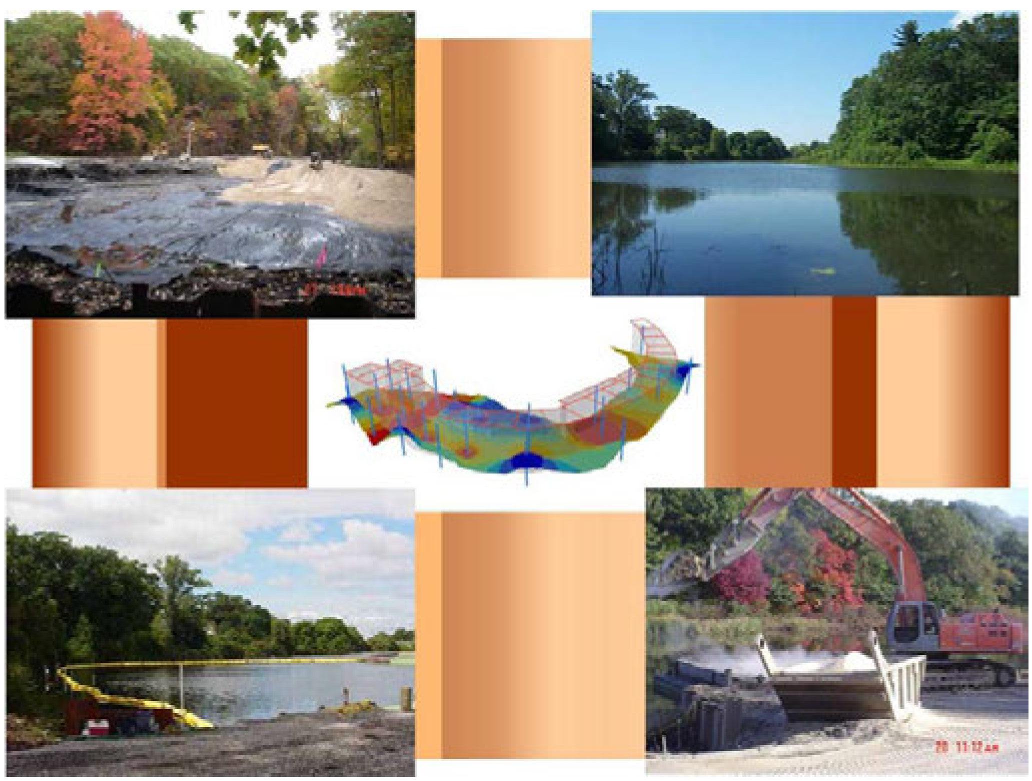
Remediation of the Ruddiman Creek Main Branch and Pond Muskegon County, Michigan

Great Lakes Legacy Act Program

March 2011



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Prepared for:

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The Ruddiman Creek Main Branch and Pond Remediation Project was accomplished through the efforts of several project partners. Marc Tuchman, Project Manager, EPA Great Lakes National Program Office and Michael Alexander, Project Manager, Michigan Department of Natural Resources and Environment wish to acknowledge the assistance of the Muskegon Lake Watershed Partnership for the Muskegon Lake Area of Concern and several other local organizations who played an active and key role in all aspects of the project and were strong advocates for their community.

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LIST OF ACRONYMS AND ABBREVIATIONS

AOC	Area of Concern
BaP	Benzo (a) Pyrene
BUI	Beneficial Use Impairment
CMI	Clean Michigan Initiative
COC	Contaminant of Concern
DQO	Data Quality Objective
EDD	Electronic Data Deliverable
EPA	U.S. Environmental Protection Agency
FSS	Field Split Sample
GLENDA	Great Lakes Environmental Database
GLLA	Great Lakes Legacy Act
GLNPO	Great Lakes National Program Office
GPS	Global Positioning System
HDPE	High Density Polyethylene
MDNRE	Michigan Department of Natural Resources and Environment
MS	Matrix Spike
MSD	Matrix Spike Duplicate
NIOSH	National Institute of Occupational Safety and Health
NOAA	National Oceanic and Atmospheric Administration
PCB	Polychlorinated Biphenyl
PVC	Polyvinyl Chloride
QAPP	Quality Assurance Project Plan
QC	Quality Control
RAP	Remedial Action Plan
RCRA	Resource Conservation and Recovery Act
RFS	Routine Field Sample
RI	Remedial Investigation
RMU	Remedial Management Unit
SVOC	Semivolatile Organic Compound
SW-846	Test Methods for Evaluating Solid Waste
VOC	Volatile Organic Compound

EXECUTIVE SUMMARY

This report describes a joint effort between the U.S. Environmental Protection Agency Great Lakes National Program Office and the Michigan Department of Natural Resources and Environment to remediate contaminated sediments in the Ruddiman Creek Main Branch and Pond in Muskegon County, Michigan. The remediation site encompasses the Main Branch of Ruddiman Creek, Ruddiman Pond, and approximately 39 acres of associated wetland area. The Ruddiman Creek watershed is part of the Muskegon Lake drainage system. Muskegon Lake is a 4,149-acre inland coastal lake located in Muskegon County, Michigan, along the eastern shoreline of Lake Michigan. The Muskegon River flows through the lake before emptying into Lake Michigan, and includes several tributaries, one of which is Ruddiman Creek.

In 1985, Muskegon Lake was designated an Area of Concern due to water quality and habitat problems associated with the historical discharge of pollutants in the Area of Concern and the potential adverse effects on Lake Michigan resulting from the associated pollutants. The Ruddiman Creek watershed historically has received direct discharges of industrial and municipal wastewater, sewer overflows, and urban runoff from the surrounding communities, and was identified as a major contributor to the degradation of Muskegon Lake. The impacts associated with the Ruddiman Creek watershed that are directly related to the presence of contaminated sediments include:

- Chemical toxins entering the food web through benthic organisms (bottom-dwelling aquatic plants and animals) exposed to or feeding on pollutants in the sediments.
- Advisories regarding fishing, boating, and swimming.
- Presence of oil sheens and debris.

The Ruddiman Creek Main Branch and Pond proposal was the third project to be accepted and funded under the Great Lakes Legacy Act of 2002. This legislation was specifically developed to address the contaminated sediment problem in the Great Lakes Areas of Concern. The primary objectives of the project were to reduce relative risk to humans, wildlife, and aquatic life, restore beneficial uses, and reduce sources of further contamination in the watershed.

Great Lakes Legacy Act project activities at the site began in August 2005 and continued through June 2006. Prior to dredging, steps were taken to divert the water flowing in Ruddiman Creek. These included building a headwater dissipation structure, active dewatering in the excavation areas using Calciment®, isolation of excavation areas with a bypass pump, and diversion of natural creek flow with sheet pile dams. Water and air monitoring strategies were also employed throughout the project to ensure the remediation activities were not adversely affecting the health of the ecosystem, surrounding environment, or the remediation staff.

Contaminated sediments were removed from the Ruddiman Creek Main Branch and Pond remediation site using environmental mechanical dredging techniques, including long-reach excavators equipped with both environmental buckets and standard excavating buckets. After completion of this first round of dredging, the remaining residual sediments were sampled and analyzed to verify the dredging activities reduced contamination to acceptable levels. Results of these analyses suggested that high concentrations of the contaminants of concern remained in some areas, and therefore additional dredging or other cleanup actions were undertaken in these areas. By the end of the effort, 89,870 cubic yards of contaminated sediments had been removed from the site. This material contained approximately:

- 2,800 pounds of cadmium.
- 204,000 pounds of chromium.
- 126,000 pounds of lead.
- 320 pounds of polychlorinated biphenyls.

After removing the contaminated sediments, various combinations of sand, geotextile fabric, and stone were installed to provide a barrier between the benthic community and any residual contaminated sediment. This cover will enhance natural attenuation, add habitat for re-growth of healthy organisms on the bottom, and reduce exposure of fish to contamination through consumption of bottom-dwelling organisms.

In addition, a rock wing dam, braided stream channels, and a detention basin were constructed downstream of the storm sewer outfall in the creek to dissipate energy during storms and to minimize the effects of storm water on downstream water quality. Native plant species were planted to stabilize the flood plain and control erosion along the creek banks. For the first time in many years, salmon have been seen swimming up the creek and the community is working on a plan to develop bike trails, nature signage, and canoeing and kayaking routes in the waterways.

The remediation project is also expected to serve as a catalyst for redeveloping not only the Ruddiman Creek Main Branch and Pond, but also the Muskegon Lake Area of Concern. The community assisted in the development of the Muskegon Lake Ecological Restoration Master Plan with funding from the U.S. Environmental Protection Agency Great Lakes National Program Office habitat program that provides a blueprint to restore the wetland, aquatic, shoreline, and riparian habitats in the Muskegon Lake Area of Concern. This blueprint was the basis for a proposal submitted to National Oceanic and Atmospheric Administration by the Great Lakes Commission on behalf of the Muskegon Lake Watershed Partnership. In June 2009, the Commission was awarded $10 million in federal “stimulus” funding under the American Recovery and Reinvestment Act for the “shovel-ready” restoration projects described in the plan. The project is expected to support 125 jobs, largely in engineering and construction, with more than $20 million contributed by local sources through in-kind services, donations of land, and conservation easements.

In 2007, the American Public Works Association awarded the Ruddiman Creek Main Branch and Pond remediation project with the Chapter and Branch Award for “Project of the Year.” This award recognized the complexity of this remediation project, and the methods used to overcome obstacles were recognized as providing technical resources necessary in future sediment remediation efforts.

1.0 PROJECT DESCRIPTION

This report describes the Great Lakes Legacy Act (GLLA) sediment remediation project in Ruddiman Creek and Pond, located in Muskegon County, Muskegon, Michigan. The remediation site encompasses the Main Branch of Ruddiman Creek, Ruddiman Pond, and approximately 39 acres of associated wetland area. The project was a joint effort between the Great Lakes National Program Office (GLNPO) of the U.S. Environmental Protection Agency (EPA) and the Michigan Department of Natural Resources and Environment (MDNRE), hereafter referred to as the project team. Funding for this project was provided by the GLLA and the Clean Michigan Initiative (CMI). Additional support for the project was provided by the surrounding cities and communities, and from several private firms operating under contract to EPA and MDNRE. A list of the organizations involved in the Ruddiman Creek and Pond site remediation effort is provided in Section 1.5.

The Ruddiman Creek watershed is part of the Muskegon Lake drainage system. Muskegon Lake is a 4,149-acre inland coastal lake located in Muskegon County, Michigan that forms an embayment along the eastern shoreline of Lake Michigan. Ruddiman Creek is one of several tributaries of the Muskegon River, which drains into Muskegon Lake, and into Lake Michigan. In 1985, Muskegon Lake was designated an Area of Concern (AOC) due to water quality and habitat problems associated with the historical discharge of pollutants in the AOC, and the potential adverse effects on Lake Michigan resulting from the associated pollutants.

The Ruddiman Creek watershed has historically received direct discharge of industrial and municipal wastewater, sewer overflows, and urban runoff from the surrounding communities; and was identified in the 1987 Muskegon Lake Remedial Action Plan (RAP) as a major contributor to the degradation of Muskegon Lake. Therefore, the Ruddiman Creek watershed was identified as part of the Muskegon Lake AOC; and the observed negative impacts within the AOC, termed beneficial use impairments (BUI), are being addressed by the development and implementation of the RAP. As is common in many AOCs, the Ruddiman Creek watershed BUIs were found to be directly related to the presence of contaminated sediments, and included:

- ***Impairments to aquatic life*** – chemical toxins entered the food web through benthic organisms (bottom-dwelling aquatic plants and animals) exposed to or feeding on pollutants in the sediments.
- ***Impairments to recreational use*** – advisories were issued on fishing, boating, and swimming.
- ***Impairments to aesthetics*** – presence of oil sheens and debris.

EPA and MDNRE identified removal of the contaminated sediments in this section of the AOC as a feasible approach to lessen or eliminate these impairments in the Muskegon Lake AOC, and conducted sediment remediation at the Ruddiman Creek and Pond site in 2005.

Sections 1.1 and 1.2 provide a description and history of the Ruddiman Creek and Pond remediation site. Section 1.3 includes a detailed description of the objectives associated with the remediation effort. Section 1.4 details sources of funding for the remediation of the site, and provides a general overview of the CMI and the GLLA as related to the remediation effort. Project and data management are described in Sections 1.5 and 1.6, respectively.

1.1 GENERAL SITE DESCRIPTION

The Ruddiman Creek and Pond remediation site, hereafter referred to as the "Ruddiman Creek site," is located in Muskegon County, Michigan. The site consists of approximately 2.3 miles of creek, 39 acres of wetlands, and the 21-acre water body designated Ruddiman Pond. There are three branches of Ruddiman Creek that flow into Ruddiman Pond: the West Branch, the North Branch, and the Main Branch, as depicted in Figure 1-1. Only the Main Branch is included in the remediation site; however, the other two branches contribute contaminants to the pond from storm runoff.

The Ruddiman Creek drainage area covers approximately 3,000 acres and includes the cities of Muskegon, Norton Shores, Muskegon Heights, and Roosevelt Park. The drainage area includes properties associated with industrial, commercial, residential, and recreational usages, which also generate runoff that flows into the storm water systems and into the Ruddiman Creek watershed. The City of Muskegon owns a small park area that surrounds Ruddiman Pond and a larger park area located to the south of Ruddiman Creek and Pond.

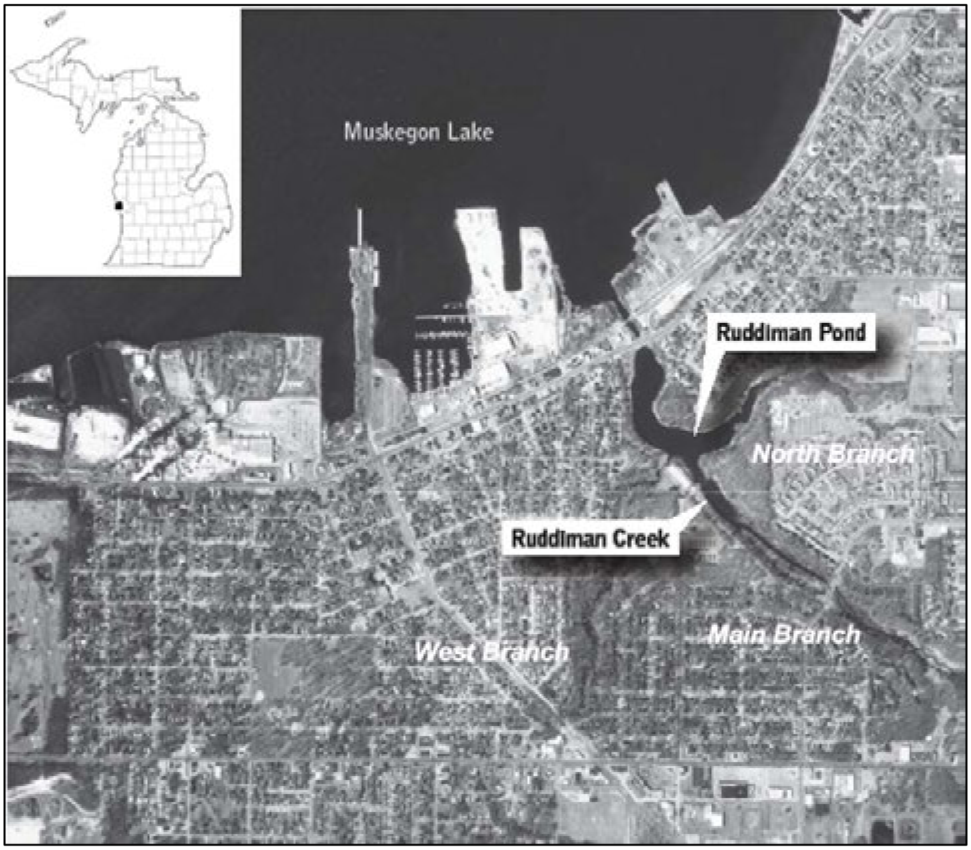

Figure 1-1 Ruddiman Creek and Pond

The Main Branch begins at a 100-inch storm sewer outfall located east of Barclay Road and flows through residential and wetland areas and discharges into the southeastern portion of Ruddiman Pond. The Main Branch varies in width from 10 to 60 feet, and typically has low-flow water depths ranging between 1 and 7 feet. The mean flow rate for the creek is 3.1 cubic feet per second. The width, depth, and flow increase during heavy rain and spring thaw.

Ruddiman Pond, where most of the remediation occurred, is bordered by McGraft Park Road to the south, Addison Street to the east, and Lakeshore Drive to the north. Ruddiman Pond discharges into Muskegon Lake through a channel flowing beneath Lakeshore Drive, and Muskegon Lake discharges into Lake Michigan, as shown in Figure 1-2. Ruddiman Pond is approximately 2,200 feet in length, with an average width of 142 feet and an average depth of 9 feet.

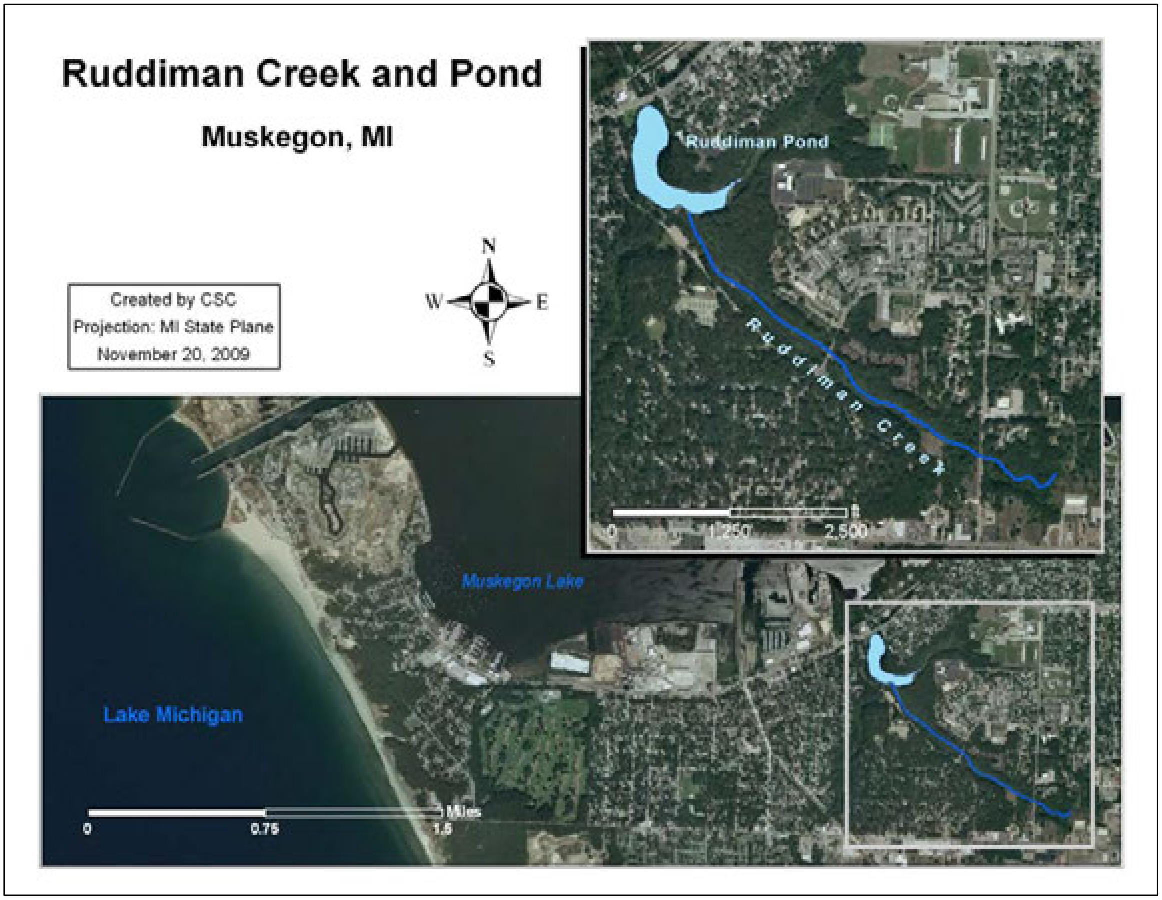

Figure 1-2 Relationship of Ruddiman Creek and Pond to Muskegon Lake and Lake Michigan

The remediation efforts described in this report addressed a portion the Ruddiman Creek watershed where previous site investigations had shown high levels of contamination (Section 1.2). Specifically, the remediation area encompassed 2.3 miles of the Main Branch of Ruddiman Creek, Ruddiman Pond, and 39 acres of associated wetland area adjacent to the pond and creek areas.

1.2 SITE HISTORY

After Muskegon Lake was designated an AOC, the Michigan Department of Natural Resources evaluated information about Ruddiman Creek and Pond, and developed a RAP to address historical contamination of sediments and surface water in the area. The 1987 version of the RAP was updated in 1994, and again in 2002, based in part on additional studies of the site.

Between 1994 and 2004, the Ruddiman Creek watershed has been the subject of several environmental studies by MDNRE, United States Army Corps of Engineers, and United States Department of Health and Human Services Agency for Toxic Substances and Disease Registry. Phase I of an environmental site assessment was completed in September 1999 and Phase II in October 2000.

A Remedial Investigation (RI) of Ruddiman Creek was conducted in 2002 to characterize the sediment contamination and to provide the basis for a remedial design to mitigate the impacts. The objectives of the RI study included:

- Vertically and horizontally delineate sediment contamination within the Ruddiman Creek watershed.
- Evaluate potential impacts to human health and aquatic life.
- Estimate the volume of affected sediments within the Ruddiman Creek watershed.
- Evaluate potential for continued sources and/or recontamination.
- Evaluate remedial alternatives.

The RI included testing for the regulatory characteristic of “toxicity” defined in Section 261.24 of the Resource Conservation and Recovery Act (RCRA). The RI also included sediment toxicity testing, which is not related to the RCRA characteristic. The results of these various investigations indicated that volatile organic compounds (VOC), semivolatile organic compounds (SVOC), polychlorinated biphenyls (PCBs), metals (lead, cadmium, and chromium), and benzo(a)pyrene (BaP) (a polycyclic aromatic hydrocarbon) were all present at concentrations exceeding the Consensus-based Sediment Quality Guidelines[1] probable effect concentrations found in MacDonald *et al.* (2000) at many sampling locations throughout the creek and pond. Based on these data and the associated potential impacts on the Muskegon Lake AOC, the project team identified PCBs, BaP, cadmium, chromium, and lead as the Contaminants of Concern (COCs) for the Ruddiman Creek site cleanup. Table 1-1 provides a summary of average and maximum concentrations of the COCs in Ruddiman Creek and Ruddiman Pond observed during an investigation of the site in 2004, as well as site-specific target levels used as cleanup criteria.

[1] Sediment Quality Guidelines (SQGs) as defined in *Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems* (MacDonald *et al.*, 2000).

Table 1-1 Average and Maximum Concentrations of Contaminants of Concern in Sediments in Ruddiman Pond and Ruddiman Creek Prior to Remediation and Site-Specific Target Levels*

Contaminant	Ruddiman Pond		Ruddiman Creek		Target Level
	Average Concentration	Maximum Concentration	Average Concentration	Maximum Concentration	
Benzo(a)pyrene	1.90 (70, 24)	3.4	2.8 (65, 22)	19	≤ 16
Total PCBs	0.77 (96, 24)	67	0.85 (57, 22)	19	≤ 1
Cadmium	5.03 (72, 23)	25	5.41 (57, 19)	31	≤ 10
Chromium	295 (72, 23)	2,090	320 (57, 19)	2,040	≤ 400
Lead	172 (72, 23)	1,200	201 (57, 19)	895	≤ 900

* All concentrations in mg/kg, dry weight, from *Earth Tech, 2004 Technical Memorandum for Ruddiman Creek Soil and Groundwater Investigation, Muskegon, Michigan*. The values shown in parentheses are the number of samples and the number of stations, respectively, used to develop the averages. The average concentrations are weighted down the length of the cores collected at each station. Appendix B provides additional comparisons of pre-remedial sediment concentrations for the site.

Contamination of the sediments was observed from 0 to 9 feet below the surface of the sediment. Figure 1-3 illustrates the relationship between total PCB concentration and depth below the surface. The results are presented in µg/kg, the units used by the laboratory that analyzed the samples (decimal points in the figure legend simply indicate that the listed ranges do not overlap).

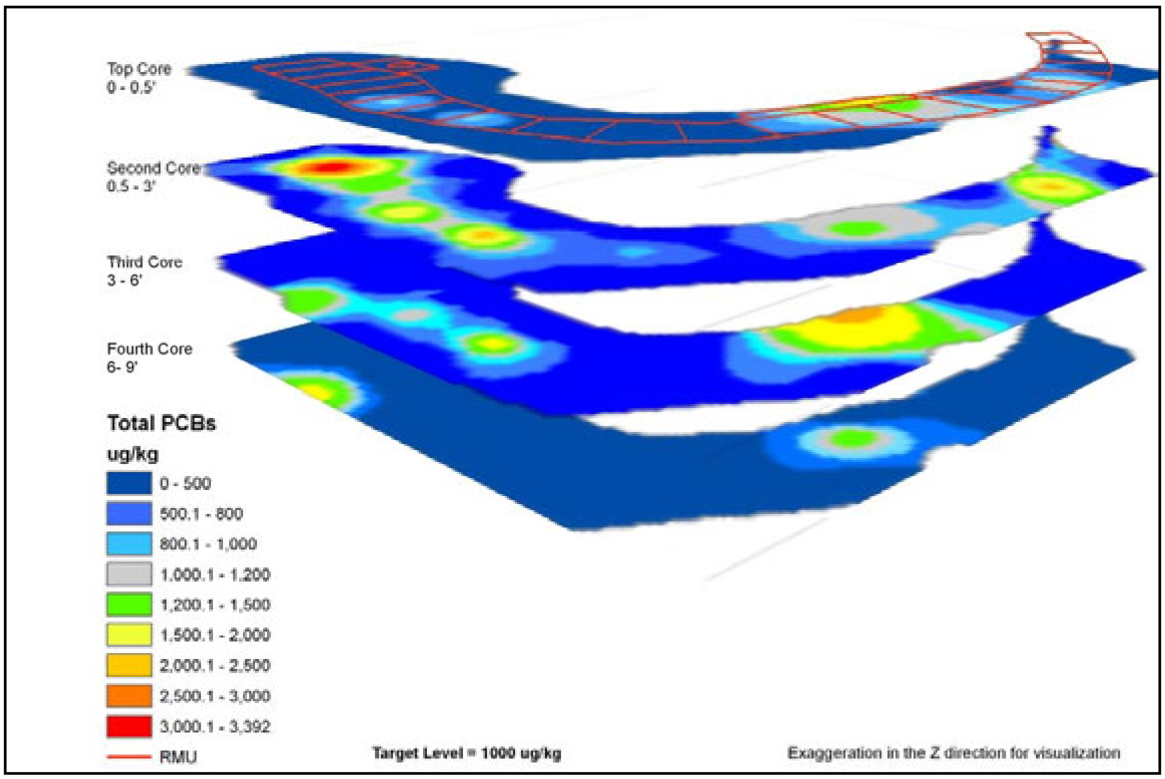

Figure 1-3 Pre-remediation sediment total PCB concentrations at depth

In March 2004, MDNRE submitted a proposal to GLNPO for GLLA funding to remediate Ruddiman Creek Main Branch and Pond. The project began in August 2005, as a partnership with federal funding from the GLLA (65 percent) and non-federal funding (35 percent) from the MDNRE CMI. Numerous other participants were involved in the successful cleanup of Ruddiman Creek site, as shown in Table 1-2 (Section 1.5).

1.3 PROJECT OBJECTIVES

The main objective of the remediation of this project was to remove an estimated 72,000 cubic yards of contaminated sediments from the site, taking the first step to substantially improve the environment by mitigating the associated BUIs. The activities were designed and implemented to accomplish the following three specific objectives:

***Objective 1:* Reduce Relative Risk to Humans, Wildlife, and Aquatic Life.** Contaminated sediments were dredged from the site to permanently reduce the amount of COCs present and available to the food chain. A residual cover was placed over the dredged areas to further reduce the bioavailability of COCs. The overall effect of remediation efforts at the Ruddiman Creek site was expected to result in reduced risks to aquatic organisms, wildlife, and humans in both the Ruddiman Creek watershed and in Muskegon Lake.

***Objective 2:* Restore Beneficial Uses.** Sediments containing elevated levels of COCs were removed and various restoration and environmental enhancement measures (e.g., riprap riffles, energy dissipation devices, braided stream channels, etc.) were implemented after remediation. Together, these efforts are expected to reduce toxic effects to aquatic biota, and therefore, improve the food chain and the entire ecosystem. These remedial measures were also expected to improve the condition and stability of the aquatic habitat, particularly for the benthic organisms, which will further enhance the rest of the aquatic environment and the higher trophic level organisms. Finally, these improvements directly resulted in improved aesthetics and potential recreational uses of the Ruddiman Creek watershed.

***Objective 3:* Source Control.** In an effort to reduce sources of further contamination in the Ruddiman Creek watershed, environmental enhancement activities, such as aggregate placement, installation of energy dissipation devices, and stream armoring, were implemented. These activities complemented other measures performed by the City of Muskegon and the MDNRE Remediation Redevelopment Division, including improvements to the storm water management programs and storm sewer infrastructure system.

1.4 PROJECT FUNDING

The Great Lakes make up one fifth of the fresh water on the earth's surface, providing water, food, recreation, and transportation to more than 35 million Americans. The quality of this resource is of great importance and, although the discharge of toxic and persistent chemicals from industrial and municipal wastes into the Great Lakes has been substantially reduced over the past 20 years, contaminated sediments remain at certain sites, affecting water quality. Recognizing the importance of this resource, the United States Congress enacted the GLLA specifically to address the problem of contaminated sediment in Great Lakes AOCs, including the Muskegon Lake AOC. The Act provides for the remediation of contaminated sediment in any AOC, of which there are 30 either wholly or partly within the United States. The GLLA was reauthorized by Congress in October 2008, providing two additional years of funding, and allowing GLNPO to continue making great strides with sediment cleanups in the Great Lakes AOCs.

The State of Michigan CMI provided the non-federal matching funds for the remediation of the Ruddiman Creek site. The CMI is a $675 million bond that was approved by Michigan voters in November 1998 to improve and protect Michigan's water resources. The major CMI programs are administered by the Michigan Departments of Environmental Quality, Natural Resources, and Community Health.

The $14.2 million remediation project at the Ruddiman Creek site was funded with the support of $8.9 million from GLNPO under the GLLA, and $5.3 million in matching funds from MDNRE under the CMI.

1.5 PROJECT MANAGEMENT

The remediation project was a collaborative effort involving multiple partners and sources of funding at the federal, state, and local level. The participants developed project planning documents, agreements, and strategies to ensure effective communication, clear understanding of responsibilities, and adherence to project requirements among all the parties involved. These documents, agreements, and strategies are summarized in the subsections below. Table 1-2 provides a list of the organizations participating in the remediation project.

Table 1-2 Organizations Participating in the Ruddiman Creek and Pond Remediation Project
Federal
▪ EPA; *federal sponsor of the GLLA project* ➢ EPA GLNPO; *lead organization on behalf of EPA* ➢ EPA Region 5; *provided contractor support to GLNPO for the project*
State
▪ State of Michigan; *non-federal sponsor of the project* ➢ MDNRE; *lead organization on behalf of the State*
Local
▪ Muskegon Lake Watershed Partnership ▪ Ruddiman Creek Task Force ▪ Illinois/Indiana Sea Grant ▪ U.S. Army Corps of Engineers ▪ City of Muskegon, Michigan ▪ City of Muskegon Heights, Michigan ▪ City of Norton Shores, Michigan ▪ City of Roosevelt Park, Michigan ▪ Muskegon County Publicly-Owned Treatment Works/Muskegon County Wastewater Management System

1.5.1 Project Planning, Training, and Permits

EPA and MDNRE entered into a project agreement for the remediation of the Ruddiman Creek and Pond. The agreement detailed the financial, technical, and logistical obligations and responsibilities of EPA and MDNRE (Section 1.4). Through this agreement, GLNPO and MDNRE developed a formal strategy of commitment and communication to facilitate successful completion of the remediation project.

A series of project planning documents was developed for the technical approaches to the remedial action. These plans detailed all necessary actions to achieve project goals while adhering to applicable federal, state, and local requirements. These project planning documents included the following:

- Work Plan.
- Site Safety and Health Plan.
- Contractor Quality Control Plan.
- Quality Assurance Project Plan (QAPP).
- Environmental Protection Plan.
- Land and Water/Sediment Surveys.

These documents were subject to approval by EPA, MDNRE, and appropriate stakeholders; and once approved, were included as appendices to the final work plan. The work plan was based primarily on engineering specifications and drawings, and discussions conducted during the project kickoff meeting and other project planning activities. The final work plan provided a mechanism for ensuring that all project objectives and strategies were clearly understood by all involved parties and that the associated strategies included a project design and quality control procedures to ensure project data would be reliable and of sufficient quality to support EPA decisions regarding the Ruddiman Creek site remediation project. Remediation and construction work began after the approval of the work plan and an official *Notice to Proceed* from the U.S. government. Copies of all required permits, licenses, and access agreements (e.g., the Joint Environmental permit, Soil Erosion Control Plan, and residential access agreements) were maintained at the project site.

A variety of training programs and related activities were conducted at the site to ensure the protection of both workers and the general public, and to prevent accidents at the work site. Examples of these programs and activities included:

- Use of an on-site orientation training module to orient new site workers in conjunction with the Site Safety and Health Plan.
- Requirement that all personnel working at the site review the Site Safety and Health Plan and sign a form documenting that they had read the plan, understood its contents, and would abide by the plan.
- Requirement that all field personnel provide current certifications to demonstrate they were qualified to perform their respective jobs and to operate the applicable equipment or machinery.

- Conducting daily "tailgate" safety meetings prior to each shift in which relevant health and safety issues were discussed.
- Conducting mandatory safety briefings prior to commencing each new task to discuss task-specific risks and precautions.

There were no lost-time injuries or reportable accidents at the site over the course of the remediation project, which reflects the effectiveness of these planning procedures.

Other planning activities included control measures that were implemented during the project mobilization and set-up stages to minimize disturbance to local residents and the general public. Such control measures included:

- Close communication and coordination with local parties (park and city officials, residents, general public, etc.) concerning planned mobilization, site set up, and work activities to ensure the safety and protection of all individuals and property.
- Routine maintenance cleaning and a street sweeping service that was hired to clean public streets twice a week during early stages of the project and as-needed thereafter.
- Construction of a perimeter fence and use of a uniformed security guard service.

1.5.2 Project Communication, Roles, and Responsibilities

GLNPO and the State of Michigan put together a team of representatives from all parties involved in major project activities to ensure communication among all participants involved in the project, address technical and logistical issues as they arose, and communicate problem resolutions to all involved parties. The communication procedures included regularly scheduled conference calls, progress meetings, daily activity reports, and project management teams.

GLNPO served as EPA's lead office on the project. Because EPA Region 5 provided extensive support, including access to the EPA Region 5 Superfund contract, representatives from both EPA offices (GLNPO and Region 5 Superfund) participated in project management and served as members of the project team. The roles and responsibilities of the key governmental project management personnel from are delineated in Table 1-3.

Table 1-3 Roles and Responsibilities of Key Governmental Project Management Personnel

Key Person, Organization, Role	Responsibility
Marc Tuchman EPA GLNPO *Project Manager*	▪ Serve as primary GLNPO contact ▪ Financial and contractual monitoring ▪ Ensure that decision objectives are met at project completion ▪ Negotiate and approve contract modifications ▪ Review and approve project plans
Mike Alexander MDNRE *Project Manager*	▪ Serve as primary contact for MDNRE ▪ Negotiate and approve contract modifications ▪ Review and approve project plans
Sam Borries EPA *Federal On-site Coordinator*	▪ Serve as primary EPA Emergency and Rapid Response Services contact ▪ Oversee site activities ▪ Approve modifications to project plans relating to site activities ▪ Review and approve Daily Activity Quality Control Report ▪ Approve all corrective actions impacting site activities ▪ Approve QAPP and work plans
Louis Blume EPA GLNPO *Quality Assurance Manager*	▪ Assist in the development of quality documentation and identification of project quality objectives ▪ Ensure that all environmental collection activities are covered by appropriate quality documentation ▪ Review and approve QAPP on behalf of GLNPO
Ida Levin EPA Region 5 Superfund *Quality Assurance Manager*	▪ Assist in the review of quality related items ▪ Ensure contract required quality items are met ▪ Review QAPP and make recommendations for QAPP approval
Susan Boehme Illinois/Indiana Sea Grant *Liaison to EPA GLNPO*	▪ Outreach to community ▪ Prepare fact sheets and update content for website

Weekly conference calls provided progress updates and status information to all involved parties. These meetings were also used as a forum to communicate new issues and challenges that required resolution or decisions. Urgent issues and challenges were communicated through *ad hoc* conference calls, meetings, or on-site discussions. The decisions resulting from on-site discussions were documented in the daily activity reports. Decisions resulting from meetings and conference calls were documented through meetings minutes and group emails.

These adaptive management techniques and open communication strategies enabled the project team to keep the Ruddiman Creek site remediation project on track, despite logistical challenges encountered during project activities. For example, one of the most significant challenges encountered was the amount of peat present at the site and its extreme depths in some locations. While attempting to build roads on which to move equipment around the site, the project participants discovered that building materials deposited in some areas promptly sank into the ground, and that an amphibious dump truck was unable to traverse through the peat formation. This obstacle was overcome by modifying the intended course of action specified in the Work Plan to allow the achievement of associated project goals; in this particular case, through the use of floating high density polyethylene (HDPE) mats that permitted traffic across the site (Section 3.1.3). The final decisions concerning resolution of this and other challenges were documented in the daily activity reports.

1.5.3 Public Outreach and Community Involvement

The project team employed a variety of approaches to keep the public informed and involved. These included public meetings and Web-based site tours to foster the involvement of the local communities. Examples include:

Figure 1-4 Community discussion of the remediation project

- August 24, 2005 site tour – photographs of preparation of the site for remediation are viewable at: http://www.epa.gov/glla/ruddiman/sitetour.html.
- October, 2005 site tour – photographs of the site and various remediation activities are available at: http://www.epa.gov/glla/ruddiman/sitetour_10_05.html.
- December 5, 2005 site tour – additional photographs illustrating continued progress of dredging through the winter are viewable at: http://www.epa.gov/glla/ruddiman/sitetour_12_05.html.
- January 9, 2006 public meeting – discussion of progress on sediment cleanup with presentation (Figure 1-3) is available at http://www.epa.gov/glla/ruddiman/pubmeetng_jan92006.html.
- April 10, 2006 public walk through – explanation of the post-dredging restoration of the site is available at http://www.epa.gov/glla/ruddiman/walkthru_4_10_06.html.

Signs were posted at the site entrance identifying the remediation effort as a jointly funded sediment cleanup project and naming the major project sponsors and participants.

EPA also maintains a website for the remediation project at: http://www.epa.gov/glla/ruddiman/index.html. The website contains general information and connections to other Web pages, including:

- Several fact sheets (Appendix C) – http://www.epa.gov/glla/ruddiman/ruddfctsht.pdf and http://www.epa.gov/glla/ruddiman/ruddimancleanup_finish.pdf.
- Engineering drawings – http://www.epa.gov/glla/ruddiman/eng_drawings.pdf.
- A photo journal – http://www.epa.gov/glla/ruddiman/ruddimancleanup_.pdf.

EPA also maintains a GLLA website, located at: http://www.epa.gov/glla/index.html, with links to topics such as:

- Executive summaries for proposed GLLA projects and proposals.
- A fact sheet about the GLLA.
- Text of the GLLA.
- GLNPO's strategy to restore and protect the Great Lakes.

1.6 DATA MANAGEMENT PROCEDURES

Data management procedures are outlined in the project planning documents, and included using standard protocols for recording field data and remedial activities, defined electronic data deliverables (EDD) for laboratory data, chain-of-custody forms for transferred samples, and a data logging system to track all field and laboratory data submitted for independent data verification.

1.6.1 Data Management

Project contractors are responsible for managing the majority of field data, laboratory data, and other project information gathered during preparation and implementation of the project, which included:

- Original planning documents developed for the project.
- All permits, licenses, and access agreements. Copies of these were maintained at the project site at all times throughout the remediation and site restoration activities.
- Site survey data, including pre-work survey data and surveys conducted throughout and upon completion of remediation activities.

- Standard forms used to document construction inspections and data quality verifications as specified by MDNRE and GLNPO. All quality control exceptions were documented on a daily form known as the Quality Control (QC) Report.
- Field information recorded each day in daily logbooks. This included weather conditions, personnel present, all field measurements and observations, and any deviations from original sampling plan. Entries into the logbooks were made as activities occurred or samples were collected. Calibrations of any field equipment were documented in the logbooks. Instrument readings taken during the remediation were documented in boring logs, in the field logbook, or both. Daily logbooks were stored at the project site and were turned over for inclusion in the project file at the completion of field activities.
- Field sampling records. Upon collection, each sediment sample was classified in the field in accordance with the Unified Soil Classification System (American Society for Testing and Materials D2487). Visual and olfactory observations were also recorded. Once samples were collected, a chain-of-custody record was created for each sample. This record then accompanied the sample to the laboratory.
- Laboratory data generated by MDNRE during analysis of sediment samples. These data were reported electronically and in hard copy.

1.6.2 Sediment Confirmation Data

Sediment samples collected during the course of the remediation were analyzed by several laboratories to confirm that dredging targets were met. To minimize costs associated with delay of field activities, the laboratories delivered the data from in the form of EDDs, as well as in hard-copy data packages. The sediment confirmation results were provided in the form of summary-level data reports that included data qualifiers. Per the QAPP, all laboratory data and records were included in final analytical reports submitted to MDNRE.

1.6.3 Database

GLNPO developed a database to archive and maintain all GLLA project sediment contamination data. This database contains sediment confirmation data for project-specific COCs and their respective location information. Field observations and all relevant collection information are also contained in this database. The database is compatible with the Query Manager Data Management System administered by the National Oceanic and Atmospheric Administration (NOAA).

1.6.4 Public Access

GLNPO has provided data generated for the Ruddiman Creek Main Branch and Pond Remediation Project to stakeholders and other interested parties. The sediment chemistry data from the project are available at the Great Lakes Environmental Database (GLENDA) website. Interested parties can access and follow the instructions provided on the GLENDA Query System page (http://www.epa.gov/glnpo/monitoring/data_proj/glenda/glenda_query_index.html) in order to receive project data. In addition, GLNPO has uploaded the sediment confirmation data to a standard GLLA database and public access can be provided through written request (see www.epa.gov/glnpo/feedpp.html for contact information).

1.7 REMEDIAL DESIGN AND CLEANUP GOALS

Based on the project objectives outlined in Section 1.3, the project team developed a remedial design and established cleanup goals, or target levels, to achieve those objectives.

1.7.1 Remedial Design

The basic elements of the remedial design consisted of mechanically dredging contaminated sediments from the creek and pond, treating the dredge soil on site with a solidification agent, dewatering the material on site, transporting it off site for disposal, installing clean cover materials over the remaining sediments, and restoring any areas of the site disturbed during remediation.

The project consisted of 19 tasks designed to achieve the remediation project objectives. The technical approaches used to accomplish these tasks are described in the subsequent sections of this report. Table 1-4 provides an overview of the primary work tasks.

Table 1-4 Primary Tasks Associated with Remediation of the Ruddiman Creek Site

Task	Description of Work Activity
1	Mobilization, project planning, and management
2	Install new fence
3	Set up and operate dewatering system
4	Establish sewer outfall system

Table 1-4 Primary Tasks Associated with Remediation of the Ruddiman Creek Site

Task	Description of Work Activity
5	Construct access roads
6	Install headwater dissipation systems
7	Set up dam and channel diversion systems
8	Dredge creek sediment
9	Construct energy dissipation devices along main branch
10	Creek/wetlands restoration
11	Transport and dispose of creek sediment
12	Install silt curtains in pond
13	Operate dewatering system for pond
14	Dredge pond sediment
15	Transport and dispose of pond sediment
16	Purchase sand backfill materials
17	Purchase rock backfill material
18	Place sand and rock backfill
19	Demobilization

1.7.2 Cleanup Target Levels for Contaminants of Concern

The MDNRE Water Division developed site-specific sediment criteria that formed the basis for the cleanup target levels for the Ruddiman Creek and Pond site remediation shown in Table 1-1 (Earth Tech, March 2004). MDNRE developed these sediment criteria through the use of a three-tiered approach. Specifically, this approach took into consideration potential impacts to human health and wildlife from bioaccumulative chemicals of concern, potential impacts to humans through direct contact with contaminated sediments, and potential impacts to aquatic life. Environmental costs, environmental benefits, and economic costs were also considered when establishing these criteria. MDNRE developed site-specific sediment criteria for cadmium, chromium, lead, benzo(a)pyrene, and total PCBs, as described below.

Cadmium and Chromium:

MDNRE developed the site-specific sediment criteria for cadmium and chromium based on toxicity testing. Standard toxicity tests using midge larvae (*Chironomus tentans*) and an amphipod (*Hyalella azteca*) were conducted using sediment collected from seven locations within the Ruddiman Creek watershed. The results of these tests indicated that sediment toxicity was closely related to the concentrations of cadmium and chromium, but not to any other chemicals. The toxicity testing also demonstrated that *Hyalella azteca* was more sensitive to cadmium and chromium than *Chironomus tentans*. *Hyalella azteca* toxicity ranged from 12 percent to 94 percent mortality, with growth showing similar correlations. Based on the toxicity testing results for *Hyalella azteca* and professional judgment, MDNRE established a site-specific sediment criterion of 10 mg/kg for cadmium and a site-specific sediment criterion of 400 mg/kg for chromium (see Section 5.1.4).

Benzo(a)pyrene:

MDNRE developed the site-specific sediment criterion for BaP based on potential human health effects resulting from direct contact with sediment. MDNRE used the same approach and equation that is used for direct contact with soil and is outlined in Part 201, Environmental Remediation of the Natural Resources and Environmental Remediation, Michigan Natural Resources and Environmental Protection Act R299.5746. The equation considers both incidental ingestion of sediment and absorption through the skin. In developing the sediment criterion, MDNRE considered the potential frequency and duration of these dermal and ingestion exposures.

Dermal exposure and ingestion are age related in humans, with children 2 to 12 years old being the most vulnerable group. Therefore, MDNRE derived the site-specific sediment criterion for children in this age range by modifying the soil dermal absorption and the soil ingestion factors used in the equation to represent this age group. Other factors modified in the equation were the ingestion rate, exposure frequency, and the dermal exposure frequency. MDNRE assumed an exposure frequency of 52 days per year for both dermal and ingestion exposures. This was based on exposure four times per week during the warmer summer months (June through August) and twice per month during the cooler months of May and September. Using the child exposure scenario resulted in a sediment value of 16 mg/kg for BaP. Given lower exposure scenarios for infants and those older than 12, the criterion affords protection of all other age groups.

Lead:

The existing MDNRE level for direct contact with lead in soil is 400 mg/kg. EPA published a sediment criterion for lead of 900 mg/kg in March 1998 (EPA, March 1998) that is based on direct contact. MDNRE decided that the sediment criterion of 900 mg/kg was sufficiently protective and applied it to this project.

Total PCBs:

Michigan's Department of Community Health has issued fish consumption advisories for both Ruddiman Creek and Muskegon Lake because of the presence of PCB and other contaminants that accumulate in fish exposed to contaminated sediments. MDNRE established a sediment quality criterion for PCBs of 1 mg/kg for Ruddiman Creek. This criterion is not based solely on sediment exposure, but also considers exposure to PCBs in fish from Muskegon Lake.

2.0 SITE PREPARATION AND SET UP

The remedial design chosen for the project focused on dredging contaminated sediments from the creek and pond, dewatering those sediments on site, and trucking them off site for final disposal. Prior to beginning those efforts, various site preparation activities were needed, including:

- Conducting pre-work site surveys, mobilizing resources to the site, and work area preparation, as described in Sections 2.1, 2.2, and 2.3.
- Constructing access roads as described in Section 2.4.
- Constructing creek dissipation, diversion, and dewatering systems, as described in Section 2.5.
- Installing containment measures and other structural devices in and around Ruddiman Pond, as described in Section 2.6.

2.1 SITE SURVEY AND RESOURCE MOBILIZATION

Prior to initiating work efforts at the site, a survey was conducted of all remediation areas associated with the Ruddiman Creek Main Branch and Pond. The site survey provided a baseline for post-dredging surveys and for subsequent calculations of the volume of sediment removed.

Mobilization of personnel, equipment, and materials began on August 8, 2005. A number of “good housekeeping” measures were instituted to mitigate dust, noise, and other possible disturbances to the public and maintain worker and public safety.

2.2 WORK AREA DELINEATION

To facilitate the dredging and remediation efforts and achievement of project objectives, the Ruddiman Creek Main Branch remediation area was partitioned into eight work areas (also known as dredge areas): B, C, D, E, F, G, H, and I. The size and location of each of these work areas was a function of the ability to access the creek from banks, the levels of contaminants in the area, and ability to control water flow. Several of these were divided into smaller sub-work areas (e.g., B1 and B2), known as remedial management units (RMU). Ruddiman Pond constituted Area A, which was subdivided into RMUs A1, A2, A3, A4, and A5. The RMUs associated with the Ruddiman Creek Main Branch remediation area are depicted in Figures 2-1 and 2-2. The RMUs associated with the Ruddiman Pond remediation area are depicted in Figure 2-3.

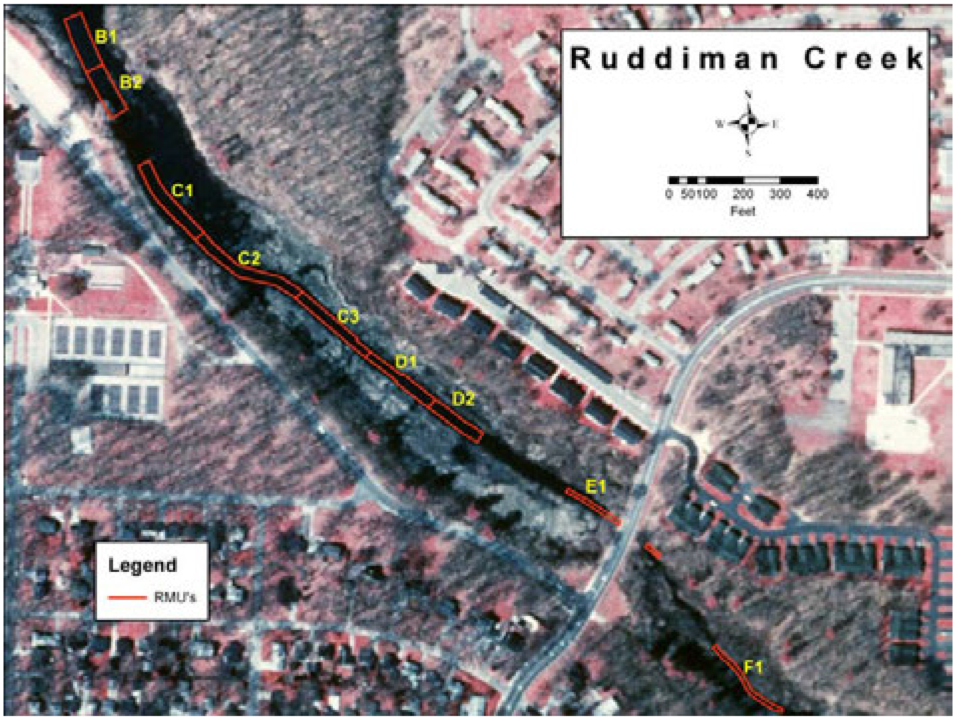

Figure 2-1 Ruddiman Creek Main Branch RMUs B, C, D, E, and F (upstream)

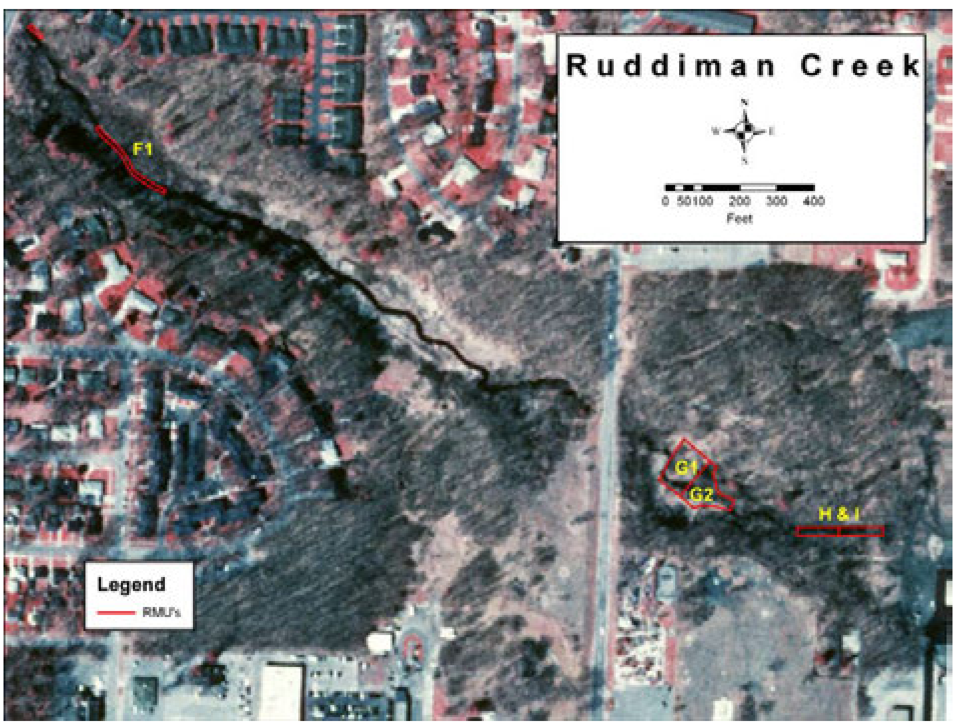

Figure 2-2 Ruddiman Creek Main Branch RMUs G, H, and I (downstream)

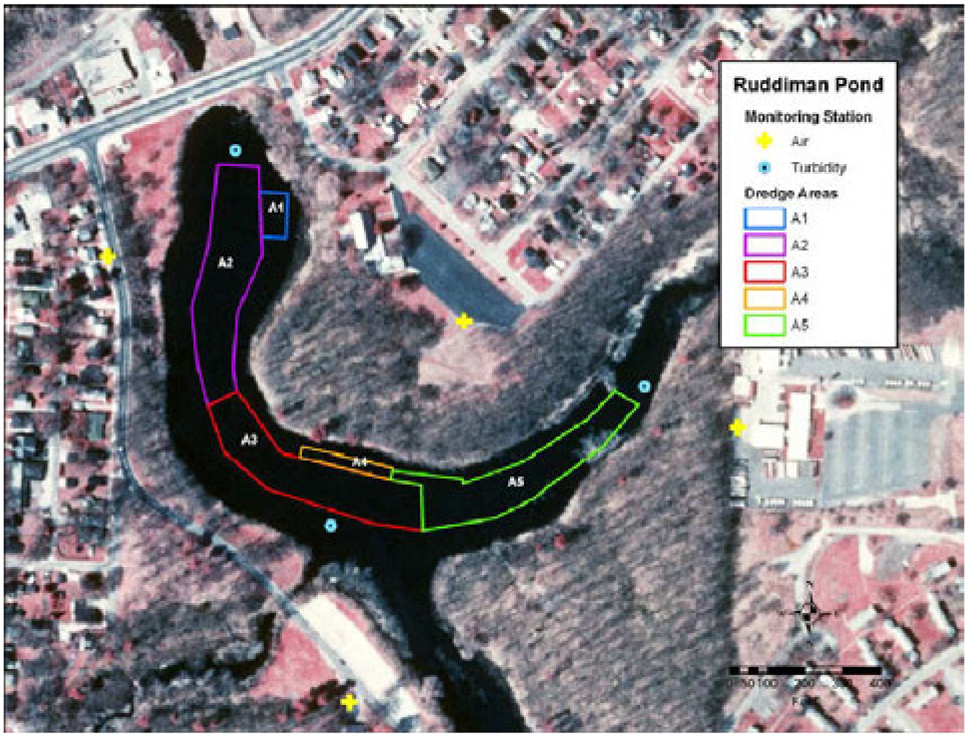

Figure 2-3 Ruddiman Pond RMUs

2.3 SITE SECURITY

Temporary fencing and signs were used to demarcate work areas. Fencing was placed around the command post area and partially around the main sediment staging and dewatering area east of McGraft Park Road to provide security for equipment and materials and to control site access by the general public. Uniformed security guards provided off-hour security. McGraft Park Road was closed to through traffic for the duration of the project to protect site personnel and the public. The road was reopened on June 2, 2006.

2.4 SITE ACCESS

Eight temporary access and haul roads (with a total area of 82,117 square feet) were constructed to support site operations. The roads extending out from Areas I, H, G, F, and E of Ruddiman Creek Main Branch were constructed using various techniques, depending on soil conditions, including:

- A soil stabilization product (e.g., GeoWeb®) made of synthetic materials that formed a web of open cells that were filled with a sand base and a gravel cap in soft areas.
- A gravel surface and geotextile fabric in more solid areas.
- Laying out multiple layers of timber swamp mats in areas where temporary roads were established (see Figure 2-4).

A combination of sand/geosynthetic/gravel roads and HDPE interlocking road mats were used to construct the roadways to reach Ruddiman Creek Main Branch Areas E, D, C, and B.

Figure 2-4 Timber swamp mat access road to Ruddiman Creek Main Branch remediation area

2.5 CONSTRUCTION OF THE CREEK DISSIPATION, DIVERSION AND DEWATERING SYSTEMS

In order to dredge contaminated sediments without releasing them into the flowing water of the creek, steps had to be taken to minimize the amount of water in the excavation areas during dredging. This was accomplished with a combination of control measures, including:

- Construction of a dissipation structure at the headwater of the creek.

- Diversion of natural creek flow with sheet pile dams.
- Isolation of excavation areas with a bypass pump.
- Active dewatering in the excavation areas using Calciment®.

Appendix D provides the design drawings illustrating where creek dissipation, diversion, and dewatering systems were installed.

2.5.1 Headwater Dissipation Structure

Figure 2-5 Headwater dissipation structure

As discussed in Section 1.1, the main branch of Ruddiman Creek begins at a 100-inch storm sewer outfall located just east of Barclay Street. The main branch subsequently flows through residential and wetland areas, until reaching the southeastern portion of Ruddiman Pond. A headwater dissipation structure was built west of the 100-inch outfall, illustrated in Figure 2-5, to preclude suspended sediments that may have eroded or been scoured by storm water surges at the outfall from settling in any of the work areas downstream.

2.5.2 Dam and Channel Diversion Systems

The excavation areas in the Ruddiman Creek Main Branch were isolated with sheet piling to block or dam the natural water flow, as illustrated in Figure 2-6. Sheet pile dams were installed upstream and downstream from each excavation area, with the exception of Areas H and I, where an earthen dam was constructed using sand, stone, and polyvinyl chloride (PVC) liner material.

Figure 2-6 Sheet piling isolating a portion of a creek channel

Diversion channels were created around Areas G and F to allow the creek to flow around the excavation areas and to minimize infiltration of water into the excavation areas (Figure 2-7).

Figure 2-7 Creating a diversion channel around Area G using a tracked excavator (left). Construction of diversion channel around Area F (right).

2.5.3 Pumping Systems

Groundwater and surface water runoff from storm events that accumulated in the excavation areas was pumped to the on-site water treatment system (Section 4.2.2). In addition, by-pass pumping occurred around Areas B, C, D, H, and I (Figure 2-8).

Figure 2-8 By-pass pumping around Areas D and C

A 6-inch diameter, 5,600-foot long HDPE pipeline was used to remove water from the work areas. The pipeline was constructed by welding together 300- to 500-foot segments, pulled into place using portable winches and was shortened as sediment removal activities were completed in the main branch and work progressed back towards the pond.

2.5.4 Sediment Dewatering

Prior to disposal, excavated sediments from most work areas were dewatered using Calciment® as a solidification agent, which was added to the sediment in a mix pit intermediate to the final staging area. Sediment was transferred to the final staging and dewatering area at the pond to sit and allow free water to decant, as illustrated in Figure 2-9. The dewatered material was transported to an off-site landfill (see Section 3.3).

Figure 2-9 Sediment dewatering pads

2.6 INSTALLATION OF CONTAINMENT MEASURES AND OTHER STRUCTURAL DEVICES IN RUDDIMAN POND

Several structures were installed in and around Ruddiman Pond to facilitate dredging operations and prevent contaminated sediments from migrating into Muskegon Lake. These included:

- A sheet wall dam at the west end of the channel that flows into Muskegon Lake. This dam was used to raise the pond level approximately two feet in order to provide added draft for the dredge plant and material barges.
- An access road to an offloading pier and a bin for storing the solidification agent (Calciment®). The road extended from McGraft Park Road to the offloading pier.
- A Calciment® storage bin west of the installed access road. The bin was constructed by laying 4-inch Geoweb® with 1- to 3-inch rock in webpockets to

maintain a hard floor for scraping the Calciment®, and building an 8-foot tall concrete block wall around the area to contain the material.

- A barge offloading pier that extended 30 feet into the pond and was approximately 40 feet wide. The pier was constructed by installing three 40-foot long sheet piling walls to make a three-sided box. The sheet piling was driven approximately 20 feet into the ground. The inner space was leveled and filled with several feet of 3-inch rock to create a solid work surface.
- Turbidity curtains and silt fence material to contain suspended sediments within Ruddiman Pond during dredging operations.

Appendix D provides the design drawings illustrating where containment and other structural devices in the pond were installed.

A combination of semi-permeable and impermeable silt curtains was used to contain contaminated sediments (Figure 2-10). Three parallel curtains were installed at the north end of Ruddiman Pond, at the west side of Ruddiman Pond, and upgradient from the outfall channel to Muskegon Lake, as the final line of defense to contain pond sediments and preclude their migration to Muskegon Lake. The curtains extended from the west shore to the east shore and downward to within less than one foot of the pond floor. A series of 3-inch diameter steel posts were driven into the bottom of the pond at 20-foot intervals on the downgradient/north side of the curtains. The posts were effective at securing the curtains against the current flow out of the pond. The northern curtain was deployed approximately 50 feet south of the Lake Shore Drive Bridge. Field observations and monitoring data indicated a fourth barrier in the outfall channel was required to control high turbidity levels observed in the spring.

With the exception of Area A3 (Figure 2-3), the turbidity curtains were reconfigured to seal off each areas as dredging was completed. For example, upon completion of dredging in Area A5, the curtains were reconfigured to exclude that area and seal off the east end of Area A3 to allow for dredging in Areas A3 and A4. While those areas were being dredged, new curtains were deployed to seal off Areas A1 and A2. The curtains in Area A3 remained in place until all dredging operations were in place because Area A3 was used for access to all other areas of the pond. All of the curtains were inspected frequently, repaired as needed, and removed after completion of dredging operations.

Figure 2-10 Isolation of Ruddiman Pond work areas using multiple silt curtains

3.0 DREDGING OPERATIONS AND DISPOSAL OF DREDGED MATERIAL

Contaminated sediments were removed from the Ruddiman Creek site using environmental mechanical dredging techniques, including long-reach excavators equipped with both environmental buckets and standard excavating buckets.

Removal activities began in the headwaters of the Ruddiman Creek Main Branch and proceeded downstream towards Ruddiman Pond. Specifically, operations began in the Ruddiman Creek Main Branch Area I, and subsequently moved downstream through work areas H, G, F, E, D, C, and B, towards Ruddiman Pond (designated Area A). Many of these work areas were divided into smaller segments, known as remedial management units or RMUs, as illustrated in Section 2.

Sediments in each RMU were dredged as specified in the QAPP with procedures modified, as necessary, to accommodate unforeseen conditions. Following completion of removal activities within each work area, samples of the remaining substrate were collected to confirm the COCs had been removed as planned. In accordance with project-specific data quality objectives (Section 5), if observed concentrations of COCs in confirmatory sampling exceeded cleanup goals, additional sediments in an RMU were removed whenever possible.

Section 3.1 describes containment, sediment removal, and sediment solidification activities within each area as work proceeded from the creek to the pond. Section 3.2 describes sediment removal operations in the Ruddiman Pond remediation area. Transportation and disposal of sediments removed from the Ruddiman Creek Main Branch and Pond are discussed in Section 3.3.

3.1 DREDGING OPERATIONS WITHIN THE RUDDIMAN CREEK REMEDIATION AREA

Excavation activities in the Main Branch of Ruddiman Creek started in Area I, and proceeded downstream towards Area B; except that Area G was started and completed prior to Areas H and I, due to issues with confirmatory sampling. In addition, excavation activities in RMUs C1 and C2 occurred prior to those in Area D, because a peat formation in Area D prevented the planned use of the long-reach excavator.

The dredging operations associated with Areas I, H, and G were performed as described in the work plan and in Section 3.1.1. Several operational challenges were encountered further downstream, in Areas F, E, D, C, and B. The original strategies for dredging these areas were modified to address those challenges, as described in Sections 3.1.2 through 3.1.5.

3.1.1 Excavation Activities in Areas I, H, and G

Areas I, H, and G are located along the Main Branch of Ruddiman Creek, east of Barclay Avenue (Figure 2-2). These areas are wooded, with large trees on the ravine slopes and in the bottom flood plain. In order to allow remediation activities to proceed, large trees were removed from the roadway footprint and the specific areas of the flood plain. Access to Areas I, H, and G was through commercial properties off Sherman Boulevard, and access to the staging pad was directly from Sherman Boulevard. The ravine was reached using a steep-sloped access road cut down into the ravine, and a culvert bridge was built to access Area G for excavation.

Area G: A 340-foot long temporary sheet pile wall was constructed along the south side of the excavation areas in Area G concurrently with extending a timber swamp mat road. After completion of a diversion ditch around Area G, excavation of the area began on September 22, 2005, and work was completed on October 13, 2005. During this period, 346 dump-truck loads of excavated sediment were hauled to the staging pad for final dewatering, yielding 6,995 tons of material for disposal.

Upon completion of excavation activities, samples were collected in the area to evaluate achievement of cleanup goals. Two RMUs in Area G initially exceeded the cleanup criteria (Section 5). Therefore, an additional four feet of sediment was removed in these RMUs. After the excavation area recharged with groundwater, a final survey of Area G was performed to determine the volume of sediment removed. The primary dredging removed 5,524 cubic yards of sediment, and secondary dredging in the three sub-areas removed an additional 700 cubic yards, for a total of 6,224 cubic yards. A geotextile membrane was placed over the excavation area and covered with a layer of sand and stone, followed by collection of more confirmation samples. The geotextile was used to prevent the sand from sinking into the peat formation at the bottom of the excavation.

Areas H and I: Areas H and I were over-dredged by one foot so that the streambed could be covered immediately after completing the confirmation sampling and post-dredging surveying. This approach was necessary to minimize the impact of potential rain events on the excavation area. Sediment removal activities in these areas began on October 14, 2005 and were completed on October 17, 2005. During this period, 364 dump-truck loads of excavated sediment, weighing a total of 1,141 tons, were hauled to the staging pad for dewatering and disposal. Confirmation sampling of the areas indicated that concentrations of COCs were below the target levels, with the exception of total PCBs. A total of 568 cubic yards of sediment were removed. A layer of sand was placed over the excavated area, followed by placement of geotextile, and then a 6-inch stone layer.

3.1.2 Excavation Activities in Areas F and E

Areas F and E each were divided into two RMUs. RMUs F2, F1, and E2 were located on the east side of Glenside Boulevard, while RMU E1 was located on the west side of the same street.

RMUs F2 and F1: After completion of the sheet pile dams and a diversion channel to dewater these RMUs, excavation activities began on November 30, 2005 and were completed on December 7, 2005. Each RMU was excavated to a depth of 5 feet, with an additional 2 feet excavated in RMU F2. Because of continual sidewall failures, the EPA On-Scene Coordinator was present during all periods of excavation below 5 feet. This prevented unauthorized over-excavating of material (i.e., soil flowing into the excavation from the work area). The EPA On-Scene Coordinator ensured that depth removal objectives were achieved. After confirmation sampling of the RMUs demonstrated the remediation objectives had been achieved and no additional excavation was needed, the isolation dams were removed. A total of 490 cubic yards of contaminated sediment were removed from Area F during the remediation process. A 3-foot layer of sand backfill was placed in Area F, covered by geotextile fabric, and a final 6-inch layer of rock backfill. In addition, a riffle structure consisting of rock check dams extending from the edge of the wetland across the creek channel was installed as an erosion control measure to minimize sediment migration during flood events.

RMUs E2 and E1: These RMUs were dredged while “wet,” i.e., through standing water. The excavation of RMU E2 was completed in a single day (December 7, 2005), and excavation of RMU E1 was completed over a two-day period from December 13 to 14, 2005. Confirmation sampling of both RMU demonstrated the remedial objectives were achieved and no additional excavation was needed. A total of 299 cubic yards of contaminated sediment were removed from Area E. A riffle structure was constructed (similar to the one in Area F) on January 5, 2006, as an erosion control measure.

3.1.3 Excavation Activities in Area D

A 41- to 43-foot thick peat formation underlay Area D and was unable to support an access road or heavy equipment. Therefore, removal tactics within this area were modified to accommodate the conditions. Several modifications were made:

- Use of an amphibious excavator for sediment removal and backfill placement.
- Use of floating, interlocking HDPE road mats on the soft soils instead of the conventional road building materials used at other locations.
- Use of crawler carriers with a 2-cubic yard capacity (tracked dump trucks that exerted low ground pressures) to move excavated sediment and backfill to and from the excavation area.
- Deciding to over-dredge the work area by one foot to increase the probability that dredging efforts removed enough contaminated sediment during the first dredging pass.

As described in Section 2.5, Area D was isolated with sheet pile dams. These sheet pile dams, positioned upstream, at RMU E1, and downstream, at RMU C2, allowed the creek flow to be pumped and redirected around Areas D and C and thus, bypass the excavation. Dredging activities in Area D were conducted from February 22 through February 28, 2006. Although active dewatering was performed during the dredging process, groundwater recharge on the isolated section was greater than the rate at which the water treatment plant could process the water. Therefore, the team dredged Area D while wet. Infiltration water was pumped to the water treatment plant, and excavated sediment was shuttled to a mix pit located adjacent to RMU C2. Calciment® was used to solidify the material in the mix pit before being transferred to the staging area for off-site disposal. A total of 2,132 tons of sediment were hauled from Area D. The post-excavation survey was performed by boat in this area, and indicated that 1,485 cubic yards of contaminated sediment were removed.

3.1.4 Excavation Activities in Area C

Although Area C is downstream of Area D, remediation activities were initiated in Area C prior to those in Area D to keep the project progressing while the access issues associated with the peat formation in Area D were resolved as described in Section 3.1.3. RMU C1, as well as part of RMU C2, could be accessed with the long-reach excavator. The remainder of RMU C2, and all of RMU C3, were excavated using the same approach used for Area D.

RMU C1 and a portion of RMU C2 were isolated by sheet pile dams and actively dewatered during the dredging process. Calciment® was mixed into the sediment *in situ*, and the solidified material was transported to a staging pad for curing and eventual off-site disposal.

The initial dredging activities in this area were completed on February 7, 2006, with a total of 1,330 tons of material removed. A silt curtain was installed to further isolate the area from flood events that might transport contaminants from the still unexcavated portions of RMUs C2, C3, and D.

The remaining portion RMU C2 and all of RMU C3 were also isolated by sheet pile dams and actively dewatered during the excavation process. The material was removed using an amphibious excavator (instead of the long-reach excavator), and shuttled wet to the mix pit with crawler carriers (instead of dump trucks). A total of 1,201 tons of material was removed from RMUs C2 and C3.

Confirmation sampling in Area C determined the cleanup objectives were not met in RMUs C1 and C3. Therefore, additional 1,309 tons of material was excavated from March 15 to 17, 2006. Confirmation samples were collected and analyzed again to verify cleanup objectives were met. A total of 3,482 tons of material was removed from Area C (2,623 cubic yards).

3.1.5 Excavation Activities in Area B

Area B was isolated by sheet pile dams and actively dewatered during the excavation process. The downstream dam was constructed of PVC sheet piling to prevent sinking into the peat formation. Excavation began on March 31, 2006. After the first 4 feet of material was removed, the hydrostatic head differential between the pond and Area B was too great, and water from the pond flowed up under the sheet wall into Area B. Several efforts were made to seal out water with Calciment® dikes, but the excavation of Area B had to be completed while wet. As a result of these conditions, Area B was over-excavated by one foot, post-removal confirmation samples were collected, and restoration proceeded without waiting for the sample results. Excavation was completed on April 14, 2006. Removed sediments were transferred to a mix pit (built adjacent to the primary staging pad), where they were solidified with Calciment®. Site conditions in Area B resulted in excessive sloughing of the creek bank and upwelling of sediment in the area, making a post-excavation survey difficult within the constraints of the project schedule. Therefore, after consultations among the project team members, the box-cut volume was estimated based on the dimensions of the dredged area and combined with information on the load volumes of the tracked crawlers used to transport the sediment to the mixing pit. That approach yielded an estimate of 2,038 cubic yards of contaminated sediment that were removed from Area B. After completion of the post-excavation sampling, a geotextile liner was placed over the entire excavation area and covered with a 6-inch layer of sand backfill. All support infrastructures were then removed.

3.1.6 Sediment Removed from Unsurveyed Areas

As noted in Section 3.1.5, portions of Area B presented difficulties conducting a post-excavation survey. Other areas of the creek also could not be surveyed due to other site-specific conditions. Therefore, after discussions amongst the project team members, the parties agreed on an estimate of 14,472 cubic yards as the total volume of sediment remove from the creek. This estimate exceeds the sum of the volumes cited for the individual areas above by approximately 745 cubic yards, and is referred to later in this report as the volume of the “unsurveyed areas.”

3.2 EXCAVATION OPERATIONS WITHIN THE RUDDIMAN POND REMEDIATION AREA

To facilitate excavation efforts in Ruddiman Pond, the water level in the pond was raised by two feet to increase the draft depth for the dredges and barges. Turbidity curtains were placed in Ruddiman Pond to contain sediments in the work areas and avoid the release of contaminated sediment during project activities, including dredging, sediment transfers, and handling (Section 2.6). The water level was maintained below the level of the outfall culvert of the West Branch of Ruddiman Creek, located west of the primary staging area, to keep water from flowing into the West Branch.

Excavation operations within Ruddiman Pond were initiated at the upgradient end of the pond and progressed toward the outfall. The dredging sequence in the pond began in RMU A5, subsequently progressing to RMUs A4, A3, and A2; and was completed in RMU A1 (Figure 2-2). Due to barge access conditions and sediment migration control measures, the original dredging sequence was modified slightly. For example, a portion of RMU A3 was dredged to gain access to RMU A5 from the barge offloading pier.

One dredge plant and two material barges were used to dredge the pond (Figure 3-1). The dredge plant consisted of:

- A 40 x 40-foot sectional barge with spud attachments to fix the position during dredging,
- A long-reach excavator equipped with a Dredge Pack/Global Positioning System (GPS) and a 2.5-cubic yard environmental bucket,
- A harbor tug to position the barge, and
- An oil containment boom and absorbent boom deployed around the barge to contain oil released during dredging operations.

Each of the two material barges consisted of a 40 x 40-foot sectional barge with a 3-foot high steel wall welded in place two to four feet from the exterior perimeter. This created an area with a storage capacity of 70 to 90 cubic yards of material. The barge and dredging equipment were mobilized and launched from the offloading pier on September 1 and 2, 2005.

Figure 3-1 Tug and barge dredging operations within the Ruddiman Pond remediation area

A total of 75,398 cubic yards of contaminated sediments were removed from the pond. Upon completion of the dredging activities, a 6-inch layer of sand was applied across the pond floor. The coverage was verified by sampling the sand layer and analyzing the sand samples for the contaminants of concern (Section 6). After COC concentrations in the sand layer were verified to be below the associated target levels, a layer of rock was applied on top of the sand across the pond area (Section 7 includes a discussion of sand and rock layer application). A total of 8,056 cubic yards of rock and 15,225 cubic yards of sand were applied in the pond.

3.3 TRANSPORT AND DISPOSAL OF CONTAMINATED SEDIMENTS

The offloading pier served as the point of departure and port for all dredging operations involving the dredge plant and material barges. The barges with dredged sediment were pumped free of standing water, which was then transferred to the on-site water treatment plant (Section 4.2.2).

An excavator was used to mix Calciment® into the contaminated sediment, as shown in Figure 3-2. Some fugitive dust was generated from the Calciment® during mixing, as seen in Figure 3-2, and while efforts were made to minimize such dust, it could not be eliminated. The sediment was solidified before being loaded into dump trucks for hauling to the staging area. The solidification process released heat from the wet sediments, resulting in the steam seen rising from the mixture in Figures 3-3 to 3-5. The primary staging area used to dewater sediments removed from the pond and from Area B of the creek was located across from McGraft Park on the north side of McGraft Park Road. Three additional, temporary staging areas were used to load and transport solidified sediments from all other areas within the creek.

Figure 3-2 Solidification of Ruddiman Pond sediment

Excavated sediment that had been mixed with Calciment® was hauled to a drying bed for dewatering and solidification. The perimeter of the specially constructed drying bed was made of interlocking concrete blocks forming a rectangle (Figure 3-3). The foundation of the drying bed was made of sand, topped by a waterproof, heat-sealed, heavy plastic membrane. All drainage from the sediment was collected in porous plastic pipe on top of the plastic liner and pumped to the treatment system (Section 4.2.2).

Figure 3-3 Sediments mixed with Calciment® in the drying bed

The original plan included solidifying the sediment from Ruddiman Creek with Calciment®, and the sediment and Calciment® mixture subsequently would be hauled to a drying bed for dewatering and solidification. However, this process was not feasible in some areas. Therefore, to minimize handling of wet sediment, active dewatering of the dredged materials was employed during dredging.

In Areas F, G, H, and I, Calciment® was added to the sediment in place. In other areas, Calciment® was added in a mix pit intermediate to the final staging area as the sediment was being removed or in the barge (Figure 3-4).

Figure 3-4 Addition of Calciment® to sediments on the dredging barge

Area E was excavated while completely wet, and then the dredged sediment was transferred to the final staging and dewatering area at the pond. The material was allowed to sit and drain so that free water could be decanted off before the material was transported to the off-site landfill.

The contaminated water from the drying bed, along with other contaminated water from sediment removal operations, was treated to a level deemed acceptable by Muskegon County, and then pumped to a sewer manhole that drains to the Muskegon County Wastewater Facility for final processing. A total of 3,241 truckloads (157,645 tons) of creek and pond sediments, staging pad materials, and road material waste were transported approximately 22 miles to the Ottawa Farms landfill in Coopersville, Michigan, for disposal (Figure 3-5).

Figure 3-5 Loading treated sediment for transportation to the Ottawa Farms landfill

4.0 ENVIRONMENTAL MONITORING OF REMEDIATION ACTIVITY IMPACTS

Environmental monitoring was undertaken to ensure the remediation activities were not adversely affecting the health of the ecosystem, the surrounding environment, or the remediation staff, and were not causing exceedances of applicable federal, state, and local standards. Air quality was monitored prior to, and throughout the project, as described in Section 4.1. Water quality was monitored during the project as described in Section 4.2.

4.1 AIR MONITORING

Air quality was monitored at the site prior to and during dredging operations. Air monitoring used National Institute for Occupational Safety and Health (NIOSH) air sampling methods for project-specific COCs, as well as real-time air monitoring for VOCs and particulates. Table 4-1 summarizes the air monitoring/sampling activities, parameters, frequencies, and action levels.

Table 4-1 Air Monitoring/Sampling Activities, Parameters, Locations, Frequencies, and Action Levels

Activity	Parameter/ Method	Locations/Tasks	Frequency	Basis for Corrective Action & Action Levels
Perimeter Air Sampling - Background	PCBs by NIOSH 5503 Metals by NIOSH 7300 Results in 2 working day	Pond: 4 locations*	All locations were sampled on 2 separate events prior to any dredging operations.	Corrective action taken if the following action levels were exceeded for one day: ▪ PCBs: 0.5 mg/m^3 ▪ Cadmium: 0.2 mg/m^3 ▪ Chromium: 0.5 mg/m^3 ▪ Lead: 0.05 mg/m^3
Perimeter Air Sampling - Definitive	PCBs by NIOSH 5503 Metals by NIOSH 7300 Results in 2 working day	Pond: 4 locations* Creek: 3 locations*	All locations were sampled the first 6 days of dredging operations and every 14 days of dredging operations thereafter.	Corrective action taken if the following action levels were exceeded for one day: ▪ PCBs: 0.5 mg/m^3 ▪ Cadmium: 0.2 mg/m^3 ▪ Chromium: 0.5 mg/m^3 ▪ Lead: 0.05 mg/m^3

Table 4-1 Air Monitoring/Sampling Activities, Parameters, Locations, Frequencies, and Action Levels

Activity	Parameter/ Method	Locations/Tasks	Frequency	Basis for Corrective Action & Action Levels
Perimeter Air Monitoring -Real Time	VOCs by MultiRAE PLUS Particulates by Personal DataRAM Results available immediately	Pond: 4 locations* Creek: 3 locations*	All locations were monitored every 2 hours throughout the work day on any day that dredging (pond) or excavation (creek) operations were conducted.	Corrective action taken if a ≥ 5 parts per million total VOCs reading was sustained for 15 minutes or if a visible dust plume was seen moving from the work areas
Personnel Air Monitoring	PCBs by NIOSH 5503 Metals by NIOSH 7300	Pond: 1 location (dredge operator) Creek: 1 location in each section of the creek (excavator operator)	Each task was sampled the first 6 days of dredging operations and every 14 days of dredging operations thereafter.	Corrective action taken if the following action levels were exceeded for one day: ▪ PCBs: 0.5 mg/m^3 ▪ Cadmium: 0.2 mg/m^3 ▪ Chromium: 0.5 mg/m^3 ▪ Lead: 0.05 mg/m^3

* Three of the four pond sampling stations were located downwind (adjacent) to pond operations to reflect site conditions and one was located upwind of pond operations to reflect daily background levels. Two of the four creek sampling stations were located downwind and one was located upwind of creek operations.

Air sampling stations were located along the perimeter of the Ruddiman Creek site as illustrated in Figure 4-1. Samples were collected from each of the pond perimeter stations prior to initiation of dredging operations on two separate days to establish background atmospheric levels for cadmium, chromium, lead, and PCBs. Upon initiation of dredging operations, samples were collected from the same stations during first six days of dredging operations and every 14 days of dredging operations thereafter. Air concentrations were determined using NIOSH Method 5503 for PCBs and NIOSH Method 7300 for metals. No exceedances were measured during work activities.

Air monitoring samples were shipped to a laboratory for analysis. The laboratory provided the analytical results within two business days of sample receipt. The analytical results were verified by reviewing the QC sample results reported by the laboratory. To ensure that project-specified action levels for cadmium, chromium, lead, and PCBs were not exceeded at the Ruddiman Creek site, the field sample data obtained from a downwind monitoring station were compared to the correlated upwind (background) field sample data and to the established project-specific action levels identified in Table 4-1.

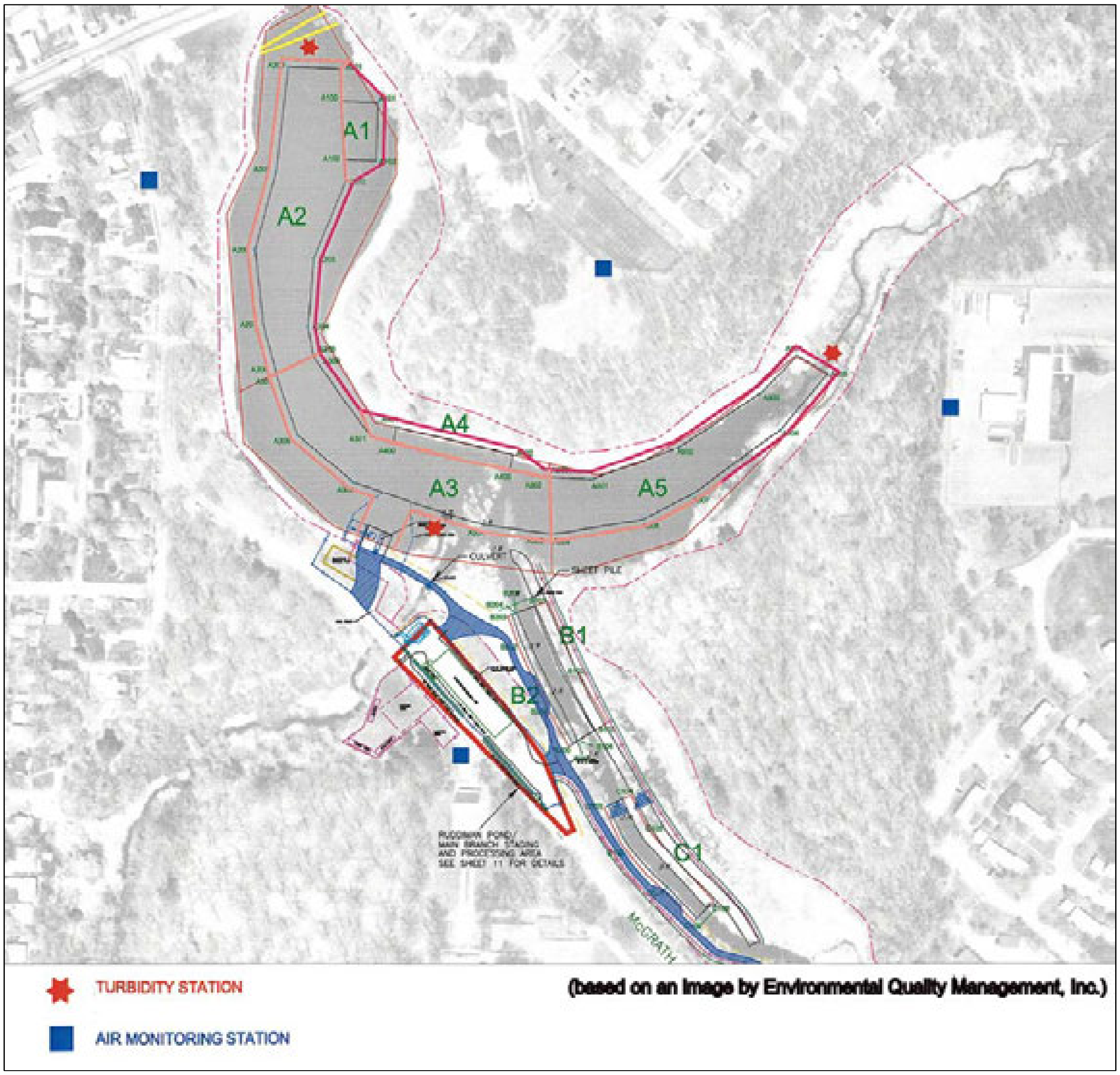

Figure 4-1 Location of monitoring stations at the Ruddiman Creek site

“Real-time” air monitoring samples were collected at the beginning and end of each work shift and at least once every two hours during work periods. “Real-time” air monitoring for VOCs and particulates was conducted using direct-read instruments stationed at each of the fixed creek and pond perimeter locations. VOCs were measured with a MultiRAE gas monitor with VOC detection capabilities. Particulates were measured with a DataRAM monitor. The data from these real-time sampling events were evaluated immediately to ensure that the action levels for perimeter air monitoring for VOCs and particulates in Table 4-1 were not exceeded.

To evaluate potential worker exposure, personnel air monitoring was conducted for those individuals identified as having the highest probability of exposure; specifically, the dredge operator at the Ruddiman Pond work area and the excavation operator at the Ruddiman Creek Main Branch work area. Personnel air monitoring for cadmium, chromium, lead, and PCBs was performed once per day during the first six days of dredging operations, and on a biweekly basis thereafter, using the NIOSH methods specified above.

4.2 WATER MONITORING AND TREATMENT

Two types of water quality monitoring were conducted during the project. Turbidity measurements were collected in Ruddiman Creek and Pond to determine the impact of dredging and sediment removal activities. These surface water monitoring activities are described in Section 4.2.1. In addition, wastewater samples were collected from the on-site wastewater treatment system and analyzed for a variety of parameters, as required by the Muskegon County Wastewater discharge permit issued for the project. These wastewater treatment and monitoring activities are described in Section 4.2.2.

4.2.1 Surface Water Monitoring

The remediation activities within Ruddiman Pond required installation of turbidity curtains to contain suspended sediments and prevent contaminated sediment from migrating off site (see Figure 2-10). In order to verify the effectiveness of the silt curtains, it was necessary to establish the baseline levels of turbidity in the creek and pond. Therefore, prior to the start of dredging, turbidity was measured every two hours, over several days, to determine baseline turbidity levels and establish action levels for later use.

Once dredging began, turbidity was measured daily in both the creek and the pond to assess water quality. Water quality samples were collected at three fixed monitoring locations. Each water quality monitoring station consisted of a TROLL 9000 turbidity meter, data logger, telemetry unit, and a solar-powered panel. The water quality monitoring stations were placed at approximately half the maximum depth of the water level at each location (Figure 4-1).

Each turbidity meter was programmed to record measurements at half-hour intervals. The turbidity data were downloaded in one-hour intervals during removal activities. Turbidity was measured in the Main Brach of Ruddiman Creek both upstream and downstream from the locations where removal activities took place. Each location was treated as an isolated work area (see Section 2.2 for a discussion of work area delineation). Grab samples of creek water were collected both upstream and downstream of a given work area each day prior removal activities and every four hours thereafter. The turbidity of these grab samples was measured using a hand-held turbidity monitor (Horiba Water Quality Checker U-10) and results were recorded in the site log book.

In addition to turbidity monitoring, surface water was monitored for oil sheens during dredging, and floating oil booms were placed around each dredge area as a precautionary measure.

As a result of difficulties in establishing baseline turbidity levels and accounting for the effect of rain events on turbidity, exceedances of the action level for turbidity tended to occur frequently. When the turbidity was elevated in the Main Branch of Ruddiman Creek or exceeded the action levels established for the pond, the reading was confirmed by taking a second measurement. If the readings continued to exceed action levels after 60 minutes, the following actions were taken:

- The turbidity meter was checked for accuracy and calibration.
- A second (hand-held) meter was used to confirm the initial readings.
- If an exceedance was observed, the result was immediately reported to the On-Scene Coordinator.
- Potential causes of the elevated levels were evaluated. This included observing conditions in the area of the monitoring location for any sign of wildlife or other external stimuli that could have caused an increase in turbidity, evaluating the readings immediately before the elevated reading(s), evaluating weather conditions, inspecting the turbidity curtain in the pond, and evaluating the controls used in the creek.
- Dredging and excavation activities were halted until the source of increased turbidity was determined or the measurements were below the action level.

4.2.2 Wastewater Monitoring and Treatment

As discussed in Section 2.5, temporary dams and diversion channels were constructed to isolate excavation areas along Ruddiman Creek Main Branch. To further minimize water in these areas, groundwater and surface water that had accumulated from storm events were pumped to an on-site water treatment system, depicted in Figure 4-2. This system was also used to treat water generated during dewatering activities at the offloading pier and at each of the sediment staging areas. A total of 5,374,850 gallons of wastewater from the combined generation points was treated with the on-site system and discharged to the Muskegon County publicly owned treatment works.

Figure 4-2 On-site treatment system

The on-site treatment system was configured to remove particles by settling and filtration and to remove organic compounds by sorption on activated carbon. The system included:

- A 21,000-gallon equalization tank.
- A 18,000-gallon weir tank.
- A 4-inch trash pump.
- Sand filters.

- Bag filters fitted with 10-micron bags.
- Cartridge filter housings fitted with 0.5-micron filters.
- An activated carbon system (configured with two parallel trains of lead vessels and lag vessels).
- A flow meter.
- An automatic sampler.

The equalization tank and weir tank were used as a reservoir when the sporadic flow of water from dewatering activities did not require operating the treatment plant. As a result, the plant operated only a few days some months (i.e., only six days in November 2005).

Composite and grab samples of treated effluent were collected using a time-based, refrigerated automated sampling device and analyzed for the water quality monitoring parameters defined in the discharge permit issued by the Muskegon County Wastewater Management System (Permit #RUDD-s01a, June 15, 2005) and detailed in Table 4-2. The samples were delivered to an analytical laboratory on the day of collection.

Table 4-2 Wastewater Quality Monitoring Parameters

Parameters for Composite Samples	Parameters for Grab Samples
Metals: Cadmium, Chromium, Copper, Lead, Mercury, Nickel, Silver Cyanide Phosphorus SVOCs: bis(2-Ethylhexyl)phthalate, Naphthalene	pH Total Suspended Solids Biochemical Oxygen Demand Flashpoint Ammonia VOCs: Acetone, Tetrachloroethene, Toluene, 1,1,1-Trichloroethane

The flow discharged from the on-site water treatment system to the Muskegon County Wastewater Management System was measured with using a flow meter. The maximum allowed flows were 200 gallons per minute and 200,000 gallons per day discharged into the 30-inch public sewer. The flow meter was monitored on an hourly-basis to document the discharge was within the permit limits.

In November and December 2005, staff at the Muskegon County Wastewater Management System notified the project team to indicate there were issues with the self-monitoring reports submitted for October and November 2005. Noted issues included that samples were collected using inappropriate techniques and reports were delivered late. In addition, the November 2005 results for biochemical oxygen demand and pH were ruled invalid; therefore, the permitting authority did not use those results. As a consequence, the on-site treatment plant was ruled out of compliance for October and November 2005. The project team corrected the sample collection procedures for all future sampling events, and records indicate the treatment plant was in compliance with its discharge permit from January 2006 through April 2006, when it ceased operations.

5.0 SEDIMENT CONFIRMATION SAMPLING AND ANALYSIS

A statistical sampling design was developed to determine if enough contaminated sediments were removed to meet the cleanup target levels for all COCs (see Section 1.7.2). The basis of the statistical sampling design is described in Section 5.1. Sections 5.2 and 5.3 provide additional details concerning implementation of the sampling design at the site, including the location of sampling points, sample collection procedures, analytical procedures, and quality control strategies.

5.1 SEDIMENT CONFIRMATION SAMPLING DESIGN

A statistical sampling design for collection and analysis of sediment confirmation samples was developed to determine whether concentrations of all COCs were below pre-established site-specific cleanup target levels in the Ruddiman Creek Main Branch and Pond remediation areas. The sampling design was developed in accordance with the Data Quality Objective (DQO) process, EPA's seven-step systematic planning process and *Guidance on Choosing a Sampling Design for Environmental Data Collection (for Use in Developing a Quality Assurance Project Plan)* (EPA QA/G-5S). The sampling design served three purposes:

- Determine whether site-specific cleanup target levels were achieved.
- Establish the level of residual contamination remaining after dredging activities were been completed.
- Establish a baseline from which to monitor residual management.

Attachment E to the QAPP provides detailed information on technical approach for the sediment confirmation sampling design and residual analysis.

5.1.1 Technical Approach to Statistical Sampling Design

To confirm that dredging activities had achieved the target levels for all COCs, a grid system was established over the entirety of the project area. The system consisted of 100 x 100-foot (10,000 square foot) grids, each of which was designated as a RMU. Thirteen RMUs were established in the dredging areas along Ruddiman Creek Main Branch and twenty-five RMUs were established along Ruddiman Pond, as presented in Table 5-1 and Figures 5-1 and 5-2.

Table 5-1 RMUs in Ruddiman Creek and Ruddiman Pond

Remediation Area	Work Area	Remedial Management Unit (RMUs)	
		Number of RMUs	RMU Designation
Ruddiman Pond	A1	1	A03
	A2	8	A01 - A02, A04 - A09
	A3	7	A10 - A15, A18
	A4	1	A16
	A5	8	A17, A19, A20 - A25
Ruddiman Creek Main Branch	B	2	B1 - B2
	C	2	C1 - C3
	D	3	D1 - D3
	E	2	E1 - E2
	F	2	F1 - F2
	G	2	G1 - G2
	H, I	2	H & I

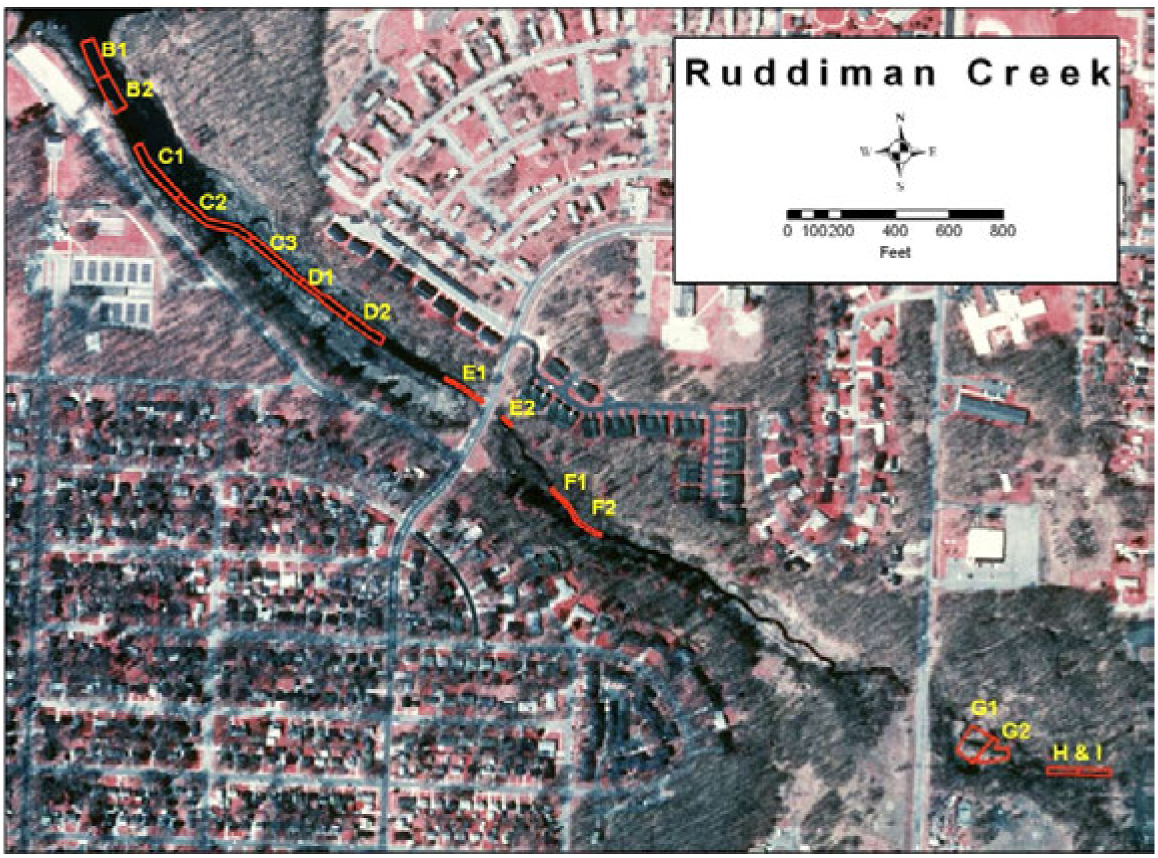

Figure 5-1 Remedial management units within Ruddiman Creek Main Branch

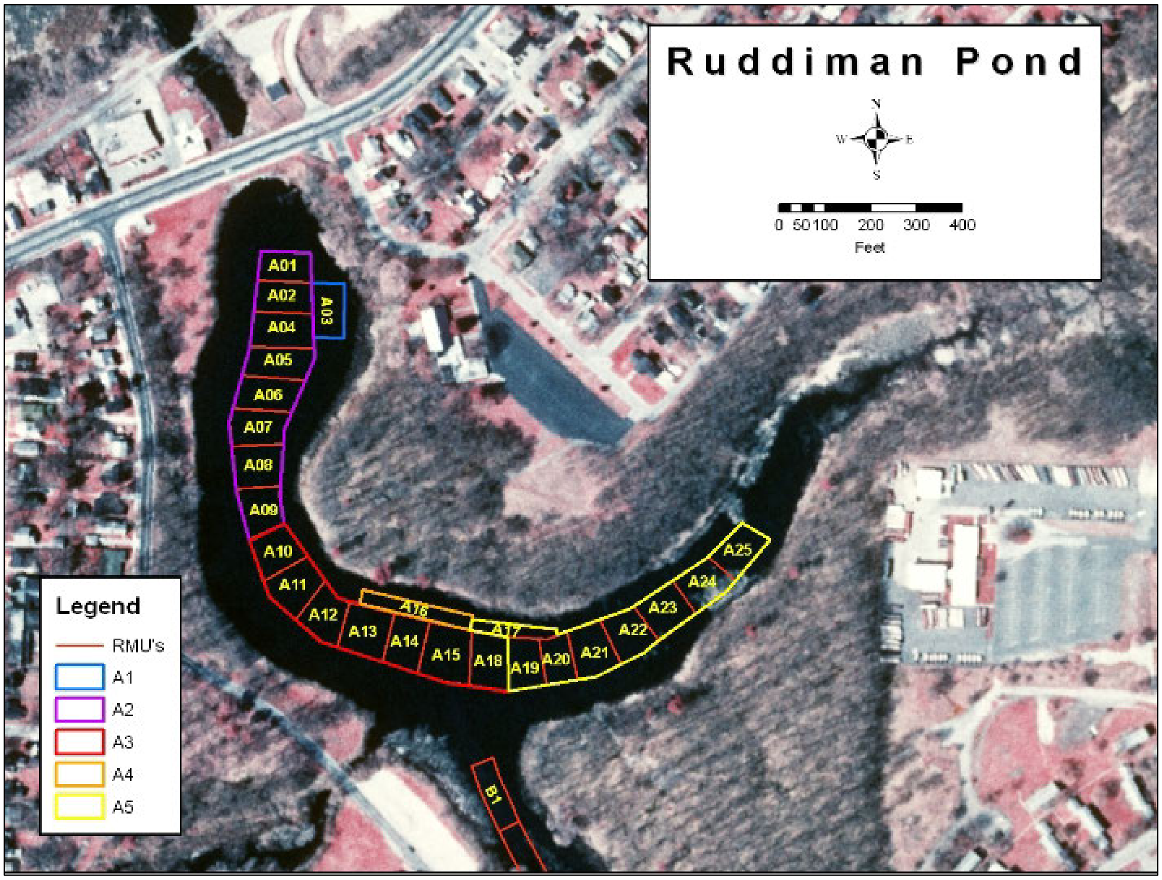

Figure 5-2 Remedial management units within Ruddiman Pond

5.1.2 Decision Statement

As part of the DQO process, a decision statement was developed for confirmation sampling. The principle study question associated with post-excavation sediment sampling and residuals analysis was identified as follows:

> *"Has the dredging removed the contaminated sediment sufficiently to proceed with placement of the residual cover?"*

It was agreed that additional remedial activities would be considered in a given RMU if the average concentration of any COC in the RMU exceeded the project-specific cleanup criteria. GLNPO and MDNRE were responsible for determining whether to perform further dredging activities or to proceed with placement of the residual cover based on analytical sediment analysis results and other project factors such as logistics and resources.

A statistical power analysis was conducted and a power curve developed for optimizing the sampling design in the style recommended by EPA's *Guidance for the Data Quality Objective Process* (EPA QA/G-4). To develop the power curve, existing sediment data were needed to estimate the variability that might be expected in the sediment confirmation sample concentrations collected in support of the remediation effort. Sediment contaminant data collected in the 1999[2] and 2002[3] pre-remediation investigations were used for this purpose. This was a conservative approach in terms of protection of the environment, since the contaminant concentrations in the post-remedial confirmation samples were expected to have lower variability than the pre-remedial samples. These historical data demonstrated strong log normality and a definable variogram[4] with a non-symmetrical range. Therefore, the data were log-transformed for use in developing the sampling design.

Part of process of developing the power curve involved specifying limits for the acceptable decision error, based on the chances of a false positive or false negative decision. For a remediation project, a false positive decision is an incorrect determination that a COC was still present above the target level, and could result in unnecessary additional remediation and dredging. A false negative decision is an incorrect determination that the COCs were no longer present at target levels, and could result in unwanted risks to human health and the environment.

The sediment confirmation sampling strategy was designed to achieve 90 percent power in detecting an exceedance of the target level when the true average concentration of a contaminant of concern in the RMU is greater than the target level. This allowed decisions to be made with false positive rates of 20 percent (or confidence of 80 percent) and false negative rates of less than 10 percent (or power of 90 percent).

[2] *Remedial Investigation of Ruddiman Creek, Muskegon, Michigan*, prepared by Earth Tech for MDNRE, Surface Water Quality Division, June 17, 2002.

[3] *Phase II Site Investigation Report*, prepared by DLZ for MDNRE, Surface Water Quality Division, October 2000.

[4] A variogram is a key function in geostatistics that can be used to characterize the roughness of a data set.

5.1.3 Confirmation Sample Locations

Based on the power curve and acceptable decision error, four sediment samples per RMU were determined to be necessary for evaluating the post-remediation site conditions against the project cleanup criteria. Therefore, each of the 100 x 100-foot RMUs was divided into four equal 50 x 50-foot cells, as illustrated in Figure 5-3, using RMU A01 as an example.

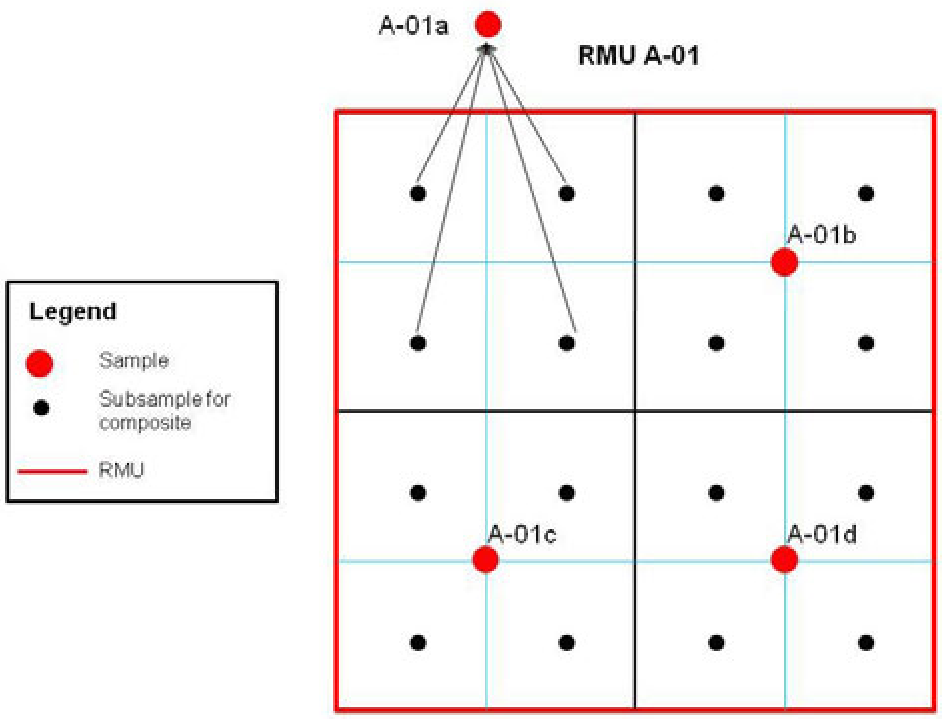

Figure 5-3 Sampling grids in Ruddiman Pond RMU A01

This approach yielded a total of 152 cells overlaying the Ruddiman Creek Main Branch and Pond dredging areas, and provided adequate coverage over the entire dredge area. Section 5.2 describes the procedures for collecting and homogenizing these confirmation samples.

5.1.4 Data Interpretation

Statistical tests were used to evaluate whether the remediation activities achieved the project-specific goals. Those tests were based on a null hypothesis (H_0) that the concentrations of the contaminants of concern were less than project-specified target levels. The decision rules for the project-specific COCs are presented in Table 5-2.

Table 5-2 Decision Rules for Achieving Project-Specific Remediation Goals

Contaminants	Null (H_0) and Alternate (H_1) Hypotheses
Cadmium and Chromium	H_0: Cadmium ≤ 10 mg/kg *or* Chromium ≤ 400 mg/kg H_1: Cadmium > 10 mg/kg *and* Chromium > 400 mg/kg
Lead	H_0: Lead ≤ 900 mg/kg H_1: Lead > 900 mg/kg
Total PCBs	H_0: Total PCBs ≤ 1 mg/kg H_1: Total PCBs > 1 mg/kg
Benzo(a)pyrene	H_0: Benzo(a)pyrene ≤ 16 mg/kg H_1: Benzo(a)pyrene > 16 mg/kg

Note that the alternate hypothesis (H_1) for cadmium and chromium is based on observing *both* cadmium above 10 mg/kg *and* chromium above 400 mg/kg. Cadmium and chromium were chosen as the two metals of greatest concern at this site. The combination of the two metals was used as the cleanup target level based on the sediment toxicity data collected during the earlier remedial investigation (Earth Tech, 2002). Specifically, the observed sediment toxicity could not be related to the observed concentrations of any single metal in the sediment samples. However, there was a correlation between the mortality of *Hyallela azteca* and the total metal concentration. Therefore, the decision rule for the metals was based on the combined effects of cadmium and chromium.

The average concentration of each COC was calculated for each of the 100 x 100-foot RMUs and compared to the respective cleanup target levels. If the average concentrations observed in a given RMU exceeded the corresponding target levels, then additional remedial activities (e.g., dredging and excavation) were considered, based on the level of exceedances observed, the distribution of contaminants, and other site-specific considerations. Section 6 provides the results and a discussion of these comparisons.

5.2 SAMPLING AND ANALYSIS

Sediment confirmation sampling was conducted after the initial remediation activities were completed, generally as described in Section 5.1. However, there were a few instances where modifications to this design were necessary due to unique operational challenges or to facilitate achievement of overall project objectives. Results of sediment confirmation sampling are presented and discussed in Section 6. Modifications to the sampling design, related operational challenges, and subsequent decision making processes are also discussed in associated area-specific sections within Section 6.

5.2.1 Sampling Methods

The sampling design called for collecting one homogenized composite sample from each 50 x 50-foot cell, yielding four routine field samples (RFS) per RMU, for a total of 160 samples collected. One surficial sample (0 to 6 inches in depth) was collected from the center of each quadrant of each of 50 x 50-foot grid, and then used to form four composite samples per RMU (Figure 5-3). Depending on conditions, samples were collected with a Ponar sampler, an Eckman dredge, or a disposable scoop. Correct grid placement for sample collection was determined and documented using GPS equipment and staking procedures. The actual sample location coordinates were recorded prior to sampling.

The four grab samples collected within each 50 x 50-foot cell were composited in a clean stainless steel bowl and thoroughly homogenized using clean stainless steel spoons and spatulas. Because thorough homogenization of the samples prior to filling the sample containers was critical for creation of representative composite samples, unrepresentative material such as stones and wood chips were removed, and the sample was mixed until uniform texture and color were obtained. The details of all sampling activities were recorded in field log books.

Due to the importance of the sediment confirmation sample results in evaluating the success of the remediation effort, the sediment confirmation samples were supplemented with a suite of QC samples, including:

- *Field Split Samples (FSS)* were prepared by using extra volume from each composite created when preparing the RFSs. At least 15 sets of these splits (i.e., a 10 percent frequency) were prepared at randomly selected locations provided where RFSs were collected. An additional two sets of splits were prepared at locations sampled after the secondary dredging activities. The FSSs were placed in the same type of jars that were used for the RFSs and labeled in the same fashion as the routine field samples. Thus, the samples were submitted to the laboratory "blind."
- *Matrix Spikes/Matrix Spike Duplicates (MS/MSD)* were prepared by using extra volume of the final homogenized composite material from the RFSs. The goal

was to collect MS/MSD aliquots at a frequency of 10 percent (i.e., 15 pairs). At least 21 sets of MS/MSD aliquots were submitted to the laboratory. Unlike the FSSs, which were sent as "blind" QC samples, the MS/MSD samples were clearly designated as QC samples for the laboratory staff. Locations of the MS/MSDs were selected at random by the samplers.

5.2.2 Analytical Methods

Sediment sample analyses were performed by the MDNRE Environmental Laboratory. SW-846 Method 8082A was used to determine PCBs. MDNRE Environmental Laboratory SOP 500, which is based on SW-846 Method 8270 and employs gas chromatography with mass spectrometry as the detection system, was used to determine BaP. MDNRE Environmental Laboratory SOP 349, which is based on EPA Method 200.8 and employs inductively coupled plasma spectrometry with mass spectrometry detection, was used to determine cadmium, chromium, and lead.

5.3 QUALITY OF SEDIMENT CONFIRMATION DATA

Due to the importance of the sediment confirmation samples in determining whether remedial activities had achieved project objectives, all the data were reviewed as described in the QAPP (Environmental Quality Management, 2005). In addition, results were evaluated to verify they provided sensitivity, precision, accuracy, representativeness, completeness, and comparability required to support these decisions. This section provides a brief description of the results of the assessment.

- *Sensitivity:* The laboratory's reporting thresholds for cadmium, chromium, and lead were sufficient to meet both the action and reporting levels specified for the project all samples analyzed. Although the laboratory's nominal reporting thresholds for BaP and PCBs were sufficient to meet both the action and reporting levels established for the project, the actual reporting levels the laboratory achieved were elevated by both the moisture and any analytical interferences present in the sediments. Both of these factors substantially increased the actual reporting limits, and a few samples exceeded the reporting limit goals established in the QAPP. In a few cases, the PCB reporting limits for an individual sample exceeded the total PCB cleanup criterion. The elevated reporting limits were still sufficient to meet the cleanup criteria specified for BaP in all samples analyzed.

- *Precision:* Precision was examined in two ways: (1) by comparing results of RFSs with their field duplicate samples to assess precision of the entire sampling and analytical system, and (2) by comparing results from MS samples with their MSD pairs to determine analytical precision. In all cases, analytical precision was within the acceptable ranges specified in the QAPP. The QAPP did not specify criteria for acceptable field precision, so a default value of 50 percent was used, and was met in all cases in which field precision could be calculated.
- *Bias:* Analytical bias was estimated by calculating recoveries of the COCs in various QC samples. Although some negative bias was observed for each COC, those biases were within the acceptance criteria specified in the QAPP.
- *Completeness and Representativeness:* The sediment confirmation sampling strategy was intended to generate data that were representative of the entire area of interest. All collected samples were analyzed for the target COCs.

  Subsequent sampling activities were targeted in areas where sample confirmation results suggested that remediation goals had not been met, as described in Section 5.1.4. For example, following the initial dredging of Ruddiman Pond Area A3, the analytical results for the confirmation samples suggested some concentrations were slightly above the established action levels. To ensure that project budgets could be directed at re-dredging those areas with the most significant contaminant residues, the technique of “kriging” was used in Area A3. Kriging is a spatial and variance interpolation method used to predict values across the site by using data from known locations. Kriging can be used to compute best linear unbiased estimates and create contours, or isopleths, of data across an area. The data for Area A3 were kriged using a smaller (10 x 10) sampling grid, which was used to identify the locations of a new subset of samples that would be representative of the areas in which re-dredging was determined to be necessary.
- *Comparability:* Comparability is the confidence with which one data set can be compared to other data sets. Sediment confirmation data were generated using standard analytical methods. All the sampling and analytical procedures used in evaluating sediment conditions in this project were well-documented and are

available in the QAPP, facilitating comparability of the sediment confirmation results.

6.0 PROJECT RESULTS

Sediment confirmation samples were collected in the Ruddiman Creek Main Branch and Pond remediation areas based on the statistical sampling design described in Section 5.1. The initial set of sediment confirmation samples was collected immediately following the first phase of dredging operations (primary dredging). In most cases, each RMU was evaluated by comparing the mean concentrations of the COCs from the four samples collected in each RMU to the target levels for the project (shown in Section 1, Table 1-1). Additional dredging or other cleanup actions were undertaken if the mean concentration exceeded the target levels for lead, total PCBs or BaP, or if the mean concentration for both chromium and cadmium exceeded their target levels. Results from the post-primary dredging sediment sampling indicated high levels of contamination still remained in a subset of RMUs in the creek and pond. In general, subsequent dredging and sampling activities were performed in accordance with project-specific decision rules as detailed in the project QAPP and described in Section 5.1.2.

Sediment confirmation sampling efforts in the creek and pond remediation areas are summarized in Sections 6.1 and 6.2, respectively. Section 6.3 describes the volumes of sediment removed. Section 6.4 describes the results of the final confirmation samples.

6.1 POST-DREDGING SEDIMENT CONFIRMATION SAMPLE RESULTS IN RUDDIMAN CREEK MAIN BRANCH

6.1.1 Post-Primary Dredging Sediment Sample Results for Ruddiman Creek

Initial removal activities were completed within the Ruddiman Creek Main Branch remediation area on September 22, 2005. A total of 60 post-primary dredging sediment samples were collected and analyzed. With the exception of RMUs C1, D2, and D3, four post-primary dredging samples were collected from each of the 13 RMUs in the creek remediation area. Additional samples were collected within RMUs C1, D2 and D3.

As discussed in Section 3.1.3, Area D was characterized by a thick formation of peat, and removal tactics and objectives were modified to accommodate these conditions. Specifically, RMUs D2 and D3 were over-dredged by an additional foot during primary dredging activities, after which, four confirmation samples were collected in each of these RMUs. Rather than wait for the results from the confirmation samples, the sand and stone cover was immediately applied in RMUs D2 and D3. However, additional problems were encountered during placement of the residual cover that required the placement of a new cover over the affected areas (see Section 7). As a result, two more samples were collected from RMUs D2 and D3 after the second placement of cover.

In response to a flood event in RMU C2, additional sampling was conducted in Area C1. As described in Section 3.1.4, because of the possibility that materials from RMU C2 could have migrated into RMU C1 during the flood event, RMU C2 was re-dredged. Therefore, four more samples were collected from RMU C1 following completion of re-dredging and upstream activities.

Table 6-1 presents summary-level results for all 60 post-primary dredging confirmation samples for the creek remediation area. The individual sample results are included in Appendix A of this report.

Table 6-1 Summary of Mean Concentrations Observed Among All RMUs in Ruddiman Creek Main Branch, Post-Primary Dredge Confirmation Samples

Contaminant of Concern	Cleanup Criterion	Number of RMUs Meeting Cleanup Criterion	RMUs with COCs Exceeding Cleanup Criterion	Pooled RMU Mean[1]	Minimum RMU Mean	Maximum RMU Mean
Total PCBs (ppb)	1,000	10/13	G1, G2, H&I	809	0	3,260
Cadmium/Chromium (ppm)	10	11/13	C1, C3	6.1	1.1	12.3
	400			375	45	812
Lead (ppm)	900	13/13	*Not applicable*	202	19	376
Benzo[a]pyrene (ppb)	16,000	13/13	*Not applicable*	3,653	2,031	7,675

[1] Calculated as the mean of the 13 individual RMU means
ppb = parts per billion = µg/kg
ppm = parts per million = mg/kg

Primary dredging effectively removed the contaminated sediments in eight of the 13 RMUs, with mean concentrations in the confirmation samples below the target levels for all the COCs in those eight RMUs. Three RMUs exceeded the target levels for total PCBs, and two RMUs exceeded the target levels for both cadmium and chromium. All 13 of the RMUs achieved target levels for lead and BaP.

RMUs G1, G2, and H and I exceeded the total PCB target level of 1,000 ppb, with mean total PCB concentrations for these RMUs ranging between 1,690 and 3,260 ppb. RMUs C1 and C3 exceeded target levels for both cadmium and chromium, with mean cadmium concentrations of 12.3 and 10.1 ppm, respectively, and mean chromium concentrations of 812 and 553 ppm, respectively.

6.1.2 Post-Secondary Dredging Sediment Sample Results for Ruddiman Creek

Eight post-secondary dredging sediment confirmation samples were collected and analyzed from the creek remediation area following secondary dredging activities; four each in RMUs C1 and C3. The mean concentrations of all the COCs in these samples fell below the target levels in RMU C1, and only exceeded the target level for chromium in RMU C3.

As discussed in Section 3.1.1, removal activities in RMUs G1 and G2 were modified due to problems with groundwater recharge. The initial secondary dredging plan included removal of two feet of sediment; however, a total of four feet of sediment was removed. A residual cover was placed in RMUs G1 and G2 without the collection of post-secondary dredging confirmation samples. RMU G1 was re-sampled after placement of the residual cover (Section 7). Results of the final confirmation samples are discussed in Section 6.4.

As discussed in Section 3.1.1, Areas H and I were over-dredged during primary dredging activities by one foot so that the streambed could be covered immediately after completing the confirmation sampling. This approach was necessary to minimize the impact of potential rain events on the excavation area; therefore, post-secondary dredging confirmation sampling was not conducted in these areas. A layer of sand was placed over the excavated area, followed by placement of geotextile, and then a 6-inch stone layer.

6.2 POST-DREDGING SEDIMENT CONFIRMATION SAMPLE RESULTS IN RUDDIMAN POND REMEDIATION AREA

6.2.1 Post-Primary Dredging Sediment Sample Results for Ruddiman Pond

Initial removal activities were completed within the Ruddiman Pond remediation area on September 19, 2005. A total of 100 post-primary dredging sediment samples were collected in the pond remediation area; four samples from each of the 25 RMUs.

Table 6-2 presents summary-level results of all 100 post-primary dredging confirmation samples for the pond remediation area. The individual sample results are included in Appendix A of this report.

Table 6-2 Summary of Mean Concentrations Observed Among All RMUs in Ruddiman Pond, Post-Primary Dredge Confirmation Samples[1]

Contaminant of Concern	Cleanup Criterion	Number of RMUs Meeting Cleanup Criterion	RMUs with COCs exceeding Cleanup Criterion	Pooled RMU Mean[2]	Minimum RMU Mean	Maximum RMU Mean
Total PCBs (ppb)	1,000	21/25	A10 - A12, A20	614	0	2,333
Cadmium/Chromium (ppm)	10	11/25	A01 - A07, A10, A11, A13, A14, A20 - A22	9.8	1.6	15.5
	400			748	111	1,744
Lead (ppm)	900	23/25	A01, A06	524	57	935
Benzo[a]pyrene (ppb)	16,000	25/25	*Not applicable*	3,861	2,246	5,425

[1] The table provides the range of all RMU means, regardless of whether the RMU exceeded the criterion.
[2] Calculated as the mean of the individual RMU means
ppb = parts per billion = µg/kg
ppm = parts per million = mg/kg

Comparison of RMU Mean Concentrations to the Cleanup Criteria after Primary Dredging of Ruddiman Pond:

Primary dredging effectively removed contaminated sediments in ten of the 25 Ruddiman Pond RMUs, with mean concentrations in confirmation samples below target levels for all the COCs in those ten RMUs. Fourteen RMUs exceeded target levels for both cadmium and chromium, and four RMUs exceeded the target level for total PCBs. All 25 of the RMUs achieved the target level for BaP.

RMUs A10, A11, A12, and A20 exceeded the total PCB target level of 1,000 ppb, with mean RMU concentrations ranging between 1,050 and 2,333 ppb. Among the 14 RMUs for which target levels for both cadmium and chromium were exceeded, mean cadmium concentrations ranged between 10.2 and 15.5 ppm, and mean chromium concentrations ranged between 596 and 1,744 ppm. Additionally, the mean lead concentration exceeded the target level of 900 ppm in RMUs A1 and A6, with mean lead concentrations of 928 and 935 ppm, respectively.

6.2.2 Post-Secondary Dredging Sediment Sample Results for Ruddiman Pond

The post-primary dredging confirmation data for the 25 RMUs in the pond indicated that secondary dredging was needed in RMUs A01-A07, A10-A14, and A20-A22. To simplify secondary dredging efforts, the kriging model shown in Figure 6-1 was used to identify specific areas within RMUs A12-A14 to target for additional dredging. In this model, stippled areas were estimated to have a high probability of exceeding the target level for at least one COC, and were selected for removal of additional sediment.

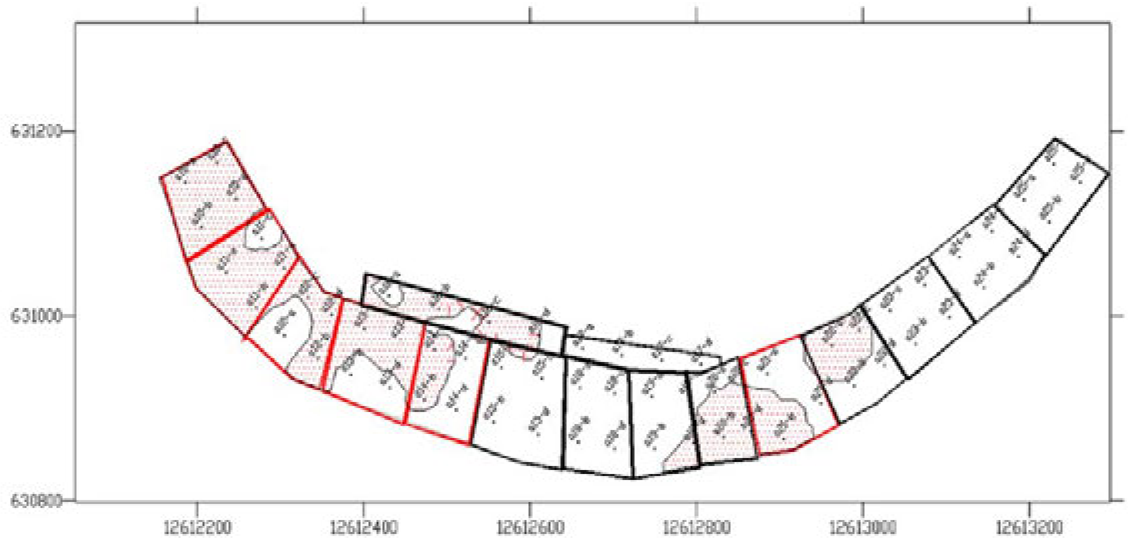

Figure 6-1 Kriging model used to determine sampling locations for RMUs A12 - A14

Table 6-3 presents summary-level results of the post-secondary dredging confirmation samples collected in the pond remediation area. The samples collected in RMUs A01-A07, A10, and A11 were analyzed for all COCs. The samples collected in RMUs A20-A22 were analyzed for only chromium and cadmium. The individual samples results are included in Appendix A of this report.

Table 6-3 Summary of Mean Concentrations Observed Among All RMUs in Ruddiman Pond, Post-Secondary Dredge Confirmation Samples[1]

Contaminant of Concern	Cleanup Criterion	Number of RMUs Meeting Cleanup Criterion	RMUs with COCs exceeding Cleanup Criterion	Pooled RMU Mean[2]	Minimum RMU Mean	Maximum RMU Mean
Total PCBs (ppb)	1,000	8/9	A06	232	0	2,333
Cadmium/Chromium (ppm)	10	9/12	A01, A05, A21	7.6	3.1	12.7
	400			487	187	716
Lead (ppm)	900	9/9	*Not applicable*	357	123	617
Benzo[a]pyrene (ppb)	16,000	9/9	*Not applicable*	4,797	3,413	7,113

[1] The table provides the range of all RMU means, regardless of whether the RMU exceeded the criterion.
[2] Calculated as the mean of the individual RMU means
ppb = parts per billion = µg/kg
ppm = parts per million = mg/kg

Comparison of RMU Mean Concentrations to the Cleanup Criteria after Secondary Dredging of Ruddiman Pond:

Secondary dredging effectively removed contaminated sediments in 11 of the 15 RMUs which exceeded the target levels after the primary dredging efforts. Mean concentrations in the secondary dredging confirmation samples fell below the target levels for all the COCs in these 11 RMUs. RMUs A01, A05, and A21 exceeded target levels for both cadmium and chromium, with mean cadmium concentrations ranging between 11.6 and 12.7 ppm, and mean chromium concentrations ranging between 543 and 716 ppm. RMU A06 exceeded the total PCBs target level of 1,000 ppb, with a mean RMU concentration of 2,333 ppb.

For the kriged samples in RMUs A12 - A14, the mean concentrations of the five samples from these RMUs were below the target levels for total PCBs, lead, and cadmium. BaP was not assessed in these three RMUs. Chromium had a mean concentration of 443.6 ppm, which exceeded the target level of 400 ppm. However, the decision rule for these two metals required that both exceed their target levels. Because the mean cadmium concentration for these RMUs fell below its target level of 10 ppm in these five samples, no further dredging action was necessary for RMUs A12 - A14.

Table 6-4 summarizes the results for each RMU based on the primary, secondary, and post-sand sediment confirmation samples. For each RMU and COC, a dot signifies the mean concentration fell below the target level, while an “x” signifies the mean concentration exceeded the target level. If a cell in the table is blank, samples were not collected in that RMU during that phase of confirmation sampling.

Table 6-4 Summary of Dredging Results by Remedial Phase for each RMU in Ruddiman Pond and Creek

Site Category	RMU	Primary Dredge				Secondary Dredge				Post Sand			
		Cd/Cr	BaP	Pb	PCB	Cd/Cr	BaP	Pb	PCB	Cd/Cr	BaP	Pb	PCB
Creek	B1	●	●	●	●								
	B2	●	●	●	●								
	C1	x	●	●	●	●							
	C2	●	●	●	●								
	C3	x	●	●	●	●							
	D1	●	●	●	●								
	D2	●	●	●	●								
	D3	●	●	●	●								
	E1	●	●	●	●								
	F1	●	●	●	●								
	G1	●	●	●	x					●	●	●	●
	G2	●	●	●	x								
	H & I	●	●	●	x								
Pond	A01	x	●	x	●	x	●	●	●	●		●	●
	A02	x	●	●	●	●	●	●	●				
	A03	x	●	●	●	●	●	●	●				
	A04	x	●	●	●	●	●	●	●				
	A05	x	●	●	●	x	●	●	●	●		●	●
	A06	x	●	x	●	●	●	●	x	●		●	●
	A07	x	●	●	●	●	●	●	●	●		●	●
	A08	●	●	●	●								
	A09	●	●	●	●								
	A10	x	●	●	x	●	●	●	●				
	A11	x	●	●	x	●	●	●	●				

Table 6-4 Summary of Dredging Results by Remedial Phase for each RMU in Ruddiman Pond and Creek

Site		Primary Dredge				Secondary Dredge				Post Sand			
Category	RMU	Cd/Cr	BaP	Pb	PCB	Cd/Cr	BaP	Pb	PCB	Cd/Cr	BaP	Pb	PCB
	A12[1]	●	●	●	x	●		●	●				
	A13[1]	x	●	●	●	●		●	●				
	A14[1]	x	●	●	●	●		●	●				
	A15	●	●	●	●								
	A16	●	●	●	●								
	A17	●	●	●	●								
Pond	A18	●	●	●	●								
	A19	●	●	●	●								
	A20	x	●	●	x	●							
	A21	x	●	●	●	x							
	A22	x	●	●	●	●							
	A23	●	●	●	●								
	A24	●	●	●	●								
	A25	●	●	●	●								

[1] RMUs A12-A14 were assessed as a single group, based on five samples (locations chosen from kriging models), rather than based on RMU-specific means.

To further illustrate the effect of dredging on COC concentrations, Figures 6-2 through 6-4 show the estimated distributions of total PCBs throughout the pond remediation area. Figure 6-2 is a three-dimensional kriging map of the distribution of total PCB concentrations prior to any remedial activities. Figure 6-3 shows the distribution of total PCB concentrations after primary dredging. As the figures illustrate, the areas exceeding the total PCBs target level of 1,000 µg/kg are found mainly in RMUs A1-A6 and A10-A12, plus an additional hotspot within RMU A20. Figure 6-4 shows the distribution of total PCB concentrations after secondary dredging. This figure illustrates the estimated total PCB concentrations fell below the target level throughout the site, with the exception of a hot spot around RMU A06 and a smaller area within RMU A12. Additional remedial activities including a sand residual cover were applied to this area, as described in Section 6.4. The exceedance at RMU A12 only covered a small area and only slightly exceeded the target level, and as stated above, mean concentrations for total PCBs did not exceed the target level in RMUs A12-A14.

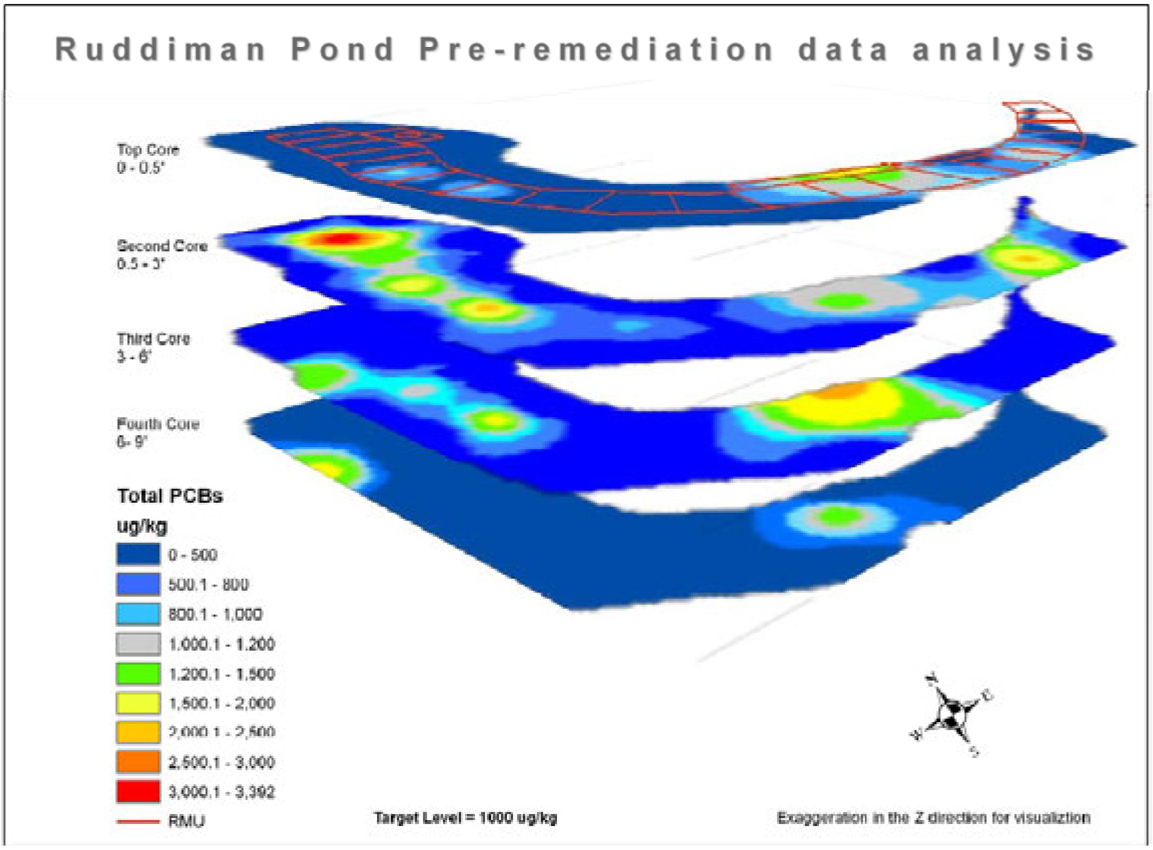

Figure 6-2 Total PCB concentrations in Ruddiman Pond prior to remediation

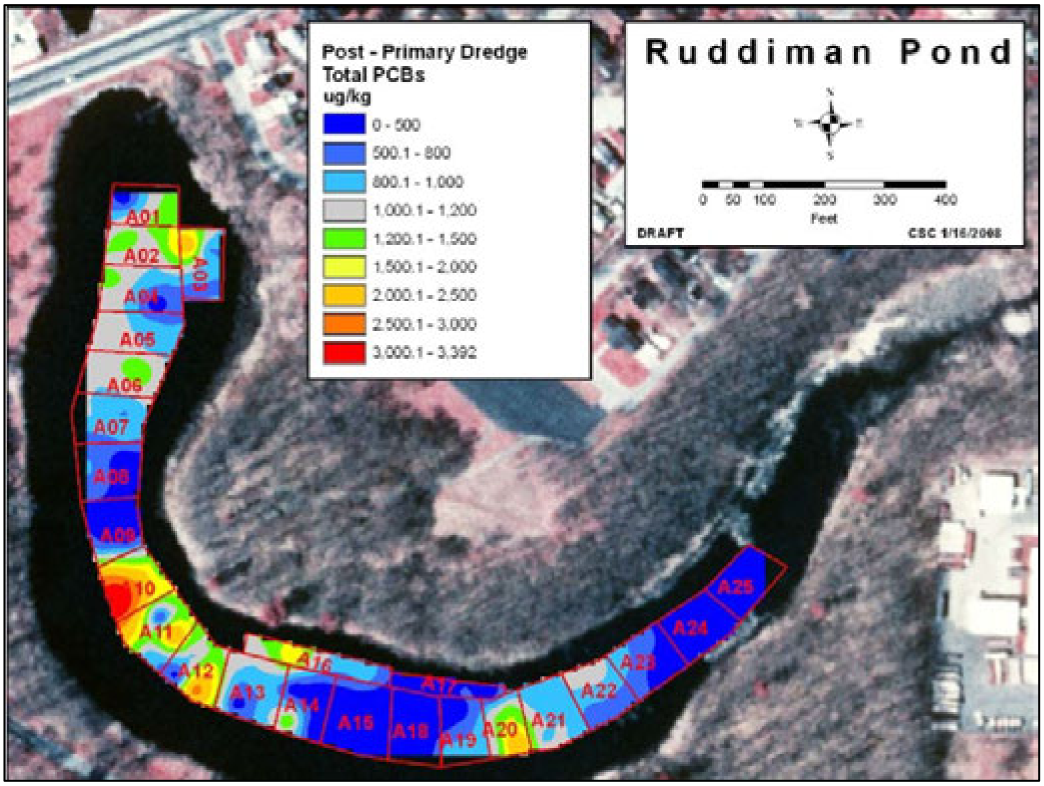

Figure 6-3 Total PCB concentrations in Ruddiman Pond after primary dredging

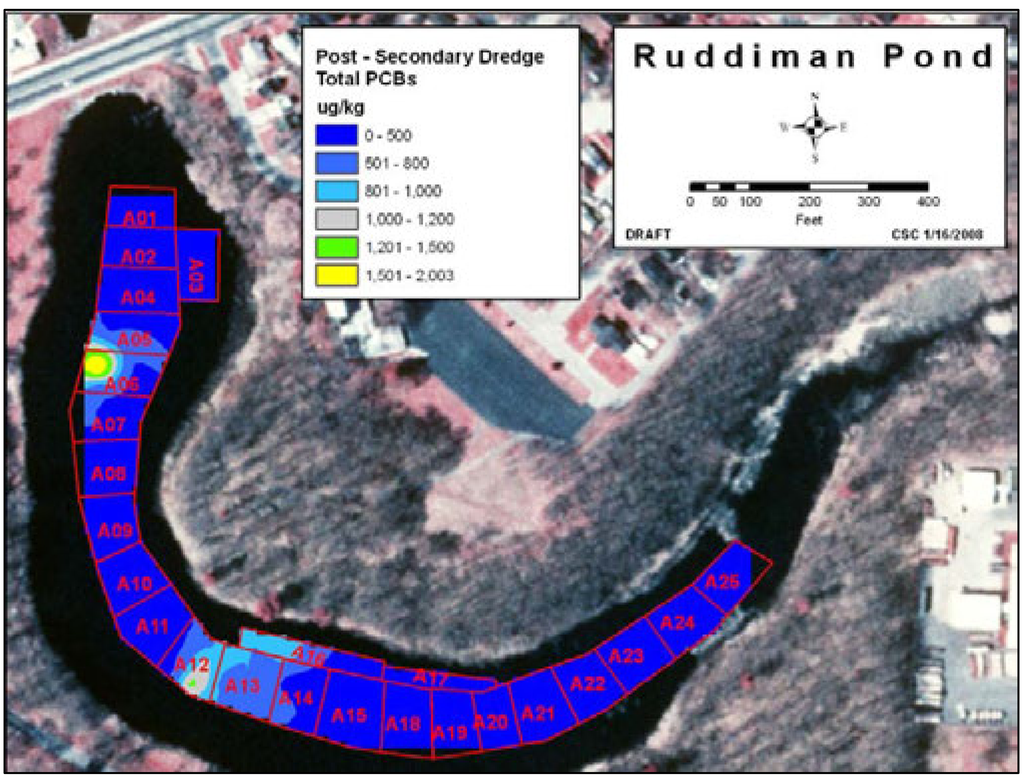

Figure 6-4 Total PCB concentrations in Ruddiman Pond after secondary dredging

6.3 SEDIMENT VOLUME REMOVED

The site was surveyed after completion of removal activities to determine the final volume of sediment removed from the Ruddiman Creek site. Based on that survey and other considerations described in Section 3.1.6, a total of 89,870 cubic yards of contaminated sediment were removed, exceeding the original project goal of 72,220 cubic yards by approximately 24 percent.

Table 6-5 displays the volumes of sediment removed based on the post-dredging survey at each location, with the exception of Ruddiman Creek Area B, where site conditions and schedule constraints precluded the survey. After consulting with the project team, the box cut volume (a simple estimate of the area excavated times the excavation depth) was used as the removal volume for Area B. An additional volume is shown for the "unsurveyed areas" described in Section 3.1.6.

Table 6-5 Volume of Sediment Removed from Ruddiman Creek and Pond, by Remediation Area

Area	Volume Estimation Method	Estimated Volume Removed (cubic yards)
Ruddiman Pond	Post-Removal Survey	75,398[1]
Creek Area B	Box Cut Volume	2,038
Creek Area C	Post-Removal Survey	2,623[1]
Creek Area D	Post-Removal Survey	1,485
Creek Area E	Post-Removal Survey	299
Creek Area F	Post-Removal Survey	490
Creek Area G	Post-Removal Survey	6,224[1]
Creek Area H & I	Post-Removal Survey	568
Unsurveyed Areas	Various	745
	Creek Total	14,472
	Creek and Pond Total	89,870

[1] Includes sediment removed during both primary and secondary dredging.

6.4 FINAL CONFIRMATION

The removal of 89,870 cubic yards of contaminated sediment from the Ruddiman Creek Main Branch and Pond remediation areas dramatically reduced the levels of COC across the site.

A layer of sand was applied to each RMU in which post-secondary dredging sample results exceeded the target level for at least one COC. Following placement of that sand cover, additional confirmation samples were collected in some of the affected RMUs.

Summaries of those post-cover application sample results are presented in Sections 6.4.1 and 6.4.2.

6.4.1 Ruddiman Creek Main Branch

Final post-sand confirmation sampling in the Ruddiman Creek Main Branch was limited to three locations in RMU G1. The mean concentrations of all of the COCs in these samples fell below the target levels.

6.4.2 Ruddiman Pond

Final post-sand confirmation sampling in Ruddiman Pond was necessary for RMUs A01, A05, A06, and A07. For RMUs A05 and A06, samples were collected at all four original locations. Two locations were sampled for RMU A01 and one location was sampled for RMU A07. As stated in Section 6.2.2, the mean concentrations of the samples collected after the secondary dredge efforts in RMU A07 met the target levels for all COCs. However, the cadmium and chromium results for one of the four post-secondary dredging samples at RMU A07 were notably higher than the others. As a precaution, an additional layer of sand was applied to RMU A07, and a final confirmation sample was collected at this location. For RMUs A01, A05, A06, and A07, the mean concentration of the post-sand confirmation samples was below the target level for each COC.

As discussed in Section 6.2.2, mean cadmium and chromium concentrations for RMU A21 exceeded their individual target levels; however, only two samples in RMU A21 exceeded the target levels for both cadmium and chromium. Due to scheduling limitations, these two sampling locations (A21_B and A21_D) were covered with sand after sampling and no further dredging or sampling was conducted.

7.0 RESIDUAL COVER PLACEMENT, DEMOBILIZATION, AND RESTORATION

Site restoration activities began in Ruddiman Creek Main Branch and Pond remediation areas following completion of excavation and dredging operations in each work area. The general objective of restoration activities was to return all disturbed areas of the site to pre-construction or improved conditions and to perform enhancements that would prevent habitat degradation. Site restoration activities included:

- Placing a cover layer of aggregate or sand in each RMU or work areas.
- Removing temporary roads and project support structures and facilities.
- Grading, seeding, and replanting of indigenous perennials and bushes removed during construction work.

Additional environmental enhancement activities in selected areas included:

- Installing energy dissipation and riprap riffle structures at strategic locations along the Ruddiman Creek Main Branch.
- Creating deeper pools.
- Armoring portions of the creek with rock.
- Leaving select diversion channels constructed during site preparation in place to create a braided stream effect.

Sections 7.1, 7.2, and 7.3 describe residual cover placement, demobilization, site restoration activities and environmental enhancements in the Ruddiman Creek site remediation areas, respectively.

7.1 PLACEMENT OF RESIDUAL COVER

7.1.1 Ruddiman Creek Main Branch

As described in Section 3, RMUs in the Ruddiman Creek Main Branch remediation area were backfilled with a combination of sand, geotextile fabric, and rock. The resulting residual cover should facilitate restoration of the creek to its natural depth; provide a series of barriers to prevent any residual contaminants from entering the creek; and provide suitable substrate for aquatic life. After completion of excavation and confirmation sampling activities within a given RMU, a layer of sand was applied as backfill to serve as the first of several barriers designed to preclude residual contamination from entering the creek. The amount of sand applied was dependent upon area-specific conditions and planned remedial activities. The sand layer in Areas D, E, and F was three feet deep and at least six inches deep in Areas B, G, H, and I. Sand was not applied in Area C. An 8-ounce layer of non-woven geotextile fabric was applied over the sand layer, followed by 6-inch thick layer of 3-inch rock backfill. This sequence was generally followed within the creek remediation area, but was modified to address challenges associated with two work areas. The geotextile fabric was applied first in Areas G and D (RMUs D2 and D3) to prevent the sand layer from sinking into the peat formation.

In RMU D1, the sand backfill and geotextile fabric broke through the bottom of the streambed and dropped into the underlying peat formation, resulting in upheavals of other areas within this RMU. The raised sections were pushed down, a new section of geotextile was applied, and then covered with another 6-inch sand layer. The final step was to cap Area D1with a 6-inch layer of stone.

7.1.2 Ruddiman Pond

After completion of excavation and confirmation sampling activities in the Ruddiman Pond remediation area, a 6-inch layer of sand backfill was spread throughout the pond, followed by a layer of rock.

7.2 DEMOBILIZATION

Demobilization activities began in phases as the remediation tasks were completed. As portions of the project were completed, resources that were no longer necessary for the remaining tasks were demobilized. The equipment was cleaned and decontaminated prior to removal and final demobilization occurred on June 9, 2006. Results for soil samples collected from the three former staging areas indicated there was no residual contamination at the site as a result of remedial activities.

7.3 SITE RESTORATION AND ENVIRONMENTAL ENHANCEMENTS

Site restoration activities at the Ruddiman Creek site were conducted throughout the course of the project. For example, after completion of work, disturbed areas were generally applied with a temporary seed. The temporary seed was applied at a rate of one to three pounds per 1,000 square feet to stabilize the disturbed area and control erosion.

Permanent seed was applied at a rate of approximately 0.3 pounds per 1,000 square feet (12 pounds per acre) during the spring of 2006 to allow the seed to become well established in the disturbed areas. A variety of herbaceous plants and shrubs were planted on some of the former site roadways, at a density of approximately 3-feet off center, or roughly 16 plants and shrubs per 100 square feet.

7.3.1 Ruddiman Creek Main Branch

An estimated 300,000 square feet (almost seven acres) of site restoration was required as a result of cleanup operations. Site restoration activities included establishing a stable slope in the excavation areas, removing operations infrastructure, re-establishing vegetation, and restoring creek flow to both the original and diversion channels. Additional site restoration activities included the creation of deep-water retention and sedimentation basins in the excavation cavities associated with Areas F and G, as well as armoring the streambed in Areas H and I with wing dams to dissipate flood stream velocity. Three riffle structures were constructed to serve as erosion-control measures to minimize sediment migration during flood events. The resulting riffle structures extended from one side of the flood plain to the other, and were built at the headwaters of Area F and at the tail waters of RMU E1 and Area C.

7.3.2 Ruddiman Pond

An estimated area of 25,000 square feet around the edge of the pond required site restoration, including the area around the temporary barge off-loading pier. The disturbed areas were re-vegetated after removal of all infrastructure and restoration of the stream bank slopes. The disturbed area adjacent to the pond remediation area was seeded with temporary seed, as well as permanent seed that included a wetland-edge mix of grasses and a flower-to-grass ratio of 5:1. Turtle flower was also planted along the pond. As in the creek area, a variety of herbaceous plants and shrubs were planted on some of the former site roadways, and were seeded with permanent seed with a flower-to-grass ratio of 10:1.

A portion of the upland areas was planted with mixed height grasses and flowers with a flower-to-grass ratio of 14:1. The remaining upland areas were planted with a roadside seed mix. The surface of the seeded areas was mulched with shredded straw.

Figures 7-1 and 7-2 illustrate some of the replanting efforts and the resulting restoration of the site.

Figure 7-1 Volunteer replanting efforts

Figure 7-2 Replanting efforts among the reestablished grass cover

8.0 CONCLUSIONS AND PROJECT ACCOMPLISHMENTS

As noted in Section 1.3, there were three objectives of this project:

1. Reduce relative risk to humans, wildlife, and aquatic life.
2. Restore beneficial uses.
3. Source control.

Although these objectives were ambitious, they were also key to the design and the successful implementation of the project.

The removal of nearly 90,000 cubic yards of contaminated sediments had an immediate positive impact on the health of the system and significantly reduced the exposure to the benthos. It will take time to determine the long-term impacts on the food web from the reductions in contaminant levels, which also is affected by other sources of contamination. However, the overall impact of the project is expected to result in reduced risks to aquatic organisms, wildlife, and humans in both the Ruddiman Creek watershed and in Muskegon Lake. Thus, it is expected that the first objective will be met over time.

The key objective for the community surrounding Ruddiman Creek and Pond was to restore their ability to use this recreational asset in their neighborhood and for some, their backyards. The creek and pond are now well suited for kayaking and canoeing and the surrounding park areas provide walking trails and can be used for other events. This is the first of many steps to achieve the second objective. The community continues to maintain and improve the restored habitat, has begun monitoring programs in the watershed, and the site is being used for education and outreach activities.

The third objective was achieved through the installation of measures such as riprap riffles, energy dissipation devices, and braided stream channels that control stormwater flows near the sources to Ruddiman Creek and Pond. Such structures have stopped high flow/high erosion events into the pond and this decreased flow is expected to decrease the introduction of toxics and sediments into Ruddiman Creek and Pond. These measures have improved the stability of the aquatic habitat, and improved aesthetics and recreational uses of the Ruddiman Creek watershed. The original channel of the Main Branch of Ruddiman Creek was restored, and open water areas were created in the once sediment-clogged and cattail-filled Ruddiman Pond. The blanket of stones placed on the bottom and sides of areas of the creek reduced stream bank erosion and decreased the amount of sand and silt flowing downstream. As described in Section 7.1.1, additional measures were completed to seal upstream sections of the Main Branch, where scouring and erosion were of particular concern. Various flow dissipation structures were installed, such as wing dams, detention ponds, streambank armoring, and riffle structures. Extensive plantings of native flora stabilized the flood plain and slopes wherever the natural ground cover was disturbed.

In addition, the project was successful in other key areas:

- Communication among project participants and stakeholders.
- Outreach to, and involvement with, the local community.
- Obstacles associated with project implementation.
- Use of specialized equipment and materials.
- Use of innovative planning tools and statistical methods.
- Recognition from outside parties regarding project achievements.

Examples of specific project achievements are presented in Table 8-1 below.

Table 8-1 Project Accomplishments and Awards

Awards

- The Ruddiman Creek Task Force and Illinois-Indiana Sea Grant won the 2006 State of the Lake Ecosystem Conference award *"for exceptional performance and dedication to the Ruddiman Creek Great Lakes Legacy Act Sediment Remediation Project."*
- The project was awarded the 2007 Chapter and Branch Award for "Project of the Year" by the American Public Water Works Association Michigan Chapter - Midwest Branch; and specifically recognized for:
  - Successfully achieving all remediation project objectives
  - Outstanding project team communication, including the use of weekly calls, which provided a forum for progress and decision making, and ensured a high level of communication between the project participants
  - Use of innovative technologies to facilitate achievement of project objectives, including using:
    - The DQO process to plan the remediation effort
    - Modified excavation tactics to account for unique conditions and facilitate achievement of project objective
    - Kriging to optimize removal of contaminated sediments at the lowest possible cost, while still achieving goal of removing public health hazards
  - Demonstrating resources for future remediation efforts (e.g., use of a mixture of Calciment® for solidification of contaminated sediment)
- The President's Volunteer Service Award was given to Theresa Bernhardt who spent thousands of hours over 12 years championing the cleanup of Ruddiman Creek and Pond.

Table 8-1 Project Accomplishments and Awards
The award was presented by then EPA Administrator Stephen Johnson in August 2008.
Contaminants Removed
▪ 89,870 cubic yards of contaminated sediments were removed, containing approximately: ➢ 2,800 pounds of cadmium ➢ 204,000 pounds of chromium ➢ 126,000 pounds of lead ➢ 320 pounds of PCBs

At the project completion celebration, United States Representative Pete Hoekstra (R-Holland) said:

> *"A lot of times, we go to Washington and we pass a bill and we declare a victory and nothing has happened. This is actually a case where we go to Washington, we pass a bill, it comes back and it almost works exactly the way we envisioned it to work, and that's because of all the folks that have come together that have shared the same vision…"*

In addition, State Senator Gerald VanWoerkom (R-Norton Shores) celebrated the removal of the polluted sediments to which wading children had been exposed. Muskegon Mayor Steve Warmington was pleased to see Ruddiman Creek and Pond returning to normal and *"breathing on its own."*

A number of challenges were encountered during the remediation project. Working in the peaty soils along Ruddiman Creek required modifications of the excavation activities, specifically with respect to road construction methods and dredging equipment. Further problems included the need for increased water quality monitoring to account for storm and flooding changes, seasonal changes, spawning activity, and algal blooms.

The project objectives were successfully accomplished in spite of these challenges, due, in part, to the high level of communication among all of the project participants. For example, road construction was impossible within the lowest branch segment upstream of Ruddiman Pond. After discussion among the participants in the weekly conference calls, interlocking HDPE mats were used to create a floating road and small crawler carriers capable of being supported by the floating road were used in the effected work area. Although improvised quickly, these amphibious removal tactics proved to be very successful and allowed completion of the removal activities.

A number of other technological innovations were utilized during both the planning and implementation of the remediation project, including: use of EPA's DQO process to develop a statistically-based sampling design for sediment confirmation analysis; and use of kriging to interpolate complex patterns of contamination and identify areas that exceed the target levels of a given contaminant of concern (see Section 5). The DQO process allowed the development of a remediation plan that minimized the collection of data that were inconsequential with respect to verifying the success of the remediation, and instead focused on ensuring confirmation data were of sufficient quantity and quality to confirm the remediation project's success at a specific degree of confidence. Kriging, on the other hand, allowed the cost-effective removal of sediment in Area A3 in Ruddiman Pond.

There were other operational successes as well. For example, laser instrumentation was used to establish the proper depth for sediment removal during excavation and enabled accurate removal of sediments to specified depths. The dewatering pads worked well, with minimal subsurface impact and enabled easy loading of materials for the next phase. Heating the wastewater treatment plant was also effective in preventing pipelines from freezing during the winter months.

Because of the significant accomplishments associated with the project, the American Public Works Association Michigan Chapter awarded the Ruddiman Creek remediation project with the 2007 "Project of the Year Award." This award recognized the complexity of the remediation project and that the methods used to overcome obstacles provided technical resources necessary in future sediment remediation efforts. The degree of cooperation between all parties was also recognized as illustrating the benefits of a teamwork concept that drove the remediation project to its successful completion.

Together, the Ruddiman Creek Task Force and Illinois-Indiana Sea Grant won the 2006 State of the Lake Ecosystem Conference *"for exceptional performance and dedication to the Ruddiman Creek Great Lakes Legacy Act Sediment Remediation Project"* (Figure 8-1).

In addition, Theresa Bernhardt, a substitute teacher, mother of three, and volunteer activist from Muskegon, Michigan, was awarded the President's Volunteer Service Award in August 2008 (Figure 8-2). This award recognized the thousands of hours that Ms. Bernhardt spent over 12 years championing the cleanup of Ruddiman Creek and Pond.

Figure 8-1 Staff from the Ruddiman Creek Task Force and Illinois-Indiana Sea Grant win the 2006 State of the Lake Ecosystem Conference award

Figure 8-2 Theresa Bernhardt receives the President's Volunteer Service Award from EPA Administrator Stephen Johnson in August 2008

9.0 FUTURE OF THE SITE

Historically, Ruddiman Creek Main Branch and Pond were severely affected by contamination from the area's industries and run-off from storm sewers. Aquatic life had all but disappeared and safe recreational opportunities were extremely limited. Following the removal of contaminated sediments from the creek and pond, salmon were seen swimming up the creek for the first time in many years and the visual appearance of the creek and pond were improved (Figures 9-1 and 9-2).

Figure 9-1 Appearance of Ruddiman Creek Main Branch remediation area six months after completion of remediation project

Figure 9-2 Appearance of Ruddiman Pond remediation area six months after completion of remediation project

In an effort to prevent the site from returning to pre-remediation conditions, local officials developed a number of plans to reduce the volume of pollutants transported to the creek via storm sewers in the greater Muskegon area. In addition, the City of Muskegon enacted a stormwater pollution control ordinance in August 2008 that requires that the site plan for any development or redevelopment project involving a site over one acre include stormwater control and treatment measures.

Although the remediation effort is over and the heavy equipment has been removed, interest in the site remains high. The site will be monitored by a number of entities. U.S. EPA will conduct post-remediation sampling and a total maximum daily load assessment. Grand Valley State University will monitor benthic invertebrates in the pond, and several groups have suggested assessing birds and reptiles in the area as well.

The community plans to develop bike trails, nature signage, and canoeing and kayaking routes in the cleaned up waterways. Community action groups are making efforts to maintain the vegetation, including a volunteer project to minimize invasive plants.

The remediation project is also expected to serve as a catalyst for redeveloping not only the Ruddiman Creek Main Branch and Pond, but also the Muskegon Lake AOC. To further ensure an improved habitat and as a follow-up to the sediment remediation project, the community assisted in the development of the Muskegon Lake Ecological Restoration Master Plan with funding from the EPA GLNPO habitat program. The plan provides a blueprint to restore the wetland, aquatic, shoreline, and riparian habitats in the Muskegon Lake AOC. This extensive blueprint provides detailed information about the projects needed to move toward a restored Muskegon AOC and delisting of beneficial use impairments.

The blueprint sets priorities for projects, identifies costs, and recommends who best undertake the work. This blueprint was the basis for a proposal submitted to NOAA by the Great Lakes Commission on behalf of the Muskegon Lake Watershed Partnership. In June 2009, NOAA awarded the Commission ten million dollars in federal “stimulus” funding under the American Recovery and Reinvestment Act for restoration projects in the AOC (http://www.glc.org/announce/09/06muskegon.html). The blueprint detailed “shovel-ready” projects to begin restoration, which were key to the stimulus funding. The project is expected to support 125 jobs, largely in engineering and construction. More than twenty million dollars will be contributed by local sources through in-kind services, donations of land, and conservation easements.

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APPENDIX A SUMMARY SEDIMENT CONCENTRATION DATA

SUMMARY SEDIMENT CONFIRMATION DATA								
Sample	Phase	Lab Sample ID	Sampling Date	Total PCBs (µg/kg)	Chromium (mg/kg)	Cadmium (mg/kg)	Lead (mg/kg)	BaP (µg/kg)
B1-A	1º Dredge	A77233	4/14/2006	720	393	3.76	194	17000
B1-B	1º Dredge	A77234	4/14/2006	ND	301	3.74	129	ND
B1-C	1º Dredge	A77235	4/14/2006	ND	224	3.09	128	ND
B1-D	1º Dredge	A77236	4/14/2006	940	639	7.22	316	ND
B2-A	1º Dredge	A77237	4/14/2006	ND	51	1.08	26	ND
B2-B	1º Dredge	A77239	4/14/2006	ND	33	0.9	10	ND
B2-C	1º Dredge	A77240	4/14/2006	ND	41	0.99	16	ND
B2-D	1º Dredge	A77241	4/14/2006	ND	56	1.38	22	ND
C1-A	1º Dredge	A74460	2/15/2006	ND	609	9.87	227	ND
C1-B	1º Dredge	A74461	2/15/2006	460	1062	11.35	462	ND
C1-C	1º Dredge	A74462	2/15/2006	440	641	7.38	431	ND
C1-D	1º Dredge	A74463	2/15/2006	270	695	6.09	253	ND
C1-A1	1º Dredge	A74791	3/3/2006	610	762	25.13	338	ND
C1-B1	1º Dredge	A74792	3/3/2006	ND	808	23.36	336	ND
C1-C1	1º Dredge	A74793	3/3/2006	960	1301	8.27	695	ND
C1-D1	1º Dredge	A74794	3/3/2006	620	621	7.34	269	ND
C1-AR	2º Dredge	A75621	3/18/2006	NA	410	8.93	NA	NA
C1-BR	2º Dredge	A75622	3/18/2006	NA	213	4.2	NA	NA
C1-CR	2º Dredge	A75623	3/18/2006	NA	461	18.69	NA	NA
C1-DR	2º Dredge	A75624	3/18/2006	NA	202	7.17	NA	NA
C2-A	1º Dredge	A74795	3/3/2006	490	455	5.8	230	ND
C2-B	1º Dredge	A74796	3/3/2006	390	366	2.83	152	ND
C2-C	1º Dredge	A74797	3/3/2006	700	322	26.87	215	ND
C2-D	1º Dredge	A74798	3/3/2006	ND	85	1.88	58	ND
C3-A	1º Dredge	A74799	3/3/2006	530	819	7.84	336	ND
C3-B	1º Dredge	A74800	3/3/2006	640	451	7.61	226	4000
C3-C	1º Dredge	A74801	3/3/2006	580	481	16.37	262	ND
C3-D	1º Dredge	A74802	3/3/2006	ND	462	8.58	195	ND
C3-AR	2º Dredge	A75425	3/16/2006	NA	149	2.67	NA	NA
C3-BR	2º Dredge	A75426	3/16/2006	NA	610	11.18	NA	NA
C3-CR	2º Dredge	A75427	3/16/2006	NA	843	14.79	NA	NA
C3-DR	2º Dredge	A75428	3/16/2006	NA	324	7.23	NA	NA
D1-A	1º Dredge	A74803	3/3/2006	660	660	5.65	220	ND
D1-B	1º Dredge	A74804	3/3/2006	2200	618	5.65	266	ND
D1-C	1º Dredge	A74805	3/3/2006	ND	684	7.77	250	ND
D1-D	1º Dredge	A74806	3/3/2006	730	251	12.07	183	ND
D2-A	1º Dredge	A74716	2/28/2006	1100	1181	18.02	260	ND
D2-B	1º Dredge	A74717	2/28/2006	ND	371	7.9	206	ND
D2-C	1º Dredge	A74718	2/28/2006	ND	275	6.5	183	ND
D2-D	1º Dredge	A74719	2/28/2006	ND	175	3.36	123	ND

SUMMARY SEDIMENT CONFIRMATION DATA								
Sample	Phase	Lab Sample ID	Sampling Date	Total PCBs (µg/kg)	Chromium (mg/kg)	Cadmium (mg/kg)	Lead (mg/kg)	BaP (µg/kg)
D2-E	1º Dredge	A74720	2/28/2006	1100	850	13.46	214	ND
D2-F	1º Dredge	A74721	2/28/06	ND	83	1.52	70	ND
D3-A	1º Dredge	A74722	2/28/06	ND	64	1.39	29	ND
D3-B	1º Dredge	A74723	2/28/06	ND	108	1.7	41	ND
D3-C	1º Dredge	A74724	2/28/06	1100	2404	17.12	1165	ND
D3-D	1º Dredge	A74726	2/28/06	ND	132	2.16	94	ND
D3-E	1º Dredge	A74727	2/28/06	ND	178	2.82	85	ND
D3-F	1º Dredge	A74728	2/28/06	ND	274	4.34	165	ND
E1-A	1º Dredge	A72820	12/15/2005	ND	170	2.7	120	ND
E1-B	1º Dredge	A72821	12/15/2005	300	56	0.92	64	ND
E1-C	1º Dredge	A72822	12/15/2005	480	59	0.92	47	4100
E1-D	1º Dredge	A72823	12/15/2005	480	380	8.1	130	6800
FL-A	1º Dredge	A72289	12/9/2005	ND	86	1.7	28	ND
FL-B	1º Dredge	A72291	12/9/2005	ND	250	4.3	96	ND
FL-C	1º Dredge	A72292	12/9/2005	930	470	13	240	ND
FL-D	1º Dredge	A72293	12/9/2005	ND	68	1.1	53	ND
G1-A	1º Dredge	A67567	10/17/2005	3400	560	5.3	610	ND
G1-B	1º Dredge	A67568	10/17/2005	500	270	4.6	410	ND
G1-C	1º Dredge	A67569	10/17/2005	2680	420	7.2	360	ND
G1-D	1º Dredge	A67570	10/17/2005	190	49	0.84	47	ND
G1-A SAND	Post Sand	A69736	11/3/2005	ND	ND	ND	ND	ND
G1-C SAND	Post Sand	A69737	11/3/2005	ND	ND	ND	ND	ND
G1-D SAND	Post Sand	A69738	11/3/2005	ND	ND	ND	ND	ND
G2-A	1º Dredge	A67572	10/17/2005	ND	70	1.5	68	ND
G2-B	1º Dredge	A67573	10/17/2005	ND	3.4	ND	2.4	ND
G2-C	1º Dredge	A67574	10/17/2005	190	62	1.9	85	ND
G2-D	1º Dredge	A67575	10/17/2005	7400	710	8.4	590	ND
H & I1-A	1º Dredge	A67612	10/17/2005	1770	160	4.2	120	ND
H & I1-B	1º Dredge	A67613	10/17/2005	2200	210	4.7	270	ND
H & I1-C	1º Dredge	A67615	10/17/2005	8200	290	4.3	270	ND
H & I1-D	1º Dredge	A67616	10/17/2005	870	430	5.8	200	5600
A01-A	1º Dredge	A75218	3/14/06	ND	891	12.73	727	ND
A01-B	1º Dredge	A75219	3/14/06	880	1457	20.1	1430	ND
A01-C	1º Dredge	A75220	3/14/06	930	903	12.64	798	ND
A01-D	1º Dredge	A75221	3/14/06	1090	856	12.96	755	ND
A01-AR	2º Dredge	A77305	4/18/06	ND	755	19.87	598	ND
A01-BR	2º Dredge	A77306	4/18/06	ND	675	10.23	607	ND
A01-CR	2º Dredge	A77307	4/18/06	ND	736	10.65	657	ND
A01-DR	2º Dredge	A77308	4/18/06	ND	681	9.92	605	ND
A01-C1	Post Sand	A78384	5/4/06	ND	102	2.03	75	NA
A01-D1	Post Sand	A78385	5/4/06	ND	266	5.22	199	NA
A02-A	1º Dredge	A75222	3/14/06	1160	1143	13.6	748	ND
A02-B	1º Dredge	A75223	3/14/06	860	1169	13.79	760	ND

SUMMARY SEDIMENT CONFIRMATION DATA								
Sample	Phase	Lab Sample ID	Sampling Date	Total PCBs (µg/kg)	Chromium (mg/kg)	Cadmium (mg/kg)	Lead (mg/kg)	BaP (µg/kg)
A02-C	1º Dredge	A75225	3/14/06	940	960	12.87	763	ND
A02-D	1º Dredge	A75226	3/14/06	820	1198	11.24	770	ND
A02-AR	2º Dredge	A77309	4/18/06	ND	672	10.03	601	ND
A02-BR	2º Dredge	A77310	4/18/06	ND	244	3.89	198	ND
A02-CR	2º Dredge	A77312	4/18/06	ND	497	8.88	439	ND
A02-DR	2º Dredge	A77313	4/18/06	ND	440	7	355	ND
A03-A	1º Dredge	A75227	3/14/06	1980	2497	12.92	1186	ND
A03-B	1º Dredge	A75228	3/14/06	470	994	13.28	409	ND
A03-C	1º Dredge	A75229	3/14/06	440	2803	22.5	449	ND
A03-D	1º Dredge	A75230	3/14/06	ND	681	5.74	232	ND
A03-AR	2º Dredge	A77928	4/26/06	ND	355	2.62	123	ND
A03-BR	2º Dredge	A77929	4/26/06	650	943	13.13	809	ND
A03-CR	2º Dredge	A77930	4/26/06	ND	96	1.43	40	ND
A03-DR	2º Dredge	A77931	4/26/06	ND	54	1.13	18	ND
A04-A	1º Dredge	A75231	3/14/06	1100	1397	15.34	1036	ND
A04-B	1º Dredge	A75232	3/14/06	800	906	13.26	775	ND
A04-C	1º Dredge	A75233	3/14/06	630	813	16.46	1030	ND
A04-D	1º Dredge	A75234	3/14/06	ND	490	7.85	360	ND
A04-AR	2º Dredge	A77314	4/18/06	ND	686	9.48	482	ND
A04-BR	2º Dredge	A77315	4/18/06	ND	489	8.06	400	ND
A04-CR	2º Dredge	A77316	4/18/06	ND	440	7.01	335	ND
A04-DR	2º Dredge	A77317	4/18/06	ND	456	7.26	358	14000
A05-A	1º Dredge	A75235	3/14/06	1000	1388	15.16	1031	5100
A05-B	1º Dredge	A75236	3/14/06	830	950	14.34	899	ND
A05-C	1º Dredge	A75237	3/14/06	640	1168	15.7	927	ND
A05-D	1º Dredge	A75238	3/14/06	580	458	7.6	334	ND
A05-AR	2º Dredge	A77318	4/18/06	ND	626	9.32	467	ND
A05-BR	2º Dredge	A77319	4/18/06	700	589	8.84	432	ND
A05-CR	2º Dredge	A77320	4/18/06	ND	399	6.4	319	ND
A05-DR	2º Dredge	A77321	4/18/06	1300	822	21.71	962	ND
A05-AS	Post Sand	A79337	5/22/06	100	23	0.33	19	NA
A05-BS	Post Sand	A79338	5/22/06	93	41	0.76	34	NA
A05-CS	Post Sand	A79339	5/22/06	ND	2.3	ND	1.6	NA
A05-DS	Post Sand	A79340	5/22/06	ND	3	ND	2.3	NA
A06-A	1º Dredge	A75239	3/14/06	990	931	13.98	802	ND
A06-B	1º Dredge	A75240	3/14/06	740	857	13.4	768	5000
A06-C	1º Dredge	A75241	3/14/06	1220	1045	14.6	868	ND
A06-D	1º Dredge	A75243	3/14/06	1000	1621	19.42	1301	5300
A06-AR	2º Dredge	A77322	4/18/06	4600	636	9.84	493	ND
A06-BR	2º Dredge	A77323	4/18/06	ND	645	9.93	499	ND
A06-CR	2º Dredge	A77324	4/18/06	ND	338	5.21	259	ND
A06-DR	2º Dredge	A77326	4/18/06	ND	313	4.86	250	ND
A06-AS	Post Sand	A79341	5/22/06	75	15	ND	12	NA

SUMMARY SEDIMENT CONFIRMATION DATA								
Sample	Phase	Lab Sample ID	Sampling Date	Total PCBs (µg/kg)	Chromium (mg/kg)	Cadmium (mg/kg)	Lead (mg/kg)	BaP (µg/kg)
A06-BS	Post Sand	A79342	5/22/06	ND	2.7	ND	2.2	NA
A06-CS	Post Sand	A79343	5/22/06	ND	2.3	ND	1.5	NA
A06-DS	Post Sand	A79344	5/22/06	ND	6.7	0.25	5.1	NA
A07-A	1º Dredge	A75360	3/15/06	780	860	14.28	775	ND
A07-B	1º Dredge	A75361	3/15/06	440	822	13.89	753	ND
A07-C	1º Dredge	A75362	3/15/06	430	864	11.04	633	ND
A07-D	1º Dredge	A75363	3/15/06	680	424	12.88	757	6400
A07-AR	2º Dredge	A77327	4/18/06	400	2120	16.81	854	ND
A07-BR	2º Dredge	A77328	4/18/06	700	157	2.65	114	ND
A07-CR	2º Dredge	A77329	4/18/06	ND	343	6.47	267	ND
A07-DR	2º Dredge	A77330	4/18/06	ND	242	3.39	173	ND
A07-A1	Post Sand	A78383	5/4/06	ND	672	9.71	425	NA
A08-A	1º Dredge	A75351	3/15/06	520	992	13.27	707	ND
A08-B	1º Dredge	A75352	3/15/06	510	1158	12.38	406	ND
A08-C	1º Dredge	A75354	3/15/06	ND	777	6.12	270	ND
A08-D	1º Dredge	A75355	3/15/06	ND	583	4.78	192	ND
A09-A	1º Dredge	A75356	3/15/06	ND	371	3.58	150	ND
A09-B	1º Dredge	A75357	3/15/06	310	351	4.34	189	ND
A09-C	1º Dredge	A75358	3/15/06	ND	9.4	0.35	3.5	ND
A09-D	1º Dredge	A75359	3/15/06	ND	26	0.33	9.9	ND
A10-A	1º Dredge	A73971	1/31/06	2400	964	17.6	765	5100
A10-B	1º Dredge	A73972	1/31/06	3500	1495	14.72	910	ND
A10-C	1º Dredge	A73973	1/31/06	1420	882	13.05	739	ND
A10-D	1º Dredge	A73974	1/31/06	2010	890	12.23	683	ND
A10-AR	2º Dredge	A74464	2/15/06	ND	112	1.85	56	ND
A10-BR	2º Dredge	A74465	2/15/06	ND	120	2.33	81	ND
A10-CR	2º Dredge	A74466	2/15/06	ND	204	3.35	152	ND
A10-DR	2º Dredge	A74467	2/15/06	ND	311	4.96	202	ND
A11-A	1º Dredge	A73894	1/30/06	1380	932	11.5	741	ND
A11-B	1º Dredge	A73895	1/30/06	530	747	15.29	775	ND
A11-C	1º Dredge	A73969	1/31/06	ND	415	7.74	336	ND
A11-D	1º Dredge	A73970	1/31/06	2290	1000	15.58	951	ND
A11-AR	2º Dredge	A74468	2/15/06	ND	194	3.83	154	ND
A11-BR	2º Dredge	A74469	2/15/06	ND	106	2.15	72	ND
A11-CR	2º Dredge	A74470	2/15/06	ND	79	1.44	49	ND
A11-DR	2º Dredge	A74471	2/15/06	ND	599	8.47	372	ND
A12-A	1º Dredge	A73890	1/30/06	ND	34	0.99	46	ND
A12-B	1º Dredge	A73891	1/30/06	2450	1968	14.71	908	ND
A12-C	1º Dredge	A73892	1/30/06	610	754	11.38	591	ND
A12-D	1º Dredge	A73893	1/30/06	1500	689	12.64	697	ND
A13-A	1º Dredge	A73886	1/30/06	550	1009	14.44	1012	ND
A13-B	1º Dredge	A73887	1/30/06	ND	293	5.91	281	ND
A13-C	1º Dredge	A73888	1/30/06	640	929	15.77	843	ND

SUMMARY SEDIMENT CONFIRMATION DATA								
Sample	Phase	Lab Sample ID	Sampling Date	Total PCBs (µg/kg)	Chromium (mg/kg)	Cadmium (mg/kg)	Lead (mg/kg)	BaP (µg/kg)
A13-D	1º Dredge	A73889	1/30/06	630	381	8.76	431	ND
A14-A	1º Dredge	A73881	1/30/06	ND	914	14.31	834	ND
A14-B	1º Dredge	A73882	1/30/06	1300	683	11.52	620	ND
A14-C	1º Dredge	A73884	1/30/06	ND	440	8.93	396	ND
A14-D	1º Dredge	A73885	1/30/06	ND	348	6.92	339	ND
S-1	Kriged Samples	A78378	5/4/06	690	491	7.15	305	NA
S-2	Kriged Samples	A78379	5/4/06	ND	186	3.76	164	NA
S-3	Kriged Samples	A78380	5/4/06	ND	99	3.67	138	NA
S-4	Kriged Samples	A78381	5/4/06	1360	1242	21.97	747	NA
S-5	Kriged Samples	A78382	5/4/06	ND	200	3.79	145	NA
A15-A	1º Dredge	A73877	1/30/06	ND	439	8.66	363	ND
A15-B	1º Dredge	A73878	1/30/06	ND	363	7.79	313	ND
A15-C	1º Dredge	A73879	1/30/06	ND	655	9.91	396	ND
A15-D	1º Dredge	A73880	1/30/06	ND	453	8.22	322	ND
A 16-A	1º Dredge	A72115	12/7/05	890	590	9.2	420	ND
A 16-B	1º Dredge	A72116	12/7/05	1640	300	4.7	190	ND
A 16-C	1º Dredge	A72117	12/7/05	620	960	12	480	ND
A 16-D	1º Dredge	A72118	12/7/05	720	900	11	460	ND
A17-A	1º Dredge	A70888	11/15/05	ND	240	3.9	130	ND
A17-B	1º Dredge	A70889	11/15/05	ND	66	0.71	32	ND
A17-C	1º Dredge	A70890	11/15/05	310	130	1.6	64	ND
A17-D	1º Dredge	A70891	11/15/05	ND	6.5	ND	2.8	ND
A18-A	1º Dredge	A73873	1/30/06	ND	97	1.73	71	ND
A18-B	1º Dredge	A73874	1/30/06	ND	411	7.59	301	ND
A18-C	1º Dredge	A73875	1/30/06	ND	5.6	ND	3.9	ND
A18-D	1º Dredge	A73876	1/30/06	ND	215	3.1	126	ND
A19-A	1º Dredge	A70966	11/16/05	ND	39	0.86	27	ND
A19-B	1º Dredge	A70967	11/16/05	720	640	9.3	360	ND
A19-C	1º Dredge	A70969	11/16/05	260	470	8	300	ND
A19-D	1º Dredge	A70970	11/16/05	540	750	11	430	ND
A20-A	1º Dredge	A70962	11/16/05	910	2500	13	1100	ND
A20-B	1º Dredge	A70963	11/16/05	870	850	12	620	ND
A20-C	1º Dredge	A70964	11/16/05	1180	760	11	430	ND
A20-D	1º Dredge	A70965	11/16/05	2200	1600	26	1200	ND
A20-A RD	2º Dredge	A72119	12/7/05	NA	500	7.7	NA	NA
A20-B RD	2º Dredge	A72120	12/7/05	NA	410	6.4	NA	NA
A20-C RD	2º Dredge	A72121	12/7/05	NA	630	8.8	NA	NA
A20-D RD	2º Dredge	A72122	12/7/05	NA	630	8.6	NA	NA
A21-A	1º Dredge	A70957	11/16/05	660	500	5.5	170	ND
A21-B	1º Dredge	A70958	11/16/05	670	880	14	760	ND
A21-C	1º Dredge	A70960	11/16/05	670	820	13	620	ND
A21-D	1º Dredge	A70961	11/16/05	810	630	8.4	380	ND
A21-A RD	2º Dredge	A72123	12/7/05	NA	150	2.1	NA	NA

SUMMARY SEDIMENT CONFIRMATION DATA								
Sample	Phase	Lab Sample ID	Sampling Date	Total PCBs (µg/kg)	Chromium (mg/kg)	Cadmium (mg/kg)	Lead (mg/kg)	BaP (µg/kg)
A21-B RD	2º Dredge	A72124	12/7/05	NA	860	11	NA	NA
A21-C RD	2º Dredge	A72126	12/7/05	NA	670	9.1	NA	NA
A21-D RD	2º Dredge	A72127	12/7/05	NA	490	25	NA	NA
A22-A	1º Dredge	A70884	11/15/05	790	1200	15	770	ND
A22-B	1º Dredge	A70885	11/15/05	340	790	9.6	450	ND
A22-C	1º Dredge	A70886	11/15/05	900	1200	11	710	ND
A22-D	1º Dredge	A70887	11/15/05	410	760	9	440	ND
A22-A RD	2º Dredge	A72128	12/7/05	NA	550	5.9	NA	NA
A22-B RD	2º Dredge	A72129	12/7/05	NA	790	10	NA	NA
A22-C RD	2º Dredge	A72130	12/7/05	NA	220	1.7	NA	NA
A22-D RD	2º Dredge	A72131	12/7/05	NA	310	3.9	NA	NA
A23-A	1º Dredge	A70879	11/15/05	620	660	9	450	ND
A23-B	1º Dredge	A70881	11/15/05	340	1100	8.7	660	ND
A23-C	1º Dredge	A70882	11/15/05	340	580	7.2	390	ND
A23-D	1º Dredge	A70883	11/15/05	ND	400	5.6	300	ND
A24-A	1º Dredge	A70875	11/15/05	ND	330	5.5	290	ND
A24-B	1º Dredge	A70876	11/15/05	ND	90	1.7	56	ND
A24-C	1º Dredge	A70877	11/15/05	ND	180	2.4	140	ND
A24-D	1º Dredge	A70878	11/15/05	ND	81	1.4	69	ND
A25-A	1º Dredge	A70870	11/15/05	ND	79	1.5	76	ND
A25-B	1º Dredge	A70871	11/15/05	ND	150	2.2	130	ND
A25-C	1º Dredge	A70872	11/15/05	ND	190	2.6	260	ND
A25-D	1º Dredge	A70874	11/15/05	ND	140	2.8	270	ND
BC-01	Staging Pad	A76660	4/7/06	ND	28	0.72	56	ND
BC-02	Staging Pad	A76661	4/7/06	ND	17	0.42	34	120
BC-03	Staging Pad	A76662	4/7/06	ND	34	0.74	47	140
BC-04	Staging Pad	A76663	4/7/06	ND	18	0.33	30	ND
GC-01	Staging Pad	A76664	4/7/06	ND	16	0.32	30	290
GC-02	Staging Pad	A76665	4/7/06	ND	12	ND	22	170
MP-1	Staging Pad	A79528	5/24/06	ND	3.3	ND	3.7	ND
MP-2	Staging Pad	A79529	5/24/06	ND	5.5	ND	4.2	ND
MP-3	Staging Pad	A79530	5/24/06	ND	8.2	ND	8.3	ND
MP-4	Staging Pad	A79531	5/24/06	ND	2.1	ND	18	ND
MP-5	Staging Pad	A79532	5/24/06	ND	3.1	ND	14	ND
MP-6	Staging Pad	A79533	5/24/06	ND	14	0.23	38	140

ND = non-detect
NA = not applicable

APPENDIX B SUMMARY SEDIMENT CONCENTRATION DATA, 2004

Sediment Concentrations from 2004 Sediment Survey			
Ruddiman Creek			
Contaminant	**Maximum Sediment Concentration (mg/kg, dry weight)**	**Cleanup Criterion (mg/kg, dry weight)**	**Ratio of Maximum Sediment Concentration to Cleanup Criterion**
Benzo(a)pyrene	19	16	1.19
Cadmium	31	10	3.10
Chromium	2,040	400	5.10
Total PCBs	19	1	19.00
Ruddiman Pond			
Benzo(a)pyrene	3.4	16	0.21
Cadmium	25	10	2.50
Chromium	2,090	400	5.23
Total PCBs	67	1	67.00

Data taken from Earth Tech, *2004 Technical Memorandum for Ruddiman Creek Soil and Groundwater Investigation, Muskegon, Michigan.*

Ruddiman Creek Main Branch and Pond

Fact Sheets: July 2005 and May 2006

EPA
United States
Environmental Protection
Agency

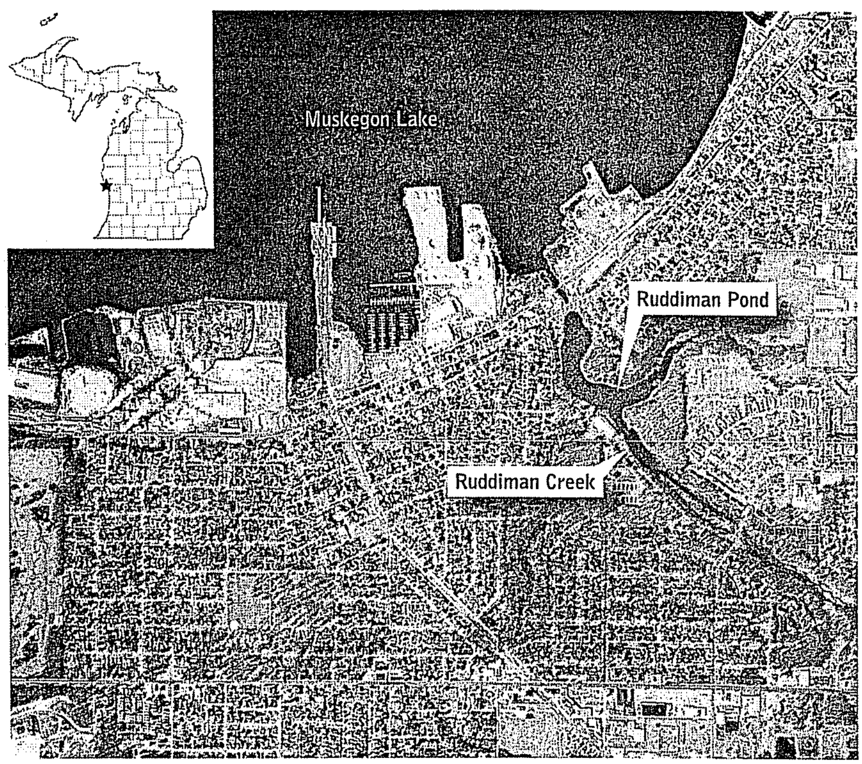
Ruddiman Creek/Pond Dredging Project Will Remove Contaminants

Muskegon Lake Area of Concern
Muskegon, Michigan July 2005

The long-awaited cleanup of Ruddiman Creek and Ruddiman Pond will begin soon, according to U.S. Environmental Protection Agency's Great Lakes National Program Office and the Michigan Department of Environmental Quality. The federal and state agencies recently agreed on details of the cleanup plan. Work on this Great Lakes Legacy Act project may begin as soon as mid-August.

Ruddiman Creek and Ruddiman Pond are part of the designated Muskegon Lake "area of concern" or AOC. Contaminants are present at high enough concentrations that they can affect human health, wildlife and aquatic life. Currently the main branch of Ruddiman Creek is posted as a no swimming, fishing or recreation area due in part to contaminated sediment. EPA and Michigan DEQ, in partnership with a local public advisory council, have developed a contaminated sediment removal and site cleanup project for the creek and the pond.

The $10.6 million project is expected to take about nine months to remove about 80,000 cubic yards of contaminated sediment (mud). Under the Great Lakes Legacy Act of 2002, $6.9 million or 65 percent of cleanup costs are paid for with federal funds. The other 35 percent or



This is an aerial view of the area where contaminated sediment will be removed from Ruddiman Creek and Ruddiman Pond.

For more information

If you would like more information on the Ruddiman Creek/Ruddiman Pond project, you may contact one of the following team members:

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To learn more about the Great Lakes Legacy Act, please visit www.epa.gov/glla/

$3.7 million must be non-federal, in this instance funds from the state's Clean Michigan Initiative.

The main contaminants of concern include cadmium, found in the sediment with a maximum level of 25 parts per million; chromium, found at 5,900 ppm; polychorinated biphenyls, usually called PCBs, found at 6 ppm; and lead, found at 1,200 ppm. This project will remove a substantial amount of these contaminants: an estimated 2,800 pounds of cadmium, 320 pounds of PCBs, 204,000 pounds of chromium and 126,000 pounds of lead.

Project details

The sediment removal and cleanup project will have different approaches for the creek and the pond. Creek sediment cleanup includes road construction to get access to the creek. The creek will be diverted and temporary walls will be constructed so the sediment can be removed under dry conditions. The pond will be dredged and any resuspended sediments will be controlled with barriers called silt curtains. The curtains will hold the material stirred up during dredging. Contaminated sediment will be hauled by truck to a licensed landfill near Muskegon, and sampling will be done during and after the project to make sure contamination levels are reduced.

Finally, after sediment cleanup, the creek and pond will be reconstructed and water flow patterns restored. Bare sections will also be replanted with native species of flowers, trees and grasses.

About the Great Lakes Legacy Act

Although discharges of toxic substances into the Great Lakes have been reduced over the last 20 years, high concentrations of pollution remain in the bottom of some rivers and harbors. That poses a potential risk to people and wildlife. As a result, states have issued advisories in most locations around the Great Lakes against eating locally caught fish. The tributaries and harbors identified as having pollution problems are known as "areas of concern," or AOCs. There are 31 AOCs on the American side of the Great Lakes. Ruddiman Creek is part of the Muskegon Lake AOC.

Congress passed and the President signed the Great Lakes Legacy Act of 2002 to address the problem of contaminated sediment in these 31 areas. The Legacy Act authorizes $270 million in funding over five years for cleanups. Fiscal Year 2004 was the first in which Legacy Act funds were available for projects, and Congress appropriated $10 million. For the current fiscal year, Congress appropriated $22.3 million.

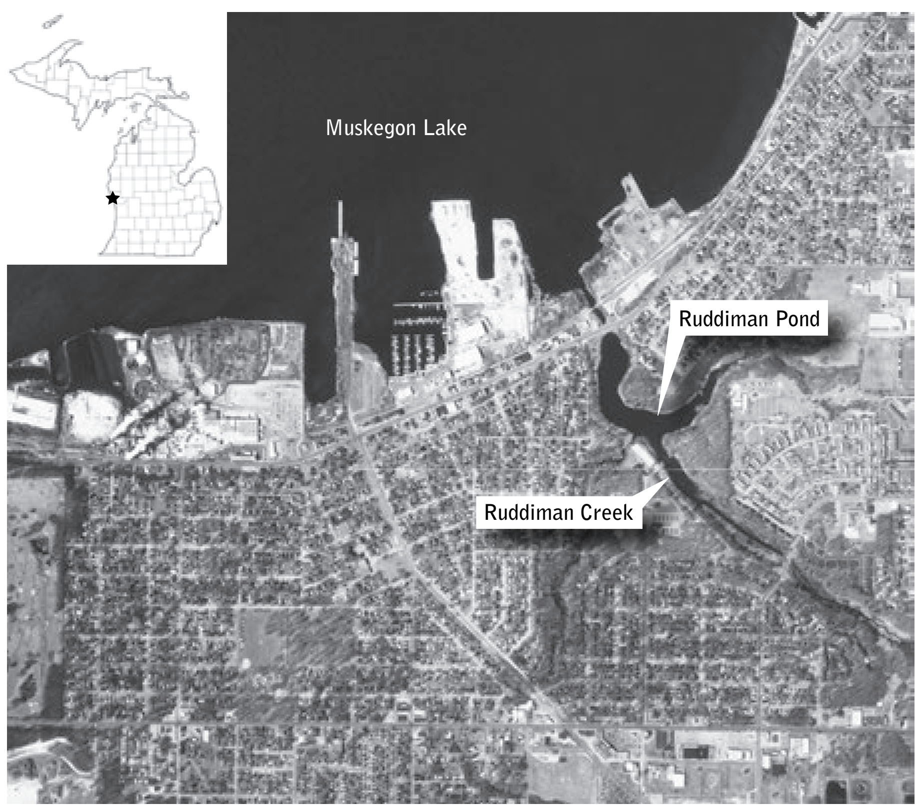
Great Lakes Legacy Act Cleanup of Ruddiman Creek Finished on Schedule

Muskegon Lake Area of Concern
Muskegon, Michigan May 2006

Federal and state government officials say the $13.5 million dredging and cleanup project for Ruddiman Creek and Ruddiman Pond finished on schedule this month and resulted in the removal of about 90,000 cubic yards of contaminated mud. U.S. Environmental Protection Agency's Great Lakes National Program Office and the Michigan Department of Environmental Quality oversaw the cleanup effort, which lasted about nine months.

Ruddiman Creek and Ruddiman Pond are part of the designated Muskegon Lake "area of concern" or AOC. Contaminants present in the creek and pond posed potential health risks to humans and wildlife exposed to the pollution. The cleanup project should help speed the lifting of fishing and recreation bans in effect on the main branch of Ruddiman Creek.

EPA and Michigan DEQ, in partnership with the citizen groups Muskegon Lake Public Advisory Council and the Ruddiman Creek Task Force, developed a contaminated sediment removal and site cleanup project for the creek and the pond. Local citizens worked for years advocating for the cleanup, which finally got moving thanks to the federal Great Lakes



This is an aerial view of the area where contaminated sediment was removed from Ruddiman Creek and Ruddiman Pond.

For more information

If you would like more information on the Ruddiman Creek/Ruddiman Pond project, you may contact one these team members:

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To learn more about the Great Lakes Legacy Act, please visit epa.gov/glla/

Legacy Act (see box last page for more details on the GLLA). Legacy Act funds paid for 65 percent, or about $8.8 million, of the Ruddiman Creek project. The other 35 percent, or $4.7 million, came from the state's Clean Michigan Initiative.

The Legacy Act strives to streamline the cleanup process while emphasizing collaboration among governments and community groups. EPA officials hailed the Ruddiman Creek project as successfully achieving these purposes.

Project details

The main contaminants of concern at Ruddiman Creek included lead, cadmium, chromium and polychorinated biphenyls, usually called PCBs. The project removed 126,000 pounds of lead, 2,800 pounds of cadmium, 204,000 pounds of chromium and 320 pounds of PCBs.

The sediment removal and cleanup project used different approaches for the creek and the pond. Creek sediment cleanup included road construction to get access to the water. The creek was diverted and temporary walls were constructed so the sediment could be removed under dry conditions. The only snag in the project occurred during the winter when a road turned out to be too soft to support equipment trying to reach the northern end of Ruddiman Creek. The problem was quickly solved by building a pontoon road and by using a special dredge mounted on floats.

The pond was dredged, and barriers called silt curtains held the material stirred up during the work. Contaminated sediment was hauled by truck to a licensed landfill near Muskegon, and sampling was done during and after the project to make sure contamination levels were reduced.

For the first time during an EPA dredging project, the Agency posted weekly updates and plotted the volume of sediment removed on an Agency Web site so people could follow the cleanup progress.

After dredging was completed, the creek and pond were reconstructed and water flow patterns restored. Workers are currently finishing up by replanting bare sections of the banks and construction roads with native species of flowers, trees and grasses. The public was given a walking tour of the area in April. The community will be responsible for follow-up care and monitoring of the restoration area. Local environmental activists say there are already reports of lake salmon returning to Ruddiman Creek. During the dredging, great blue herons perched on silt curtains to watch for fish.

About the Great Lakes Legacy Act

Although discharges of toxic substances into the Great Lakes have been reduced over the last 20 years, high concentrations of pollution remain in the bottom of some rivers and harbors. That poses a potential risk to people and wildlife. As a result, states have issued advisories in most locations around the Great Lakes against eating locally caught fish. The tributaries and harbors identified as having pollution problems are known as "areas of concern," or AOCs. There are 31 AOCs on the American side of the Great Lakes. Ruddiman Creek is part of the Muskegon Lake AOC.

Congress passed and the President signed the Great Lakes Legacy Act of 2002 to address the problem of contaminated sediment in these 31 areas. The Legacy Act authorizes $270 million in funding over five years for cleanups. Fiscal Year 2004 was the first in which Legacy Act funds were available for projects, and Congress appropriated $9.9 million. In 2005 Congress appropriated $22.3 million, and $29.6 million was appropriated in 2006 for Legacy Act cleanups. The President has requested $49.6 million in the proposed 2007 budget. Ruddiman Creek joins the Black Lagoon near Detroit and Hog Island in Superior, Wis., as completed Legacy Act projects. The largest Legacy Act project to date in both cost ($50 million) and volume (600,000 cubic yards of sediment) is currently underway in Ashtabula, Ohio.

Ruddiman Creek Main Branch and Pond

Design Drawings

ENVIRONMENTAL QUALITY MANAGEMENT, INC.
1800 CARILLON BLVD.
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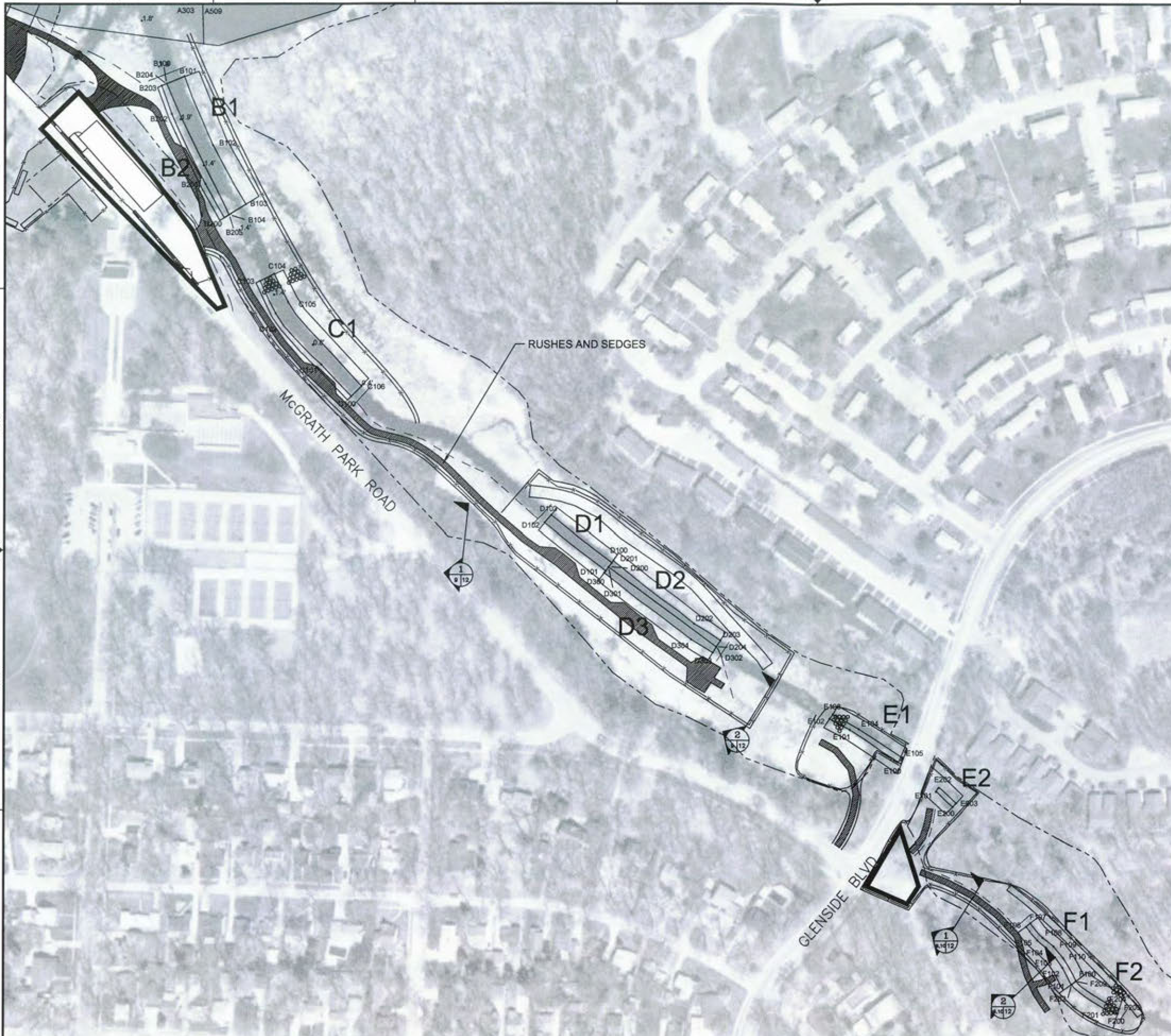
F (513)825-7495

DRAWN	D.TOMO	3/18/05
CHECKED	T.HILGEMAN	6/28/05
APPROVED	N.MORSTADT	6/28/05
SCALE:	1=100	

RUDDIMAN CREEK
BARCLAY ROAD AREA

ORIGINAL SIZE	PROJECT NO.	DWG NO.	REV
D	030228.0036	FIGURE A-1	0



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DRAWN	D.TOMO	3/18/05
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SCALE:	1=100	

RUDDIMAN CREEK
GLENSIDE BLVD. AREA

ORIGINAL SIZE	PROJECT NO.	DWG NO.	REV
D	030228.0036	FIGURE A-2	0

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RUDDIMAN CREEK
LAGOON AREA

DRAWN	D.TOMO	3/18/05
CHECKED	T.HILGEMAN	6/28/05
APPROVED	N.MORSTADT	6/28/05
SCALE:	1=100	

ORIGINAL SIZE	PROJECT NO.	DWG NO.	REV
D	030228.0036	FIGURE A-3	0