

TECHNICAL MEMORANDA

Ecological Risks from Ground Water at NCBC IR Sites 06, 08, 11, and 13

Ecological Risk-Based Surface Soil Remediation Evaluation at NCBC IR Site 13

Prepared for:

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01 July 1997
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TECHNICAL MEMORANDUM

Ecological Risk from Ground Water at Site 06

01 July 1997

TECHNICAL MEMORANDUM

TO: Christine Williams, EPA Region I and Richard Gottlieb, RIDEM
FROM: Philip Otis, Navy RPM, NCBC Davisville
SUBJECT: Evaluation of Ecological Risk from Ground Water at IR Site 06

In April 1997, an agreement was reached involving assessment of risks from ground water on a site-specific, rather than basewide, basis. Based on discussions during a 2 April 1997 Base Realignment and Closure (BRAC) Cleanup Team (BCT) meeting in Boston, the Navy was directed to evaluate the risks from ground water at each site, and incorporate the results in a Technical Memorandum for each site. The Navy developed a stepwise protocol for evaluating ecological risk from ground water, analogous to that previously developed for surface soil (see Site 13 Technical Memo, this document). The ground-water protocol differs in certain aspects from the soil protocol because of different fate and transport issues and exposure pathways. The ground-water protocol is described as follows.

Protocol Description

- Step 1 Assemble Ground Water and Watershed Surface Water and Sediment Analytical Data.
- Step 2 Select a Risk Threshold. This is the concentration of a chemical constituent in ground water, as reflected in the Concentration Ratio (CR), above which it is deemed necessary to evaluate for potential contribution of ground water to watershed surface water or sediment risks. The CR is calculated by dividing the ground-water concentration of a chemical constituent by the higher of Ambient Water Quality Criteria (AWQC) or background value for that constituent. For this evaluation, the risk threshold is set at CR=1. Because some of the screening criteria are background and not toxicologically based, the term Concentration Ratio is used in lieu of the toxicologically-related Hazard Quotient (HQ). The term Hazard Quotient is retained for surface water and sediment where screening criteria are largely toxicologically based. If the CR is exceeded for any constituent, the constituent is designated as a Constituent of Concern (COC), and the evaluation proceeds to Step 3. This is a conservative evaluation since it does not take into account the physical properties and organic content of soil that typically retard transport of chemical constituents in ground water. The

constituent concentrations discharged to surface water are often less than those measured in the wells.

- Step 3 Based on the hydrogeology of the site, determine whether chemical constituents would be expected to migrate to nearby surface water. If not, proceed to Step 7. If yes, go to Step 4.
- Step 4 Based on the chronology of documented releases at a site, determine whether sufficient time has passed to permit migration of the chemical constituents to nearby surface water. If not, go to Step 6. If yes, go to Step 5.
- Step 5 Determine if Constituents Exceeding Risk Threshold in Ground Water Were Detected in Watershed Surface Water or Sediment. If a constituent was detected in surface water and/or sediment, and its HQ exceeded 1, the evaluation proceeds to Step 6. If not detected or surface water/sediment HQ < 1, proceed to Step 7.
- Step 6 Provide Narrative Discussing Potential for Constituent in Ground Water to Impact the Watershed. Include, as appropriate, elements of fate and transport (e.g., hydrogeology, chemistry, attenuation, etc.).
- Step 7 Summarize and Document Ecological Risk/No Risk Determination for Ground Water in the Watershed.

Site 06 Evaluation

Step 1 - Assemble Data

The ground-water data used for this evaluation were from the Phase II Remedial Investigation (RI) of Installation Restoration (IR) Program Site 06 (TRC 1994) and the Basewide Ground-Water Study (Stone & Webster 1996). The Phase I data were not included because sampling was not performed using low-flow methods. The data are from five wells on and near the site, plus one Hall Creek background well. This evaluation utilizes ground-water data compilations and maps (Figure 1) provided by Stone & Webster. The data used to evaluate chemical constituent occurrence in surface water and sediment in the Hall Creek Watershed are available in the *Draft Final Facility-Wide Freshwater/Terrestrial Ecological Risk Assessment* (EA 1996a) (Tables 4-4, 4-9, 6-1, 6-5), and in the December 1996 *Technical Memoranda and Responses to Comments on Soil and Related Ecological Risk Evaluations at NCBC Sites 06, 10, and 11* (EA 1996b, Table 4-4 amended).

Step 2 - Select Risk Threshold

The designated risk threshold of CR=1.0 was exceeded for four constituents in four wells at Site 06 (Table 1). Iron, lead, manganese, and bis(2-ethylhexyl)phthalate ground-water concentrations

all exceeded screening criteria, although not excessively, as evidenced in the relatively low ground-water CRs. The CRs > 1 trigger Step 3.

Step 3 - Determine if Ground-Water Constituents Can Migrate to Surface Water

Based on the Phase I and Phase II ground-water studies (TRC 1994), and a more recent basewide ground-water study by Stone & Webster (1996), it is anticipated that ground water at Site 06 enters nearby Hall Creek. Ground water was encountered at depths below surface of three to eight feet, and flow was determined to be in a general northeast direction, that is toward Hall Creek, approximately 800 feet away.

Step 4 - Determine if Historical Releases Could Have Reached Surface Water

Base records indicate that Site 06 was used as a chlorinated-solvent disposal area between 1970 and 1972. Based on average linear velocities calculated during Phase II, it would take between three and four years for ground water to migrate from the site to Hall Creek. Given that the previous documented releases at the site were 25 years ago, it is concluded that ground water from the site would have reached Hall Creek prior to the sampling of surface water and sediment in 1993 and 1995. Although chemical constituents do not necessarily move (if at all) at the same rate as ground water, the length of time involved suggests that constituents introduced in the early 1970s, given mobilization in the ground water, would have reached Hall Creek by the 1990s. Therefore, the evaluation of COCs in surface water and sediment is required (Step 5).

Step 5 - Determine if Ground-Water COCs Exceeded Criteria in Surface Water/Sediment

Of the four constituents exceeding ground-water screening criteria (Table 1), lead and manganese were also screened in surface water and sediment. For both metals, HQs in surface water were less than 1.0, therefore there is no presumption of risk. However, HQs for both metals exceeded 1.0 in sediment, and evaluation under Step 6 is required. Iron and bis(2-ethylhexyl)phthalate slightly exceeded ground-water screening criteria. These constituents were not previously screened in surface water because iron is an essential nutrient and bis(2-ethylhexyl)phthalate is a common laboratory contaminant. Nonetheless, these are also discussed under Step 6.

Step 6 - Provide Narrative Discussing Potential for Watershed Risks from Ground Water

Iron in ground water is not likely to pose ecological risk in the Hall Creek surface water environment. The concentration exceeded the (background) screening criterion by only 30 percent. It is also noteworthy that the ground-water screening criterion for iron was exceeded in only one well (MW06-3S), which is an upgradient well (Figure 1). The absence of exceedance in wells on and down-gradient from the site suggests that iron is not generally elevated in ground water at the site. In the absence of anthropogenic sources, dissolved iron is often found in ground water due to naturally occurring mildly reducing conditions. The mildly reducing conditions result in the conversion of insoluble Fe(III) species to soluble Fe(II) species. When

Fe(II) reaches the surface, it is expected to rapidly convert to Fe(III) which is much less soluble and tends to precipitate as iron oxyhydroxides on the surface of stream sediments. This iron oxyhydroxide phase is a natural component of nearly all soil types.

The exceedance of the ground-water criterion for bis(2-ethylhexyl)phthalate was recorded for one well, MW06-5S, which is downgradient of the site. Regarding this organic compound, TRC (1994) stated that it was most likely a sampling artifact. TRC further pointed out that the compound was not detected in any of the wells during the Phase I sampling which employed a different sampling technique. This fact, coupled with its presence in only one well, and with a CR of less than 2.0, suggests no surface-environment ecological risk from bis(2-ethylhexyl)phthalate.

Manganese was detected above the screening criterion only in the background well for the Hall Creek Watershed (MWZ2-3)(Table 1). Given the prevailing ground-water flow from Site 06, it is unlikely that Site 06 was the source of manganese in this well (Figure 1). Therefore, it may be dismissed as an ecological risk issue with regard to Site 06. The detection of manganese at this location appears to be isolated. Other than Site 06, the most likely source would be Site 13 (Figure 1) and manganese did not exceed the screening criterion there.

Lead was detected and exceeded the screening criterion in two wells, MW06-3S and MW06-2S. The former is an upgradient well, and the latter was identified as a downgradient well by TRC (Figure 1). In Hall Creek, lead did not exceed the surface-water screening criterion, but did exceed the sediment screening criterion (Table 1). Attributing sediment concentrations of lead to ground water from Site 06 is problematic in that wells on the site proper and downgradient to the northeast did not exceed the screening criterion. Regardless of the source of the lead, its behavior in the ground-water environment may not suggest a contribution to ecological risk in Hall Creek sediment. Lead typically adsorbs strongly to aquifer materials and sediments. In particular, adsorption of lead to amorphous iron oxyhydroxide phases is very strong. As a result, elevated dissolved lead concentrations tend to remain localized to shallow, near-site areas unless unusual geochemical conditions are present or low levels of adsorbents appear in the aquifer materials. The ground water data examined in this report show elevated levels of lead upgradient of Site 06, but levels are below the threshold in most downgradient samples. These data do not support a determination of Site 06 ground water as a source of lead in Hall Creek sediment.

Step 7 - Summarize and Document Risk/No Risk Findings

This evaluation of ecological risk from ground water is largely theoretical in that it depends on circumstantial evidence of linkage of ground-water constituents and constituents in the watershed streams. There is no direct measurement of movement of chemical constituents, nor has there been "tagging" of material in ground water that could then be re-identified in the watershed. Knowledge of the ground-water environment is used in conjunction with constituent concentrations in both ground water and surface water and sediment to infer possible linkages between the ground water and surface water environments.

At Site 06, the potential linkage of chemical constituents between ground water and surface water has been assumed, and judgements regarding ecological risk from ground water were based on the number of common COCs in the two environments, their concentration in both environments, their distribution in ground water, and geochemical considerations. Four constituents exceeded screening criteria in ground water: iron, manganese, lead, and bis(2-ethylhexyl)phthalate. None were greatly elevated in ground water. Iron was only detected above screening values in an upgradient well, and manganese was only detected above screening levels in a background well. (Note that most screening values for metals, including manganese, were calculated as the 95 percent Upper Confidence Limit (UCL) on the mean of several wells. Therefore, as in the case of manganese, the concentration in an individual background well can exceed the background screening criterion.) The phthalate compound was strongly implicated as a sampling artifact (TRC 1994). Lead was detected above screening levels in two wells, one up- and one downgradient of Site 06. However, lead did not exceed the screening criterion in samples from wells directly on Site 06, or immediately downgradient to the northeast, the prevailing direction of ground-water flow. The concentration of lead in Hall Creek surface water was well below the screening criterion. Lead was moderately elevated over the screening criterion in Hall Creek sediment.

The source of the lead in Hall Creek sediment cannot be established by this evaluation. There is no strong "signature" that would implicate ground water, i.e., consistently elevated concentrations from up- to downgradient wells. Also, there are many other possible sources, both on- and off site. Further, based on geochemical considerations mentioned above, lead would be unlikely to migrate in the ground-water environment.

Based on the above assessment, ecological risk from ground water at Site 06 is determined to be minimal.

References

- EA. 1996a. *Draft Final Facility-Wide Freshwater/Terrestrial Ecological Risk Assessment Naval Construction Battalion Center, Davisville, Rhode Island*. Prepared for Department of the Navy, Northern Division, Naval Facilities Engineering Command, Lester, Pennsylvania. EA Engineering, Science, and Technology, Hunt Valley, MD.
- EA. 1996b. *Technical Memoranda and Responses to Comments on Soil and Related Ecological Risk Evaluations at NCBC Sites 06, 10, and 11*. Prepared for Department of the Navy, Northern Division, Naval Facilities Engineering Command, Lester, Pennsylvania. EA Engineering, Science, and Technology, Hunt Valley, MD.
- Stone & Webster. 1996. *Basewide Ground Water Inorganics Study Report NCBC Davisville, Rhode Island*. Prepared for Department of the Navy, Northern Division, Naval Facilities Engineering Command, Lester, Pennsylvania. Stone & Webster Environmental, Boston, MA.

TRC. 1994. *Draft Final Remedial Investigation Report: Naval Construction Battalion Center, Davisville, Rhode Island*. Prepared for Northern Division, Naval Facilities Engineering Command, Lester, Pennsylvania. TRC Environmental Corporation, Windsor, CT.

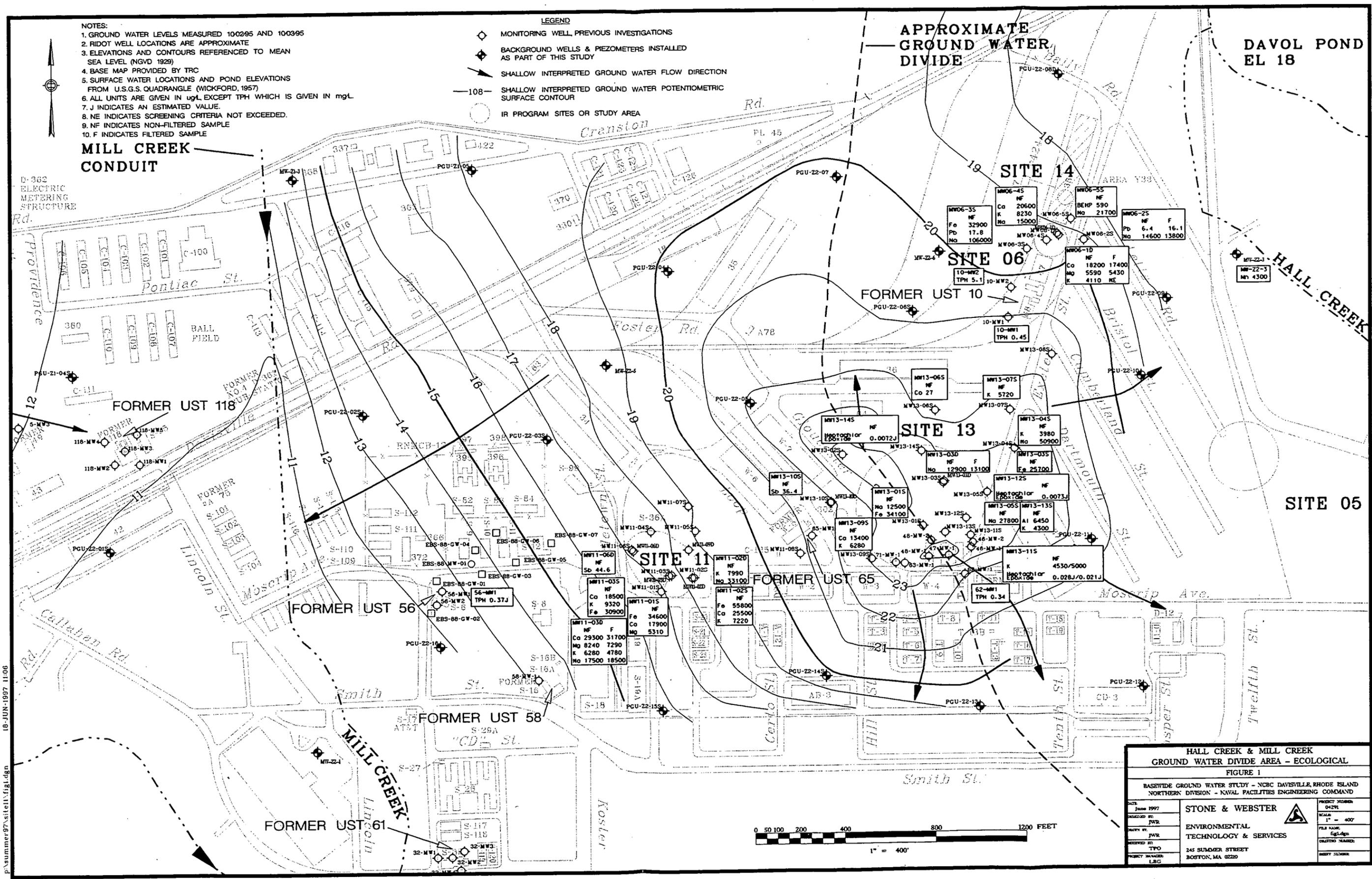
TABLE 1. COMPARISON OF COCs BETWEEN NCBC IR SITE 06 GROUND WATER AND HALL CREEK SURFACE WATER AND SEDIMENT

<u>Well</u>	<u>Analyte</u>	Ground-water <u>Conc. (ppb)</u>	Ground-water <u>Screening Criteria (ppb)</u>	Ground-water <u>CR</u>	<u>Status in Surface Water</u>	<u>Status in Sediment</u>
MW06-3S	Iron	32900	25500	1.3	not screened	not screened
MW06-3S	Lead	17.8	4.8	3.7	Mean HQ=0.5; Max HQ=0.8	Mean HQ=2.1; Max HQ=6.5
MW06-2S	Lead	16.1	4.8	3.4	Mean HQ=0.5; Max HQ=0.8	Mean HQ=2.1; Max HQ=6.5
MWZ2-3	Manganese	4300	3292	1.3	Mean HQ=0.1; Max HQ=0.3	Mean HQ=2.9; Max HQ=8.9
MW06-5S	bis(2-ethylhexyl)phthalate	590	360	1.6	not screened	not screened

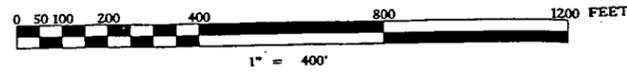
Notes: Ground-water screening criteria are the higher of background or AWQC
 CR = Concentration Ratio = ground-water concentration/screening criteria
 Manganese sediment HQ based on background screen due to lack of criterion
 Well MWZ2-3 is Hall Creek watershed background well
 Surface water and sediment concentrations of bis(2-ethylhexyl)phthalate and iron were not screened in Freshwater/Terrestrial ERA
 Ground-water concentration data and screening criteria from TRC (1994) and Stone & Webster (1996)
 Surface water and sediment data are from Draft Final Facility-Wide Freshwater/Terrestrial Ecological Risk Assessment (EA 1996a)

- NOTES:**
1. GROUND WATER LEVELS MEASURED 100295 AND 100395
 2. RIDOT WELL LOCATIONS ARE APPROXIMATE
 3. ELEVATIONS AND CONTOURS REFERENCED TO MEAN SEA LEVEL (NGVD 1929)
 4. BASE MAP PROVIDED BY TRC
 5. SURFACE WATER LOCATIONS AND POND ELEVATIONS FROM U.S.G.S. QUADRANGLE (WICKFORD, 1957)
 6. ALL UNITS ARE GIVEN IN $\mu\text{g/L}$, EXCEPT TPH WHICH IS GIVEN IN mg/L .
 7. J INDICATES AN ESTIMATED VALUE.
 8. NE INDICATES SCREENING CRITERIA NOT EXCEEDED.
 9. NF INDICATES NON-FILTERED SAMPLE
 10. F INDICATES FILTERED SAMPLE

- LEGEND**
- ◇ MONITORING WELL, PREVIOUS INVESTIGATIONS
 - ◆ BACKGROUND WELLS & PIEZOMETERS INSTALLED AS PART OF THIS STUDY
 - SHALLOW INTERPRETED GROUND WATER FLOW DIRECTION
 - 108- SHALLOW INTERPRETED GROUND WATER POTENTIOMETRIC SURFACE CONTOUR
 - IR PROGRAM SITES OR STUDY AREA



HALL CREEK & MILL CREEK GROUND WATER DIVIDE AREA - ECOLOGICAL	
FIGURE 1	
BASESIDE GROUND WATER STUDY - NCB DAVISVILLE, RHODE ISLAND NORTHERN DIVISION - NAVAL FACILITIES ENGINEERING COMMAND	
DATE: June 1997	PROJECT NUMBER: 04201
DESIGNED BY: JWR	SCALE: 1" = 400'
DRAWN BY: JWR	FILE NAME: fig1.dgn
REVIEWED BY: TPO	CHECKED: []
PROJECT MANAGER: LBG	DATE: []
STONE & WEBSTER ENVIRONMENTAL TECHNOLOGY & SERVICES 245 SUMMER STREET BOSTON, MA 02210	



TECHNICAL MEMORANDUM

Ecological Risk from Ground Water at Site 08

01 July 1997

TECHNICAL MEMORANDUM

TO: Christine Williams, EPA Region I and Richard Gottlieb, RIDEM
FROM: Philip Otis, Navy RPM, NCBC Davisville
SUBJECT: Evaluation of Ecological Risk from Ground Water at IR Site 08

Discussions among Navy, the Environmental Protection Agency (EPA), and other BCT participants in April 1997 resulted in the discontinuance of a basewide ground-water evaluation in favor of a site-specific approach. Accordingly, the Navy was tasked with assessing risk to both human health and the environment from ground water at individual IR sites. To address ecological risk from ground water, the Navy developed a stepwise protocol that first involved screening chemical constituents in ground water against protective criteria such as AWQC or background. If any constituent exceeds screening criteria, the hydrogeology of the site is investigated to determine if ground-water constituents from historical releases at a site could have reached surface water and sediment in the watershed in which the site is located, prior to surface water/sediment sampling in the mid-1990s. If migration of ground-water constituents is judged to be likely, then surface water and sediment concentrations are examined to determine whether they may have resulted from ground water. This stepwise protocol is employed in concurrent Technical Memoranda for IR Sites 06, 11, and 13.

At Site 08, implementation of the full stepwise protocol is rendered unnecessary because none of the chemical constituents in ground water being examined for risk exceeded screening criteria in wells on and downgradient of Site 08. Data evaluated for ecological risk include low-flow sampling data from the Phase II RI (TRC 1994) and background (Stone & Webster 1996). The ground water data indicate that a single constituent, aluminum, exceeded the screening criterion in the Sandhill Brook Watershed background well (MW-WD-2), approximately 1,700 ft to the southwest and upgradient of Site 08 (Figure 1). The aluminum concentration of 13,200 ug/L in this well exceeded the screening criterion (background) of 5,315 ug/L. However, it should be noted that the background screening value for aluminum was based on the 95 percent UCL on the mean of all Base background wells, therefore a concentration from an individual well can exceed the screening level. None of the onsite or downgradient wells at Site 08 contained aluminum in excess of the screening criterion. The source of the aluminum in the background well is unknown, but is assumed to be natural since aluminum is a typical constituent of most soils.

The fact that none of the constituents screened for ecological risk in ground water exceeded screening criteria in Site 08 wells permits a determination of no ecological risk in the Sandhill Brook Watershed from Site 08 ground water.

References

- Stone & Webster. 1996. *Basewide Ground Water Inorganics Study Report NCBC Davisville, Rhode Island*. Prepared for Department of the Navy, Northern Division, Naval Facilities Engineering Command, Lester, Pennsylvania. Stone & Webster Environmental, Boston, MA.
- TRC. 1994. *Draft Final Remedial Investigation Report: Naval Construction Battalion Center, Davisville, Rhode Island*. Prepared for Northern Division, Naval Facilities Engineering Command, Lester, Pennsylvania. TRC Environmental Corporation, Windsor, CT.

TECHNICAL MEMORANDUM

Ecological Risk from Ground Water at Site 11

01 July 1997

TECHNICAL MEMORANDUM

TO: Christine Williams, EPA Region I and Richard Gottlieb, RIDEM

FROM: Philip Otis, Navy RPM, NCBC Davisville

SUBJECT: Evaluation of Ecological Risk from Ground Water at IR Site 11

In April 1997, an agreement was reached involving assessment of risks from ground water on a site-specific, rather than basewide, basis. Based on discussions during a 2 April 1997 BCT meeting in Boston, the Navy was directed to evaluate the risks from ground water at each site, and incorporate the results in a Technical Memorandum for each site. The Navy developed a stepwise protocol for evaluating ecological risk from ground water, analogous to that previously developed for surface soil (see Site 13 Technical Memo, this document). The ground-water protocol differs in certain aspects from the soil protocol because of different fate and transport issues and exposure pathways. The ground-water protocol is described as follows.

Protocol Description

- Step 1 Assemble Ground Water and Watershed Surface Water and Sediment Analytical Data.
- Step 2 Select a Risk Threshold. This is the concentration of a chemical constituent in ground water, as reflected in the CR, above which it is deemed necessary to evaluate for potential contribution of ground water to watershed surface water or sediment risks. The CR is calculated by dividing the ground-water concentration of a chemical constituent by the higher of AWQC or background value for that constituent. For this evaluation, the risk threshold is set at CR=1. Because some of the screening criteria are background and not toxicologically based, the term Concentration Ratio is used in lieu of the toxicologically related HQ. The term Hazard Quotient is retained for surface water and sediment where screening criteria are largely toxicologically based. If the CR is exceeded for any constituent, it is designated as a COC, and the evaluation proceeds to Step 3. This is a conservative evaluation since it does not take into account the physical properties and organic content of soil that typically retard transport of chemical constituents in ground water. The constituent concentrations discharged to surface water are often less than those measured in the wells.

- Step 3 Based on the hydrogeology of the site, determine whether chemical constituents would be expected to migrate to nearby surface water. If not, proceed to Step 7. If yes, go to Step 4.
- Step 4 Based on the chronology of documented releases at a site, determine whether sufficient time has passed to permit migration of the chemical constituents to nearby surface water. If not, go to Step 6. If yes, go to Step 5.
- Step 5 Determine if Constituents Exceeding Risk Threshold in Ground Water Were Detected in Watershed Surface Water or Sediment. If a constituent was detected in surface water and/or sediment, and its HQ exceeded 1, the evaluation proceeds to Step 6. If not detected or surface water/sediment HQ<1, proceed to Step 7.
- Step 6 Provide Narrative Discussing Potential for Constituent in Ground Water to Impact the Watershed. Include, as appropriate, elements of fate and transport (e.g., hydrogeology, chemistry, attenuation, etc.).
- Step 7 Summarize and Document Ecological Risk/No Risk Determination for Ground Water in the Watershed.

Site 11 Evaluation

Step 1 - Assemble Data

The ground-water data used for this evaluation were from the Phase II RI of IR Program Site 11 (TRC 1994). The Phase I data were not included because sampling was not performed using low-flow methods. The data are from six wells on and near the site. This evaluation utilizes ground-water data compilations and maps (Figure 1) provided by Stone & Webster. The data used to evaluate chemical-constituent occurrence in surface water and sediment in the Mill Creek Watershed are available in the February 1996 *Draft Final Facility-Wide Freshwater/Terrestrial Ecological Risk Assessment* (EA 1996a) (Tables 4-3, 4-8, 6-1, 6-4), and in the December 1996 *Technical Memoranda and Responses to Comments on Soil and Related Ecological Risk Evaluations at NCBC Sites 06, 10, and 11* (EA 1996b) (Table 4-3 amended).

Step 2 - Select Risk Threshold

The designated risk threshold of CR=1 was exceeded for two constituents in four wells at Site 11 (Table 1). Iron concentrations exceeded the screening criterion in three wells, and antimony exceeded the screening criterion in one well. As evidenced by the ground-water CRs between 1.2 and 2.2, the concentrations were not greatly elevated; nonetheless, the CRs > 1 trigger Step 3.

Step 3 - Determine if Ground-Water Constituents Can Migrate to Surface Water

Based on the Phase I and Phase II ground-water studies by TRC (1994), and the more recent basewide ground-water study by Stone & Webster (1996), it is anticipated that ground water at Site 11 flows toward Mill Creek, approximately 1,200 ft to the southwest. Ground water was encountered at depths below surface of about seven feet.

Step 4 - Determine if Historical Releases Could Have Reached Surface Water

Between the mid-1940s and 1955, Site 11 was reportedly used as a fire-fighting training area. Unknown quantities of waste oils, solvents, and thinners were poured onto the ground, ignited, and extinguished. Based on hydrogeological investigations by TRC (1994), it is estimated that shallow ground water can reach Mill Creek in two to ten years. Although chemical constituents do not necessarily move (if at all) at the same rate as ground water, the length of time involved provides comfort that constituents introduced in the 1940s and 1950s, given mobilization in the ground water, would have reached Hall Creek prior to surface water and sediment sampling in the 1990s. Therefore, the evaluation of COCs in surface water and sediment is required (Step 5).

Step 5 - Determine if Ground-Water COCs Exceeded Criteria in Surface Water/Sediment

Of the two constituents detected above screening criteria in Site 11 ground water, antimony was not detected in Mill Creek sediment, and concentrations in surface water were well below screening levels. Therefore no further evaluation of antimony is required. Iron was not screened in sediment and surface water because it is an essential nutrient. It is discussed further under Step 6.

Step 6 - Provide Narrative Discussing Potential for Watershed Risks from Ground Water

Iron in ground water is not likely to pose ecological risk in the Mill Creek surface water environment. Iron was detected in excess of screening criteria in 3 of 6 wells at the site. The exceedances (CRs) were low, and there was no pattern in ground water suggestive of substantial anthropogenic releases. In the absence of anthropogenic sources, dissolved iron is often found in ground water due to naturally occurring mildly reducing conditions. The mildly reducing conditions result in the conversion of insoluble Fe(III) species to soluble Fe(II) species. When Fe(II) reaches the surface, it is expected to rapidly convert to Fe(III) which is much less soluble and tends to precipitate as iron oxyhydroxides on the surface of stream sediments. This iron oxyhydroxide phase is a natural component of nearly all soil types.

Step 7 - Summarize and Document Risk/No Risk Findings

This evaluation of ecological risk from ground water is largely theoretical in that it depends on circumstantial evidence of linkage of ground-water constituents and constituents in the watershed streams. There is no direct measurement of movement of chemical constituents, nor has there been "tagging" of material in ground water that could then be re-identified in the watershed. Knowledge of the ground-water environment is used in conjunction with chemical-constituent

concentrations in both ground water and surface water and sediment to infer possible linkages between the ground water and surface water environments.

At Site 11, the potential linkage of constituents between ground water and surface water has been assumed, and judgements regarding ecological risk from ground water were based on the number of common COCs in the two environments, their concentration in both environments, their distribution in ground water, and geochemical considerations. The results (Table 1) allow for a rather simple evaluation, since antimony was well below screening levels in Mill Creek surface water, and was not detected at all in sediment. As expected, iron was present in ground water and exceeded the screening criterion slightly in three wells. The low level of exceedance of iron in ground water and its natural occurrence in ground water suggests little potential for ecological risk in the surface water environment.

Based on the above assessment, ecological risk from ground water at Site 11 is determined to be minimal.

References

- EA. 1996a. *Draft Final Facility-Wide Freshwater/Terrestrial Ecological Risk Assessment Naval Construction Battalion Center, Davisville, Rhode Island*. Prepared for Department of the Navy, Northern Division, Naval Facilities Engineering Command, Lester, Pennsylvania. EA Engineering, Science, and Technology, Hunt Valley, MD.
- EA. 1996b. *Technical Memoranda and Responses to Comments on Soil and Related Ecological Risk Evaluations at NCBC Sites 06, 10, and 11*. Prepared for Department of the Navy, Northern Division, Naval Facilities Engineering Command, Lester, Pennsylvania. EA Engineering, Science, and Technology, Hunt Valley, MD.
- Stone & Webster. 1996. *Basewide Ground Water Inorganics Study Report NCBC Davisville, Rhode Island*. Prepared for Department of the Navy, Northern Division, Naval Facilities Engineering Command, Lester, Pennsylvania. Stone & Webster Environmental, Boston, MA.
- TRC. 1994. *Draft Final Remedial Investigation Report: Naval Construction Battalion Center, Davisville, Rhode Island*. Prepared for Northern Division, Naval Facilities Engineering Command, Lester, Pennsylvania. TRC Environmental Corporation, Windsor, CT.

TABLE 1. COMPARISON OF COCs BETWEEN NCBC IR SITE 11 GROUND WATER AND MILL CREEK SURFACE WATER AND SEDIMENT

<u>Well</u>	<u>Analyte</u>	Ground-water <u>Conc. (ppb)</u>	Ground-water <u>Screening Criteria (ppb)</u>	Ground-water <u>CR</u>	<u>Status in Surface Water</u>	<u>Status in Sediment</u>
MW11-06D	Antimony	44.6	30	1.5	Mean HQ<0.1; Max HQ<0.1	not detected
MW11-03S	Iron	30900	25500	1.2	not screened	not screened
MW11-01S	Iron	34600	25500	1.4	not screened	not screened
MW11-02S	Iron	55800	25500	2.2	not screened	not screened

Notes:

Ground-water screening criteria are the higher of background or AWQC

CR = Concentration Ratio = ground-water concentration/screening criteria

Surface water and sediment concentrations of iron were not screened in Freshwater/Terrestrial ERA

Ground-water concentration data and screening criteria from TRC (1994) and Stone & Webster (1996)

Surface water and sediment data are from Draft Final Facility-Wide Freshwater/Terrestrial Ecological Risk Assessment (EA 1996a)

Plot Request: fig1.m from: J. William Raymond@bsnt1746.swec.com on Wed Jun 18 11:07:07 EDT 1997

- NOTES:
1. GROUND WATER LEVELS MEASURED 100295 AND 100395
 2. RIDOT WELL LOCATIONS ARE APPROXIMATE
 3. ELEVATIONS AND CONTOURS REFERENCED TO MEAN SEA LEVEL (NGVD 1929)
 4. BASE MAP PROVIDED BY TRC
 5. SURFACE WATER LOCATIONS AND POND ELEVATIONS FROM U.S.G.S. QUADRANGLE (WICKFORD, 1957)
 6. ALL UNITS ARE GIVEN IN UG/L EXCEPT TPH WHICH IS GIVEN IN MG/L
 7. J INDICATES AN ESTIMATED VALUE
 8. NF INDICATES SCREENING CRITERIA NOT EXCEEDED.
 9. NF INDICATES NON-FILTERED SAMPLE
 10. F INDICATES FILTERED SAMPLE

- LEGEND
- ◇ MONITORING WELL PREVIOUS INVESTIGATIONS
 - ◆ BACKGROUND WELLS & PIEZOMETERS INSTALLED AS PART OF THIS STUDY
 - SHALLOW INTERPRETED GROUND WATER FLOW DIRECTION
 - 108- SHALLOW INTERPRETED GROUND WATER POTENTIOMETRIC SURFACE CONTOUR
 - IR PROGRAM SITES OR STUDY AREA

MILL CREEK CONDUIT

APPROXIMATE GROUND WATER DIVIDE

DAVOL POND EL 18

SITE 14

SITE 06

FORMER UST 10

SITE 13

SITE 11

FORMER UST 65

SITE 05

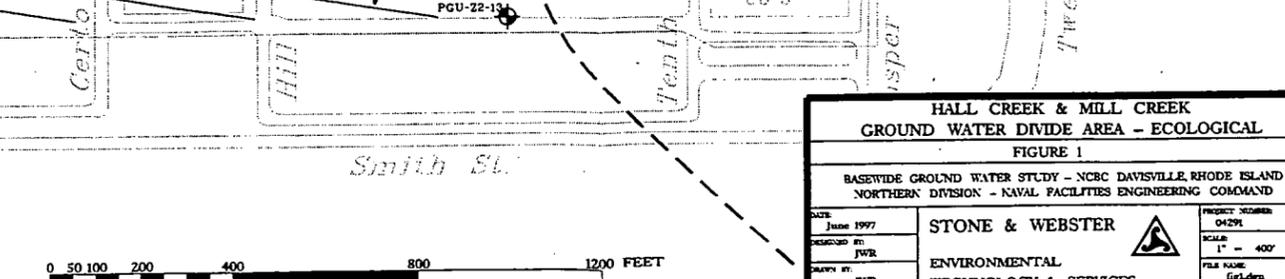
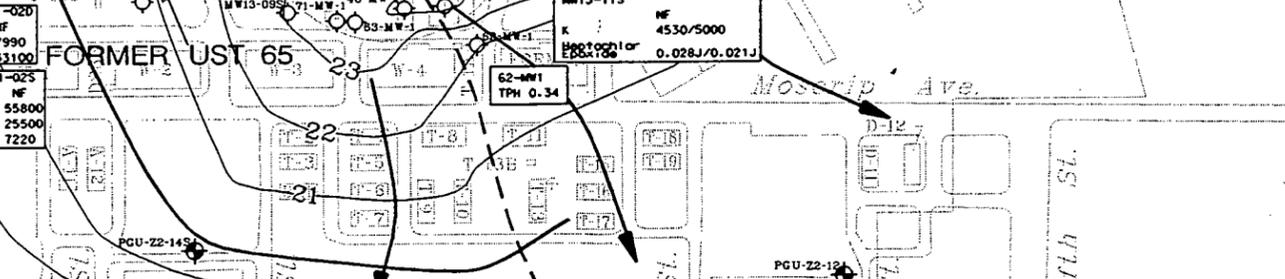
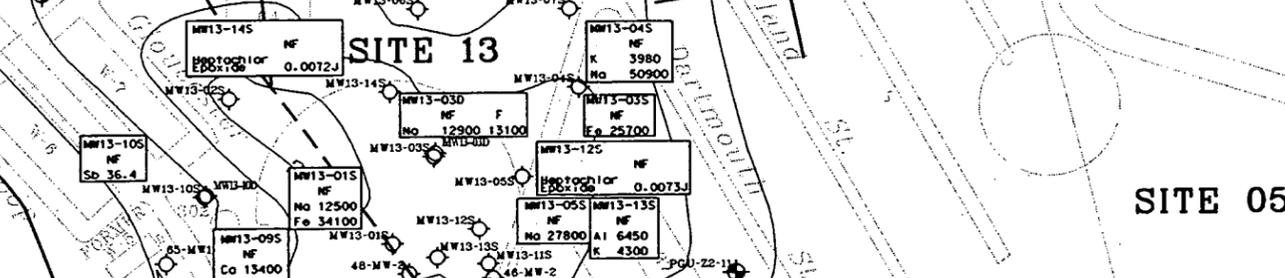
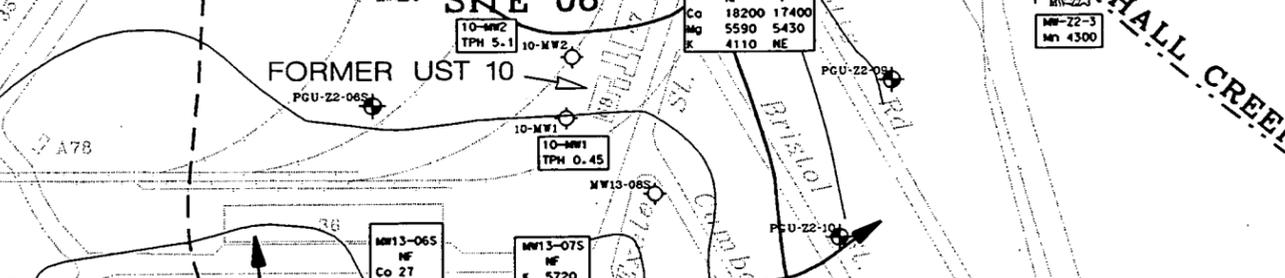
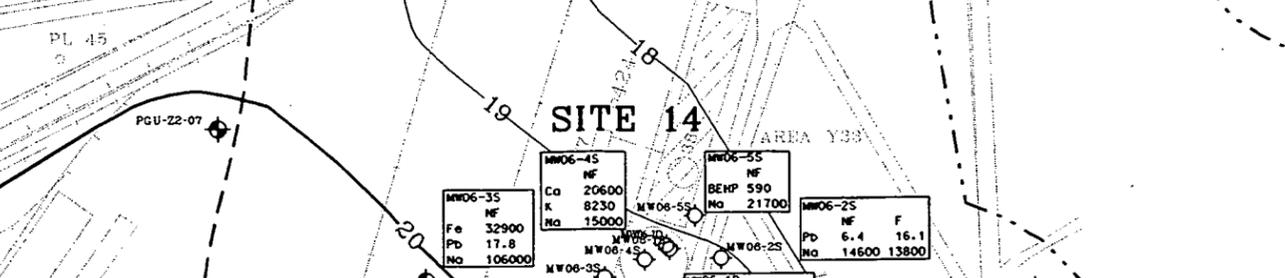
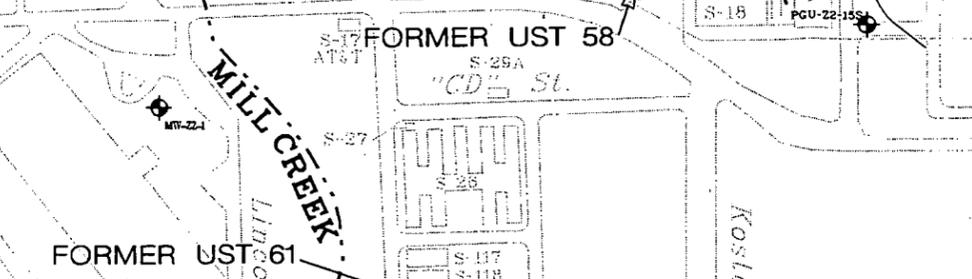
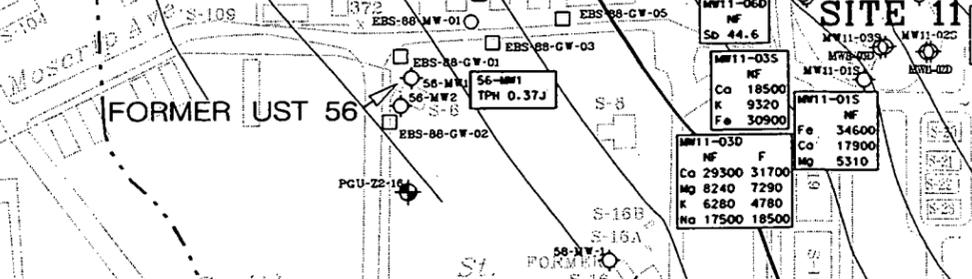
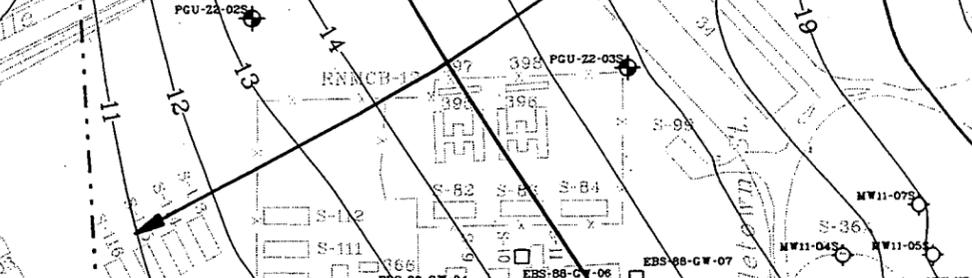
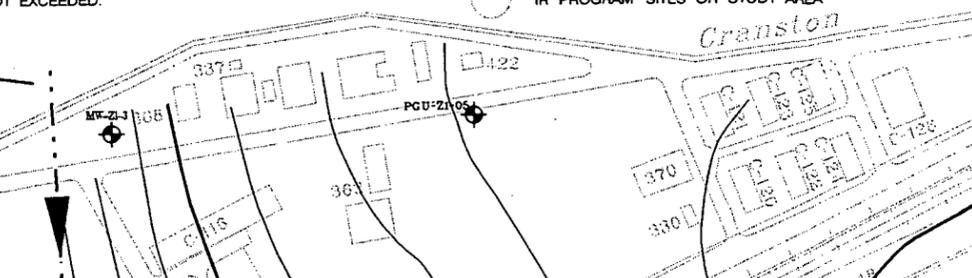
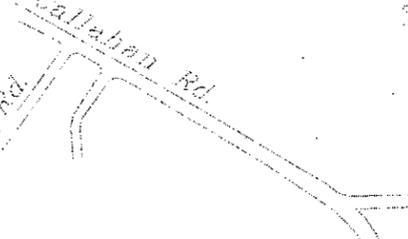
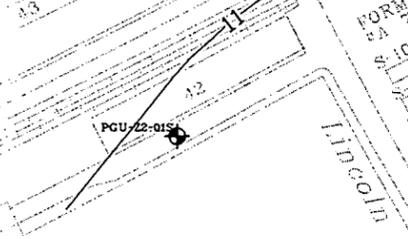
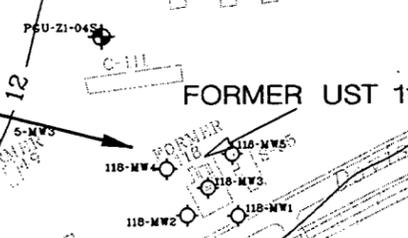
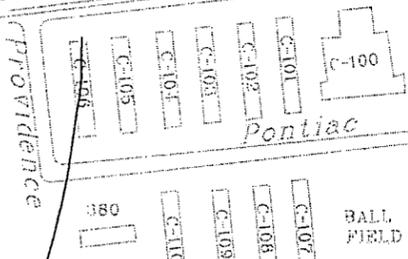
FORMER UST 118

FORMER UST 56

FORMER UST 58

FORMER UST 61

D-362 ELECTRIC METERING STRUCTURE



MW06-35	NF
Ca	20600
K	8230
Na	15300
Fe	32900
Pb	17.8
Mo	106000

MW06-35	NF
Ca	20600
K	8230
Na	15300
Fe	32900
Pb	17.8
Mo	106000

MW06-35	NF
Ca	20600
K	8230
Na	15300
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MW06-35	NF
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Na	15300
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MW06-35	NF
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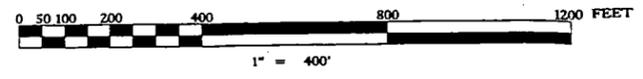
MW06-35	NF
Ca	20600
K	8230
Na	15300
Fe	32900
Pb	17.8
Mo	106000

HALL CREEK & MILL CREEK
GROUND WATER DIVIDE AREA - ECOLOGICAL
FIGURE 1

BASEWIDE GROUND WATER STUDY - NCRB DAVISVILLE, RHODE ISLAND
NORTHERN DIVISION - NAVAL FACILITIES ENGINEERING COMMAND

DATE	June 1997	PROJECT NUMBER	04291
DESIGNED BY	JWR	SCALE	1" = 400'
DRAWN BY	JWR	FILE NAME	fig1.dgn
CHECKED BY	TPO	DATE PLOTTED	
PROJECT MANAGER	LEG	PROJECT NUMBER	

STONE & WEBSTER
ENVIRONMENTAL
TECHNOLOGY & SERVICES
245 SUMMER STREET
BOSTON, MA 02210



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TECHNICAL MEMORANDUM

Ecological Risk from Ground Water at Site 13

and

Ecological Risk-Based Surface Soil Remediation Evaluation

01 July 1997

TECHNICAL MEMORANDUM

TO: Christine Williams, EPA Region I and Richard Gottlieb, RIDEM
FROM: Philip Otis, Navy RPM, NCBC Davisville
SUBJECT: Ground-Water Risk Evaluation and Ecological Risk-Based Soil Remediation Evaluation at IR Site 13

The information provided in this Technical Memorandum serves to document evaluations of ecological risk from surface soil and ground water at Site 13. The format has evolved through iterative discussions among the Navy, EPA, and other members of the BCT. In August 1996, the Navy submitted to the BCT a protocol to address the need for remediation of surface soil at IR sites at NCBC (*Use of Ecological Risk Assessment Results to Support Remedial Decision-Making: An Example at the NCBC Davisville*). This protocol employed a stepwise process of balancing ecological risk estimates for surface soil with available toxicological-based screening criteria and background information. The protocol culminates in a judgement regarding the need for remediation of surface soil at a site. After extensive comment by EPA and other reviewers, the Navy prepared and submitted in December 1996 a document, *Technical Memoranda and Responses to Comments on Soil and Related Ecological Risk Evaluations at NCBC Sites 06, 10, and 11* (EA 1996a). This document contained the Navy's responses to comments on the August 1996 draft of the protocol, and responses to outstanding comments of the February 1996 *Draft Final Facility-Wide Freshwater/Terrestrial Ecological Risk Assessment* (EA 1996b). Based on review of the technical memo and response document and subsequent discussions among all parties, the Navy submitted in February 1997 several text sections that EPA wanted to have included in the Technical Memos. These text sections concerned additivity of similar chemicals, selection of the risk threshold for the soil evaluation, documentation of soil benchmark criteria, and a revised metals screen of NCBC data. These were reviewed, revised, and are incorporated herein for Site 13.

In April 1997, an agreement was reached involving assessment of risks from ground water on a site-specific, rather than basewide, basis. Based on discussions during a 2 April 1997 BCT meeting in Boston, the Navy was directed to evaluate the risks from ground water at each site, and incorporate the results in the existing draft (soil) Technical Memorandum for each site. The Navy developed a stepwise protocol for evaluating ecological risk from ground water, similar to that developed for surface soil. Note that subsequent to the 2 April 1997 meeting, it was agreed by all parties that soil and ground-water evaluations would be combined in one Technical Memorandum only for Site 13.

The soil and ground-water evaluations are provided in the following two sections of this Technical Memorandum.

1.0 Soil-Based Remediation Evaluation at Site 13

As noted above, a protocol for evaluating the need for remediation of surface soil at NCBC sites was first submitted to the EPA in August 1996. Subsequently, the protocol was subjected to extensive review, discussion, and revision. The protocol consists of 10 sequential steps directed at identifying and validating chemical risk drivers, selecting Preliminary Remediation Goals (PRGs), and determining the need for, and extent of, remediation of surface soil.

- Step 1 Conduct the ERA—for Site 13 and other NCBC sites, the baseline document is the *Facility-Wide Freshwater Terrestrial Ecological Risk Assessment at NCBC Davisville* (EA 1996b).
- Step 2 Select a Risk Threshold—A HQ of 10 is selected as a threshold for terrestrial-based Receptors of Concern (ROC) (robin, hawk, shrew) based on the maximum COC concentration in surface soil in the watershed containing the IR site (data based on ERA modeling). The robin, hawk, and shrew, unlike other receptors such as the great blue heron and mink, receive their entire chemical dose via surface soil, either through the food web or by direct ingestion. Therefore, basing the soil-remediation evaluation on these receptors is the most conservative approach. (Reader note that the potential for chemical constituents in Site 13 and other IR site soils having been transported to nearby watershed sediment and surface water is evaluated under separate cover in a report, *Watershed Evaluation Report*.)
- Step 3 Identify Watershed-Specific Risk Drivers—All COC/ROC HQ combinations in the watershed that exceed the risk threshold are identified (data from ERA).
- Step 4 Determine if Risk Drivers Occur at Site Being Evaluated and, if so, Validate Risk Drivers—If none of the risk drivers occur at the site in question (they are at one or more other sites in the watershed), then the process stops here for this site. If risk driver(s) occur at the site in question, then maximum soil concentrations are compared to published benchmark soil concentrations (background, criteria, detection limits). This comparison allows one to evaluate whether the HQ(s) represent unacceptable risk, and is necessitated by the sizable uncertainty associated with the TRVs (Toxicity Reference Values) used in the food-web modeling. If benchmark data and elevated HQs are few, this comparison may be done as a tabulation. If not, visual displays are employed (Step 5).
- Step 5 Create Decision Diagram for Ecological Risk-Based Cleanup (DDERC)—If a number of HQs and benchmark data are involved, the risk validation of step 4 is best done graphically.

- Step 6 Select an Ecological Risk-Based Preliminary Remediation Goal (PRG)—Using the graphical and/or tabular data, a PRG is identified that will reduce ecological risk to desired level.
- Step 7 Identify Sample Locations Exceeding PRG in Site Under Investigation
- Step 8 Repeat Steps 4 Through 7 for Each Designated Risk Driver COC
- Step 9 Determine Extent of Projected Site-Specific Remediation
- Step 10 If Necessary, Reassess PRG Selection in Light of Projected Level of Remediation Effort and Ecological Risk Reduction—The PRG selection and proposed remediation effort are evaluated in light of perceived risk reduction and take into account the areal extent of COCs and other factors.

As indicated above, the EPA and other reviewers raised several issues bearing on earlier drafts of the Technical Memo protocol for ecological risk-based soil-remediation evaluation. They asked that these issues be addressed in the Technical Memoranda. Each of the four issues is addressed below, prior to actually describing the soil protocol-evaluation results for Site 13.

HQ=1 vs. HQ=10 for Risk Management Threshold

The Navy's use of HQ=10 as a threshold for evaluating the necessity for remediation (Step 2 above) was questioned by reviewers. The concern was raised that a real risk could be overlooked by ignoring HQs < 10. The Navy's position on this has to do with the difference between risk assessment and risk management.

A threshold of HQ=1 was used in the ERA document (February 1996) to select COCs and to model ecological risks to terrestrial receptors. Selecting a threshold of HQ=1 is generally appropriate at this stage to avoid false negatives (i.e., concluding there is *de minimus* risk when, in fact, significant risks may exist).

In contrast to the ERA, the soil evaluation portion of this Technical Memorandum is a risk management document designed to support remedial decision-making for soils at Site 13. A threshold of HQ=10 is used in this risk management Technical Memorandum to help identify chemicals that are risk-drivers. To do this, one must filter some of the "noise" present in the ERA. We have selected a threshold of HQ=10 based, in part, on general guidance offered by Menzie et al. (1993) for interpreting the importance of HQs.

- HQ between 1.0 and 10 suggests some small potential for environmental effects
- HQ between 10 and 100 suggests a significant potential that greater exposures could result in environmental effects
- HQ greater than 100 indicates that effects may be expected

Menzie et al. (1993) suggest that HQs greater than 1.0 do not necessarily indicate that an effect will occur, but only that a lower threshold of toxicity may have been exceeded. This guidance is based on a great deal of data and experience of the authors conducting a variety of ecological risk assessment projects.

By basing the site-specific action/no action remedial decision on a threshold above which there is a *significant potential that greater exposures could result in environmental effects*, an environmentally protective decision has been preserved. In contrast, basing a clean up decision solely on a HQ=1 (*small potential for environmental effects*) provides only marginal incremental environmental protection but at a much higher cost.

Guidance provided by EPA for conducting ecological risk assessments at Superfund sites (EPA 1994) also suggests that one should manage risk at the remedial assessment stage to a level less restrictive than that represented by an HQ=1. The HQ ratio is based on the following:

$$HQ = \frac{\text{Estimated Exposure}}{\text{Toxicity Benchmark}}$$

To be conservative, the estimated exposures represent an upper bound calculation based on maximum site concentrations. The Toxicity Benchmark is an exposure associated with no chronic, sublethal toxic effects. In practice, the value is a published or estimated NOAEL (No Observable Adverse Effect Level). During the risk assessment, both the estimated exposure and Toxicity Benchmark are selected to be environmentally conservative to avoid false negatives. Thus, if the HQ is less than 1.0, one can be very certain that no unacceptable impacts are occurring or can be expected. If the HQ exceeds 1.0, there is some probability (negligible to high) of effect (risk). Due to its conservative nature, HQs that exceed 1.0 by a small amount are probably not "risky". (Hence, the guidance from Menzie et al. 1993 as discussed above.)

EPA (1994) recommends that risk management decisions should lead to an action that will result in residual contaminant levels that are somewhat above the NOAELs. This translates into a HQ > 1. This is precisely what is done in this Technical Memorandum when a HQ=10 is used as a threshold to begin the risk management process.

Benchmark Screening Value Documentation

The appropriateness of the benchmark screening values used in Step 4 of the protocol was questioned by reviewers. The expressed concern was that some or all of the benchmark values may not be ecologically relevant. The Navy agreed to document the nature of the benchmark values, to the extent possible, for those values used in this Site 13 Technical Memorandum, as follows.

20 mg/kg Oak Ridge earthworm screen for cadmium (Will and Suter 1995a) - This benchmark value is based on 16 toxicity studies conducted with earthworms in the laboratory. Test species included *Eisenia fetida*, *E. andrei*, *Lumbricus rubellus* and *Dendrobaena rubida*. Endpoints included survival growth and reproduction. Exposure was in soil of various types ranging from sand to horse manure. Although the earthworm was not designated as a formal ROC in the Facility-Wide ERA, it is nonetheless an important and integral component of the ecosystem at NCBC. Their presence at NCBC was confirmed by EA Engineering during field sampling in spring 1995. The specimens collected were analyzed for tissue concentrations of chemical constituents, and the results used in food web modeling in the ERA. Their close contact with the soil makes them an excellent indicator of risk levels from soil constituents.

3 mg/kg Oak Ridge plant screen for cadmium (Will and Suter 1995b) - This benchmark value is based on 26 toxicity studies conducted with plants exposed via soil. Tested species included a wide variety of agricultural plants, grains, grasses, flowers and trees. Growth was by far the most common test endpoint. Most test soils were representative of agricultural loam.

5 mg/kg Beyer (Dutch) screen for cadmium (Beyer 1990) - The technical basis for this benchmark value is unknown. Beyer adopts the 5 mg/kg concentration from a secondary source, the "B" value soil criteria promulgated under the Dutch Soil Cleanup (Interim) Act. Beyer does not discuss the technical basis for the Dutch criteria. Our own investigations indicate the "B" values are probably based on a consideration of background and toxicological studies (human health and ecological). Only a translation of the original technical documents (in Dutch) upon which the Dutch criteria are based, can reveal the exact technical nature of this benchmark value.

12 mg/kg cadmium; 230 mg/kg chromium; 720 mg/kg zinc; 60 mg/kg phthalates - New Dutch Ecotox Intervention values (Ministry of Housing, Spatial Planning and Environment (1994) - The values represent concentrations that warrant evaluation of potential clean up. The specific technical underpinnings of the values are not available in English at this time. However, the author specifically distinguishes and presents values that are "ecotoxicologically-based."

0.22 - 3.5 mg/kg cadmium; 2 - 62 mg/kg chromium; 5 - 505 mg/kg zinc; Rhode Island background ranges for metals (O'Conner1995) - The technical basis for these ranges of benchmark values is that they represent the range of concentrations representative of background conditions in Rhode Island soil. The latter are based on a Rhode Island Department of Environmental Management, Division of Site Remediation, compilation of metals concentrations from 106 background sites throughout the state.

57,000 mg/kg aluminum; 25,000 mg/kg iron - Mean of Eastern U.S. background (Shacklette and Boerngen (1984) - U.S. Geological Survey nationwide soil-sampling program, 1961 - 1975.

0.52U - 0.59U mg/kg cadmium; 4.9 - 7.3 mg/kg chromium; 6,390 - 9,400 mg/kg aluminum; 10,100 - 11,900 mg/kg iron; 0.36U - 1.4 mg/kg bis(2-ethylhexyl)phthalate - NCBC background surface soil

Additivity of Chemical Effects

EPA and other reviewers expressed concern that the effects of some chemicals may be additive if the chemical effects are expressed in a similar mode and/or target organ of the receptor. This is not taken into account in the present protocol which deals with individual chemicals only if they exceed HQ=10 (Step 2 above). The circumstance was proposed whereby several chemicals with similar mode and target organ may individually have HQs less than 10, but collectively could add up to greater than 10 and represent collective risk. In support of draft Technical Memos for Sites 6, 10, and 11, the Navy agreed to identify those chemicals that were detected and which had food-web based HQs greater than 1.0, and to do a systematic literature search for pertinent information on additive effects of chemicals. The results of this search were provided to reviewers in late February 1997, and are summarized below as applicable to Site 13.

A number of the chemical constituents that were found at Sites 6, 10, and 11 were also found at Site 13, e.g., the metals cadmium and zinc, pesticide/PCBs such as DDT, dieldrin, and Aroclor-1254, and PAHs such as benzo(a)anthracene and phenanthrene.

Several national data bases and resources were accessed, of which the National Library of Medicine's Hazardous Substances Data Bank (HSDB) proved to have the most pertinent information. The search focused on identifying toxicity data and modes of action, particularly for oral exposure routes for non-human terrestrial receptors (mice, rats, guinea pigs, and birds). In general the search revealed little pertinent information on "target organs" and the toxicological mode of action was not always clearly identified. The similarity of target organ(s) and mode of action is critical to the acceptance of additivity of chemical effects.

The clearest case of additivity potential exists for PAHs. Compounds such as anthracene, benzo(a)anthracene, and phenanthrene are reported to cross nuclear membranes and bind with DNA. This event is believed to initiate effects that are manifested in different ways (e.g., enzyme induction, carcinogenesis). The primary target organ for PAHs appears to be the liver.

Additivity among the chlorinated hydrocarbons (aldrin, dieldrin, DDT, and Aroclor 1254) is also possible although the picture is less clear. The first three are neural toxicants (primarily CNS) and adversely affect the liver. Aroclors affect the liver, kidney and reproductive system. Based upon chemical structure and breakdown products, aldrin and dieldrin are probably additive. One study indicated that DDT and aldrin *increased* the excretion rate of dieldrin, which would tend to minimize chemical interactions. Another reference stated that aldrin and dieldrin together reduced the toxicity of organophosphates. Thus, an assumption of additivity may not be unreasonable for aldrin and dieldrin, but the inclusion of DDT and Aroclor 1254 is uncertain.

The potential for additivity among metals is least clear. To provide clarity, it is useful to group metals into categories following Klaassen et al. (1986). Metals such as manganese and zinc fall

into the category of essential trace elements. In "trace" concentrations, these are required for normal biological function. Determining the threshold between concentrations of these metals that are physiologically essential, and those that may be detrimental or toxic, is very difficult, if at all possible. At high concentrations, manganese has been shown to affect the central nervous system in mammals, by interfering with synaptic transmission. Manganese toxicity has been reported to increase with exposure to lead, and decrease with exposure to vanadium. In mammals, most zinc is present in muscle, bone, liver, kidney and pancreas tissues. It can cause depression of the central nervous system, lowered leucocyte counts, and enteritis. Zinc deficiency is more common than poisoning, and antagonism has been reported between zinc and cadmium.

Barium and vanadium are considered "Minor Toxic Metals" that are not known to be essential nor highly toxic. The literature on barium is very limited. No relevant target organ studies were listed, and HSDB reported "No Data" for modes of action. Accidental poisoning from ingestion of soluble barium salts by humans resulted in gastroenteritis, muscular paralysis, decreased pulse rate and ventricular fibrillation. The chemistry of vanadium is complex. Elevated exposures have been reported to affect the blood, liver, kidney and spleen. Hormone effects have been reported in pigeons. Toxicity of vanadium has been attributed to enzyme inhibition (e.g., ATPase). Interactions with other metals (Cu, Cr, Mn, Zn) is inconsistent, and probably related to vanadium speciation:

Several metals, including cadmium and lead are grouped as "Toxic Metals with Multiple Effects." Toxicity is moderated somewhat by their induction of intracellular metallothioneins (MT), which are low molecular-weight proteins rich in sulfhydryl residues. However, if the magnitude and/or duration of metal exposure is sufficient, the ameliorating effects of MT is overridden, and toxic effects may ensue. The presence of MT greatly confounds the additivity criteria of similar modes of action and target organs. Cadmium affects primarily the kidney and liver, with renal dysfunction being the major effect on humans. Cadmium is poorly absorbed via oral exposure (5-8%), and toxicity is believed to occur after the MT binding capacity is exceeded. Lead affects primarily the central nervous system, the hematopoietic system and the renal system. The mode of action appears to be the uncoupling of oxidative phosphorylation and ion transport. Exposure to lead induces MT synthesis, and zinc in the diet with lead protected horses against toxic effects.

The results of the literature search clearly do not support any attempt to quantify additive effects. There are too many unknowns and uncertainties, not the least of which involves the lack of (or confounding nature of) information on target organs and modes of action—the mechanisms that must be documented before additivity can be accepted. The prudent risk assessor and risk manager must remain aware of the potential for additive effects, notwithstanding the lack of any basis for quantifying such effects. At best, additivity may be incorporated into risk management judgements in a qualitative fashion, particularly if the evidence of additivity is fairly strong, such as for PAHs.

Because there is some support for additivity of PAHs, their occurrence in surface soil at Site 13 was investigated. Based on Table 6-9 of the Freshwater/Terrestrial ERA, eight PAH compounds produced food-web modeled HQs greater than 1. A data base query was conducted and it was

determined that five of these PAHs—acenaphthylene, benzo(a) anthracene, benzo(g,h,i)perylene, fluorene, and phenanthrene—were detected in at least one location at Site 13. The highest combined total concentration was 0.5 mg/kg for acenaphthylene, benzo(a)anthracene, and phenanthrene at Sample Location 13-SS-22 (Phase II). For the recent samples collected in association with the excavation, the greatest number of PAHs (9) occurred at Sample Location DV13SW12A. The combined total concentration for these 9 PAHs was 0.57 mg/kg. Using this value, and scaling against the maximum HQ for a PAH in ERA Table 6-9, an equivalent HQ of 1.7 was calculated for the combined effect of nine PAH compounds at DV13SW12A. Thus, there is clearly no risk from additivity of PAH compounds in Site 13 surface soil.

"New" COCs in Hall Creek Watershed

The COC-screening procedure employed in the February 1996 Freshwater/Terrestrial ERA was criticized by reviewers because the maximum site concentrations were not compared to mean background concentrations. The concern was that a chemical constituent could represent a risk, and yet not be chosen as a COC and further evaluated. Because this could have implications in this surface soil risk-management evaluation, the Navy agreed to re-screen the analytical data, report any "new" COCs, and address these herein in the context of Site 13.

COCs selected in the ERA were determined by comparing maximum on-site concentration to three times the mean site-specific (NCBC) background level and appropriate benchmark screening values. Constituents that exceeded both screens were retained as COCs. If there was no benchmark screen due to lack of suitable screening criteria, the constituent was retained as a COC.

To address reviewer concerns, an additional background screen was conducted to ensure hot spots did not pass through the screening process undetected. For this second screen, the maximum watershed concentration was compared to the mean background level. When this was done, the following constituents in surface soil and sediment were identified, and termed "new COCs":

- Aluminum (sediment)
- Arsenic (surface soil)
- Manganese (surface soil)
- Lead (sediment)

Three of these (arsenic, manganese, lead) had already been identified as COC in another medium. When a constituent was identified in at least one medium, it was retained as a COC in all media. That constituent in all media was included in the terrestrial food web model for the watershed (ERA). Therefore, there is really only one "new" constituent (aluminum) in the Hall Creek Watershed and it does not represent significant ecological risk for the following reasons.

Aluminum is not a concern because 1) the maximum watershed concentration (13,000 mg/kg) is less than a benchmark value (57,000 mg/kg) and 2) the mean watershed concentration (5356 mg/kg) is less than the mean background (5,795 mg/kg). The benchmark value represents background concentration of aluminum in Eastern U.S. soil (Shacklette and Boerngen 1984). Aluminum is one of the most common elements in soil and sediment and it exists in several chemical states. A relatively small fraction of the total aluminum content of soil or sediment exists in a form that can be absorbed by and is toxic to plants and animals. Aluminum must be present in very high concentrations to cause a toxic response in animals or plants. Unlike some other metals, toxicity of aluminum to plants is at least equal to that of animals.

Specific aluminum concentrations at Site 13 are discussed in the next section.

1.1 Application of Ecological Risk-Based Soil-Remediation Evaluation at Site 13

1.1.1 Description of Site 13

Site 13 is a 6-acre grassy field partially surrounded by paved roads and buildings. There are three catch basins in the area. The site also includes several devegetated areas. Fencing restricts access. Buildings W-3, W-4, and T-1 were used for vehicle repair from 1945 to 1955, during which time 36,000 gal of waste oil, paint thinners, and solvents were spread on the field. Surface water runoff is collected by storm drains that drain east into Hall Creek. Ground water under most of the site drains northeastward toward Davol Pond and Hall Creek. Due to a ground-water divide under the site, portions of the southwestern site may drain to the west into Mill Creek. Based on elevated concentrations of PCBs in surface soil at Site 13 identified in Phase I/II sampling (TRC 1994), Foster Wheeler Environmental Corporation performed a soil removal action in a portion of the site between July 1996 and March 1997 (Foster Wheeler 1997). The results of this action are taken into consideration in the soil remediation evaluation described below.

1.1.2 Evaluation of Site 13

Site 13 was evaluated with the stepwise protocol described above, adjusted as necessary where indicated below to accommodate the recent soil-removal action at the site.

Step 1 Conduct the ERA

A Freshwater/Terrestrial Ecological Risk Assessment for NCBC was completed in 1995 and results reported in the Draft Final version dated 15 February 1996. References to ERA results herein refer to that document.

Step 2 Select a Risk Threshold

A risk threshold of $HQ = 10$ was chosen based on modeled results for terrestrial receptors whose food base derives ultimately from soil (rather than aquatic sediment). These receptors were the hawk, robin, and shrew.

Step 3 Identify Watershed-Specific Risk Drivers

Identification of watershed-specific risk drivers was a two-tiered operation necessitated by the recent removal action at the site. First, based on examining Table 6-9 of the Draft Final ERA, all COC/ROC pairs exhibiting an HQ in excess of 10 for either the hawk, robin, or shrew were identified as possible risk drivers in the watershed. This table contains food web-based, modeled HQs based on the maximum COC concentration in a given watershed. The maximum HQs were used in lieu of average because the latter might cause one to overlook a "risky" location in a watershed containing more than one site.

A total of 17 COC/ROC pairs exhibited HQs exceeding 10. These ranged from $HQ = 20.3$ for Aroclor 1254/robin to $HQ = 2,508.7$ for Aroclor 1260/shrew (Table 6-9, Draft Final ERA). Maximum surface soil concentrations corresponding to those values were 17.5 mg/kg Aroclor 1254 and 12,000 mg/kg for Aroclor 1260. In all, 10 COC were associated with maximum HQs exceeding 10 in Hall Creek Watershed. In addition to Aroclors 1254 and 1260, there were cadmium, fluorene, DDT, DDE, Aroclor 1248, dieldrin, endrin, and endrin ketone. These are considered potential risk drivers in surface soil at one or more sites in the Hall Creek Watershed.

This list of potential watershed-risk drivers is based on analyses and evaluations prior to the soil removal action at Site 13. The possibility that the removal action at the site would affect the list of watershed-risk drivers (either adding or subtracting) is dealt with under Step 4 below.

Step 4 Determine Occurrence and Validation of Risk Drivers

Because there are five IR sites in the Hall Creek Watershed, the surface soil data for Site 13 were examined to determine if the site contained any of the potential risk drivers. The data are available in hardcopy in Appendix A and B of the *Revised Draft Facility-Wide Freshwater/Terrestrial Ecological Risk Assessment* (August 1995). The electronic version of this data base was used in this evaluation. It was determined that all 10 constituents identified as potential watershed risk drivers were detected in surface soil at Site 13. The next step was to determine the maximum soil concentration of these constituents at the site, and calculate equivalent (site-specific maximum) HQs for the terrestrial receptors at Site 13. This step is illustrated in Table 1. This table shows that, although the risk threshold was exceeded for at least one receptor somewhere in the watershed, five constituents—fluorene, DDE, DDT, dieldrin, and endrin—did not exceed the risk threshold for any receptor at Site 13. For the area of Site 13 not involved in the recent soil-removal action, these constituents are considered no further.

For those constituents with HQs > 10 at Site 13, the data were examined to see which, if any, were a result only of previous (Phase I/II) samples from the area recently excavated. It was determined that endrin ketone and Aroclor-1260 exceedances of the risk threshold (HQ=10) were due solely to samples from inside the excavated zone. Therefore, with regard to the area of Site 13 outside of the excavated area, these constituents need be considered no further.

The three remaining constituents—cadmium, Aroclor-1248, and Aroclor-1254—exceeded the risk threshold in at least one sample location outside of the excavated area.

Constituent	Sample Location	Concentration (ppm)	HQ Equivalent
Cadmium	13-SS20	1.3	15.7 (shrew)
Aroclor-1248	S-13-08-00-S	1.1	59.8 (shrew)
Aroclor-1254	B-13-06-00-S	1.3	32.4 (shrew)
Aroclor-1254	S-13-08-00-S	1.4	34.9 (shrew)

The sample locations are illustrated on Figure 1.

As noted above, a portion of the soil at Site 13 was recently removed (Figure 1). Any Phase I/II samples from that area containing constituent concentrations exceeding the risk threshold were removed from the evaluation. However, two rounds of surface soil samples were taken just outside of the excavated area to support evaluation of ecological and human health risk. These are new samples for Site 13 that must be considered in addition to the original Phase I/II sample data. The origin, conduction, and results of the soil removal action are described in close-out reports for Site 13 (Foster Wheeler 1997; Stone & Webster 1997). Data from this action are evaluated below to determine if any constituents from the new samples exceed risk thresholds and thus warrant further evaluation for soil remediation.

The soil removal action at Site 13 was precipitated by elevated levels of PCB identified in Phase I/II sampling. A RIDEM clean up criterion of 10 mg/kg was designated as the target. Removal was conducted in two phases, with risk assessment soil samples collected after each. These samples were taken as near to previous TRC sampling locations as possible (Foster Wheeler 1997). In several cases, analysis of samples after Round 1 removal indicated that the PCB concentration still exceeded 10 mg/kg; excavation continued in these areas in Round 2. After Round 2, the data were assembled for risk assessment consisting of those Round 1 samples that triggered no more excavation, and all Round 2 samples. Six field and one duplicate sample are included.

All priority pollutants that were detected in these surface soil samples were compiled in Table 2. Iron and aluminum, although not priority pollutants, were included. A screening threshold was developed and a screening quotient calculated to determine if a constituent exceeded the threshold and thus warranted any further evaluation for remediation. Consistent with Step 2 of the protocol, the screening threshold for most constituents was set equal to the concentration

equivalent to an HQ of 10 for the most sensitive terrestrial receptor, based on food-web modeling in the Freshwater/Terrestrial ERA. Iron and aluminum were not initially modeled, and there are no appropriate screening criteria, so they were screened against NCBC background. Because the removal action was based on the RIDEM 10 mg/kg criterion for total PCB, Aroclors detected were added and screened against this criterion.

The shaded blocks in Table 2 indicate that six constituents exceeded the screening threshold although the concentrations of two—chromium and aluminum—were virtually identical to the screening threshold concentrations. When these potential "new" risk drivers are added to those identified above for the area outside of the excavation, a total of seven constituents warrant further consideration under this protocol, as shown below.

Constituent	Sample Location	Concentration (ppm)	HQ Equivalent
Cadmium	13-SS20	1.3	15.7 (shrew)
Chromium	DV13SW135RC	63.0	10.2 (shrew)
Zinc	DV13SW135RC	5,690.0	51.1 (hawk)
Aluminum	DV13SW135RC	8,320.0	----
Iron	DV13SW135RC	36,600.0	----
Bis(2-ethylhexyl)phthalate	DV13SW135RC	1.4	----
Total PCB	B-13-06-00-S	1.3	----
Total PCB	S-13-08-00-S	2.5	----
Total PCB	DV13SW12A	22.0	----

The sample locations may be viewed in Figure 1. Each of the constituent/location pairs is evaluated below with regard to potential need for remediation. In this validation step, the concentration of each constituent is compared to available benchmark data.

Cadmium

The concentration of cadmium at Station 13-SS20 is lower than commonly available soil screening benchmark values (Figure 2). The concentration at Station 13-SS20 exceeds NCBC background; cadmium was not detected in limited background samples. However, the cadmium concentration at this location falls in the lower half of the Rhode Island background range. The fact that cadmium concentrations equivalent to HQs between 1 (the traditional presumptive risk threshold) (0.08 mg/kg) and 15.7 (1.3 mg/kg) do not exceed or approach the common screening levels, and fall within the Rhode Island background range, suggests that the HQ derivation (through food web modeling) is overly conservative. Therefore, the cadmium concentration at Sample Location 13-SS20 is considered not to represent unacceptable ecological risk, and

further evaluation of remediation is unwarranted. For cadmium, the stepwise evaluation is terminated at Step 4.

Chromium

The concentration of chromium at Sample Location DV13SW135RC (63 mg/kg) exceeded NCBC background and, by a slight margin, the mean background for the Eastern U.S. (Figure 3). The Site 13 concentration was virtually equal to the upper limit of Rhode Island background. The site concentration was markedly below toxicologically-based benchmark screening levels. Notwithstanding the sample's moderate elevation relative to background, it did not exceed protective screening levels, and produced an equivalent HQ for the most sensitive receptor (10.2) that just barely exceeds the screening threshold (10.0). Therefore, it is recommended that chromium at this sample location warrants no further remediation evaluation.

Zinc

The single zinc concentration at Sample Location DV13SW135RC of 5,690 mg/kg clearly exceeds all relevant benchmark values. The latter range from 5 mg/kg (low end of Rhode Island background) to 720 mg/kg (new Dutch Ecotox Intervention value). This value was "J"-qualified during data validation indicating an estimated value. The concentration must be considered valid for risk assessment/risk management purposes. The evaluation of zinc continues in subsequent steps of the protocol.

Aluminum

Lacking relevant toxicologically-based screening criteria, the aluminum concentration from Sample Location DV13SW1354RC was screened against the mean of NCBC background and was included in the above table as a potential risk driver because it just barely exceeded the mean background. The fact that the concentration of 8,320 mg/kg fell within the NCBC background range of 6,390 to 9,400 mg/kg supports removing the constituent from any further consideration of remediation. All values were considerably below the mean of 57,000 mg/kg for Eastern U.S. soils.

Iron

The iron concentration at Sample Location DV13SW135RC exceeded NCBC background by just over three times (Table 1). The value of 36,600 mg/kg also exceeds mean Eastern U.S. background (25,000 mg/kg). Although the site value is somewhat elevated relative to background, the fact that iron is a common constituent of soil, is not a priority pollutant, and is in fact an essential nutrient, does not strongly support consideration of further remedial action based on iron alone.

Bis(2-Ethylhexyl)Phthalate

This compound was included in the above table as a potential risk driver because the concentration at Sample Location DV13SW135RC exceeded the NCBC background mean by just over two times (Table 1). However, the site concentration was equal to the upper end of the NCBC background range of 1.4 mg/kg. The only available toxicologically-based benchmark data available are the new Dutch values, where the Ecotox intervention value—the concentration at which consideration of remediation is recommended—for phthalates is 60 mg/kg. The concentration at Site 13 is not recommended for further remedial evaluation.

Total PCB

Early in this Step 4, PCBs (Aroclors) were identified as potential risk drivers at two Sample Locations at Site 13 outside of the excavated area, based on exceedance of the risk-based threshold of HQ=10. Detected Aroclors at these locations were added together to represent total PCB and were carried forward into the above table. However, these total PCB values for Sample Locations B-13-06-00-S and S-13-08-00-S were well below the RIDEM clean-up criterion of 10 mg/kg, therefore these locations are removed from further consideration of remediation. The concentration of 22 mg/kg total PCB in the single sample from location DV13SW12A clearly exceeds the RIDEM clean-up criterion of 10 mg/kg. Under present agreements, and given no other considerations, this level of total PCB would require remediation. It is discussed further under Step 10.

Step 5 Create Decision Diagram for Ecological Risk-Based Cleanup

Two such diagrams were employed—one for chromium and one for cadmium—and referenced under Step 4 above.

Step 6 Select an Ecological Risk-Based Preliminary Remediation Goal (PRG)

In Step 4, two constituents—zinc and total PCB—were judged to require further consideration of possible remediation. The PRG for total PCB has been established as the RIDEM criterion of 10 mg/kg. Regarding zinc, the Navy recognizes that the concentration at Sample Location DV13SW135RC represents potential ecological risk. However, it is felt that the selection of a PRG for zinc is premature until all information is considered and an ultimate decision regarding the need for remediation is made. Additional discussion is provided under Step 10 below.

Step 7 Identify Sample Locations Exceeding PRG

As indicated above, with the exception of total PCB, PRGs are not established at this time. The sample locations containing all potential risk drivers, including zinc and total PCB, are identified in Figure 1.

Step 8 Repeat Steps 4 Through 7 for Each Designated Risk Driver

All potential risk drivers were identified and discussed under Step 4 above.

Step 9 Determine Extent of Projected Site-Specific Remediation

As already indicated, the necessity for additional remediation at Site 13 has been deferred to discussions under Step 10 below.

Step 10 If Necessary, Reassess PRG Selection in Light of Projected Level of Remediation Effort and Ecological Risk Reduction

The concentration of zinc representing potential risk to the hawk was measured at Sample Location DV13SW135RC (Figure 1). The extent of the elevated zinc appears to be limited based on sample data for other locations. Of the nearby samples taken in association with the removal action, and which were not themselves "removed," the highest concentration of zinc was at Sample Location DV13SW77 (463 mg/kg, Table 1). This concentration is equivalent to a hawk HQ of 4.2, well below the pre-established risk threshold of 10. Two additional nearby sample locations (Phase II)—13-SS17 and 13-B11-01—located one to two hundred feet to the west and northwest of DV13SW135RC, were examined in the data base and the highest concentration of zinc was 351 mg/kg at 13-SS17. This is equivalent to a hawk HQ of 3.2.

When the apparently small area of elevated zinc is viewed in the context of a small exposure zone in an area of low quality ecological habitat, the Navy finds little impetus for remediation of zinc based on ecological issues alone. The Navy believes the ecological protection that would be achieved is minimal and clearly outweighed by cost.

The situation with 22 mg/kg total PCB at Sample Location DV13SW12A is similar to that with zinc. The Round 1 sample at this location contained 2,620 mg/kg total PCB (Foster Wheeler 1997). Excavation then continued in this area in a northerly, lateral direction, then a second round risk-assessment soil sample was collected just outside of the newly excavated area. This sample (DV13SW12A) contained the 22 mg/kg total PCB being addressed herein. This sample location was within approximately 15 feet of the previous sample that contained 2,620 mg/kg total PCB. There is apparently a very steep concentration gradient from the area of the (former) hot spot just to the south of DV13SW12A. This was further confirmed by examining Phase I/Phase II surface soil data at locations approximately 125 to 150 feet to the north and northwest of DV13SW12A (Figure 1). Of these sample locations (13-SS13, S-13-08-00-S, B-13-06-00-S, and 13-B9-01), the highest total PCB concentration was 2.5 mg/kg at S-13-08-00-S, suggesting that concentrations rapidly decrease with distance to the north of the excavated former hot spot.

As with zinc, the area of elevated total PCB represented by Sample Location DV13SW12A appears to be isolated and small. Given the isolated exposure zone, and the low attractive potential of the ecological habitat, the Navy believes that continued excavation of PCB in this area may not be warranted, based solely on ecological risk considerations.

As noted earlier, the possibility of migration of surface-soil constituents from this and other IR sites to nearby streams is evaluated in a separate document, *Watershed Evaluation Report*. Based upon the foregoing, there appears to be little potential for the isolated concentrations of zinc and (post-remediation) PCB to act as sources for transport to Hall Creek surface water or sediment.

2.0 Assessment of Ecological Risk of Ground Water from Site 13 in the Hall Creek Watershed

2.1 Protocol Description

A step-wise protocol was developed to assess ground-water risks. The protocol is analogous to that previously described for surface soil, but differs in certain aspects because of different fate and transport issues and exposure pathways. The protocol is described as follows.

- Step 1 Assemble Ground Water and Watershed Surface Water and Sediment Analytical Data.
- Step 2 Select a Risk Threshold. This is the concentration of a constituent in ground water, as reflected in the Concentration Ratio (CR), above which it is deemed necessary to evaluate for potential contribution of ground water to watershed surface water or sediment risks. The CR is calculated by dividing the ground-water concentration of a chemical constituent by the higher of Ambient Water Quality Criteria (AWQC) or background value for that constituent. For this evaluation, the risk threshold is set at CR=1. Because some of the screening criteria are background and not toxicologically based, the term Concentration Ratio is used in lieu of the toxicologically-related Hazard Quotient (HQ). The term Hazard Quotient is retained for surface water and sediment where screening criteria are largely toxicologically based. If the CR is exceeded for any constituent, the constituent is designated a Constituent of Concern (COC), and the evaluation proceeds to Step 3. This is a conservative evaluation since it does not take into account the physical properties and organic content of soil that typically retard transport of chemical constituents in ground water. The constituent concentrations discharged to surface water are often less than those measured in the wells.
- Step 3 Based on the hydrogeology of the site, determine whether chemical constituents would be expected to migrate to nearby surface water. If not, proceed to Step 7. If yes, go to Step 4.
- Step 4 Based on the chronology of documented releases at a site, determine whether sufficient time has passed to permit migration of the chemical constituents to nearby surface water. If not, go to Step 6. If yes, go to Step 5.

- Step 5 Determine if Constituents Exceeding Risk Threshold in Ground Water Were Detected in Watershed Surface Water or Sediment Above Screening Levels. If an constituent was detected in surface water and/or sediment, and its HQ exceeded 1, the evaluation proceeds to Step 6. If not detected or surface water/sediment HQ < 1, proceed to Step 7.
- Step 6 Provide Narrative Discussing Potential for Constituent in Ground Water to Impact the Watershed. Include, as appropriate, elements of fate and transport (e.g., hydrogeology, chemistry, attenuation, etc.).
- Step 7 Summarize and Document Ecological Risk/No Risk Determination for Ground Water in the Watershed.

2.2 Site 13 Evaluation

Step 1 - Assemble Data

The ground-water data used for this evaluation were from the Phase II Remedial Investigation (RI) of IR Program Site 13 (TRC 1994). The Phase I data were not included because sampling was not performed using low-flow methods. The data are from fourteen wells on and near the site. This evaluation utilizes ground-water data compilations and maps (Figure 4) provided by Stone & Webster. The data used to evaluate constituent occurrence in surface water and sediment in the Hall Creek Watershed are available in the *Draft Final Facility-Wide Freshwater/Terrestrial Ecological Risk Assessment* (EA 1996b) (Tables 4-4, 4-9, 6-1, 6-5), and in the December 1996 *Technical Memoranda and Responses to Comments on Soil and Related Ecological Risk Evaluations at NCBC Sites 06, 10, and 11* (Table 4-4 amended) (EA 1996a).

Step 2 - Select Risk Threshold

The designated ground-water risk threshold of 1 was exceeded for five constituents in eight wells at Site 13 (Table 3). Four metals, antimony, iron, cobalt, and aluminum, and the pesticide heptachlor epoxide exceeded screening criteria. The exceedances of the metals in particular were minimal, as evidenced by the ground-water CRs between 1.0 and 1.3. The concentrations were not greatly elevated; nonetheless, the CRs > 1 trigger Step 3.

Step 3 - Determine if Ground-Water Constituents Can Migrate to Surface Water

It was established during Phase I and II hydrogeology studies (TRC 1994) that ground water from Site 13 would migrate toward local surface waters. The direction of ground-water flow is complex at this site because it straddles a ground-water divide between the Hall Creek and Mill Creek watersheds (Figure 4). However, this comparison assessment focuses only on Hall Creek, for reasons developed below. In the Phase I/II study, ground water was encountered at depths below surface of from 6 to 12 feet, depending on well and measurement date. Site 13 ground

water has been reported at depths as shallow as 3.5 feet in more recent studies (Stone & Webster 1996; Foster Wheeler 1997).

Step 4 - Determine if Historical Releases Could Have Reached Surface Water

Between 1945 and 1955, The NCBC Davisville Construction Equipment Division (CED) was housed in the area of Site 13. Documented releases at the site include approximately 300-gal. per month of waste oils that were spread on the field north of Buildings W-3 and W-4. Establishing whether chemical constituents in Site 13 ground water in 1955 could have reached Hall Creek by the early 1990s is an approximate process, given the distance of the site from the stream (approximately 1,700 feet). Using the highest average linear velocities of shallow ground water determined for the site (0.13 ft/day) (TRC 1994), it can be calculated that 1955 shallow ground water could have reached Hall Creek by 1990, prior to implementation of surface water and sediment sampling programs. Although chemical constituents do not necessarily move (if at all) at the same rate as ground water, the length of time involved permits the assumption that any constituents destined to migrate in ground water would have reached the creek. Therefore, the evaluation of COCs in surface water and sediment is required (Step 5).

This assessment starts with constituent concentrations in ground water and includes an inherent assumption that hazardous releases are likely to have reached ground water. That this is not necessarily true has been confirmed recently where ground-water samples at Site 13 were non-detect for PCB in an area where soil concentrations had elevated concentrations of PCB (Foster Wheeler 1997).

Step 5 - Determine if Ground-Water COCs Exceeded Criteria in Surface Water/Sediment

Two of the constituents that exceeded ground-water screening criteria do not require evaluation under Step 6 because they were either not detected, or did not exceed screening criteria in surface water and sediment. Antimony was detected in Hall Creek surface water, but well below the screening criterion. It was not detected in sediment (Table 3). As noted above, ground-water flow direction is complex at Site 13. Well MW13-10S, in which antimony exceeded the ground-water criterion, is located in an area where the flow could reasonably be expected to go toward Mill Creek, rather than Hall Creek, based on the Phase I and II evaluations (TRC 1994), and the basewide ground-water study (Stone & Webster 1996). However, antimony was not detected in Mill Creek sediment, and did not exceed the screening level in Mill Creek surface water. Similarly, heptachlor epoxide, which slightly exceeded the ground-water screening criterion in three wells, was not detected in either surface water or sediment in Hall Creek, and need not be evaluated under Step 6. The remaining metals, cobalt, aluminum, and iron, require evaluation under Step 6, because two exceeded criteria in surface water or sediment (cobalt, aluminum), and one was not previously screened (iron).

Step 6 - Provide Narrative Discussing Potential for Watershed Risks from Ground Water

Iron in ground water is not likely to pose ecological risk in the Hall Creek surface-water environment. Iron occurred in excess of screening criteria in 2 of 14 wells at the site. The exceedances (CRs) were low, and there was no pattern in ground water suggestive of substantial anthropogenic releases. In the absence of anthropogenic sources, dissolved iron is often found in ground water due to naturally occurring mildly reducing conditions. The mildly reducing conditions result in the conversion of insoluble Fe(III) species to soluble Fe(II) species. When Fe(II) reaches the surface, it is expected to rapidly convert to Fe(III) which is much less soluble and tends to precipitate as iron oxyhydroxides on the surface of stream sediments. This iron oxyhydroxide phase is a natural component of nearly all soil types.

Neither aluminum nor cobalt exceeded screening criteria in surface water, but both exceeded criteria in sediment, at least when the maximum value for the watershed was used (Table 3). Their exceedance in ground water was minimal; the recorded concentrations were within 10 to 20 percent of the criteria value. It is doubtful that the concentrations and criteria would be statistically distinguishable. Given the low levels of cobalt and aluminum in both ground water and Hall Creek sediment, correlation of concentrations in those two media is not possible. Regardless of the source of the metals, the concentrations appear too low to represent significant ecological risk.

Step 7 - Summarize and Document Risk/No Risk Findings

This evaluation of ecological risk from ground water is largely theoretical in that it depends on circumstantial evidence of linkage of ground-water constituents and constituents in the watershed streams. There is no direct measurement of movement of chemical constituents, nor has there been "tagging" of material in ground water that could then be re-identified in the watershed. Knowledge of the ground-water environment is used in conjunction with constituent concentrations in ground water, surface water, and sediment to infer possible linkages between the ground water and surface water environments.

At Site 13, the potential linkage of chemical constituents between ground water and surface water has been assumed. Judgements regarding ecological risk from ground water were based on the number of common COCs in the two environments, their concentration in both environments, their distribution in ground water, and geochemical considerations. The results (Table 3) allow for a rather straightforward evaluation. Only cobalt and aluminum exceeded screening criteria in Hall Creek sediment, but they were not greatly elevated. As expected, iron was present in ground water and exceeded the screening criterion slightly in two wells. The low level of exceedance of iron in ground water and its natural occurrence in that medium suggests little potential for ecological risk in the surface environment.

Based on the above assessment, ecological risk from ground water at Site 13 is determined to be minimal.

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TABLE 1 SITE-SPECIFIC HQs FOR TERRESTRIAL RECEPTORS AT SITE 13 (NON-EXCAVATED AREA)

Constituent	Watershed Max. (ppm)	Watershed Max. HQ			Site 13 Max. (ppm)	Site 13 max. HQ		
		Robin	Hawk	Shrew		Robin	Hawk	Shrew
cadmium	2.35	0.2	0.2	28.3	1.3	0.11	0.11	15.66
fluorene	13.5	2.3	40.6	0.8	0.13	0.02	0.39	0.01
DDE	1.75	3.5	24.5	2.4	0.02	0.04	0.28	0.03
DDT	3.3	58.2	78.4	2.1	0.11	1.94	2.61	0.07
dieldrin	1.75	7.2	25	139.3	0.0014	0.01	0.02	0.11
endrin	1.75	1.6	9	72.6	0.003	0.00	0.02	0.12
endrin ketone	1.75	2.1	9	102.7	0.83	1.00	4.27	48.71
Aroclor-1248	8.5	7	29	461	1.2	0.99	4.09	65.08
Aroclor-1254	17.5	20	86	436	1.4	1.60	6.88	34.88
Aroclor-1260	12000	478.9	1809.4	2509.7	12000	478.90	1809.40	2509.70

TABLE 2 RESULTS OF SCREENING NEW SURFACE SOIL DATA AT SITE 13

<u>Field Sample</u>	<u>Class</u>	<u>Constituent</u>	<u>Concentration (mg/kg)</u>	<u>Screening Threshold (mg/kg)</u>	<u>Screening Quotient</u>
DV13SW11RC	Inorganic	Lead	149.000	3503	0.04
DV13SW11RC	Inorganic	Arsenic	1.800	21.1	0.09
DV13SW11RC	Inorganic	Barium	32.100	1338.6	0.02
DV13SW11RC	Inorganic	Vanadium	8.000	54.9	0.15
DV13SW11RC	Inorganic	Beryllium	0.830	409.6	0.00
DV13SW11RC	Inorganic	Copper	112.000	5784.5	0.02
DV13SW11RC	Inorganic	Iron	10000.000	10867	0.92
DV13SW11RC	Inorganic	Chromium	9.800	61.8	0.16
DV13SW11RC	Inorganic	Cobalt	7.000	181.1	0.04
DV13SW11RC	Inorganic	Zinc	438.000	1113.3	0.39
DV13SW11RC	Inorganic	Aluminum	3930.000	8060	0.49
DV13SW11RC	Inorganic	Manganese	154.000	644.9	0.24
DV13SW11RC	Inorganic	Nickel	40.900	7918	0.01
DV13SW11RCDL	Pesticide/PCB	Aroclor 1254	3.300	---	---
DV13SW11RC	Pesticide/PCB	Aroclor 1260	1.300	---	---
DV13SW11RC	Pesticide/PCB	Aroclor 1248	0.750	---	---
DV13SW11RC	Pesticide/PCB	Total PCB	5.350	10	0.54
DV13SW11RC	Semivolatile	2-Methylnaphthalene	0.082	32.6	0.00
DV13SW11RC	Semivolatile	Phenanthrene	0.039	40	0.00
DV13SW12A	Inorganic	Aluminum	3100.000	8060	0.38
DV13SW12A	Inorganic	Arsenic	0.360	21.1	0.02
DV13SW12A	Inorganic	Silver	0.990	1034.4	0.00
DV13SW12A	Inorganic	Zinc	40.000	1113.3	0.04
DV13SW12A	Inorganic	Vanadium	6.100	54.9	0.11
DV13SW12A	Inorganic	Barium	18.800	1338.6	0.01
DV13SW12A	Inorganic	Lead	41.300	3503	0.01
DV13SW12A	Inorganic	Manganese	96.900	644.9	0.15
DV13SW12A	Inorganic	Iron	6790.000	10867	0.62
DV13SW12A	Inorganic	Chromium	3.800	61.8	0.06
DV13SW12A	Inorganic	Copper	14.600	5784.5	0.00
DV13SW12A	Inorganic	Beryllium	0.410	409.6	0.00
DV13SW12A	Pesticide/PCB	Aroclor 1254	10.000	---	---
DV13SW12A	Pesticide/PCB	Aroclor 1248	12.000	---	---
DV13SW12A	Pesticide/PCB	Total PCB	22.000	10	2.20
DV13SW12A	Semivolatile	Benzo(a)anthracene	0.045	8.3	0.01

DV13SW12A	Semivolatile	Fluoranthene	0.098	777.8	0.00
DV13SW12A	Semivolatile	Pyrene	0.094	1333.3	0.00
DV13SW12A	Semivolatile	Benzo(a)pyrene	0.048	118.4	0.00
DV13SW12A	Semivolatile	Benzo(g,h,i)perylene	0.046	10.7	0.00
DV13SW12A	Semivolatile	Chrysene	0.079	3150	0.00
DV13SW12A	Semivolatile	Phenanthrene	0.046	40	0.00
DV13SW12A	Semivolatile	Benzo(k)fluoranthene	0.057	5500	0.00
DV13SW12A	Semivolatile	Benzo(b)fluoranthene	0.061	3666.7	0.00
DV13SW12A	Semivolatile	bis(2-Ethylhexyl)phthalate	0.053	0.59	0.09
DV13SW135RC	Inorganic	Beryllium	8.100	409.6	0.02
DV13SW135RC	Inorganic	Chromium	63.000	61.8	1.02
DV13SW135RC	Inorganic	Cobalt	59.700	181.1	0.33
DV13SW135RC	Inorganic	Selenium	0.180	0.65	0.28
DV13SW135RC	Inorganic	Iron	36600.000	10867	3.37
DV13SW135RC	Inorganic	Barium	168.000	1338.6	0.13
DV13SW135RC	Inorganic	Copper	1160.000	5784.5	0.20
DV13SW135RC	Inorganic	Nickel	533.000	7918	0.07
DV13SW135RC	Inorganic	Zinc	5690.000	1113.3	5.11
DV13SW135RC	Inorganic	Manganese	489.000	644.9	0.76
DV13SW135RC	Inorganic	Aluminum	8320.000	8060	1.03
DV13SW135RC	Inorganic	Vanadium	14.800	54.9	0.27
DV13SW135RC	Inorganic	Lead	869.000	3503	0.25
DV13SW135RC	Pesticide/PCB	Aroclor 1254	0.580	---	---
DV13SW135RC	Pesticide/PCB	Aroclor 1248	0.580	---	---
DV13SW135RC	Pesticide/PCB	Aroclor 1260	0.730	---	---
DV13SW135RC	Pesticide/PCB	Total PCB	1.890	10	0.19
DV13SW135RC	Semivolatile	bis(2-Ethylhexyl)phthalate	1.400	0.59	2.37
DV13SW135RC	Semivolatile	Pyrene	0.042	1333.3	0.00
DV13SW135RC	Semivolatile	Fluoranthene	0.045	777.8	0.00
DV13SW139A	Inorganic	Cobalt	3.300	181.1	0.02
DV13SW139A	Inorganic	Iron	7030.000	10867	0.65
DV13SW139A	Inorganic	Chromium	8.400	61.8	0.14
DV13SW139A	Inorganic	Manganese	92.500	644.9	0.14
DV13SW139A	Inorganic	Lead	10.900	3503	0.00
DV13SW139A	Inorganic	Beryllium	0.390	409.6	0.00
DV13SW139A	Inorganic	Vanadium	7.000	54.9	0.13
DV13SW139A	Inorganic	Zinc	145.000	1113.3	0.13
DV13SW139A	Inorganic	Barium	17.500	1338.6	0.01
DV13SW139A	Inorganic	Copper	15.200	5784.5	0.00

DV13SW139A	Inorganic	Aluminum	3240.000	8060	0.40
DV13SW139A	Pesticide/PCB	Aroclor 1254	0.320	---	---
DV13SW139A	Pesticide/PCB	Aroclor 1260	0.150	---	---
DV13SW139A	Pesticide/PCB	Aroclor 1248	0.091	---	---
DV13SW139A	Pesticide/PCB	Total PCB	0.561	10	0.06
DV13SW77	Inorganic	Aluminum	3170.000	8060	0.39
DV13SW77	Inorganic	Manganese	117.000	644.9	0.18
DV13SW77	Inorganic	Arsenic	0.450	21.1	0.02
DV13SW77	Inorganic	Lead	41.500	3503	0.01
DV13SW77	Inorganic	Iron	6500.000	10867	0.60
DV13SW77	Inorganic	Zinc	463.000	1113.3	0.42
DV13SW77	Inorganic	Barium	71.200	1338.6	0.05
DV13SW77	Inorganic	Copper	109.000	5784.5	0.02
DV13SW77	Inorganic	Beryllium	0.450	409.6	0.00
DV13SW77	Inorganic	Nickel	59.800	7918	0.01
DV13SW77	Inorganic	Cobalt	3.000	181.1	0.02
DV13SW77	Inorganic	Chromium	6.400	61.8	0.10
DV13SW77	Pesticide/PCB	Aroclor 1248	0.730	---	---
DV13SW77	Pesticide/PCB	Aroclor 1260	0.320	---	---
DV13SW77	Pesticide/PCB	Aroclor 1254	0.770	---	---
DV13SW77	Pesticide/PCB	Total PCB	1.820	10	0.18
DV13SW7A	Inorganic	Aluminum	3290.000	8060	0.41
DV13SW7A	Inorganic	Zinc	245.000	1113.3	0.22
DV13SW7A	Inorganic	Nickel	23.500	7918	0.00
DV13SW7A	Inorganic	Chromium	5.600	61.8	0.09
DV13SW7A	Inorganic	Beryllium	0.560	409.6	0.00
DV13SW7A	Inorganic	Cobalt	3.700	181.1	0.02
DV13SW7A	Inorganic	Manganese	151.000	644.9	0.23
DV13SW7A	Inorganic	Lead	16.900	3503	0.00
DV13SW7A	Inorganic	Copper	44.000	5784.5	0.01
DV13SW7A	Inorganic	Iron	7270.000	10867	0.67
DV13SW7A	Pesticide/PCB	Aroclor 1248	1.000	---	---
DV13SW7A	Pesticide/PCB	Aroclor 1260	0.420	---	---
DV13SW7A	Pesticide/PCB	Aroclor 1254	0.980	---	---
DV13SW7A	Pesticide/PCB	Total PCB	2.400	10	0.24
DV13SW7A	Semivolatile	bis(2-Ethylhexyl)phthalate	0.066	0.59	0.11
DV13SW8RC	Inorganic	Cobalt	4.000	181.1	0.02
DV13SW8RC	Inorganic	Chromium	4.400	61.8	0.07

DV13SW8RC	Inorganic	Barium	20.300	1338.6	0.02
DV13SW8RC	Inorganic	Beryllium	0.470	409.6	0.00
DV13SW8RC	Inorganic	Vanadium	7.200	54.9	0.13
DV13SW8RC	Inorganic	Aluminum	4800.000	8060	0.60
DV13SW8RC	Inorganic	Lead	10.200	3503	0.00
DV13SW8RC	Inorganic	Manganese	76.000	644.9	0.12
DV13SW8RC	Inorganic	Nickel	8.100	7918	0.00
DV13SW8RC	Inorganic	Zinc	74.000	1113.3	0.07
DV13SW8RC	Inorganic	Iron	8160.000	10867	0.75
DV13SW8RC	Pesticide/PCB	Aroclor 1260	0.820	--	--
DV13SW8RC	Pesticide/PCB	Aroclor 1254	0.500	--	--
DV13SW8RC	Pesticide/PCB	Total PCB	1.320	10	0.13
DV13SW8RC	Semivolatile	Benzo(g,h,i)perylene	0.360	10.7	0.03

Note: Screening threshold for aluminum, iron, and bis(2-ethylhexyl)phthalate based on mean NCBC background
Screening threshold for total PCB is RIDEM soil clean up criterion (10 mg/kg)
Screening thresholds for all other analytes set equal to the soil concentration equivalent to a Hazard Quotient (sensitive terrestrial receptor in the ERA food web modeling)
Shading indicates screening quotient exceeds 1.0
Data provided by Foster Wheeler Environmental Corporation

TABLE 3. COMPARISON OF COCs BETWEEN NCBC IR SITE 13 GROUND WATER AND HALL CREEK SURFACE WATER AND SEDIMENT

<u>Well</u>	<u>Analyte</u>	<u>Ground-water Conc. (ppb)</u>	<u>Ground-water Screening Criteria (ppb)</u>	<u>Ground-water CR</u>	<u>Status in Surface Water</u>	<u>Status in Sediment</u>
MW13-10S	Antimony	36.4	30	1.2	Mean HQ<0.1; Max HQ<0.1	not detected
MW13-03S	Iron	25700	25500	1.0	not screened	not screened
MW13-01S	Iron	34100	25500	1.3	not screened	not screened
MW13-06S	Cobalt	27	24.9	1.1	Mean HQ<0.1; Max HQ<0.1	Mean HQ=1.9; Max HQ=4.4
MW13-13S	Aluminum	6450	5315	1.2	Mean HQ=0.1; Max HQ=0.3	Mean HQ=0.9; Max HQ=2.2
MW13-14S	Heptaclor epoxide	0.0072	0.0038	1.9	not detected	not detected
MW13-12S	Heptaclor epoxide	0.0073	0.0038	1.9	not detected	not detected
MW13-11S	Heptaclor epoxide	0.028	0.0038	7.4	not detected	not detected

Notes:

Ground-water screening criteria are the higher of background or AWQC

CR = Concentration Ratio = ground-water concentration/screening criteria

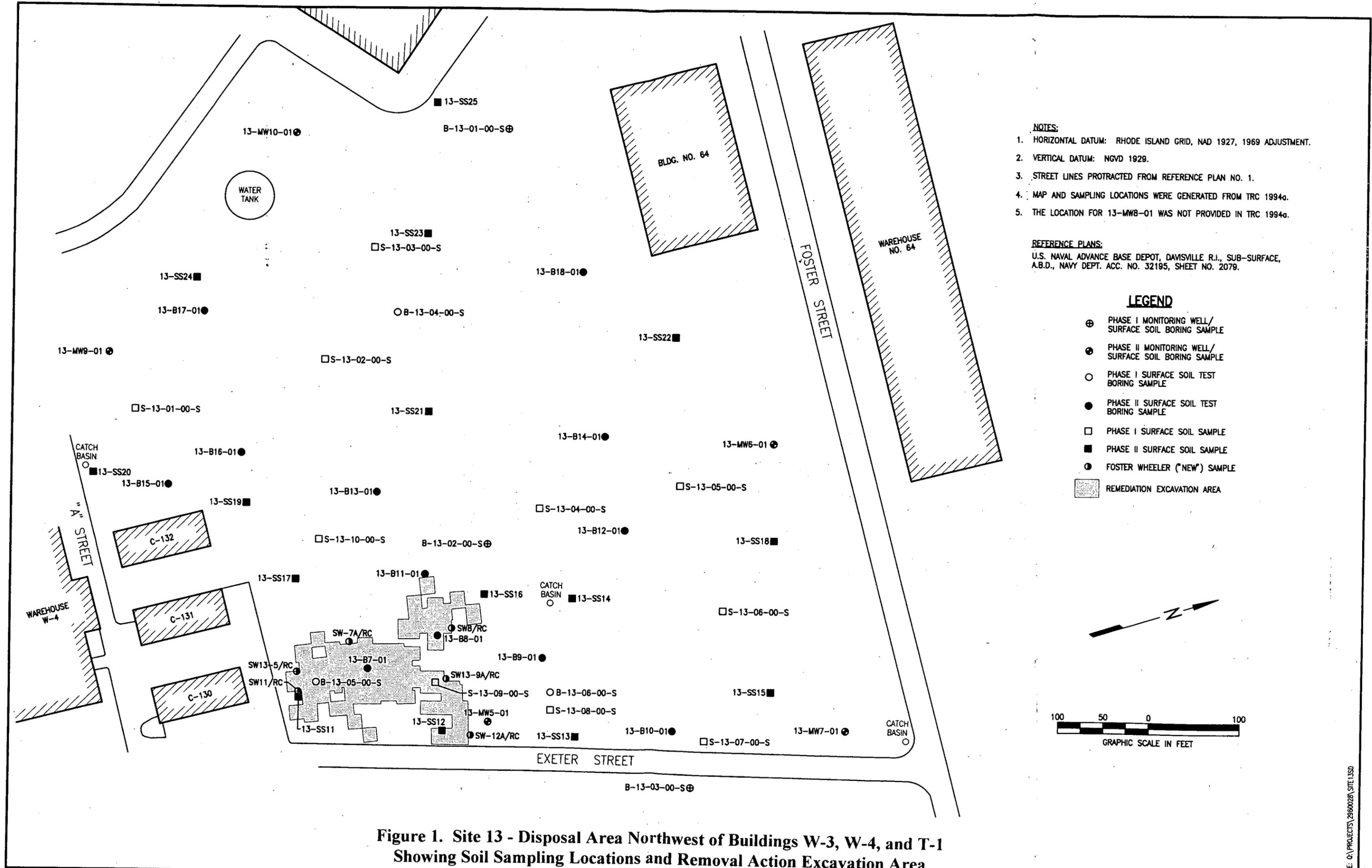
Sediment HQs for aluminum and cobalt are based on background screen because no criteria are available

Surface water HQs for aluminum also based on background

Surface water and sediment concentrations of iron were not screened in Freshwater/Terrestrial ERA

Ground-water concentration data and screening criteria from TRC (1994) and Stone & Webster (1996)

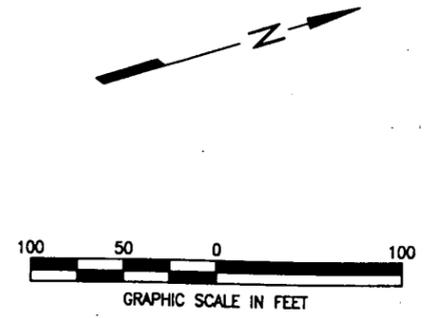
Surface water and sediment data are from Draft Final Facility-Wide Freshwater/Terrestrial Ecological Risk Assessment (EA 1996a)



- NOTES:**
1. HORIZONTAL DATUM: RHODE ISLAND GRID, NAD 1927, 1969 ADJUSTMENT.
 2. VERTICAL DATUM: NGVD 1929.
 3. STREET LINES PROTRACTED FROM REFERENCE PLAN NO. 1.
 4. MAP AND SAMPLING LOCATIONS WERE GENERATED FROM TRC 1994d.
 5. THE LOCATION FOR 13-MW8-01 WAS NOT PROVIDED IN TRC 1994d.

REFERENCE PLANS:
 U.S. NAVAL ADVANCE BASE DEPOT, DAVISVILLE R.I., SUB-SURFACE, A.B.D., NAVY DEPT. ACC. NO. 32195, SHEET NO. 2079.

- LEGEND**
- ⊕ PHASE I MONITORING WELL/
SURFACE SOIL BORING SAMPLE
 - ⊙ PHASE II MONITORING WELL/
SURFACE SOIL BORING SAMPLE
 - PHASE I SURFACE SOIL TEST
BORING SAMPLE
 - PHASE II SURFACE SOIL TEST
BORING SAMPLE
 - PHASE I SURFACE SOIL SAMPLE
 - PHASE II SURFACE SOIL SAMPLE
 - FOSTER WHEELER ("NEW") SAMPLE
 - ▨ REMEDIATION EXCAVATION AREA



**Figure 1. Site 13 - Disposal Area Northwest of Buildings W-3, W-4, and T-1
 Showing Soil Sampling Locations and Removal Action Excavation Area**

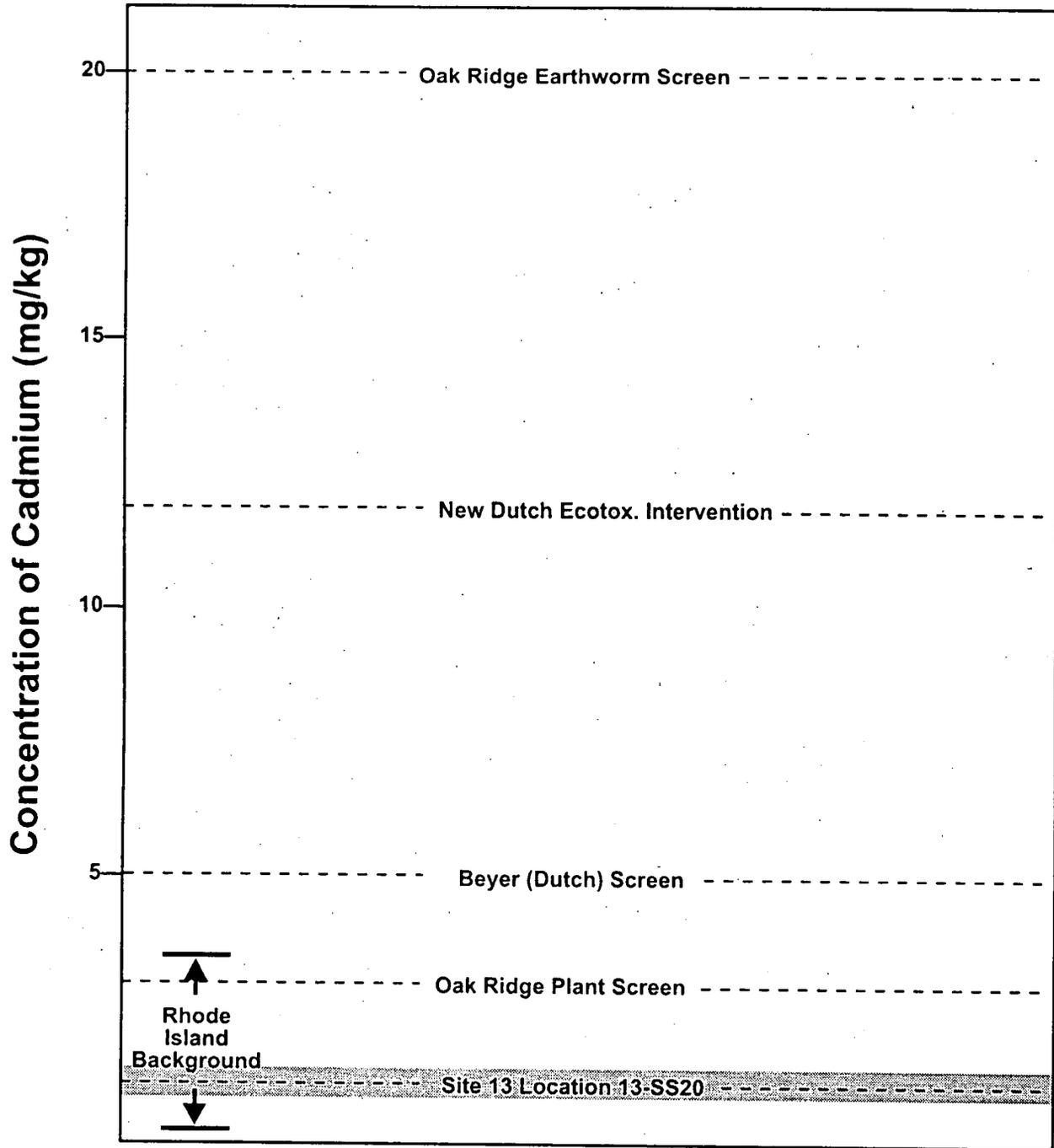


Figure 2. Concentration of cadmium in Site 13 surface soil compared to benchmark values.

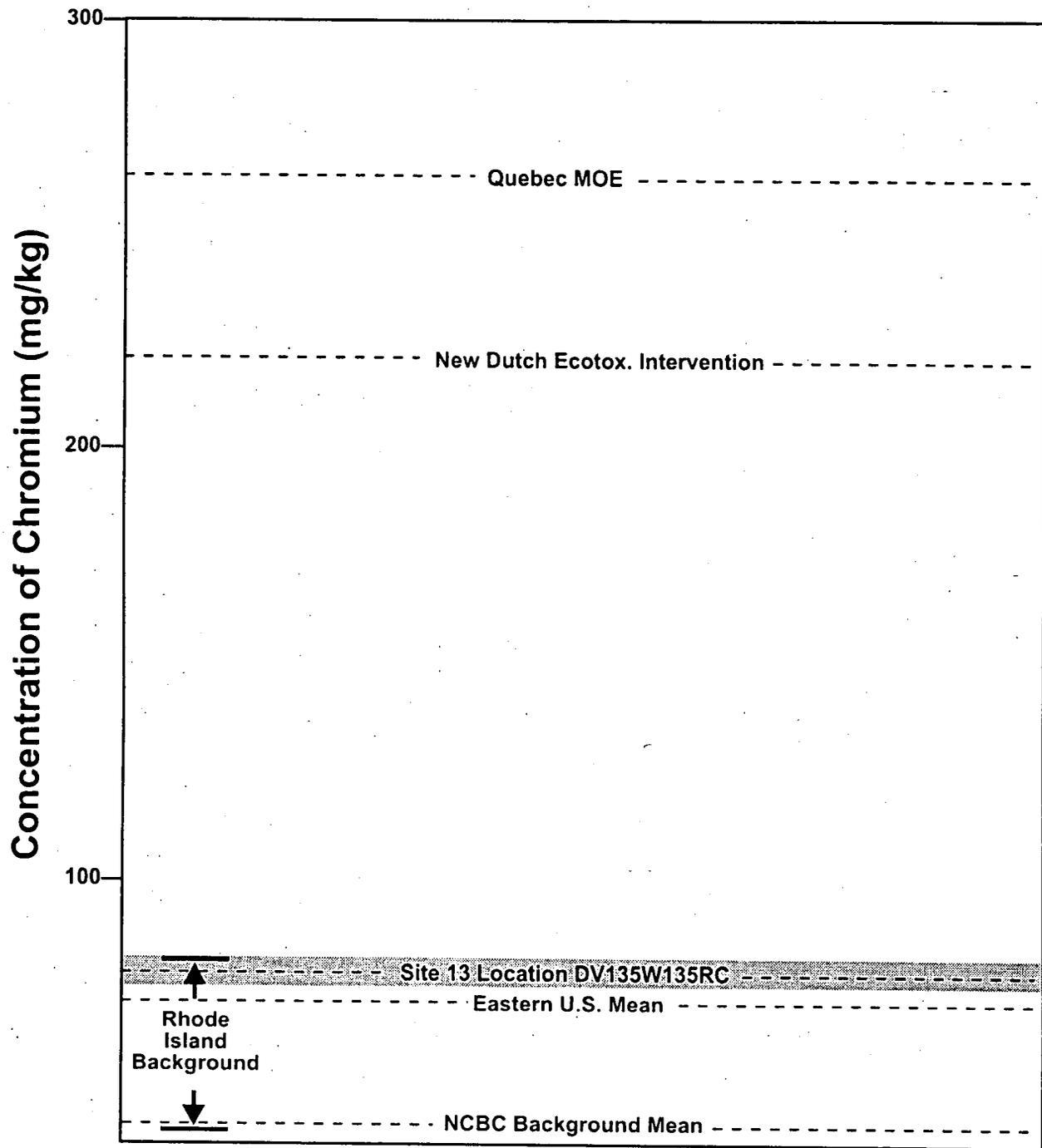
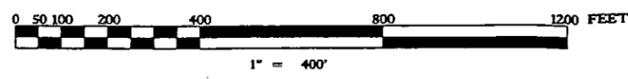
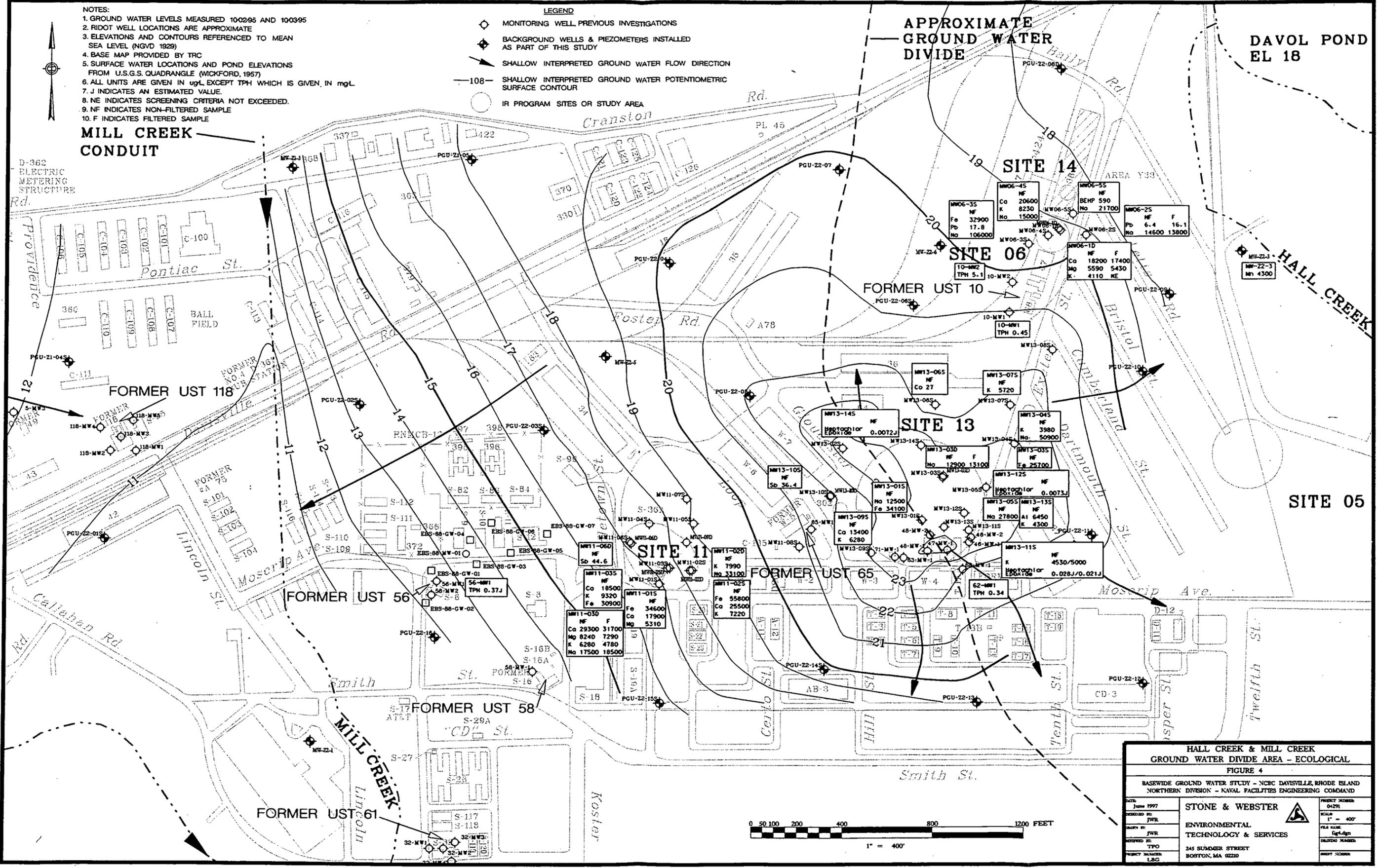


Figure 3. Concentration of chromium in Site 13 surface soil compared to benchmark values.

IPlot Request: fig4.m from: J. William Raymond@bsnt1746.swec.com on Wed Jun 18 11:26:56 EDT 1997

- NOTES:**
1. GROUND WATER LEVELS MEASURED 100295 AND 100395
 2. RIDOT WELL LOCATIONS ARE APPROXIMATE
 3. ELEVATIONS AND CONTOURS REFERENCED TO MEAN SEA LEVEL (NGVD 1929)
 4. BASE MAP PROVIDED BY TRC
 5. SURFACE WATER LOCATIONS AND POND ELEVATIONS FROM U.S.G.S. QUADRANGLE (WICKFORD, 1957)
 6. ALL UNITS ARE GIVEN IN $\mu\text{g/L}$ EXCEPT TPH WHICH IS GIVEN IN mg/L
 7. J INDICATES AN ESTIMATED VALUE
 8. NE INDICATES SCREENING CRITERIA NOT EXCEEDED.
 9. NF INDICATES NON-FILTERED SAMPLE
 10. F INDICATES FILTERED SAMPLE

- LEGEND**
- MONITORING WELL PREVIOUS INVESTIGATIONS
 - ◆ BACKGROUND WELLS & PIEZOMETERS INSTALLED AS PART OF THIS STUDY
 - SHALLOW INTERPRETED GROUND WATER FLOW DIRECTION
 - 108— SHALLOW INTERPRETED GROUND WATER POTENTIOMETRIC SURFACE CONTOUR
 - IR PROGRAM SITES OR STUDY AREA



**HALL CREEK & MILL CREEK
GROUND WATER DIVIDE AREA - ECOLOGICAL**

FIGURE 4

BASEWIDE GROUND WATER STUDY - NCRC DAVISVILLE, RHODE ISLAND
NORTHERN DIVISION - NAVAL FACILITIES ENGINEERING COMMAND

DATE: June 1997	PROJECT NUMBER: 04291	DRAWN BY: JWR	SCALE: 1" = 400'
DESIGNED BY: JWR	PROJECT MANAGER: L.B.G.		
STONE & WEBSTER ENVIRONMENTAL TECHNOLOGY & SERVICES		FILE NAME: fig4.dgn PLOTTED: [blank] PRINT: [blank]	
245 SUMNER STREET BOSTON, MA 02210			

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