NTH Consultants, Ltd.

Corrective Action Plan

City Maintenance Garage
City of Ann Arbor
721 North Main Street
Ann Arbor, Michigan

Prepared For:

City of Ann Arbor
Engineering Division
Ann Arbor, Michigan

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EXECUTIVE SUMMARY

The release of gasoline and diesel fuel from two underground storage tanks (UST) at the City of Ann Arbor City Garage located at 721 North Main Street in Ann Arbor, Michigan has impacted soil and groundwater with petroleum at the site. Utilizing the results of site investigation and contaminant characterization for the gasoline UST, completed by The Traverse Group, Inc. (TGI) and the results of additional site investigation and pilot testing of several remediation technologies by NTH Consultants, Ltd. (NTH), we have prepared this corrective action plan (CAP) for the impacted soil and groundwater at the site. This report includes a brief review of previous studies; information regarding the additional site investigation by NTH; background information including site geology, hydrogeology, and contaminant distribution; a description of the pilot test methods and results; and a conceptual remedial design. Information provided in this document will be used to prepare the project construction drawings.

Our site investigation included drilling seven test borings; installing three monitoring wells, three piezometer nests and a single shallow piezometer; and the completion of a chemical testing program of groundwater and soil samples. In addition, our investigation in the diesel tank location included collecting soil samples from the excavation adjacent to the tank; drilling 10 GeoProbe® borings; installing five monitoring wells, and completion of a chemical testing program for groundwater and soil samples.

Based on TGI and NTH investigations, the site geology across the zone of impacted soil and groundwater consists of the following layers from top to bottom: Fill; fine to medium sand; and soft to stiff silty clay. Both investigations indicated that the groundwater table is relatively level across the site typically at 792.3 feet in August 1995 (NTH) and at 793.4 feet in July 1993 (TGI). Based on this information, it appears that little of the impacted sandy soils below the clayey silt layer are unsaturated. Based on the results of TGI investigation and NTH additional investigation, we estimated the extent of impacted groundwater and soils in accordance with Tier 1 Residential Cleanup Criteria.

Our pilot testing program evaluated several remediation technologies including pump and treat, soil vapor extraction (SVE), bioventing (BV), and air sparging (AS). Using the pilot study data, we estimated the hydraulic properties of the soils and collected information regarding the response of the impacted soils to the different remediation methods.

Based on available subsurface information and results of our pilot testing, we developed a conceptual remedial system for the impacted soils and groundwater. The proposed system consists of the following:(1) two dewatering wells; (2) two SVE/BV wells; (3) one AS well; and (4) an above ground treatment system. The dewatering and AS wells will be used to remedy the impacted groundwater and saturated soil. The SVE/BV wells will address the unsaturated soil.

The above-ground treatment system for the liquid and vapor phase will consist of adsorption by granular activated carbon. The above-ground treatment system will be housed inside the garage or in a winterized shed located adjacent to the garage. After securing the required disposal permits, treated water may be discharged to the Allen Creek Drain.

Review of the previous work conducted at the site and earlier discussions with the City indicated that the site should be remediated to Type B cleanup criteria. However, since the soil and groundwater criteria have recently changed based on PA 451 amendments (Part 213, PA 451), the cleanup goals used to develop this final CAP followed the recently published MDEQ Tier 1 Risk Based Corrective Action (RBCA) soil and groundwater cleanup criteria for residential sites.

1.0 INTRODUCTION

The City of Ann Arbor (City) reported a release from a 2,000-gallon gasoline underground storage tank (UST) located at the their maintenance garage at 721 North Main Street, Ann Arbor, Michigan, (see Plate 1). The tank was owned and operated by the City. The UST was removed from the site on December 14, 1989. Visual and olfactory evidence of hydrocarbon release was noted during the removal and initial abatement measures were initiated including removal, transportation and disposal of 45 cubic yards of soil at the Ann Arbor landfill in Ann Arbor, Michigan.

The City contracted the services of The Traverse Group, Inc. (TGI) to characterize the site geology and hydrology, to assess the nature and extent of contamination and to conduct a preliminary feasibility analysis of viable remedial alternatives for the site cleanup. TGI completed numerous boreholes and monitoring wells and collected and analyzed soil and groundwater samples. In addition, they also installed a free product recovery system to remove free-phase product previously detected at the site. The results of these activities are reported in the following reports:

- 45-Day Report, dated January 29, 1990.
- Site Investigation Report for an Underground Storage Tank Release, dated October 30, 1990.
- Type A Closure Report, dated April 7, 1992.
- Gasoline Tank Supplemental Site Investigation and Work Plan, dated October 2, 1992.
- Gasoline Tank Supplemental Site Investigation Work Plan, dated February 23, 1993.
- Gasoline Tank Supplemental Site Investigation, dated June 21, 1993.
- Feasibility Study, dated April 15, 1994.

Site investigations by TGI confirmed that petroleum-related substances had impacted site soils and groundwater. In addition, there is a 100- gallon used oil UST exists on the site. The tank was reportedly installed in 1991 replacing a leaking 550 gallon used oil UST. The area of the previous leaking used oil UST obtained a "Type A: Closure from the MDNR in August 1993. Furthermore, a release of gasoline and/or diesel fuel occurred from the underground piping for the two above-ground storage tanks (ASTs) on the site. Subsequent remediation included soil removal and purge well installation. The approximate location of the purge well is shown on Plate 2.

Subsequently, the City retained NTH Consultants, Ltd., (NTH) in December, 1994 to complete the design, construction and startup of a remedial system for the site and also to operate and maintain the system. NTH reviewed the previous reports for the site prepared by TGI and the results presented in these reports provided the basis for NTH's approach.

NTH completed an additional site investigation and designed and implemented a pilot study at the site. The purpose of the additional site investigation was to better characterize the source area soil and groundwater conditions to facilitate design and implementation of both the pilot study and the full-scale remediation system.

In June 1995, a release was reported by NTH from a 1000- gallon diesel fuel UST located as shown on Plate 2. Due to the proximity of the diesel UST to the maintenance building, it was closed in-place. NTH monitored and documented the closure activities in a report entitled "UST In-Place Closure Status Report, " dated July 13, 1995. Following the closure of the UST, NTH completed a field investigation to characterize the source area soil and groundwater conditions. An "Initial Assessment Report" was completed on December 26, 1995, summarizing the findings. The diesel UST remediation has been incorporated into the gasoline release remediation presented in this CAP.

Based on the information provided by TGI, the additional site investigation, the diesel fuel UST investigation, and the results of the pilot study, NTH developed a remedial system for the site cleanup. Details of NTH activities and the proposed remedial system are reported in this Corrective Action Plan (CAP).

Consistent with the appropriate and applicable regulations in 1994, the City recommended that the site be remediated to MDNR Type B soil and groundwater criteria. However, since the soil and groundwater criteria have recently changed, The City has agreed to develop this CAP based on cleanup goals consistent with newly promulgated and somewhat similar MDEQ RBCA Tier 1 soil and groundwater cleanup criteria for residential sites.

2.0 ADDITIONAL SITE INVESTIGATION

2.1 PURPOSE AND SCOPE

The purpose of the additional investigation was to better characterize the soil and groundwater conditions in the area of the release to facilitate design and implementation of both the pilot study and the full-scale remediation system. Specific tasks of the investigation included:

- Drilling and Soil Sampling - A total of seven soil borings were completed in and around the gasoline release (see Plate 2). Soil samples were collected for classification and analysis. The borings were used for determining soil types and for the installation of test wells and piezometers.

- Installation of Test Wells and Piezometers - Three test wells, three piezometer nests and a single shallow piezometer well were installed for the additional investigation and for the pilot study. The three test wells consist of a 4-inch diameter soil vapor extraction/recovery well, a 4-inch diameter air sparging well, and a 2-inch bioventing well. Each of the three piezometer nests contains three 1-inch diameter piezometer. The shallow piezometer consist of a one inch diameter well.

- Analytical Testing - Analytical testing for soil and groundwater samples included BTEX, MTBE, PNAs and/or Lead.

- Evaluation - The data from the additional investigation has been compiled and evaluated as presented later in this report.

2.2 INVESTIGATIVE METHODS

2.2.1 Drilling and Soil Sampling

Seven test borings (TB-1 through TB-7) were drilled and sampled by Geo Tek, Inc. of Lowell, Michigan under the technical supervision of NTH personnel between April 12 and 15, 1995. The test borings were also used for the installation of test wells and piezometers for the pilot study. The approximate locations of the borings are shown on Plate 2.

The test borings were advanced to depths ranging from 5 to 17 feet below ground surface with a trailer mounted CME-45 rotary drill rig equipped with 4 -1/4 inch inside diameter hollow stem augers. An NTH field technician maintained a log of each boring which included a description of the soil samples collected, information on groundwater conditions encountered during drilling and other pertinent data. In general, soil samples were collected at 2.5 and 5.0 foot depth intervals using a 2- inch outside diameter split barrel sampler according to ASTM D-1586. Information from the standard penetration test, namely the standard penetration resistance (N) and the blow counts were recorded on the log for each boring.

After opening the split barrel soil sampler and describing the contents, a representative soil sample was placed in laboratory-supplied glass containers for chemical testing and another portion of the soil sample was collected in a plastic storage bag with a sealable top for field headspace testing (screening). The samples collected in storage bags were allowed to reach approximately 70 degrees Fahrenheit and then the approximate concentration of total volatile organic compounds (VOCs) in the air-space inside the bag was measured with a portable photoionization (HNu) meter. The sample "screening" was performed by inserting the probe tip of the HNu meter into a small opening in the seal of the plastic storage bag. The HNu response to the headspace gas inside the bag was then observed and recorded on the field log. Soil samples for chemical testing were placed in iced coolers and were transported to an analytical laboratory using standard Chain-of-Custody procedures.

Prior to arrival on site and between borings, the drilling and sampling equipment were steam cleaned to minimize the potential for cross contamination of samples. In addition, the split barrel sampler was decontaminated between successive samples at each boring.

Soil and groundwater conditions encountered in the test borings have been evaluated and are presented in the form of individual Test Boring Logs and are attached as Figures 1 through 7 in Appendix A. Our General Notes describing nomenclature used on the logs is also attached as Exhibit A. The test boring logs have been prepared on the basis of field classification of the soils encountered. The stratification lines shown on the logs represent the approximate boundary between soil types, but the actual transition may be more gradual. The boring logs also present information relating to soil sample data, standard penetration test results, groundwater conditions observed in the borings, personnel involved and other pertinent data.

Upon completion of soil sampling, test boring Nos. TB-1 through TB-7 were then over-drilled using 6 1/4 or 8 1/4 inch inside diameter hollow stem augers to allow for test well or piezometer nest installation.

2.2.2 Installation of Groundwater Recovery/Injection Test Wells

A soil vapor extraction/recovery well (SVE-1), a bioventing well (BV-1) and an air sparge well (AS-1) were installed in test boring Nos. TB-1, TB-2, and TB-7, respectively. These wells were installed for soil vapor extraction, groundwater pump recovery, bioventing, and air sparging testing for the pilot study and also can serve as groundwater monitoring wells. Components of each well are described below.

- SVE-1 consist of a 4-inch diameter by 15 foot long PVC screen (0.010 inch slot) flush-coupled with a 4-inch diameter PVC riser pipe, (see Figure 8 in Appendix A);

- BV-1 consists of a 2-inch diameter by 6 foot long PVC screen (0.010 inch slot) flush coupled to a 2-inch diameter PVC riser pipe, (see Figure 9 in Appendix A); and

- AS-1 consists of a 4-inch diameter by 2-foot long PVC screen (0.010 inch slot) flush-coupled to a 4-inch diameter PVC riser pipe, (see Figure 10 in Appendix A).

Following completion of over drilling with 6 -1/4 and 8 - 1/4 inch ID augers, well assemblies for SVE-1, BV-1, and AS-1 were lowered in the bottom of the respective borings through the hollow stem augers.

The annular space was then filled with washed silica sand, followed by hydrated bentonite pellets and cement-bentonite grout. Each well head was secured with a steel protective cover.

Information regarding well installation procedures and materials used are presented in the form of individual well logs, presented as Figures No. 8 through 10 in Appendix A.

The top of the casing elevations were surveyed to the nearest 0.01 foot using conventional surveying techniques. NTH personnel used the casing tops of previously installed wells for benchmark reference to determine the top of casing elevations for recently installed wells. Monitoring wells previously installed at the site were surveyed by a registered surveyor to determine the top of casing elevations correlated with USGS benchmark datum to the nearest 0.01 foot.

2.2.3 Installation of Piezometer Nests

Following over drilling with the 6 1/4 or 8 1/4 inch hollow stem augers, nested piezometers P-1, P-2 and P-3 were installed in test boring TB-5, TB-3 and TB-4, respectively. Each nested piezometer contains three piezometers. The piezometers are constructed of one inch diameter by 1-foot or 2-foot long PVC screens (0.010 inch slot) flush coupled to one inch diameter PVC riser pipe. In each piezometer nest, the screen tips are set at 5, 10, and 17 feet below existing ground surface. Piezometer P-4 was installed in test boring TB-6. The screen for P-4 was set at 5 feet below ground surface. The annular space around each screen contains washed silica sand. The well screens within each piezometer nest are separated by bentonite seals. Each piezometer nest was completed with a 1-foot thick concrete pad and a steel protective cover at the ground surface. Piezometer construction details are provided in Figures 11 through 14 in Appendix A.

2.2.4 Groundwater Sampling and Analysis

On September 5, 1995 NTH personnel collected groundwater samples from three recently installed piezometer wells, P-1, P-2 and P-3 (9'-10' screened interval), and from previously installed well MW-7. The piezometers were sampled using a peristaltic pump and clear PVC tubing (a new section of tubing was utilized for each sample). Monitoring well MW-7 was sampled using bottom filling disposable

HDPE bailers. Prior to sampling, each piezometer or well was purged of at least 3 well volumes of water. These containers have been properly disposed of by the City of Ann Arbor.

The collected samples were placed in laboratory supplied sample bottles with appropriate preservatives. The sample bottles were then placed in a field cooler with ice and were transported to National Environmental Testing, Inc. (NET) in Auburn Hills, Michigan for chemical testing under standard Chain-of-Custody protocol. The groundwater samples collected from the wells were analyzed for the presence of BTEX, MTBE, PNAs and dissolved lead according to the proper EPA SW-846 Test Methods. The portion of each groundwater sample analyzed for dissolved lead was filtered at the time of sampling by NTH personnel using 0.45 micron disposable filters. The results of the groundwater chemical testing are provided on Table 1 in Appendix B. The laboratory analytical reports and laboratory QA/QC data are also provided in Appendix B.

2.2.5 Analytical Testing of Soil Samples

A total of seven soil samples (two from TB-1; one from TB-2; two from TB-3; and two from TB-4) collected from the test borings for this investigation were analyzed by NET for the presence of BTEX, MTBE, PNAs and Total Lead according to the proper EPA SW-846 Test Methods. No samples from TB-5, TB-6, or TB-7 were analyzed. The chemical testing data is summarized on Table 1 in Appendix B. Laboratory data reports and laboratory QA/QC data are also provided in Appendix B.

3.0 DIESEL FUEL UST INVESTIGATION

3.1 PURPOSE AND SCOPE

The 1,000-gallon diesel UST was closed in place in June 1995. During closure activities, soil and groundwater samples were analyzed for BTEX and PNAs. The results indicated that the soil and groundwater adjacent to the tank were impacted. For more details about closure and initial assessment activities refer to a report titled "UST In-Place Closure Status Report, dated July 13, 1995 and an "Initial Assessment Report" dated December 26, 1995. The purpose of this investigation was to characterize the source area soil and groundwater conditions to facilitate the design and implementation of the full-scale remediation system. Specific tasks of the investigation included:

- Drilling and Soil Sampling - A total of ten GeoProbe(R) borings were completed in and around the diesel fuel UST source area, (see Plate 2). Soil samples were collected for classification and analysis. The borings were used for determining soil types and to define the extent of contamination.

- Installation of Test Wells - Five monitoring wells were installed for the UST investigation to determine if the groundwater had been impacted by the diesel fuel release.

- Analytical Testing - Analytical testing for soil and groundwater samples included BTEX, MTBE and PNAs.

- Evaluation - The data from the additional investigation has been compiled and evaluated as presented later in this report.

3.2 INVESTIGATIVE METHODS

3.2.1 Drilling and Soil Sampling

Ten GeoProbe(R) test borings (GP-1 through GP-10) were drilled and sampled by All Terrain Services (ATS) under the technical supervision of NTH personnel on August 29-30, 1995. The approximate locations of the borings are shown on Plate 2.

The test borings were advanced to an average depth of 12.5 feet below ground surface with GeoProbe(R) soil sampling machine. An NTH field technician maintained a log of each boring which included a description of the soil samples collected, information on groundwater conditions encountered during drilling and other pertinent data. Soil samples were collected on a continuous basis using a 2-inch outside diameter by 4 feet long macro sampler with an acetate inner liner.

After opening the split barrel soil sampler and describing the contents, a representative soil sample was placed in laboratory-supplied glass containers for chemical testing and another portion of the soil sample was collected in a plastic storage bag with a sealable top for field headspace testing (screening). The samples collected in storage bags were allowed to reach approximately 70 degrees Fahrenheit and then the approximate concentration of total volatile organic compounds (VOCs) in the air-space inside the bag was measured with a portable photoionization (HNu) meter. The sample "screening" was performed by inserting the probe tip of the HNu meter into a small opening in the seal of the plastic storage bag. The HNu response to the headspace gas inside the bag was then observed and recorded on the field log. Soil samples for chemical testing were placed in iced coolers and were transported to an analytical laboratory using standard Chain-of-Custody procedures.

Prior to arrival on site and between borings, the drilling and sampling equipment were steam cleaned to minimize the potential for cross contamination of samples. In addition, the macro sampler was decontaminated between successive samples at each boring and a new acetate liner was used for each sample collected.

Soil and groundwater conditions encountered in the test borings have been evaluated and are presented in the form of individual Geo Probe Boring Logs and are attached as Figures 15 through 17 in Appendix A. The test boring logs have been prepared on the basis of field classification of the soils encountered. The indicated depths shown on the logs represent the approximate boundary between soil types, but the actual transition may be more gradual. The boring logs also present information relating to soil sample data, groundwater conditions observed in the borings, personnel involved and other pertinent data.

3.2.2 Installation of Groundwater Monitoring Wells

On August 31, 1995, GP-1, GP-8, GP-6, GP-10 and GP-9 were converted to monitoring wells number MW-101 through MW-105, respectively. The GeoProbe locations were over drilled by Geo-Tek, Inc. using 4 1/4 inch inside diameter hollow stem augers driven by a trailer mounted CME-45 drill rig.

Each well consisted of a 2-inch diameter by 5-foot long PVC screen (0.01 inch slot) flush-coupled with 2-inch diameter PVC riser pipe. Following completion of over drilling, well assemblies were lowered in the bottom of the respective borings through the hollow stem augers (completed well depths averaged 10.5 feet). The annular space was then filled with washed silica sand, followed by hydrated bentonite pellets and cement-bentonite grout. Each well head was secured with a steel protective cover.

The borings and well installations were performed under the supervision of NTH personnel. Information regarding well installation procedures and materials used are presented in the form of individual well logs, presented as Figures No. 18 through 22 in Appendix A.

The top of the casing elevations of well numbers MW-101 through MS-105 were surveyed to the nearest 0.01 foot using conventional surveying techniques. NTH personnel used the casing tops of nearby previously installed TGI wells for reference. The elevations of the TGI wells were reported to be correlated with USGS benchmark datum to the nearest 0.01 foot.

The wells were developed by surging and then over-bailing on September 1, 1995. Water was removed until it was relatively sediment free, and temperature and pH had stabilized. The well development water was stored temporarily on-site in DOT approved containers. These containers have been later properly disposed by the City of Ann Arbor.

3.2.3 Groundwater Sampling and Analysis

On June 16, 1995, during the in-place closure of the UST, NTH collected one groundwater sample from the tank excavation . The result of the groundwater chemical testing for the UST excavation sample is provided on Table 3 in Appendix B.

On August 29 and 30, 1995 NTH personnel collected groundwater samples from GP-2, GP-5 and GP-7 during soil sampling activities. The samples were collected by setting a temporary well point and using a peristaltic pump and disposable Tygon(R) tubing. A new section of tubing was used for each sampling event. On September 5, 1995, monitoring wells MW-101 through 105 were sampled using bottom filling, disposable HDPE bailers. Prior to sampling, each well was purged of at least 3 well volumes of water. The purged water was temporarily stored on-site in DOT approved metal containers which have been properly disposal at a later time by the City of Ann Arbor.

The collected samples were placed in laboratory supplied sample bottles with appropriate preservatives. The sample bottles were then placed in a field cooler with ice and were transported to National Environmental Testing, Inc. (NET) in Auburn Hills, Michigan for chemical testing under standard Chain-of-Custody protocol. The groundwater samples collected from the wells were analyzed for the presence of BTEX, and PNAs according to EPA SW-846 Test Methods 8020 and 8310, respectively. The results of the groundwater chemical testing for the GeoProbe and monitoring well samples are provided on Table 2 in Appendix B. The laboratory analytical reports and laboratory QA/QC data are also provided in Appendix B.

3.2.4 Analytical Testing of Soil Samples

On June 16, 1995, five samples were collected from the UST excavation. The results of the groundwater and soil chemical testing for the UST excavation samples are provided on Table 3 in Appendix B.

On August 29 and 30, 1995, a total of ten soil samples (one from each) were collected from the GeoProbe borings and analyzed by NET for the presence of BTEX, and PNAs using EPA SW-846 Test Methods 8020 and 8310, respectively. The results of the groundwater chemical testing for the GeoProbe samples are provided on Table 2 in Appendix B. The laboratory analytical reports and laboratory QA/QC data are also provided in Appendix B.

4.0 SITE GEOLOGY, HYDROGEOLOGY, AND CONTAMINANT DISTRIBUTION

4.1 SITE GEOLOGY

Based on site investigations completed by TGI and NTH, the general subsurface soil conditions observed across the zone of petroleum impacted soil and groundwater consists of the following three layers, from top down: (1) Fill Material; (2) Fine to Medium Sand; and (3) soft to stiff clay. The three layers are described below:

Fill Material: The fill materials consisted of silty sand, clayey silt, silty clay, and organic matter. Occasional debris was encountered. The bottom depth of this layer ranges from 6.5 feet to 9.0 feet.

Native Fine to Medium Sand: The sand layer is dominated by silty sand and coarse sand and gravel. The depth of the bottom of this layer ranges from 6.5 feet to 23.0 feet.

Soft to Stiff Silty Clay: This layer consist of gray silty clay with varying consistencies ranges from soft to stiff. It extends from the bottom of the sand layer to the maximum explored depth of 29 feet.

4.2 SITE HYDROGEOLOGY

Based on information reported by TGI, during their March 1993 investigation, the groundwater elevations across the site varied from 768.73 to 776.69 feet. Based on groundwater elevations collected by NTH on September 1 and November 28, 1995, the groundwater elevation across the site ranged from 768.78 feet at the location of monitoring well MW-9 to 776.01 feet at the location of monitoring well MW-103. Using November 28, 1995 groundwater information, we prepared a groundwater elevation contour map presented as Plate 3.

Different monitoring wells were measured by TGI in order to establish the ground-water flow direction and the hydraulic gradient. Based on this information, the groundwater flow direction is south 45 degrees east (S 45° E) and the hydraulic gradient is 0.025.

The site lies in a 100-year flood plain and some of the site lies within the flood way of the Allen Creek drainage basin. Allen Creek Drain serves as the main storm sewer for the City of Ann Arbor. The main branch of Allen Creek Drain enters the site from the south heading north and turns northeast in the middle of the site.

4.3 CONTAMINANT DISTRIBUTION

During previous and current investigations, the soil and groundwater samples were analyzed for indicator parameters of gasoline; benzene, toluene, ethyl benzene and xylene (BTEX), methyl(tert)butylether (MTBE), polynuclear aromatics (PNAs), and lead. The following methods were applied for the analysis:

- BTEX and MTBE Method 8020
- PNAs Method 8310
- Total Lead Method 7421 (furnace)

Based on the results of this testing, we estimated the extent of the impacted soil and groundwater in accordance with Tier 1 Residential Cleanup Criteria.

The concentrations of VOCs and PNAs detected in the soil and groundwater samples tested by NTH are summarized in Tables 1 through 3 in Appendix B. The concentrations of VOCs and PNAs detected in the soil and groundwater samples tested by TGI are summarized in Tables 4 and 5 in Appendix B. Comparison of the parameter concentrations with the Part 213 Tier 1 criteria, also summarized in Tables 1 through 5, reveals several compounds which exceed one or more criteria.

4.3.1 Extent of Petroleum Impacted Soil

During the NTH investigation, as shown on the boring logs provided in Appendix A, positive field screened HNu readings were reported for most of the collected soil samples. Typically, the HNu values ranged from 50 ppm to 400 ppm in the vadose zone soils and then decreased significantly, ranging from <1 ppm to 5 ppm, with increasing depth.

As part of TGI's investigations, thirty-three soil samples were tested for the presence of BTEX and/or PNAs. Soil sampling depths ranged from one foot to seventeen feet below grade. A review of the analytical data for the testing performed by TGI, indicates that no contaminants (BTEX or PNAs) were detected in excess of Tier 1 Residential Direct Contact or Soil Leaching to Groundwater cleanup criteria. See Table 5 in Appendix B for a summary of soil sample analytical testing performed by TGI.

As part of NTH's pilot study, seven soil samples were analyzed for the presence of BTEX and Total Lead. Soil sampling depths ranged from five feet to ten feet below ground surface (bgs). A review of the analytical data indicates that none of the samples have BTEX contaminant concentration in excess of Tier 1 Residential Soil Direct Contact cleanup criteria. However, six of the samples have benzene concentrations in excess of Tier 1 Residential Soil Leaching to Groundwater cleanup criteria. In addition, one sample (TB-3 @ 10' bgs) had toluene and ethylbenzene concentrations above Tier 1 Residential Soil Leaching to Groundwater cleanup criteria. Lead was detected in all seven samples, however, except for one sample (TB-4 @ 5' bgs), the concentrations were all below the MDEQ statewide default value for Lead. TB-4 @ 5' bgs had a Lead concentration above the statewide default value, but well below the Tier 1 Residential Soil Direct Contact cleanup value. Soil samples were not analyzed for the presence of PNAs as part of the pilot study. See Table 1 in Appendix B for a summary of the soil sample analytical testing performed for the pilot study.

As part of NTH's initial investigation during the in-place closure of the diesel fuel UST, five soil samples were collected from floor and sidewalls of the excavation. The samples were analyzed for the presence of BTEX and PNAs. None of the excavation samples had contaminant concentrations in excess of Tier 1 Residential Soil Direct Contact cleanup criteria. However, all five samples had contaminant concentrations in excess of Tier 1 Residential Soil Leaching to Groundwater cleanup criteria. The contaminants of concern in these samples include benzene, ethylbenzene, naphthalene and phenanthrene. See Table 3 in Appendix B for a summary of the excavation soil sample analytical testing.

As part of NTH's supplemental investigation for the in-place closure of the diesel fuel UST, ten soil samples collected from GeoProbe(R) borings were analyzed for the presence of BTEX and PNAs. A review of the analytical data indicates that all but one of the samples had contaminant concentrations below Tier 1 Residential Soil Direct Contact and Soil Leaching to Groundwater cleanup criteria. One sample (GP-2 @ 4.5'-6.5' bgs) had an ethylbenzene concentration below Tier 1 Soil Direct Contact, but above Soil Leaching to Groundwater cleanup criteria. See Table 2 for a summary of the supplemental investigation soil sample analytical data.

An approximation of the extent soil contamination in excess of MDEQ Tier 1 Residential Soil Leaching to Groundwater cleanup criteria is shown on Plate 4, **Extent of Soil Contamination Plan**. The extent of contamination plan is based on previous analytical data collected by TGI and on chemical data collected by NTH during the pilot study, the diesel fuel UST in-place closure and the supplemental investigation for the in-place UST closure.

4.3.2 Extent of Petroleum Impacted Groundwater

As part of TGI's investigations, thirty-seven groundwater samples were tested for the presence of BTEX and/or PNAs. Groundwater sampling depths ranged from four feet to twenty-seven feet below ground surface. A review of the analytical data for the testing performed by TGI, indicates that contaminants were detected in excess of Tier 1 Residential Direct Contact and/or Groundwater/Surface Water Interface cleanup criteria. The contaminants of concern included acenaphthene, acenaphthylene, benzo(a)anthracene, benzene, toluene, ethylbenzene and xylenes. See Table 4 for a summary of groundwater sample analytical testing performed by TGI.

As part of NTH's pilot study, four groundwater samples (P-1, P-2, P-3 and MW-7) were analyzed for the presence of BTEX, MTBE, PNAs and dissolved lead. Groundwater sampling depths ranged from 7 feet to 16 feet below ground surface (bgs). A review of the analytical data indicates that none of the samples had BTEX, MTBE, PNA or dissolved lead contaminant concentration in excess of Tier 1 Residential Direct Contact or Groundwater/Surface Water Interface (GSI) cleanup criteria, except for the sample from P-3, which had benzene contamination above the Direct contact value, but below the GSI value. See Table 1 for a summary of the groundwater sample analytical testing performed for the pilot study.

Three groundwater samples were also collected as part of NTH's pilot study during the execution of the pump test at well SVE-1. The first sample, referred to as WS-1, was collected just prior to the start of pumping. The second and third water samples, referred to as WS-2 and WS-3, were collected about thee and six hours after the start of pumping, respectively. These samples were analyzed for the presence of BTEX and total and dissolved lead. The results of these analyses are presented in Table 6 in Appendix B. Sample WS-1 had benzene concentrations above the direct contact value, and benzene and xylene levels above their respective GSI values. Sample WS-2 and WS-3 both had benzene levels above the direct contact value, but below the GSI value.

As part of NTH's initial investigation during the in-place closure of the diesel fuel UST, one groundwater sample was collected from floor of the excavation. The sample was analyzed for the presence of BTEX and PNAs. The excavation sample had contaminant concentrations in excess of Tier 1 Residential Direct Contact and/or GSI cleanup criteria. The contaminants of concern include naphthalene, phenanthrene and ethylbenzene. See Table 3 for a summary of the excavation groundwater sample analytical testing.

As part of NTH's supplemental investigation for the in-place closure of the diesel fuel UST, eight groundwater samples, collected from GeoProbe(R) borings and monitoring wells were analyzed for the presence of BTEX and PNAs. A review of the analytical data indicates that all but one of the samples showed no evidence of BTEX or PNAs, above method detection limits (MDL). One sample (MW-103) had a xylenes concentration just above the MDL, but well below Tier 1 Direct Contact and GSI cleanup criteria. See Table 2 for a summary of the supplemental investigation groundwater sample analytical data.

An approximation of the extent groundwater contamination in excess of MDEQ Tier 1 Residential Direct Contact and GSI cleanup criteria is shown on Plate 5, **Extent of Groundwater Contamination Plan**. The extent of contamination plan is based on previous analytical data collected by TGI and on chemical data collected by NTH during the pilot study, the diesel fuel UST in-place closure and the supplemental investigation for the in-place UST closure. Groundwater contamination in excess of Tier 1 limits was not encountered at depth below fifteen feet bgs.

4.3.3 Free Product Distribution

Free product was first discovered by NTH in MW-4 on April 25, 1995. Free product was not detected in any other wells at the site at that time or at any other times. The free product in MW-4 was linked to the diesel second UST located by NTH in June 1995. The tank was characterized by NTH as a 1,000-gallon diesel fuel UST which was found to contain product. As detailed in the closure report, all free product was removed from the tank, after which the tank was cleaned and properly closed. On June 16, 1995, during the diesel fuel UST in-place closure, approximately ½-gallon of product was recovered from MW-4 using a bailer. The recovered free product was put into a drum with the residual tank contents. the drum was later transported off-site for proper disposal. The thickness of free product was not recorded on June 16, 1995.

Beginning on November 28, 1995 and continuing through December 6, 1995, free product was recovered from MW-4 using a bailer. The recovered free product and water were placed into a 55-gallon drum and stored on-site awaiting proper disposal. Product thickness during this period ranged from 0.72 inches to 2.64 inches. An estimated total of 1.15 gallons of product was recovered during this period.

On December 8, 1995 and again on December 11, 1995 and December 22, 1995, no free product was found in MW-4, indicating that previous removal efforts had recovered all the free product. During the course of free product recovery, an estimated total of 1.65 gallons of free product was recovered.

5.0 PILOT STUDIES

5.1 INTRODUCTION

A series of pilot studies was conducted at the City of Ann Arbor Maintenance Garage, 721 North Main Street, to evaluate the following remediation technologies:

- Pump and Treat (P & T).
- Pump and treat and soil vapor extraction (P&T and SVE).
- Pump and treat, soil vapor extraction and air sparging (P&T, SVE and AS).
- Bioventing (BV)

The data collected during the pilot study were analyzed to evaluate flow characteristics of groundwater or air (permeability), the rate of biological oxygen consumption in the unsaturated zone and the radius of influence of the technologies evaluated. The data from the pilot tests and the results from the analysis are presented in the following sections.

5.2 PUMP TEST

The following approach was followed in the groundwater pumping test:

- The SVE-1 well was used as the pumping well. The pumping well was pumped at four constant rates. Each succeeding rate was higher than the previous pumping rate. The pumping rates and their associated duration are shown in Table 5.1.

- The hydraulic response of the groundwater system to pumping was monitored at piezometers P-1 through P-3. These monitoring points were located at different distances and at different directions around the pumping well. The hydraulic response was monitored at two depths, 10 and 17 feet. The locations of these monitoring points are shown in Plate 2 and their distances from the pumping well, depth below ground and screened interval are included in Table 5.2. The monitoring field data including time, drawdown, and pumping rate were summarized in tables and were used to determine the aquifer hydraulic properties. These data are presented in Appendix C.

TABLE 5.1

PUMPING CONDITIONS
STEP DRAW-DOWN PUMPING TEST

Pumping Rate (GPM)	Incremental Increase (GPM)	Duration (minutes)
1.3	1.3	34
5.3	4.0	29
10.0	4.7	120
14.9	4.9	160

TABLE 5.2

PHYSICAL SETTING OF PIEZOMETERS AND MONITORING WELLS
GROUNDWATER PUMPING TEST

Monitoring Location	Distance From Pumping Well (feet)	Depth Below Ground (feet)	Screened Interval (feet)
Piezometer P- 1	9.8	10.0, 16.5	2
Piezometer P-2	31.0	10.5, 17.2	2
Piezometer P-3	18.0	10.2, 17.5	2

- During the execution of the pump test, three water samples were collected from the pumping well and tested for BTEX, MTBE, PNAs, Total and Dissolved Lead. The first sample was collected just prior to pumping operations. The other two samples were collected at later stages during pumping operations. The results of the chemical testing for these samples are summarized in Table (6) attached to Appendix B and are discussed later in this section.

- The equation that describes radial flow to a pumping well was solved graphically to determine the transmissivity (T), storativity (S), and hydraulic conductivity (K) for several sets of data from the monitoring locations. Although the project site is not completely homogeneous and isotropic, this method provides a reasonable approximation for the water-bearing soils at the site. The hydraulic properties were estimated by analyzing the pump test results using Theis Method for piezometers P-1 and P-3. In addition, the radius of influence (R) was determined by plotting and analyzing the drawdown versus radial distance data for these piezometers. These graphical solutions are included in Appendix C. The results for T, S, and K are summarized in Table 5.3. The radius of influence is discussed below.

Radius of Influence: Based on the graphical analysis of drawdown versus log radial distance for Piezometers P-1 and P-3, a representative value for the radius of influence for a well being pumped at 14.9 gpm for a duration of 183 minutes is greater than 160 feet.

Hydraulic Properties (Water): As shown on Table 5.3, the values for hydraulic conductivity (K) range from 1.9×10^{-2} cm/sec (53.7 ft/day) to 2.2×10^{-2} cm/sec (63.2 ft/day) with an average value of 2.1×10^{-2} cm/sec (58.4 ft/day). These values are relatively higher than the average hydraulic conductivity of 2.5×10^{-5} cm/sec reported by TGI.

The transmissivity (T) ranged from 1180.6 ft^2/day to 1390.2 ft^2/day and averaged 1285.4 ft^2/day. The storativity (S) ranged from 1.1×10^{-2} to 4.2×10^{-2} and averaged 2.7×10^{-2}.

Concentration Of Contaminants: Based on the results of the chemical testing completed on the three groundwater samples collected from the recovery well (SVE-1), the concentration of contaminants was reduced significantly during the pumping operations. For example, the concentration of benzene was 170 ppm prior to pumping. Approximately three hours after pumping, the benzene concentration dropped to 10 ppm. After 6 hours of pumping, the benzene concentration was measured at 14 ppm, still an order of magnitude below the pre-pumping concentration.

TABLE 5.3 SUMMARY OF AQUIFER HYDRAULIC PROPERTIES STEP DRAWDOWN PUMP TEST			
Monitoring Location	Theis		
	T ft^2/d	S	K ft/d
Piezometer P-1	1180.7	$4.2x10^{-2}$	53.7
Piezometer P-3	1390.2	$1.1x10^{-2}$	63.2

5.3 SOIL VAPOR EXTRACTION TEST

The soil vapor extraction test was conducted in combination with groundwater pumping because of up-welling of groundwater in the SVE well when under vacuum and in the absence of pumping. The SVE test was conducted under the following conditions: (A) average groundwater pumping rate of 5.14 gpm for 110 minutes and then of 8.74 gpm for an additional 80 minutes; and (B) average vacuum and air flow from the SVE well of 16.3 inches of water and 41.2 actual cubic feet per minute (acfm) for 105 minutes, followed by 23.2 inches of water and 55 acfm for an additional 50 minutes, and 34.5 inches of water and 68 acfm for an additional 35 minutes. The response of the subsurface to the applied vacuum at the SVE well was monitored by manometers connected to monitoring points at five locations: P1, P2, P3, P4, and the bioventing well (BV-1). These monitoring points were located at radial distances of 9.8, 31, 18, 30.8, and 10.2 feet, respectively, from the SVE well. Monitoring locations P1, P2, and P3 had two monitoring piezometers with 2-foot long screens within each borehole; a shallow (S) piezometer at about a 4-foot depth, and a medium (M) piezometer at about a 10-foot depth. P4 is a single, 1-foot long monitoring

monitoring screen at a depth of about 4.5 feet, while BV-1 is also a single monitoring point having a 2-foot long screen at a depth of about 8.5 feet.

The response of the monitoring points at the end of each of the three periods of applied vacuum are given in Table 5.4

TABLE 5.4

Soil Vapor Extraction Pilot Study Results

Time (min)	SVE Well		P1		P2		P3		P4	BV-1
	Air Flow (acfm)	Vacuum (inches of water)	S	M	S	M	S	M	S	M
105	41.2	16.3	0	0.4	0.15	0.8	0.05	1.75	0.2	0.6
155	55	23.2	0	1.55	0.2	1.2	0.1	2.4	0.2	0.8
190	68	34.5	0	1.8	0.25	1.6	0.2	2.7	0.2	0.8
Distance from SVE (feet)			9.8		31		18.0		30.8	10.2

NOTES: S = Shallow piezometer
M = Medium Piezometer

The following observations can be made from a comparison of the responses at the monitoring points: (1) All the monitoring points responded to the applied vacuum at the SVE well (except P1-S, which either malfunctioned or was installed in low permeability soil zone). This indicates that the radius of influence of the pilot test extended to at least the radial distance of these monitoring locations. (2) The shallow monitoring points, including P4, responded to a lesser extent than the deeper (M) monitoring points. This suggests that the shallower subsurface zone is less permeable to air flow that the deeper zone (about 8 to 10 feet below ground). (3) As shown in Appendix D, the results of vacuum versus radial distance from the SVE well for the medium piezometers, P4 and the BV-1 are not adequately represented by a linear relationship as is expected for homogeneous and isotropic geological systems. As an example, the response at P3-M (18 feet from the SVE well) is consistently higher than that at P1-M, which is only 9.8 feet from the SVE well. these results suggest that the site's subsurface, above the water table, is spatially heterogeneous with respect to air flow that is induced by the application of a vacuum to a well that is screened through this zone.

In the absence of a single straight line relationship between the values of soil vacuum measured at the monitoring wells and their radial distances from the SVE well, a single value for the radius of influence of the SVE pilot system could not be determined. As such, the final design of the SVE portion of the remedial system will be guided by both the data presented above and the values of the calculated intrinsic permeability for each of the monitoring locations.

The intrinsic permeability was calculated using the modified field drawdown method recommended by the USEPA Risk Reduction Engineering Laboratory. This evaluation , presented in Appendix D, yielded an estimate of intrinsic permeability of 7.3×10^{-8} cm^2. The pilot study results indicate that the radius of influence at 41.2 acfm is at least 10 feet in the shallow zone, and at least 30 feet in the deeper zone.

5.4 AIR SPARGING TEST

This test involved the combination of three technologies: air sparging, soil vapor extraction to capture the sparged air, and groundwater pumping to control mounding that results from air sparging. The test was conducted to evaluate the optimum groundwater pumping rate, air injection rate and air extraction rates for the pilot study that can be applied for the site remediation.

- Water was pumped form the SVE-1 at 8.5 gpm and after 35 minutes of pumping, a vacuum was applied at the same well. Groundwater pumping was conducted to lower the water table and avoid upwelling in the recovery well during soil vapor extraction and air sparging. After 70 minutes of the start of the test, air sparging was applied through the air sparging well (AS-1). The air injection rates and duration are summarized below

Air Injection Rate (scfm)	Duration (minutes)
1.72	70
3.85	48
5.78	28

- The response of the groundwater/air system due to the combination of pumping, soil vapor extraction and air sparging was monitored at several piezometers and wells. These piezometers and wells were located in different directions and at different distances from the air sparging well in order to monitor the spatial response of the groundwater system. The locations of these monitoring points are shown in Plate 2, and their distance from the air sparging well are summarized in Table 5.5.

- The equations that describe radial flow to a pumping well were solved graphically to determine the transmissivity (T), storativity (S), and air conductivity (K) for data from piezometer P-2. As an approximation we have used the graphical solution for radial groundwater flow to a pumping well to represent radial air flow. In addition, the radius of influence (R) was estimated by plotting and analyzing the results of drawdown versus log radial distance. These graphical solutions are included in Appendix E. The results for T, S , and K are summarized in Table 5.6. The radius of influence (R) is discussed below.

Radius of influence: Based on the graphical analysis of pressure level vs log radial distance at time = 100 minutes and injection rate of 40.7 scfm, the estimated effective radius of influence is about 46 feet from the air sparging well.

Hydraulic Properties (Air in saturated zone): As shown on Table 5.6, on the basis of the graphical analysis by applying Theis approach, the air conductivity is 6.9 x 10^{-2} cm/sec (196 ft/day).

TABLE 5.5

PHYSICAL SETTING OF PIEZOMETERS AND MONITORING WELLS AIR SPARGING TEST

Monitoring Location	Distance From Air Sparging Well (feet)
Piezometer P-1	14.0
Piezometer P-2	15.6
Piezometer P-3	14.4
SVE-1 Well	14.4
BV-1	24.3
Monitoring Well MW-3	15.3
Monitoring Well MW-7	8.0

TABLE 5.6

SUMMARY OF AQUIFER HYDRAULIC PROPERTIES PUMPING, SOIL VAPOR EXTRACTION, AND AIR SPARGING TEST

Monitoring Location	Theis		
	T (ft^2/d)	S	K (ft/d)
Piezometer 2	**4311.2**	**8.9×10^{-2}**	**196.0**

5.5 BIOVENTING TEST

A bioventing pilot test was conducted at the site. The purpose of the test was to determine the biodegradation rate of the gasoline-impacted soil in the unsaturated zone. A secondary purpose of this test was to determine the radius of influence of the air injected into the biovent well.

Air was continuously injected into the soil from the bioventing well BV-1 for three weeks at a flow rate of approximately 1 scfm and an injection pressure less than 2 psi. During injection and following the completion of the injection operations, the concentration of the carbon dioxide and oxygen were monitored at the bioventing well and piezometers P-1 through P-4. The results of the monitoring operations are summarized on Table 5.7. The amount of increase in carbon dioxide levels and decrease in oxygen levels provide information about the biodegradation rate of gasoline in the impacted soils.

Prior to the test, at the location of piezometers BV-1 and P-2 through P-4, soil oxygen gas concentrations were less than 3 percent. The above results indicate an oxygen deficient soil due to the biodegradation occurring at the site. The soil oxygen levels at piezometer P-1 was at atmospheric levels, possibly indicating a lack of microbial activity. After 21 days of air injection at BV-1, the oxygen concentration ranged from zero at P-2 location to 17 percent at P-4 location.

Piezometer P-4, located 20 feet from BV-1, responded to the bioventing operations. As shown in Table 5.7, following cessation of air injection operations, the concentration of carbon dioxide was increasing while the concentration of oxygen was reducing. This is an indication of gasoline biodegradation within the impacted soils.

TABLE 5.7
SUMMARY OF MONITORING DATA
BIOVENTING TEST

Date	Sampling Time	Biovent Well		P1- at 5'		P2- at 5'		P3- at 5'		P-4		
		% O_2	% CO_2	% O_2	% CO_2	% O_2	% CO_2	% O_2	% CO_2	% O_2	% CO_2	
5/10/95	10:00	1.5	7.5	19.0	0.0	2.5	6.5	2.0	7.5	1.0	8.5	Background Concentration
5/12/95	10:00	20.5	0	20.0	0.0	2.0	8.0	0.5	7.0	0.0	7.5	air inject
5/18/95	9:30	-	-	-	-	1.0	6.5	1.5	11.5	13.5	5.0	air inject
6/01/95	10:00	20.0	0	-	-	0.0	10.0	4.5	14.5	17.0	4.0	air off
6/02/95	9:00	13.0	0	-	-	-	-	-	-	5.0	5.0	air off
6/05/95	11:30	0.0	1.0	18	0	0.0	10.0	0.0	14.5	0.0	8.0	air off

Using the data collected at Piezometer P-4 location, a biodegradation rate is determined. The soil gas oxygen level decreased from 17 percent to 0 percent in the 96 hour monitoring period (6/01/95 to 6/05/95). The soil gas carbon dioxide level increased from 4 percent to 8 percent in the same period. During aerobic respiration, 3.1 lb. of oxygen is consumed per lb of hydrocarbon degraded. At an air injection rate of 1 scfm, the amount of oxygen injected into the soil is calculated as follows:

1 scfm x 0.075 lbs/cf x 60 min/hr x 0.17 oxygen = <u>0.76 lbs/hr of oxygen.</u>

The corresponding amount of hydrocarbon (HC) undergoing biodegradation is presented below:

0.76 / 3.1 lbs oxygen per lb of HC = <u>0.24 lbs/hr of HC.</u>

The carbon dioxide levels do not indicate that all the oxygen was used for aerobic respiration so the actual amount of HC degradation is probably less than 0.24 lbs/hr.

At the degradation rate of 50 percent of the above calculated value, 0.12 lbs/hr of HC contamination is degraded. Using this value, the rate of HC degradation at this site due to bioventing is about 0.5 gallon of gasoline per day.

Piezometer P-3 (located 27 feet from BV-1) responded to the air injection at the bioventing well to a lesser degree than piezometer P-4 (located approximately 15 feet from BV-1). Piezometers P-1 and P-2 (located 40 feet from BV-1), did not respond to air injection operations.

The soil gas measurements at the biovent well indicate that the soil at this point of the site is no longer producing a significant rate of carbon dioxide. This may indicate that this particular volume of soil near the biovent well has been remediated to a degree.

Since piezometer P-4 is located approximately 20 feet from the bioventing well, it has been demonstrated that the radius of influence during bioventing is at least 20 feet.

In summary, the bioventing results indicate that intrinsic biodegradation is occurring in the petroleum-impacted soil at the site. It also appears that biodegradation through bioventing the vadose zone is a viable method to remediate the vadose zone.

5.6 SUMMARY OF PILOT TEST RESULTS

Based on the pilot studies completed and our knowledge of site conditions the design criteria shown on Table 5.8 were determined.

TABLE 5.8 SUMMARY OF PILOT TEST RESULTS			
Type of Test	**Radius of Influence (feet)**	**Hydraulic/Air Conductivity (cm/s)**	**Operating Conditions**
Groundwater Pumping	160 (Saturated Zone)	1.8×10^{-2}	Pumping rate = 14.9 gpm
Soil Vapor Extraction (1)	10 to 30 (Vadose Zone)	7.3×10^{-8} (K_i)	Vacuum = 17 inches of water and air flow rate of 40.7 acfm
Air Sparging (1)	46 (Saturated Zone)	6.1×10^{-3}	Air injection rate = 6 scfm
Bioventing	20 (Vadose Zone)	N/A	Injection rate = 6 scfm, biodegradation rate ≥ 0.24 lb/hr
(1) As described in Sections 5.3 and 5.4, groundwater pumping was necessary to successfully implement this test			

The results summarized in Table 5.8 will used in the development of a conceptual remediation system and will discussed in Section 6 of this CAP.

6.0 DESIGN OF REMEDIATION SYSTEM

6.1 INTRODUCTION

A feasibility study was performed by NTH to identify the most appropriate remediation method. The feasibility study is presented in Appendix F. Based on the results of the study, the City selected active remediation methods (Alternative 2) to achieve the most rapid remediation. The design of this system is presented in this section.

Alternative 3 was not selected by the City because it would require a deed restriction on the property and may require the City to enforce control on drinking water from the aquifer. Alternative 1 was not selected by the City because the area of contamination was only approximated, and it was not certain how much material under the building and under the new fuel dispenser island, was required to be removed. As a result the City decided to implement Alternative 2, since it is expected to achieve levels below Tier 1 in a short time, it does not require deed restrictions and it is capable of remediating the impacted area beneath the building and the new dispenser island without having to interrupt or interfere with the regular use of these service facilities.

The following design has been developed based on the site investigation data presented in Sections 2 and 3; the extent of contamination requiring cleanup as determined by comparison with RBCA Tier 1 values presented in Section 4; and the results of the pilot tests presented in Section 5.

The soil and groundwater zones requiring cleanup are presented in Plates 4 and 5, respectively, and the specific contaminants and their concentration ranges are presented in Section 4. Generally, the contaminants of interest include benzene, toluene, ethylbenzene, the xylene isomers, MTBE and naphthalene.

In the following sections we present remediation designs for hydraulic containment of the plume; remediation of the groundwater; and remediation of the soils above the water table.

6.2 HYDRAULIC CONTAINMENT SYSTEM

The objective of this system is to hydraulically contain contaminated groundwater by creating an adequate hydraulic gradient for the contaminated groundwater to flow to recovery wells to minimize the potential for migration which would increase the extent of the contaminated plume. The number and location of the recovery wells are based on several factors including the radius of influence of each well and the lateral extent of contaminated groundwater. The estimated extent of the contaminated groundwater is shown on Plate 5.

The results of the pump test indicate that this objective can be achieved by pumping water at approximately 1.3 gpm, creating a radius of influence of 36 feet. Therefore, two recovery wells will be used at a rate ranging from 0.5 to 1.5 gpm with a total pumping rate ranging from 1 to 2 gpm. As shown on Plate 6, the wells will be installed in the diesel tank area and the former gasoline release area.

The new dewatering (DW) wells will have a 10-ft long, 4-inch ID, PVC screen attached to a 4-inch PVC riser. The wells will be installed to a depth of about 17 feet and will be finished in a 2-ft wide by 2-ft long by 4-ft deep flush mounted manhole (Plate 7). A submersible pump will be installed in each well to recover and remove groundwater.

6.3 REMEDIATION OF THE UNSATURATED ZONE

Remediation of the unsaturated zone will be addressed by the combination of soil vapor extraction and bioventing methods. The results of the SVE pilot study indicate that an induced vacuum of 17 inches of H_2O and a flow rate of 40 acfm will provide a radius of influence of 10 feet near the ground surface and 30 feet near the groundwater surface. Based on these results, one SVE/BV well is proposed for each remediation area (see Plate 6). As shown on Plate 6, the zone of influence for the wells is expected to span the zone of soil contamination. The existing SVE-1 will be used in the area of the gasoline release. One new SVE well will be installed in the diesel tank area. The well will be screened to approximately 1 foot below the water table and will be constructed from 2-inch ID PVC screen and 2-inch ID PVC riser. The well will be finished in 2-ft long by 2-ft wide by 4-ft deep flush mounted manholes (Plate 8).

Bioventing will be accomplished by the air (oxygen) being drawn through the contaminated soil zone by the SVE system.

6.4 REMEDIATION OF THE SATURATED ZONE

In addition to the contributions of the DW system to remediation of the groundwater zone, we will implement an air sparging system to accelerate remediation of this zone. Air sparging will contribute to the cleanup in two ways:

(1) Volatilizing the BTEX from the groundwater and soil beneath the water table. These volatilized contaminants will be collected by the SVE wells in the unsaturated zone, and

(2) Injecting air within the saturated zone will also provide molecular oxygen to the groundwater and increase the level of DO in the groundwater. This additional oxygen will become available for in-situ biodegradation of the targeted contaminants, MTBE and naphthalene, and will contribute to the remediation of the saturated zone.

The results of the air sparging pilot test indicate that an air injection rate of 1 scfm will create an effective radius of influence of 20 feet. One AS well is proposed to assist with the remediation of the impacted saturated zone in the former gasoline release area. Air sparging is not proposed at the location of the diesel tank due to the presence of the tank and due to the proximity of the maintenance garage. The AS well is already installed and was used during the pilot study. The radius of influence of this well will extend over the zone of highest groundwater contamination. As shown on Plate 6, the area of influence for the air sparging wells occurs within the area of influence for the SVE/BV well. Therefore, the SVE system is expected to capture contaminated sparged air escaping the groundwater and to minimize the potential for migration of contaminated air to the maintenance garage.

6.5 MECHANICAL COMPONENTS

The two DW wells will be connected to a power supply to operate an electrical submersible pump for groundwater pumping. A water-level sensor will be located in each DW well to maintain the water level at preset levels. Each wellhead will be instrumented with sampling ports for groundwater. The groundwater discharge lines will be insulated (with all other lines) in a trench extending below the frost line (3 to 4 feet bgl).

The SVE/BV wells will be connected to a regenerative blower to create the needed vacuum for each well. The AS well will be connected to an air compressor capable of generating up to 2.0 scfm of air for injection into the saturated zone. Each wellhead will be instrumented with pressure or vacuum gauges, air sampling ports and a valve that will allow for independent control of each well.

All the aboveground instrumentation including compressor, regenerative blower, product/recovery holding tanks and treatment systems will be housed in the existing maintenance garage or an on-site treatment shed. The proposed locations of treatment facilities are shown in Plate 6.

6.6 TREATMENT SYSTEM

Based on an evaluation of the above-ground technologies the following treatment technologies are recommended for this site. Plate 10 illustrates the conceptual layout of the treatment system.

6.6.1 Groundwater Treatment

Groundwater containing dissolved phase gasoline constituents will be pumped from the two DW wells and treated by granular activated carbon. Based on the concentration of BTEX, MTBE and naphthalene in the site's groundwater, the estimated maximum dissolved phase concentration of VOCs in the groundwater is 50 mg/L. As such, the carbon treatment system will be designed to treat groundwater containing a maximum of 50 mg/L dissolved contaminants.

6.6.2 Vapor Treatment

A granular activated carbon system will be designed to provide treatment of the soil gas which will be extracted by the SVE system.

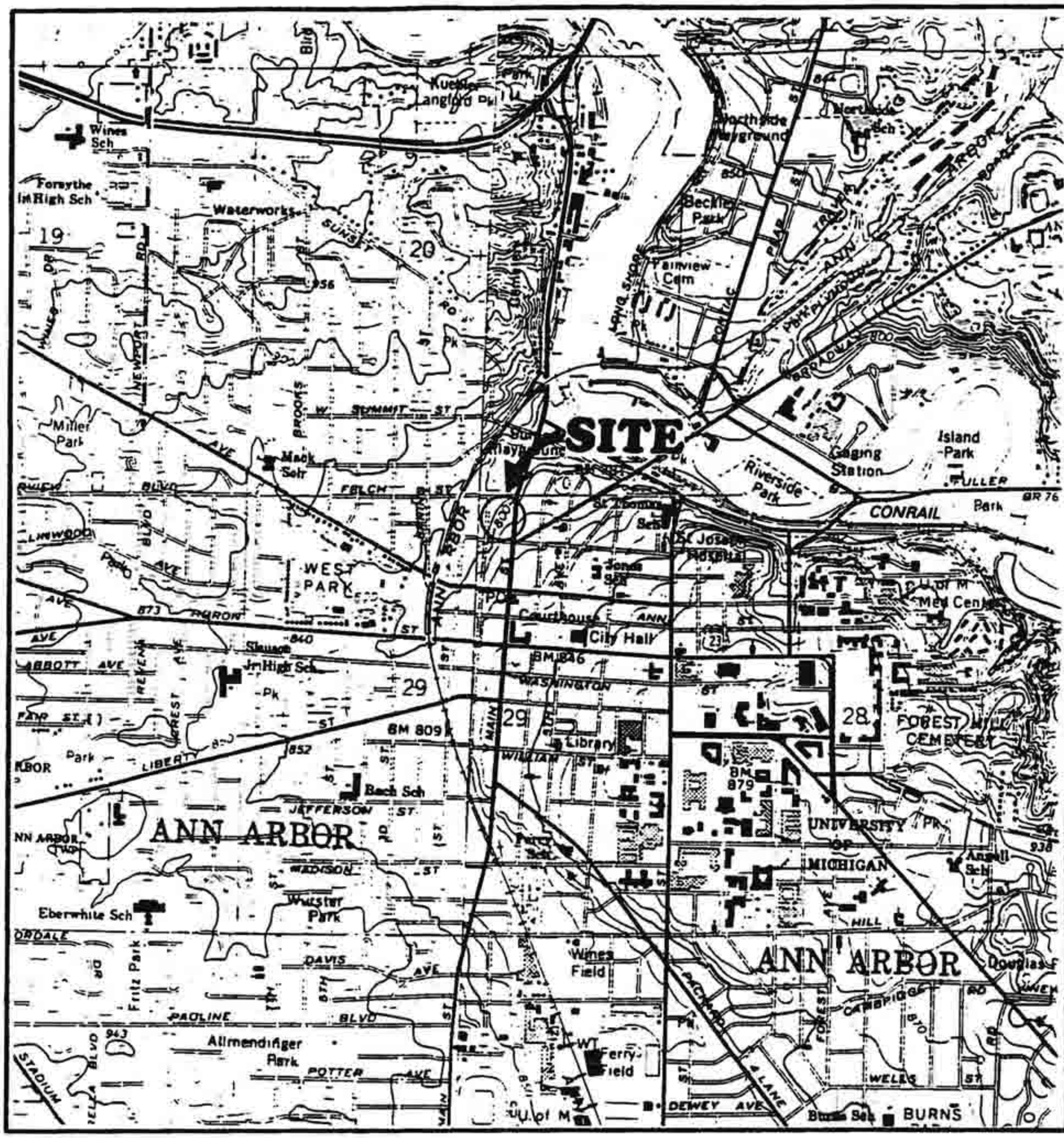
6.6.3 Discharge Permits

We will obtain a permit from MDEQ to discharge the treated air from the carbon system. Discharge alternatives for the treated groundwater include: (1) discharge to surface water, (2) discharge to a public owned treatment works (POTW), and (3) re-injection of treated groundwater. It is anticipated that approval for re-injection of groundwater from the MDEQ will be difficult to obtain. Discharge to a POTW is technically feasible, but discussions with POTW personnel indicate that this is not a permanent option. Therefore, the most feasible and cost-effective alternative appears to be discharge to surface water under an NPDES permit into Allen Creek Drain. Due to the nature of the contaminants, we have assumed that an NPDES general permit will be applicable for this site.

Furthermore, we will obtain a building permit for the treatment building and a flood plain, or floodway development permit for the proposed remediation activities.

6.6.4 Implementation Schedule

The schedule for the construction and operation of the remediation system is shown on Plate 11. As shown on Plate 11, the construction of the system is expected to start on July 27, 1996 and the system operation is expected to start on September 14, 1996.

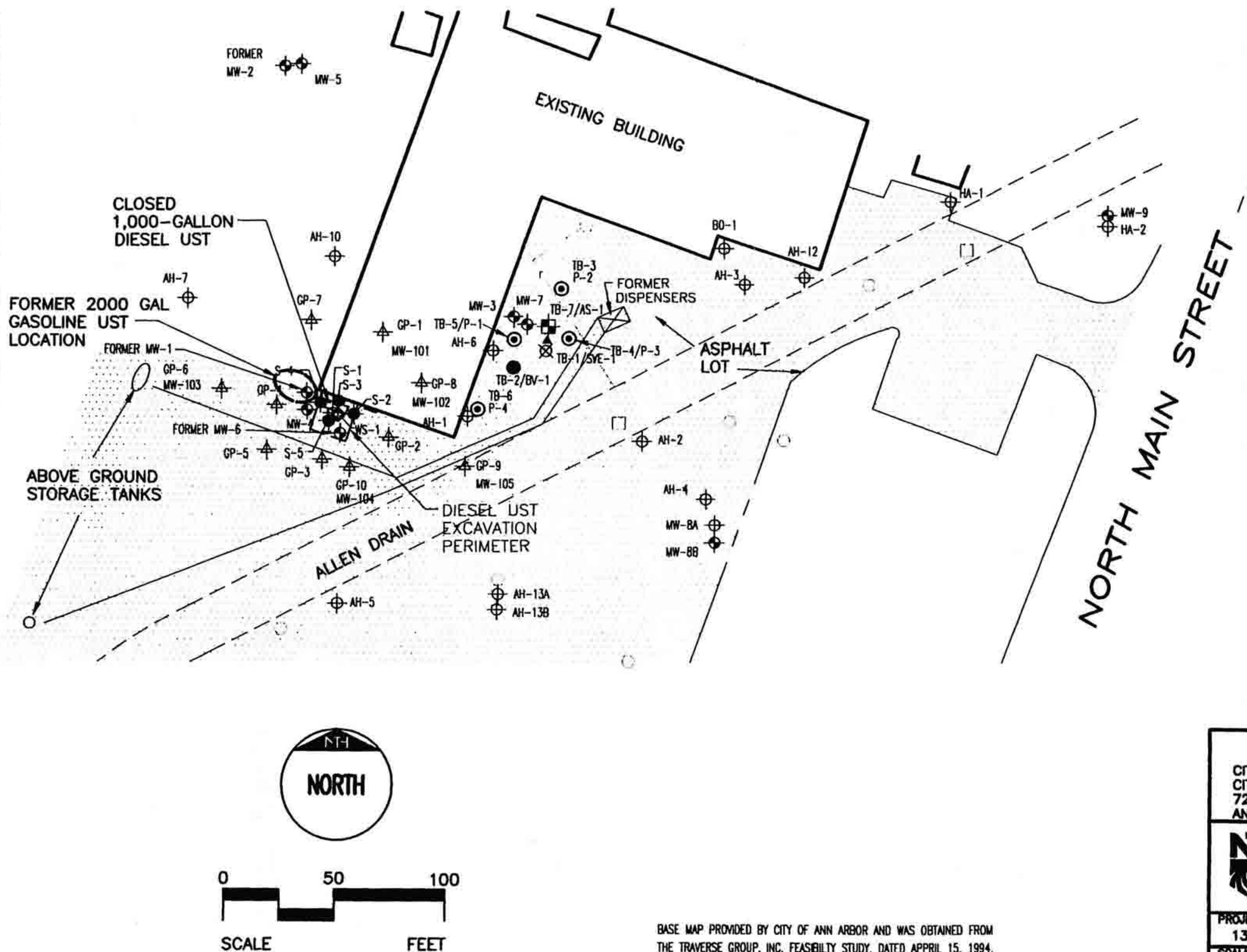


SITE LOCATION MAP

CITY MAINTENANCE GARAGE
CITY OF ANN ARBOR
721 NORTH MAIN STREET
ANN ARBOR, MICHIGAN

NTH CONSULTANTS, LTD.
Professional Engineering & Environmental Services
Farmington Hills, Michigan

PROJECT NO.	DRAWN BY:	DATE:	PLATE NO:
13-5000	KRH	06-12-95	1
SCALE: 1"=2000'	CHECKED BY: RCA	SHEET 1 OF 1	



LEGEND:

- ▲ BARREL/PURGE WELL
- BOREHOLES ADVANCED BY THE TRAVERSE GROUP IN BETWEEN JUNE 1990 AND MARCH 1993.
- MONITORING WELL INSTALLED BY THE TRAVERSE GROUP IN BETWEEN JUNE 1990 AND MARCH 1993
- PIEZOMETER WELLS INSTALLED BY NTH CONSULTANTS, LTD. AS PART OF PILOT STUDY APRIL 1995.
- AIR SPARGING WELL INSTALLED BY NTH CONSULTANTS, LTD. AS PART OF PILOT STUDY APRIL 1995.
- ● BIOVENTING INSTALLED BY NTH CONSULTANTS, LTD. AS PART OF PILOT STUDY APRIL 1995.
- ⊠ SOIL VAPOR EXTRACTION (SVE)/GROUNDWATER RECOVERY WELL INSTALLED BY NTH CONSULTANTS, LTD. AS PART OF PILOT STUDY APRIL 1995.
- DIESEL FUEL UST EXCAVATION SOIL SAMPLE COLLECTED BY NTH CONSULTANTS, LTD. JUNE 16, 1995.
- ◇ DIESEL FUEL UST EXCAVATION WATER SAMPLE COLLECTED BY NTH CONSULTANTS, LTD. JUNE 16, 1995.
- GEOPROBE BORINGS/MONITORING WELLS INSTALLED BY NTH CONSULTANTS, LTD. AUGUST 29-31, 1995.
- —— s —— EXISTING SANITARY
- —— r —— EXISTING STORM SEWER
- ○ EXISTING STORM SEWER CATCH BASIN
- □ EXISTING STORM MANHOLE

BASE MAP PROVIDED BY CITY OF ANN ARBOR AND WAS OBTAINED FROM THE TRAVERSE GROUP, INC. FEASIBILTY STUDY, DATED APPRIL 15, 1994.

WELLS AND TEST BORINGS LOCATION PLAN

CITY MAINTENANCE GARAGE
CITY OF ANN ARBOR
721 NORTH MAIN STREET
ANN ARBOR, MICHIGAN

NTH CONSULTANTS, LTD.
Professional Engineering & Environmental Services
Farmington Hills, Michigan

PROJECT NO.	DRAWN BY:	DATE:	PLATE NO:
13-5000-03	JD	04-01-96	2
SCALE: AS SHOWN	CHECKED BY: HRH	SHEET 1 OF 1	

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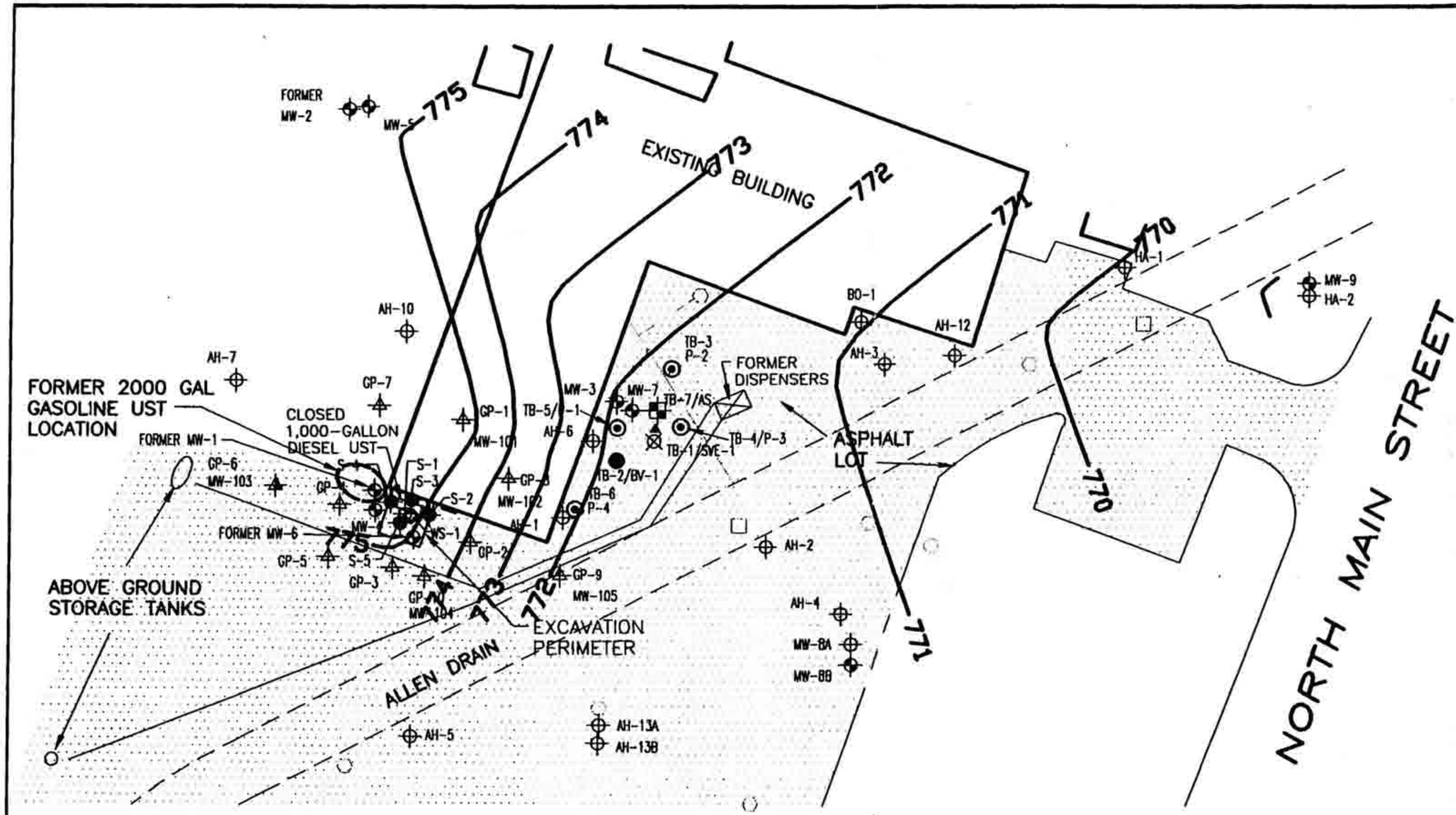

LEGEND:

- ▲ BARREL/PURGE WELL
- BOREHOLES ADVANCED BY THE TRAVERSE GROUP IN BETWEEN JUNE 1990 AND MARCH 1993.
- MONITORING WELL INSTALLED BY THE TRAVERSE GROUP IN BETWEEN JUNE 1990 AND MARCH 1993
- PIEZOMETER WELLS INSTALLED BY NTH CONSULTANTS, LTD. AS PART OF PILOT STUDY APRIL 1995.
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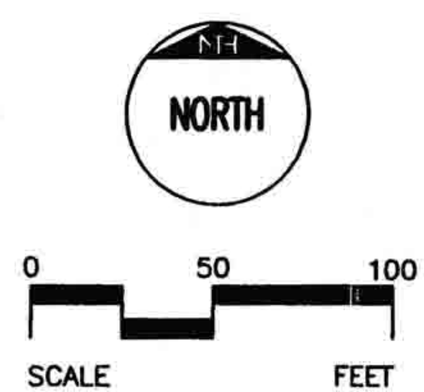
- ● BIOVENTING INSTALLED BY NTH CONSULTANTS, LTD. AS PART OF PILOT STUDY APRIL 1995.
- SOIL VAPOR EXTRACTION (SVE)/GROUNDWATER RECOVERY WELL INSTALLED BY NTH CONSULTANTS, LTD. AS PART OF PILOT STUDY APRIL 1995.
- ◆ DIESEL FUEL UST EXCAVATION SOIL SAMPLE COLLECTED BY NTH CONSULTANTS, LTD. JUNE 16, 1995.
- ◇ DIESEL FUEL UST EXCAVATION WATER SAMPLE COLLECTED BY NTH CONSULTANTS, LTD. JUNE 16, 1995.
- GEOPROBE BORINGS/MONITORING WELLS INSTALLED BY NTH CONSULTANTS, LTD. AUGUST 29-31, 1995.
- s EXISTING SANITARY
- r EXISTING STORM SEWER
- ○ EXISTING STORM SEWER CATCH BASIN
- □ EXISTING STORM MANHOLE

GROUNDWATER ELEVATIONS
NOVEMBER 28, 1995

WELL ID	ELEVATION (ft)
MW-3	771.91
MW-4	775.88
MW-5	775.39
MW-7	771.76
MW-8b	771.34
MW-9	768.78
BIO	771.76
SVE	771.73
AS	771.76
P-1	771.75
P-2	771.72
MW-101	775.53
MW-102	773.69
MW-103	776.01
MW-104	774.47
MW-105	771.80



NOTE:
GROUNDWATER LEVELS MEASURED NOVEMBER 28, 1995.

BASE MAP PROVIDED BY CITY OF ANN ARBOR AND WAS OBTAINED FROM THE TRAVERSE GROUP, INC. FEASIBILTY STUDY, DATED APPRIL 15, 1994.

GROUNDWATER ELEVATION CONTOURS

CITY MAINTENANCE GARAGE
CITY OF ANN ARBOR
721 NORTH MAIN STREET
ANN ARBOR, MICHIGAN

NTH CONSULTANTS, LTD.
Professional Engineering & Environmental Services
Farmington Hills, Michigan

PROJECT NO.	DRAWN BY:	DATE:	PLATE NO:
13-5000-03	JD	04-01-96	3
SCALE: AS SHOWN	CHECKED BY: HRH	SHEET 1 OF 1	

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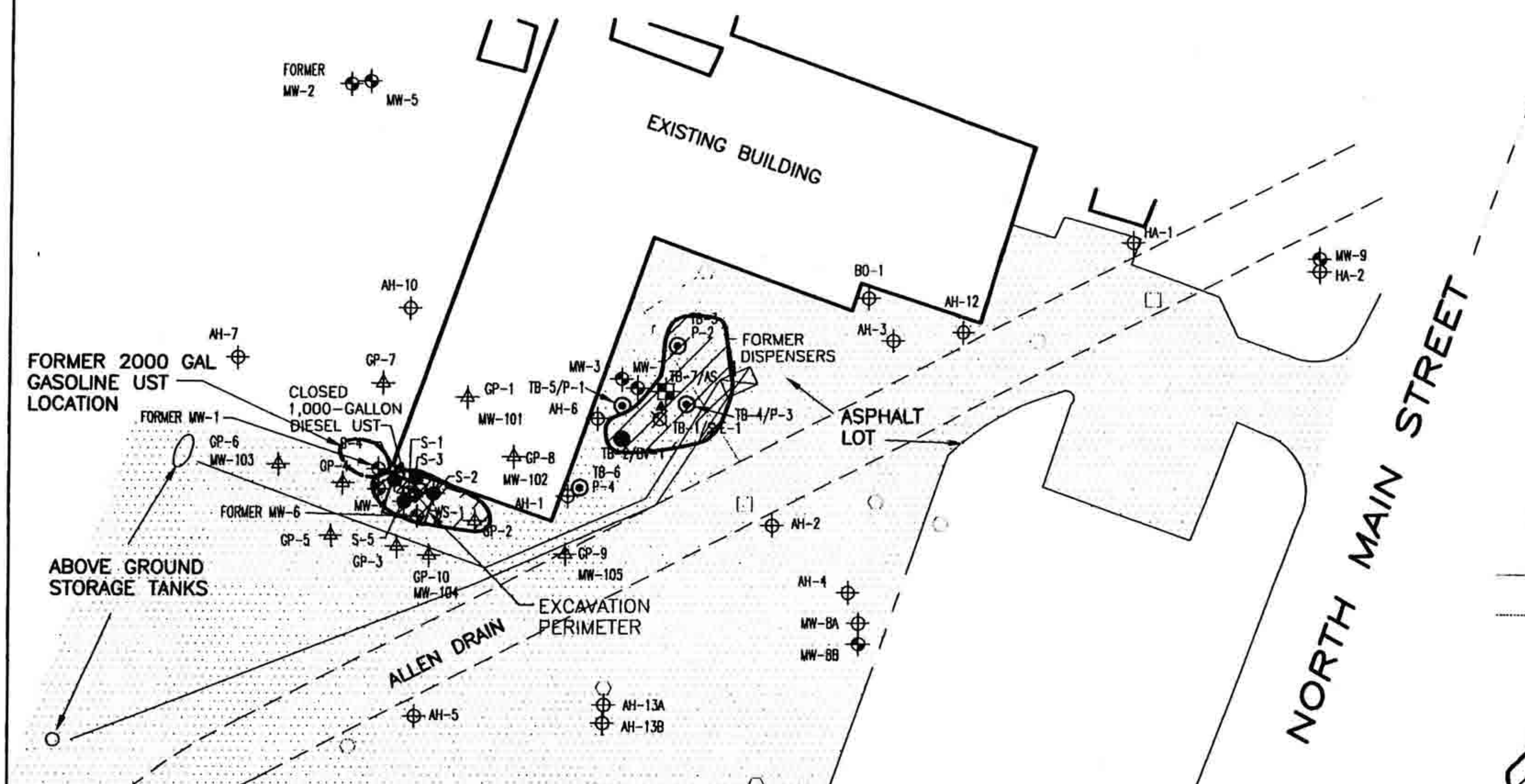

LEGEND:

- ▲ BARREL/PURGE WELL
- BOREHOLES ADVANCED BY THE TRAVERSE GROUP IN BETWEEN JUNE 1990 AND MARCH 1993.
- MONITORING WELL INSTALLED BY THE TRAVERSE GROUP IN BETWEEN JUNE 1990 AND MARCH 1993
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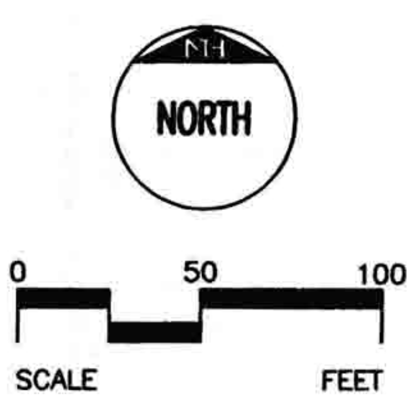
- GEOPROBE BORINGS/MONITORING WELLS INSTALLED BY NTH CONSULTANTS, LTD. AUGUST 29-31, 1995.
- —— s —— EXISTING SANITARY
- ------ r ------ EXISTING STORM SEWER
- ○ EXISTING STORM SEWER CATCH BASIN
- □ EXISTING STORM MANHOLE
- ESTIMATED EXTENT OF SOIL CONTAMINATION IN EXCESS OF TIER I RESIDENTIAL SOIL LEACHING TO GROUNDWATER CLEANUP CRITERIA



NOTE:
EXTENT OF CONTAMINATION DERIVED FROM DATA COLLECTED BY THE TRAVERSE GROUP, INC. FROM AUGUST 1990 THROUGH MARCH 1993 AND FROM DATA COLLECTED BY NTH CONSULTANTS, LTD. FROM APRIL 1995 THROUGH SEPTEMBER 1995.

BASE MAP PROVIDED BY CITY OF ANN ARBOR AND WAS OBTAINED FROM THE TRAVERSE GROUP, INC. FEASIBILTY STUDY, DATED APRIL 15, 1994.

EXTENT OF SOIL CONTAMINATION PLAN

CITY MAINTENANCE GARAGE
CITY OF ANN ARBOR
721 NORTH MAIN STREET
ANN ARBOR, MICHIGAN

NTH CONSULTANTS, LTD.
Professional Engineering & Environmental Services
Farmington Hills, Michigan

PROJECT NO.	DRAWN BY:	DATE:	PLATE NO:
13-5000-03	JD	04-01-96	4
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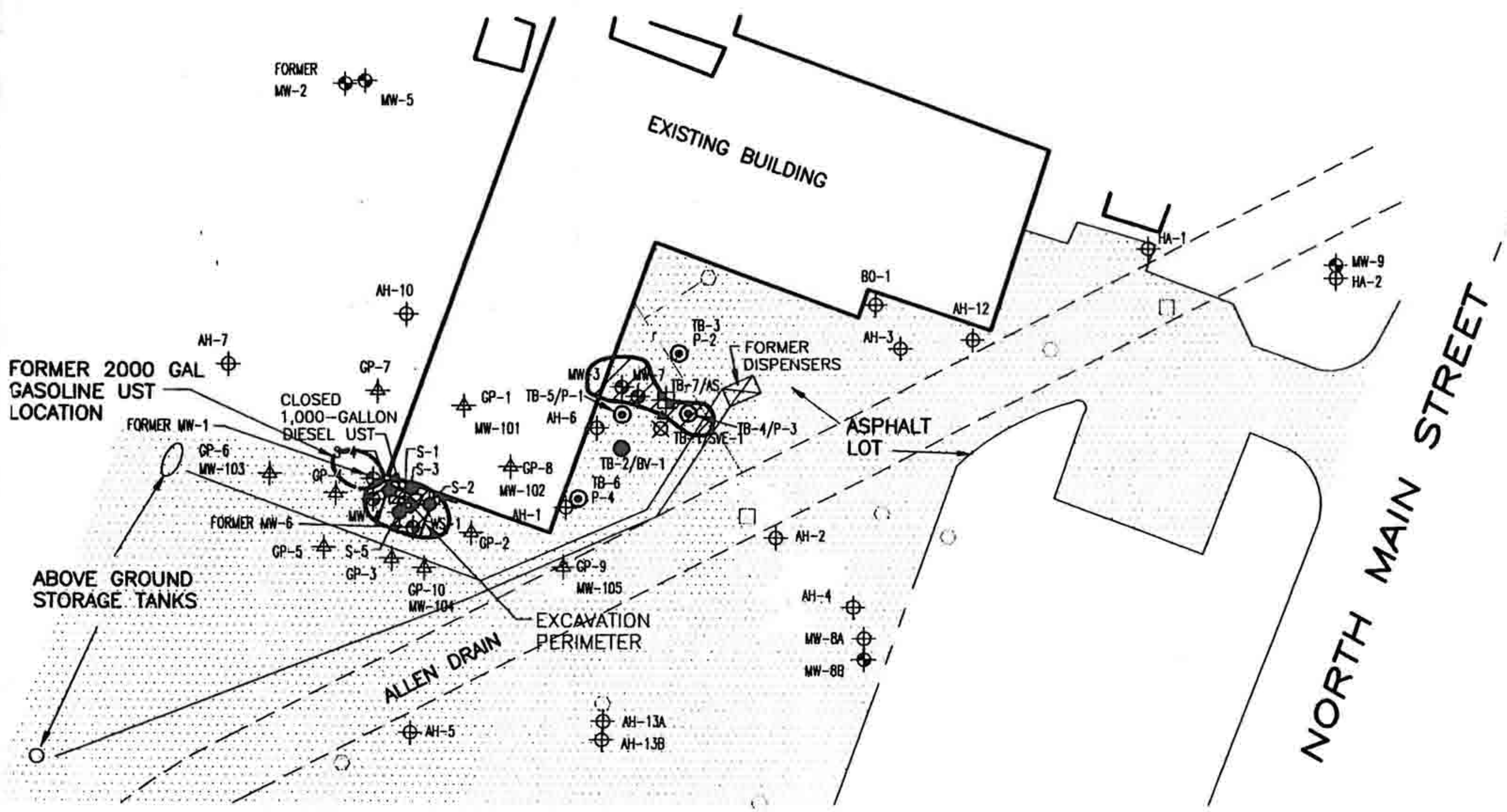

LEGEND:

- ▲ BARREL/PURGE WELL
- BOREHOLES ADVANCED BY THE TRAVERSE GROUP IN BETWEEN JUNE 1990 AND MARCH 1993.
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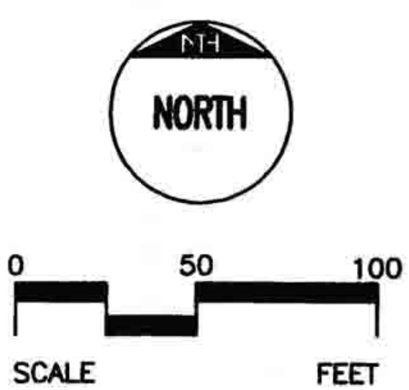
- GEOPROBE BORINGS/MONITORING WELLS INSTALLED BY NTH CONSULTANTS, LTD. AUGUST 29-31, 1995.
- EXISTING SANITARY
- EXISTING STORM SEWER
- EXISTING STORM MANHOLE
- ESTIMATED EXTENT OF GROUNDWATER CONTAMINATION IN EXCESS OF TIER I RESIDENTIAL GSI CLEANUP CRITERIA



NOTE:
EXTENT OF CONTAMINATION DERIVED FROM DATA COLLECTED BY THE TRAVERSE GROUP, INC. FROM AUGUST 1990 THROUGH MARCH 1993 AND FROM DATA COLLECTED BY NTH CONSULTANTS, LTD. FROM APRIL 1995 THROUGH SEPTEMBER 1995.

BASE MAP PROVIDED BY CITY OF ANN ARBOR AND WAS OBTAINED FROM THE TRAVERSE GROUP, INC. FEASIBILTY STUDY, DATED APPRIL 15, 1994.

EXTENT OF GROUNDWATER CONTAMINATION PLAN

CITY MAINTENANCE GARAGE
CITY OF ANN ARBOR
721 NORTH MAIN STREET
ANN ARBOR, MICHIGAN

NTH CONSULTANTS, LTD.
Professional Engineering & Environmental Services
Farmington Hills, Michigan

PROJECT NO.	DRAWN BY:	DATE:	PLATE NO:
13-5000-03	JD	04-01-96	5
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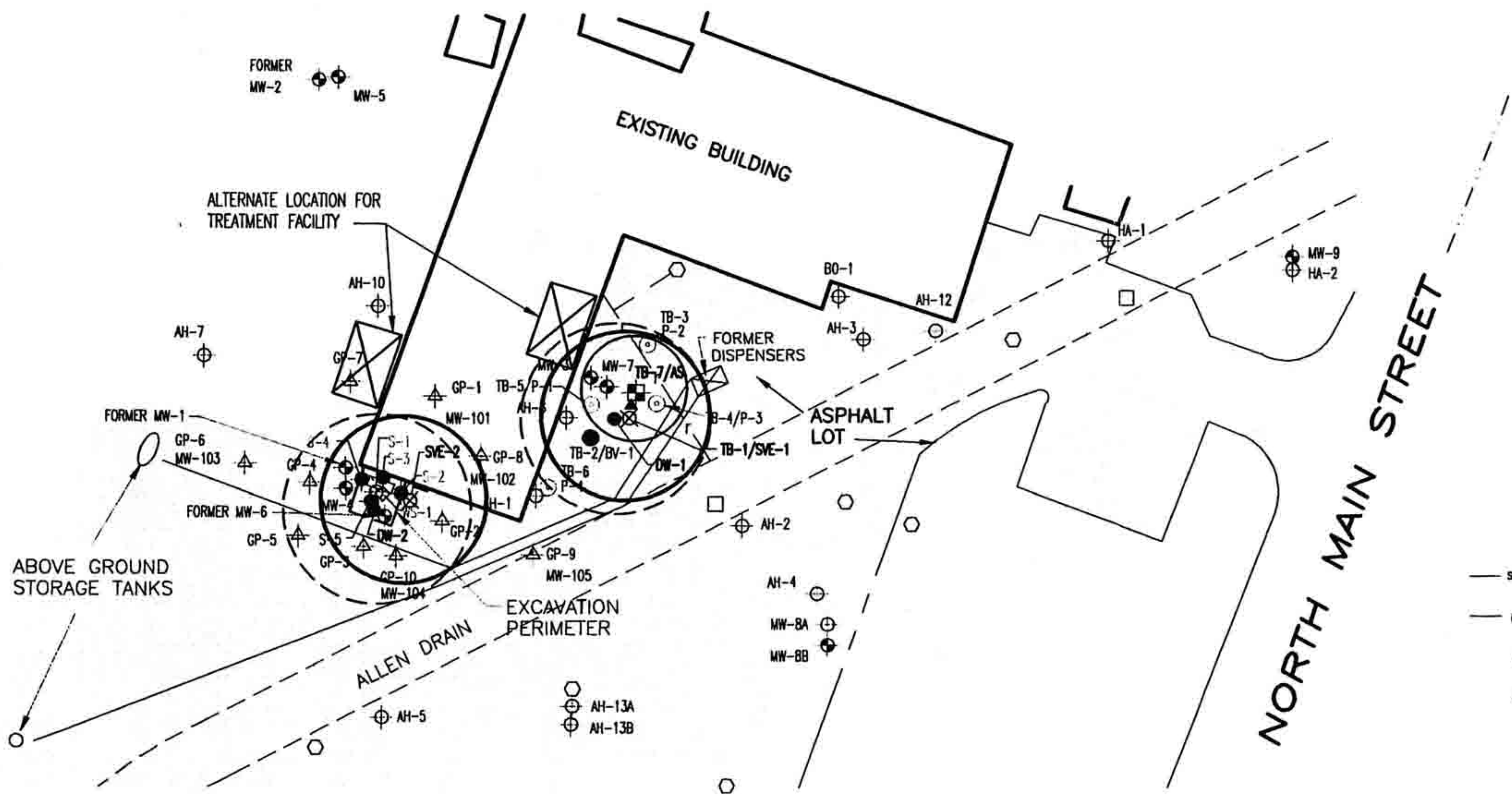

LEGEND:

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- MONITORING WELL INSTALLED BY THE TRAVERSE GROUP IN BETWEEN JUNE 1990 AND MARCH 1993
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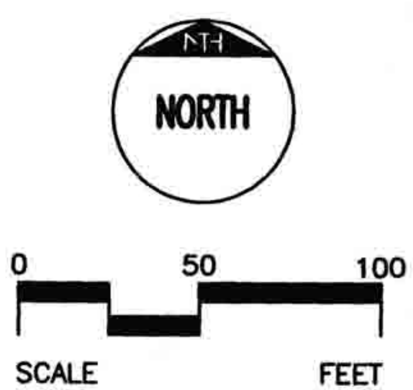
- — s — EXISTING SANITARY
- — r — EXISTING STORM SEWER
- EXISTING STORM SEWER CATCH BASIN
- EXISTING STORM MANHOLE



LEGEND:

AS AIR SPARGING WELL
DW DEWATERING WELL
SVE SOIL VAPOR EXTRACTION WELL
AIR SPARGING RADIUS OF INFLUENCE (ROI)
DEWATERING WELL ROI
SOIL VAPOR EXTRACTION WELL ROI

BASE MAP PROVIDED BY CITY OF ANN ARBOR AND WAS OBTAINED FROM THE TRAVERSE GROUP, INC. FEASIBILITY STUDY, DATED APPRIL 15, 1994.

LAYOUT OF REMEDIATION SYSTEM

CITY MAINTENANCE GARAGE
CITY OF ANN ARBOR
721 NORTH MAIN STREET
ANN ARBOR, MICHIGAN

NTH CONSULTANTS, LTD.
Professional Engineering & Environmental Services
Farmington Hills, Michigan

PROJECT NO.	DRAWN BY:	DATE:	PLATE NO:
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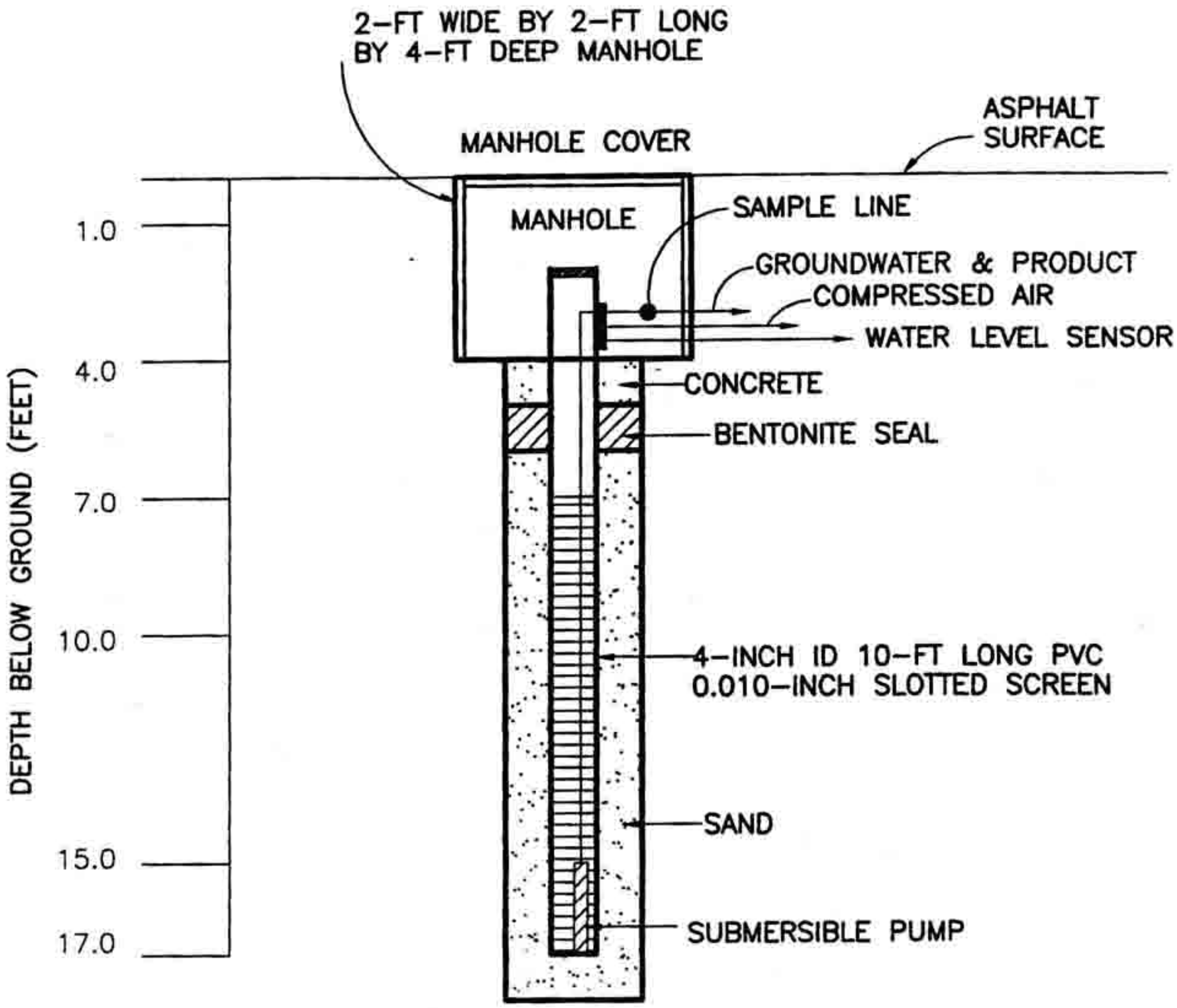

SCHEMATIC OF DEWATERING WELL

CITY MAINTENANCE GARAGE
721 N. MAIN STREET
ANN ARBOR, MICHIGAN

NTH CONSULTANTS, LTD.
Professional Engineering & Environmental Services
Farmington Hills, Michigan

PROJECT NO.	DRAWN BY:	DATE:	PLATE NO:
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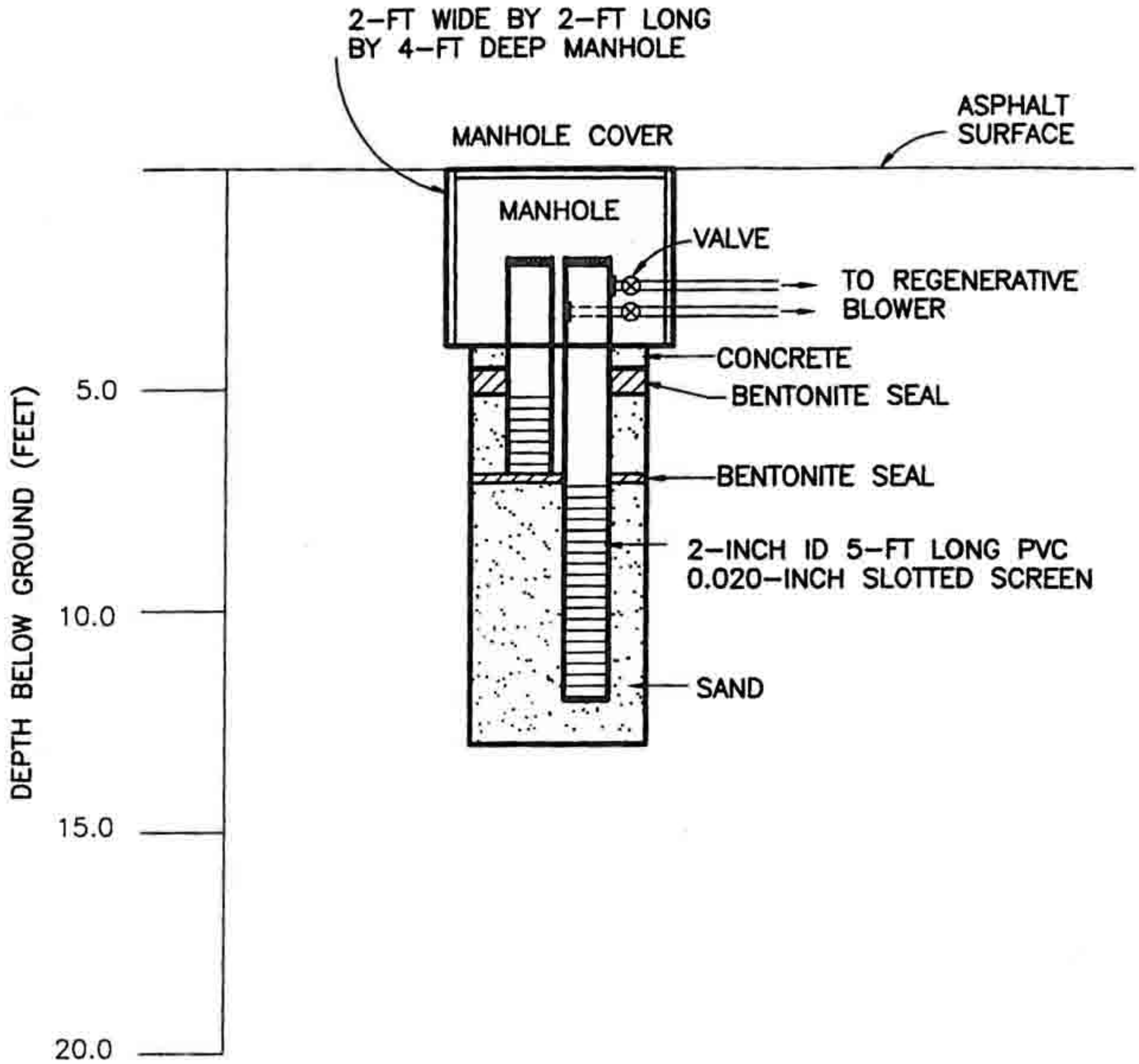

SCHEMATIC OF SOIL VAPOR EXTRACTION/ BIOVENTING WELL

CITY MAINTENANCE GARAGE
721 N. MAIN STREET
ANN ARBOR, MICHIGAN

NTH CONSULTANTS, LTD.
Professional Engineering & Environmental Services
Farmington Hills, Michigan

PROJECT NO.	DRAWN BY:	DATE:	PLATE NO:
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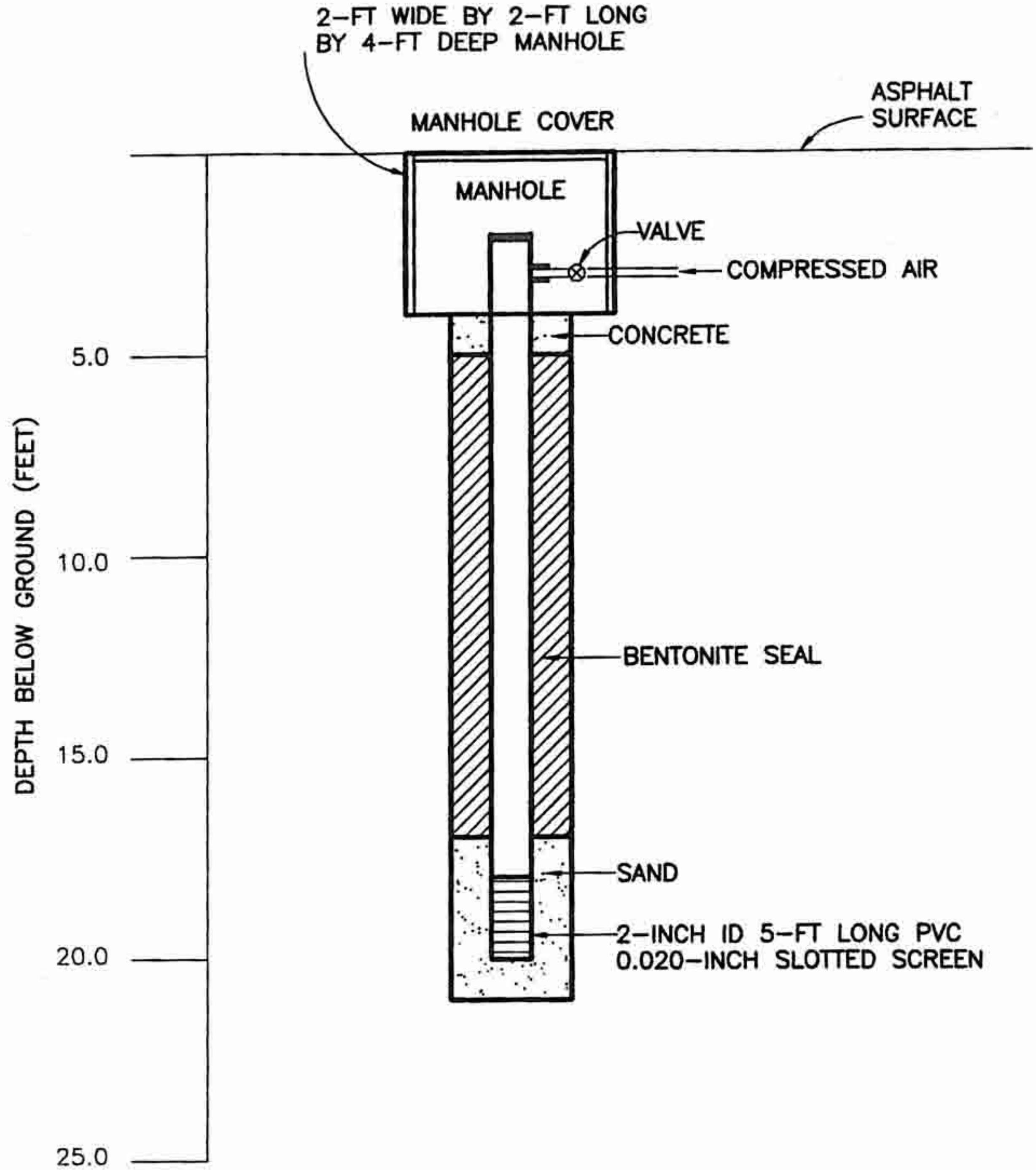

SCHEMATIC OF AIR SPARGING WELL

CITY MAINTENANCE GARAGE
721 N. MAIN STREET
ANN ARBOR, MICHIGAN

NTH CONSULTANTS, LTD.
Professional Engineering & Environmental Services
Farmington Hills, Michigan

PROJECT NO.	DRAWN BY:	DATE:	PLATE NO:
13-5000-04	DAG	03-15-96	9
SCALE: NONE	CHECKED BY: LMB	SHEET 1 OF 1	

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CONTAMIAI
SOIL GAS
SVE/BV W

LEGEND:

LIQUID

VAPOR/AIR

CONCEPTUAL TREATMENT SYSTEM DESIGN

TY MAINTENANCE GARAGE
1 N. MAIN STREET
N ARBOR, MICHIGAN

NTH CONSULTANTS, LTD.
Professional Engineering & Environmental Services
Farmington Hills, Michigan

ECT NO.	DRAWN BY:	DATE:	PLATE NO:
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E:	CHECKED BY:	SHEET	
T TO SCALE	LMB	1 OF 1	

C:\13\5000041X Fri Mar 15 16:31:57 1996 <3>

Plate 11 - Implementation Schedule
City of Ann Arbor Maintenance Garage
UST Remediation