceptance.

Each of these nine criteria were described in Section 1.1.3 and are assessed in the following sections to allow a thorough and consistent analysis of the remedial alternatives. Since the public and the State have not been provided with a formal opportunity to review the detailed analysis, only the first seven criteria have been discussed in this FS report.

It must be stressed that the alternatives described in the following analyses are conceptual. Any characteristics of these alternatives (such as remediation locations, depths, and extraction rates) should be considered to be approximate.

In addition, it is recognized that some of the alternatives may potentially impact the on-site scrub-shrub wetlands to a minor extent. During remedial design, the estimates of the potential wetland impacts will be refined and restoration and/or mitigation methods will be developed, if necessary.

4.3 DETAILED ANALYSES OF GROUNDWATER ALTERNATIVES

4.3.1 ALTERNATIVE GW-1: NO ACTION

Description:

This alternative includes a single sampling event and a review of site conditions at the end of five years to determine whether or not the contamination has spread. Under this alternative, groundwater samples would be collected from eight existing shallow bedrock monitoring wells (MW-2S, MW-3S, MW-4S, MW-5S, MW-6S, MW-7S, MW-8S and MW-9S) and eight existing deep bedrock monitoring wells (MW-2D, MW-3D, MW-4D, MW-5D, MW-6D, MW-7D, MW-8D and MW-9D). All samples would be analyzed for TCL organics and TAL inorganics. A review of site conditions would occur at the end of five years to determine whether or not the contamination has spread. If necessary, appropriate action would be considered at that time. Also, the groundwater that is purged from these monitoring wells during that single sampling event will have to be sent for offsite disposal as a hazardous waste.

Analysis:

Short-Term Effectiveness

In the short-term, this alternative would not remediate the groundwater at the site. No construction activities are associated with this alternative so it does prevent the potential for any ingestion and inhalation of contaminants from the groundwater. The persons performing the one-time sampling activities would follow OSHA health and safety procedures and wear the necessary personal protective equipment. There are no short-term risks to site workers from the groundwater; therefore, this alternative is protective of site workers.

The contaminant plume is not discharging into any onsite surface water bodies; therefore, in the short-term, this alternative is protective of the environment.

Long-Term Effectiveness and Permanence

- Magnitude of Residual Risks: This alternative relies on natural attenuation and flushing processes like biodegradation, dispersion, dilution through advection and recharge, adsorption, and volatilization that would ultimately tend to reduce the concentration of contaminants. However, this alternative will not restore the water quality of the fractured bedrock aquifer for a very long time. The contaminated groundwater will continue to move downgradient towards the PASNY conduits. Future potential risks from the possible use of groundwater for drinking and showering due to inhalation and ingestion would continue indefinitely. Emergency measures may have to be undertaken in the event a future risk arises, because this alternative does not reduce long-term risks.

- Adequacy of Controls: This alternative does not provide for any controls on the use of the fractured bedrock aquifer by private residences or commercial/industrial establishments.

- Reliability of Controls: There are no controls associated with this alternative.

Reduction of Toxicity, Mobility, or Volume through Treatment

This alternative does not involve any containment or removal of contaminants. It does provide for some limited treatment of the organics in the groundwater by the natural attenuation processes discussed earlier. These biodegradation processes may convert some of the organic contaminants to carbon dioxide, chlorides, and water; thereby, partially reduce the toxicity of the groundwater. The natural dilution of the contaminated groundwater would also reduce the toxicity, but the volume of contaminated groundwater would increase.

Implementability

- Technical Feasibility: This alternative only requires using standard sampling and analytical methods to implement; therefore it is very easy to implement.

- Administrative Feasibility: All the monitoring wells are not on the Forest Glen property. Until the one-time sampling event occurs, the only administrative task would be to protect the integrity of the monitoring wells. Those tasks including offsite disposal of the purged groundwater are very simple to implement.

- Availability of Services and Materials: All the services and materials needed to implement this alternative are readily available.

Costs

The net present worth of this alternative, calculated at a 5% discount rate is estimated to be $35,000.

- Capital Cost: There is no capital cost associated with this alternative.

- O & M Cost: The annual operation and maintenance costs for this alternative are estimated at $35,000 (one-time cost at the end of 5 years).

A summary of the details of the cost estimate for this alternative is given in Table 4-1.

Compliance with ARARs

This alternative does not meet chemical-specific Federal and State ARARs (MCLs) for the groundwater at the present time and this situation is not expected to be changed for many years. Since there is no active remedial action associated with this alternative, action-specific ARARs do not apply.

Overall Protection of Human Health and the Environment

This alternative relies on natural processes of dispersion and biotransformation reactions to restore groundwater quality over a relatively long time frame. There are no health risks to site workers for the short or long-term because there are no direct exposure pathways. Future potential human health risks from the possible use of groundwater for drinking and showering due to inhalation and

ingestion would continue indefinitely. As the plume migrates, the volume of contaminated groundwater in the fractured bedrock aquifer would continue to increase and thereby degrade the environment. The contaminant plume is not discharging into any onsite surface water bodies; therefore, in the short-term, this alternative is protective of the environment.

State Acceptance

Not addressed at this time.

Community Acceptance

Not addressed at this time.

4.3.2 ALTERNATIVE GW-4(A AND B): EXTRACTION OF GROUNDWATER AND DISCHARGE TO POTW

Description:

The major features of this remedial alternative include: groundwater extraction (pumping and collection) from the Forest Glen plume as depicted in Figures 10, 10A and 11 of Appendix B; discharge of the untreated water to the City of Niagara Falls POTW; and a performance monitoring program.

For alternative GW-4, Option A consists of groundwater extraction from the onsite plume using two extraction wells and monitored natural attenuation of the offsite plume. Option B consists of groundwater extraction from the onsite and offsite plume using four extraction wells. Table 3-1 presents the average concentration of the groundwater contaminants in the entire (onsite and offsite) oval shaped plume as shown in Figure 2-1. Table 3-2 presents the average concentration of the groundwater contaminants in the offsite plume (west of the Subdivision beneath the Conrail Foote Railroad yard).

Groundwater Extraction System

Under Option A, groundwater would be extracted at an average rate of 30 gpm from the onsite plume using extraction wells 5D and PROP1. As stated in Appendix B, well 5D and well PROP1 would be pumped at 15 gpm each, and groundwater would be extracted from the onsite shallow and deep portions of the Lockport Dolomite fractured bedrock aquifer. It has been estimated that this groundwater extraction would continue for a seven year period (see Appendix C).

Under Option B, groundwater would be extracted at an average rate of 40 gpm from the onsite and offsite plume using extraction wells 5D, PROP1, PROPRR1 and PROPRR2. As stated in Appendix B, wells 5D, PROP1, PROPRR1 and well PROPRR2 would be pumped at 10 gpm each, and groundwater would be extracted from both the onsite and offsite shallow and deep portions of the Lockport Dolomite fractured bedrock aquifer. The addition of wells PROPRR1 and PROPRR2 to the extraction system would allow capture of contaminated groundwater from offsite areas west of the Subdivision beneath the Conrail Foote Railroad yard. It has been estimated that this groundwater extraction would continue for a thirteen year period (see Appendix C).

Each extraction well would be constructed of 6 inch diameter stainless steel casing installed 5 feet into competent rock (approximately 20 feet below ground surface) with an open hole to a depth of 70 feet. The well would be constructed with a buried concrete vault (4' x 6' x 6') that is flush with the ground surface. Each extraction well would be equipped with a submersible pump, a level probe and a flowmeter. It would also be equipped with an automatic/manual control to protect the pump if the well runs dry and/or to protect against overflow conditions at the storage tank. From each well the extracted groundwater would be conveyed through a 2 inch nominal diameter Schedule 80 PVC carrier pipe enclosed within a 4 inch nominal diameter Schedule 80 PVC containment pipe. At suitable locations, these pipes would be manifolded together and would be connected to the onsite storage tank. This piping would be buried below the frost line after implementation of the source control (soil) remedy so that most of the site could be restored to beneficial use. A power conduit and control line conduit would also be installed in the same trench as the groundwater extraction line. This pipe would be placed in steel sleeves encased in concrete lined tunnels beneath railroad crossings in the Conrail Foote Railroad yard. This pumping is expected to continue for the estimated duration stated above for Options A and B, or until the contaminant mass is reduced such that contaminant concentrations show no significant change even after extraction is stopped for an extended period.

Monitored Natural Attenuation For Option A

The offsite portion of the plume (which has much lower concentrations than the onsite plume as shown in Table 3-2) would not be captured and it would be allowed to naturally attenuate. For this option, a baseline investigation and groundwater modeling to determine and evaluate intrinsic biodegradation and other natural attenuation processes would be performed as described in section D.1.7 of Appendix D. Since the offsite portion of the plume has much lower contaminant concentrations, it has been estimated that approximately 12 years would be required to attain Federal and State MCLs through MNA for the offsite groundwater. After initial baseline conditions are established, existing and new monitoring wells offsite would be used to conduct a long-term groundwater monitoring program which would track offsite contaminant migration in the Lockport Dolomite bedrock aquifer for an estimated 12 year period.

Onsite Storage Tank And Discharge System

For both Options A and B, the extracted groundwater would be collected in an onsite storage tank with a 12 hour holding capacity. The storage tank would be housed inside a pre-engineered steel building with a small office for the operator. The effluent from this storage tank would be piped through a continuous reading totalizing flowmeter with a digital display to the sanitary sewer. The effluent pipe would be connected to a refrigerated composite sampler that would allow for collection of a 24-hour composite sample as required by the City of Niagara Falls POTW. The collected groundwater would be discharged to the City of Niagara Falls POTW via a proposed connection to an existing sanitary sewer manhole in the cul-de-sac on Carrie Drive. The locations of the proposed storage tank and extraction wells are shown in Figure 3-1.

Offsite Treatment System

At the City of Niagara Falls POTW contaminated groundwater would be treated using activated carbon adsorption to action levels defined by the Federal and State MCLs for public drinking water supplies or natural background, or Federal and State Surface Water Quality Standards, as appropriate.

Performance Monitoring Program

Quarterly sampling from the storage tank effluent pipe would be conducted as required by the City of Niagara Falls POTW. These samples would be analyzed for TSS, soluble organic carbon, chloroform, dichloroethenes, toluene, benzene, trichloroethanes, trichloroethene, tetrachloroethene, vinyl chloride, monochlorotoluenes, and total phenols. Quarterly reports would be prepared and submitted to EPA and the POTW. An annual inspection of the onsite facilities would be conducted with inspectors from the POTW as required.

For the natural attenuation of the offsite plume under Option A, samples collected from ten new and four existing monitoring wells (MW-7S, MW-8S, MW-7D and MW-8D) would be analyzed on a quarterly basis for TCL organics, TAL inorganics, BOD, COD, TDS, TSS, dissolved organic carbon, oxygen, and carbon dioxide, redox potential, methane, ethane, ethene, ferrous iron, nitrate and sulfate. The natural attenuation and migration of the offsite contamination plume would be assessed annually utilizing the data collected during the monitoring activities.

Sixteen existing monitoring wells (MW-2S, MW-3S, MW-4S, MW-5S, MW-6S, MW-7S, MW-8S, MW-9S, MW-2D, MW-3D, MW-4D, MW-5D, MW-6D, MW-7D, MW-8D and MW-9D) at the site would be used to conduct an annual long-term groundwater monitoring program which would track contaminant migration/plume containment in the aquifer for at least 5 years beyond the estimated duration of groundwater extraction. All samples would be collected on a quarterly basis and analyzed for TCL organics and TAL inorganics. The data would be compared to action levels defined by the Federal and State MCLs for public drinking water supplies or natural background, as appropriate. In cases where MCLs or groundwater quality standards have not been promulgated, the cleanup level would be defined as the upper contaminant limit for which the average lifetime risk is within the range of 10^{-4} to 10^{-6} (for carcinogens) or for which the cumulative hazard index is less than one (for non-carcinogens). The contaminant mass removal and containment of the plume would be assessed annually utilizing the data collected during all of the monitoring activities stated above.

Analysis:

Short-Term Effectiveness

In the short-term, this alternative would partially remediate the groundwater at the site. The workers performing the sampling activities, construction of the new monitoring wells and the new buried influent piping from the extraction wells to the influent storage tank would have health and safety training and use appropriate health and safety protocols to minimize any unacceptable exposure to the contamination by inhalation, direct contact or ingestion. Therefore, there are no short-term risks to site workers and this alternative is protective of site workers.

To the best of our knowledge, there are no commercial or industrial or private wells within the contaminated plume at present, therefore this alternative is protective of the public health. Potential risks associated with this alternative from future use of the bedrock aquifer are partially reduced because of the periodic monitoring of the plume.

The contaminant plume is not discharging into any onsite surface water bodies; therefore, in the short-term, this alternative is protective of the environment.

Long-Term Effectiveness and Permanence

- Magnitude of Residual Risks: Long-term risks do exist to workers at the site from potential inhalation of vapors from the storage tank or the sanitary sewer. However, this risk from inhalation of vapors has been minimized by venting the tank and the use of protective health and safety equipment. Completion of the remedial action is not anticipated for at least 13 years, so all potential health risks to humans or the environment from the organic contaminants would not be completely eliminated for a long time. The waste streams produced by the sampling would need to be managed as a hazardous or non-hazardous waste as determined by analytical testing and there is some risk associated with handling these generated wastes. Option A of this alternative does capture all of the contaminated groundwater. The preliminary groundwater modeling performed by CDM Federal shows that extraction wells 5D and PROP1 appear to capture all of the contaminated groundwater from the onsite plume and that extraction wells PROPRR1 and PROPRR2 appear to capture all of the contaminated groundwater from the offsite plume. These projected capture zones will have to be investigated further during the remedial design stage.

  Under Option A, the offsite portion of the plume that has much lower contaminant concentrations, relies on natural attenuation and flushing processes to achieve reduction in toxicity of contaminants. The contaminated groundwater that is not captured by the extraction wells under Option A will continue to move downgradient towards the PASNY conduits.

- Adequacy of Controls: The most probable pathway for long-term risk is from potential air emissions. There are no specific air pollution controls provided on the storage tank other than vents. It has been estimated that all of the vinyl chloride present in the groundwater would likely volatilize in the sanitary sewer before the groundwater reaches the POTW. Further, the amount of activated carbon used at the POTW is very large (approximately 5 million pounds). Hence any vinyl chloride that does reach the POTW would be effectively removed. The 40 gpm groundwater extraction rate is well within the reserve capacity of the POTW as designed and is available at present. At the City of Niagara falls POTW, the GAC system has been designed to have at least two carbon adsorbers operating in series provides very adequate control of long-term risks. The downstream adsorber is essentially a backup to the upstream adsorber in the event of an unexpected breakthrough of organics occurs much sooner than expected. The possible release of contaminated groundwater from the extraction operation is controlled by the use of containment piping with sensors to detect leaks. This would provide adequate control of contaminated groundwater leaking onto the site. The storage tank would be constructed within a curbed area capable of storing all the groundwater from the largest vessel and it has alarms and sensors that would shut down the system if it detected the presence of water at a predetermined level.

- Reliability of Controls: All of the treatment technologies considered are reliable technologies. The onsite storage tank and the City of Niagara Falls treatment plant has been designed with many safety interlocks, alarms and controls that provide

adequate warnings to the plant operators if and when certain process or other external failures do occur. Regular O & M, with the necessary replacement of defective components (pumps, switches, transducers, etc.) from the onsite spares inventory would allow for a very reliable operation. Redundancy has been built into the system with extra pieces of critical components (spare blowers and pumps) that provide a very high reliability of controlling long-term risk.

Reduction of Toxicity, Mobility, or Volume through Treatment

This alternative does provide for considerable reduction of toxicity, mobility and volume of the contaminant plume. All the organic contaminants in the extracted groundwater are either volatilized in the sewer or are collected on liquid phase carbon (GAC) at the POTW. When the carbon is regenerated, the organic contaminants would be converted to carbon dioxide, water and hydrochloric acid, thereby eliminating the toxicity. The extraction system for this alternative has been designed to capture contaminated groundwater up to a depth of 70 feet which would eliminate the mobility of the contaminants in the environment and thus reduce the volume of the contaminant plume.

Implementability

- Technical Feasibility: All the technologies for implementation of this alternative are very well established. However, this alternative does involve numerous process steps that must be properly executed (at the POTW). In addition, skilled operators are needed to properly operate and maintain the treatment system at the POTW.

- Administrative Feasibility: The City of Niagara Falls treatment plant has already been built and has been in operation for the past several years. The proposed groundwater extraction system (for both options A and B) would have to be installed in trenches dug after completion of the source control (soil) remedy. The future installation of a buried influent pipe can be expected to require a modest amount of administrative effort in obtaining the necessary approvals and coordination with EPA, NYSDEC and local engineering and public works departments. For Option B, an additional access agreement would have to be obtained from Conrail to install well PROPRR2. A portion of this buried pipeline may potentially have to cross areas designated as scrub-shrub wetlands.

- Availability of Services and Materials: Almost all of the services and materials needed to implement this alternative are readily available commercially.

Costs

The net present worth of this alternative, calculated at a 5% discount rate is estimated to be $4,115,200 (for Option A) and $5,206,600 (for Option B).

- Capital Cost: The capital cost of this alternative is estimated to be $683,300 (for Option A) and $453,200 (for Option B).

- O & M Cost: The annual operating and maintenance costs for this alternative are estimated to be $3,431,900 (Option A for 12 years) and $4,753,400 (Option B for 18 years) and include annual reviews of the site conditions for 5 years beyond the respective durations of groundwater extraction.

A summary of the details of the cost estimate for this alternative is given in Tables 4-2 and 4-3.

Compliance with ARARs

This alternative would eventually meet chemical-specific Federal and State ARARs for the organic and inorganic contaminants in all of the groundwater beneath the site. Although extracted groundwater would be treated to meet Federal and State ARARs, it is estimated that many of the remediation goals would be attained over a long period of time. As stated earlier, the water quality in the fractured bedrock aquifer is not expected to be restored to below MCLs or background levels for at least 13 years. This alternative is expected to meet location-specific and action-specific Federal and State ARARs.

Overall Protection of Human Health and the Environment

The extraction system for this alternative has been designed to capture contaminated groundwater up to a depth of 70 feet which would eliminate the mobility of the contaminants in the environment and thus reduce the volume of the contaminant plume. Completion of the remedial action is not anticipated for at least 13 years, so all potential health risks to humans or the environment from the organic contaminants would not be completely eliminated for a long time. This alternative uses reliable, well established technologies and is considerably effective in protecting potential risks to human health and the environment. Option B is more effective than Option A.

State Acceptance

Not addressed at this time.

Community Acceptance

Not addressed at this time.

4.3.3 ALTERNATIVE GW-5(A AND B): EXTRACTION OF GROUNDWATER, TREATMENT WITH CHEMICAL PRECIPITATION FOLLOWED BY AIR STRIPPING / CHEMICAL OXIDATION ENHANCED WITH UV PHOTOLYSIS AND DISCHARGE TO SURFACE WATER

Description:

The major features of this remedial alternative include: groundwater extraction (pumping and collection) from the Forest Glen plume as depicted in Figures 10, 10A and 11 of Appendix B; groundwater treatment to MCLs or natural background, or surface water quality standards, as appropriate; discharge of the treated water; and a performance monitoring program.

For alternative GW-5, Option A consists of groundwater extraction from the onsite plume using two extraction wells and monitored natural attenuation of the offsite plume. Option B consists of groundwater extraction from the onsite and offsite plume using four extraction wells. Table 3-1 presents the average concentration of the groundwater contaminants in the entire (onsite and offsite) oval shaped plume as shown in Figure 2-1. Table 3-2 presents the average concentration of the groundwater contaminants in the offsite plume (west of the Subdivision beneath the Conrail Foote Railroad yard).

Groundwater Extraction System

Under Option A, groundwater would be extracted at an average rate of 30 gpm from the onsite plume using extraction wells 5D and PROP1. As stated in Appendix B, well 5D and well PROP1 would be pumped at 15 gpm each, and groundwater would be extracted from the onsite shallow and deep portions of the Lockport Dolomite fractured bedrock aquifer. It has been estimated that this groundwater extraction would continue for a seven year period (see Appendix C).

Under Option B, groundwater would be extracted at an average rate of 40 gpm from the onsite and offsite plume using extraction wells 5D, PROP1, PROPRR1 and PROPRR2. As stated in Appendix B, wells 5D, PROP1, PROPRR1 and well PROPRR2 would be pumped at 10 gpm each, and groundwater would be extracted from both the onsite and offsite shallow and deep portions of the Lockport Dolomite fractured bedrock aquifer. The addition of wells PROPRR1 and PROPRR2 to the extraction system would allow capture of contaminated groundwater from offsite areas west of the Subdivision beneath the Conrail Foote Railroad yard. It has been estimated that this groundwater extraction would continue for a thirteen year period (see Appendix C).

Each extraction well would be constructed of 6 inch diameter stainless steel casing installed 5 feet into competent rock (approximately 20 feet below ground surface) with an open hole to a depth of 70 feet. The well would be constructed with a buried concrete vault (4' x 6' x 6') that is flush with the ground surface. Each extraction well would be equipped with a submersible pump, a level probe and a flowmeter. It would also be equipped with an automatic/manual control to protect the pump if the well runs dry and/or to protect against overflow conditions at the storage tank. From each well the extracted groundwater would be conveyed through a 2 inch nominal diameter Schedule 80 PVC carrier pipe enclosed within a 4 inch nominal diameter Schedule 80 PVC containment pipe. At suitable locations, these pipes would be manifolded together and would be connected to the onsite storage tank. This piping would be buried below the frost line after implementation of the source control (soil) remedy so that most of the site could be restored to beneficial use. A power conduit and control line conduit would also be installed in the same trench as the groundwater extraction line. This pipe would be placed in steel sleeves encased in concrete lined tunnels beneath railroad crossings in the Conrail Foote Railroad yard. This pumping is expected to continue for the estimated duration stated above for Options A and B, or until the contaminant mass is reduced such that contaminant concentrations show no significant change even after extraction is stopped for an extended period.

Monitored Natural Attenuation for Option A

The offsite portion of the plume (which has much lower concentrations than the onsite plume as shown in Table 3-2) would not be captured and it would be allowed to naturally attenuate. For this option, a baseline investigation and groundwater modeling to determine and evaluate intrinsic

biodegradation and other natural attenuation processes would be performed as described in section D.1.7 of Appendix D. Since the offsite portion of the plume has much lower contaminant concentrations, it has been estimated that approximately 12 years would be required to attain Federal and State MCLs through MNA for the offsite groundwater. After initial baseline conditions are established, existing and new monitoring wells offsite would be used to conduct a long-term groundwater monitoring program which would track contaminant migration in the Lockport Dolomite bedrock aquifer for an estimated 12 year period.

Onsite Groundwater Treatment Plant

For both Options A and B, the extracted groundwater would be collected at the onsite groundwater treatment plant in an onsite influent storage tank with a 12 hour holding capacity. The storage tank would be housed inside a pre-engineered steel building with a small office for the operator. Treatment of the extracted groundwater would consist of chemical precipitation to remove inorganics like iron and manganese. It would then be followed by either air stripping (sub-option 1) or chemical oxidation enhanced with ultra-violet (UV) photolysis (sub-option 2) to remove volatile chlorinated aliphatic hydrocarbons from the contaminated groundwater.The treated groundwater would be stored in an onsite effluent storage tank with a 12 hour holding capacity before it is discharged to East Gill Creek via a proposed outfall located south west of the cul-de-sac on Carrie Drive. The effluent from this storage tank would be piped through a continuous reading totalizing flowmeter with a digital display to the proposed outfall. The effluent pipe would be connected to a refrigerated composite sampler that would allow for collection of a 24-hour composite sample. The locations of the proposed groundwater treatment plant and extraction wells are shown in Figure 3-1.

At the onsite treatment plant, contaminated groundwater would be treated to action levels defined by the Federal and State MCLs for public drinking water supplies or natural background,or Federal and State Surface Water Quality Standards, as appropriate. In cases where MCLs or surface water quality standards have not been promulgated, the cleanup level would be defined as the upper contaminant limit for which the average lifetime risk is within the range of 10^{-4} to 10^{-6} (for carcinogens) or for which the cumulative hazard index is less than one (for non-carcinogens).

Inorganics Treatment

High concentrations of iron and manganese in the groundwater could precipitate and foul the process equipment designed to remove or destroy organic contaminants (air stripper or chemical oxidation system enhanced with UV photolysis). Therefore, pretreatment of the extracted groundwater would be included as part of this alternative to remove the iron and manganese before reaching the process equipment for treating the organic contaminants. The pretreatment would consist of precipitation of the metals and clarification, combined with filtration.

The proposed metals precipitation process would consist of aeration and pH adjustment for enhanced precipitation, flash mixing for coagulation, polymer addition, flocculation, clarification, and neutralization. The influent storage tank allows for equalization of hydraulic and groundwater quality variability. This also allows minor repairs or maintenance to be performed without shutting down the groundwater extraction system. It is equipped with a level sensor, alarm and low level shut off control for a forward flow pump, which is utilized to transfer equalized groundwater to the inorganics treatment system. From the influent storage tank, the extracted groundwater would be

pumped into an aeration tank where soluble ferrous compounds would be oxidized to less soluble ferric compounds by the oxygen in the air stream. The aerated groundwater would be pumped into a flocculation tank.. A reagent feed system would monitor a controlled amount of sodium hydroxide and sodium hypochlorite into the extracted groundwater. The feed rate of the sodium hydroxide and sodium hypochlorite would be provided by feedback control of the pH in the second chamber of the flocculation tank. The pH would be maintained between 10 and 10.5 to ensure removal of the manganese compounds. The flocculation tank would have two chambers: the first chamber, a mix tank with a 15 minute residence time, would provide flash mixing of the reagents and polymer added by a polymer feed system to enhance floc formation; and the second chamber would have a residence time of one hour to provide sufficient time for formation and settling of floc. The flocculation tank would be elevated for gravity flow into an inclined parallel plate clarifier. The clarifier would provide a surface loading rate of approximately 0.40 gpm/sq ft to allow for thorough removal of the solids.

A sulfuric acid feed system would feed sulfuric acid to a flash mixing vessel integrally mounted to the clarifier slump so that the pH of the groundwater is reduced to 7 before it is filtered. The sulfuric acid feed rate would be controlled by the pH measured directly in the flash mixing vessel. The flash mixing tank would be sized to provide a minimum detention time of 20 seconds at the maximum flow.

A mechanical thickener, across the width of the sludge collection chamber of the inclined plate clarifier, would move the solids to a discharge nozzle. Settled solids removed from the clarifier would be pumped from the unit to the sludge thickener. A sludge level detector installed in the sludge chamber of the clarifier would detect the sludge/water interface and provide automatic on/off control of the sludge pump. An air operated double diaphragm pump with air regulator, filter, lubricator and solenoid valve would provide intermittent (or continuous) sludge transfer from the clarifier to a sludge storage tank. Sludge from the process train would be recycled back to the flocculation tank to increase the solids concentration and improve metals removal. A sludge recycle rate of approximately 1 to 3 percent of the forward flow would be used. To reduce the volume of sludge to be disposed of from the metals removal process, equipment would be provided to thicken and dewater the sludge prior to disposal off-site. Thickened sludge would be pumped to a thickened sludge holding tank. An air operated, diagram pump would be provided, to transfer the thickened sludge into holding tank. The sludge holding tank would have a capacity to provide a minimum sludge storage capacity of seven days. The thickened sludge would be pumped by a high pressure progressive cavity feed pump to a plate and frame press to dewater the sludge. The press would be operated one cycle per week and would produce a sludge cake containing approximately 50 percent solids. The filter cake would be emptied into a roll-off container and would be transported to an appropriate treatment/disposal facility by a licensed hauler.

Duplex dual media pressure filters (one standby) would be provided to minimize the loading of suspended solids to the downstream processes. Each filter would be backwashed at a time, while putting the remaining filter in service. Backwashing of each filter bed would be accomplished by introducing water through a bottom distributor at a rate of approximately 10 gpm/sq ft. Following the backwash cycle, the filter would rinsed to drain and set the bed, and to assure the removal of any turbidity which may remain in the bottom sector of the filter media or which may be introduced as a result of backwashing with unfiltered water. The duration of the service cycle for each filter is

estimated to be 24 hours. Effluent from the pressure filter would be pumped to the treatment processes for the removal or destruction of organic compounds described below.

Organics Treatment

Inorganics treatment would be followed by either air stripping (sub-option 1) or chemical oxidation enhanced with ultra-violet (UV) photolysis (sub-option 2) to remove volatile chlorinated aliphatic hydrocarbons from the contaminated groundwater.

Air Stripping

In Sub-option 1, groundwater would be pumped to the top of the air stripper and flow down through the packing, in countercurrent contact with the upflow of air. The air stripping tower (30 feet high) would be packed with 25 feet of 3.5 inch Lanpac polypropylene packing. The tower would be 1.5 feet in diameter and would be made of fiber reinforced plastic (FRP). The tower would also be equipped with a mist eliminator, inlet distributor, packing media support, and a built-in sump. The sump would have a level sensor and alarm to allow for proper control. Groundwater from the air stripper would be subsequently transferred to the effluent storage tank via a transfer pump. Forced air blowers (two - one plus one standby) having a capacity of 250 standard cubic feet per minute (scfm) @ 6 inches water column (WC) provide the required air flow through the tower that has been designed for a 40:1 air:water ratio. The blowers would be equipped with sensors and controls that are interlocked with the water transfer pump.

The air stripper discharge must comply with the requirements of NYS Air Guide-1, "Guidelines for the Control of Toxic Ambient Air Contaminants" (1991), and Air Guide-29, "Air Stripper and Soil Vapor Extraction Control Strategy". It is anticipated that no treatment is required for vapors discharged from the air stripper.

Chemical Oxidation Enhanced with UV Photolysis

For Sub-option 2, the proposed organics treatment system would treat groundwater with hydrogen peroxide and/or ozone in the presence of UV light. The peroxide or ozone forms hydroxyl radicals that are highly reactive in the presence of UV light with the organic constituents found in the groundwater at the site. The treatment system consist of a series of parallel stainless steel tubes containing the UV tubes in the center. Groundwater, mixed with small quantities of hydrogen peroxide and/or ozone flows through the tubes and the organic constituents are oxidized by the hydroxyl radicals in the presence of the UV light to carbon dioxide, water and chloride salts. The size of the system would be dependent on pilot testing performed at a vendor facility with the actual groundwater (possibly spiked with the volatile constituents to make up for volatilization losses during transport). In general, the retention time of groundwater through the tubes should be in the one to two minute range. The treated groundwater would be stored in an onsite efffluent storage tank with a 12 hour holding capacity.

Effluent Discharge System

The treated groundwater would be discharged to East Gill Creek via a proposed outfall located south west of the cul-de-sac on Carrie Drive. The effluent discharge pipe to East Gill Creek is buried and follows the western boundary of the site to an outfall structure constructed using riprap to dissipate energy and to provide protection from erosion.

Performance Monitoring Program

For the natural attenuation of the offsite plume under Option A, samples collected from ten new and four existing monitoring wells (MW-7S, MW-8S, MW-7D and MW-8D) would be analyzed on a quarterly basis for TCL organics, TAL inorganics, BOD, COD, TDS, TSS, dissolved organic carbon, oxygen, and carbon dioxide, redox potential, methane, ethane, ethene, ferrous iron, nitrate and sulfate. The natural attenuation and migration of the offsite contamination plume would be assessed annually utilizing the data collected during the monitoring activities.

Sixteen existing monitoring wells (MW-2S, MW-3S, MW-4S, MW-5S, MW-6S, MW-7S, MW-8S, MW-9S, MW-2D, MW-3D, MW-4D, MW-5D, MW-6D, MW-7D, MW-8D and MW-9D) at the site would be used to conduct an annual long-term groundwater monitoring program which would track contaminant migration/plume containment in the aquifer for at least 5 years beyond the estimated duration of groundwater extraction. All samples would be collected on a quarterly basis and analyzed for TCL organics and TAL inorganics. In addition, for Alternative GW-5, two samples would be collected from East Gill Creek (one upstream and one downstream of the proposed outfall) every quarter. The stream samples would be analyzed for TCL organics, TAL inorganics, and conventional water parameters (such as BOD, COD, TDS, TSS, etc.). The data would be compared to action levels defined by the Federal and State MCLs for public drinking water supplies or natural background, or Federal and State Surface Water Quality Standards, as appropriate. In cases where MCLs or surface water quality standards have not been promulgated, the cleanup level would be defined as the upper contaminant limit for which the average lifetime risk is within the range of 10^{-4} to 10^{-6} (for carcinogens) or for which the cumulative hazard index is less than one (for non-carcinogens). The contaminant mass removal and containment of the plume would be assessed annually utilizing the data collected during all of the monitoring activities stated above.

Analysis:

Short-Term Effectiveness

In the short-term, this alternative would partially remediate the groundwater at the site. The workers performing the sampling activities, construction of the new monitoring wells and the new buried influent piping from the extraction wells to the influent storage tank would have health and safety training and use appropriate health and safety protocols to minimize any unacceptable exposure to the contamination by inhalation, direct contact or ingestion. Therefore, there are no short-term risks to site workers and this alternative is protective of site workers.

To the best of our knowledge, there are no commercial or industrial or private wells within the contaminated plume at present, therefore this alternative is protective of the public health. Potential risks associated with this alternative from future use of the bedrock aquifer are partially reduced because of the periodic monitoring of the plume.

The contaminant plume is not discharging into any onsite surface water bodies; therefore, in the short-term, this alternative is protective of the environment.

Long-Term Effectiveness and Permanence

- Magnitude of Residual Risks: Long-term risks do exist to workers at the site from potential inhalation of vapors from the treatment plant. However, this risk from inhalation of vapors has been minimized by venting the storage tanks and the air stripping towers. Completion of the remedial action is not anticipated for at least 13 years, so all potential health risks to humans or the environment from the organic contaminants would not be completely eliminated for a long time. The waste streams produced by the sampling events and the treatment plant would need to be managed as a hazardous or non-hazardous waste as determined by analytical testing and there is some risk associated with handling these generated wastes. Workers operating the treatment plant would have a potential exposure to hydrogen peroxide, ozone, or UV light, but these risks would be minimized through the use of proper protective equipment. Option A of this alternative does capture all of the contaminated groundwater. The preliminary groundwater modeling performed by CDM Federal shows that extraction wells 5D and PROP1 appear to capture all of the contaminated groundwater from the onsite plume and that extraction wells PROPRR1 and PROPRR2 appear to capture all of the contaminated groundwater from the offsite plume. These projected capture zones will have to be investigated further during the remedial design stage.

  Under Option A, the offsite portion of the plume that has much lower contaminant concentrations, relies on natural attenuation and flushing processes to achieve reduction in toxicity of contaminants. The contaminated groundwater that is not captured by the extraction wells under Option A will continue to move downgradient towards the PASNY conduits.

- Adequacy of Controls: The most probable pathway for long-term risk is from potential air emissions. The treatment system has been designed with alarms and controls that shut down the blowers for the air stripping towers and the extraction well pumps, if necessary in the event of a process failure. Volatile organic compounds that are emitted from the air stripper are expected to be below Federal and State ARARs without requiring any emission controls. Sludge from the inorganics treatment and backwashing of the pressure filters will require off-site disposal as a non-hazardous waste. The possible release of contaminated groundwater from the extraction operation is controlled by the use of containment piping with sensors to detect leaks. This would provide adequate control of contaminated groundwater leaking onto the site. The treatment plant has been constructed within a curbed area capable of storing all the groundwater from the largest vessel and it has alarms and sensors that would shut down the system if it detected the presence of water at a predetermined level.

- Reliability of Controls: All of the treatment technologies considered are reliable technologies. The treatment plant has been designed with many safety interlocks, alarms and controls that provide adequate warnings to the plant operators if and when certain process or other external failures do occur. Regular O & M, with the

necessary replacement of defective components (pumps, switches, transducers, etc.) from the onsite spare parts inventory would allow for a very reliable operation. Redundancy has been built into the system with extra pieces of critical components (spare blowers and pumps) that provide a very high reliability of controlling long-term risk.

Reduction of Toxicity, Mobility, or Volume through Treatment

This alternative does provide for significant reduction of toxicity, mobility and volume of the contaminant plume. All the organic contaminants in the extracted groundwater are either destroyed by chemical oxidation or are vented to the atmosphere (air stripping). The extraction system for this alternative has been designed to capture all of the contaminated groundwater up to a saturated zone depth of 70 feet, which would eliminate the mobility of the contaminants in the environment and thus reduce the volume of the contaminant plume.

Implementability

- Technical Feasibility: All the technologies for implementation of this alternative are very well established. However, this alternative does involve numerous process steps that must be properly executed. In addition, skilled operators are needed to properly operate and maintain the treatment system.

- Administrative Feasibility: Sufficient land is available onsite to build the treatment plant. A NYSPDES permit equivalent from NYSDEC and /or local authorities would have to be obtained for the proposed outfall. The proposed groundwater extraction system (for both options A and B) would have to be installed in trenches dug after completion of the source control (soil) remedy. The future installation of a buried influent pipe can be expected to require a modest amount of administrative effort in obtaining the necessary approvals and coordination with EPA, NYSDEC and local engineering and public works departments. For Option B, an additional access agreement would have to be obtained from Conrail to install well PROPRR2. A portion of this buried pipeline may potentially have to cross areas designated as scrub-shrub wetlands.

- Availability of Services and Materials: All of the services and materials needed to implement this alternative are readily available commercially.

Costs

The net present worth of the options for this alternative, calculated at a discount rate of 5%, is, $5,512,000 (for Option A Sub-option 1), $6,048,200 (for Option A Sub-option 2), $7,318,900 (for Option B Sub-option 1), and $8,178,800 (for Option B Sub-option2) respectively.

- Capital Cost: The capital cost of this alternative is estimated to be $1,328,800 (for Option A Sub-option 1), $1,432,600 (for Option A Sub-option 2), $1,139,600 (for Option B Sub-option 1), and $1,258,600 (for Option B Sub-option2).

- O & M Cost: The estimated annual operation and maintenance costs of the options range from $4,183,200 (for Option A Sub-option 1) to $4,615,600 (for Option A Sub-option 2) for a period of 12 years. The estimated annual operation and maintenance costs of the options range from $6,179,300 (for Option B Sub-option 1) to $6,920,200 (for Option B Sub-option 2) for a period of 18 years. The annual operating and maintenance costs for this alternative include annual reviews of the site conditions for 5 years beyond the respective durations of groundwater extraction.

A summary of the details of the cost estimate for this alternative is given in Tables 4-4, 4-5, 4-6 and 4-7.

Compliance with ARARs

This alternative would eventually meet chemical-specific Federal and State ARARs for the organic and inorganic contaminants in all of the groundwater beneath the site. Although extracted groundwater would be treated to meet Federal and State ARARs, it is estimated that many of the remediation goals would be attained over a long period of time. As stated earlier, the water quality in the fractured bedrock aquifer is not expected to be restored to below MCLs or background levels for at least 13 years. This alternative is expected to meet location-specific and action-specific Federal and State ARARs.

Overall Protection of Human Health and the Environment

The extraction system for this alternative has been designed to capture all of the contaminated groundwater upto a saturation zone depth of 70 feet which would eliminate the mobility of the contaminants in the environment and thus reduce the volume of the contaminant plume. Completion of the remedial action is not anticipated for at least 13 years, so all potential health risks to humans or the environment from the organic contaminants would not be completely eliminated for a long time. This alternative uses reliable, well established technologies and is very effective in protecting potential risks to human health and the environment. Option B is more effective than Option A. Sub-option 2 destroys the organic contaminants and is therefore more protective of the environment than Sub-option 1.

State Acceptance

Not addressed at this time.

Community Acceptance

Not addressed at this time.

TABLE 4-1

FOREST GLEN GROUNDWATER REMEDIATION
COST ESTIMATE FOR NO ACTION

ITEM	Unit Cost ($)	Size/Quantity	Capital Cost ($)	O & M COSTS ($)	
				5th Year	Present Worth
ONE-TIME 5-YEAR REVIEW					
-- Groundwater sampling and testing			$0	$23,100	$18,100
-- Report Writing			$0	$7,500	$5,900
SUBTOTAL			$0	$30,600	$24,000
Bid Contingency		15 %	$0		$3,600
Scope Contingency		30 %	$0		$7,200
TOTAL ESTIMATED COSTS			$0	$30,600	$34,800
NET PRESENT WORTH OF COSTS			**$34,800**	**say**	**$35,000**

Discount rate: 5%

TABLE 4-2

FOREST GLEN GROUNDWATER REMEDIATION
COST ESTIMATE FOR ON-SITE REMEDIATION AND OFF-SITE NATURAL ATTENUATION
GROUNDWATER EXTRACTION AND POTW DISCHARGE

Item	Unit Cost	Size/Quantity	Capital Cost	O & M COSTS	
				Annual	Present Worth*
ON-SITE REMEDIATION					
EXTRACTION SYSTEM (7 yrs)					
Extraction Wells	$25,200 ea	2	$50,400	$2,300	$13,300
Piping	$53,600 ls	1 ls	$53,600	$700	$4,100
STORAGE AREA (7 yrs)					
Area Preparation and Building	$22,400 ls	1 ls	$22,400	$0	$0
Storage tank / Discharge Pump	$15,100 ls	1 ls	$15,100	$5,800	$33,600
POTW DISCHARGE (7 yrs)					
Discharge Fees			$0	$53,300	$308,600
Discharge Sampling/Testing	$7,000 ls	1 ls	$7,000	$2,800	$16,200
Discharge Report			$0	$8,000	$46,300
MONITORING (12 yrs)					
Monthly Monitoring, 1st Year			$0	$361,300	$343,200
Quart. Monitoring, 2nd-12th Years			$0	$120,500	$953,200
Report Writing, 1st Year			$0	$90,000	$85,500
Report Writing, 2nd-12th Years			$0	$30,000	$237,300
OFF-SITE NATURAL ATTENUATION (12 yrs)					
Groundwater Modeling	$120,000 ls	1 ls	$120,000		$0
Baseline Investigation	$80,000 ls	1 ls	$80,000		$0
Additional Quarterly Monitoring			$0	$19,500	$172,800
CONSTRUCTION SUBTOTAL			$348,500	$694,200	$2,214,100
Health and Safety		10 %	$34,850		$221,410
Bid Contingency		15 %	$52,275		$332,115
Scope Contingency		30 %	$104,550		$664,230
CONSTRUCTION TOTAL			$540,175		$3,431,855
Permitting & Legal		5 %	$27,009		$0
Services During Construction		10 %	$54,018		$0
TOTAL IMPLEMENTATION COSTS			$621,201		$3,431,855
Engineering & Design		10 %	$62,120		$0
TOTAL ESTIMATED COSTS			$683,321		$3,431,855
NET PRESENT WORTH OF COSTS			**$4,115,176**	**say**	**$4,115,200**

Discount rate: 5%

TABLE 4-3

FOREST GLEN GROUNDWATER REMEDIATION
COST ESTIMATE FOR ON-SITE AND OFF-SITE PLUME REMEDIATION
GROUNDWATER EXTRACTION AND POTW DISCHARGE

Item	Unit Cost	Size/Quantity	Capital Cost	O & M COSTS	
				Annual	Present Worth*
EXTRACTION SYSTEM (13 yrs)					
Extraction Wells	$25,200 ea	4	$100,800	$4,500	$42,300
Piping	$79,800 ls	1 ls	$79,800	$700	$6,600
STORAGE AREA (13 yrs)					
Area Preparation and Building	$22,400 ls	1 ls	$22,400	$0	$0
Storage tank / Discharge Pump	$21,100 ls	1 ls	$21,100	$7,900	$74,200
POTW DISCHARGE (13 yrs)					
Discharge Fees			$0	$71,510	$671,500
Discharge Sampling/Testing	$7,000 ls	1 ls	$7,000	$2,720	$25,500
Discharge Report			$0	$8,000	$75,100
MONITORING (18 yrs)					
Monthly Monitoring, 1st Year			$0	$389,200	$369,700
Quart. Monitoring, 2nd-18th Years			$0	$129,800	$1,394,100
Report Writing, 1st Year			$0	$90,000	$85,500
Report Writing, 2nd-18th Years			$0	$30,000	$322,200
CONSTRUCTION SUBTOTAL			$231,100	$734,330	$3,066,700
Health and Safety		10 %	$23,110		$306,670
Bid Contingency		15 %	$34,665		$460,005
Scope Contingency		30 %	$69,330		$920,010
CONSTRUCTION TOTAL			$358,205		$4,753,385
Permitting & Legal		5 %	$17,910		$0
Services During Construction		10 %	$35,821		$0
TOTAL IMPLEMENTATION COSTS			$411,936		$4,753,385
Engineering & Design		10 %	$41,194		$0
TOTAL ESTIMATED COSTS			$453,129		$4,753,385
NET PRESENT WORTH OF COSTS			**$5,206,514**	**say**	**$5,206,600**

Discount rate: 5%

TABLE 4-4

FOREST GLEN GROUNDWATER REMEDIATION
COST ESTIMATE FOR ON-SITE REMEDIATION AND OFF-SITE NATURAL ATTENUATION
GROUNDWATER EXTRACTION, TREATMENT AND SURFACE WATER DISCHARGE
(AIR STRIPPING)

Item	Unit Cost	Size/Quantity	Capital Cost	O & M COSTS	
				Annual	Present Worth*
ON-SITE REMEDIATION					
EXTRACTION SYSTEM (7 yrs)					
Extraction Wells	$25,200 ea	2	$50,400	$2,300	$13,300
Piping	$22,700 ls	1 ls	$22,700	$700	$4,100
TREATMENT SYSTEM (7 yrs)					
Treatment Area and Building	$99,100 ls	1 ls	$99,100	$0	$0
Air Stripping System	$79,000 ls	1 ls	$79,000	$13,500	$78,200
Metal Treatment System	$226,500 ls	1 ls	$226,500	$140,100	$811,200
MONITORING (12 yrs)					
Monthly Monitoring, 1st Year			$0	$361,300	$343,200
Quart. Monitoring, 2nd-12th Years			$0	$120,500	$953,200
Report Writing, 1st Year			$0	$90,000	$85,500
Report Writing, 2nd-12th Years			$0	$30,000	$237,300
OFF-SITE NATURAL ATTENUATION (12 yrs)					
Groundwater Modeling	$120,000 ls	1 ls	$120,000	$0	$0
Baseline Investigation	$80,000 ls	1 ls	$80,000	$0	$0
Additional Quarterly Monitoring			$0	$19,500	$172,800
CONSTRUCTION SUBTOTAL			$677,700	$777,900	$2,698,800
Health and Safety		10 %	$67,770		$269,880
Bid Contingency		15 %	$101,655		$404,820
Scope Contingency		30 %	$203,310		$809,640
CONSTRUCTION TOTAL			$1,050,435		$4,183,140
Permitting & Legal		5 %	$52,522		$0
Services During Construction		10 %	$105,044		$0
TOTAL IMPLEMENTATION COSTS			$1,208,000		$4,183,140
Engineering & Design		10 %	$120,800		$0
TOTAL ESTIMATED COSTS			$1,328,800		$4,183,140
NET PRESENT WORTH OF COSTS			**$5,511,940**	**say**	**$5,512,000**

Discount rate: 5%

TABLE 4-5

FOREST GLEN GROUNDWATER REMEDIATION
COST ESTIMATE FOR ON-SITE AND OFF-SITE PLUME REMEDIATION
GROUNDWATER EXTRACTION, TREATMENT AND SURFACE WATER DISCHARGE
(AIR STRIPPING)

Item	Unit Cost	Size/Quantity	Capital Cost	O & M COSTS	
				Annual	Present Worth*
EXTRACTION SYSTEM (13 yrs)					
Extraction Wells	$25,200 ea	4	$100,800	$4,500	$42,300
Piping	$37,900 ls	1 ls	$37,900	$700	$6,600
TREATMENT SYSTEM (13 yrs)					
Treatment Area and Building	$99,100 ls	1 ls	$99,100	$0	$0
Air Stripping System	$90,500 ls	1 ls	$90,500	$15,200	$142,700
Metal Treatment System	$252,900 ls	1 ls	$252,900	$172,900	$1,623,500
MONITORING (18 yrs)					
Monthly Monitoring, 1st Year			$0	$389,200	$369,700
Quart. Monitoring, 2nd-18th Year			$0	$129,800	$1,394,100
Report Writing, 1st Year			$0	$90,000	$85,500
Report Writing, 2nd-18th Years			$0	$30,000	$322,200
CONSTRUCTION SUBTOTAL			$581,200	$832,300	$3,986,600
Health and Safety		10 %	$58,120		$398,660
Bid Contingency		15 %	$87,180		$597,990
Scope Contingency		30 %	$174,360		$1,195,980
CONSTRUCTION TOTAL			$900,860		$6,179,230
Permitting & Legal		5 %	$45,043		$0
Services During Construction		10 %	$90,086		$0
TOTAL IMPLEMENTATION COSTS			$1,035,989		$6,179,230
Engineering & Design		10 %	$103,599		$0
TOTAL ESTIMATED COSTS			$1,139,588		$6,179,230
NET PRESENT WORTH OF COSTS			**$7,318,818**	**say**	**$7,318,900**

Discount rate: 5%

TABLE 4-6

FOREST GLEN GROUNDWATER REMEDIATION
COST ESTIMATE FOR ON-SITE REMEDIATION AND OFF-SITE NATURAL ATTENUATION
GROUNDWATER EXTRACTION, TREATMENT AND SURFACE WATER DISCHARGE
(CHEMICAL OXIDATION ENHANCED WITH UV PHOTOLYSIS)

Item	Unit Cost	Size/Quantity	Capital Cost	O & M COSTS	
				Annual	Present Worth*
ON-SITE REMEDIATION					
EXTRACTION SYSTEM (7 yrs)					
Extraction Wells	$25,200 ea	2	$50,400	$2,300	$13,300
Piping	$22,700 ls	1 ls	$22,700	$700	$4,100
TREATMENT SYSTEM (7 yrs)					
Treatment Area and Building	$99,100 ls	1 ls	$99,100	$0	$0
Treatability studies	$13,500	1 ls	$13,500	$0	$0
Oxidation System	$118,400 ls	1 ls	$118,400	$61,700	$357,200
Metal Treatment System	$226,500 ls	1 ls	$226,500	$140,100	$811,200
MONITORING (12 yrs)					
Monthly Monitoring, 1st Year			$0	$361,300	$343,200
Quart. Monitoring, 2nd-12th Years			$0	$120,500	$953,200
Report Writing, 1st Year			$0	$90,000	$85,500
Report Writing, 2nd-12th Years			$0	$30,000	$237,300
OFF-SITE NATURAL ATTENUATION (12 yrs)					
Groundwater Modeling	$120,000 ls	1 ls	$120,000		$0
Baseline Investigation	$80,000 ls	1 ls	$80,000		$0
Additional Quarterly Monitoring			$0	$19,500	$172,800
CONSTRUCTION SUBTOTAL			$730,600	$826,100	$2,977,800
Health and Safety		10 %	$73,060		$297,780
Bid Contingency		15 %	$109,590		$446,670
Scope Contingency		30 %	$219,180		$893,340
CONSTRUCTION TOTAL			$1,132,430		$4,615,590
Permitting & Legal		5 %	$56,622		$0
Services During Construction		10 %	$113,243		$0
TOTAL IMPLEMENTATION COSTS			$1,302,295		$4,615,590
Engineering & Design		10 %	$130,229		$0
TOTAL ESTIMATED COSTS			$1,432,524		$4,615,590
NET PRESENT WORTH OF COSTS			**$6,048,114**	**say**	**$6,048,200**

Discount rate: 5%

TABLE 4-7

FOREST GLEN GROUNDWATER REMEDIATION
COST ESTIMATE FOR ON-SITE AND OFF-SITE PLUME REMEDIATION
GROUNDWATER EXTRACTION, TREATMENT AND SURFACE WATER DISCHARGE
(CHEMICAL OXIDATION ENHANCED WITH UV PHOTOLYSIS)

Item	Unit Cost	Size/Quantity	Capital Cost	O & M COSTS	
				Annual	Present Worth*
EXTRACTION SYSTEM (13 yrs)					
Extraction Wells	$25,200 ea	4	$100,800	$4,500	$42,300
Piping	$37,900 ls	1 ls	$37,900	$700	$6,600
TREATMENT SYSTEM (13 yrs)					
Treatment Area and Building	$99,100 ls	1 ls	$99,100	$0	$0
Treatability studies	$13,500	1 ls	$13,500	$0	$0
Oxidation System	$137,700 ls	1 ls	$137,700	$66,100	$620,700
Metal Treatment System	$252,900 ls	1 ls	$252,900	$172,900	$1,623,500
MONITORING (18 yrs)					
Monthly Monitoring, 1st Year			$0	$389,200	$369,700
Quart. Monitoring, 2nd-18th Years			$0	$129,800	$1,394,100
Report Writing, 1st Year			$0	$90,000	$85,500
Report Writing, 2nd-18th Years			$0	$30,000	$322,200
CONSTRUCTION SUBTOTAL			$641,900	$883,200	$4,464,600
Health and Safety		10 %	$64,190		$446,460
Bid Contingency		15 %	$96,285		$669,690
Scope Contingency		30 %	$192,570		$1,339,380
CONSTRUCTION TOTAL			$994,945		$6,920,130
Permitting & Legal		5 %	$49,747		$0
Services During Construction		10 %	$99,495		$0
TOTAL IMPLEMENTATION COSTS			$1,144,187		$6,920,130
Engineering & Design		10 %	$114,419		$0
TOTAL ESTIMATED COSTS			$1,258,605		$6,920,130
NET PRESENT WORTH OF COSTS			**$8,178,735**	**say**	**$8,178,800**

Discount rate: 5%

5.0 COMPARATIVE ANALYSES OF ALTERNATIVES

This section provides an overall comparison among the various remedial alternatives examined in Section 4.3. The sensitivity of the cost estimates for groundwater alternatives to various factors such as the extraction flow rates and assumptions regarding the properties of the bedrock are also presented in this section. The sensitivity of the cost estimates for groundwater alternatives to various treatment time frames are also presented in this section.

5.1 COMPARISON AMONG GROUNDWATER ALTERNATIVES

5.1.1 SHORT-TERM EFFECTIVENESS

All the groundwater alternatives selected for detailed evaluation provide short-term effectiveness in protecting the site workers and neighboring communities from the risks due to ingestion and inhalation of VOCs. Alternatives GW-4(A and B) and GW-5(A and B) would pose a low level risk to site workers during construction; however, this risk can be managed by use of appropriate health and safety measures.

5.1.2 LONG-TERM EFFECTIVENESS AND PERMANENCE

- Magnitude of Residual Risks: Alternative GW-1 provides the least amount of long-term protection to site workers and neighboring communities. These risks are minimal for site workers because administrative controls on the Forest Glen site would prevent completion of exposure pathways from the groundwater to site workers. Alternatives GW-4(A and B) and GW-5(A and B) do provide varying amounts of containment of the contaminated groundwater, so long term risks to neighbouring communities would be considerably reduced. However, none of these alternatives are expected to restore the quality of the groundwater to chemical-specific ARARs for at least 13 years, so some long-term risks to site workers and neighboring residences would remain for that duration. Alternatives GW-4(A and B) and GW-5(A and B) do entail a risk to site workers from potential inhalation of vapors in the treatment plant, however preventive measures have been incorporated into the design. Alternatives GW-5(A and B) produce a filter cake that needs to be disposed of as a non-hazardous waste. This waste results in some risk to the environment but should be minimized by proper disposal practices. Alternatives GW-5(A and B) also result in emission of organic vapors (below Federal and State ARARs) for the air stripping option.

- Adequacy of Controls: Alternative GW-1 provides the least amount of controls for protection of human health and the environment. It does not provide for annual monitoring of the contaminated groundwater. Alternatives GW-4(A and B) and GW-5(A and B) have well designed controls that are expected to minimize/prevent releases of VOCs to the air and prevent discharges of contaminated groundwater over the life

of these alternatives.

- Reliability of Controls: Alternative GW-1 provides no physical control of the contaminated groundwater; it only provides for monitoring of the plume after a five year period. Alternatives GW-4(A and B) and GW-5(A and B) both provide for quarterly monitoring and physical control over the contaminated groundwater. The sampling and analyses of the groundwater is a reliable method to confirm the degree of remediation that has been completed. All of the technologies used in Alternatives GW-4(A and B) and GW-5(A and B) are very reliable.

5.1.3 REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT

Alternative GW-1 relies on natural attenuation processes and dilution to reduce the toxicity of the groundwater; it does not reduce the mobility of the contaminants except for minor retardation by the adsorption and desorption from aquifer formation material particles, and it results in an increase in the volume of the contaminated groundwater. Alternatives GW-4(A and B) and GW-5(A and B) reduce the toxicity and volume of contamination from the extracted groundwater. The mobility of the contaminants is completely controlled by the pump-and-treat alternatives to the extent that the groundwater is within the capture zone of the wells.

5.1.4 IMPLEMENTABILITY

- Technical Feasibility: All the alternatives are technically feasible but Alternatives GW-4(A and B) and GW-5(A and B) require skilled operators to successfully implement the remedy. All of the technologies used are well established.

- Administrative Feasibility: All the alternatives are administratively feasible. The required activities for the pump-and-treat alternatives would occur on Forest Glen property or at the City of Niagara Falls POTW. The treatment plant for the POTW has already been built and has been in operation for several years. The sanitary sewer line for the discharge to the POTW (Alternatives GW-4(A and B)) already exists at the site even though it is not currently being used. The pump-and-treat alternatives require substantive compliance with specified treated water discharge limits and a permit equivalent. Alternative GW-1 involves the least administrative effort since it only requires protecting the integrity of the monitoring wells for the five year period and completion of one sampling event.

- Availability of Services and Materials: All the services needed to implement the alternatives are readily available commercially. The pump-and-treat alternatives require the most services since they require operation of the treatment train and offsite disposal of the filter cake.

5.1.5 COSTS

The net present worth of Alternative GW-1 is the lowest at $35,000 and the highest present worth cost is for Alternative GW-5B (sub-option2) at $8,178,800. Alternative GW-1 has no capital cost and Alternative GW-5B (sub-option2) has the highest capital cost of $1,258,600. Alternative GW-1 has the least O & M cost of $35,000 and Alternative GW-5B (sub-option 2) has the highest annual O & M cost of $6,920,200.

5.1.6 COMPLIANCE WITH ARARs

Alternative GW-1 relies on natural attenuation processes such as dispersion and biotransformation to restore groundwater quality and is not expected to restore the water quality to below chemical specific ARARs within the fractured bedrock aquifer for a very long time as compared with other groundwater alternatives based on active treatment processes. Hence Alternative GW-1 would take much longer to show any noticeable improvement. The pump-and-treat alternatives GW-4(A and B) and GW-5(A and B) are expected to achieve chemical-specific Federal and State ARARs for the treated water before it is discharged and for the air emissions before they are released. The pump-and-treat alternatives GW-4(A and B) and GW-5(A and B) are expected to achieve location-specific and action-specific Federal and State ARARs.

5.1.7 OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

Alternative GW-1 does not contain the plume and relies on natural attenuation processes such as dispersion and biotransformation to improve groundwater quality, therefore, it is expected to be the least protective of human health and the environment. All of the other groundwater alternatives better protect human health and the environment by containing varying amounts of the most contaminated groundwater beneath the site. Option B for Alternatives GW-4 and GW-5 is the most protective beause it is expected to capture contaminated groundwater from both onsite and offsite plumes.

5.1.8 STATE ACCEPTANCE

Not addressed at this time.

5.1.9 COMMUNITY ACCEPTANCE

Not addressed at this time.

5.2 COST SENSITIVITY ANALYSIS

The sensitivity of the cost estimates for groundwater alternatives to various factors such as the fraction of organic carbon in the bedrock, the percentage of bedrock that is contaminated, and the

groundwater extraction rate are presented in Tables 5-1 through 5-6. These factors increase or decrease the time for a single flush (see Table C-2 in Appendix C) and therefore result in increased or decreased treatment time frames. Additional work (such as groundwater modeling, pumping tests, and additional groundwater sampling) will have to be performed during remedial design to further refine the cost estimates.

TABLE 5-1

FOREST GLEN GROUNDWATER REMEDIATION
COST ESTIMATE FOR ON-SITE PLUME REMEDIATION
SENSITIVITY ANALYSIS 1: foc=0.1% and foc=0.5%

ALTERNATIVE NUMBER	ALTERNATIVE	MIN foc=0.1%	MAX foc=0.5%
GW-1	No Action	$35,000	$35,000
GW-4	Groundwater Extraction and POTW Discharge (Off-Site Natural Attenuation)	$3,094,400	$5,322,200
GW-5	Groundwater Extraction, Treatment and Surface Water Discharge (Off-Site Natural Attenuation)		
5.1	Chemical Precipitation and Air Stripping	$4,092,700	$7,185,800
5.2	Chemical Precipitation and Chemical Oxidation Enhanced with UV Photolysis	$4,399,400	$7,990,600

TABLE 5-2

FOREST GLEN GROUNDWATER REMEDIATION
COST ESTIMATE FOR ON-SITE AND OFF-SITE PLUME REMEDIATION
SENSITIVITY ANALYSIS 1: foc=0.1% and foc=0.5%

ALTERNATIVE NUMBER	ALTERNATIVE	MIN foc=0.1%	MAX foc=0.5%
GW-1	No Action	$35,000	$35,000
GW-4	Groundwater Extraction and POTW Discharge	$3,337,200	$6,607,300
GW-5	Groundwater Extraction, Treatment and Surface Water Discharge		
5.1	Chemical Precipitation and Air Stripping	$5,190,300	$9,342,100
5.2	Chemical Precipitation and Chemical Oxidation Enhanced with UV Photolysis	$5,710,100	$10,525,500

TABLE 5-3

FOREST GLEN GROUNDWATER REMEDIATION
COST ESTIMATE FOR ON-SITE PLUME REMEDIATION
SENSITIVITY ANALYSIS 2A: Contaminated Rock=5% and 15%

ALTERNATIVE NUMBER	ALTERNATIVE	MIN v=5%	MAX v=15%
GW-1	No Action	$35,000	$35,000
GW-4	Groundwater Extraction and POTW Discharge (Off-Site Natural Attenuation)	$3,361,000	$4,773,500
GW-5	Groundwater Extraction, Treatment and Surface Water Discharge (Off-Site Natural Attenuation)		
5.1	Chemical Precipitation and Air Stripping	$4,467,100	$6,420,400
5.2	Chemical Precipitation and Chemical Oxidation Enhanced with UV Photolysis	$4,835,900	$7,100,400

TABLE 5-4

FOREST GLEN GROUNDWATER REMEDIATION
COST ESTIMATE FOR ON-SITE AND OFF-SITE PLUME REMEDIATION
SENSITIVITY ANALYSIS 2B: Contaminated Rock=5% and 15%

ALTERNATIVE NUMBER	ALTERNATIVE	MIN v=5%	MAX v=15%
GW-1	No Action	$35,000	$35,000
GW-4	Groundwater Extraction and POTW Discharge	$3,973,400	$5,992,300
GW-5	Groundwater Extraction, Treatment and Surface Water Discharge		
5.1	Chemical Precipitation and Air Stripping	$5,539,300	$8,453,800
5.2	Chemical Precipitation and Chemical Oxidation Enhanced with UV Photolysis	$6,115,100	$9,495,000

TABLE 5-5

FOREST GLEN GROUNDWATER REMEDIATION
COST ESTIMATE FOR ON-SITE PLUME REMEDIATION
SENSITIVITY ANALYSIS 3: Pumping Rate=35 gpm

ALTERNATIVE NUMBER	ALTERNATIVE	MIN Q=35 gpm	MAX Q=30 gpm
GW-1	No Action	$35,000	$35,000
GW-4	Groundwater Extraction and POTW Discharge (Off-Site Natural Attenuation)	$3,976,000	$4,115,200
GW-5	Groundwater Extraction, Treatment and Surface Water Discharge (Off-Site Natural Attenuation)		
5.1	Chemical Precipitation and Air Stripping	$5,365,300	$5,512,000
5.2	Chemical Precipitation and Chemical Oxidation Enhanced with UV Photolysis	$5,857,600	$6,048,200

TABLE 5-6

FOREST GLEN GROUNDWATER REMEDIATION
COST ESTIMATE FOR ON-SITE AND OFF-SITE PLUME REMEDIATION
SENSITIVITY ANALYSIS 4: Pumping Rate=50 gpm

ALTERNATIVE NUMBER	ALTERNATIVE	MIN Q=50 gpm	MAX Q=40 gpm
GW-1	No Action	$35,000	$35,000
GW-4	Groundwater Extraction and POTW Discharge	$4,847,900	$5,206,600
GW-5	Groundwater Extraction, Treatment and Surface Water Discharge		
5.1	Chemical Precipitation and Air Stripping	$6,900,700	$7,318,900
5.2	Chemical Precipitation and Chemical Oxidation Enhanced with UV Photolysis	$7,656,800	$8,178,800

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GLOSSARY OF ABBREVIATIONS

AMSL	Above Mean Sea Level
AOC	Area of Concern
ARARs	Applicable or Relevant and Appropriate Requirements
ARCS	Alternative Remedial Contracting Strategy
ATSDR	Agency for Toxic Substances and Disease Registry
ASTM	American Standard Testing Methods
BNA	Base-Neutral/Acid Extractables
BOD	Biochemical Oxygen Demand
BGS	Below Ground Surface
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act of 1980
CLP	Contract Laboratory Program
COCs	Contaminants of Concern
COD	Chemical Oxygen Demand
CRDL	Contract Required Detection Limit
1,1-DCA	1,1-Dichloroethane
1,2-DCE	1,2-Dichloroethene (total)
DOT	Department of Transportation
EPA	United States Environmental Protection Agency
Eh	Redox Potential
ERT	Environmental Response Team
FIT	Field Investigation Team
FEMA	Federal Emergency Management
FFS	Focused Feasibility Study

FS	Feasibility Study
GIS	Geographical Information System
HSL	Hazardous Substance List
ID	Inner Diameter
LEL	Lowest Effect Level
MCLs	Maximum Contaminant Levels
MCLGs	Maximum Contaminant Level Goals
MSL	Mean Sea Level
NAAQS	National Ambient Air Quality Standards
NCHD	Niagara County Health Department
NCP	National Contingency Plan
NESHAPs	National Emission Standards for Hazardous Air Pollutants
NHP	New York Natural Heritage Program
NPDES	National Pollution Discharge Elimination Systems
NPL	National Priorities List
NYCRR	New York Code of Rules and Regulations
NUS	NUS Corporation
NYSDEC	New York State Department of Environmental Conservation
NYSDOH	New York State Department of Health
OSHA	Occupational Health and Safety Act
OSWER	Office of Solid Waste and Emergency Response
PAHs	Polyaromatic hydrocarbons
PASNY	Power Authority for the State of New York
PCBs	Polychlorinated Biphenyls

PPB	Parts Per Billion
PRAP	Proposed Remedial Action Plan
PRP	Potentially Responsible Party
PVC	Polyvinyl Chloride
RA	Risk Assessment
RAS	Routine Analytical Services
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
SARA	Superfund Amendments and Reauthorization Act of 1986
SDWA	Safe Drinking Water Act
SEL	Severe Effect Level
SOW	Statement of Work
SVOC	Semivolatile Organic Compounds
TAGM	Technical Administrative Guidance Memorandum
TAL	Target Analyte List
TAT	Technical Assistance Team
1,1,1-TCA	1,1,1-Trichloroethane
TCE	Tetrachloroethene
TBC	"To Be Considered" Guidance Values
TCL	Target Compound List
TDS	Total Dissolved Solids
TICs	Tentatively Identified Compounds

TKN	Total Kjelhald Nitrogen
TOC	Total Organic Carbon
TOG	Technical Operating Guidance
TSCA	Toxic Substance Control Act
USFWS	United States Fish and Wildlife Service
USC	United State Code
USDA	United States Department of Agriculture
USDI	United States Department of the Interior
USGS	United States Geological Survey
VOC	Volatile Organic Compound

APPENDIX A

AQUIFER PERFORMANCE TEST ANALYSIS

FOREST GLEN AQUIFER PERFORMANCE TEST ANALYSIS

Aquifer performance tests (APTs) are a means by which a production well combined with one or more nearby observation wells can be utilized to estimate the hydraulic properties of saturated subsurface media. Hence, to estimate the hydraulic properties (transmissivity in particular) of the bedrock aquifer at the Forest Glen Site, an approximate 10-hour APT was conducted in the upper 50 feet of this aquifer. The test setup, procedures, and results; the methods of analysis; and the analysis results for this APT is presented in detail below. An analysis of the area of influence of the test is also presented below.

TEST SETUP, PROCEDURES, AND RESULTS

The parameters pertinent to the analysis of the APT conducted at the Forest Glen Site include: test well construction details, test well layout, production well discharge rate, rainfall variations, atmospheric pressure changes, antecedent water levels, and aquifer geometry. These parameters, as well as the test procedures and results, are presented below for the APT. The layout of the Forest Glen test wells is shown in **Figure 1**. The construction details of the test wells are provided in **Table 1**. Monitor well MW-5S was used as the production well while monitor wells MW-3S, MW-4S, MW-4D, MW-5D, MW-6S, MW-6D, MW-9S, MW-10S, MW-14S, MW-14D, and MW-15S were used as observation wells.

The pumping phase of the APT was initiated at 13:00 hours on September 11, 1997. Prior to initiating the test, however, background water level measurements were collected from all the test wells for a period of approximately 7 days to determine the impacts of rainfall on ground water levels, as well as any natural water level trend (rise or decline) which may have affected the test results. The measured water level changes for the test wells during this approximate 7-day period are shown in **Figures 2** and **3**. Daily rainfall totals during this period, as well as during the APT, are provided in **Figure 4**. Note that based on these data, it is apparent that ground water levels at the site respond rapidly to rainfall, but in significantly varying degrees depending on the location.

During the test, the pump operated for a period of 10.5 hours. Flow was measured approximately every hour by using a stopwatch to record the time needed to fill a beaker with a known volume. During the test, the flow was fairly steady, but there was a period (at approximately 410 minutes into the test) when the pump malfunctioned and flow was completely shutoff. This problem, however, was quickly remedied (within 15 minutes) and therefore is not expected to have a significant impact on the overall test analysis. The average flow rate for the test is estimated to be 22 gallons per minute (gpm). All water pumped from the production well was discharged to a temporary holding tank during the test.

Drawdown was measured in each of the test wells during the 10.5-hour pumping period and for a recovery period of approximately 9 hours at predetermined time increments. These

FIGURE 1
MONITORING WELL LOCATIONS
FOREST GLEN SITE

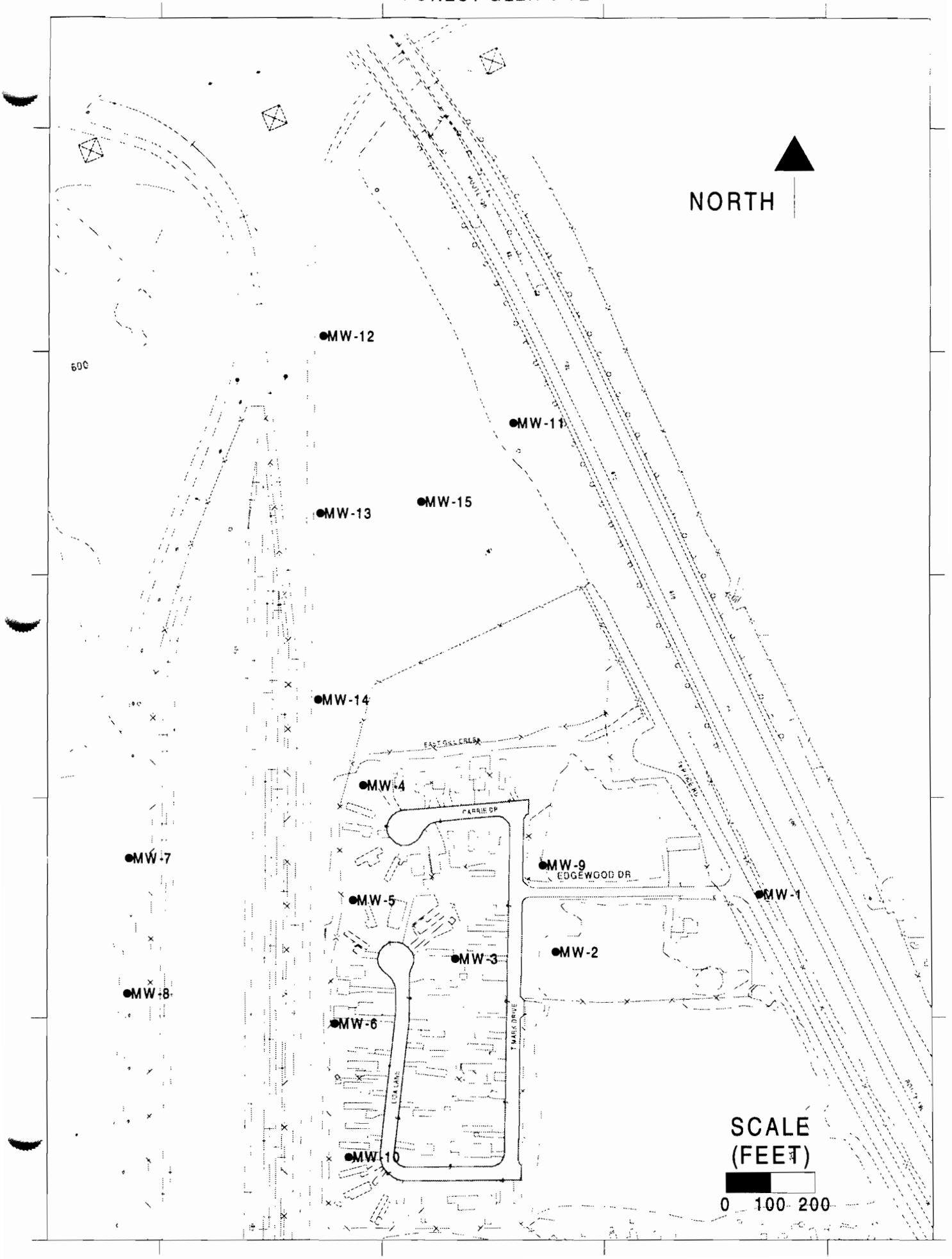


TABLE 1

TEST WELL CONSTRUCTION DETAILS
FOREST GLEN SITE
NIAGARA FALLS, NEW YORK

Well ID	Well Coordinates		Well Diameter (inches)	Screen or Open Hole Depth (feet)	Screen or Open Hole Length (feet)	Water Depth (feet)
	Northing	Easting				
MW-3S	1,134,133.4	388,667.0	4	28	10	16
MW-4S	1,134,527.1	388,460.1	4	20	10	14
MW-4D	1,134,523.2	388,455.1	4	59	29	14
MW-5S	1,134,266.7	388,436.4	4	26	10	13
MW-5D	1,134,253.8	388,433.2	4	50	23	13
MW-6S	1,133,987.2	388,394.6	4	27	10	15
MW-6D	1,133,978.8	388,394.1	4	55	28	15
MW-9S	1,134,345.8	388,865.4	4	25	10	13
MW-10S	1,133,688.1	388,425.0	4	30	10	15
MW-14S	1,134,720.3	388,359.0	4	30	10	15
MW-14D	1,134,702.6	388,358.0	4	50	20	15
MW-15S	1,135,165.3	388,591.5	4	31	10	14

Note: All depths are measured from ground surface.

FIGURE 2

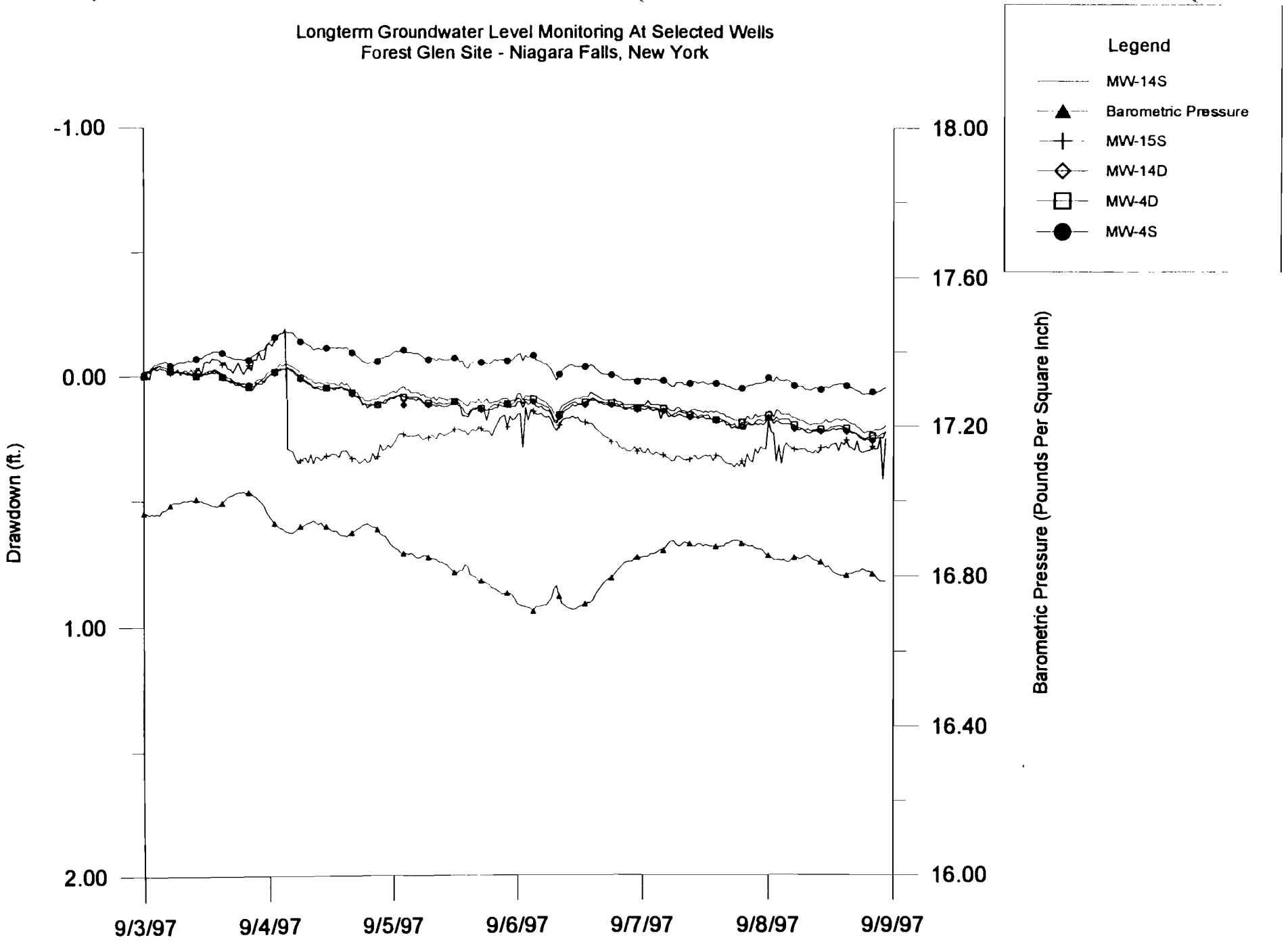

Longterm Groundwater Level Monitoring At Selected Wells
Forest Glen Site - Niagara Falls, New York
Legend
MW-14S
Barometric Pressure
MW-15S
MW-14D
MW-4D
MW-4S
-1.00
0.00
1.00
2.00
18.00
17.60
17.20
16.80
16.40
16.00
Drawdown (ft.)
Barometric Pressure (Pounds Per Square Inch)
9/3/97
9/4/97
9/5/97
9/6/97
9/7/97
9/8/97
9/9/97

FIGURE 3

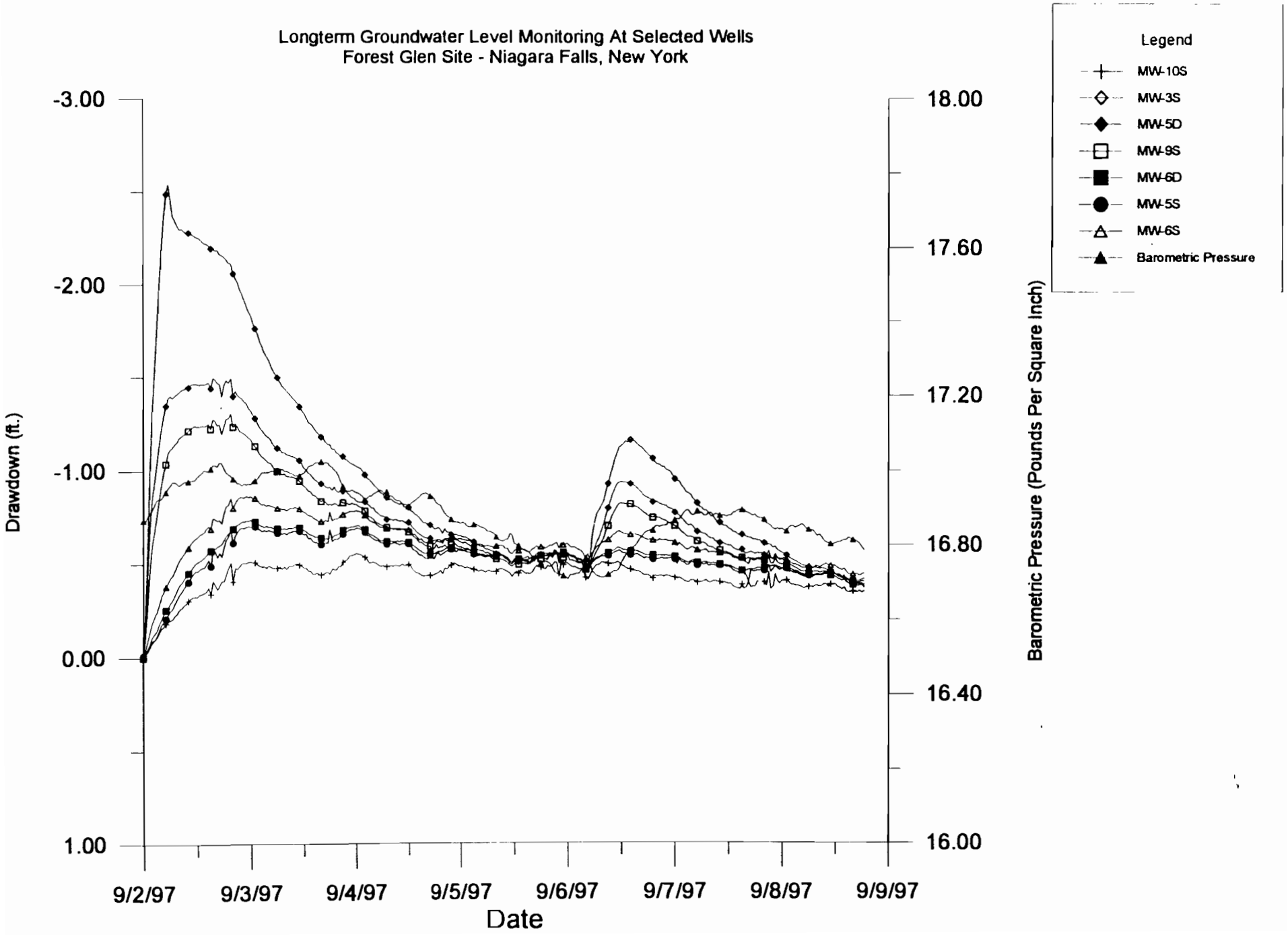
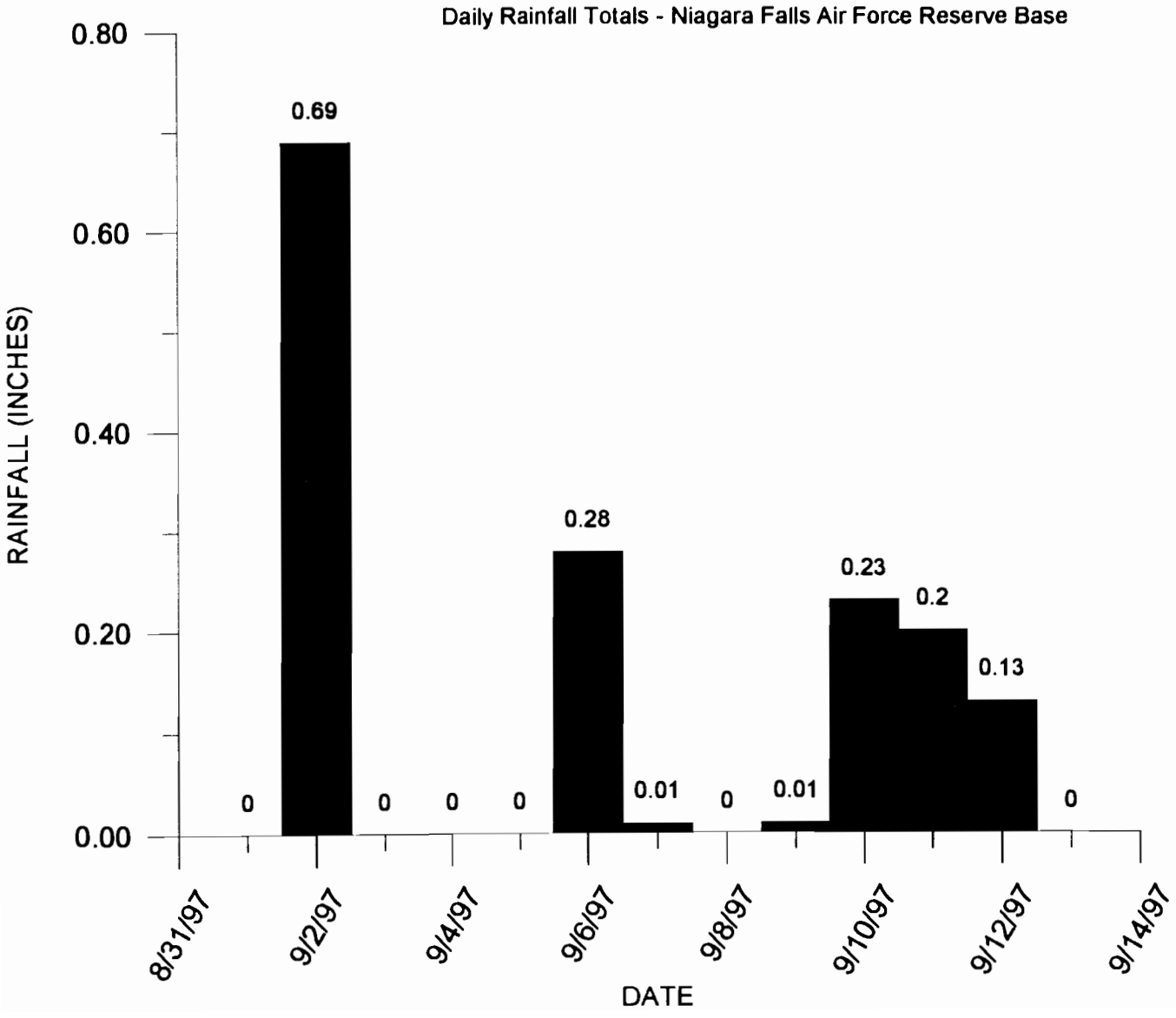

Longterm Groundwater Level Monitoring At Selected Wells
Forest Glen Site - Niagara Falls, New York
Legend
MW-10S
MW-3S
MW-5D
MW-9S
MW-6D
MW-5S
MW-6S
Barometric Pressure
Drawdown (ft.)
-3.00
-2.00
-1.00
0.00
1.00
Barometric Pressure (Pounds Per Square Inch)
18.00
17.60
17.20
16.80
16.40
16.00
9/2/97
9/3/97
9/4/97
9/5/97
9/6/97
9/7/97
9/8/97
9/9/97
Date

FIGURE 4


Daily Rainfall Totals - Niagara Falls Air Force Reserve Base
RAINFALL (INCHES)
0.80
0.60
0.40
0.20
0.00
0.69
0.28
0.23
0.2
0.13
0.01
0.01
0
0
0
0
0
0
8/31/97
9/2/97
9/4/97
9/6/97
9/8/97
9/10/97
9/12/97
9/14/97
DATE

measurements were collected using pressure transducers and the HERMIT 2000 Environmental Datalogger. The measured drawdown curves in the observation wells for both the pumping and recovery phases of the APT are provided in **Figures 5** and **6**.

As indicated in Figure 3, rainfall occurred both prior to and during the APT. Atmospheric pressure, however, varied only slightly during the APT and thus should not have had any significant impact on the ground water level measurements during the test.

METHODS OF ANALYSIS

As is indicated above, the APT conducted at the Forest Glen Site included two phases: a pumping phase and a recovery phase. The methods of analysis used for each of these two phases are described below.

Pumping Phase Analysis

The pumping tests conducted at the Forest Glen Site can best be described as unsteady flow to a well in an unconfined (water table) aquifer with delayed gravity response. Therefore, for this phase of the APT, the hydraulic properties of the aquifer were estimated using the following equation (Neuman, 1975):

$$s = \frac{Q}{4\pi T} \int_0^\infty 4\, y\, J_o(y\beta^{1/2})\, [u_o(y) + \sum_{n=1}^{\infty} u_n(y)]\, dy \qquad \text{(Equation 1)}$$

where

$$u_o(y) = \frac{\{1 - \exp[-t_s\beta(y^2 - \gamma_o^2)]\} \tanh(\gamma_o)}{\{y^2 + (1 + \sigma)\gamma_o^2 - (y^2 - \gamma_o^2)^2/\sigma\}\, \gamma_o}$$

$$u_n(y) = \frac{\{1 - \exp[-t_s\beta(y^2 + \gamma_n^2)]\} \tanh(\gamma_n)}{\{y^2 - (1 + \sigma)\gamma_n^2 - (y^2 + \gamma_n^2)^2/\sigma\}\, \gamma_n}$$

$$\beta = \frac{r^2 K_v}{m^2 K_h}$$

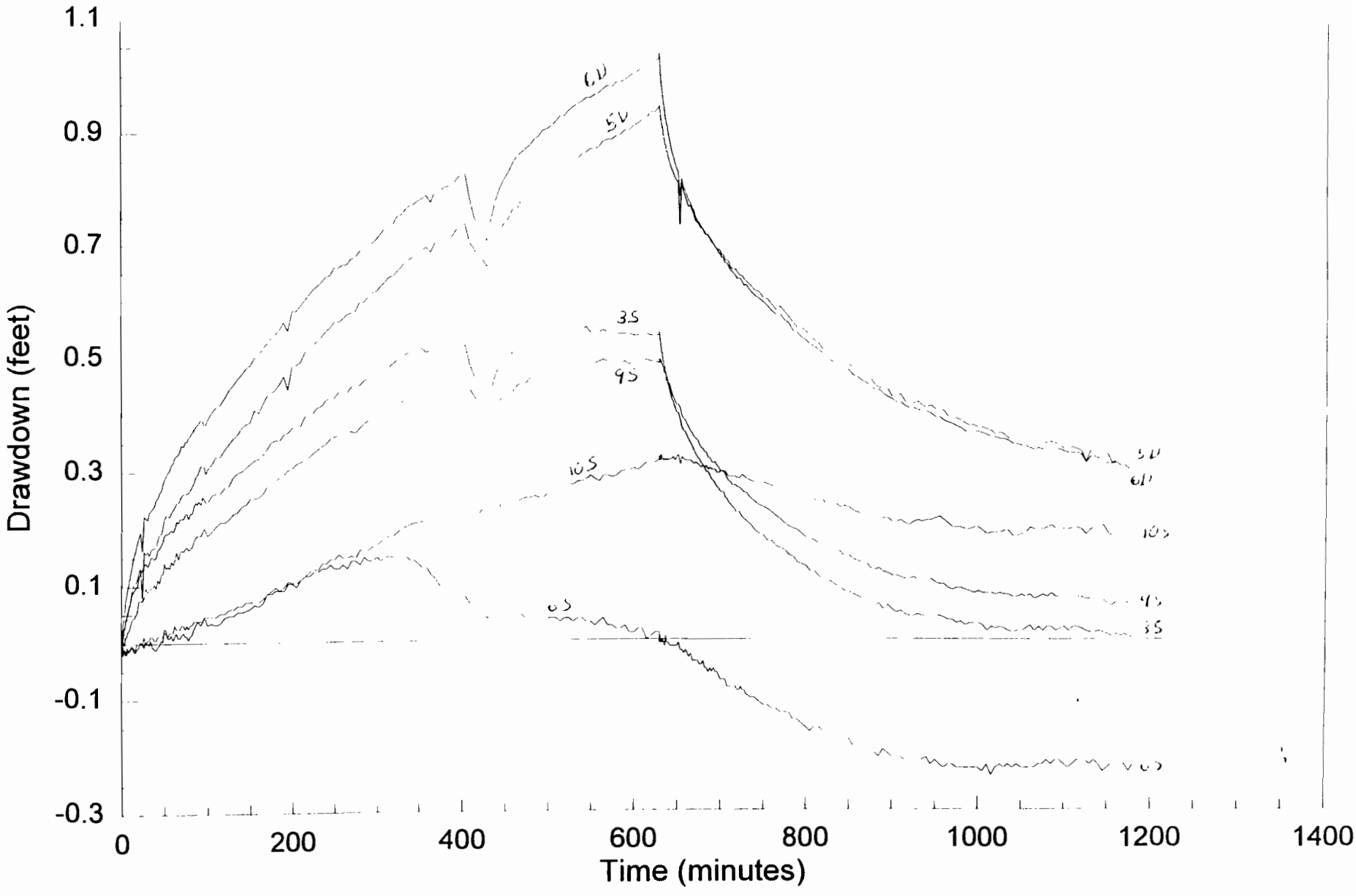

APT Uncorrected Drawdown Curves
Drawdown (feet)
1.1
0.9
0.7
0.5
0.3
0.1
-0.1
-0.3
0
200
400
600
800
1000
1200
1400
Time (minutes)
6V
5V
3S
9S
10S
6S

FIGURE 5

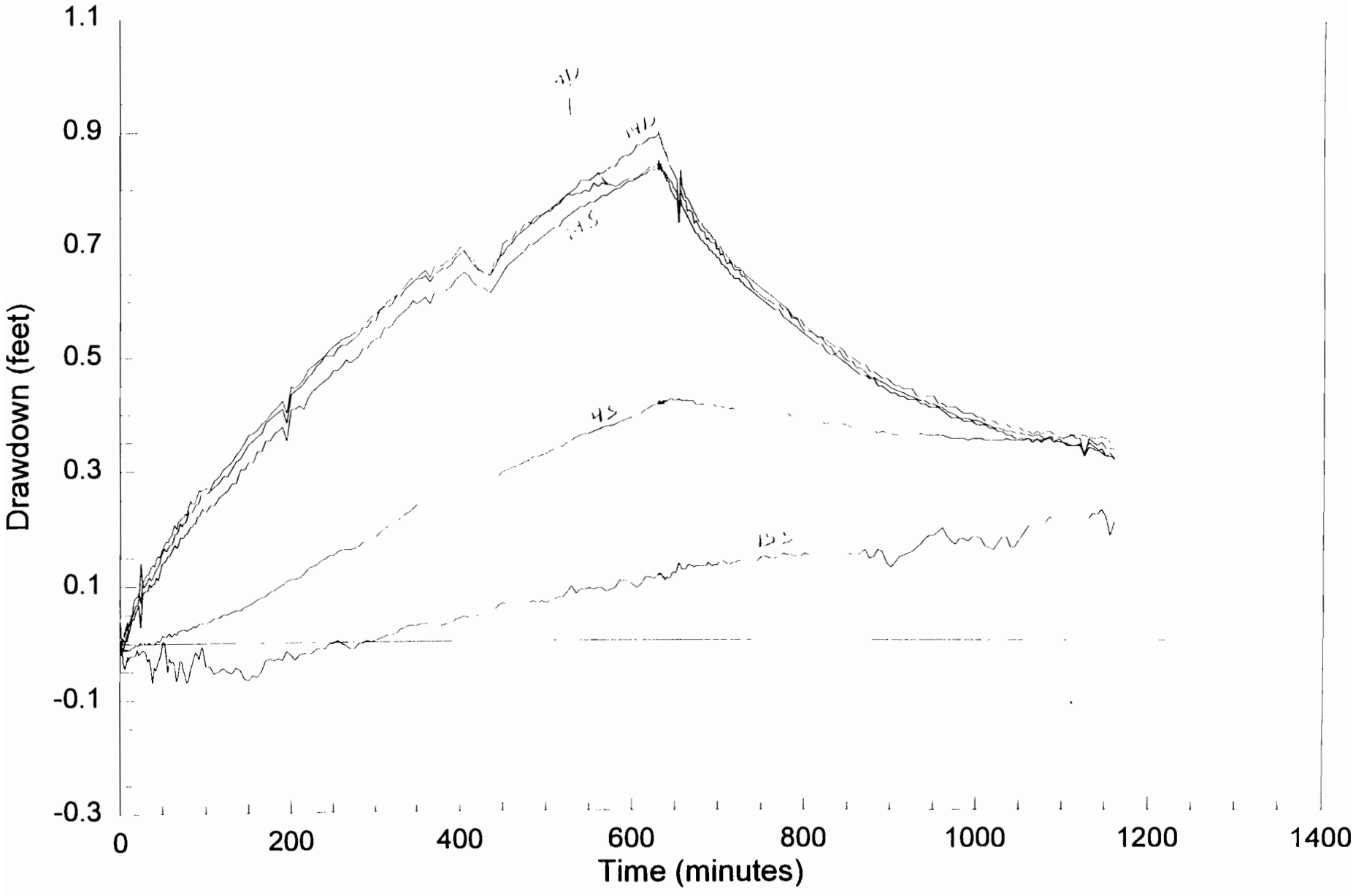

APT Uncorrected Drawdown Curves
Drawdown (feet)
1.1
0.9
0.7
0.5
0.3
0.1
-0.1
-0.3
0
200
400
600
800
1000
1200
1400
Time (minutes)

FIGURE 6

$$\sigma = \frac{S}{S_y}$$

The terms "γ_o" and "γ_n" are the roots of the following equations:

$$\sigma \gamma_o \sinh(\gamma_o) - (y^2 - \gamma_o^2) \cosh(\gamma_o) = 0 , \qquad \gamma_o^2 < y^2$$

$$\sigma \gamma_n \sin(\gamma_n) + (y^2 + \gamma_n^2) \cos(\gamma_n) = 0 , \qquad (2n - 1)(\pi/2) < \gamma_n < n\pi , \; n \geq 1$$

and

s	=	observation well drawdown
Q	=	production well pumping rate
T	=	aquifer transmissivity
y	=	variable of integration
J_o (x)	=	zero-order Bessel function of the first kind
t_s	=	dimensionless time with respect to S, equal to Tt/Sr^2
t	=	time after pumping started
r	=	radial distance of observation well from production well
S	=	aquifer storage coefficient
S_y	=	aquifer specific yield
K_h	=	aquifer horizontal hydraulic conductivity
K_v	=	aquifer vertical hydraulic conductivity
m	=	initial saturated aquifer thickness

The simplifying assumptions inherent in this method of analysis include the following:

- The aquifer has infinite areal extent
- The aquifer is homogeneous and has uniform thickness
- The aquifer potentiometric surface is initially horizontal
- The pumping rate is constant
- The diameter of the pumping well is very small so that storage in the well can be neglected

Values of the integral in Equation 1 calculated in terms of a selected range of u_o, u_n, and β, can be presented as a family of type curves. To estimate the aquifer properties, the drawdowns in the observation wells (corrected as described below) were plotted against values of time after pumping started to describe time-drawdown field data curves. The field data curves were then matched to the appropriate type curves whereby the aquifer properties were estimated by the *type curve graphical method* described by Walton (1970).

Note that a distance-drawdown method of analysis was also considered for estimating the aquifer properties using the APT data, but because none of the drawdown curves appear to have reached steady-state (i.e., gravity drainage was not fully realized in any of the observation wells), such a method of analysis could not be considered to be valid for this APT.

Equation 1 assumes that the natural water table elevation remains constant over the duration of the APT. However, because rainfall occurred prior to and during the APT, it is likely the natural water table elevation did not remain constant over the duration of the APT at some of the test wells. As indicated previously, ground water levels at the site appear to respond quickly to rainfall, but in varying degrees depending on the location. Hence, the observed drawdowns needed to be corrected for the natural trend created by rainfall variation before they were used to estimate the aquifer properties. For this APT, the trend drawdown correction was estimated at each well using the following equation:

$$s_t = \frac{s_r * t}{t_r} \qquad \text{(Equation 2)}$$

where

s_t = trend drawdown correction at time t
t = time after pumping started
s_r = drawdown at the end of the recovery phase
t_r = time after pumping started to the end of the recovery phase

The observed drawdowns were corrected by subtracting the trend drawdown correction, s_t, from the observed drawdown.

Recovery Phase Analysis

For the recovery phase of the APT, the hydraulic properties of the aquifer were estimated using the following equation (Theis, 1935):

$$s'' = \frac{Q}{4\pi T}\left[\ln(t/t'') - \ln(S')\right] \qquad \text{(Equation 3)}$$

where

$$S' = S/S''$$

and

Q	=	production well pumping rate
T	=	aquifer transmissivity
s"	=	observation well residual drawdown
S	=	storage coefficient during pumping
S"	=	storage coefficient during recovery
t	=	time since pumping started
t"	=	time since pumping stopped

The simplifying assumptions inherent in this method of analysis include the following:

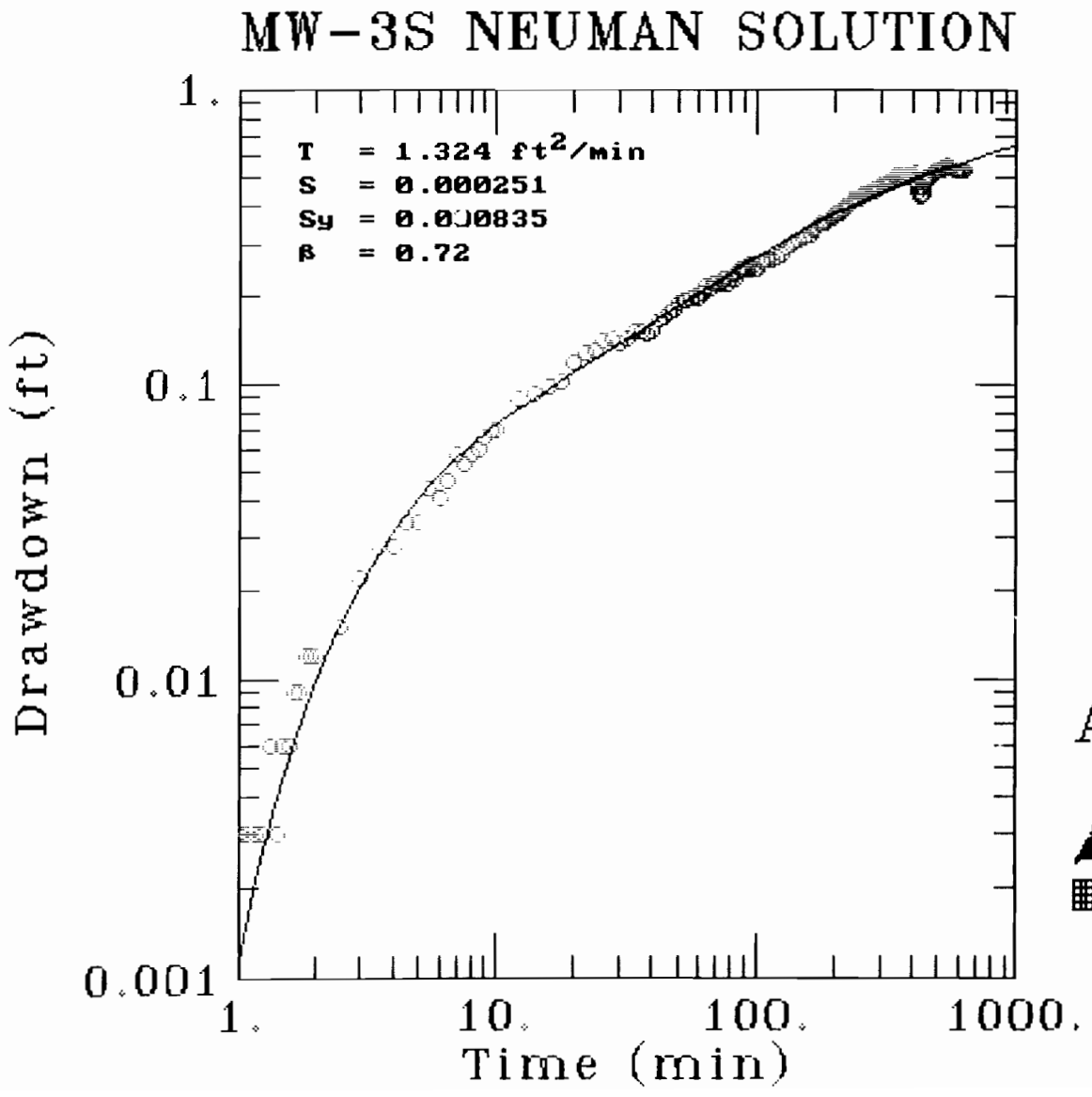
- The aquifer has infinite areal extent
- The aquifer is homogeneous, isotropic, and has uniform thickness
- The aquifer potentiometric surface is initially horizontal
- The pumping rate is constant
- The pumping well is fully penetrating
- The aquifer is confined
- Water is released instantaneously from storage with decline of hydraulic head (i.e., no delayed response)
- The diameter of the pumping well is very small so that storage in the well can be neglected

Note that although the actual site conditions at Forest Glen likely violate several of these simplifying assumptions, the recovery phase of the APT was still conducted and analyzed accordingly to provide a quick and inexpensive order of magnitude check of the hydraulic properties (transmissivity in particular) estimated based on the more rigorous analysis of the pumping phase of the APT described above.

To estimate the aquifer properties, the residual drawdowns in the observation wells (corrected for trend as described above) were plotted against values of log(t/t') to describe time-drawdown field data curves. Using the straight line portion of the field data curve, the aquifer properties were estimated by the *straight-line method* described by Walton (1970).

ANALYSIS RESULTS

The analysis of the Forest Glen Site APT data was performed using the AQTESOLV computer software program developed and released by Geraghty & Miller, Inc. in October 1991 (Version 1.1). The analysis results for the pumping and recovery phases are graphically displayed in **Figures 7** through **24**, and tabulated in **Table 2**. Note that the drawdown data presented in Figures 7 through 24 are the corrected drawdowns based on the procedures described above. Note also that the corrections for trend had a relatively minor impact on the drawdown curves and hence the analysis results. No analysis was conducted on the drawdown data collected from monitor well MW-15S as ground water at this monitor well was apparently unaffected by pumping at MW-5S during the APT. No analysis was conducted on the



AQTESOLV

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FIGURE 7

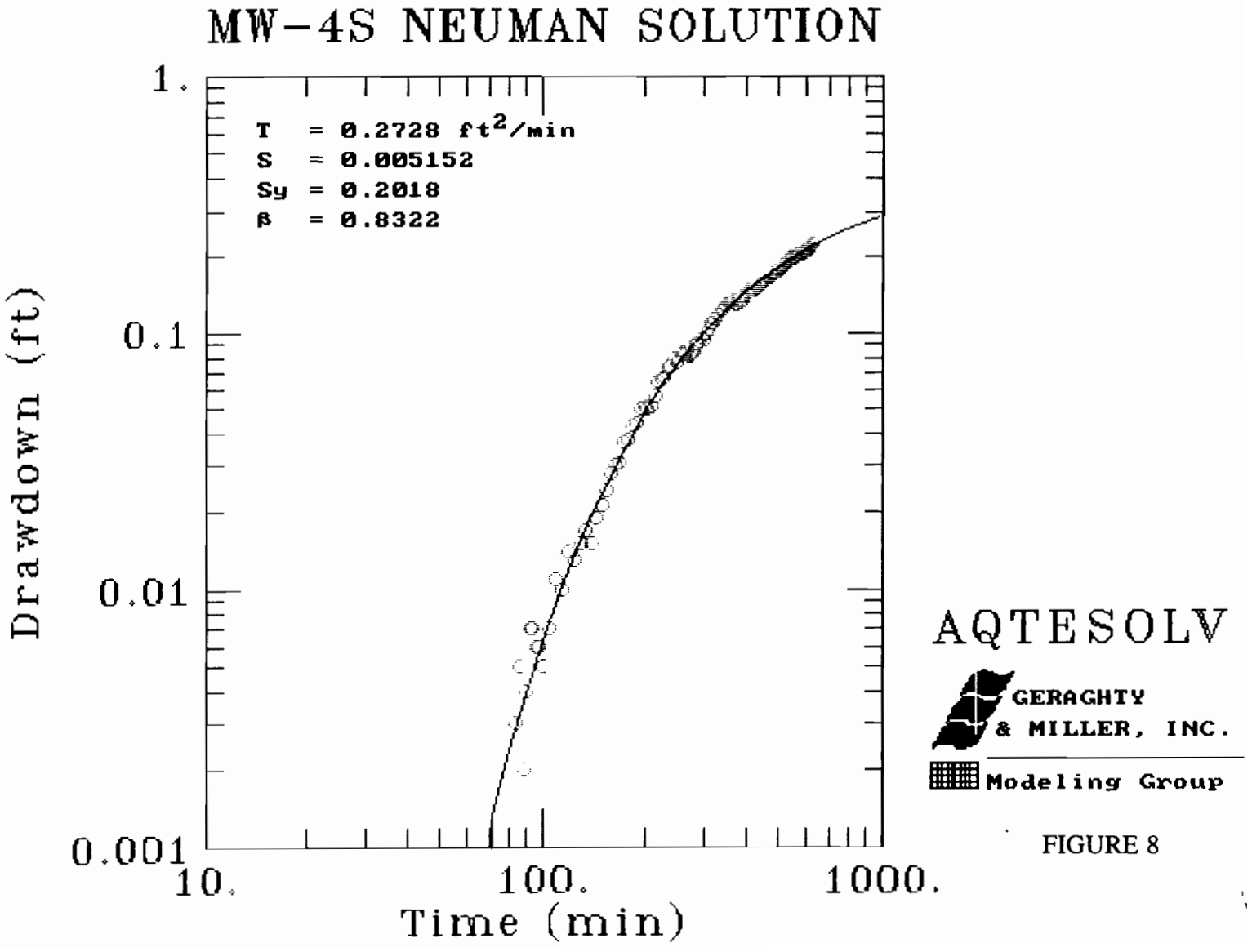
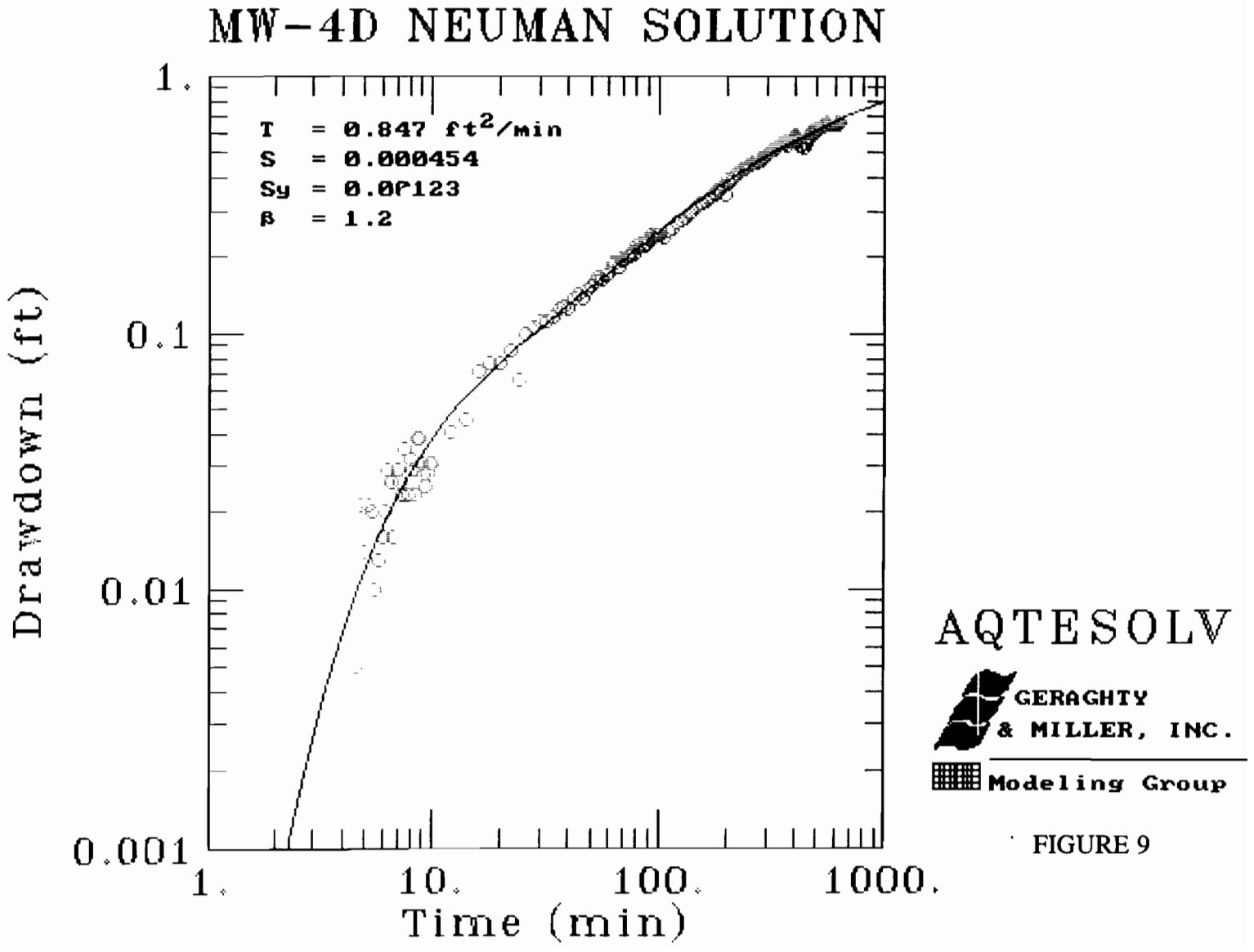

MW-4S NEUMAN SOLUTION
T = 0.2728 ft²/min
S = 0.005152
Sy = 0.2018
β = 0.8322
1.
0.1
0.01
0.001
Drawdown (ft)
10.
100.
1000.
Time (min)
AQTESOLV
GERAGHTY & MILLER, INC.
Modeling Group

FIGURE 8


MW-4D NEUMAN SOLUTION
T = 0.847 ft²/min
S = 0.000454
Sy = 0.0P123
ß = 1.2
Drawdown (ft)
1.
0.1
0.01
0.001
1.
10.
100.
1000.
Time (min)
AQTESOLV
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Modeling Group

FIGURE 9

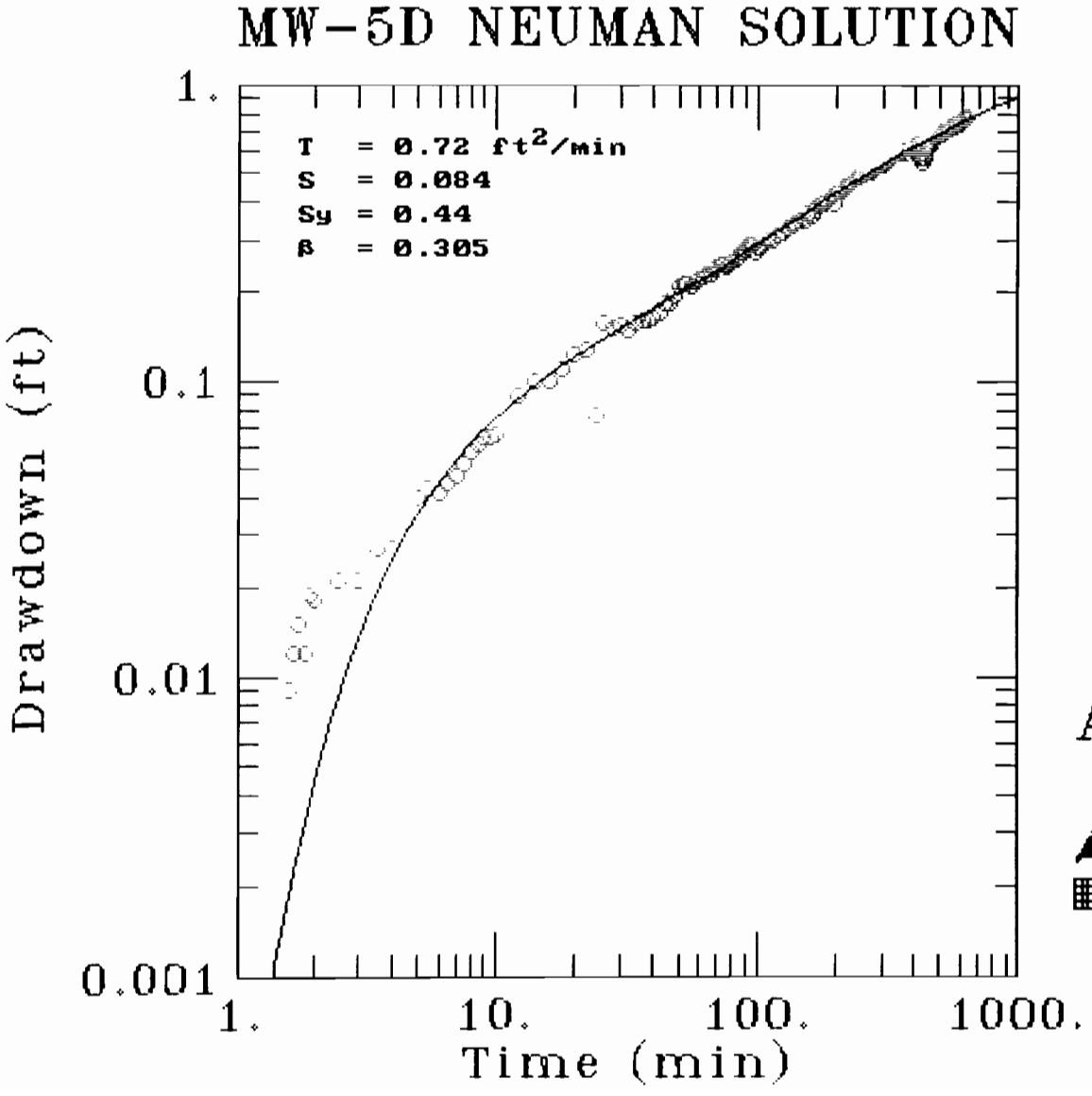

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FIGURE 10

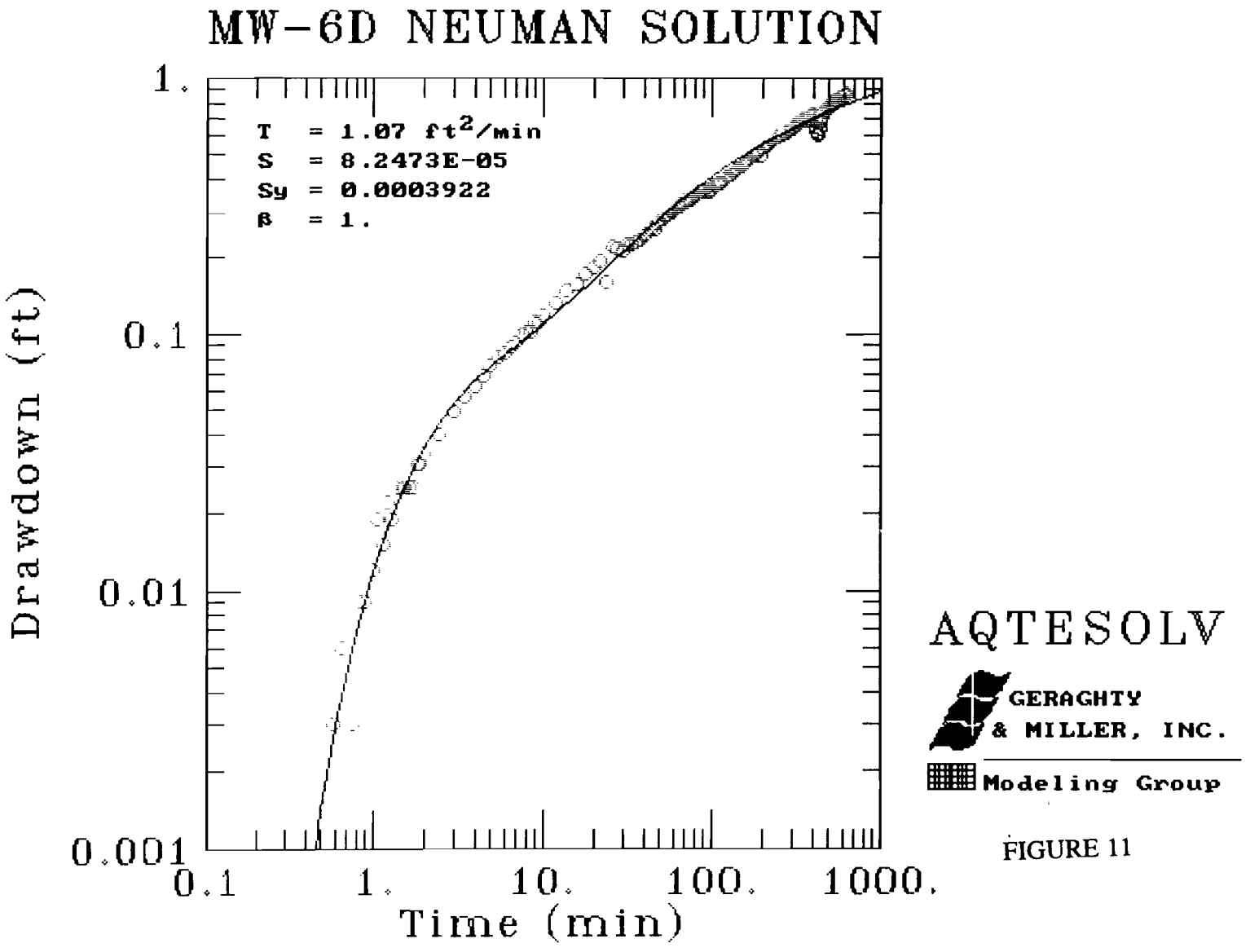
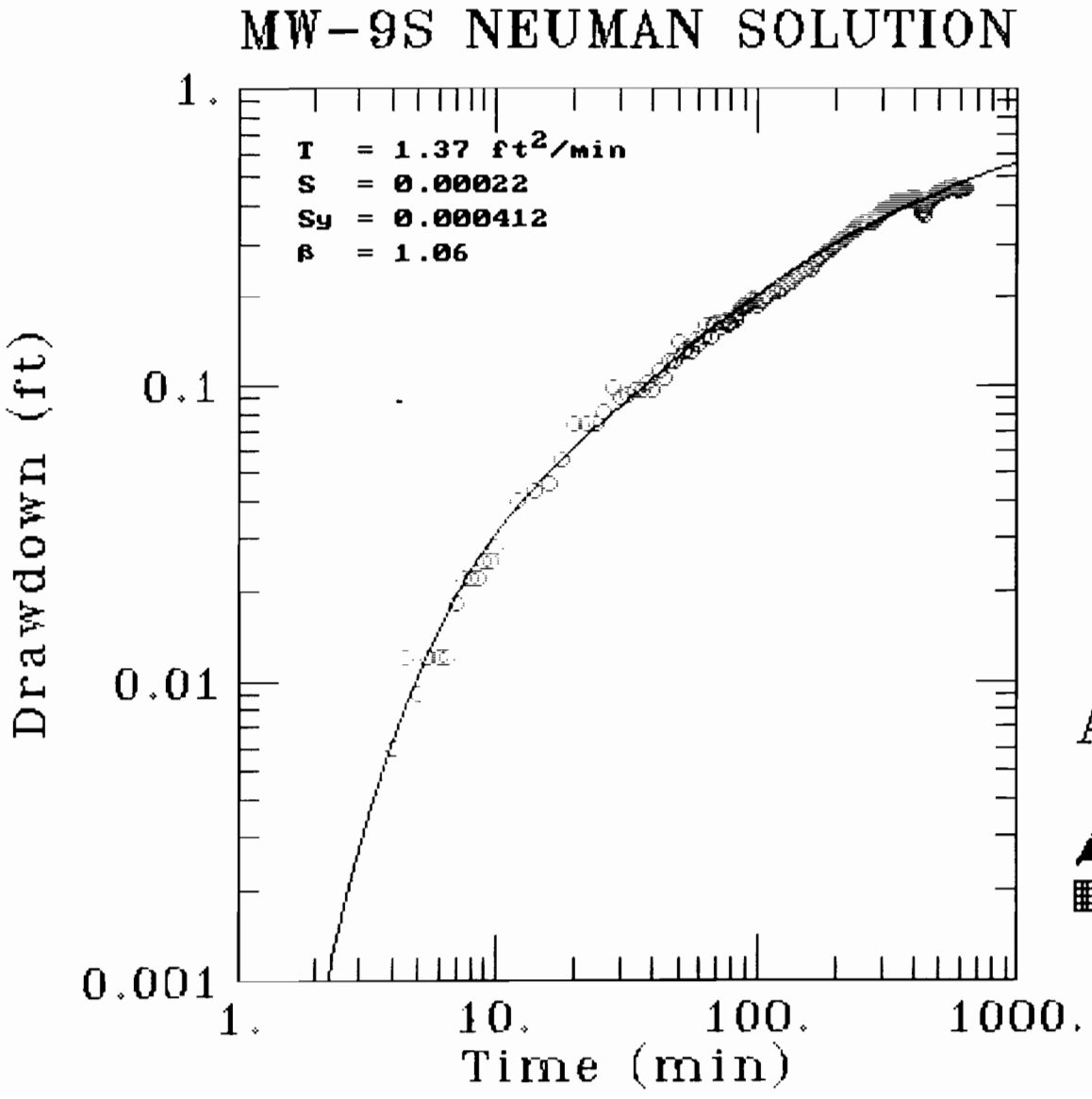

MW-6D NEUMAN SOLUTION
T = 1.07 ft²/min
S = 8.2473E-05
Sy = 0.0003922
β = 1.
Drawdown (ft)
1.
0.1
0.01
0.001
0.1
1.
10.
100.
1000.
Time (min)
AQTESOLV
GERAGHTY & MILLER, INC.
Modeling Group

FIGURE 11



AQTESOLV

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FIGURE 12

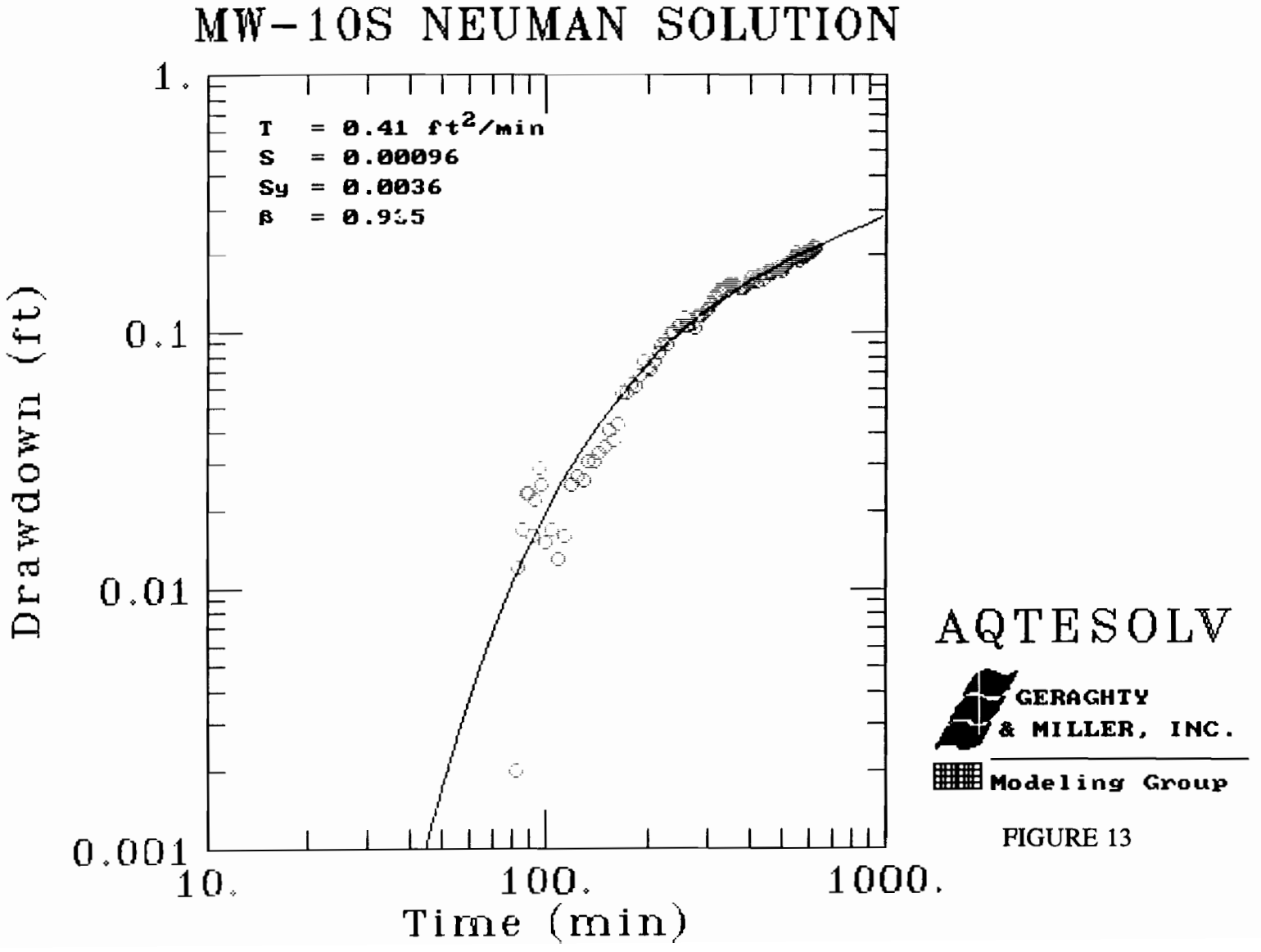
MW-10S NEUMAN SOLUTION
T = 0.41 ft²/min
S = 0.00096
Sy = 0.0036
β = 0.935
Drawdown (ft)
1.
0.1
0.01
0.001
10.
100.
1000.
Time (min)
AQTESOLV
GERAGHTY & MILLER, INC.
Modeling Group

FIGURE 13

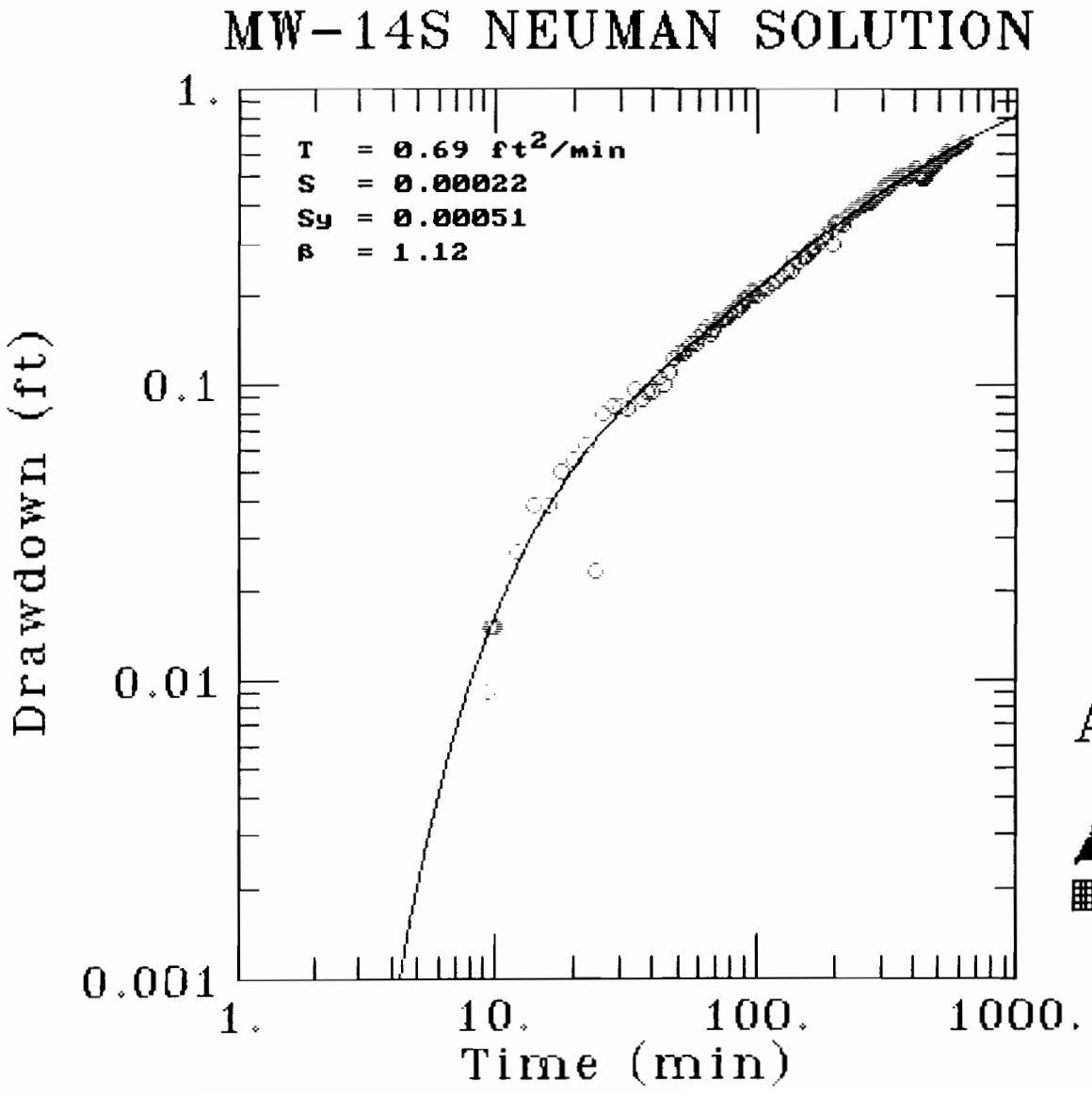

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FIGURE 14

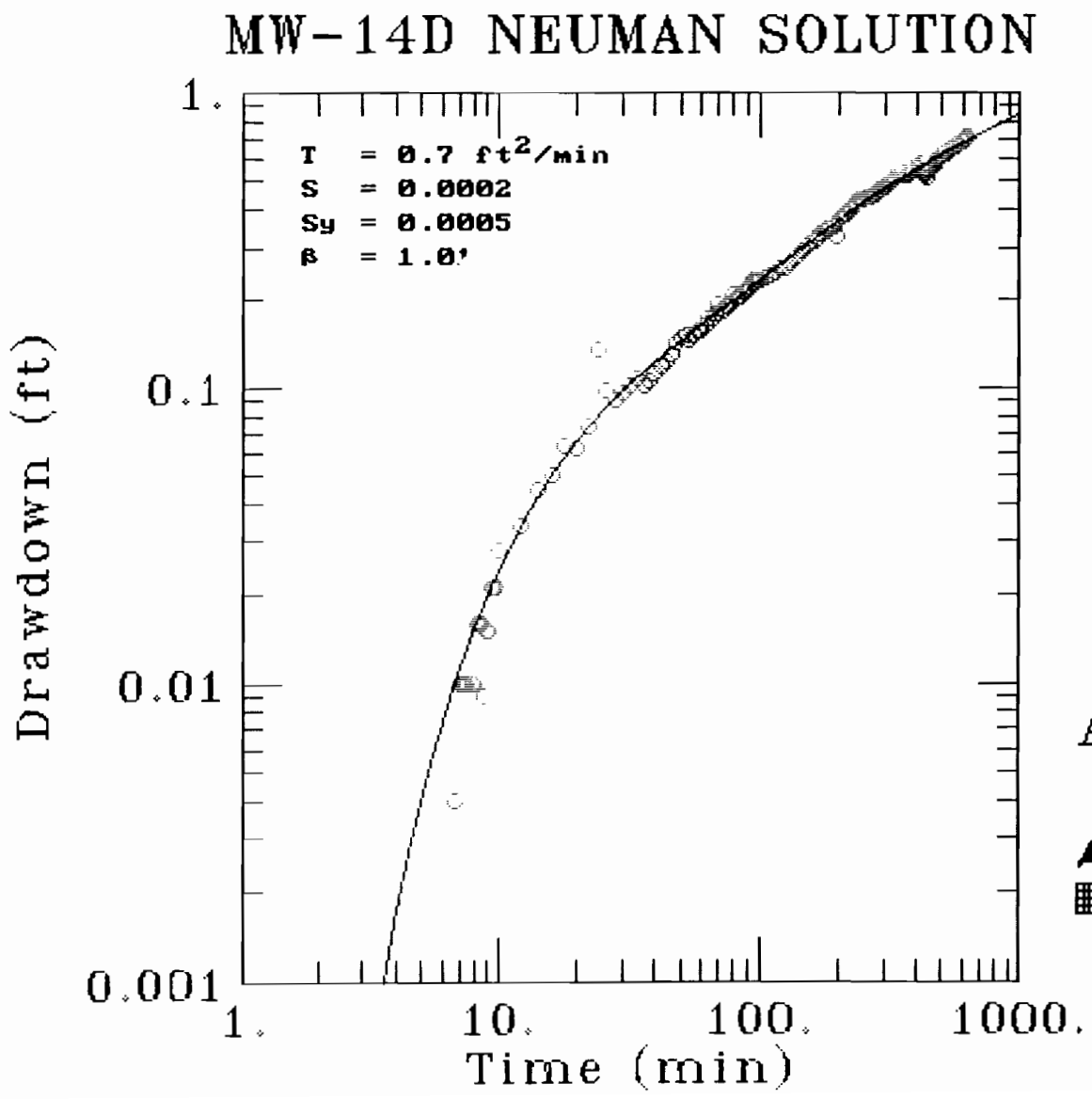

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FIGURE 15

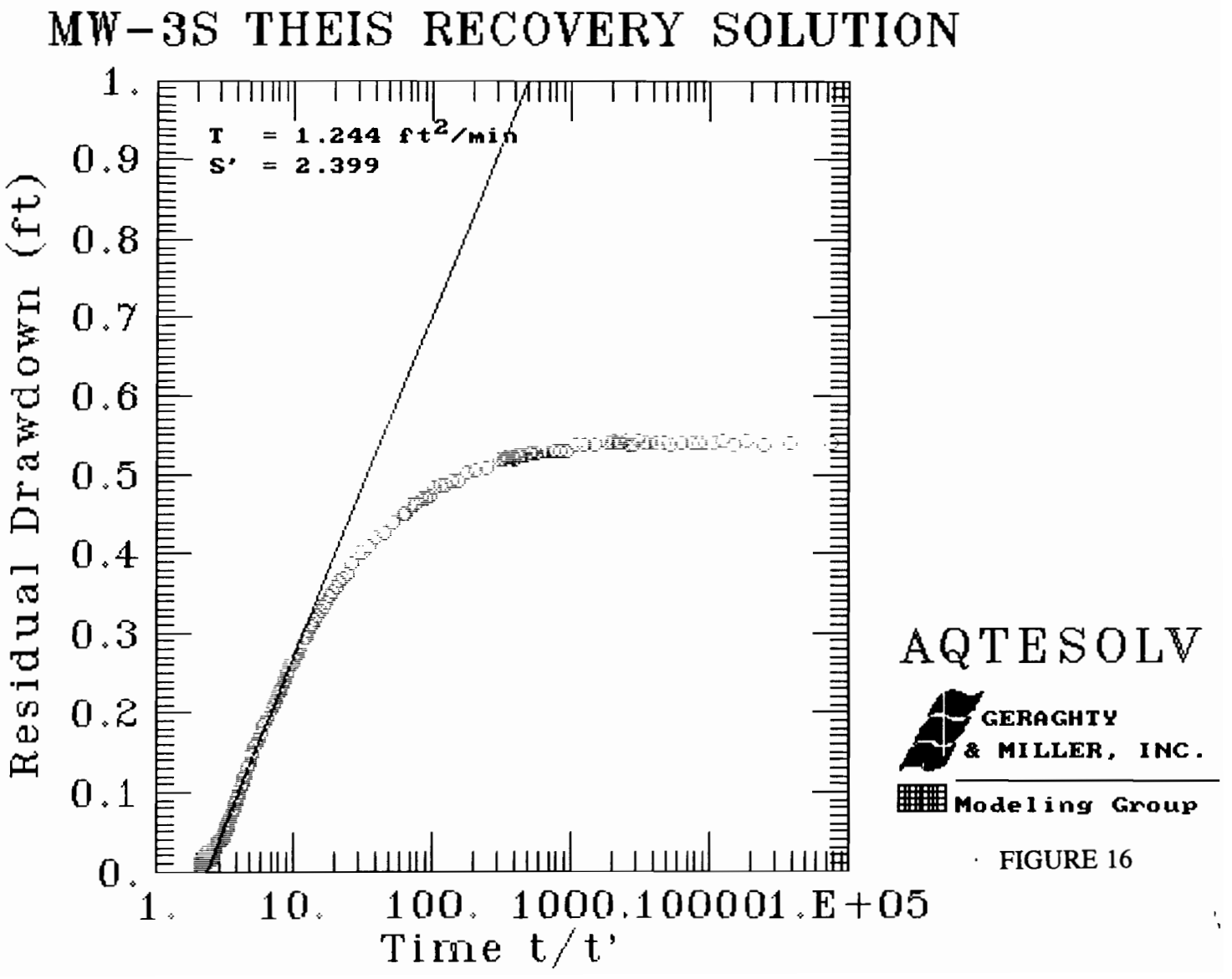
MW-3S THEIS RECOVERY SOLUTION
T = 1.244 ft²/min
S' = 2.399
Residual Drawdown (ft)
1.
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.
1.
10.
100.
1000.
100001.
E+05
Time t/t'
AQTESOLV
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FIGURE 16

MW-4S THEIS RECOVERY SOLUTION

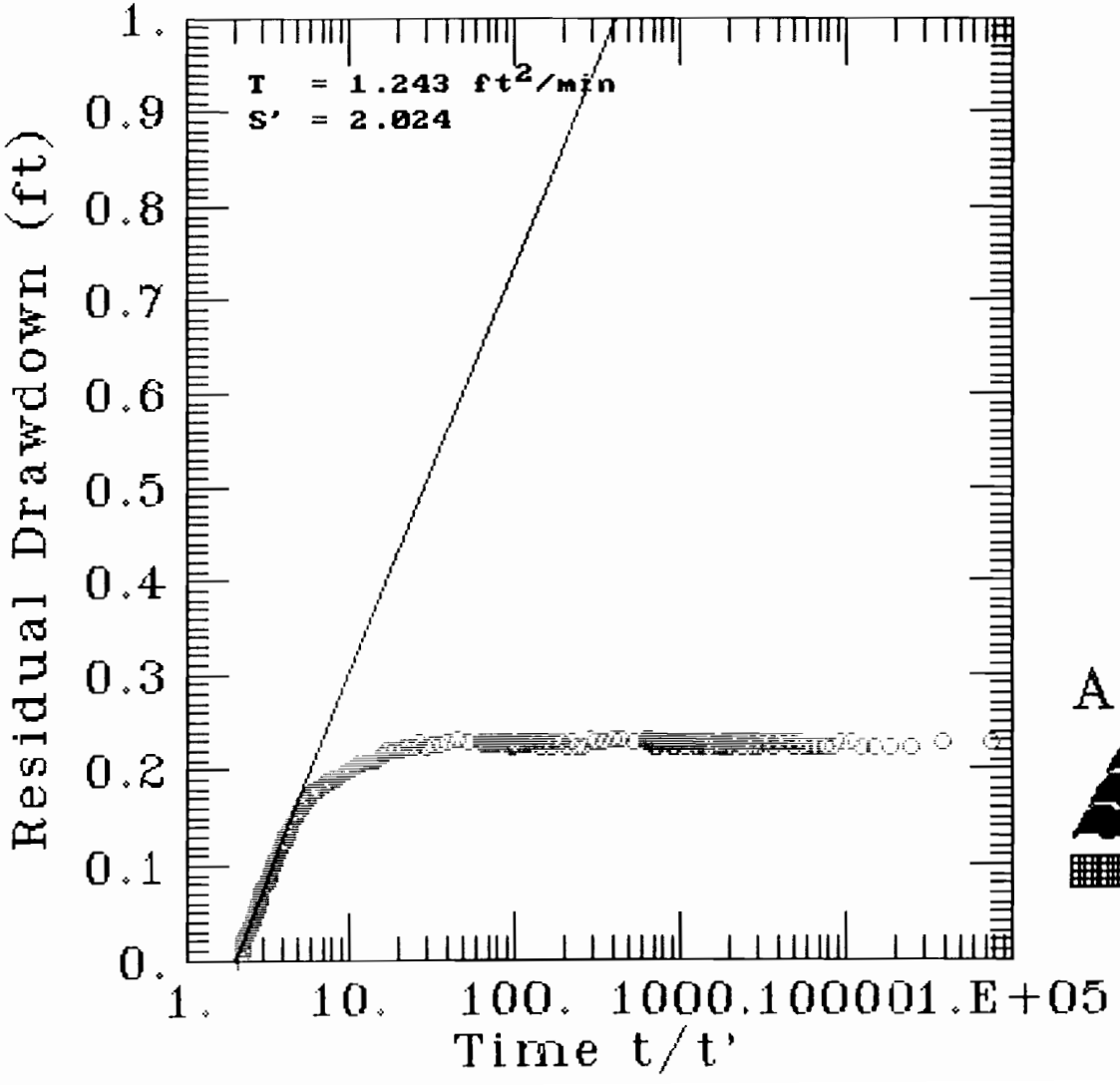

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FIGURE 17

MW-4D THEIS RECOVERY SOLUTION

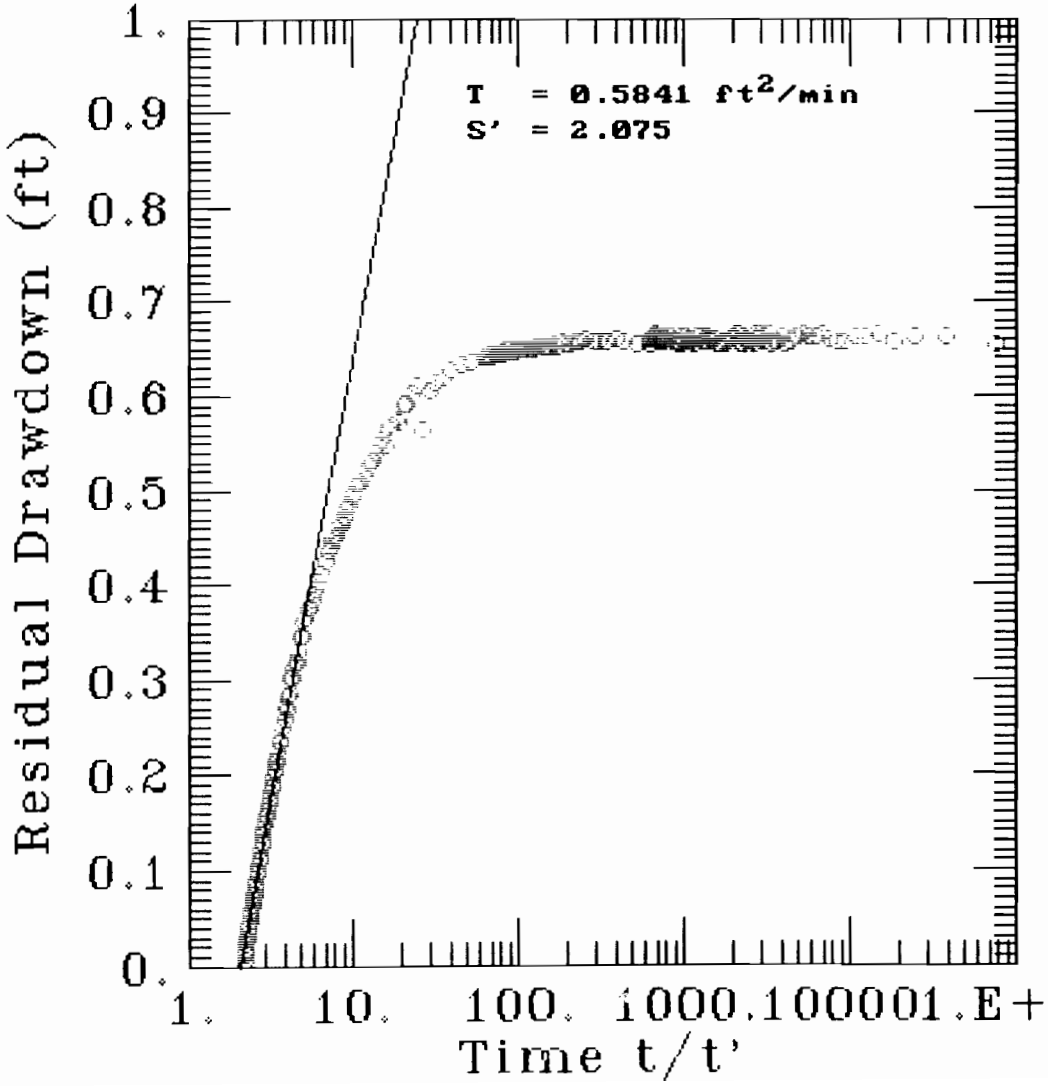

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FIGURE 18

MW-5D THEIS RECOVERY SOLUTION

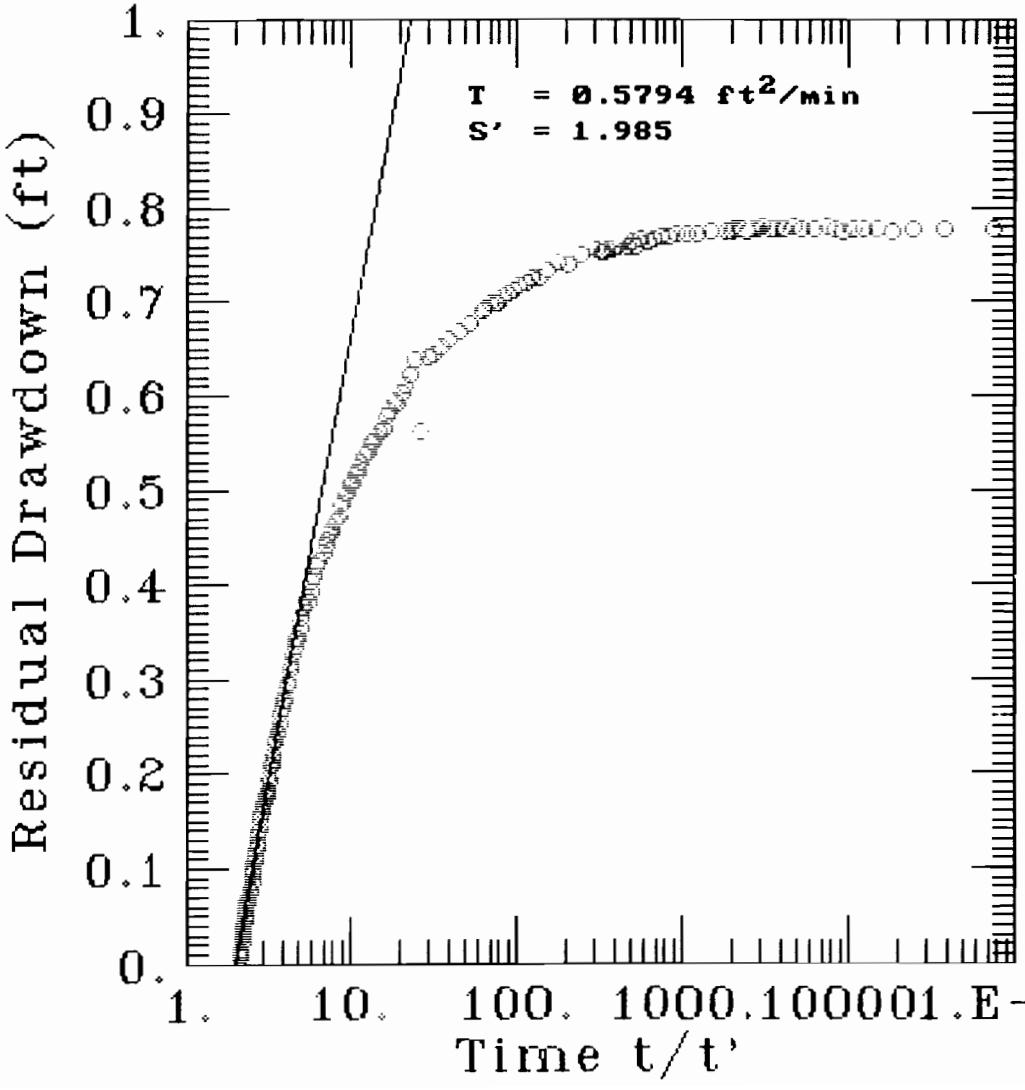

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FIGURE 19

MW-6D THEIS RECOVERY SOLUTION

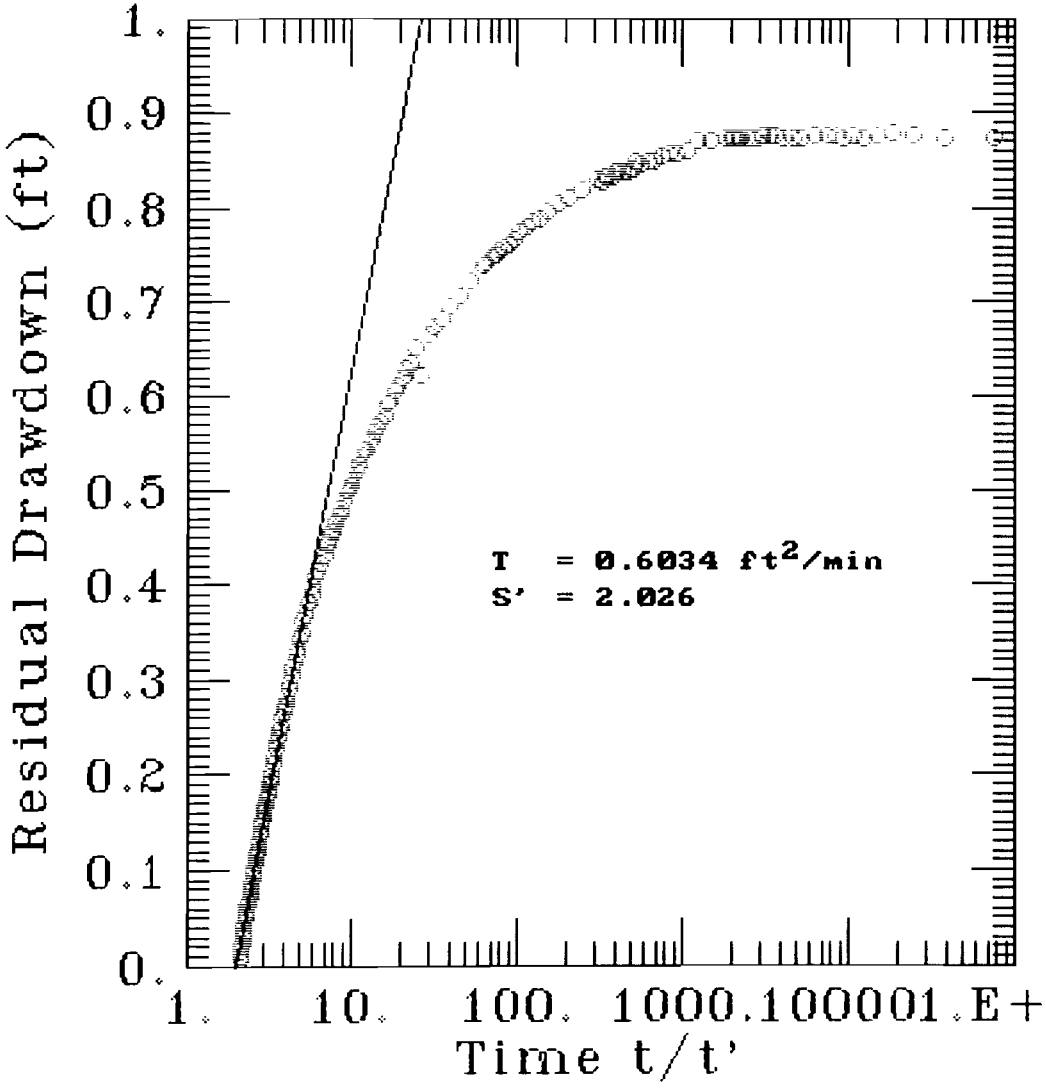

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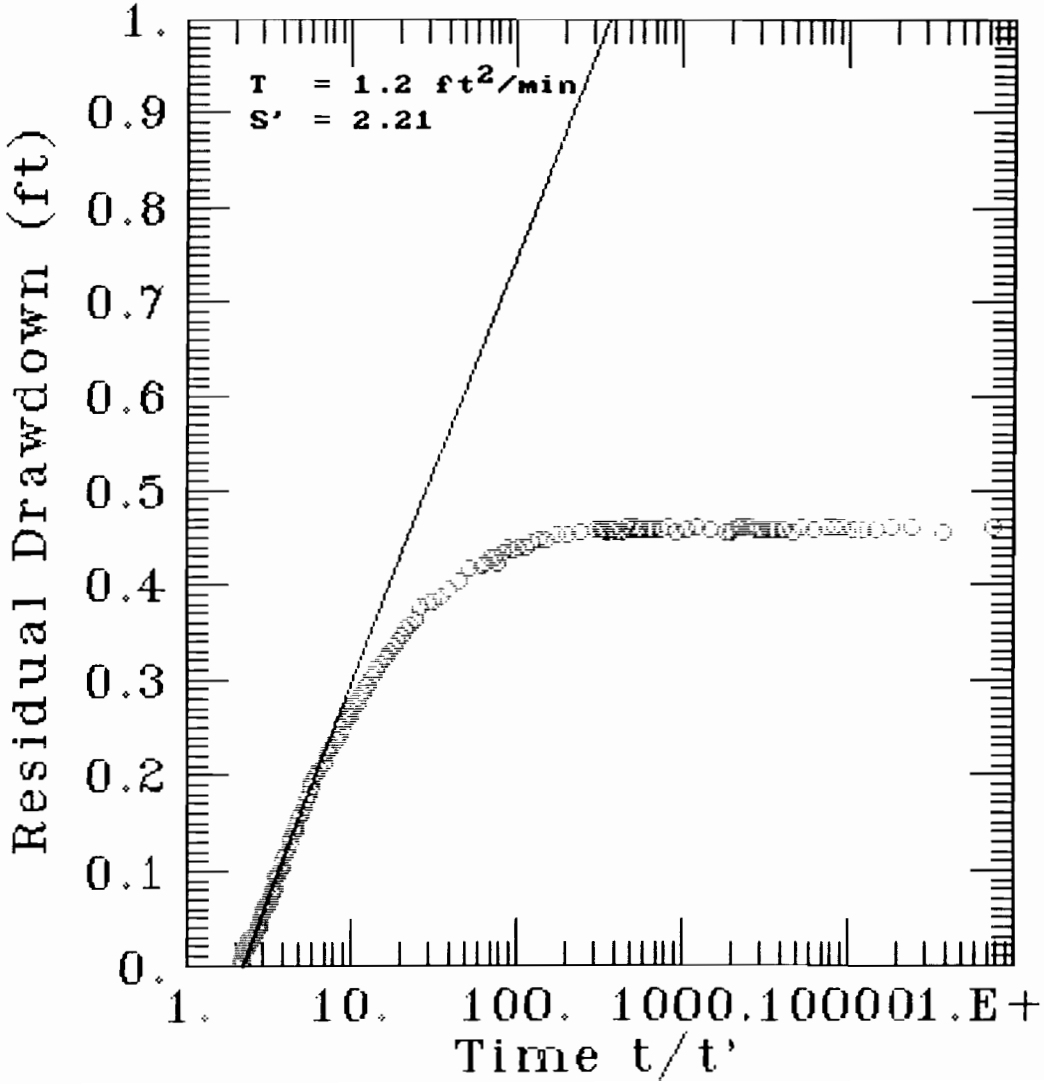
FIGURE 20

MW-9S THEIS RECOVERY SOLUTION



AQTESOLV

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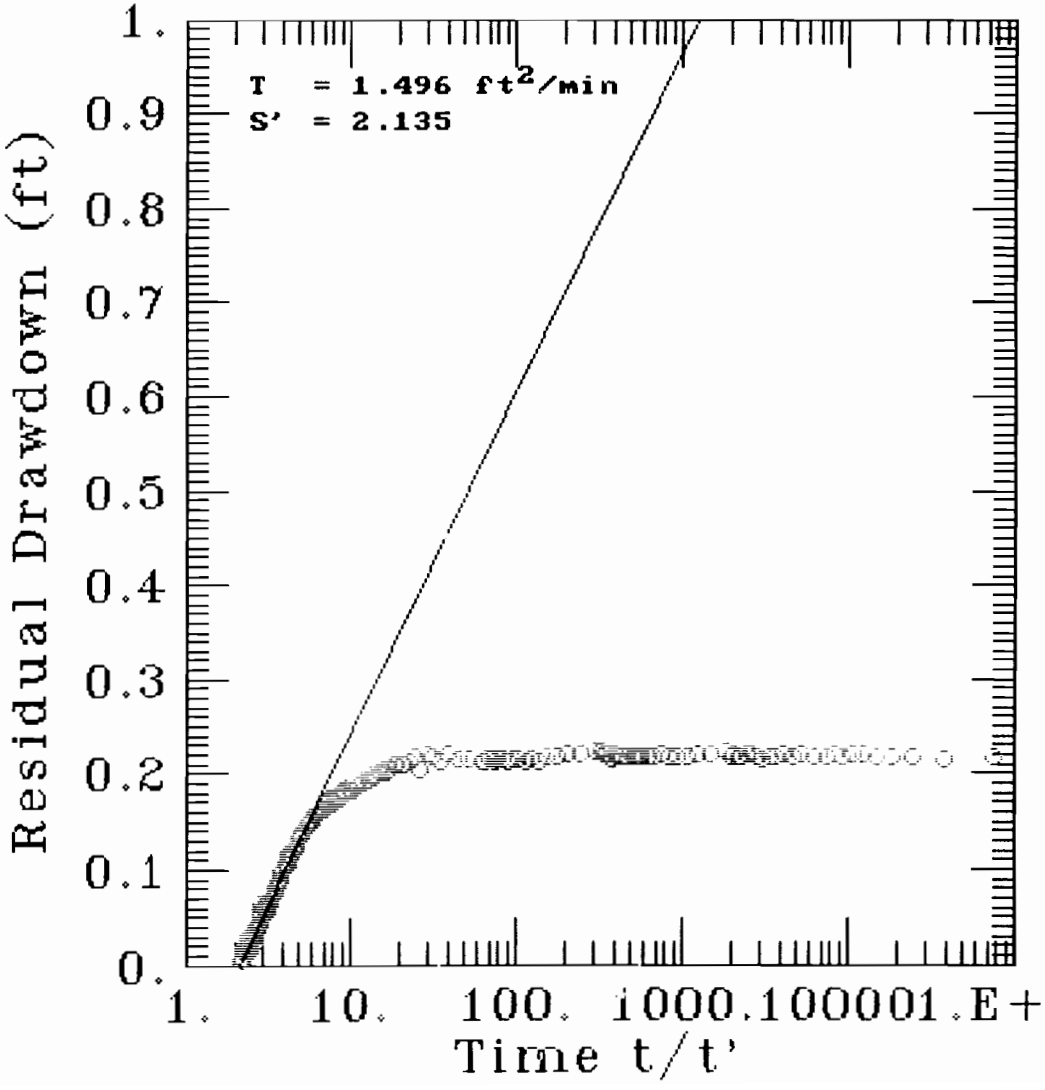
FIGURE 21

MW-10S THEIS RECOVERY SOLUTION



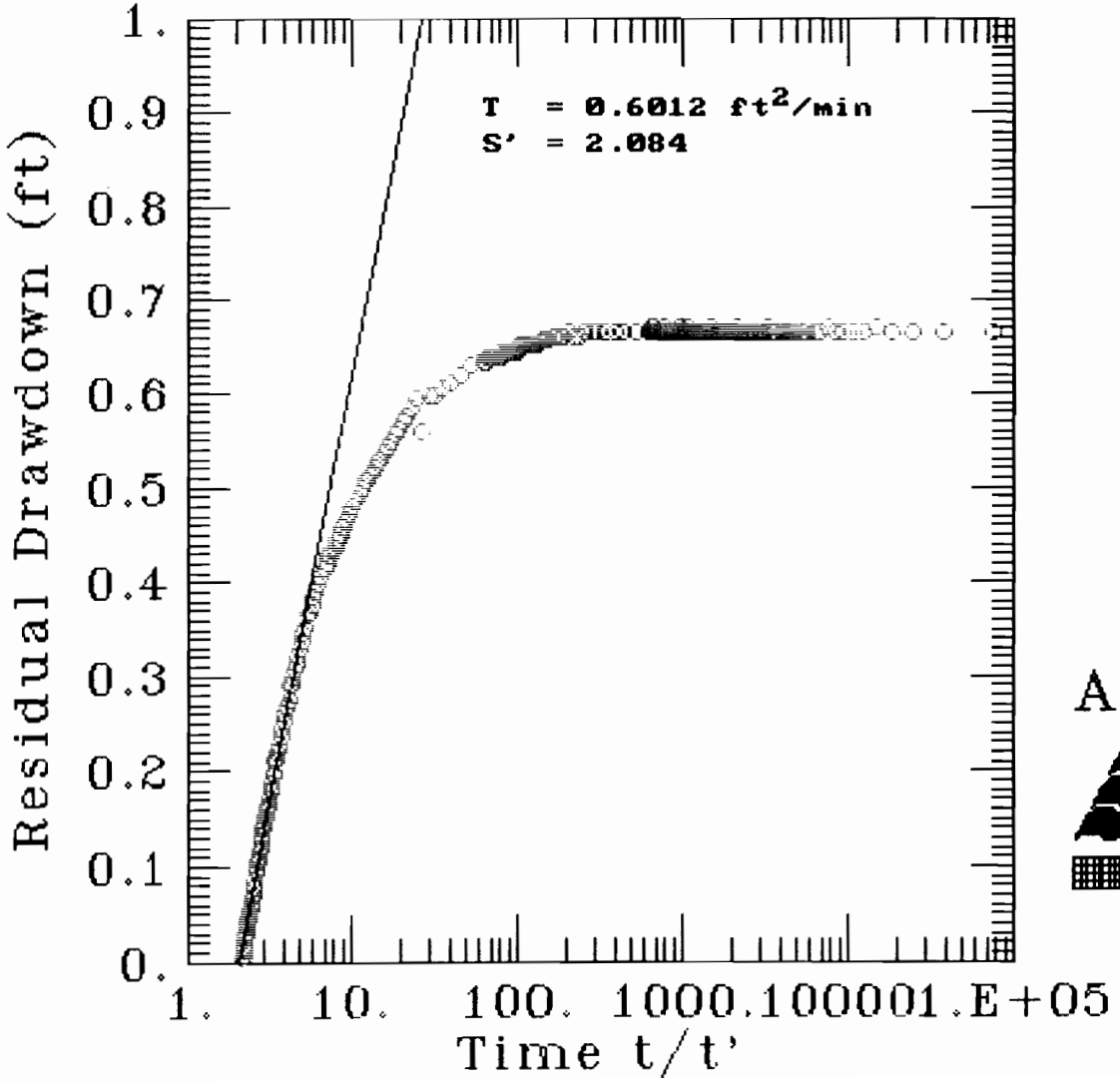
AQTESOLV

GERAGHTY & MILLER, INC.

Modeling Group

FIGURE 22

MW-14S THEIS RECOVERY SOLUTION



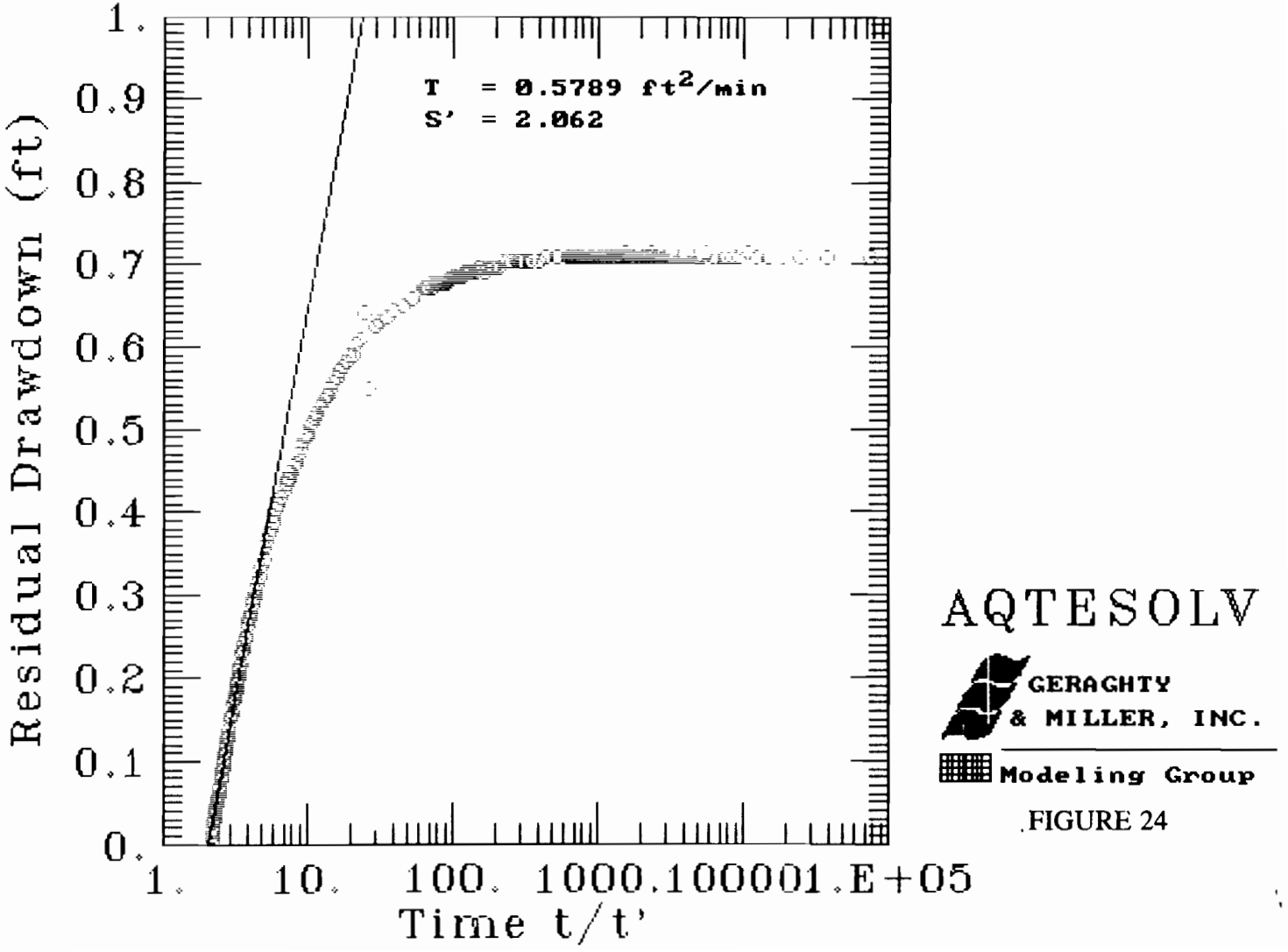
AQTESOLV

GERAGHTY & MILLER, INC.

Modeling Group

FIGURE 23

MW-14D THEIS RECOVERY SOLUTION



AQTESOLV

GERAGHTY & MILLER, INC.

Modeling Group

FIGURE 24

TABLE 2

APT RESULTS SUMMARY
FOREST GLEN SITE
NIAGARA FALLS, NEW YORK

Observation Well ID	Transmissivity ($feet^2$/day)	Storage Coefficient
MW-3S	1900	0.00025
MW-4S	400	0.0052
MW-4D	1200	0.00045
MW-5D	1000	0.084
MW-6D	1500	0.000082
MW-9S	2000	0.00022
MW-10S	600	0.00096
MW-14S	1000	0.00022
MW-14D	1000	0.00020
Average	**1100**	**0.0007**

drawdown data collected from monitor well MW-6S as these data are remarkably abnormal (possibly due to a transducer/data logger malfunction), and hence could not be analyzed.

The APT pumping phase analysis results presented in Figures 7 through 15 indicate that the transmissivity of the bedrock aquifer at the site varies from approximately 400 to 2000 feet^2/day and averages approximately 1100 feet^2/day. The pumping phase analysis results also indicate that the storage coefficient varies from approximately 0.000082 to 0.084 and averages 0.0007, while the specific yield may range from approximately 0.00039 to 0.44 and average 0.003. Note, however, that because the APT was only 10.5 hours long, the estimates for specific yield should not be considered reliable as the test may not have been run long enough to measure the full impacts of delayed gravity drainage. As indicated above, the primary purpose of the APT was to estimate the transmissivity of the bedrock aquifer, and hence, the APT was designed and run accordingly. Note also that all average values of aquifer properties presented above and below were calculated using a geometric mean, as recommended by Schilfgaarde (1974).

The APT recovery phase analysis results presented in Figures 16 through 24 indicate the transmissivity of the bedrock aquifer may vary from approximately 800 to 2200 feet^2/day. These values are very close to the values estimated based on the more rigorous pumping phase analysis, and thus provide supporting evidence that the pumping phase analysis results are reasonably accurate.

APT AREA OF INFLUENCE

To help estimate the area of influence of the APT, periodic water level measurements were also collected manually from all the remaining monitor wells not used as test wells for the APT, both prior to and during the APT. The drawdown data for these wells are plotted in **Figures 25** through **27**. The drawdown curves presented in these figures indicate that while ground water levels at monitor wells MW-2S, MW-2D, MW-3D, MW-7D, MW-8D, MW-9D, and MW-10D were affected by the APT (inside the area of influence), water levels at monitor wells MW-1S, MW-1D, MW-7S, MW-8S, MW-11S, MW-11D, MW-12S, MW-12D, MW-13S, MW-13D, and MW-15D were not significantly affected by the APT (outside the area of influence).

The drawdowns at the end of the pumping phase of the APT, corrected for trend via Equation 2, were calculated for each monitor well and are presented in **Tables 3** and **4**. Using these corrected drawdown data, drawdown contour maps for both the shallow and deep portions of the bedrock aquifer were prepared and are presented in **Figures 28** and **29**. These drawdown contour maps indicate that the radius of influence of the APT was approximately 600 feet. It should be noted, however, that because water levels were still falling at the end of the pumping phase of the APT, it is likely the final radius of influence, if pumping at monitor well MW-5S were allowed to continue until steady state water levels were achieved, would be

significantly greater than 600 feet. Thus, it is apparent that pumping from one extraction well can impact water levels over a large area at the Forest Glen Site.

Non-APT Well Drawdown Measurements

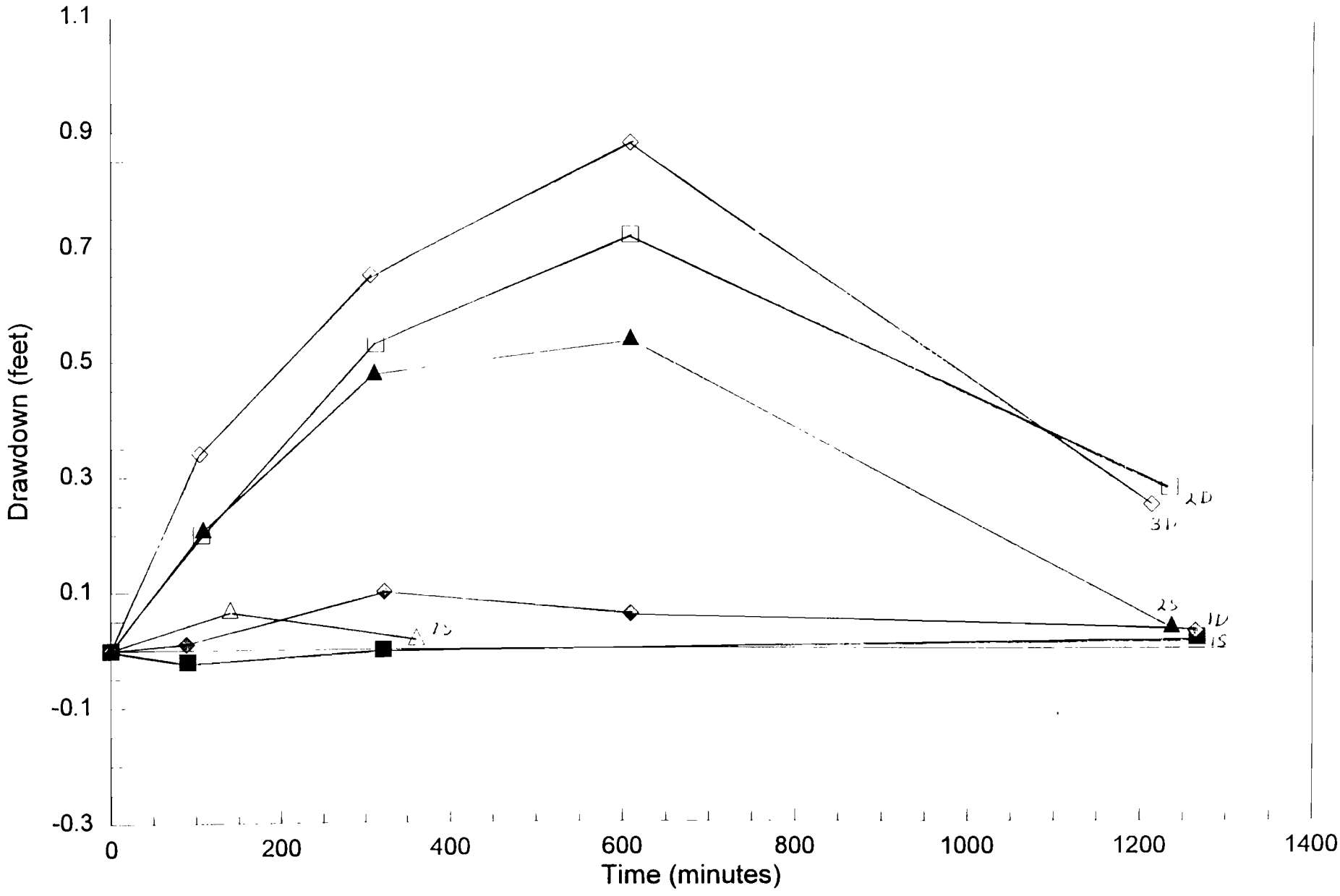


FIGURE 25

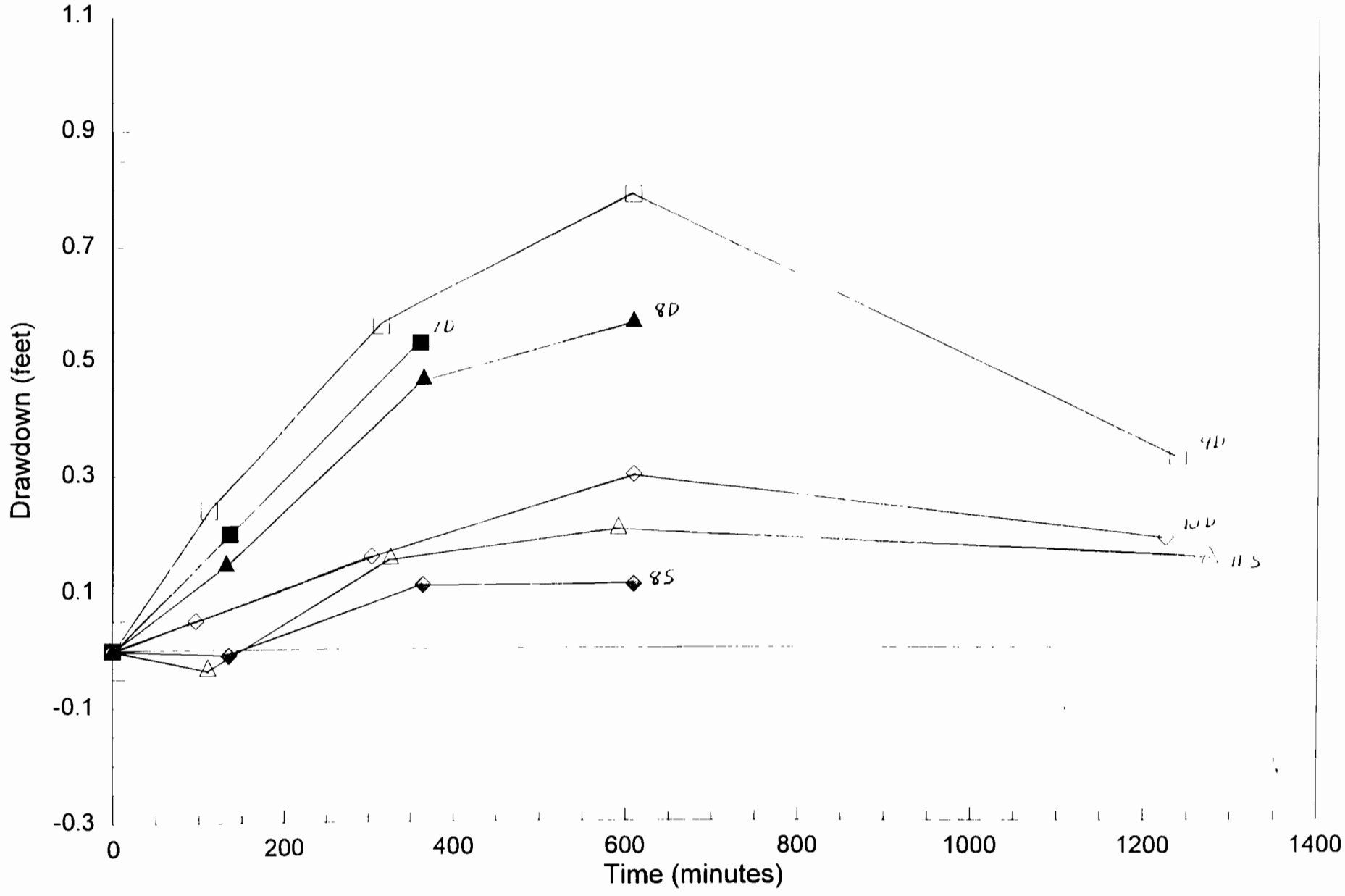

Non-APT Well Drawdown Measurements
Drawdown (feet)
1.1
0.9
0.7
0.5
0.3
0.1
-0.1
-0.3
0
200
400
600
800
1000
1200
1400
Time (minutes)
8D
8S

FIGURE 26

Non-APT Well Drawdown Measurements

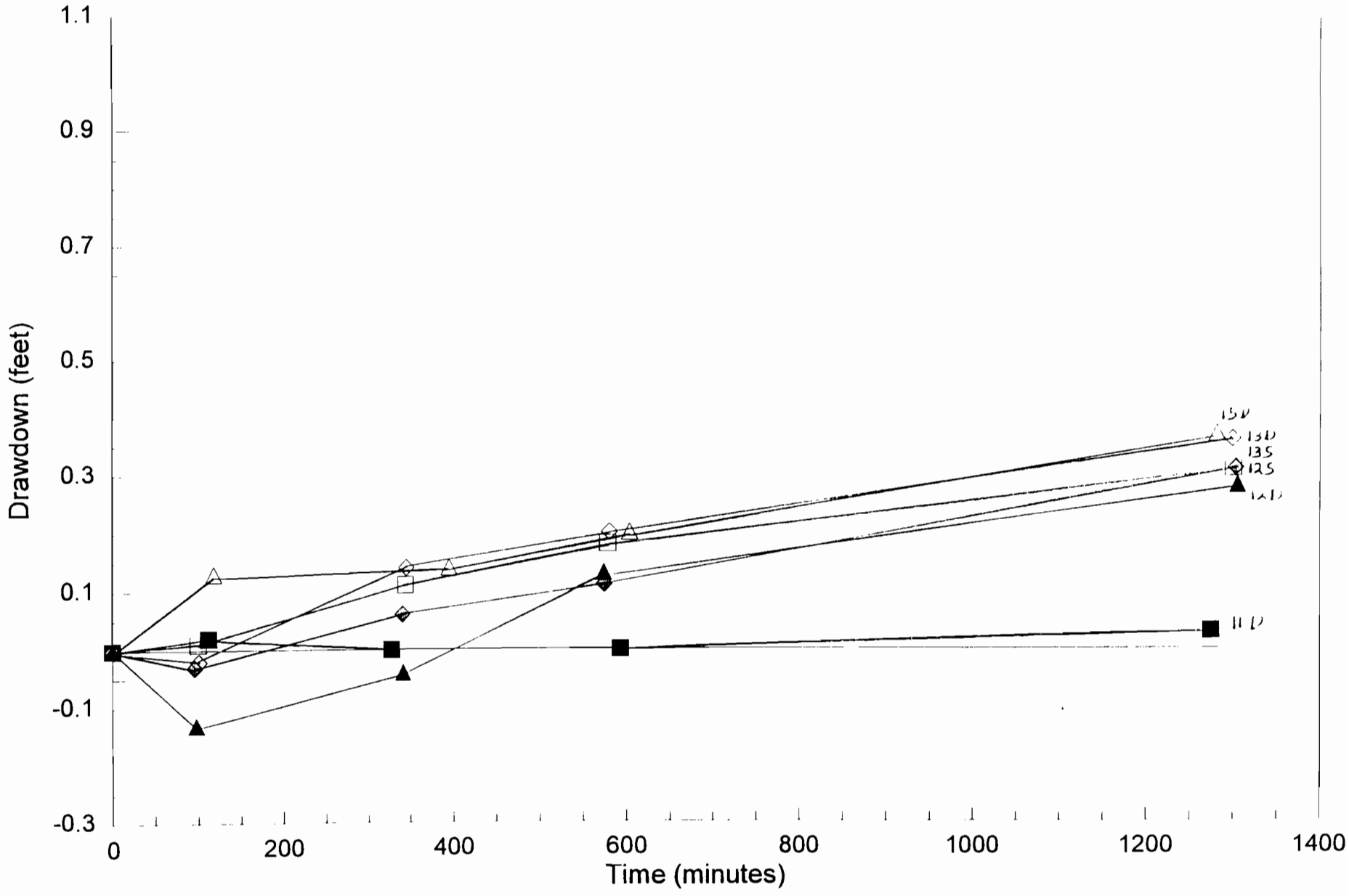


FIGURE 27

TABLE 3

APT SHALLOW AQUIFER FINAL CORRECTED DRAWDOWN RESULTS
FOREST GLEN SITE
NIAGARA FALLS, NEW YORK

Monitor Well ID	Final Corrected Drawdown (feet)
MW-1S	0
MW-2S	0.5
MW-3S	0.5
MW-4S	0.2
MW-5S	1.7
MW-6S	Unknown
MW-7S	0
MW-8S	0
MW-9S	0.5
MW-10S	0.2
MW-11S	0
MW-12S	0
MW-13S	0
MW-14S	0.7
MW-15S	0

TABLE 4

APT DEEP AQUIFER FINAL CORRECTED DRAWDOWN RESULTS
FOREST GLEN SITE
NIAGARA FALLS, NEW YORK

Monitor Well ID	Final Corrected Drawdown (feet)
MW-1D	0
MW-2D	0.6
MW-3D	0.8
MW-4D	0.7
MW-5D	0.8
MW-6D	0.9
MW-7D	0.6
MW-8D	0.6
MW-9D	0.6
MW-10D	0.2
MW-11D	0
MW-12D	0
MW-13D	0
MW-14D	0.7
MW-15D	0

FIGURE 28
CORRECTED DRAWDOWN CONTOUR MAP IN
SHALLOW BEDROCK ZONE WELLS DURING AQUIFER TEST

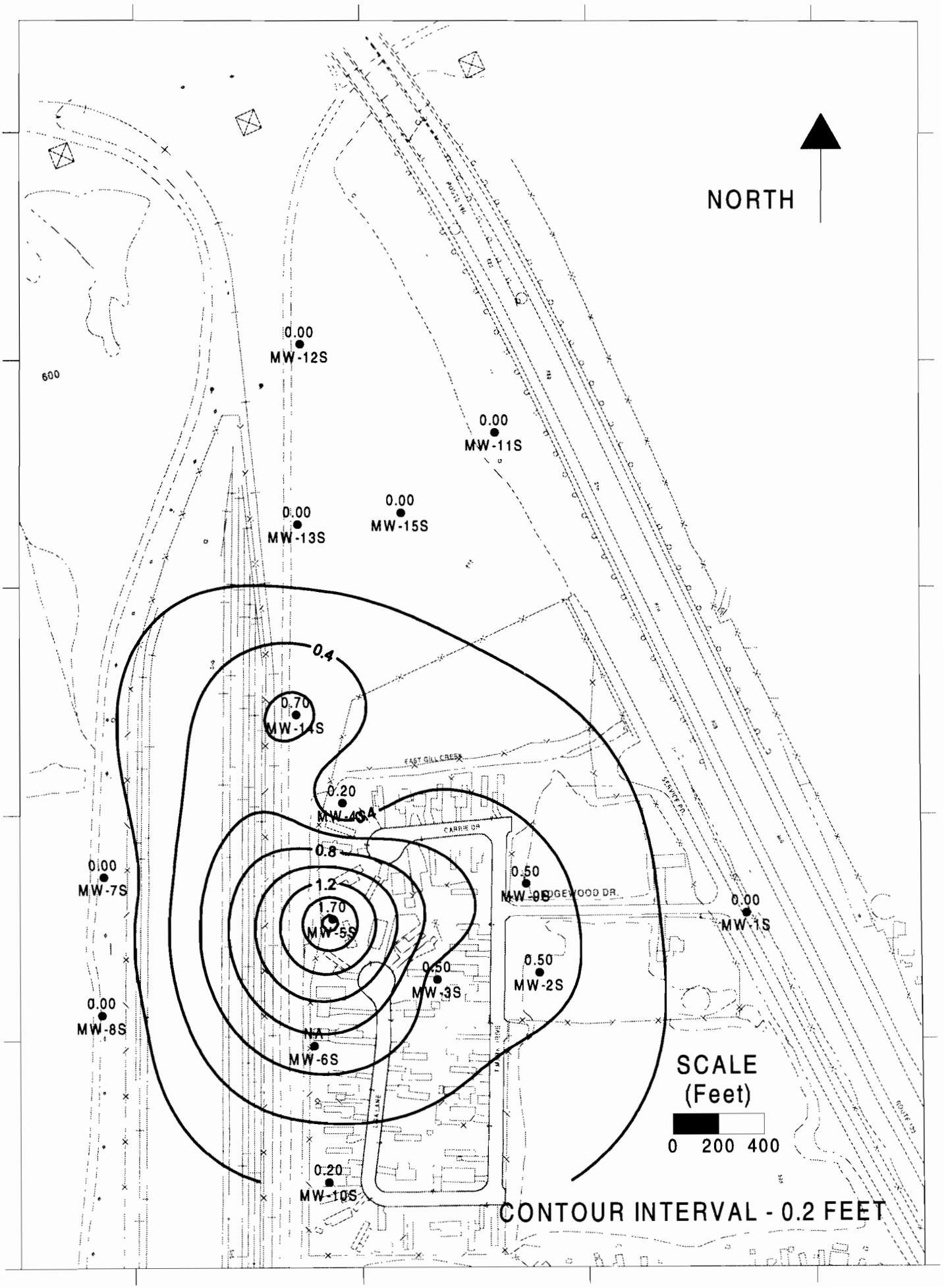
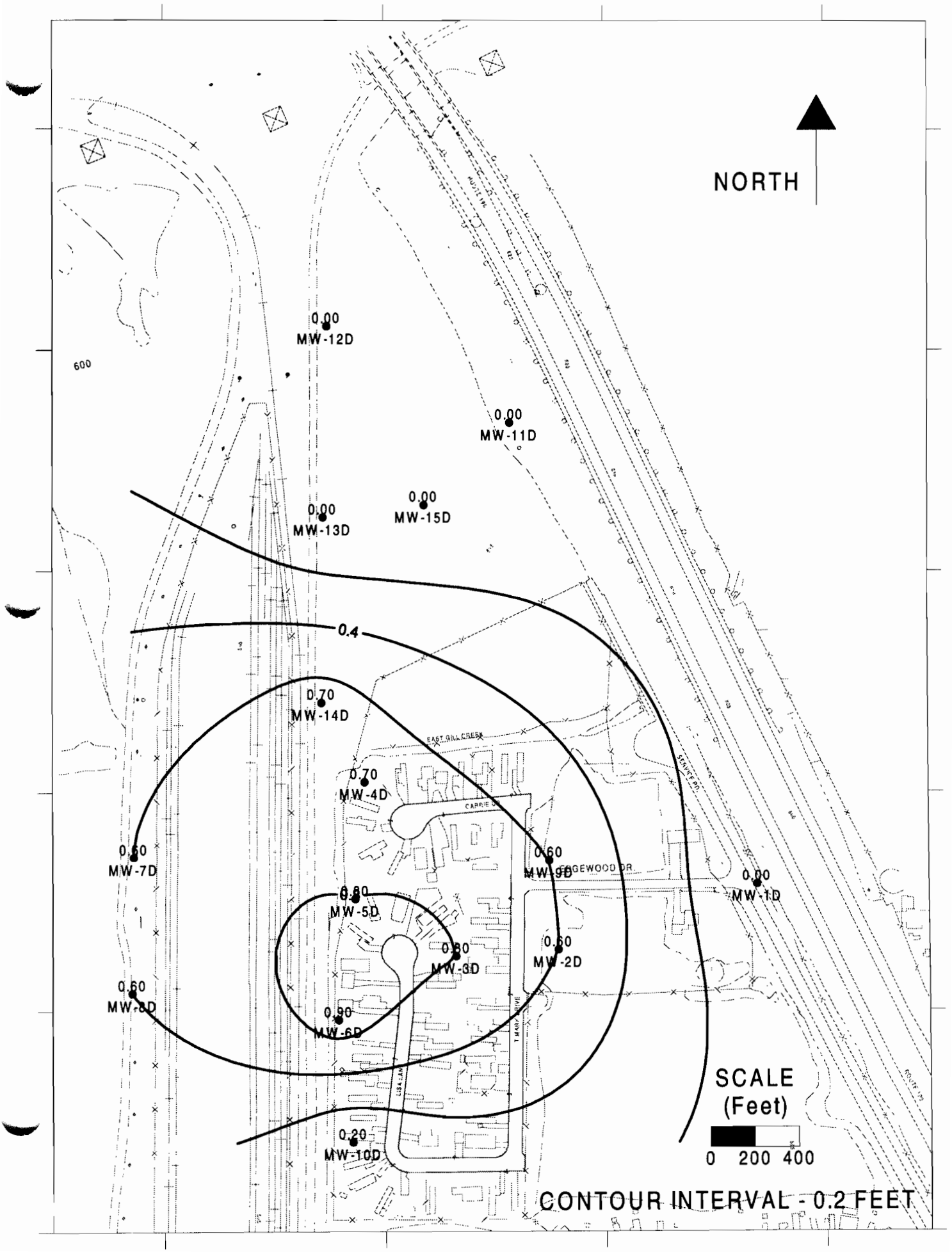


FIGURE 29
CORRECTED DRAWDOWN CONTOUR MAP IN
DEEP BEDROCK ZONE WELLS DURING AQUIFER TEST



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Neuman, S. P., 1975. *Analysis of Pumping Test Data from Anisotropic Unconfined Aquifers Considering Delayed Gravity Response.* Water Resources Research, No. 11.

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Theis, C. V., 1935. *The Relation Between the Lowering of the Piezometric Surface and the Rate and Duration of Discharge of a Well Using Groundwater Storage.* Am. Geophys. Union Trans., Vol. 16.

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APPENDIX B

PRELIMINARY GROUNDWATER MODELING

Technical Memorandum for Preliminary Groundwater Modeling
Feasibility Study on Pumping Well Capture Zones
Forest Glen Site, Niagara County, New York

Introduction

This memorandum presents the results of preliminary groundwater modeling performed as part of the Feasibility Study (FS) for the Forest Glen Site in Niagara Falls, Niagara County, New York. The purpose of the preliminary groundwater model is to develop a reasonable estimate of the number of pumping wells and the required pumping rate to capture contaminated groundwater both onsite and offsite to the west beneath the Conrail Foote Railroad yard.

The groundwater modeling was done with a fully three dimensional, finite element model called DYNFLOW. The model is considered preliminary because of the limited amount of data available to develop the model, and the limited degree to which the model has been calibrated. Nevertheless, the model is a much better representation of site conditions than available analytical capture zone analysis programs which are not suited to partially penetrating, non-homogeneous conditions such as those present at this site. The model was used to develop estimated capture zones for various well configurations. Through a series of simulations, two efficient alternative well configurations have been developed. One alternative is designed to capture all contaminated groundwater onsite using two extraction wells. The other alternative adds two additional extraction wells to the west to capture contaminated groundwater beneath the Conrail Foote Railroad yard.

This technical memorandum assumes the reader is familiar with the Final Remedial Investigation (RI) Report for the Forest Glen Superfund Site and will not duplicate information found in the RI report. The sections that follow discuss sources of data and information, the conceptual model of the area and site hydrogeology, model structure and calibration, model simulation results, and conclusions.

Sources of Information

A full listing of data and information sources for area hydrogeology are provided in the RI report. For the preliminary groundwater modeling, the RI report served as the most up to date source of data and information to develop the model. In addition, two primary sources of information for the preliminary modeling study were also used:

- (USGS, 1964) Johnston R.H., 1964, "Groundwater in the Niagara Falls Area, New York, with Emphasis on the Water-Bearing Characteristics of the Bedrock", USGS, Bulletin GW-53.

- CDM Federal Programs Corporation, 1998, " Forest Glen Aquifer Performance Test Analysis"

The USGS report provided the information and data needed to develop the conceptual model of the site, including the behavior of groundwater flow in the Lockport Dolomite. It also provided reasonable estimates for fixed head boundaries at the perimeter of the model with the use of water elevations in the reservoir to the north, as well as heads in the north to south conduit between the reservoir and the Niagara River. The aquifer performance test conducted by CDM Federal provided the data for the calibration of the model as well as more site specific values of storativity and transmissivity.

Area and Site Hydrogeology

The Forest Glen site is located in Niagara Falls, New York. The entire area was shaped by the action of advancing and retreating glaciers, which scoured and eroded the underlying bedrock and deposited material known as lodgement till. The topography is generally flat and poorly drained, with the regional overburden consisting of glaciolacustrine deposits (clay) and clay till generally less than 20 feet thick.

Beneath the overburden material, the underlying bedrock consists of approximately 150 to 160 feet of Lockport Dolomite, which contains both horizontal and vertical fractures. The Lockport Dolomite dips gently to the south at 29 feet per mile. Beneath the Lockport Dolomite lies the relatively impermeable Rochester Shale, which can be considered a no flow boundary for groundwater in the Lockport Dolomite aquifer.

Groundwater is found in the Lockport Dolomite in bedding joints, vertical joints, and small cavities. The bedding joints, or horizontal fractures, are the most important water bearing features, and at least seven, distinct horizontal fracture zones have been identified in the Lockport (USGS, 1964). These bedding joints transmit nearly all the water moving through the formation, and seem to persist laterally for distances of several miles. The separation between the joints is small, making them an effective conduit for horizontal groundwater flow. The zones are thin, usually less than 1 foot in thickness, with thick intervening layers of massive rock which transmit little or no water. **Because of the continuity and interconnectedness of the joints, horizontal groundwater flow in these joints can be effectively modeled as if they were an equivalent porous medium, separated by relatively impermeable layers.** Within the water bearing zones, open vertical joints also occur, forming interconnections between the bedding plane fractures. At the site, it appears from the pump test data that bedding planes in the shallow and deep Lockport Dolomite are connected by vertical fractures and operate effectively as one interconnected aquifer. However, because there is some overlap between the uncased holes of the shallow and deep wells at each cluster, the degree of interconnectedness is difficult to assess. In most cases, vertical fractures only occur in the shallow or upper few feet of the Lockport.

Conceptual Model of Area

In order to meet the objective of calculating a sufficient zone of capture for the contaminant plume while keeping the three-dimensional model simple for the purposes of the FS analysis, the Lockport Dolomite was only divided into three distinct layers (two layers were also assigned to the overburden material). Thus, bedding planes in the shallow and deep Lockport were modeled as equivalent porous medium as if the entire model layer transmitted water. In reality, the water is transmitted in relativly thin, highly porous zones with intervening impermeable rock. This means that the model can effectively simulate the horizontal extent of the capture zone under equilibrium conditions, but will not accurately simulate the rate of groundwater flow within the fractures. The model will also overestimate the reaction time of the aquifer's response to pumping, and may not accurately simulate the vertical extent of groundwater capture.

The model contains five layers representing the overburden and Lockport Dolomite. Locally at the site, the overburden is relatively thin, ranging from 5 to 17 feet in thickness. It consists of fill, clay, and clay till. The RI report provides cross-sections across the site showing the thickness of the overburden. For the purposes of the model, the overburden is divided into two layers. The top layer contains the more permeable fill in those areas where fill exists. In undisturbed areas the top layer consists of clay/silty clay. Beneath the top layer, the model contains a layer for the clay till that overlies the Lockport Dolomite. Shelby tube results indicate that the clay/silty clay has a vertical hydraulic conductivity of only about 0.00003 feet per day, making the overburden material a confining unit for the underlying Lockport Dolomite aquifer.

The lower three model layers represent the Lockport Dolomite. The Lockport Dolomite is characterized at the site by a shallow and deep zone. The shallow zone is moderately fractured. The horizontal fractures are parallel to the gently dipping bedding plane, with some vertical fractures. The shallow zone is approximately 10 to 15 feet thick. Beneath this zone is a less highly fractured zone with fewer vertical fractures, called the deep zone. The deep zone is approximately 20 feet thick. The model simulates both the shallow and deep Lockport zones as equivalent porous medium, with the vertical hydraulic conductivity set high enough to simulate a high degree of interconnectedness between the horizontal fracture zones found in the upper 25 to 35 feet of the aquifer. Below this, the Lockport Dolomite continues another 120 feet until the impermeable Rochester Shale is encountered. This lower unit also contains horizontal fractures, however, it is less well connected to the upper two Lockport Dolomite zones, and is simulated in the model with a low vertical hydraulic conductivity.

A ten-hour pump test was performed at monitoring well MW-5S to provide estimates of transmissivity across the site for the shallow and deep zones. Estimates at the site ranged from 400 to 2000 ft^2 per day, with an average of approximately 1100 ft^2 per day. Calculated storage coefficients ranged from 0.000082 to 0.084, with an average of 0.0007 (no dimension). In order to model the Lockport, the transmissivity values must be converted to hydraulic conductivities by dividing by the aquifer thickness. Because of the nature of the aquifer and the difficulty in

assessing the degree of vertical fracturing, the aquifer thickness contributing to the pump test is unknown. Assuming both the shallow and deep zones are contributing, which is suggested by the pump test results, then the aquifer thickness is about 35 feet. This would indicate a range of horizontal hydraulic conductivities of 11 to 57 feet per day. This is somewhat higher than the range reported at a nearby site by Woodward Clyde of 0.28 to 28 feet per day.

Based on the USGS (1964) report, it was decided to develop a groundwater model centered on the Forest Glen site, but with boundaries extending out several thousand feet to reach identifiable natural boundaries. In this way, the model results at the site would not be affected by the conditions set at the boundary, and yet the general reproduction of heads and regional flow direction could be checked as an additional validation of the model's ability to reproduce the groundwater flow system. The selected boundaries are indicated in **Figure 1** (reproduced from Figure 3 of USGS, 1964), which shows that the northern model boundary is located approximately 8000 feet north of the site. Fixed heads were set at the average reservoir surface elevation of 645 feet msl. Heads in the deeper Lockport Aquifer were set from the general flow map and adjusted during model calibration.

The western boundary is set along the conduit leading from the reservoir to the Niagara River, which according to the USGS report, acts as a major regional groundwater drain. The conduit invert elevation controls heads in the Lockport aquifer along the entire length of the conduit. This boundary is about 3000 feet west of the site. Heads were set at 520 to 540 feet msl based on the regional map and adjustments made during the calibration. The southern and eastern boundaries were set approximately 4000 feet south and east of the site to avoid having the boundary heads affect the modeling results at the site. Fixed heads were taken from the regional map and adjusted during calibration. Heads along the southern boundary were fixed at elevations of 520 to 570 feet msl. Heads along the eastern boundary were fixed at elevations of 540 to 600 feet msl. The bottom of the model, the Rochester Shale, was set as a no flow boundary.

Recharge, the amount of precipitation that seeps into the overburden and recharges the groundwater system, is relatively low in this area according to the USGS (1964). With an average annual rainfall of 30 inches, it was assumed that 8 inches of rainfall recharges the groundwater, with the remaining 22 inches lost as runoff or to evapotranspiration. The model response of the Lockport Dolomite to changes in pumping was not very sensitive to recharge changes because the overburden material is relatively impermeable.

No external pumping influences outside of the proposed remedial pumping at the site were included in the model. Because the model is being used in a capture zone analysis, only relative changes to the groundwater flow pattern are important. Since the model is adequately simulating present flow patterns at the site, the lack of comprehensive and accurate pumping data within the model area should not have a significant effect on the results of the capture zone analysis.

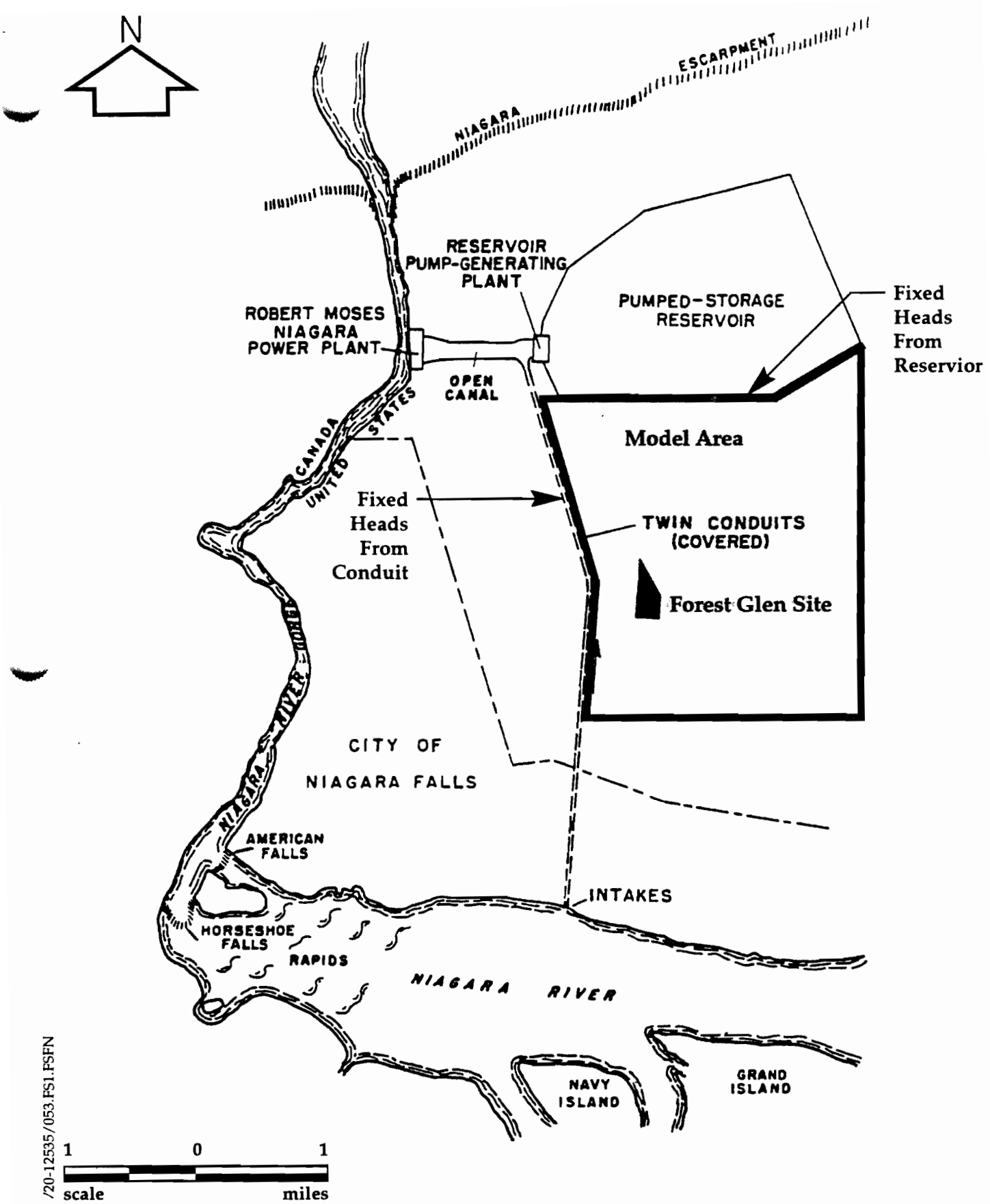

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Figure 1
Model Area Map
Forest Glen Feasibility Report

Model Structure

Based upon the conceptual model of the groundwater system described above, a 6 level, 5 layer model was developed. The grid is a variable sized, finite element grid shown in **Figure 2.** The grid was extended to the boundaries discussed above in the conceptual model, with a relatively coarse grid spacing near the boundaries and a tight, 50 foot grid spacing at the site. **Figure 3** shows the model grid in detail at the site, as well as the locations of the monitoring wells.

A cross-section from west to east across the site is shown in **Figure 4**. The figure shows the five model layers and the properties assigned to each layer. The numerical values for the assigned hydraulic properties are given in **Table 1**. Model layers are numbered from 1 (bottom of the Lockport Dolomite) to 5 (surface deposition of overburden material). The specific yield of the Lockport Dolomite was set at 0.01, with a specific storativity range of $1x10^{-6}$ to $1x10^{-4}$ based on the results of the pump test calibration. The distribution of materials by model layer is shown in figures M-1 through M-5 attached to the back of this document.

Table 1: Model Layers and Stratigraphy

Model Layer	Stratigraphic Unit Name	Bott. Elev. at site (ft. msl)	Thickness (Ft.)	Horiz. Hydraul. Conductivity (Ft./day)	Vertical Hydraul Conductivity (Ft./day)
1	Basal Lockport	420	125	1	0.01
2	Deep Lockport	545	21	20	0.01
3	Shallow Lockport	565	14	30	0.3
				55	1.0
				25	0.05
4	Clay/Till	579	10	0.1	0.01
5	Fill	589	5	50	5
	Clay/Till	589	5	0.1	0.01

A regional groundwater flow map was reproduced from an earlier publication as Figure 3-19 of the RI report. The figure shows that flow is generally west to southwest across the site, influenced by the high heads in the reservoir to the north, the draining effect of the conduit dug into the Lockport Dolomite to the west, and by the Niagara River to the south. By adjusting boundary heads, recharge, and aquifer properties within the bounds of the literature and mapped values taken from the RI report and the USGS (1964) report, the model was first calibrated in a general sense to reproduce the regional flow patterns. **Figure 5** shows the heads in the shallow Lockport aquifer as simulated by the model, which successfully reproduces the general regional flow patterns. **Figure 6** shows heads across the site. These heads and the flow pattern provide a good match of the heads and flow directions which are estimated to occur at the site based on field data.

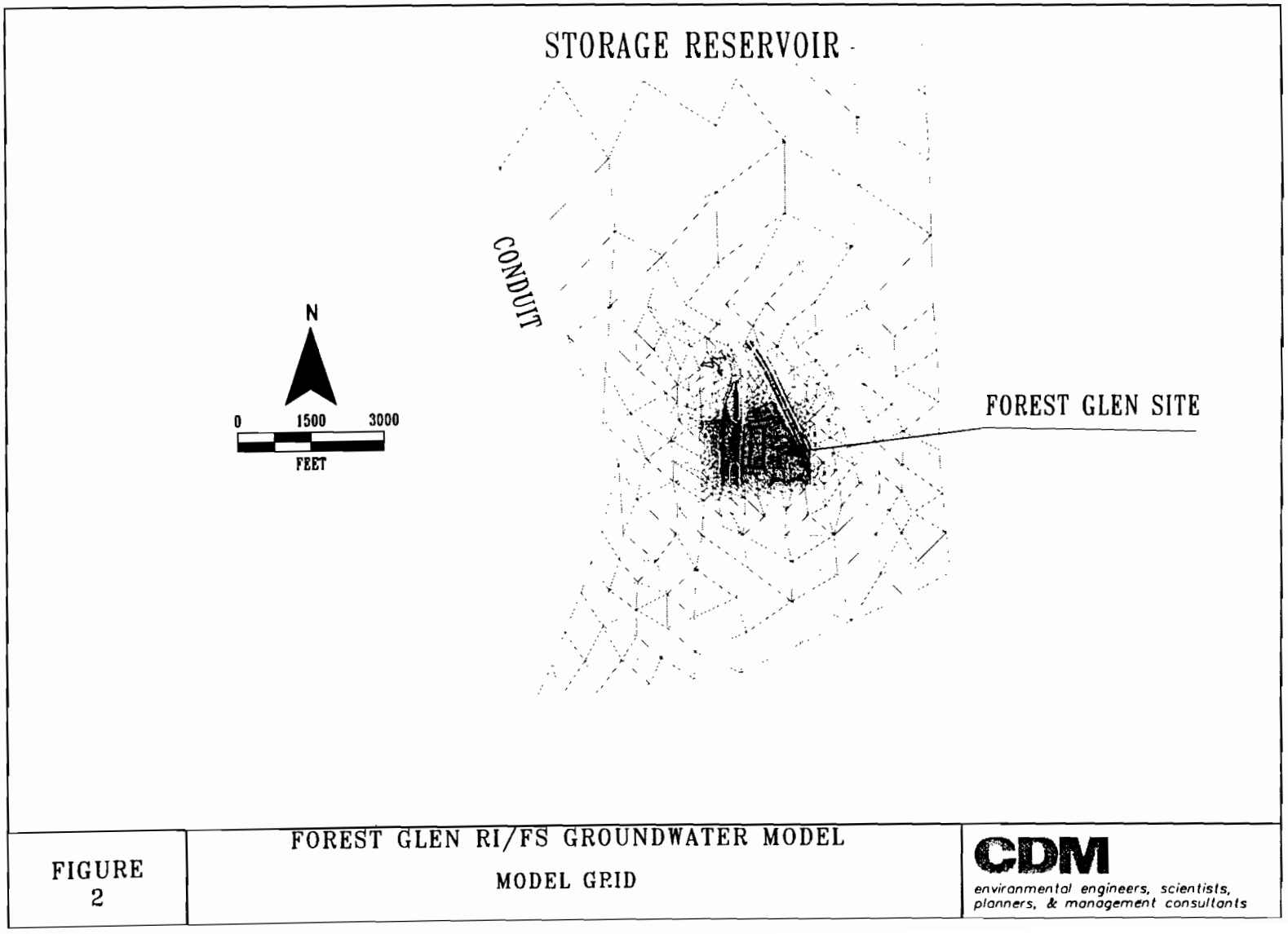

FIGURE 2

FOREST GLEN RI/FS GROUNDWATER MODEL

MODEL GRID

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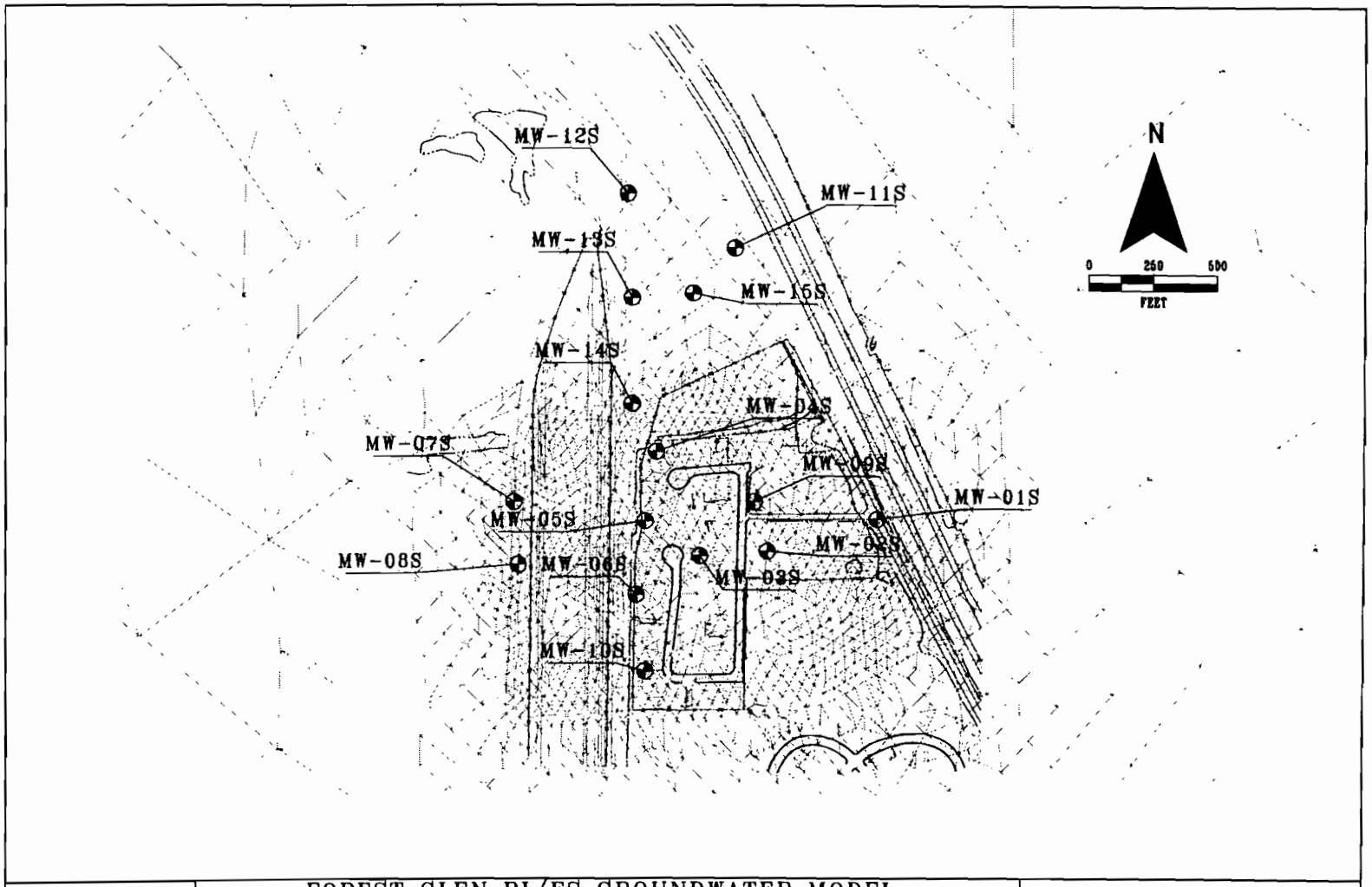
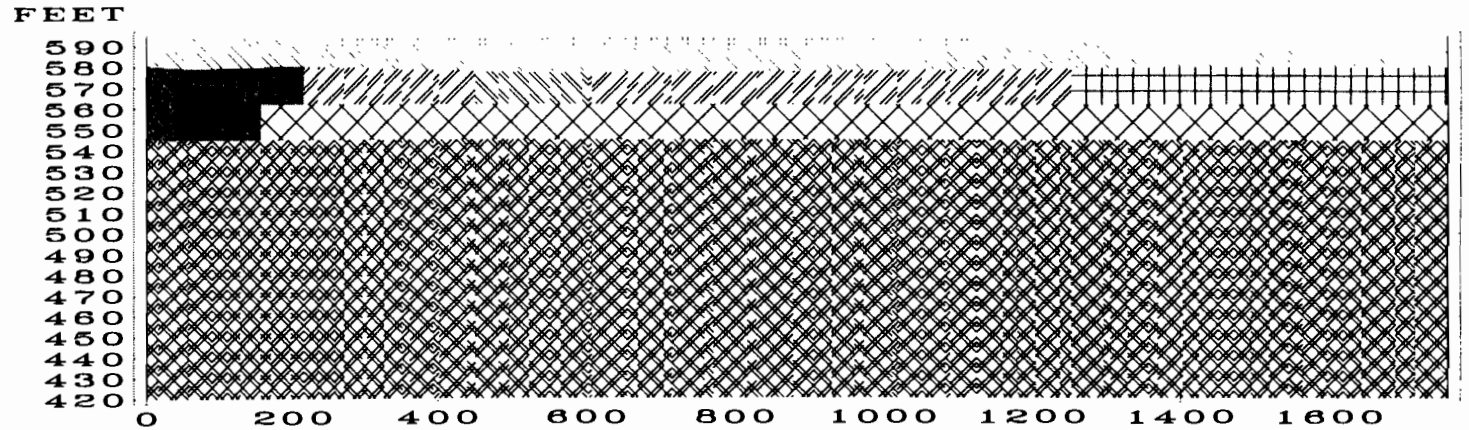


FIGURE 3	FOREST GLEN RI/FS GROUNDWATER MODEL SITE MONITORING WELLS AND MODEL GRID DETAIL	CDM environmental engineers, scientists, planners, & management consultants



MATERIALS CROSS SECTION AA

- SHALLOW LOCKPORT 30
- SHAL. LOCKPORT 31
- FILL 50
- SHAL. LOCKPORT 32
- DEEP LOCKPORT 20
- CLAY/TILL 40
- LOCKPORT 33
- BASAL LOCKPORT 10

CROSS SECTION AA

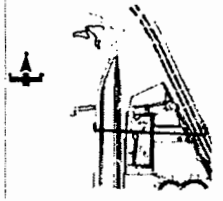


FIGURE 4

FOREST GLEN RI/FS GROUNDWATER MODEL

WEST TO EAST CROSS SECTION THROUGH SITE MODEL LAYERS AND PROPERTIES

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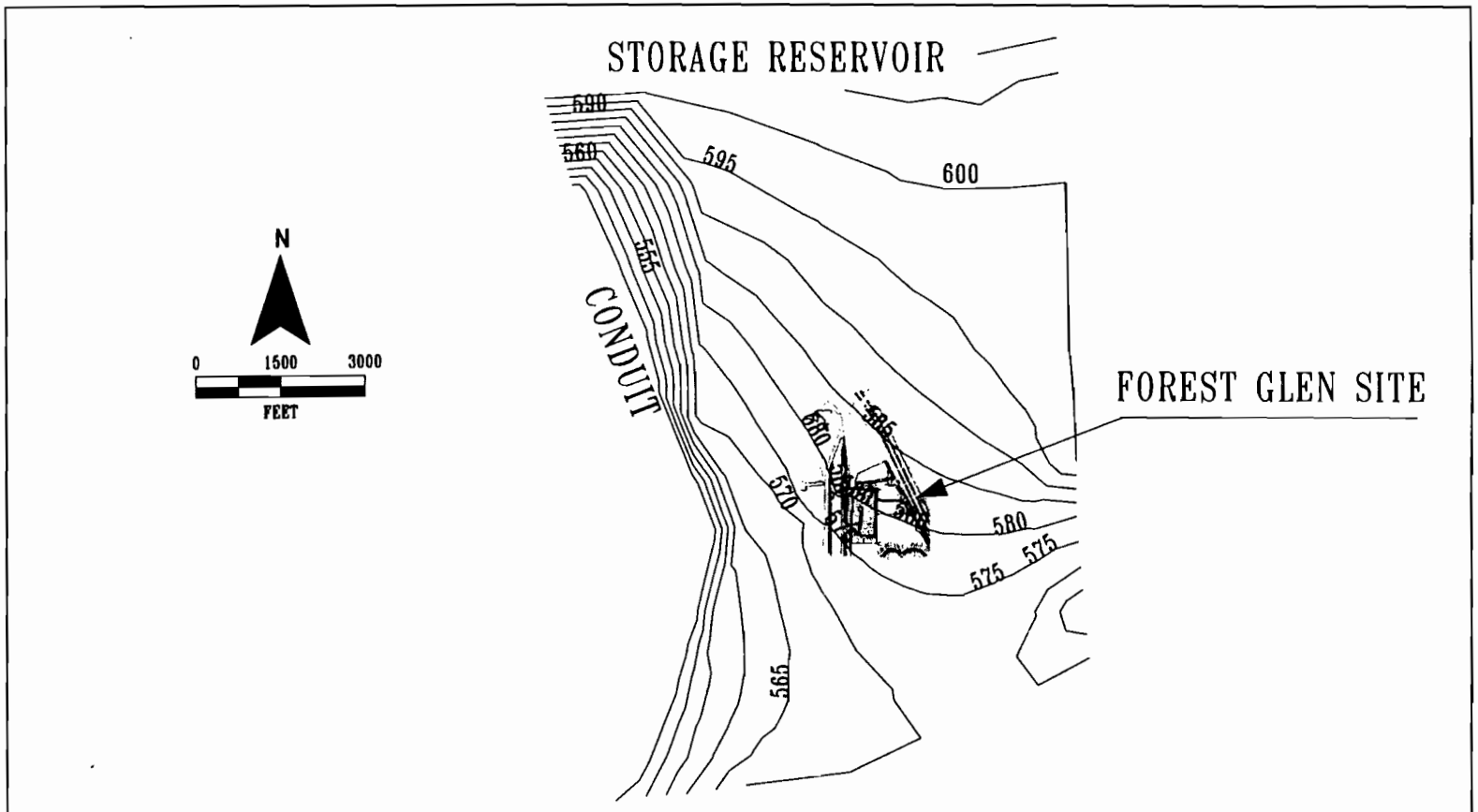

FIGURE 5

FOREST GLEN RI/FS GROUNDWATER MODEL

SIMULATED REGIONAL GROUNDWATER HEADS
LOCKPORT DOLOMITE AQUIFER

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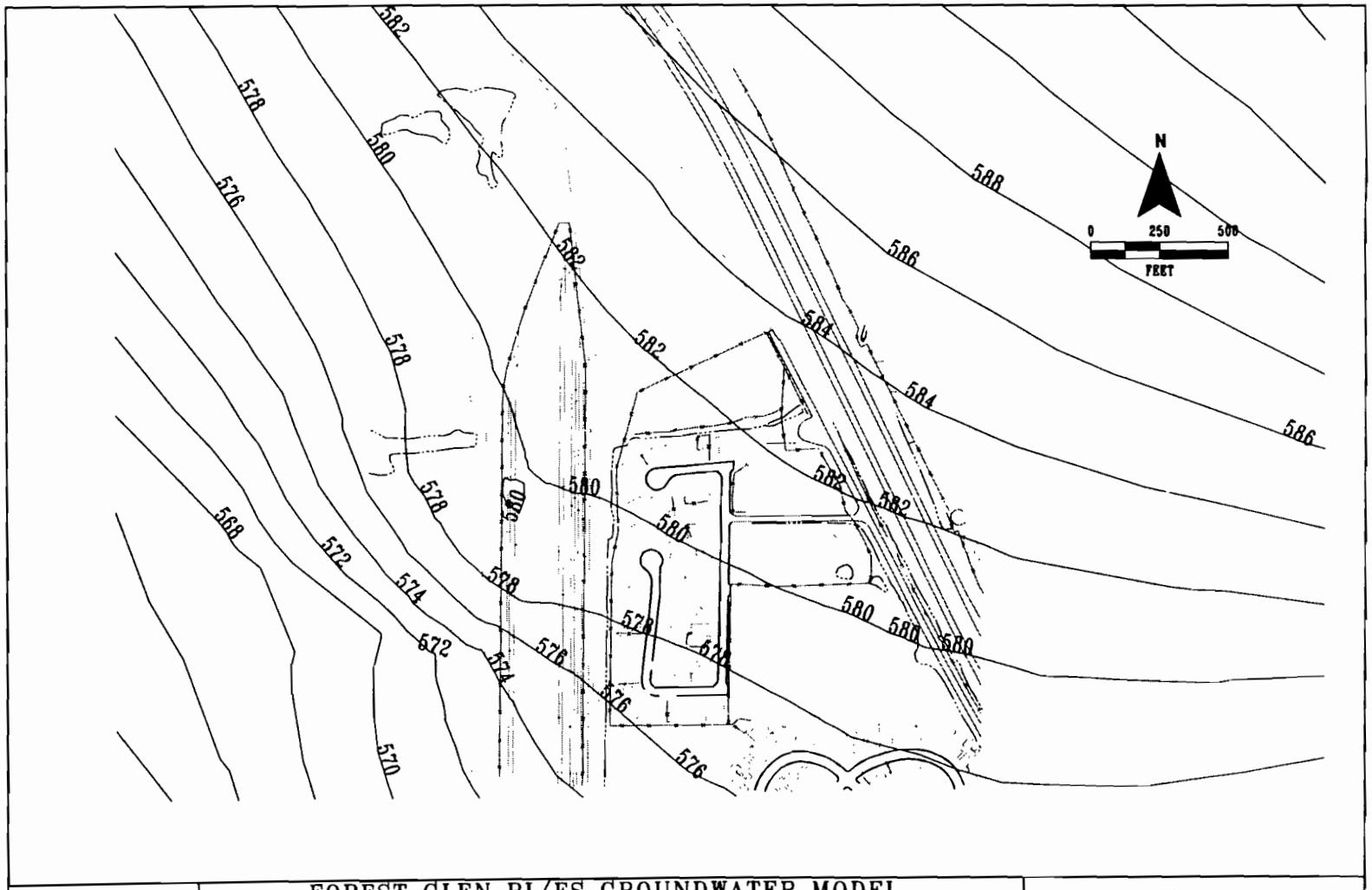

FIGURE 6

FOREST GLEN RI/FS GROUNDWATER MODEL

SIMULATED GROUNDWATER HEADS AT SITE
LOCKPORT DOLOMITE AQUIFER

CDM
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Model Calibration

Once the model demonstrated that it could adequately reproduce regional and local flow patterns, the hydraulic parameters at the site were fine tuned. This was done in two steps.

The first calibration step made use of the 10.5 hour pump test data to calibrate the model. **Figure 7** shows the contoured drawdown of the Lockport Dolomite aquifer after 10.5 hours of pumping at MW-5S based on field measured data. The drawdown contours range from 0.2 to 1.6 feet. These data represent a transient state of drawdown. The pump test data clearly show that drawdown at the wells had not reached equilibrium at the end of the pump test. Additional drawdown would have occurred if the pump test had been continued. The drawdown values used to create the contours in Figure 7 represent the maximum value of either the shallow or deeper well at each well cluster, and are corrected for rainfall during the pump test as described in the pump test report. Because the uncased length of both the deeper well and the shallow well at each well cluster overlap, the degree of vertical interconnection between the shallow and deep Lockport is not known, making the approach of using the largest of the two drawdown values at each cluster the most practical. Note that Figure 7 does not indicate any pronounced anisotropy in the horizontal direction. The measured drawdowns in the surrounding monitoring wells show an almost circular zone of influence. These results suggested that the model could reasonably assume horizontally homogenous aquifer properties in the Lockport Dolomite.

The model results of the transient simulation with well MW-5S pumping at 22 gpm showed that the aquifer slowly draws down over a period of days before equilibrium is reached. The pump test of 10.5 hours was not long enough for the aquifer to reach equilibrium, thus a transient simulation length had to be selected that provided a match with the data. In porous media, model simulations of pump tests can be calibrated to match both the rate and degree of drawdown. In fractured bedrock, however, this is more difficult because drawdown usually occurs much more rapidly than in an equivalent porous medium. The model simulates the Lockport fractured bedrock aquifer as an equivalent porous medium, thus the hydraulic properties selected mimic the overall porosity and hydraulic conductivity of the bedrock as if it were evenly distributed through a porous matrix. In the field, however, the porosity and groundwater flow is concentrated in fractures, with the intervening bedrock almost completely impervious to flow. Thus, flow rates and aquifer response in the field are much faster than the equivalent model response, even if the ultimate equilibrium response of the model accurately matches the equilibrium response in the field. For this reason, the transient simulation had to be extended beyond the 10.5 hours of the field test to match the response in the field. **Figure 8** shows the model simulated, 48 hour drawdown of the Lockport aquifer based on 22 gpm pumping of MW-5S. The results indicate that the model can accurately reproduce the drawdown experienced during the pump test, although not necessarily the rate of drawdown. This is not a concern in a capture zone analysis, where the capture zone under equilibrium conditions must be demonstrated.

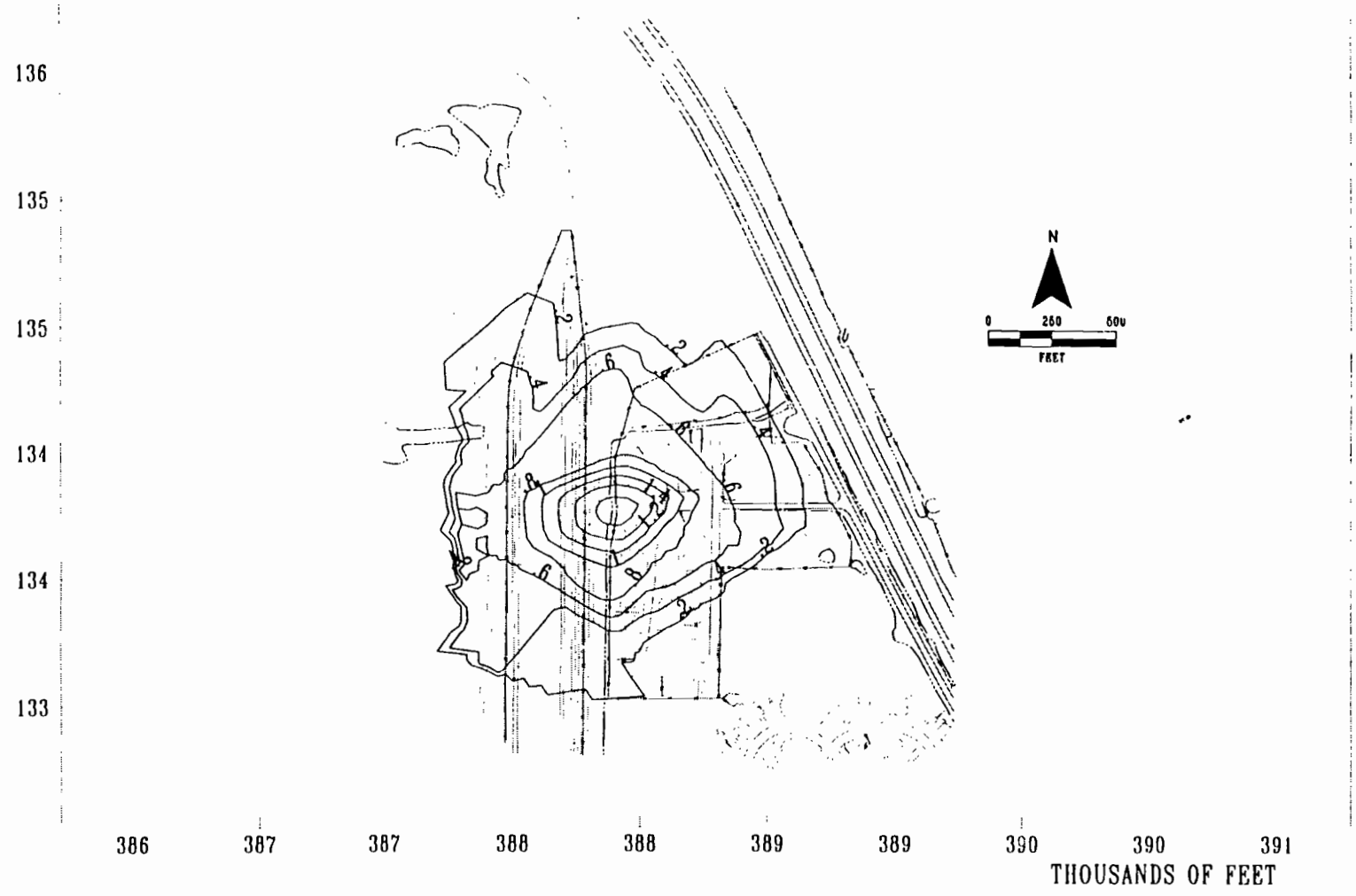

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Figure 7
Drawdown Contours (In Feet) Based On 10-Hour Corrected Drawdown Data; Maximum Value Of Drawdown At Each Cluster Used
Forest Glen Feasibility Report

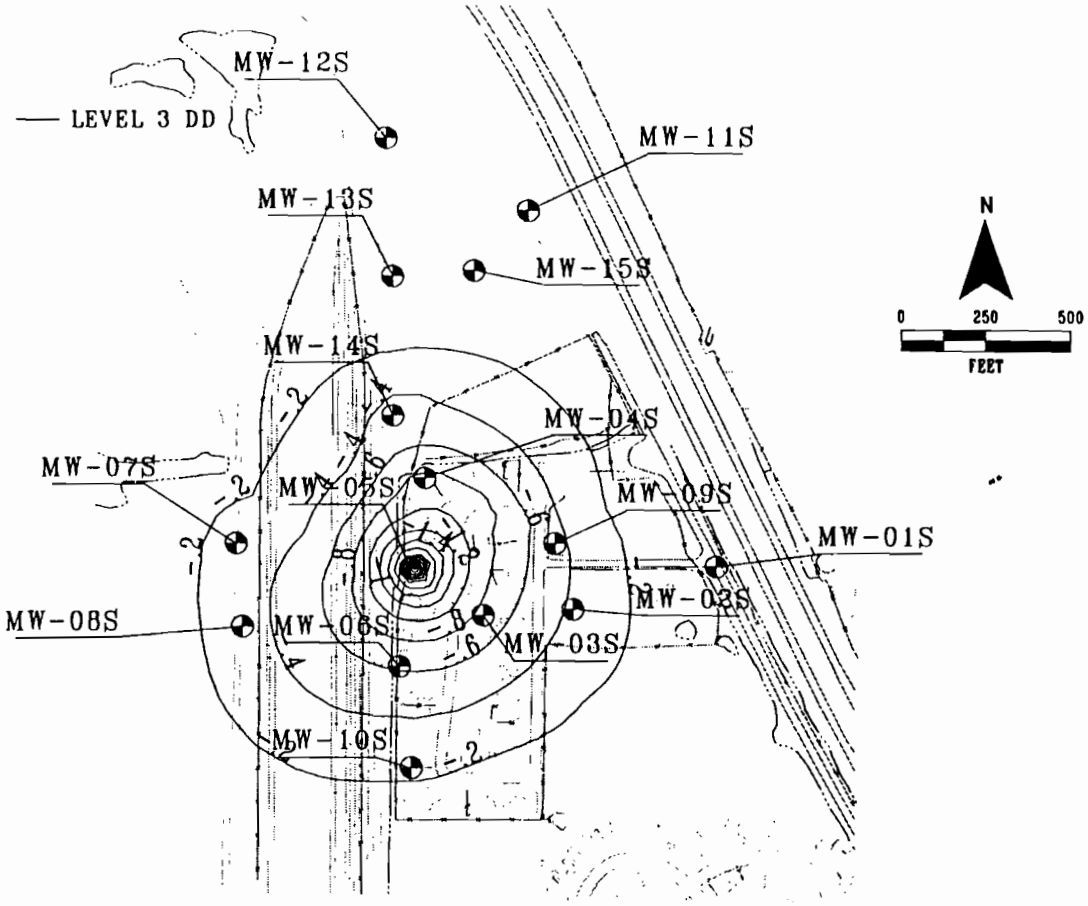

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Figure 8
Simulated Zone Of Influence MW-5 at 22 GPM After 48 Hour Simulation
Drawdown In Feet In Model Level 3
Forest Glen Feasibility Report

After the pump test data was being adequately represented by the model, the calibration was checked by making a steady state run with no onsite pumping. This represents the situation at the site when heads were measured in August 1997. The measured head at each well was compared with the model simulated head. Simulated heads were interpolated from the model grid to points in the model that represent the exact location and depth of each monitoring well. **Figure 9** shows the results of the steady state calibration. The figure shows the "residual" difference, in feet, at each well location. The residual is the difference between the model simulated head and the field measured head, and is used to assess the adequacy of the model calibration. A negative value means the model is simulating a lower head than the head obtained from the field measurement. A positive value indicates that the model is simulating a higher head than the field measured value.

Table 2 presents the data on model residuals in table form. The field measured heads are compared to the model simulated heads, and the residuals at each monitoring well are calculated. Overall, the mean difference between simulated heads and measured heads (August 1997 data) was -0.135 feet with a standard deviation of 1.88 feet using data from all 29 wells. These results indicate that the model is adequately representing the groundwater system at the site, and can be used for estimating capture zones at proposed recovery wells.

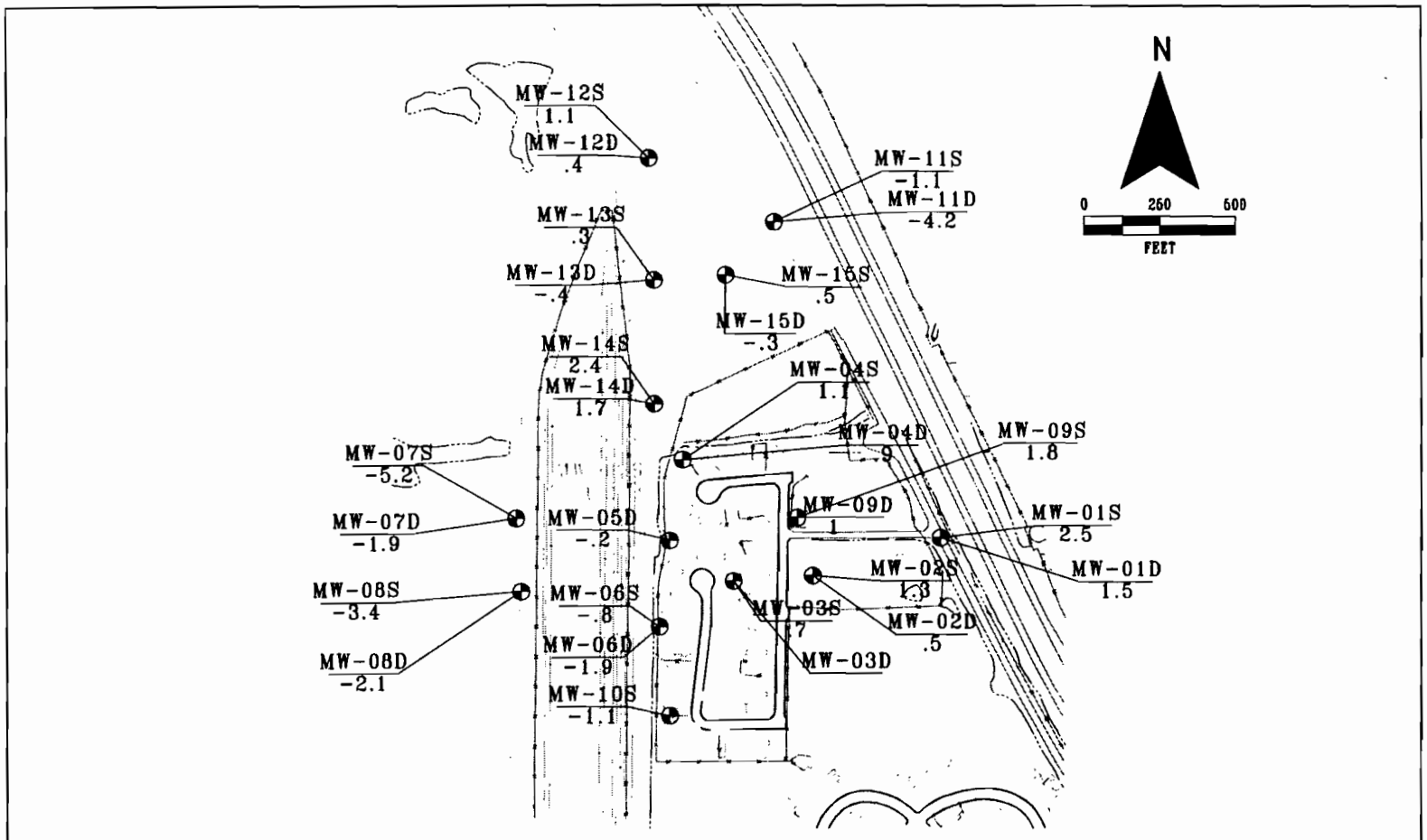


FIGURE 9	FOREST GLEN RI/FS GROUNDWATER MODEL DIFFERENCE IN FEET BETWEEN SIMULATED AND MEASURED HEADS LOCKPORT DOLOMITE MONITORING WELLS	CDM environmental engineers, scientists, planners, & management consultants

TABLE 2: COMPARISON OF MEASURED HEADS WITH SIMULATED HEADS

WELL IDENTIFIER	SIMULATED HEAD	OBSERVED HEAD	DIFFERENCE
MW-01D	580.638	579.090	1.547
MW-02D	579.059	578.570	.489
MW-03D	578.788	578.830	-.042
MW-04D	579.391	578.540	.851
MW-05D	578.336	578.510	-.174
MW-06D	576.670	578.560	-1.890
MW-07D	576.486	578.390	-1.904
MW-08D	574.964	577.040	-2.076
MW-09D	579.771	578.790	.981
MW-11D	583.504	587.720	-4.216
MW-12D	582.647	582.290	.357
MW-13D	581.395	581.770	-.375
MW-14D	580.219	578.520	1.699
MW-15D	582.040	582.350	-.310

MEAN DIFFERENCE FOR DEEP ZONE = -.36
STANDARD DEVIATION FOR DEEP ZONE = 1.64
NUMBER OF WELLS FOR DEEP ZONE = 14

WELL IDENTIFIER	SIMULATED HEAD	OBSERVED HEAD	DIFFERENCE
MW-01S	581.675	579.210	2.465
MW-02S	580.240	578.940	1.300
MW-03S	579.626	578.900	.726
MW-04S	580.616	579.480	1.136
MW-05S	579.809	578.650	1.159
MW-06S	578.301	579.070	-.769
MW-07S	578.936	584.180	-5.244
MW-08S	577.571	580.990	-3.419
MW-09S	580.913	579.160	1.753
MW-10S	576.463	577.550	-1.087
MW-11S	584.270	585.410	-1.140
MW-12S	583.453	582.320	1.133
MW-13S	582.248	581.960	.288
MW-14S	580.950	578.580	2.370
MW-15S	583.134	582.660	.474

MEAN DIFFERENCE FOR SHALLOW ZONE = .07
STANDARD DEVIATION FOR SHALLOW ZONE = 2.12
NUMBER OF WELLS FOR SHALLOW ZONE = 15

Model Simulation Results

The purpose of the development of the FS groundwater model is to evaluate various extraction well configurations and pumping rates and to recommend two alternative recovery scenarios. The first scenario is designed to control and capture the contaminated groundwater onsite, and requires a minimum of two wells. The second scenario is designed to capture the entire zone of contamination, including areas west of the railroad tracks. This alternative requires four wells.

To estimate the capture zone for recovery wells, particle tracking was performed using the DYNTRACK code. DYNTRACK uses a steady-state flow field generated by DYNFLOW. From the computed set of heads, the mean flow velocity in each component direction is determined for each model element. The particle of mass is assumed to move at the same rate as the groundwater flow, and is tracked from one location to another over a specified period of time. By placing particles in a regular, rectangular grid, all those particles that eventually are captured by the pumping wells provide a map of the capture zone of the recovery wells. On the basis of these particle tracking runs, the outline of the capture zone can be drawn. When the outline of the capture zone is combined with flow direction arrows and overlain on a basemap of the site, the capture zone can be easily recognized.

Scenario 1

Scenario 1 makes use of one existing monitoring well, MW-5D as the centrally located extraction well, and adds a second well, labeled PROP1 to extend the capture zone south to approximately the location of MW-10. Both wells are assumed to have uncased open boreholes to a depth of 70 feet below surface (elevation 525 feet msl). Both MW-5D and PROP1 would be pumped at 15 gpm for a total of 30 gpm. This well configuration provides a capture zone that extends from MW-10 north to approximately the location of MW-14, capturing all flow coming from the northeast onto the site. The capture zone does not extend beyond the eastern edge of the railroad tracks. **Figure 10** shows the extent of the capture zone by means of a rectangular grid of particles. The edge of the capture zone is indicated by the heavy line, with all groundwater in the shallow and deep Lockport Dolomite zones within the indicated capture zone line eventually reaching either of the two recovery wells. The area of the plume is indicated in the figure by a light octagonal line. **Figure 10A** provides the flow direction arrows and capture zone superimposed in one figure.

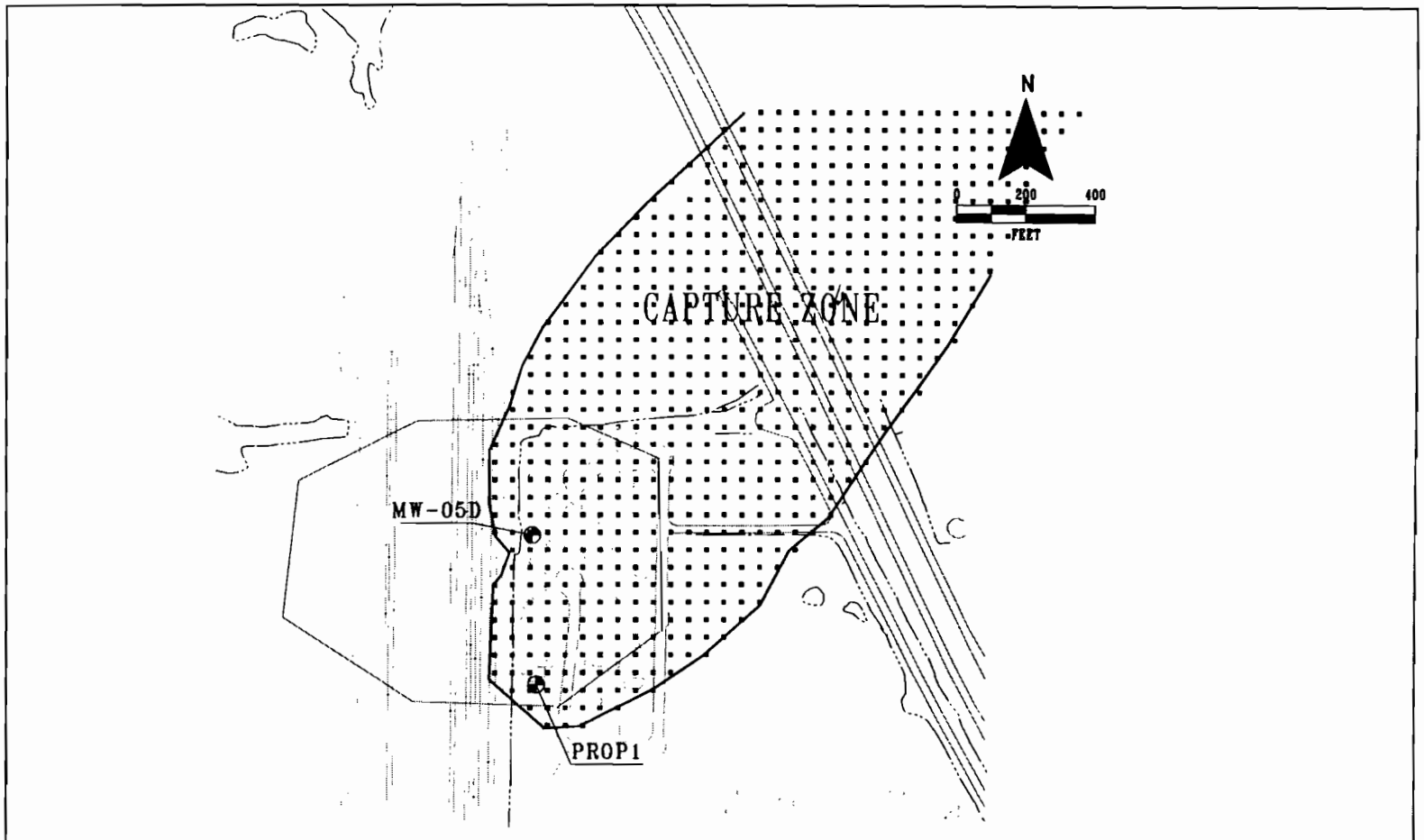


FIGURE 10	FOREST GLEN RI/FS GROUNDWATER MODEL CAPTURE ZONE OF PROPOSED ONSITE RECOVERY SYSTEM MW-5D AND PROP1 AT 15 GPM EACH	CDM environmental engineers, scientists, planners, & management consultants

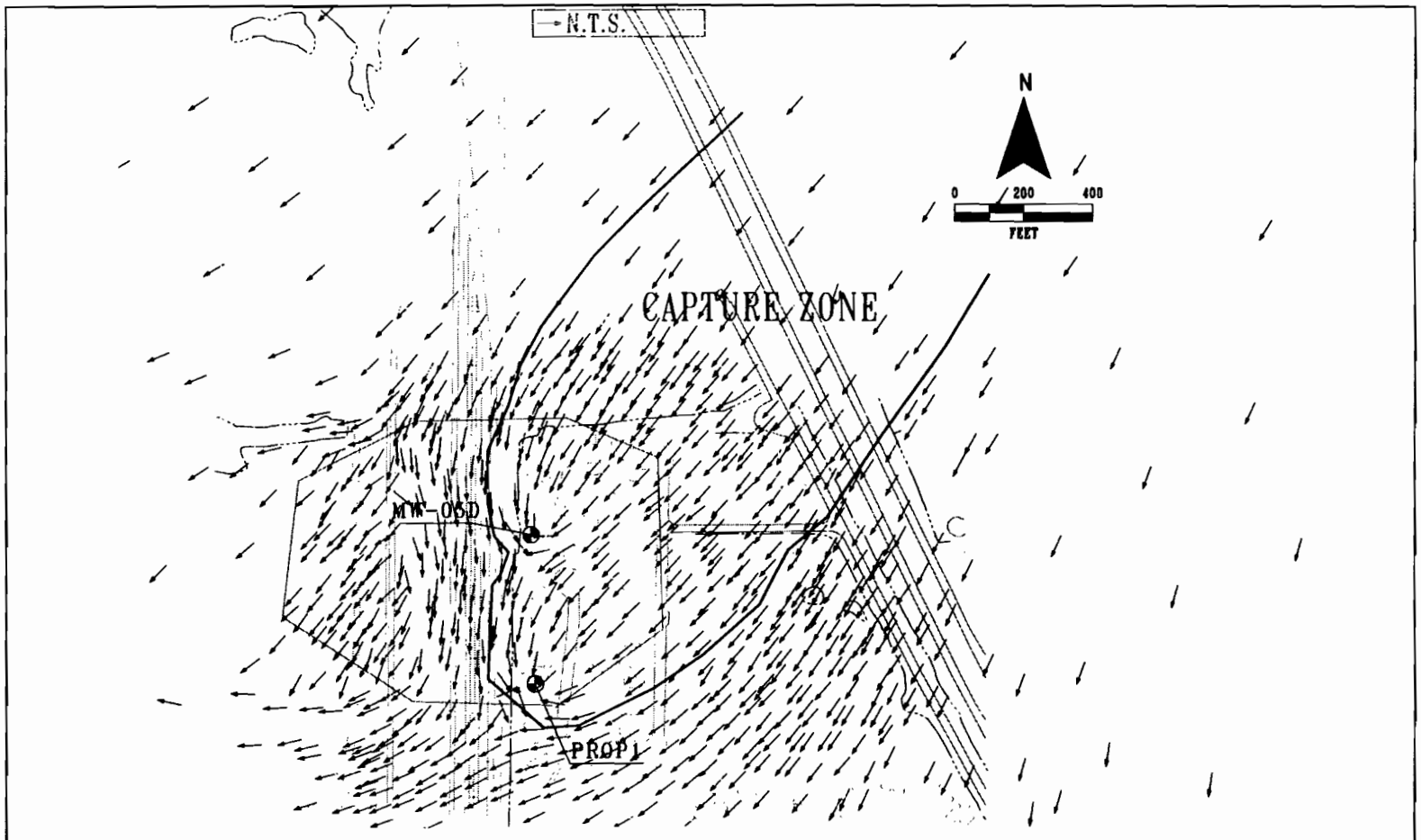


FIGURE 10A	FOREST GLEN RI/FS GROUNDWATER MODEL FLOW DIRECTION ARROWS CAPTURE ZONE OF PROPOSED ONSITE RECOVERY SYSTEM MW-5D AND PROP1 AT 15 GPM EACH	CDM environmental engineers, scientists, planners, & management consultants

Scenario 2

Scenario 2 makes use of one existing monitoring well, MW-5D, and adds three additional wells to make a four well extraction system. The additional wells are the above mentioned PROP1, as well as two offsite wells, PROPRR1 and PROPRR2 west of the railroad tracks. All four wells are assumed to have open boreholes to a depth of 70 feet, and would have to be pumped at a minimum of 10 gpm each for a total of 40 gpm to provide full capture of the onsite and offsite plume. This well configuration provides a capture zone that extends from an area west of MW-7 and MW-8 eastward to beyond the locations of MW-9 and MW-2, and covers the entire area defined as the zone of contamination. **Figure 11** shows the extent of the capture zone by means of flow direction arrows and a capture zone delineation line. The edge of the capture zone is indicated by the heavy line, and all water within the line eventually is captured by one of the four proposed recovery wells. Note that the entire plume area (denoted by the light octagonal line) is captured under this pumping scenario.

The horizontal extent of the capture zones delineated in Figures 10 and 11 are simulated for both the shallow and deep Lockport Dolomite zones (between a depth of 15 and 70 feet below groundwater surface). The extraction system assumes that an open hole is drilled to a depth of 70 feet below ground surface, and that the open hole captures water from horizontal fractures in both the shallow and deep Lockport Dolomite zones. Because the bedrock aquifer system consists of numerous horizontal fractures along bedding planes in the shallower parts of the Lockport Dolomite, the model can adequately simulate horizontal flow in both the shallow and deep zones. The model cannot, however, accurately simulate vertical flow in the more sparsely occurring vertical fractures. The model simulates resistance to vertical flow by relatively low hydraulic conductivities in the vertical direction, thus assuming some degree of interconnectedness between the discrete, bedding plane fractures. This may not be the case except within the top several feet of Lockport Dolomite. For this reason, the model in its present form should not be used to assess the depth of capture beneath the deep Lockport Dolomite at depths of more than 70 feet from land surface.

Despite the model's limitation, it is likely that adequate capture of the zone of contamination will occur in the shallow and deep Lockport Dolomite if the wells are designed to span both units. It is not known if contamination has reached beyond a depth of 60 feet below land surface. In areas where vertical migration can occur, however, it would occur through the presence of vertical fractures. These same vertical fractures would also be affected by the pumping of the upper strata. Thus, if vertical fractures have allowed penetration of contaminants into deeper fracture zones, then these same fractures would also allow for adequate capture of water in the impacted lower bedding planes.

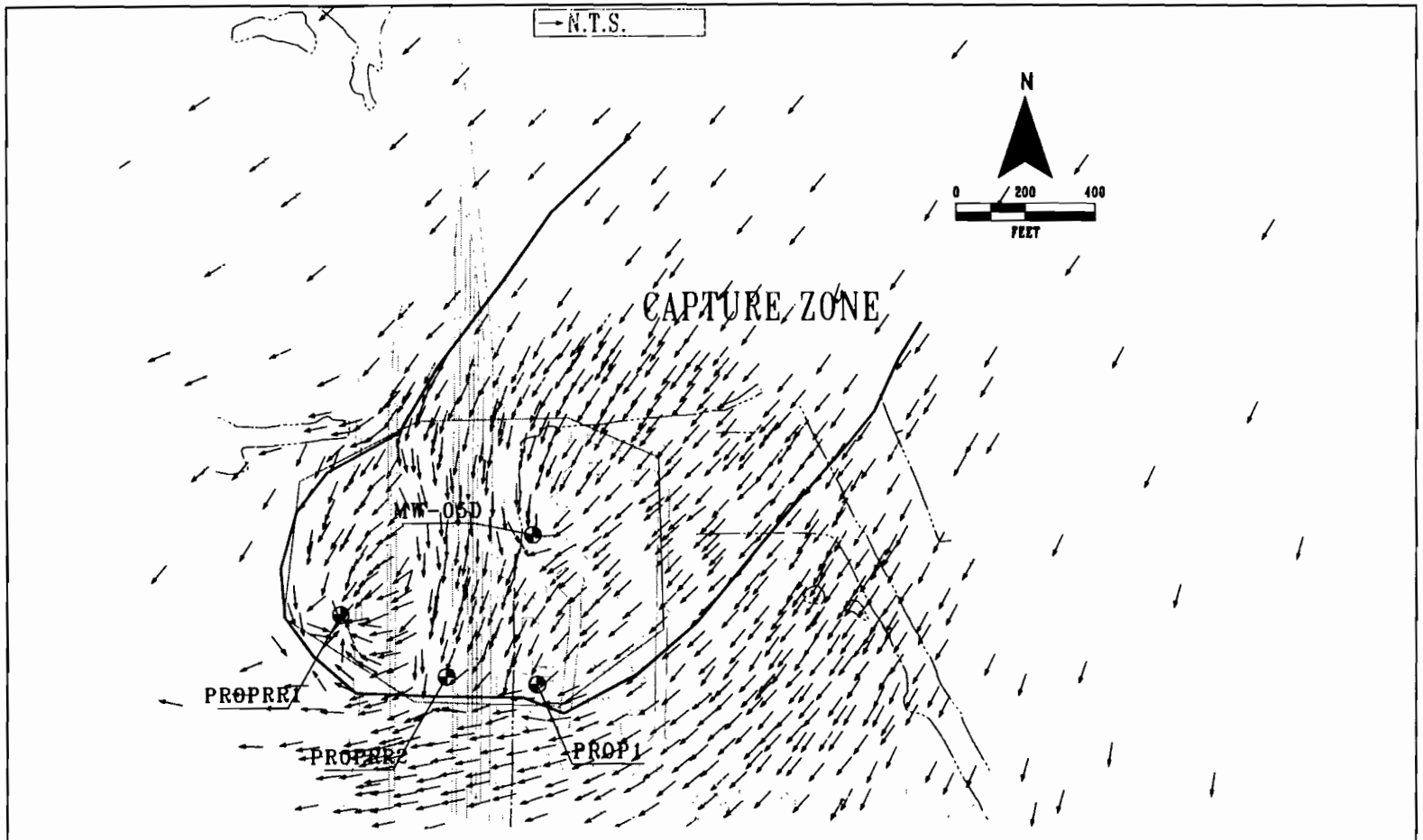


FIGURE 11	FOREST GLEN RI/FS GROUNDWATER MODEL FLOW DIRECTION ARROWS CAPTURE ZONE OF PROPOSED ONSITE/OFFSITE SYSTEM ALL FOUR WELLS AT 10 GPM EACH	CDM environmental engineers, scientists, planners, & management consultants

Conclusions

The following conclusions can be drawn from the groundwater modeling results.

- The preliminary groundwater model of the Forest Glen site is an adequate representation of horizontal flow in the overburden and Lockport Dolomite formations. The calibration results made use of synoptic water levels and a 10.5 hour pump test, and results suggest that the model can provide accurate estimates of horizontal flow.

- Based on the results of the 10.5 hour pump test, no apparent horizontal anisotropy occurs in the Lockport Dolomite, and the aquifer response to pumping is similar in all directions.

- Because of the nature of the fractured bedrock formations at the site, vertical flow occurs only in vertical fractures, and bedding plane fracture zones are not well connected beneath the zone defined as the deep Lockport (elevation 545 msl). For this reason, it is unlikely that the model can accurately simulate vertical flow and capture zones below elevation 545 feet msl.

- Scenario 1 provides a two-well, 30 gpm recovery system that adequately captures the area of contamination onsite east of the railroad tracks. Two wells are recommended, MW-5D and PROP1, located between MW-6 and MW-10. Both wells should consist of productive open holes reaching to an elevation of 525 feet mean sea level to capture contaminants in the shallow and deep zones.

- Scenario 2 provides a four-well, 40 gpm recovery system that adequately captures the entire area of groundwater contamination both onsite and beneath the adjacent railroad yard to the west. In addition to the two wells MW-5D and PROP1, two proposed recovery wells labeled PROPRR1 and PROPRR2 are located west of the site. All four wells should be designed to have productive open holes reaching to an elevation of 525 feet mean sea level to capture contaminants in the shallow and deep zones. If all four wells are pumped at 10 gpm, the model simulation indicates that adequate capture of the entire zone of contamination will be achieved.

It is important to note that these should be considered FS level model simulations. The scenarios presented are based on reasonable preliminary design simulations, however, the model should be upgraded to a design level model prior to final system design. This could be achieved by changing the model layers to better represent thin, horizontal fracture zones and intervening massive rock layers, and by performing a longer duration pump test. This would allow for a more accurate calibration of the model based on a more realistic representation of the stratigraphy and better field data.

(D:\frstglen\fgreport.wpd)

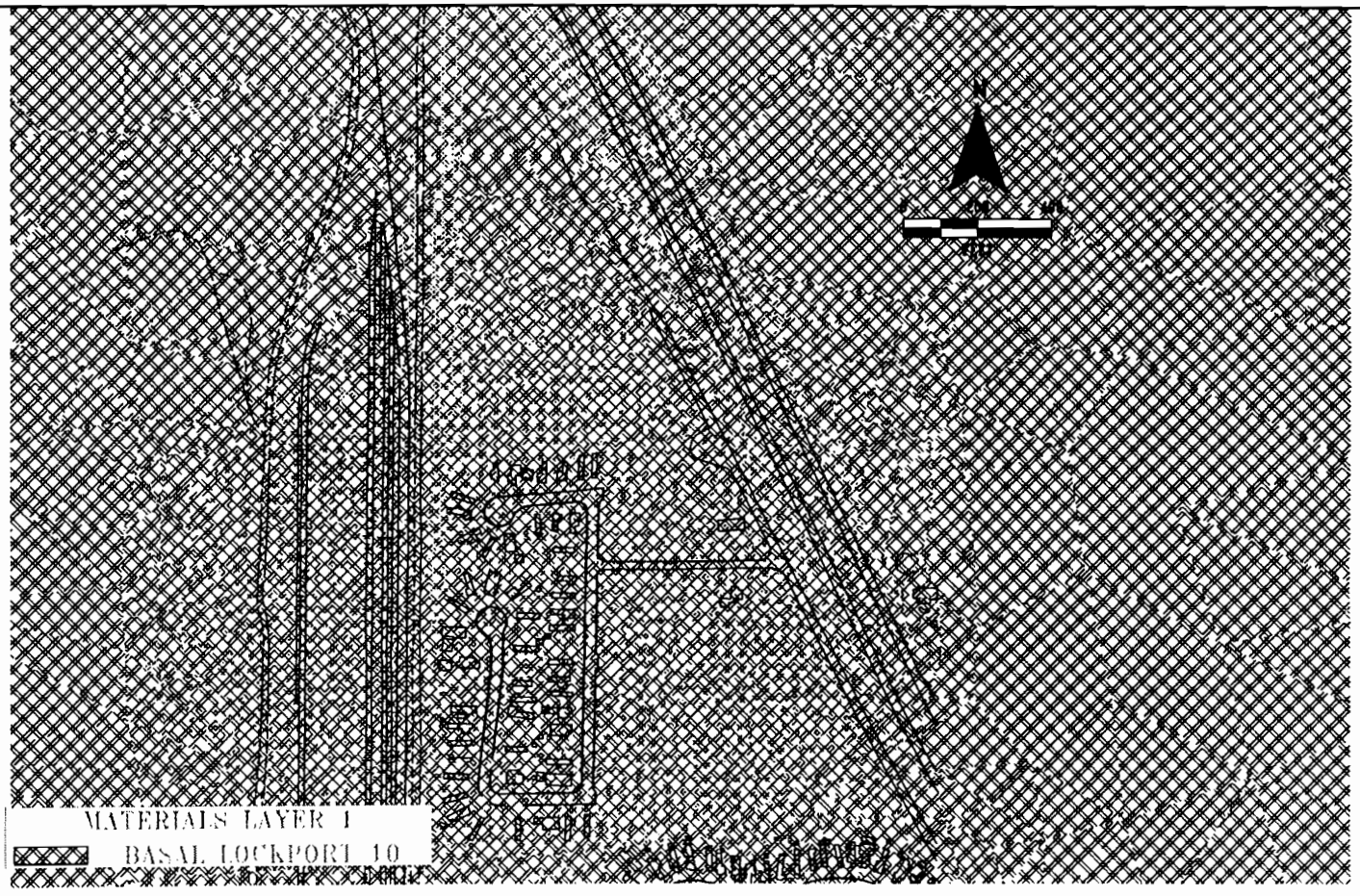


FIGURE M-1	FOREST GLEN RI/FS GROUNDWATER MODEL PLOT OF MATERIAL DISTRIBUTION BENEATH SITE MODEL LAYER 1	CDM environmental engineers, scientists, planners, & management consultants

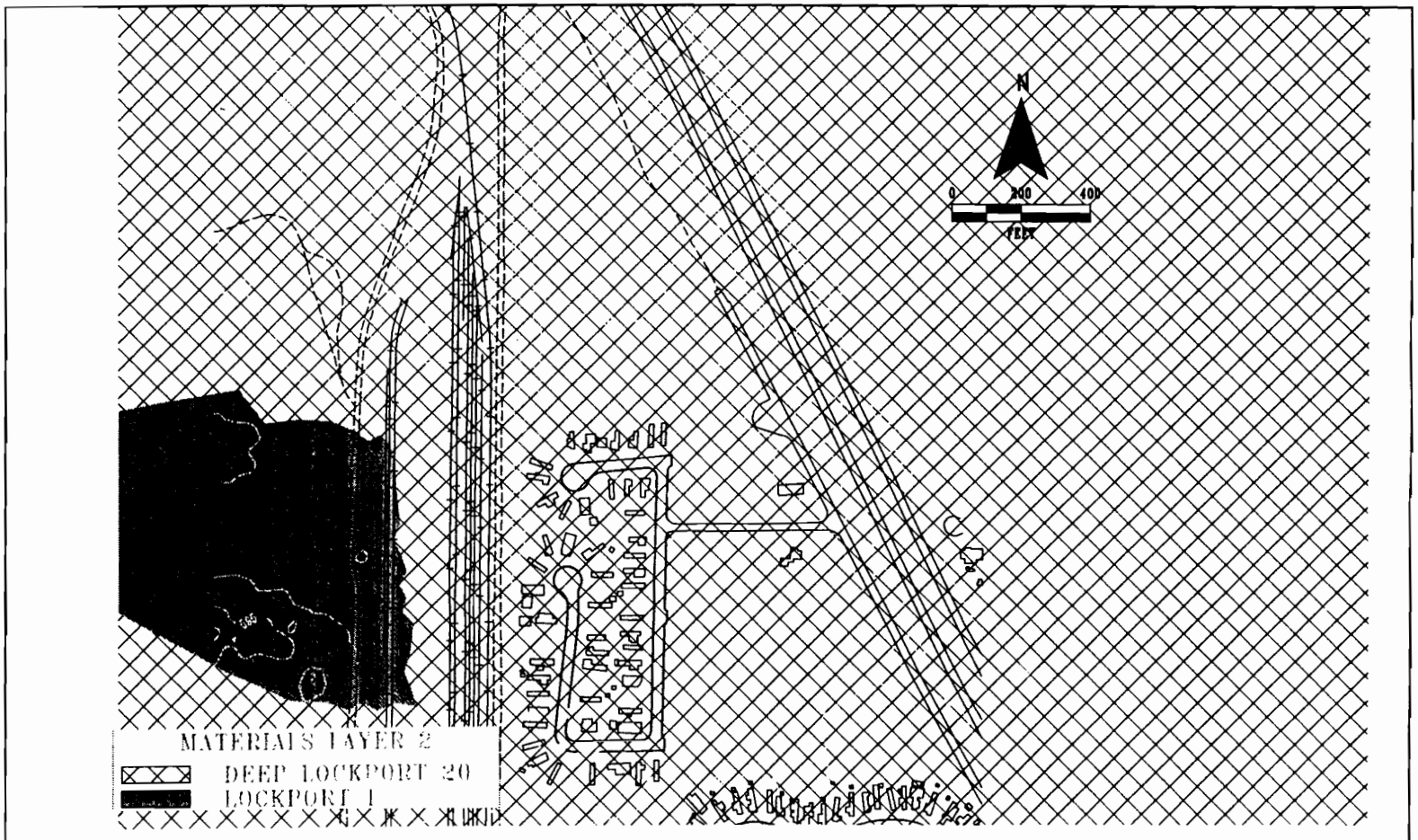


FIGURE M-2

FOREST GLEN RI/FS GROUNDWATER MODEL

PLOT OF MATERIAL DISTRIBUTION BENEATH SITE MODEL LAYER 2

CDM
environmental engineers, scientists, planners, & management consultants

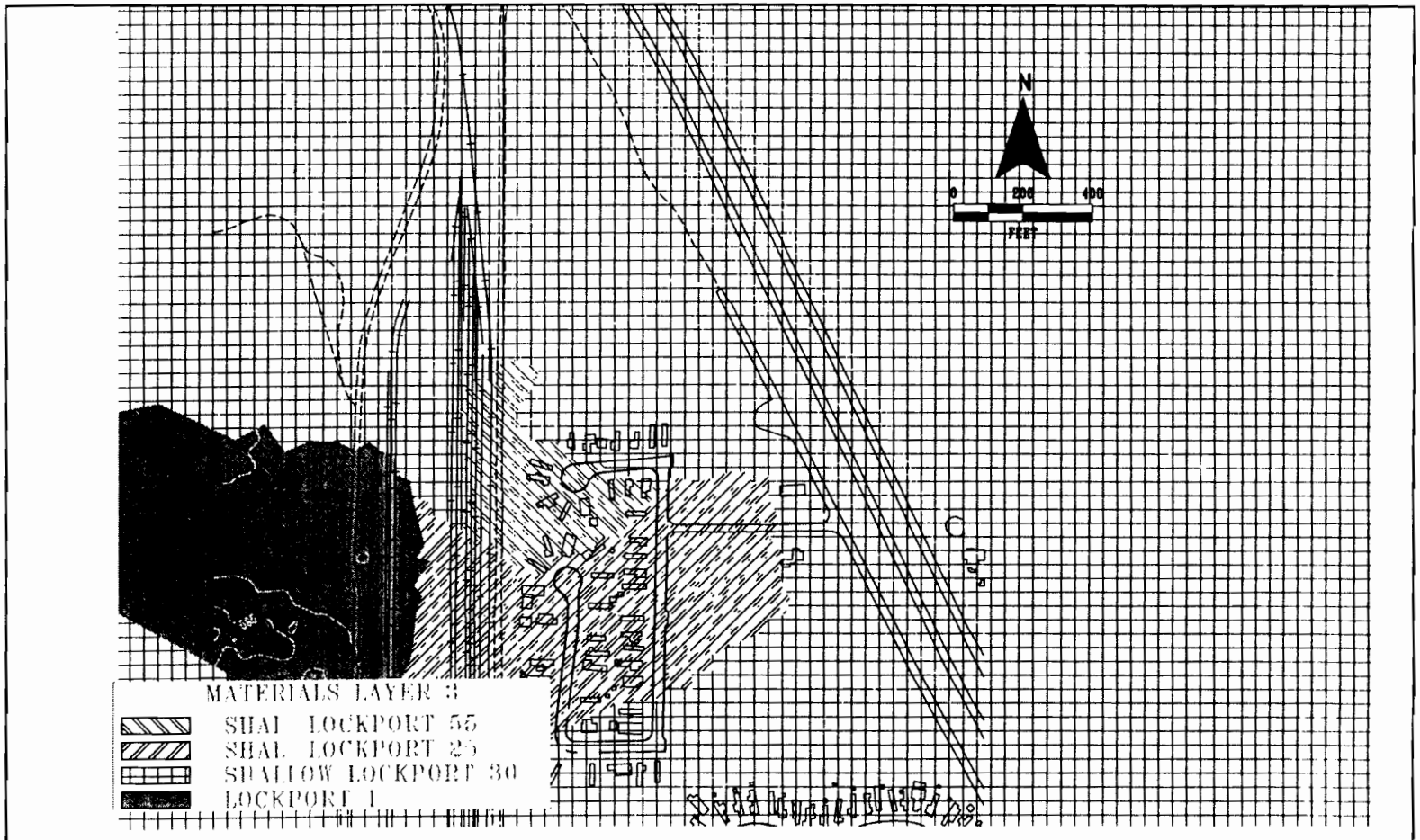


FIGURE M-3	FOREST GLEN RI/FS GROUNDWATER MODEL PLOT OF MATERIAL DISTRIBUTION BENEATH SITE MODEL LAYER 3	CDM environmental engineers, scientists, planners, & management consultants

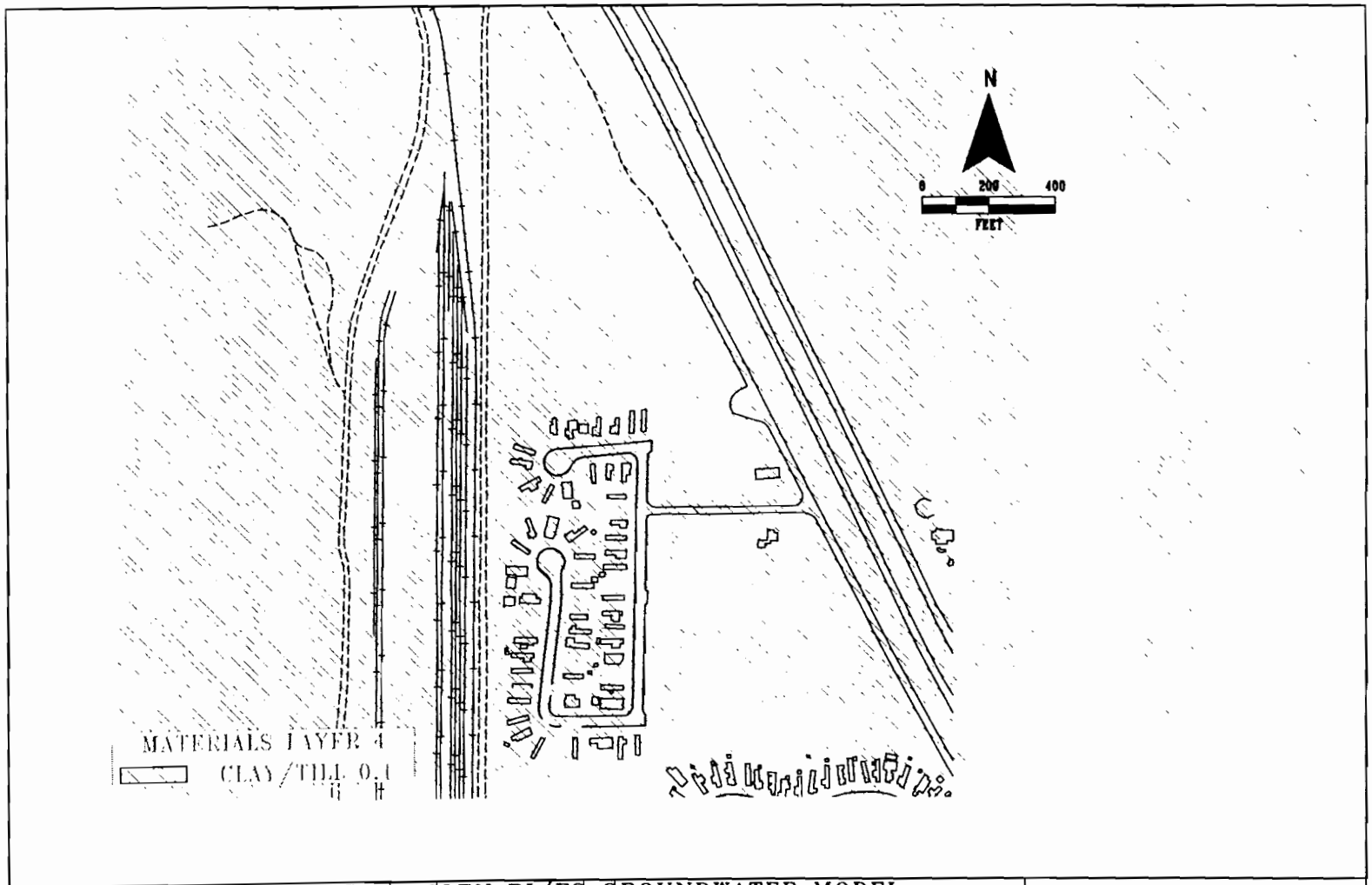


FIGURE M-4	FOREST GLEN RI/FS GROUNDWATER MODEL PLOT OF MATERIAL DISTRIBUTION BENEATH SITE MODEL LAYER 4	CDM environmental engineers, scientists, planners, & management consultants

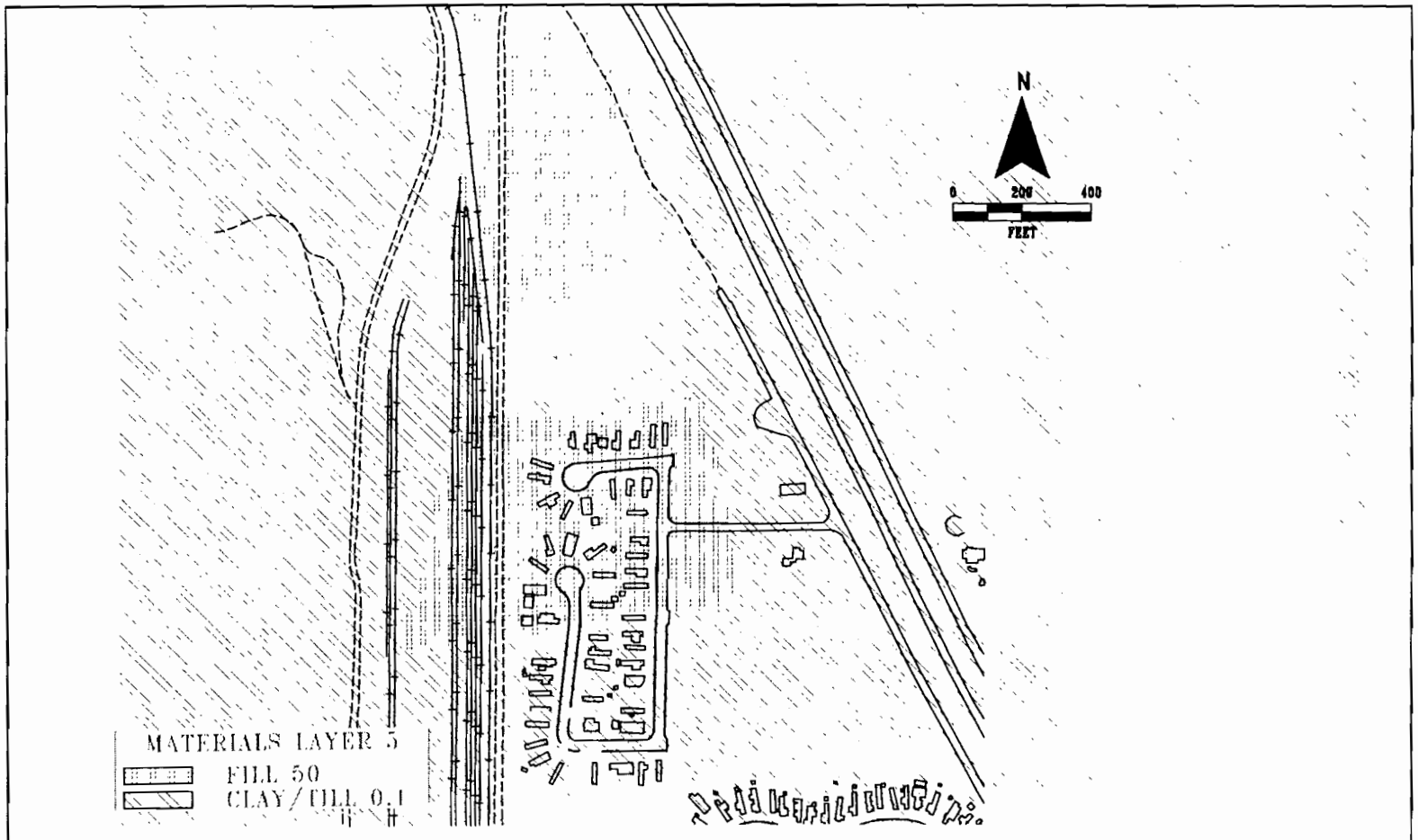


FIGURE M-5	FOREST GLEN RI/FS GROUNDWATER MODEL PLOT OF MATERIAL DISTRIBUTION BENEATH SITE MODEL LAYER 5	CDM environmental engineers, scientists, planners, & management consultants

APPENDIX C

ESTIMATED DURATION FOR GROUNDWATER TREATMENT

The approach used for estimating the duration of treatment operations associated with the groundwater at Forest Glen involved the application of the "Batch Flush" model described in the US. EPA's "Guidance on Remedial Actions for Contaminated Groundwater at Superfund Sites, December 1988." Application of this model to Forest Glen assumes that the fractured bedrock can be modeled as if it were an equivalent porous medium. The groundwater contained in a given volume of saturated aquifer is considered to constitute one "batch." The "Batch Flush" model assumes that equilibrium conditions are attained (for the partition of a chemical between the soil [rock] and water) prior to the "flushing" of every batch of water. This equilibrium model is assumed to be adequate for the level of alternatives analysis (-30% to +50% cost range) required by the FS.

The Batch Flush model can be expressed as:

$$Cs_i = Cs_{i-1} - Cw_i E/d, \qquad \text{---- Eq (1)}$$

where:

Cs_i = soil concentration after i flushes, [mg contaminant/kg soil];
Cs_{i-1} = soil concentration after previous ($i\text{-}1^{th}$) flush, [mg contaminant/kg soil];
Cw_i = equilibrium concentration in groundwater from i^{th} flush, [mg contaminant/l water]; E = effective porosity, [l voids/l total volume]; and
d = soil bulk density, [kg soil/l total volume].

Substituting the equilibrium equation:

$$Cw_i = Cs_i/K_d, \qquad \text{---- Eq (2)}$$

where:

K_d = soil-water partition coefficient of chemical, l water/kg soil

into Eq (1), the following equation is obtained:

$$Cs_i = Cs_{(i-1)} (1+E/K_d d)^{-1}. \qquad \text{---- Eq (3)}$$

The expression for the number of pore volumes or "flushes" of water (n) which must be circulated through the contaminated zone to achieve clean-up standards (ARARs) can be derived as follows:

For 1 flush:

$Cs_1 = Cs_o (1+E/K_d d)^{-1}$,

where:

Cs_1 = soil concentration after 1 flush, and
Cs_o = initial soil concentration.

For 2 flushes:

$Cs_2 = Cs_1 (1+E/K_d d)^{-1} = [Cs_o (1+E/K_d d)^{-1}] (1+E/K_d d)^{-1}$, or

$Cs_2 = Cs_o (1+E/K_d d)^{-2}$.

For n flushes,

$$Cs_n = Cs_o [1+E/K_d d]^{-n}$$

$$n = \frac{\ln(Cs_n/Cs_o)}{\ln[(1+E/K_d d)^{-1}]} = \frac{\ln(Cw_n/Cw_o)}{\ln[(1+E/K_d d)^{-1}]} \qquad \text{---- } Eq(4)$$

Solving for "n" and using Eq (2):
From Eq (4), the expression for "n" can be written in terms of both soil concentrations [middle term in Eq (4)] and groundwater concentrations [last term in Eq (4)]. For projects involving remediation of contaminated soil by flushing/washing, clean-up standards (ARARs) are usually specified for soils (i.e., Cs_n's are known) and the middle term of Eq (4) can be used for determining "n." On the other hand, for projects involving groundwater remediation, clean-up standards (ARARs) are usually specified for groundwater (i.e., Cw_n's are known) and the last term of Eq (4) can be used for determining "n." In this appendix (Appendix C), Eq (4) will be applied to groundwater remediation for Forest Glen.

In the feasibility study, the time required to achieve the clean-up standards under various remedial alternatives must be calculated. This was accomplished in this study by simulating the various groundwater remedial alternatives and determining the extraction rates required for the capture

of contaminated groundwater (in Appendix B); then determining the time required for one pore volume of groundwater to flush through the contaminated volume of the aquifer (by dividing one pore volume by the extraction rate); and multiplying this time by the required number of pore volumes [determined by applying Eq (4)].

These calculations are shown on Table C-1.

Summary

For the capture of the onsite plume at least 22 flushes are estimated to be required for groundwater cleanup. At 30 gpm continuous pumping rate (as recommended in Appendix B), cleanup of this area (22 flushes) will require approximately 7 years.

For the capture of the onsite and offsite plumes, at least 22 flushes are estimated to be required for groundwater cleanup. At 40 gpm continuous pumping rate (as recommended in Appendix B), cleanup of this area (22 flushes) will require approximately 13 years.

Please note that the engineers and scientists performing the remedial investigation and the feasibility study have used their best professional judgement in making assumptions concerning the properties of the bedrock based on field observations (examination of rock cores) and other site-specific data. However, changes in the numerical values for the fraction of organic carbon in the bedrock, the percentage of bedrock that is assumed to be contaminated, and the groundwater extraction rate will change the duration of one flush and therefore change the duration of the proposed remedial action. The results of changes in bedrock properties and other such effects are presented in Table C-2.

TABLE C-1

FOREST GLEN, NIAGARA FALLS, NY
GROUNDWATER REMEDIATION FEASIBILITY STUDY
ESTIMATION OF THE CLEAN-UP TIME BY THE BATCH FLUSH METHOD

Compound	Co*	Cn	Koc	Kd	Number of Flushes Required	Estimated Clean-up Time (yrs)	
						30 gpm	40 gpm
cis-1,2-DCE	1,709	5	140	0.35	18	6	10
trans-1,2-DCE	1,709	5	180	0.45	22	**7**	**13**
vinyl chloride	240	2	2.5	0.00625	2	1	1
1,1-DCA	92	5	30	0.075	3	1	2
1,1,1-TCA	110	5	150	0.375	10	3	6
TCE	230	5	130	0.325	11	3	6

Number of flushes required = ln(Cn/Co)/ln(DxKd/(DxKd+E'))

Co: Initial groundwater concentration, ug/l
Cn: Final groundwater concentration, ug/l (New York State surface water discharge requirement)
D: Bedrock bullk density
E: Porosity (volume of voids/total volume), dimensionless; estimated as 0.036
E': Effective porosity = E / percent volume of contaminated rock
(assumption: only 10% of the bedrock around the fractures is contaminated; E' is estimated as 0.036/0.10=0.36)
foc: Fraction of organic carbon in the soil, dimensionless
Kd: Partition coefficient of chemical between soil and water (Koc x foc)
Koc: Octanol/Water partition coefficient, l/kg

* Highest concentration from the four rounds of sampling
** Rounded up to the nearest integer

TABLE C-2

FOREST GLEN, NIAGARA FALLS, NY
GROUNDWATER REMEDIATION FEASIBILITY STUDY
ESTIMATED DURATION OF ON-SITE PLUME AND ENTIRE PLUME REMEDIATION
FOR VARIOUS SENSITIVITY FACTORS

Sensitivity Factors	On-Site Plume (yrs)	Entire Plume (yrs)
Assumed site conditions	7	13
Sensitivity 1.1 (foc=0.1)	3	6
Sensitivity 1.2 (foc=0.5)	13	23
Sensitivity 2.1 (v=5%)	4	7
Sensitivity 2.2 (v=15%)	10	18
Sensitivity 3.1 (Q=35 gpm)	6	NA
Sensitivity 3.2 (Q=50 gpm)	NA	10

foc: Fraction Organic Carbon
v: Percentage of contaminated rock
Q: Groundwater extraction rate
NA: Not applicable

APPENDIX D

DETERMINATION OF THE FEASIBILITY OF NATURAL ATTENUATION AND ENHANCED *IN-SITU* BIOREMEDIATION AT THE FOREST GLEN SITE

D.1 NATURAL ATTENUATION

The feasibility of natural attenuation as a remedial technology for contaminants at the Forest Glen Site was investigated using the *BIOSCREEN* software. The following sections provide a description of the modeling software, the input parameters used during modeling, and the conclusions of the model simulations.

D.1.1 MODEL DESCRIPTION

Natural attenuation modeling using the *BIOSCREEN* software (USEPA 1996a) was performed to develop a rough prediction for the extent of chlorinated Contaminants of Concern (COC) migration downgradient of the site. The intended use of the *BIOSCREEN* software is as a screening tool to assist in identifying whether natural attenuation at sites contaminated with fuel hydrocarbons is likely to be protective of human health and the environment. The application of *BIOSCREEN* software in this section to the natural attenuation feasibility study of chlorinated organics, although adequate for the intended application, provides only a crude prediction for the expected extent of COC migration. *CHLORBIO* software, which is under development by AFCEE (Air Force Center for Environmental Excellence) for use in modeling natural attenuation of chlorinated organics, has not been released at the time of this feasibility study.

The *BIOSCREEN* software is based on the Domenico three-dimensional analytical solute transport model. The Domenico solute transport model accounts for effects of advective transport, three-dimensional dispersion, adsorption, and first-order decay. The Domenico solution has been adapted in *BIOSCREEN* to provide three different model types. Two of the model types are used in this evaluation: 1) transport with 'No Degradation', 2) transport with '1st Order Decay'. The first model type includes dispersion and adsorption attenuation mechanisms only and represents movement of a conservative tracer within the aquifer. The second adds a solute degradation rate that is proportional to the solute concentration (first order decay) and does not account for the presence of available electron acceptors or biodegradation of the source term.

D.1.2 MODEL INPUT PARAMETERS

D.1.2.1 APPROACH TO MODELING

Feasibility modeling for the natural attenuation of contaminants at the Forest Glen Site using both the 'No Degradation' and '1st Order Decay' models requires: identification of model contaminants; representative biodegradation rates of those contaminants; source characteristics and distribution; and estimates of general hydrogeologic parameters. These items are discussed later in this section.

Groundwater from source area(s) across the site is believed to discharge to the PASNY conduits, located approximately 3,000 feet downgradient. For this reason, *BIOSCREEN* modeling was limited to a maximum contaminant travel distance of 3,000 feet.

D.1..2.2 MODEL CONTAMINANTS

Preliminary investigations at the Forest Glen Site indicate that cis-1,2-DCE and VC are the primary COCs observed at levels significantly above NY State and Federal action levels (MCLs) within the shallow and deep Lockport Dolomite aquifer. It should be noted that cis-1,2-DCE and VC are generally not source contaminants, instead, they are biodegradation products of more chlorinated compounds such as PCE and TCE. Thus, the presence of cis-1,2-DCE and VC indicates active biodegradation processes.

1,1,1-TCA and its degradation products, 1,1-DCE and 1,1-DCA, are observed at levels above the NY State and Federal action levels (MCLs) in the shallow and deep Lockport Dolomite aquifer. However, these compounds are at levels significantly below those observed for PCE and its degradation product chain (approx. 1 order of magnitude).

Thus, PCE and its degradation product chain (i.e., PCE, TCE, cis-1,2-DCE, VC, and ethene/ethane) are the only model contaminants considered for this preliminary investigation.

D.1.2.3 BIODEGRADATION RATES

To date, only limited field data have been collected at the Forest Glen site and therefore estimation of site specific biodegradation rates is not possible. Thus, literature biodegradation rates were used for this feasibility determination. Ellis (USEPA 1996b) reported average first-order dechlorination rate coefficients for PCE, TCE, cis-1,2-DCE, and VC estimated from data for 7, 15, 12, and 9 separate field investigations, respectively. The first-order dechlorination rates describing biotransformation of PCE to TCE (0.58 yr^{-1}); TCE to DCE (0.58 yr^{-1}); DCE to VC (0.66 yr^{-1}); and VC to ethene (0.57 yr^{-1}) represent the mean of a wide range of site-specific rates as they were estimated from sites with varying hydrogeological conditions and environments.

As described in Section 2.7, the reductive dechlorination of COCs at Forest Glen site is a sequential process. This process may be represented by the following equation:

$$\text{a PCE} \xrightarrow{k1} \text{b TCE} \xrightarrow{k2} \text{c cis-1,2-DCE} \xrightarrow{k3} \text{d VC} \xrightarrow{k4} \text{e ethene/ethane} \quad (1)$$

where k1, k2, k3, and k4 are first-order dechlorination rate coefficients
k1 =0.58 yr^{-1}
k2 =0.58 yr^{-1}
k3 = 0.66 yr^{-1}
k4 = 0.57 yr^{-1}
a = b = c = d = e = stoichiometric coefficients = 1

Based on Equation 1, individual reaction rates for PCE (rPCE), TCE (rTCE), cis-1,2-DCE (rcis-1,2-DCE), and VC (rVC) may be expressed as:

rPCE = d[PCE]/dt =- k1 [PCE]
rTCE = d[TCE]/dt =k1 [PCE] - k2 [TCE]
rcis-1,2-DCE = d[cis-1,2-DCE]/dt =k2 [TCE] - k3 [cis-1,2-DCE]
rVC = d[VC]/dt =k3 [cis-1,2-DCE] - k4 [VC]

Since the dechlorination of PCE, TCE, cis-1,2-DCE, and VC proceeds as a sequential reaction, the overall reaction rate, R, describing the complete dechlorination of these compounds to innocuous ethene and ethane is limited by the slowest individual reaction rate (i.e., rPCE, rTCE, rcis-1,2-DCE, or rVC). Furthermore, since the first order dechlorination rate coefficients for PCE, TCE, cis-1,2-DCE, and VC (k1, k2, k3, and k4, respectively) have similar values, the overall reaction rate may be expressed as:

R = koverall [Sum of CAHs] (2)

where koverall = slowest dechlorination rate constant of k1, k2, k3, and k4
[Sum of CAHs] = highest molar sum of PCE, TCE, cis-1,2-DCE, and VC recorded

The use of Equation 2 to model the dechlorination rate of COCs at the Forest Glen Site simplifies *BIOSCREEN* modeling, since individual reaction rates for each COC, which are complicated by source (daughter products) and sink terms, do not need to be addressed. Thus, an overall reaction rate for the complete dechlorination of COCs to innocuous ethene and ethane may be estimated using Equation 2.

D.1.2.4 SOURCE CONCENTRATIONS, LOCATION, AND DISTRIBUTION

A review of historical data indicates that the highest summed concentrations of PCE and its degradation products was at monitoring well MW-05S (1,880 µg/L). Thus, *BIOSCREEN* modeling assumed a source concentration of 1,880 µg/L, or 1.88 mg/L, originating at the MW-5S location.

BIOSCREEN allows for input of the source thickness in the saturated zone as well as subdivisions of the transverse distribution of source concentrations into a maximum of five segments that are symmetrical around the plume centerline. However, since *BIOSCREEN* output results were presented along the plume centerline and transverse and vertical dispersivity values are minimal, input values for source thickness and the transverse distribution of contaminants have little effect on the maximum contaminant plume concentrations predicted along the centerline. Arbitrary values for the source width (100 feet) and vertical source thickness (55 feet; depth from bottom of overburden to bottom of the deep bedrock aquifer) were assumed.

BIOSCREEN allows for the source mass, or half-life. Since information regarding the source mass is not available, an infinite source half-life was assumed for modeling purposes, and is conservative.

D.1.2.5 GENERAL HYDROLOGIC PARAMETERS

An average seepage velocity estimated for groundwater flow in the shallow and deep Lockport Dolomite aquifer of 1.76 ft/day, or 640 ft/yr was estimated. The seepage velocity was calculated using site related hydraulic conductivities, hydraulic gradients and porosities. Hydraulic conductivities were determined from aquifer test data described in Appendix A and an average value was used. Hydraulic gradients for the shallow and deep bedrock zones were calculated from synoptic water levels measured from onsite monitoring wells. An average value beneath the Subdivision was used. Porosities were estimated from fracture percentages in the rock cores that were collected during the remedial investigation. The retardation of contaminants within the bedrock aquifers was assumed to be negligible during *BIOSCREEN* modeling, and retardation coefficients of 1.0 were entered into *BIOSCREEN*.

Default dispersivity values were used in *BIOSCREEN* modeling and are dependent on the contaminant plume length. A contaminant plume length of 3,000 feet, which is equivalent to the maximum allowable plume travel distance, was assumed.

All input parameters for *BIOSCREEN* modeling are presented below in Table D-1.

TABLE D-1
BIOSCREEN Input Parameters

Parameter	*Input Value*
Seepage Velocity (ft/yr)	640
Allowable Plume Travel Distance (ft)	3,000
Horizontal Dispersivity (ft)	37.4
Transverse Dispersivity (ft)	3.7
Vertical Dispersivity (ft)	0
Retardation Coefficient	1.0
Overall First Order Decay Coefficient (yr^{-1})	0.57
Source Vertical Extent (ft)	10
Source Concentration	1.88 mg/L
Source Half Life	Infinite

D.1.3 MODELING RESULTS

The *BIOSCREEN* model input sheet is shown in Figure D.1. Results from model simulation times of 2, 4, 6, 8, and 20 years along the plume centerline for the '1st Order Decay' and 'No Degradation' models are shown in Figures D.2 through D.6, respectively.

Model predictions from the 2, 4, and 6-year simulation times indicate the downgradient migration of contaminants under the '1st Order Decay' model. This is evident from the downgradient progression of the leading edge of the contaminant plume. After 6 years, the downgradient migration of the contaminant plume slows. This is evident from summed contaminant concentrations of similar value, at a downgradient distance of 3,000 feet for the 6 year (69 µg/L) and 8 year (71 µg/L) simulation times. Predicted contaminant profiles for the 8 and 20 year simulation times are identical, indicating that the contaminant front has stopped migrating downgradient, and that the contaminant plume has reached steady-state conditions after 8 years from the source release. An approximate discharge concentration (sum of contaminants) of 71 µg/L is predicted to be released to the PASNY conduits.

Model predictions from the 2, 4, 6, and 8-year simulation times indicate the downgradient migration of contaminants under the 'No Degradation' model. This is evident from the downgradient progression of the leading edge of the contaminant plume. After 8 years, the downgradient migration of the contaminant plume reaches steady-conditions, which is evident from identical contaminant profiles predicted by the model for the 8 and 20 year simulation times. An approximate discharge concentration (sum of contaminants) of 931 µg/L is predicted to be released to the PASNY conduits.

D.1.4 ESTIMATED DURATION OF NATURAL ATTENUATION FOR OFF-SITE PLUME

The duration of the natural attenuation for the off-site plume is estimated using the modeling results for the overall plume (i.e., 30 years) and an estimated factor showing the concentration variations between the off-site plume and the overall plume. For this purpose, the average vinyl chloride and 1,2-DCE concentrations for off-site monitoring wells are compared with average concentrations for the overall wells. It is estimated that the *off-site/on-site* ratio for average vinyl chloride concentrations is 1:2.5, and the same ratio is 1:4.5 for 1,2-DCE. The result for vinyl chloride is selected, which provided a more conservative estimate (i.e., 12 years) for natural attenuation of the off-site plume.

D.1.5 MODEL ASSUMPTIONS/QUALIFICATIONS

Inherent in the *BIOSCREEN* modeling are several key assumptions and qualifications that are relevant to the interpretation of model results. These items are discussed below:

- The *BIOSCREEN* software is intended only as screening tool for predicting the natural attenuation of contaminants. Therefore, although predicted contaminant concentrations have been presented and discussed in this section, these values are only crude estimates, at best.

- Predicted contaminant profiles are highly dependent on the estimated groundwater velocities. Furthermore, these groundwater velocities are only rough approximates and may be further revised with future field investigations.

- A sensitivity analysis for the *BIOSCREEN* modeling was not performed due to the limited application of these results and preliminary extent of the model input data.

- First-order biodegradation rate coefficients used in the '1st Order Decay' model assume anaerobic site conditions, enabling the reductive dechlorination of PCE to at least the level of cis-1,2-DCE. Cis-1,2-DCE and its degradation product, VC, may then be biodegraded to innocuous ethene/ethane under anaerobic or aerobic conditions. Aerobic biodegradation of these compounds is generally much faster than the anaerobic biodegradation, therefore, the anaerobic biodegradation rate coefficients used in this modeling are conservative. The redox condition of the site groundwater is not currently available.

- Potential discharge of contaminants to the PASNY conduits, which is located 3,000 feet downgradient from source area(s), is expected to enhance the natural attenuation of contaminants via contaminant dilution and aerobic biodegradation. It is unclear whether the conduit acts as an environmental receptor.

D.1.6 CONCLUSIONS OF THE NATURAL ATTENUATION FEASIBILITY DETERMINATION

Preliminary natural attenuation modeling using the *BIOSCREEN* software indicates a potential for contaminant discharge to the PASNY conduits located approximately 3,000 feet downgradient from the site. Steady-state predictions of summed contaminant concentrations discharged to the conduit are above individual regulated levels (i.e., 0.002 to 0.005 mg/L) for the 'No Degradation' (0.931mg/L) and '1st Order Decay' models (0.071 mg/L). Since the primary COCs at the site are cis-1,2-DCE and VC, both biodegradation products, evidence of active biodegradation processes exists. Therefore, the '1st Order Decay' model is expected to be more representative of site conditions than the 'No Degradation' model. Results from the '1st Order Decay' model indicate significant attenuation of contaminant concentrations, approaching regulatory levels, prior to discharge at the conduit. Model results warrant future investigation of monitored natural attenuation as an acceptable remedial technology for contaminants at the Forest Glen Site.

D.1.7 SCOPE OF NATURAL ATTENUATION INVESTIGATION TASKS

If natural attenuation is selected as a potential remedial option, then a detailed evaluation will be necessary to determine whether natural attenuation mechanisms are protective of human health and the environment. Such an evaluation will encompass, but not be limited to, the following tasks:

- perform field screening activities for evaluation of intrinsic biodegradation and other natural attenuation processes

- identify the location of contaminant sources and receptor exposure pathways
- identify biotic and abiotic processes that govern volatile organic compound mass removal
- develop electron acceptor/metabolic by-product contour maps to determine the groundwater reducing environment
- calculate an assimilative capacity based on electron acceptor/metabolic by-product data
- develop parent and metabolic by-product contour maps
- evaluate historical contaminant time-trends
- determine groundwater flow and contaminant transport parameters
- refine the predicted extent of contaminant migration using contaminant fate and transport models
- determine whether natural attenuation mechanisms are protective of human health and the environment and, if so, develop a long term monitoring program

The estimated cost of performing a detailed natural attenuation evaluation is shown in Section 3.0 and includes performance of all of the above listed items.

D.2 ENHANCED *IN-SITU* BIOREMEDIATION

In the event natural attenuation is found to be an ineffective remedial alternative based on further field investigations and groundwater modeling (as described under D.1.7), enhanced anaerobic biodegradation (EAB) can be investigated as an alternative remedial action or as a means of enhancing the natural biodegradation rate. EAB relies on the addition of sufficient organic compounds to contaminated groundwater to induce highly reducing methanogenic conditions necessary to achieve complete reductive dechlorination of chlorinated solvents. Inherent in the technically and economically feasible implementation of EAB is that site groundwaters have only low levels of alternative electron acceptors, such that only a minimal addition of organic compounds is necessary to achieve and sustain a highly reduced groundwater environment. The feasibility of this remedial alternative is currently unknown and will rely largely on results from electron acceptor analyses of the site groundwaters (performed as part of a natural attenuation evaluation), results from microcosm studies, and a field pilot study.

Enhanced anaerobic biodegradation is an innovative technology which has been implemented at relatively few sites. However, EPA and the USAF have developed guidelines for determining its feasibility and implementation.

D.2.1 LABORATORY STUDIES

Laboratory microcosm studies would be conducted to determine the optimum level of electron donors to reduce the contaminant concentration to methanogenic conditions. The studies would also determine the approximate rate of dechlorination activity as well as the extent of biodegradation. These studies are necessary to optimize a field pilot study. Full scale implementation would depend upon the successful completion of these studies.

The microcosm studies would evaluate the following factors that may be limiting the biodegradation rate:

- insufficient electron donor to complete the dechlorination reactions,
- lack of requisite dechlorinating microorganisms,
- potential for soil toxicity, and
- lack of adequate nutrients

The microcosm studies would be conducted in batch-type tests using serum bottles. Each sampling time would involve sacrificing a set of bottles for each experimental type. The microcosm would be constructed according to the draft protocol for evaluating the enhanced anaerobic biodegradation (Air Force Center for Environmental Excellence, 1996). The duration of the tests should be at least three months but could be extended based upon the earlier sampling results.

Microcosms would be constructed with site soils and groundwater after first purging with nitrogen to remove CAHs. Microcosms would be amended with three electron donors: lactate, methanol and acetate. In addition, one set of microcosms would receive a nutrient supplement used by the Air Force Center for Environmental Excellence at their test site at Dover Air Force Base. Site soils and groundwater would be incubated with no amendments (unamended controls), and amended but autoclaved to kill the microbial populations (killed controls). One set of microcosms would be innoculated with a known dechlorinating culture to serve as a positive control. Triplicate microcosms would be set up and incubated in the dark for the three month period. The microcosm would be analyzed for the same parameters as the field groundwater samples in addition to the available electron donor.

A final report would be prepared, summarizing the findings of the laboratory microcosm study and the technical and economic feasibility of EAB.

D.2.2 FIELD-SCALE PILOT STUDY

A field-scale pilot study would be conducted if electron acceptor/metabolic by-product data and the microcosm study indicate the technical and economic feasibility of EAB. The field-scale pilot study would be designed to verify the findings of the microcosm study and to ensure proper scale-up procedures and operation prior to the full-scale implementation of EAB. The following is a limited list of considerations and tasks that would be necessary to perform a field-scale pilot study:

- Selection of an appropriate test-plot location
- Development and regulatory approval of a site investigation work plan
- Application and attainment of required permits and field clearances
- Hydrogeologic characterization of the test plot area. This would require collection of soil and groundwater samples and performance of dye tracer studies.
- Development of an test system operation plan

- Continued operation and maintenance of the test system, including soil and groundwater sampling.
- Data analysis and interpretation
- Final technology assessment

REFERENCES

Air Force Center for Environmental Excellence (AFCEE). 1996. *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater*. November

Bradley P.M and F.H. Chapelle. 1998. Effect f Contaminant Concentration on Aerobic Microbial Mineralization of DCE and VC in Stream-Bed Sediments. *Environmental Science and Technology*. Vol. 32, No. 5, p.553 -557.

Bradley P.M and F.H. Chapelle. 1997. Kinetics of DCE and VC Mineralization under Methanogenic and Fe(III)-Reducing Conditions. *Environmental Science and Technology*. Vol. 31, No. 9, p.2692 -2696.

USEPA Office of Research and Development. 1996a. *BIOSCREEN* Natural Attenuation Decision Support System. User's Manual. Version 1.3. August.

USEPA Office of Research and Development. 1996b. Ellis, D.E. Intrinsic Remediation in the Industrial Marketplace. Symposium on Natural Attenuation of Chlorinated Organics in Ground Water. September.

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.4*

Filename: Forest.xls

Forest Glen Site
Lockport Bedrock

Data Input Instructions:

115 (or 0.02 x) — 1. Enter value directly...or 2. Calculate by filling in grey cells below. (To restore formulas, hit button below).

Variable* — Data used directly in model.

20 — Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	Vs	640.0	(ft/yr)
or		*or*	
Hydraulic Conductivity	K		(cm/sec)
Hydraulic Gradient	I		(ft/ft)
Porosity	n		(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	37.4	(ft)
Transverse Dispersivity*	alpha y	3.7	(ft)
Vertical Dispersivity*	alpha z	0.0	(ft)
or		*or*	
Estimated Plume Length	Lp	3000	(ft)

3. ADSORPTION

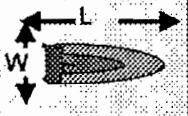
Retardation Factor*	R	1.0	(-)
or		*or*	
Soil Bulk Density	rho		(kg/l)
Partition Coefficient	Koc		(L/kg)
FractionOrganicCarbon	foc		(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	5.7E-1	(per yr)
or		*or*	
Solute Half-Life	t-half	1.22	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO		(mg/L)
Delta Nitrate*	NO3		(mg/L)
Observed Ferrous Iron*	Fe2+		(mg/L)
Delta Sulfate*	SO4		(mg/L)
Observed Methane*	CH4		(mg/L)

5. GENERAL

Modeled Area Length*	3000	(ft)
Modeled Area Width*	100	(ft)
Simulation Time*	20	(yr)



6. SOURCE DATA

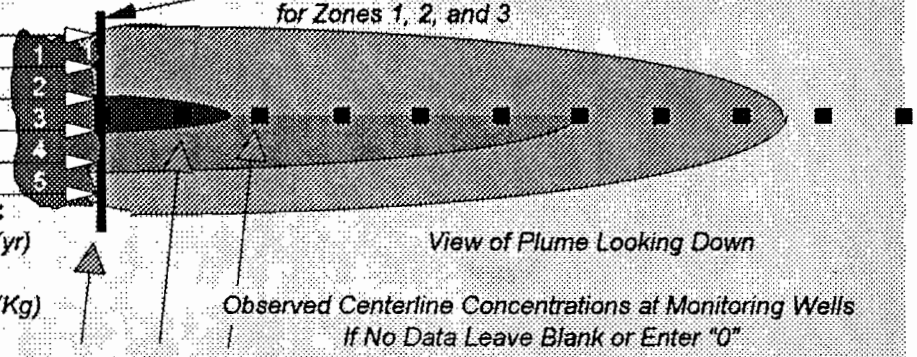
Source Thickness in Sat.Zone* 55 (ft)

Source Zones:

Width* (ft)	Conc. (mg/L)*
100	1.88

Source Halflife (see Help):

Infinite	Infinite	(yr)
Inst. Reactor	1st Order	
Soluble Mass In Source NAPL, Soil	infinite	(Kg)



7. FIELD DATA FOR COMPARISON

Dist. from Source (ft)	0	300	600	900	1200	1500	1800	2100	2400	2700	3000
Concentration (mg/L)											

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — View Output

RUN ARRAY — View Output

Help

Recalculate This Sheet

Paste Example Dataset

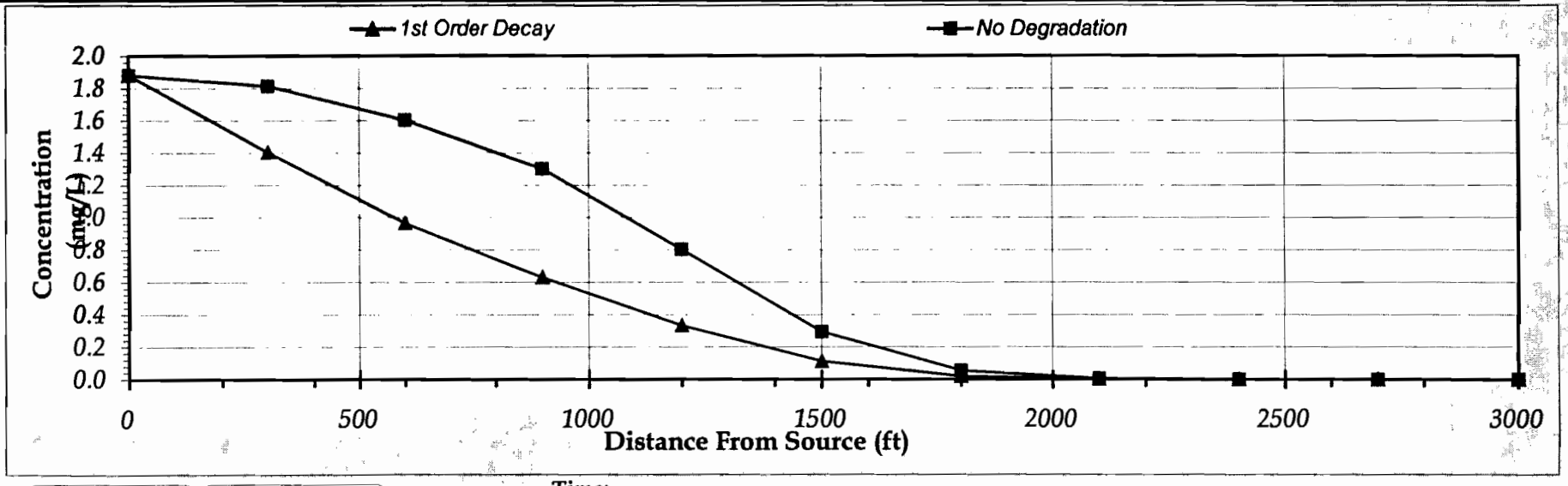
Restore Formulas for Vs, Dispersivities, R, lambda, other

CONTAMINANT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L at Z=0)

Filename: Forest.xls

Distance from Source (ft)

TYPE OF MODEL	0	300	600	900	1200	1500	1800	2100	2400	2700	3000
No Degradation	1.880	1.813	1.602	1.300	0.802	0.294	0.053	0.004	0.000	0.000	0.000
1st Order Decay	1.880	1.402	0.963	0.628	0.332	0.111	0.019	0.002	0.000	0.000	0.000



Replay Animation | Next Timestep | Prev Timestep

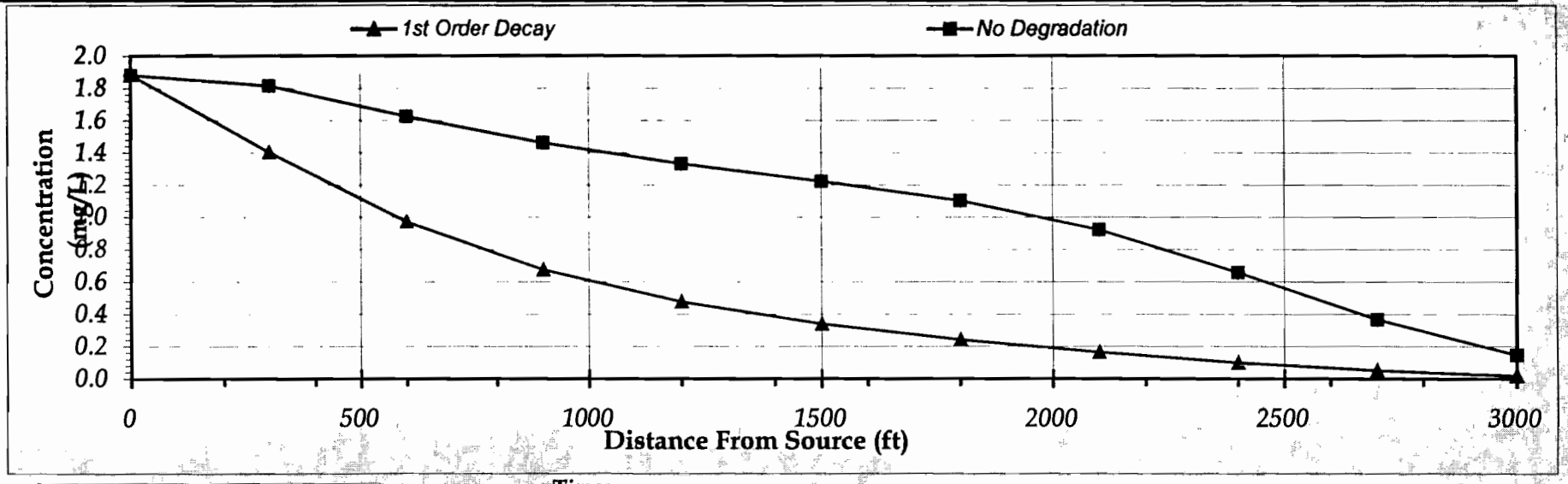
Time: 2 Years

Return to Input | Recalculate This Sheet

CONTAMINANT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L at Z=0)

Filename: Forest.xls

	Distance from Source (ft)										
TYPE OF MODEL	**0**	**300**	**600**	**900**	**1200**	**1500**	**1800**	**2100**	**2400**	**2700**	**3000**
No Degradation	1.880	1.815	1.625	1.461	1.331	1.221	1.101	0.922	0.658	0.365	0.147
1st Order Decay	1.880	1.402	0.970	0.674	0.475	0.338	0.240	0.164	0.100	0.050	0.019



Replay Animation | Next Timestep | Prev Timestep

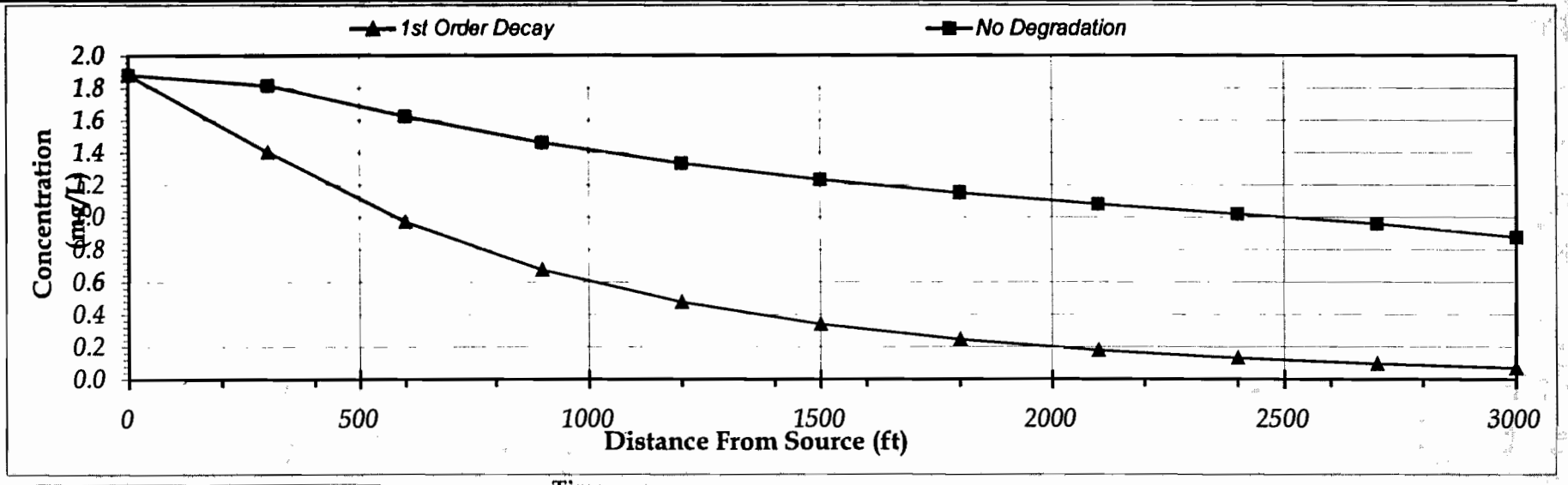
Time: *4 Years*

Return to Input | Recalculate This Sheet

CONTAMINANT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L at Z=0)

Filename: Forest.xls

	Distance from Source (ft)										
TYPE OF MODEL	0	300	600	900	1200	1500	1800	2100	2400	2700	3000
No Degradation	1.880	1.815	1.625	1.461	1.332	1.231	1.149	1.080	1.020	0.958	0.877
1st Order Decay	1.880	1.402	0.970	0.674	0.475	0.339	0.244	0.178	0.130	0.095	0.069



Replay Animation | Next Timestep | Prev Timestep

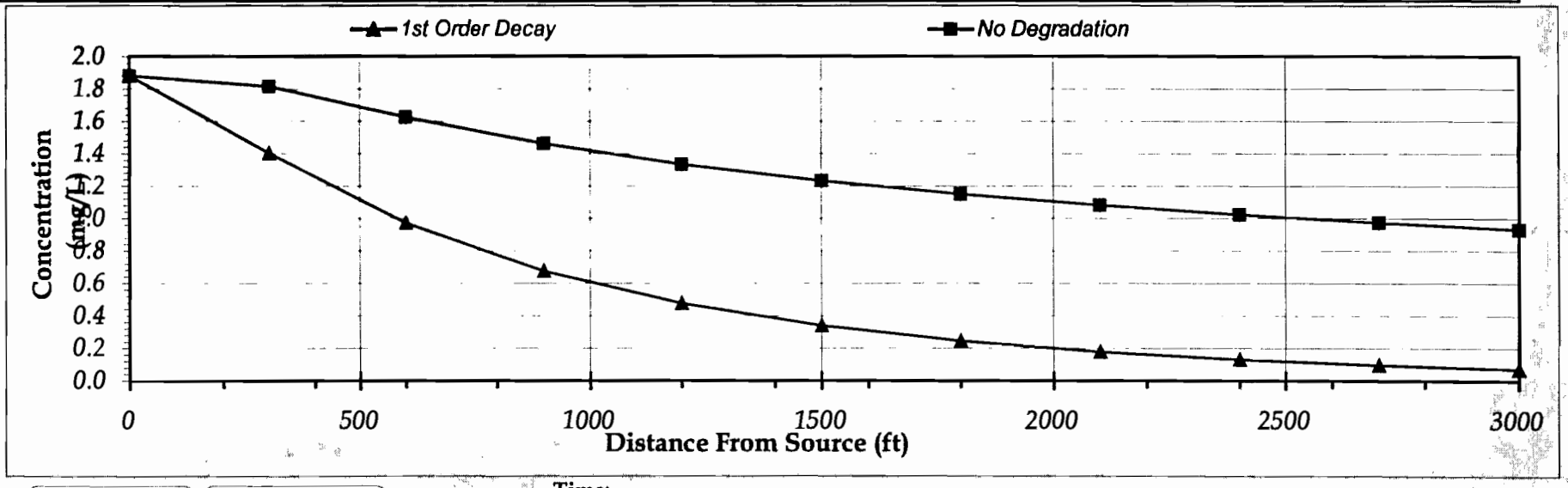
Time: 6 Years

Return to Input | Recalculate This Sheet

CONTAMINANT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L at Z=0)

Filename: Forest.xls

	Distance from Source (ft)										
TYPE OF MODEL	0	300	600	900	1200	1500	1800	2100	2400	2700	3000
No Degradation	1.880	1.815	1.625	1.461	1.332	1.231	1.149	1.081	1.024	0.974	0.931
1st Order Decay	1.880	1.402	0.970	0.674	0.475	0.339	0.244	0.178	0.130	0.096	0.071



Replay Animation | Next Timestep | Prev Timestep

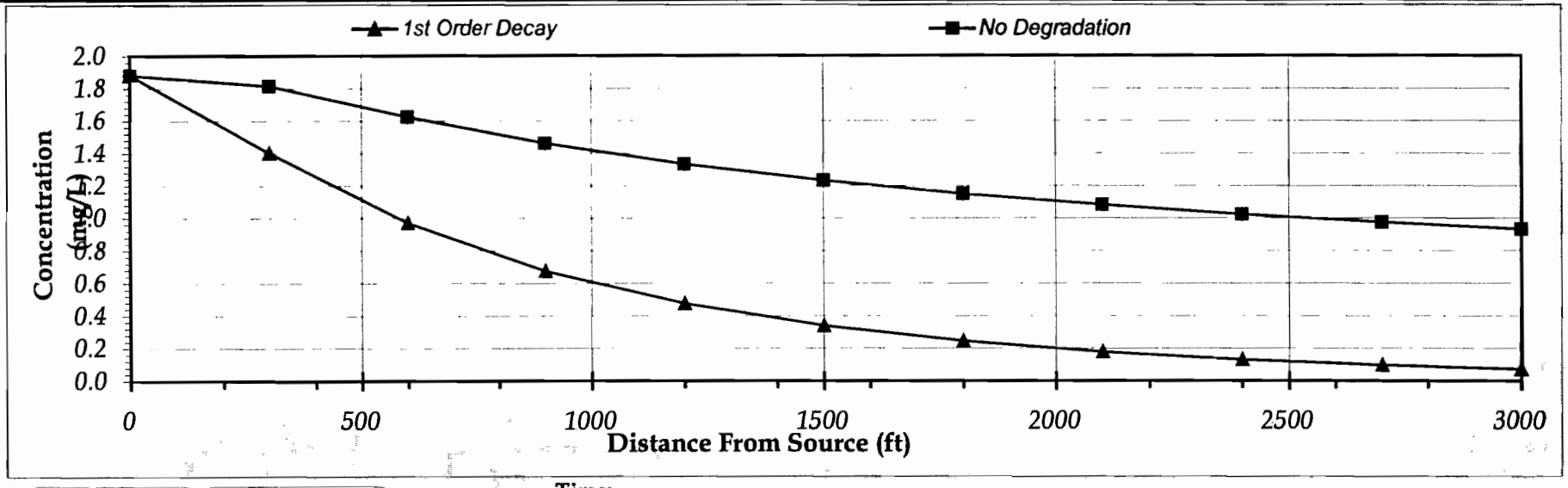
Time: 8 Years

Return to Input | Recalculate This Sheet

CONTAMINANT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L at Z=0)

Filename: Forest.xls

	Distance from Source (ft)										
TYPE OF MODEL	**0**	**300**	**600**	**900**	**1200**	**1500**	**1800**	**2100**	**2400**	**2700**	**3000**
No Degradation	1.880	1.815	1.625	1.461	1.332	1.231	1.149	1.081	1.024	0.974	0.931
1st Order Decay	1.880	1.402	0.970	0.674	0.475	0.339	0.244	0.178	0.130	0.096	0.071



Replay Animation | Next Timestep | Prev Timestep

Time: *20 Years*

Return to Input | Recalculate This Sheet