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FEASIBILITY STUDY REPORT

FARRAND CONTROLS SITE

Valhalla, Westchester County, New York
(Site Registry No. 3-60-046)

CONTRACT NO. D003600-8

Prepared For

New York State Department of Environmental Conservation

OCTOBER 2000

DVIRKA AND BARTILUCCI
CONSULTING ENGINEERS
A DIVISION OF WILLIAM F. COSULICH ASSOCIATES, P.C.

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Prepared for

NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION

by

DVIRKA AND BARTILUCCI CONSULTING ENGINEERS
WOODBURY, NEW YORK

OCTOBER 2000

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FEASIBILITY STUDY REPORT
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VALHALLA, NEW YORK

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

List of Appendices

List of Figures

List of Tables

Section 1

1.0 INTRODUCTION

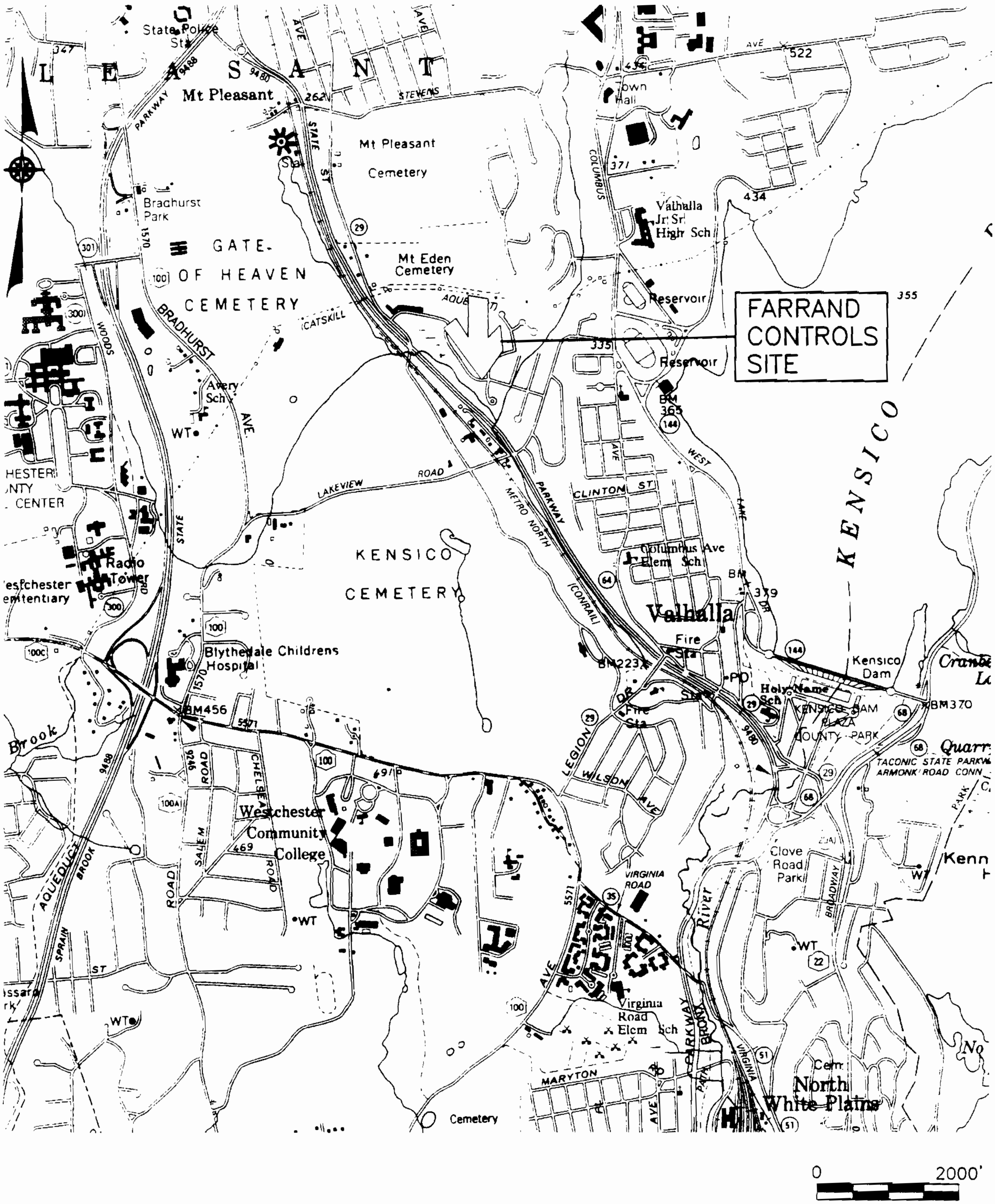
This section presents the purpose of the feasibility study for the Farrand Controls Site, a description of the site, summary of the remedial investigation results and risk assessment, definition of the remedial action objectives and approach to the feasibility study.

1.1 Purpose and Site Background

As part of New York State's program to investigate and remediate hazardous waste sites, the New York State Department of Environmental Conservation (NYSDEC) issued a Work Assignment to Dvirka and Bartilucci Consulting Engineers (D&B) of Woodbury, New York, under its Superfund Standby Contract with NYSDEC, to conduct a remedial investigation and feasibility study (RI/FS) for the Farrand Controls Site located in Valhalla, Westchester County, New York (see Figure 1-1). The Farrand Controls Site is listed as a Class 2 site in the NYSDEC Registry of Inactive Hazardous Waste Disposal Sites (Site No. 3-60-046). A Class 2 site is one that represents a "significant threat to public health or environment and some action is required."

The objectives of the RI/FS are to determine the nature, source(s) and extent of contamination; identify contaminant migration pathways and potential receptors; determine impacts to human health and the environment; evaluate the need for corrective action; identify and evaluate remedial alternatives; and select a long-term, cost-effective remediation plan.

The site is currently owned by Farrand Controls, Inc., Division of Ruhle Companies, Inc., and is an active electronic component manufacturing facility. The site is approximately 6 acres in size. The northeastern area, approximately 60 percent of the site is a hill, with bedrock outcrop at its base, and is undeveloped. The developed area of the property extends from the bedrock outcrop to the property boundaries to the northwest, west and south, and is hereafter referred to as the site and illustrated on Figure 1-2. The site currently consists of a 28,255 square foot, one-story block and steel framed manufacturing building constructed in 1958 (see Figure 1-2). The original building of approximately 5,000 square feet was expanded in 1972. There is also an 8,312 square foot, wood frame "Quonset" style building on the site,



SOURCE: USGS WHITE PLAINS, QUADRANGLES

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FARRAND CONTROLS SITE
VALHALLA, NEW YORK

SITE LOCATION MAP

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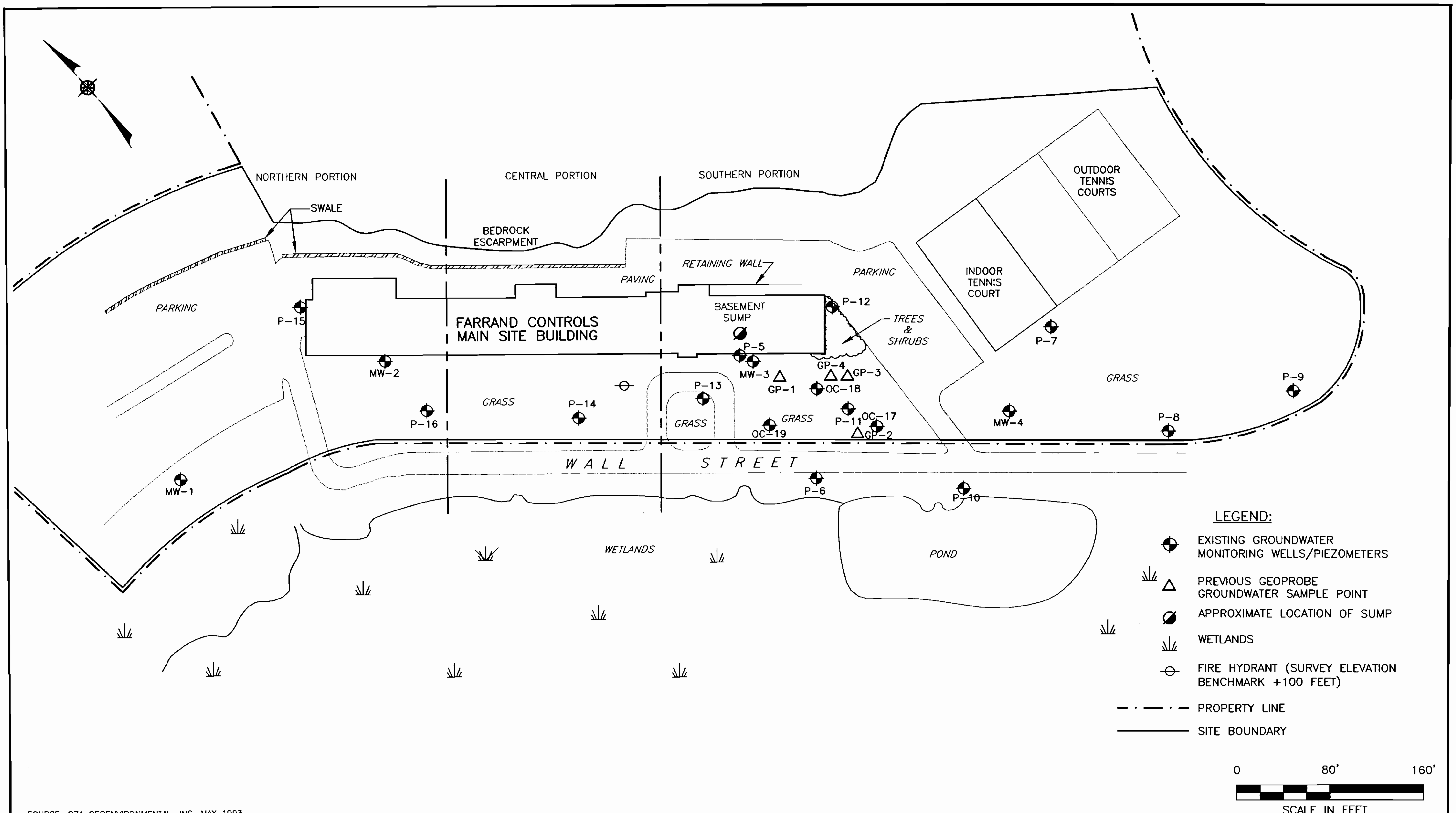
FIGURE 1-1



SOURCE: GZA GEOENVIRONMENTAL, INC. MAY 1993

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FARRAND CONTROLS SITE
REMEDIAL INVESTIGATION/FEASIBILITY STUDY

SITE PLAN

FIGURE 1-2

DIR: 1617 FILE:1617-6A.DWG (T.MCC/10-8-00) which was constructed in 1958 as an indoor tennis court. Except for the eastern portion of the site and the bedrock escarpment, the site is primarily grassed and slopes gently to the west.

The Farrand Controls Site has been served by a municipal public water and sanitary sewer system since 1958, when the facility was constructed. The surrounding residential and commercial/industrial area is also served by public water and municipal sanitary sewers. Storm water is collected by an on-site storm sewer system that discharges to the wetlands located to the south and west of the facility.

The Farrand Controls main site building and most of the property boundaries are situated diagonally with respect to geographic north. To facilitate discussion of site information and evaluation of the remedial investigation findings, areas of the site and site main building will be referenced as southern, central and northern portions as designated in Figure 1-2.

Based on a review of aerial photography of the site, prior to 1958, the site was undeveloped with respect to building construction. The photographs indicate that portions of the site before 1958, were heavily disturbed as the result of surface mining, possibly a borrow pit or sand and gravel mine.

Operations at the site included machining of metals, photolithographic processing (including cupric etching), soldering, and electronic and mechanical assembly. In the basement of the original building, a sump was used to collect liquids from various floor drains. When the building was expanded in 1972, this sump was reportedly deactivated and a number of floor drains that emptied into the sump were plugged. Solvents used at the time of the sump deactivation included acetone, 1,1,1-trichloroethane (TCA), freon, methylene chloride and isopropyl alcohol.

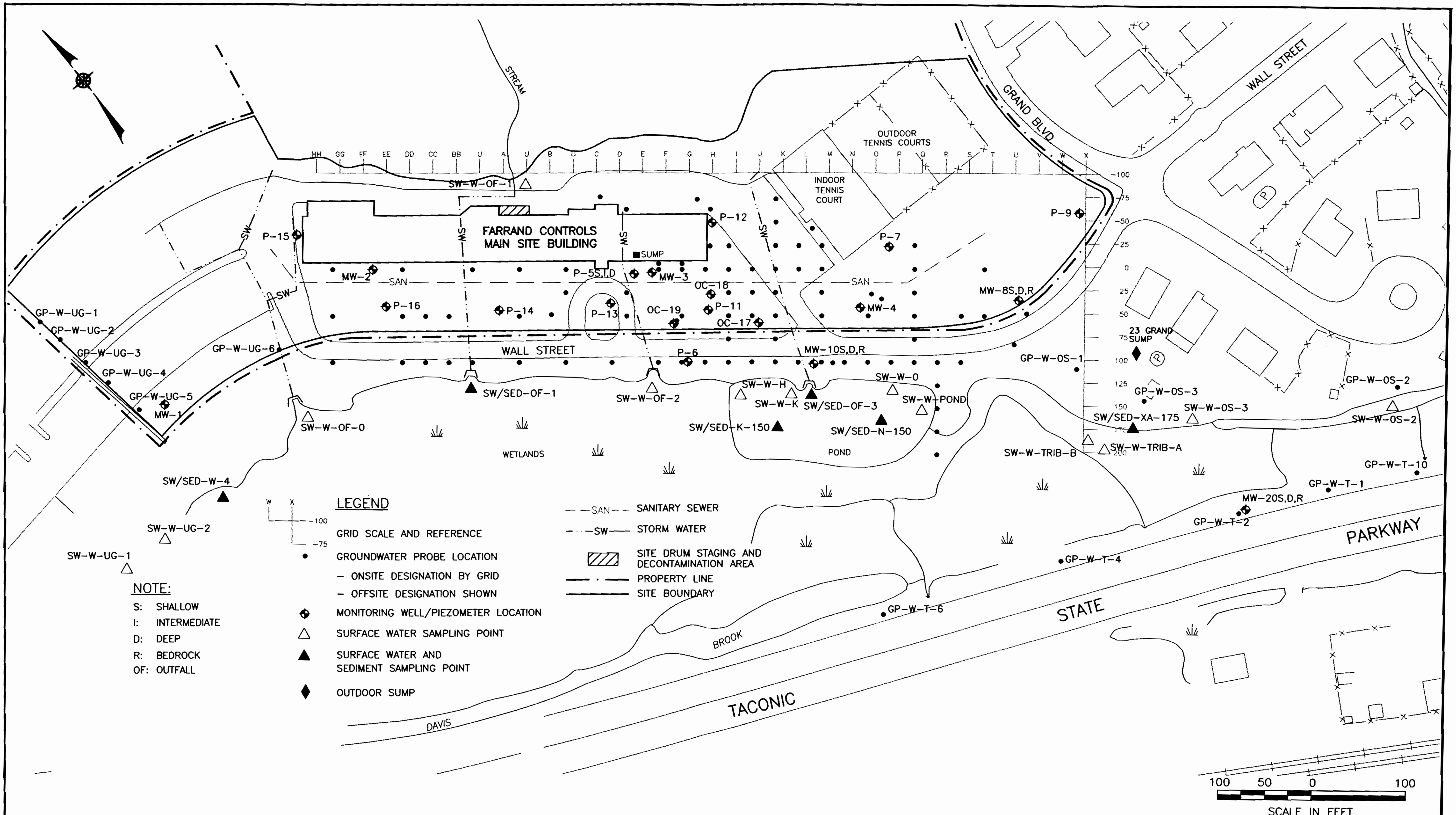
Since required by regulations, spent solvents at Farrand Controls have been drummed and staged on-site pending off-site disposal (personal communication from M. Frenz [Farrand Controls, Inc.] to A. Jaroszewski [D&B], 2/11/00). The drums were staged behind the main site building near the south central portion of the building. Prior to this period, it is not known how the spent solvents were managed.

In 1993, it was reported that Ruhle Companies cleaned out the accumulated sludge from the sump. Tests of the sludge confirmed the presence of TCA. In 1996, the sump contents, base and underlying shallow soil were removed by Farrand Controls personnel. This activity generated one drum of solids and one drum of liquids. Analysis of the liquids showed the presence of Freon 113, 1,1-dichloroethene (DCE), methylene chloride, 1,1-dichloroethane (DCA) and TCA in concentrations between 65,000 and 25,000,000 ug/l. The sump was reportedly sealed after the materials were removed and is no longer in use.

This feasibility study has been prepared based on the results of the remedial investigation and in accordance with the federal Comprehensive Emergency Response, Compensation and Liability Act (CERCLA), Superfund Amendments and Reauthorization Act (SARA) and the New York State Superfund Program, including the NYSDEC Technical and Administrative Guidance Memorandum (TAGM HWR-90-4030) for "Selection of Remedial Actions at Inactive Hazardous Waste Sites."

1.2 Remedial Investigation Results

The following is a summary of the findings and conclusions resulting from the remedial investigation and risk assessment conducted for the Farrand Controls Site as a function of the media investigated. These findings and conclusions are based on comparison of the investigation results to standards, criteria and guidelines (SCGs) selected for the site. The results of the investigation are described in detail in the Remedial Investigation Report, dated June 2000. Groundwater, surface water and sediment sampling locations are presented on Figure 1-3.



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FARRAND CONTROLS SITE
REMEDIAL INVESTIGATION/FEASIBLITY STUDY

GROUNDWATER, SURFACE WATER AND SEDIMENT SAMPLING LOCATIONS

Dvirka and Bartilucci
Consulting Engineers
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FIGURE 1–3

Site Geology

Most of the Farrand Controls Site is immediately underlain by sandy, silty unconsolidated materials, probably deposited as alluvium (sediment deposited by water), glacial till and/or outwash. These deposits occur below approximately 2 to 5 feet of fine sandy silty loam soil. The unconsolidated deposits are of two main types. The primary unit that underlies most of the site consists predominantly of fine to medium-grained sands containing some gravel and silt. A less extensive fine-grained unit overlies the medium-grained sands near the wetlands where it is approximately 25 feet thick at monitoring well cluster MW-10 and pinches out northward between monitoring well MW-3 and the main site building. The fine-grained unit is comprised of interbedded silt, clay, silty and clayey sands.

Geoprobe probeholes indicate a "refusal surface" of significantly higher relief than exists at the ground surface. The refusal surface indicates that the bedrock escarpment rising above the site probably continues beneath it, under the rear portion of the Farrand Controls main building. Several small, southwest-trending swales cross the refusal surface, particularly beneath the parking area west/northwest of the main site building, and beneath the eastern end of the building where a subsurface swale continues southwestward beneath the lawn. An anomalous approximately 100-foot wide, 200-foot long topographic mound marks the refusal surface roughly between the tennis courts and the main site building, descending toward the wetland. This mound is likely a buried landslide deposit.

Geologic materials exposed in the cliff face immediately west of the site consist of an intensely folded and jointed black and white banded gneiss. Observed bedrock is consistent with the Manhattan formation, a pelitic garnetamphibolite schist and schistose gneiss which is mapped at the site on the *Geologic Map of New York* (Fischer, Isachsen and Rickard, 1970). Irregularly spaced, mainly steeply dipping joints and localized layers of highly foliated, mica bearing schistose rock transmit groundwater which was observed "weeping" from the cliff face in October and November 1999.

Site Hydrogeology

Horizontal groundwater flow at the Farrand Controls Site is predominantly southward with southeast and southwest components in different parts of the site. The shallow water table has been encountered within approximately 10 feet of the ground surface. Differences in head within clustered monitoring wells and piezometers provide evidence that the southern portion of the site is characterized by upwelling of deep overburden groundwater, while downward flow of shallow overburden groundwater occurs near the main building.

Hydraulic conductivities for unconsolidated sands and silts at the site range from 3.87×10^{-2} cm/sec to 8.44×10^{-3} cm/sec. Groundwater flow velocity in the overburden sand unit was calculated to be 1.04 ft/day.

One slug test was performed in a bedrock well, however, the screen of MW-10R sits in a highly weathered saprolitic/fracture zone that yielded a hydraulic conductivity of 5.38×10^{-4} cm/sec.

Surface Soil Quality

Based on the results of the remedial investigation, surface soil at the Farrand Controls Site does not appear to be contaminated and warrants no further action.

Subsurface Soil Quality

The investigation results indicate that soils in the vadose and saturated zones beneath the basement sump are not significantly contaminated, which indicates that prior removal of contaminated sediment in the sump and underlying soil was effective in remediating this source of contamination in the immediate area of the sump. However, contaminated subsurface soil was detected in deep Geoprobe samples, below the water table, in the area of the building's eastern corner, southern corner and along the southwestern building wall near the sump. SCGs were exceeded for only two compounds (TCA and TCE) in one sample which was located at the buildings southern corner.

Groundwater Quality

The following summarizes the results of the groundwater investigation:

- Groundwater at the site is significantly contaminated with volatile organic compounds, and dense non-aqueous phase liquid (DNAPL) may be present in the subsurface overlying bedrock and the Geoprobe refusal surface. The VOCs detected in groundwater are trichloroethene (TCE) and its breakdown products, cis-DCE, trans-DCE and vinyl chloride (VC); TCA and its breakdown products cis-DCE, DCA, chloroethane and VC; and Freon 113. The primary contaminants are TCE, TCA and Freon. These solvents were used and disposed at the site in the basement sump in the southern portion of the building.

- Based on the investigation results, there are shallow and deep overburden plumes of contaminated groundwater that migrate from the southern portion of the building. The shallow plume extends off-site in a southerly direction and appears to discharge to the adjacent surface waters. The deep plume appears to migrate also in a southerly direction beneath the pond and wetlands, and discharges, at least in part, also to the pond and wetlands, and shallow groundwater beyond the surface water system and in the vicinity of the Taconic State Parkway. The discharge to the wetlands and pond significantly impacts surface water quality. The downward flow of groundwater in the vicinity of the building and DNAPL are likely factors for the migration of contaminants to the underlying bedrock and Geoprobe refusal surface. Based on the sample results, contaminated groundwater was detected in bedrock south of the main site building.

- Although the deep overburden plume is primarily located south of the main site building, contamination is also present in the deep overburden groundwater west of the building, between the building and wetlands. The VOC concentrations in this area are sporadic and are not as high as in the narrower plume south of the main site building. The occurrence of this contamination may likely be associated with varied localized groundwater flow components, preferential flow pathways, the drain tile along the front of the building (if it is present), and the storm water sewer pipes, in particular, the pipe that runs adjacent to the sump from beneath the building to the wetlands.

- In addition to the plumes originating from the area of the sump and southern portion of the building, groundwater contamination was also detected along the northwestern site boundary, which appears to be the result of an off-site source. Also, the VOC fingerprint found in this area (primarily DCA and VC) is different from that found in the above areas of the site.

- Since the sump was effectively remediated, the source of groundwater contamination south of the building, at least in the shallow overburden groundwater, may result from: 1) significant contamination and possible DNAPL being retained in the capillary zone and soil pore space beneath the building and downgradient of the sump or 2) residual contamination in drain tile along the front of the building (if it does exist). The source of contaminated groundwater in the deep overburden is likely due to continuing migration of contamination from the shallow overburden and also from highly contaminated groundwater and likely DNAPL overlying bedrock and the dense surface defined by Geoprobe refusal.

- The preferential pathways for migration of highly contaminated groundwater and possible DNAPL appear to be along surfaces of localized clay and silt layers, highly permeable material along reported subsurface drains, building footings and bedrock, and Geoprobe refusal surfaces.

- In addition to the sources described above, a source of contamination may exist in subsurface soil in the vadose zone near the building's eastern corner, near the machine shop. This source, if it exists, may have resulted from disposal and/or spills of solvents to ground surface or perhaps to a pit.

Based on the results of the remedial investigation, remediation of groundwater to mitigate off-site contaminant migration and contamination of the wetlands and pond is recommended. Remediation should address both containment and treatment of the dissolved plume at the property boundary and more highly contaminated groundwater and possibly DNAPL in the interior of the site, which is acting as a continuing source for the dissolved plume.

Elevated levels of VOCs detected in one bedrock well screened in the highly fractured zone south of the main site building and the downward flow of groundwater in the vicinity of the building indicates the potential for a larger area of contamination in the highly fractured rock than currently defined. Without additional sampling points, conservative assumptions have been made for the purposes of preparation of this feasibility study: 1) the highly fractured bedrock underlies the entire site, 2) the deep overburden and underlying highly fractured bedrock are hydraulically connected throughout the site 3) the contamination in the highly fractured bedrock is as extensive (horizontally) as the contamination in the deep overburden and 4) the depth of this zone is estimated to be approximately 10 feet.

Surface Water Sediment Quality

Based on the results of the investigation, sediments in the wetlands and pond adjacent to the site are not significantly contaminated and warrant no further action.

Surface Water Quality

Surface water in the wetlands and pond adjacent to the site appears to be significantly contaminated with VOCs, primarily TCE and TCA, resulting from discharges of contaminated groundwater to the surface water and possibly discharges from the storm water outfall that runs beneath the site and adjacent to the basement sump. It is believed that this outfall was once connected to the source sump.

Indoor Air

Based on the sampling results and comparison to recommended occupational exposure levels, concentrations of volatile organic compounds in air in the main site building basement are within established limits and no further action is warranted with regard to indoor air under present conditions.

1.3 Risk Assessment Results

Risks at and in the vicinity of the Farrand Controls Site were evaluated on the basis of the site environmental setting and information on the nature and extent of contamination. The risk assessment addresses the current and potential human contact with contaminants of concern at potential locations where human exposure could occur, and potential impacts to ecological receptors. The human health exposure assessment and wildlife habitat survey are included in the Remedial Investigation Report.

1.3.1 Human Health Exposure Assessment

Based upon the results of the exposure assessment there are currently no complete pathways for human exposure associated with contamination in media on the Farrand Controls Site or migrating from the site.

There are inorganic contaminants of potential concern (COPCs) present in all media sampled at the site. However, the concentrations of these COPCs are generally within an order of magnitude of their SCGs, and exposure to these COPCs would be limited. Therefore, exposure to inorganic COPCs present in site-related media are not of concern from the perspective of human health risk.

The following exposure pathways involving volatile organic COPCs are currently not complete, but could potentially become complete for the following receptors:

On-site Farrand Controls workers

- Inhalation of VOCs released to air from groundwater in the basement of the main building
- Dermal contact with VOC-contaminated groundwater in the basement of the main building
- Inhalation exposure to VOCs released to air from soil and groundwater from a hypothetical open subsurface construction near the sump source area

On-site workers engaged in subsurface utility repairs or subsurface construction

- Oral, dermal and inhalation exposure to VOCs in subsurface soil at the southern corner of the building.
- Dermal and inhalation exposure to VOCs in shallow groundwater which may be present in an excavation near the sump source area, or near the secondary plume on the western side of the main building

On-site trespassers or recreationists

- Dermal exposure to VOCs in surface water or discharging groundwater (remote possibility)

Nearby downgradient residents and commercial establishments

- Oral, dermal and inhalation exposure to VOCs in groundwater

1.3.2 Ecology and Wildlife Habitat Survey

The results of the habitat-based assessment conducted for the Farrand Controls Site indicate that the open water and forested wetland areas represent high value habitats. These habitats are prominent in primary productivity, nutrient transport and food chain support, while also providing aesthetic and recreational opportunities that would likely not otherwise be available in this location. The assessment indicates that there is one area of the wetland which raises concern. There is an area in the wetlands in the vicinity of the former sump outfall (Outfall No. 2) where biological activity and plant growth is sparse and several trees in this path are dead, which is not common throughout the wetlands and in other areas of storm water discharge to the wetlands. This area also coincides with high volatile organic compound concentrations in a surface water sample collected from the outfall at this location. A sediment sample collected from this area of apparent vegetative stress exceeded aquatic sediment guidance values for surface water sediment's lowest effect levels for antimony, barium, chromium, copper, iron, lead, magnesium, manganese, mercury, nickel and zinc. A conclusive determination cannot be derived from evaluation of the available information whether this vegetative anomaly is the result of chemical contamination or environmental hydrologic fluctuations in the wetlands.

Past practices at the Farrand Controls Site have resulted in the discharge of volatile organic compounds into the ground as a subsurface discharge. These chemicals had the potential to migrate through groundwater and storm sewers that exist on-site. Groundwater flow in the site vicinity provides much of the hydrologic make-up of the forested wetland adjacent to the site. Groundwater in the vicinity of the main site building discharges to the wetland area. Site storm water runoff and discharges from the basement sump were also directed to the wetland.

With the exception of one small area of stressed vegetation in the wetland, there is limited indication that an ecological impact related to chemical contamination has occurred at the Farrand Controls Site. The area of stressed vegetation probably shows more an effect of discharge from sewer Outfall No. 2 beneath the building that culverts a stream and received discharges from the basement sump. A review of file information on the Farrand Controls manufacturing processes gave no indication that metals such as seen in the wetland sediments were generated by the manufacturing processes at Farrand Controls. The detected metals in the area of the stressed vegetation are common elements and are likely from runoff. The cause of the stressed vegetation may be from the elevated VOCs detected in Outfall No. 2 sample and in the ponded surface water.

Based on the soil and water sample analytical results, it would suggest that the potential pathways of concern for potential contaminant migration and exposure would be groundwater (VOCs), surface water (VOCs) and wetland sediments (metals).

1.4 Remedial Action Objectives

Remedial action objectives are goals developed for the protection of human health and the environment. Definition of these objectives requires an assessment of the contaminants and media of concern, migration pathways, exposure routes and potential receptors. Typically, remediation goals are established based on standards, criteria and guidelines to protect human health and the environment. SCGs for the Farrand Controls Site, which were developed as part of the remedial investigation, include NYSDEC Technical and Administration Guidance Memorandum (TAGM) No. 4046, *Determination of Soil Cleanup Objective and Cleanup Levels (1994)*, NYSDEC Technical and Operational Guidance Series (TOGS) (1.1.1), *Ambient Water Quality Standards And Guidance Values and Groundwater Effluent Limitations (1998) and NYSDEC Division of Fish and Wildlife/Division of Marine Resources Technical Guidance for Screening*

Contaminated Sediment (January 1999). Based on these SCGs and the results of the remedial investigation, the remedial action objectives developed for the site are the following:

1. Protection of human health and the environment; and
2. Reduction of contaminant levels to groundwater standards and prevention of further migration of contaminated groundwater off-site.

In addition to consideration of SCGs to meet the remedial action objectives, Applicable or Relevant and Appropriate Requirements (ARARs) are to be considered when formulating, screening and evaluating remedial alternatives, and selecting a remedial action. ARARs may be categorized as contaminant-specific, location-specific or action-specific. Federal statutes, regulations and programs may apply to the site where state or local standards do not exist. Potentially applicable contaminant-specific, location-specific and action-specific ARARs for the Farrand Controls Site, along with guidance, advisories, criteria, memoranda and other information issued by regulatory agencies to be considered (TBC), are presented in Tables 1-1, 1-2 and 1-3. As a note, many of the NYSDEC ARARs include federal requirements which have been delegated to New York State. Generally, federal ARARs are referenced when state requirements do not exist.

1.5 Feasibility Study Description

The Technical and Administrative Guidance Memorandum (TAGM) prepared by NYSDEC entitled, "Selection of Remedial Actions at Inactive Hazardous Waste Sites," describes the feasibility study as a process to identify and screen potentially applicable remedial technologies, combine technologies into alternatives and evaluate appropriate alternatives in detail, and select an appropriate remedial action plan. The objective of this feasibility study is to meet the goal of this guidance document, as well as USEPA guidance in a focused, concise manner.

The approach of a feasibility study is to initially develop remedial action objectives for medium-specific or operable unit-specific goals to protect human health and the environment. The goals consider the contaminants and contaminant concentrations as determined by the remedial

Table 1-1

POTENTIALLY APPLICABLE CHEMICAL SPECIFIC ARARs/TBCs
FARRAND CONTROLS SITE

Citation/ Reference	Title	Applicable Media	Potential ARAR/TBC	Regulatory Agency
6 NYCRR 212	General Process Emission Sources	Air	ARAR	NYSDEC
6 NYCRR 257	Air Quality Standards	Air	ARAR	NYSDEC
6 NYCRR 371	Identification and Listing of Hazardous Waste	Hazardous Waste	ARAR	NYSDEC
6 NYCRR 376	Land Disposal Restrictions	Hazardous Waste	ARAR	NYSDEC
6 NYCRR 700-705	Surface Water and Groundwater Classifications and Standards	Surface Water/ Groundwater	ARAR	NYSDEC
6 NYCRR 750-758	State Pollutant Discharge Elimination System	Wastewater Discharge	ARAR	NYSDEC
State Sanitary Code - Part 5	Drinking Water Supply	Water Supply	ARAR	NYSDOH
TOGS 1.1.1	Ambient Water Quality Standards and Guidance Values	Surface Water/ Groundwater	TBC	NYSDEC
TOGS 1.3.1	Waste Assimilative Capacity Analysis & Allocation for Setting Water Quality Based Effluent Limits	Wastewater Discharge	TBC	NYSDEC
TOGS 1.3.1C	Development of Water Quality Based Effluent Limits for Metals Amendment	Wastewater Discharge	TBC	NYSDEC
TOGS 1.3.2	Toxicity Testing in the SPDES Program	Wastewater Discharge	TBC	NYSDEC
Air Guide No. 1	Guideline for the Control of Toxic Ambient Air Contaminants	Air	TBC	NYSDEC
TAGM HWR-4046	Determination of Soil Cleanup Objectives and Cleanup Levels	Soil	TBC	NYSDEC

Table 1-2

POTENTIALLY APPLICABLE LOCATION SPECIFIC ARARs/TBCs
FARRAND CONTROLS SITE

Citation/ Reference	Title	Applicable Media	Potential ARAR/TBC	Regulatory Agency
6 NYCRR 256	Air Quality Classification System	Air	ARAR	NYSDEC
N/A	Fish and Wildlife Impact Analysis for Inactive Hazardous Waste Sites	Hazardous Waste Sites	TBC	NYSDEC

Table 1-3

POTENTIALLY APPLICABLE ACTION SPECIFIC ARARs/TBCs
FARRAND CONTROLS SITE

Citation/ Reference	Title	Applicable Media	Potential ARAR/TBC	Regulatory Agency
6 NYCRR 200	General Provision	Air	ARAR	NYSDEC
6 NYCRR 201	Permits and Registrations	Air	ARAR	NYSDEC
6 NYCRR 211	General Prohibitions	Air	ARAR	NYSDEC
6 NYCRR 212	General Process Emission Sources	Air	ARAR	NYSDEC
6 NYCRR 364	Waste Transporter Permits	Solid/Hazardous Waste	ARAR	NYSDEC
6 NYCRR 370	Hazardous Waste Management System – General	Hazardous Waste	ARAR	NYSDEC
6 NYCRR 372	Hazardous Waste Manifest System and Related Standards for Generators, Transporters and Facilities	Hazardous Waste	ARAR	NYSDEC
6 NYCRR 373	Hazardous Waste Management Facilities	Hazardous Waste	ARAR	NYSDEC
6 NYCRR 375	Inactive Hazardous Waste Disposal Site Remedial Program	Hazardous Waste	ARAR	NYSDEC
6 NYCRR 376	Land Disposal Restrictions	Hazardous Waste	ARAR	NYSDEC
6 NYCRR 617 and 618	State Environmental Quality Review	All Media	ARAR	NYSDEC
6 NYCRR 621	Uniform Procedures	All Media	ARAR	NYSDEC
6 NYCRR 624	Permit Hearing Procedures	All Media	ARAR	NYSDEC
6 NYCRR 650	Qualifications of Operators of Wastewater Treatment Plants	NA	ARAR	NYSDEC
6 NYCRR 700-705	Classifications and Standards of Quality and Purity	Surface Water/ Groundwater	ARAR	NYSDEC
6 NYCRR 750-758	State Pollutant Discharge Elimination System	Surface Water/ Groundwater	ARAR	NYSDEC
Air Guide No. 1	Guideline for the Control of Toxic Ambient Air Contaminants	Air	TBC	NYSDEC

Table 1-3 (continued)

POTENTIALLY APPLICABLE ACTION SPECIFIC ARARs/TBCs
FARRAND CONTROLS SITE

Citation/ Reference	Title	Applicable Media	Potential ARAR/TBC	Regulatory Agency
Air Guide No. 29	Technical Guidance for Regulating and Permitting Air Emissions from Air Strippers, Soil Vapor Extraction Systems and Cold-Mix Asphalt Units	Air	TBC	NYSDEC
Air Guide No. 41	Permitting for Landfill Gas Energy Recovery	Air	TBC	NYSDEC
TAGM HWR-4030	Selection of Remedial Actions at Inactive Hazardous Waste Disposal Sites	Hazardous Waste	TBC	NYSDEC
TAGM HWR-4031	Fugitive Dust Suppression and Particulate Monitoring Programs at Inactive Hazardous Waste Sites	Air	TBC	NYSDEC
TAGM HWR-4046	Determination of Soil Cleanup Objectives and Cleanup Levels	Soil	TBC	NYSDEC
N/A	Analytical Services Protocol	All Media	TBC	NYSDEC
TOGS 1.3.1	Waste Assimilative Capacity Analysis & Allocation for Setting Water Quality Based Effluent Limits	Wastewater Discharge	TBC	NYSDEC
TOGS 1.3.1C	Development of Water Quality Based Effluent Limits for Metals Amendment	Wastewater Discharge	TBC	NYSDEC
TOGS 1.3.4	BPJ Methodologies	Wastewater Discharge	TBC	NYSDEC
TOGS 2.1.2	UIR at Groundwater Remediation Sites	Groundwater	TBC	NYSDEC
TOGS 2.1.3	Primary & Principal Aquifer Determinations	Groundwater	TBC	NYSDEC
29 CFR 1910.120	Hazardous Waste Operations and Emergency Response	NA	ARAR	USDOL
40 CFR 122	EPA Administered Permit Programs: The National Pollutant Discharge Elimination System	Wastewater Discharge	ARAR	USEPA

investigation, the exposure routes and potential receptors as determined by the baseline risk assessment, and the acceptable contaminant or risk levels or range of levels.

In the initial phase of the feasibility study, identified remedial technologies which are not technically applicable to contamination found, or are unproven and/or are not commercially available, will be eliminated from further consideration. The technologies remaining after initial screening will be assembled into remedial alternatives for evaluation. Preliminary evaluation of alternatives will consider effectiveness, implementability and relative costs.

Effectiveness evaluation includes consideration of the following:

- The potential effectiveness of process options in handling the estimated areas or volumes of contaminated media, and meeting the remediation goals identified by the remedial action objectives;

- The potential impacts to human health and the environment during the construction and implementation phase; and

- The proven effectiveness and reliability of the process with respect to the contaminants and conditions at the site.

Implementability includes both the technical and administrative feasibility of utilizing the technology or alternative. Administrative feasibility considers institutional factors, such as the ability to obtain necessary permits for on-site or off-site actions, and the ability to restrict land use based on specific remediation measures. Technical feasibility considers such aspects as the ability to comply with SCGs, availability and capacity of treatment, storage and disposal facilities, the availability of equipment and skilled labor to implement the technology, the ability to design, construct and operate the alternative, and acceptability to the regulatory agencies and the public.

Preliminary costs are considered at this stage of the feasibility study process for the purpose of relative cost comparison among the alternatives.

The results of the preliminary evaluation includes potentially viable technologies or combinations of technologies/alternatives for the site which will be carried forward for detailed evaluation.

The guidance requires that a feasibility study provide a detailed analysis of the potential remedial alternatives based on consideration of the following evaluation criteria for each alternative.

- Threshold Criteria
  - Compliance with standards, criteria and guidelines/ARARs
  - Protection of human health and the environment
- Balancing Criteria
  - Short-term impacts and effectiveness
  - Long-term effectiveness and permanence
  - Reduction in toxicity, mobility and/or volume of contamination
  - Implementability
  - Cost

In addition to the above listed Threshold and Balancing Criteria, the guidance also provides the following modifying criteria:

- Modifying criteria
  - Regulatory agency acceptance
  - Community acceptance

Provided below is a description of each of the feasibility study criteria.

Compliance with applicable regulatory standards, criteria and guidelines applies the federal and New York State ARARs/SCGs identified for the Farrand Controls Site to provide both action-specific guidelines for remedial work at the site and contaminant-specific cleanup standards for the alternatives under evaluation. In addition to action-specific and contaminant-specific guidelines, there are also location-specific guidelines that pertain to such issues as restrictions on actions at historic sites.

Protection of human health and the environment is evaluated on the basis of estimated reductions in both human and environmental exposure to contaminants for each remedial action alternative. The evaluation focuses on whether a specific alternative achieves adequate protection, and how site risks are eliminated, reduced or controlled through treatment, engineering or institutional controls. An integral part of this evaluation is an assessment of long-term residual risks to be expected after remediation has been completed. Evaluation of the human health and environmental protection factor is generally based, in part, on the findings of a risk assessment. The risk assessment performed for this site incorporates the qualitative estimation of the risk posed by carcinogenic and noncarcinogenic contaminants detected during the remedial investigation.

Evaluation of short-term impacts and effectiveness of each alternative examines health and environmental risks likely to exist during the implementation of a particular remedial action. Principal factors for consideration include the expediency with which a particular alternative can be completed, potential impacts on the nearby community and on-site workers, and mitigation measures for short-term risks required by a given alternative during the necessary implementation period.

Examination of long-term impacts and effectiveness for each alternative requires an estimation of the degree of permanence afforded by each alternative. To this end, the anticipated service life of each alternative must be estimated, together with the estimated quantity and characterization of residual contamination remaining on-site at the end of this service life. The magnitude of residual risks must also be considered in terms of the amount and concentrations of contaminants remaining following implementation of a remedial action, considering the persistence, toxicity and mobility of these contaminants, and their propensity to bioaccumulate.

Reduction in toxicity, mobility and volume of contaminants is evaluated on the basis of the estimated quantity of contamination treated or destroyed, together with the estimated quantity of waste materials produced by the treatment process itself. Furthermore, this evaluation considers whether a particular alternative will achieve the irreversible destruction of contaminants, treatment of the contaminants or merely removal of contaminants for disposal elsewhere.

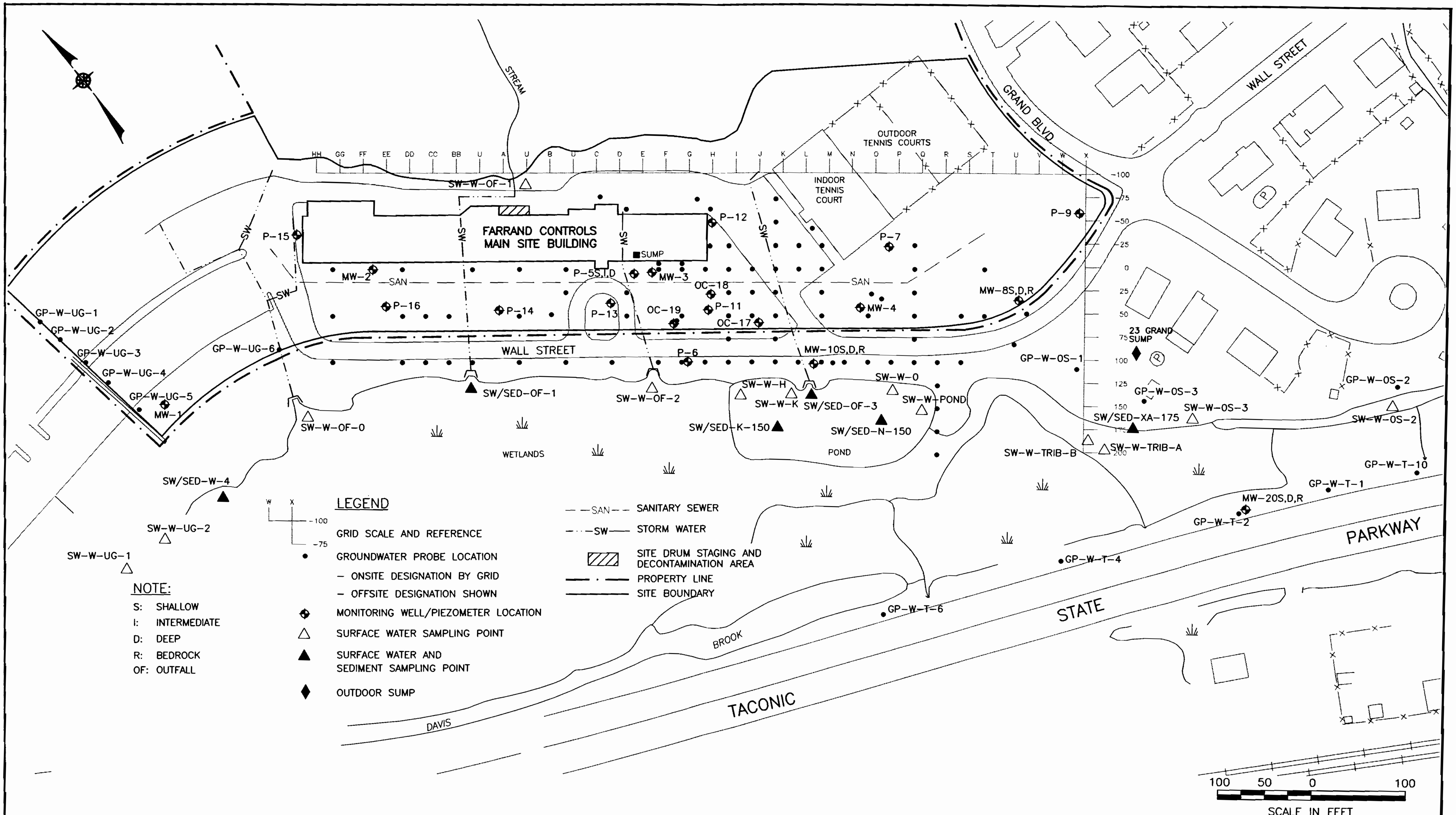
Evaluation of implementability examines the difficulty associated with the installation and/or operation of each alternative on-site and the proven or perceived reliability with which an alternative can achieve system performance goals (primarily the SCGs discussed above). The evaluation examines the potential need for future remedial action, the level of oversight required by regulatory agencies, the availability of certain technology resources required by each alternative and community acceptance of the alternative.

Cost evaluations presented in this document estimate the capital, and operation and maintenance (O&M) costs, including monitoring, associated with each remedial action alternative. From these estimates, a total present worth for each option is determined.

Regulatory agency and community acceptance evaluates the technical and administrative issues and concerns which the agencies or the community may have regarding each of the alternatives.

1.6 Approach to Feasibility Study

In this feasibility study, technologies are organized, identified and screened by media. Results of the remedial investigation indicate that groundwater located in the overburden and highly fractured bedrock is significantly contaminated on-site and is migrating off-site, impacting surface waters. Groundwater contamination in the overburden and highly fractured bedrock primarily poses a threat to the environment, as well as a potential threat to human health, and as a result, remediation of groundwater will be the focus of evaluation in this evaluated as part of the feasibility study. Due to limited information obtained on the extent of contamination in the bedrock aquifer, technologies for remediation of groundwater in competent bedrock will not be evaluated. Although no significant soil contamination has been detected on-site, the elevated levels of groundwater detected on-site indicate the potential presence of a continuing source of groundwater contamination in the vadose zone. If a source area is located during subsequent investigation at the site, remediation of this soil would be necessary to mitigate future impacts to groundwater. Therefore, soil remediation technologies that are applicable to the contaminants of concern for the site are also identified and screened as part of this feasibility study, and can be used as a basis for future soil remediation at the site, if necessary.



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FARRAND CONTROLS SITE
REMEDIAL INVESTIGATION/FEASIBLITY STUDY

GROUNDWATER, SURFACE WATER AND SEDIMENT SAMPLING LOCATIONS

FIGURE 1-3

Dvirka and Bartilucci
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Section 2

2.0 IDENTIFICATION AND SCREENING OF REMEDIAL TECHNOLOGIES

2.1 Introduction

In general, response actions which satisfy remedial objectives for a site include institutional, isolation, containment, removal or treatment actions. In addition, United States Environmental Protection Agency guidance under the Comprehensive Emergency Response, Compensation and Liability Act requires the evaluation and comparison of a no-action alternative to the action alternatives. Each response action for each medium of interest must satisfy the remedial action objectives for the site or the specific area of concern. Technologies and process options, which are available commercially and have been demonstrated successfully, are identified in this feasibility study along with selected emerging technologies. The screening of process options or technology types is performed by evaluating the ability of each technology to meet specific remedial action objectives, technical implementability, and short-term and long-term effectiveness. A discussion of selected response actions and their applicability to the Farrand Controls Site is provided below. Preliminary evaluation/screening of the response action and remedial technologies will be based on technical effectiveness as it relates to the specific physical and chemical characteristics of the site. However, where appropriate, consideration will also be given to implementability and cost.

2.2 No Action

The no-action alternative will be considered, and as described above, will serve as a baseline to compare and evaluate the effectiveness of other actions. Under the no-action scenario, limited remedial response actions may be considered, including monitoring. Monitoring would consist of periodic groundwater and surface water sampling to evaluate changes over time in conditions at the site, and to ascertain the level of any natural attenuation which may occur or any increase in contamination which may necessitate further remedial action. Natural attenuation (under the no action alternative), as opposed to active remediation, relies on naturally occurring physical, chemical and biological processes (dilution, dispersion and degradation) to reduce contaminant concentrations.

2.3 Institutional Controls

Institutional controls may include site access restrictions, resource restrictions, and deed restrictions. Access restrictions, such as eliminating access to the surface waters by fencing and posting of signs warning the public of the presence of contamination, are considered potentially applicable to the Farrand Controls Site. Since no significant surface or subsurface soil contamination has been detected on-site, limiting access to the site itself is not potentially applicable or necessary. Deed restrictions could be imposed to limit uses of and activities at the site. Current zoning for industrial use is an institutional control to limit site use and activities. Deed restrictions, in addition to zoning, which prohibit/restrict future use and development of the site, would also be a potentially applicable alternative for the site.

Other potentially applicable institutional controls could include groundwater use restrictions to ensure that groundwater is not utilized for potable, irrigation or industrial uses. Restrictions could also include restriction of the use of the surface water and wetlands for recreational purposes.

2.4 Groundwater Remediation Technologies

Treatment, collection and containment technologies, which could be applicable to remediation of groundwater contaminated with volatile organic compounds, such as those found at the Farrand Controls Site, are identified and evaluated below.

2.4.1 Extraction and Treatment

Extraction and treatment, or "pump and treat" technologies, are widely used for groundwater remediation and/or containment. Provided below is a description and discussion of extraction and ex-situ treatment technologies.

2.4.1.1 - Extraction Technologies

Extraction is a remedial technology generally used in combination with treatment technologies to control and remove contaminants in groundwater. Two extraction technologies, pumping wells and interceptor trenches, are described below.

2.4.1.1.1 - Wells

Technology Description: The use of wells to pump contaminated groundwater to the surface for treatment is widely used as a remedial technology. With this technology, contaminated groundwater can be extracted for on-site or off-site treatment and disposal. Groundwater modeling and/or pump rests are generally utilized to determine optimal pumping rates and well locations.

Initial Screening Results: Extraction wells represent a potentially viable technology for remediation of groundwater at the Farrand Controls Site. Therefore, this technology will be retained for further evaluation.

2.4.1.1.2 - Interceptor Trenches

Technology Description: As opposed to wells, which can extract shallow and deep contaminated groundwater, interceptor trenches have been successfully used to extract groundwater in situations where the depth to groundwater is shallow, contamination is limited to the upper portion of the aquifer, and soils can be excavated without causing structural damage and interfering with underground utilities.

Initial Screening Results: Although depth to groundwater at the Farrand Controls Site is shallow (less than 10 feet), the depth of the groundwater contamination in the overburden extends to bedrock. Depth to bedrock/refusal ranges between approximately 15 feet below ground surface in the vicinity of the building to 60 feet below ground surface near the pond and wetlands. Therefore, since groundwater contamination is not limited to the upper portion of the aquifer, construction of deep interceptor trenches for groundwater remediation would be difficult and would not be as effective as extraction wells. Therefore, this technology will not be considered further.

2.4.1.2 – Ex-Situ Treatment Technologies

Once extracted, contaminated groundwater must be treated to meet discharge standards. As discussed in Section 1.0, groundwater at the Farrand Controls Site has been defined as being contaminated with significantly elevated levels of volatile organic compounds (VOCs), including trichloroethene and its breakdown products cis-1,2-dichloroethene, trans-1,2-dichloroethene and vinyl chloride; 1,1,1-trichloroethane and its breakdown products dichloroethane and chloroethane; and Freon 113. The levels of contamination detected indicate the likely presence of dense non-aqueous phase liquids in the subsurface overlying the bedrock.

In addition to the VOCs, three metals, iron, manganese and sodium, exceed groundwater standards in numerous samples collected. Groundwater treatment for metals may be required prior to removal of the VOCs in order to reduce operational difficulties, such as precipitation of iron and/or formation of iron bacteria during treatment which would clog the stripping media. In addition, metals may also require treatment in order to meet discharge requirements. Treatment technologies discussed in the following sections include biological, chemical and physical processes. Many of these technologies can be combined to form an overall treatment system for groundwater.

2.4.1.2.1 - Air Stripping

Technology Description: Air stripping involves a process by which volatile organic compounds are partitioned from groundwater by greatly increasing the surface area of the contaminated water exposed to air. Types of aeration methods include packed towers, diffused aeration, tray aeration and spray aeration. Air stripping is a widely used, proven and commercially available technology.

The applicability and effectiveness of air stripping depends on the potential for inorganic or biological fouling of the equipment. Clogging of the stripping column packing material due to inorganics in the groundwater (especially dissolved ferrous iron, which precipitates out as insoluble ferrous hydroxide species upon aeration) and biofouling (iron bacteria) are common problems if not taken into consideration during design. In addition, the Henry's Law constant of the organic compounds in the water stream will determine the effectiveness of air stripping.

Initial Screening Results: Air stripping represents a potentially viable technology for treatment of extracted groundwater at the Farrand Controls Site. As discussed above, air stripping is applicable to the treatment of VOCs and could be utilized as part of an overall treatment system for the site. Therefore, this technology will be retained for further evaluation.

2.4.1.2.2 - Carbon Adsorption (Liquid Phase)

Technology Description: Carbon adsorption involves a process by which groundwater is pumped through a series of canisters containing granular activated carbon to which dissolved contaminants adsorb. The technology requires periodic replacement or regeneration of saturated carbon. Carbon adsorption (liquid phase) is a widely used, proven and commercially available technology. The applicability and effectiveness of carbon adsorption may be limited by the presence of certain compounds which can foul the system, high contaminant concentration levels and the physical properties of the contaminants, among other factors.

Initial Screening Results: This technology has been very effective in the removal of VOCs from contaminated groundwater which are associated with the Farrand Controls Site. Therefore, this technology will be retained for further evaluation as part of an overall treatment system for the site.

2.4.1.2.3 - Oxidation

Technology Description: Ultraviolet (UV) radiation, ozone and/or hydrogen peroxide may be used to destroy contaminants as groundwater flows into a treatment tank. An ozone destruction unit is used to treat off-gas from the treatment tank. UV oxidation is a commercially available technology which is effective in the treatment of volatile organic compounds.

Initial Screening Results: Oxidation is a potentially viable technology for treatment of extracted groundwater at the Farrand Controls Site. Therefore, this technology will be retained for further evaluation.

2.4.1.2.4 – Biological Treatment

Technology Description: Typically, this technology involves the introduction of groundwater into biological treatment units where enzymes and microorganisms decompose organic contaminants into carbon dioxide, water and nonhazardous by-products. Supplemental nutrients may be added to assist the biological process. Biological treatment occurs at the rate of decomposition, which may be low. Biodegradation may also be accomplished in situ through the same biological processes.

Initial Screening Results: Biological treatment is generally less effective than available alternative technologies for chlorinated organic contaminants which are present in the groundwater at the Farrand Controls Site. Therefore, this technology will not be considered further.

2.4.1.2.5 - Reverse Osmosis

Technology Description: Osmosis is a process which occurs when two solutions of different solute concentrations 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 to 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% of the feed volume. This concentrated waste will require additional treatment.

Reverse osmosis has been demonstrated to be effective for treatment of brackish waters, aqueous inorganic wastes and radionuclides, and recent findings indicate that it is useful in removing some specific organic compounds 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.

Initial Screening Results: Since more effective and proven methods for treatment of volatile organic contaminants are readily available such as air stripping and carbon adsorption and large volumes of reject water would be generated using this technology, reverse osmosis will not be considered further.

2.4.1.2.6 - Filtration

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

Initial Screening Results: Filtration is used to remove suspended solids and colloidal particles as part of a water treatment process. Therefore, this process will be retained for further consideration as part of an overall treatment system, in particular for iron removal.

2.4.1.2.7 - Ion Exchange

Technology Description: Ion exchange is a process in which ions are removed from solution by exchange with non-toxic ions supplied by the ion exchange material. Inorganic compounds can be removed by this process. Generally, a train of resin beds in series containing different resins for cation and anion removal are used. The beds must 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.

Initial Screening Results: The ion exchange process may be suitable for the removal of inorganic compounds from extracted groundwater as part of an overall water treatment system. Therefore, this technology will be retained for further consideration.

2.4.1.2.8 - Chemical Precipitation and Clarification

Technology 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. This is generally achieved by adding a chemical that reacts directly with the contaminant to form an insoluble settleable 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 can be adjusted to optimize the precipitation process. 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.

Initial Screening Results: Chemical precipitation may be utilized for the removal of inorganics as part of an overall groundwater treatment system. Therefore, this technology will be retained for further consideration.

2.4.1.3 - Discharge Options

Groundwater extraction and treatment systems will generate a treated wastewater discharge requiring proper management and disposal. Several discharge options are identified below. In addition, many of the treatment processes produce residuals that will require proper disposal.

2.4.1.3.1 - Publicly Owned Treatment Works

Technology Description: Under this option, treated, pretreated and/or untreated discharge would be routed to the Westchester County sanitary sewer system. The effluent would have to meet the County's discharge requirements.

Initial Screening Results: Although discharge to the sewer system represents a potentially viable option for disposal of treated groundwater, preliminary conversations with Westchester County Department of Environmental Facilities, indicate it would not be able to accept wastewater at discharge rates greater than 15 gallons per minute (gpm). Since it is likely that higher volumes of groundwater will need to be extracted to meet remediation goals, this option does not appear to be feasible. Therefore, this technology will not be retained for further evaluation.

2.4.1.3.2 - Surface Water

Technology Description: Discharge to surface water would entail meeting the substantive requirements of a State Pollution Discharge Elimination System (SPDES) permit, which would require treatment to standards for discharge to the wetland/pond complex, along with routine monitoring of the discharge. Construction of a piping system would be required to convey the treated discharge to the receiving surface water.

Initial Screening: Discharge to the nearby surface water represents a potentially viable option for disposal of treated groundwater assuming all of the requirements of a SPDES permit can be met. Therefore, this technology will be retained for further evaluation.

2.4.1.3.3 - On-Site Recharge/Reinjection

Technology Description: Recharge/reinjection options include discharge of treated groundwater to a recharge basin, injection wells or leaching pool(s). Again, the substantive requirements of a SPDES permit would need to be met. This option, if implemented on or near the site would have to be evaluated with respect to potential impacts on the groundwater extraction strategy being implemented.

Initial Screening: Recharge of large volumes of water on-site may complicate an already complex on-site groundwater flow system as defined by the remedial investigation. Potential changes in the groundwater flow regime would therefore complicate groundwater extraction design. Although on-site soils in the overburden appear to be applicable to on-site recharge/reinjection, the availability of discharge to the surface water makes this alternative less desirable. Therefore, this discharge technology will not be considered further.

2.4.2 In-Situ Treatment

In-situ treatment technologies for remediation of groundwater involve both proven and "emerging" techniques as described below.

2.4.2.1 - Air Sparging

Technology Description: Air sparging involves injecting air through wells into a saturated matrix to create an underground VOC stripping mechanism that removes contaminants through volatilization. It is a widely used, proven and commercially available technology for the treatment of VOCs. The technology is designed to operate at sufficient air flow rates in order to effect volatilization. At lower air flow rates the system is used to increase groundwater oxygen concentrations to stimulate biodegradation. Generally, air sparging must operate in conjunction with a soil vapor extraction (SVE) system that captures volatile contaminants in the unsaturated zone as they are stripped from the saturated zone. Air extracted from the SVE wells are treated aboveground and released to the atmosphere.

Air stripping wells must be appropriately placed to overlap the radius of influence for each well and effectively remediate the contaminated zone. Well screens are typically placed 5 feet below the contamination in order to ensure treatment through the contamination zone. For the deep overburden contamination, placement of the well screens below the contamination is not likely possible due to the presence of contamination immediately overlying the bedrock/refusal surface. Sparging and collection of vapors from the deeper overburden contamination (up to 60 feet) may be difficult. Low permeability soils may not allow adequate airflow. The majority of the overburden at the site is defined as sand, sand with gravel or sand and silty sand, which would likely be applicable to air sparging. Air sparging would likely not be effective for remediation of VOCs in the bedrock aquifer at this site. Since the depth to groundwater at the site is relatively shallow (less than 10 feet), difficulties with the collection of the sparged air may be encountered. Collection and then separation and treatment of water entrained in the vapor extraction system may be necessary. Air sparging is a widely used, proven and commercially available technology for the treatment of VOCs.

Initial Screening Results: Although this technology would not be applicable to remediation of contamination in the deep groundwater overlying bedrock up to approximately 60 feet below the water table, it may be potentially applicable to remediation of the shallow contamination. Therefore, this technology will be retained for further consideration.

2.4.2.2 - In-Well Air Stripping

Technology Description: In-well air stripping is a process by which air is injected into a well, lifting contaminated groundwater in the well and allowing additional groundwater flow into the well. Once inside the well, the volatile organic compounds in the contaminated groundwater are transferred from the water to air bubbles which rise and are collected at the top of the well by vapor extraction. Extracted vapors are collected in a vacuum system and treated aboveground (i.e., carbon adsorption) and released to the atmosphere. The partially treated groundwater is not brought to the surface, but rather, it is forced into the saturated or unsaturated zone, and the process is repeated. As groundwater circulates through the treatment system in-situ, contaminant concentrations are reduced. The flow rate and well spacing may be varied in order to achieve the desired radius of influence and capture zone.

In-well air stripping is typically not applicable to remediation of contamination in bedrock. However, it has been completed at sites where the geology of the rock permits appropriate recirculation of the groundwater. Detailed characterization of the geology/hydrogeology of the site is required to ensure the wells in both overburden or bedrock provide appropriate groundwater recirculation.

In-well air stripping has been combined with an extraction system within the recirculation well, which would allow for extraction of water from the bedrock and discharge of the water (once treated within the well) into the overburden. Again, in order to ensure that the water being pulled into the bedrock by the pumping system is being captured, a detailed understanding of the geology/hydrogeology would be required.

Impacts potentially impacting the effectiveness of in-well air stripping include subsurface anomalies, such as low permeability units and subsurface utilities, which could short circuit the system. As discussed with ex-situ air stripping, elevated levels of metals, such as levels of iron greater than 0.5 ppm, could cause problems with clogging of the well screens. Acid injection into the well may be required to control precipitation of the metals. In-well air stripping is an emerging technology, however there are several vendors currently implementing these systems, and therefore, it is a commercially available system.

Initial Screening Results: Although there is concern regarding clogging of the screens with iron and iron bacteria, as well as adequate treatment utilizing groundwater recirculation, in-well air stripping represents a potentially viable technology for removal of volatile organic compounds in the overburden aquifer without any aboveground water discharge. The applicability of in-well air stripping to the contamination in the highly fractured bedrock aquifer is questionable due to the limited information available on the extent of contamination in this zone as well as the geology/hydrogeology of this zone, and therefore, would require additional investigation to evaluate its applicability to the site. However, since it is a potentially viable technology for the overburden groundwater contamination, this technology will be retained for further consideration.

2.4.2.3 - Bioremediation

Technology Description: Anaerobic biodegradation is typically used to degrade chlorinated solvents. Aerobic bioremediation can be used to complete biodegradation of the partially dechlorinated compounds. Aerobic bioremediation can also be combined with oxygen enhancement, which can be performed using various methods. One method involves injecting air under pressure below the water table to increase groundwater oxygen concentrations and enhance the rate of biological degradation of organic contaminants by naturally occurring microbes. The injection of air also increases mixing in the saturated zone, which increases the contact between groundwater and soil. The ease and low cost of installing small-diameter air injection points allows considerable flexibility in the design and construction of a remediation system. A second method involves the use of a dilute solution of hydrogen peroxide which is circulated throughout a contaminated groundwater zone to increase the oxygen content of groundwater and enhance the rate of aerobic degradation of organic contaminants by naturally occurring microbes.

However, utilizing solely aerobic bioremediation, contaminants may be degraded to intermediate or more hazardous contaminants than the original, parent compounds. For example, TCE biodegrades to the persistent and more toxic vinyl-chloride. The use of cometabolism, in which the presence of another alkane (i.e., methane) microorganisms can produce enzyme that can initiate the oxidation of a variety of compounds including chlorinated compounds, is more appropriate for the compounds of concern at this site.

For best results, factors that must be considered for bioremediation include redox conditions, saturation rates, presence of nutrient trace elements, pH, temperature and permeability of the subsurface materials. If nutrients such as nitrogen and phosphorous are not present in sufficient amount, they can be added to the subsurface. Similar to the other in-situ remedial technologies discussed above, subsurface anomalies, such as low permeability zones and utilities, can impact the effective distribution of oxygen in the subsurface.

Bioremediation is a full-scale commercially available technology. However, the applicability and effectiveness of the process may be limited by the potential for migration of vapors through the vadose zone and release into the atmosphere or subsurface structures. Also limited information is available on the effectiveness of bioremediation on Freon 113.

Initial Screening Results: Due to the potential problems with degradation of the chlorinated compounds to more toxic compounds and the limited demonstrated effectiveness of use of other alkanes to enhance cometabolization and limited information regarding effectiveness to freon, this technology will not be retained for further consideration.

2.4.2.4 - Dual Phase Extraction

Technology Description: Dual phase extraction involves applying a high vacuum system to simultaneously remove liquid (groundwater) and gas (volatile vapors) from low permeability or heterogeneous formations. The vacuum extraction well includes a screened section in the zone of contaminated soils and groundwater. As a vacuum is applied to the well, soil vapor is extracted and groundwater is entrained by the extracted vapors. Groundwater recovery is enchanced through the increased pressure gradient. Groundwater can also be recovered by pumping at or below the water table. Once above ground surface the extracted vapors and groundwater are separated and treated through technologies described in Section 2.4.1.

Dual phase extraction is applicable to the treatment of the VOCs detected at the site. However, it would require significant treatment equipment since it would be treating both extracted vapor and groundwater. Vacuum lift limitations are approximately 30 feet, therefore, in order to reach contaminated groundwater deeper than 30 feet, submersible pumps would be required. Dual phase extraction is a full-scale commercially available technology.

Initial Screening Results: This technology may be applicable to the groundwater and soil contamination located near a source area. It is most applicable to shallow groundwater contamination in low permeability zones. Therefore, because a soil source area has not been defined at this time, the depth of groundwater contamination in the overburden is significant (up to 60 feet) and availability of more effective in-situ treatment processes (e.g., extraction and treatment in-well air stripping), this technology will not be considered further.

2.4.2.5 – Chemical Oxidation

Technology Description: Chemical oxidation involves the use of an oxidant to treat or destroy organic contaminants in groundwater. Various types of oxidants that have been used include hydrogen peroxide, permanganate and ozone. The following provides a brief description of each oxidant and its use.

Hydrogen peroxide typically is used in conjunction with ferrous iron to produce hydroxyl radicals which can break the carbon-hydrogen bonds of organic molecules allowing this reaction to degrade chlorinated solvents, polyaromatic hydrocarbons and petroleum products. Since it is a destruction process, there is no potential for intermediate chlorinated, potentially more toxic compounds to be produced as in the bioremediation/oxygen enhancement process discussed in Section 2.4.2.3. Some of the disadvantages of the use of hydrogen peroxide is the hazardous nature of handling hydrogen peroxide, the potential for reduction of permeability of the soil due to formation of particulates during the reaction and difficulties with delivery of the hydrogen peroxide to the contaminated zone, since it can easily breakdown to water vapor and oxygen. The reaction is typically exothermic and can cause the mobilization of NAPL to the dissolved state in groundwater and the release of off-gases. The use of various catalysts and mobility control agents has been shown to better control the increase in temperature and mobility of contaminants.

Potassium permanganate can react with organic compounds to produce manganese dioxide and either carbon dioxide or intermediate organic compounds. Permanganate has been shown to oxidize organic compounds, such as alkenes, aromatics, polycyclic aromatic hydrocarbons (PAHs) phenols, pesticides and organic acids. Permanganate is more stable than hydrogen peroxide and is easier to handle, however, there is a potential for permeability reduction due to the formation of particulates during the reaction.

Ozone is a very strong oxidant, reacts quickly in the subsurface and is difficult to deliver to the contaminated zone. Ozone must be generated on-site and can be used in a process similar to air sparging where it is injected in to the groundwater via wells. It has been shown to effectively treat chlorinated solvents, PAHs and petroleum products.

A primary concern with the use of strong oxidants is the corrosive and potentially explosive characteristics of the oxidant. Design and operation of the chemical oxidation system must take into account the potential hazards of the chemicals used to ensure protection of health and safety of on-site personnel.

Several vendors are currently utilizing various forms of the above processes to treat contaminated groundwater. Chemical oxidation has also been utilized to treat contaminated groundwater in bedrock aquifers. Although developing as a technology, it has full-scale application and is commercially available.

Factors associated with the effective implementation of this process include detailed understanding of the nature and extent of contamination in order to effectively place the chemical oxidant. Subsurface anomalies, such as underground utilities, can potentially short circuit the system if not adequately considered. The oxidants are also non-selective to both organic contaminants and natural organic matter. The presence of high natural organic matter content in the soils could consume a large portion of the oxidants making treatment less economically feasible. Effective treatment of contaminated groundwater in bedrock requires detailed understanding of zones or fractures that are transporting the contamination in order for the oxidant can be appropriately injected. Mounding of the groundwater resulting from the injection of the oxidants is also a potential limitation. Demonstration of the effectiveness of this technology at the Farrand Controls Site would likely require a pilot study.

Initial Screening Results: Due to its potential ability to treat the contaminants of concern at the Farrand Controls Site and its potential applicability to groundwater contamination in the highly fractured bedrock and limited disruption to the surface, this technology will be considered further.

However, since this is still a developing technology it would likely require both bench and pilot scale testing prior to final determination of its applicability to the site.

2.4.2.6 - Reactive Walls

Technology Description: The use of reactive walls involves installing a permeable reaction wall across the flow path of a contaminant plume, allowing the plume to passively move through the wall. Typically, the contaminants are degraded by reactions with a mixture of porous media and a metal catalyst. The use of passive treatment walls is an emerging technology which is applicable only in relatively shallow aquifers, because a trench must be constructed down to the level of the bedrock or a low permeability geologic unit in order to effectively install the reactive wall. In addition, passive treatment walls are often only effective for a short time because they lose their reactive capacity, requiring replacement of the reactive medium.

Initial Screening Results: Due to potential difficulties with construction of a trench to bedrock approximately 60 feet, effectively tieing the wall into bedrock, disruption at the surface during installation and potential difficulties with short reactive capacity life due to the very high levels of contamination at the site, this technology will not be considered further.

2.4.2.7 - Chemical Reduction

Technology Description: Injection of zero-valent colloidal iron into the subsurface through injection wells is developing as an alternative to installation of a passive treatment wall for the remediation of contaminated groundwater. Iron powder in a liquid slurry form is injected under pressure along with a nitrogen gas stream. When the iron comes in contact with water, hydrogen gas, hydroxyl ions and ferrous iron are formed. The hydrogen gas then combines with the organic compound which is then dehalogenated. End products of the reaction are ferrous iron, chloride ions and the dehalogenated compounds. Injection wells can be installed much deeper than walls and can also, through the use of nano-meter colloids, generate a larger reactive surface area and thus more efficient use of iron. Difficulties with effective injection of the iron to the contaminated areas with low permeability soils, such as silt and clays, can be mitigated through the use of pneumatic fracturing.

Although this process has limited demonstrated effectiveness in bedrock aquifers, it is expected to be as effective in bedrock units as in unconsolidated formations. Factors impacting the effectiveness of the process include appropriate placement of the iron and placement of sufficient amount of iron to react with contaminants of concern, in addition, large quantities of the injected iron can reduce the permeability of the soils and contact with the contaminants. Although it is an emerging technology, it is commercially available.

Initial Screening Results: Due to the potential applicability to the contaminants in the overburden and highly fractured bedrock at the site potential effectiveness for containment and source remediation and the limited disruption to the surface, this technology will be considered further.

2.4.2.8 - Funnel and Gate

Technology Description: Another emerging passive groundwater remediation technology, that is very similar to and incorporates the treatment/reactive wall technology, is the funnel-and-gate system. Like treatment walls, the funnel-and-gate system includes the installation of a permeable wall containing a mixture of porous media and treatment media which degrade the contaminants in groundwater and allow the treated water to passively move through the wall. The primary difference between the two technologies is that the funnel-and-gate system includes the installation of low permeability or impermeable cut-off walls (or "funnels"), such as slurry or sheet pile walls, in the path of the contaminated groundwater or plume which direct or "funnel" the contaminated groundwater to a treatment/reactive wall (or "gate"). The "gate" passes the contaminated groundwater through the treatment wall, which then remediates the groundwater.

Advantages, disadvantages and limitations of the funnel-and-gate technology are similar to those of treatment walls. However, slurry walls, sheet piling and other materials that are used to form the funnel having a greater impact on altering groundwater flow than on the continuous treatment wall. For both technologies, it is necessary to keep the reactive zone permeability equal to or greater than the permeability of the aquifer to avoid mounding of water behind the wall, and diversion of flow under and around the wall or flowing around the ends. Accurately modeling the hydraulic characteristics of the aquifer to appropriately design the funnel and gate system to avoid the problems described above is often difficult.

Initial Screening Results: Similar to passive treatment walls, the funnel and gate system would be difficult to install to the depth of bedrock and tie into bedrock, be disruptive to the surface and may have limited reactive life. Therefore, this technology will not be considered further.

2.4.2.9 - Phytoremediation

Technology Description: Phytoremediation is a developing technology in which vegetation is used to remediate contaminants in groundwater. The process involves the use of vegetation to remove contaminants from the groundwater and convert the contaminants to less toxic metabolites. In addition, the vegetation allows for the transfer of oxygen to the root zone for the enhancement of aerobic degradation of organic contaminants. Through the increase of organic carbon in the shallow root zone, the migration of organic chemicals and metals is reduced. Therefore, even if the vegetation cannot remove the contaminants, the vegetation/root system may mitigate the movement of the contaminants.

Phytoremediation is particularly applicable to sites with low concentrations of contaminants or sites where it can be utilized in conjunction with other remedial technologies and contamination is shallow. Potential problems with phytoremediation include long remediation time, potential contamination of the vegetation and food chain, and difficulty with establishing and maintaining the vegetation. Since it is a developing technology, long-term monitoring and evaluation of this technology is still needed. Significant research has been completed using hybrid poplar trees. These trees are extremely fast growing and appear to tolerate high concentrations of organic chemicals. The rooting system of these trees are to a depth of 6 to 8 feet below ground surface.

Initial Screening Results: Since the depth of contaminated groundwater in the overburden aquifer ranges up to 60 feet on-site, phytoremediation is not an applicable technology and will not be considered further.

2.4.2.10 - Natural Attenuation

Technology Description: Natural attenuation is an alternative whereby natural processes, such as dilution, dispersion, volatilization, biodegradation, adsorption and chemical reactions with subsurface materials, are allowed to reduce contaminant concentrations to acceptable levels. Consideration of this option requires evaluation of contaminant degradation rates to determine the feasibility and special regulatory approvals may be needed. In addition, groundwater sampling and analysis must be conducted throughout the process to confirm that attenuation is proceeding at a rate consistent with meeting cleanup objectives and that any potential receptors will not be impacted. Several disadvantages of natural attenuation include: intermediate degradation products may be more mobile and more toxic than the original contaminant; it should be considered only where there are no potential impacts on receptors; contaminants may migrate before they are degraded; regulatory agency acceptability is generally not favorable; and community acceptability is generally poor, in particular, where it is the only remediation measure proposed.

Initial Screening Results: Data collected during the remedial investigation did not indicate that natural attenuation is significantly occurring at the Farrand Controls Site. Therefore, this alternative, in and of itself, will not be retained for further consideration. However, it may be considered in combination with other technologies, such as for the remediation of residual contamination after physical, chemical or biological treatment.

2.4.3 Containment Barriers

Containment barriers include subsurface structures such as vertically excavated trenches that are filled with a slurry or grout, sheet pile walls and adaptations of sheet pile walls with interlocking sealable joints. The following describes some of the different types of barriers that could be considered for the site.

2.4.3.1 - Slurry Walls

Technology Description: Slurry walls are typically constructed through excavation of soil to a desired depth, generally into a low permeability material such as clay or bedrock, and placement of a bentonite water slurry to maintain trench stability. Soil-bentonite backfill is placed in the slurry to form the soil-bentonite slurry trench cutoff wall. Cement can also be used in the slurry. Slurry walls can be constructed up to depths of 200 feet, and depending upon the mixture of soil, bentonite and cement walls can have hydraulic conductivities between 10^{-6} to 5×10^{-9} cm/sec. Disadvantages of a slurry wall include the volume of soil generated that would require disposal during installation of the wall and the potential for the wall to degrade or deteriorate over time due to contaminants in the soil or groundwater, or freeze/thaw cycles.

Initial Screening Results: Since containment of the shallow and deep overburden plume through the use of a physical barrier is not necessary for the purposes of remediation and because of the potential difficulties in installation of a barrier to bedrock, this technology will not be considered further.

2.4.3.2 - Sheet Pile Walls

Technology Description: Sheet pile walls are constructed by driving vertical strips of steel, precast concrete, aluminum or wood into the soil forming a subsurface barrier wall. The sheets are assembled before installation and driven or vibrated into the ground a few feet at a time to the desired depth, generally into a low permeability unit. A continuous wall can be constructed by joining the sheets together. The joints between the sheet piles are vulnerable to leakage, and therefore, the hydraulic conductivities are generally higher than slurry walls.

Initial Screening Results: As discussed above, since containment of the shallow and deep groundwater plume is not necessary for remediation, sheet pile walls will not be considered further.

2.4.3.3 - Waterloo Barrier

Technology Description: As noted above, due to the problems with leakage in the joints of sheet pile walls, the Waterloo Barrier was developed in order to address the leakage of the joints. The Waterloo Barrier is designed to have interlocking sealable joints. The sheet piles are driven into the ground and the interlocking joint cavity is flushed to remove soil and debris and a clay based, cementitious, polymer or mechanical sealants are injected into the cavity. The barrier can achieve hydraulic conductivities of less than 10^{-8} cm/sec.

Initial Screening Results: As discussed above, containment of the plume is not necessary, and therefore, this technology will not be considered further.

2.4.3.4 – Freeze Walls

Technology Description: Freeze walls or cryogenic barriers are constructed by artificially freezing soil pore water thereby decreasing the permeability of the soil and forming a low permeability barrier. Once the barrier is no longer needed, the cryogenic system can be turned off allowing the barrier to melt. A cryogenic wall is constructed through the placement of thermoprobes into the ground and circulating a refrigerant through them. Refrigerants such as liquid nitrogen, calcium chloride brine and carbon dioxide can be used. Laboratory tests have shown hydraulic conductivities as low as 4×10^{-10} cm/sec. Cryogenic walls are a developing technology and there is no long-term data available for full-scale wall efficiencies.

Initial Screening Results: Due to the fact that freeze walls are a developing technology, and that containment of the plume is not necessary. This technology will not be considered further.

2.5 Soil Remediation Technologies

As discussed in Section 1.0, significant soil contamination in the vadose zone has not been detected at the Farrand Controls Site. However, the elevated levels of groundwater contamination detected at the site suggest that there likely is a continuing source in soil or in the capillary zones immediately above groundwater. Therefore, the following section identifies technologies that may be applicable to remediation of soil containing elevated levels of volatile organic compounds. Several technologies that are not applicable to the remediation of volatile organic compounds, have not been demonstrated effective on a full-scale level and may not be as effective as the technologies discussed below, were not presented. These technologies include, but are not limited to soil washing, thermal separation, stabilization/solidification and solvent extraction.

2.5.1 Containment/Isolation

Technology Description: Potentially applicable isolation and containment technologies include surface barriers, such as low permeability caps to prevent infiltration of precipitation through contaminated subsurface soils. These technologies are designed to prevent infiltration but do not provide any treatment of the contaminated soil. Various forms of surface barriers currently exist to significantly reduce the infiltration of precipitation into contaminated soil.

Examples of low permeability caps include Part 360 and RCRA caps which are typically used for closure of landfills. These caps are typically 2 to 5 feet thick, respectively and generally preclude utilization of the areas capped. Pavement and building caps are also considered low permeability caps and are typically applicable in commercial/industrial settings.

Initial Screening Results: Due to the active, industrial nature of the site, and the thickness of the RCRA and Part 360 caps, these types of low permeability caps will not be evaluated further. In lieu of these caps, in keeping with the industrial nature of the site, low permeability asphalt or concrete caps will be evaluated further as the most applicable form of containment/isolation for the site. An asphalt or concrete surface would significantly reduce the amount of infiltration through contaminated soil. In addition, it could be implemented as part of site development/improvement, such as construction of buildings and asphalt parking areas. Efforts may need to be undertaken to design appropriate drainage systems to redirect surface runoff that currently infiltrates the site. Pavement cover, which would be about 1-foot in thickness, would not be as thick as the RCRA cap (5 feet) or the Part 360 cap (2 to 3 feet), and the slope could be reduced to 2% to promote runoff.

Maintenance would be required in order to ensure that cracks due to weathering, settlement or traffic are repaired.

Since containment in the form of asphalt/concrete capping would limit infiltration of precipitation and allow for development at the site, this technology will be considered further.

2.5.2 In-Situ Soil Treatment

There are a number of demonstrated/commercially available technologies for the treatment of contaminated soil. Some treatment technologies can be performed in-situ and other technologies require treatment of the soil ex-situ. Ex-situ soil treatment processes would require excavation of the soil prior to treatment. Due to the industrial nature of the site and the limited space available for ex-situ treatment of the soil, and the potential for exposure to on-site workers during remediation, ex-situ treatment of soils will not be considered further, unless the amount of soil requiring removal is not significant. Provided below is a discussion of a number of in-situ soil treatment technologies considered to be potentially applicable to the contaminants of concern for the site.

2.5.2.1 – Chemical Oxidation

Technology Description: Similar to the discussion provided for chemical oxidation for groundwater, chemical oxidation of soils involves the use of an oxidant, such as hydrogen peroxide, permanganate and ozone, to treat or destroy organic contaminants. Several vendors are currently utilizing various forms of these processes to treat contaminated groundwater and soil. Therefore, although developing as a technology, it is a full-scale, commercially available remediation method technology. Factors associated with the effective implementation of this treatment process include detailed understanding of the nature and extent of contamination in order to effectively place the oxidant. Subsurface anomalies, such as underground utilities, can potentially short circuit the system if not adequately addressed.

Initial Screening Results: Chemical oxidation may be effective in reducing the levels of VOCs in the soil to remediation goals. Therefore, this technology will be considered further.

2.5.2.2 - Chemical Reduction

Technology Description: As discussed for the treatment of VOCs in groundwater, chemical reduction is a process which involves the injection of zero-valent colloidal iron into the subsurface through injection wells. The reaction causes reductive dechlorination of the contaminants. The reactive slurry that is injected into the subsurface consists of iron powder, water and nitrogen gas. The gas is used to pressure the slurry for injection and to maintain subsurface anaerobic conditions. Limitations of this technology include appropriate placement of iron and placement of sufficient iron to react with contaminants of concern.

Initial Screening Results: Due to the potential applicability of chemical reduction to the remediation of soil contaminated with VOCs, this technology will be considered further.

2.5.2.3 - Soil Vapor Extraction

Technology Description: Soil vapor extraction is a remediation technology that utilizes a vacuum applied to extraction wells to remove VOCs from contaminated subsurface soil. The vacuum creates a pressure gradient which induces the VOCs to migrate from the soil to the air. Air is extracted from the wells and is treated above ground and released to the atmosphere. Soil vapor extraction systems are best applied at sites where the contamination is in homogeneous, unsaturated soils with a relatively high permeability. The technology is limited to treating soils contaminated with VOCs and some SVOCs. Heterogeneity in the subsurface soils can significantly affect the removal rate and the radius of influence of the system. Where depth to contaminated soil is shallow, placement of a cap over the surface of the site may reduce short circuiting of the process.

High moisture content in the soils would require removal of the moisture prior to treatment of the air. Treatment of the air would include use of technologies such as carbon adsorption or catalytic oxidation. Soil vapor extraction would not require the excavation or handling of contaminated soils, and can be combined with air sparging to remediate contaminated groundwater (see Section 2.4.2.1). The majority of on-site soils are defined as sand to sand and silt. If the contamination is detected in these sandy units, SVE would likely be effective. In addition, the contamination is likely to be detected in the vicinity of the building where the depth to water is shallow, approximately 10 feet. This may cause additional moisture/condensate removal prior to treatment of the air.

Initial Screening Results: Soil vapor extraction may be effective in reducing the levels of VOCs in the soil. Once soil contamination is defined, this technology will be considered further.

2.5.2.4 - Bioventing

Technology Description: Bioventing is a process in which microorganisms degrade organic contaminants. The degradation of the contaminants is accomplished by metabolizing the contaminants and either using them as a source of carbon or energy, or possibly not as a source of nutrients at all. Microorganisms can adapt to degrade synthetic compounds depending upon whether or not the compound is toxic, or whether or not it is in high enough concentration to support microbial growth. Many different methodologies have been utilized to identify applicable microorganisms, including isolation of pure strains from current contaminated situations to utilizing genetic engineering to produce a microorganism capable of degrading a specific compound. Bioventing also comprises the stimulation of indigenous microorganisms. This technology incorporates small-diameter wells connected to a blower or vacuum pump through a piping network. The system can be installed with minimum disturbance to the site.

Bioventing is effective for the treatment of volatile organic compounds such as petroleum hydrocarbons and nonchlorinated solvents. Aerobic biodegration of many chlorinated compounds may not be effective unless there is a co-metabolite present or an anaerobic cycle. Bioventing generally requires the addition of nutrients, oxygen, moisture and possibly the addition of microbes to the soil.

Initial Screening Results: Since bioventing has not been proven effective for the treatment of chlorinated solvents without the use of another alkane to enhance cometabolization, this technology will not be considered further.

2.5.3 Excavation and Removal

Technology Description: Excavation and removal would require excavation of contaminated soil and transportation to an approved/permitted secure landfill or incinerator. In addition, excavation may require construction of structural supports, such as sheeting to protect buildings, and vapor and particulate emission controls may also be required. Clean soil would be required to backfill the excavated area. Excavation of soil adjacent to a building would require support of the foundation and walls.

Initial Screening Results: Since removal of the contaminated soil would substantially reduce the potential for exposure to contaminated soil and release of contaminants to groundwater, this technology will be considered further.

A summary of the identification and screening of the soil and groundwater technologies discussed above is presented in Tables 2-1 and 2-2.

2.6 Summary Evaluation of Remedial Technologies

Based on the screening of remedial technologies, provided below is summary of the technologies that are retained for further consideration, either as remedial alternatives in and of themselves, or in combination with other technologies to form alternatives. In addition to the below listed technologies, no action and institutional controls will also be evaluated further.

Groundwater Remediation

- Extraction technologies
  - wells
- Ex-situ treatment technologies
  - air stripping
  - carbon adsorption
  - oxidation
  - filtration
  - ion exchange

- Discharge management
  - surface water

- In-situ treatment technologies
  - air sparging
  - in-well air stripping
  - chemical oxidation
  - chemical reduction
  - natural attenuation

Soil Remediation

- Containment/isolation
  - pavement cap

- Treatment technologies
  - soil vapor extraction
  - chemical oxidation
  - chemical reduction

- Excavation and removal

Table 2-1

INITIAL SCREENING OF GROUNDWATER REMEDIATION TECHNOLOGIES
FARRAND CONTROLS SITE
WESTCHESTER COUNTY, NEW YORK

General Response Action	Remedial Technology	Description	Summary of Initial Screening Results
Groundwater Extraction	Wells	Extraction wells are constructed to pump contaminated groundwater to the surface for treatment.	Retained for further consideration.
	Interceptor Trenches	Trenches are constructed to intercept shallow groundwater plumes.	Not retained for further consideration due to depth of groundwater contamination.
Ex-situ Treatment Technologies	Air Stripping	VOCs are partitioned from water phase to gas phase via packed tower or aeration.	Retained for further consideration for VOC removal.
	Carbon Adsorption	Groundwater is pumped through canisters containing activated carbon or alternate adsorbent.	Retained for further consideration for VOC removal.
	Oxidation	Contaminants are destroyed by ultraviolet radiation, ozone and/or hydrogen peroxide.	Retained for further consideration for VOC removal.
	Biological Treatment	Microorganisms decompose organic contaminants in treatment units.	Not retained for further consideration due to availability of more effective methods for treatment of groundwater contaminated with chlorinated organic compounds.

Table 2-1 (continued)

INITIAL SCREENING OF GROUNDWATER REMEDIATION TECHNOLOGIES
FARRAND CONTROLS SITE
WESTCHESTER COUNTY, NEW YORK

General Response Action	Remedial Technology	Description	Summary of Initial Screening Results
Ex-Situ Treatment Technologies (continued)	Reverse Osmosis	Semi-permeable membrane and high pressure are used to obtain a concentrated solution of contaminants.	Not retained for further consideration due to availability of more effective methods for treatment of groundwater contaminated with chlorinated organic compounds and concentrated waste that would be generated and require additional treatment/disposal.
	Filtration	Suspended particles are removed by entrapment on a media (i.e., filter).	Retained for further consideration as part of overall treatment process if required to ensure effective removal of VOCs or to meet discharge criteria.
	Ion Exchange	Ions are removed via substitution with alternate ions supplied by the ion-exchange material.	Retained for further consideration as part of overall treatment process if required to ensure effective removal of VOCs or to meet discharge criteria.
	Chemical Precipitation and Clarification	Physical/chemical techniques are used to form insoluble settleable compounds to remove contaminants from solution.	Retained for further consideration as part of overall treatment process if required to ensure effective removal of VOCs or to meet discharge criteria.

Table 2-1 (continued)

INITIAL SCREENING OF GROUNDWATER REMEDIATION TECHNOLOGIES
FARRAND CONTROLS SITE
WESTCHESTER COUNTY, NEW YORK

General Response Action	Remedial Technology	Description	Summary of Initial Screening Results
Discharge Options	Publicly Owned Treatment Works	Route treated discharge to nearest municipal sanitary sewer system.	Not retained for further consideration due to discharge rate limitations.
	Surface Water	Route treated discharge to surface water body.	Retained for further consideration.
	On-site Recharge/Reinjection	Discharge treated groundwater to recharge basin, injection wells or leaching pools.	Not retained for further consideration due to potential interference with groundwater remediation and availability of a more effective discharge methods (surface water).
In-Situ Treatment and Containment	Air Sparging	Air is injected into groundwater to strip volatile contaminants which are recovered by vapor extraction.	Retained for further consideration.
	In-Well Air Stripping	Air is injected into a well, displacing contaminated groundwater and stripping VOCs which are treated in the gas phase at the surface.	Retained for further consideration.

Table 2-1 (continued)

INITIAL SCREENING OF GROUNDWATER REMEDIATION TECHNOLOGIES
FARRAND CONTROLS SITE
WESTCHESTER COUNTY, NEW YORK

General Response Action	Remedial Technology	Description	Summary of Initial Screening Results
In-Situ Treatment and Containment (continued)	Bioremediation	Contaminants are biologically degraded.	Not retained for further consideration due to potential for degradation of primary contaminants to more toxic compounds and the need for addition of an alkane to enhance cometabolization.
	Dual Phase Extraction	Vacuum is applied to the saturated and unsaturated zones. Vapor and liquid phases are recovered and treated at the surface.	Not retained for further consideration since soil contamination in the vadose is not defined and equally effective groundwater treatment processes are available.
	Chemical Oxidation	Oxidants are injected into the groundwater to treat organic contaminants.	Retained for further consideration.
	Reactive Walls	Permeable reaction wall is installed across flow path of plume to treat organic contaminants.	Not retained for further consideration due to the depth of contaminated groundwater in the overburden.
	Chemical Reduction	Injection of zero-valent iron to the subsurface through injection wells to treat organic contaminants.	Retained for further consideration.

Table 2-1 (continued)

INITIAL SCREENING OF GROUNDWATER REMEDIATION TECHNOLOGIES
FARRAND CONTROLS SITE
WESTCHESTER COUNTY, NEW YORK

General Response Action	Remedial Technology	Description	Summary of Initial Screening Results
In-Situ Treatment and Containment (continued)	Funnel and Gate	Cut-off walls are installed to direct groundwater flow to a permeable wall with treatment media which degrades the contaminants.	Not retained for further consideration due to the depth of contaminated groundwater in the overburden.
	Phytoremediation	Vegetation is used to uptake and/or immobilize contaminants.	Not retained for further consideration due to depth of contaminated groundwater in the overburden.
	Natural Attenuation	Natural subsurface processes are used to reduce contaminant concentrations.	Although data from the remedial investigation did not indicate that significant natural attenuation was occurring, this technology will be retained for further consideration since it is potentially applicable if combined with other technologies to remediate residual contamination.
	Containment Barrier	Subsurface low permeability structure installed to impede groundwater flow.	Not retained for further consideration since physical containment of the shallow plume is not necessary for remediation and installation the barrier into the bedrock would be difficult.

Table 2-2

INITIAL SCREENING OF SOIL REMEDIATION TECHNOLOGIES
FARRAND CONTROLS SITE
WESTCHESTER COUNTY, NEW YORK

General Response Action	Remedial Technology	Description	Summary of Initial Screening Results
Containment	RCRA Cap	2-foot vegetated topsoil and soil layer above a geotextile over a 1-foot sand and gravel drainage layer which is underlain by a flexible membrane liner and 2-foot compacted soil/clay layer.	Not retained for further consideration since less costly, thinner and more cost effective caps are available.
	Part 360 Cap	A four-layered system: vegetated topsoil upper layer, underlain by a 1 to 2-foot drainage/barrier layer followed by a geosynthetic membrane followed by a 1-foot gas venting layer.	Not retained for further consideration since less costly, thinner and more cost-effective caps are available.
	Pavement Cap	A cap comprised of an asphalt or concrete surface or building structure.	Retained for further consideration.
Excavation and Removal	Off-site Disposal	Contaminated soil is excavated and transported to an approved landfill or treatment facility.	Retained for further consideration.

Table 2-2 (continued)

INITIAL SCREENING OF SOIL REMEDIATION TECHNOLOGIES
FARRAND CONTROLS SITE
WESTCHESTER COUNTY, NEW YORK

General Response Action	Remedial Technology	Description	Summary of Initial Screening Results
Treatment	Chemical Oxidation	Injection of an oxidant into subsurface soil to treat organic contaminants.	Retained for further consideration.
	Soil Vapor Extraction	A vacuum is applied to subsurface soil and extracted air is treated for removal of VOCs.	Retained for further consideration.
	Bioventing	Microorganisms are used to degrade organic contaminants	Not retained for further consideration due to the potential for degradation of primary contaminants to more toxic compounds and the need for the addition of an alkane to enhance cometabolization.
	Chemical Reduction	Injection of zero-valent iron to subsurface soils to treat organic contaminants.	Retained for further consideration.

Section 3

3.0 DEVELOPMENT AND PRELIMINARY EVALUATION OF ALTERNATIVES

Based on the screening of remedial technologies in Section 2.0, the next phase of the feasibility study process is to develop remedial alternatives for preliminary evaluation based on effectiveness, implementability and relative cost. These alternatives can comprise either a single technology, if only one medium at a site is of concern and/or only one treatment process is required, or a combination of technologies if multiple media are of concern and/or multiple treatment processes are required.

As described previously, the media of concern identified at the Farrand Controls Site is groundwater in the shallow and deep overburden and in the highly fractured shallow bedrock. Since no significant soil contamination has been detected on-site to date, soil remediation technologies will not be combined into alternatives and screened, and evaluated at this time.

At the completion of the Phase I Feasibility Study, several groundwater remediation technologies were selected for further evaluation. Many of these technologies have been combined to form the below alternatives. However, some of those technologies will not be evaluated further. Although air sparging is a widely used, demonstrated technology for the remediation of VOCs in groundwater, there are several site limiting factors that may impede the effectiveness of the technology at the site. The shallow depth to groundwater, thickness of contaminated water column and questionable applicability in the highly fractured bedrock, are all site factors that would inhibit the effectiveness of air sparging, and therefore, air sparging will not be considered further.

In addition, both chemical oxidation and chemical reduction are developing technologies, and limited information on the long-term effectiveness of these technologies, as well as the demonstrated effectiveness on full-scale projects, is available. Since chemical oxidation is currently being utilized at more sites than chemical reduction, and has been utilized on a full scale in bedrock, chemical oxidation will be evaluated further as a developing, potentially applicable alternative for the site.

As a result of this further evaluation, the following four alternatives have been developed for remediation of groundwater contamination at the Farrand Controls Site:

- Groundwater extraction and treatment and discharge to surface water with long-term groundwater monitoring
- In well air stripping with long-term groundwater monitoring
- In-situ chemical oxidation with long-term groundwater monitoring
- No action with long-term groundwater monitoring

3.1 Description of Remedial Alternatives

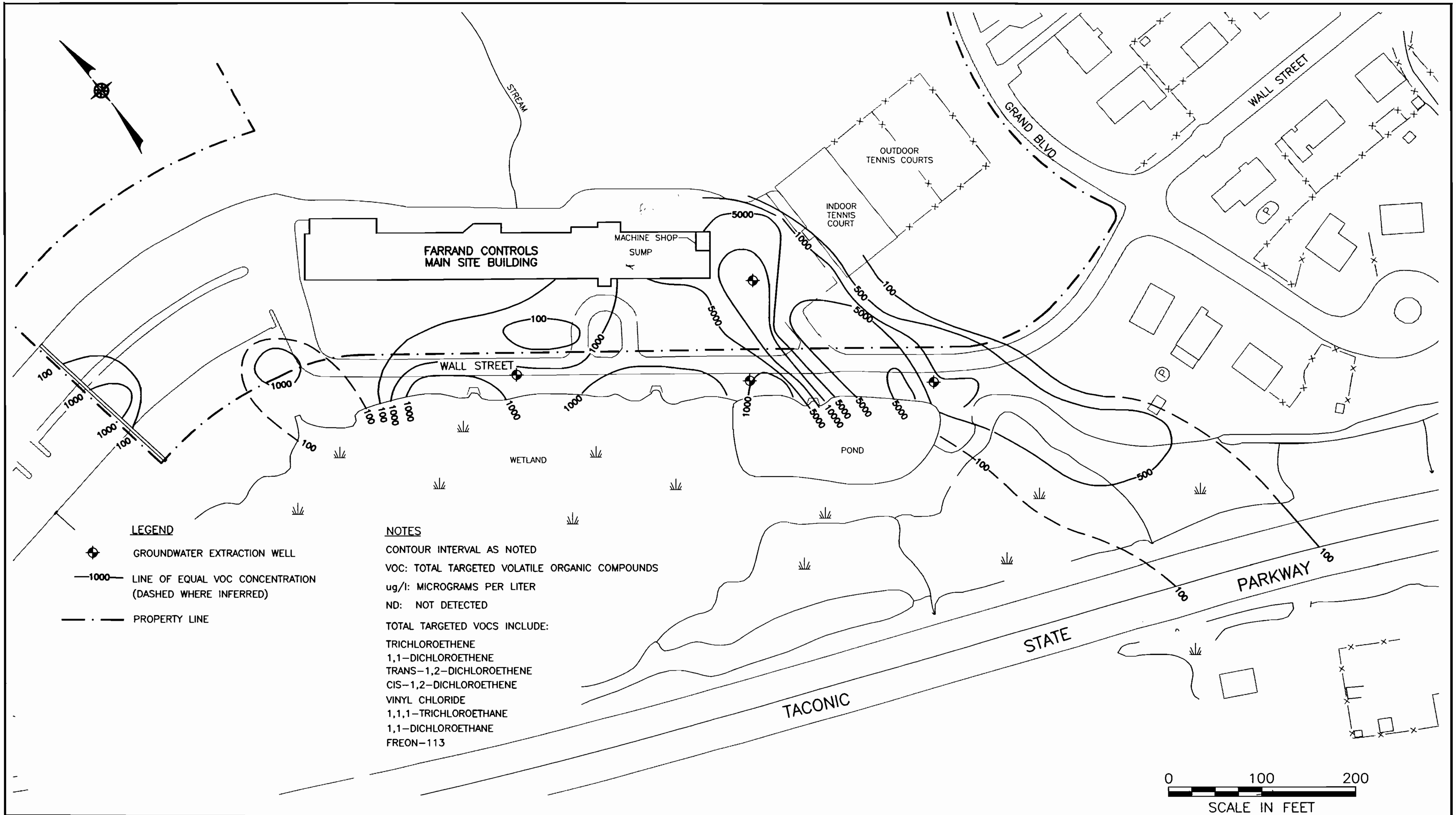
3.1.1 Alternative 1 – Groundwater Extraction and Treatment and Discharge to Surface Water with Long-term Groundwater Monitoring

Prior to installation of a groundwater extraction and treatment system, a pumping test will need to be performed to determine the hydraulic characteristics of the overburden and bedrock to design an effective groundwater extraction system, including number of wells, well spacing and pumping rates to remediate the contaminant plume. For the purposes of this alternative, it is assumed that a minimum of four observation wells and one extraction well will need to be installed to perform the pump test. The pump test will be run continuously for 24 hours at varying extraction rates. Groundwater elevations will be recorded continuously in the new observation wells, the pumping well and any existing groundwater monitoring wells in the vicinity of the extraction well. Groundwater samples will also be collected during the pumping test to evaluate water quality.

Without the results of a pump test, a two-dimensional groundwater flow model (WINFLOW) was utilized to estimate the capture zone for the shallow and deep overburden plumes, as well as the shallow bedrock for the purposes of development of this alternative. Available site specific data was utilized as input for the flow model, however, additional site specific data will be required in order to optimally screen and locate the extraction wells. Based on the results of the two-dimensional modeling, it is anticipated that remediation of the groundwater can be accomplished by placement of three 4-inch extraction wells along the southern property line and one extraction well located in the area of highest groundwater contamination (see Figure 3-1). It is estimated that each of the wells would need to extract between 50 to 100 gpm to contain the plume and prevent migration of contaminated groundwater to the off-site wetland/pond complex.

The extracted groundwater will be treated for contaminants that exceed Class C surface water quality standards in order to discharge treated water directly to the wetlands/pond. Contaminants in groundwater that currently exceed surface water standards are VOCs, including tetrachloroethene, trichloroethene, methylene chloride and chlorobenzene. Several of the metals detected in the groundwater exceed surface water standards, and therefore, will also require treatment. These metals include aluminum, iron, mercury, selenium and silver. In addition, pretreatment of groundwater will be required for the removal of iron and manganese prior to treatment for VOC removal in order to prevent fouling of the air stripping system and ensure effective operation of the remediation system. Based on experience, the treatment process selected to address these contaminants as part of this alternative are the following in sequence from influent to effluent: aeration tank and rapid mix/coagulation/plate settler greensand filter, ion exchange for metals removal, aeration tower for bulk VOC removal and granular activated carbon for polishing. Off-gas from the aeration tank and tower will be treated using a thermal oxidizer.

Long-term groundwater monitoring will be conducted to evaluate the effectiveness of the groundwater extraction and treatment system. Long-term groundwater monitoring will involve the sampling of shallow and deep overburden, as well as shallow bedrock wells. One upgradient monitoring well cluster, which includes one shallow overburden well, one deep overburden well and one shallow bedrock well will be installed and utilized to establish background groundwater quality at the site. Due to the width of the downgradient deep plume, approximately 800 feet wide, five well clusters will be installed and utilized for downgradient groundwater monitoring. Four existing wells, P-6 and MW-10 (S, D and R) will be utilized and nine additional wells (one shallow overburden, four deep overburden and four shallow bedrock) will need to be installed for long-term monitoring. The wells will be sampled quarterly for select volatile organic



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FARRAND CONTROLS SITE
REMEDIAL INVESTIGATION/FEASIBLITY STUDY

APPROXIMATE LOCATION OF GROUNDWATER EXTRACTION WELLS

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FIGURE 3-1

compounds for the first 5 years, semi-annually for the next 5 years and annually for the remaining 20 years.

3.1.2 Alternative 2 – In-well Air Stripping with Long-term Groundwater Monitoring

In-well air stripping is a potentially viable alternative for the reduction of VOCs in groundwater at the site. However, since this technology is dependant on site-specific conditions, to evaluate its efficiency at the Farrand Controls Site, it is likely that a pilot-scale study will be required prior to selection as the preferred remedy, and determination of the number and location of wells required for full-scale remediation. Based on information provided by Wasatch Environmental, Inc., a pilot test will include installation of one groundwater recirculation well and four nested piezometers. Piezometers will also be installed adjacent to the groundwater recirculation well for the purposes of monitoring the inflow and outflow of the groundwater recirculation well. Pressurized air will be supplied to the well by a blower, air emissions will be exhausted to the atmosphere after treatment with activated carbon, and a full-time acid drip system will be installed to reduce mineral precipitation. The system will operate for at least 12 weeks. Testing will include a dye tracer study and periodic measurements of field parameters. Groundwater samples will be collected from the 12 piezometers and from the groundwater recirculation well approximately once a week for chemical analysis and air samples will also be collected on a weekly basis. Assumptions have been made based on experience in utilizing technology and based on site-specific information to develop the following alternative in order to evaluate this technology further.

In this alternative, groundwater within the source area will be remediated through the use of 18 shallow and 12 deep in-well air stripping wells. Mitigation of migration of contaminated groundwater off-site and to the pond/wetlands will be completed through the use of 20 in well air stripping wells. Contaminated groundwater will be captured by the wells and VOCs will be removed by the air stripping action. Off-gases from the in-well air stripping wells will be treated, if necessary, and discharged to the atmosphere.

The in-well air stripping system will involve the installation of a double-cased/double screened well with hydraulically separated upper and lower screened intervals within the same aquifer. The lower screen through which contaminated groundwater will enter will be placed at the bottom of the contaminated zone to be remediated, immediately above the bedrock surface. The upper screen, through which treated groundwater will be discharged will be installed at or above the water table or in a deeper zone depending on the required radius of influence. Due to the shallow depth to water, stick up risers may need to be utilized to provide additional hydraulic lift.

Groundwater can also be extracted from the shallow rock, allowed to flow through the well, treated and discharged at a shallower depth in the overlying overburden. If additional information obtained from a pre-design investigation indicates that an appropriate recirculation cell can be created in the shallow bedrock, separate wells can be installed to address contamination in the bedrock. In addition, information obtained from the vendors indicate that the radius of influence of the recirculation wells may extend below the lower screened interval which may allow for contaminated groundwater in the shallow bedrock to be remediated without the construction of an additional well or well screen in this zone.

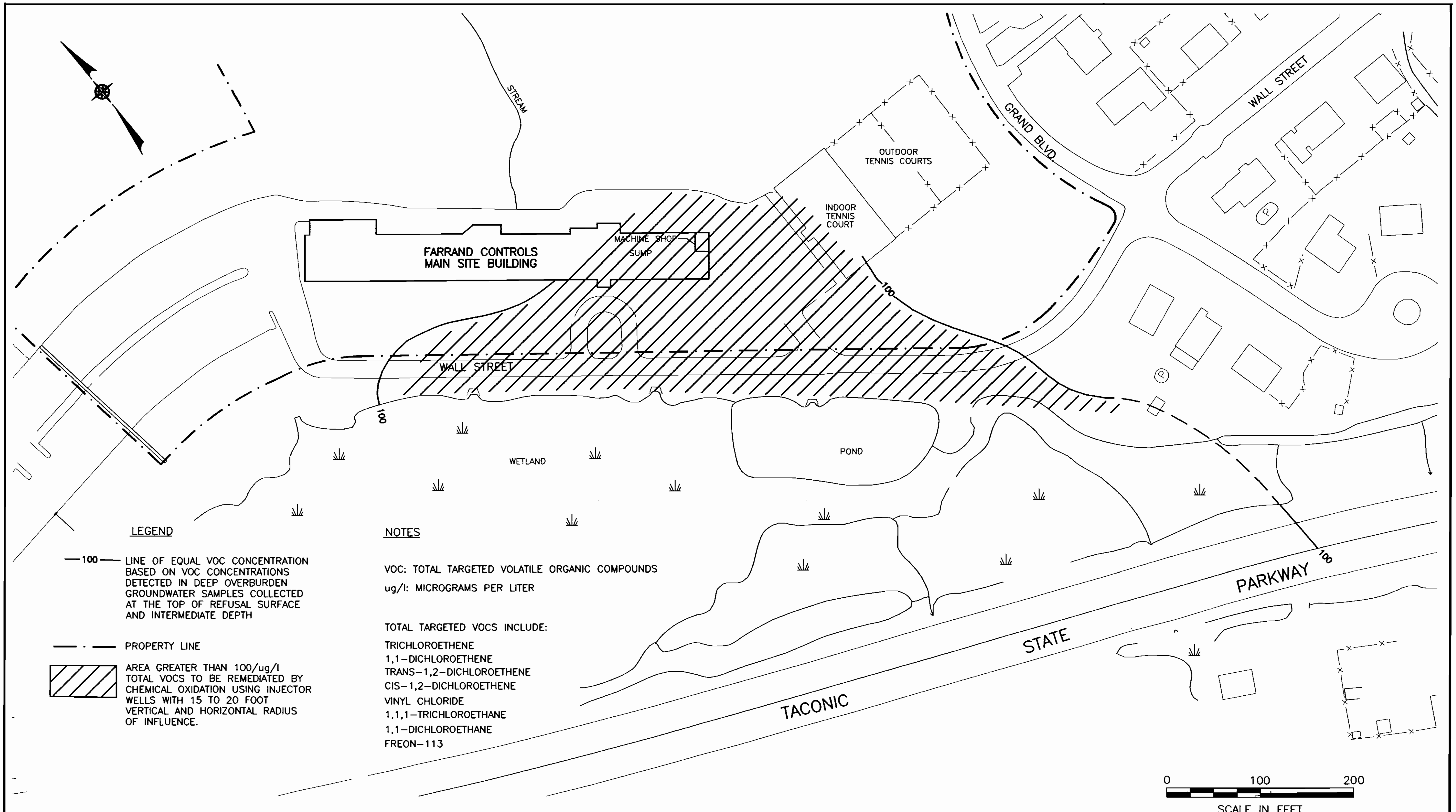
Due to the elevated levels of iron, manganese and magnesium in the groundwater, and the potential for clogging of the well screens, it is anticipated that acid injection would need to be utilized to control precipitation of these elements.

As discussed above, long-term groundwater monitoring will be conducted to evaluate the effectiveness of the in-well air stripping system. Long-term groundwater monitoring will involve the sampling of one upgradient well cluster and five downgradient well clusters as discussed in Alternative 1.

3.1.3 Alternative 3 – In-situ Chemical Oxidation with Long-term Groundwater Monitoring

In-situ chemical oxidation is a potentially viable alternative for the reduction of VOCs in groundwater at the site. However, as discussed above for in-well air stripping, since chemical oxidation is a developing technology and is also dependant on site-specific conditions, it is likely that a bench-scale treatability study and a pilot-scale study will be required prior to selection as the preferred remedy. The bench-scale treatability study and pilot-scale study will provide information on the number and location of treatment points required for full-scale remediation. The pilot scale study, based on information provided by Geocleanse International, Inc., will include installation of approximately 16 injector points at various depths. Hydrogen peroxide will be injected into the injector points and samples will be collected for chemical analysis from surrounding monitoring wells and the injector wells prior to and after the injection to evaluate radius of influence, effectiveness and rebound potential. Information obtained from vendors experienced in performing this form of remediation and based on this information, the following remediation alternative has been developed in order to evaluate this technology further. It should be noted that this remedial alternative will likely require modification following the results of both bench-scale and pilot scale studies. Specific concerns from more than one vendor indicated that although Freon 113 should be suitable for oxidation, there is no information on oxidation of this compound in the field.

The chemical oxidation system design presented by the vendor would be installed to reduce the dissolved volatile organic compound concentrations in shallow and deep overburden and shallow bedrock groundwater within the 100 ppb and greater plume line as defined in the Remedial Investigation Report. The chemical oxidation injector wells have an anticipated radius of influence of approximately 15 to 20 feet horizontally and vertically. Multiple injection zones within one injector well may cause short circuiting, therefore, one injection well is needed for each vertical zone requiring remediation. Based on a plume area of approximately 90,000 square feet ranging in thickness from 5 to 50 feet and vendor-supplied information, an estimate of over 250 injector wells would be required (see Figure 3-2).



LEGEND

—100— LINE OF EQUAL VOC CONCENTRATION BASED ON VOC CONCENTRATIONS DETECTED IN DEEP OVERBURDEN GROUNDWATER SAMPLES COLLECTED AT THE TOP OF REFUSAL SURFACE AND INTERMEDIATE DEPTH

— · — PROPERTY LINE

AREA GREATER THAN 100/ug/l TOTAL VOCS TO BE REMEDIATED BY CHEMICAL OXIDATION USING INJECTOR WELLS WITH 15 TO 20 FOOT VERTICAL AND HORIZONTAL RADIUS OF INFLUENCE.

NOTES

VOC: TOTAL TARGETED VOLATILE ORGANIC COMPOUNDS

ug/l: MICROGRAMS PER LITER

TOTAL TARGETED VOCS INCLUDE:

TRICHLOROETHENE
1,1–DICHLOROETHENE
TRANS–1,2–DICHLOROETHENE
CIS–1,2–DICHLOROETHENE
VINYL CHLORIDE
1,1,1–TRICHLOROETHANE
1,1–DICHLOROETHANE
FREON–113

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FARRAND CONTROLS SITE
REMEDIAL INVESTIGATION/FEASIBLITY STUDY

APPROXIMATE LOCATION OF CHEMICAL OXIDATION REMEDIATION ZONE

Dvirka and Bartilucci
Consulting Engineers
A Division of William F. Cosulich Associates, P.C.

FIGURE 3–2

Since all work will be completed in-situ, there will be no above ground treatment equipment required, however, additional sampling of the groundwater within the treatment zone during the treatment process would be required in order to evaluate the effectiveness of the treatment process.

Following treatment, continued groundwater monitoring would be required to evaluate the processes effectiveness over the long-term. Long-term groundwater monitoring will involve the sampling of one upgradient well cluster and five downgradient well clusters. Due to the expected shorter remediation period for in-situ chemical oxidation, the wells will be sampled quarterly for select volatile organic compounds for the first 2 years and semi-annually for the next 3 years for a total of 5 years of monitoring.

3.1.4 Alternative 4 – No Action with Long-term Groundwater Monitoring

This alternative provides for no active remediation of the groundwater and relies solely on natural attenuation. The "no action" alternative provides for long-term monitoring. Since no remedial action will be taken, the monitoring will consist of sampling the wells described for Alternative 1, quarterly for 30 years.

Provided below is a preliminary evaluation of these alternatives for effectiveness, implementability and relative costs. A description of these criteria is provided in Section 1.4.

3.2 Evaluation of Alternatives

3.2.1 Alternative 1

Effectiveness

Alternative 1, groundwater extraction and treatment with discharge to the surface water and long-term groundwater monitoring, would meet the remedial action objectives established for the site. Through extraction and treatment of the groundwater, this alternative would mitigate potential contact with contaminated groundwater and migration of contaminated groundwater to the pond/wetland complex off-site and would therefore protect human health and the environment. Water discharged to the pond/wetlands would be treated for VOCs and metals to achieve Class C surface water standards established for the protection of water quality in the pond/wetlands.

Implementability

Construction, operation and maintenance of all the technologies associated with Alternative 1 are readily implementable. The necessary labor, equipment, materials and supplies are commercially available. Placement of the treatment system on-site will require coordination with the current property owner. Disposal of treated groundwater will require coordination with the New York State Department of Environmental Conservation in order to obtain appropriate approval to discharge treated water to the pond/wetlands.

Cost

The cost of Alternative 1 is high. Treatment for metals in addition to VOCs and disposal of sludge residuals at an off-site permitted facility results in costs for this alternative above Alternative 2 (in-well air stripping) and Alternative 3 (in-situ chemical oxidation).

3.2.2 Alternative 2

Effectiveness

Alternative 2, in-well air stripping will likely meet both of the remedial action objectives for the site. Groundwater contamination in the overburden will likely be significantly reduced, although without the results of a pilot study, remediation efficiencies and radius of influence cannot be confirmed. If the in-well air stripping system is effective in significantly reducing the levels of contaminants in the groundwater, this alternative would likely provide protection for human health and the environment, and prevent migration of contaminants off-site. Extraction of groundwater in the highly fractured bedrock, if effective, will mitigate migration of contaminated groundwater in the shallow bedrock off-site.

Implementability

Installation of the in-well air stripping wells will not be difficult and equipment is readily available. Potential problems exist with clogging of the well screens due to metals precipitation and biofouling. Installation of the wells and associated piping would require coordination with the property owner.

Cost

The cost for Alternative 2 will be moderate. Alternative 2 would not be as costly as Alternative 1, groundwater extraction and treatment, and it would be comparable to the cost for Alternative 3, chemical oxidation. It would be slightly more costly than Alternative 3, because it would need to have an air emissions control system associated with it in order to treat contaminated vapors created by the system prior to discharge to the atmosphere.

3.2.3 Alternative 3

Effectiveness

Alternative 3 would likely meet both of the remedial action alternatives for the site. A bench-scale test would need to be performed to address treatment effectiveness and a pilot-scale test would be required to determine treatment material quantities, efficiency, radial extent of influence/treatment, injection mechanism and number of points and site-specific chemical formulation. This alternative should be effective in reducing VOC-contaminant levels, however, the pilot study would evaluate the potential for this technology to reduce levels of contaminants to below groundwater standards, and therefore, mitigate migration of VOC-contaminated groundwater to the wetland/pond complex. Several factors can affect the efficiency of this alternative, including total organic carbon content of the soil and heterogeneity of the subsurface soils.

Although chemical oxidation has been utilized to treat contaminated groundwater in bedrock, additional site-specific information would need to be obtained on the bedrock characteristics and the extent of the contamination in the bedrock prior to full evaluation of the potential effectiveness/pilot test of this alternative in the bedrock. As discussed in Section 1.0, assumptions have been made based on the single monitoring well in the shallow bedrock for the purposes of preparation of this feasibility study.

Implementability

This alternative can be readily implemented. Since it is an in-situ technology, and does not require piping to connect the injection points, limited disruption of the surface is required. Also it does not require above ground equipment, such as the treatment systems required for groundwater extraction and treatment, and in-well air stripping. All of the necessary labor, equipment, materials and supplies are readily available.

Cost

The cost for this alternative would likely be moderate. The results of a pilot study would provide additional information on the volume of oxidant and the number of injection points required, as well as the cost for remediation. However, the overall cost would likely be significantly lower than Alternative 1, and slightly lower than, but comparable to Alternative 2.

3.2.4 Alternative 4

Effectiveness

Alternative 4 would not meet any of the remedial action objectives which have been established for the Farrand Controls Site as discussed in Section 1.4 of this document, since no physical remedial action will be undertaken. Since this alternative relies solely on natural attenuation of contamination, it would not be protective of human health and the environment due to the potential for contact with the groundwater and the continued migration of contaminated groundwater to the pond/wetlands and off-site.

Implementability

This alternative is readily implementable physically, however, since no action does not mitigate the migration of contaminated groundwater off-site and adverse impacts on surface waters, it is not implementable from a regulatory perspective.

Cost

The cost associated with this alternative comprises the cost for long-term groundwater monitoring. The cost for long-term groundwater monitoring would be significantly lower than the alternatives discussed above.

3.3 Summary of Evaluation of Alternatives

Provided in Table 3-1 is a summary of the preliminary evaluation of the remedial alternatives developed for the Farrand Controls Site.

With regard to selection of alternatives to be evaluated further in detail in order to select a remedial plan for the site, all of the remedial alternatives discussed above (Alternatives 1 through 3) are considered viable and will be evaluated further in detail in Section 4.0, together with the no action alternative (Alternative 4) as required by the guidance.

Table 3-1

SUMMARY OF PRELIMINARY EVALUATION OF GROUNDWATER REMEDIAL ALTERNATIVES FARRAND CONTROLS SITE

Remedial Alternative		Effectiveness	Ease of Implementation	Relative Cost	Retained
Alternative G1	Groundwater Extraction and Treatment and Discharge to Surface Water with Long-term Groundwater Monitoring	High	Moderate (will require significant aboveground treatment systems)	High	Yes
Alternative G2	In-well Air Stripping and Long-term Groundwater Monitoring	Moderate*	Moderate(may encounter difficulties due to high metals content and clogging of system and shallow depth to water)	Moderate	Yes
Alternative G3	In-Situ Chemical Oxidation With Long-term Groundwater Monitoring	Moderate*	Moderate (may encounter difficulties due to shallow depth to water and small radius of influence/treatment)	Low to Moderate	Yes
Alternative G4	No Action with Long-term Groundwater Monitoring	Low	High (however, will likely not be acceptable to regulatory agencies or the public)	Low	Yes (required by feasibility study guidance)

*Needs to be evaluated with site-specific pilot test and effectiveness determined/confirmed.

Section 4

4.0 DETAILED ANALYSIS OF ALTERNATIVES

Based on the preliminary evaluation of the remedial alternatives selected for the Farrand Controls Site in Section 3.0, all of the alternatives developed for the site have been retained for detailed analysis. The following summarizes the alternatives to be evaluated in detail for remediation of groundwater in this section:

Alternative 1 - Extraction and Treatment and Discharge to Surface Water with Long-term Groundwater Monitoring

Alternative 2 - In-well Air Stripping with Long-term Groundwater Monitoring

Alternative 3 - In-situ Chemical Oxidation with Long-term Groundwater Monitoring

Alternative 4 - No Action with Long-term Groundwater Monitoring

Groundwater extraction and treatment is a demonstrated commercially available technology that has been utilized at numerous sites to reduce levels of dissolved contaminants in groundwater and mitigate off-site migration of contaminated groundwater. However, the applicability of groundwater extraction and treatment to source treatment, such as DNAPL, has not been fully demonstrated. Although some site specific information will need to be obtained for the purposes of design of the extraction and treatment system, such as a pumping test, information on the effectiveness on this type of remediation at many sites over the long-term is readily available and has been utilized to evaluate this alternative in this section.

In-well air stripping and in-situ chemical oxidation are developing technologies with limited information on the long-term effectiveness for remediation of both dissolved plumes and DNAPL source areas. The effectiveness of both in-well air stripping and in-situ chemical oxidation is highly dependant on site-specific characteristics. Evaluation of actual effectiveness at the Farrand Controls Site would require the performance of bench scale and/or pilot scale studies. Without the results of these studies, only the potential effectiveness of the technologies can be utilized as the basis for a detailed evaluation. Potential effectiveness is based upon information provided by vendors, as well as information prepared by independent sources, such as the United States Environmental Protection Agency (USEPA). The following sections evaluate the Alternatives 2 and 3 based on their *potential* effectiveness for remediation of groundwater contamination at the site.

Provided below is a detailed evaluation of the alternatives. Based on this detailed evaluation, a remedial plan for the site will be selected for regulatory agency and public comment. In accordance with federal (USEPA) and New York State guidance, the following feasibility study evaluation criteria will be addressed in this evaluation.

- Threshold Criteria
  - Protection of human health and the environment
  - Compliance with standards, criteria and guidelines/ARARs
- Balancing Criteria
  - Short-term impacts and effectiveness
  - Long-term effectiveness and permanence
  - Reduction in toxicity, mobility and/or volume of contamination
  - Implementability
  - Cost
- Modifying Criteria
  - Regulatory agency acceptance
  - Community acceptance

A detailed description of each of these criteria is provided in Section 1.4 of this document.

Provided below is a comparative analysis of the remedial alternatives to each of the evaluation criteria presented above.

4.1 Protection of Human Health and the Environment

Alternative 1, groundwater extraction and treatment and discharge to the adjacent pond/wetlands, and long-term groundwater monitoring, is a proven technology that would be protective of human health and the environment, since it would treat all contaminants in exceedance of groundwater standards and would mitigate migration of contaminants off-site to the surface waters. As described in the risk assessment performed for the Farrand Controls Site, although no exposure pathways to contaminated groundwater are currently complete there are several exposure pathways that potentially could be complete, including inhalation and dermal contact with volatile organic contaminated groundwater by on-site workers exposed to groundwater in open excavations, on-site trespassers or recreationalists exposed to discharging groundwater, and nearby downgradient residents and commercial establishments exposed to water supply.

Alternative 2, in-well air stripping with long-term groundwater monitoring, will likely be effective in reducing the levels of volatile organic compound contamination in groundwater, and mitigating further migration of VOC contaminated groundwater off-site to the pond/wetlands. As discussed above, the effectiveness of an in-well air stripping system, and therefore, overall reduction of contaminants by this remediation alternative, would need to be evaluated in a pilot study. Factors potentially affecting the effectiveness of this technology include shallow depth to water and shallow depth to bedrock, which will limit the height of the stripping column in the well, and therefore, the removal efficiencies of the system. In addition, the elevated levels of metals, in particular iron, may cause precipitation of the metals and/or biofouling and potential clogging of the well screens, thereby reducing the recirculation of the groundwater.

In-well air stripping has been demonstrated to be effective at reducing levels of contamination in bedrock aquifers at sites where the aquifer is amenable to recirculation of the groundwater, such as highly fractured bedrock, similar to that which exists at the Farrand Controls Site. The air stripping well(s) can be designed to be screened within the bedrock to extract contaminated groundwater from the rock and treat the groundwater within the well. The results of a pilot study and additional investigation at the site would provide data to determine most efficient way to remediate contamination in the shallow bedrock.

As stated above, there is a potential for exposure to contaminated groundwater by on-site workers, on-site trespassers or recreationalists, and nearby downgradient residents and commercial establishments. Although the actual reduction in VOCs by in-well air stripping cannot be determined at this time, it is likely that the reduction would be significant enough to mitigate any potential risk. Similarly, it is anticipated that any potential impacts to the environment could be reduced though implementation of this alternative.

In-situ chemical oxidation (Alternative 3) is a developing technology that would require a bench scale treatability study, as well as a pilot scale study, to demonstrate the effectiveness of the technology in remediating the contaminants of concern in groundwater at the site. Information provided by vendors indicates that this technology would also be applicable to contamination in highly fractured bedrock. Laboratory and pilot studies would provide information on the reduction of contaminants that the system could achieve in the groundwater. According to vendors, this alternative would also be effective in reducing sources of contamination including the areas of the site where the presence of DNAPL is likely. Remediation of the source/DNAPL is necessary since this technology will not be effective as intended (short-term remediation less than one year) if there is a continued release of contaminants from source areas to groundwater. Significant reduction in the levels of VOCs in groundwater will likely mitigate any potential risk and off-site migration of contaminants, and result in protection of human health and the environment. Factors potentially impacting the effectiveness of the system include subsurface heterogeneities, such as underground utilities, or high or low permeability units that would cause preferential flow of the oxidant.

Alternative 4, no action with long term groundwater monitoring, will not be protective of human health and the environment, since natural attenuation of the groundwater, without some form of active remediation, will not be effective in the 30-year planning period. The potential for exposure to contaminated groundwater and environmental impacts through the migration of contaminated groundwater to the off-site pond/wetlands will remain.

As a result of this comparative analysis, Alternative 1 would be the most protective of human health and the environment due to its long-term proven effectiveness. The effectiveness of Alternatives 2 and 3 would need to be demonstrated in bench scale/pilot scale studies, however, since chemical oxidation is a process in which the organic contaminants are destroyed, and since it does not require recirculation of the groundwater and recapture of contaminants, Alternative 3 will likely be more effective, if proven to be effective, at reducing the levels of

VOCs in groundwater than Alternative 2 and in a shorter period of time. Alternative 4 would not be protective of human health and the environment.

4.2 Compliance with Standards, Criteria and Guidelines/ARARs

Alternative 1 will be compliant with all of the SCGs and ARARs established for the site through the treatment of all contaminants in excess of groundwater standards and guidance values, and the use of vapor controls to meet emission requirements. This alternative would also meet State Pollutant Discharge Elimination System (SPDES) requirements for discharge of treated water to the pond/wetlands. Alternative 1 would likely require a minimum of 15 years to achieve groundwater remediation standards. A continuing source of contamination will require the extraction and treatment system to operate for a significantly longer period of time.

Alternative 2, in well air stripping, and Alternative 3, in-situ chemical oxidation, may not meet the groundwater standards for VOCs, but would likely significantly reduce the levels of contaminants to concentrations which would further allow for natural attenuation to further reduce concentrations to meet SCGs. As stated above, chemical oxidation may be more effective at reducing the levels of VOCs in groundwater as compared to in-well air stripping. Both alternatives would meet all other applicable SCGs and ARARs established for the site, including vapor emission requirements for Alternative 2.

Alternative 2 will likely require a minimum of 15 years of operation to significantly reduce levels of VOCs in groundwater. Although groundwater SCGs may not be achieved, as stated above, the concentrations would be reduced to levels that would likely allow natural attenuation to achieve groundwater standards.

According to information provided by vendors, Alternative 3, chemical oxidation, could significantly reduce levels of VOCs in groundwater in less than 1 year (if proven to be effective). However, similar to Alternative 2, natural attenuation of contaminants may be required to reduce contaminant levels to below groundwater SCGs.

Alternative 4, no action, will not be compliant with any of the SCGs established for the site, since significant natural attenuation of the groundwater is not expected and off-site migration of contaminants will continue.

Based on the above comparison, Alternative 1 would be the most compliant with the SCGs established for the site since it is most likely to meet the groundwater SCGs, followed by Alternatives 3 and 2, respectively. Although both Alternatives 2 and 3 may not achieve groundwater SCGs, Alternative 3 will be completed in a much shorter period of time as compared to Alternative 2. Alternative 4 will not be compliant with SCGs/ARARs.

4.3 Short-term Impacts and Effectiveness

Alternative 1 will have no significant adverse short-term impacts and will be immediately effective in mitigating migration of contaminants to the pond/wetlands and reducing elevated levels of contaminants in groundwater. Groundwater extraction wells would need to be installed and a portion of the site would need to be utilized for the treatment system. Extracted groundwater would need to be pumped to the treatment system and treated water would need to be routed to the pond/wetlands. Therefore, underground piping would need to be installed at the site. Additional groundwater monitoring wells will need to be installed for long-term groundwater monitoring. Installation of the extraction and monitoring wells and underground piping may cause temporary disruption of some on-site facilities, such as use of parking and recreational areas. This alternative can be implemented within 12 to 18 months of the initiation of remedial design.

Alternative 2, likely will not have any significant adverse short-term impacts and will be immediately effective in reducing the levels of VOCs in groundwater. Similar to Alternative 1, the installation of air stripping and groundwater monitoring wells, as well as piping for the system, may cause temporary disruption of on-site facilities. Alternative 2 will also require utilization of a potion of the site for the housing of systems equipment such as blowers and compressors. If an on-site pilot study demonstrates the effectiveness of this technology, this alternative also can be implemented within 12 to 18 months of selection of this alternative and implementation of the remedial design. Potential problems may occur with the migration of contaminated groundwater outside of the recirculation cells. However, with proper design and installation, the release of contaminated groundwater off-site can be minimized.

Once the effectiveness of in-situ chemical oxidation has been demonstrated based on the results of a bench scale/pilot-scale study, Alternative 3 can be implemented within approximately 9 to 12 months of the implementation of the remedial design, will have no significant short-term adverse impacts and will be immediately effective in reducing the levels of VOCs in groundwater. Since all work will be completed in-situ, there will be no aboveground construction of treatment facilities and below ground construction of piping systems. This alternative will require the installation of over 280 injection wells and additional groundwater monitoring wells which may cause temporary disruption of on-site parking and recreational facilities. Although this alternative will likely use a potentially hazardous material, such as hydrogen peroxide as the oxidant, appropriate handling, and health and safety precautions will reduce the potential hazards associated with using these materials.

Alternative 4 will have minimal short-term adverse impacts relative to the disruption of on-site facilities and can be implemented immediately. Additional groundwater monitoring wells are expected to be required for long-term monitoring, and therefore, some impacts to the site may occur during installation of these monitoring wells. This alternative will not be effective in the short-term in preventing the migration of contaminants off-site to the pond/wetlands or in the reduction of VOCs in groundwater.

Based on this comparative analysis, Alternative 4 will have the least short-term impacts followed by Alternative 3 since no above ground facilities would be required. Alternatives 1 and 2 would both require above ground facilities with Alternative 1 requiring a much larger area for treatment of the groundwater and require discharge of treated water. Therefore, Alternative 2 would have less short term impacts compared to Alternative 1.

4.4 Long-Term Effectiveness and Permanence

By hydraulically controlling and treating contaminated groundwater, it is expected that Alternative 1 will be effective and permanent in the long-term. This alternative will reduce levels of VOCs and metals in groundwater, and mitigate migration of contaminants to the pond/wetlands. The risks posed by the generation of treatment residuals will be minimal or non-existent, since these residuals will be contained and disposed of off-site at a permitted treatment facility. The effectiveness of the hydraulic control in the highly fractured bedrock will need to be evaluated in a pumping test.

Alternative 2, in-well air stripping, will likely be effective and permanent in the long-term with respect to reduction of VOCs in groundwater. The levels of reduction and ability to mitigate off-site migration of contamination (system effectiveness) would need to be demonstrated in a pilot study. The potential for clogging of the well screens due to the precipitation of metals and biofouling may impact long-term the effectiveness of the system.

Since chemical oxidation (Alternative 3) is a developing technology there is not sufficient information regarding the long-term effectiveness or permanence of this alternative. The effectiveness of this alternative with regard to its potential to reduce groundwater contamination within a short period of time is dependant on mitigation of the source of contamination. Unlike Alternatives 1 and 2, which will continue to operate for a long period of time after installation, chemical oxidation typically relies on one, and possibly a few, oxidant injection events within a relatively short period of time. If the source of contamination is remediated, since the basis of the technology is to destroy contaminants, it is expected that chemical oxidation would be a permanent remedy. The results of a bench scale and pilot scale study would demonstrate the effectiveness of this alternative relative to this site.

Alternative 4, which is no action, will not be effective or permanent in the long term.

In summary, since Alternative 1 would reduce all of the contaminants of concern in the extracted groundwater, and it has been demonstrated to be effective in the long-term in controlling the migration of contamination, it likely would be more effective in the long-term compared to Alternative 2. Results of a pump test will evaluate the effectiveness in the system in the highly fractured bedrock. The effectiveness of both Alternatives 2 and 3 will need to be demonstrated as part of bench and/or pilot scale studies. However, if effective at reducing the source of contamination, Alternative 3 will likely be more effective than Alternative 2. Alternative 4, no action, will not be an effective or permanent remedy for the site.

4.5 Reduction of Toxicity, Mobility or Volume Through Treatment

Alternative 1 will be effective at reducing the toxicity, mobility and volume of all contaminants in groundwater at the site. The use of extraction wells will mitigate migration of contaminated groundwater from the overburden, and likely in the bedrock, to the pond/wetlands and emissions controls will mitigate the release of vapors to the atmosphere. Removal and destruction of all the contaminants of concern from groundwater allows this alternative to be considered irreversible.

Alternative 2 likely will be effective in reducing the toxicity, mobility and volume of VOCs in groundwater at the site through treatment and will also be effective in the control of releases of volatile organic vapors to the air. However, as discussed above, the effectiveness of the system will need to be verified by a pilot study. Removal of the contaminants from the groundwater will reduce the toxicity and volume of contaminated groundwater. Recirculation of contaminated groundwater for treatment will reduce the mobility of groundwater to migrate off-site.

Alternative 3 likely will be effective at reducing the levels of VOCs in groundwater through in-situ chemical destruction, thereby reducing the toxicity, mobility and volume of the contaminants in groundwater. However, this alternative will also require a pilot study to demonstrate its effectiveness.

Alternative 4 will not be effective in reducing the toxicity, mobility or volume of contaminants at the site, since natural attenuation is not expected to be effective in the foreseeable future and contaminants will continue to migrate off-site to the pond/wetlands.

Based on this comparative analysis, Alternative 1 will be the most effective followed by Alternatives 3 and 2, respectively. Alternative 4 will not be effective.

4.6 Implementability

Alternative 1, groundwater extraction and treatment, is a commercially available technology with all necessary labor, materials and supplies readily accessible. It has been demonstrated at many sites to meet all remediation goals, as well as to prevent migration of contamination off-site. A pumping test likely will be required to optimally locate groundwater extraction wells. The effectiveness of this alternative can be easily monitored through the use of groundwater monitoring wells and can also be easily combined with a source remediation alternative if a significant source area of contamination is defined at a later date. This alternative will require approval of the regulatory agencies for the discharge of treated groundwater to the pond/wetlands. Since the water will be treated to meet surface water quality standards and the substantive requirements of a SPDES permit it is not expected that difficulties will occur with regard to approval for discharge to the surface water.

Completion of Alternative 1 would likely require a minimum of 15 years if remediation of the source is completed. A continuing source of contamination will require the extraction and treatment system to operate for a longer period of time. A portion of the site will need to be used to house the treatment system throughout the duration of the remediation. The area needed for implementation of this alternative may be currently utilized for parking or recreational purposes and may cause difficulties. Coordination with the property Owner will be required.

Implementation of Alternative 2 will not be difficult since all of the necessary labor, equipment, materials and supplies are readily available. Potential difficulties may occur due to clogging of the well screens due to metals precipitation and biofouling. Low permeability units may impact the ability of the wells to effectively recirculate groundwater, resulting in potential migration of contamination off-site. Determining the actual radius of influence of the wells can be difficult without significant studies including dye tracer testing. Difficulties may also be encountered in obtaining competitive bids for this technology due to the low number of vendors currently marketing this technology.

Installation of air stripping wells in areas of the site currently utilized by the property owner for parking or for recreational purposes may cause difficulties. Installation of piping across the site would also require coordination with the property owner. However, no significant impediments to implementation are expected.

Completion of Alternative 2 will likely require a minimum of 15 years assuming source area mitigation. During this time a portion of the site being utilized by the treatment system and several stickup well risers will be located throughout the site. Stick up well risers may be required due to the shallow depth to water and the need for additional hydraulic lift in the well.

Based on discussions with vendors, it appears that although Alternative 3 (chemical oxidation) is a developing technology, all the necessary labor, equipment, materials and supplies for installation of this system are readily available and will not cause delays in implementation. Difficulties may be encountered due to low permeability units and injection of the chemical oxidant. If the oxidant is able to contact contaminated groundwater, it is expected to meet performance goals. Similar to Alternatives 1 and 2, monitoring the effectiveness of the system includes the collection of groundwater samples from upgradient and downgradient wells. Installation of the injection wells in areas currently utilized by the property owner may cause difficulties and will require coordination with the property owner.

According to the information provided by vendors, remediation of the groundwater using chemical oxidation can be completed within a year (if proven to be effective). The actual injection program, once all of the injection points are installed, will take less than one month and reduction in the VOC levels is expected to occur immediately. Additional time would be required within the one year period for additional injection of oxidants to address residual contamination. Therefore, potentially this alternative would be complete in a substantially shorter period of time as compared to Alternatives 1 and 2.

Except for the installation of new wells to monitor groundwater, Alternative 4 can be easily implemented, since there will be no action.

All of the alternatives will be readily implementable with the simplest to implement being Alternative 4. Due to the relative complexity of the remediation systems required for Alternatives 1 and 2, and the time required to complete these alternatives, it is expected that Alternative 3 will be easier to implement and potentially less time to complete as compared to Alternatives 1 and 2, respectively.

4.7 Cost

The estimated capital costs, and long-term (30-year) operation and maintenance (O&M), and monitoring present worth costs associated with the alternatives are presented in Table 4-1. A detailed breakdown of each estimate is provided in Appendix A.

The following assumptions were utilized in the preparation of the cost estimates:

- Costs are rounded to the nearest thousand dollars.
- All site work costs (e.g., well installation, etc.) were estimated using Means Site Work Cost Data for 1999, experience in construction and adjusted for hazardous site remediation, and discussion with remedial contractors and disposal facilities.

Alternative 4, no action, would have the lowest cost, since the only capital costs associated with this alternative is the installation of additional groundwater monitoring wells for long-term monitoring. Alternatives 2 and 3, in-well air stripping and chemical oxidation, have comparable costs of $1,908,000 and $1,992,000, respectively, with in-well air stripping being slightly less costly that chemical oxidation. However, both of these costs were provided by vendors with limited site-specific information and without the results of bench and/or pilot bench scale studies, and therefore, these costs are subject to change with the results of these studies.

Table 4-1

ALTERNATIVES COST SUMMARY
FARRAND CONTROLS SITE

Alternative	Estimated Capital Cost	Estimated Contingency and Engineering Fees	Present Worth of Annual Operating Maintenance and Monitoring Costs	Total Estimated Costs Based on Present Worth
1	$3,144,000	$943,000	$2,188,000	$6,275,000
2	$1,021,000	$357,000	$530,000	$1,908,000
3	$1,512,000	$378,000	$102,000	$1,992,000
4	$62,000	$28,000	$443,000	$533,000

Alternative 1, groundwater extraction and treatment, is much more costly than the other alternatives, being in excess of $6,000,000. Costs for this alternative are high due to the volume of water requiring treatment, approximately 300 gallons per minute, and treatment of metals, including silver to meet standards for discharge to the pond/wetlands.

4.8 Community Acceptance

Since Alternative 1 is a proven, commercially available alternative for the treatment of groundwater, it is expected that this alternative will be acceptable to the community.

Since Alternatives 2 and 3 are developing technologies it may not be as acceptable as Alternative 1 to the community. However, if pilot scale studies can demonstrate the effectiveness of these technologies at the site, both alternatives will likely be acceptable to the community. Alternative 3 may be more acceptable to the community, since it can be completed within a shorter period of time.

Due to the continued migration of contaminated groundwater to the pond/wetlands and the potential risks associated with the contaminated groundwater, it is not expected that Alternative 4 will be acceptable to the community.

Therefore, Alternative 1 would be the most acceptable followed by Alternatives 3, 2 and 4, respectively.

The community will have an opportunity to review and provide written comments on the remedial alternatives and the recommended remedy during the Preferred Remedial Alternative Plan (PRAP) comment period and at the public meeting for the PRAP.

A summary of the comparison of alternatives is provided in Table 4-2.

Table 4-2

SUMMARY OF REMEDIAL ALTERNATIVE COMPARATIVE ANALYSIS FARRAND CONTROLS SITE

Evaluation Criteria	Alternative 1 – Extraction and Treatment and Discharge to Surface Water with Long-term Groundwater Monitoring	Alternative 2 – In-well Air Stripping with Long-term Groundwater Monitoring	Alternative 3 – In-situ Chemical Oxidation with Long-term Groundwater Monitoring	Alternative 4 – No Action with Long-term Groundwater Monitoring
Protection of Human Health and the Environment	1	3	2	4
Compliance with Standards, Criteria and Guidelines	1	3	2	4
Short-term Impacts and Effectiveness	4	3	2	1
Long-term Effectiveness and Permanence	1	3	2	4
Reduction of Toxicity, Mobility or Volume through Treatment	1	3	2	4
Implementability	4	3	2	1
Cost	4 ($6,275,000)	2 ($1,908,000)	3 ($1,992,000)	1 ($533,000)
Regulatory Agency Acceptance	1	3	2	4
Community Acceptance	1	3	2	4
Total	18	26	19	27

Note: Lowest numerical score is highest ranking.
Assume that Alternatives 2 and 3 will prove effective in pilot tests.

Appendix A

APPENDIX A

DETAILED COST ESTIMATE

Alternative 1
Farrand Controls Site
Groundwater Extraction and Treatment and Discharge to Surface Water
with Long-term Groundwater Monitoring
Cost Estimate

Item	Quantity	Units	Unit Cost	Total
Capital Costs				
Pumping test (inlcudes installation of pumping well and 4 observation wells and sampling)	-	Lump Sum	$72,000	$72,000
Groundwater Extraction and Treatment System				
Mobilization/demobilization*	-	Lump Sum	$200,000	$200,000
Installation of 4 extraction wells and pump system	-	Lump Sum	$150,000	$150,000
Aeration tank and blowers	-	Lump Sum	$410,000	$410,000
Thermal oxidizer	-	Lump Sum	$260,000	$260,000
Rapid mix/coag/plate settler	-	Lump Sum	$270,000	$270,000
Iron/manganese greensand filter	-	Lump Sum	$300,000	$300,000
Ion exchange	-	Lump Sum	$120,000	$120,000
Air stripper	-	Lump Sum	$200,000	$200,000
Granular activated carbon	-	Lump Sum	$100,000	$100,000
Pumps/piping/chemical feed/controls	-	Lump Sum	$200,000	$200,000
Electrical supply	-	Lump Sum	$300,000	$300,000
Building	-	Lump Sum	$300,000	$300,000
Miscellaneous equipment and site work	-	Lump Sum	$200,000	$200,000
Long-term Monitoring				
Installation of montioring wells (1 shallow, 4 deep and 4 shallow bedrock)	-	Lump Sum	$62,000	$62,000
		Estimated Capital Cost		**$3,144,000**
Contingency and Engineering Fees				
Contingency allowance (10%)				$314,000
Engineering fees (20%)**				$629,000
Estimated Contingency and Engineering Fees				$943,000
TOTAL ESTIMATED CAPITAL COST				**$4,087,000**

Alternative 2
Farrand Controls Site
In-Well Air Stripping and Long-term Groundwater Monitoring
Cost Estimate (continued)

Annual Operating and Maintenance Costs				
In-well air stripping system				
Redevelopment of wells	100	Hours	$50	$5,000
Electrical service	-	Lump Sum	$5,000	$5,000
Disposal of development water	30	Drums	$200	$6,000
System O&M labor	100	Hours	$50	$5,000
	Annual cost			$21,000
	Present worth of annual operation & maintenance cost for 15 yrs (i=5%)			$218,000
Groundwater Monitoring Costs Per Event				
Groundwater sampling	5	Mandays	$600	$3,000
Purge water disposal	8	Drums	$200	$1,600
Equipment, materials and supplies	-	Lump Sum	$1,000	$1,000
Sample analysis****	16	Samples	$100	$1,600
	Estimated per event monitoring costs			$7,200
	Present worth of annual groundwater monitoring (30 yrs, i=5%)*****			$312,000
	Remedial Alternative 2 Total Estimated Costs			**$1,908,000**

*Based on costs provided by Wasatch Environmental Inc.
**Includes bonds, insurance, temporary facilities, pre-construction submittals and as built drawings,in addition to mobilization to and demobilization from the site.
*** Includes design and construction inspection.
****Sample analysis includes volatile organic compounds
*****Sampling frequency includes 4 times per year for the first 10 years, 2 times per year for the next 10 years and 1 time per year for the next 10 years.

Alternative 3
Farrand Controls Site
In-situ Chemical Oxidation
Cost Estimate

Item	Quantity	Units	Unit Cost	Total
Capital Costs				
Bench and pilot scale tests* (includes water sample analysis during pilot test)	-	Lump Sum	$110,000	$110,000
Chemical Oxidation System*				
Mobilization/demobilization**	-	Lump Sum	$100,000	$100,000
Injector fabrication and installation including drilling	-	Lump Sum	$380,000	$380,000
Chemical injection (2 periods)	-	Lump Sum	$810,000	$810,000
Project documentation	-	Lump Sum	$10,000	$10,000
Pre and post sampling (includes installation of 6 additional monitoring wells and sampling of 8 existing monitoring wells)	-	Lump Sum	$40,000	$40,000
Long-term Monitoring				
Installation of montioring wells (1 shallow, 4 deep and 4 shallow bedrock)	-	Lump Sum	$62,000	$62,000
		Estimated Capital Cost		**$1,512,000**
Contingency and Engineering Fees				
Contingency allowance (15%)				$227,000
Engineering fees (10%)***				$151,000
Estimated Contingency and Engineering Fees				$378,000
TOTAL ESTIMATED CAPITAL COST				**$1,890,000**

Alternative 3
Farrand Controls Site
In-situ Chemical Oxidation
Cost Estimate (continued)

Annual Operating and Maintenance Costs

Groundwater Monitoring Costs Per Event

Groundwater sampling	5	Mandays	$600	$3,000
Purge water disposal	8	Drums	$200	$1,600
Equipment, materials and supplies	-	Lump Sum	$1,000	$1,000
Sample analysis****	16	Samples	$100	$1,600
	Estimated per event monitoring costs			$7,200
	Present worth of annual groundwater monitoring (5 yrs, i=5%)*****			$102,000
	Remedial Alternative 3 Total Estimated Costs			**$1,992,000**

*Based on costs provided by Geocleanse International, Inc.
**Includes bonds, insurance, temporary facilities, pre-construction submittals and as built drawings
*** Includes design and construction inspection.
****Sample analysis includes volatile organic compounds
*****Sampling frequency includes 4 times per year for the first 3 years, 2 times per year for the next 2 years.

Alternative 4
Farrand Controls Site
No Action with Long-term Groundwater Monitoring
Cost Estimate

Item	Quantity	Units	Unit Cost	Total
Capital Costs				
Installation of montioring wells (1 shallow, 4 deep and 4 shallow bedrock)	-	Lump Sum	$62,000	$62,000
		Estimated Capital Cost		**$62,000**
Contingency and Engineering Fees				
Contingency allowance (15%)				$9,000
Engineering fees (30%)**				$19,000
Estimated Contingency and Engineering Fees				$28,000
TOTAL ESTIMATED CAPITAL COST				**$90,000**
Groundwater Monitoring Costs Per Event				
Groundwater sampling	5	Mandays	$600	$3,000
Purge water disposal	8	Drums	$200	$1,600
Equipment, materials and supplies	-	Lump Sum	$1,000	$1,000
Sample analysis*	16	Samples	$100	$1,600
	Estimated per event monitoring costs			$7,200
	Present worth of annual groundwater monitoring (30 yrs, i=5%)**			$443,000
	Remedial Alternative 4 Total Estimated Costs			**$533,000**

*Sample analysis includes volatile organic parameters
**Sampling frequency includes 4 times per year for the first 15 years, 2 times per year for the next 15 years.

38,8