WORK PLAN FOR THE SECOND OPERABLE UNIT REMEDIAL INVESTIGATION AT THE SYOSSET LANDFILL, SYOSSET, NEW YORK

April 1991

Prepared for

Town of Oyster Bay

Prepared by

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Geraghty & Miller, Inc. appreciates the opportunity to work for the Town of Oyster Bay at the Syosset Landfill, Syosset, New York site. If you have any questions or comments concerning this report, please contact one of the individuals listed below.

Respectfully submitted,

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INTRODUCTION

This work plan follows the terms of the Remedial Investigation/Feasibility Study (RI/FS) work plan (Geraghty & Miller 1985a), approved by the USEPA as part of the Administrative Order signed with the Town of Oyster Bay on June 19, 1986, and the Site Operations Plan (SOP) also approved by the USEPA (Geraghty & Miller 1986a).

Geraghty & Miller's report, entitled "Interim Remedial Investigation Report Syosset Landfill, Syosset, New York," (dated August 1989) was approved by the U.S. Environmental Protection Agency (USEPA) in its February 23, 1990 letter to the Town of Oyster Bay Department of Public Works, the owner of the Syosset Landfill. In this letter, the USEPA determined that further work at the site would be conducted in two operable units: the First Operable Unit and the Second Operable Unit. The First Operable Unit concerns on-site conditions and the Second Operable Unit concerns off-site conditions.

The USEPA issuance of the Record of Decision (ROD) for the site, dated September 27, 1990, marks the completion and approval of the RI/FS for the First Operable Unit. The First Operable Unit has therefore entered the remedial design phase and the Second Operable Unit RI will begin upon USEPA approval of this work plan. The First Operable Unit Remedial Investigation Report (Interim RI Report) concluded that landfill impacts to ground-water quality have resulted in a plume of leachate which may extend off-site; this conclusion is based on the contaminant profile defined by the on-site shallow and deep monitoring wells and forms the basis for this work plan. In addition, the First Operable Unit RI report indicated the need for an off-site subsurface gas study in the southwestern portion of the site, where elevated concentrations of landfill gases were detected during the First

Operable Unit RI. This work plan constitutes the Second Operable Unit RI Work Plan for conducting an off-site ground-water study and an off-site subsurface gas study that will provide the necessary data for the Second Operable Unit Feasibility Study (FS).

REMEDIAL INVESTIGATION

1.0 SCOPING

1.1 Previous Studies

The First Operable Unit RI was preceded by several studies, including investigations of landfill gas migration, an assessment of ground-water contamination, and the design of a site closure plan. These studies were reviewed by Geraghty & Miller and were used to develop the On-Site RI/FS Work Plan (Geraghty & Miller 1985a). The First Operable Unit RI was carried out to fill data gaps remaining from previous investigations and was divided into three distinct studies: On-Site Ground-Water Study, Landfill Dimension Study, and Subsurface Gas Study (on-site). The First Operable Unit RI Report contained specific conclusions regarding the following issues:

- Ground-water flow direction (horizontal and vertical).
- Ground-water quality.
- Landfill dimensions, including its areal extent and thickness.
- Characterization of fill material.
- The nature and extent of landfill gas.

1.2 Off-Site Ground-Water Study

An Off-Site Ground-Water Study will be carried out to determine the nature and extent of contamination attributable to the landfill. During this investigation, the fate and transport of the contaminants and the rate of contaminant migration will be determined. Historical water-quality data, and data from water samples that will be collected and analyzed from off-site public water supply wells and Nassau County observation wells, will be used to determine the background water quality (see Section 2.1.2). Cluster Wells SY-6 and SY-6D will serve as the upgradient shallow and intermediate depth wells for the investigation because these wells are optimally located with respect to the landfill, adjoining property and the regional ground-water divide. In addition, a deep upgradient monitoring well will be installed in the vicinity of Wells SY-6 and SY-6D. These wells are located about 200 feet from the edge (upgradient) of the landfill (see Figure 13 in the Interim [OU-1] RI report) and at the southwestern property boundary with Cerro Wire Company property. In addition, it was determined during the Interim (OU-1) RI that these wells were minimally impacted from the landfill (Geraghty & Miller 1989). It is unlikely to have a better location for monitoring wells upgradient of the site because of the proximity of the regional ground-water divide. Potential impacts to public supply wells in the vicinity will be addressed in addition to the possible relationship between the landfill and water-quality degradation observed in public supply well N4133 before it was abandoned in 1980 and sealed in 1982. The primary reason why the Jericho Water District closed Well N-4133 was due to "taste and odor" problems. Although the concentrations of certain monitoring parameters had increased in Well N-4133, no drinking water standard was ever exceeded.

1.3 Off-Site Subsurface Gas Study

The Off-Site Subsurface Gas Study will be conducted to determine the extent of off-site subsurface gas migration from the southwestern portion of the landfill where elevated concentrations of methane were detected during the First Operable Unit RI. New wells will be installed and monitored for methane, total volatile organic compounds (TVOCs), and individual volatile organic compounds (VOCs).

1.4 Baseline Risk Assessment

Data collected during the Second Operable Unit RI will be utilized to identify the potential exposure pathways and baseline risks from contaminants that may be emanating from the site.

2.0 SAMPLING PLAN

2.1 Off-Site Ground-Water Study

The purpose of the Off-Site Ground-Water Study is to determine the off-site extent of ground-water contamination and to confirm the direction (horizontal and vertical) of ground-water flow. The methodology of the Off-Site Ground-Water Study will be to advance two cased exploratory borings at the selected drilling locations (Figure 1) and obtain ground-water samples at regular and frequent depth intervals for field analysis of landfill leachate indicator parameters (see Section 2.1.8). In this manner, the areal and vertical extent of the plume of landfill leachate-impacted ground water will be determined both on-site and off-site. This method was highly successful in the determination of an off-site plume at the Old Bethpage Landfill site (Geraghty & Miller 1985b; 1986b). After the bottom of the plume has been determined, geophysical logging will be conducted. The geophysical log will be combined with the geologic information and the water-quality data generated during the drilling of the borings to compile a vertical profile of the plume and subsurface lithology. This profile will be used to select screen settings for the proposed monitoring wells. The on-site exploratory boring will be drilled as the deep well to form a cluster with existing Wells SY-3 and SY-3D. Three wells will be installed at the off-site exploratory boring location (shallow, intermediate, and deep) and an appropriate number of wells will be installed at the two remaining drilling locations flanking the off-site exploratory drilling site to the east and west. It is anticipated that either 3 or 4 monitoring wells will be installed at the two drilling sites flanking the off-site exploratory drilling location. The exact number of monitoring wells will be determined by technical representatives of the Town of Oyster Bay in consultation with technical representatives of the USEPA. This determination will be based on the plume geometry at the off-site exploratory boring location and the lithologic profile determined from geophysical logging at the 2 flanking drilling sites. In addition, a third upgradient monitoring well will be installed as a deep well in the vicinity of existing Cluster Wells SY-6 and SY-6D. This well will be screened at a depth similar to the deep downgradient monitoring wells so that a comparison of the water quality from the same zone can be made.

After the extent of the plume has been determined and monitoring well clusters installed, water levels will be measured, and water-quality samples will be collected and analyzed for the list of analytical parameters given in Appendix A.

2.1.1 Selection of Boring Locations

The locations of the proposed three off-site borings/monitoring wells and the locations of the on-site upgradient boring/monitoring well and exploratory boring are shown on Figure 1. If additional wells are deemed necessary, then additional borings may be drilled, based on the data collected from the exploratory borings and after consultation with technical representatives of the USEPA and the Town of Oyster Bay. The on-site exploratory boring will be drilled next to existing on-site cluster wells SY-3 and SY-3D to determine the bottom of the plume at the property boundary (see Section 2.1). The locations of the three off-site well clusters were selected using the following criteria:

- Ground-water flow directions and velocities determined from the results of the On-Site Ground-Water Study and reported by other investigators (e.g., the U.S. Geological Survey). The results of the Interim (OU-1) RI report show that the site-specific and regional direction of ground-water flow in the shallow zone (115 to 153 feet) of the Magothy aquifer was northeasterly (Geraghty & Miller 1989). In the deeper zone of the Magothy aquifer (182 to 200 feet), the direction of ground-water flow was northerly. The ground-water flow velocities for the Magothy aquifer in the horizontal and vertical directions are summarized in Table 1. The horizontal ground-water flow velocity was calculated from the hydraulic gradient (I_h) determined during the Interim RI (see Table 6 of the Interim RI report) and using published values for hydraulic conductivity (K_h) and porosity (n) (McClymonds & Franke 1972). However, although there are data for the vertical hydraulic gradient (I_v) from the on-site RI, published values for the vertical hydraulic conductivity (K_v) are highly variable and rarely determined. Therefore, a published value for the vertical ground-water flow velocity (V_v) is used in Table 1 (Franke & Cohen 1972). This value of V_v represents a general value of V_v in the vicinity of the regional ground-water divide and was developed by the USGS from regional modeling studies conducted on Long Island.

- Age of the landfill. The length of time since landfilling began at the site (approximately 58 years) was used to calculate the vertical and horizontal distances that contaminated ground-water emanating from the landfill could have theoretically moved, based on ground-water flow velocities (see Table 1).

- Size of the landfill. The relationship of the landfill dimensions to the ground-water flow direction was examined to determine the spatial distribution of the proposed off-site well cluster locations.

- Accessibility. Preference for property owned or controlled by the Town of Oyster Bay, Nassau County, or the State of New York.

Two of the three proposed off-site monitoring well clusters are located on public land; the eastern most location is proposed inside Nassau County Recharge Basin No. 218 and the middle location is within a park owned by the Town of Oyster Bay. The third, or westernmost location is on private property. In all three cases, work easements will have to be obtained before drilling at these sites can proceed.

Based on a study conducted by the USGS and the Long Island Regional Planning Board, the impact on ground water from storm-water infiltration through the recharge basin is likely to be minimal (Long Island Regional Planning Board 1982). The results of this study indicated that the potential contaminants from storm-water runoff to the ground water are chloride, nitrogen, lead and chromium, with lead and chromium being attenuated during infiltration through the unsaturated zone. An evaluation of the analytical results of water samples collected during the OU-2 RI should provide determination as to whether the recharge basin and/or the landfill has impacted ground-water quality (see Section 2.1.8). There were no mounding affects observed from the recharge basins adjacent to the landfill during the OU-1 RI (Geraghty & Miller 1989). Therefore, ground-water flow directions were apparently not impacted.

Drilling will begin with the proposed on-site exploratory boring located next to Wells SY-3 and SY-3D. In this way, the plume thickness can be determined on-site, thereby providing a conception of the potential plume geometry off-site. The next drilling location for the other proposed exploratory boring will be located directly downgradient on the Town of Oyster Bay property (town park). The third drilling site will be at the Nassau County Recharge Basin and the fourth drilling site will be on the privately owned property near the Long Island Railroad. The fifth and final drilling site will be the deep on-site, upgradient monitoring well which will be installed in the vicinity of existing upgradient Monitoring Wells SY-6 and SY-6D.

2.1.2 Termination of Exploratory Borings

The two exploratory borings will be terminated when it is demonstrated that the bottom of the plume has been reached based on a comparison of the water-quality data from the boring with ambient water quality. Action levels, derived from historical and recent ambient ground-water quality data (see discussion below), will be established and the boring will be terminated when the concentrations of primary leachate indicators in two consecutive samples are lower than their respective action levels (see Section 2.1.8). Previous studies (e.g., Old Bethpage Landfill) have shown that some problems can arise in the termination demonstration. For example, one primary indicator parameter may remain slightly above its action level in consecutive samples while the other parameters indicate that the bottom of the plume has been reached. In a case such as this, secondary leachate indicators will be employed for the termination demonstration. However, in the event that the Raritan Clay is encountered before the termination criteria are met, the exploratory boring will be terminated and the deep well will be set on top of the clay. The Raritan Clay is a regional aquitard, approximately 160 feet thick located approximately 630 feet below land surface at the site (McClymonds and Franke 1972). Because of the thickness and low permeability of the Raritan Clay, the underlying Lloyd aquifer is not considered to be a migration pathway for contaminants (leachate) from the Syosset Landfill. Assuming that contamination is found at the Raritan/Magothy interface, the flow direction of the contaminated ground water will change from predominantly vertical (downward) to predominantly horizontal (northerly). This is because the permeability is substantially greater in the horizontal direction (Magothy) than the vertical direction (Raritan Clay), thereby providing less resistance and, consequently, an easier flow path.

If action levels are not exceeded by a depth of approximately 450 feet below land surface, the off-site exploratory boring will be terminated. This depth was selected because in the 58 years since landfilling began the resultant leachate would have traveled approximately 450 feet downward discounting attenuation and retardation factors (see Table 1). Geraghty & Miller, in consultation with representatives of the USEPA and the Town of Oyster Bay will decide whether a well(s) should be installed at the exploratory drilling location if leachate is not detected as described above.

Action levels for the termination demonstration will be established in the following manner:

1. Historical water-quality data (for the leachate indicator parameters, see Section 2.1.8) from Nassau County monitoring wells and public supply wells (less than 500 feet in depth), located within a 1-mile radius of the site, will be compiled to determine ambient water quality (see Figure 10, Interim RI Report).

2. One round of water-quality samples will be collected from these wells, if they are accessible. Samples will be analyzed for the leachate indicator parameters by field testing methods and also by a USEPA-approved laboratory.

3. The average concentration and the standard deviation for each leachate indicator parameter will be calculated using all the data from all the wells (i.e., historical data and recently collected data). The resulting action level for each leachate indicator parameter will then be defined as the average concentration plus two standard deviations.

2.1.3 Drilling Methodology

Three drilling techniques will be employed during the Off-Site Ground-Water Study: (1) the cased boring method (air rotary), (2) the mud rotary method (modified) and 3) the hollow-stem auger method. The cased boring method (air rotary) will be used for drilling the two exploratory borings (one on-site and one off-site) and installing a deep well at these locations, while the mud rotary method (modified) will be used to drill and install the remaining wells except the shallow wells which will be installed by the hollow-stem method. The reasons for the selection of these drilling methods are outlined in Sections 2.1.3.1, 2.1.3.2, and 2.1.3.3.

2.1.3.1 Exploratory Cased Borings (Deep)

The purpose of the exploratory borings will be to provide vertical characterization of the water quality (plume thickness) and lithology. These borings will be drilled by the cased-boring (air rotary) method to allow for the collection of representative water-quality and formation samples. Based on the results of the First Operable Unit RI, it is anticipated that these borings may have to be advanced to a maximum depth of up to 600 feet below the ground surface to identify the vertical extent of the potential off-site plume. The available drilling methods for installing wells to these depths while also providing accurate water-quality data are the cable tool and cased boring (air rotary) methods. Currently, two other drilling methods, reverse rotary and mud rotary, are also available for drilling to the anticipated depths; however, both methods rely on the introduction of drilling fluids (mud or water) to the formation, which would require intensive and time-consuming development to remove the drilling fluid to ensure the collection of representative water samples at each 20-foot interval. Therefore, these methods were eliminated from further consideration for the two water-quality exploratory borings. The advantages and disadvantages for the cable tool and cased boring drilling methods are described below.

Cable Tool. The cable tool method advances a boring in unconsolidated formations by driving steel casing to a desired depth. The "cuttings" or formation material must be removed from the casing by bailing at regular intervals so the casing can continue to be advanced. The addition of some water is required to facilitate bailing in unsaturated formations. The advantages of using the cable tool method include the following: representative water and formation samples can be collected at the desired depths; the boring is stabilized during the drilling process; and drilling fluid is not introduced into the formation (except when some water is added to facilitate the removal of cuttings in the unsaturated zone).

The primary disadvantage of the cable tool method, however, is the slow drilling rate, and the anticipated depth of the borings (approximately 600 feet) approaches the normal limits of this method. It will take up to five times longer to install a well using the cable tool method compared to other drilling methods (e.g., cased boring). Two other disadvantages of the cable tool method are that the method is noisy (drilling will be conducted in a residential area) and the casing can potentially break during removal, especially in the deep exploratory borings. This latter problem occurred during the Old Bethpage Landfill investigation, which resulted in casing sections being left in the ground (Geraghty & Miller 1985b).

Cased Boring. The cased boring method (air rotary) will be employed using a Barber™ rig, which advances the boring by hydraulically rotating the steel casing into the ground while simultaneously drilling with a roller bit. Cuttings are continuously removed from the casing by forcing compressed air through the drilling rods. Small volumes of water are used for controlling dust while drilling through the unsaturated zone. The advantages of using the cased boring method include the following: representative water and formation samples can be collected at the desired depths; the boring is stabilized during the drilling process; negligible amounts of drilling fluid are introduced into the formation; and drilling is accomplished in a relatively timely manner.

Thus, although both the cable tool and cased boring methods would provide the data required for the exploratory boring program (i.e., establish the on-site and off-site vertical water-quality profile and determine the lithology), the cased boring method is more appropriate because it will result in a more timely and cost-effective investigation.

2.1.3.2 Mud Rotary (Modified) Cluster Borings (Intermediate and Deep)

As discussed previously, two of the three off-site drilling locations will include cluster wells without an exploratory cased boring. The depths and numbers of these cluster wells will be determined based on the water-quality profile established from the two exploratory borings. Geraghty & Miller, in consultation with representatives of the USEPA and the Town of Oyster Bay, will make this determination. In addition to the two off-site cluster locations, a shallow and an intermediate well will be clustered with the off-site exploratory drilling location and a deep upgradient well will be installed on-site in the vicinity of existing Cluster Wells SY-6 and SY-6D. Formation samples will be collected only from the deepest boring at these two cluster sites and from the deep upgradient boring. The methods available for drilling these borings are: auger, cable tool, cased boring (air rotary), reverse rotary mud rotary and modified mud rotary. The advantages and disadvantages of each method are discussed below.

Auger. The auger method is used to drill shallow monitoring wells and this method rarely can drill beyond 130 feet. Because the depth of the intermediate and deep borings are expected to be well below 200 feet, the auger method will not be considered further.

Cased Boring (Air Rotary). As previously explained (Section 2.1.3.1), the cased boring method advances casing while simultaneously drilling and removes cuttings by blowing compressed air through the drilling rods. The advantages of using this method are that it is rapid, it provides for borehole stability, and negligible amounts of drilling fluid (water) are introduced to the formation. Since sampling is not required for the shallow and intermediate borings, the advantage of collecting representative samples using the cased boring method no longer applies. The disadvantage of using the cased boring method is that it is relatively expensive. In addition, only one exploratory or cluster well at a time would likely be installed because of the scarcity of Barber™ rigs. Thus, the time required to install the wells would be at a maximum.

Cable Tool. The cable tool drilling method was described previously in Section 2.1.3.1. The same advantages that were described above for the cased boring method also apply to the cable tool method. In addition, for the shallow borings, it is relatively inexpensive. The disadvantages of using the cable tool method are that it is noisy and would take several times longer to drill wells than any of the other methods described in this section. The cable tool drilling method is considered inappropriate because the off-site drilling program will be conducted in a residential area where the drilling time and noise should be minimized.

Reverse Rotary. The reverse rotary drilling method uses water as a drilling fluid. This water flows down the annular space between the drilling pipe and the boring wall and is then pumped up the drill rod carrying cuttings into a pit at the surface. The boring is stabilized by completely filling the annular space with water up to land surface. The advantage of the reverse rotary method is the rapid drilling rate. One of the disadvantages of this method is that a large volume of drilling fluid (water) is introduced into the formation and must be removed by intensive well development. This method is also relatively expensive.

Mud Rotary. The mud rotary method uses a roller bit that loosens formation material (cuttings) for removal. The cuttings are removed by a drilling fluid that is composed of water mixed with a mud slurry that is 100 percent bentonite clay and contains no additives. The viscosity of the drilling fluid (mud) can be varied in response to formation changes. The mud rotary method is a direct rotary drilling method whereby drilling fluid is pumped down the drill pipe and forced up through the annular space between the drill pipe and borehole wall to the land surface. The advantages of using the mud rotary method are that it is quiet, it proceeds at a rapid rate, and it is relatively inexpensive. The only disadvantage is that a drilling fluid is introduced to the formation in the vicinity of the screen zone. Although this mud can be removed from the formation (i.e, near the screen zone), it will require intensive well development.

Modified Mud Rotary. The proposed modified mud rotary method consists of drilling each well boring to within 20 feet of the screen zone by employing the conventional mud rotary method using a Failing F-10 drilling rig. For the mud rotary drilling method, the drilling fluid (mud) will be pumped down the drilling rods and forced up the well annulus and out of the boring. The final 30 feet of each boring will be drilled by the reverse rotary method. For the reverse rotary drilling method, the drilling fluid (water) is pumped up the drilling rods to the land surface and recirculated into the borehole through the well annulus. The same drilling rig (Failing F-10) for both drilling methods (mud rotary and reverse rotary), or a conventional reverse rotary (Failing Reverse Rotary/Mud Rotary Rig - trailer mounted) drilling rig may be used to complete each well boring. The transition in drilling techniques will be accomplished in the following manner: After drilling to depth using the mud rotary method, the swivel on the drilling head will be changed; it is estimated that this will take approximately one-half day to complete. Then the mud will be flushed out of the boring by pumping fresh potable water through the drilling rods to force the mud out of the well annulus. The drilling mud will be pumped into a tanker truck and will be hauled away for proper disposal at a NYSDEC - approved facility. As soon as the mud is removed, the reverse rotary method will be employed. A one-inch diameter air line will be inserted inside the three-inch diameter drilling rods. Compressed air pumped through the air line will force the water (drilling fluid) out of the drilling rods and induce water from the well annulus to flow back up into the drilling rods constantly replacing the water removed through the drilling rods and out of the boring. Although a residual mud cake will remain on the borehole wall in the depth interval drilled using mud, there will still be some fluid or water loss to the aquifer. Thus, it will be necessary to add potable water to the well annulus to supplement the water being recirculated into the boring. Formation samples will be collected at 20-foot intervals for the entire depth of the two deep off-site well borings flanking the off-site exploratory boring and the on-site deep upgradient well. There should not be a problem in preventing the borehole from collapsing as long as a head of water or other drilling fluid is maintained in the borehole. Therefore, permanent casing in the borehole is not necessary except for the upper 100 feet of the formation (see Section 2.1.6.2).

The proposed modified mud-rotary drilling method has all the advantages of the mud rotary drilling method and drilling mud is not introduced into the formation in the vicinity of the screen zone. Thus, the need for intensive well development is eliminated. The disadvantages of using the modified mud rotary drilling method is that some water will be introduced into the screen zone of the formation during the reverse rotary drilling phase. However, only a minimum of water is expected to be lost and this will be easily removed during the course of well development.

The vertical profiles of lithology and water quality (as defined by field testing for leachate indicators) needed to select screen zones will have been obtained previously. Because formation samples and ground-water samples will not be collected from the modified mud-rotary borings during drilling (except for the three deepest of these borings where only formation samples will be collected), these boreholes can be advanced at a faster rate and will provide for a more timely investigation. This is in keeping with the spirit of RI/FS Guidance Documents "to conduct an efficient and effective RI/FS that achieves high quality results in a timely and cost-effective manner (U.S. Environmental Protection Agency 1988)."

This evaluation of the methods available to drill the borings at the two cluster locations, the deep upgradient boring, and the intermediate borings to be clustered with the off-site exploratory boring, indicates that the modified mud rotary method is most appropriate. This method can be used in a timely and cost-effective manner and it should eliminate any uncertainties associated with the introduction of drilling fluid in the vicinity of the screen zones.

2.1.3.3 Hollow-Stem Auger Boring

The hollow-stem auger method will be employed for drilling/installing the shallow monitoring wells only, provided that the total depth of these wells, as determined by the water-quality profile from the off-site exploratory boring, does not exceed the depth limits of the method (approximately 165 feet ± 20 feet). This limit applies to the Failing F-10 drilling rig, which has considerably more torque than conventional auger rigs used on Long Island. If the screen zones for the shallow wells are determined to be below 170 feet, then the modified mud rotary method will be used to install these wells as described above. The size of the auger flights will be 6 3/4-inch inside diameter and 10 1/2-inch outside diameter. The hollow-stem auger method was selected for drilling/installing the shallow monitoring wells because no drilling fluids are introduced to the formation and this method is the least disturbing to the formation.

2.1.4 Sampling

During the drilling of the on-site and off-site exploratory borings by the cased boring method, ground-water samples will be collected at 20-foot intervals until the boring is terminated (see Section 2.1.2). This sampling interval was selected to minimize the delays resulting from sand heaving while also providing sufficient data to accurately characterize subsurface water quality. Composite formation samples will be collected on a continuous basis and in conjunction with the geophysical logs (see Section 2.1.5) will provide for an excellent lithologic profile at the two exploratory boring locations.

Sand heaving has been a major problem encountered during a recently completed investigation on Long Island (Islip Landfill) in a similar hydrogeologic setting. However, to expedite formation sampling and minimize the potential for sand heaving, formation samples will not be collected using split spoons through the drill rods, but rather, from the cyclone discharge. The cyclone is a device that reduces the pressure of cuttings traveling up the boring to a gravity feed and permits sample collection at ground surface. Ground-water samples, however, will be collected through the drilling rods with a bailer at each 20-foot sampling interval. Both formation and ground-water samples will represent the sampling depth because the rest of the boring will be cased off: the only pathway for formation material or ground water to enter the casing or drilling rods is from the bottom of the boring. Therefore, cross-contamination of formation material or ground water from different levels is not possible.

2.1.5 Geophysical Logging

Geophysical logging will be performed using the gamma method in the deepest boring at each of the four drilling locations. Electric logging will also be carried out in the deep mud rotary borings but will not be possible in the exploratory borings because of interference from the steel casing. Interpretation of the gamma and electric logs in conjunction with the geologic log from each borehole will be carried out to define the subsurface lithology at each drilling site and will also provide a better understanding of vertical head relationships and overall hydrogeology of the system. This information and the water-quality data obtained during the cased drilling process will be used to determine optimal screen settings for the wells in each cluster.

2.1.6 Well Construction

The monitoring wells to be installed in the cased borings, modified mud-rotary borings and hollow-stem auger borings will be constructed of the same materials and follow the same protocols as the wells installed during the On-Site Ground-Water Study.

PVC casing was selected for use over stainless steel or Teflon™ during the Second Operable Unit RI because ground-water quality monitoring at the Syosset Landfill includes analysis for both organic and inorganic compounds, particularly metals, and PVC has been shown to be the best choice under such conditions (Parker et al, 1990). In that study, Teflon™ casing exhibited appreciable sorption of organic compounds and stainless steel exhibited leaching of certain metals. Although both Teflon™ and stainless steel ranked high in some tests, PVC ranked well in all tests and was judged best for situations where both organic and inorganic contaminants were present. A copy of this paper is given in Appendix B. Stainless steel screens will be used, however, in place of PVC because it will allow for better well development in removing fine-grained formation material and residual drilling muds. Since only 10 feet of screen will be used in each well, not much surface area is available for contact with the ground water and impacts discussed above in using stainless steel as screen are thus minimized.

In addition to being a superior well casing material for overall ground-water quality monitoring, PVC is also less expensive and easier to handle during installation than stainless steel or Teflon™. PVC screen and casing were used at the Old Bethpage Landfill in 1984; no problems attributable to the screen or casing have been experienced to date. Given that permanent pumps are to be installed in the proposed wells (similar to the Old Bethpage Landfill program) and that the wells will be properly protected at land surface with an outer steel casing, durability should not be a concern.

Each well will be constructed with threaded, flush-joint, 4-inch diameter, Schedule 40 PVC casing and stainless well screen (0.010 inch openings). The wells will be installed with gravel pack (No. 1 J. Morie Co. sand) placed around the well screen from the bottom of the boring to 3 to 6 feet above the top of the screen. The well screen (0.010-inch openings) and No. 1 sand were selected because experience in countless projects on Long Island has shown this combination to be the most effective for monitoring wells installed in the Magothy Formation. If field conditions show that the formational material is different from what is anticipated, then an appropriate screen and sand size will be selected based on the grain-size distribution of the interval of formation to be screened. A bentonite seal will be emplaced above the gravel pack. The remaining annular space will be pressure-grouted to land surface (bentonite slurry or cement-bentonite grout). The grout will act as a seal and prevent contaminants from migrating vertically in the borehole. To protect against vandalism, all wells will be capped and completed with either locking flush-mounted curb box assemblies or aboveground, locking steel protective casings depending on location or other factors. Well construction details for wells installed in the cased borings and wells installed in the mud rotary borings will be slightly different; the differences are described below.

2.1.6.1 Monitoring Wells Installed in Cased Borings

The construction details of the monitoring wells to be installed in the cased borings are depicted on Figure 2A. Temporary 14-inch diameter surface casing will be installed to the water table (approximately 100 feet below land surface) to reduce the surface friction on the 10-inch diameter inside casing, which will be installed to a depth where excessive resistance is encountered based on field conditions which will likely vary from boring to boring. At this point, an 8-inch diameter casing will be used to complete the boring. After the 8-inch diameter casing has been advanced to its full depth, the 4-inch diameter screen and casing will be set inside the 8-inch casing and the gravel pack and bentonite seal will be emplaced as the 8-inch diameter casing is pulled back to the water table and left for the final well construction. The annulus between the 8-inch casing and the 4-inch well casing will be grouted to within 2 to 4 feet of ground surface and given adequate time to set (if cement-bentonite grout is used). Then the 10-inch diameter casing will be removed. The annulus between the 8-inch and 14-inch diameter casings will then be grouted to ground surface as the 14-inch diameter casing is being removed. Grouting will be done in two stages to avoid potential damage from the heat generated when the grout cures. This heat, or heat of hydration, is proportionally more intense as the diameter of the boring increases. Thus, the heat of hydration will be less if concentric layers of the boring are grouted separately. The 14-inch casing will be left in the ground if there is an excessive loss of grout to the formation as the casing is being removed.

If the 8-inch diameter casing becomes too difficult to advance before the termination criteria are met (see Section 2.1.2), 6-inch diameter casing will be used to complete the boring to the termination depth. However, since the deep well will be a 4-inch diameter well, it cannot be properly constructed inside a 6-inch diameter casing when adding gravel pack material and a bentonite seal. Therefore, the deep monitoring well will not be installed in the exploratory boring. Instead, the intermediate depth monitoring well, which will also be constructed of 4-inch diameter casing (PVC) and screen (stainless steel), will be installed in this boring since the screen for the well will most likely be set at a depth above the bottom of the 8-inch casing. In this case, cement-bentonite grout will be pumped through a tremie pipe from the bottom of the borehole to between 5 and 10 feet of the bottom of the selected screen setting for the intermediate depth well. The 6-inch diameter casing will be pulled back during the grouting process and well construction will continue in the prescribed fashion (see discussion above). Because the vertical profile of the water quality and lithology would have already been obtained from the exploratory boring where the intermediate well would be installed, the deep monitoring well will be drilled and installed by the mud rotary method.

2.1.6.2 Monitoring Wells Installed in the Modified Mud Rotary Borings

The construction details of the monitoring wells to be installed in the modified mud rotary borings are depicted on Figure 2B. As previously mentioned (Section 2.1.6.1), the upper permeable deposits comprising the Upper Glacial Formation will be cased off (10-inch diameter steel casing) to a depth of approximately 100 feet below land surface to prevent the loss of drilling fluid. The boring will be continued at a diameter of 8 inches until the completion depth has been reached (the final 30 feet of drilling to be accomplished by the reverse rotary method), whereupon well construction will proceed as described previously.

2.1.6.3 Monitoring Wells Installed in the Hollow-Stem Auger Borings

The shallow monitoring wells will be installed in the approximately 11-inch diameter boreholes according to the same procedure described above. To minimize the loss of cement grout to the upper 100 feet of the borehole, the grout mixture will be reinforced with fine mason sand.

2.1.7 Well Development

After the wells are installed, compressed air, a submersible pump and/or surge block will be used to develop the wells. The purpose of development is to remove the finer grained materials from the gravel pack and wall of the borehole. Development will also remove fine sand, silt, and clay from the natural formation that immediately surrounds the gravel pack and well screen so that the well will yield water relatively free of these finer grained materials. A turbidity meter will be used to measure water clarity. Attempts will be made to achieve turbidity levels of less than 50 NTUs; however, in some instances well water may have noticeably high-turbidity levels due to a relatively high percentage of finer grained deposits intrinsic to the formation.

2.1.8 Field Testing For Leachate Indicators

Leachate indicator parameters were identified in the First Operable Unit (Interim) RI Report. The parameters that will be employed for the field testing are given below:

Primary	Secondary
Hardness	pH
Alkalinity	Temperature
Ammonia	Chloride
	Specific Conductance

These parameters are the same parameters used in other RI/FS work on Long Island (Islip Landfill, Old Bethpage Landfill). The appropriateness of these parameters has been described in the Final Design Report for the Old Bethpage Landfill investigation (Geraghty & Miller 1984), as well as in other publications (Kimmel and Braids 1980; Saar and Braids 1983). These parameters can be analyzed using fairly simple techniques based on methodologies contained in "Standard Methods for the Examination of Water and Wastewater" (American Public Health Association 1989). Quality control will be addressed by analyzing standards and duplicates, as well as by submitting a minimum of 10 percent duplicate samples for laboratory analysis.

Because some of the leachate indicators can easily be derived from other common sources (for example, chloride may result from road salting), certain indicators such as hardness, alkalinity, and ammonia, which are less likely to be derived from other sources, will be the primary indicators. Chloride, pH, specific conductance, and temperature will be secondary indicators. Ground water will be defined as leachate when the action level of two or more primary leachate indicator parameters exceed their respective action levels or when one primary indicator and two secondary indicators exceed their respective action levels. Although temperature must be measured to obtain proper specific conductance measurements, an action level will not be established for temperature.

If action levels are not exceeded by a depth of approximately 450 feet below land surface, the off-site exploratory boring will be terminated. Geraghty & Miller, in consultation with representatives of the USEPA and the Town of Oyster Bay will decide whether a well(s) should be installed.

2.1.9 Monitoring Well Depths

As stated earlier, vertical profiles at each proposed drilling location will be compiled from the geophysical logs and the geologic information and water-quality data generated during the drilling of the exploratory borings. Appropriate screen zones will be selected to allow the plume dimensions to be confirmed and monitored. These depths will be determined based on field conditions and in consultation with technical representatives of the Town of Oyster Bay and the USEPA. As described earlier (Section 2.1.2), the screens of the deep wells will be set at the depth where the termination criteria are met or on top of the Raritan Clay, whichever is shallower. The screens of the intermediate wells will be set where the concentrations of leachate indicators are the highest and the screens of the shallow wells will be set between the first sampling depth where ground water is defined as leachate and the sampling interval just above that definition.

2.1.10 Measurement of Water Levels

On-Site. After all the monitoring wells are installed and developed, several rounds of synoptic water level measurements will be collected from these new monitoring wells and the on-site monitoring wells on a weekly basis for two months. Thereafter, the water levels will be monitored on a monthly basis for 10 months. Officials from the Town of Oyster Bay and their consultants will make a reasonable effort to gain access to measure water levels in the nearby Cerro Wire property wells to provide additional data. If the Town is unsuccessful, the USEPA has agreed to intervene on their behalf. Water-level elevation data collected from these monitoring wells (i.e., at and in the vicinity of the Cerro Wire property and Syosset Landfill) will be used to prepare potentiometric surface maps of the shallow (approximately 115 to 150 feet), intermediate (approximately 180 to 210 feet) and deep (likely greater than 400 feet) zones of the Magothy aquifer. These maps will depict the direction of ground-water flow in each zone.

Regional. Four quarterly synoptic rounds of water-level measurements will be collected from 18 Nassau County Observation wells. These are the same wells that were monitored during the on-site RI and are all screened in the shallow portion of the Magothy aquifer and are located within approximately 3 miles from the site. The measurement of these wells will be schedule to coincide with the water level monitoring of monitoring wells at and in the immediate vicinity of the site. Potentiometric surface maps for each monitoring event will be prepared to depict the ground-water flow direction and illustrate the position of the regional ground-water divide. An analysis of the vertical ground-water flow component will be made and site specific and region flow maps will be compared to gain a comprehensive understanding of the ground-water flow system.

2.1.11 Ground-Water Sampling and Analysis

Following installation and development of the monitoring wells, two rounds of water-quality samples will be collected from existing on-site monitoring wells and the new on-site and off-site monitoring wells (Figure 1). These samples will be collected approximately one month apart and will be analyzed for the same parameters (Appendix A) employed during the First Operable Unit RI. Unfiltered and filtered samples will be collected for metals analysis. The analytical results for the unfiltered samples will reflect the total metals concentrations including metals sorbed onto colloidal particles, whereas the analytical results for the filtered samples will reflect the concentrations of metals in aqueous solution.

The protocols set forth in the SOP (Geraghty & Miller, Inc. 1986a), which were followed during the On-Site Ground-Water Study, will also be followed during the Second

Operable Unit RI. Dedicated submersible pumps, which will be permanently installed in each well, will be used to evacuate the wells. Samples will be collected directly from the discharge of the pumps following evacuation of each well.

2.2 Off-Site Subsurface Gas Study

Three shallow gas monitoring wells will be installed on or in the vicinity of the Great Eastern Printing Company property, which is located adjacent to the southwestern portion of the landfill but separated from the site by the Long Island Railroad (LIRR) (see Figure 1). The same methodology and protocol followed for installing the on-site gas monitoring wells will be employed to install the off-site wells. This will ensure consistency in the monitoring results and allow for a comparison of the on-site and off-site monitoring data. However, the off-site wells will be completed at grade level with protective covers (plates) to prevent the vandalism experienced during the First Operable Unit RI. Because the Great Eastern Printing Company is on private property, it is likely that a work easement will have to be obtained to install the gas monitoring wells.

2.2.1 Construction of Gas Monitoring Wells

The gas monitoring wells will be constructed of hand-slotted, 1-inch diameter PVC casing, installed in boreholes drilled with a hand-operated bucket auger or a power auger, depending on soil conditions. Each borehole will be backfilled with clean sand to within 1 foot of land surface, and then sealed with a bentonite slurry. The gas monitoring wells will be installed at depths of 3 to 5 feet below land surface. The construction details of a typical gas monitoring well are shown on Figure 3. The tops of the wells will be capped and fitted with short lengths of polyethylene and silicone tubing to allow attachment of sampling and gas monitoring equipment.

2.2.2 Subsurface Gas Monitoring

The three off-site gas monitoring wells and the on-site gas monitoring wells in the southwestern portion of the site and gas monitoring Wells G-13 and G-14 will be monitored for methane and total VOCs on three days of low barometric pressure. A Century Systems Model 88 organic vapor analyzer (OVA) will be used for these measurements. (This is the same instrument that was used during the First Operable Unit RI). A charcoal filter probe will be used for measuring methane because the charcoal adsorbs essentially all other organic vapor except methane. A standard probe will be used to measure total VOCs (including methane).

FEASIBILITY STUDY

The Second Operable Unit FS will address remedial alternatives for conditions determined by the Second Operable Unit RI. Both passive and active systems for remediation will be evaluated during the FS process.

DELIVERABLES AND SCHEDULE

The results of the Second Operable Unit RI will be presented in a draft report to the USEPA. The report will be finalized after receipt of USEPA comments. This report combined with the First Operable Unit (Interim) RI Report will constitute the completed RI. A Second Operable Unit FS work plan will be submitted within 15 days after we receive approval of the Second Operable Unit RI report. A schedule for the Second Operable Unit RI is depicted on Figure 4.

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TABLES

Table 1. Horizontal and Vertical Ground-Water Flow Velocity Calculations, Syosset Landfill, Syosset, New York.

Using the equation for the pore velocity of ground water:

$$V = \frac{KI}{n}$$

where: v = the velocity of ground water in feet per day (ft/day)
K[a] = the hydraulic conductivity or permeability in ft/day
I[b] = the hydraulic gradient (dimensionless)
n[a] = the porosity in percent

<u>Horizontal Velocity (v_h)</u>

$$V_h = \frac{KI}{n} = \frac{50(0.0006)}{0.30}$$

$$= 0.1 \text{ ft/day}$$

The distance that the ground-water could have traveled since landfilling began (i.e., 58 years ago) =
v_h x 58 years x 365 days/year = 0.1 ft/day x 58 years x 365 days/year = 2,117 ft.

<u>Vertical Velocity (v_v)</u> = 5.8 ft/year[c] near the regional ground-water divide.

The depth that the ground water could have traveled since landfilling began = v_v x 58 years x 365 days/year
= 5.8 ft/year x 58 years = approximately 340 ft (from the water table surface) + 110 ft (depth to water) =
approximately 450 ft below land surface.

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a) from McClymonds & Franke 1972. Water Transmitting Properties of Aquifers on Long Island, New York. USGS Professional Paper 627-E.
b) from Geraghty & Miller, Inc. 1989. Interim Remedial Investigation Report, Syosset Landfill, Syosset, New York.
c) from Franke and Cohen 1972. Regional Rates of Ground-Water Movement on Long Island, New York. USGS Professional Paper 800-C, Pages C-271 to C-277.

FIGURES

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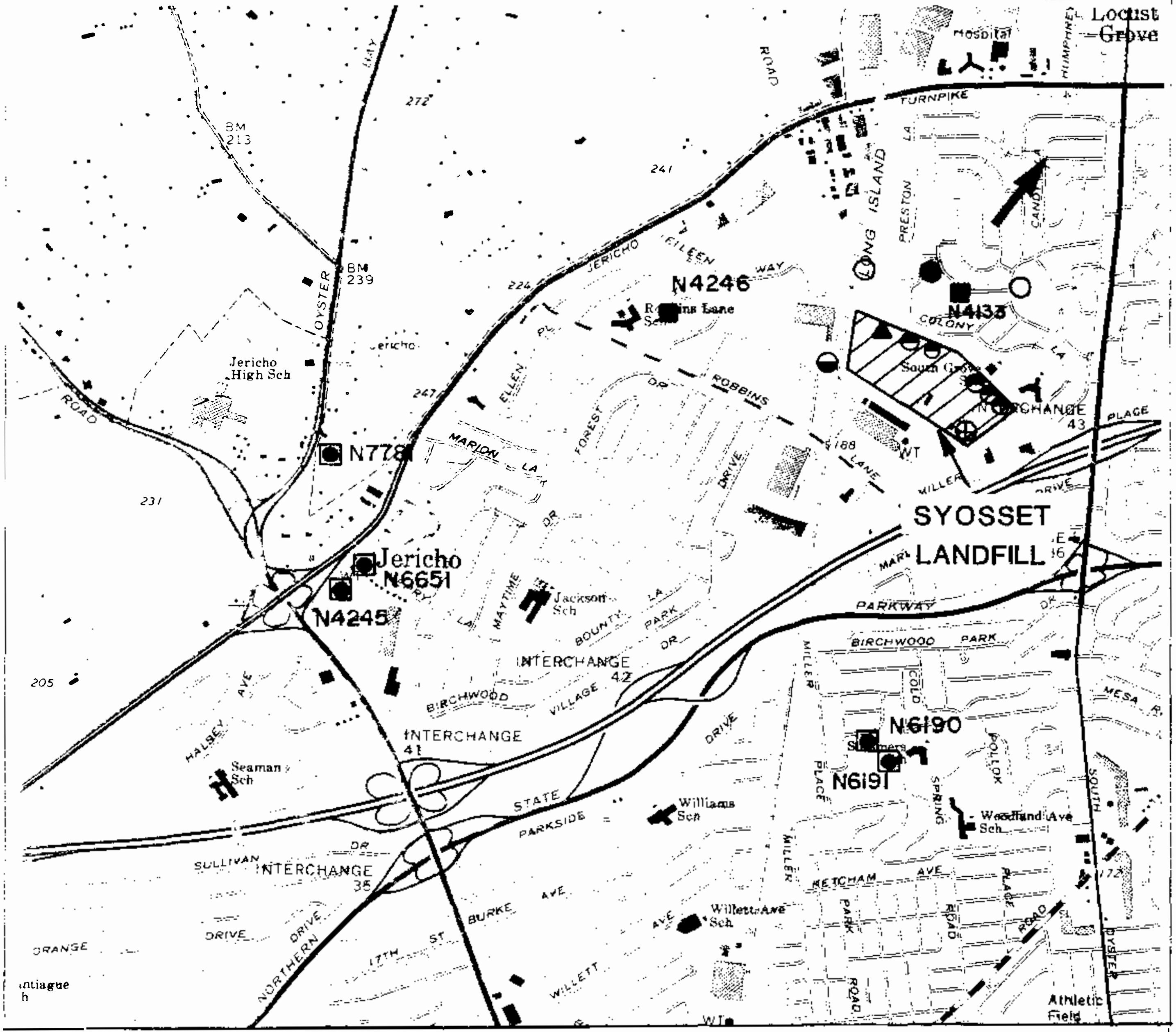
Ground-Water Consultants

COMPILED BY: V.J. GLASSER	DATE: 2/89	SCALE: ~~SHOWN~~	PREPARED FOR:
PREPARED BY: E. DeLUCA	FILE NO:		LOCKWOOD, KESSLER & BARTLETT
PROJECT MGR.: V.J. GLASSER	NY0340SL4-1115		Syosset, New York



EXPLANATION

N7781 ⊡ LOCATION AND DESIGNATION OF FUNCTIONING PUBLIC SUPPLY WELL

● LOCATION OF PROPOSED OFF-SITE EXPLORATORY BORING/MONITORING WELL CLUSTER

▲ LOCATION OF PROPOSED ON-SITE EXPLORATORY BORING/MONITORING WELL

○ LOCATION OF PROPOSED OFF-SITE CLUSTER BORINGS/MONITORING WELLS

N4133 ■ LOCATION AND DESIGNATION OF ABANDONED PUBLIC SUPPLY WELL

⊖ LOCATION OF THE THREE PROPOSED OFF-SITE GAS MONITORING WELLS

⊖ LOCATION OF PROPOSED ON-SITE (OU-1 RD)* GAS MONITORING WELLS

⊕ LOCATION OF PROPOSED DEEP ON-SITE UPGRADIENT MONITORING WELL

→ GROUND-WATER FLOW DIRECTION

NORTH

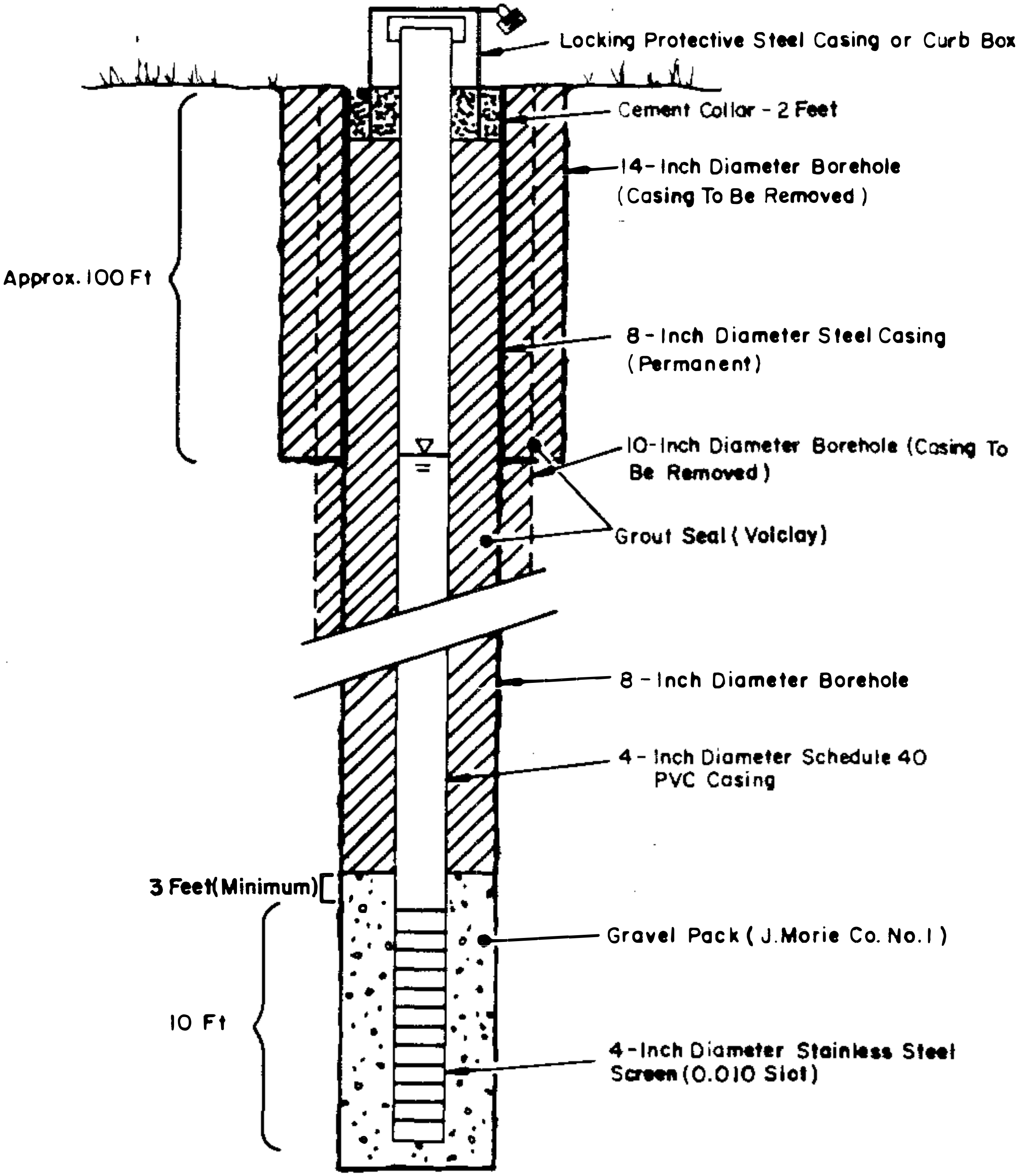
* RD= Remedial Design Program

SUBJECT: LOCATIONS OF PROPOSED GROUND-WATER AND GAS MONITORING WELLS, Syosset Landfill, Syosset, New York

FIGURE 1

141991

GERAGHTY & MILLER, INC. Ground-Water Consultants	COMPILED BY: V.J. GLASSER PREPARED BY: E.DeLUCA CHECKED BY: V.J. GLASSER	DATE: 2/89 FILE NO: NY02908-1115	SCALE: NONE	PREPARED FOR: LOCKWOOD, KESSLER & BARTLETT Syosset, New York



SUBJECT: GENERALIZED CONSTRUCTION OF MONITORING WELL INSTALLED IN EXPLORATORY BORING, Syosset Landfill, Syosset, New York

FIGURE 3

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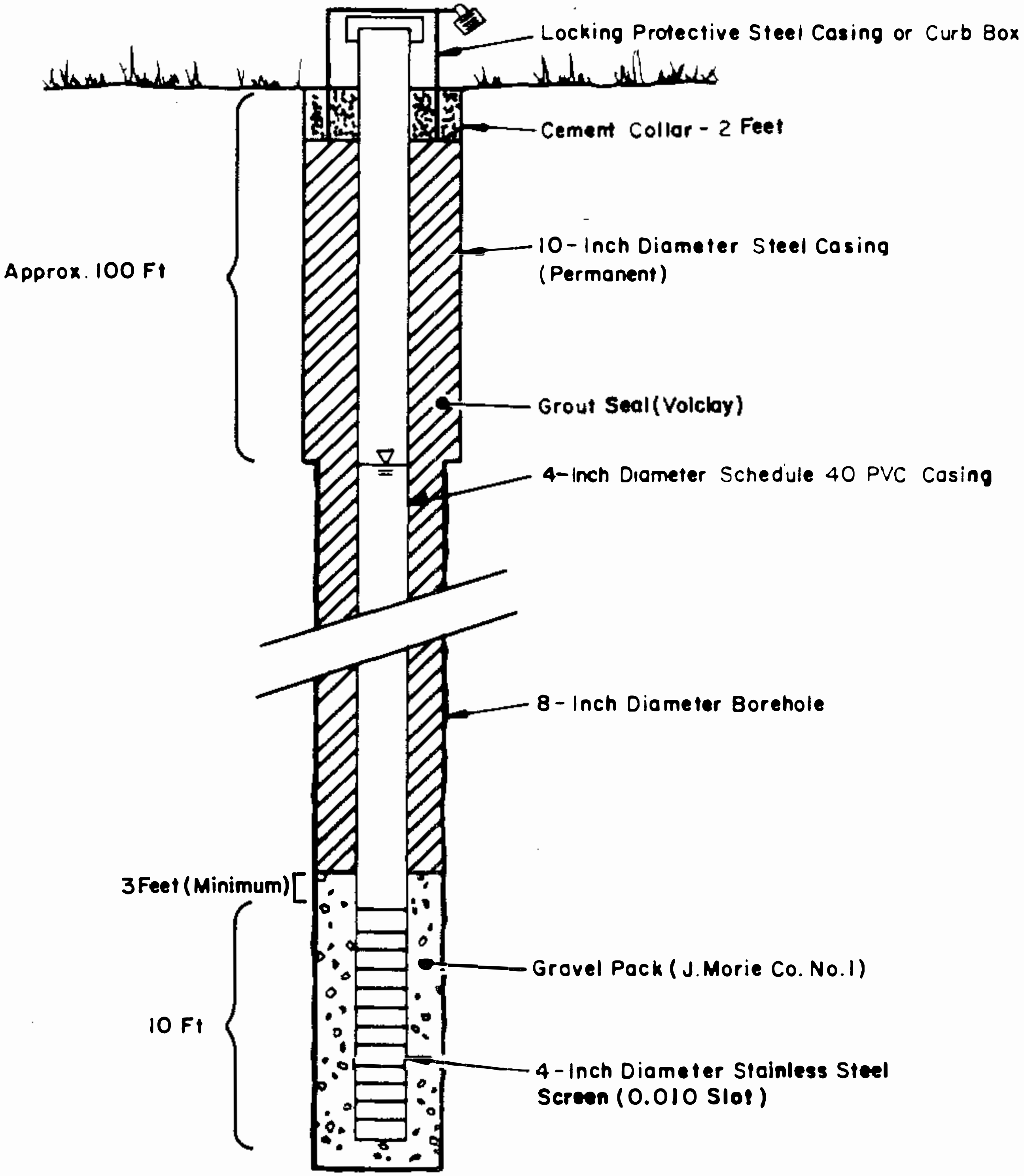
PREPARED BY: E. DeLUCA	FILE NO: NY02908-1115		
PROJECT MGR: V.J. GLASSER			



SUBJECT: GENERALIZED CONSTRUCTION OF MONITORING WELL INSTALLED IN MUD ROTORY BORING, Syosset Landfill, Syosset, New York

FIGURE 4

GERAGHTY & MILLER, INC.
Ground-Water Consultants

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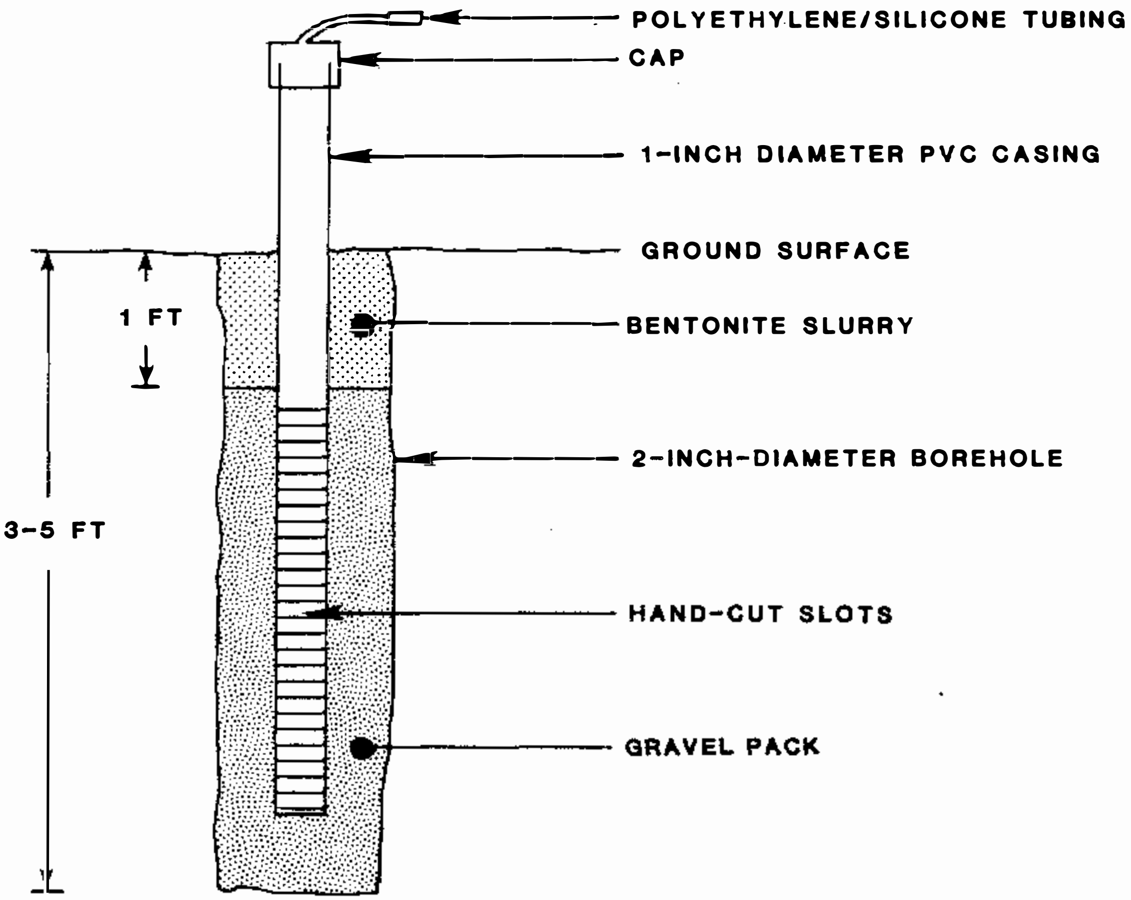
PREPARED BY: E. De LUCA	FILE NO: NY02904-1115		**LOCKWOOD, KESSLER & BARTLETT** **Syosset, New York**
PROJECT MGR.: V.J. GLASSER			



SUBJECT:

GENERALIZED CONSTRUCTION OF SUBSURFACE GAS MONITORING WELL.

FIGURE
4

SYOSSET LANDFILL OU2 REMEDIAL INVESTIGATION

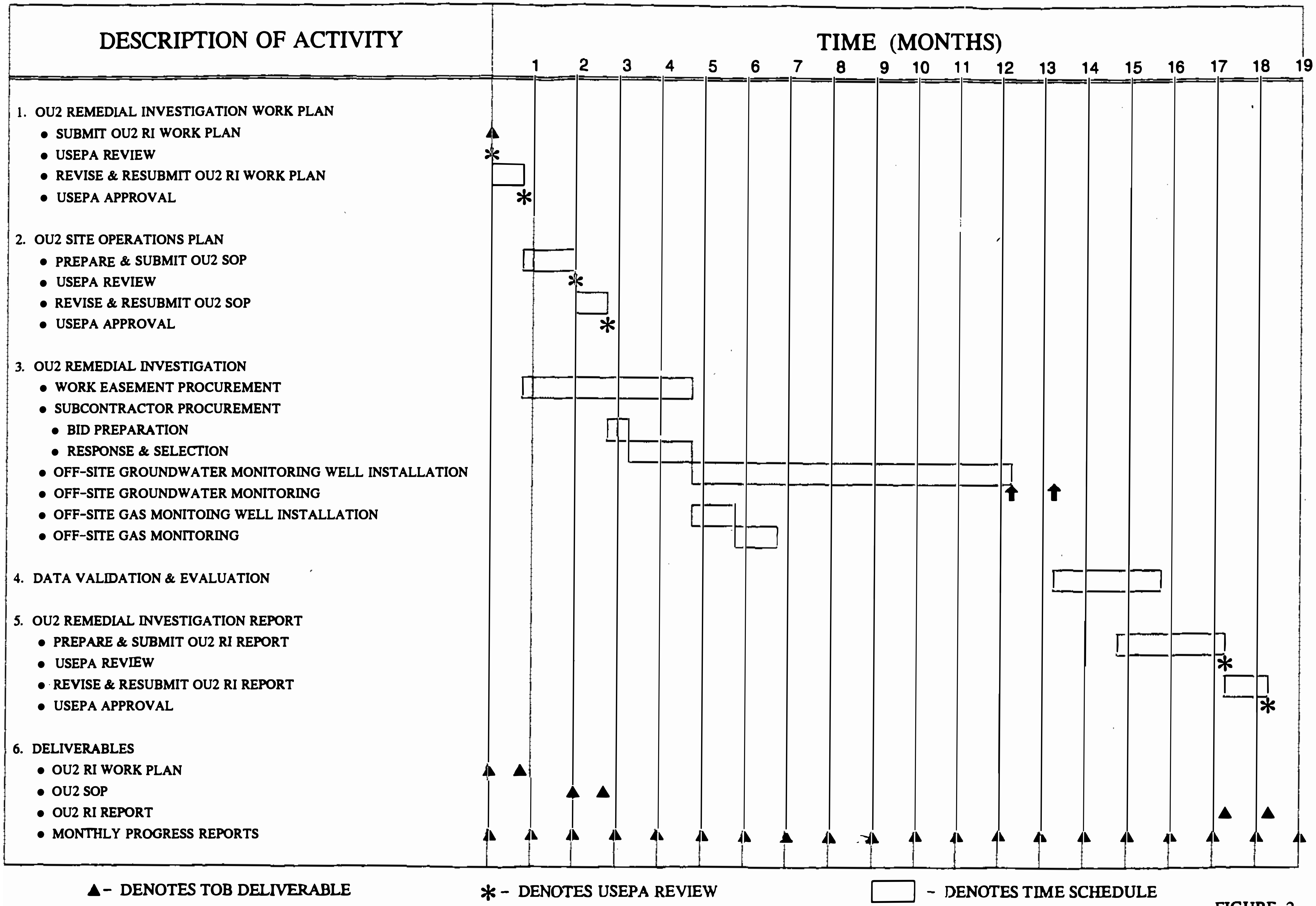


FIGURE 2

LKB

OU2 RI PROJECT SCHEDULE

APPENDIX A

APPENDIX A

Parameter List

APPENDIX A

SELECTED ENVIRONMENTAL PROTECTION AGENCY PRIORITY POLLUTANTS

Base-Neutral Extractable Organics

Acenaphthene
Acenaphthylene
Anthracene
Benzidine
Benzo(a)anthracene
Benzo(a)pyrene
3-4,Benzofluoranthene
Benzo(ghi)perylene
Benzo(k)fluoranthene
bis(2-Chloroethoxy)methane
bis(2-Chloroethyl)ether
bis(2-Chlorisopropyl)ether
bis(2-Ethylhexyl)phthalate
4-Bromophenyl phenyl ether
Butyl benzyl phthalate
2-Chloronaphthalene
4-Chlorophenyl phenyl ether
Chrysene
Dibenzo(a,h)anthracene
1,2-Dichlorobenzene
1,3-Dichlorobenzene
1,4-Dichlorobenzene
3,3'-Dichlorobenzidine
Diethyl phthalate
Dimethyl phthalate
Di-n-butyl phthalate
2,4-dinitrotoluene
2,6-dinitrotoluene
Di-n-octyl phthalate
1,2-diphenylhydrazine
Fluoranthene
Fluorene
Hexachlorobenzene
Hexachlorobutadiene
Hexachlorocyclopentadiene
Hexachloroethane
Indeno(1,2,3-c,d)pyrene
Isophorone
Naphthalene
Nitrobenzene
N-Nitrosodimethylamine
N-Nitrosodi-n-propylamine
N-Nitrosodiphenylamine
Phenanthrene
Pyrene
1,2,4-Trichlorobenzene

Volatile Organics

Benzene
Bromoform
Carbon tetrachloride
Chlorobenzene
Chlorodibromomethane
Chloroethane
2-Chloroethyl vinyl ether
Dichlorobromomethane
Dichlorodifluoromethane
1-1-Dichloroethane
1,2-Dichloroethane
1,1-Dichloroethylene
1,2-Dichloropropane
1,3-Dichloropropylene
Ethylbenzene
Methyl bromide
Methyl chloride
Methylene chloride
1,1,2,2-Tetrachloroethane
Tetrachloroethylene
Toluene
trans-1,2-Dichloroethylene
1,1,1-Trichloroethane
1,1,2-Trichloroethane
Trichloroethylene
Trichlorofluoromethane
Vinyl chloride

Acid Extractable Organics

2-Chlorophenol
2,4-Dichlorophenol
2,4-Dimethylphenol
4,6-Dinitro-o-cresol
2,4-Dinitrophenol
2-Nitrophenol
4-Nitrophenol
p-Chloro-m-cresol
Pentachlorophenol
Phenol
2,4,6-Trichlorophenol

Metals

Antimony
Arsenic
Beryllium
Cadmium
Chromium
Copper
Lead
Mercury
Nickel
Selenium
Silver
Thallium
Zinc

PCBs

PCB-1242
PCB-1254
PCB-1221
PCB-1232
PCB-1248
PCB-1260
PCB-1016

Additional Parameters

Total Cyanides
Total Dissolved Solids
Specific Conductance
pH
Chloride
Nitrate
Ammonia
Hardness
Bicarbonate
Carbonate
Sulfate
Sodium
Potassium
Barium
Iron

APPENDIX B

APPENDIX B

"Influences of Casing Materials on Trace-Level Chemicals in Well Water," Louise V. Parker, Alan D. Hewitt, and Thomas F. Jenkins as published in Ground Water Monitoring Review, Spring 1990, Volume 10, No.2.

Influence of Casing Materials on Trace-Level Chemicals in Well Water

by *Louise V. Parker, Alan D. Hewitt, and Thomas F. Jenkins*

Abstract

Four well casing materials — polyvinyl chloride (PVC), polytetrafluoroethylene (PTFE), and stainless steel 304 (SS 304) and 316 (SS 316) — were examined to determine their suitability for monitoring inorganic and organic constituents in well water.

The inorganic study used a factorial design to test the effect of concentration of mixed metals (arsenic [As], chromium [Cr], lead [Pb], and cadmium [Cd]), pH, and organic carbon. Sample times were 0.5, 4, 8, 24, and 72 hours. Except for slow loss of Pb, PTFE well casings had no significant effect on the concentration of metals in solution. For the other casings, changes in analyte concentration often exceeded 10 percent in eight hours or less and, thus, could bias analyses of samples taken from wells constructed with these materials. Specifically, PVC casings sorbed Pb and leached Cd; SS 316 casings sorbed As and Pb and leached Cd; and SS 304 casings sorbed As, Cr, and Pb and leached Cd. Both stainless steel casing materials showed markedly poorer performance than the PVC casings.

The well casings were also tested for sorption/desorption of 10 organic substances from the following classes: chlorinated alkenes, chlorinated aromatics, nitroaromatics and nitramines. Sample times were 0, 1, 8, 24, and 72 hours, seven days, and six weeks. There were no detectable losses of analytes in any of the sample solutions containing stainless steel well casings. Significant loss of some analytes was observed in sample solutions containing plastic casings, although losses were always more rapid with the PTFE casings than with PVC. Chlorinated organic substances were lost most rapidly. For samples containing PTFE casings, losses of some of these compounds were rapid enough (>10 percent in eight hours) to be of concern for ground water monitoring. Losses of hydrophobic organic constituents in samples containing PTFE casings were correlated with the compound's octanol/water partition coefficient.

Introduction

The U.S. Environmental Protection Agency's (EPA's) RCRA Ground Water Monitoring Technical Enforcement Guidance Document (TEGD) (U.S. EPA 1986a) states that only fluorocarbon resins or stainless steel (SS) casings should be used for monitoring volatile organics in the saturated zone. The original draft of this document (U.S. EPA 1985) suggested that Teflon® or stainless steel 304 be used for all ground water monitoring at RCRA sites. The EPA was concerned that many of the casing materials used for ground water monitoring could either affect the quality of the ground water or did not have the long-term structural characteristics required of RCRA monitoring wells. With respect to the EPA's first concern, a review of the literature published prior to 1986 did not reveal substantial evidence to support the position taken by the EPA in either edition of this document (Parker et al. 1989).

Few studies have specifically addressed the possible interactions between well casing materials and metal species. There is considerable evidence, however, that sorption of metals by plastic and glass containers can be significant (Eicholz et al. 1965, Robertson 1968, Batley and Gardner 1977, and Masse et al. 1981). In one study of PVC well casings, there was negligible loss of chromium but large losses of lead from a deionized water solution (Miller 1982). Other studies with Pyrex glass and polyethylene also found that lead was the most rapidly lost analyte (Shendrikar et al. 1976). Barcelona and Helfrich (1986) compared the concentrations of several metal species in samples taken from adjacent PVC, PTFE, and SS wells. They found increased levels of iron in water samples from the non-purged SS well to be the only statistically significant difference. In a previous in situ study by Houghton and Berger (1984), a steel-cased well appeared to leach a number of metal species, including iron, cadmium, chromium, copper, manganese, molybdenum, selenium, and zinc, when compared with a PVC well and one constructed of acrylonitrile-butadiene-styrene (ABS).

Sorption of organic solutes by well casing materials has been reported in several publications. Miller (1982) tested PVC well casing for sorption of trace levels (2-14 ppb) of six halogenated organic compounds (bromoform, trichlorofluoromethane, trichloroethylene, 1,1,1-trichloroethane, 1,1,2-trichloroethane, and tetrachloroethylene) in aqueous solution and found slow losses of tetrachloroethylene (25-50 percent in six weeks).

Reynolds and Gillham (1986) tested both PVC and PTFE materials for sorption of trace levels (ppb) of five halogenated organics. They found rapid sorption of tetrachloroethylene by PTFE, slow sorption of 1,1,1-trichloroethane, 1,1,2,2-tetrachloroethane and hexachloroethane, and no sorption of bromoform. They also found slow sorption of all the analytes except trichloroethane by PVC. While 50 percent of the tetrachloroethylene was sorbed by the PVC in five weeks, the same amount was sorbed by PTFE in only eight hours. They attributed loss of these organics to absorption and developed a model where uptake of the compound proceeds by sorption/dissolution into the polymer surface, followed by diffusion into the polymer matrix. However, Reynolds and Gilham (1986) could not predict which organic chemicals were most susceptible to absorption.

Sykes et al. (1986) compared sorption of several organics by PVC, SS, and PTFE well casings. The casing materials were equilibrated for seven days (5 C) in analyte solution, placed in fresh analyte solution, and then tested for losses due to sorption after one and 24 hours. After 24 hours they did not find any significant losses for any of the casing materials.

While these studies indicate that sorption of some organics may be a significant problem for plastic casings over the long term, only the study by Miller (1982) examined desorption during the first two weeks. In that study, he observed some desorption (25 percent) of the tetrachloroethylene that had been previously sorbed by the PVC casings.

Casing materials may also leach a variety of organic substances. In two studies (Miller 1982, Parker and Jenkins 1986), analytical interferences in leachates from PVC well casings were sought but none were found. Curran and Tomson (1983) also examined the leachates from the plastics, including PVC and PTFE. They found that PTFE leached the fewest contaminants and that nonglued PVC was a close second. While it is possible that organic substances such as lubricants used during manufacture or inks from printing could leach from stainless or plastic casings, no information currently available in the literature confirms this.

It is interesting to note that despite the literature that is available regarding sorption of organics by PTFE, articles have recently been published that claim it is superior for sampling organic substances (e.g., Bryden and Smith 1989).

The purpose of the studies conducted by the authors was to determine the suitability of four well casing materials (PVC, PTFE, SS304, and SS316) for monitoring inorganic and organic solutes in ground water. To do this, two separate studies were conducted, one for inorganics and one for organics.

General Comments on the Inorganic and Organic Studies

Two-inch (inner) diameter well casings manufactured specifically for ground water monitoring were used in all studies. These casings were purchased specifically for the studies and were stored in a cool, dry room prior to use. Precautions were taken while the casings were being cut to prevent contamination from grease, dirt, oil, solvents, and excessive handling. The ground water used in the studies was obtained from a domestic well (249 feet [76m] deep) in Weathersfield, Vermont. No attempt was made to maintain the native dissolved oxygen level. As a general guideline for evaluating our results, we considered any change in concentration (relative to the control samples) of 10 percent in an eight-hour period to be the maximum change tolerable.

Inorganic Study

Experimental

Mixed metal solutions were prepared by spiking ground water with arsenic (As), cadmium (Cd), chromium (Cr) and lead (Pb) at two concentrations: 50 and 100 μg/L (ppb) for As, Cr, and Pb, and 10 and 2 μg/L for Cd. The higher concentrations are the current maximum concentration limits set by the EPA for drinking water (U.S. EPA 1986b). Prior to treatment, the ground water used in this study was analyzed and found to contain no detectable amounts of any of these metals at the sensitivity levels used for analysis. To simulate a wider range of ground water conditions, the tests were run at the natural pH (7.8) of the well water plus a lower pH (5.8) and at two levels of organic carbon. HCl (reagent grade) was added to lower the pH and 5 mg/L (ppm) of humic acid was added to raise the organic carbon content. A complete (2^3) factorial experiment was used to test the effect of these treatments (concentration of metals, pH and organic carbon content) (Table 1).

Because the wall thicknesses varied between the plastic and the two stainless steel casings, the casings

TABLE 1
Matrix Design for Inorganic Study

Test Condition	Metal Concentrations[1]	pH	Organic Carbon Added[2]
1	high	7.8	no
2	high	7.8	yes
3	high	5.8	no
4	high	5.8	yes
5	low	7.8	no
6	low	7.8	yes
7	low	5.8	no
8	low	5.8	yes

[1] High metal concentrations were 50 μg/L As, Cr, Pb, and 10 μg/L Cd. Low metal concentrations were 10 μg/L As, Cr, Pb, and 2 μg/L Cd.
[2] 5 mg/L humic acid was added as a source of organic carbon.

were cut to different lengths so that the surface area of each was constant (80 cm^2). Cut sections were rinsed with deionized water and air-dried before use. Individual well casings were then placed in 125mL polypropylene jars containing 100mL of test solution; the ratio of casing surface area to aqueous volume was 0.82 cm^2/mL. Similar jars that contained the test solutions without any casings were used for control samples. The sample vessels were covered, stored at 24 C and kept from natural light. Duplicates were run for each combination of variables and each casing material.

Sample aliquots (2.5mL) were taken from each container after 0.5, 4, 8, 24, and 72 hours. The aliquots were placed in clean 7.5mL polyethylene vials and acidified to a pH of less than 1 with nitric acid to prevent sorption by the containers. Metal concentrations were obtained by graphite furnace atomic absorption spectroscopy (Perkin-Elmer, model 703 atomic absorption spectrophotometer coupled with a PE model 2200 heated graphite atomizer). The concentrations of metals given in this study were measured as total.

The metal concentrations were normalized by dividing the values obtained for sample solutions that contained well casings by the values found for equivalent controls. This allowed the results for both concentrations to be analyzed by a single analysis of variance (ANOVA). Thus, it was possible to simultaneously test for the effect of solute concentration, pH and organic carbon at each sample time for each casing material. If a casing exerted no influence on analyte concentration, the expected value would be 1.00. An increase in the ratio indicates that the well casing released metal into the solution, while a decrease in the ratio indicates that metal was sorbed by the casing.

Results and Discussions

Approximately half of the stainless steel casings showed signs of surface rust. In some cases (SS 316 at a low pH), sufficient oxidation occurred to form a hydrous iron oxide precipitate. This precipitate was never observed in the control samples or those with PVC or PTFE casings. While the authors realize that rusting of the stainless casings is very condition-specific, the test conditions should be generally representative of shallow wells. Also, it was noticed that the casings had rusted some during storage prior to any testing.

Table 2 gives the normalized mean values and standard deviations for each analyte, well casing and time.

TABLE 2
Normalized Mean Metal Values[1] for Samples as a Function of Time

Time (hr)	Pipe	Arsenic Mean Value	Arsenic Standard Deviation	Cadmium Mean Value	Cadmium Standard Deviation	Chromium Mean Value	Chromium Standard Deviation	Lead Mean Value	Lead Standard Deviation
0.5	PVC	0.991 ±	0.038	1.01 ±	0.025	1.01 ±	0.018	0.999 ±	0.009
	PTFE	0.999 ±	0.050	1.01 ±	0.011	1.01 ±	0.007	1.00 ±	0.026
	SS304	0.997 ±	0.057	1.06 ±	0.036	1.01 ±	0.016	1.02 ±	0.008
	SS316	0.994 ±	0.040	1.04 ±	0.021	1.02 ±	0.015	1.01 ±	0.025
4.0	PVC	1.02 ±	0.045	1.13 ±	0.037	0.999 ±	0.013	0.889 ±	0.030
	PTFE	0.993 ±	0.052	1.03 ±	0.054	1.01 ±	0.011	0.974 ±	0.019
	SS304	0.978 ±	0.063	1.17 ±	0.15	0.957 ±	0.037	0.784 ±	0.035
	SS316	0.945 ±	0.060	1.24 ±	0.49	0.921 ±	0.052	0.803 ±	0.077
8.0	PVC	1.00 ±	0.045	1.15 ±	0.037	1.00 ±	0.014	0.893 ±	0.035
	PTFE	1.01 ±	0.098	1.03 ±	0.016	0.989 ±	0.019	0.985 ±	0.032
	SS304	0.962 ±	0.057	1.16 ±	0.14	0.972 ±	0.16	0.699 ±	0.031
	SS316	0.945 ±	0.068	1.30 ±	0.47	0.872 ±	0.10	0.804 ±	0.10
24.0	PVC	0.994 ±	0.064	1.16 ±	0.056	1.00 ±	0.016	0.808 ±	0.051
	PTFE	0.992 ±	0.054	1.03 ±	0.017	1.01 ±	0.024	0.951 ±	0.040
	SS304	0.894 ±	0.051	1.12 ±	0.12	1.03 ±	0.37	0.538 ±	0.042
	SS316	0.853 ±	0.080	1.36 ±	0.68	0.855 ±	0.11	0.793 ±	0.19
72.0	PVC	1.03 ±	0.046	1.14 ±	0.049	1.01 ±	0.018	0.743 ±	0.064
	PTFE	1.02 ±	0.045	1.02 ±	0.022	1.00 ±	0.013	0.899 ±	0.034
	SS304	0.891 ±	0.084	1.03 ±	0.14	1.03 ±	0.42	0.452 ±	0.061
	SS316	0.874 ±	0.083	1.25 ±	0.66	0.836 ±	0.099	0.720 ±	0.17

[1] $$\frac{\text{(Concentration for samples with casing)}}{\text{(Concentration for control samples)}} = \text{Normalized mean value}$$

These normalized values are the mean of all the treatments (i.e., for both pHs, organic carbon content, and concentration).

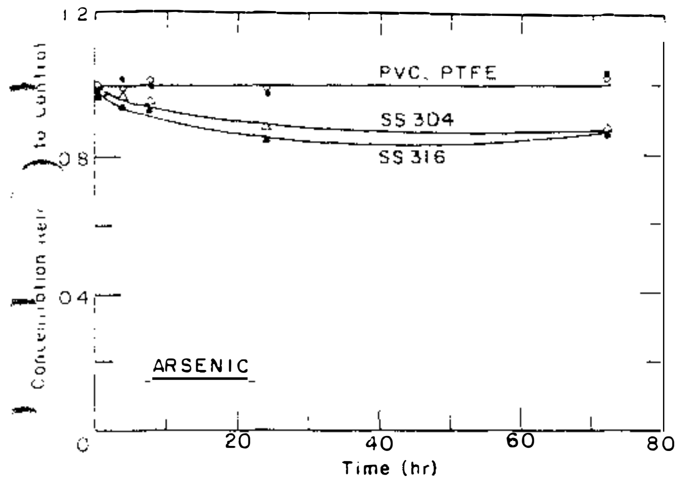


Figure 1. Trends in mean arsenic concentration for four well casing materials.

In general, there was no change in arsenic concentration for the sample solutions containing either the PVC or PTFE casings during the 72-hour test period (Figure 1), and no consistent pattern of effects was evident from the ANOVA. The reason As did not interact with these casings may be because As exists in natural waters in the anionic form (Fowler et al. 1979). Masse et al. (1981) found that anions do not strongly associate with plastic (polyethylene and PTFE) surfaces, which are known for their cation exchange capacity. The samples containing the stainless steel casings, on the other hand, showed a 10 percent decrease in aqueous arsenic concentration relative to the controls after 24 hours (Figure 1). It appears that there was no further loss of this analyte after 24 hours. Although these results cannot be used to predict exactly what losses might occur under field conditions, it is doubtful that this loss was rapid enough to impact water quality measurements (losses were less than 10 percent after eight hours).

The results for Cd are quite different. After only four hours, Cd concentrations in the samples containing PVC and stainless steel casings had increased by more than 10 percent (Figure 2), with the most leaching occurring in the samples containing the SS 316 casings. Cadmium may have been added to the PVC as a UV stabilizer (Wilson et al. 1982), and may have been added to the stainless steel to enhance resistance to chloride cracking (Sedricks 1979). The concentration of Cd in the samples containing PVC casings leveled off after eight hours. ANOVA revealed that pH had a significant effect (at the 95 percent confidence level) for this casing. Although the same amount of Cd leached in all the samples (approximately 0.5 mg/L), concentration was also significant (at the 95 percent confidence level), but only because relatively more was leached in the low-concentration samples. Concentrations in samples containing SS 304 casings decreased after eight hours and after 72 hours had returned to the same levels that were found in the control samples. Again, more Cd leached in the low pH samples. Cd was leached most rapidly in samples containing SS 316 casings. There was a large discrepancy between duplicate treatments for the samples that contained stainless steel casings. With the exception of the first set of samples (t = 0.5 hr), the relative standard deviations ranged from 12 to 15 percent for samples containing SS 304 and from 47 to 68 percent for those containing SS 316. In contrast, the standard deviations for samples containing PVC and PTFE casings were consistently below 6 percent. Because the variance in the samples containing SS 316 was so large, there was no consistent detectable effect of pH for these casings. However, surface oxidation appeared to be the major source of this variance. With respect to the leaching of metal stabilizers from PVC pipes, the literature indicates that loss can be a surface phenomenon that can be reduced or eliminated by either washing (with detergent) or soaking in dilute mineral acid before use (Packham 1971). It may be that the loss of Cd from PVC casings can also be reduced by a similar treatment, although we did not test this possibility.

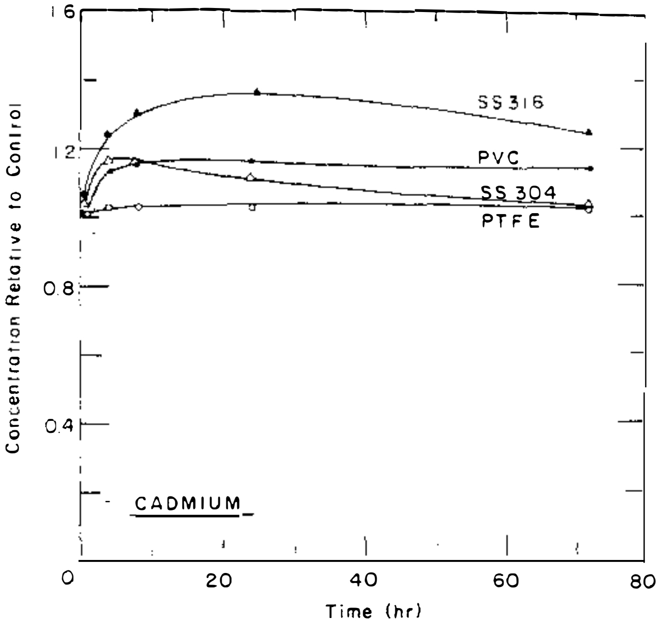


Figure 2. Trends in mean cadmium concentration for four well casing materials.

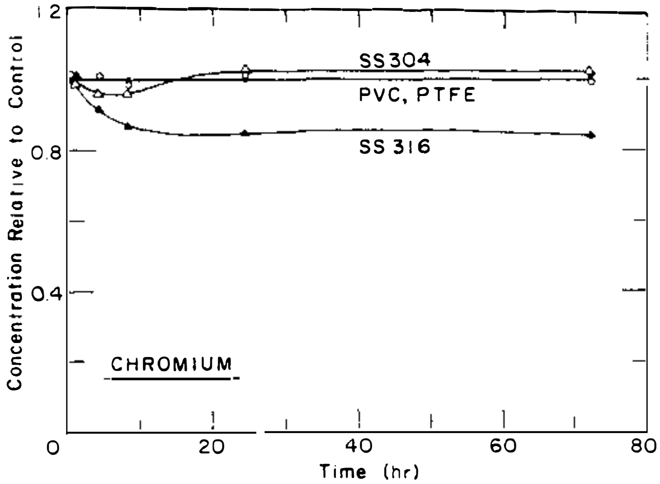


Figure 3. Trends in mean chromium concentration for four well casing materials.

There was no measurable sorption of chromium by the PTFE, PVC, and SS 304 casings (Figure 3). Absence of interaction with the plastic casings may be due to chromium speciation. In solution, chromium exists predominantly as dichromate and chromate ($Cr_2O_7^{2-}$, CrO_4^{2-}) and, as mentioned previously, anions are not as likely to exchange with plastic surfaces. However, loss of chromium was rapid enough (13 percent after eight hours) for SS 316 casing material to be of concern for ground water monitoring. Losses were greater at the higher pH; Cr speciation is known to be affected by pH and may be responsible for some of these differences. Surface oxidation was greater at the lower pH, which likely contributed to the larger variability. Also, for those samples where a hydrous iron oxide precipitate was formed, co-precipitation may have contributed to the losses from solution. Again, the standard deviations were considerably greater for the samples containing the stainless steel casings. Humic acids apparently increased the stability of aqueous Cr, perhaps by acting as a complexing agent (Stumm and Morgan 1970s).

Lead was by far the most actively sorbed metal species. While all sample solutions containing casing materials showed some loss of Pb with time (Figure 4), PTFE was the least active surface and SS 304 was the most active. The losses for samples containing PTFE casings do not appear to be of concern with respect to ground water monitoring; losses were only 5 percent after 24 hours. However, losses for samples containing PVC and stainless casings are of concern; losses were 10 percent after only four hours in the samples containing PVC casings and 20 percent in those containing stainless casings. Although loss was initially rapid in samples containing SS 316 casings, it leveled off after eight hours. The standard deviation was higher for the samples containing SS 316 casings than for the other casings. For both stainless steel casings, there was less sorption of Pb at the lower pH where hydrogen ions may have competed for sorption sites. Added humic material apparently acted as a complexing agent in solution, making lead less prone to sorption. Concentration had no consistent effect.

Undoubtedly, there were shifts in the chemical equilibria of the well water solutions from the time the well water was collected until the end of the experiment. Ground water that is removed from an anoxic environment and exposed to oxygen-rich air may undergo redox and precipitation reactions (Stumm and Morgan 1970b). Also, lowering the pH shifts the carbonate equilibrium in solution from predominantly bicarbonate species toward carbon dioxide (Manahan 1972) and causes shifts in Cr speciation. Clearly, such changes would alter the trace metal species distribution. These possible changes were not monitored in this experiment.

For further details on this portion of the study, refer to Hewitt (1989).

Organic Study

Experimental

The four well casing materials were also tested for sorption/desorption of low levels of 10 organic substances. The substances tested were hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX), 1,3,5-trinitrobenzene (TNB), cis- and trans-1,2-dichloroethylene (CDCE and TDCE), m-nitrotoluene (MNT), trichloroethylene (TCE), chlorobenzene (CLB), and o-, p- and m-dichlorobenzene (ODCB, PDCB, MDCB). The criteria used for selecting these analytes included being an EPA priority pollutant, molecular structure, solubility in water, K_{ow} value, and retention time (using reversed-phase high performance liquid chromatography [HPLC] analysis). HPLC analysis of the ground water used in these studies revealed no detectable levels of any of these substances.

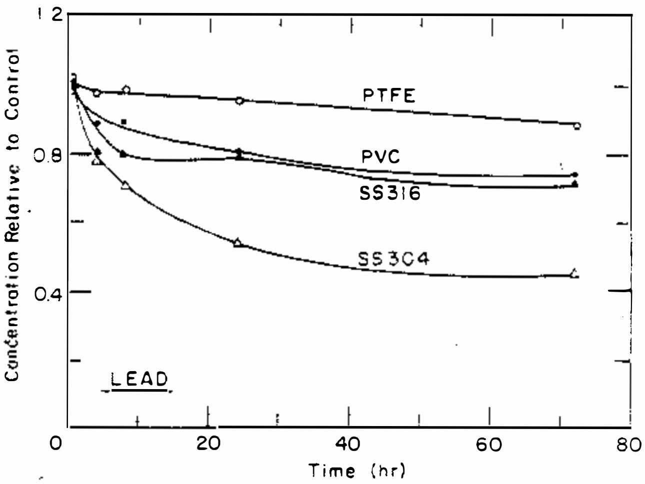


Figure 4. Trends in mean lead concentration for four well casing materials.

For these experiments, casings were cut into 11- to 14mm-long sections, which were then cut into quarters. Again, the length was varied so that the surface area could be maintained constant. The casings were washed in solutions of detergent and deionized water, rinsed many times with deionized water, drained and left to air dry. Two pieces of each type of casing were placed in 40mL glass vials that were filled with the aqueous test solution so there was no head space, and capped with Teflon-lined plastic caps. Vials with test solution but no well casing material served as controls. These controls allowed us to eliminate any effects such as those that might be due to the vials or caps. The ratio of casing surface area to solution volume was 0.79 cm^2/mL. The ratio of solution volume to volume of casing material was approximately 10:1.

In the first experiment, the test solution was prepared by adding known amounts of each of the organic solutes directly to 2.2 L of well water in a glass-stoppered bottle, which was stirred overnight. The final concentration was approximately 2 mg/L for each organic constituent. The solution also contained 40 mg/L of $HgCl_2$, which was added to prevent biodegradation of the organics. Separate vials were prepared for each sample time so that the test solution could be discarded after sampling; there were three replicate samples for each material and time. Contact times were 0 hours, one hour, eight hours, 24 hours, 72 hours (three days), 168 hours (seven days), and approximately 1000 hours (six weeks).

After an aliquot was removed for analysis from each

TABLE 3

Normalized[1] Average Concentrations of Organic Analytes for the Four Well Casings with Time

Analyte	Treatment	1 Hour	8 Hours	24 Hours	72 Hours	168 Hours	1000 Hours
X	PTFE	1.03	1.00	1.00	1.02	0.91	0.99
	PVC	1.01	1.00	0.98	1.00	1.02	1.00
	SS304	0.99	0.99	1.01	1.02	1.10	0.98
	SS316	1.01	0.99	1.01	1.02	1.11	1.00
NB	PTFE	1.01	1.00	1.00	0.98	0.95	1.01
	PVC	1.01	1.00	0.98	1.02	1.01	1.02
	SS304	0.99	1.00	1.00	1.05	1.07	1.00
	SS316	1.02	0.99	1.01	1.07	1.06	1.02
C12DCE	PTFE	1.01	0.96*	0.96*	0.94	0.91*	0.79*
	PVC	1.00	0.99	0.95*	0.96	0.95	0.90
	SS304	0.97	1.00	1.00	0.96	1.04	0.98
	SS316	0.95	0.99	1.00	1.01	0.98	0.99
12DCE	PTFE	1.00	0.92*	0.88*	0.83	0.66	0.56*
	PVC	1.00	0.98	0.93*	1.06	0.83	0.83
	SS304	0.95*	1.00	1.00	0.96	1.11	1.00
	SS316	1.00	0.99	1.00	1.12	1.03	1.00
MNT	PTFE	1.03	1.00	0.99	0.99	0.90	0.90*
	PVC	1.02	1.00	0.98	1.05	0.99	0.94
	SS304	1.00	1.00	1.01	1.00	1.08	1.07
	SS316	1.02	1.00	1.02	1.08	1.10	0.99
[illegible]	PTFE	1.00	0.90*	0.85*	0.78*	0.64*	0.40*
	PVE	1.01	0.98	0.94*	0.99	0.94*	0.88*
	SS304	0.96	1.00	1.01	0.96	1.04	0.99
	SS316	1.00	0.99	1.00	1.04	0.98	1.00
CLB	PTFE	1.01	0.93*	0.90*	0.85*	0.74*	0.51*
	PVC	1.01	0.98	0.95*	0.98	0.94*	0.86*
	SS304	0.98	1.00	1.00	0.97	1.05	0.99
	SS316	0.99	0.99	1.01	1.04	0.98	0.99
DCB	PTFE	1.01	0.91*	0.88*	0.81*	0.68*	0.43*
	PVC	1.02	0.97*	0.94*	0.98	0.93	0.86*
	SS304	0.98	0.99	1.00	0.99	1.04	1.00
	SS316	1.01	0.98*	1.01	1.03	0.98	1.00
PDCB	PTFE	0.92*	0.84*	0.77*	0.64*	0.47*	0.26*
	PVC	0.95	0.95*	0.92*	0.97	0.88*	0.80*
	SS304	0.91*	0.98	1.00	0.98	1.02	1.02
	SS316	0.94	0.97*	1.00	1.04	0.97	1.02
DCB	PTFE	1.00	0.84*	0.78*	0.66*	0.48*	0.26*
	PVC	1.02	0.95*	0.92*	0.97	0.88*	0.80*
	SS304	0.99	0.96*	1.00	0.99	1.02	1.02
	SS316	1.03	0.96*	1.00	1.04	0.96	1.01

ues are determined by dividing the mean concentration of a given analyte at a given time and for a particular well casing by the mean concentration the same analyte) of the control samples taken at the same time.

Values significantly different from control values (α = 0.05) of the 1000-hour samples, the vials were emptied and the pieces of casing were rinsed with approximately 40mL of fresh well water to remove any residual solution adhering to the surfaces. The casing pieces were then placed in new vials, and fresh unspiked well water was added. The vials were capped with new caps and allowed to equilibrate for three days. Aliquots were then taken from these samples and analyzed to determine if desorption had occurred.

In the second experiment 2.0 g/L of NaCl was also added to the test solution to determine the effect of increased ionic strength on the rates of sorption. Sampling times were the same except that the last samples were taken after approximately 1200 hours (seven weeks).

All analytical determinations were made by reversed-phase high performance liquid chromatography. A modular system was employed that consisted of a Spectra Physics SP 8810 isocratic pump, a Dynatech LC-241 autosampler with a 100-µL loop injector, a Spectra-Physics SP8490 variable wavelength UV detector set at 210 nm, a Hewlett-Packard 3393A digital integrator, and a Linear model 555 strip chart recorder. Separations were obtained on a 25cm x 4.6mm (5 µm) LC-18 column (Supelco) eluted with 1.5 mL/min of 62/38 (v/v) methanol-water. Baseline separation was achieved for all 10 analytes. Detector response was obtained from the digital integrator operating in the peak height mode. Analytical precision ranged from 0.4 to 3.98 percent, as determined by the pooled standard deviation of triplicate initial measurements.

For each analyte and sample time, a one-way analysis of variance (ANOVA) was performed to determine if the well casing material had a significant effect on analyte concentration. Where significant differences were found, Duncan's multiple range test was performed to determine which samples were significantly different from the controls.

Before the two experiments described previously were performed, a preliminary leaching study was conducted to determine if any substances that could interfere with the analytical determinations leached from the casing materials. For this study, two pieces of each type of well casing were placed in each of two vials. The vials were filled with fresh well water so that there was no headspace, capped and allowed to sit for one week. An aliquot was taken from each vial and analyzed. No detectable peaks were observed in any of the samples.

Results and Discussion

The data for the first experiment are summarized in Table 3, where the normalized concentrations for solutions containing well casings are given as a function of time. Neither type of stainless steel casing affected the concentrations of any of the analytes in solution. However, significant loss of solute did occur in the solutions that contained plastic casings. While the rate of loss differed dramatically from analyte to analyte, losses were always greater for PTFE than PVC.

For RDX and TNB there was no loss of analyte from solutions containing either plastic casing, even after 1000 hours. There was some loss of MNT in the sample solutions that contained PTFE casings but the loss only became significant after 1000 hours (10 percent loss); there was no loss with the PVC casings. TDCE was lost much more readily in samples containing PTFE casings than was its isomer pair, CDCE (Figure 5). (The solid lines shown in this figure and Figures 6-9 were fitted manually.) Figure 6 shows the losses of TCE for the four well casings. Figure 7 shows the rate of loss of the three DCB isomers and CLB in the samples that contained PTFE casings. The order of loss was PDCB and MDCB > ODCB > CLB. While the rate of loss did not exceed 10 percent in eight hours for any of the previous solutes, it is noted that losses of PDCB and MDCB were 16 percent in eight hours and thus were rapid enough to be of concern with respect to ground

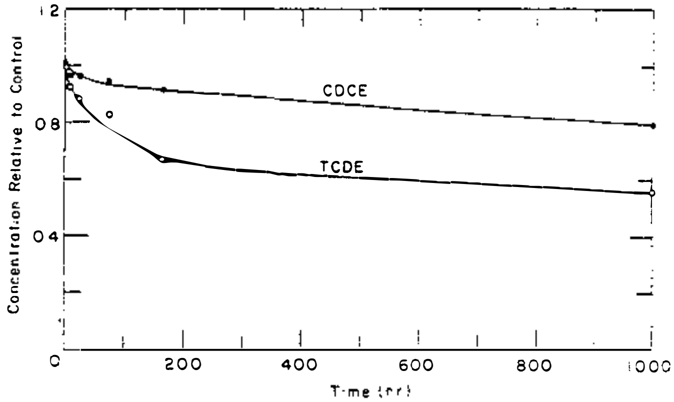


Figure 5. Sorption of CDCE and TDCE by PTFE well casings.

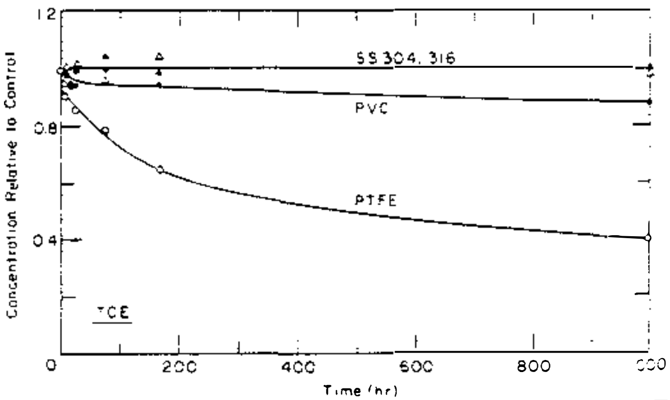


Figure 6. Sorption of TCE by the four well casing materials.

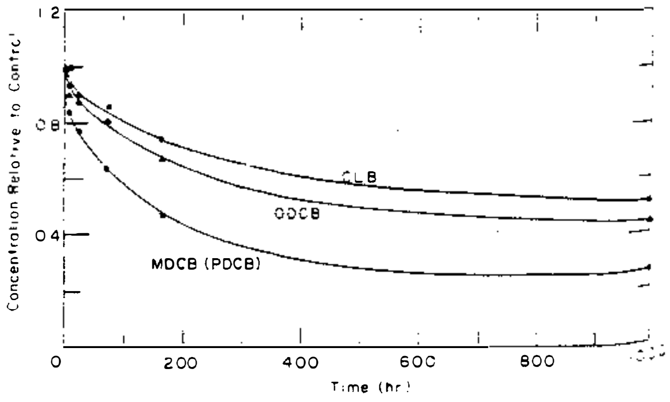


Figure 7. Sorption of CLB, ODCB, MDCB and PDCB by PTFE well casings.

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TABLE 4
Results of Desorption Study

Casing Material	Concentration in mg/L after three days equilibration									
	RDX	TNB	CDCE	TDCE	MNT	TCE	CLB	ODCB	PDCB	MDCB
Teflon	ND	ND	0.20	0.43	0.075	0.47	0.28	0.38	0.30	0.35
	ND	ND	0.21	0.45	0.076	0.48	0.28	0.35	0.34	0.36
	ND	ND	*	*	0.074	*	*	*	*	*
PVC	ND	ND	0.079	0.15	0.046	0.14	0.10	0.15	0.17	0.18
	ND	ND	0.080	0.14	0.046	0.14	0.10	0.15	0.16	0.21
	ND	ND	0.080	0.15	0.043	0.13	0.11	0.16	0.16	0.20

* Results not presented because of additional loss of volatiles, probably resulting from a loose cap on this vial.
ND = Not detected.

water monitoring. For PVC, losses never reached 0 percent in eight hours for any of the organics tested, and thus the authors believe that PVC is clearly superior to PTFE for wells where water samples will be analyzed for organic constituents.

To determine if the loss of organic solutes was reversible, the pieces of casing that had been exposed to test solution for 1000 hours were rinsed and then exposed o fresh well water for three days. Measurable quantities of all the organics were recovered where significant losses had been observed (Table 4). Thus, loss was due o sorption and was at least partially reversible. hough this experiment did not give us information the kinetics of desorption, the amount of analyte desorbed after three days generally paralleled the amount sorbed. However, PDCB and MDCB were sorbed to the greatest extent while TCE and TDCE were desorbed to the greatest extent. Therefore, it may be that diffusion out of the polymer is more rapid for maller molecules.

In the second experiment NaCl was added to raise the chloride concentration above 1000 mg/L. High chloride concentrations are known to corrode 304 stainless steel. Specifically, tests were performed to determine if rusting would alter the sorptivity of the stainless steel urfaces. It is also possible that sorption on plastic materials would change with increasing ionic strength of the test solution.

While addition of NaCl caused rapid rusting of both ainless steel casings (<24 hr), it did not cause sorption of any of the organic solutes by them. In addition, the increased ionic strength had no detectable effect on the ate of sorption by either plastic casing (for example, Figures 8 and 9). These two figures also demonstrate the excellent reproducibility of the results from these vo experiments.

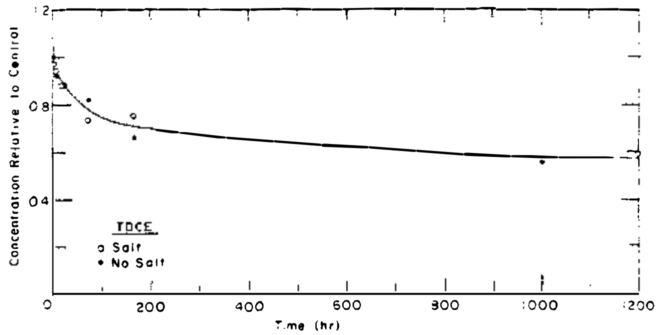

Figure 8. Sorption of TDCE by PTFE well casings in the presence and absence of salt.

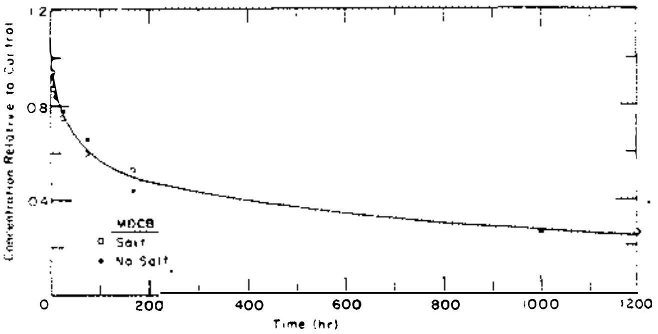

Figure 9. Sorption of MDCB by PTFE well casings in the presence and absence of salt.

deling the Sorption Process

These organic studies clearly demonstrated that the oss of organic chemicals from solutions exposed to plastic casing materials is via some reversible sorption process. However, it was uncertain whether this loss was ue to sorption on the surface or whether there was penetration into the polymer matrix. The rate of sorption was found to be slow, with no established equilibrium after hundreds of hours. One explanation for this slow rate was that penetration into the polymer was occurring, with the rate controlled by slow diffusion within the bulk polymer and/or the rate of penetration into the small pores on the polymer surface. If it is assumed that this is the case, the process can be kinetically modeled by treating the plastic casing as an immiscible liquid phase in contact with water and relating the degree of partitioning for individual analytes to their octanol/water partition coefficients (K_{ow}). While there are immiscible liquids other than octanol that are better structural models for PTFE or PVC, the most extensive collection of partition coefficients is available for octanol.

If it is assumed that sorption is a reversible process,

$$A_w \underset{k_2}{\overset{k_1}{\rightleftarrows}} A_s \ , \qquad (1)$$

and is first order in both directions, then the rate equation can be written as (Gould 1959):

$$\frac{d[A_w]}{dt} = -k_1 [A_w] + k_2 [A_s] \qquad (2)$$

where $[A_w]$ is the concentration of solute A in aqueous solution, $[A_s]$ is the concentration of solute A in the plastic casing material, and k_1 and k_2 are the first-order rate constants for sorption and desorption, respectively.

Integration of the rate equation results in a nonlinear relationship for A_w as a function of time t and two constants a and b (Equation 3), where a and b are defined in Equations 4 and 5:

$$\frac{\ln (a[A_w] + b)}{a} = t \qquad (3)$$

$$a = k_1 + k_2 \qquad (4)$$

$$b = 10k_2 [A_o] \qquad (5)$$

where A_o is the initial concentration of solute A in aqueous solution.

Optimal values for a and b were obtained for each solute exposed to PTFE by application of the Gauss-Newton method of non-linear curve fitting using the measured concentrations at 1, 8, 24, 72, 128, and 1000 hours (Parker et al. 1989). Using determined values for a and b, the authors simultaneously solved Equations 4 and 5 for each solute to obtain estimates of k_1 and k_2. Because the process described is assumed to be reversible and first order, the ratio of the rate constants, k_1/k_2, is the equilibrium constant, K_{eq}.

When the eight values of K_{eq} were plotted vs. Log K_{ow}, six of the eight points appeared to fall on a straight line, while the points for MNT and ODCB did not (Figure 10). The poor fit for MNT and the lack of significant sorption for TNB and RDX can be explained by the tendency of nitro-containing organic molecules to form strong hydrogen bonds, which keeps them in solution. While octanol can be a donor in hydrogen bonding, PTFE cannot. Thus, if the authors predict partitioning into PTFE for these molecules based on their octanol/water coefficients, the amount of sorption for these types of compounds will be overestimated.

The poor prediction for ODCB can be explained by the well-documented "ortho effect," which is a complex combination of electronic and steric interactions that often results in ortho di-substituted aromatic molecules behaving much differently than the meta- and para-isomers.

A similar model predicting the loss of analyte for PVC was not created because the percent sorbed was small when compared with the experimental error and this would produce an unacceptable degree of uncertainty in the calculated rate constants.

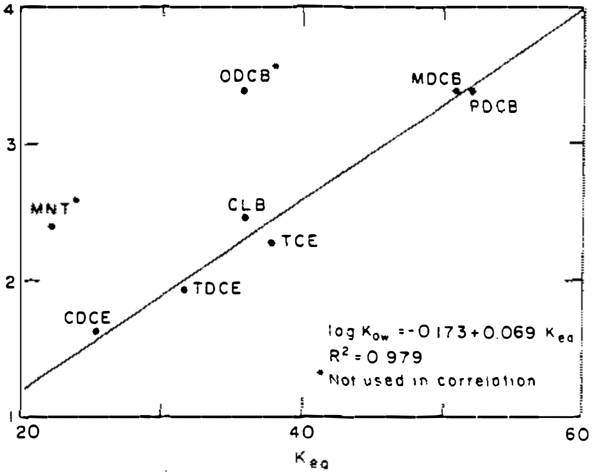

Figure 10. Correlation between log K_{ow} and K_{eq} for solutes exposed to PTFE casings.

Therefore, it is concluded that for hydrophobic organic molecules that are not subject to hydrogen bonding, the relationship presented in Figure 10 can be used to estimate the equilibrium partitioning of an analyte between the aqueous phase and PTFE. It is expected that losses in new wells would occur for some time until equilibrium with the water is achieved.

While K_{eq} will determine the equilibrium concentrations of each analyte in the water and plastic phases, it is the magnitude of k_1 that will determine how quickly various analytes are depleted. For small, planar molecules like TCE, the k_1 values are quite high compared to the other analytes. This may explain the rapid loss of tetrachloroethylene from solutions containing PTFE casings observed by Miller (1982) and Reynolds and Gillham (1986).

Because the rate of sorption appears to be first order, the relative concentration (concentration at a given time relative to its initial concentration) is independent of initial concentration (Castellan 1964). Thus, the percent loss at a given exposure time is expected to be independent of concentration, as was also predicted by the model of Reynolds and Gillham (1986). We did not confirm this, however, by conducting the test at several concentrations.

For further details on the organic portion of this study, refer to Parker et al. (1989).

Summary and Conclusions

In summary, the inorganic study indicated that three of the metals (As, Cr and Pb) were sorbed by one or more of the casing materials. Specifically, Cr was sorbed by SS 316 casings, As was sorbed by both 304 and 316 stainless steel casings, and Pb was sorbed by all four casings. On the other hand, Cd leached from the stainless steel and PVC casings, although subsequent sorption lowered concentrations in the samples containing stainless steel casings. While sorption of As was slow enough that it is probably not of concern for ground water monitoring, the changes in the Cr, Cd and Pb concentrations are of concern. Both SS 304 and 316 casings were subject to surface oxidation, presumably by galvanic action, which apparently provided active sites for sorption and release of major and minor constituents. Sorption and leaching of metal species was affected in some cases by the ground water composition (pH and organic carbon content). Specifically, there was more leaching of Cd and less sorption of Pb at the lower pH. Our results indicate that humic material may have acted as a complexing agent, making lead and chromium less prone to sorption. If chemical interactions are used as the only criterion, PTFE is clearly the best candidate for monitoring metal species in ground water. PVC would be a good second choice because its performance was considerably better than either SS 304 or SS 316 casing.

In contrast, the organic studies clearly indicated that PTFE was the poorest choice of the four well casing materials tested. PTFE casings sorbed all the chlorinated compounds and one nitroaromatic compound, and losses of PDCB and MDCB were rapid enough to be of concern for ground water monitoring. PVC casings also sorbed some of the same compounds, but always at rates that were considerably slower than those observed for PTFE casings. The rates of these losses on PVC were slow enough that they did not appear to be of concern for ground water monitoring. There was no loss of any of the organic solutes in the presence of either type of SS casing.

The desorption study showed that the loss of organics from aqueous solution is due to a sorption process that was reversible, or at least partially so. Desorption from contaminated casings could potentially result in falsely high concentrations of analytes if the ncentrations of the analytes in the ground water were to drop.

The loss of hydrophobic organic constituents in the samples containing PTFE casings could be correlated with the substance's K_{ow} values. However, this correlation overestimates losses for hydrophilic organic substances.

There are several effects that make extrapolating these test data to a real monitoring situation difficult:

- Casings were tested and not well screens. The rate of sorption could be substantially greater in the screened portions of the well because the surface area of the screened portion would be greater.
- This experiment was conducted under static conditions. The effect of sorption under real conditions would be mitigated to some degree, depending on the rate of exchange of water between the aquifer and well casing.

Clearly, choosing one casing material for samples that will be analyzed for both trace metals and organics nvolves compromise. However, based on the results of the tests that the authors have performed to date, PVC appears to be the best compromise choice of the four casing materials tested.

Future studies will examine leaching of inorganic l organic solutes, the effect of low dissolved oxygen on interactions between the metals and well casings, and the suitability of other materials for ground water monitoring.

Acknowledgments

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Biographical Sketches

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***Alan D. Hewitt** is also a research physical scientist at CRREL (72 Lyme Rd., Hanover, NH 03755-1290). He has a B.A. in chemistry from the University of New Hampshire and an M.S. in chemical oceanography from the University of Connecticut. His areas of interest are inorganic hazardous waste chemistry and the chemistry of ice and snow.*

***Thomas F. Jenkins** is a research chemist at CRREL (72 Lyme Rd., Hanover, NH 03755-1290). He received his B.S. in chemistry from the University of Missouri at St. Louis, his M.S. in chemistry at the University of Colorado, and his Ph.D. in chemistry at the University of New Hampshire. His research interest is environmental analytical chemistry.*

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TOWN OF OYSTER BAY
DEPARTMENT OF PUBLIC WORKS
150 MILLER PLACE
SYOSSET, NEW YORK 11791-5699

KARL J. LEUPOLD, P.E.
COMMISSIONER

(516) 921-7347

June 26, 1991

Ms. Carole Peterson, Chief
New York/Caribbean Superfund Branch II
Region II
26 Federal Plaza
New York, New York 10278

RE: SYOSSET LANDFILL - SECOND OPERABLE UNIT
CONTRACT NO. DPW 90-535

Dear Ms. Peterson:

In accordance with your letter of June 18, 1991 regarding the Syosset Landfill, enclosed are ten (10) copies of the Amendment to the previously submitted "Work Plan for the Second Operable Unit Remedial Investigation". This Amendment includes the modifications set fourth in your June 18, 1991 letter and per discussions at the June 4, 1991 meeting.

Upon receipt of USEPA approval for this OU2 Remedial Investigation Work Plan, we will proceed within 35 days of approval to submit for review and approval a detailed Site Operations Plan (S.O.P.), for the performance of an OU2 Remedial Investigation (RI).

The Town requests submission of any pertinent information related to the Nassau County Health Department sampling of Gas Monitoring Wells located near the ventilation trench on the South Grove School, along with ambient air sampling. This would include protocols used, test data and instrumentation used.

If you have any questions regarding this submittal, please contact Richard W. Lenz, P.E. of this office at (516) 921-7347.

Very truly yours,

KARL J. LEUPOLD, P.E.
COMMISSIONER/PUBLIC WORKS

KJL/JMB/RWL/ew
cc: Sherrel Henry, EPA
John Venditto, Esq., Town Attorney (w/a)
Robert LoPresti, Director Legislative Affairs (w/a)
Anthony Maurino, Esq., Deputy Commissioner/Env. Ctl.
✓John Lekstutis, P.E., Lockwood, Kessler & Bartlett, Inc.
Andrew Barber, Geraghty & Miller, Inc.

AMENDMENT
TO THE
WORK PLAN FOR THE
SECOND OPERABLE UNIT
REMEDIAL INVESTIGATION
AT THE
SYOSSET LANDFILL
TOWN OF OYSTER BAY, NEW YORK

Five new on-site landfill gas monitoring cluster wells will be installed at the locations shown in Figure 5 as part of the First Operable Unit (OU1) Remedial Design program. Each cluster well will consist of two wells at depths of 15 feet and 35 feet each. The cluster wells will be installed using the hollow stem auger method in a common borehole as shown in Figure 6. Each well will be constructed of two inch diameter Schedule 80 PVC well casing and screen. The screen lengths will be five feet each and the screened intervals will be separated by a bentonite seal. The five new cluster wells will be sampled during the OU1 Remedial Design program along with the 11 and 35 foot deep wells of existing cluster well CW-2 for TCL-VOC's and combustible gas on two occasions during falling barometric pressure conditions. The gas monitoring results will be identified and discussed in the Second Operable Unit Remedial Investigation Report.

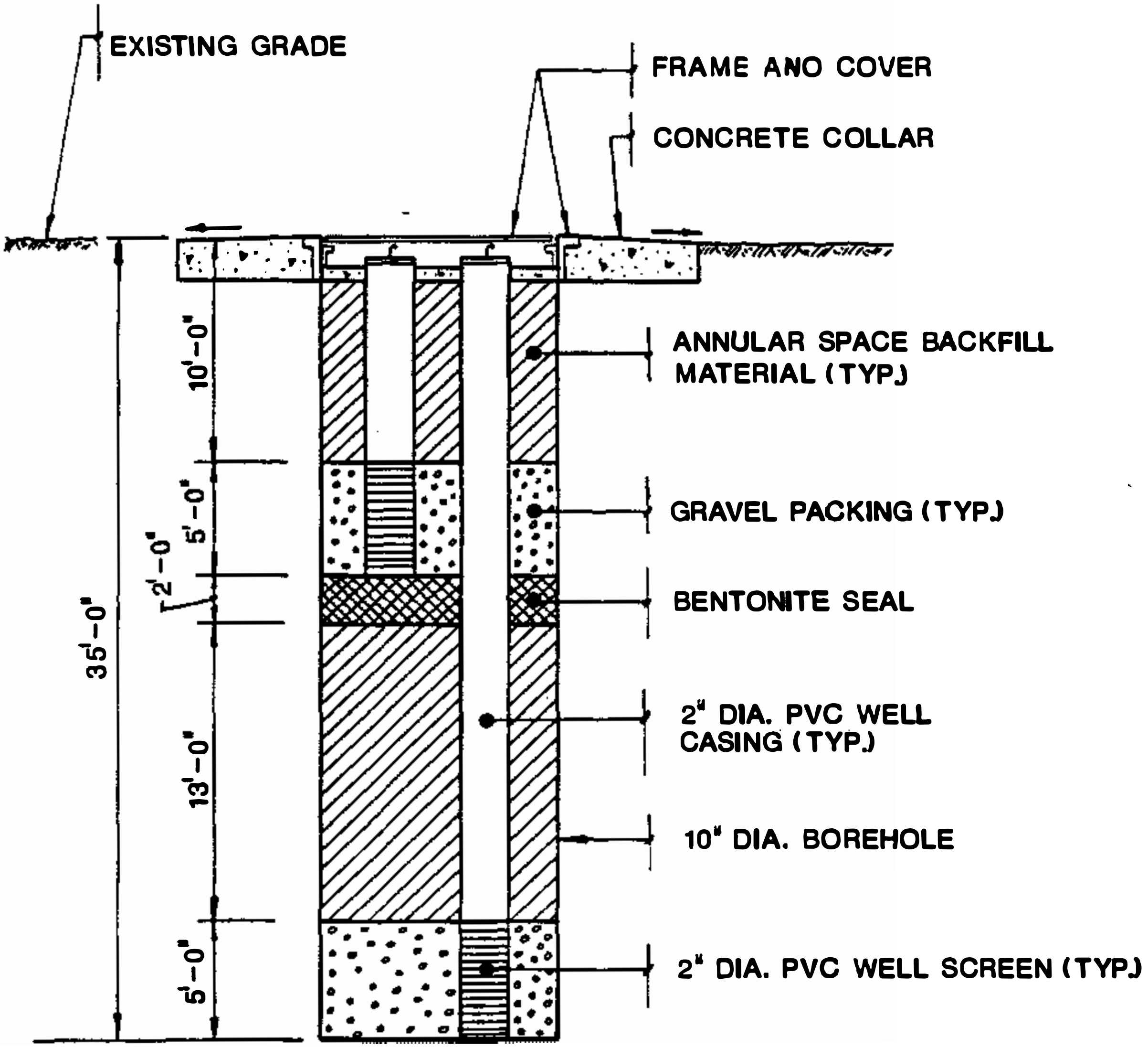

FIGURE 6

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TYPICAL LANDFILL GAS CLUSTER WELL