

## **TITTABAWASSEE RIVER SEGMENT 1 (OU 1) RESPONSE PROPOSAL**



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## Acronyms and Abbreviations

µm	microns
2,3,7,8-TCDD	2,3,7,8-tetrachlorodibenzo-p-dioxin
Agencies	EPA and DEQ
amsl	above mean sea level
AOC	Administrative Settlement Agreement and Order of Consent
ARAR	applicable or relevant and appropriate requirement
BMP	best management practice
CAG	Community Advisory Group
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
cfs	cubic feet per second
cm/s	centimeters per second
cm/y	centimeters per year
COI	constituent of interest
C-R	concentration-response
CSM	conceptual site model
CWA	Clean Water Act
cy	cubic yards
DDD	Dichlorodiphenyldichloroethane
DDE	Dichlorodiphenyldichloroethylene
DEQ	Michigan Department of Environmental Quality
DNAPL	dense non-aqueous phase liquid
DNRE	Michigan Department of Natural Resources and Environment (now DEQ)
Dow	Dow Chemical Company
EE/CA	Engineering Evaluation/Cost Analysis
eMACT	Maximum Achievable Control Technology
EPA	U.S. Environmental Protection Agency
EqP	equilibrium partitioning
ERM	Environmental Resources Management
ESA	Endangered Species Act
ESLBs	ecological screening level benchmarks
ESB	equilibrium sediment benchmark

EVS	Environmental Visualization System
FS	Feasibility Study
ft	feet or foot
GCL	geosynthetic clay liner
GLEC	Great Lakes Environmental Center
gpm	gallons per minute
GPS	Global positioning system
GRA	General Response Action
GU	guideline unit
HASP	Health and Safety Plan
HCB	hexachlorobenzene
HDPE	High-density polyethylene
IRA	interim response action
LDR	Land Disposal Restrictions
LWAc	length-weighted average
MACT	Maximum Achievable Control Technology
MDCH	Michigan Department of Community Health
mg/kg	milligrams per kilogram
mi	miles
MIOSHA	Michigan Occupational Health and Safety Administration
MNFI	Michigan Natural Features Inventory
MNR	monitored natural recovery
NAPL	non-aqueous phase liquid
NAVD88	North American Vertical Datum of 1988
NCP	National Contingency Plan
NHPA	National Historic Preservation Act
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NSR	no significant risk
NTCRA	Non-Time-Critical Removal Action
OC	organic carbon
oPP	ortho-phenylphenol
OSHA	Occupational Safety and Health Administration

OU	operable unit
PAH	polynuclear aromatic hydrocarbon
PCOI	primary constituent of interest
PER	potential for exposure/risk
PLER	potential for low exposure/risk
ppt	parts per trillion
QAPP	quality assurance project plan
RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act
RGIS	revetment groundwater interception system
RRA	Residual Risk Assessment
RTK	Real-time kinematic
SCDM	Superfund Chemical Data Matrix
SCOI	secondary constituents of interest
Site	Tittabawassee River/Saginaw River & Bay Site
SMA	sediment management areas
SOW	Statement of Work
SPMD	semi-permeable membrane device
sq ft	square foot (or feet)
sq mi	square mile(s)
SWAC	surface-weighted average concentrations
TBC	to be considered guidance
TMDL	total maximum daily load
TEQ	toxic equivalent concentration
TIC	tentatively identified compounds
TIN	triangular irregular network
TRV	toxicity reference value
TOC	total organic carbon
T-pond	tertiary treatment pond
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
VOC	volatile organic compound

WPCA                Federal Water Pollution Control Act  
WWTP Wastewater Treatment Plant

## Executive Summary

In January 2010, The Dow Chemical Company (Dow) entered into an Administrative Settlement Agreement and Order on Consent (AOC) for Remedial Investigation, Feasibility Study and/or Engineering Evaluation and Cost Analysis (EE/CA), and Response Design with the U.S. Environmental Protection Agency (EPA) and the Michigan Department of Environmental Quality (DEQ; collectively the “Agencies”) to evaluate current conditions and assess response options for the Tittabawassee River/Saginaw River & Bay Site (“Site”) in a sequential upstream-to-downstream process. This Segment 1 Response Proposal addresses the 3.1-mile reach of the Site that begins at the confluence of the Chippewa and Tittabawassee Rivers.

Dow owns most of the land along both banks of Segment 1 and actively uses these areas for industrial purposes. Segment 1 is characterized by engineered banks (e.g., embankments, riprap, and sheet pile), and includes limited floodplain (predominantly on the west side of the river), which includes Dow buildings, roads, water impoundments, drainage channels, and grassy areas maintained to protect the industrial berms along the river.

Under the oversight of the Agencies, Dow successfully implemented a decades-long series of source control actions at the Site, including development and operation of a wastewater treatment system, elimination of multiple wastewater outfalls, and installation of a groundwater intercept system. These substantial investments and continued operations have dramatically reduced and controlled discharges of chemicals of potential concern to the river from the facility. Dow and the Agencies are continuing to monitor the effectiveness of these source control actions, as source control is a critical first step towards achieving sediment cleanup objectives.

Since 2007, Dow has also implemented a number of early sediment cleanup actions in the Tittabawassee River and associated floodplains under the oversight of the Agencies. Early actions in the upstream reaches of Segment 1 (above the Dow Dam) included focused sediment and debris removal and capping, and monitoring to date has documented significant reductions in the concentrations of chemicals of potential concern in Segment 1. Long-term monitoring and management, as necessary to ensure the continued effectiveness of these early actions is being incorporated into the overall Segment 1 response action.

This Segment 1 Response Proposal characterizes the nature and extent of current conditions in Segment 1. The site characterization is based on a detailed analysis of information gathered during a series of site-specific investigations, modeling efforts, and removal actions undertaken at the Site since 1998. The existing body of knowledge is sufficient to characterize the nature and extent of impacted sediment in Segment 1 and to support a comparative analysis of alternatives for this Response Proposal.

Multiple lines of information were used to define Segment 1 sediment management areas (SMAs) and evaluate response options to address those areas. A total of six SMAs were delineated in Segment 1 based on the location of sediment deposits containing elevated chemical concentrations, also considering the three-dimensional distribution of sediment chemicals of potential concern, sediment stability assessments along with the active bed depth, the depth of

underlying confining layers, and initial engineering design. The SMA boundaries delineated for this Segment 1 Response Proposal are subject to further refinement during the remedial design phase, including additional sampling as necessary.

Remedial action objectives (RAOs) were developed for Segment 1 to clarify what remedial actions should accomplish based on an understanding of media, potential exposure pathways, and potential receptors that may be impacted. For Segment 1, in-channel sediments are the primary media of interest. The interactions between sediments, aquatic biota, and terrestrial biota or humans determine whether there are potentially complete exposure pathways, and whether a response is warranted. The Segment 1 RAOs were developed in consultation with the Agencies, and focus on reducing potential exposures to and transport of impacted media. Achievement of the RAOs will be evaluated based on follow-on monitoring and residual risk evaluations as described in the AOC.

This Segment 1 Response Proposal describes 12 potential response alternatives (three alternatives each for four SMA groupings). The SMA-specific alternatives included appropriate combinations of monitored natural recovery, containment, and removal. Each of these alternatives is evaluated based on overall effectiveness, implementability, and cost, in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), and Agency guidance.

Each of the 12 SMA-specific response option alternatives for Segment 1 are evaluated – both individually and comparatively – against decision-making criteria required by CERCLA and the NCP. The individual and comparative evaluations, along with results of site-specific modeling and data analyses, indicate that all 12 alternatives can be implemented, and are projected to achieve RAOs.

Based on the evaluations in this Segment 1 Response Proposal, and in accordance with EPA's regulations, guidance and policy, EPA will select an appropriate combination of technologies specific to each SMA that will be effective and implementable, resulting in a protective and cost-effective approach with minimal short-term impacts. Dow is working with the Agencies to achieve an effective long-term remedy for the Site. In-water construction within Segment 1 is anticipated to take place in 2012 and 2013, following a projected 2011 Action Memorandum and follow-on remedial design and EPA implementation agreements.

## 1.0 Introduction

The Administrative Settlement Agreement and Order on Consent (AOC) for the Tittabawassee River/Saginaw River & Bay Site (“Site”) (Settlement Agreement No. V-W-10-C-942) and associated Statement of Work (SOW; Attachment A of AOC), effective January 21, 2010, set forth requirements for conducting evaluations of current conditions and assessments of response options at the Site. Task 8 of the SOW describes the development of sequential upstream-to-downstream segment-specific Response Proposals for the Site beginning with the most upstream Segment 1 (Reaches A to H; Figure 1-1). Consistent with the SOW requirements, the overall objectives of the Segment 1 Response Proposal are to:

1. Characterize the nature and extent of hazardous substances that have been released from Dow’s Midland facility to Segment 1
2. Develop Segment 1 response remedial action objectives (RAOs)
3. Identify and evaluate alternatives for achieving Segment 1 RAOs

This Segment 1 Response Proposal was prepared for the U.S. Environmental Protection Agency (EPA) and the Michigan Department of Environmental Quality (DEQ; collectively the “Agencies”) by the Tittabawassee & Saginaw River Team, comprised of The Dow Chemical Company (Dow), Anchor QEA, ENVIRON, and ATS.

### 1.1 Basis for Non-Time-Critical Removal Action (NTCRA) Process

As discussed in SOW Task 8.4.2 - Response Process, EPA’s Removal and/or Remedial Programs under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), as amended, and National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (40 C.F.R. Part 300), as amended, may be used to develop the Segment-Specific Response Proposals, potentially using one or more of the following processes:

- The Non-Time-Critical Removal Action (NTCRA) process, which would result in an EPA-issued Action Memorandum;
- The Remedial Program process, which would result in an EPA-issued Record of Decision; or
- A combination of approaches.

Consistent with the AOC requirements, the Segment 1 Response Proposal scoping meeting between the Agencies and Dow occurred on February 25, 2010. During the scoping meeting, the general requirements of the Segment 1 Response Proposal were discussed, and the Site characterization data available for Segment 1 were broadly summarized. Additionally, the criteria to distinguish whether the Removal or Remedial Programs might be more appropriate for Segment 1 were discussed, particularly the considerations for a NTCRA.

In May 2010, Dow submitted to the Agencies a request to use the NTCRA process for this Segment 1 Response Proposal, based on a detailed review of the removal and remedial approaches, which concluded that the NTRCA process provides the optimal combination of

protectiveness and efficiency to develop a response action for Segment 1, consistent with the requirements of the AOC/SOW. On November 8, 2010, EPA concluded that the conditions at Segment 1 meet the NCP criteria for a removal action.

This Segment 1 Response Proposal is an Engineering Evaluation/Cost Analysis (EE/CA) prepared in accordance with CERCLA and NCP requirements and in accordance with the requirements of SOW Section VIII.G. Under the NTCRA process, an EE/CA serves as the site-specific Response Proposal to identify and evaluate appropriate response options that protect human health and the environment. A subsequent Action Memorandum to be issued by the EPA will serve as the Segment 1 decision document.

## **1.2 Response Proposal Organization**

This Segment 1 Response Proposal includes the following sections:

- Section 1 - Introduction
- Section 2 – Site Description and Background
- Section 3 – Summary of Segment 1 Conditions
- Section 4 – Segment 1 RAOs
- Section 5 – Segment 1 Response Technology Screening
- Section 6 – Segment 1 Response Action and Options
- Section 7 – Response Action Alternative Evaluation
- Section 8 – Response Proposal
- Section 9 - References

Appendices attached to this Segment 1 Response Proposal present detailed descriptions of the differential bathymetry data (Appendix A), Segment 1 biological data (Appendix B), development of the sediment transport model (Appendix C), a review of response technologies implemented at other sites (Appendix D), preliminary engineering evaluations performed to assess sediment caps (Appendix E), and cost estimates for response alternatives (Appendix F).

## **2.0 Site Description and Background**

### **2.1 Tittabawassee River (OU 1) Description**

The Tittabawassee River, a tributary of the Saginaw River, drains approximately 2,600 square miles (sq mi) of land within the Saginaw River watershed. The headwaters of the Tittabawassee River begin in Roscommon and Ogemaw Counties, approximately 26 miles (mi) to the north of Midland and Saginaw Counties. The river flows south and southeast for approximately 80 mi to its confluence with the Shiawassee River, approximately 22 mi southeast of the City of Midland. Most of the Tittabawassee River watershed upstream of Midland is forested or agricultural. The Pine and Chippewa Rivers are two of the tributaries of the Tittabawassee River and together contribute approximately 40 percent of the Tittabawassee flow at Midland (DNRE 1988).

Upstream of the Midland plant, the Tittabawassee River's flow is regulated by the Ross, Secord, Smallwood, Edenville, and Sanford Dams. The current operation of the hydroelectric station at the Sanford Dam results in water releases from Sanford Dam during peak electricity usage periods to provide peaking power. The Tittabawassee River's flow rate and water level can fluctuate daily in response to the variable releases from the dam in accordance with the dam's operating permit.

The Tittabawassee River comprises approximately 40 percent of the Saginaw sub-basin and, on average, contributes 40 percent of the Saginaw River's flow. The average and 100-year flood discharges for the Tittabawassee River (based on data from 1937 to 1984) are approximately 1,700 cubic feet per second (cfs) and 45,000 cfs, respectively. The relatively large variance between the long-term average and 100-year flood discharge is characteristic of highly variable flow regimes in the Tittabawassee River, which change rapidly in response to rainfall and snow melt.

The average monthly discharge from 1937 to 2003 for the Tittabawassee River measured approximately 0.4 mi downstream of the Dow Dam varies seasonally, ranging from approximately 600 cfs (in August) to 3,900 cfs (in March), again with an annual average of 1,700 cfs. Discharge is typically highest during March and April spring snow melt and runoff. The maximum recorded historical crest of the Tittabawassee River occurred in 1986. A large storm in September 1986 produced up to 14 inches of rain in 12 hours. The discharge of the river near the Dow Dam reached nearly 40,000 cfs, and the river stage was 10 feet (ft) above flood stage at its crest. Flows greater than 20,000 cfs have occurred in 22 of the 95 years between 1910 and 2004, with flows greater than 30,000 cfs occurring in 1912, 1916, 1946, 1948, and 1986. In March 2004, the river discharge reached approximately 24,000 cfs (ATS 2009).

### **2.2 Segment Description**

#### **2.2.1 Physical Location**

As defined in the SOW, Segment 1 of the Tittabawassee River begins at the confluence of the Chippewa and Tittabawassee Rivers, and extends approximately 3.1 mi to the confluence with Lingle Drain. Segment 1 is located within the City of Midland and Midland Township; Dow's Midland facility is adjacent to a significant portion of this segment. The Dow Dam, constructed in

1939 to increase the depth of the river upstream to facilitate withdrawal of water from the river for the Dow plant and the City of Midland (Schrouder et al. 2008), is located approximately one-third of the way through Segment 1. The normal river stage in Segment 1 downstream of the dam is approximately 590 ft above mean sea level (amsl, North American Vertical Datum of 1988 [NAVD 88]), while Segment 1 water levels upstream of the dam average approximately 596.5 ft amsl. Water pumped from the upstream side of the dam continues to be used at the facility for cooling and other purposes. Figure 2-1 shows the layout of Segment 1.

Two small channelized streams discharge into Segment 1. Bullock Creek flows along the south and east sides of Dow's Tertiary Treatment Pond (T-Pond) and discharges to the Tittabawassee River in the downstream portion of Segment 1. Lingle Drain flows along the east side of the main facility from north to south, and discharges into the river at the terminus of Segment 1. A constructed drainage channel discharges to the west bank of the river in the upper reaches of Segment 1.

### **2.2.2 Floodplain and Upland Land Ownership and Uses**

The uplands that border Segment 1 are currently used for industrial uses. Dow owns most of the land along both banks of Segment 1 and actively uses these areas for industrial purposes. Midland Cogeneration Venture operates a natural gas-powered electrical generation station on the southwest bank in the downstream portion of Segment 1. Segment 1 includes limited floodplain, which is owned by either Dow or the Midland Cogeneration Venture. Other limited floodplain adjacent to Segment 1 (predominantly on Dow's west side of the river), includes buildings, roads, water impoundments, drainage channels, and grassy areas maintained to protect the industrial berms along the river. There are minimal wetlands in the floodplain areas in and along Segment 1. The locations of wetlands are presented in the Task 7.2.1 Technical Memorandum (Dow 2011), which summaries available wetlands information for Operable Unit 1(OU1). The Task 7.2.1 Technical Memorandum was submitted concurrently with this report. Wetland areas are not anticipated to be impacted by the remedy actions. Dow's on-site floodplains are addressed under the license.

### **2.2.3 Geomorphological Characteristics**

Segment 1 is characterized by engineered banks (e.g., embankments, riprap, and sheet pile), low sinuosity (the ratio between channel length and valley length), highly channelized flow, and a moderately narrow river valley. The Segment 1 channel is relatively straight, and the channel width is relatively uniform, ranging from approximately 200 to 400 ft wide. During low-flow conditions, the water depth in Segment 1 upstream of the Dow Dam typically ranges from 10 to 12 ft, and downstream of the Dow Dam within Segment 1 ranges from less than 1 ft to greater than 5 ft deep depending on flow conditions. The approximate extent of the 100-year flood in Segment 1 is shown on Figure 2-1. The Segment 1 floodplain is generally contained within narrow engineered embankments.

## 2.2.4 Threatened and Endangered Species and National Historic Preservation Act Properties

Threatened and endangered species for the Tittabawassee River, Saginaw River, and Saginaw Bay were discussed in the 2008 Current Conditions Report for the Tittabawassee River (ENVIRON 2008). This list has been reviewed and updated for consideration in this Segment 1 Response Proposal and the updated evaluation is summarized in Table 2-1a and Table 2-1b. Sources used in this updated evaluation included federal (U.S. Fish and Wildlife Service [USFWS]) and state (DEQ) lists of threatened and endangered species, as well as the Michigan Natural Features Inventory (MNFI) website and the watershed-level biodiversity assessment completed by MNFI staff (Soule et al. 1998).

Our review indicated that two federally listed species and 31 state listed species have the potential to occur within the counties of interest (Bay, Saginaw, and Midland). The northern riffleshell (*Epioblasma torulosa rangiana*) is federally listed as endangered, and the eastern prairie white-fringed orchid (*Platanthera leucophaea*) is federally listed as threatened. Segment 1 does not provide the critical habitat required for either species, and there are no documented occurrence of either species in Midland County (NatureServe 2010; MNFI 2007, 2009).

The only state listed species with potential exposure to Segment 1 sediments is the slippershell mussel (*Alasmodonta viridis*), which is a listed threatened species that was documented in Midland county in 1979 (MNFI 2007). However, the habitat for this species is marginal in Segment 1, as the species is typically found in creeks and headwaters of rivers. It has been reported in larger rivers and in lakes (MNFI 2009); but, this mussel requires fish hosts for reproduction (MNFI 2009) including the Johnny darter (*Etheostoma nigrum*) and the mottled sculpin (*Cottus bairdi*). Both of these species may have suitable habitat in portions of Segment 1. In fall 2010, a benthic survey was performed in Segment 1. The survey found no evidence of the slippershell mollusk in Segment 1, nor the reference locations. Results of the survey will be reported separately.

There are no known National Historic Preservation Act (NHPA) properties located in or immediately adjacent to Segment 1. The nearest NHPA property to Segment 1 is located approximately one 1/4 mile north of the Tridge, the upstream boundary of Segment 1.

## 2.3 Regional Geology and Geomorphology

### 2.3.1 Historic River Morphology

As discussed in ATS (2009), minimal bank erosion or channel disturbances have been observed to date in Segment 1, in large part due to constructed armored channel banks and the backwater influences of the Dow Dam. The downstream river channel is heavily influenced by anthropogenic structures including embankments, riprap, and sheet pile. The location and morphology of the Segment 1 river channel has changed little during the past 70 years. The channel was enlarged just upstream of the Dow Dam to create an area for water intake for the Dow facility. The channel immediately downstream of the Dow Dam was widened and shifted only slightly to the west.

In 1969, a compensatory cut was constructed on the south bank of the lower reaches of Segment 1 during the construction of the Midland Cogeneration Venture facility. This compensatory cut

resulted in a wider channel in this area of Segment 1, compared to 1937 conditions, and led to the subsequent deposition of a sand bar on the north riverbank (ATS 2009).

Further discussion of sediment stability characteristics in Segment 1 is presented in Section 3.3.

### **2.3.2 Geologic Stratigraphy Below the River**

The geologic units that underlie Segment 1, from deepest to shallowest, include bedrock, sands/gravels that form the regional aquifer, glacial till, lakebed (lacustrine) clay, and surface sediments. The conceptual geologic model shown on Figure 2-2 includes each of these units; a brief description of each unit is provided below.

The bedrock beneath Segment 1 is composed of the Pennsylvanian Age Saginaw Formation, which consists of shale with interbedded sandstone seams and coal beds. Most of the water present in the bedrock is naturally brackish and is not suitable as a water supply. Deeper bedrock units contain calcium chloride brine, which Dow has historically pumped from deep wells to extract inorganic compounds. Prior to the Pleistocene Age glaciation, an extensive erosional surface developed on the bedrock with incised valleys. The bedrock valleys became filled with well-sorted outwash sands and gravels, which were thickest in the center of the valley and became thinner in the upland regions. These glaciofluvial deposits form the regional aquifer. The underlying bedrock aquifer exhibits a potentiometric head higher than the head in the overlying regional aquifer, which results in an upward hydraulic gradient and the slow leakage of mineralized water into the regional aquifer. The regional aquifer behaves like a confined aquifer with an upward artesian head in the area of the Midland facility (Dow 2002).

The glacial till unit is a confining layer that overlies the regional aquifer; this till unit is composed of silty and sandy clay with some pebbles and cobbles. It is typically 100 to 200 ft thick, very dense, with low-permeability. Hydraulic conductivity values for this unit (as measured at the Salzburg Landfill) range from  $1.2 \times 10^{-7}$  centimeters per second (cm/s) to  $2.8 \times 10^{-8}$  cm/s, contributing to very slow groundwater flow rates through the glacial till unit (Dow 2002).

The glacial till unit contains some interbedded sand and gravel lenses. These sand lenses are relatively thick in places. The hydraulic conductivity of the till sands varies, but is significantly higher than in the glacial till unit. Three till sand units have been identified beneath or adjacent to Segment 1. Only the most upstream (above Dow Dam) and downstream glacial till sand units cross the river. In these localized areas, the sand units within the glacial till are in hydraulic connection with the river but are hydraulically contained by the RGIS.

Overlying the glacial till unit is the lakebed clay unit. This clay unit represents shallow lake deposits formed near the end of the Wisconsin Glacial period. The lakebed clay unit consists of stratified layers of clay with small amounts of silt and fine sand. There are also some thin layers of sand and sandy gravel present, but these thin layers are not extensive. The lakebed clay unit varies in thickness from 0 to 24 ft, but has been eroded from many areas in the river channel. The lakebed clay functions as an aquitard, although some water is contained in interbedded, thin, discontinuous silt layers. The lakebed clay acts as a barrier to downward movement of groundwater (Dow 2002).

The surface sediment unit contains stratified sands and silts with thin clay seams that form a variable surface veneer over the underlying clays, ranging in thickness from 0 ft to as much as 15 ft. Within the river, this unit has likely been reworked in areas, particularly near the riverbed. Woody debris deposits are also found within this unit. The surface sediment unit and associated fill forms a discontinuous unconfined aquifer outside the river where it is present.

## 2.4 Facility History

In 1890, Herbert Henry (H.H.) Dow, along with partner John H. Osborne, formed the Midland Chemical Company to extract bromine from cold brine using a novel electrolytic bromine recovery system. Early products included iron bromide, potassium bromide, and bromine purifier (Brandt 1997; Dow 1938; Dow 1926; Leddy 1989; Levenstein 1998; Haynes 1954). In 1893, an early experimental attempt to construct and operate a chlorine cell in Midland resulted in an explosion due to a build-up and mixing of hydrogen and chlorine gases. The Midland Chemical Company decided against further expansion in chlorine. H.H. Dow left the company, moving to Navarre, Ohio, to continue his experiments with electrolytic chlorine cells. He joined with James Pardee and several other backers to form the Dow Process Company in Navarre. By 1896, Dow had completed development on the chlorine cell and had established a manufacturing process for the production of bleach or “chloride of lime” (calcium hypochlorite). H.H. Dow closed the Ohio plant and returned to Midland, Michigan. He built a small electrolytic chlorine cell room and bleaching powder plant, leasing land from the Midland Chemical Company and purchasing its debrominated brine for the process (Brandt 1997; Dow 1926; Haynes 1954; Karpiuk 1984).

By 1897, the “new” Dow Process Company in Midland had been reorganized as The Dow Chemical Company and began the manufacture of bleaching powder using waste brine from bromine production operations. The chlorine plant consisted of nine electrolytic chlorine production cells fabricated of inexpensive, readily available materials including culled arc-light carbon rods for anodes, tar-coated pine and hemlock for wooden vessels, and a slaked lime absorber to form the calcium hypochlorite bleaching powder. Dow inserted wooden troughs around each bank of carbon rods to “trap” the chlorine.

Eventually there were 16 large wooden cell buildings (40 ft wide by 368 ft long) for the manufacture of chlorine (Haynes 1954, Karpiuk 1984, Leddy 1989).

The first commercial sales of bleaching powder began in 1898. During this early stage, Dow also began production of sulfur chloride, various bromides, mining salts, Epsom salts, and magnesium carbonate, maximizing the capture of the rich mineral resources available in the brine (Levenstein 1998).

By 1908, Dow’s principal products were bromides and bleaching powder. Small volume products based on bromine and chlorine extraction included mining salts, chemical insecticides, food preservatives, sulfur chloride, benzyl chloride, benzoic acid, carbon tetrachloride, and chloroform.

Between 1911 and 1914, Dow scientists improved brine processing by developing a more sophisticated and efficient cell design. The result was purer chlorine and caustic soda product streams. These new “bipolar cells” were constructed of more durable materials, such as concrete

in place of tar-coated wood, and impregnated graphite instead of culled arc-light carbon electrodes and utilized steel as the cathode and impregnated graphite as the anode (Karpiuk 1984). In 1914, Dow developed bipolar, filter-press style cells and H.H. Dow announced the company would halt the manufacture of bleaching powder. Dow produced its last bleach powder in July 1915.

During World War I (1914 to 1918), Dow began the manufacture of phenol for use in producing trinitrophenol for artillery shells (Whitehead 1968). Other wartime-introduced products included dichloroethylsulfide (for mustard agent), chlorobenzene (for explosives), and hexachloroethane (for smoke screens). In 1918, the U.S. Army operated a plant manufacturing mustard agent based on chlorine at the Midland facility. The U.S. Army manufactured up to 10,000 pounds per day of mustard agent (Brandt 1997).

The diversity and volume of chemical products produced by the Midland facility grew in the 1920s to include synthetic amino acids, phenylethyl alcohol, vinyl chloride, carbonic acid, ethylene dibromide, ethylene dichloride, propylene dichloride, synthetic ammonia, trichloroethane, and trichloroacetic acid. Steady growth continued throughout the 1930s with addition of the plastic manufacturing facilities. By 1940, the Midland facility covered more than 525 acres and produced more than 500 different organic and inorganic chemicals.

During World War II, additional plant facilities were made available for synthetic rubber production. Several new products were introduced, many in response to wartime needs. In addition, Dow operated the Midland Chemical Warfare Service Plant for the production of CC-2 from February 1943 to April 1944 (Brandt 1997). CC-2, also known as impregnite, was used during World War II for the impregnation of clothing for protection against vesicant agents such as mustard agent and lewisite.

By the 1970s, the Midland facility covered 1,900 acres, producing more than 1,000 different chemicals. In the 1980s and 1990s, the Midland facility reduced its production capacity and limited the number of chemicals manufactured. The pentachlorophenol facility and the chlorine-caustic soda facility were closed, the brine business was ended, and the manufacture of household products increased. The Midland facility now maintains 30 production facilities and is Dow's main research and development center.

## **2.5 Waste Management and Source Control**

Throughout the facility's history, Dow has strived to use the most modern waste management and source control systems to meet or exceed the requirements of state and federal regulations, including the federal Clean Air Act and the Clean Water Act. The current waste management and source control systems are composed of the following components:

- Wastewater management and treatment system
- Incinerators
- Storm water management
- Outfall closure and consolidation

- Groundwater containment:
  - Revetment Groundwater Interception System (RGIS)
  - Sand bar containment system

A description of each component and a brief description of their historical development are presented below.

### **2.5.1 Wastewater Management**

The wastewater management history at Dow closely mirrors the chemical production history described above. Wastewater management practices at the Dow Midland facility were continuously advanced and upgraded as technologies evolved and knowledge on environmental stewardship increased. The timeline for aqueous waste management improvements is summarized on Figure 2-3.

During the early 1900s, consistent with the practices of most industrial facilities at that time and a key criterion for locating early industry along waterways, wastes were discharged directly into the Tittabawassee River. Concerns over river discharges developed in 1915, after the company began the production of organic products such as phenol and chlorobenzene. In response to these concerns, as early as 1917, Dow began a new practice of “ponding” to retain and treat water on the facility’s site instead of discharging aqueous waste directly into the river. Sewers discharging to the river were sealed and wastewater was redirected to wastewater treatment ponds located adjacent to the river.

The first pond was built prior to 1920 to treat waste generated during organic chemical production. The treatment process was later adapted to control inorganic waste streams. By 1931, there were approximately 600 acres of waste ponds. The full extent of the ponds can be seen on the 1938 aerial photo, included as Figure 2-4. The ponds also prevented accidental releases of concentrated organics to the river. As wastewater entered the ponds, solids and liquids that were heavier than water settled to the base of the ponds. Dissolved oxygen levels in the water were allowed to recover prior to discharge to the river. To minimize the effects of the discharge to the Tittabawassee River, water from the ponds was discharged to the river during high-flow events.

Significant volumes of spent brine were generated at the Midland facility during the 20th century. Spent brine was disposed of either by re-injecting the brine back into the ground or by storage in the brine pond for release during high-flow events. Dow constructed a brine pond (now known as 6 Pond) by 1938. This pond is located on the southwest side of the river. Extraction of brine from deep bedrock wells was discontinued in May 1986. Brine wells were subsequently plugged and sealed.

A trickling filter wastewater treatment plant was constructed in 1937, well ahead of the standard of practice in the industry. Wastewater containing phenols was treated at the trickling filter plant using state-of-the-art biological treatment processes. The trickling filter consisted of a mixing chamber, a clarifier, the trickling filter media chamber, and a polishing pond. A wastewater treatment plant (WWTP) was constructed in 1945. The location of the WWTP is shown on Figure

2-5. This WWTP included primary treatment, an activated sludge treatment unit, and final clarification. Both the trickling filter and the WWTP relied on biological processes suited to the organic waste streams produced at the plant (Velz 1958).

By 1962, Dow was treating approximately 55 million gallons per day. In the 1970s, the amount of water requiring treatment was reduced with the addition of cooling towers, and the wastewater treatment system was upgraded by adding the T-Pond to: 1) further control the effluent discharge temperature; 2) provide additional retention time before discharging water to the river; and 3) reduce total dissolved solids loading to the river. Effluent was transported to the T-Pond (located across the river from the plant) via pipeline. The T-Pond can be seen on the 1978 aerial photo, included as Figure 2-6.

The Dow Michigan Division Wastewater Treatment Plant currently operates under a National Pollutant Discharge Elimination System (NPDES) Permit (No. MI0000868) issued in June 2004. The current WWTP uses primary clarifiers, activated sludge for secondary treatment, secondary clarifiers, the T-Pond, ballasted clarification, and sand filtration prior to discharge to the Tittabawassee River. The treatment system receives and treats an approximately 15 million gallons of water daily, including diluted waste streams from manufacturing processes, non-contact cooling water, sanitary wastes, storm water runoff, and collected groundwater, among other sources. All wastewater streams are initially combined into a single stream in which the pH is adjusted. The wastewater stream then passes through a coarse screen to remove large solids before entering the primary clarifier for separation of fine particles of sand and grit. Water from the primary clarifier is mixed with activated sludge containing microorganisms in the aeration basins. The organic compounds in the water are consumed by the microorganisms and mineralized into carbon dioxide and water. A mixture of treated water and activated sludge flows from the aeration basins to the secondary clarifier for sludge recovery. Clean water from the secondary clarifier is pumped into the 200-acre T-Pond for temperature and discharge management.

As a final treatment step to remove low concentrations of suspended solids, wastewater discharged from the T-Pond is passed through a state-of-the-art ballasted clarification and sand filtration system before being discharged into the Tittabawassee River. The ballasted clarification and sand filtration systems are operated to meet the permitted discharge requirements for furans and dioxins under the NPDES permit. A carbon filtration system is also available for final treatment on an as-needed basis. The T-Pond allows discharge rates to be managed during low river flow conditions in order to control the salinity and temperature of the water being discharged to the river. Monitoring data to verify compliance with NPDES permit requirements are reported to DEQ.

### **2.5.2 Incineration**

As early as 1930, the Dow Midland facility managed organic liquid tars by incineration using liquid tar burners and rotary kiln solid waste incineration, again well ahead of the industry standard of practice. Continual improvements in burn efficiency and environmental controls were implemented since the 1930s. In 2003, Dow completed construction and start up of a new incinerator and shut down two older incinerators to meet the EPA's Maximum Achievable Control Technology (MACT)

standards for industrial incineration devices (Dow 2006a). Dow currently relies on state-of-the-art technologies to continuously improve the performance of thermal destruction devices (Dow 2006a).

### **2.5.3 Solid Waste Disposal**

Solid waste from the facility was sent to the Poseyville Road Landfill up until approximately 1980. The Poseyville Landfill is located outside of the Midland facility fence line west of Brine Pond No. 6. It was operated to manage municipal waste by the City of Midland and was purchased by Dow in 1955. In the early 1980s, a leachate collection system was constructed around the perimeter of the landfill. Leachate collected from this system is transmitted to the Dow WWTP. Groundwater contamination from Poseyville Landfill is addressed via an Resource Conservation and Recovery Act (RCRA) corrective action.

Dow constructed the Salzburg Road Landfill in 1981. This landfill is licensed for both hazardous and non-hazardous waste. Dow currently sends its hazardous waste, as well as some non-hazardous waste, to the Salzburg Landfill. Non-hazardous waste is mostly sent to the City of Midland Municipal Landfill on a case-by-case basis after proper characterization of the waste.

Dow operated a sludge management facility from 1974 until its closure was completed under interim status in 1989. The facility was used to dewater the wastewater treatment sludge. Recovered water was pumped back into Dow's WWTP. The sludge management facility was located at the corner of Saginaw and Salzburg Roads, across the CSX Railroad to the west of Salzburg Road Landfill. The former location of the sludge management facility and the current location of the Salzburg Road Landfill are shown on Figure 2-6.

### **2.5.4 Storm Water Management**

Nearly all storm water at the Dow Midland facility is captured and treated at Dow's WWTP system before it is discharged to the river.

### **2.5.5 Outfall Closures**

Numerous outfalls have been constructed at the Dow facility since its inception in the late 1800s. Many outfalls were re-routed to the decant ponds starting in 1917 and were later directed to the WWTP following initial construction in 1937. Dow continued to close outfalls in the 1950s and 1960s. By 1971, only 10 outfalls existed at the Dow facility and most of these outfalls were closed in the late 1970s.

Dow currently relies on one primary NPDES permitted outfall (Outfall 031). All water discharged from the facility is treated by the wastewater treatment system and discharges to the river through Outfall 031. Figure 2-7 shows the location of the historic outfalls. Outfall 031 is shown on Figure 2-7.

Cores collected from Segment 1 in 2009 showed evidence of Non-Aqueous Phase Liquid (NAPL) product in the sediment down gradient of some outfalls. The location and description of the product is described in Section 3 of this Response Proposal. The source controls discussed in this

section, namely the closure/control of outfall discharges, prevents future discharges of this material to the river.

## **2.5.6 Groundwater Containment**

Source control is a fundamental principle for contaminated sediment sites, and RGIS is an integral component of source control system protecting the river. Operation and maintenance (O&M) of RGIS is designed to protect the river against potential operational interruptions, and thus is designed to protect the river from potential subsurface chemical releases. Details of the O&M activities are provided in the following discussion; results of these activities are reported to the State as part of the Plant Operating License.

### **2.5.6.1 Revetment Groundwater Interception System (RGIS)**

RGIS is a groundwater containment system installed along the river to intercept groundwater from the Dow facility, and was constructed to protect the river from groundwater discharges. The RGIS was installed along both sides of the river in phases, with the first portion installed as early as 1979. Operation and maintenance of RGIS is an ongoing requirement of the facility's RCRA license Part 111 Hazardous Waste Management Facility Operating License.

The first two phases of RGIS installation (RGIS I and RGIS II) were completed along the northeast bank in 1981. RGIS III was installed along the northeast bank and the southwest bank in 1987, and purge wells W-1 to W-6 were installed in 1988. RGIS was extended around the Brine Pond in 1989 and 1990, and RGIS IV was installed around the T-Pond in 1992. The total length of RGIS is more than 30,000 ft.

A large volume of hydraulic data documenting the effectiveness of RGIS have been collected and submitted to DEQ since 1989. These data, along with modeling results from the initial Hydraulic Loading and Flow Study (Radian 1998), have documented that RGIS functions successfully under a wide range of hydraulic conditions, effectively preventing groundwater discharge from the Dow Midland facility from entering the Tittabawassee River. After a short loss of gradient reversal at RGIS (in 1994 in the Lift Station #4 to Lift Station #5 area), a Hydraulic Loading and Flow Study was conducted in 1998 as required by the 1997 RGIS Consent Order. The study concluded that RGIS did not lose hydraulic containment and that RGIS would not lose hydraulic containment as long as water was being removed from the RGIS tile. The study also indicated that the only time containment would be lost would be if "production from the tile completely ceased for an extended period of time." Since 1995, all but a small section of the original main plant RGIS installations have been upgraded with heavy duty SDR 21 perforated collection pipe, automated instruments in lift stations and piezometers with air or nitrogen bubblers, automated alarms, and redundant pumping systems in the lift stations for added reliability and assured performance. RGIS upgrades undergo a detailed hydrogeologic design phase to insure a conservative hydraulic capacity is incorporated into the design. Regular maintenance and monitoring activities are conducted for RGIS to ensure the system performance is maintained. Since the RGIS upgrades, there has been no extended period of time when RGIS water production has been significantly reduced or ceased to result in a loss of containment. The 1998 Hydraulic Loading and Flow Study went on to state that RGIS is able to maintain a reversal of groundwater conditions even during flood events.

Figure 2-8 shows a schematic diagram of the typical construction for RGIS, which consists of a water collection trench with a sheet pile wall for much of the system. Sheet piling was driven into the riverbank to stabilize the bank prior to the construction of the water collection trench. The sheet piling also reduces the volume of river water that infiltrates from the river into the RGIS collection tile. The installation depth of the sheeting ranges from 10 ft to 30 ft below ground surface. The sheet pile wall is located on the river side of the collection trench and is keyed into the top of the till unit, where the till is present. Portions of RGIS installed along the southwest bank do not contain the sheet pile wall (see discussion below).

A perforated pipe is located at the base of the collection trench. In most locations, the collection trench was excavated into the clay/till substrate. The elevation of the perforated pipe is lower than the bottom of the Tittabawassee River for the portions of RGIS installed adjacent to a sheet pile wall. The initial RGIS construction (1981 to 1992) used 6-inch diameter corrugated HDPE tile. The majority of the original perforated tile was changed to 8-inch diameter perforated SDR 21 High-density polyethylene (HDPE) pipe during subsequent upgrades to the system (McDowell 2000).

The RGIS collection trench is typically 3 ft wide and filled with a coarse drainage media. The surface of the collection trench is capped with 2 ft of compacted clay or, in some places, a layer of geosynthetic clay liner to reduce surface water infiltration during flood events. Water captured by the collection trench flows by gravity to lift stations where it is pumped to the WWTP for treatment prior to discharge to the river.

In locations where the lakebed clay and till unit are absent and till sands are in contact with the surface sands, the RGIS sheet pile wall could not be keyed into the underlying clay or till unit. In one location, a purge well (in addition to the RGIS tile) was installed to ensure capture of groundwater. In another location where there is no RGIS sheet pile wall, a series of purge wells were installed to capture the groundwater. Figure 2-9 shows a schematic diagram of the typical construction for RGIS with a purge well. The locations of the purge wells are shown on Figure 2-10. Along with other elements of the RGIS collection system, these purge wells provide effective hydraulic capture for the water within these till sand units (Radian 1998).

Figure 2-10 shows the current RGIS alignment. Upgrades to the RGIS collection tile and lift station began in the 1990s. Upgrades were conducted along the northeast bank in 1992 through 2001. New tile and a lift station system were installed along Saginaw Road in 2002. Upgrades to the system near the Lingle Drain and the Brine Pond were completed in 2005. A portion of RGIS along the northeast bank, upstream of the Dow Dam, was upgraded in 2008 and the additional Purge Well #7 on the west side of the river was also installed in 2008.

Regular maintenance and monitoring activities are conducted for RGIS to ensure that system performance is maintained. Monitoring activities include post-flood inspections, lift station inspections, and camera inspection of the collection trench tile on an as-needed basis. Analytical samples are collected from different lift stations on an annual basis to monitor the system performance. Water levels immediately adjacent to RGIS on the northeast side of the river are

monitored using automated piezometers and process control computers along with pumping flows and levels from the RGIS lift stations. The computers also monitor and control the RGIS lift station levels and pump operation.

Regular operation and maintenance duties include calibration of the automated piezometers and annual jetting of the collection trench tile. The automated piezometers provide water level information to the central monitoring station and the annual jetting is used to evaluate and remove sediment buildup within the collection trench tile.

#### **2.5.6.2 Sandbar Containment and Pumping System**

During the 1970s, a sand bar emerged above normal water level elevations in front of the former 001 outfall location, on the northeast bank of Reach G. Acceleration of sediment deposition within the sand bar is believed to be the result of geomorphic responses in the river from a compensatory cut made on the south bank of Reach G in 1969 during the construction of the cogeneration facility. In 1997, during reconstruction of RGIS, dense non-aqueous phase liquid (DNAPL) was discovered in the area of the former 001 outfall, inside the sandbar. In 1998, Dow installed a sheet piling wall around the perimeter of the sand bar and a horizontal well within the sand bar to control possible discharges of groundwater to the river. The horizontal well was installed at an approximate depth 12 ft below the top of the sand bar, along the length of most of the sand bar. The combined wall and extraction well creates a hydraulic containment system, similar to RGIS, which prevents DNAPL and associated groundwater from migrating to the river. Water and DNAPL captured by the horizontal well is pumped to the WWTP for treatment prior to discharge to the river.

#### **2.5.7 T-Pond Dredging**

Monitoring of the T-Pond (constructed in the 1970s) revealed that sediments containing elevated chemical concentrations accumulated over time within the T-Pond. In order to ensure the continued effectiveness of the WWTP and facility source controls, accumulated sediments were dredged from the T-Pond between 1996 and 2005. The dredged solids were dewatered and placed at the Dow Salzburg Landfill. Approximately 125,000 cubic yards (cy) of solids were disposed of at the landfill. A T-Pond Solids Maintenance Plan has been implemented since 2006. This plan ensures appropriate management of solids before excessive quantities can accumulate.

### **2.6 Previous Segment 1 Response Actions**

The sections above outline the considerable source control efforts that have been completed and are ongoing at the Dow facility, the continued effectiveness of which are being monitored under NPDES and RCRA authorities administered by DEQ. As described in EPA's eleven Risk Management Principles (EPA 2002) and sediment remediation guidance (EPA 2005), early source control is a critical initial step to achieve effective sediment cleanup. As described above, Dow, under the oversight of DEQ, has successfully completed a decades-long series of source control actions at the Site, which have dramatically reduced contaminant discharges to the river from the facility.

Since 2007, Dow has also implemented a number of early sediment cleanup actions in the Tittabawassee River under the oversight of DEQ and EPA to further protect and accelerate

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recovery of the river system. Early actions constructed in Reaches B and D of Segment 1 (above the Dow Dam) are briefly described in the sections below. Long-term monitoring and management as necessary to ensure the continued protectiveness of these actions is incorporated into the overall Segment 1 response action.

### **2.6.1 Reach B Capping**

In 2007, during the construction at the former 47 Building site, contractors identified demolition materials that had originally been placed to armor the northeast bank of river near the outside bend in Reach B. This armoring material consisted, in part, of concrete chlorine cell debris that appears to have originated from the early 20th century chlorine manufacturing operations. Approximately 19,260 cy of soil and debris were removed from upper elevations of the Reach B bank (above normal water levels) as part of the 2007 to 2009 Interim Response Action (IRA; Dow 2009). The chlorine cell debris contained relatively high concentrations of contaminants; the bank debris and potentially impacted soil was accordingly disposed of at the Salzburg Landfill (URS 2009c). The removal area was capped with clean material.

Additional removal and capping activities were conducted in 2009 below the normal water level along the Reach B bank and northern portion of the channel, and included the removal of visible in-channel graphite anodes and plates that were intermixed with concrete rubble and other demolition debris present in the area of concern within Reach B. This in-channel removal was conducted in July 2009 using marine divers. Large debris (such as logs) that had the potential to impact the sediment cap construction was also removed during the anode and plate removal activities (URS 2009c).

After the in-channel removal activities were completed, an engineered cap was constructed to effectively contain any remaining debris and associated contaminated sediments. The cap was designed to provide permanent physical isolation of buried contaminated sediments and to minimize diffusive migration of contaminants through the cap. The primary design elements for the Reach B cap consisted of:

- Physical isolation layer of a minimum of 6 inches of granular material (sand) with a minimum total organic carbon (TOC) concentration of 0.5 percent
- A primary armor layer of at least 2 to 3 inches of coarse aggregate with a medium grain size diameter ( $D_{50}$ ) of 0.9 inches to protect the physical isolation layer
- A surf zone armor layer of at least 9 inches of riprap to protect this area from waves
- Appropriate quality control procedures conducted during construction
- Performance monitoring and maintenance

The subaqueous Reach B cap was installed between August and October 2009. The cap extends between 42 ft and 91 ft (average 60 ft wide) from the edge of the access roadway (river bank) and is approximately 700 ft long. Ongoing cap monitoring activities are summarized in Section 2.6.3.

## 2.6.2 Reach D Dredging and Capping

In October 2006, two Reach D sediment cores were collected from inside a historical wastewater flume (identified as E Flume) previously used to convey facility wastewater discharge below the Dow Dam. The flume was originally installed in 1939 and used until the 1970s, and was bounded by the RGIS sheet piling along the east bank of the river and a line of offshore sheet piling constructed in the river in the 1930s and 1940s, approximately 5 to 40 ft from the east bank. Eight discrete sediment samples collected from two sediment cores advanced in the E flume contained elevated concentrations of a range of contaminants, including chlorinated organic compounds, metals, polynuclear aromatic hydrocarbons (PAHs), and chlorinated dibenzofurans and dibenzodioxins. The initial sediment sampling data were summarized in the Reach D Project Characterization Plan (URS 2007), which also presented a work plan to fully characterize conditions in this area of Segment 1.

Additional river sediment characterization activities were conducted by Dow in 2007 and were used to define the Reach D sediment removal prism located in and adjacent to E Flume, along the eastern bank of Reach D. Work plans for removal, transportation, and disposal of this sediment, along with temporary sheet piling wall installation and sediment dewatering containment facility operations, were developed by Dow in April 2007. EPA issued an Administrative Settlement AOC for Removal Action in July 2007. The Reach D project work plan was approved by EPA in August 2007.

Dow performed sediment removal operations at Reach D between August and December 2007. These activities included the installation of approximately 1,500 ft of temporary sheet piling barrier and the removal of approximately 19,000 cy of impacted river sediments to underlying native soils. Dow contractors used a combination of removal methods including hydraulic dredging, mechanical excavation, scarification, and debris segregation to address the complex sediment conditions in the Reach D removal area. All sediment material removed from Reach D was disposed at the Salzburg Landfill. Additional residual sediment removal was conducted in April 2008. The final report on Reach D removal activities was prepared by Dow in July 2008, and was approved by EPA in October 2008.

Also in 2008, Dow developed plans for the removal of the Reach D temporary sheet piling wall and construction of a protective sediment cap for the area enclosed within the wall. The basis of design for the Reach D cap was prepared in September 2008 (Dow et al. 2008). Similar to the Reach B cap described above, the Reach D cap was designed to provide permanent physical isolation of buried contaminated sediments and to minimize diffusive migration of contaminants through the cap. The primary design elements for the Reach D cap consisted of:

- Physical isolation layer of a minimum of 12 inches of granular material (sand) placed in at least two 6-inch lifts
- An armor layer of at least 6 inches of coarse aggregate to protect the physical isolation layer
- Appropriate quality control procedures conducted during construction
- Performance monitoring and maintenance

Further details of the construction of the cap were provided in the *Sediment Cap Installation and Temporary Sheet Piling Removal Plan* prepared in January 2009 (URS 2009a). Following discussions with DEQ, revisions to the work plan were completed in June 2009. Construction of the cap and removal of the temporary sheet piling occurred from June to September 2009. The constructed cap extends 30 ft to 85 ft offshore of the permanent RGIS sheet piling, and is referred to as the Reach D post-removal cap area.

During bathymetric surveys performed in early 2009 to assess the stability of sediments in Reach D, areas of disturbed sediment were identified immediately offshore of the temporary sheet piling. Sediment disturbance in these channel areas, which extended up to approximately 12 ft below the pre-removal (2007) sediment surface, was determined to have resulted from significantly increased turbulent shear stresses caused by the installation of the Reach D temporary piling wall. Sediment disturbance in these areas between 2007 and 2009 exposed previously buried sediment contaminants. However, initial hydrodynamic and sediment transport analyses performed by Dow suggested that natural sediment deposition within this area was likely to provide adequate protection following removal of the sheet pile, based on the following:

- Accretion of new sediment in this area, denoted the natural deposition cap area, was anticipated to occur at a rate ranging from 0.5 ft/year to 2 ft/year, primarily during higher flow events
- An initial accretion rate of at least 0.5 ft/year for 1 to 2 years should ensure protective containment of underlying buried sediment contaminants

Recent monitoring activities have verified that initial accretion rates have significantly exceeded 0.5 ft/year, suggesting that natural sedimentation rates are providing the desired protection and recovery. Ongoing monitoring activities at the Reach D post-removal cap and natural deposition cap areas are summarized in Section 2.6.3.

### **2.6.3 Ongoing Reach B and D Cap and Natural Recovery Monitoring**

Draft monitoring plans for the Reach D and B caps were prepared by Dow in November and in December 2009, respectively (URS 2009b, URS 2009c). Initial comments on the cap monitoring plans were provided by the Agencies in September 2010. The revised Reach B and D cap monitoring program, which will be reviewed for approval by EPA as part of Task 4 – Site-Wide Monitoring elements of the AOC/SOW, is anticipated to include the following components:

- Physical integrity monitoring – including periodic high-resolution hydrographic surveys and cap inspections
- Chemical monitoring – including surface sediment chemical sampling and analysis
- Contingent biological monitoring – based on the results of the chemical monitoring

Details of the Reach B and D cap monitoring plans will be developed as part of the Task 4 – Site-Wide Monitoring Plan.

## 3.0 Summary of Segment 1 Conditions

### 3.1 Summary of Existing Documents and Data

The need for and scope of Segment 1 response options as presented in this Response Proposal was based on a review of data obtained during a series of detailed site investigations conducted by Dow over the period from 1998 to 2009. These investigations characterized the nature and extent of a wide range of constituents of interest (COIs) in Segment 1 sediments, assessed sediment stability, evaluated the potential transport of sediment-associated COIs, and evaluated the potential human health and ecological risks resulting from exposure to Segment 1 COIs.<sup>1</sup> The scope of these investigations, which were reviewed and approved by the DEQ and EPA under various regulatory programs including RCRA, CERCLA, and NPDES, included the following:

- Sediment sampling and analysis
- Bedload and suspended load sampling and analysis
- Bathymetry surveys
- Surface water hydrologic monitoring
- Hydrodynamic and sediment transport modeling
- In-channel and floodplain geomorphology assessment
- In-channel bed pin/chain measurements
- Ice assessment
- Bank pin measurements
- Bank stability assessments
- Sediment toxicity tests
- Wild fish contaminant monitoring
- Caged fish contaminant monitoring
- Semi-permeable membrane device (SPMD) studies

Table 3-1 lists existing reports that support the physical, chemical, and biological characterization of Segment 1. Analytical data and geographical files associated with Segment 1 investigations were included in a database submitted to EPA and DEQ July 20, 2010 and updated on January 26, 2011 per Section 6.3 of Appendix A of the SOW. As discussed in more detail in the sections below, the available Segment 1 data meet the requirements of an EE/CA (as set forth in the AOC/SOW and the NCP), and the existing body of knowledge concerning the nature and extent of sediment contamination in Segment 1 is sufficient to support a comparative analysis of alternatives and to develop this Response Proposal. Multiple lines of information were used to define Segment

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<sup>1</sup> While risk-based evaluations were used in the development of this Response Proposal, risk assessments for Segment 1 will be provided as part of Task 10 of the AOC SOW.

1 sediment management areas (SMAs) and evaluate response options to address potential risks to human health and the environment within each SMA.

### **3.2 Nature and Extent of Sediment Contamination**

To characterize the distribution of COIs in the river sediments, sampling was conducted in Segment 1 during 2006 to 2007 as part the Tittabawassee River Site Investigation (ATS 2009), in 2007 as part of the Reach D removal delineation and post-removal verification investigation, and in 2008 to 2009 as part of the H-12 Historical Outfall Site Investigation (URS 2010). Validated sediment chemistry data from the cumulative 2006 to 2009 sediment investigations is provided in Appendix G. These data were used to delineate chemical concentration distributions in Segment 1 sediments, both laterally and vertically. Chlorinated dibenzofurans and dibenzodioxins (furans and dioxins) were the primary focus of the 2006 to 2007 site investigations (ATS 2006a), and thus are referred to as the primary constituents of interest (PCOIs) in Segment 1 sediments and floodplain soils. For convenience, all other chemicals measured in sediment and floodplain soils are collectively referred to as secondary constituents of interest (SCOIs), consistent with the terminology used in the 2006 to 2007 site investigations (ATS 2009).

During the 2006 to 2007 sampling program, sediment cores were collected along regularly-spaced cross-river transects using a stratified sampling design. Sediment samples submitted for chemical analysis typically included surface samples that were obtained from depths of 0 to 6 inches (0 to 15 cm) below the sediment bed surface and subsurface samples that were obtained from distinct sediment layers. Occasionally, composite samples from the entire length of the core were collected. Complete descriptions of sediment coring and sediment sampling methods employed during the 2006 to 2007 site investigations are included in the Agency-approved sampling and analysis plans that supported those efforts (ATS 2006a, 2007a). A complete list of analytes included in the characterization of in-channel sediments is provided in Table 3-2a. Sample handling procedures, analytical methods, and data validation procedures are outlined in the Quality Assurance Project Plans (QAPPs) that supported the Tittabawassee River investigation (ATS 2006b, 2007b).

One of the findings from the 2006 to 2007 site investigations was that a historical outfall located in Reach D (above the Dow Dam) contributed to elevated SCOI concentrations detected in Reach D sediment deposits located along the northeast side of the river channel (ATS 2009; see Section 2.6.2). To further delineate the sediment impacted by the Reach D outfall and define the Reach D sediment removal area (see Section 2.6.2), additional sediment samples were collected from Reaches B, C, and D in 2007. Following sediment removal from Reach D, but prior to sediment capping, verification samples were also collected from within the Reach D removal area. The additional sediment samples collected from Reaches B, C, and D (including the Reach D verification samples) were analyzed for PCOIs and for the subset of SCOIs that were measured at elevated concentrations in the original 2006 sediment samples near the Reach D outfall. A complete list of analytes included in the characterization of these additional Reach B, C, and D samples is provided in Table 3-2b.

As a result of the findings from Reach D outfall area, the Agencies requested a follow-on site investigation, which was conducted in 2008 and 2009 under RCRA Compliance Schedule Activity H-12. A focused (statistically biased) sampling design was used to specifically target Segment 1 sediment deposits located near historical outfall locations that could have been a source of SCOIs to the river sediments. In the summer of 2008, the *Tittabawassee River Historic Outfall Investigation Activity Work Plan* (URS 2008a) was reviewed and approved by the Agencies. Subsequently, sediment samples from the historic outfall locations were collected and analyzed for SCOIs. Selected archived sediment samples from the 2006 to 2007 site investigation were also analyzed for SCOIs.

The results of the 2008 historical outfall investigation confirmed that elevated SCOI concentrations were present in localized sediment deposits adjacent to historical outfall locations. Specifically, elevated sediment SCOI concentrations were detected in isolated sediment deposits in Reaches E, F, G, and H below the Dow Dam. To further delineate the extent of these sediment SCOI deposits, the Agencies requested additional sediment sampling and analysis in these specific areas (biased “step-out” sampling). In October 2009, a work plan for Phase II of the H-12 Tittabawassee Outfall Investigation was reviewed and approved by the Agencies (URS 2009). Subsequently, during fall 2009, additional sediment samples from near the historic outfall locations were collected and analyzed for SCOIs.

The target analyte list for the H-12 historical outfall site investigation, which included a wide range of compounds that were representative of potential historical releases from the Midland facility, was reviewed and approved by the Agencies as part of the 2008 H-12 Historic Outfall Investigation Work Plan (URS 2008a); this target list is summarized in Table 3-2c. During the 2008 phase of the H-12 Investigation, surface sediment samples were obtained from depths of 0 to 6 inches (0 to 15 cm) and subsurface sediment samples were obtained from unique stratigraphic layers. During the 2009 phase of the H-12 Investigation, sediment samples were obtained from depths of 0 to 6 inches, 6 to 12 inches, and from unique stratigraphic layers below 12 inches. A complete description of the sediment coring, sampling, and analytical methods employed during the H-12 site investigation are provided in the Agency-approved H-12 Outfall Investigation Work Plans (URS 2008a, 2009).

### **3.2.1 Primary Constituents of Interest**

Figures 3-1A and 3-1B show the locations of sediment samples collected in Segment 1 and analyzed for PCOIs. The cumulative 2006 to 2009 investigations resulted in:

- 359 Segment 1 sediment core locations sampled for PCOIs
- 1,524 individual Segment 1 sediment samples analyzed for PCOIs

Following Agency guidance, the cumulative concentration of PCOIs (i.e., the sum of 17 individual furan and dioxin congeners) is expressed as 2,3,7,8-tetrachlorodibenzo-p-dioxin toxic equivalents (TEQs) calculated based on human/mammalian toxic equivalency factors developed by the World Health Organization (Van den Berg et al. 2006). The vertical distribution of Segment 1 sediment TEQ levels is presented in Figure 3-2. Figure 3-2 shows vertical profiles of sediment TEQ

concentrations across the length of Segment 1 to delineate the general distribution of TEQ concentrations with depth below the sediment surface.

Surface-weighted average concentrations (SWACs) for TEQ were calculated for all of Segment 1 and also for smaller 1-mile intervals within Segment 1 as a sensitivity analysis. All Segment 1 surface sediment data were included in the SWAC calculations. At some sample locations, TEQ data are available for more than one surface sediment interval, so a length-weighted average (LWAc) TEQ was calculated for the conservative surface active bed interval of 0 to 2 ft at each location. The LWAc TEQ level was computed for each core location using the following formula:

$$LWAc = \frac{\sum_{i=1}^n (C_i \times L_i)}{\sum_{i=1}^n L_i}$$

Where:

$C_i$  = TEQ level (parts per trillion [ppt])

$L_i$  = Sample length (ft)

$n$  = Number of samples at a specific core location

Segment 1 TEQ SWACs were calculated using Thiessen polygons, utilizing the LWAc TEQ level for each sample location to represent each Thiessen polygon. The size and shape of the Thiessen polygons were based on the location of neighboring sediment samples; each polygon contained one sample location and the boundaries of the polygon were equidistant from the neighboring sample locations. The 0 to 2 ft LWAc TEQ level for each Segment 1 Thiessen polygon is presented in Figure 3-3.

The LWAc TEQ level for each sample location and the surface area of the Thiessen polygon were then used to calculate the TEQ SWAC over a specified area using the following formula:

$$SWAC = \frac{\sum_{i=1}^n (LWAc_i \times SA_i)}{\sum_{i=1}^n SA_i}$$

Where:

$LWAc_i$  = Length-weighted average TEQ level (ppt)

$SA_i$  = Surface area (ft<sup>2</sup>)

$n$  = Number of samples within area of interest

TEQ SWAC values for Segment 1 were calculated for conditions prior to the early response actions completed in Reaches B and D (see Section 2.6) utilizing the above formulas. These TEQ SWAC values were calculated to represent the entire Segment 1 as well as approximate 1-mi intervals. The overall Segment 1 TEQ SWAC was 183 ppt while the 1-mi intervals were 330 ppt, 135 ppt and 70 ppt from upstream to downstream. These Segment 1 SWAC values are presented in Figure 3-4A and summarized in Table 3-3.

Post Reach B and D actions justify new TEQ SWAC concentration calculations to represent the current conditions as a result of the early response actions. The TEQ SWAC values represented in Figure 3-4B represent the Segment 1 current conditions. The current Segment 1 TEQ SWAC of 68 ppt reveals that these early actions reduced the Segment 1-wide SWAC by approximately 60 percent. The current condition, post-Reach B and D actions, TEQ SWACs for the approximate 1-mi intervals of the Segment are 8 ppt, 135 ppt, and 70 ppt.

### 3.2.2 Secondary Constituents of Interest

Figures 3-1A and 3-1B show the locations of the sediment samples collected in Segment 1 and analyzed for SCOIs. The cumulative 2006 to 2009 investigations resulted in:

- 227 Segment 1 sediment core locations sampled for SCOIs
- 791 individual Segment 1 sediment samples analyzed for SCOIs

To understand which SCOIs in Segment 1 sediments may result in benthic toxicity, a comprehensive screening process in which all SCOIs detected in Segment 1 sediment samples were compared to sediment concentrations that are protective of benthic organisms. A thorough explanation of the screening approach and the results of the evaluation are discussed in Section 3.4 (Evaluating the Basis for Action) and in Appendix B2 (Sediment SCOI Screening Using Dry Weight and TOC -Normalized Concentrations). The SCOI screening approach considered multiple independent evaluations including:

- Comparisons of detected concentrations with ecological screening level benchmarks (ESLBs) from EPA Region 5 and other published sources
- Development of SCOI potential risk zone concentrations based on site-specific sediment toxicity test results
- Comparisons of detected concentrations with other literature-based toxicity testing data
- Regional background evaluations, including sediment toxicity testing in the Chippewa River

Of the 283 SCOIs detected in one or more of the Segment 1 surface sediment samples, 90 were identified as having detected concentrations greater than the ESLBs and/or regional background concentration. A total of 35 of these individual chemicals were confirmed as target SCOIs based on follow-on toxicity testing (see Section 3.4). These 35 individual SCOIs were further categorized into six Segment 1 target SCOI groupings, as follows:

- Total chlorobenzenes
- Total chlorophenols
- PAHs
- Arsenic
- Ortho-phenylphenol (oPP)
- Ethyl parathion

The lateral and vertical distributions of Segment 1 sediment concentrations of these six target SCOI groupings are presented in Figures 3-5A to 3-5F. The distributions of SCOI concentrations are presented on a logarithmic scale. The Thiessen polygon maps at the top of Figures 3-5A to 3-5F show the maximum SCOI concentration at each sample location within the conservative surface 2-ft active bed interval (i.e., any sediment sample with a mid-depth of 2 ft or less). The lower half of Figures 3-5A to 3-5F show vertical profiles of sediment SCOI concentrations across the length of Segment 1 to delineate the general distribution of SCOI concentrations with depth below the sediment surface.

As discussed above, the Segment 1 sediment site characterization samples were collected over a period of four years in a series of sampling programs, including initial stratified (transect-based) sampling designs, followed by more focused sampling designs that targeted specific areas with the greatest potential for elevated concentrations. Sediment sampling performed in 2006 and 2007 was designed to provide an initial broad survey of PCOI concentrations and included a subset of samples analyzed for SCOIs. In contrast, sampling performed in 2008 and 2009 focused more closely on areas with the greatest potential for elevated SCOI concentrations, based on their proximity to former outfalls or to previously collected samples that exhibited elevated concentrations (“step-out” samples). The 2008 to 2009 sampling targeted areas downstream of the Dow Dam, since early actions were already underway in Reaches B and D (see Section 2.6). In addition, many of the archived 2006 and 2007 sediment survey sample extracts originally analyzed only for PCOIs were subsequently analyzed in 2009 for SCOIs (within holding times) to complete the site characterization. In Segment 1 downstream of the Dow Dam (i.e., in Reaches E to H), a total of 36 cores were collected in 2006 and 2007, and another 74 cores were collected in 2008 and 2009; multiple intervals of these cores were analyzed for SCOIs.

A follow-on comparison of Segment 1 target SCOI concentrations with site-specific sediment concentrations that are protective of benthic organisms (potential for low exposure/risk; PLER) was conducted as a further evaluation of these SCOI deposits. The site-specific risk-based evaluation is presented in Section 3.4, and was used to identify SMAs for further consideration in this Response Proposal (see Section 3.5 below).

The relative frequency of sediment SCOI concentrations exceeding PLERs at any depth interval during the two Segment 1 sampling programs can be used to perform an initial statistical assessment of the efficiency of the different sampling designs in delineating the nature and extent of elevated SCOI concentrations in Segment 1. During the 2006 and 2007 sampling program (including archive analyses), 12 percent of the Segment 1 SCOI cores collected downstream of the Dow Dam contained at least one interval that exceeded a PLER. During the 2008 and 2009 program, this frequency was substantially higher at 31 percent, suggesting that this more focused follow-on sampling successfully targeted areas with elevated SCOI concentrations, compared with the survey-based 2006 and 2007 program. Given the complexity of the various data collection programs and other confounding factors such as the varying number and magnitude of chemicals exceeding PLERs, detailed statistical evaluations of these data would provide limited value. Nonetheless, as requested by the Agencies, a simple illustrative statistical test using all SCOI data collected in the main channel of Segment 1 below the Dow Dam was performed using the indicator metric mentioned above: each core was assigned a “1” or “0” depending on whether there was or

was not an exceedance of a PLER anywhere in the core. Thus, indicator statistics applied in this manner are only appropriate for PLER compounds. There is a statistically significant difference in PLER exceedance frequencies between the 2006 and 2007 stratified sampling versus the 2008 and 2009 outfall focused sampling programs (i.e., 12 percent vs. 31 percent; significant at the 2 percent probability level based on a one-tailed test of the z-score; Fleiss et al. 2003), confirming the overall success of the outfall sampling strategy. This result supports the use of the 2008 and 2009 focused sampling design in completing the overall Segment 1 SCOI site characterization, which is described in more detail in the sections below.

### 3.2.3 SCOI Deposit Characterization

Notations in the core logs from the 2006 to 2009 sediment investigations suggested the presence of SCOI deposits within localized areas of Segment 1, particularly those located adjacent to historic outfalls. Further evaluation of these SCOI deposits was performed through multiple approaches. Multiple approaches are commonly employed at contaminated sediment sites because they integrate results from various analyses to reduce uncertainty and thus provide greater confidence in the overall characterization. To further characterize the nature and extent of these deposits, the following information was evaluated:

- All core logs collected in Segment 1 were reviewed for notations indicating the presence of SCOI deposits, including notations of “brown liquid,” “metallic sheen,” and “oily sheen,” among other descriptors.
- Retain samples were inspected where core logs noted brown liquid, metallic sheen, or oily sheen characteristics to evaluate these visual observations.
- The top-of-till elevation in each SCOI deposit area was evaluated to delineate potential depressions in the till that may have accumulated historic SCOI releases.
- Detailed chemical characterization, including a supplemental chemical analysis of tentatively identified compounds (TICs), was performed on all sediment samples that were originally noted as brown liquid, metallic sheen, or oily sheen in the core logs.
- Product recovery test wells were installed at each of the five SCOI deposit locations and monitored for the potential presence of recoverable product.

The findings from each of these evaluations are described below.

#### Core Log Review

During the 2006 to 2009 investigations, 291 cores were collected from throughout Segment 1 (Reaches A to H), as presented in Figures 3-1A and 3-1B; 134 cores were analyzed for PCOIs and SCOIs, 110 cores were analyzed for PCOIs only, and 47 cores were analyzed for SCOIs only). Of the 291 cores collected in Segment 1, a total of 14 had notations of brown liquid, metallic sheen, or oily sheen in the core logs. The locations of these 14 cores are shown in Figure 3-6. One core was collected from the area of Reach D that was subsequently dredged and capped (see Section 2.6), and the remaining 13 cores were clustered within five specific areas within Segment 1:

- Reach E, near station 73+50

- Reach F, near station 83+00
- Reach G, near station 137+50
- Reach H, near station 145+00
- Reach H, near station 151+00

Geologic profiles of these 13 cores are provided in Figures 3-7A to 3-7M. These figures show that field notations of “sheen” and “brown liquid” are restricted to core intervals directly on top of the till, at the base of the sandy sediments, or within layers of vegetation or woody debris above the till that have a higher sorption capacity for SCOs.

### **Retain Sample Inspection**

In February and March of 2010, available retain sediment samples with field notes containing sheen and brown liquid were visually inspected. During the inspection, the sediment retain samples were mixed with a stainless steel spoon and any evidence of NAPL product or sheen on the spoon or in the sediment sample was recorded. The sediment was also tested with a test paper impregnated with a hydrophobic dye that reacts with NAPL. Results from the inspection of the retain samples are noted in the core profiles in Figures 3-7. The majority of the retain samples showed no evidence of product or sheen. Residual product and sheen was observed in some retain samples from the deposit areas in Reaches E and F. No product was observed in retain samples from Reach G and H.

### **Total Chlorobenzene Concentrations in SCOI Deposits**

Detected SCOI concentrations in sediment samples that were noted in the core logs as sheen or brown liquid were predominantly comprised of chlorobenzene compounds. Core profiles of total chlorobenzene concentrations at each of the 5 SCOI deposit locations are presented in Figures 3-7. As shown in these figures, the highest concentrations of total chlorobenzenes in the cores corresponded to sediment intervals where sheen or brown liquid was noted in the core logs. The highest total chlorobenzene concentrations measured in Segment 1 (concentrations greater than 10,000 milligrams per kilogram [mg/kg]) were detected in cores where sheen or brown liquid were noted in Reach E (near station 73+50) and Reach F (near station 83+00), which are located immediately adjacent to historic outfalls. Sediment concentrations of non-polar organic chemicals such as chlorobenzenes in excess of 10,000 mg/kg (greater than 1 percent of sediment mass) is an indicator of the presence of NAPL product (EPA 1993). The maximum total chlorobenzene concentrations in the Reach H deposit near station 145+00 is approximately 2,550 mg/kg; total chlorobenzene concentrations in deposits from Reaches G and H (near station 150+00) are less than 1,000 mg/kg.

For core locations where the bottom of the core is composed of a large percentage of gravel, a liquid portion of the sample could potentially drain from the cores as they are being extracted from the sediment. If this situation occurs, the chemical analysis may not adequately reflect the conditions at the bottom of the core as described above. For this reason, chemical concentrations in the sediment samples submitted for analysis represent only one of the methods for determine the presence of product.

The overall distribution of total chlorobenzene concentrations in Segment 1 sediments is depicted in Figure 3-5A-E. This figure shows the vertical profile of Segment 1 total chlorobenzene concentrations; all total chlorobenzene concentrations greater than 100 mg/kg in Segment 1 (a conservative initial screening criterion to identify the potential presence of SCOI deposits) are located within the five SCOI deposit areas listed above.

### Top-of-Till Evaluation

To further delineate the likely boundary of SCOI deposits in Segment 1, the elevation of the top of the till in the deposit areas was evaluated using available geologic data. The delineation of the geologic till surface was based on core logs from the 2006 to 2007 site investigations (ATS 2009), and the 2008 and 2009 H-12 Outfall Investigation (URS 2010); deeper borings advanced during RGIS implementation (Radian 1998; McDowell 2000); and bathymetric data collected during 2006 to 2009 (ATS 2009). Using these data, an interpolation of the surficial sand unit and the top-of-till elevation between core locations was conducted using three-dimensional ordinary kriging with Environmental Visualization System (EVS) software (EVS PRO 9.42). Ordinary kriging is a weighted moving average interpolation method that minimizes the variance of a predicted point with the weighted average of its neighbors. The EVS software determines an optimal semivariogram model for calculating the weighting factors and the variance for pairs of samples, and is particularly well suited for interpretation of geologic data.

The interpolated top-of-till elevation resulting from the three-dimensional EVS ordinary kriging is presented in Figures 3-8A to 3-8E. These figures show geologic and chemical cross-sections of each of the five SCOI deposit areas. Cross-river and longitudinal cross-sections are provided for each location. In addition to the geologic profile, vertical profiles of total chlorobenzene concentrations for samples within the SCOI deposit areas are also shown. The till elevation profiles and total chlorobenzene profiles in these figures further verify that the delineated SCOI deposit areas are generally confined to low elevation till areas within Reaches E to H.

### Composition

To further characterize the SCOI deposit areas, the distribution of organic compounds from each area was reviewed. Figure 3-9 shows the distribution of the organic compounds, based on concentration, for the subsurface sample with the maximum total organic compound concentration from each SCOI deposit area. The distributions are presented for total chlorobenzenes, total chlorophenols, PAHs, other volatile organic compounds (VOCs; besides chlorobenzene), other SCOIs (includes pesticides and phthalates), and TICs<sup>2</sup>. Chlorobenzenes comprised the majority (59 to 91 percent) of the organic compound fraction in the samples from deposit areas in Reaches F, G, and H. Other VOCs represented the majority (61 percent) of the organic compounds from

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<sup>2</sup> The sample with the maximum total organic compound concentration from the potential deposit in Reach H, Station 151+50 was not analyzed for VOCs (core location 151+50-IC33). Therefore, the organic compound distribution from this deposit is based on the samples with the two highest organic compound concentrations; an average concentration was calculated for compounds analyzed in both samples, and the VOC concentrations, including chlorobenzene, are represented by the one sample analyzed for VOCs. Thus, all chlorobenzene compounds were included in the chlorobenzene summation. Additional neighboring core locations not analyzed for chlorobenzene and additional VOCs include 151+00-IC144 and 151+50-IC92. Maximum total chlorobenzene concentrations, excluding chlorobenzene, across all depths at these two locations are 9.0 mg/kg and 6.3 mg/kg, respectively.

the deposit in Reach E. The VOCs in the Reach E sample were comprised predominantly of 1,2-dibromoethane, benzene, and tetrachloroethene. While no TICs were identified in the SCOI deposit sample in Reach E, 1,1-biphenyl-2-phenoxy was identified in the SCOI deposits in Reaches F, G, and H. Other identified TICs include diphenyl ether and terphenyl-2-ol. VOCs and TIC compounds detected within each SMA will be addressed during remedy design such that each respective remedy appropriately addresses the full range of detected compounds.

A review of the VOCs and TICs detected in Segment 1 sediment outside the SCOI deposit areas was conducted. As discussed in Section 3.4 and in Appendix B1, VOC and TIC compounds were included in the screening analysis of the 283 SCOIs detected in Segment 1 sediment samples. None of the other VOCs and TICs were carried forward as “target” SCOIs for this Segment 1 Response Proposal based on the comprehensive screening analysis performed.

### **Product Recovery Testing**

To verify the presence or absence of recoverable product, nine recovery test wells were installed in the five localized SCOI deposit areas in November 2010. Two wells were installed in each of the four upstream deposits, and one well was installed at the lower Reach H deposit (near station 150+00). The locations of the recovery wells are provided in Figures 3-10A to 3-10B. During installation, each well was advanced into the till so that the bottom of the well screen was located below the top of the till. A description of the test well installation and monitoring is provided in the January 2011 Segment 1 Product Recovery Report (Dow 2011).

The test wells were monitored over a period of 22 to 31 days for product recovery and product detection. Product recovery indicates measureable product was pumped from the test well. Product detection indicates free-phase product was detected in the test well using an oil water interface probe, but measureable product was not recovered from the well via pumping. The results of the product recovery testing are summarized as follows:

- Reach E, near station 73+50 – Product detected and recovered (RTW-1 only)
- Reach F, near station 83+00 – Product detected (RTW-7 only)
- Reach G, near station 137+50 – No product detected
- Reach H, near station 145+00 – No product detected
- Reach H, near station 151+00– Product detected and recovered (RTW-5)

While the 2010 testing provided important confirmatory observations of the presence of potentially recoverable product, there were nevertheless uncertainties associated with the product recovery testing. For instance, the thickness of the product measured in the test wells likely overestimates the thickness of product that is actually located on top of the till unit. This is due to the placement of the bottom of the test well screen below the top of the till surface. As the product flows into the test well it rises to the elevation that is approximately equal to the top of the product in the sediment, but the thickness of the product in the test well extends below the surface of the till. Also, silt accumulated in the wells increased the difficulty of measuring the product thickness in the

well. Depending on the alternatives chosen, additional product recovery testing may be required during the design phase to address these uncertainties.

### **Summary of SCOI Deposit Evaluation**

An evaluation of multiple approaches (core log notations, total chlorobenzene concentrations in sediment, observations from retain sample inspection, till elevation, and product recovery tests) suggest the presence of SCOI deposits in five isolated areas in Segment 1. Review of the core logs and till elevation suggest these deposits are bound vertically by the low-permeable till surface and are confined laterally by low-lying areas of the till.

The five deposits were further differentiated through the inspection of retain samples and product recovery tests. These evaluations suggest the deposits in Reach E, F, and lower H (near station 151+00) contain free-phase product. In contrast, the deposits in Reach G and upper H (near station 145+00) do not indicate the presence of free-phase product; these deposits likely contain only residual material. Further evaluation of the potential mobility of SCOIs in these five deposits, based on site-specific contaminant transport modeling, was used to evaluate remedy alternatives and is presented in Section 3.3.

### **Origin of SCOI Deposits**

There are no known continuing SCOI sources to Segment 1 sediments, and the source control information presented in Section 2 indicates that the SCOI deposits are more than 30 years old (also see Section 3.3.3). The chemical and physical data and product recovery testing results for the SCOI deposits in Reaches G and upper H (near station 145+00) indicate that the material is likely old, weathered residual material. The weathering process typically results in preferential degradation of the more volatile NAPL components and leaves behind a less soluble residue that may exhibit some of the physical appearances of the unweathered deposits (EPA 1993). The sediment SCOI characterization data collected in these areas reveal that many of the chemical constituents have since degraded, resulting in relatively low sediment sample concentrations detected in the Reach G and upper H SCOI deposits.

The SCOI deposits in Reach E, F, and lower H are also old in that they are expected to have predated the RGIS installation and outfall closure and control activities that occurred in the 1970s and 1980s. Further, the SCOI deposits in Reach E, F, and lower H may also contain weathered residual material, although the evidence presented above indicates that free-phase product is also present. Based on a review of the Dow Midland facility development and historical aerial photographic records, the location of all five SCOI deposit areas correlate well with the location of historic storm water outfalls and ditches. Figure 3-11 shows the locations of the SCOI deposits and historic outfalls. Both the Reach E and F potential deposits are located immediately adjacent to and downstream of former outfall locations. The outfall adjacent to the Reach E SCOI deposit can be seen on the 1952 aerial photograph (Figure 2-5). The outfall adjacent to the Reach F SCOI deposit is a former storm water trench that extended from the production area to the river. Between 1945 and the 1960s, the storm water trenches and outfalls were diverted to the WWTP.

### 3.3 Sediment and Contaminant Transport

#### 3.3.1 Segment 1 Bed Stability Evaluation

The stability of river sediments in Segment 1 was evaluated, based on the information available to date and analyses performed to date, to determine the active bed depth (i.e., depth to which sediments may be mixed due to physical processes). This was accomplished using an evaluation that combined empirical information with numerical modeling, consistent with EPA (2005) guidance, to provide greater confidence in the overall characterization. There is ongoing work to further evaluate Segment 1 sediment bed stability (e.g., additional bed pin and bathymetry measurements planned in 2011, modeling of potential RGIS work and the potential effects on adjacent sediment, additional evaluation of the information). These further evaluations will be incorporated into the remedial design, as appropriate. The empirical component of the Segment 1 bed stability evaluation included the following:

- Comparison of bathymetry measurements collected at various points in time (i.e., differential bathymetry analysis)
- Examination of longitudinal variations in bed elevation throughout Segment 1 (i.e., bedform analysis)
- Examination of bed elevation changes at discrete bed pin locations situated throughout Segments 1 and 2 (i.e., bed pin analysis).

Bedforms—primarily dunes—are characteristic and expected features in a sand-bedded system such as the Tittabawassee River, and thus, a general understanding of the processes involved in their development is crucial in interpreting bathymetry measurement comparisons and bedform geometry and their relation to the active bed depth. Bedforms observed in the Tittabawassee River typically develop during higher flow conditions and migrate due to bedload transport. The migration rates and geometric characteristics change in response to river flow rates and water depths (Mohrig and Smith 1996; Wilbers and ten Brinke 2003). Bedforms are, in essence, sediment waves, and like a wave, their height is measured as the vertical distance between the peak and trough of the wave form.

Figure 3-12 displays a schematic view of bedform development. The top panel depicts the sediment bed prior to bedform formation. The lighter brown area at the top of the sediment bed represents the depth of the bed affected during bedform formation. As the bedform develops, sediment is moved from the upstream end of the bedform and deposited on the downstream end. This movement of sediment results in a bedform with height  $h$  when measured from the upstream trough to the downstream peak. During formation and subsequent downstream migration, no net accretion or loss of material occurs over the length of the bedform; the bedform corresponds to a redistribution of sediment (i.e., change in bed morphology) along the sediment bed. As shown in the bottom panel of Figure 3-12, the depth of sediments affected by bedform formation is only half the total bedform height (i.e.,  $h/2$ ). This process also applies to the comparisons of bed elevations obtained at different points in time. This is an important concept that must be considered when interpreting the evaluation results discussed below.

The three empirical analyses are discussed further in the subsections below. The follow-on numerical modeling component consisted of the development and application of hydrodynamic and sediment transport models to further characterize the stability of sediments within Segment 1, including within specific areas. The hydrodynamic and sediment transport models and sediment stability estimates for Segment 1 are discussed in Section 3.3.2.

### **3.3.1.1 Differential Bathymetry Analysis**

Four bathymetry surveys have been conducted in Segment 1 to date: a single-beam sonar survey in 2003 and three multi-beam sonar surveys, one each in 2007, 2008, and 2009 (ATS 2009). The single-beam survey was conducted in December 2003 and consisted of the collection of bed elevation measurements along two longitudinal transects situated on either side of the river channel and 390 lateral transects spaced approximately every 0.1 mi (see Appendix A1 for transect locations within Segment 1). The 2007, 2008, and 2009 multi-beam surveys were conducted in the spring of each year and consisted of the collection of bed elevations across the entire river bottom that were aggregated up to a density of one measurement for every square ft of river bottom (ATS 2009). The 2007 and 2009 multi-beam surveys covered the entirety of Segment 1; however, due to ongoing remediation-related construction activities in the upper reaches of Segment 1 (Reach D) in 2008, Reaches C and D were not surveyed in 2008. Figures showing the bed elevation data obtained in Segment 1 during the three multi-beam surveys are provided in Appendix A1. The data obtained during these bathymetry surveys were compared to characterize changes in bed elevation for three time periods: 2003 to 2007, 2007 to 2008, and 2008 to 2009.

Real-time kinematic (RTK) global positioning system (GPS) survey techniques were used to obtain multibeam elevation measurements of the Tittabawassee River bed. The functionality and accuracy of the RTK GPS positioning were checked daily through verification of one or more control points established along the river, following survey techniques defined by the U.S. Army Corps of Engineers (USACE) Engineering and Design - Hydrographic Surveying manual (EM-1110-2-1003; 2002) and equipment manufacturers' documentation. These positioning checks indicate horizontal positioning differences of 0.03 to 0.20 ft and vertical positioning differences of 0.04 to 0.20 ft between the measurement units and the known control points (ATS 2009). These horizontal and vertical inaccuracies are recognized in the differential bathymetry analysis discussed below. Elevation differences of less than 0.5 ft are considered to be within the precision of the instrument measurements and cannot be considered true changes in elevation. This definition is consistent with that used at other sites (e.g., Alcoa 2009).

### **Comparison of Multi-Beam Surveys**

Differential bathymetry analyses for the 2007 to 2008 and 2008 to 2009 periods were generated by overlaying the respective multi-beam bathymetry grids (i.e., 1 ft by 1 ft squares) and subtracting the values in the older grid from the matched values in the more recent grid (e.g., 2009 measurements minus the 2008 measurements equal changes in elevation over the 2008 to 2009 period). This calculation resulted in a differential grid where positive values represent an increase in elevation and negative values represent a decrease in elevation over the time period. Measurable changes in sediment elevation were defined as those in excess of 0.5 ft, considering the precision of the bathymetry surveys between various years, as discussed above. Apparent shifts along the side

slopes are an artifact of the measurement techniques employed in 2007; the 2007 multi-beam data along these slopes were thus excluded from the differential calculations. Figure 3-13 shows the results of the multi-beam differential calculation in Reach G for the 2008 to 2009 period as an example. The complete set of Segment 1 multi-beam differential bathymetry figures for the 2007 to 2008 and 2008 to 2009 periods are provided in Appendix A.

### **Comparison of Multi-Beam and Single-Beam Surveys**

Due to the nature of the 2003 survey (i.e., single-beam transects, which do not provide complete coverage of the riverbed), a different approach was used in calculating the differential bathymetry for the 2003 to 2007 period. For this comparison, each 2003 single-beam measurement was paired with an overlapping 2007 multi-beam measurement. Each 2003 elevation measurement was then subtracted from its paired 2007 multi-beam elevation measurement to compute the change in elevation between the two surveys. Bed elevation changes between the 2003 and 2007 surveys were then examined in two ways: on a point-by-point basis (i.e., without interpolation between points); and through interpolation using a triangular irregular network (TIN) to provide full coverage of the river bottom in Segment 1.

Two variations of the TIN interpolation were computed and the resulting surfaces were compared to assess the sensitivity of the differential bathymetry analysis to the interpolation scheme used. The first surface in the comparison was generated using all of the single-beam measurements (i.e., both lateral and longitudinal transects) and the second was generated using only measurements along the lateral transects (see top and bottom panels of Figure 3-14, respectively). As can be seen in Figure 3-14, both interpolation schemes yield results that are qualitatively similar (i.e., both show bed elevation increases and decreases in the same general areas). Both interpolation schemes were considered for this analysis. A complete set of figures showing the 2003 to 2007 interpolated differential bathymetry surfaces for Segment 1 is provided in Appendix A.

### **Results of Differential Bathymetry Analysis**

The areal distributions of bed elevation changes within Segment 1 for each of the three comparison periods (i.e., 2003 to 2007, 2007 to 2008, and 2008 to 2009) formed the basis for the differential bathymetry analysis. Figure 3-15 summarizes the bed elevation changes in Segment 1 for the 2007 to 2008 and 2008 to 2009 multi-beam comparisons (top and bottom panels, respectively). Areas upstream of the Dow Dam (i.e., Reaches A through D) were excluded due to the absence of bathymetry data from portions of this reach during the 2008 survey. For this assessment, bed elevation changes were grouped into 0.5-ft intervals and the surface area within Segment 1 that experienced a change in bed elevation within each respective group was summed. For example, for the 2007 to 2008 comparison (see top panel of Figure 3-15), 13 percent of the area within Segment 1 experienced a decrease in bed elevation of 0.5 to 1 ft (i.e., 6 to 12 inches), while 6.3 percent of the area within Segment 1 experienced an increase in bed elevation of 0.5 to 1 ft (6 to 12 inches). As discussed above, elevation changes of less than 0.5 ft were considered within the uncertainty of the comparisons and were identified as areas of no measurable change.

Because the interpolation of the 2003 to 2007 differential bathymetry is complicated by comparisons of single- and multi-beam data, the distribution of bed elevation changes between

these surveys was also examined on a point-by-point basis (i.e., without interpolation between points). Using the same bed elevation groupings as the areal distributions, the point-by-point distribution was computed by grouping the individual measurement points into 0.5-ft intervals and counting the number of points falling within each interval. This distribution, as well as the areal distributions of bed elevation change for the two interpolation methods, is summarized in Figure 3-16.

Results of the 2007 to 2008 and 2008 to 2009 bathymetry analysis yielded similar results; 73 to 75 percent of the area within Segment 1 experienced no measurable change (i.e., changes within +/- 0.5 ft), and 94 to 95 percent of the area experienced a change in bed elevation of 1 ft or less. Less than 0.2 percent of the area within Segment 1 experienced a decrease in bed elevation of 2 ft or more.

The 2003 to 2007 comparisons yielded relatively similar results; 46 to 57 percent of Segment 1 experienced no measurable change in bed elevation, 82 to 88 percent of the area experienced a change in bed elevation of 1 ft or less, and less than 2 percent of the area experienced a decrease of bed elevation in excess of 2 ft. Uncertainties introduced by comparing the single-beam and multi-beam surveys may account for the differences in the 2003 to 2007 comparisons. Such uncertainties are not a factor for the multi-beam to multi-beam comparisons, providing greater confidence in the multi-beam differential bathymetry results.

### **3.3.1.2 Bedform Analysis**

The 2007, 2008, and 2009 multi-beam data discussed above were also used to evaluate longitudinal variations in bed elevations caused by migrating bedforms within Segment 1. Bedforms observed in the Tittabawassee River are typically formed during higher flow conditions. Because the multi-beam surveys were conducted during spring high flows, the multi-beam measurements capture typical springtime bedform heights, and thus can be used to assess bedform-related elements of the active bed depth in Segment 1.

The bedform analysis consisted of cutting three longitudinal transects through the bedforms observed in the multi-beam bathymetry measurements from Segment 1 (Figure 3-17). Three longitudinal transects (one running roughly through the center of the bed forms and one spaced 50 ft to either side of the middle transect) were selected to capture representative lateral variations in bedform heights. The elevations measured along these three transects are shown for an example stretch of Segment 1 (within Reach F) in Figure 3-18. The height of each bed form was computed from the low elevation preceding the bed form to its apex (i.e., distance between the peak and trough of the bedform). Cumulative probability distributions of the bedform heights calculated along each longitudinal transect are compared for each multi-beam survey in Figure 3-19.

Results of the bedform analysis indicate that 95 percent of the bedform heights computed from the 2007 through 2009 multi-beam bathymetry measurements are about 0.8 ft or less. Less than 0.5 percent of the bedform heights exceed 2 ft, with an overall maximum bedform height of 2.2 ft (in 2007).

### 3.3.1.3 Bed Pin Analysis

Bed pin surveys provide independent estimates of bed elevation changes at discrete locations within the river. Bed pins are pieces of rebar that are driven vertically into the sediment bed until only 1 ft of the pin extends above the sediment surface. Upon installation, a baseline sediment elevation measurement was obtained at each bed pin location. Subsequent surveying of these bed pins provides a time series of bed elevation changes at each bed pin location (ATS 2009). The time series of bed elevations were used to determine a maximum change in bed elevation that occurred at each pin bed location during the survey period.

In August 2009, bed pins were installed at locations along each of three transects within Segment 1 (in Reaches E, F, and H) (ATS 2009). The Segment 1 bed pins were re-surveyed in 2010, providing two measurements of bed elevation change at each bed pin location. Given the limited data from these Segment 1 bed pins, additional bed elevation data obtained from Segment 2 bed pin locations were also considered in this analysis, given similar geomorphology between Segments 1 and 2. Segment 2 bed pins were installed along 21 transects (in Reaches J, K, L, M, N, P, and Q) between October 2007 and August 2009, and several follow-up surveys were conducted between 2008 and 2010 (see Table 3-4 for details). The positions of the Segment 1 and Segment 2 bed pins are shown in Appendix A3.

Figure 3-20 shows the August 2009, May 2010, and September 2010 sediment elevation measurements for each Segment 1 bed pin transect; similar figures for Segment 2 bed pin transects are provided in Appendix A4. Figure 3-21 shows the cumulative frequency distributions of the maximum elevation changes within Segments 1 and 2. The bed pin measurements show that the maximum change in sediment elevation in Segments 1 and 2 was a decrease of 2.1 ft, which occurred at a single location in Reach F (Segment 1) where bedforms are routinely observed in the spring multi-beam bathymetry data. All other bed pins showed a change of less than 1.7 ft, with a median change of about 0.7 ft.

### 3.3.1.4 Evaluation of Empirical Analyses

The stability of Segment 1 sediments was based on three empirical measurements: 1) differential bathymetry analysis of four sonar bathymetry surveys; 2) estimation of bedform heights measured under typical spring high-flow conditions; and 3) comparison of bed elevation measurements collected at discrete bed pin locations. The findings from each of these analyses are listed below:

- Comparison of the 2003, 2007, 2008, and 2009 sonar bathymetry measurements indicated that less than 2 percent of the area within Segment 1 experienced decreases in bed elevation of 2 ft or more. Much less of the Segment 1 area experienced a bed elevation decrease of 2 ft or more (less than 0.2 percent) if only the multi-beam bathymetry data are considered. Additionally, the individual comparisons (i.e., 2003 to 2007, 2007 to 2008, and 2008 to 2009) show that bed elevation changes (i.e., increases and decreases) occur consistently in the same general areas of Segment 1.
- Analysis of the 2007, 2008, and 2009 multi-beam bathymetry data showed that more than 99 percent of the observed bedform heights measured in Segment 1 were 2 ft or less. The

maximum bed form height computed from the multi-beam bathymetry measurements was 2.2 ft.

- Examination of the Segments 1 and 2 bed pin data indicates that 84 of the 85 locations (about 99 percent) experienced a bed elevation change less than 1.7 ft. Only one location exhibited a change in bed elevation in excess of 2 ft (2.1 ft at location EP2 in transect RF-103+50).

The empirical data for Segment 1 demonstrates that the vast majority of the sediment bed in Segment 1 experiences annual elevation changes on the order of 1 ft or less, and only a small fraction of the area experiences changes that approach or exceed 2 ft. These results indicate an active bed depth less than 2 ft (based on bedform dynamics discussed in Section 3.3.1), and support the use of 2 ft as a conservative initial upper-bound estimate of the active bed depth throughout Segment 1. Refined estimates of the active bed within individual SMAs are presented below.

### **3.3.2 Hydrodynamic and Sediment Transport Modeling**

Linked hydrodynamic and sediment transport models were applied to Segment 1 and used to address (i.e., along with sediment stability measurements summarized above in Section 3.2.1) the following questions:

- What is the potential for in-channel bed movement at specific locations in Segment 1 during high-flow events?
- What is the fate of sediment within the active bed at specific locations within Segment 1?
- How might response actions in Segment 1 affect sediment conditions in downstream areas?

As discussed in ATS (2009), Dow previously developed a detailed two-dimensional, vertically averaged hydrodynamic model of the Tittabawassee River for use in the GeoMorph® Site Characterization. The calibrated hydrodynamic model, which extends from the confluence of the Upper Tittabawassee and Chippewa Rivers to the Sixth Street Turning Basin in the Saginaw River, simulates spatial and temporal variations in current velocity and water surface elevation (water depth) throughout the river channel and floodplain. The model is capable of simulating overbank flow in the floodplain areas during high-flow events, and incorporates the effects of vegetation on bed shear stress.

The numerical grid for the hydrodynamic model includes the river channel and adjacent floodplain, with six grid cells used to delineate the channel in the lateral direction. A total of about 9,000 grid cells are used in the model, with approximately 3,000 grid cells within the river channel. Incoming flow rate at the upstream boundary of the model is specified on a daily-average basis using discharge data collected at a U.S. Geological Survey (USGS) gaging station. The effects of changes in water surface elevation in Lake Huron are incorporated into the downstream boundary of the model.

The hydrodynamic model was calibrated and validated using current velocity and water surface elevation data collected at several locations throughout the Tittabawassee River. The predictive capability of the model was evaluated over a range of flow conditions in the river. In addition, the

capability of the model to predict the extent of floodplain inundation during a high-flow event was also investigated. The results of the calibration and validation process verified the predictive capability of the hydrodynamic model and its utility as a tool for sediment management in Segment 1. For example, the hydrodynamic model was previously used to estimate the range of bed shear stresses and design protective cap armor specifications for early actions completed in Reaches B and D (see Dow 2008).

Concurrent with the preparation of this Segment 1 Response Proposal, a linked sediment transport model was developed for the Tittabawassee River to simulate suspended load transport of clay/silt and sand (four size classes), and bedload transport of sand and gravel (20 size classes). A detailed discussion of the linked hydrodynamic and sediment transport models is presented in Appendix C). As discussed in Appendix C, an approximate method was used to simulate the interactions between hydrodynamics and sediment transport due to bed elevation changes in the river channel. The sediment transport model simulates temporal and spatial changes in:

- Bed elevation in the channel
- Physical composition of the surface layer of the sediment bed
- Suspended sediment concentrations
- Bedload transport
- Depth and elevation of the bedform mixing layer.

Site-specific data (discussed in Appendix C) were used to specify the following inputs to the sediment transport model:

- Magnitude and composition of suspended and bedload at the upstream boundary
- Spatial distribution of bed properties (i.e.,  $D_{50}$ , initial composition)
- Dry density
- Effective bed roughness (i.e.,  $D_{90}$ ), which is used to calculate bed shear stress).

The main channel of Segment 1 is a sand-bed river, with typical median particle diameters ( $D_{50}$ ) of about 500 microns ( $\mu\text{m}$ ; medium/coarse sand). The average annual load of sediment entering Segment 1 is approximately 160,000 metric tons/year, with about 60 to 70 percent of that load being comprised of sand and gravel materials.

The sediment transport model was calibrated and validated over a 20-month period (March 2008 through October 2009). Three parameters and inputs were adjusted during the model calibration process: 1) coefficients in the active surface layer thickness equation (affects erosion of suspended sediment); 2) effective diameter of medium to coarse sand in the suspended load transport sub-model; and 3) thickness of the surface layer in the bedload transport sub-model. The reliability of the model was evaluated using the following quantitative comparisons between predicted and measured values: 1) bed elevation change based on multi-beam bathymetry data collected in May 2008 and May 2009; 2) bed elevation change based on bed pin data collected in August 2008 and

November 2009; and 3) bedload transport rate data collected during 2008, 2009, and 2010. In addition, geomorphologic data were used to qualitatively evaluate the predictive capability of the model. The results of the validation and calibration process, described in Appendix C, demonstrate that the model is capable of reliably simulating sediment transport processes in Segment 1, and that it can be used as a management tool to answer the questions listed above.

The sediment transport conceptual site model (CSM) includes components relating to both short-term (i.e., episodic) localized effects and longer-term (i.e., annual) average effects. The hydrodynamic and sediment transport models were used to evaluate sediment transport processes in Segment 1 over two temporal scales: 1) a relatively high-flow event that occurred during August to October 1986 (approximately a 50-year flood); and 2) more typical conditions occurring over a 10-year period. These simulations provided information relevant to the study questions outlined above. The modeling results, which are presented in Appendix C, were used to characterize sediment transport in Segment 1 during high-flow events and over multi-year periods. The output of the hydrodynamic and sediment transport modeling, when interpreted in a weight-of-evidence evaluation that also considered the empirical data discussed in Section 3.3.1, supports the following:

- Generally, the Segment 1 sediment bed is in a state of dynamic equilibrium, with bed elevations oscillating about a datum on a monthly to yearly time scale with little or no net deposition or erosion when spatially averaged over the entire bed.
- The depth of the active bed layer is spatially and temporally variable, with typical depths of less than 1 ft.
- Bedload transport occurs over a wide range of flow conditions, while significant suspended load transport only occurs during high-flow events (e.g., overbank flow conditions).
- During a relatively high-flow event (i.e., the 50-year flood that occurred in 1986), about 10 percent of the incoming load deposits in the river channel and another 10 percent deposits in the floodplain.
- During the 50-year flood event, about 40 percent of the Segment 1 bed area is net erosional, with typical decreases in depths of about 0.2 ft and a maximum decrease in depth of about 0.8 ft (the depth of the bottom of the active bed layer is typically about 0.3 ft, with a maximum depth of 1 ft).

The sediment transport model predictions of bed elevation change during a high-flow event, as described above and in Appendix C, correspond to the spatial scale of a model grid element, which is typically about 17,000 sq ft (i.e., 50 ft in the cross-channel direction and 330 ft in the along-channel direction). These predictions do not include the effects of bedform movement on sediment bed morphology, which can occur at a smaller sub-grid spatial scale (i.e., 1 to 10 sq ft). Empirical information such as the multibeam bathymetry measurements provides the information needed to assess bed elevation changes on smaller, sub-grid scales.

The active bed depth varies temporally and spatially within Segment 1 during multi-year periods due to changes in bed elevation and bedform height. The spatial distribution of the maximum

predicted depth of the active bed during a multi-year period (i.e., 10-year simulation) in Segment 1 is shown in Figure 3-22. These results show that the maximum depth of the active bed during the 10-year simulation period is less than 1 ft over large portions of Segment 1. Maximum depths of the active bed layer in the six Segment 1 SMAs (see Section 3.5 for discussion of SMAs) during the 10-year simulation period are listed in Table 3-5.

### 3.3.3 Mobility Potential of SCOI Deposit

The data and evaluations from multiple lines of evidence (core logs, retain samples, SCOI concentrations, till elevations, and product recovery investigation results), as well as the site history and source control information, were used to evaluate the SCOI deposits for the presence of free-phase product. This evaluation resulted in the following observations that support the conclusion that the product, where present, is no longer migrating through the sediments:

- There is no known continuing source of SCOIs to the Segment 1 channel. All known product releases to the river have been eliminated through the operation of Dow's state-of-the-art wastewater treatment facilities and through the operations of RGIS and other source control measures described in Section 2.
- The product deposits are likely more than 30 years old and movement of the product to resting places has likely already occurred. Chemical releases that contributed to the SCOI deposits likely occurred prior to the construction of the WWTP in 1945; and any potential subsurface migration pathways to the river began to be intercepted by RGIS starting at the end of the 1970's.
- Product has moved to low-till elevation depression areas y. The localized low areas in the till surface create stable low permeability surfaces to support the product. Hydraulic conductivity values for the till unit (as measured at the Salzburg Landfill) are indicative of an aquitard. They range from  $1.2 \times 10^{-7}$  cm/s to  $2.8 \times 10^{-8}$  cm/s (Dow 2002). The low-permeability of the till unit inhibits further downward migration of the product.

### 3.3.4 Groundwater Flux Potential

As discussed in Section 2.3, previous hydrogeologic and engineering investigations and evaluations within and adjacent to Segment 1 have revealed that stratified and reworked sands and silts with thin clay seams form a variable surface veneer over the site area, ranging in thickness from 0 to as much as 15 ft. This surface sand unit forms a discontinuous unconfined aquifer beneath the river. Because of the presence of a thick underlying low-permeability till unit and pumping of localized groundwater into RGIS, vertical groundwater discharges into the river through the surficial sandy sediments is unlikely, particularly near RGIS.

Five vertical sets of piezometers in the immediate Site vicinity were utilized to characterize hydrogeologic conditions and support chemical isolation modeling for the Reach B cap design. Based on these piezometers and the hydraulic conductivity of the clay and till units underlying the sandy sediments in Reach B, a maximum upward vertical groundwater flow rate of 0 to 0.1 centimeter per year (cm/yr) was calculated for the Reach B area. A full description of the Reach B

chemical isolation modeling is presented in the July 2009 Reach B Tittabawassee River, Basis for Offshore Cap Design (Anchor QEA 2009).

In some areas of Segment 1, a strong downward vertical hydraulic gradient exists in the sandy sediments, particularly in portions of the Site where the clay and till unit is absent. The strong vertical hydraulic gradient in these areas is due to the RGIS purge water wells that are screened in the till sand units. These purge wells continuously draw groundwater from the deeper portions of the till sands adjacent to the river, resulting in a downward hydraulic gradient in the overlying surficial sandy sediments. A detailed description of the till sand units is presented in the Radian (2000) report titled *Identification and Description of Glacial Till Sand Units in Areas Along the Tittabawassee River*; an assessment of the hydraulic capture of the till sand groundwater by RGIS is presented in hydrogeology report contained as Section III of the 2002 RCRA License Reapplication (Dow 2002).

The RGIS collection trenches located along the boundaries of Segment 1 affect the horizontal hydraulic gradients within the sandy sediments overlying the clay/till units. The extraction of groundwater through RGIS (via pumping wells and trenches along the shoreline) also results in a lateral hydraulic gradient across the river toward the river bank. In 1998, a hydraulic investigation was conducted for RGIS to quantify the hydraulic loading of each section of RGIS and to determine the system's capability to retrieve groundwater in the unlikely event of a temporary gradient reversal. A description of the extraction of river water through the surficial sediments and sheet pile wall is presented in the 1998 report (McDowell 2000).

The multiple data assessments summarized above reveal that groundwater within the surficial sandy sediments of Segment 1 flows downward from the river surface water into the surficial sand layer and/or horizontally within the surficial sand layer towards RGIS.

### **3.4 Evaluating the Basis for Action**

This section evaluates the basis for action in Segment 1, based on potential exposure and potential risks to human health and the environment posed by the presence of PCOIs and SCOIs in Segment 1 sediments. The NCP (40 C.F.R. §300.415(b)(2)(i)) sets forth goals to reduce the actual and potential exposures at contaminated sediment sites. The overall objective of this Segment 1 Response Proposal is consistent with the NCP and will inform the basis for action in Segment 1. Task 10 of the AOC/SOW requires a post-response residual risk assessment (RRA) for Segment 1. The RRA, which will be initiated after completion of the Segment 1 response actions described herein, will be conducted in accordance with EPA guidance included in Section VIII D of the AOC/SOW. The outcome of the RRA will determine whether post-response conditions in Segment 1 are protective of human health and the environment. There is ongoing work to further evaluate the basis for action in Segment 1 (e.g., incorporate results of the fall 2010 benthic community assessments, and potential fall 2011 benthic community and/or habitat assessment results). Consistent with EPA (2005) Guidance and EPA's (2002) eleven Risk Management Principles for "Management of Contaminated Sediment Sites," the understanding of chemical exposure risks will be updated as new information or analysis becomes available, for example during remedial design and/or during development of the Task 10 RRA.

This evaluation is intended to accomplish the following:

- Describe potential pathways of potential SCOI exposure associated with Segment 1.
- Describe the process that was used to identify “target” SCOIs that form the basis for action in this Response Proposal.
- Describe a framework for the development of site-specific screening levels that can be used to define site-specific target SCOI levels for the purpose of this Segment 1 Response Proposal.
- Identify how PCOIs are addressed in the Segment 1 Response Proposal with regard to each potential pathway identified.

### **3.4.1 Potential Pathways of Exposure and Potential Risks in Segment 1**

In Segment 1, potential SCOI exposures to human and ecological receptors can occur via:

- Direct contact for ecological receptors
- Bioaccumulation and potential food web exposures
- Direct contact for humans

Each of these potential pathways is addressed in the sections below.

### **3.4.2 Direct Contact for Ecological Receptors**

Sediment-dwelling organisms may be in direct contact with and ingest contaminated sediment and food items. Potential toxicity to other receptors (fish, birds, mammals, and humans) from exposure to contaminated sediment is typically through the ingestion of contaminated prey items and the incidental ingestion of sediment that occurs during foraging activities. This is discussed in more detail below.

Evaluation of potential toxicity to sediment-dwelling organisms from potential exposure to SCOIs in Segment 1 sediments requires the following information:

- A sufficient characterization of the concentrations of SCOIs in sediments, both from the perspective of the number of SCOIs measured and the spatial distribution of these SCOIs in surficial sediments (i.e., in the biologically active zone).
- A measure of the potential risks to sediment-dwelling organisms to permit the evaluation and selection of sediment-based response actions that may be required to reduce potentially unacceptable exposures.

Sections 3.1 and 3.2 describe the existing sediment chemistry data that has been collected to date in Segment 1. This dataset is comprehensive with respect to the number of SCOIs that have been measured and the spatial extent of these measurements, and it is suitable to support the evaluation of potential sediment toxicity in Segment 1. The development of site-specific screening

levels that can inform the development of appropriate response actions in Segment 1 is discussed in detail in the following subsection and includes the following:

- A comprehensive SCOI screening analysis
- Analysis of site-specific sediment toxicity tests
- Development and validation of a site-specific framework for the development of site-specific screening levels

These topics are discussed in detail in the appendices to this Segment 1 Response Proposal for SCOI screening (Appendix B1), site-specific sediment toxicity testing (Appendix B2), and the site-specific screening level framework (Appendices B2 and B3). The remainder of this section provides an overview of these efforts; additional details are provided in the cited appendices. Because PCOIs are not directly toxic to sediment-dwelling organisms, they are not considered further in the evaluation of this ecological exposure pathway. However, other PCOI pathways are addressed in later sections.

#### **3.4.2.1 SCOI Screening Analysis**

A screening analysis was performed to identify those SCOIs in Segment 1 sediments that may contribute to sediment toxicity, and thus may form the basis for action in Segment 1. The SCOI screening analysis completed for this purpose is presented in detail in Appendix B1, and included the following steps:

- Identify the data used for the SCOI screening analysis
- Describe the screening process, including elements that incorporate typical components and considerations identified in EPA guidance (1997, 2001)
- Present the results of the SCOI screening analysis, including the target SCOIs as well as other SCOIs that were closely considered but ultimately not retained as target SCOIs
- Compare the range of target SCOI concentrations in the Segment 1 sediment dataset to the site-specific sediment toxicity testing samples to demonstrate that the range of SCOI concentrations in the sediment toxicity test samples were consistent with the Segment 1 sediment data and therefore appropriate for use in setting response goals
- Present the TOC data in the Segment 1 sediment dataset and describe the approach for TOC-normalized SCOI screening

The SCOI screening process was a comprehensive, iterative process that followed components of EPA guidance for identifying chemicals of potential concern (EPA 2001, 1997). The SCOI screening analysis considered the following components:

- ESLBs from EPA Region 5 and other published sources if Region 5 values were not available
- Chemicals detected in background river samples, including sediment toxicity testing samples from the Chippewa River
- The frequency of detection

- Site-specific sediment toxicity testing results and screening levels derived using the site-specific testing results, particularly in Segment 1 samples with biological responses similar to those seen at reference locations
- Individual chemical characteristics such as bioaccumulation potential
- Chemical benchmark concentrations available in ecotoxicity-based literature
- The magnitude of detection limits compared to ESLBs

As described in Appendix B1, the steps in the SCOI screening analysis were completed multiple times using updated sediment datasets and updated considerations of sediment toxicity testing results. As a result of these multiple iterations, SCOI screening analyses identified a number of “target” SCOIs. The SCOI screening and the identification of chemicals exceeding ESLBs and background concentrations are summarized in Appendix B1. A key component of the identification of target SCOIs was the use of the site-specific sediment toxicity testing data, as described in Appendix B2. The SCOI screening results revealed that of the 283 SCOIs detected in Segment 1 sediment samples, six groupings of SCOIs were carried forward as “target” SCOIs for this Segment 1 Response Proposal:

- Total chlorobenzenes
- Total chlorophenols
- Total PAHs
- Arsenic
- oPP
- Ethyl parathion

The SCOI screening also included consideration of TOC-normalized data, particularly with respect to how TOC-normalized data affected the designation of SMAs. This process is described in Appendix B1. The results of the TOC-based evaluation were consistent with dry-weight based evaluations.

#### **3.4.2.2 Analysis of Site-Specific Biological Exposure Tests**

A series of recent site-specific biological exposure tests paired with sediment chemistry measurements, using Segment 1 sediments, were reviewed to determine their suitability for evaluating potential impacts to benthic organisms exposed to SCOIs in Segment 1. Site-specific toxicity tests provide a strong basis to understand if there are potential risks to sediment-dwelling organisms. The review of the adequacy of these existing tests and the comprehensive analysis of the results is included in Appendix B2. This comprehensive analysis included the following steps:

- Description of the studies, along with the dates the tests were conducted and the laboratories that conducted the tests
- Summaries of the chemical and biological data associated with test samples.

- Summaries of the biological data in both actual values and reference (or control) normalized values, showing the variability within the datasets
- Analysis of the data in terms of chemical concentrations and biological responses for target SCOs in both dry weight values and TOC-normalized values

Sediment toxicity testing was conducted over five sampling events between November 2008 and November 2009, using two biological organisms (the midge *Chironomus tentans*, and the amphipod *Hyalella azteca*). Each organism was evaluated for two endpoints (survival and growth). A total of 16 locations in the Tittabawassee River were sampled, and a single Chippewa River reference location was included with each sampling event. Toxicity testing was conducted at a primary laboratory (Environmental Resources Management (ERM) and confirmatory splits were tested at a second laboratory (Great Lakes Environmental Center (GLEC)). Evaluation of these site-specific sediment toxicity data, discussed in Appendix B2, verified these data can reliably inform the Segment 1 Response Proposal. The tests were conducted using standard test protocols and the test results passed all acceptability criteria.

Chemical testing was conducted concurrent with toxicity testing to provide a synoptic dataset. Sediment samples were analyzed for up to 175 SCOs including, but not limited to metals, chlorobenzenes, chlorophenols, PAHs, and pesticides. TOC also was analyzed concurrently in all sediment toxicity testing samples. Chemical and TOC data were used to identify the chemicals most likely contributing to the biological responses observed in the tested samples, as described in Appendix B2. For those compounds that have the potential to contribute to observed toxicity, concentration-response (C-R) graphs were then developed— these graphs plotted increasing sediment concentrations of an individual SCOI (e.g., arsenic) or a group of similar SCOs (e.g., total chlorobenzenes) on the x-axis vs. a biological response on the y-axis (percent survival or growth of a test organisms relative to a reference or control result). These graphics were used as part of the framework to develop site-specific effects levels to inform this Segment 1 Response Proposal.

Organic carbon influences the bioavailability of organic chemical compounds. The site-specific sediment toxicity tests included sediments that contained a range of TOC concentrations. Because Segment 1 contains a range of sediment TOC concentrations, C-R graphs were also developed that plotted the degree of biological response vs. organic-carbon-normalized chemical concentrations, in order to determine whether TOC levels were influencing the derivation of site-specific screening levels. That is, C-R graphs were developed on both a dry weight and TOC-normalized basis; these graphs are also presented in Appendix B2. These graphics were also used as part of the framework to develop site-specific screening levels to inform this Segment 1 Response Proposal.

#### **3.4.2.3 Framework to Develop Site-Specific Screening Levels**

Different levels or degrees of biological responses in whole sediment toxicity tests can be used to evaluate the overall level of potential risk to sediment-dwelling organisms posed by exposure to various SCOs. Greater adverse responses (e.g., lower survival or growth) correspond to greater potential risks to the overall health of the benthic community. At some threshold level, the risk of

potential adverse response on the overall health of the benthic community is estimated or determined to be significant enough to warrant some level of sediment-based response action to reduce these risks to acceptable levels. A number of methods have been developed to evaluate the level of potential risk to benthic organisms posed by exposure to contaminated sediments. Following collaborative discussions between the Agencies and Dow, an approach used by EPA was selected for evaluation of Segment 1 sediments. This methodology is summarized below and a detailed description of the approach is included in Appendix B2.

The evaluation method using for this Segment 1 Response Proposal was originally used by EPA to provide a consistent approach to evaluating potential risk at former manufactured gas plant sites (Exponent 2009). This multi-site framework approach is also applicable to other Site conditions, including Segment 1 sediments; therefore, this approach was recommended for use in Segment 1 by EPA. The method involves the identification of the following exposure/risk zones:

- Ambient Conditions – Chemical and biological conditions are similar to upstream areas
- No Significant Risk (NSR) – The range of chemical concentrations in sediments is above ambient but below the concentrations at which toxicity was sometimes observed. Site-specific toxicity testing did not reveal incremental increases in toxicity, although sediment concentrations may be elevated relative to ambient conditions.
- PLER – Higher chemical concentrations are detected in sediment that are associated with potential toxicity. Toxicity begins to be observed in laboratory tests but is not consistent and it is possible to have false positives. Toxicity is uncertain.
- Potential for Exposure/Risk (PER) – As chemical concentrations in sediments increase within this category, toxicity is consistently observed.

The biological response zones associated with the framework described above (NSR, PLER, and PER) were defined as follows for Segment 1:

- NSR – Locations with greater than 80 percent survival and growth compared to the Chippewa River reference location (or laboratory control when the reference location was unavailable)
- PLER – Locations with 60 to 80 percent survival and growth compared to the Chippewa River reference location (or laboratory control when the reference location was unavailable)
- PER – Locations with less than 60 percent survival and growth compared to the Chippewa River reference location (or laboratory control when the reference location was unavailable)

Sediment toxicity testing data, as described in 3.4.2.2, were used to establish response zones using the biological response zones mentioned above. The derivation of PLERs and PERs are described in Appendix B2. Table 3-6 presents a summary of these NSRs and PLERs based on dry weight sediment values and TOC-normalized sediment values. PERs are also shown on Table 3-6 for chemicals where data supported PER development. The PER reflects the biological response where toxicity is consistently observed and would therefore be the concentration threshold where sediment management is warranted. However, for purposes of establishing conservative site-specific screening levels to inform the Segment 1 Response Proposal, the PLER

threshold was defined as the concentration for use in designating SMAs (see Section 3.5 of this Response Proposal); this approach was used to provide an appropriately conservative metric for designating SMAs. Appendices C2 and C3 describe the use of the dry weight and TOC-normalized PLERs for the identification of SMAs, and describes the independent validation of the PLERs.

#### **3.4.2.4 Independent Approach: Integrated Model of Multiple SCOs**

The derivation of PLERs for the target SCOs was based on the results of site-specific toxicity studies. On that basis, these PLERs are expected to be accurate indicators of the potential for sediment toxicity in Segment 1 sediments. However, additional independent approaches were used to evaluate the reasonableness of the PLER and PER values by comparing these site-specific results to values calculated using more theoretical exposure and effects modeling approaches. These more theoretical approaches can be used as independent evidence to verify that the site-specific analyses are appropriate. Following collaborative discussions between Dow and the Agencies, the approach used to complete this analysis was the EPA's Equilibrium Partitioning (EqP) approach, since this approach fundamentally addresses issues of cumulative toxicity related to multiple chemicals that exert a similar mode of toxic response. The EPA EqP approach specifically addresses nonionic target SCOI compounds such as PAHs (EPA 2003) and chlorobenzenes (EPA 2008), and can readily be applied to other target SCOs that exert a narcotic toxic response, such as chlorophenols, oPP, and, to a certain extent, ethyl parathion.

The EPA EqP approach acknowledges that the bioavailability of non-ionic organic chemicals in sediments and, therefore, the C-R relationship for the biological effect of concern, is related to the chemical partitioning behavior of the specific chemical in sediments. As such, knowledge of the partitioning of chemicals between the solid, natural organic carbon and aqueous phases in sediments is important. EqP is the method used to understand these relationships. If there is sufficient knowledge of chemical partitioning behavior and organic carbon concentrations in sediments, then the EqP model can be used to quantify the exposure concentration for a benthic organism. Conversely, if an effects-based concentration can be developed, then the sediment concentration corresponding to the threshold porewater concentration can be calculated. This sediment concentration is defined as the EqP sediment benchmark (ESB).

The EqP results are described as a single metric of potential toxicity called the "guideline unit" (GU). A GU is defined as the ratio of the sediment concentration of a particular chemical to the ESB calculated using the EqP approach such that a GU value equal to 1 is a "no effect" threshold value below which no toxicity to sediment-dwelling organisms would be expected. GU values greater than 1 correspond to an increasing probability of effects. The GU value at which toxicity begins to be observed is a function of a number of site-specific conditions that can be understood through the use of site-specific toxicity test results to develop a site-specific GU. Because site-specific factors such as sediment organic carbon content do influence/reduce the bioavailability of sediment-associated contaminants, the GU value at which toxicity is anticipated is frequently greater than 1 and often greater than 4 or 5. Therefore, GUs were calculated using site-specific sediment toxicity testing to determine or establish an "effects" threshold GU value that correlates with observed toxicity (i.e., at the PLER concentration) and is consistent with the multi-site framework described in Section 3.1.4.2. GUs were also calculated for the Segment 1 surficial

sediment dataset (approximately 300 samples). Appendix B3 provides the derivation of GUs for each of the classes of target SCOIs. Arsenic is also a target SCOI but is not an organic compound so EqP theory does not apply. Appendix B3 also derives an integrated cumulative GU model for the evaluation of those target SCOI organic compounds and classes of compounds that act through the same mode of narcosis-based toxicity.

The “GU” model represents an independent approach used to validate the use of site-specific screening levels (i.e., PLERs). The findings are presented in detail in Appendix B3 and corroborate the use of PLERs derived for the target SCOIs using site-specific toxicity tests. Specifically, Appendix B3 presents:

- Detailed application of the EPA EqP approach for the Tittabawassee River Segment 1 sediment data, including the description of EqP methods.
- Derivation of conversion factors for PAHs to incorporate alkylated PAH compounds into the calculation of total PAHs.
- Identification of the Segment 1 sediment data to which the approach was applied.
- A description of the approach that was developed for the application of GUs for ethyl parathion where narcosis represents only one potential mode of toxicity. For ethyl parathion, a second independent GU approach was implemented based on the development of an understanding of species sensitivity to ethyl parathion and the development of study sensitivity distributions so that the level of potential toxic response unrelated to narcotic effects also was considered.

The integrated model of total GUs reflecting a narcosis mode of toxicity is provided in Figure 3-23 for the samples included in sediment toxicity testing, and in Figure 3-24A and 3-24B for the full Segment 1 surface sediment dataset. The site-specific sediment toxicity testing results indicate that the integrated narcosis-related GUs range from less than 1 to a value of 6.2 (Figure 3-23). Some of these samples shown in Figure 3-24 are the same samples used to designate PLERs, as identified in Table 3-6. It is important to note that not all target SCOIs were measured in all of the sediment toxicity samples and, as a result, the GU values shown in Figure 3-23 underestimate to some degree the actual GU at that location. The biological responses for samples RF-82+50 and RD 54+75 had the highest Gus, and those biological results were within the range considered appropriate for the designation of PLERs based on biological responses compared to the Chippewa reference sample. Therefore, the use of a site-specific GU of 6.2 is appropriate. The designation of the site-specific GU is discussed further in Appendix B3, including a detailed description of the biological responses associated with GUs in Figure 3-24.

The cumulative frequency distributions of the GUs for the integrated narcosis model for all target SCOIs and the full Segment 1 surficial sediment dataset indicates that approximately 4 percent of the Segment 1 surface sediment samples had GUs greater than 5 (Figure 3-24A). Specifically, the integrated model GUs were greater than 5 in fifteen sediment samples collected from nine locations in Segment 1 (Figure 3-24B). In addition, the following observations can be made:

- Chlorobenzenes made up the largest portion of the 15 samples with GUs greater than 5.

- Six of the 15 samples had GUs greater than 20 (Figure 3-24B) and those samples corresponded to the two locations (RE-73+50-IC30 and RF-83+00-IC33) with subsurface SCOI deposits (see Section 3.2.3).
- Fifteen samples had GUs greater than 5; most were from samples with very low TOC (i.e., less than or equal to 0.3 percent). As discussed in Appendix B3, very low sediment TOC values distort the GU-based evaluation.

Appendix B3 presents a comparison of ESBs derived using the EqP approach with the site-specific PLERs developed based on the sediment toxicity test results, further confirming the validity of the site-specific PLERs. The PLERs are shown on a dry weight and TOC-normalized basis (Table 3-6). These results verify that the site-specific PLERs are consistent with the range of values calculated using EPA's EqP approach. These values are summarized on Table 3-7. Finally, toxicity data were compiled from EPA's ECOTOX database to develop a sensitivity distribution for ethyl parathion so that the more sensitive mode of action could be evaluated as well (cholinesterase inhibition). This result is also presented in Table 3-7. The results of this independent evaluation demonstrate that the use of site-specific PLERs is appropriate to inform the Response Proposal.

### 3.4.3 Bioaccumulation and Potential Food Web Exposures

The bioaccumulation and food web exposure pathway is related to the potential uptake of PCOIs and SCOIs in biological tissues and potential exposure to humans and wildlife through food web transfer processes. As part of evaluations to inform this Segment 1 Response Proposal, three different bioaccumulation-related data collection activities and corresponding datasets (i.e., wild fish, caged fish, and SPMDs) were reviewed and are discussed in detail in Appendix B4.

As summarized in Appendix B4, wild fish, caged fish, and SPMDs were collected at various times and from various locations within Segment 1, as follows:

- Wild fish
  - Approximately 150 wild fish tissue samples from Segment 1 were analyzed for a broad range of SCOIs as well as PCOIs. These included both whole body and fillet samples. The wild fish dataset includes measurements of SCOIs in addition to the "target" SCOIs identified for direct toxicity evaluation in Section 3.4.2.1 above (with the exception of oPP and ethyl parathion, which were not measured in fish samples). A full list of analytes analyzed for in fish tissues (including those not detected) is provided in Appendix B4.
  - As part of the NPDES sampling program implemented by Dow on a periodic basis, fish tissue samples have been collected over time and analyzed for PCOIs, hexachlorobenzene (HCB), and polychlorinated biphenyls (PCBs).
- Caged Fish
  - Caged fish studies were performed at five locations in Segment 1 in 1997 and in 2001.
  - Caged fish tissues were analyzed for chlorobenzenes, chlorophenols, and PCOIs.

- SPMDs
  - SPMD studies were placed at 12 locations in Segment 1 in 2007 and 2008.
  - SPMDs were analyzed for chlorobenzenes in the 2007 sampling effort and for PCOIs in both 2007 and 2008.

The bioaccumulation evaluation described in detail in Appendix B4 for wild fish revealed that detected concentrations of SCOs in wild fish tissue are limited to infrequent detections of chlorobenzenes and several of the SCOs at relatively low concentrations. Detected concentrations of these chemicals were compared with EPA screening levels for the ingestion of fish for both ecological receptors and humans. Detected SCOI concentrations in Segment 1 have been less than these screening levels, often orders of magnitude less than the screening values. Moreover, response actions directed toward control of benthic exposures as summarized in Section 3.4.2 above will result in further reductions in potential bioaccumulation exposures (see Section 8). Other SCOs detected in wild fish were detected at concentrations consistent with or lower than regional reference locations (e.g., PCB 126, arsenic, and Dichlorodiphenyldichloroethane/ Dichlorodiphenyldichloroethylene [DDD/DDE]). Additional consideration of the toxicity of bioaccumulative compounds to non-benthic species will be considered, as necessary and appropriate, during the Task 10 risk assessment process.

The Michigan Department of Community Health (MDCH) has issued advisories for the consumption of fish contaminated with furan and dioxin compounds and PCBs in the Tittabawassee River, reportedly based on TEQ levels in fish. However, early actions completed in Reaches B and D (see Section 2.6) reduced the Segment 1-wide SWAC by approximately 60 percent (see Section 3.2.1). The overall TEQ SWAC for Segment 1 is currently approximately 68 ppt, and Segment 1 TEQ SWAC levels are expected to decline further following the implementation of response actions in other areas of Segment 1 and through natural recovery processes (e.g., see Section 7.2.1). An RAO that establishes a goal of contributing to the reduction of Segment 1 TEQ levels in sediment is included as part of this Segment 1 Response Proposal to address this potential pathway (see Section 4). Fish PCOI levels in Segment 1 and elsewhere in the Tittabawassee River will also be affected by downstream responses, and thus require a more comprehensive response that considers downstream segments of the river, which will be performed as part of follow-on segment specific response activities as described in the AOC/SOW.

#### **3.4.4 Direct Contact for Recreational Users of Segment 1**

The potential direct human contact exposure pathway is related to the potential uptake of SCOs by recreational users of the Tittabawassee River that may experience dermal contact and incidental sediment ingestion exposure during the portage of boats into and out of the river. The dam portage, that use to be located at the Reach D remediation area at the east end of the dam, has been relocated to move the users farther away from the faster water flow across the dam. The above dam portage entry now utilizes the quiescent water intake basin on the west side of the river. The downstream portage entry location now utilizes a boat launch area on the west side of the river approximately 200 ft below the dam. Potential human health risks resulting from a possible direct contact exposure were considered. However, there are no sediment screening

levels for these SCOI's. EPA's soil screening levels, protective of human exposures based on residential and industrial exposure scenarios, were used for an alternative evaluation. Only three SCOIs (arsenic, benzo(a)pyrene, and benzo(a)anthracene) had one or more sample concentration that was greater than the EPA soil screening levels. For these SCOI's, additional consideration was given using more appropriate reach-specific exposure assumptions. The results of this evaluation did not identify additional SCOIs or potential areas of concern in Segment 1 that require further consideration for direct contact as part of this Segment 1 Response Proposal. The exposure/risk analysis procedure is further described in detail in Section 4 of Appendix B1.

### **3.5 Sediment Management Areas**

SMA in Segment 1 were identified to develop and evaluate potential response options that achieve the RAOs presented in Section 4. SMA locations (Section 3.5.1) were identified based on sediment toxicity and the location of SCOI deposits. Once general SMA locations were identified, the delineation of the SMA boundaries (Section 3.5.2) was determined through the consideration of the three-dimensional distribution of SCOIs, depth of till, and initial engineering design.

#### **3.5.1 Identification of SMA Locations in Segment 1**

To identify Segment 1 SMAs, target SCOI concentrations in the surface sediment interval (0 to 2 ft based on the active bed depth analysis summarized in Section 3.3.1) were compared to the following chemical specific benthic toxicity PLERs summarized in Section 3.4. As discussed in Section 3.3 and 3.4, these evaluations may be further refined:

- Total chlorobenzenes: 33 mg/kg
- Total chlorophenols: 26 mg/kg
- Total PAHs: 15 mg/kg
- Arsenic: 150 mg/kg
- oPP: 92 mg/kg
- Ethyl parathion: 0.36 mg/kg

Consistent with EPA (2005) guidance and EPA's (2002) eleven Risk Management Principles for "Management of Contaminated Sediment Sites," the understanding of potential chemical exposure risks will be updated as new information or analysis becomes available, for example during remedial design and/or during development of the Task 10 RRA.

Figure 3-25 presents a Thiessen polygon approach to identify locations where sediment concentrations in the surface interval are greater than their respective target SCOI PLER values. The specific SCOIs exceeding the PLER values and the maximum SCOI concentration also are shown in Figure 3-25. In summary, surface sediment SCOI concentrations are greater than the PLER values at the following Segment 1 locations:

- Reach E, near station 61+50 (PAHs and arsenic)
- Reach E, near station 73+50 (chlorobenzenes and chlorophenols)

- Reach F, near station 83+00 (chlorobenzenes, chlorophenols, PAHs, and oPP)
- Reach F, near station 93+50 (ethyl parathion)
- Reach H, near station 151+00 (ethyl parathion)

The locations of SCOI deposits provide another independent approach for identifying Segment 1 SMAs. The locations of the SCOI deposits were presented in Figure 3-6 and are confined to five specific areas within Segment 1:

- Reach E, near station 73+50 – Product detected and recovered (RTW-1 only)
- Reach F, near station 83+00– Product detected (RTW-7 only)
- Reach G, near station 137+50 – No product detected
- Reach H, near station 145+00 – No product detected
- Reach H, near station 151+00 – Product detected and recovered (RTW-5)

Segment 1 locations where surface sediment concentrations are greater than the PLER value, and locations with SCOI deposits are both identified in Figure 3-26. This information was used to identify Segment 1 SMAs. The location of the six SMAs is listed below.

- SMA 1: Reach E, near station 61+50
- SMA 2: Reach E, near station 73+50
- SMA 3: Reach F, near station 83+00
- SMA 4: Reach G, near station 137+50
- SMA 5: Reach H, near station 145+00
- SMA 6: Reach H, near station 151+00

A more thorough description of the SMAs and the delineation of SMA boundaries is provided in the following sections and a summary of the SMA 1 to 6 characteristics is provided in Table 3-8.

### **3.5.2 Lateral and Vertical Delineation of SMAs**

Once the general location of SMAs was established, the lateral boundaries of each SMA were delineated based on the following information and considerations:

- Existing sediment sample density and Thiessen polygons
- Geostatistical interpolations (three-dimensional EVS kriging, which considers measured concentrations, both laterally and vertically, to predict sediment concentrations between sample locations)
- Depth of sediment above till layer
- Initial engineering design
- Best professional judgment

The SMA boundaries delineated for this Segment 1 Response Proposal are subject to further refinement during the remedial design phase, including additional sampling as necessary. The characteristics of each SMA and the delineation of SMA boundaries used to develop this Response Proposal are discussed below.

### **Sediment Management Area 1 (SMA 1)**

SMA 1 is located near station 61+50 and characterized by concentrations of arsenic and total PAHs greater than the benthic toxicity PLER value in surface sediments. SMA 1 is presented in Figure 3-27; the shaded Thiessen polygons represent sample locations with arsenic and total PAH concentrations greater than their respective sediment toxicity PLER values. Total PAH concentrations at sample locations 61+50-CI37 (0.0 to 0.5 ft) and 62+00-IC60 (0.5 to 1.0 ft) are 25.4 and 15.9 mg/kg, respectively, and are slightly above the total PAH PLER value of 15 mg/kg. The arsenic concentration at sample location 61+50-IC98 (0.0 to 0.5 ft) is 310 mg/kg, which is greater than the arsenic PLER value of 150 mg/kg. A subsurface sample (depth interval of 1.1 to 3.0 ft) at location 62+00-IC60 has an arsenic concentration of 220 mg/kg. The depth of contamination in SMA 1 ranges from 0.5 to 3 ft; that is, at sediment depths greater than 3 ft, all target SCOI concentrations in SMA 1 are below the PLER value. The measured till depth at SMA 1 ranges from approximately 5.7 to 9.0 ft below the sediment surface.

In addition to Thiessen polygons, Figure 3-27 shows the lateral boundary of the three-dimensional interpolations of arsenic and total PAHs concentrations above the PLER for all sediment depths. While the Thiessen polygon boundaries are strictly equidistant between neighboring sample locations, the three-dimensional interpolated values take into consideration both lateral and vertical sediment concentrations at known sample locations to predict concentrations between sample locations. The interpolated boundaries of the arsenic and total PAH concentrations greater than the PLER values do not extend much beyond the sediment sample location from which the elevated total PAH and arsenic concentrations were measured, which is due to the relatively low arsenic and PAH concentrations vertically above and below the samples exceeding the PLER values.

Based on the Thiessen polygons and three dimensional interpolations, lateral boundaries for SMA 1 have been delineated for this Segment 1 Response Proposal, as depicted on Figure 3-27. SMA 1 includes sediment sample locations where the arsenic and total PAH concentrations are greater than the PLER value in surface sediments. Due to its proximity to the surface sample locations greater than the PLER value, the location with a subsurface exceedance of the arsenic PLER value (location 62+00-IC60) is also captured within the SMA. The boundaries of SMA 1 are also presented in Figure 3-28, which provides lateral and longitudinal cross sections of arsenic and total PAH concentrations in the vicinity of SMA 1. The surface area of SMA 1 is approximately 8,000 sq ft, and a summary of SMA 1 characteristics is provided in Table 3-8.

### **Sediment Management Area 2 (SMA 2)**

SMA 2 is located near station 73+50 along the east side of the river channel, as shown in Figure 3-29. SMA 2 contains total chlorobenzene and total chlorophenol concentrations greater than the PLER values in the surface sediment. The sample location (73+50-IC30) where surface sediment

concentrations exceed the PLER values is represented by the shaded Thiessen polygon in Figure 3-29. Sample location 73+50-IC30 was also identified as a free-phase product area with total chlorobenzene concentrations greater than 10,000 mg/kg in the subsurface and product was recovered above the till during the product recovery testing. As discussed in Section 3.2, this SCOI deposit is comprised primarily of chlorobenzenes and VOCs, and is present within the subsurface sediments overlying the till in SMA 2. The measured till depth at SMA 2 is approximately 3.3 ft below the sediment surface.

A three-dimensional interpolation of total chlorobenzene concentrations across all sediment depths was performed for lower Segment 1 (Reaches E-H). The EVS settings and input parameters used in the interpolation of total chlorobenzene concentrations are provided in Table 3-9. As discussed in Section 3.2, sediment total chlorobenzene concentrations greater than a conservative screening value of 100 mg/kg across all sediment depths was used as another approach for the delineation of SMAs. Figure 3-29 presents the lateral boundary of the interpolated total chlorobenzene concentrations greater than 100 mg/kg across all sediment depths for SMA 2. The total chlorobenzene concentration from the sample interval just above the till at core location 73+50-IC30 is greater than 10,000 mg/kg.

Based on the approaches discussed above, lateral boundaries for SMA 2 have been delineated as depicted on Figure 3-29. The boundaries of SMA 2 are also presented in Figure 3-30, which shows lateral and longitudinal cross sections of total chlorobenzene concentrations in the vicinity of SMA 2. The surface area of SMA 2 is approximately 7,000 sq ft and addresses the following:

- Thiessen polygon representing the surface sediment location with total chlorobenzene and total chlorophenol concentrations greater than the PLER value
- Interpolated area greater than 100 mg/kg total chlorobenzenes across all sediment depths

### **Sediment Management Area 3 (SMA 3)**

SMA 3 is presented Figure 3-31 and is characterized by surface sediment concentrations of total chlorobenzenes, total chlorophenols, total PAHs, and oPP greater than the benthic toxicity PLER values at location 83+00-IC33.

Core locations 82+50-IC75, 83+00-IC33, and 83+00-IC69 were also identified as SCOI deposits with elevated total chlorobenzene concentrations both in the subsurface just above the till and within woody debris layers several ft above the till. As discussed in Section 3.2, SMA 3 contains subsurface total chlorobenzene concentrations greater than 10,000 mg/kg, and product was detected above the till during the product recovery testing. The measured till depth at SMA 3 ranges from 4.2 to 6.2 ft below the sediment surface.

As described for SMA 2, the elevated total chlorobenzene concentrations associated with potential deposits are expected to be contained within the three-dimensional interpolated boundary of concentrations greater than 100 mg/kg at all depths. The interpolated total chlorobenzene boundary for SMA 3 is presented in Figure 3-31. Sediment sample results showed total chlorobenzene concentrations greater than 10,000 mg/kg at core locations 83+00-IC33 and 83+00-IC69 and greater than 100 mg/kg at core location 82+50-IC75.

Based on the evaluations discussed above, lateral boundaries for SMA 3 have been delineated, as depicted on Figure 3-31. The boundaries of SMA 3 are also presented in Figure 3-32, which shows lateral and longitudinal cross sections of total chlorobenzene concentrations in the vicinity of SMA 3. SMA 3 is approximately 21,000 sq ft and addresses the following:

- Surface sediment Thiessen polygon representing the location with total chlorobenzenes, total chlorophenols, total PAHs, and oPP concentrations greater than the PLER value
- Approximate localized low in the till elevation
- Interpolated area greater than 100 mg/kg total chlorobenzenes across all sediment depths

#### **Sediment Management Area 4 (SMA 4)**

SMA 4 is located in Reach G near station 137+50, as shown in Figure 3-33. Surface sediment concentrations at SMA 4 are below the PLER value for all target SCOIs. Based on the core logs notes, a lower concentration residual SCOI deposit is present just above the till layer at locations 137+50-IC71, 137+50-IC147, and 138+00-IC115. The measured till depth at SMA 4 ranges from 4.2 to 6.5 ft below the sediment surface.

As discussed in Sections 3.2.3 and 3.3.3, the subsurface sediment contaminants detected in SMA 4 are likely comprised of a weathered, residual SCOI deposit that is not subject to migration. Product was not detected in SMA 4 during product recovery testing. The maximum total chlorobenzene concentration at SMA 4 (approximately 820 mg/kg) is more than an order of magnitude less than the total chlorobenzene concentrations measured at SMAs 2 and 3.

Figure 3-33 show the lateral boundary of the three-dimensionally interpolated total chlorobenzene concentrations greater than 100 mg/kg across all sediment depths. The interpolated boundary surrounds core location 137+50-IC71, which contains the maximum total chlorobenzene within SMA 4; sediment samples from neighboring cores had total chlorobenzene concentrations less than 70 mg/kg, and are therefore not included within the interpolated boundaries.

The lateral boundaries for SMA 4 have been delineated, as depicted on Figure 3-33. The boundaries of SMA 4 are also presented in Figure 3-34, which provides lateral and longitudinal cross sections of total chlorobenzene concentrations in the vicinity of SMA 4. SMA 4 is approximately 5,000 sq ft and addresses the following:

- Interpolated area greater than 100 mg/kg total chlorobenzenes across all sediment depths
- Approximate localized low in the till elevation

#### **Sediment Management Area 5 (SMA 5)**

SMA 5 is located in Reach H near station 145+00, as shown in Figure 3-35. SMA 5 is similar to SMA 4 in that surface sediment concentrations are below the PLER value for all target SCOIs, but subsurface residual sediment is present at depth. The measured till depth in SMA 5 is approximately 3.1 ft. Only one core section sample in SMA 5 (145+00-IC118) contained an elevated total chlorobenzene concentration of 2,530 mg/kg. Product was not detected in SMA 5

during product recovery testing. Again, the subsurface sediment contaminants detected in SMA 5 are likely comprised of a weathered, residual SCOI deposit that is not subject to migration.

The SMA 5 boundary of interpolated total chlorobenzenes greater than 100 mg/kg across all sediment depths is shown in Figure 3-35. The elevated total chlorobenzene concentrations associated with potential SCOI deposits are expected to be contained within the three-dimensional interpolated boundary of concentrations greater than 100 mg/kg. The boundaries of SMA 5 are also presented in Figure 3-36, which provides lateral and longitudinal cross sections of total chlorobenzene concentrations in the vicinity of SMA 5.

SMA 5 is approximately 11,000 sq ft and addresses the following:

- Interpolated area greater than 100 mg/kg total chlorobenzenes across all sediment depths

### **Sediment Management Area 6 (SMA 6)**

SMA 6 is located in Reach H near stations 150+00 through 151+50 along the northeast side of the channel, as presented in Figure 3-37. SMA 6 contains one surface sediment location with an ethyl parathion greater than the PLER value; no other target SCOI exceeded their respective PLER values in the surface sediment at SMA 6. At location 151+50-IC33, the ethyl parathion concentration is 520 mg/kg at a depth of 0.0 to 1.0 ft. However, nine additional sediment samples were analyzed for ethyl parathion from this core location (sandy sediment sample depths ranged from 1.0 to 10.0 ft) and all concentrations were 0.6 mg/kg or less. In addition, ethyl parathion was not detected in samples from neighboring cores at any sediment depths.

The measured till depth at SMA 6 ranges from 7.2 to 9.4 ft below the sediment surface. As discussed in Sections 3.2.3 free-phase product is present above the till surface in SMA 6 and product was recovered. The SMA 6 boundary of interpolated total chlorobenzenes greater than 100 mg/kg across all sediment depths is shown in Figure 3-37. The elevated total chlorobenzene concentrations associated with potential SCOI deposits are expected to be contained within the three-dimensional interpolated boundary of concentrations greater than 100 mg/kg. The boundaries of SMA 6 are also presented in Figure 3-38, which provides lateral and longitudinal cross sections of total chlorobenzene concentrations in the vicinity of SMA 6.

SMA 6 is approximately 30,000 sq ft and addresses the following:

- Surface sediment Thiessen polygon representing the surface sediment location with an ethyl parathion concentration greater than the PLER value
- Interpolated area greater than 100 mg/kg total chlorobenzenes across all sediment depths
- Approximate localized low in the till elevation.

### **3.5.3 Segment 1 TEQ SWACs Under Post-Response Conditions**

In addition to addressing locations where surface sediment concentrations are greater than the PLER value and locations with SCOI deposits, response actions that may be performed in Segment 1 SMAs 1 through 6 will also further reduce the TEQ SWAC in Segment 1. Table 3-10

shows the TEQ SWACs under current conditions and the estimated TEQ SWACs following the implementation of response actions at SMAs 1 to 6. As discussed in Section 3.2, the early response actions in Reach B and D reduced the Segment 1 TEQ SWAC by approximately 60 percent. Following future response actions that may be performed in SMAs 1 to 6, the Segment 1 TEQ SWAC is expected to be further reduced by approximately 30 percent as compared to current conditions. The response actions at the SMAs that may be performed would contribute the approximate portions of this further reduction (SMA 1 – 15%, SMA 2 – 1%, SMA 3 – 6%, SMA 4 – 0%, SMA 5 – 0%, and SMA 6 – 9%).

### **3.6 Other Areas in Segment 1**

The six SMAs identified in Segment 1 include locations where surface sediment concentrations are greater than PLER values for target SCOIs, or where SCOI deposits were identified in the subsurface, just above the till layer. A few additional areas within Segment 1, but outside of the Segment 1 SMAs, contain target SCOI concentrations above the PLER values and were further evaluated to determine whether these areas warrant a response action. These additional areas include the following:

- Reach F, Sample 93+50-IC248
- Lingle drain
- Buried subsurface target SCOI concentrations greater than PLER values

An evaluation of the TEQ SWAC for the Consumers Energy floodplain was also conducted. The results of these evaluations are discussed in this section and demonstrate that these areas do not warrant a response action, and therefore were not identified as SMAs.

#### **3.6.1 Reach F, Sample 93+50-IC248**

Sample location 93+50-IC248 is located in Reach F, towards the west bank of the river (Figure 3-25). The ethyl parathion concentration at this location at a depth of 0.0 to 0.5 ft is 0.42 mg/kg, slightly higher than the ethyl parathion PLER value of 0.36 mg/kg. However, ethyl parathion was not detected in subsurface samples at this location (i.e., sample depths of 2.2 to 3.4 ft and 6.7 to 7.2 ft), and concentrations of the additional five target SCOIs were below their respective PLER values for all sample depths at this location. Further, 19 additional sediment samples were collected from four other locations in this area of Segment 1, between river station 90+00 and 100+00. The target SCOI concentrations were below their respective PLER values for all 19 samples.

These results demonstrate that the surface sediment ethyl parathion concentration at 93+50-IC248 is an isolated sample slightly greater than the PLER value that is not part of a larger sediment deposit with elevated SCOI concentrations. This location does not pose an unacceptable current or future risk of toxicity to benthos and therefore does not warrant a response action.

### 3.6.2 Lingle Drain

Lingle Drain is located on the east side of the Tittabawassee River near station 160+00, just upstream of the Segment 1 downstream boundary. Lingle Drain serves as a multi-use surface water storm water drain that extends through the City of Midland, oriented adjacent to the Dow Corning facility and Dow Chemical's Midland Plant, eventually discharging into the Tittabawassee River at the downstream end of Reach H. The contribution of Lingle Drain to the Tittabawassee River is very small compared to that of the entire Tittabawassee River watershed.

Surface sediment samples were collected from three locations in Lingle Drain. Sample locations and corresponding location IDs are provided in Figure 3-39. Target SCOI concentrations from these surface samples were compared to the PLER values. The three surface samples from Lingle Drain contain concentrations below the PLER values for five of the six target SCOIs.

At two Lingle Drain locations (Lingle Drain DEQ and RH-161+50-T-NE265), the total PAH concentrations were greater than the PLER value of 15 mg/kg; the total PAH concentration at Lingle Drain DEQ was 16.7 mg/kg and the total PAH concentration at RH-161+50-T-NE265 was 49.2 mg/kg. The total PAH concentration of the third Lingle Drain surface sample (RH-161+50-T-NE50) was well below the PLER value at 0.8 mg/kg. The average total PAH concentration in surface sediments within Lingle Drain (22.2 mg/kg) upstream of its discharge into Segment 1 is slightly greater than the PLER value of 15 mg/kg.

The target SCOI concentrations of three sample locations within the Tittabawassee River channel, just downstream of Lingle Drain also were reviewed. The concentrations for 14 samples from these three locations were below the target SCOI PLER values at all depths, indicating that the sediment PAH concentrations within Lingle Drain are not contributing to elevated PAH concentrations above the PLER value within the river channel.

DEQ also collected a surface sediment sample from Lingle Drain, and submitted this sample for sediment toxicity testing. While a toxic response was observed at this location for *Hyalella* growth, toxicity in this case was not attributable to target SCOIs. These results demonstrate that surface sediment concentrations of the target SCOIs in Lingle Drain are generally below the PLER values, and are not responsible for the observed toxic response at this location. Furthermore, sediment concentrations in the Tittabawassee River at the mouth of Lingle Drain are below the PLER values at all depths, demonstrating that Lingle Drain does not contribute to target SCOI concentrations above the PLER values in downstream areas of Segment 1. Lingle Drain does not pose a current or future potential risk of toxicity to benthos and therefore does not warrant a response action.

### 3.6.3 Buried Subsurface Target SCOI Concentrations Greater than PLER Values

PLER values for the target SCOIs were developed for comparison with surface sediment concentrations, protective of benthic organisms (see Section 3.4). To identify Segment 1 SMAs, target SCOI concentrations in the upper 2 ft of sediment were compared to the PLER values. The upper 2 ft of sediment represents a conservative estimate of the active bed depth within Segment 1 (see Section 3.3). Isolated locations outside of the Segment 1 SMA footprints contain target SCOI concentrations greater than the PLER values at sediment depths greater than 2 ft. These

locations, the corresponding target SCOI, and the depths at which the SCOI concentrations are greater than the PLER value are identified in Figure 3-40. At depths of 2 ft or more below the sediment surface, elevated concentrations of target SCOIs are not expected to pose a potential risk to benthic organisms, as the bioactive zone in freshwater sediments is much less than the 2 ft active bed thickness discussed in Section 3.3 (USACE 2008; US Navy 2003; ENVIRON 2008). Furthermore, the evaluation of sediment stability and differential bathymetry presented in Section 3.3 demonstrate the sediment elevation changes in Segment 1 are on the order of 1 ft or less, and only a small fraction of the area experiences changes that approach or exceed 2 ft. Figures 3-40A and 3-40B show the areas with subsurface deposits of SCOIs greater than the PLER value in comparison to the predicted bed elevation changes under an approximate 50-year flow event (see Appendix C). As shown in the figure, predicted bed elevation changes are expected to be 0.5 ft or less in all areas with subsurface SCOI deposits. Figure 3-40C shows the Segment 1 2007-2009 differential bathymetry in comparison to subsurface deposits of SCOIs greater than the PLER value. The differential bathymetry shows bed elevation changes of 0.5 ft or less in areas with buried deposits of SCOIs in Reaches E-H. In Reach D, the 2007 to 2009 differential bathymetry shows a decrease in bed elevation of greater than 2 ft. This change in bed elevation resulted from the Reach D construction activities conducted in 2007 to 2009. Hydrodynamic and sediment transport analyses presented in Appendix C and Figures 3-40A and 3-40B do not predict bed elevation changes greater than 0.5 ft in Reach D. Thus, areas of Segment 1 with sediment SCOI concentrations greater than the PLER values at depths of 2 ft or more are not at a significant risk of being exposed.

### **Consumers Energy Floodplain**

A 51-acre parcel within the 100-year floodplain boundary along the east side of the Tittabawassee River is owned by Consumers Energy. This parcel of floodplain property is located along Reaches G and H as shown in Figure 3-41. In 2006, floodplain soil samples were collected from 23 locations within this parcel and 174 samples were analyzed for furan and dioxin TEQ. The soil sample locations and the TEQ values for each surface soil sample are presented in Figure 3-41. Surface soil TEQ results were used to calculate an average TEQ for the 51-acre floodplain parcel based on TEQ levels within the floodplain geomorphic units (ATS 2009). The resulting average TEQ value for the Consumers Energy floodplain parcel is 160 ppt. These concentrations are below potential levels of concern for this industrial use property. Thus, further evaluation of these floodplain soils is not necessary for this Segment 1 Response Proposal.

## 4.0 Segment 1 Remedial Action Objectives

Remedial action objectives (RAOs) comprise a framework for developing safe, implementable, and effective remedial alternatives. Additionally, RAOs provide a basis for evaluating different sediment remedy options by describing what the remedial actions are intended to accomplish. The remedy evaluation process determines the feasibility and implementability of remedial action alternatives while determining the extent to which remedies are expected to achieve the RAOs.

RAOs are developed based on an understanding of the media, exposure pathways, and receptors that may be impacted at a particular site and are closely tied to a site-specific CSM. The CSM considers the nature, extent, fate and transport characteristics of Segment 1 to identify potential exposure pathways that may contribute to unacceptable risks, which in turn inform the development of RAOs. For Segment 1, in-channel sediments are the primary media of concern. The interactions between sediments, aquatic biota, and terrestrial biota or humans determine whether complete exposure pathways exist (e.g., direct contact by biological organisms with sediment, human consumption of fish, or wildlife consumption of fish), and whether a response is warranted.

Segment 1 RAOs were developed in consultation with the Agencies and in accordance with the AOC/SOW. As discussed in more detail above, the available Segment 1 data meet the requirements of an EE/CA (as set forth in the AOC/SOW and the NCP). Moreover, in accordance with the AOC/SOW, the considerable site characterization data available for Segment 1 have been reviewed by Dow and the Agencies and there are no data gaps that limit appropriate development and evaluation of alternative remedy options for this Response Proposal.

The RAOs are media-specific and identify the contaminants to be addressed. Each RAO is classified as short-term (expected to be met shortly after construction) or long-term (requires more time—and/or requires response actions in other segments of the river—to be met).

In accordance with the AOC/SOW, each RAO for Segment 1 consists of:

- General response objectives
- Performance objectives
- Measurable metrics

General response objectives identify the exposure pathway to be addressed in order to address potential risks to human health and the environment. Associated performance objectives identify specific targets intended to fulfill the general response objective. Measurable metrics consist of quantitative criteria that establish whether performance objectives have been met.

### 4.1 Segment 1 Conceptual Site Model and Basis for Action

Figure 4-1 depicts the Segment 1 CSM, developed to evaluate the basis for action in Segment 1. This CSM focuses on the three major environmental compartments relevant to understanding the need for a response action: 1) the source of chemicals to the river and the extent to which sources

are controlled; 2) the chemically impacted media—in this case, in-channel sediment; and 3) potential receptors. The goal of the CSM is to inform the basis for action in Segment 1 not to depict all chemical interactions among all media, nor is it a risk assessment CSM. Consistent with EPA (2005) guidance and EPA's (2002) eleven Risk Management Principles for "Management of Contaminated Sediment Sites," the CSM will be updated as appropriate, possibly during remedial design and/or during development of Task 10.

There are three historical transport pathways from the Dow Midland facility to sediments and the water column: 1) surface water; 2) wastewater; and 3) groundwater. As discussed in Sections 2.5 and 2.6, Dow has been implementing waste management and source control measures since the early 1900s. Figure 4-1 shows that current waste management operations include the collection and treatment of all wastewater generated at the facility, the collection and treatment of surface water runoff, and the interruption of groundwater transport to the river via RGIS and treatment of all RGIS-generated water. Source control is a continuous process. Water treatment is conducted in accordance with NPDES permitting requirements. All treated water is discharged to the river through a single outfall to facilitate efficient and effective water and wastewater management. Although not depicted on Figure 4-1, the facility also treats air discharges before releasing gasses into the atmosphere.

Figure 4-1 depicts that historical discharges from the Dow Midland facility previously affected both sediments and the water column of Segment 1. As discussed in Section 3.2.3, the location of five 5 SMAs in Segment 1 correlates well with the location of historic storm water outfalls and ditches from the production areas. However, direct discharges to the Segment 1 water column have been controlled for decades and are no longer a source of toxicity or bioaccumulation. Some chemicals in sediment, on the other hand, are persistent and warrant consideration for further response actions. The CSM depicts two pathways of potential concern associated with sediment-bound chemicals: 1) a known pathway to benthic organisms; and 2) a potential pathway to fish and consumers of fish. These pathways are discussed below. A third pathway, direct contact with sediment, was considered and eliminated from further consideration as discussed in Section 3.4.4 and in Appendix B.2. The direct contact pathway was considered for the uptake of SCOs by recreational users of the river that may experience dermal contact and incidental ingestion during the portage of boats into and out of the river, or during fishing activities, and for workers during construction along Segment 1. This assessment did not identify additional SCOs for consideration. Dermal contact by construction workers can also be managed using institutional controls or project-specific health and safety plans for workers, as needed.

#### **4.1.1 Known Pathway to Benthic Organisms**

At elevated concentrations, some sediment-bound chemicals can impair growth or productivity of benthic organisms via the movement or partitioning of chemicals from their sediment-bound phase to the organisms. Chemical exposure in this case involves the partitioning of chemicals between the sediment organic phase (sediment organic carbon OC), the sediment aqueous phase (the interstitial water between sediment particles), and sediment-dwelling organisms. The site-specific exposure and toxicity evaluation presented in Section 3.4 examined toxicity relationships on a dry weight and OC-normalized basis, and employed an equilibrium partitioning model in accordance with EPA (2005) guidance to further address the bioavailable fraction of sediment-bound chemicals

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in the sediment aqueous phase. These evaluations revealed that dry weight-based sediment concentrations of target SCOIs were well correlated with potential exposure and risk to benthic organisms in Segment 1. These site-specific evaluations also informed the identification of appropriate SMAs in Segment 1.

#### **4.1.2 Potential Pathway to Fish and Fish Consumers for SCOIs**

Although some bioaccumulative SCOI compounds such as chlorobenzenes have been detected in wild fish collected from Segment 1, their levels are generally at or below regulatory screening levels established for the protection of human health and wildlife (Appendix B4). For human health, bioaccumulative SCOI compounds in wild fish are at or below an excess lifetime cancer risk level of 1 in 1 million or  $10^{-6}$  and below a hazard quotient of 1. For wildlife, SCOI concentrations are well below their respective wildlife toxicity reference values (TRVs).

Although concentrations in wild fish in Segment 1 are currently at or below regulatory screening values, the Agencies requested that the Segment 1 CSM include a “potential pathway” between sediments and fish and between fish and consumers of fish (Figure 4-1) to acknowledge that, while unlikely, future conditions in Segment 1 could potentially result in higher bioaccumulation exposures. Thus, the term “potential pathway” in the CSM identifies the potential connection between sediment (which can include porewater) and fish, but recognizes that fish in Segment 1 are currently at or below regulatory screening values for SCOIs.

#### **4.1.3 Potential Pathway to Fish and Fish Consumers for PCOIs**

The potential exposure between sediments and fish and between fish and human consumers of fish depicted in the Segment 1 CSM (Figure 4-1) also recognizes that MDCH has issued a fish advisory in the Tittabawassee River for PCOIs (furan and dioxin compounds) and PCBs, both measured and reported as TEQ levels in fish (MDCH 2010).

As discussed in Section 2.6, Dow recently completed early actions in upstream areas of Segment 1 (Reaches B and D) that significantly reduced furan and dioxin exposure in Segment 1. Specifically, these 2007 to 2009 actions reduced the sediment TEQ SWAC throughout Segment 1 by approximately 60 percent (see Section 3.2.1). Because of relatively low sediment TEQ levels in this area, Segment 1 has not been identified as a targeted source of TEQ bioaccumulation exposure to wild fish in the Tittabawassee River. Moreover, further reductions in TEQ levels are expected following implementation of response actions in Segment 1 (as described in this Response Proposal), and as a result of continuing natural recovery processes (e.g., see Section 7.2.1).

### **4.2 Segment 1 Remedial Action Objectives**

The Segment 1 RAOs were developed to address the known and potential pathways identified in the segment-specific CSM, as summarized above. Each RAO is presented with its respective general response objective, performance objective, and measurable metrics, consistent with AOC/SOW requirements. As stated in the AOC/SOW, these RAOs focus on reducing exposures to and transport of contaminated media for the purposes of achieving acceptable levels of human

health and ecological risks, to be demonstrated in accordance with Task 10. Performance objectives and measurable metrics may be refined during remedial design.

#### **4.2.1 Remedial Action Objective 1**

*General Response Objective:* Reduce actual or potential unacceptable risks (current or future) to benthic receptors associated with contaminated surface sediments.

*Performance Objective:* Reduce and maintain concentrations of SCOs in surface sediments within Segment 1 SMAs to below site-specific sediment quality criteria.

Measureable Metrics:

- The short-term component of RAO 1 will include confirmation that surface sediment SCOI concentrations are at or below PLER levels in each SMA following construction.
- The long-term component of RAO 1 addresses the potential for recontamination of surface sediment by SCOs at levels that exceed PLER goals. This measurable metric will require long-term monitoring of surface sediment recontamination potential (also see RAO 3 below).
- Sampling requirements and details (including statistical criteria) to demonstrate that short- and long-term measurable metrics are achieved will be determined during design and incorporated into the site-wide monitoring plan.

#### **4.2.2 Remedial Action Objective 2**

*General Response Objective:* Reduce potential TEQ exposure in Segment 1.

*Performance Objective:* Conduct and/or maintain Segment 1 response actions that sustain a reduction in Segment 1 TEQ SWAC

Measureable Metrics:

- The short-term component of RAO 2 will include calculation of reductions in surface sediment TEQ SWAC levels in Segment 1, considering both early removal actions in Reaches B and D and future response actions implemented under this Response Proposal.
- The long-term component of RAO 2 will include monitoring of the overall stability of Segment 1 conditions (also see RAO 3 below).
- Sampling requirements and details (including statistical criteria) to demonstrate that long-term measurable metrics are achieved will be determined during design and incorporated into the site-wide monitoring plan.

#### **4.2.3 Remedial Action Objective 3**

*General Response Objective:* Mitigate unacceptable exposures to subsurface contaminated sediment deposits. Mitigate the potential for exposure of subsurface contaminated sediment deposits that may contribute to future unacceptable risks.

*Performance Objective:* As necessary, reduce the potential for sediment erosion that would lead to unacceptable SCOI surface sediment conditions.

Measureable Metrics:

- The short-term component of RAO 3 will include monitoring during construction to minimize construction-related resuspension and release.
- The long-term component of RAO 3 will include monitoring surface sediment bed elevations. Allowable bed elevation changes will be defined during remedial design
- Post-construction monitoring may also include focused chemistry measurements, depending on the results of the sediment stability measurements.
- Monitoring requirements and details (including statistical criteria) to demonstrate that long-term measurable metrics are achieved will be determined during design and incorporated into the site-wide monitoring plan.

### **4.3 Applicable or Relevant and Appropriate Requirements**

Any response actions implemented under the Segment 1 Response Proposal must comply with substantive elements of applicable or relevant and appropriate requirements (ARARs), unless the ARAR is waived. Although on-site response actions performed under formal CERCLA authorities (e.g., a Consent Decree) are exempt from the procedural requirements of federal, state, and local environmental laws, the action must nevertheless comply with the substantive requirements of such laws.

According to the NCP (40 CFR 300.5), applicable requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site. A requirement may not be applicable, but nevertheless could be relevant and appropriate. Relevant and appropriate requirements address problems or situations sufficiently similar to those encountered at CERCLA sites that their use is well-suited to the particular site.

In addition, some federal, state, and local environmental and public health agencies may develop criteria, advisories, guidance documents, and proposed standards that are not legally enforceable but that contain useful information for implementing a cleanup remedy or selecting cleanup levels. These fall into the category of criteria “to be considered” (referred to as TBCs); TBCs are not mandatory but may complement the identified ARARs.

ARARs may be categorized as: 1) chemical-specific; 2) action-specific; or 3) location-specific. Some ARARs fit neatly into a single category, while others may fall into more than one category. Tables 4-1 to 4-3 identify chemical-, action-, and location-specific ARARs that may be applicable to response actions in Segment 1.

#### **4.3.1 Potential Chemical-Specific Requirements or TBCs**

Chemical-specific ARARs are either the numerical values or the methods for developing such values. These ARARs are used to establish the acceptable amount or concentration of a chemical that may remain in or be discharged to the environment. Identified in Section 3.2.1 above, are 17 PCOIs, all of which are furan and dioxin congeners. Also identified in Section 3.2.2 are 35 SCOIs, which can be grouped as follows: total chlorobenzenes, total chlorophenols, PAHs, arsenic, oPP, and ethyl parathion.

The medium being addressed in the Segment 1 Response Proposal is sediment for which there are no chemical-specific requirements. Although there are standards or requirements for water, such as the Clean Water Act and State of Michigan water quality standards, these are only triggered by certain actions, such as when water is being discharged to surface water from dewatering or treatment areas. They are not generally applicable. Thus, both the Clean Water Act and the State of Michigan water quality standards are appropriately included in Section 4.3.2 Potential Action-Specific Requirements below.

#### **4.3.2 Potential Action-Specific Requirements or TBCs**

Action-specific ARARs are performance, design, or other requirements that may place controls or restrictions on a particular response action. Action-specific ARARs are typically technology- or activity-based requirements or limitations on actions, and these requirements may include chemical-specific standards or criteria that must be met as the result of an action. For response actions in Segment 1, these requirements are not necessarily triggered by the presence of specific contaminants in sediments, but rather by specific activities related to managing contaminated sediment. Action-specific ARARs that may influence the Segment 1 Response Proposal are summarized in Table 4-2; several are briefly described below.

##### **Clean Water Act – Federal Surface Water Quality Standards**

Federal Water Quality Standards are the foundation of the water quality-based pollution control program mandated by Section 303 of the Clean Water Act. Water standards are provisions of state, tribal, or federal law that define the water quality goals of a water body, or segment thereof, by designating the use or uses to be made of the water body; establishing criteria based on sound science that are protective of applicable uses; and protecting water quality through antidegradation requirements (See 40 CFR Part 131). States and tribes adopt water quality standards to protect public health or welfare, enhance the quality of water, and serve the purposes of the Act. These standards may be ARARs for the Site (point source discharges to the river). If a state has not adopted water quality standards, federal water quality standards are used. The state of Michigan has developed standards for the protection of water quality, which are discussed below.

##### **Clean Water Act – Federal Ambient Water Quality Criteria**

Section 304 of the Clean Water Act requires EPA to develop criteria for water quality that accurately reflects the latest scientific knowledge. These criteria are based solely on data and scientific judgments on pollutant concentrations and environmental or human health effects. These criteria are published pursuant to Section 304(a) of the Clean Water Act and provide guidance for

states and tribes to use in adopting water quality standards. EPA has national recommended water quality criteria for the protection of aquatic life and human health in surface water for approximately 150 pollutants. These pollutants include dioxin, chlorobenzene, and chlorophenol. These federal standards may be TBCs for OU1 Segment 1 when water is being discharged to surface water from dewatering or treatment areas, when there is turbidity during river bottom work, or as effluent from confined disposal areas.

### **Michigan Water Quality Standards**

The state of Michigan has developed standards for the protection of water quality. These water quality standards can be found in Part 4 of the Michigan Administrative Rules. For protection of aquatic life in surface waters, the standards include arsenic and parathion. For protection of human health, the standards include chlorobenzene and 2,3,7,8-TCDD (dioxin). These standards may be ARARs for OU1 Segment 1 when water is being discharged to surface water from dewatering or treatment areas, when there is turbidity during river bottom work, or as effluent from confined disposal areas.

### **Resource Conservation and Recovery Act**

The RCRA addresses the generation and transportation of hazardous waste and waste management activities at facilities that treat, store, or dispose of hazardous wastes. Subtitle C (Hazardous Waste Management) mandates the creation of a cradle to grave management and permitting system for hazardous wastes. RCRA regulates "solid wastes" that are hazardous because they may cause or significantly contribute to an increase in mortality or serious illness, or because they pose a substantial hazard to human health or the environment when improperly managed. One objective of RCRA is to minimize both the generation and land disposal of hazardous waste by encouraging process substitution, materials recovery, recycling and reuse, and treatment (see RCRA Section 3003). To further this objective, EPA has set various goals for the Waste Minimization National Plan, including reducing the generation and mobility of hazardous wastes and establishing treatment standards as part of several rulemakings under the Land Disposal Restrictions (LDR) in 40 CFR Part 268.

### **Endangered Species Act**

The Endangered Species Act (ESA), 16 U.S.C. Section 1531 et seq., provides a program for the conservation of threatened and endangered plants and animals and the habitats in which they are found. The USFWS maintains a worldwide list of endangered species. Species include birds, insects, fish, reptiles, mammals, crustaceans, flowers, grasses, and trees. The law requires federal agencies, in consultation with the U.S. FWS and/or the U.S. National Oceanic and Atmospheric Administration (NOAA) Fisheries Service to ensure that actions they authorize, fund, or carry out are not likely to jeopardize the continued existence of any listed species or result in the destruction or adverse modification of designated critical habitat of such species. If threatened or endangered species exist in certain areas of the Tittabawassee River, this law may constitute an action-specific ARAR for OU1 Segment 1.

### **4.3.3 Potential Location-Specific Requirements or TBCs**

Location-specific ARARs are restrictions placed on an action based solely on the action's location. Location-specific ARARs may restrict or preclude certain response actions or may apply only to certain portions of Segment 1. This group of ARARs includes consideration of floodplains, wetlands, and navigation features. Location-specific ARARs that may influence the Segment 1 Response Proposal are summarized in Table 4-3; several are briefly described below.

#### **Floodplain and Wetland Regulations and Executive Orders 11988 and 11990**

The requirements of 40 CFR § 264.18(b) (regulating hazardous waste facilities located in floodplains) and Executive Orders 11988 (Protection of Flood Plains) and 11990 (Protection of Wetlands), may be relevant and appropriate at OU1 Segment 1, which includes floodplains and may include wetlands.

#### **Clean Water Act**

Under Section 303(d) of the Clean Water Act, states are required, on a periodic basis, to submit lists of "impaired waterways" to EPA. In 2010, the state of Michigan submitted its most recent list. The Tittabawassee River ("From the Saginaw River confluence upstream to Dow Midland") is included on the list. A total maximum daily load (TMDL) for dioxin is scheduled for 2014. The Segment 1 Response Proposal contemplates completing in-water construction in 2013, which is before the TMDL is anticipated. If the TMDL is finalized, Dow and EPA will evaluate whether it is applicable to or relevant and appropriate for Segment 1 response activities.

#### **National Historic Preservation Act**

The NHPA, 16 U.S.C. Section 470 et seq., preserves historical and archaeological sites in the United States. In particular, it provides protection for properties on or eligible for inclusion on the National Register of Historic Places (see 36 CFR Part 800). In selecting a response action, adverse effects to such properties are to be avoided. NHPA may be an ARAR for this Site to the extent there is a property at OU1 Segment 1 which is on or eligible for the National Historical Register.

### **4.4 Early Response Actions in Segment 1**

The overall objectives of the AOC/SOW are to streamline Site investigation studies, quickly identify and assess remedial options, and accelerate remedy design in order to initiate any needed response actions rapidly. As discussed in Sections 2.5, Dow has completed source control efforts for decades as a critical initial step to achieve effective sediment cleanup, consistent with EPA (2005) guidance. Since 2007, Dow has also implemented a number of early sediment cleanup actions in the Tittabawassee River under the oversight of DEQ and EPA to further protect and accelerate recovery of the river system. Early actions constructed in Reaches B and D reduced the TEQ SWAC values in Segment 1 by approximately 60 percent (see Table 3-3) and also significantly reduced sediment SCOI concentrations in this area of Segment 1. Long-term monitoring and management as necessary to ensure the continued protectiveness of these actions is incorporated into the overall Segment 1 response action to further verify that these early actions continue to meet RAOs, as indicated by the initial monitoring data. In 2008 to 2009, early sediment

response actions in Reach B of Segment 1 included the removal of debris and soils from the Reach B bank, and an in-channel removal of debris along the eastern bank of a portion of Reach B. Following the removal activities, an engineered cap was constructed in-channel to effectively contain any remaining debris and contaminated sediments. In Reach D, during the period of 2007 to 2009, river sediments impacted with elevated concentrations of furans and dioxins, metals, and PAHs were removed from the east side of the channel. The removal area was capped to provide permanent physical isolation of contaminated dredge residuals.

Per Task 8.2 of the SOW, this section demonstrates how these early response actions completed in Reaches B and D are consistent with the Segment 1 RAOs presented in Section 4.

#### **4.4.1 Early Response Actions Evaluated Against RAO 1**

The early response actions conducted at Reach B and D achieve the RAO 1 general response objective and performance objective by reducing surface sediment SCOI concentrations to below the site-specific PLER sediment quality criteria.

Under pre-early action conditions, three surface sediment locations near the shoreline of the Reach B contained total PAH concentrations greater than the PLER value of 15 mg/kg. All three of these locations were captured within the boundary of the Reach B early action response.

Under pre-early action conditions, one surface sediment location at the downstream end of the Reach D, near the north shoreline, exceeded the PLER criteria for multiple SCOs (total PAHs, total chlorobenzenes, and arsenic). This sample location was addressed as part of the Reach D early response action.

#### **4.4.2 Early Response Actions Evaluated Against RAO 2**

The early response actions conducted at Reach B and D achieve the RAO 2 general response objective and performance objective by reducing the Segment 1 TEQ SWAC as shown in Figure 4-2. Figure 4-2 shows surface and subsurface TEQ levels under pre-response action conditions in Reaches B and D. Figure 4-2 shows a vertical profile of TEQ levels at depths below the sediment surface. Those samples included within the boundary of the early response actions are marked with an "X" in the vertical profile.

As discussed in Section 3.2, the Reach B and Reach D early actions reduced the Segment 1-wide SWAC by approximately 60 percent (see Table 3-3).

#### **4.4.3 Early Response Actions Evaluated Against RAO 3**

The early response actions also achieve the RAO 3 general response objective of mitigating the potential exposure of subsurface contaminated sediment deposits. This objective was achieved in Reach B and Reach D through both the removal and the capping of subsurface SCOs and TEQ deposits. Furthermore, monitoring of the Reach B and D caps will be included as part of Task 4 – Site-Wide Monitoring elements of the AOC/SOW. Results from the monitoring will be used to assess the long-term integrity of the cap.

## 5.0 Segment 1 Response Action and Remedial Technology Screening

This section discusses the identification and initial screening of response actions and remedial technologies that were subsequently assembled into response action alternatives for Segment 1 (see Section 6). Response action alternatives for cleanup of aquatic sediments generally have the following three components (EPA 2005):

- **General Response Actions** – major categories of response activities such as monitored natural recovery, institutional controls, containment, removal, or treatment.
- **Potentially Applicable Remedial Technologies** – general categories of technologies such as different in situ containment options (e.g., lateral containment or sediment capping) or removal methods (e.g., sediment removal or product recovery).
- **Process Options** – technology implementation details, such as mechanical or hydraulic dredging methods.

The identification and assembly of response actions/remedial technologies into a focused set of segment-specific alternatives was performed in accordance with CERCLA guidance, consistent with the AOC/SOW, and as detailed in the sections below. Potentially applicable remedial technologies were identified and retained for assembly into Segment-1 SMA-specific response action alternatives in Section 6.

Remedial technologies evaluated for possible application to Segment 1 were organized under general response actions (GRAs) that represent different conceptual approaches to remediation. Consistent with EPA (2005), five different GRAs have been identified:

- **Removal and Disposal/Treatment:** Includes removal of sediment via dredging or excavation followed by subsequent management, such as dewatering and landfill disposal. This GRA also includes removal of liquid contaminants using hydraulic wells or other removal methods.
- **In- Situ Treatment:** Includes application of sequestering agents (e.g., activated carbon), biodegradation, immobilization, and/or other potentially appropriate treatment technologies to reduce levels and/or movement of Site contaminants.
- **In situ Containment:** Includes capping and/or sand cover and lateral containment to isolate SCOs contained in the river from the water column and biological receptors.
- **Institutional Controls:** Includes non-engineered instruments, such as administrative and legal controls, to minimize the potential for exposure and to ensure the long-term integrity of the remedy.
- **Monitored Natural Recovery:** Includes monitoring to document the effectiveness of natural processes in removing or containing Segment 1 contaminants.

The evaluation of technologies potentially applicable to response actions in Segment 1 was carried out in two steps consistent with CERCLA guidance (EPA 1988). The first evaluation step, presented in this section identified an array of possible remedial technologies and evaluated these

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technologies based on technical effectiveness and implementability in Segment 1. Technologies that have clearly not been demonstrated as effective in addressing similar conditions at other sediment sites, or that cannot be implemented due to site-specific conditions, were eliminated from further consideration in this Segment 1 Response Proposal. The second evaluation step, presented in Sections 6 and 7, assembled the retained remedial technologies into a range of potentially viable response action alternatives that were further evaluated based on the NCP criteria (EPA 1988) overall effectiveness, implementability, and relative cost (EPA 1988) following NCP criteria:

- **Effectiveness.** The effectiveness criterion evaluates the technology or alternative relative to its ability to achieve RAOs in a reasonable timeframe. Both short-term and long-term effectiveness are evaluated. Short-term effectiveness encompasses potential effects to human health and environment during the construction and implementation periods, while long-term effectiveness encompasses the reliability and protectiveness of the technology or alternative after implementation.
- **Implementability.** The implementability criterion evaluates the technology or alternative for technical and administrative feasibility. Technical feasibility refers to the ability to construct, operate, maintain, and monitor the action during and after construction and meet technology-specific regulations during construction. Technical feasibility also applies to the availability of necessary equipment, personnel, and services for implementation or construction. Administrative feasibility refers to the ability to obtain approvals (on-site response actions defined under CERCLA are exempt from the procedural requirements of federal, state and local environmental laws, though the action must nevertheless comply with the substantive requirements of such laws; see Section 4.3).
- **Cost.** The cost criterion is used to compare different technologies or alternatives. The total cost of a given technology is not normally estimated during the initial screening described in this section. However, knowledge of typical technology costs obtained from vendors, cost-estimating guides, prior projects, and engineering judgment are used to evaluate the relative costs of technologies (including overall construction, operation, maintenance, and monitoring costs) and compare costs with those of other similar technologies during the initial screening phase. Detailed costs for each alternative are developed during the comparative evaluation (see Section 7).

The evaluation and initial screening of potentially applicable remedial technologies for each GRA (i.e., Step 1) is described below and summarized in Table 5-1.

## 5.1 Removal and Disposal/Treatment

Dredging and excavation are the two most common means of removing contaminated sediment from a waterbody (EPA 2005), either while the sediment is submerged (dredging) or after water has been diverted or drained (excavation). Both methods typically necessitate transporting the sediment to a location for treatment and/or disposal. Whereas this GRA removes contaminant mass from the aquatic environment, such removal can also lead to short-term releases via resuspension and release to the water column. Moreover, even the most state-of-the-art dredging and excavation equipment methods have technical limitations that often result in contaminant

release and residuals left behind that require further management to achieve the desired risk reductions. In addition, removal requires additional handling of dredged or excavated sediment including dewatering, transport, and disposal, each of which involves additional costs and the potential for further releases.

Three potentially applicable removal technologies were identified for potential application to Segment 1 under the GRA of removal and disposal/treatment:

- Sediment excavation (using typical earthwork equipment)
- Sediment dredging (mechanical or hydraulic)
- Removal of recoverable product (using direct removal via wells or other methods)

Each of these removal technologies is described below.

### **5.1.1 Sediment Excavation**

Sediment excavation involves the use of excavators, backhoes, and other conventional earth moving equipment to remove contaminated sediment after water has been diverted or drained (i.e., “in the dry” removal). Diversion of water of the excavation area can be facilitated through the installation of temporary cofferdams, sheet piling, or other water management structures and the subsequent lowering of the surface water elevation within the excavation area. Following dewatering of the area, equipment can be positioned on the riverbed within excavation area or immediately adjacent to the dewatered excavation area. It should be noted that installation of sheet pile or temporary cofferdams to support dry excavation could cause erosion adjacent to the work area due to constricted river flow or other hydrodynamic forces, as was observed during the previous Reach D response action. In addition, sheet pile installation may be inhibited by the presence of debris and/or other natural obstructions.

Impacts of sediment removal on the integrity and stability of existing structures within or adjacent to the excavation area (e.g., sheet piling for RGIS) must be considered and addressed during design. For instance, removal of near shore sediments could potentially reduce the foundation support and stability of the RGIS sheet pile wall. If this technology is selected by EPA, remedial design would need to consider removal methods that minimize the risk to RGIS. The potential need for construction monitoring and/or protective measures would need to be understood and considered to ensure that sediment cleanup actions do not affect RGIS operations.

Sediment excavation has been implemented at many sites including in the Tittabawassee River (e.g., previous response actions performed by Dow in 2007 within Reach O, downstream of Segment 1). The Reach O removal action included the installation of sheet piling to contain the removal area and subsequent dewatering of the area to allow excavation equipment direct access to the targeted sediments. Implementation of this technology is typically limited to near shore areas that can be accessed with conventional earthwork equipment from shore or by the practicability of diverting river flow from an area to facilitate excavation. Appendix D presents a summary of previously completed remedial projects that included sediment excavation.

Following removal, excavated sediments may require dewatering by passive or active draining and/or mixing with an amendment (e.g., Portland cement) prior to transport and disposal at an approved disposal facility. The degree and duration of gravity drainage and the need to mix amendments depends on the characteristics of the excavated material. For instance, non-cohesive sediments such as sand and gravel that are prevalent in Segment 1 SMAs typically drain rapidly and may not require a dewatering amendment. Conversely, fine-grained or cohesive sediments such as silt and clay require more effort to dewater. An upland area is often necessary to support dewatering activities; an existing sediment dewatering facility is currently available at the Dow Midland facility.

It is likely that the excavation equipment will not effectively remove all of the contaminated sediment, leaving behind a thin layer of contaminated sediment, commonly referred to as “residuals.” Although case studies of residuals for sediment excavation projects have not been well documented, it is expected that residuals will remain, although likely to a lesser degree than with dredging (i.e., sediment removal under submerged conditions; see Section 5.1.2). Management of potential post-excavation residuals, either by placement of backfill/sand cover or natural recovery, is commonly considered in the evaluation of excavation as a remedial technology.

Based on observations during early actions in the Tittabawassee River (e.g., sediment removal in Reaches D and O), difficult excavation/dredging conditions are anticipated in Segment 1, because the targeted sediments generally reside on a layer of hard till, and a considerable amount of debris is likely present in subsurface sediments throughout the Tittabawassee River.

Compared with the other GRAs discussed below, the costs associated with excavation, dewatering, and disposal are relatively high. Dewatered fluids may also require disposal or treatment prior to discharge back to the river.

Sediment removal, possibly via excavation, was retained for evaluation in all SMAs.

### **5.1.2 Sediment Dredging**

Dredging is a method of excavation that allows the removal of sediments without water diversion or draining (i.e., “in the wet” removal). Dredging is generally accomplished using one of two technologies: hydraulic (a method that generally involves pumping sediment and water in a slurry) or mechanical (typically involving the use of a clamshell bucket on a derrick barge).

Hydraulic dredging typically involves using a cutterhead or similar equipment to remove sediments from the sediment bed. Hydraulically dredged material can be transported via piping directly to a staging/processing area. Relative to mechanical dredging, a greater volume of water is entrained with the sediment slurry removed by the dredge and must be subsequently separated from the sediment solids and discharged and/or treated (EPA 2005). The solids content of hydraulically dredged slurries normally averages less than 10 percent by weight, but it can vary considerably with the specific gravity, grain size, and distribution of the sediment, and depth and thickness of the dredge cut. In general, hydraulic dredges cannot remove rocks and large debris, which are

expected to be present in Segment 1 sediment deposits. In addition, hydraulic dredges cannot operate in very shallow water, and typically require water depths of at least 2 ft.

Hydraulic dredging has been implemented at many sites, including the Tittabawassee River at Reach D as part of previous response actions (see Appendix D). However, shallower water depths and debris within Segment 1 downstream of the Dow Dam may limit the use of hydraulic dredging and ancillary floating equipment.

Mechanical dredges have been used extensively and are widely available. These dredges remove sediment at about the same water content as the in situ material, thereby minimizing the amount of water removed (EPA 2005). They can also operate in areas with limited space, can remove large debris, and are highly maneuverable, but typically cannot operate in water less than about 2 to 3 ft deep due to draft requirements for the supporting barges. Mechanically dredged sediment may need to be transported by barge or entrained in a slurry and piped short distances. However, because mechanical dredges pose a risk of spillage during dredging and unloading, dredge operations generally try to minimize the number of material transfers. Additionally, the water contained within the bucket/sediment during dredging will need to be managed.

Dewatering of hydraulically or mechanically dredged sediments is typically required prior to transport and disposal. Hydraulically dredged sediments can be dewatered using passive or active methods, and can require settling basins due to the relatively large volume of water added for slurry transport. Similar to the dewatering of excavated sediments discussed above, mechanically dredged sediments are typically dewatered using gravity draining and/or mixing with a dewatering amendment (e.g., Portland cement). The degree of dewatering effort necessary prior to transport depends on the physical properties (e.g., grain size and permeability) of the removed sediment and the amount of free water entrained during the removal process. Dewatering of mechanically or hydraulically dredged sediments typically requires an upland staging area, usually in close proximity to the dredge area. With mechanical dredging, a dock/berthing area also may be necessary at the upland staging area to facilitate offloading of sediment transport barges.

Experience at other sites indicates that dredge equipment is not effective at completely removing all contaminated sediments, leaving behind a layer of residuals on the post-dredge surface. The residual sediment reduces the risk-reduction of the remedy, and consequently, reduces the effectiveness of the dredging remedy (NRC 2007). Research has shown that residual sediment remaining on the post-dredge surface (typically ranging from 2 to 11 percent of the remaining contaminated sediment mass prior to the final production dredge pass) have been observed during most environmental dredging projects, particularly when targeted sediments overlie a layer of hard material (e.g., rock or till) and where rocks/cobbles, logs, or other debris are present on the river bottom (Desrosiers and Patmont 2009). Management of potential post-removal residuals, by placement of a cap, backfill/sand cover, or natural recovery, is commonly considered in the evaluation of dredging as a remedial technology.

Release and resuspension of contaminants (dissolved or sorbed to suspended sediment particles) to the water column and potential downstream transport may result in downstream impacts during dredging, even if the removal area is enclosed by turbidity control devices. Experience at similar

sites indicates that an estimated 2 to 4 percent of the dredged contaminant mass is typically resuspended in the water column and transported (often as dissolved phase contaminants) out of the removal area (Palermo et al. 2008). Whereas sediment turbidity impacts in the removal area can be minimized in certain applications through the use of best management practices (BMPs) such as silt curtains or temporary sheet piling, such BMPs have been demonstrated to be generally ineffective in reducing the downstream release of dissolved contaminants.

Section 7 presents a more detailed discussion of resuspension and release specific to the Tittabawassee River.

Sediment removal, possibly via dredging, was retained for evaluation in all SMAs.

### **5.1.3 Removal of Recoverable Product**

Product recovery wells may be feasible where potentially recoverable quantities of free-phase product were identified during fall 2010 field investigations (see Section 3.2.3). Recovery wells are used extensively at upland sites, although their success depends on the nature of the extracted material and subsurface site conditions. Removal of free-phase product may involve installation of a trench, sump, or well screened within the product (within the fluvial sediments overlying the low-permeability till layer for the deposits identified in Segment 1). Recovered product and/or subsurface water extracted from the well(s) would likely be treated on-site.

Wells can be installed either vertically or horizontally (angled) within a targeted deposit. The main advantage of vertical wells is that they are able to intersect the targeted deposits that may reside in low-permeability layers like the till unit. However, vertical wells have a limited radius of influence and multiple vertical wells may be needed to remove targeted deposits.

Horizontal drilling techniques have been used at some cleanup sites to install non-vertical wells that provide access to areas where the surface is inaccessible to drilling rigs or where maintenance of vertical wells would not be feasible (e.g., within the river channel). A single horizontal well can be installed across the targeted deposit, resulting in a significant radius of influence, if positioned so that the well screen intersects the free-phase portion of the deposit. Horizontal drilling would need to be conducted from the shoreline or riverbank without leaving any well structures exposed in the river. A disadvantage of a horizontal well is that it is difficult to precisely target the top of the till surface where the free-phase product. Construction of horizontal recovery wells has been less widespread than that of vertical wells, but it may be feasible in Segment 1. Appendix D presents a summary of previously completed remedial projects that included extraction wells in an aquatic environment.

Some technical challenges exist with using pumping technologies to successfully remove subaqueous deposits. For example, the thickness and characteristics of the liquid deposit (e.g., viscosity and degree of weathering) can limit the effectiveness of removal efforts in some settings. The thickness and characteristics of the sediments that contain the targeted deposit and other sediment layers may also control the effectiveness of the system.

Pilot-scale testing during remedial design is often performed to verify that recoverable quantities of free-phase product are present and to provide engineering data for design. Pilot testing is typically performed using temporary wells that may extend above the river surface. If the pilot extraction process is successful, a more permanent well or series of wells could be installed. A pilot study also provides an opportunity to determine whether the target deposit is extractable; if not, the residual material may be defined as sufficiently weathered and immobile.

If determined to be feasible based on site conditions, recovery wells can be an effective means of removing free-phase non-aqueous deposits without the short-term risks associated with excavation or dredging. Treatment of extracted liquids would likely be integrated into existing on-site treatment systems such as the facility WWTP described in Section 2.5.1; alternatively, the liquids could be incinerated at the Dow Midland facility (see Section 2.5.2). Relative to other GRAs, the implementation costs associated with removal and treatment of the extracted materials are medium.

Because site characteristics suggest that potentially recoverable quantities of free-phase product are likely present immediately above the till contact in SMAs 2, 3, and 6, removal of free-phase product was retained for evaluation in these SMAs.

## **5.2 In situ Treatment**

In situ treatment options identified for the treatment of target Segment 1 SCOIs include injection of zero valent iron, in situ oxidation by sodium persulfate, in situ treatment using permanganate, and in situ reactive capping. Of these technologies only in situ reactive capping has been implemented successfully beyond the bench- or pilot-scale and is considered implementable in Segment 1. In permeable reactive/sorptive capping, a permeable cap is placed above impacted sediments, and a material (such as organoclay or activated carbon) is placed within the sediment cap to sorb dissolved-phase contaminants, often facilitating further biodegradation, and limiting migration into overlying sediment porewater and surface water. In certain applications, sorptive caps may lose their effectiveness when the sorptive material becomes saturated. Therefore, for continued effectiveness, a sorptive cap should be designed such that one or more of the following design goals are achieved:

- A sufficient volume of sorptive material is added such that its operating lifetime is longer than the projected remediation/restoration timeframe.
- A mechanism for removal and/or replacement of the sorptive layer is incorporated into the design.
- The cap is designed to also biodegrade sorbed contaminants, thereby maintaining or regenerating the material's sorptive capacity.

Within Segment 1, a reactive engineered cap may be effective and applicable to areas with relatively high subsurface sediment concentrations where in situ containment alone may not be fully effective. Reactive caps can be designed to permanently treat some contaminants.

Reactive engineered capping is an innovative technology that has been successfully applied at several sites. Activated carbon and other cost-effective materials such as coal and coke have been used at a number of sites as a sorptive barrier, and several promising reactive cap amendments and sediment treatment technologies have been successfully demonstrated in the field. Appendix D presents a summary of previously completed remedial projects involving the use of reactive engineered caps.

Organoclay (a modified clay that absorbs free-phase NAPL and other hydrocarbons) has long been used in water treatment systems to remove sheen or free-phase petroleum before treatment of dissolved-phase contaminants by activated carbon. Organoclay has recently been successfully applied as a capping material for sediments that previously contained free-phase hydrocarbon seeps (see Appendix D).

The costs associated with reactive engineered caps are considered moderate due to both the expense of the reactive material within the cap and the additional cost associated with installing an often neutrally buoyant material. On some sites, reactive caps have been implemented as an interim measure or require long-term maintenance/replacement. Elsewhere, reactive caps have been designed for long-term permanence without replacement.

In situ treatment, specifically reactive engineered caps, is retained for evaluation in SMAs 2, 3, and 6 where free-phase product was detected during the fall 2010 product recovery investigations, as discussed in Section 3.2.3. Other in situ treatment options that are not proven are not retained for further consideration.

### **5.3 In situ Containment**

In situ containment involves confining contaminated substances in situ through placement of physical barriers or hydraulic controls. Containment technologies may be designed to prevent contact with and/or migration of the contaminated substances. Use of in situ containment technologies does not typically result in releases of hazardous substances during construction and may provide an effective method of reducing the potential for exposure. For the purposes of this Response Proposal, in situ containment technologies have been grouped in the following categories:

- Lateral containment
  - Sheet pile walls
  - Slurry walls
- Vertical containment
  - Clean sediment cap
  - Low-permeability cap
- Hydraulic control/pumping (potentially in combination with the above)

Each of these remedial technologies is described below.

### **5.3.1 Lateral Containment**

Lateral containment involves the use of an impermeable vertical barrier to enclose or isolate the targeted sediments, thereby controlling the mobility of product and/or dissolved-phase contaminants in groundwater. The vertical barrier would be driven down from the top of sediment and embedded into the underlying low-permeability till, inhibiting lateral movement of contaminants outside of the contained area.

Groundwater flow within the surficial sand sediments of Segment 1 is influenced by the thick, underlying low-permeability till unit and to some extent by the adjacent RGIS, such that no groundwater flows up from the sediments into the river surface water (see Section 3.3.4 for additional details). The specific groundwater flow condition in the SMA would need to be validated or investigated during the remedial design to support final design of this technology.

If appropriate, a lateral containment technology could be evaluated in conjunction with vertical containment and a hydraulic groundwater control system in the contained area. This could involve installation of a hydraulic well within the contained area to extract groundwater flow, creating a slight negative pressure within the laterally contained areas. Hydraulically connecting the vertically and horizontally contained areas with the Dow RGIS system may be another method of hydraulic controls. Lateral containment would be applicable to areas of potential subsurface contaminant migration to control lateral movement within the sediment bed or into the Tittabawassee River surface water. This technology has been successful at other sediment remediation sites (see Appendix D).

Lateral containment is considered a medium-cost technology. Significant costs include materials (e.g., sheet pile) and the operation, maintenance, and monitoring costs associated with a potential hydraulic pumping well to maintain a downward groundwater flow.

Lateral containment with potential hydraulic control was retained for evaluation in SMAs 2, 3, and 6 where potentially recoverable product has been observed.

### **5.3.2 Vertical Containment**

Vertical containment involves the placement of a cap or cover above the contaminated sediments. The cap could include a clean sediment cap or an impermeable cap as described below.

#### **5.3.2.1 Clean Sediment Cap**

A cap refers to the placement of an engineered subaqueous covering or cap of clean material over contaminated sediment that will remain in place. A cap would be designed to effectively contain and isolate contaminated sediments from the biologically active surface zone. As described in EPA (2005), in situ caps can quickly reduce exposure to contaminants and typically require less infrastructure than ex-situ technologies (e.g., dewatering, treatment, and disposal). Depending on site conditions, natural deposition of clean sediments can also form an effective cover serving both the chemical isolation and erosion protection functions. A factor in evaluating the feasibility of sediment covers or engineered caps is the stability of the material in the context of site-specific

conditions. Long-term monitoring and potential maintenance to ensure appropriate protectiveness of the remedy is typically required (EPA 2005).

The cap would be designed to be thick enough to effectively control contaminant transport via advection and/or diffusion. Armoring is sometimes needed to maintain cap integrity over the design life. Caps typically contain chemical isolation and stabilization/erosion protection components, which can be composed of one or more materials, depending on the sediment and waterbody characteristics. Preliminary cap modeling for the Segment 1 SMAs, using EPA-approved methods to address contaminant transport, indicates that a chemical isolation layer of varying composition and thickness specific to each SMA could provide protection such that surface sediments in the biologically active zone remain below PLER values (see Appendix E).

Within Segment 1, individual SMAs may have varying erosion protection (i.e., armor) requirements to resist design flow events and other area-specific forcing conditions (e.g., ice formation potential, vessel wake, and wind waves). Caps have been applied successfully at numerous sediment sites (see Appendix D) and have been recently constructed in Reaches B and D. Caps could be placed by a number of mechanical and hydraulic methods. Mechanical placement was effectively used for the caps constructed in Reaches B and D.

Capping is considered a medium-cost technology due to the expense of the materials, installation (especially in complex, multi-material caps), and long-term monitoring and maintenance requirements. Engineered caps and backfill/sand covers were retained for evaluation for all SMAs.

#### **5.3.2.2 Low-Permeability Cap**

A low-permeability cap is comprised of a low-permeability material, which could be a natural material such as clay, a synthetic material such as HDPE, or combinations such as geosynthetic clay liners. Low-permeability caps offer similar advantages and disadvantages to sediment caps (see Section 5.3.2.1) and incorporate a hydraulic containment component. Therefore, low-permeability caps could be used in combination with lateral containment to reduce groundwater flow into surface waters. Furthermore, low-permeability caps could be used in combination with product recovery wells to reduce the groundwater flow capture by the recovery wells, thereby reducing the amount of water that requires treatment.

Low-permeability caps have been used at a number of sites for vertical hydraulic containment (see Appendix D). They are considered a medium-cost technology due to the cost of the low-permeability material within the cap, the additional cost associated with installing a neutrally buoyant material, and costs associated with long-term monitoring and maintenance requirements.

Low-permeability caps were retained for evaluation in SMAs 2 and 3.

### **5.4 Monitored Natural Recovery (MNR)**

Natural recovery is the process by which contaminant concentrations in sediment are reduced through a combination of naturally occurring physical, chemical, and/or biological processes to the point that surface sediment concentrations are acceptable. Some natural processes (e.g.,

deposition of cleaner sediments onto impacted sediments) act as containment mechanisms, while others (e.g., biodegradation of contaminants by native bacteria) act as in situ treatment mechanisms. Predictive modeling of natural recovery processes using site-specific tools (such as the sediment transport model) can be performed to predict sediment recovery rates by assessing the rate at which new sediments from upstream mix with existing sediments within a particular deposit. Performance monitoring of sediments at specified intervals can be performed to verify model predictions and to document the presence and effectiveness of the natural processes in reducing risks.

Within Segment 1, MNR is applicable to areas of where contamination is buried below cleaner sediment that does not exceed threshold criteria (e.g., PLER) or areas where sediment bedload transport may provide a source of clean sediment deposition within impacted areas. MNR is also applicable in areas where biodegradation of contaminants is expected to reduce sediment concentrations to below the PLER within reasonable timeframes. MNR has been well demonstrated at numerous sediment sites, as summarized in Appendix D. MNR is highly implementable and cost-effective and was retained for consideration in SMAs 1, 4, 5, and 6.

## 5.5 Institutional Controls

As defined in EPA (2005), institutional controls are non-engineered instruments, such as administrative and legal controls, that may be included as part of a response action to minimize the potential for human health or ecological exposure to sediment contamination and ensure the long-term integrity of the remedy. EPA guidance on institutional controls is provided in OSWER Directive 9355.0-74FS-P, *Institutional Controls: A Site Manager's Guide to Identifying, Evaluating, and Selecting Institutional Controls at Superfund and RCRA Corrective Action Cleanups* (EPA 2000) and OSWER Directive 9355.0-106, *Strategy to Ensure Institutional Control Implementation at Superfund Sites* (EPA 2004).

Institutional controls typically are grouped into the following categories (EPA 2005):

- Proprietary land use restrictions and maintenance agreements that may involve legal instruments
- Enforcement and permit devices
- Governmental controls including permit conditions for future actions
- Informational devices including signage and fish consumption advisories that may be required until RAOs are met

Institutional controls were retained for evaluation in all SMAs.

## 6.0 Segment 1 Response Actions and Options

### 6.1 Assembly of Response Action Alternatives by SMA

The preliminary technology screening presented in Section 5 identified a range of remedial technologies that are potentially applicable within Segment 1. In this section, the technologies retained from the preliminary screening are incorporated into a range of potentially viable response action alternatives for each SMA (see Figure 3-26).

For the purposes of assembling these alternatives, the remedial technologies included in the alternatives have been broadly defined with respect to remedial process options (e.g., what type of dredging method to employ, or the type of cap to be placed). Selection of specific process options depends on the context in which the technology is applied, and will be resolved during remedial design. However, for the purposes of developing this Response Proposal, several potential process options were carried forward through the alternative evaluation process, and a representative process option was assumed for developing cost estimates in the comparative evaluation of alternatives (Section 7). Again, the final process options will be identified during remedial design.

The components of the response action alternatives for each SMA are shown in Table 6-1. A description of how each component is applied is provided below.

Based on similar characteristics, the SMAs were subdivided into the following four groups for development of response action alternatives: SMA 1, SMAs 2 and 3, SMAs 4 and 5, and SMA 6. This grouping helped streamline response action development and evaluation in this Response Proposal (see Section 3.5).

#### 6.1.1 Common Elements

There are several elements such as source controls, existing regulatory requirements, institutional controls, and site-wide monitoring that are common to all of the alternatives evaluated in this section. Common elements that are relevant to the Segment 1 Response Proposal include the following:

- Control of known sources to Segment 1 has been completed, and maintenance of these controls is ongoing at the Dow facility. The continued effectiveness of these source controls is being monitored under separate NPDES and RCRA authorities administered by DEQ (see Section 2.5).
- A hydraulic assessment will be performed to determine whether the Segment 1 remedy (to be selected by EPA based on this Response Proposal) has the potential to affect flooding elevations.
- In-water construction within Segment 1 is anticipated to take place in 2012 and 2013, following a projected 2011 Action Memorandum and follow-on remedial design and the issuance of an agreed or unilateral order directing implementation.

- Dewatering and water/product treatment as necessary for the response actions would be performed as practicable at the Dow facility and is anticipated to be addressed as an on-site CERCLA action, similar to the prior Reach D early action. Depending on the specific disposal site identified during remedial design, disposal of materials (e.g., excavated sediment, potentially following on-site treatment as necessary) may occur either as an on-site CERCLA action or in accordance with the off-site rule (CERCLA Section 121[d][3]) and with the disposal facility's permit requirements.
- Site-wide monitoring performed under Task 4 of the AOC/SOW will be coordinated with this Segment 1 Response Proposal. The objective of the Site-Wide Monitoring Plan is to document baseline and ongoing conditions and to provide a basis for assessing the effectiveness of response options. The draft Site-Wide Monitoring Plan was submitted to the Agencies in 2011 (Dow 2011) and includes plans for periodic bathymetric surveys in areas of Segment 1, among other monitoring elements.
- Verification that early actions in Reaches B and D continue to meet RAOs, as indicated by the initial monitoring data. This includes monitoring and maintenance (if necessary) of engineered caps previously constructed in Reaches B and D, as well as monitoring of the natural deposition cap within Reach D.
- Operations and maintenance, with details to be provided in future submittals, will be performed for response actions selected based on this Segment 1 Response Proposal.
- Future remedial design evaluations may be required for any response action selected. Construction monitoring will be performed for any response action implemented. Details of the construction monitoring will be developed during remedial design..

## 6.2 SMA 1

Based on the characteristics of SMA 1 (Section 3.5) and preliminary screening of a wide array of possible remedial technologies for technical effectiveness and implementability in Segment 1 (Section 5), the following three alternatives were identified for evaluation:

- Alt 1: Monitored natural recovery (MNR)
- Alt 2: In situ containment
- Alt 3: Removal of sediment

Each of these alternatives is described in further detail below.

### 6.2.1 SMA 1 – Alt 1: Monitored Natural Recovery

This alternative would build on the source control achieved for the Dow plant operations (see Section 2.5) and upstream sediment remediation actions in Segment 1 (see Section 2.6). MNR would utilize natural sedimentation, mixing, and chemical biodegradation—collectively referred to as natural recovery processes—to reduce sediment concentrations in active bed sediments over time to achieve RAOs.

The elevated sediment concentrations (up to 2 times PLER chemical screening criteria) in SMA 1 are limited to near-surface sediments collected within the top 1 to 3 ft below the sediment surface (see Sections 2.5 and 3.3). Chemicals of potential concern detected within the surficial SMA 1 sediments (i.e., that do not meet RAOs) are limited to arsenic and PAHs. Given the depositional and mixing characteristics of near-surface sediments in SMA 1, and also given the success of upstream source control actions, sediment concentrations within the SMA 1 deposit are anticipated to be reduced progressively by natural processes over time (i.e., mixing and deposition with cleaner bedload sediments, and PAH biodegradation). The anticipated rate of recovery and time to attain RAOs is discussed in Section 7. A sediment monitoring program would be developed as part of this alternative to verify the expected attainment of RAOs.

### **6.2.2 SMA 1 – Alt 2: In Situ Containment**

This alternative would involve the installation of an in situ containment cap that would isolate sediments and control chemical migration, physical erosion, and biological contact with underlying sediment contaminants. Preliminary cap design evaluations were performed in general accordance with EPA guidance and using conservative assumptions (e.g., maximum sediment concentrations and peak shear stresses) to develop an appropriate conceptual-level cap design that would remain protective over time (Palermo et al. 1998; Lampert and Reible 2009; see Appendix E for details of preliminary cap design evaluations). The hydrodynamic and sediment transport model discussed in Section 3.3.2 was used to develop preliminary specifications (i.e., thickness and material size) for the cap armor layer to ensure that the cap retains its integrity under worst-case shear stress conditions. A monitoring and maintenance program would be developed to ensure the long-term protectiveness of the remedy.

The cap for SMA 1 would cover approximately 8,000 sq ft and would consist of a chemical isolation layer (approximately 4 inches of sand based on preliminary chemical flux evaluations; Appendix E) overlain with an armor layer for physical isolation (approximately 6 inches of gravel based on preliminary hydrodynamic modeling). Figure 6-1 presents a conceptual design for this alternative. Given the relatively shallow water depths that occur during the construction season in this portion of the Tittabawassee River, cap placement may need to be performed using small mechanical equipment (e.g., backhoe or similar excavator with a fixed arm, or a telescoping conveyor belt) operating from the shoreline, a temporary platform constructed in shallow water, and/or a shallow-draft barge, depending on the water depths at the time of construction. The SMA 1 shoreline can be accessed from the northeastern shoreline where an existing maintenance road parallels the river.

### **6.2.3 SMA 1 – Alt 3: Removal of Sediment**

This alternative would involve the removal of sediments within SMA 1 to achieve RAOs. An approximate volume of 1,600 cy would be targeted for removal, extending a depth between 1 to 3 ft below the sediment surface (Figure 6-2).

Given that the water depth within SMA 1 is typically shallower than a few feet during the summer and fall construction period, sediment removal may need to be performed using conventional earthwork equipment working from the shoreline and/or temporary access roads constructed within

the river. As discussed above, SMA 1 can be accessed from the northeastern shoreline where an existing maintenance road parallels the river.

For the purposes of this Response Proposal, and based on sediment removals performed at other similar sites, temporary flow control measures (e.g., soldier piles and steel plates, or jersey barriers) may be installed upstream of the excavation area to attempt to partially divert the flow and reduce the velocity of water flowing directly through the dredge area. However, these flow control measures would not dewater the SMA 1 area. In addition to the flow control, turbidity control devices (e.g., silt curtains) may be installed with a goal of reducing the potential for downstream transport of sediments resuspended by the removal operations.

Dredged sediments could be loaded directly into lined trucks for transport to nearby dewatering pads and water treatment facilities available within the Dow facility. Given that the targeted near-surface sediments in SMA 1 are primarily granular (i.e., primarily sand and gravel), dewatering via gravity draining would likely be sufficient to reduce the moisture content of the sediment to a point that they are suitable for overland transport (e.g., passing the paint filter test) to a suitable landfill for disposal.

Based on experience at other sites, even state-of-the-art removal equipment cannot remove all contaminants (Patmont and Palermo 2007); thus, a layer of residual sediments exceeding RAOs will likely remain at the base of SMA 1 following dredging. To address these residuals, a thin backfill layer of sand could be placed on the dredged surface. This sand layer could be placed using the same equipment anticipated for sediment removal. The need for a post-dredge residual sand cover can be verified at the time of construction based on the result of post-dredge verification sampling.

### **6.3 SMAs 2 and 3**

Based on the characteristics of SMAs 2 and 3 (Section 3.5) and the preliminary screening of a wide array of possible remedial technologies for technical effectiveness and implementability in Segment 1 (Section 5), the following three alternatives have been identified for evaluation:

- Alt 1: In situ containment with hydraulic control
- Alt 2: Removal of recoverable product/treatment and in situ containment with hydraulic control
- Alt 3: Removal of sediment and post-dredge in situ containment

#### **6.3.1 SMAs 2 and 3 – Alt 1: In Situ Containment with Hydraulic Control**

This alternative would involve installation of the following:

- In situ containment with a low-permeability cap over the impacted sediments in SMAs 2 and 3 to inhibit vertical chemical migration into overlying surface water
- Lateral containment barrier (e.g., sheet pile) placed around areas of SMAs 2 and 3 with subsurface contaminants to inhibit lateral chemical migration

- Passive hydraulic control of groundwater as provided by the existing RGIS system to help ensure an inward hydraulic gradient to further inhibit chemical migration into surface water

The cap would cover approximately 7,000 and 21,000 sq ft in SMA 2 and SMA 3, respectively, and would consist of a low-permeability chemical isolation layer and an armor layer. For the purposes of this Response Proposal, a geosynthetic clay liner (GCL) is a representative process option for the low-permeability chemical isolation layer, which would be overlain by approximately 6 inches of gravel-sized material for protection against disturbances based on preliminary hydrodynamic modeling. Other protective cap designs would be considered during remedial design as appropriate.

Within SMA 2, the lateral containment system would enclose an area approximately 55 ft by 120 ft for a total of 230 linear ft (Figure 6-3). The lateral containment system in SMA 3 would enclose an area approximately 130 ft by 160 ft for a total of 420 linear ft (Figure 6-4). The lateral containment system could be connected to the RGIS sheet pile wall, which is designed to allow inflow from the river through the RGIS sheet piling interlocks. The influence of RGIS on the connected SMA containment area would induce a negative hydraulic gradient into the SMAs, thereby minimizing the potential for contaminant transport outside of the lateral and vertical containment area. Based on preliminary evaluations, which would be refined during remedial design, relatively small groundwater flow rates (on the order of several gallons per minute) would achieve the desired negative hydraulic gradients in SMAs 2 and 3 under this alternative. If the natural “passive” leakage into RGIS is not adequate, the system would be evaluated for ways to accomplish the necessary hydraulic influence from the RGIS system (see Alternative 2). Should this alternative be selected by EPA, one of the primary detailed design objectives would be to ensure that the remedy does not interfere with the RGIS ability to maintain existing groundwater controls. The remedial design would need to consider potential impacts on RGIS and appropriate provisions would need to be incorporated into the design and implementation of the remedy to ensure RGIS is not compromised. Groundwater removed from the SMAs would be treated by Dow’s existing water treatment system via RGIS.

SMA 2 and SMA 3 can be accessed from the northeastern shoreline where an existing maintenance road parallels the river. Given the relatively shallow water depths (generally less than 3 ft) that occur in this portion of the Tittabawassee River during the construction season, placement of the GCL component of the cap may be performed using mechanical equipment (e.g., backhoe or crane) operating either from a temporary platform constructed in shallow water or from a shallow-draft barge, depending on the water depths at the time of construction. Placement of the armor layer may similarly be performed using mechanical equipment (e.g., backhoe or similar excavator with a fixed arm or a telescoping conveyor belt).

Installation of a sheet pile wall for lateral containment would need to be performed using mechanical equipment (e.g., crane) operating from the shoreline, a temporary platform constructed in shallow water, and/or a shallow-draft barge, depending on the water depths at the time of construction.

### **6.3.2 SMAs 2 and 3 – Alt 2: Removal/Treatment of Recoverable Product and In Situ Containment with Hydraulic Control**

This alternative is similar to Alternative 1, but includes additional components for a more active hydraulic control system as well as removal of recoverable product via wells (as practicable) and treatment of the removed product and water. Figures 6-5 and 6-6 depict the conceptual configuration for this alternative in SMAs 2 and 3, respectively.

A series of product recovery wells would be installed to intersect potentially recoverable product located at the sediment till interface, and would be operated to capture recoverable product in SMAs 2 and 3 (see Section 3.2.3 for a summary of recoverable product investigations conducted to date). Similar to Alternative 1 discussed above, hydraulic controls would be provided by the existing RGIS. However, Alternative 2 would involve a more “active” hydraulic control system than Alternative 1 to achieve a negative hydraulic gradient within the isolation cell. Recovered liquids would be treated by Dow’s existing water treatment system (as discussed above, treatment at the Dow facility would be addressed as an on-site CERCLA action). Similar to Alternative 1, remedial design would need to understand potential impacts on RGIS and appropriate provisions would need to be incorporated into the design and implementation of the remedy to ensure RGIS is not compromised.

Construction methods for the low-permeability cap and lateral containment barrier would be identical to those discussed for Alternative 1. Product recovery wells would need to be installed within the SMA depending on the characteristics and location of the deposit of recoverable product, which would be further investigated/evaluated as part of the remedial design. The wells would need to be screened to interface the till layer and overlying product that resides on the till surface. The duration of operation for product recovery wells will be dependent on the quantity and rate of product recovery.

### **6.3.3 SMAs 2 and 3 – Alt 3: Removal of Sediment and Post-Dredge In Situ Containment**

This alternative would involve the removal of sediments within SMAs 2 and 3 to achieve RAOs, targeting removal of sediments above and in contact with the till surface within each SMA. Removal would need to extend to a depth of approximately 3.5 ft below the sediment surface in SMA 2, and approximately 6.5 ft below the sediment surface in SMA 3 (Figures 6-7 and 6-8). Approximate sediment removal volumes of 2,300 and 5,700 cy would be targeted from SMA 2 and SMA 3, respectively, under this alternative.

Given that the water depths in SMAs 2 and 3 during the summer/fall construction season are typically only a few ft, sediment removal may be performed using mechanical dredge equipment (e.g., long-reach excavator or a crane with an environmental bucket) operating from the shoreline, a temporary platform constructed in shallow water, and/or a shallow-draft barge, depending on the water depths at the time of construction.

Due to the presence of recoverable product in these two SMAs and the potential for remobilization and release of contaminants during removal activities, controls may need to be installed to

minimize downstream transport of resuspended sediments, sheen, and dissolved contaminants released into surface water. Installation of temporary controls surrounding the deposit may be used for this purpose. However, if sheet piling was used, the short-term impact on surface water flow conditions and the extent to which reducing the conveyance capacity of the river could result in increased flow rates and lead to disturbance of the adjacent sediment bed, as occurred during the Reach D early action, would need to be addressed (see Section 2.5).

Dredged sediments could be barged or placed directly into lined trucks for transport to the nearby upland passive dewatering and water treatment facility on Dow property. Subject to a waste characterization during the remedial design, dredged sediments from SMAs 2 and 3 may require treatment prior to disposal. Following dewatering (and treatment, if necessary), dredged sediments could be loaded into trucks for off-site transport and disposal at a suitable permitted facility.

Based on experience at other sites, even state-of-the-art removal equipment cannot remove all contaminants (Patmont and Palermo 2007), thus a layer of residual sediments exceeding PLER criteria are anticipated to remain at the base of SMAs 2 and 3 following dredging. Because of the relatively high subsurface sediment concentrations present in these SMAs (e.g., greater than 10,000 mg/kg total chlorobenzenes and the product present above the till; see Section 3), a reactive cap consisting of organoclay or granular activated carbon (placed as a geotextile mat or in bulk potentially mixed with sand) would be placed on the post-dredge surface to manage the anticipated residual contamination. This reactive cap would most likely be placed using the same equipment anticipated for sediment removal or other conventional equipment depending on the type of cap (e.g., bulk granular material or geotextile mat). With time, the excavation area would backfill naturally as upstream clean sediment migrates into the area. If this alternative is selected by the EPA, further sediment transport analysis would be performed during remedial design to determine whether natural sedimentation will provide sufficient protection or if backfilling of the excavation needs to be incorporated into the design.

Following completion of the remedial activities, the resuspension controls (i.e., temporary sheet piling or other systems) would be removed and decontaminated.

#### **6.4 SMAs 4 and 5**

Based on the characteristics of SMAs 4 and 5 (Section 3.5) and preliminary screening of a wide array of possible remedial technologies for technical effectiveness and implementability in Segment 1 (Section 5), the following three alternatives have been identified for evaluation:

- Alt 1: Monitored natural recovery (MNR)
- Alt 2: In situ containment
- Alt 3: Removal of sediment

Each of these alternatives is described in further detail below.

#### **6.4.1 SMAs 4 and 5 – Alt 1: Monitored Natural Recovery**

This alternative would build on the source control achieved for the Dow plant operations (see Section 2.5) and upstream sediment remediation actions in Segment 1 (see Section 2.6), and would consist of monitoring SMAs 4 and 5 to verify continued protection over time. As discussed in Section 3, the potential active bed sediments in SMAs 4 and 5 contain SCOI concentrations below the PLERs, with a total of 2.6 to 3.7 ft of clean sediment deposits overlying elevated subsurface SCOI deposits in these SMAs. These clean near-surface sediment deposits have established a protective natural cap of sufficient thicknesses to control potential chemical migration and exposure. The occurrence of the natural sediment caps in these SMAs is consistent with preliminary cap design calculations using conservative assumptions of maximum sediment concentrations and chemical transport, indicating that this natural cap is likely to remain protective over time (see Appendix E). In addition, both empirical data and modeling results reveal that the bed surfaces in SMAs 4 and 5 are not likely to fluctuate by more than 0.5 ft over time (see Figures 3-38 A to C). Therefore, no additional cap material is necessary to achieve RAOs in SMAs 4 and 5.

As discussed in Section 3, relatively deeply buried subsurface sediments present in SMAs 4 and 5 contain a complex mixture of chlorobenzenes and C10 to C28 organics at relatively low concentrations. Unlike SMAs 2, 3, and 6 (see above), the field investigation did not detect product in SCOI deposits in SMAs 4 and 5. All lines of evidence considered, the relatively deeply buried subsurface sediment present in SMAs 4 and 5 is stable and effectively isolated by a significant thickness of overlying clean sediment.

A sediment monitoring program would be developed as part of this alternative to verify that active bed sediments in SMAs 4 and 5 remain at acceptable levels (e.g., below the site-specific PLER values thereby achieving RAOs) and continue to protect the underlying subsurface sediment from contacting the surface water.

#### **6.4.2 SMAs 4 and 5 – Alt 2: In Situ Containment**

This alternative would involve the installation of an armor layer designed to supplement the existing natural sediment cap overlying subsurface SCOI deposits. As discussed in Section 6.4.1, preliminary cap design evaluations using conservative assumptions indicate that the existing layer of clean surface sediments (measuring 3.7 and 2.6 ft thick in SMA 4 and SMA 5, respectively) provides permanent and protective chemical isolation of the underlying subsurface contaminated sediments. To supplement the natural cap, an armor layer would be placed in these SMAs to protect against disturbance. The armor layer would be designed to withstand forces such as hydrodynamic flows, wind-induced waves, vessel-induced waves, and vessel propeller wash during both normal conditions and the maximum shear event.

The caps for SMA 4 and SMA 5 would cover approximately 5,000 and 11,000 sq ft, respectively, consisting of an armor layer (approximately 6 inches of gravel-sized material based on preliminary hydrodynamic modeling; see Appendix E). Figures 6-9 and 6-10 depict the conceptual configuration of the caps for this alternative.

Both SMAs 4 and 5 are located near the center of the Tittabawassee River (greater than 50 ft from either shoreline) with water depths ranging from approximately 2 to 5 ft during the construction season. Given the distance from shoreline and water depth, cap placement may be performed using small mechanical equipment (e.g., backhoe or similar excavator with a fixed arm or a telescoping conveyor belt) operating from a shallow-draft barge or a temporary platform. Equipment access to the SMAs may be via floating vessels or an access road connected to shore. In the event that a temporary access road is used, it most likely will need to be designed to allow water passage due to the location of the SMA relative to the thalweg. This would most likely involve installation of a temporary platform constructed atop culverts that allow water passage or a temporary bridge structure.

#### **6.4.3 SMAs 4 and 5 – Alt 3: Removal of Sediment**

This alternative would involve the removal of sediments within SMA 4 and SMA 5 to achieve RAOs. Approximately 1,500 cy would be targeted for removal to depths between approximately 3.7 to 6.5 ft below the sediment surface in SMA 4 (Figure 6-11). Approximately 2,000 cy would be targeted for removal to depths between approximately 2.6 to 3.1 ft below the sediment surface in SMA 5 (Figure 6-12).

Turbidity controls may need to be installed to minimize downstream transport of resuspended sediment, sheen, and dissolved contaminants released into the surface water during construction. Contaminants from the relatively deeply buried SCOI deposits identified in SMAs 4 and 5 could be remobilized as a result of the removal activities. Installation of BMPs, such as turbidity controls consisting of silt curtains or temporary sheet piling surrounding the deposit, may need to be performed. However, if sheet pile was used, the short-term impact on surface water flow conditions and the extent to which reducing the conveyance capacity of the river could result in increased flow rates and lead to disturbance of the adjacent sediment bed, as occurred during the Reach D early action, would need to be addressed (see Section 2.5).

Since SMAs 4 and 5 are located near the center of the river (greater than 50 ft from either shoreline) and in existing water depths ranging from approximately 2 to 5 ft (up to 12 ft following removal), sediment removal (dredging) would likely be performed using mechanical equipment (e.g., long-reach excavator or a crane with an environmental bucket) operating from a shallow-draft barge or a temporary access road from shore. As described above for Alternative 2, the temporary access road may need to be designed to allow water conveyance through the river, because the access route crosses the thalweg. This would most likely involve installation of a temporary platform constructed atop culverts that would allow water passage or a temporary bridge structure.

Dredged sediment may be loaded onto barges or directly into lined trucks for transport to Dow's nearby upland passive dewatering facility. If dredging is performed from floating equipment, removed sediment would need to be placed into lined roll-off containers secured atop shallow draft barges that could be transported to a shoreside offloading area for subsequent truck transport to Dow's passive dewatering facility. Following dewatering, dredged sediments would be loaded into trucks for off-site transport and disposal at a suitable landfill.

Based on experience at other sites, even state-of-the-art dredging equipment cannot remove all contaminants (Patmont and Palermo 2007), thus a layer of residual sediments exceeding PLER criteria is anticipated to remain at the base of the SMAs 4 and 5 dredging areas. Therefore, it may be necessary to place a backfill/sand cover layer on the dredged surface to manage anticipated residual contamination. This post-dredge backfill/sand cover would likely be placed using the same equipment anticipated for sediment removal or other conventional equipment. With time, the excavation area would backfill naturally as upstream clean sediment migrates into the area. If this alternative is selected by the EPA, further sediment transport analysis would be performed during remedial design to determine whether natural sedimentation will provide sufficient protection or if backfilling of the excavation needs to be incorporated into the design.

## 6.5 SMA 6

Based on the characteristics of SMA 6 (Section 3.5) and preliminary screening of a wide array of possible remedial technologies for technical effectiveness and implementability in Segment 1 (Section 5), the following three alternatives have been identified for evaluation:

- Alt 1: Removal/treatment of recoverable product, removal of near shore ethyl parathion deposit, and MNR of remaining area
- Alt 2: Removal/treatment of recoverable product, removal of near shore ethyl parathion deposit, and in situ containment with hydraulic control of remaining area
- Alt 3: Removal of sediment

As summarized above, and consistent with initial discussions with the Agencies, given the relatively high concentration of ethyl parathion detected in these surface sediments relative to the PLER (more than 1,000 times greater than PLER), each of the three alternatives for SMA 6 includes removal of the sediments impacted by ethyl parathion in the nearshore area. For Alternatives 1 and 2, non-removal actions are considered for the remaining sediment portions of SMA 6, due to the presence of existing natural caps that cover the remaining deposits. The existing active sediment bed outside of the near shore ethyl parathion deposit contains SCOI concentrations below the PLERs with on average more than 5 ft of clean sediments overlying elevated subsurface SCOI deposits.

Each of these alternatives is described in further detail below.

### 6.5.1 SMA 6 – Alt 1: Removal /Treatment of Recoverable Product, Removal of Near Shore Ethyl Parathion Deposit, and Monitored Natural Recovery

This alternative would consist of a combination of remedies within SMA 6:

- Removal and treatment of recoverable product in the SMA
- Removal of near shore sediments with elevated ethyl parathion concentrations  
MNR of remaining area

### **Product Recovery and Treatment**

Recovery wells would be installed to intersect potentially recoverable product located at the sediment till interface and would be operated to capture recoverable product in SMA 6 (see Section 3.2.3 for a summary of recoverable product investigations conducted to date). The number and configuration of product recovery wells that would be installed within the SMA depends on the characteristics and location of the recoverable product, which would be further investigated as part of the remedial design. The wells would need to be screened to interface the till layer and overlying product that resides on the till surface. The duration of operation for product recovery wells will depend on the quantity and rate of product recovery.

### **Removal of Near Shore Ethyl Parathion-Impacted Sediments**

This portion of the alternative involves the removal of near shore sediments within the active bed of SMA 6 that exceed the PLER for ethyl parathion. Sediments in this near shore area (approximately 7,000 sq ft) would be targeted for removal to 1 ft below the existing sediment surface (Figure 6-13). An approximate volume of 500 cy would be targeted for removal under this alternative.

Given that the water depth within this portion of SMA 6 is typically shallower than a few feet during the summer and fall construction season and the majority of the ethyl parathion-impacted sediments are located within 50 ft of the shoreline, sediment removal in this area may be performed using conventional earthwork equipment (e.g., long-reach excavator) working from shoreline and/or temporary access roads constructed within the river. SMA 6 can be accessed from the northeastern shoreline where an existing maintenance road parallels the river. Temporary flow control measures (e.g., soldier piles and steel plates, or jersey barriers) may be installed upstream of the excavation area to attempt to partially divert the flow and reduce the velocity of water flowing directly through the excavation area. Turbidity control devices (e.g., silt curtains) may be used with a goal of reducing the downstream transport of sediments resuspended by the removal operations. Removed sediments would be placed directly into lined trucks and transported to the nearby existing Dow passive dewatering facility for dewatering and water treatment. Following dewatering, removed sediments would be loaded into trucks for off-site transport and disposal at a suitable landfill.

A layer of residual sediments potentially exceeding PLERs is anticipated to remain at the base of SMA 6 following dredging. Therefore, under Alternative 1, where additional sediment removal or capping is not planned, a thin backfill/cover layer of sand would be placed on the dredged surface to manage anticipated residual contamination. This sand layer most likely would be placed using the same equipment anticipated for sediment removal. The need for a post-dredge residual sand cover under Alternative 1 would be verified at the time of construction based on the result of post-dredge verification sampling. Since Alternatives 2 and 3 involve additional remediation (sediment removal and/or capping), placement of a backfill/cover following sediment removal of the near shore ethyl parathion impacted sediments is not necessary.

### **Monitored Natural Recovery of Remaining Areas**

Existing sediments within the active bed and deeper in the area outside of the near shore area with ethyl parathion-impacted sediments are well below PLER screening criteria (see Section 3). An average of more than 5 ft (1.8 to 8.5 ft in four cores) of clean sediments (below PLER screening criteria) overlie more deeply buried subsurface deposits of sediment with elevated SCOI concentrations, including recoverable product identified during focused field investigations in fall 2010 (see Section 3.2.3). Similar to the SMA 4 and 5 deposits (see Section 6.4.1 above), relatively deeply buried sediment contaminants in SMA 6 are stable and effectively isolated by a significant thickness of overlying clean sediment. Also similar to Alternative 1 for SMAs 4 and 5, this alternative builds on the source control achieved for the Dow plant operations (see Section 2.5) and upstream sediment remediation actions in Segment 1 (see Section 2.6) to maintain sediment concentrations in active bed sediments below the PLER, thereby achieving RAOs.

Preliminary cap design evaluations using conservative assumptions indicate that the existing layer of clean surface sediments (more than 5 ft thick on average) provides sufficient and effective chemical isolation of the underlying subsurface contaminated sediments (see Appendix E). A sediment monitoring program would be developed as part of this alternative to verify that the sediments in the active bed remain at acceptable levels (e.g., below the site-specific PLER values) and continue to protect the underlying subsurface sediment from coming into contact with the active bed.

#### **6.5.2 SMA 6 – Alt 2: Removal/Treatment of Recoverable Product, Removal of Near Shore Ethyl Parathion Deposit, and In Situ Containment with Hydraulic Control**

As with Alternative 1 (see Section 6.5.1), Alternative 2 would consist of a combination of remedies within SMA 6:

- Removal and treatment of recoverable product
- Removal of near shore sediment with ethyl parathion concentrations above the PLER
- In situ containment with a low-permeability cap over the impacted sediments to inhibit vertical chemical migration into overlying surface water
- Lateral containment barrier (e.g., sheet pile) placed around SMA 6 to inhibit lateral chemical migration
- Active hydraulic control of groundwater as provided by the RGIS system to help ensure an inward hydraulic gradient

The removal and treatment of recoverable product and the removal of the near shore ethyl parathion-impacted sediments would be the same process as described in Section 6.5.1; therefore, only the details of in situ vertical and lateral containment with hydraulic control of the remaining areas are presented below.

### **In Situ Containment with Hydraulic Control of Remaining Areas**

This alternative involves the installation of a low permeability chemical isolation layer and an armor layer designed to supplement the existing natural sediment cap overlying subsurface SCOI deposits over the SMA covering approximately 30,000 sq ft. For the purposes of this Response Proposal, a geosynthetic clay liner (GCL) is a representative process option for the low-permeability chemical isolation layer, which would be overlain by approximately 6 inches of gravel-sized material for protection against disturbances based on preliminary hydrodynamic modeling (see Appendix E). Other protective cap designs would be considered during remedial design as appropriate.

As discussed for Alternative 1 (Section 6.5.1), preliminary cap design evaluations indicate that the existing clean surface sediment deposits (e.g., average of more than 5 ft for the SMA) effectively function as a natural sediment cap. The cap placed as part of this alternative would supplement the existing natural cap and together with the lateral containment system (discussed below), would provide complete isolation of the SMA 6 impacted sediments.

Given the relatively shallow water in this portion of the river, cap placement would most likely be performed using small mechanical equipment (e.g., backhoe or similar excavator with a fixed arm and/or telescoping conveyor belt) operating either from a temporary platform constructed in shallow water or from a shallow-draft barge, depending on the water depths at the time of construction. Access to the SMA would be from the northeastern shoreline where an existing maintenance road parallels the river.

In addition to the vertical containment cap, this alternative involves installation of a lateral containment barrier (e.g., sheet pile wall) to inhibit lateral migration of contaminants. The length of the lateral containment structure would be approximately 750 linear ft (Figure 6-14). The lateral containment system would be connected to the RGIS sheet pile wall, with potential modifications to provide active hydraulic control, which would induce a negative hydraulic gradient into the SMA, thereby minimizing the potential for contaminant transport outside of the lateral and vertical containment area. Recovered liquids would be treated by Dow's existing water treatment system (as discussed above for SMAs 2 and 3, treatment at the Dow facility would be addressed as an on-site CERCLA action). Depending on water depths at the time of construction, installation of a sheet pile wall for lateral containment would need to be performed using mechanical equipment (e.g., crane) operating from the shoreline, a temporary platform constructed in shallow water, and/or a shallow-draft barge.

Should this alternative be selected by EPA, one of the primary detailed design objectives would be to ensure that the remedy does not interfere with the RGIS ability to maintain existing groundwater controls. The remedial design would need to consider potential impacts on RGIS and appropriate provisions would need to be incorporated into the design and implementation of the remedy to ensure RGIS is not compromised.

### 6.5.3 SMA 6 – Alt 3: Removal of Sediment

This alternative would involve the removal of surface sediments in the near shore area with ethyl parathion concentrations exceeding the PLER and deeply buried SCOI deposit. Sediments in the near shore area (approximately 7,000 sq ft) that would be targeted for removal to the underlying till (approximately 9 ft deep) include an approximate volume of 3,100 cy. In addition to the removal of the near shore ethyl parathion impacted sediments, this alternative includes targeted removal of sediments within the SMA to address SCOI deposits extending to approximately 5 to 8 ft below the existing top of sediments. An approximate volume of 12,400 cy is targeted for removal within the offshore SCOI deposit (separate from the 3,100 cy of nearshore sediments). Combined, an approximate total sediment volume of 15,500 cy would be targeted for removal within the near shore and offshore portions of SMA 6 under Alternative 3. Figure 6-15 depicts the conceptual sediment removal prisms for both areas in this alternative.

Dredging of targeted sediments may be performed using mechanical equipment (e.g., excavator or a crane) operating from the shoreline, temporary access roads constructed within the river, and/or floating equipment depending on distance from shore and water depth during the construction period. Because of the potential for remobilization of subsurface sediment contaminants during removal activities, controls may need to be installed to minimize downstream transport of turbidity, sheen, and resuspended material. Installation of temporary systems surrounding the deposit may be used for these controls. However, the design would need to consider the short-term impact on surface water flow conditions and the extent to which reducing the conveyance capacity of the river could result in increased flow rates and lead to disturbance of the adjacent sediment bed, as occurred during the Reach D early action (see Section 2.5).

Depending on distance from the shoreline, excavated sediments may be placed directly in lined trucks for transport to the nearby, upland passive dewatering and potential water treatment facility on Dow property. Alternatively, excavated material may need to be placed in roll-off containers secured atop shallow draft barges that could be transported to a shore-side offloading area and transported for passive dewatering at the existing Dow sediment processing facility. Subject to a waste characterization during the remedial design, dredged sediments from SMA 6 may require treatment of volatile compounds prior to disposal. Following dewatering (and treatment if necessary), excavated sediments would be loaded into trucks for off-site transport and disposal.

The presence of recoverable product may warrant the placement of a post-dredge cap (potentially including reactive materials) to manage anticipated residual contamination. The post-dredge cap could be placed using the same equipment anticipated for sediment removal or using other conventional equipment. With time, the excavation area would backfill naturally as upstream clean sediment migrates into the area. If this alternative is selected by the EPA, further sediment transport analysis would be performed during remedial design to determine whether natural sedimentation will provide sufficient protection or if backfilling of the excavation needs to be incorporated into the design.

## 7.0 Response Action Alternative Evaluation

This section presents a detailed evaluation of the SMA-specific response action alternatives assembled in Section 6, evaluating each of the alternatives against CERCLA criteria. The CERCLA evaluation criteria are described in Section 7.1, followed by SMA-specific evaluations of response action alternatives in Sections 7.2 through 7.5. The analysis of alternatives was based on SMA-specific characterization data and fate and transport analyses that are summarized in Section 3.

### 7.1 EE/CA Evaluation Criteria

As discussed in Section 1.1, the NTCRA process provides the optimal combination of protectiveness and efficiency to develop a response action for Segment 1, consistent with the requirements of the AOC/SOW. This Segment 1 Response Proposal is an EE/CA prepared in accordance with CERCLA and NCP requirements and following the SOW General Document Requirements Section VIII.G. An Action Memorandum to be issued by the EPA will serve as the Segment 1 decision document.

This EE/CA incorporates three main evaluation criteria—effectiveness, implementability, and cost—that have been established by EPA to address the overall requirements of CERCLA and the NCP (EPA 1988). The three EE/CA criteria (with effectiveness further subdivided into five categories) used in this Response Proposal evaluation are summarized below:

#### Effectiveness Criteria

- *Overall Protection of Human Health and the Environment:* Addresses the overall ability of an alternative to eliminate, reduce, or control potential exposures to SCOs in both the short and long term.
- *Compliance with ARARs:* Assesses whether the alternative attains the identified chemical-specific, action-specific, and location-specific ARARs (see Section 4.3).
- *Short-term Effectiveness:* Assesses effects and potential risks to human health and the environment related to construction and implementation of each alternative. Considerations include short-term impacts on workers and the community during the remedial action, potential environmental effects of the remedial action, effectiveness of mitigation measures, and the time until protection is achieved through consideration of near-term improvements resulting from remedy implementation.
- *Long-term Effectiveness and Permanence:* Evaluates the alternative for the long-term effectiveness and permanence with respect to the ability to achieve RAOs. Factors considered under this criterion include the magnitude of residual risk remaining after implementation, along with the adequacy and reliability of control measures (e.g., containment systems and institutional controls).
- *Reduction of Toxicity, Mobility, or Volume through Treatment:* Addresses the degree to which an alternative reduces the toxicity, mobility, or volume of chemical constituents.

### Implementability Criteria

- Evaluates the implementability of the alternative by considering technical feasibility, administrative feasibility, and availability of services and materials required for implementation.
- Evaluation of community and State acceptance of the alternative will be evaluated by EPA following public review of this Response Proposal.

### Cost Criteria

- Evaluates present-worth (present day dollars) direct and indirect construction, operating, and maintenance costs of implementing an alternative.

Table 7-1 presents the EE/CA criteria used in this Segment 1 Response Proposal to evaluate response alternatives.

Sections 7.2 through 7.5 present a detailed evaluation of each alternative for the SMAs. Section 7.6 presents a comparative analysis of the alternatives for each SMA.

## **7.2 SMA 1**

Section 6 identified the following three alternatives for evaluation in SMA 1:

- Alt 1: Monitored natural recovery (MNR)
- Alt 2: In situ containment
- Alt 3: Removal of sediment

### **7.2.1 Effectiveness**

The effectiveness of each response action alternative was evaluated against the five elements described in Table 7-1. Each of these criteria is discussed in the sections below.

#### **7.2.1.1 Protection of Human Health and Environment**

**SMA 1: Alternative 1 (MNR)** would result in a continuing decline of SCOI concentrations in sediments within the active bed of SMA 1 through prior source controls and natural recovery processes (primarily sedimentation, mixing, and biodegradation), reducing risks associated with potential exposure to SCOIs over time. Historical upstream source control actions completed by Dow, including those completed between 2007 and 2009, are described in Section 2. For the purpose of this Segment 1 Response Proposal, the anticipated rate of natural recovery in SMA 1 was evaluated based on SMA-specific characterization data and output from the sediment transport model described in Section 3.3 using the SEDCAM analytical equation (Jacobs et al. 1988), as follows:

$$C(t) = \left[ \frac{S_a}{(S_a + kS)} * C_p * \left( 1 - e^{\frac{-(kS + S_a) * t}{S}} \right) \right] + \left[ C_o * \left( e^{\frac{-(kS + S_a) * t}{S}} \right) \right]$$

where:

$C_{(t)}$  = SCOI concentration in sediments at time  $t$

$S_a$  = rate of sediment deposition

$S$  = total accumulation of sediments in the active bed layer during the period under consideration

$k$  = combined 1st order rate constant for chemical loss through decay and diffusion (in this application,  $k$  was conservatively set to zero)

$C_p$  = concentration of SCOI in bed load input sediments

$t$  = natural recovery time period

$C_o$  = initial SCOI concentration in surface sediments

As discussed in Section 3.5.2, the highest concentrations of SCOIs in SMA 1 sediments (arsenic and total PAHs) were detected in samples collected from within the active bed layer (which in SMA 1 ranges up to 0.9 ft below the sediment surface; see Table 3-5. During the most recent sampling in 2009 (close to the completion of upstream source control actions), the maximum concentrations of SCOIs in SMA 1 active bed sediments were arsenic at 310 mg/kg (at location 61+50-IC98; 0.0 to 0.5 ft), and total PAH at 25.4 mg/kg (at location 61+50-CI37; 0.0 to 0.5 ft). As discussed in Appendix C, bedload dominates the transport of clean sediment into SMA 1, and the sediment transport model predicts that active bed sediments in SMA 1 will recover relatively rapidly, specifically during the next several years. The sediment transport model calculated recovery rates as the “half-time” (i.e., the time required to reduce the original bed sediment concentration by 50 percent due to sedimentation and mixing), which in SMA 1 ranges from approximately 5 to 7 years. This half-time range was then input to the SEDCAM analytical model described above. SCOI concentrations in bedload inputs to SMA 1 ( $C_p$ ) were based on current Segment 1 surface sediment concentrations of arsenic and total PAHs of 3 mg/kg and 1 mg/kg, respectively, upstream of SMA 1.

Incorporating the range of predicted half-times (5 to 7 years), the SEDCAM model predicted that maximum sediment arsenic concentrations in SMA 1 will recover to below PLER levels between 2014 and 2016, while maximum total PAH concentrations in this area are anticipated to recover to below the PLER levels between 2013 and 2015. This recovery timeframe to achieve protection of human health and the environment is within several years of the capping and removal alternatives discussed below, given that in-water construction in Segment 1 (e.g., under Alternatives 2 or 3 below) is anticipated to take place in 2012 and 2013 (following a projected 2011 Action Memorandum and follow-on remedial design and the issuance of an agreed upon or unilateral order directing implementation). Although PCOIs are not a specific focus of near-term response

actions in Segment 1 (see Section 4), peak TEQ concentrations in SMA 1 active bed sediments are nevertheless anticipated to be similarly reduced over time through natural recovery processes. If Alternative 1 (MNR) is selected by the EPA for SMA 1, additional analyses may be needed during remedial design to refine the projected recovery rates discussed above. In addition, a sediment monitoring program would be developed during remedial design and implemented as part of this alternative to verify the expected attainment of RAOs.

**SMA 1: Alternative 2 (In Situ Containment)** provides overall protection and risk reduction by installing an in situ containment cap that would isolate sediments and control chemical migration, physical erosion, and biological contact with SMA 1 sediments that exceed the PLER. As discussed in Appendix E, preliminary cap design evaluations were performed following EPA guidance using conservative assumptions (e.g., maximum sediment concentrations and peak shear stresses) to develop an appropriate conceptual-level cap design that would remain protective over time (Palermo et al. 1998; Lampert and Reible 2009; see Appendix E for details of preliminary cap design evaluations). The sediment cap for SMA 1 would consist of a chemical isolation layer (approximately 4 inches of sand) overlain with an armor layer for physical isolation (approximately 6 inches of gravel-sized material; see Figure 6-1). A monitoring and maintenance program would be implemented to ensure the long-term effectiveness of the cap.

**SMA 1: Alternative 3 (Removal of Sediment)** provides overall protection of human health and environment through the removal and disposal of approximately 1,600 cy of surface sediments in SMA 1 that exceed the PLER. Based on experience at other sites, a layer of residual sediments will likely remain at the base of SMA 1 following removal, given that even state-of-the-art equipment cannot remove all contaminants (Patmont and Palermo 2007). To address these residuals, a thin backfill/cover layer of sand would likely be placed on the dredged surface. The need for and appropriate design of a post-dredge residual sand cover would be determined at the time of construction based on the result of post-dredge verification sampling.

#### 7.2.1.2 Compliance with ARARs

As discussed in Section 4, there are no chemical-specific ARARs that are applicable to the Segment 1 Response Proposal, since sediment cleanup levels for response actions under CERCLA are based on site-specific evaluations. Tables 4-2 and 4-3 summarize action-specific and location-specific ARARs, respectively.

**SMA 1: Alternative 1 (MNR)** would not include invasive actions resulting in action-specific or location-specific ARARs, so those ARARs would not apply.

Implementation of **SMA 1: Alternative 2 (In Situ Containment)** includes placement of an approximate 10-inch-thick cap in SMA 1, and could potentially trigger the substantive requirements of action-specific ARARs applying to fill activities (see Table 4-2). In order to demonstrate compliance of this alternative with these ARARs, a hydraulic assessment would be performed to assess whether placing material in the river channel would have the potential to affect flooding elevations. The limited extent of capping actions in SMA 1 (i.e., 10 inches placed over 0.2 acres) suggests that changes to flood elevations are unlikely to occur under this alternative. Alternative 2 complies with other identified action-specific or location-specific ARARs (see Tables 4-2 and 4-3).

Implementation of **SMA 1: Alternative 3 (Removal of Sediment)** complies with identified action-specific or location-specific ARARs (see Tables 4-2 and 4-3).

### 7.2.1.3 Short-Term Effectiveness

No construction activities are associated with **SMA 1: Alternative 1 (MNR)**, thus there are no short-term construction-related impacts associated with this alternative. Moreover, as discussed in Section 7.2.1.1, the anticipated natural recovery timeframe to achieve protection of human health and the environment is within several years of the recovery timeframe with the capping and removal alternatives discussed below (subject to verification during remedial design), assuming that anticipated implementation of in-water remedial actions in Segment 1 takes place in 2012 and 2013.

Under **SMA 1: Alternative 2 (In Situ Containment)**, the limited potential short-term effects of capping would occur during construction. These short-term effects could include localized turbidity from placement of the capping materials and potential impacts to the benthic and fish communities due to the placement of new materials within the river. The potential impacts on the benthic community are also expected to be restricted to the short term, as evidence from previous projects indicates that benthic recolonization of caps with suitable substrate typically occurs within weeks to months following the completion of construction (Sumeri 1996; Alcoa 2002; Simpson 2004). On the other hand, capping provides an immediate benefit, because it creates an instantaneous clean sediment surface.

Under **SMA 1: Alternative 3 (Removal of Sediment)**, the short-term effects of dredging include resuspension and release of both particulate- and dissolved-phased chemicals from sediments to surface water, localized turbidity impacts, and impacts to the fish and benthic communities. Use of turbidity controls (e.g., silt curtains) at the downstream boundary of dredging activities can reduce but not eliminate the transport of particulate-phase chemicals and turbidity, and some amount of downstream transport is anticipated even with the use of these turbidity control measures. The short-term effects of release would last for several months or longer during and after implementation. The effect of resuspension could persist depending on where resuspended chemicals settle.

Dredging under Alternative 3 would eliminate the benthic community in the short term. Removal of sediment (with or without backfill/sand cover) typically results in slower benthic recolonization rates compared with capping; benthic recolonization of removal areas typically occurs within months or several years (Herbich 2000; Szymelfenig et al 2006; Alcoa 2008).

Dredging of sediment is also anticipated to result in residual materials remaining on the sediment surface (including in areas downstream of the removal area) following removal activities. These residuals can pose a long-term risk as well. Transport of dredged sediments to the dewatering pad and final disposition in a landfill also presents potential short-term risks to construction workers (e.g., potential exposure to contaminants) and to the public (e.g., traffic accidents, spills, noise, and air pollution). Potential short-term impacts to construction workers would be reduced through measures specified in the site-specific Health and Safety Plan (HASp) and by making sure workers have the appropriate training to implement the remedy.

Short-term impacts common to both **SMA 1: Alternatives 2 and 3** include temporary disruption of upland/shoreline areas along the river to construct access points and potential transportation accidents (both in water and upland). Access and staging areas would be constructed on Dow property, thereby minimizing potential effects to the community. Under these alternatives, measures would be implemented to minimize the potential for transportation accidents (including floating equipment accidents in the river and truck accidents associated with transport of dredged sediment to the dewatering facility and landfill as well as transport of clean capping material). Appropriate health and safety practices (Michigan Occupational Safety and Health Administration [MIOSHA]) would be followed through implementation of a project-specific HASP.

#### **7.2.1.4 Long-Term Effectiveness and Permanence**

Long-term reductions in sediment concentrations would continue under **SMA 1: Alternative 1 (MNR)** as a result of previous source control activities and ongoing natural recovery processes that would continue to reduce exposures over time. As described in Section 7.2.1.1, recovery assessments using the sediment transport model indicate that SCOI concentrations in SMA 1 sediments would be reduced to below PLER criteria between 2013 and 2016, subject to verification during remedial design. A sediment monitoring program would be developed as part of this alternative to verify the expected attainment of RAOs. Moreover, ongoing source control measures and existing permitting requirements for future in-water construction would continue to ensure the long-term effectiveness and permanence of the remedy.

**SMA 1: Alternative 2 (In Situ Containment)** would provide long-term effectiveness and permanence from potential exposure risks in SMA 1 through placement of an engineered cap. Based on site-specific data, design considerations, and preliminary modeling results described in Appendix E, cap effectiveness is expected to be permanent. Preliminary cap design evaluations indicate that a chemical isolation layer of 4 inches is protective. An analysis of armor stone size using results of the hydrodynamic modeling indicates coarse gravel-sized materials (nominal 1- to 2-inch diameter) would protect the cap and maintain its integrity under worst-case shear stress conditions (e.g., 100-year peak shear stress event). Proper design and installation, coupled with post-construction monitoring, will be key factors in reducing/eliminating the frequency and extent of maintenance. In the event that damage to the cap occurs, affected areas would be identified during monitoring and subsequently addressed. Similar to Alternative 1, ongoing source control measures and existing permitting requirements for future construction would continue to ensure the long-term effectiveness of the remedy.

**SMA 1: Alternative 3 (Removal of Sediment)** would provide long-term protectiveness and permanence from potential exposure risks through sediment removal. The long-term effectiveness of this alternative would be partly dependent on the completeness of the sediment removal and the degree of resuspension, release, and residuals remaining following dredging. Based on significant experience of other sites, as discussed in greater detail in Section 5, a layer of residual sediments will likely remain on the post-dredge surface in SMA 1 (Patmont and Palermo 2007; NRC 2007). Therefore, placement of a backfill/sand cover for post-dredge residual management is included as part of this alternative. Additionally, the removal of sediments would form a depression within the sediment bed that would act as a sedimentation basin for subsequent accumulation of clean sediments. The specific evaluation of accumulation rates after removal of the target sediments

from SMA 1 has not been performed with the OU 1 sediment transport model. However, the expectation of post-removal accumulation of sediments is consistent with multibeam bathymetry measurements collected from outside of the sheetpile in Reach D in fall 2009 and spring 2010, which showed several feet of sediments had accumulated in the Reach D depression over an approximate 6-month period.

Sediments removed as part of Alternative 3 would be disposed of at a suitable landfill. This disposal facility would provide effective long-term management of the dredged materials, controlling potential future exposure to human and ecological receptors.

#### **7.2.1.5 Reduction of Toxicity, Mobility or Volume**

Reduction in toxicity, mobility, or volume through treatment would not occur for any of the alternatives evaluated for SMA 1 because none of the alternatives include a treatment component. However, MNR would reduce the toxicity, mobility, and volume of PAHs over time through biodegradation. Cap placement under Alternative 2 would reduce the mobility of underlying SCOIs through isolation. Mobility would be similarly reduced in Alternative 3 by placing the sediments in an engineered landfill. All three alternatives would result in reduced toxicity by reducing the concentrations of SCOIs in surface sediments (but not through “treatment”).

#### **7.2.2 Implementability**

There are no administrative or technical implementability concerns associated with the monitoring included in **SMA 1: Alternative 1 (MNR)**.

Implementation of **SMA 1: Alternatives 2 (In Situ Containment) and 3 (Removal of Sediment)** would require an appropriate shoreline or upland staging area. The size and number of staging areas would be dependent on the type and extent of remediation included in the alternatives. It is expected that necessary access and staging areas to support these alternatives would be constructed on property owned by Dow, thereby facilitating implementation. For example, the dewatering area previously developed on Dow’s property could be reused for implementation of Alternative 3.

Should removal of sediment from SMA 1 be selected by the EPA, during remedial design an evaluation of the impacts on the RGIS sheet pile system would need to be performed. The remedial design would consider removal methods that minimize the risk of negative effects on RGIS. Construction monitoring and/or protective measures would need to be understood and implemented to ensure that sediment removal actions would not affect RGIS and its operations.

Dow has successfully completed a number of capping and dredging actions in the Tittabawassee River (e.g., in Reaches B, D, and O), and based on these prior experiences, both Alternatives 2 and 3 are administratively and technically implementable. Necessary personnel for the various tasks (i.e., crane and loader operators) are readily available. Under Alternative 2, the placement of the engineered cap would likely use methods similar to those used during the Reach B and D capping activities (e.g., mechanical placement from shoreline, telescoping conveyor belt, etc.). Similarly, a combination of removal methods used for Reaches D and O, including mechanical dredging/excavation and debris segregation, would be employed under Alternative 3. Proven

methods of passively dewatering dredged sediments at a nearby dewatering pad at the Dow facility would be applied for Alternative 3. Finally, a local permitted landfill would be the primary location for permanent disposal of dredged materials.

### 7.2.3 Cost

Cost estimates for each alternative were developed based on a review of prior Dow project data, a review of cost data available for similar projects completed at other sites, and initial input from prospective Dow contractors. Consistent with EPA/USACE guidance (2000), the cost estimates for each alternative are anticipated to be accurate within the range of -30 to +50 percent. A future discount rate of 7 percent was used for the present worth calculation as specified by EPA/USACE guidance. For costing purposes and comparison of alternatives, a 30-year monitoring period was assumed for in situ alternatives (in this case, Alternatives 1 and 2). Details of the cost estimates for each alternative are provided in Appendix F.

The estimated present worth of Alternatives 1, 2, and 3 are approximately \$30K, \$250K, and \$490K, respectively (provided in present day [2010] dollars). For **SMA 1: Alternative 1 (MNR)**, the present worth analysis was performed assuming that a long-term monitoring program (30-year sampling starting in 2012 and thereafter at approximately 5-year intervals) would include bathymetry surveys and surface sediment sampling. The cost estimate for **SMA 1: Alternative 2 (In Situ Containment)** is based on the anticipated construction activities for the placement of the engineered cap followed by a 30-year post-construction monitoring and maintenance period, and also includes an additional allowance for potential cap maintenance (based on records from other similar capping sites). For **SMA 1: Alternative 3 (Removal of Sediment)**, the cost estimate is based on the anticipated construction activities and construction monitoring. Long-term monitoring is a component of all alternatives and will be detailed in the Site-Wide Monitoring Plan; see Section 8.1.1).

## 7.3 SMA 2 and SMA 3

Section 6 identified the following three alternatives for evaluation in SMA 2 and SMA 3:

- Alt 1: In situ containment with hydraulic control
- Alt 2: Removal of recoverable product/treatment and in situ containment with hydraulic control
- Alt 3: Removal of sediment and post-dredge in situ containment

### 7.3.1 Effectiveness

The effectiveness of each response action alternative was evaluated against the five elements described in Table 7-1. Each of these criteria is discussed in the sections below.

#### 7.3.1.1 Protection of Human Health and Environment

**SMA 2/3: Alternative 1 (In Situ Containment with Hydraulic Control)** provides overall protection and risk reduction by installing an in situ containment cap and lateral containment structures (e.g., vertical barrier walls) that would isolate sediments and control chemical migration, physical erosion,

and biological contact with SMA 2 and 3 sediments that exceed the PLER. As discussed in Section 6.3.1, preliminary cap design evaluations were performed following EPA guidance using conservative assumptions to develop an appropriate conceptual-level cap design that would remain protective over time (Palermo et al. 1998; Lampert and Reible 2009; see Appendix E for details of preliminary cap design evaluations). The cap design model integrates contaminant fate and transport mechanisms including advection, diffusion, dispersion, and first-order biodegradation, and also incorporates the complexities of the sediment-water interface, including biological mixing of sediments. The Lampert and Reible (2009) model is widely used by EPA and others to support cap designs under Superfund and other cleanup programs.

As discussed in Section 3.5.2, both SMAs 2 and 3 contain total chlorobenzene and total chlorophenol concentrations greater than the PLER values in surface sediment. Surface sediment in SMA 3 also exceeds PLER values for total PAHs and oPP. Relative to surface sediment concentrations, higher SCOI concentrations are present at depth in these SMAs. Potentially recoverable product comprised primarily of chlorobenzenes and other VOCs is present within the subsurface sediments overlying the till in these SMAs. To determine if these subsurface SCOI deposits could be a potential ongoing source of contaminants to overlying sediments, further analysis was performed to ensure that the cap designs would remain protective over time.

The steady-state cap modeling used the following assumptions:

- Maximum subsurface sediment concentrations present at depth in these SMAs were used in the modeling, and were not assumed to degrade or dissipate over time, thus representing a potential continuing source.
- Multiple lines of evidence summarized in Section 3.3.3 reveal a downward groundwater flowpath within the surficial sandy sediments in SMAs 2 and 3, away from the river surface and towards RGIS, and this flow condition was assumed for the cap modeling. However, in order to ensure the protectiveness of caps in SMAs 2 and 3, additional hydraulic controls were assumed to be needed to further ensure that such downward gradients are maintained on a long-term basis, as needed.
- Conservative values (i.e., from the lower end of ranges reported in the literature) for compound-specific SCOI biodegradation rates were used in the model. Different biodegradation rates were used for aerobic and anaerobic conditions as appropriate in surface and subsurface sediments, respectively. The values were also derived from the EPA-supported EPI Suite™ (BIOWIN™ model) environmental fate estimation program. These rates were found to be generally consistent with those reported in other biodegradation rate compilations (e.g., EPA's Superfund Chemical Data Matrix [SCDM] and Howard et al. 1991), and were found to be conservative (i.e., slower degradation) as compared to those reported in the literature (based on a review of several experimental studies for a limited subset of SCOIs).

The preliminary cap modeling described in more detail in Appendix E indicated that while several Alternative 1 cap options exist, including placement of reactive cap media would be protective in SMAs 2 and 3, the most promising in situ containment process option for Alternative 1 consists of

placement of a low-permeability cap over the SMAs, along with lateral containment structures and maintenance of a downward flux of groundwater through connection with RGIS, which is designed to allow inflow from the river through RGIS sheet piling interlocks. For the purposes of this Response Proposal, a GCL was identified as a representative process option for the low-permeability chemical isolation layer, which would be overlain by approximately 6 inches of gravel-sized material for erosion protection. Other protective cap designs would be considered during remedial design as appropriate.

The lateral containment systems in SMAs 2 and 3 (e.g., vertical barrier walls; see Figures 6-3 and 6-4, respectively) would be installed and joined to the RGIS sheet pile wall. When combined with the low-permeability cap and lateral containment structures, the RGIS would influence the groundwater flow in the containment area to ensure that an inward hydraulic gradient is maintained in these SMAs, providing additional confidence that the potential for contaminant transport outside of the lateral and vertical containment area is controlled. Based on preliminary evaluations, relatively small groundwater flow rates into RGIS (on the order of several gallons per minute per SMA) would achieve the desired negative hydraulic gradients in SMAs 2 and 3 under this alternative. The adequacy of the hydraulic control provided by RGIS without modification would be assessed during the remedial design phase. If the hydraulic control is determined to be insufficient, refinements to the design would need to be incorporated. Subsurface water removed from the SMAs would be treated by Dow's existing water treatment system via RGIS. A monitoring and maintenance program would be implemented to further ensure the long-term protectiveness of the in situ containment system.

Similar to Alternative 1, **SMA 2/3: Alternative 2 (Removal of Recoverable Product/Treatment with In Situ Containment and Hydraulic Control)** in SMAs 2 and 3 would provide protection of human health and the environment through isolation of SCOI-containing sediments using barrier walls that surround the deposit for lateral isolation of SCOIs and the placement of a low-permeability cap on the existing sediment surface for vertical isolation of SCOIs. Alternative 2 also would incorporate the removal of recoverable product through recovery wells installed within the contained area. Hydraulic removal within the containment areas would further induce a negative hydraulic gradient in these SMAs, providing additional protection. Treatment of extracted liquids would likely be integrated into existing on-site treatment systems such as the facility WWTP or incineration system. Product and subsurface water removal would provide for reduction of volume and toxicity of contaminants in these SMAs (see Section 7.3.1.5). The overall level of protection of human health and the environment for Alternative 1 is similar to Alternative 2 because of the effectiveness of the containment system.

In **SMA 2/3: Alternative 3 (Removal with In Situ Containment)**, approximately 2,300 and 5,700 cy of contaminated sediments, including potentially recoverable product in SMAs 2 and 3, respectively, would be removed. Short-term resuspension and releases of contaminants into the water column during the dredging operation (e.g., from contaminant desorption or release from resuspended sediments, dredging residuals, and molecular diffusion from the dredging cut face) limits the overall protectiveness of this alternative. A detailed discussion of these short-term releases is presented below in Section 7.3.1.3.

As discussed in Section 5.1, no removal technology can remove every particle of contaminated sediment, and all dredging operations leave behind residual contaminated sediment, which can result in difficulties or failure to achieve risk-based levels in sediments. The inevitability of post-dredging residuals (Patmont and Palermo 2007; NRC 2007) and their influence on risk has been increasingly recognized over the last decade (Bridges et al. 2010). Dredging residuals can limit the protectiveness of Alternative 3, particularly because residual concentrations in SMAs 2 and 3 are likely to be more contaminated than current surface sediment levels (see below). Complicating factors in the dredging process (e.g., the presence of debris and potential product in the sediment bed) can make the sediment removal process and achievement of risk-based cleanup levels very difficult.

The state of practice in modeling dredging processes is not sufficient to make precise predictions of post-dredging residual contaminant concentrations. In the absence of such modeling capability, empirical approaches have been used at dredging projects (Bridges et al. 2010). Existing data suggest that the average concentration of contaminants in generated residuals will approximate the mass-weighted average sediment concentration in the final production cut profile (Reible et al. 2003; Palermo et al. 2008). As discussed above, SMAs 2 and 3 have significantly elevated concentrations of chlorobenzenes at subsurface sediment depths and product is present, as observed during fall 2010 investigations. These elevated concentrations and product are anticipated to remain on the post-dredge surface. Estimates of the relative mass of contaminants remaining following dredging have been presented for 12 well documented environmental dredging projects (Desrosiers and Patmont 2009). At those sites, the residuals represented approximately 2 to 11 percent of the mass of solids dredged during the last dredge production cut.

Because relatively high sediment concentrations (and product) are anticipated to remain on the surface of the SMA 2 and 3 dredge cut under Alternative 3, a post-dredging reactive cap would need to be placed over dredged areas within SMAs 2 and 3. Furthermore, the depressions remaining after excavation and post-dredge reactive capping would backfill naturally with time as upstream clean sediment migrates into the area. Though the post-dredge reactive cap and natural backfill would not address issues associated with contaminant releases during dredging, they would improve the long-term protection to human health and the environment of Alternative 3.

#### **7.3.1.2 Compliance with ARARs**

As discussed in Section 4.3.1, no chemical-specific ARARs apply to any of the alternatives.

Implementation of SMA 2/3: Alternative 1 (In Situ Containment with Hydraulic Control) or Alternative 2 (Removal of Recoverable Product /Treatment and In Situ Containment with Hydraulic Containment) would include placement of a 6- to 8-inch-thick cap in SMAs 2 and 3 (GCL overlain by 6 inches of armor), and could potentially trigger the substantive requirements of action-specific ARARs applying to fill activities (see Table 4-2). In order to demonstrate compliance of this alternative with these ARARs, a hydraulic assessment may need to be performed to assess whether placing additional material in the river channel would have the potential to affect flooding elevations. The limited extent of capping actions in SMAs 2 and 3 (i.e., roughly 6 to 8 inches placed over a total of 0.6 acres) suggests that changes to flood elevations are unlikely to occur

under this alternative. Alternatives 1 and 2 also comply with other identified action-specific or location-specific ARARs (see Tables 4-2 and 4-3).

Implementation of **SMA 2/3: Alternative 3 (Removal with In Situ Containment)** complies with identified action-specific or location-specific ARARs (see Tables 4-2 and 4-3).

### 7.3.1.3 Short-Term Effectiveness

Similar to the discussion in Section 7.2.1.3 for SMA 1, short-term impacts would occur for all of the SMA 2 and 3 alternatives as a result of temporary disruption of upland/shoreline areas along the river to construct access points and staging areas. The short-term effects of implementing **SMA 2/3: Alternative 1 (In Situ Containment with Hydraulic Control)** and **Alternative 2 (Removal of Recoverable Product/Treatment and In Situ Containment with Hydraulic Control)** could result in temporary, localized impacts, particularly during installation of the barrier walls and from placement of the capping materials. These impacts will primarily be in the form of turbidity from the capping materials themselves, but could potentially include dissolved and particulate releases of contaminants from the existing sediments during barrier wall installation. However, results from other sites (Anchor QEA and ARCADIS 2010) indicate that contaminant releases during installation of barrier walls are often lower than those resulting from excavation/dredging. Installation of the cap would temporarily disrupt the existing benthic community and could also disrupt existing fish communities. The impacts on the benthic community and fish are expected to be restricted to the short term, as evidence from previous projects indicates that benthic recolonization of caps with suitable substrate is relatively rapid and typically occurring within weeks to months following the completion of construction (Sumeri 1996; Alcoa 2002; Simpson 2004). On the other hand, capping provides an immediate benefit, because it creates an instantaneous clean sediment surface.

Similar to Alternatives 1 and 2, **SMA 2/3: Alternative 3 (Removal with In Situ Containment)** could result in short-term impacts, potentially including dissolved and particulate releases of contaminants during installation and removal of the temporary controls (e.g., sheet piling) surrounding the SMA. For example, at several sites in the Pacific Northwest, piling removal resulted in documented releases of contaminants and recontamination of adjacent sediments up to several hundred feet from the removed piling (King County 2006; Anchor QEA 2011). In addition, there is the potential for unintended sediment disturbances outside of the temporary enclosure due to changes in hydrodynamic conditions caused by the enclosure (e.g., constriction of the river cross section).

Under Alternative 3, there would also be short-term effects from dredging including increased turbidity and resuspension/release of both particulate- and dissolved-phased chemicals from the sediments to the water column. The release pathway is particularly important because dissolved contaminants are readily bioavailable to fish and other biota (Eggleton and Thomas 2004). As discussed in Bridges et al. (2010), dredging operations can release contaminants through a variety of mechanisms, including contaminant desorption from resuspended sediments, dredging residuals, or other fluid layers with high suspended solids concentration. Other potentially significant contaminant release mechanisms in SMAs 2 and 3 include molecular diffusion from the dredging cut face and from exposed product.

The empirical data available for environmental dredging sites suggest that dissolved and total contaminant concentrations resulting from dredging-related resuspension and release can vary greatly in all dimensions at distances of 300 to 1,000 ft from the dredge due to variability in the dredging operations and dilution by turbulent diffusion in the water column (Hayes et al. 2000). A few quantitative evaluations of contaminant release have been undertaken at dredging sites (e.g., Steuer 2000; Connolly et al. 2007; EPA 2009). These data suggest that roughly 2 to 4 percent of the dredged contaminant mass is transported downstream of the dredging area outside of silt curtains, and much of this release occurs in the dissolved phase (Bridges et al. 2010). Short-term releases directly to the water column from dredging operations may be 1 to 3 orders of magnitude greater than pre-dredging releases from the sediment bed for the same period of time (Sanchez et al. 2002). Several environmental dredging projects (e.g., in the Grasse River and Hudson River, New York) have also documented a concomitant increase in fish tissue concentrations for many miles downstream of the dredging operations.

The short-term effects of release would last for several months or longer during and after implementation. The effect of resuspension could persist depending on where resuspended chemicals settle. Sediment removal activities are also anticipated to result in residual materials at the sediment bed. The long-term effects of the residual material would be mitigated through placement of a residual reactive cap to control the flux of residual product exposed by the removal activities, but not fully captured by the dredge.

Dredging under Alternative 3 would eliminate the benthic community in the short term. Removal of sediment and post-dredge capping results in slower benthic recolonization rates compared with capping; benthic recolonization of removal areas typically occurs within months or years (Herbich 2000; Szymelfenig et al 2006; Alcoa 2008).

Transport of dredged sediments to the dewatering pad and final disposition in a landfill under Alternative 3 also presents potential short-term risks to construction workers (potential exposure to contaminants) and to the public (traffic accidents, spills, noise, and air pollution). Potential short-term impacts to construction workers would be addressed by following the procedures set forth in the site-specific HASP.

#### **7.3.1.4 Long-Term Effectiveness and Permanence**

Both SMA 2/3: Alternative 1 (In Situ Containment with Hydraulic Control) and Alternative 2 (Removal of Recoverable Product /Treatment and In Situ Containment with Hydraulic Control) would provide long-term effectiveness and permanence from potential exposure risks associated with elevated sediment concentrations in the Segment 1 through placement of a barrier wall and low-permeability cap. Based on design considerations and preliminary modeling results described in Appendix E, the benefits provided by the barrier walls and caps are expected to be permanent. Preliminary cap design evaluations indicate that a negative hydraulic gradient could be achieved within the laterally and vertically contained area through connection with the existing RGIS system in Alternative 1, and also through active hydraulic controls in Alternative 2. Maintenance of the barrier walls and low-permeability cap would be necessary to ensure the hydraulic control system is operating as designed and providing long-term effectiveness and permanence. Alternative 2

would also incorporate removal of recoverable product through recovery wells installed within the contained area.

**SMA 2/3: Alternative 3 (Removal with In Situ Containment)** would provide long-term protectiveness and permanence from potential exposure risks through sediment removal. Long-term effectiveness would be achieved through placement of a reactive cap following dredging to contain dredging residuals. Sediments removed as part of Alternative 3 would be disposed of at a suitable landfill. This disposal facility would provide effective long-term management of the dredged materials, controlling potential future exposure to human and environmental receptors.

Existing institutional controls would be continued to ensure the long-term effectiveness and permanence of the remedy under all alternatives.

#### **7.3.1.5 Reduction of Toxicity, Mobility or Volume**

SMA 2/3: Alternative 1 (In Situ Containment with Hydraulic Control) and Alternative 2 (Removal of Recoverable Product /Treatment and In Situ Containment with Hydraulic Control) would provide a reduction in mobility of SCOIs through the isolation of sediments beneath a low-permeability cap and within a lateral containment system. Alternative 2 would also result in the reduction of volume and toxicity through removal and treatment of recoverable product and through subsurface water removed and treated through RGIS as part of the hydraulic control system, thereby contributing to the effectiveness of the alternative.

Under **SMA 2/3: Alternative 3 (Removal with In Situ Containment)**, approximately 2,300 and 5,700 cy of sediments in SMAs 2 and 3, respectively, would be removed and disposed of in a permitted landfill, reducing the mobility of SCOIs. The installation of an appropriately designed reactive cap to manage post-dredge residuals may impede migration and immobilize oily product (EPA 2005; RMT 2009; Reible et al. 2010), reducing the toxicity and mobility of residual sediments.

#### **7.3.2 Implementability**

Implementation of any of the SMA 2 or 3 alternatives would require appropriate shoreline or upland staging areas, which are available. It is expected that necessary access and staging areas to support these alternatives would be constructed on property owned by Dow, thereby facilitating implementation. For example, the dewatering area previously developed on Dow's property could be reused for implementation of Alternative 3, although additional infrastructure may be required if treatment of removed sediments is required prior to disposal.

An evaluation of the impacts on the RGIS sheet pile system would need to be performed for all three alternatives. The remedial design would consider removal methods that minimize the risk of negative effects on RGIS. Construction monitoring and/or protective measures would need to be understood and implemented to ensure that sediment removal actions would not affect RGIS and its operations.

Installation of barrier walls and placement of a low-permeability cap (components of Alternatives 1 and 2) have been applied to similar sediment sites (see Appendix D) and are both administratively and technically implementable for the Tittabawassee River. Necessary personnel for the various

tasks (i.e., crane and loader operators) are readily available. Barrier walls (e.g., sheet pile) and caps would be installed using similar methods to those used during Reaches B and D capping activities. Similarly, a combination of removal methods used for Reaches D and O, including mechanical dredging/excavation, and debris segregation would be employed under Alternative 3. Finally, a local permitted landfill would be the primary location for permanent disposal of dredge materials.

In fall 2010, Dow initiated a focused investigation of SMAs 2 and 3 which verified that recoverable product is present in SMA 2 and detected in SMA 3 (other Segment 1 SMAs were also investigated concurrently), as discussed in Section 3.2.3. The visual, semi-quantitative observations from the fall 2010 investigations increase confidence that the product recovery component included in Alternative 2 is implementable.

### **7.3.3 Cost**

Cost estimates for each alternative were developed based on a review of prior Dow project data, a review of cost data available for similar projects completed at other sites, and initial input from prospective Dow contractors. Consistent with EPA/USACE (2000) guidance, the cost estimates for each alternative are anticipated to be accurate within the range of -30 percent to +50 percent. A future discount rate of 7 percent was used for the present worth calculation as specified by EPA/USACE guidance. Details of the cost estimates for each alternative are provided in Appendix F.

The estimated present worth of Alternatives 1, 2, and 3 are approximately \$1,200K, \$1,800K, and \$2,300K (\$7,400K if sediment treatment is required prior to disposal), respectively (provided in present day [2010] dollars). For costing purposes and comparison of alternatives, a 30-year monitoring and maintenance period was assumed for in situ alternatives (in this case, all three alternatives). Long-term monitoring is a component of all alternatives, and will be detailed in the Site-Wide Monitoring Plan; see Section 8.1.1).

## **7.4 SMA 4 and SMA 5**

Section 6 identified the following three alternatives for evaluation in SMA 4 and SMA 5:

- Alt 1: MNR
- Alt 2: In situ containment
- Alt 3: Removal of sediment

Each of these alternatives is evaluated independently below.

### **7.4.1 Effectiveness**

The effectiveness of each response action alternative was evaluated against the five elements described in Table 7-1. Each of these criteria is discussed in the sections below.

#### 7.4.1.1 Protection of Human Health and Environment

Human health and the environment are currently protected in SMAs 4 and 5 by the presence of approximately 2.6 to 3.7 ft of clean sediment (SCOI concentrations below the PLERs) overlying elevated subsurface SCOI deposits. (The active bed layer in SMA 4 and SMA 5 ranges up to 0.7 ft and 1.0 ft, respectively, below the sediment surface; see Table 3-5.) The clean, near-surface sediments have established a protective natural cap of sufficient thicknesses to control potential chemical migration and exposure. Therefore, implementation of **SMA 4/5: Alternative 1 (MNR)** would monitor the active bed concentrations to verify that sediment concentrations remain at acceptable levels.

To further ensure that the existing natural sediment caps in SMAs 4 and 5 will remain protective, the steady-state cap modeling described in Section 7.3.1.1 was applied to these SMAs using the following conservative assumptions:

- Maximum subsurface sediment concentrations present at depth in these SMAs were used in the modeling, and were not assumed to degrade or dissipate over time, thus representing a long-term source).
- Multiple lines of evidence summarized in Section 3.3.3 reveal a downward groundwater flowpath within the surficial sandy sediments in SMAs 4 and 5, away from the river surface water and toward RGIS. For the purpose of the conservative cap modeling, no net advection was assumed in this application.
- Conservative values (i.e., from the lower end of ranges reported in the literature) for compound-specific SCOI biodegradation rates were used in the model. Different values were used for aerobic and anaerobic conditions as appropriate in surface and subsurface sediments, respectively. The values were derived from the EPA-supported EPI Suite™ (BIOWIN™ model) environmental fate estimation program. These rates were found to be generally consistent with those reported in other biodegradation rate compilations (e.g., EPA's SCDM and Howard et al. 1991), and were found to be conservative (i.e., slower degradation) as compared to those reported in the literature (based on a review of several experimental studies for a limited subset of SCOIs).

The modeling outlined above confirmed that SCOI concentrations within the active bed layer in SMAs 4 and 5 will remain below PLER values on a long-term basis. These results provide further confidence that Alternative 1 is protective of human health and the environment.

Under **SMA 4/5: Alternative 2 (In Situ Containment)**, the placement of in situ physical containment caps (e.g., armor layers) would further protect human health and the environment by armoring the clean, near-surface sediments to help maintain their integrity in the future. However, as discussed in Section 3.3, multiple lines of evidence reveal that existing sediments are currently protected from erosive forces without the additional armor layer.

**SMA 4/5: Alternative 3 (Removal of Sediment)** would remove approximately 1,500 and 2,000 cy of sediments from SMAs 4 and 5, respectively, to address subsurface SCOI deposits. These removal volumes include approximately 900 and 800 cy of clean sediments that currently overlie

the subsurface SCOI deposits in SMAs 4 and 5, respectively, which would otherwise not require removal to achieve the RAOs. Overall protectiveness of Alternative 3 would be achieved by constructing a post-dredge residual backfill/sand cover that would be placed over dredged areas within SMAs 4 and 5 following dredging.

#### 7.4.1.2 Compliance with ARARs

**SMA 4/5: Alternative 1 (MNR)** would not include any invasive action; therefore, no action-specific or location-specific ARARs would apply.

Implementation of **SMA 4/5: Alternative 2 (In Situ Containment)** would include placement of a 6-inch-thick armor layer in SMAs 4 and 5, and could potentially trigger the substantive requirements of action-specific ARARs applying to fill activities (see Table 4-2). In order to demonstrate compliance of this alternative with these ARARs, a hydraulic assessment may need to be performed to assess whether placing additional material in the river channel would have the potential to affect flooding elevations. The limited extent of capping actions in SMAs 4 and 5 (i.e., 6 inches placed over a total of 0.4 acres) suggests that changes to flood elevations are unlikely to occur under this alternative. Alternative 2 complies with other identified action-specific or location-specific ARARs (see Tables 4-2 and 4-3).

Implementation of **SMA 4/5: Alternative 3 (Removal of Sediment)** complies with identified action-specific or location-specific ARARs (see Tables 4-2 and 4-3).

#### 7.4.1.3 Short-Term Effectiveness

No construction activities are associated with **SMA 4/5: Alternative 1 (MNR)**; thus, there are no short-term construction-related impacts associated with this alternative. Moreover, existing surface sediments in SMAs 4 and 5 are currently below PLER levels and thus are already protective of human health and the environment.

Under **SMA 4/5: Alternative 2 (In Situ Containment)**, the short-term effects of cap armor placement would occur only during construction. These short-term effects would include localized turbidity from placement of the capping materials, and potential impacts to the benthic and fish communities due to the placement of new materials within the river. The impacts on the benthic community also would be expected to be restricted to the short term, as evidence from previous projects indicates that benthic recolonization of caps with suitable substrate typically occurs within weeks to months following the completion of construction (Sumeri 1996; Alcoa 2002; Simpson 2004).

Under **SMA 4/5: Alternative 3 (Removal of Sediment)**, the short-term effects of dredging include resuspension and release of both particulate- and dissolved-phased chemicals from sediments to surface water, localized turbidity impacts, and impacts to the fish and benthic communities. Dredging under Alternative 3 would eliminate the benthic community in the short term. Removal of sediment (with or without backfill/sand cover) results in slower benthic recolonization rates compared with capping; benthic recolonization of removal areas typically occurs within months or several years (Herbich 2000; Szymelfenig et al 2006; Alcoa 2008).

Transport of particulate-phase chemicals and turbidity can be reduced through use of turbidity controls (e.g., silt curtains) at the downstream boundary of dredging activities. However, some amount of downstream transport is anticipated, even with the use of these turbidity control measures. The short-term effects of release would last for several months or longer during and after implementation. The effect of resuspension could persist depending on where resuspended chemicals settle. Dredging of sediment is also anticipated to result in residual materials remaining on the sediment surface following removal activities, which would be addressed by placing a post-dredge backfill/sand cover.

Short-term impacts common to both Alternatives 2 and 3 include temporary disruption of upland/shoreline areas along the river to construct access points and potential transportation accidents (both in water and upland). Access and staging areas would be constructed on Dow property, thereby minimizing potential effects to the community. Under these alternatives, measures would be implemented to minimize the potential for transportation accidents (including floating equipment accidents in the river and truck accidents associated with transport of dredged sediment to the dewatering facility and landfill as well as transport of clean capping material). Appropriate health and safety practices (MIOSHA) would be followed through implementation of a project-specific HASP.

#### **7.4.1.4 Long-Term Effectiveness and Permanence**

Clean (SCOI concentrations below the PLERs) near-surface sediments have established a protective natural cap of sufficient thicknesses to control potential chemical migration and possible exposure. As discussed above, preliminary cap design evaluations have confirmed that SCOI concentrations within the active bed layer in SMAs 4 and 5 will remain below PLER values on a long-term basis. These results provide further confidence that **SMA 4/5: Alternative 1 (MNR)** would provide long-term effectiveness and permanence. Long-term effectiveness would be ensured through monitoring. Moreover, existing institutional controls would be continued to ensure the long-term effectiveness and permanence of the remedy.

Similar to Alternative 1, **Alternative 2 (In Situ Containment)** would provide long-term effectiveness and permanence through the presence of the natural cap and also incorporates a physical barrier to further protect against disturbance of the natural sediment cap. The physical barrier would be designed to resist forces associated with peak bed shear stresses. Long-term effectiveness would be ensured through monitoring and maintenance as necessary. In the event that damage to the caps occurs, affected areas would be identified during monitoring and subsequently addressed. Existing institutional controls would be continued to ensure the long-term effectiveness and permanence of the remedy.

**SMA 4/5: Alternative 3 (Removal of Sediment)** provides long-term protectiveness and permanence from potential exposure risks through sediment removal. Additional long-term effectiveness would be achieved through placement of a residual backfill/sand cover following dredging to mitigate remaining residual sediments. The removal of sediments would form a depression within the sediment bed that would act as a sedimentation basin for rapid accumulation of clean sediments.

#### 7.4.1.5 Reduction of Toxicity, Mobility, or Volume

Reduction in toxicity, mobility, or volume through treatment would not occur for any of the alternatives evaluated for SMAs 4 and 5 because none of the alternatives include a treatment component. However, the clean, near-surface sediment deposits overlying subsurface SCOI-containing deposits are currently acting as a “natural” cap and act to reduce the mobility of SCOIs through physical and chemical isolation of sediments. **SMA 4/5: Alternative 2 (In Situ Containment)** includes the placement of a physical isolation cap (e.g., armor layer).

Under **SMA 4/5: Alternative 3 (Removal of Sediment)**, the volume of contaminated sediment within the Tittabawassee River would be reduced by removing approximately 3,500 cy of sediments (including approximately 1,700 cy of overlying clean sediments). Short-term increases in mobility of recoverable SCOI deposits could occur during the dredging period, thus potentially increasing mobility of buried and isolated contaminants; however, in the long term, mobility of the chemicals within the dredged sediments would be reduced via disposal in a permitted landfill. Placement of a residual backfill sand cover to manage post-dredge residuals would decrease the long-term mobility of resuspended and residual sediments.

#### 7.4.2 Implementability

There are no administrative or technical implementability concerns associated with the monitoring included in **SMA 4/5: Alternative 1 (MNR)**.

Implementation of **SMA 4/5: Alternative 2 (In Situ Containment)** and **Alternative 3 (Removal of Sediment)** would require an appropriate shoreline or upland staging area. The size and number of staging areas would depend on the type and extent of remediation included in the alternatives. It is expected that necessary access and staging areas to support these alternatives would be constructed on property owned by Dow, thereby facilitating implementation. For example, the dewatering area previously developed on Dow’s property could be reused for implementation of Alternative 3.

As discussed in Section 7.2.1, dredging and capping of sediments in the Tittabawassee River are both administratively and technically implementable, as demonstrated during the Reaches B, D, and O response actions. Necessary personnel for the various tasks (i.e., crane and loader operators) are readily available. Under Alternative 2, the placement of the physical barrier (e.g., armor layer cap) would be similar to methods used during Reach B and Reach D capping activities (e.g., mechanical placement from shoreline, telescoping conveyor belt, etc.). Similarly, a combination of removal methods used for Reaches D and O, including mechanical dredging/excavation, and debris segregation would be employed under Alternative 3. Finally, a local permitted landfill would be the primary location for permanent disposal of dredge materials.

#### 7.4.3 Cost

Cost estimates for each alternative were developed based on a review of prior Dow project data, a review of cost data available for similar projects completed at other sites, and initial input from prospective Dow contractors. Consistent with EPA/USACE (2000) guidance, the cost estimates for each alternative are anticipated to be accurate within the range of -30 to +50 percent. A future

discount rate of 7 percent was used for the present worth calculation as specified by EPA/USACE guidance. Details of the cost estimates for each alternative are provided in Appendix F.

The estimated present worth of Alternatives 1, 2, and 3 are approximately \$60K, \$600K, and \$1,700K, respectively (provided in present day [2010] dollars). For costing purposes and comparison of alternatives, a 30-year monitoring period was assumed for in situ alternatives (in this case, Alternatives 1 and 2). For **SMA 4/5: Alternative 1 (MNR)**, the present worth analysis was performed assuming that a long-term monitoring program (approximately 30 years) would include surface sediment sampling. The cost estimate for **SMA 4/5: Alternative 2 (In Situ Containment)** is based on the construction of the sediment cap followed by a 30-year post-construction monitoring and maintenance period. For **SMA 4/5: Alternative 3 (Removal of Sediment)**, the cost estimate is based on anticipated construction activities and construction monitoring. Long-term monitoring is a component of all alternatives, and will be detailed in the Site-Wide Monitoring Plan; see Section 8.1.1).

## 7.5 SMA 6

Section 6 identified the following three alternatives for evaluation in SMA 6:

- Alt 1: Removal/treatment of recoverable product, removal of near shore ethyl parathion deposit, and MNR
- Alt 2: Removal/treatment of recoverable product, removal of near shore ethyl parathion deposit, and in situ containment with hydraulic control
- Alt 3: Removal of near shore ethyl parathion deposit and removal/post-dredge backfill of remaining area

Each of these alternatives is evaluated independently below.

### 7.5.1 Effectiveness

The effectiveness of each response action alternative was evaluated against the five elements described in Table 7-1.

#### 7.5.1.1 Protection of Human Health and Environment

As discussed in Section 3.5.2, SMA 6 contains one surface sediment location with an ethyl parathion concentration greater than the PLER value (520 mg/kg detected at location 151+50-IC33 [0.0 to 1.0 ft], relative to the PLER of 0.36 mg/kg); no other target SCOIs exceeded their respective PLER values in the surface sediment at SMA 6. As discussed in Section 6.5, and consistent with initial discussions with the Agencies, each of the three alternatives for SMA 6 includes removal of the sediments impacted by ethyl parathion in the nearshore area; removal was identified for the ethyl parathion deposit due to relatively high concentrations detected (more than 1,000 times above the PLER) and the proximity of those detections to the sediment surface. The measured till depth at SMA 6 ranges from 7.2 to 9.4 ft below the sediment surface. As discussed in Sections 3.2.3, the fall 2010 field investigations indicate that at least a portion of the SCOI deposit in SMA 6 contains recoverable product. The highest detected total chlorobenzene concentration in SMA 6

(404 mg/kg) was collected at a sample depth of 8.5 to 9.4 ft below the sediment surface (sample location 151+50-IC33), well below the active bed layer (which in SMA 6 ranges up to 0.9 ft below the sediment surface; see Table 3-5).

All three alternatives for SMA 6 include removal of approximately 500 cy of near shore sediments within the active bed of SMA 6 that exceed the PLER for ethyl parathion. Sediments in this near shore area would be targeted for removal to 1 ft below the sediment surface (Figure 6-13). A layer of residual sediments potentially exceeding PLERs is anticipated to remain at the base of SMA 1 following dredging. To ensure the protectiveness of this component of the alternative, a thin backfill/cover layer of sand would be placed on the dredged surface under Alternative 1 to manage anticipated residuals. The need for and design of the post-dredge residual backfill/sand cover under Alternative 1 would be verified at the time of construction based on the result of post-dredge verification sampling. Since Alternatives 2 and 3 involve additional remediation (sediment removal and/or capping), placement of a backfill/cover following sediment removal of the near shore ethyl parathion impacted sediments is not necessary.

Beyond the ethyl parathion removal area, **SMA 6: Alternative 1 (Product Removal/Treatment, Removal of Near Shore Ethyl Parathion Deposit, and MNR)** for SMA 6 would provide protection of human health and the environment through removal and treatment of recoverable product via recovery wells installed within the contained area. Treatment of extracted liquids would likely be integrated into existing on-site treatment systems. Product and subsurface water removal would provide for reduction of volume and toxicity of contaminants in this SMA (see Section 7.5.1.5).

Alternative 1 would also monitor existing natural caps that cover the remaining deposits in SMA 6. Similar to SMAs 4 and 5, the existing active sediment bed outside of the near shore ethyl parathion deposit contains SCOI concentrations below the PLERs, with approximately 1.8 to 8.5 ft (average of more than 5 ft) of clean sediments overlying elevated subsurface SCOI deposits. This existing layer of clean sediments currently provides protection of human health and the environment through isolation of subsurface sediments with elevated SCOI concentrations. Cap modeling described in Appendix E, and using the same conservative assumptions employed for SMAs 4 and 5, confirmed that SCOI concentrations within the active bed layer in SMA 6 will remain below PLER values. These results provide further confidence that Alternative 1 is protective of human health and the environment.

SMA 6: Alternative 2 (Product Removal/Treatment, Removal of Near Shore Ethyl Parathion Deposit, and In Situ Containment with Hydraulic Control) would provide removal and treatment of recoverable product via recovery wells, similar to Alternative 1. Alternative 2 also incorporates the installation of a barrier wall with active hydraulic controls (e.g., connection to RGIS) and a low permeability cap that would isolate sediments and control chemical migration, physical erosion, and biological contact with SMA 6 sediments that exceed the PLER. Hydraulic removal within the containment area would further induce a negative hydraulic gradient in this SMA, providing additional protection. Subsurface water removed from the SMA would be treated by Dow's existing water treatment system via RGIS. A monitoring and maintenance program would be implemented to further ensure the long-term protectiveness of the in situ containment system.

Under **SMA 6: Alternative 3 (Removal of Sediment)**, an additional 15,000 cy of relatively deeply buried subsurface sediments containing elevated SCOI concentrations would be removed from SMA 6. This volume is in addition to the approximately 500 cy of surface sediments impacted by elevated ethyl parathion concentrations. Furthermore, this removal volume includes approximately 7,500 cy of clean sediments that currently overlie the subsurface SCOI deposit, which would otherwise not require removal to achieve the RAOs. Short-term resuspension and releases of contaminants into the water column during the dredging operation (e.g., from contaminant desorption or release from resuspended sediments, dredging residuals, and molecular diffusion from the dredging cut face) limits the overall protectiveness of this alternative. A detailed discussion of these short-term releases is presented in Section 7.3.1.3.

As discussed in Section 5.1, post-dredging residuals can limit the effectiveness of Alternative 3, particularly because residual concentrations in SMA 6 are likely to be more contaminated than current surface sediment levels. Because recoverable product exists at depth and residuals are anticipated to remain on the surface of the SMA 6 dredge cut under Alternative 3, a post-dredging cap (potentially including reactive materials) would likely need to be placed over dredged areas. Furthermore, the depressions remaining after excavation and post-dredge capping would backfill naturally with time as upstream clean sediment migrates into the area. Though the post-dredge cap and natural backfill would not address issues associated with contaminant releases during dredging, they would improve the long-term effectiveness of Alternative 3.

#### **7.5.1.2 Compliance with ARARs**

Beyond the ethyl parathion removal area, **SMA 6: Alternative 1 (Product Removal/Treatment, Removal of Near Shore Ethyl Parathion Deposit, and MNR)** would not include any intrusive action; therefore, no additional action-specific or location-specific ARARs would apply.

Implementation of SMA 6: Alternative 2 (Product Removal/Treatment, Removal of Near Shore Ethyl Parathion Deposit, and In Situ Containment with Hydraulic Control) also includes placement of a 6-inch-thick armor layer in SMA 6. Due to the removal of the ethyl parathion deposit (cut) in the river, the addition of the cap should not trigger the substantive requirements of action-specific ARARs applying to fill activities (see Table 4-2). In order to demonstrate compliance of this alternative with these ARARs, a cut/fill evaluation would need to be completed during design. If the fill is significantly greater than the removal volume, a hydraulic assessment may need to be performed to assess whether placing additional material in the river channel would have the potential to affect flooding elevations. The limited extent of capping actions in SMA 6 (i.e., 6 inches placed over a total of 0.5 acres) along with the removal action suggests that changes to flood elevations are unlikely to occur under this alternative. Alternative 2 complies with other identified action-specific or location-specific ARARs (see Tables 4-2 and 4-3).

Implementation of **SMA 6: Alternative 3 (Removal of Sediment)** complies with identified action-specific or location-specific ARARs (see Tables 4-2 and 4-3).

### 7.5.1.3 Short-Term Effectiveness

All of the SMA 6 alternatives include temporary disruption of upland/shoreline areas along the river to construct access points to remove the near shore ethyl parathion deposit. Access and staging areas would be constructed on Dow property, thereby minimizing potential effects on the community. Under these alternatives, measures would be implemented to minimize the potential for transportation accidents (including floating equipment accidents in the river and truck accidents associated with transport of dredged sediment to the dewatering facility and landfill as well as transport of clean capping material). Appropriate health and safety practices (MIOSHA) would be followed through implementation of a project-specific HASP.

The short-term effects of removal of the ethyl parathion-impacted sediments included as a component of all three alternatives include anticipated resuspension/release of both particulate- and dissolved-phased chemicals within the sediments, increased turbidity within the water column, and impacts to fish and benthic habitats. Transport of particulate-phase chemicals and turbidity can be reduced through use of turbidity controls (e.g., silt curtains) at the downstream boundary of dredging activities. However, some amount of downstream transport is likely even with these controls in place. The short-term effects of release would last for several months or longer during and after implementation. The effect of resuspension could persist depending on where resuspended chemicals settle. Removal of the ethyl parathion-impacted sediments is also anticipated to result in residual materials at the sediment bed. Both short- and long-term effects of the residual material would require placement of a residual backfill/sand cover.

Beyond the ethyl parathion removal area, there are no additional short-term construction-related impacts associated with **SMA 6: Alternative 1 (Product Removal/Treatment, Removal of Near Shore Ethyl Parathion Deposit, and MNR)**. Moreover, existing surface sediments in SMA 6 beyond the ethyl parathion deposit are currently below PLER levels and thus are already protective of human health and the environment.

Under SMA 6: Alternative 2 (Product Removal/Treatment, Removal of Near Shore Ethyl Parathion Deposit, and In Situ Containment with Hydraulic Control), additional short-term effects from installation of the barrier walls and cap placement. These impacts could potentially also include dissolved and particulate releases of contaminants from the existing sediments during barrier wall installation. However, results from other sites (Anchor QEA and ARCADIS 2010) indicate that contaminant releases during installation of barrier walls are often lower than those resulting from excavation/dredging. Contaminant release from existing sediments is not expected in SMA 6 since surface sediments are currently below PLER levels.

The impacts on the benthic community are also expected to be restricted to the short term, as evidence from previous projects indicates that benthic recolonization of caps with suitable substrate typically occurs over a period from weeks to months following the completion of construction (Sumeri 1996; Alcoa 2002; Simpson 2004).

Under **SMA 6: Alternative 3 (Removal of Sediment)**, the additional short-term effects of dredging include resuspension and release of both particulate- and dissolved-phased chemicals from sediments to surface water, localized turbidity impacts, and fish and benthic habitat impacts.

Transport of particulate-phased chemicals and turbidity can be reduced through use of turbidity controls (e.g., silt curtains or temporary sheet piling) at the boundary of dredging activities. However, some amount of downstream transport is anticipated even with the use of these turbidity control measures. Installation of sheet piling for turbidity control could result in short-term impacts, potentially including dissolved and particulate releases of contaminants, during installation and removal of the temporary controls. For example, at several sites in the Pacific Northwest, piling removal resulted in documented releases of contaminants and recontamination of adjacent sediments up to several hundred feet from the removed piling (King County 2006; Anchor QEA 2011). In addition, there is the potential for unintended sediment disturbance outside of the temporary enclosure, due to changes in hydrodynamic conditions caused by the enclosure (e.g., constriction of the river cross section). The short-term effects of release would last for several months or longer during and after implementation. The effect of resuspension could persist depending on where resuspended chemicals settle. Dredging of sediment is also anticipated to result in residual materials remaining on the sediment surface following removal activities, which would be addressed by post-dredge capping.

Dredging under Alternative 3 would eliminate the benthic community in the short term. Removal of sediment (with or without backfill/sand cover) results in slower benthic recolonization rates compared with capping; benthic recolonization of removal areas typically occurs within months or several years (Herbich 2000; Szymelfenig et al 2006; Alcoa 2008).

#### **7.5.1.4 Long-Term Effectiveness and Permanence**

All of the SMA 6 alternatives incorporate removal of the near shore ethyl parathion deposit to provide long-term protectiveness and permanence. Long-term effectiveness would be achieved through placement of a residual backfill/sand cover following dredging to mitigate remaining residual sediments. Additionally, the removal of sediments would form a depression within the sediment bed that would act as a sedimentation basin for rapid accumulation of clean sediments.

**SMA 6: Alternative 1 (Product Removal/Treatment, Removal of Near Shore Ethyl Parathion Deposit, and MNR)** will provide long-term effectiveness through the removal and treatment of recoverable product. Furthermore, similar to SMAs 4 and 5, clean (SCOI concentrations below the PLERs), near-surface sediment deposits have established a protective natural cap of sufficient thicknesses to control potential chemical migration and prevent direct contact with the active bed. As discussed above, preliminary cap design evaluations confirmed that SCOI concentrations within the active bed layer in SMA 6 (which ranges up to 0.9 ft below the sediment surface, as discussed in Section 3.3.2) will remain below PLER values. These results provide further confidence that Alternative 1 will provide long-term effectiveness and permanence.

Similar to Alternative 1, SMA 6: Alternative 2 (Product Removal/Treatment, Removal of Near Shore Ethyl Parathion Deposit, and In Situ Containment with Hydraulic Control) would also provide long-term effectiveness and permanence through product removal and treatment. Alternative 2 also incorporates the placement of a low permeability cap and lateral containment barriers (e.g., sheet pile wall) to provide further control from potential future contaminant migration, though contaminant release from existing sediments is not expected in SMA 6, since surface sediments are currently below PLER levels. The low permeability cap and lateral barrier would be designed to inhibit

migration of contaminants by inducing a negative hydraulic gradient within the enclosed area through connection to RGIS. The low permeability cap would also be designed to resist forces associated with peak bed shear stresses. Long-term effectiveness would be ensured through monitoring and maintenance as necessary. In the event that damage to the lateral containment barrier or in situ containment cap occurs, affected areas would be identified during monitoring and subsequently addressed. In addition, existing institutional controls would be continued to ensure the long-term effectiveness and permanence of this alternative.

**SMA 6: Alternative 3 (Removal of Sediment)** would provide long-term protectiveness and permanence from potential exposure risks through sediment removal. Long-term effectiveness would be achieved through placement of a residual cap following dredging to mitigate remaining residual sediments. Additionally, the removal of sediments would form a depression within the sediment bed that would act as a sedimentation basin for rapid accumulation of clean sediments. Sediments removed as part of Alternative 3 would be disposed of at a suitable landfill. This disposal facility would provide effective long-term management of the dredged materials.

#### **7.5.1.5 Reduction of Toxicity, Mobility, or Volume**

All of the SMA 6 alternatives include removal of the near shore ethyl parathion-impacted sediments (approximately 500 cy). In the long term, mobility of the chemicals within these dredged sediments would be reduced via disposal in a permitted landfill.

Beyond the ethyl parathion removal area, **SMA 6: Alternative 1 (Product Removal/Treatment, Removal of Near Shore Ethyl Parathion Deposit, and MNR)** would maintain the clean, near-surface sediment deposits overlying subsurface SCOI-containing deposits that are currently acting as a “natural” cap and act to reduce the mobility of SCOIs through physical and chemical isolation of sediments. **SMA 6: Alternative 2 (Product Removal/Treatment, Removal of Near Shore Ethyl Parathion Deposit, and In Situ Containment with Hydraulic Control)** would also provide an engineered cap, further reducing the potential mobility of contaminants.

Reduction in toxicity, mobility, and volume of contaminants would occur through the treatment of recovered product under SMA 6: Alternative 1 (Product Removal/Treatment, Removal of Near Shore Ethyl Parathion Deposit, and MNR) and SMA 6: Alternative 2 (Product Removal/Treatment, Removal of Near Shore Ethyl Parathion Deposit, and In Situ Containment with Hydraulic Control). Under Alternative 2, additional reduction in toxicity, mobility and volume would occur through removal of subsurface water as part of the hydraulic control system and treatment in RGIS, thereby contributing to the effectiveness of the alternative.

Under **SMA 6: Alternative 3 (Removal of Sediment)**, the volume of contaminated sediment within the Tittabawassee River would be reduced by removing an additional 15,000 cy of sediments beyond the approximately 500 cy targeted in the near shore ethyl parathion removal area. Short-term increases in mobility of buried and naturally sequestered deposits could occur during the dredging period, thus potentially increasing mobility of buried and isolated contaminants; however, in the long term, mobility of the chemicals within the dredged sediments would be reduced via disposal in a permitted landfill. Placement of a residual backfill/sand cover layer to manage post-dredge residuals would decrease the long-term mobility of resuspended and residual sediments.

### 7.5.2 Implementability

All three alternatives involve construction activities and would require appropriate shoreline or upland staging areas. Staging areas would be located on Dow's property to facilitate implementation. The size and number of staging areas would depend on the type and extent of remediation included in the alternative. Previously developed staging and processing areas (e.g., dewatering pad) could be reused for implementation of the construction activities, as necessary; although additional infrastructure may be required if treatment of removed sediments is required prior to disposal.

An evaluation of the impacts on the RGIS sheet pile system would need to be performed under all three alternatives. The remedial design would consider removal methods that minimize the risk of negative effects on RGIS. Construction monitoring and/or protective measures would need to be understood and implemented to ensure that sediment removal actions would not affect RGIS and its operations.

As described above, dredging and capping of sediments in the Tittabawassee River is both administratively and technically implementable based on efforts conducted during the Reaches B, D, and O response actions. Necessary personnel for the various tasks (i.e., crane and loader operators) are readily available. Under **SMA 6: Alternative 2 (Product Removal/Treatment, Removal of Near Shore Ethyl Parathion Deposit, and In Situ Containment with Hydraulic Control)**, the placement of the cap over non-removal areas would be similar to methods used during Reach B and Reach D capping activities (e.g., mechanical placement from shoreline, telescoping conveyor belt, etc.). Similarly, a combination of removal methods used for Reaches D and O, including mechanical dredging/excavation, and debris segregation would be employed under Alternative 3 and portions of Alternatives 1 and 2 that contain removal. Proven methods of passively dewatering dredged sediments at a nearby dewatering pad at the Dow facility would be applied for these alternatives. Finally, a local permitted landfill would be the primary location for permanent disposal of dredge materials.

### 7.5.3 Cost

Cost estimates for each alternative were developed based on a review of prior Dow project data, a review of cost data available for similar projects completed at other sites, and initial input from prospective Dow contractors. Consistent with EPA/USACE (2000) guidance, the cost estimates for each alternative are anticipated to be accurate within the range of -30 percent to +50 percent. A future discount rate of 7 percent was used for the present worth calculation as specified by EPA/USACE guidance. Details of the cost estimates for each alternative are provided in Appendix F.

The estimated present worth of Alternatives 1, 2, and 3 are approximately \$2,200K, \$3,100K, and \$3,800k (\$8,700K, if sediment treatment is required prior to disposal), respectively (provided in present day [2010] dollars). For costing purposes and comparison of alternatives, a 30-year monitoring period was assumed for in situ alternatives (in this case, Alternatives 1 and 2). For **SMA 6: Alternative 1 (Product Removal/Treatment, Removal of Near shore Ethyl Parathion Deposit, and MNR)**, costs are included for the removal component, product recovery, and the

MNR component assuming that a long-term monitoring program (approximately 30 years) would include surface sediment sampling. For **SMA 6: Alternative 2 (Product Removal/Treatment, Removal of Near Shore Ethyl Parathion Deposit, and In Situ Containment with Hydraulic Control)**, the cost estimate includes the removal of near shore sediments, product recovery, and in situ containment of the remaining areas followed by a 30-year post-construction monitoring and maintenance period. For **SMA 6: Alternative 3 (Removal of Sediment)**, the cost estimate includes anticipated construction activities and construction monitoring. Long-term monitoring is a component of all alternatives, and will be detailed in the Site-Wide Monitoring Plan; see Section 8.1.1).

## 8.0 Response Proposal

Section 7 presented a detailed analysis of SMA-specific response option alternatives for Segment 1 using EE/CA evaluation criteria. The evaluation also addressed the overall requirements of CERCLA and the NCP, which were integrated into the EE/CA evaluation. This section summarizes the results of that analysis and compares the relative advantages and disadvantages of the various alternatives identified for each SMA or SMA groups, and reviews EPA (1988 and 2005) guidance regarding selection of a recommended alternative based on the results of comparative analysis.

### 8.1 Comparative Evaluation of Alternatives

Detailed evaluations of the individual SMA-specific alternatives are presented in Sections 7.2 through 7.5. This section organizes that discussion according to each EE/CA evaluation criterion (e.g., according to effectiveness [with five sub-criteria], implementability, and cost), and compares relative advantages and disadvantages of the alternatives for each SMA and SMA group.

#### 8.1.1 Effectiveness – Protection of Human Health and the Environment

As discussed in EPA (2005), the long-term effectiveness of any remedy depends on source control. The NCP evaluation of overall protectiveness for MNR, containment, and removal remedies is location-specific, and recognizes the following general attributes of these three remedial technologies:

- **MNR** relies (in addition to source control) upon natural sedimentation and biodegradation processes to provide long-term protection; the rate and degree of protection is location-specific.
- **Containment** relies on the isolation of sediment contaminants from human and ecological receptors, and generally relies upon adequate containment system design and long-term maintenance for protection; risk reduction is nearly instantaneous because a clean surface is provided; containment can provide a high level of protection depending upon areal extent, design, and long-term maintenance.
- **Removal** relies upon sediment or contaminant extraction and generally relies upon adequate process design and post-removal management of residuals for protection; removal can provide moderate to high level of protection, depending on resuspension, releases, residual characteristics, and whether the remedy is combined with backfilling, capping, and/or MNR.

Although the level of protectiveness and timeframes vary, all of the alternatives evaluated in Section 7 are projected to reduce sediment SCOI concentrations within a reasonable timeframe (by approximately 2012 to 2016; recovery rates may be refined during remedial design) and, therefore, achieve the Segment 1 RAOs. By achieving the RAOs, these response alternatives provide an acceptable degree of protection to human health and the environment. Nonetheless, there are varying degrees of protectiveness. For example, response action alternatives that include provisions to prevent the release or remobilization of SCOIs into Segment 1 provide more protectiveness than those that do not. Because removal options leave behind residual contaminated sediment, which can result in difficulties or failure to achieve risk-based levels in

sediments, all of the removal alternatives incorporate either a reactive engineered cap (in SMAs 2 and 3 and possibly SMA 6) or a post-removal backfill/sand cover (all other SMAs) to provide an effective means of reducing surface sediment concentrations to further ensure the overall protectiveness of the alternative and its ability to achieve RAOs. Long-term monitoring is a component of all alternatives and will be detailed in the Site-Wide Monitoring Plan.

The SMA-specific evaluations are summarized below, as regards to the *Overall Protection of Human Health and the Environment* criterion:

### SMA 1

- **Alt 1: MNR.** This alternative provides human health and ecological protection and would achieve RAOs through completed source control actions and ongoing natural recovery processes. Bedload dominates the transport of clean sediment into SMA 1, and the sediment transport and natural recovery model predicts that SCOI concentrations in active bed sediments in SMA 1 will decrease to below PLER criteria relatively rapidly, specifically between 2013 and 2016. PCOI (furan and dioxin) concentrations would also be reduced over time. If Alternative 1 is selected by the EPA, additional analyses may be needed during remedial design to refine the projected recovery rates discussed above. In addition, a sediment monitoring program would be developed during the remedial design and implemented as part of this alternative.
- **Alt 2: In situ containment.** This alternative would provide human health and ecological protection and would achieve RAOs by installing an in situ containment cap that would isolate sediments and control chemical migration, physical disturbance, and biological contact with SMA 1 sediments that exceed the PLER. The protection achieved by in situ containment would be comparable to that achieved through MNR, though the containment option would achieve RAOs more quickly than MNR. Protective cap designs for this alternative would be developed following EPA guidance. Sediment stability monitoring and modeling analyses, taken together in a weight-of-evidence evaluation, indicate that a properly designed cap will be protective over time. A monitoring and maintenance program would be implemented to further ensure the long-term effectiveness of the cap.
- **Alt 3: Removal of sediment.** This alternative would provide human health and ecological protection and would achieve RAOs by removing approximately 1,600 cy of surface sediments in SMA 1 that exceed the PLER. The removal option would achieve RAOs more quickly than MNR, but would be comparable to capping. However, the removal option also has potential risks for downstream transport of sediment contaminants without providing measurable improvements compared to capping. Based on significant experience at other sites, a layer of residual sediments will likely remain at the base of SMA 1 that will require management to further ensure the protectiveness of this alternative. The need for and appropriate design of a post-dredge residual backfill sand cover would be determined at the time of construction based on the results of post-dredge verification sampling.

### SMA 2 and 3

- **Alt 1: In situ containment with hydraulic control.** This alternative would provide human health and ecological protection and would achieve RAOs by installing an in situ containment cap and lateral containment structures that would isolate sediments and control chemical migration, physical disturbance, and biological contact with SMA 2 and 3 sediments that exceed the PLER. Several preliminary cap designs for this alternative were developed following EPA guidance, and the most promising option consists of placement of a low-permeability cap and overlying gravel armor layer, coupled with vertical barrier walls joined to the existing RGIS sheet pile wall, ensuring that a negative (downward) hydraulic gradient would be maintained in these SMAs. A monitoring and maintenance program would be implemented to ensure the long-term effectiveness of the containment system.
- **Alt 2: Removal of recoverable product/treatment and in situ containment with hydraulic control.** This alternative would provide human health and ecological protection and achieves RAOs by incorporating all of the in situ containment elements described above, for Alternative 1. This alternative also incorporates removal of recoverable product through recovery wells installed within the contained area, and a hydraulic well pumping system within the containment areas would further induce a negative hydraulic gradient in these SMAs. Product and subsurface water removal would reduce the volume and toxicity of contaminants in the SMAs (see below), providing an additional level of protection by controlling contaminant movement within the containment area. Overall protection of human health and the environment is similar between Alternatives 1 and 2 in so far as both employ similar containment systems, but Alternative 2 provides additional protection through product and subsurface water removal/treatment and active hydraulic control. A monitoring and maintenance program would be implemented to ensure the long-term effectiveness of the containment system.
- **Alt 3: Removal of sediment and post-dredge in situ containment.** Relative to the other SMA 2 and 3 options evaluated, this alternative would provide a moderate degree of protection by removing a total of approximately 8,000 cy of contaminated sediments, including potentially recoverable product from SMAs 2 and 3. Releases of contaminants into the water column during the dredging operation limit the overall protectiveness of this alternative and may limit the ability for sediment removal to achieve RAOs. In addition, relatively high sediment SCOI concentrations (and potential product) are anticipated to remain on the surface of the SMA 2 and 3 dredge cuts under this alternative. A post-dredging reactive cap would need to be placed over the dredged areas to ensure long-term protectiveness. The need for and appropriate design of a post-dredge reactive cap would be determined at the time of construction based on the result of post-dredge verification sampling. A monitoring and maintenance program would be implemented to further ensure the long-term effectiveness of the post-dredge cap.

### SMA 4 and 5

- **Alt 1: MNR.** This alternative would provide human health and ecological protection and would achieve RAOs through completed source control actions and natural recovery processes. Currently, several feet of sediments with concentrations below the PLERs overlie

subsurface sediment SCOI deposits in these SMAs. These surface sediments have established a protective natural cap of sufficient thicknesses to permanently control potential chemical migration and prevent direct contact with the active bed, maintaining sediments below PLER values over time. A sediment monitoring program would be implemented as part of this alternative.

- **Alt 2: In situ containment.** This alternative would provide human health and ecological protection and would achieve RAOs by supplementing the protective natural cap in SMAs 4 and 5 with an armor layer, further ensuring that the clean, near-surface sediment deposits maintain their integrity in the future. However, multiple lines of evidence reveal that existing sediments are currently protected from erosive forces without the additional armor layer. Thus, the protection achieved by in situ containment would be comparable to that achieved through MNR and capping. A cap monitoring and maintenance program would be implemented as part of this alternative.
- **Alt 3: Removal of sediment.** Relative to the other SMA 4 and 5 options evaluated, this alternative would provide a moderate degree of protection by removing a total of approximately 3,500 cy of sediments from SMAs 4 and 5, including clean sediments that currently overlie the subsurface SCOI deposits. Releases of contaminants into the water column during the dredging operation limit the overall protectiveness of this alternative and limit the ability for sediment removal to achieve RAOs. A post-dredging sand cover would need to be placed over the dredged areas to help ensure long-term protectiveness. The need for and appropriate design of a post-dredge residual backfill/sand cover would be determined at the time of construction based on the results of post-dredge verification sampling.

## SMA 6

- **Near shore ethyl parathion deposit.** Only the removal alternative is being considered for the SMA 6 near shore ethyl parathion deposit. This portion of the SMA 6 alternatives provides human health and ecological protection and achieves RAOs through the removal of the ethyl parathion deposit from the river. A post-dredging backfill/sand cover would need to be placed over the dredged areas to further ensure long-term protectiveness. The need for and appropriate design of a post-dredge residual backfill/sand cover would be determined at the time of construction based on the results of post-dredge verification sampling.
- **Alt 1: Product removal/treatment, removal of near shore ethyl parathion deposit, and MNR.** For SMA 6 areas outside of the near shore ethyl parathion deposit, this alternative would provide human health and ecological protection and would achieve RAOs by removal and treatment of recoverable product through recovery wells installed within the SMA. Product removal provides an additional level of protection by controlling contaminant movement. Further protection would be provided by completed source control actions and ongoing natural recovery processes. Currently, several feet of sediments with concentrations below the PLERs overlie the subsurface sediment deposit. These surface sediments have established a protective natural cap of sufficient thicknesses to permanently control potential chemical migration and prevent direct contact with the active bed, maintaining sediments below PLER values over time. A sediment monitoring program would be implemented as part of this alternative.

- **Alt 2:** Product removal/treatment, removal of near shore ethyl parathion deposit, and in situ containment with hydraulic control. This alternative would provide human health and ecological protection and would achieve RAOs by installing an in situ containment cap and lateral containment structures that would isolate sediments and control chemical migration, physical disturbance, and biological contact with SMA 6 sediments that exceed the PLER. Based on preliminary cap modeling performed consistent with EPA guidance, a protective design would consist of a low-permeability cap and overlying gravel armor layer, coupled with vertical barrier walls to ensure that a negative (downward) hydraulic gradient would be maintained in the SMA. In addition, protection would be provided by the removal and treatment of recoverable product and subsurface water through wells installed within the SMA as described above for Alternative 1. A sediment monitoring program would be implemented as part of this alternative.
- **Alt 3: Removal of sediment.** Relative to the other SMA 6 options evaluated, this alternative provides protection by removing approximately 15,000 cy of sediments from SMA 6 (beyond the near shore ethyl parathion deposit discussed above), including clean sediments that currently overlay the subsurface deposits. Releases of contaminants into the water column during the dredging operation limit the overall protectiveness of this alternative and limit the ability to achieve RAOs. In addition, a post-dredging cap (potentially including reactive materials) would need to be placed over the dredged areas to further ensure long-term protectiveness. The need for and appropriate design of a post-dredge residual cap would be determined at the time of construction based on the results of post-dredge verification sampling.

### 8.1.2 Effectiveness – Compliance with ARARs

The NCP evaluation of ARARs is site-specific, and addresses the following general attributes of remedial technologies (EPA 2005):

- **MNR.** No action-specific and location-specific ARARs would apply.
- **Containment.** Key ARARs to be addressed include the regulation of fill materials into waters of the U.S. and the regulation of navigable waterways.
- **Removal.** Solid waste and hazardous waste rules are generally ARARs for disposal of dredged material in solid or hazardous waste landfills.

No chemical-specific ARARs apply to any of the alternatives, because sediment cleanup criteria for response actions under CERCLA are based on site-specific risk evaluations. All alternatives comply with action-specific and location-specific ARARs.

### 8.1.3 Effectiveness – Short-term Effectiveness

This criterion is used to evaluate the effects and potential risks during remedy implementation considering protection of the community and workers and the expected effects on the environment. This criterion also considers the effectiveness of mitigation measures. The NCP evaluation of short-term effectiveness addresses the following general attributes of remedial technologies (EPA 2005):

- **MNR.** In those areas where surface sediments exceed cleanup levels, the short-term effectiveness of MNR depends on the rates of natural processes and contaminant bioavailability. When the time to design, implement, and manage residuals from a removal remedy are considered, the time to achieve RAOs may not differ much. In Segment 1, the remediation timeframe is not a consideration in those SMAs with clean surface sediments (i.e., concentrations below PLERs), because those areas already achieved RAOs. Moreover, there are no additional impacts to ecological communities and public/worker protection from MNR.
- **Containment.** Typically, containment is associated with the shortest time to achieve RAOs because a clean surface is placed. Benthic recolonization of caps with suitable substrate typically occurs within weeks to months following the completion of construction (Sumeri 1996; Alcoa 2002; Simpson 2004). Generally, there is a low potential for health impacts to the public and to workers from contaminant releases during cap placement.
- **Removal.** Removal is expected to result in a significantly higher degree of short-term impacts compared to MNR or containment. Effectiveness of removal is generally more uncertain, due to the difficulty of accurately predicting residual contamination and resuspension/release to the environment during dredging. The presence of residual product in dredge material or at the dredge cut face further exacerbates potential risks and extends the time until RAOs are achieved. There is a potential for health impacts to workers from contaminant releases during dredging. Removal typically results in slower benthic recolonization rates compared with capping; benthic recolonization of removal areas typically occurs within months or several years (Herbich 2000; Szymelfenig et al 2006; Alcoa 2008). Other potential short-term impacts could result from increased traffic associated with the transport of dredged material to disposal facilities.

The SMA-specific evaluations of short-term effectiveness are summarized below:

#### **SMA 1**

- **Alt 1: MNR.** There are no short-term construction-related impacts associated with this alternative. The timeframe to achieve protection of human health and the environment, and thus to achieve RAOs, is within several years of that achieved with the containment and removal alternatives discussed below.
- **Alt 2: In situ containment.** Short-term impacts of this alternative include localized turbidity from placement of the capping materials, mostly generated from the cap material itself, and impacts to benthic and fish communities due to the placement of new materials on existing habitat. Additional impacts may include temporary disruption of upland/shoreline areas due to construction access points, and potential transportation accidents.
- **Alt 3: Removal of sediment.** Impacts of this alternative include resuspension and release of particulate- and dissolved-phase chemicals from sediments to surface water, which may result in increased bioavailability, relocation of those chemicals downstream of the SMAs, as well as localized turbidity impacts. Dredging of sediment is also anticipated to result in residual materials remaining on the sediment surface following removal activities. Transport of dredged sediments to the dewatering pad and final disposition in a landfill also present

potential short-term risks. Additional impacts may include benthic and fish community impacts, temporary disruption of upland/shoreline areas due to construction access points, and potential transportation accidents.

### **SMA 2 and 3**

- **Alt 1: In situ containment and hydraulic control.** Short-term impacts of this alternative include localized turbidity from placement of the capping materials, mostly generated from the cap material itself, and impacts to benthic and fish communities due to the placement of new materials on existing habitat. Short-term impacts could occur during installation of the barrier walls and from placement of the capping materials. These impacts will primarily be in the form of turbidity from the capping materials themselves, but could potentially also include dissolved and particulate releases of contaminants from the existing sediments during barrier wall installation. However, results from other sites (e.g., Anchor QEA and ARCADIS 2010) indicate that contaminant releases during installation of barrier walls are often lower than those resulting from excavation/dredging. Additional impacts may include temporary disruption of upland/shoreline areas due to construction access points, and potential transportation accidents.
- **Alt 2: Removal/treatment of recoverable product and in situ containment with hydraulic control.** Same as Alternative 1.
- **Alt 3: Removal of sediment and post-dredge in situ containment.** Short-term impacts of this alternative include resuspension and release of particulate- and dissolved-phase chemicals from sediments and product to surface water, which may result in increased bioavailability, relocation of those chemicals downstream of the SMAs, as well as localized turbidity impacts. Dredging of sediment is also anticipated to result in residual materials remaining on the sediment surface following removal activities. In addition, there is the potential for unintended sediment disturbances related to a temporary enclosure installation due to changes in hydrodynamic conditions caused by the enclosure. Transport of dredged sediments to the dewatering pad and final disposition in a landfill also present potential short-term risks. Additional impacts may include temporary disruption of upland/shoreline areas due to construction access points, and potential transportation accidents.

### **SMA 4 and 5**

- **Alt 1: MNR.** There are no short-term construction-related impacts associated with this alternative. Surface sediments in these SMAs are currently below PLERs, and thus currently achieve RAOs.
- **Alt 2: In situ containment.** Short-term impacts of this alternative include localized turbidity from placement of the capping materials, mostly generated from the cap material itself, and impacts to benthic and fish communities due to the placement of new materials on existing habitat. Additional impacts may include temporary disruption of upland/shoreline areas due to construction access points, and potential transportation accidents.
- **Alt 3: Removal of sediment.** Impacts of this alternative include resuspension and release of particulate- and dissolved-phase chemicals from sediments and potential SCOI deposit

materials to surface water, which may result in increased bioavailability, relocation of those chemicals downstream of the SMAs, as well as localized turbidity impacts. Dredging of sediment is also anticipated to result in residual materials remaining on the sediment surface following removal activities. Transport of dredged sediments to the dewatering pad and final disposition in a landfill also present potential short-term risks. Additional impacts may include temporary disruption of upland/shoreline areas due to construction access points, and potential transportation accidents.

## SMA 6

- **Near shore ethyl parathion deposit.** Only the removal alternative is being considered for the SMA 6 near shore ethyl parathion deposit (see Alternative 3 discussion below, for a discussion of short-term effectiveness associated with removal).
- **Alt 1: Product removal/treatment, removal of near shore ethyl parathion deposit, and MNR.** There are no short-term construction-related impacts associated with this alternative. Surface sediments in SMA 6 beyond the ethyl parathion deposit are currently below PLERs, and thus currently achieve RAOs.
- **Alt 2: Product removal/treatment, removal of near shore ethyl parathion deposit, and in situ containment with hydraulic control.** Short-term impacts of this alternative include localized turbidity from placement of the capping materials (mostly due to the capping material itself) and impacts to benthic and fish communities (due to the placement of new materials on existing habitat). Short-term impacts could potentially also include dissolved and particulate releases of contaminants from the existing sediments during barrier wall installation. However, results from other sites (e.g., Anchor QEA and ARCADIS 2010) indicate that contaminant releases during installation of barrier walls are often lower than those resulting from excavation/dredging. Contaminant release from existing sediments is not expected in SMA 6, since surface sediments are currently below PLER levels. Additional impacts may include temporary disruption of upland/shoreline areas due to construction access points, and potential transportation accidents.
- **Alt 3: Removal of sediment.** Impacts of this alternative include resuspension and release of particulate- and dissolved-phased chemicals from sediments and potential SCOI deposit materials to surface water, which may result in increased bioavailability, the potential relocation of those chemicals downstream, and localized turbidity impacts. Dredging of sediment is also anticipated to result in residual materials remaining on the sediment surface following removal activities. Transport of dredged sediments to the dewatering pad and final disposition in a landfill also present potential short-term risks. In addition, there is the potential for unintended sediment disturbances related to a temporary enclosure installation due to changes in hydrodynamic conditions caused by the enclosure. Additional impacts may include temporary disruption of upland/shoreline areas due to construction access points, and potential transportation accidents.

#### 8.1.4 Effectiveness – Long-term Effectiveness and Permanence

As discussed in EPA (2005), the NCP evaluation of long-term effectiveness and permanence addresses the following general attributes of remedial technologies with respect to the risk reduction, residual risk, and adequacy and reliability of controls for residual risk:

- **MNR.** With respect to the risk reduction and residual risk, MNR may provide an acceptable level of risk reduction depending on processes being relied upon and site-specific characteristics that might enhance the long-term isolation or destruction of contaminants. In all cases where MNR is identified as a response alternative, site-specific conditions are expected to achieve RAOs within a reasonable timeframe or already have achieved RAOs based on existing sediment chemistry.
- **Containment.** With respect to risk reduction and residual risk, containment provides a high level of risk reduction and results in low to moderate residual risk, depending on cap design and maintenance to address site characteristics that might otherwise inhibit long-term isolation of contaminants. With respect to the adequacy and reliability of controls to manage residual risk, containment can be designed to provide a high level of control with respect to cap stability and contaminant migration through the cap.
- **Removal.** With respect to risk reduction and residual risk, removal may provide moderate to high level of risk reduction and low to moderate residual risk, depending on the effectiveness of dredging and the use of caps or backfill/sand cover material to address dredging residuals. Whereas product removal can be implemented in a controlled manner that creates little risk of off-site chemical releases, sediment removal can disrupt current conditions that contribute to low risks by resuspending contaminated sediment, releasing particulate and dissolved phase chemicals from sediments, and generating a surficial layer of residual contaminated sediment. Thus, removal can significantly exacerbate potential risks, thereby reducing its long-term effectiveness. With respect to the adequacy and reliability of controls for residual risk, removal may provide high control due to removal of contaminants, if residual contamination is addressed through backfill/sand covers or capping.

Evaluations of the long-term effectiveness and permanence provided by each alternative in Section 6 considered factors such as the magnitude of potential risk remaining following implementation and the adequacy of control measures. The potential success of each alternative in meeting the RAOs identified in Section 4.2 forms the basis for the comparative assessment of long-term effectiveness and permanence.

The SMA-specific evaluations of long-term effectiveness and permanence are summarized below:

##### SMA 1

- **Ait 1: MNR.** In this alternative, reductions in potential exposures and risks would continue as a result of previous source control activities and ongoing natural recovery processes, achieving RAO 1 between 2013 and 2016, subject to refinement during remedial design. Long-term monitoring and existing source controls and institutional controls would achieve RAO 3, ensuring the long-term effectiveness and permanence of the remedy.

- **Alt 2: In situ containment.** In this alternative, all RAOs would be achieved through placement of a cap, which is expected to be permanent based on design. Long-term monitoring and existing source controls and institutional controls would ensure the long-term effectiveness and permanence of the remedy.
- **Alt 3: Removal of sediment.** In this alternative, all RAOs would be achieved through sediment removal and placement of a post-dredge residual backfill cover. The long-term effectiveness of this alternative will partly depend on the completeness of the sediment removal and the degree of resuspension and residuals remaining following dredging, as well as ongoing source control measures.

### SMA 2 and 3

- **Alt 1: In situ containment and hydraulic control.** In this alternative, all RAOs would be achieved through placement of a barrier wall/cap and associated hydraulic controls, which is expected to be permanent based on design. Long-term monitoring and institutional controls would ensure the long-term effectiveness and permanence of the remedy.
- **Alt 2: Product removal/treatment and in situ containment with hydraulic control.** This alternative would achieve a higher overall effectiveness and permanence compared to Alternative 1, due to the removal of recoverable product through recovery wells installed within the contained area. Hydraulic controls would help further ensure long-term protectiveness by providing additional hydraulic control on contaminant migration and by extracting contaminants from the environment for treatment.
- **Alt 3: Removal of sediment and post-dredge in situ containment.** In this alternative, all RAOs would be achieved through removal and placement of a reactive cap to contain dredging residuals. The long-term effectiveness of this alternative would be partly dependent on the completeness of the sediment removal, the degree of resuspension and residuals remaining following dredging, and the degree of off-site contaminant release during removal, as well as ongoing source control measures.

### SMA 4 and 5

- **Alt 1: MNR.** Clean, near-surface sediment deposits in SMA 4 and 5 currently achieve RAO 1, and TEQ concentrations will also continue to decline over time through natural recovery processes, contributing to achievement of RAO 2. Long-term monitoring and existing institutional controls would achieve RAO 3, ensuring the long-term effectiveness and permanence of the remedy. Sediment stability monitoring and modeling analyses, taken together in a weight-of-evidence evaluation, indicate that the sediment bed is stable, contributing to RAO 3.
- **Alt 2: In situ containment.** In this alternative, all RAOs would be achieved through placement of a cap armor layer. Long-term monitoring and existing institutional controls would also ensure the long-term effectiveness and permanence of the remedy.
- **Alt 3: Removal of sediment.** In this alternative, all RAOs would be achieved through sediment removal and placement of a post-dredge residual backfill sand cover. The long-term effectiveness of this alternative would be partly dependent on the completeness of the

sediment removal, the degree of resuspension and residuals remaining following dredging, and the degree of off-site contaminant release during removal, as well as ongoing source control measures.

## SMA 6

- **Near shore ethyl parathion deposit.** Only the removal alternative is being considered for the SMA 6 near shore ethyl parathion deposit (see Alternative 3 discussion below for a discussion of long-term effectiveness associated with removal).
- **Alt 1: (Product removal/treatment, removal of near shore ethyl parathion deposit, and MNR).** This alternative will provide long-term effectiveness through the removal and treatment of recoverable product, along with removal of the near shore ethyl parathion deposit and placement of a post-dredge backfill/sand cover. Furthermore, clean near-surface sediment deposits in SMA 6 (outside of the near shore ethyl parathion deposit) currently achieve RAO 1, and TEQ concentrations will continue to decline over time through natural recovery processes, contributing to achievement of RAO 2. Long-term monitoring and existing institutional controls would achieve RAO 3, ensuring the long-term effectiveness and permanence of the remedy. Sediment stability monitoring and modeling analyses, taken together in a weight-of-evidence evaluation, indicate that the sediment bed is stable, also contributing to RAO 3.
- **Alt 2: Product removal/treatment, removal of near shore ethyl parathion deposit, and in situ containment with hydraulic control.** In this alternative, all RAOs would be achieved through a combination of product removal and treatment, removal of the near shore ethyl parathion deposit, and placement of a low permeability cap and lateral containment barriers (e.g., sheet pile wall). Long-term monitoring and existing institutional controls would also ensure the long-term effectiveness and permanence of the remedy.
- **Alt 3: Removal of sediment.** In this alternative, all RAOs would be achieved through sediment removal and placement of a post-dredge cap. The long-term effectiveness of this alternative will be partly dependent on the completeness of the sediment removal, the degree of resuspension and residuals remaining following dredging, and the degree of off-site contaminant release during removal, as well as ongoing source control measures.

### 8.1.5 Effectiveness – Reduction of Toxicity, Mobility, or Volume

The NCP evaluation of reduction of toxicity, mobility, or volume through treatment addresses the following general attributes of remedial technologies (EPA 2005):

- **MNR.** No treatment is involved beyond natural in situ biodegradation processes. Mobility and bioavailability of contaminants can be reduced significantly by natural capping processes.
- **Containment.** Typically, no treatment is involved in capping. However, the potential mobility and bioavailability of the contaminants is significantly reduced by placement of the cap material. Furthermore, consistent with EPA guidance and experience from other sites, installation of an appropriately designed low permeability and/or reactive cap impedes

contaminant migration and immobilizes oily product, reducing the toxicity and mobility of residual sediments.

- **Removal.** The removal and treatment of recoverable product and subsurface water containing dissolved phase contaminants would reduce toxicity, mobility, and volume. Mobility and volume can also be reduced to the extent that the contaminant mass is successfully removed, but only for the removed fraction of contaminant mass. Post-dredge residuals that remain can be more mobile and thus more bioavailable than they are prior to dredging due to the disturbance of the cohesive sediment bed and/or the exposure of higher subsurface SCOI concentrations that are present at depth.

The degree to which each alternative reduces the toxicity, mobility, or volume through treatment was evaluated in Sections 7.2 through 7.5. In-river reductions in mobility and toxicity are expected to occur through implementation of all alternatives evaluated. The SMA-specific evaluations of reduction of toxicity, mobility, or volume are summarized below.

### SMA 1

- **Alt 1: MNR.** This alternative contributes to the reduction in contaminant volume, toxicity, and mobility via long-term sedimentation and biodegradation of SCOIs (e.g., PAHs).
- **Alt 2: In situ containment.** Same as Alternative 1; cap placement under Alternative 2 would further reduce the mobility of underlying SCOIs through isolation.
- **Alt 3: Removal of sediment.** In this alternative, mobility would be reduced by removing contaminated sediment from the river and placing the sediments in an engineered landfill.

### SMA 2 and 3

- **Alt 1: In situ containment with hydraulic control.** In this alternative, mobility of SCOIs would be reduced through the isolation of sediments beneath a low-permeability cap and within a lateral containment and hydraulic control system.
- **Alt 2: Product removal/treatment and in situ containment with hydraulic control.** In addition to reducing the mobility and bioavailability of SCOIs through the isolation of sediments beneath a low-permeability cap and within a lateral containment system, this alternative also reduces contaminant volume and toxicity through removal and treatment of recoverable product and capture of subsurface water by the hydraulic containment system and treatment using the WWTP. Only Alt 2 includes product treatment and thus a reduction in contaminant volume.
- **Alt 3: Removal of sediment and post-dredge in situ containment.** In this alternative, reduction of toxicity and mobility might be realized if treatment of dredged sediments is required prior to offsite disposal, subject to waste characterization during remedial design. In addition, mobility would be reduced by removing contaminated sediment from the river and placing the sediments in an engineered landfill. The installation of an appropriately designed reactive cap to manage post-dredge residuals can permanently impede migration and immobilize oily product, reducing the toxicity and mobility of residual sediments. This alternative risks increasing contaminant mobility and toxicity during construction through the

release of contaminants during dredging. This is the only alternative that risks increasing mobility and toxicity.

#### **SMA 4 and 5**

- **Alt 1: MNR.** The clean, near-surface sediment deposits overlying subsurface SCOI-containing deposits are currently acting as a “natural” cap and act to reduce the mobility of SCOIs through physical and chemical isolation of sediments.
- **Alt 2: In situ containment.** Same as Alternative 1, but mobility of underlying SCOIs would be further reduced through isolation capping.
- **Alt 3: Removal of sediment.** In this alternative, mobility would be reduced by removing contaminated sediment from the river and placing the sediments in an engineered landfill. This alternative risks increasing contaminant mobility and toxicity during construction through the release of naturally sequestered and isolated contaminants during dredging. This is the only alternative that risks increasing mobility and toxicity.

#### SMA 6

- **Near shore ethyl parathion deposit.** Only the removal alternative is being considered for the SMA 6 near shore ethyl parathion deposit (see Alternative 3 discussion below, for a discussion of the reduction of toxicity, mobility, or volume associated with removal).
- **Alt 1: Product removal/treatment, removal of near shore ethyl parathion deposit, and MNR.** Reduction in toxicity, mobility, and volume of contaminants would occur through the treatment of recovered product under this alternative.
- **Alt 2: Product removal/treatment, removal of near shore ethyl parathion deposit, and in situ containment with hydraulic control.** Same as Alternative 1 but mobility of underlying SCOIs would be further reduced through isolation capping.
- **Alt 3: Removal of sediment.** In this alternative, reduction of toxicity and mobility might be realized if treatment of dredged sediments is required prior to offsite disposal, subject to waste characterization during remedial design. In addition, mobility would be reduced by removing contaminated sediment from the river and placing the sediments in an engineered landfill. This alternative risks increasing contaminant mobility and toxicity during construction through the release of naturally sequestered and isolated contaminants during dredging. This is the only alternative that risks increasing mobility and toxicity.

#### **8.1.6 Implementability**

The NCP evaluation of implementability addresses the following general attributes of remedial technologies (EPA 2005):

- **MNR.** Generally, no construction is required, and thus MNR is readily implementable.
- **Containment.** Typically, cap placement and barrier wall installation methods are well established, and reliability is generally high depending on site-specific conditions and the degree of monitoring and maintenance. Past experience in Reaches B and D show that

capping is implementable in Segment 1. Challenges associated with capping include ensuring that capping is implemented under optimal hydrodynamic conditions and identifying and constructing access points to the river while minimizing impacts to the natural environment.

- **Removal.** While dredging methods are also well established, the technical feasibility of dredging is highly location-specific, dependent on the extent of debris and dredge residual contamination. Past experience at Reaches D and O show that removal can impose unique implementability challenges, including managing river flow conditions, achieving low target SCOI and PCOI concentrations, and conducting the removal work under normal flow conditions. Furthermore, sediment removal adjacent to the RGIS sheet piling or other structures could result in impacts to the integrity or stability of RGIS. An evaluation of the impacts on the RGIS sheet pile system would need to be performed if removal alternatives are selected, and the remedial design would consider removal methods that minimize the risk of negative effects on RGIS. Construction monitoring and/or protective measures would need to be understood and implemented to ensure that sediment removal actions would not affect RGIS and its operations.

All of the SMA-specific alternatives are implementable. All equipment, personnel, and materials necessary to implement the alternatives are anticipated to be locally available.

### 8.1.7 Cost

As discussed in EPA (2005), the NCP evaluation of cost addresses the following general attributes of remedial technologies:

- **MNR.** Generally, there is no construction cost, but long-term monitoring costs typically continue until RAOs are met.
- **Containment.** Typically, construction costs for capping are higher than MNR and lower than dredging.
- **Removal.** Typically, construction costs for dredging are higher than for capping. All removal alternatives include a cap or cover (as appropriate) for residual management. An additional consideration with removal costs is the degree of uncertainty in the volume of sediments to be removed, and the likely need for post-dredge residual management activities.

Table 8-1 presents a comparison of costs for each SMA alternative.

## 8.2 Consistency with EPA's National Policy

According to EPA's (2005) national policy: "The focus of remedy selection should be on selecting the alternative best representing the overall risk reduction strategy for the site according to the NCP remedy selection criteria .... EPA's policy has been and continues to be that there is no presumptive remedy for any contaminated sediment site, regardless of the contaminant or the level of risk." Moreover, at many sites "a combination of sediment cleanup methods may be the most effective way to manage the risk" (EPA 2005).

EPA's (2002) eleven Risk Management Principles were developed to provide guidance to EPA site managers in "making scientifically sound and nationally consistent risk management decisions at contaminated sediment sites." As such, the risk management principles contained within the 2002 Principles "should be tailored to the size and complexity of the site, to the magnitude of site risks, and to the type of action contemplated" (EPA 2002). These eleven risk management principles were incorporated into and expanded upon in EPA's (2005) guidance. The following briefly summarizes these principles (*in italics*) and describes how efforts completed to date align with each principle.

1. *Control sources early* – Throughout the facility's history, Dow has strived to use the state-of-the-art waste management and source control systems, meeting or exceeding the requirements of state and federal regulations, including the federal CWA. The current waste management and source control systems are composed of the following components:
  - Wastewater management and treatment
  - Incinerators and emissions control systems
  - Storm water management and treatment
  - RGIS groundwater containment
  - Sand bar containment system

A description of each source control component and a brief description of their historical development are presented in Section 2.5.

2. *Involve the community early and often* – Extensive community involvement activities have been conducted to keep the local community informed and provide a mechanism for the community to interact with EPA, DEQ, and Dow. These activities include the following:
  - Formation of a Community Advisory Group (CAG) for the project, numerous public availability sessions, and public meetings
  - Development of a Community Involvement Plan (EPA 2010).
  - Development and maintenance of active internet sites by EPA (<http://www.epa.gov/region5/sites/dowchemical>) and Michigan DEQ (<http://www.michigan.gov/deqdioxin>).
  - Public review periods to allow the public to review this draft Response Proposal and to submit comments to the Agencies
3. *Coordinate with States, Local Governments, Tribes, and Natural Resource Trustees* – This principle is administered by EPA and has been accomplished through routine technical team meetings and information sharing and collaboration.
4. *Develop and refine a conceptual site model that considers sediment stability* – The Segment 1 CSM was developed based on a substantial dataset generated from considerable site-specific studies. The extensive work conducted on the river to date, combined with

hydrodynamic and sediment transport modeling, provide a cohesive weight of evidence with regards to sediment stability, supporting the remedy evaluation process.

5. *Use an iterative approach in a risk-based framework* – Multiple early actions have been conducted (e.g., Reach B and D actions; see Section 2.6) to evaluate remedial technologies and advance the remediation of the river.
6. *Carefully evaluate the assumptions and uncertainties associated with site characterization data and site models* – Extensive use of targeted data collection efforts have been made throughout the project to reduce uncertainty tied both to the conceptual site model and the nature and extent of contamination.
7. *Select site-specific, project-specific, and sediment-specific risk management approaches that will achieve risk-based goals* – This Segment 1 Response Proposal presents the results of the analysis of site-specific data, CERCLA evaluation criteria including the NCP criteria, RAOs, and potential remedial alternatives.
8. *Ensure that sediment cleanup levels are clearly tied to risk management goals* – Under each potential alternative, RAOs intended to protect human and ecological receptors have been established. Metrics tied to these RAOs were used to evaluate expected changes resulting from implementation of each potential remedial alternative.
9. *Maximize the effectiveness of institutional controls and recognize their limitations* – Institutional controls are already in place for Segment 1, and will be maintained as long as necessary.
10. *Design remedies to minimize short-term risks while achieving long-term protection* – This Response Proposal evaluates short-term and long-term risk associated with each alternative. The recommended approach to be selected by EPA is expected to provide the fewest short-term risks while achieving long-term protection.
11. *Monitor during and after sediment remediation to assess and document remedy effectiveness* – Monitoring during remediation activities and long-term monitoring are components of all alternatives, and will be detailed in SMA-specific monitoring plans or in the Site-Wide Monitoring Plan.

Based on the evaluations in this Segment 1 Response Proposal, EPA will select an appropriate combination of technologies specific to each SMA that will be effective and implementable, resulting in a protective and cost-effective approach with minimal short-term impacts.

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