Naval Facilities Engineering Command

ENGINEERING AND EXPEDITIONARY WARFARE CENTER

TECHNICAL MEMORANDUM
TM-NAVFAC EXWC-EV-1439

A REVIEW OF GREEN AND SUSTAINABLE REMEDIATION PRACTICES AT NAVFAC ENVIRONMENTAL RESTORATION SITES

By

Issis Long, NAVFAC EXWC
Deepti Nair, Battelle

June 2014

Distribution Statement A: Approved for public release distribution is unlimited

This report was prepared under contract to the Department of Defense. The publication of this document does not indicate endorsement by the Department of Defense or NAVFAC EXWC, nor should the contents be construed as reflecting the official policy or position of any of those Agencies. Mention of specific product names, vendors or source of information, trademarks, or manufacturers does not constitute an endorsement or recommendation by the Department of Defense or NAVFAC EXWC.

REPORT DOCUMENTATION PAGE

FORM APPROVED
OMB NO. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. **PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.**

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From – To)*
08-07-2014	Tech Memo	2014

4. TITLE AND SUBTITLE

A REVIEW OF GREEN AND SUSTAINABLE REMEDIATION PRACTICES AT NAVFAC ENVIRONMENTAL RESTORATION SITES

5a. CONTRACT NUMBER
N/A

5b. GRANT NUMBER
N/A

5c. PROGRAM ELEMENT NUMBER
N/A

6. AUTHOR(S)

Issis Long, NAVFAC EXWC
Deepti Nair, Battelle

5d. PROJECT NUMBER
N/A

5e. TASK NUMBER
N/A

5f. WORK UNIT NUMBER
N/A

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Naval Facilities Engineering and Expeditionary Warfare Center
1000 23rd Avenue
Port Hueneme, CA 93043

8. PERFORMING ORGANIZATION REPORT NUMBER
TM-NAVFAC EXWC-EV-1439

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR / MONITOR'S ACRONYM(S)
N/A

11. SPONSOR / MONITOR'S REPORT NUMBER(S)
N/A

12. DISTRIBUTION / AVAILABILITY STATEMENT

Distribution Statement A: Approved for public release; distribution is unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

The objective of this white paper is to examine the use of GSR within the Navy's ER Program. The white paper provides an overview of policies related to GSR evaluations from the DoD and the DON to explain the significance of GSR in environmental remediation and the drivers behind its use. A review is then provided of the best management practices (BMPs) and lessons learned from the application of GSR metrics at Navy and Marine Corps sites nationwide.

As part of this effort, a total of 60 ER sites that have conducted a GSR evaluation and/or implemented GSR BMPs were identified. Among these 60 sites, project documentation was readily available for 32 of the sites to summarize detailed information on their site-specific GSR approach as included in this white paper and Appendix A. The information obtained was then used to identify and categorize BMPs and their potential impact on the remedy footprint and to track overall trends in the adoption of GSR practices across Naval Facilities Engineering Command (NAVFAC).

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
					Amy Hawkins
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			**19b. TELEPHONE NUMBER** ***(include area code)***
Click here	Click here	Click here	U	213	805-982-4890

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18

CONTENTS

APPENDICES i
FIGURE i
TABLES ii
ACRONYMS AND ABBREVIATIONS iii

1.0 INTRODUCTION 1

2.0 POLICY BACKGROUND 2
- 2.1 Executive Orders 2
- 2.2 DOD and DON Policies 2
- 2.3 Navy GSR Metrics 2

3.0 CASE STUDY REVIEW 4

4.0 OVERVIEW OF GSR BEST MANAGEMENT PRACTICES 13
- 4.1 Energy Consumption 17
  - 4.1.1 Energy Usage for Groundwater and Soil Remedies 17
  - 4.1.2 Renewable Energy Usage 25
- 4.2 Greenhouse Gas Emissions 25
- 4.3 Criteria Air Pollutants 26
- 4.4 Water Consumption 26
- 4.5 Ecological Impacts 28
- 4.6 Resource Consumption and Waste Generation 28
- 4.7 Worker Safety 30
- 4.8 Community Impacts 30

5.0 CONCLUSIONS 31

6.0 REFERENCES 33

APPENDICES

APPENDIX A: NAVFAC GSR CASE STUDIES
APPENDIX B: T2 SURVEY 2012 GSR RESPONSES
APPENDIX C: T2 SURVEY 2013 GSR RESPONSES

FIGURE

Figure 1. GSR Case Study Locations 4
Figure 2. GSR Efforts by NAVFAC Component 5
Figure 3. GSR Efforts by CERCLA Phase 5
Figure 4. Footprint Reduction Recommendations from GSR Evaluations (T2 Survey 2013) 16
Figure 5. Water Consumption for Groundwater Technologies 27

TABLES

Table 1. Navy GSR Metrics Evaluated by SiteWise™ 3
Table 2. Summary of NAVFAC ER Sites with GSR Evaluations and/or GSR BMPs 7
Table 3. Top Ten BMPs from Navy Case Study Reviews 13
Table 4. Energy Comparison for Groundwater Technologies 19
Table 5. BMPs for the Most Prevalent Groundwater Remedies Based on Navy Case Study Reviews 21
Table 6. Energy Comparison for Soil Technologies 23
Table 7. BMPs for the Most Prevalent Soil Remedies Based on Navy Case Study Reviews 24
Table 8. Water Consumption for Groundwater Technologies 27

ACRONYMS AND ABBREVIATIONS

AS/SVE	air sparge/soil vapor extraction
BMP	best management practice
BRAC	Base Realignment and Closure
BTU	British thermal unit
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CH_4	methane
CO_2	carbon dioxide
COC	contaminant of concern
CTC	Cost-to-Complete
DERP	Defense Environmental Restoration Program
DMF	diesel multistage filter
DOC	diesel oxidation catalyst
DoD	Department of Defense
DON	Department of the Navy
DPF	diesel particulate filter
DPT	direct push technology
EO	Executive Order
EOS	emulsified oil substrate
EPA	U.S. Environmental Protection Agency
ER	environmental restoration
ERH	electrical resistive heating
FEC	Facilities Engineering Command
FS	Feasibility Study
GAC	granular activated carbon
GHG	greenhouse gas
GSR	green and sustainable remediation
GWETS	Groundwater extraction system
HFC	hydrofluorocarbon
ISCO	in situ chemical oxidation
LTM	long-term monitoring
LUC	land use control
MMA	the management and monitoring approach
MNA	monitored natural attenuation
N_2O	nitrous oxide
NAVFAC	Naval Facilities Engineering Command
NCP	National Contingency Plan
NIRIS	Naval Installation Restoration Information Solution

NOx	nitrogen oxide
O&M	operation and maintenance
PFC	perfluorocarbon
PM	particulate matter
PRB	permeable reactive barrier
RAA	remedial alternatives analysis
RA-O	remedial action operation
RPM	Remedial Project Manager
SCR	selective catalytic reduction
SF_6	sulfur hexafluoride
SOx	sulfur oxide
T2	Technology Transfer
TCH	thermal conductive heating
UCL	upper confidence limit
USACE	U.S. Army Corps of Engineers
VOC	volatile organic compound
ZVI	zero valent iron

1.0 INTRODUCTION

Green and sustainable remediation (GSR) uses strategies that consider all environmental effects of remedy implementation and operation and incorporates options to maximize the overall environmental benefit of environmental response actions (Department of Defense [DoD], 2012). The Department of the Navy (DON) has implemented GSR as part of its existing optimization program as stated in the *Policy for Optimizing Remedial and Removal Actions at All DON Environmental Restoration (ER) Program Sites* (DON, 2012a). Released in April 2012, this policy requires optimization and GSR evaluations at the remedy evaluation and selection, design, remedial action operation (RA-O), and long-term management phases.

The objective of this white paper is to examine the use of GSR within the Navy's ER Program. The white paper provides an overview of policies related to GSR evaluations from the DoD and the DON to explain the significance of GSR in environmental remediation and the drivers behind its use. A review is then provided of the best management practices (BMPs) and lessons learned from the application of GSR metrics at Navy and Marine Corps sites nationwide.

As part of this effort, a total of 60 ER sites that have conducted a GSR evaluation and/or implemented GSR BMPs were identified. Among these 60 sites, project documentation was readily available for 32 of the sites to summarize detailed information on their site-specific GSR approach as included in this white paper and Appendix A. The information obtained was then used to identify and categorize BMPs and their potential impact on the remedy footprint and to track overall trends in the adoption of GSR practices across Naval Facilities Engineering Command (NAVFAC).

The white paper is organized as follows:

- Section 2.0 describes relevant Executive Orders (EOs), DoD, and DON policies related to GSR and defines the DON GSR metrics;
- Section 3.0 provides a review of GSR case studies organized by NAVFAC component;
- Section 4.0 summarizes GSR BMPs and provides an analysis of key GSR metrics; and
- Section 5.0 provides the overall conclusions of the study.

2.0 POLICY BACKGROUND

Several EOs, DoD policies, and DON policies support the use of GSR practices for ER Program activities.

2.1 Executive Orders

GSR practices are primarily driven by two EOs (13423[1] and 13514[2]) which call for federal agencies to operate in a sustainable manner. EO 13423, released in 2007, calls for federal agencies to conduct their environmental, transportation, and energy-related activities under the law in support of their respective missions in an environmentally, economically and fiscally sound, integrated, continuously improving, efficient, and sustainable manner. EO 13514, released on October 8, 2009, calls for a reduction in greenhouse gas (GHG) emissions, energy consumption, and potable and industrial water use by federal agencies.

2.2 DOD and DON Policies

In addition, the Office of the Under Secretary of Defense released a GSR memorandum in August 2009 (DoD, 2009) stating its commitment to conducting its environmental program in a sustainable manner. The DoD Memorandum was superseded by the March 2012 revision of the Defense Environmental Restoration Program (DERP) Manual 4715.20 (DoD, 2012).

The 2012 DERP Manual instructs DoD components to consider and implement GSR opportunities when feasible and ensure the use of GSR remediation practices where practicable based on economic and social benefits, as well as costs in the following ways:

- Use natural resources and energy efficiently;
- Reduce negative impacts on the environment;
- Minimize or eliminate pollution at its source; and
- Reduce waste to the greatest extent possible.

The *Policy for Optimizing Remedial and Removal Actions at all DON ER Program Sites* mandates optimization throughout the ER process and includes the following actions (DON, 2012a):

(1) GSR be incorporated into the optimization process

(2) Ensure the use of the SiteWise™ tool for GSR analysis during the Feasibility Study .

2.3 Navy GSR Metrics

The Navy's GSR metrics were initially developed and defined based on the core elements described in the DoD's GSR memorandum (DoD, 2009), EOs, and by the U.S. Environmental Protection Agency (EPA) in its Green Primer (EPA, 2008). Details on each of these metrics are available in the *DON Green and Sustainable Remediation Guidance* (DON, 2012b). The Navy's GSR metrics are as follows:

Energy Consumption. Consumption of energy from non-renewable versus renewable sources is an important metric because of the need to conserve the U.S. energy supply and reduce dependence on foreign sources of energy. Energy consumption also results in the generation of GHGs.

---

[1] http://www.epa.gov/oaintrnt/practices/eo13514.htm
[2] http://www.epa.gov/oaintrnt/practices/eo13423.htm

GHG Emissions. The quantification of GHG emissions is an important metric because of growing concern over climate change. Examples of GHGs that directly influence climate change include carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6).

Criteria Pollutant Emissions. Air emission of criteria pollutants, regulated by the Clean Air Act of 1970, can cause smog and adverse health effects such as asthma, bronchitis, lung cancer, and eye irritation. Criteria air pollutants include: sulfur oxides (SOx), oxides of nitrogen (NOx), particulate matter (PM), ozone, and ozone precursors.

Water Impacts. Water can be a lost resource if water from an aquifer is wasted. In addition, water is consumed to produce electricity and manufacture consumables used during remedial activities.

Resource Consumption. The resource consumption metric tracks consumption of resources that are not specifically identified in other metrics. These include landfill space occupied by hazardous and non-hazardous waste produced during remedial actions or the amount of top soil brought to a site for backfill.

Worker Safety. Worker safety/accident risk is the risk of fatality or injury of carrying out a specific task of a remedial activity. The guiding principle of any activity undertaken by DON is to "operate safely." Therefore, worker safety is crucial and is also a part of NAVFAC's strategic plan.

Ecological Impacts. Ecological impacts include adverse effects such as: introduction of invasive species, changes in ecosystem structure or shifts in the geographic distribution and extent of major ecosystem types, disturbance to soil, sediments, surface water bodies, and destruction of habitats.

Community Impacts. Community impacts are local disturbances and health and safety issues caused by remedial activities, such as: noise; traffic issues, including accidents during transportation; odor; dust; and emissions of volatile organic compounds (VOCs) and other contaminants.

Table 1 presents an overview of these Navy GSR metrics as evaluated by SiteWise™ (NAVFAC, 2013). SiteWise™ is the Navy's preferred tool for GSR metric evaluations; its use is required by Navy policy. It was developed jointly by the U.S. Navy, the U.S. Army, the U.S. Army Corps of Engineers (USACE), and Battelle. This white paper focuses primarily on sites utilizing SiteWise™ for GSR analyses, although other case studies involving GSR BMPs and/or other remedy footprint analysis tools are incorporated.

Table 1. Navy GSR Metrics Evaluated by SiteWise™

Metric	Description
Energy Consumption	British Thermal Units (BTUs) Includes renewable and non-renewables
Greenhouse Gas Emissions	Metric tons CO_2e (includes CO_2, CH_4, and N_2O)
Criteria Pollutant Emissions	NOx, SOx, PM in metric tons On-site and total emissions
Water Impacts	Expressed as gallons
Resource Consumption	Landfill space, top soil
Worker Safety and Accident Risk	Accidental injury and death and lost hours
Ecological Impacts	Qualitative (e.g., land, surface water, and aquifer impacts)
Community Impacts	Qualitative (e.g., noise, traffic, odor)

3.0 CASE STUDY REVIEW

The ultimate goal of the application of GSR principles is to assist in the selection and implementation of optimized, sustainable, and cost-effective remedies at Navy sites. This review was undertaken to track the implementation of GSR practices to date at ER sites nationwide and to track recommendations made related to GSR BMPs. Several sources of information were reviewed in order to collect information on GSR applications NAVFAC-wide. The sources of information consulted include: Administrative Record documents collected from the Naval Installation Restoration Information Solution (NIRIS), input to the NORM Optimization module on GSR metrics, NAVFAC success stories, and information obtained from Navy contractors.

As summarized in Table 2, a total of 60 ER sites were identified that have conducted a GSR evaluation and/or implemented GSR BMPs. Figure 1 illustrates the location of the ER sites identified (there are 36 unique installations). Among the 60 ER sites identified, project documentation was readily available in NIRIS for 32 of the sites in order to prepare case studies as summarized in Appendix A. Both Table 2 and Appendix A are organized by NAVFAC component including: NAVFAC Atlantic/Mid-Atlantic, NAVFAC Midwest, NAVFAC Northwest, NAVFAC Southeast, NAVFAC Southwest, NAVFAC Washington, NAVFAC Pacific, and Base Realignment and Closure (BRAC).

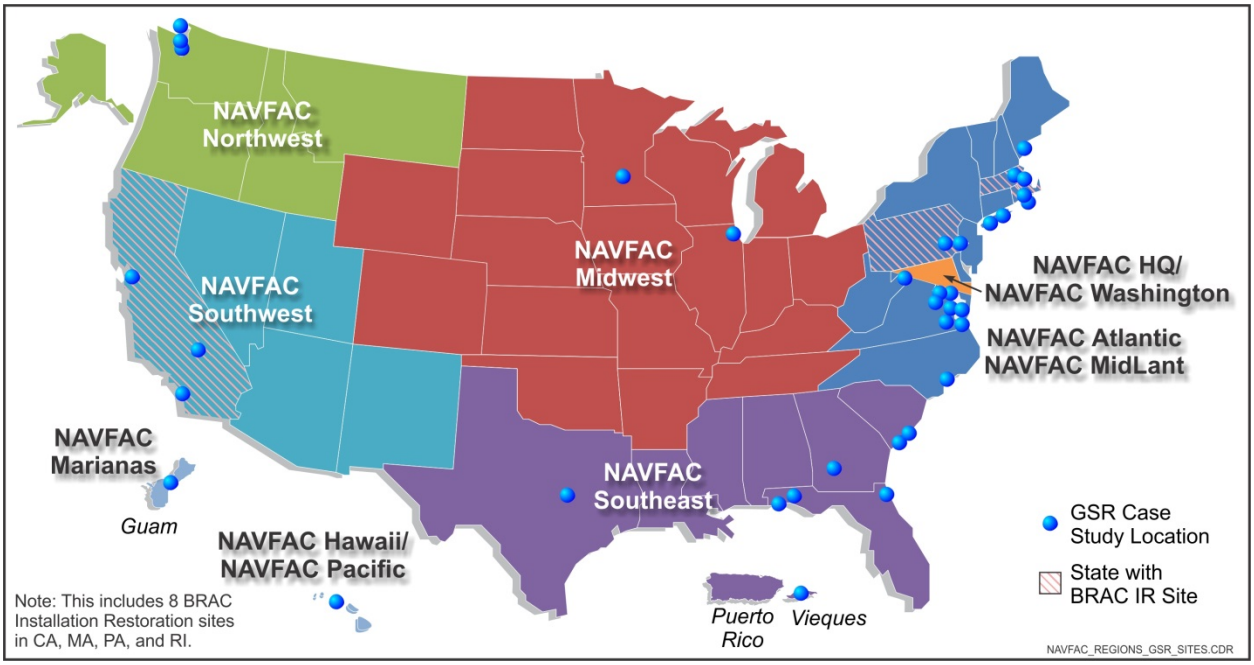


Figure 1. GSR Case Study Locations

Figure 2 shows a breakdown of the ER sites identified by NAVFAC component. The largest percentage of sites was located in the NAVFAC Atlantic/Mid-Atlantic region at 39% followed by NAVFAC Southeast at 20%. This indicates that additional outreach on GSR policy implementation may be beneficial on a regional basis as some Facilities Engineering Commands (FECs) seem to have relatively few examples identified of GSR evaluations compared to others within NAVFAC. Figure 3 shows a breakdown of the ER sites by Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) phase at the time of the GSR evaluation. The majority at 67% of the GSR evaluations collected for this effort were performed at the Feasibility Study (FS) phase. The findings of the

Technology Transfer (T2) Program surveys from 2012 and 2013 also indicated that the majority of GSR evaluations had been performed in the FS phase to date (on average at 46% as noted in Appendices B and C, respectively). This suggests that the use of GSR is still in the early phases of selecting and planning for remedies; its use in remedial design and remedy implementation has occurred at roughly one third of sites based on the collected case studies and T2 survey input. Although it should be noted that the use of GSR in the FS phase is the most readily documented because of the need to include this information in the CERCLA Administrative Record. It is recommended that the use of the NORM Optimization module for GSR be more widely adopted to serve as a means of formally documenting GSR evaluations and implementation as they move beyond the FS stage. In addition, Remedial Project Managers (RPMs) could be encouraged to document the outcome of GSR and optimization efforts in the Administrative Record and within the NIRIS repository to the extent possible.

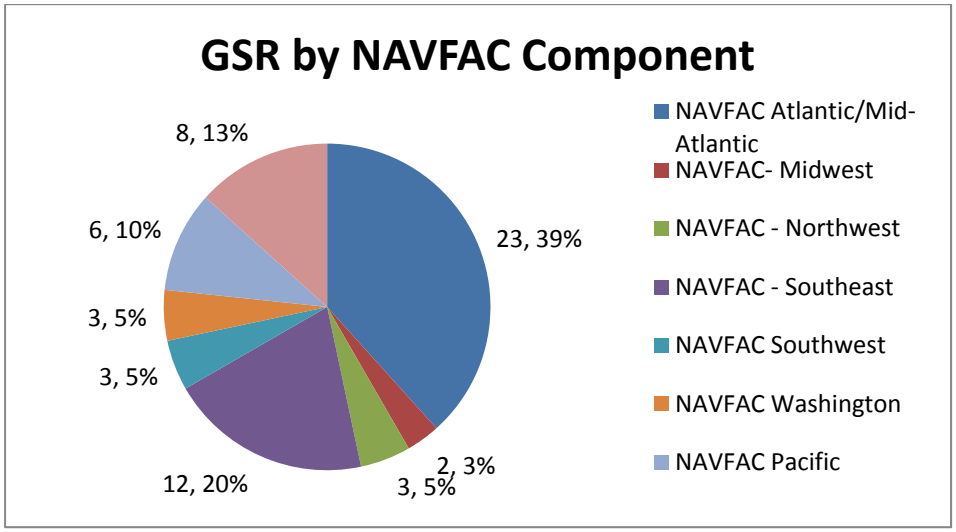


Figure 2. GSR Efforts by NAVFAC Component

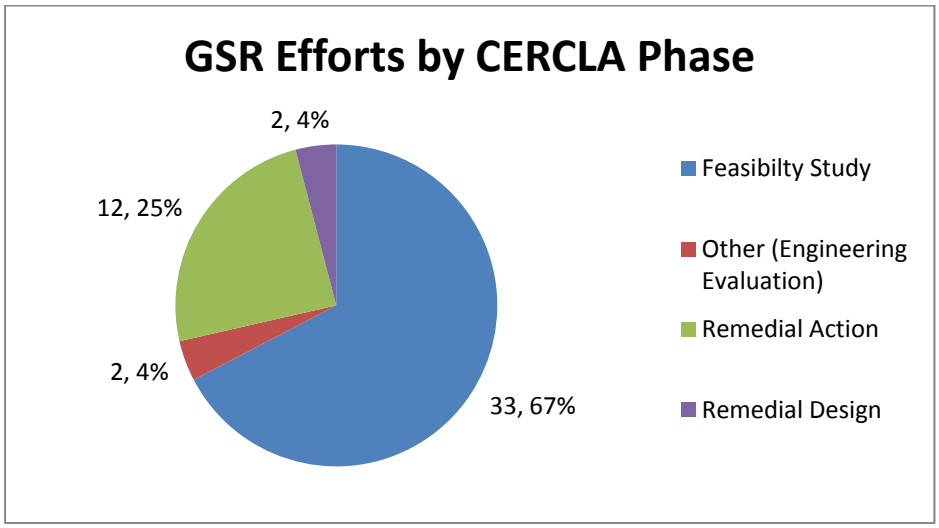


Figure 3. GSR Efforts by CERCLA Phase

Table 2 provides a succinct summary of the lessons learned from the 60 case studies including details on the selected remedy (as applicable), specific footprint reduction methods identified, and whether or not the GSR evaluation resulted in the lowest footprint and/or lowest cost remedial option being selected. Among those sites where a remedy was selected, the results show that 84% of the GSR evaluations resulted in the selection of the lowest footprint remedy and 69% resulted in the selection of the lowest cost remedy. These results suggest that the remedy evaluation process, including a GSR evaluation, is in fact leading to the selection of more sustainable and cost-effective remedies at Navy sites. Although there is a clear correlation showing that most of the selected remedies have the lowest footprint of all those evaluated, the extent to which the GSR evaluation has influenced the selection of the preferred remedy is unknown. At the very least, the GSR evaluation provides documentation that the more sustainable remedies are selected and helps to guide the RPMs in developing footprint reduction recommendations. Therefore, it would be beneficial to continue to promote the practice of GSR evaluations throughout the life cycle of the ER Program.

Appendix A includes a sub-selection of 32 case studies that were chosen for the preparation of a more detailed review of the resulting GSR recommendations. These detailed case studies summarize the site background, contaminants of concern (COCs), impacted media, and remedial technologies under consideration. The GSR evaluation approach is provided including the use of SiteWise™ in conjunction with the National Contingency Plan (NCP) nine criteria. Other tools used at Navy sites to supplement SiteWise™ are documented including GSRx, CleanSWEEP, SimaPro, and the Navy Renewable Energy Screening Tool. The information collected from these case studies was then used to analyze and categorize the GSR BMPs as summarized in Section 4 of this white paper.

Table 2. Summary of NAVFAC ER Sites with GSR Evaluations and/or GSR BMPs

Case Study	NAVFAC Location	Installation	Site Name	Location	GSR Evaluation Tool	Impacted Media	CERCLA Stage	Date	Selected Remedy	Lowest Footprint*	Lowest Cost	Footprint Reduction Method identified	Footprint Method Details	Comments/Benefit
1	NAVFAC Atlantic	Former Vieques Naval Training Range	SWMU 1, Vieques, Puerto Rico	Vieques, Puerto Rico	SiteWise™	Soil	Feasibility Study	April 2011	Enhanced Native Soil Cover and Institutional Controls	Yes	Yes	Yes	• Use of enhanced native soil cover to minimize fill import	• Protective of human health and the environment under current and projected future land use as a wildlife refuge. • Prohibit future residential and industrial land use. • Ensures the soil cover and ICs are adequate.
2	NAVFAC Mid-Atlantic	Allegany Ballistics Laboratory	Former Disposal Pits 1 and 3 (Soil)	Rocket Center, West Virginia	SiteWise™	N/A	N/A	April 2013	Not available	N/A	N/A	N/A	Not available	
3	NAVFAC Mid-Atlantic	Joint Expeditionary Base Little Creek	SWMU 3, Pier 10 Sandblast Yard	Virginia Beach, Virginia	SiteWise™	Sediment	Engineering Evaluation	December 2012	Mechanical dredging, upland disposal, and replacement with clean fill	No	No	No		
4	NAVFAC Mid-Atlantic	Joint Expeditionary Base Little Creek	SWMU 7b, Small Boats Sandblast Yard	Virginia Beach, Virginia	SiteWise™	Sediment	Engineering Evaluation	January,2013	Mechanical dredging, upland disposal, and replacement with clean fill	No	No	No		
5	NAVFAC Mid-Atlantic	Marine Corps Base Camp Lejeune	UXO-14, MCB Camp Lejeune	Jacksonville, North Carolina	SiteWise™	N/A	N/A	May 2012	Not available	N/A	N/A	N/A	Not available	
6	NAVFAC Mid-Atlantic	Marine Corps Base Camp Lejeune	UXO-19, MCB Camp Lejeune	Jacksonville, North Carolina	SiteWise™	N/A	N/A	June 2013	Not available	N/A	N/A	N/A	Not available	
7	NAVFAC Mid-Atlantic	Marine Corps Base Camp Lejeune	Site 69 OU 14 (Groundwater), Camp Lejeune	Jacksonville, North Carolina	SiteWise™	Groundwater	Feasibility Study	April 2012	MNA	Yes	Yes	No		• Monitored natural attenuation (MNA) had the lowest overall relative impacts for the viable groundwater alternatives.
8	NAVFAC Mid-Atlantic	Marine Corps Base Camp Lejeune	Site 69 OU 14 (Soil), Camp Lejeune	Jacksonville, North Carolina	SiteWise™	Soil	Feasibility Study	April 2012	LUCs	Yes	Yes	No		• The selected remedy has the lowest impact and cost.
9	NAVFAC Mid-Atlantic	Marine Corps Base Camp Lejeune	Site 89, OU 16 (Source Area), Camp Lejeune	Jacksonville, North Carolina	SiteWise™	Groundwater	Feasibility Study	February 2012	Enhanced reductive dechlorination	Yes	No	No		• Project will benefit from implementing the lowest impact alternative. • The remedy is about ~$300,000 more expensive than the least expensive alternative.
10	NAVFAC Mid-Atlantic	Naval Air Station Oceana	Naval Auxiliary Landing Field Fentress	Virginia Beach, Virginia	SiteWise™	N/A	N/A	February 2013	Not available	N/A	N/A	N/A	Not available	
11	NAVFAC Mid-Atlantic	Naval Station Newport	Site 8 Disposal Area - Naval Undersea Systems Center (NUSC)	Newport, Rhode Island	SiteWise™ and GSRx	Groundwater	Feasibility Study	July 2012	No selection	NA	NA	Yes	• Consideration of using one wellhead is used to serve more than one well during the injection periods. • Consideration of other chemicals for ISCO reagent. • Reducing engine idle time and staging work for equipment use. • Alternative transportation - carpooling or public transportation, alternate fuel.	
12	NAVFAC Mid-Atlantic	Naval Station Newport	Site 19, On-Shore Derecktor Shipyard	Newport, Rhode Island	SiteWise™	N/A	Feasibility Study	January 2013	Not available	N/A	N/A	N/A	Not available	
13	NAVFAC Mid-Atlantic	Naval Weapons Industrial Reserve Plant Calverton	Southern Area Groundwater Plume, NWIRP	Calverton, New York	SiteWise™	Groundwater	Feasibility Study	March 2011	No selection	N/A	N/A	Yes	• Optimize routine site activities, minimize travel distances, monitoring program (reduce monitoring frequency, number of monitoring wells and analyses) and use emission control measures, alternate fuel • Consider material minimization/substitution - steel, fly ash in all concrete mixtures for well pad. • Optimize mechanical/treatment components to reduce overall electricity usage and treatment residuals/additives. • Perform an evaluation for waste and material minimization. • Continually assess remedial action operations and the results of treatment. • Reduce the footprint of target treatment zones and the frequency and/or duration of treatment as warranted by	

Table 2. Summary of NAVFAC ER Sites with GSR Evaluations and/or GSR BMPs (Continued)

Case Study	NAVFAC Location	Installation	Site Name	Location	GSR Evaluation Tool	Impacted Media	CERCLA Stage	Date	Selected Remedy	Lowest Footprint*	Lowest Cost	Footprint Reduction Method identified	Footprint Method Details	Comments/Benefit
													monitoring results. Transition to MNA when favorable.	
14	NAVFAC Mid-Atlantic	Naval Weapons Industrial Reserve Plant Bedford	NWIRP Bedford	Bedford, Massachusetts	SiteWise™	N/A	Feasibility Study	February 2013	Not available	N/A	N/A	N/A	Not available	
15	NAVFAC Mid-Atlantic	Naval Weapons Industrial Reserve Plant Bethpage	Site 4 - Former Underground Storage Tanks	Bethpage, New York	SiteWise™	N/A	Feasibility Study	January 2013	Not available	N/A	N/A	N/A	Not available	
16	NAVFAC Mid-Atlantic	Naval Weapons Station Yorktown Cheatham Annex (CAX)	AOC 7, CAX	Yorktown, Virginia	SiteWise™	N/A	N/A	August 2013	Not available	N/A	N/A	N/A	Not available	
17	NAVFAC Mid-Atlantic	Naval Weapons Station Yorktown	UXO 003, Munitions Loading Piers	Yorktown, Virginia	SiteWise™	N/A	N/A	May 2013	Not available	N/A	N/A	N/A	Not available	
18	NAVFAC Mid-Atlantic	Portsmouth Naval Shipyard	OU7 Portsmouth Naval Shipyard	Kittery, Maine	SiteWise™ and GSRx	Soil, groundwater, sediment, surface water	Feasibility Study	June 2013	No selection	N/A	N/A	Yes	• Consider reduction in transportation use, alternate fuel and emission control measures. • Consider revisions and optimization of clean borrow soil. • Consider the option of obtaining clean fill from on-site sources, or from the closest source available. • Consider optimization of the use of equipment use, type of equipment. • Additional testing and characterization of excavated soils during the remedial investigation. • Consider disposal of hazardous waste via alternate transportation	
19	NAVFAC Mid-Atlantic	Portsmouth Naval Shipyard	OU9 Portsmouth Naval Shipyard	Kittery, Maine	SiteWise™ and GSRx	Soil	Feasibility Study	May 2013	No selection	N/A	N/A	Yes	• Consider optimizing equipment use, and even the type of equipment used during operations. • Consider optimizing the amount of soil needed for backfill of the treatment areas; soil residue • Consider the optimization of the electricity use through the generator. • Consider reduction in transportation use, alternate fuel and emission control measures; different modes of transportation for soil residues as a result of excavation.; use of renewable energy	
20	NAVFAC Mid-Atlantic	St. Juliens Creek Annex	Site 2, St. Juliens Creek Annex	Chesapeake, Virginia	SiteWise™ and SimaPro	Soil	Remedial Design	October 2011	Design Basis- use of broken concrete incidental foundation removal + soil removed to construct the wetland and BMP	Yes	N/A	Yes	• Re-using materials for the cover fill: broken concrete from incidental foundation removal + soil removed to construct the wetland and BMP (Design Basis) instead of purchasing soil and concrete disposal.	
21	NAVFAC Mid-Atlantic	St. Juliens Creek Annex	Site 5, St. Juliens Creek Annex	Chesapeake, Virginia	SiteWise™	N/A	N/A	N/A	N/A	N/A	N/A	Yes	• Use of closer landfill for disposal of CERCLA waste	
22	NAVFAC Mid-Atlantic	St. Juliens Creek Annex	Site 21, St. Juliens Creek Annex	Chesapeake, Virginia	SiteWise™	Groundwater	Feasibility Study	October 2011	In situ chemical reduction with enhanced reductive dechlorination	N/A	N/A	Yes	• Proposed a different formulation of Emulsified Vegetable Oil (EVO) than described in original remedial design for ERD. • Change in formulation would result in a 30% reduction in GHGs and energy consumption, but a 1% increase in water consumption.	• The selected remedy is easy to implement and has low associated cost.
23	NAVFAC Mid-Atlantic	Yorktown Defense Fuel Supply Point	Yorktown Fuel Farm	Central York County, Virginia	SiteWise™	Soil	Remedial Action	June 2011	No selection	N/A	N/A	Yes	• The optimization recommendations for the site are broken down into two categories: • Those that reduce the annual cost and footprint for operating the system and • Those that expedite remediation of the site to reduce the time the system needs to operate and thus reduce overall life cycle cost and footprint. • Recommended to optimize the existing system through purchase of a more efficient boiler and jar testing to optimize chemical usage.	

Table 2. Summary of NAVFAC ER Sites with GSR Evaluations and/or GSR BMPs (Continued)

Case Study	NAVFAC Location	Installation	Site Name	Location	GSR Evaluation Tool	Impacted Media	CERCLA Stage	Date	Selected Remedy	Lowest Footprint*	Lowest Cost	Footprint Reduction Method identified	Footprint Method Details	Comments/Benefit
													• In addition, a recommendation was made to pilot test an alternative remedy of multi-phase extraction.	
24	NAVFAC-Midwest	Naval Industrial Reserve Ordinance Plant (NIROP)	Operable Unit 1 (OU1)	Fridley, Minnesota	SiteWise™, CleanSWEEP, Navy Renewable Energy Screening Tool	Groundwater	Remedial Action	May 2013	Not available	N/A	N/A	Yes	• Energy optimization - Replace Air Stripper Feed Pumps and Motors with variable frequency drives (VFDs). • Replace Air Stripper Blower Motors and Effluent Discharge Pump Motors with Premium Efficiency Motors.	
25	NAVFAC - Midwest	Naval Station Great Lakes	Site 5 (Transformer Storage Boneyard), 9 (Camp Moffett Ravine Fill Area) Great Lakes	Great Lakes, Illinois	SiteWise™	N/A	Feasibility Study	March 2013	Not available	N/A	N/A	N/A	Not available	
26	NAVFAC - Northwest	Naval Base Kitsap Bangor	EO 300, Small Arms Range	Silverdale, Washington	SiteWise™	N/A	Feasibility Study	October 2011	Not available	N/A	N/A	N/A	Not available	
27	NAVFAC - Northwest	Naval Base Kitsap Bangor	Site F	Bangor, Washington	SiteWise™, CleanSWEEP, Navy Renewable Energy Screening Tool	Groundwater	Remedial Action	May 2013	Not available	N/A	N/A	Yes	• Energy optimization - pressure gauges installed at each well head prior to the flow control valves to allow for the collection of data required to evaluate the extraction well pump efficiencies	
28	NAVFAC-Northwest	Naval Air Station Whidbey Island	Shoreline Landfill	Oak Harbor, Washington	Footprint reduction	Landfill	Remedial Action	January 2013	Seawall stabilization using marine mattress technology	Yes	Yes	Yes	• Use of recycled concrete rubble to fill marine mattresses for shoreline stabilization and the use of vegetable oil as biodegradable hydraulic fluids (e.g., vegetable oil) for lubrication to avoid issues of potential spills to nearby coastal waters.	
29	NAVFAC - Southeast	Marine Corps Air Station Beaufort	SWMU 6 & 14, Beaufort MCAS	Beaufort, South Carolina	SiteWise™	N/A	Feasibility Study	July 2012	Not available	N/A	N/A	N/A	Not available	
30	NAVFAC - Southeast	Marine Corps Logistics Base (MCLB) Albany	Site 3 , MCLB Albany	Albany, Georgia	N/A	N/A	N/A	June 2010	N/A	N/A	N/A	Yes	• Reduce number of wells and analytes sampled. • Reduce frequency of sampling selected wells.	
31	NAVFAC-Southeast	Marine Corps Logistics Base (MCLB) Albany	OU6 MCLB Albany	Albany, Georgia	SiteWise™	Groundwater	Feasibility Study	April 2011	Optimized remedy and monitoring	Yes	Yes	Yes	• The team plans to conduct additional optimization reviews on a two to three-year cycle. • Continued optimization of the monitoring program (reducing sampling locations, analyte list, frequency) , including consideration of innovative methods, e.g., passive sampling devices. • Optimizing the extent of the target treatment zone by dramatically reducing the number of required injection points for zero valent iron (ZVI) and in situ chemical oxidation (ISCO) and therefore the quantity of reagents needed.	
32	NAVFAC - Southeast	Marine Corps Recruit Depot (MCRD) Parris Island	Site 9, 16, 27 and 55, Parris Island	Parris Island, South Carolina	SiteWise™	N/A	Feasibility Study	September 2012	Not available	N/A	N/A	N/A	Not available	
33	NAVFAC-Southeast	Marine Corps Recruit Depot (MCRD) Parris Island	Site 45 MCRD Parris Island	Parris Island, South Carolina	SiteWise™	Soil and groundwater	Feasibility Study	September 2009	Enhanced bioremediation coupled with shallow excavation	Yes	N/A	Yes	• Minimize the volume of soil that is excavated. • Implement emission control methods/green fuel from excavation equipment, drill rigs, trucks and possibility of alternate transportation choices for soil disposal such as rail shipment. • Additional characterization to minimize the area in which treatment is to be applied. • Additional design and pilot testing to optimize the manner in which injections are performed; reduce mass of materials. • Optimization of the monitoring plans.	
34	NAVFAC - Southeast	Naval Air Station Cecil Field	OU5, Site 15, Cecil Field, Blue 10	Jacksonville, Florida	SiteWise™	N/A	Feasibility Study	July 2012	Not available	N/A	N/A	N/A	Not available	

Table 2. Summary of NAVFAC ER Sites with GSR Evaluations and/or GSR BMPs (Continued)

Case Study	NAVFAC Location	Installation	Site Name	Location	GSR Evaluation Tool	Impacted Media	CERCLA Stage	Date	Selected Remedy	Lowest Footprint*	Lowest Cost	Footprint Reduction Method identified	Footprint Method Details	Comments/Benefit
			Ordnance Disposal Area											
35	NAVFAC - Southeast	Naval Air Station Pensacola	Site 22, Underground Storage Tank	Pensacola, Florida	SiteWise™	N/A	Remedial Action Plan	January 2010	Not available	N/A	N/A	N/A	Not available	
36	NAVFAC - Southeast	Naval Air Station Pensacola	Site 43, OU-18, Demolition Debris Disposal Area	Pensacola, Florida	SiteWise™	Soil and groundwater	Remedial design	November 2011	Remedy optimization	N/A	N/A	Yes	• Optimizing the excavation remedy by performing additional site characterization and/or a higher tier risk assessment. • Appropriate testing and characterization of excavated soils to minimize amount of excavated soil • Use of emission control measures, alternate fuel. • Continual life-cycle optimization of remedy and monitoring plan. • Calculating the 95% upper confidence limit (UCL) for comparison with the industrial soil cleanup target levels (SCTLs) to determine more limited hot spot areas • Geostatistical methods to help reduce the required area of excavation	
37	NAVFAC - Southeast	Naval Air Station Pensacola	Site 46, OU-21, Former Building 72	Pensacola, Florida	SiteWise™ and GSRx	Soil and groundwater	Feasibility Study	September 2010	No selection	N/A	N/A	Yes	• Operate the air sparge/soil vapor extraction (AS/SVE) with variable frequency drives, high efficiency motors, and/or as a pulsed operation versus continuous operation. • Use remote telemetry for data collection to minimize routine operation and maintenance (O&M) events. • Optimization of operation and maintenance, monitoring and institutional controls to reduce overall transportation requirements. • Consider reducing the number of existing monitoring wells, sampling frequency, use of passive sampling devices. • Use of hybrid vehicles, alternate fuel, and emission control measures.	
38	NAVFAC - Southeast	Naval Air Station Pensacola	UST Site 18	Pensacola, Florida	SiteWise™	N/A	Remedial Action Plan Addendum	March 2010	Not available	N/A	N/A	N/A	Not available	
39	NAVFAC - Southeast	Naval Air Station (NAS) Whiting Field,	Site 7	Milton, Florida	SiteWise™ CleanSWEEP, Navy Renewable Energy Screening Tool	Soil	Remedial Action	May 2013	Not available	N/A	N/A	Yes	• Energy optimization - Installation of a Photovoltaic System to Offset Electricity Costs	
40	NAVFAC-Southeast	Naval Weapons Industrial Reserve Plant	McGregor Area M	McGregor, Texas	SiteWise™	Groundwater	Remedial Action	July 2013	No selection	N/A	N/A	N/A	• Optimization of existing extraction system - reduce the amount of water to be treated; reduce electricity by modifying pumps	
41	NAVFAC - Southwest	Naval Air Weapons Station (NAWS) China Lake	Site 44, NAWS China Lake	China Lake, California	Footprint reduction	N/A	Remedial Action	N/A	Skimming	Yes	Yes	Yes	• The use of solar-powered skimmers for free product removal - Belt skimmer and pneumatic skimmers. • The use of renewable technology optimized the product recovery, cost, time and environmental footprint.	
42	NAVFAC-Southwest	Marine Corps Base Camp Pendleton	Site 1114, MCB Camp Pendleton	Camp Pendleton, California	SiteWise™	Groundwater	Removal Action	April 2013	Source area excavation and in situ enhanced bioremediation	No	No	No		• Provides the highest level of effectiveness. • Permanently remove saturated zone soils that may serve) as a continuing source • Overall cost for implementing is moderate in comparison to other alternatives.
43	NAVFAC-Southwest	Marine Corps Base Camp Pendleton	Site 7, Box Canyon Landfill	Camp Pendleton, California	Footprint reduction	N/A	N/A	N/A	Landfill gas recovery	N/A	N/A	Yes	• The use of photovoltaic cells and a microturbine to recover and produce energy from landfill gas	
44	NAVFAC - Washington	Naval Air Station Patuxent River	Site 5 Naval Air Station Patuxent River	St. Mary's County, Maryland	SiteWise™	Groundwater	Remedial Action	October 2012	Excavation with GSR	Yes	Yes	Yes	• Several footprint reduction methodologies were proposed including avoidance of importing fill; recycling of scrap metal; and recycling of concrete. • 38.66 tons of concrete were recycled;	• Compares two alternatives (excavation) where one implements GSR and one does not. • Selecting the alternative with GSR reduces footprint and cost to the project.

Table 2. Summary of NAVFAC ER Sites with GSR Evaluations and/or GSR BMPs (Continued)

Case Study	NAVFAC Location	Installation	Site Name	Location	GSR Evaluation Tool	Impacted Media	CERCLA Stage	Date	Selected Remedy	Lowest Footprint*	Lowest Cost	Footprint Reduction Method identified	Footprint Method Details	Comments/Benefit
45	NAVFAC Washington	Naval Support Facility Indian Head	Site 38 Rum Point Landfill	Indian Head, Maryland	SiteWise™ and GSRx	Soil and groundwater	Feasibility Study	June 2013	No selection	N/A	N/A	Yes	• Use of emission control measures, alternate fuel and reduction in transportation use; different modes of transportation. • Consider optimizing equipment use- dozer, compactor, excavator. • Consider alternate pieces of equipment • Design an optimized sampling schedule, lower samples • Consider the revision of the amount of geotextile and borrow soil; use of a more environmentally friendly material for geotextile. • Consider residual handling operation using rail to the closest disposal facility • Consider the use of a closer source of borrow soil.	
46	NAVFAC Washington	Marine Corps Base Quantico	SWMU 13; Building 2113	Quantico, Virginia	SiteWise™ and GSRx	Soil vapor and groundwater	Feasibility Study	November 2012	No selection	N/A	N/A	Yes	• Consider the use of recycled materials for the asphalt pavement repair • Use of emission control measures, alternate fuel and reduction in transportation to reduce vehicle mileage. • Consider optimization of equipment use and equipment type. • Optimize samples, sampling analysis. • Use of PV panels for system operation. However, through the GSR analysis, it was determined that the use of solar panels does not represent major savings in any of the impact categories evaluated due to the low energy requirement of the proton reduction system proposed for bioremediation	
47	NAVFAC Pacific	Joint Base Pearl Harbor-Hickam (JBPHH)	Building 394 Battery Shop	Oahu, Hawaii	SiteWise™	Soil	Feasibility Study	June 2012	Capping with land use controls (LUCs)	Yes	Yes	No		• The remedy would be the most effective in the short-term because no excavation, transportation, or disposal of impacted soil is involved. • It is protective of human health and the environment • Easily implemented, and the most cost-effective.
48	NAVFAC Pacific	Joint Base Pearl Harbor-Hickam (JBPHH)	Site ST01 Kipapa Fuel Storage Annex	Oahu, Hawaii	SiteWise™	Soil	Feasibility Study	January 2011	Long-term monitoring (LTM), LUCs, Lead-Impacted Soil Excavation, and Bioventing	Yes	No	Yes	• The inclusion of bioventing helped the footprint reduction of the remediation technology. • The time frame for completing alternative 3 is 10 years - reduced footprinting comparison to 20 years for alternative 2.	• Selected remedy provided the best balance of satisfying the two threshold criteria and five balancing criteria. • Although this was the most expensive alternative, it was also the most protective of human health and the environment.
49	NAVFAC Pacific	Joint Base Pearl Harbor-Hickam (JBPHH)	Site H13	Oahu, Hawaii	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Yes	• To approve the deactivation of the multiphase extraction (MPX) systems and reduce the LTM frequency to every two years vice every year.	• The MPX operations were deactivated after that. The regulator, however, did not approve conducting the LTM every two years.
50	NAVFAC Pacific	Joint Base Pearl Harbor-Hickam (JBPHH) West Loch Annex	4th Street Coral Pit	Oahu, Hawaii	SiteWise™	Soil	Feasibility Study	February 2012	LUCs	Yes	Yes	No		• Implementing the alternative with lowest footprint and cost benefits the project.
51	NAVFAC Pacific	Naval Base Guam Munitions Site (NBGMS)	Site 35, Guam	Near Santa Rita, Guam	N/A	N/A	N/A	N/A	LTM with LUCs	Yes	N/A	Yes	• Recommended to include additional remedial action that specifies partial clean closure of site	• LUCs will be applied across the entire site. Deforestation is a concern in this area due to old growth limestone forest.
52	NAVFAC Pacific	Naval Base Guam Munitions Site (NBGMS)	Tear Gas Burial Site, Guam	Near Santa Rita, Guam	SiteWise™	Soil	Feasibility Study	September 2011	LUCs	Yes	Yes	No		• The selected remedy is protective, reasonable, and is the most cost-effective to address the site.
53	BRAC	Former Naval Construction Battalion Center Davisville	Site 16 NCBC	North Kingstown, Rhode Island	SiteWise™	Soil and groundwater	Feasibility Study	May 2012	No selection	N/A	N/A	Yes	• Use of emission control measures, alternate fuel and reduction in transportation use. • Consider optimizing equipment use – direct push technology (DPT) drill rig. • Consider the optimization of the use of materials – emulsified oil substrate (EOS) during the treatment stage, injection water, regenerated granular activated carbon (GAC) instead of virgin GAC • Design an optimized sampling schedule and analysis, number of samples analyzed during operation and monitoring stages • Consider optimization on the amount of energy used.	

Table 2. Summary of NAVFAC ER Sites with GSR Evaluations and/or GSR BMPs (Continued)

Case Study	NAVFAC Location	Installation	Site Name	Location	GSR Evaluation Tool	Impacted Media	CERCLA Stage	Date	Selected Remedy	Lowest Footprint*	Lowest Cost	Footprint Reduction Method identified	Footprint Method Details	Comments/Benefit
54	BRAC	Naval Air Warfare Center (NAWC) Warminster	OU1A, 3, 4, Groundwater Treatment System	Warminster, Pennsylvania	SiteWise™	Groundwater	Remedial action	July 2011	Ground water extraction system (GWETS)with ISCO/ZVI	Yes	Yes	Yes	• Modifying the GWETS by removing the air stripper to reduce the impact of several sustainability metrics (GHG emissions, air emissions, and accident risk). • Source area treatment would be beneficial to reduce the timeframe that the GWETS would need to be operated. • Operating the optimized GWETS for 25 years after source zone treatment was found to represent a near breakeven point compared to 30-year operation of the current system	• GHG emissions and total energy use are reduced by over 40% if source treatment (using ZVI or ISCO) is implemented. • The impact is considerably reduced if source treatment with ISCO or ZVI is conducted at the site. • The operational timeframe of the optimized GWETS system can be reduced.
55	BRAC	Former Naval Air Station (NAS) Alameda	OU2C, NAS Alameda	Alameda, California	SiteWise™	Soil	Feasibility Study	February 2010	No selection	N/A	N/A	Yes	• Implement emission control measures, greener fuel, after treatment technologies idle control plan etc. • Additional characterization to minimize the volume of soil that is excavated and shipped • Use of rail shipments	
56	BRAC	Former Naval Air Station Alameda	OU2B (Alameda)	Alameda, California	SiteWise™	Soil and groundwater	Feasibility Study	July 2013	No selection	N/A	N/A	N/A	Not available	
57	BRAC	Former Naval Air Station South Weymouth	Building 81, Former Naval Air Station South Weymouth	Weymouth, Massachusetts	SiteWise™ and GSRx	Soil and groundwater	Feasibility Study	April 2013	No selection	N/A	N/A	Yes	• Considerations on material use such as amount of concrete, EOS, etc. • Reduction in emission control measures, alternate fuel and reduction in transportation use. • Consider optimizing equipment use-DPT drill rig, and other types of equipment. • Consider reduction in sample analysis, sample number during operation and monitoring.	
58	BRAC	Former Naval Air Station South Weymouth	Building 82, Former Naval Air Station South Weymouth	Weymouth, Massachusetts	SiteWise™ and GSRx	Groundwater, soil and surface water	Feasibility Study	July 2012	No selection	N/A	N/A	Yes	• Consider revision of amount of materials - Fenton Reagent, EOS • Consider optimizing equipment use -DPT drill rig, and even the type of equipment used during operations. • Design an optimized sampling schedule and number and analysis. • Consider emission control methods, alternate fuel and reduction in transportation use.	
59	BRAC	Former Naval Air Station South Weymouth	Site 11, Solvent Release Area	Weymouth, Massachusetts	SiteWise™ and GSRx	Surface water, groundwater	Feasibility Study	December 2012	No selection	N/A	N/A	Yes	• Use of emission control measures, alternate fuel and reduction in transportation use. • Consider optimizing of equipment use. • Consider the use of an alternate material - mulch for the treatment barriers, • Optimize the sample schedule, number, and analysis • Optimize amount of injection water, amount of EOS	
60	BRAC	Willow Grove Naval Air Station	Site 3	Willow Grove, Pennsylvania	SiteWise™	N/A	Feasibility Study	July 2012	Not available	N/A	N/A	N/A	Not available	

Note: Blue shading indicates sites identified as having conducted a GSR evaluation and/or implemented GSR practices, but full documentation was not available to prepare a case study.
N/A = not applicable

4.0 OVERVIEW OF GSR BEST MANAGEMENT PRACTICES

Based upon the case study review described in Section 3, the most prevalent BMPs were reviewed and categorized. The top 10 BMPs are listed in Table 3 in order of their frequency of appearance as a suggested and/or implemented GSR approach. The different categories include: 1) material and waste minimization; 2) optimized equipment use; 3) emission control measures; 4) optimized transportation; 5) alternative fuels; 6) monitoring program optimization, 7) alternate material use, 8) remedy optimization, 9) renewable energy, and 10) optimized water consumption. First, the footprint reduction techniques are described below for each category of BMP. Then further analyses were conducted to map the various footprint reduction recommendations to the corresponding Navy GSR metrics as discussed in Sections 4.1 to 4.8 from energy consumption to community impacts.

Table 3. Top 10 BMPs from Navy Case Study Reviews

BMP	Number of Times BMPs Featured in Case Studies
Material and waste minimization	23
Optimized equipment use	17
Emission control measures	14
Optimized transportation	14
Alternative fuels	14
Monitoring program optimization	13
Alternate material use	12
Remedy optimization	10
Renewable energy	7
Optimized water consumption	4

A detailed listing of the specific BMPs by each category is included below. The number of times each topic is featured in the identified case studies is indicated within the parentheses. This count provides a general overview of the relative prevalence of each BMP among the collected case studies. In addition, input on specific GSR BMPs received through the T2 survey is also incorporated into the categories below, although not included in the site counts (see Appendices B and C).

Material and waste minimization (23)

- An evaluation for waste and material minimization opportunities should be performed for every phase of the remedial alternative. A few examples include:
  - Recycling concrete and scrap metal wastes;
  - Treated soil re-use and lead separation and recycling;
  - Use of bulk shipping/containers for chemicals to return to vendor when done
- Any opportunity for material minimization should be considered (e.g., using less chemicals/substrate such as EOS, less clean borrow soil, less geotextile, etc.).
- Optimize the excavation remedy by performing additional site characterization and/or a higher tier risk assessment. Excavation requires soil disposal that uses landfill space. Ways to minimize excavated soil should be considered, while being protective of human health and other ecological receptors.

- Optimize the extent of the target treatment zone by dramatically reducing the number of required injection points and therefore the quantity of reagents needed.
- Consider using one wellhead that serves more than one well during the injection period.

Optimized equipment use (17)

- Optimize mechanical/treatment components to reduce overall electricity usage (e.g., variable speed motors, high efficiency motors, or a microblower for bioventing).
- Pulsed or intermittent operation of equipment.
- Consider optimization of the use of equipment and type of equipment such as a DPT drill rig.

Emission control measures (14)

- After-treatment technologies to reduce emissions from excavation equipment, drill rigs and trucks. Examples of after-treatment technologies include: diesel oxidation catalysts (DOCs), diesel particulate filters (DPFs), selective catalytic reduction (SCR), and/or diesel multistage filters (DMFs).
- Reduce engine idle time for drilling equipment, excavation equipment.
- Staging work during equipment and chemical delivery is considered to decrease energy consumption and criteria air pollution.

Optimized transportation (14)

- The impacts from transportation of personnel could be lowered with the use of alternative modes of transportation (e.g., rail, carpool, and bus, etc.)
- Routine site activities can be optimized such that travel requirements are minimized. For example, the number of groundwater monitoring trips and distance traveled can be optimized to reduce the GHG emissions.
- Site workers can be encouraged to carpool to the site to reduce total vehicle mileage and related energy use and emissions.
- Minimize transportation and material transportation distances to reduce fuel use impacts. For example, select a closer treatment and disposal facility.
- The transportation of excavated soil should consider rail shipment as it reduces the GHG emissions.
- Consider the use of barge transport of excavated wastes if feasible versus trucking.
- Use adjacent soil for backfill/soil cover material at a landfill to reduce truck trips and emissions.

Alternative fuels (14)

- Use alternative fuel/green fuel such as biodiesel.

Monitoring program optimization (13)

- Reduce the monitoring frequency from annual to biannual or every five years as warranted by periodic optimization reviews of monitoring results.
- Design an optimized sampling schedule that minimizes the number of samples that need to be analyzed and maximizes the results.
- Implement low flow sampling.

Alternate material use (12)

- Minimize the need for clean fill and/or transport of clean fill as follows:
  - Use of enhanced native soil cover to minimize fill import.
  - Use of clean fill from on-site sources or closer sources during excavation.
  - Beneficial reuse of excavated soil for daily landfill cover.
  - Reuse soil from mitigation wetland to place as cover fill for site.
- Chemical manufacturing processes produce a substantial amount of GHG emissions. Future consideration of other chemicals for the ISCO reagent or bioremediation amendment should be made in order to have a lower impact.
- Any opportunity for material substitution should be considered to reduce GHG emissions (e.g., cement, steel, or fill). Steel is a large contributor to resource consumption, energy use, and GHG emissions for all alternatives. If an alternative to steel is available, it should be utilized.
- Consider the use of a material that has a lower environmental impact such as mulch for treatment barriers.
- Use of a more environmentally-friendly material for geotextile.

Optimized remedy (10)

- As part of periodic optimization reviews, continually assess remedial action operations and the results of treatment.
- Reduce the footprint of target treatment zones and the frequency and/or duration of treatment as warranted by monitoring results.
- Additional design and pilot testing to optimize the manner in which injections are performed.
- Optimize pump-and-treat systems.
- Select passive technologies such as phytoremediation or MNA.
- Select more technologies with less power requirements such as bioventing versus SVE or biosparging versus AS/SVE.
- Transition to MNA as soon as conditions are favorable to effectively remediate residual contaminants.

Renewable energy (7)

- Consider use of renewable energy sources to power remedial systems such as photovoltaic panels (particularly for solar powered skimmers as these are low energy systems that can eliminate the need to run power to remote areas) and wind power.

Optimized water consumption (4)

- Optimize amount of injection water used during the remedial action.
- Use a more concentrated formula of EOS.

As part of the 2013 T2 survey, 42% of the survey respondents indicated that specific footprint reduction approaches were recommended as part of the outcome of the GSR evaluation at their sites (see Appendix C). For the case studies reviewed, 72% identified specific footprint reduction measures. It is suggested that additional outreach would be beneficial so that ultimately all GSR evaluations would result in specific footprint reduction recommendations. A standardized list of GSR BMPs tied to specific footprint reduction measures could be developed for the most commonly selected remedial technologies to serve as

a template to be adopted to site-specific conditions (as discussed further below). This GSR BMP template could be made available on the NAVFAC Environmental Restoration and BRAC (ERB) Web site, along with being supplied to RPMs by NAVFAC Workgroup members, or through the RAA process.

For those T2 survey respondents indicating that specific footprint reduction approaches were recommended as part of their GSR evaluations, GHG emission reductions and energy reductions were the largest footprint reduction categories noted (at 20% and 16%, respectively). Figure 4 presents a breakdown of the footprint reduction recommendations from GSR evaluations from the T2 Survey. The following sections explore how the suggested BMPs and footprint reduction methodologies relate to the Navy GSR metrics including energy consumption, GHG emissions, criteria air pollutants, water consumption, resource consumption, worker safety, ecological impacts, and community impacts.

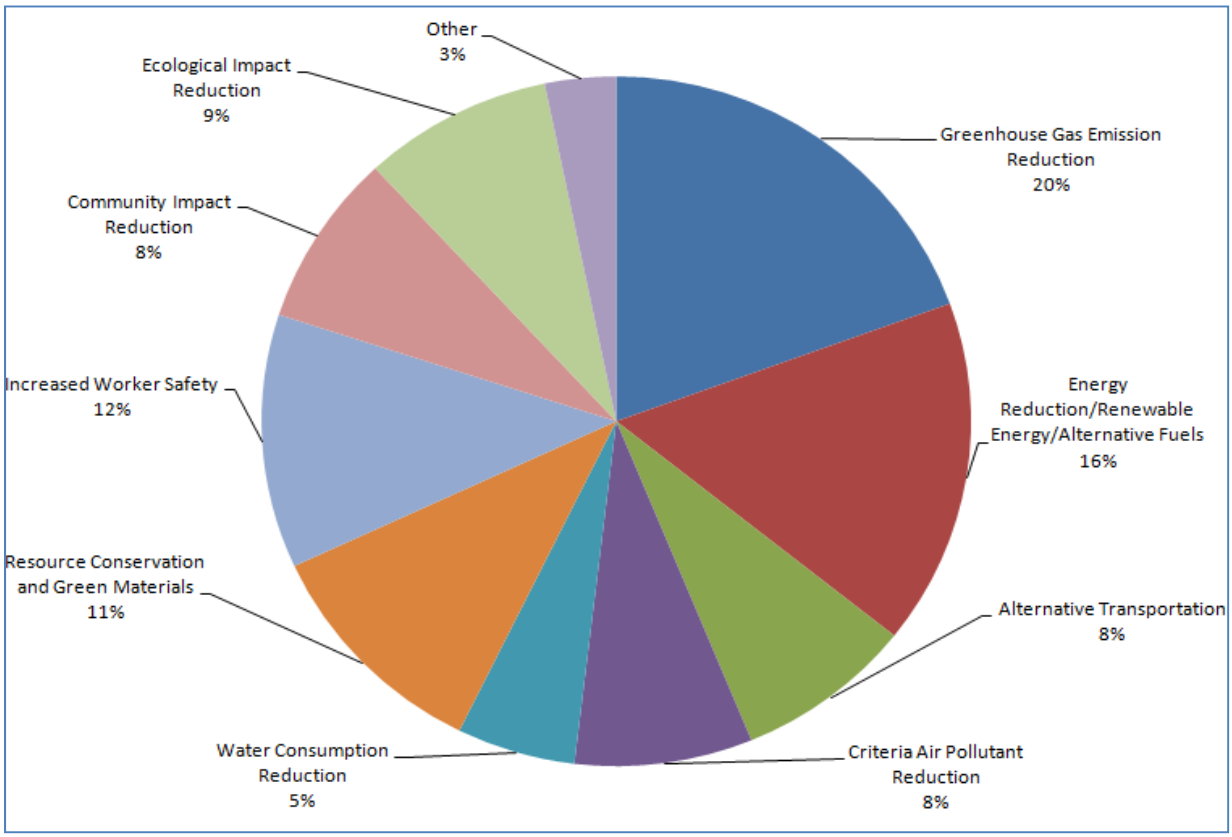


Figure 4. Footprint Reduction Recommendations from GSR Evaluations (2013 T2 Survey)

4.1 Energy Consumption

Most categories of GSR BMPs directly impact the energy consumption. The most effective means of reducing energy consumption is to select a remedy with the lowest energy usage footprint at the outset of the project. Therefore, the overall magnitude of energy used for the various groundwater and soil remedies was analyzed. A secondary consideration is the use of renewable sources of energy, which may be suitable and cost-effective based upon site-specific conditions and the local energy market. These two aspects of energy consumption are discussed below in more detail.

4.1.1 Energy Usage for Groundwater and Soil Remedies. The estimated energy usage for various types of groundwater and soil remedial technologies was compared based upon the GSR evaluations in the collected case studies. This detailed analysis was performed for energy usage as it is the most influential metric that also ultimately drives GHG emissions, criteria air pollutant emissions, and water consumption.

Table 4 summarizes energy consumption for groundwater remediation technologies including AS, bioremediation, electrical resistive heating (ERH)/thermal conductive heating (TCH), groundwater extraction, ISCO, MNA, permeable reactive barriers (PRBs), and ZVI injection. The table lists the total number of sites considering each technology, along with the site-specific ratios of the energy footprint.

Because the size of the target treatment zone (e.g., extent and depth) can vary drastically from site to site, this energy usage ratio was developed by comparing energy usage in MMBTU across all of the alternatives for a single site. The minimum, average, and maximum values of the energy usage ratios were then tabulated for all of the groundwater sites in Table 4. This information provides a quick overview of which technologies are the most energy intensive compared to other alternatives. This can be seen by examining the number of times the alternative has a higher energy use and at the value of the energy usage ratios. For example, ERH/TCH was a remedy considered at two sites (see Table 4). In all cases, as expected, this technology had higher energy usage than bioremediation (up to 44 times); groundwater extraction (up to 1.2 times); ISCO (up to 26 times); and ZVI (up to 23 times). Any ratio less than 1.0 means the technology is less energy intensive such as MNA having 0.01 (or $1/100^{th}$) of the energy usage on average compared to AS (see Table 4).

As shown in Table 4, bioremediation (10 sites) and ISCO (10 sites) were the two most commonly used groundwater remediation technologies in the case study review. Table 5 also compiles all of the BMPs documented during the case study review specific to bioremediation and ISCO that would influence energy usage and the other associated GSR metrics. It is suggested that this list of BMPs be reviewed and updated to prepare a GSR BMP template for frequently used groundwater remedial technologies such as bioremediation and ISCO. Improved design practices for these two remedial technologies could be promoted, along with a standardized list of GSR BMPs that could be adapted to site-specific conditions. For example, opportunities to expand upon the BMPs already identified by the case studies include using site water for chemical mixing/injection and high resolution site characterization to better understand and target the strata in which treatment is needed.

Among the 32 case studies, there are 10 sites where bioremediation was proposed as the groundwater remedy (see Table 4). Bioremediation was observed to be 7.7 times more energy intensive than MNA on average. It tended to be less energy intensive on average than AS (0.14), ERH/TCH (0.02), groundwater extraction and treatment (0.08), ISCO (0.53), and ZVI (0.52). In one out of two case studies, it was more energy intensive than a configuration with a PRB (biobarrier) and in only one out of eight case studies it was equivalent in energy usage to ISCO. This analysis suggests that bioremediation is a less energy intensive remedial alternative, especially in comparison to ISCO.

Among the 32 case studies, there were 10 sites where ISCO was proposed as a groundwater remedy (see Table 4). Based on the case study review, ISCO was observed to be nine and 91 times more energy intensive on average than bioremediation and MNA, respectively. On average, ISCO was less energy intensive than AS (0.68), ERH/TCH (0.41), groundwater extraction and treatment (0.45), and ZVI (0.94).

For one site, it was also noted that PRBs using ZVI, although a passive technology, had relatively high footprints when compared to other in situ technologies. The ZVI PRB had the highest remedy footprint compared to MNA, bioremediation, and ISCO primarily due to equipment use and consumables (ZVI) used during construction of the PRB. The ZVI PRB was 16 times more energy intensive than MNA and 1.6 times more energy intensive than ISCO. Because of its relatively high footprint, this suggests that ZVI PRBs would be more suitable as an alternative at sites where groundwater extraction and treatment was among the remedial alternatives under consideration.

Although many factors drive the remedial design and therefore site-specific estimates of energy usage, trends in the magnitude of energy usage were fairly consistent across the categories of remedies evaluated.

Table 4. Energy Comparison for Groundwater Technologies

Technology	Total Number of Sites with Alternative	Air Sparging		PRB		Bioremediation		ERH/TCH	
		No. Times Higher Energy Use	Range (Average) Ratio of Footprints (ALT/AS)	No. Times Higher Energy Use	Range (Average) Ratio of Footprints (ALT/PRB)	No. Times Higher Energy Use	Range (Average) Ratio of Footprints (ALT/BIO)	No. Times Higher Energy Use	Range (Average) Ratio of Footprints (ALT/ERH)
AS	3	N/A	N/A	N/A	N/A	2/2	5 to 15 (10)	N/A	N/A
Bioremediation	10	0/2	0.06 to 0.21 (0.14)	1/2	0.42 to 4.7 (2.6)	N/A	N/A	0/1	0.02 (0.02)
ERH/TCH	2	N/A	N/A	N/A	N/A	1/1	44 (44)	N/A	N/A
GWE&T	3	1/1	1.3 (1.3)	N/A	N/A	2/2	6.1 to 244 (125)	0/1	0.9 (0.9)
ISCO	10	0/1	0.68 (0.68)	1/2	0.6 to 5 (3)	7/8	0.9 to 21 (9)	0/2	0.04 to 0.78 (0.41)
MNA	8	0/2	0.01 to 0.02 (0.01)	0/1	0.06 (0.06)	1/7	0.05 to 1.16 (0.3)	N/A	N/A
PRB	2	N/A	N/A	N/A	N/A	1/2	0.2 to 2.4 (1.3)	N/A	N/A
ZVI	2	N/A	N/A	N/A	N/A	1/1	1.9 (1.9)	0/2	0.04 to 0.77 (0.4)

Note: PRB includes ZVI barriers and mulch biobarriers; ZVI includes injection only.
GWE&T = groundwater extraction and treatment

Table 4. Energy Comparison for Groundwater Technologies (Continued)

Technology	Total Number of Sites with Alternative	GWE&T		ISCO		MNA		ZVI	
		No. Times Higher Energy Use	Range (Average) Ratio of Footprints (ALT/ISCR)	No. Times Higher Energy Use	Range (Average) Ratio of Footprints (ALT/ISCO)	No. Times Higher Energy Use	Range (Average) Ratio of Footprints (ALT/MNA)	No. Times Higher Energy Use	Range (Average) Ratio of Footprints (ALT/ISCR)
Air Sparging	3	0/1	0.79 (0.79)	1/1	1.5 (1.5)	2/2	65 to 99 (82)	N/A	N/A
Bioremediation	10	0/2	0.004 to 0.17 (0.08)	1/8	0.03 to 1 (0.53)	6/7	0.86 to 21 (7.7)	0/1	0.52 (0.52)
ERH/TCH	2	1/1	1.2 (1.2)	2/2	1.3 to 26.4 (13.8)	N/A	N/A	2/2	1.3 to 22.8 (12)
GWE&T	3	N/A	N/A	2/2	1.1 to 167.8 (84.5)	2/2	125 to 1,904 (1,015)	1/1	1.1 (1.1)
ISCO	10	0/2	0.01 to 0.9 (0.45)	N/A	N/A	5/5	1.5 to 358 (91)	1/2	0.9 to 1 (0.94)
MNA	8	0/2	0.0005 to 0.008 (0.004)	0/5	0.003 to 0.7 (0.2)	N/A	N/A	N/A	N/A
PRB	2	N/A	N/A	1/2	0.2 to 1.6 (0.9)	1/1	16.4 (16.4)	N/A	N/A
ZVI	2	0/1	0.9 (0.9)	1/2	1.2 to 0.99 (1.1)	N/A	N/A	N/A	N/A

Note: PRB includes ZVI barriers and mulch biobarriers; ZVI includes injection only.
GWE&T = groundwater extraction and treatment

Table 5. BMPs for the Most Prevalent Groundwater Remedies Based on Navy Case Study Reviews

Bioremediation BMPs
Material and Waste Minimization • Consider the optimization of the use of materials such as EVO during the treatment stage • Consider using one wellhead to serve more than one well during the injection periods • Use additional characterization to minimize the area in which treatment is to be applied • Reduce the number of required injection points and therefore the quantity of reagents needed • Consider additional design and pilot testing to optimize the manner in which injections are performed
ISCO BMPs
Consider Alternate Material Use • Consider alternate chemicals for ISCO reagent **Material and Waste Minimization** • Consider using one wellhead to serve more than one well during the injection periods • Use additional characterization to minimize the area in which treatment is to be applied • Optimize the extent of the target treatment zone by dramatically reducing the number of required injection points for ISCO and therefore the quantity of reagents needed • Consider additional design and pilot testing to optimize the manner in which injections are performed
Common BMPs for ISCO and Bioremediation
Optimize Transportation • Consider reduction in transportation use; number of trip for mobilization, operation and monitoring **Alternative Fuel** • Consider use of green fuel for DPT drill rigs, trucks **Emission Control Measures** • Implement emission control methods such as after treatment technologies on DPT drill rigs, trucks • Implement idle control on chemical delivery trucks, field trucks, etc. **Optimize Equipment Use** • Consider optimizing equipment use for DPT drill rig and other types of equipment **Optimize Monitoring Program** • Consider reduction in sample analysis, sample schedule, and sample number during operation and monitoring **Optimize Water Consumption** • Optimize amount of injection water during remedial action

Table 6 summarizes energy consumption for soil remediation technologies. As shown in Table 6, excavation (three sites) and soil capping (three sites) were the two most commonly used soil remediation technologies in the case study review. This is followed by technologies that include SVE (two sites), geotextile capping (one site), and bioventing (one site). Table 7 lists the BMPs noted during the case study review specific to excavation and soil capping. A GSR BMP template could be developed to promote "green" excavation and capping projects that could be adjusted to site-specific conditions. For example, an opportunity to expand upon the BMPs already identified by the case studies includes the development of idle management plans.

Based on the case study review, on average, excavation was shown to be 5.6 times more energy intensive than soil capping. Similarly, excavation was observed to be 1.2 times and 1.8 times more energy intensive than SVE and bioventing, respectively. It was noted that geotextile capping was found to be 2.5 times more energy intensive than excavation (although there was only one site). This was due to the energy consumed during the production of the geotextile. Based on the case study review, soil capping was less energy intensive in all cases than excavation (0.3) and SVE (0.21).

Table 6. Energy Comparison for Soil Technologies

Technology	Total Number of Sites with Alternative	Excavation		Soil Capping		Geotextile Capping		Soil Vapor Extraction		Bioventing	
		No. Times Higher Energy Use	Range (Average) Ratio of Footprints (ALT/EXC)	No. Times Higher Energy Use	Range (Average) Ratio of Footprints (ALT/Soil Cap)	No. Times Higher Energy Use	Range (Average) Ratio of Footprints (ALT/Geotex)	No. Times Higher Energy Use	Range (Average) Ratio of Footprints (ALT/SVE)	No. Times Higher Energy Use	Range (Average) Ratio of Footprints (ALT/BIOV)
Excavation	3	N/A	N/A	3/3	2 to 9 (5.6)	0/1	0.004 (0.004)	1/1	1.2 (1.2)	1/1	1.8 (1.8)
Soil Capping	3	0/3	0.11 to 0.5 (0.3)	N/A	N/A	N/A	N/A	0/1	0.21 (0.21)	N/A	N/A
Geotextile Capping	1	1/1	2.5 (2.5)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Soil Vapor Extraction	2	0/1	0.8 (0.8)	1/1	4.8 (4.8)	N/A	N/A	N/A	N/A	N/A	N/A
Bioventing	1	0/1	0.54 (0.54)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 7. BMPs for the Most Prevalent Soil Remedies Based on Navy Case Study Reviews

Excavation BMPs
Consider Alternate Material Use • Consider the option of obtaining clean fill from on-site sources or from the closest source available (e.g., the use of enhanced native soil to minimize fill import) **Material and Waste Minimization** • Consider revisions and optimization of clean borrow soil • Consider additional testing and characterization of excavated soils during the remedial investigation to minimize the amount of soil excavated • Consider optimizing the excavation remedy by performing a higher tier risk assessment • Consider the use of geostatistical methods to reduce the required area of excavation **Optimize Transportation** • Consider reduction in transportation use; for example use a closer landfill for disposal of CERCLA waste • Consider disposal of hazardous waste via alternate transportation such as rail shipment
Soil Capping BMPs
Consider Alternate Material Use • Use of clean fill from on-site sources or closer sources **Optimize Transportation** • Consider reduction in transportation use **Material and Waste Minimization** • Consider the revision of volumes of borrow soil needed for capping
Common BMPs for Excavation and Soil Capping
Material and Waste Minimization • Perform an evaluation for waste and material minimization **Alternative Fuel** • Consider use of green fuel for excavation equipment, compactors, trucks **Emission Control Measures** • Implement emission control methods from excavation equipment, trucks **Optimize Equipment Use** • Consider optimizing equipment use (e.g., dozer, compactor, and excavator)

4.1.2 Renewable Energy Usage. Seven case studies considered, implemented, or proposed the use of renewable energy during environmental restoration. Geographically, these case studies were from NAVFAC Northwest (one site), Midwest (one site), Mid-Atlantic (two sites), Southeast (one site), and Southwest (two sites). It was determined that solar energy sources were suitable at three sites that were located in California (two) and Florida (one). This suggests that regional strategies for renewable energy usage could be adopted where it has the most potential for a positive cost-benefit. The case studies evaluating renewable energy sources included the following:

Photovoltaic Cells/Panels

- A photovoltaic system was recommended at Naval Air Station Whiting Field, Florida (Site 7) during a renewable energy screening. The system would decrease the cost of operation of the SVE system (blower, transfer pump, and the heat exchanger).
- At Marine Corps Base Camp Pendleton, California (Site 7, Box Canyon Landfill), photovoltaic cells were designed and installed on the landfill cover. A 30 kW methane microturbine capable of running efficiently at low methane concentrations (~7%) is fed into the photovoltaic panel system to generate power.
- At Marine Corps Base Quantico, Virginia (SWMU 13), a solar panel operated bioremediation system was compared against the bioremediation system using electricity from the grid. Through the GSR analysis, it was determined that the use of solar panels did not represent major savings in any of the impact categories evaluated due to the low energy requirement of the bioremediation system.

Solar or Wind Power

- A renewable energy screening was performed at two sites (Naval Base Kitsap Bangor, Washington [Site F] and Naval Industrial Reserve Ordnance Plant (NIROP) Fridley, Minnesota [OU-1]) that were both operating GWETS. Results were not positive for the use of solar or wind power in either case.
- At former Naval Construction Battalion Center Davisville, Rhode Island (Site 16) alternative sources of energy (such as solar if possible) were recommended to be used during the 30-year lifetime of the GWETS to reduce the load of generating electricity through the grid.

Solar-Powered Skimmers

- Solar-powered skimmers (belt skimmer and pneumatic skimmers) were used for free product removal at Naval Air Weapons Station China Lake, California. The use of renewable technology optimized the product recovery, cost, time and environmental footprint.

4.2 Greenhouse Gas Emissions

GHG emissions from remediation projects primarily include CO_2, N_2O, and CH_4. Quantification of GHG emissions is an important metric because of growing concern over climate change. Activities resulting in GHG emissions include: equipment and electrical use on site; transportation of personnel, materials, and equipment; and production of consumables associated with the remedy. As a consequence, most energy consumption activities influence GHG emissions. A total of 14 case studies each proposed/implemented emission control measures, alternative fuels, and the optimization of transportation, respectively. Additionally, other BMPs that influence GHG emissions include material and waste minimization (23 sites), optimization of equipment use (17 sites), optimization of monitoring program (13 sites), consideration of alternate material use (12 sites), and remedy optimization (10 sites). An example of the direct reduction of GHG emissions through the use of biodiesel is listed below:

- At Naval Air Station Pensacola (Site 43), the remedial action alternatives were compared using biodiesel or diesel for the excavation equipment. It was observed that there was no significant reduction in criteria pollutants or energy consumption in using biodiesel rather than diesel at the site. However, CO_2e emissions could be reduced by approximately 22% through the use of biodiesel in vehicles and excavation equipment.

4.3 Criteria Air Pollutants

Air emission of criteria pollutants, regulated by the Clean Air Act of 1970, can cause smog and adverse health effects such as asthma, bronchitis, lung cancer, and eye irritation. Criteria air pollutants include: SOx, NOx, PM, ozone, and ozone precursors due to various activities such as transportation, electrical usage, and heavy machinery and equipment use during remedy implementation. Similar to GHG emission, most energy consumption activities influence criteria air pollutants. A total of 14 case studies each proposed/implemented emission control measures, alternative fuels and optimized transportation, respectively. Other BMPs that influence criteria air pollutants include material and waste minimization (23 sites), optimization of equipment use (17 sites), optimization of monitoring program (13 sites), consideration of alternate material use (12 sites), and optimization of remedy (10 sites).

At Naval Air Station Pensacola Site 43, the remedial action (excavation) was compared using biodiesel and diesel as mentioned in Section 4.2. No significant reductions were observed in criteria pollutant emissions by the use of biodiesel as a fuel source. However, as previously mentioned, it was estimated that GHG emissions would be reduced.

Several sites considered BMPs to reduce criteria air pollutant emissions from excavation equipment, drill rigs, and trucks. For example, the use of after-treatment technologies was considered, along with reducing idle time for several excavation projects as listed below. These sites could be followed up to evaluate best practices in implementing GSR for excavation sites.

- Former Naval Air Station Alameda, Operable Unit 2 C, Alameda, California
- Marine Corps Recruit Depot Parris Island Site 45, Parris Island, SC
- Naval Support Facility Indian Head Site 38 Rum Point Landfill, Indian Head, Maryland
- Portsmouth Naval Shipyard, OU 7 Kittery, Maine
- Portsmouth Naval Shipyard, OU 9 Kittery, Maine

4.4 Water Consumption

A review of the available case studies revealed the trends in water consumption for groundwater technologies. This includes groundwater extracted during the remedial action, water used for injection, and water consumed to manufacture consumables used during remedial activities. A total of four case studies referred to BMPs for optimizing water consumption as follows:

- At Marine Corps Logistics Base (MCLB) Albany (OU 6), Naval Construction Battalion Center (NCBC) Davisville (Site 16), and Naval Air Station South Weymouth (Site 11 SRA), it was recommended to optimize the amount of injection water or reagent injected during injection application.

- At Naval Weapons Industrial Reserve Plant (NWIRP) McGregor Area M, it was recommended to optimize the groundwater extraction and treatment system to reduce the overall amount of water treated.

Table 8 provides the minimum, maximum, and median water consumption for groundwater technologies evaluated in the case studies. As shown in Figure 5, the top three water consuming technologies were groundwater extraction, thermal technologies, and AS. On average approximately 5,000 gallons of water was used by soil remedial technologies. These values are benchmarked against volume of water used by the average American family at 109,500 gallons per year.[3]

Table 8. Water Consumption for Groundwater Technologies

Groundwater Technologies	Minimum (gal)	Maximum (gal)	Median (gal)
ZVI	56,000	56,000	56,000
Biobarrier	83,100	304,656	149,284
Bioremediation	7,240	1,684,655	178,838
ISCO	1,401	516,000	322,094
AS	403,529	4,150,000	1,040,000
ERH	3,900,000	3,900,000	3,900,000
Groundwater extraction	3,970,000	1,400,000,000	208,429,602
Average American Family Water Usage (U.S. EPA[4])	109,500 gallons/year		

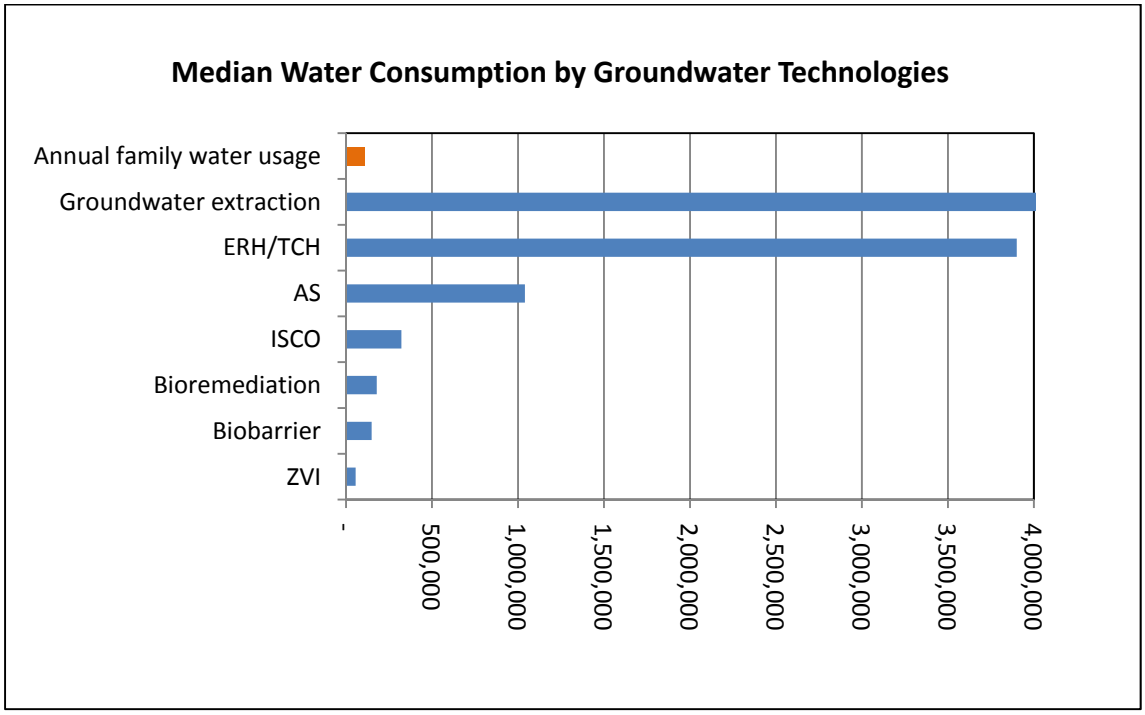


Figure 5. Water Consumption for Groundwater Technologies (Median values are plotted.)

[3] http://www.epa.gov/watersense/our_water/water_use_today.html

4.5 Ecological Impacts

Most sites had an ecological risk assessment performed as part of the FS process to identify any ecological impacts from the contamination. However, only four sites provided an assessment of the impact of the remedy itself on the local ecology and/or recommended BMPs to reduce the ecological impact. BMPs included the use of MNA and LUCs to promote resource conservation and reduce ecological impacts and minimize vegetation clearance. Four examples are provided below at sites where the ecological considerations played a key role in remedy selection:

- **Naval Base Guam Munitions Site.** Long-term management and LUCs were selected as the remedy at the Naval Base Guam Munitions Site to avoid a remedy that would impair an old growth forest.
- **Former Vieques Naval Training Range SWMU 1.** At the Former Vieques Naval Training Range SWMU 1, the selected remedy included a 2 ft enhanced native soil cover over the exposed landfill debris (less than 2 acres) to avoid site clearance of vegetation and a soil cap over the entire 41 acres of the site. With the higher footprint remedy, wildlife habitat would have been destroyed for some time until vegetation was re-established. The lower footprint remedy satisfied all human health and ecological concerns and was the most compatible with the future use of the property, which was to maintain it as a wildlife refuge.
- **Marine Corps Base Camp Pendleton Site 114.** The selected remedy included source area excavation with in situ enhanced bioremediation to remove residual source mass bound to the fine grained saturated soils. This remedy had a moderate impact in comparison to the others on the local protected habitat and vernal pools.
- **Naval Underwater Systems Center (NUSC) Newport Site 8 Disposal Area.** The remedies considered during the FS included MNA and LUCs, enhanced in situ bioremediation, and ISCO. There was no selected remedy. However, the Navy determined that enhanced in situ bioremediation would be the "Least Environmentally Damaging Practicable Alternative" to protect wetland resources, because it addressed contamination within and adjacent to wetlands and waterways, and minimized both temporary and permanent alteration of wetlands and aquatic habitats on site. Enhanced in situ bioremediation would more quickly remediate the groundwater plumes compared to MNA. The strong chemical oxidants of ISCO would impact wetland areas.

The ecological impact metric is not a quantitative metric within SiteWise™, so its application is less straightforward. As part of the T2 survey input in 2013, RPMs requested more guidance on qualitative evaluations to be completed for ecological impacts. It was indicated that SiteWise™ could be improved by making the high, medium, and low ranking a semi-quantitative measure and by providing a list of ecological impact evaluation features to consider. The RPMs for the sites identified above could be engaged to assist in the development of more detailed ecological impact metrics.

4.6 Resource Consumption and Waste Generation

A total of 23 case studies implemented or proposed waste and material minimization techniques. Examples of various methods for resource conservation and waste minimization are listed below by NAVFAC component:

NAVFAC Atlantic

- **Former Vieques Naval Training Range SWMU-1 Vieques, Puerto Rico.** The selected remedy included the use of a 2 ft enhanced native soil cover over exposed landfill debris to minimize fill import.

NAVFAC Mid-Atlantic

- **St. Juliens Creek Annex, Site 21.** A different formulation of EVO was specified for a bioremediation project during the remedial design phase. This change would result in a 30% reduction in GHG and energy consumption. However, it would result in a 1% increase in water consumption.
- **St. Juliens Creek Annex, Site 2.** The broken concrete from foundation removal was used as fill for the soil cover instead of purchasing soil. In addition, soil removed to construct the wetland was also used as fill. This allowed for cost savings from purchasing soil and concrete disposal. This strategy conserved resources and minimized waste effectively.

NAVFAC Northwest

- **Naval Air Station Whidbey Island.** The use of recycled concrete rubble to fill marine mattresses for shoreline stabilization was an innovative feature at the shoreline landfill to reduce the use of resources and minimize waste. Additionally, machinery used only biodegradable hydraulic fluids (e.g., vegetable oil) for lubrication.

NAVFAC Washington

- **Naval Air Station Patxutent River, Site 5.** The recommended remedy included footprint reduction methods through recycling scrap metal and concrete. This resulted in recycling 38.66 tons of concrete. The landfill space for 94 tons of waste (approximate amount of waste generated by 100 people in 1 year) was saved and 9,600 tons of clean soil was saved from consumption.
- **Marine Corps Base Quantico SWMU 13 Building 2113.** One of the BMP recommendations for resource conservation was to use recycled materials for the asphalt pavement repair.
- **Naval Support Facility Indian Head Site 38 Rum Point Landfill.** The FS recommended considering a few BMPs during the alternative that included capping the landfill. The use of a closer source for borrow soil was suggested. Additionally, the amount and type of geotextile used for capping purposes could be reviewed and replaced with a more environmentally-friendly material.

BRAC

- **Former Naval Construction Battalion Center Davisville Site 16 NCBC.** BMPs for the groundwater extraction system included considering the use of regenerated GAC rather than virgin GAC during the replacement of the fill of the chambers.
- **Former Naval Air Station Alameda OU2C**. Additional soil characterization was recommended for an excavation remedy to minimize the volume of soil to be excavated and shipped off site.
- **Former Naval Air Station South Weymouth Site 11, Solvent Release Area**. The GSR evaluation recommended considering the use of mulch for PRBs to lower environmental impacts.

4.7 Worker Safety

The primary way to reduce worker risk was found to be the minimization of travel distances. A total of 14 case studies proposed BMPs to reduce and optimize transportation.

4.8 Community Impacts

The most common form of community impact noted was the potential for increased noise, traffic, and exposure (due to chemicals or contaminated soils) to the community during remedial action such as excavation and transport activities.

At the Naval Air Warfare Center Warminster, PA (OU 1A, 3, and 4), it was noted that two of the five proposed alternatives related to groundwater extraction and treatment would have the highest impacts to community due to the delayed property transfer.

Below is a list of the NAVFAC locations where the community impacts were noted as a key consideration in remedy selection due to the need for increased transportation and the resulting increase in traffic, noise, or exposure potential.

- Former Naval Air Station South Weymouth Building 81, Weymouth, Massachusetts;
- Former Naval Air Station South Weymouth Site 11 Solvent Release Area, Weymouth, Massachusetts;
- Joint Expeditionary Base Little Creek SWMU Unit 3, Virginia Beach, Virginia;
- Joint Expeditionary Base Little Creek SWMU Unit 7b Virginia Beach, Virginia;
- Marine Corps Recruit Depot Parris Island Site 45, Parris Island, South Carolina;
- Marine Corps Base Quantico SWMU M-13 Building 2113 Quantico, Virginia;
- Naval Base Guam Munitions Site Tear Gas Burial Site, Guam; and
- Naval Support Facility Indian Head Site 38 Rum Point Landfill, Maryland.

As part of the T2 survey input in 2013, RPMs requested more guidance on qualitative evaluations to be completed for community impacts. The RPMs for the sites identified above could be engaged to assist in the development of more detailed community impact metrics.

5.0 CONCLUSIONS

The objective of this white paper was to examine the use of GSR within the Navy's ER Program. Specifically, the study tracked the implementation of GSR practices to date at ER sites nationwide. The information obtained was used to identify BMPs and their potential impact on the remedy footprint. Several recommendations are provided below for future GSR efforts to continue to ensure that cost-effective and sustainable remedies are promoted within the ER Program.

Below are some of the major observations from the case study review:

- A total of 60 GSR case studies were identified across the NAVFAC components. Among the 60 case studies, project documentation was readily available for 32 of the case studies. These 32 case studies were then summarized in detail to track trends in GSR implementation. Approximately 90% of the case studies calculated the primary metrics for GSR and 72% identified specific footprint reduction measures.
- Among 32 sites where a remedy was selected, the results show 84% of GSR evaluations resulted in the selection of the lowest footprint remedy and 69% resulted in the selection of the lowest cost remedy. These results suggest that the remedy evaluation process, which includes GSR evaluation, is in fact leading to the selection of more sustainable and cost-effective remedies at Navy sites. Although there is a clear correlation showing that most of the selected remedies have the lowest footprint of all those evaluated, the extent to which the GSR evaluation has influenced the selection of the preferred remedy is unknown. At the very least, the GSR evaluation provides documentation that the more sustainable remedies are selected and helps to guide the RPMs in developing footprint reduction recommendations. Therefore, it would be beneficial to continue to encourage the ongoing practice of GSR evaluations throughout the life cycle of the ER Program.
- The largest percentage of sites was located in the NAVFAC Atlantic/Mid-Atlantic region at 39% and some FECs had much smaller amounts of sites identified than others. This indicates that additional outreach to RPMs and contractors on GSR policy implementation may be beneficial on a regional basis to facilitate increased utilization.
- The majority (67%) of the GSR evaluations collected for this effort were performed at the FS phase. This suggests that the use of GSR is still in the early phases of selecting and planning for remedies. Its use in remedial design and remedy implementation has occurred at roughly one third of sites based on the collected case studies and T2 survey input. As GSR efforts mature and move out of the FS phase, it will be important to document their outcome. It is recommended that the use of the NORM Optimization module for GSR be more widely adopted to serve as a means of formally documenting GSR implementation beyond the FS stage. In addition, RPMs could be encouraged to include GSR and optimization outcomes in the CERCLA Administrative Record in NIRIS as appropriate to document site activities. It is suggested that a NAVFAC-wide document template be developed to encourage the written documentation of GSR implementation efforts.
- The top 10 BMPs utilized in the case studies included: 1) material and waste minimization; 2) optimized equipment use; 3) emission control measures; 4) optimized transportation; 5) alternative fuels; 6) monitoring program optimization, 7) alternate material use, 8) remedy optimization, 9) renewable energy, and 10) optimized water consumption.
- Bioremediation and ISCO were the two most commonly used groundwater remediation technologies in the case study review. Excavation and soil capping were the two most commonly used soil remediation technologies in the case study review. A standardized list of GSR BMPs

tied to specific footprint reduction measures could be developed for the most commonly selected remedial technologies. It is suggested that a GSR BMP template be prepared for bioremediation, ISCO, excavation, and capping technologies. Improved design practices for these remedial technologies could be promoted, along with a standardized list of GSR BMPs that could be adapted to site-specific conditions.

- Considering the large percentage of CTC allocated to soil excavation, it is suggested that GSR BMPs and best practices for soil excavation be further studied. Sites considering "greener" excavation practices at the FS stage were identified as part of this review and could be followed up to assess the footprint reductions achieved as part of a cost, performance, and sustainability review.
- Only four sites provided an assessment of the impact of the remedy itself on the local ecology and/or recommended BMPs to reduce the ecological impact. The ecological impact metric is not a quantitative metric within SiteWise™, so its application is less straightforward. As part of the T2 survey input in 2013, RPMs requested more guidance on qualitative evaluations to be completed for ecological impacts. Additional support could be provided by developing a list of ecological impact evaluation features to consider. The RPMs for the sites identified in this study could be engaged to assist in the development of more detailed ecological impact metrics.
- As part of the T2 survey input in 2013, RPMs requested more guidance on qualitative evaluations to be completed for community impacts. RPMs for the sites identified in this study could be engaged to assist in the development of more detailed community impact metrics.
- Overall, it is recommended that approximately 25% of the case studies identified in this report in the FS stage be followed up to track on their use of GSR BMPs into the remedial design and remedy implementation. This would help to assess how the GSR BMPs planned in the FS stage transition into the full-scale application.

6.0 REFERENCES

Department of Defense (DoD). 2009. *Consideration of GSR Practices in the Defense Environmental Restoration Program*. August.

DoD. 2012. "*Department of Defense Manual, Defense Environmental Restoration Program (DERP) Management*," Publication Number 4715.20 (9 March 2012). http://www.dtic.mil/whs/directives/corres/pdf/471520m.pdf

Department of Navy (DON). 2012a. *Policy for Optimizing Remedial and Removal Actions at All DON Environmental Restoration Program Sites*. April

DON. 2012b. *Guidance on Green and Sustainable Remediation*. UG-2093-ENV Rev.1. April.

Naval Facilities Engineering Command (NAVFAC). 2013. *SiteWise™ Version 3 User's Guide*. UG-NAVFAC-EXWC-ENV-1302. July.

United States Environmental Protection Agency (EPA). 2008. *Green Remediation: Incorporating Sustainable Environmental Practices into Remediation of Contaminated Sites*. EPA 542-R-08-002. April.

APPENDIX A

NAVFAC GSR CASE STUDIES

NAVFAC Atlantic/Mid-Atlantic

Former Vieques Naval Training Range Solid Waste Management Unit 1 Vieques, Puerto Rico 1
Joint Expeditionary Base Little Creek Solid Waste Management Unit 3 Virginia Beach, Virginia 5
Joint Expeditionary Base Little Creek Solid Waste Management Unit 7b Virginia Beach, Virginia 10
Marine Corps Base Camp Lejeune Site 69, Operable Unit 14 (Groundwater) Jacksonville, North Carolina 15
Marine Corps Base Camp Lejeune Site 69, Operable Unit 14 (Soil) Jacksonville, North Carolina 21
Marine Corps Base Camp Lejeune Site 89, Operable Unit 16 (Source Area) Jacksonville, North Carolina 26
Naval Undersea Systems Center (NUSC) Newport Site 8 Disposal Area Newport, Rhode Island 31
Naval Weapons Industrial Reserve Plant Calverton Southern Area Groundwater Plume Calverton, New York 37
Portsmouth Naval Shipyard Operable Unit 7 Kittery, Maine 43
Portsmouth Naval Shipyard Operable Unit 9 Kittery, Maine 48
St. Juliens Creek Annex Site 21 Chesapeake, Virginia 53
Yorktown Defense Fuel Supply Point Yorktown Fuel Farm Central York County, Virginia 58

NAVFAC Southeast

Marine Corps Logistics Base Albany Operable Unit 6 Albany, Georgia 62
Marine Corps Recruit Depot Parris Island Site 45 Parris Island, South Carolina 66
Naval Air Station Pensacola Site 43, Operable Unit 18, Pensacola, Florida 71
Naval Air Station Pensacola Site 46, Operable Unit 21, Pensacola, Florida 76

NAVFAC Southwest

Naval Air Weapons Station China Lake Site 44 China Lake, California 83
Marine Corps Base Camp Pendleton Site 1114 Camp Pendleton, California 85
Marine Corps Base Camp Pendleton Site 7 Box Canyon Landfill Camp Pendleton, California 90

NAVFAC Washington

Naval Air Station Patuxent River Site 5 St. Mary's County, Maryland 93
Naval Support Facility Indian Head Site 38 Rum Point Landfill Indian Head, Maryland 96
Marine Corps Base Quantico Solid Waste Management Unit M-13, Building 2113 Quantico, Virginia 101

NAVFAC Pacific

Joint Base Pearl Harbor-Hickam Building 394 Battery Shop Oahu, Hawaii 108
Joint Base Pearl Harbor-Hickam ST-01 Kipapa Fuel Storage Annex Oahu, Hawaii 113
Joint Base Pearl Harbor-Hickam 4th Street Coral Pit Oahu, Hawaii 118
Naval Base Guam Munitions Site Tear Gas Burial Site Guam 123

Base Closure and Realignment (BRAC)

Former Naval Construction Battalion Center Davisville Site 16, North Kingstown, Rhode Island 129
Naval Air Warfare Center Warminster Operable Unit 1A, 3 and 4 Warminster, Pennsylvania 135
Former Naval Air Station Alameda Operable Unit 2C Alameda, California 138
Former Naval Air Station South Weymouth Building 81 Weymouth, Massachusetts 142
Former Naval Air Station South Weymouth Building 82 Weymouth, Massachusetts 148
Former Naval Air Station South Weymouth Site 11 Solvent Release Area Weymouth, Massachusetts 154

NAVFAC ATLANTIC/MID-ATLANTIC

Former Vieques Naval Training Range
Solid Waste Management Unit 1
Vieques, Puerto Rico

FEC	**NAVFAC Atlantic**
Installation	Former Vieques Naval Training Range
Location	Vieques, Puerto Rico
Site Number	Solid Waste Management Unit 1 (SWMU 1)
Site Name	SWMU 1
Phase/Milestone/Date	Streamlined Remedial Investigation/Feasibility Study Report (April 2011)
Site Background	SWMU 1 is located at the former Vieques Naval Training Range (VNTR) in the central portion of Vieques, Puerto Rico. SWMU 1 is approximately 41 acres in size and was a landfill used from 1954 to 1978 for the disposal of municipal waste from Camp García (see Figure 1). Approximately 1,800 to 3,120 tons of waste was disposed in the landfill and no hazardous materials reportedly were placed in the disposal area. Materials were disposed in a trench, which was then covered with about 6 inches of soil to control blowing of litter. A final 2-foot (ft) thick soil cover, consisting of compacted native soils, was placed over the trench. The landfill is densely vegetated and only small, isolated areas of landfill waste were exposed on the surface.
Contaminants	VOCs, SVOCs, pesticides/polychlorinated Biphenyls (PCBs), herbicides, explosives, metals (aluminum, antimony, arsenic, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, cyanide, iron, lead, magnesium, manganese, mercury, nickel, potassium, selenium, silver, sodium, thallium, tin, vanadium, zinc)
Impacted Media	The impacted media are soil and groundwater.
Remedial Technologies	This case study discusses remedial alternatives for soil to prevent direct contact to landfill debris and address potential future risk associated with future releases of waste material as a result of erosion. • **Alternative 1:** No Further Action • **Alternative 2:** Enhanced Native Soil Cover and Institutional Controls (ICs) • **Alternative 3:** Additional Soil Cover and ICs
GSR Evaluation Approach	The alternatives were evaluated against CERCLA nine criteria. In addition, the sustainability analysis was performed using SiteWise™ (see Table 1). The discussion below is focused on alternatives 2 and 3. Alternative 1 no further action is not reviewed for this case study.
Footprint Reduction Methodologies	Use of enhanced native soil cover to minimize fill import.
Greenhouse Gas Emissions	Alternative 3 had the highest GHG emissions primarily driven by the personnel transportation, equipment use, and installation of the 2 foot soil cover during the remedial construction phase. • Alternative 2 (Enhanced Native Soil Cover and ICs): 93.1 metric ton • Alternative 3 (Additional Soil Cover and ICs): 279.3 metric ton.
Energy Consumption	The energy use for Alternative 3 is estimated to be four times higher than the energy use for Alternative 2. This is mostly due to personnel transportation, equipment use, and installation of the 2 foot soil cover during the remedial construction phase. • Alternative 2 (Enhanced Native Soil Cover and ICs): 1,220 MMBTU • Alternative 3 (Additional Soil Cover and ICs): 4,810 MMBTU

Former Vieques Naval Training Range Solid Waste Management Unit 1 Vieques, Puerto Rico	
Criteria Air Pollutants	Pollutant and dust were the highest for Alternative 3 due to personnel transportation (air and road) during annual cover inspection and renovation of remedial action operation period.
Water Usage	This metric is not discussed in the report.
Ecological Impacts	Alternative 2 has limited impacts to the landscape, because of the small area requiring soil cover. Alternative 3 has significant temporary impacts, including site clearing of existing vegetation over 41 acres. Wildlife habitat will be destroyed for some time until vegetation is re-established for Alternative 3.
Resource Consumption	Alternative 3(~170,000 cy) uses 85 times more imported fill and top soil than alternative 2 (~2,000 cy).
Waste Generation	This metric is not discussed in the report.
Worker Safety	The accident risk for alternative 3 is the highest due to the personnel travel, borrow and fill import, equipment use for earthwork and soil coverage for the 41 acre landfill.
Community Impacts	This metric is not discussed in the report.
Conclusions	Based on the focused evaluation presented herein, the recommended remedial action alternative for the site is Alternative 2 as the environmental footprint and impact of Alternative 2 is considerably less than Alternative 3. ***Overall Protection of Human Health and the Environment.*** Alternatives 2 and 3 are both protective of the human health and environment. ***Compliance with Applicable or Relevant and Appropriate Requirements (ARARs).*** Alternatives 2 and 3 are compliant with the ARARs. ***Long-Term Effectiveness and Permanence.*** Since Alternative 3 provides additional 2-foot soil cover over the existing 2-foot native soil cover, Alternative 3 would provide a higher level long-term protection against erosion compared to Alternative 2, although the long-term effectiveness of erosion control for Alternative 2 is adequate with proper annual inspection and maintenance. ***Reduction in Toxicity, Mobility, or Volume through Treatment.*** None of the alternatives would result in any reduction of volume, toxicity or mobility by treatment. ***Short-Term Effectiveness.*** Short-term impacts of Alternative 3 are substantially higher than those of Alternative 2. Alternative 3 has significant temporary impacts, including site clearing of existing vegetation over 41 acres. ***Implementability.*** Alternatives 2 and 3 have technical implementability relative to soil cover installation. Alternative 3 would be the most complex alternative to implement because of much larger scale of construction, compared to Alternative 2. In terms of administrative feasibility, Alternative 3 would involve more erosion control permitting, since a 41-acre area would be disturbed. ***Cost*** • Alternative 2 (Enhanced Native Soil Cover and ICs): $1,258,000 • Alternative 3 (Additional Soil Cover and ICs): $6,611,000

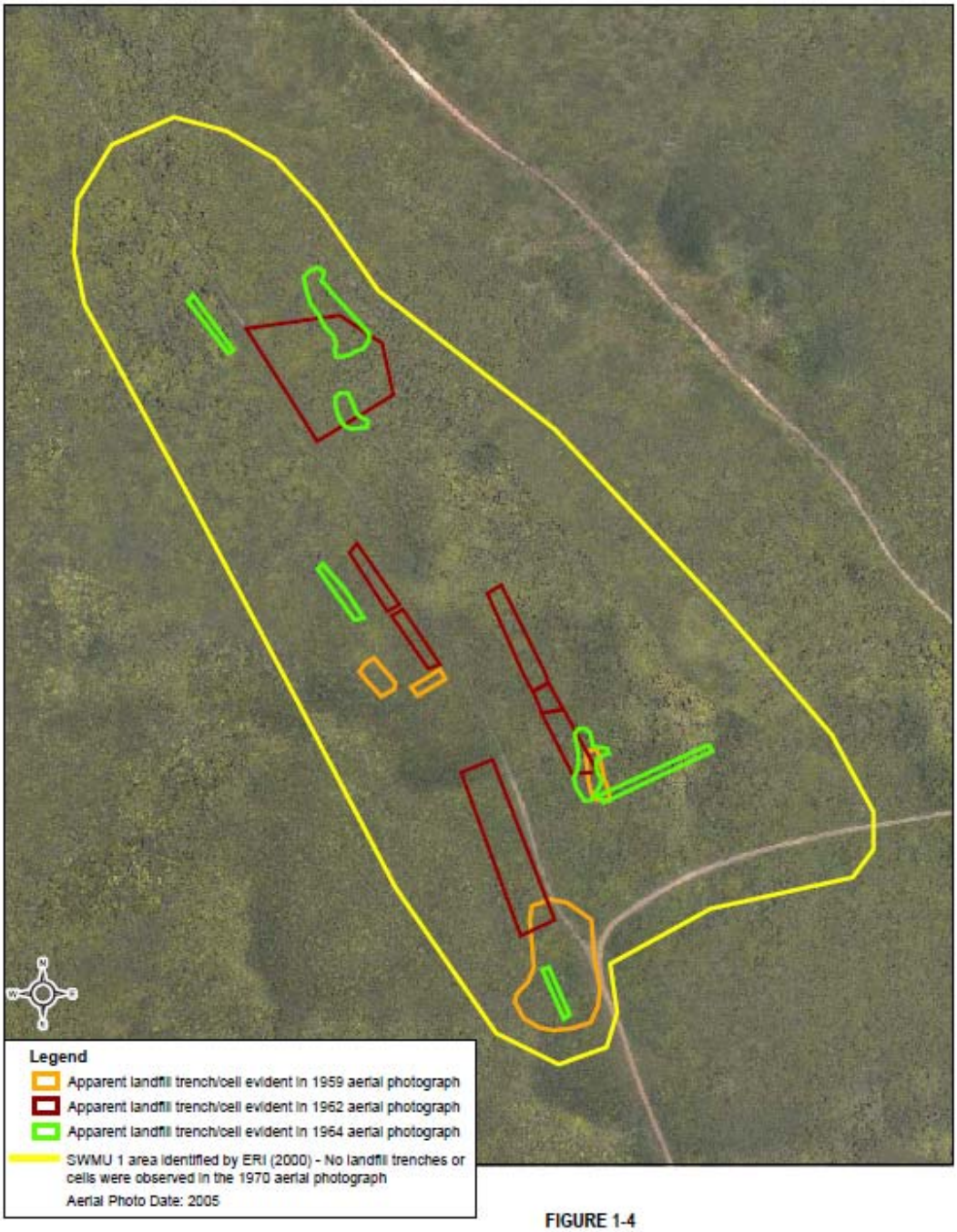


FIGURE 1-4
Composite of Features from
1959, 1962, and 1964 Aerial Photographs
Streamlined RI/FS Report for SWMU 1 (Camp Garcia Landfill)
Former Vieques Naval Training Range
Vieques, Puerto Rico

Figure 1. Site Layout for SWMU 1 Former Vieques Naval Training Range

Table 1. GSR Metrics Summary for SWMU 1 Former Vieques Naval Training Range

Remedial Alternatives	GHG Emissions (metric ton)	Total Energy Used (MMBTU)	NOx Emissions (metric ton)	SOx Emissions (metric ton)	PM10 Emissions (metric ton)	Accident Risk Fatality	Accident Risk Injury
Alternative 1 - No Action	27.1	3.15E+02	6.43E+01	1.34E+01	3.07E+00	1.44E-05	3.44E-04
Alternative 2 – Enhanced Native Soil Cover and ICs	93.1	1.22E+03	1.98E+02	4.14E+01	9.48E+00	1.31E-04	1.46E-02
Alternative 3 - Additional Soil Cover and ICs	279.3	4.81E+03	2.58E+02	5.39E+01	1.23E+01	1.46E-03	1.48E-01

Joint Expeditionary Base Little Creek Solid Waste Management Unit 3 Virginia Beach, Virginia	
FEC	**NAVFAC Mid-Atlantic**
Installation	Joint Expeditionary Base Little Creek
Location	Virginia Beach, Virginia
Site Number	Solid Waste Management Unit (SWMU) 3
Site Name	SWMU 3, Pier 10 Sandblast Yard
Phase/Milestone/Date	Engineering Evaluation /Cost Analysis (December 2012)
Site Background	SWMU 3 is located in a developed area on Little Creek Harbor's western side (see Figure 2). The site was used for sandblasting boats, anchors, and chains between 1962 and 1995. Paint chips and blast grit covered the unpaved ground south of the pad to the water's edge and the near-shore bottom of Little Creek Harbor. Historical releases from SWMU 3 likely occurred when sandblasting residue was lying directly on the ground surface or contaminants were transported via sheet flow through a catch basin connected to a Virginia Pollution Discharge Elimination System permitted outfall discharging to Little Creek Harbor. Currently, residual abrasive blast material is present on the unpaved ground surface to the water's edge and in Little Creek Harbor sediment. Previous site investigations identified potentially unacceptable risk to ecological receptors associated with exposure to metals in sediment.
Contaminants	Contaminants of concern (COCs) at the site include copper, lead, nickel, tin, zinc
Impacted Media	sediment
Remedial Technologies	This case study discusses remedial alternatives to address sediment contamination. The remedial alternatives included in the GSR analysis were as follows: • **Alternative 1**: No action • **Alternative 2**: Mechanical dredging, upland disposal, and replacement with clean fill • **Alternative 3**: Mechanical dredging, onsite solidification, upland disposal, and replacement with clean fill • **Alternative 4**: Mechanical dredging, onsite passive dewatering via geotube, upland disposal and replacement with clean fill This case study reviews Alternative 2 through 4.
GSR Evaluation Approach	The alternatives were evaluated against the NCP evaluation criteria. In addition, SiteWise™ was used to evaluate the sustainability analysis of alternatives (see Table 2).
Footprint Reduction Methodologies	This was not discussed in the report.
Greenhouse Gas Emissions	Alternative 2 has the highest GHG emissions among the alternatives evaluated. The impact driver for the GHG emissions for Alternative 2 is the use of production of Portland cement. • Alternative 2 (Mechanical dredging, upland disposal, and replacement with clean fill): 1,910 metric ton • Alternative 3 (Mechanical dredging, onsite solidification, upland disposal, and replacement with clean fill): 1,880 metric ton • Alternative 4 (Mechanical dredging, onsite passive dewatering via geotube, upland disposal and replacement with clean fill): 171 metric ton

Joint Expeditionary Base Little Creek Solid Waste Management Unit 3 Virginia Beach, Virginia	
Energy Consumption	Energy consumption is highest for Alternative 2 followed by alternative 3. The activity that consumes the most energy is the production of Portland cement. • Alternative 2 (Mechanical dredging, upland disposal, and replacement with clean fill): 11,600 MMBTU • Alternative 3 (Mechanical dredging, onsite solidification, upland disposal, and replacement with clean fill): 11,500 MMBTU • Alternative 4 (Mechanical dredging, onsite passive dewatering via geotube, upland disposal and replacement with clean fill): 2,870 MMBTU
Criteria Air Pollutants	Alternative 4 had the highest SO_X footprints from electricity to power the compressor. Alternative 3 had the highest NOx and PM10 emissions primarily due to electricity to power the compressor.
Water Usage	Alternative 4 had the highest water use from longer duration of the field work (running the compressor longer). Alternative 2 and 3 water consumption is from electricity used to power the compressor for the turbidity curtain (cooling water at the power plant). • Alternative 2 (Mechanical dredging, upland disposal, and replacement with clean fill): 23,300 gallons • Alternative 3 (Mechanical dredging, onsite solidification, upland disposal, and replacement with clean fill): 23,300 gallons • Alternative 4 (Mechanical dredging, onsite passive dewatering via geotube, upland disposal and replacement with clean fill): 31,100 gallons
Ecological Impacts	There are no potentially unacceptable ecological risks from exposure to soil, groundwater, or surface water at SWMU 3. Potentially unacceptable risks to lower-trophic level receptors from exposure to copper, lead, nickel, tin, and zinc in sediment were identified.
Resource Consumption	This metric is not discussed.
Waste Generation	This metric is not discussed.
Worker Safety	Alternative 4 also had the highest accident risk footprints primarily due to the higher number of on-site labor hours.
Community Impacts	Because excavated sediment from each alternative would require transportation and offsite disposal, there is a potential for exposing surrounding communities to the contaminants during transport and disposal.
Conclusions	Alternative 2 is effective in eliminating the potential for exposure to metals in sediment surrounding the dry dock and anchoring system that may pose potential ecological risk. Implementation of this alternative is moderately difficult using common construction practices. Costs associated with Alternative 2 are moderate, similar to Alternative 3, and less expensive than Alternative 4. Alternative 2 is the recommended alternative ***Overall Protection of human health and the environment*** Alternatives 2, 3 and 4 are very effective in eliminating potentially unacceptable risk to ecological receptors. ***Compliance with ARARs and TBCs*** Alternative 2, 3 and 4 achieves the chemical-, location-, and action-specific ARARs.

Ability to achieve removal action objective

Alternatives 2, 3 and 4 meets the remedial action objective to reduce concentrations of site COCs in sediment surrounding the dry dock and anchoring system such that remaining concentrations do not pose unacceptable risk to ecological receptors. Removal of contaminated sediment would permanently eliminate the potential threat to the environment through removal of the exposure pathway. An immediate reduction in the contaminant levels, toxicity, and volume in the sediment would be anticipated. Because the excavated materials will be disposed of at a landfill, the alternative would not meet the NCP preference of onsite treatment and site reuse over land disposal.

Sustainability

Alternative 2, 3 and 4 pose a potential environmental impact due to transportation of equipment, operation of equipment, and residual handling.

Implementability

All three alternatives would be moderate to implement. Alternatives 2, 3, and 4 are technically and administratively feasible, and resources for implementing the alternatives are readily available. Alternatives 2, 3, and 4 will follow all applicable federal and state regulations for offsite transportation and disposal activities. Alternatives 2, 3, and 4 can be accomplished utilizing standard construction methods and readily available resources.

Cost

- Alternative 2 (Mechanical dredging, upland disposal, and replacement with clean fill): $3,533,200
- Alternative 3 (Mechanical dredging, onsite solidification, upland disposal, and replacement with clean fill): $3,512,100
- Alternative 4 (Mechanical dredging, onsite passive dewatering via geotube, upland disposal and replacement with clean fill): $4,142,900

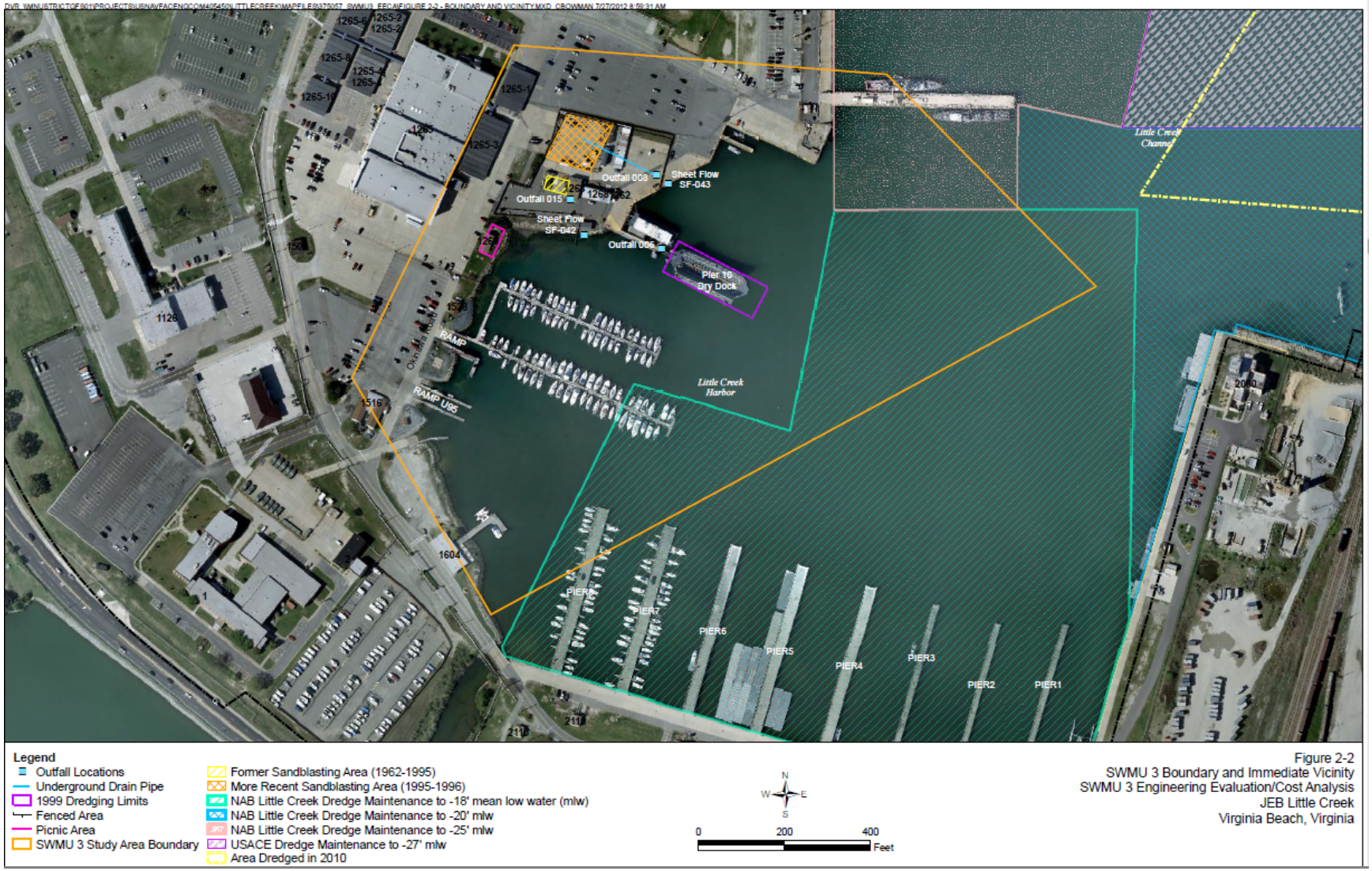


Figure 2-2
SWMU 3 Boundary and Immediate Vicinity
SWMU 3 Engineering Evaluation/Cost Analysis
JEB Little Creek
Virginia Beach, Virginia

Figure 2. Site Layout for SWMU 3 JEB Little Creek

Table 2. GSR Metrics Summary for SWMU 3 JEB Little Creek

Remedial Alternatives	GHG Emissions	Total energy Used	Water Used	NO_x emissions	SO_x Emissions	PM10 Emissions	Accident Risk Fatality	Accident Risk Injury
	metric ton	MMBTU	gallons	metric ton	metric ton	metric ton		
Alternative 1- No Action	0	0	0	0	0	0	0	0
Alternative 2 - Mechanical dredging, offsite solidification, upland disposal, and enhanced natural recovery	1.91E+03	1.16E+04	2.33E+04	1.81E-01	1.30E-01	1.13E-02	4.89E-04	9.09E-02
Alternative 3 - Mechanical dredging, onsite solidification, upland disposal, and enhanced natural recovery	1.88E+03	1.15E+04	2.33E+04	1.94E-01	1.30E-01	1.24E-02	6.22E-04	1.02E-01
Alternative 4 - Mechanical dredging, onsite passive dewatering via Geotube, upland disposal, and enhanced natural recovery	1.71E+02	2.87E+03	3.11E+04	1.42E-01	1.57E-01	8.01E-03	7.18E-04	1.28E-01

Remedial Alternatives	GHG Emissions	Total energy Used	Water Used	NO_x emissions	SO_x Emissions	PM10 Emissions	Accident Risk Fatality	Accident Risk Injury
	metric ton	MMBTU	gallons	metric ton	metric ton	metric ton		
Alternative 1- No Action	Low	Low	Low	Low	Low	Low	Low	Low
Alternative 2 - Mechanical dredging, offsite solidification, upland disposal, and enhanced natural recovery	High	High	High	High	High	High	Medium	High
Alternative 3 - Mechanical dredging, onsite solidification, upland disposal, and enhanced natural recovery	High	High	High	High	High	High	High	High
Alternative 4 - Mechanical dredging, onsite passive dewatering via Geotube, upland disposal, and enhanced natural recovery	Low	Low	High	High	High	Medium	High	High

The relative impact is a qualitative assessment of the relative footprint of each alternative, a rating of High for an alternative is assigned if it is at least 70 percent of the maximum footprint, a rating of Medium is assigned if it is between 30 and 70 percent of the maximum footprint, and a rating of Low is assigned if it is less than 30 percent of the maximum footprint.

Notes:

MMBTU - million British Thermal Unit

NOx - Nitrogen Oxides

SOx - Sulfur Oxides

PM10 - Particulate Matter

GHG - Greenhouse Gases

Joint Expeditionary Base Little Creek Solid Waste Management Unit 7b Virginia Beach, Virginia	
FEC	**NAVFAC Mid-Atlantic**
Installation	Joint Expeditionary Base Little Creek
Location	Virginia Beach, Virginia
Site Number	Solid Waste Management Unit (SWMU) 7b
Site Name	SWMU 7b Small Boats Sandblast Yard
Phase/Milestone/Date	Engineering Evaluation /Cost Analysis (January 2013)
Site Background	SWMU 7 is located in the north-central portion of the Base (see Figure 3). The site was used to sandblast and paint ships until 1996, when sandblasting activities were moved to an indoor facility. Approximately, 4,000 cubic yards (yd^3) of spent abrasive blast material (ABM) was stored in open piles in areas surrounding Desert Cove. No release controls were identified at SWMU 7; therefore, spent ABM was historically released to soils and Desert Cove.
Contaminants	Contaminants of concern (COCs) at the site include copper, lead, nickel, tin, zinc
Impacted Media	Sediment
Remedial Technologies	This case study discusses remedial alternatives to address sediment contamination. The remedial alternatives included in the GSR analysis were as follows: • **Alternative 1**: No action • **Alternative 2**: Mechanical dredging, upland disposal, and replacement with clean fill • **Alternative 3**: Mechanical dredging, on-site solidification, upland disposal, and replacement with clean fill • **Alternative 4**: Mechanical dredging, on-site passive dewatering via geotube, upland disposal and replacement with clean fill This case study reviews Alternative 2 through 4.
GSR Evaluation Approach	The alternatives were evaluated against the NCP evaluation criteria. In addition, SiteWise™ was used to evaluate the sustainability analysis of alternatives (see Table 3).
Footprint Reduction Methodologies	This was not discussed in the report.
Greenhouse Gas Emissions	Alternative 2 has the highest GHG emissions among the alternatives evaluated. The impact driver for the GHG emissions for Alternative 2 is the use of production of Portland cement. • Alternative 2 (Mechanical dredging, upland disposal, and replacement with clean fill): 563 metric ton • Alternative 3 (Mechanical dredging, onsite solidification, upland disposal, and replacement with clean fill): 553 metric ton • Alternative 4 (Mechanical dredging, onsite passive dewatering via geotube, upland disposal and replacement with clean fill): 316 metric ton
Energy Consumption	Energy consumption is highest for Alternative 2 followed by alternative 3. The activity that consumes the most energy is the production of Portland cement. • Alternative 2 (Mechanical dredging, upland disposal, and replacement with clean fill): 3640 MMBTU • Alternative 3 (Mechanical dredging, onsite solidification, upland

	disposal, and replacement with clean fill): 3620 MMBTU • Alternative 4 (Mechanical dredging, onsite passive dewatering via geotube, upland disposal and replacement with clean fill): 2450 MMBTU
Criteria Air Pollutants	Alternative 4 had the highest emissions from electricity to power the compressor and because of the longer duration of the field work.
Water Usage	Alternative 4 had the highest water use from electricity used to power the compressor for the turbidity curtain (cooling water at the power plant) and decontamination water. • Alternative 2 (Mechanical dredging, upland disposal, and replacement with clean fill): 11,300 gallons • Alternative 3 (Mechanical dredging, onsite solidification, upland disposal, and replacement with clean fill): 16,300 gallons • Alternative 4 (Mechanical dredging, onsite passive dewatering via geotube, upland disposal and replacement with clean fill): 19,400 gallons
Ecological Impacts	Potentially unacceptable risks to lower trophic-level receptors from exposure to arsenic, copper, lead, nickel, selenium, silver, tin, zinc and PAHs in sediment were identified.
Resource Consumption	This metric is not discussed.
Waste Generation	This metric is not discussed.
Worker Safety	Alternative 4 also had the highest accident risk footprints primarily due to the higher number of onsite labor hours.
Community Impacts	Because excavated sediment from each alternative would require transportation and offsite disposal, there is a potential for exposing surrounding communities to the contaminants during transport and disposal.
Conclusions	The recommended removal alternative is mechanical dredging, upland disposal, and replacement with clean fill, as described in Alternative 2. Alternative 2 will require removal of contaminated sediment and site restoration through placement of a clean sand layer. The sediment will be disposed of off-site following waste characterization. Upon completion of the removal action, the potential risk to ecological receptors will be mitigated and no further action (NFA) will be required for sediment. ***Overall protection of human health and the environment*** Alternatives 2, 3 and 4 are very effective in eliminating potentially unacceptable risk to ecological receptors. ***Compliance with ARARs and TBCs*** Alternative 2, 3 and 4 achieves the chemical-, location-, and action-specific ARARs. ***Ability to achieve removal action objective*** Alternatives 2, 3 and 4 meet the remedial action objective to reduce concentrations of site COCs in sediment such that remaining concentrations do not pose unacceptable risk to ecological receptors. Removal of contaminated sediment would permanently eliminate the potential threat to the environment through removal of the exposure pathway. An immediate reduction in the contaminant levels, toxicity, and volume in the sediment would be anticipated.

Because the excavated materials will be disposed of at a landfill, the alternative would not meet the NCP preference of onsite treatment and site reuse over land disposal.

Sustainability
Alternatives 2, 3 and 4 pose a potential environmental impact due to transportation of equipment, operation of equipment, and residual handling.

Implementability
Alternatives 2, 3, and 4 are technically and administratively feasible, and resources for implementing the alternatives are readily available. Alternatives 2, 3, and 4 will follow all applicable federal and state regulations for off-site transportation and disposal activities. Alternatives 2, 3, and 4 can be accomplished utilizing standard construction methods and readily available resources. Alternatives 3 and 4 are slightly more difficult to implement than Alternative 2 as they require construction of onsite material staging areas and would require haul truck access.

Cost

- Alternative 2 (Mechanical dredging, upland disposal, and replacement with clean fill): $1,273,600
- Alternative 3 (Mechanical dredging, on-site solidification, upland disposal, and replacement with clean fill): $1,254,300
- Alternative 4 (Mechanical dredging, on-site passive dewatering via geotube, upland disposal and replacement with clean fill): $1,738,600

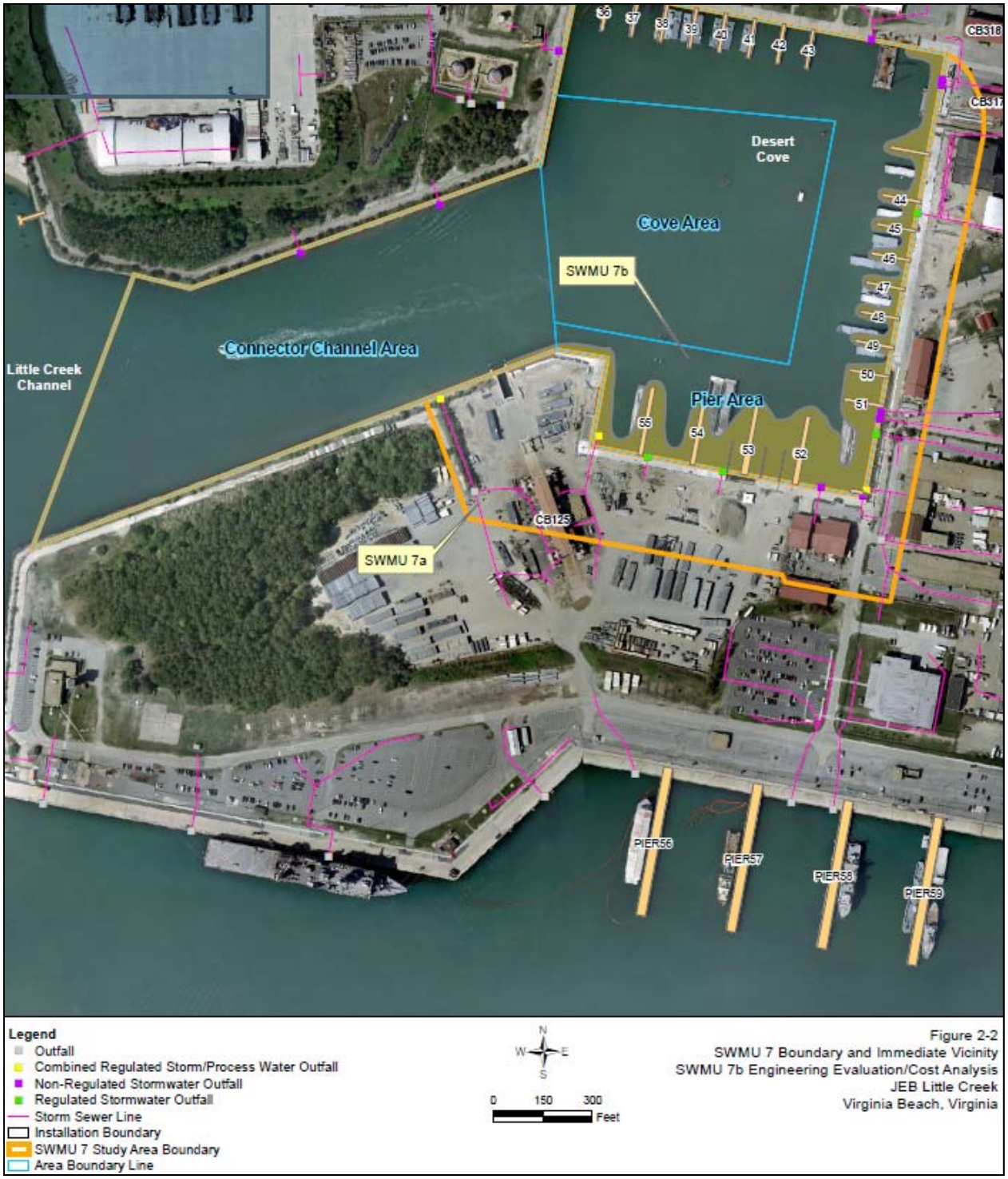


Figure 3. Site Layout for SWMU 7B Little Creek

Table 3. GSR Metrics Summary for SWMU 7B JEB Little Creek

TABLE D-4

Relative Impact of Alternatives

SWMU 7b EE/CA, JEB Little Creek, Virginia

Remedial Alternatives	GHG Emissions	Total energy Used	Water Used	NO_x emissions	SO_x Emissions	PM10 Emissions	Accident Risk Fatality	Accident Risk Injury
	metric ton	MMBTU	gallons	metric ton	metric ton	metric ton		
Alternative 1- No Action	0	0	0	0	0	0	0	0
Alternative 2 - Mechanical dredging, upland disposal, and sand layer placement	5.63E+02	3.64E+03	1.13E+04	5.33E-02	4.29E-02	3.81E-03	1.98E-04	3.48E-02
Alternative 3 - Mechanical dredging, onsite solidification, upland disposal, and sand layer placement	5.53E+02	3.62E+03	1.63E+04	5.80E-02	4.30E-02	4.23E-03	2.49E-04	3.89E-02
Alternative 4 - Mechanical dredging, onsite passive dewatering via Geotube, upland disposal, and sand layer placement	3.16E+02	2.45E+03	1.94E+04	6.23E-02	5.94E-02	4.21E-03	2.96E-04	5.05E-02

Remedial Alternatives	GHG Emissions	Total energy Used	Water Used	NO_x emissions	SO_x Emissions	PM10 Emissions	Accident Risk Fatality	Accident Risk Injury
	metric ton	MMBTU	gallons	metric ton	metric ton	metric ton		
Alternative 1- No Action	Low	Low	Low	Low	Low	Low	Low	Low
Alternative 2 - Mechanical dredging, upland disposal, and sand layer placement	High	High	Medium	High	High	High	Medium	Medium
Alternative 3 - Mechanical dredging, onsite solidification, upland disposal, and sand layer placement	High	High	High	High	High	High	High	High
Alternative 4 - Mechanical dredging, onsite passive dewatering via Geotube, upland disposal, and sand layer placement	Medium	Medium	High	High	High	High	High	High

The relative impact is a qualitative assessment of the relative footprint of each alternative, a rating of High for an alternative is assigned if it is at least 70 percent of the maximum footprint, a rating of Medium is assigned if it is between 30 and 70 percent of the maximum footprint, and a rating of Low is assigned if it is less than 30 percent of the maximum footprint.

Notes:

GHG - Greenhouse Gases

MMBTU - million British Thermal Unit

NOx - Nitrogen Oxides

PM10 - Particulate Matter

SOx - Sulfur Oxides

Marine Corps Base Camp Lejeune Site 69, Operable Unit 14 (Groundwater) Jacksonville, North Carolina	
FEC	**NAVFAC Mid-Atlantic**
Installation	Marine Corps Base Camp Lejeune
Location	Jacksonville, North Carolina
Site Number	Site 69
Site Name	Site 69, Operable Unit 14 (Groundwater)
Phase/Milestone/Date	Feasibility Study (April 2012)
Site Background	From 1950 to 1976, Site 69 was reportedly used to dispose of chemical wastes that included PCBs, solvents, and pesticides and chemical agents (see Figure 4). A letter dated October 6, 1982 refers to an interview with a former heavy equipment operator indicating that drums of possibly nerve or mustard agent were buried in trenches at Site 69 in 1953 or 1954. A second documented disposal incident occurred in 1970 when 5-gallon cans and 55-gallon drums of chlorodiphenyltrichloroethane (DDT), trichloroethene (TCE), and calcium hypochlorite were placed together in a common pit. As soil was being placed over the containers, an explosion occurred, resulting in a brush fire and ejection of drums as far as 120 ft from the pit. The source area at Site 69 appears to be the waste disposal area. The primary contaminants in the groundwater at Site 69 are chlorinated volatile organic compounds (CVOCs). The continued presence of buried waste at the site suggests that soil within the waste disposal area is contaminated.
Contaminants	1,2-DCA, 1,2,4-trichlorobenzene, 4,4-DDT, aroclor-1260, chromium, cis-1,2-DCE, dieldrin, endrin, gamma-chlordane, heptachlor epoxide, methoxychlor, TCE, trans-1,2-DCE, and VC.
Impacted Media	The impacted media is soil, surface water, sediment, and groundwater.
Remedial Technologies	Remedial alternatives for soil and groundwater are discussed in the report. The remedial alternatives for groundwater are discussed in this case study: • **Alternative 1:** No Further Action • **Alternative 2:** MNA with LUCs • **Alternative 3:** PRB with MNA and LUCs • **Alternative 4:** ERD with Bioaugmentation, MNA, and LUCs (vertical wells) • **Alternative 4b:** ERD with Bioaugmentation, MNA, and LUCs (horizontal wells) • **Alternative 5:** ISCO with MNA and LUCs
GSR Evaluation Approach	The sustainability analysis was performed using SiteWise™ (see Table 4). In addition all alternatives were compared using NCP criteria. The discussion below is focused on alternatives 2, 3, 4 and 5. Alternative 1 no further action is not reviewed for this case study.
Footprint Reduction Methodologies	This report did not address specific strategies to reduce the environmental footprint. Optimization of the environmental footprint is projected to be performed during the design phase of the project.
Greenhouse Gas Emissions	Alternative 3 had the highest GHG emissions primarily due to equipment use and consumables (ZVI) during construction of the PRB. • Alternative 2 (MNA with LUCs): 45.7 metric ton • Alternative 3 (PRB with MNA and LUCs): 810 metric ton • Alternative 4a (ERD vertical wells): 93.5 metric ton

	• Alternative 4b (ERD horizontal wells): 214 metric ton • Alternative 5 (ISCO with MNA and LUCs): 378 metric ton
Energy Consumption	Alternative 3 (PRB with MNA and LUCs) had the highest total energy consumption primarily due to equipment use and consumables (ZVI) used during construction of the PRB. • Alternative 2 (MNA with LUCs): 641 MMBTU • Alternative 3 (PRB with MNA and LUCs): 10,500 MMBTU • Alternative 4a (ERD vertical wells): 1,670 MMBTU • Alternative 4b (ERD horizontal well): 4,450 MMBTU • Alternative 5 (ISCO): 6,540 MMBTU
Criteria Air Pollutants	The alternative 3(PRB with MNA and LUCs) footprints for NOX, SOX, and PM10 emissions are highest among the groundwater alternatives and they are primarily driven by equipment use during installation of the PRB.
Water Usage	Alternative 5, ISCO, had the highest relative water use, driven by water requirements during injections. • Alternative 2 (MNA with LUCs): 0 • Alternative 3 (PRB with MNA and LUCs): 83,100 gallons • Alternative 4a (ERD vertical wells): 91,500 gallons • Alternative 4b (ERD horizontal wells): 126,000 gallons • Alternative 5 (ISCO): 516,000 gallons
Ecological Impacts	This metric was not discussed in the report.
Resource Consumption	This metric was not discussed in the report.
Waste Generation	This metric was not discussed in the report.
Worker Safety	The potential accident risk for alternative 3 is the highest of the groundwater alternatives, and is primarily due to personnel transportation to the Site for construction and long term monitoring. The potential accident risk for alternative 4a is the lowest.
Community Impacts	This metric was not discussed in the report.
Conclusions	Based on the comparative analysis, Alternative 3 had the highest GHG emissions, energy use, criteria pollutant emissions, and the highest accident risk for injury and fatality. Alternative 5, ISCO, had the highest relative water use, driven by water requirements during injections. The ERD alternatives, 4a and 4b, had similar overall environmental impacts which were slightly lower than Alternative 5, ISCO. Alternative 2, MNA, had the lowest overall relative impacts for the viable groundwater alternatives. ***Overall Protection of Human Health and the Environment***. Groundwater Alternatives 2 through 5 are suitable for treatment of groundwater contaminated with chlorinated solvents and for the reduction of risk to human and ecological risk receptors. Groundwater Alternatives 3, 4, and 5 provide active treatment to meet the RAOs. Alternative 3 is likely the best option as it is protective of human health and the environment, easily implementable and less expensive than Alternative 5. Alternative 4a is the least expensive active treatment option, however, it provides potential issues with short-term and long-term ineffectiveness due to groundwater extraction capabilities. No alternative will permanently reduce the risks as long as the contaminant source area remains intact.

Compliance with Applicable or Relevant and Appropriate Requirements (ARARs). All alternatives are expected to meet ARARs. Alternatives 2 through 5 are suitable for treatment of groundwater contaminated with chlorinated solvents and for reducing the risk to human and ecological risk receptors. Alternatives 3, 4, and 5 provide active treatment to meet RAOs.

Long-Term Effectiveness and Permanence. Alternatives 2 through 5 are expected to be effective in the long term, although "rebound" is a potential issue with any injection scenario. Active treatment is intended to treat the area of the plume with the highest concentrations of COCs and allow MNA to reduce groundwater contaminant concentrations preventing migration towards the New River. Alternative 2 (MNA) would take the longest time to achieve RAOs without active treatment. Alternative 3 (PRB) would take the longest of the active treatment alternatives because it relies on the plume to flow through the PRB, but is protective to downgradient receptors. Alternative 4 (ERD) relies on biological degradation rather than chemical or physical processes to remove contaminant mass, taking longer than Alternative 5 (ISCO), which would likely remove COCs the fastest. Distribution and rebound may hinder the effectiveness of ERD and ISCO.

Reduction in Toxicity, Mobility, or Volume through Treatment. Alternative 5 (ISCO) will quickly reduce the toxicity and volume of the plume, while under Alternative 4 (ERD) toxicity, mobility, and volume will be reduced at a relatively slower rate. Toxicity, mobility, and volume will be reduced outside of the source area with Alternative 3 (PRB) as the plume migrates. Alternative 2 (MNA) provides reduction in toxicity, mobility, or volume. Under Alternative 1, natural biodegradation will occur at unmonitored rates and at unknown locations; therefore, it must be assumed that no contaminants are treated or destroyed.

Short-Term Effectiveness. The duration of short-term exposure risk associated with implementing alternatives 3 through 5 ranges from approximately 100 days for Alternative 3 (PRB) to 3 years for Alternative 4 (ERD). Alternative 5 (ISCO) has a higher short-term risk because of the use of oxidants. Alternatives 4 and 5 are most likely to achieve RAOs in the shortest period of time because of enhanced distribution of relatively fast acting reagents, particularly chemical oxidation. Subsurface distribution is key to the effectiveness and treatment time-frame of Alternatives 4 and 5 (microbes, ERD substrate or oxidant). The time frame associated with complete dechlorination via bioremediation can be many years. Alternative 2 (MNA) likely would exhibit the least short-term effectiveness because the remediation timeline would be dictated by the rate of natural biodegradation, and Alternative 3 would be limited because it relies on groundwater to flow through the PRB as it migrates towards the New River.

Implementability. Each alternative is implementable, with materials and services readily available. However, subsurface injections rely heavily on the ability to distribute reagents uniformly at acceptable quantities. In Alternative 4, injection through vertical injection and extraction wells (Alternative 4a) would be more difficult to implement than injection through horizontal wells (Alternative 4b). Further, implementation of a trenchless PRB would be easier than injections through horizontal wells. Alternative 5 (ISCO) would require

extra health and safety precautions for the handling of the oxidant. Alternatives 4 and 5 would involve installation of 20 injection/extraction wells or 5,600 linear ft of horizontal wells.

Cost

- Alternative 2 (MNA with LUCs): $957,000
- Alternative 3 (PRB with MNA and LUCs): $6,204,000
- Alternative 4a (ERD with Bioaugmentation, MNA, and LUCs vertical wells): $2,630,000
- Alternative 4b (ERD with Bioaugmentation, MNA, and LUCs horizontal wells): $4,839,000
- Alternative 5 (ISCO with MNA and LUCs): $7,613,000

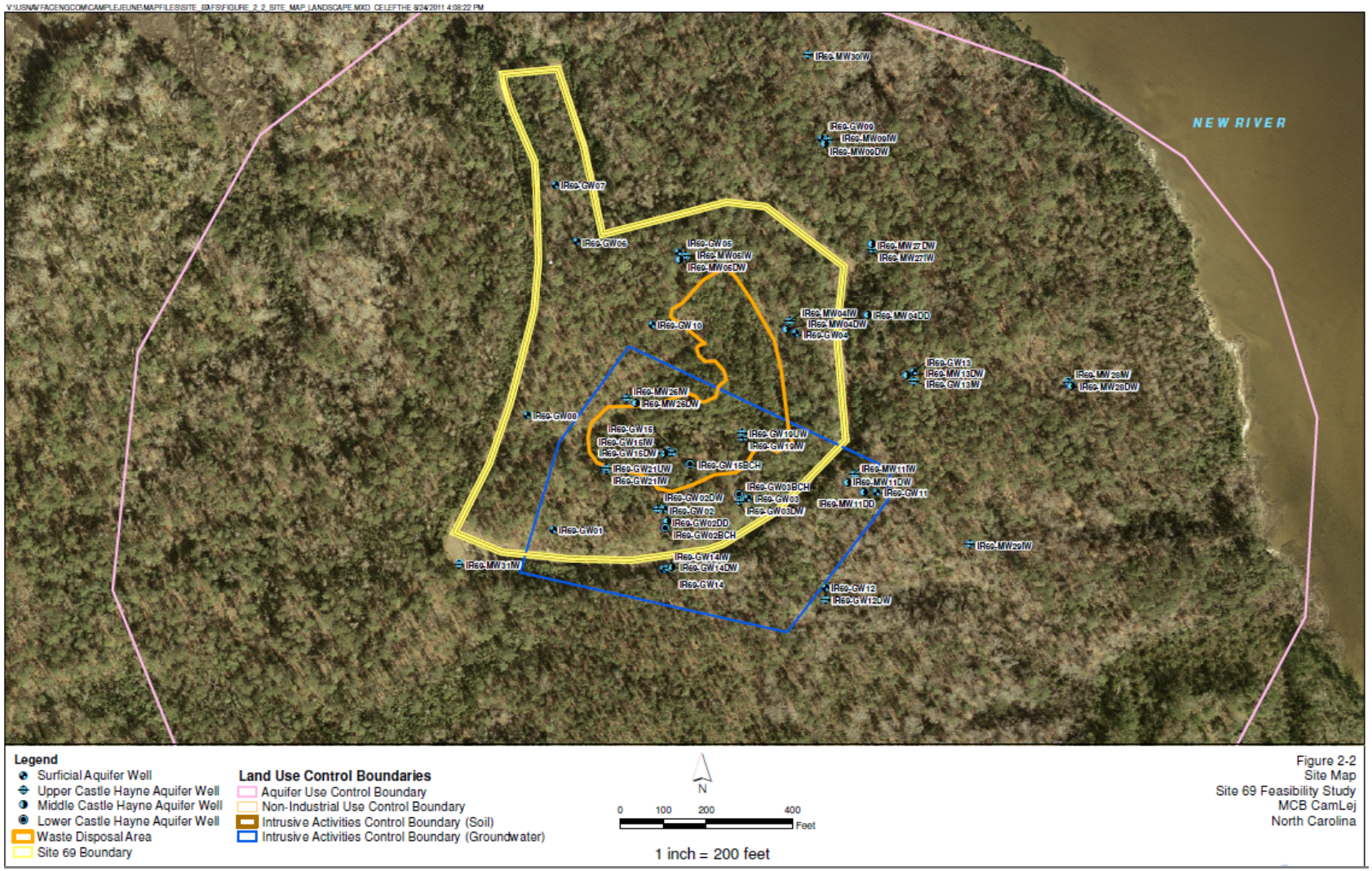


Figure 4. Site Layout for Site 69 MCB Camp LeJeune

Table 4. GSR Metrics Summary for Site 69 MCB Camp LeJeune

Sustainability Analysis Metrics Quantified for Each Groundwater Alternative

Operable Unit No. 14 (Site 69)

Feasibility Study

Marine Corps Base Camp Lejeune, North Carolina

Remedial Alternatives	GHG Emissions	Total energy Used	Water Consumption	NOx emissions	SOx Emissions	PM10 Emissions	Accident Risk Fatality	Accident Risk Injury
	metric ton	MMBTU	gallons	metric ton	metric ton	metric ton		
Alternative 1 - No Action	0	0	0	0	0	0	0	0
Alternative 2 - MNA	4.57E+01	6.41E+02	0.00E+00	4.90E-02	1.12E-02	7.29E-03	6.10E-04	4.99E-02
Alternative 3 - ZVI PRB	8.10E+02	1.05E+04	8.31E+04	2.24E+00	4.66E-01	2.04E-01	1.17E-03	1.02E-01
Alternative 4a - ERD - Vertical Wells	9.35E+01	1.67E+03	9.15E+04	1.97E-01	9.77E-02	2.01E-02	8.13E-04	6.91E-02
Alternative 4b - ERD - Horizontal Wells	2.14E+02	4.45E+03	1.26E+05	6.37E-01	1.33E-01	6.14E-02	9.53E-04	8.76E-02
Alternative 5 - ISCO	3.78E+02	6.54E+03	5.16E+05	1.01E+00	2.01E-01	9.79E-02	9.72E-04	9.49E-02

Relative Ranking

Remedial Alternatives	GHG Emissions	Total energy Used	Water Consumption	NO_x emissions	SO_x Emissions	PM_{10} Emissions	Accident Risk Fatality	Accident Risk Injury	Overall Rank
	metric ton	MMBTU	gallons	metric ton	metric ton	metric ton			
Alternative 1 - No Action	0	0	0	0	0	0	0	0	0
Alternative 2 - MNA	1	1	1	1	1	1	1	1	1
Alternative 3 - ZVI PRB	5	5	2	5	5	5	5	5	5
Alternative 4a - ERD - Vertical Wells	2	2	3	2	2	2	2	2	2
Alternative 4b - ERD - Horizontal Wells	3	3	4	3	3	3	3	3	3
Alternative 5 - ISCO	4	4	5	4	4	4	4	4	4

Notes:
MNA - monitored natural attenuation
PRB - permeable reactive barrier
ERD - enhanced reductive dechlorination
ISCO - in situ chemical oxidation
MMBTU - million Britsh Thermal Unit
NOx - Nitrogen Oxides
SOx - Sulfur Oxides
PM10 - Particulate Matter
GHG - Greeenhouse Gases
Overall Rank is the calculated average of the relative ranks rounded to the nearest whole number.

Marine Corps Base Camp Lejeune
Site 69, Operable Unit 14 (Soil)
Jacksonville, North Carolina

FEC	**NAVFAC Mid-Atlantic**
Installation	Marine Corps Base Camp Lejeune
Location	Jacksonville, North Carolina
Site Number	Site 69
Site Name	Site 69, Operable Unit 14 (Soil)
Phase/Milestone/Date	Feasibility Study (April 2012)
Site Background	From 1950 to 1976, Site 69 was reportedly used to dispose of chemical wastes that included PCBs, solvents, and pesticides and chemical gents (CA). A letter dated October 6, 1982 refers to an interview with a former heavy equipment operator indicating that drums of possibly nerve or mustard agent were buried in trenches at Site 69 in 1953 or 1954. A second documented disposal incident occurred in 1970 when 5-gallon cans and 55-gallon drums of chlorodiphenyltrichloroethane (DDT), trichloroethene (TCE), and calcium hypochlorite were placed together in a common pit. As soil was being placed over the containers, an explosion occurred, resulting in a brush fire and ejection of drums as far as 120 ft from the pit. The source area at Site 69 appears to be the waste disposal area. The primary contaminants in the groundwater at Site 69 are chlorinated volatile organic compounds (CVOCs). The continued presence of buried waste at the site suggests that soil within the waste disposal area is contaminated.
Contaminants	1,2-DCA, 1,2,4-trichlorobenzene, 4,4-DDT, aroclor-1260, chromium, cis-1,2-DCE, dieldrin, endrin, gamma-chlordane, heptachlor epoxide, methoxychlor, TCE, trans-1,2-DCE, and VC.
Impacted Media	The impacted media is soil, surface water, sediment and groundwater.
Remedial Technologies	Remedial alternatives for soil and groundwater are discussed in the report. The remedial alternatives for soil are discussed in this case study: • **Alternative 1:** No Further Action • **Alternative 2:** Land use controls (LUCs) • **Alternative 3:** Capping with LUCs • **Alternative 4:** Removal
GSR Evaluation Approach	The alternatives were evaluated against the NCP nine evaluation criteria. In addition, the sustainability analysis was performed using SiteWise™ (see Table 5). The discussion below is focused on alternatives 2 and 3. Alternative 1 no further action is not reviewed for this case study.
Footprint Reduction Methodologies	Footprint reduction will be performed in the design phase of the project to explore opportunities to optimize the environmental footprint and to integrate sustainable remediation best practices into the design, construction, and operation of the selected alternative.
Greenhouse Gas Emissions	The highest contributor for GHG emissions is alternative 4. This is primarily due to residual handling and fills transportation. • Alternative 2 (LUCs) : 61.1 metric tons • Alternative 3 (Capping with LUCs): 363 metric tons • Alternative 4 (Removal): 5,040 metric tons.
Energy Consumption	Alternative 4 has the highest energy consumption as approximately 80% of the total energy used is from residual handling and fill transportation.

	• Alternative 2 (LUCs) : 6.63 MMBTU • Alternative 3 (Capping with LUCs): 10,300 MMBTU • Alternative 4 (Removal): 92,100 MMBTU
Criteria Air Pollutants	Alternative 4 has the highest criteria air pollutants. This is because of residual handling and equipment use.
Water Usage	Alternative 4 has the highest water usage. This is because the alternative has highest residual handling and the water is used for dust suppression. • Alternative 2 (LUCs): 0 gallons • Alternative 3 (Capping with LUCs): 11,100 gallons • Alternative 4 (Removal): 21,600 gallons
Ecological Impacts	Alternative 2 alone will not prevent any ecological exposure. Alternative 3 would decrease the potential for ecological exposure. Alternative 4 would result in site disturbance, but would ultimately remove the contamination from the site.
Resource Consumption	This metric was not discussed in the report.
Waste Generation	Alternative 4 involves the removal of 140,741 cy of buried waste and impacted soils. Alternative 4 would generate the highest waste as part of removal of contaminated soil. Alternative 3 requires vegetation clearing, monitoring well abandonment and placing clean fill over the area to provide a level grade for the landfill cap. The total fill volume is estimated to be 23,664 cubic yards.
Worker Safety	Alternative 4 has the highest accident risk and fatality. This is because residual handling is the primary driver of accident risk due to the high number of trips to and from the landfill.
Community Impacts	This metric is not discussed in the report.
Conclusions	The alternatives were evaluated against the NCP criteria as listed below: ***Overall Protection of Human Health and the Environment*** Alternatives 3 and 4 are suitable for addressing buried waste and affected soil for the reduction of risk to human and ecological risk receptors, and provide an active approach to meet the RAOs. Alternative 3 is the most protective of human health and the environment as it controls the exposure to the buried waste and minimizes leaching of contaminants to groundwater. ***Compliance with ARARs*** All alternatives, except No Action and Alternative 2, are expected to meet ARARs. ***Long-term Effectiveness and Permanence*** Alternatives 3 and 4 are expected to be effective at reducing impacts of COCs in the long term. Alternative 4 will provide the most immediate solution for long-term effectiveness. Alternatives 2 and 3 are considered to meet permanence goals by maintaining LUCs over time. Alternative 4 would be a permanent remedy by effectively removing the source. ***Reduction of Toxicity, Mobility or Volume through Treatment*** Treatment is not involved with Alternative 2, so there would be no reduction in the toxicity, mobility, or volume of COCs. Alternative 3 would reduce mobility through minimized infiltration; however, no treatment is involved to reduce toxicity or volume. Reduction of toxicity, mobility, or volume would be achieved with Alternative 4.

Short-term Effectiveness

Short-term effectiveness in terms of risks to workers, the community, and the environment are minimized for Alternative 2, LUCs. Alternatives 3, Capping, and 4, Removal, pose an elevated risk to workers through the use of heavy equipment and significant soil movement, and Alternative 4 would also pose potential risk of exposure to chemicals. These risks would be minimized through the use of safety controls, appropriate PPE, and air monitoring. The duration of short-term exposure risk associated with implementing Alternative 3, Capping, is expected to be approximately 5 months. Alternative 4 would present the greatest short-term risk to workers and the community near the disposal transportation route and the environment due to the nature of materials potentially disposed of at the site; however, it also would exhibit the shortest remediation timeline while effectively addressing the source. The duration of short-term exposure risk associated with implementing Alternative 4, Removal, is expected to be approximately 6 months.

Implementability

Each alternative is implementable, with materials and services readily available. The potential presence of Chemical agent at the site requires extra health and safety precautions as well, making Alternative 4 the most difficult to implement. Additionally, there are no permitted disposal facilities that will accept CA impacted soil. Further action regarding Alternative 4 would require substantial interagency coordination with US Army Engineering and Support Center (Huntsville).

Costs

- Alternative 2 (LUCs): $46,000
- Alternative 3 (Capping with LUCs): $5,513,000
- Alternative 4 (Removal): $24,502,000

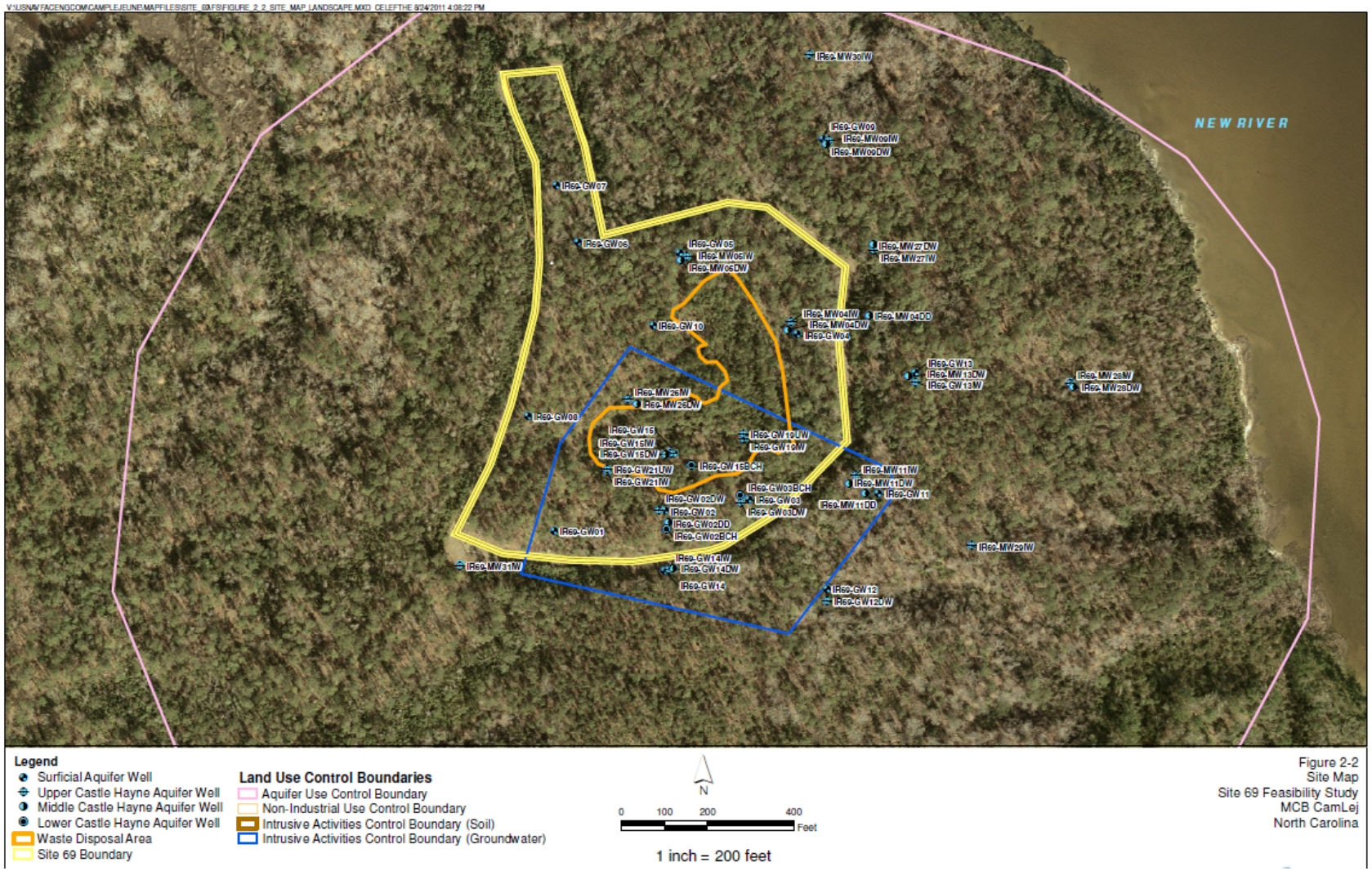


Figure 5. Site Layout for Site 69 MCB Camp LeJeune

Table 5. GSR Metrics Summary for Site 69 MCB Camp LeJeune

Sustainability Analysis Metrics Quantified for Each Soil Alternative

Operable Unit No. 14 (Site 69)

Feasibility Study

Marine Corps Base Camp Lejeune, North Carolina

Remedial Alternatives	GHG Emissions	Total energy Used	Water Consumption	NO_x emissions	SO_x Emissions	PM_{10} Emissions	Accident Risk Fatality	Accident Risk Injury
	metric ton	MMBTU	gallons	metric ton	metric ton	metric ton		
Alternative 1 - No Action	0	0	0	0	0	0	0	0
Alternative 2 - LUCs	6.11E-01	6.63E+00	0.00E+00	4.89E-04	1.58E-04	1.06E-04	1.11E-05	7.93E-04
Alternative 3 - Capping	3.62E+02	1.03E+04	1.11E+04	7.83E-01	1.74E-01	7.91E-02	7.47E-04	1.07E-01
Alternative 4 - Removal	5.04E+03	9.21E+04	2.16E+04	8.40E+00	1.75E+00	9.86E-01	1.53E-02	3.13E+00

Relative Ranking

Remedial Alternatives	GHG Emissions	Total energy Used	Water Consumption	NO_x emissions	SO_x Emissions	PM_{10} Emissions	Accident Risk Fatality	Accident Risk Injury	Overall Rank
	metric ton	MMBTU	gallons	metric ton	metric ton	metric ton			
Alternative 1 - No Action	0	0	0	0	0	0	0	0	0
Alternative 2 - LUCs	1	1	1	1	1	1	1	1	1
Alternative 3 - Capping	2	2	2	2	2	2	2	2	2
Alternative 4 - Removal	3	3	3	3	3	3	3	3	3

Notes:
LUCs - land use controls

MMBTU - million Britsh Thermal Unit
NOx - Nitrogen Oxides
SOx - Sulfur Oxides
PM10 - Particulate Matter
GHG - Greeenhouse Gases
Overall Rank is the calculated average of the relative ranks rounded to the nearest whole number.

Marine Corps Base Camp Lejeune Site 89, Operable Unit 16 (Source Area) Jacksonville, North Carolina	
FEC	**NAVFAC Mid-Atlantic**
Installation	Marine Corps Base (MCB) Camp Lejeune
Location	Jacksonville, North Carolina
Site Number	Site 89
Site Name	Site 89, Operable Unit 16 (Source Area)
Phase/Milestone/Date	Final Feasibility Study (February, 2012)
Site Background	Site 89 encompasses approximately 50 acres (see Figure 6). MCB Camp Lejeune covers approximately 236 square miles and is a training base for the United States Marine Corps. Site 89 is located on Camp Geiger, near the intersection of G and 8th Streets. The base motor pool operated on the site until 1988 and reportedly used solvents such as acetone, trichloroethene (TCE), and 2-butanone (methyl-ethylketone [MEK]) for cleaning parts and equipment. A steel 550-gallon underground storage tank (UST) was used for the storage of waste oil from 1983 until its removal in 1993. The Defense Reutilization and Marketing Office (DRMO) was operated by the Defense Logistics Agency (DLA) on the site until 2000, and the area was used as a storage yard for items such as scrap and surplus metal, electronic equipment, vehicles, rubber tires, and fuel bladders.
Contaminants	PCE, TCE, VC, 1,1,2,2-PCA, 1,1,2-TCA, cis-1,2-DCE, PCE, trans-1,2-DCE
Impacted Media	The impacted media is surface water and groundwater.
Remedial Technologies	Remedial alternatives for the downgradient area, source area, and surface water are discussed in the report. The source area remedial alternatives for groundwater are discussed in this case study: • **Alternative 1:** No Further Action • **Alternative 2:** Enhanced Reductive Dechlorination (ERD) • **Alternative 3:** In Situ Chemical Oxidation (ISCO) • **Alternative 4:** Air Sparging (AS) via Horizontal Directionally Drilled (HDD) wells
GSR Evaluation Approach	The sustainability analysis was performed using SiteWise™ (see Table 6). In addition, all alternatives were compared using NCP criteria. The discussion below is focused on alternatives 2, 3 and 4. Alternative 1 no further action is not reviewed for this case study.
Footprint Reduction Methodologies	This report did not address strategies to reduce the environmental footprint of the groundwater cleanup actions.
Greenhouse Gas Emissions	Alternative 4 (HDD AS) had the highest relative GHG primarily due to water demands and emissions from power plants supplying electricity to run the compressor and AS equipment during operation. • Alternative 2 (ERD): 74.46 metric ton • Alternative 3 (ISCO): 1041.43 metric ton • Alternative 4 (HDD AS): 1065.6 metric ton
Energy Consumption	Alternative 4 (HDD AS) had the highest total energy consumption primarily due to water demands and emissions from power plants supplying electricity to run the compressor and AS equipment during operation**.** • Alternative 2 (ERD): 1,370 MMBTU • Alternative 3 (ISCO): 14,400 MMBTU • Alternative 4 (HDD AS): 21,100 MMBTU

Marine Corps Base Camp Lejeune Site 89, Operable Unit 16 (Source Area) Jacksonville, North Carolina	
Criteria Air Pollutants	Alternative 4 (HDD AS) had the highest NOx, and SOx emissions, primarily due to emissions from power plants supplying electricity to run the compressor and AS equipment during operation. Alternative 3 (ISCO) had the highest relative PM10 emissions due to the manufacturing, transportation, and onsite handling of the large amount of persulfate required to treat the SOD of the proposed treatment area.
Water Usage	Alternative 4 (HDD AS) had the highest water consumption primarily due to water demands and emissions from power plants supplying electricity to run the compressor and AS equipment during operation. • Alternative 2 (ERD): 164,000 gallons • Alternative 3 (ISCO): 489,000 gallons • Alternative 4 (HDD AS): 1,040,000 gallons
Ecological Impacts	This metric was not discussed in the report.
Resource Consumption	This metric was not discussed in the report.
Waste Generation	This metric was not discussed in the report.
Worker Safety	Alternative 3 (ISCO) had the highest accident risk fatality and injury, primarily due to the manufacturing, transportation, and onsite handling of the large amount of persulfate required to treat the SOD of the proposed treatment area.
Community Impacts	This metric was not discussed in the report.
Conclusions	Based on comparative analysis, Alternative 2 (ERD) had the lowest relative impacts in all categories for the active treatment options. Alternative 3 (ISCO) and Alternative 4 (HDD AS) had the same overall rank. In general, the footprints for Alternative 3 (ISCO) and Alternative 4 (HDD AS) were within one order of magnitude of each other, with the exception of SOx emissions, which were almost two orders of magnitude higher for Alternative 4 (HDD AS). In general, emissions, water consumption, and energy use are greatest for Alternative 4 due to water demands and emissions from power plants supplying electricity to run the compressor and AS equipment during operation. ***Overall Protection of Human Health and the Environment***. Alternatives 2 through 4 are suitable for the treatment of groundwater containing COCs and for the reduction of risk to human receptors. ***Compliance with Applicable or Relevant and Appropriate Requirements (ARARs)***. Alternatives 2 through 4 are all expected to have similar action-specific ARARs to comply with (injections, well installation, and residuals handling). ***Long-Term Effectiveness and Permanence***. All alternatives are expected to be effective in the long-term, although "rebound" is a potential issue with any injection scenario or AS. Active treatment is intended to treat a majority of the remaining contamination and allow NA to reduce groundwater contaminant concentration to levels below regulatory limits. Alternative 2 would take the longest of the active treatment alternatives because it relies on biological degradation rather than chemical or physical processes to remove contaminant mass. Since ISCO rapidly oxidizes COCs to innocuous compounds on contact, Alternative 3 would likely remove COCs in the shortest

amount of time; however, distribution and rebound could limit the overall effectiveness of ISCO. Alternative 4 would also remove COCs within a relatively short amount of time, and air may be more effective than liquid injection if contact with impacted media is limited. Due to the possibility of rebound, multiple injections (or system restart for AS) may be required for Alternatives 2, 3, and 4; however, it is less labor- and material-intensive to restart the compressor than to reinject large quantities of substrate or oxidant. AS requires higher maintenance than the other source area alternatives. Subsurface distribution is key to the effectiveness and treatment time-frame of Alternatives 2 and 3 (microbes, ERD substrate, or oxidant).

Reduction in Toxicity, Mobility, or Volume through Treatment. Alternatives 2 through 4 would reduce toxicity, mobility and volume through treatment. Source Area Alternatives 3 and 4 would quickly reduce the toxicity and volume of COCs in groundwater through chemical oxidation or air stripping, while with Alternative 2, the toxicity, mobility, and volume of COCs would be reduced at a relatively slower rate because it is dependent on biological processes.

Short-Term Effectiveness. Short-term effectiveness, in terms of risks to workers, the community, and the environment, would be minimized

for Alternative 2 through 4 through the use of appropriate PPE and air monitoring. Alternative 3 has a highest short-term risk to the worker due to the use of oxidants and strongly corrosive chemicals and the possibility of re-injection. Alternatives 3 and 4 are most likely to achieve RAOs in the shortest period of time because of the enhanced distribution of relatively fast-acting reagents, particularly ISCO. Alternative 4 will take the shortest time to install compared with Alternatives 2 and 3.

Implementability. Each alternative is implementable, with materials and services readily available. However, subsurface liquid injections rely heavily on the ability to distribute reagents uniformly at acceptable quantities. In addition, Alternative 3(ISCO) would require extra health and safety precautions for the handling of both the oxidant and the activator. Similarly, Alternative 4 (HDD AS) relies upon a relatively uniform distribution of air. Air injected beneath the cemented sand layer or any clay lenses would likely follow this layer until it reaches the point where it is discontinuous. Alternatives 2, 3, and 4 would involve significant construction activities during installation of 105 injection wells (5,875 linear feet total) or 2,950 linear feet of horizontal wells. While HDD is more specialized than vertical drilling, the two horizontal wells can be installed from one location so set-up and breakdown costs would be relatively minor compared to 105 different well locations for Alternatives 2 and 3.

Cost

- Alternative 2 (ERD): $1,682,000
- Alternative 3 (ISCO): $4,137,000
- Alternative 4 (HDD AS): $1,360,000

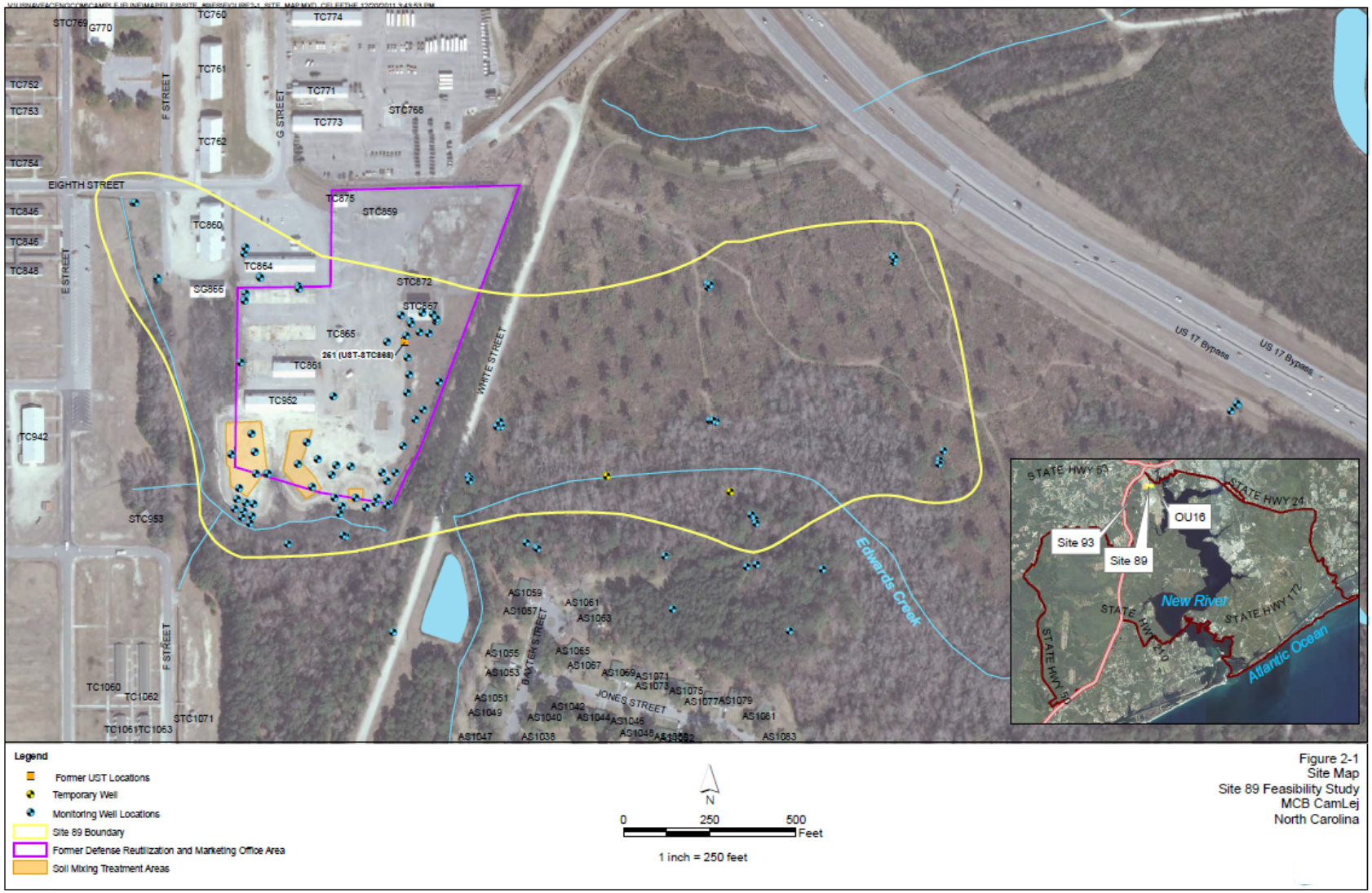


Figure 6. Site Layout for Site 89 MCB Camp LeJeune

Table 6. GSR Metrics Summary for Site 89 MCB Camp LeJeune

Sustainability Analysis Metrics Quantified for Each Source Area Alternative
Site 89 Feasibility Study
MCB CamLej
North Carolina

Remedial Alternatives	GHG Emissions	Total energy Used	Water Consumption	NO_x emissions	SO_x Emissions	PM_{10} Emissions	Accident Risk Fatality	Accident Risk Injury
	metric ton	MMBTU	gallons	metric ton	metric ton	metric ton		
ERD	74.46	1.37E+03	1.64E+05	2.27E-01	4.07E-02	1.95E-02	8.04E-05	1.84E-02
ISCO	1041.43	1.44E+04	4.89E+05	3.00E-01	5.46E-02	2.92E-02	1.82E-04	3.96E-02
HDD AS	1065.60	2.11E+04	1.04E+06	1.50E+00	5.24E+00	6.71E-03	1.20E-04	1.43E-02

Relative Ranking

Remedial Alternatives	GHG Emissions	Total energy Used	Water Consumption	NO_x emissions	SO_x Emissions	PM_{10} Emissions	Accident Risk Fatality	Accident Risk Injury	Overall Rank
	metric ton	MMBTU	gallons	metric ton	metric ton	metric ton			
ERD	1	1	1	1	1	2	1	2	1
ISCO	2	2	2	2	2	3	3	3	2
HDD AS	3	3	3	3	3	1	2	1	2

Notes:

MMBTU - million Britsh Thermal Unit

NOx - Nitrogen Oxides

SOx - Sulfur Oxides

PM10 - Particulate Matter

GHG - Greeenhouse Gases

Overall Rank is the calculated average of the relative ranks rounded to the nearest whole number.

Naval Undersea Systems Center (NUSC) Newport
Site 8 Disposal Area
Newport, Rhode Island

FEC	**NAVFAC Mid-Atlantic**
Installation	Naval Station Newport
Location	Newport, Rhode Island
Site Number	Site 8
Site Name	Site 8 Disposal Area Naval Undersea Systems Center (NUSC) Newport
Phase/Milestone/Date	Feasibility Study (July 2012)
Site Background	Site 8 is located within the Naval Undersea Warfare Center (NUWC), which is a tenant of the overall Naval Station (NAVSTA) Newport facility (see Figure 7). The NUSC Disposal Area is an area where historical operations (including materials storage, on-site disposal of inert materials, and other industrial processes within adjacent buildings) resulted in the contamination of soil, groundwater, and sediment at the site. Specific records of materials spilled or disposed since site operations began in the early 1950s are not available. However, the central, upland portion of Site 8 in the Building 185 Area is known to have been used for equipment storage, temporary hazardous waste storage, and the disposal of miscellaneous materials, including scrap lumber, tires, wire, cable, empty paint canisters, and drums containing a tar-like substance. Several former NUSC operations, including industrial plating, anodizing and chemical cleaning in a former nearby building, as well as PCB storage at an unnamed location, also had the potential to generate hazardous materials.
Contaminants	1,1-DCA, 1,1-DCE, 1,1,1-TCA, CT, Ethylbenzene, PCE, TCE, VC, 1,4-Dioxane, Arsenic, Chromium, Cobalt, Lead, Manganese, Nickel, Vanadium
Impacted Media	The impacted media are soil, groundwater, and sediment. This case study focuses on the groundwater GSR evaluation. The groundwater COCs include: • **VOCs:**1,1-DCA, 1,1-DCE, 1,1,1-TCA, CT, Ethylbenzene, PCE, TCE, VC • **SVOCs:** 1,4-Dioxane • **Inorganics**: Arsenic, Chromium, Cobalt, Lead, Manganese, Nickel, Vanadium
Remedial Technologies	The remedial alternatives included: • **GW1:** No Further Action • **GW2:** Monitored Natural Attenuation (MNA) and Land Use Controls (LUCs) • **GW3:** Enhanced In Situ Bioremediation (EISB), MNA, and LUCs • **GW4:** In Situ Chemical Oxidation (ISCO), MNA, and LUCs
GSR Evaluation Approach	The remedial alternatives were evaluated according to their ability to meet the CERCLA nine criteria as documented in the FS. In addition, the relative environmental sustainability was examined with respect to greenhouse gas and criteria pollutant emissions, energy usage, water consumption, and worker safety. This evaluation was performed using both SiteWise V2.0 tool and the GSRx model (as appropriate for some site-specific items). Refer to Table 7 for more details on a comparison of GSR metrics. The discussion below is focused on alternatives GW2, GW3, and GW4 (e.g., GW1 no further action is not reviewed for this case study, although addressed in the FS).
Footprint Reduction Methodologies	There were several considerations proposed to reduce the footprint for the groundwater remediation alternatives as follows: • For the groundwater remediation alternatives, an innovative design was considered for portable injection wellheads to be used at each well location when needed. Instead of equipping each injection well with a separate wellhead, a threaded fitting or flange could be used where the one wellhead is used to serve more than one well during the injection periods.

	• For GW4 (ISCO), it was noted that future consideration of other chemicals for the ISCO reagent should be made in order to have a lower impact during the chemical manufacturing process. • For equipment use, reducing engine idle time and staging work was considered during chemical delivery for GW3 (EISB) and GW4 (ISCO) alternatives. • Alternative transportation of personnel was considered such as carpooling or public transportation. The impacts from transportation of personnel could be lowered if the use of alternative fuels or fleet vehicles is possible. Finding transportation and materials transportation distance that are shorter than the model assumptions will also reduce fuel use impacts.
Greenhouse Gas Emissions	Alternative GW4 (ISCO) has the highest GHG emissions (by a factor of 24 to 40 times the other alternatives). This is due to contribution from the production of the ISCO reagent (the oxidant assumed for analysis is hydrogen peroxide - emissions for the production of this material are 8,558.11 metric tons of CO_2e). Refer to Table 7 for GHG emissions. • GW2 (MNA): 218.26 metric tons of CO_2e • GW3 (EISB): 374.36 metric tons of CO_2e • GW4 (ISCO): 8,876.66 metric tons of CO_2e
Energy Consumption	Energy consumption for alternative GW4 (ISCO) was highest (by a factor of 21 to 71 times the other alternatives). This is due primarily to the energy consumption in the production of hydrogen peroxide (e.g., the ISCO reagent). Refer to Table 7 for more details. • GW2 (MNA): 3,219.73 MMBTU • GW3 (EISB): 10,773.76 MMBTU • GW4 (ISCO): 230,975.13 MMBTU
Criteria Air Pollutants	Emissions for NOx, SOx, and PM10 were lowest for alternative GW2 (MNA) primarily from the use of laboratory analytical services. The highest emissions for SOx and PM10 were for GW4 (ISCO) due to the production of the ISCO reagent. The highest emissions for NOx were for GW3 (EISB) due to the use of laboratory analytical services.
Water Usage	Water consumption was highest for alternative GW3 (EISB) due to the production of vegetable oil (by a factor of 5 over GW4 [ISCO]). The water usage for alternative GW4 (ISCO) was due primarily to PVC production used for ISCO injection wells. Refer to Table 7 for more details. • GW2 (MNA): 0 gallons • GW3 (EISB): 178,838 gallons of water • GW4 (ISCO): 38,253 gallons of water
Ecological Impacts	No environmental impacts were noted for GW2 (MNA). For GW3 (EISB), the impacts from the injection of electron-donor compound were considered minimal as long as transport to surface water was minimized (low risk). For GW4 (ISCO), the impacts from ISCO injection were considered moderate as long as transport to surface water was minimized (moderate risk). The Navy determined that Alternative GW3 (EISB) would be the "Least Environmentally Damaging Practicable Alternative" to protect wetland resources, because it addresses contamination within and adjacent to wetlands and waterways, and minimizes both temporary and permanent alteration of wetlands and aquatic habitats on-site. GW3 (EISB) would more quickly remediate the groundwater plumes compared to GW2 (MNA) and without the strong chemical oxidants of GW4 (ISCO) that could impact wetland areas.

Naval Undersea Systems Center (NUSC) Newport Site 8 Disposal Area Newport, Rhode Island	
Resource Consumption	This metric was not addressed in this report for the groundwater remedy.
Waste Generation	This metric was not addressed in this report for the groundwater remedy.
Worker Safety	For all alternatives, the activity with the highest risk of fatality and injury is the transportation of personnel. Refer to Table 7 for more details. Alternative GW2 (MNA) had the lowest accident risk fatality and the lowest accident risk injury.
Community Impacts	It was determined that the implementation of Alternatives GW2, GW3, and GW4 would not adversely impact the surrounding community.
Conclusions	The report provides an evaluation of viable remedial alternatives but does not recommend a preferred alternative. ***Overall Protection of Human Health and the Environment***. Alternatives GW2, GW3 and GW4 would all be protective of human health through the reduction of COCs over time and the implementation of LUCs and/or active remediation to prevent exposure to COCs during the interim. Alternative GW4 provides the best protection, because ISCO would treat the areas with high concentrations of CVOCs in what may be the shortest amount of time; however, the timeframe for remediation under Alternative GW3 is comparable. In Alternative GW2, CVOCs would persist for the longest period of time due to the slower rate of natural attenuation. ***Compliance with Applicable or Relevant and Appropriate Requirements (ARARs)***. Alternatives GW2, GW3, and GW4 would comply with location- and action-specific ARARs and to-be-considered (TBC) criteria. ***Long-Term Effectiveness and Permanence***. Alternatives GW3 and GW4 would provide long-term effectiveness and permanence through a combination of treatment, MNA, and LUCs, whereas Alternative GW2 would provide effectiveness and permanence through MNA and LUCs alone. The treatment technologies involved in Alternative GW3 and GW4 are reliable for the target COCs. Alternative GW4 (5 to 30 years) has the potential to achieve chemical-specific ARARs in a shorter timeframe than GW3 (15-35 years). ***Reduction in Toxicity, Mobility, or Volume through Treatment.*** Alternative GW3 and GW4 would effectively reduce the toxicity, mobility, and volume of groundwater COCs through active treatment of the highest CVOC concentrations and MNA of the residual plume. EISB and ISCO would permanently and irreversibly remove an estimated 0.33 pounds of CVOCs (0.001 pounds of PCE, 0.08 pounds of TCE, 0.003 pound of vinyl chloride, 0.03 pounds of 1,1,1-TCA, 0.22 pounds of 1,1-DCA and 0.00001 pounds of carbon tetrachloride) from groundwater. In addition, ISCO would remove 0.0007 pounds of 1,4-dioxane from groundwater. ***Short-Term Effectiveness.*** Alternative GW2 would result in the lowest short-term risk to site workers, with the potential for exposure only during monitoring well installation and groundwater sampling. During Alternative GW4, workers would also be required to handle strongly oxidizing (hazardous) chemicals. The nutrient substrate to be used under Alternative GW3 is non-hazardous. ***Implementability.*** For all three alternatives, contractors and equipment are readily available. Alternative GW2 would be the easiest to implement because of the minimal construction effort and the ease of conducting a long-term monitoring program. Technical implementation of the various components of Alternatives GW3 and GW4 would be feasible, although handling of the oxidizing agent in Alternative GW4 would

add to the difficulty of implementation. Under Alternatives GW3 and GW4, there is uncertainty associated with the distribution of chemicals injected into the bedrock because of the heterogeneity in bedrock fractures.

Cost.

- GW2 (MNA): $1,880,000
- GW3 (EISB): $7,177,000
- GW4 (ISCO): $6,913,000

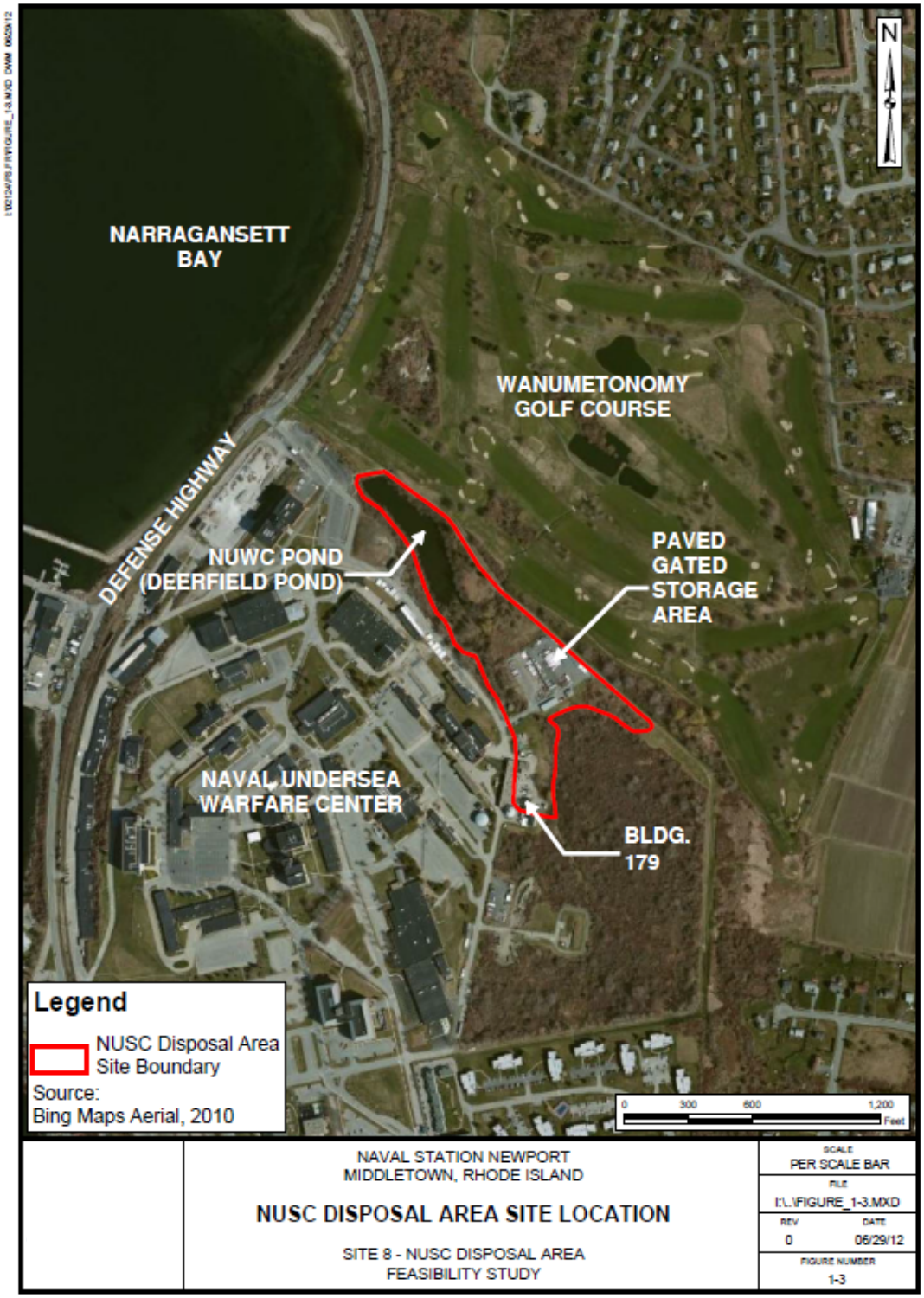


Figure 7. Site Layout for the NUSC Newport Site 8 Disposal Area

Table 7. GSR Metrics Summary for the NUSC Newport Site 8 Disposal Area

Alternative	Activities	GHG Emissions	Total Energy Used	Water Impacts	NOx Emissions	SOx Emissions	PM10 Emissions	Accident Risk Fatality	Accident Risk Injury
		metric ton	MMBTU	gallons	metric ton	metric ton	metric ton		
GW2	Materials Production	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	NA	NA
	Transportation-Personnel	16.01	201.33	NA	5.92E-03	2.09E-04	1.20E-03	3.28E-04	2.64E-02
	Transportation-Equipment	0.00	0.00	NA	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Equpiment Use and Misc	202.26	3,018.40	0.00	7.00E-01	4.67E-01	1.77E-02	0.00E+00	0.00E+00
	Residual Handling	0.00	0.00	NA	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	218.26	3,219.73	0.00	7.06E-01	4.67E-01	1.89E-02	3.28E-04	2.64E-02
GW3	Materials Production	78.67	6,591.74	141,552.91	1.24E-01	1.24E-01	1.33E-02	NA	NA
	Transportation-Personnel	33.00	415.13	NA	4.30E-04	4.30E-04	2.48E-03	6.75E-04	5.44E-02
	Transportation-Equipment	1.71	22.32	NA	9.51E-06	9.51E-06	4.78E-05	4.42E-06	3.56E-04
	Equpiment Use and Misc	232.63	3,727.04	37,285.17	4.84E-01	4.84E-01	4.10E-02	8.98E-05	2.26E-02
	Residual Handling	1.34	17.52	NA	7.46E-06	7.46E-06	3.75E-05	3.90E-06	3.14E-04
	Total	347.36	10,773.76	178,838.08	6.08E-01	6.08E-01	5.68E-02	7.74E-04	7.76E-02
GW4	Materials Production	8,596.38	226,690.73	36,198.99	0.00E+00	1.40E+01	5.30E+00	NA	NA
	Transportation-Personnel	31.44	395.47	NA	1.16E-02	4.10E-04	2.36E-03	6.44E-04	5.18E-02
	Transportation-Equipment	10.17	132.78	NA	3.20E-03	5.66E-05	2.84E-04	2.54E-05	2.04E-03
	Equpiment Use and Misc	237.70	3,743.49	2,053.66	9.70E-01	5.09E-01	3.58E-02	6.57E-05	1.65E-02
	Residual Handling	0.97	12.66	NA	3.05E-04	5.39E-06	2.71E-05	3.12E-06	2.51E-04
	Total	8,876.66	230,975.13	38,252.65	9.85E-01	1.46E+01	5.34E+00	7.38E-04	7.06E-02

Naval Weapons Industrial Reserve Plant Calverton Southern Area Groundwater Plume Calverton, New York

FEC	**NAVFAC Mid-Atlantic**
Installation	Naval Weapons Industrial Reserve Plant Calverton
Location	Calverton, New York
Site Number	N/A
Site Name	Southern Area Groundwater Plume NWIRP
Phase/Milestone/Date	Corrective Measure Study (CMS)/Feasibility Study (FS) (March 2011)
Site Background	NWIRP Calverton was a government-owned, contractor-operated (GOCO) facility owned by the Navy and operated by Northrop Grumman Corporation (NGC). The facility supported aircraft design and production at NGC-operated NWIRP Bethpage, also on Long Island in New York. Hazardous waste generation at the facility was related to metal finishing processes such as metal cleaning and electroplating. The painting of aircraft and components resulted in additional waste generation. The operations at NWIRP Calverton ceased in 1996 and the land was returned to Navy control. Currently, there are no operational activities or process-type operations being conducted at the Calverton facility that could generate hazardous waste. The Southern Area plume begins within NWIRP boundaries at Sites 6A and 10B and extends off property to the southeast with the downgradient edge ending at the Peconic River.
Contaminants	VOCs including DCA, TCA, DCE, VC, TCB, PCE, DCBs, benzene, ethylbenzene, naphthalene, total xylenes, isopropyl benzene, chloroethane, methylene chloride
Impacted Media	The impacted media is groundwater, surface water and sediments.
Remedial Technologies	There would be no adverse impacts to human health or ecological risks from exposure to site-related contaminants in surface water or sediment in the Peconic River. Additionally, there were no constituent of concern (COC) exceedances of the chemical-specific ARARs or TBCs for these media. Therefore, remedial alternatives directly addressing surface water and sediment were not necessary. This case study discusses remedial alternatives for groundwater in detail: • **Alternative 1:** No Further Action • **Alternative 2:** Land Use Controls (LUCs) • **Alternative 3:** LUCs and Monitored Natural Attenuation (MNA) • **Alternative 4:** Air Sparge (AS), MNA, and LUCs • **Alternative 5:** Anaerobic Enhanced in Situ Biodegradation (EISB), MNA and LUCs • **Alternative 6:** EISB, AS, MNA, and LUCs • **Alternative 7:** Groundwater Extraction, Treatment and Infiltration Gallery, MNA, and LUCs
GSR Evaluation Approach	This evaluation was performed using a hybrid model consisting of the Navy's SiteWise™ tool supplemented with Tetra Tech's GSRx model as appropriate for some site-specific items. In addition, all alternatives were compared using NCP criteria. The discussion below is focused on alternatives 2, 3, 4, 5, 6 and 7. Alternative 1 no further action is not reviewed for this case study.
Footprint Reduction Methodologies	All Alternatives: • Optimize routine site activities such that travel requirements are minimized. Similarly, encourage site workers to carpool to the site to reduce total vehicle mileage and related energy use and emissions.

	• Worker risk can be minimized if travel distances are minimized. • Any opportunity for material minimization or substitution should be taken. Steel is a large contributor to energy use and GHG emissions for all alternatives. If an alternative to steel is available it should be utilized. • Perform an evaluation for waste and material minimization. Alternatives 3 through 7: • Some reduction of the environmental footprint, particularly GHG emissions, could be realized for all alternatives during implementation through the possible use of emission control measures such as alternate fuel sources (e.g., biodiesel), equipment exhaust controls (e.g., diesel), and equipment idle reduction. • As part of periodic optimization, reduce the monitoring frequency from annual to biannual or every five years as warranted by periodic optimization reviews of monitoring results. Likewise, periodically reduce the number of monitoring wells and analyses as warranted by monitoring results. Alternatives 4 through 7: • Consider using fly ash in all concrete mixtures for well pads. Alternatives 4, 6, and 7: • Optimize mechanical components and treatment components (e.g., variable speed motors and pulse operation of the air sparge system) to reduce overall electricity usage and treatment residuals/additives. Alternatives 4, 5, 6, and 7: • As part of periodic optimization, continually assess RAOs and the results of treatment. Reduce the footprint of target treatment zones and the frequency and/or duration of treatment as warranted by monitoring results. Transition to MNA as soon as conditions are favorable to effectively remediate residual contaminants.
Greenhouse Gas Emissions	The largest contributor of GHG emissions is Alternative 7 due to GHG generated during production of electricity for operating the extraction system during the RA-O phase. GHG emissions for Alternatives 2, 3, and 5 are minimal compared to the Alternatives 4, 5, 6 and 7. Production of electricity for operating the air sparge system is the primary GHG impact driver for Alternatives 4 and 6. GHG emissions for Alternative 3 are driven by production of steel for bollards and Alternative 5 is driven by the production of emulsified oil injected as part of the EISB remedy component. Transportation is the only driver for Alternative 2. • Alternative 2 (LUCs): 3.51 metric ton • Alternative 3(LUCs and MNA): 35.85 metric ton • Alternative 4 (AS, MNA, and LUCs): 4915.91 metric ton • Alternative 5 (EISB, MNA and LUCs) : 395.6 metric ton • Alternative 6 (EISB, Air Sparge, MNA, and LUCs): 3,754.94 metric ton • Alternative 7 (Groundwater Extraction, Treatment, and Infiltration Gallery, MNA, and LUCs): 5,447.78 metric ton required.
Energy Consumption	The largest amount of energy is consumed during implementation of Alternative 7 due to the electricity demand required during the RA-O phase. Alternatives 4 and 6 are less, but comparable in magnitude of energy usage (97,600 and 85,000

	MMBTU, respectively) due to electricity demand of mechanical equipment during the RA-O phase. Energy use for Alternative 5 is driven by manufacture of emulsified oil product. • Alternative 2 (LUCs): 38.44 MMBTU • Alternative 3 (LUCs and MNA): 982.97 MMBTU • Alternative 4 (Air Sparge, MNA, and LUCs) : 97,643.91 MMBTU • Alternative 5 (EISB, MNA and LUCs): 20,318.92 MMBTU • Alternative 6 (EISB, Air Sparge, MNA, and LUCs): 85,300 MMBTU • Alternative 7 (Groundwater Extraction, Treatment and Infiltration Gallery, MNA, and LUCs): 123,000 MMBTU
Criteria Air Pollutants	Alternative 7 results in the highest emissions of SOx and PM10 emissions (4.83 and 0.16 tons, respectively). The SOx emissions for Alternative 7 are primarily during the RA-O phase from extraction and treatment system operation and PM10 emissions are driven by manufacture of the high density polyethylene (HDPE) material for the system tanks.
Water Usage	The highest level of water usage is associated with Alternative 4. Alternative 4 water usage is driven by water demand associated with producing electricity that is required for operating the air sparge equipment during the RA-O phase. Alternatives 6 and 7 consume less, but comparable amounts of water related to production of electricity required for operating mechanical systems during the RA-O phase (3.2 and 4 million gallons, respectively). Water usage for Alternative 5 was less than Alternatives 4, 6, and 7 and the primary contributor to Alternative 5 water usage is EISB substrate dilution. • Alternative 2 (LUCs): 0 • Alternative 3(LUCs and MNA): 8530 gallons • Alternative 4 (AS, MNA, and LUCs): 4,150,000 gallons • Alternative 5 (EISB, MNA and LUCs): 381,000 gallons • Alternative 6 (EISB, Air Sparge, MNA, and LUCs): 3,180,000 gallons • Alternative 7 (Groundwater Extraction, Treatment and Infiltration Gallery, MNA, and LUCs): 3,970,000 gallons
Ecological Impacts	No unacceptable ecological risks are identified with the Southern Area plume.
Resource Consumption	This metric is not discussed in the report.
Waste Generation	Alternatives 3, 4, 5, 6 and 7 would generate waste. None of the waste generated would be classified as RCRA hazardous waste. Alternative 7 would generate the maximum waste (approximately 75 tons per year of dewatered sludge and 160 million gallons of water per year to an infiltration gallery for treatment).
Worker Safety	Alternative 7 has the greatest worker risk because of the large amount of travel needed for frequent O&M of the treatment system and to regularly manage and dispose of wastes, such as generated treatment sludge.
Community Impacts	This metric is not discussed in the report.
Conclusions	The life cycle cost for Alternative 7 (GW Extraction) is the highest ($20.2 million) and this alternative also presents the highest environmental impact, followed by Alternatives 6 (EISB/AS at $11.7 million) and 4 (AS/MNA at $9.6 million), respectively. If Alternative 6 (EISB/AS) is chosen over Alternative 7 (GW Extraction), this offers a 30 percent reduction in GHG and a 42 percent reduction in cost. If Alternative 4 (AS/MNA) is chosen over Alternative 7 (GW

Extraction), GHG emissions would be reduced by 10 percent with a 52 percent decrease in cost. If Alternative 5 (EISB/MNA) is chosen, when compared to Alternative 4 (AS/MNA), Alternative 5 will emit 92 percent less GHG emissions if implemented and cost 30 percent less.

Overall Protection of Human Health and the Environment. Alternative 2, 3, 4 5, 6 and 7 would be protective of human health and the environment.

Compliance with Applicable or Relevant and Appropriate Requirements (ARARs). Alternative 2 and 3 would not comply with New York State groundwater quality classification (GA) (6NYCRR 701.15) and associated MCLs (10NYCRR5, Subpart 5-1.51 to 5-1.52) for the sole source aquifer in Suffolk County, New York. In the long term, alternatives 4, 5, 6 and 7 would comply with ARARs.

Long-Term Effectiveness and Permanence. Alternative 2, 3, 4, 5, 6 and 7 would be effective in the long term.

Reduction in Toxicity, Mobility, or Volume through Treatment. There would be no reduction of toxicity, mobility, or volume through treatment under alternative 2 and 3. There would be reduction of toxicity but no reduction in mobility or volume through alternative 4, 5, 6 and 7.

Short-Term Effectiveness. There would be no risk to human health or the community during implementation of alternative 2, 3, 4, 5 and 6.

Implementability. Alternative 2, 3 and 4 can be easily implemented. Alternative 5 and 6 can be easily implemented with the exception of biobarrier No. 5, which would require several approvals. Implementation of Alternative 7 would be challenging as parts of the alternative would require approvals from several government agencies and private property owners.

Cost

- Alternative 2 (Land Use Controls (LUCs): $207,000
- Alternative 3 (LUCs and MNA): $2,400,000
- Alternative 4 (Air Sparge, MNA, and LUCs): $9,600,000
- Alternative 5 (EISB, MNA and LUCs): $6,700,000
- Alternative 6 (EISB, Air Sparge, MNA, and LUCs): $11,700,000
- Alternative 7 (Groundwater Extraction, Treatment and Infiltration Gallery, MNA, and LUCs): $20,000,000

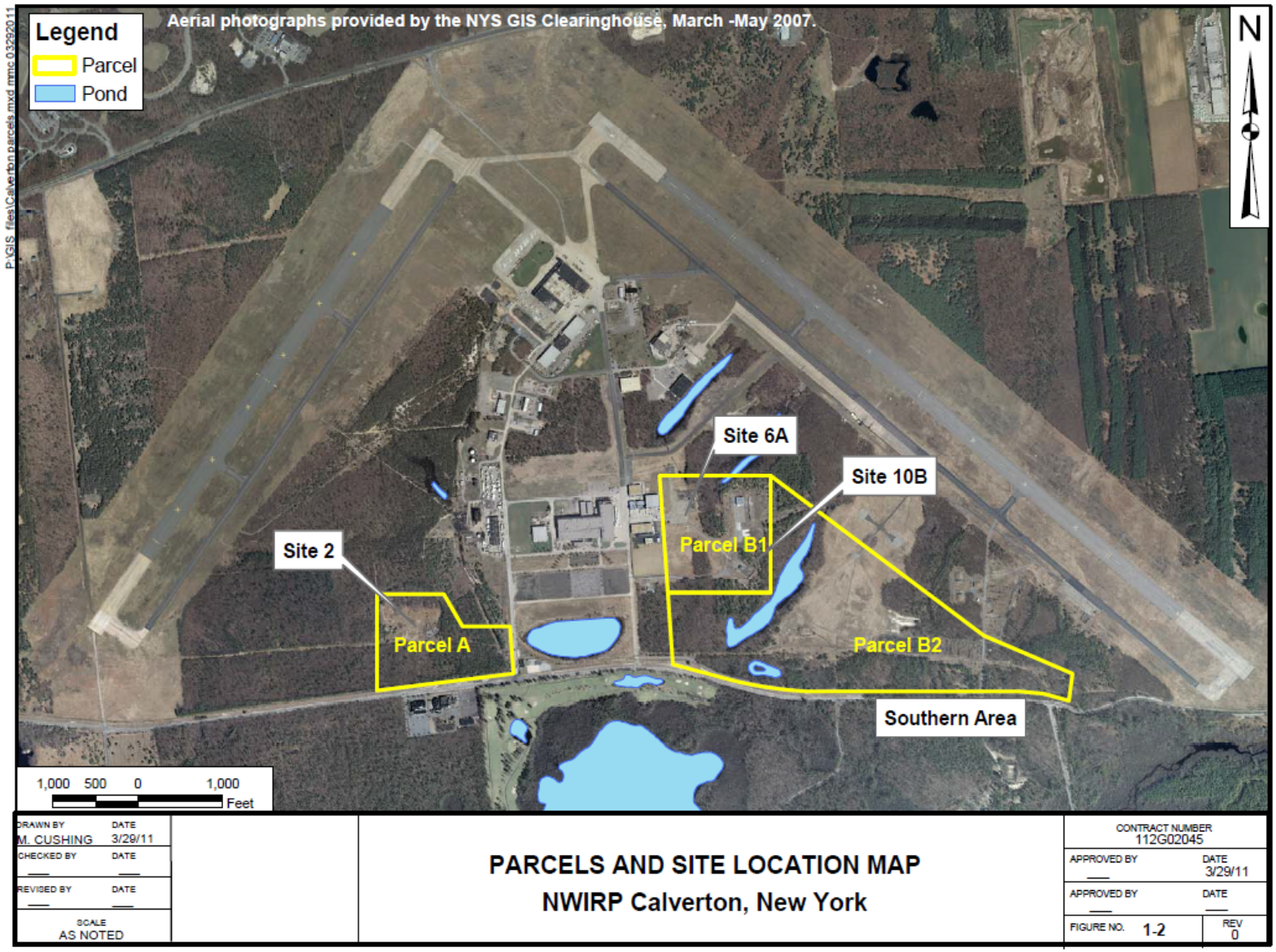


Figure 8. Site Layout for Southern Area Groundwater Plume NWIRP Calverton

Table 8. GSR Metrics Summary for Southern Area Groundwater Plume NWIRP Calverton

SUSTAINABILITY EVALUATION SUMMARY OF RESULTS
SOUTHERN AREA PLUME CORRECTIVE MEASURES STUDY
NWIRP CALVERTON, NEW YORK

Remedial Alternative	GHG Emissions (metric ton)	Total Energy Used (MMBTU)	Water Consumption (gallons)	NO_x Emissions (metric ton)	SO_x Emissions (metric ton)	PM_{10} Emisssions (metric ton)	Accident Risk Fatality	Accident Risk Injury
Alternative 2								
Land-Use Controls (LUCs)	3.51	38.44	0	3.78E-03	9.07E-04	5.67E-04	7.91E-05	5.67E-03
Alternative 3								
Monitored Natural Attenuation (MNA) & LUCs	35.85	982.97	8.53E+05	6.57E-02	1.46E-02	6.26E-03	2.96E-04	2.14E-02
Alternative 4								
Air Sparge, MNA, & LUCs	4,915.91	97,643.91	4.15E+06	9.99E+00	4.62E+00	1.15E-01	1.84E-03	1.33E-01
Alternative 5								
Anaerobic Enhanced In Situ Bioremediation (EISB), MNA, & LUCs	395.60	20,318.92	3.81E+05	6.97E-01	2.78E-01	7.22E-02	6.51E-04	4.85E-02
Alternative 6								
Air Sparge, Anaerobic EISB, MNA, & LUCs	3,754.94	8.53E+04	3.18E+06	7.60E+00	3.41E+00	1.44E-01	1.93E-03	1.41E-01
Alternative 7								
Extraction, Treatment, Infiltration, MNA, & LUCs	5,447.78	1.23E+05	3.97E+06	8.47E+00	4.83E+00	1.60E-01	4.52E-03	3.28E-01

Portsmouth Naval Shipyard Operable Unit 7 Kittery, Maine	
FEC	**NAVFAC Mid-Atlantic**
Installation	Portsmouth Naval Shipyard
Location	Kittery, Maine
Site Number	N/A
Site Name	Operable Unit (OU 7)
Phase/Milestone/Date	Feasibility Study (June 2013)
Site Background	OU7 is located along the northern boundary of PNS and consists of Site 32 Topeka Pier Site (see Figure 9). OU7 encompasses approximately 19 acres (including the shoreline area). The OU7 site boundary is defined by the historical fill in this area. There are two interim offshore monitoring stations (MS-03 and MS-04) located in OU4, which could potentially be impacted by OU7 in the future if shoreline controls would fail. Currently, land use at OU7 includes office parking, equipment storage, vehicle and rail car maintenance, transducer repair, boat launching, and a hotel (Building H23 in the southeastern corner of the site). A boat ramp near Topeka Pier provides access to the intertidal area.
Contaminants	Contaminants of concern (COCs) at the site include VOCs, SVOCs, PAHs, pesticides, dioxins/furans, and inorganics.
Impacted Media	Soil, groundwater, sediment, surface water
Remedial Technologies	This case study discusses remedial alternatives to address soil contamination. The remedial alternatives included in the GSR analysis were as follows: • **Alternative 1:** No action • **Alternative 2:** Land use controls (LUCs) and Long term management of shoreline controls, • **Alternative 3:** Limited excavation in Former Timber Basin Area, Residential LUCs and Long term management of Shoreline Controls
GSR Evaluation Approach	GSR evaluation was performed using a hybrid model of SiteWise™ tool supplemented with the TetraTech developed model GSRx (see Table 9). In addition, the alternatives were evaluated against the NCP nine evaluation criteria.
Footprint Reduction Methodologies	Some recommended footprint reduction methods include: All Alternatives : • Consider ways to reduce vehicle mileage to reduce worker risk as well as energy use and emissions. Encourage site workers to carpool daily to the site to reduce total vehicle mileage. • Some reduction of the environmental footprint, particularly GHG emissions and energy consumption, could be realized for all alternatives through the possible use of emission control measures such as alternate fuel sources (e.g. biodiesel), equipment exhaust controls (e.g. diesel), and equipment idle reduction. Alternative 3: • The amount of soil needed for backfilling has a high impact on the amount of energy consumed; consider revisions and optimization of this amount to lower the need of clean borrow soil. • Consider the option of obtaining clean fill from on-site sources, or from

	the closest source available, to reduce material transportation emissions. • Consider optimization of the use of equipment, and even the type of equipment used during operations could make a difference in the environmental impacts. • Additional testing and characterization of excavated soils during the remedial investigation may reduce the amount of hazardous waste soils requiring transport to a hazardous waste facility. • If warranted by the amount of soils and transportation distance, consider transporting hazardous waste via in order to reduce emissions and energy consumption.
Greenhouse Gas Emissions	Alternative 3 has the highest greenhouse gas emissions due to the use of the excavator and the production of HDPE and borrow soil. • Alternative 2 (LUCs and Long term management of shoreline controls): 15.64 metric ton • Alternative 3 (Limited excavation , Residential LUCs and Long term management of Shoreline Controls): 51.18 metric ton
Energy Consumption	Alternative 2 has the highest energy consumption due to production of materials such as borrow soil, gravel, and equipment use. • Alternative 2 (LUCs and Long term management of shoreline controls): 525.88 MMBTU • Alternative 3 (Limited excavation , Residential LUCs and Long term management of Shoreline Controls): 1,541.39 MMBTU
Criteria Air Pollutants	Alternative 3 had the highest air emissions generated primarily during equipment use (excavator) and production of materials such as asphalt.
Water Usage	Alternative 3 has water consumption due to water used during decontamination and production of HDPE. • Alternative 2 (LUCs and Long term management of shoreline controls): 0 gallons • Alternative 3 (Limited excavation , Residential LUCs and Long term management of Shoreline Controls): 2,091.8 gallons
Ecological Impacts	OU7 provides limited habitat for some ecological receptors. No known endangered, threatened, or protected species or critical habitats are located within the boundaries of PNS, including OU7.
Resource Consumption	Alternative 3 will generate 270 tons of non-hazardous waste and 29 tons of hazardous waste.
Waste Generation	Alternative 3 generates the highest amount of waste due to limited excavation as compared to alternative 2. The bulk of the waste generated would be characterized as RCRA non-hazardous waste disposed in a permitted Treatment, Storage, and Disposal (TSD) facility.
Worker Safety	Alternative 3 had the highest risk due to transportation of personnel.
Community Impacts	This metric was not discussed in the report.
Conclusions	Alternative 3 had the overall highest environmental impact. The impact in GHG emissions and nitrous and sulfur oxide emissions are considered high and the highest contribution to this impact is the use of the excavator for soil excavation and for potential long-term maintenance activities for the shoreline controls. The impact of Alternative 3 on particulate matter emissions is also considered high with the highest contribution to these emissions being the production of asphalt. The impact that Alternative 3 has on the energy consumption is considered high

and the production of borrow soil is the highest consumer of energy. The total amount of water consumed through Alternative 3 is estimated as 2,091.8 gallons of water, where decontamination water as part of soil excavation is the activity with the highest consumption of water, making the impact on water use to be high.

Overall protection of human health and the environment
Alternatives 2 and 3 would be protective of human health and the environment.

Compliance with ARARs
Both alternatives would comply with ARARs.

Long-term effectiveness and permanence
Alternatives 2 would provide long term effectiveness and permanence so long as the LUCs are active and maintained. Alternative 3 would provide long-term effectiveness and permanence by removing contaminated soil in the former timber basin to reduce concentrations to acceptable levels in surface soil (residential) and in subsurface soil (industrial) receptors.

Reduction of toxicity, mobility, or volume through treatment
Both alternatives would not reduce contaminant toxicity, mobility, or volume through treatment because no treatment would occur.

Short-term effectiveness
Alternative 2 would not result in any short-term risk to site workers or adversely impact the surrounding community or environment because no construction actions would occur. Alternative 3 would require appropriate use of PPE and best management practices to prevent exposing site workers, the surrounding community, and the environment to contaminated materials during excavation and offsite disposal activities.

Implementability
Alternative 2 will be readily implementable. Alternative 3 is moderately implementable.

Cost

- Alternative 2: $381,000
- Alternative 3: $1,127,000

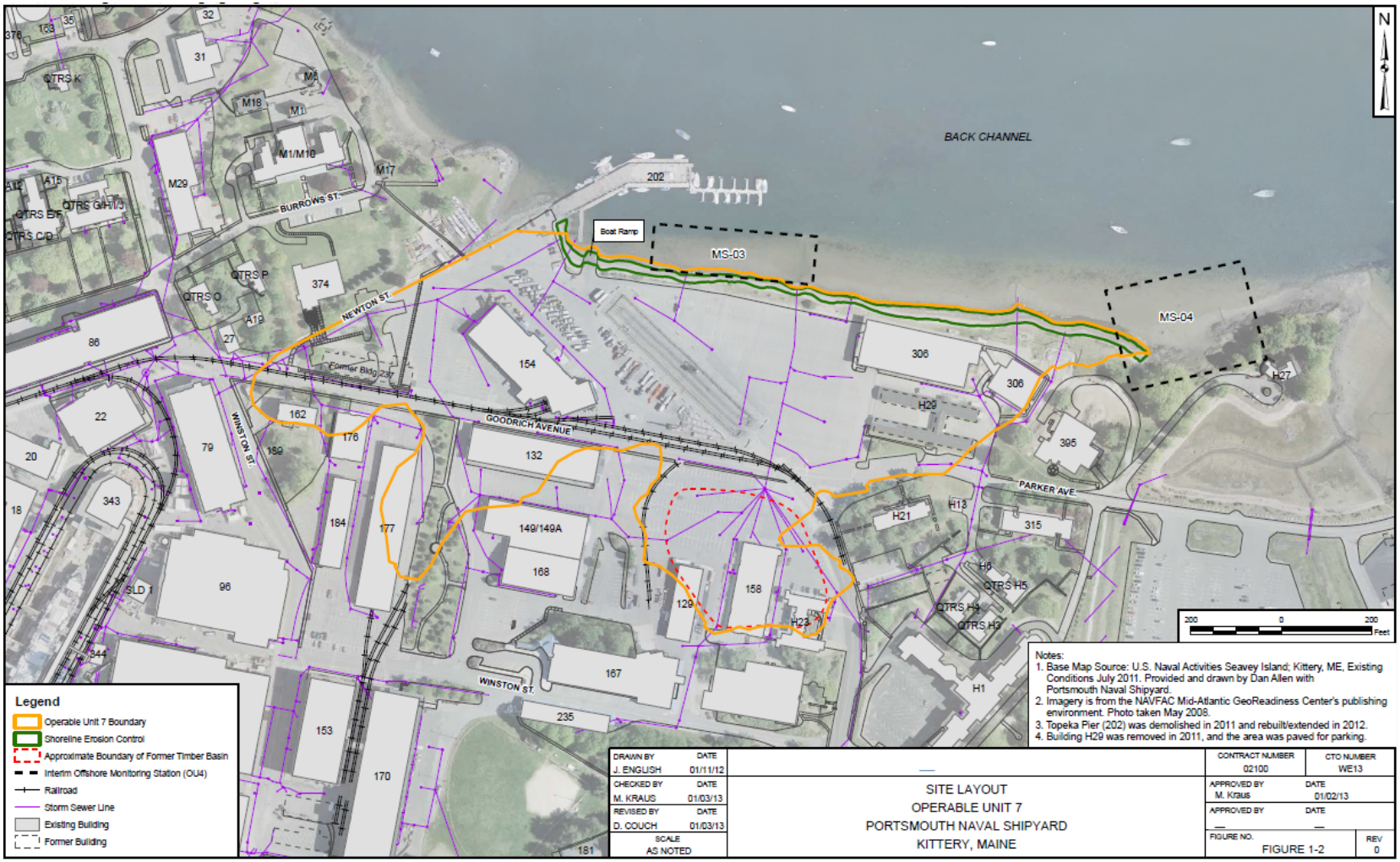


Figure 9. Site Layout for OU 7 Portsmouth Naval Shipyard

Table 9. GSR Metrics Summary for OU 7 Portsmouth Naval Shipyard

Alternative	Activities	GHG Emissions	Total Energy Used	Water Impacts	NOx Emissions	SOx Emissions	PM10 Emissions	Accident Risk Fatality	Accident Risk Injury
		metric ton	MMBTU	gallons	metric ton	metric ton	metric ton		
Alternative 2	Materials Production	0.64	52.12	0.000	0.0E+00	0.0E+00	0.0E+00	NA	NA
	Transportation-Personnel	1.26	15.82	NA	4.7E-04	1.6E-05	9.4E-05	2.6E-05	9.2E-05
	Transportation-Equipment	1.60	21.45	NA	5.1E-04	1.6E-05	4.3E-05	4.0E-06	9.7E-06
	Equipment Use and Misc	12.14	436.50	0.000	5.8E-02	1.5E-02	6.0E-03	1.2E-05	2.7E-05
	Residual Handling	0.00	0.00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.1E-05
	Total	15.64	525.88	0.000	5.9E-02	1.5E-02	6.1E-03	4.1E-05	1.4E-04
Alternative 3	Materials Production	17.69	1089.16	1006.3	0.0E+00	1.4E-02	2.1E-01	NA	NA
	Transportation-Personnel	4.50	56.56	NA	1.7E-03	5.9E-05	3.4E-04	2.1E-03	7.4E-03
	Transportation-Equipment	3.93	51.25	NA	1.2E-03	2.2E-05	1.1E-04	3.2E-04	7.8E-04
	Equipment Use and Misc	17.97	267.25	1085.6	1.1E-01	3.2E-02	1.2E-02	2.9E-03	6.8E-03
	Residual Handling	7.11	77.16	NA	2.0E-02	1.0E-02	5.5E-02	0.0E+00	9.0E-04
	Total	51.18	1541.39	2091.8	1.4E-01	5.6E-02	2.8E-01	5.3E-03	1.6E-02

Portsmouth Naval Shipyard Operable Unit 9 Kittery, Maine	
FEC	**NAVFAC Mid-Atlantic**
Installation	Portsmouth Naval Shipyard
Location	Kittery, Maine
Site Number	N/A
Site Name	Operable Unit (OU 9)
Phase/Milestone/Date	Feasibility Study (May 2013)
Site Background	OU9 is an industrial area (see Figure 10). Building 62 and Building 62 Annex are used for storage of non-hazardous materials. The majority of OU9 is relatively flat, with a gentle slope from the south of the site toward the north of Building 62 and a steep slope to the water's edge at the shoreline of the Piscataqua River Back Channel. OU9 consists of Site 34 Former Oil Gasification Plant, Building 62. The primary source of contamination at OU9 is ash from past industrial activities at Building 62 (i.e., oil gasification and blacksmithing).
Contaminants	Contaminants of concern (COCs) at the site include carcinogenic PAHs (benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenzo(a,h)anthracene, and indeno(1,2,3-CD)pyrene)
Impacted Media	Soil
Remedial Technologies	This case study discusses remedial alternatives to address soil contamination. The remedial alternatives included in the GSR analysis were as follows: • **Alternative 1**: No action • **Alternative 2**: Land use controls (LUCs) and Long term management of shoreline controls • **Alternative 3**: Excavation • **Alternative 4**: In Situ Chemical Oxidation This case study reviews Alternative 2 through 4.
GSR Evaluation Approach	GSR evaluation was performed using a hybrid model of SiteWise™ tool supplemented with the TetraTech developed model GSRx (see Table 10). In addition, the alternatives were evaluated against the NCP nine evaluation criteria.
Footprint Reduction Methodologies	Some recommended footprint reduction methods include: Alternatives 3 and 4: • Some reduction of the environmental footprint, particularly GHG emissions and energy consumption, could be realized for these alternatives through the possible use of emission control measures such as alternate fuel sources (e.g. biodiesel), equipment exhaust controls (e.g. diesel), and equipment idle reduction. • Consider optimizing of the use of equipment, and even the type of equipment used during operations. Alternative 3: • Consider optimizing the amount of soil needed for backfill of the treatment areas. • Consider options of different modes of transportation for the soil residues as a result of the excavation purposes. The optimization of

	amount of residues and the mode of transportation could reduce impacts. Alternative 4: • Consider the optimization of the electricity use through the generator. This optimization can be achieved by either changing generators (model, size) or considering another type of fuel. The use of renewable sources of energy (if possible) could be an option. All Alternatives: • Consider ways to reduce vehicle mileage to reduce worker risk as well as energy use and emissions. Encourage site workers to carpool daily to the site to reduce total vehicle mileage.
Greenhouse Gas Emissions	Alternative 3 has the highest greenhouse gas emissions due to the use of the excavator. • Alternative 2 (LUCs and Long term management of shoreline controls): 0.69 metric tons • Alternative 3 (Excavation): 21.28 metric tons • Alternative 4 (In Situ Chemical Oxidation): 9.89 metric tons
Energy Consumption	Alternative 3 has the highest energy consumption due to production of borrow soil followed by alternative 2 (due to use of diesel power generator). • Alternative 2 (LUCs and Long term management of shoreline controls): 8.63 MMBTU • Alternative 3 (Excavation) : 442.35 MMBTU • Alternative 4 (In Situ Chemical Oxidation): 220.11 MMBTU
Criteria Air Pollutants	Alternative 3 has the highest air emissions generated primarily during the use of equipment use (excavator) and hazardous residue handling operations. This was followed by alternative 4 where the emissions were primarily due to the use of diesel power generator.
Water Usage	Alternative 4 has the highest water consumption due to water used during decontamination followed by alternative 3. • Alternative 2 (LUCs and Long term management of shoreline controls): 0 • Alternative 3 (Excavation) : 1,271 gallons • Alternative 4 (In Situ Chemical Oxidation): 1,401 gallons
Ecological Impacts	Ecological exposure at OU9 is not considered significant because the site is currently and was historically located within an industrial area of PNS, and no ecological habitat was identified at the site.
Resource Consumption	Alternative 3 will consume the most top soil: 62 tons of top soil. Alternative 4 will consume 16 cubic yards of top soil.
Waste Generation	Alternative 3 generates 78 tons of hazardous waste followed by alternative 4.
Worker Safety	Alternative 3 had the highest risk due to transportation of personnel.
Community Impacts	This metric was not discussed in the report.
Conclusions	Overall, Alternative 3 had the highest footprint and costs followed by Alternative 4 and 2, respectively. ***Overall protection of human health and the environment*** All the alternatives would be protective of human health.

Compliance with ARARs
All the alternatives would comply with ARARs

Long-term effectiveness and Performance
All the alternatives would provide long term effectiveness and permanence. Alternative 2 and 3 would provide by LUCs and removing contamination in the elevated PAH area. Alternative 4 would treat the contamination.

Reduction of contaminant toxicity, mobility or volume through treatment
Alternatives 2 and 3 would not reduce contaminant toxicity, mobility or volume through treatment because no treatment would occur. Alternative 4 would reduce contaminant toxicity, mobility and volume through treatment.

Short-term effectiveness
Alternative 2 would not result in any short term risk. Alternative 3 and 4 would require appropriate use of PPE and best management practices to prevent exposing onsite workers, community and environment.

Implementability
Alternative 2 is the easiest to implement among all the alternatives.

Cost

- Alternative 2 (LUCs and Long term management of shoreline controls): $197,000
- Alternative 3 (Excavation) : $ 605,000
- Alternative 4 (In Situ Chemical Oxidation): $538,000

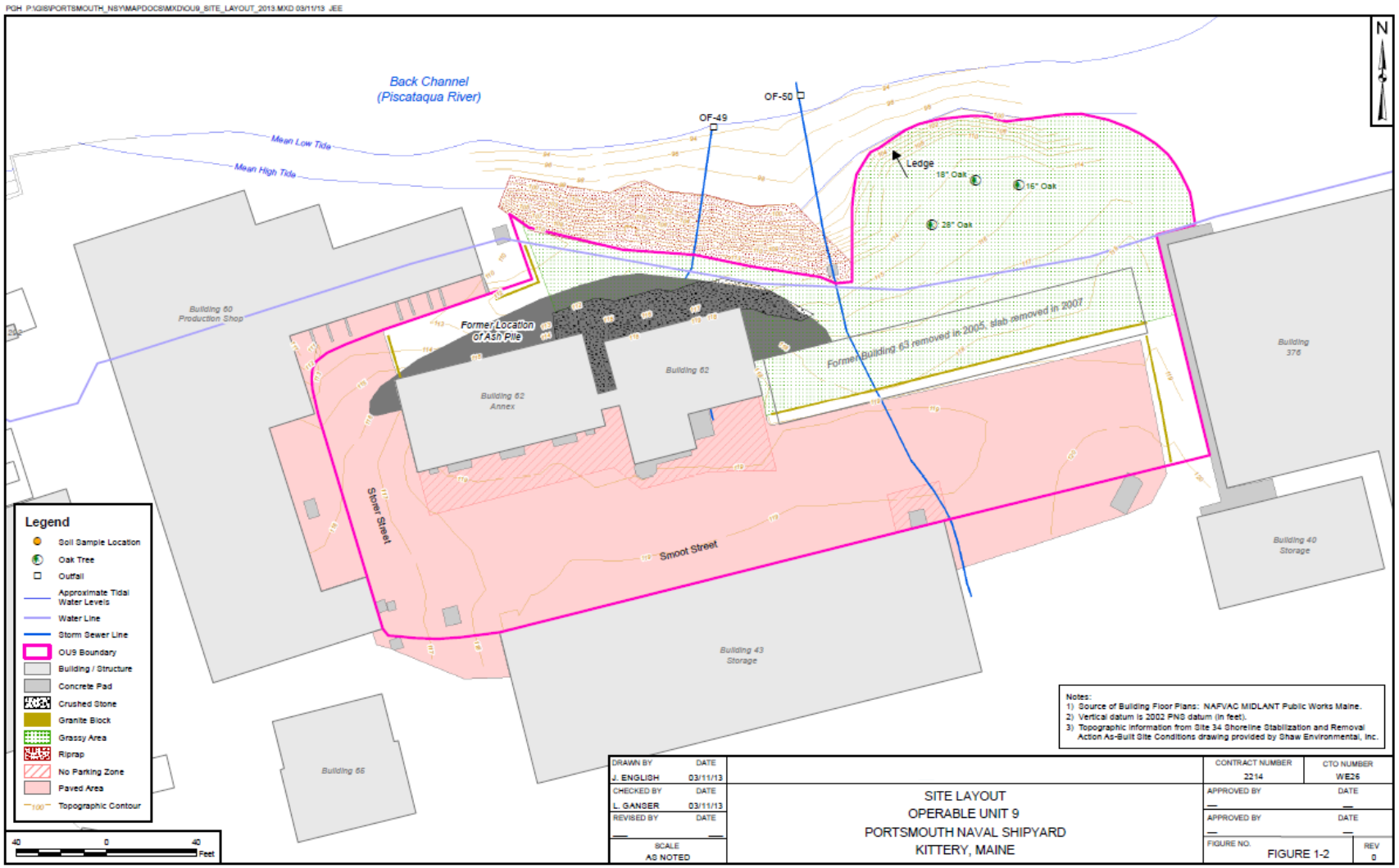


Figure 10. Site Layout for OU 9 Portsmouth Naval Shipyard

Table 10. GSR Metrics Summary for OU 9 Portsmouth Naval Shipyard

Alternative	Activities	GHG Emissions	Total Energy Used	Water Impacts	NO_X Emissions	SO_X Emissions	PM_{10} Emissions	Accident Risk Fatality	Accident Risk Injury
		Metric Ton CO_2e	MMBTU	Gallons	Metric Ton	Metric Ton	Metric Ton		
Alternative 2	Materials Production	0.00	0.00	0	0.0E+00	0.0E+00	0.0E+00	NA	NA
	Transportation-Personnel	0.69	8.63	NA	2.5E-04	8.9E-06	5.1E-05	1.40E-05	1.13E-03
	Transportation-Equipment	0.00	0.00	NA	0.0E+00	0.0E+00	0.0E+00	0.00E+00	0.00E+00
	Equipment Use and Misc	0.00	0.00	0	0.0E+00	0.0E+00	0.0E+00	0.00E+00	0.00E+00
	Residual Handling	0.00	0.00	NA	0.0E+00	0.0E+00	0.0E+00	0.00E+00	0.00E+00
	Total	0.69	8.63	0	2.5E-04	8.9E-06	5.1E-05	1.40E-05	1.13E-03
Alternative 3	Materials Production	3.27	181.89	271	1.7E-08	3.6E-03	5.2E-04	NA	NA
	Transportation-Personnel	2.97	37.39	NA	1.1E-03	3.9E-05	2.2E-04	6.08E-05	4.90E-03
	Transportation-Equipment	1.42	18.50	NA	4.5E-04	7.9E-06	4.0E-05	3.51E-06	2.83E-04
	Equipment Use and Misc	9.15	138.46	1,000	5.7E-02	1.6E-02	5.2E-03	8.78E-06	2.21E-03
	Residual Handling	4.46	66.11	NA	6.5E-03	2.9E-03	1.6E-02	9.05E-06	7.28E-04
	Total	21.28	442.35	1,271	6.5E-02	2.2E-02	2.2E-02	8.22E-05	8.12E-03
Alternative 4	Materials Production	2.17	82.31	401	8.5E-09	3.7E-03	5.3E-04	NA	NA
	Transportation-Personnel	1.92	24.21	NA	7.1E-04	2.5E-05	1.4E-04	3.94E-05	3.17E-03
	Transportation-Equipment	0.78	10.23	NA	2.5E-04	4.4E-06	2.2E-05	2.50E-06	2.01E-04
	Equipment Use and Misc	4.86	101.41	1,000	3.2E-02	6.4E-03	3.8E-03	4.76E-06	1.20E-03
	Residual Handling	0.15	1.95	NA	4.7E-05	8.3E-07	4.2E-06	7.80E-07	6.28E-05
	Total	9.89	220.11	1,401	3.3E-02	1.0E-02	4.5E-03	4.74E-05	4.63E-03

St. Juliens Creek Annex Site 21 Chesapeake, Virginia	
FEC	**NAVFAC Mid-Atlantic**
Installation	St. Juliens Creek Annex
Location	Chesapeake, Virginia
Site Number	Site 21
Site Name	Site 21, St. Juliens Creek Annex
Phase/Milestone/Date	Remedial Design (2011)
Site Background	St. Juliens Creek Annex (SJCA) is approximately 490 acres at the confluence of St. Juliens Creek and the Southern Branch of the Elizabeth River in the City of Chesapeake in southeastern Virginia. SJCA was one of the largest ammunition depots in the United States involving wartime transfer of ammunitions to various other naval facilities. Site 21 is located in a former industrial area in the south-central portion of SJCA**.** The site vicinity, including the boundary, existing and demolished buildings, and other site features. Although the site was initially identified as Building 187, the Site 21 boundary has been expanded to encompass the shallow groundwater CVOC plume that underlies a number of nearby industrial buildings. Buildings at Site 21 were historically used as machine, vehicle, and locomotive maintenance shops; electrical shops; and munitions loading facilities. Outdoor areas were used for equipment and chemical storage. Several of these buildings and/or their surrounding areas were designated as former Installation Restoration (IR) sites (Sites 9, 10, 11, 12, 13, 14, 18, and Area of Concern E).
Contaminants	TCE, cis-1,2-DCE, VC and 1,1-DCE
Impacted Media	The impacted media is groundwater.
Remedial Technologies	Based on the initial screening of groundwater technologies, four remedial alternatives were retained for development and detailed comparative analysis. • **Alternative 1:** No Action • **Alternative 2:** Monitored Natural Attenuation (MNA) and LUCs • **Alternative 3:** In Situ Chemical Reduction (ISCR) and Enhanced Reductive Dechlorination (ERD) • **Alternative 4:** In Situ Chemical Oxidation (ISCO) and ERD
GSR Evaluation Approach	The alternatives were evaluated against the NCP nine evaluation criteria in the ROD. Later at the Remedial Design Phase, SiteWise™ was run to optimize the ERD design for the selected remedy (Alternative 3). See Table 11 for the SiteWise™ results.
Footprint Reduction Methodologies	During the remedial design phase, the contractor proposed a different formulation of Emulsified Vegetable Oil (EVO) than described in original remedial design for ERD. SiteWise™ was run and indicated that the change in formulation would result in a 30% reduction in greenhouse gasses (GHG) and energy consumption, but a 1% increase in water consumption. The different formulation was approved and implemented during the remedial action. The contractor was directed to monitor the effectiveness of the revised formulation after injection into the subsurface.
Greenhouse Gas Emissions	The revised EVO formulation reduced GHG by 30%.
Energy Consumption	The revised EVO formulation reduced energy consumption by 30%.

St. Juliens Creek Annex Site 21 Chesapeake, Virginia	
Criteria Air Pollutants	This metric was not discussed in the report.
Water Usage	Water usage was increased due to the revised formulation.
Ecological Impacts	The ecological risk screening conducted during the SSA concluded that Site 21 provides little terrestrial habitat and no aquatic habitat for potential ecological receptors.
Resource Consumption	This metric was not discussed in the report.
Waste Generation	This metric was not discussed in the report.
Worker Safety	This metric was not discussed in the report
Community Impacts	This metric was not discussed in the report.
Conclusions	Based on the comparative analysis, the final selected remedy to address risk associated with shallow groundwater is Alternative 3, consisting of ISCR and ERD. Alternative 3 was selected as the remedy based upon the following rationale. Alternative 2 does not actively treat the source area and is anticipated to take significantly longer to achieve the RAOs than Alternatives 3 and 4. Alternative 3 was chosen over Alternative 4 based on ease of implementation and lower associated cost. Alternative 4 requires the reversing of oxidizing effects caused by the ISCO before the ERD can be implemented; whereas the naturally occurring conditions present at the site are favorable for the treatment included in Alternative 3. ***Compliance with ARARs*** Alternatives 2, 3, and 4 are expected to comply with the Federal and State ARARs. ***Long-term Effectiveness and Permanence*** Alternatives 2, 3, and 4 are each expected to effectively reduce concentrations of CVOCs in shallow groundwater to allow for unlimited use and unrestricted exposure after RAOs are achieved. ***Reduction in Toxicity, Mobility, or Volume through Treatment*** Only Alternatives 3 and 4 have treatment components, which is the statutory preference. While Alternative 2 (MNA) is not considered an active treatment, the natural reduction of contaminant concentrations through a variety of physical, chemical, or biological activities is expected over time. ***Short-term effectiveness*** Alternatives 3 and 4 have similar potential impacts to the environment because each may result in a temporary mobilization of naturally occurring metals, whereas Alternative 2 would not. Because Alternative 2 relies on natural degradation rather than active treatment, it results in the lowest rate of reduction in COCs and therefore is anticipated to take significantly longer to achieve RAOs than Alternatives 3 and 4. Alternative 3 is the most effective in the short term. ***Implementability*** Alternatives 2, 3, and 4 can each be implemented using standard and widely available technologies and monitored for effectiveness. Alternatives 3 and 4 are more difficult to implement than Alternative 2 due to the logistical challenges of

working in an industrial area (e.g., the presence of buildings and utilities and active vehicle and pedestrian traffic). Alternative 3 would be slightly easier to implement than Alternative 4 because Alternative 3 relies on naturally occurring conditions that promote groundwater treatment, whereas Alternative 4 would require the reversal of the naturally occurring reducing conditions for the initial phase of treatment (ISCO) then return to reducing for the second phase (ERD)

Costs

- Alternative 2: $570,000
- Alternative 3: $4.3 million
- Alternative 4: $5.7 million

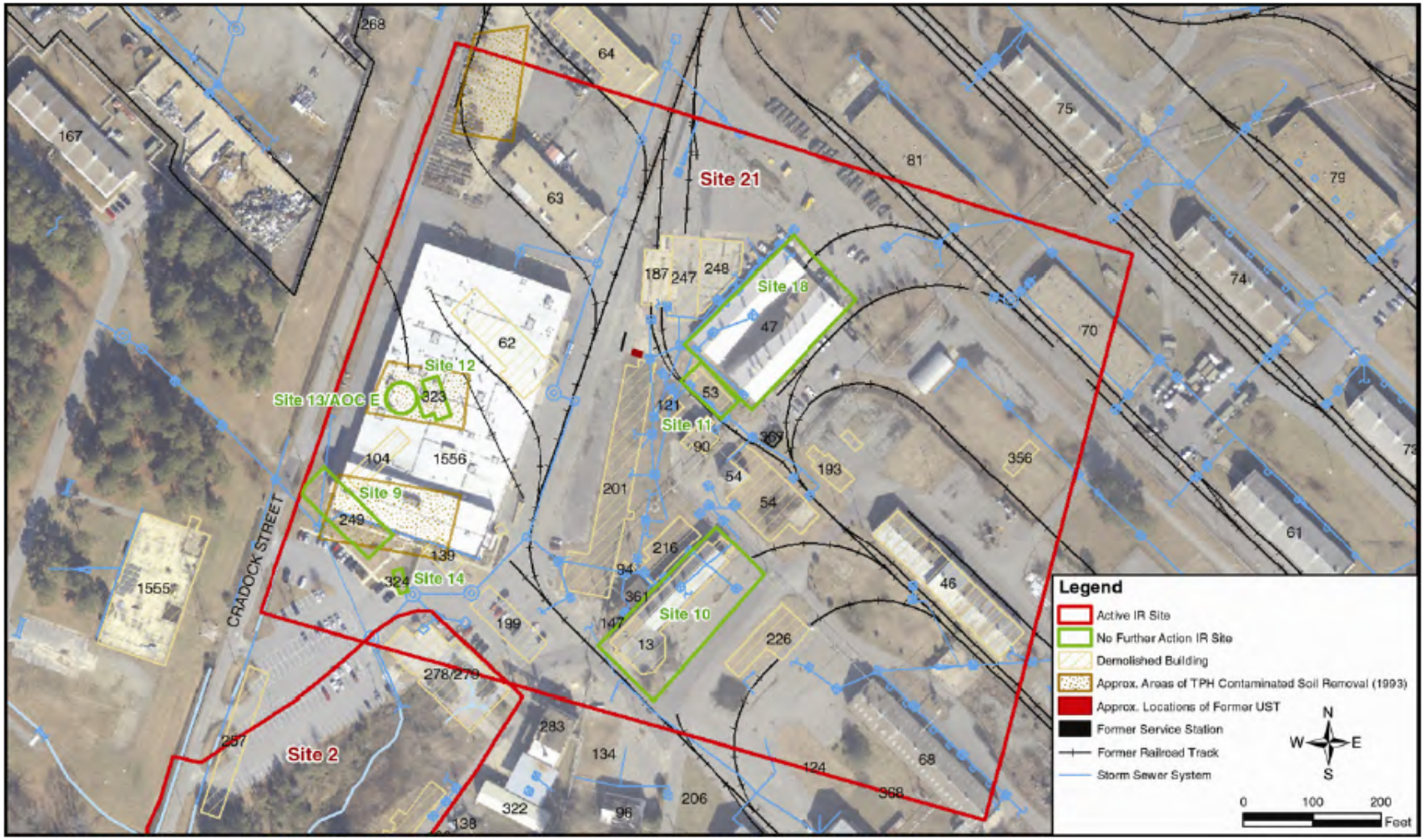


Figure 11. Site Layout for Site 21 St. Juliens Creek Annex

Table 11. GSR Metrics Summary for Site 21 St. Juliens Creek Annex

Remedial Alternatives	GHG Emissions	Total energy Used	Water Consumption	NO_x emissions	SO_x Emissions	PM_{10} Emissions	Accident Risk Fatality	Accident Risk Injury
	metric ton	MMBTU	Gallons	metric ton	metric ton	metric ton		
60% EVO	1912.83	4.63E+04	3.82E+05	1.92E-01	3.18E-02	1.46E-02	2.78E-04	1.05E-01
40% EVO	2852.83	6.93E+04	3.78E+05	1.92E-01	3.18E-02	1.46E-02	2.78E-04	1.05E-01

Yorktown Defense Fuel Supply Point Yorktown Fuel Farm Central York County, Virginia	
FEC	**NAVFAC Mid-Atlantic**
Installation	Yorktown Defense Fuel Supply Point
Location	Central York County, Virginia
Site Number	Yorktown Fuel Farm
Site Name	Yorktown Fuel Farm
Phase/Milestone/Date	Remedial Action Operations (Technical Memorandum June 3, 2011)
Site Background	The Yorktown Defense Fuel Supply Point is located in central York County in Yorktown, Virginia. The facility is a U.S. Navy fuel depot that presently stores and distributes JP-8 aviation fuel to a number of Department of Defense (DoD) customers. Yorktown is bound by a U.S. Coast Guard (USCG) training center to the northeast, Wormley creek to the south and a national park to the north and south. The Yorktown site is located within the York River basin near the York River that flows northeast of the site. The facility was activated through eight underground storage tanks (USTs) that could hold 90,000 gallons of Navy Special Fuel Oil (NSFO). During the course of operations, NSFO leaked from the USTs to the subsurface. Site characterization efforts have determined the presence of 1.2 to 3.0 million gallons of mobile NSFO in the subsurface at Yorktown.
Contaminants	Free product
Impacted Media	Soil
Remedial Technologies	The free product recovery system was evaluated to determine ways to: improve remedial effectiveness to expedite cleanup; (1) reduce operating cost; and (2) enhance the overall sustainability of the remedy.
GSR Evaluation Approach	The GSR analysis was performed using SiteWise™ (see Tables 12 and 13). Specific goals of this analysis included identifying opportunities to: (1) improve remedial effectiveness to expedite cleanup; (2) reduce operating cost; and (3) enhance the overall sustainability of the remedy.
Footprint Reduction Methodologies	The optimization recommendations for the site are broken down into two categories: (1) those that reduce the annual cost and footprint for operating the system and (2) those that expedite remediation of the site to reduce the time the system needs to operate and thus reduce overall life cycle cost and footprint. It was recommended to optimize the existing system through purchase of a more efficient boiler and jar testing to optimize chemical usage. In addition, a recommendation was made to pilot test an alternative remedy of multi-phase extraction.
Greenhouse Gas Emissions	Based on total equipment use, the boiler use has the highest greenhouse gas emissions. • Boiler use: 844.88 metric ton • Electric Use: 312.08 metric ton Based on total material use, flocculent has the highest greenhouse gas emissions. • Acid use: 35% • Flocculent (aluminum chlorohydrate [ACH] surrogate hypochlorite): 50% • GAC: 15%

Yorktown Defense Fuel Supply Point Yorktown Fuel Farm Central York County, Virginia	
Energy Consumption	Under equipment use, boiler use (10,300 MMBTU) was the highest energy. • Boiler use: 10,300 MMBTU • Electric Use: 5860 MMBTU Under material use, acid use (52%) used the highest energy. • Acid use:52% • Flocculent(ACH surrogate hypochlorite):44% • GAC:4%
Criteria Air Pollutants	The equipment use at the site leads to emission of almost 13 metric tons of nitrogen oxides (NOx).
Water Usage	This metric is not discussed in the report.
Ecological Impacts	This metric is not discussed in the report.
Resource Consumption	This metric is not discussed in the report.
Waste Generation	This metric is not discussed in the report.
Worker Safety	Based on this analysis the annual risk of a fatality is 0.0013 and the annual risk of an injury is 0.3. The site has been a zero accident facility since inception approximately 10 years ago. The site operators were performing safer than statistical averages.
Community Impacts	This metric is not discussed in the report.
Conclusions	The GSR evaluation determined that the equipment use, primarily the use of the boiler at the site to produce steam, contributed the most to the overall environmental footprint of the facility. The boiler accounts for the greatest footprint, followed by electrical equipment, and then the material use, primarily ACH. The optimization recommendations for the site are broken down into two categories: (1) those that reduce the annual cost and footprint for operating the system and (2) those that expedite remediation of the site to reduce the time the system needs to operate and thus reduce overall life cycle cost and footprint. • Recommendations to reduce annual cost and footprint include replacing the existing boiler with a more efficient unit and performing jar testing to optimize treatment chemical use. • Recommendations to expedite cleanup include consideration of multi-phase extraction (MPE) coupled with the current system and consideration of aggressive remediation with high temperature thermal treatment such as electrical resistive heating (ERH). Prior to considering MPE, a pilot test is recommended to confirm that this technology is suitable at this site and will expedite remediation and to obtain design data. The option of ERH was presented for consideration (although there was high capital cost that was cost prohibitive.). The cost of operating the current system at $950,000 per year O&M for 30 years would be approximately $20 million net present value (NPV) at 2.3% discount rate for a 30-year period.

Table 12. Largest Footprint Contributors to the Total Equipment Use Footprint

Remedial Activity	CO_2e Emission (metric ton)	Energy Used (MMBTU)	NOx Emission (metric ton)	SOx Emission (metric ton)	PM Emissions (metric ton)
Electric Use	312.08	5.86E+03	4.13E-01	1.51E+00	0.00E+00
Boiler Use	844.88	1.03E+04	1.23E+01	2.75E-03	5.67E-02
% Total of Equipment Use (Electric Use)	27%	36%	3%	98%	0%
% Total of Equipment Use (Boiler Use)	72%	63%	96%	0%	98%

Table 13. Largest Footprint Contributors to the Total Material Use Footprint

Remedial Activity	CO_2e Emission (metric ton)	Energy Used (MMBTU)	CO_2e Emission (metric ton)	Energy Used (MMBTU)
Acid Use	35%	52%	4%	7%
Flocculent (ACH surrogate hypochlorite)	50%	44%	5%	6%
GAC	15%	4%	2%	1%

NAVFAC SOUTHEAST

Marine Corps Logistics Base Albany
Operable Unit 6
Albany, Georgia

FEC	**NAVFAC Southeast**
Installation	Marine Corps Logistics Base (MCLB) Albany
Location	Albany, Georgia
Site Number	Operable Unit (OU 6)
Site Name	Operable Unit (OU 6)
Phase/Milestone/Date	Streamlined Remedial Investigation/Feasibility Study Report (April, 2011)
Site Background	MCLB Albany in Georgia is a 3,579 acre supply and logistics facility for the US Marine Corps. Remedial activities have been on-going for several years at a variety of locations on base. OU 6 is defined as groundwater throughout the site (see Figure 1).
Contaminants	tetrachloroethene (PCE), trichloroethene (TCE) and daughter products, benzene, methylene chloride, antimony, thallium, cadmium, and arsenic
Impacted Media	The impacted media is groundwater.
Remedial Technologies	This case study discusses the analysis of three optimization scenarios: • **Scenario 1:** Original proposed remedy (88 ZVI, 102 ISCO injections, and MNA for 20 years) • **Scenario 2:** Optimized Remedy (18 ZVI, 21 ISCO injections, and MNA for 30 years) • **Scenario 3:** Optimized Remedy and Monitoring (18 ZVI, 21 ISCO injections, and optimized MNA for 30 years)
GSR Evaluation Approach	The sustainability analysis was performed using SiteWise™ (see Table 1).
Footprint Reduction Methodologies	The team plans to conduct additional optimization reviews on a two to three-year cycle. Footprint reduction approaches included optimizing the extent of the target treatment zone by dramatically reducing the number of required injection points for ZVI and ISCO and therefore the quantity of reagents needed. In addition, it is planned to continue to optimize the MNA monitoring program by reducing sampling locations, the analyte list, and monitoring frequency over time. The use of passive sampling devices is also under consideration to minimize water consumption.
Greenhouse Gas Emissions	Scenario 3 produced the lowest GHG emissions. The primary factor in decreasing CO_2e emissions was the significant reductions in the number of injection wells and in ZVI and $NaMnO_4$ material usage. Optimization also decreased transportation and installation requirements. The approximate 67% reduction in GHG in Scenario 3 is directly related to the reduction in number of monitoring locations, analytes (reporting for only COCs listed in the ROD), and sampling frequency (semi-annual to annual for most wells). • Scenario 1 (Original proposed remedy): 1,957 tonnes • Scenario 2 (Optimized Remedy): 482 tonnes • Scenario 3 (Optimized Remedy and Monitoring): 425 tonnes
Energy Consumption	Remedy optimization resulted in a life-cycle net energy reduction of approximately 3,700 megawatt-hours, and monitoring optimization further reduced energy consumption by approximately 130 megawatt-hours. • Scenario 1 (Original proposed remedy): 4,897 MWhr • Scenario 2 (Optimized Remedy): 1,211 MWhr • Scenario 3 (Optimized Remedy and Monitoring): 1,082 MWhr

Marine Corps Logistics Base Albany Operable Unit 6 Albany, Georgia	
Criteria Air Pollutants	Life-cycle emissions of NOx calculated for Scenario 1, 2, and 3 were 4.11, 1.02, and 0.90 tonnes, respectively. Emissions of NOx were determined to be primarily influenced by the operation of ultra-sonic drill rigs used for reagent injection. Transportation for mobilization/demobilization and site activities also contributed to NOx emissions. The SOx emissions estimated for Scenario 1, 2, and 3 were 0.50, 0.25, and 0.12 tonnes, respectively, and were predominantly influenced by material manufacturing. PM10 emissions were 0.22, 0.05, and 0.05 tonnes, respectively, and were most affected by operation of ultra-sonic drill rigs for injection.
Water Usage	Production of injection reagents and dilution of reagents during on-site injection contributed to the majority of water usage. Scenario 3 decreased life-cycle water usage from scenario 2 by approximately 89,000 gallons. • Scenario 1 (Original proposed remedy): 1,533,000 gallons • Scenario 2 (Optimized Remedy): 417,000 gallons • Scenario 3 (Optimized Remedy and Monitoring): 328,000 gallons
Ecological Impacts	This metric was not discussed in the report.
Resource Consumption	This metric was not discussed in the report.
Waste Generation	This metric was not discussed in the report.
Worker Safety	This metric was not discussed in the report
Community Impacts	This metric was not discussed in the report.
Conclusions	The sustainability evaluation determined that the remedy optimization resulted in a life-cycle net energy reduction of approximately 3,700 megawatt-hours, and the LTM optimization further reduced energy consumption by approximately 130 megawatt-hours. The remedy optimization reduced reagent quantities and dilution requirements decreasing life-cycle water usage by approximately 1.1 million gallons. Optimizing the LTM further reduced water usage by approximately 90,000 gallons. ***Cost*** • Scenario 1 (Original proposed remedy): $17,000,000 • Scenario 2 (Optimized Remedy): $7,250,000 • Scenario 3 (Optimized Remedy and Monitoring): $5,000,000

Figure 1. Site Layout for OU 6 MCLB Albany

Table 1. GSR Metrics Summary for OU 6 MCLB Albany

Table 1 - MCLB Albany OU 6 Sustainability Evaluation Results

Remedial Alternative	Greenhouse Gas Emissions				Criteria Pollutant Emission			Energy Consumption	Water Consumption
	CO_{2e}	CO_2	N_2O	CH_4	NO_x	SO_x	PM_{10}		
	tonnes							MWhr	gal x 1,000
Scenario 1: Original Remedy	1,957	1,941	0.024	0.403	4.11	0.503	0.221	4,897	1,533
Scenario 2: Optimized Remedy	482	477	0.009	0.086	1.02	0.246	0.053	1,211	417
Scenario 3: Optimized Remedy and Monitoring	425	421	0.006	0.084	0.90	0.122	0.047	1,082	328

Source: Tetra Tech NUS (2010)

Marine Corps Recruit Depot Parris Island
Site 45
Parris Island, South Carolina

FEC	**NAVFAC Southeast**
Installation	Marine Corps Recruit Depot (MCRD) Parris Island
Location	Parris Island, South Carolina
Site Number	Site 45
Site Name	MCRD Parris Island
Phase/Milestone/Date	Feasibility Study (September 2009)
Site Background	The Parris Island dry cleaning facility (Building 193) was located in the Main Post area of MCRD Parris Island. Environmental investigations at the site began in 1994 when an aboveground storage tank overflowed, while being filled with tetrachloroethene (PCE).
Contaminants	PCE
Impacted Media	The impacted media is soil and groundwater.
Remedial Technologies	This case study discusses treatment train alternatives for soil and groundwater. • **Alternative 1**: No further action • **Alternative 2**: Enhanced bioremediation, shallow excavation, MNA, monitoring, LUCs • **Alternative 3**: In Situ Chemical Oxidation, shallow excavation, MNA, monitoring, LUCs • **Alternative 4**: In Situ Chemical Reduction, shallow excavation, MNA, monitoring, LUCs • **Alternative 5**: Electrical Resistive Heating, monitoring, LUCs • **Alternative 6**: Excavation, MNA, monitoring, LUCs
GSR Evaluation Approach	GSR analysis was performed using SiteWise™ (see Table 2).
Footprint Reduction Methodologies	Following footprint reduction methods were discussed: • Minimize the volume of soil that is excavated and shipped off-site, while still being protective of human health. • Investigate the possibility of rail shipments for soil disposal. • Use green fuels and/or after-treatment technologies to reduce emissions from excavation equipment, drill rigs and trucks. Examples of after-treatment technologies include: diesel oxidation catalyst (DOC), diesel particulate filter (DPF), selective catalytic reduction (SCR), and/or diesel multistage filter (DMFs). • Implement an idle control plan and other operating strategies to improve efficiency of site activities. • Additional characterization to minimize the area in which treatment is to be applied. • Additional design and perhaps pilot testing to optimize the manner in which injections are performed to reduce the mass of materials injected while still meeting treatment requirements. • Optimization of the monitoring plans to reduce trips to the site while still meeting the objectives of the program.
Greenhouse Gas Emissions	Alternative 5 has the highest GHG footprint, an order of magnitude higher than the other remedial alternatives. This is primarily due to high electrical usage. • Alternative 2 (Enhanced bioremediation): 117 metric ton

Marine Corps Recruit Depot Parris Island Site 45 Parris Island, South Carolina	
	• Alternative 3 (In Situ Chemical Oxidation): 143 metric ton • Alternative 4 (In Situ Chemical Reduction): 205 metric ton • Alternative 5 (Electrical Resistive Heating): 4,036 metric ton • Alternative 6 (Excavation): 526 metric ton
Energy Consumption	Alternative 5 has the highest energy usage leading to high emissions of GHGs primarily due to electrical consumption. • Alternative 2 (Enhanced bioremediation): 1,500 MMBTU • Alternative 3 (In Situ Chemical Oxidation): 2,500 MMBTU • Alternative 4 (In Situ Chemical Reduction): 2,900 MMBTU • Alternative 5 (Electrical Resistive Heating): 66,000 MMBTU • Alternative 6 (Excavation): 7,300 MMBTU
Criteria Air Pollutants	Alternative 5(ERH) had the lowest PM10 footprint.
Water Usage	ERH had the greatest potential for lost groundwater due to vaporization. High temperatures almost near the boiling point of water would be applied to the subsurface, causing the groundwater to evaporate. If the vaporized groundwater was not condensed, treated and re-injected into the aquifer or otherwise beneficially used, then this would be considered a lost resource. Dewatering during excavation would also result in high volumes of lost groundwater unless treated and re-injected or beneficially used. Enhanced bioremediation, ISCO and ISCR had the lowest water loss compared to ERH and excavation. • Alternative 2 (Enhanced bioremediation): 7,600 gallons • Alternative 3 (In Situ Chemical Oxidation): 110,000 gallons • Alternative 4 (In Situ Chemical Reduction): 56,000 gallons • Alternative 5 (Electrical Resistive Heating): 3,900,000 gallons • Alternative 6 (Excavation): 9,000 gallons
Ecological Impacts	This metric is not discussed in this report.
Resource Consumption	The main resource consumed at Parris Island was landfill space. Alternative 6 (Excavation) led to the highest use of landfill space; therefore, had the highest footprint. On the other hand alternatives 3, 4 and 5 all had similar footprints in terms of landfill space, which was much less than alternative 6.
Waste Generation	This metric is not discussed in the report.
Worker Safety	Alternative 5 (ERH) had the second highest accident risk. The accident risk leading to fatality and injury was due to the transportation activities undertaken to transport used granular activated carbon (GAC) for groundwater treatment and personnel for monitoring.
Community Impacts	Community impacts due to increased traffic volume associated with each remedial action were qualitatively evaluated. An increase in traffic and noise for the work undertaken was similar for all of the groundwater remedial alternatives. However, community impact due to excavation in Alternative 6 was large in comparison to all other remedial alternatives.
Conclusions	Among the six alternatives, alternative 2 (enhanced bioremediation coupled with shallow excavation) had the lowest environmental footprint overall. Alternative 5 (ERH) on the other hand had the highest footprint. The CO_2e emissions carbon footprint), is the smallest for enhanced bioremediation. Carbon footprint for ISCO and ISCR are larger because of higher emissions during the production of oxidant and reducing agents respectively compared to the production of the agent used as a biostimulant. The carbon footprint of ISCO and ISCR exceeds that of enhanced bioremediation by approximately 22% and 75%, respectively.

In general, the environmental footprint of the alternatives followed this order: Alternative 2 (enhanced bioremediation < alternative 3 (ISCO) < alternative 4 (ISCR) < alternative 6 (excavation) < alternative 5(ERH).

Cost:

- Alternative 2 (Enhanced bioremediation): $3,000,000
- Alternative 3 (In Situ Chemical Oxidation): $3,500,000
- Alternative 4 (In Situ Chemical Reduction): $5,000,000
- Alternative 5 (Electrical Resistive Heating): $6,500,000
- Alternative 6 (Excavation): Not listed in the report.

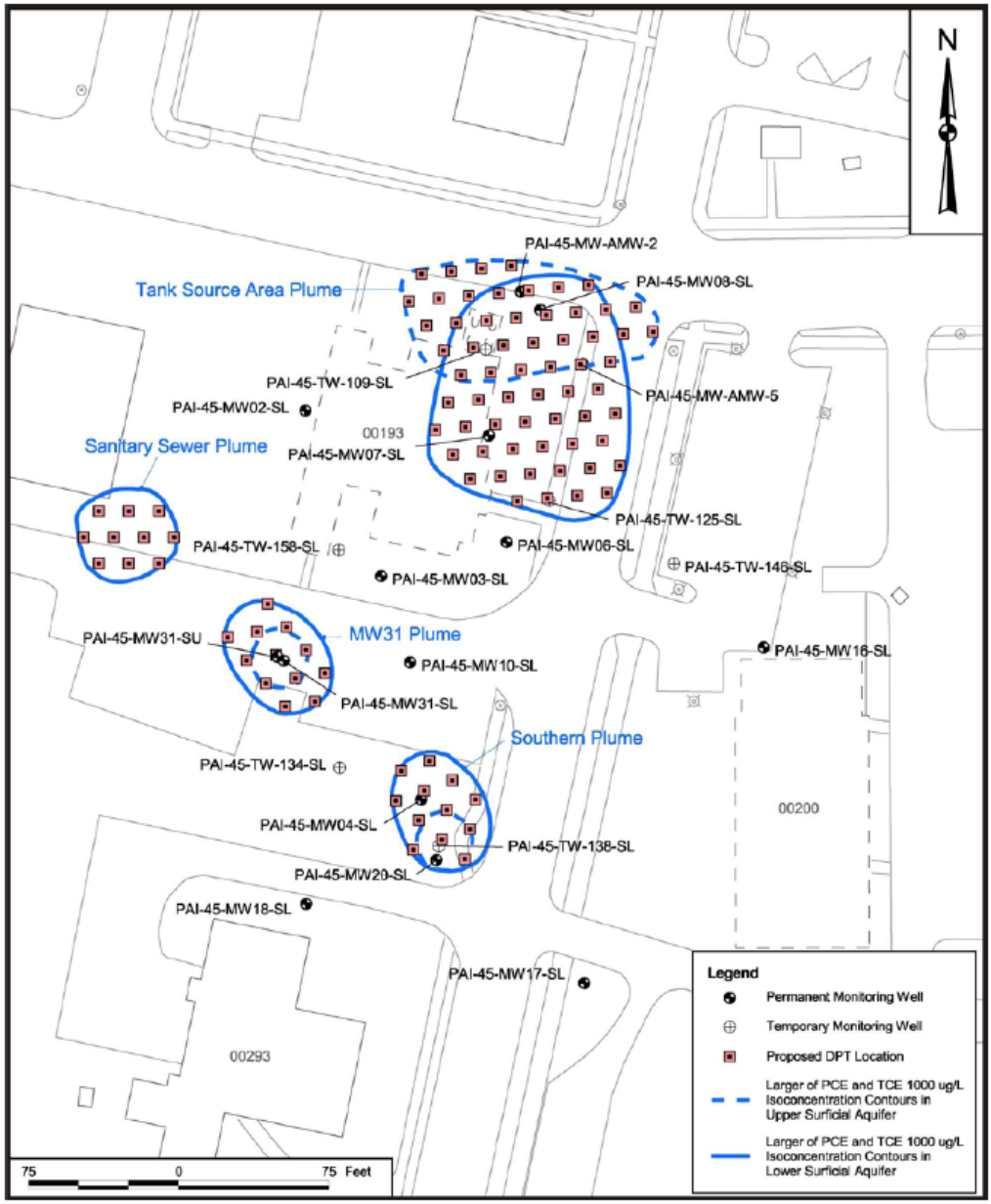


Figure 2. Site Layout for Site 45 MCRD Parris Island (Enhanced Bioremediation)

Table 2. GSR Metrics Summary for Site 45 MCRD Parris Island

Remedial Alternative	CO_2e emissions	NOx emissions	SOx emissions	PM_{10} emissions	Total Energy Usage	Electrical Energy Usage	Water Usage	Collateral Risk	Collateral Risk
	metric ton	metric ton	metric ton	metric ton	MMBTU	MWH	gallons	Fatality	Injury
Enhanced Bioremediation	117	4.8E-01	2.9E-02	1.4E-02	1.5E+03	1.3E-01	7.6E+03	1.1E-04	6.5E-02
ISCO	143	5.2E-01	4.7E-02	1.5E-02	2.5E+03	1.6E-01	1.1E+05	1.2E-04	7.1E-02
ISCR	205	5.1E-01	8.2E-02	1.3E-02	2.9E+03	1.6E-01	5.6E+04	1.0E-04	6.5E-02
ERH	4036	5.7E+00	2.1E+01	4.2E-03	6.6E+04	7.7E+03	3.9E+06	4.9E-04	7.1E-02
Excavation	526	2.2E+00	1.0E-01	5.6E-02	7.3E+03	1.7E+01	9.0E+03	7.8E-04	2.4E-01

Naval Air Station Pensacola Site 43, Operable Unit 18 Pensacola, Florida	
FEC	**NAVFAC Southeast**
Installation	Naval Air Station Pensacola
Location	Pensacola, Florida
Site Number	Site 43
Site Name	Operable Unit 18, Site 43, Demolition Debris Disposal Area
Phase/Milestone/Date	Remedial Design (November 2011)
Site Background	The history of Site 43 begins in December 1992, when a civilian using a metal detector discovered a partially exposed drum east of the tennis court. A site reconnaissance found an additional partially buried drum. One drum was in a vertical position; and its end was punctured revealing standing water in the interior. The second drum also appeared to be in a vertical position, but was not obviously punctured. A third iron object resembling a drum rim was observed east of the tennis court. Smaller, rusted metal debris was observed at the surface. Odors were not discernible and visible soil stains or other indications of contaminant release were not observed. The area surrounding the buried drums was fenced to prevent general access until further investigations could be conducted (see Figure 3).
Contaminants	Contaminants of concern (COCs) at the site include lead, arsenic, barium, copper, vanadium, benzo(a)pyrene equivalent (BEQ)
Impacted Media	Soil, groundwater
Remedial Technologies	This case study discusses optimization for remedial design implemented for soil and groundwater at Site 43 which includes three components: • **Component 1**: limited excavation and offsite disposal of contaminated soil • **Component 2**: groundwater monitoring • **Component 3**: LUCs to prohibit future residential use to ensure maintenance of paved areas and prohibit groundwater use This case study reviews life cycle metrics for the components mentioned above Specifically, two scenarios were evaluated where diesel and biodiesel were used as a fuel source for excavation.
GSR Evaluation Approach	GSR evaluation was performed using SiteWise™ tool (see Table 3).
Footprint Reduction Methodologies	• Optimizing the excavation remedy by performing additional site characterization and/or a higher tier risk assessment may help reduce the size of the target treatment zone (excavation area) and thereby reduce quantities and the related environmental footprint, as well as costs. • Calculating the 95% upper confidence limit (UCL) for comparison with the industrial soil cleanup target levels (SCTLs) could help to determine more limited hot spot areas that require excavation to bring the overall exposure area within acceptable risk levels. • Similarly, geostatistical methods can also help reduce the required area of excavation based on a calculation of average exposure concentration over the industrial site exposure domain for comparison with the industrial SCTL.

	• It was assumed that all excavated soils will be classified as non-hazardous. The environmental footprint of the remedy could be significantly increased if any excavated soils are classified as hazardous and require transportation to a hazardous waste facility. Appropriate testing and characterization of excavated soils should be performed to eliminate or minimize the amount of any hazardous waste soils requiring transport to a hazardous waste facility. • Some reduction in emissions, particularly CO_2e, may be possible through the use of emission control measures such as alternate fuel sources (e.g., biodiesel), equipment exhaust controls (e.g. diesel oxidation catalyst and particulate filters), and equipment idle reduction. However, given the relatively small size of the remedy, the additional costs, maintenance, and perhaps limited availability of such equipment should be considered. • Continual life-cycle optimization of the remedy and monitoring plan may improve remedy effectiveness, control costs, and minimize the life-cycle environmental footprint of the project.
Greenhouse Gas Emissions	For the diesel scenario, the primary driver for CO_2e emissions was from materials production (6.6 tonnes, or 44% of CO_2e), mostly related to imported soil backfill and decontamination pad concrete. Secondary CO_2e emissions were from transportation (5.4 tonnes, or 36% of CO_2e), mostly related to transporting personnel, excavated soil disposal, and imported backfill. Remaining CO_2e emissions were mostly from excavation equipment. CO2e emissions could be reduced approximately 22% through the use of biodiesel in vehicles and excavation equipment. • Excavation (diesel fuel): 15 tonnes • Excavation (biodiesel): 12 tonnes
Energy Consumption	Total energy consumption consisted primarily of fuel for transportation and equipment operation. Primary drivers for energy consumption were front loader operation (8.8 MWhr) and transportation of site support personnel (8.5 MWhr). A secondary driver was transportation of excavated soil for disposal (6.2 MWhr). The use of biodiesel as a fuel source instead of diesel would not change the amount of energy consumed. • Excavation (diesel fuel): 36 MWhr • Excavation (biodiesel): 36 MWhr
Criteria Air Pollutants	Criteria pollutant emissions for NOx, SOx, and PM10 were estimated for both the diesel and biodiesel scenarios. Asphalt patching materials resulted in the of largest PM10 emissions of 0.06 tonnes. Emissions from other components did not exceed 0.02 tonnes. A significant reduction in criteria pollutant emissions was not observed by the use of biodiesel as a fuel source.
Water Usage	The only significant component of water usage for the remedy is associated with decontamination. Five thousand gallons were assumed to be utilized throughout the project duration. • Excavation (diesel fuel): 5,000 gallons • Excavation (biodiesel): 5,000 gallons
Ecological Impacts	This metric was not discussed in the report.
Resource Consumption	This metric was not discussed in the report.

Naval Air Station Pensacola Site 43, Operable Unit 18 Pensacola, Florida	
Waste Generation	The excavated soil (146.3 yd^3) will be disposed of based on its hazardous waste characterization in accordance with the Resource Conservation and Recovery Act (RCRA). Soil samples will be collected for Toxicity Characteristic Leaching Procedure (TCLP), which will be used to determine whether the soil would be considered hazardous waste and require treatment prior to disposal.
Worker Safety	This metric was not discussed in the report.
Community Impacts	This metric was not discussed in the report.
Conclusions	In general, optimization of the remedial design for this relatively small site could potentially further reduce the environmental footprint of the remedy, i.e., GHG and criteria pollutant emissions, energy usage, and water consumption. A sensitivity analysis considering elements of the remedy that have the greatest impact on remedy effectiveness, life-cycle cost, and sustainability metrics may provide additional insight into appropriate optimization.

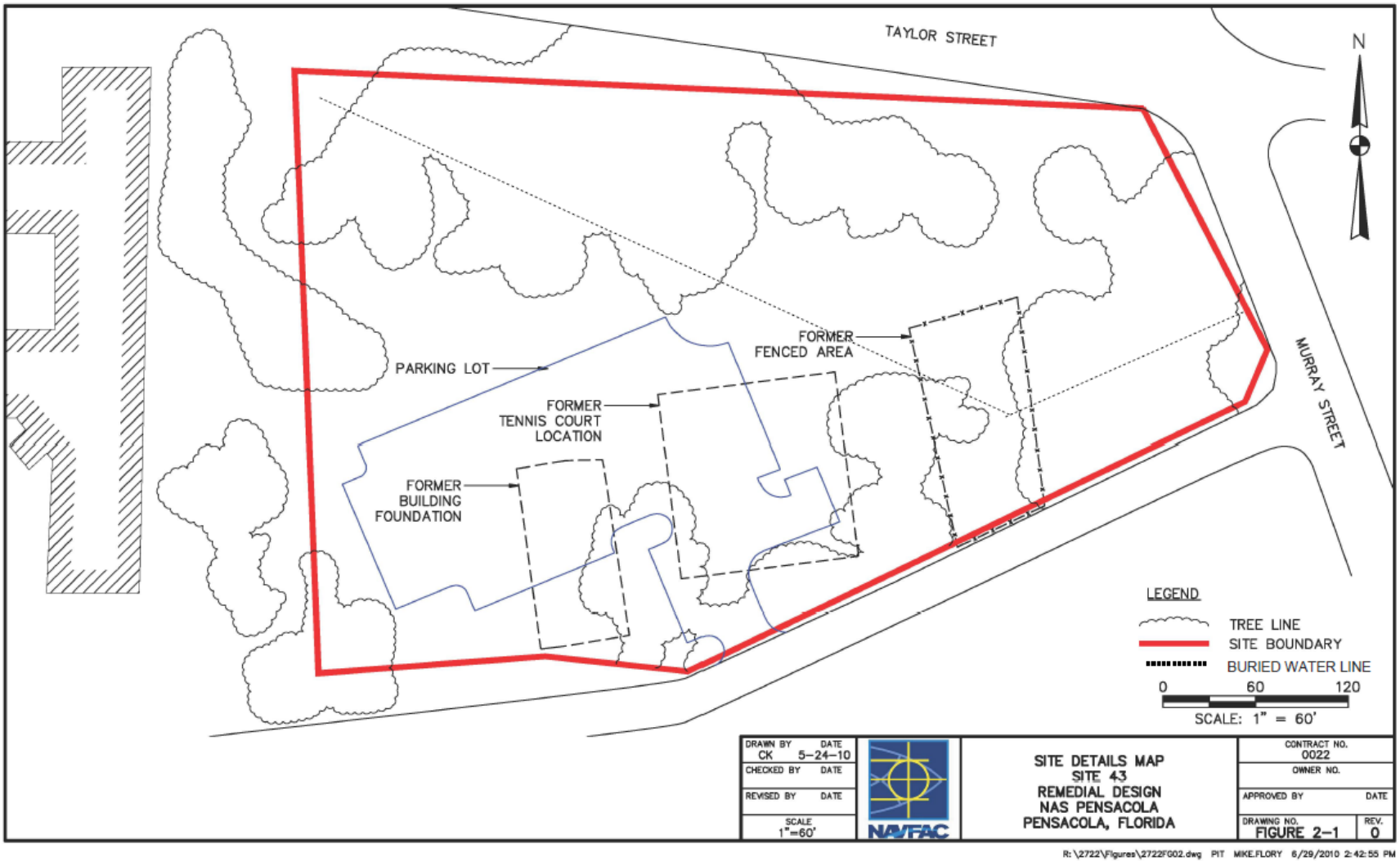


Figure 3. Site Layout for Site 43 Naval Air Station Pensacola

Table 3. GSR Metrics Summary for Site 43 Naval Air Station Pensacola

SUSTAINABILITY EVALUATION
SUMMARY TABLE
REMEDIAL DESIGN
SITE 43
NAVAL AIR STATION PENSACOLA
PENSACOLA, FLORIDA

Remedial Alternative	Greenhouse Gas Emissions				Criteria Pollutant Emission			Energy Consumption	Water Consumption
	$CO_{2\ equiv}$	CO_2	N_20	CH_4	NO_x	SO_x	PM_{10}		
	tonnes							MWhr	gal x 1000
Excavation (diesel fuel)	↑ **15**	↑ **15**	↑ **0.000**	↑ **0.005**	↑ **0.040**	↑ **0.005**	↑ **0.068**	↑ **36**	↑ **5**
Life Cycle Cost: -Materials	7	7	0.000	0.000	0.000	0.001	0.063	1	5
$275,673 -Transportation	5	5	0.000	0.004	0.014	0.000	0.001	21	0
(30 year NPW) -Equipment	3	3	0.000	0.001	0.025	0.004	0.004	14	0
-Operating Consumption	0	0	0.000	0.000	0.000	0.000	0.000	0	0
Excavation (biodiesel fuel)	↓ **12**	↓ **12**	↓ **0.000**	↓ **0.002**	↓ **0.017**	↓ **0.001**	↓ **0.064**	↑ **36**	↑ **5**
Life Cycle Cost: -Materials	7	7	0.000	0.000	0.000	0.001	0.063	1	5
Not available[1] -Transportation	3	3	0.000	0.001	0.006	0.000	0.000	21	0
(30 year NPW) -Equipment	2	2	0.000	0.001	0.010	0.000	0.001	14	0
-Operating Consumption	0	0	0.000	0.000	0.000	0.000	0.000	0	0

[1] Life-cycle costs for the biodiesel were not costed, but could include additional costs such as biodiesel fuel, emissions controls (e.g. scrubbers, diesel catalysts, etc), and specialized equipment

Naval Air Station Pensacola
Site 46, Operable Unit 21
Pensacola, Florida

FEC	**NAVFAC Southeast**
Installation	Naval Air Station Pensacola
Location	Pensacola, Florida
Site Number	Site 46
Site Name	Site 46, Operable Unit 21 Former Building 72
Phase/Milestone/Date	Feasibility Study (September 2010)
Site Background	Site 46 is located in the southeastern portion of NAS Pensacola. The site is located approximately 90 feet west of the former Building 71 footprint (see Figure 4). Buildings 71 and 72, constructed in the early 1920s, were steel-framed structures with metal roofs approximately 100 feet wide by 160 feet long. Prior to 1935, these buildings were sea plane hangars used for aircraft storage and maintenance. From 1935 until the late 1970s, the buildings were used for aircraft paint stripping and painting. Both buildings were demolished in mid-1993. An estimated 400 gallons per day (gpd) of acrylic and epoxy paint stripper and another 400 gpd of ketone were used at these buildings during paint stripping operations. Other chemicals, including phenols and trichloroethene (TCE), may have been used at the site.
Contaminants	Contaminants of concern (COCs) at the site include TCE, lead, VC, Naphthalene, arsenic, cadmium
Impacted Media	Soil and groundwater
Remedial Technologies	This case study discusses remedial alternatives to address groundwater contamination. The remedial alternatives included in the GSR analysis were as follows: • **Alternative 1**: No action • **Alternative 2**: Natural attenuation, LUCs and monitoring • **Alternative 3**: In situ AS/SVE of the TCE plume, natural attenuation, LUCs and monitoring This case study reviews Alternative 2 and 3.
GSR Evaluation Approach	GSR evaluation was performed using a hybrid model of SiteWise™ tool supplemented with TetraTech developed model GSRx (see Table 4). In addition, the alternatives were evaluated against the NCP nine evaluation criteria.
Footprint Reduction Methodologies	Some recommended footprint reduction methods include: Optimization of process equipment: • Evaluate sizing of AS/SVE blowers (pilot-testing may be required); • Operate the AS/SVE with variable frequency drives, high efficiency motors, and/or as a pulsed operation versus continuous operation; and • Use remote telemetry for data collection to minimize routine O&M events, such that O&M visits are primarily dedicated to system sampling and preventative maintenance rather than normal data acquisition.

	Optimization of operation and maintenance, monitoring and institutional controls to reduce overall transportation requirements (Alternatives 2 and 3). • In the design phase, consider reducing the number of existing monitoring wells to be retained and focus on wells in area that exceeds MCLs and downgradient Alternative 2 and 3). • Continually reduce the sampling frequency and the number of sampling locations over time as warranted by monitoring results trend analysis (Alternative 2 and primarily 3). Long-term monitoring through passive sampling devices, where feasible (Alternatives 2 and 3). Some reduction of the environmental footprint, particularly CO_2e emissions, could be realized for all alternatives through the possible use of hybrid vehicles and emission control measures such as alternate fuel sources (e.g., biodiesel), equipment exhaust controls (e.g., diesel oxidation catalyst and particulate filters), and equipment idle reduction (both alternatives).
Greenhouse Gas Emissions	Alternative 3 contained the highest CO_2e emissions (483 tonnes), largely due to emissions from electrical demand from operating the two assumed 30 horsepower AS/SVE blowers (439 tonnes). Alternative 2 CO_2e emissions (12 tonnes) largely result from personnel transportation (10 tonnes) requirements during long term monitoring and institutional control activities. • Alternative 2 (Natural attenuation, LUCs, and monitoring): 11.6 metric ton • Alternative 3 (In situ AS/SVE of the TCE plume, natural attenuation, LUCs and monitoring): 482.76 metric ton
Energy Consumption	Energy demand for Alternative 3 was the highest of the alternatives due to the energy demand associated with AS/SVE system operation. Energy demand for Alternative 2 was driven by long term monitoring and institutional control inspection transportation. • Alternative 2 (Natural attenuation, LUCs and monitoring): 134 MMBTU • Alternative 3(In situ AS/SVE of the TCE plume, natural attenuation, LUCs and monitoring): 8,649.48 MMBTU
Criteria Air Pollutants	Of the alternatives, the highest quantity of criteria pollutants was associated with Alternative 3 with NOx, SOx, and PM10 emissions of 0.94 tonnes, 0.44 tonnes, and 0.002 tonnes, respectively. They were primarily attributed to electrical demand from operating the blowers for AS/SVE.
Water Usage	Water usage associated with electricity production for Alternative 3 resulted in the highest water usage. • Alternative 2 (Natural attenuation, LUCs and monitoring): 3,750 gallons • Alternative 3 (In situ AS/SVE of the TCE plume, natural attenuation, LUCs and monitoring): 403,528.66 gallons
Ecological Impacts	The ecological risk assessment evaluated factors that affect potential exposures such as quality of the habitat, and potential use of the site by ecological receptors. The overall level of ecological risk associated with detected contaminants is considered to be minimal. Potential risk is low to soil invertebrates and plants from TCE and lead at Site 46. This risk is lessened by the limited area of exposed soil available to soil invertebrates and plants.

Resource Consumption	There is no topsoil consumption in any of the alternatives.
Waste Generation	There is no landfill space used in any of the alternatives.
Worker Safety	Alternative 3 has a higher associated risk than Alternative 2 due to the relatively transportation-intense aspect of remedial system operation and maintenance (O&M). The risk associated with Alternative 2 is primarily due to the amount of personnel transportation required over the extended long term monitoring timeframe.
Community Impacts	Implementation of Alternative 2 and 3 would not adversely impact the surrounding community or environment.
Conclusions	Overall, alternative 5 had the highest GHG emissions, energy use, water consumption and criteria emissions. ***Overall Protection of human health and the environment*** Alternative 3 employs active remediation and it would be more protective than Alternative 2. The LUCs and monitoring components of this alternative would be the same as Alternative 2 but would occur over a shorter period of time. ***Compliance with ARARs and TBCs*** Alternatives 2 and 3 would comply with chemical-specific ARARs. In the long-term, these alternatives would comply with chemical-specific ARARs such as the Florida MCLs/GCTLs as cleanup goals are attained either through active remediation and/or natural attenuation; this would be verified through monitoring. ***Long-term Effectiveness and Permanence*** Alternative 3 would be more effective than Alternative 2, because, in addition to the natural attenuation, LUCs, and monitoring components, this alternative would also include an active treatment component that would effectively treat the areas of greatest groundwater contamination and thus accelerate the removal of remaining TCE and VC through natural attenuation. ***Reduction of toxicity, mobility or volume through treatment*** Alternative 2 would not achieve any reduction of toxicity, mobility, or volume of COCs through treatment. However, Alternative 2 would eventually achieve reduction of the toxicity and volume of COCs through natural attenuation. Alternative 3 would achieve reductions in TCE and VC toxicity and volume through treatment. Alternative 3 would permanently and irreversibly remove TCE and VC by treating the groundwater using an AS/SVE system. Alternative 3 would not generate treatment residues. ***Short-term effectiveness*** Implementation of Alternative 2 and 3would result in a slight possibility of exposing site workers to contaminated groundwater during remediation activities. However, these risks of exposure would be effectively controlled by compliance with proper site-specific health and safety procedures. ***Implementability*** Technical implementation of the various components of Alternatives 2 and 3 would be relatively simple. The administrative implementation of Alternative 3 would be slightly more difficult than that of Alternative 2.

Cost

- Alternative 2 (Natural attenuation, LUCs and monitoring): $264,000
- Alternative 3 (In situ AS/SVE of the TCE plume, natural attenuation, LUCs and monitoring): $527,000

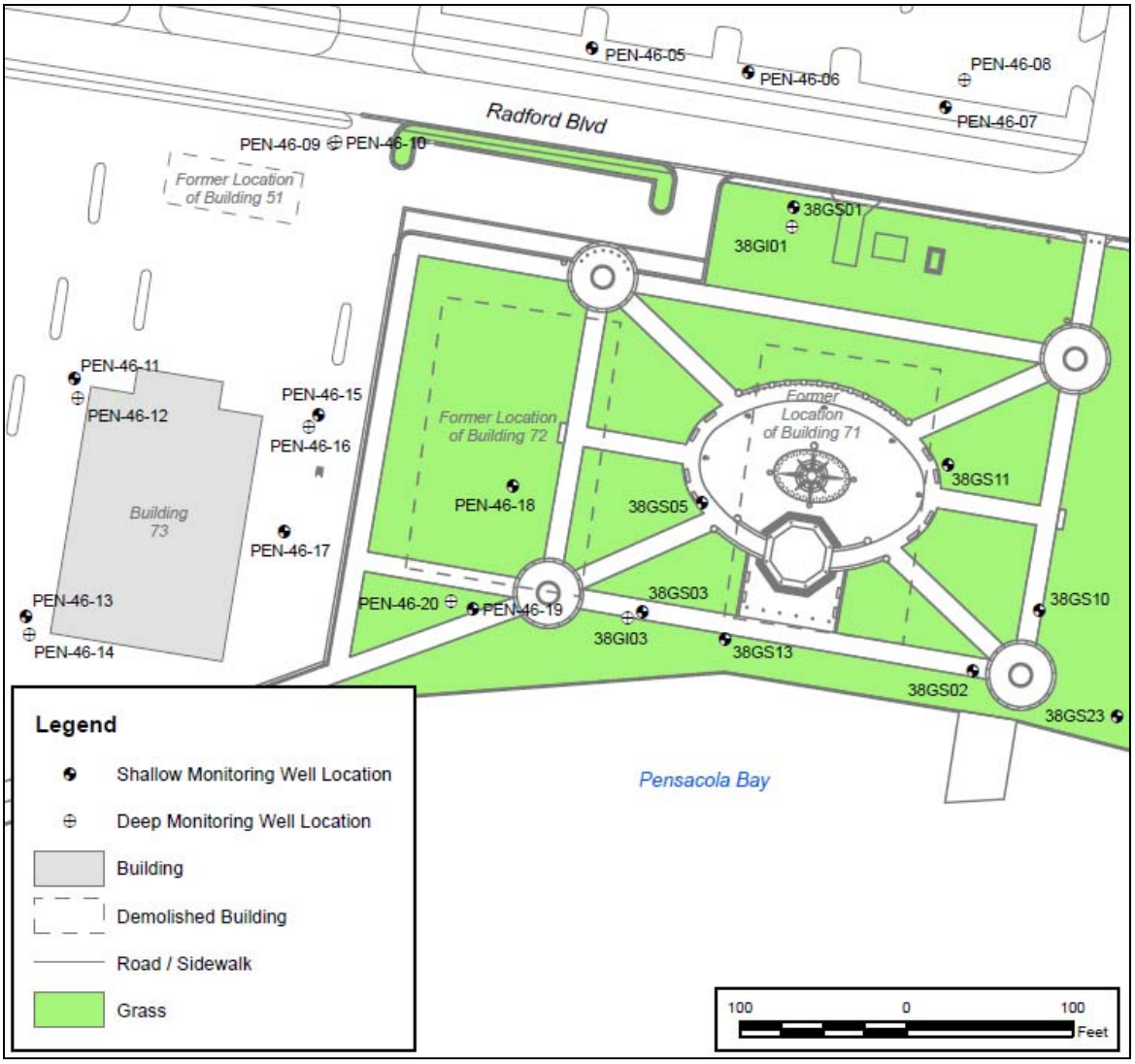


Figure 4. Site Layout for Site 46, OU 21, Naval Air Station Pensacola

Table 4. GSR Metrics Summary for Site 46, OU 21, Naval Air Station Pensacola

Remedial Alternatives	GHG Emissions metric ton	Total energy Used MMBTU	Water gallons	NO_x emissions metric ton	SO_x Emissions metric ton	PM_{10} Emissions metric ton	Accident Risk Fatality	Accident Risk Injury
Remedial Alternative G-2	11.60	1.34E+02	3.75E+03	0.0	0.0033	0.0020	1.84E-04	1.37E-02
Remedial Alternative G-3	482.76	8649.48	403528.66	0.9402	0.4433	0.0066	3.50E-04	2.75E-02

NAVFAC SOUTHWEST

Naval Air Weapons Station China Lake Site 44 China Lake, California	
FEC	**NAVFAC Southwest**
Installation	Naval Air Weapons Station (NAWS) China Lake
Location	China Lake, California
Site Number	Site 44
Site Name	Site 44, NAWS China Lake
Phase/Milestone/Date	Remedial Action Operations 2013
Site Background	Site 44 at NAWS China Lake, CA is a former firefighting training area (FFTA) with free product present in monitoring and extraction wells. Site 44 operated as a FFTA from 1945 to 1988. The FFTA consisted of one pad, where techniques for fighting petroleum fires were practiced. Unburned gasoline, JP-5 fuel, and water would evaporate or flow off the pad and percolate into the surrounding soil. Site 44 also encompasses POI 197, called the "Water Road Fuel Dump," located 750 ft east of the old FFTA.
Contaminants	Free product
Impacted Media	The impacted media is soil.
Remedial Technologies	Two passive skimmer technologies were selected for solar-powered free product recovery system at Site 44 as follows: • Alternative 1 (Abanaki PetroXtractor, a belt skimmer) • Alternative 2 (Geotech Solar Sipper, a pneumatic skimmer) Five units of each system were purchased and installed at Site 44.
GSR Evaluation Approach	No GSR analysis was performed.
Footprint Reduction Methodologies	The use of solar-powered skimmers for free product removal.
Greenhouse Gas Emissions	Vendor estimates indicated that each solar-powered unit saves approximately 0.15 pounds of CO_2 per hour of continuous operation compared to traditional electrical powered units.
Energy Consumption	The energy usage by each system is estimated at: • Alternative 1 (belt skimmer): 17 kWh/year • Alternative 2 (pneumatic skimmer): 36kWh/yr
Criteria Air Pollutants	This metric was not discussed in the presentation.
Water Usage	This metric was not discussed in the presentation.
Ecological Impacts	This metric was not discussed in the presentation.
Resource Consumption	This metric was not discussed in the presentation.
Waste Generation	This metric was not discussed in the presentation.
Worker Safety	This metric was not discussed in the presentation.
Community Impacts	This metric was not discussed in the presentation.

Naval Air Weapons Station China Lake
Site 44
China Lake, California

Conclusions

The Remedial Design recommended installation of a solar-powered passive skimming system to take advantage of the readily available solar energy. Vendor estimates indicated that each solar-powered unit saves approximately 0.15 pounds of CO_2 per hour of continuous operation compared to traditional electrical powered units. The passive skimmer system resulted in reduced O&M activities compared to the original mobile product recovery system, resulting in additional remedy footprint reductions.

The main savings in cost, time, and environmental footprint is the elimination of grid-based or generator-powered electricity, especially at remote sites.

Cumulative product removal (from October 2010 through March 2013)

- Alternative 1 (belt skimmer) : ~592.25 gal
- Alternative 2 (pneumatic skimmer) : ~250.59 gal

Power consumption is low. Electrical cost for operation is not the primary consideration for selecting solar-powered systems.

- Alternative 1 (belt skimmer – 80 watt solar panel) : 17kWh/yr
- Alternative 2 (pneumatic skimmer – 65 watt solar panel) : 36kWhr/yr

Figure 1. Solar-Powered Skimmer for Site 44 NAWS China Lake

Marine Corps Base Camp Pendleton Site 1114 Camp Pendleton, California	
FEC	**NAVFAC Southwest**
Installation	Marine Corps Base Camp Pendleton
Location	Camp Pendleton, California
Site Number	Site 1114
Site Name	Site 1114, MCB Camp Pendleton
Phase/Milestone/Date	Non-Time Critical Removal Action (April 2013)
Site Background	MCB Camp Pendleton is located in northern San Diego County, California and covers approximately 125,000 acres. The primary mission of MCB Camp Pendleton is to operate a training base that promotes the combat readiness of the Operating Forces and the mission of other tenant commands by providing training opportunities, facilities, services and support responsive to the needs of Marines, sailors, and their families. IR Site 1114 exists within an undeveloped arroyo drainage on a coastal terrace located on the western portion of MCB Camp Pendleton. The site contains elevated PCE concentrations in groundwater from an undocumented release.
Contaminants	PCE
Impacted Media	The impacted media is soil and groundwater.
Remedial Technologies	Several treatment technologies for groundwater were evaluated for IR Site 1114. • **Alternative 1:** No further action • **Alternative 2:** Monitored natural attenuation (MNA) and Institutional controls (ICs) • **Alternative 3:** In situ enhanced bioremediation(ISEB) • **Alternative 4:** In situ chemical oxidation (ISCO) • **Alternative 5:** Source area excavation with ISEB
GSR Evaluation Approach	The GSR analysis was performed using SiteWise™ Version 2.0 (see Table 2).
Footprint Reduction Methodologies	This metric was not discussed in the report.
Greenhouse Gas Emissions	Alternative 5 has the highest greenhouse gas emissions among all of the remedial alternatives. This is primarily due to excavation activities, treatment of the dewatered excavated area, and injection of in situ enhanced bioremediation. • Alternative 2 (MNA and ICs): 222.46 metric ton • Alternative 3 (ISEB): 194.29 metric ton • Alternative 4 (ISCO): 449.56 metric ton • Alternative 5 (Source area excavation and ISEB): 328.74 metric ton
Energy Consumption	Alternative 5 has the highest energy usage among all of the remedial alternatives. This is primarily due to excavation activities, treatment of the dewatered excavated area and injection of in situ enhanced bioremediation. • Alternative 2 (MNA and ICs): 3,230 MMBTU • Alternative 3 (ISEB): 2,790 MMBTU • Alternative 4 (ISCO): 4,810 MMBTU • Alternative 5 (Source Area excavation and ISEB): 3,920 MMBTU
Criteria Air Pollutants	Alternative 5 has the highest NOx, SOx and PM10 emissions in comparison to all other alternatives.

Marine Corps Base Camp Pendleton Site 1114 Camp Pendleton, California	
Water Usage	Alternative 5 has the highest water usage among all the remedial alternatives. This is primarily due to dewatering the excavation area and treatment of the water stream. • Alternative 2 (MNA and ICs): 0 gallons • Alternative 3 (ISEB): 0 gallons • Alternative 4 (ISCO): 26,000 gallons • Alternative 5 (Source area excavation and ISEB): 250,000 gallons
Ecological Impacts	A screening level ecological risk assessment (SLERA) and human health risk assessment (HHRA) were conducted for IR Site 1114 using the soil gas and groundwater data collected during the RI. The SLERA identified that potential site receptors were not expected to be adversely impacted by VOCs in soil gas at the site. Since groundwater does not discharge to the surface, the groundwater exposure pathway is incomplete for ecological receptors.
Resource Consumption	This metric is not discussed in this report.
Waste Generation	Alternative 5 is the highest (73.25 tons) generator of non-hazardous waste in comparison to all other alternatives. Alternative 5 is the only alternative that would generate hazardous waste (1,050 tons).
Worker Safety	Alternative 5 has the highest accident risk fatality and risk injury.
Community Impacts	This metric is not discussed in this report.
Conclusions	Based on the evaluation of the five removal action alternatives, the recommended removal action alternative for IR Site 1114 is Alternative 5. Alternative 5 has the highest environmental footprint impact due to equipment use and transportation during the removal action and post-removal activities. ***Implementability*** Alternative 2 is considered highly implementable and uses common remediation tools and equipment to perform routine monitoring. Alternatives 3 and 4 each include an injection program and monitoring program and would be moderately implementable. Alternative 4 would involve use of strong oxidants and would require engineering controls and PPE to effectively minimize site worker exposure. Alternative 5 is highly implementable because all components of this option are mature technologies that can be easily implemented at the site. Site worker exposure during the excavation can be minimized by use of engineering controls and PPE. ***Environmental footprint*** Alternative 2 has a relatively moderate environmental footprint impact due to transportation and laboratory use. Alternative 3 would have a relatively moderate environmental footprint impact and Alternative 4 would have a relatively high environmental footprint impact mainly due to equipment usage and transportation. Alternative 5 would have a relatively high environmental footprint impact due to equipment use and transportation. ***Long-term effectiveness*** Over the long term, Alternative 2 is expected to be highly effective as the processes of natural attenuation diminish the concentrations of PCE in groundwater to acceptable levels. Alternatives 3 and 4 are expected to be highly effective because these options actively reduce contaminant mass through the

acceleration of degradation processes. Alternative 5 is ranked highest in long-term effectiveness and permanence because excavation of low permeability aquifer materials will remove residual source mass bound to the fine grained saturated soils, and enhanced bioremediation is expected to further decrease any residual contamination.

Short-term effectiveness

Alternative 2 is expected to be moderately effective in the short term because PCE in groundwater may remain untreated for some time. Alternatives 3 and 4 are expected to be highly effective because these options actively reduce contaminant mass through the acceleration of degradation processes. Short-term effectiveness for Alternative 5 is considered moderate due to the impact of excavation activities on the local protected habitat and vernal pools.

Cost

- Alternative 2 (MNA and ICs): $2,176,150
- Alternative 3 (ISEB): $2,398,106
- Alternative 4 (ISCO): $2,842,664
- Alternative 5 (Source area excavation and ISEB): $2,309,632

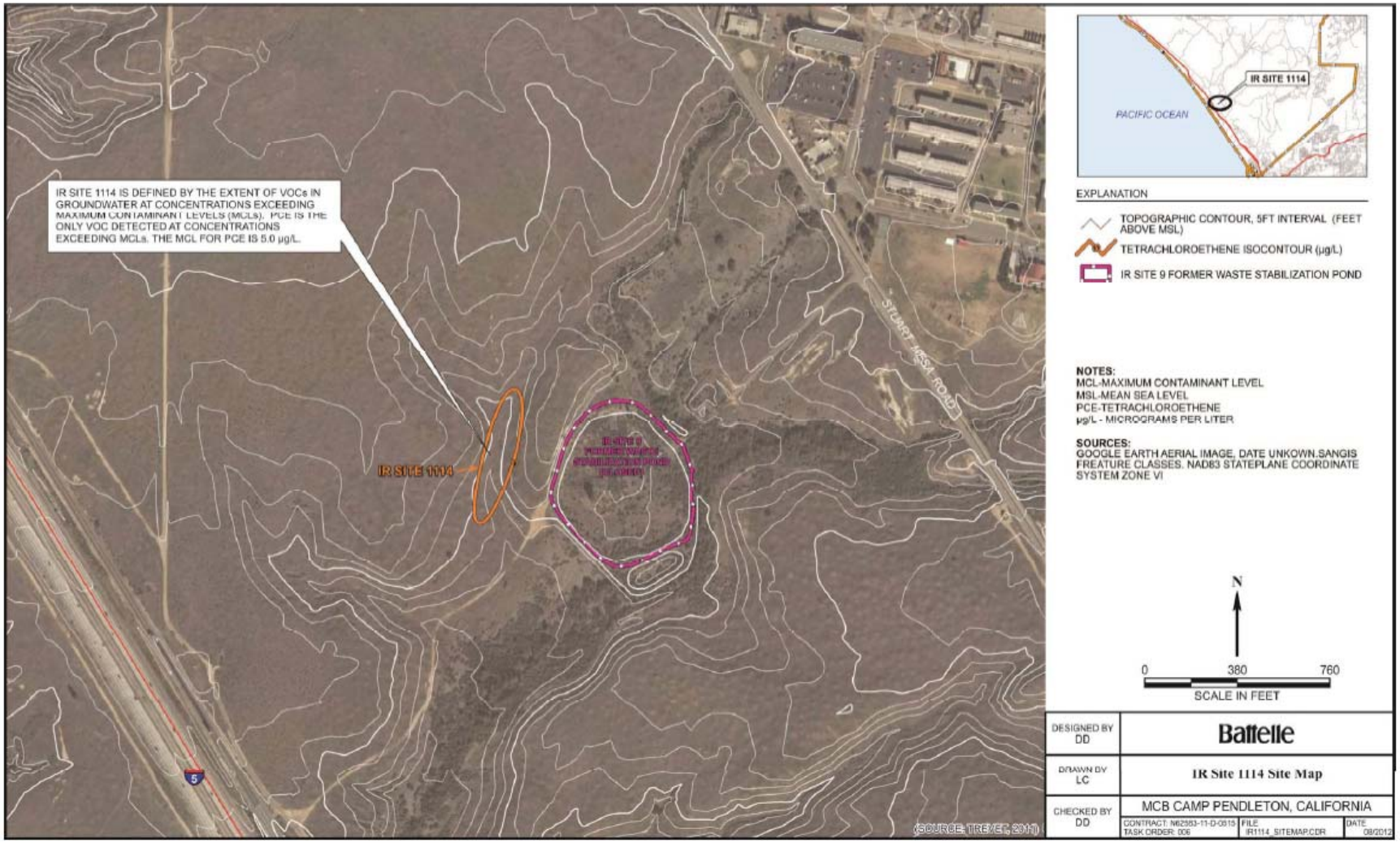


Figure 2. Site Layout for Site 1114 MCB Camp Pendleton

Table 1. GSR Metrics Summary for Site 1114 MCB Camp Pendleton

Remedial Alternatives	GHG Emissions metric ton	Total energy Used MMBTU	Water gallons	NO_x emissions metric ton	SO_x Emissions metric ton	PM_{10} Emissions metric ton	Accident Risk Fatality	Accident Risk Injury
Alternative 2	222.46	3.23E+03	0.00E+00	7.93E-01	4.37E-01	4.35E-02	2.78E-04	2.60E-02
Alternative 3	194.29	2.79E+03	0.00E+00	6.83E-01	3.51E-01	4.22E-02	3.00E-04	2.96E-02
Alternative 4	449.56	4.81E+03	2.60E+04	5.70E-01	2.67E-01	4.04E-02	3.90E-04	4.03E-02
Alternative 5	328.74	3.92E+03	2.50E+05	7.69E-01	3.49E-01	2.57E-01	5.75E-04	5.51E-02

Additional Sustainability Metrics

Remedial Alternatives	Non-Hazardous Waste Landfill Space tons	Hazardous Waste Landfill Space tons	Topsoil Consumption cubic yards	Costing $	Lost Hours - Injury	Final Cost with Footprint Reduction $
Alternative 2	66.25	0.00E+00	0.00E+00	1.81E+06	2.08E-01	1.81E+06
Alternative 3	66.25	0.00E+00	0.00E+00	2.00E+06	2.37E-01	2.00E+06
Alternative 4	66.25	0.00E+00	0.00E+00	2.37E+06	3.23E-01	2.37E+06
Alternative 5	73.25	1.05E+03	0.00E+00	1.92E+06	4.41E-01	1.92E+06

Relative Impact

Remedial Alternatives	GHG Emissions	Energy Usage	Water Usage	NOx emissions	SOx Emissions	PM10 Emissions	*Accident Risk Fatality	*Accident Risk Injury	Community Impacts	Resources Lost
Alternative 2	Medium	Medium	Low	High	High	Low	Medium	Medium	user select	user select
Alternative 3	Medium	Medium	Low	High	High	Low	Medium	Medium	user select	user select
Alternative 4	High	High	Low	High	Medium	Low	Medium	High	user select	user select
Alternative 5	High	High	High	High	High	High	High	High	user select	user select

Relative Impact (User Override)

Remedial Alternatives	GHG Emissions	Energy Usage	Water Usage	NOx emissions	SOx Emissions	PM10 Emissions	*Accident Risk Fatality	*Accident Risk Injury	Community Impacts	Resources Lost
Alternative 2	Medium	Medium	Low	High	High	Low	Medium	Medium	user select	user select
Alternative 3	Medium	Medium	Low	High	High	Low	Medium	Medium	user select	user select
Alternative 4	High	High	Low	High	Medium	Low	Medium	High	user select	user select
Alternative 5	High	High	High	High	High	High	High	High	user select	user select

*Accident Risk is an estimate of how many accidents may occur. This risk is not the same as Cancer Risk, which is the probablity (for a single person) of getting cancer. Accident risk is not comparable to Cancer Risk due to inherent fundamental differences.

Marine Corps Base Camp Pendleton Site 7 Box Canyon Landfill Camp Pendleton, California	
FEC	**NAVFAC Southwest**
Installation	Marine Corps Base Camp Pendleton
Location	Camp Pendleton, California
Site Number	Site 7
Site Name	Site 7, Box Canyon Landfill
Phase/Milestone/Date	Remedial Action Operations
Site Background	The landfill encompasses a 28-acre open area (see Figure 3). Monitored methane gas levels at the landfill fluctuate above and below target levels. Ongoing activities include landfill gas monitoring, groundwater monitoring, and site maintenance.
Contaminants	Methane gas
Impacted Media	Not applicable
Remedial Technologies	Use of two GSR technologies : • Photovoltaic cells are used to collect gas and produce energy • A Microturbine is connected to methane gas collection wells and is capable of adapting to low methane production and fluctuations in gas volumes. The energy produced is fed into Photovoltaic system.
GSR Evaluation Approach	Use of GSR alternative energy technologies (see Figure 4).
Footprint Reduction Methodologies	The use of photovoltaic cells and a microturbine to recover and produce energy from landfill gas.
Greenhouse Gas Emissions	This metric was not discussed in the presentation.
Energy Consumption	This metric was not discussed in the presentation.
Criteria Air Pollutants	This metric was not discussed in the presentation.
Water Usage	This metric was not discussed in the presentation.
Ecological Impacts	This metric was not discussed in the presentation.
Resource Consumption	This metric was not discussed in the presentation.
Waste Generation	This metric was not discussed in the presentation.
Worker Safety	This metric was not discussed in the presentation.
Community Impacts	This metric was not discussed in the presentation.
Conclusions	A photovoltaic cells is designed and installed on the landfill cover. A 30kW methane microturbine capable of running efficiently at low methane concentrations (~7%) is fed into the photovoltaic panel system to generate power.

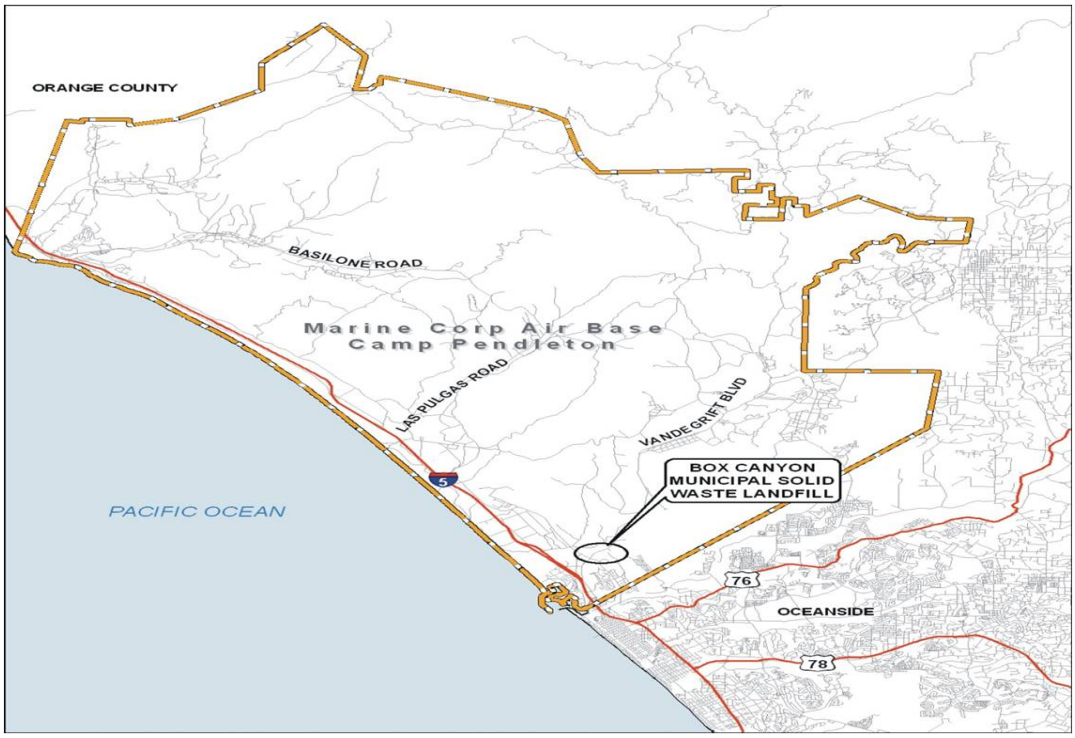


Figure 3. Site Layout for Site 7 Box Canyon Landfill MCB Camp Pendleton

Figure 4. Photovoltaic Panels at Box Canyon Landfill MCB Camp Pendleton

NAVFAC WASHINGTON

Naval Air Station Patuxent River
Site 5
St. Mary's County, Maryland

FEC	**NAVFAC Washington**
Installation	Naval Air Station Patuxent River
Location	St. Mary's County, Maryland
Site Number	Site 5
Site Name	Site 5, Naval Air Station Patuxent River
Phase/Milestone/Date	Interim Removal Action (Technical Memorandum, October 2012)
Site Background	This case study discusses the analysis of the two alternatives where one alternative uses GSR practices. The interim removal action (IRA) consisted of excavating surface debris and subsurface waste and soil, mechanically screening and separating waste streams (munitions debris for disposal, metal and concrete for recycling, and soil and waste for disposal), confirmation inspection, and sampling of excavation extents and site grading using on-site soils.
Contaminants	Not applicable
Impacted Media	The impacted media is soil.
Remedial Technologies	The technologies evaluated included an IRA with and without GSR best practices. • **Alternative 1:** Interim Removal Action (IRA) with GSR • **Alternative 2:** Interim Removal Action without GSR
GSR Evaluation Approach	The evaluation was performed using SiteWise™ Version 2.0 (see Table 1).
Footprint Reduction Methodologies	Several footprint reduction methodologies were proposed including avoidance of importing fill; recycling of scrap metal; and recycling of concrete.
Greenhouse Gas Emissions	Alternative 2 had higher GHG emissions as the remedial action involved more transportation of materials (fill) to the site and equipment to place the fill. • Alternative 1 (IRA with GSR): 279.35 metric ton • Alternative 2 (IRA without GSR): 403.76 metric ton
Energy Consumption	Alternative 2 consumed more energy due to increased transportation of materials (fill) to the site and equipment to place the fill. • Alternative 1 (IRA with GSR) : 4,530 MMBTU • Alternative 2 (IRA without GSR): 6,180 MMBTU
Criteria Air Pollutants	Alternative 2 has higher criteria pollutant emissions than alternative 1, primarily as it required more transportation of materials and equipment.
Water Usage	This metric was not discussed in the technical memorandum.
Ecological Impacts	This metric was not discussed in the technical memorandum.
Resource Consumption	The landfill space for 94 tons of waste (approximate amount of waste generated by 100 people in 1 year) was saved and 9,600 tons of clean soil was saved from consumption.
Waste Generation	The difference between the waste handling phases of both alternatives was relatively low as the total volume of material generated was relatively high for both alternatives. However, landfill space was saved through recycling and recovery efforts described below. • Alternative 1 (IRA with GSR): 9,598.1 ton • Alternative 2 (IRA without GSR): 9,692.3 ton
Worker Safety	This metric was not discussed in the technical memorandum.

Naval Air Station Patuxent River Site 5 St. Mary's County, Maryland	
Community Impacts	This metric was not discussed in the technical memorandum.
Conclusions	It is important to note that the quantities in Table 1 are not the total sustainability footprints for each alternative; rather, they are the footprints of each action that would result in a difference between the two alternatives. Alternative 2 had a higher footprint, as expected, primarily because it requires more transportation of materials (fill) to the site and equipment to place the fill. • The cost avoidance from not importing 9,600 tons (or approximately 8,000 cubic yards) of fill was approximately $300,000. • Recycling the scrap metal recovered through the screening process resulted in a credit of $11,826.47; alternatively, disposal of the metal at a landfill would have cost approximately $3,200, resulting in a total savings of approximately $15,000 for metal recycling. • Additionally, 38.66 tons of concrete were recycled at a cost of $21.46 per ton, less than half of the landfill disposal cost of $58/ton and resulting in a savings of approximately $1,400. • The total cost avoidance is estimated at $316,400 for utilizing Alternative 1 with best GSR practices over Alternative 2.

Table 1. GSR Metrics Summary for Site 5 Naval Air Station Patuxent

Activities	GHG Emissions metric ton	Total energy Used MMBTU	NOx emissions metric ton	SOx Emissions metric ton	PM10 Emissions metric ton	Accident Risk Fatality	Accident Risk Injury
Alternative 1							
Consumables	0.00	0.0E+00	NA	NA	NA	NA	NA
Transportation-Personnel	0.00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Transportation-Equipment	0.00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Equipment Use and Misc	0.00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Residual Handling	279.35	4.5E+03	6.6E-01	3.3E-01	1.7E+00	7.6E-04	6.1E-02
Total Alternative 1	279.35	4.53E+03	6.63E-01	3.27E-01	1.75E+00	7.60E-04	6.12E-02
Alternative 2							
Consumables	0.00	0.0E+00	NA	NA	NA	NA	NA
Transportation-Personnel	0.00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Transportation-Equipment	116.10	1.5E+03	3.6E-02	6.5E-04	3.2E-03	5.1E-04	4.1E-02
Equipment Use and Misc	5.71	9.7E+01	3.6E-02	8.7E-03	2.5E-03	2.2E-05	5.6E-03
Residual Handling	281.95	4.6E+03	6.7E-01	3.3E-01	1.8E+00	7.7E-04	6.2E-02
Total Alternative 2	403.76	6.18E+03	7.42E-01	3.40E-01	1.77E+00	1.30E-03	1.08E-01
Net GSR Benefit (Alternative 1 minus Alternative 2)							
Total	**124**	**1,655**	**7.89E-02**	**1.26E-02**	**2.29E-02**	**5.38E-04**	**4.71E-02**

Notes:

MMBTU - million British Thermal Unit

NOx - Nitrogen Oxides

SOx - Sulfur Oxides

PM10 - Particulate Matter

NA - Not Applicable

GHG - Greenhouse Gases

Naval Support Facility Indian Head
Site 38 Rum Point Landfill
Indian Head, Maryland

FEC	**NAVFAC Washington**
Installation	Naval Support Facility Indian Head
Location	Indian Head, Maryland
Site Number	Site 38
Site Name	Site 38, Rum Point Landfill
Phase/Milestone/Date	Feasibility Study (June 2013)
Site Background	Site 38 covers approximately 0.85 acres in the eastern portion of the Stump Neck Annex west of Rum Point Road (see Figure 1). The landfill was originally intended for disposal of biodegradable waste and has been inactive since December 1989. The date when waste disposal began is not known, and little is known about the site history. Ash from a thermal treatment tank may have been disposed at the site on a onetime basis. Wastes observed during previous site visits included scrap metal, tires, wood, and concrete construction debris. Contaminants present in the waste would have been deposited in the immediate area of disposal and could have migrated to shallow groundwater and intermittent streams that border the site. The surface of the site is mostly covered with grasses, with some trees present. The area surrounding the landfill is wooded, and trees have grown on the landfill slopes. Site observations indicate that the landfill was probably layered, with soil pushed south to north toward the toe of the landfill.
Contaminants	Contaminants of concern (COCs) at the site include arsenic and benzo(a)pyrene in soil; and manganese in groundwater
Impacted Media	Soil and groundwater
Remedial Technologies	This case study discusses remedial alternatives to address both shallow groundwater and soil contamination. The remedial alternatives included in the GSR analysis were • Alternative 1: No Action • Alternative 2: Capping with Land Use Controls (LUCs), • Alternative 2: Landfill Removal with LUCs The case study discusses alternatives 2 and 3.
GSR Evaluation Approach	GSR evaluation was performed using a hybrid model of SiteWise™ tool supplemented with TetraTech developed model GSRx (see Table 2).
Footprint Reduction Methodologies	Some recommended footprint reduction methods include: • Some reduction of the environmental footprint, particularly GHG emissions and energy consumption, could be realized for all alternatives through the possible use of emission control measures such as alternate fuel sources (e.g. biodiesel), equipment exhaust controls (e.g. diesel), and equipment idle reduction. • Consider optimizing of the use of equipment, particularly the use of the dozer, compactor and excavator. Consider the use of alternate pieces of equipment that will be able to perform the work without being a burden to the environmental impact categories. • Design an optimized sampling schedule that minimizes the number of samples that need to be analyzed and maximizes the results. Lowering the amount of samples will mean a reduction of environmental impacts. • Consider ways to reduce vehicle mileage to reduce worker risk as well

	as energy use and emissions. Encourage site workers to carpool daily to the site to reduce total vehicle mileage. Alternative 2: Consider the revision of volumes of borrow soil needed for the capping activities. Consider the use of a closer source of borrow soil. Consider the revision of the amount of geotextile needed. The use of HDPE Geotextile highly contributes to environmental impacts. Consider the use of a more environmentally friendly material for geotextiles or the amount of geotextile used for capping purposes. Alternative 3: Consider different modes of transportation for the residual handling operations. An option for residual handling operations is to transport the excavated material by rail to the closest disposal facility.
Greenhouse Gas Emissions	Alternative 2 has the highest greenhouse gas emissions due to production of 3,471 cubic yards of borrow soil followed by production of 150,000 square feet of HDPE geotextile. • Alternative 2 (Capping with LUCs): 303.33 metric ton • Alternative 3 (Landfill Removal with LUCs): 240.32 metric ton
Energy Consumption	Alternative 2 has the highest energy consumption due to production of borrow soil, gravel, and HDPE geotextile. • Alternative 2 (Capping with LUCs): 14,667,89 MMBTU • Alternative 3 (Landfill Removal with LUCs): 5,911.3 MMBTU
Criteria Air Pollutants	Alternative 3 had the highest air emissions generated primarily during residual handling operations.
Water Usage	Alternative 2 has the highest water consumption due to water used during the production of materials (HDPE geotextile and PVC liners). • Alternative 2 (Capping with LUCs): 17,480.7 gallons • Alternative 3(Landfill Removal with LUCs): 2,661.37 gallons
Ecological Impacts	The ecological risk screening evaluation included comparison of detected chemical concentrations in Site 38 samples to EPA ecological screening levels and alternative guidelines and food-chain modeling.
Resource Consumption	Non-hazardous waste generated by alternative 3 is 6,200 tons. The top soil consumption was 810 tons.
Waste Generation	Alternative 3 generates the highest amount of waste due to landfill removal as compared to alternative 2.
Worker Safety	Alternative 3 had the highest risk due to transportation of personnel and equipment use.
Community Impacts	Alternative 3 would have short term impact to community due to additional traffic during hauling wastes. Alternative 2 would not have impacts to community.
Conclusions	Alternative 2 has the greatest greenhouse gas emissions, energy use, and water consumption of the two alternatives evaluated, which is attributed to the materials needed to construct the cap. Alternative 3 has a similar impact to Alternative 2 for energy use and greenhouse gas emissions, but a higher cost. ***Overall protection of human health and the environment*** Alternative 3 (Landfill Removal, Monitoring and LUCs) would protect human health and the environment to the greatest extent by removing all landfill waste and monitoring natural degradation processes for groundwater. Alternative 2

(Engineered Cap) would protect human health to a lesser extent through implementation of LUCs to restrict land and groundwater use.

Compliance with ARARs
Alternatives 2 and 3 would comply with action-specific ARARs, including state sanitary landfill closure requirements.

Long-term effectiveness and permanence
Alternative 3 would be the most protective over the long term because all landfill waste would be removed from the site. Alternative 2 would be less effective in the long term because the landfill waste and contaminated surface soil would remain on site, and LUCs would be needed to restrict land and groundwater use.

Reduction of toxicity, mobility, or volume through treatment
None of the alternatives include treatment to reduce the toxicity, mobility, or volume of contaminants at the site.

Short-term effectiveness
There would be no adverse impact on the community from implementation of Alternative 2. For Alternative 3, hauling wastes off site would generate additional traffic. Although there would be a potential for spills during transport, all materials would be solids that could easily be placed into the transport container.

Implementability
Alternatives 2 and 3 are readily implementable.

Cost
- Alternative 2: $1,641,000
- Alternative 3: $1,987,000

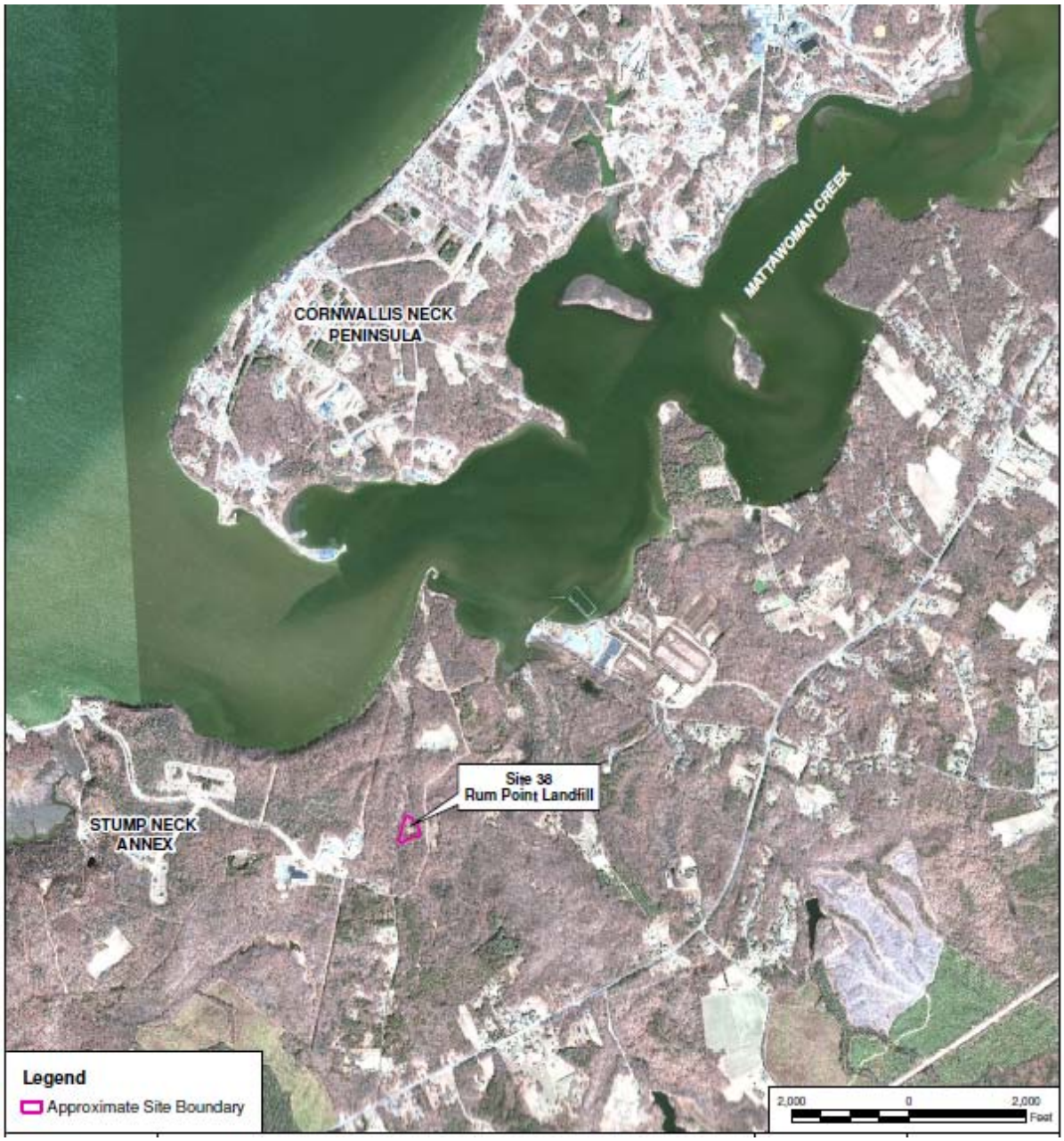


Figure 1. Site Layout for Site 38 Rum Point Landfill, Naval Support Facility Indian Head

Table 2. GSR Metrics Summary for Site 38 Rum Point Landfill, Naval Support Facility Indian Head

Alternative	Activities	GHG Emissions	Total Energy Used	Water Impacts	NO_X Emissions	SO_X Emissions	PM_{10} Emissions	Accident Risk Fatality	Accident Risk Injury
		Metric Ton CO_2e	MMBTU	Gallons	Metric Ton	Metric Ton	Metric Ton		
Alternative 1	Materials Production	217.02	13,405.07	16,480.70	4.05E-07	1.93E-01	2.79E-02	NA	NA
	Transportation-Personnel	6.08	76.46	NA	2.25E-03	7.92E-05	4.56E-04	1.24E-04	1.00E-02
	Transportation-Equipment	31.53	411.57	NA	9.91E-03	1.75E-04	8.81E-04	7.81E-05	6.28E-03
	Equipment Use and Misc	48.23	768.73	1,000.00	2.72E-01	7.08E-02	2.15E-02	5.45E-05	1.37E-02
	Residual Handling	0.46	6.06	NA	1.46E-04	2.58E-06	1.30E-05	1.56E-06	1.26E-04
	Total	303.33	14,667.89	17,480.70	2.85E-01	2.64E-01	5.07E-02	0.000	0.030
Alternative 2	Materials Production	28.75	2,413.60	661.37	6.33E-03	6.33E-03	6.93E-04	NA	NA
	Transportation-Personnel	7.41	93.24	NA	9.66E-05	9.66E-05	5.56E-04	1.52E-04	1.22E-02
	Transportation-Equipment	6.93	90.45	NA	3.85E-05	3.85E-05	1.94E-04	1.72E-05	1.38E-03
	Equipment Use and Misc	78.69	1,203.46	2,000.00	1.10E-01	1.10E-01	3.93E-02	7.21E-05	1.81E-02
	Residual Handling	118.54	2,110.55	NA	2.09E-01	2.09E-01	1.12E+00	1.21E-04	9.76E-03
	Total	240.32	5,911.30	2,661.37	3.26E-01	3.26E-01	1.16E+00	0.000	0.041

Marine Corps Base Quantico
Solid Waste Management Unit M-13, Building 2113
Quantico, Virginia

FEC	**NAVFAC Washington**
Installation	Marine Corps Base Quantico
Location	Quantico, Virginia
Site Number	Solid Waste Management Unit (SWMU) M-13
Site Name	SWMU M-13, Building 2113
Phase/Milestone/Date	Feasibility Study (November 2012)
Site Background	SWMU M-13 is the former concrete pad, sump, associated underground piping, and loading/unloading area that serviced SWMU TA-01 (Building 2113 Underground Tank), which was a 103,000-gallon unlined concrete tank that was part of a system supplying fuel to the heating plant located in Building 2113. The heating plant operated from 1941 to approximately 1985 to 1986, when the last boiler was shut down. Building 2113 is located within the Mainside of MCBQ along the Potomac River adjacent to Bauer Road. SWMU M-13 is located approximately 75 feet south of Building 2113. No. 6 fuel oil was the primary fuel; however, waste motor oil, paint stripper and thinner, and possibly halogenated solvents were also added to the fuel oil. All tanks have been removed or closed in place. Fuel oil impacted soil was noted during the tank and piping closure, with some soil being removed and disposed off-site. Building 69 was a motor pool and Building 5108 was a flammable material storage shed associated with the motor pool. The main impacts to groundwater are chlorinated solvents, which are centered in the area of the former storage shed. It is believed that the chlorinated solvents are associated with the motor pool and storage shed and not the actual SWMU.
Contaminants	Contaminants of concern (COCs) at the site include VOCs (1,1,2,2-tetrachloroethane (PCA), 1,1,2-trichloroethane (TCA), 1,2,3-trichlorobenzene (TCB), 1,2,4-TCB, 1,3-dichlorobenzene (DCB), 1,4-DCB, chloroform, tetrachloroethene (PCE), trichloroethene (TCE), cis-1,2-dichloroethene (DCE), and vinyl chloride (VC).
Impacted Media	Soil vapor and groundwater
Remedial Technologies	This case study discusses remedial alternatives to address groundwater contamination. The remedial alternatives included in the GSR analysis were as follows: • **Alternative 1**: No action • **Alternative 2**: MNA with Land use Controls (LUCs) • **Alternative 3a**: Enhanced Bioremediation with LUCs (using photovoltaic [PV] panels for operation of system) • **Alternative 3b**: Enhanced Bioremediation with LUCs (using electricity from grid for operation of system) This case study reviews Alternative 2, 3a, and 3b.
GSR Evaluation Approach	GSR evaluation was performed using SiteWise™ supplemented with a TetraTech developed model GSRx (see Table 3). In addition, the alternatives were evaluated against the NCP nine evaluation criteria.

Footprint Reduction Methodologies	Some recommended footprint reduction methods include: Alternatives 3a and 3b: • Consider the use of recycled materials for the asphalt pavement repair, especially since it is not a major operation and the repair area would not be of high occupancy. • Some reduction of the environmental footprint, particularly GHG emissions and energy consumption, could be realized for all alternatives through the possible use of emission control measures such as alternate fuel sources (e.g., biodiesel), equipment exhaust controls (e.g. diesel), and equipment idle reduction. • Consider optimization of the use of equipment, and even the type of equipment used during operations could make a difference in the environmental impacts. • Use of PV panels for system operation (Alternative 3a). However, through the GSR analysis, it was determined that the use of solar panels does not represent major savings in any of the impact categories evaluated due to the low energy requirement of the proton reduction system proposed for bioremediation. All Alternatives: • Consider ways to reduce vehicle mileage to reduce worker risk as well as energy use and emissions. Encourage site workers to carpool daily to the site to reduce total vehicle mileage. • Optimize the number of samples analyzed during the LTM stage given that the laboratory analysis service is one of the major drivers in most of the impact categories.
Greenhouse Gas Emissions	Alternative 3a and 3b has the highest greenhouse gas emissions. The difference in GHG emissions is the calculation of electricity losses from the production and distribution through the grid. The difference from the production of electricity from solar and grid electricity is negligible. • Alternative 2 (MNA with LUCs): 22.96 metric ton • Alternative 3a: Enhanced Bioremediation with LUCs (using PV panels for operation of system) : 40.19 metric ton • Alternative 3b: Enhanced Bioremediation with LUCs (using electricity from grid for operation of system): 42.01 metric ton
Energy Consumption	Alternative 3a and 3b have the highest energy consumption due to the equipment use (laboratory analysis services) and production of materials. • Alternative 2 (MNA with LUCs): 339.66 MMBTU • Alternative 3a: Enhanced Bioremediation with LUCs (using PV panels for operation of system) : 772.53 MMBTU • Alternative 3b: Enhanced Bioremediation with LUCs (using electricity from grid for operation of system): 772.53 MMBTU
Criteria Air Pollutants	Alternative 3a and 3b has the highest air emissions generated primarily during laboratory analysis services and production of materials (asphalt).

Water Usage	Alternative 3a and 3b have the highest water consumption due to water used during decontamination, production of PV for piping of wells and conduits and steel. • Alternative 2 (MNA with LUCs): 46 gallons • Alternative 3a: Enhanced Bioremediation with LUCs (using PV panels for operation of system) : 7,240.49 gallons • Alternative 3b: Enhanced Bioremediation with LUCs (using electricity from grid for operation of system) : 7,240.49 gallons
Ecological Impacts	There no unacceptable risks to ecological receptors.
Resource Consumption	This metric is not discussed in the report.
Waste Generation	This metric is not discussed in the report.
Worker Safety	Alternative 3a and 3b had the highest risk due to transportation of personnel.
Community Impacts	A slight increase in traffic is expected during the well installation associated with Alternative 3, which is anticipated to take less than 1 month.
Conclusions	Alternative 3b (In-Situ Enhanced Bioremediation with LUCs) is the recommended alternative for SWMU M-13. This alternative would be protective of human health and the environment by controlling potential exposure via LUCs, complies with RAOs within 1 month of implementation, and is expected to achieve SRGs within approximately 5 to 10 years. LUCs will reduce the human health risk to acceptable levels and provide assurance that future changes in site use would not result in the potential for future human exposure to groundwater contaminants via a completed ingestion and/or dermal contact pathway. In addition, groundwater monitoring would be conducted to provide verification of the effectiveness of this remedial action, by providing a mechanism to confirm that the contaminant plume is stable or diminishing and is not migrating at unacceptable levels. A five-year review process would also be implemented to evaluate the status of the site, ensure that remedial goals are met, and provide direction for further action, if required. After remedial goals are met, LUCs and monitoring requirements can be eliminated with concurrence from the governing regulatory agencies. Given that the operation of the proton reduction system consumes little energy, the use of solar panels does not represent major savings in any of the impact categories evaluated in this report. It should be noted that Alternative 2 would also meet the RAOs identified for SWMU M-13; however, it is estimated that remediation goals would not be reached for approximately 20 years. ***Overall protection of human health and the environment*** Alternative 3 would provide the same benefits as Alternative 2 but with the potential to reduce the time needed to meet SRGs ***Compliance with ARARs*** Alternatives 2 and 3 would provide mechanisms to ensure that exposure pathways are not complete and to monitor natural attenuation until the site is eventually in compliance with ARARs.

Long-term effectiveness and permanence
Because Alternatives 2 and 3 would involve the use of passive and active groundwater remediation via biodegradation, they are expected to be effective at decreasing groundwater contaminant levels over the long term. Alternatives 2 and 3 would provide continued monitoring in accordance with a long-term monitoring plan, groundwater use restrictions, and reliable LUCs

Reduction of Toxicity, mobility or volume through treatment
Alternatives 1 and 2 would not include active treatment to reduce the toxicity, mobility, or volume of hazardous substances in groundwater. Alternative 3 should stimulate the reduction of toxicity and volume of hazardous substances at an accelerated rate over the MNA approach (Alternative 2).

Short-term Effectiveness
No risks to the community, current or future on-site workers, or the environment are anticipated during the implementation of the groundwater alternatives. However, a slight increase in traffic is expected during the well installation associated with Alternative 3, which is anticipated to take less than 1 month.

Implementability
All three of the remedial alternatives are implementable

Cost

- Alternative 2 (MNA with LUCs) : $504,900
- Alternative 3a: Enhanced Bioremediation with LUCs (using PV panels for operation of system): $790,500
- Alternative 3b: Enhanced Bioremediation with LUCs (using electricity from grid for operation of system): $790,500

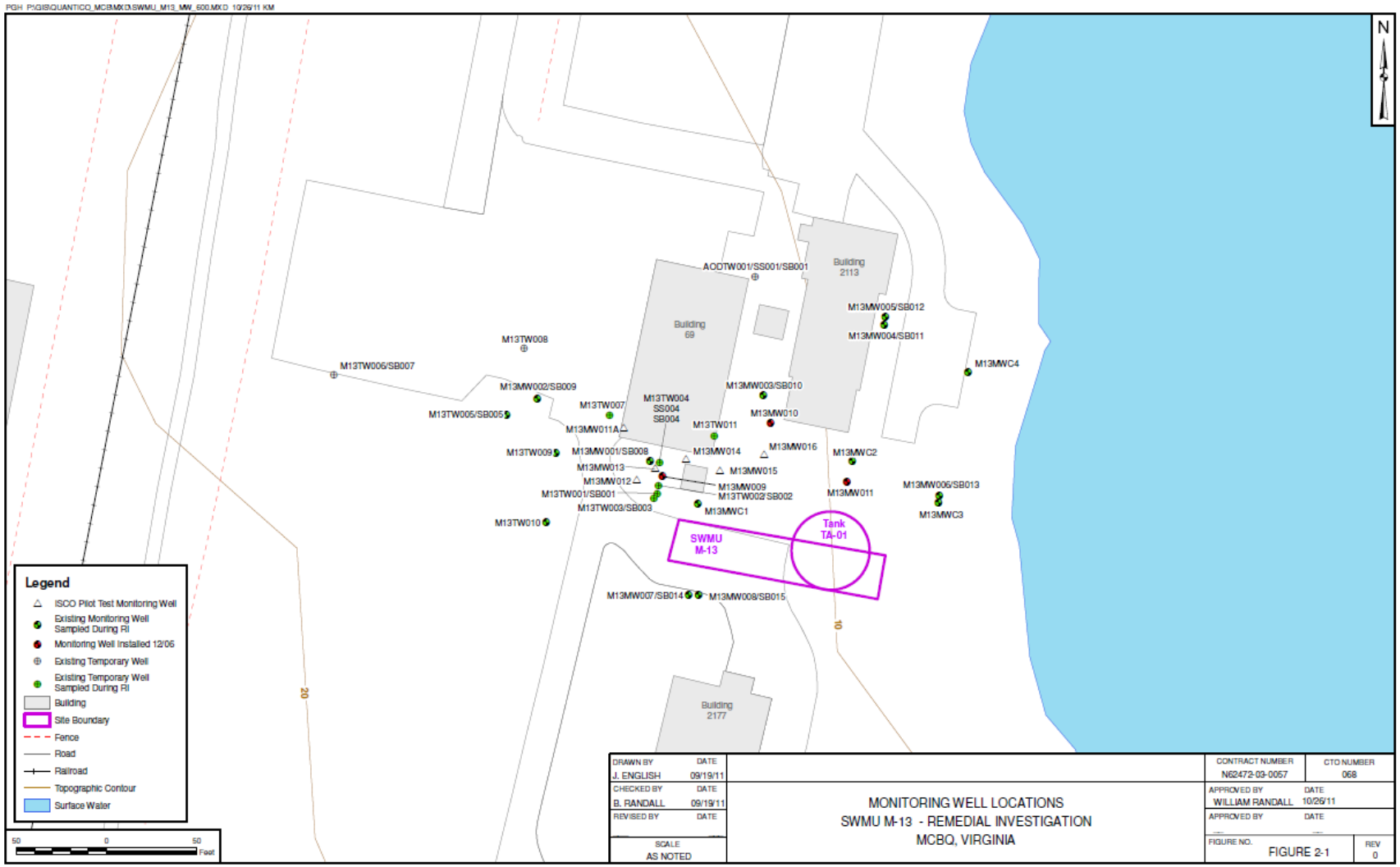


Figure 2. Site Layout for SWMU-13 MCB Quantico

Table 3. GSR Metrics Summary for SWMU-13 MCB Quantico

Alternative	Activities	GHG Emissions	Total Energy Used	Water Impacts	NOx Emissions	SOx Emissions	PM10 Emissions	Accident Risk Fatality	Accident Risk Injury
		metric ton	MMBTU	gallons	metric ton	metric ton	metric ton		
Alternative 2	Materials Production	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	NA	NA
	Transportation-Personnel	1.26	15.82	NA	4.65E-04	1.64E-05	9.44E-05	2.57E-05	2.07E-03
	Transportation-Equipment	0.00	0.00	NA	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Equipment Use and Misc	21.70	323.84	46.00	7.51E-02	5.01E-02	1.90E-03	0.00E+00	0.00E+00
	Residual Handling	0.00	0.00	NA	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	22.96	339.66	46.00	0.076	0.050	0.002	0.000	0.002
Alternative 3a	Materials Production	14.37	370.47	6,131.64	1.03E-02	1.03E-02	7.42E-02	NA	NA
	Transportation-Personnel	2.42	30.44	NA	3.15E-05	3.15E-05	1.82E-04	4.95E-05	3.99E-03
	Transportation-Equipment	0.37	4.95	NA	2.96E-06	2.96E-06	1.02E-05	1.17E-06	9.42E-05
	Equipment Use and Misc	22.72	362.79	1,108.85	5.30E-02	5.30E-02	2.21E-03	1.58E-05	3.98E-03
	Residual Handling	0.30	3.88	NA	1.65E-06	1.65E-06	8.32E-06	1.56E-06	1.26E-04
	Total	40.19	772.53	7,240.49	0.063	0.063	0.077	0.000	0.008
Alternative 3b	Materials Production	14.37	370.47	6,131.64	8.16E-06	1.03E-02	7.42E-02	NA	NA
	Transportation-Personnel	2.42	30.44	NA	8.95E-04	3.15E-05	1.82E-04	4.95E-05	3.99E-03
	Transportation-Equipment	0.37	4.95	NA	1.18E-04	2.96E-06	1.02E-05	1.17E-06	9.42E-05
	Equipment Use and Misc	24.54	362.79	1,108.85	8.79E-02	5.30E-02	2.21E-03	1.58E-05	3.98E-03
	Residual Handling	0.30	3.88	NA	9.35E-05	1.65E-06	8.32E-06	1.56E-06	1.26E-04
	Total	42.01	772.53	7,240.49	0.089	0.063	0.077	0.000	0.008

NAVFAC PACIFIC

Joint Base Pearl Harbor-Hickam
Building 394 Battery Shop
Oahu, Hawaii

FEC	**NAVFAC Pacific/NAVFAC Hawaii**
Installation	Joint Base Pearl Harbor-Hickam (JBPHH)
Location	Oahu, Hawaii
Site Number	N/A
Site Name	Building 394 Battery Shop
Phase/Milestone/Date	Remedial Investigation/Feasibility Study (June 2012)
Site Background	The project site was an open air facility used to clean, disassemble, and restore lead/sulfuric acid submarine batteries from approximately 1960 to 1991. Since 1991, the project site has been unused. The batteries were cleaned in the former battery disassembly area, on a concrete-bermed battery washout pad. Spent battery acid and lead residue were discharged from the washout pad to an unlined settling pit. Between 1960 and 1980, rainwater that accumulated in the former battery disassembly area sumps was routed to two onsite dry wells. Both sumps were abandoned and backfilled with concrete. The dry wells are currently inactive. The unlined settling pit was backfilled in 1981 and is currently covered with gravel. After 1981, discharges from the battery washout pad were routed to a 15,000-gallon underground storage tank (UST). The UST contents were pumped out periodically for treatment and disposal. In 1990, the tank and pipelines were tested for tightness. The tank tested tight, but the pipelines did not. The 15,000-gallon UST, two aboveground tanks, and all associated piping and appurtenances were removed in 1995.
Contaminants	Lead, Antimony, Zinc, Arsenic, Beryllium, Copper, Nickel
Impacted Media	The impacted media are soil and groundwater. This case study discusses soil media.
Remedial Technologies	The remedial alternatives for soil included: • **Alternative 1:** No Further Action • **Alternative 2:** Capping with LUCs • **Alternative 3:** Excavation and Disposal
GSR Evaluation Approach	SiteWise™ was used for the GSR evaluation. The discussion below is focused on alternative 2 and alternative 3 (e.g., Alternative 1 no further action is not reviewed for this case study, although addressed in the report).
Footprint Reduction Methodologies	This report did not address strategies to reduce the environmental footprint of the soil cleanup actions.
Greenhouse Gas Emissions	GHG emissions and energy use are estimated to be more than twice as high for Alternative 3 compared to Alternative 2. GHG emissions and energy use during the remedial action construction phase for Alternative 2 are mainly associated with consumables required for the construction of the A.C. pavement cover at the project site. Other activities associated with GHG emissions and energy use for Alternative 2 include residual handling, equipment use, equipment and personnel transportation during the remedial action construction phase, as well as personnel transportation during the long-term monitoring phase. The largest component of GHG emissions and energy use for Alternative 3 is from equipment transportation, which includes transportation of clean soil to the project site. • Alternative 2 (Capping with LUCs): 152.05 metric tons of CO_2e • Alternative 3 (Excavation and Disposal): 358.07 metric tons of CO_2e

Joint Base Pearl Harbor-Hickam Building 394 Battery Shop Oahu, Hawaii	
Energy Consumption	Energy use is estimated to be more than twice as high for Alternative 3 compared to Alternative 2 due to equipment transportation, which includes transportation of clean soil to the project site. • Alternative 2 (Capping with LUCs): 2,020 MMBTU • Alternative 3 (Excavation and Disposal): 4,100 MMBTU
Criteria Air Pollutants	Pollutant/dust emissions are estimated to be one order of magnitude higher for Alternative 3 compared to Alternative 2. The majority of pollutant/dust emissions estimated for Alternative 2 are associated with residual handling (i.e., transportation of waste) during the remedial action construction phase with smaller portions accounted for by equipment use, equipment and personnel transportation during the remedial action construction phase as well as personnel transportation during the long-term monitoring phase. The largest component of pollutant/dust emissions is residual handling associated with the transportation and disposal of the excavated soil from the project site to the U.S. Ecology landfill in Beatty, Nevada.
Water Usage	Water use estimated for Alternative 3 is slightly higher than Alternative 2 because of the longer duration of the construction phase of Alternative 3. • Alternative 2 (Capping with LUCs): 12,500 gallons • Alternative 3 (Excavation and Disposal): 15,000 gallons
Ecological Impacts	An ecological risk assessment was not conducted for the project site because no significant onsite ecological receptors exist at the project site and there are no potential exposure pathways identified for offsite ecological receptors.
Resource Consumption	Topsoil consumption estimated for Alternative 2 is higher compared to Alternative 3 due to the total amount of fill material required for the construction of the permanent cover at the project site.
Waste Generation	The estimated quantities of non-hazardous waste to be generated for Alternatives 2 and 3 are the same. The estimated quantity of hazardous waste to be generated for Alternative 3 is three orders of magnitude higher compared to Alternative 2. No hazardous waste will be generated for Alterative 2 because impacted soil will remain in place.
Worker Safety	The risks of injuries/fatalities and lost hours due to injury for Alternative 2 are higher compared to Alternative 3 due to the long duration of the long-term monitoring phase and continued visits to the project site for 30 years.
Community Impacts	This metric was not discussed in the report.
Conclusions	Although some of the sustainability metrics for Alternative 2 are higher than the estimated metrics for Alternative 3, the overall environmental footprint and impact of Alternative 3 is greater because of the much larger quantities of energy used, and GHG and pollutant/dust emissions during the construction phase and shipping of residual material overseas to the continental US. Following comparative analysis, the remedial action alternative with the highest overall rating was Alternative 2 (Capping, with LUCs). This alternative received the highest overall rating based on the following: • Effectively mitigates exposure routes • Reduces potential for surface water infiltration and future impacts to groundwater • Minimizes risk during implementation because lead-impacted soil will not be disturbed • Uses equipment readily available on island

Alternative 2 is protective of human health and the environment, easily implemented, and the most cost effective. Therefore, Alternative 2 (Capping, with LUCs) is recommended for implementation as the remedial action at the project site.

Overall Protection of Human Health and the Environment. Alternative 2 would provide a higher degree of protection of human health and environment than alternative 3 since impacted soils would be covered and there would be no excavation which could result in potential contact with lead and antimony impacted soil.

Compliance with Applicable or Relevant and Appropriate Requirements (ARARs). Both alternatives would comply fully with applicable ARARs.

Long-Term Effectiveness and Permanence. Alternative 3 offers more long term effectiveness than alternative 2 as affected soils will be removed permanently removed from the project site.

Reduction in Toxicity, Mobility, or Volume through Treatment. Both alternatives will not reduce toxicity, mobility or volume through treatment.

Short-Term Effectiveness. Alternative 2 would achieve maximum short-term effectiveness since there would be no excavation, transportation or disposal of impacted soil.

Implementability. Both alternatives 2 and 3 would be easily implementable.

Cost

- Alternative 2 (Capping with LUCs): $1,054,186
- Alternative 3 (Excavation and Disposal): $1,859,501

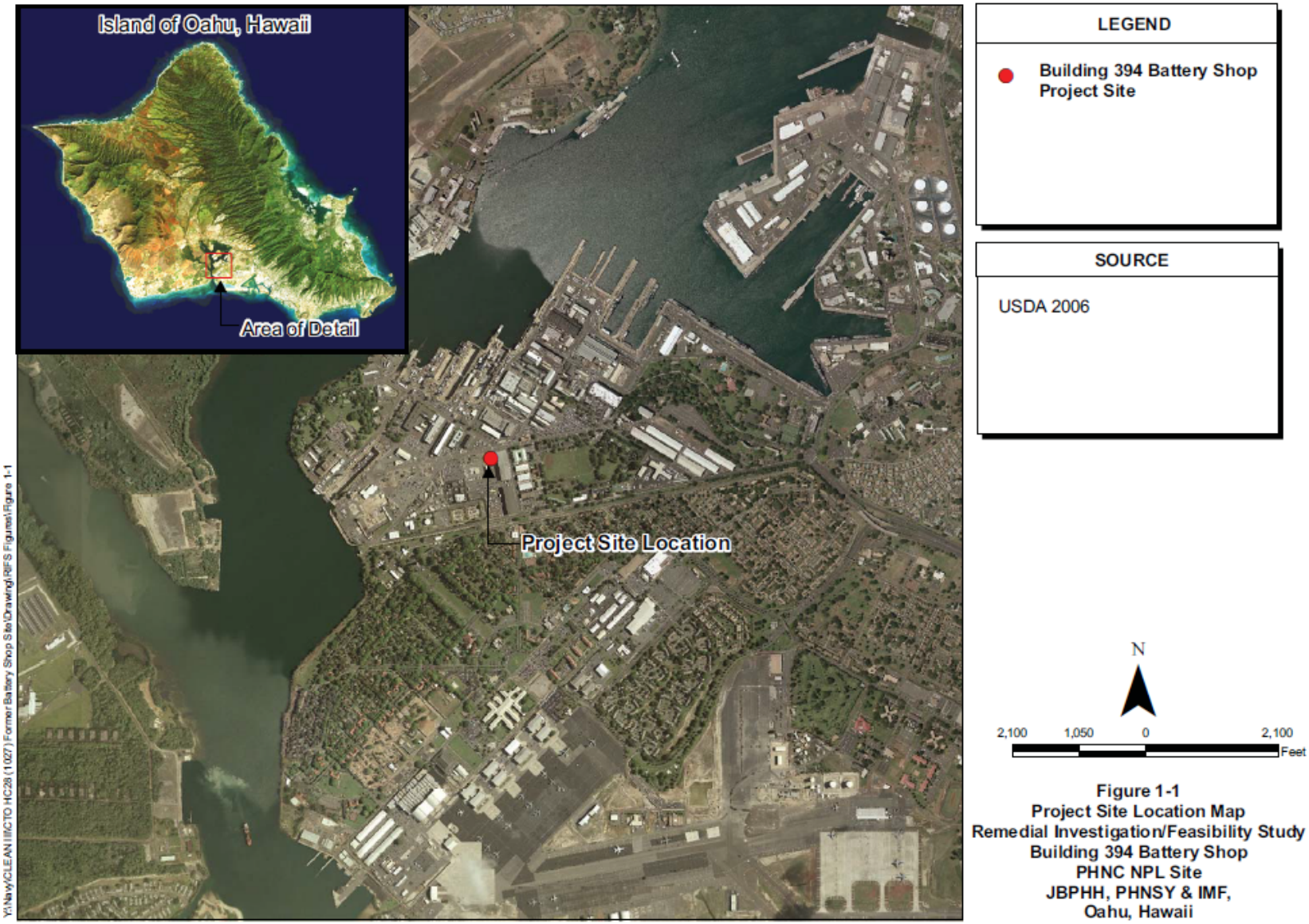


Figure 1. Site Layout for JBPHH Building 394 Battery Shop

Table 1. GSR Metrics Summary for JBPHH Building 394 Battery Shop

Table I-4: Environmental Footprint Summary Comparison

Remedial Alternatives	GHG Emissions	Total energy Used	Water	NO_x emissions	SO_x Emissions	PM_{10} Emissions	Accident	Accident
	metric ton	MMBTU	gallons	metric ton	metric ton	metric ton	Risk Fatality	Risk Injury
Alt.2 Capping with LUCs	152.05	2.02E+03	1.25E+04	3.94E-02	1.68E-02	8.43E-02	3.71E-04	3.47E-02
Alt.3 Excavation and Disposal	358.07	4.10E+03	1.50E+04	1.94E-01	9.78E-02	4.18E-01	2.54E-04	2.62E-02

Additional Sustainability Metrics

Remedial Alternatives	Non-Hazardous Waste Landfill Space	Hazardous Waste Landfill Space	Topsoil Consumption	Costing	Lost Hours - Injury	Final Cost with Footprint Reduction
	tons	tons	cubic yards	$		$
Alt.2 Capping with LUCs	456.00	0.00E+00	2.21E+03	1.55E+06	2.77E-01	1.55E+06
Alt.3 Excavation and Disposal	456.00	1.66E+03	1.11E+03	4.35E+05	2.10E-01	4.35E+05

Relative Impact

Remedial Alternatives	GHG Emissions	Energy Usage	Water Usage	NOx emissions	SOx Emissions	PM10 Emissions	*Accident Risk Fatality	*Accident Risk Injury	Community Impacts	Resources Lost
Alt.2 Capping with LUCs	Medium	Medium	High	Low	Low	Low	High	High	Low	Low
Alt.3 Excavation and Disposal	High	High	High	High	High	High	Medium	High	Low	Low

Relative Impact (User Override)

Remedial Alternatives	GHG Emissions	Energy Usage	Water Usage	NOx emissions	SOx Emissions	PM10 Emissions	*Accident Risk Fatality	*Accident Risk Injury	Community Impacts	Resources Lost
Alt.2 Capping with LUCs	Medium	Medium	High	Low	Low	Low	High	High	Low	Low
Alt.3 Excavation and Disposal	High	High	High	High	High	High	Medium	High	Low	Low

Joint Base Pearl Harbor-Hickam
ST-01 Kipapa Fuel Storage Annex
Oahu, Hawaii

FEC	**NAVFAC Pacific/NAVFAC Hawaii**
Installation	Joint Base Pearl Harbor-Hickam (JBPHH)
Location	Oahu, Hawaii
Site Number	ST-01
Site Name	Site ST-01 Kipapa Fuel Storage Annex
Phase/Milestone/Date	Record of Decision (January 2012)
Site Background	The Kipapa FSA is a former fuel storage facility operated by the DoD from May 1943 until February 1993 on Oahu, Hawaii. Site ST01 (Figure 2) includes three subsites: ST01A (sludge disposal area), ST01B (USTs and surrounding area), and ST01C (former drum filling plant). An abandoned drum site (Site DA30) east of Site ST01 across Kipapa Stream is not a part of site ST01. There have been no regulatory enforcement activities related to Site ST01. All remedial response activities have been conducted in accordance with CERCLA, DERP, and the Hawaii SCP.
Contaminants	VOCs, SVOCs, TPH, Lead
Impacted Media	Impacted media is soil and groundwater
Remedial Technologies	This case study discusses remedial alternatives for soil as follows: • **Alternative 1**: No Further Action (includes well abandonment) • **Alternative 2**: Lead-Impacted Soil Removal, Land Use Controls & Long Term Monitoring • **Alternative 3**: Bioventing, Lead-Impacted Soil Removal, Land Use Controls and Long Term Monitoring
Evaluation Criteria	The remedial alternatives were evaluated according to their ability to meet the CERCLA nine criteria. In addition, the alternatives were evaluated using the SiteWise™ Tool to assess the environmental footprint of each remedial alternative (see Table 2).
Footprint Reduction Methodology	The inclusion of bioventing helped the footprint reduction of the remediation technology. Bioventing accelerates reductions in toxicity, mobility, and volume (TMV) of hydrocarbons in soil with concurrent incidental reduction of TMV for contaminants in groundwater and soil vapor. This technology provides protection of human health and the environment and long-term effectiveness by increasing the rate of reduction of contaminant concentrations in soil, as well as reducing the soil vapor hazard for current and potential future land uses at or near the site. The time frame for completing alternative 3 is 10 years and this helps in reducing the footprint in comparison to the longer time frame of 20 years for alternative 2.
Greenhouse Gas Emissions	Greenhouse gas emissions were lower for alternative 3. • Alternative 2 (Soil Removal): 76,419 metric ton • Alternative 3 (Bioventing/Soil Removal): 41,733 metric ton
Energy Consumption	Energy consumption for alternative 3 was at least 54% less than energy consumed by alternative 2. This is in part due to the shorter remediation timeframe of 10 years for alternative 3 in comparison to the 20 years for alternative 2. • Alternative 2 (Soil Removal): 480,000 MMBTU • Alternative 3 (Bioventing/Soil Removal): 260,000 MMBTU
Criteria Air Pollutants	Emissions for criteria air pollutants were lower for alternative 3.

Water Usage	Water consumption was highest for alternative 3 due to an increase in water usage during bioventing operations. • Alternative 2 (Soil Removal): 8,000 gal • Alternative 3 (Bioventing/Soil Removal):18,000 gal
Ecological Impacts	This metric was not addressed in this report.
Resource Consumption	This metric was not addressed in this report.
Waste Generation	This metric was not addressed in this report.
Worker Safety	Alternative 3 had a lower accident risk injury during remedy implementation.
Community Impacts	Among all of the alternatives, Alternative 3 is the most protective of human health and the environment, and it provides ARAR compliance. Alternative 3 consists of bioventing that provides protection of human health and the environment by increasing the rate of reduction of contaminant concentrations in soil, as well as reducing the soil vapor hazard for current and potential future land uses at or near the site.
Conclusion	Based on the comparative analysis of alternatives using the NCP evaluation criteria, Alternative 3 (bioventing, lead-impacted soil removal, land use controls and long term monitoring) provides the best balance of satisfying the two threshold criteria and five balancing criteria. Although this is the most expensive alternative, it is also the most protective of human health and the environment, and it provides ARAR compliance. In general, Alternative 2 has the largest environmental footprint, which is due largely to the anticipated duration of LTM of 20 years, which is greater than in the assumed duration in Alternative 3 of five years past the bioventing operations and maintenance period (total of 10 years). ***Overall Protection of Human Health and the Environment***. Both Alternatives 2 and 3 provide the same amount of overall protection to human health and the environment. Alternative 3 provides protection by increasing the rate of reduction of contaminant concentrations in soil as wells as reducing the soil vapor hazard for land use. ***Compliance with Applicable or Relevant and Appropriate Requirements (ARARs)***. Both Alternatives 2 and 3 are compliant with the ARARs. ***Long-Term Effectiveness and Permanence*** Both Alternatives 2 and 3 offer the same long term effectiveness and permanence. ***Reduction in Toxicity, Mobility, or Volume through Treatment.*** Both alternatives reduce the toxicity. In addition, bioventing in alternative 3 reduces toxicity, mobility and volume of contaminant concentration in soil, as well as reducing the soil vapor hazard. ***Short-Term Effectiveness.*** Both Alternatives 2 and 3 provide short term effectiveness as excavation eliminates direct exposure to soil contamination. ***Implementability.*** Both alternatives are implementable.

Joint Base Pearl Harbor-Hickam
ST-01 Kipapa Fuel Storage Annex
Oahu, Hawaii

Cost:

- Alternative 2 (Soil Removal): $3,760,000
- Alternative 3 (Bioventing/Soil Removal): $4,770,000

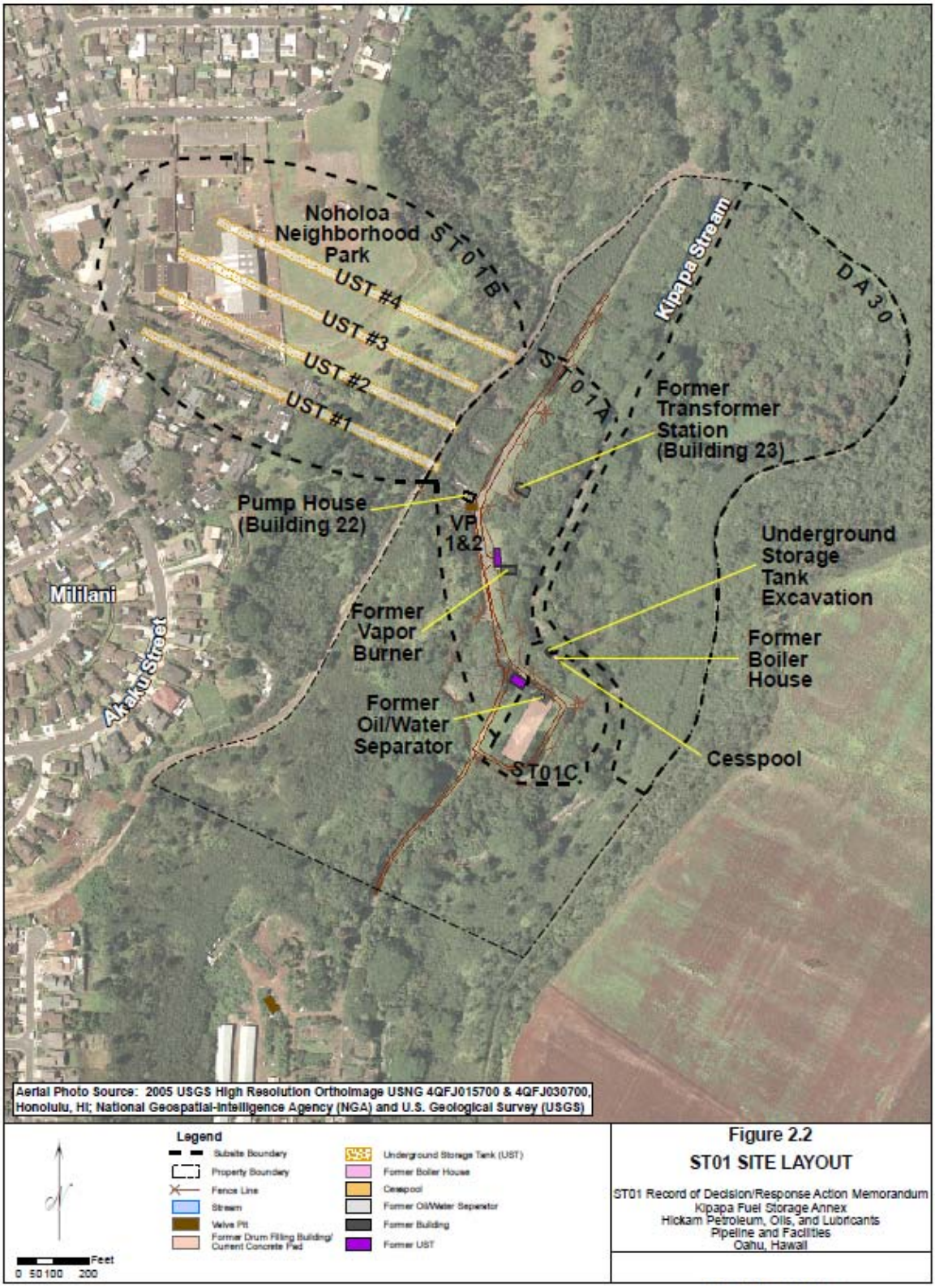


Figure 2. Site Layout for JBPHH ST-01 Kipapa Fuel Storage Annex

Table 2. GSR Metrics Summary for JBPHH ST-01 Kipapa Fuel Storage Annex

REMEDIAL PHASE (units)	GHG Emissions [a] (metric ton)	Total Energy Used [e] (MMBTU)	Water Consumption (gallons)	NOx Emissions [b] (metric ton)	SOx Emissions[c] (metric ton)	PM10 Emissions[d] (metric ton)	Accident Risk Fatality	Accident Risk Injury
REMEDIAL ALTERNATIVE 1 - No Action (includes well abandonment)								
Remedial Investigation	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Remedial Action Construction	3.30E+01	4.30E+02	2.00E+03	1.80E-01	2.90E-02	1.30E-02	3.50E-05	7.80E-03
Remedial Action Operations	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Long Term Monitoring	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOTAL	**3.30E+01**	**4.30E+02**	**2.00E+03**	**1.80E-01**	**2.90E-02**	**1.30E-02**	**3.50E-05**	**7.80E-03**
REMEDIAL ALTERNATIVE 2 - LTM, LUCs, and Lead-Impacted Soil Excavation[f]								
Remedial Investigation	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Remedial Action Construction	4.80E+01	6.50E+02	3.00E+03	1.90E-01	3.30E-02	1.50E-02	7.40E-05	1.30E-02
Remedial Action Operations	1.10E+00	1.90E+01	0.00E+00	6.90E-03	1.90E-03	7.20E-04	1.10E-06	4.50E-04
Long Term Monitoring	7.60E+04	4.80E+05	5.00E+03	3.10E+02	1.10E+02	4.00E+01	1.20E-04	8.50E-03
TOTAL	**7.60E+04**	**4.80E+05**	**8.00E+03**	**3.10E+02**	**1.10E+02**	**4.00E+01**	**1.90E-04**	**2.20E-02**
REMEDIAL ALTERNATIVE 3 - LTM, LUCs, Lead-Impacted Soil Excavation, and Bioventing								
Remedial Investigation	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Remedial Action Construction	5.30E+01	7.30E+02	4.30E+03	2.40E-01	4.00E-02	1.80E-02	9.20E-05	1.40E-02
Remedial Action Operations	2.40E+01	3.00E+02	1.30E+04	3.90E-02	4.40E-02	9.80E-04	3.70E-05	3.00E-03
Long Term Monitoring	4.20E+04	2.60E+05	3.00E+02	1.70E+02	6.00E+01	2.20E+01	6.40E-05	4.60E-03
TOTAL	**4.20E+04**	**2.60E+05**	**1.80E+04**	**1.70E+02**	**6.00E+01**	**2.20E+01**	**1.90E-04**	**2.10E-02**

Notes:

(a) GHG = Greenhouse Gas
(b) NO_x = total mass of mono-nitrogen oxides NO and NO_2
(c) SO_x = total mass of mono-sulfur oxides SO and SO_2
(d) PM_{10} = particulate matter composed of particles of 10 micrometers or less
(e) MMBTU = 1 million metric British thermal units
(f) LTM = Long term monitoring; LUC = Land use controls

Joint Base Pearl Harbor-Hickam
4th Street Coral Pit
Oahu, Hawaii

FEC	**NAVFAC Pacific/NAVFAC Hawaii**
Installation	Joint Base Pearl Harbor-Hickam (JBPHH)
Location	Oahu, Hawaii
Site Number	N/A
Site Name	4th Street Coral Pit
Phase/Milestone/Date	Feasibility Study (February 2012)
Site Background	The 4th Street Coral Pit site is a former solid waste disposal area with characteristics similar to that of a landfill with the potential for low-level, long-term exposure (see Figure 3). The Coral Pit is approximately 1,000 feet in length with a maximum width of about 250 feet. In the 1930s, the site was excavated as a source of coral for use as road construction materials. During World War II, the Coral Pit was used as a waste disposal site for solvent cans, paint sludges, paint cans, empty transformers, acid-filled automotive batteries, and dunnage. The Coral Pit was partially backfilled with coral rock by the U.S. Army Corps of Engineers in the mid-1970s to preclude further disposal of potentially hazardous materials; at that time, the Coral Pit was still 12 feet deep. Subsequent to covering the old Coral Pit, scrap metal disposal was permitted at the site, although unauthorized disposal of other materials reportedly continued. The site remained undeveloped after its closure and the current Coral Pit surface remains approximately 3 to 7 feet below grade.
Contaminants	Residual Range Organics (RRO), Polynuclear Aromatic Hydrocarbons (PAHs), Total Petroleum Hydrocarbons (TPH), TCE, 1,2,4-Trimethylbenzene, Arsenic, Copper, Nickel, Zinc, Chromium
Impacted Media	The impacted media are surface soil, groundwater and soil gas.
Remedial Technologies	The remedial alternatives for soil included: • **Alternative 1:** No Further Action • **Alternative 2:** Land Use Controls (LUCs) • **Alternative 3:** Surface Debris Removal and LUCs • **Alternative 4:** Surface Debris Removal, Soil Cap, and LUCs • **Alternative 5:** Clean Closure (no LUCs)
GSR Evaluation Approach	The remedial alternatives were evaluated to assess the relative performance of each alternative with respect to the nine criteria identified in the NCP. SiteWise™ was used to evaluate the five RA alternatives developed for soil. Sustainability metrics such as energy consumption, greenhouse gas emissions, pollutant emissions, water consumption, and worker safety were evaluated.
Footprint Reduction Methodologies	No specific footprint reduction methodologies were listed in the report.
Greenhouse Gas Emissions	GHG emissions for Alternative 2 (LUCs) were estimated to be less than half the emissions for Alternative 3 (Surface Debris Removal/LUCs). Alternative 5 (Clean Closure) has the highest expected emissions due to the excavation of contaminated soil and debris (101,059 cubic yard, and the amount of backfill. • Alternative 2 (LUCs): 22 metric tons of CO_2e • Alternative 3 (Surface Debris Removal and LUCs): 46 metric tons of CO_2e • Alternative 4 (Surface Debris Removal, Soil Cap and LUCs): 4,619 metric tons of CO_2e • Alternative 5 (Clean Closure): 7,982 metric tons of CO_2e

Joint Base Pearl Harbor-Hickam 4th Street Coral Pit Oahu, Hawaii	
Energy Consumption	Energy consumption for Alternatives 2 and 3 was estimated to be two orders of magnitude less than Alternative 4 and three orders of magnitude less than Alternative 5. Alternative 5 is the highest due to the amount of backfill needed following the removal of soil and debris from the site. • Alternative 2 (LUCs): 270 MMBTU • Alternative 3 (Surface Debris Removal and LUCs): 680 MMBTU • Alternative 4 (Surface Debris Removal, Soil Cap and LUCs): 62,600 MMBTU • Alternative 5 (Clean Closure): 120,000 MMBTU
Criteria Air Pollutants	The sulfur oxide and particulate matter emissions for Alternative 5 are at least two orders of magnitude higher compared to Alternatives 2 through 4. The largest component of the NOx, SOx and PM10 emissions is due to the removal and transportation of soil and debris from the site.
Water Usage	Water usage was minimal for all alternatives with Alternative 5 the highest. • Alternative 2 (LUCs): 50 gallons • Alternative 3 (Surface Debris Removal and LUCs): 50 gallons of water • Alternative 4 (Surface Debris Removal, Soil Cap and LUCs): 50 gallons of water • Alternative 5 (Clean Closure): 100 gallons of water
Ecological Impacts	A Tier 1 ecological Screening Risk Assessment and a Tier 2 Step 3a Baseline Ecological Risk Assessment (BERA) was performed to evaluate risks potentially attributable to analytes detected in soil at the site. The results of the Tier 2, Step 3a BERA indicated that the potential risk of adverse ecological effects from exposure to onsite soils and groundwater is acceptable and No Further Action is necessary at the site to protect ecological receptors.
Resource Consumption	Top soil consumption was the highest in Alternative 5 (1,250,000 cubic yards) followed by alternative 4 (500,000 cubic yards)
Waste Generation	Alternative 3 and 4 used the same amount of non-hazardous waste landfill space (940 tons). Alternative 5 used the highest non-hazardous waste landfill space (79,820 tons) due to the disposal of contaminated soil and debris.
Worker Safety	Risks of injuries/fatalities for Alternatives 4 and 5 are estimated to be two orders of magnitude higher than Alternatives 2 and 3. The injury and fatality risks were highest for Alternative 5 due to the removal and transportation of soil and debris from the site.
Community Impacts	This metric was not addressed in this report.
Conclusions	Based on the screening of remedial action alternatives, the evaluation and comparative analysis of retained alternatives, the recommended RA alternative was Alternative 2 (LUCs). Alternative 2 would limit future exposure to contaminated soil and subsurface debris to acceptable levels, and was the most cost-effective given the existing and intended future site uses. The largest component of GHG emissions and the energy used is based on the amount of backfill needed following the removal of soil and debris from the site. The largest component of the NOx, SOx, and PM10 emissions, as well as the injury/fatality risks is due to the removal and transportation of soil and debris from the site. ***Overall Protection of Human Health and the Environment***. Alternatives 2 through 5 are considered protective of human health and the environment.

Compliance with Applicable or Relevant and Appropriate Requirements (ARARs). Alternatives 2 through 5 are compliant with the ARARs.

Long-Term Effectiveness and Permanence. Alternatives 2 through 5 provide long-term effectiveness.

Reduction in Toxicity, Mobility, or Volume through Treatment. None of these alternatives would reduce the toxicity or volume of the contaminants through treatment.

Short-Term Effectiveness. The short-term effectiveness of Alternative 2 is rated higher than Alternatives 3, 4, or 5, based on the metrics evaluated by SiteWise.

Implementability. The implementability of Alternative 2 and 3 is rated higher than Alternatives 4 or 5.

Cost

- Alternative 2 (LUCs): $390,733
- Alternative 3 (Surface Debris Removal and LUCs): $460,607
- Alternative 4 (Surface Debris Removal, Soil Cap and LUCs): $3,351,756
- Alternative 5 (Clean Closure): $21,977,026

Figure 1
4th Street Coral Pit Site Location
4th Street Coral Pit Site
PHNC NPL Site
JBPHH, Oahu, Hawaii

Figure 3. Site Layout for JBPHH 4th Street Coral Pit

Table 3. GSR Metrics Summary for JBPHH 4th Street Coral Pit

Table A-7: Environmental Footprint Summary Comparison

Remedial Alternatives	GHG Emissions metric ton	Total energy Used MMBTU	Water gallons	NO_x emissions metric ton	SO_x Emissions metric ton	PM_{10} Emissions metric ton	Accident Risk Fatality	Accident Risk Injury
Alt. 1: No Action	1.13	8.81E+00	5.00E+01	2.59E-04	6.57E-05	1.63E-05	6.44E-06	5.18E-04
Alt. 2: LUCs	21.71	2.68E+02	5.00E+01	7.87E-03	3.34E-04	1.56E-03	4.28E-04	3.44E-02
Alt. 3: Surface Debris Removal and LUCs	45.80	6.77E+02	5.00E+01	7.87E-02	3.42E-02	1.73E-01	5.58E-04	4.99E-02
Alt. 4: Surface Debris Removal, Soil Cap, and LUCs	4619.09	6.26E+04	5.00E+01	1.33E+00	5.85E-02	2.85E-01	1.92E-02	1.59E+00
Alt. 5: Clean Closure	7981.89	1.20E+05	1.00E+02	6.76E+00	2.80E+00	1.46E+01	2.19E-02	1.84E+00

Additional Sustainability Metrics

Remedial Alternatives	Non-Hazardous Waste Landfill Space tons	Hazardous Waste Landfill Space tons	Topsoil Consumption cubic yards	Costing $	Lost Hours - Injury	Final Cost with Footprint Reduction $
Alt. 1: No Action	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.57E+04
Alt. 2: LUCs	0.00	0.00E+00	0.00E+00	1.89E+05	2.75E-01	1.89E+05
Alt. 3: Surface Debris Removal and LUCs	940.00	0.00E+00	0.00E+00	2.59E+05	3.99E-01	2.59E+05
Alt. 4: Surface Debris Removal, Soil Cap, and LUCs	940.00	0.00E+00	5.00E+05	1.74E+06	1.27E+01	1.74E+06
Alt. 5: Clean Closure	79820.00	0.00E+00	1.25E+06	2.14E+07	1.47E+01	2.14E+07

Relative Impact

Remedial Alternatives	GHG Emissions	Energy Usage	Water Usage	NOx emissions	SOx Emissions	PM10 Emissions	*Accident Risk Fatality	*Accident Risk Injury	Community Impacts	Resources Lost
Alt. 1: No Action	Low	Low	Medium	Low	Low	Low	Low	Low	user select	user select
Alt. 2: LUCs	Low	Low	Medium	Low	Low	Low	Low	Low	user select	user select
Alt. 3: Surface Debris Removal and LUCs	Low	Low	Medium	Low	Low	Low	Low	Low	user select	user select
Alt. 4: Surface Debris Removal, Soil Cap, and LUCs	Medium	Medium	Medium	Low	Low	Low	High	High	user select	user select
Alt. 5: Clean Closure	High	High	High	High	High	High	High	High	user select	user select

Relative Impact (User Override)

Remedial Alternatives	GHG Emissions	Energy Usage	Water Usage	NOx emissions	SOx Emissions	PM10 Emissions	*Accident Risk Fatality	*Accident Risk Injury	Community Impacts	Resources Lost
Alt. 1: No Action	Low	Low	Medium	Low	Low	Low	Low	Low	user select	user select
Alt. 2: LUCs	Low	Low	Medium	Low	Low	Low	Low	Low	user select	user select
Alt. 3: Surface Debris Removal and LUCs	Low	Low	Medium	Low	Low	Low	Low	Low	user select	user select
Alt. 4: Surface Debris Removal, Soil Cap, and LUCs	Medium	Medium	Medium	Low	Low	Low	High	High	user select	user select
Alt. 5: Clean Closure	High	High	High	High	High	High	High	High	user select	user select

*Accident Risk is an estimate of how many accidents may occur. This risk is not the same as Cancer Risk, which is the probablity (for a single person) of getting cancer. Accident risk is not comparable to Cancer Risk due to inherent fundamental differences.

Naval Base Guam Munitions Site
Tear Gas Burial Site
Guam

FEC	**NAVFAC Pacific/NAVFAC Marianas**
Installation	Naval Base Guam Munitions Site (NBGMS)
Location	Near Santa Rita, Guam
Site Number	N/A
Site Name	Tear Gas Burial Site
Phase/Milestone/Date	Focused Feasibility Study (September 2011)
Site Background	The NBGMS was commissioned as the Naval Ammunition Depot in 1945. Toward the end of World War II, the depot was shipping and receiving nearly 30,000 tons of ammunition a month and had 75,000 tons in storage. In 1949, the depot was redesigned as the Naval Magazine (NAVMAG), Guam. The NAVMAG was renamed to Ordnance Annex in 2008 and subsequently was renamed to the NBGMS in 2010. The Tear Gas Burial Site is approximately 1 acre in size (see Figure 4) and is located within in a forested area of the NBGMS. Historic records indicated that up to 350 pounds of tear gas had been buried at this location. However, the site investigation did not reveal any evidence that tear gas and/or tear gas canisters had been present at the site. Soil sample analytical results did indicate the presence of polynuclear aromatic hydrocarbons (PAHs), total petroleum hydrocarbons (TPH), and antimony exceeding project-screening criteria and background concentrations in the portion of the site containing the soil pile and burn debris areas.
Contaminants	Polynuclear aromatic hydrocarbons, total petroleum hydrocarbon, antimony
Impacted Media	The impacted media is soil.
Remedial Technologies	This case study discusses remedial alternatives for contaminated soil in detail: • **Alternative 1:** No Further Action • **Alternative 2:** Land Use Controls (LUCs) • **Alternative 3:** Clean Closure • **Alternative 4:** Consolidation, vegetated soil cover, and LUCs
GSR Evaluation Approach	A comparative analysis of the four alternatives was conducted to assess the relative performance of each alternative with respect to the nine criteria identified in the NCP. In addition, the alternatives were also evaluated using SiteWise™. The discussion below is focused on alternatives 2, 3 and 4. Alternative 1 no further action is not reviewed for this case study.
Footprint Reduction Methodologies	This metric was not discussed in this report.
Greenhouse Gas Emissions	GHG emissions are estimated to be at least two orders of magnitude higher for Alternative 3 compared to Alternatives 2 and 4. This is due to transport of residual waste soil by boat. • Alternative 2 (LUCs) : 6.51 metric ton • Alternative 3 (Clean Closure) : 2,622.42 metric ton • Alternative 4 (Consolidation, vegetated soil cover, and LUCs): 53.90 metric ton required.
Energy Consumption	The energy use for Alternative 3 is estimated to be two orders of magnitude higher than the energy use for Alternative 2 and Alternative 4.This is mostly due to transportation of equipment and residual waste. • Alternative 2 (LUCs) :150 MMBTU

	• Alternative 3 (Clean Closure) : 29,800 MMBTU • Alternative 4 (Consolidation, vegetated soil cover, and LUCs): 919 MMBTU
Criteria Air Pollutants	Pollutant and dust are estimated to be at least two orders of magnitude higher for Alternative 3 (Clean Closure) compared to Alternatives 2 and 4 due to the transportation of equipment and residual waste.
Water Usage	The estimated water use for Alternatives 3 and 4 are higher compared to Alternative 2, which requires no water usage. • Alternative 2 (LUCs) : 0 gallons • Alternative 3 (Clean Closure) : 60,000 gallons • Alternative 4 (Consolidation, vegetated soil cover, and LUCs) : 60,000 gallons
Ecological Impacts	Based on Tier 1 (ecological screening risk assessment [SRA]) and Tier 2 (baseline ecological risk assessment [BERA]) ecological screening risk evaluations, it was determined that no further action was necessary to protect ecological receptors at the site.
Resource Consumption	This metric was not discussed in the report.
Waste Generation	Alternative 3 (4,400 cubic yards) will generate waste twice more than alternative 4 (2,000 cubic yards).
Worker Safety	The risks of injuries/fatalities for Alternative 3 are two orders of magnitude higher compared to Alternative 2 and one order of magnitude higher than Alternative 4. This is due to the residual handling via truck transport from the site to Apra harbor and from the port of Long Beach to the US Ecology landfill in Beatty, Nevada.
Community Impacts	Alternatives 3 and 4 would result in excavation and earth-moving activities at the site, which could result in exposure to onsite workers and possibly the public
Conclusions	Based on the focused evaluation presented herein, the recommended remedial action alternative for the site is Alternative 2, LUCs, to prevent disturbance and exposure to contaminated soil. Environmental footprint and impact of Alternative 2 is considerably less than Alternative 3 and slightly less than Alternative 4. ***Overall Protection of Human Health and the Environment***. Alternatives 2, 3, and 4 are protective of human health and the environment. ***Compliance with Applicable or Relevant and Appropriate Requirements (ARARs)***. Alternatives 2, 3, and 4 are compliant with the ARARs. ***Long-Term Effectiveness and Permanence.*** Alternatives 2, 3, and 4 provide long-term effectiveness. ***Reduction in Toxicity, Mobility, or Volume through Treatment.*** None of these alternatives reduces the toxicity or volume of the contaminants. Alternative 4 does reduce the mobility of contaminants through consolidation, not through treatment. ***Short-Term Effectiveness.*** The short-term effectiveness of Alternative 2 is rated higher than Alternatives 3 and 4 because Alternatives 3 and 4 would result in excavation and earth-moving activities at the site, which could result in exposure to onsite workers and possibly the public.

Implementability. All alternatives are implementable.

Cost

- Alternative 2(LUCs): $ 245,106
- Alternative 3 (Clean Closure) : $11,590,677
- Alternative 4 (Consolidation, vegetated soil cover, and LUCs) : $670,890

Figure 4. Site Layout for Tear Gas Burial Site, NBGMS Guam

Table 4. GSR Metrics Summary for Tear Gas Burial Site, NBGMS Guam

Remedial Alternatives	GHG Emissions metric ton	Total Energy Used MMBTU	Water Consumption gallons	NO_x Emissions metric ton	SO_x Emissions metric ton	PM_{10} Emissions metric ton	Accident Risk Fatality	Accident Risk Injury
Alternative 1 NFA	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Alternative 2 LUCs	6.51	1.50E+02	0.00E+00	1.53E+01	3.19E+00	7.29E-01	8.82E-06	4.70E-04
Alternative 3 Clean Closure	2622.42	2.98E+04	6.00E+04	4.00E+03	3.99E+03	4.49E+03	9.47E-04	1.96E-01
Alternative 4 Consolidation and LUCs	53.90	9.19E+02	6.00E+04	2.11E+01	4.41E+00	1.01E+00	5.62E-05	7.82E-03

BASE CLOSURE AND REALIGNMENT (BRAC)

Former Naval Construction Battalion Center
Davisville Site 16
North Kingstown, Rhode Island

FEC	**BRAC**
Installation	Former Naval Construction Battalion Center Davisville
Location	North Kingstown, Rhode Island
Site Number	Site 16
Site Name	Site 16, NCBC
Phase/Milestone/Date	Feasibility Study (May 2012)
Site Background	The former NCBC Davisville facility is located in the Town of North Kingstown, Rhode Island. In 1989, NCBC Davisville was placed on the USEPA's National Priorities List (NPL). In 1991, the closure of NCBC Davisville was announced, and operations were reduced to minimum staffing levels for public works, maintenance, security, and personnel. NCBC Davisville was decommissioned in 1994, and closed in April 1994; under the Base Realignment and Closure (BRAC) program. Environmental investigations were initiated at Site 16 as it was identified as potential contaminant release areas (see Figure 1).
Contaminants	Contaminants of concern (COCs) at the site include cPAHs, arsenic, dioxins/furans. Lead, naphthalene, benzene, PCE, TCE, cis-1,2-DCE, VC, antimony, cobalt, chromium, iron, manganese
Impacted Media	Soil and groundwater
Remedial Technologies	This case study discusses remedial alternatives to address groundwater contamination. The remedial alternatives included in the GSR analysis were as follows: • **Alternative 1**: No action • **Alternative 2**: Monitored natural attenuation (MNA) and land use controls (LUCs) • **Alternative 3**: In situ chemical oxidation (ISCO) - high concentration areas, MNA, LUCs • **Alternative 3a**: ISCO – source area, MNA, and LUCs • **Alternative 4**: Enhanced bioremediation (high concentration areas), MNA, and LUCs • **Alternative 5**: Groundwater extraction and treatment (high concentration areas), MNA, and LUCs • **Alternative 6**: Enhanced Bioremediation , MNA, LUCs (reduced remediation time) This case study reviews Alternative 2, 3, 3a, 4, 5 and 6.
GSR Evaluation Approach	GSR evaluation was performed using a hybrid model of SiteWise™ tool supplemented with TetraTech developed model GSRx (see Table 1).
Footprint Reduction Methodologies	Some recommended footprint reduction methods include: All Alternatives: • Some reduction of the environmental footprint, particularly greenhouse gas (GHG) emissions and energy consumption, could be realized for all alternatives through the possible use of emission control measures such as alternate fuel sources (e.g., biodiesel), equipment exhaust controls (e.g., diesel), and equipment idle reduction.

	• Consider optimizing of the use of equipment, particularly the use of the direct push technology (DPT) drill rig, and even the type of equipment used during operations. • Consider the optimization of the use of emulsified oil substrate (EOS) during the treatment stage. The environmental impact of this chemical has an influence in most of the impact categories evaluated. • Design an optimized sampling schedule that minimizes the number of samples that need to be analyzed and maximizes the results (for this alternative laboratory analytical services are the main driver for most of the impact categories evaluated). • Optimize the number of samples analyzed during the operation and monitoring stages given that the laboratory analytical services is one of the major drivers in some of the impact categories. • Consider ways to reduce vehicle mileage to reduce worker risk as well as energy use and emissions. Encourage site workers to carpool daily to the site to reduce total vehicle mileage. • Consider the optimization of the use of injection water. The amount of water used during the treatment stage is high. Alternative 5: • Consider optimization on the amount of energy used during the 30 year lifetime of the alternative. Consider alternative sources of energy (such as solar if possible) to reduce the load of generating electricity through the grid. • Consider the use of using a certain amount of regenerated GAC instead of virgin granular activated carbon (GAC) during the replacement of the fill of the chambers during the treatment.
Greenhouse Gas Emissions	Alternative 5 has the highest greenhouse gas emissions due to electricity to run the treatment system. • Alternative 2 (MNA and LUCs):150.32 metric ton • Alternative 3 (ISCO (high concentration areas), MNA, LUCs): 1,176.71 metric ton • Alternative 3a (ISCO (source area), MNA, and LUCs): 354.93 metric ton • Alternative 4 (Enhanced bioremediation (high concentration areas), MNA, and LUCs): 353.62 metric ton • Alternative 5 (groundwater extraction and treatment (high concentration areas), MNA, and LUCs): 198,232.56 metric ton • Alternative 6 (Enhanced Bioremediation, MNA, LUCs (reduced remediation time): 580.83 metric ton
Energy Consumption	Alternative 5 has the highest energy consumption due to the electricity used to run the treatment system. • Alternative 2 (MNA and LUCs): 2,230.95 MMBTU • Alternative 3 (ISCO (high concentration areas), MNA, LUCs): 25,313.86 MMBTU • Alternative 3a (ISCO (source area), MNA, and LUCs): 6,043.22 MMBTU • Alternative 4 (Enhanced bioremediation (high concentration areas), MNA, and LUCs): 17,423.19 MMBTU

	• Alternative 5 (groundwater extraction and treatment (high concentration areas), MNA, and LUCs): 4,247,670.64 MMBTU • Alternative 6 (Enhanced Bioremediation, MNA, LUCs (reduced remediation time): 40,055.62 MMBTU
Criteria Air Pollutants	Alternative 5 has the highest air emissions (NOx and SOx) generated primarily due to electricity used to run the treatment system. Alternative 3 has the highest PM10 emissions due to the DPT drill rig.
Water Usage	Alternative 5 had the highest water usage with much of the water associated with the production of steel for the treatment building and treatment equipment. Alternative 2 had the lowest water usage followed by Alternatives 3A, 3, 4, and 6, although the water usage of each of the last four alternatives is similar. • Alternative 2 (MNA and LUCs): 0 gallons • Alternative 3 (ISCO (high concentration areas), MNA, LUCs): 449,433.90 gallons • Alternative 3a (ISCO (source area), MNA, and LUCs): 426,312.99 gallons • Alternative 4 (Enhanced bioremediation (high concentration areas), MNA and LUCs): 1,684,655.16 gallons • Alternative 5 (groundwater extraction and treatment (high concentration areas) , MNA, and LUCs): 208,429,602.17 gallons • Alternative 6 (Enhanced Bioremediation , MNA, LUCs (reduced remediation time): 4,949,570.67 gallons
Ecological Impacts	The screening-level ecological risk assessment (SLERA) presented in the Phase III RI for Site 16 focused on surface soil in the undeveloped portion of Site 16 because the developed area of Site 16 is largely paved (i.e., viable habitat is very limited in this area). As a consequence of the refined analysis, the assessment concluded that no chemicals should be retained as COPCs for terrestrial vegetation, soil invertebrates, or birds and mammals.
Resource Consumption	There is no topsoil consumption in any of the alternatives.
Waste Generation	There is no landfill space used in any of the alternatives.
Worker Safety	Alternative 5 had the highest risk due to transportation of personnel. Alternatives 3, 3a, 4, 5 and 6 would result in a possibility of exposing site workers to contaminated groundwater as a result of the remediation activities. This risk would be reduced through compliance with appropriate site-specific health and safety procedures.
Community Impacts	There would be no risk to the surrounding community or the environment.
Conclusions	Overall, alternative 5 had the highest GHG emissions, energy use, water consumption and criteria emissions. ***Overall Protection of human health and the environment*** Alternatives 2, 3, 3A, 4, 5, and 6 would all provide protection to human health and the environment. Alternatives 3 (ISCO) and 5 (groundwater extraction) would provide the best protection because they treat the high-TCE concentration areas in the shortest amount of time. ***Compliance with ARARs and TBCs*** Alternatives 2, 3, 3A, 4, 5, and 6 would comply with location- and action-specific ARARs and TBCs.

Long-term Effectiveness and Permanence
Alternatives 2, 3, 3A, 4, 5, and 6 would provide long-term effectiveness and permanence. Alternatives 3, 3A, 4, 5, and 6 provide essentially equal levels of long-term effectiveness and permanence through a combination of treatment, MNA, and LUCs.

Reduction of toxicity, mobility or volume through treatment
Alternatives 3, 3A, 4, and 6 would achieve reductions in COC toxicity and volume through treatment. Alternative 5 would achieve reductions in COC volume through treatment assuming that the spent GAC is regenerated or destroyed by a thermal process off site.

Short-term effectiveness
Implementation of Alternatives 2, 3,3A, 4, 5 and 6 would result in a slight possibility of exposing site workers to contaminated groundwater during the installation, maintenance, and sampling of new and existing monitoring wells and during active remediation.

Implementability
Alternative 2 would be the easiest to implement. Alternatives 3, 3A, 4, and 6 would be the next easiest to implement, although handling of the oxidizing agent in Alternatives 3 and 3A would be slightly more difficult. Alternative 5 would be more complicated to implement and would require long-term O&M

Cost
- Alternative 2 (MNA and LUCs): $1,124,000
- Alternative 3 (ISCO (high concentration areas), MNA, LUCs): $9,350,000
- Alternative 3a (ISCO (source area), MNA, and LUCs): $5,587,000
- Alternative 4 (Enhanced bioremediation (high concentration areas), MNA and LUCs): $9,656,000
- Alternative 5 (groundwater extraction and treatment (high concentration areas), MNA, and LUCs): $9,932,000
- Alternative 6 (Enhanced Bioremediation , MNA, LUCs (reduced remediation time): $24,505,000

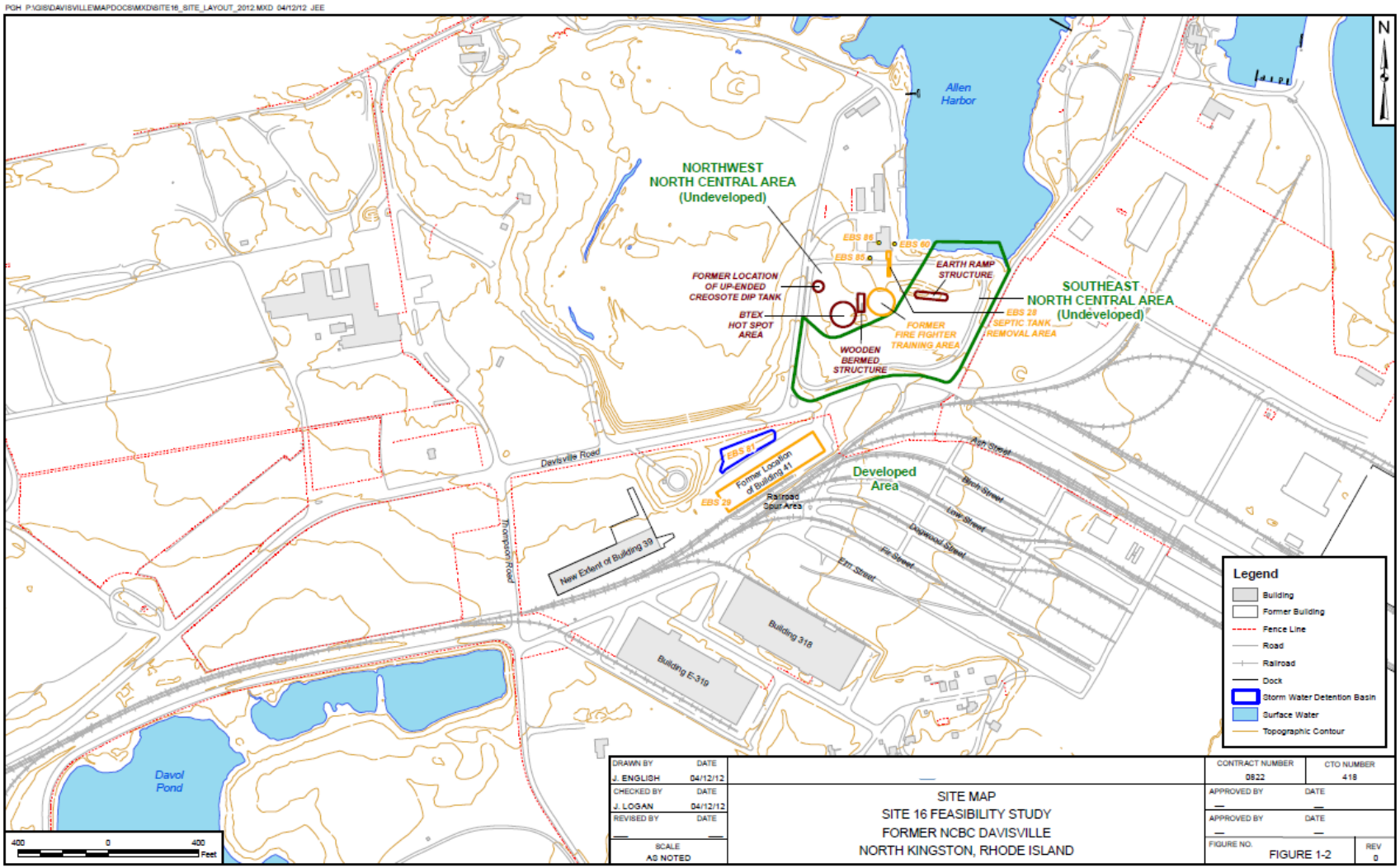


Figure 1. Site Layout for Site 16 Former Naval Construction Battalion Center Davisville

Table 1. GSR Metrics Summary for Site 16 Former Naval Construction Battalion Center Davisville

Environmental Impact Results
Site 16, NCBC Davisville
Davisville, Rhode Island
Page 1 of 2

Alternative	Activities	GHG Emissions	Total Energy Used	Water Impacts	NOx Emissions	SOx Emissions	PM10 Emissions	Accident Risk Fatality	Accident Risk Injury
		metric ton	MMBTU	gallons	metric ton	metric ton	metric ton		
G-2	Materials Production	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	NA	NA
	Transportation-Personnel	5.26	66.15	NA	1.95E-03	6.85E-05	3.95E-04	1.08E-04	8.66E-03
	Transportation-Equipment	0.00	0.00	NA	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Equipment Use and Misc	145.06	2,164.80	0.00	5.02E-01	3.35E-01	1.27E-02	0.00E+00	0.00E+00
	Residual Handling	0.00	0.00	NA	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	150.32	2,230.95	0.00	5.04E-01	3.35E-01	1.31E-02	1.08E-04	8.66E-03
G-3	Materials Production	786.51	6,608.19	444,468.62	1.76E-04	2.01E-01	1.90E-02	NA	NA
	Transportation-Personnel	11.43	143.81	NA	4.23E-03	1.49E-04	8.58E-04	2.30E-04	1.85E-02
	Transportation-Equipment	18.17	237.09	NA	5.71E-03	1.01E-04	5.08E-04	1.53E-05	1.23E-03
	Equipment Use and Misc	360.42	18,322.38	4,965.29	5.39E-01	6.73E-01	1.12E-01	4.58E-05	1.15E-02
	Residual Handling	0.18	2.38	NA	5.74E-05	1.02E-06	5.11E-06	1.56E-06	1.26E-04
	Total	1,176.71	25,313.86	449,433.90	5.49E-01	8.74E-01	1.32E-01	2.92E-04	3.13E-02
G-3A	Materials Production	135.63	1,083.80	71,004.32	3.04E-05	3.50E-02	3.34E-03	NA	NA
	Transportation-Personnel	11.22	141.17	NA	4.15E-03	1.46E-04	8.42E-04	2.34E-04	1.88E-02
	Transportation-Equipment	6.00	82.05	NA	1.93E-03	7.67E-05	1.57E-04	4.50E-05	3.62E-03
	Equipment Use and Misc	201.76	4,732.10	355,308.67	6.30E-01	4.37E-01	3.16E-02	1.76E-04	4.42E-02
	Residual Handling	0.31	4.10	NA	9.86E-05	1.74E-06	8.77E-06	7.80E-07	6.28E-05
	Total	354.93	6,043.22	426,312.99	6.36E-01	4.72E-01	3.60E-02	4.55E-04	6.67E-02
G-4	Materials Production	139.15	14,207.53	349,760.82	0.00E+00	1.76E-01	1.11E-02	NA	NA
	Transportation-Personnel	21.08	265.09	NA	7.80E-03	2.75E-04	1.58E-03	4.31E-04	3.47E-02
	Transportation-Equipment	23.64	308.57	NA	7.43E-03	1.31E-04	6.61E-04	5.85E-05	4.71E-03
	Equipment Use and Misc	169.55	2,639.43	1,334,894.34	6.31E-01	3.75E-01	2.19E-02	4.36E-05	1.10E-02
	Residual Handling	0.20	2.58	NA	6.21E-05	1.10E-06	5.52E-06	7.80E-07	6.28E-05
	Total	353.62	17,423.19	1,684,655.16	6.46E-01	5.52E-01	3.52E-02	5.34E-04	5.05E-02
G-5	Materials Production	3,027.92	30,592.48	229,653.12	1.40E+01	1.49E+00	1.95E-02	NA	NA
	Transportation-Personnel	87.58	1,101.58	NA	3.24E-02	1.14E-03	6.57E-03	1.79E-03	1.44E-01
	Transportation-Equipment	6.94	90.56	NA	2.18E-03	3.86E-05	1.94E-04	1.74E-05	1.40E-03
	Equipment Use and Misc	195,109.94	4,215,883.65	208,199,949.05	1.60E+02	4.36E+02	1.10E-02	2.87E-05	7.22E-03
	Residual Handling	0.18	2.38	NA	5.74E-05	1.02E-06	5.11E-06	7.80E-07	6.28E-05
	Total	198,232.56	4,247,670.64	208,429,602.17	1.74E+02	4.38E+02	3.72E-02	1.84E-03	1.53E-01
G-6	Materials Production	353.65	36,601.27	920,532.92	2.56E-07	4.36E-01	1.95E-02	NA	NA
	Transportation-Personnel	26.11	328.36	NA	9.66E-03	3.40E-04	6.57E-03	5.34E-04	4.30E-02
	Transportation-Equipment	69.64	908.93	NA	2.19E-02	3.87E-04	1.94E-04	1.72E-04	1.39E-02
	Equipment Use and Misc	131.00	2,211.45	4,029,037.75	5.06E-01	2.73E-01	1.10E-02	7.70E-05	1.93E-02
	Residual Handling	0.43	5.61	NA	1.35E-04	2.39E-06	5.11E-06	1.56E-06	1.26E-04
	Total	580.83	40,055.62	4,949,570.67	5.38E-01	7.10E-01	3.72E-02	7.85E-04	7.64E-02

Naval Air Warfare Center Warminster
Operable Unit 1A, 3 and 4
Warminster, Pennsylvania

FEC	**BRAC Program Management Office, Northeast**
Installation	Naval Air Warfare Center (NAWC) Warminster
Location	Warminster, Pennsylvania
Site Number	Operable Units 1A, 3, 4
Site Name	Operable Units 1A, 3, 4Groundwater Treatment System
Phase/Milestone/Date	Remedial Action (Final Source Area Treatment Evaluation Report, July 2011)
Site Background	NAWC is an 824-acre facility located in Warminster Township, Northampton Township, and Ivyland Borough, Bucks County, Pennsylvania. Commissioned in 1944, the facility's main function was research, development, testing, and evaluation for naval aircraft systems. NAWC Warminster also conducted studies in anti-submarine warfare systems and software development. Historically, wastes were generated during aircraft maintenance and repair, pest control, firefighting training, machine and plating-shop operations, spray painting, and various materials research and testing activities in laboratories. These wastes, including paints, solvents, sludges from industrial wastewater treatment, and waste oils, were disposed of in several pits, trenches, and landfills throughout the facility property. NAWC Warminster was listed on the Superfund National Priorities List in 1989. This list includes six sites where uncontrolled hazardous substance releases present the most significant potential threats to human health and the environment. These sites have been grouped within the following areas on NAWC property: Area A (Sites 1, 2, and 3); Area C (Sites 4 and 8); and Area D (Site 9).
Contaminants	TCE, PCE, CCl_4, 1,1-dichloroethene (1,1-DCE), vinyl chloride (VC), *cis*-1,2-DCE, 1,1,2-trichloroethane (1,1,2-TCA), benzene, and chloroform
Impacted Media	The impacted media is groundwater.
Remedial Technologies	Based on the initial screening of technologies, five remedial alternatives were retained for development and detailed comparative analysis. This case study discusses the scenario where GWET system operating for 25 years. • **Alternative 1**: Current groundwater extraction treatment system (GWETS) • **Alternative 2**: Optimized GWETS • **Alternative 3**: ISCO source treatment with optimized GWETS Operation • **Alternative 4**: ZVI source treatment with optimized GWETS operation • **Alternative 5**: Thermal conductive heating (TCH) source treatment with optimized GWETS operation
GSR Evaluation Approach	The sustainability analysis was performed using SiteWise™ (see Table 2).
Footprint Reduction Methodologies	The report suggests modifying the GWETS by removing the air stripper to reduce the impact of several sustainability metrics (GHG emissions, air emissions, and accident risk). It was also determined that source area treatment would be beneficial to reduce the timeframe that the GWETS would need to be operated. Operating the optimized GWETS for 25 years after source zone treatment was found to represent a near breakeven point compared to 30-year operation of the current system.

Naval Air Warfare Center Warminster Operable Unit 1A, 3 and 4 Warminster, Pennsylvania	
Greenhouse Gas Emissions	Alternative 1 has the highest greenhouse gas emissions due to the production of virgin GAC and electricity usage. • Alternative 1(Current GWETS): 6,776 metric ton • Alternative 2 (Optimized GWETS): 4,235 metric ton • Alternative 3 (ISCO with Optimized GWETS):3,895 metric ton • Alternative 4 (ZVI with Optimized GWETS): 3,880 metric ton • Alternative 5(TCH with optimized GWETS): 5,155 metric ton
Energy Consumption	Alternative 1 is the highest due to the virgin GAC production and electricity usage. This is followed by Alternative 5 which primarily driven by production of virgin GAC, electricity usage and drilling. • Alternative 1(Current GWETS): 130,000 MMBTU • Alternative 2 (Optimized GWETS):80,000 MMBTU • Alternative 3 (ISCO with Optimized GWETS): 72000 MMBTU • Alternative 4 (ZVI with Optimized GWETS): 71000 MMBTU • Alternative 5(TCH with optimized GWETS): 92000 MMBTU
Criteria Air Pollutants	The emission of criteria air pollutants for alternative 1 is primarily the result of electric usage by the system.
Water Usage	Alternative 1 and 2 have the highest water use due to pumping and discharging water. • Alternative 1(Current GWETS): 1.4E09 gallons • Alternative 2 (Optimized GWETS): 1.4E09 gallons • Alternative 3 (ISCO with Optimized GWETS): 1.2E09 gallons • Alternative 4 (ZVI with Optimized GWETS): 1.2E09 gallons • Alternative 5(TCH with Optimized GWETS): 1.2E09 gallons
Ecological Impacts	This metric was not discussed in the report.
Resource Consumption	Alternative 1 and 2 had the highest resources lost due to groundwater pumped (discharged to surface water body).
Waste Generation	This metric was not discussed in the report
Worker Safety	Accident risk is highest in alternative 1 due to personnel transportation for system operation.
Community Impacts	Alternative 1 and 2 had the highest impacts to community due to delayed property transfer.
Conclusions	Overall, Alternative 1 (current GWETS operation) had the highest GHG emissions, energy use, air emissions, accident risks, community impact, water use and resources lost.

Table 2. GSR Metrics Summary for Operable Units 1A, 3, 4 NAWC Warminster

Remedial Alternative	GHG Emissions	Total Energy Usage	Water Usage	NOx Emissions	SOx Emissions	PM_{10} Emissions	Accident Risk	Accident Risk
	metric ton	MMBTU	gallons	metric ton	metric ton	metric ton	Fatality	Injury
GWETS	6,776	1.3E+05	1.4E+09	7.3E+00	3.4E+01	4.1E-02	2.9E-03	2.1E-01
Optimized GWETS	4,235	8.0E+04	1.4E+09	4.2E+00	1.9E+01	2.9E-02	2.0E-03	1.4E-01
ISCO	3,895	7.2E+04	1.2E+09	4.6E+00	1.6E+01	1.1E-01	1.8E-03	1.4E-01
ZVI	3,880	7.1E+04	1.2E+09	4.6E+00	1.6E+01	1.0E-01	1.7E-03	1.4E-01
TCH	5,155	9.2E+04	1.2E+09	1.0E+01	2.1E+01	4.9E-01	2.3E-03	2.5E-01

Former Naval Air Station Alameda
Operable Unit 2C
Alameda, California

FEC	**BRAC**
Installation	Former Naval Air Station (NAS) Alameda
Location	Alameda, California
Site Number	OU 2C
Site Name	Operable Unit 2C (OU 2C)
Phase/Milestone/Date	Feasibility Study (February 19, 2010)
Site Background	OU-2C, a 53-acre parcel of land, is located on the eastern side of San Francisco Bay (see Figure 2). It has been used as a base of operations for naval surface craft from before 1940 until its closure in 1993. Site investigations determined that the soil, shallow first water bearing zone groundwater (referred to here as shallow groundwater), and deep first and second water bearing zones groundwater (referred to here as deep groundwater) were contaminated with VOCs. Several remedial alternatives were investigated in the FS to meet the remedial action objectives (RAOs) of protecting future receptors, preventing exposure to radionuclides, and providing source control.
Contaminants	Contaminants of concern (COCs) at the site include heavy metals, volatile organic compounds (VOCs), and a radioactive contaminant (radium-226).
Impacted Media	Groundwater and soil
Remedial Technologies	Remedial alternatives were proposed for the soil, shallow groundwater and the deep groundwater matrices. This case study discusses the soil remedial alternatives. The soil remedial alternatives included in the GSR analysis were • **Alternative 1**: Excavation and engineered cap (Eng Cap), • **Alternative 2**: Excavation only, and • **Alternative 3**: Excavation and soil vapor extraction (SVE).
GSR Evaluation Approach	The GSR evaluation was performed using SiteWise™ (see Table 3).
Footprint Reduction Methodologies	The following footprint reduction methods were proposed: • Additional characterization to minimize the volume of soil that is excavated and shipped off-site, while still being protective of human health; • Rail shipments; • Use of After-treatment Technologies for Emission Reduction, such as: Diesel Oxidation Catalyst (DOC), Diesel Particulate Filter (DPF), Selective Catalytic Reduction (SCR), and/or Diesel Multistage Filter (DMFs) for excavation equipment and trucks; and • Implementation of an idle control plan and other operating strategies to improve efficiency of site activities.
Greenhouse Gas Emissions	Alternative 2 has the highest greenhouse gas emissions due to transportation of equipment. • Alternative 1 (Excavation and Eng Cap): 294 metric ton • Alternative 2 (Excavation only): 1,700 metric ton • Alternative 3 (Excavation and SVE): 1,430 metric ton

Former Naval Air Station Alameda Operable Unit 2C Alameda, California	
Energy Consumption	Alternative 2 has the highest energy consumption due to transportation of equipment. • Alternative 1 (Excavation and Eng Cap): 1,180 MWH • Alternative 2 (Excavation only): 6,820 MWH • Alternative 3 (Excavation and SVE): 5,700 MWH
Criteria Air Pollutants	Alternative 1 had the lowest air emissions. Alternative 2 had the highest air emissions primarily due to transportation of equipment.
Water Usage	This metric was not discussed in the case study.
Ecological Impacts	This metric was not discussed in the case study.
Resource Consumption	Landfill space requirements were evaluated outside of the SiteWise™ tool. Alternative 2 used the highest amount of landfill space due to the contaminated soil excavated from the site and disposed of in a landfill.
Waste Generation	Alternative 2 generates the highest amount of waste (hazardous).
Worker Safety	Alternative 2 had the highest risk due to transportation of equipment.
Community Impacts	This metric was not discussed in the presentation.
Conclusions	Alternative 1 (excavation combined with an engineered cap) appeared to have the lowest environmental footprint of the three soil alternatives evaluated. Alternative 2 (excavation alone) had the highest environmental footprint, but was only slightly higher than Alternative 3 (excavation combined with SVE option). The footprint associated with excavation was mainly due to system construction and operation, specifically transportation of equipment and materials. The activity contributing most to the environmental footprint of excavation was the large volume of soil that would be disposed of and transported to landfills (much of it to a hazardous waste landfill located 200 miles from the site) and the subsequent import of clean fill. Alternative 2 (excavation alone) required more than 10 times the amount of soil to be excavated than alternative 1(excavation combined with engineering cap). Landfill space, a resource that is consumed from remediation activities, was also evaluated outside of the tool. Alternative 2(excavation only) used the highest amount of landfill space due to the greater volume of contaminated soil excavated from the site and disposed of in a landfill.

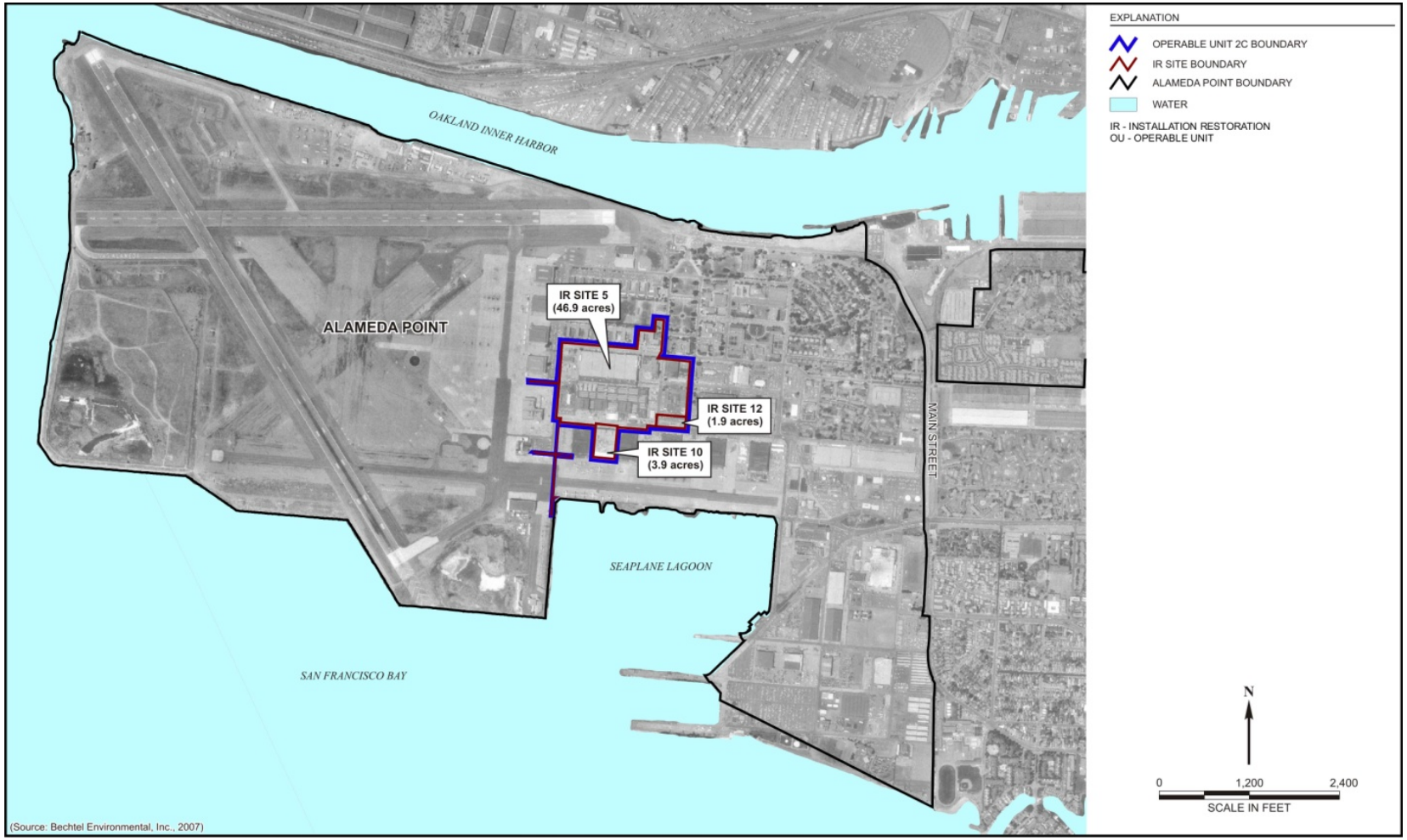


Figure 2. Site Layout for OU 2C Former NAS Alameda

Table 3. GSR Metrics Summary for OU 2C Former NAS Alameda

Remedial Alternative	CO_2 Emissions metric ton	NOx Emissions metric ton	SOx Emissions metric ton	PM10 Emissions metric ton	Energy Usage MWH	Accident Risk Fatality	Accident Risk Injury
Soil Alternatives							
Excavation and Eng Cap	2.94E+02	1.19E+00	1.13E-02	2.17E-01	1.18E+03	2.26E-04	5.30E-02
Excavation	1.70E+03	6.85E+00	5.52E-02	1.25E+00	6.82E+03	1.15E-03	2.59E-01
Excavation /SVE	1.43E+03	5.65E+00	5.58E-02	1.03E+00	5.70E+03	9.46E-04	2.08E-01

Former Naval Air Station South Weymouth
Building 81
Weymouth, Massachusetts

FEC	**BRAC**
Installation	Former Naval Air Station South Weymouth
Location	Weymouth, Massachusetts
Site Number	Building 81
Site Name	Building 81, Former Naval Air Station South Weymouth
Phase/Milestone/Date	Feasibility Study (April 2013)
Site Background	The Building 81 site is located in the central portion of former NAS South Weymouth, approximately 4,500 feet (ft) southeast of the main entrance to the Base on Route 18. Building 81 was used for motor pool (i.e., vehicle maintenance) activities from the time of its construction until Base closure. The exact age of Building 81 is not available; however, facility drawings dated March 1955 indicate that the building was present at that time and was used by the National Guard for motor pool activities. The facility was later taken over by Marine reservists.
Contaminants	Contaminants of concern (COCs) at the site include VOCs (tetrachloroethene, (PCE), toluene, benzene, cis-1,2-dichloroethene [DCE], trichloroethene (TCE), vinyl chloride [VC])
Impacted Media	Groundwater and soil
Remedial Technologies	This case study discusses remedial alternatives to address groundwater contamination. The remedial alternatives included in the GSR analysis were • **Alternative 1**: No action • **Alternative 2**: Biobarriers, land use controls (LUCs), and monitored natural attenuation (MNA) • **Alternative 3**: In situ bioremediation, biobarriers, LUCs and MNA • **Alternative 4**: In situ chemical oxidation (ISCO), biobarriers, LUCs, and MNA This case study reviews Alternative 2, 3 and 4.
GSR Evaluation Approach	GSR evaluation was performed using a hybrid model of the SiteWise™ tool supplemented with the TetraTech developed model GSRx (see Table 4).
Footprint Reduction Methodologies	Some recommended footprint reduction methods include: All Alternatives : • Consider revision of the amount of concrete used for the preparation of the site to support the equipment used during this alternative; this would reduce significantly the amount of GHG emissions released to the atmosphere, as well as the amount of energy utilized. • Some reduction of the environmental footprint, particularly GHG emissions and energy consumption, could be realized for all alternatives through the possible use of emission control measures such as alternate fuel sources (e.g. biodiesel), equipment exhaust controls (e.g. diesel), and equipment idle reduction. • Consider optimizing of the use of equipment, particularly the use of the DPT drill rig, and even the type of equipment used during operations. • Consider the optimization of the use of EOS during the treatment stage. The environmental impact of this chemical has an influence in most of the impact categories evaluated.

	• Design an optimized sampling schedule that minimizes the number of samples that need to be analyzed and maximizes the results (for this alternative laboratory analytical services are the main driver for most of the impact categories evaluated). • Optimize the number of samples analyzed during the operation and monitoring stages given that the laboratory analytical services is one of the major drivers in some of the impact categories. • Consider ways to reduce vehicle mileage to reduce worker risk, as well as energy use and emissions. Encourage site workers to carpool daily to the site to reduce total vehicle mileage.
Greenhouse Gas Emissions	Alternative 3 has the highest greenhouse gas emissions due to laboratory analytical services, production of concrete and vegetable oil. • Alternative 2 (Biobarriers, LUCs, and MNA): 165.51 metric ton • Alternative 3 (In situ bioremediation, bio-barriers, LUCs, and MNA): 172.69 metric ton • Alternative 4 (ISCO, bio-barriers, LUCs and MNA): 169.31 metric ton
Energy Consumption	Alternative 3 has the highest energy consumption due to production of vegetable oil and concrete and laboratory analytical service. • Alternative 2 (Biobarriers, LUCs, and MNA): 1,387.96 MMBTU • Alternative 3 (In situ bioremediation, biobarriers, LUCs, and MNA: 6,507.32 MMBTU • Alternative 4 (ISCO, LUCs, and MNA): 6,477.55 MMBTU
Criteria Air Pollutants	Alternative 2 has the highest air emissions generated primarily during laboratory analysis services.
Water Usage	Alternative 4 has the highest water consumption due to water used during decontamination followed by alternative 3. • Alternative 2 (Biobarriers, LUCs, and MNA): 304,655.78 gallons • Alternative 3 (In Situ Bioremediation, biobarriers, LUCs and MNA): 359,266.5 gallons • Alternative 4 (ISCO, biobarriers, LUCs and MNA): 349,510.51 gallons
Ecological Impacts	There were no potential impacts to ecological receptors so an ecological risk assessment was not performed.
Resource Consumption	There is no topsoil consumption in any of the alternatives.
Waste Generation	There is no landfill space used in any of the alternatives.
Worker Safety	Alternative 3 had the highest risk due to transportation of personnel.
Community Impacts	Alternative 3 and 4 would result in a possibility of exposing site workers to contaminated groundwater during installation of injection wells, injection of emulsified oil substrate and ISCO reagents, and monitoring activities. This risk would be reduced through compliance with appropriate site-specific health and safety procedures. There would be slight risk to the surrounding community from transport of oxidizers under alternative 4.

Conclusions

Overall, alternative 3 provides the shortest overall cleanup timeframe since the PRGs would be met in the overburden and deep bedrock upon completion of the source treatment. For sustainability, Alternative 3 has the highest impact based on emissions, energy (equal to Alternative 4), and highest impact on water consumption.

Overall protection of human health and the environment
Alternatives 2 through 4 would all provide protection to human health and the environment. Alternative 4 would provide the greatest protection because it treats the source areas with high-CVOC concentrations in the shortest timeframe using ISCO and controls the plume migration by treating it at its leading edge using bio-barriers.

Compliance with ARARs
Alternatives 2 through 4 would comply with location- and action-specific ARARs and TBCs. Alternatives 2 through 4 would eventually comply with chemical-specific ARARs and TBCs as they attain PRGs through a combination of in-situ treatment and MNA.

Long-term effectiveness and Permanence
Alternatives 2 through 4 would provide long-term effectiveness and permanence through a combination of treatment, MNA, and LUCs. Alternatives G-3 and G-4 provide a higher level of permanence compared to Alternative G-2 because the source area treatment component would permanently remove most of the contamination in the high concentration areas.

Reduction of toxicity, mobility or volume through treatment
Alternatives 3 and 4 would achieve the greatest reductions in COC toxicity and volume through a combination of active treatment in source areas and passive treatment at the plume's leading edge. Alternative 2 would achieve a lower level reduction in COC toxicity and volume through passive treatment by the bio-barriers.

Short-term Effectiveness
Short-term effects of Alternatives 2 through 4 would result in a possibility of exposing site workers to contaminated groundwater during the maintenance and sampling of monitoring wells and during remedial construction and operation. Alternative 2 would result in the lowest short-term risk, with the potential for exposure only during installation of the injection wells and injection of emulsified oil substrate for the bio-barriers and groundwater sampling.

Implementability
Alternative 2 would be the second easiest of the remaining alternatives to implement because only the bio-barriers would need to be installed in addition to groundwater monitoring. Alternatives 3 and 4 would both be more difficult to implement than Alternative 2 because installation of active treatment with enhanced bioremediation or ISCO would be required for the high concentration source areas.

Cost

- Alternative 2 (Biobarriers, LUCs, and MNA): $3,545,000
- Alternative 3 (In situ bioremediation, biobarriers, LUCs and MNA): $3,791,000
- Alternative 4 (ISCO, biobarriers, LUCs and MNA): $4,333,000

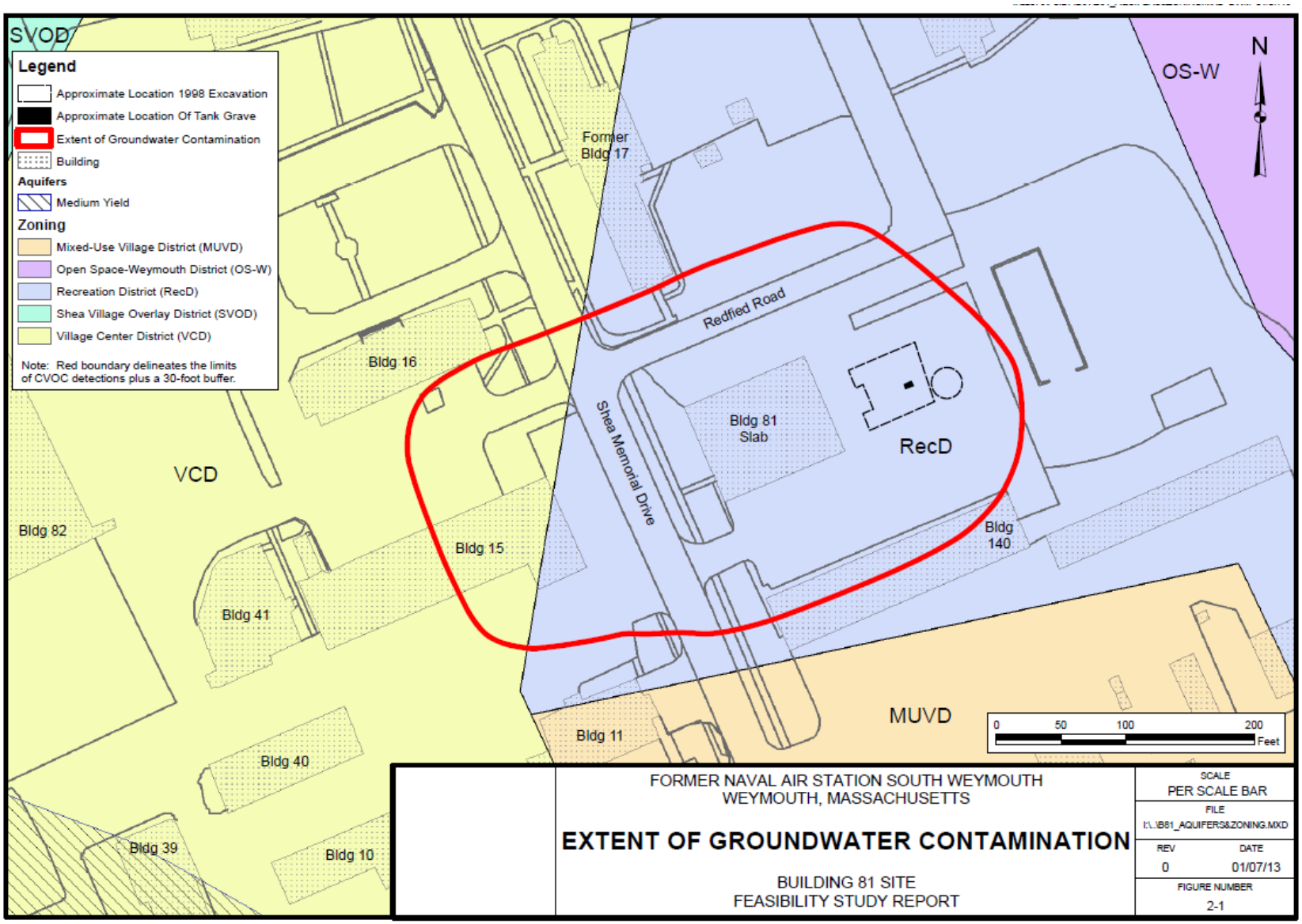


Figure 3. Site Layout for Building 81 Former Naval Air Station South Weymouth

Table 4. GSR Metrics Summary for Building 81 Former Naval Air Station South Weymouth

Alternative	Activities	GHG Emissions	Total Energy Used	Water Impacts	NOx Emissions	SOx Emissions	PM10 Emissions	Accident Risk Fatality	Accident Risk Injury
		metric ton	MMBTU	gallons	metric ton	metric ton	metric ton		
G-2	Materials Production	84.30	187.04	38,274.64	0.00E+00	5.83E-02	4.84E-03	NA	NA
	Transportation-Personnel	19.26	242.32	NA	7.13E-03	2.51E-04	1.45E-03	3.94E-04	3.17E-02
	Transportation-Equipment	6.38	83.30	NA	2.01E-03	3.55E-05	1.78E-04	1.70E-05	1.37E-03
	Equipment Use and Misc	55.20	870.64	266,381.14	1.86E-01	1.24E-01	7.05E-03	0.00E+00	0.00E+00
	Residual Handling	0.36	4.65	NA	1.12E-04	1.98E-06	9.96E-06	1.56E-06	1.26E-04
	Total	165.51	1,387.96	304,655.78	1.96E-01	1.83E-01	1.35E-02	0.000	0.033
G-3	Materials Production	88.29	5,258.05	86,439.33	1.60E-07	6.52E-02	5.70E-03	NA	NA
	Transportation-Personnel	21.59	271.56	NA	7.99E-03	2.81E-04	1.62E-03	4.42E-04	3.56E-02
	Transportation-Equipment	6.61	86.23	NA	2.08E-03	3.67E-05	1.85E-04	1.76E-05	1.41E-03
	Equipment Use and Misc	55.85	886.82	272,827.17	1.92E-01	1.25E-01	7.61E-03	2.04E-05	5.13E-03
	Residual Handling	0.36	4.65	NA	1.12E-04	1.98E-06	9.96E-06	1.56E-06	1.26E-04
	Total	172.69	6,507.32	359,266.50	2.02E-01	1.90E-01	1.51E-02	0.000	0.042
G-4	Materials Production	83.43	4,880.27	82,231.61	1.37E-06	4.56E-02	2.91E-03	NA	NA
	Transportation-Personnel	23.65	297.44	NA	8.75E-03	3.08E-04	1.77E-03	4.84E-04	3.90E-02
	Transportation-Equipment	3.40	44.43	NA	1.07E-03	1.89E-05	9.51E-05	9.61E-06	7.73E-04
	Equipment Use and Misc	58.46	1,250.61	267,278.89	2.05E-01	1.31E-01	8.03E-03	6.95E-06	1.75E-03
	Residual Handling	0.37	4.80	NA	1.15E-04	2.04E-06	1.03E-05	1.56E-06	1.26E-04
	Total	169.31	6,477.55	349,510.51	2.15E-01	1.77E-01	1.28E-02	0.001	0.042

Former Naval Air Station South Weymouth
Building 82
Weymouth, Massachusetts

FEC	**BRAC**
Installation	Former Naval Air Station South Weymouth
Location	Weymouth, Massachusetts
Site Number	Building 82
Site Name	Building 82 (also referred to as Hangar 2)
Phase/Milestone/Date	Feasibility Study (July 2012)
Site Background	A former aircraft hangar, Building 82, was constructed in 1956 as an aircraft hangar (maintenance facility) for fixed wing aircraft (see Figure 4). It was continuously used by the United States Marine Corps for that purpose from 1956 through 1996, when operations at the Base ceased. During that time, oils, lubricants, and solvents necessary for aircraft maintenance were used and stored in the building. Following Base closure, Building 82 was used for the storage of miscellaneous Navy-owned vehicles (i.e., plows, backhoes, buses, etc.) until 2000. Building 82 is currently vacant; however, the building may be occasionally occupied by Navy personnel during routine building maintenance inspections.
Contaminants	Contaminants of concern (COCs) at the site include TCE, 1,1,1-TCA, 1,1-DCA, n-nitroso-di-n-propylamine (NNPA) and manganese
Impacted Media	Groundwater, surface water and soil
Remedial Technologies	This case study discusses remedial alternatives to address groundwater contamination. The remedial alternatives included in the GSR analysis were • **Alternative 1**: No action • **Alternative 2**: Chemical Oxidation, LUCs, MNA • **Alternative 2**a: Chemical Oxidation, LUCs, Monitoring • **Alternative 3**: In Situ Enhanced Bioremediation, LUCs, MNA • **Alternative 4**: LUCs and MNA This case study reviews Alternative 2, 2a, 3 and 4.
GSR Evaluation Approach	GSR evaluation was performed using a hybrid model of SiteWise™ tool supplemented with a TetraTech developed model GSRx (see Table 5). In addition, the alternatives were evaluated against the NCP nine evaluation criteria.
Footprint Reduction Methodologies	Some recommended footprint reduction methods include: Alternatives 2 and 2a: • Consider revision of the amount of Fenton Reagent used during the treatment; this would reduce significantly the amount of GHG emissions released to the atmosphere, as well as the amount of energy utilized. Alternatives 2, 2a and 3: • Consider optimizing of the use of equipment, particularly the use of the DPT drill rig, and even the type of equipment used during operations. Alternatives 3: • Consider the optimization of the use of EOS during the treatment stage. The environmental impact of this chemical has an influence in most of the impact categories evaluated.

	Alternative 4: • Design an optimized sampling schedule that minimizes the number of samples that need to be analyzed and maximizes the results, for these alternative laboratory analytical services are the main driver for most of the impact categories evaluated. All Alternatives: • Some reduction of the environmental footprint, particularly GHG emissions and energy consumption, could be realized for all alternatives through the possible use of emission control measures such as alternate fuel sources (e.g., biodiesel), equipment exhaust controls (e.g., diesel), and equipment idle reduction. • Optimize the number of samples analyzed during the LTM stage given that the laboratory analytical services are one of the major drivers in some of the impact categories. • Consider ways to reduce vehicle mileage to reduce worker risk as well as energy use and emissions. Encourage site workers to carpool daily to the site to reduce total vehicle mileage.
Greenhouse Gas Emissions	Alternative 2a has the highest greenhouse gas emissions due to the production of hydrogen peroxide used as the Fenton's Reagent during treatment. • Alternative 2 (Chemical Oxidation, LUCs, MNA): 4,735.48 metric ton • Alternative 2a (Chemical Oxidation, LUCs, Monitoring): 8,589.92 metric ton • Alternative 3 (In Situ Enhanced Bioremediation, LUCs, MNA): 115.02 metric ton • Alternative 4 (LUCs and MNA): 42.11 metric ton
Energy Consumption	Alternative 2a has the highest energy consumption due to production of production of hydrogen peroxide, PVC. • Alternative 2 (Chemical Oxidation, LUCs, MNA): 123,794.34 MMBTU • Alternative 2a (Chemical Oxidation, LUCs, Monitoring): 224,879.14 MMBTU • Alternative 3 (In Situ Enhanced Bioremediation, LUCs, MNA): 7454.29 MMBTU • Alternative 4 (LUCs and MNA): 628.36 MMBTU
Criteria Air Pollutants	Alternative 2a has the highest air emissions generated primarily during laboratory analysis services and production of hydrogen peroxide (used as Fenton's' reagent during treatment).
Water Usage	Alternative 2a has the highest water consumption due to water used for injection purposes, production of PVC and decontamination water. • Alternative 2 (Chemical Oxidation, LUCs, MNA): 177,062.07 gal • Alternative 2a (Chemical Oxidation, LUCs, Monitoring): 322,093.76 gal • Alternative 3 (In Situ Enhanced Bioremediation, LUCs, MNA): 253,290.79 gal • Alternative 4 (LUCs and MNA): 300.90 gal

Former Naval Air Station South Weymouth Building 82 Weymouth, Massachusetts	
Ecological Impacts	No COCs were retained during the ecological risk assessment, because it was determined in the RI that the risks to terrestrial plants and invertebrates, sediment invertebrates, aquatic organisms, and terrestrial receptors at the Site were not great enough for any chemicals to warrant further evaluation of ecological risk at this Site.
Resource Consumption	There is no topsoil consumption in any of the alternatives.
Waste Generation	There is no landfill space used in any of the alternatives.
Worker Safety	Alternative 2a had the highest risk due to transportation of personnel. Alternatives 2, 2a, 3, and 4 would result in a possibility of exposing site workers to contaminated groundwater as a result of the injection of Fenton's reagent and monitoring activities. This risk would be reduced through compliance with appropriate site-specific health and safety procedures. Least potential for short term risks.
Community Impacts	There would be no risk to the surrounding community or the environment.
Conclusions	Overall, alternative 2a had the highest GHG emissions, energy use, water consumption and criteria emissions. Alternative 3 is the most difficult to implement because of multiple injection events over an extended period of time. ***Overall protection of human health and the environment*** Alternatives 2, 2A, 3, and 4 would all provide protection to human health and the environment. Alternative 2A would provide the best protection because chemical oxidation would treat the entire VOC plume in the shortest amount of time. ***Compliance with ARARs*** Alternatives 2, 2A, 3, and 4 would comply with location- and action-specific ARARs and TBCs. Alternative 2A would comply with chemical-specific ARARs and TBCs for VOCs shortly after chemical injection is completed. Alternatives 2, 3, and 4 would not immediately comply with chemical specific ARARs and TBCs, but these alternatives would eventually achieve compliance as they attain PRGs through active treatment and/or natural attenuation. ***Long-term effectiveness and permanence*** Alternatives 2, 2A, 3, and 4 would provide long-term effectiveness and permanence. Alternatives 2, 2A, and 3 provide essentially equal levels of long-term effectiveness and permanence through a combination of active treatment and LUCs, although Alternative 2A provides the largest amount of treatment and permanent removal. Alternative 4 may be less permanent than Alternatives 2, 2A, and 3 because sorption, dilution, and dispersion components of the remedy are likely and may leave a slightly larger mass of COCs at the site in comparison to alternatives involving active treatment. ***Reduction of toxicity, mobility or volume through treatment*** Alternatives 2, 2A, and 3 and would achieve reductions in COC toxicity and volume through treatment. There is no active treatment in Alternative 4. ***Short-term effectiveness*** Under Alternatives 2, 2A, 3, and 4, potential short-term risk to site workers from exposure to contaminated groundwater during the installation, maintenance, and

sampling of new and existing monitoring wells and during active remediation would be effectively avoided by proper planning. Alternative 4 would result in the lowest short-term risk to site workers, with the potential for exposure only during monitoring well installation and groundwater sampling

Implementability
Of the remaining three alternatives, Alternative 4 would be the easiest to implement because of the minimal amount of field work and monitoring that would be required. Alternative 2 would be easier to implement than 2A and 3 since it is assumed that only one injection event will be required. Alternative 2A would be easier to implement than 3.

Cost

- Alternative 2 (Chemical Oxidation, LUCs, MNA): $2,727,000
- Alternative 2a (Chemical Oxidation, LUCs, Monitoring): $3,272,000
- Alternative 3 (In Situ Enhanced Bioremediation, LUCs, MNA): $2,771,000
- Alternative 4 (LUCs and MNA): $1,297,000

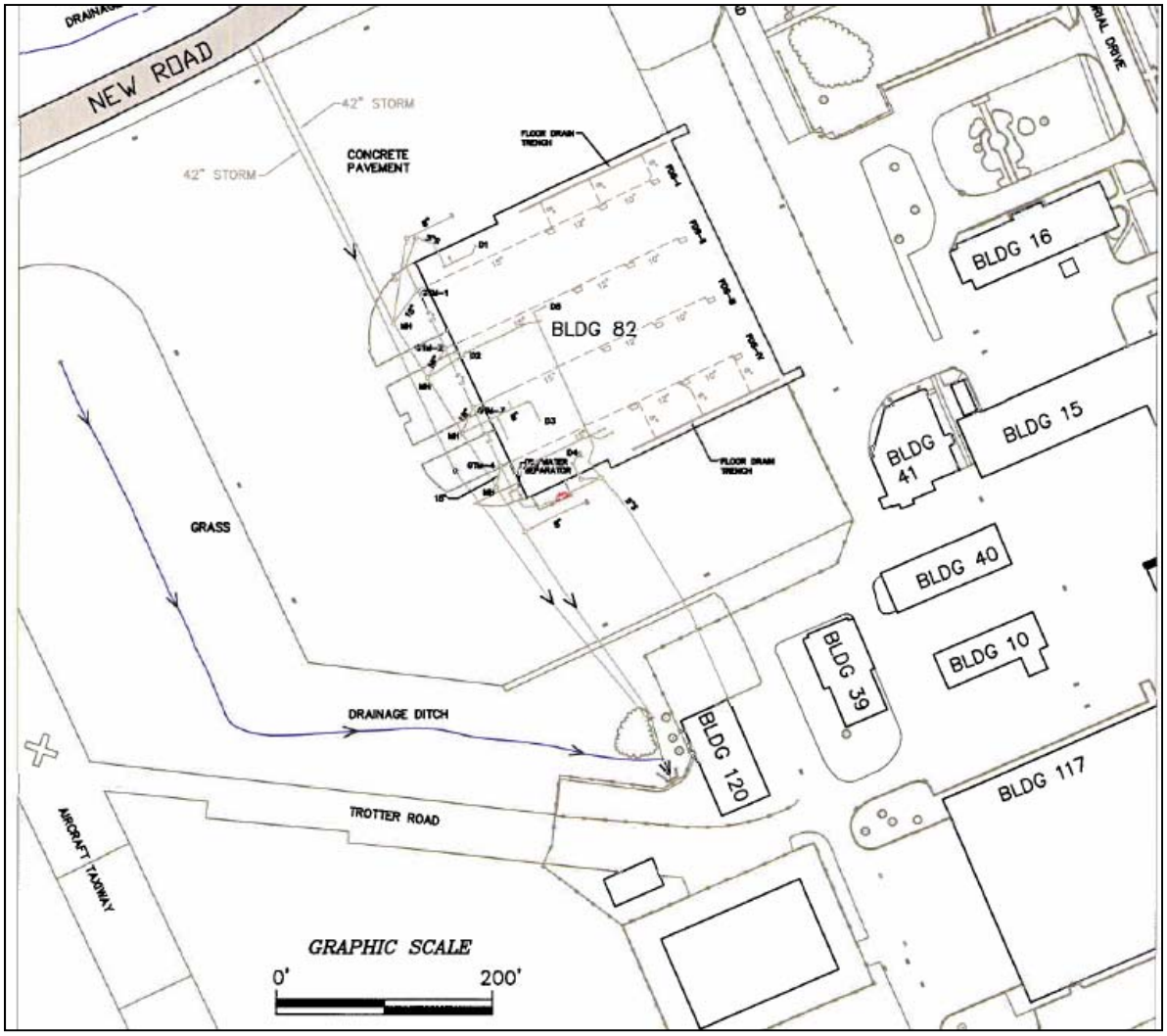


Figure 4. Site Layout for Building 82 Former Naval Air Station South Weymouth

Table 5. GSR Metrics Summary for Building 82 Former Naval Air Station South Weymouth

Alternative	Activities	GHG Emissions	Total Energy Used	Water Impacts	NOx Emissions	SOx Emissions	PM10 Emissions	Accident Risk Fatality	Accident Risk Injury
		metric ton	MMBTU	gallons	metric ton	metric ton	metric ton		
G-2	Materials Production	4,676.47	122,925.62	8,550.94	0.00E+00	7.64E+00	2.89E+00	NA	NA
	Transportation-Personnel	10.67	134.27	NA	3.95E-03	1.39E-04	8.01E-04	2.18E-04	1.76E-02
	Transportation-Equipment	8.17	106.69	NA	2.57E-03	4.54E-05	2.28E-04	2.11E-05	1.70E-03
	Equipment Use and Misc	39.85	623.73	168,511.13	1.54E-01	8.63E-02	7.41E-03	2.51E-05	6.30E-03
	Residual Handling	0.31	4.04	NA	9.72E-05	1.72E-06	8.64E-06	1.56E-06	1.26E-04
	Total	4,735.48	123,794.34	177,062.07	0.160	7.726	2.898	0.000	0.026
G-2a	Materials Production	8,510.87	223,702.10	14,706.40	0.00E+00	1.39E+01	5.26E+00	NA	NA
	Transportation-Personnel	12.12	152.49	NA	4.49E-03	1.58E-04	9.10E-04	2.48E-04	2.00E-02
	Transportation-Equipment	14.53	189.67	NA	4.57E-03	8.08E-05	4.06E-04	3.68E-05	2.96E-03
	Equipment Use and Misc	52.08	830.70	307,387.36	2.06E-01	1.10E-01	1.13E-02	4.35E-05	1.09E-02
	Residual Handling	0.32	4.18	NA	1.01E-04	1.78E-06	8.95E-06	1.56E-06	1.26E-04
	Total	8,589.92	224,879.14	322,093.76	0.215	14.013	5.272	0.000	0.034
G-3	Materials Production	60.22	6,640.78	164,625.47	5.48E-09	6.77E-02	2.30E-03	NA	NA
	Transportation-Personnel	11.59	145.77	NA	4.29E-03	1.51E-04	8.70E-04	2.37E-04	1.91E-02
	Transportation-Equipment	2.53	32.99	NA	7.94E-04	1.41E-05	7.06E-05	7.11E-06	5.73E-04
	Equipment Use and Misc	40.38	630.75	88,665.32	1.49E-01	8.89E-02	6.33E-03	1.84E-05	4.62E-03
	Residual Handling	0.31	4.00	NA	9.63E-05	1.70E-06	8.57E-06	1.56E-06	1.26E-04
	Total	115.02	7,454.29	253,290.79	0.154	0.157	0.01	0.000	0.024
G-4	Materials Production	0.30	18.76	300.90	0.00E+00	5.85E-04	8.44E-05	NA	NA
	Transportation-Personnel	6.39	80.34	NA	2.36E-03	8.32E-05	4.79E-04	1.31E-04	1.05E-02
	Transportation-Equipment	0.24	3.16	NA	7.61E-05	1.35E-06	6.76E-06	1.17E-06	9.42E-05
	Equipment Use and Misc	35.04	524.26	0.00	1.22E-01	8.06E-02	3.27E-03	1.28E-06	3.22E-04
	Residual Handling	0.14	1.84	NA	4.43E-05	7.83E-07	3.94E-06	7.80E-07	6.28E-05
	Total	42.11	628.36	300.90	0.125	0.081	0.004	0.000	0.011

Former Naval Air Station South Weymouth
Site 11 Solvent Release Area
Weymouth, Massachusetts

FEC	**BRAC**
Installation	Former Naval Air Station South Weymouth
Location	Weymouth, Massachusetts
Site Number	Site 11
Site Name	Site 11, Solvent Release Area
Phase/Milestone/Date	Feasibility Study (December 2012)
Site Background	NAS South Weymouth was commissioned during the 1940s to support dirigible aircraft used to patrol the North Atlantic during World War II. The facility was closed in 1949 and then reopened in 1953 as a naval air station for aviation training. NAS South Weymouth was designated for closure under the Base Realignment and Closure Act of 1990 (BRAC), as part of the BRAC Commission's 1995 Base Closure List (BRAC IV). In September 1996, operational closure of NAS South Weymouth began with the transfer of aircraft to other Navy facilities, and through personnel reduction. The site is located just north of the East Mat in the eastern portion of the Base (see Figure 5). The East Mat is an open, flat area, which was used for mooring the lighter-than-air aircraft.
Contaminants	Contaminants of concern (COCs) at the site include VOCs- PCE, TCE, cis-1,2-DCE, VC, PCP, arsenic, barium, 3,3'-dichlorobenzidine
Impacted Media	Groundwater, surface water, and sediment
Remedial Technologies	This case study discusses remedial alternatives to address soil contamination. The remedial alternatives included in the GSR analysis were • **Alternative 1**: No action • **Alternative 2**: Monitoring, engineering controls (ECs), and land use controls (LUCs) • **Alternative 3**: One overburden mulch PRB, monitoring, ECs, and LUCs • **Alternative 4**: Two Overburden mulch PRBs, monitoring, ECs and LUCs • **Alternative 5**: Overburden and bedrock source area enhanced bioremediation, one overburden PRB, monitoring, ECs, and LUCs • **Alternative 5A**: Overburden and bedrock source area enhanced bioremediation, two overburden PRBs, monitoring, ECs, and LUCs This case study reviews Alternative 2 through 5A.
GSR Evaluation Approach	The alternatives were evaluated against the NCP nine evaluation criteria. A hybrid version of SiteWise™ and GRx was used (see Table 6).
Footprint Reduction Methodologies	Alternatives 3,4,5 and 5A: • Some reduction of the environmental footprint, particularly GHG emissions and energy consumption, could be realized for all alternatives through the possible use of emission control measures such as alternate fuel sources (e.g., biodiesel), equipment exhaust controls (e.g., diesel), and equipment idle reduction. • Consider optimizing of the use of equipment, and even the type of equipment used during operations. • Consider the use of a material similar to mulch for the treatment barriers

	that have lower environmental impacts. • Consider the optimization of the use of EOS during the treatment stage. The environmental impact of this chemical has an influence in most of the impact categories evaluated. Alternative 4 and 5A: • Consider optimizing the amount of injection water that is used during the treatment stage All Alternatives: • Optimize the number of samples analyzed during the LTM stage given that the laboratory analytical services is one of the major drivers in most of the impact categories. • Consider ways to reduce vehicle mileage to reduce worker risk as well as energy use and emissions. Encourage site workers to carpool daily to the site to reduce total vehicle mileage.
Greenhouse Gas Emissions	Alternative 5A has the highest GHG emissions among the alternatives evaluated. The impact driver for the GHG emissions for Alternative 5A is the use of laboratory analytical services. • Alternative 2 (Monitoring, ECs, and LUCs): 109.54 metric ton • Alternative 3 (One overburden Mulch PRB, monitoring, ECs, and LUCs): 214.46 metric ton • Alternative 4 (Two overburden mulch PRBs, monitoring, ECs, and LUCs): 285.94 metric ton • Alternative 5 (Overburden and bedrock source area enhanced bioremediation, one overburden PRB, monitoring, ECs, and LUCs): 240.4 metric ton • Alternative 5A (Overburden and bedrock source area enhanced bioremediation, two overburden PRBs, monitoring, engineering controls and LUCs): 311.15 metric ton
Energy Consumption	Energy consumption is highest for Alternative 5A. The activity that consumes the most energy is the production of vegetable oil, which is used as EOS for the injection treatment through the lifetime of the project. • Alternative 2 (Monitoring, Engineering Controls and LUCs):1656.59 MMBTU • Alternative 3 (One Overburden Mulch PRB, monitoring, ECs, and LUCs): 6734.35 MMBTU • Alternative 4 (Two overburden mulch PRBs, monitoring, ECs, and LUCs): 10,565.57 MMBTU • Alternative 5 (Overburden and bedrock source area enhanced bioremediation, one overburden PRB, monitoring, ECs, and LUCs): 7332.09 MMBTU • Alternative 5A (Overburden and bedrock source area enhanced bioremediation, two overburden PRBs, monitoring, ECs, and LUCs): 11,148.79 MMBTU
Criteria Air Pollutants	Alternative 5A has the highest amount of NOx and PM10 emissions due to the use of laboratory analytical services. The alternative with the highest amount of SO_X is alternative 5A, with 0.74 ton, where the production of mulch, used for revegetation purposes and the treatment barriers, is the activity with the highest SOX emissions.

Water Usage	Alternative 5A has the highest consumption of water due to the injection waters used through the treatment. • Alternative 2 (Monitoring, Engineering Controls and LUCs): 613.47 gallons • Alternative 3 (One Overburden Mulch PRB, monitoring, ECs, and LUCs): 149,283.57 gallons • Alternative 4 (Two Overburden mulch PRBs, monitoring, ECs, and LUCs): 267,604.86 gallons • Alternative 5 (Overburden and bedrock source area enhanced bioremediation, one overburden PRB, monitoring, ECs, and LUCs): 158,183.79 gallons • Alternative 5A (Overburden and bedrock source area enhanced bioremediation, two overburden PRBs, monitoring, engineering controls and LUCs): 276,696.56 gallons
Ecological Impacts	Adverse effects to terrestrial receptors, wildlife, aquatic organisms and terrestrial plants and invertebrates were not predicted. There are no significant impacts to sediment invertebrates that could occur from PAHs and pesticides in the sediment, and there are no significant impacts to sediment invertebrates that could occur from PCBs in the sediment.
Resource Consumption	None of the alternatives used top soil.
Waste Generation	None of the alternatives used landfill space.
Worker Safety	Alternatives 5 and 5A would result in high accident risk due to transportation of personnel.
Community Impacts	Implementation of the groundwater alternatives that have treatment components would have slight adverse impacts on the surrounding community or environment. Alternative 3 would have the least impact due to the transport of contaminated soil from the mulch PRB for off-site disposal. Alternatives 4 and 5A would have the highest impacts due to transport of more contaminated soil from the second mulch PRB for off-site disposal.
Conclusions	Overall, alternative 5A had the highest greenhouse emissions, energy use, water consumption, criteria emissions and accident risk. ***Overall protection of human health and the environment*** Alternatives 2 through 5A would all provide protection to human health and the environment. Engineering Controls and LUCs would provide protection of human health until PRGs are met by restricting the use of groundwater and by preventing exposure through vapor intrusion by controlling building design and construction methods. Alternative 5A would provide the greatest protection because it treats the high-PCE concentration source areas in overburden and bedrock with enhanced bioremediation and part of the plume with two PRBs ***Compliance with ARARs and TBCs*** Alternatives 2 through 5A would comply with location- and action-specific ARARs and TBCs. Alternatives 2 through 5A would not immediately comply with chemical-specific ARARs and TBCs, but these alternatives would eventually achieve compliance as they attain PRGs through a combination of in situ treatment and LUCs.

Long-term Effectiveness and Permanence
Alternatives 2 through 5A would provide long-term effectiveness and permanence through a combination of monitoring, engineering controls, and LUCs and treatment for Alternatives 3 through 5A.

Reduction of toxicity, mobility or volume through treatment
Alternatives 3 through 5A would achieve reductions in COC toxicity and volume through treatment. Alternative 2 would not achieve any reduction of toxicity, mobility, or volume of COCs because no treatment would occur.

Short-term effectiveness
Short-term effects of Alternatives 2 through 5A would result in a possibility of exposing site workers to contaminated groundwater during the maintenance and sampling of existing monitoring wells and during remedial construction and operation.

Implementability
Alternative 2 would be the second easiest of the remaining alternatives to implement because of the minimal amount of field work and monitoring that would be required. Alternatives 3 and 4 would be the next easiest to implement, although the one-pass trenching equipment is somewhat specialized. Alternatives 5 and 5A would be more difficult to implement than Alternatives 3 and 4 because they would require installation of injection wells into the overburden and the bedrock.

Cost
- Alternative 2 (Monitoring, ECs, and LUCs): $1,103,000
- Alternative 3 (One Overburden Mulch PRB, monitoring, ECs, and LUCs): $2,612,000
- Alternative 4 (Two Overburden mulch PRBs, monitoring, ECs, and LUCs): $3,181,000
- Alternative 5 (Overburden and bedrock source area enhanced bioremediation, one overburden PRB, monitoring, ECs, and LUCs): $3,602,000
- Alternative 5A (Overburden and bedrock source area enhanced bioremediation, two overburden PRBs, monitoring, ECs, and LUCs): $4,140,000

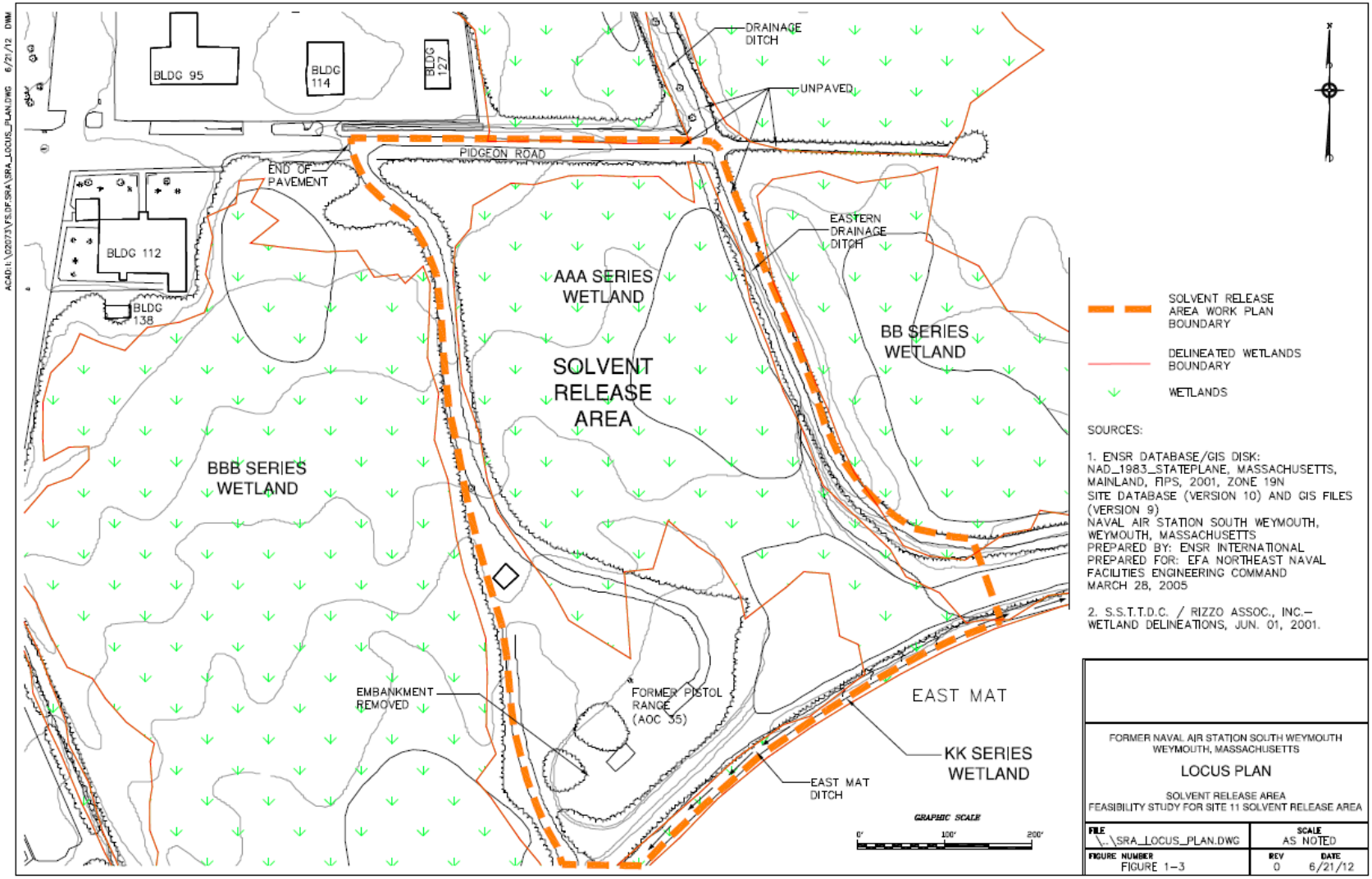


Figure 5. Site Layout for Site 11 Solvent Release Area, Former Naval Air Station South Weymouth

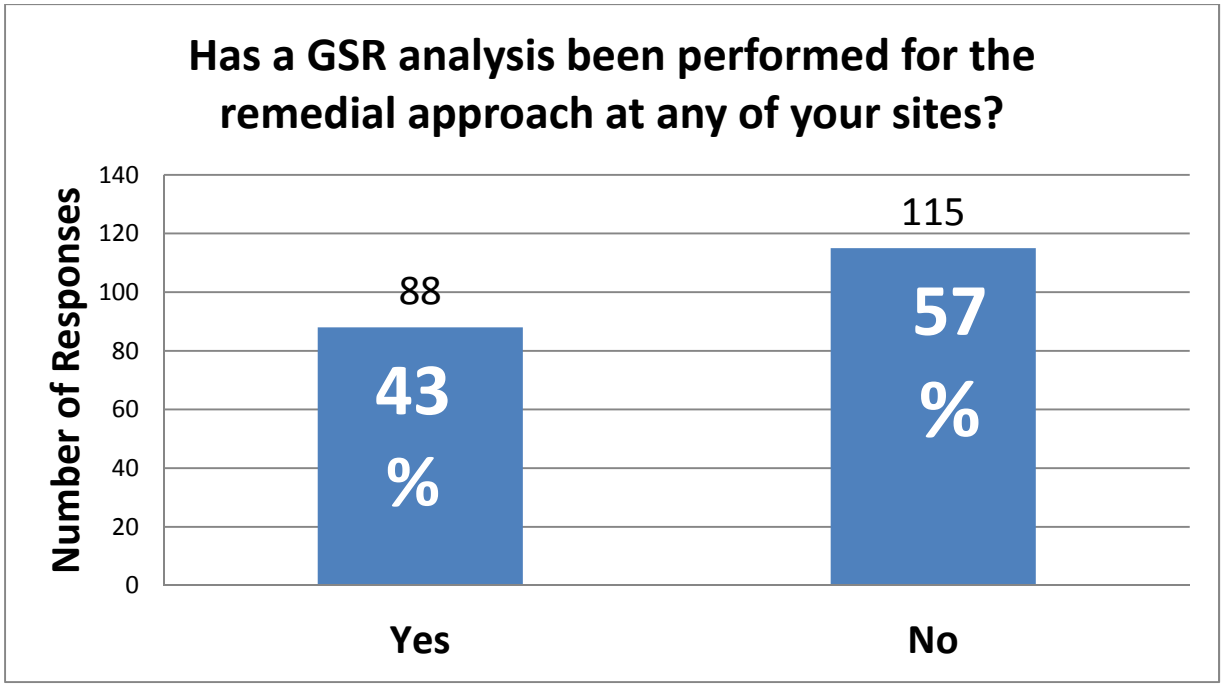
Table 6. GSR Metrics Summary for Site 11 Solvent Release Area, Former Naval Air Station South Weymouth

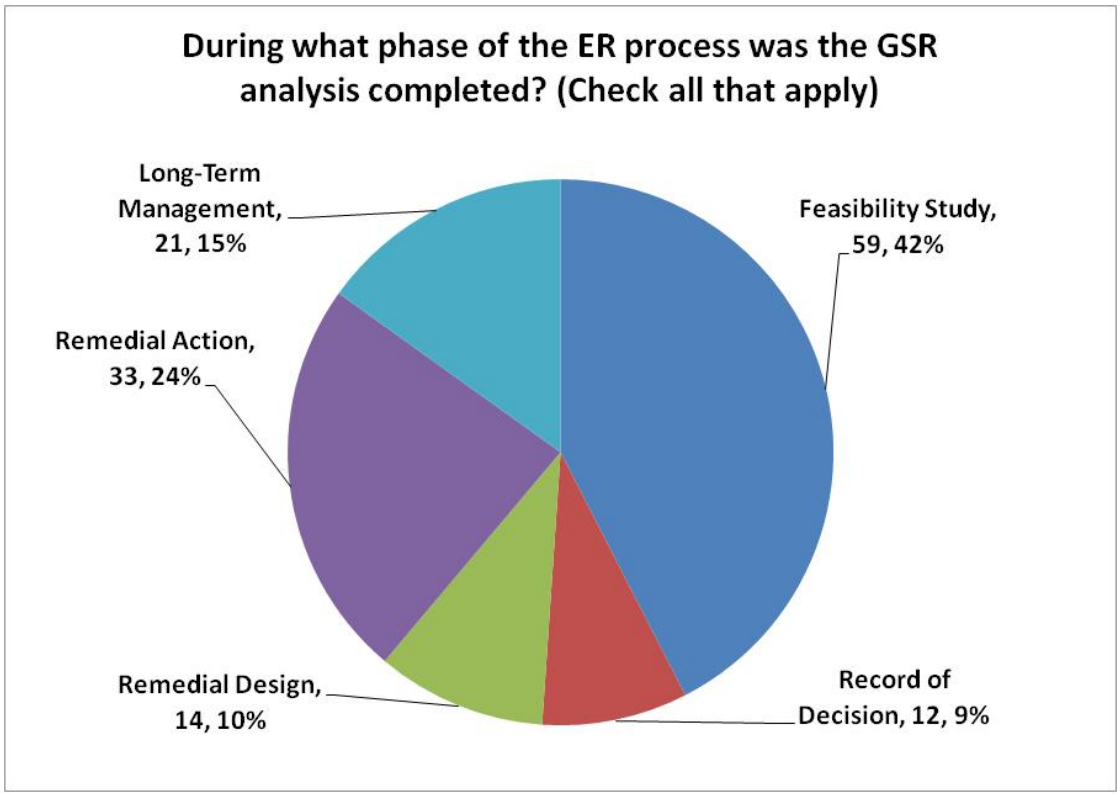
Alternative	Activities	GHG Emissions	Total Energy Used	Water Impacts	NO_X Emissions	SO_X Emissions	PM_{10} Emissions	Accident Risk Fatality	Accident Risk Injury
		Metric Ton CO_2e	MMBTU	gallons	Metric Ton	Metric Ton	Metric Ton		
G-2	Materials Production	0.76	43.60	613.47	8.16E-07	9.46E-04	9.14E-05	NA	NA
	Transportation-Personnel	4.94	62.08	NA	1.83E-03	6.43E-05	3.70E-04	1.01E-04	8.13E-03
	Transportation-Equipment	0.23	3.03	NA	7.28E-05	1.29E-06	6.48E-06	1.17E-06	9.42E-05
	Equipment Use and Misc	103.47	1,545.96	0.00	3.60E-01	2.38E-01	9.78E-03	4.76E-06	1.20E-03
	Residual Handling	0.15	1.92	NA	4.63E-05	8.19E-07	4.12E-06	7.80E-07	6.28E-05
	Total	109.54	1,656.59	613.47	3.61E-01	2.39E-01	1.03E-02	1.08E-04	9.48E-03
G-3	Materials Production	89.13	4,876.85	64,313.90	2.95E-05	2.22E-01	1.80E-02	NA	NA
	Transportation-Personnel	8.08	101.63	NA	2.99E-03	1.05E-04	6.06E-04	1.65E-04	1.33E-02
	Transportation-Equipment	6.05	78.92	NA	1.90E-03	3.36E-05	1.69E-04	1.50E-05	1.21E-03
	Equipment Use and Misc	110.43	1,666.76	84,969.66	3.97E-01	2.50E-01	1.24E-02	1.10E-05	2.76E-03
	Residual Handling	0.78	10.20	NA	2.46E-04	4.35E-06	2.18E-05	3.12E-06	2.51E-04
	Total	214.46	6,734.35	149,283.57	4.02E-01	4.72E-01	3.12E-02	1.94E-04	1.75E-02
G-4	Materials Production	147.01	8,506.25	115,155.86	5.32E-05	3.75E-01	2.83E-02	NA	NA
	Transportation-Personnel	9.89	124.39	NA	3.66E-03	1.29E-04	7.42E-04	2.02E-04	1.63E-02
	Transportation-Equipment	8.26	107.79	NA	2.60E-03	4.59E-05	2.31E-04	2.04E-05	1.65E-03
	Equipment Use and Misc	116.68	1,773.63	152,449.00	4.29E-01	2.63E-01	1.46E-02	1.58E-05	3.98E-03
	Residual Handling	4.10	53.51	NA	1.29E-03	2.28E-05	1.15E-04	1.09E-05	8.79E-04
	Total	285.94	10,565.57	267,604.86	4.36E-01	6.38E-01	4.41E-02	2.50E-04	2.28E-02
G-5	Materials Production	97.50	5,233.04	69,037.80	3.05E-05	2.33E-01	1.95E-02	NA	NA
	Transportation-Personnel	11.80	148.36	NA	4.36E-03	1.54E-04	8.85E-04	2.41E-04	1.94E-02
	Transportation-Equipment	6.82	89.06	NA	2.14E-03	3.79E-05	1.91E-04	1.71E-05	1.38E-03
	Equipment Use and Misc	120.25	1,806.62	89,145.99	4.44E-01	2.69E-01	1.52E-02	2.10E-05	5.29E-03
	Residual Handling	4.03	55.01	NA	1.30E-03	5.03E-05	1.06E-04	1.09E-05	8.79E-04
	Total	240.40	7,332.09	158,183.79	4.52E-01	5.02E-01	3.59E-02	2.90E-04	2.70E-02
G-5A	Materials Production	154.65	8,823.70	119,717.13	5.41E-05	3.85E-01	2.97E-02	NA	NA
	Transportation-Personnel	12.48	156.99	NA	4.62E-03	1.63E-04	9.37E-04	2.55E-04	2.06E-02
	Transportation-Equipment	9.03	117.86	NA	2.84E-03	5.02E-05	2.52E-04	2.26E-05	1.82E-03
	Equipment Use and Misc	130.86	1,996.28	156,979.42	4.89E-01	2.92E-01	1.78E-02	2.53E-05	6.37E-03
	Residual Handling	4.13	53.96	NA	1.30E-03	2.30E-05	1.16E-04	1.09E-05	8.80E-04
	Total	311.15	11,148.79	276,696.56	4.98E-01	6.77E-01	4.89E-02	3.14E-04	2.96E-02

APPENDIX B

T2 SURVEY 2012 GSR RESPONSES

T2 Survey 2012 GSR Responses





DC RITS:

- Performed SiteWise w/ Tetra Tech add-in for several FS reports and future LTM to support optimization for remedial design.
- Past Sites: only to 'document' ways the remedy had GSR benefits. Current projects: no directive in task order scope or in RPM directive to do so.
- Plan to do in upcoming work (SiteWise) for FS considered in selection of in situ bioremediation action, but not formally analyized by us (RPM may have)
- Not able to find opportunity that provides cost saving outcome.

Jacksonville RITS:

- As part of an FS (reviewed in the FS)
- GSR is considered when evaluating remedies
- Not yet, but planning on one or two
- GSR considered in evaluation of remedial alternatives - subjective scoring
- NAS Meridian, 3B. GSR focused on recycling on-site materials (landfill), re-establishing low maintenance surface.
- Army project
- Phytoremediation
- AS/SVE; GSR too much off gas and carbon

Norfolk RITS:

- Recycle, beneficial reuse of waste as daily cover.
- Monitored natural attenuation for arsenic in groundwater.
- Was evauated in RAA and FS, implementation pending.
- NWIRP Calverton.
- Each FS (willow grove site 3, Davisville site 16)
- P&T optimization: Warminster site 1
- Was considered in remedial action and cost avoidance, not formulated.
- Use of SiteWise RAA/FS.
- At one site EPA paid for an evaluation and determined a potential wind turbine location at my other sites EPA doesn't agree we've done a GSR analysis.
- For an upcoming FS, GSR will be included.
- Just looking at this for the first time.
- GSR was performed to compare in situ remedies vs. excavation approaches. GSR was incorporated into remedy performance during execution of the project.

San Diego RITS:

- It is standard practice FS short-term effectiveness considerations.
- We considered phytoremediation as part of a remedy.
- GSR for LNAPL removal options at fuel farm site.
- They were considered in the remedial design of an air sparging/soil vapor extraction system installed at a chlorinated VOC site at Concord.
- After GSR, we determined that treatment plant power consumption could be partially offset by re-installation of solar panels, so we installed 16 panels on re-treatment bldg roof.
- Solar powered belt used to extract free product.

- Conducted preliminary GSR analysis prior to excavation of metals-impacted soil and offsite disposal, analysis very late in process (prior to RD implementation) that and due to ROD requiring excavation did not allow for significant modification.
- Completed for EE/CA, only "dig and haul" soil site, and with CA regulations on air quality, the SiteWise didn't really add anything to project, hopefully better for more involved remediation.
- Fuel farm LNAPL recovery.

Silverdale RITS:

- Remedial alternatives analysis (RAA); feasibility study alternatives.
- Not since I took over site in 2009, it is under consideration for remedy repair alternative efforts.
- Feasibility study only - Jackson Park Housing, Benzene Release Area.
- Range project with treated soil re-use and lead separation and recycling.
- Former range work - recycle lead billets from soil; avoided trucking as part of design indicating environmental issues as part of rationale (emissions & truck traffic)
- Tech memo for Andrew Lake Seawall, used GSR as an evaluation tool for why dredging for 6 years may or may not make sense, ADEC and EPA did not care, did not see this as a valid evaluation tool compared to munitions risk.
- Evaluation of alternatives in a FS.

Hawaii RITS:

- Analysis was performed as part of FS, proposed alternatives were bioventing, air sparging, ORC injection, LUCs and MNA and lead soil excavation.
- For an excavation removal action with landfill disposal.
- We are incorporating GSR evaluations using SiteWise and other tools into all of our feasibility studies and engineering evaluations/cost analysis.

Online Survey:

- Reduced footprint of landfill cap, recycled scrap metal, solar powered monitoring in remote areas, waste vegetable oil for diesel fuel, use of SiteWise tool in all Feasibility Studies
- More concentrated formula of EVO, closer location for T&D, reusing soil from mitigation wetland to place as cover fill in IR Site.
- Used the Sitewise tool to calculate the green footprint for a soil removal action.
- Currently for Charleston Beach Remedy Repair alternatives.
- A GSR analysis was performed for the FS for Tear Gas Burial Site, Naval Magazine, Guam in 2011. The results of this analysis were integrated into the "Short-Term Effectiveness Evaluation". The GSR analysis inlcuded, Energy Consumption, Green House Gas (GHG) Emissions: The GHG emissions estimated were carbon dioxide, methane, and nitrous oxides (N2O), Pollutant Emissions: The pollutants estimated included carbon monoxide (CO), oxides of sulfur (SOx), oxides of nitrogen (NOx), and particulate matter (PM), Water Consumption, and Worker Safety. The SiteWise Tool (SWT), developed by the U.S. Navy, U.S. Army Corps of Engineers, and its partners, was used to quantify the above metrics for this evaluation. SWT relies on several resources, including published emission factors by the EPA and Argonne National Laboratory (ANL) as well as life cycle inventory from the National Renewable Energy Laboratory.
- Always consider short-term effectiveness and implementability plus the state required CEQA checklist that look at the footprint created during remediation activities (i.e. noise, expenditure on other resources to operate, etc) and afterward.

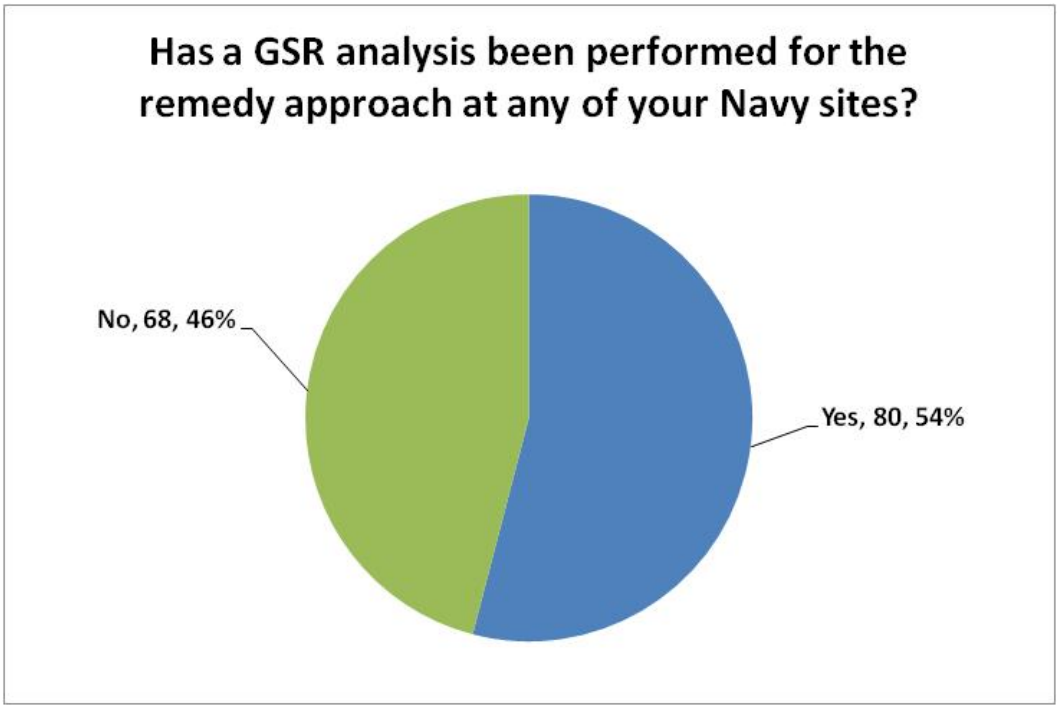
- We haven't performed GSR analyses very much. However, for a remedial action project that pertained to removal of three 20,000 gallon USTs, I demonstrated a three to one benefit to remedial actions vs. potential impacts that may be incurred by the actions themselves.
- Intalled CAP at former landfill for use as a golf course
- At an approx. 41 acre trench and fill landfill on Vieques, the Navy and EPA Region 2, in consultation with Puerto Rico Environmental Quality Board selected a remedy that involved only the covering of exposed landfill debris (asssumed to be <2 acres) with 2 ft. of soil cover versus other more site intrusive remedies, such as site clearance of vegetaion and 2 ft. soil cap over entire 41 acres. This remedy satisfied all human health and ecological concerns and was the most compatible with the future use of the property, which was to maintain it as a wildlife refuge.
- Several remedial systems at NAS Whiting Field are currently being evaluated based based upon GSR pratices.
- Performed GSR evaluations for several FS documents as well as a means of optimizing existing remedial systems
- Goats are being used for brush control. Barges are used to bring in material instead of trucks.
- During the preparation of the FS, Sitewise was used.
- My projects are not at that phase yet.
- Reducing the landfill footprint by 1/3 by consolidating shallow waste into the landfill. Using adjacent soil for backfill/soil cover material at a landfill reducing truck trips and emissions.
- Alternatives evaluated via Sitewise for a landfill
- Review of available power sources at Site 3 NAS Cecil Field indicated solar option most appropriate.

APPENDIX C

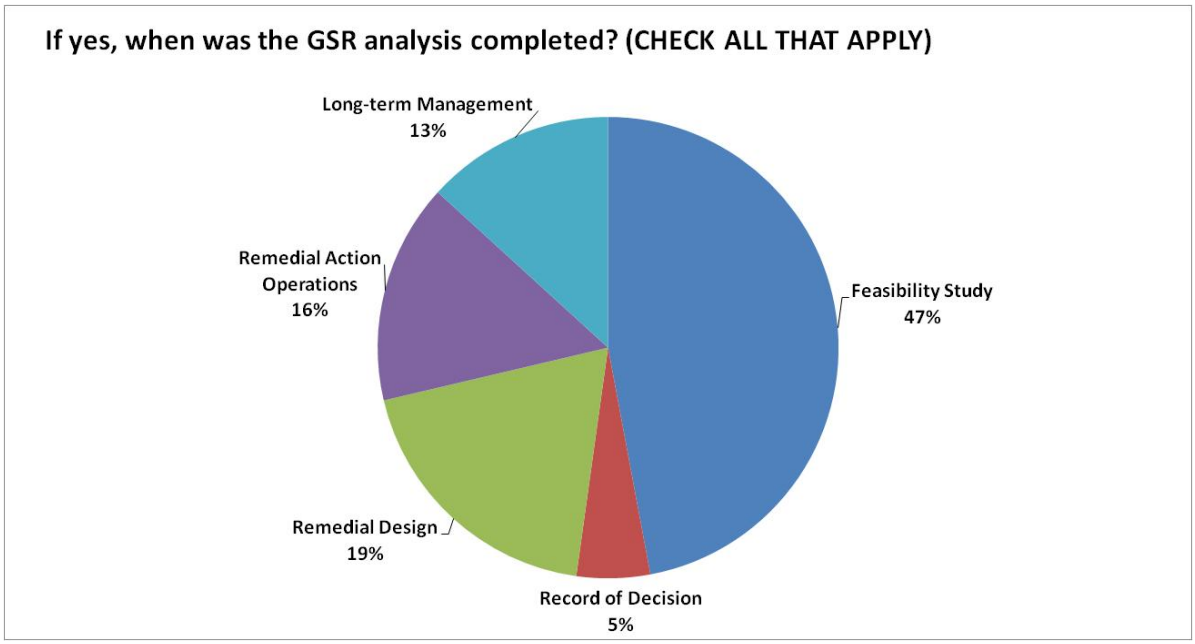
T2 SURVEY 2013 GSR RESPONSES

T2 Survey 2013 GSR Responses

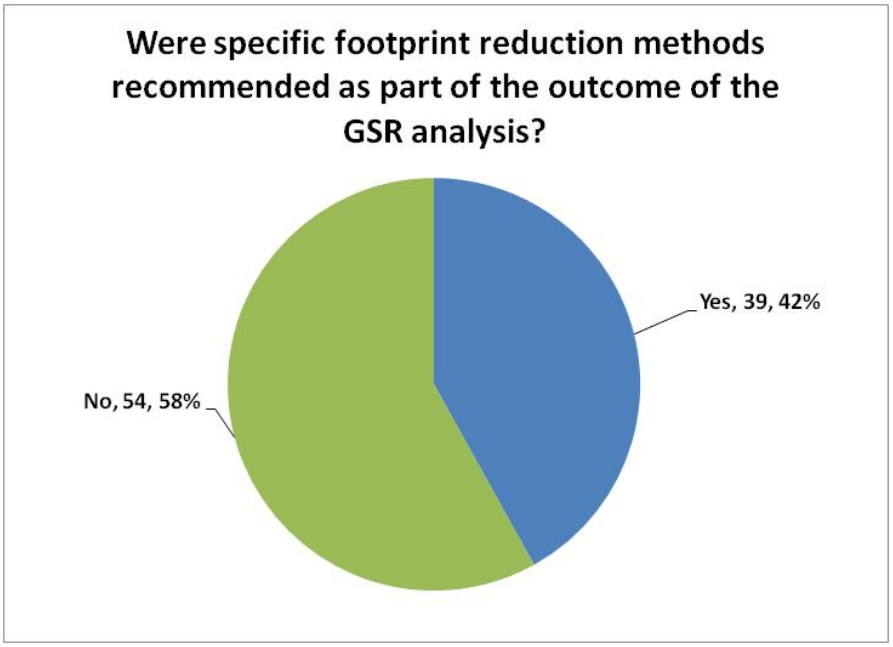
Has a GSR analysis been performed for the remedy approach at any of your Navy sites?

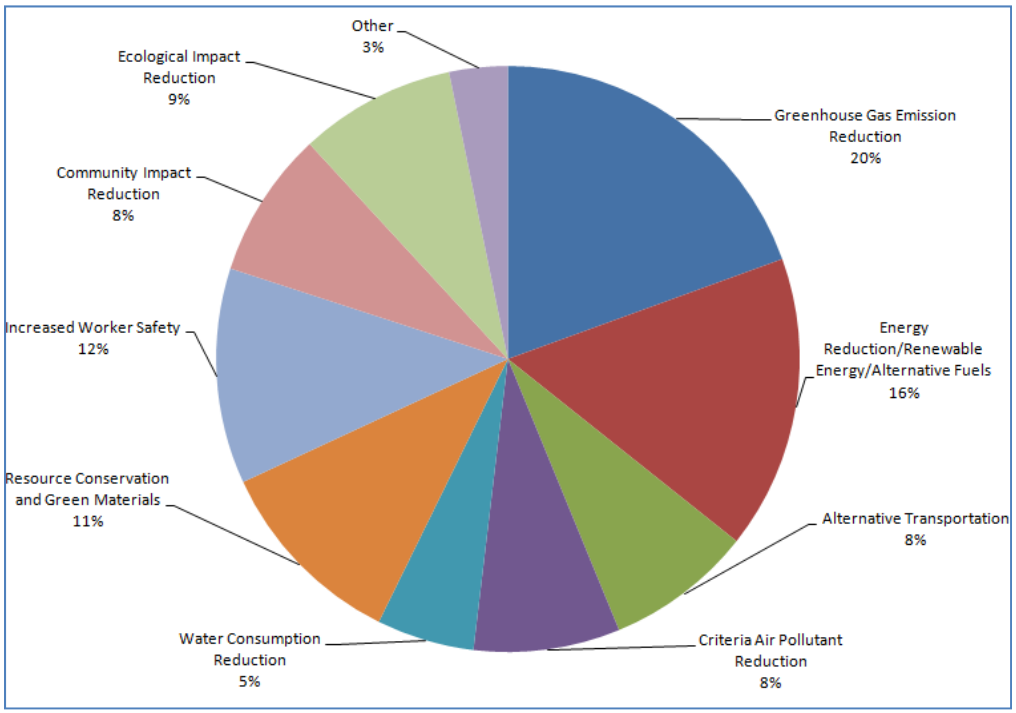


If yes, when was the GSR analysis completed?

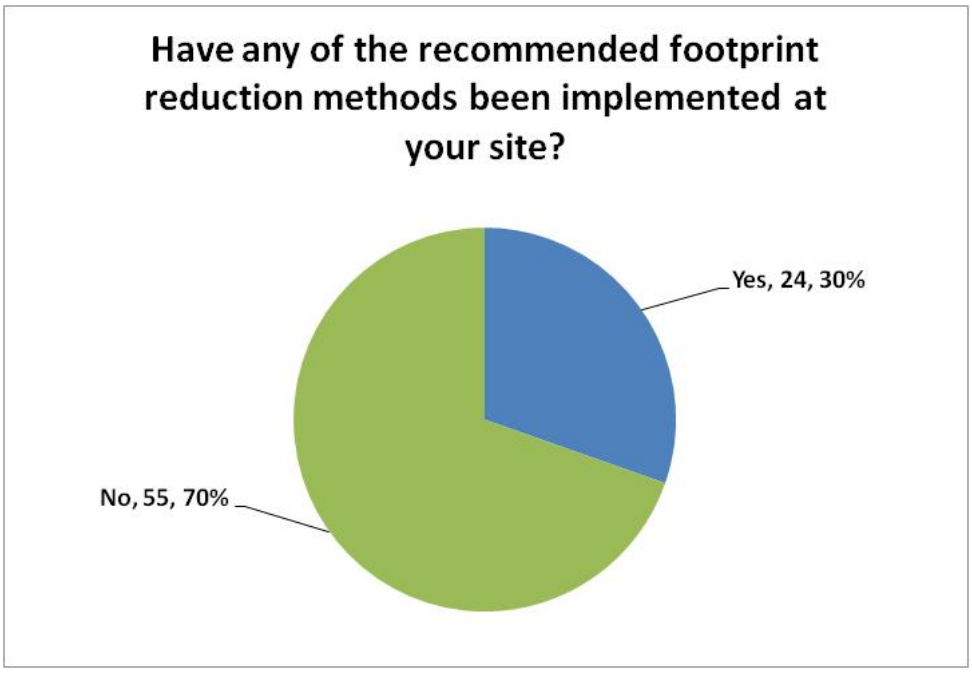


Were specific footprint reduction methods recommended as part of the outcome of the GSR analysis? If yes, CHECK ALL THAT APPLY





Have any of the recommended footprint reduction methods been implemented at your site?



Footprint Reduction Methods Implemented

- **Passive Technologies/Treatment Train**
  - Decided on a passive (bioventing) system instead of aggressive AS/SVE
  - Biosparging instead of air sparging/SVE system eliminating extra power needs
  - Treatment train based on GSR
- **Alternative Energy Source**
  - Solar technology to run SVE
- **Optimized Systems**
  - Using a microblower to biovent a small fuel spill site. Originally planned to use a small low cost windmill to sparge, but the base facilities manager did not like the windmill (but could not articulate why).
  - Variable phase motors
  - Use low emission equipment with exhaust filter
  - GHG emission reduction for SVE
  - Landfill size reduction
- **Reuse/Recycling**
  - Use bulk shipping/containers for chemicals - return to vendor when done.
  - Recycle concrete/metal
  - Reuse excavated soil for landfill cover (2)
- **Transportation**
  - Minimizing transportation; barge vs. truck; Less equipment in high traffic areas
- **Optimized Sampling**
  - Reduction in monitoring activities and sampling events.
  - Implemented low impact sampling and optimized sampling plan.
- **Minimizing Ecological Impacts**
  - Attenuation/LUCs to promote resource conservation and reduce ecological impact
  - One of the remedies was going to impair an old growth forest, so placed land use controls and used MNA as preferred alternative

Reasons Footprint Reduction Methods Not Implemented

- Still in Feasibility Study, planning, or design stage (6)
- Funding issues
- Regulators don't really care about a footprint reduction, they concentrate on the site.
- Footprint reduction measures did not factor heavily into the remedy selection process
- Remedies selected have little availability for GSR to be incorporated (i.e., ISCO, excavation - offsite disposal, ZVI via soil mixing).
- Used site-wide average to reduce footprint so GSR supported, but did not reduce footprint
- In Hawaii, there are only a small number of sites
- We planned to ship non-hazardous soil to a local landfill