Table of Contents

CONTAMINATED SEDIMENTS SUCCESSFULLY REMOVED AND CAPPED, ENABLING WATERFRONT DEVELOPMENT IN BUFFALO, NEW YORK

John T. Finn[1] and Mark R. Hofferbert[2]

ABSTRACT

Sediments contaminated with coal tar were present in a 488 meter (1,600-foot) reach of an urban waterway in Buffalo, New York. Remedial action involved damming and diverting the streamflow around the work area, excavating and stabilizing 15,290 cubic meters (20,000 cubic yards) of hot-spot sediments, placing 8,826 square meters (95,000 square feet) of geosynthetic clay liner (GCL) and sand/armor stone cap, installation and operation of two deep DNAPL recovery wells, restoring aquatic and terrestrial plants, and long-term site monitoring.

Capping entailed placement of an impermeable GCL followed by 45 cm (18 inches) of sand, geofabric, and a minimum of 15 cm (6 inches) of armor stone. Scour modeling and design calculations were performed to determine the size of the armor stone and thickness of the sand layer to ensure the long-term physical stability of the cap. Diffusion modeling was done to ensure the long-term mitigation of contaminant migration. The GCL was a reinforced composite liner consisting of a layer of sodium bentonite between two geotextiles which are needlepunched together and laminated to a membrane liner of 0.10 millimeter (4 mil) polyethylene. Topsoil was placed over selected cap sections and then planted with aquatic and emergent species.

The cap was completed in 1999. Annual monitoring of the physical condition of the cap has been conducted, including two underwater video surveys. No sheens or other evidence of cap failure have been observed during the past 6 years. No erosion or uplifting of the cap is evident to date. The banks and shallows throughout the capped area have complete vegetation coverage. Numerous fish and animal species have been observed in the area, such as turtles, ducks, crayfish, and beavers.

The project has enabled esthetic and economic improvements to the local community, including a recreational pathway adjacent to the waterway which is part of the City of Buffalo Local Waterfront Revitalization Plan.

Keywords: Capping, armoring, geosynthetic-clay liner, stability, climate change.

INTRODUCTION

Starting in 1897, gas was produced from coal in a large plant in north Buffalo. This manufactured gas plant (MGP) was situated immediately adjacent to a navigable waterway which flowed to the Niagara River. Coal was delivered to the plant by barge via this waterway, and byproducts, including tar, were barged out. The gas was used to light the streets of north Buffalo, and to provide heating and lighting for manufacturing facilities, schools, and homes in the area. The gas was stored temporarily in a large telescoping holder characteristic of MGPs. The plant ceased operations in 1953 and was dismantled some years later to make room for a pharmaceutical manufacturing facility and an elevated four-lane highway. Figure 1 shows an aerial view of the site.

[1] Senior Engineer/Operations Manager, The RETEC Group, Inc., 1001 West Seneca Street, Ithaca, New York 14850-3342, USA, T: 607-277-5716, Fax: 607-277-9057, Email: jfinn@retec.com.
[2] Senior Engineer., The RETEC Group, Inc., 1001 West Seneca Street, Ithaca, New York 14850-3342, USA, T: 607-277-5716, Fax: 607-277-9057, Email: mhofferbert@retec.com.

Figure 1. Aerial view of the site.

After discovery of tar in subsurface soils and the sediment, the site was placed on the New York State registry of Hazardous Waste Sites in 1989. From 1990 to 1996, a remedial investigation and feasibility study (RI/FS) process was conducted by at the site to determine the nature and extent of chemical contaminants in the soil, groundwater, and sediments which remained from the MGP era.

At the same time, plans were being developed by the City of Buffalo for the redevelopment of the Buffalo waterfront, including plans for a greenway and recreational pathway along the waterway next to the site. It became clear that the cleanup of the site, including the contaminated sediments and bank areas, needed to occur prior to construction of the pathway and creation of the greenway.

The RETEC Group, Inc. (RETEC) completed the remedial investigation, and designed and oversaw implementation of the sediment remedy on behalf of the National Fuel Gas Distribution Corp. and with the approval of the New York State Department of Environmental Conservation (NYSDEC) and the City of Buffalo.

CONTAMINATED SEDIMENTS

Tar-like material released during decades of gas production was present in sediments along a 488 meter (1,600-foot) reach of the waterway, which ranged in width from 12 to 34 meters (40 to 110 feet). Below the surface sediments, the tar was present to depths in interbedded layers of sand and silt to a depth of 6 meters (20 feet). The material was identified as a carbureted water-gas tar using forensic chemistry techniques and contained a mixture of organic compounds, including benzene and polycyclic aromatic hydrocarbons (PAHs). Disturbance of the sediments raised a sheen at the surface of the 3-meter (10-foot) deep waterway.

REMEDIAL OBJECTIVES AND DESIGN CONSTRAINTS

The following objectives were established for the sediment remedy:

1. Removal, to the extent practicable, of all sediments containing total PAHs in excess of site-specific background, established as 50 mg/kg, and removal of all grossly impacted subsurface materials, defined as those exhibiting a sheen.

2. Isolation of the remaining impacted materials so that sheen-producing materials are not in direct contact with surface water. Isolation cap will have a minimum design life of 30 years.

3. Protection of existing structures and properties within and adjacent to the site.

4. Restoration of the waterway to provide a suitable habitat for fish and wildlife.

5. Restoration of the waterway in a manner which does not increase the existing predicted flood stage.

6. Protection of human health and the environment during the remediation.

During the remedy selection process it was recognized that the complete removal of the grossly impacted materials could not be accomplished, due primarily to the presence of pile-supported highway columns, and also due to the steep banks and nearby buildings. In order to protect the structural integrity of the pile-supported highway columns, the New York State Department of Transportation imposed restrictions which effectively limited the removal to a maximum depth of 1.8 meters (6 feet). Figure 2 is a plan view of the waterway, showing the locations of the highway columns in the midst of the remediation area. These design constraints are depicted in a typical cross section provided in Figure 3.

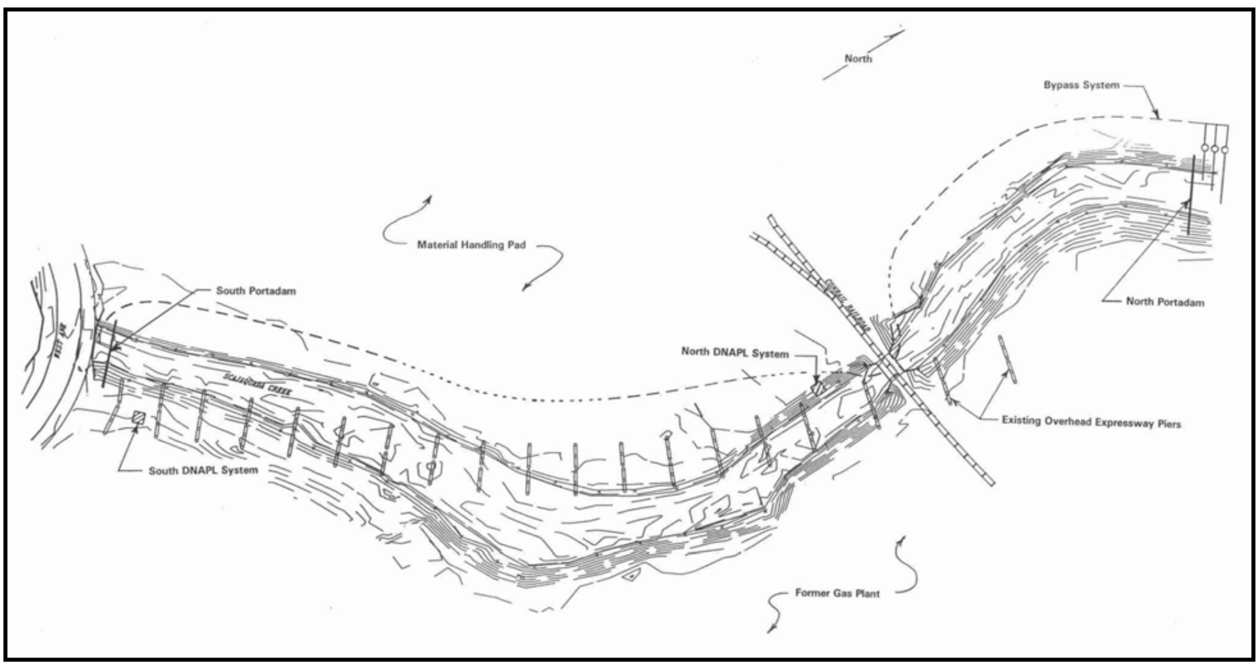

Figure 2. Plan view of the remediation area.

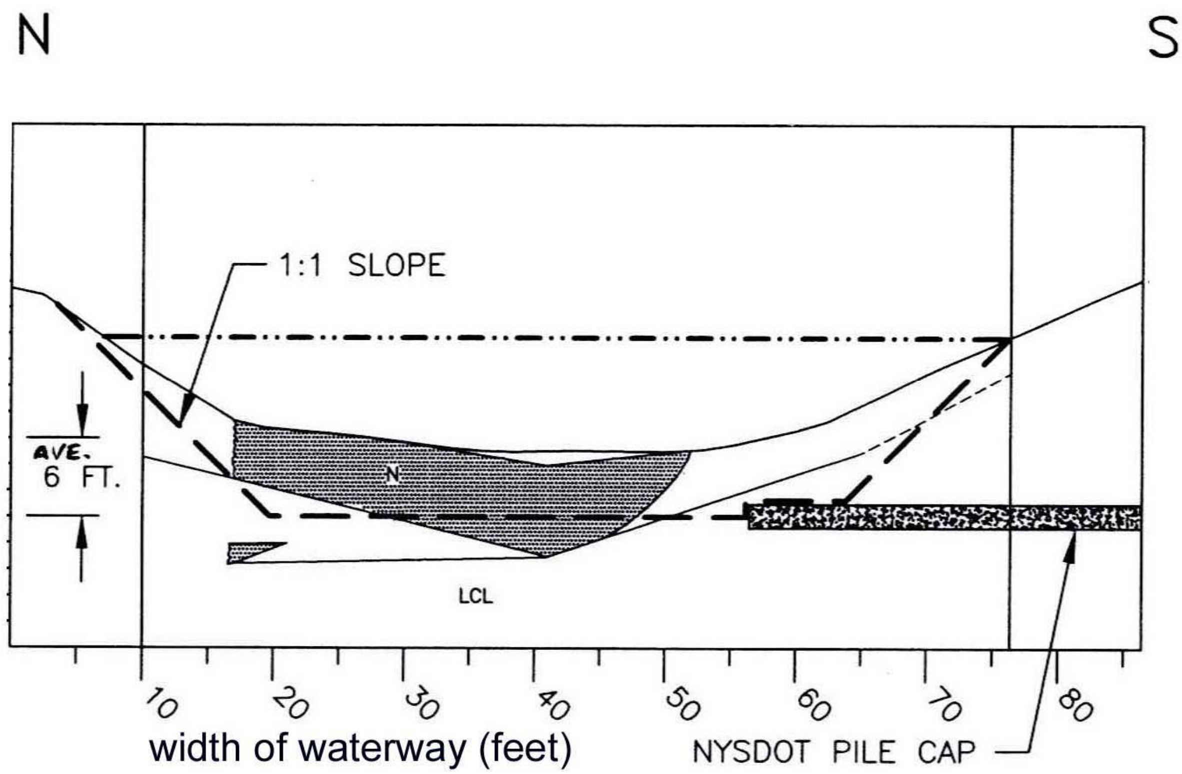

Figure 3. Typical cross section showing constraints to complete removal of impacted sediments. [Unit conversion: 1 foot = 0.3048 meters]

A cap was therefore required to isolate the impacted materials which would remain after removing the top 1.8 meters (6 feet). The cap would need to be effective in isolating grossly impacted materials, and would need to be limited in thickness to allow for habitat restoration while not increasing the flood stage. The cap would need to be constructable under wet, or nearly wet conditions, and would need to be sufficiently resistant to the forces of extreme storm events and ice scour to remain intact for at least 30 years.

REMEDIAL DESIGN

To address all of the remedial objective and design constraints, a multi-layer cap was designed with the following features:

- Top anchor/habitat stone. This layer was a minimum of 15 cm (6 inches) of rounded gravel. It served as both an anchor for the physical stability of the lower layers, and as a habitat zone for fish and aquatic organisms.

- Geotextile. This was a woven geotextile fabric. It served both as a physical support to the stone (so that the stone did not sink into the sand beneath it) and as a physical barrier preventing physical contact of aquatic organisms with the sand layer.

- Sand. This layer was a minimum of 45 cm (18 inches) of sand. The sand was an additional physical barrier between aquatic organisms and impacted materials below the cap.

- Geosynthetic Clay Liner (GCL). This composite liner consisted of two geotextiles needlepunched together and laminated to a 0.10 millimeter (4 mil) polyethylene liner, encapsulating a 1.3 cm (½-inch) dry layer of Volclay sodium bentonite, specifically designed for surface water impoundment applications. When hydrated, the liner had a very low permeability (less than 1 x 10^{-9} cm/second), which served to isolate the

Table of Contents

contaminants remaining in materials below the cap. The GCL selected was Bentomat CL, manufactured by CETCO, Inc.

The cap must provide resistance to erosion caused by ice scour, stream currents, groundwater forces, and waves, as well as a barrier to the effects of burrowing by bottom dwelling organisms (bioturbation). Waves and groundwater forces were determined not to be of sufficient magnitude to cause cap erosion. Propeller wash will not be a problem since large ships are not, and are not likely to become, common in this reach of the waterway. Although bioturbation can be a significant problem in salt water environments, in freshwater systems burrowing organisms are generally limited to the top 10 cm (4 inches) of the sediments (USEPA, 1994). The major causes of potential erosion will be ice scour and stream flows. To resist these forces, we specified a D_{30} (the 30^{th} percentile of the stone diameter) of 7.5 cm (3 inches) with a maximum of 15 cm (6 inches).

Figure 4 shows a schematic cross section of the cap. This specification was designed to be protective for the flow velocity associated with the 50-year storm, as based on US Army Corps of Engineers standards (USACE, 1994). Rounded stone was used on the bottom of the channel, and angular stone was used along the steeper backs to prevent sloughing.

The average depth of the waterway during winter conditions was greater than 3 meters (10 feet). Therefore, ice scour was of primary concern at the banks. To protect the underlying cap in these areas, large-diameter rip rap (greater than 1 meter) existing on the site banks at the narrow portions of the waterway was placed back on the banks after remediation was complete.

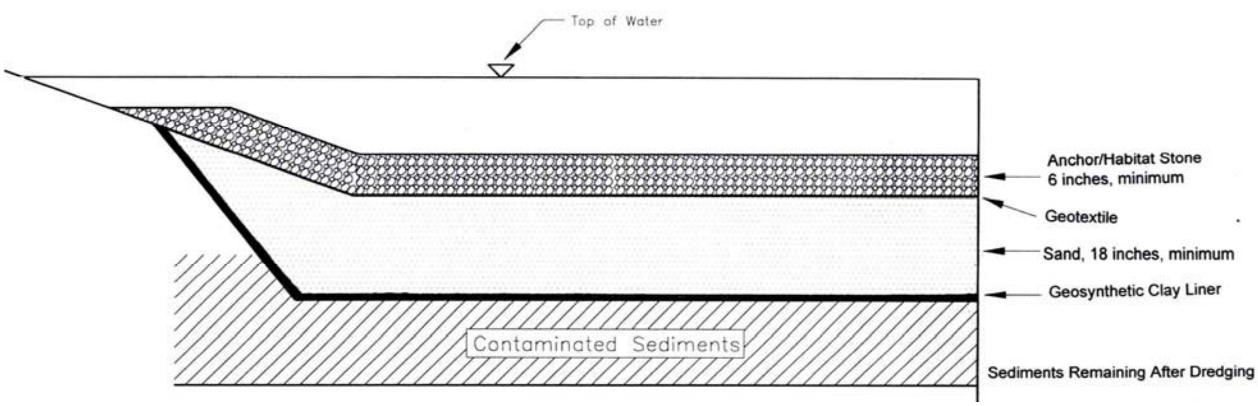

Figure 4. Cap schematic cross section.

REMEDIAL CONSTRUCTION

Remedial construction began in August, 1998 and site restoration was completed in June, 1999. A bypass system was constructed, consisting of three pumps and two HDPE bypass pipelines. Each pump had a 30-cm (12-inch) diameter intake and a capacity of 20,900 liters (5,500 gallons) per minute. The pipelines were 30 cm (12-inches) and 45 cm (18-inches) in diameter with a length of 488 meters (1600 feet). Temporary fabric dams at both ends of the waterway were installed and the work area was continuously pumped out so that the excavation and capping could be performed under partially dewatered conditions.

A specialized amphibious excavator was used to remove the sediments. It had a reach of 12 meters (40 feet) and was supported by large pontoon tracks which prevented the vehicle from sinking. Excavated material was stabilized with Portland cement so that it would be dry enough for truck transport to a secure landfill facility. A total of 25,400 metric tons (28,000 tons) were shipped from the site, constituting the 15,290 cubic meters (20,000 cubic yards) of contaminated sediment and debris that were removed from the waterway. Figure 5 shows the excavation of grossly impacted sediment.

Figure 5. Photograph of amphibious excavator removing impacted sediment.

The work proceeded from upstream to downstream, to prevent re-contamination of the completed cap. The excavation and capping operations were performed in a controlled sequence, such that dredging proceeded a maximum of 30 meters (100 feet) downstream ahead of capping. The layers of cap materials were placed using equipment stationed on the banks and in the channel. The GCL was placed in overlapping 4.4 meter (14.5-foot) wide strips across the width of the channel. Granulated bentonite was placed between a 0.6 meter (2-foot) overlap as specified for the seaming of the GCL strips. A total of 8,826 square meters (95,000 square feet) of GCL were placed. The sand used was angular limestone screenings from stone milling, which allowed steep design slopes of the banks to be achieved without sloughing. Placement of the cap is shown in Figures 6 and 7.

Throughout the excavation and capping operations, multiple survey control points were used to ensure that the design dimensions were achieved. A stormwater flow model was then run using the as-built survey data, which confirmed that the cap did not raise the predicted flood elevations.

Figure 6. Placement of the geosynthetic clay liner.

Figure 7. Placement of sand and stone cap elements.

During the course of the remedial construction it was determined that a portion of the bank which would eventually support the City of Buffalo's recreational pathway was characterized by loose fill materials and was unstable. Although this bank area was outside of the remediation area, RETEC, in coordination with the City's pathway design engineer, designed a bank stabilization program consisting of construction of 24 linear meters (80 linear feet) of steel sheet pile wall and excavation and replacement of loose materials. The bank stabilization was designed and completed within one month and benefited both the remedial construction activities and the eventual pathway construction.

Site restoration included planting of native species of grass, trees, and shrubs along the banks that were disturbed during remedial construction. The selection and placement of the trees and shrubs was done in coordination with the City's pathway landscape architect to establish the greenway associated with the pathway route. A total of 134 individual trees and shrubs constituting 14 species were planted.

The sediment remediation constituted an opportunity to establish native species of submergent and emergent plants. Organic fiber rolls and topsoil were used to create beds for the plants. A total of 4,532 individual plants constituting 10 species were planted.

Figure 8 shows the condition of the area 3 years after the restoration was complete.

Figure 8. Restored waterway with recreational path and greenway.

LONG-TERM MONITORING

Annual monitoring of the physical condition of the cap has been conducted by RETEC and NYSDEC since the work was completed in 1999. During the first two annual monitoring events, underwater video surveys were conducted along the entire length of the affected channel bottom to document the condition of the cap. The cap has been very stable. No sheens or other evidence of cap failure have been observed during the past 7 years. No substantial erosion and no uplifting of the cap is evident to date. The highest rainfall event, a 8.6 cm (3.4-inch) 24-hour storm which occurred in September of 2004, was approximately a 50-year event and did not have any observable effect on the condition of the cap.

The banks and shallows throughout the capped area have complete vegetation coverage. However, non-native species, particularly knot-weed, have overtaken the area. Numerous fish and animal species have been observed in the area, such as turtles, ducks, crayfish, and beavers.

DISCUSSION

Early in the project, dredging and capping under wet conditions, without damming and dewatering, was contemplated as a means of saving costs and time. However, it was quickly realized that cap placement under wet conditions would be very difficult, since the cap materials would be placed through contaminated water and since the GCL, which contained dry bentonite, was not designed for wet placement and would hydrate prematurely and fail during placement.

Nonetheless, dewatered excavation and capping had its difficulties as well. The risk of a severe weather event causing the overtopping of the temporary dams was a major concern during the planning phase of the remedial construction. Although the contractor allowed for excess pumping capacity, storm events caused flooding of the work area on seven occasions during the six months of active work in the channel. There was a slow response to the first flooding event, and the delay pushed the project into the fall and winter when more severe wind and precipitation events caused additional flooding and additional delays. These delays could have been avoided by a more realistic assessment on the part of both the engineer and the contractor of the risk of work zone flooding. Additional pumping capacity to avoid floods could have been in place at the start of the work, and procedures to be followed in response to treat the flooded work conditions could have been anticipated.

The fact that the cap has not been damaged over the past 7 years, while a welcome result, is no guarantee that the cap will not be damaged in the coming decades. Indeed, among the effects of global warming will be increased frequency and severity of storm events, including non-hurricane storms in North America (IPCC, 2001 and Asrar, et al., 2001). We would expect and anticipate that the design of the cap structure, completed in 1998 using hydrologic event frequency data compiled from the last century, would be inadequate for the changed conditions which are emerging at the start of this century.

CONCLUSIONS AND RECOMMENDATIONS

The composite cap consisting of a geosynthetic clay liner, sand, and armor/habitat stone appears to have successfully isolated heavily tar-impacted sediments for 7 years and has allowed flora and fauna to repopulate the waterway.

The project has enabled esthetic and economic improvements to the local community, including a recreational pathway adjacent to the waterway which is part of the City of Buffalo Local Waterfront Revitalization Plan.

It is recommended that future project design and implementation use a realistic assessment of storm event risks, and rely upon the most current understanding of the emerging hydrologic conditions at the site. The most visible manifestation expected from climate warming will be changes in the distribution of precipitation and evaporation, and the exacerbation of extreme hydrologic events, floods and droughts. These new conditions should be taken into account by engineers and contractors engaged in the planning and construction of similar sediment remediation projects.

REFERENCES

Asrar, G., Kaye, J.A., Morel, P. (2001). “NASA research strategy for earth system science: climate component,” *Bull. Am. Meteorol. Soc.*, 1309-1329

IPCC (2001). "North America," Chapter 15 of: *Intergovernmental Panel on Climate Change (IPCC).* 2001. *Climate Change 2001: Impacts, Adaptation and Vulnerability*. Cambridge University Press.

USACE (1994). “US Army Corps of Engineers, Engineering and Design – Hydraulic Design of Flood Control Channels,” EM 1110-2-1601. Washington, D.C., June 1994.

USEPA (1994). “Assessment and Remediation of Contaminated Sediments (ARCS) Program”. Remediation Guidance Document EPA 905-R94-002. Great Lakes National Program Office, 77 West Jackson Boulevard, Chicago, Illinois, October 1994.