CanonieEngineers

Canonie Engineers, Inc.
800 Canonie Drive
Porter, Indiana 46304

Phone: 219-926-8651

February 7, 1986

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CH 85-096

Mr. Gregory Shkuda, Ph.D.
New York State Department of Law
Two World Trade Center
New York, NY 10047

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SOLID WASTE MAN
DEC REGION

Transmittal
Aquifer Performance Test
Initial Off-Site Plume Recovery Wells
Mitchel Field Remedial Action

Dear Mr. Shkuda:

Enclosed is a copy of the documentation for the aquifer performance test to be conducted at the Mitchel Field site. This document is being submitted for your review and approval, and contains the technical specifications for the well installation, the program for the performance of the aquifer testing, and information on the proposed water treatment system.

Should you have any questions while reviewing this document, please call.

Very truly yours,

Timothy J. Harrington /BJB

Timothy J. Harrington
Project Manager

TJH/tl

cc: Mr. Charles McDonald
Mr. Albert Machlin, P.E.
Mr. Norman Nosenchuck, P.E.

Canonie Engineers

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AQUIFER PERFORMANCE TEST

INITIAL OFF-SITE PLUME RECOVERY WELLS

MITCHEL FIELD REMEDIAL ACTION

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MITCHEL FIELD REMEDIAL ACTION

1.0 INTRODUCTION

Two of the off-site plume recovery wells proposed in the Camp, Dresser and McKee (CDM) conceptual design will be installed to test the aquifer system at the Mitchel Field site. Data from the test will be used to prepare the final design of the off-site plume recovery system. The two full-scale wells installed for this test will become part of the plume recovery system at the site. Observation wells installed near the plume recovery wells will be used during the test to measure piezometric levels.

The individual pumping of each well for periods of up to 72 hours will provide information on the transmissivity, storage coefficient, and the radius of influence of a full-scale pumping well. The installation and pumping of a well in the upper sand and gravel, and a separate installation and pumping of a well in the upper Magothy aquifer will provide information on the vertical interaction between these two formations. This information is critical to the final design, and will impact the placement, pumping schedule, and rates at which water may be removed for treatment. After the aquifer performance test, these wells will be secured and will remain idle until the off-site plume recovery system and the water treatment facility is completed.

During the aquifer performance test, water will be withdrawn from the wells at rates of 250 to 500 gallons per minute. This water will be recharged in the area near the Phase 1A slurry wall containment as allowed in the Consent Order, or will be treated by carbon adsorption and discharged to the Oak Street recharge basin. Water discharged to the basin will be treated to the effluent standards set in Table 1 of the Consent Order.

2.0 WELL INSTALLATION

A production well to test the upper sand and gravel aquifer will be installed near the location designated as 102 in CDM's Phase 2 report. A second production well will be installed near location 183 in CDM's Phase 2 report to withdraw water from the upper Magothy aquifer. Observation wells will be installed near each of these wells in order to measure the piezometric levels at varying depths and at horizontal locations in the vicinity of the well. Piezometric levels further from the pumping production wells will be measured using the existing observation wells at the site. This includes a number of wells on the MSBA bus garage property which are being preserved for this aquifer performance test. These wells will no longer be available once construction of foundations begins for the new bus garage facility.

The well installation procedure will be as follows:

1. An exploratory borehole will be advanced at both well locations 102 and 183 to recover soil samples for grain size analysis. The results of this analysis will be used to select the screen slot opening and gravel pack for the production wells;
2. The observation wells for the measurement of piezometric levels will be installed around each proposed pumping well location;
3. The pumping wells will be drilled by the reverse circulation method, and will be completed to the bottom of the upper sand and gravel for Well 102, and to a depth of approximately 110 feet for Well 183;
4. After completion of the well installations, a temporary pump will be set in Well 102, and an aquifer performance test will be run;

5. The temporary pump will be moved to Well 183, the water levels will be allowed to stabilize, and a second aquifer performance test will be run drawing water from the deeper Magothy aquifer.

Technical specifications, including plans and details for the construction of the production wells and observation wells, are presented in Attachment A.

3.0 AQUIFER PERFORMANCE TEST

The aquifer performance testing at each well will consist of two phases:

1. Step drawdown test;
2. Continuous pumping test.

Before any aquifer performance testing, the well will be developed by surging or pumping to remove any fines or sand that entered the screen during the installation. Water generated during this well development will be pumped to a recharge pit near the MSBA bus garage (as is allowed per Consent Order). Immediately after well development, a step drawdown test will be run to measure the response of the well at various multiples of the anticipated pumping rate. Water withdrawn during the step drawdown test will also be discharged to the recharge pit near the MSBA bus garage. The step drawdown test will be less than 8 hours.

After completion of the step drawdown test, water levels in nearby wells will be monitored to ensure that water levels have recovered. As soon as recovery is complete, and water treatment equipment is in place, a continuous pumping test will be started using a pumping rate established from the step drawdown test. The anticipated rates are 500 gpm for Well 102, and 250 gpm for Well 183. During the continuous pumping test, recharging of water to the pit at the MSBA bus garage will not be possible since the pit is within the expected cone of influence of the pumping wells. Therefore, water removed during the continuous pumping test will be treated with carbon, and discharged to the Oak Street recharge basin. The continuous pumping test will continue until steady-state piezometric elevations are obtained in the monitored wells. After completion of the pumping tests at Well 102, the water levels will be allowed to stabilize, and a pumping analysis will be performed at Well 183.

The specific test procedures and a discussion of the proposed observation wells and data to be collected is presented in Attachment B.

4.0 WATER TREATMENT

During the continuous pumping portion of the aquifer performance test, water from the pumping well must be discharged outside of the cone of influence of the well. The recharge pit used for the step drawdown test is within the expected cone of influence. Therefore, discharge of water into the sanitary or storm sewer will be used to remove the water from the pump test. The sanitary sewer does not have strict treatment requirements. However, the sewage treatment plant does not have a capacity for excess flow and cannot be used for the pump test. Therefore, water generated during the continuous pumping part of the test will be treated to meet the discharge criteria in Table 1 of the Consent Order, and placed in the storm sewer leading to the Oak Street recharge basin.

During the development of the well and the step drawdown test, water will be disposed of in a recharge pit near the MSBA bus garage. This is possible during the step drawdown test because the only water levels measured are in the well itself. This also provides an interval during which fresh water induced into the aquifer by the reverse circulation well drilling technique will be withdrawn, and water typical of the ground water quality will be recovered for testing. During the later stages of the step drawdown test, samples of water will be recovered for testing using Calgon Carbon Corporation's accelerated column test. This test procedure will require approximately 3 to 5 days, and will provide performance criteria for the specific volatile organic levels in the production wells. Attachment C includes information on the accelerated column test, and data on the performance of activated carbon treating water streams containing trichloroethylene, perchloroethylene, 1-1-1 trichloroethane, and toluene, the primary constituents in the ground water at both well locations 102 and 183.

The removal efficiencies of trichloroethylene and perchloroethylene at flow rates of approximately the same magnitude as proposed for this test are shown in Attachment C. Influent loading at well locations 102 and 183 is expected to be less than 10 ppm of any specific compound. The values in Attachment C show that carbon removes trichloroethylene and perchloroethylene to levels of less than 1 ppb from influent streams in the 1 ppm to 10 ppm range.

The continuous pumping portion of the test, with discharge to the Oak Street recharge basin, will not begin until the accelerated column test data is generated, and all parties are assured that the discharge criteria in the Consent Order will be met. The full-scale carbon treatment system will consist of two 10-foot-diameter portable carbon treatment vessels, each capable of a hydraulic flow of approximately 250 gpm. Because of the high flow rate, hydraulics rather than contact time or carbon usage rate controls the water treatment system. Each carbon vessel will contain approximately 16,000 to 20,000 pounds of carbon.

During the continuous pumping test, water will be discharged directly from the carbon treatment system to the Oak Street recharge basin. During the test, water samples will be retrieved once every 12 hours, starting at the beginning of the test, and will be submitted to a local laboratory certified by the state of New York, for analysis of halogenated organics and aromatics by EPA Methods 601 and 602. Turn-around time for these analyses will be 24 hours for verbal results. These analyses will provide the quality assurance for the water treatment system.

ATTACHMENT A

TECHNICAL SPECIFICATION
PHASE 2A - INITIAL OFF-SITE PLUME RECOVERY
WELL INSTALLATION AND TESTING
MITCHEL FIELD REMEDIAL ACTION PROJECT

PART 1: GENERAL

1.01 SCOPE OF WORK

A. Contractor shall furnish all labor, materials, equipment, and expendables required to install and test two 12-inch-diameter plume recovery wells in the locations, and to the details shown on the attached drawings (Figures 1, 2, and 3). The contract shall include the development and test pumping of each well and the pre-well installation of an exploratory boring at each well location. The contract shall also include the installation of seven 2-inch-diameter observation wells for the measurement of piezometric levels. Subcontracting of any part of the well installation and testing shall not be permitted.

B. The well installation and testing shall include:

1. Drilling, soil sampling, and logging of the well borehole.

2. Setting and sealing the well casing and screen.

3. Developing the well, installing a temporary pump, and performing a pumping test.

4. Securing the well with a protective cap.

A permanent pump installation, piping, and valving will be installed at a later date under a separate contract.

C. Contractor shall be responsible for obtaining all required well drilling permits.

1.02 DEFINITIONS

A. Contractor shall mean the licensed state of New York water well contractor responsible for the work.

B. Engineer shall mean Canonie Engineers, Inc., of Porter, Indiana.

C. Owner shall mean T.P. Industrial, Inc., of Lakewood, California.

1.03 SUBMITTALS

A. The Contractor shall maintain a drilling log showing:

1. The depth at which each change of formation occurs;

2. The identification of the material in each soil strata;

3. The depth and diameters of protective casings and the hole diameters.

B. During the well drilling, formation samples shall be collected and preserved in a manner approved by the Engineer. Samples shall be labeled with the following:

1. Name or number of the well;

2. Approximately depth interval of the sample;

3. Date and time taken.

C. On completion of each well, the Contractor shall also submit to the Engineer a copy of the well installation log filed with the state of New York.

1.04 QUALIFICATIONS

A. The Contractor shall be a licensed water well contractor in the state of New York. Well Contractor shall employ competent workmen for the execution of this work, and all work shall be performed under the direct supervision of an experienced well driller satisfactory to the Engineer.

B. The well driller shall be capable of maintaining complete and current well logs, daily notes, and developing and testing the wells.

C. On request, the Contractor shall furnish satisfactory evidence that all materials to be incorporated in the work meet the specifications, and that all equipment is in good working order.

D. The Contractor shall complete the work described in this specification in accordance with the applicable portions of the Environmental Conservation Law of New York State.

1.05 HANDLING OF MATERIALS

A. Contractor shall be responsible for obtaining and providing water from the nearest city water supply point to the well drilling location.

B. The excavation of in-ground pits for the recirculation of drilling water, and the settling of solids shall be allowed. On completion of the well drilling activities, sediments in the pit shall be covered with a minimum of two feet of clean fill from the pit excavation. Contractor shall grade and compact soil over the pit. Soil shall be compacted to at least 90 percent of standard Proctor density ASTM D-698.

C. During well testing, Contractor shall provide piping, including connections for the discharge of test waters to a recharge pit and a water treatment unit both supplied by others. The water treatment system shall be located near Well 102 at the approximate location shown on Figure 1. The recharge pit shall be located near the MSBA garage as shown on Figure 1.

1.06 WELL ACCEPTANCE CRITERIA

A. The wells shall be accepted by the Engineer when performance testing indicates that the wells produce at 80 percent efficiency for a continuous period of at least 24 hours.

1.07 WARRANTY

All materials and workmanship for these well installations shall be warranted by Contractor for a period of one year from date of acceptance by the Engineer. Any manufacturer's warranties on materials shall run concurrent with Contractor's warranty. If any part of the well should fail during the warranty period, it shall be replaced and serviced at no additional expense to the Owner or Engineer.

PART 2: MATERIALS

2.01 PURGE WELL CASING

Permanent well casing shall be new material conforming to ASTM A53, Type E or Type S specification for standard steel pipe. Casings shall be 12-inch inside diameter. Temporary casing installed for constructing surface seals, or as a temporary borehole support, may be of alternate materials or alternate thicknesses satisfactory to the Engineer. All steel casing shall be welded in the field as required and as approved by the Engineer.

2.02 PURGE WELL SCREENS

Well screens shall be 12-inch-diameter ASTM A276 Type 304 stainless steel screens. Slot size shall be selected by the Contractor, based on the results of grain size testing of formation materials, and shall be approved by the Engineer. Screens shall be as manufactured by the Johnson Division/UPO, Inc., or approved equal providing a "vee slot" configuration.

2.03 GRAVEL PACK

Gravel shall be well rounded, washed, sized silica gravel with a diameter and gradation compatible with both the aquifer formation and the selected screen slot size. Samples of the gravel proposed by the Contractor for the well installation shall be submitted to the Engineer for approval.

2.04 OBSERVATION WELL CASING AND SCREEN

The observation well casing shall be 2-inch-diameter Schedule 40 PVC with threaded joints. The screen shall be machine slotted 2-inch-diameter Schedule 40 PVC with at least three rows of slots. Slot size shall be 0.01 inches for wells in the Magothy aquifer, and 0.02 inches for wells in the glacial sand and gravel. Screen sections shall be threaded for attachment to the well casing and other screen sections.

2.05 PROTECTIVE COVERS AND CASINGS

Contractor shall construct a protective cap with ring flange and fastening system for each purge well. The protective cap shall be constructed of ASTM A53 or A36 steel.

Contractor shall also construct a protective casing with locking cap for each observation well. The protective casing with cap shall be a section of Schedule 40 steel pipe, and shall be long enough to provide a minimum three-foot embedment in the surface seal.

2.06 SANITARY SEALS

Sanitary seals shall consist of a mixture of Type 1 Portland cement, bentonite, sand, and water. This mixture shall consist of an equal volume of dry sand and cement/bentonite. The cement and bentonite shall be 95 percent cement and 5 percent bentonite by volume. Approximately 6 gallons of clean water shall be added to the mixture for each 100 pounds of the cement/bentonite.

PART 3: EXECUTION

3.01 EXPLORATORY BORING

Contractor shall install an exploratory boring at each well location prior to starting the drilling of the well. Contractor shall install the exploratory boring using hollow-stem augers or other drilling methods suitable to the Engineer. Contractor shall recover three soil samples from the top, middle, and bottom of the proposed screen zone for each plume recovery well, Figures 2 and 3. Contractor shall analyze these samples for grain size distribution (ASTM D-422) and use the results for screen slot and gravel pack selection. A copy of the grain size curves shall be supplied to the Engineer.

3.02 WELL DRILLING METHOD

The wells shall be drilled by the reverse circulation method, and shall have at least a 24-inch diameter. The borehole shall be drilled to the bottom of the glacial sand and gravel for Well 102, and shall be drilled to a depth of 50 feet below the top of the Magothy aquifer for Well 183. Only clear water shall be used in the drilling. Bentonite, revert, or other additives shall not be permitted.

During installation of the well, formation samples shall be taken from the return flow at 10-foot intervals. These samples shall be preserved and provided to the Engineer.

3.03 WELL CASING AND SCREEN INSTALLATION

For both Wells 102 and 183, the well screen shall be 20-foot long, 12-inch-diameter Johnson well screen or equivalent as specified in Section 2.0. The well screen shall have a 2-foot blank stub at the bottom and be sealed with a welded steel plate. The screen shall be attached to the well casing by field welding. Additional casing lengths shall be attached by field welding.

All casings and screening shall be constructed plumb and true to line, and shall be installed in the center of the borehole using centralizers. The well casing shall not deviate from vertical by more than three inches per 100 feet.

The screen slot size shall be selected by the Contractor on the basis of formation grain size, and the selected gravel pack. Contractor's selected screen slot size and gravel pack gradation shall be submitted to the Engineer for approval prior to installation.

3.04 OBSERVATION PIEZOMETERS

Contractor shall install observation wells for the measurement of piezometric levels at the seven locations shown on Figures 4 and 5. Observation wells shall be installed using a hollow-stem auger or other method approved by the Engineer. Bentonite shall not be allowed in the boreholes for the observation wells.

Observation wells shall have a 5-foot section of slotted screen with plug and riser pipe. Observation wells in the Magothy aquifer shall have a 2-foot-thick bentonite pellet seal 5 feet above the top of the screen, and shall be grouted to the ground surface. Observation wells in the upper sand and gravel shall have a 3-foot-thick surface seal. Collapse of the natural formation soils around the screens shall be allowed. Each observation well shall have a protective surface casing with locking cap.

During drilling for the observation wells, soil samples shall be collected with a standard split-spoon sampler at 5-foot intervals starting 10 feet above the proposed screen zone. Samples shall be submitted to the Engineer.

3.05 GRAVEL PACK

The gravel pack shall be installed by tremie pipe and shall be brought up to the elevations shown on the drawings.

3.06 SANITARY SEAL AND BACKFILL

The sanitary seal shall be installed by tremie pipe, and shall conform to the elevations shown on Figures 2 and 3.

3.07 WELL DEVELOPMENT

After well installation, the well screen shall be thoroughly surged and agitated to remove fines from the gravel pack and the adjacent water bearing formation. Well efficiency shall be not less than 80 percent at a pumping rate of 500 gallons-per-minute for Well 102, and 250 gallons-per-minute for Well 183. Chemicals shall not be used in the well development process.

Water produced during the well development and step drawdown test shall be pumped to the recharge pit shown on Figure 1. Contractor shall supply the piping for transporting the water to the recharge pit. The recharge pit shall be supplied by others.

Water produced during the continuous aquifer performance test shall be piped directly to the water treatment plant. Contractor shall supply piping to the water treatment plant, and a pipe from the water treatment plant to the nearest storm water drain on Oak Street.

PART 4: PERFORMANCE TEST

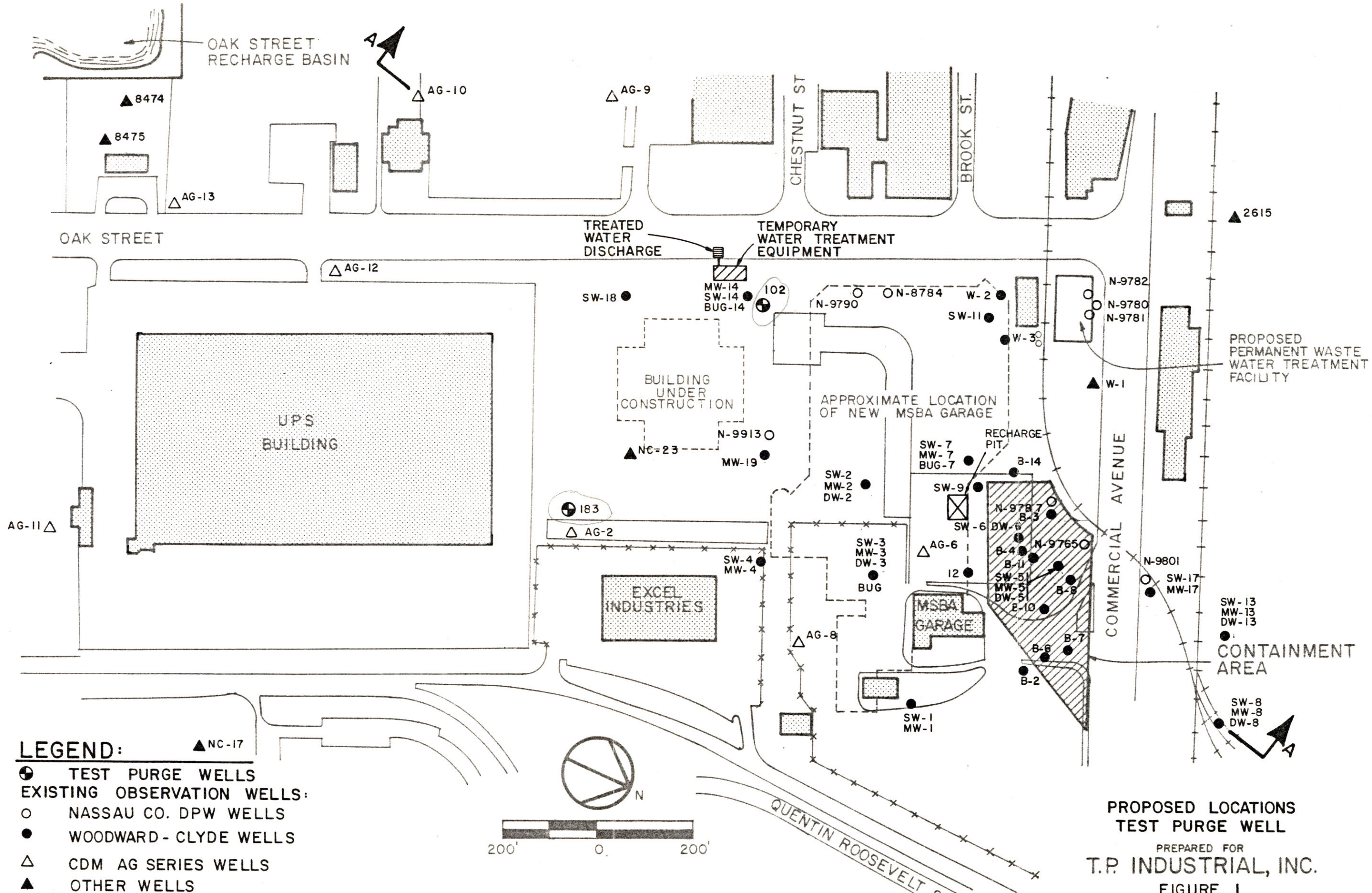
The Contractor shall furnish and install a temporary deep well vertical or submersible turbine test pump of at least 500 gpm capacity, but with the capability to vary the pumping rate. Each well shall be pumped individually at stepped rates to estimate the maximum continuous pumping capacity and to clear and free the well of fines. When the well water is clear, and after a minimum of 12 hours without pumping, the Contractor shall run a continuous pumping test for at least 24 hours, and no more than 72 hours, at a constant rate set by the Engineer. The Contractor shall furnish a cumulative flow meter for measuring and verifying the pumping rate and amount pumped.

The Contractor shall install a 3/4-inch-diameter pipe with slotted or perforated screen for the measurement of water level within the pumping well. Contractor shall provide at least one pump operator at all times during the test pumping activities.

On completion of the pumping test, Contractor shall remove the temporary deep-well turbine pump, complete site cleanup, and install the temporary well caps on the purge wells.

DRAWING NUMBER CH85-096-B2

DRAWN BY SP 8-27-85 | CHECKED BY | APPROVED BY



REFERENCE
— CAMP DRESSER & McKEE REMEDIAL ACTION PLAN FOR THE PUREX SITE, FIGURE 6-1.

PROPOSED LOCATIONS
TEST PURGE WELL

PREPARED FOR

T.P. INDUSTRIAL, INC.

FIGURE 1

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Canonie

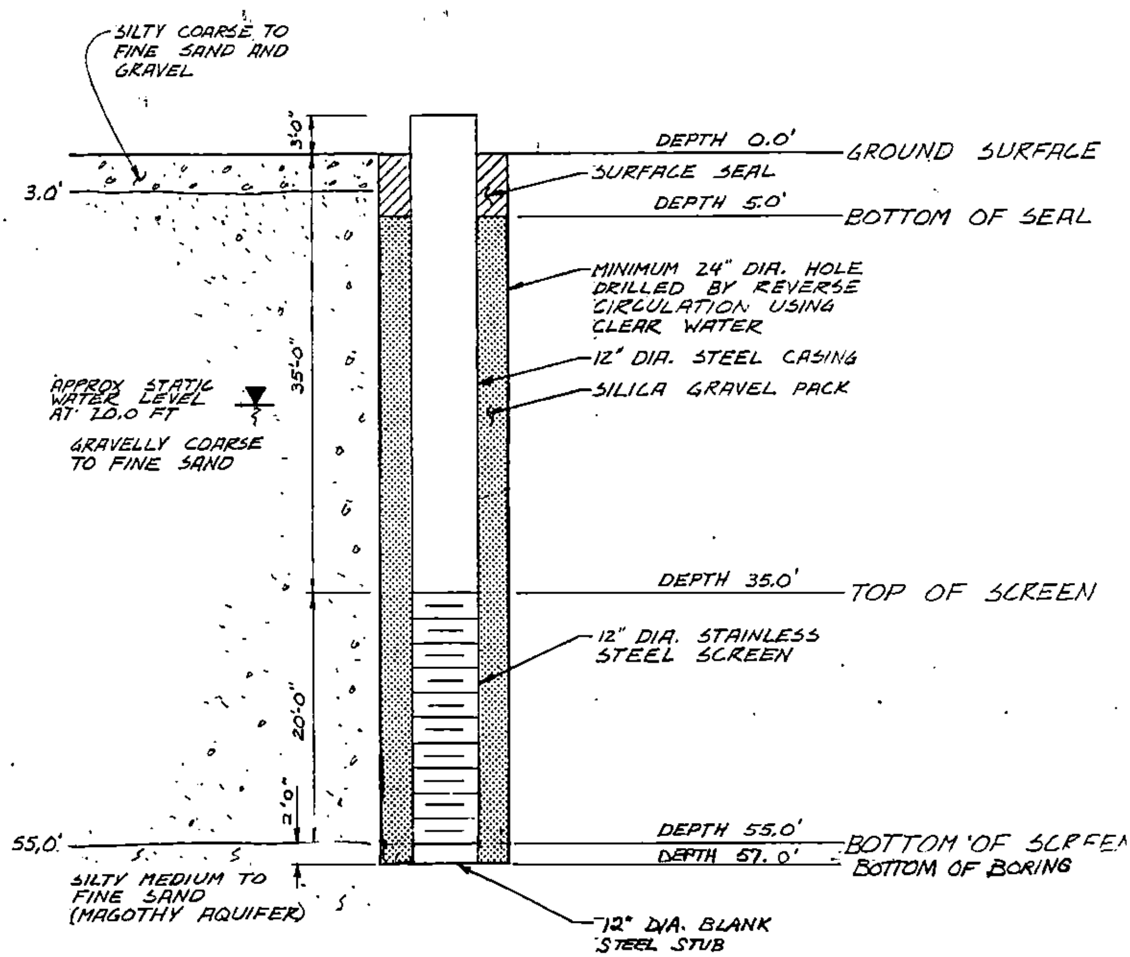
Purge Well Details

PROJECT No. CH 85-096

WELL No. 102 (PROPOSED)

PROJECT NAME T.P. INDUSTRIAL INC.

BORING LOCATION ______ DATE ______ BY ______



NOTES:

1. SOIL DESCRIPTION FROM BORING LOG MW-14

HORIZONTAL SCALE

2'-0" 0 2'-0"

VERTICAL SCALE

10'-0" 0 10'-0"

FIGURE 2

Canonie

Purge Well Details

PROJECT No. CH 85-096

WELL No. 183 (PROPOSED)

PROJECT NAME T.P. INDUSTRIAL INC.

BORING LOCATION ______ DATE ______ BY ______

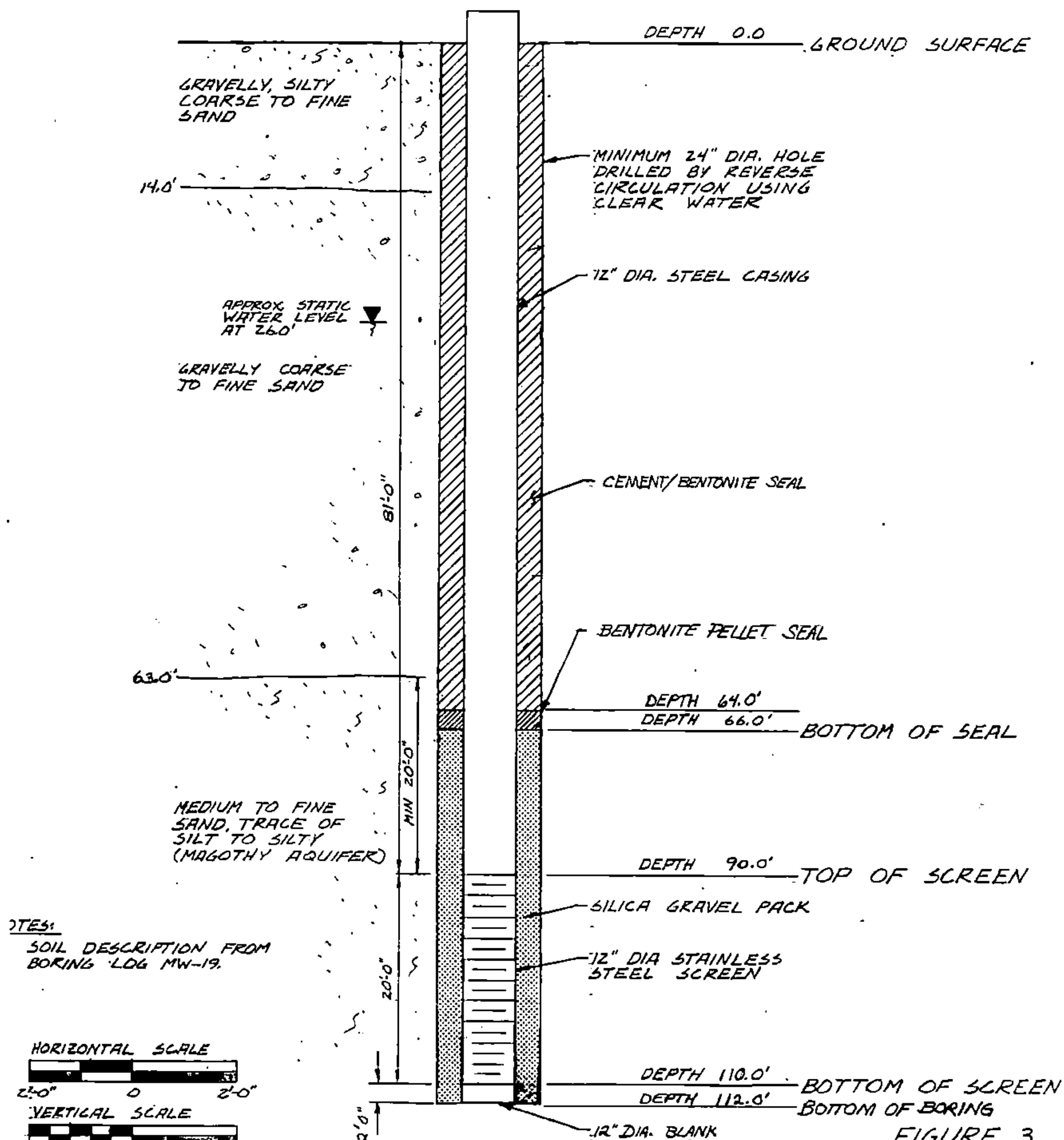


FIGURE 3

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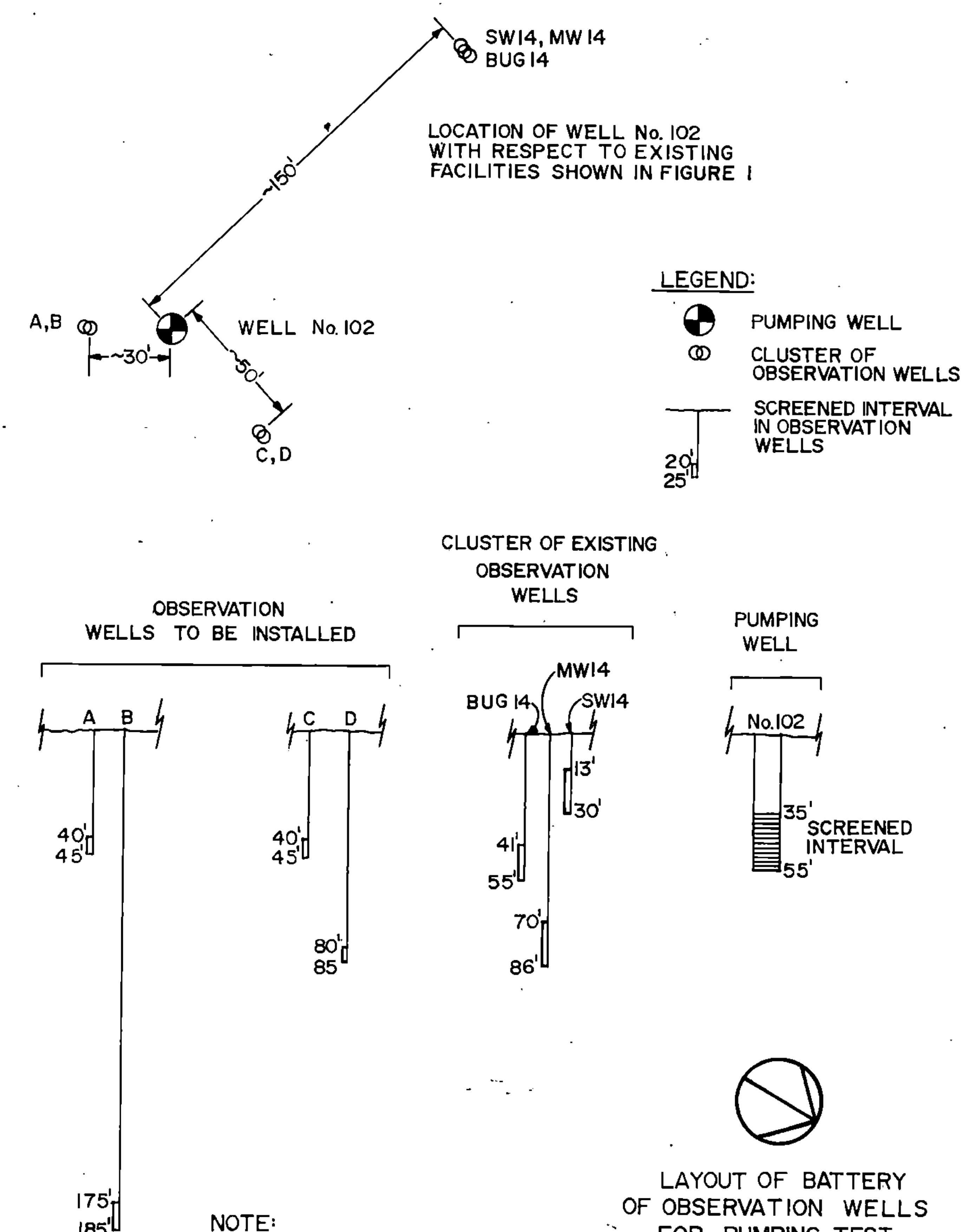

NOTE:

EXACT LOCATION OF THE NEW WELLS WILL DEPEND ON SITE ACCESSIBILITY. EXACT LOCATION OF THE SCREENED INTERVALS WILL DEPEND ON SUBSURFACE LITHOLOGY

LAYOUT OF BATTERY OF OBSERVATION WELLS FOR PUMPING TEST IN WELL No. 102

FIGURE 4

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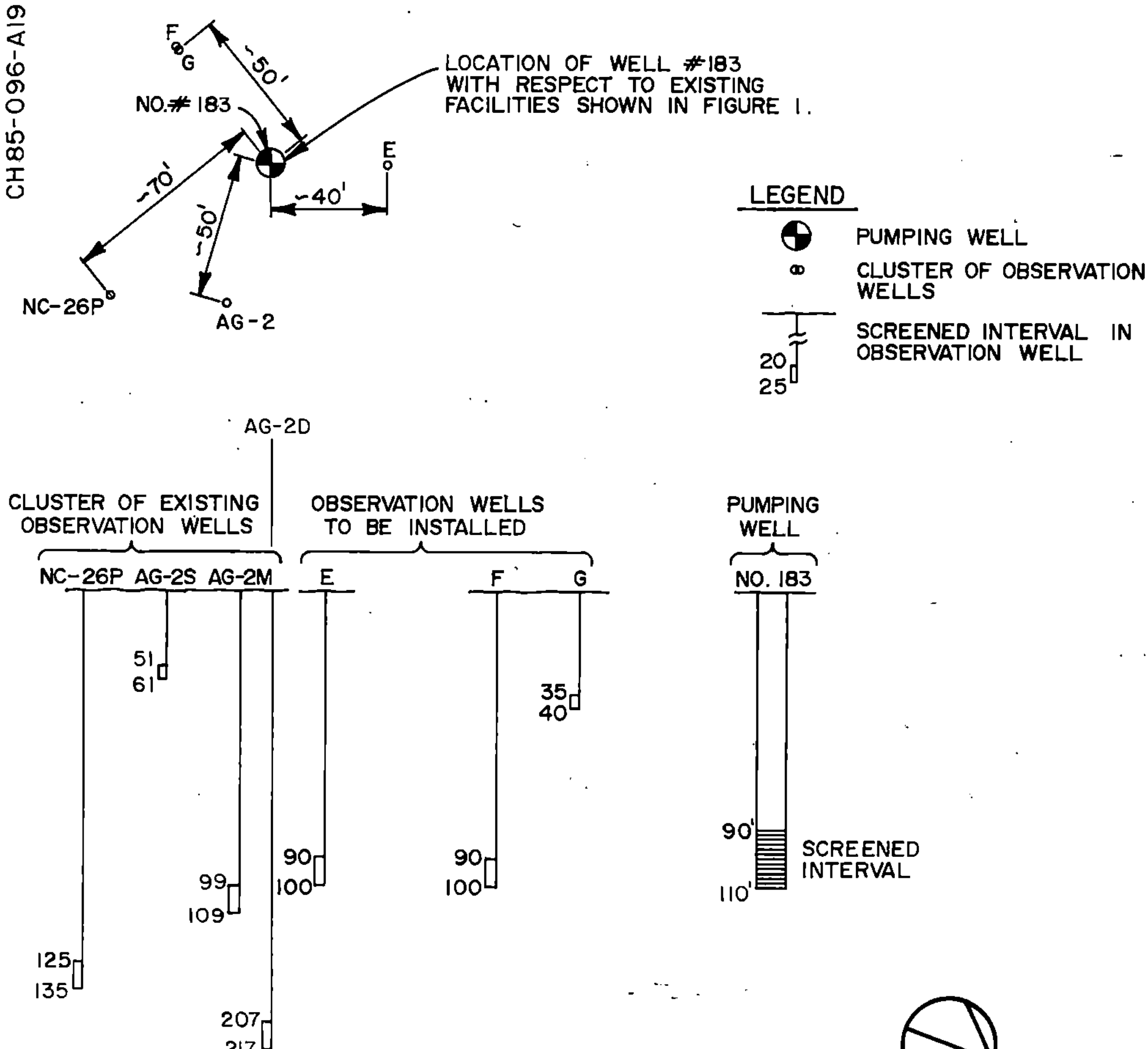

NOTE

EXACT LOCATION OF THE WELLS WILL DEPEND ON THE SITE ACCESSIBILITY. EXACT LOCATION OF SCREENED INTERVAL WILL DEPEND ON SUBSURFACE LITHOLOGY.

LAYOUT OF BATTERY OF OBSERVATION WELLS FOR PUMPING TEST IN WELL #183

FIGURE 5

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ATTACHMENT B

Technical Program
Aquifer Performance Test
Mitchel Field Remedial Action

The technical program will quantify the hydraulic properties of the aquifer system at the Mitchel Field Remedial Action site. The program is divided into three tasks, each having specific objectives and technical attributes. These tasks are 1) step-drawdown test in Wells 102 and 183; 2) pumping test in Well 102 installed in the uppermost glacial aquifer; and 3) pumping test in Well 183 installed in the Upper Magothy aquifer.

Prior to starting the pumping tests, several new observation wells will be installed near the pumping wells. A detailed examination and inventory of all existing observation wells will also be completed prior to pumping.

Following is a discussion of objectives, performance, data collection, and methods of analysis, and interpretation for each task.

B1: Step-Drawdown Tests in Wells 102 and 183

The objectives of the step-drawdown tests are:

1. Determine the depth of pump setting and optimal pumping rate in each well for the long-term pumping tests;
2. Calculate the efficiency of the well. This information will serve as a benchmark against which future performance of the wells will be examined;
3. Remove fines remaining within well casing or gravel pack after development;

Performance of the Step-Drawdown Tests: Step-drawdown tests will be performed in each well (102 and 183) prior to conducting the long-term pumping test. Four (4) steps are planned for each well with the following approximate pumping rates:

Well 102: Step I - 350 gpm; Step II - 450 gpm; Step III - 550 gpm; and Step IV - 650 gpm.

Well 183: Step I - 150 gpm; Step II - 225 gpm; Step III - 300 gpm; and Step IV - 375 gpm.

Pumping for each step will continue until the water level stabilizes. The stabilization is expected to take place within two hours from the start of each step. A sample of ground water for an accelerated column test will be collected from each well at the end of the step-drawdown tests.

Data Collection: Water levels will be read in each well with an electric well sounder. To prevent entangling of the sounder with the power cable or pump drop pipe, the well sounder will be lowered through a 3/4-inch tube affixed to the pump drop pipe. The tube will be open at the bottom and the bottom five (5) feet of the tube will be slotted.

Data on well discharge (flow rate and cumulated volume) will be collected with a cumulative water meter capable of handling flows of approximately 750 gpm for Well 102 and 500 gpm for Well 183. A constant flow rate will be maintained for each step.

Data Analysis and Interpretation: Data collected during the test, i.e., drawdown vs. pumping rate for each step, will be analyzed immediately in the field as the testing progresses. The test results will be used to determine the optimal range of pumping rates and depth of pump intake in each well. Efficiency of the well will also be calculated.

B2: Pumping Test in Well 102

Well 102 is installed in the unconfined, glacial sand and gravel aquifer. The well fully penetrates the glacial aquifer with the bottom of the well located at the top of the Upper Magothy aquifer approximately 55 feet below ground surface. The well is screened from a depth of 35 feet to 55 feet, or through approximately 60 percent of saturated thickness of the test aquifer.

Test Objective: Testing in Well 102 is expected to quantify the following aquifer properties:

1. Aquifer transmissivity and definition of its directional components (major and minor axes of transmissivity);

2. Specific storage not affected by delayed yield;

3. Interaction between the glacial and Magothy aquifers in response to pumping;

4. Percentage of flow contributed from the Magothy aquifer in response to pumping;

5. Empirically determined radii of influence for the glacial and Magothy aquifers. This includes directional distortion of the radii due to horizontal anisotropy.

Data Collection: Water level measurements will be made in all observation wells located within the site regardless of their depth of completion. This includes wells installed in the shallow glacial aquifer and at various depths in the Magothy aquifer. The inventory of observation wells which may be available for observations in the shallow (glacial) and Magothy aquifers are shown on Figures 1, 2, and 3.

In addition to the existing wells, four (4) additional observation wells will be installed in close proximity to Well 102. The proposed location of the wells and screened intervals are shown on Figure 4. These new wells will be used to determine the directional components of transmissivity. For this procedure, wells situated in at least three directional arrays are required. Positioning of the new observation wells close to the pumping well where the stress on the aquifers is greatest is expected to produce the best information on interaction between glacial and Magothy aquifers.

The newly installed wells will have two-inch-diameter PVC, Schedule 40 casing. These new wells will be used only for gathering data on aquifer performance. At this stage in the planning, they are not intended for monitoring ground water quality.

Prior to the pumping test, all existing wells will be inspected for their accessibility and actual depth. Water level readings prior to the onset of the test will be collected in all accessible wells.

It is tentatively planned that electronic pressure transducers with computerized data acquisition/analysis systems will be used for 10-15 observation wells closest to the pumping well where the changes in water levels will be most rapid. Water levels in the remaining wells will be measured with calibrated electric well sounders.

Data from the pumping test will be reduced and analyzed in the field as the testing progresses. This will allow for immediate alteration to the test procedures (i.e., changes in pumping rate, change in test time) should such a need arise.

Data Analysis and Interpretation: The reduction and cursory analysis of field data will be done with "AQTEST" semi-analytical program for HP-41 hand held computer. Final analysis will be conducted in the office and will employ appropriate methods for unconfined and possibly leaky aquifer systems with potential delayed yield effects.

B3: Pumping Test in Well 183

Well 183 is installed in the Upper Magothy aquifer which appears to be separated from the overlying glacial sand by a silty sand layer. The Magothy aquifer consists of fine sand with discontinuous lenses of lower permeability silty material. Based on this information, the Magothy aquifer may have vertical permeability significantly lower than the horizontal permeability. Well 183 is completed to a depth of 110 feet with the bottom 20 feet screened.

Test Objectives: Testing in Well 183 is expected to quantify the following properties of the Upper Magothy aquifer:

1. Aquifer transmissivity with its directional components (major and minor axes of transmissivity);
2. Horizontal to vertical permeability ratio;
3. Percentage of contribution of water from glacial aquifer to the Magothy aquifer during pumping;
4. Storage coefficient;
5. Empirically demonstrated radii of influence in the Magothy and glacial aquifers. This includes directional distortion of the radii due to horizontal anisotropy.

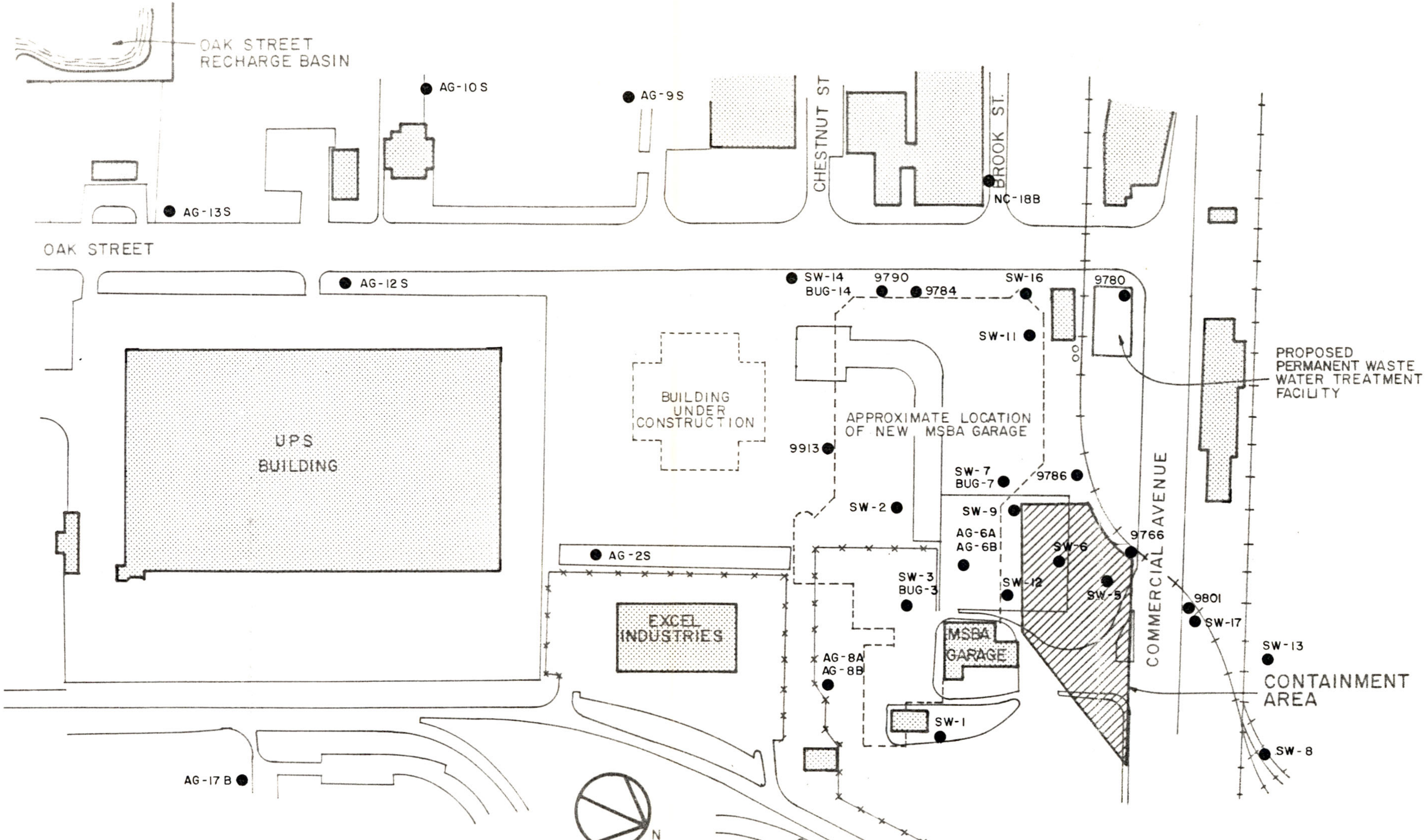
The pumping well is assumed to be partially penetrating given the current information on the thickness of the Magothy aquifer. Therefore, pumping will cause convergence of flow in the proximity of the screened section. If the observation piezometers are located at various elevations with respect to the screen, a definition of the ratio of horizontal to vertical permeabilities may be possible.

Data Collection: The network of monitoring wells for this pumping test will essentially be the same as that discussed for Well 102. The inventory of monitoring wells is shown on Figures 1, 2, and 3. The only addition will be four new wells which will be installed close to Well 183.

The proposed location of the new wells and their screened intervals are shown on Figure 5. The sole purpose of these new observation wells will be to gather data on aquifer performance. They are not intended for monitoring ground water quality.

Procedures for data gathering will also be identical to those used for Well 102. The pumping rate is expected to be within the range of 200-300 gpm. The duration of the test will depend on the aquifer response to pumping.

Data Analysis and Interpretation: As with Well 102, data will be analyzed in the field during the test. In addition to the methods commonly used to analyze an aquifer with a partially penetrating well, the Week's method to determine horizontal to vertical permeability ratios will be used. It is expected that the pumping test in Well 183 will further refine information on the interaction between the shallow and deeper ground water systems.



GLACIAL SAND AND GRAVEL WELLS
MITCHEL FIELD REMEDIAL ACTION
PREPARED FOR
T.P. INDUSTRIAL, INC.

FIGURE 1

Canonie Engineers

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APPROVED BY	
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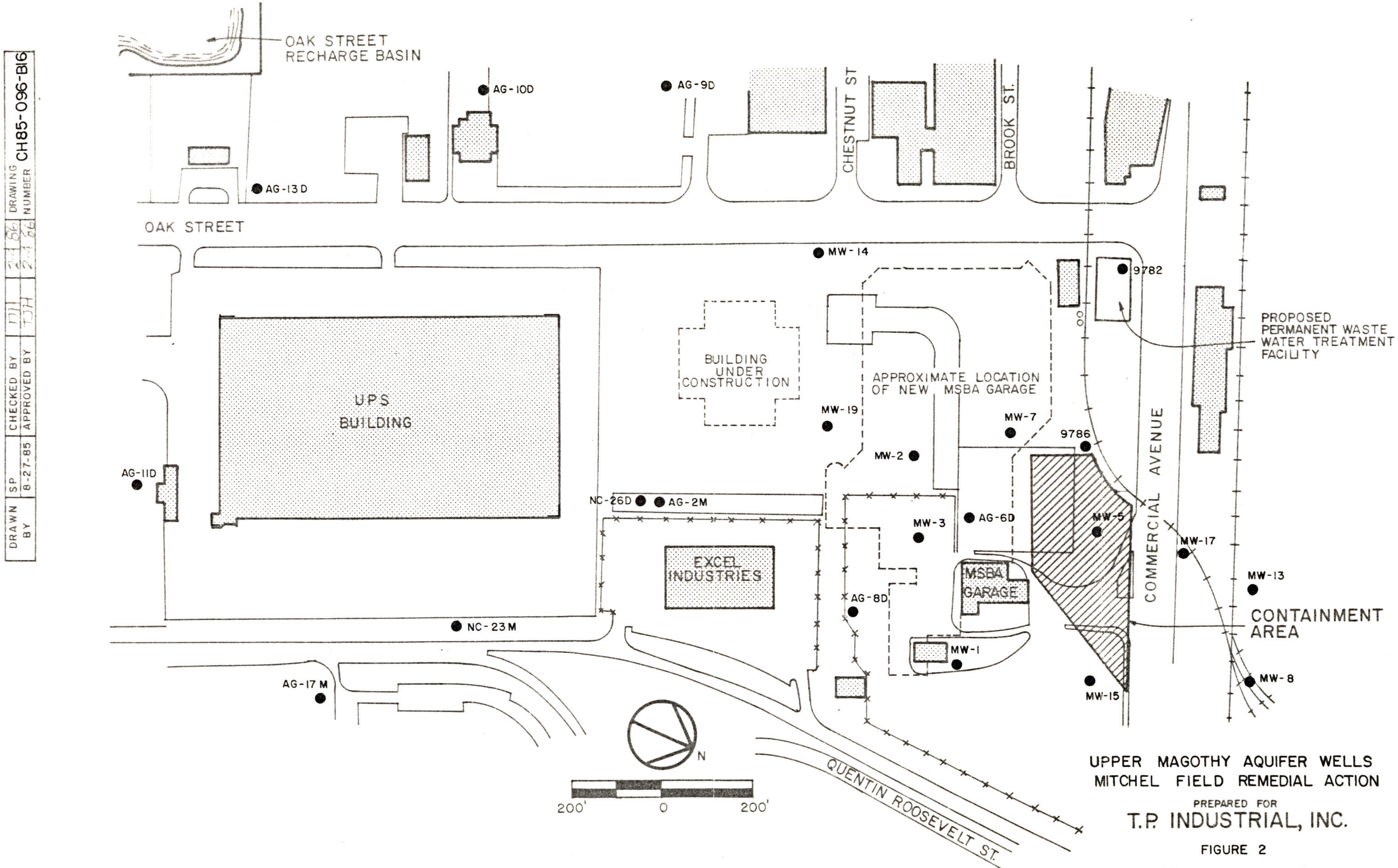

UPPER MAGOTHY AQUIFER WELLS
MITCHEL FIELD REMEDIAL ACTION

PREPARED FOR

T.P. INDUSTRIAL, INC.

FIGURE 2

Canonie Engineers

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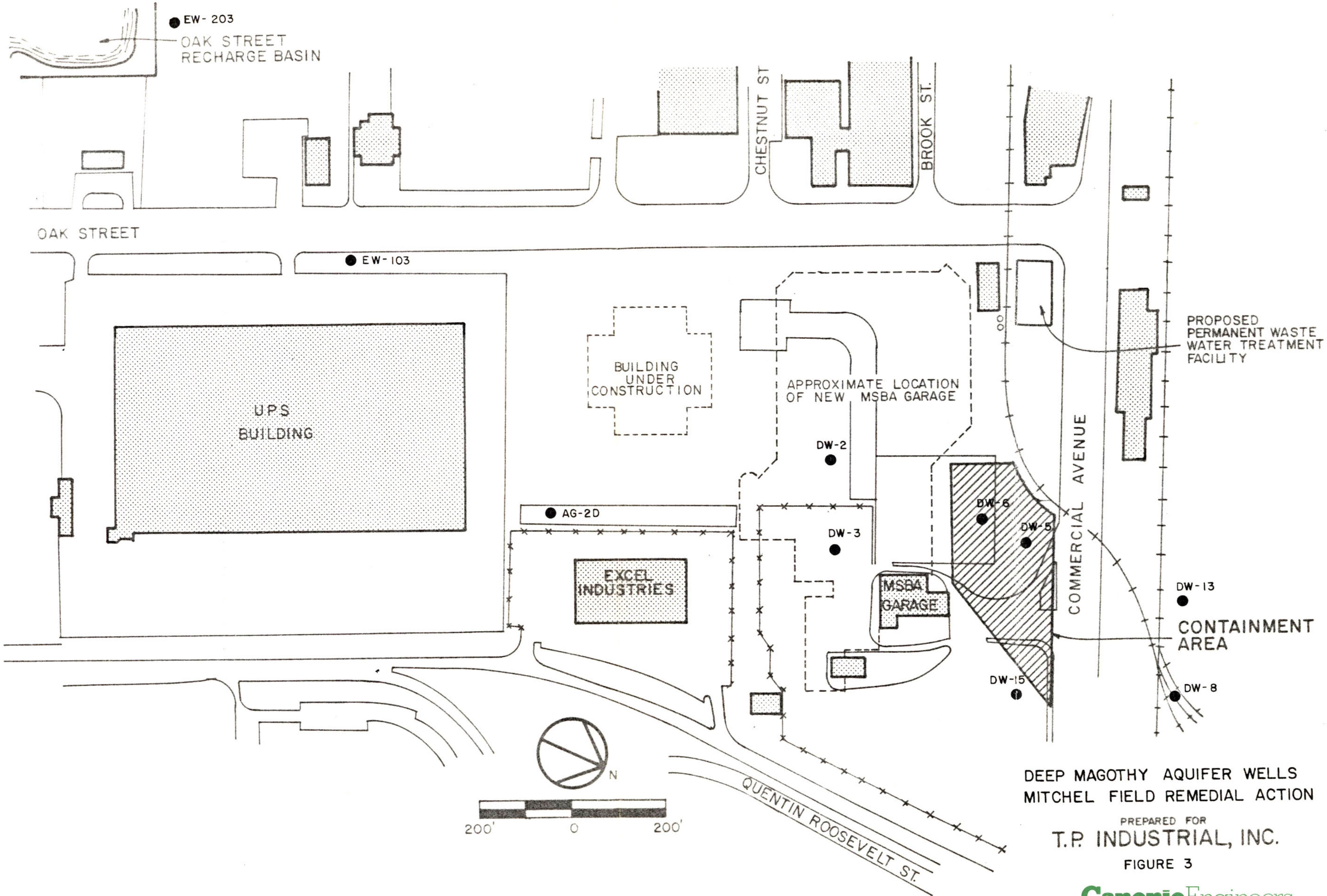

DEEP MAGOTHY AQUIFER WELLS
MITCHEL FIELD REMEDIAL ACTION

PREPARED FOR
T.P. INDUSTRIAL, INC.

FIGURE 3

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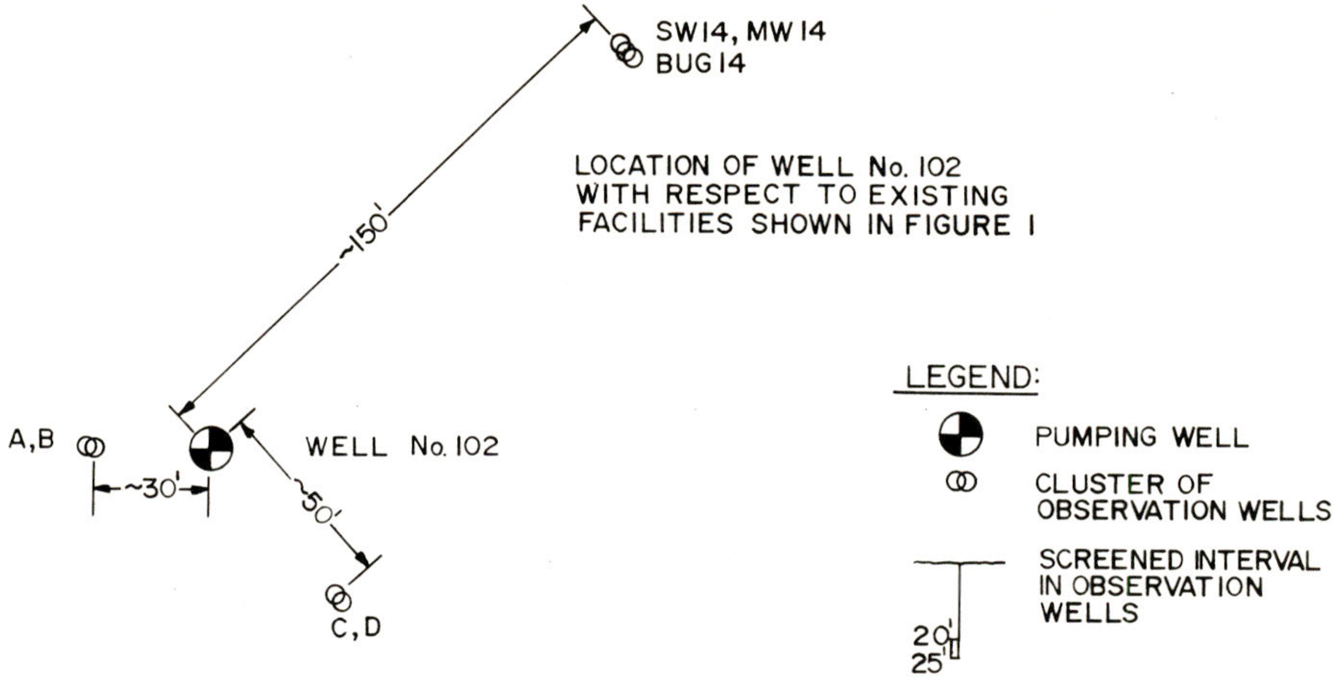
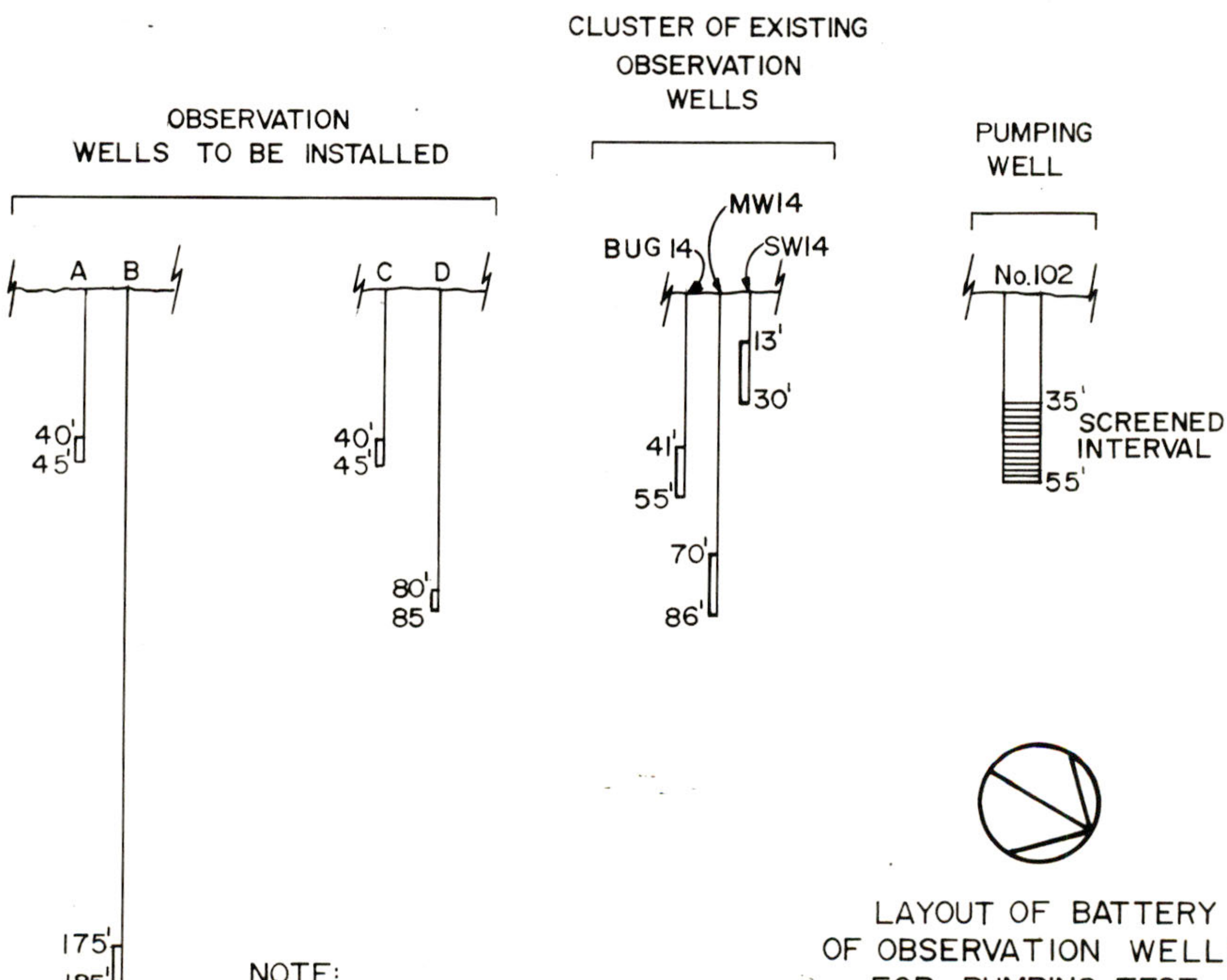
CH85-096-A19





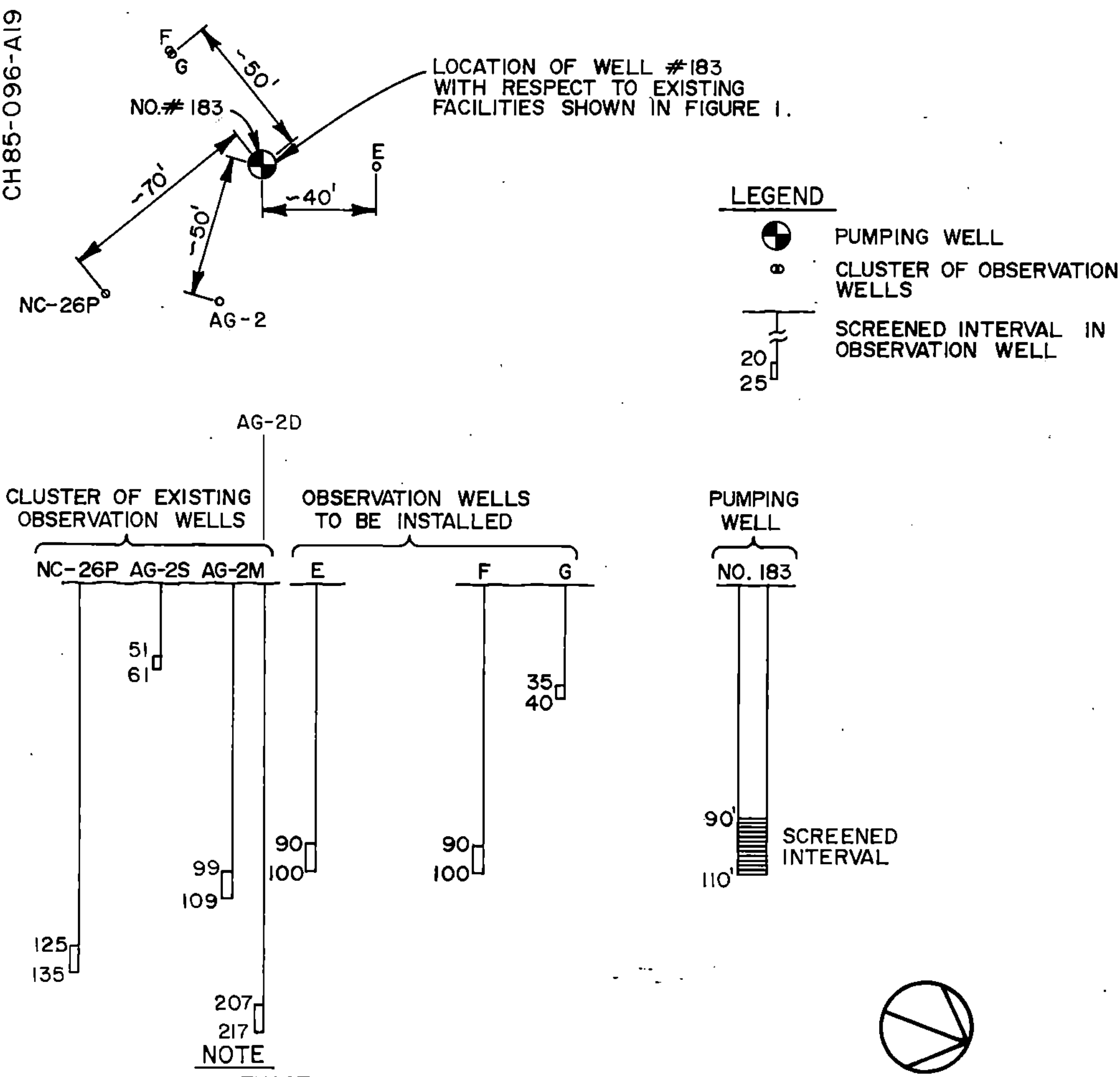
NOTE:
EXACT LOCATION OF THE NEW WELLS WILL DEPEND ON SITE ACCESSIBILITY.
EXACT LOCATION OF THE SCREENED INTERVALS WILL DEPEND ON SUBSURFACE LITHOLOGY

LAYOUT OF BATTERY
OF OBSERVATION WELLS
FOR PUMPING TEST
IN WELL No. 102

FIGURE 4

CanonieEngineers

CH85-096-A19



NOTE

EXACT LOCATION OF THE WELLS WILL DEPEND ON THE SITE ACCESSIBILITY. EXACT LOCATION OF SCREENED INTERVAL WILL DEPEND ON SUBSURFACE LITHOLOGY.

LAYOUT OF BATTERY OF OBSERVATION WELLS FOR PUMPING TEST IN WELL #183

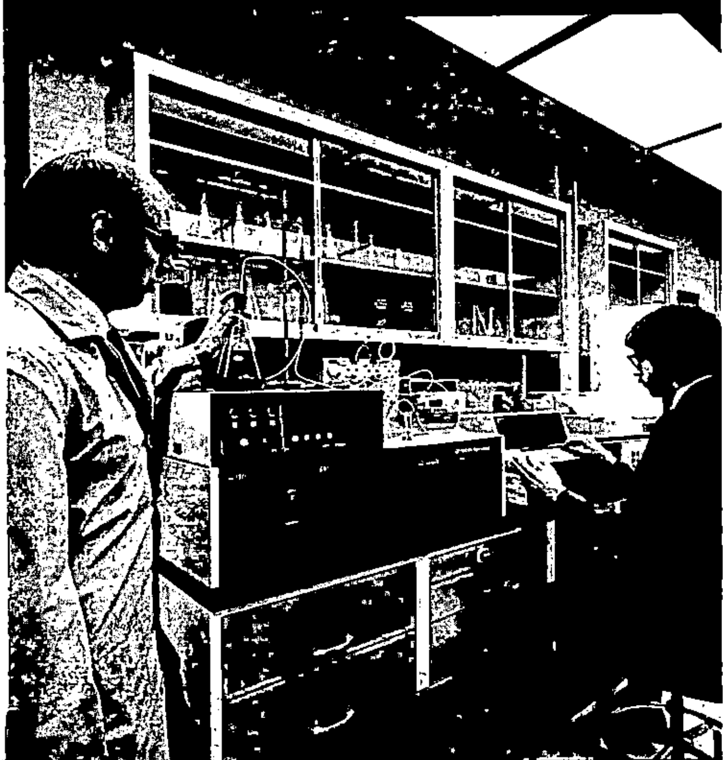
FIGURE 5

Canonie Engineers

ATTACHMENT C

Calgon® Accelerated Column Test

to evaluate activated carbon for liquid phase applications



CALGON

SUBSIDIARY OF MERCK & CO., INC.

Testing to evaluate the removal of organic impurities from liquids with activated carbon previously has been accomplished with static isotherm testing or dynamic pilot testing. Isotherm testing is quick but only predicts a theoretical carbon usage, or "ball park" estimate for 100% removal of the parameter of concern. Pilot testing predicts more accurate carbon usage and design data, but is very time-consuming and expensive.

Calgon Carbon Corporation has developed the Accelerated Column Test, an improved technique for testing the removal of organic impurities that combines the speed of an isotherm test with the accuracy of a pilot column.

Benefits

As a customer of Calgon, use of the Accelerated Column Test provides you with many benefits including:

- **Saves time**—The Accelerated Column Test can simulate most liquid phase process conditions in just a few days of laboratory testing. By comparison, other dynamic tests normally require several weeks or months to predict component break-through. Thus, you obtain meaningful dynamic data much more quickly and economically than with older methods.
- **Offers technical validity**—Correlation studies with other column testing procedures have demonstrated that the Accelerated Column Test is a consistently accurate evaluation technique. You can have full confidence in translating the test results into a full-scale system design.
- **Prevents degradation**—Because only a few days are required to perform the test, there is less opportunity for degradation of the sample stream through biological activity. As a result, the test can more accurately simulate actual stream conditions, and thus generate more reliable data. You are assured that the laboratory simulation is based on "real world" operating conditions.
- **Provides dynamic data**—The Accelerated Column Test simulates actual process performance, providing dynamic data rather than equilibrium capacity data generated by an isotherm. This assures full consideration of flow conditions and the effects of flow on adsorption capacity.
- **Is reliable for volatile impurities**—The Accelerated Column Test results in more reliable evaluation of streams containing volatile impurities, which is especially critical in groundwater applications. The accelerated test achieves a degree of accuracy that is difficult to achieve with other methods.
- **Provides additional data points**—The accelerated test method makes it possible to generate many more data points than are practical or economical with previous techniques. The additional data help insure proper system design by allowing all types of alternate treatment flows and schemes to be tested for optimum treatment conditions of a particular stream.
- **Requires smaller samples**—Because the Accelerated Column Test requires considerably smaller quantities of sample influents for testing purposes, sample collection and handling are greatly simplified. In many cases, a few gallons of the stream being treated is all that is required. By comparison, one-inch column tests often require several 55-gallon drums of sample influent, and field tests can require thousands of gallons.

General description

Acceleration of the carbon adsorption cycle is achieved through a scaling down of the conventional column testing hardware. Except for their reduced scale, the other components of the test system (reservoir, pump, tubing, etc.) and the overall system design are essentially identical to larger scale laboratory or field evaluation systems (Figure 1).

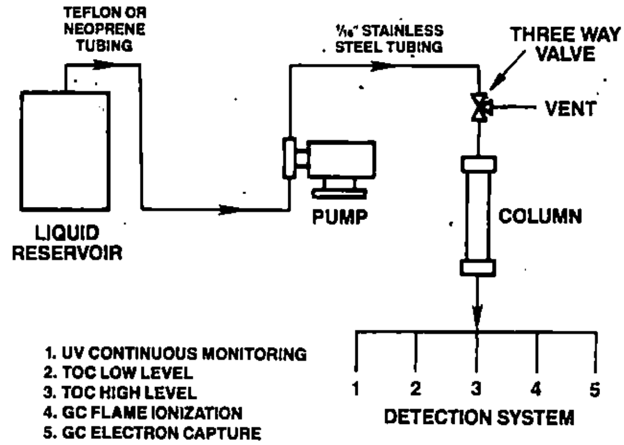


Figure 1 Basic System

The technology behind the Accelerated Column Test is based upon Calgon discoveries relating to the basic kinetics of carbon adsorption. These discoveries enabled Calgon scientists to develop a mathematical model of the column adsorption process, upon which the accelerated test is based.

With this mathematical model, breakthrough curves for full-scale adsorption systems can be readily calculated from data generated by the scaled-down accelerated column.

Laboratory Test Results

The Accelerated Column Test has demonstrated consistent correlation with other column test procedures in the prediction of component breakthrough curves. In virtually all comparative tests run to date, the Calgon accelerated test has generated data identical to the conventional method. This performance has been demonstrated with a wide variety of carbons over a broad range of operating conditions.

In one series of correlation tests, the Accelerated Column Test was evaluated against a conventional one-inch column for the prediction of breakthrough for both strongly and weakly adsorbed components. For the purpose of this test, a synthetic stream was created, containing acetoxime and paranitrophenol. As Figure 2 illustrates, the accelerated test successfully predicted the performance of the one-inch column. This degree of correlation was maintained in thirty additional tests under a variety of operating parameters.

Customer Case Studies

Upon completion of the laboratory correlation studies, the Accelerated Column Test was applied to the evaluation of actual user treatment problems. In each case, the technique successfully predicted breakthrough in a fraction of the time required for conventional column runs, resulting in significant cost savings for the user.

- **Wastewater Treatment**
  The Accelerated Column Test was employed to evaluate the performance of a Calgon carbon in an industrial wastewater treatment application. A chemical processing facility was discharging 195 PPM of chloroform and 30 PPM of carbon tetrachloride. New regulations required that the chloroform discharge be reduced to 50 PPB and carbon tetrachloride discharge cut to 100 PPB. Because of the high concentration of chloroform, separate tests were run to determine breakthrough for each component.

  The Accelerated Column Test demonstrated that adsorption could be successfully utilized to comply with the new regulations. This data was generated in much less time than it would have taken to run a field or lab column test, and it provided a basis for economic analysis.

  Figure 3 shows the breakthrough curve predicted by the accelerated test for the removal of chloroform from the plant's effluent.

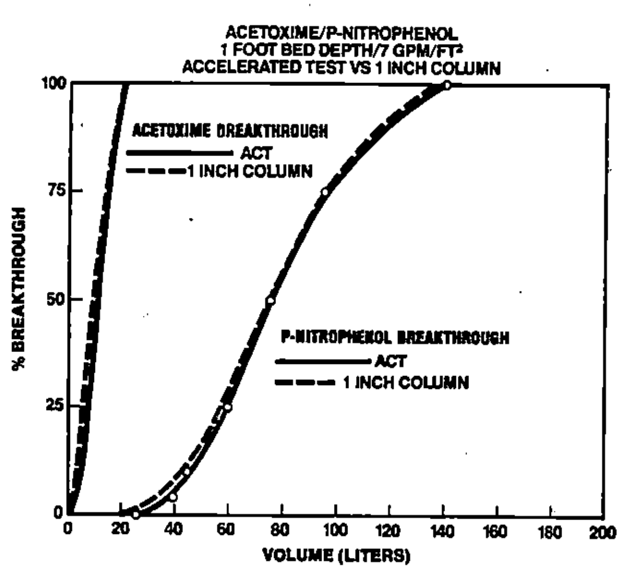


Figure 2 Multicomponent Adsorption

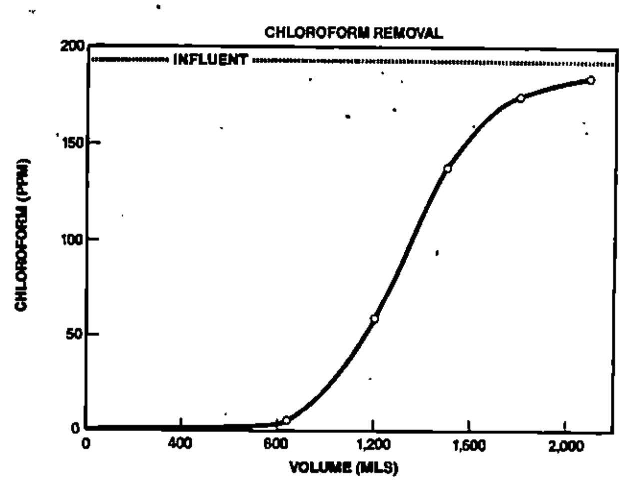


Figure 3 Accelerated Column Validation

- **Groundwater Purification**
  The Accelerated Column Test has been employed in a number of municipal and industrial groundwater purification applications, with consistent technical reliability. Many of these evaluation studies involved highly volatile components.

The test was applied to a complex groundwater problem involving multiple contaminants at an eastern manufacturing facility. Because of the cost-effectiveness of the test, Calgon was able to determine breakthrough curves for four different contaminants—benzene, methylene chloride, toluene and trichloroethane. In addition, the test made it possible to evaluate the performance of both virgin and thermally reactivated carbons in the removal of these contaminants.

Quick detection of the corresponding breakthrough patterns enabled Calgon to make technically-validated recommendations to the user regarding the redesign of the in-plant treatment system. The test simulated 60 days of operation, requiring only 8 days to complete.

Figure 4 shows breakthrough curves comparing the performance of virgin and thermally reactivated carbon for the removal of toluene.

Testing Requirements

In order to properly apply the Accelerated Column Test to your specific requirements, a Calgon carbon specialist works with you to identify the data and samples required.

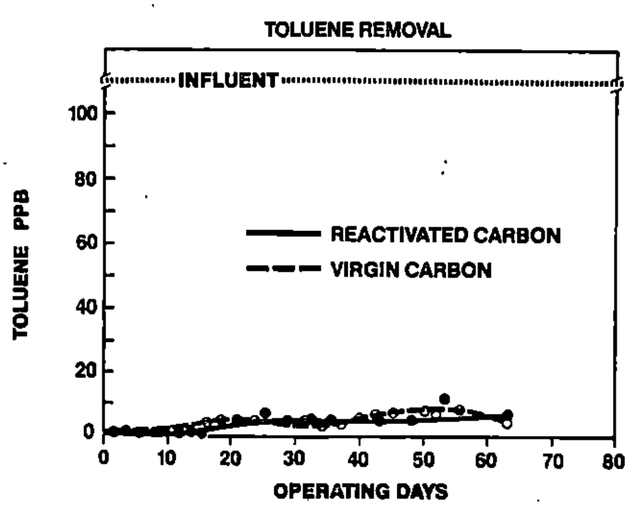


Figure 4 Accelerated Column Validation

Test Report Contents

Upon completion of an Accelerated Column Test, you receive a technical evaluation of the treatment situation. Where you so desire, the report can include such information as:

- **Analysis of sample**—If components in the sample are unknown, Calgon can perform required analytical tests prior to the column run to properly characterize the stream.
- **Analysis of column effluent**—A complete breakdown of remaining components, including their relative concentration levels subsequent to treatment, would also be documented.
- **Breakthrough curve**—Separate curves will be provided for each component of interest.
- **Carbon usage rate**—Including the estimated time the adsorber unit will be on-line before the carbon should be replaced.
- **Design recommendations**—Including suggestions for preliminary or supplemental treatment technologies, if required, plus general system design recommendations and suggested carbon type.

There is an Answer to Groundwater Contamination

by Robert P. O'Brien and J.L. Fisher

File No. 27-86

During the last few years much valuable experience has been gained in treating water containing organic contaminants with granular activated carbon.

There is an Answer to Groundwater Contamination

by Robert P. O'Brien and J.L. Fisher

With increasing regularity, many areas of the U.S. are finding the groundwater from which they draw their potable supplies are contaminated with potentially hazardous organic compounds. Industry, government and the public now recognize that haphazard and improper waste disposal practices in the past, chemical spills, and leachates from lagoons and dumpsites are major causes of groundwater contamination.

What is not so well known is that there is a proven technology which is being used more and more to treat and purify contaminated groundwater.

That technology is adsorption with granular activated carbon (GAC), and a significant amount of operating experience has now been obtained. Results from 31 operating plants that employ granular carbon to remove toxic organic compounds from groundwater supplies are now available in detail. These plants have been treating contaminated flows ranging from 5 to 2,250 gpm, and the knowledge gained from running these facilities promises to be valuable in implementing future groundwater strategies and treatment.

The causes of the groundwater contamination at the 31 different sites for which Calgon Carbon Corporation provided carbon adsorption equipment and adsorption technology were classified three ways: leachate from lagoons and dumpsites; industrial accidents and spills; and spills resulting from railroad or truck accidents. Industrial accidents accounted for 22 out of the 31 sources **(Table 1)**.

As these sources of contamination are different, so too are the reasons for groundwater treatment. The same table shows that in 15 of the 31 cases, carbon treatment was applied to prevent the spread of contamination throughout an aquifer. This was accomplished by drilling purge wells around the site of a spill or accident. These wells were pumped at a set rate to create a cone of depression and prevent further migration or spread of the organic contaminants. Granular carbon systems were used to treat water from the purge wells prior to discharge to a receiving stream, re-injection to the well field, or reuse.

A further twelve carbon systems were used for the purification of potable water, and the remaining four were operated for the decontamination of plant process water. Since the wells already existed in these situations, granular carbon systems, designed for pressure operation, were easily added to well discharge lines.

Data available from these treatment systems clearly show the ability of GAC to remove a wide range of organ-

Aquifer Contaminated By	Occurrences
Leachate from lagoons or dumpsites	4
Industrial accidents (chemical spills, tank leaks)	22
Chemical spills due to railroad or truck accidents	5
Total	31

Primary Reason for Treating Groundwater	Occurrences
Clean-up of aquifer (with purge wells) to prevent spread of contamination	15
Plant process water use	4
Potable use	12
Total	31

Organic Compounds in Groundwater	Number of Occurrences	Influent* Concentration Range	Carbon Effluent* Concentration Achieved
Carbon tetrachloride	4	130 ug/l-10 mg/l	<1 ug/l
Chloroform	5	20 ug/l-3.4 mg/l	<1 ug/l
Dibromochloropropane	1	2-5 mg/l	<1 ug/l
DDD	1	1 ug/l	<.05 ug/l
DDE	1	1 ug/l	<0.05 ug/l
DDT	1	4 ug/l	<0.05 ug/l
CIS-1,2-dichloroethylene	8	5 ug/l-4 mg/l	<1 ug/l
Dichloropentadiene	1	450 ug/l	<10 ug/l
Diisopropyl ether	2	20-34 ug/l	<1 ug/l
Tertiary methyl-butylether	1	33 ug/l	<5.0 ug/l
Diisopropyl methyl phosphonate	1	1,250 ug/l	<50 ug/l
1,3-dichloropropene	1	10 ug/l	<1 ug/l
Dichlorethyl ether	1	1.1 mg/l	<1 ug/l
Dichloroisopropylether	1	0.8 mg/l	<1 ug/l
Benzene	2	0.4-11 mg/l	<1 ug/l
Acetone	1	10-100 ug/l	<10 ug/l
Ethyl acrylate	1	200 mg/l	<1 mg/l
Trichlorotrifloroethane	1	6 mg/l	<10 ug/l
Methylene chloride	2	1-21 mg/l	<100 ug/l
Phenol	2	63 mg/l	<100 ug/l
Orthochlorophenol	1	100 mg/l	<1 mg/l
Tetrachloroethylene	10	5 ug/l-70 mg/l	<1 ug/l
Trichloroethylene	15	5 ug/l-16 mg/l	<1 ug/l
1, 1, 1-trichloroethane	6	60 ug/l-25 mg/l	<1 ug/l
Vinylidiene chloride	2	5 ug/l-4 mg/l	<1 ug/l
Toluene	1	5-7 mg/l	<10 ug/l
Xylenes	3	0.2-10 mg/l	<10 ug/l

**Analyses conducted by Calgon Carbon Corporation conformed to published U.S.EPA protocol methods. Tests in the field were conducted using available analytical methods.*

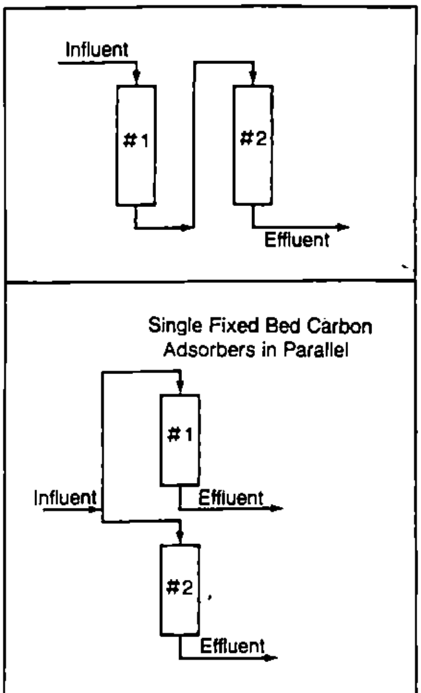
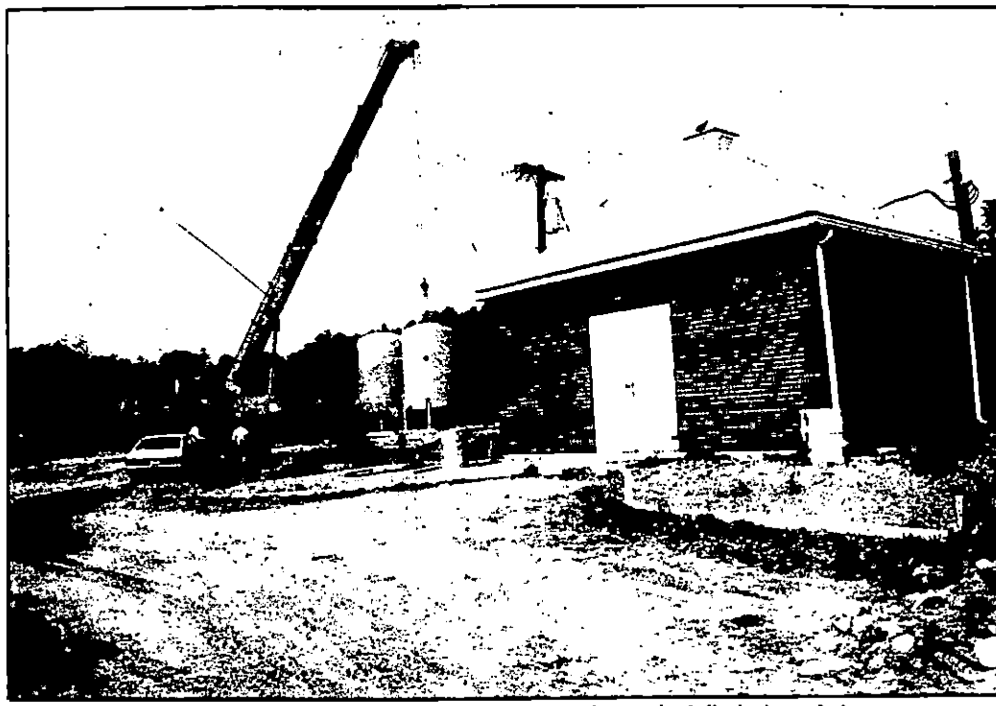


Figure 1. Carbon adsorbers in series operation (top); carbon adsorbers in parallel, single fixed bed operation (below).



GAC adsorbers destined to treat a municipal water supply are installed at an Acton, Massachusetts site, one of the 31 applications reviewed in this article.

ic compounds. **Table 2** (page 30) lists the organic compounds found in the groundwater supplies along with their influent and effluent concentrations before and after treatment. Even though the type and concentration of the organics varied from location to location, the GAC process consistently reduced them to levels below detectable limits. Thus, all 31 operating systems demonstrated that a properly designed granular carbon system can produce very high-quality water from a contaminated groundwater supply.

Trichloroethylene and tetrachloroethylene were the most frequently detected compounds at the treatment sites. They are used extensively in industry as metal degreasers, drying agents and extraction solvents.

A few of the aquifers had extremely high levels of contamination, with an organic total above 100 mg/l (parts per million, ppm). However, most groundwater applications call for the removal of contaminants with concentrations in the low mg/l or lower still in the ug/l (parts per billion, ppb) range. The ability of GAC to effectively remove low as well as high concentrations of organics is an important consideration.

Having designed and operated over 250 fixed bed units, in both series and parallel configuration, and over 150 moving bed units, our experience with both types of adsorption systems has demonstrated that a downflow fixed bed is more cost-effective than a pulsed bed for groundwater treatment. This is especially true in those applications where the carbon usage rate is nominal and the adsorption wavefront is short (e.g. 2 to 3 ft vs. 30 to 40 ft in some process applications). In fact, a properly designed fixed bed can operate with the same carbon usage rate as a pulsed bed, yet costs less to build.

Each adsorber at the treatment sites had a capacity of 20,000 lb, or a full truckload, of granular carbon. The size of the units allowed the carbon to be handled in bulk, which reduced freight. Each adsorber also contained a proven underdrain system comprising a pipe lateral network with nozzles.

Spent or exhausted carbon was always removed when organics were detected in the system effluent. Carbon removal was accomplished by using air pressure for automatic transfer out of an adsorber unit as a slurry. The slurry was piped to a waiting truck which returned the carbon to a reactivation center. The entire transfer procedure was accomplished in a closed system with no worker exposure to the carbon.

At 22 of the 31 sites, treatment of groundwater prior to carbon adsorption was not required. These contaminated groundwater supplies were stable and contained low concentrations of suspended solids which could be removed in the carbon bed without impeding adsorption or creating a high pressure drop. Thus pH adjustment, prefiltration or backwashing of the carbon adsorbers was not necessary. The hydraulic surface loading ranged from 0.25 to 9.6 gpm sq/ ft.

Seven of the locations employed multi-media filtration ahead of carbon adsorption as a safety factor because the quality of the contaminated water (as possibly affected by suspended solids) was not initially known. The hydraulic surface loading at these locations ranged from 1.0 to 4.5 gpm sq/ft.

At three sites, air stripping was used before carbon adsorption. The purpose of this was to reduce the levels of volatile organic contaminants and allow the carbon adsorption system to act as a final polishing unit.

Also, at six sites the treatment system design included backwashing of the adsorption beds. This feature was incorporated either due to high surface loading rates of 5.7 to 9.6 gpm sq/ft, or for solids removal in certain potable projects.

One of the most critical design parameters for any adsorption system is contact time. This is the length of time that the contaminated water is in intimate contact with the activated carbon. Increasing the depth of carbon for a fixed flow rate or decreasing the flow rate for a fixed depth of carbon both serve to increase contact time.

This important design parameter is generally expressed as *superficial contact time*, or the volume occupied by the activated carbon divided by the water flow rate. The *real contact time* is approximately one-half the superficial. Generally a superficial contact time of 7.5 min. is adequate for treating water that exhibits taste and odor problems. Longer times, however, are usually required as the types of organic compounds in groundwater increase in number and concentration, and approach the mg/l range.

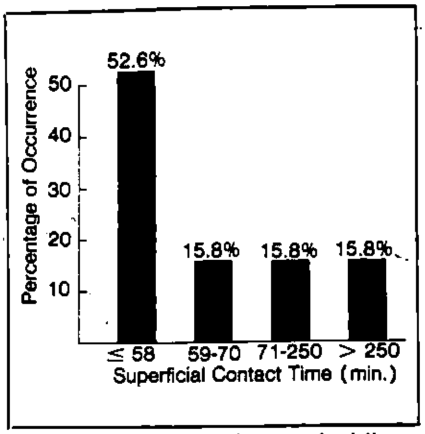


Figure 2. Range of carbon contact times for groundwater treatment projects (mg/l levels).

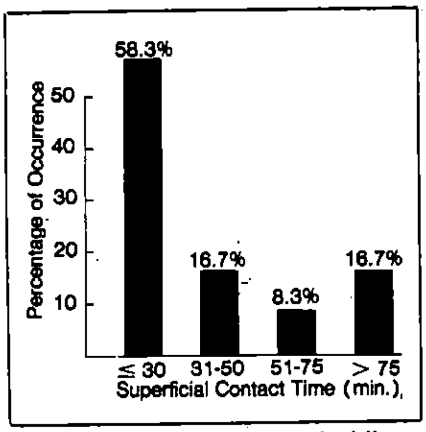


Figure 3. Range of carbon contact times for groundwater treatment projects (ug/l levels.)

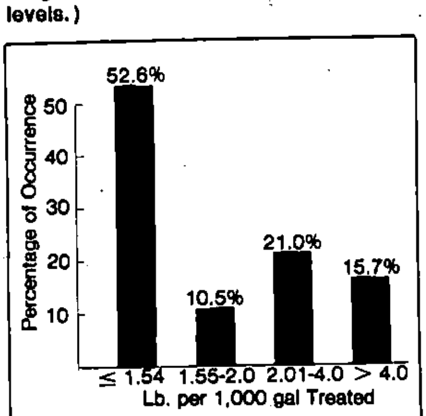


Figure 4. Range of carbon usage for groundwater treatment projects (mg/l levels).

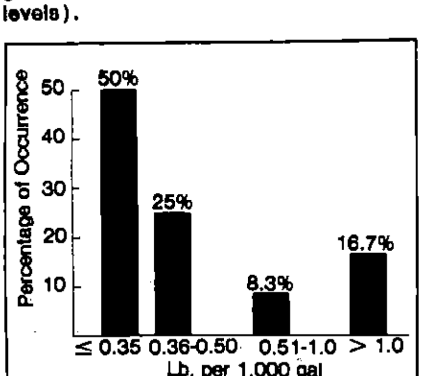


Figure 5. Range of carbon usage for groundwater treatment projects (ug/l levels.)

To improve carbon efficiency where longer contact times are required, two adsorbers are usually connected in series **(Fig. 1, page 33)**. When the effluent from the second, or polishing, bed begins to approach the desired objective, just the first, or lead, bed is removed from service. Removing only completely exhausted carbon in this manner assures maximum carbon efficiency. When placed back on-stream, the second bed becomes the lead and a fresh bed of carbon assumes the polishing position.

Operating conditions and results for those systems treating groundwater with organic contaminants at mg/l levels are displayed in **Table 3** (page 34). Of these 19 systems, 16 employed two or more beds in series. Successful treatment was accomplished with total superficial contact time as low as 16 min.

Similarly, **Table 4** (page 34) shows the results for those systems treating groundwater with organic contaminants at the ug/l levels. Of these 12 systems, four had two or more beds operated in series and eight had one or more beds in a parallel mode. Successful treatment was accomplished for these systems with total superficial contact time as low as 12 min.

Figures 2 and **3** depict the range of contact times used in the projects as a function of percent occurrence. **Fig. 2** reveals that almost 53 percent of the systems treating mg/l levels of contaminants employed a contact time equal to or less than 58 min. In the same manner, **Fig. 3** shows that over 58 percent of those processing ug/l levels of contaminants used a contact time equal to or less than 30 min.

Single fixed beds arranged in the parallel mode were installed at the majority of the sites where influent contamination was at ug/l levels, because of the lower contact time requirements. The single fixed bed design provided the advantages of a simple piping network, savings in capital dollars and short installation time. This latter advantage was very important in dealing with emergency situations.

Contact times listed in **Tables 3** and **4** were the actual times used at the sites, but they should not be construed as the optimum contact time for removing the particular organic compounds listed. In responding to emergencies such as spills, standard, readily available adsorption equipment was used. Response time and assured performance took precedence over the optimization of contact time in these situations. Thus the contact times used at some sites could have actually provided a substantial margin of safety. A minimum of 12-15 min. contact time is normally recommended for treatment of contaminated groundwater.

Virgin or reactivated carbon was used for all of these projects. Virgin carbon (Filtrasorb 300) was used on the 13 projects where the treated effluent was used for potable purposes. Reactivated carbon was used at the remaining 18 sites where the effluent was either discharged into a receiving stream or re-injected into the related well field.

Activated carbon for organic wastewater treatment can be used on a throw-away basis, reactivated on-site or transported for reactivation off-site. Use of carbon on a throw-away basis can be considered for potable water projects where carbon life is measured in years. On-site reactivation is common on permanent projects where the carbon requirements are large. Most of the carbon used at the 31 treatment sites under study was returned to the company's reactivation facilities. This approach provides both economical carbon reuse and the total destruction of the organic compounds adsorbed on the carbon.

As **Table 3** shows, the carbon consumption rates for the contaminant concentrations in the mg/l range varied from 0.45 lb of carbon per 1,000 gal to 13.3 lb of carbon per 1,000 gal. The contaminant concentration varied from 2.0 mg/l to 200 mg/l of organics.

Predictably, the carbon use rate was lower at those sites where the organic contaminants were at the ug/l levels **(Table 4)**. Carbon consumption varied from 0.1 lb of carbon per 1,000 gal to a high of 7.7 lb of carbon per 1,000 gal.

The range of carbon consumption rates as a function of percent occurrence are exhibited in **Figures 4** and **5**. The former shows that almost 53 percent of the systems handling mg/l levels of contaminants used less than 1.54 lb of virgin carbon for every 1,000 gal of treated water (the median carbon dosage). **Figure 5** indicates that 50 percent of those treating ug/l levels of contaminants used less than 0.35 lb of virgin carbon per 1,000 gal. of water.

Operating costs associated with granular activated carbon treatment is dependent on a number of factors. These include flow rates, concentration and type of organics, type of application (potable or other), site requirements, timing requirements, and length of the processing project. These factors together can define equipment, carbon and reactivation needs. Generalizations about costs can be difficult when comparing a variety of applications, but some observations can be made.

As expected, the operating cost for GAC treatment was lower in the case of those projects with lower average influent levels of contaminants. Treatment costs for the situations shown in

Table 3
Operating Results—Influent Contaminants at mg/l Levels

System No.	Source of Contaminants	Contaminants	Typical Influent Conc. (mg/l)	Typical Effluent Conc. (ug/l)	Flow per Train (gpm)	Surface Loading gpm/ft²	Total Contact Time (min.)	Carbon Usage Rate (lb. 1,000 gal.)	Carbon Type	Carbon System Pretreatment	Carbon System Back-Washable	Operating Mode	Disposition of Effluent
1	Truck spill	Methylene chloride 1,1,1-Trichloroethane	21 25	<1.0 <1.0	20	0.25	534	3.9	Reactivated	None	No	2 beds in series	Discharge to surface water
2	Rail car spill	Phenol Orthochloro-phenol	63 100	<1.0 <1.0	80	1.0	201	5.8	Reactivated	Filtration	No	3 beds in series	Discharge to surface water
3	Rail car spill	Phenol Vinylidine chloride	32-40 2-4	<10.0 <10.0	875 Ttl* 173	2.2	60	2.1	Reactivated	None	No	2 beds in series	Discharge to surface water
4	Rail car spill	Ethyl acrylate	200	<1.0	300 Ttl* 100	2.0	52	13.3	Reactivated	Filtration	No	3 beds in series	Discharge to surface water
5	Chemical spill	Chloroform Carbon tetrachloride Trichloroethylene Tetrachloroethylene	3.4 130-135 2-3 70	<1.0 <1.0 <1.0 <1.0	40	0.5	262	11.6	Reactivated	None	No	2 beds in series	Process water
6	Chemical spill	Chloroform Carbon tetrachloride Trichloroethylene Tetrachloroethylene	0.8 10.0 0.4 10-20	<1.0 <1.0 <1.0 <1.0	180	2.3	58	2.8	Reactivated	None	No	2 beds in series	Process water
7	On-site storage tanks	CIS-1,2-Dichloroethylene Trichloroethylene Tetrachloroethylene	0.5 1.0 7.0	<1.0 <1.0 <1.0	165	2.1	64	0.8	Virgin FS-300	None	@ installation only	2 beds in series	Process and potable use
8	On-site storage tanks	Methylene chloride 1,1,1,-Trichloroethane	1.5 3.3	<100 <1.0	20	0.25	526	4.0	Reactivated	None	No	2 beds in series	Discharge to surface water
9	Chemical spill	Dichloroethyl ether Dichloroisopropyl ether	1.1 0.8	<1.0 <1.0	2250 Ttl* 750	9.6	16	0.45	Reactivated	None	Yes	2 beds in series	Process and potable use
10	Chemical spill	Benzene Tetrachloroethylene	0.4 4.5	<1.0 <1.0	95	1.21	112	1.9	Reactivated	None	No	2 beds in series	Discharge to surface water
11	Landfill site	TOC Chloroform Carbon tetrachloride Etc., etc.	20 1.4 1.0 14.0	<5.0 mgl <1.0 <1.0 <1.0	20	1.6	41	1.15	Reactivated	Filtration	No	Dual mini in series	Discharge to surface water
12	Gasoline spill	Benzene Toluene Xylene	9-11 5-7 6-10	<100 Total	5	0.4	214	<1.01	Virgin FS-300	None	No	Dual mini in series	Discharge to surface water
13	On-site storage tanks	Trichloroethylene Xylene Isopropyl alcohol Acetone	3-8 .2-.5 .2 .1	<1.0 <1.0 <10.0 <10.0	30	2.4	36	1.54	Reactivated	None	No	Dual mini in series	Ground recharge
14	On-site storage tanks	1,1,1-Trichloroethane 1,2 Dichloroethylene Xylene	12 0.5 8.0	<5.0 <1.0 <1.0	200	2.5	52	1.0	V-R	None	No	2 beds in series	Discharge to sewer
15	Chemical spill	DBCP	2.5	<1.0	250	3.2	21	0.7-3.0	Virgin FS-300	Filtration	No	1 bed upflow	Ground recharge
16	On-site well storage tanks	CIS-1,2-Dichloroethylene Trichloroethylene Tetrachloroethylene	0.2 0.5 2.0	<1.0 <1.0 <1.0	150	1.91	70	0.75	Virgin FS-300	None	No	2 beds in series	Process and potable use
17	Chemical by-products	Di-Isopropyl methyl phosphonate Dichloropentadiene	1.25 0.45	<50 <10	175	2.2	30	0.7	Reactivated	Filtration	No	1 bed	Groundwater reinjection
18	Manufacturing residues	DDT TOC 1,3 Dichloropropene	0.004 9.0 0.01	<0.5 <1.0	160	2.0	31	1.1	Reactivated	Filtration	Yes	1 bed	Discharge to surface water
19	Chemical spill	1,1,1-Trichloroethane Carbon tetrachloride Trichlorotrifloroethane Tetrachloroethylene	0.42 0.464 5.977 5.800	<10 Each Comp.	200	2.5	53	1.5	Reactivated	None	No	2 beds in series	Discharge to surface water
	Median Levels						58	1.54					

his value represents total volume of liquid being treated with granular activated carbon at this site.

Table 4
Operating Results—Influent Contaminants at ug/l Levels

System No.	Source of Contaminants	Contaminants	Typical Influent Conc. (ug/l)	Typical Effluent Conc. (ug/l)	Flow per Train (gpm)	Surface Loading gpm/ft²	Total Contact Time (min.)	Carbon Usage Rate (lbs. 1,000 gal.)	Carbon Type	Carbon System Pretreatment	Carbon System Back-Washable	Operating Mode	Disposition of Effluent
1	Solvent spill	1,1,1-Trichloroethane Trichloroethylene Tetrachloroethylene	143 8.4 26	<1.0 <1.0 <1.0	350	4.5	15	0.40	Virgin FS-300	None	@ Installation only	1 bed	Potable use
2	Gasoline tank leakage	Methyl T-Butyl Ether Di-isopropyl Ether Trichloroethylene	30-35 30-40 50-60	<5.0 <1.0 <1.0	450	5.7	12	0.62	Virgin FS-300	None	Yes	2 beds in parallel	Potable use
3	On-site storage tanks	Chloroform Trichloroethylene	300-500 5-10	<100 <1.0	200	2.5	26	1.19	Virgin FS-300	None	@ Installation only	4 beds in parallel	Process and potable use
4	Rail car spill	Chloroform	20	<1.0	30	0.6	160	7.7	Reactivated	Air strip	No	1 bed	Discharge to surface water
5	On-site storage tanks	Trichloroethylene	30-250	<1.0	350	4.5	30	0.16	Virgin FS-300	Filtration air strip	No	2 beds in series	Potable use
6	Chemical solvents	Trichloroethylene Tetrachloroethylene	30-40 140-200	<1.0 <1.0	260	3.3	21	0.21	Virgin FS-300	None	Yes	3 beds in parallel	Potable use
7	Chemical landfill	1,1,1-Trichloroethane 1,1-Dichloroethylene	60-80 5-15	<1.0 <1.0	350	4.5	30	<0.45	Virgin FS-300	None	Yes	2 beds in series	Potable use
8	Gasoline tank leakage	Trichloroethylene Di-isopropyl Ether	40-50 20-30	<1.0 <1.0	450	5.7	12	0.10	Virgin FS-300	Air strip	Yes	2 beds in parallel	Potable use
9	Chemical solvents	Trichloroethylene CIS-1,2-Dichloroethylene	20-25 10-15	<1.0 <1.0	160	2.0	35	<0.32	Virgin FS-300	None	@ Installation only	1 bed	Potable use
10	On-site storage tanks	Trichloroethylene	50	<1.0	250	1.6	42	0.38	Virgin FS-300	None	No	2 beds in parallel	Potable use
11	Chemical spill	CIS-1,2-Dichloroethylene Trichloroethylene Tetrachloroethylene	5 5 10	<1.0 <1.0 <1.0	85	1.1	121	0.25	Virgin FS-300	None	No	2 beds in series	Potable use
12	Chemical spill	CIS-1,2-Dichloroethylene Trichloroethylene Tetrachloroethylene	5 5 10	<1.0 <1.0 <1.0	150	1.91	70	0.25	Virgin FS-300	None	No	2 beds in series	Potable use
	Median Levels						30	0.35					

Table 4 (ug/l influent) which were installed on a permanent basis range from approximately $0.22/1,000 gal to $0.55/1,000 gal. Operating costs of the facilities covered in **Table 3** (mg/l influent) and installed on a permanent basis ranged from $0.45/1,000 gal to $2.52/1,000 gal. **Figure 6** displays all of these costs in simple graphic form. The level of contamination was reduced to less than detectable levels in each project.

The cost figures listed for the 31 cases include allowances for all the necessary equipment installation costs, and the supply of granular carbon as required. Cost of treatment with granular carbon is well within the range of conventional treatment processes. Coupled with the fact that GAC can remove a wide range of toxic organics, this data helps show that the granular carbon approach is a cost-effective answer to the recovery and reuse of contaminated groundwater.

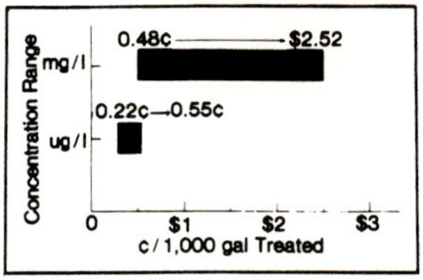


Figure 6. Granular carbon operating costs for groundwater treatment.

Based on these and other experiences in the treatment of industrial and municipal wastewaters with granular carbon, the following observations should be considered in the operation of a groundwater contaminant removal system.

- Some well water supplies could possibly have a high pH and be unstable with respect to the precipitation of calcium salts. pH adjustment of the water, or feeding of a scale inhibitor, may be necessary to prevent precipitation in the lines or carbon adsorbers.
- A monitoring program of the carbon system effluent needs to be established, with trace organic analyses performed on a scheduled basis in order to change the granular carbon at the optimum time.
- Chlorination should follow carbon treatment in those systems where the well water is being used for potable purposes.

In the future, the use of proper hazardous waste disposal techniques will help ensure the preservation of underground water resources. However, the operating results in these full-scale plants have demonstrated that granular activated carbon is an effective and efficient treatment process for removing organic compounds from groundwater supplies that have already become contaminated.

The 31 treatment systems studied and documented have shown that granular activated carbon treatment:

- Reduces a wide range of organic compounds to levels below their detection limits.
- Has been accomplished at remote locations without pre-filtration or backwashing of the carbon beds.
- Has been an effective adsorption process with total superficial contact times as low as 12 min.
- Has achieved carbon usage rates as low as 0.1 lb of carbon per 1,000 gal of water treated.
- Can provide a source of high-quality water at a total operating cost as low as $0.22/1,000 gal.

About the Authors
Robert P. O'Brien is manager of water quality engineering and J.L. Fisher is water quality engineer, both with the Calgon Carbon Corporation, Pittsburgh, PA. This article is an updated adaptation of a paper read to the Division of Environmental Chemistry, American Chemical Society in Atlanta, GA, March 29-April 3, 1981, by Robert P. O'Brien, David M. Jordan and Walter R. Musser, all of Calgon Corporation.

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