APPROVED

January 16, 2015

Pamela Green
Kansas Department of Health and Environment
Bureau of Environmental Remediation, Site Restoration Unit
Charles Curtis State Office Building
1000 SW Jackson Street
Topeka, Kansas 66612-1367

Re: Revised Groundwater Pilot Test Work Plan, NuStar Pipeline Release Site, Quail Crossing Neighborhood
Response to KDHE Comments
Consent Agreement and Final Order 12-E-36 BER
Andover, Kansas
1641-06

Dear Ms. Green:

On behalf of NuStar Pipeline Operating Partnership L.P. (NuStar), Apex Companies, LLC (Apex) prepared this letter in response to the Kansas Department of Health and Environment (KDHE) comments provided in a December 17, 2014 letter to NuStar. The comments pertained to the Groundwater Pilot Test Work Plan, Quail Crossing Neighborhood (Work Plan), prepared by Apex and submitted to KDHE on November 13, 2014. The Groundwater Pilot Test Work Plan was revised where appropriate, and is attached to this letter. The Work Plan was prepared as part of a continuing response to the release of gasoline from a pipeline in the Quail Crossing Neighborhood (the Neighborhood) in Andover, Kansas. KDHE comments are presented below in *Italics*, followed by NuStar's response to each comment.

1. *In Section 3.3.1, the text indicates "the extent of petroleum constituents has been defined". KDHE agrees with this statement on a broad scale but believes the extent needs to be further refined, particularly to the north. Since this is being addressed during excavation activities, no response to this comment is necessary.*

   Response: Comment acknowledged.

2. *Section 3.3.2 discusses the decreased concentrations in MW-1, MW-5, and MW-9, the general size of the dissolved phase petroleum constituents between August 2013 and August 2014, and that the reductions are due to a number of factors. KDHE recommends revising the sentence to say that "preliminary data suggests ongoing aerobic biodegradation". In addition, plume size may have reduced due to other factors, such as discontinued use of irrigation wells in the vicinity over the last year. It may be helpful to also note the increase in concentrations in MW-3 and MW-4.*

   Response: The last two paragraphs in Section 3.3.2 were revised as follows:

   The magnitude and extent of gasoline constituents in groundwater has significantly decreased since the 2012 release. In the summer of 2013, seven monitoring wells (MW-1, MW-2, MW-3, MW-4, MW-5, MW-6, and MW-9) exhibited dissolved-phase petroleum concentrations that exceeded the corresponding Tier 2 RBSVs. As of August 2014, only four monitoring wells (MW-1, MW-3, MW-4, MW-5) exhibited dissolved-phase petroleum concentrations above the corresponding Tier 2 RBSVs. Between the summers of 2013 and 2014, the benzene concentrations in groundwater at wells MW-1, MW-5, and MW-9 decreased by an average of 97 percent, and the benzene concentration in well MW-2 decreased from 0.15 milligrams per liter

(mg/L) to a non-detectable concentration. The benzene concentrations in two wells (MW-3 and MW-4) exhibited moderate increases during the same time period (benzene in MW-3 increased from 1.2 mg/L to 1.8 mg/L, and benzene in well MW-4 increased from 0.035 mg/L to 0.11 mg/L). Overall, during this period, the approximate extent of the benzene above the Tier 2 RBSV of 0.005 mg/L decreased by approximately 70 percent.

The reduced magnitude and extent of dissolved-phase petroleum constituents in groundwater, shown on Figure 5, are attributed to a number of factors, including: (1) removal of source material at the pipeline release location (during the initial response activities); (2) discontinued use of several Neighborhood irrigation wells; (3) NuStar's continuing response activities; and (4) natural attenuation processes (biodegradation, sorption, dilution, and/or volatilization). Preliminary data including dissolved oxygen and oxidation-reduction potential, methane, potassium, nitrogen, sulfate, orthosulfate, and ammonia suggest aerobic biodegradation of petroleum constituents in the subsurface is occurring at the Site. Additionally, ongoing groundwater recharge from the stormwater retention pond aids these natural attenuation processes as well.

3. *Section 3.3.3, the text states, "NuStar is implementing an ongoing, aggressive SPH removal program; therefore, additional SPH treatment is not included in the scope of this Work Plan." KDHE recognizes that NuStar plans to evaluate the need for further addressing SPH in the Corrective Action Study. No response to this comment is necessary.*

   Response: Comment acknowledged.

4. *Section 3.4 provides a list of constituents that have been detected in groundwater samples at concentrations that exceed Tier 2 Risk-Based Standards for Kansas (RSK) Screening Levels. Ethylbenzene and isopropylbenzene were omitted from the list. Please add.*

   Response: Section 3.4 was revised to include ethylbenzene and isopropylbenzene.

5. *Section 5.4 lists the parameters that will be analyzed for the groundwater sampling program in evaluating the effectiveness of enhanced aerobic bioremediation. KDHE recommends including carbon dioxide to evaluate the stimulation of microbial activity, and alkalinity to assist in evaluating the buffering capacity of the aquifer.*

   Response: The analytical program in Section 5.4 was revised to include carbon dioxide and alkalinity.

Please do not hesitate to contact me at sjackson@ashcreekassociates.com or 503-924-4704 x111 or Renee Robinson at 210-918-2975 or renee.robinson@nustarenergy.com with questions regarding these responses.

Sincerely,

Sam Jackson
Associate Engineer

Attachment: Revised Groundwater Pilot Test Work Plan

cc: Renee Robinson, NuStar Energy L.P. (electronic deliverable)

Revised Groundwater Pilot Test Work Plan
Quail Crossing Neighborhood
Andover, Kansas

Prepared for:
NuStar Pipeline Operating Partnership, L.P.

January 16, 2015
1641-06

APEX

Revised Groundwater Pilot Test Work Plan
Quail Crossing Neighborhood
Andover, Kansas

Prepared for:
NuStar Pipeline Operating Partnership, L.P.

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A ORC Advanced® Specifications

1.0 Introduction

This Groundwater Pilot Test Work Plan (Work Plan) was prepared on behalf of NuStar Pipeline Operating Partnership L.P. (NuStar) as part of a continuing response to the release of gasoline from a pipeline in the Quail Crossing Neighborhood (the Neighborhood) in Andover, Kansas. The area in the vicinity of the release, or the Site, is shown on Figures 1 and 2. This Work Plan was prepared in accordance with the Consent Agreement and Final Order (CAFO) dated May 10, 2013, and joint NuStar and Kansas Department of Health and Environment (KDHE) project discussions.

Data gathered at the Site between June 2013 and August 2014 indicate that groundwater in some Site areas contains concentrations of gasoline constituents that exceed drinking water screening levels established by KDHE; therefore, corrective action is required. The purpose of the groundwater pilot test is to evaluate a groundwater remedial technology that may be appropriate for treating groundwater at the Site as part of NuStar's continuing response.

The effectiveness and feasibility of groundwater remediation systems are contingent on a number of factors, including the type and extent of contamination, geological and hydrogeological conditions, and land and water uses in the vicinity of the affected area. Because subsurface conditions can be difficult to characterize, pilot tests are performed to evaluate a remedial technology prior to full-scale implementation. This Work Plan: (1) evaluates technologies that may be appropriate for treating groundwater at the Site; (2) recommends a preferred remedial approach; and (3) describes the scope and methods for implementing a pilot test that is intended to evaluate the actual effectiveness of the recommended remedial alternative. The pilot test will be implemented following KDHE approval. Information developed during the pilot test will subsequently be used for expanding the pilot test or implementing the selected remedial alternative, assuming the selected pilot test approach is effective.

1.1 Work Plan Organization

This Work Plan is organized as follows:

Background (Section 2) – A summary of previous investigations and remedial measures implemented at the Site.

Site Description (Section 3) – A description of the physical setting of the Site, local geology and hydrogeology, and a discussion of the nature and extent of gasoline in soil and groundwater.

Technology Screening (Section 4) – An evaluation of groundwater corrective action technologies and selection of a technology that is likely to be effective at the Site.

Pilot Test Plan (Section 5) – A presentation of the methods proposed for implementing the pilot test, including performance monitoring.

Reporting and Schedule (Section 6) – A timeline for the implementation of the pilot test, data evaluation, and reporting.

2.0 Background

The pipeline release was discovered in June 2012 after separate-phase hydrocarbons (SPH) were detected in the irrigation well at 2006 N Colt Court, Andover, Kansas. The NuStar pipeline release location was approximately 80 feet north of the affected irrigation well. Upon notification of the discovery of SPH in the irrigation well, NuStar immediately mobilized to the Site and implemented several initial response and abatement activities, including repairs to the pipeline, deactivation of the irrigation well at 2006 N Colt Court, and removal of SPH from the irrigation well.

Following the initial response activities, NuStar: (1) performed a number of interim remedial measures (IRMs); (2) planned and implemented a Comprehensive Investigation [CI]); (3) performed additional investigation to refine the understanding of petroleum constituents in vadose-zone soil; (4) designed and implemented a soil vapor extraction pilot test; and (5) implemented an ongoing groundwater monitoring program. These activities are described in detail in reports previously prepared by Apex (2014a, b, c, d, and e).

During the CI, 16 groundwater monitoring were installed at the Site, at the locations shown on Figure 2. Since installation, on a weekly basis, the monitoring wells have been gauged for the presence of SPH and to measure depth to water. On a quarterly frequency, groundwater samples have been collected from the 16 monitoring wells and approximately 17 Neighborhood irrigation wells and analyzed for dissolved-phase petroleum constituents.

Information obtained during the activities outlined above indicates that the magnitude and extent of gasoline constituents in groundwater at the Site has substantially decreased in the two years since the release occurred. For example, between the summers of 2013 and 2014, the extent of benzene in groundwater that exceeds the KDHE screening criterion has decreased by approximately 70 percent. Despite the significant reduction, gasoline constituents remain in soil and groundwater in a limited area near the pipeline release location at concentrations that exceed KDHE drinking water screening criteria.

Concurrent with preparation of this document, NuStar is developing an excavation design to address residual petroleum constituents in soil. The soil excavation design report is scheduled for submittal to KDHE in November 2014.

3.0 Site Description

The Site is located in the northern portion of the City of Andover, in Butler County, Kansas (Figure 1), approximately 1/3 mile southeast of the intersection of North 159th Street East and West 21st Street. Land use at and surrounding the Site is residential. A stormwater pond is located approximately 250 feet south of the pipeline. The stormwater pond has not been affected by the release.

Residents in the Neighborhood use municipal water for domestic purposes. In addition to the municipal water supply, some residents in the Neighborhood have irrigation water wells that are used for outdoor irrigation and landscape purposes. The irrigation wells range in total depth from approximately 80 to 116 feet below the ground surface (bgs). In most irrigation wells, the screened interval extends from total well depth to approximately 40 feet bgs; gravel filter packs typically extend from the total well depth to approximately 20 feet bgs. As part of NuStar's response, nine irrigation systems have been converted to municipal service; these converted wells/irrigation systems are shown on Figure 2.

3.1 Geology

The regional geology in Butler County consists of unconsolidated sediments, including Tertiary and Quaternary alluvium and Quaternary loess at the ground surface, overlying lower Permian limestone and shale of the Council Grove and Chase Groups (Aber, 1991). O'Connor et al. (1982) report that the uppermost bedrock unit at the Site is the Permian Wellington Formation, which reportedly consists of up to 100 feet of light gray and green silty shale, with some thin limestone and gypsum beds. The Wellington Formation is underlain by the Nolans Limestone formation, which is approximately 20 to 30 feet thick, and consists of a light-buff limestone and dolomite in the upper part.

Geological conditions at the Site are generally consistent with regional conditions, based on information presented in irrigation well construction logs (surface to 116 feet bgs) and temporary boring logs (surface to 65 feet bgs). At the Site, yellowish brown clay (loess) is generally encountered from the surface to depths of approximately 10 to 15 feet bgs. The clay is underlain by gray, yellow, and olive brown shale of the Wellington Formation; the Wellington Formation is weathered at the interface between consolidated and unconsolidated sediments. Thin layers of gypsum are occasionally encountered in the shale.

3.2 Groundwater / Aquifer Characteristics

This Section describes the regional and local groundwater conditions.

3.2.1 Regional Groundwater Conditions

The Site and surrounding area are generally flat, although regional topography slopes gently to the east, toward the Whitewater River, which is approximately 4 miles east of the Site. O'Connor et al. (1982) report

that the uppermost water-bearing unit at the Site is the Wellington Formation. The productivity and quality of water from the Wellington Formation are limited. A regional groundwater elevation map prepared by O'Connor et al. (1982) indicates that groundwater in the Wellington formation exhibits an easterly gradient (0.005 foot per foot [ft/ft]) near the Site.

O'Connor et al. also report that the shale units in southwest Butler County are relatively impermeable or of very low permeability with respect to vertical groundwater flow below approximately 50 feet.

3.2.2 Groundwater Conditions at the Site

During the most recent monitoring period (July through September 2014), depths to groundwater in monitoring wells at the Site ranged from approximately 15 to 53 feet bgs (equivalent to approximately 1298 to 1334 feet above msl). Groundwater elevations are generally highest in the vicinity of the stormwater retention pond, resulting in radial groundwater flow away from the pond. Further from the pond, in the vicinity of groundwater monitoring wells MW-4, MW-11, MW-12, MW-14, MW-15, and MW-16, groundwater exhibits a more easterly flow component and shallower gradient, consistent with regional patterns (O'Connor et al., 1982). Figure 3 shows August 2014 groundwater elevations and the inferred groundwater flow direction.

3.3 Nature and Extent of Gasoline in Soil and Groundwater

3.3.1 Soil

Data obtained from samples collected between 2012 and 2014 demonstrate that residual gasoline constituents are present in the vadose zone at depths of 7 to 18 feet bgs in the vicinity of the pipeline release location. Gasoline constituents have also been detected in soil below the vadose zone; however, the constituents in soil detected below the vadose zone are attributed to constituents in groundwater. Vadose zone soil analytical data (7 to 18 feet bgs) are summarized on Figure 4 and described in more detail in the *Soil Investigation Report and Proposed Soil Excavation Work Plan* (Apex, 2014e). As discussed in the approved Soil Investigation Report, the extent of petroleum constituents has been defined. Residual petroleum in soil will be addressed by: (1) removal and off-site disposal of affected soil; and (2) placement of oxygen-releasing compound in excavation backfill of the excavation to treat residual hydrocarbons.

3.3.2 Groundwater

The nature and extent of gasoline constituents in groundwater at the Site has been characterized based on samples collected from a network of 16 groundwater monitoring wells and 17 Neighborhood irrigation wells. During the most recent monitoring event (August 2014), four groundwater monitoring wells (MW-1, MW-3, MW-4, MW-5) exhibited gasoline constituents (gasoline-range organics [GRO], 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, benzene, naphthalene, and/or toluene) at concentrations that exceeded the

corresponding KDHE Tier 2 Risk-Based Screening Values (RBSVs) for drinking water. The highest concentrations were detected in monitoring well MW-1, which is approximately 50 feet from the pipeline release location. Groundwater data are summarized on Figure 5.

The magnitude and extent of gasoline constituents in groundwater has significantly decreased since the 2012 release. In the summer of 2013, seven monitoring wells (MW-1, MW-2, MW-3, MW-4, MW-5, MW-6, and MW-9) exhibited dissolved-phase petroleum concentrations that exceeded the corresponding Tier 2 RBSVs. As of August 2014, only four monitoring wells (MW-1, MW-3, MW-4, MW-5) exhibited dissolved-phase petroleum concentrations above the corresponding Tier 2 RBSVs. Between the summers of 2013 and 2014, the benzene concentrations in groundwater at wells MW-1, MW-5, and MW-9 decreased by an average of 97 percent, and the benzene concentration in well MW-2 decreased from 0.15 milligrams per liter (mg/L) to a non-detectable concentration. The benzene concentrations in two wells (MW-3 and MW-4) exhibited moderate increases during the same time period (benzene in MW-3 increased from 1.2 mg/L to 1.8 mg/L, and benzene in well MW-4 increased from 0.035 mg/L to 0.11 mg/L). Overall, during this period, the approximate extent of the benzene above the Tier 2 RBSV of 0.005 mg/L decreased by approximately 70 percent.

The reduced magnitude and extent of dissolved-phase petroleum constituents in groundwater, shown on Figure 5, are attributed to a number of factors, including: (1) removal of source material at the pipeline release location (during the initial response activities); (2) discontinued use of several Neighborhood irrigation wells; (3) NuStar's continuing response activities; and (4) natural attenuation processes (biodegradation, sorption, dilution, and/or volatilization). Preliminary data including dissolved oxygen and oxidation-reduction potential, methane, potassium, nitrogen, sulfate, orthosulfate, and ammonia suggest aerobic biodegradation of petroleum constituents in the subsurface is occurring at the Site. Additionally, ongoing groundwater recharge from the stormwater retention pond aids these natural attenuation processes as well.

3.3.3 Separate-Phase Hydrocarbons

Mobile SPH are limited to the area in the vicinity of the irrigation well at 2006 N Colt Court. SPH have not been observed in well MW-1, which is located 30 feet from the irrigation well at 2006 N Colt Court, and SPH have not been observed in any other irrigation wells or monitoring wells at the Site. Additionally, SPH were not encountered during installation of 13 borings in the vicinity of the release. NuStar is implementing an ongoing, aggressive SPH removal program; therefore, additional SPH treatment is not included in the scope of this Work Plan.

3.4 Groundwater Constituents of Interest

Between 2012 and 2014, the following constituents have been detected in one or more groundwater samples at concentrations that exceed KDHE Tier 2 RBSVs:

- GRO;
- 1,2,4-trimethylbenzene;
- 1,3,5-trimethylbenzene;
- Benzene;
- Ethylbenzene;
- Isopropylbenzene;
- Naphthalene; and
- Toluene.

For pilot test planning, these chemicals are considered constituents of potential concern. The pilot test will target these constituents for remediation.

4.0 Corrective Action Technology Screening

The U.S. Environmental Protection Agency (EPA, 2004) has identified a number of corrective action technologies (EPA, 2004) that, in general, can be effective for treating gasoline-impacted groundwater. These technologies, which include groundwater extraction, chemical oxidation, enhanced aerobic bioremediation, air sparging/biosparging, *in situ* groundwater bioremediation, and dual-phase extraction, are described below, along with site-specific advantages and disadvantages. In Section 4.2, these alternatives are evaluated based on: (1) demonstrated effectiveness for the constituents of interest; (2) compatibility with geological and hydrogeological conditions at the Site; and (3) compatibility with the Neighborhood setting and community concerns. Based on the results of the screening, a preferred technology is recommended for pilot testing.

4.1 Corrective Action Technologies

Corrective action technologies that may be applicable at the Site are described below.

4.1.1 Groundwater Extraction

Groundwater extraction systems include a network of extraction well(s) with submersible pumps. These systems are normally used to lower the water table, creating hydraulic gradients that direct contaminant migration into one or more extraction wells. Groundwater is pumped and discharged to a permitted facility. Groundwater extracted at the Site would likely require treatment before discharge. Groundwater extraction systems typically require a range of infrastructure, including extraction wells, pumps, piping, treatment systems, and power supply systems. Treatment duration varies, depending on the type and extent, aquifer characteristics, and system design. Monitored natural attenuation (MNA) is commonly implemented

following the groundwater extraction remedy. The requirement for significant aboveground infrastructure, including some noise-generating equipment, is a critical site-specific disadvantage because Neighborhood representatives and the residents closest to the release location have previously stated that these types of facilities are considered unacceptable to them, citing concerns about noise, emissions, and the appearance of above-ground infrastructure.

4.1.2 Dual-Phase Extraction

Dual-phase extraction, also known as multi-phase extraction, vacuum-enhanced extraction, or bioslurping, is an *in situ* technology that uses pumps to remove various combinations of contaminated groundwater, separate-phase petroleum product, and hydrocarbon vapor from the subsurface. Extracted liquids and vapor are treated and collected for disposal, or re-injected to the subsurface (where permissible). Dual-phase extraction systems can be effective in removing SPH from the subsurface, thereby reducing concentrations of petroleum hydrocarbons in both the saturated and unsaturated zones of the subsurface. Dual-phase extraction systems are typically designed to maximize extraction rates; however, the technology also stimulates biodegradation of petroleum constituents in the unsaturated zone by increasing the supply of oxygen.

Dual-phase extraction systems require significant aboveground and underground infrastructure and are most appropriate for sites with significant SPH impacts. SPH impacts at the Site are limited to a small area in the vicinity of the irrigation well at 2006 N Colt Court. The requirement for significant aboveground infrastructure, including a blower, piping, and water/vapor treatment systems, is a critical site-specific disadvantage because Neighborhood representatives and the residents closest to the release location have previously stated that these types of facilities are considered unacceptable.

4.1.3 Chemical Oxidation

Chemical oxidation involves injection of material (e.g., peroxides, permanganates, or ozone) that chemically convert gasoline constituents. Typically, oxidants are introduced to the subsurface through a network of temporary or permanent injection wells. Commonly, multiple phases of injection are required. This technology can be effective in destroying separate- and dissolved-phase hydrocarbons, although the effectiveness can be limited in low-permeability soil and in soil that contains significant organic carbon. Chemical oxidation can cause settling in organic soils. Some chemical oxidants (e.g., Fenton's Reagent) can produce explosive off-gassing. The EPA recommends against using chemical oxidants in the vicinity of petroleum underground storage tanks or pipelines due the possible adverse effects on buried infrastructure.

4.1.4 Enhanced Anaerobic Bioremediation

Enhanced anaerobic bioremediation technologies are similar to aerobic bioremediation technologies in that one or more substances (e.g., lactic acid, molasses, high fructose corn syrup, propionate, and butyrate) are

introduced to the subsurface to stimulate anaerobic microbial degradation processes. Substances can be introduced through permanent injection points (e.g., monitoring wells) or temporary borings. The fundamental difference between enhanced aerobic and enhanced anaerobic bioremediation is that anaerobic bioremediation relies on the absence of oxygen. Enhanced anaerobic bioremediation is rarely implemented at petroleum hydrocarbon sites because anaerobic processes are generally slower than aerobic processes, resulting in a longer remediation timeframe. Another significant disadvantage is that methane is a byproduct of anaerobic biodegradation, and accumulation of methane in the subsurface is not compatible with the Neighborhood setting.

4.1.5 Enhanced Aerobic Bioremediation

Enhanced aerobic bioremediation technologies are used to accelerate naturally occurring *in situ* bioremediation of petroleum hydrocarbons by indigenous microorganisms in the subsurface. These technologies work by providing a supplemental supply of oxygen to the subsurface, which becomes available to aerobic, hydrocarbon degrading bacteria (EPA, 2004). Enhanced aerobic bioremediation offers several advantages, including: (1) it produces no significant waste (off-gases or fluid discharges); (2) it causes minimal disturbance; (3) it destroys the contamination in place; (4) it is potentially more reliable than other, more active remedial technologies (e.g., groundwater extraction and treatment); and (5) it can be used in tandem with other remedial technologies to address soil and groundwater contamination. Some disadvantages of enhanced aerobic bioremediation include: (1) it may have a longer remedial time frame than other more aggressive approaches; (2) it typically requires long-term groundwater monitoring; and (3) it often must be accompanied by other technologies (e.g., SPH recovery) to address source areas. Groundwater data collected at the Site indicate that oxygen levels in groundwater are relatively low in areas with dissolved-phase petroleum constituents, suggesting that oxygen concentrations in groundwater at the Site may be a limiting factor in microbial degradation of petroleum hydrocarbons at the Site. Three enhanced aerobic bioremediation technologies are discussed below.

<u>Air Sparging/Biosparging.</u> Air sparging is a remedial technology that involves the injection of contaminant-free air into the subsurface saturated zone. The air is then vented through the unsaturated zone. Air sparging can treat volatile constituents in groundwater through two processes: (1) it enables a phase transfer of hydrocarbons from a dissolved state to a vapor phase; and (2) it provides oxygen that can stimulate biodegradation of petroleum hydrocarbons. Air sparging normally occurs through a network of sparging wells that are distributed throughout the treatment area and connected through a network of aboveground or underground piping. Air is provided to the sparging points by a blower, typically housed in a remediation building. A soil vapor extraction system is commonly installed concurrent with an air sparging system, to capture fugitive vapors. Soil vapor extraction systems also normally include a network of extraction wells that are connected through a network of aboveground or underground piping. Vacuum is induced to the soil vapor extraction system by a blower, which is typically housed in in a remediation building.

Air sparging equipment is readily available and treatment can be rapid under optimal conditions. Some of the disadvantages of air sparging are that it can result in complex physical, chemical, and biological interactions that limit its effectiveness, it can induce migration of constituents, and effectiveness can be limited in stratified soils. A critical site-specific disadvantage is that air sparging requires significant aboveground infrastructure, particularly when combined with a soil vapor extraction system. These systems generate noise (although it can be mitigated) and require protective structures. As previously discussed, Neighborhood representatives and the residents closest to the release location have previously stated that these types of aboveground facilities are considered unacceptable.

Pure Oxygen Injection. Injecting pure oxygen into groundwater can be a relatively efficient means of increasing dissolved oxygen levels in groundwater to promote aerobic biodegradation of petroleum hydrocarbons. In contrast to oxygen releasing compounds, there is no carrier (e.g., calcium peroxide) or delivery media associated with pure oxygen injection. Oxygen is several times more soluble in groundwater when it is introduced in pure form than if the oxygen is derived from atmospheric air (EPA, 2004). One common pure oxygen injection system, the iSOC® System, injects pure oxygen into groundwater via infusers that are deployed in groundwater wells. The iSOC® unit saturates the treatment well with dissolved oxygen, which disperses around the well into the adjacent groundwater. The system requires an oxygen source, which generally consists of compressed oxygen cylinders that are deployed adjacent to injection wells. The expected radius of influence (ROI) for an iSOC® unit in a groundwater well at the Site is in the range of 5 to 10 feet, although the actual ROI is dependent on the permeability of the water-bearing zone and rates of groundwater advection, diffusion, and dispersion. Some benefits of pure oxygen injection are safety (e.g., no off-gassing), no electricity/power source needed, and relatively low capital and operating costs. Some limitations of pure oxygen injection include the need for aboveground infrastructure (e.g., oxygen cylinders at injection locations), requirement for frequent replacement of oxygen cylinders, and reliance on groundwater advection, dispersion, and diffusion.

Oxygen Releasing Compounds. Various enhanced aerobic bioremediation approaches rely on oxygen releasing compounds to remediate petroleum contamination (EPA, 2004). Commonly, calcium and magnesium peroxides are introduced to the saturated zone in a solid or slurry phase. Oxygen releasing compounds can be introduced into the subsurface using several methods, including placing the compounds into drilled wells or excavations, injecting a slurry into direct-push borings, mixing into excavation backfill, and suspending oxygen releasing compounds in “socks” in groundwater monitoring wells. Oxygen releasing compounds offer the benefits of treating contamination in saturated and unsaturated soil, safety (e.g., no off-gassing), no electricity/power source needed, and relatively low capital and operating costs. The effectiveness of oxygen releasing compounds can be limited due to reliance on groundwater advection, dispersion, and diffusion, and multiple applications can be required.

4.2 Technology Screening

The corrective action technologies described in Section 4.1 are summarized in Table 1. The technologies are screened below to select a technology that is compatible with Site conditions and warrants pilot testing.

Broadly, the corrective action technologies described in Section 4.1 fall into two categories: (1) technologies that rely on significant aboveground infrastructure, such as blowers, piping, electrical power supplies, water and vapor treatment systems, and structures; and (2) technologies that do not rely on aboveground infrastructure, and instead, can be implemented through the injection of substances into the subsurface that stimulate biodegradation or have oxidizing effects, ultimately causing the remediation of petroleum hydrocarbons.

4.2.1 Technologies That Require Aboveground Infrastructure

The following technologies may be effective at the Site; however, all require significant aboveground infrastructure, including blowers, power supplies, piping, and groundwater/vapor treatment systems:

- Groundwater extraction,
- Air sparging/biosparging, and
- Dual-phase extraction.

Neighborhood representatives and the residents closest to the release location have previously stated that the aboveground infrastructure required for these technologies is unacceptable, citing concerns about noise, emissions, and appearance. Therefore, these technologies are considered incompatible with the Neighborhood and are not further evaluated.

4.2.2 Other Technologies

The following technologies require very little to no permanent aboveground infrastructure:

- Chemical oxidation;
- Enhanced anaerobic bioremediation;
- Enhanced aerobic bioremediation using oxygen-releasing compounds; and
- Enhanced aerobic bioremediation using pure oxygen.

<u>Chemical Oxidation.</u> Chemical oxidation is normally performed through the injection of oxidizers to the subsurface through temporary or permanent injection points. Chemical oxidation is considered incompatible with the Neighborhood because it can lead to accumulation of explosive gases and damage to underground utilities, including the NuStar pipeline.

<u>Enhanced Anaerobic Bioremediation.</u> Enhanced anaerobic bioremediation is normally performed through the injection of one or more nutrients to the subsurface through temporary or permanent injection points,

leading to removal of oxygen from the subsurface, and stimulating anaerobic processes. Enhanced anaerobic bioremediation is not a preferred technology because it is less effective than aerobic bioremediation and it can lead to the accumulation of methane in the subsurface.

Enhanced Aerobic Bioremediation. Enhanced aerobic bioremediation, using oxygen-releasing compounds or using pure oxygen, are preferred approaches for the Site because both:

- Do not require any significant, permanent aboveground infrastructure;
- Are safe and compatible with the Neighborhood;
- Are effective for the constituents of interest;
- Do not generate noise or off-gassing;
- Are compatible with planned concurrent soil corrective action efforts; and
- Are readily scaled up for full-scale corrective action.

While both enhanced aerobic bioremediation technologies are expected to be similarly effective, enhanced aerobic bioremediation using pure oxygen is considered more difficult to implement and less acceptable to the Neighborhood because this approach would require the construction of multiple underground oxygen tank storage vaults in the Neighborhood. The construction of the vaults would cause some temporary disturbance and the long term storage of compressed oxygen tanks (approximately 12 months) would pose a potential safety concern in a residential setting.

Enhanced aerobic bioremediation using oxygen releasing compounds is the remedial approach that is most likely to be effective and compatible with Neighborhood concerns because: (1) the technology has been successfully implemented at numerous other sites; (2) it can be implemented with minimal disturbance to the Neighborhood; (3) no permanent infrastructure is necessary, with the exception of monitoring points, and (4) there are no associated safety concerns. The proposed approach for implementing a pilot test using oxygen releasing compounds is presented below.

5.0 Groundwater Pilot Test

A variety of oxygen releasing compounds were considered for pilot testing (e.g., Oxygen Release Compound [ORC®], Advanced Formula Oxygen Release Compound [ORC Advanced®], PermeOx Plus®, and O-SOX™). ORC Advanced®, a calcium oxy-hydroxide, which produces a controlled release of molecular oxygen into groundwater, was selected for the Site because it is a safe food-grade compound that has a long track record of success at sites throughout the U.S. and it is available in a number of forms (slurry, pellets, or "socks" that are deployed in wells), allowing flexibility in pilot test and remediation design. ORC Advanced®, like most must substances intended to enhance aerobic bioremediation, normally must be

injected two or more times at a target location to sufficiently stimulate aerobic biodegradation. ORC Advanced® specifications are included in Appendix A.

ORC Advanced® can be introduced to the subsurface via temporary injection points or permanent monitoring wells. Both temporary injection points and permanent monitoring wells are installed using similar drilling equipment. The benefit of temporary injection points is that no permanent features remain at the Site following each injection phase.

Based on Neighborhood feedback, NuStar understands that a minimum number of permanent monitoring and injection wells are desired. Accordingly, the benefits of utilizing temporary injection borings for ORC Advanced® outweigh the drawbacks. Therefore, the pilot test will rely on temporary injection borings for introduction of ORC Advanced® to the subsurface.

Permanent monitoring points are required to evaluate the effectiveness of the pilot test; therefore, three monitoring wells will be installed as part of the pilot test. The monitoring wells will be installed in the City of Andover right-of-way, approximately at the locations shown on Figure 6.

Details of the proposed test are presented below. A Quality Assurance Project Plan (QAPP), Health and Safety Plan (HASP), and Analytical Laboratory Quality Assurance Manual were previously provided to KDHE.

5.1 Pilot Test Location

The proposed pilot test will be performed hydraulically downgradient from the pipeline release location and planned soil excavation, as shown on Figure 7. The pilot test location was selected because: (1) the test area is representative of Site-wide geological conditions; (2) gasoline concentrations in the test area are elevated; (3) groundwater levels and gradient in the test area are relatively stable; (4) dissolved oxygen concentrations in the test area (e.g., well MW-1) are below the aerobic threshold; and (5) the pilot test injection borings and monitoring wells can be installed in the NuStar pipeline easement.

5.2 Pilot Injection Boring and Monitoring Well Locations and Purpose

The pilot test will consist of advancement of borings at 12 locations. ORC Advanced® will be introduced in nine temporary borings. Three of the borings will be completed as monitoring wells to evaluate pilot test performance.

5.2.1 Injection Wells

Nine temporary injection borings (IB-1 through IB-9) will be advanced at the locations generally shown on Figure 2, and depicted in detail on Figure 6. The temporary Injection borings will be used to inject ORC Advanced® into the saturated zone and introduce oxygen to the aquifer.

5.2.2 Monitoring Wells

Monitoring wells MW-17 through MW-19 will be installed at locations north and east of the injection wells to monitor groundwater quality and assess the performance of ORC Advanced®. The proposed wells are in positions inferred to be hydraulically downgradient of the injection area. Other, previously installed, monitoring wells in the vicinity of the injection area (e.g., monitoring wells MW-1, MW-4, MW-5, and MW-11) will also be used to monitor groundwater conditions.

5.3 Pilot Test Injection Boring and Monitoring Well Installation Procedures

Soil borings will be advanced to approximately 40 feet bgs at 12 locations, using sonic drilling equipment. ORC Advanced® will be injected in nine of the borings, and immediately thereafter, the injection borings will be decommissioned. Three of the borings will be completed as monitoring wells (MW-17 through MW-19). The following sections briefly describe the methods to be used for drilling, soil logging, and pilot test well construction.

5.3.1 Drilling

The borings will be completed using sonic drilling equipment. Sonic drilling equipment is proposed because it has the capability to penetrate the dense soil and weathered bedrock at the Site and tooling is available for pressurized injection of ORC Advanced®.

The borings will be advanced to depths approximately 10 feet below first encountered groundwater. Based on groundwater gauging in monitoring wells MW-1, MW-4, and MW-5, near the pilot test location, the groundwater is anticipated to be encountered at approximately 30 feet bgs.

5.3.2 Soil Logging

Continuous soil samples will be collected from the borings to confirm hydrogeological conditions. Soil conditions will be logged in general accordance with ASTM 2487/2488.

5.3.3 Pilot Test Well Construction

Pilot test monitoring wells will be installed in accordance with KDHE SOP BER-06 – Installation of Monitoring Wells. In general, a 2-inch-diameter pilot test well, constructed using Schedule 80 polyvinyl

chloride (PVC) casing and screen, will be installed in each boring. It is anticipated that the pilot test monitoring wells will include 15-foot screen intervals that intersect the water table. Based on the anticipated depth to groundwater (approximately 30 feet), the monitoring wells will be screened between approximately 25 and 40 feet bgs. Actual well construction details will be determined based on field observations. If field observations suggest that the bottom of the well screen should be placed at a depth shallower than the base of the boring, the excess boring interval will be backfilled with bentonite grout, overlain by two feet of silica sand. Silica sand will be placed in the screen interval annular space and two feet above the screen. Bentonite grout will be emplaced in the annular space from the top of the sand pack to approximately one-foot bgs. The pilot test wells will be completed at the ground surface in flush-mount traffic-rated monuments. A well completion record (WWC-5) will be completed for each well and submitted to KDHE.

5.3.4 Pilot Test Well Development

The pilot test wells will be allowed to set for at least 24 hours prior to initiating well development. Wells will be developed by over-pumping and surging to remove excess turbidity and improve hydraulic communication with the adjacent water-bearing zone.

5.3.5 Pilot Test Well Location Control

The horizontal locations of temporary borings and the pilot wells will be surveyed by a Kansas-licensed land surveyor. The top-of-well casing and cap elevations for monitoring wells will also be measured to the nearest hundredth of a foot, relative to mean sea level.

5.3.6 Quality Assurance and Quality Control

Quality assurance / quality control (QA/QC) procedures that will be used throughout this project, including during drilling, groundwater sampling, and ORC Advanced® injection, will be implemented consistent with KDHE policy and the previously approved QAPP.

5.3.7 Investigation-Derived Waste

Investigation-derived waste (IDW) will consist of soil cuttings, excavated soil from well monument construction, decontamination water, purge water, and personal protection equipment (PPE). Soil and water IDW will be placed in drums or bins. Water IDW will be removed from container(s) via vacuum truck and disposed of appropriately. Soil containers will be properly labeled with the project name, general contents, and date. The soil will be profiled and transported to an appropriate facility for disposal upon approval. PPE will be disposed of as unregulated solid waste.

5.4 Groundwater Sampling and Analytical Program – Baseline Conditions

No sooner than 48 hours after development of monitoring wells MW-17 through MW-19, baseline groundwater samples will be collected from wells MW-1, MW-4, MW-5, and MW-17 through MW-19. The baseline sampling program is intended to evaluate aquifer conditions prior to implementation of the pilot test. Baseline data will provide a basis for subsequent evaluation of pilot test data. General water quality parameters (e.g., dissolved oxygen, ORP, temperature, conductivity, and pH) will be measured during groundwater sampling activities.

Groundwater samples will be submitted to an accredited analytical laboratory for the following analyses:

- GRO by Iowa Method OA-1;
- VOCs by EPA Method 8260B;
- Methane by method RSK-175;
- Potassium and iron by EPA Method SW6020;
- Nitrogen as nitrate, sulfate, and dissolved orthophosphate by EPA Method E300.0;
- Alkalinity by EPA Method 310.1;
- Carbon dioxide by Standard Method (SM) 9060A; and
- Ammonia by SM 4500.

The GRO and VOCs analyses are intended to evaluate pre-test constituent concentrations in groundwater. The other analyses are intended to provide baseline data for subsequent evaluation of the effectiveness of ORC Advanced® for stimulating biodegradation.

5.5 Pilot Test Implementation

Following baseline sampling, ORC Advanced® will be injected at locations IB-1 through IB-9 using direct-injection techniques. ORC Advanced® will be mixed with water to form an injectable slurry (approximately 1.5 gallons of water per 10 pounds of ORC Advanced®) which is then pressure injected (using an above-ground pump) into the saturated zone. Mixing of the solution will occur on-site and will be injected within 30 minutes after preparing the slurry.

For the typical injection point, approximately 142 gallons of slurry will be injected from ten feet above to ten feet below the approximate groundwater elevation; this vertical profile is anticipated to accommodate seasonal groundwater fluctuations at the Site. This volume is expected to initially affect an aquifer area on the order of 63 cubic feet surrounding each injection point. Assuming a porosity of 0.3, which is common for shale, this volume equates to an approximate radius of approximately 1.0 foot surrounding the injection location. The total slurry volume injected will be approximately 1,280 gallons. Once in the aquifer, ORC

Advanced® will produce a controlled-release of oxygen that is expected to affect a significantly larger area. The controlled release is expected to last for approximately nine months.

5.5.1 Performance Monitoring

Starting one month after introduction of ORC Advanced® to the subsurface, groundwater quality will be monitored at monitoring wells MW-1, MW-4, MW-5, and MW-17 through MW-19. Monitoring will be performed on a bi-monthly (once every other month) schedule for approximately 12 months, although the duration and frequency of monitoring may be modified based on monitoring results. Performance monitoring will consist of the measurement of general water quality parameters (e.g., dissolved oxygen, ORP, temperature, conductivity, and pH) and collection and analysis of groundwater samples for the analyses listed in Section 5.4. When possible, the performance monitoring program described above will be performed concurrently with the routine site-wide quarterly groundwater monitoring.

5.5.2 Data Analysis and Performance Evaluation

Groundwater chemical analytical data collected during the pilot test will be used to evaluate the effects of ORC Advanced® on groundwater quality in the pilot test area. The fundamental goal of the testing is to determine if the introduction of ORC Advanced® significantly stimulates microbial degradation of petroleum constituents in groundwater. In addition to addressing this fundamental question, data from the pilot test will be used to: (1) assess the effects of oxygen introduction on microbial degradation processes, (2) estimate the radius of influence of ORC Advanced® at the injection area; and (3) optimize future applications of ORC Advanced®, if warranted. These conclusions will be used to determine if ORC Advanced® is effective and feasible for full-scale implementation, and if so, to expand the pilot test or to optimize and design a full-scale system.

6.0 Reporting and Schedule

The initial phase of the groundwater pilot test (i.e., injection of ORC Advanced® through temporary borings and installation of monitoring wells) will be implemented within 90 days of KDHE's approval of this Work Plan, barring delays beyond the control of NuStar. We anticipate that well drilling, construction, development, baseline testing, and introduction of ORC Advanced® will require approximately two weeks.

An Interim Groundwater Pilot Test Implementation Report will be submitted to KDHE approximately six months after ORC Advanced® is introduced to the aquifer. The interim report will document the pilot test well installation methods and observations, ORC Advanced® injection details, and groundwater chemical analytical data collected during the initial six months of the pilot test. The interim report will include preliminary conclusions about the effectiveness of ORC Advanced®. If data collected during the initial six months are sufficient to draw final conclusions about the effectiveness of ORC Advanced®, the interim report

will be issued as a final pilot test evaluation report. If issued in final format, the report will include recommendations for full-scale application of ORC Advanced®, or recommendations for other approaches for addressing gasoline constituents in groundwater.

A Final Pilot Test Implementation Report will be submitted to KDHE approximately 60 days after conclusion of the pilot test and receipt of final analytical data. The final report will include a compilation and evaluation of analytical data, including levels of dissolved oxygen in groundwater, indications of microbial activity, and gasoline constituent concentration trends. These data will be used to draw conclusions about the effectiveness of ORC Advanced® at the Site. If ORC Advanced® is determined to be effective and suitable for full-scale application, the report will include general design criteria for full-scale application as an IRM, including ORC Advanced® introduction methodology, injection point locations and spacing, ORC Advanced® replacement interval, a proposed monitoring program, and schedule. In the event that full-scale implementation is proposed, NuStar will coordinate with KDHE and Neighborhood representatives regarding design, implementation, and schedule.

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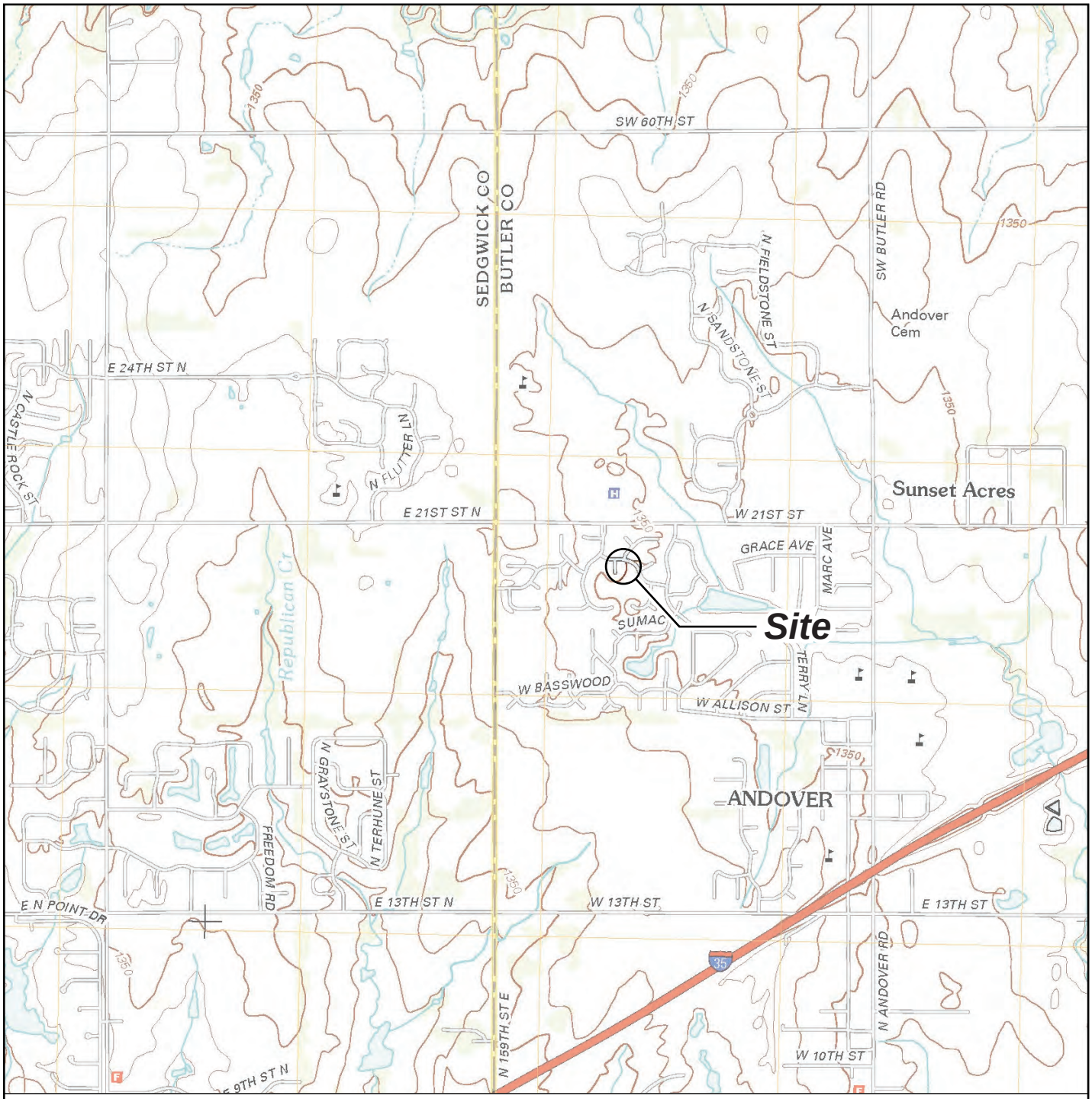
Table 1
Technology Screening
Andover Colt Court Release Site
Andover, Kansas

General Response Action	Technology	Description	Screening Comments
IN SITU BIOLOGICAL TREATMENT	Bioremediation	Adding nutrients, electron donors/acceptors, selected microbial cultures, or other amendments, via wells or temproary injection points, to enhance bioremediation.	Produces no significant waste (off-gases or fluid discharges). Causes minimal disturbance. Destroys the contamination in place. May have a longer remedial time frame than other more aggressive approaches. Typically requires long-term groundwater monitoring.
	Oxygen Releasing Compounds	Oxygen releasing compounds are added to the subsurface, through wells or temporary injection points, to enhance bioremediation of petreoleum hydrocarbons.	Produces no significant waste (off-gases or fluid discharges). Causes minimal disturbance. Destroys the contamination in place. May have a longer remedial time frame than other more aggressive approaches. Typically requires long-term groundwater monitoring.
	Oxygen Injection	Pure oxygen is injected into groundwater via infusers installed in wells, to stimulate aerobic biodegradation of petreoleum hydrocarbons.	Produces no significant waste (off-gases or fluid discharges). Destroys the contamination in place. May have a longer remedial time frame than other more aggressive approaches. Requires some aboveground infrastructure (oxygen cyclinders and tubing). Typically requires long-term groundwater monitoring.
	Monitored Natural Attenuation	Using natural processes to reduce contaminant concentrations to acceptable levels.	May be effective; however, KDHE policy genrally requires more active remediation prior to implementation of MNA.
IN SITU PHYSICAL/ CHEMICAL/ THERMAL TREATMENT	Chemical Oxidation	Mix reagent into the groundwater to chemically convert hazardous contaminants to less toxic compounds by oxidation.	Effective on constituents of interest. Some implementation risk due to buried utilities and nearby dwellings. Effectiveness can be limiited in low permeability soil and in organic-rich soil. Settling can occur in organic soils. Some chemical oxidants (e.g., Fenton's Reagent) can produce explosive off-gassing.
	Air Sparging/Bio-Sparging	Inject air into groundwater to transfer constituents from the dissolved phase to vapor phase and addition of oxygen to groundwater to stimulate biodegradation.	Requires significant infrastructure, which might include pumps, piping, and power supply systems. Neighborhood representatives and the residents closest to the release location have previously stated that the aboveground infrastructure required for this technology is unacceptable. Treatment duration varies, depending on the magnitude and extent of impacts, aquifer characteristics, and system design.
EX SITU PHYSICAL/ CHEMICAL/ THERMAL TREATMENT	Groundwater Extraction	Groundwater is extracted using a network of pumps in extraction wells. Extracted groundwater is treated and discharged to an appropriate receiving faciity.	Requires significant infrastructure, including extraction wells, pumps, piping, treatment systems, and power supply systems. Neighborhood representatives and the residents closest to the release location have previously stated that the aboveground infrastructure required for this technology is unacceptable. reatment duration varies, depending on the magnitude and extent of impacts, aquifer characteristics, and system design. Follow-up treatment is often necessary.
	Dual-phase Extraction	An in-situ technology that uses pumps to remove various combinations of contaminated groundwater, separate-phase petroleum product, and hydrocarbon vapor from the subsurface.	Requires significant of infrastructure, including extraction wells, pumps, piping, vapor and water treatment systems, and power supply systems. Most effective on SPH-impacted sites; very limited extent of SPH on Site. Neighborhood representatives and the residents closest to the release location have previously stated that the aboveground infrastructure required for this technology is unacceptable.



Note: Base map prepared from USGS 7.5-minute quadrangles of Andover, KS, dated 2012 as provided by USGS.gov.

0 2,000 4,000

Approximate Scale in Feet

KANSAS

N

Site Location Map

Groundwater Pilot Test Work Plan
NuStar Pipeline Operating Partnership L.P.
Andover, Kansas

APEX Apex Companies, LLC 3015 SW First Avenue Portland, Oregon 97201	Project Number	1641-06	Figure
	November 2014		1

N

Legend:

- MW-1 Monitoring Well Location
- Irrigation Well
- P-1 Soil Vapor Monitoring Point
- B-1 Boring Location
- Property Line
- Pipeline
- Pipeline Easement Boundary
- HOA Lot Owned by Quail Crossing Homeowner's Association
- Deactivated Irrigation Well
- Excavation Area

0 100 200

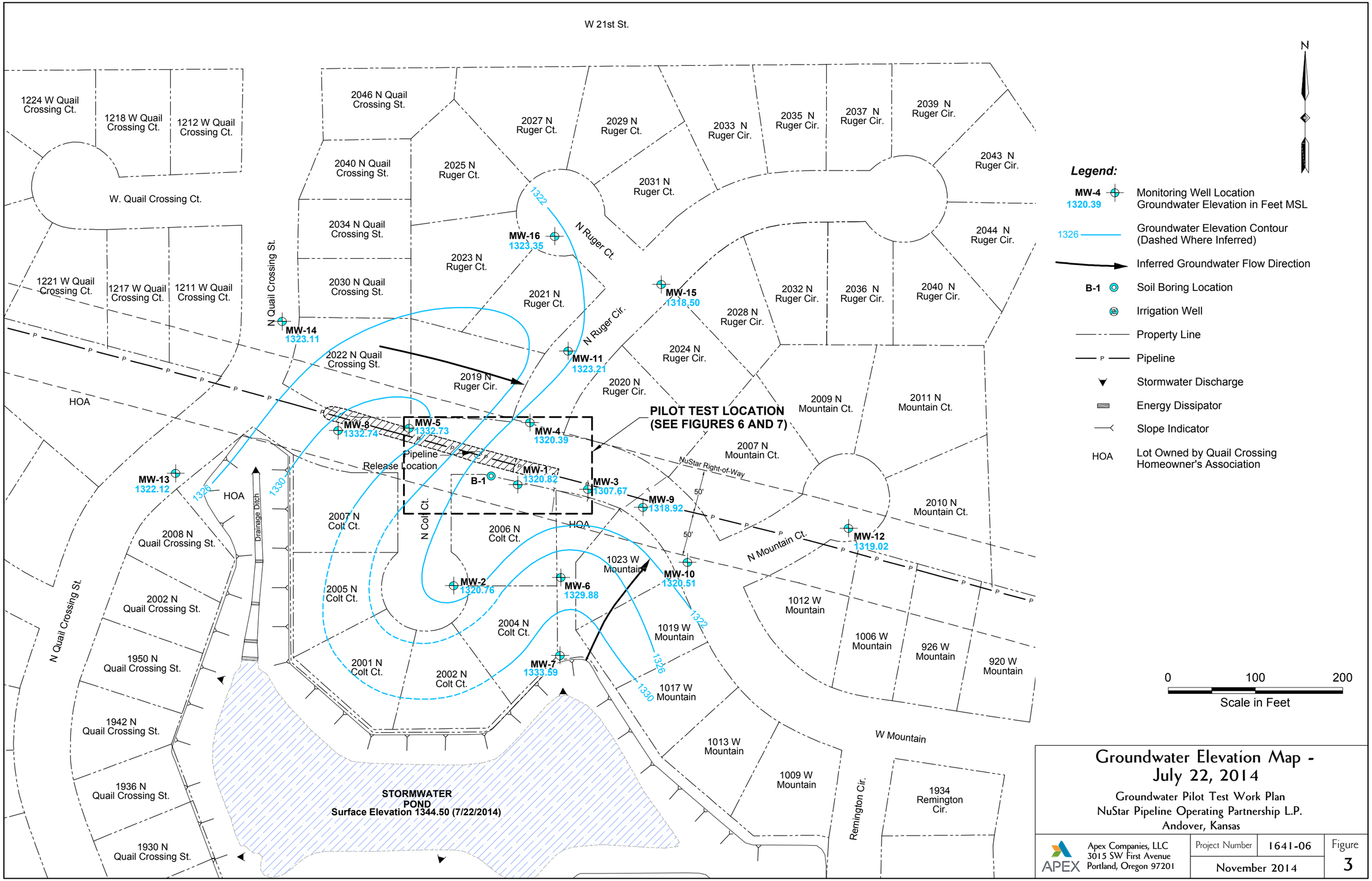
Scale in Feet

Site Plan and Pilot Test Location Map

Groundwater Pilot Test Work Plan
NuStar Pipeline Operating Partnership L.P.
Andover, Kansas

Apex Companies, LLC
3015 SW First Avenue
Portland, Oregon 97201

Project Number	1641-06	Figure
November 2014		2

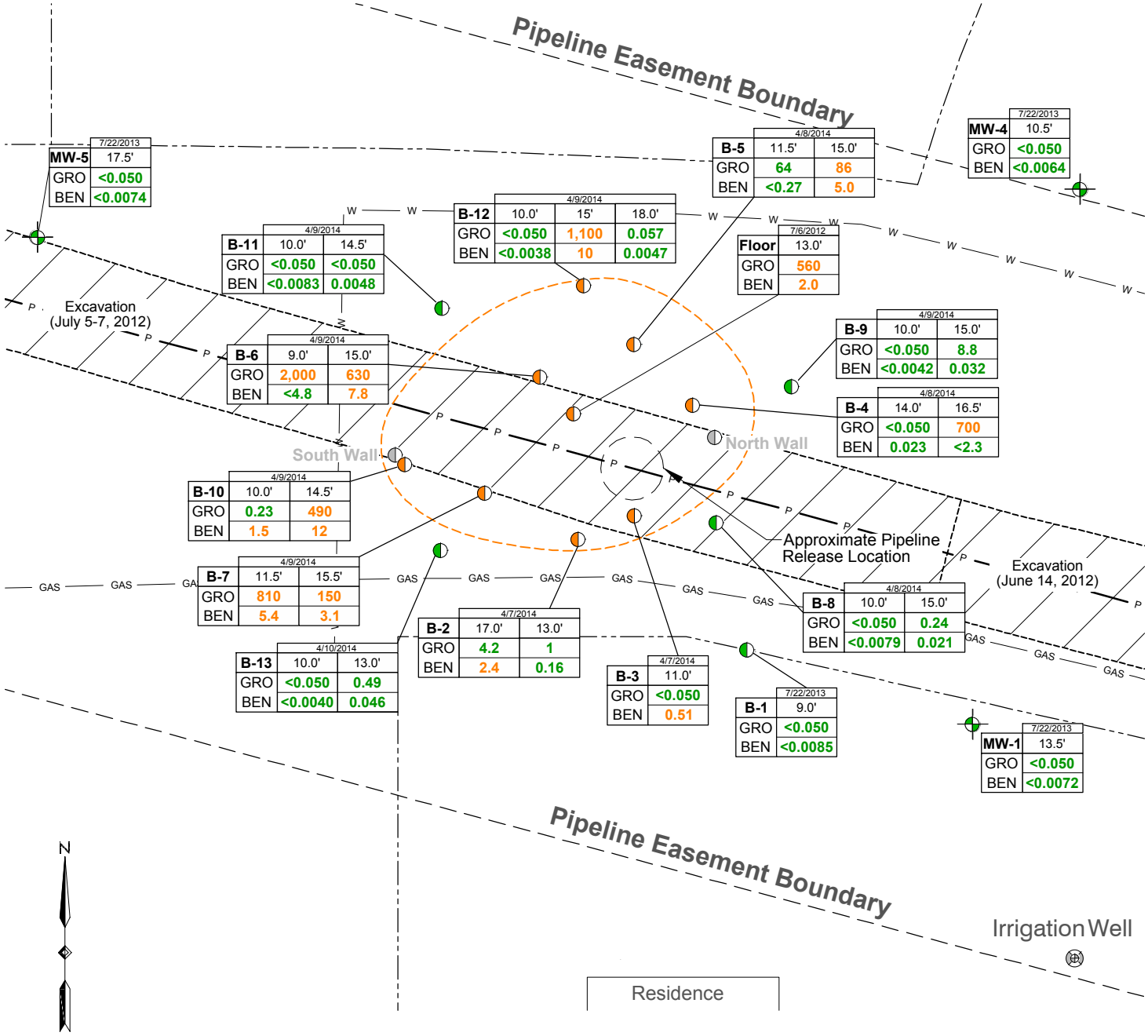


Groundwater Elevation Map - July 22, 2014

Groundwater Pilot Test Work Plan
NuStar Pipeline Operating Partnership L.P.
Andover, Kansas

Apex Companies, LLC
3015 SW First Avenue
Portland, Oregon 97201

Project Number	1641-06	Figure
November 2014		3



Legend:

- **MW-1** Monitoring Well Location
- **B-1** Boring Location
- Irrigation Well
- Property Line
- Pipeline
- Pipeline Easement Boundary
- Approximate Gas Line
- Approximate Water Line
- Dissolved-Phase Constituent Concentrations > KDHE Tier 2 RBSVs
- Dissolved-Phase Constituent Concentrations Not Detected or < KDHE Tier 2 RBSVs

B-13	4/10/2014 10.0'
GRO	<0.050
BEN	<0.0040

- Sample Date
- Sample Depth (Feet)
- Concentration in mg/kg
- Analyte Sampled

Extent of Petroleum Constituents in Soil > KDHE Tier 2 RBSVs

Abbreviations	
GRO	Total Petroleum Hydrocarbons Gasoline-Range
BEN	Benzene

0 20 40

Scale in Feet

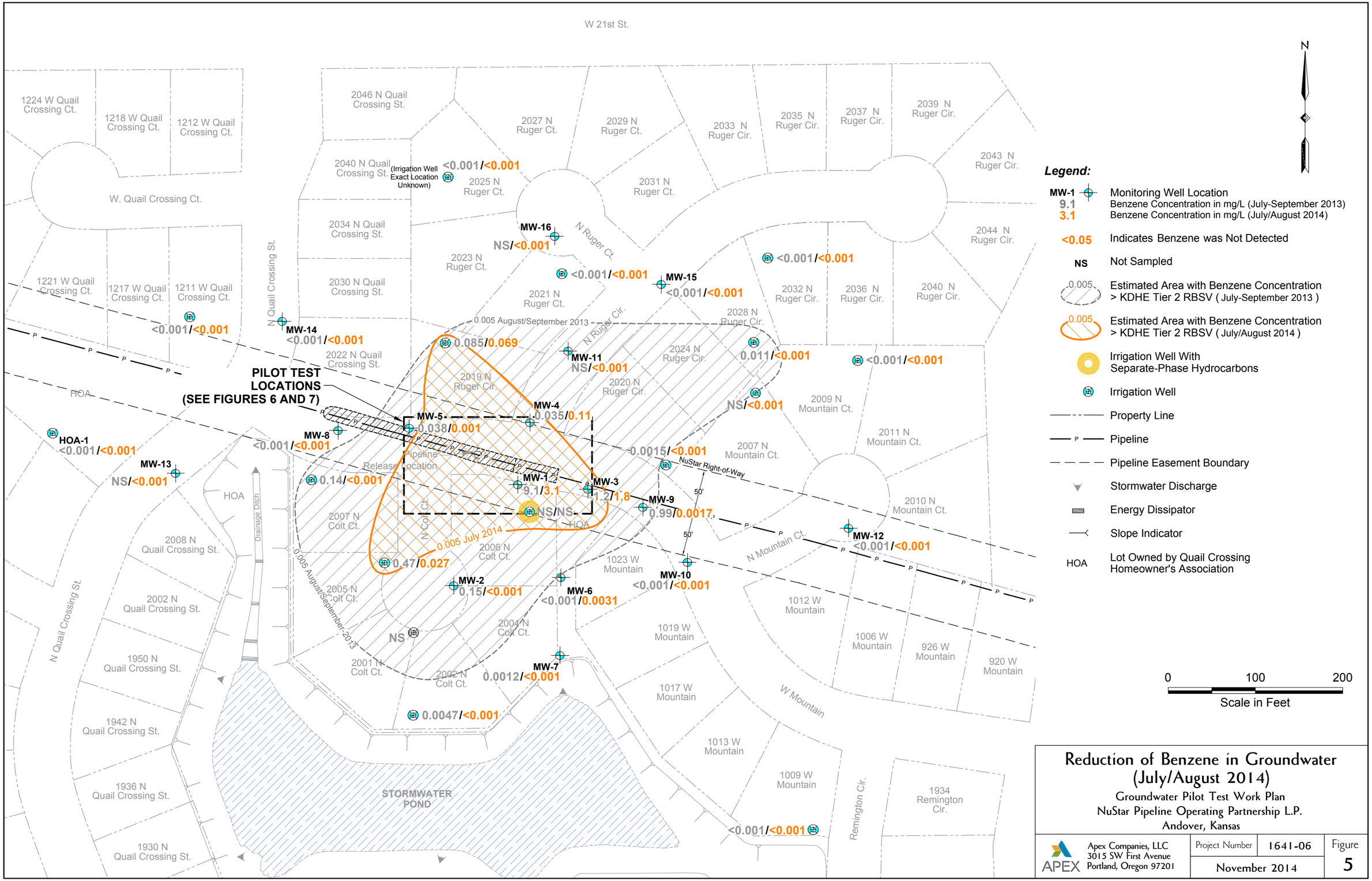
Petroleum Constituents in Vadose-Zone Soil (7 to 18 Feet Below Ground Surface)

Groundwater Pilot Test Work Plan
NuStar Pipeline Operating Partnership L.P.
Andover, Kansas

APEX

Apex Companies, LLC
3015 SW First Avenue
Portland, Oregon 97201

Project Number	1641-06	Figure
November 2014		4

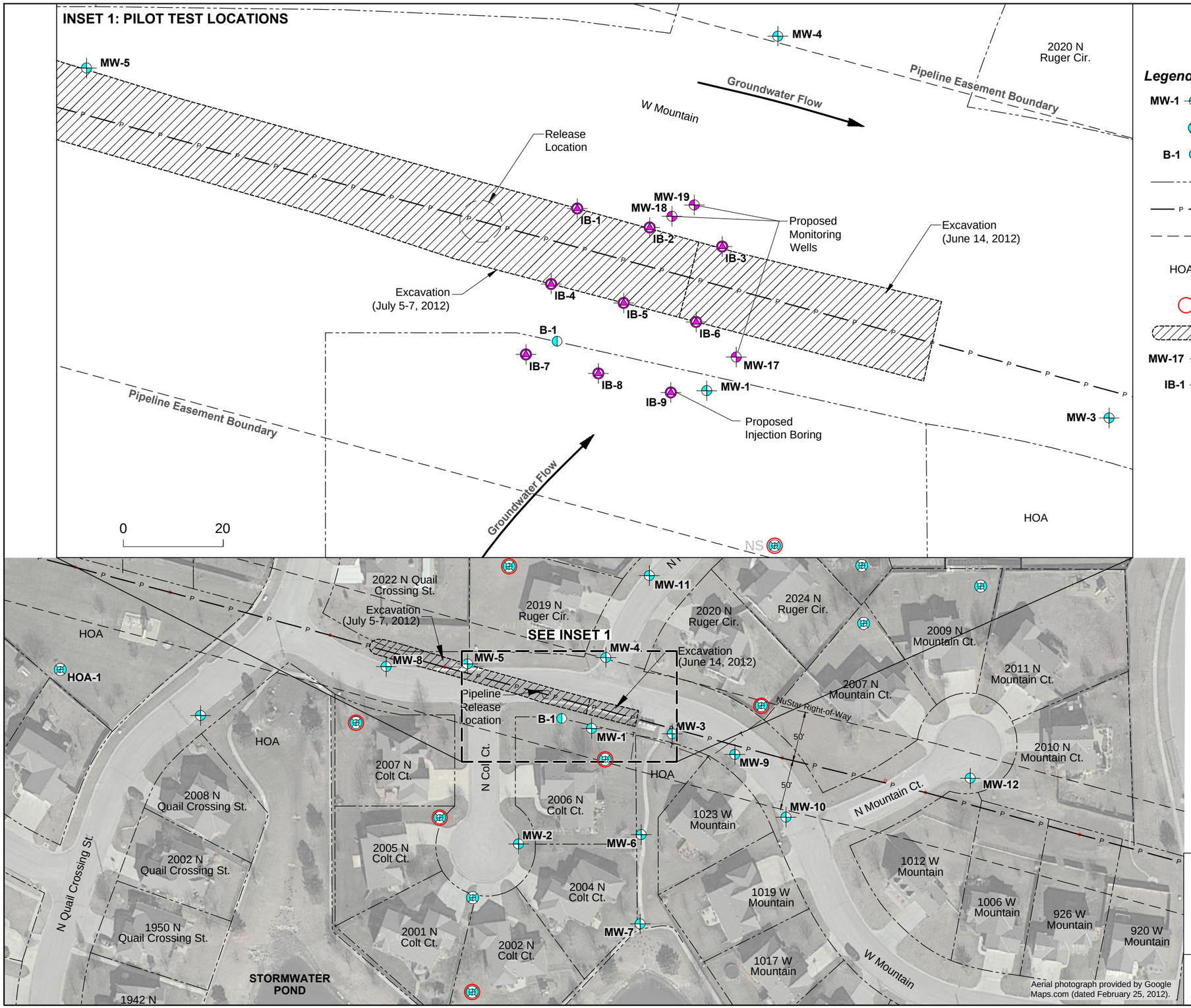


Reduction of Benzene in Groundwater (July/August 2014)

Groundwater Pilot Test Work Plan
NuStar Pipeline Operating Partnership L.P.
Andover, Kansas

APEX
Apex Companies, LLC
3015 SW First Avenue
Portland, Oregon 97201

Project Number	1641-06	Figure
November 2014		5



Legend:

- **MW-1** Monitoring Well Location
- Irrigation Well
- **B-1** Soil Boring Location (July 2013)
- Property Line
- Pipeline
- Pipeline Easement Boundary
- HOA — Lot Owned by Quail Crossing Homeowner's Association
- Deactivated Irrigation Well
- Excavation Area
- **MW-17** Proposed Monitoring Well Location
- **IB-1** Proposed Injection Boring Location

N

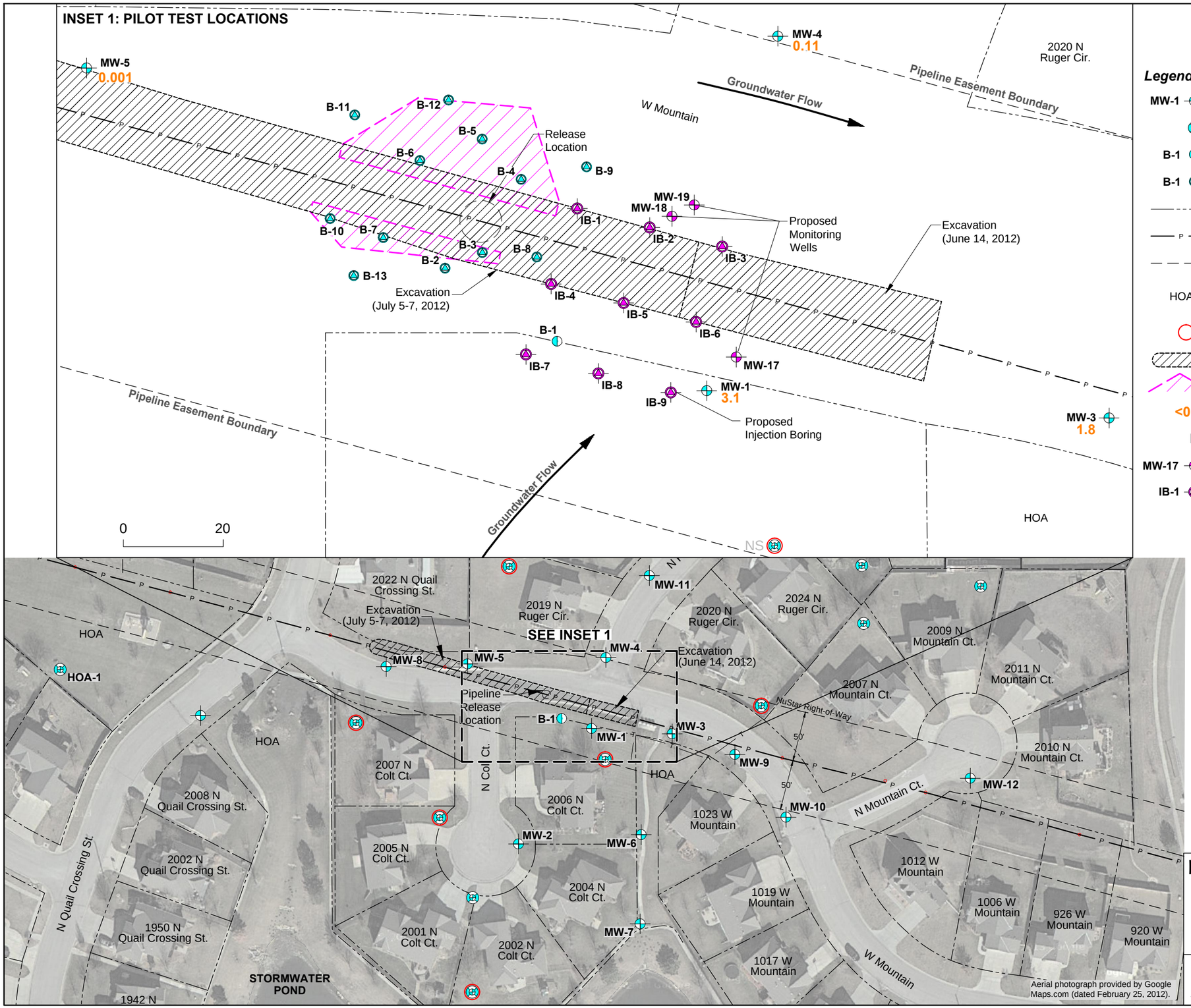
0 100 200

Scale in Feet

Pilot Test Injection Boring and Monitoring Well Locations

Groundwater Pilot Test Work Plan
NuStar Pipeline Operating Partnership L.P.
Andover, Kansas

APEX — Apex Companies, LLC, 3015 SW First Avenue, Portland, Oregon 97201	Project Number	1641-06	Figure
	November 2014		6



Pilot Test Location, Benzene in Groundwater, and Proposed Soil Excavation Area

Groundwater Pilot Test Work Plan
NuStar Pipeline Operating Partnership L.P.
Andover, Kansas

APEX	Apex Companies, LLC 3015 SW First Avenue Portland, Oregon 97201	Project Number 1641-06 November 2014	Figure 7

Appendix A

ORC Specifications and Installation Instructions

REGENESIS

ORC ADVANCED® OXYGEN RELEASE COMPOUND

Highest amount of active oxygen in a controlled-release, oxygen producing compound

PRODUCT OVERVIEW

ORC Advanced® is the state-of-the-art technology for stimulating aerobic bioremediation. It offers unparalleled, maximum oxygen release for periods up to 12 months on a single injection and is specifically designed to minimize oxygen waste while maximizing contaminated site remediation.

ORC Advanced is a formulation of calcium oxyhydroxide which, upon hydration, releases oxygen and forms simple calcium hydroxide and water.

$$CaO(OH)_2 + H_2O \longrightarrow \tfrac{1}{2}O_2 + Ca(OH)_2 + H_2O$$

PRODUCT BENEFITS

PRODUCT BENEFITS

HIGHEST AVAILABLE OXYGEN CONTENT

More active oxygen (17%) plus Regenesis' patented controlled-release technology (CRT™) saves time and money by increasing degradation rates and improving remediation performance by providing more oxygen on a single injection. It is particularly effective at higher demand sites where oxygen may be limited and scavenged by competing carbon sources.

PATENTED CONTROLLED-RELEASE TECHNOLOGY (CRT™)

Based on the same proven technology employed in the industry standard Oxygen Release Compound (ORC®), CRT allows for an efficient, long-term release of oxygen providing the optimal conditions for sustained aerobic biodegradation. This can save time and money by reducing the potential need for multiple applications. Also, oxygen release "lock-up" is avoided – an unfortunate problem experienced with commodity chemicals.

IN SITU APPLICATION

Remediation with ORC Advanced is typically more cost-effective than *ex situ* treatments. With the use of ORC Advanced there is minimal site disturbance with no above-ground piping or mechanical equipment, no operations and maintenance costs and no hazardous materials handling or disposal.

CRT

DEFINING THE SCIENCE BEHIND CONTROLLED-RELEASE TECHNOLOGY (CRT™)

Early on, Regenesis researchers noted that in order to optimally stimulate the natural attenuation of aerobically degradable contaminants, biologically usable oxygen was best supplied in low but constant concentrations. Big bursts of oxygen are wasteful and simply "bubble off", often generating undesirable foaming and producing unwanted preferential flow paths in the subsurface. Regenesis sought to solve this problem by controlling the rate of oxygen release from solid oxygen sources.

The answer was provided by the development of CRT. The CRT process involves intercalating (embedding) phosphates into the crystal structure of solid peroxygen molecules. This patented feature, now available in the ORC Advanced® formulation, slows the reaction that yields oxygen within the crystal, minimizing "bubble off" which can waste the majority of oxygen available in common solid peroxygen chemicals.

FIGURE 1:
FILLING A PUMP WITH ORC ADVANCED SLURRY

CRT provides "balance" – it slows down the rate of oxygen release while at the same time preventing "lock-up". Commodity solid peroxygen chemicals, when in contact with water, will produce an initial rapid and uncontrolled-release of oxygen. Then, as hydroxides form, a significant portion of the oxygen deeper in the crystal is made unavailable or becomes"locked-up." This undesirable effect is inefficient and costly. CRT prevents lock up and controls the rate of oxygen release, representing the state-of-the-art technology in passive oxygen delivery.

1011 Calle Sombra San Clemente California 92673-6244 Telephone: 949.366.8000 Fax: 949.366.8090 www.regenesis.com

REGENESIS

The original controlled-release oxygen compound, since 1994

ORC® OXYGEN RELEASE COMPOUND

PRODUCT OVERVIEW

The original Oxygen Release Compound (ORC®) is a fine, powdery material comprised of a patented formulation of phosphate-intercalated magnesium peroxide. The intercalation or embedding of phosphates within the magnesium peroxide is Regenesis' patented, controlled-release mechanism.

Upon hydration, ORC is designed to produce a controlled-release of oxygen (10% by weight) into the subsurface in accordance with the following reaction:

$$MgO_2 + H_2O \longrightarrow \tfrac{1}{2}O_2 + Mg(OH)_2$$

This process can proceed for periods of up to one year depending on site conditions. In the presence of this long-lasting oxygen source, aerobic microbes flourish - accelerating the naturally slow rates of aerobic biodegradation.

BENEFITS

PRODUCT BENEFITS

By enhancing bioremediation using ORC, in situ treatment of contaminants can result in an efficient, simple and cost-effective alternative to traditional technologies. With low capital costs, no operations and maintenance, minimal site disturbance and proven effectiveness, ORC can restore water quality and property values at a reasonable cost.

PRODUCT APPLICATION

MATERIAL APPLICATION

Most contaminated sites are treated using ORC slurry which is a prescribed and easily injectable water and ORC mixture (Figure 2). The direct - injection of ORC slurry maximizes ORC and oxygen distribution in the subsurface increasing the range of enhanced biodegradation. ORC is dosed in pounds per vertical foot of material treated. The amount of ORC recommended depends greatly on various factors such as contaminant concentrations, oxygen sinks, groundwater flow rates and subsurface geology. It is recommended that a Regenesis Technical Services Representative be contacted for detailed design information.

ORC treatment approaches or designs may consist of one, or combinations of the following: Source Area Grids, Plume Area Grids or Barriers, Excavations and Biopiles.

SUBSURFACE EMPLACEMENT

- Direct – Push Injection
- Hollow Stem Augers
- Existing Wells
- Recirculating Wells
- Replaceable Filter Socks (existing wells)
- Excavations
- Trenches

CONTAMINANTS

TREATABLE CONTAMINANTS

ORC can treat a wide range of contaminants and most any aerobically degradable compound including: gasoline and fuel additives (BTEX and MTBE), diesel, kerosene, jet fuel, gas condensates, fuel oils, lubricants, bunker oil, PAHs, certain metals (arsenic), certain pesticides/herbicides and certain industrial solvents (alcohols and ketones).

FIGURE 2: ORC SLURRY

1011 Calle Sombra San Clemente California 92673-6244 Telephone: 949.366.8000 Fax: 949.366.8090 www.regenesis.com

REGENESIS

Oxygen Release Compound (ORC®) Installation Instructions

(Slurry Mixing)

1. OPEN 5 GALLON BUCKET, AND REMOVE PRE-MEASURED BAG OF ORC.
2. MEASURE AND POUR WATER INTO THE 5-GALLON BUCKET ACCORDING TO THE FOLLOWING DESIRED CONSISTENCY:

65% Solids Slurry	Mix .63 gallons of water per 10 pounds of ORC powder.	
	Example:	Mix 20 pounds of ORC with 1.26 gallons of water.
		Mix 30 pounds of ORC with 1.89 gallons of water.
60% Solids Slurry	Mix .79 gallons of water per 10 pounds of ORC powder.	
	Example:	Mix 20 pounds of ORC with 1.58 gallons of water.
		Mix 30 pounds of ORC with 2.37 gallons of water.
50% Solids Slurry	Mix 1.19 gallons of water per 10 pounds of ORC powder.	
	Example:	Mix 20 pounds of ORC with 2.38 gallons of water.
		Mix 30 pounds of ORC with 3.57 gallons of water.
25% Solids Slurry	Mix 3.57 gallons of water per 10 pounds of ORC powder.	
	Example:	Mix 10 pounds of ORC with 3.57gallons of water.

3. ADD THE APPROPRIATE ORC QUANTITY TO THE WATER. Check weight of each bucket (see label). The 5 gallon shipping bucket weighs 2 pounds. An additional 4 pounds of ORC would require one additional quart of water, at the 65% solids level.
4. USE AN APPROPRIATE MIXING DEVICE TO THOROUGHLY MIX ORC AND WATER. A hand held drill with a “jiffy mixer” or a stucco mixer on it may be used in conjunction with a small paddle to scrape the bottom and sides of the container. Standard environmental slurry mixers may also be used, following the equipment instructions for operation. For small quantities a usable slurry can be mixed by hand, if care is taken to blend all lumps into the mixture thoroughly.

CAUTION: ORC MAY SETTLE OUT OF SLURRY IF LEFT STANDING. ALSO, ORC EVENTUALLY HARDENS INTO A CEMENT-LIKE COMPOUND, AND CANNOT BE RE-MIXED AFTER THAT HAS HAPPENED. THEREFORE:

Mix immediately before using. Do not let stand more than 30 minutes, and re-mix immediately before use, to be sure the mixture has not settled out. If a mechanical slurry mixer attached to a pump is being used, the material may be cycled back through the mixer to maintain slurry suspension and consistency.

5. CHECK SLURRY CONSISTENCY FOR POURABILITY. ADD WATER IF NECESSARY (IN 1 CUP INCREMENTS) TO ACHIEVE THE CORRECT CONSISTENCY.

For direct assistance or answers to any questions you may have regarding these instructions, contact Regenesis Technical Services at 949-366-8000.

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Oxygen Release Compound (ORC®) Installation Instructions

(Direct-Injection Slurry Application)

SAFETY:

Pure ORC is shipped to you as a fine powder rated at -325 mesh (passes through a 44 micron screen). It is considered to be a mild oxidizer and as such should be handled with care while in the field. Field personnel should take precautions while applying the pure ORC. Typically, the operator should work upwind of the product as well as use appropriate safety equipment. These would include eye and respiratory protection, and gloves as deemed appropriate by exposure duration and field conditions.

Personnel operating the field equipment utilized during the installation process should have appropriate training, supervision and experience.

GENERAL GUIDELINES:

ORC may be installed in the contaminated saturated zone in the ground utilizing hand augered holes, Geoprobe® type hydraulic punch equipment, or hollow stem augers. This set of instructions is specific for Geoprobe equipment. Alternate instructions may be obtained from the Regenesis Technical Support Department.

For optimum results the ORC slurry installation should span the entire vertical contaminated saturated thickness, including the capillary fringe and “smear zone”.

Two general installation approaches are available. The first is to backfill only the probe hole with slurry. This is a simple approach, in that it is easy, straightforward, and the location of the ORC slurry is precisely known after installation. However, this method requires significantly more probe holes than the alternative, and may take more time for the completion of the remediation process. A separate set of instructions for this method utilizing Geoprobe equipment is available from Regenesis.

The second method is to inject the slurry through the probe holes into the contaminated saturated zone. This method requires fewer probe holes, is less disruptive to the site, and aids the spread of oxygen by spreading the ORC source material. However, it may be difficult to know the exact, final disposition of the ORC installed with this method. This is the method described in these instructions.

Note: It is important that the installation method and specific ORC slurry point location be established prior to field installation. It is also important that the ORC slurry volume and solids content for each drive point be predetermined. The Regenesis Technical Service Department is available to discuss these issues, and Helpful Hints at the end of these instructions offers relevant information. Regenesis also has available Technical Bulletins covering source treatments with ORC.

SPECIFIC INSTALLATION PROCEDURES

1. Identify the location of all underground structures, including utilities, tanks, distribution piping, sewers, drains, and landscape irrigation systems.
2. Identify surface and aerial impediments.
3. Adjust planned installation locations for all impediments and obstacles.
4. Pre-mark the installation grid point locations, noting any that have special depth requirements.
5. Set up the Geoprobe unit over each specific point, following manufacturer recommended procedures. Care should be taken to assure approximate vertical probe holes.
6. Penetrate surface pavement, if necessary, following standard Geoprobe procedures.
7. Drive the 1 1/2" (one-and-one-half inch) pre-probe (part #AT-148B) with the expendable tip (part #AT142B) to the desired maximum depth. Standard 1" (one inch) drive rods (part AT104B) should be used, after the pre-probe. (Hint: Pre-counted drive rods should be positioned prior to the installation driving procedure to assure the desired depth is reached.)
8. Disconnect the drive rods from the expendable tip, following standard Geoprobe procedures.
9. Mix the appropriate quantity of ORC slurry for the current drive point. (See separate "Directions for ORC® Slurry Mixing" and Helpful Hints). **Note: Do not mix more slurry than will be used within a 30 minute period.**
10. Set up and operate an appropriate slurry pump according to manufacturer's directions. Based on our experience, a Geoprobe model GS-1000 pump is recommended. Connect the pump to the probe grout pull cap (GS-1054) via a 1 inch diameter delivery hose. The hose is then attached to the 1" drive rod with its quick connector fitting. Upon confirmation of all connections add the ORC slurry to the pump hopper/tank.
11. Withdraw the pre-probe and drive stem 4' (four feet). (Also note Helpful Hints - Operations at end of instructions.)
12. Optional pretreatment step. (See Helpful Hints - Operations at end of instructions). Pump one to two gallons of tap water into the aquifer to enhance dispersion pathways from the probe hole.
13. Pump the predetermined quantity of ORC slurry for the depth interval being injected. Observe pump pressure levels for indications of slurry dispersion or refusal into the aquifer. (Increasing pressure indicates reduced acceptance of material by the aquifer).
14. Remove one 4' section of the 1" drive rod. The drive rod will contain slurry. This slurry should be returned to the ORC bucket for reuse.
15. Repeat steps 11, 13, and 14 until treatment of the entire affected thickness has been achieved. It is generally recommended that the procedure extend to the top of the capillary fringe/smear zone.
16. Install an appropriate seal, such as bentonite, above the ORC slurry through the entire vadose zone. This helps assure that the slurry stays in place and prevents contaminant migration from the surface. Depending on soil conditions and local regulations, a bentonite seal can be pumped through the slurry pump or added via chips or pellets after probe removal.
17. Remove and decontaminate the drive rods and pre-probe.

18. Finish the probe hole at surface as appropriate (concrete or asphalt cap, if necessary).
19. Move to the next probe point, repeating steps 5 through 18.

HELPFUL HINTS:

A. Physical characteristics

A1. Slurry

The ORC slurry is made using the dry ORC powder (rated at -325 mesh). It makes a smooth slurry, with a consistency that depends on the amount of water used.

A thick, but pumpable, slurry that approaches a paste can be made by using 65-67% solids. This material would normally be used for back-filling a bore or probe hole. It is especially useful where maximum density is desired such as where ground water is present in the hole or there are heaving sands.

Thinner slurries can be made by using more water. Typical solids for the thinner slurries content will range from 35% to 62%. Such slurries are useful for injecting through a probe or bore hole into the saturated aquifer.

As a rule, it is best to mix the first batch of slurry at the maximum solids content one would expect to use. It can then be thinned by adding additional water in small increments. By monitoring this process, the appropriate quantities of water for subsequent batches can be determined.

The slurry should be mixed at about the time it is expected to be used. It is best to not hold it for more than 30 minutes. Thinner slurries, especially, can experience a separation upon standing. All ORC slurries have a tendency to form cements when left standing. If a slurry begins to thicken too much, it should be mixed again and additional water added if necessary.

Care should be taken with slurry that may be left standing in a grout pump or hose. Problems can generally be avoided by periodically re-circulating the slurry through the pump and hose back into the pump's mixing or holding tank.

A2. Equipment

Most geotechnical grout pumping equipment has a holding tank with a capacity sufficient for injection.

When applying measured volumes of ORC slurry to probe holes, it is sometimes useful to know the volumes and content of the delivery system lines. The following information may be useful in this regard.

Geoprobe pump: At the end of a pump stroke virtually no deliverable slurry remains in the pump.

5/8" O.D. connecting hose (10 feet long):	0.2 gallons (26 fluid ounces).
Four foot (4') length of 1" drive rod:	.04 gallons (5 fluid ounces).
Three foot (3') length of 1 1/2" pre-probe:	.03 gallons (4 fluid ounces).

Cleaning and maintenance:

Pumping equipment and drive rods can be lightly cleaned by circulating clear water through them. Further cleaning and decontamination (if necessary due to subsurface conditions) should be performed according to the equipment supplier's standard procedures and local regulatory requirements.

B. Operating characteristics

B1. Operations - General

Judgment will be needed in the field when injecting ORC slurries. In general, it is relatively easy to inject ORC slurries into sandy soils, and this can usually be accomplished at very moderate pressures. Silts and clays require more pressure, and may accept less slurry.

Careful observation of pressure during slurry pumping is the best indication of the effectiveness of the slurry injection. To test the soil's ability to accept the slurry and to "precondition" the injection point for the slurry, it is sometimes useful to inject a small volume of plain water prior to the slurry. Normally, one-half (0.5) gallons to two (2) gallons would be appropriate.

During injection, increasing pressure and decreasing flow rate are signs of refusal by the soil matrix to accept the slurry. The site geologist should determine whether to increase pressure, and possibly fracture ("frac") the soil matrix to achieve ORC slurry installation in a tight site that has refused the slurry at lower pressures.

B2. Fill Volumes

Probe hole back-filling

Probe hole capacities:

Per 10' (Ten Foot) Length			
Theoretical		**Operating Volume**	
(Gallons/Fluid Ounces/Cubic Inches)		**(Gallons/Fluid Ounces)**	
Sand, Silts & Clay		**Sand**	**Silts & Clay**
1" Diameter	.41 gal/52 fl. oz./94.2 cu. in.	.61 gal/78 fl. oz.	.51 gal/65 fl. oz.
1 1/2" Diameter	.92 gal/117 fl. oz./212.0 cu. in.	1.38 gal/176 fl. oz.	1.15 gal/146 fl. oz.
2" Diameter	1.63 gal/209 fl. oz./376.8 cu. in.	2.44 gal/313 fl. oz.	2.04 gal/261 fl. oz.
2 1/4" Diameter	2.06 gal/264 fl. oz./476.9 cu. in	3.09 gal/396 fl. oz.	2.57 gal/330 fl. oz.

Note that the operating volumes include a 50% excess above the theoretical volume in sands and 25% in clays and silts. This is important to successful treatment. The additional material allows for a small degree of infiltration of the slurry into the surrounding soil and fractures, as well as hole diameter variability. It is important to assure that the entire contaminated saturated zone is treated (including the capillary fringe), since this is often the area of highest pollution concentration. Failure to treat this area due to improper installation can undermine an otherwise successful remediation effort.

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