
Draft

Feasibility Study Gowanus Canal

Prepared for
U.S. Environmental Protection Agency

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Prepared by
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Executive Summary

This draft feasibility study (FS) report was prepared for the U.S. Environmental Protection Agency (USEPA) Region 2 by CH2M HILL to present the results of the feasibility analysis of remedial alternatives for the Gowanus Canal Superfund Site, in Brooklyn, Kings County, New York. This draft FS was prepared under Task Order 072 of the USEPA AES10 contract.

On March 2, 2010, USEPA placed the Gowanus Canal (USEPA ID#: NYN000206222) on its National Priorities List of hazardous waste sites requiring further evaluation. Accordingly, USEPA Region 2 performed a remedial investigation and feasibility study (RI/FS) of the canal according to the requirements of the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA, or “Superfund”), as amended. The RI was completed in January 2011 (USEPA, 2011) and the FS was initiated. The results of this FS will be used to develop a Proposed Plan for remedial action and a Record of Decision for the canal.

Feasibility Study Objectives and Scope of Work

This FS develops and evaluates remedial alternatives for Gowanus Canal sediments that will reduce or eliminate unacceptable risks to human health and the environment from exposure to contaminated sediment and surface water in the canal. The FS was prepared following USEPA’s *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (USEPA, 1988) and *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* (USEPA, 2005).

Addressing contaminant contributions to the canal from upland properties, combined sewer overflows (CSOs), and other pipe outfalls is a prerequisite to a sustainable remedy for canal sediments, and as such, USEPA is seeking to reduce or eliminate these sources. The New York State Department of Environmental Conservation (NYSDEC) is addressing investigations and response actions related to the upland properties adjacent to the canal. The New York City Department of Environmental Protection (NYCDEP), through an Administrative Order on Consent¹ with NYSDEC, has begun to address CSOs. It is anticipated that additional CSO measures will be required to prevent recontamination of the canal. Discharges to the canal from unpermitted outfall structures must also be addressed. Source control measures are in the process of being developed, and these measures are included by reference as a component of all of the alternatives for contaminated sediments presented in this FS.

Remedial Action Objectives

The remedial action objectives for the Gowanus Canal are as follows:

¹ DEC Case #CO2-20000107-8 dated January 14, 2005, and updated April 14, 2008.

- Ecological
 - Reduce to acceptable levels toxicity to benthic organisms in the canal from direct contact with polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and metals in sediment
 - Reduce to acceptable levels the risk to herbivorous birds from dietary exposure to PAHs
- Human Health
 - Reduce to acceptable levels the risk to human health from the incidental ingestion of and dermal contact with PAHs in sediment and surface water during recreational use of the canal or from exposure to canal overflow
 - Reduce the risk to human health from ingestion of PCB-contaminated fish and shellfish collected from the canal
- NAPL Mitigation
 - Prevent the migration of non-aqueous-phase liquid (NAPL) into the canal after the remedial action is completed
 - Prevent NAPL from serving as a source of contaminants to groundwater discharging to the canal

NAPL mitigation will require a combination of upland source control measures and the use of sediment remediation technologies to prevent recontamination of the canal after the remedy is implemented.

Development and Application of Preliminary Remediation Goals

Because there are no promulgated standards or criteria that apply to the cleanup of contaminated sediments in New York, preliminary remediation goals (PRGs) for sediments in the Gowanus Canal were developed based on the results of the ecological risk assessment (ERA) and human health risk assessment (HHRA) that were performed during the RI.

The comparison of PAH concentrations in sediment to PRGs shows that the entire soft-sediment column throughout the project area should be addressed in the FS. In addition, PAH concentrations in the majority of native sediment underlying the soft sediment north of the Gowanus Expressway also exceed PRGs.

Additionally, NAPL is present in native sediment north of the Gowanus Expressway to at least the maximum depth investigated in the RI (i.e., generally 6 feet below the interface between soft and native sediments). NAPL saturation was not observed in the native sediment south of the Gowanus Expressway.

Identification and Screening of Remedial Technologies

Technology screening was conducted following the technology-screening guidance described in the USEPA *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (USEPA, 1988). In addition, the technologies identified and screened are

consistent with the USEPA *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* (USEPA, 2005). Potential remedial technologies and process options were screened according to the following three established criteria:

- Technical effectiveness
- Implementability
- Cost

Remedial technologies and process options that would not effectively address sediment contamination within the Gowanus Canal were eliminated. The technologies and process options that were retained from the initial screening process were carried forward for the development of remedial alternatives.

Development and Screening of Remedial Alternatives

The descriptions of the remedial alternatives in this FS are conceptual and have been developed to a level of detail sufficient for the purposes of evaluating the alternatives against the National Contingency Plan (NCP) criteria, developing cost estimates of plus 50 to minus 30 percent, and comparing the alternatives. The alternative that will eventually be selected for the site will be further developed during the remedial design process, and the specific methodologies and construction sequences utilized may change based on additional information that is gathered as part of predesign investigations.

The following alternatives were developed:

- Alternative 1: No Action
- Alternative 2
 - Dredge soft sediment to a specified elevation
 - Cap with isolation layer and armor layer
- Alternative 3
 - Dredge soft sediment to a specified elevation
 - Cap with treatment layer, isolation layer, and armor layer
- Alternative 4
 - Dredge entire soft sediment column
 - Cap with isolation layer and armor layer
- Alternative 5
 - Dredge entire soft sediment column
 - Cap with treatment layer, isolation layer, and armor layer
- Alternative 6
 - Dredge entire soft sediment column
 - Solidify top 3-5 feet of native sediment in targeted areas
 - Cap with isolation layer and armor layer
- Alternative 7
 - Dredge entire soft sediment column
 - Solidify top 3-5 feet of native sediment in targeted areas
 - Cap with treatment layer, isolation layer, and armor layer

The following treatment and disposal options for dredged sediments were also identified:

- Option A: Offsite thermal desorption and beneficial use
- Option B: Offsite disposal (landfill)
- Option C: Offsite cogeneration and beneficial use
- Option D: Offsite stabilization and offsite beneficial use
- Option E: Onsite stabilization and onsite beneficial use
- Option F: Offsite stabilization and placement in onsite constructed confined disposal facility (CDF)
- Option G: Onsite stabilization and placement in onsite constructed CDF

Alternatives 2 through 7 include bulkhead stabilization throughout the entire canal and the removal of some native sediment in remediation target area (RTA) 2 to accommodate a cap and maintain the depths required for navigation. An alternative including partial removal of soft sediment in RTA 2 was not considered due to the high degree of NAPL contamination throughout the soft sediment in that area of the canal. It is anticipated that the remedial action in the canal will be performed using a phased approach, with the upper and middle reaches of the canal (RTA 1 and RTA 2) remediated first.

In order for any of the proposed remedial alternatives to be effective, upland sources of contamination – including discharges from CSOs, from the former MGP sites and other contaminated sites along the canal, and from the unpermitted pipes along the canal – must be controlled. These upland source controls need to be coordinated and implemented in concert with the selected sediment remedy to prevent recontamination of the canal following remedy implementation. All of the alternatives in this FS rely upon the successful implementation of these controls; therefore, they are included as the first component of all alternatives. The source control measures that will be developed are included by reference in this FS.

Emerging sediment remediation technologies may be evaluated during the remedial design and may be incorporated into the selected remedy, if determined to be effective and implementable during bench testing or pilot studies. In situ stabilization (ISS) is one such technology that may be further examined. If additional analyses and testing indicate that it would be implementable and effective within the canal, this technology may be integrated into the selected alternative. ISS may be considered for areas where NAPL-impacted native sediment is exposed after dredging. If determined to be implementable and effective, this technology could be applied to further reduce the potential for NAPL migration from the native sediment to the canal.

Potential alternatives were screened first with respect to effectiveness, implementability, and cost to reduce the number of alternatives to be analyzed in detail. On the basis of that screening evaluation, Alternatives 1, 5, and 7 were retained for further development and detailed evaluation.

Evaluation of Remedial Alternatives

The NCP defines nine criteria, classified as threshold, balancing, or modifying, to be used for the detailed analysis of remedial alternatives. The remedial alternatives were evaluated against the first seven of nine criteria:

- Threshold criteria
 - Overall protection of human health and the environment
 - Compliance with applicable or relevant and appropriate requirements
- Balancing criteria
 - Long-term effectiveness and permanence
 - Reduction of toxicity, mobility, or volume through treatment
 - Short-term effectiveness
 - Implementability
 - Cost

The two modifying criteria – public and state acceptance – are used later in the process to evaluate the proposed remedy. In addition to the NCP criteria, the alternatives were qualitatively evaluated with respect to sustainability and green remediation metrics.

The detailed analysis was performed using a two-step process. During the first step, each alternative was evaluated individually against the NCP criteria and the sustainability/green remediation metrics. In the second step, a comparative analysis was performed using the same criteria to identify key differences between alternatives. Tables ES-1a through ES-1c and ES-2a through ES-2c present the results of the individual and comparative evaluation of the alternatives for each RTA, respectively.

Remedial Design Considerations

The evaluations performed in this FS have identified a number of elements that may require further consideration during the remedial design. The surveys, evaluations, and analyses listed below are not prescriptive or inclusive but simply summarize possible data collection activities identified during the development and analysis of alternatives.

- Development of a groundwater model for the entire project area
- Additional data collection and analysis to determine NAPL seepage rates
- Additional evaluation of ISS or other developing technologies that could increase the overall protection and permanence of the remedy
- Additional evaluation and analysis of the sustainability impacts of the selected remedy
- Other data collection activities and surveys such as a bulkhead stability evaluation, bathymetric and sediment-probing surveys to refine volumes and establish baseline conditions prior to remedial action, and sediment chemistry surveys to establish baseline, or preremedy, conditions
- Additional bench-scale testing to support disposal options
- Hydrodynamic modeling to support cap design

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TABLE ES-1a

Detailed Evaluation of Alternatives – RTA 1
 Gowanus Canal Feasibility Study
 Brooklyn, New York

Criteria	Alternative 1: No Action	Alternative 5: Dredge Entire Column of Soft Sediment Cap with Treatment Layer, Sand-and-Gravel Layer, Armor Layer	Alternative 7: Dredge Entire Column of Soft Sediment Solidify Top 3–5 Feet of Native Sediment in Targeted Areas Cap with Treatment Layer, Sand-and-Gravel Layer, Armor Layer
Threshold Criteria			
Overall protection of human health and the environment	Alternative will not provide protection of human health and the environment. <ul style="list-style-type: none"> • RAOs would not be achieved • Human health and ecological risks associated with contaminated sediment would not be reduced or eliminated. • NAPL migration to the water column would continue. • Contaminant concentrations in other media (e.g. surface water) would not be reduced. 	Alternative will provide protection of human health and the environment. <ul style="list-style-type: none"> • RAOs would be achieved upon completion of the remedy, which is estimated to be approximately 5 years after the start of construction. • Removal of soft sediment and capping of native sediment would reduce and control long-term risks associated with contaminated sediment. Placement of a cap would: <ul style="list-style-type: none"> ○ Control risks associated with remaining sediment by preventing exposure. ○ Reduce and control toxicity to benthic organisms and eliminate risks to herbivorous birds. ○ Control risks to human health via direct contact and incidental ingestion. ○ Prevent NAPL migration from sediment to the water column. • Surface water quality would be improved by preventing contact between surface water and sediment; sheens would be controlled or eliminated. 	Alternative would provide protection of human health and the environment. Application of ISS in targeted areas is expected to provide additional protectiveness against NAPL migration from sediment.
Compliance with ARARs	<ul style="list-style-type: none"> • ARARs are not applicable because no remedial action is taken. 	Alternative can be designed to comply with substantive requirements of the ARARs.	Same as Alternative 5.
Balancing Criteria			
Long-term effectiveness and permanence	Low - Alternative would not result in any significant change in the risks associated with contaminated sediment.	Alternative would provide a high level of long-term effectiveness and permanence: <ul style="list-style-type: none"> • Alternative would meet RAOs. • Alternative would result in significant, permanent risk reduction due to soft sediment removal. • The sediment cap would provide long-term control of the risks associated with the native sediment remaining in the canal, provided that appropriate long-term monitoring and maintenance plans are implemented. • Long-term effectiveness of disposal options are: <ul style="list-style-type: none"> ○ High for Options A, B, and C because material is transferred offsite and treated or contained in a managed landfill. ○ Low to moderate for Options D and E. <ul style="list-style-type: none"> ▪ The long-term effectiveness will depend on the actual beneficial use and the conditions to which the stabilized sediment will be exposed. A greater degree of effectiveness would be expected from a use where the material is relatively contained and not subjected to significant water fluctuations or freeze/thaw cycles. ▪ Stabilization would be performed to a degree such that the sediment associated contaminants would be bound within the matrix and the stabilized sediment would remain onsite under Option E. ▪ The stabilized sediment would need to meet the end-use performance criteria. ▪ Permanent institutional controls and long-term monitoring would be needed under Option E. 	Alternative would provide a high level of long-term effectiveness and permanence. <ul style="list-style-type: none"> • Same as Alternative 5, except that targeted ISS would provide additional long-term control of the NAPL migration in the canal.
Magnitude and type of residual risk		This evaluation is focused on the magnitude and management of residual risks associated with sediment remaining onsite (i.e., sediment that is stabilized and beneficially used onsite and contaminated sediment remaining in the canal following remedy implementation). Sediment treated and disposed at offsite facilities are not included in this discussion because it would be removed from the site. <ul style="list-style-type: none"> • Sediment removal and capping would: <ul style="list-style-type: none"> ○ Alleviate the risks associated with the sediments removed from the canal. ○ Reduce the risks associated with contaminated native sediments that remain in the canal by capping. ○ Provide long-term control of risks associated with sediment remaining in the canal. Adsorptive caps to control NAPL migration can be designed for a set life expectancy where NAPL migration rates are known (see Appendix A for additional discussion). Additional data collection and evaluation to determine site-specific NAPL seepage rates will be required during remedial design to determine the appropriate cap design (i.e., granular oleophilic clay layer thickness). • Residual risks associated with disposal Option E (onsite stabilization and onsite beneficial use) would be as follows: <ul style="list-style-type: none"> ○ Treatment residuals would consist of stabilized sediment, which would significantly reduce the mobility of sediment contaminants and reduce the associated risks. ○ Onsite beneficial use of the stabilized material will require identifying a beneficial use and will also require the stabilized material to meet leachability specifications and strength specifications appropriate to the identified use. ○ The ability of the stabilized sediment to meet performance criteria will depend upon the designated end use of the material, and further testing is required for these disposal options. 	Same as Alternative 5, with the addition that the implementation of ISS would be expected to further reduce risk of NAPL migration, if proven to be effective and implementable during pilot and treatability testing.

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		<ul style="list-style-type: none"> o The FS assumes that the end use would be such that direct human and ecological contact with the stabilized sediment would be limited. o The level of residual risk would be considered low to moderate for this alternative because treatment does not destroy the contaminants and the treated material would remain onsite. o Remedy can be designed so that the sediments stabilized and beneficially used are those with fewer NAPL impacts. 	
Adequacy and reliability of controls		<ul style="list-style-type: none"> • Dredging <ul style="list-style-type: none"> o Mechanical dredging is an established technology and would meet the performance specifications for the removal component of the alternative. o Bathymetric surveys would be conducted to confirm target removal depths and samples would be collected on a defined grid to confirm sediment cap layer thicknesses. • Capping <ul style="list-style-type: none"> o Capping is an established technology and can be designed to meet the performance specifications of the alternative, provided that effective source controls have been implemented and the cap is constructed and maintained in accordance with the design specifications established for long-term isolation of the contaminated sediments. As noted above, additional data collection and evaluation are required to finalize the cap design. o Long-term monitoring and periodic maintenance would be required to assure cap integrity. o The O&M plan developed during the remedial design would determine the monitoring and maintenance frequencies required to assure and maintain cap integrity based on site-specific factors. o Physical (e.g., bathymetric) surveys and the collection of samples on a defined grid would be needed to assess cap layer thickness, cap performance and integrity, contaminant movement, and/or recontamination concerns. Samples for chemical analysis should also be collected at regular predetermined intervals. o The long-term monitoring plan should also specify monitoring requirements after severe storm events to assess cap integrity. o Cap repairs would be performed as needed. o Component failures (i.e., sediment cap failure) could potentially result in sheens on the water surface and limited exposure to ecological or human receptors; however, catastrophic failure of the cap is unlikely if appropriate long-term O&M plans are implemented. • Disposal <ul style="list-style-type: none"> o Disposal Options A (thermal treatment), and C (co-generation) would be expected to meet required performance specifications following treatability and pilot testing. o Option B (offsite landfill) is an established means of disposal. o Disposal Options D (offsite stabilization and offsite beneficial use) and E (onsite stabilization and beneficial use) require identifying a beneficial use and also require the stabilized material to meet leachability specifications, as well as strength specifications appropriate to the identified use. The ability of the stabilized sediment to meet performance criteria will depend upon the designated end use of the material and further testing is required for these disposal options. The FS assumes that the end use would be such that direct contact human and ecological contact with the stabilized sediment would be limited. o Additional O&M beyond that associated with the sediment cap would be required for Options A, B, C, or D. Long-term monitoring would be required for Option E (onsite stabilization and beneficial use). o Permanent institutional controls would also be required for Option E. The institutional controls would specify appropriate measures for digging within the fill material, and long-term monitoring would be applied to review their sustained application. The institutional controls may need to be applied to one or more properties, depending on where the material is used. Depending on the number of properties and the location where the fill is placed, significant effort and coordination may be needed to ensure successful implementation and enforcement of these controls. 	Same as Alternative 5, with the addition that if additional evaluations and pilot studies indicate that in situ solidification (ISS) is implementable and effective within the canal, targeted areas of NAPL-saturated native sediment would be treated with ISS to further reduce the potential for NAPL migration. The conceptual cap specifications have been designed to be protective without the use of ISS; however, if ISS is determined to be viable for the Gowanus Canal, then its application would be expected to provide additional protection and support the long-term effectiveness of the selected remedy.
Reduction of toxicity, mobility, or volume through treatment	<p>Low</p> <p>Alternative does not include a treatment component and does not meet the statutory preference for treatment as a principal element of a remedy.</p>	<p>The overall reduction of NAPL mobility by the oleophilic cap is expected to be high.</p> <p>The reduction of toxicity, mobility, or volume (TMV) of the dredged sediment by treatment ranges from moderate to high depending on the disposal option.</p> <p>Alternative 5 is considered to have high overall reduction of TMV based on the volume of sediment removed from the canal.</p>	Same as Alternative 5, with the addition that the implementation of ISS would be expected to further reduce NAPL mobility, if ISS is proven to be effective and implementable during pilot and treatability testing.

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Reduction in toxicity, mobility, or volume (TMV)		<ul style="list-style-type: none"> • Dredging does not reduce toxicity, mobility or volume through treatment. • The granular oleophilic clay cap component of the alternative will reduce the mobility of NAPL and is considered a treatment technology. • The reduction of TMV of the dredged sediment is summarized below. Thermal treatment (Option A) and cogeneration (thermal destruction, Option C) meet the statutory preference for treatment as a principal element. The relative reductions of TMV of the disposal/beneficial use options are: <ul style="list-style-type: none"> ○ Option A (thermal treatment): High reduction of TMV. Dredged sediments would be treated using thermal desorption. The TMV associated with the organic contaminants would be significantly reduced. ○ Option B (offsite landfill): Moderate reduction of TMV. Dredged sediments would be stabilized prior to transfer to a landfill. Volume and toxicity would not be affected, but contaminant mobility would be reduced by placing the material in a controlled environment. Overall TMV would be transferred to the offsite disposal facility. ○ Option C (co-generation): High reduction of TMV. Organic contaminants would be destroyed through treatment. The overall ranking of this disposal option is high. ○ Option D (offsite stabilization and offsite beneficial use): Moderate reduction of TMV. Dredged sediments would be stabilized prior to transfer to offsite beneficial use location. Volume and toxicity would not be affected, but contaminant mobility would be reduced. Overall TMV would be transferred to the offsite location. ○ Option E (onsite stabilization and onsite beneficial use): Moderate reduction of TMV. Dredged sediments would be stabilized prior to placement in onsite beneficial use location. Volume and toxicity would not be affected, but contaminant mobility would be reduced. Overall TMV would remain onsite. 	Same as Alternative 5, except that the overall reduction in NAPL mobility is anticipated to be greater with the addition of ISS in targeted areas of the canal.
Irreversibility		<ul style="list-style-type: none"> • Sorption in the oleophilic clay cap is irreversible, but once the cap is saturated, it will not be able to absorb more NAPL. • Solidification and stabilization are considered irreversible if the stabilized material is placed into a controlled environment. • Thermal treatment (Option A), thermal destruction (Option C), and the stabilization component of Option B is irreversible. The degree of irreversibility of stabilization associated with Options D and E will depend upon the selected beneficial use and the conditions to which the stabilized material is exposed. 	Same as Alternative 5, with the addition that ISS is also an irreversible process.
Type and quantity of treatment residuals and associated risks		<p>The type and quantity of residuals and the associated magnitude and management of risks is dependent upon the disposal option, as follows:</p> <ul style="list-style-type: none"> • Option A (thermal treatment): <ul style="list-style-type: none"> ○ Residuals would consist of treated sediment. ○ Treated sediment would be beneficially used (e.g., daily cover at landfills). ○ Level of residual risk associated with this option is low since contaminants would be desorbed and destroyed in an afterburner. • Option B (offsite landfill): <ul style="list-style-type: none"> ○ Would not result in treatment residuals. ○ Stabilized sediment would be disposed in a landfill. ○ Residual risk associated with this option is low because material is disposed in a controlled offsite facility. • Option C (co-generation): <ul style="list-style-type: none"> ○ Residuals would consist of treated sediment. ○ Treated sediment would be beneficially used (e.g., daily cover at landfills). ○ The level of residual risk associated with this option is low since organic contaminants would be destroyed. • Options D (offsite stabilization and offsite beneficial use) and E (onsite stabilization and onsite beneficial use): <ul style="list-style-type: none"> ○ Stabilized sediment would be beneficially used either offsite (Option D) or onsite (Option E). ○ The level of residual risk would be considered low to moderate because treatment stabilizes but does not destroy the contaminants. The contaminant mobility would be significantly reduced, and the treated material would be beneficially used. The residual risk for Option D is lower because the material would be transferred offsite. • Sediment treated by thermal treatment (Option A) and co-generation (Option C) may contain concentrated levels of inorganic constituents, which may limit the beneficial use of the material. 	Same as Alternative 5.
Short-term effectiveness	High; no actions are taken under this alternative.	<p>The short-term effectiveness of this alternative is moderate due to construction duration and the potential risks and environmental impacts described below.</p> <ul style="list-style-type: none"> • Short-term effectiveness of all disposal options is considered moderate to high. 	Same as Alternative 5.

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Risks to community, workers, and the associated controls		<ul style="list-style-type: none"> • Potential risks to the community would include noise and vibrations during bulkhead replacement and increased levels of traffic, dust, noise, and odors during the dredging and handling of contaminated sediment. Engineering controls and best management practices can mitigate most potential risks: <ul style="list-style-type: none"> ○ Access to the active work and support zones would be prohibited. ○ Notification of schedule for bulkhead repair and remedy implementation would be provided to the property owners and tenants. ○ Dust and noise levels would be monitored. ○ Work periods may be restricted to specific timeframes for especially noisy operations (e.g., sheet pile installation). ○ Traffic effects can be managed by performing work in canal from barges and using water transport to move materials to and from the canal. ○ Staging areas would need to be established in areas zoned for industrial use. ○ Odors are expected during dredging and may not be able to be fully controlled. • Potential risks to workers would include physical hazards associated with general construction, potential exposure to and direct contact with dredged sediment and NAPL, noise, odors, dust, and vapors. These would be mitigated through: <ul style="list-style-type: none"> ○ Engineering controls and best management practices. ○ Compliance with appropriate health and safety plans and site management plans. ○ Use of appropriate personal protective equipment. 	Same as Alternative 5. Implementation of ISS would likely be restricted to specific timeframes. Potential exposure risks from ISS would be mitigated as described under Alternative 5.
Environmental Impacts of Remedy and Controls		<ul style="list-style-type: none"> • Short-term environmental effects during implementation may include potential NAPL releases to surface water, turbidity increases within the canal, and releases of some sediment-associated contamination. Example control measures to mitigate these impacts include the following: <ul style="list-style-type: none"> ○ Dredge cells would contain suspended sediments (turbidity and sediment associated contaminants) and NAPL releases that result from the dredging process. Water within the dredge cells would be removed and treated before the sheet piles are removed. ○ The duration of these releases would be very short and would only occur during construction. 	Same as Alternative 5, with the addition that ISS would be performed within the dredge cells to contain potential NAPL and turbidity releases.
Duration of short-term risks		<ul style="list-style-type: none"> • The duration of the short-term risks would be the time required for construction, which is estimated to be approximately 5 years. 	Same as Alternative 5.
Implementability	Not applicable; no actions are taken under this alternative.	The overall implementability this alternative is moderate . The implementability of the disposal options is variable.	Same as Alternative 5 for dredging, capping, and disposal options. Implementability of ISS is likely to be more limited since this technology is not yet commercially proven for application to marine environments for the control of NAPL migration.
Technical feasibility		<ul style="list-style-type: none"> • Alternative is technically implementable and dredging and capping are established, field-proven technologies; however, pilot testing may be required to determine the most suitable cap placement methods based on the site-specific sediment characteristics. • Dredging and capping would be performed from barges using standard construction equipment. • The potential interference from debris within the canal will need to be considered during design. • Bulkhead repair and replacement will require property-specific designs, and construction must be planned and proceed and be coordinated carefully to minimize / prevent effects on the adjacent, upland properties. • The short- and long-term monitoring requirements can be performed using standard practices and technologies. • Implementability and feasibility of additional actions would be limited if penetration of the cap is required. 	Same as Alternative 5 for dredging and capping aspects. Treatability studies and pilot testing will be required during remedial design to determine the stabilization reagents and dosages, delivery mechanism, and overall technical feasibility of ISS.
Administrative feasibility		<ul style="list-style-type: none"> • Alternative will require coordination between regulatory agencies (USEPA, USACE, NYSDEC, and NYCDEP), PRPs, property owners along the canal, and other stakeholders. • Bulkhead repair and replacement will require coordination with property owners and tenants. Due to the number of different properties and type of bulkheads affected, this effort will be considerable. • Implementation of disposal Option E (onsite stabilization and onsite beneficial use) is dependent upon stakeholder acceptability and effective implementation of institutional controls. This disposal option may be challenging to implement due to stakeholder acceptance. • Permanent institutional controls would also be required for disposal Option E. Depending on the number of properties and the location where the fill is placed, significant effort and coordination may be needed to ensure successful implementation and enforcement of these controls. The difficulties associated with implementation of institutional controls are also further discussed in Section 4.6.3. 	Same as Alternative 5.

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Availability of services and materials		<ul style="list-style-type: none"> Equipment and specialists required for the sheet piling installation, dredging, and capping would be commercially available. The volume of capping materials required is large and procuring large quantities of specialty materials, such as the oleophilic clay, will require significant advance coordination and possibly use of multiple vendors. Available thermal treatment and co-generation facilities (Options A and C, respectively) are also limited within the geography, which may restrict the ability to competitively bid these services. Landfill capacity for contaminated river sediments within the geography may be limited. Landfill availability will influence the implementability of disposal Option B (offsite landfill) within the region. Available landfill facilities and associated capacities will need to be identified during the remedy selection process. Facilities outside the region could be used; however, transportation costs would increase. Onsite and offsite beneficial uses of stabilized sediment would need to be identified. In order for Options D and E to be implemented, an end use would need to be determined and treatability testing would need to be performed to evaluate the stabilization agents and dosing required and to assess whether the treated material would meet all the end-use requirements (e.g., leachability and strength characteristics). Treatability testing will be needed to determine if available thermal treatment and co-generation facilities can accept solidified/stabilized sediment and to determine the final waste characterization. 	Same as Alternative 5 for dredging, capping, and disposal components. ISS is an emerging technology, and there are few contractors with a proven performance of ISS implementation in marine environments.
Cost (\$Million)¹	0	Option A: 45 Option B: 47 Option C: 52 Option D: 45 Option E: 38	Option A: 48 Option B: 50 Option C: 55 Option D: 48 Option E: 41

Notes:
¹ Total present worth cost; cost does not include O&M or base implementation cost. Values presented include cost of dredging, capping, ISS (Alternative 7 only), and disposal. See Table 4-7 for additional cost detail for each alternative and associated disposal options. Further, source control measures will be needed to ensure that the sediment remedy achieves the RAOs and is sustainable. Source control is the first component of all alternatives except No Action. Source control measures are in the process of being developed; therefore, the costs are not included in this FS. The source control measures are included by reference in this FS.

ARAR – applicable or relevant and appropriate requirement
 CDF – confined disposal facility
 ISS – in-situ solidification
 NAPL – non aqueous phase liquid
 NYCDEP – New York City Department of Environmental Protection
 NYSDEC – New York State Department of Environmental Conservation
 O&M – operations and maintenance

PRP – potentially responsible party
 RAO – remedial action objective
 RTA – remediation target area
 TMV – toxicity, mobility, or volume
 USACE – United States Army Corps of Engineers
 USEPA – United States Environmental Protection Agency

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TABLE ES-1b

Detailed Evaluation of Alternatives – RTA 2
 Gowanus Canal Feasibility Study
 Brooklyn, New York

Criteria	Alternative 1: No Action	Alternative 5: Dredge Entire Column of Soft Sediment Cap with Treatment Layer, Sand-and-Gravel Layer, Armor Layer	Alternative 7: Dredge Entire Column of Soft Sediment Solidify Top 3–5 Feet of Native Sediment in Targeted Areas Cap with Treatment Layer, Sand-and-Gravel Layer, Armor Layer
Threshold Criteria			
Overall protection of human health and the environment	Alternative will not provide protection of human health and the environment. <ul style="list-style-type: none"> • RAOs would not be achieved • Human health and ecological risks associated with contaminated sediment would not be reduced or eliminated. • NAPL migration to the water column would continue. • Contaminant concentrations in other media (e.g. surface water) would not be reduced. 	Alternative will provide protection of human health and the environment. <ul style="list-style-type: none"> • RAOs would be achieved upon completion of the remedy, which is estimated to be approximately 5 years after the start of construction. • Removal of soft sediment and capping of native sediment would reduce and control long-term risks associated with contaminated sediment. Placement of a cap would: <ul style="list-style-type: none"> ○ Control risks associated with remaining sediment by preventing exposure. ○ Reduce and control toxicity to benthic organisms and eliminate risks to herbivorous birds. ○ Control risks to human health via direct contact and incidental ingestion. ○ Prevent NAPL migration from sediment to the water column. • Surface water quality would be improved by preventing contact between surface water and sediment; sheens would be controlled or eliminated. 	Alternative would provide protection of human health and the environment. Application of ISS in targeted areas is expected to provide additional protectiveness against NAPL migration from sediment.
Compliance with ARARs	<ul style="list-style-type: none"> • ARARs are not applicable because no remedial action is taken. 	Alternative can be designed to comply with substantive requirements of the ARARs.	Same as Alternative 5.
Balancing Criteria			
Long-term effectiveness and permanence	Low - Alternative would not result in any significant change in the risks associated with contaminated sediment.	Alternative would provide a high level of long-term effectiveness and permanence: <ul style="list-style-type: none"> • Alternative would meet RAOs. • Alternative would result in significant, permanent risk reduction due to soft sediment removal. • The sediment cap would provide long-term control of the risks associated with the native sediment remaining in the canal, provided that appropriate long-term monitoring and maintenance plans are implemented. • Long-term effectiveness of disposal options are: <ul style="list-style-type: none"> ○ High for Options A, B, and C because material is transferred offsite and treated or contained in a managed landfill. 	Alternative would provide a high level of long-term effectiveness and permanence. <ul style="list-style-type: none"> • Same as Alternative 5, with the exception that targeted ISS would provide additional long-term control of the NAPL migration in the canal.
Magnitude and type of residual risk		This evaluation is focused on the magnitude and management of residual risks associated with sediment remaining onsite (i.e., sediment that is stabilized and beneficially used onsite and contaminated sediment remaining in the canal following remedy implementation). Sediment treated and disposed at offsite facilities are not included in this discussion because it would be removed from the site. <ul style="list-style-type: none"> • Sediment removal and capping would: <ul style="list-style-type: none"> ○ Alleviate the risks associated with the sediments removed from the canal. ○ Reduce the risks associated with contaminated native sediments that remain in the canal by capping. • Provide long-term control of risks associated with sediment remaining in the canal. Adsorptive caps to control NAPL migration can be designed for a set life expectancy where NAPL migration rates are known (see Appendix A for additional discussion). Additional data collection and evaluation to determine site-specific NAPL seepage rates will be required during remedial design to determine the appropriate cap design (i.e., granular oleophilic clay layer thickness). There are no residual risks associated with the three disposal options considered for RTA 2, because all sediment would be transferred offsite. 	Same as Alternative 5, with the addition that the implementation of ISS would be expected to further reduce the risk of NAPL migration, if proven to be effective and implementable during pilot and treatability testing.
Adequacy and reliability of controls		<ul style="list-style-type: none"> • Dredging <ul style="list-style-type: none"> ○ Mechanical dredging is an established technology and would meet the performance specifications for the removal component of the alternative. ○ Bathymetric surveys would be conducted to confirm target removal depths and samples would be collected on a defined grid to confirm sediment cap layer thicknesses. • Capping <ul style="list-style-type: none"> ○ Capping is an established technology and can be designed to meet the performance specifications of the alternative, provided that effective source controls have been implemented and the cap is constructed and maintained in accordance with the design specifications established for long-term isolation of the contaminated sediments. As noted above, additional data collection and evaluation are required to finalize the cap design. ○ Long-term monitoring and periodic maintenance would be required to assure cap integrity. 	Same as Alternative 5, with the addition that if additional evaluations and pilot studies indicate that in situ solidification (ISS) is implementable and effective within the canal, targeted areas of NAPL-saturated native sediment would be treated with ISS to further reduce the potential for NAPL migration. The conceptual cap specifications have been designed to be protective without the use of ISS; however, if ISS is determined to be viable for the Gowanus Canal, then its application would be expected to provide additional protection and support the long-term effectiveness of the selected remedy.

TABLE ES-1b

Detailed Evaluation of Alternatives – RTA 2
 Gowanus Canal Feasibility Study
 Brooklyn, New York

Criteria	Alternative 1: No Action	Alternative 5: Dredge Entire Column of Soft Sediment Cap with Treatment Layer, Sand-and-Gravel Layer, Armor Layer	Alternative 7: Dredge Entire Column of Soft Sediment Solidify Top 3–5 Feet of Native Sediment in Targeted Areas Cap with Treatment Layer, Sand-and-Gravel Layer, Armor Layer
		<ul style="list-style-type: none"> ○ The O&M plan developed during the remedial design would determine the monitoring and maintenance frequencies required to assure and maintain cap integrity based on site-specific factors. ○ Physical (e.g., bathymetric) surveys and the collection of samples on a defined grid would be needed to assess cap layer thickness, cap performance and integrity, contaminant movement, and/or recontamination concerns. Samples for chemical analysis should also be collected at regular predetermined intervals. ○ The long-term monitoring plan should also specify monitoring requirements after severe storm events to assess cap integrity. ○ Cap repairs would be performed as needed. ○ Component failures (i.e., sediment cap failure) could potentially result in sheens on the water surface and limited exposure to ecological or human receptors; however, catastrophic failure of the cap is unlikely if appropriate long-term O&M plans are implemented. ● Disposal <ul style="list-style-type: none"> ○ Disposal Options A (thermal treatment) and C (co-generation) would be expected to meet required performance specifications following treatability and pilot testing. ○ Option B (offsite landfill) is an established means of disposal. ○ Additional O&M beyond that associated with the sediment cap would not be required for the disposal and treatment options evaluated for RTA 2. 	
Reduction of toxicity, mobility, or volume through treatment	Low Alternative does not include a treatment component and does not meet the statutory preference for treatment as a principal element of a remedy.	<p>The overall reduction of NAPL mobility by the oleophilic cap is expected to be high.</p> <p>The reduction of toxicity, mobility, or volume (TMV) of the dredged sediment by treatment ranges from moderate to high depending on the disposal option.</p> <p>Alternative 5 is considered to have high overall reduction of TMV based on the volume of sediment removed from the canal.</p>	Same as Alternative 5, with the addition that the implementation of ISS would be expected to further reduce NAPL mobility, if proven to be effective and implementable during pilot and treatability testing.
Reduction in toxicity, mobility, or volume (TMV)		<ul style="list-style-type: none"> ● Dredging does not reduce toxicity, mobility or volume through treatment. ● The granular oleophilic clay cap component of the alternative will reduce the mobility of NAPL and is considered a treatment technology. ● The reduction of TMV of the dredged sediment is summarized below. Thermal treatment (Option A) and cogeneration (thermal destruction, Option C) meet the statutory preference for treatment as a principal element. The relative reductions of TMV of the disposal/beneficial use options are: <ul style="list-style-type: none"> ○ Option A (thermal treatment): High reduction of TMV. Dredged sediments would be treated using thermal desorption. The TMV associated with the organic contaminants would be significantly reduced or alleviated. ○ Option B (offsite landfill): Moderate reduction of TMV. Dredged sediments would be stabilized prior to transfer to a landfill. Volume and toxicity would not be affected, but contaminant mobility would be reduced by placing the material in a controlled environment. Overall TMV would be transferred to the offsite disposal facility. ○ Option C (co-generation): High reduction of TMV. Organic contaminants would be destroyed through treatment. The overall ranking of this disposal option is high. 	Same as Alternative 5, except that the overall reduction in NAPL mobility is anticipated to be greater with the addition of ISS in targeted areas of the canal.
Irreversibility		<ul style="list-style-type: none"> ● Sorption in the oleophilic clay cap is irreversible, but once the cap is saturated, it will not be able to absorb more NAPL. ● Solidification and stabilization are considered irreversible if the stabilized material is placed into a controlled environment. ● Thermal treatment (Option A), thermal destruction (Option C), and the stabilization component of Option B are irreversible. 	Same as Alternative 5, with the addition that ISS is also an irreversible process.
Type and quantity of treatment residuals and associated risks		<p>The type and quantity of residuals and the associated magnitude and management of risks is dependent upon the disposal option, as follows:</p> <ul style="list-style-type: none"> ● Option A (thermal treatment): <ul style="list-style-type: none"> ○ Residuals would consist of treated sediment. ○ Treated sediment would be beneficially used (e.g., daily cover at landfills). ○ Level of residual risk associated with this option is low since contaminants would be desorbed and destroyed in an afterburner. ● Option B (offsite landfill): <ul style="list-style-type: none"> ○ Would not result in treatment residuals. ○ Stabilized sediment would be disposed in a landfill. ○ Residual risk associated with this option is low because material is disposed in a controlled offsite facility. 	Same as Alternative 5.

TABLE ES-1b

Detailed Evaluation of Alternatives – RTA 2
 Gowanus Canal Feasibility Study
 Brooklyn, New York

Criteria	Alternative 1: No Action	Alternative 5: Dredge Entire Column of Soft Sediment Cap with Treatment Layer, Sand-and-Gravel Layer, Armor Layer	Alternative 7: Dredge Entire Column of Soft Sediment Solidify Top 3–5 Feet of Native Sediment in Targeted Areas Cap with Treatment Layer, Sand-and-Gravel Layer, Armor Layer
		<ul style="list-style-type: none"> • Option C (co-generation): <ul style="list-style-type: none"> ○ Residuals would consist of treated sediment. ○ Treated sediment would be beneficially used (e.g., daily cover at landfills). ○ The level of residual risk associated with this option is low since organic contaminants would be destroyed. • Sediment treated by thermal treatment (Option A) and co-generation (Option C) may contain concentrated levels of inorganic constituents, which may limit the beneficial use of the material. 	
Short-term effectiveness	High; no actions are taken under this alternative.	The short-term effectiveness of this alternative is moderate due to construction duration and the potential risks and environmental impacts described below. <ul style="list-style-type: none"> • Short-term effectiveness of all disposal options is considered moderate to high. 	Same as Alternative 5.
Risks to community, workers, and the associated controls		<ul style="list-style-type: none"> • Potential risks to the community would include noise and vibrations during bulkhead replacement and increased levels of traffic, dust, noise, and odors during the dredging and handling of contaminated sediment. Engineering controls and best management practices can mitigate most potential risks: <ul style="list-style-type: none"> ○ Access to the active work and support zones would be prohibited. ○ Notification of schedule for bulkhead repair and remedy implementation would be provided to the property owners and tenants. ○ Dust and noise levels would be monitored. ○ Work periods may be restricted to specific timeframes for especially noisy operations (e.g., sheet pile installation). ○ Traffic effects can be managed by performing work in canal from barges and using water transport to move materials to and from the canal. ○ Staging areas would need to be established in areas zoned for industrial use. ○ Odors are expected during dredging and may not be able to be fully controlled. • Potential risks to workers would include physical hazards associated with general construction, potential exposure to and direct contact with dredged sediment and NAPL, noise, odors, dust, and vapors. These would be mitigated through: <ul style="list-style-type: none"> ○ Engineering controls and best management practices. ○ Compliance with appropriate health and safety plans and site management plans. ○ Use of appropriate personal protective equipment. 	Same as Alternative 5. Implementation of ISS would likely be restricted to specific timeframes. Potential exposure risks from ISS would be mitigated as described under Alternative 5.
Environmental Impacts of Remedy and Controls		<ul style="list-style-type: none"> • Short-term environmental effects during implementation may include potential NAPL releases to surface water, turbidity increases within the canal, and releases of some sediment-associated contamination. Example control measures to mitigate these impacts include the following: <ul style="list-style-type: none"> ○ Dredge cells would contain suspended sediments (turbidity and sediment associated contaminants) and NAPL releases that result from the dredging process. Water within the dredge cells would be removed and treated before the sheet piles are removed. ○ The duration of these releases would be very short and would only occur during construction. 	Same as Alternative 5, with the addition that ISS would be performed within the dredge cells to contain potential NAPL and turbidity releases.
Duration of short-term risks		<ul style="list-style-type: none"> • The duration of the short-term risks would be the time required for construction, which is estimated to be approximately 5 years. 	Same as Alternative 5.
Implementability	Not applicable; no actions are taken under this alternative.	The overall implementability this alternative is moderate . The implementability of the disposal options is variable.	Same as Alternative 5 for dredging, capping, and disposal options. Implementability of ISS is likely to be more limited since this technology is not yet commercially proven for application to marine environments for the control of NAPL migration.
Technical feasibility		<ul style="list-style-type: none"> • Alternative is technically implementable and dredging and capping are established, field-proven technologies; however, pilot testing may be required to determine the most suitable cap placement methods based on the site-specific sediment characteristics. • Dredging and capping would be performed from barges using standard construction equipment. • The potential interference from debris within the canal will need to be considered during design. • Bulkhead repair and replacement will require property-specific designs, and construction must be planned and proceed and be coordinated carefully to minimize / prevent effects on the adjacent, upland properties. • The short- and long-term monitoring requirements can be performed using standard practices and technologies. • Implementability and feasibility of additional actions would be limited if penetration of the cap is required. 	Same as Alternative 5 for dredging and capping aspects. Treatability studies and pilot testing will be required during remedial design to determine the stabilization reagents and dosages, delivery mechanism, and overall technical feasibility of ISS.

TABLE ES-1b

Detailed Evaluation of Alternatives – RTA 2
 Gowanus Canal Feasibility Study
 Brooklyn, New York

Criteria	Alternative 1: No Action	Alternative 5: Dredge Entire Column of Soft Sediment Cap with Treatment Layer, Sand-and-Gravel Layer, Armor Layer	Alternative 7: Dredge Entire Column of Soft Sediment Solidify Top 3–5 Feet of Native Sediment in Targeted Areas Cap with Treatment Layer, Sand-and-Gravel Layer, Armor Layer
Administrative feasibility		<ul style="list-style-type: none"> Alternative will require coordination between regulatory agencies (USEPA, USACE, NYSDEC, and NYCDEP), PRPs, property owners along the canal, and other stakeholders. Bulkhead repair and replacement will require coordination with property owners and tenants. Due to the number of different properties and type of bulkheads affected, this effort will be considerable. 	Same as Alternative 5.
Availability of services and materials		<ul style="list-style-type: none"> Equipment and specialists required for the sheet piling installation, dredging, and capping would be commercially available. The volume of capping materials required is large and procuring large quantities of specialty materials, such as the oleophilic clay, will require significant advance coordination and possibly use of multiple vendors. Available thermal treatment and co-generation facilities (Options A and C, respectively) are also limited within the geography, which may restrict the ability to competitively bid these services. Landfill capacity for contaminated river sediments within the geography may be limited. Landfill availability will influence the implementability of Option B (offsite landfill) within the region. Available landfill facilities and associated capacities will need to be identified during the remedy selection process. Facilities outside of the region could be used; however, transportation costs would increase. Treatability testing will be needed to determine if available thermal treatment and co-generation facilities can accept solidified/stabilized sediment and to determine the final waste characterization. 	Same as Alternative 5 for dredging, capping, and disposal components. ISS is an emerging technology, and there are few contractors with a proven performance of ISS implementation in marine environments.
Cost (\$Million)¹	0	Option A: 117 Option B: 122 Option C: 136	Option A: 130 Option B: 135 Option C: 149

Notes:
¹ Total present worth cost; cost does not include O&M or base implementation cost. Values presented include cost of dredging, capping, ISS (Alternative 7 only), and disposal. See Table 4-7 for additional cost detail for each alternative and associated disposal options. Further, source control measures will be needed to ensure that the sediment remedy achieves the RAOs and is sustainable. Source control is the first component of all alternatives except No Action. Source control measures are in the process of being developed; therefore, the costs are not included in this FS. The source control measures are included by reference in this FS.

ARAR – applicable or relevant and appropriate requirement
 CDF – confined disposal facility
 ISS – in-situ solidification
 NAPL – non aqueous phase liquid
 NYCDEP – New York City Department of Environmental Protection
 NYSDEC – New York State Department of Environmental Conservation
 O&M – operations and maintenance

PRP – potentially responsible party
 RAO – remedial action objective
 RTA – remediation target area
 TMV – toxicity, mobility, or volume
 USACE – United States Army Corps of Engineers
 USEPA – United States Environmental Protection Agency

TABLE ES-1c

Detailed Evaluation of Alternatives – RTA 3
 Gowanus Canal Feasibility Study
 Brooklyn, New York

Criteria	Alternative 1: No Action	Alternative 5: Dredge Entire Column of Soft Sediment Cap with Treatment Layer, Sand-and-Gravel Layer, Armor Layer	Alternative 7: Dredge Entire Column of Soft Sediment Solidify Top 3-5 Feet of Native Sediment in Targeted Areas Cap with Treatment Layer, Sand-and-Gravel Layer, Armor Layer
Threshold Criteria			
Overall protection of human health and the environment	Alternative will not provide protection of human health and the environment. <ul style="list-style-type: none"> • RAOs would not be achieved • Human health and ecological risks associated with contaminated sediment would not be reduced or eliminated. • NAPL migration to the water column would continue. • Contaminant concentrations in other media (e.g. surface water) would not be reduced. 	Alternative will provide protection of human health and the environment. <ul style="list-style-type: none"> • RAOs would be achieved upon completion of the remedy, which is estimated to be approximately 5 years after the start of construction. • Removal of soft sediment and capping of native sediment would reduce and control long-term risks associated with contaminated sediment. Placement of a cap would: <ul style="list-style-type: none"> ○ Control risks associated with remaining sediment by preventing exposure. ○ Reduce and control toxicity to benthic organisms and eliminate risks to herbivorous birds. ○ Control risks to human health via direct contact and incidental ingestion. ○ Prevent NAPL migration from sediment to the water column. • Surface water quality would be improved by preventing contact between surface water and sediment; sheens would be controlled or eliminated. 	Alternative would provide protection of human health and the environment. Application of ISS in targeted areas is expected to provide additional protectiveness against NAPL migration from sediment.
Compliance with ARARs	<ul style="list-style-type: none"> • ARARs are not applicable because no remedial action is taken. 	Alternative can be designed to comply with substantive requirements of the ARARs.	Same as Alternative 5.
Balancing Criteria			
Long-term effectiveness and permanence	Low - Alternative would not result in any significant change in the risks associated with contaminated sediment.	Alternative would provide a high level of long-term effectiveness and permanence: <ul style="list-style-type: none"> • Alternative would meet RAOs. • Alternative would result in significant, permanent risk reduction due to soft sediment removal. • The sediment cap would provide long-term control of the risks associated with the native sediment remaining in the canal, provided that appropriate long-term monitoring and maintenance plans are implemented. • Long-term effectiveness of disposal options are: <ul style="list-style-type: none"> ○ High for Options A, B, and C because material is transferred offsite and treated or contained in a managed landfill. ○ Low to moderate for Options D and E. <ul style="list-style-type: none"> ▪ The long-term effectiveness will depend on the actual beneficial use and the conditions to which the stabilized sediment will be exposed. A greater degree of effectiveness would be expected from a use where the material is relatively contained and not subjected to significant water fluctuations or to freeze/thaw cycles. ▪ Stabilization would be performed to a degree such that the sediment-associated contaminants would be bound within the matrix and the stabilized sediment would remain onsite under Option E. ▪ The stabilized sediment would need to meet the end-use performance criteria. ▪ Permanent institutional controls and long-term monitoring would be needed under this option. ○ High for Options F and G as the material would be solidified/stabilized to such a degree that the sediment-associated contaminants would be permanently bound within the matrix prior to its placement in an onsite engineered facility. 	Alternative would provide a high level of long-term effectiveness and permanence. <ul style="list-style-type: none"> • Same as Alternative 5, with the exception that targeted ISS would provide additional long-term control of the NAPL migration in the canal.
Magnitude and type of residual risk		This evaluation is focused on the magnitude and management of residual risks associated with sediment remaining onsite (i.e., sediment that is stabilized and beneficially used onsite, and contaminated sediment remaining in the canal following remedy implementation). Sediment treated and disposed at offsite facilities are not included in this discussion because it would be removed from the site. <ul style="list-style-type: none"> • Sediment removal and capping would: <ul style="list-style-type: none"> ○ Alleviate the risks associated with the sediments removed from the canal. ○ Reduce the risks associated with contaminated native sediments that remain in the canal by capping. ○ Provide long-term control of risks associated with sediment remaining in the canal. Adsorptive caps to control NAPL migration can be designed for a set life expectancy where NAPL migration rates are known (see Appendix A for additional discussion). Additional data collection and evaluation to determine site-specific NAPL seepage rates will be required during remedial design to determine the appropriate cap design (i.e., granular oleophilic clay layer thickness). • Residual risks associated with disposal Option E (onsite stabilization and onsite beneficial use), F (offsite stabilization and onsite CDF), and G (onsite stabilization and onsite CDF) would be as follows: <ul style="list-style-type: none"> ○ Treatment residuals would consist of stabilized sediment, which would significantly reduce the mobility of sediment contaminants and reduce the associated risks. 	Same as Alternative 5, with the addition that the implementation of ISS would be expected to further reduce risk of NAPL migration, if proven to be effective and implementable during pilot and treatability testing.

TABLE ES-1c

Detailed Evaluation of Alternatives – RTA 3
 Gowanus Canal Feasibility Study
 Brooklyn, New York

Criteria	Alternative 1: No Action	Alternative 5: Dredge Entire Column of Soft Sediment Cap with Treatment Layer, Sand-and-Gravel Layer, Armor Layer	Alternative 7: Dredge Entire Column of Soft Sediment Solidify Top 3-5 Feet of Native Sediment in Targeted Areas Cap with Treatment Layer, Sand-and-Gravel Layer, Armor Layer
		<ul style="list-style-type: none"> ○ Onsite beneficial use of the stabilized material will require identifying a beneficial use and will also require the stabilized material to meet leachability specifications and strength specifications appropriate to the identified use. ○ The ability of the stabilized sediment to meet performance criteria will depend upon the designated end use of the material, and further testing is required for these disposal options. ○ The FS assumes that the end use would be such that direct contact human and ecological contact with the stabilized sediment would be limited. ○ Placement in constructed CDF (Options F and G) would require routine monitoring and maintenance to assure materials remain isolated. ○ The level of residual risk would be considered low to moderate for these alternatives because treatment does not destroy the contaminants and the treated material would remain onsite. ○ Remedy can be designed so that the sediments stabilized and beneficially used or placed in the onsite CDF are those with fewer NAPL impacts. 	
Adequacy and reliability of controls		<ul style="list-style-type: none"> ● Dredging <ul style="list-style-type: none"> ○ Mechanical dredging is an established technology and would meet the performance specifications for the removal component of the alternative. ○ Bathymetric surveys would be conducted to confirm target removal depths and samples would be collected on a defined grid to confirm sediment cap layer thicknesses. ● Capping <ul style="list-style-type: none"> ○ Capping is an established technology and can be designed to meet the performance specifications of the alternative, provided that effective source controls have been implemented and the cap is constructed and maintained in accordance with the design specifications established for long-term isolation of the contaminated sediments. As noted above, additional data collection and evaluation are required to finalize the cap design. ○ Long-term monitoring and periodic maintenance would be required to assure cap integrity. ○ The O&M plan developed during the remedial design would determine the monitoring and maintenance frequencies required to assure and maintain cap integrity based on site-specific factors. ○ Physical (e.g., bathymetric) surveys and the collection of samples on a defined grid would be needed to assess cap layer thickness, cap performance and integrity, contaminant movement, and/or recontamination concerns. Samples for chemical analysis should also be collected at regular predetermined intervals. ○ The long-term monitoring plan should also specify monitoring requirements after severe storm events to assess cap integrity. ○ Cap repairs would be performed as needed. ○ Component failures (i.e., sediment cap failure) could potentially result in sheens on the water surface and limited exposure to ecological or human receptors; however, catastrophic failure of the cap is unlikely if appropriate long-term O&M plans are implemented. ● Disposal <ul style="list-style-type: none"> ○ Disposal Options A (thermal treatment), and C (co-generation) would be expected to meet required performance specifications following treatability and pilot testing. ○ Option B (offsite landfill) is an established means of disposal. ○ Options D (offsite stabilization and offsite beneficial use) and E (onsite stabilization and beneficial use) require identifying a beneficial use and also require that the stabilized material meet leachability specifications as well as strength specifications appropriate to the identified use. The ability of the stabilized sediment to meet performance criteria will depend upon the designated end use of the material, and further testing is required for these disposal options. The FS assumes that the end use would be such that direct contact human and ecological contact with the stabilized sediment would be limited. ○ Additional O&M beyond that associated with the sediment cap would be required for Options A, B, C, or D. Long-term monitoring would be required for Options E (onsite stabilization and beneficial use), F, or G (stabilization and onsite CDF). The O&M for the CDF would consist of inspections and a low level of maintenance. ○ Institutional controls would be required if disposal Options E, F, or G are selected. ○ The permanent institutional controls required for disposal Option E would specify appropriate measures for digging within the fill material, and long-term monitoring would be applied to review their sustained application. The institutional controls may need to be applied to one or more properties, depending on where the material is used. Depending on the number of properties and the location where the fill is placed, significant effort and coordination may be needed to ensure successful implementation and enforcement of these controls. 	Same as Alternative 5, with the stipulation that if additional evaluations and pilot studies indicate that in situ solidification (ISS) is implementable and effective within the canal, targeted areas of NAPL-saturated native sediment would be treated with ISS to further reduce the potential for NAPL migration. The conceptual cap specifications have been designed to be protective without the use of ISS; however, if ISS is determined to be viable for the Gowanus Canal, then its application would be expected to provide additional protection and support the long-term effectiveness of the selected remedy.

TABLE ES-1c

Detailed Evaluation of Alternatives – RTA 3
 Gowanus Canal Feasibility Study
 Brooklyn, New York

Criteria	Alternative 1: No Action	Alternative 5: Dredge Entire Column of Soft Sediment Cap with Treatment Layer, Sand-and-Gravel Layer, Armor Layer	Alternative 7: Dredge Entire Column of Soft Sediment Solidify Top 3-5 Feet of Native Sediment in Targeted Areas Cap with Treatment Layer, Sand-and-Gravel Layer, Armor Layer
Reduction of toxicity, mobility, or volume through treatment	Low Alternative does not include a treatment component and does not meet the statutory preference for treatment as a principal element of a remedy.	The overall reduction of NAPL mobility by the oleophilic cap is expected to be high . The reduction of toxicity, mobility, or volume (TMV) of the dredged sediment by treatment ranges from moderate to high depending on the disposal option. Alternative 5 is considered to have high overall reduction of TMV based on the volume of sediment removed from the canal.	Same as Alternative 5, with the addition that the implementation of ISS would be expected to further reduce NAPL mobility, if proven to be effective and implementable during pilot and treatability testing.
Reduction in toxicity, mobility, or volume (TMV)		<ul style="list-style-type: none"> • Dredging does not reduce toxicity, mobility or volume through treatment. • The granular oleophilic clay cap component of the alternative will reduce the mobility of NAPL and is considered a treatment technology. • The reduction of TMV of the dredged sediment is summarized below. Thermal treatment (Option A) and cogeneration (thermal destruction, Option C) meet the statutory preference for treatment as a principal element. The relative reductions of TMV of the disposal/beneficial use options are: <ul style="list-style-type: none"> ○ Option A (thermal treatment): High reduction of TMV. Dredged sediments would be treated using thermal desorption. The TMV associated with the organic contaminants would be significantly reduced. ○ Option B (offsite landfill): Moderate reduction of TMV. Dredged sediments would be stabilized prior to transfer to a landfill. Volume and toxicity would not be affected, but contaminant mobility would be reduced by placing the material in a controlled environment. Overall TMV would be transferred to the offsite disposal facility. ○ Option C (co-generation): High reduction of TMV. Organic contaminants would be destroyed through treatment. The overall ranking of this disposal option is high. ○ Option D (offsite stabilization and offsite beneficial use): Moderate reduction of TMV. Dredged sediments would be stabilized prior to their transfer to an offsite beneficial-use location. Volume and toxicity would not be affected, but contaminant mobility would be reduced. Overall TMV would be transferred to the offsite location. ○ Option E (onsite stabilization and onsite beneficial use): Moderate reduction of TMV. Dredged sediments would be stabilized prior to placement in onsite beneficial-use location. Volume and toxicity would not be affected, but contaminant mobility would be reduced. Overall TMV would remain onsite. ○ Options F and G (stabilization and onsite CDF): Moderate reduction of TMV. Solidification and stabilization agents added to the dredged sediment would result in material forming a solid monolith. The toxicity and volume would not be reduced, but the mobility of the contaminants would be significantly reduced. The sediments placed in the CDF would be those with fewer NAPL impacts. 	Same as Alternative 5, except that the overall reduction in NAPL mobility is anticipated to be greater with the addition of ISS in targeted areas of the canal.
Irreversibility		<ul style="list-style-type: none"> • Sorption in the oleophilic clay cap is irreversible, but once the cap is saturated, it will not be able to absorb more NAPL. • Solidification and stabilization are considered irreversible if the stabilized material is placed into a controlled environment. • Thermal treatment (Option A), thermal destruction (Option C), and the stabilization component of Options B, F, and G are irreversible. The degree of irreversibility of stabilization associated with Options D and E will depend upon the selected beneficial use and the conditions to which the stabilized material are exposed. 	Same as Alternative 5, with the addition that ISS is also an irreversible process.
Type and quantity of treatment residuals and associated risks		<p>The type and quantity of residuals and the associated magnitude and management of risks is dependent upon the disposal option, as follows:</p> <ul style="list-style-type: none"> • Option A (thermal treatment): <ul style="list-style-type: none"> ○ Residuals would consist of treated sediment. ○ Treated sediment would be beneficially used (e.g., daily cover at landfills). ○ Level of residual risk associated with this option is low since contaminants would be desorbed and destroyed in an afterburner. • Option B (offsite landfill): <ul style="list-style-type: none"> ○ Would not result in treatment residuals. ○ Stabilized sediment would be disposed in a landfill. ○ Residual risk associated with this option is low because material is disposed in a controlled offsite facility. • Option C (co-generation): <ul style="list-style-type: none"> ○ Residuals would consist of treated sediment. ○ Treated sediment would be beneficially used (e.g., daily cover at landfills). ○ The level of residual risk associated with this option is low since organic contaminants would be destroyed. • Options D (offsite stabilization and offsite beneficial use) and E (onsite stabilization and onsite beneficial use): <ul style="list-style-type: none"> ○ Stabilized sediment would be beneficially used either offsite (Option D) or onsite (Option E). ○ The level of residual risk would be considered low to moderate because treatment stabilizes but does not 	Same as Alternative 5.

TABLE ES-1c

Detailed Evaluation of Alternatives – RTA 3
 Gowanus Canal Feasibility Study
 Brooklyn, New York

Criteria	Alternative 1: No Action	Alternative 5: Dredge Entire Column of Soft Sediment Cap with Treatment Layer, Sand-and-Gravel Layer, Armor Layer	Alternative 7: Dredge Entire Column of Soft Sediment Solidify Top 3-5 Feet of Native Sediment in Targeted Areas Cap with Treatment Layer, Sand-and-Gravel Layer, Armor Layer
		destroy the contaminants. The contaminant mobility would be significantly reduced, and the treated material would be beneficially used. The residual risk for Option D is lower because the material would be transferred offsite. <ul style="list-style-type: none"> • Sediment treated by thermal treatment (Option A) and co-generation (Option C) may contain concentrated levels of inorganic constituents, which may limit the beneficial use of the material. • Options F and G (stabilization and onsite CDF): <ul style="list-style-type: none"> ○ Stabilized sediment would be placed in a CDF. ○ CDF would require routine monitoring and maintenance to assure materials remain isolated. ○ The level of residual risk would be considered low to moderate because treatment stabilizes but does not destroy the contaminants, and the treated material would remain onsite. • Materials with fewer NAPL impacts can be placed in the CDF. 	
Short-term effectiveness	High; no actions are taken under this alternative.	The short-term effectiveness of this alternative is moderate due to construction duration and the potential risks and environmental impacts described below. <ul style="list-style-type: none"> • Short-term effectiveness of all disposal options is considered moderate to high. 	Same as Alternative 5
Risks to community, workers, and the associated controls		<ul style="list-style-type: none"> • Potential risks to the community would include noise and vibrations during bulkhead replacement and increased levels of traffic, dust, noise, and odors during the dredging and handling of contaminated sediment. Engineering controls and best management practices can mitigate most potential risks: <ul style="list-style-type: none"> ○ Access to the active work and support zones would be prohibited. ○ Notification of schedule for bulkhead repair and remedy implementation would be provided to the property owners and tenants. ○ Dust and noise levels would be monitored. ○ Work periods may be restricted to specific timeframes for especially noisy operations (e.g., sheet pile installation). ○ Traffic effects can be managed by performing work in canal from barges and using water transport to move materials to and from the canal. ○ Staging areas would need to be established in areas zoned for industrial use. ○ Odors are expected during dredging and may not be able to be fully controlled. • Potential risks to workers would include physical hazards associated with general construction, potential exposure to and direct contact with dredged sediment and NAPL, noise, odors, dust, and vapors. These would be mitigated through: <ul style="list-style-type: none"> ○ Engineering controls and best management practices. ○ Compliance with appropriate health and safety plans and site management plans. ○ Use of appropriate personal protective equipment. 	Same as Alternative 5. Implementation of ISS would likely be restricted to specific timeframes. Potential exposure risks from ISS would be mitigated as described under Alternative 5.
Environmental Impacts of Remedy and Controls		<ul style="list-style-type: none"> • Short-term environmental effects during implementation in RTA 3 may include turbidity increases within the canal and releases of some sediment-associated contamination. Significant releases of NAPL from RTA 3 are not anticipated. Example control measures to mitigate these impacts include the following: <ul style="list-style-type: none"> ○ Silt curtains would control turbidity in RTA 3. ○ The duration of these releases would be very short and would only occur during construction. 	Same as Alternative 5, with the addition that ISS would be performed within the dredge cells to contain potential NAPL and turbidity releases.
Duration of short-term risks		<ul style="list-style-type: none"> • The duration of the short-term risks would be the time required for construction, which is estimated to be approximately 5 years. 	Same as Alternative 5.
Implementability	Not applicable; no actions are taken under this alternative.	The overall implementability this alternative is moderate . The implementability of the disposal options is variable.	Same as Alternative 5 for dredging, capping, and disposal options. Implementability of ISS is likely to be more limited since this technology is not yet commercially proven for application to marine environments for the control of NAPL migration.
Technical feasibility		<ul style="list-style-type: none"> • Alternative is technically implementable and dredging and capping are established, field-proven technologies; however, pilot testing may be required to determine the most suitable cap placement methods based on the site-specific sediment characteristics. • Dredging and capping would be performed from barges using standard construction equipment. • The potential interference from debris within the canal will need to be considered during design. • Bulkhead repair and replacement will require property-specific designs, and construction must be planned and proceed and be coordinated carefully to minimize / prevent effects on the adjacent, upland properties. 	Same as Alternative 5 for dredging and capping aspects. Treatability studies and pilot testing will be required during remedial design to determine the stabilization reagents and dosages, delivery mechanism, and overall technical feasibility of ISS.

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Detailed Evaluation of Alternatives – RTA 3
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Criteria	Alternative 1: No Action	Alternative 5: Dredge Entire Column of Soft Sediment Cap with Treatment Layer, Sand-and-Gravel Layer, Armor Layer	Alternative 7: Dredge Entire Column of Soft Sediment Solidify Top 3-5 Feet of Native Sediment in Targeted Areas Cap with Treatment Layer, Sand-and-Gravel Layer, Armor Layer
		<ul style="list-style-type: none"> The short- and long-term monitoring requirements can be performed using standard practices and technologies. Implementability and feasibility of additional actions would be limited if penetration of the cap is required. 	
Administrative feasibility		<ul style="list-style-type: none"> Alternative will require coordination between regulatory agencies (USEPA, USACE, NYSDEC, and NYCDEP), PRPs, property owners along the canal, and other stakeholders. Bulkhead repair and replacement will require coordination with property owners and tenants. Due to the number of different properties and type of bulkheads affected, this effort will be considerable. Implementation of disposal Option E (onsite stabilization and onsite beneficial use) is dependent upon stakeholder acceptability, and effective implementation of institutional controls. This disposal option may be challenging to implement due to stakeholder acceptance. Permanent institutional controls would also be required for disposal Option E. Depending on the number of properties and the location where the fill is placed, significant effort and coordination may be needed to ensure successful implementation and enforcement of these controls. The difficulties associated with implementation of institutional controls are also further discussed in Section 4.6.3. Implementation of disposal Options F and G (onsite constructed CDF) is dependent on the identification of a suitable location(s), concurrence from other stakeholders, and effective implementation of institutional controls. This option may be difficult to implement due to stakeholder acceptability challenges. 	Same as Alternative 5.
Availability of services and materials		<ul style="list-style-type: none"> Equipment and specialists required for the sheet piling installation, dredging, and capping would be commercially available. The volume of capping materials required is large and procuring large quantities of specialty materials, such as the oleophilic clay, will require significant advance coordination and possibly use of multiple vendors. Available thermal treatment and co-generation facilities (Options A and C, respectively) are also limited within the geography, which may restrict the ability to competitively bid these services. Landfill capacity for contaminated river sediments within the geography may be limited. Landfill availability will influence the implementability of disposal Option B (offsite landfill) within the region. Available landfill facilities and associated capacities will need to be identified during the remedy selection process. Facilities outside of the region could be used; however, transportation costs would increase. Onsite and offsite beneficial uses of stabilized sediment would need to be identified. In order for disposal options D and E to be implemented, an end use would need to be determined and treatability testing would need to be performed to evaluate the stabilization agents and dosing required and to assess whether the treated material would meet all the end-use requirements (e.g., leachability and strength characteristics). Treatability testing will be needed to determine if available thermal treatment and co-generation facilities can accept solidified/stabilized sediment and to determine the final waste characterization. 	Same as Alternative 5 for dredging, capping, and disposal components. ISS is an emerging technology and contractors with a proven performance of ISS implementation in marine environments are few.
Cost¹	0	Option A: 131 Option B: 137 Option C: 155 Option D: 133 Option E: 107 Option F: 103 Option G: 96	Option A: 131 Option B: 137 Option C: 155 Option D: 133 Option E: 107 Option F: 103 Option G: 96

Notes:
¹ Total present worth cost; cost does not include O&M or base implementation cost. Values presented include cost of dredging, capping, ISS (Alternative 7 only), and disposal. See Table 4-7 for additional cost detail for each alternative and associated disposal options. Further, source control measures will be needed to ensure that the sediment remedy achieves the RAOs and is sustainable. Source control is the first component of all alternatives except No Action. Source control measures are in the process of being developed; therefore, the costs are not included in this FS. The source control measures are included by reference in this FS. Areas for ISS have not been identified in RTA 3; therefore costs have not been included in this FS. ISS may be applied to RTA 3 if predesign investigations indicate areas of NAPL saturated sediment where ISS may be beneficial.

ARAR – applicable or relevant and appropriate requirement
 CDF – confined disposal facility
 ISS – in-situ solidification
 NAPL – non aqueous phase liquid
 NYCDEP – New York City Department of Environmental Protection
 NYSDEC – New York State Department of Environmental Conservation
 O&M – operations and maintenance

PRP – potentially responsible party
 RAO – remedial action objective
 RTA – remediation target area
 TMV – toxicity, mobility, or volume
 USACE – United States Army Corps of Engineers
 USEPA – United States Environmental Protection Agency

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TABLE ES-2a
 Comparative Analysis of Alternatives RTA 1
 Gowanus Canal Feasibility Study
 Brooklyn, New York

Dredging and Capping Alternatives	Threshold Criteria		Balancing Criteria				
	Overall Protection of Human Health and the Environment	Compliance with ARARs	Long-Term Effectiveness	Reduction of Toxicity, Mobility, or Volume	Short-Term Effectiveness	Implementability	Cost (\$Million) ¹
Alternative 1 No Action	⌚	⌚	⌚	⌚	●	●	0
Alternative 5 Dredge entire column of soft sediment Cap with treatment layer, isolation sand layer, and armor layer	●	●	●	●	◐	◐	15
Alternative 7 Dredge entire column of soft sediment Solidify top 3-5 feet of underlying native sediment in select areas Cap with treatment layer, isolation sand layer, and armor layer	●	●	● ²	●	◐	◑	18
Disposal Options Associated with Dredging and Capping alternatives							
Option A: Thermal desorption, offsite beneficial use	●	●	●	●	◑	◐	30
Option B: Offsite disposal (landfill)	●	●	●	◐	◑	◑	32
Option C: Co-gen, offsite beneficial use	●	●	●	●	◑	◐	37
Option D: Offsite stabilization, offsite beneficial use ³	●	●	◑	◐	◑	◐	30
Option E: Onsite stabilization, onsite beneficial use ³	●	●	◑	◐	◑	◐	23

¹Present worth: 30-year period of performance (*i* = 2.3 percent). Cost does not include O&M or base implementation cost. See Table 4-7 and Appendix F for additional cost detail.

² If pilot testing and treatability studies indicate ISS will be effective and implementable within the canal, Alternative 7 would be expected to have greater long-term effectiveness than Alternative 5.

³The relative rankings of the stabilization and beneficial use disposal options could be modified following the identification of a specific beneficial use.

Source control measures will be needed to ensure that the sediment remedy achieves the RAOs and is sustainable. Source control is the first component of all alternatives except No Action. Source control measures are in the process of being developed; therefore, the costs are not included in this FS. The source control measures are included by reference in this FS

Legend:

Threshold Criteria:

- ⌚ Does not satisfy criterion
- Satisfies criterion

Balancing Criteria:

- ⌚ Low
- ◑ Low to Moderate
- ◐ Moderate
- ◑ Moderate to High
- High

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TABLE ES-2b
 Comparative Analysis of Alternatives RTA 2
 Gowanus Canal Feasibility Study
 Brooklyn, New York

Dredging and Capping Alternatives	Threshold Criteria		Balancing Criteria				
	Overall Protection of Human Health and the Environment	Compliance with ARARs	Long-Term Effectiveness	Reduction of Toxicity, Mobility, or Volume	Short-Term Effectiveness	Implementability	Cost (\$Million) ¹
Alternative 1 No Action	⌚	⌚	⌚	⌚	●	●	0
Alternative 5 Dredge entire column of soft sediment Cap with treatment layer, isolation sand layer, and armor layer	●	●	●	●	◐	◐	35
Alternative 7 Dredge entire column of soft sediment Solidify top 3-5 feet of underlying native sediment in select areas Cap with treatment layer, isolation sand layer, and armor layer	●	●	● ²	●	◐	◑	48
Disposal Options Associated with Dredging and Capping alternatives							
Option A: Thermal desorption, offsite beneficial use	●	●	●	●	◑	◐	82
Option B: Offsite disposal (landfill)	●	●	●	◐	◑	◑	87
Option C: Co-gen, offsite beneficial use	●	●	●	●	◑	◐	101

¹Present worth: 30-year period of performance (*i* = 2.3 percent). Cost does not include O&M or base implementation cost. See Table 4-7 and Appendix F for additional cost detail.

² If pilot testing and treatability studies indicate ISS will be effective and implementable within the canal, Alternative 7 would be expected to have greater long-term effectiveness than Alternative 5. Source control measures will be needed to ensure that the sediment remedy achieves the RAOs and is sustainable. Source control is the first component of all alternatives except No Action. Source control measures are in the process of being developed; therefore, the costs are not included in this FS. The source control measures are included by reference in this FS.

Legend:

Threshold Criteria:

- ⌚ Does not satisfy criterion
- Satisfies criterion

Balancing Criteria:

- ⌚ Low
- ◑ Low to Moderate
- ◐ Moderate
- ◑ Moderate to High
- High

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TABLE ES-2c
 Comparative Analysis of Alternatives RTA 3
 Gowanus Canal Feasibility Study
 Brooklyn, New York

Dredging and Capping Alternatives	Threshold Criteria		Balancing Criteria				
	Overall Protection of Human Health and the Environment	Compliance with ARARs	Long-Term Effectiveness	Reduction of Toxicity, Mobility, or Volume	Short-Term Effectiveness	Implementability	Cost (\$Million) ¹
Alternative 1 No Action	⌚	⌚	⌚	⌚	●	●	0
Alternative 5 Dredge entire column of soft sediment Cap with treatment layer, isolation sand layer, and armor layer	●	●	●	●	◐	◐	29
Alternative 7 Dredge entire column of soft sediment Solidify top 3-5 feet of underlying native sediment in select areas Cap with treatment layer, isolation sand layer, and armor layer	●	●	● ²	●	◐	◑	29
Disposal Options Associated with Dredging and Capping alternatives							
Option A: Thermal desorption, offsite beneficial use	●	●	●	●	◑	◐	102
Option B: Offsite disposal (landfill)	●	●	●	◐	◑	◑	108
Option C: Co-gen, offsite beneficial use	●	●	●	●	◑	◐	126
Option D: Offsite stabilization, offsite beneficial use ³	●	●	◑	◐	◑	◐	104
Option E: Onsite stabilization, onsite beneficial use ³	●	●	◑	◐	◑	◐	78
Option F: Offsite stabilization, disposal in onsite CDF	●	●	◑	◐	◑	◐	74
Option G: Onsite stabilization, disposal in onsite CDF	●	●	◑	◐	◑	◐	67

¹Present worth: 30-year period of performance (i = 2.3 percent). Cost does not include O&M or base implementation cost. See Table 4-7 and Appendix F for additional cost detail.

² If pilot testing and treatability studies indicate ISS will be effective and implementable within the canal, Alternative 7 would be expected to have greater long-term effectiveness than Alternative 5.

³The relative rankings of the stabilization and beneficial use disposal options could be modified following the identification of a specific beneficial use.

Source control measures will be needed to ensure that the sediment remedy achieves the RAOs and is sustainable. Source control is the first component of all alternatives except No Action. Source control measures are in the process of being developed; therefore, the costs are not included in this FS. The source control measures are included by reference in this FS.

Legend:

Threshold Criteria:

- ⌚ Does not satisfy criterion
- Satisfies criterion

Balancing Criteria:

- ⌚ Low
- ◑ Low to Moderate
- ◐ Moderate
- ◑ Moderate to High
- High

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Abbreviations and Acronyms

ARAR	applicable or relevant and appropriate requirement
BERA	baseline ecological risk assessment
BTEX	benzene, toluene, ethylbenzene, and xylenes
BTU	British Thermal Unit
CDF	Confined Disposal Facility
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act of 1980
CESP	Clean Earth of Southeast Pennsylvania
CSM	conceptual site model
CSO	combined sewer overflow
CTE	central tendency exposure
DO	dissolved oxygen
EC ₂₀	20 percent effects concentration
ERA	ecological risk assessment
ESB	equilibrium sediment benchmark
FCV	final chronic value
FS	feasibility study
GEI	GEI Consultants, Inc.
GRA	general response action
HHRA	human health risk assessment
ISS	in situ stabilization
LTCP	long-term control plan
MGP	manufactured-gas plant
MLLW	mean lower low water
MNR	monitored natural recovery
NAPL	non-aqueous-phase liquid
NAVD88	North American Vertical Datum of 1988
NCP	National Contingency Plan
NOAEC	no observed adverse effect concentration
NPDES	National Pollutant Discharge Elimination System
NRHP	National Register of Historic Places
NYCDEP	New York City Department of Environmental Protection
NYSDEC	New York State Department of Environmental Conservation
O&M	operations and maintenance
OSWER	USEPA Office of Solid Waste and Emergency Response
PAH	polycyclic aromatic hydrocarbon

PCB	polychlorinated biphenyl
PRG	preliminary remediation goal
RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act
RI	remedial investigation
RME	reasonable maximum exposure
RTA	remediation target area
SLERA	screening level ecological risk assessment
SVOC	semivolatile organic compound
TBC	to be considered
TCLP	toxicity characteristic leaching procedure
TOC	total organic carbon
TRAP	Toxicity Response Analysis Program
TU	toxicity unit
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
VOC	volatile organic compound

SECTION 1

Introduction

This draft feasibility study (FS) report was prepared for the U.S. Environmental Protection Agency (USEPA) Region 2 by CH2M HILL to present the results of the feasibility analysis of remedial alternatives for the Gowanus Canal Superfund Site, in Brooklyn, Kings County, New York. This draft FS was prepared under Task Order 072 of the USEPA AES10 contract.

The Gowanus Canal is a 1.8-mile-long, man-made canal in the Brooklyn Borough of New York City, in Kings County, New York (Figure 1-1). The canal was built in the 1860s by bulkheading and dredging a tidal creek and surrounding lowland marshes. Following construction, the canal quickly became one of the nation's busiest industrial waterways, servicing heavy industries that included manufactured-gas plants (MGPs), coal yards, cement manufacturers, tanneries, paint and ink factories, machine shops, chemical plants, and oil refineries. It was also the repository of untreated industrial wastes, raw sewage, and surface-water runoff for decades, causing it to become one of New York's most polluted waterways. Although the level of industrial activity along the canal has declined over the years, high levels of contamination remain in the sediments.

On March 2, 2010, USEPA placed the Gowanus Canal (USEPA ID#: NYN000206222) on its National Priorities List of hazardous waste sites requiring further evaluation. Accordingly, USEPA Region 2 performed a remedial investigation and feasibility study (RI/FS) of the canal according to the requirements of the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA, or "Superfund"), as amended. The RI was completed in January 2011 (USEPA, 2011) and this FS was initiated. The results of this FS will be used to develop a Proposed Plan for remedial action and a Record of Decision for the canal.

This FS focuses on remedial alternatives for contaminated sediments within the Gowanus Canal. Addressing contaminant contributions to the canal from upland properties, combined sewer overflows (CSOs) and other pipe outfalls is a prerequisite to a sustainable remedy for canal sediments and as such, USEPA is seeking to reduce or eliminate these sources. The New York State Department of Environmental Conservation (NYSDEC) is addressing investigations and response actions related to the upland properties adjacent to the canal. The New York City Department of Environmental Protection (NYCDEP), through an Administrative Order on Consent¹ with NYSDEC, has begun to address CSOs. It is anticipated that additional CSO measures will be required to prevent recontamination of the canal. Discharges to the canal from unpermitted outfall structures must also be addressed. Source control measures are in the process of being developed and these measures are included by reference as a component of all of the alternatives for contaminated sediments presented in this FS.

¹ DEC Case #CO2-20000107-8 dated January 14, 2005, and updated April 14, 2008.

1.1 Purpose and Organization of Report

This FS develops and evaluates remedial alternatives for Gowanus Canal sediments that will reduce or eliminate unacceptable risks to human health and the environment from exposure to contaminated sediment and surface water in the canal. The FS was prepared following USEPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (USEPA, 1988) and *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* (USEPA, 2005). The report is organized into the following five sections:

1. **Introduction.** Briefly describes the regulatory framework, FS purpose and organization, and site setting; summarizes the results of the RI; and presents a conceptual site model (CSM) for the canal.
2. **Development and Application of Remediation Goals.** Presents the remedial action objectives (RAOs) and remediation goals for the canal, and summarizes the potential applicable or relevant and appropriate requirements (ARARs). This section also identifies the area and depth of the sediments to be targeted by the remediation.
3. **Identification and Screening of Remedial Technologies.** Identifies and describes a range of remedial approaches, technologies, and process options that could be used to address contaminated sediments in the canal, and screens them based on effectiveness, implementability, and cost.
4. **Development and Evaluation of Remedial Alternatives.** Develops remedial alternatives for canal sediments by combining the remedial approaches, technologies, and process options that were retained after the screening described in Section 3; screens the alternatives based on effectiveness, implementability, and cost; and presents detailed individual and comparative analyses of the remedial alternatives that were retained using the evaluation criteria defined in the National Oil and Hazardous Substance Pollution Contingency Plan (NCP).
5. **References.** Provides the references cited in the report.

The report appendixes provide supporting information as follows:

- A – Non-Aqueous-Phase Liquid (NAPL) Technical Appendix
- B – Groundwater and Combined Sewer Overflow Discharge Evaluation
- C – Development of Remediation Goals
- D – Gowanus Canal Propeller Wash Calculations
- E – Dredging Volume Estimates
- F – Estimated Costs

Additionally, the identification of historic properties within the Area of Potential Effect for the Gowanus Canal Superfund Site is being carried out by USEPA under Section 106 of the National Historic Preservation Act. Initial characterizations of the historic contexts of the canal were developed by the U.S. Army Corps of Engineers (USACE) in 2004 (Hunter Research et al., 2004). This study indicated the eligibility of the canal for nomination to the National Register of Historic Places. Subsequent investigations by USEPA in 2010 (USEPA, 2011), carried out as part of the RI, further examined large-sized objects residing on the

surface of the canal bottom sediments. Further evaluation of the historic bulkheads, themselves an integral component of the canal, was also carried out.

Additional archeological research carried out under this FS focuses on two tasks: evaluating lands immediately adjacent to the canal with respect to their potential for containing intact historic properties and carrying out the initial steps in the recording the historic bulkheads lining the canal. The latter is in anticipation of any potential adverse effects in conjunction with the proposed cleanup activities.

The lands adjacent to the canal were evaluated initially from a review of historic documentation drawn from a wide range of public and corporate repositories, along with an examination of a number of private archival holdings. This is accompanied by an interpretation of soil boring data taken from current and past projects along the canal to indicate the nature of existing stratigraphic sequences relevant to any potential for surviving historical contexts.

The initial bulkhead recordation efforts are focused on the techniques of construction and maintenance as revealed in engineering and planning documents. Additional considerations address construction materials selection, evolution of design parameters, securing of historical photographic documentation, and the contemporary photo documenting of these features prior to the cleanup.

The results of this additional research will be compiled in an addendum to this FS report.

1.2 Site Setting

The Gowanus Canal is a tidally influenced, dead-end channel that opens to Gowanus Bay and Upper New York Bay (Figure 1-2). The canal experiences a semidiurnal tidal cycle (i.e., two high tides and two low tides of unequal height each tidal day), with a vertical tidal range from 4.7 to 5.7 feet. The only freshwater inflows to the canal are wet-weather CSO and stormwater discharges. Because of its narrow width, limited freshwater input, and enclosed upper end, the canal has low current speeds and limited tidal exchange with Gowanus Bay. Circulation is enhanced by the addition of water from a flushing tunnel located at the head of the canal, when the flushing tunnel is operating (NYCDEP, 2008a). The flushing tunnel is described further in Section 1.2.1.

The Gowanus Canal project area is shown in Figure 1-1. There are five east-west bridge crossings over the canal, at Union Street, Carroll Street, 3rd Street, 9th Street, and Hamilton Avenue. The Gowanus Expressway and the Culver Line of the New York City Subway pass overhead. North of Hamilton Avenue, the canal is approximately 5,600 feet long and 100 feet wide, with a maximum water depth of approximately 15 feet in the main channel at low tide. There are four short turning basins that branch to the east of the main channel at 4th Street, 6th Street, 7th Street, and 11th Street. A former basin at 1st Street and an extension of the 4th Street basin that had been referred to as the 5th Street basin were filled in between 1953 and 1965 (Hunter Research et al., 2004). An extension of the 7th Street basin has also been filled. The bottom sediments near the head of the canal and at the heads of the turning basins are exposed at low tide. South of Hamilton Avenue, the canal widens to approximately 2,200 feet and ranges in depth from -15 to -35 feet mean lower low water

(MLLW).² The vast majority of the shoreline of the canal is lined with retaining structures or bulkheads.

The canal is located in a mixed residential-commercial-industrial area, and it borders several residential neighborhoods, including Gowanus, Park Slope, Cobble Hill, Carroll Gardens, and Red Hook. The waterfront properties abutting the canal are primarily commercial and industrial.

1.2.1 Site History

Prior to being developed, the area around the Gowanus Canal was occupied by Gowanus Creek, its tributaries, and lowland marshes. Before the mid-1840s, the creek and its tributaries were dammed and used primarily to power tide mills (Hunter Research et al., 2004). By the mid-1840s, Brooklyn was rapidly growing, and the Gowanus marshes were considered to be a detriment to local development. In 1848, the State of New York authorized construction of the Gowanus Canal to open the area to barge traffic, flush away sewage, receive stormwater, and fill the adjacent lowlands for development. The canal was constructed between 1853 and approximately 1868, and rapid industrial development followed.

In 1911, New York City constructed and began operating the Gowanus Canal flushing tunnel to address serious water quality issues in the canal. The tunnel was constructed to connect the head of the canal with Buttermilk Channel in Upper New York Bay (Figure 1-2). It was designed to improve circulation and flush pollutants from the canal by pumping water in either direction. The tunnel starts at Degraw Street on Buttermilk Channel and ends on the west side of the canal at Douglass Street. The tunnel was operated until the mid-1960s, when it fell into disrepair and funding was unavailable to fix it. The flushing tunnel was rehabilitated and reactivated in 1999 by the NYCDEP, pumping water only from Buttermilk Channel to the Gowanus Canal using the 1911 technology. The flushing tunnel was shut down by the NYCDEP on July 19, 2010, for an extended period of facility improvements to modernize the technology and improve operations (see Section 1.2.4).

1.2.2 Dredging History and Navigational Requirements

Minimal recent dredging of the Gowanus Canal has been performed, and documentation of historical dredging is sparse. North of Hamilton Avenue, any dredging would have been performed by New York City or local commercial interests. Historical documents suggest that dredging was very limited and, when it was performed, most likely targeted the accumulation of material near outfalls on the canal (Hunter Research et al., 2004). The upper reaches of the canal were dredged by NYCDEP in 1975 (NYCDEP, 2008a). In 1998, the area near the flushing tunnel was dredged, and nearly 1,100 cubic yards (yd³) of material was removed to allow the tunnel to be reactivated (GEI, 2007). These sediments were removed to facilitate construction and assure an unobstructed discharge from the tunnel. There are no federal, state, or local regulatory requirements related to the depth of the canal north of Hamilton Avenue (Carr, 2011).

Below Hamilton Avenue, the USACE previously performed maintenance dredging. In 1896, the federal channel was authorized to a depth of 26 feet south of Percival Street (between

² The average of the lower low water height each tidal day.

Halleck and Bryant Streets, Figure 1-1). In 1952, federal work to Hamilton Avenue was authorized, with a 100-foot-wide, 18-foot-deep channel from Hamilton Street to Sigourney Street (between Bay and Halleck Streets), deepening to 30 feet between Sigourney and Percival Streets, and continuing from Percival Street to 28th Street (south of the project area), with a channel widening from 200 to 500 feet.³ USACE suspended regular maintenance dredging in 1955, and the last maintenance dredging event occurred in 1971, where nearly 74,000 yd³ of sediment was removed between 28th Street and Hamilton Avenue (GEI, 2007; NYCDEP, 2008a).

A number of businesses use the canal for maritime commerce. All but one of these businesses are located south of 9th Street, and none are located north of 4th Street. Commercial navigation in the canal is expected to continue in the future. A dredging alternatives analysis performed by USACE assumed a depth of -16 feet relative to North American Vertical Datum 1988 (NAVD88) for navigation between 3rd Street and Hamilton Street, and no commercial navigation north of 3rd Street (USACE, 2009).

1.2.3 Adjacent Land Use

The canal waterfront, or riparian area (defined as all blocks wholly or partially within one quarter mile of the canal), is occupied primarily by commercial and industrial properties. The riparian areas are classified as 18 percent residential, 6 percent park, and 76 percent mixed use. The entire watershed is 53 percent residential, 2 percent park, and 45 percent mixed use (NYCDEP, 2008a). Current commercial and industrial land use along the canal is shown in Figure 1-3. Current land use was identified in October 2010 based on a windshield survey of the properties along the canal coupled with a review of current tax maps. The survey did not include interviews with property owners or property inspections to refine property-use classification. Based on the windshield survey, the waterfront properties along the canal are currently used mostly for consumer-oriented businesses and operations (e.g., retail stores, small business offices), commercial purposes, municipal operations, and industrial purposes. Areas of historical commercial and industrial land use are also shown in Figure 1-3, including the locations of three former MGP sites (Fulton, Carroll Gardens/Public Place, and Metropolitan).

1.2.4 Combined Sewer Overflow and Stormwater Discharges

As noted, CSO and stormwater discharges are the only major sources of freshwater to the Gowanus Canal. Combined sewers (i.e., sewers that receive both sewage and stormwater flows) serve 92 percent of the Gowanus Canal watershed, storm sewers serve only 2 percent, and direct runoff drains 6 percent of the watershed (NYCDEP, 2008a). During wet weather, runoff enters the combined sewers and exceeds the capacity of the system when an appreciable rate of rainfall occurs. There are two combined sewer systems in the watershed that overflow to the canal: the Red Hook and Owls Head water pollution control plants. Between these systems, there are 12 permitted CSOs to the project area; 10 of these are active. In addition, there are three known stormwater outfalls discharging to Gowanus

³ Federally authorized depths are reported by the USACE relative to MLLW. In this FS, depths and elevations are reported relative to NAVD88. The federally authorized channel depths of 18 feet and 30 feet MLLW are equivalent to approximately -21 feet and -33 feet NAVD88, respectively.

Canal. Figure 1-4 shows the locations of the outfalls. There are also highway drains discharging to the canal; these are not shown in the figures.

The greatest annual discharge volumes are from outfalls RH-034, at the head of the canal; RH-035, at the intersection of Bond and 4th Streets; and OH-007, at the north end of 2nd Avenue (121 million gallons, 111 million gallons, and 69 million gallons, respectively; NYCDEP, 2008a). A floatables boom is installed in the canal at Sackett Street to retain floating debris that enters the canal from the RH-034 outfall.

In 2008, the NYCDEP prepared the *Gowanus Canal Waterbody/Watershed Facility Plan Report* as part of its City-Wide Long-Term CSO Control Planning Project (NYCDEP, 2008a). This work is being performed under an Administrative Order on Consent between NYCDEP and NYSDEC.⁴ The goal of the project is to implement a series of improvements to achieve compliance with water quality standards. Specific objectives of the plan include eliminating odors, reducing floatables, and improving dissolved oxygen (DO) concentrations to meet surface-water-quality standards. NYCDEP's planned improvements for the Gowanus Canal have the following six components: (1) continued implementation of programmatic controls, (2) modernization of the Gowanus Canal flushing tunnel, (3) reconstruction of the Gowanus Wastewater Pump Station, (4) cleaning/inspection of the OH-007 floatables/solids trap, (5) periodic water body floatables skimming, and (6) dredging. These improvements were proposed collectively to reduce the loading of contaminants to the canal in addition to improving overall water quality.

The modernization of the flushing tunnel includes replacing the existing tunnel pumping system with more-efficient pumping systems. This modernization effort will increase the volume of water conveyed through the tunnel by approximately 40 percent. In early 2010, an aeration pipe was installed within the canal to circulate super-oxygenated water while the flushing tunnel was shut down for repair. The aeration pipe went online in early July 2010, and the repairs were initiated with the flushing tunnel being shut down, on July 19, 2010. The completion date is anticipated to be September 2014.

The reconstruction of the Gowanus Wastewater Pump Station will address the pumping station at the head of the canal. The reconstruction will increase the pump station capacity, restore force main flow, and add floatables-screening devices at outfall RH-034 at the head of the canal. These improvements are anticipated to decrease CSO discharges to the canal by 127 million gallons per year (approximately 34 percent), provide screening for 32 percent of the annual CSO discharge, and reduce solids by approximately 37 percent. Improvements to the RH-034 pumping facility were initiated in February–March 2010. The completion date of this construction is also anticipated to be September 2014.

In addition, NYCDEP proposes dredging 750 feet of the canal from its head downstream and applying a 2-foot-thick sand cap so that the final water depth will be -3 feet MLLW. The dredging is intended to eliminate exposed sediments and associated odors observed at low tide, improve aesthetics, and provide improved benthic habitat. The canal has not yet been dredged. The timeline specified by the long-term control plan (LTCP) indicated that permit applications would be submitted by June 2010 and that dredging would begin within 3 years, and be completed within 5 years, of receipt of the final permits.

⁴ NYSDEC Case No. CO2-20000107-8 dated January 14, 2005, and updated on April 14, 2008.

1.3 Remedial Investigation Summary

The following activities were performed for the Gowanus Canal RI, which was completed in three phases:

- Phase 1
 - Bathymetric survey
 - Survey of outfall features, including identifying outfall features, collecting and analyzing outfall water samples, and tracing outfall features to their origin
 - Cultural resources survey, including a bulkhead study
- Phase 2: Sediment coring
- Phase 3
 - Surface sediment sample collection and analysis
 - Surface water sample collection and analysis
 - Fish and shellfish tissue sample collection and analysis
 - Air sample collection and analysis
 - CSO sediment and water sample collection and analysis
 - Hydrogeologic investigation, which included (1) groundwater-monitoring-well installation and development; (2) groundwater sampling; (3) groundwater-surface water interaction sampling; (4) synoptic measurements of water levels; (5) tidal evaluation; and (6) oversight of well installation and soil-sampling activities performed by National Grid and New York City

This section summarizes the major findings of the RI.

1.3.1 Gowanus Canal Physical Characteristics

Physical characteristics of the Gowanus Canal, including bathymetry, debris, sediment characteristics, bulkhead characteristics, geology and hydrogeology, and historical and cultural characteristics, are described below.

Bathymetry

The bathymetry of the Gowanus Canal, based on a January 2010 survey, is shown in Figures 1-5a through 1-5c. The measured bottom depth elevations ranged from approximately -0.13 feet to -38 feet NAVD88. The bottom depth elevations measured within the canal north of Hamilton Avenue were typically between -0.13 feet and approximately -18 feet NAVD88 (Figures 1-5a and 1-5b); much lower sediment surface elevations were measured south of Hamilton Avenue (Figure 1-5c). The sediment surface at the head of the canal and in the eastern ends of many of the turning basins is exposed at low tide. Evidence of propeller scour in the form of a deeper sediment surface was noted in the southern portion of the canal; this area is subject to frequent tugboat activity to move and position oil and gravel barges at the various commercial terminals near the mouth of the canal.

Debris and Obstructions

Debris such as tires, sunken barges, concrete rubble, timbers, gravel, and general trash is widespread throughout the canal. Ocean Surveys, Inc., performed a debris survey in late

2005 on behalf of National Grid using magnetometer, sub-bottom profiling, and side-scan sonar technologies. The combined observations from the 2005 geophysical surveys and the 2010 field observations are illustrated in Figures 1-6a through 1-6c. Briefly, the key observations are as follows:

- Gravel covers the sediment surface of the entire main channel south of the concrete plant at the end of 5th Street to south of the 9th Street bridge and the area adjacent to the New York City asphalt plant south of Hamilton Avenue.
- Debris piles (generally concrete, iron beams, and other large, construction-type debris) were often observed near the ends of streets that ended at the canal.
- The channel, particularly the western shoreline approximately one city block downstream of the Hamilton Avenue bridge, is covered with debris.
- All the turning basins have significant accumulations of debris, including a sunken barge in the 6th Street turning basin and multiple large debris piles and wreckage of a small boat in the 4th Street turning basin.
- Tires and smaller objects identified as anomalies by side-scan sonar and magnetometer surveys are widespread throughout the canal.
- A steel and concrete gas tunnel passes under the canal in the vicinity of the Carroll Gardens/Public Place former MGP site.

A second high-resolution side-scan sonar survey was performed in 2010 as part of USEPA's cultural resources survey. Several areas of debris were also identified during this survey, as shown in Figures 1-6d through 1-6f. The 2010 survey identified a number of anomalies with potentially significant historical characteristics, as detailed in the RI report. The results of the 2005 and 2010 surveys are very similar, and the recent survey confirms that the data collected earlier are still usable.

Sediment Stratigraphy and Characteristics

The sediments within and beneath the Gowanus Canal consist of two distinct layers, as shown in Figure 1-7. The upper layer is referred to as "soft" sediment. The soft sediments have accumulated in the canal over time since the canal was first constructed. The soft sediment layer ranges in thickness from approximately 1 foot to greater than 20 feet, with an average thickness of about 10 feet. The thickest deposits were found at the head of the canal and within the turning basins. The soft sediment consists generally of a dark-gray-to-black sand-silt-clay mixture that contains variable amounts of gravel, organic matter (e.g., leaves, twigs, vegetative debris), and trash. Odors described as "organic," "septic-like," "sulfur-like," and "hydrocarbon-like" were commonly observed in the soft sediment during the RI, as were visible sheens.

The soft sediments are underlain by the alluvial and marsh deposits of the Gowanus Creek complex that were originally present. These deposits are referred to as "native" sediments in this report and consist of brown, tan, and light-gray sands, silts, silty sand, sandy clay, clay, and peat.

Table 1-1 summarizes the total organic carbon (TOC) content, grain size distribution and total percent fines content (silt plus clay fractions), percent solids, sulfide, bulk density, and percent moisture for each stratigraphic unit within the canal. Data for the reference area in Gowanus Bay and Upper New York Bay are also shown.

Shoreline and Bulkhead Characteristics

NYCDEP (2008b) documented that the shorelines of the Gowanus Canal are entirely altered and are dominantly bulkheads with small areas of riprap or piers; the bulkheads north of Hamilton Avenue are generally constructed of wood or steel. The NYCDEP report also noted four areas where the shoreline consisted of riprap: between 11th Street and the Gowanus Expressway, between 17th and 19th Streets on the eastern side of the canal, between Sigourney Street and Halleck Street, and on the eastern end of Bryant Street on the western side of the canal.

A bulkhead inventory performed along the entire length of the canal by Brown Marine Consulting (2000) indicated that there are four primary types of bulkheads:

- Crib-type bulkheads, which are constructed of interlocking timbers or logs that are filled with backfill to form a type of gravity retaining structure
- Gravity retaining walls, which are built so that the weight of the wall itself provides stability
- Relieving platforms, which consist of a deck of timber or concrete supported on piles, typically timbers or logs, at an elevation high enough above the mean low water line to not require underwater construction techniques but low enough to keep the pilings continuously submerged
- Steel sheet pile bulkheads, which are a flexible wall constructed of steel sheets with interlocking joints. The steel is capped with concrete or masonry construction. Anchorage systems prevent outward movement and consist of a tie-rod and anchors (e.g., structures buried inshore of the bulkhead, such as massive concrete blocks or steel sheet piles)

Hunter Research et al. (2004) also surveyed bulkhead conditions, in 2003. That survey determined that approximately 73 percent of the bulkheads along the main canal and turning basins were crib-type bulkheads with timber construction. Approximately 10 percent of the bulkheads consisted of concrete or bridge abutments, and 17 percent were timber or steel sheet-piling-type barriers.

The 2000 survey (Brown Marine Consulting, 2000) concluded that the existing structures were sufficient only to support present loading conditions, and that any type of dredging activities could threaten bulkhead stability due to the deteriorated condition of the structures. The 2000 survey was based only on visual examinations of structures without physical or laboratory testing and recommended that a more thorough investigation of bulkhead integrity be performed if dredging is planned. The report also noted that an estimated 41.7 percent of the bulkhead length was in fair condition or worse.

Historical and Cultural Characteristics

As part of the RI activities, Dolan Research, Inc., and JMA performed a review of the bulkheads along the canal to assess their significance and their potential eligibility for nomination to the National Register of Historical Places (NRHP). This review was based on historical information from the sources cited in the previous section as well as on a 1-day bulkhead inspection from water conducted on October 19, 2010. The report from Dolan Engineering and JMA is provided in Appendix M of the RI report.

Documentary research and a high-resolution side-scan sonar survey identified known historic resources in the form of the canal bulkheads, as well as anomalies on the canal bottom, that will be subject to further investigation. The variety of bulkheads reflects an evolution of technology, a varied use of materials, and an effective means of maintaining the function of the canal, thus ensuring its role in the commercial development of Brooklyn. These resources, depending on their individual integrity, are considered to be eligible for nomination to the NRHP. Should the bulkheads be subject to adverse effects as a result of cleanup actions, a wide range of mitigating measures would be investigated and considered as part of the remedy. These measures would likely include additional documentation of bulkhead characteristics and the incorporation of archaeological and architectural investigations as appropriate.

Potential configurations of new construction that are in keeping with the historic character of the setting would be considered. As remediation methods are considered, further examination of anomalies on and within the sediments will need to be examined. This investigation could encompass further remote sensing or direct examination of the canal bottom. USEPA is in process of completing a historical study of the Gowanus Canal. The results will be made available after the date of this Draft FS Report.

Geology and Hydrogeology

The following geologic units (in order of increasing depth and age) lie beneath the area surrounding the Gowanus Canal:

- Fill
- Alluvial/marsh deposits
- Glacial sands and silts
- Bedrock

Fill materials are associated with canal construction and subsequent industrialization and regrading of the area, much of which was originally marshland. The fill consists of silts, sands, and gravels mixed with fragments of brick, metal, glass, concrete, wood, and other debris.

The alluvial/marsh deposits lie below the fill and are composed of sands (alluvial deposits from flowing water bodies), peat, organic silts, and clays (marsh deposits). These alluvial/marsh deposits are associated with the original wetlands complex (i.e., native sediment) that was present when the area was settled.

A thick sequence of glacial deposits occurs below the alluvial/marsh deposits. The full thickness of the glacial deposits was not penetrated in the RI, but the observed glacial deposits were composed mostly of coarser grain sediments (sands and gravel) and

occasional beds of silt. These glacial sands, silts, and gravel were deposited as glacial ice melted during the retreat of the last ice age. At the base of the glacial sequence lies a layer of dense clay, deposited by the glacier or prior to glaciation.

Weathered and competent bedrock underlies the glacial deposits. The bedrock consists of a medium- to coarse-grained metamorphic rock known as the Fordham Gneiss (GEI, 2005).

The primary aquifer beneath the Gowanus Canal and surrounding uplands is identified as the Upper Glacial Aquifer, which generally occurs in the thick sequence of glacial deposits but may include sandy units in the alluvial/marsh sediments. The Upper Glacial Aquifer appears to be generally unconfined, although local beds of silt and clay may confine underlying sand beds. In the Upper Glacial Aquifer, regional groundwater flows to the west/southwest toward Gowanus Bay. Groundwater-bearing zones in the fill and alluvial/marsh deposits discharge to the Gowanus Canal.

Multiple lines of evidence were developed in the RI to characterize the hydraulic relationships between local groundwater and the Gowanus Canal. Potentiometric surfaces developed from the synoptic (instantaneous point in time) measurement events suggests that, at the water table, groundwater flows towards the Gowanus Canal. Potentiometric data from intermediate wells screened in the glacial deposits depict a more-complex pattern, with groundwater generally flowing upward toward the canal, which is typical of a discharge area. Data from a 5-day tidal evaluation indicate that at specific locations adjacent to the canal, canal elevations at high tide consistently exceeded groundwater elevations in the shallow fill/alluvium, creating hydraulic conditions for surface water to intermittently flow into shallow aquifer sediments.

1.3.2 Nature and Extent of Contamination

The horizontal and vertical distribution and extent of contamination in surface sediment (0-to-6-inch depth interval), soft sediment (from a depth of 6 inches below the sediment surface to the contact with the native Gowanus Creek sediments), and native sediment (i.e., original Gowanus Creek alluvial and marsh deposits) were characterized on the basis of field observations and chemical analysis of sediment samples. Contaminant concentrations in surface water and ambient air samples were also measured. The nature and extent of contamination in each medium are summarized below.

Sediment

Gowanus Canal sediments are affected by contaminants that are adsorbed to sediment particles and by NAPL. Contaminant concentration data for surface, subsurface soft, and native sediment samples are summarized in Table 1-2. In surface sediments (0-to-6-inch depth interval), the following constituents were found to be contributing to unacceptable ecological and human health risks (Section 1.3.3): polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and seven metals (barium, cadmium, copper, lead, mercury, nickel, and silver). Concentrations of these constituents in surface sediment were significantly higher in the canal than at reference locations in Gowanus Bay and Upper New York Bay.

Subsurface sediment-sampling data indicated that total PAHs and volatile organic compounds (VOCs), particularly benzene, toluene, ethylbenzene, and xylenes (BTEX), were

frequently detected at high concentrations in both the soft and native sediment units. PCBs and metals were all frequently detected in the soft sediment but were infrequently detected or detected at lower concentrations in the native sediments. In the subsurface soft sediment, VOCs (primarily BTEX), PAHs, PCBs, and metals were all detected at higher concentrations than those found in the surface sediments.

The sediment-coring effort indicated that NAPL contamination is present in native sediments underneath the canal between the head of the canal and the Gowanus Expressway, and in the overlying soft sediment primarily in the middle reach of the canal. The NAPL appears to be coal tar waste from three former MGP sites (Fulton, Carroll Gardens/Public Place, and Metropolitan) that is migrating through subsurface soils, under or through the bulkheads, and into the sediments in and under the canal. PAHs and BTEX are major constituents of coal tar. Appendix A provides additional information about the NAPL found in Gowanus Canal sediments, including a more detailed description of the NAPL properties and its distribution in canal sediments.

In most areas north of the Gowanus Expressway, NAPL and high-PAH concentrations were found in sediment to the maximum depth of the investigation activities, which was targeted to be 6 feet below the contact between the soft and native sediment layers. Deep borings installed in the canal adjacent to the Carroll Gardens/Public Place former MGP site by National Grid in 2010 indicate that contamination extends to a depth of greater than 50 feet.

Surface Water

VOCs, semivolatile organic compound (SVOCs), and metals were detected in surface water samples collected under wet-weather and dry-weather conditions for the RI. Pesticides and PCBs were not detected in any surface water sample. BTEX compounds were the most common VOCs detected, and PAHs were the most common SVOCs detected. Concentrations of benzene, PAHs, and manganese in the canal surface water were significantly higher than their concentrations at the Gowanus Bay and Upper New York Bay reference locations in both dry- and wet-weather conditions.

Ambient Air

The sampling results for air samples collected from canoe-level and street-level locations along the length of the canal and from three background locations (Figure 2-9 of the RI report) indicate that the types and concentrations of VOCs and PAHs detected in air samples were similar regardless of sample location. The constituents detected were typical of those found in urban environments.

1.3.3 Summary of Ecological and Human Health Risk Assessments

The Gowanus Canal has no natural shoreline, wetlands, or upland areas. The community of potential ecological receptors using the canal includes fish-eating birds; dabbling ducks; invertebrates such as worms, amphipods, and mollusks; and crabs and fish. The potential ecological risk to these receptors from exposure to surface water and sediment in the canal was evaluated in the ecological risk assessment (ERA). The human health risk assessment (HHRA) evaluated potential risks to recreational users, anglers, residents, and industrial workers near the canal.

Ecological Risk Assessment

The combined screening level ecological risk assessment (SLERA) and baseline ecological risk assessment (BERA) performed for the Gowanus Canal completed Steps 1 and 7 of the eight-step ERA process described in the USEPA (1997) *Ecological Risk Assessment Guidance for Superfund* and its updates. The survival and reproduction of the following receptor groups were selected for evaluation in the ERA:

- Benthic (sediment)-dwelling macroinvertebrate communities
- Water-column-dwelling aquatic life communities,
- Avian wildlife (aquatic herbivores, aquatic omnivores, and aquatic piscivores)

The following summarizes the key investigation methods and findings and conclusions for each receptor group.

Risks to benthic macroinvertebrate communities were evaluated primarily through the use of laboratory-based sediment bioassays, which were conducted with two sediment-dwelling invertebrates (amphipods and polychaetes), and through the comparison of sediment chemical concentrations to literature-based screening benchmarks. The analyses indicate the following:

- Sediment bioassays indicate a site-related potential for adverse effects to benthic communities from chemicals in sediment, with the greatest potential for adverse effects occurring in the central portion of the canal. The bioassay results also indicate the potential for less severe, but site-related adverse effects to the benthic community at several other locations scattered throughout the canal.
- Chemical analysis indicates the presence of organic chemicals (primarily PAHs and PCBs) and metals in sediment at concentrations that are likely to be causing the adverse effects observed in the sediment bioassays. The highest concentrations of those chemicals were detected primarily in the central portion of the canal, which coincides with the locations where the most severe effects to the sediment bioassay organisms were also observed.
- PAHs were consistently detected in sediment at the highest concentrations relative to their ecological screening benchmarks and are considered to represent the greatest site-related risk to the benthic community. Other chemicals, most notably PCBs and seven metals (barium, cadmium, copper, lead, mercury, nickel, and silver), were also detected at concentrations above their ecological screening benchmarks and at concentrations above those detected in reference area sediments, and are also considered to represent a potential site-related risk to the benthic community.

Risks to water-column-dwelling aquatic life communities were evaluated primarily through the comparison of surface water chemical concentrations, which were sampled both during a dry and wet (while CSO outfalls were discharging) periods, to literature-based screening benchmarks. Chemical concentrations in surface water indicate very little site-related potential for adverse effects to water-column-dwelling aquatic life.

Risks to avian aquatic wildlife were evaluated by modeling the potential exposure of these receptors to chemicals ingested in prey (fish and crabs) and through the ingestion of sediment. The analyses indicate the following:

- Potential risk to aquatic herbivores (represented by black duck) from exposure to PAHs. PAHs were detected onsite (in sediments) at concentrations above those detected in reference area locations and represent a site-related risk to aquatic herbivores.
- Potential risk to avian omnivores (represented by heron) from exposure to mercury and selenium. However, mercury was the only metal that was frequently detected both in fish and crab tissues at elevated concentrations and that was also detected onsite (in sediments) at a concentration above those detected in reference area locations, and thus represents a site-related risk to avian omnivores.
- There is no potential risk to avian piscivores such as the double-crested cormorant from the ingestion of fish in the canal.

Human Health Risk Assessment

The HHRA was conducted to evaluate the potential human health risks associated with direct contact with surface sediment and surface water in the Gowanus Canal, ingestion of fish and crabs, direct contact with sediment and surface water that overtop the canal during extreme tidal or storm surge conditions, and inhalation of emissions from the canal into the ambient air near the canal. Two scenarios were evaluated: (1) a reasonable maximum exposure (RME), which uses conservative exposure factors to estimate the reasonable maximum exposures anticipated for the canal, and (2) a central tendency exposure (CTE), which describes a more typical or average exposure. Two types of effects were evaluated: noncarcinogenic hazards and carcinogenic risks. Acceptable risk levels are defined in National Contingency Plan (40CFR300.430(e)(2)(I)(A)).

For an adult, an adolescent, and a child using the canal for recreational purposes, the risks associated with exposure to surface water and surface sediment (from exposed and near-shore locations) in the canal and from ambient air at canal level while swimming were evaluated. The HHRA assumed that recreational use/swimming in the canal would occur at frequencies, durations, and exposures that are typical of most water bodies, even though the actual use of the canal is lower given its nature. The total RME noncarcinogenic hazard associated with exposure to all of the media for all recreational users was within USEPA acceptable risk levels. However, exposure to all of the media by recreational adults, adolescents, and children may result in carcinogenic risks above USEPA's target risk range. These risks are associated primarily with exposure to carcinogenic PAHs in the surface water and the surface sediment. The total noncarcinogenic hazard based on the CTE assumptions was within or below USEPA's acceptable risk levels; however, carcinogenic risk was above USEPA's target range.

The risks associated with exposure to ambient air at street level and with surface water and surface sediment from canal overflow were evaluated for residential adults and children and for industrial workers. RME noncarcinogenic hazards and carcinogenic risks associated with exposure to these media by the industrial worker are within acceptable levels. Exposure to all of the media by residential adults and children may result in carcinogenic risks above USEPA's acceptable risk levels. The RME carcinogenic risk for the adult/child

resident is associated with carcinogenic PAHs in sediment (with a smaller contribution from surface water). The total carcinogenic risk evaluated under the CTE assumptions was within or below USEPA's acceptable risk levels.

Risks associated with ingesting fish and crabs from the Gowanus Canal were evaluated for the angler adult, adolescent, and child. The HHRA assumed fishing/crabbing and ingestion of the fish/crab from the canal at typical recreational angler fish/crab consumption rates, which is very conservative given the nature of the canal. The RME and CTE total noncarcinogenic hazards and/or carcinogenic risks for all receptors exceeded USEPA acceptable levels. The noncarcinogenic hazards and carcinogenic risks are associated with PCBs in fish and crab. The average concentrations of PCBs in the canal fish and crab samples were about two times higher than the average PCB concentrations in the reference area samples collected from Gowanus Bay and Upper New York Bay. However, the PCB concentrations in the reference samples would also result in noncarcinogenic hazards and carcinogenic risks above USEPA acceptable levels.

1.4 Conceptual Site Model

The CSM for the Gowanus Canal summarizes and integrates information about historical and ongoing sources of contamination, the nature and extent of contamination (Section 1.3.2), contaminant fate and transport mechanisms, and risks to humans and wildlife from exposure to contaminated sediments in the Gowanus Canal (Section 1.3.3). Sources of contamination and fate and transport mechanisms are described below. A schematic representation of the CSM for the Gowanus Canal is provided in Figure 1-8. This CSM is used as the basis for developing remedial alternatives for canal sediments.

1.4.1 Sources of Contamination

The Gowanus Canal has been affected by numerous known and potential sources of contamination for a period of about 140 years. The major sources of contamination to the canal are (1) historical industrial activities, (2) upland contaminated sites, (3) CSO and stormwater discharges, and (4) discharges from other pipe outfalls. All of these sources except for historical industrial activities continue to contribute contaminants to the canal. These sources, including an assessment of the potential for ongoing sources to recontaminate canal sediments after a remedy is implemented, are described further below. Active sources should be controlled prior to remediation of Gowanus Canal sediments to prevent recontamination.

Direct Discharges from Historical Industrial Activities

These activities included manufactured-gas production; bulk handling of products such as petroleum, coal, chemical fertilizers, oil, and scrap metal; various manufacturing activities; and other industrial operations. Wastes from many of these operations were discharged directly into the canal. Based on the site history and the poor environmental practices typical of the era, a large quantity of waste was likely released through this pathway. Direct discharges from industrial activities were substantially reduced or controlled over time because of declining industrial activity and the implementation of the Clean Water Act in the early 1970s. Discharges from present-day industrial operations are regulated and permitted under the National Pollutant Discharge Elimination System (NPDES). The higher

concentrations of most contaminants in subsurface (buried) soft sediments compared to those in surface sediments may reflect the contribution of historical sources of contamination that are no longer present along the canal as well as historical contributions from CSOs, although some of the historical contamination would have been removed by past dredging events.

Discharges from Upland Contaminated Sites Adjacent to the Canal

Contaminants from upland contaminated sites can be transported into the Gowanus Canal by migration of NAPL through subsurface soils, groundwater discharge of dissolved-phase contaminants, and surface runoff (i.e., overland transport of contaminated soils). The RI sampling results indicate that NAPL contamination is present in native and soft sediment in the canal, primarily in native sediment north of the Gowanus Expressway and soft sediment in the middle reach of the canal. The NAPL has migrated and continues to migrate from the three former MGP sites under and possibly through the bulkheads into the sediments in and beneath the canal. NAPL is present at depths of greater than 6 feet below the contact between the soft and native sediments at many locations in the canal. Therefore, any NAPL remaining in place after a sediment remedy is implemented could act as an ongoing source of contamination to overlying canal sediments. An analysis of the potential for upward migration of NAPL from native to soft sediments indicates that upward migration may be occurring in some areas (Appendix A). Any NAPL seeping into the canal from the shoreline (e.g., seepage through the bulkheads) could also act as an ongoing source of contamination to canal sediments; this pathway will be addressed as part of the upland source control measures.

The RI sampling results indicated that the transport of dissolved-phase contaminants to the canal by groundwater discharge is occurring at some locations. Analytical results for groundwater samples collected during the RI were evaluated to assess the potential for contaminated groundwater discharge to recontaminate canal sediments following a remedial action. The evaluation focused on the constituents that were found to be contributing to unacceptable ecological and human health risks: PAHs, PCBs, and metals (barium, cadmium, copper, lead, mercury, nickel, and silver).

There are no established criteria for evaluating PAH concentrations in groundwater with respect to potential risk from groundwater discharge to surface water bodies. Therefore, a screening approach based on USEPA's equilibrium sediment benchmark (ESB) guidance for PAH mixtures (USEPA, 2003) was developed to identify and prioritize upland sites along the canal with the potential to recontaminate canal sediment with PAHs by groundwater transport. The full screening analysis is provided in Appendix B and is summarized below.

The screening approach is based on the following assumptions:

- No attenuation, transformation, or binding of PAHs will occur; therefore, PAH concentrations in groundwater equal potential PAH concentrations in sediment pore water.
- The principal form of toxicity elicited by PAHs to benthic invertebrates is narcosis. Narcotic toxicants demonstrate additive toxicity; that is, the effects of narcotic toxicants can be added together to summarize the total amount of toxicity present in a mixture of such chemicals (as occurs in sediments).

The following procedure was used to screen upland sites for potential concern:

- Select final chronic values (FCVs) for the 34 PAHs listed in USEPA's guidance document for PAH mixtures (USEPA, 2003). The FCVs are based on USEPA's National Water Quality Criteria, and are the concentrations of chemicals in water that are considered to be protective of the presence of aquatic life. The document recommends that 34 PAHs be analyzed when assessing the risk represented by PAHs in contaminated sediments. However, the Gowanus Canal groundwater samples were analyzed only for the 16 PAHs that are part of the Target Compound List. If results are available for only a subset of the 34 PAHs (i.e., 13 or 23 commonly quantified PAHs), the benchmark document provides uncertainty factors that can be applied to account for the missing PAHs. An uncertainty factor of 11.5 was selected for this analysis, as detailed in Appendix B.
- Calculate the ratios of the concentrations of 13 individual PAHs in each groundwater sample to the corresponding FCVs.
- Sum the ratios for the 13 individual PAHs into a toxicity unit (TU) for each sample.
- Multiply each TU by 11.5 to account for the PAHs that were not analyzed.
- Rank all sites with TUs greater than 1 from highest to lowest. If the calculated TU is less than 1, then the site is assumed to pose no risk to the sediment from groundwater discharge. Because some attenuation of PAH concentrations is expected to occur as groundwater discharges to the canal, sites with TUs between 1 and 10 were assumed to pose minimal risk to the canal from groundwater discharge.

The TU for each groundwater sample is summarized in Table 1-3. Figures 1-9a and 1-9b show the locations of shallow and intermediate groundwater samples, respectively, with PAH TUs that exceed 10. These figures also show the locations where NAPL was observed in monitoring wells. In shallow wells, TUs were highest (i.e., greater than 100) in four areas: near the Fulton former MGP site, near President Street, immediately downstream of 9th Street, and near Halleck Street. NAPL was observed in wells in three of these four areas. In intermediate wells, TUs of greater than 1,000 were identified near 4th Street and immediately downstream of 9th Street. TUs of greater than 100 were identified in the same areas as the shallow wells, as well as near Carroll Street, the infilled 1st Street basin, the infilled portion of the 4th Street basin, and near the 6th Street basin. These areas may pose a risk of recontamination from ongoing transport of PAHs to the canal by groundwater discharge.

PCBs were not detected in groundwater samples. For metals, the results of the screening evaluation performed for the RI were examined to identify the frequency and magnitude of sample concentrations that were elevated above screening criteria. Metals concentrations were within a factor of 10 times the screening criteria at all locations except one, and locations with concentrations above criteria were generally dispersed across the length of the canal with no indication of significant, pervasive contaminant plumes. Based on these results, ongoing discharge of metals and PCBs to the canal by groundwater transport does not appear to be a concern.

CSO and Stormwater Discharges

The Gowanus Canal served as an open sewer when it was initially constructed in the late 1860s. By the late 1870s, sewers entering the canal carried a combination of household waste, industrial effluent from gas works and other industries, and stormwater runoff (Hunter Research et al., 2004). Prior to the implementation of the Clean Water Act, the contaminant load in sewage and stormwater discharges to the canal was greater than it is under present-day conditions.

New York City has taken various measures over the years to mitigate the impacts of sewage and stormwater discharges, and a variety of additional upgrades and control measures is in progress or planned as part of the LTCP. Today, CSOs occur only during wet weather, discharging a mixture of sanitary sewage and stormwater to the canal. Of the 10 active CSOs, four discharge 95 percent of the total annual wet-weather discharge (RH-034, RH-035, OH-007, and RH-031; Figure 1-4). CSO discharges result in point source loading of high-organic-content solids. Collection system modeling performed for the LTCP indicates that the current annual loading of total suspended solids (TSS) to the canal is approximately 259,000 lbs (approximately 222,000 lbs from CSOs and 37,000 lbs from stormwater discharges) (NYCDEP, 2007). The reconstruction of the Gowanus Wastewater Pump Station is expected to decrease CSO discharges to the canal by approximately 34 percent and reduce the total annual TSS load (CSO and stormwater) by 32 percent, to 177,000 lbs.

Sampling results for wet-weather flow samples collected from the CSO system for the RI indicate that VOCs, SVOCs (primarily PAHs), and metals are discharged to the canal during overflow events. VOCs, SVOCs (primarily PAHs), metals, pesticides, and PCBs were detected in residual sediment collected from the CSO pipes during dry-weather conditions. The CSO wet-weather water-sampling data collected for the RI, in conjunction with information about discharge volumes, were used to estimate contaminant loading from the CSOs under present-day conditions. The estimated ranges of PAH and metal concentrations attributable to the ongoing deposition of CSO solids was determined based on CSO wet-weather water sample data (Table 1-4; details are provided in Appendix B). PCBs were not included because they were detected in only one wet-weather CSO water sample. CSO sediment data were not used in this analysis because the residual sediments in the sewer lines were notably sandier than the surface sediments in the canal and, therefore, are considered to be less representative of the solids discharged to the canal.

The values reported in Table 1-4 represent the estimated range of PAH and metals concentrations on CSO solids discharged from the outfalls that convey 95 percent of annual CSO and stormwater discharge (RH-034, RH-035, OH-007, and RH-031), assuming that all of the contamination is associated with the particulate phase. Because the CSO wet-weather water samples are considered to represent the quality of solids discharged from the CSOs, CSOs are a major source of solids to the canal, and CSO solids settle within the canal, these levels would be expected to persist in canal surface sediments if no CSO reductions are made. It should be noted that the quantity and possibly the quality of CSO solids may differ in the future as a result of the CSO management actions currently being taken by New York City.

Table 1-4 shows the average concentrations of the PAHs and metals in surface sediments in the upper, middle, and lower reaches of the canal. The ranges of PAH concentrations

correspond well to the estimated ranges of CSO solids except in the middle reach of the canal, which is more heavily influenced by PAH contamination from the Carroll Gardens/Public Place former MGP site. The ranges of metals concentrations also generally correspond, although the ranges are larger. Given that CSOs are the major source of solids in the canal, these results suggest that contaminant concentrations in surface sediments are influenced by the CSO solids and dominated more so in the upper and lower reaches of the canal than in the middle reach.

Other Pipe Outfalls

Nearly 250 outfall features were identified in the RI, most of which were pipes. Twenty-five of these pipe outfalls were observed to be actively discharging during dry weather. The effluent from 14 of the 25 active outfalls could not be attributed to tidal drainage (i.e., drainage of seawater that entered the pipe at high tide). Samples from 12 of these 14 outfall discharges contained VOCs, SVOCs (primarily PAHs), and metals (two of the discharges were not sampled due to low flow rates). Pesticides and PCBs were not detected. The flow rate from all but one of the active outfalls was very small (< 1 L/min).

A review of NYSDEC and USEPA databases identified five active permitted discharges to the canal. Three of these permitted outfalls were not observed to discharge during the RI. Two of the permitted outfalls could not be clearly identified during the RI because of the large number of outfall features in their vicinity.

Contaminant loading from outfalls other than the CSO outfalls was not estimated because the annual discharge volumes are not known. Discharges from these unpermitted outfalls will be eliminated as part of the remedy for the canal.

Other Sources

Other potentially active sources of contamination to the Gowanus Canal include uncaptured stormwater runoff from adjacent upland sites and streets, and sediments and contaminants from Buttermilk Bay by the flushing tunnel and from Upper New York Bay through tidal flow. However, impacts from these potential sources are expected to be relatively minor compared to the active sources identified above. Uncaptured stormwater runoff drains only 6 percent of the Gowanus Canal watershed, whereas combined sewers and storm sewers drain 94 percent of the watershed (NYCDEP, 2008a). Sediments from Upper New York Bay, as represented by reference area sediment samples collected for the RI, have significantly lower concentrations of PAHs, PCBs, and metals than surface sediments in the canal, as well as a lower TOC content and higher percent fines than the sediments in the canal. If Upper New York Bay was a major source of sediments and contaminants to the canal, then the reference area and canal sediments would show greater similarity.

1.4.2 Contaminant Fate and Transport

A variety of physical and chemical processes influences the fate and transport of contaminants and NAPL in the Gowanus Canal sediments, as described below.

Fate and Transport Processes for Sediment-Associated Contaminants

Many of the contaminants detected in canal sediments (e.g., SVOCs, PCBs, and metals) have a low solubility and an affinity for fine-grained sediment particles and organic matter.

Contaminants with a higher solubility and volatility (i.e., VOCs and some of the low-molecular-weight SVOCs) tend to disperse in the water column. Therefore, the accumulation of soft sediments in the canal over time has resulted in the accumulation of high levels of persistent contaminants. Because of low current velocities and limited tidal exchange with Gowanus Bay, the contaminated sediments have accumulated in the canal rather than being flushed out to the bay. Bathymetric survey data indicate that 1 to 3 feet of sediment was deposited in the upper canal between 3rd Street and Sackett Street between 2003 and 2010 (USEPA, 2011). The upper canal is the reach most affected by the deposition of solids from CSO discharges. Radioisotope analyses of sediment cores from other areas of the canal (i.e., south of 3rd Street) indicated net sediment accumulation rates on the order of 1 to 2 in./yr (GEI, 2007), although most of the cores that were dated showed evidence of disturbances that reduce the accuracy of the age-dating estimates.

Because many of the contaminants that are present at high levels in the Gowanus Canal soft sediments have an affinity for fine-grained sediment particles and organic matter, the fate and transport of these contaminants is related to the fate and transport of the sediments. Sediments deposited in Gowanus Canal may be resuspended by currents, propeller wash, dredging, and other disturbances. The canal is a low-velocity environment, with current velocities generally less than 0.5 ft/s (USACE ERDC, undated). These current speeds are insufficient to substantially erode sediment deposits on the bottom of the canal. Currents generated by the flushing tunnel apparently eroded sediments near the outlet of the tunnel, but the sediments settled out where the current velocities decreased farther down the canal between Sackett and 3rd streets.

Sediments in Gowanus Canal appear to be frequently resuspended and mixed by propeller wash from vessel traffic. The effects of propeller wash are particularly evident in the reach between the Gowanus Expressway and 3rd Street, where minimal sediment accumulation was observed between 2003 and 2010. This reach experiences frequent tug and barge traffic associated with the concrete plant at the end of 5th Street. Evidence of propeller scour was also seen near the southern end of the canal project area in the 2010 bathymetric survey.

Given the low-current velocities in the canal, most of the sediments resuspended by propeller wash likely settle out relatively quickly in the same reach of the canal. However, finer-grained sediment particles that remain suspended in the water column for a longer period of time may be transported out of the canal by tidal currents. The amount of sediment transported out of (or into) the canal in typical weather conditions or during storm events has not been measured or estimated; however, a substantial drop in contaminant concentrations in surface sediments from the middle reach of the canal to the lower reach, and the additional drop from the lower reach of the canal to the Gowanus Bay and Upper New York Bay reference locations (Table 1-5) indicates that much of the sediment-associated contamination remains within the canal.

Groundwater Discharge

As noted in Section 1.4.1, contaminants from upland sites can be transported into the Gowanus Canal in the dissolved phase by groundwater discharge. Figures 1-9a and 1-9b identify areas where transport of PAHs into the canal by groundwater discharge may be occurring. Transport of metals and PCBs to the canal by groundwater discharge does not appear to be a concern, as discussed in Section 1.4.1 and Appendix B.

NAPL Fate and Transport Processes

NAPL in the canal sediments can be transported through the sediments into the water column through several transport mechanisms, including ebullition, seep migration, sheen migration, and groundwater advection.

Ebullition is the production of gas due to anaerobic biological activity in sediment (Viana et al., 2007a). Mineralization of organic matter by bacteria in the sediment generates gases such as methane, nitrogen, and carbon dioxide (Reible, 2004). Ebullition is commonly observed in the soft sediments in the Gowanus Canal, which are rich in organic matter (i.e., average total organic carbon content of 12 percent). The bubbles produced during ebullition tend to accumulate hydrophobic contaminants and colloids, such as NAPL sheen, on their surfaces (Viana et al., 2007b). NAPL can then migrate out of the sediment and upwards through the water column, and be deposited on the water surface as sheen.

A NAPL *seep* is defined as a NAPL discharge when the following occur:

- NAPL is moving under a sustained gradient
- A source that provides the driving force is located at some distance from the seep
- A recent or ongoing release is typically in association with the discharge
- NAPL saturations are above residual

NAPL seeps can migrate with groundwater through sediments that are not impacted by NAPL (i.e., NAPL is nonwetting), but migrate more readily through sediments previously impacted with NAPL (NAPL is the wetting phase) (Sale, 2011). When NAPL is nonwetting, water is the wetting phase and the NAPL migrates when the NAPL head exceeds the pore entry pressure of the groundwater. This allows NAPL to migrate to areas previously unaffected by NAPL. When NAPL is the wetting fluid, NAPL discharge is likely continuous because the driving head of NAPL continues to release NAPL along the NAPL-wetted pathway.

An analysis of NAPL impacts at the contact between native and soft sediments in the Gowanus Canal suggests that seep migration is occurring at some locations (Appendix A). The potential for upward NAPL migration in areas where NAPL impacts were observed on both sides of the native-soft sediment contact was investigated further using an equation that balances the resulting forces of the groundwater velocity and the NAPL density (Cohen and Mercer, 1993). The analysis presented in Appendix A indicates that upward groundwater velocities can potentially result in the upward NAPL migration under certain conditions.⁵ This is essentially because the upward vertical groundwater velocity appears to be sufficient to overcome the downward density and capillary forces of the NAPL.

NAPL *sheen* is defined as a NAPL discharge when the following occur:

- A very limited amount of oil is discharged as a sheen on the water surface
- Ephemeral sheen behavior may be observed
- Former seeps have occurred
- NAPL saturations are close to or below residual

⁵ The general site conditions were used to grossly estimate the potential for NAPL migration. The actual conditions at specific locations can vary substantially. Additional data collection and evaluation would be necessary to verify NAPL mobility at specific locations.

NAPL sheens migrate by the difference in the surface tensions that result in a positive spreading coefficient as described in Appendix A. In the upland area, NAPL spreads on the groundwater surface in the same way as surface water sheen. In this way, NAPL sheen spontaneously enters water-coated, air-filled pores through capillary forces. These forces overcome gravitational forces and NAPL migrates. However, surface tensions alone are insufficient for the sheen to exceed the pore entry pressure of the groundwater and migrate through nonwetted areas (areas absent of NAPL impacts). Hence, sheen migration occurs only in a previous NAPL-wetted pathway at the interface of groundwater and the vadose zone such as through vadose zone transport from an upland source. Sheens may migrate into the canal where the groundwater surface intersects the canal.

NAPL transport by *groundwater advection* occurs when the groundwater velocity is sufficient to overcome the density and capillary forces required to move the NAPL in the direction of groundwater flow.

SECTION 2

Development and Application of Remediation Goals

This section presents the RAOs, preliminary remediation goals (PRGs), and remediation target areas (RTAs) for the Gowanus Canal. The RAOs are a general description of what the cleanup is expected to accomplish. The RAOs provide the basis for developing numerical remediation goals, which are used to identify the extent of the cleanup (i.e., the RTAs) needed to achieve the RAOs. This section also describes the potential ARARs that must be met by the cleanup.

Remedial actions at CERCLA sites must be protective of human health and the environment. For the Gowanus Canal, numerical remediation goals are based on the site-specific risk assessments rather than ARARs because there are no promulgated federal or New York State sediment cleanup standards. The RAOs are based on the findings of the ERA and HHRA and specify (1) the contaminant of concern, (2) the exposure route(s) and receptor(s), and (3) an acceptable contaminant level (or range of levels) for each exposure route. USEPA's (2005) *Contaminated Sediment Remediation Guidance* states the following:

When developing RAOs, project managers should evaluate whether the RAO is achievable by remediation of the site or if it requires additional actions outside the control of the project manager . . . the RAOs should reflect objectives that are achievable from the site cleanup.

This FS evaluates remedial alternatives for sediments in the Gowanus Canal. Ongoing discharges to the canal from CSOs and stormwater outfalls are managed by NYCDEP, and migration of contaminants from upland properties to the canal are regulated by NYSDEC. Discharges to the canal through unpermitted outfall structures must also be addressed. Contaminant contributions from these sources must be reduced or eliminated before remediation of Gowanus Canal sediments to prevent recontamination of the canal.

NAPL contamination in native sediment beneath the canal north of the Gowanus Expressway extends beyond the maximum depth of a practical removal remedy for sediments. For example, deep borings installed in the canal adjacent to the Carroll Gardens/Public Place former MGP site indicate that contamination extends to a depth of greater than 50 feet (GEI, 2010). Therefore, the remedy for canal sediments must also prevent recontamination by any deep NAPL that is not removed.

Total suspended solids, grit, and other solids discharged from CSOs that settle in the canal will influence the long-term quality of surface sediment. Long-term contributions of CSO solids should be reduced to the maximum extent practicable to prevent recontamination of the canal.

2.1 Remedial Action Objectives

The RAOs for the Gowanus Canal are as follows:

Ecological

- Reduce to acceptable levels toxicity to benthic organisms in the canal from direct contact with PAHs, PCBs, and metals in sediment
- Reduce to acceptable levels the risk to herbivorous birds from dietary exposure to PAHs

Although the BERA concluded that mercury poses a site-related risk to omnivorous birds, additional analysis of the sediment and tissue data collected for the RI indicates that mercury levels in the Gowanus Canal are similar to those in the Gowanus Bay and Upper New York Bay reference areas (Appendix C). Therefore, an RAO specifically for the protection of omnivorous birds from exposure to mercury was not developed. However, it is expected that the RAO developed for the other contaminants will provide protection from exposure to site-related mercury as well.

Human Health

- Reduce to acceptable levels the risk to human health from the incidental ingestion of and dermal contact with PAHs in sediment and surface water during recreational use of the canal or from exposure to canal overflow
- Reduce the risk to human health from ingestion of PCB-contaminated fish and shellfish collected from the canal

NAPL Mitigation

- Prevent the migration of NAPL into the canal after the remedial action is completed
- Prevent NAPL from serving as a source of contaminants to groundwater discharging to the canal

NAPL mitigation will require a combination of upland source control measures and the use of sediment remediation technologies to prevent recontamination of the canal by NAPL that remains in deep canal sediments after the remedy is implemented. Upland source control measures may also be required to ensure that there is no driving force (pressure head) to cause NAPL seep migration into the canal or sheen migration on the groundwater surface.

2.2 Development of Remediation Goals

Because there are no promulgated standards or criteria that apply to the cleanup of contaminated sediments in New York,¹ remediation goals for sediments in the Gowanus Canal were developed based on the results of the ERA and HHRA. Risk-based PRGs were developed for the contaminants, exposure pathways, and receptors associated with unacceptable risks. Estimated ranges of contaminant concentrations associated with CSO solids were also developed for comparison to the PRGs. In Section 2.4.1, PRGs are used to define the extent of cleanup needed to achieve the RAOs.

¹ New York's Technical Guidance for Screening Contaminated Sediments (NYSDEC, 1999) states the following: "Sediments with contaminant concentrations that exceed the criteria listed in this document are considered to be contaminated, and potentially causing harmful impacts to marine and aquatic ecosystems. These criteria do not necessarily represent the final concentrations that must be achieved through sediment remediation. Comprehensive sediment testing and risk management are necessary to establish when remediation is appropriate and what final contaminant concentrations the sediment remediation efforts should achieve."

2.2.1 Risk-Based Preliminary Remediation Goals

The approach used to develop ecological and human health risk-based PRGs and the results of the analysis are summarized below. The detailed analysis is provided in Appendix C.

Ecological

PRGs were developed for the protection of benthic (sediment-dwelling) organisms and herbivorous birds.

Protection of the Benthic Community. PRGs for the protection of benthic organisms were based on the site-specific toxicity test and collocated sediment chemistry data collected for the RI. Concentrations of PAHs, PCBs, and metals (barium, cadmium, copper, lead, mercury, nickel, and silver) were greater than screening values in many samples, and the observed toxicity in laboratory tests could have resulted from the effects of one or a combination of these contaminants. The toxicity test results cannot be used to distinguish which contaminants were causing the effects, although the results for simultaneously extracted metals/acid volatile sulfide analyses presented in the ERA (USEPA, 2011) indicate that the bioavailability of metals is low; thus, it is likely that PAHs caused a significant portion of the observed toxicity in laboratory tests. Therefore, target areas for remediation will be developed based on PRGs for total PAHs and then checked to verify that the potential for adverse effects from exposure to PCBs and metals are also addressed.

PRGs for total PAHs were derived through an analysis of the site-specific toxicity test results and collocated sediment chemistry data to identify the highest total PAH concentration that did not result in unacceptable effects. Sediment toxicity data were available for the following endpoints and test species: (1) survival, growth, and reproduction of the amphipod *Leptocheirus plumulosus*, and (2) survival and growth of the polychaete *Nereis virens*. Two approaches were used to derive PRGs for total PAHs:

- **Graphical**—prepared plots of each toxicity test endpoint versus total PAH concentration in sediment (both the dry weight concentration and TOC-normalized concentration), then identified (1) the lower bound of the range of toxicity test results for the Gowanus Bay and Upper New York Bay reference samples (i.e., the lower bound of the reference envelope), and (2) the level of toxicity associated with a 20 percent reduction relative to control. The lower of these two thresholds was defined as the adverse effects level. The highest no observed adverse effect concentration (NOAEC) was selected as the PRG.
- **Toxicity Response Analysis Program (TRAP)²**—used TRAP to estimate the total PAH concentration associated with various percent reductions in response and selected the 20 percent effects concentration (EC₂₀) as the PRG. The EC₂₀ is typically considered a chronic response threshold. The TRAP analysis was performed for the amphipod endpoints only because they were more sensitive to chemical contamination than the polychaetes. The 95 percent confidence intervals around the EC₂₀ estimates were large, indicating high variability of the dose-response relationships. None of the relationships were statistically significant. Therefore, the TRAP results were used only to verify the PRGs developed using the graphical approach.

² http://www.epa.gov/med/Prods_Pubs/trap.htm.

The PRGs for total PAHs that address risk to the benthic community through direct contact with sediment are summarized in Table 2-1. These PRGs range from 7.8 to 290 mg/kg. The recommended sediment PRG is 7.8 mg/kg because this value is the no-effect level for the most sensitive toxicity test endpoints (amphipod growth and reproduction).

To evaluate whether the selected PRG for total PAHs would also be protective of the effects of metals and PCBs, total PAH concentrations were plotted against metal and PCB concentrations. In general, samples with elevated PAH concentrations relative to reference locations also had elevated metals and PCB concentrations relative to reference locations (Appendix C). Therefore, remedial actions to address total PAH concentrations above the PRG at most locations should also address potentially toxic concentrations of metals and PCBs.

Protection of Herbivorous Birds. The BERA found unacceptable risks to herbivorous birds through dietary exposure to PAHs. A total PAH PRG for protection of herbivorous birds was derived using the food web model developed for the BERA. The model was used to estimate the total PAH concentration in sediment that would not pose an unacceptable risk to water fowl eating aquatic plants in the Gowanus Canal. The PRG for this endpoint was 230 mg/kg (Table 2-1).

Human Health

Based on the results of the HHRA, risk-based human health PRGs were developed for exposure pathways where individual carcinogenic PAHs contributed a cancer risk greater than 10^{-6} (i.e., one per one million) to a cumulative cancer risk of greater than 10^{-4} (i.e., one per 10,000). PRGs were developed for six carcinogenic PAHs for exposure to nearshore surface sediment and surface water during recreational use of the canal by adults, adolescents, and children. PRGs were calculated based on the site-specific exposure data presented in the HHRA. The ratio between the target risk and the calculated risk was determined for each PAH, and then the ratio was multiplied by the exposure point concentration (EPC) from the HHRA to calculate the PRG (Appendix C). A 10^{-5} target risk level was used for each individual PAH so that the cumulative risk from exposure to all carcinogenic PAHs would not exceed 10^{-4} . The lowest (most protective) PRGs for the recreational use scenario for sediment and surface water are presented in Tables 2-1 and 2-2, respectively.

PRGs were not developed to address potential risk from exposure to sediment deposited adjacent to the canal after overflow events because sediment remediation based on the recreational use scenario will also address potential risks from canal overflow.

The HHRA results indicated potentially unacceptable risk from the consumption of PCB-contaminated fish and crabs from the Gowanus Canal. Numerical PRGs were not calculated for this exposure scenario because remediation target areas that are developed based on PRGs for PAHs will also address PCBs.

2.2.2 Ongoing Deposition of CSO Solids

As described in Section 1.4.1, the estimated range of PAH concentrations attributable to the ongoing deposition of CSO solids was determined based on CSO wet-weather water sample data collected as part of the RI (Table 1-4). Because the CSO wet-weather water samples

collected for the RI are considered to represent the quality of solids discharged from the CSOs, these levels would be expected to persist in canal surface sediments if no CSO improvements were completed. However, the quality of CSO solids may differ in the future as a result of any management actions that are taken. Although CSO discharges are not the only source of solids to the canal, they provide a large contribution.³

The risk-based ecological and human health PRGs were compared to the estimated range of concentrations on CSO solids to determine whether RAOs are likely to be achieved under current site conditions. The total PAH concentrations on CSO solids are higher than the most protective ecological PRG, which is based on the protection of the benthic community.

The risk-based human health PRGs for four of the six carcinogenic PAHs are higher than the estimated concentration ranges on CSO solids, and the PRGs for two of the PAHs (benzo(a)pyrene and dibenz(a,h)anthracene) are within the ranges. The cumulative cancer risk from direct exposure to PAHs associated with CSO solids under current conditions is within USEPA's acceptable risk range (Appendix C).

2.3 Potential Applicable or Relevant and Appropriate Requirements (ARARs)

Section 121(d) of CERCLA requires that remedial alternatives attain ARARs unless they are waived in accordance with CERCLA. ARARs are regulations, standards, criteria, or limitations promulgated under federal or more-stringent state laws. An ARAR may be either "applicable" or "relevant and appropriate," but not both. NCP defines applicable, relevant and appropriate, and to-be-considered (TBC) criteria as follows:

- Applicable requirements are those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal or state law that directly and fully address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site.
- Relevant and appropriate requirements are those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal or state law that, while not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar (relevant) to those encountered at a CERCLA site (relevant) that their use is well suited (appropriate) to the particular site.
- TBC criteria are advisories, criteria, or guidance developed by USEPA, other federal agencies, or states that may be useful in developing CERCLA remedies. They are neither promulgated nor enforceable; however, they may be useful for determining protectiveness or how a remedial action could be performed.

To qualify as a state ARAR under CERCLA and the NCP, a state requirement must be (1) a standard, requirement, criterion, or limitation under a state environmental or facility citing law; (2) promulgated (of general applicability and legally enforceable); (3) substantive (not

³ The estimated annual load of total suspended solids to the canal from CSO and stormwater discharges is approximately 259,000 lbs (NYCDEP, 2008).

procedural or administrative); (4) more stringent than the federal requirement; (5) identified by the state in a timely manner; and (6) consistently applied.

Another factor in identifying the requirements that must be addressed by remedial alternatives is whether the requirement is substantive or administrative.

“Onsite” CERCLA response actions must comply with the substantive but not the administrative requirements of environmental laws and regulations. Substantive requirements are those pertaining directly to actions or conditions in the environment.

Administrative requirements are mechanisms that facilitate the implementation of the substantive requirements of an environmental law or regulation. In general, administrative requirements prescribe methods and procedures (fees, permitting, inspection, reporting requirements, etc.) by which substantive requirements are made effective for the purposes of a particular environmental or public health program. Offsite actions must comply with all legally applicable requirements, both substantive and administrative.

Specifically, the onsite components of the developed remedial alternatives are evaluated in this FS on the basis of whether they can be designed to meet substantive requirements. For example, onsite noncommercial treatment facilities constructed and operated to dewater or to stabilize sediments prior to their transport to an offsite facility for further treatment or disposal must be designed to comply with effluent limitations. Administrative requirements, such as obtaining a permit, would not be applicable. An offsite commercial facility where the sediments may be transported for offsite stabilization would be required to comply with both the administrative (have the appropriate permits) and substantive requirements. All alternatives (with the exception of the No Action alternative) include at least onsite dewatering; some alternatives include additional elements that would be performed onsite (for example, stabilization) and that also would need to comply with substantive requirements.

ARARs are grouped into three types: chemical-specific, action-specific, and location-specific. Tables 2-3 through 2-5 provide the chemical-specific, action-specific, and location-specific ARARs and TBCs that may apply to remedial actions in the Gowanus Canal.

Chemical-specific ARARs include laws and requirements that define health- or risk-based numerical values or methodologies applied to site-specific conditions that can be used to establish remediation goals. Many potential ARARs associated with specific remedial actions (i.e., discharges) can be characterized as action-specific but include numerical values or methodologies to establish them, so they fit in both the chemical- and action-specific categories. Table 2-3 lists the preliminary chemical-specific ARARs for the Gowanus Canal.

Action-specific ARARs regulate the specific type of action or technology under consideration, including the management of regulated materials. Table 2-4 lists the preliminary action-specific ARARs identified for the Gowanus Canal.

Location-specific ARARs are requirements that relate to the geographical position of the site. State and federal laws and regulations that apply to the protection of wetlands, construction in floodplains, and protection of endangered species are examples of location-specific ARARs. Preliminary location-specific ARARs for the Gowanus Canal are provided in Table 2-5.

2.4 Remediation Target Areas

The following criteria were used to divide the Gowanus Canal into target areas for remediation:

- Comparison of PAH concentrations in surface and subsurface sediment to ecological and human health-based PRGs
- Occurrence and distribution of NAPL in soft and native sediments
- Present day channel depth and depth required for commercial navigation

Each of these criteria is described further in Sections 2.4.1 through 2.4.3, and a description of the RTAs defined by considering all criteria is provided in Section 2.4.4.

2.4.1 Application of Preliminary Remediation Goals

Ecological Protection

Total PAH concentrations in surface and subsurface sediments in the Gowanus Canal were compared with risk-based PRGs to identify target areas for remediation. Surface sediment (the 0-to-6-inch depth interval) represents the biologically available zone and is the layer of sediment that poses the greatest risk to humans and ecological receptors. However, receptors could be exposed to subsurface sediment if the surface sediment was eroded (for example, due to propeller wash) or removed (for example, if soft sediments were partially dredged). Therefore, the PRGs were also compared to the subsurface soft and native sediments.

Total PAH concentrations in surface sediment, soft sediment, and native sediment throughout the Gowanus Canal are shown in Figures 2-1a through 2-1c, respectively. These figures also show the PRGs that are related to the protection of ecological receptors (Table 2-1). The surface sediment plot (Figure 2-1a) also shows the estimated range of PAH concentrations on CSO solids. A logarithmic scale was used to display total PAH concentrations because of the wide range of concentrations measured.

Total PAH concentrations in all of the surface sediment samples exceed the PRG based on the protection of the benthic community, but most are lower than the PRG based on the protection of herbivorous birds (Figure 2-1a). Total PAH concentrations in surface sediment are within the range measured on CSO solids discharged from the four major CSO outfalls except near the Carroll Gardens/Public Place and Metropolitan former MGP sites, where PAH concentrations are substantially higher. PAH concentrations in surface sediment are also relatively higher near and immediately downstream of the Fulton former MGP site.

Total PAH concentrations in almost all of the soft sediment samples upstream of the Gowanus Expressway exceed the most protective ecological PRG, in some cases by more than three orders of magnitude (Figure 2-1b). As with surface sediments, the highest total PAH concentrations are found in the vicinity of the Carroll Gardens/Public Place and Metropolitan former MGP sites. Downstream of the Gowanus Expressway, total PAH concentrations in most of the soft-sediment samples exceed the most protective PRG, but overall concentrations are lower than those upstream of the expressway.

Total PAH concentrations in the majority of native sediment samples north of the Gowanus Expressway exceed the ecological PRGs (Figure 2-1c). Approximately 1,500 feet south of the Gowanus Expressway, total PAH concentrations in most native sediment samples are below the PRGs.

Based on these comparisons, remedial alternatives will be developed and evaluated for the entire sediment column throughout the length of the canal. In native sediment, the vertical extent of NAPL contamination and high PAH concentrations in most areas north of the Gowanus Expressway are greater than the vertical limit of investigation. South of the Gowanus Expressway, the average total PAH concentration in native sediment is substantially lower.

Human Health Protection

As described in Section 2.2.1, the human-health PRGs for six carcinogenic PAHs are based on a cancer risk of 10^{-5} , so that the cumulative risk from exposure to all six PAHs will not exceed 10^{-4} . The following procedure was used to identify specific locations where the cumulative risk from exposure to the six individual PAHs in surface sediments exceeds 10^{-4} :

- Identify the PAH concentration in each sample collected from a location that was determined to be a human health exposure point in the HHRA (USEPA, 2011)
- Calculate the ratio of each PAH concentration to the PRG
- Add the ratios for all PAHs at each sample location
- Identify samples with a sum of greater than 10, which corresponds to a cumulative risk of greater than 10^{-4}

The results of this analysis are provided in Table 2-6. This table shows the ratio of each PAH to the PRG at each sample location, and identifies the sample locations where the sum of the ratios exceeds 10. Based on this analysis, the sediment at the head of the 6th Street basin poses the greatest human health risk.

Human health exposure points within the Gowanus Canal were defined in the HHRA as areas with shallow or exposed sediments. Although most of the subsurface sediments in the canal are too deep to be human health exposure points if the overlying surface sediments were eroded or removed, the subsurface soft sediment data were compared with human-health-based PRGs to provide a general indication of potential risk if they were remobilized and deposited in shallow areas (Appendix C). This analysis indicates that PAH concentrations in subsurface soft sediments in the middle reach of the canal most frequently exceed the human-health-based PRGs.

Human-health-based surface water PRGs were not used directly to identify target areas for remediation. However, the remediation of PAH-contaminated sediments in the canal is expected to reduce PAH concentrations in surface water to acceptable levels.

2.4.2 NAPL Occurrence and Distribution

The occurrence and distribution of NAPL-saturated intervals in soft and native sediments vary by reach in the Gowanus Canal, as follows:

- Between the head of the canal and approximately 4th Street, including the 4th Street basin, soft sediments contain only localized NAPL impacts, and native sediments contain many NAPL-saturated intervals.
- Between approximately 4th Street and 9th Street, including the 6th and 7th Street basins, NAPL saturation is widespread in both soft and native sediments.
- Between approximately 9th Street and the south side of the Gowanus Expressway, including the 11th Street basin, soft sediments have localized NAPL impacts near the Metropolitan former MGP site, and native sediments have many NAPL-saturated intervals.
- South of the Gowanus Expressway, soft sediments contain only localized NAPL impacts near Bryant Street; no NAPL-saturated intervals were identified in native sediments.

2.4.3 Navigational Depth Requirements

The Gowanus Canal can be divided into the following reaches based on its depth and use for commercial navigation:

- Between the head of the canal and 3rd Street (Reach 1): depths of less than -15 feet NAVD88; no commercial navigation
- Between 3rd Street and the Gowanus Expressway/Hamilton Avenue (Reach 2): depths generally between -8 and -16 feet NAVD88; used for commercial navigation but not a federally authorized channel; navigational depth requirement of -16 feet NAVD88 estimated by USACE in a dredging alternatives analysis (USACE, 2009)
- Between the Gowanus Expressway/Hamilton Avenue and Sigourney Street (Reach 3a): depths generally between -15 and -20 feet NAVD88; used for commercial navigation and federally authorized to a depth of -21 feet NAVD88⁴
- Between Sigourney Street and the south end of the study area (Reach 3b): depths of greater than -20 feet NAVD88; used for commercial navigation and federally authorized to a depth of -33 feet NAVD88⁵

The bathymetric map of the lower reach of the canal (Figure 1-5c) shows a steep increase in channel depth at Sigourney Street corresponding to the increase in federally authorized channel depth.

2.4.4 Summary of Remediation Target Areas

The comparison of PAH concentrations in sediment to PRGs shows that the entire soft-sediment column throughout the study area should be addressed. In addition, PAH concentrations in the majority of the native sediment samples collected north of the Gowanus Expressway and many of the native sediment samples collected south of the expressway also exceed PRGs.

⁴ -18 feet MLLW.

⁵ -30 feet MLLW.

NAPL distribution in the soft sediments is most pervasive in Reach 2. Soft sediments in Reach 1 and Reach 3 contain localized areas of NAPL contamination.

In native sediment, NAPL is present in Reaches 1 and 2 to at least the maximum depth investigated in the RI (i.e., generally 6 feet below the interface between soft and native sediments, although some cores recovered up to 13 feet of native sediment). Additionally, borings installed by National Grid near the Carroll Gardens/Public Place former MGP site in Reach 2 indicate NAPL contamination to depths of greater than 50 feet. NAPL saturation was not observed in the native sediment in Reach 3.

These data indicate that the vertical extent of contamination exceeds the practical limit of a sediment removal remedy in most areas north of the Gowanus Expressway. Therefore, the remedial alternatives developed in this FS must ensure that deeper NAPL contamination left in place does not cause recontamination of canal surface sediments through seep migration, ebullition, or groundwater advection (including NAPL transport by advection and NAPL solubilization to groundwater).

Navigational depth requirements also were considered. The navigational depth requirement differs within each reach of the canal. These differences may result in different remedial approaches for each reach.

Based on the characteristics identified above, the canal was divided into three RTAs, as shown in Table 2-7 and Figure 2-2. Average concentrations of other constituents of concern in each RTA are shown in Table 2-8.

RTA 1, which corresponds to Reach 1, includes the main channel from the head of the canal to 3rd Street. RTA 1 has the following characteristics:

- Relatively lower soft-sediment PAH concentrations than RTA 2
- Localized NAPL impacts in soft sediment and widespread NAPL impacts in native sediments
- No commercial navigation

RTA 2, which generally corresponds to Reach 2, includes the main channel from 3rd Street to the south side of the Gowanus Expressway, including the 4th, 6th, 7th, and 11th Street basins. RTA 2 has the following characteristics:

- The highest soft-sediment PAH concentrations in the project area
- Widespread NAPL impacts in soft sediments adjacent to the Carroll Gardens/Public Place former MGP site, localized impacts in soft sediments near the Metropolitan former MGP site, and widespread NAPL impacts in native sediments
- Commercial navigation in a channel with no federal authorization

RTA 3, which corresponds to Reach 3, extends from the south side of the Gowanus Expressway to the south end of the project area. RTA 3 has the following characteristics:

- The lowest soft-sediment PAH concentrations relative to the other RTAs
- Minimal NAPL impacts in soft and native sediments

- Commercial navigation in a federally authorized channel.

RTA 3 is further divided into RTAs 3a and 3b on the basis of channel depth, with RTA 3a (corresponding to Reach 3a) extending from the south side of the Gowanus Expressway to Sigourney Street, and RTA 3b (corresponding to Reach 3b) from Sigourney Street to the south end of the study area.

The RTAs identified above are addressed by the remedial alternatives presented in Section 4.

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SECTION 3

Identification and Screening of Remedial Technologies

This section presents the process by which potential remedial technologies for Gowanus Canal sediments are identified and screened. The following three-step process was used:

1. Identify general response actions (GRAs) that can accomplish the RAOs identified in Section 2
2. Establish the process for initial screening of potential remedial technologies and evaluation criteria
3. Identify and screen potential remedial technologies against the evaluation criteria and in consideration of the nature and extent of contamination and other site-specific factors

3.1 General Response Actions

GRAs are broad categories of action that, with the exception of the No Action alternative, can be expected to accomplish the RAOs. GRAs may be used in combination with one another. The No Action alternative is included as it is required by NCP (Title 40 Code of Federal Regulations § 300.430(e)), as a baseline alternative against which all other alternatives are compared.

The GRAs selected to address the RAOs were developed from nine primary remediation strategy categories. Table 3-1 lists the GRAs that are appropriate for consideration at the Gowanus Canal.

3.2 Technology Screening Process and Evaluation Criteria

Technology screening was conducted following the technology screening guidance described in the USEPA *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (USEPA, 1988). In addition, the technologies identified and screened are consistent with the USEPA *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* (USEPA, 2005). Potential remedial technologies and process options were screened according to the following three established criteria:

- Technical effectiveness
- Implementability
- Cost

3.2.1 Technical Effectiveness

The technical effectiveness of a technology/process option was evaluated based on its ability to meet the RAOs under the conditions and limitations present at the site. The

technical effectiveness criterion was used to determine which remedial technologies would be effective based on the nature and extent of contamination, site characteristics, and other engineering considerations. The NCP defines effectiveness as the “degree to which an alternative reduces toxicity, mobility, or volume through treatment, minimizes residual risk, affords long-term protection, complies with ARARs, minimizes short-term impacts, and how quickly it achieves protection.” Remedial technologies that are not likely to be effective for addressing sediment contamination within the Gowanus Canal are screened out and not retained for further evaluation.

3.2.2 Implementability

“Implementability” refers to the relative degree of difficulty anticipated in implementing a particular technology/process option under the regulatory and technical constraints posed at the site. Implementability is evaluated in terms of the technical and administrative feasibility of constructing, operating, and maintaining the technology/process option, as well as the availability of services and materials. Technical feasibility refers to the ability to construct, reliably operate, and comply with regulatory requirements during implementation of the technology/process option. Technical feasibility also refers to the future operation, maintenance, and monitoring after the technology/process option has been completed. Administrative feasibility refers to the ability to coordinate with and obtain approvals and permits from regulatory agencies. Availability of services and materials may include the availability and capacity of treatment, storage, and disposal services; the availability of bulk materials; and the requirements for and availability of specialized equipment and technicians. Remedial technologies that cannot be implemented at the site are screened out and not retained for further evaluation.

3.2.3 Cost

The primary purpose of the cost-screening criterion is to allow for a comparison of rough costs associated with the technologies/process options. The cost criterion addresses costs to implement the technology/process option and long-term costs to operate and maintain the remedy. At this stage of the process, the cost criterion is qualitative and used for rough comparative purposes only.

Each technology was evaluated on a scale of 1 to 4 for each of the established screening criteria, with 1 being the lowest ranking and 4 being the highest ranking. The qualitative definitions for each screening criteria are presented in Table 3-2. The ranking numbers are qualitative only and are not used as the basis of screening (i.e., whether a technology/process option is retained or not).

3.3 Identification of Remedial Technologies and Initial Screening

This section presents an overview of the remedial technologies and process options that were identified to address the impacted sediment at the Gowanus Canal Superfund Site. GRAs may be addressed by several types of remedial technologies and process options. Remedial technologies (e.g., capping, disposal) are general categories of technologies and process options (e.g., reactive cap, landfill) are specific processes within a remedial

technology category. The identification of remedial technologies and process options and the initial screening process are intended to evaluate the various technologies identified against the established criteria (effectiveness, implementability, and cost) and eliminate technologies and process options that are inappropriate or infeasible for addressing RAOs established for the site. Remedial technologies/process options that are retained after screening are then combined into potential remedial alternatives for the site. Table 3-3 presents the descriptions of the remedial technologies and process options that were identified and the initial screening evaluation as they apply to sediment within the Gowanus Canal.

3.4 Results of Technology Screening Using Established Criteria

The initial screening process evaluated the remedial technologies and process options for effectiveness, implementability, and cost. Remedial technologies and process options that would not effectively address sediment contamination within the Gowanus Canal were eliminated. Table 3-3 screens technologies and process options. Table 3-4 summarizes the results of the screening and the technologies and representative process options that were retained and carried forward for the development of remedial alternatives in Section 4. Note that often there are multiple process options within a remedial technology type that could be applied within the canal. In many cases, one representative process option was carried forward for use in developing remedial alternatives and estimating the associated costs in the FS. During remedial design, other process options may be used in addition to or instead of the representative process options listed in this FS. The process options incorporated into the remedial design will achieve the established RAOs and support the long-term effectiveness of the selected remedy.

As described in USEPA *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* (USEPA, 2005), three potential remedy approaches should be evaluated at every sediment site: dredging, in situ capping, and monitored natural recovery (MNR). Dredging and in situ capping were retained in the technology-screening process for the Gowanus Canal, but MNR was not, because site conditions in the Gowanus Canal are not conducive to MNR. Some of the site conditions that are conducive to MNR are as follows (USEPA, 2005):

- Anticipated land uses or new structures are not incompatible with natural recovery
- Natural recovery processes have a reasonable degree of certainty to continue at rates that will contain, destroy, or reduce the bioavailability or toxicity of contaminants within an acceptable timeframe
- Sediment bed is reasonably stable and likely to remain so
- Sediment is resistant to resuspension (e.g., sediment is cohesive or well-armored)
- Contaminant concentrations in biota and in the biologically active zone of sediment are moving towards risk-based goals on their own
- Contaminant concentrations are low and cover diffuse areas

The canal is used for navigation in RTA 2 and RTA 3. Therefore, future dredging may be required, which would expose higher contaminant concentrations in subsurface sediments. Furthermore, contaminant concentrations in CSO solids are expected to control the long-term quality of the surface sediment and inhibit any measureable recovery that might occur in surface sediments that currently have relatively lower contaminant concentrations. If discharges of CSO solids were reduced or eliminated, then the timeframe needed to reduce surface sediment concentrations to acceptable levels could be unacceptably long. Additionally, sediments in RTA 2 and RTA 3 are resuspended by propeller wash, and the stability of the sediment bed in RTA 1 could be affected by increased current velocities resulting from flushing tunnel upgrades. These factors collectively would reduce the effectiveness of MNR as an approach for achieving RAOs in an acceptable timeframe.

SECTION 4

Development, Screening, and Analysis of Remedial Alternatives

The purpose of this section is to develop, screen, and evaluate remedial alternatives that will address the RAOs for the Gowanus Canal. The remedial alternatives were developed by assembling the remedial technologies and process options retained in Section 3. This section defines the criteria to be used in screening and evaluating alternatives; describes the alternatives; and screens them on the basis of effectiveness, implementability, and cost. The alternatives that are retained following the screening are then described in more detail and analyzed individually and comparatively using the established evaluation criteria.

4.1 Evaluation Process and Criteria

The NCP defines nine criteria – classified as threshold, balancing, or modifying – to be used for the evaluation and analysis of remedial alternatives. The definitions of these criteria from the USEPA RI/FS guidance (USEPA, 1988) are presented below. The alternatives were also qualitatively evaluated with respect to sustainability and green remediation metrics.

Potential alternatives were first screened with respect to effectiveness, implementability, and cost to reduce the number of alternatives to be analyzed in detail. For the alternatives that were retained, the detailed analysis was performed using a two-step process. During the first step, each alternative was evaluated individually against the NCP criteria and the sustainability/green remediation metrics. In the second step, a comparative analysis was performed using the same criteria to identify key differences between alternatives. The detailed analysis presents the significant components of each alternative, the assumptions used, and the uncertainties associated with the assessment.

4.1.1 NCP Threshold Criteria

To be eligible for selection, an alternative must meet the threshold criteria described below, or in the case of compliance with ARARs, a waiver, if necessary, must be justified.

Overall Protection of Human Health and the Environment

This criterion evaluates whether an alternative can protect human health and the environment. This criterion draws on the analyses performed for other evaluation criteria, particularly long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs. Evaluation of overall protection of human health and the environment offered by each alternative focuses on the following:

- Determining whether an alternative achieves adequate protection
- Considering how site risks associated with each exposure pathway are either eliminated, reduced, or controlled through treatment, engineering, or institutional controls

- Determining if an alternative will result in any unacceptable short-term or cross-media effects

Compliance with ARARs

This evaluation criterion is used to determine whether an alternative meets the substantive portions of the federal and state ARARs defined in Section 2 and in Tables 2-3, 2-4, and 2-5. It must be noted that under CERCLA, permits are not required for actions conducted onsite; however, the substantive requirements of the associated ARARs must be met.

CERCLA authorizes the waiver of an ARAR with respect to a remedial alternative if any of the following bases exist (USEPA, 1988):

- The alternative is an interim measure that will become part of a total remedial action that will attain the ARAR
- Compliance with the requirement will result in greater risk to human health and the environment than other alternatives
- Compliance with the requirement is technically impracticable from an engineering perspective
- The alternative will attain a standard of performance that is equivalent to that required under the otherwise applicable standard, requirement, or limitation through use of another method
- With respect to a state requirement, the state has not consistently applied, or demonstrated the intention to consistently apply, the promulgated requirement in similar circumstances at other remedial actions within the state
- For Superfund-financed response actions only, an alternative that attains the ARAR will not provide a balance between the need for protection of human health and the environment at the site and the availability of Fund monies to respond to other sites.

4.1.2 NCP Balancing Criteria

Alternatives meeting the threshold criteria are further evaluated using the following five primary balancing criteria.

Long-Term Effectiveness and Permanence

The assessment against this criterion evaluates the long-term effectiveness of the alternatives in maintaining consistent protection of human health and the environment after the RAOs have been met. A key component of this evaluation is to consider the extent and effectiveness of controls that may be required to manage risk posed by treatment residuals and/or untreated waste. The long-term effectiveness of an alternative is assessed by considering the following two factors:

- **Magnitude of residual risk** assesses the residual risk remaining from untreated waste or treatment residuals at the conclusion of the remedial activities.

- **Adequacy and reliability of controls** evaluates the capability and suitability of controls, if any, that are used to manage treatment residuals or untreated wastes that remain at the site.

Reduction of Toxicity, Mobility, or Volume Through Treatment

This evaluation criterion addresses the statutory preference for selecting remedial actions that employ treatment technologies resulting in the permanent and significant reductions of toxicity, mobility, or volume of the hazardous substances as their principal element. This preference is satisfied when treatment is used to reduce the principal threats at a site through destruction of toxic contaminants, irreversible reduction in contaminant mobility, or reduction of total volume of contaminated media. The following six factors are considered when evaluating alternatives against this criterion:

- The treatment processes the remedy will employ and the materials they will treat
- The amount of hazardous materials that will be destroyed or treated (including how the principal threat(s) will be addressed)
- The degree of expected reduction in toxicity, mobility, or volume measured as a percentage of reduction (order of magnitude)
- The degree to which the treatment is irreversible
- The type and quantity of treatment residuals remaining following treatment
- Whether the alternative satisfies the statutory preference for treatment as a principal element

Of particular importance in evaluating this criterion is the assessment of whether treatment is used to reduce principal threats, including the extent to which toxicity, mobility, or volume is reduced either alone or in combination.

Short-Term Effectiveness

This criterion assesses the effects of the alternative during its construction and implementation until the RAOs are met. Alternatives are evaluated with respect to their effects on human health and the environment during their implementation. The following factors are considered when evaluating alternatives against this criterion:

- **Protection of the community during remedial actions** addresses any risk resulting from the remedy implementation. Examples include dust from excavations, transportation of hazardous materials, and air-quality impacts.
- **Protection of workers during remedial actions** assesses threats potentially posed to workers and the effectiveness and reliability of protective measures that would need to be taken.
- **Environmental impacts** considers the environmental impacts potentially resulting from the construction and implementation of the alternative and assesses the reliability of available mitigation measures for preventing or reducing those impacts.

- **Time until RAOs are achieved** includes an estimate of the time required to achieve protection for either the entire site or individual elements associated with specific site areas or threats.

Implementability

The implementability criterion assesses the technical and administrative feasibility of implementing an alternative and the availability of various services and materials required during the remedy implementation. The following factors are considered when evaluating alternatives against this criterion:

- **Technical feasibility** includes the following:
 - **Construction and operation** relates to the technical difficulties and unknowns associated with a technology.
 - **Reliability of technology** focuses on the likelihood that technical problems associated with the implementation will result in schedule delays.
 - **Ease of undertaking additional remedial action** includes a discussion of what, if any, future remedial actions may need to be performed and how difficult it would be to implement those actions.
 - **Monitoring considerations** addresses the ability to monitor the effectiveness of the remedy and includes an evaluation of exposure risk should monitoring be insufficient to detect a failure.
- **Administrative feasibility** assesses the activities required to coordinate with other offices and agencies (e.g., access, right-of-way).
- **Availability of services and materials** includes an evaluation of the availability of appropriate offsite treatment, storage capacity, and disposal services; necessary equipment and specialists; services and materials (including the potential for competitive bidding); and the availability of prospective technologies.

Cost

This criterion includes all the engineering, construction, and operations and maintenance (O&M) costs incurred over the life of the project. The evaluation of cost includes three principal components:

- **Capital costs** includes direct (construction) and indirect (nonconstruction and overhead) costs. Equipment, labor, and materials required for the installation of the remedy are considered direct costs. Indirect costs consist of those expenses related to the engineering, financial, and other services that are necessary to complete the remedy installation but are not part of the actual installation or construction activities.
- **Annual O&M costs** refers to postconstruction expenditures required to ensure continued effectiveness of the remedial action. Components of annual O&M costs include auxiliary materials, monitoring expenses, equipment or material replacement, and 5-year review reporting.

- **Present worth analysis** is a method of evaluating expenditures such as construction and O&M that occur over different lengths of time. This allows costs for remedial alternatives to be compared by discounting all costs to the year that the alternative is implemented. The present worth of a project represents the amount of money, which if invested in the initial year of the remedy and disbursed as needed, would be sufficient to cover all costs associated with the remedial action.

The level of detail required to analyze each alternative with respect to the cost criteria depends on the nature and complexity of the site, the types of technologies and alternatives being considered, and other project-specific considerations. The analysis is conducted in sufficient detail to understand the significant aspects of each alternative and to identify the uncertainties associated with the evaluation.

The cost estimates presented for each alternative have been developed for the purpose of comparing the alternatives. The final costs of the selected remedy will depend on actual labor and material costs, competitive market conditions, final project scope, the implementation schedule, and other variables. The cost estimates are order-of-magnitude estimates with an intended accuracy range of plus 50 to minus 30 percent. The range applies only to the alternatives as they are described in this report and does not account for changes in the scope of the alternatives. Selection of specific technologies or processes to configure remedial alternatives is not intended to limit flexibility during remedial design but to provide a basis for preparing cost estimates. The specific details of the selected remedial alternative and the corresponding cost estimate need to be refined during the final remedial design.

4.1.3 NCP Modifying Criteria

The two modifying criteria are state acceptance and community acceptance. The evaluation of these criteria is typically not completed until state and public comments are received on the Proposed Plan.

4.1.4 Sustainability

The USEPA Office of Solid Waste and Emergency Response (OSWER), as well as USEPA Region 2, have a goal to implement sustainable and/or green practices as part of remedial actions, where practicable. The OSWER Technology Primer titled *Green Remediation: Incorporating Sustainable Environmental Practices into Remediation of Contaminated Sites* (USEPA, 2008) cites the following six core elements of green remediation:

- Energy requirements of the treatment system
- Air emissions
- Water requirements and impacts on water resources
- Land and ecosystem impacts
- Material consumption and waste generation
- Long-term stewardship actions

Similarly, USEPA Region 2 has implemented a “Clean & Green” Policy that establishes a preference for the following (USEPA, 2010):

- One hundred percent use of renewable energy, and energy conservation and efficiency approaches, including EnergyStar equipment
- Cleaner fuels and clean diesel technologies and strategies
- Water conservation and efficiency approaches, including WaterSense products
- Sustainable site design
- Industrial material reuse or recycling within regulatory requirements
- Recycling applications for materials generated at or removed from the site
- Environmentally preferable purchasing
- Greenhouse gas emission reduction technologies

The disposal options considered in this FS are evaluated qualitatively against a number of sustainability metrics that include these principal elements. The intent of this evaluation is to highlight differences among the disposal options with respect to sustainability and green practices or elements.

4.2 Summary of Alternatives

Six remedial alternatives were developed for the Gowanus Canal using various combinations of the remedial technologies that were retained in the screening evaluation in Section 3. A combined approach will be necessary to achieve the RAOs for the canal. USEPA's *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* (USEPA, 2005) identifies NCP remedy expectations and their potential application to contaminated sediments. These factors, summarized below, were considered in the development of remedial alternatives for the canal:

- **Use treatment to address principal threats wherever practicable.** In situ and ex situ treatment options were incorporated into the alternatives for the canal.
- **Use engineering controls such as containment for waste that poses a relatively low long-term threat or where treatment is impractical.** Capping is incorporated into the remedial alternatives for the canal to address contaminated sediments that cannot be removed or effectively treated.
- **Use a combination of methods, as appropriate, to achieve protection of human health and the environment.** The remedial alternatives for the canal are various combinations of dredging, capping, treatment, disposal, and beneficial-use options.
- **Use institutional controls as needed to supplement engineering controls to prevent or limit exposure.** Institutional controls will be incorporated into the remedy for the canal as needed to assist in maintaining the long-term integrity of the cap and for controlling long-term exposure from treated materials that are beneficially used onsite.
- **Consider using innovative technologies when they offer the potential for comparable or superior treatment performance or implementability.** Innovative in situ and ex situ treatment technologies have been incorporated into the alternatives; in particular, in situ

stabilization (ISS) has been evaluated as a potential measure for reducing the mobility of NAPL that cannot be practicably removed from the canal.

- **Prevent further migration of groundwater plumes and exposure to contaminants in groundwater.** The alternatives for the canal sediments include a source control component that will address ongoing migration of NAPL and dissolved-phase contaminants in groundwater into the canal.

Each of the alternatives (except No Action) has dredging and capping components. Capping is a component of all alternatives because NAPL-contaminated sediments are present to depths that exceed the practicable depth of removal. However, a capping-only alternative is not included for the following reasons: (1) a cap in the upper reach of the canal (RTA 1) would further restrict the water depth in the canal and result in a relatively large area of exposed sediment at low tide; (2) a cap in the middle reach of the canal (RTA 2) would compress soft sediments and mobilize the NAPL within them; and (3) a capping-only remedy would be incompatible with the continued use of the canal for commercial navigation.

The sediments dredged under any of the alternatives could be treated and/or disposed of using a variety of methods; treated sediments may be beneficially used. The dredging and capping alternatives are combined with one or more of the treatment/disposal options to create a complete remedial alternative.

In order for any of the proposed remedial alternatives to be effective, upland sources of contamination—including discharges from CSOs, from the former MGP sites and other contaminated sites along the canal, and from the unpermitted pipes along the canal—must be controlled. These upland source controls need to be coordinated and implemented in concert with the selected sediment remedy to prevent recontamination of the canal following remedy implementation. All of the alternatives in this FS rely upon the successful implementation of these controls; therefore, they are included as the first component of all the alternatives. The source control measures that will be developed are included by reference in this FS.

The following dredging and capping alternatives were developed for the Gowanus Canal:

- Alternative 1: No Action
- Alternative 2
 - Dredge soft sediment to a specified elevation
 - Cap with isolation layer and armor layer
- Alternative 3
 - Dredge soft sediment to a specified elevation
 - Cap with treatment layer, isolation layer, and armor layer
- Alternative 4
 - Dredge entire soft sediment column
 - Cap with isolation layer and armor layer
- Alternative 5
 - Dredge entire soft sediment column
 - Cap with treatment layer, isolation layer, and armor layer

- Alternative 6
 - Dredge entire soft sediment column
 - Solidify top 3–5 feet of native sediment in targeted areas
 - Cap with isolation layer and armor layer
- Alternative 7
 - Dredge entire soft sediment column
 - Solidify top 3–5 feet of native sediment in targeted areas
 - Cap with treatment layer, isolation layer, and armor layer

The following treatment and disposal options for dredged sediments were identified:

- Option A: Offsite thermal desorption and beneficial use
- Option B: Offsite disposal (landfill)
- Option C: Offsite cogeneration and beneficial use
- Option D: Offsite stabilization and offsite beneficial use
- Option E: Onsite stabilization and onsite beneficial use
- Option F: Offsite stabilization and placement in onsite constructed CDF
- Option G: Onsite stabilization and placement in onsite constructed CDF

The dredging-and-capping alternatives and treatment/disposal options are briefly described in Sections 4.2.1 and 4.2.2, respectively. The dredging-and-capping alternatives and treatment/disposal options are screened separately in Section 4.3. The alternatives and treatment/disposal options that were retained for detailed evaluation after the screening step are detailed in Section 4.4.

4.2.1 Dredging-and-Capping Alternatives

Table 4-1 presents the major components of each alternative. Alternatives 2 through 7 include the following common elements, which are detailed in Section 4.4:

- Predesign investigation
- Upland source control
- Preconstruction and bulkhead stabilization and repair
- Dredging
- Sediment dewatering and stabilization
- Cap placement
- Dredge cell dewatering and water treatment

Alternative 1

Per the NCP requirement, the No Action alternative is carried through the entire FS process as the baseline condition against which the performance of the remaining alternatives is evaluated.

Alternative 2

In Alternative 2, the soft sediment in RTAs 1 and 3 would be removed to a specified elevation, and all of the soft sediment would be removed from RTA 2. Partial removal of soft sediment in RTA 2 was not considered because of the high degree of NAPL contamination in these sediments. The upper canal (RTA 1) is no longer used for

commercial navigation; however, this reach of the canal must have depth sufficient to operate the flushing tunnel, and vessels will need to navigate this reach of the canal to perform cap monitoring and maintenance as well as sewer system and flushing tunnel maintenance.

The final elevation was determined on the basis of the two following objectives: (1) ensure that the final sediment surface remains submerged throughout the tidal

cycle and (2) minimize remedy implementation challenges (e.g., allow sufficient water depth for construction work throughout the tidal cycle). In RTA 2, a navigation depth of -16 feet NAVD was assumed (see Section 2.4.3). Therefore, all of the soft sediment and some native sediment would be removed to accommodate the cap thickness and allow for continued commercial vessel use in this reach. The removal elevations in RTA 3 were determined on the basis of the conceptual cap thickness and the federally authorized navigation depths.

The conceptual cap for this alternative is 2.5 feet thick, consisting of the following layers, from top to bottom:

- Armor layer: 1.5 feet of stone with a median diameter of 0.75 feet. Approximately 0.5 feet of sand will be placed on top of the armor layer to fill in the voids between the stones in order to facilitate benthic recolonization.
- Isolation layer: 0.5 feet of gravel and 0.5 feet of sand.

Alternative 3

Alternative 3 is the same as Alternative 2, except that the conceptual cap design includes an oleophilic clay treatment layer in addition to the isolation and armor layers. The treatment layer will mitigate the impacts of ebullition and upward migration of NAPL and dissolved-phase contaminants in groundwater.

The target dredge elevations for this alternative are slightly deeper in RTAs 1 and 3 because the cap is thicker.

The conceptual cap for this alternative is 3.5 feet thick in RTA 1 and RTA 2 and 3 feet thick in RTA 3. The cap consists of the following layers (from top to bottom):

Final Target Elevations, Cap Thickness, and Dredge Elevations: Alternative 2

	RTA 1	RTA 2	RTA 3a	RTA 3b
Final target elevation (NAVD88)	-7	-16	-21	-33
Buffer thickness (ft)	2	2	2	2
Cap surface elevation (NAVD88)	-9	-18	-23	-35
Cap thickness (ft)	2.5	2.5	2.5	2.5
Target dredge elevation (NAVD88)	-11.5	-20.5	-25.5	-37.5

Final Target Elevations, Cap Thickness, and Dredge Elevations: Alternative 3

	RTA 1	RTA 2	RTA 3a	RTA 3b
Final target elevation (NAVD88)	-7	-16	-21	-33
Buffer thickness (ft)	2	2	2	2
Cap surface elevation (NAVD88)	-9	-18	-23	-35
Cap thickness (ft)	3.5	3.5	3.0	3.0
Target dredge elevation (NAVD88)	-12.5	-21.5	-26.0	-38.0

- Armor layer: 1.5 feet of stone with a median diameter of 0.75 feet. Approximately 0.5 feet of sand will be placed on top of the armor layer to fill in the voids between the stones in order to facilitate benthic recolonization.
- Isolation layer: 0.5 feet of gravel and 0.5 feet of sand.
- Treatment layer (oleophilic clay): 1 foot in RTA 1 and RTA 2, and 0.5 feet in RTA 3.

Alternative 4

In Alternative 4, all of the soft sediment within the canal would be removed, and a cap would be placed on top of the native sediment. The conceptual cap for this alternative is the same as the cap described for Alternative 2, one consisting of an armor layer and an isolation layer. The native sediment surface elevation is variable within the canal; therefore there is not a single specific removal elevation in RTAs 1 or 3 under this alternative. In RTA 1, the native surface elevation ranges from -11.8 to -25.6 feet NAVD88. In RTA 3, the native surface elevation – and therefore the target dredge elevation – ranges from -18.9 to -44.2 feet NAVD88. The removal of all the soft sediment in RTA 1 and RTA 3 will allow for the placement of the cap and at the same time meet navigational needs. The target dredge elevation for RTA 2 is the same as that listed for Alternative 2.

Alternative 5

In Alternative 5, all of the soft sediment within the canal would be removed, and a cap would be placed on top of the native sediment surface. The conceptual cap for this alternative is the same as the cap described for Alternative 3, one consisting of an armor layer, an isolation layer, and an oleophilic clay treatment layer. The removal elevations correspond to the native sediment surface elevation, and are summarized for RTAs 1 and 3 under Alternative 4. The removal of all the soft sediment in RTA 1 and RTA 3 will allow for the placement of the cap and at the same time meet navigational needs. The target dredge elevation for RTA 2 under Alternative 5 is the same as what is listed for Alternative 3.

Alternative 6

In Alternative 6, all of the soft sediment within the canal would be removed, and ISS would be applied to targeted areas of native sediment to immobilize NAPL with upward migration potential. ISS would be performed to a depth of 3 to 5 feet and would consist of incorporating pozzolanic additives into the native sediment to solidify the material. ISS would be applied to areas where data indicate the potential for active upward NAPL migration from the native sediment. The stabilization material would be delivered to the in situ sediment from a barge using large augers without dewatering the canal. The area being stabilized would be surrounded by temporary sheet piling to contain the contaminants that would be released when the augers are in use.

The conceptual cap for this alternative is the same as the cap described for Alternative 2, one consisting of an armor layer and an isolation layer. The removal elevations correspond to the native sediment surface elevation and are summarized for RTAs 1 and 3 under Alternative 4. The target dredge elevation for RTA 2 under Alternative 6 is the same as what is listed for Alternative 2.

Alternative 7

Alternative 7 is the same as Alternative 6, except that the conceptual cap for this alternative is the same as the cap described for Alternative 3, one consisting of an armor layer, an isolation layer, and an oleophilic clay treatment layer. The removal elevations correspond to the native sediment surface elevation, and are summarized for RTAs 1 and 3 under Alternative 4. The target dredge elevation for RTA 2 under Alternative 7 is the same as what is listed for Alternative 3.

4.2.2 Treatment and Disposal Options

Each treatment and disposal option considered for the canal sediments is briefly described below. The options that are retained after the screening step are described in greater detail in Section 4.4.

Option A: Offsite Thermal Desorption and Beneficial Use

Option A consists of transporting dredged and dewatered sediment by barge to an offsite commercial facility for stabilization followed by transport of the stabilized sediment to another offsite facility for thermal desorption treatment. The treatment residuals would be destroyed in an afterburner, and treated sediment would be transported for use as daily cover at a landfill or for another beneficial use at an offsite location. It is assumed that transport following stabilization would occur by truck.

Option B: Offsite Disposal (Landfill)

Option B consists of transporting dredged and dewatered sediment by barge to an offsite commercial facility for stabilization followed by transport of stabilized sediment to an offsite landfill. It is assumed that transport to the offsite disposal facility would occur by truck. Disposal at a RCRA Subtitle D landfill is assumed for the stabilized sediment.

Option C: Offsite Cogeneration and Beneficial Use

Option C consists of transporting dredged and dewatered sediment by barge to an offsite commercial facility for stabilization followed by transport of stabilized sediment to an offsite cogeneration electrical plant. The stabilized sediment would be mixed with coal and then burned to generate electricity. Treatment would include thermal destruction (i.e., burning) of the organic contaminants through heating of the sediments at high temperatures (greater than 1,400°C). The treated sediment would then be transported for use as daily cover at a landfill or for another beneficial use at an offsite location. It is assumed that transport following stabilization would occur by truck.

Option D: Offsite Stabilization and Beneficial Use

Option D consists of transporting dredged and dewatered sediment by barge to an offsite commercial facility for stabilization followed by transport of stabilized sediment to an offsite location for beneficial use. The degree of stabilization necessary for direct offsite beneficial use without further treatment will be more substantial than under Options A through C, where the stabilization process would be utilized to prepare sediments for offsite transport via truck to be followed by treatment before final disposition. A specific beneficial use has not been determined in this FS, but potential uses of the stabilized sediment include fill and daily landfill cover.

Option E: Onsite Stabilization and Beneficial Use

Option E includes stabilizing dredged sediment onsite and beneficially using the treated sediment in areas adjacent to the canal. As with Option D, the degree of stabilization necessary for direct onsite beneficial use without further treatment will need to be more substantial than the stabilization under Options A through C, where the stabilization process would be utilized to prepare sediments for offsite transport by truck to be followed by treatment before final disposition. A specific beneficial use has not been determined in this FS, but potential uses include fill or creation of concrete blocks. Additional physical and chemical testing and cost analyses would be required to evaluate potential beneficial uses.

Option F: Offsite Stabilization and Disposal in Onsite-Constructed CDF

Option F consists of transporting dredged and dewatered sediment by barge to an offsite commercial facility for stabilization followed by transport by barge of the stabilized material back to the site for placement into a constructed onsite CDF. The CDF would be constructed by installing a single-sheet pile wall on the sides adjacent to land and a installing a double-sheet pile wall on the side of the CDF adjacent to water. The void in the double sheet pile wall would be filled with bentonite-augmented soil or a similar low-permeability material. This FS assumes that three sides of the CDF will be adjacent to land and one side will be adjacent to water. Under this option, enough stabilization agents would be added to the dewatered sediment such that a relatively impermeable monolithic mass would result. The material would be transferred into the constructed CDF before the material has completely hardened and would be placed using standard material-handling equipment. The final design of the CDF would depend on location of the CDF and the characteristics of the stabilized sediment. Testing would need to be performed before this design could be developed.

Option G: Onsite Stabilization and Disposal in Onsite-Constructed CDF

Option G consists of stabilizing dredged sediment onsite and then transferring the sediment into a constructed onsite CDF. The description of the CDF is provided in the description of disposal Option F.

4.3 Alternative Screening

The dredging-and-capping alternatives and treatment/disposal options were each screened on the basis of effectiveness, implementability, and cost to reduce the number of alternatives and options carried forward for detailed evaluation. Because the base components of Alternatives 2 through 7 are very similar, the implementability of the dredging-and-capping alternatives is not expected differ markedly among alternatives. The relative costs of the dredging-and-capping alternatives and the treatment/disposal options are discussed in the following sections.

4.3.1 Dredging and Capping Alternative Screening

The screening analysis for the dredging-and capping-alternatives is presented in Table 4-2. Alternatives 2 and 3 include only partial removal of the soft sediment column. Capping extremely soft, fine-grained sediments with high water content poses technical challenges due to the sediments' low bearing capacity (USACE, 2000; Reible, 2005). The physical

characteristics of the soft sediments in the canal suggest that they may have insufficient load-bearing capacity to support a cap or could be destabilized by the uneven placement of cap material. Capping over these could destabilize any NAPL present in the soft sediments (Reible, 2005). Given these considerations, this FS assumes the removal of all the soft sediment, and the alternatives that require removal of only a portion of the soft sediments were screened out.

Alternatives 2, 4, and 6 include installation of a two-layer cap, with isolation and armor layers. These alternatives were not retained because an armored sand cap is not sufficient to control the long-term flux of NAPL and dissolved-phase contaminants. NAPL mitigation is a major concern in RTA 1 and RTA 2. Although little NAPL is present in RTA 3, groundwater upwelling through PAH-contaminated sediments in some portions of RTA 3 may pose a concern. Therefore, a thinner oleophilic clay treatment layer was included for RTA 3 in this FS. Conceptual cap designs will be refined during remedial design.

The relative cost rankings for the dredging-and-capping alternatives are influenced by the volume of sediment removed, the presence or absence of an oleophilic clay treatment layer in the cap, and inclusion or exclusion of ISS. The approximate dredging, capping, and ISS costs of Alternatives 2 through 7 range from \$152 million for Alternative 2 to \$191 million for Alternative 7. These cost estimates do not include disposal costs. The difference between the highest and lowest cost is 23 percent.

Based on this screening evaluation, Alternatives 1, 5, and 7 were retained for further development and detailed evaluation.

4.3.2 Treatment and Disposal Option Screening

The screening analysis for the treatment/disposal options is presented in Table 4-3. This evaluation was specific to each RTA because the differences in the degree of NAPL impacts and contamination levels influence the expected effectiveness of some of the options.

Options D and E (offsite and onsite stabilization and beneficial use, respectively) were not retained for RTA 2. The soft sediments within RTA 2 have pervasive NAPL impacts that would inhibit successful stabilization of the dredged sediment for beneficial use.

Options F and G (offsite or onsite stabilization and placement in a constructed CDF, respectively) were not retained for further evaluation for RTA 1 or RTA 2 because of the higher levels of contamination encountered and the space constraints on constructing a CDF with sufficient capacity to accommodate the dredged sediments from all RTAs. Therefore, this FS assumes that the CDF would be used to contain the least contaminated sediments from the canal (i.e., those from RTA 3). However, this does not preclude the use of this option for sediments from RTA 1 or RTA 2 in the selected remedy, if areas of lower contamination are identified during the design and if additional CDF capacity becomes available.

The relative cost rankings for these disposal and treatment options are influenced by tipping fees, specific treatment technology, and transport distance required. The approximate costs for the treatment and disposal options range from approximately \$170 to \$320 per-ton.

As described in Sections 4.4 and 4.7, additional evaluation of the selected treatment and disposal option(s) will be required during remedial design.

4.4 Detailed Description of Retained Alternatives

The descriptions of the remedial alternatives provided herein are conceptual and have been developed to a level of detail sufficient for the purposes of evaluating the alternatives against the NCP criteria and developing cost estimates with an expected accuracy of plus 50 to minus 30 percent. The selected alternative will be further developed during the remedial design process, and the specific methodologies and construction sequences utilized may change on the basis of additional information that is gathered as part of predesign investigations.

The following three alternatives are evaluated in the detailed analysis:

- Alternative 1: No Action, retained as a the baseline condition per NCP requirements
- Alternative 5: Dredge entire soft sediment column and cap with treatment layer, sand-and-gravel isolation layer, and armor layer
- Alternative 7: Dredge entire soft sediment column, solidify top 3–5 feet of native sediment in targeted areas, and cap with treatment layer, sand-and-gravel isolation layer, and armor layer

Seven treatment and disposal options are evaluated as part of Alternatives 5 and 7:

- Option A: Offsite thermal desorption and beneficial use
- Option B: Offsite disposal (landfill)
- Option C: Offsite cogeneration and beneficial use
- Option D: Offsite stabilization and beneficial use
- Option E: Onsite stabilization and beneficial use
- Option F: Offsite stabilization and placement in onsite constructed CDF
- Option G: Onsite stabilization and placement in onsite constructed CDF

Alternatives 5 and 7 include bulkhead stabilization throughout the entire canal and the removal of some native sediment in RTA 2 to accommodate a cap and maintain the depths required for navigation. As described in Section 4.2, it is anticipated that the remedial action in the canal will be performed using a phased approach, with the upper and middle reaches of the canal (RTA 1 and RTA 2) being remediated first.

In order for any of the remedial alternatives to be effective, upland sources of contamination – such as discharges from CSOs, from the former MGP sites and other contaminated sites along the canal, and from the unpermitted pipes along the canal – must be controlled in parallel with or prior to the implementation of the selected sediment remedy. These upland source controls need to be coordinated and implemented in concert with the selected sediment remedy to prevent recontamination of the canal following remedy implementation. All of the alternatives in this FS rely upon the successful implementation of these controls; therefore, they are included as the first component of all alternatives. The source control measures that will be developed are included by reference in this FS.

Emerging sediment remediation technologies may be evaluated during the remedial design and may be incorporated into the selected remedy, if determined to be effective and implementable during bench testing or pilot studies.

Table 4-1 presents the major components of each alternative. The following section provides a more detailed description of each alternative and the disposal options, including the assumptions regarding technologies and materials used, volume of sediment removed, quantities of material needed for the capping and/or treatment, proximity of treatment and disposal facilities, and the conceptualized construction sequence and construction duration. The alternative descriptions and construction sequences are generally applicable to all the RTAs in the canal; differences among the RTAs, such as sediment volumes removed, capping requirements, and conceptual cap design parameters are noted in the text and in the associated tables containing the detailed components and construction sequence.

4.4.1 Alternative 1: No Action

Per the NCP requirement, the No Action alternative is carried through the entire FS process as the baseline condition against which the performance of the remaining alternatives is evaluated. This alternative would not include any active remediation of the Gowanus Canal but could include performing 5-year reviews. Additional monitoring and implementation of institutional controls are not included components of this alternative.

4.4.2 Alternatives 5 and 7

This section presents a conceptual construction sequence and the assumptions used as the basis of estimate for the primary components of Alternatives 5 and 7. Figures 4-1a and 4-1b present process diagrams depicting the primary components, including the treatment and disposal options. In general, the only difference between the alternatives is Alternative 7's inclusion of ISS in RTAs 1 and 2. Alternative 7 is also retained for RTA 3 should predesign investigations determine that there are areas with NAPL in RTA 3 that could benefit from ISS application. Based on the above, the detailed components and construction sequencing for both Alternatives 5 and 7 are presented only once, in Table 4-4. The assumptions related to quantities, production rates, and materials used are specified in this table, and differences between the two alternatives are identified. The quantities of sediment removed in each RTA are summarized in Table 4-5. Sections 4.2.3 through 4.2.5 provide details specific to each alternative.

Predesign Investigation

A predesign investigation is anticipated to be needed to collect specific information to support the design of the selected remedy.

Upland Source Control

Source control measures will be needed to ensure that the sediment remedy achieves the RAOs and is sustainable. Source control is the first component of all alternatives except No Action. Source control measures are in the process of being developed, and therefore the costs are not available for inclusion in this FS. The source control measures are included by reference in this FS.

Potential source control measures include sealing unpermitted pipe outfalls to the canal, controlling discharges of suspended solids in CSOs, and controlling the discharge of NAPL and contaminated groundwater to the canal from upland sources. The existing pipe outfalls will need to be reviewed to identify those that are not permitted to discharge to the canal. Pipe outfalls that are not permitted will need to be sealed to eliminate these sources of contamination to the canal. Examples of methods that can be used to control discharge of PAH- and metal-containing CSO solids include constructing deep tunnels, retention tanks to temporarily store discharges during storms, green infrastructure, and sewer separation. Approximately 95 percent of the CSO discharges occur from outfalls RH-034 at the head of the canal, RH-035 at Bond Street, OH-007 at 2nd Avenue, and RH-031 at Creamer Street.

Preconstruction and Bulkhead Stabilization /Repair

Preconstruction activities would include setting up staging areas (e.g., clearing an area, constructing security fencing, and setting up job-site trailers and utility services) and evaluating and stabilizing the bulkheads. Specifically, the existing bulkheads along the canal are degraded in many areas and, in order to prevent their collapse, these bulkheads should be reinforced, stabilized, or replaced. Additional structural surveys of the bulkheads will need to be performed during the remedial design to determine the specific conditions and corresponding appropriate actions to stabilize the bulkheads. The remedial design will also need to consider the effects on the bulkhead stabilization of any upland NAPL source control measures that are proposed or implemented by third parties. The upland controls may include the installation of collection trenches or barrier walls near the shorelines. Table 4-4 provides details regarding the assumptions used in this FS on how the bulkheads will be addressed and the percentage of the canal shoreline that is assumed to require bulkhead reinforcement or rebuilding. It is anticipated that the removal action in the canal will occur using a phased approach, and that the upper and middle reaches of the canal (RTA 1 and RTA 2) will be remediated first.

It is assumed for the FS that any reinforcing or stabilizing structures installed to address bulkhead stability would be permanent. Targeted debris removal required for the bulkhead stabilization or reinforcement would be performed by the subcontractor selected to perform this component of the work. This debris removal is not the same as the debris removal required prior to dredging. A small amount of residual sediment may be left between the existing bulkhead structures and the new or reinforcing structures. Any gaps between the existing bulkheads and the new or reinforcing structures would be filled with sand, gravel, or other freely draining material. Residual sediment remaining between the new and old bulkhead structures would be isolated from contact with ecological receptors and humans.

Dredging

Enclosed cells for dredging would be created by driving temporary sheet piling into the native sediment in RTA 1 and RTA 2. These cells would serve to contain potential releases of contaminants that occur during sediment removal, which could include NAPL, suspended solids, and dissolved organics. The dredge cells would be placed along one-half of the width of the canal at a given time to allow tidal exchange throughout the reach and to allow flushing tunnel flow to flow past. It is assumed that while work is taking place in one cell, construction would be occurring to create the next cell, so that dredge cell construction does not delay dredging activities.

Dredge cells would not be constructed in RTA 3. The soft sediment in RTA 3 does not generally exhibit significant NAPL saturation, and the potential for NAPL releases during dredging is much lower. Additionally, the construction of dredge cells in RTA 3 would interfere with navigation in the lower canal. Turbidity and sheens in this area would be controlled with silt curtains and oil booms.

Debris removal would be performed using an excavator positioned on a barge. Larger debris might require removal using a crane and clamshell bucket. The debris would be removed after each dredge cell is constructed so that sheens and turbidity releases can be controlled. Upon removal, the debris would be decontaminated, sorted, and recycled or disposed of as appropriate. This process and the associated waste streams will be determined during remedial design.

Sediment removal would be performed using mechanical dredges outfitted with standard clamshell buckets in RTA 1 and RTA 2 and with environmental buckets in RTA 3. Standard clamshell buckets are assumed for RTAs 1 and 2 because dredging would be performed within enclosed dredge cells that would prevent sheens and turbidity from spreading beyond the immediate work area. Dredge cells would not be constructed in RTA 3; therefore an environmental bucket is assumed for dredging in this reach. The dredges would be positioned on barges to allow for easier movement within the canal and to minimize effects to the upland businesses and residents. Dredged sediment would be loaded onto material barges and moved to an onsite staging area for dewatering. The clamshell and environmental buckets are expected to be able to remove the gravel present throughout RTA 2 and in portions of RTA 3a.

Dewatering/Stabilization

Dredged sediment would undergo passive dewatering at an onsite staging area. The dredged material would be allowed to sit in scows for a period of time so that the solids would settle to the bottom of the barge. The overlying water would be pumped off into holding tanks, treated in an onsite temporary water treatment system, and discharged back to the canal.

The dewatered sediment would then be transported by barge to a treatment facility for stabilization. For the purposes of the FS, it was assumed that an existing, offsite treatment facility would be used for disposal options A, B, C, D, and F. An offsite facility was assumed for these options because (1) there is currently an existing facility within the greater New York region that can accept material transported by barge, and (2) existing offsite facilities could readily handle the predicted daily volumes of dredged materials. Disposal options E and G consider the use of an onsite stabilization facility.

The materials and reagent quantities required for the stabilization are dependent upon the final disposal method selected and will be determined during design but are expected to be portland cement, blast furnace slag, or a combination of the two. After stabilization, the material would be further treated and/or disposed using one of the following options: offsite thermal treatment, offsite landfill, offsite cogeneration, onsite or offsite beneficial use, or an onsite CDF. The degree of stabilization needed would depend on the disposition of the stabilized material (i.e., preparing the sediments for transport is expected to require less stabilization than to prepare them for placement in a CDF or for beneficial use). Table 4-4

details the assumptions for the reagents and quantities required for sediment stabilization for each disposal option.

In Situ Stabilization

ISS is the only component that is different between Alternatives 5 and 7. In Alternative 7, ISS would be used in the native sediment in targeted areas of RTAs 1 and 2 to further reduce or prevent NAPL migration. Appendix A presents an analysis of NAPL impacts on both sides of the native sediment-soft sediment interface at sampling locations throughout the canal. These NAPL impacts are considered indicative of the potential for active upward NAPL migration from the native sediment to the soft sediment. The degree of migration is considered greater in cases where NAPL-saturated sediments occur on both sides of the interface. The locations where the application of ISS is proposed are those areas that exhibit NAPL saturation on either side of the native sediment-soft sediment interface. Other site-specific characteristics were also taken into account. Figure 4-2 illustrates the areas where ISS is included in this FS:

- RTA 1: The ISS area includes the entire width of canal from approximately 100 feet from the head of the canal (Douglass Street) to the southern boundary of the Fulton former MGP site (Sackett Street). This distance is approximately 600 feet. Although NAPL-saturated soft sediments were not found at the native sediment-soft sediment interface in this reach, soft sediment impacts may have been affected by dredging and possibly flushing tunnel operations.
- RTA 2: NAPL saturations across the native sediment-soft sediment interface were identified in the main channel of the canal from the 7th Street turning basin to the southern boundary of the Metropolitan former MPG site. This distance is approximately 1,400 feet. The ISS footprint also includes the area from the northern boundary of the Carroll Gardens/Public Place former MPG site to the 7th Street turning basin (approximately 500 feet).
- 4th Street Turning Basin: The ISS footprint for this turning basin includes the eastern end of the basin. This distance is approximately 250 feet. This turning basin is approximately 100 feet wide in this area.
- 6th Street Turning Basin: NAPL saturations on either side of the native sediment-soft sediment interface were noted in the western third of this basin. The proposed ISS footprint includes a distance of approximately 250 feet from the confluence with the canal. This turning basin is approximately 100 feet wide.
- 7th Street Turning Basin: NAPL saturations on either side of the native sediment-soft sediment interface were noted in the western two-thirds of this basin. The proposed ISS footprint includes a distance of approximately 300 feet from the confluence with the canal. This turning basin is approximately 100 feet wide.

ISS is currently not proposed for RTA 3. Based on the available data, the NAPL impacts in the southern portion of the project area are much less significant and less pervasive than those observed in the upper reaches of the canal. Alternative 7 may be applied in RTA 3 if, during predesign, areas that would benefit from ISS application are identified. Because these areas have not been identified at the time of preparation of this FS, no costs for this option have been included.

The FS assumes that the in situ delivery of stabilization material to the native sediment would be performed from a barge using large augers to a depth of approximately 5 feet below the native sediment surface and that delivery would be performed without dewatering the canal. If Alternative 7 is the selected remedy for any of the RTAs within the canal, the remedial design should include further evaluation of the areas where ISS should be applied, the delivery method to be used, and bench testing and pilot testing to determine the appropriate reagent mix.

Cap Placement

Upon completion of the sediment removal in Alternative 5 or upon completion of ISS in Alternative 7, a cap would be placed over the remaining sediment. The purpose of the cap is to prevent direct human or ecological exposure to the contaminated sediments and to prevent the migration of NAPL in the underlying sediment to the overlying water column. The conceptual cap designs are based on the extent of NAPL saturation expected to remain in the underlying sediment following dredging and thus the design varies by RTA. Appendix A provides a detailed discussion of possible cap designs for the different RTAs within the canal based on the expected presence of NAPL. A brief description is provided below.

Dredging activities are expected to release some NAPL to the water column. Control measures to avoid placing capping materials through a NAPL-affected water column will be defined in the remedial design. Examples of these types of mitigation measures may include allowing the NAPL to settle out of the water column for a period of time before placing the isolation (clay) layer, or placing a portion of the isolation layer and treating a volume of water from the dredge cell and then placing the remaining portion of the clay layer.

The conceptual cap design consists of a three-layer cap comprising a treatment layer, a sand-and-gravel isolation layer, and an armoring layer. The sand-and-gravel layer will provide a transition in particle size from the granular clay treatment layer to cobble-sized armor stone and will protect the clay layer from bioturbation. Appendix D provides the assumptions and calculations used to determine the shear stresses and water velocities associated with propeller wash, as well as the calculations to determine the median particle size and thickness required for the armor layer of the cap. For the purposes of this FS, it is assumed that the same armor layer will be used throughout the canal; however, further evaluation during design may indicate that different materials or thicknesses may be appropriate in RTAs 1 and 3 based on navigational or other considerations. Sand will be placed on top of the armor layer to fill some of the voids between the stones in order to facilitate benthic colonization. Epibenthic fauna such as crabs and mussels could colonize areas with relatively larger stone sizes, and benthic infauna could colonize areas with finer-grained particles that fill in the gaps between the cobbles. However, if not controlled, soft sediment from the ongoing CSO outfalls will be deposited and will accumulate on top of the cap over time.

The treatment layer of the conceptual cap design is assumed to be composed of oleophilic clay, which is a surface-modified clay that is effective for adsorbing insoluble and partially insoluble compounds. Oleophilic clay is hydrophobic and permeable and would allow ebullition bubbles to pass through the cap, preventing cap uplifting, while adsorbing the

NAPL, and thus preventing transport of the NAPL into the water column. The oleophilic clay is also designed to retain high permeability upon organic adsorption.

Two different oleophilic clay materials are possible: granular oleophilic clay emplaced much like a sand layer, and reactive core mats consisting of a thin layer of oleophilic clay material sandwiched between two permeable geotextile layers made of biodegradation-resistant synthetic fibers. The advantage of granular oleophilic clay is that it can be emplaced to any specified thickness to meet site-specific adsorptive capacity requirements. The disadvantage of granular oleophilic clay, like sand caps, is that improper emplacement over soft sediments can cause resuspension of the soft sediment layer, leading to settling of contamination both in and on top of the cap layer. Specific construction quality control measures are needed for proper placement. For the conceptual cap designs presented in this FS, granular oleophilic clay is assumed for the treatment layer. Appendix A provides additional discussion on the rationale for the selection of the treatment layer material.

Based on the evaluations performed in Appendix D, a 1.5-foot-thick armor layer with a median stone size of approximately 0.75 feet would be required in RTA 2. For purposes of this FS, this armor size and thickness have been assumed for all RTAs. It is possible that a smaller armor size would be protective in RTAs 1 and 3; however, further analysis for the current and predicted vessel use, as well as potential habitat requirements, is required to refine the cap design. The cap designs will be finalized during the remedial design.

Dredge Cell Dewatering and Water Treatment

After the sediment is removed, ISS has been performed (if Alternative 7 is implemented), and the cap has been placed, the water in the cell would be tested, and, if needed, pumped through the onsite water treatment processes and discharged back to the canal. Water from the canal outside of the dredge cell would be allowed to flow into the cell as pumping occurs in order to minimize the differential pressure against the sheet piling. For the purposes of cost estimating for this FS, it is assumed that the water treated in each cell will be approximately two cell volumes at mean high tide. The site for the temporary water treatment plant will be determined during the remedial design.

Treatment and Disposal Options

The following section describes the seven treatment and disposal or beneficial-use options that are included for Alternatives 5 and 7. As noted in the screening analysis (Section 4.3), some of the treatment and disposal options are not applicable to all RTAs. The seven treatment and disposal options are:

- Option A: Offsite thermal desorption and beneficial use (RTAs 1, 2, and 3)
- Option B: Offsite disposal (landfill; RTAs 1, 2, and 3)
- Option C: Offsite cogeneration and beneficial use (RTAs 1, 2, and 3)
- Option D: Offsite stabilization and offsite beneficial use (RTAs 1 and 3)
- Option E: Onsite stabilization and onsite beneficial use (RTAs 1 and 3)
- Option F: Offsite stabilization and placement in onsite constructed CDF (RTA 3)
- Option G: Onsite stabilization and placement in onsite constructed CDF (RTA 3)

Table 4-4 provides additional details with respect to the construction sequence, assumed construction specifications, volumes of sediment treated, stabilization reagents used and the

associated mix percentages, and expected production rates. Table 4-5 summarizes the sediment volumes to be treated and disposed for each RTA.

Additional treatability testing and sampling is needed for all disposal options. Further testing of stabilized sediment will be required to confirm that dredged sediment can be accepted by thermal desorption (Option A) and cogeneration (Option C) facilities. Selection of Option B (offsite landfill) will require testing of stabilized dredged sediment to confirm that it will meet acceptance criteria. Options D, E, F, and G will require further evaluations to determine the appropriate reagents and dosing required for stabilization and to assess the leachability of the stabilized material. Options D and E will further require a beneficial use to be identified and a determination as to whether the stabilized sediment will meet the associated beneficial-use requirements. Options F and G will require the identification of a suitable area of sufficient size within the project area to construct a CDF.

Option A: Thermal Desorption and Offsite Beneficial Use. Option A consists of transporting dewatered, dredged sediment that has been stabilized to the degree required to pass the paint filter test at the offsite dredge material processing facility to an offsite thermal desorption facility for thermal treatment. The treatment residuals would be destroyed in an afterburner. Thermally-treated sediment would be transported for use as daily cover at a landfill or other beneficial use. It is assumed that transport to the offsite thermal desorption facility and from the facility to the location of its beneficial use would occur by truck.

A preliminary evaluation of the soft-sediment data collected during the RI was performed with respect to the acceptance criteria at the thermal treatment plant operated by Clean Earth of Southeast Pennsylvania (CESP) in Morrisville, Pennsylvania. The data represent sediment prior to the addition of any stabilization amendments. A summary of the comparison of the acceptance criteria and the untreated soft sediment data is presented in the inset at right. The total PCB and lead concentrations present in the sediment may preclude this treatment option for some areas of the canal.

Comparison of Gowanus Canal Soft Sediment to CESP Acceptance Criteria

Parameter	CESP Criterion (mg/kg)	Canal Sediment Exceedances
Arsenic	<53	2/376
Lead	<450 ^a	246/376
TPH	45,000	1/382 ^b
Total PCBs	<4	102/381

^a Dependent upon back-end facility.

^b Total PAH used as a proxy for screening; exceedances are presented in number of exceedances / number of samples analyzed.

Option B: Offsite Disposal (Landfill). Option B consists of transporting the stabilized sediment from the offsite dredge material processing facility to an appropriate landfill. It is assumed that transport from the dredge-material-processing facility to the disposal facility would occur by truck. Disposal at a RCRA Subtitle D landfill is assumed for the stabilized sediment. Stabilization would be performed to the degree needed for the dredged sediment to pass the paint filter test.

Option C: Cogeneration and Offsite Beneficial Use. Option C consists of transporting dredged, dewatered sediment that has been stabilized to the degree required to pass the paint filter test at the offsite dredge-material-processing facility to an offsite cogeneration electrical plant. The stabilized sediment would be mixed with coal and then burned to generate electricity, which would then be distributed to the receiving electrical grid. Treatment would include thermal destruction (i.e., burning) of the organic contaminants through

burning of the sediments at high temperatures (greater than 1,400°C). The treated sediment would then be transported for use as daily cover at a landfill or other beneficial use. It is assumed that transport from the offsite dredge-material-processing facility to the cogeneration plant and from the cogeneration plant to the location where the treated sediment would be beneficially used would occur by truck.

This disposal option is considered for sediment originating from all three RTAs. Additional bench-scale testing is required to determine whether the sediment in all areas of the canal would provide sufficient energy value (in British Thermal Units, or BTUs) to make cogeneration a feasible treatment/disposal option for the entire canal and to determine which areas of the canal contain sediment with the greatest BTU value.

The Piney Creek Power Plant, a cogeneration facility in Clarion, Pennsylvania, was contacted to determine if treatment through cogeneration was possible for sediments from the canal. Based on discussions with facility personnel, this facility would be able to accept dewatered canal sediments for burning. Canal coal tar waste classified as MGP waste is exempt from toxicity characteristic leaching procedure (TCLP) testing in Pennsylvania and will require only pH, reactivity, and ignitability testing to confirm the waste is nonhazardous prior to shipment. TCLP and reactivity, pH, and ignitability data collected during the RI on selected composite samples of entire sediment cores indicate that untreated sediment (i.e., not stabilized or solidified) is not considered a characteristic hazardous waste as defined by the Resource Conservation and Recovery Act (RCRA). Bench testing would be required to determine the amount of stabilization materials needed to reduce the moisture content of the material to approximately 20 percent (the desired limit for the receiving facilities).

Option D: Offsite Stabilization and Offsite Beneficial Use. Option D is applicable to RTAs 1 and 3 and consists of transporting dewatered sediment to an offsite facility via barge, where the sediment will be stabilized. The treated material would then be transported via truck or rail (assumed to be by truck in this FS) to the offsite beneficial use location. A beneficial use would need to be identified and further evaluations would be required to determine the amounts and types of solidifying agents that should be added to the sediment to result in the desired physical and chemical properties. Tests to assess the leachability of NAPL and other contaminants, as well as the material strength, would need to be performed on the stabilized material in order to determine whether it would meet the beneficial use requirements.

The fines content (i.e., clays and silts), organic carbon content, NAPL impacts, and other contaminants in the sediment will influence the possible beneficial use options. The average total organic carbon content for RTAs 1, 2, 3a, and 3b are approximately 14,000 mg/kg, 26,000 mg/kg, 27,000 mg/kg, and 6,800 mg/kg, respectively. RTA 2 exhibits the greatest degree of NAPL impacts and RTA 3 exhibits the least. It is the NAPL impacts in RTA 2 that preclude the application of this option to sediment from RTA 2.

Potential beneficial use options include the stabilized sediment's use as fill or landfill daily cover, or its incorporation into construction materials such as concrete. For the purposes of this FS, it is assumed that the sediment would be stabilized and used as fill material in a controlled location (e.g., landfill cover). Table 4-4 provides additional assumptions related to

the reagent types, dosages, transport distances, and other parameters used as the basis of the cost estimate.

Option E: Onsite Stabilization and Onsite Beneficial Use. Option E is also applicable only to RTAs 1 and 3 and includes stabilizing dewatered sediment onsite and beneficially using the material onsite or within the area immediately adjacent to the project area. Characteristics of the sediments and the rationale for excluding sediment from RTA 2 were described under Option D. Sediments would need to be stabilized to a degree consistent with their beneficial use including considerations on the leachability of contaminants.

A beneficial use for this material would need to be identified; the limitations, additional data needs, and further evaluations described for Option D also apply to Option E. The FS assumes that the beneficial use would be in a permanently controlled environment (e.g., long-term potential human and ecological direct contact exposures and contaminant release are appropriately limited) and that long-term monitoring would be performed. Permanent institutional controls would be required to ensure the long-term effectiveness of this option.

A temporary onsite stabilization facility would need to be constructed and a location for this facility would need to be identified. Table 4-4 includes the specifications for this facility that were used to develop the cost estimate. Final disposition of the stabilized sediment is assumed to be a net zero cost following onsite stabilization.

Option F: Offsite Stabilization, Transport of Treated Material Back to Site, Placement in Onsite Constructed CDF. Option F is considered only for RTA 3 sediments because the space requirements to construct a CDF that could contain the contaminated sediments from all three RTAs would be significant. The remedy can be designed so that the sediments placed in the CDF are those with fewer NAPL impacts and less contamination and the sediments sent for offsite disposal or treatment are those with greater NAPL impacts and contamination. However, the selected remedy may utilize this disposal option for sediment from other reaches of the canal, especially those from RTA 1 if areas of lower contamination are identified during design and additional CDF capacity becomes available.

This option consists of transporting the stabilized sediment from the offsite treatment facility back to the site by barge, and then transferring the sediment into an onsite constructed CDF. The containment facility would be constructed by installing single sheet pile wall on the sides adjacent to land and a installing a double sheet pile wall on the side of the CDF that was adjacent to water. The void in the double sheet pile wall would be filled with bentonite-augmented soil or a similar low-permeability material. This FS assumes that three sides of the CDF will be adjacent to land and one side will be adjacent to water. Under this option, enough stabilization agents (e.g., portland cement and/or blast furnace slag) would be added to the dewatered sediment such that a monolithic mass would result. The material would be transferred into the constructed CDF before it was completely hardened and would be placed using standard material-handling equipment.

Once the treated sediment has hardened, leaching is expected to be negligible, so no leachate collection system is assumed for this alternative. Upon placement of the sediment, the CDF would be capped. This FS assumes that the top layer of the cap will be asphalt, allowing use of the surface. Surveys would be required on a regular basis to monitor the

long-term integrity of the cap. Cap maintenance would include placement of additional clean materials to replace damaged areas of the cap.

Bench-scale testing is recommended to determine the amounts of stabilizing/solidifying agents that should be added to the sediment to result in the desired consistency. Tests to assess the leachability of NAPL and other contaminants would also be performed on the stabilized material in order to refine the CDF design.

For the purposes of this FS, it has been assumed that a CDF able to accommodate the entire volume of sediment removed from RTA 3 could be constructed. The volume of in situ sediment in RTA 3 has been estimated at 281,000 cubic yards (Table 4-5), and an expansion factor of approximately 1.15 has been estimated for stabilized material for this disposal option, resulting in a CDF capacity of approximately 323,000 cubic yards. If the CDF is constructed such that the thickness of stabilized sediment is 20 feet, the area required for the CDF would be approximately 436,000 ft², or 10 acres.

Option G: Onsite Stabilization and Disposal in Onsite Constructed CDF. The description of disposal under Option F is applicable to Option G, with the exception that the stabilization will be performed onsite and transport of sediment to and from an offsite stabilization facility would not be needed. For the purposes of this FS, it is assumed that an onsite temporary stabilization facility would be constructed near or adjacent to the CDF location. The proposed onsite stabilization facility is described in Table 4-4.

Short-Term Monitoring

Short-term monitoring would be required during the construction phase to protect human health and the environment. Monitoring requirements could include turbidity and water quality monitoring, dust and air quality monitoring, and noise monitoring. The monitoring requirements will be defined during the remedial design.

Institutional Controls

Institutional controls limiting the size of vessels using the canal, the speeds at which vessels can use the canal, and limitations on anchoring or mooring would be needed to minimize damage to areas where a cap was placed. If disposal Option E is utilized, institutional controls to limit construction activities and exposure to the stabilized, beneficially used sediment would be required. If disposal Option F or G is utilized, institutional controls to limit access and future use of the CDF site would be required.

Long-Term Monitoring and Maintenance

Surveys would need to be performed on a regular basis to monitor the long-term integrity of the capped areas and to assess the potential for recontamination. Annual surveys may be appropriate in some areas (e.g., near-CSO discharge points and in areas with higher vessel traffic or higher potential for scour) to confirm layer thickness. At defined intervals, surveys on a defined grid would need to be conducted across the entire RTA to assess layer thickness, cap performance, and integrity. Cap performance metrics may include assessment of cap adsorptive capacity and monitoring for sheens on the water surface. Surveys after severe storm events may also be needed to assess cap integrity. Cap maintenance could include placement of additional clean materials and/or increased armoring to supplement or replace damaged areas of the cap. Cap repairs would be performed as needed. A long-

term monitoring plan developed as part of the remedial design would describe the performance metrics to be used and the appropriate monitoring and repair requirements. Table 4-4 lists the assumptions used to develop the long-term monitoring and maintenance costs.

4.5 Detailed Analysis of Alternatives

Detailed analyses of Alternatives 1, 5, and 7 and the associated disposal options were performed for each RTA. Tables 4-6a through 4-6c present the detailed analysis of the alternatives against the NCP criteria defined in Section 4.1. These tables provide only the present-worth costs for comparison purposes. Table 4-7 presents the capital costs, periodic operations and maintenance costs, and present-worth costs for each alternative and the associated disposal options. Appendix F contains the detailed cost estimates.

A semiquantitative evaluation of the disposal options relative to the sustainability metrics is presented in Table 4-8. Because the only substantive difference between Alternatives 5 and 7 is the inclusion of targeted ISS, the goal of this evaluation was to identify differences between the disposal options. This evaluation focused on the metrics that are the most significant for the alternatives evaluated.

4.6 Comparative Analysis

The comparative analysis was also performed by RTA, and Tables 4-9a, 4-9b, and 4-9c present the results of the comparative analysis for RTAs 1, 2, and 3, respectively. The following sections explain the relative ranking of alternatives for each of the seven NCP criteria and discuss the comparative sustainability considerations among the disposal options. The subcriteria within each of the seven NCP criteria were considered during the detailed and comparative evaluation; however, the following discussion focuses on the ranking of the alternatives with respect to the primary criteria. This narrative is relevant to all three RTAs with respect to the alternatives' dredging, capping, and ISS components. The discussion of the disposal options herein is RTA specific because only a subset of the disposal options considered were retained for evaluation in RTAs 1 and 2.

4.6.1 Overall Protection of Human Health and the Environment

Alternative 1, No Action, would not provide overall protection of human health and the environment. This alternative would not achieve the RAOs for the canal. Contaminated sediments would remain onsite and exposed. Exposure to these sediments would continue to pose human health and ecological risks. NAPL migration from the sediment to the surface water would continue, and the potential for direct contact with NAPL would remain.

Alternatives 5 and 7 are expected to be protective of human health and the environment. These alternatives would meet the RAOs by removing contaminated soft sediment and placing a cap to reduce and control the long-term risks associated with the native sediment. Placing a cap over contaminated native sediment remaining in the canal would prevent exposure to human and ecological receptors, thereby reducing and controlling toxicity to benthic organisms and eliminating the risks to herbivorous birds. The cap would also

prevent direct contact with NAPL and prevent NAPL migration to the surface water of the canal. The implementation of ISS in targeted areas as part of Alternative 7 would be expected to provide additional protectiveness against NAPL migration from the native sediment.

Implementation of Alternatives 5 or 7 would improve the surface water quality of the Gowanus Canal by controlling and eliminating sheens and preventing contact of the surface water with the contaminated sediment.

4.6.2 Compliance with ARARs

Because no action is taken under it, Alternative 1 would not trigger the chemical-, action-, or location-specific ARARs.

Alternatives 5 and 7 can be designed to comply with the substantive components of the ARARs.

4.6.3 Long-Term Effectiveness and Permanence

Alternative 1 would not result in any significant change in risk associated with contaminated sediment or NAPL. This alternative receives a low ranking for this criterion.

Alternatives 5 and 7 would result in significant, permanent reduction of the risks associated with canal sediments and would meet the RAOs. Both alternatives would provide long-term protection of human health and the environment. The risks associated with contaminated sediment and NAPL in the canal would be reduced over the implementation period of the alternatives as the sediments are removed from the canal.

The cap layout described in this FS would provide long-term control of the risks associated with the native sediment in the canal, provided that appropriate long-term cap monitoring and maintenance plans are implemented. Adsorptive caps to control NAPL migration can be designed for a set life expectancy where the NAPL migration rate is known. At the McCormick & Baxter Superfund site in Portland, Oregon, the NAPL discharge rate to the cap was estimated and a design life of over 100 years established (Blischke and Olsta, 2009). NAPL discharge rates at the Gowanus Canal should be determined prior to cap design to establish the appropriate adsorptive cap thickness requirements.

Alternatives 5 and 7 are considered to have a high degree of effectiveness because all the soft sediment would be removed, and risks associated with the native sediment would be controlled by the cap. The application of ISS to targeted areas of native sediment in Alternative 7 is expected to further reduce the NAPL mobility from the native sediment; however, treatability and pilot testing will need to be performed to determine the effectiveness and implementability of ISS within the canal.

The seven disposal options were also ranked with respect to long-term effectiveness and permanence. Options A, B, and C rank high with respect to this criterion because the material will be transferred offsite and treated or contained in a managed landfill, alleviating the associated risk.

Options D and E (stabilization and beneficial use) are considered to have low to moderate long-term effectiveness. The effectiveness would depend on the actual beneficial use. Use as

an offsite landfill cover, as is assumed for Option D, would be effective and permanent since the material is used in a controlled, monitored environment. Use as onsite fill could potentially be effective and permanent but would require testing to ensure that appropriate treatment is applied and would require a suitable, controlled, end-use location to be identified. Long-term monitoring would also be needed to assure that performance criteria continue to be achieved. Permanent institutional controls would be needed to ensure that long-term potential human and ecological direct contact exposures are appropriately limited. The institutional controls would need to restrict digging or construction activities within the fill material and may need to be applied to one or more properties, depending on where the material is used. Depending on the number of properties and where on the properties the fill is placed, more effort and coordination may be needed to ensure successful implementation and enforcement of these controls. Institutional controls would require sustained application and monitoring to assure their success.

Options F and G (stabilization and placement into a constructed CDF) are considered to have a moderate to high ranking for this criterion because the sediment will remain onsite but will be contained in an engineered CDF. Under Options F and G, the sediment would be permanently stabilized into a relatively impermeable monolithic mass, which is the primary mechanism for reducing or controlling long-term risk. The CDF could be designed to provide additional protection of human health and the environment through additional containment. As previously noted, the remedy can be designed so that the sediments placed in the CDF are those with fewer NAPL impacts. Long-term monitoring, periodic repair, and maintenance would be needed to assure that the CDF continues to function effectively. Institutional controls, which would be relatively straightforward to implement and maintain, would be required to assure that the CDF would remain undisturbed.

4.6.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternative 1 does not include a treatment component and therefore is ranked low for this criterion.

The granular oleophilic clay layer included in the cap layouts under Alternatives 5 and 7 will reduce the mobility of NAPL and is considered a treatment technology. The overall reduction of NAPL mobility expected to be achieved by this oleophilic clay layer is high. Alternative 7 is considered to have a higher ranking because the capping component is the same as that included in Alternative 5, but its effectiveness is supplemented by ISS. The application of ISS to targeted areas of native sediment in Alternative 7 is expected to further reduce the NAPL mobility from the native sediment; however, treatability and pilot testing will need to be performed to determine the effectiveness and implementability of ISS within the canal.

The reduction of toxicity, mobility, or volume of the dredged sediment is dependent upon the disposal option selected; therefore, the four disposal options are also evaluated and ranked. Thermal treatment (Option A) and cogeneration (Option C) are both ranked high. Both treatment options would significantly reduce or eliminate the toxicity, mobility, and volume associated with the dredged sediment, and both options would satisfy the statutory preference for treatment as a principal element of the alternative. Disposal Options B (offsite landfill disposal), D and E (stabilization and beneficial use), and F and G (stabilization and placement into a constructed CDF) are all ranked as moderate for this criterion. Stabilization

of the sediment would reduce contaminant mobility, but toxicity and volume would not be affected.

Thermal treatment (Option A) and thermal destruction through cogeneration (Option C) are irreversible. The stabilization components of Options F and G are considered irreversible since the treated sediment would be placed in a controlled and monitored disposal facility. The irreversibility of stabilization for Options D and E (beneficial use) will be dependent upon the conditions where the material is placed and the degree of stabilization performed. Additional testing will be required to determine if an irreversible stabilization process can be developed on the basis of beneficial use.

4.6.5 Short-Term Effectiveness

The short-term effectiveness of Alternative 1, No Action, is considered to be high because no construction activities would occur.

The preconstruction site work, sediment removal, and capping components of Alternatives 5 and 7 are considered to have moderate short-term effectiveness due to the construction duration and the associated potential risks and environmental impacts described in Tables 4-6a through 4-6c.

The short-term effectiveness of the disposal options is evaluated based on the potential short-term impacts to the site associated with transportation and the transportation distance required. The short-term effectiveness is considered moderate to high for all seven disposal options evaluated (Tables 4-9a through 4-9c).

The transportation distance of dredged material to the final treatment or disposal facility is an important consideration for short-term effectiveness. Options E (onsite stabilization and onsite beneficial use) and G (onsite stabilization and disposal in onsite CDF) do not require the dredged sediment to be transported offsite, although stabilization reagents (e.g., cement and blast furnace slag) would need to be transported to the onsite facility. Of the remaining disposal options, Option F (offsite stabilization and disposal in onsite CDF) offers the shortest transport distance for the dredged sediment (approximately 60 nautical miles round trip), all of it by barge. Disposal Option A (thermal treatment) consists of approximately 30 nautical miles of barge transport from the site to the offsite-dredge-material-processing facility and from there approximately 60 miles of transport by truck to the thermal treatment facility used as the example facility in this FS. The transport distance for Option B (offsite landfill) is estimated to be approximately 30 nautical miles by barge to the processing facility and then approximately 110 miles by truck to a disposal facility. Option C (cogeneration) is estimated to include approximately 30 nautical miles of transport to the processing facility and approximately 350 miles by truck to the cogeneration plant used as the example facility in this FS. The offsite beneficial use for sediment under Option D has been assumed to be landfill cover; thus, for purposes of this FS, it has been assumed that the material will need to be transported approximately 110 miles by truck from the offsite stabilization facility to the disposal facility.

4.6.6 Implementability

Alternative 1 is considered to be readily implementable (high ranking) because no remedial actions would be performed; however, this alternative would not be administratively feasible because it would not meet any of the RAOs for the site.

The dredging and capping components of Alternatives 5 and 7 are considered moderately implementable. Both alternatives will require significant coordination among USEPA, USACE, NYSDEC, New York City, potentially responsible parties, and property owners and tenants along the canal from the start of the design through completion of construction. The specific characteristics of the canal (e.g., debris, degraded bulkheads, space limitations, and the surrounding lively metropolitan residential and commercial community) and the large volumes of capping materials required will pose challenges to the remedy implementation. The amount of material required for the cap construction may require using several vendors, advanced planning, and stockpiling material in advance of the construction to assure that enough material is available during the implementation period. It is anticipated that appropriate planning and engineering measures can address these issues. Alternative 5 is considered to have moderate overall implementability. Because there are more uncertainties associated with the ISS component of Alternative 7 and additional treatability and pilot testing are required to determine the overall feasibility and effectiveness of this technology, Alternative 7 is considered to have low to moderate implementability.

The implementability of the different disposal options is more variable:

- Option A (offsite thermal desorption and beneficial use): moderate
- Option B (offsite land fill disposal): moderate to high
- Option C (offsite cogeneration and beneficial use): moderate
- Option D (offsite stabilization and offsite beneficial use): moderate
- Option E (onsite stabilization and onsite beneficial use): moderate
- Option F (offsite stabilization and disposal in onsite constructed CDF): moderate
- Option G (onsite stabilization and disposal in onsite constructed CDF): moderate

Thermal treatment and cogeneration facilities (Options A and C, respectively) are limited within the geography, which will restrict the ability to competitively bid these services. The total PCB and lead concentrations in the soft sediment in some portions of the canal may also limit the potential for beneficial use after thermal treatment. Treatability testing will be needed to confirm that the available treatment facilities can accept the dewatered and stabilized sediment.

The availability of landfill facilities that will accept contaminated river sediment as waste and the existing capacity at these facilities within the geography is limited. Based on inquiries of Subtitle D landfills in the region, few facilities in the region will accept materials originating from outside the county they serve, and only a subset of these facilities will accept dredged material. Because Option B includes offsite landfill disposal of the stabilized dredged sediment, the implementability of this option is reduced for disposal facilities within the region; however, additional disposal facilities are available outside the region. Use of these facilities would result in increased transport costs. The beneficial use of treated sediment under Options A and C is expected to be readily implementable as long as treated sediment meets the end-use requirements.

The implementation of Options D and E (stabilization and beneficial use) will require identifying an offsite or onsite beneficial use of the stabilized material as well as defining the performance standards for the end-use requirements. The stabilized material will need to meet the chemical and physical performance standards (e.g., short- and long-term leachability and strength characteristics) in order for this alternative to be implemented. Additionally, onsite use of the stabilized material will require stakeholder acceptance and the sustained application of institutional controls. Due to these unknowns and challenges, these two disposal options are considered to have moderate implementability. The offsite beneficial-use option has a slightly higher ranking due to the possibility of more beneficial-use applications. The onsite beneficial-use option also is ranked slightly lower due to the potential difficulties associated with effective sustained implementation of institutional controls described in Section 4.6.3.

Implementation of disposal Options F and G (stabilization and onsite CDF) is dependent on the identification of a suitable location and acceptance from stakeholders. This option may be difficult to implement due to administrative considerations. This option received a moderate ranking.

4.6.7 Cost

A summary of the estimated cost for each alternative and the associated disposal options within RTAs 1, 2, and 3 is provided in Table 4-7. Appendix F presents the detailed cost estimates and associated assumptions. The detailed components presented in Table 4-4 provide the basis of the cost estimate. Source control measures will be needed to ensure that the sediment remedy achieves the RAOs and is sustainable. Source control is the first component of all alternatives except No Action. Source control measures are in the process of being developed; therefore, the associated costs are not included in this FS. The source control measures that will be developed are included by reference in this FS.

4.6.8 Sustainability

The sustainability evaluation of the seven disposal options is presented in Table 4-8. This evaluation is qualitative and was performed by considering four areas of potential sustainability impacts that are considered to be the most significant. The evaluation did not focus on water requirements or impacts on water resources because that was not considered to be a significant criterion for the evaluation of the disposal options. The four criteria evaluated were also assigned a ranking of relative importance (a "1" ranking was the most significant and "4" the least significant). The ranking assigned is as follows:

1. Energy consumption/fossil fuel depletion
2. Waste reduction, reuse, recycling
3. Greenhouse gas and other air emissions
4. Transportation impacts

The overall ranking of the sustainability impacts for each disposal option is as follows:

- Option A (offsite thermal desorption and beneficial use): high
- Option B (offsite land fill disposal): moderate to high
- Option C (offsite cogeneration and beneficial use): moderate
- Option D (offsite stabilization and offsite beneficial use): moderate

- Option E (onsite stabilization and onsite beneficial use): low
- Option F (offsite stabilization and disposal in onsite constructed CDF): low
- Option G (onsite stabilization and disposal in onsite constructed CDF): low

4.7 Remedial Design Considerations

The evaluations performed in this FS have identified a number of elements that may require further consideration during the remedial design. The surveys, evaluations, and analyses listed below are not prescriptive or inclusive, but simply summarize possible data collection activities identified during the development and analysis of alternatives.

The remedial design will need to include development of a groundwater model to determine whether proposed upland source control measures such as slurry walls or barrier walls and the potential ISS of the native sediment will alter the groundwater flow patterns within and around the canal such that the remedy is affected. Additional data collection and evaluation to determine NAPL seepage rates will be required in order to determine the final cap designs. Hydrodynamic modeling may also be required to support the final cap designs.

The design should also incorporate technologies that could increase the overall protection and permanence of the remedy but had not yet been proven or established at the time this FS was written. ISS is a developing technology that will require further evaluation if included in the selected remedy. Pilot studies and treatability testing will be required to determine the stabilization reagents and dosage required as well as an effective and implementable delivery mechanism.

The remedial design may also include additional evaluation and analysis of the sustainability impacts of the selected alternative and consider potential ways to reduce the overall environmental footprint of the remedy. Although the sustainability evaluation herein focused on the disposal options, all components of the alternative should be evaluated with respect to increasing the overall sustainability. Examples include considering approaches to minimize energy and fuel use by reducing transportation distances and utilizing the most efficient form of transportation possible for both supplies (e.g., capping materials) and dredged material, reducing the amount of material requiring disposal, and maximizing the beneficial use of treated material.

In addition to determining NAPL seepage rates, other data collection activities and surveys performed during the remedial design may include a bulkhead stability evaluation, a bathymetry- and sediment-probing survey to refine volumes and establish baseline conditions prior to remedial action, and sediment chemistry surveys to establish baseline, or preremedy, conditions.

Additional bench-scale testing will be needed to support all the treatment and disposal options considered in order to determine the stabilization materials that would be needed and their quantities. These evaluations will also need to confirm that the stabilized materials meet the acceptance criteria of the treatment or disposal facilities or will meet specified performance criteria for beneficial-use options. A beneficial use for stabilized sediment would need to be identified for Options D and E, and the associated performance criteria for the end purpose would need to be determined; corresponding appropriate institutional

controls would need to be identified and sustained long term. The sediment samples used for these evaluations would need to be collected following a sampling scheme that results in composite samples representative of the approximate sampling frequency required by the receiving facilities (e.g., one sample per 4 to 5 tons of material).

SECTION 5

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