FOCUSED FEASIBILITY STUDY ADDENDUM FOR GROUND WATER

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CONTENTS

TABLES

FIGURES

APPENDICES

PLATES

1.0 INTRODUCTION

Remedial Engineering, P.C. (Remedial Engineering) was retained by Pfizer Inc (Pfizer) to prepare an addendum to the "Focused Feasibility Study For Source Control" (FFS) prepared by Golder Associates for the former Deknatel, Inc. facility located at 96-20 222nd Street in Queens Village, New York (Site). Pfizer presently owns the Site through one of its wholly owned subsidiaries. The Site was previously owned and operated by Deknatel, Inc., a business formerly owned by Pfizer. The Site location is shown in Figure 1.

The FFS addressed remediation of soil impacted by hexavalent chromium (Cr^{+6}) beneath the Site. The impacted soil is a source of Cr^{+6} to ground water beneath and downgradient of the Site. Although remediation of the impacted soil as recommended in the FFS will eliminate the source of Cr^{+6}, ground water immediately downgradient of the Site is currently impacted by Cr^{+6} from the soil source. Therefore, the objectives of this FFS addendum are to:

- evaluate the post-remediation fate and transport of the existing Cr^{+6} in ground water; and
- develop a recommended approach for ground water that ensures protection of human health and the environment.

To achieve these objectives, the FFS addendum is organized as follows. Current ground-water flow and quality conditions are summarized in Section 2.0. The ground-water geochemistry of Cr^{+6} is reviewed in Section 3.0 to provide a basis for evaluating the potential fate and transport of Cr^{+6} in ground water downgradient of the Site. Regional ground-water use (both public and private) and quality data are reviewed in Section 4.0 to provide a basis for assessing the potential for impact of the Site on water supply wells. The potential for impact of the Site on water supply wells is assessed in Section 5.0. Remedial action alternatives are identified and evaluated in Section 6.0. Conclusions and a recommended approach for ground water are presented in Section 7.0.

Background information regarding the Site geographical setting, chromium waste disposal history, and extent of impacted soil may be obtained from the Remedial Investigation (RI) report prepared by Recra Environmental, Inc. (1992), and the FFS.

2.0 GROUND-WATER CONDITIONS

A thorough understanding of ground-water flow and quality conditions has been developed based upon previous investigations conducted at the Site. The results of these investigations are presented in the following reports:

- "Remedial Investigation Report, Pfizer Hospital Products Group, Inc." (RI Report) dated October 1992 (Recra Environmental, Inc. 1992); and
- "Off-Site Ground-Water Investigation and Additional Source Investigation" (OGI/ASI) dated May 28, 1993 (Roux Associates, Inc. 1993).

This section summarizes the understanding of ground-water conditions based upon the results of these investigations. This section also incorporates data obtained from an additional monitoring well (MW-15), which was installed and sampled on two occasions subsequent to the completion of the field investigation for the OGI/ASI.

2.1 Hydrogeology

Previous investigations have characterized hydrogeologic conditions by performing the following tasks:

- drilling of 16 test borings;
- installation of 17 monitoring wells;
- conducting synoptic rounds of water-level measurements on 14 occasions since May 1992 to characterize ground-water flow directions and gradients;
- conducting slug tests and short-term specific capacity tests to characterize aquifer hydraulic conductivity; and
- reviewing published data regarding regional ground-water conditions.

The key findings regarding the hydrogeologic conditions are summarized below.

- The Site is directly underlain by unconsolidated deposits comprising the Upper Glacial aquifer on Long Island. The deposits are characterized as orange to brown, medium to coarse-grained sand, with occasional fine sand and gravel. Depth to ground water is approximately 55 feet beneath the Site. The saturated thickness of the Upper Glacial aquifer beneath the Site is approximately 70 feet (Roux Associates, Inc. 1992). The Upper Glacial aquifer is underlain by the Magothy aquifer, which is comprised of fine to medium-grained sand, with lenses of coarse sand and clay. The thickness of the Magothy aquifer beneath the Site is approximately 300 feet (Buxton et al. 1981; McClymonds and Franke 1972).

- Ground water flows to the west and southwest beneath the Site and primarily southwest downgradient of the Site. Figure 2 shows ground-water flow directions based upon the water levels measured on June 29, 1993, incorporating data from newly-installed Monitoring Well MW-15. The water-level data are summarized in Table 1. The flow directions are consistent with those previously determined for the Site, and also with published data regarding regional flow (Doriski 1987).
- The ground-water flow rate beneath and downgradient of the Site has been calculated to be approximately 1 foot per day (ft/d) (Recra 1992). This value is based upon an average measured hydraulic gradient of approximately 0.0013 ft/ft, an average measured hydraulic conductivity for the aquifer beneath the Site of approximately 210 ft/d, and a porosity of 30 percent (Roux Associates, Inc. 1992).
- Based upon the data obtained from monitoring well clusters (MW-8 and MW-8D, and MW-9 and MW-9D in Figure 2) there is no indication of a downward vertical component of ground-water flow within the upper 35 feet of the aquifer (Roux Associates, Inc. 1993).
- Water levels beneath the Site have risen approximately 8 feet since March of 1988. This is part of a regional rise of the water table, which has been occurring since 1976. The water table has been rebounding in response to reduced aquifer usage by the Jamaica Water Supply Company (Roux Associates, Inc. 1992).

2.2 Ground-Water Quality

Since May 1992, five comprehensive sampling rounds have been conducted. In addition, there have been four additional confirmatory sampling rounds of a limited number of Site monitoring wells. The results of the ground-water sampling indicate that Cr^{+6} is the primary constituent of concern. Table 2 summarizes ground-water quality data collected at the Site since January 1993.

As of April and May 1993, total chromium (total Cr), Cr^{+6}, copper (Cu) and lead (Pb) were detected beneath the southwest portion and immediately southwest of the Site at concentrations that exceeded their New York State (NYS) Class GA Ground-Water Quality Standards as summarized below:

Monitoring Well	Total Cr	Cr^{+6}	Cu	Pb
MW-5	1,930	1,730	--	--
MW-7	2,100	2,020	254	--
MW-10	1,520	911	354	135

Monitoring Well	Total Cr	Cr^{+6}	Cu	Pb
MW-11	347	298	--	68.5
MW-12	340	236	887	180
MW-13	1,610	1,590	529	--
NYS Standard	**50**	**50**	**200**	**25**
-- Compound concentration below NYS Class GA Standard. Concentrations in micrograms per liter.				

Off-site ground-water quality data indicate that concentrations of total Cr, Cr^{+6}, copper, and lead do not exceed the NYS Class GA Ground-Water Quality Standards at downgradient monitoring wells 140 ft west (MW-8 and MW-9), 440 ft west-southwest (MW-15) or 190 ft southwest (MW-14) of the Site.

As discussed in OGI/ASI, Monitoring Well MW-15 was installed to determine if Cr^{+6} is migrating in ground water between Monitoring Wells MW-9 and MW-14. As shown in Plate 1, Cr^{+6} was not detected in the first sample collected from MW-15. The second sample collected indicated a concentration of 16 $\mu g/L$. These results indicate that Cr^{+6} above the water-quality standard of 50 $\mu g/L$ has not migrated offsite as far as MW-15.

Figure 3 depicts the modeled extent of Cr^{+6} in ground water downgradient of the Site based upon the measured concentration of Cr^{+6} in ground water in May and June 1993. The modeled extent was generated using the analytical transport model Random Walk (Prickett et al. 1981) according to the procedures outlined in Appendix A, and was used during chromium transport simulations. Moreover, the modeled extent enabled estimates of the mass of Cr^{+6} in the aquifer to be made.

Based upon the distribution of Cr^{+6} depicted in Figure 3, approximately 4 pounds of Cr^{+6} are present in ground water. Details regarding the mass calculation are presented in Appendix A.

3.0 ENVIRONMENTAL GEOCHEMISTRY OF HEXAVALENT CHROMIUM

Two primary chemical processes have been identified that affect the transport and fate of Cr^{+6} in ground water:

- reduction of Cr^{+6} to Cr^{+3} and subsequent removal from solution; and
- adsorption of Cr^{+6} on the aquifer matrix.

Physical processes that govern the fate and transport of Cr^{+6} include advection and hydrodynamic dispersion. The combined effects of the chemical and physical processes on the transport of Cr^{+6} is to reduce the concentrations in ground water relatively rapidly, thereby mitigating significant downgradient transport. The geochemical processes will be described below and then discussed in the context of the current distribution of Cr^{+6} in the aquifer downgradient of the Site.

3.1 Reduction of Cr^{+6} to Cr^{+3}

Numerous studies have concluded that under conditions of Eh (redox potential) and pH similar to those encountered in the aquifer beneath and downgradient of the Site (Eh ranging from 144 to 260 millivolts and pH ranging from 4.6 to 6.2 standard units; Table 2), Cr^{+6} is irreversibly reduced to Cr^{+3}. Since Cr^{+3} is relatively immobile in ground water (Eary and Rai 1987; and, Fendorf and Zasoski 1992), irreversible reduction results in removal from solution and cessation of transport.

Naturally-occurring reducing agents that may cause the reduction of Cr^{+6} to Cr^{+3} in an aquifer include ferrous iron (Fe^{+2}), in solution or in mineral phases, reduced sulfur compounds and dissolved organic matter (Palmer and Wittbrodt 1991; Rai et al., 1989; Eary and Rai 1991; and, Saleh et al., 1989). Relatively small amounts of Fe^{+2} contained in hematite and biotite minerals can rapidly reduce Cr^{+6} to Cr^{+3} (Eary and Rai 1991). The deposits that comprise the Upper Glacial aquifer beneath the Site contain iron-stained quartz and biotite, among other minerals and igneous and metamorphic rock fragments (Perlmutter and Geraghty 1963), thereby presenting sources of Fe^{+2} in the aquifer. Rai et al. (1989) concluded that due to the ubiquitous presence of Fe^{+2} and dissolved organic matter in most aquifers, Cr^{+6} will be reduced to Cr^{+3} in many natural ground-water systems. Saleh et al., (1989) indicates that Cr^{+3} is the most stable form of chromium under the redox conditions found in most natural systems.

The reduction of Cr^{+6} to Cr^{+3} is an irreversible process under conditions similar to those encountered beneath and downgradient of the Site. Only oxygen and manganese oxides have been identified as potential oxidizing agents for Cr^{+3}. However, oxygen does not react appreciably with Cr^{+3} (Palmer and Wittbrodt 1991; and, Rai et al., 1989). Manganese oxides have been shown experimentally to oxidize Cr^{+3} to Cr^{+6} (Eary and Rai 1987; and, Fendorf and Zasoski 1992). However, reduction of Cr^{+6} to Cr^{+3} is reported to occur at least ten times faster than oxidation of Cr^{+3} to Cr^{+6} (Saleh et al., 1989). Selim et al., (1989) reported the reduction of Cr^{+6} to Cr^{+3} by organic matter and Fe^{+2} to be irreversible; followed by precipitation of Cr^{+3} onto mineral surfaces or as hydrous Cr^{+3} oxides.

3.2 Adsorption of Cr^{+6}

Adsorption of Cr^{+6} from solution onto aquifer solids can retard the migration of Cr^{+6}. Hexavalent chromium, in the form of chromate (CrO_4^{-2}) may be adsorbed by aluminum- and iron-oxides on aquifer solids surfaces (Rai et al., 1989; Zachara et al., 1987; and, Selim et al., 1989). Iron-oxide coatings on Upper Glacial aquifer material have been reported to be an effective scavenger of chromium and cadmium (Ku et al., 1978).

Adsorption of Cr^{+6} is expected to increase with decreasing pH (Palmer and Wittbrodt 1991). In acidic to neutral water, iron oxides are the predominant adsorbing medium for chromate (Rai et al., 1989). The pH range for ground water in the aquifer beneath the Site was measured to be between 4.6 and 6.2 standard units during the off-site investigation (Roux Associates, 1993).

3.3 Geochemistry and Current Cr^{+6} Distribution

The Site data indicate that chemical reduction and sorption processes are limiting downgradient migration of Cr^{+6}. Evidence for the effect of these processes on the fate and transport of Cr^{+6} downgradient of the Site is discussed below.

The history of disposal practices at the Site indicates that chromium-containing wastes were discharged between 1956 and 1976 (Recra Environmental, Inc. 1992). Recent water-quality data for off-site monitoring wells suggest that the source is still active, probably due to dissolution of Cr^{+6} from soil beneath the source area via infiltrating precipitation and direct contact of contaminated soil with ground water. Therefore, it can be assumed that the Cr^{+6} source has been active for up to 37 years. Based upon measured ground-water flow rates of 1 ft/d and a 37-year time period, the calculated maximum potential migration distance is 13,500 feet. However, the data obtained during the off-site investigation indicate that low-level Cr^{+6} has migrated less than 500 feet downgradient of the Site. Moreover, concentrations of Cr^{+6} exceeding NYS Class GA Standards were observed no farther than 110 feet downgradient of the Site. This limited migration indicates that geochemical processes are removing Cr^{+6} from solution and preventing long-term migration from occurring.

As discussed in Section 3.1, the stable form of chromium in ground water is Cr^{+3}, which is relatively immobile. Figure 4 shows the Eh-pH diagram for aqueous chromium species. The Eh and pH ranges for ground water measured during the off-site investigation define the cross-hatched field superimposed on the diagram. As indicated in Figure 4, offsite ground-water conditions are in the stability field for Cr^{+3} in the form of $CrOH^{+2}$. Also as discussed in Section 3.1, the Upper Glacial aquifer contains Fe^{+2}, which is a naturally occurring reducing agent. Therefore, the geochemical conditions in the aquifer favor reduction of Cr^{+6} to Cr^{+3}.

Chromium analyses of aquifer sediment samples obtained from below the water table at the locations of Monitoring Wells MW-12 and MW-13 also provide evidence for reduction. At both locations the aquifer sediments had elevated total chromium concentrations (11.6 milligrams per kilogram [mg/kg] and 18.6 mg/kg, respectively) relative to background concentrations (approximately 5 mg/kg). However, only ten percent of the chromium on the aquifer sediments was in the form of Cr^{+6}. Moreover, 70 to 100 percent of the dissolved chromium at these locations was Cr^{+6}. Therefore, the source of elevated chromium concentrations on the aquifer sediments downgradient of the Site must be Cr^{+6} in solution that was reduced to Cr^{+3} and precipitated. This suggests that natural conditions in the aquifer are acting to prevent long-term downgradient migration of Cr^{+6}. Laboratory reports for the aquifer sediment samples are presented in the OGI/ASI (Roux Associates 1993).

Prior to reduction of Cr^{+6} to Cr^{+3}, there is evidence that adsorption retards the migration of Cr^{+6} downgradient of the Site. An estimate of the rate of migration of Cr^{+6} relative to the ground-water flow rate was obtained by determining the distribution coefficient (K_d) for Cr^{+6} between aquifer solids and in solution, and then calculating the retardation factor (R_f) for transport of Cr^{+6} in ground water. These calculations were performed for soil and ground-water samples obtained from Monitoring Wells MW-11 and MW-13 as described in Appendix B. The range in K_d obtained is 0.12 to 0.73 milliliters per gram (ml/g). These values of K_d yielded values of R_f ranging from 1.8 to 5.9. This suggests that prior to reduction to Cr^{+3} and permanent removal from solution, Cr^{+6} will travel between approximately one-half to one-sixth the rate of ground-water flow off-site. The site-specific range of R_f is comparable to a published R_f of 2 for Cr^{+6} in a sandy soil (Mehran 1991).

The current distribution of Cr^{+6} in ground water also reflects the recent trend of increasing concentrations at the Site. For example, concentrations of Cr^{+6} in on-site Monitoring Well MW-5 have increased from 282 μg/L in May 1992 to over 1,700 μg/L in April 1993. This suggests that concentrations of Cr^{+6} in ground water may reflect a relatively recent re-activation of the source. Site-specific water-level data indicate an eight-foot rise in water levels from 1988 to 1992. Since soil-quality data indicate that most of the impacted soil at Disposal Point DP-2 occurs at relatively shallow depths in the unsaturated zone, it is possible that ground water had not encountered significant soil Cr^{+6} until the water-table rose into what had previously been unsaturated sediments. Recent Site activities, such as the demolition of two Site storage buildings, may have also resulted in increased infiltration of precipitation through impacted sediments.

Despite recent increases in dissolved Cr^{+6} in ground water, the lack of long-term migration since the source has been active suggests that dissolved Cr^{+6} concentrations will decrease downgradient of the Site due to the combined effects of dispersion and the geochemical processes previously described.

4.0 REGIONAL GROUND-WATER USE

As part of the hydrogeologic investigation performed at the Site in 1992, Roux Associates performed a well search for all New York State Department of Environmental Conservation (NYSDEC) registered wells within one mile of the Site. The results of the well search are presented in Figure 5 and Table 3. In addition, Roux Associates has had discussions and written correspondence with Jamaica Water Supply Company (JWSC) personnel regarding ground-water quality and usage in the area. JWSC is the only public water supply company in the vicinity of the Site.

4.1 Private Water Supply Wells

Based upon a review of the well record search, there are 31 private water supply wells (i.e., non-JWSC) within one mile of the Site. Of these, 12 are located in the downgradient flow direction from the Site. However, none of the wells are located in the area impacted by Cr^{+6}. Five of the downgradient wells are reported to be screened in the Upper Glacial Aquifer (i.e., less than 90 feet deep). The reported purpose of the five Upper Glacial wells was for air conditioning cooling water. However, four of the wells are over 30 years old and one of the wells is over 40 years old; therefore, they may no longer be in service.

4.2 Public Water Supply Wells

Based upon a review of the results of the well search, three JWSC wells are located approximately 3,400 feet downgradient (i.e., to the west-southwest) of the Site at location 3 indicated in Figure 3. This location places the wells approximately 3,000 feet downgradient of the area impacted by Cr^{+6}. Well Q1535T was a test well that is now abandoned. Well Q1534 is screened from 78 to 98 feet below land surface in the Upper Glacial Aquifer. Well Q1629 is screened from 236 to 276 feet below land surface in the Magothy Formation.

Based upon discussions with JWSC personnel, and the results of the Brooklyn/Queens Aquifer Study (O'Brien & Gere 1987), Well Q1534 has been inactive since the early 1980s due to contamination by organic compounds unrelated to the Site, including chloroform, tetrachloroethylene and trichloroethylene. JWSC personnel have indicated that there are no current plans for using Well Q1534 for water supply in the foreseeable future (Dydland, personal communication 1993).

Well Q1629 is a peak demand well that is only used during emergency peak demand situations (i.e., long, hot, dry spells, or fire hydrant supply). Moreover, Well Q1629 is the last well that would be turned on in a peak demand situation (Dydland, personal communication 1993). Well Q1629 was last used for a short time in 1991. It was not used in 1990, 1992 and 1993. Its use has been described as very intermittent (Dydland, personal communication 1993).

4.3 Regional Ground-Water Quality

The Brooklyn/Queens Aquifer Study (O'Brien & Gere Engineers, Inc. 1987) provided a survey of ground-water quality for the Upper Glacial aquifer in Queens. In the study, it was reported that by 1983, 12 JWSC wells in the Upper Glacial aquifer had to be closed due to contamination by organic compounds. Half of these wells were located along the Queens/Nassau county border. It was assumed in the study that the organic contamination represented regional degradation of ground-water quality due to impacts from multiple sources. During a 1984 sampling program for the study, the presence of volatile organic compounds (VOCs) was detected in 46 out of 50 wells sampled. JWSC Well Q1534 was closed in the 1980s due to this contamination. Due to these regional degradation problems, there are no plans in the foreseeable future for the JWSC to develop new potable supply wells from the Upper Glacial aquifer (Dydland, Personal Communication 1993).

4.4 Administrative Controls on Regional Ground-Water Use

According to the Building Code of New York City (Title 27, Chapter 1, Subchapter 16, 27-896[f]), wells for water supply cannot be installed in New York City without the approval of the New York City Department of Health (NYCDOH) or the New York City Department of Environmental Protection (NYCDEP). Moreover, based upon a May 6, 1993 telephone conversation with Mr. Jim Lahrman of the NYCDOH, potable wells are no longer allowed to be installed in New York City (Lahrman, Personal Communication 1993). All potable water supplies in the City must be obtained from street mains where available (Title 27, Chapter 16, 27-906[a]). Therefore, there are administrative controls in place to prevent the development of potable water supplies downgradient of the Site.

5.0 POTENTIAL FOR IMPACT OF Cr^{+6} ON JWSC WELLS

Roux Associates has performed an assessment of the potential for existing Cr^{+6} in ground water to impact the nearest downgradient JWSC wells. JWSC public supply wells (Q1534 and Q1629) are located 3,400 feet west-southwest of the Site (Figure 5). Well Q1534 is screened from 78 to 98 feet below land surface and has been closed since the early 1980s due to regional degradation of water quality in the Upper Glacial aquifer. Well Q1629 is screened from 236 to 276 feet below land surface in the Magothy aquifer.

Roux Associates performed analytical transport modeling using Random-Walk (Appendix A) to assess the worst-case potential for impact of existing Cr^{+6} on the JWSC wells. Figure 3 represents the current extent of the existing Cr^{+6} in ground water. Random-Walk was used to simulate migration of the existing Cr^{+6} following remediation of the source as proposed in the FFS. A summary of the hydraulic parameters used in the simulation is provided in Appendix A. To ensure a worst-case estimate was obtained, the model did not consider reduction of Cr^{+6} to Cr^{+3} as a geochemical control on migration. In addition, the minimum site-specific retardation factor (calculated as discussed in Section 3.3), of 1.8 was used. The model was run for a simulated time period of 17 years, which represents the approximate length of time for the center of mass of existing Cr^{+6} to travel the 3,400 feet to the JWSC wells.

The results of the long-term transport model suggest that by the time it would take the Cr^{+6} to travel to the vicinity of the JWSC wells, dispersion will have reduced the maximum concentration of Cr^{+6} to less than 20 μg/L.

Based upon the above assessment, there is no potential for impact of Cr^{+6} from the Site on JWSC wells for the following reasons:

- there has been no significant downgradient migration of Cr^{+6} in the 37 years since Cr-containing wastes were first discharged at the Site;
- the source will be remediated, eliminating the potential for continued supply of Cr^{+6} to ground water;

- transport modeling suggests that even without the expected reduction of Cr^{+6} to Cr^{+3}, dispersion would reduce the maximum concentration of Cr^{+6} to below NYS Class GA Standards in the vicinity of the JWSC wells; and

- The Cr^{+6} would reside in the upper portion of the Upper Glacial aquifer, which is not used for water supply. The only active well is screened from 236 to 276 feet below land surface in the Magothy aquifer.

6.0 IDENTIFICATION AND EVALUATION OF REMEDIAL ALTERNATIVES

As summarized in Table 2 and Plate 1, ground water beneath and downgradient of the Site contains Cr^{+6}, lead and copper at concentrations exceeding NYS Class GA Standards. To facilitate the identification and evaluation of alternatives for ground water, the following remedial action objectives were established:

- protect public health and the environment by ensuring that ground water containing Cr^{+6}, lead and copper at concentrations exceeding NYS Class GA Standards does not migrate to potential receptors; and
- restore ground water impacted by the Site to concentrations that satisfy NYS Class GA Standards.

The identification and evaluation of source control alternatives are described in the FFS (Golder Associates 1993). The identification and evaluation of alternatives considered to address the remedial action objectives for ground water are described below.

6.1 Identification of Alternatives

The remedial alternatives evaluated for ground water are as follow:

1. No Action;

2. Natural Attenuation with Monitoring;

3a. Ground-Water Extraction at Leading Edge of Plume and Discharge to Sewer;

3b. Ground-Water Extraction at Leading Edge of Plume, Treatment, and Discharge to Sewer;

3c. Ground-Water Extraction at Leading Edge of Plume, Treatment, and Discharge to Ground Water;

4a. Ground-Water Extraction at Leading Edge of Plume and Onsite, and Discharge to Sewer;

4b. Ground-Water Extraction at Leading Edge of Plume and Onsite, Treatment, and Discharge to Sewer;

4c. Ground-Water Extraction at Leading Edge of Plume and Onsite, Treatment, and Discharge to Ground Water; and

5a. Ground-Water Extraction Onsite and Discharge to Sewer;

5b. Ground-Water Extraction Onsite, Treatment and Discharge to Sewer;

5c. Ground-Water Extraction Onsite, Treatment, and Discharge to Ground Water; and

6. Enhanced In-Situ Reduction.

Note that for the remedial alternatives which involve pumping (Alternatives 3 through 5), the extraction well locations were selected based upon land availability constraints. Discussions with the owner of the property west of the Site indicate that access to the property is not available in an expeditious manner. In addition, physical access to install an extraction well on the Long Island Railroad right-of-way is precluded by a 5-foot retaining wall, and then a steep grade up to tracks. Because of these constraints, the extraction well locations for alternatives evaluated in the FFS Addendum are limited to a location downgradient of the Long Island Railroad right-of-way, and an on-site location.

A description of each remedial alternative is provided below.

Alternative 1: No Action

Under this alternative no action would be taken with respect to ground water. As described in the FFS, a ground-water monitoring program is planned to monitor the effectiveness of the source control action in preventing continued impact to off-site ground water. However, this monitoring program will be limited to areas immediately downgradient of the Site, and will not include monitoring potential migration of impacted ground water farther downgradient.

Alternative 2: Natural Attenuation with Monitoring

Under this alternative natural attenuation would be relied upon to reduce the concentrations of constituents of concern in ground water to concentrations that satisfy NYS Class GA Standards, and to prevent migration of impacted ground water to potential receptors (i.e., JWSC wells). As described in Section 3.0, geochemical conditions in the aquifer are conducive to in-situ reduction of Cr^{+6} to Cr^{+3}, which in turn will be removed from solution by precipitation or sorption processes. In addition, natural attenuation via dispersion within the aquifer will further reduce constituent concentrations in ground water during migration.

The effectiveness of natural attenuation would be monitored bi-annually using existing monitoring wells that define the extent of impacted ground water. The ground-water monitoring data would be evaluated on an annual basis to determine the effectiveness of the source control in preventing future ground-water impacts; and to determine the effectiveness of natural attenuation in controlling migration of Cr^{+6}.

Alternative 3a: Ground-Water Extraction at Leading Edge of Plume and Discharge to Sewer

Under this alternative, ground water would be extracted from the leading edge of the plume (i.e., at MW-15) and discharged directly to the municipal sewer in the vicinity of the well head. The ground-water extraction rate required to hydraulically capture the plume with a well located at MW-15 was calculated to be approximately 21 gallons per minute (gpm). This rate is based upon the distribution of Cr^{+6} depicted in Figure 3 and the site-specific aquifer parameters determined during the RI. Supporting calculations are provided in Appendix A.

In addition to performing the capture zone calculations described in Appendix A, the numerical model Flowpath was used to simulate the effects of a pumping well at the leading edge of the plume. Flowpath is a two-dimensional steady-state ground-water flow model for the calculation of hydraulic heads, ground-water velocities, pathlines, and capture zones.

Figure A-2 (Appendix A) depicts the capture zone anticipated from a pumping well located at the leading edge of the contaminant plume, along with the modeled extent of Cr^{+6} in ground water. The modeling results show that the 21 gpm pumping rate should be sufficient to capture the plume.

The effectiveness of this alternative, and all remaining alternatives (i.e., Alternatives 3b, 3c, 4a - 4c, 5a - 5c and 6), in achieving remedial action objectives would be monitored biannually using those monitoring wells which define the extent of impacted ground water. A Site status report would be prepared on an annual basis to document the results of the monitoring program.

Alternative 3b: Ground-Water Extraction at Leading Edge of Plume, Treatment, and Discharge to Sewer

Under this alternative ground-water extraction would proceed as described in Alternative 3a. The extracted ground water would be pumped through a force main back to the Site and treated using physicochemical treatment methods to reduce concentrations of Cr^{+6} to below 50 μg/L prior to discharge to the sewer.

Figure 6 depicts the process train that would be utilized to achieve the necessary reduction in Cr^{+6} concentrations, and other constituents that may be present in the extracted ground water. The main components of the system (in process sequence) include:

- addition of acid and ferrous sulfate to reduce pH to cause reduction of Cr^{+6} to Cr^{+3};
- addition of caustic to raise pH and precipitate metal hydroxides, and addition of polymer to enhance flocculation;
- clarification and filtration to remove solids; and
- final pH adjustment.

As indicated in Figure 6, sludge generated during the treatment process would be passed through a filter press and sent offsite for disposal.

Alternative 3c: Ground-Water Extraction at Leading Edge of Plume, Treatment, and Discharge to Ground Water

Under this alternative ground-water extraction and treatment would proceed as described in Alternative 3b, with the addition of carbon adsorption polishing to remove any organics that may be present due to regional ground-water degradation. The treated water would then be injected back to the aquifer through a recharge well located as shown in Figure A-3 (Appendix A). Flowpath was used to evaluate the potential effect of the recharge well on the capture zone. The modeling results indicate that the recharge well will not adversely affect capture of the contaminants migrating from the Site (Figure A-3).

Alternative 4a: Ground-Water Extraction at Leading Edge of Plume and Onsite, and Discharge to Sewer

Under this alternative ground water would be extracted from the leading edge of the plume (i.e., MW-15) and onsite from the area where the highest concentrations of Cr^{+6} have been detected (i.e., MW-5 and MW-7). The extracted ground water from the leading edge would be discharged directly to the municipal sewer in the vicinity of the well head, while the water extracted from the on-site well would be discharged into the existing Site connection to the municipal sewer. The well located onsite would pump approximately 14 gpm and capture ground water currently containing the highest concentrations of Cr^{+6}. Following source remediation the on-site well would also capture any residual Cr^{+6} migrating from the Site. The portion of the plume that is currently further downgradient from the Site would be captured by the well located at Monitoring Well MW-15 pumping at approximately 21 gpm.

The pumping rates described above are based upon the distribution of Cr^{+6} depicted in Figure 3 and the site-specific aquifer parameters determined during the RI. Supporting calculations are provided in Appendix A. Flowpath was also used to simulate the effects of pumping wells at both the leading edge of the plume and immediately downgradient of the Site. The results indicate that the two pumping wells at the locations shown will effectively capture the plume (Figure A-4).

Alternative 4b: Ground-Water Extraction at Leading Edge of Plume and Onsite, Treatment and Discharge to Sewer

Under this alternative ground-water extraction would proceed as described in Alternative 4a. The extracted ground water would be pumped through a force main back to the Site and treated using physicochemical treatment methods identical to those described in Alternative 3b. System components would be sized accordingly for the increased flow rate.

Alternative 4c: **Ground-Water Extraction at Leading Edge of Plume and Onsite, Treatment, and Discharge to Ground Water**

Under this alternative ground-water extraction and treatment would proceed as described in Alternative 4b, with the addition of carbon adsorption polishing. The treated water would then be injected back to the aquifer through two recharge wells located as shown in Figure A-5 (note that the two recharge wells are represented by one grid node). Flowpath was used to evaluate the potential effect of the recharge wells on the capture zone. The modeling results indicate that the recharge wells will not adversely affect capture of the contaminants migrating from the Site (Figure A-5).

Alternative 5a: **Ground-Water Extraction Onsite and Discharge to Sewer**

Under this alternative ground water would be extracted onsite from the area where the highest concentrations of Cr^{+6} have been detected (i.e., MW-5 and MW-7). The pumping rate for the extraction well in this alternative was increased to 30 gpm, relative to the 14 gpm for the on-site extraction well in Alternative 4. The rate was increased to expand the downgradient extent of the capture zone, thereby enabling capture of a greater amount of Cr^{+6} while pumping from only the on-site location.

The extraction well in this alternative would capture ground water currently containing the highest concentrations of Cr^{+6}, and following source remediation would also capture any residual Cr^{+6} migrating from the Site. The portion of the plume that is currently further downgradient from the Site would be addressed via natural attenuation.

The pumping rate described above is based upon the distribution of Cr^{+6} depicted in Figure 3 and site-specific aquifer parameters determined during the RI. Flowpath was used to simulate the effects of an extraction well at the location indicated in Figure A-6. The results of the steady-state simulation indicate that an extraction well pumping 30 gpm at the location shown will remove approximately 40 percent of the mass of Cr^{+6} in the aquifer and prevent future impacts of the Site on downgradient ground water (Figure A-6). Supporting details are provided in Appendix A.

Alternative 5b: Ground-Water Extraction Onsite, Treatment and Discharge to Sewer

Under this alternative ground-water extraction would proceed as described in Alternative 5a (Figure A-6). The extracted ground water would be treated onsite using physicochemical treatment methods identical to those described in Alternative 3b. Following treatment the water would be discharged through the existing Site connection to the municipal sewer.

Alternative 5c: Ground-Water Extraction Onsite, Treatment, and Discharge to Ground Water

Under this alternative ground-water extraction and treatment would proceed as described in Alternative 5b, with the addition of carbon adsorption polishing. The treated water would then be injected back to the aquifer through one recharge well located as shown in Figure A-7. Flowpath was used to evaluate the potential effect of the recharge well on the capture zone. The modeling results indicate that the recharge well will not adversely affect capture of the contaminants migrating from the Site (Figure A-7).

Alternative 6: Enhanced In-Situ Reduction

Under this alternative water containing a reducing agent would be injected into the portion of the aquifer impacted by Cr^{+6} in an attempt to enhance the natural processes that are currently limiting migration of the Cr^{+6} downgradient of the Site. The reducing agent could be injected at the leading edge of the plume, onsite, or at both locations. The reducing agents could be an organic material, iron or sulfur, or a combination of agents.

Based upon a preliminary evaluation of the viability of this alternative, the following concerns were identified:

- the technical feasibility of mixing the reducing agents throughout the impacted ground water;
- injecting liquids into or downgradient of the impacted ground water will create a ground-water mound and result in hydraulic spreading of the contaminant plume;
- reducing agents injected into the ground may precipitate or cause precipitation of other naturally occurring metals (i.e., iron), thereby clogging the aquifer and causing operational problems; and
- administrative feasibility (permitting requirements) associated with injecting chemicals into the aquifer.

Due to the concerns regarding implementability and effectiveness described above, enhanced in-situ reduction (Alternative 6) was not retained for further evaluation.

6.2 Evaluation of Alternatives

As required by NYSDEC regulations (6 NYCRR Part 275), each of the remaining alternatives was evaluated with respect to the following criteria:

- compliance with Standards, Criteria and Guidelines (SCGs);
- overall protectiveness of public health and the environment;
- short-term effectiveness;
- long-term effectiveness;
- reduction of toxicity, mobility and volume;
- implementability; and
- cost.

A description of each of these criteria can be found in the FFS for source control. The evaluation of remedial alternatives for ground water with respect to the criteria is presented below.

6.2.1 Compliance with SCGs

Table 4 identifies the federal, state and local SCGs that apply to the alternatives for ground water. Table 5 summarizes the assessment of each alternative with respect to the identified SCGs. All alternatives will satisfy the chemical specific SCGs for Site related constituents in ground water (6 NYCRR Part 703) and drinking water (10 NYCRR Part 5), which are the primary remedial action objectives for ground water. Chemical specific SCGs related to discharge of extracted ground water or treatment residues will also be satisfied. Action and location specific SCGs will also be satisfied as applicable for each alternative.

6.2.2 Protection of Public Health and the Environment

Based upon the analysis in Section 5.0, there is no potential for Cr^{+6} in ground water impacted by the Site to migrate to JWSC wells at concentrations exceeding NYS Class GA Ground-Water Quality Standards. There are no private wells located downgradient of the

Site that are threatened by any potential migration of impacted ground water. In addition, there are institutional controls that preclude the installation of private wells for potable purposes downgradient of the Site. Therefore, based upon the available data, the no action alternative (Alternative 1) is protective of public health under existing ground-water use conditions and potential future use conditions.

The other alternatives (Alternatives 2 through 5) provide a greater degree of assurance of protection of public health due to use of either monitoring to document the effectiveness of natural attenuation, or pumping to hydraulically capture impacted ground water.

Given the depth to the impacted ground water, and the absence of any surface water receptors, all of the alternatives are protective of the environment.

6.2.3 Short-Term Effectiveness

Under the no action alternative, it is conservatively estimated that ground water downgradient of the Site should attain NYS Class GA standards within ten years following source remediation. This estimate is based upon the analytical transport modeling described in Appendix A. As described in Appendix A, the modeling was conservative because the reduction of Cr^{+6} to Cr^{+3}, which will occur downgradient of the Site and accelerate the decline of Cr^{+6} concentrations in ground water downgradient of the Site was not considered.

In general, the pumping alternatives will attain NYS Class GA Standards within a shorter timeframe than the no action alternative. However, the short-term effectiveness of installing a pumping well at the leading edge of the plume (Alternatives 3 - 4) is considered low for the following reasons.

- Ground water in the area of MW-15 is currently within NYS Class GA Standards. Therefore, ground water pumped from this area will be "clean." In fact, ground water at MW-15 may never exceed NYS Class GA Standards due to geochemical controls on Cr^{+6} migration. Pumping at this location may have the adverse affect of increasing the hydraulic gradient in the aquifer and causing the migration of higher concentrations of Cr^{+6} into previously unimpacted areas.

- Installing a pumping system at the leading edge of the plume will require significant time to implement due the need to establish a Revocable Consent agreement with New York City. Revocable Consent is the approval required to install subsurface structures and piping on New York City property. Based upon our experience, the estimated minimum time period for the Revocable Consent review and approval process is one year. The one year process includes preparation of the Revocable Consent petition by Pfizer, extensive review and comment on the petition by New York City (NYC), a public hearing and comment period, and drafting and executing the Revocable Consent lease agreement between Pfizer and NYC.

- The location of a well at the leading edge of the plume is on a narrow street in a residential area. During construction there would be short-term impacts to residents due to presence of drill rigs, backhoes, and support trucks; temporary road closing; driveway interferences; and, construction noise.
- Conveying extracted ground water from the leading edge of the plume back to the Site for treatment would require obtaining approval to construct a force main through Long Island Rail Road LIRR and/or New York City property, additional time for construction, and related short-term community impacts (e.g., road construction).

In contrast to pumping at the leading edge, a well located onsite (Alternative 5) has high potential for short-term effectiveness for the following reasons.

- The extraction well located onsite is in the area where Cr^{+6} concentrations are highest. Therefore, pumping from this area will result in the capture and extraction of the ground water containing the highest concentrations of Cr^{+6}.
- The extraction well located onsite does not require access agreements with outside parties. In addition, Pfizer has already received written approval from the NYCDEP regarding the conceptual plan to discharge untreated water into the sewer (Farag 1993). NYCDEP's approval of the conceptual plan was based upon their review of the ground-water quality data for the Site. Their review confirmed that constituent concentrations do not exceed permissible limits for discharge to the sewer (5,000 $\mu g/L$ for Cr^{+6}). Specific details, including final well location and indemnification need to be finalized. Therefore, it is expected that this alternative can be implemented quickly. Following implementation this alternative will capture any chromium released from the Site prior to completion of the source remediation.
- There would be no impacts to residential areas during construction and operation of this alternative.

Those alternatives that involve treatment (Alternatives 3b, 3c, 4b, 4c, 5b and 5c) will require additional time to implement due to treatability testing, design and construction requirements.

6.2.4 Long-Term Effectiveness and Permanence

As previously described, all alternatives will result in the restoration of ground water to NYS Class GA Standards (for Site related constituents) in the aquifer downgradient of the Site. For all alternatives this effectiveness (i.e, attaining NYS Class GA Standards) will be permanent due to the elimination of the source as described in the FFS. Therefore, no continued long-term monitoring will be required once remedial action objectives have been achieved.

6.2.5 Reduction of Toxicity, Mobility and Volume

Alternatives 1 and 2 will reduce the toxicity, mobility and volume of impacted ground water due to the natural chemical reduction of Cr^{+6} to Cr^{+3} in the aquifer. As previously described, Cr^{+6} is considered toxic and mobile, while Cr^{+3} is less toxic and relatively immobile. As a result of Cr^{+6} reduction, the volume of impacted ground water will decrease over time, until all ground water satisfies NYS Class GA Standards. Given the geochemical conditions within the aquifer, the reduction of Cr^{+6} to Cr^{+3} should be irreversible.

Alternatives 3 through 5 will reduce mobility and volume via hydraulic capture and extraction of impacted ground water. Capture zones propagated under Alternative 3 and 4 will intercept greater than 98 percent of the impacted ground water.

The capture zone propagated by Alternative 5 will intercept a minimum of 40 percent of the impacted ground water. Reduction of toxicity, mobility and volume of the remaining 60 percent of impacted ground water will occur due to the natural chemical reduction of Cr^{+6} to Cr^{+3} in the aquifer as described previously.

Alternatives 3b, 3c, 4b, 4c, 5b and 5c utilize above-ground treatment to remove chromium from the ground water, resulting in a reduction of toxicity of the extracted ground water prior to discharge. This chromium is then concentrated in a sludge, that will require off-site disposal. The sludge may be considered a hazardous waste depending upon waste characterization testing. For the alternatives that discharge directly to the sewer without treatment, it is anticipated that the strong reducing conditions of the sewer (i.e., high organic carbon content) will quickly reduce the Cr^{+6} to Cr^{+3}, resulting in a reduction of toxicity without the generation of an additional waste stream.

6.2.6 Implementability

Given the complete elimination of the source as described in the FFS, all of the alternatives are expected to be very reliable in achieving the remedial action objectives, without any future remedial action being necessary.

Alternatives 1 and 2 are the easiest alternatives to implement from both the administrative and technical feasibility perspectives.

Alternatives 3 and 4 will require obtaining Revocable Consent from New York City prior to implementation. Due to the duration of the Revocable Consent process described in Section 6.2.3, there would be potential for regulatory changes (e.g., changes in effluent standards) which would have adverse impacts on the implementability of the discharge to sewer alternatives (Alternatives 3a and 4a).

Only Alternatives 3b, 3c, 4b and 4c are considered difficult to construct. These alternatives require installation of a force main from the area of the MW-15 back to the Site, and construction of a treatment system. Due to the presence of the LIRR and/or extensive work required on NYC streets, these alternatives are considered more difficult from a technical feasibility perspective. Access agreements would be required with LIRR, and Revocable Consent will be required from New York City. The construction on LIRR property will be within 50 feet of the tracks, requiring extensive coordination with LIRR. In addition, construction in New York City streets is typically difficult due to the uncertainties regarding locations of utilities (current and abandoned), lateral building connections, and unanticipated structures.

Within the New York City area there are vendors who can supply the technologies, materials, equipment and services required to implement each alternative.

6.2.7 Cost

The capital cost, operation and maintenance cost, and total present net worth of each alternative are summarized in Table 6. A more detailed breakdown of the cost estimates is provided in Appendix C.

The cost analysis indicates that natural attenuation with monitoring (Alternative 2) will cost approximately $399,000.

Alternatives 3a and 5a (ground-water extraction with one well, and discharge to sewer) have a net present worth of $660,000 and $684,000, respectively. Alternative 4a (ground-water extraction with two wells, and discharge to sewer) has a net present worth of approximately $795,000.

The alternatives involving ground-water extraction and treatment range in cost from approximately $1,586,000 to $1,807,000.

7.0 CONCLUSIONS AND RECOMMENDATIONS

The data collected during the off-site investigation indicate that reduction of Cr^{+6} to Cr^{+3}, and subsequent removal from solution, is preventing significant downgradient migration of chromium in ground water. Once the source has been remediated as described in the FFS, concentrations of Cr^{+6} in off-site ground water will gradually decrease to levels in compliance with NYS drinking water standards without any potential for transport and impact to off-site receptors (i.e., JWSC wells).

Based upon these findings, Alternative 2: Natural Attenuation with Monitoring is sufficient to attain remedial action objectives for ground water for the following reasons:

- existing Cr^{+6} impacts in off-site ground water do not threaten public water supplies or any off-site receptors;
- removal of the source as described in the FFS will prevent future impacts to ground water;
- natural attenuation will result in remediation of ground water via reduction of Cr^{+6} to Cr^{+3}, and dispersion;
- ground-water monitoring would be continued to confirm that there is no significant downgradient migration of Cr^{+6}, and track the decrease in concentration of Cr^{+6} in ground water following source remediation; and
- regional degradation of ground-water quality precludes using the Upper Glacial aquifer in Queens as a potable water resource in the foreseeable future.

7.1 Remedial Action Recommendation

Although the technical data indicate that Alternative 2 is sufficient to achieve remedial action objectives, Alternative 5a (Ground-Water Extraction Immediately Downgradient of Site and Discharge to Sewer) is recommended. The reasons for this recommendation are as follow:

- It is expected that Alternative 5a can be implemented quickly, prior to source remediation. Quick implementation will provide hydraulic capture to address the recent trend of increasing concentrations of Cr^{+6} observed beneath the Site (e.g., MW-5), and prevent any further migration of ground water known to contain the high concentrations of Cr^{+6} (e.g., at concentrations detected in Monitoring Wells MW-5, MW-7, MW-10, MW-11, and MW-12). All Cr^{+6} input to ground water prior to the completion of the source remediation would also be captured.

- It is estimated that at least 40 percent of the Cr^{+6} currently in the aquifer would be captured. The remaining Cr^{+6} will not threaten any off-site receptors and will be addressed through natural attenuation via reduction to Cr^{+3} and dispersion.

- Relative to Alternative 2, Alternative 5a represents an incremental cost increase of $285,000.

- Relative to Alternative 2, alternatives involving ground-water extraction and treatment represent an incremental cost increase ranging from $1,187,000 to $1,408,000, and are not necessary to achieve remedial action objectives.

- Alternatives involving ground-water extraction from the leading edge of the plume will have limited effectiveness, may be difficult to implement, and may adversely affect clean portions of the aquifer as previously described in Section 6.2.

7.2 Proposed Remediation System Description

The proposed locations of remediation system components for Alternative 5a are depicted in Figure 7. The extraction well will be located in the southwest corner of the Site near Monitoring Well MW-5, and as close as possible to the western Site boundary. The pump controls, flow meter and sampling port will be located in the northwest corner of the Site. The extracted ground water will be routed around the existing building through a force main, and discharged to the municipal sewer via the existing building connection.

The ground water model developed for the Site (Appendix A) was used to assess the remediation of Cr^{+6} in ground water in response to pumping at the proposed extraction well location. As described in Section 6.1, the simulated pumping rate for the well was 30 gpm. The model was run for a period of two years in one-year increments.

The results of the modeling indicate that within one year following source remediation, 92 percent of the Cr^{+6} that is within the capture zone of the extraction well will be removed. After two years of pumping, 97 percent of the Cr^{+6} that is within the capture zone of the on-site extraction well will be removed. The actual time to remediate may vary from that predicted due to the inability of the model to account for all processes and site-specific conditions which may affect aquifer cleanup at the Site. For example, the model does not consider chemical reduction of Cr^{+6} to Cr^{+3}; aquifer heterogeneities (i.e., spatial variation in hydraulic conductivity); potential for residual source impacts; and potential impacts of regional ground-water degradation. In addition, experience with ground-water remediation indicates that following initiation of pumping there is a rapid decrease in constituent concentrations, followed by a leveling off to an asymptotic concentration. If this occurs at the Site it may not be cost-effective or feasible to achieve standards by continued pumping. Therefore, the actual duration of pumping will be based upon an evaluation of the ground-water quality data with respect to NYS Class GA Standards, and assessment of the cost-effectiveness of continued pumping.

Sampling for ground-water quality will be performed bi-annually (i.e., spring and fall) for the duration of the remedial action. A report will be submitted on an annual basis to summarize the ground-water quality data, and evaluate the effectiveness of the remediation system and need for continued operation. The annual report will also evaluate the effectiveness of natural attenuation in controlling migration of Cr^{+6} not captured by the extraction well.

Respectfully Submitted,

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TABLES

Table 1. Ground-Water Elevation Data Collected by Roux Associates, Inc. on June 29, 1993, 96-20 222nd Street, Queens Village, New York

Monitoring Well Designation	Measuring Point Elevation (ft above msl)	Depth to Water (ft below mp)	Water-Level Elevation (ft above msl)
MW-1	75.56	52.92	22.64
MW-2	75.23	52.58	22.65
MW-3	75.39	52.85	22.54
MW-4	74.99	52.20	22.79
MW-5	73.94	51.31	22.63
MW-6	75.52	52.87	22.65
MW-7	75.94	53.34	22.60
MW-8	75.47	53.03	22.44
MW-8D	75.72	53.27	22.45
MW-9	75.58	53.18	22.40
MW-9D	75.57	53.17	22.40
MW-10	76.78	54.18	22.60
MW-11	76.80	54.14	22.66
MW-12	75.70	53.12	22.58
MW-13	75.39	52.89	22.50
MW-14	73.77	51.41	22.36
MW-15	75.25	53.30	21.95

ft - feet
msl - mean sea level
mp - measuring point

Table 2. Summary of Analytical Results for Ground-Water Samples Collected by Roux Associates, Inc. During January through June 1993, 96-20 222nd Street, Queens Village, New York

Sample Designation: Sample Date:	MW-01 1/20/93	MW-01 4/13/93	MW-02 1/20/93	MW-02 4/13/93	MW-03 1/20/93	MW-03 4/13/93	MW-04 1/20/93	MW-04 4/13/93	MW-05 1/20/93	MW-05R 1/20/93	MW-05 4/13/93	Ground-Water Standards
Copper	10 U	11 **B**	35	10 **B**	10 U	10 U	21 **B**	10 U	45	50	19 **B**	200
Lead	3 U	5 **J**	24 **J**	4 **J**	13 **J**	3 **UJ**	15 **J**	3 **UJ**	9 **J**	9 **J**	3 **UJ**	25
Total Chromium	10 U	10 U	46	25 **U**	10 U	10 U	14	10 **U**	829	878	1930	50
Iron	50 U	NS	50 **B**	NS	50 **B**	NS	60 **B**	NS	50 **B**	60 **B**	NS	300
Hexavalent Chromium	10 **UJ**	10 U	36 **J**	17	10 **UJ**	10 U	10 **J**	10 U	737 **J**	825 **J**	1730	50
Total Phosphorous	20 U	20 U	480 **J**	720	20 U	20 U	150 **J**	20 U	1100 **J**	1000 **J**	1400	NA
Eh	194.8	180.0	169.2	210.0	172.5	190.0	185.7	180.0	182.5	182.5	215.0	NA
pH	5.70	4.80	5.68	5.70	5.71	5.40	5.80	5.20	5.76	5.76	6.04	NA

NOTES: Analytical results and standards reported in micrograms per liter except for Eh which is in millivolts, and pH which is in standard units
Bold qualifier represents Data Validator's qualifier
Unbold qualifier represents Laboratory Validator's qualifier

R - Replicate sample
U - Analyte not detected at or below the Contract Required Detection Limit, or the compound is not detected due to qualification through the method or field blank
B - Value greater than or equal to the Instrument Detection Limit but less than the Contract Required Detection Limit
J - Analyte present, reported value is estimated
UJ - Analyte not present, sample quantitation limit is estimated
NA - No standard
NS - No sample collected

Ground-water standards obtained from New York Codes, Rules, and Regulations, Title 6, Part 703.5.

Table 2. Summary of Analytical Results for Ground-Water Samples Collected by Roux Associates, Inc. During January through June 1993, 96-20 222nd Street, Queens Village, New York

Sample Designation: Sample Date:	MW-06 1/20/93	MW-06 4/13/93	MW-07 1/20/93	MW-07 2/3/93	MW-07R 2/3/93	MW-07 3/2/93	MW-07 4/13/93	MW-07R 4/13/93	MW-08 1/20/93	MW-08 2/3/93	MW-08 4/13/93	Ground-Water Standards
Copper	10 **B**	10 U	394	250	272	282	254	270	96	46	18 **B**	200
Lead	5 **J**	3 **UJ**	150 J	75	83	86.5 **J**	23 **J**	32 **J**	NS	NS	13 **J**	25
Total Chromium	46	28 **U**	1240	1050 **J**	1120 **J**	1190	2100	2170	55	27 **J**	14 U	50
Iron	70 **B**	NS	170	90 **B**	60 **B**	60 **J**	50 U	50 U	50 U	50 U	50 U	300
Hexavalent Chromium	29 **J**	27	1070 J	960 **J**	977 **J**	1190 **J**	2020	1790	15 **J**	10 **J**	10 U	50
Total Phosphorous	54 **J**	20 U	6800 J	5400	5400	4300	3400	1700	NS	NS	NS	NA
Eh	172.3	215.0	215.6	205.8	205.8	215.9	230.0	230.0	178.3	174.4	215.0	NA
pH	5.75	5.90	5.58	5.58	5.58	5.56	5.00	5.00	6.05	6.00	5.80	NA

NOTES: Analytical results and standards reported in micrograms per liter except for Eh which is in millivolts, and pH which is in standard units
Bold qualifier represents Data Validator's qualifier
Unbold qualifier represents Laboratory Validator's qualifier

R - Replicate sample
U - Analyte not detected at or below the Contract Required Detection Limit, or the compound is not detected due to qualification through the method or field blank
B - Value greater than or equal to the Instrument Detection Limit but less than the Contract Required Detection Limit
J - Analyte present, reported value is estimated
UJ - Analyte not present, sample quantitation limit is estimated
NA - No standard
NS - No sample collected

Ground-water standards obtained from New York Codes, Rules, and Regulations, Title 6, Part 703.5.

Table 2. Summary of Analytical Results for Ground-Water Samples Collected by Roux Associates, Inc. During January through June 1993, 96-20 222nd Street, Queens Village, New York

Sample Designation: Sample Date:	MW-08D 1/20/93	MW-08D 2/3/93	MW-08D 4/13/93	MW-09 1/20/93	MW-09 2/3/93	MW-09 4/13/93	MW-09D 1/20/93	MW-09D 2/3/93	MW-09D 4/13/93	MW-10 3/2/93	MW-10R 3/2/93	Ground-Water Standards
Copper	10 U	10 U	10 U	26	21 **B**	10 U	10 U	10 U	10 U	580	566	200
Lead	NS	NS	3 **UJ**	NS	NS	3 **UJ**	NS	NS	3 **UJ**	220	210	25
Total Chromium	10 U	10 U	10 U	23	11 **J**	10 **U**	10 U	10 U	11 **U**	1620	1480	50
Iron	60 **B**	50 U	50 U	100	250	50 U	50 **B**	50 U	50 U	1380 **J**	120 **J**	300
Hexavalent Chromium	10 **UJ**	10 **UJ**	10 U	10 **UJ**	10 **UJ**	10 U	10 **UJ**	10 **UJ**	10 U	1410 **J**	1060 **J**	50
Total Phosphorous	NS	NS	NS	NS	NS	NS	NS	NS	NS	14900	17700	NA
Eh	164.3	143.8	215.0	188.8	184.9	210.0	167.2	144.3	220.0	198.6	198.6	NA
pH	5.86	5.87	5.75	6.03	6.04	5.80	5.80	5.79	5.65	5.91	5.91	NA

NOTES: Analytical results and standards reported in micrograms per liter except for Eh which is in millivolts, and pH which is in standard units
Bold qualifier represents Data Validator's qualifier
Unbold qualifier represents Laboratory Validator's qualifier

R - Replicate sample
U - Analyte not detected at or below the Contract Required Detection Limit, or the compound is not detected due to qualification through the method or field blank
B - Value greater than or equal to the Instrument Detection Limit but less than the Contract Required Detection Limit
J - Analyte present, reported value is estimated
UJ - Analyte not present, sample quantitation limit is estimated
NA - No standard
NS - No sample collected

Ground-water standards obtained from New York Codes, Rules, and Regulations, Title 6, Part 703.5.

Table 2. Summary of Analytical Results for Ground-Water Samples Collected by Roux Associates, Inc. During January through June 1993, 96-20 222nd Street, Queens Village, New York

Sample Designation: Sample Date:	MW-10 4/13/93	MW-11 3/2/93	MW-11 4/13/93	MW-12 4/13/93	MW-12 4/21/93	MW-12R 4/21/93	MW-13 4/13/93	MW-13 4/21/93	MW-13 5/26/93	MW-14 4/13/93	MW-14 4/21/93	Ground-Water Standards
Copper	354	873	10 U	729	887 **J**	1080 **J**	564	449 **J**	529	10 U	56 **J**	200
Lead	135 **J**	202	68.5 J	18 **J**	180 **J**	196	11 **J**	15	3 **UJ**	3 **UJ**	14	25
Total Chromium	1520	612	347	292	340 **J**	395 **J**	1740	659 **J**	1610	10 **U**	26 **U**	50
Iron	50 **J**	70 **J**	50 U	60 **J**	300 **J**	100 **J**	200 **J**	160 **J**	NS	50 U	130 **J**	300
Hexavalent Chromium	911	295 **J**	298	262	236	254	1770	602	1590	10 U	10 **UJ**	50
Total Phosphorous	6600	3600	190	NS	NS	NS	NS	NS	1500 **J**	NS	NS	NA
Eh	170.0	205.6	175.0	260.0	255.0	255.0	255.0	255.0	225.0	210.0	200.0	NA
pH	4.55	5.48	5.00	5.05	5.28	5.28	5.10	5.39	5.70	5.45	5.59	NA

NOTES: Analytical results and standards reported in micrograms per liter except for Eh which is in millivolts, and pH which is in standard units
Bold qualifier represents Data Validator's qualifier
Unbold qualifier represents Laboratory Validator's qualifier

R - Replicate sample
U - Analyte not detected at or below the Contract Required Detection Limit, or the compound is not detected due to qualification through the method or field blank
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Ground-water standards obtained from New York Codes, Rules, and Regulations, Title 6, Part 703.5.

Table 2. Summary of Analytical Results for Ground-Water Samples Collected by Roux Associates, Inc. During January through June 1993, 96-20 222nd Street, Queens Village, New York

Sample Designation: Sample Date:	MW-14 5/26/93	MW-15 5/26/93	MW-15R 5/26/93	MW-15 6/3/93	MW-15R 6/3/93	Ground-Water Standards
Copper	73.2	12.2 B	10 U	12 B	10 U	200
Lead	17 **J**	5 **J**	3 **J**	6 **J**	5 **J**	25
Total Chromium	20.5	10 U	10.2	20 U	16 **U**	50
Iron	NS	NS	NS	NS	NS	300
Hexavalent Chromium	10 U	10 U	10 U	16 **J**	11 **J**	50
Total Phosphorous	20 **UJ**	20 **UJ**	20 **UJ**	20 U	20 U	NA
Eh	145.0	140.0	140.0	149.6	149.6	NA
pH	6.20	6.00	6.00	6.21	6.21	NA

NOTES: Analytical results and standards reported in micrograms per liter except for Eh which is in millivolts, and pH which is in standard units
Bold qualifier represents Data Validator's qualifier
Unbold qualifier represents Laboratory Validator's qualifier

R - Replicate sample
U - Analyte not detected at or below the Contract Required Detection Limit, or the compound is not detected due to qualification through the method or field blank
B - Value greater than or equal to the Instrument Detection Limit but less than the Contract Required Detection Limit
J - Analyte present, reported value is estimated
UJ - Analyte not present, sample quantitation limit is estimated
NA - No standard
NS - No sample collected

Ground-water standards obtained from New York Codes, Rules, and Regulations, Title 6, Part 703.5.

Table 3. New York State Department of Environmental Conservation Registered Wells Within a One-Mile Radius of Deknatel Site, Queens Village, New York

NYSDEC Well Designation	Owner	Location			Use	Depth (ft below land surface)	Screen Zone (ft below top of casing)	Date Completed
Q-313	Jamaica Water Supply Well #13	214-01 214th St. near Hillside Ave.	Jamaica	NY	Public Supply (1)	109	63 - 108	5/5/64
Q-1600	Jamaica Water Supply Well #13A	Corner 214th St. & 89th Ave.	Queens Village	NY	Public Supply (2)	295	270 - 290	12/19/50
Q-2000	Jamaica Water Supply Well #39	Springfield Blvd. & 91st Ave.	Queens Village	NY	Public Supply (1)	112	75 - 96	3/2/54
Q-1982T	Jamaica Water Supply	NW Corner 91st Ave & Springfield Blvd.	Queens Village	NY	Test Well-abandoned	393	NA	9/11/55
Q-2188	Jamaica Water Supply Well #39A	Springfield Blvd. & 91st Ave.	Queens Village	NY	Public Supply (1)	263	214 - 254	4/5/56
Q-1534	Jamaica Water Supply Well #29	216th St. & 102nd Ave.	Queens Village	NY	Public Supply (1)	97.9	77.9 - 97.9	4/51
Q-1535T	Jamaica Water Supply	216th St. & 102 Ave.	Queens Village	NY	Test Well-abandoned	407	386 - 406	5/15/50
Q-1629	Jamaica Water Supply Well #29A	216th St. & 102nd Ave.	Queens Village	NY	Public Supply (1)	281	236 - 276	4/51
Q-2321	Jamaica Water Supply Well #49	E. Side 219th St., S. Hempstead Tpke.	Queens Village	NY	Public Supply (1)	130	110 - 130	5/23/60
Q-2343	Jamaica Water Supply Well #49A	E. Side 219th St., S. Hempstead Tpke.	Queens Village	NY	Public Supply (1)	235	190 - 230	9/60
Q-1849	Reliance Federal Savings	216th St. and Jamaica Ave.	Queens Village	NY	Air Conditioning	61	51 - 61	5/24/52
Q-2100	Conifed Realty Corp.	215-32 Jamaica Ave.	Queens Village	NY	Cooling	112	91 - 112	8/12/54
Q-93	EM & FR Amusement Corp.	215-32 Jamaica Ave.	Queens Village	NY	NA	60	NA	1935
Q-1076D	F.W. Woolworth Co.	217-05-09 Jericho Tpke.	Queens Village	NY	Air Cooling	~50	38.5 - 49	8/24/39
Q-1072	F.W. Woolworth Co.	217-05-09 Jericho Tpke.	Queens Village	NY	Air Conditioning	152.7	131 - 152	11/22/39
Q-357D	S.S. Kresge Co.	219-05 Jamaica Ave.	Queens Village	NY	NA	36	16 - 36	9/25/37
Q-361	S.S. Kresge Co.	219-05 Jamaica Ave.	Queens Village	NY	Air Conditioning	91	79 - 91	9/25/37
Q-1728	Commerical Hotel, Inc.	96-43 Springfield Blvd.	Queens Village	NY	Air Conditioning	NA	NA	6/28/61
Q-2355D	Commerical Hotel, Inc.	96-43 Springfield Blvd.	Queens Village	NY	Air Conditioning	38	27 - 38	1/5/61
Q-2313	Frank Antun	218-85 97th Ave.	Hollis	NY	Air Conditioning	87	82 - 87	6/11/59
NA	Commerical Restaurant	96-43 Springfield Blvd.	Queens Village	NY	Cooling	96	86 - 96	6/28/50
Q-1372	J.A. Deknatel & Son, Inc.	222nd St. & 96th Ave.	Queens Village	NY	Air Conditioning	220	158 - 184	1/31/45
Q-1384D	J.A. Deknatel & Son, Inc.	222nd St. & 96th Ave.	Queens Village	NY	Diffusion	60	35 - 50	7/27/45
Q-1490D	Queens Theatre	219-36 Jamaica Ave.	Queens Village	NY	Diffusion	78	55 - 76	6/15/48
Q-115	Queens Theatre	219-36 Jamaica Ave.	Queens Village	NY	Air Conditioning	91	69 - 91	7/24/35
NA	Huanck Construction #948	Jamaica Ave. & Springfield Blvd.	Queens	NY	Cooling (not in use)	90	70 - 90	7/14/35
NA	Huanck Construction #948D	Jamaica Ave. & Springfield Blvd.	Queens	NY	Diffusion	63	NA	NA
Q-2680	Our Lady of Lourdes Church	92-96 220th St.	Queens Village	NY	Lawn Sprinkler	97	88 - 97	11/20/65

NA - Information not available
(1) - Inactive supply well
(2) - Active supply well
ft - Feet

NOTE: Data obtained from original Well Completion Reports filed with the NYSDEC.

Table 3. New York State Department of Environmental Conservation Registered Wells Within a One-Mile Radius of Deknatel Site, Queens Village, New York

NYSDEC Well Designation	Owner	Location			Use	Depth (ft below land surface)	Screen Zone (ft below top of casing)	Date Completed
Q-1365	Ciano Candle Co.	96-45 222nd St.	Queens Village	NY	Cooling	85	73 - 85	7/15/44
Q-1940D	Ciano Candle Co.	96-45 222nd St.	Queens Village	NY	Diffusion	53	43 - 53	2/10/53
Q-73	Rubel Corp.	E. 222nd St. 100' S. of LIRR	Queens Village	NY	Ice Machine	123	58 - 78	1929
Q-1448	Rubel Corp.	222nd St. & 97th Ave.	Queens Village	NY	Condensers	96	76 - 96	5/23/47
Q-1248T	N.Y.C. Dept. of Water Supply	100th Rd. & Cross Isand Pkwy.	Queens Village	NY	Test Well	49	NA	9/14/44
Q-1289	N.Y.C. Dept. of Water Supply	Springfield Blvd. & 110th Ave.	Queens Village	NY	Test Well	32	NA	9/14/44
Q-1249	U.S. Geological Survey	NW Corner 216th St. & 106th Ave.	Queens Village	NY	Test Well	89	NA	9/30/59
Q-2105	G. Frishman	103rd Ave. & 221st St.	Queens	NY	Lawn Sprinkler	59	54 - 59	6/30/54
Q-2009	Sam Loicdice	237-17 Jamaica Ave.	Queens Village	NY	Sink, Bathroom, Hose	65	NA	3/3/54
Q-2956	Sam Loicdice	237-17 Jamaica Ave.	Queens Village	NY	Sink, Bathroom, Hose	98	NA	11/26/66
Q-3012	LOCAL 1500 Bldg., Inc.	Jamaica Ave. & 222nd St.	Queens Village	NY	Air Conditioning	223	203 - 223	6/5/70
Q-3013D	LOCAL 1500 Bldg., Inc.	Jamaica Ave. & 222nd St.	Queens Village	NY	Diffusion	264	234 - 264	9/27/70
N-10731	Nassau County Dept. Public Water	Wellington Rd., S. Hempstead Tpke.	Elmont	NY	Monitoring Well	196	171 - 191	4/17/87

NA - Information not available
(1) - Inactive supply well
(2) - Active supply well
ft - Feet

NOTE: Data obtained from original Well Completion Reports filed with the NYSDEC.

Table 4. Identification of Potential Federal, State and Local Standards, Criteria and Guidelines, 96-20 222nd Street, Queens Village, New York

Citation	Promulgated Standard
Chemical Specific:	
10 NYCRR Part 5	Public Water Supply Regulations - provides lists of maximum contaminant levels for constituents of concern
6 NYCRR Parts 750 through 758	Regulations on State Pollution Discharge Elimination System Permits - provides effluent standards
6 NYCRR Part 703	Water Classification and Quality Standards - provides surface-water and ground-water quality standards and effluent standards
6 NYCRR Part 371	Identification and Listing of Hazardous Wastes - lists regulatory levels for characteristic wastes
6 NYCRR Part 376	Land Disposal Restriction Regulations - provides treatment standards for hazardous waste to be land disposed
NYCDEP Bureau of Water Pollution Control and Bureau of Sewers	Rules and Regulations Relating to the Use of the Public Sewers, including Sewer discharges - Title V lists toxic substances conditionally accepted including Cr^{+6}
Action Specific:	
New York Environmental Conservation Law-Article 17	Water Pollution Control - prevents new pollution and requires abatement of existing pollution
6 NYCRR Part 360	Solid Waste Management Facilities Rules - provides an exemption for beneficial use of a solid waste
6 NYCRR Part 372	Hazardous Waste Manifest Systems and Related Standards for Generators, Transporters, and Facilities - use of manifest documents for transporting hazardous waste
6 NYCRR Part 375	Rules for Inactive Hazardous Waste Disposal Sites - includes public participation and remedy selection criteria
6 NYCRR Part 364	Waste Transport Permit Regulation - provides permit requirements for collection, transport, and delivery of hazardous wastes
Building Code of the City of New York	Establishes requirements for engineering designs
49 CFR Parts 170 through 189	Hazardous Material Transportation Act (HMTA) - provides requirements for training, labeling, packaging, etc. for transport of hazardous waste
40 CFR Part 144	United States Environmental Protection Agency (USEPA) Permit Regulations for the Underground Injection Control Program - requirements for permits and authorization of underground injection wells

Table 4. Identification of Potential Federal, State and Local Standards, Criteria and Guidelines, 96-20 222nd Street, Queens Village, New York

Citation	Promulgated Standard
Location Specific:	
6 NYCRR Part 361	Rules for Siting Industrial Hazardous Waste Facilities - states criteria for location of landfills
6 NYCRR Part 373	Hazardous Waste Treatment, Storage, and Disposal Facility Permitting Requirements - provides location and design standards for landfills
New York City Local Laws and Ordinances	Requirements for hours of operation, noise, traffic, etc.
To Be Considered Requirements:	
SW-89-2002	Division of Solid Waste Technical and Administrative Guidance Memorandum (TAGM): Construction and Demolition Debris (12-26-89) - provides clarification on the definition of construction and demolition debris
SW-89-5001	Division of Solid Waste TAGM - New York State's Solid Waste Management Policy Guidance (4-5-89) - lists preferred solid waste management methodologies
HWR-88-4015	Division of Hazardous Waste Remediation TAGM - Policy Regarding Alteration of Ground Water Samples Collected for Metals Analysis (9-30-88) - criteria for filtering samples
HWR-89-4023	Division of Hazardous Waste Remediation TAGM - Citizen Participation Plan
HWR-90-4030	Division of Hazardous Waste Remediation - Revised TAGM - Selection of Remedial Action at Inactive Hazardous Waste Sites (5-15-90) - Evaluates treatment technologies and discusses using focused approach to feasibility studies
HWR-90-4032	Division of Hazardous Waste Remediation - Disposal of Drill Cuttings (11-29-89) - describes methods of disposal for cuttings from installation of monitoring wells or soil borings from remedial investigations or near Class II sites
Division of Water Technical and Operational Guidance Series (TOGS) (1.1.1) Ambient Water Quality Standards and Guidance Values (11-15-91) - supplements 6 NYCRR Parts 700 through 703	
Division of Water TOGS (1.3.3) - SPDES Permit Development for Publicly Owned Treatment Works (POTWs) (12-90) - cites the minimum requirements for surface-water discharge, disposal of sewage sludge, and the toxic pollutant surface-water discharge requirement	
Division of Water TOGS (1.6.1) Regional Authorization for Temporary Discharge (4-1-88) - provides information to establish discharge on temporary basis (less than 6 month duration) for remedial activities	
Antidegradation Policy (40 CFR 131.12) - to maintain water quality to protect existing uses	

Table 5. Evaluation of Remedial Alternatives With Respect to Standards, Criteria and Guidelines, 96-20 222nd Street, Queens Village, New York

Standard, Criteria, or Guideline	Alternative 1 No Action	Alternative 2 Natural Attenuation/ Monitoring	Alternative 3a, 4a, 5a Ground-Water Extraction/Discharge to Sewer	Alternative 3b, 4b, 5b Ground-Water Extraction/Treatment/ Discharge to Sewer	Alternative 3c, 4c, 5c Ground-Water Extraction/ Treatment/ Reinjection
Chemical Specific:					
10 NYCRR Part 5	Will meet MCLs at public water supply well locations	Same as 1	Same as 1	Same as 1	Same as 1
6 NYCRR Part 750-758 (SPDES Permits)	Does not apply	Does not apply	Does not apply	Does not apply	Permit or authorization will be obtained
6 NYCRR Part 703	Will meet NYS Class GA standard following source remediation	Same as 1	Same as 1	Same as 1	Will meet NYS Class GA standard and effluent standard
6 NYCRR Part 371	Does not apply	Does not apply	Does not apply	Treatment residue will be tested for hazardous characteristics	Same as 3b, 4b, 5b
6 NYCRR Part 376	Does not apply	Does not apply	Does not apply	Hazardous waste will be treated as necessary to comply with land disposal restrictions	Same as 3b, 4b, 5b
NYCDEP Water Pollution Control	Does not apply	Does not apply	Will meet NYCDEP standards for discharge to sewers	Same as 3a, 4a, 5a	Does not apply
Action Specific:					
6 NYCRR Part 360	Does not apply	Does not apply	Does not apply	If treatment residue is non-hazardous, landfill will comply with these requirements	Same as 3b, 4b, 5b

Table 5. Evaluation of Remedial Alternatives With Respect to Standards, Criteria and Guidelines, 96-20 222nd Street, Queens Village, New York

Standard, Criteria, or Guideline	Alternative 1 No Action	Alternative 2 Natural Attenuation/ Monitoring	Alternative 3a, 4a, 5a Ground-Water Extraction/Discharge to Sewer	Alternative 3b, 4b, 5b Ground-Water Extraction/Treatment/ Discharge to Sewer	Alternative 3c, 4c, 5c Ground-Water Extraction/ Treatment/ Reinjection
NY ECL - Article 17	Pollution abatement achieved via source control and natural attenuation	Same as 1	Pollution abatement achieved via source control and ground-water extraction	Same as 3a, 4a, 5a	Same as 3a, 4a, 5a
6 NYCRR Part 372	Does not apply	Does not apply	Does not apply	If treatment residue is hazardous, manufacturing requirements will be met	Same as 3b, 4b, 5b
6 NYCRR Part 375	Will meet remedy selection criteria and Public Participation Requirements	Same as 1	Same as 1	Same as 1	Same as 1
6 NYCRR Part 364	Does not apply	Does not apply	Does not apply	Any hazardous waste removal will be performed by permitted haulers	Same as 3b, 4b, 5b
49 CFR Parts 170-189	Does not apply	Does not apply	Does not apply	All hazardous waste will be removed in compliance with HMTA	Same as 3b, 4b, 5b
40 CFR Part 144	Does not apply	Does not apply	Does not apply	Does not apply	Permitting for injection well will be required
Building Code - NYC	Does not apply	Does not apply	Engineering designs will be in accordance with building codes	Same as 3a, 4a, 5a	Same as 3a, 4a, 5a

Table 5. Evaluation of Remedial Alternatives With Respect to Standards, Criteria and Guidelines, 96-20 222nd Street, Queens Village, New York

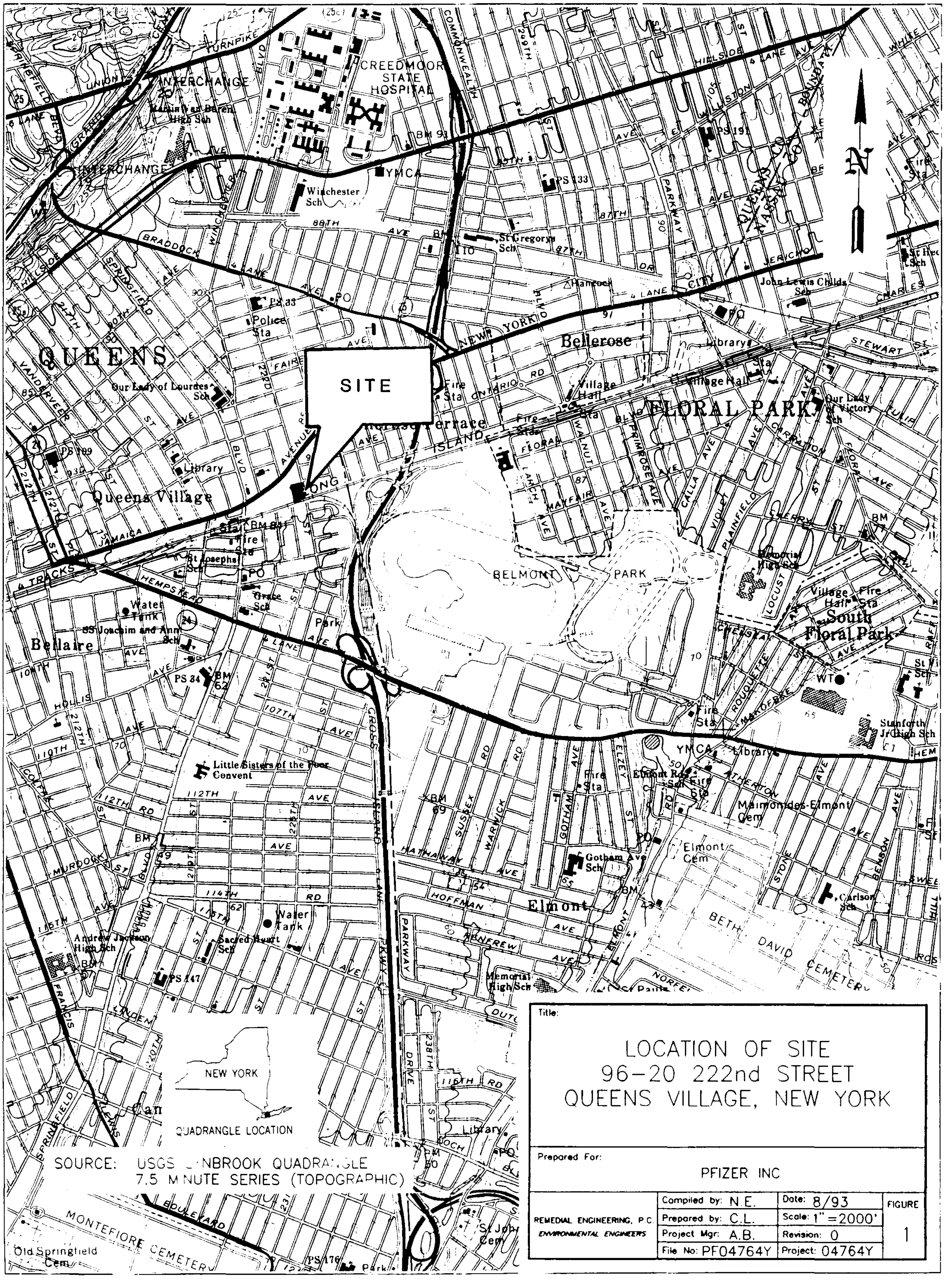
Standard, Criteria, or Guideline	Alternative 1 No Action	Alternative 2 Natural Attenuation/ Monitoring	Alternative 3a, 4a, 5a Ground-Water Extraction/Discharge to Sewer	Alternative 3b, 4b, 5b Ground-Water Extraction/Treatment/ Discharge to Sewer	Alternative 3c, 4c, 5c Ground-Water Extraction/ Treatment/ Reinjection
Location Specific:					
6 NYCRR Part 361	Does not apply	Does not apply	Does not apply	For non-hazardous waste, landfill used will meet siting requirements	Same as 3b, 4b, 5b
6 NYCRR Part 373	Does not apply	Does not apply	Does not apply	For hazardous waste, landfill meet location and design requirements	Same as 3b, 4b, 5b
NYC Local Laws and Ordinances	Does not apply	Will be implemented in accordance with local laws and ordinances	Same as 2	Same as 2	Same as 2

Table 6. Summary of -30/+50 Percent Cost Estimates for Remedial Alternatives, 96-20 222nd Street, Queens Village, New York

Alternative	Capital Cost	Annual O&M Costs	Total Net Percent Value
1. No Action	$0	$0	$0
2. Natural Attenuation with Ground-Water Monitoring	$0	$46,000*	$399,000
3a. Ground-Water Extraction at Leading Edge of Plume; Discharge to Sewer	$171,000	$113,000	$660,000
3b. Ground-Water Extraction at Leading Edge of Plume; Treatment and Discharge to Sewer	$590,000	$230,000	$1,586,000
3c. Ground-Water Extraction at Leading Edge of Plume; Treatment and Discharge to Ground Water	$688,000	$211,000	$1,602,000
4a. Ground-Water Extraction at Leading Edge of Plume and Immediately Downgradient of Site; Discharge to Sewer	$232,000	$130,000	$795,000
4b. Ground-Water Extraction at Leading Edge of Plume and Immediately Downgradient to Site; Treatment and Discharge to Sewer	$623,000	$267,000	$1,779,000
4c. Ground-Water Extraction at Leading Edge of Plume and Immediately Downgradient of Site; Treatment and Discharge to Ground Water	$785,000	$236,000	$1,807,000
5a. Ground-Water Extraction Immediately Downgradient of Site; Discharge to Sewer	$151,000	$123,000	$684,000
5b. Ground-Water Extraction Immediately Downgradient of Site; Treatment and Discharge to Sewer	$532,000	$253,000	$1,627,000
5c. Ground-Water Extraction Immediately Downgradient of Site; Treatment and Discharge to Ground Water	$630,000	$226,000	$1,609,000

* For Alternative 2, year 6 O&M would be $76,000 and annual O&M for years 7 through 10 would be $54,000.

FIGURES



SOURCE: USGS LYNBROOK QUADRANGLE
7.5 MINUTE SERIES (TOPOGRAPHIC)

Title:

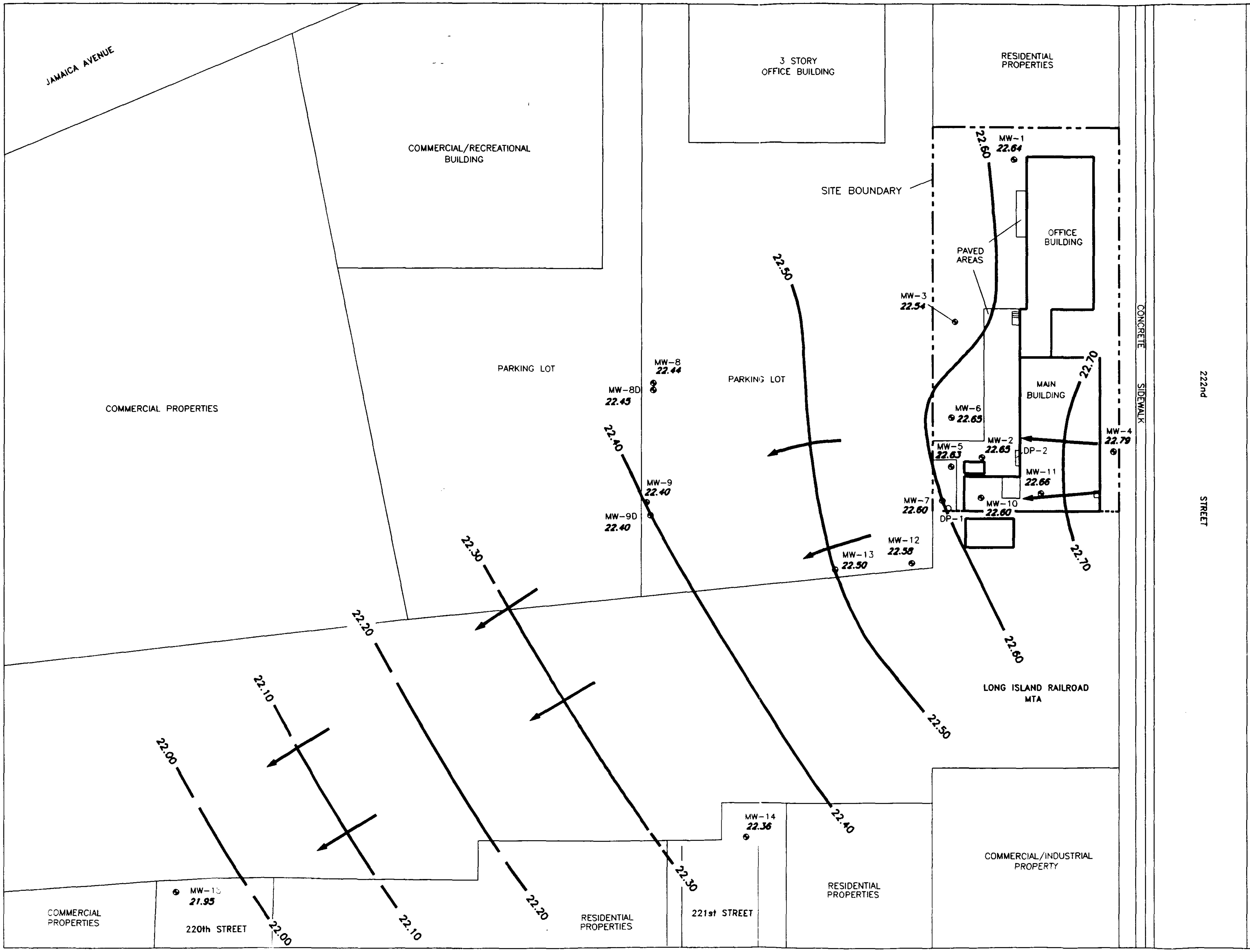
LOCATION OF SITE
96-20 222nd STREET
QUEENS VILLAGE, NEW YORK

Prepared For:

PFIZER INC

REMEDIAL ENGINEERING, P.C.
ENVIRONMENTAL ENGINEERS

Compiled by: N.E.	Date: 8/93	FIGURE
Prepared by: C.L.	Scale: 1" = 2000'	
Project Mgr: A.B.	Revision: 0	1
File No: PF04764Y	Project: 04764Y	



EXPLANATION

MW-3 ⊗ MONITORING WELL LOCATION AND DESIGNATION

DP-1 ○ DISPOSAL POINT LOCATION AND DESIGNATION

– – – SITE BOUNDARY

22.54 WATER-TABLE ELEVATION IN FEET ABOVE MEAN SEA LEVEL

22.60 LINE OF EQUAL WATER-TABLE ELEVATION IN FEET ABOVE MEAN SEA LEVEL, DASHED WHERE INFERRED

← INFERRED DIRECTION OF GROUND-WATER FLOW

NOTE: WATER LEVELS MEASURED IN MONITORING WELLS MW-2, MW-8D AND MW-9D NOT INCLUDED IN MAP CONSTRUCTION BECAUSE THEY ARE NOT WATER-TABLE MONITORING WELLS.

0 25 50 FT.

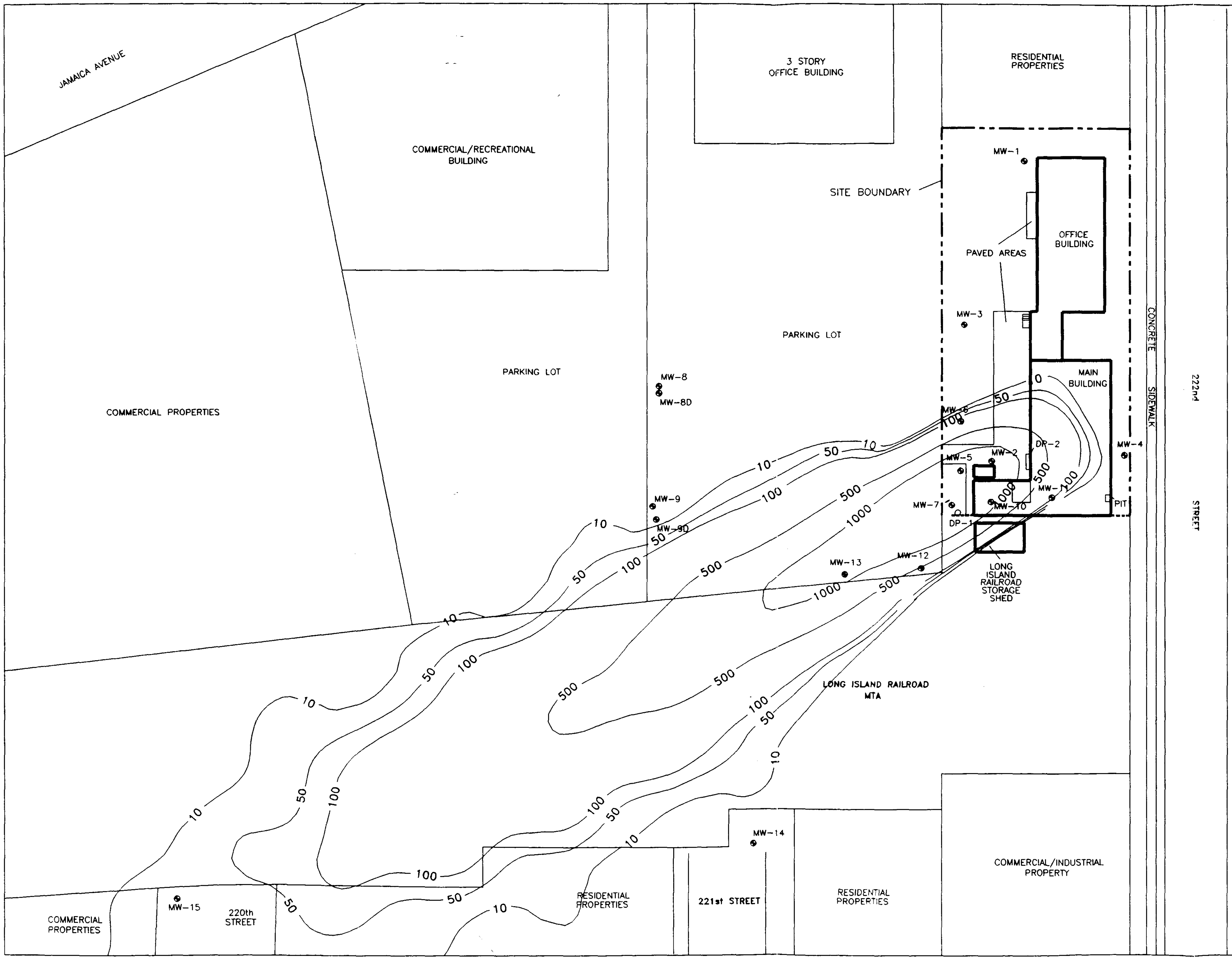
Title:

WATER-TABLE ELEVATION AND
DIRECTION OF GROUND-WATER FLOW
JUNE 29, 1993

Prepared For:

PFIZER INC

REMEDIAL ENGINEERING, P.C. ENVIRONMENTAL ENGINEERS	Compiled by: J.M.	Date: 6/93	FIGURE
	Prepared by: J.R.	Scale: SHOWN	2
	Project Mgr: A.B.	Revision: 0	
	File No: PF764B61	Project: 04764Y	



EXPLANATION

MW-3 ⊗ MONITORING WELL LOCATION AND DESIGNATION

DP-1 ○ DISPOSAL POINT LOCATION AND DESIGNATION

- - - - SITE BOUNDARY

—10— ISOCONCENTRATION LINES FOR SIMULATED HEXAVALENT CHROMIUM DISTRIBUTION IN MICROGRAMS PER LITER

0 25 50 FT.

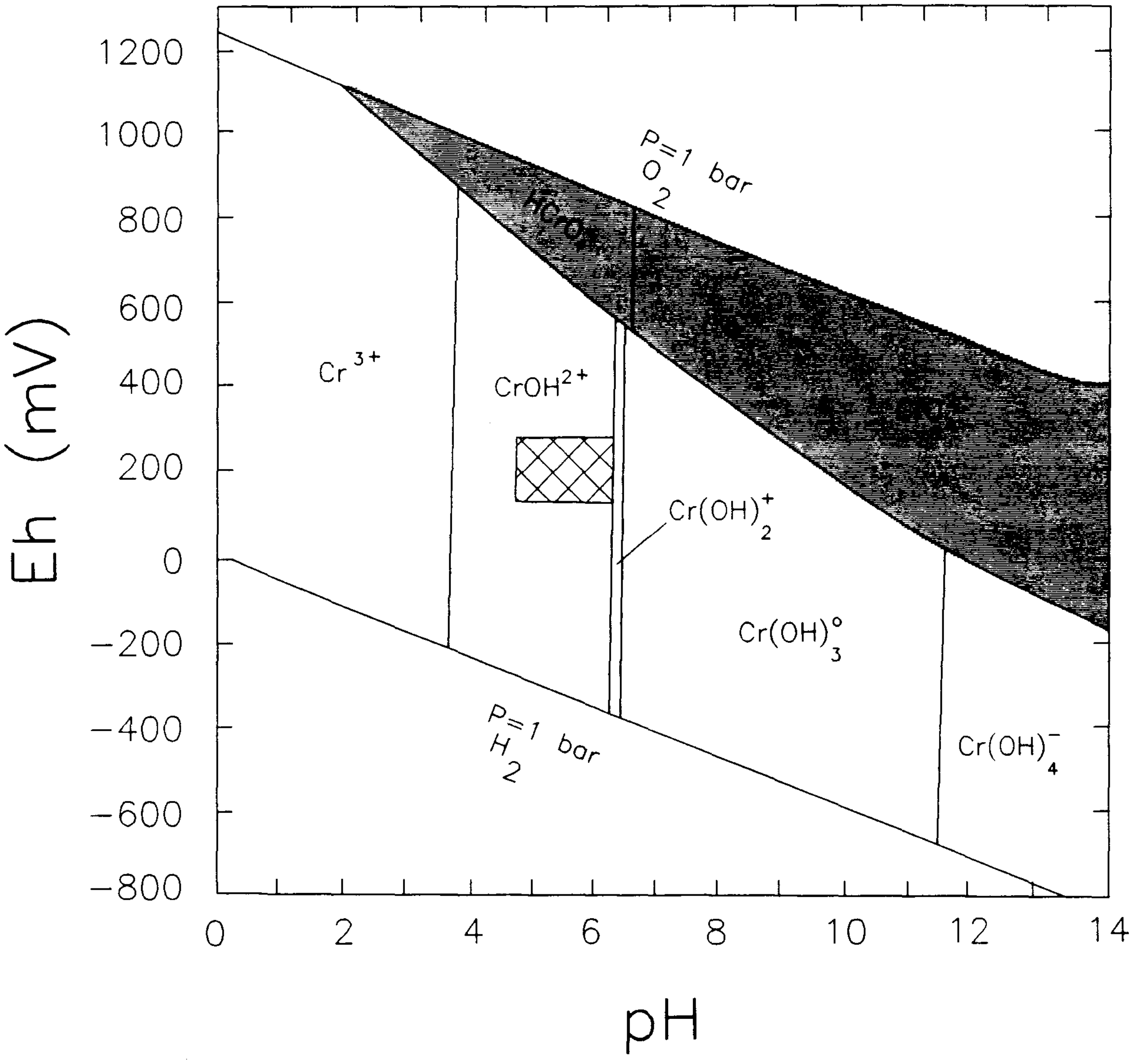
Title:

MODELED EXTENT OF HEXAVALENT CHROMIUM IN GROUND WATER JUNE 1993

Prepared For:

PFIZER INC

REMEDIAL ENGINEERING, P.C. *ENVIRONMENTAL ENGINEERS*	Compiled by: N.E.	Date: 8/93	FIGURE
	Prepared by: J.R.	Scale: SHOWN	3
	Project Mgr: A.B.	Revision: 0	
	File No: PF764B60	Project: 04764Y	



EXPLANATION

▨ RANGE OF Eh−pH CONDITIONS ENCOUNTERED IN OFF-SITE GROUND WATER.

▩ STABILITY FIELD FOR HEXAVALENT CHROMIUM

mV − MILLIVOLTS

SOURCE: ADAPTED FROM "PROCESSES AFFECTING THE REMEDIATION OF CHROMIUM−CONTAMINATED SITES," PALMER AND WITTBRODT, 1991.

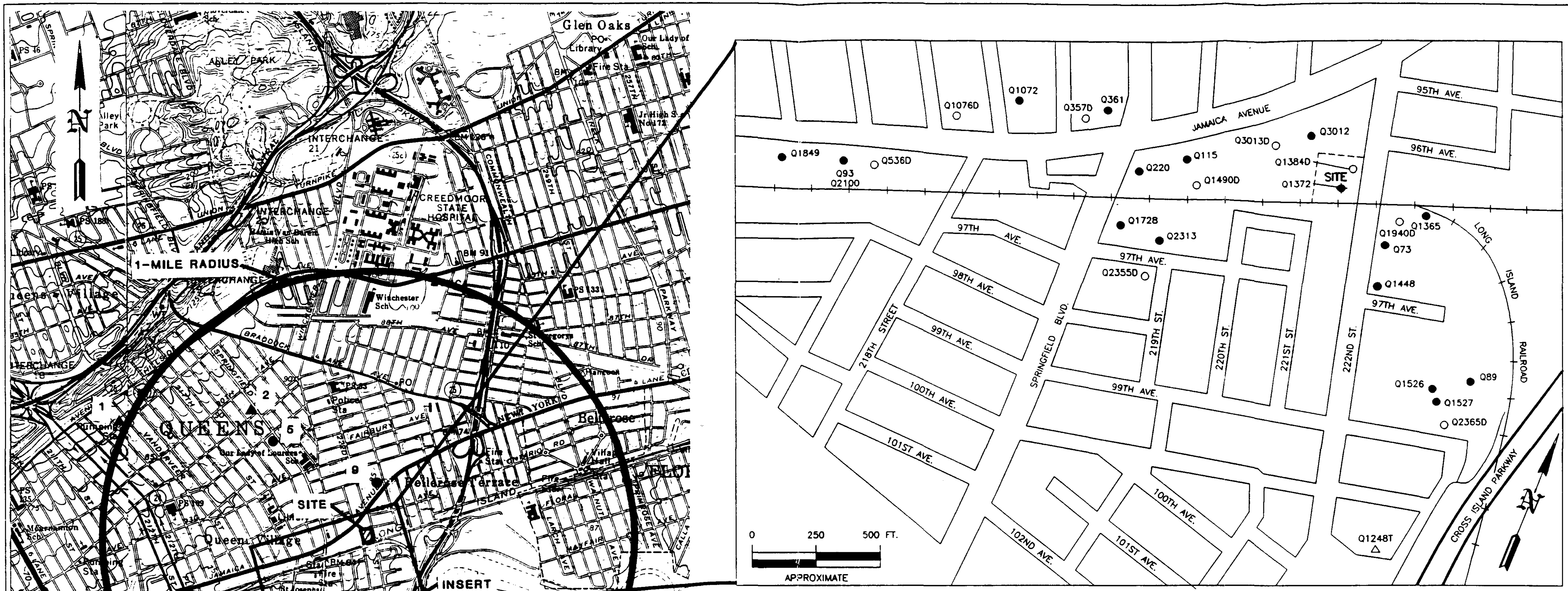
Title:

Eh−pH DIAGRAM FOR AQUEOUS CHROMIUM SPECIES

Prepared For:

PFIZER INC

REMEDIAL ENGINEERING, P.C. *ENVIRONMENTAL ENGINEERS*	Compiled by: N.E.	Date: 6/93	FIGURE
	Prepared by: J.R.	Scale: NONE	4
	Project Mgr: A.B.	Revision: 0	
	File No: PF764F49	Project: 04764Y	



MAP LOCATION NO.	NYSDEC WELL NO.
1	Q313 Q1600
2	Q2188 Q2000 Q1982T
3	Q1534 Q1535T Q1629
4	Q2321 Q2343
5	Q2680
6	Q1249
7	Q2105
8	Q1289
9	Q2009 Q2956
10	N10731

EXPLANATION

Q1534 ▲	JAMAICA WATER SUPPLY COMPANY - PUBLIC SUPPLY WELLS AND ASSOCIATED TEST WELLS
Q1849 ●	PRIVATE SUPPLY WELL
Q357D ○	PRIVATE DIFFUSION WELL
Q1248T △	TEST WELL

NOTES:

INSERT ADAPTED FROM: "WORK PLAN FOR A SUPPLEMENTAL RI/FS AT THE DEKNATEL FACILITY, QUEENS VILLAGE, NEW YORK", AUGUST, 1989, FIGURE 2-11, PREPARED BY RECRA ENVIRONMENTAL, INC. IN CONJUNCTION WITH ROUX ASSOCIATES, INC.

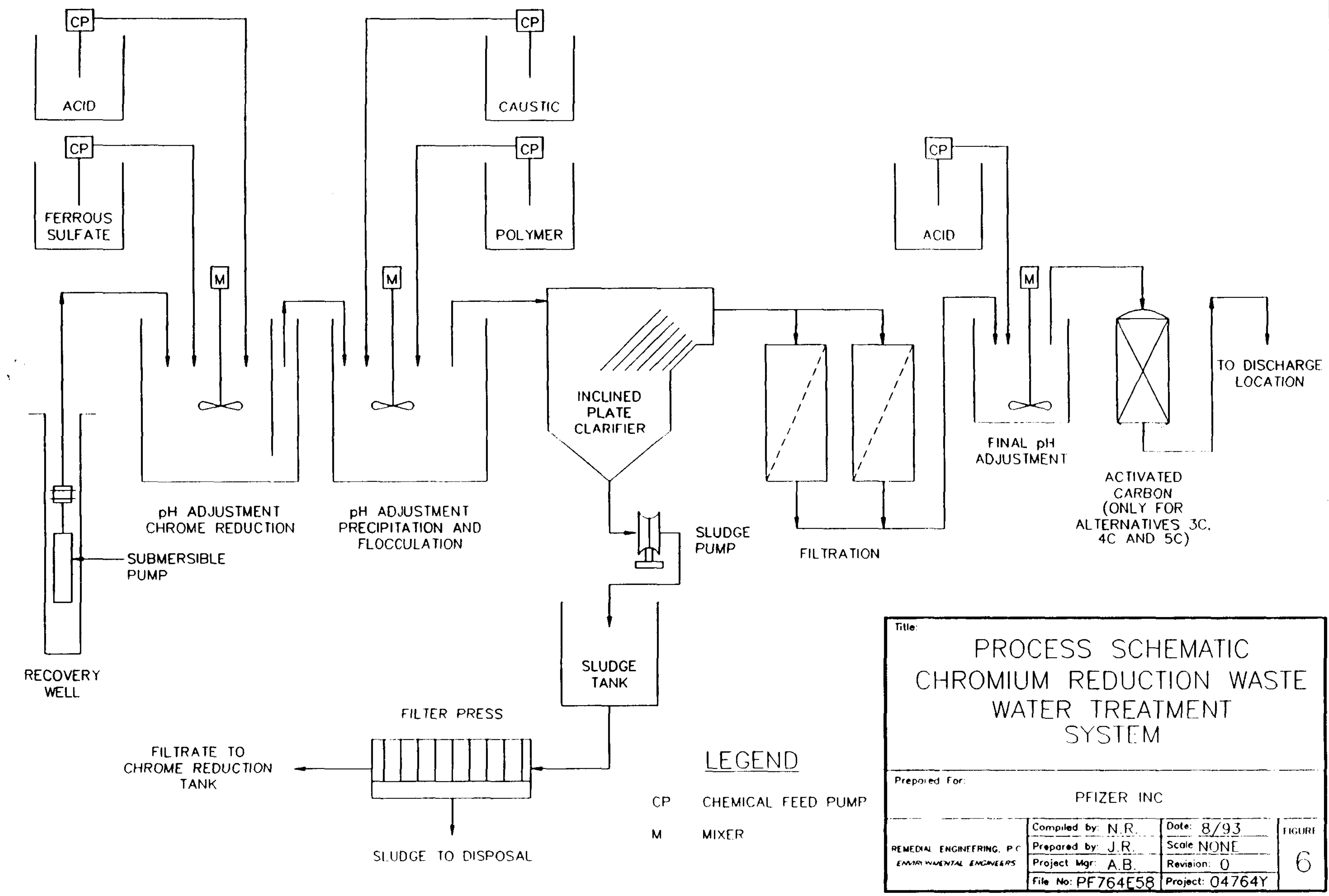
LOCATIONS OF WELLS Q89, Q220, Q536D, Q1526, Q1527, Q2365D BASED UPON **ABOVE-MENTIONED** REPORT. DATA CONCERNING THESE WELLS WERE NOT AVAILABLE IN THE 1992 WELL SEARCH.

Title:

NYSDEC REGISTERED WELLS
WITHIN A
1-MILE RADIUS OF SITE

Prepared For:
PFIZER INC

REMEDIAL ENGINEERING, P.C. ENVIRONMENTAL ENGINEERS	Compiled by: N.E.	Date: 6/93	FIGURE
	Prepared by: C.L.	Scale: SHOWN	5
	Project Mgr: A.B.	Revision: 0	
	File No: PF04764Y	Project: 04764Y	



Title:

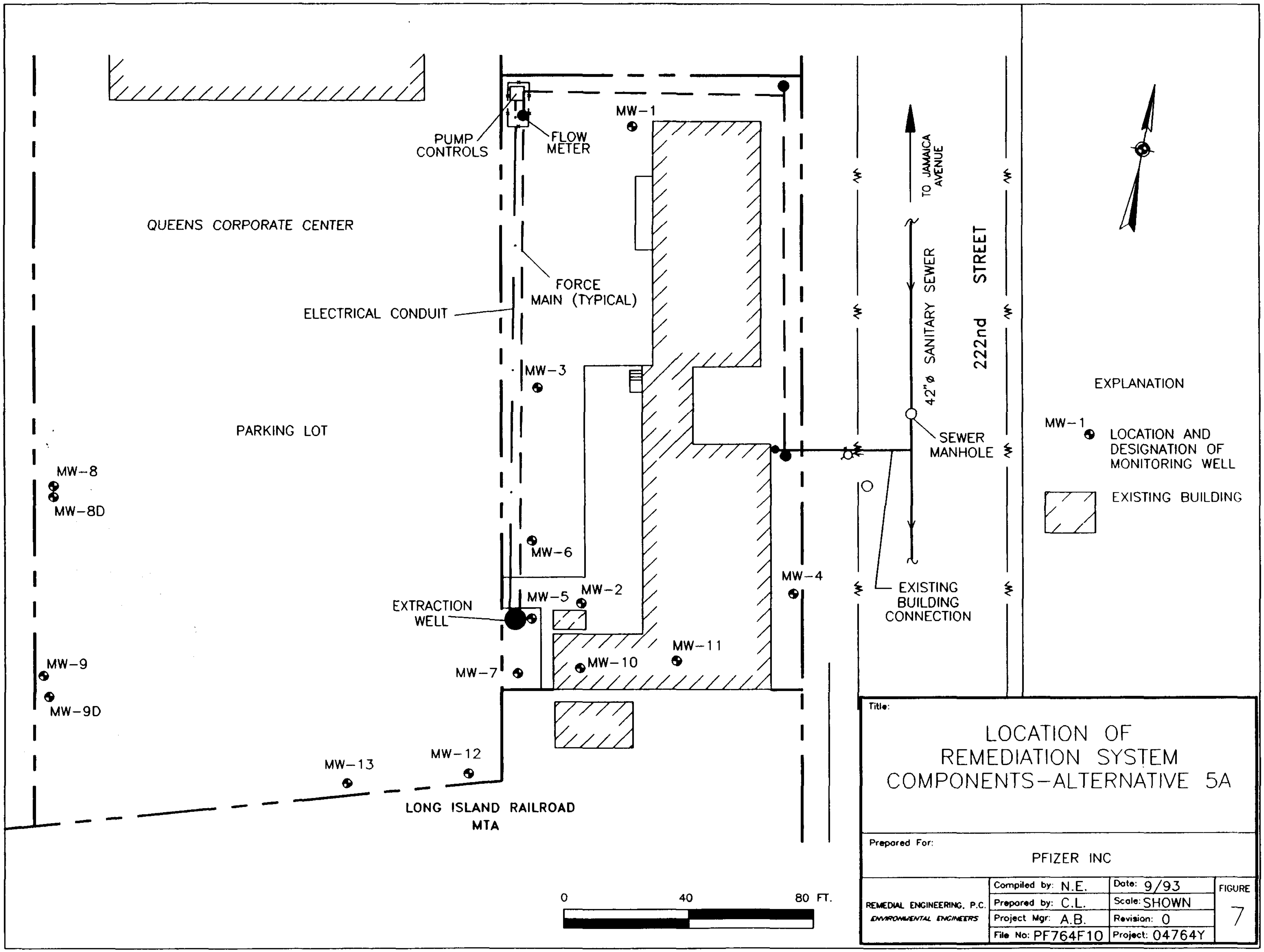
PROCESS SCHEMATIC CHROMIUM REDUCTION WASTE WATER TREATMENT SYSTEM

Prepared For:

PFIZER INC

REMEDIAL ENGINEERING, P.C.
ENVIRONMENTAL ENGINEERS

Compiled by: N.R.	Date: 8/93	FIGURE
Prepared by: J.R.	Scale NONE	6
Project Mgr: A.B.	Revision: 0	
File No: PF764E58	Project: 04764Y	



Title:

LOCATION OF
REMEDIATION SYSTEM
COMPONENTS-ALTERNATIVE 5A

Prepared For:

PFIZER INC

REMEDIAL ENGINEERING, P.C.
ENVIRONMENTAL ENGINEERS

Compiled by: N.E.
Prepared by: C.L.
Project Mgr: A.B.
File No: PF764F10
Date: 9/93
Scale: SHOWN
Revision: 0
Project: 04764Y
FIGURE
7

APPENDICES

APPENDIX A

APPENDIX A

Capture Zone Calculations and Modeling

CONTENTS

TABLES

FIGURES

1.0 INTRODUCTION

Engineering, P.C. has performed analytical capture zone analysis and analytical and numerical ground-water modeling for the former Deknatel, Inc. facility located at 96-20 222nd Street in Queens Village, New York (Site). The purpose of the modeling is to both assess the impact of existing hexavalent chromium in off-site ground water and to investigate several pumping scenarios that may mitigate the impact.

The modeling proceeded in steps as follow:

1. a computer model of the current (June 1993) extent of hexavalent chromium (Cr^{+6}) in ground water was constructed and calibrated;
2. analytical calculations were performed to estimate the minimum pumping rates necessary to achieve capture of the current extent of Cr^{+6} contaminated ground water;
3. ground-water flow modeling was performed to investigate several pumping and recharge scenarios with respect to capture of the existing Cr^{+6} plume;
4. analytical transport modeling was performed to estimate the efficacy of pumping of ground water with high concentrations of Cr^{+6}; and
5. long-term analytical transport modeling was performed to assess the potential downgradient impact of existing Cr^{+6} on Jamaica Water Supply Company (JWSC) wells assuming no action is taken to remediate ground water.

The ground-water flow modeling was performed using Flowpath (Franz and Guiger 1992) and the analytical transport modeling was performed using "Random-Walk" (Prickett et al. 1981).

1.1 Parameters

Ground-water flow parameters for input into the models were obtained from previous hydrogeologic investigations of the Site, recent water-level and water-quality data, and from literature sources for hydraulic parameters of the Upper Glacial aquifer on Long Island, New York.

The following table lists the model parameters used, and the sources for the parameters:

Parameter	Value	Source
Hydraulic Conductivity	210 feet per day (ft/d)	Hydrogeologic Investigation Report (Roux Associates 1992)
Flow Rate	1 ft/d	Hydrogeologic Investigation Report
Porosity	0.3	McClymonds and Franke (1972)
Saturated Thickness	67 feet (ft)	Hydrogeologic Investigation Report

For purposes of analytical capture zone calculations, ground-water flow and contaminant transport modeling, an effective saturated thickness of 50 feet was assumed for the Upper Glacial aquifer. The justification for this value is discussed below.

Hexavalent chromium has been detected only in the upper 20 feet of the aquifer (Roux Associates 1993). Therefore, to avoid pumping large volumes of clean ground water, the modeled pumping wells were assumed to be partially penetrating with screens extending from the water table to approximately 30 feet below the water table. Although ground-water flow is dominantly horizontal immediately downgradient of the Site (Roux Associates 1993), some vertical component of flow near the pumping well was assumed. However, it was also assumed that the entire saturated thickness of 70 feet would not contribute water to the pumping well. Fifty feet was chosen as a conservative estimate of the effective saturated thickness of the aquifer contributing water to the pumping well.

Using the above-mentioned values for hydraulic conductivity and effective saturated thickness, a transmissivity of 10,500 square feet per day (ft^2/day) or 78,534 gallons per day per foot (gpd/ft), was calculated and used in the modeling.

2.0 MODELING

Two computer programs were used to perform ground-water flow and contaminant transport modeling: "Random-Walk" and Flowpath. The "Random-Walk" (Prickett et al. 1981) solute transport model, as adapted for personal computers (Thomas A. Prickett & Associates 1984), was used to simulate Cr^{+6} transport in the aquifer beneath the Site. "Random-Walk" is a widely used, well-documented program. The program simulates solute transport via the use of "particles" and can account for transport mechanisms including dispersion and retardation.

Flowpath (Franz and Guiger 1992) is a numerical steady-state, two-dimensional horizontal flow model. Flowpath can simulate hydraulic head response to pumping scenarios and includes a particle tracking option to delineate flowpaths in ground water under steady-state flow conditions. Flowpath was used in a semi-analytical mode by assuming a uniform flow field across the Site.

2.1 Computer-Generated Representation of June 1993 Extent of Hexavalent Chromium

"Random-Walk" was used to approximate the extent of Cr^{+6} in the aquifer beneath and downgradient of the Site as measured in June 1993. Computer representation of the mass and extent of Cr^{+6} in the plume was achieved using 5000 particles, each with a particle mass of 0.0058 pounds per particle, and retardation coefficient of 1.8 (see Appendix B for calculations of Site-specific retardation factors). The particle mass was chosen to give a minimum resolution for Cr^{+6} concentration of 10 micrograms per liter ($\mu g/L$) for a grid cell size of 18 feet by 18 feet. The particles were input to achieve a distribution of Cr^{+6} in the model that approximated the measured concentrations from ground-water samples obtained in May and June 1993. The resulting distribution of Cr^{+6} was used as a basis for determining capture zone widths, for assessing the efficacy of pumping on contaminant reduction, for long-term transport modeling, and for contaminant mass calculations.

2.1.1 Calculation of Mass of Hexavalent Chromium in Aquifer

To calculate an estimate of the mass of hexavalent chromium (Cr^{+6}) in the aquifer beneath and downgradient of the Site, the assumptions below were made.

- Within the area encompassed by each of the isoconcentration contours in Figure 3 of the FFS Addendum, the concentration of Cr^{+6} is equal to the encompassing contour. For example, within the 1000 μg/L contour, Cr^{+6} is at 1000 μg/L. Between the 500 and the 1000 μg/L contours, Cr^{+6} is at 500 μg/L. The areas were obtained by importing Figure 3 into AutoCad, and using the "area" utility.
- All of the Cr^{+6} is contained and uniformly distributed within the upper 20 feet of the aquifer at the concentrations as defined above. The volume of aquifer that contained Cr^{+6} at each concentration interval was obtained by multiplying the areas as defined above by 20 feet.
- The porosity is 30 percent. The volume of ground water that contains Cr^{+6} at the concentrations defined above was obtained by taking the aquifer volumes calculated above and multiplying by the porosity.

A spreadsheet was used to perform the mass calculations. The spreadsheet is included as Table A-1 of this appendix.

Similar methodology was used to estimate the mass of Cr^{+6} encompassed by the capture zones created in the pumping scenarios discussed in Section 2.3. In each case, the area of the plume upgradient and within each capture zone was determined using AutoCad as described above.

2.2 Analytical Calculations of Pumping Rates Based Upon Capture Zone Width

Prior to performing capture zone modeling using Flowpath, the approximate minimum discharge rates for pumping wells necessary to capture the existing Cr^{+6} in the aquifer were calculated using the following equation, which can be derived by superposition of radial and one-dimensional flow fields:

$$-\frac{y}{x}=\tan\left[\frac{2\pi K b i}{Q}y\right] \qquad \text{Equation 1}$$

(Todd 1980)

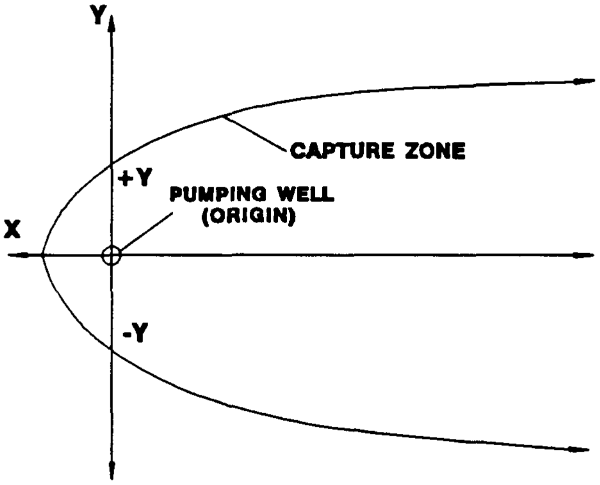
where

y and x = rectangular coordinates as illustrated in the generalized plot below

K = hydraulic conductivity (ft/d)

b = effective saturated thickness (ft)
i = hydraulic gradient (ft/ft)
Q = pumping rate (ft^3/d)
tan = tangent of an angle in radians

A generalized plot of Equation 1 is shown graphically below:



Based upon the "Random-Walk" simulation, the approximate width of the leading edge of Cr^{+6} in the vicinity of Monitoring Well MW-15 is 150 feet. Therefore, 'y' was set equal to 75 feet, and 'x' equal to 0.1 feet. The hydraulic gradient (i) was set equal to 0.0013; the measured gradient at the Site. Solving Equation 1 for 'Q' gave a pumping rate of 4098 ft^3/d or 21 gallons per minute (gpm). Therefore, to achieve capture of the Cr^{+6} downgradient of the Site, a pumping well in the vicinity of Monitoring Well MW-15 would have to pump at a minimum rate of 21 gpm.

At the proposed location of the on-site pumping well (i.e., in the vicinity of Monitoring Well MW-5), the width of the plume is approximately 68 feet. However, the proposed location of the pumping well is off-center with respect to the plume by 13.5 feet. Therefore, a capture zone width of 95 feet is necessary to encompass the plume at the Site boundary. Setting 'y' equal to 47.5 feet and using the same parameters as discussed above yields a pumping rate of approximately 2,695 ft^3/d or 14 gpm for a 95-foot wide capture zone at the Site boundary.

2.3 Flow Modeling and Capture Zone Analysis

Five simulations were performed using Flowpath to provide a more rigorous assessment of capture zones created by various configurations of pumping and injection wells beneath and downgradient of the Site. The model simulations provided confirmation that the capture zones created by several proposed pumping and injection well configurations would be sufficient to encompass the extent of Cr^{+6} in the aquifer.

The Flowpath model grid was set up to simulate a uniform flow field across the Site. Although there are small-scale (i.e., 0.05 ft) perturbations to uniform flow at the Site, ground-water flow on a more regional basis is relatively uniform downgradient of the Site.

A 50 feet by 50 feet cell grid was constructed (Figure A-1) covering an area 770 feet long by 660 feet wide. The grid was constructed so that the x-axis was parallel to the principal direction of ground-water flow (i.e., west-southwest). Constant head boundaries were placed at the eastern and western borders of the grid (22.9 foot elevation in the east and 21.8 foot elevation in the west) to achieve the field-measured hydraulic gradient of 0.0014 ft/ft across the Site. The elevation of the bottom of the unconfined aquifer in the model was -27 feet, giving an effective saturated thickness that ranged from 48.8 feet to 49.9 feet.

Due to the lack of hydraulic head data downgradient of Monitoring Well MW-15 or upgradient of Monitoring Well MW-4, the model grid boundaries were placed less than the required minimum distance from the simulated pumping or injection wells. This minimum distance is equal to the radius of influence of the pumping or injection well, which is calculated using the following equation:

$$r_o = \sqrt{\frac{Q}{\pi W}}$$

Equation 2

(Todd 1980)

where

r_o = the radius of influence of the pumping or injection well (ft);

Q = the discharge rate of the pumping or injection well (ft^3/d); and

W = recharge rate from precipitation (feet per day [ft/d]).

With an annual recharge rate from precipitation for Long Island of approximately 24 inches per year (in/yr), or 0.0055 ft/d and a pumping or injection rate of 4,098 ft^3/d, r_o was calculated to be 487 feet. If pumping or injection wells are placed in a model grid closer to the constant head boundaries than the radius of influence of the pumping or injection wells, then the boundary conditions will influence drawdown or mounding at the well. However, the widths of the simulated captures zones from the Flowpath models were approximately equal to the width calculated in Section 2.2. Therefore, it was assumed that the boundary effects on the pumping wells were minimal. The deflection of the flow field caused by mounding at the injection wells was also approximately equal to that obtained by analytical calculations. Moreover, the boundary effects would tend to result in an underestimate of the extent of the capture zone that would be achieved in the absence of boundary effects. The boundary effects will tend to underestimate the effect of recharge from the injection wells on the simulated flow field. However, as discussed, these effects are minimal in the model.

Prior to emplacement of pumping and recharge wells in the model grid, a simulation was run to compare modeled hydraulic heads with those measured during June 1993. The following table summarizes the results:

Monitoring Well	**Measured Head (ft above mean sea level)**	**Modeled Head (ft above mean sea level)**	**Residual (ft)**
MW-1	22.64	22.69	0.05
MW-3	22.54	22.60	0.06
MW-4	22.79	22.65	-0.14
MW-5	22.63	22.55	-0.08
MW-6	22.65	22.56	-0.09
MW-7	22.60	22.53	-0.07
MW-8	22.44	22.41	-0.03
MW-9	22.40	22.37	-0.03
MW-10	22.60	22.56	-0.04
MW-11	22.66	22.60	-0.06

Monitoring Well	**Measured Head (ft above mean sea level)**	**Modeled Head (ft above mean sea level)**	**Residual (ft)**
MW-12	22.58	22.50	-0.08
MW-13	22.50	22.45	-0.05
MW-14	22.36	22.32	-0.04
MW-15	21.95	21.93	-0.02
		Residual Mean	**-0.04**

The residual mean, or average deviation of the modeled heads from the measured heads, was only -0.04.

With the exception of Monitoring Well MW-4, the differences between the modeled hydraulic heads and the measured heads (residuals) were all less than 0.1 feet. Seven out of the 14 wells had residuals of 0.05 feet or less. Monitoring well MW-2 was not included in the residual analysis because its screen does not intersect the water table.

2.3.1 Simulated Pumping Scenarios

With the exception of Pumping Scenarios 5 and 6, the discharge rates for each of the simulated pumping wells was 21 gpm, the minimum rate calculated in Section 2.2. Three simulations, Pumping Scenario 2, Pumping Scenario 4, and Pumping Scenario 6, included injection wells placed at the northeast corner of the Site to assess the potential impact of reinjection of treated ground water on the capture zones created by the pumping wells.

The following pumping/injection simulations were performed using Flowpath:

Pumping Scenario 1 - one pumping well placed at the location of Monitoring Well MW-15 (i.e., the leading edge of Cr^{+6} in ground water);

Pumping Scenario 2 - similar to Pumping Scenario 1, with an injection well located onsite;

Pumping Scenario 3 - two pumping wells, one located at Monitoring Well MW-15 and one located at on-site Monitoring Well MW-5;

Pumping Scenario 4 - similar to Pumping Scenario 3, with two injection wells located onsite;

Pumping Scenario 5 - one pumping well discharging at 30 gpm located onsite at MW-5; and

Pumping Scenario 6 - similar to Pumping Scenario 5, with an injection well located onsite.

After each pumping simulation was run, Flowpath's particle tracking option was used to delineate capture zones for the pumping wells. The results of the particle tracking, and the flowlines generated, are presented in Figures A-2 through A-7. In each Figure, the capture zone was inferred to lie between a pair of adjacent flowlines, one leading to the pumping well, and one that bypassed the pumping well.

The results of the Flowpath modeling indicate the following:

- the extents of the capture zones predicted by the analytical calculations has been verified;
- the calculated minimum pumping rate of 14 gpm for the on-site pumping well creates a capture zone that encompasses approximately 23 percent of the existing mass of Cr^{+6} in the aquifer (Table A-2);
- increasing the on-site pumping well discharge rate to 30 gpm results in a capture zone that encompasses approximately 40 percent of the existing mass of Cr^{+6} in the aquifer (Table A-3);
- capture of existing Cr^{+6} at the leading edge of the plume is achieved with a minimum pumping rate of 21 gpm; and
- an on-site pumping well located onsite at MW-5 results in capture of all of the Cr^{+6} upgradient of the pumping well.

The modeled pumping rates in the scenarios described above represent estimates of the pumping rate required to effectively capture Cr^{+6} downgradient of the Site. The actual pumping rates should be adjusted during implementation of the selected scenario to achieve the required hydraulic capture with the minimum pumping rate.

2.4 Analytical Transport Modeling

Analytical contaminant transport modeling was performed using "Random-Walk" to assess the reduction of Cr^{+6} mass in response to Pumping Scenario 5 (pumping at the Site boundary in the vicinity of MW-5.

The modeling was performed starting with the simulated Cr^{+6} distribution as described in Section 2.1. A simulated pumping well was located as shown in Figure A-6. The modeled discharge rate for the pumping well was 30 gpm. The model was run for a simulated time period of 2 years in increments of 90 days, after which the amount of particles removed by the pumping well was noted, as was the maximum concentration of Cr^{+6} left in the aquifer.

The results of the modeling suggest that after 1 year, 92 percent of the dissolved Cr^{+6} within the capture zone created by the on-site pumping well would be removed. After 2 years, 97 percent of the dissolved Cr^{+6} within the pumping well capture zone would be removed. This pumping configuration is shown in Pumping Scenario 5 (Figure A-6). Moreover, the maximum concentration of Cr^{+6} remaining in the aquifer after 2 years of pumping was approximately 380 μg/L, at a distance of 400 feet downgradient of the pumping well. At the start of the simulation, the maximum concentration was approximately 2,000 μg/L.

The model was run forward for another 3-year time increment with the pumping well turned off. This simulated the effect of dispersion on continued migration of Cr^{+6} that was not removed by pumping. At the end of the simulation, on average none of the existing Cr^{+6} left in the aquifer exceeded 50 μg/L.

The modeling did not account for the effects of reduction in further decreasing dissolved Cr^{+6} concentrations.

2.5 Long-Term Analytical Contaminant Transport Modeling

To assess the potential impact of Cr^{+6} on JWSC wells located 3,400 feet downgradient of the Site, analytical transport modeling was performed using "Random-Walk." The modeling was performed starting with the simulated Cr^{+6} distribution as described in Section 2.1. In addition to the parameters discussed in Section 1.1, longitudinal dispersivity was set at 70 feet, and transverse dispersivity was set at 14 feet. These values are believed to be typical for glacial deposits in the Upper Glacial aquifer on Long Island, New York (Walton 1991), and have been used in previous contaminant transport models for the Upper Glacial Aquifer (Pinder 1973).

The results of the long-term transport modeling suggest that after 10 years of transport, dispersion will reduce the maximum concentration of Cr^{+6} in the aquifer to approximately 50 μg/L. The center of mass of Cr^{+6} in the aquifer is estimated to reach the vicinity of the JWSC wells in approximately 17 years. By that time, dispersion will have reduced the maximum concentration of Cr^{+6} in the aquifer from 2,000 μg/L to approximately 20 μg/L.

Table A-1. Spreadsheet for Calculation of the Mass of Dissolved Hexavalent Chromium in Ground Water

Isoconcentration Interval (micrograms per liter)	Area of Interval (square feet)	Depth of impacted Interval (feet)	Porosity	Conversion Factor (cubic feet to liters)	Mass of Cr^{+6} Within Isoconcentration Interval (micrograms)
10	19,536	20	0.3	28.31	3.32E+07
50	9,462	20	0.3	28.31	8.04E+07
100	21,600	20	0.3	28.31	3.67E+08
500	8,320	20	0.3	28.31	7.07E+08
1,000	3,680	20	0.3	28.31	6.25E+08
				Total Mass	**1.81E+09**

1.81E+09	**micrograms**
1.81E+03	**grams**
64.7	**ounces**
4.0	**pounds**

Table A-2. Mass of Cr^{+6} Encompassed by Capture Zone at 14 gpm

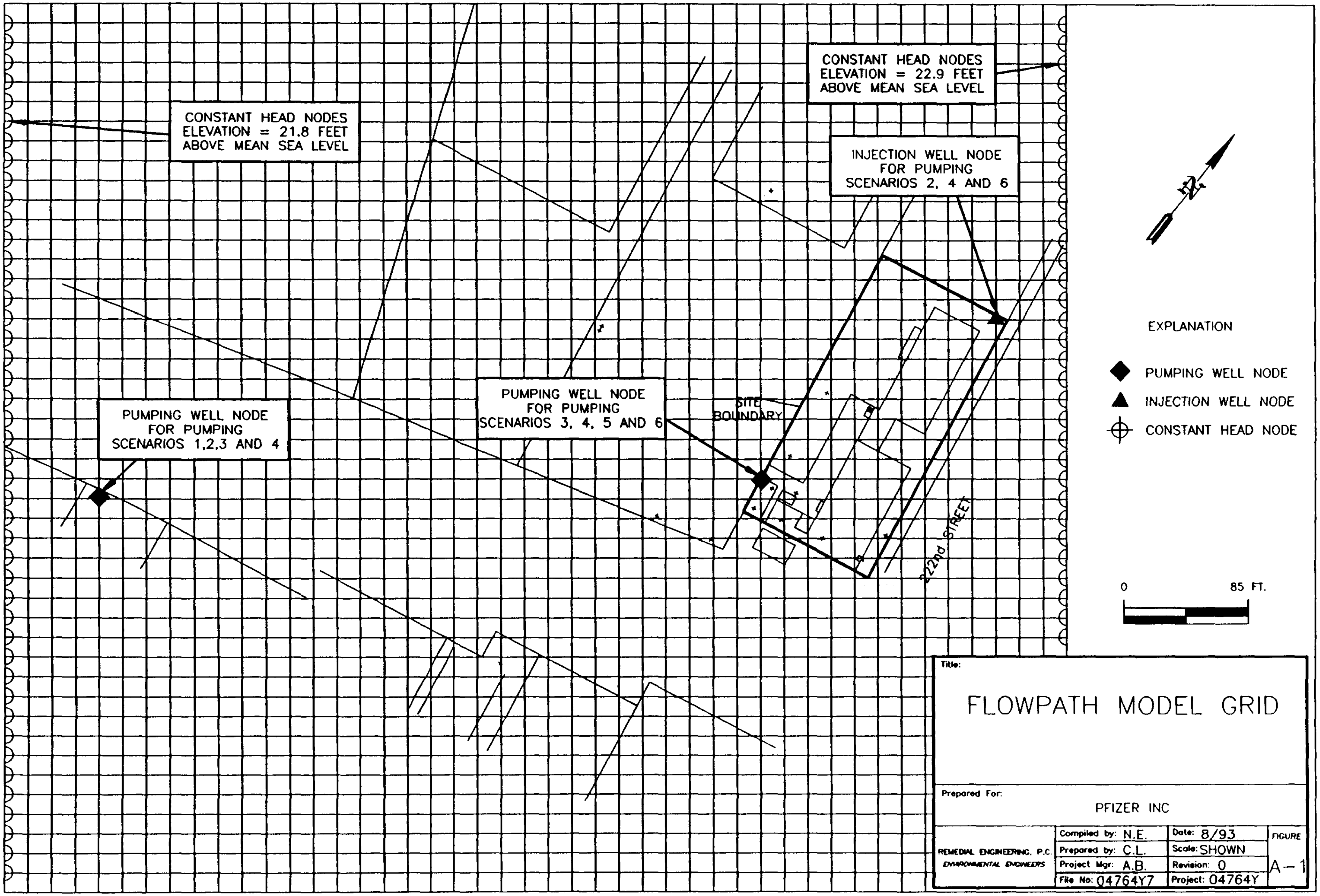
Isoconcentration Interval (micrograms per liter)	Area of Interval (square feet)	Depth of impacted Interval (feet)	Porosity	Conversion Factor (cubic feet to liters)	Mass of Cr^{+6} Within Isoconcentration Interval (micrograms)
10	629	20	0.3	28.31	1.07E+06
50	487	20	0.3	28.31	4.14E+06
100	1,853	20	0.3	28.31	3.15E+07
500	1,217	20	0.3	28.31	1.03E+08
1,000	1,632	20	0.3	28.31	2.77E+08
				Total Mass	**4.17E+08**

4.17E+08	**micrograms**
4.17E+02	**grams**
14.9	**ounces**
0.9	**pounds**

Table A-3. Mass of Cr^{+6} Encompassed by Capture Zone at 30 gpm

Isoconcentration Interval (micrograms per liter)	Area of Interval (square feet)	Depth of impacted Interval (feet)	Porosity	Conversion Factor (cubic feet to liters)	Mass of Cr^{+6} Within Isoconcentration Interval (micrograms)
10	883	20	0.3	28.31	1.50E+06
50	753	20	0.3	28.31	6.40E+06
100	2,871	20	0.3	28.31	4.88E+07
500	2,067	20	0.3	28.31	1.76E+08
1,000	2,861	20	0.3	28.31	4.86E+08
				Total Mass	7.18E+08

7.18E+08	micrograms
7.18E+02	grams
25.6	ounces
1.6	pounds



Title:

FLOWPATH MODEL GRID

Prepared For:

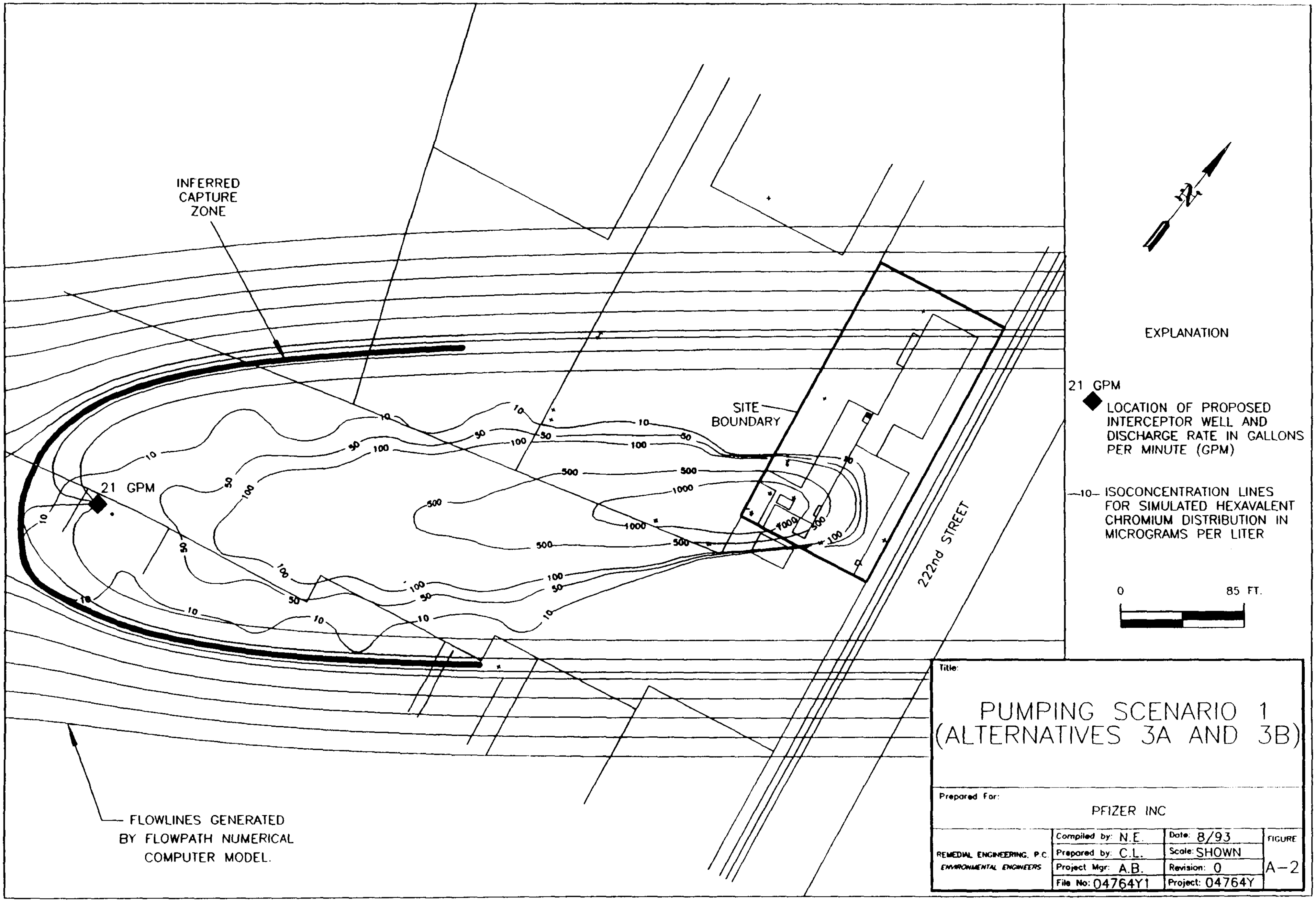
PFIZER INC

REMEDIAL ENGINEERING, P.C.
ENVIRONMENTAL ENGINEERS

Compiled by: N.E.
Prepared by: C.L.
Project Mgr: A.B.
File No: 04764Y7

Date: 8/93
Scale: SHOWN
Revision: 0
Project: 04764Y

FIGURE
A-1



Title:

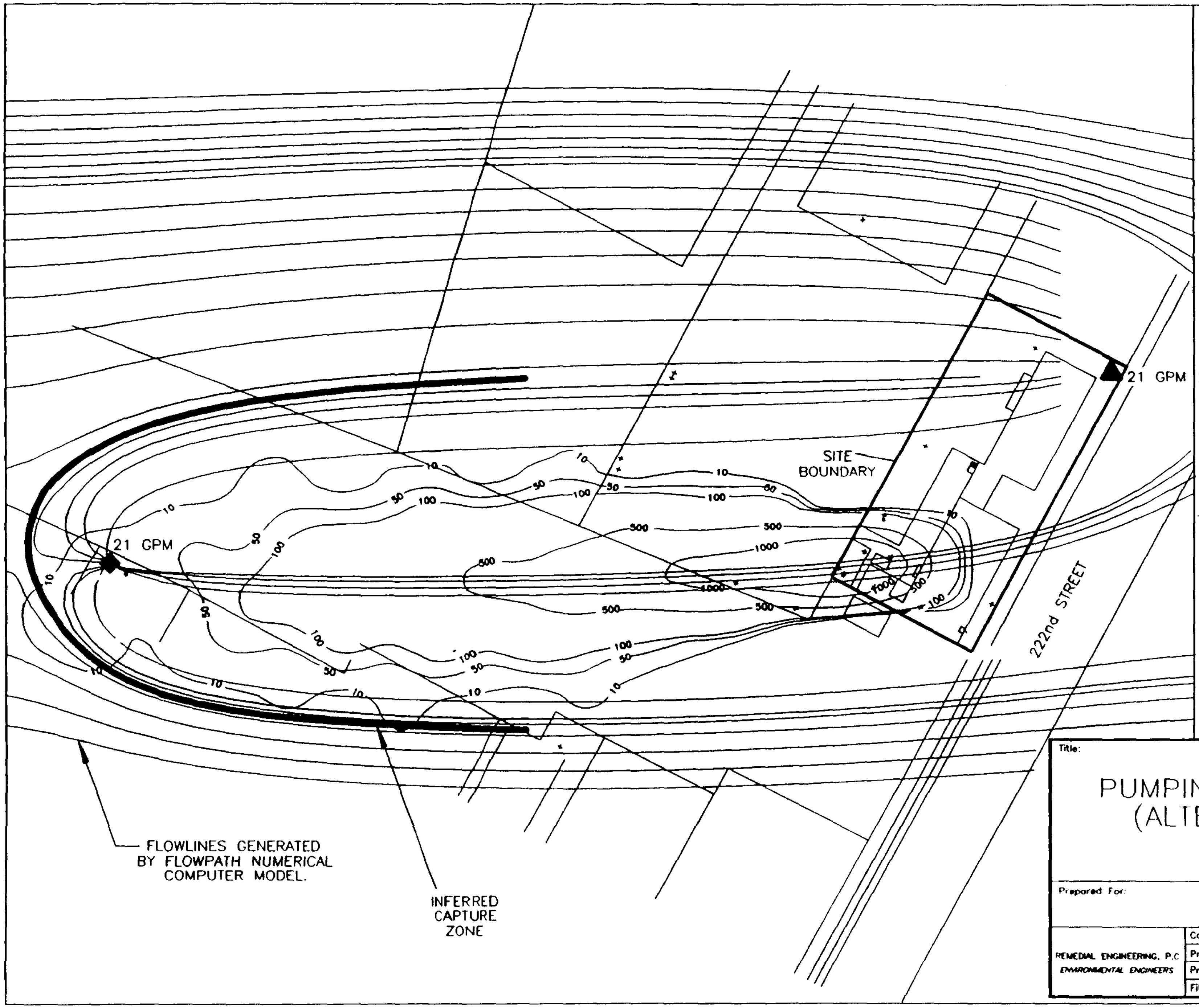
PUMPING SCENARIO 1 (ALTERNATIVES 3A AND 3B)

Prepared For:

PFIZER INC

REMEDIAL ENGINEERING, P.C.
ENVIRONMENTAL ENGINEERS

Compiled by: N.E.	Date: 8/93	FIGURE
Prepared by: C.L.	Scale: SHOWN	
Project Mgr: A.B.	Revision: 0	A–2
File No: 04764Y1	Project: 04764Y	



EXPLANATION

21 GPM ◆ LOCATION OF PROPOSED INTERCEPTOR WELL AND DISCHARGE RATE IN GALLONS PER MINUTE (GPM)

—10— ISOCONCENTRATION LINES FOR SIMULATED HEXAVALENT CHROMIUM DISTRIBUTION IN MICROGRAMS PER LITER

21 GPM ▲ LOCATION AND DESIGNATION OF PROPOSED RECHARGE WELLS AND RECHARGE RATE IN GALLONS PER MINUTE (GPM)

0 85 FT.

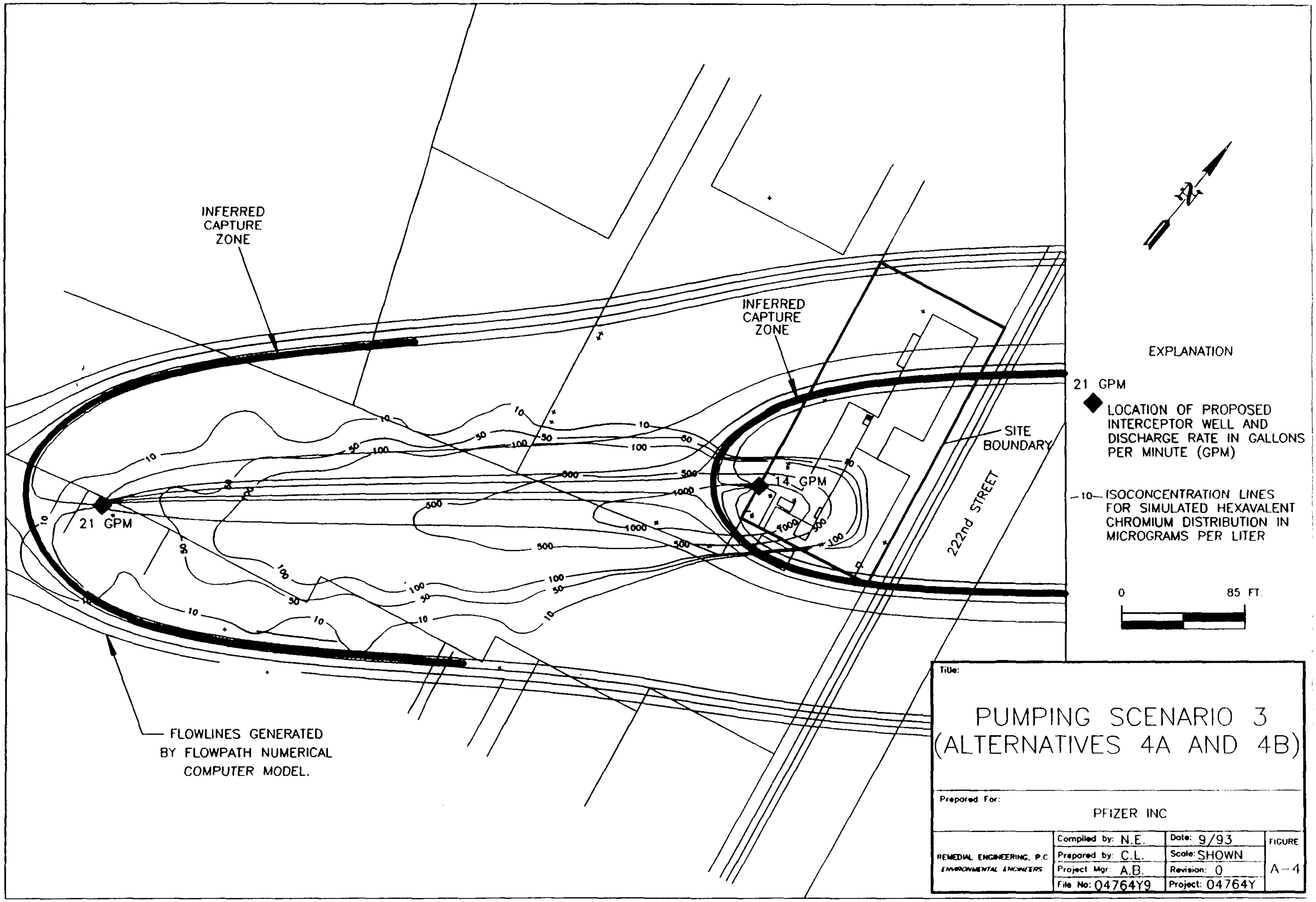
Title:

PUMPING SCENARIO 2
(ALTERNATIVE 3C)

Prepared For:

PFIZER INC

REMEDIAL ENGINEERING, P.C ENVIRONMENTAL ENGINEERS	Compiled by: N.E.	Date: 8/93	FIGURE
	Prepared by: C.L.	Scale: SHOWN	A-3
	Project Mgr: A.B.	Revision: 0	
	File No: 04764Y2	Project: 04764Y	



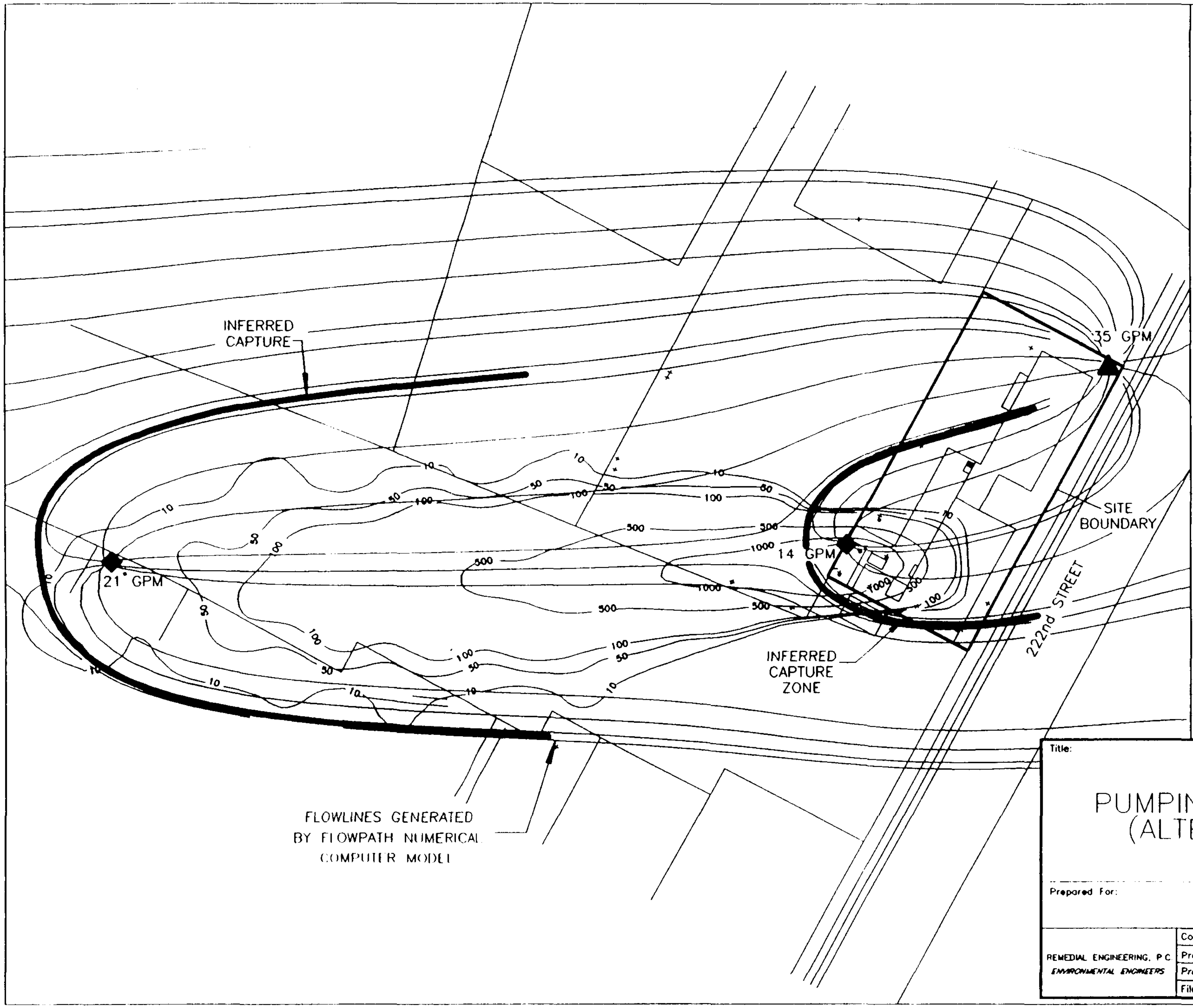
Title:

PUMPING SCENARIO 3 (ALTERNATIVES 4A AND 4B)

Prepared For:

PFIZER INC

REMEDIAL ENGINEERING, P.C *ENVIRONMENTAL ENGINEERS*	Compiled by: N.E.	Date: 9/93	FIGURE
	Prepared by: C.L.	Scale: SHOWN	A-4
	Project Mgr: A.B.	Revision: 0	
	File No: 04764Y9	Project: 04764Y	



EXPLANATION

21 GPM
◆ LOCATION OF PROPOSED INTERCEPTOR WELL AND DISCHARGE RATE IN GALLONS PER MINUTE (GPM)

10 — ISOCONCENTRATION LINES FOR SIMULATED HEXAVALENT CHROMIUM DISTRIBUTION IN MICROGRAMS PER LITER

35 GPM
▲ LOCATION OF PROPOSED RECHARGE WELLS AND RECHARGE RATE IN GALLONS PER MINUTE (GPM)

0 85 FT.

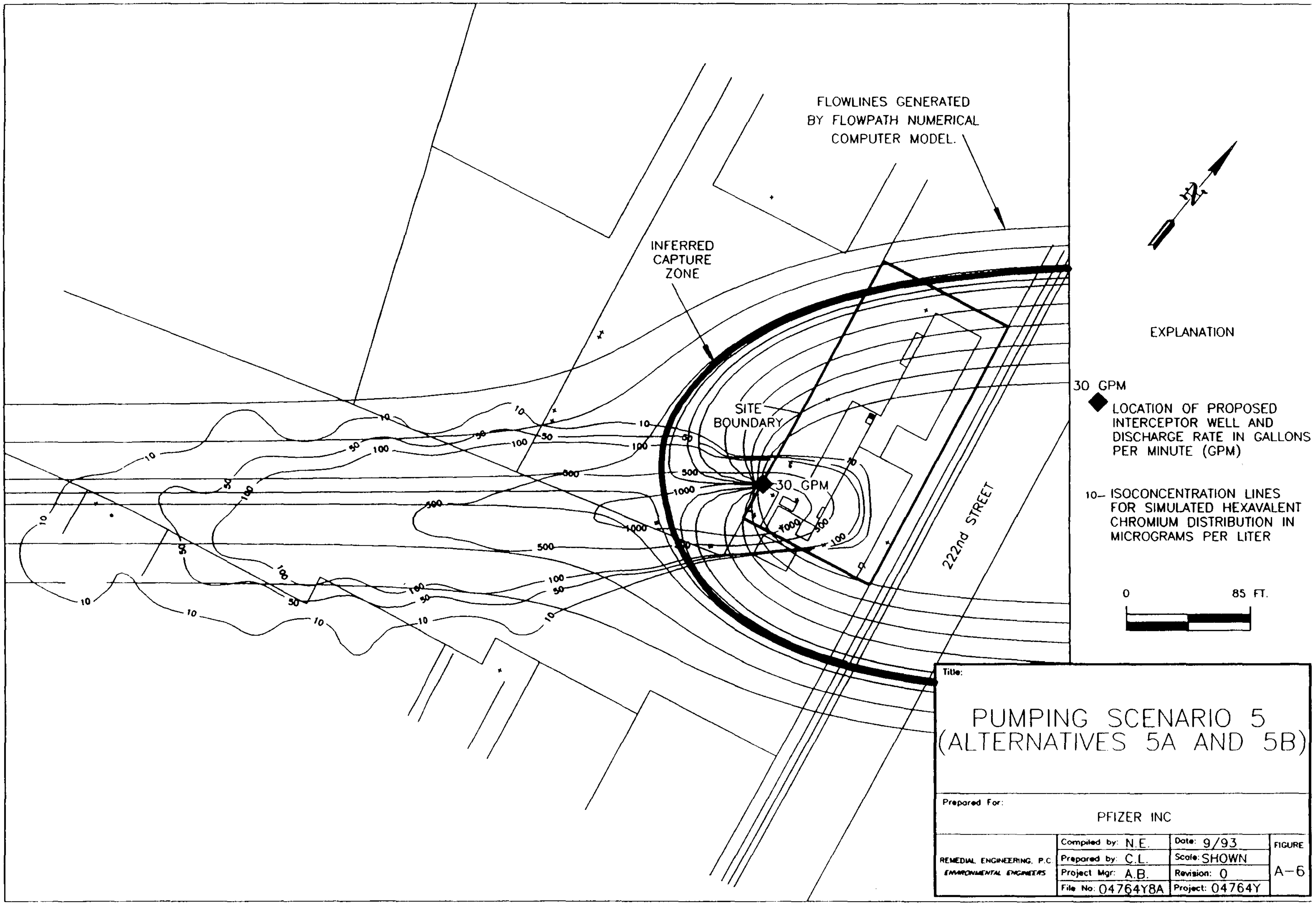
Title:

PUMPING SCENARIO 4 (ALTERNATIVE 4C)

Prepared For:
PFIZER INC

REMEDIAL ENGINEERING, P.C.
ENVIRONMENTAL ENGINEERS

Compiled by: N.E.
Prepared by: C.L.
Project Mgr: A.B.
File No: 04764Y10
Date: 9/93
Scale: SHOWN
Revision: 0
Project: 04764Y
FIGURE
A-5



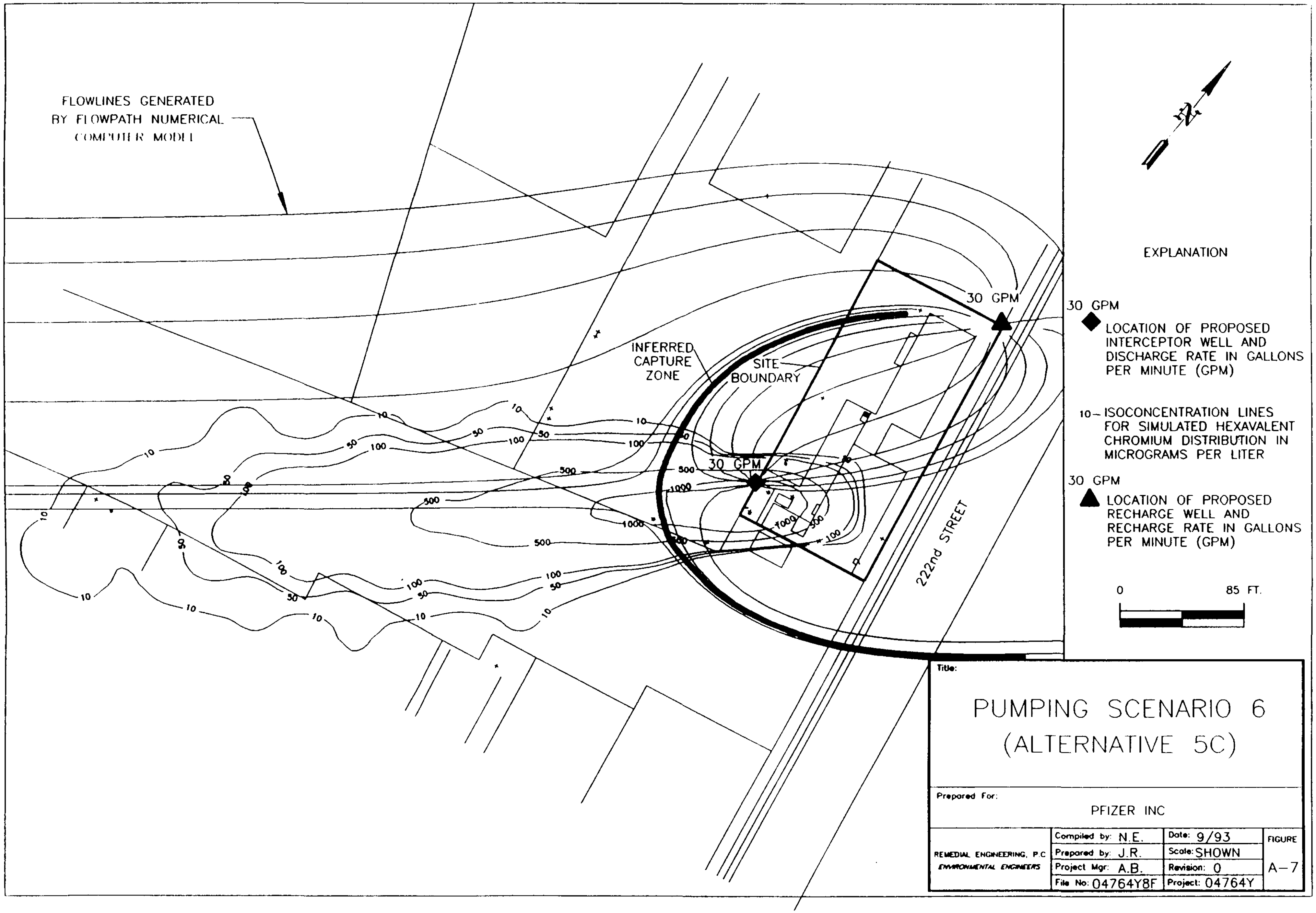
Title:

PUMPING SCENARIO 5 (ALTERNATIVES 5A AND 5B)

Prepared For:

PFIZER INC

REMEDIAL ENGINEERING, P.C ENVIRONMENTAL ENGINEERS	Compiled by: N.E.	Date: 9/93	FIGURE
	Prepared by: C.L.	Scale: SHOWN	A-6
	Project Mgr: A.B.	Revision: 0	
	File No: 04764Y8A	Project: 04764Y	



Title:

PUMPING SCENARIO 6
(ALTERNATIVE 5C)

Prepared For:

PFIZER INC

REMEDIAL ENGINEERING, P.C *ENVIRONMENTAL ENGINEERS*	Compiled by: N.E.	Date: 9/93	FIGURE
	Prepared by: J.R.	Scale: SHOWN	A-7
	Project Mgr: A.B.	Revision: 0	
	File No: 04764Y8F	Project: 04764Y	

APPENDIX B

APPENDIX B

Calculation of Site-Specific Distribution Coefficient and Retardation Factor for Cr^{+6}

Calculation of Site-Specific Distribution Coefficient (K_d) and Retardation Factor (R_f) for Cr^{+6}

$$K_d = \frac{AdsorbedConcentration(\mu g/kg)}{DissolvedConcentration(\mu g/L)} = \frac{L}{kg} = \frac{ml}{g}$$ (Freeze and Cherry 1979)

$$R_f = 1+\frac{\rho_b}{n}K_d$$ (Freeze and Cherry 1979)

Where,

ρ_b = soil bulk mass density (g/ml)
n = porosity (decimal, unitless)
K_d = distribution coefficient (ml/g)

Monitoring Well MW-11

In the screen zone (50 through 65 feet below land surface):

Cr^{+6} (adsorbed) = 217 μg/kg (average of 3 analyses)

In first ground-water sample obtained after well installation:

Cr^{+6} (dissolved) = 295 μg/L

Distribution Coefficient:

$$K_d = \frac{217\ \mu g/kg}{295\ \mu g/L} = 0.73\ L/kg = 0.73\ ml/g$$

Retardation Factor:

Assume: n=0.3 (Roux Associates 1992)
$\rho_b \approx 2$ g/ml (Freeze and Cherry 1979)

$$R_f = 1+\frac{2}{0.3}(0.73) = 5.9$$

Monitoring Well MW-13

In the screen zone (55 through 57 feet below land surface):

$$Cr^{+6} \text{ (adsorbed)} = 210 \ \mu g/kg$$

In first ground-water sample obtained after well installation:

$$Cr^{+6} \text{ (dissolved)} = 1{,}770 \ \mu g/L$$

Distribution Coefficient:

$$K_d = \frac{210 \ \mu g/kg}{1{,}770 \ \mu g/L} = 0.12 \ L/kg = 0.12 \ ml/g$$

Retardation Factor:

$$R_f = 1 + \frac{2}{0.3}(0.12) = 1.8$$

APPENDIX C

APPENDIX C

Cost Estimates for Remedial Alternatives

Table C-1. Cost Estimate for Alternative 2 - Natural Attenuation with Ground-Water Monitoring

Assumptions:

- Biannual sampling of 8 wells for years 1-5; $15,000/year.
  Installation of 4 additional wells in year 6; $22,000.
  Biannual sampling of 12 wells for years 6-10; $23,000/year.
- Ten years of monitoring prior to project closure.
- Pfizer labor included as "Technical Oversight and Monitoring".
- Two letter reports and one annual "site status" report per year.
  Letter reports included in sampling costs.

Cost Estimate Summary

Technical Oversight and Monitoring	$ 23,000
Ground-Water Sampling and Reporting	$ 15,000
Annual Report	$ 8,000
Annual O&M Years 1 - 5	**$ 46,000**
5 Years O&M, Net Present Value (NPV), 5% Discount Rate	**$199,000**
Year 6: Technical Oversight and Monitoring	$ 23,000
Ground-Water Sampling and Reporting	$ 23,000
Annual Report	$ 8,000
Well Installation	$ 22,000
Year 6 O&M	**$ 76,000**
NPV, 5% Discount Rate: Year 6	**$ 57,000**
Years 7-10: Technical Oversight and Monitoring	$ 23,000
Ground-Water Sampling and Reporting	$ 23,000
Annual Report	$ 8,000
Annual O&M Years 7-10	**$ 54,000**
NPV, 5% Discount Rate: Years 7-10	**$143,000**

Table C-1. Cost Estimate for Alternative 2 - Natural Attenuation with Ground-Water Monitoring

Total O&M Costs - Natural Attenuation, NPV, 5% Discount Rate

Years 1-5		$199,000
Year 6		$ 57,000
Years 7-10		$143,000
	Total	**$399,000**

Table C-2. Cost Estimate for Alternative 3a: Ground-Water Extraction at Leading Edge of Plume, Discharge to Sewer

Assumptions

- Average flow 21 gallons per minute; maximum flow 28 gallons per minute.
- Pretreatment of ground water is not required prior to discharge to Sewer.
- Connect to sewer within 100 feet of recovery well.
- 5 year operation and monitoring period.

Cost Estimate Summary

Capital Costs	
Final Design/Permits	$ 15,000
System Installation/Structures	$ 20,000
Revocable Consent	$ 30,000
Pumping, Conveyance and Discharge Systems	$ 84,000
Contingency (15%)	$ 22,000
Subtotal Capital Costs	**$171,000**
Operation and Maintenance Costs (annual)	
Labor	$ 43,000
Maintenance Services	$ 10,000
Utility Services	$ 27,000
Ground-Water Monitoring/Reporting	$ 33,000
Subtotal Annual O&M Costs	**$113,000**
5 Years O&M, NPV, 5% Discount Rate	**$489,000**
Total Capital and Operation and Maintenance Costs	**$660,000**

Table C-3. Cost Estimate for Alternative 3b: Ground-Water Extraction at Leading Edge of Plume; Treatment and Discharge to Sewer

Assumptions

- Average flow 21 gallons per minute; maximum flow 28 gallons per minute.
- No activated carbon treatment required for discharge to sewer.
- Total length of piping/trenching is 1,300 linear feet.
- 5 year operating and monitoring period.
- Design/permit costs included with system installation/structures and pumping, conveyance and discharge systems as appropriate.

Cost Estimate Summary

Capital Costs	
Treatment Equipment	$ 105,000
System Installation/Structures	$ 245,000
Revocable Consent	$ 30,000
Pumping, Conveyance and Discharge Systems	$ 126,000
Treatability Studies	$ 7,000
Contingency (15%)	$ 77,000
Subtotal Capital Costs	**$590,000**

Operation and Maintenance Costs (Annual)	
Labor	$ 83,000
Maintenance Services	$ 27,000
Utility Services	$ 36,000
Chemical Utilization	$ 13,000
Sludge Disposal	$ 18,000
Ground-Water Monitoring/Reporting	$ 53,000
Subtotal Annual O&M Costs	**$ 230,000**
5 Years O&M, Net Present Value, 5% Discount Rate	**$ 996,000**
Total Capital and Operating and Maintenance Costs	$1,586,000

Table C-4. Cost Estimate for Alternative 3c: Ground-Water Extraction at Leading Edge of Plume; Treatment and Discharge to Ground Water

Assumptions

- Average flow 21 gallons per minute; maximum flow 28 gallons per minute.
- Requires installation of 2 Carbtrol Model L-5 Adsorbers for GAC treatment prior to discharge.
- Total length of piping/trenching is 1,300 linear feet.
- 5 year operating and monitoring period.
- Design/permit costs included with system installation/structures and pumping, conveyance and discharge systems where appropriate.

Cost Estimate Summary

Capital Costs	
Treatment Equipment	$ 122,000
System Installation/Structures	$ 285,000
Revocable Consent	$ 30,000
Pumping, Conveyance and Discharge Systems	$ 154,000
Treatability Studies	$ 7,000
Contingency (15%)	$ 90,000
Subtotal Capital Costs	**$ 688,000**

Operation and Maintenance Costs (Annual)	
Labor	$ 83,000
Maintenance Services	$ 27,000
Utility Services	$ 12,000
Chemical Utilization	$ 18,000
Sludge Disposal	$ 18,000
Ground-Water Monitoring/Reporting	$ 53,000
Subtotal Annual O&M Costs	**$ 211,000**
5 Years O&M, NPV, 5% Discount Rate	**$ 914,000**
Total Capital and Operating and Maintenance Costs	**$1,602,000**

Table C-5. Cost Estimate for Alternative 4a: Ground-Water Extraction at Leading Edge of Plume and Onsite; Discharge to Sewer

Assumptions

- Average flow 35 gallons per minute; maximum flow 47 gallons per minute.
- Pretreatment of ground water is not required prior to discharge to sewer.
- Connect to sewer within 100 feet of recovery well MW-15 and within 500 feet of recovery well near MW-13.
- 5 year operating and monitoring period.

Cost Estimate Summary

Capital Costs	
Final Design/Permits	$ 20,000
System Installation/Structures	$ 30,000
Revocable Consent	$ 30,000
Pumping, Conveyance and Discharge Systems	$ 122,000
Contingency (15%)	$ 30,000
Subtotal Capital Costs	**$ 232,000**
Operation and Maintenance Costs (Annual)	
Labor	$ 43,000
Maintenance Services	$ 10,000
Utility Services	$ 44,000
Ground-Water Monitoring/Reporting	$ 33,000
Subtotal Annual O&M Costs	**$ 130,000**
5 Years O&M, NPV, 5% Discount Rate	**$ 563,000**
Total Capital and Operating and Maintenance Costs	**$ 795,000**

Table C-6. Cost Estimate for Alternative 4b: Ground-Water Extraction at Leading Edge of Plume and Onsite; Treatment and Discharge to Sewer

Assumptions

- Average flow 35 gallons per minute; maximum flow 47 gallons per minute.
- No activated carbon treatment required for discharge to sewer.
- Total length of piping/trenching is 1,500 linear feet.
- 5 year operating and monitoring period.
- Design/permit costs included with system installation/structures and pumping, conveyance and discharge systems where appropriate.

Cost Estimate Summary

Capital Costs	
Treatment Equipment	$ 107,000
System Installation/Structures	$ 250,000
Revocable Consent	$ 30,000
Pumping, Conveyance and Discharge Systems	$ 148,000
Treatability Studies	$ 7,000
Contingency (15%)	$ 81,000
Subtotal Capital Costs	**$ 623,000**
Operation and Maintenance Costs (Annual)	
Labor	$ 83,000
Maintenance Services	$ 27,000
Utility Services	$ 54,000
Chemical Utilization	$ 22,000
Sludge Disposal	$ 28,000
Ground-Water Monitoring/Reporting	$ 53,000
Subtotal Annual O&M Costs	**$ 267,000**
5 Years O&M, NPV, 5% Discount Rate	**$1,156,000**
Total Capital and Operating and Maintenance Costs	**$1,779,000**

Table C-7 Cost Estimate for Alternative 4c: Ground-Water Extraction at Leading Edge of Plume and Onsite; Treatment and Discharge to Ground Water

Assumptions

- Average flow 35 gallons per minute; maximum flow 47 gallons per minute.
- Requires installation of 2 Carbtrol Model L-5 Adsorbers for Granular Activated Carbon (GAC) treatment prior to discharge.
- Total length of piping/trenching is 1,500 linear feet.
- Total ground-water monitoring for period of 5 years.
- Design/permit costs included with system installation/structures and pumping, conveyance and discharge systems where appropriate.

Cost Estimate Summary

Capital Costs	
Treatment Equipment	$ 124,000
System Installation/Structures	$ 289,000
Revocable Consent	$ 30,000
Pumping, Conveyance and Discharge Systems	$ 233,000
Treatability Studies	$ 7,000
Contingency (15%)	$ 102,000
Subtotal Capital Costs	**$ 785,000**
Operation and Maintenance Costs (Annual)	
Labor	$ 83,000
Maintenance Services	$ 27,000
Utility Services	$ 15,000
Chemical Utilization	$ 30,000
Sludge Disposal	$ 28,000
Ground-Water Monitoring/Reporting	$ 53,000
Subtotal Annual O&M Costs	**$ 236,000**
5 Years O&M, NPV, 5% Discount Rate	**$1,022,000**
Total Capital and Operating and Maintenance Costs	**$1,807,000**

Table C-8 Cost Estimate for Alternative 5a: Ground-Water Extraction Onsite; Discharge to Sewer

Assumptions

- Average flow 30 gallons per minute; maximum flow 40 gallons per minute.
- Pre-treatment of ground water is not required prior to discharge to sewer.
- Connect to sewer within 500 feet of recovery well.
- 5 year operating and monitoring period.

Cost Estimate Summary

Capital Costs	
Final Design/Permits	$ 15,000
System Installation/Structures	$ 20,000
Pumping, Conveyance and Discharge Systems	$96,000
Contingency (15%)	$ 20,000
Subtotal Capital Costs	**$151,000**
Operation and Maintenance Costs (Annual)	
Labor	$ 43,000
Maintenance Services	$ 10,000
Utility Services	$ 37,000
Ground-Water Monitoring/Reporting	$ 33,000
Subtotal Annual O&M Costs	**$123,000**
5 Years O&M, NPV, 5% Discount Rate	**$533,000**
Total Capital and Operating and Maintenance Costs	**$684,000**

Table C-9 Cost Estimate for Alternative 5b: Ground-Water Extraction Onsite; Treatment and Discharge to Sewer

Assumptions

- Average flow 30 gallons per minute; maximum flow 40 gallons per minute.
- No activated carbon treatment required for discharge to sewer.
- Total length of piping/trenching is 700 linear feet.
- 5 year operating and monitoring period.
- Design/permit costs included with system installation/structures and pumping, conveyance and discharge systems where appropriate.

Cost Estimate Summary

Capital Costs	
Treatment Equipment	$ 105,000
System Installation/Structures	$ 245,000
Pumping, Conveyance and Discharge Systems	$ 106,000
Treatability Studies	$ 7,000
Contingency (15%)	$ 69,000
Subtotal Capital Costs	**$ 532,000**
Operation and Maintenance Costs (Annual)	
Labor	$ 83,000
Maintenance Services	$ 27,000
Utility Services	$ 46,000
Chemical Utilization	$ 19,000
Sludge Disposal	$ 25,000
Ground-Water Monitoring/Reporting	$ 53,000
Subtotal Annual O&M Costs	**$ 253,000**
5 Years O&M, NPV, 5% Discount Rate	**$1,095,000**
Total Capital and Operating and Maintenance Costs	**$1,627,000**

Table C-10 Cost Estimate for Alternative 5c: Ground-Water Extraction Onsite; Treatment and Discharge to Ground Water

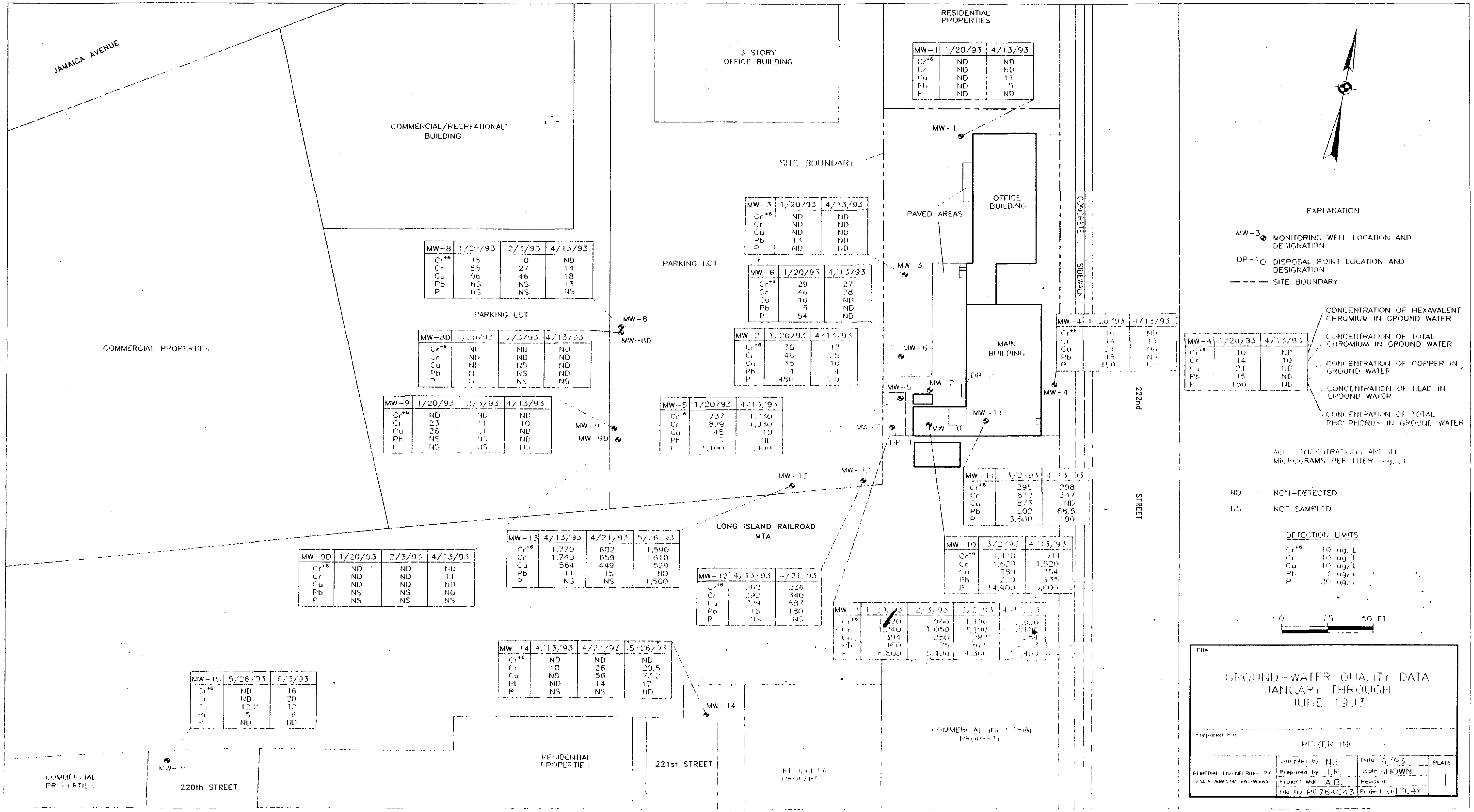
Assumptions

- Average flow 30 gallons per minute; maximum flow 40 gallons per minute.
- Requires installation of 2 Carbtrol Model L-5 Adsorbers for GAC treatment prior to discharge.
- Total length of piping/trenching is 700 linear feet.
- 5 year operating and monitoring period.
- Design/permit costs included with system installation/structures and pumping, conveyance and discharge systems where appropriate.

Cost Estimate Summary

Capital Costs	
Treatment Equipment	$ 122,000
System Installation/Structures	$ 285,000
Pumping, Conveyance and Discharge Systems	$ 134,000
Treatability Studies	$ 7,000
Contingency (15%)	$ 82,000
Subtotal Capital Costs	**$ 630,000**
Operation and Maintenance Costs (Annual)	
Labor	$ 83,000
Maintenance Services	$ 27,000
Utility Services	$ 12,000
Chemical Utilization	$ 26,000
Sludge Disposal	$ 25,000
Ground-Water Monitoring/Reporting	$ 53,000
Subtotal Annual O&M Costs	**$ 226,000**
5 Years O&M, NPV, 5% Discount Rate	**$ 979,000**
Total Capital and Operating and Maintenance Costs	**$1,609,000**

PLATES



MW-1	1/20/93	4/13/93
Cr^{+6}	ND	ND
Cr	ND	ND
Cu	ND	11
Pb	ND	5
P	ND	ND

MW-2	1/20/93	4/13/93
Cr^{+6}	36	17
Cr	46	25
Cu	35	10
Pb	4	4
P	480	[illegible]

MW-3	1/20/93	4/13/93
Cr^{+6}	ND	ND
Cr	ND	ND
Cu	ND	ND
Pb	13	ND
P	ND	ND

MW-4	1/20/93	4/13/93
Cr^{+6}	10	ND
Cr	14	10
Cu	21	ND
Pb	15	ND
P	150	ND

MW-5	1/20/93	4/13/93
Cr^{+6}	737	1,730
Cr	829	[illegible]
Cu	45	10
Pb	[illegible]	ND
P	1,100	1,400

MW-6	1/20/93	4/13/93
Cr^{+6}	29	27
Cr	46	28
Cu	10	ND
Pb	5	ND
P	54	ND

MW-7	1/20/93	2/3/93	3/2/93	4/13/93
Cr^{+6}	[illegible]	960	1,100	[illegible]
Cr	1,240	1,050	1,190	[illegible]
Cu	304	250	[illegible]	254
Pb	150	75	[illegible]	[illegible]
P	[illegible]	5,400	4,300	[illegible]

MW-8	1/20/93	2/3/93	4/13/93
Cr^{+6}	15	10	ND
Cr	55	27	14
Cu	96	46	18
Pb	NS	NS	13
P	NS	NS	NS

MW-8D	1/20/93	2/3/93	4/13/93
Cr^{+6}	ND	ND	ND
Cr	ND	ND	ND
Cu	ND	ND	ND
Pb	[illegible]	NS	ND
P	[illegible]	NS	NS

MW-9	1/20/93	2/3/93	4/13/93
Cr^{+6}	ND	ND	ND
Cr	23	11	10
Cu	26	21	ND
Pb	NS	NS	ND
P	NS	NS	NS

MW-9D	1/20/93	2/3/93	4/13/93
Cr^{+6}	ND	ND	ND
Cr	ND	ND	11
Cu	ND	ND	ND
Pb	NS	NS	ND
P	NS	NS	NS

MW-10	3/2/93	4/13/93
Cr^{+6}	1,410	911
Cr	1,620	1,520
Cu	580	754
Pb	[illegible]	135
P	14,900	6,600

MW-11	3/2/93	4/13/93
Cr^{+6}	295	298
Cr	612	347
Cu	873	ND
Pb	102	68.5
P	3,600	190

MW-12	4/13/93	4/21/93
Cr^{+6}	262	236
Cr	292	340
Cu	729	987
Pb	16	180
P	NS	NS

MW-13	4/13/93	4/21/93	5/26/93
Cr^{+6}	1,770	602	1,590
Cr	1,740	659	1,610
Cu	564	449	529
Pb	11	15	ND
P	NS	NS	1,500

MW-14	4/13/93	4/21/93	5/26/93
Cr^{+6}	ND	ND	ND
Cr	10	26	20.5
Cu	ND	56	73.2
Pb	ND	14	17
P	NS	NS	ND

MW-15	5/26/93	6/3/93
Cr^{+6}	ND	16
Cr	ND	20
Cu	12.2	12
Pb	5	6
P	ND	ND

ALL CONCENTRATIONS ARE IN MICROGRAMS PER LITER (ug/L)

ND -- NON-DETECTED

NS NOT SAMPLED

DETECTION LIMITS

Cr^{+6}	10 ug/L
Cr	10 ug/L
Cu	10 ug/L
Pb	3 ug/L
P	20 ug/L

Title

GROUND-WATER QUALITY DATA JANUARY THROUGH JUNE 1993

Prepared For

PFIZER INC

REMEDIAL ENGINEERING, P.C.
ENVIRONMENTAL ENGINEERS

Compiled by N.F.	Date 6/93	PLATE
Prepared by J.R.	Scale SHOWN	1
Project Mgr. A.B.	Revision	
File No. PF764043	Project [illegible]	