Operations, Maintenance, and Monitoring Plan

Groundwater Remediation System

Prepared for
Flint Hills Resources Alaska, LLC

October 2014

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1.0 Introduction

1.1 Purpose

On behalf of Flint Hills Resources Alaska, LLC (FHRA), Barr Engineering Company (Barr) has prepared this Operation, Maintenance and Monitoring (OMM) Plan for the groundwater remediation system at the Flint Hills Resources Alaska, LLC (FHR) North Pole Terminal located in North Pole, Alaska. The groundwater remediation system includes multiple groundwater recovery wells, two treatment systems, and light non-aqueous phase liquid (LNAPL) recovery and recycling. This OMM Plan summarizes the methods and schedules for operation, maintenance, and monitoring of this remediation system. The groundwater remediation system was designed to protect onsite workers, enhance LNAPL recovery, remediate the groundwater plume, and eliminate offsite migration of contaminants. This plan adopts and references information, work, and analysis described in more detail in the Revised Sampling and Analysis Plan (RSAP; ARCADIS 2014a). A Long Term Monitoring Plan (LTM; ARCADIS 2014b) has also been prepared to document groundwater monitoring frequency and schedules for the site.

1.2 Process Overview

Groundwater recovery wells are utilized to extract impacted groundwater and provide hydraulic control of dissolved phase hydrocarbons and sulfolane in order to prevent offsite migration of contaminants. The recovered groundwater is treated within two onsite treatment systems, the original (East) and expanded (West) treatment systems. Both treatment systems use granular activated carbon (GAC). The two systems are referred to below as "GAC East" and "GAC West", respectively.

LNAPL is present in the soil in portions of the site and it accumulates in some site monitoring, observation and recovery wells. Recovery of LNAPL from site wells constitutes hydrocarbon contaminant source removal.

1.3 Process Description

Primary components of the groundwater remediation system include nine groundwater recovery wells (six of which have dual-phase capability for LNAPL recovery), two groundwater treatment systems, and numerous LNAPL recovery wells (Figure 1). The FHRA Groundwater Remediation Operating Manual includes a detailed description of the groundwater remediation system components and procedures for their operation.

The groundwater remediation system includes two separate treatment systems (GAC East and GAC West). Treated groundwater from GAC East is pumped to the South Gravel Pit under Alaska Department of Environmental Conservation (ADEC) wastewater disposal permit No. 2005 DB-0012. A discharge monitoring report (DMR) is submitted to ADEC on a monthly basis. The GAC West system discharges treated groundwater to the North Gravel Pit with monthly monitoring and quarterly DMR submittal to ADEC.

1.4 Estimated Duration of Treatment System

It is currently estimated that the groundwater remediation systems will be operated for approximately 30 years. The duration may change based on the rate of contaminant concentration decline across the site and at the property boundary, in addition to the finalization of the sulfolane cleanup level for the site. FHRA anticipates that the data collected through the operation and monitoring of the remediation system will be sufficient to determine when part or all of the groundwater treatment systems operations can be terminated.

The sulfolane cleanup level for the site is under ADEC review. Until the final cleanup level is established by ADEC, the system will remain in operation until the sulfolane performance standard of 15 micrograms per liter (µg/L) is met at the VPT wells without the need of the systems. Once the sulfolane cleanup level for the site is established, the groundwater extraction and treatment systems will be operated until the sulfolane cleanup level for the site can be met at the VPT wells without the need of the systems. Five year reviews of the groundwater extraction and treatment systems and LNAPL recovery programs will be documented and submitted to ADEC for review. The five year reviews will assess progress toward cleanup objectives including system performance and exit strategy. A technical memo will be submitted to ADEC for approval to discontinue operation of each remedial approach once it has been determined that they are no longer necessary to meet cleanup objectives. For further information regarding closure of remediation activity, see Sections 5.2.5 and 5.4.10 of the Final Onsite Cleanup Plan (OCP, ARCADIS 2014c).

2.0 Operations and Maintenance

The layout of the groundwater remediation system is depicted on Figure 1. Included on Figure 1 are wells that recover groundwater, wells with capability to recover both groundwater and LNAPL, wells in which LNAPL has been recovered, and the two groundwater treatment systems (GAC East and GAC West). The remainder of this section presents the operating manual and maintenance schedule for the groundwater remediation system.

FHRA maintains a Groundwater Remediation Operating Manual for the groundwater remediation system which is used by FHRA operators of the groundwater remediation system. This manual is reviewed on an annual basis and revised as necessary. The design groundwater recovery flow rates for the nine recovery wells are shown below. The collective groundwater remediation system flow rate has been determined through a combination of hydraulic capture modeling and groundwater level measurements that demonstrate capture. The target flow rates listed below are subject to adjustment pending aquifer testing and observed capture (Section 4).

- R-21 – 40 to 50 gallons per minute (gpm)
- R-35R – 50 to 65 gpm
- R-42 – 60 to 85 gpm
- R-43 – 60 to 85 gpm
- R-44 – 60 to 90 gpm
- R-45 – 50 to 65 gpm
- R-46 – 30 to 40 gpm
- R-47 – maximum 80 gpm (flow range to be determined based on aquifer testing and observed capture)
- R-48 – maximum 120 gpm (flow range to be determined based on aquifer testing and observed capture)

If the target flow rates cannot be achieved due to limitations of a recovery well or treatment system capacity, operations staff shall notify the FHRA Environmental Department. This notification will trigger evaluation of measured hydraulic capture width/depth and development of a corrective action plan for restoring the flowrate if deemed necessary. Corrective action will include:

1. The onsite remediation Compliance System Owner will meet with the operator on duty or supervisor of operations with other key discipline leaders such as reliability/ third party remediation engineer.
2. The problem will be defined and a root cause analysis performed.
3. The site operations manual will be consulted.

4. Corrective actions will be implemented.
5. Performance will be re-checked.
6. Knowledge will be captured if the problem is resolved or the problem definition process will be restarted.

Monthly DMRs will reflect corrective actions taken. FHRA will notify ADEC of any maintenance event that FHRA believes will impact the performance of the system. This notification will occur within 7 days of FHRA's knowledge of the event. FHRA will notify ADEC of any catastrophic event within 24 hours of knowledge of the event.

FHRA will continue LNAPL recovery operations which include skimming (through both the existing groundwater extraction system and individual skimming systems) and intermittent mechanical (e.g., vacuum truck) or hand recovery (e.g., hand pumps). Periodic LNAPL baildown tests will be conducted to evaluate transmissivity and recoverability of LNAPL in accessible areas of the site per the Revised Sampling and Analysis Plan (RSAP; ARCADIS 2014a). Ongoing continuous and seasonal LNAPL skimming will recover mobile LNAPL, reduce LNAPL mass, and support natural source zone depletion (NSZD).

FHRA staff or its consultants currently perform LNAPL baildown testing semiannually, generally in March and late October to target water table minima. The results are then evaluated and used to optimize mechanical recovery operations as discussed in Section 4.4. In general, the product recovery systems are pneumatic skimmers which consist of a submersible air-driven pump, with an intake located behind a hydrophobic filter. The intake and filter are located on a vertical slide apparatus; the density of the filter allows the intake to be placed at the LNAPL/water interface.

The typical operational configuration of a skimming system will include the following components:

- Two-inch-diameter monitoring well or 4-inch-diameter recovery well
- Compressed air supply for the skimmer pump
- Collection drums for the recovered product
- Well houses to insulate the skimmer systems for winter operations

Wells identified for continuous LNAPL recovery will be equipped with a product recovery system and LNAPL will be collected in a 55-gallon drum (or larger tank as needed) for recycling. During periods of high water table elevation (generally during the summer months) when the LNAPL smear zone may be submerged, flow of LNAPL into recovery wells is expected to be minimal and skimming may be discontinued until groundwater elevations drop.

At locations where LNAPL transmissivity is found to be low, or other restrictions prevent installation of a permanent skimmer pump, non-continuous or seasonal LNAPL skimming may be implemented. Evaluation factors for LNAPL recovery operations are provided in Section 4.

2.1 Routine maintenance and schedule

The following table summarizes routine maintenance for the groundwater remediation system.

Groundwater Recovery Wells			
Process Unit or Equipment	**Maintenance Task**	**Frequency or Initiation Trigger**	**Additional Notes on Maintenance Activities**
Recovery Wells	Inspection of recovery wells	Every two to three years unless reduced pumping capacity is observed (within 2 feet of pump intake)	
	Cleaning and redevelopment of recovery wells	As needed, based on inspection results	
Recovery Well Pumps	Check well pump level	As needed based on flow rate and well drawdown (avoid cavitation)	Pump should be set at least 2 feet off the well bottom. Setting is controlled by support cable
	Inspect well pump condition	At least once every 16,000 hours – can be completed during well inspection once per two years	
Recovery Well Flowmeters	Removal and cleaning of meter flow tube	In response to error messages on magnetic flowmeter output	Wells R-42, R-47, and R-48 can continue operating with meter flow tube removed; use meter bypass line in well house
Product Recovery Skimmers	Inspect pump bladder and repair/replace if needed	As indicated by loss of flow from pump or other operational issues	

GAC East System			
Process Unit or Equipment	**Maintenance Task**	**Frequency or Initiation Trigger**	**Additional Notes on Maintenance Activities**
Pre-filters	Replace pre-filter media	Based on differential pressure trigger of 25 psi	
Coalescer	Change out coalescer media	Based on differential pressure trigger of 10 psi	
	Remove free product accumulating in coalescer	Inspected once per shift per operating manual; remove as needed and inspect product recovery system upstream	
Air Strippers	Alternate off-line air stripper unit	Based on benzene, toluene, ethyl benzene, and xylenes (BTEX) concentrations in effluent of operating units	
	Inspection blower condition	Completed during downtime for saddle-chip media replacement	
	Replace air stripper saddle-chip media	Completed when vessel is switched to the off-line unit based on BTEX concentrations	
Gallery Pond	Remove accumulated solids from pond bottom	Inspect at the end of every winter season and remove solids if needed for operation	
Sand Filters	Replace sand media	Based on excessive pressure drop if treatment capacity is limited	

GAC Vessels	Replace GAC media	Based on contaminant breakthrough with consideration of weather conditions and operational situation	Alternatively, GAC changeout can be completed based on excessive pressure drop if treatment capacity becomes limited. Follow FHR procedures. A GAC change out procedure is included in the FHRA procedures for the operation of the system.
GAC West System			
Process Unit or Equipment	**Maintenance Task**	**Frequency or Initiation Trigger**	**Additional Notes on Maintenance Activities**
Gallery Pond	Monitoring volume in seepage collection area between liners	Measure depth to water level in collection area weekly; follow FHRA procedure if pump-out is required	Pumping of the seepage water should be completed if the water level reading in the collection area is 5 feet (or an angled distance to water of about 22 feet in the monitoring pipe)
	Remove accumulated solids from pond bottom	Inspect at the end of every winter season and remove solids if needed for operation	
	Inspect and clean aeration diffusers	Complete when pond solids are being removed	Potential plugging issues can be identified by uneven distribution among the four diffusers during operation
Greensand Filter Unit (Horizontal Pressure Filter, HPF)	Regeneration of Greensand Plus media with Potassium Permanganate	Once per every 6-12 months (operation dependent)	Follow FHRA procedure
	Assessment of media condition and recharge or replacement of media	If high head loss shutdown differential pressure of 30 psi (default value) is reached	High head loss pressure is set above the default differential pressure for a backwash of 8 psi Follow FHRA procedure for recharge or media replacement if needed

GAC Vessels	Replace GAC media	Based on contaminant breakthrough, with consideration of weather conditions and operational situation	Alternatively, GAC changeout can be completed based on excessive pressure drop if treatment capacity becomes limited. Follow FHRA procedures. A GAC change out procedure is included in the FHRA procedures for operation of the system.
	Change process series of GAC vessels (move lead to former lag vessels)	In response to media change-out in lead vessel	Starting in A/B-C-D order; rotate based on change-out; order (series versus parallel) subject to change based on observed performance
Chemical Feed System	Refill sodium hypochlorite tote from delivery truck	Twice per month	Frequency subject to change if dose needs to be increased or decreased based on operation; follow FHRA procedure for assisting with and observing delivery

3.0 Groundwater Remediation System Performance Monitoring

Performance of the existing groundwater remediation system is described in Section 5.4 of the OCP (ARCADIS 2014c) and has been verified to date by:

- Evaluating hydraulic capture using field measurements of groundwater levels and using the site groundwater flow model.
- Evaluating contaminant capture based on contaminant concentration trends in monitoring wells in the vicinity of the groundwater remediation system.
- Recording groundwater pumping rates from recovery wells and groundwater remediation system up time.
- Monitoring recovered groundwater quality.
- Monitoring treated groundwater discharge quality per associated permits.
- Measuring LNAPL transmissivity, recovery volume and rate from each well at which these measurements or activities are completed.

Performance goals, targets, and ongoing performance monitoring for the OMM Plan are described below.

Sampling and analysis of groundwater, surface water, effluent, and water treatment media will be performed according to the methods described in the RSAP.

3.1 Groundwater recovery performance goal and targets

The performance goal for the groundwater recovery component of the remediation system is to maintain operation of recovery wells to maintain capture of the upgradient sulfolane plume above 15 µg/L. Downtime events must be managed to maximize recapture of any groundwater movement in the recovery zone during the downtime events. Target flow rates for the recovery wells to achieve the performance goal are presented in Section 2.1.

3.2 Treatment system performance

FHRA will collect water samples from the influent and discharge of the two treatment systems on a monthly basis. Samples from the GAC East system will be analyzed for sulfolane and additional parameters required by the discharge permit (BTEX, pH, and polyaromatic hydrocarbons [PAHs]). Samples from the GAC West system will be analyzed for sulfolane, pH, iron, manganese, and total organic carbon (TOC) in accordance with the monitoring requirements set by ADEC. Additional samples may be collected from either of the treatment systems as needed to evaluate performance of the individual components of the system, or adjust monitoring parameters depending on future permit conditions. For both treatment

systems, FHRA will collect samples for analysis of Perfluorooctanoic Sulfonate (PFOS) and Perfluorooctanoic acid (PFOA) from the influent and effluent for three consecutive months.

The water quality data will be used to confirm that the treatment systems are effectively treating hydrocarbon compounds (in the GAC East system) and sulfolane and to confirm compliance with the discharge permit and monitoring requirements. Influent and discharge water quality will be presented in the routine groundwater monitoring reports. If sulfolane breakthrough above 15 µg/L (or the final cleanup level for the site when established) or petroleum hydrocarbon breakthrough above the ADEC Table C (18 AAC 75.345) groundwater cleanup levels occurs, corrective action will be performed as outlined in Section 2. ADEC (Contaminated Sites project manager) will be notified within 7 days of corrective action.

3.3 Capture zone monitoring

Monitoring of the capture zone of the groundwater recovery component of the remediation system consists of 1) hydraulic capture estimation based on field measurements of water levels in selected monitoring wells, and 2) contaminant capture monitoring based on the groundwater sampling from selected monitoring wells. Details on these two aspects of the capture zone monitoring are presented below.

3.3.1 Hydraulic capture

As proposed in the Revised Interim Remedial Action Plan Addendum (ARCADIS 2013) and the OCP (ARCADIS 2014c), and presented in Evaluation of Recovery Well Replacement, Start-up Aquifer Testing for Recovery System Hydraulic Capture Performance Monitoring (Barr 2013), FHRA will measure groundwater levels in select monitoring wells and nests to evaluate the horizontal and vertical hydraulic capture of the groundwater remediation system. The depth to groundwater will be measured and used to generate water table elevation contour plots and plots of hydraulic heads in cross section. The capture zone extent at the water table and in cross section will be estimated following the methods presented by Barr (2013).

The hydraulic capture performance monitoring network is summarized in Table 1 and shown on Figure 2. Groundwater pressure sensors with data recording units are installed in several of the wells listed in Table 1. The pressure sensors provide continuous groundwater elevation data to evaluate variations in groundwater elevations between measurement events.

Hydraulic capture data associated with wells pumping to the GAC East treatment system have been collected and analyzed monthly since August 2013 (except November 2013). Recovery wells R-47 and R-48 began operation as part of the GAC West system on June 26, 2014. The first hydraulic capture measurement event with the expanded system in operation occurred on June 30, 2014. Hydraulic capture data will be collected and analyzed monthly for the GAC West system for 12 months, through June 2015. The hydraulic capture data collection frequency will then change to quarterly beginning in the third quarter of 2015. It is anticipated that frozen wells may prevent collection of the complete groundwater elevation data set during some measurement events. Evaluation of hydraulic capture will be presented in the routine groundwater monitoring reports.

3.3.2 Contaminant Capture

FHRA will collect groundwater samples for sulfolane and BTEX quarterly and semiannually, respectively, to evaluate contaminant capture (Table 1). Monitoring well locations are shown on Figures 3 and 4, and are categorized as upgradient, within the treatment zone, and downgradient as listed below:

- Upgradient locations: O-6, O-19, O-19-55/90, MW-130-25, MW-175-90, S-43, MW-369-16/55/75, and S-51.
- Within the treatment zone locations: O-2, O-3, O-5, O-5-65, MW-113-15, MW-125-25, MW-186A-15/B-60/E-75, MW-199-150, MW-309-15/66, MW-334-15/65, MW 344-15/55/75, MW-345-15/55/75, and MW-370-15/55/75.
- Downgradient locations: MW-127-25, MW-129-40, MW-139-25, MW-142-20, MW-145-20, MW-154A-75/B-95, MW-351-15/55/75/150, MW-371-15/55/75/125, O-4, O-12, O-12-65, O-24, O-24-65, O 26, and O-26-65.

In addition to the groundwater monitoring program above, FHRA will collect groundwater samples monthly in 2014 from all groundwater recovery wells, including wells R-47 and R-48 which began operation in June 2014. Groundwater samples from the recovery wells will be submitted for BTEX and sulfolane analysis. The groundwater quality data from the recovery wells will provide another line of evidence that the groundwater recovery component of the remediation system is capturing contaminants. The recovery well groundwater sample collection frequency will change to quarterly beginning in the first quarter of 2015, with the exception of R-47 and R-48. The sample collection frequency will be monthly for R-47 and R-48 through one year of operation (June 2015), and then switch to a quarterly frequency.

Evaluation of contaminant capture will be presented in the routine groundwater monitoring reports.

3.4 LNAPL Recovery Performance Monitoring

The OCP (ARCADIS 2014c) specifies that LNAPL transmissivity and LNAPL recovery volumes and rates will be used as metrics to evaluate the performance and effectiveness of LNAPL recovery operations.

Wells that are currently included in the LNAPL monitoring network are shown on Figure 5 and in Table 2. Table 2 also specifies the current monitoring frequency at each well. LNAPL monitoring wells and schedules are also included in Table 3-2 and 3-3 of the LTM Plan (ARCADIS 2014b). Monitoring results from this network will identify candidate wells at which LNAPL transmissivity testing may be completed. Results of transmissivity testing, either from skimming or baildown testing, are used to select wells for LNAPL recovery. Future modifications to the LNAPL recovery system are discussed in Section 4.4. Data gathered from the LNAPL monitoring network and LNAPL thickness monitoring will be used to evaluate the locations within the monitoring network and their respective frequencies. This evaluation and subsequent adjustments to the network will be completed on an annual basis. Changes to the LNAPL monitoring program will be documented in both an updated OMM Plan and LTM Plan (ARCADIS 2014b).

3.4.1 Light Nonaqueous Phase Liquid Transmissivity

LNAPL transmissivity will be calculated from data collected during baildown testing and manual and automated skimming in accordance with the RSAP (which includes a detailed description of the data to be used and relevant definitions). Baildown testing is attempted semi-annually in wells within the LNAPL monitoring network in which an LNAPL accumulation of 0.5 feet or greater is present. An LNAPL baildown test is initiated by quickly removing accumulated LNAPL from a well. The rate of LNAPL flow into the well is a function of the soil and LNAPL properties and the magnitude of the initial hydraulic gradient toward the well developed during LNAPL removal. The baildown test response is influenced by the prevalent fluid levels at the time of testing. A routine LNAPL baildown test program has been initiated that will measure the range of LNAPL transmissivity under different fluid level conditions.

Groundwater levels will be recorded during LNAPL transmissivity testing events and compared to seasonal water levels in the monitoring reports. A representative graph of groundwater table elevation from a nearby well with a pressure transducer will be provided to show relative water level, if available.

LNAPL transmissivities calculated from baildown test and/or skimming data will inform and determine the method of LNAPL recovery operations for each well as discussed above. LNAPL transmissivity measurement and data analysis methods are consistent with the Standard Guide for Estimation of LNAPL Transmissivity (ASTM International 2012).

3.4.2 Light Nonaqueous Phase Liquid Recovery Volume

LNAPL recovery volumes from individual recovery systems will be used as a performance metric to assess the effectiveness of LNAPL recovery. Recoverability of LNAPL generally decreases as remediation progresses and as the volume of recoverable LNAPL decreases. Each recovery system will be monitored to track the volume of product recovered. The locations of the individual systems are modified, as necessary, to relocate the systems to wells with the highest recovery potential.

4.0 Performance Monitoring Evaluation

Criteria for future modifications to the groundwater remediation system include system components, sampling frequency, and/or number of sample locations, and are presented in this section.

4.1 Treatment system performance

For the two treatments system (GAC East and GAC West), FHRA will evaluate the treatment system performance by evaluating analytical results against the requirements of the applicable discharge permit. FHRA intends to continue monitoring and reporting in accordance with the discharge permit and DMR requirements. The frequency of additional sampling and analysis completed by FHRA to evaluate system performance may be increased or decreased based on the reliability and effectiveness of the treatment system components.

If the discharge monitoring indicates inadequate treatment, FHRA will resample to determine if the problem is a short-term deviation or a long-term issue. In the case of a long-term issue, FHRA will evaluate potential modifications or enhancements to the treatment systems.

FHRA continues to review the system effectiveness, reliability, and ease of operation. FHRA will review and consider the potential effect operational changes would have towards meeting treatment system goals.

4.2 Hydraulic capture performance

The methods and current and future frequency of hydraulic capture performance monitoring of the groundwater water recovery and treatment systems are described in Section 3.3.1. If the hydraulic capture monitoring continues to indicate consistent capture, the frequency of the evaluation will be reassessed. Annual hydraulic capture zone evaluations may be adopted in the future.

Maintaining the target pumping rates described in Section 2.1 and meeting the contaminant capture performance criteria described below (Section 4.3) are also indicators of hydraulic capture. If the target pumping rates cannot be maintained on a consistent basis or the contaminant capture performance criteria are not met (considering seasonal variations), the frequency of hydraulic capture zone monitoring will be reassessed. If hydraulic capture monitoring and contaminant capture monitoring (discussed in Section 4.3) indicates capture at reduced flow rates, FHRA will evaluate reductions of the target flow rate ranges as described in Section 2.1.

Prior to any adjustment, a pre-scoping meeting will be held if FHRA deems it necessary. Upon request by FHRA to modify evaluation frequency, ADEC will act upon the request within thirty days provided the submittal is complete.

4.3 Contaminant capture performance

The current and future frequency of contaminant capture performance monitoring of the groundwater water recovery and treatment systems are described in Section 3.3.2. Over time, the number of

monitoring locations and the frequency of monitoring will be modified on a well by well basis using the criteria described below. Recently installed wells will be monitored for four quarters before applying these criteria.

If sulfolane or BTEX concentrations in the downgradient locations continue to decline over time (after taking seasonal variations into account), a reduction in the number of monitoring locations and the frequency of monitoring may be proposed for ADEC review. Prior to any adjustment, a pre-scoping meeting will be held if FHRA deems it necessary. Upon request by FHRA to modify evaluation frequency, ADEC will act upon the request within thirty days provided the submittal is complete. If sulfolane or BTEX concentrations in the downgradient locations show consistent increases over time, without indications of seasonal decreases, a corrective action plan for addressing the situation will be prepared and submitted to ADEC for review. The scope of corrective action will depend on the conditions at the time. Monitoring schedule and frequency will be reevaluated on an annual basis and results of the evaluations will be provided annually in the groundwater monitoring reports or more frequently, if appropriate.

4.4 LNAPL recovery performance

The results of performance monitoring will be used as criteria to evaluate potential future modifications to the LNAPL recovery system. Modifications may include expansion or reduction in locations with LNAPL recovery. The LNAPL monitoring network is shown on Figure 5 and will be reviewed annually and changes to the monitoring locations and their respective frequencies will be made according to the criteria presented in the LTM Plan (ARCADIS 2014b). Proposed changes will be submitted to ADEC for its review if there are any deviations from the criteria in the LTM Plan (ARCADIS 2014b).

In accordance with the RSAP (which includes a detailed description of the data to be used and applicable definitions), if LNAPL in a well increases to a thickness that is greater than 0.5 feet, transmissivity testing will be completed. Conversely, if the thickness of LNAPL decreases below 0.5 feet, it will not be tested for transmissivity. Manual recovery will be initiated in wells with LNAPL thicknesses greater than 0.5 feet.

The results of transmissivity testing will be used to determine which wells will be added or removed from the LNAPL recovery network. The Interstate Technology and Regulatory Council (ITRC) suggests as 0.1 to 0.8 square feet per day (ft2/day) as the LNAPL recoverability threshold for beneficial reduction in overall LNAPL mass.

FHRA has evaluated wells in its LNAPL recovery network for transmissivity and based on site specific characteristics has determined that 0.8 ft^2/day, is the appropriate transmissivity level to initiate mechanical recovery of LNAPL in wells. For a well that has not previously contained LNAPL, an evaluation of the transmissivity will be undertaken.

Manual LNAPL recovery efforts will be suspended when LNAPL thicknesses decrease to less than 0.5 feet. Wells that are removed from routine LNAPL recovery operations will be monitored for 3 years. LNAPL monitoring changes proposed in future OMM Plan updates will consider at least 3 years of monitoring data.

LNAPL recovery rates and volumes will be monitored. The locations and frequency of monitoring of the individual systems may be modified, if necessary, to relocate the systems to wells with the highest recovery potential.

5.0 Documentation of Changes to OMM Plan

Modifications to the performance monitoring networks, the LNAPL Transmissivity Testing Networks, and schedules will be documented in the OMM Plan, which will updated as necessary and submitted as a stand-alone document at least annually. The RSAP will be updated with the Fourth Quarter 2014 Groundwater Monitoring Report. With this update, the RSAP will only describe sampling methodologies and procedures; schedules and monitoring networks pertaining to system performance will be retained and updated in the OMM Plan.

6.0 OMM Reporting Schedule

System performance results will continue to be reported in quarterly groundwater monitoring reports through fourth quarter 2014. Beginning in 2015 groundwater monitoring reports will be submitted semi-annually on or before July 31st and January 31st of each year and will include an overview and evaluation of system performance.

7.0 References

ARCADIS U.S., Inc. 2013. Revised Interim Remedial Action Plan Addendum. July 31, 2013.

ARCADIS U.S., Inc. 2014a. Flint Hills Resources Alaska, LLC North Pole Refinery, Revised Sampling and Analysis Plan. Revision #6, January 2014

ARCADIS U.S., Inc. 2014b. Flint Hills Resources Alaska, LLC North Pole Refinery, Long-Term Monitoring Plan. October 2014

ARCADIS U.S., 2014c. Flint Hills Resources Alaska, LLC Final Onsite Cleanup Plan. North Pole Refinery, North Pole, Alaska. October 2014

ASTM International 2012, Standard Guide for Estimation of LNAPL Transmissivity.

Barr Engineering Company. 2013. Evaluation of Recovery Well Replacement, Start-up Aquifer Testing for Recovery System Hydraulic Capture Performance Monitoring. August 2013.

Tables

Table 1
Performance Monitoring Well Network

Groundwater Remediation System Operations, Maintenance and Monitoring Plan
Flint Hills North Pole Refinery
North Pole, Alaska

Groundwater Extraction System - Sulfolane Monitoring (Quarterly)	Groundwater Extraction System - BTEX Monitoring (Semiannual)	Groundwater Extraction System - Hydraulic Capture (Monthly to Quarterly)†
O-2	O-2	O-2
O-3	O-3	O-3
O-4	O-4	O-4
O-5, O-5-65	O-5	O-5, O-5-65
O-6	O-6	O-6
O-12, O-12-65	O-12	O-11
O-19, O-19-55, O-19-90	O-19, O-19-55	O-12, O-12-65
O-24, O-24-65	O-24	O-19, O-19-55, O-19-90
O-26, O-26-65	O-26	O-24, O-24-65
S-43	S-43	O-32
MW-113-15	MW-113-15	S-32
MW-125-25	MW-125-25	S-43
MW-127-25	MW-127-25	S-44
MW-129-40	MW-129-40	S-50
MW-130-25	MW-130-25	S-51
MW-139-25	MW-139-25	R-14A
MW-142-20	MW-142-20	R-18
MW-145-20	MW-145-20	R-22
MW-154A-75	MW-186A-15	R-39
MW-154B-95	MW-309-15	R-40
MW-175-90	MW-334-15	MW-113-15
MW-186A-15	MW-369-16	MW-125-25
MW-186B-60	MW-370-15	MW-130-25
MW-186E-75	MW-351-15, MW-351-55	MW-135-20
MW-199-150	MW-344-15, MW-344-55	MW-136-20
MW-309-15	MW-345-15, MW-345-55	MW-137-20
MW-309-66	MW-371-15	MW-174-15, MW-174A-50, MW-174B-90
MW-334-15	S-51	MW-175-90
MW-334-65		MW-186A-15, MW186B-60, MW-186C-100, MW-186D-135, MW-186E-75
MW-369-16/55/75		MW-197A-65, MW-197B-150
MW-370-15/55/75		MW-199-150
MW-351-15, MW-351-55, MW-351-75, MW-351-150		MW-301-70, MW-301-CMT-10
MW-344-15, MW-344-55, MW-344-75		MW-304-15
MW-345-15, MW-345-55, MW-345-75		MW-306-15
MW-371-15/55/75/125		MW-307-150
S-51		MW-309-15, MW-309-66
		MW-310-15, MW-310-110
		MW-334-15, MW-334-65
		MW-369-16/55/75
		MW-370-15/55/75
		MW-351-15, MW-351-55, MW-351-75, MW-351-150
		MW-344-15, MW-344-55, MW-344-75
		MW-345-15, MW-345-55, MW-345-75
		MW-371-15/55/75/125
		North Gravel Pit

Notes:
†Hydraulic capture data will be collected and analyzed monthly through 2014. The hydraulic capture data collection frequency will then change to quarterly beginning in the first quarter of 2015.
BTEX = benzene, toluene, ethylbenzene, total xylenes

Table 2
LNAPL Monitoring Network

Groundwater Remediation System Operations, Maintenance and Monitioring Plan
Flint Hills North Pole Refinery
North Pole, Alaska

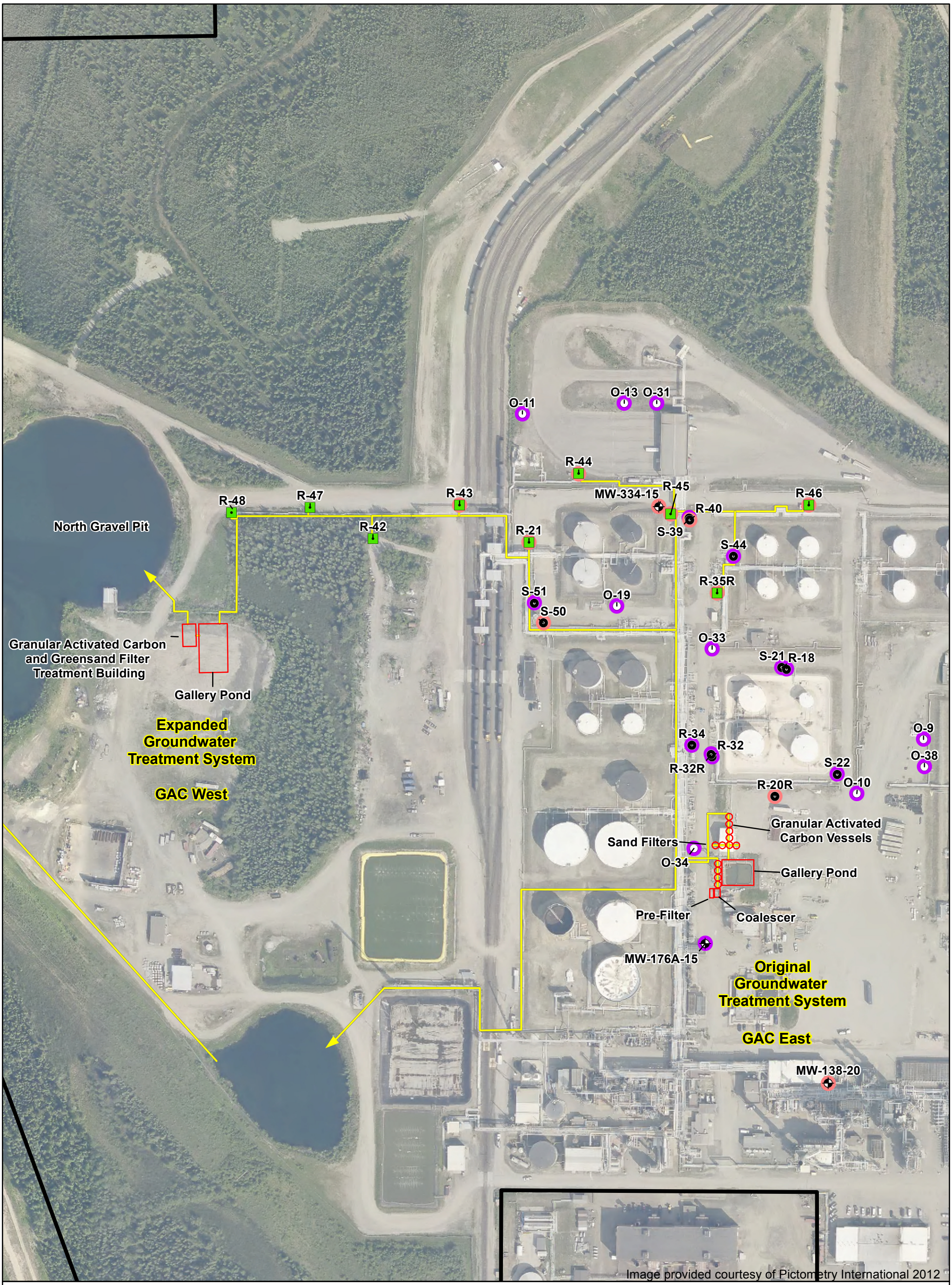
Well	Frequency	Notes
MW-135-20	Semi-annual	
MW-138-20	Quarterly	skimmer pump used when applicable
MW-139-25	Semi-annual	
MW-140-25	Annual	
MW-142-20	Annual	
MW-144A-25	Annual	
MW-145-20	Quarterly	
MW-176A-15	Quarterly	
MW-178A-15	Annual	
MW-179A-15	Annual	
MW-180A-15	Annual	
MW-186A-15	Semi-annual	
MW-195A-15	Annual	
MW-196-15	Annual	
MW-334-15	Monthly	skimmer pump used when applicable
MW-336-15	Semi-annual	
MW-348-15	Semi-annual	
MW-354-15	Semi-annual	
O-1	Annual	
O-2	Semi-annual	
O-3	Quarterly	
O-4	Quarterly	
O-5	Semi-annual	
O-6	Semi-annual	
O-7	Semi-annual	
O-8	Annual	
O-9	Quarterly	
O-10	Quarterly	
O-11	Quarterly	
O-12	Quarterly	
O-13	Quarterly	
O-14	Annual	
O-15	Annual	
O-16	Annual	
O-17	Annual	
O-18	Annual	
O-19	Quarterly	
O-20	Annual	
O-21	Semi-annual	
O-22	Annual	
O-23	Annual	
O-24	Quarterly	
O-25	Quarterly	
O-26	Quarterly	
O-27	Semi-annual	
O-28	Annual	
O-29	Annual	
O-30	Annual	
O-31	Quarterly	
O-32	Semi-annual	
O-33	Quarterly	
O-34	Quarterly	
O-35	Semi-annual	
O-36	Semi-annual	
O-37	Semi-annual	

Table 2
LNAPL Monitoring Network

Groundwater Remediation System Operations, Maintenance and Monitioring Plan
Flint Hills North Pole Refinery
North Pole, Alaska

Well	Frequency	Notes
O-38	Quarterly	
S-9	Semi-annual	
S-21	Quarterly	
S-22	Quarterly	
S-32	Semi-annual	
S-39	Semi-annual	
S-43	Semi-annual	
S-44	Quarterly	
S-50	Quarterly	skimmer pump used when applicable
S-51	Quarterly	
R-3	Annual	Well is a 3 foot diameter culvert--typically frozen or dry.
R-14A	Semi-annual	
R-18	Quarterly	
R-20R	Quarterly	
R-21	Monthly	active recovery well
R-32	Quarterly	
R-32R	Quarterly	replaced well R-32
R-33	Semi-annual	
R-34	Quarterly	
R-35R	Monthly	active recovery well
R-39	Semi-annual	
R-40	Quarterly	
R-42	Monthly	active recovery well
R-43	Monthly	active recovery well
R-44	Monthly	active recovery well
R-45	Monthly	active recovery well
R-46	Monthly	active recovery well

Figures



Recovery Well
Monitoring Well
Recovery Well
Observation Well
Manual Product Recovery*
Installed Product Recovery System
Remediation System Piping
FHRA Property Boundary

*Includes locations with minor recovery volumes during activities such as LNAPL baildown testing.

N

0 100 200 400

Feet

Figure 1
GROUNDWATER REMEDIATION SYSTEM LAYOUT
North Pole Refinery
Flint Hills Resources Alaska, LLC

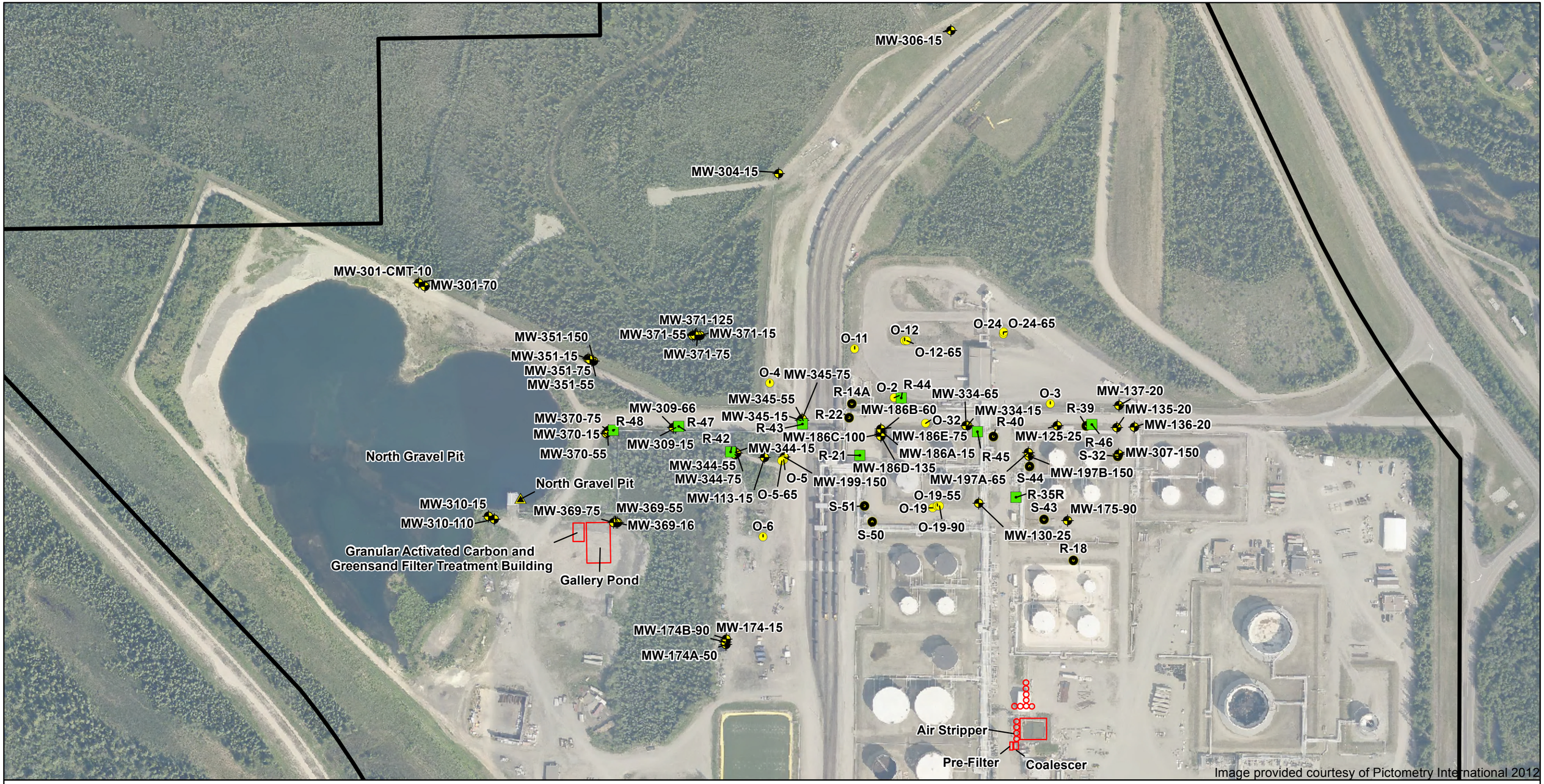


Image provided courtesy of Pictometry International 2012

- Recovery Well
- Monitoring Well
- Observation Well
- Recovery Well
- Surface Water

N

0 125 250 500

Feet

Figure 2
HYDRAULIC CAPTURE ZONE PERFORMANCE
MONITORING NETWORK
North Pole Refinery
Flint Hills Resources Alaska, LLC

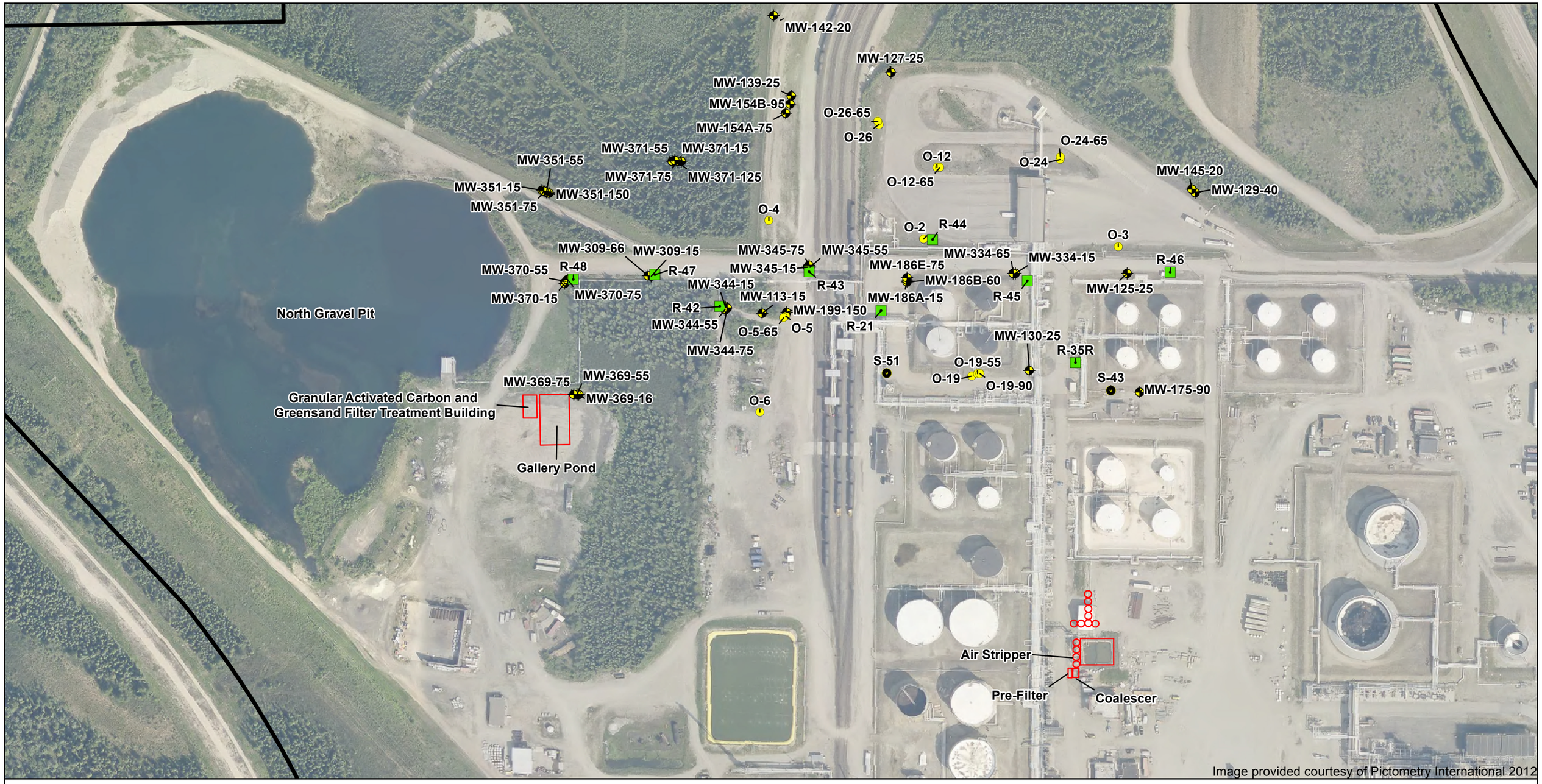


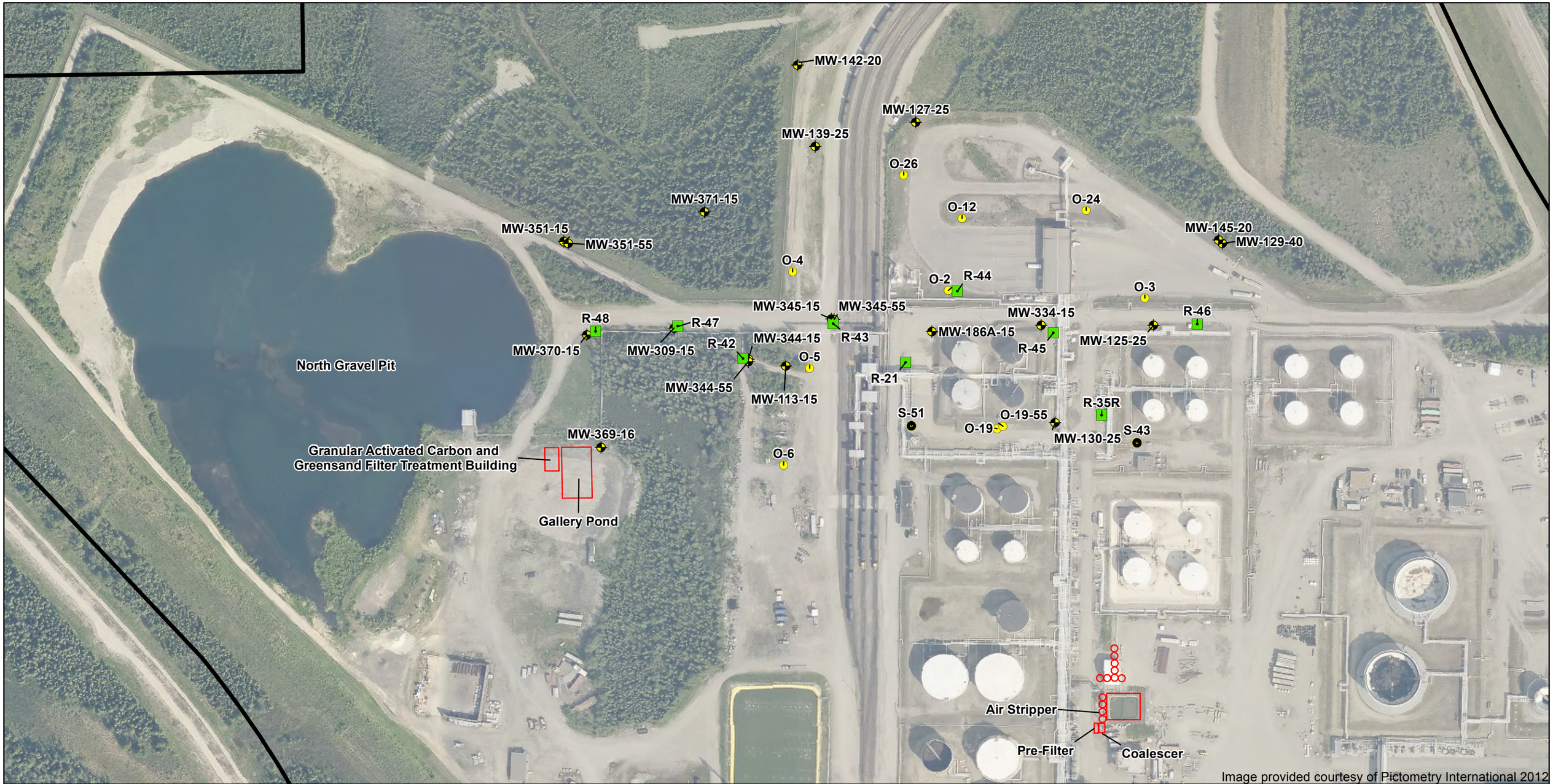
Image provided courtesy of Pictometry International 2012

- Recovery Well
- Monitoring Well
- Observation Well
- Recovery Well
- Surface Water

0 100 200 400

Feet

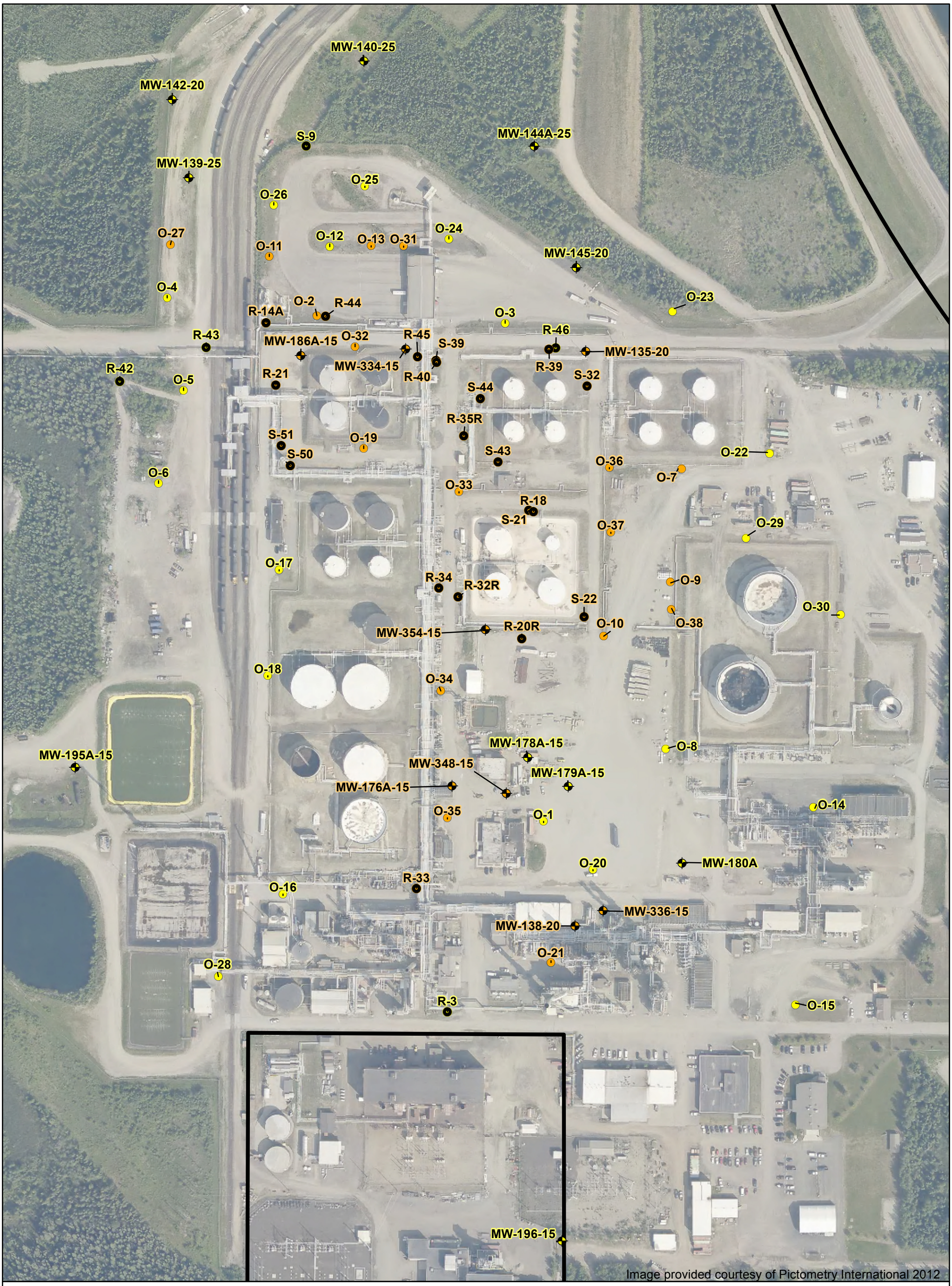
Figure 3
SULFOLANE PERFORMANCE MONITORING NETWORK
North Pole Refinery
Flint Hills Resources Alaska, LLC



- Recovery Well
- Monitoring Well
- Observation Well
- Recovery Well
- Surface Water

0 100 200 400
Feet

Figure 4
BTEX PERFORMANCE MONITORING NETWORK
North Pole Refinery
Flint Hills Resources Alaska, LLC



- Monitoring Well
- Observation Well
- Recovery Well
- LNAPL Migration Monitoring Network
- LNAPL Thickness Monitoring Network
- FHRA Property Boundary

0 100 200 400

Feet

Figure 5
LNAPL MONITORING
WELL NETWORK
North Pole Refinery
Flint Hills Resources Alaska, LLC