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Gowanus Canal Superfund Site

Kings County, New York

December 2012

PURPOSE OF THIS PROPOSED PLAN

This Proposed Plan describes the remedial alternatives considered for the Gowanus Canal Superfund site and identifies the preferred remedy with the rationale for this preference. This document was developed by the U.S. Environmental Protection Agency (EPA) in consultation with the New York State Department of Environmental Conservation (NYSDEC). EPA is issuing this document as part of its public participation responsibilities under Section 117(a) of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended (CERCLA) and Sections 300.430(f) and 300.435(c) of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). The nature and extent of the contamination at the site and the remedial alternatives summarized in this document are described in detail in the January 2011 remedial investigation (RI) report, December 2011 feasibility study (FS) report and December 2012 FS report addendum. EPA encourages the public to review these documents to gain a more comprehensive understanding of the site and EPA's cleanup proposal.

For the upper and mid-reaches of the canal, the preferred remedy consists of dredging the entire column of hazardous substance-contaminated sediments referred to as "soft sediments," which have accumulated above the native sediments, installation of a multilayered cap to prevent the migration of nonaqueous phase liquid (NAPL)[1] from native sediments and in-situ stabilization (ISS)[2] of those native sediments in select areas contaminated with high levels of NAPL. For the lower reach of the canal, the preferred remedy consists of dredging the entire soft sediment column and constructing a multilayer cap. Sediment treatment and disposal methods would vary based on the reach and contaminant levels. The NAPL-impacted sediments dredged from the upper and mid-reaches of the canal would be treated through thermal desorbtion[3] and reused off-site (*e.g.*, landfill cover). The less contaminated sediments dredged from the lower reach of the canal and sediments not impacted by NAPL would be stabilized and reused off-site. It is also technically feasible to place these stabilized sediments in an on-site confined disposal facility (CDF) properly designed to contain them[4] (the CDF will be evaluated based upon community acceptance during the comment period and approval from NYSDEC and other appropriate governmental regulatory authorities). The preferred remedy would also include the excavation and restoration of the filled-in 1st Street Turning Basin, a former lateral canal extension which contains contaminated fill overlying contaminated sediment. Institutional controls would incorporate the existing fish consumption advisories (modified, as needed) and would include other controls to protect the integrity of the cap and the CDF, if a CDF were constructed.

The estimated present-worth cost of the preferred remedy ranges from $467 - $504 million.

To prevent recontamination, the upland sources of hazardous substances, including discharges from three former manufactured gas plants (MGPs), combined sewer overflows (CSOs)[5] to the canal, other contaminated areas along the canal and unpermitted pipes along the canal, must be controlled. The former MGP sites are being addressed by National Grid, a potentially responsible party (PRP) for these sites and the federal site, under NYSDEC oversight. Based upon the first NYSDEC-selected remedy at one of these sites, it is assumed that each would prevent the migration of contamination from the former MGP into the canal. In the unlikely event that a timely and effective State-selected remedy is not implemented at a given former MGP site, EPA may implement actions pursuant to CERCLA to ensure the protectiveness of the preferred remedy.

NYSDEC is currently overseeing work being performed by New York City (NYC) to reduce CSOs to the canal by approximately 34 percent. These reductions, however, affect only the mid- and lower canal CSO outfalls. To prevent recontamination of the canal, a number of CSO control measures for the upper reach of the canal were evaluated. EPA presumed that in-line storage tanks would be constructed to capture and reduce contaminated sediment from CSO discharges. Controls related to future sewer capacity would be necessary to maintain the effectiveness of the CSO measures. Since it is unlikely that permanent measures to control the CSO discharges would be in place before the commencement of the remediation of the sediments, interim controls may be necessary to mitigate sediment from the CSO discharges until permanent measures can be implemented. In addition, EPA and NYSDEC are coordinating measures to control discharges from other upland contaminated areas adjacent to the canal. Under the preferred remedy, unpermitted pipe outfalls will be either controlled or eliminated.

Changes to the preferred remedy or a change from the preferred remedy to another remedy may be made if public comments or additional data indicate that such a change will result in a more appropriate remedial action. The final decision regarding the selected remedy will be made after EPA has taken into consideration all public comments. EPA is soliciting comment on all of the alternatives considered because EPA may select a remedy other than the preferred remedy.

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1 Concentrated liquid contamination, typically oil-like, that forms a separate phase and does not dissolve in water.
2 Mixing of materials, such as concrete, into the sediments to bind the contaminants physically/chemically.
3 Utilization of heat to increase the volatility of contaminants so that they can be removed.
4 A secure structure designed to contain dredged sediments (in this case after stabilization) within a waterway.
5 Combined sewers receive both sewage and stormwater flows and discharge to the canal when the sewer system's capacity is exceeded.

MARK YOUR CALENDAR

January 23, 2013 at 7:00 P.M.: Public meeting at Public School 58 (the Carroll School), 330 Smith Street, Brooklyn, New York.

January 24, 2013 at 7:00 P.M.: Public meeting at Joseph Miccio Community Center, 110 West 9th Street, Brooklyn, New York.

March 28, 2013: Close of the public comment period related to this Proposed Plan.

Copies of supporting documentation are available on-line at http://www.epa.gov /region02/superfund/npl/gowanus/ and at the following information repositories:

Carroll Gardens Library
396 Clinton St.
Brooklyn, NY 11231

Joseph Miccio Community Center
110 West 9th Street
Brooklyn, NY 11231

EPA-Region II
Superfund Records Center
290 Broadway, 18th Floor
New York, NY 10007-1866
212-637-4308

COMMUNITY ROLE IN SELECTION PROCESS

EPA relies on public input to ensure that the concerns of the community are considered in selecting an effective remedy for each Superfund site. To this end, the RI report, FS report, FS report addendum, and this Proposed Plan have been made available to the public for a public comment period that concludes on March 28, 2013.

Two public meetings will be held during the public comment to present the conclusions of the RI/FS, elaborate further on the reasons for recommending the preferred remedy and receive public comments (see the text box above for the details about the meetings).

Comments received at the public meetings, as well as written comments received during the comment period, will be documented in the Responsiveness Summary Section of the Record of Decision (ROD), the document that formalizes the selection of the remedy.

Written comments on the Proposed Plan should be addressed to:

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SCOPE AND ROLE OF ACTION

EPA has the primary responsibility under CERCLA for investigating and remediating the canal sediments. By agreement between EPA and NYSDEC, NYSDEC has the primary responsibility for the investigation and response actions related to the upland properties adjacent to the canal and the CSOs under the Clean Water Act (CWA). Addressing ongoing contaminant contributions to the canal from active sources is a prerequisite to a sustainable remedy for canal sediments.

The primary objective of the response action addressed in this Proposed Plan is to remediate the contaminated sediments in the Gowanus Canal in order to reduce or eliminate unacceptable human health and ecological risks from exposure to the contaminated sediments and to prevent recontamination of the sediments after the remedy is implemented.

This response action does not address the contaminated groundwater that is migrating to the canal from the upland sources. The groundwater contamination will be addressed as part of the upland source remediation.

SITE BACKGROUND

Site Description

The Gowanus Canal is a 1.8-mile-long, man-made canal in the Brooklyn Borough of NYC, in Kings County, New York (see Figure 1) (all figures are attached hereto).

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 a viaduct for NYC subway trains 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. South of Hamilton Avenue, the canal widens to a maximum of approximately 2,200 feet and ranges in depth from -15 to -35 feet mean lower low water (MLLW).[6] 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. It borders several residential neighborhoods, including Gowanus, Park Slope, Cobble Hill, Carroll Gardens and Red Hook, with housing located within one block of the canal. The waterfront properties abutting the canal are primarily commercial and industrial. Re-zoning of canal-front parcels to high density residential began in 2009 and further such re-zoning is anticipated. During major storm events, canal flooding affects broad areas which are industrial, residential and commercial in nature.

A number of businesses use the canal for maritime commerce. All but two of the businesses are located south of 9th Street and none are located north of 4th Street. The canal is also regularly used by recreational boaters (primarily, canoers and kayakers). A limited number of people reside in houseboats on the canal.

Despite a New York State Department of Health fish advisory covering the entire Gowanus Canal, posted warnings and public outreach efforts, the canal is regularly used for fishing, particularly subsistence fishing by environmental justice communities surrounding the canal.

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 storm water and fill the adjacent lowlands for development. The canal was constructed in the mid-1800s by bulkheading and dredging.

The former 1st Street basin[7] was originally utilized to deliver coal via barges to the former Brooklyn Rapid

[6] The canal has two high tides and two low tides of unequal height each tidal day. MLLW is the lower low water height.
[7] The 1st Street basin is described in detail since it will be addressed under the proposed remedy.

Transit Power House. The Power House consumed large quantities of coal. During its operating era, large coal piles surrounded the building until the plant became obsolete and was removed from service. As was noted above, the 1st Street basin was filled in. Portions of the building were also torn down over time. By 1969, the 125-foot tall smokestack and dynamo sections of the Power House had been demolished and the currently extant section of the Power House was the only part of the original building still standing.

Following its construction, the canal quickly became one of the nation's busiest industrial waterways, servicing heavy industries that included MGPs, coal yards, cement manufacturers, tanneries, paint and ink factories, machine shops, chemical plants and oil refineries. The Gowanus Canal served as an open sewer when it was initially constructed in the late 1860s. As a result of the poor environmental practices typical of the era, large quantities of wastes from many of these operations were discharged directly into the canal. By the late 1870s, sewers entering the canal carried a combination of household waste, industrial effluent from the MGPs and other industries and storm water runoff (Hunter Research *et al.*, 2004). These discharges, which contained hazardous substances, such as polycyclic aromatic hydrocarbons (PAHs) (a semi-volatile organic compound [SVOC]), polychlorinated biphenyls (PCBs), pesticides, metals and volatile organic compounds (VOCs), caused the canal to become one of New York's most polluted waterways.

The initial canal design recognized the likelihood of stagnant pollution problems and proposed various flushing solutions. These were not, however, implemented. Studies and commissions have repeatedly examined methods of addressing the contamination. A series of unsuccessful solutions were implemented, including directing additional sewage discharges to the canal in order to improve flow. In 1911, NYC began operating the Gowanus Canal Flushing Tunnel to address the canal's serious water quality issues. The Flushing Tunnel connects the head of the canal with Buttermilk Channel in Upper New York Bay. It was designed to improve circulation and flush pollutants from the canal by pumping water in either direction. The Flushing Tunnel starts at Degraw Street on Buttermilk Channel and ends on the west side of the canal at Douglass Street. The Flushing Tunnel operated until the mid-1960s, when it fell into disrepair.

The Flushing Tunnel was rehabilitated and reactivated in 1999 by the New York City Department of Environmental Protection (NYCDEP), pumping cleaner harbor water from Buttermilk Channel to the canal using a rebuilt version of the 1911 propeller-based pump system. Thereafter, NYCDEP determined that the 1990s Flushing Tunnel repairs were inadequate, with the custom-made pumping system being poorly designed, difficult to maintain and unable to function properly at low tide.

Direct discharges to the canal from industrial activities were substantially reduced or controlled over time because of declining industrial activity and the implementation of the CWA in the early 1970s. Discharges from present-day industrial operations are regulated and permitted under the CWA's National Pollutant Discharge Elimination System (NPDES) and its state counterpart, the State Pollutant Discharge Elimination System (SPDES).

Although the level of industrial activity along the canal declined over the years as industry shifted away from the canal, high levels of hazardous substances remain in the sediments and upland sources. Discharges from upland contaminated areas adjacent to the canal, CSOs, storm sewers and unpermitted pipe outfalls continue to contribute contaminants to the canal. The history of these sources is summarized below.

Discharges from Upland Contaminated Areas Adjacent to the Canal

Contaminated areas adjacent to the Gowanus Canal are being investigated and remediated under the direction of NYSDEC. EPA is coordinating with NYSDEC on these matters. Environmental investigations or cleanups are in progress at the Fulton, Carroll Gardens/Public Place (formerly known as "Citizens Gas Works") (hereinafter, "Public Place")[8] and Metropolitan former MGP sites along the canal. Until these sites are remediated, contaminants from them will continue to be transported into the Gowanus Canal primarily by the migration of NAPL through subsurface soils and groundwater discharge of dissolved-phase contaminants. PAHs are the primary contaminants of concern (COCs) from these sources.

The former MGP sites are being addressed under the State Superfund and Brownfield Cleanup programs by National Grid, a PRP for these sites as well as for the canal. EPA and NYSDEC have agreed to a coordinated schedule for the former MGP sites and canal sediment cleanup efforts based on the anticipated timing of the dredging in the canal (which would commence at the head of the canal). In January 2012, NYSDEC directed National Grid to begin the expedited remedial design of a cutoff wall as an interim remedial measure for the Fulton former MGP, near the head of the canal. The purpose of this wall is to prevent subsurface migration of NAPL from the Fulton former MGP site into the sediments at the bottom of the canal. For the Public Place former MGP, centrally situated near the curve in the canal (see Figure 2), the remedy includes a combination of excavation and a subsurface barrier wall and tar extraction wells. An investigation and partial source control cleanup was implemented at the Metropolitan site, the third and most southerly former MGP, in 2003 under the State's Voluntary Cleanup program. Since there are potential source areas at this site that were not addressed by the actions taken in 2003, an RI for this site is currently underway.

[8] A remedy was selected for the Public Place former MGP in 2007. The design of the selected remedy is approximately 50% complete.

Based on the results of EPA's RI, additional upland areas were found to have the potential to contribute contaminated groundwater to the canal and were referred to NYSDEC for investigation and, if necessary, remediation under the State Superfund program. Remediation schedules will be coordinated with the schedule for the canal remedy. Relative to the former MGP sites, these areas are much smaller potential sources and are thus, expected to require only a fraction of the time and cost to address.

Discharges from Combined Sewer Overflows and Stormwater

The Owls Head and Red Hook wastewater treatment plants (WWTPs) serve the area. When an appreciable amount of rainfall occurs, runoff enters the combined sewers and exceeds the capacity of the system and the Owls Head and Red Hook combined sewer systems overflow to the canal. There are 10 active CSOs and three stormwater outfalls discharging to the Gowanus Canal (see Figure 3 for the locations). Four of the CSO outfalls account for 95 percent of the annual discharge. The greatest annual discharge volume is from outfall RH-034, located at the head of the canal (121 million gallons; NYCDEP, 2008a). The CSO discharges result in point source loading of high-organic-content solids and associated hazardous substances to the canal.

In 2008, NYCDEP prepared a *Gowanus Canal Waterbody/Watershed Facility Plan Report* (WB/WS Plan) 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 (AOC) between NYCDEP and NYSDEC.[9] The goal of that project is to implement a series of improvements to achieve compliance with water quality standards under the CWA. Specific objectives of the plan include eliminating odors, reducing floatables and improving dissolved oxygen concentrations to meet surface-water-quality standards. NYCDEP's planned improvements for the Gowanus Canal include continued implementation of programmatic controls, modernization of the Gowanus Canal Flushing Tunnel, reconstruction of the Gowanus Wastewater Pump Station, cleaning/inspection of the outfall OH-007 floatables/solids trap, repairs to the Bond-Lorraine Street sewer main, periodic water body floatables skimming and CSO sediment mound dredging.

In July 2010, the Flushing Tunnel was shut down by NYCDEP to perform facility improvements. This effort includes the installation of more efficient pumping systems, which will increase the volume of water by approximately 40 percent under a peak design flow. Completion of the effort is anticipated by September 2014. The reconstruction of the Gowanus Wastewater Pump Station, which began in February 2010, will increase the pumping capacity to deliver sewage to the Red Hook WWTP. All of these ongoing improvements are projected to decrease the overall discharge to the entire canal by approximately 34 percent.

However, the greatest changes in annual CSO discharge are concentrated in the middle and lower portions of the canal. Although outfall RH-034 at the head of the canal has been projected to experience fewer discharge events per year, its total annual flow is projected to increase approximately 5 percent. Annual CSO discharges from RH-034 and OH-007 will still contribute 97 percent of the total annual CSO flow into the canal.

The completion of these improvements is anticipated by September 2014. The cumulative impact of these projected flow reductions and flushing improvements on sediment transport and deposition throughout the canal cannot currently be predicted with a high degree of confidence. Following the upgrades to the Flushing Tunnel and pump station, NYCDEP will conduct post-construction monitoring and then will begin the planning and public participation related to a CWA Long-Term Control Plan (LTCP),[10] which will analyze the next stage of CSO-related improvements for the canal. The LTCP is to be submitted to NYSDEC in June 2015.

NYCDEP also plans a sewer separation project in a 96-acre area around Carroll Street for flood control purposes. It is projected that this effort would result in an additional overall CSO reduction of 5 percent when it is completed in 2022. However, the PAHs in the stormwater component of the CSO will still discharge to the canal.

NYCDEP is also undertaking a green infrastructure effort[11] that would result in an estimated 10 percent CSO reduction in stormwater discharges to the entire Canal over an extended period of time (20-30 years) (NYCDEP, 2012). Two pilot projects for the control of street runoff along the Gowanus Canal (the DL and Studio's Sponge Park at 2nd Street, on the Carroll Gardens side of the canal and the Gowanus Conservancy green infrastructure at 2nd Avenue on the Park Slope side) are being supported by federal and NYC grants.

Unpermitted Pipe Outfalls

Nearly 250 outfalls were identified in the RI, most of which were pipes located on private property. In general, these are unused pipes associated with historic industrial activities. Twenty-five of these pipe outfalls were observed to be actively discharging during dry weather (about a third of these discharges may be tidal backflow). The flow rate

[9] NYSDEC Case No. CO2-20000107-8 dated January 14, 2005 and updated on April 14, 2008, September 3, 2009 and March 8, 2012.

[10] An LCTP is a phased approach for control of CSOs that requires a permittee to develop and submit an approvable plan that will ultimately result in compliance with CWA requirements and New York State water quality standards.

[11] Green infrastructure is a network of open spaces and natural areas, such as rooftop gardens and vegetated swales, which naturally manage storm water, thereby reducing storm runoff into the storm sewers.

from all but one of the active outfalls was very small (the majority are estimated to be less than 1 liter/minute).

Permitted Pipe Outfalls

A review of NYSDEC and EPA databases identified five active permitted discharges to the canal. During the RI, discharges were not observed in three of these permitted outfalls. Two of the permitted outfalls could not be clearly identified because of the large number of outfalls in their vicinity.

Prior Dredging of the Canal

The canal's narrow 100-foot width upstream of the Gowanus Expressway represents the entire navigational channel, unlike many river and harbor sites where the shipping channel represents a fraction of the total area of the water body. In the upper two thirds of the canal, NYC has primary responsibility for maintaining the navigational depths.

Limited recent dredging of the canal has been performed and documentation of historical dredging is sparse. There are no federal, state or local regulatory requirements related to the depth of the canal north of Hamilton Avenue. Below Hamilton Avenue, the U.S. Army Corp of Engineers (USACE) previously performed maintenance dredging.

While NYCDEP has obtained State approvals for successive water quality improvement-related dredging (1983, 1993 and 2008), no major dredging has been performed in the canal in three decades. The current plan for dredging the CSO mounds at the head of the canal is scheduled for completion in 2017.

Prior Studies

Since 1983, NYCDEP has compiled four separate major reports on water quality and CSOs controls for the canal, each of which was approved by NYSDEC for implementation. Since 2003, the USACE and National Grid have each issued about a dozen reports regarding the canal. National Grid has completed numerous reports regarding its former MGP sites and studies and/or cleanups have been conducted at another dozen or more upland areas.

Listing on National Priorities List

In April 2009, the Gowanus Canal was proposed for inclusion on the National Priorities List (NPL) pursuant to the Superfund law at the request of NYSDEC. Following the proposal for inclusion on the NPL, EPA commenced an RI. On March 2, 2010, EPA placed the Gowanus Canal on the NPL.

In April 2010, EPA entered into administrative consent orders with New York City and National Grid to perform work in support of EPA's RI/FS. The RI report was completed in January 2011 and the draft FS report was completed in December 2011. An FS addendum report was completed in December 2012.

SITE CHARACTERISTICS

Site Hydrology

The Gowanus Canal is a tidally influenced, dead-end channel that opens to Gowanus Bay and Upper New York Bay (see Figure 1). 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 fresh surface water 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 the Flushing Tunnel located at the head of the canal, when it is operating (NYCDEP, 2008a).

The canal upstream of the Gowanus Expressway has been designated Use Class SD, which indicates that the surface waters are suitable for fish survival, as described in Title 6 NYCRR Part 701. The area downstream of the Gowanus Expressway is designated Use Class I, which indicates that the waters are suitable for finfish propagation and survival as described in Title 6 NYCRR Part 701.

Site Hydrogeology

Four 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 ash and 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 canal.

The canal is located within the area designated for the Brooklyn Queens Sole Source Aquifer. Groundwater is not, however, used as a potable water supply in this part of Brooklyn.

Multiple lines of evidence were developed in the RI to characterize the hydraulic relationships between local groundwater and the canal. Potentiometric surfaces developed from the synoptic (instantaneous points in time) measurement events suggest that, at the water table, groundwater flows toward the 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 five-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.

Sediment Characteristics

The sediments in the canal consist of two distinct layers. The upper layer is referred to as soft sediment. The soft sediment has 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 are 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)[12] and trash. Odors described as "organic," "septic-like," "sulfur-like," and "hydrocarbon-like" were commonly detected 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 present prior to the canal's construction. These deposits are referred to as "native" sediments and consist of brown, tan and light-gray sands, silts, silty sand, sandy clay, clay and peat.

Sediment coring data produced by EPA and National Grid document the presence of high-organic content sediments that absorbs and concentrates contaminants, including PAHs.

Specifically, the total organic carbon (TOC) content is substantially higher in Gowanus Canal surface sediments than in the Gowanus Bay and Upper New York Bay reference area sediments, with averages of 6.4 and 2.8 percent, respectively. The high TOC content of the surface of the soft sediment reflects the impact of CSO discharges to the canal. NYCDEP has estimated the loading of biochemical oxygen demand (BOD) to the canal and noted that CSOs dominate these loadings relative to stormwater runoff (NYCDEP, 2008a). BOD is another measure of organic matter in a sample. High concentrations of organic contaminants (*i.e.,* PAHs associated with NAPL) appear to have increased the TOC measurements in some samples. Other physical characteristics of each sediment type in the Gowanus Canal and Upper New York Bay reference area (*i.e.*, grain size distribution, percent solids, sulfide concentration and bulk density) are described in the FS report.

Shoreline and Bulkhead Characteristics

NYCDEP (NYCDEP, 2008b) has documented that the shorelines of the Gowanus Canal are entirely altered and are dominated by bulkheads. (NYCDEP, 2008b). 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[13] 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 tie-rods and anchors (*e.g.*, structures buried inshore of the bulkhead, such as massive concrete blocks or steel sheet-piles). The bulkheads north of Hamilton Avenue are generally constructed of wood or

[12] While the soft sediments are comprised of naturally-occurring organic material, as is noted in the "Nature and Extent of Contamination" section, below, these sediments are heavily contaminated with PAHs, PCBs, metals, and VOCs.

[13] The average of all the low water heights.

steel.

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 Brown Marine Consulting survey concluded that the existing structures were sufficient only to support present loading conditions and that any type of dredging activity could threaten bulkhead stability due to the deteriorated condition of the structures. The 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 42 percent of the bulkhead length was in fair condition or worse.

The NYCDEP report (NYCDEP, 2008b) also noted areas where the shoreline consisted of riprap and piers.

Areas of Archaeological or Historical Importance

In 2006, the Gowanus Canal Historic District was found eligible for the National and State Registers of Historic Places by the New York State Historic Preservation Office (SHPO).[14] The district was identified as a result of an eligibility study undertaken by Hunter Research in 2004 for the USACE. Additional contributing resources were identified by the SHPO in 2008 following a cultural resources study undertaken in response to the proposed Toll Brothers project at 363-365 Bond Street.

EPA supplemented this information during the RI/FS. Documentary research and a high-resolution side-scan sonar survey performed for the RI identified known historic resources in the form of the canal bulkheads, as well as anomalies on the canal bottom, which will be the subject of 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.

A historical and archaeological study of the Gowanus Canal was carried out as part of the FS to assist EPA in meeting its obligations under Section 106 of the National Historic Preservation Act and its implementing procedures (36 CFR Part 800). The study's objectives were to establish prehistoric and historic contexts for identifying and evaluating potential subsurface features of interest that may have been buried following the draining and filling of the Gowanus Creek marsh during the construction of the canal from *circa* 1853 to 1870. As part of this report, a Historic American Engineering Record (HAER) narrative history of the Gowanus Canal was prepared.

One conclusion of the study was that sites of potential archaeological interest exist within the Gowanus Canal project area. These include an area of prehistoric potential from the 1st Street basin up to Degraw Street, the sites of three tide mill complexes, two corridors of battle action from the Battle of Brooklyn during the Revolutionary War and two potential sites of soldier burials.

A geotechnical evaluation of soil borings indicated that the likelihood for these sites to have survived intact is very low to low but not entirely without potential. Their state of integrity is unconfirmed, but if intact, they will be deeply buried at depths of at least 15 feet at the edges of the canal, with the greatest likelihood of intact survival existing just outside of the canal bulkheads (about 20 feet from the edge of the canal). Moving away from the canal, any surviving cultural stratigraphy generally will be buried less deeply (based on documented patterns of filling in the former tidal marshes) and have a much higher likelihood of having been disturbed by more than 150 years of intensive urban development.

Of greater certainty are the survival of archaeological resources associated with the Gowanus Canal itself and the industries that grew beside it in the mid- to late 19th century. The canal and its basins include more than two miles of timber cribwork bulkheads that have been identified as part of the canal's historic fabric and are likely to contain important information about the canal's design and construction. Within the canal itself are the remains of at least four shipwrecks and a high likelihood that several other ship hulls have survived within the fill of the 1st Street basin. Canal-side industrial archaeology sites also have the potential to yield information related to specific industries and research questions about those industries' activities and their impact on the natural and human environment.

The study also identified recommendations for further archaeological studies and considerations to be included in the remedial design in order to avoid or mitigate remedy impacts on potential archaeological resources. Recommendations for additional cultural resources work during the remedial design phase include the refinement of the archaeological Area of Potential Effect; targeted research on canal-related, mid- to late-19th-century industrial sites that may be impacted by ground disturbances; additional, targeted geotechnical investigation; and archaeological monitoring of the removal/stabilization of timber cribwork bulkheads with documentation of sample bulkheads. Specifically related to the recommended monitoring, the additional effort will document the design and construction of the canal's

[14] The district is a linear corridor following the canal channel from a point opposite Percival and 17th Streets extending approximately 6,500 feet northeast to a point between Douglass and Butler Streets. It includes the canal channel and bulkheads, and 13 related contributing buildings and structures, sharing a context within the industrial landscape that developed adjacent to the canal following its initial phase of construction and improvement from *circa* 1853 to 1870.

timber cribwork and include the preparation of drawings as appropriate for inclusion in a supplemental HAER documentation package. Other resources identified for monitoring include any identified potential industrial archaeological resources, maritime resources identified by side-scan sonar in 2010 and the buried ships reportedly located in the 1st Street basin.

Should the bulkheads be subject to adverse effects as a result of cleanup actions, a wide range of mitigating measures could be implemented as part of the remedy. As noted above, the appropriate measures would likely include additional documentation of bulkhead characteristics and the incorporation of archaeological and architectural investigations. Where new bulkhead construction is required, bulkhead configurations that are in keeping with the historic character of the setting would be considered.

Further examination of anomalies on and within the sediments will need to be performed as remediation proceeds. This investigation would likely encompass further remote sensing and/or direct examination of items in the canal bottom.

RESULTS OF THE REMEDIAL INVESTIGATION

Based upon an analysis of the extensive prior studies and reports that were prepared for the canal and upland areas, the following additional work was performed as part of the RI: 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; sediment coring; 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; and hydrogeological investigation, which included groundwater-monitoring-well installation and development, soil sampling, groundwater sampling, groundwater–surface water interaction sampling, synoptic measurements of water levels and tidal evaluation.

Geophysical Surveys

The bathymetry of the canal was measured in a January 2010 survey using the same methodology as the 2003 USACE bathymetry study performed in a joint investigation with NYCDEP. The measured bottom depth elevations ranged from approximately -0.13 feet to -38 feet North American Vertical Datum 1988 (NAVD88). The bottom depth elevations measured within the canal north of Hamilton Avenue were typically between -0.13 feet and approximately -18 feet NAVD88; much lower sediment surface elevations were measured south of Hamilton Avenue. 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, such as tires, sunken barges, concrete rubble, timbers, gravel and general trash, is widespread throughout the canal. A debris survey was performed in late 2005 by National Grid using magnetometer, sub-bottom profiling and side-scan sonar technologies. The combined observations from the 2003 and 2005 geophysical surveys and the 2010 RI field observations were used to characterize the distribution of debris and obstructions in the canal. Detailed observations are provided in the RI/FS reports.

Extent of Contamination

<u>Sediment</u>

The horizontal and vertical distribution 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.

The canal, especially the upper reach, is a water body contained in a constructed confined space of relatively regular geometry and relatively shallow depth. Its only surface water inputs are from the New York Harbor through tidal exchanges from the south end of the canal and through Flushing Tunnel flow at the northern end (small amounts of rooftop and surface drainage from areas adjacent to the canal might also drain into the canal). Deposition of solids in the canal from these sources constitute the "background" level of contamination *(i.e*., regional contamination from Upper New York Bay with no contribution from Gowanus Canal sources) and are similar in contaminant concentration to the reference area sampling stations in the harbor. For the harbor reference stations sampled during the RI, PAH concentrations ranged from 1 mg/kg to 14 mg/kg, with an average concentration of 6 mg/kg. See Table 1 for a summary of the range and average concentrations for harbor reference data for PAHs, PCBs, copper and lead (all tables are attached hereto). Previous studies have shown that for the entire New York/New Jersey harbor system, total PAH concentrations in the sediment ranged from 0.7 mg/kg to 22.1 mg/kg (EPA, 1998).[15]

All other major inputs of chemical contamination to the canal are from anthropogenic activities and sources, such as exposed soil, historic fill and rooftop and surface

[15] Sediments in near-shore areas can have higher PAH levels than those found in open water. Another study carried out in near-shore areas elsewhere in the New York Harbor estuary suggested a higher background level (AECOM, 2009).

drainage in the immediate vicinity of the canal (usually within a city block) and from discharges in the larger canal drainage area transported to the canal via the CSO system. EPA has identified several upland point sources of contamination to the canal, including the three former MGP sites and the CSOs.

Canal sediments are affected by contaminants that are adsorbed to sediment particles and by the upwelling and horizontal transport of NAPL, which contains PAHs. In surface sediments (0-to-6-inch depth interval), PAHs, PCBs and seven metals (barium, cadmium, copper, lead, mercury, nickel and silver) were found to be contributing to unacceptable ecological and human health risks. Concentrations of these constituents in surface sediment were statistically significantly higher in the canal than at reference locations in Gowanus Bay and Upper New York Bay. The average total PAH concentration in surface sediment from the canal is two orders of magnitude higher than the average concentration in reference area surface sediment. Average total PAH concentrations in subsurface soft and native sediment are three orders of magnitude higher than samples from the reference area.

Subsurface sediment sampling data indicated that total PAHs and VOCs, particularly benzene, toluene, ethylbenzene and xylene (BTEX), were frequently detected at high concentrations, with PAHs detected up to 4,800 mg/kg in both the soft and native sediment units. The highest PAH concentrations were measured in samples that contained NAPL. 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 substantially higher concentrations than those found in the surface sediments.

Table 2 summarizes the physical characteristics of surface, soft and native sediments in the canal and surface sediment in the reference area. Table 3 shows the average concentrations of selected constituents in surface, soft and native sediments in the canal and surface sediment in the reference area. Table 4 shows the average concentrations of selected constituents in surface sediment in the upper, middle and lower reaches of the canal.

The sediment coring effort showed that NAPL contamination is present in native sediments underneath the canal between the head of the canal and the Gowanus Expressway, in portions of the upper reach of the canal and in the overlying soft sediment primarily in the middle reach of the canal. The NAPL from the three former MGPs is, primarily, coal tar waste that is migrating through subsurface soils, under and through the bulkheads and into the soft and native sediments. PAHs and BTEX are major constituents of coal tar.

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 six feet below the interface between the soft and native sediment layers. Deep borings installed in the canal adjacent to the Public Place former MGP site by National Grid in 2010 indicate that NAPL contamination extends to a depth in excess of 50 feet below the sediment surface.

While the NAPL accounts for the majority of the PAH mass and the highest PAH concentrations in canal sediments, PAH concentrations in the top 6 inches of sediments (the bioactive zone) in the upper reach of the canal are primarily associated with contaminants introduced through CSO discharges. Existing sediments in the canal are covered by newer contaminated CSO sediments and, to a much lesser extent, solids transported from the harbor through tidal transport or through the Flushing Tunnel when it is in operation. Thus, surface sediments are newer and deeper sediments are older. The deeper sediments become more heavily contaminated over time by NAPL or NAPL-derived contaminants migrating upward from below.

Combined Sewer Overflows

The results for wet weather CSO water samples (*i.e.*, samples collected from the sewer system during wet weather overflow events) indicate that CSOs containing VOCs, PAHs, PCBs, pesticides and metals discharge to the canal during wet weather events. The wet weather CSO water samples represent actual discharges to the canal. Samples were collected from the combined sewer regulators, approximately one block from the discharge points, to eliminate potential backflow (tidal intrusion) from the canal. Sampling results for residual CSO sediments collected from within sewer pipes indicate that, if mobilized during wet weather events, these would discharge VOCs, PAHs, PCBs, pesticides and metals to the canal.[16]

Unpermitted Pipe Outfalls

Effluent from 14 of the 25 active outfalls identified during the RI 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, PAHs and metals (two of the discharges were not sampled due to low flow rates). Pesticides and PCBs were not detected. Contaminant loading from unpermitted outfalls was estimated to be very low since observed pipe discharges were at very low flow rates (estimated to be less than 1 liter per minute). Based on these estimates and measurements (according to NYCDEP's 2008 study), these loadings are insignificant by comparison to other sources, such as the CSOs and the Flushing Tunnel.

Surface Water

VOCs, SVOCs and metals were detected in surface water samples collected from the canal under wet-weather and dry-weather conditions for the RI. Pesticides and PCBs

[16] Additional data is being collected. It will be reviewed as it becomes available.

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 contaminants, including benzene and PAHs in the Gowanus Canal surface water samples were significantly higher than their concentrations at the Gowanus Bay and Upper New York Bay reference locations during 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 (two blocks west of the canal) 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.

Groundwater

Groundwater samples were collected from 44 shallow and 46 intermediate monitoring wells. With the exception of PCBs, all classes of contaminants that were sampled for (VOCs, SVOCs, PCBs, pesticides and metals), were detected in samples from both the shallow and intermediate groundwater throughout the length of the canal (PCBs were not detected in any of the sampled monitoring wells). Chemical concentrations in the groundwater were higher in wells where NAPL saturation was observed in the soil borings. VOC concentrations were higher than screening values in approximately 33 percent of the shallow monitoring wells and 67 percent of the intermediate monitoring wells along the canal. Similarly, SVOC concentrations were higher than screening values in approximately 33 percent of the shallow monitoring wells and in half of the intermediate monitoring wells. Pesticides, however, were detected in only one shallow monitoring well and in one intermediate monitoring well and exceeded the screening value at the intermediate monitoring well location. With regard to metals, all of the shallow and intermediate monitoring wells contained at least one metal (arsenic, barium, lead, nickel or sodium) above its screening value.

For the shallow groundwater, a number of PAHs (2-methylnaphtalene, acenaphthene, acenaphtylene, anthracene, fluoranthene, fluorine, naphthalene, phenanthrene, and pyrene) were found in more than half of the collected shallow groundwater samples and 93.2% of all samples contained at least one PAH. The compounds that showed the most exceedances of various applicable standards were the VOCs benzene, ethylbenzene, isopropylbenzene, and xylene. The same general pattern is true for the intermediate groundwater with 97.8% of all intermediate groundwater samples containing at least one PAH.

A component of the contaminated groundwater migrates into the canal. EPA analyzed the groundwater data to determine whether contaminated groundwater discharge to the canal could potentially lead to continuing sediment contamination. This evaluation was performed by calculating Equilibrium-Partitioning Sediment Benchmark Toxic Units (TUs) for PAHs in each groundwater sample collected along the canal during the RI. Briefly, the TUs were calculated by comparing PAH concentrations in groundwater samples to their corresponding Final Chronic Values (FCV) based on EPA's National Water Quality Criteria (EPA, 2003). These FCVs represent the concentrations of the PAHs in water that are considered to be protective of the presence of aquatic life.

Contaminant Fate and Transport

A variety of physical and chemical processes influence the fate and transport of contaminants and NAPL in the Gowanus Canal sediments.

Sediment Transport and Deposition

Many of the contaminants detected in canal sediments (*e.g.*, SVOCs, PCBs, high molecular weight PAHs 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 one to three feet of sediment was deposited in the upper canal between 3rd Street and Sackett Street between 2003 and 2010. 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 one to two inches/yr (GEI, 2007), although most of the cores that were dated showed evidence of disturbances that reduce the accuracy of the age-dating estimates.

Since 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 are related to the fate and transport of the sediments. Sediments deposited in Gowanus Canal may be re-suspended by currents, propeller wash, dredging and other disturbances. The canal is a low-velocity environment, with average current velocities less than 0.5 feet per second. 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 the Gowanus Canal appear to be frequently re-suspended 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 boat 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 Gowanus Canal (*i.e.,* north of Bryant and 22nd Streets) in the 2010 bathymetric survey.

Given the low current velocities in the canal, most of the sediments re-suspended 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. 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 indicate that much of the sediment-associated contamination remains within the canal, north of the Gowanus Expressway.

Solids Impacts from Combined Sewer Overflows

CSO solids impacts are most apparent in the upper reach of the canal because the outfall at the head of the canal (RH-034) is the single largest contributor to CSO discharges. Solids from CSO discharges are transported down the canal and deposited as the velocity from the CSOs dissipates with increasing distance from the head of the canal. Currents from the Flushing Tunnel, when operating, may facilitate transport, but also dissipate. This is consistent with NYCDEP's conclusions in its 2008 WB/WS Plan: "Historical discharges by CSOs and stormwater have impacted almost the entire canal bottom." In that report, NYCDEP concluded that "CSOs dominate the loadings of . . . total suspended solids . . . to Gowanus Canal," and that discharges from the outfall at the head of the canal (RH-034) "dominate the CSO impacts throughout the entire Canal."

Hazardous substance levels in surface sediments in the upper reach are less influenced by releases from the former MGP sites than surface sediments in the middle reach. The sediments in the upper reach are less susceptible to re-suspension by propeller wash from vessel traffic, due to the low levels of such traffic in the upper reach. As noted previously, bathymetric studies from 2003 to 2010 indicate that one to three feet of sediment was deposited between 3rd and Sackett Streets. These shallow sediments were deposited after the period of greatest industrial activity in the canal and are, therefore, more influenced by CSO and stormwater discharges than by legacy contamination from historical industrial activity.

Other sources of solids to the upper reach of the Gowanus Canal include inflow from Buttermilk Channel through the Flushing Tunnel (when it is operating) and tidal advection-dispersion from Upper New York Bay through Gowanus Bay at the south end of the project area (when the flushing tunnel is not operating). A portion of the suspended sediments in these inflows settles in the canal as the current velocities decrease to slack tide.

The mass of solids delivered by each source (CSO/stormwater discharges and inflow from Upper New York Bay) was not quantified in the RI/FS or in the water quality model developed by NYCDEP for its CSO control planning, although that included modeling of TSS and separated TSS into outfall and background (*i.e.,* Upper New York Bay) components to distinguish between the heavier, more-settleable solids discharged from sewers and the lighter, less-settleable solids suspended in receiving waters (NYCDEP, 2007).

EPA has concluded that multiple lines of physical and chemical evidence demonstrate that CSO and stormwater solids have a significantly greater influence on the quality of sediments in the 0-2-foot depth interval in the upper reach of the canal than incoming sediments from Upper New York Bay. These lines of evidence include:

- CSO solids have high TOC content. The TOC content of the surface sediment is about 6 percent. Based upon the results of the RI and EPA (1998), the TOC levels in Upper New York Bay sediments are, on average, about 3 percent. Accordingly, if suspended sediments in tidal inflow or Flushing Tunnel flows from Upper New York Bay were contributing the majority of the deposited mass, the TOC of the surface sediment would be closer to 3 percent.
- The concentrations of PAHs, copper and lead in the surface sediment and in the CSO solids are similar. The concentrations of these chemicals are much lower in the reference sediments in the harbor; therefore, deposition of suspended sediments in harbor water (or from the Flushing Tunnel which brings in harbor water) could not be the predominant source of high concentration of PAHs, copper and lead in the canal surface sediments. Aluminum and iron are not good indicators of CSO solids since they are "crustal" elements, *i.e.,* they are very common in soils and sediments and are not COCs at this site.
- Sewage indicators, such as fecal coliform (GEI, 2011) and steroids (Kruge *et al.*, 2007), are found consistently in the surface sediment in the canal. The highest concentrations are located in the upper portion of the canal where most of the CSOs are located.
- EPA's bathymetric study shows that most of the accumulation of sediment coincides with the canal location (upper reach) where most of the CSOs are located and the highest CSO volumetric discharges take place. It has been reported and visually noted that CSOs discharge heavier mass solids. These heavier solids are typically expected to settle to the bottom of the canal within a short distance from the point of discharge unless high horizontal velocities

disperse the solids downstream.

- Overall, the surface sediments in the upper canal have higher sand content and lower silt and clay content than the Harbor reference locations. The sediments in the lower canal, closer to the Harbor, have similar silt and clay content to the reference stations. This indicates that the upper canal surface sediment is more influenced by the deposition of CSO solids than the area near the mouth of the canal. This is consistent with NYCDEP's conclusion that CSOs predominately contribute heavy grain sediments, while fine grain sediments are a mixture of CSO discharges and Flushing Tunnel and harbor tidal contributions.

The multiple lines of evidence summarized above strongly support the conclusion that surface sediment contaminant concentrations in the upper reach of the canal are significantly influenced by CSO solids.[17] Further refinement of the sediment transport and contaminant mass balance is constrained by the constant variability in inputs, including the frequency, size and nature of storm events and infrastructure changes, such as the Flushing Tunnel and pump station upgrades and on-going development. EPA's remedial design will be informed and refined by the results of additional sampling and modeling and by coordination with NYSDEC and NYCDEP on the LTCP.

Nonaqueous Phase Liquid Fate and Transport

NAPL in the canal sediments can be transported upward 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[18] of organic matter by bacteria in the sediment generates gases such as methane, nitrogen and carbon dioxide which cause ebullition (Reible, 2004). Ebullition is commonly observed in the soft sediments in the Gowanus Canal, which are rich in organic matter. 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 upward through the water column and be deposited on the water surface as a sheen. A NAPL seep is defined as a NAPL discharge when one or more of 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 associated with the discharge
- NAPL saturations are above residual levels

[17] CSO solids are the particles that are discharged to the canal during overflow events, whereas CSO sediment is the residual material found in the sewer pipes.

[18] Mineralization is the decomposition or oxidization of the chemical compounds in organic matter into plant-accessible forms.

Although NAPL seeps can migrate with groundwater through sediments that are not impacted by NAPL (*i.e.*, where NAPL is not coating the solid particle surfaces and occupies the smaller pore spaces), NAPL tends to migrate more readily through sediments previously impacted with NAPL (*i.e.,* NAPL is coating the solid particles). (Sale, 2011).

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. An analysis presented in the FS report indicates that upward groundwater velocities can potentially result in the upward NAPL migration under certain conditions.[19] 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 one or more of 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 levels

NAPL sheens migrate as a result of the difference in the surface tensions that result in a positive spreading coefficient. In the upland area, NAPL spreads on the surface of the groundwater in the same way as surface water sheen. In this way, NAPL sheen spontaneously enters water-coated, air-filled pores on the surface of the water table and NAPL migrates. Sheens may migrate into the canal where the groundwater surface intersects the canal.

Droplets of NAPL can also be transported along the length of the canal by tidal currents and redeposited in areas some distance from the points where they originally entered the canal.

SITE RISKS

The human health risk assessment (HHRA) for the Gowanus Canal evaluated potential current and future risks to recreational users, anglers, residents and industrial workers in and near the canal. The HHRA evaluated the potential human risks from exposure to surface water, sediment, ambient air and ingestion of fish and shellfish (crabs). 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

[19] The general site conditions were used to approximate 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 for purposes of remedial design.

potential ecological risk to these receptors from exposure to surface water and sediment in the canal was evaluated in the ecological risk assessment (ERA).

Human Health Risk Assessment

A four-step human health risk assessment process was used for assessing site-related cancer risks and noncancer health hazards. The four-step process is comprised of: Hazard Identification, Exposure Assessment, Toxicity Assessment and Risk Characterization (see the adjacent textbox, "What is Risk and How is it Calculated," for more details on the risk assessment process).

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 volatile 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 such exposures anticipated for the canal and (2) a central tendency exposure (CTE), which describes the average exposure to an individual. Two types of effects were evaluated: noncarcinogenic hazards and carcinogenic risks. Acceptable risk levels are defined in the NCP at 40 CFR 300.430(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, boating, fishing or crabbing 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 current nature. The total RME noncarcinogenic hazard associated with exposure to surface water and sediment for all recreational users was within EPA acceptable risk levels. However, exposure to surface water and sediment by recreational adults, adolescents and children may result in a carcinogenic risk of 1×10^{-3} which is above EPA'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 EPA's acceptable risk range; however, the carcinogenic risk of 3×10^{-4} was above EPA's target range.

The risks associated with exposure to surface water and surface sediment from canal overflow and ambient air at street level 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 resi-

WHAT IS RISK AND HOW IS IT CALCULATED?

A Superfund baseline human health risk assessment is an analysis of the potential adverse health effects caused by hazardous substance releases from a site in the absence of any actions to control or mitigate the hazardous substances under current- and future-land uses. A four-step process is utilized for assessing site-related human health risks for reasonable maximum exposure scenarios.

Hazard Identification: In this step, the chemicals of potential concern (COPCs) at the site in various media (for the Gowanus Canal , sediment, surface water, air and tissue) are identified based on such factors as toxicity, concentration and fate and transport of the contaminants in the environment, concentrations of the contaminants in specific media, mobility, persistence and bioaccumulation.

Exposure Assessment: In this step, the different exposure pathways through which people might be exposed to the COPCs in the various media identified in the previous step are evaluated. Examples of exposure pathways include incidental ingestion of and dermal contact with contaminated surface water and sediment. Factors relating to the exposure assessment include, but are not limited to, the concentrations in specific media that people might be exposed to and the frequency and duration of that exposure. Using these factors, a "reasonable maximum exposure" scenario, which portrays the highest level of human exposure that could reasonably be expected to occur, is calculated. A "central tendency exposure" scenario, which portrays the average or typical level of human exposure that could occur, is calculated when the reasonable maximum exposure scenario results in unacceptable risks, as discussed below under *Risk Characterization.*

Toxicity Assessment: In this step, the types of adverse health effects associated with chemical exposures and the relationship between magnitude of exposure and severity of adverse effects are determined. Potential health effects are chemical-specific and may include the risk of developing cancer over a lifetime or other noncancer health hazards, such as changes in the normal functions of organs within the body (*e.g.*, changes in the effectiveness of the immune system). Some chemicals are capable of causing both cancer and noncancer health hazards.

Risk Characterization: This step summarizes and combines outputs of the exposure and toxicity assessments to provide a quantitative assessment of site risks for all COPCs. Exposures are evaluated based on the potential risk of developing cancer and the potential for noncancer health hazards. The likelihood of an individual developing cancer is expressed as a probability. For example, a 10^{-4} cancer risk means a "one-in-ten-thousand excess lifetime cancer risk"; or one additional cancer may be seen in a population of 10,000 people as a result of exposure to site contaminants under the conditions identified in the Exposure Assessment. Current Superfund regulations for exposures identify the range for determining whether remedial action is necessary as an individual excess lifetime cancer risk of 10^{-4} to 10^{-6}, corresponding to a one-in-ten-thousand to a one-in-a-million excess cancer risk. For noncancer health effects, a "hazard index" (HI) is calculated. The key concept for a noncancer HI is that a threshold (measured as an HI of less than or equal to 1) exists below which noncancer health hazards are not expected to occur. The goal of protection is 10^{-6} for cancer risk and an HI of 1 for a noncancer health hazard. Chemicals that exceed a 10^{-4} cancer risk or an HI of 1 are typically those that will require remedial action at the site.

dential adults and children may result in carcinogenic risks of 3 x 10^{-4}, which is above EPA'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 EPA'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 EPA's acceptable levels as shown in Table 5. The noncarcinogenic hazards and carcinogenic risks are associated with PCBs in fish and crabs. Because PAHs normally metabolize quickly, the fish tissue samples were not analyzed for PAHs. To assess whether the canal's high levels of PAHs pose a risk in a scenario where PAHs were not metabolized before consumption, PAHs in fish tissue were estimated using an assumption that fish tissue concentrations of PAHs are similar to the concentrations of PAHs in crab tissue. The estimated carcinogenic risks from PAH exposure were below EPA's acceptable risk range. 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 EPA acceptable risk range.

Ecological Risk Assessment

A combined screening level ecological risk assessment (SLERA) and baseline ecological risk assessment (BERA) was performed for the Gowanus Canal in accordance with EPA's (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).

Risks to benthic macroinvertebrate communities were evaluated primarily through the use of laboratory-based sediment bioassays (*i.e.*, toxicity tests), 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, where contaminant levels are highest. 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 to literature-based screening benchmarks. The surface water was sampled during both dry and wet (*i.e.,* while CSO outfalls were discharging) periods. 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 food items including prey (*e.g.*, fish and crabs) and through the incidental ingestion of sediment. The analyses indicate the following:

- Potential risk to aquatic herbivores (represented by black duck) from exposure to PAHs. PAHs were detected on-site (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. Mercury was the only metal that was frequently detected both in fish and crab tissues at elevated concentrations and that was also detected in canal sediments at a concentration above those detected in reference area locations. Mercury, 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.
- As indicated in the human health section, PAHs were not analyzed in fish tissue. Using an assumption that fish tissue concentrations of PAHs are similar to the concentrations of PAHs in crab tissue, food web modeling shows no risk from PAHs to avian wildlife from the consumption of fish.

<u>Summary of Human Health and Ecological Risks</u>

The HHRA indicated completed human risk exposure pathways with unacceptable risk levels for surface water/sediment contact and fish consumption.

Human exposure to hazardous substances in surface water and surface sediment by recreational adults, adolescents and children may result in carcinogenic risks above EPA'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 was within or below EPA's acceptable risk levels.

Human exposure to surface water and surface sediment from canal overflow by residential adults and children may result in carcinogenic risks above EPA's target risk range. The RME carcinogenic risk for the adult/child resident is associated with PAHs in sediment (with a smaller contribution from surface water). The total carcinogenic risk evaluated under the CTE assumptions was within or below EPA's target risk range.

The RME and CTE total noncarcinogenic hazards and/or carcinogenic risks for angler adult, adolescent and child receptors exceed EPA's target risk range. The noncarcinogenic hazards and carcinogenic risks are associated with PCBs in fish and crab. The average concentrations of PCBs in 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. It should be noted, however, that the PCB concentrations in the reference samples also result in noncarcinogenic hazards and carcinogenic risks above EPA's target risk range. The HHRA showed that risk for airborne exposure from the canal was within the acceptable range.[20]

The key results of the ERA indicated that PAHs, PCBs and metals in the sediment are toxic to benthic organisms. PAHs were detected in sediment at the highest concentrations relative to their ecological screening benchmarks and represent the greatest site-related risk to the benthic community. 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 significantly higher than those detected in reference area sediments and also represent a potential site-related risk to the benthic community. PAHs were found to be a potential risk to aquatic herbivores (represented by the black duck) and mercury was found to be a potential risk to avian omnivores (represented by the heron).

REMEDIAL ACTION OBJECTIVES

Remedial action objectives are specific goals to protect human health and the environment. These objectives are based on available information and standards, such as applicable or relevant and appropriate requirements (ARARs), to-be-considered guidance, site-specific risk-based levels and background (*i.e.,* reference area) concentrations.

The following remedial action objectives were established for the site:

- Reduce the cancer risk to human health from the incidental ingestion of and dermal contact with PAHs in sediment during recreational use of the canal or from exposure to canal overflow to levels that are within or below EPA's excess lifetime cancer risk range of 10^{-6} to 10^{-4};
- Reduce the contribution of PCBs from the Gowanus Canal to fish and shellfish by reducing the concentrations of PCBs in Gowanus Canal sediment to levels that are within the range of Gowanus Bay and Upper New York Bay reference concentrations;
- Reduce the risks to benthic organisms in the canal from direct contact with PAHs, PCBs and metals in the sediments by reducing sediment toxicity to levels that are comparable to reference conditions in Gowanus Bay and Upper New York Bay;
- Reduce the risk to herbivorous birds from dietary exposure to PAHs;
- Eliminate the migration of NAPL into the canal; and
- Prevent or minimize NAPL from serving as a source of contaminants to the canal.

Preliminary Remediation Goals

Because there are no promulgated standards or criteria that apply to the cleanup of contaminated sediments in New York,[21] site-specific, preliminary remediation goals

[20] Although not considered for CERCLA remedy selection purposes, a screening level risk assessment for CSO pathogens that was performed by National Grid found significant risk to child and adult recreational users and workers from CSO-related pathogen exposure.

[21] 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."

(PRGs) for sediments in the Gowanus Canal were developed. PRGs are used to define the extent of cleanup needed to achieve the RAOs. A "clean" surface would be established at the bottom of the Gowanus Canal at the end of remedy construction. The PRGs will be used as performance targets for this "clean" surface.

It should be noted that for the following reasons, the PRGs that are being presented are unique to the Gowanus Canal. The canal, especially the upper portion, is a water body contained in a constructed confined space of relatively regular geometry and relatively shallow depth. Its only natural surface water inputs are from the New York Harbor through tidal exchanges from the south end of the canal and through Flushing Tunnel flow at the northern end. Deposition of solids in the canal from these two main sources and small amounts of exposed soil, historic fill and rooftop and surface drainage would constitute the background (*i.e*., regional) level of contamination that should be similar in contaminant concentration to the reference harbor sampling stations. As was noted above, the average PAH concentration for the harbor reference stations collected during the RI is 6 mg/kg. The post-remediation level of contamination that would be expected in the Gowanus Canal after all of the major canal-related sources of contamination have been reduced or controlled is likely to be at the upper end of the range of reference concentrations in Upper New York Bay sediments, *i.e.,* 14 mg/kg PAHs, because of ongoing contributions from uncontrolled surface water runoff and stormwater discharges.

Human Health

Risk-based human health PRGs were developed to address the identified site risk using information developed from the HHRA. PRGs were developed for six carcinogenic PAHs for exposure to near-shore surface sediment during recreational use of the canal by adults, adolescents and children. PRGs were not included for surface water because the concentrations of carcinogenic PAHs in canal surface water are not significantly different than concentrations in the Gowanus Bay and Upper New York Bay reference area. 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 from the HHRA to calculate the PRG. 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}, which is the upper bound of EPA's acceptable risk range. Additional PRGs were developed based on a cumulative cancer risk of 10^{-6}, which is the lower bound of EPA's acceptable risk range. The PRGs for the recreational use scenario for sediment and surface water are presented in Table 6.

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 would 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. However, game fish and blue crabs do not forage solely in the canal and the PCB concentrations in their tissues reflect cumulative uptake from all of the areas that they inhabit. Therefore, the objective is to reduce the contribution of PCBs from the Gowanus Canal to fish and crab tissue by reducing the concentrations of PCBs in Gowanus Canal sediments to levels that are within the range of Gowanus Bay and Upper New York Bay reference concentrations. The maximum concentration in reference area surface sediment was selected as the PRG (see Table 6).

Ecological

PRGs were developed for the protection of benthic (sediment-dwelling) organisms and herbivorous birds. The recommended PRGs and their basis are presented below.

<u>Protection of the Benthic Community</u>

PRGs for the protection of benthic organisms were derived from a statistical analysis based on the site-specific toxicity test and co-located 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 as shown in Table 7. 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 (SEM/AVS) analyses presented in the ERA (EPA, 2011a) 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 were developed based on PRGs for total PAHs and then checked to verify that the potential for adverse effects from exposure to PCBs and metals were also addressed.

Sediment toxicity data are available for two test species: a polychaete (*Nereis virens*) and an amphipod (*Leptocheirus plumulosus*). Survival and growth of the polychaete and survival, growth and reproduction of the amphipod were measured in sediment samples from 17 locations, five of which represented Gowanus Bay and Upper New York Bay reference conditions. Laboratory control sediment was also used in each test. Because greater responses were seen in the amphipod tests, only those results were used to derive PRGs. Amphipod results are consistent with toxicity tests conducted by National Grid (GEI, 2011).

Two alternative potential PRG calculation approaches for total PAHs that represent different levels of protection were determined through graphical analysis of toxicity test results (*i.e.*, examination of plots of total PAH concentration versus toxicity for each station tested). The first potential PRG was determined by identifying the lowest observed adverse effect concentration (LOAEC). The second potential PRG was determined by selecting the concentration immediately below the LOAEC, which is the greatest no observed adverse effect concentration (NOAEC). The potential PRGs based on the NOAEC ranged from 39 mg/kg for amphipod survival to 7.8 mg/kg for amphipod growth and reproduction. Potential PRGs based on the LOAEC for total PAHs ranged from 67 mg/kg for amphipod survival to 14 mg/kg for amphipod growth and reproduction.

Because of the sample size and the variability of the site-specific dose-response relationships, there is uncertainty in the NOAECs and LOAECs identified above for each endpoint. This uncertainty was addressed using the following approach:

- Identify all potential NOAECs and LOAECs from the site-specific data using graphical analysis;
- Normalize the potential NOAECs and LOAECs for TOC content because organic carbon is a key parameter influencing PAH bioavailability and the TOC content of samples from the key stations varied;
- Calculate the geometric means of the TOC-normalized NOAECs and LOAECs; and
- Convert the geometric means of the TOC-normalized NOAECs and LOAECs to a dry weight basis using the mean canal-wide surface sediment TOC concentration of 6 percent.

The NOAEC represents the concentration assumed to not cause adverse effects based on the site-specific data. The LOAEC represents the lowest concentration associated with measureable effects. The threshold where effects start can be assumed to fall between those two concentrations. This threshold is commonly calculated at the geometric mean of the NOAEC and LOAEC. Therefore, the PRG for total PAHs was calculated as the geometric mean of the LOAEC and the NOAEC (see Table 8).

Additional data and analyses from the RI were considered in selecting PRGs. Site-specific bioavailability of PAHs is important in interpreting sediment toxicity test results. The bioavailability and potential toxicity of total PAHs in Gowanus Canal sediments were evaluated using the Equilibrium-partitioning Sediment Benchmark Toxic Unit approach described in EPA (2003), which estimates the bioavailable and potentially toxic fraction of the total PAHs in the bulk sediment. The results indicate that the PAHs are generally bioavailable and potentially toxic in the canal samples. These results are consistent with recent sediment pore water sampling results presented in *Sediment and Surface Water Sampling Winter Report for the Gowanus Canal Superfund Site* (GEI, 2011). Calculated toxic units based on PAHs measured in sediment porewater samples show that PAHs are bioavailable and potentially toxic throughout the canal.

The RI also identified metals as contributing to unacceptable ecological risks to benthic organisms. Based on measured concentrations in sediment, copper and lead were identified as the metals most likely associated with adverse effects. However, geochemical analyses (*i.e.*, SEM/AVS) indicate that these metals currently are not bioavailable and should not cause toxicity. However, metals may become bioavailable in the future if geochemical conditions in the canal change and do not favor the formation of insoluble sulfides. Therefore, PRGs for copper and lead are necessary in the event that metals become bioavailable and toxic in the future. The maximum Gowanus Bay and Upper New York Bay concentrations for the reference stations that showed no toxicity were selected as the PRGs for copper and lead (see Table 8).

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.

Preliminary Remediation Goals for Protection of Ecological Community

PRGs for the protection of the ecological community for the post-remedy clean surface are summarized in Table 8. The PRGs will be used as performance standards for the post-remedy clean surface.

The PAH PRG of 20 mg/kg is specific to this site. It is also within the range of published and commonly accepted sediment quality values for PAHs (Ingersoll *et al*., 1996; Long and Morgan, 1991; MacDonald, 1994; and Swartz, 1999) (see below).[22] These values have been shown to be broadly predictive of sediment toxicity. However, they generally represent sediments with lower total organic carbon content of approximately 2 percent as compared to 6 percent for the site. Techniques for directly measuring PAH toxicity and assessment methodology continue to develop (*e.g.,* Burgess, 2009). EPA will evaluate relevant new information and data as they become available.

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

[22] Background data is being collected in connection with the Newtown Creek NPL site RI in various locations around the New York/New Jersey harbor estuary. The data is expected to be available in early 2013; it will be reviewed at that time.

To facilitate the management and evaluation of the remedial alternatives, the Gowanus Canal was divided into 3 Remediation Target Areas (RTAs) that correspond to the upper reach (RTA 1), middle reach (RTA 2) and lower reach (RTA 3) (see Figure 2).

SUMMARY OF REMEDIAL ALTERNATIVES

CERCLA Section 121(b)(1), 42 U.S.C. Section 9621(b)(1), mandates that remedial actions be protective of human health and the environment, cost-effective, comply with ARARs and utilize permanent solutions, alternative treatment technologies and resource recovery alternatives to the maximum extent practicable. Section 121(b)(1) also establishes a preference for remedial actions which employ, as a principal element, treatment to reduce the volume, toxicity or mobility of the hazardous substances, pollutants and contaminants at a site permanently and significantly. CERCLA Section 121(d), 42 U.S.C. Section 9621(d), further specifies that a remedial action must attain a level or standard of control of the hazardous substances, pollutants and contaminants, which at least attains ARARs under federal and state laws, unless a waiver can be justified pursuant to CERCLA Section 121(d)(4), 42 U.S.C. Section 9621(d)(4). Remedial alternatives are described below for the sediment and source control.

Sediment Alternatives

Detailed descriptions of the remedial alternatives for addressing the contaminated sediments can be found in the FS report. Seven dredging and capping remedial alternatives were considered in the FS report:

- Alternative 1: no action
- Alternative 2: partially dredge soft sediment and cap with isolation layer and armor layer
- Alternative 3: partially dredge soft sediment and cap with treatment layer, isolation layer and armor layer
- Alternative 4: dredge entire soft sediment column and cap with isolation layer and armor layer
- Alternative 5: dredge entire soft sediment column and cap with treatment layer, isolation layer and armor layer
- Alternative 6: dredge entire soft sediment column, stabilize top 3–5 feet of native sediment in targeted areas and cap with isolation layer and armor layer
- Alternative 7: dredge entire soft sediment column, stabilize top 3–5 feet of native sediment in targeted areas and cap with treatment layer, isolation layer and armor layer

Alternatives 1, 5 and 7 were retained for further development and detailed evaluation; Alternatives 2, 3, 4 and 6 were screened out for the following reasons. 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). In addition, soft sediments in the canal could be destabilized by the uneven placement of cap material. Capping over these soft sediments could destabilize any NAPL present in the soft sediments (Reible, 2005). Partial removal would leave a larger volume and broader range of residual contamination than would complete removal, increasing the risks posed if cap failure occurred. Partial removal would also result in shallower cap depth, increasing cap damage potential from shipping. Given these risk management considerations, all of the soft sediment would need to be removed.

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.

While the temporary draining of all or portions of the canal to facilitate implementation of the remedy was considered, it was ruled out for the entire canal for several reasons: removal of canal water could induce canal wall and bottom instabilities due to increased exerted pressures; draining of the canal for remedy implementation would also limit remedial and commercial barge access and conflict with the current configuration for CSO and stormwater discharges; and odor control for such a large area of dewatered sediments would be difficult.

Factors which determine the necessary depth of dredging include the extent of sediment chemical contamination and the presence of NAPL, navigational needs and remedy implementation needs, described below. RTA 1 is no longer used for commercial navigation. However, this reach of the canal must have sufficient depth 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 dredge depth would need to ensure that the final sediment surface remains submerged throughout the tidal cycle and 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 NAVD88 was used based on a 2009 dredging alternative analysis performed by the USACE which selected that depth for maintaining commercial navigation. The dredging depth in RTA 3 is in accordance with the federally authorized navigation depth south of Hamilton Avenue.

Capping is a component of all alternatives, except the No-Action alternative, because NAPL-contaminated sediments are present to depths that exceed the practicable depth of removal. A capping-only alternative was not included since a cap in RTA 1 would further restrict the water depth in the canal and result in a relatively large area of exposed sediment at low tide, a cap in RTA 2 would compress soft sediments and mobilize the NAPL within them and 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 can be treated and/or disposed of using a variety of methods. The following treatment and disposal options for dredged sediments were identified and retained for further development and detailed evaluation:

- Option A: Off-site thermal desorption and beneficial use
- Option B: Off-site disposal (landfill)
- Option C: Off-site cogeneration and beneficial use
- Option D: Off-site stabilization and off-site beneficial use
- Option E: On-site stabilization and on-site beneficial use
- Option F: Off-site stabilization and placement in on-site constructed CDF
- Option G: On-site stabilization and placement in on-site constructed CDF

Source Control Remedial Components and Costs

There are multiple sources of contamination causing on-going releases into the canal which must also be controlled, the primary ones being the three former MGPs and the CSOs in the upper part of the canal (outfalls RH-034 and OH-007). If left unabated, the contaminant contributions from the former MGPs and the CSOs would impact the protectiveness and sustainability of any remedy. Therefore, implementation of control measures to address the former MGPs and CSOs, either through existing legal obligations or selection as part of this remedy, are common and integral to ensuring the effectiveness of both of the sediment action alternatives.

Former Manufacture Gas Plant Source Control Measures and Costs

While NYSDEC has not yet completed the remedy selection process for the Fulton and Metropolitan former MGP sites, NYSDEC has selected a remedy for the Public Place former MGP site. All of the major reports for the three former MGP sites, including the screening of remedial alternatives for Public Place, have been reviewed by EPA and are included in EPA's Administrative Record. New York State regulations governing the State Superfund program require source removal or control for all remedies. This will ensure that the remedies for the two other former MGP sites, will adequately address the sources. The costs for addressing the Public Place former MGP site are estimated by National Grid at $175-200 million, based on NYSDEC's selected remedy and National Grid's remedial design work performed to date. It is assumed that the costs for these sites would each be in the same range or less.

CSO Solids Control Measures and Costs

To address the discharge of hazardous substances, such as PAHs associated with typical urban drainage, the following CSO control measures were screened based on effectiveness, implementability, and cost (see the FS report addendum): no action; optimization of existing trap chamber in CSO OH-007; CSO sediment trap at CSO RH-034; silt curtains and/or netting facilities, maintenance dredging; sewer cleaning and CSO storage. The permanent installation of silt curtains was screened out based on the fact that they would not provide sufficient solids control and they would deteriorate and require extensive maintenance over the long term with the surface water velocities in the canal once the flushing tunnel is put back into operation. The temporary use of silt curtains during dredging operations will be evaluated as part of the remedial design.

As is noted above, to ensure continued protection of the canal remedy, future permanent CSO sediment controls are required. Scientific literature suggests that it can be assumed that the "first flush" comprises approximately 20% of the total discharge volume and contains between 30% and 60% of the total PAH load of the discharge (Stein, 2006). It is anticipated that capturing approximately twice the amount of the "first flush" of the design storm event from CSO outfalls RH-034 and OH-007 (WB/WS Plan)[23] would ensure that the protectiveness of the remedy is maintained. In order to achieve this minimum level of CSO solids control, based on the preliminary screening, in-line retention tanks[24] are presumed to be constructed near outfalls RH-034 and OH-007; tank volumes of 6- to 8-million gallons and 3- to 4-million gallons were preliminarily selected for outfalls RH-034 and OH-007, respectively, on the basis of their capacity to reduce CSO volume and solids that will be protective of the Superfund remedy.

For costing purposes, an 8-million-gallon in-line storage tank (estimated by EPA to cost $46,429,000) would be installed for outfall RH-034 and a 4-million-gallon in-line storage tank (estimated by EPA to cost $31,272,000) would be installed for outfall OH-007, These estimates do not include operation and maintenance costs associated with CSO controls. For the purpose of developing construction costs associated with CSO control, it was assumed that these tanks could be located on available NYC-owned land in the vicinity of the outfalls. The confirmation of the availability of these locations, as well as further evaluations of measures to achieve the post remedial objectives for the canal sediments, will be completed during the remedial design and under the contemporaneous LTCP development process. These efforts may identify more efficient cost-effective and protective alternatives to achieve the remedial goals.

NYC is under order with New York State to achieve the

[23] EPA recognizes that, in the future, there may be more frequent large rainfall events due to climate change.

[24] As was noted above, combined sewers receive both sewage and stormwater flows and discharge to the canal when the sewer system's capacity is exceeded. Rather than discharging the sewage and stormwater to the surface water when the system's capacity is exceeded, the excess flow would be diverted to tanks, which would store it until the wet weather subsides, when it would be pumped to the WWTP.

water quality goals of the CWA and must ultimately meet the "highest attainable use" per EPA's LTCP guidance. The optimum combination of CSO solids control measures and CSO capture volumes will be refined during the LTCP development process. The LTCP, which is due to the State in June 2015, will, at a minimum, meet EPA's remedial performance goals for CSO solids control. EPA and NYSDEC are committed to work together throughout the development of the remedial design and the contemporaneous LTCP development process to ensure that both the Superfund and CWA goals are met in a timely, cost-effective manner. However, recognizing that planning and construction of permanent long term CSO controls for the Superfund remedy might not take place by the time remedial dredging is carried out, EPA in consultation with NYSDEC, would develop interim CSO solids control measures during the remedial design to control the discharges until the permanent measures are implemented.

Current and future high density residential redevelopment along the banks of the canal and within the sewershed should be consistent with recently adopted NYC criteria for on-site storm water control and green infrastructure (NYCDEP, 2012) so as to not contribute discharges to the canal that would result in compromising the remedy. Separated stormwater outfalls may also require source controls pursuant to applicable SPDES permits and best management practices.

Additional Source Control Measures and Costs

The costs to address the other (non-MGP) upland sources will vary from parcel to parcel and will depend on source control options that may include excavation, cutoff walls and other measures. EPA has not estimated the costs of remediating these additional parcels as part of the FS and, thus, those costs are not included in the overall remedy costs. However, EPA believes that, in comparison to the overall anticipated canal remedy cost, the cost of addressing each of these parcels would be small. EPA anticipates that separate cleanup determinations will be made for such parcels under the appropriate cleanup program. Based upon discussions with property owners willing to implement such measures for redevelopment purposes voluntarily, such measures are likely to cost several million dollars or less per property.

The costs to address the open pipes are expected to be minimal in comparison to the overall site remedy costs and would involve either sealing the pipes or requiring the property owner to obtain the necessary permit to continue the discharge. To reduce sewer, stormwater and runoff contaminant inputs, EPA and NYCDEP have also discussed the use of "Best Management Practices" by various business sectors (*e.g.,* auto repair, vehicle storage) near the canal.

Sediment Dredging, Capping and Disposal Alternatives

The construction time of approximately five years for each alternative reflects only the time required to construct or implement the remedy and achieve the RAOs. This period does not include the time required to design the remedy, negotiate the performance of the remedy with PRPs or procure contracts for design and construction.

The sediment dredging, capping and disposal remedial alternatives are:

Alternative 1: No Action

Capital Cost:	$0
Annual Operation and Maintenance (O&M) Cost:	$0
Present-Worth Cost:	$0
Construction Time:	0 months

The Superfund program requires that the "no-action" alternative be considered as a baseline for comparison with the other alternatives. The no-action remedial alternative does not include any physical remedial measures that address the contamination at the site.

Because this alternative would result in contaminants remaining above levels that allow for unrestricted use and unlimited exposure, CERCLA requires that the site be reviewed at least once every five years. If justified by the review, remedial actions may need to be implemented to remove, treat or contain the contaminated soils and sediments.

Alternative 5: Dredge Entire Soft Sediment Column; Cap with Treatment, Isolation and Armor Layers

Volume of Sediment Removed:	588,000 cy
Capital Cost:	$270,000,000[25]
Annual O&M Costs:	$2,000,000[26]
Present-Worth Cost:	$272,000,000
Construction Time:	5 years

Under this alternative, all of the soft sediment within the canal would be removed and a cap would be placed on

[25] The cost includes $172,000,000 to address the contaminated sediments (this cost does not include treatment and disposal of dredged sediment which are dependent upon the disposal and treatment option selected), $77,701,000 to install in-line storage tanks for outfalls RH-034 and OH-007 (8 million gallons and 4 million gallons, respectively) and $20,000,000 for the excavation and disposal of the material in the 1st Street basin. The cost does not include remedial measures, such as the installation of cut-off walls, source removal or groundwater/NAPL collection systems at the 3 former MGPs, which will be implemented under State authorities.

[26] This cost includes only O&M related to the contaminated sediments. It does not include O&M costs related to the 3 former MGPs and for CSO solids controls (such as in-line storage tanks).

top of the native sediment surface.

The native sediment surface elevation is variable within the canal; therefore, there is not a single specific removal depth 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 would allow for the placement of the cap and, at the same time, meet maintenance considerations in RTA 1 and navigational needs in RTAs 2 and 3.

In RTA 2, a navigation depth of -16 feet NAVD88 was assumed based on present commercial navigational needs. 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 cap for this alternative would consist of an armor layer, an isolation layer and an active treatment layer as follows from top to bottom:

- Armor layer: 1.5 feet of stone with a median diameter of 0.75 feet. Sufficient sand would be placed on top of the armor layer to fill in the voids between the stones and to establish sufficient depth of soft sediment in order to facilitate benthic re-colonization.
- Isolation layer: 0.5 feet of gravel and 0.5 feet of sand to provide transition and erosion protection of the oleophilic clay material from the overlying heavier armor layer.
- Treatment layer (represented in the FS by oleophilic clay): 1 foot in RTA 1 and RTA 2 and 0.5 feet in RTA 3.

The cap would need to be designed to be able to withstand future maintenance dredging operations in the canal for the removal of contaminated solids that might settle on top of it. If possible, the cap treatment layer would be designed to have an adequate life expectancy for absorbing NAPL without replacement. If this is not feasible, the alternative may include the replacement of portions of the treatment layer (replacing the treatment layer would also necessitate the removal and replacement of the overlying sand and armor layers).

This alternative would also include institutional controls to protect the integrity of the cap (treatment, isolation and armor layers). The institutional controls would also include the existing fish advisory (modified, as needed).

Because this alternative would result in contaminants remaining on-site above levels that allow for unrestricted use and unlimited exposure, CERCLA requires that the site be reviewed at least once every five years.

Alternative 7: Dredge Entire Soft Sediment Column; Perform In-Situ Sediment Stabilization; Cap with Treatment, Isolation and Armor Layers

Volume Sediment Removed:	588,000 cy
Capital Cost:	$286,000,000[27]
Annual O&M Costs:	$2,000,000
Present-Worth Cost:	$288,000,000[28]
Construction Time:	5 years

Under this alternative, 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 stabilize 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 sediment in-situ 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 depth of removal for RTAs 1, 2 and 3 would be the same as Alternative 5.

The conceptual cap for this alternative would be the same as the cap described for Alternative 5, an armor layer, an isolation layer and a treatment layer (represented in the FS by oleophilic clay).

The cap would need to be designed to be able to withstand future maintenance dredging operations in the canal for the removal of contaminated solids that might settle on top of it. If possible, the cap treatment layer would be designed to have an adequate life expectancy for absorbing NAPL without replacement. If this is not feasible, the alternative may include the replacement of portions of the treatment layer (replacing the treatment layer would also necessitate the removal and replacement of the overlying sand and armor layers).

This alternative would also include institutional controls to protect the integrity of the cap (treatment, isolation and

[27] The cost includes $188,000,000 to address the contaminated sediments (this cost does not include treatment and disposal of dredged sediment which are dependent upon the disposal and treatment option selected) and $77,701,000 to install in-line storage tanks for outfalls RH-034 and OH-007 (8 million gallons and 4 million gallons, respectively) and $20,000,000 for the excavation and disposal of the material in the 1st Street basin. The cost does not include remedial measures, such as the installation of cut-off walls, source removal or groundwater/NAPL collection systems at the 3 former MGPs, which will be implemented under State authorities.

[28] This cost includes only O&M related to the contaminated sediments. It does not include O&M costs related to the 3 former MGPs and for CSO solids controls (such as in-line storage tanks).

armor layers). The institutional controls would also include the existing fish advisory (modified, as needed).

Because this alternative would result in contaminants remaining on-site above levels that allow for unrestricted use and unlimited exposure, CERCLA requires that the site be reviewed at least once every five years.

Treatment and Disposal Options

The following section describes the treatment and disposal or beneficial-use options that may be utilized to address sediments removed through the above-noted dredging and capping alternatives. All treatment and disposal facility selection and beneficial use determinations would be subject to EPA oversight and approval. Due to the differences in the extent of NAPL contamination in different areas of the canal, some of the treatment and disposal options are not applicable to all RTAs. The seven treatment and disposal options with the RTAs to which they apply (noted in parenthesis) are:

- Option A: Off-site thermal desorption and beneficial use (RTAs 1, 2 and 3)
- Option B: Off-site disposal (landfill; RTAs 1, 2 and 3)
- Option C: Off-site cogeneration and beneficial use (RTAs 1, 2 and 3)
- Option D: Off-site stabilization and off-site beneficial use (RTAs 1 and 3)
- Option E: On-site stabilization and on-site beneficial use (RTAs 1 and 3)
- Option F: Off-site stabilization and placement in on-site constructed CDF (RTA 3)
- Option G: On-site stabilization and placement in on-site constructed CDF (RTA 3)

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.

All of the treatment/disposal options include barging of the dredged sediment to a local, on-site dewatering and transfer facility.

Additional treatability testing and sampling would be needed for all of the options. Further testing of stabilized sediment would be required to confirm that dredged sediment can be accepted by thermal desorption (Option A) and cogeneration (Option C) facilities. Utilization of Option B (off-site landfill) would require testing of the stabilized dredged sediment to confirm that it would meet acceptance criteria. Options D, E, F and G would 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 would further require a beneficial use to be identified and a determination as to whether the stabilized sediment would meet the associated beneficial-use requirements. A CDF would be constructed under Options F and G, if selected based upon community acceptance and approval by NYSDEC and other appropriate governmental regulatory authorities.

Option A: Off-Site Thermal Desorption and Beneficial Use

Option A consists of transporting dredged and dewatered sediments by barge to an off-site commercial facility for stabilization, followed by transport of the stabilized sediment to another off-site facility for thermal desorption treatment. The treatment residuals would be destroyed in an afterburner and treated sediment would be transported for beneficial use, such as daily cover at a landfill, or for another beneficial use at an off-site location. To develop the estimated costs, the FS assumed that transport following stabilization would occur by truck. The total PCB and lead concentrations present in the sediment may preclude this treatment option for some areas of the canal.

Option B: Off-Site Disposal (Landfill)

Option B consists of transporting the stabilized sediment from the off-site 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 Resource Conservation and Recovery Act (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.[29]

Option C: Off-Site Cogeneration and Beneficial Use

Option C consists of transporting dredged, dewatered sediments that has been stabilized, as necessary, at the off-site dredge-material-processing facility to an off-site 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. The organic contaminants in the sediment would be destroyed through burning of the sediments at high temperatures (greater than 1,400°C) during the co-generation process. 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 off-site 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.

Additional bench-scale testing would be required to determine whether the sediment in all areas of the canal would provide sufficient energy value (in British Thermal

[29] This test method is used to determine the presence of free liquids in a representative sample of waste. A predetermined amount of material is placed in a paint filter. If any portion of the material passes through and drops from the filter within the 5-minute test period, the material is deemed to contain free liquids.

Units, or BTUs) to make cogeneration a feasible treatment/disposal option for all of the dredge sediments and to determine which areas of the canal contain sediment with the greatest BTU value. Bench testing would also 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: Off-Site Stabilization and Beneficial Use

Option D consists of transporting dewatered sediments to an off-site dredge material processing facility via barge, where the sediment would be stabilized to a greater degree than for mere disposal. The treated material would then be transported via truck or rail (assumed to be by truck) to the off-site beneficial use location. 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. A specific beneficial use applicant would need to be identified and further evaluations would be required to confirm the amounts and types of stabilizing 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.

Option E: On-Site Stabilization and Beneficial Use

Option E includes stabilizing dredged sediment on-site and beneficially using the treated sediment in areas adjacent to the canal. As with Option D, the degree of stabilization necessary for direct on-site beneficial use without further treatment would need to be more substantial than the stabilization under Options A through C, where the stabilization process would be utilized to prepare sediments for off-site transport by truck to be followed by treatment before final disposition. A specific beneficial use has not been determined, 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. 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. It is assumed 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 on-site stabilization facility would need to be constructed and a location for this facility would need to be identified.

Option F: Off-Site Stabilization and Disposal in On-Site-Constructed CDF

Lesser-contaminated, stabilized sediments could be placed in the CDF[30] if approved by NYSDEC and other appropriate governmental regulatory authorities,[31] which would be filled and covered to match the existing ground surface elevation.

Option F would apply only to sediments at RTA 3 contaminant levels. RTA 3 sediments are less contaminated and with fewer NAPL impacts than the RTA 1 and 2 sediments. For this reason, RTA 3 sediments are more suitable for treatment via stabilization and placement in a CDF. Limiting Option F to RTA 3 sediments (and, space permitting, equivalent low level sediments from other areas, especially in RTA 1, that may be identified during design sampling) would also limit the space requirements needed to construct a CDF. The disposal of the lesser contaminated sediments in a CDF is projected to result in cost savings relative to the off-site disposal options.

This option consists of transporting the stabilized sediment from the off-site treatment facility back to the site by barge and then transferring the sediment into an on-site constructed CDF. The CDF layout developed in the FS is for a CDF that borders water on one side and land on three sides. The layout includes installing a single sheet-pile wall on the sides adjacent to land and 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. 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. The CDF design would need to ensure long-term effectiveness in a coastal marine environment, and be approved by NYSDEC and other appropriate governmental regulatory authorities.

Once the treated sediment has hardened, leaching would be expected to be negligible, so no leachate collection system is assumed for this treatment/disposal alternative. Upon placement of the sediment, the CDF would be capped. The top layer of the cap is assumed to be asphalt. Surveys would be required on a regular basis to monitor the long-term integrity of the cap. Cap maintenance would include the placement of additional clean materials to replace damaged areas of the cap.

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[30] EPA has identified a potential CDF location on privately-owned property at the Gowanus Bay Terminal on Columbia Street in Red Hook. The CDF could be constructed within an existing slip there or within other areas of the property.

[31] EPA will follow OSWER Directive 9355.7-03, *Permits and Permit "Equivalency" Processes for CERCLA On-Site Response Actions*.

Bench-scale testing would be needed to determine the amounts of stabilizing 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 need to be performed on the stabilized material in order to refine the CDF design. The design of the CDF would depend on its location and the characteristics of the stabilized sediment. Permanent institutional controls would be required to protect the long-term integrity of the CDF.

Option G: On-Site Stabilization and Disposal in On-Site-Constructed CDF

Option G consists of stabilizing dredged sediment on-site and then transferring the sediment to a constructed on-site CDF. The CDF would be the same as described in disposal Option F.

The disposal under Option G is the same as Option F, with the exception that the stabilization would be performed on-site and transport of sediment to and from an off-site stabilization facility would not be needed. It is assumed that an on-site temporary stabilization facility would be constructed near or adjacent to the CDF location. Three concrete mixing facilities are located on the canal, of which two have expressed interest in providing stabilization services for the project.

The costs for the disposal options by RTA are summarized in Table 9.

COMPARATIVE ANALYSIS OF ALTERNATIVES

During the detailed evaluation of remedial alternatives, each alternative is assessed against nine evaluation criteria, namely, overall protection of human health and the environment, compliance with ARARs, long-term effectiveness and permanence, reduction of toxicity, mobility or volume through treatment, short-term effectiveness, implementability, cost and state and community acceptance.

The evaluation criteria are described below.

- Overall protection of human health and the environment addresses whether or not a remedy provides adequate protection and describes how risks posed through each exposure pathway (based on a reasonable maximum exposure scenario) are eliminated, reduced or controlled through treatment, engineering controls or institutional controls.
- Compliance with ARARs addresses whether or not a remedy would meet all of the ARARs of other federal and state environmental statutes and regulations or provide grounds for invoking a waiver.
- Long-term effectiveness and permanence refers to the ability of a remedy to maintain reliable protection of human health and the environment over time, once cleanup goals have been met. It also addresses the magnitude and effectiveness of the measures that may be required to manage the risk posed by treatment residuals and/or untreated wastes.
- Reduction of toxicity, mobility or volume through treatment is the anticipated performance of the treatment technologies, with respect to these parameters, a remedy may employ.
- Short-term effectiveness addresses the period of time needed to achieve protection and any adverse impacts on human health (*e.g.,* odors, noise and worker safety) and the environment that may be posed during the construction and implementation period until cleanup goals are achieved.
- Implementability is the technical and administrative feasibility of a remedy, including the availability of materials and services needed to implement a particular option.
- Cost includes estimated capital and O&M costs and net present-worth costs.
- State acceptance indicates if, based on its review of the RI/FS and Proposed Plan, the state concurs with the preferred remedy at the present time.
- Community acceptance will be assessed in the ROD and refers to the public's general response to the alternatives described in the Proposed Plan and the RI/FS reports.

A comparative analysis of these alternatives based upon the evaluation criteria noted above follows.

Overall Protection of Human Health and the Environment

Alternative 1 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 and 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 capping with an active treatment layer to reduce and control the long-term risks associated with the native sediment. Placing such an active cap over the 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 active cap would also prevent direct contact with NAPL and prevent NAPL migration to the surface water of the canal. Contingent upon positive bench and pilot-scale study results, 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.

The upland former MGP source controls (and other upland source areas) that have been or are anticipated to be selected by NYSDEC are expected to be protective of human health and the environment by removing the primary source areas and minimizing the migration pathways into the canal.

Implementation of source controls to address CSO-related releases of hazardous substances associated with CSO solids, beyond those currently being implemented by NYCDEP, is necessary to provide overall protection of human health and the environment. In particular, such controls are necessary to protect the integrity of the canal remedy. By reducing discharges and accumulation of CSO solids, contaminant concentrations in surface sediments after remedy implementation are expected to meet the PRGs, which are considered protective of human health and the environment. Absent additional controls, solids contaminated with hazardous substances will continue to be discharged through the CSOs, affecting sediments in the canal.

Compliance with ARARs

ARARs are identified in Tables 2-3 through 2-5 of the FS report. Below are the principal chemical-specific, action-specific and location-specific ARARs for the site.

Since there are currently no federal or state promulgated standards for contaminant levels in sediments in New York, PRGs for sediments in the Gowanus Canal were developed based on the results of the HHRA and ERA.

EPA and New York State have promulgated surface water standards which are enforceable standards for various surface water contaminants. The New York State surface water quality standards are set forth at 6 NYCRR Part 703.

While Alternatives 5 and 7 would be expected to comply with all of the designated chemical-specific ARARs, Alternative 1 would not, since there would be no active remediation associated with the sediments.

During the implementation of Alternatives 5 and 7, any short-term excursions above surface water ARARs in the canal due to dredging and capping would be expected to be limited to the area in the vicinity of the work zone. Sufficient engineering controls would need to be put in place during dredging and capping to prevent excursions of surface water ARARs outside of the work zone.

Disposal of solids and liquid collected as part of CSO solids controls would be implemented in a manner that would achieve chemical-specific ARARs under the CWA. If storage tanks are used, it is anticipated that any stored sewage would be processed by the existing WWTPs in accordance with each facility's permits at the conclusion of storm events. In the event that solids are generated for disposal at the CSO solids control (*e.g.,* via maintenance of an in-line CSO storage facility), such disposal would be implemented in a manner which complied with RCRA requirements.

The principal action-specific ARARs include CWA Sections 401, 402 and 404; the Rivers and Harbors Act Section 10; the New York Environmental Conservation Law (ECL) Articles 15 Water Resources, Article 17 Water Pollution Control and Article 27 Collection, Treatment and Disposal of Refuse and Other Solid Waste; and associated implementing regulations. Consideration of a CDF will be subject to approval by NYSDEC and other appropriate governmental regulatory authorities.

The CWA Section 401 Water Quality Certification (WQC) is implemented by NYSDEC through ECL Article 15 and the associated regulations in 6 NYCRR Part 608 Use and Protection of Waters. The WQC may establish conditions such as preventive measures to minimize re-suspension of sediment and water quality monitoring during dredging, so that the proposed activity would not exceed water quality standards. Placement of fill (such as a cap, or construction of an in-water confined disposal facility) and temporary discharges of decanted waters from dredge barges into waters of the United States would also be addressed through a WQC. The dredging or placement of fill or structures such as bulkheads or in-water confined disposal facilities within navigable waters of the United States and other activities which may adversely affect aquatic ecosystems are regulated by the Rivers and Harbors Act Section 10. Similar activities in any waters of the United States are addressed by CWA Section 404 for which the USACE has jurisdiction.

CWA Section 402 is implemented by NYSDEC through the ECL Article 17 SPDES requirements, which regulate the discharge of pollutants into waters of the state. Pre-treatment or monitoring of decanted water may be imposed and would be applicable to dewatering of the sediment at an on-site noncommercial facility.

RCRA is the federal law addressing the storage, transportation and disposal of solid and hazardous waste. NYSDEC implements RCRA in New York under ECL Article 27. The dredged sediment would be considered solid waste; however, it can be exempted from being solid waste through the WQC program. If not exempted, RCRA requirements would be applicable.

The principal location-specific ARAR in addition to ARARs described above, is the Federal Coastal Zone Management Act administered by the National Oceanic and Atmospheric Administration and the associated implementing NYSDEC regulations which apply to placement of bulkhead, sheet-piling within the canal, barge/boat docks, barge offloading facilities, boat launches, bridge abutment bulkhead protection, utility protection and dredging.

Since both of the action alternatives include dredging and active capping within the canal, the final design of the remedy must meet the substantive requirements of the regulations. Both action alternatives are expected to be able to comply with all of the designated location-specific and action-specific ARARs.

The former MGP and outfall source controls would comply with all of the designated chemical-specific, location-specific and action-specific ARARs.

Long-Term Effectiveness and Permanence

Alternative 1 would not result in any significant change in risk associated with contaminated sediment or NAPL.

Alternatives 5 and 7 would result in significant, permanent reduction of the risks associated with contaminated 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 contaminated sediments constitute principal threat waste[32] for which removal and treatment is warranted.

The active cap 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 and Baxter Superfund site in Portland, Oregon, the NAPL discharge rate to the cap was estimated and a design life of more than 100 years established (Blischke and Olsta, 2009). NAPL discharge rates at the Gowanus Canal would need to 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 the exposure risks associated with the native sediment would be controlled by the active cap. The application of ISS to targeted areas of native sediment in Alternative 7 would be expected to reduce further the NAPL mobility from the native sediment; however, treatability and pilot testing would need to be performed to determine the effectiveness and implementability of ISS within the canal.

The seven treatment and disposal options were ranked with respect to long-term effectiveness and permanence. Options A, B and C rank high with respect to this criterion because the material would be transferred off-site 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 off-site 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 on-site fill or concrete blocks 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 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 would remain on-site but would 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. 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 and periodic 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.

The former MGP and upland source controls which have been or are anticipated to be selected are expected to have a high degree of effectiveness because significant source areas would be removed by excavation and extraction and residual soil contamination would be controlled by barrier technologies, such as cutoff walls and capping.

The commingling of solids and associated PAHs and other chemical constituents from the CSO outfalls with sediment and chemical constituents in the canal would potentially impact the integrity and long-term effectiveness of each of the active alternatives. CSO solids control would reduce the mass of contaminated CSO solids accumulating in the canal and, thus, reduce the residual risk from contaminants in newly deposited sediments after remedy implementation. Treatment of any stored sewage material would occur at the WWTPs in accordance with each facility's permits at the conclusion of storm events. CSO

[32] Principal threat wastes are source materials that include or contain hazardous substances that act as a reservoir for the migration of contamination to groundwater, surface water, or air, or act as a source for direct exposure. These materials are considered to be highly toxic or highly mobile and, generally, cannot be reliably contained.

solids controls can be designed and implemented to provide reliable control of discharges at the selected design criteria, thus, reducing the potential for recontamination and the residual risk after remedy implementation. The reliability of CSO solids control would require regular inspections and maintenance of the controls to ensure that they are operated in accordance with design criteria. Site management controls relating to future sewer capacity would be necessary to maintain the effectiveness of the CSO measures. Specifically, controls would be utilized to ensure that current and future high density residential redevelopment projects along the banks of the canal and within the sewershed would be constructed consistent with current NYC guidelines (NYCDEP, 2012) so as to not contribute sewage discharges to the canal that would result in compromising the remedy. Separated stormwater outfalls may also require discharge treatment controls.

NYCDEP's WB/WS Plan, which followed EPA's LTCP guidance, was developed and approved by the State of New York on July 14, 2009 to achieve planned levels of CSO reductions for a typical rainfall year. The control technologies considered by NYCDEP for the WB/WS Plan are typical of reliable CSO solids control employed by NYCDEP and other cities around the world.

Monitoring of controls in support of the preferred remedy can be integrated into NYCDEP's monitoring plans under the WB/WS and LTCP. Specifically, following the implementation of the WB/WS Plan, NYCDEP will perform post-construction monitoring to assess the effectiveness of its plan. Monitoring will consist of collecting relevant sampling data from the canal, as well as collecting relevant precipitation data and data characterizing the operation of the sewer system (NYCDEP, 2009). Analyses will be performed to assess compliance with water quality standards as a measure of the effectiveness of the WB/WS Plan. Using the collected information, NYCDEP will assess whether or not additional CSO controls are needed to achieve compliance with the CWA as part of an Adaptive Management Approach. NYCDEP will then submit in June 2015, an LTCP, which may include additional CSO controls needed for compliance with the CWA and requiring further long-term post-construction monitoring. This monitoring will likely be added to NYCDEP's SPDES permits and can integrate the monitoring of controls implemented in support of the preferred remedy for the canal.

Reduction in Toxicity, Mobility or Volume through Treatment

Alternative 1 would not result in the reduction in toxicity, mobility or volume of contaminants nor does it include a treatment component.

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

The reduction of toxicity, mobility and volume of the dredged sediment is dependent upon the treatment/disposal option selected; therefore, the four treatment/disposal options are 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 (off-site 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) would be dependent upon the conditions where the material is placed and the degree of stabilization performed. Additional testing would be required to determine if an irreversible stabilization process can be developed on the basis of beneficial use.

The former MGP and upland source controls, including elimination of unpermitted pipes, will reduce the volume of contaminants discharged to the canal. Excavated soil and extracted NAPL from uplands cleanups would then undergo appropriate treatment and disposal.

CSO solids control would reduce the volume of contaminants discharged to the canal. The controls would permanently reduce the mobility of contaminants by capturing and containing solids prior to being discharged to the canal. The captured solids would then undergo appropriate treatment and/or disposal, with the specific methods to be determined during the remedial design. It is assumed that stored sewage would be managed at the WWTPs in accordance with each facility's permits at the conclusion of storm events. The capture of the solids would be irreversible, since the solids would be prevented from discharging to the canal. The reduction of toxicity and volume achieved would be at design criteria such that CSO solids control would result in surface sediment concentrations below the established PRGs. CSO reductions needed to achieve the PRGs in surface sediments after remedy implementation are estimated to be in the range of 58 to 74 percent.

Short-Term Effectiveness

Alternative 1, No Action, does not include any physical construction measures in any areas of contamination and, therefore, would not present any potential adverse impacts to on-property workers or the community as a result of its implementation.

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 potential construction-associated risks and short-term environmental impacts (traffic, odors, noise, etc.). Effective controls can be implemented to address short-term environmental impacts from temporary on-site sediment handling and dewatering. Barges would be used for the transport of dredged sediment. Barges would also be used, to the extent possible, to limit traffic impacts related to the delivery of equipment and supplies and the transport of materials from the work area. Appropriate measures could be taken to limit noise, odors, and other impacts associated with dredging and processing of the sediments. The short-term effectiveness of the treatment and 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 treatment and disposal options evaluated.

The transportation distance of dredged material to the final treatment or disposal facility is an important consideration for short-term effectiveness. Distances were estimated in the FS for the purposes of comparing options and developing costs. Options E (on-site stabilization and on-site beneficial use) and G (on-site stabilization and disposal in an on-site CDF) do not require the dredged sediment to be transported off-site, although stabilization reagents (*e.g.*, cement and blast furnace slag) would need to be transported to the on-site facility. Of the remaining disposal options, Option F (off-site stabilization and disposal in an on-site 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 off-site-dredge-material-processing facility and from there approximately 60 miles of transport by truck to the thermal treatment facility. The transport distance for Option B (off-site 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. The off-site beneficial use for sediment under Option D has been assumed to be landfill cover; thus, it has been assumed that the material would need to be transported approximately 110 miles by truck from the off-site stabilization facility to the disposal facility.

CSO solids controls can be designed, constructed and operated in a manner that does not present short-term implementation risks to the community and workers, manages environmental impacts and meet ARARs.

The former MGP and upland source controls which have been or are anticipated to be selected are expected to have moderate short-term effectiveness due to the construction duration and the potential construction-associated risks and short-term environmental impacts (odors, noise, etc.). These measures can be designed, constructed and operated in a manner that does not present short-term implementation risks to the community and workers and manages environmental impacts. EPA and NYSDEC are coordinating to ensure that the former MGP sites are addressed in a manner consistent with the anticipated remedial dredging schedule.

Ideally, CSO solids control would be in place before the implementation of the remedy for canal sediments. Alternatively, temporary CSO control measures (*e.g.,* solids capture in upper reach with periodic removal) may be needed to maintain remedy protectiveness while the permanent CSO solids control are being implemented. At the time of the completion of the canal remedy, the canal surface would be “clean,” with surface sediment contaminant concentrations expected to increase over time as a result of new sediment deposition in the canal. However, as noted, the CSO control design criteria would be selected such that the deposition of solids from CSOs would not result in surface sediment concentrations above the PRGs.

It is estimated that the design and construction of both action alternatives would take 3 years and 5 years, respectively.

Implementability

Alternative 1 is considered to be readily implementable 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 would require significant coordination between EPA, USACE, NYSDEC, NYCDEP, PRPs and the 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 would 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 confirm the overall feasibility and effectiveness of this technology, Alternative 7 is considered to have moderate implementability, but to a lesser degree than Alternative 5. The location and construction of a temporary on-site sediment handling and dewatering facility is considered to have moderate implementability.

The implementability of the different treatment and disposal options is more variable:

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

Thermal treatment and cogeneration facilities (Options A and C, respectively) are limited within the geography, which would 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 would be needed to confirm that the available treatment facilities can accept the dewatered and stabilized sediment.

The availability of landfill facilities that would 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 area, few facilities would accept materials originating from outside the county they serve and only a subset of these facilities would accept dredged material. Because Option B includes off-site landfill disposal of the stabilized dredged sediment, the implementability of this option is reduced for disposal facilities in the area; however, additional disposal facilities are available outside of the area. 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) would require identifying an off-site or on-site beneficial use of the stabilized material, as well as defining the performance standards for the end-use requirements. The stabilized material would need to meet the chemical and physical performance standards (*e.g.*, short- and long-term leachability and strength characteristics) in order for these options to be implemented. Additionally, on-site use of the stabilized material would be dependent upon property owner 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 off-site beneficial-use option has a slightly higher ranking due to the possibility of more beneficial-use applications. The on-site beneficial-use option also is ranked slightly lower due to the potential difficulties associated with effective sustained implementation of institutional controls.

Implementation of disposal Options F and G (stabilization and on-site CDF) is dependent on the acceptance from the community, approval of NYSDEC and other appropriate governmental regulatory authorities and the sustained application of institutional controls. These options may be difficult to implement due to administrative considerations and, therefore, received a moderate ranking.

The former MGP and upland source controls which have been or are anticipated to be selected are expected to be implemented successfully. Excavation, capping, NAPL extraction and containment wall technologies have been successfully implemented at other MGP sites. Given the number of affected former MGP and other source areas, extensive coordination among landowners, responsible parties and local, state and federal agencies will be required.

Various approaches to CSO solids control exist and have been successfully implemented elsewhere. NYCDEP has demonstrated that CSO discharges can be reduced through successful implementation of various grey and green infrastructure techniques.

Cost

A summary of the estimated cost for each alternative and the associated treatment and disposal options is provided in Table 9.

Support Agency Acceptance

NYSDEC concurs with the proposed remedy.

Community Acceptance

Community acceptance of the preferred remedy will be assessed in the ROD following review of the public comments received on the Gowanus Canal RI/FS reports and the Proposed Plan.

PROPOSED REMEDY

Based upon an evaluation of the various alternatives, EPA recommends sediment dredging, capping and treatment/disposal, source control and institutional controls. The estimated present-worth cost of the preferred remedy ranges from $467 - $504 million depending upon the treatment/disposal option that is selected (see Table 10). The components of the preferred remedy are as follows:

Dredging, Capping and Treatment/Disposal

The following dredging, capping and treatment/disposal components are recommended for each RTA:

RTAs 1 and 2: Alternative 7 (dredge entire soft sediment column, targeted ISS of native sediment in areas with potential for active upward NAPL migration from the native sediment and cap with treatment, isolation and armor layers). The armor layer would consist of 1.5 feet of stone with a median diameter of 0.75 feet. Sufficient sand would be placed on top of the armor layer to fill in the voids between the stones and to establish sufficient depth of soft sediment in order to facilitate benthic re-colonization.

RTA 3: Alternative 5 (dredge entire soft sediment column and cap with treatment, isolation and armor layers)

The remedy would also include the excavation and restoration of the filled-in 1st Street Turning Basin.[33] This would mitigate the loss of surface water area as a result of new bulkhead encroachment into the canal.[34]

In addressing the PAHs, the other risk-driving chemicals (PCBs and metals) would also be addressed because they are collocated.

The cap would need to be designed to be able to withstand future maintenance dredging operations in the canal for the removal of contaminated solids that might settle on top of it. If possible, the cap treatment layer would be designed to have an adequate life expectancy for absorbing NAPL without replacement. If this is not feasible, the remedy may include the replacement of portions of the treatment layer (replacing the treatment layer would also necessitate the removal and replacement of the overlying sand and armor layers).

Treatability and pilot testing would be performed to assess whether or not large-scale ISS of NAPL-impacted native sediments would have an adverse impact on groundwater flow and to design a stabilization layer to mitigate the adverse impact.

Following on-site dewatering, the disposition of the dredged sediments would be as follows:

RTA 1: NAPL Impacted Areas, Option A—Off-site thermal desorption/beneficial use; Non-NAPL Impacted Areas, Option D—Off-site stabilization/beneficial use

RTA 2: Option A—Off-site thermal desorption/beneficial use (NAPL impacts throughout RTA 2)

RTA 3: Option D—Off-site stabilization/beneficial use. As a contingency, Option G—On-site stabilization of lesser contaminated sediments and placement in on-site CDF—would be evaluated based upon community acceptance and the approval of NYSDEC and other appropriate governmental regulatory authorities

Source Controls

In order for the proposed remedy to be effective, the upland sources of contamination, including impacts from the former MGP sites, discharges from the CSOs in the upper part of the canal (particularly, outfalls RH-034 and OH-007), other contaminated areas along the canal and the unpermitted pipes along the canal, must be controlled. EPA would coordinate with NYSDEC the remedy described in this Proposed Plan with the source area investigations and remediation at the three former MGPs. To address the contaminant contributions from the former MGPs, New York State regulations governing the State Superfund program requiring source removal or control for all remedies, make it clear that the remedies for the two other former MGP sites, will adequately address the sources at those sites. NYSDEC and EPA have developed a coordinated schedule for the implementation of the former MGP cleanups.

To address the discharge of hazardous substances from CSOs, it is presumed that in-line storage tanks would have to be constructed near outfalls RH-034 and OH-007. Tank volumes of 6- to 8-million gallons and 3- to 4-million gallons were selected for outfalls RH-034 and OH-007, respectively, on the basis of their capacity to capture approximately twice the amount of the "first flush" of the largest discharge event (WB/WS Plan).[35] Scientific literature suggests that it can be assumed that the "first flush" comprises 20% of the total discharge volume and that it contains between 30% and 60% of the total PAH load of the discharge (Stein, 2006). These tanks would be constructed in available NYC-owned land in the vicinity of the outfalls. The exact volumes would be defined during the design phase.

[33] Analytical data obtained during the RI in the former 1st Street turning basin showed the existence of significant contamination in soil and groundwater above cleanup standards. As with other former basins along the canal, it is believed that contaminated sediments within the 1st Street basin were left in place when the basin was filled in. In addition, there are indications that the fill itself may have included waste materials. The filled-in basin may also have been subject to later spills and dumping. The basin is hydraulically connected to the canal (with no bulkhead standing between the canal and the basin) such that contaminants within the basin are an on-going source of contamination. Finally, unlike other filled in portions of former turning basins, the 1st Street basin has no standing structures on it.

[34] It would also offset any loss of surface water area if a CDF is approved for use in the project.

[35] EPA recognizes that, in the future, there may be more frequent large rainfall events due to climate change.

It is uncertain whether permanent measures to control the discharges from outfalls RH-034 and OH-007 would be in place by the time that dredging is carried out. Therefore, interim controls would be assessed during the remedial design and under the contemporaneous LTCP development process to control the discharges from these outfalls until the permanent measures are implemented.

Control of the upland contaminated areas located adjacent to the canal that were referred to NYSDEC and the control of discharges from the unpermitted pipe outfalls would need to be coordinated and implemented in concert with the sediment remedy to prevent recontamination of the canal following remedy implementation. EPA will work in coordination with NYCDEP and NYSDEC to either permit or permanently seal these pipes.

It is anticipated that temporary sheet-piling would be required for dredging and capping in locations where the condition of bulkheads would warrant additional structural support. Other than in locations where bulkhead replacement will likely be a component of the remedy (*e.g.,* the former MGP sites), it is anticipated that bulkhead replacement would not be part of the remedy, unless a substandard bulkhead is judged to present a threat to the integrity of the remedy.

A temporary on-site facility would be necessary for dewatering and transfer of dredged sediments.

Barges would be used for the transport of dredged sediment. Barges would also be used, to the extent possible, to limit traffic impacts related to the delivery of equipment and supplies and the transport of materials from the work area. Appropriate measures would be taken to limit noise, odors, and other impacts associated with dredging and processing of the sediments.

Current and future high density residential redevelopment along the banks of the canal and within the sewershed would be consistent with current NYC criteria (NYCDEP, 2012) so as to not contribute sewage discharges to the canal that would result in compromising the remedy.

Because this remedy would result in contaminants remaining on-site above levels that allow for unrestricted use and unlimited exposure, CERCLA requires that the site be reviewed at least once every five years.

Institutional Controls

Institutional controls are part of the preferred remedy. The existing fish consumption advisory would be included because of the anticipated unacceptable human health risk associated with the consumption of PCB-contaminated fish and shellfish after the remedy is implemented. This existing fish consumption advisory for Upper New York Bay identifies PCBs as one of the contaminants of concern.

Institutional controls would also be used to protect the integrity of the cap and in-situ stabilized material. NYC owns the canal (with the exception of certain turning basins), and is among the government entities that regulates bulkhead construction. The institutional controls would include restrictions to prevent damage to the cap, limitations on construction within the canal, including bulkhead maintenance, and navigation dredging within the canal. For example, EPA approval would be required prior to the issuance of bulkhead maintenance permits. Where cutoff walls and other upland cleanup measures are implemented under either NYSDEC or EPA oversight, appropriate protective easements or other deed restrictions would be implemented.

For materials placed in the CDF, if a CDF were constructed, the institutional controls would include restrictions on digging or drilling within stabilized fill material or within the CDF, limitations on the types of structures, if any, that can be placed on top of the CDF and limits on the types and size of plants, if any, which could be allowed to grow on top of the CDF.

As was noted in the “Scope and Role of Action” section, above, contaminated groundwater that is migrating to the canal from the upland areas will be investigated and addressed as part of the upland source remediation, as necessary.

Basis for Remedy Preference

Dredging, Capping and Treatment/Disposal Components

While remedial alternatives are typically compared against each other with the intent of selecting one alternative, due to the different conditions at each of the RTAs, under the preferred remedy, both action alternatives would be utilized. Alternative 7 would be employed at RTAs 1 and 2 and Alternative 5 would be utilized at RTA 3. The basis for the preference is as follows:

- Removal of all the soft sediment would remove the PAHs, metals and PCBs which are found only in the soft sediment at concentrations of concern and is the most appropriate approach to principal threat waste.
- Removal of all soft sediment would limit the potential for future contaminant transport in the event of cap failure.
- With the removal of all soft sediment, sediment stabilization would be needed only in select areas where the native sediment is contaminated with NAPL so as to control NAPL mobility.
- The native sediment would provide a base for the cap with a likely higher long-term reliability for supporting the cap than without stabilization.
- If the soft sediment were to be left in place, stabilization of the soft sediment might be needed to provide the needed cap support along the entire Canal, rather than only in areas of NAPL mobility in native sediment; widespread stabilization may alter groundwater flow and/or result in localized flooding and would require removal of swelled material

produced during the stabilization process for disposal.

- Removal of the soft sediment would provide for deeper water depths to support current navigation uses and would better protect the cap and prevent damages from barges.
- Removal of much of the soft sediment is necessary for implementation of the remedy and future maintenance of the remedy and canal infrastructure such as bulkheads.
- Treatment and disposal options provide for beneficial use of the dredged sediments.

The primary reason for the removal of the accumulated soft sediment is the removal and treatment of the principal threat waste represented by the grossly-contaminated accumulated sediments. Removal of the accumulated sediments would result in the removal of contaminants of concern in that stratum, thereby reducing the risk of recontamination in the event of a cap failure. In addition, the removal of the majority of the accumulated sediments is necessary for constructability reasons. Nearly half of the soft sediment must be removed to create sufficient depth for work boats that would implement the remedy (debris removal, installing/removing temporary sheet-pilings, dredging, disposal barges and cap placement); maintain the cap and conduct future repairs to bulkheads and other infrastructure throughout the canal and avoid propeller wash cap damage by existing commercial barge navigation in the lower two thirds of the canal.

Expected development projects in the area have the potential to bring more people to upland portions of the canal, adding to the number of people subject to the identified exposure pathways. NYC has previously identified such redevelopment pressures as justification for the timely implementation of a remedy. EPA believes that, after approximately 3 years of design work, the remedy can be implemented in 5 years.

EPA acknowledges that the community has expressed support for remedial treatment and disposal methods which utilize local industry and workers and which reduce or avoid transferring the disposal burden onto outside communities. For these reasons, some community groups have also expressed preliminary support for a temporary on-site stabilization facility as well as interest in a permanent, fully permitted stabilization facility to handle sediments from Newtown Creek and other sites. Permitting a facility for handling non-Gowanus Canal sediments would require a separate process outside the scope or legal authority of this project or Proposed Plan. Community acceptance of potential disposal options will be addressed in the ROD following review of the public comments received on the Proposed Plan.

Bulkhead Replacement

EPA recognizes that bulkhead conditions are a significant public concern. As a result, EPA has prepared a series of approaches to coordinate and expedite bulkhead replacement regardless of the extent to which such bulkhead replacement is part of the remedy. EPA has held talks with the USACE, NYSDEC and NYC about cooperative approaches to address bulkhead replacement and restoration along the canal. To the extent that bulkhead replacement occurs, appropriate consideration would be given to bulkhead preservation, aesthetics, the use of soft edges and wetlands mitigation.

For the replacement of bulkheads which are not part of the remedy, the possible methods include a standardized design and promoting coordination among interested owners to reduce their costs through economies of scale. Where replacement is not needed for purposes of the remedy, EPA will facilitate a streamlined permitting approach to reduce transaction costs and expedite approval. Where replacement is needed for the remedy, EPA will apply the CERCLA permit exemption to further expedite the process. EPA has met with several property owners who are interested in replacing their properties' bulkheads. EPA is developing a standard approach for performing such work which would ensure that the bulkheads are upgraded in a manner consistent with the canal remedy and the substantive NYSDEC requirements. This work would be carried out under an EPA administrative order with EPA oversight. Such an order can also provide appropriate CERCLA liability protection for the owners performing work in the canal.

EPA believes that there are a moderate number of locations where bulkheads are so deteriorated that they may fail when the temporary sheet-piling is removed after dredging. In such cases, EPA intends to cooperate with NYC on inspection and enforcement of existing NYC bulkhead maintenance requirements. To reduce costs for affected bulkhead owners, EPA will facilitate permitting approval, design and construction.

While EPA will continue working with all of the stakeholders, it recognizes that it is not possible to insure that all of the bulkheads that need to be replaced will be replaced. Therefore, some substandard bulkheads may still remain. If the continued presence of such substandard bulkheads is judged to present a threat to the integrity of the canal remedy, available CERCLA authorities and/or resources would be used as necessary to ensure their repair.

Source Control Components

The coordination of upland cleanups, CSO control and the sediment remedy is necessary for a comprehensive and sustainable remedy.

With respect to the former MGPs and other upland source areas, EPA and NYSDEC are closely coordinating and EPA is confident that these source areas can be appropriately addressed within the anticipated remedial approach and schedule for the canal remedy.

EPA and NYSDEC have agreed to a coordinated schedule for the former MGP sites and canal sediment cleanup efforts based on the anticipated timing of the dredging in the canal (which would commence at the head of the canal).

Because the upland contamination source areas which may impact groundwater have been referred to NYSDEC for investigation and remediation, if necessary, EPA believes that a separate groundwater remedy is not required as part of this remedy. As a result, the proposed remedy would not rely on dilution or dispersion of contaminated groundwater which is discharging into the canal.

CSO controls are needed to prevent the discharge and transport of CSO solids which are contaminated with comparatively low levels of hazardous substances associated with urban CSO discharges. These solids also serve to capture and concentrate other contaminants. Such controls would ensure the long-term viability of a restored canal

As was noted in the "Site Background" section, above, a number of planned sewer system improvements will decrease the overall CSO discharges to the canal. As a result, EPA does not foresee a need for additional CSO controls in the lower reaches of the canal, where all the CSO control improvements now underway are taking place. Although the WB/WS Plan will achieve an overall estimated 34 percent reduction of CSOs to the canal, discharges at outfall RH-034 at the head of the canal are estimated by NYCDEP to increase by 5 percent. Planned development in the area has the potential to increase sewage flows further, which can contribute to increases in CSO discharges.

The preferred remedy would not be inconsistent with the LTCP and the CWA. The canal's current uses, fishing and recreation, and the physical conditions which lead to frequent flooding with the potential to distribute sediments and sewage contaminated with hazardous substances, provide a further basis for implementing additional CSO solids controls. Significant residential and commercial redevelopment pressures that exist adjacent to the canal increase the need for sediment, upland and CSO remedy components. However, new construction would be subject to updated NYC building codes and stormwater rules which will help reduce the impacts of such development.

EPA is committed to achieving cost savings by working closely with NYCDEP to accomplish an effective Superfund cleanup while also realizing CSO benefits through synergies and economies of scale. NYCDEP will complete a full assessment of achieving CWA goals with submission of the LCTP in June 2015 pursuant to the CSO Consent Order. The design of this Superfund remedy will also be informed by NYC's work in developing the LTCP. EPA will work with NYC to advance both Superfund and CWA goals by allowing NYCDEP to evaluate locating CSO control facilities in areas where upland site-related source removal work might take place, creating a synergy between programs that potentially could save time in site acquisition and permitting and significant construction costs.

Community Outreach Considerations

Although public comment on the proposed plan is the primary formal comment phase of the remedial process, EPA is committed to maintaining a transparent, pro-active community interaction process during each cleanup phase, with informal comment opportunities on all key elements of the design and implementation.

Despite posted warnings, the canal is regularly used for fishing, particularly subsistence fishing by several separate environmental justice communities surrounding the canal. A NYCDEP survey of residents indicated that fishing is the number one canal use by area residents. (NYCDEP 2008). EPA believes that the preferred remedy would reduce risks to these communities by reducing sources which contribute to these risks. Because the preferred remedy will not fully eliminate the need for fishing advisories due to contaminants from New York Harbor, EPA intends to continue to coordinate fishing advisory education and awareness efforts with the appropriate governmental agencies.

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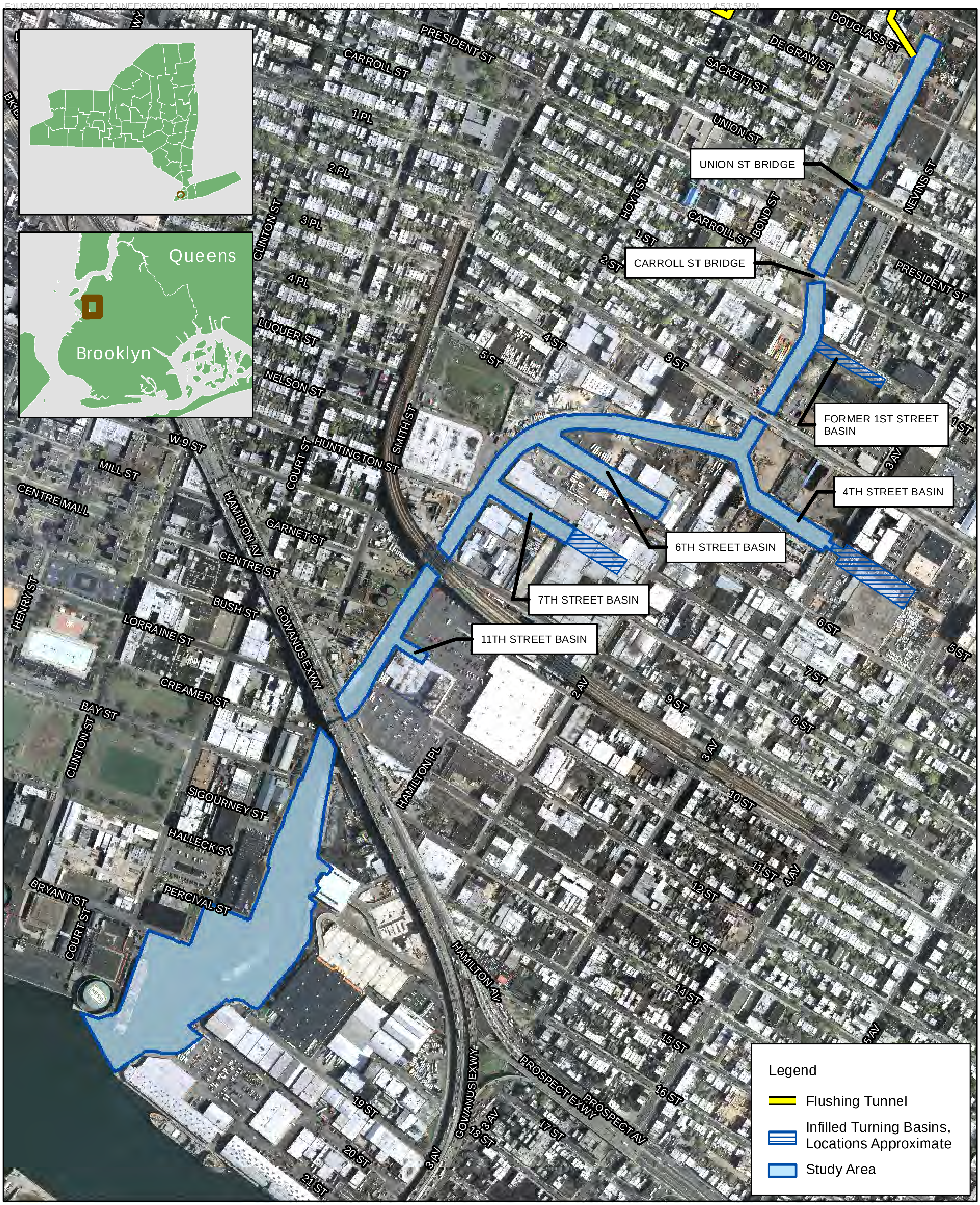


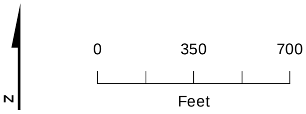
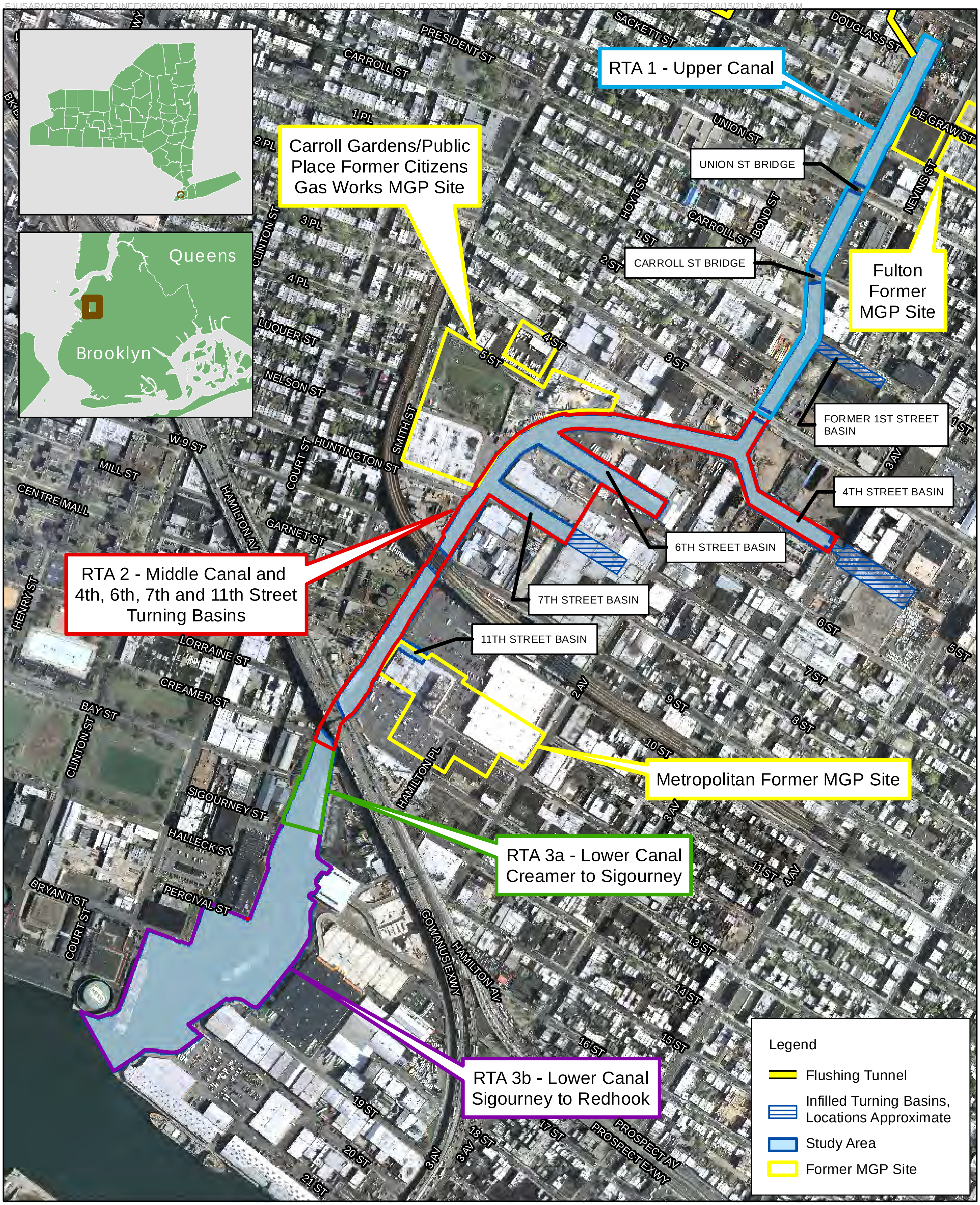


FIGURE 1
Site Location Map
Gowanus Canal Feasibility Study
Brooklyn, New York

CH2MHILL



0 350 700

Feet

N

FIGURE 2
Remediation Target Areas
Gowanus Canal Feasibility Study
Brooklyn, New York

CH2MHILL

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0 350 700

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FIGURE 3
Stormwater/CSO Outfall Locations
Gowanus Canal Feasibility Study
Brooklyn, New York

CH2MHILL

Table 1: Average Contaminant Concentrations at Reference Stations

Contaminant	Reference Average (mg/kg)	Reference Range (mg/kg)
Total PAHs	6	1 - 14
Total PCBs[1]	0.47	0.47 - 0.48
Copper	81	15 - 242
Lead	93	26 - 244

Notes:
[1] Total PCB congeners, excluding one station with total PCB = 1.7 mg/kg

Table 2: Summary of Sediment Physical Characteristics

	Canal Surface Sediment			***Reference Area Surface Sediment***		
Surface Sediment Data	**Minimum**	**Maximum**	**Average**	**Minimum**	**Maximum**	**Average**
Total Organic Carbon (mg/kg)	25,100	137,000	64,385	2,980	43,400	28,358
Percent Sand	10	58	39	9.7	44	28
Percent Silt	35	74	52	44	72	57
Percent Clay	4.9	15	8.9	12	21	15
Total Percent Fines	42	90	61	56	90	72
Percent Solids	26	78	36	27	70	41
Sulfide (mg/kg)	51	8,790	3,448	383	2,160	1,167
	Soft Sediment			***Native Sediment***		
Sediment Core Data	**Minimum**	**Maximum**	**Average**	**Minimum**	**Maximum**	**Average**
Total Organic Carbon (mg/kg)	730	490,000	119,650	550	168,000	18,677
Percent Sand	10	80	35	0	100	51
Percent Silt	18	70	54	0	81	38
Percent Clay	1.2	24	11	0	74	10
Total Percent Fines	20	90	65	0.53	100	49
Percent Solids	25	99	54	48	91	81
Sulfide (mg/kg)	184	8,330	3,909	7.6	7,300	145
Bulk Density (g/cm^3)	0.31	2.0	0.83	0.59	2.1	1.5

Surface sediment is 0-6 inch interval.

Statistics were generated using 1/2 the detection limit for non-detected results

Statistics for surface sediment were generated using only USEPA 2010 data.

Total percent fines is the sum of percent silt and percent clay.

Total Organic Carbon and Percent Solids summary statistics for soft sediment from sediment cores were calculated using the USEPA 2010 and National Grid 2005 data sets. The summaries for native sediment were determined using only the USEPA 2010 data set.

Sulfide and Total Percent Fines summary statistics for soft and native sediment for sediment cores were determined using only the USEPA 2010 data set.

Bulk density for soft sediment was determined using only the National Grid 2005 data set. This parameter was not measured in the 2010 investigation. Bulk density values for native sediment were obtained from GEI (2007).

mg/kg = milligram per kilogram
g/cm^3 = grams per cubic centimeter

Table 3: Average Concentrations of Selected Constituents in Surface Sediment, Soft Sediment, and Native Sediment

Constituent	Average Concentration (mg/kg)			
	Canal Surface Sediment	Canal Soft Sediment	Canal Native Sediment	Reference Surface Sediment
Total BTEX	0.36	188	233	ND
Total PAHs	527	3490	2920	5.8
Total PCB Aroclors	0.43	3.5	0.026	ND
Barium	175	441	32	67
Cadmium	6.30	9.70	0.32	2.31
Copper	226	388	12	81
Lead	533	770	14	93
Mercury	1.27	2.63	0.095	1.12
Nickel	44	78	15	32
Silver	3.40	11	0.61	2.15

mg/kg - milligrams/kilogram

ND - not detected

BTEX - benzene, toluene, ethylbenzene, and xylenes
Reference area in Gowanus Bay and Upper New York Bay

Table 4: Average Concentrations of Selected Constituents in Surface Sediment in the Upper, Middle, and Lower Canal

Constituent	Average Concentration (mg/kg)			
	Upper Reach (Head of Canal to 3rd St.)	Middle Reach (3rd St. to Creamer St.)	Lower Reach (Creamer St. to South End of Study Area)	Reference (Gowanus Bay and Upper New York Bay)
Total PAHs	56	951	34	5.8
Total PCB Aroclors	0.055	0.83	0.046	ND
Barium	112	250	106	67
Cadmium	3.99	7.28	7.88	2.31
Copper	223	255	139	81
Lead	613	491	192	93
Mercury	1.23	1.32	1.09	1.12
Nickel	36	51	40	32
Silver	2.93	4.31	1.75	2.15

Notes:
Surface sediment is 0-to-6-inch interval
mg/kg -
milligrams/kilogram
ND - not detected

Table 5: Total Noncarcinogenic Hazards and Carcinogenic Risks

Receptor	Fish		Crab	
	HI	***ELCR***	***HI***	***ELCR***
Reasonable Maximum Exposure				
Adult	17	7×10^{-4}	37	3×10^{-4}
Adolescent	13		3	
Child	27		5	
Central Tendency Exposure				
Adult	2	$<1 \times 10^{-6}$	2	$<1 \times 10^{-6}$
Adolescent	2		1	
Child	3		3	

Notes:
HI – hazard index; ELCR – excess lifetime cancer risk

Table 6: Summary of Human Health Preliminary Remediation Goals for Sediment (mg/kg)

COC	Recreational Use		Fish/Crab Ingestion[3]
	Upperbound[1]	**Lowerbound[2]**	
BAA	24	0.40	--
BAP	2.4	0.040	--
BBF	24	0.40	--
BKF	240	4.0	--
DA	2.4	0.040	--
ID	24	0.40	--
Total PCBs[4]	--	--	0.48

Notes:
BAA - benzo(a) anthracene;
BAP - benzo(a)pyrene;
BBF - benzo(b)fluoranthene;
BKF - benzo(k)fluoranthene;
DA - dibenzo(a,h)anthracene;
ID - indeno(1,2,3-c,d) pyrene

[1] Achieves a cumulative risk that does not exceed 1×10^{-4}

[2] Achieves a cumulative risk that does not exceed 1×10^{-6}

[3] Maximum Gowanus Bay and Upper New York Bay reference area concentration; estimates of reference area concentrations may be refined during monitoring

[4] Total PCB congeners

Table 7: Protection of the Benthic Community

Contaminant	Canal Average (mg/kg)	Screening Value (mg/kg)
Total PAH	527	4
Total PCB[1]	2.8	0.0598
Barium	175	130
Cadmium	6.3	1.2
Copper	226	34
Lead	533	47
Mercury	1.27	0.15
Nickel	44	21
Silver	3.4	1
Notes: [1]Total PCB congeners		

Table 8: Preliminary Remediation Goals for Protection of Ecological Community

Contaminant of Concern	Preliminary Remediation Goal	
	Concentration (mg/kg)	Basis
Total PAH [1, 2]	20[3]	Geo-mean of TOC-normalized potential NOAECs and LOAECs for amphipod growth
Copper	80	Maximum non-toxic reference samples[4]
Lead	94	Maximum non-toxic reference samples[4]
[1] At 6 percent TOC [2] Total PAH PRG for protection of herbivorous birds is 230 mg/kg [3] Geometric mean of NOAEC and LOAEC points [4] PRGs for metals may be applied post-remedy if metals are found to be bioavailable and toxic. Estimates of reference area concentrations may be refined during monitoring.		

Table 9: Summary of Costs for Alternatives Undergoing Detailed Evaluation--Dredging, Treatment and Disposal, and O&M Cost by RTA

Alternative Description	Base Implementation Capital Cost[1]	Dredging, Capping, Treatment and Disposal Capital Cost by RTA[2,3]			Total Capital Cost	Present-Worth O&M Cost[4]	Total Estimated Total Cost
		RTA 1	RTA 2	RTA 3			
Dredging and Capping Alternatives							
Alternative 1: No Action	$0	$0	$0	$0	$0	$0	$0
Alternative 5: Dredge entire column of soft sediment and cap with treatment layer, isolation sand layer, and armor layer	$190,700,000	$15,000,000	$35,000,000	$29,000,000	$269,700,000	$2,000,000	$271,700,000
Alternative 7: Dredge entire column of soft sediment; solidify top 3-5 feet of underlying native sediment in targeted areas and cap with treatment layer, isolation sand layer, and armor layer	$190,700,000	$18,000,000	$48,000,000	$29,000,000	$285,700,000	$2,000,000	$287,700,000
Treatment and Disposal Options							
A - Offsite thermal desorption, beneficial use	NA	$30,000,000	$82,000,000	$102,000,000	NA	NA	$214,000,000
B - Offsite disposal (landfill)	NA	$32,000,000	$87,000,000	$108,000,000	NA	NA	$227,000,000
C - Offsite Co-gen	NA	$37,000,000	$101,000,000	$126,000,000	NA	NA	$264,000,000
D - Offsite stabilization, beneficial use	NA	$30,000,000	NA	$104,000,000	NA	NA	$104,000,000
E - Onsite stabilization, beneficial use	$5,400,000	$23,000,000	NA	$78,000,000	NA	$2,000,000	$108,000,000
F - Offsite stabilization and disposal in on-site CDF	NA	NA	NA	$74,000,000	NA	$160,000	$74,000,000
G - Onsite stabilization and disposal in on-site CDF	$5,400,000	NA	NA	$67,000,000	NA	$160,000	$73,000,000

Notes:

1. Base implementation costs for the dredging and capping alternatives consist of the following cost items: remedial design and pre-design sampling and testing; pre-remediation site work, facility costs, bulkhead upgrade/stabilization, short term morning costs, and confirmation sampling costs. The base implementation cost for disposal options E and G includes setting up the onsite sediment stabilization facility. These costs include costs for excavation of the former 1st Street Basin (estimated at $20 million) and costs for storage tanks at CSOs RH-034 and OH-007 (8 million and 4 million tanks, respectively, estimated to cost $77.7 million; details presented in a separate technical memorandum).

2. Dredging and Capping costs consist of the following cost items: installation and removal of sheet pile cells (RTAs 1 and 2), silt curtain (RTA 3 only), sediment removal, cap placement, dewatering, and dewatering/dredge cell water treatment.

3. Treatment and Disposal costs are summarized by RTA and include the costs associated with transport to the stabilization facility, stabilization, treatment or disposal, and transport to end destination.

4. O&M costs are included under the dredging and capping alternatives are for the cap. Costs included for the treatment and disposal options are for the CDF associated with options F and G and for monitoring associated with the onsite beneficial use in Option E. The present worth cost is determined using a discount rate of 7%.

Table 10: Preferred Remedy Costs

Item	Option D for RTA 3	Option G for RTA 3
Dredge RTAs 1, 2 and 3 Remove 1st Street basin fill Stabilize within RTAs 1 and 2 Cap RTAs 1, 2, and 3 CSO tanks	$285,700,000	$285,700,000
Present-Worth O&M	$2,000,000	$2,000,000
Treat and Disposal Options A or D for RTA 1 (no cost difference between A or D) Option A for RTA 2 Option D or G for RTA 3 (cost difference shown)	$216,000,000	$179,000,000
Total	$503,700,000	$466,700,000