

# Mare Island Investigation Area C1, Installation Restoration Site 15 (IR15)

## Biostimulation–Bioaugmentation–Excavation–EHC<sup>®</sup>–Permeable Reactive Barrier–Monitored Natural Attenuation

**Name:** Mare Island Investigation Area C1, IR15

**Site Location:** Mare Island, Vallejo, California

**Technology Used:**

- Bioaugmentation
- Biostimulation
- Excavation
- EHC<sup>®</sup> (Zero Valent Iron [ZVI] with controlled release carbon)
- Permeable Reactive Barrier (PRB)
- Monitored Natural Attenuation (MNA)

**Regulatory Program:** California Superfund Program

**Remediation Scale:** Full

**Project Duration:** December 2010 to present

**Site Information:** IR15 encompasses an area of approximately 4 acres associated with former electroplating operations. It is part of the former Mare Island Naval Shipyard. Electroplating operations were conducted in Building 225 until 1988. Building 101 housed seven 1,500-gallon pipe-cleaning vats that were used in pipe-cleaning activities until the vats were removed from the building in 1987. Building 273 housed an electrical and optical shop until the 1960s, when it was converted to office space. The site abuts the Mare Island Strait and is covered by buildings or pavement.

**Contaminants:** Some site soils are contaminated with lead and cadmium. There is widespread contamination of the groundwater with tetrachloroethene (PCE) and its degradation products (trichloroethene [TCE], 1,2-dichloroethene [DCE], vinyl chloride [VC]), carbon tetrachloride (CT), and hexavalent chromium. The PCE concentrations are indicative of presence of dense non-aqueous phase liquids (DNAPL).

**Hydrogeology:** The stratigraphy of the site consists of fill overlying fluvial deposits overlying bedrock. The fill layer varies in thickness from 1 ft in the western portion of the site to 25 ft in the

east. The fill layer is mainly composed of clay and silt and in many locations may contain crushed bedrock that was excavated from other parts of Mare Island, as well as gravel, fragmented brick, anchor chain, shredded metal fragments, asphalt, and wood debris.

The approximately 5 ft thick fluvial layer, composed of silt to fine sand and shell fragments, is found only in the eastern portion of IR15, near Mare Island Strait.

The underlying bedrock unit is part of the Panoche Formation that consists predominantly of siltstone and fine-grained sandstone, with occasional claystone interbeds. The uppermost portion of the bedrock was observed to be weathered in some locations. Where a weathering zone was observed, it was generally 0.5 ft or less and usually consisted of vertical fracturing.

The depth to groundwater in IR15 ranges from approximately 2 to 17 ft below ground surface (bgs), with an average water level of approximately 8 ft bgs. The geometric means of hydraulic conductivities reported from slug tests for the wells screened in the fill and the wells screened across the fill and bedrock interface were  $6.29 \times 10^{-3}$  and  $7.39 \times 10^{-4}$  centimeters per second (cm/sec), respectively. The fill wells were not found to be tidally influenced (CH2MHill 2010).

**Project Goals:**

The remedial action objectives (RAO) given in CH2MHill 2010 are:

- Demonstrate that concentrations of PCE, VC, and other PCE breakdown products in groundwater do not pose an unacceptable risk to human health. For this RAO, other PCE breakdown products are TCE, and DCE.

- Demonstrate that concentrations of cadmium and lead in soil do not pose an unacceptable risk to human health.
- Maintain concentrations of PCE and its breakdown products that do not adversely affect the current and future beneficial use of IR15 groundwater as freshwater replenishment to the surface water of Mare Island Strait. For this RAO, PCE breakdown products are TCE, *cis*-1,2-DCE, *trans*-1,2-DCE, and VC.
- Demonstrate that hexavalent chromium and CT concentrations continue not to pose an unacceptable risk to the current and future beneficial use of IR15 groundwater as freshwater replenishment to the surface water of Mare Island Strait.
- Restore the site to the extent necessary to support the existing and proposed future commercial/industrial land use.

Table 1 displays the contaminant concentration cleanup goals.

Table 1. Contaminant Concentration Cleanup Goals			
Matrix	COCs and COC Break-down Products	Human Health-based Cleanup Goals	Aquatic Habitat-based Cleanup Goals <sup>1</sup>
Soil	Lead	320 mg/kg	Not applicable
	Cadmium	7.5 mg/kg	Not applicable
Groundwater	PCE	202 µg/L (deep utility area) 3,000 µg/L (shallow utility area)	120 µg/L
	TCE	1,800 µg/L (deep utility area) 50,000 µg/L (shallow utility area)	360 µg/L
	<i>cis</i> -1,2-DCE	50,000 µg/L (both deep and shallow utility areas)	590 µg/L
	<i>trans</i> -1,2-DCE	266 µg/L (deep utility area) 2,600 µg/L (shallow utility area)	590 µg/L
	VC	32 µg/L (deep utility area) 416 µg/L (shallow utility area)	780 µg/L
	CT	Not applicable	9.8 µg/L
	Cr+6	Not applicable	11 µg/L

<sup>1</sup> Aquatic habitat goals apply to the wells within 50 feet of Mare Island Strait.  
Source: CH2MHill 2010

### Cleanup Approach:

Soil under and around Building 225 with lead and cadmium concentrations above action levels was excavated and disposed of offsite. The concrete floor slab in Building 225 that was removed during implementation of the remedy, as well as areas inside Building 225 that had been previously excavated, were repaired to provide a concrete cap over the soil. Soil removal areas outside Building 225 were capped with asphalt pavement (CH2MHill 2011b).

A pilot enhanced reductive dechlorination study was performed during 2008 using cheese whey, nutrients, and a base for acid control. Two areas were chosen for the study. Area A was within building 225 where an excavation around a drain had removed soil and the area had been back-filled with gravel. Area B was in the source zone with more permeable soil and thicker saturated thickness than Area A, which was near the bedrock surface. The amendments were introduced to the subsurface between April 18 and 21, 2008. In Area A, the amendments were introduced using the gravel as an infiltration galley. Amendments in Area B were pressure injected. Amendments in Area A did not show a significant impact. The amendment in Area B resulted in a distinct drop in contaminant concentrations. A second injection was initiated between August 14 and 15, 2008. This injection included calcium carbonate to prevent the pH from falling as it had following the first injection. The pilot was expanded in 2009 to include bioaugmentation in one area and EHC<sup>®</sup> in another. The results were favorable and this approach would be used in the full scale application (Attachment B9 CH2MHill 2010a).

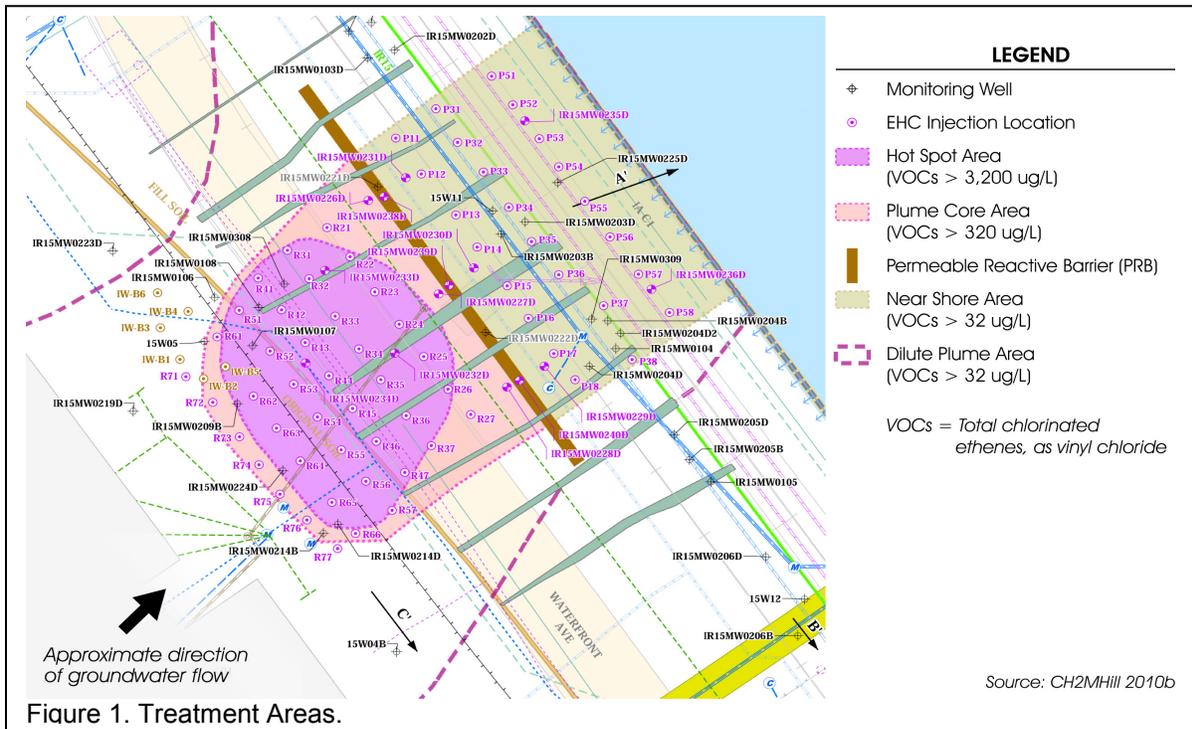


Figure 1. Treatment Areas.

The final plan was to install a permeable reactive barrier downgradient from the source area and perpendicular to the groundwater flow, in order to reduce the contaminant flux that could enter the Mare Island Strait. The source zone, plume core, and near shore area would be treated by injecting EHC<sup>®</sup> into the saturated zone followed by a solution of cheese whey, nutrients and base for pH control (Figure 1).

The PRB was installed from December 27, 2010 to January 21, 2011. The upper 10 ft of soil along the length of the PRB were removed using vacuum excavation to expose subsurface obstructions. The PRB was excavated by a long-stick excavator. Biopolymer slurry was added to the trench during soil removal for sidewall support. A tremie tube was used to place the reactive media mix, which consisted of sand and ZVI, into the PRB trench to avoid bridging and voids. The reactive media mix was placed from the base of the trench to a depth of 4.5 ft bgs, and an additional 1 ft of ZVI was added to bring the reactive media up to 3.5 ft bgs. The upper surface of the ZVI was covered with a nonwoven geotextile. The remaining excavation depth was backfilled with low-strength flowable fill to approximately 4 inches below the surrounding

grade. The remaining 4 inches of grade were patched with asphalt concrete. Three wells were installed in the PRB to monitor the conditions in the reactive media (CH2MHill 2011a). The PRB was 30 inches wide, 105 ft long, and 29.5 to 32.5 ft deep (Hodges et al. 2012).

In February 2011, approximately 37,000 pounds of EHC<sup>®</sup> was injected into 62 borings by direct push rigs. In March 2011, approximately 50,000 gallons of electron donor amendments, along with a *Dehalococcoides* culture to bioaugment the native bacteria, was injected into 64 wells. The injection system had both injection and extraction wells to create a recirculation pattern for better distribution of the amendments. Amendment injection (about 29,000 gallons) without bioaugmentation was repeated in October of 2011 (Hodges et al. 2012). Because monitoring indicated one area had not achieved conditions for successful biodegradation, a third amendment injection was done in May 2013 to address this area.

MNA was implemented for the areas not directly treated by EHC<sup>®</sup> and electron donor amendments.

**Project Results:** Concentrations of PCE and TCE in the active treatment areas have been decreasing, indicating that reductive dechlorination is occurring. A rise in DCE and VC has been observed, but concentrations of these contaminants should decline with time. Figure 2 shows a representative concentration time line at well IR15W04. The PRB has reduced the flux from the source area toward the Strait; along with the injections, PRB has contributed to the decrease in the near shore plume area (Figure 3).

Continued monitoring is being conducted to ensure that the RAOs are met.

**Sources:**

CH2MHill. 2010a. IR15 Feasibility Study/Remedial Action Plan, Investigation Area C1, Lennar Mare Island, Vallejo, California.  
[http://www.envirostor.dtsc.ca.gov/public/final\\_documents2.asp?global\\_id=48330003&doc\\_id=6022005](http://www.envirostor.dtsc.ca.gov/public/final_documents2.asp?global_id=48330003&doc_id=6022005)

CH2MHill. 2010b. IR15 Remedial Design Work Plan, Investigation Area C1, Lennar Mare Island Vallejo, California.  
[http://www.envirostor.dtsc.ca.gov/public/final\\_documents2.asp?global\\_id=48330003&doc\\_id=60254165](http://www.envirostor.dtsc.ca.gov/public/final_documents2.asp?global_id=48330003&doc_id=60254165)

CH2MHill. 2011. IR15 Groundwater Monitoring Report, Baseline and First Quarter 2011, Investigation Area C1, Lennar Mare Island, Vallejo, California.

[http://www.envirostor.dtsc.ca.gov/regulators/deliverable\\_documents/5098103165/NLH4550\\_NoApps.pdf](http://www.envirostor.dtsc.ca.gov/regulators/deliverable_documents/5098103165/NLH4550_NoApps.pdf)

CH2MHill. 2011a. IR15 Groundwater Monitoring Report, Baseline and First Quarter 2011, Investigation Area C1, Lennar Mare Island, Vallejo, California.

[http://www.envirostor.dtsc.ca.gov/public/final\\_documents2.asp?global\\_id=48330003&doc\\_id=60268887](http://www.envirostor.dtsc.ca.gov/public/final_documents2.asp?global_id=48330003&doc_id=60268887)

CH2MHill. 2011b. IR15 Groundwater Monitoring Report, Second Quarter 2011, Investigation Area C1, Lennar Mare Island, Vallejo, California.

[http://www.envirostor.dtsc.ca.gov/regulators/deliverable\\_documents/4432743668/NLH4592\\_Part1.pdf](http://www.envirostor.dtsc.ca.gov/regulators/deliverable_documents/4432743668/NLH4592_Part1.pdf)

Hodges, Alan (ahodges@ch2m.com), Terry Feng, and Abe Northup. 2012. Concurrent Application of Biological and Chemical Reduction Technologies to Treat DNAPLs in Groundwater. Eighth International Conference on Remediation of Chlorinated and Recalcitrant Compounds (Monterey, CA; May 2012).

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