Paper J-01, in: Bruce M. Sass (Conference Chair), *Remediation of Chlorinated and Recalcitrant Compounds—2006.* Proceedings of the Fifth International Conference on Remediation of Chlorinated and Recalcitrant Compounds (Monterey, CA; May 2006). ISBN 1-57477-157-4, published by Battelle Press, Columbus, OH, www.battelle.org/bookstore.

Risk-Based Cleanup Actions for Closure of a Brownfield Site

James B. Feild, Leonard C. Farr Jr., Kristin L. Winter, and
Heidi W. Rice (heidi.rice@amec.com)
(AMEC Earth & Environmental, Inc., Portland, Oregon, USA)

ABSTRACT: Operating as a rail yard from approximately 1908 to 1987, Station Place is a 7.1-acre (4,046 square-meters) property located in the Downtown Portland, Oregon, River District Urban Renewal Area. The site soils were impacted with metals and poly-nuclear aromatic hydrocarbon compounds (PAHs). Benzene and select PAHs were detected in the shallow groundwater. Residual NAPL was detected within the shallow saturated zone between 15 and 40 feet (4.5 to 12 meters) below grade and in the Troutdale Formation at depths of up to 80 feet (24 meters). Site closure was obtained and redevelopment was completed at the site, by the Portland Development Commission, following the preparation of a baseline deterministic human health risk assessment, and beneficial land and water use determination to assess whether exposure to groundwater and soil posed a threat to human health. The property now provides affordable housing for the elderly and a city-owned parking garage. The affordable housing provides substantial community benefit, allowing elderly people to live in a vibrant, exciting part of the city. Portland's city-owned parking garages also provide much needed parking space at very affordable rates. Both of these additions have changed an underused brownfield into affordable facilities in a lively urban environment.

BACKGROUND

The Station Place Redevelopment Site (Site) is a 7.1-acre (4,046 square-meters) property subdivided into seven lots, referred to as Lots 1 through 7. The site is located near the western bank of the Willamette River in Portland, Oregon, within the River District Urban Renewal Area. The Site operated as a rail yard from approximately 1908 to 1987. The Site is roughly triangular in shape. A locomotive fueling and maintenance facility is located across NW 9th Avenue west of the Site. The property to the south of the site is currently owned by the United States Postal Service (USPS) and was formerly occupied by a Pintsch manufactured-gas plant (MGP).

Historically, several buildings and associated fuel underground storage tanks (USTs) historically were located at the Site. The Portland Development Commission purchased this former industrial property in hopes of creating a vital new mixed-use and mixed-income neighborhood. Remedial Investigation (RI) activities were initiated in 1999 under the Oregon Department of Environmental Quality's (DEQ's) Voluntary Cleanup Program to evaluate the environmental conditions at the Site.

The general near-surface geology of the area adjacent to the River consists of Quaternary Alluvium soils and lacustrine (lake) deposits composed of clay, silt, sand, and gravel. The alluvium along the west bank of the river ranges in thickness from less than 50 feet (15 meters) to more than 100 feet (30 meters). The area northwest of the Site historically was occupied by Couch Lake prior to the 1890s. This lake was filled prior to the construction of the nearby Union Station train depot in the 1890s. A significant

amount of fill also was placed at the Site during development of the area in the late 1800s.

Beneath the Quaternary Alluvium soils is the Troutdale Formation. The Troutdale Formation in the area of the Site is approximately 100 to 200 feet (30 to 60 meters) thick and consists of dense gravel and sand, partially cemented in places. The gravels are composed mostly of Columbia River Basalt rock with minor amounts of quartzite, granite, and metamorphic rocks. The Troutdale Formation is encountered at depths ranging from approximately 40 to 95 feet (12 to 29 meters) at the Site.

RESULTS OF REMEDIAL INVESTIGATION

AMEC Earth & Environmental, Inc. (AMEC) performed a remedial investigation (RI) at the Site, between October 1999 and June 2002, to characterize the nature and extent of hazardous materials present in soil and groundwater at the Site, and to evaluate the level of risk associated with identified hazardous materials. AMEC collected soil and/or groundwater samples during multiple exploration phases during the RI. A total of 78 direct-push borings were completed to depths ranging from 4.5 to 94 feet (1.4 to 28.5 meters). Seven borings were drilled to a depth of more than 100 feet (30 meters) below ground surface (BGS) using air-rotary drilling techniques. A total of 14 monitoring wells were installed in these borings, nine in direct-push borings, and five in air-rotary borings.

Impacted soil was identified across all seven lots comprising the Site. Site-specific contaminants of concern (COCs) impacting the soil included arsenic and the polynuclear aromatic hydrocarbon (PAHs). However, relative concentrations of PAHs generally were higher on Lots 1 and 2, located on the southern end of the property (Figure 1). Detected concentrations of principally benzo(a)pyrene were high enough on Lots 1 and 2 to constitute a highly concentrated hot spot. Hot spot removal activities were conducted as an interim corrective action for Lots 1 and 2. Surface or storm water infiltration through the ground surface could transport dissolved-phase COCs from the unsaturated zone to the deeper subsurface, and to groundwater. However, results of PAH leachability testing indicated that PAHs are not migrating via this pathway at the Site (AMEC, 2002a). Hot spot removal actions were undertaken at the site on three separate events, removing an estimated 1,375 cubic yards (1,050 cubic meters) of impacted soil.

FIGURE 1. Lots 1 and 2 at beginning of construction.

Two water bearing zones (WBZs) were identified at the site. The shallow alluvial WBZ was encountered at approximately 11 feet (3.4 meters) BGS. Groundwater flow within this WBZ is generally to the west. Yields from the alluvial water bearing zone are low, and high iron content is found in groundwater within the alluvial WBZ. Impacted groundwater was identified within the shallow alluvial WBZ. Groundwater COCs in this WBZ include benzene, naphthalene, benzo(a)pyrene, and dibenzo(a,h)anthracene. The COCs detected in the shallow WBZ are believed to be derived from historical operations at a former MGP, located south of the Site. Based upon the age and operational history of the MGP, releases may have occurred between 65 and 100 years ago, and initial masses or concentrations of hazardous substances released are not known. Elevated concentrations of dissolved-phase COCs occur in an approximately 30,000 square foot (2,787 square-meters) area in the southwestern corner of the Site. The highest concentration of benzene (2.5 mg/l) was detected in the shallow alluvial WBZ, near the southwestern corner of the Site. Residual NAPL was identified within the saturated zone at the Site, generally between 15 and 40 feet (4.5 to 12 meters).

The second WBZ, located in the deeper Troutdale Formation, is encountered at an approximate depth of 40 feet (12 meters) below grade and flows to the east-northeast. Groundwater from the Troutdale Formation is used extensively as a water resource in East Portland where the City of Portland taps the Troutdale Formation to subsidize the Bull Run Watershed, the primary source of water for the City. In the Site vicinity, however, the Troutdale Formation generally is not used as a source of domestic, industrial, or irrigation water. As with water within the alluvial WBZ, water within the Troutdale Formation typically contains high iron concentrations.

The distribution of dissolved-phase COCs in the Troutdale Formation covers an area of approximately 80,000 square feet (7,432 meters). Releases of hazardous substances to the Troutdale Formation WBZ may be partly associated with a tar well or other MGP features, located immediately south of the Site. Substances in the form of liquid or tarry wastes potentially migrated downward from the MGP into the Troutdale Formation, and then migrated north-northeast onto the Site. The maximum naphthalene and benzene concentrations detected in groundwater samples were 11 mg/l and 12.4 mg/l, respectively. Residual NAPL was observed in the Troutdale Formation as deep as 80 feet (24.5 meters) BGS.

An evaluation of constituent transport pathways at the Site indicated utility corridors in NW 9th Avenue may act as preferential migration pathways and may enhance advective flow of dissolved constituents. A potential for COCs existing in the dissolved-phase, or as a NAPL denser than water, to migrate downward through the shallow or deep saturated zones by gravity drainage is possible, however, the NAPL encountered at the Site is highly viscous, slightly denser than water, and has a low solubility. The NAPL source is thought to have occurred more than 80 years ago and has reached a state of residual saturation. All these factors combined result in residual NAPL with very little potential to migrate under any reasonably likely hydraulic conditions. Therefore, migration of NAPL, whether by advection hydraulic displacement or by density-driven flow, is not anticipated to occur on- or off-Site. The residual NAPL is suspected to be a longer-term source for benzene and naphthalene in the shallow alluvial WBZ. Vapors resulting from the dissolved-phase or NAPL constituents were considered a viable transport path-

way that could deliver limited quantities of COCs through vadose zone soils and COCs into indoor and outdoor air.

A beneficial water use determination (BWUD) was completed for the Site. Contaminant distribution and hydrogeologic data for the Site was used to delineate a locality of facility (LOF) as part of the BWUD. No current or reasonably likely future beneficial water uses were identified for either of the two WBZs within the LOF. Because no current or reasonably likely future beneficial groundwater uses are likely to be affected by MGP constituents detected in groundwater at the Site, no potential groundwater hot spots were delineated.

A baseline deterministic human health risk assessment evaluated direct and indirect human exposure pathways for residential, urban residential, occupational worker, excavation worker, and construction worker receptors. Urban residents were included in the risk assessment in addition to residents, because the resident exposure scenario, which models a single-family residential setting, was considered improbable for the Site. The principal difference between the urban resident and resident exposure scenarios is exposure duration: 11 years for urban resident and 30 years for resident.

Based on risk benchmarks of 1×10^{-5} for multiple carcinogens (OAR 340-122-115(3)(a); 1×10^{-6} (OAR 340-122-115(2)(a) for individual carcinogens; and hazard index greater than 1 (OAR 340-122-115(4)(a) for noncarcinogens, the receptors/pathways that resulted in unacceptable risk for Lots 1 and 2 at the Site as summarized in Table 1.

RESULTS OF FEASIBILITY STUDY

The Feasibility Study (FS) assimilated data obtained from the soil and groundwater RI phases, and used that data to evaluate remedial action alternatives to address specific COCs that exceeded the risk benchmarks. A summarized list of remedial action objectives is summarized in Table 2.

The FS was conducted for the Site in general accordance with the Oregon Administrative Rules, the DEQ “Final Guidance for Conducting Feasibility Studies” dated July 1, 1998, and the Office of Solid Waste and Emergency Response Directive, "Guidance for Conducting Remedial Investigations and Feasibility Studies under the Comprehensive Environmental Response, Compensation and Liability Act". Remedial treatment and/or containment technologies that could potentially be used to achieve remedial goals and objectives were identified and screened, based on protectiveness, effectiveness, long-term reliability, implementability, implementation risk, and cost. Technologies considered as part of the initial screening included air sparging, steam enhanced soil vapor extraction (SVE), soil solidification/stabilization (S/S), ex-situ soil washing, excavation with off-site disposal, fencing and erosion control, surface capping, and natural attenuation with groundwater monitoring.

Following an initial screen of the technologies, a detailed analysis of compiled remedial alternatives was conducted. The alternatives were screened using the remedy selection balancing factors listed above; and compared to one another.

TABLE 1. Results of the baseline human health risk assessment.

Exposure Unit	Receptor	COC Associated with Unacceptable Risk	Media Associated with Unacceptable Risk	Pathways Associated with Unacceptable Risk
Lots 1 & 2	Resident	Arsenic	Soil	DE / II
		Benzo(a)anthracene	Soil	DE / II
		Benzo(a)pyrene	Soil	DE / II
		Benzo(b)fluoranthene	Soil	DE / II
		Dibenzo(a,h)anthracene	Soil	DE / II
		Indeno(1,2,3-c,d)pyrene	Soil	DE / II
		Benzene	Groundwater	IAI
	Urban Resident	Arsenic	Soil	II
		Benzo(a)pyrene	Soil	DE / II
		Dibenzo(a,h)anthracene	Soil	II
		Benzene	Groundwater	IAI
	Occupational Worker	Arsenic	Soil	II
		Benzo(a)pyrene	Soil	DE / II
	Excavation Worker	Benzo(a)pyrene	Soil	DE / II
		Benzo(a)anthracene	Soil	DE / II
		Dibenzo(a,h)anthracene	Groundwater	DE
		Benzene	Groundwater	DE / OAI
		Naphthalene	Groundwater	OAI
	Construction Worker	Arsenic	Soil	II
		Benzo(a)anthracene	Soil	DE / II
		Benzo(a)pyrene	Soil	DE / II
		Benzo(b)fluoranthene	Soil	DE / II
		Dibenzo(a,h)anthracene	Soil	DE / II
		Indeno(1,2,3-c,d)pyrene	Soil	DE / II

Notes:
DE = Dermal Exposure
II = Incidental Ingestion
IAI = Indoor Air Inhalation
OAI = Outdoor Air Inhalation

TABLE 2. Site-specific RAOs.

Medium	Remedial Action Objectives	Risk-based Concentrations
Soil	**Human Health** - Prevent exposure to soil posing a lifetime excess cancer risk > 1E-06 for individual carcinogens or >1E-05 for multiple carcinogens. Soil contamination exposure exceeds one or both of these risk thresholds via the ingestion and/or dermal contact pathways for all evaluated receptor groups on Lots 1 & 2, and for all evaluated receptor groups except construction workers on other Site Lots.	Arsenic: 7 mg/kg [a] Benzo(a)anthracene: 0.62 mg/kg [b] Benzo(a)pyrene: 0.062 mg/kg [b] , 27 mg/kg [c] (Under Ramp) Benzo(b)fluoranthene: 0.62 mg/kg [b] Dibenzo(a,h)anthracene: 0.062 mg/kg [b] Indeno(1,2,3-c,d)pyrene: 0.62 mg/kg [b]
	Migration - Prevent migration of soil via surface water runoff from reaching the Willamette River via storm water catch basins located in NW 9th Avenue.	This remedial action objective was achieved as an interim remedial action measure.
	Hot Spots of Contamination - Treat or remove hot spot contamination.	This remedial action objective was achieved as an interim remedial action measure.
Ground-water	**Human Health** - Prevent exposure to groundwater posing a lifetime excess cancer risk >1E-06 for individual carcinogens or >1E-05 for multiple carcinogens. Groundwater contaminant exposure exceeds the 1E-06 risk for individual carcinogen threshold for Lot 1 & 2 residents (vapor intrusion into buildings) and for excavation workers (dermal exposure and outdoor air inhalation) on all Site lots.	Benzo(a)pyrene: 0.24 µg/L [c] Dibenzo(a,h)anthracene: 0.088 µg/L [c] Benzene: 180 µg/L [c] Naphthalene: 240 µg/L [c]
	Migration - Prevent migration of groundwater to the Willamette River via preferential migration pathway (i.e., deep NW 9th Avenue utilities).	This remedial action objective was achieved as an interim remedial action measure.
Soil Vapor	**Human Health** - Prevent exposure to soil vapor posing a lifetime excess cancer risk >1E-06 for individual carcinogens or >1E-05 for multiple carcinogens. Soil vapor exposure exceeds the 1E-06 risk for individual carcinogen threshold for Lot 1 & 2 residents (vapor intrusion into buildings) and for excavation workers (outdoor air inhalation) on Lots 1 & 2.	Benzene: 0.30 µg/m^3 [c] (residential); 0.65 µg/m^3 [c] (occupational) Naphthalene: 3.1 µg/m^3 [c] (residential); 4.4 µg/m^3 [c] (occupational)
NAPL	**Migration** - Prevent migration of non-aqueous phase liquids (NAPLs) to the Willamette River via preferential migration pathways (i.e., deep NW 9th Avenue utilities).	This remedial action objective was achieved as an interim remedial action measure.

[a] Washington State Department of Ecology Memorandum dated October 1994.
[b] Environmental Protection Agency (EPA) Region IX Preliminary Remediation Goals (PRGs) Table, October 2002.
[c] DEQ Risk-Based Decision Making (RBDM) for the Remediation of Petroleum Contaminated Sites. 1999.
[d] Calculated in Interim Remedial Action Work Plan for Infrastructure Improvements Construction Project, Station Place Redevelopment Site, AMEC, October 2002.

SITE CLOSURE

Site closure was obtained through mitigation of the remaining risks to human health, following the completion of the interim action measures and included the following actions:

1. Capping the site with hardscaped and landscaped areas to mitigate the risk associated with direct contact to Site soils.
2. A vapor barrier and vapor mitigation system installed below the residential tower constructed on Lot 1 to mitigate inhalation risk due to benzene vapor intrusion into the proposed residential building tower from shallow groundwater.
3. Engineering and institutional controls including worker notification and controlling surface water runoff were implemented to manage the exposure to outdoor air inhalation risk associated with shallow groundwater and off-site migration of COCs as a result of surface water runoff during construction activities at the Site.
4. Indoor air monitoring semi-annually for a minimum of 5 years.
5. Groundwater monitoring for a minimum of 5 years.

CONCLUSIONS

During the completion of a RI at a former rail yard, hazardous substances associated with a former Pintch MGP and general railroad operations were discovered. Risk assessment indicated that these hazardous substances threatened human health and required mitigation. To mitigate threats to human health, the following actions were taken:

1. 1,375 cubic yards (1,051 cubic meters) of highly concentrated hot spot soils were excavated and transported off-Site for disposal as an interim removal action.
2. A risk-based cleanup plan including surface capping, vapor barrier and venting system installation, institutional controls, and indoor air and groundwater monitoring was implemented.

By using a risk-based approach to closure, and implementing the approach concurrent with Site redevelopment, threats to human health at the Site were efficiently and cost-effectively resolved.

The property now provides affordable housing for the elderly and additional parking for the patrons of nearby businesses. The affordable housing, developed as part of this project, shown in Figure 2, provides substantial community benefit, allowing elderly people to live in a vibrant, exciting part of the city. The parking garage also provides much needed parking space at reasonable rates. These additions have substantially improved this underutilized former industrial site or brownfield.

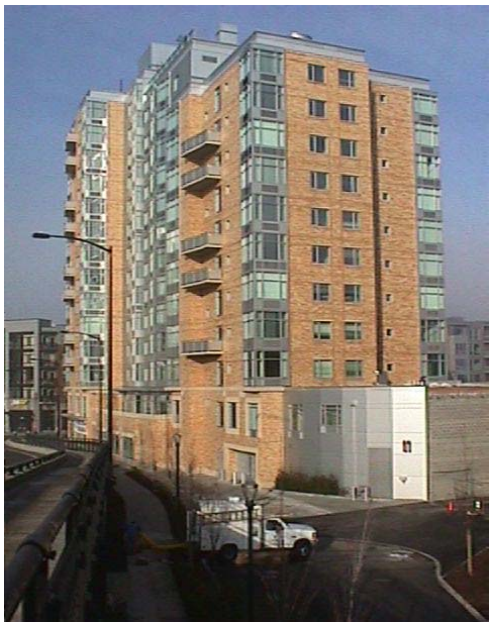

FIGURE 2. Station Place residential tower.

REFERENCES

AMEC Earth & Environmental, 1999. *Phase I Environmental Site Assessment, Horse Barn Site, NW 9th and Lovejoy, Portland, Oregon.* April 199.

AMEC Earth & Environmental, Inc., 2002a. *Comprehensive Soil Remedial Investigation Report.* July 2002.

AMEC Earth & Environmental, Inc., 2002b. *Comprehensive Groundwater Remedial Investigation Report*. September 2002.

AMEC Earth & Environmental, Inc., 2002c. *Interim Remedial Action Work Plan for Infrastructure Improvements Construction Project, Station Place Redevelopment Site*. October 2002.

AMEC Earth & Environmental, Inc., 2003. *Remedial Action Work Plan, Station Place Redevelopment Site, Portland Oregon*. July 25, 2003.

Oregon Department of Environmental Quality, 1998. *Final Guidance for Conducting Feasibility Studie*s. July 1, 1998.

Oregon Department of Environmental Quality, 2003. *Record of Decision, Station Place Redevelopment Site, Portland Oregon, Portland, Oregon*. May 2003.

United States Environmental Protection Agency, 2002. *Region IX PRG Table*. October 1, 2002.