UTILIZING MULTIPLE INNOVATIVE REMEDIATION TECHNOLOGIES TO REMEDIATE AND CONTAIN A GROUNDWATER PLUME AT THE DOE PORTSMOUTH SITE, OHIO

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ABSTRACT

The nature and extent of a trichloroethene (TCE) groundwater plume at the southern portion of the U.S. Department of Energy Portsmouth Gaseous Diffusion Plant near Piketon, Ohio, requires the use of multiple remediation methods and approaches for long-term corrective actions and short-term flexibility to contain and reduce groundwater contamination. Interim source control actions included closure in the early 1990s of landfills identified as the primary sources of the contaminated groundwater. The unlined landfills were closed by installing bentonite barrier walls and groundwater collection trenches for groundwater contamination source control and installing multi-layer landfill caps to reduce infiltration. In 1994, a barrier wall was installed along the southern boundary of the site to prevent plume off-site migration. The South Barrier Wall, installed to bedrock by deep soil mixing using a tandem auger system, was designed to be effective for 5-7 years while final groundwater corrective actions were investigated for implementation.

The selected final remedy for the groundwater plume was source isolation using barrier walls and groundwater interceptor trenches and plume remediation using an innovative phytoremediation technology. The phytoremediation corrective action was implemented in phases in 2002 and 2003 by planting approximately 28 acres (0.1 sq. km) of hybrid poplar trees in a trench and sand-pipe design within the plume area.

Groundwater monitoring data in 2002-2003 from the southern site boundary showed that TCE concentrations were increasing in many of the monitoring wells. These monitoring results indicated that the TCE groundwater plume was close to moving off-site at the center and west end of the South Barrier Wall. Even though the phytoremediation has been implemented, effective remediation might not start until the trees reach a more mature state. In addition, the placement of the trees may not fully contain the very leading edge of the plume.

An enhanced bioremediation technology was selected to mitigate plume movement through injection of a hydrogen release compound (HRC) into the plume leading edge to accelerate the

natural attenuation of the TCE through reductive dechlorination in a passive application. HRC injection was implemented in early 2004 using direct push technology. HRC was injected into the water-bearing unit in the vicinity of the South Barrier Wall. The injections create zones designed to react with the TCE and reduce contaminant levels as the groundwater flows through the area. The short-term (HRC injection) and long-term (source control and phytoremediation) actions will be monitored to evaluate the success of plume control and reduction in achieving the objectives of the corrective action.

INTRODUCTION

Since the initiation of Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) and Cleanup Alternatives Study/Corrective Measures Study (CAS/CMS) activities at the Department of Energy (DOE) Portsmouth Gaseous Diffusion Plant (PORTS), soil and groundwater contamination has been identified at a number of areas at the PORTS site. The dominant groundwater contaminant is trichloroethene (TCE), but other volatile organic compounds (VOCs), radionuclides (particularly technetium-99) and metals have been considered as constituents of potential concern. Elevated levels of groundwater TCE contamination have been identified in five distinct groundwater plume areas at PORTS.

A variety of remedial actions have been implemented for most of the contaminated sites at PORTS since the environmental program began in the late 1980s. Several groundwater remediation systems are currently in operation, and five groundwater treatment facilities have been constructed to treat the contaminated groundwater extracted from the remediation systems. The largest TCE groundwater plume is in the southern portion of the facility, and it is the only groundwater plume that is migrating toward the DOE site boundary. As such, a great effort has been focused on the area over the years, and innovative technologies have been implemented in the area to contain and remediate the groundwater plume by source isolation and hydraulic control, plume mass reduction through phytoremediation, hydraulic containment, and more recently, enhanced bioremediation technology.

The environmental program at PORTS has entered a new phase. The program focus has evolved from remedial investigation and remedial action implementation to environmental monitoring, remedial action/system assessments, and enhancements.

BACKGROUND

The PORTS facility is located in a rural area of Pike County, Ohio on a 3,714-acre (15 sq. km) federal reservation. The site is 2 miles (3.2 km) east of the Scioto River in a small valley running parallel to and approximately 120 ft (36.6 m) above the Scioto River floodplain. The PORTS site location is shown on Figure 1.

PORTS began operation in 1954 as one of three uranium enrichment facilities in the United States. In 1993, DOE leased the uranium enrichment production and operations facilities at PORTS to the United States Enrichment Corporation (USEC). Enriched uranium at PORTS was produced for use in commercial nuclear power reactors until May 2001, when production was ceased based on a USEC business decision. USEC has placed the production facilities at PORTS into a cold standby mode under a contract with DOE.

Geological Setting

The PORTS facility is located within the mile-wide paleo pre-glacial river valley of the ancient Portsmouth River. The facility is situated in the Appalachian Plateau physiographic province, approximately 20 miles (32.2 km) south of the limits of Pleistocene glaciation in Ohio. As a result, the site’s topographic setting has been heavily influenced by drainage associated with

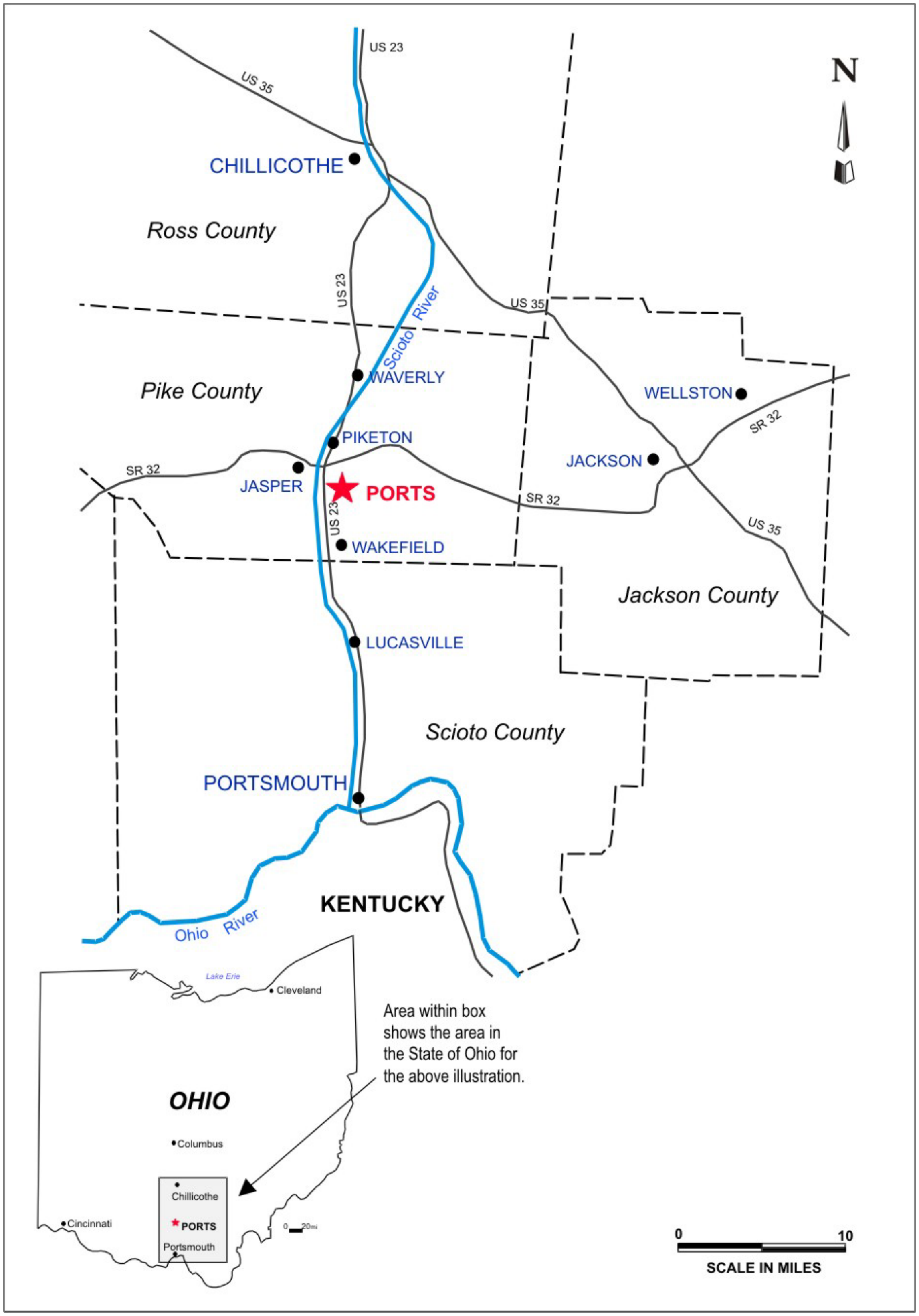

Fig. 1. PORTS site location map

glacial events. The naturally formed knolls and lowlands of the paleo-river valley were modified by cut and fill processes during construction activities in and around the facility. Much of the industrialized area of PORTS is located on fill that was removed from higher elevations of the plant site and placed in existing drainage valleys and depressions.

A schematic block diagram showing the geology at PORTS is presented in Figure 2. Shallow bedrock formations, from oldest to youngest, consist of the Bedford Shale, the Berea Sandstone, the Sunbury Shale, and the Cuyahoga Shale. The unconsolidated sediments are the Gallia Sand and Gravel (Gallia) member and the Minford Silt and Clay (Minford) member of the Teays Formation.

The Minford member of the Teays Formation is a lacustrine deposit consisting of an upper unit, composed of clay with silt and sand, and a lower unit, composed of silty clay with some very-fine to fine-grained sand. The Gallia member of the Teays Formation is a fluvial deposit underlying the Minford member at approximately 25 ft (7.6 m) below ground surface. It overlies bedrock and has a mean thickness of slightly greater than 3 ft (0.9 m). The Gallia is discontinuous across the site, commonly absent near bedrock highs such as bedrock valley walls. It typically consists of red-brown, clayey, medium to coarse sand and poorly sorted gravel that contains silts and clay, as well as numerous pebble- to cobble-sized rock fragments.

The Cuyahoga Formation is the uppermost bedrock formation in the geographic area that forms hills surrounding the facility but is not found beneath the industrial portion of PORTS. The Sunbury Shale is typically the uppermost bedrock unit beneath the facility area. It is competent black shale that ranges from 5 to 20 ft (1.5 to 6.1 m) in thickness beneath the eastern portion of the site, except where it is dissected by local streams. Beneath the western portion of the site, the ancestral Portsmouth River eroded through the Sunbury Shale and exposed the Berea Sandstone. The Berea Sandstone is continuous beneath the industrial portion of PORTS. It underlies the Sunbury Shale on the eastern portion of the site and the unconsolidated Minford and Gallia members on the western portion of the site. The sandstone is approximately 30 ft (9.1 m) thick. The Bedford Formation underlies the Berea Sandstone beneath PORTS. It is a shale-dominated formation, averaging 100 ft (30.5m) in thickness.

Surface soils at PORTS are composed of loess, colluvium, and more recently deposited alluvium. During construction of the PORTS facility, up to 20 ft (6.1 m) of fill was emplaced in some areas. The fill consists predominantly of Minford silts and clays removed from higher areas at PORTS and relocated to low areas.

Aquifer Characteristics

The groundwater flow system at PORTS is defined by four hydrostratigraphic units: the Minford Clay, the Gallia Sand, the Sunbury Shale and the Berea Sandstone. The water-bearing units are the Gallia and the Berea, with the Minford and the Sunbury acting as aquitards.

The Gallia Sand has the highest average hydraulic conductivity of any of the PORTS geologic units and is the primary groundwater flow and contaminant migration pathway. However, the Gallia is a low-yield, water-bearing unit in most areas beneath the PORTS reservation. The

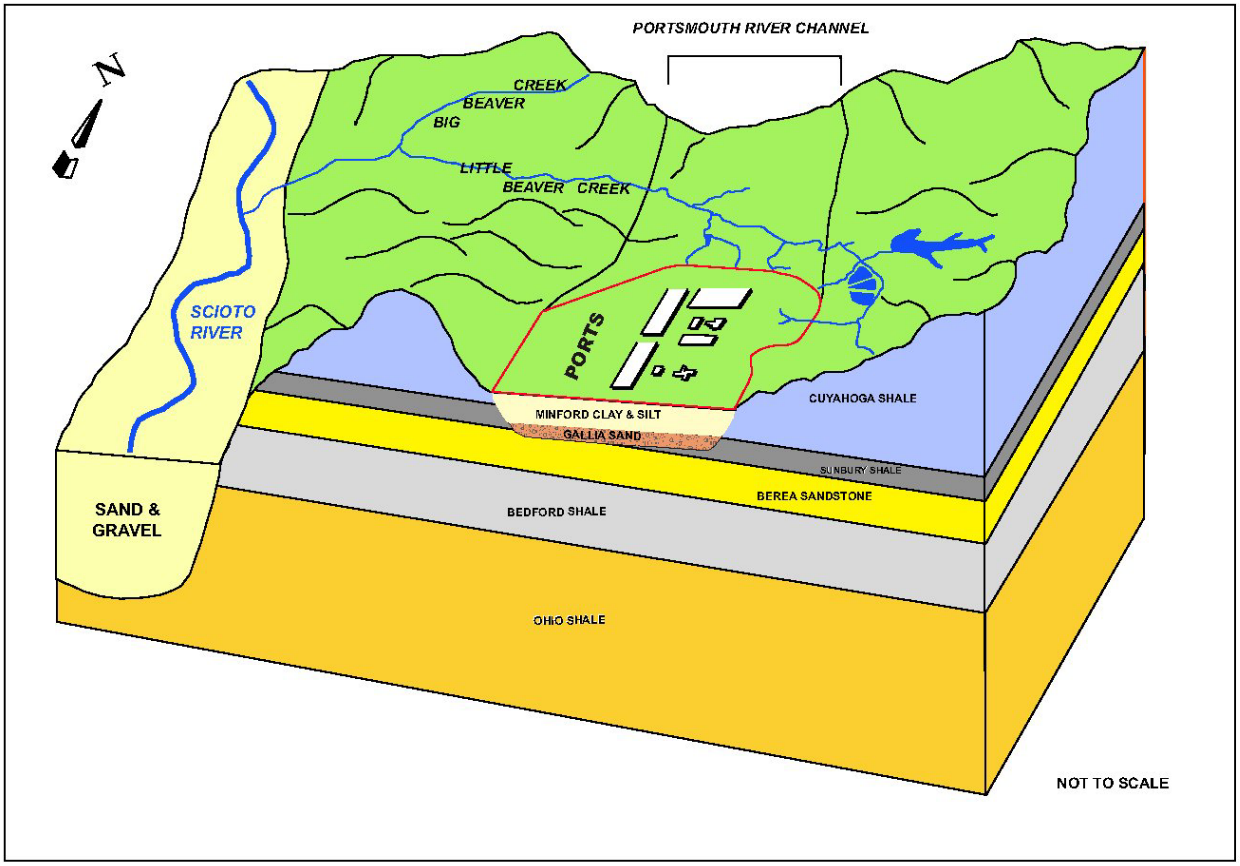

Fig. 2. Schematic block diagram showing geology at PORTS

hydraulic conductivity of the Minford Silt member is somewhat lower than that of the Gallia. The Gallia and the saturated portion of the Minford Silt have a gradational contact and act as a single hydrostratigraphic unit. The Berea Sandstone is the shallowest bedrock water-bearing unit, and its hydraulic conductivity is higher than that of the shales lying above and below this unit.

The Minford Clay, Sunbury Shale, and Bedford Shale are lower hydraulic conductivity units. The Minford Clay member forms a semi-confining layer above the Gallia Sand. The Sunbury Shale, where present, forms a confining layer above the Berea Sandstone that restricts the downward migration of groundwater and contaminants from the Gallia to the Berea. The Bedford Shale acts as a basal confining layer in the groundwater flow system due to its great thickness and shale composition.

The primary source of groundwater recharge is precipitation. Recharge also varies depending on land use and the presence and thickness of undisturbed surficial Minford Clay. Recharge rates range from 0.0 to 7.8 inches (0.0 to 19.8 cm) per year across the facility area. Additional, but unquantified, recharge is known to occur from infrastructure leakage from potable water supply, firewater, and recirculating cooling water lines.

The natural geochemical characteristic of the Gallia water-bearing interval is described as an iron-rich, alkaline water. The natural geochemical characteristic of the Berea water-bearing unit is described as a sulfate-laden water. The site-wide median depth to water is approximately 15 ft (4.6 m). The average hydraulic gradient in the Gallia is approximately 0.005. In general, a downward vertical gradient has been observed through each of the four hydrostratigraphic units of interest. However, as the Sunbury thins to the west on the site, groundwater communication increases and the vertical gradient decreases. Groundwater in the unconsolidated sediments (Gallia and Minford) leaves the PORTS site area by subsurface flow and discharge to surface streams, ditches, and holding ponds or by groundwater extraction systems. Gallia groundwater also, to a lesser extent, migrates downwards into the Berea. Groundwater in the Berea leaves the PORTS site by subsurface flow and to surface streams and ditches that are incised into the top of the sandstone.

GROUNDWATER CONTAMINATION

Soil and groundwater contamination has been identified at a number of areas at the PORTS site. The dominant groundwater contaminant has been identified as TCE, but other VOCs, radionuclides, and metals have been considered as constituents of concern (COCs). Contamination is primarily limited to the shallow Gallia water-bearing interval and, to a lesser extent, slightly elevated levels of these constituents can be found in the Berea Sandstone at isolated locations.

Since the initiation of the RFI and CAS/CMS activities at PORTS beginning in the 1990s, remedial actions and remediation systems have been implemented for most of the contamination sites. Groundwater treatment facilities have been operated at PORTS to treat the contaminated groundwater extracted from the remediation systems, and building and pond sumps. Primarily based on groundwater flow, the PORTS site was divided into four quadrants to facilitate and manage the remediation and restoration process.

Quadrant I encompasses the southern portion of the PORTS industrial areas. Groundwater monitoring and remedial actions are concentrated at two areas: the 5-Unit Groundwater Investigation Area Plume located in the northeastern portion of the Quadrant, and the X-749/X-120 Area Groundwater Plume located in the south-central area of the Quadrant. The Quadrant I RFI Investigation was completed in 1996 (Geraghty & Miller, Inc. 1996) and the CAS/CMS was completed in 2000 (DOE 2000). The plume currently of interest, due to the leading edge of the plume nearing the southern site boundary, is the X-749/X-120 Area Groundwater Plume.

REMEDIAL ACTIONS AT THE X-749/X-120 PLUME

At the southern portion of PORTS (Quadrant I), multiple sources resulted in the commingling of groundwater plumes to form the largest area of groundwater contamination (X749/X-120 Groundwater Plume) at the site (Figure 3). Interim remediation actions have been implemented in this area, since this plume has the greatest potential to reach off-site receptors. Implementation of final remedies was completed in 2003, yet additional, more recent remedial actions were required to prevent off-site migration of groundwater contamination until the selected final remedies reached maturity to contain the plume.

Early Closure And Interim Remedial Measures

In the southern portion of Quadrant I adjacent to the southern boundary of the site, groundwater concerns focus on three contaminant sources: two landfills and a former training facility containing paint and metal fabrication shops. Closure activities for the X-749 Landfill were initiated in 1989. They included installing slurry walls (north side and northern portion of the west side) and groundwater collection trenches (southwest and east sides) for groundwater contamination source control (completed March 1991) and installing a multi-layer landfill cap (completed December 1992) to reduce infiltration.

When contaminants associated with the X-749/X-120 Groundwater Plume were observed in monitoring wells near the southern PORTS facility boundary in 1992, a 1,400 foot (427 m)-long barrier wall was constructed as part of an Interim Remedial Measure (IRM). The barrier was installed in 1994 along the southern boundary of the PORTS site by deep soil mixing using a tandem auger system. The wall was keyed into the underlying Sunbury Shale. The barrier, commonly referred to as the South Barrier Wall, was designed to impede contaminated groundwater from migrating off-site while additional plume remedial actions were investigated and installed.

During the Quadrant I RFI, several intermittent seeps were discovered along the eastern side of the Peter Kiewit (PK) Landfill, northeast of the X-749 Landfill. An IRM was initiated in March 1994 to relocate a portion of Big Run Creek, install a seep collection system, and initiate treatment of the collected seep water (completed in November 1994). A RCRA Subtitle D cap for the PK Landfill was completed in 1998 to limit recharge into and through the landfill. A seep

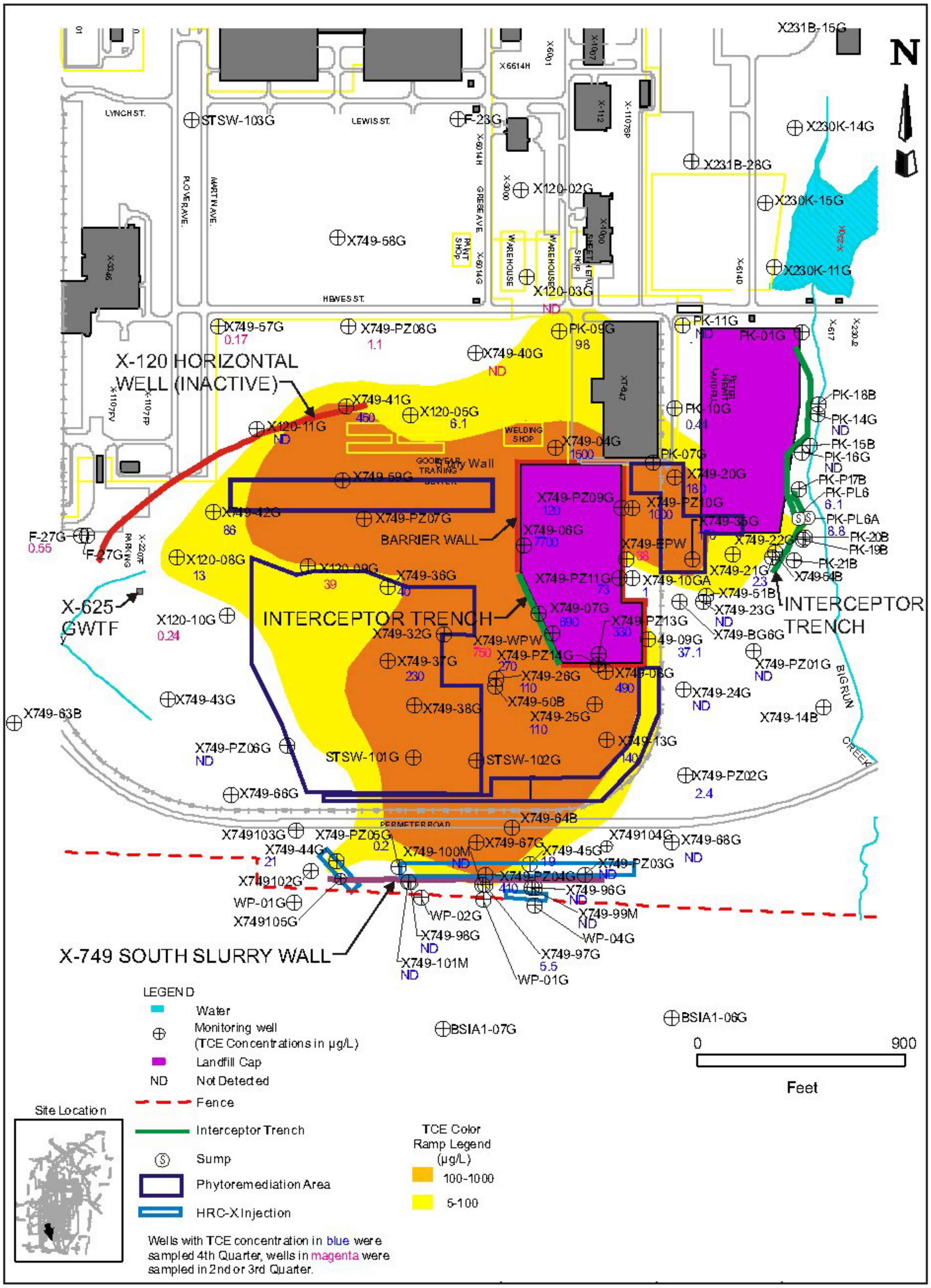
N
X-120 HORIZONTAL WELL (INACTIVE)
BARRIER WALL
INTERCEPTOR TRENCH
X-625 GWTF
X-749 SOUTH SLURRY WALL
BIG RUN CREEK
LEGEND
Water
Monitoring well (TCE Concentrations in µg/L)
Landfill Cap
ND Not Detected
Fence
Interceptor Trench
Sump
Phytoremediation Area
HRC-X Injection
Wells with TCE concentration in blue were sampled 4th Quarter, wells in magenta were sampled in 2nd or 3rd Quarter.
Site Location
TCE Color Ramp Legend (µg/L)
100-1000
5-100
0
900
Feet

Fig. 3. Quadrant I X-749/X-120 groundwater monitoring area

collection system was also constructed to reduce the potential for contaminants from entering Big Run Creek.

In 1996, a horizontal well was installed along the northeastern extent of the plume area as part of a treatability study to test the effectiveness of a gravity-drained treatment facility utilizing various passive media to treat groundwater contaminated with chlorinated solvents. The screened section of this well formerly collected and transferred contaminated groundwater by gravity drainage to the treatment facility. The X-120 Horizontal Well and treatment system was placed in standby (ceased operation) in 2003 due to low volume of groundwater collected as the result of sediment and geochemical clogging of the well and treatment unit. Detection of the contaminants has remained below the regulatory levels in the southwest drainage ditch.

A Vacuum-Enhanced Recovery (VER) pilot test was conducted in 1998 as part of a technology demonstration project in the X-749 area. The test location was southwest of the X-749 Landfill. The system used multiple pumps to remove liquids and vapors. The pilot test demonstrated the ability of VER to dewater the Gallia and remove vapor mass in both the Gallia and the Minford but was not selected for implementation as the final remedy.

CAS/CMS Actions

The final remedial actions selected by the Ohio Environmental Protection Agency (Ohio EPA) in 2000 for the X-749/X-120 Groundwater Plume included construction of a barrier wall on the south and east sides of the X-749 Landfill (replacing the groundwater collection trenches along the east side of the landfill) and phytoremediation. Construction of the barrier wall which began in 2001 and was completed in 2002, required removal of the groundwater collection system and associated east pumping well on the northern half of the landfill's eastern side. The barrier walls were installed along the X-749 Landfill southern and eastern boundaries.

The innovative phytoremediation corrective action was implemented in 2002 and 2003 in the X-749/X-120 Groundwater Plume to reduce VOC contaminant concentrations. The corrective action included phytoremediation using poplar trees planted along the X-749/X-120 Plume's eastern, southern, and western margins. Trenches were dug 10 to 15 ft (3.1 to 4.6 ft) deep and sand stacks (gravel filled borings) were installed from the base of the trenches to bedrock. The potentiometric head of the Gallia water-bearing unit fills the bottom of the trenches with contaminated groundwater where trees are planted. During the growing seasons, the tree roots and associated microorganisms remove or destroy the VOC contamination associated with the contaminated groundwater. The corrective action was expanded in 2003 to include most of the groundwater plume area to the southwest, west, and northwest of the X-749 Landfill. A total of approximately 3000 hybrid poplar trees were planted over approximately 28 acres (0.1 sq. km) of the X-749/X-120 Groundwater Plume area. The trees, when mature, are expected to control any further movement and to reduce the footprint of the plume within the site. Tree maturity is expected approximately 5 years after planting.

PLUME MONITORING, DATA EVALUATION AND IMPLEMENTATION OF ADDITIONAL REMEDIATION ACTIONS

TCE concentrations are varied at selected wells near the X-749 Landfill area. Overall, the TCE concentrations at the wells outside of the landfill show a decreasing trend since 1992, after source isolation remedial actions were completed. The actions included installing slurry walls (north side and northern portion of the west side) and groundwater collection trenches (southwest and east sides) for groundwater contamination source control and placing a multi-layer landfill cap over the entire facility (DOE 2004).

TCE concentrations show limited variation at selected wells near the PK Landfill area. The TCE plume originates from the X-749 Landfill, flows through the southwest corner of the PK Landfill and discharges to the groundwater collection system prior to Big Run Creek.

Because the X-120 Horizontal Well is a plume leading edge extraction system and contaminant mass continuously moves from the plume center of the X-749 Landfill area, most of the monitoring wells, located between the horizontal well and plume center, show relatively little change in TCE concentration. However, the TCE concentration in one well, next to the horizontal well, dropped to non-detect in 2003.

Groundwater TCE data from the X-749 South Barrier Wall indicate that TCE concentrations have increased in many of the monitoring wells since 2000. A monitoring well located at the west end of the barrier wall (X749-44G), exhibited TCE concentrations of 20 μg/L in 2003. TCE concentrations have increased to slightly above the maximum contaminant level (MCL) of 5 μg/L in groundwater collected from monitoring well X749-97G, located a few feet south (downgradient) of the barrier wall. These monitoring results indicate that the X-749/X-120 TCE groundwater plume is close to moving off-site at the center and west end of the barrier wall. The South Barrier Wall, located along the site boundary, is considered functional but is reaching the limit of its ability to serve its intended purpose without additional actions. Groundwater contamination may be moving around the west side and possibly under or through the wall.

Immediate actions were implemented to address the potential problem by combining an expanded monitoring program, a short-term remediation technology screening study, and conducting a multi-well aquifer characterization pumping test in the vicinity of the South Barrier Wall. The expanded monitoring program suggested groundwater contamination had not reached off-site locations, but the future usefulness of the wall was in question, with the potential for groundwater contamination to migrate around and/or through wall.

An enhanced bioremediation technology through injection of hydrogen release compounds (HRC) into the plume leading edge was selected to mitigate plume movement. HRC-X™ is an organic compound of glycerol tripolylactate, which slowly releases lactic acid. Glycerol tripolylactate is an environmentally safe, food-quality polylactate ester used to accelerate the natural attenuation of the TCE through reductive dechlorination in a passive application. The remedial selection was based on a need to implement a relatively inexpensive remedial option requiring minimal engineering design and field implementation that would act quickly and supplement the current remedial action (phytoremediation).

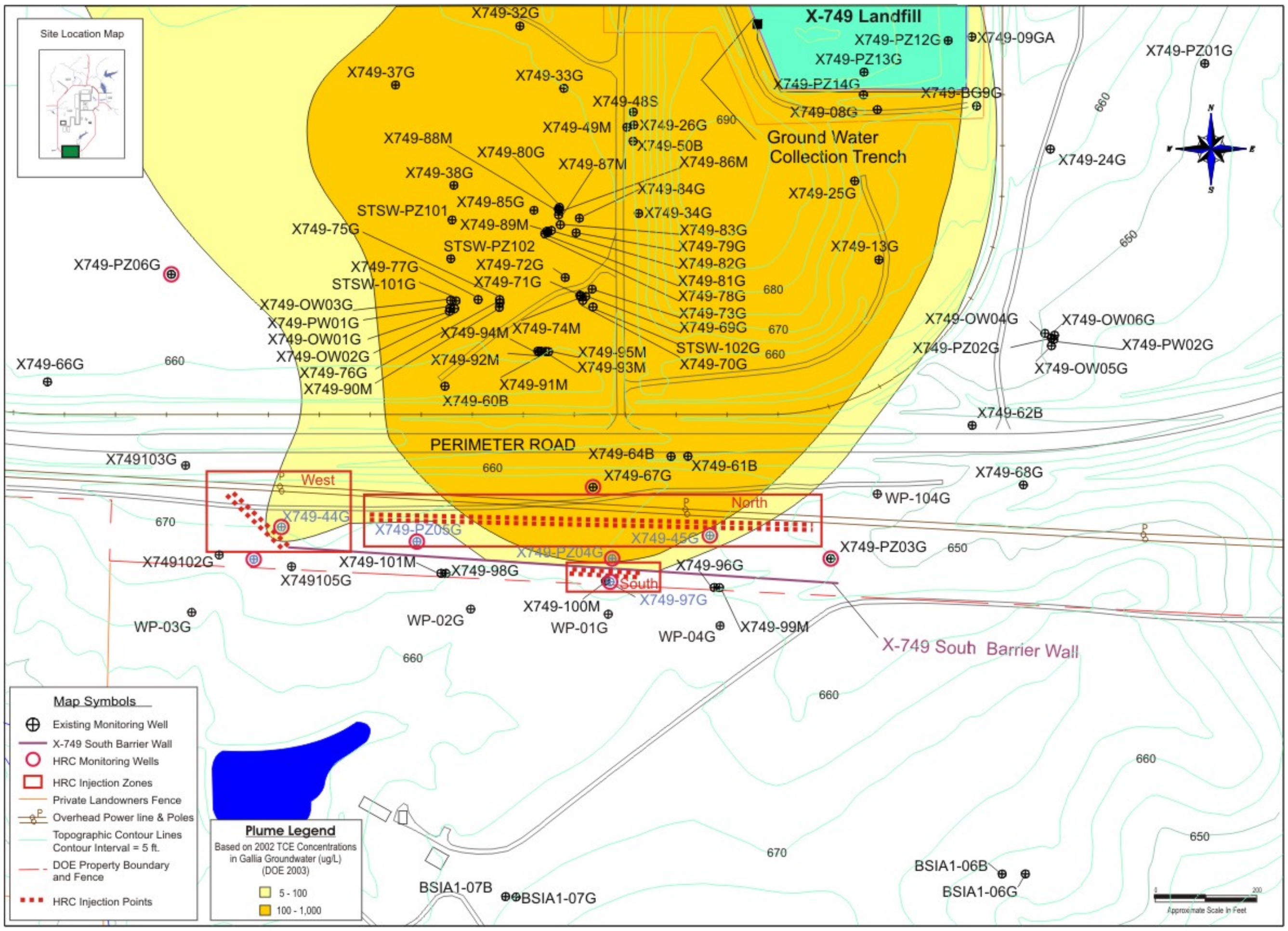

Fig. 4. HRC injections at the X-749 South Barrier Wall

HRC-X™ injection was implemented in early 2004 using direct push technology (DPT). HRC-X™ was injected into the shallow water-bearing unit in the vicinity of the South Barrier Wall (Figure 4). The injections create zones designed to react with the TCE and reduce contaminant levels as the groundwater flows through the area. HRC-X™ was injected through 183 DPT boreholes in three zones in the X-749 South Barrier Wall area: the western end of the barrier wall, north of the barrier wall, and south of the barrier wall (in the vicinity of monitoring well X749-97G). The HRC-X™ was injected to the Gallia sandy silt water-bearing unit above the Sunbury Shale. The HRC-X™ injection zone creates a reactive barrier that will intercept and treat the groundwater as it flows through the barrier. The implementation process also allowed the opportunity to evaluate the top elevation of the bedrock surface. This information, along with the information collected during past monitoring well and barrier wall installations, provided a more detailed conceptual model of geologic conditions and potential plume movement in the vicinity of the reservation's southern site boundary.

With the completion of the enhanced remedial action by injecting HRC-X™ at the South Barrier Wall area in April 2004, it is expected that the TCE concentration at the plume's leading edge will slowly decrease. The injection treatment zone is expected to last up to 5 years, allowing additional time for the monitoring of phytoremediation effects to the groundwater plume.

A focused groundwater monitoring program is being conducted for the newly implemented HRC-X™ injection remedial actions at the X-749 South Barrier Wall area. This monitoring plan incorporates elements of the site-wide monitoring program (DOE 2003) and is based on the unique and specific aspects of the HRC-X™ application. The objective of the monitoring plan is to validate the HRC-X™ enhancement of reductive dechlorination processes. The first groundwater sampling event since the injection indicated decreasing contaminant concentrations in most of the monitoring well. A decision to continue with bioremediation, to implement a more aggressive action, or to take no other action will be determined utilizing the monitoring program.

CONCLUSION

Various remedial actions have been implemented for groundwater contamination remediation and source control at the site. As the remedial alternatives identified by the CAS/CMS have mostly been implemented, the environmental program at PORTS has entered a new phase. The program focus has evolved from remedial investigation and remedial action implementation to environmental monitoring and remedial action/system assessment.

The implementation of HRC to compliment the existing phytoremediation system is just one aspect of the need to modify and enhance remediations systems as they mature and expectations are met or require enhancement. Following the successful completion of injection, a groundwater monitoring plan was developed based on the site-specific conditions and uniqueness of the HRC-X™ application. Validation and monitoring of enhanced bioremediation processes will be accomplished by collecting groundwater samples from wells in specified areas and comparing areal and temporal effects. The short-term (HRC-X™ injection) and long-term (source control and phytoremediation) actions will be monitored to evaluate the success of plume control and reduction to achieve the objectives of the corrective action.

The remediation and monitoring activities for the groundwater plume at PORTS indicated the importance of using multiple remediation methods and approaches for long-term corrective actions while permitting the short-term flexibility to contain and reduce groundwater contamination.

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