STRATUS CONSULTING

Natural Resource Damage Assessment Plan for the Tittabawassee River System Assessment Area

Prepared under contract for:

Remediation and Redevelopment Division
Michigan Department of Environmental Quality
PO Box 30426
Lansing, MI 48909
Contact: Judith Gapp

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Acronyms and Abbreviations

AM	Assessment Manager
AO	authorized official
ATS	Ann Arbor Technical Services
BERA	baseline ecological risk assessment
BIA	Bureau of Indian Affairs
CAS	Chemical Abstracts Service
CDF	confined disposal facility
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cfs	cubic feet per second
COC	chain of custody
CWA	Clean Water Act (Federal Water Pollution Control Act)
DM	Department Manual
DOI	U.S. Department of the Interior
DQO	data quality objective
EPA	U.S. Environmental Protection Agency
ERA	ecological risk assessment
FCA	fish consumption advisory
FEMA	Federal Emergency Management Agency
FS	feasibility study
FTL	Field Team Leader
GPS	global positioning system
IRA	interim response action
MDA	Michigan Department of Agriculture
MDAG	Michigan Department of the Attorney General
MDCH	Michigan Department of Community Health
MDEQ	Michigan Department of Environmental Quality
MDL	method detection limit
MDNR	Michigan Department of Natural Resources
MGD	million gallons per day

NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NPDES	National Pollutant Discharge Elimination System
NRDA	natural resource damage assessment
NREPA	Natural Resources and Environmental Protection Act
NWR	National Wildlife Refuge
PBBs	polybrominated biphenyls
PCBs	polychlorinated biphenyls
PCDDs	polychlorinated dibenzo-p-dioxins
PCDFs	polychlorinated dibenzofurans
PCOI	primary constituents of interest
PI	Principal Investigator
PM	Project Manager
ppm	parts per million
pptr	parts per trillion
PRP	potentially responsible party
QA	quality assurance
QAPP	quality assurance project plan
QC	quality control
RCDP	restoration and compensation determination plan
RCRA	Resource Conservation and Recovery Act
RGIS	revetment groundwater interceptor system
RI	remedial investigation
RIWP	remedial investigation work plan
RPD	relative percent difference
SAP	sampling and analysis plan
SDWA	Safe Drinking Water Act
SLERA	Screening Level Ecological Risk Assessment
SOP	standard operating procedure
SRM	standard reference material
2,4-D	2,4-dichlorophenoxyacetic acid
TCDD	2,3,7,8-tetrachlorodibenzo-*p*-dioxin
TEQ	toxicity equivalent
TRSAA	Tittabawassee River System Assessment Area
TRV	toxicity reference value
TSA	Technical System Audit

USFWS	U.S. Fish and Wildlife Service
UTR	Upper Tittabawassee River
WWI	World War I
WWII	World War II
WWTP	wastewater treatment plant

1. Introduction

1.1 Statement of Purpose

The State of Michigan, represented by the Michigan Department of Environmental Quality (MDEQ), the Michigan Department of Natural Resources (MDNR), and the Michigan Department of the Attorney General (MDAG); the Saginaw Chippewa Tribe; and the U.S. Department of the Interior (DOI), represented by the U.S. Fish and Wildlife Service (USFWS) and the Bureau of Indian Affairs (BIA), collectively the Trustees, are conducting a natural resource damage assessment (NRDA) to restore natural resources, and the services they provide, that have been injured as a result of releases of hazardous substances[1] at and from the Dow plant property in Midland, Michigan to the Tittabawassee River System Assessment Area (TRSAA). Dow has been identified as a potentially responsible party (PRP) for those releases. The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [42 USC §§ 9607 *et. seq.*], the Federal Water Pollution Control Act (Clean Water Act or CWA) [33 USC §§ 1321 *et. seq.*], the Oil Pollution Act [33 USC §§ 2701 *et. seq.*], and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) [40 CFR § 300, Subpart G] provide the Trustees authority to seek damages and to make the public whole for injuries to natural resources. The Trustees prepared a Preassessment Screen and Determination following federal regulations at 43 CFR § 11.23. The Preassessment Screen was a review of readily available information, from which the Trustees determined that hazardous substance releases[2] at and from Dow were likely to have injured natural resources (USFWS, 2006). The Trustees therefore concluded that an assessment should proceed.

This Assessment Plan also has been prepared in accordance with federal regulations at 43 CFR Part 11.[3] The purpose of the Assessment Plan is to describe the Trustees' approach for conducting an NRDA in the TRSAA and to propose assessment work to determine and quantify natural resource restoration necessary to make the public whole for losses caused by natural resource injuries resulting from Dow's releases of hazardous substances.

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1. In this document, the term "hazardous substances" refers to hazardous substances as defined in federal regulations at 40 CFR § 302.4 and Part 201 of the Michigan Natural Resources and Environmental Protection Act (NREPA), M.C.L. 324.20101 *et seq*.

2. CERCLA Section 101(22) defines "release" as any "spilling, leaking, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing into the environment."

3. The application of these regulations is not mandatory, and the Trustees have the option of diverging from them. However, assessments performed in compliance with these regulations have the force and effect of a rebuttable presumption in any administrative or judicial proceeding under CERCLA [42 USC § 9607(f)(2)(C)].

1.2 Trusteeship Authority

This section describes natural resource trusteeship. Multiple Trustees may share trusteeship for specific TRSAA natural resources.

1.2.1 State trustees

Pursuant to federal regulations at 40 CFR § 300.605, state trustees "shall act on behalf of the public as trustees for natural resources, including their supporting ecosystems, within the boundary of the state or belonging to, managed by, controlled by or appertaining to such state." The Dow plant and surrounding area are within the boundaries of the State of Michigan, and the Tittabawassee River, Saginaw River, and Saginaw Bay are waters of the State of Michigan. The governor of a state may designate state trustee agencies. The Directors of the MDEQ, the MDNR, and the Attorney General of the State of Michigan have been designated as natural resource trustees for the State of Michigan, pursuant to Section 107(f)(2)(B) of CERCLA.

1.2.2 Federal trustees

As directed by CERCLA [42 USC § 9607(f)(2)(A)], the President has designated in the NCP the federal officials who are authorized to serve as natural resource trustees [40 CFR § 300.600(b)]. The Secretary of the DOI has trustee authority under the NCP for natural resources "belonging to, managed by, held in trust by, appertaining to, or otherwise controlled" by the DOI [40 CFR §§ 300.600(b), (b)(2), and (b)(3)]. Such natural resources include "land, fish, wildlife, biota, air, water, groundwater, drinking water supplies, and other such resources" [40 CFR § 300.600(a)], as well as "their supporting ecosystems" [40 CFR § 300.600(b)]. In addition to the trustee responsibility set forth in federal regulations at 40 CFR Part 300, the Secretary of the DOI is also charged under other authorities as a trustee for the trust assets of Indian tribes. Such trusteeship is based on statute, treaty, and case law. "It is the policy of the Department of the Interior to recognize and fulfill its legal obligations to identify, protect, and conserve the trust resources of federally recognized Indian tribes and tribal members" [512 Departmental Manual (DM) 2.1].

U.S. Fish and Wildlife Service

The Secretary of the Interior has delegated to bureau directors the authority to act on behalf of the DOI as the authorized official (AO) in conducting NRDA activities [207 DM 6.3B]. The Regional Director of USFWS Region 3 serves as DOI's AO for the TRSAA. Acting through the USFWS AO, the DOI is authorized by CERCLA [42 USC § 9007(f)] to act on behalf of the Secretary to conduct NRDA, restoration planning, and implementation for DOI's natural resources. The statutory bases for USFWS trusteeship include, but are not limited to, the

National Wildlife Refuge System Improvement Act [16 USC §§ 668dd *et seq*.], as amended by the National Wildlife Refuge System Improvement Act of 1997, the Fish and Wildlife Act [16 USC §§ 742a *et seq*.], the Migratory Bird Conservation Act [16 USC §§ 715 *et seq*.], the Refuge Recreation Act [16 USC §§ 460k-1], the Migratory Bird Treaty Act [16 USC §§ 703 *et seq*.], the Bald and Golden Eagle Protection Act [16 USC §§ 668 *et seq*.], and the Endangered Species Act [16 USC §§ 1531 *et seq*.].

Bureau of Indian Affairs

BIA has management authority and trust responsibility to protect, preserve, and defend the trust resources of the Saginaw Chippewa Indian Tribe of Michigan. BIA is a co-trustee over the same natural resources as the tribe under CERCLA [42 USC § 9607(f)(2)(A)] and the NCP [40 CFR § 300.600(b)(2)].

1.2.3 Tribal trustees

An Indian tribe is a trustee for “natural resources belonging to, managed by, controlled by, or appertaining to such tribe, or held in trust for the benefit of such tribe, or belonging to a member of such tribe if such resources are subject to a trust restriction on alienation” [42 USC § 9607(f)(1)]. Such natural resources including “their supporting ecosystems” [40 CFR § 300.610]. The NCP recognizes the chairman of an Indian tribe as a natural resource trustee acting on behalf of the tribe [40 CFR § 300.610]. The Saginaw Chippewa Indian Tribe of Michigan is a Trustee of the TRSAA.

1.3 Decision to Perform a Type B Assessment

Federal regulations at 43 CFR Part 11 describe two types of assessments: Type A and Type B. Trustees may select between performing a Type A or a Type B NRDA [43 CFR § 11.33]. Type A procedures are “simplified procedures that require minimal field observation” [43 CFR § 11.33(a)], while Type B procedures require more extensive field observation [43 CFR § 11.33(b)] and are implemented in multiple phases [43 CFR § 11.60(b)]. The simplified Type A models have been developed only for Great Lakes environments and coastal and marine environments [43 CFR § 11.33(a)]. These models are appropriate for discrete spills of hazardous substances and/or petroleum products up to a few days in duration, with injuries based on acute exposure via the surface water pathway only [see publication incorporated by reference at 43 CFR § 11.18(a)(5)]. Since none of these conditions apply to the TRSAA, a Type A assessment is inappropriate. Furthermore, the nature of the releases and natural resource injuries require more extensive field observations, making a Type B assessment appropriate [43 CFR § 11.33(b)]. Therefore, the Trustees are conducting a Type B assessment in this NRDA.

1.4 Natural Resource Damage Assessment Process

NRDA is a process by which trustees of natural resources determine natural resource restoration sufficient to make the public whole, for losses caused by injuries resulting from releases of hazardous substances that are not prevented by response actions. The measure of such restoration may include the “cost of restoration, rehabilitation, replacement, and/or acquisition of the equivalent of the injured natural resources and the services those resources provide,” and the “compensable value of all or a portion of the services lost to the public for the time period from the . . . release until the attainment of the restoration, rehabilitation, replacement, and/or acquisition of equivalent of the resources and their services to baseline” [43 CFR § 11.80(b)], where baseline is the condition of the resources and services that would exist had the release of hazardous substances not occurred.

The Trustees intend to follow federal regulations at 43 CFR Part 11 for the Tittabawassee NRDA to the extent practical. In addition, the Trustees intend to conduct elements of the assessment cooperatively with Dow. The Trustees have entered into a funding and participation agreement with Dow that is available on the MDEQ and USFWS websites. The agreement specifies how parts of the NRDA can be conducted cooperatively with Dow. The Trustees envision an assessment based on Dow-implemented cooperative work, Trustee-implemented cooperative work, and (as needed to accomplish Trustee goals) independent Trustee work. The Trustees intend to oversee and participate fully in any cooperative studies and related activities implemented by Dow, and the Trustees intend to allow Dow to participate in any cooperative studies and related activities implemented by the Trustees. The public will be given the opportunity to review any formal plans for assessment work by the Trustees, as appropriate. Assessment work currently planned by the Trustees is described in Chapter 5 of this Assessment Plan. Additional assessment work formally proposed by the Trustees (whether cooperative or independent) will be described in future Assessment Plan addenda, study plans, and standard operating procedures (SOPs) for public review, as appropriate.

The four major phases in a Type B NRDA process are the preassessment phase, the assessment plan phase, the assessment phase, and the post-assessment phase.

1.4.1 Preassessment phase

The preassessment phase of an NRDA is the first step in conducting an NRDA. Trustees must rapidly review available data, determine whether or not to proceed with an assessment [43 CFR § 11.13(b)], and then document this decision in a preassessment screen and determination [43 CFR § 11.23(c)]. The preassessment screen and determination for the TRSAA was completed on November 3, 2006 (USFWS, 2006). A copy of the preassessment screen and determination is listed on the MDEQ and USFWS websites. In accordance with the criteria at 43 CFR § 11.23(e), the preassessment screen and determination demonstrates that:

- A discharge or release of hazardous substances has occurred
- Natural resources for which the Trustees may assert trusteeship under CERCLA have been or are likely to have been adversely affected
- The quantity of the release is sufficient to potentially cause injury
- Data to perform an assessment are available or obtainable at a reasonable cost
- Response actions do not or will not sufficiently remedy the injury to natural resources without further action [43 CFR § 11.23(e)].

Thus, the Trustees concluded that they should proceed with an NRDA to develop a damage claim under CERCLA [42 USC § 9607] and other applicable law.

1.4.2 Assessment plan phase

After deciding to perform an NRDA, Trustees prepare an assessment plan. The assessment plan ensures that the assessment is well planned, conducted systematically, and that the selected methods for assessment are cost-effective [43 CFR § 11.13(c)]. The assessment plan confirms the exposure of natural resources to hazardous substances and/or petroleum products (Chapter 4 of this plan), describes the objectives of any testing and sampling for injury or pathway determination (Chapter 5 of this plan), and provides a quality assurance project plan (QAPP) to ensure quality control in testing and sampling (Chapter 6 of this plan) [43 CFR § 11.31(c)(2)].

The assessment plan may also include a restoration and compensation determination plan (RCDP). However, if insufficient information is available to develop the RCDP at the time of the rest of assessment plan preparation, the RCDP may be developed later [43 CFR § 11.31(c)(4)]. This assessment plan contains an approach to conduct restoration planning and scaling (Chapter 5); a complete RCDP will be developed later, potentially in phases.

1.4.3 Assessment phase

The assessment phase is when the evaluation of injuries and damages is conducted. The parts of a Type B assessment are summarized here and described in greater detail in Chapter 5.

1. **Injury determination**: Injury determination establishes whether and what natural resources have been injured as a result of the release of hazardous substances [43 CFR § 11.13(e)(1)]. It also involves determining the pathway, or route, through which the hazardous substances were transported from sources to the injured resource [43 CFR § 11.61(c)(3)].

2. **Quantification**: Quantification establishes the amount or natural resource restoration necessary to offset the losses caused by natural resource injuries. The extent and degree of injuries, the ability of the resource to recover, and the reduction in services can be included in the quantification [43 CFR § 11.71(c)].

3. **Damage determination**: Damage determination establishes the amount of appropriate compensation expressed as a dollar amount required to accomplish sufficient natural resource restoration as compensation for the injuries [43 CFR § 11.13(e)(3)]. Damages may include the cost of "restoration, rehabilitation, replacement, and/or acquisition of the equivalent of the natural resources and the services those resources provide" and the value of losses from the time of the release to the reestablishment of the services to baseline conditions [43 CFR § 11.80(b)]. Baseline conditions are the conditions that "would have existed at the assessment area had the discharge of oil or release of the hazardous substance under investigation not occurred" [43 CFR § 11.14(e)]. Damages also include the costs of performing the assessment.

1.4.4 Post-assessment phase

The post-assessment phase is the final step in an NRDA process. After the assessment is complete, the Trustees produce a report of assessment containing the results of the NRDA [43 CFR § 11.90]. The Trustees may then seek recovery of damages from the PRP [43 CFR § 11.91], and such damages may include direct and indirect costs "necessary to complete all actions identified in the selected alternative for restoration, rehabilitation, replacement, and/or acquisition of equivalent resources" [43 CFR § 11.83(b)]. If damages are awarded, or a settlement is reached, a restoration plan is developed and implemented using the recovered money.

1.5 Natural Resource Damage Coordination with Response Actions

An NRDA must account for any response actions such as cleanup indicated by a remedial investigation/feasibility study (RI/FS) or decided by a record of decision [43 CFR § 11.31(a)(3)]. The Trustees realize that implementing a protective remedy, whether as corrective actions under

Resource Conservation and Recovery Act (RCRA) licenses or as cleanup under CERCLA, is of primary importance for protection of natural resources. However, cleanup cannot achieve full restoration of injured natural resources and the services provided by those resources because injuries have already occurred and will continue while and after cleanup actions are implemented. In general, the more protective (speed and degree) the cleanup, the less residual injury to natural resources. Consequently, less extensive restoration is then required to return the resources to their baseline condition and less compensation is required to make the public whole for interim losses. The Trustees have coordinated, and will continue to coordinate, with MDEQ and the U.S. Environmental Protection Agency (EPA) as they implement corrective actions and response activities.

The goals of this coordination are to avoid duplication, reduce costs, and achieve multiple objectives where practical. At a minimum, the Trustees intend to consider the objectives of RCRA corrective actions, CERCLA removal actions, and CERCLA remedial actions during the continued planning and implementation of the NRDA. Whenever practical, the Trustees will explicitly coordinate damage assessment activities with other investigations and will ensure, whenever possible, that parties undertaking remediation or corrective activities understand the Trustees' NRDA objectives and how their activities impact natural resource injuries, services, and restoration.

1.6 Public Review and Comment

The Trustees intend for this Assessment Plan to communicate the assessment approach to the public so that the public can become engaged and actively participate in, or comment on, assessment activities. Public input may also provide the Trustees with new information and ideas that they may incorporate into their assessment.

The Assessment Plan is available for public review and comment, as required by 43 CFR § 11.33. The public comment period will last for 30 days, with reasonable extensions granted, if appropriate. The public comment period begins on the date the notice of availability is published in the Federal Register. Any comments received by the Trustees, together with responses to those comments, will be included in the report of assessment. Comments on this Assessment Plan may be submitted in writing to:

Lisa Williams, Lead Administrative Trustee
U.S. Fish and Wildlife Service
2651 Coolidge Road, Suite 101
East Lansing, MI 48823

The Assessment Plan may be modified at any stage of the assessment as new information becomes available. However, any significant modification to the assessment plan will be made available for public comment and review for 30 days [43 CFR § 11.32(e)].

1.7 Organization of the Assessment Plan

This Assessment Plan is divided into six sections. Chapter 1 introduces the plan by describing the authority and process by which the Trustees have undertaken the development of the assessment. Chapter 2 discusses the geography, ecology, and natural resources of the assessment area. Chapter 3 presents a history of the Dow plant and describes the nature and sources of the releases of hazardous substances as they relate to RIs, site characterization study results, and current and past response actions in the TRSAA. Chapter 4 confirms that natural resources in question have been exposed to hazardous substances released from the Dow plant. Chapter 5 presents the approaches for assessing and quantifying injuries to different natural resources, and Chapter 6 describes the QAPP. The list of all references cited in the document follows Chapter 6.

2. Description of the Assessment Area

In this chapter we provide descriptions of the three broad geographical regions included in the TRSAA: (1) the Tittabawassee River and floodplain, the Saginaw River and floodplain, and Saginaw Bay; (2) the areas affected by aerial deposition of airborne matter originating from the plant property; and (3) Dow's Midland manufacturing plant property.

Section 2.1 describes the Tittabawassee River, the Saginaw River, and the Saginaw Bay with respect to their location, geomorphology, and relevant anthropogenic influences. Section 2.2 describes the currently known extent of the area affected by aerial deposition. Section 2.3 describes the tertiary treatment ponds located on the plant property. It is anticipated that, as the assessment progresses, additional areas within the Dow property may be identified for inclusion in the NRDA. Finally, Section 2.4 describes the biota of the TRSAA.

2.1 River System

2.1.1 Tittabawassee River location, geomorphology, hydrology, and anthropogenic influences

Geographical location

The Tittabawassee River (Figure 2.1) drains a 2,600 square mile watershed in the east-central Lower Peninsula of Michigan and is a tributary to the Saginaw River [Ann Arbor Technical Services (ATS), 2007]. The headwaters of the Tittabawassee River originate in the largely forested landscape of Roscommon and Ogeman counties north of Midland County. The Pine and Chippewa rivers join the Tittabawassee River upstream of the City of Midland. Bullock Creek flows into the Tittabawassee River though the southern end of Dow's Midland plant. Upstream of the Midland plant, river flow is regulated by four hydroelectric dams: the Secord, Smallwood, Edenville, and Sanford dams (FERC, 1998). Of the four, the Sanford Dam exerts the greatest influence on river flow, causing diurnal fluctuations in response to hydroelectric energy demand and production (ATS, 2007). The Dow Dam is located adjacent to the Midland plant, and below this dam the river is free flowing until it reaches its confluence with the Shiawassee and Saginaw rivers.

On the stretch of river below Midland, the river flows south and southeast for 22 miles before its confluence with the Shiawassee and Saginaw rivers. Within this reach, there are numerous small agricultural drains that flow into the river. The Towns of Mapleton, Freeland, and Shields are located along the river. The Tittabawassee River joins the Shiawassee River in the Shiawassee National Wildlife Refuge (NWR) to form the Saginaw River just south of the City of Saginaw.

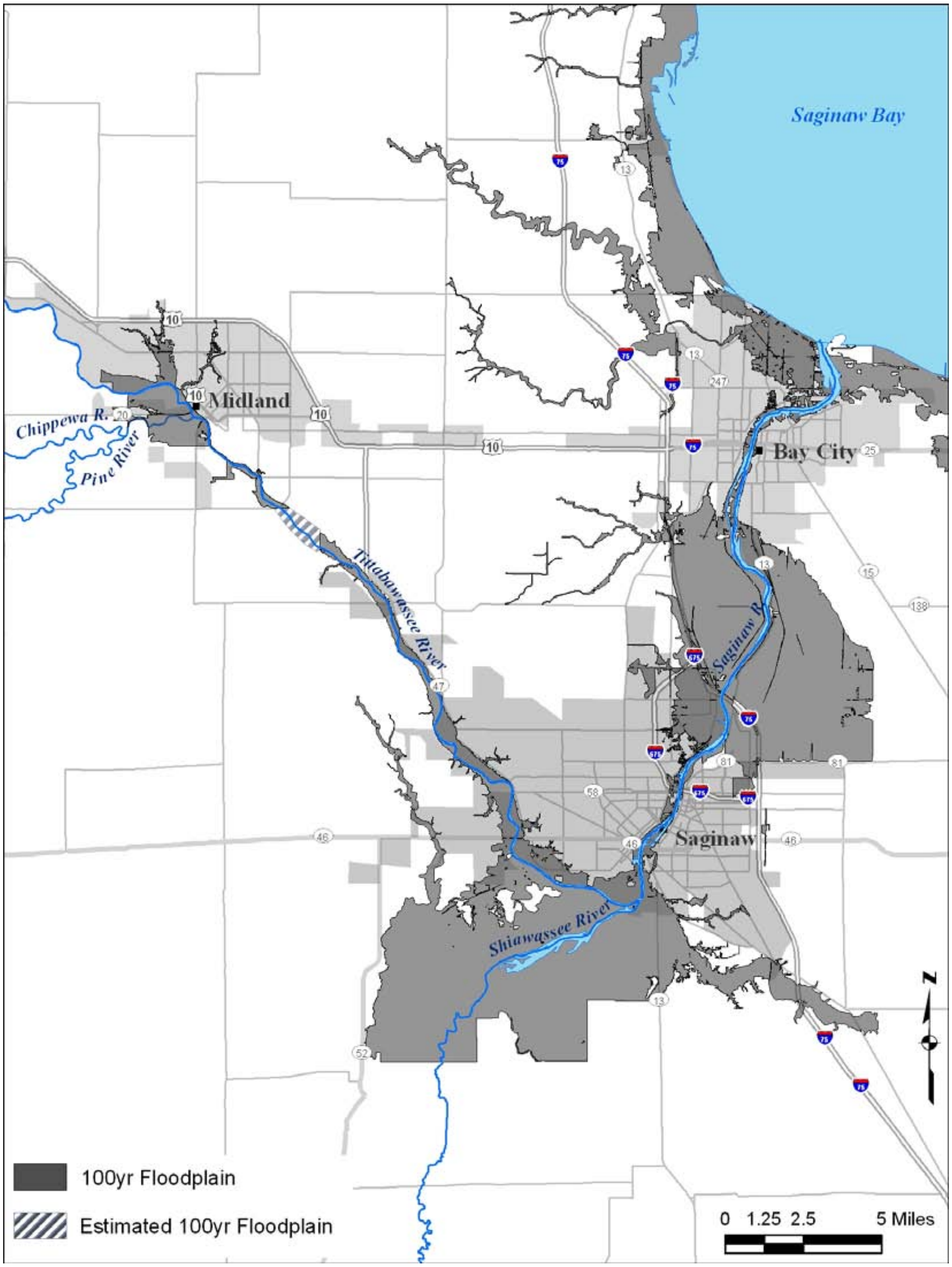

Figure 2.1. Map of the Tittabawassee River, Saginaw River, Saginaw Bay, and their 100-year floodplains. Dark gray demarcates the 100-year floodplain. Hatched gray indicates areas for which the Federal Emergency Management Agency (FEMA) does not currently have floodplain data (FEMA, 1995).

Geomorphology

Between Midland and Saginaw, the Tittabawassee River valley is characterized by relatively flat floodplains extending to a steep scarp rising to upland areas. The river channel varies from relatively straight between the Dow Midland plant and Freeland Park (approximately 4.5 river miles), to a more sinuous system downstream of Freeland Park. The straight nature of the upper part of the river is the result of anthropogenic activities and restrictions, including historical logging operations, extensive sheet pile along the riverbank, and steep constructed banks along the Midland plant (ATS, 2006b, 2007).

Between Freeland Park and the confluence with the Shiawassee River, there are fewer laterally constraining anthropogenic features. Moving downstream, the channel becomes more sinuous and meanders through a broadening floodplain, displaying erosional and depositional features, such as cut banks, point bars, levees, and overbank deposits. Erosion tends to occur on the outsides of the river bends, forming cut banks, and deposition tends to occur on the insides, forming point bars. Depositional features also occur within the floodplain, including levees and overbank deposits. Overbank deposits are found in low-lying areas of the floodplain where fine materials settle out of suspension following floods. Levees are ridges or embankments of sand and silt that are built by the river on its floodplain along both banks of its channel. Levees accrue particularly during flood events when water overflowing the normal banks slows and deposits larger grained particles. The Tittabawassee River has a distinct double-levee geomorphology, consisting of what are often referred to as “pre-industrial” and “post-industrial” natural levees. The formation of the levees is thought to be associated with changes to the hydrology and hydraulics of the river caused by dam installation, first during the logging era (“pre-industrial” levees), and later for flood control and hydroelectric power generation (“post-industrial” levees; ATS, 2006b, 2007). In particular, the construction of the Sanford Dam in 1925 caused a narrowing of the river channel, which formed the younger “post-industrial” levees interior to the older “post-industrial” levees (ATS, 2006b). Studies are ongoing to develop a better understanding of the fluvial dynamics and geomorphology of the river (ATS, 2006b, 2007).

Flow regime

The Tittabawassee River flow regime is “flashy,” meaning that it has highly variable flows with a rapid rate of change (ATS, 2007). The average and 100-year flood flow rates for the river, based on data from 1937 and 1984, are approximately 1,700 cubic feet per second (cfs) and 45,000 cfs, respectively (Johnson Co., 2001, as cited in ATS, 2006b). The Tittabawassee River has a long history of flooding, with flows greater than 20,000 cfs occurring in 22 of the 95 years of monitoring. The flood stage of the river at Midland is 24 feet (17,300 cfs), but at 20 feet (approximately 9,000 cfs) some bank overflow begins in isolated areas (NOAA, 2007).

Anthropogenic influences

The Tittabawassee River's geomorphology has been affected by many human activities, including extensive logging, construction of dams for flood control and hydroelectric power generation, and riverbank stabilization by riprap or sheet piling. Daily fluctuations in river water levels due to the four dams upstream of Midland may play a significant role in bank erosional processes. Forested headwaters of the Tittabawassee River, north of Midland, were once dominated by eastern hemlock (*Tsuga Canadensis*), eastern white pine (*Pinus strobus*), and sugar maple (*Acer saccharum*; MNFI, 1998, as cited in ATS, 2007). Beginning in about 1847, this forest was extensively logged (ATS, 2006b). Saw logs were rafted down the river to mills in the City of Saginaw. The intensive logging substantially reduced vegetative cover and affected the hydrology of the watershed. Erosion and sedimentation increased due to increased surface runoff, and base flow decreased. Logjams were common and also affected river flow, erosion, deposition patterns, and aquatic riparian habitat. The Dow Dam, constructed at the Dow Midland plant in Midland in 1945 to provide a reliable water source for Dow plant operations, further altered river geomorphology. Sheet piling and other construction on the riverbank along the Dow plant site also have had substantial impacts on in-stream and riparian habitats (ATS, 2006b, 2007). For example, artificial stabilization of riverbanks at the site likely increased the incision of the river within its current channel, which may have decreased habitat complexity.

2.1.2 Saginaw River location, geomorphology, and anthropogenic influences

Location

The Saginaw River begins at the confluence of the Tittabawassee and Shiawassee rivers, and runs in a generally northeasterly direction, emptying into Saginaw Bay of Lake Huron, approximately 90 miles north of Detroit, Michigan. The Saginaw River is 22 miles long and most of its flow originates from four major tributaries: the Cass, Flint, Shiawassee, and Tittabawassee rivers. The Saginaw River is a relatively low energy river that varies in width from 375 feet to 800 feet.

Geomorphology

The channel of the Saginaw River is relatively straight. In the urban areas of Saginaw and Bay City, the shoreline is dominated by industry, but a few parks are also present. The banks here are armored with various types of riprap and sheet pile (ATS, 2006b). Between the two urban areas, the river corridor largely consists of agricultural lands and the Crow Island State Game Area (Figure 2.2).

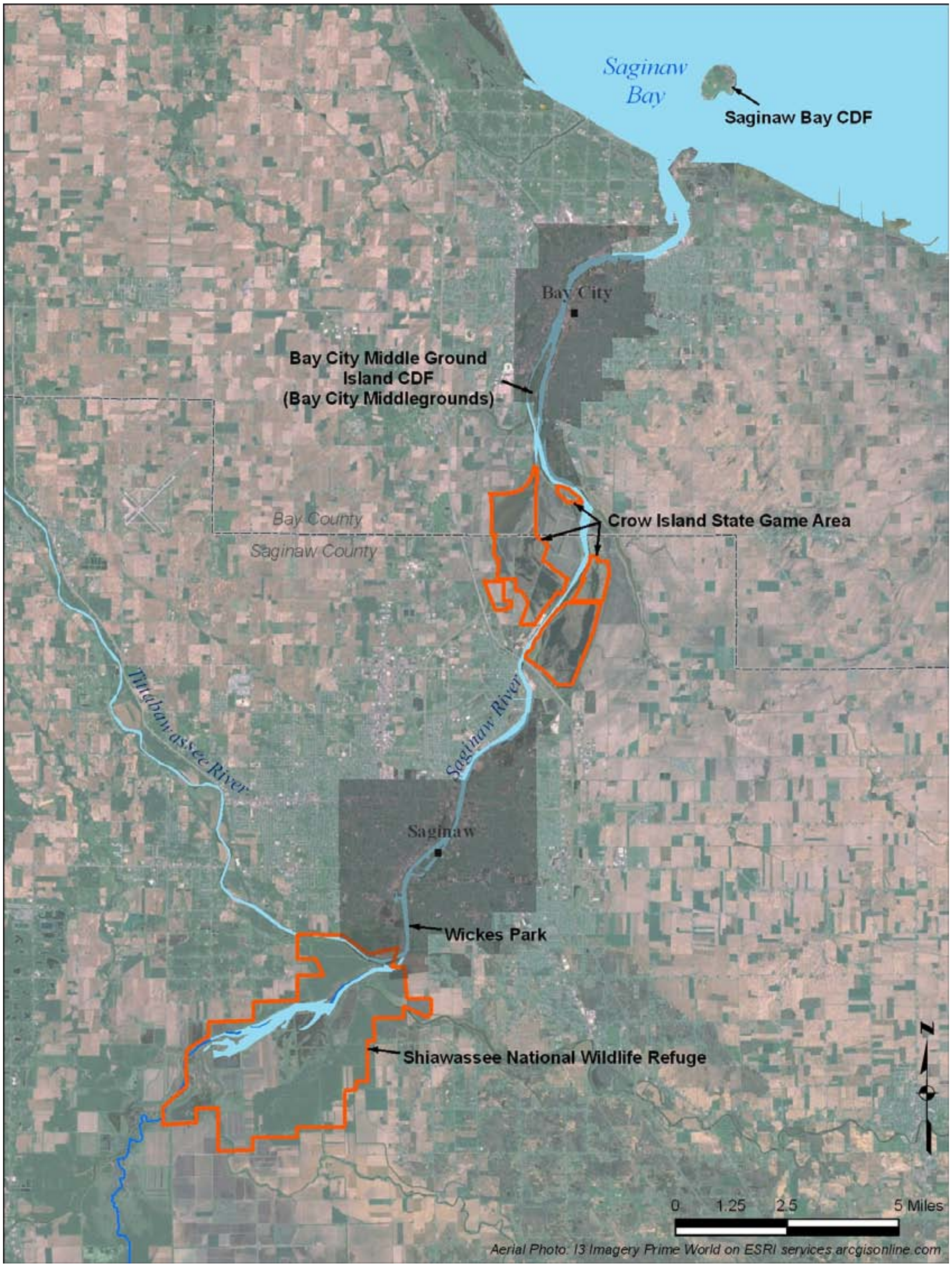

Figure 2.2. Map of the Saginaw River and Saginaw Bay showing the Shiawassee National Refuge, the Crow Island State Game Area, and the Saginaw Bay and Middle Ground Island confined disposal facilities (CDFs).

Anthropogenic influences

The U.S. Army Corps of Engineers has actively dredged the Saginaw River channel since 1963 to accommodate commercial shipping activity (USACE, 2007). Dredged sediments have either been placed in open water out in the Bay, or deposited in one of two CDFs (see Figure 2.2). Sediments dredged from parts of the navigation channel in the Saginaw River and Saginaw Bay have elevated levels of polychlorinated biphenyls (PCBs; PSC, 2002), and hence require confined disposal. Dredging activities have likely redistributed contaminated sediments within the TRSAA. Shipping along the Saginaw River may also contribute significantly to the redistribution of contaminated sediments.

Like the Tittabawassee River, the Saginaw River has been affected by historical activities related to logging. The Saginaw River was the site of numerous sawmills in the 1800s and early 1900s. It also served as a port for Great Lakes vessels. Later, the bicycle and automobile industries replaced lumber mills, bringing their own industrial impacts. General Motors owned and operated four major automobile manufacturing plants along the Saginaw River beginning in the 1910s (CRA, 1992). Municipal wastewater treatment plants (WWTPs) are also located along the Saginaw River in the City of Saginaw and Bay City. Urbanization of the watershed, channelization of the river, active dredging, commercial shipping, and industry all have altered aquatic habitats.

2.1.3 Saginaw Bay

Saginaw Bay is on the western shore of Lake Huron. The Bay has a drainage basin of 8,700 square miles. Twenty-eight rivers, creeks, and drainages flow directly into Saginaw Bay, but approximately 75% of the tributary hydraulic load comes from the Saginaw River (Beeton et al., 1967). The Bay is 26 miles wide at the mouth and 51 miles long from the midpoint to the mouth of the Saginaw River. Saginaw Bay has a surface area of 1,143 square miles (MDNR, 1994e). A broad shoal between Big Charity Island and Sand Point divides the Bay into outer and inner zones. The outer zone is considerably deeper (mean depth 48 feet, maximum 133 feet) than the inner zone (mean depth 15 feet, maximum 46 feet). The eastern shore of the outer bay is rocky and the western is sandy. The Bay has several islands; the most prominent is Big Charity Island between Whitestone and Oak points. A group of marshy low-lying islands (North, Stony, and Katechay) lies southwest of Sand Point on the southeast shore of the Bay. These islands are surrounded by marshy shallows that provide important habitat for waterfowl (PSC, 2002).

The typical surface current in the Bay is counterclockwise, due to a strong Lake Huron current that flows down the western edge of the outer bay. Long-term chloride monitoring by Dow indicates that waters from the Saginaw River flow north along the eastern shore of the Bay toward the open waters of Lake Huron. The Bay freezes in the winter and ice flows along the deeper water west of the Coreyon Reef (Batchelder, 1973).

2.2 Aerial Deposition Area Associated with the Dow Plant

Sources of airborne matter from the plant include emissions from incinerators, open burning of wastes, wind blown dust, and emissions from production units and power plants. The extent of aerial deposition has not yet been fully characterized, but it extends approximately 3 miles from the Dow plant in some places (CH2M Hill, 2005a). Current studies, such as the Midland Area Soils Study (Dow Chemical, 2007b), are focused on residential, commercial, industrial, and recreational/undeveloped properties surrounding the Midland plant (Dow Chemical, 2007b). These areas likely provide habitat for wildlife species, including songbirds and small mammals. Further, the regional topography of the area indicates that surface waters within aerial deposition areas generally drain toward the Tittabawassee River (Dow Chemical, 2007b). Storm water runoff that passes through the aerial deposition area could carry contaminated sediment and thus could serve as a pathway to TRSAA contamination.

2.3 Dow Midland Plant Property

The Dow Midland plant property covers approximately 1,900 acres. Within this area, there are historical waste burial sites and multiple surface water impoundments, including brine and treatment ponds (Figure 2.3). The historical waste burial sites have been identified as potential sources of groundwater contamination (ATS, 2006a, 2006b), and may have been historical sources of exposure to terrestrial biota.

In 1974, Dow constructed three tertiary wastewater treatment ponds (ATS, 2006b; Dow Chemical, 2007b). These ponds, commonly referred to as “T-ponds,” are uncovered and have a combined total surface area of approximately 200 acres with a capacity of 780,000,000 gallons (MDEQ, 2006e) (Figure 2.3). Operation of the T-ponds has been regulated by Dow’s National Pollutant Discharge Elimination System (NPDES) permit since 1988. The ponds collect wastewater from the plant, and the water is filtered to remove particulates before being discharged into the Tittabawassee River (Dow Chemical, 2007b). The T-ponds could fall within the 100-year floodplain, but FEMA does not have floodplain data for the brine and T-ponds complex geographical area (FEMA, 1995). However, the available FEMA data suggest that the ponds fall within the 100-year floodplain. The ponds were inundated in at least one documented flood, which occurred in 1986, and untreated or partially treated chemical wastes entered the Tittabawassee River (MDCH, 2004b).

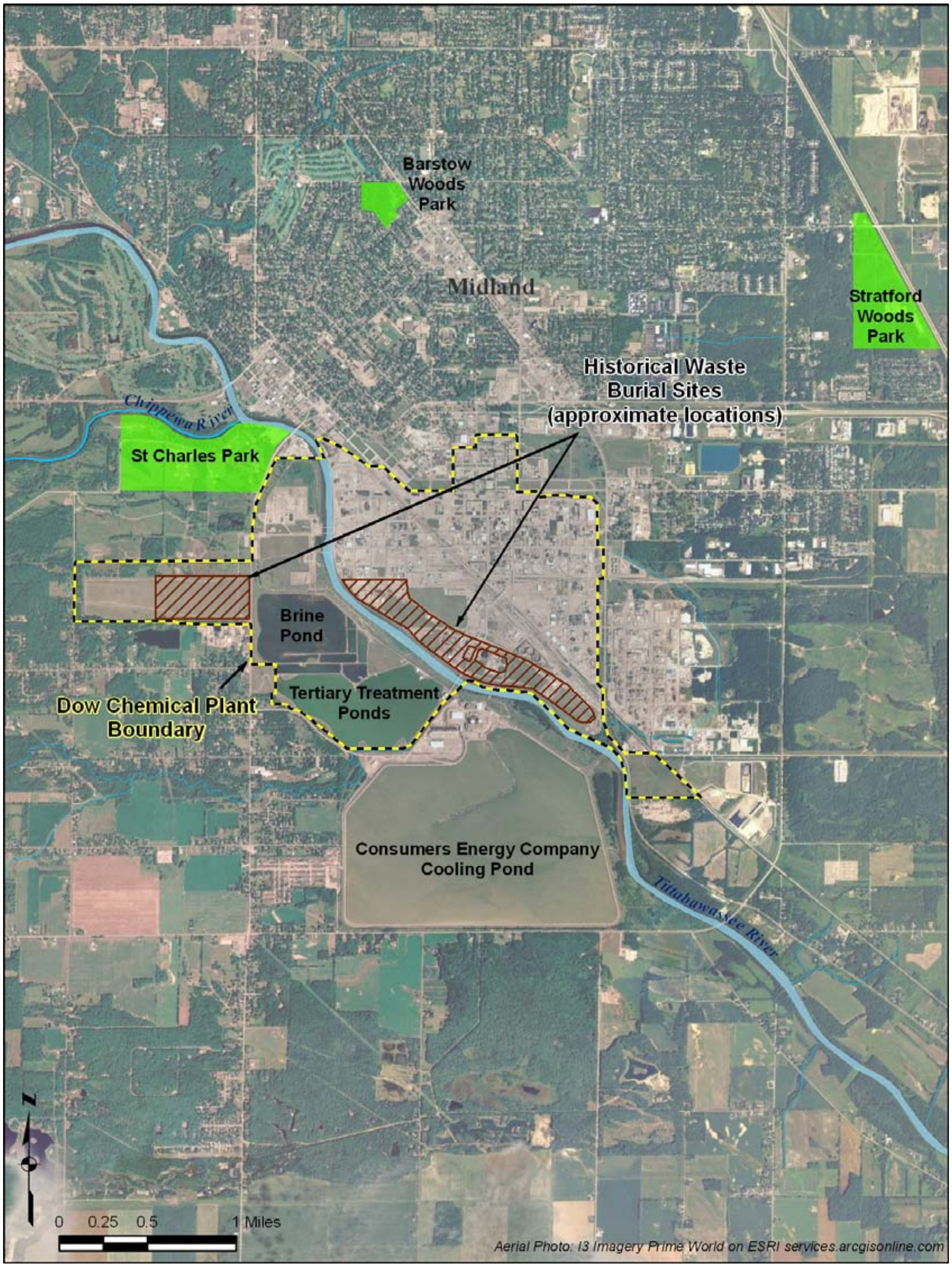

Figure 2.3. Map showing the Dow Midland manufacturing plant property boundary, tertiary treatment ponds, known historical waste burial sites, and parks near the Dow plant (ATS, 2006b).

Since the ponds are uncovered, aquatic birds can be attracted to their open waters. Terrestrial wildlife in the area might also utilize the T-ponds for drinking water. The release of stored wastes from the ponds during flooding events could also expose aquatic biota downstream of the Dow plant to contaminants.

2.4 TRSAA Biota

2.4.1 Aquatic biota

Benthic macroinvertebrates

Benthic macroinvertebrates live on or near the river bottom and serve several ecological functions, including degrading and digesting plant material and serving as prey for fish, birds, and small mammals. They can also serve as indicators of pollution. Data from the 1970s and 1980s show that the Tittabawassee and Saginaw rivers were dominated by pollution-tolerant invertebrates, such as aquatic worms (*Limnodrilus* spp.) and midges (*Chironomus* spp.; Zillich, 1972; Zillich et al., 1973; Sylvester, 1974; Gersich et al., 1985). For example, Zillich et al. (1973) investigated substrate-dependent (i.e., hard structure-dependent and non-burrowing) macroinvertebrate communities, and found that communities downstream of the Dow plant were lower in diversity and density than those from sites upstream of the plant.

The mayfly *Hexagenia limbata* is a particularly important benthic invertebrate in the Great Lakes region, as it is a major component of the fish forage base. Mayfly nymphs are normally common in silt bottoms of large, clean streams and lakes throughout the region. Historically, this species was abundant in the Tittabawassee and Saginaw rivers and their tributaries. In fact, Krieger (1998) reports historical descriptions of mayflies covering buildings and darkening the skies. This immense biomass of high quality prey likely supported the fisheries in the area. However, as with other invertebrate species, the presence of the Dow plant seemed to detrimentally affect this species. In 1971, mayflies (*Hexagenia* spp.) were present in samples collected from the Pine and Cass rivers (tributaries to the Tittabawassee and Saginaw rivers, respectively), but not in the Tittabawassee River downstream of Dow. Mayflies were also absent from samples taken from the lower Tittabawassee River in the summer of 1974 (Sylvester, 1974). In 1985, very few mayflies were collected in sediment grab samples taken near the Dow Midland plant instream diffuser (Gersich et al., 1985); pollution tolerant oligochaetes and chironomids dominated the samples.

The patterns observed in the Tittabawassee and Saginaw rivers were paralleled by changes in Saginaw Bay. Again, the mayfly, *H. limbata*, was abundant in Saginaw Bay before the mid-1950s. However, by 1955, only a few individuals were present in sediment samples, and by 1971, mayflies had entirely disappeared, likely because of poor water quality (Surber, 1955b;

Batchelder, 1973). Mayflies were still rare in the Bay in 1994 (MDNR, 1994b). Degraded environmental conditions in Saginaw Bay are further underscored by the disappearance of crustacean and clam (e.g., *Pisidium* spp.) populations. These species were absent in the Bay in 1970; as with the Saginaw and Tittabawassee rivers, pollution tolerant aquatic worms and midges dominated (Batchelder, 1973).

More recent benthic invertebrate surveys conducted in the TRSAA have shown that benthic and aquatic invertebrates have increased in diversity since these earlier studies. In November 2003 and February 2004, Michigan State University researchers collected benthic and aquatic emergent invertebrates from the Tittabawassee River and reference sites along the Chippewa and Pine rivers. The study revealed that the highest diversity was found at the reference sites. However, at least one or two members of pollution-sensitive taxa, including mayfly (Ephemeroptera), stonefly (Plecoptera), and caddisfly (Trichoptera) taxa were found at each site sampled below the Dow plant (Matthew Zwiernik, personal communication, March 20, 2008), indicating that downstream sites are capable of supporting sensitive invertebrate species. Other invertebrates found at downstream sites include mussels, snails, crayfish, dragonfly nymphs, amphipods, aquatic beetles, and diptera midges (Matthew Zwiernik, personal communication, March 20, 2008), most of which are relatively tolerant to pollution (Barbour et al., 1999).

Benthic aquatic invertebrate communities in the TRSAA have also changed following the introduction and establishment of exotic species, most notably, after the introduction of zebra mussels (*Dreissena polymorpha*) and quagga mussels (*Dreissena rostriformis bugensis*) in the early to mid-1990s (USGS, 2006). In the Great Lakes, exotic mussels alter benthic invertebrate communities (Botts and Patterson, 1996), accumulate and subsequently expose biota to contaminants (Bruner et al., 1994), provide prey for important fish species (Cobb and Watzin, 2002), and out compete native bivalves (Haag et al., 1993).

Fish

Historical and recent surveys in the TRSAA indicate the presence of a variety of fish species, including sizeable populations of carp (*Cyprinus carpio*), channel catfish (*Ictalurus punctatus*), quillback (*Carpiodes cyprinus*), and freshwater drum (*Aplodinotus grunniens*). In addition, moderate to heavy spawning runs of walleye[1] (*Sander vitreus vitreus*), white bass (*Morone chrysops*), suckers (*Catostomus* spp.), and other species pass through the Saginaw River on their way up to various tributaries (MDNR, 1994e).

1. Walleye egg and milt collected from spawning migrations of walleye in the Tittabawassee River have been supplied to hatcheries that are used to stock waters across Michigan (Fielder and Thomas, 2006).

The shallow waters of Saginaw Bay once provided outstanding habitat for a wide variety of fish and were among the most productive waters in the Great Lakes (MDNR, 1994e). Although human activities and invasive species have reduced this historic productivity and reduced the abundance of certain species, the Bay is still attractive to a broad range of species. Its highly diverse aquatic habitats provide spawning and nursery areas as well as food sources for larval and adult fish. These waters support commercial fishing for yellow perch (*Perca flavescens*), channel catfish, and carp and are also popular for recreational fishing and waterfowl hunting. Attachment A contains additional information on fish and other species found in the vicinity of Saginaw Bay and its tributaries, including the Tittabawassee and Saginaw rivers.

Populations of several important species have declined from historical levels, and the fish community in the Bay is substantially different from the one that existed before 1900 (MDNR, 1994e). For example, lake herring (*Coregonus artedi*) were once an important part of the commercial fishery in Saginaw Bay, but have nearly vanished. Lake trout (*Salvelinus namaycush*) were also abundant in outer Saginaw Bay, but populations are now maintained through stocking of hatchery-reared fish. Walleye were once naturally abundant in the region, but pollution and over-fishing through the early 1900s, coupled with an influx of exotic species like alewife (*Alosa pseudoharengus*) and rainbow smelt (*Osmerus mordax*), contributed to the decline of walleye populations as early as the late 1940s. Decreases in fish productivity in the Bay and associated tributaries may also have been caused, at least in part, by the shift in benthic macroinvertebrate communities from pollution-intolerant/high-quality prey species to pollution-tolerant/low-quality prey species.

Walleye populations have rebounded since the late 1940s, in part from efforts by the MDNR. In the late 1970s, the MDNR began maintaining the walleye population through the plantings of artificially propagated fish (MDNR, 2004). From these historic lows, the walleye fishery has grown and developed into an important fishery. Currently, growth rates in Saginaw Bay are 135% of the state average, and the average walleye is 4-5 pounds (MDNR, 2004). Recent fish surveys also suggest that about 80% of recent walleye year classes were the result of natural reproduction (Fielder and Thomas, 2006). Improvements in the walleye fishery have been principally attributed to the decline and near absence of adult alewives, which are believed to prey upon, and compete with, newly hatched walleye fry. Ideal spring climate conditions are also thought to have aided reproduction in 2003.

Birds

USFWS (2007b) composed a list of aquatic bird species found in the Shiawassee NWR. The list contains 277 species, including 32 species of swans, geese, and ducks, 29 species of sandpipers, and 14 species of gulls and terns, as well as bald eagle, five species of heron, and three egret species. In addition, Saginaw Bay's shallow marshes and sandy islands provide ideal habitat for waterfowl during annual migrations through the region, and many of the aquatic bird species found in the NWR are also observed in the Bay (Peters, 2008).

2.4.2 TRSAA terrestrial and wetland biota

The Tittabawassee River, Saginaw River, and Saginaw Bay watersheds lie within the Huron/Erie Lake Plains Ecoregion (U.S. EPA, 2002). That ecoregion is a broad, fertile, nearly flat plain punctuated by relic sand dunes, beach ridges, and glacial end moraines. Before disturbance by human activities, elm-ash swamp and beech-white pine upland forests dominated the area. Oak savanna was typically restricted to sandy, well-drained dunes and beach ridges. Today, most of the area has been cleared and artificially drained and contains highly productive farms. The bulk of current land use in the Tittabawassee and Saginaw River subwatersheds is agriculture (Table 2.1). Soybeans and grain corn were the dominant crops by acreage in 2002 (PSC, 2002).

Table 2.1. Summary of land use in the Saginaw Bay watershed

Land use	Percent cover
Agriculture	46%
Forest	29%
Open lands	11%
Urban	8%
Wetlands	4%
Water	2%

Source: PSC, 2002.

The remaining forested areas within the Tittabawassee and Saginaw River watersheds occur in patches, and are generally in a mid-successional stage. Using the Michigan Natural Features Inventory Community Classification system, these areas are classified as mesic northern forest, which is characterized by varying dominance of conifers and hardwoods and includes a defined scrub-shrub layer and a diverse herb layer (Cohen, 2004). Attachment A lists plant species common to mesic northern forests. The largest remaining single contiguous forest within the Tittabawassee watershed is located in the Shiawassee NWR, consisting of approximately 3,500 acres (USFWS, 2001). The Shiawassee NWR is perhaps more similar to the region's pre-settlement conditions than any other location in the watershed.

Prior to human settlement, wetlands of the Great Lakes region included marshes, river prairies, lowland hardwoods, and lowland conifer swamps (Albert, 1995). These areas were nourished by seasonal flooding, which was common in both spring and autumn. The most extensive marshes occurred along Saginaw Bay, which extended into water depths up to four to five feet, were one to two miles wide in places, and extended for miles up major rivers, including the Saginaw. Shoreward of the marshes were extensive wet and wet-mesic prairies. While only about half of the historical acreage of Saginaw Bay coastal marshes remains today, National Wetlands Inventory maps suggest that several classes of wetlands occur within or near the Tittabawassee and Saginaw River floodplains (USFWS, 2008b). These include emergent, forested, and scrub-shrub wetlands. Figure 2.4 shows a typical riparian wetland community on the Tittabawassee River.

Figure 2.4. Typical riparian wetland community on the Tittabawassee River floodplain in the Shiawassee NWR. Picture taken by Douglas Beltman on May 29, 2007.

Many public lands and parks are located within the Tittabawassee and Saginaw River floodplains. These include Tittabawassee Park, Bayou Golf Club, Imerman Memorial Park, West Michigan Park, Freeland Festival Park, and part of the Shiawassee NWR downstream of Midland on the Tittabawassee River. Along the Saginaw River, public lands and parks include Wickes Park, Ojibway Island Park, Hoyt Park, Potthoff Park, Roosevelt Park, Crow Island State Game Area, and Veterans Memorial Park, as well as multiple public boat launch facilities (ATS, 2006b).

Wildlife species present within the TRSAA floodplain are typical of the remaining natural forest and wetland communities (ATS, 2007). Resident upland game species include whitetail deer (*Odocoileus virginianus*), ring-necked pheasant (*Phasianus colchicus*), and wild turkey (*Meleagris gallopavo*). Common bird species include tree swallow (*Tachycineta bicolor*), eastern bluebird (*Sialia sialis*), house wren (*Troglodytes aedon*), and wood duck (*Aix sponsa*). Common reptiles and amphibians include green frog (*Rana clamitans*), northern leopard frog (*Rana pipiens*), eastern garter snake (*Thamnophis sirtalis sirtalis*), and brown snake (*Storeria dekayi*). Common small mammals include deer mouse (*Peromyscus* spp.), house mouse (*Mus musculus*), meadow vole (*Microtus pennsylvanicus*), masked shrew (*Sorex cinereus*), eastern chipmunk (*Tamias striatus*), and northern flying squirrel (*Glaucomys sabrinus*). Other common bird, reptile, amphibian, and mammal species are listed in Attachment A.

2.4.3 Threatened and endangered species

There are seven plant and 23 animal species that have been found within Midland or Saginaw counties and are listed as endangered, threatened, or animal species of special concern by the State of Michigan (Table 2.2). Members of the last category are not afforded legal protection, but many of these species are of concern because of declining or relict populations in the state (MNFI, 2007). In addition, three species listed in Table 2.2 also fall under the federal Endangered Species Act. The eastern prairie fringed orchid (*Platanthera leucophaea*) and the Indiana bat (*Myotis sodalis*) are listed as a threatened species, and the eastern massasauga rattlesnake (*Sistrurus catenatus*) has been identified as a candidate for federal protection. Candidates are species that have been sufficiently studied and proposed for threatened or endangered status. Although the bald eagle (*Haliaeetus leucocephalus*) is no longer listed as threatened under the federal Endangered Species Act in Michigan, it is still protected by the Migratory Bird Treaty Act and the Bald and Golden Eagle Protection Act (USFWS, 2008a).

Table 2.2. State-listed threatened species, endangered species, or animal species of special concern documented in Midland or Saginaw counties

Common name/species	Threatened	Endangered	Special concern
Eastern prairie fringed orchid (*Platanthera leucophaea*)		X	
Three-awned grass (*Aristida longespica*)	X		
Weak stellate sedge (*Carex seorsa*)	X		
Beak grass (*Diarrhena americana*)	X		
Showy orchids (*Galearis spectabilis*)	X		
Whorled pagonia (*Isotria verticillata*)	X		
Hairy mountain-mint (*Pycnanthemum pilosum*)	X		
Red-shouldered hawk (*Buteo lineatus*)	X		
Common tern (*Sterna hirundo*)	X		
King rail (*Rallus elegans*)		X	
Indiana bat (*Myotis sodalis*)		X	
Eastern massasauga rattlesnake (*Sistrurus catenatus*)			X
Spotted turtle (*Clemmys guttata*)	X		
Blanding's turtle (*Emys blandingii*)			X
Wood turtle (*Glyptemys insculpta*)			X
Eastern fox snake (*Pantherophis gloydi*)	X		
Channel darter (*Percina copelandi*)		X	
River darter (*Percina shumardi*)		X	
Lake sturgeon (*Acipenser fulvescens*)	X		
River redhorse (*Moxostoma carinatum*)	X		
Elktoe mussel (*Alasmidonta marginata*)			X
Snuffbox mussel (*Epioblasma triquetra*)		X	
Ellipse mussel (*Venustaconcha ellipsiformis*)			X

Source: MNFI, 2007.

3. Hazardous Substances Released by Dow

This chapter presents a history of operations and waste management at or near the Dow plant (Section 3.1), and a history of remedial activities, site characterization studies, and environmental risk assessment activities at and near the plant (Section 3.2).

The Midland plant is Dow's headquarters and has historically been their primary chemical research facility and chemical manufacturing facility. As a consequence, Dow has released an extremely wide range of hazardous substances, many in very large quantities, into the environment for a period of over a century. Many of those releases occurred without careful waste minimization or disposal, particularly before the 1980s. Therefore, past releases are critically important to a complete and accurate assessment of natural resource damages, both to address the era when hazardous substance releases and environmental concentrations were greatest, and to address persistent toxins.

Hazardous substances released from the plant have been the focus of remedial activities within the TRSAA and are the focus of this NRDA. Many of these substances are widely distributed in sediments and soils in the assessment area, and may accumulate in biota. They may further be re-released and transported as the sediments, soils, and biota move in the environment.

3.1 Operational History of the Dow Midland Plant

The Midland Chemical Company was founded in 1890 and became the Dow Chemical Company in 1897. The primary product in the 1800s was bleach, which is a chlorine product also known as chloride of lime or calcium hypochlorite. Dow used an electrolytic process that generated chlorine from brine, and bleach was Dow's dominant product until its production stopped in 1914. Dow continued to produce other chlorine-based products, including chlorine gases, caustic soda, liquid chlorine, chlorinated phenols, chlorobenzenes, agricultural products, plastics, synthetic rubber, and STYROFOAM™. Production methods changed over time, but electrolytic processes using carbon electrodes were used at the plant until the 1980s, and likely produced significant amounts of the dioxins and furans[1] that were released to the TRSAA.

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1. The term "dioxin" refers to a group of chemicals called "polychlorinated dibenzodioxins." These chemicals consist of two benzene rings linked by two oxygen atoms, with between 1 and 8 chlorine atoms attached at different locations on the benzene rings.

The term "furans" refers to "polychlorinated dibenzofurans," which are similar to dioxins, except that they have a slightly different aromatic cyclic structure. Dioxins and furans are toxic at extremely low *(cont.)*

Tables B.1 through B.5 in Attachment B list chemicals that were produced by Dow before World War I (WWI), during WWI, between the World Wars, during World War II (WWII), and after WWII, respectively. These tables expand upon the tables on pages 3-46 through 3-48 of the remedial investigation work plan (RIWP; ATS, 2006b). This list may be further expanded as investigations of the history of the Dow plant continue. For example, it may be expanded based on the primary constituents of interest (PCOI) list.[2] The list includes hundreds of chemicals associated with Dow's present and historical production processes, many of which are also listed hazardous substances. Attachment C lists chemicals on the PCOI list that are hazardous substances.

A general summary of chemical production at Dow's Midland plant over the last century follows.

- *WWI, WWII, and intra-war years*. Dow was a major producer of war-related products, including mustard gas, monochlorobenzene, carbon tetrachloride, plastics, magnesium metals, phenols, and other chemicals (Karpiuk, 1984; Brandt, 1997). Between WWI and WWII, Dow expanded the range of products produced, and began to produce a significant volume of plastics, including ethyl cellulose (Dow's first plastic), Thiokol synthetic rubber, polystyrene, and vinyl chloride for a variety of applications (Brandt, 1997). Saran™ was developed just prior to WWII and used as a war product, and was adapted for commercial sale as their first direct consumer product in the early 1950s (Brandt, 1997). Dow also began production of herbicides, pesticides, and fungicides, including 2,4-dichlorophenoxyacetic acid (2,4-D) in the 1930s, and continued production into the 1980s. Production of chlorinated phenols also began in the 1930s; were produced as intermediaries to many products, including herbicides and pesticides. By the end of 1949, Dow's Midland plant was producing more than half of the phenols (including chlorinated phenols) in the United States.

(cont.) concentrations, and accumulate in biota and humans. In animals, they can cause weight loss, hepatotoxicity, porphyria, dermal toxicity, gastric lesions, thymus atrophy and immunotoxicity, teratogenicity, reproductive effects, carcinogenicity, and death (IPCS, 1989). In humans, exposure can lead to skin lesions; altered liver function; impairment of the immune system, nervous system, endocrine system, and reproductive functions; and death (WHO, 2007).

2. In June 2006, Dow submitted a list to MDEQ that contained over 800 chemicals that were either produced or used throughout the history of the plant. ATS and MDEQ reviewed the listed chemicals for the likelihood to persist in the environment, and categorized them. This process is described in Appendix G of the RIWP (ATS, 2006b). The PCOI list currently contains target volatile organics, semi-volatile organics, dioxins, furans, PCBs, phenols, chlorinated pesticides, chlorinated hydrocarbons, organophosphorus compounds, chlorinated herbicides, and metals.

- *1950s*. Dow continued to produce older lines of products while expanding into newer product lines, including plastics and agricultural chemicals. Major new products of the 1950s included various herbicides, soil fumigants, latexes, acrylic acid, acrylamide, ethanolamines, and phenolics. By the end of the 1950s, plastics made up 35% of Dow's total sales, and other specific chemical offerings made up 53% (Brandt, 1997).

- *1960s*. Dow continued to expand capacity and the number and range of products manufactured at the Midland plant in the 1960s. Two new plants were added in the late 1960s: a trichlorophenol plant and a chlor-alkali plant. In 1969, Dow introduced Ziploc bags as a consumer product (Dow Chemical, 2007c).

- *1970s*. Production levels were maintained or expanded (particularly agricultural products) during the 1970s. Dow began full-scale production of chlorpyrifos insecticides (Dursban™ and Lorsban™; household and agricultural markets, respectively) and opened a new 2,4-D herbicide plant. Additionally, Dow began manufacturing 2-chloro-*N*-isopropylacetanilide, the chlorine/caustic soda facilities were modernized, and the chlorinated benzene facilities were replaced and expanded to increase production efficiency (ATS, 2006b).

- *1980s and 1990s*. Dow reduced onsite production, capacity, and range, moving major production facilities off the Midland plant site. In October 1980, the Midland pentachlorophenol manufacturing facility was closed. During the mid-1980s, the chlorine and caustic soda facilities were shut down and Dow left the brine and magnesium businesses. Dow added household product lines during this period, including expansion of the Saran™, Handi-Wrap™, and Scrubbing Bubbles® lines and the introduction of Drytech™, an absorbent in diapers. Additionally, Dow introduced a new pharmaceutical product, the antihistamine Seldane™ (ATS, 2006b).

The Midland plant remains active and is Dow's corporate headquarters as well as an important research and development center for the company. However, the Midland plant is no longer Dow's primary chemical production plant.

Several dozen of the hazardous substances either used or produced at the Dow plant have been identified in the TRSAA, including metals, such as arsenic, lead, cadmium, and mercury, and organic chemicals, such as chlorobenzenes, organophosphorous compounds, phthalates, chlorostyrenes, chlorinated phenols, dioxins, and furans (ATS, 2007). Dioxins and furans, in particular, are extremely elevated (compared to toxic thresholds) in and along the Tittabawassee River and have been a primary focus of Dow's hazardous waste license, agency cleanup actions, and private party law suits. Hence, processes at the Dow plant that produced dioxins and furans are summarized below. It is anticipated that, as the assessment proceeds, Dow plant processes that used or produced other hazardous substances will also be investigated.

3.1.1 Early sources of dioxins and furans: electrolytic production of chlorine using carbon electrodes

The RIWP (ATS, 2006b) documents that chlorine electrolysis methods of the late 1800s and early 1900s likely produced dioxins and furans, which were released directly into the environment. Dioxins and furans likely formed from the carbon of the electrodes in the presence of the chloride-rich brine water and oxygen, with their formation driven by the applied electrical currents. They were then likely released to the environment as the wooden troughs and carbon electrodes deteriorated and became part of the production waste stream. Until the 1920s, all such production waste was discharged directly to the Tittabawassee River without treatment. Dow has reported that a significant proportion of the dioxins and furans found in the soils of the TRSAA are associated with a cellulosic layer that probably originated from the carbon electrodes and wooden troughs that captured chlorine gas (ATS, 2006b), though elevated levels of dioxins and furans have also been identified in samples that do not contain cellulosic material (ATS, 2007).

History of electrolysis techniques to produce chlorine. The first commercial-scale electrolytic chlorine production by Dow used chlorine electrolytic cells composed of a row of 6-inch carbon electrodes on a 16-inch board with a series of holes drilled for carbon electrodes (half of each carbon electrode on either side of the board; Karpiuk, 1984). The carbon anode ends were covered with an inverted wood trough that collected the chlorine gas, which was produced from oxidized chloride in the circulated brine when current was applied. At the cathode, brine water was reduced to hydrogen gas and hydroxide. The chlorine troughs were set in a large, shallow tank that was approximately 16 feet wide. The chlorine collected from the traps was transported through rubber tubing and was dried by passing over scrap zinc prior to mixing with lime to form bleach powder (Karpiuk, 1984; Stock and Orna, 1989).

In 1899, Dow began to soak the carbon electrodes in molten paraffin (135°F melting point) to prevent continuing explosions. Dow scientists theorized that the explosions were caused because hydrogen gas, produced at the cathode, was able to diffuse through the porous electrodes and mix with the chlorine gas formed at the anode (Karpiuk, 1984). By impregnating the electrodes with paraffin wax, these pores were plugged (Karpiuk, 1984). Also during this time, anecdotal accounts indicate that the tarred pine boards housing the carbon electrodes became spongy with exposure to corrosive chemicals and were routinely replaced to improve efficiency.

In the early 1900s, Dow expanded the chlorine electrolytic operation by housing the electrolytic cells in nine 40-foot by 90-foot “cell houses” and adding a 40-foot wide by 368-foot long slaked lime absorber (Karpiuk, 1984). Still in the early 1900s, the plant was further expanded to include 2 million carbon rods in 26,000 traps.

In 1913, Dow began constructing a new electrolytic process that employed vertical filter-press cells housed in concrete frames with electrodes of steel (cathode) and graphite (anode). Each filter-press series had 75 cells and were used through the 1980s (Stock and Orna, 1989). In the 1980s, Dow began using nickel cathodes with activated metal coatings (Stock and Orna, 1989).

Amount of chlorine produced. During WWI, Dow manufactured 30 million pounds of chlorine (Brandt, 1997). Additionally, they produced 1 million pounds of chlorine for chloroform, 10 million pounds of carbon tetrachloride, and 2 million pounds of monochlorobenzene (Brandt, 1997). By the end of the 1930s, Dow was the largest domestic producer of chlorine, which was used primarily in manufacturing Dow products (ATS, 2006b).

3.1.2 Later sources of dioxins and furans: electrolytic production of chlorophenols

Chlorinated phenol production began in the mid-1930s. Chlorinated phenols were produced for a variety of end purposes, including direct use as fungicides, bactericides, and polystyrene production, which was produced commercially beginning in 1938. Dioxins and furans are known to be an unintentional byproduct of electrolytic production of chlorophenols (ATS, 2006b).

During the 1970s, Dow began larger-scale production of chlorophenoxy herbicides with the opening of a new 2,4-D herbicide plant. It is well documented that dioxins and furans were unintentionally produced as impurities to many chlorophenoxy herbicides, including 2,4-D. The improper disposal and heavy use of chlorophenoxy herbicide wastes have been recognized as major sources of environmental dioxin pollution in the United States (IPCS, 1989). It is reported in Appendix F of the RIWP (ATS, 2006b) that Dow discontinued production of 2,4-D chlorophenoxy herbicides by 1985.

While general waste management practices at the Dow plant are described in the RIWP (ATS, 2006b), it is not specified how the wastes from chlorinated phenol production were managed. Furthermore, the discharge of suspended solids into the Tittabawassee River likely continued to be significant until the construction of the tertiary treatment ponds in 1974, and during high-water events that flooded the ponds after their construction (ATS, 2006b). Hence, it is possible that significant amounts of dioxins and furans continued to be released into the Tittabawassee River well into the 1970s and 1980s.

3.1.3 Dioxins and furans produced by incineration practices

The incomplete combustion of liquid tars released dioxins and furans. In the past, Dow used incinerators that did not burn waste and other waste streams at a high enough temperature to eliminate dioxins and furans, and they did not capture particulates or scrub gas emissions. This was likely a significant source of atmospheric deposition of dioxins and furans, which were then distributed through the atmosphere to soils and water (ATS, 2006b).

3.1.4 Dow waste management history

Historical waste management practices allowed large releases of hazardous substances, both those manufactured as products and those that were produced as waste.

Early waste management (brine related production, 1890-1918)

There was no treatment of wastewaters at the Midland Chemical Company and the Dow Chemical Company from 1890 until the 1920s. All wastes were discharged directly into the Tittabawassee River. Prior to 1948, solid waste was buried onsite or stockpiled for open air burning. The Tittabawassee River floods regularly and significantly, and floods often inundated the Midland plant causing stored brine, wastewater, and solid waste to discharge into the river. For example, a newspaper article from 1912, recounted in a *Midland Daily News* article of 1950, recounts a significant flood in Midland during which the lower half of the Dow plant was inundated with water; buildings on that part of the property were under 15- to 20-feet of water, and any stored waste in the area was immersed and discharged to the river (*Midland Daily News*, 1950).

Deposition of ash from the air was probably a major source of dioxin and furan contamination of soils in and around Midland throughout most of the history of the Midland plant. Early air emissions came from burning stockpiled solid waste in the open air (ATS, 2006b).

WWI waste management (war-time products and post-bleach manufacturing)

During the WWI manufacturing years, all waste was still discharged directly into the Tittabawassee River without treatment, solid waste was buried onsite or burned in the open air, and waste process gases were vented directly to the atmosphere.

Intra-war years waste management

In 1920, Dow created a network of collection ditches, pipelines, and pumps that directed wastewater to storage ponds. During high-flow periods in the Tittabawassee River, wastewater was discharged from the ponds into the river. Sludge was stored in a 64-acre pond. Organic wastes (defined by odor) were stored in long-term retention ponds. Acid waste was stored in a 109-acre pond during cold months and released to the Tittabawassee River during warm months, based on temperature and stream condition. Clear-water wastes (e.g., condenser and cooling waters) were discharged into the river. In the 1930s, two storage ponds were added, increasing the effective storage capacity by two years at contemporary waste brine production rates.

Periodically, the discharge was measured for sodium chloride concentrations and phenol content. During this time, leaching from waste impoundments likely discharged into the groundwater and the river (ATS, 2006b).

Also in the 1930s, Dow constructed a WWTP with trickling filters, which was secondary to the storage ponds constructed in the 1920s (Michigan Stream Control Commission, 1937), to treat phenolic wastes. Dow also began using tar burners to incinerate liquid organic tars during this period. Solid waste was still disposed of by onsite burial at the Midland plant during the intra-war years (ATS, 2006b).

WWII waste management

A 1937 report about water quality in Saginaw Bay and in the Saginaw Valley identified the major sources of pollution in the Tittabawassee and Saginaw rivers as oil waste, chemical plant wastes, chemical process wastes, sugar beet plant wastes (seasonal pollution), oil production wastes from refining and transportation, and sewage and municipal waste from the principal cities (Michigan Stream Control Commission, 1937). Commercial fishing in the region was affected by river pollution that caused taste and odor problems (Michigan Stream Control Commission, 1937). At this time, Dow began making efforts to reduce their discharges and changed their waste routing practices in order to reduce the volume of waste discharged into the river, which improved water quality of the Tittabawassee River and Saginaw River and Bay (Michigan Stream Control Commission, 1937).

Dow's primary wastes in 1937 were sludge disposal waste, organic system waste, acid waste, and clear-water waste. The sludge disposal waste was discharged from a sludge pond (64 acres, 3-feet deep) and consisted of wastewater with suspended matter. The effluent was clear and contained chlorine concentration (as sodium chloride) of approximately 1,800 parts per million (ppm). Phenol discharge was reduced from 450 pounds per day to 100 pounds per day. The organic system wastes were a mixture of organic wastes that reached a neutral pH after some time in holding ponds. The estimated volume of organic wastes was 260,000 cubic feet per day with an average chlorine concentration of 1,000 ppm (as sodium chloride). The acid wastes were a mix of concentrated phenolic and aromatic compound wastes that were treated in 109 acres of ponds. Clear-water wastes consisted of condenser and cooling waters, which were discharged at an average rate of 8,600,000 cubic feet per day. Dow attempted to keep the chlorine concentration in clear-water wastes below 500 ppm (as sodium chloride) (Michigan Stream Control Commission, 1937).

In 1945, the WWTP was upgraded to include preliminary and activated sludge treatments, as well as final clarification. The WWTP treated process and sanitary wastewaters of the plant. Other wastewaters were not directed to the WWTP during this period.

Post-WWII to present waste management practices

After WWII, waste management practices were significantly and continually upgraded. By 1947, Dow spent $2 million to improve the waste disposal system and planned to spend between $430,000 and $500,000 to complete it (Stoll, 1947). Beginning in 1948, solid waste was incinerated in a rotary kiln from which exhaust gas and particulates were vented directly into the atmosphere. Incinerated materials included rubbish, solid waste, packs, and liquid tars. During the incineration process, various liquids were sprayed into the front of the kiln. Ash was buried onsite (ATS, 2006b).

In the 1970s and 1980s, improvements to the WWTP included construction of tertiary treatment ponds (1974) and construction of mixed media sand filters to remove particulate matter after tertiary treatment and before discharge into the Tittabawassee River (1985). In 1988, operation of the tertiary treatment ponds was regulated through Dow's NPDES permit. Historically, only flows from the process areas and sanitary waste waters were diverted to the WWTP; however, in the 1970s and 1980s additional flows were directed to the WWTP, including waste scrubber water, rotary kiln incinerator and tar burner ash dewatering, cooling tower blowdown, non-contact cooling water, water softener backwash, tank car washings, surface water runoff, and leachate from the Salzburg landfill. Currently, sanitary and lab sink waste and plant wastes from the Midland Cogeneration Venture are diverted to the Midland municipal WWTP (ATS, 2006b).

Construction of the revetment groundwater interceptor system (RGIS) began in the late 1970s, with periodic upgrades and expansions through to the present. The RGIS system captures groundwater at the Dow Midland plant before it enters the Tittabawassee River and redirects it back to the WWTP (McDowell and Associates, 1984). One major documented failure in 1990 led to the release of an estimated 900,000 gallons of potentially contaminated groundwater into the Tittabawassee River (MDNR, 1990d), and a consent decree between Dow and MDEQ in 1991. Significant failures also occurred in 1994 and 1995. A resulting consent order required Dow to pay approximately $900,000 in fines and penalties, and to replace parts of the RGIS system over the subsequent 10 years.

WWTP effluent is currently discharged to the Tittabawassee River via one main outfall, one emergency backup outfall, and several storm water outfalls. Historically, there were up to 11 outfalls from the Midland plant into the Tittabawassee River. In 1984, Dow's wastewater discharge was reduced from 35.4 million gallons per day (MGD) to 20 MGD. The discharge continued to be reduced throughout the 1980s and 1990s through improved recovery, reclamation, and facilities construction.

In the early 1980s, Dow stopped using deep disposal wells for phenolic waste. An investigation of historical deep-well disposal, limited to wells located on the Dow plant property, is being conducted as a part of MDEQ's On-Site Corrective Action Program (ATS, 2006b). The wells discharged into the Sylvania and Dundee formations; therefore, deep groundwater sources may be contaminated. Numerous additional sources of groundwater contamination are reported in the RIWP (ATS, 2006b), including historic solid waste burial sites, the T-ponds, spent brine ponds, and the clay pits used for sludge dewatering (see Figure 4-1 of the RIWP).

Air emissions have also undergone significant improvements in the post-WWII era. In 1958, a new dual-rotary kiln system was constructed, replacing the previous rotary kiln. The new kiln system was used to burn paper and wood trash, chemical waste, chemically contaminated waste equipment, and a variety of liquid wastes. Waste was burned at temperatures between 500 and 900°C. In 1970, a secondary afterburner, using natural gas as a supplemental fuel, was added to reduce stack particulate emissions. In 1978, research indicated that waste needed to be burned at temperatures greater than 1,000°C in order to completely destroy dioxins and furans. Natural gas was added to the afterburner to increase the incineration temperature. In 1984, the operating temperature of the afterburner was increased to 1,000-1,100°C. With these improvements, the kiln destroyed half of the dioxins and furans and the exhaust scrubber equipment captured 95% of the remaining dioxins and furans. Further improvements throughout the 1980s led to more efficient incineration, reduced dioxin and furan formation, and reduced particulate emissions, resulting in permits for 99.99 to 99.999% efficiency.

In 2003, a new kiln began operating. The old incinerators were closed down due to requirements under RCRA. Dow reduced the capacity by improving their recycling processes and, by 2003, met maximum achievable control technology standards. Between 1995 and 2006, Dow reduced its dioxin and furan emissions by approximately 95% (ATS, 2006b).

3.2 Response Actions and Risk Assessments in the TRSAA

This section describes remedial and interim response actions, RI activities, removal actions, and risk assessments that have occurred and/or are underway in the TRSAA.

3.2.1 Historical remedial actions (1980s-1990s)

Many of the early actions that occurred at the site were ordered by the State in two separate "final order of abatement" orders. The first order was issued to Dow in 1984 (MDNR, 1984b). The order was based on the findings of studies (Dow Chemical, 1984; U.S. EPA, 1985a; Amendola and Barna, 1986), that the State used to determine that Dow was unlawfully discharging "injurious substances into waters of the State." The order set effluent limitations for

2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD).[3] When drafted, these effluent limitations were not achievable by Dow which led to a complex settlement between Dow and the State, the details of which are briefly summarized in the Preassessment Screen and Determination (USFWS, 2006). In addition to interim and final effluent limitations, the 1984 order established a dioxin minimization program for wastewater and waste incineration systems. Dow was required to identify major sources and report findings on how to reduce the discharge of TCDD using best available and economically achievable control technology. Based on the findings of this study, Dow was required to submit a remedial action plan to reduce the discharge of TCDD. The key remedial actions taken are described in Table 3.1, including the RGIS and later actions.

Table 3.1. Summary of historic remedial actions, interim response actions (IRAs), and CERCLA removal actions conducted in the TRSAA

Date	Actions	Reference
	Historic remedial actions	
1984	Final order of abatement: Dow Chemical, Midland, Michigan ▸ Established a dioxin minimization program for wastewater and waste incineration systems	MDNR, 1984b
1979 to present	Installation of a riverbank RGIS, Dow Facilities, Midland, Michigan ▸ Intercepts contaminated groundwater originating on-site from entering the Tittabawassee River ▸ Continual modifications and expansions from 1994 to present	McDowell and Associates, 1984; U.S. EPA, 1988b
1985	WWTP upgrade ▸ Installed a filtration system for the entire discharge to the Tittabawassee River	U.S. EPA, 1988b
1986	Implemented a plant-wide dust suppression program ▸ Paving or planting grasses over sand and gravel areas ▸ Spraying and sweeping for non paved and paved roads	U.S. EPA, 1988b
1986	Capped on-site soil and limited access to areas with high levels of soil contamination	U.S. EPA, 1988b
1986 to 1987	Wastewater conveyance system upgrades ▸ Replaced open ditches with enclosed sewers ▸ Isolated highly contaminated areas from the plant wastewater treatment system	U.S. EPA, 1988b
1987	Provided preliminary treatment of incinerator scrubber water prior to commingling with other process wastewaters	U.S. EPA, 1988a

3. TCDD is one particular congener of dioxin containing four chlorine atoms. TCDD is the most toxic form of dioxin, at least for many well-studied biological endpoints.

Table 3.1. Summary of historic remedial actions, interim response actions (IRAs), and CERCLA removal actions conducted in the TRSAA (cont.)

Date	Actions	Reference
	Historic remedial actions (cont.)	
1988	Final order of abatement: Dow Chemical, Midland, Michigan ▸ Required Tittabawassee River native fish monitoring ▸ End-of-pipe control measures: A feasibility study on three or more technologies for reducing TCDD discharge ▸ Submit an analysis of tertiary pond sediments; TCDD concentrations, total volume, and resuspended sediment analyses ▸ Incinerator wastewater pretreatment system performance characterization	MDNR, 1988b
Started in August 1996	Tertiary pond solids removal project ▸ Management decision to remove contaminated tertiary treatment pond sediments ▸ Solids were dredged from the ponds, pumped to a dewatering/drying system, and incinerated	MDEQ, 1998; Michigan Newswire, 2003
April 2002	Consent order to settle reimbursement of costs and penalties that occurred as result of incinerator violations and mishandling of the T-Pond solids at the Midland facility	Michigan Newswire, 2003
	IRAs	
June 2003 to present	IRAs to address risk communication ▸ Set up and maintain seven community information centers ▸ Prepare and distribute public information materials describing what dioxins and furans are and how to limit their exposure ▸ Set up a Public Participation Plan to organize activities to inform residents of the corrective action process	MDEQ, 2003a; Dow Chemical, 2007b
June 2003 to present	IRAs to address exposure to dioxins and furans in soil ▸ Identify and implement mitigation options to limit or prevent land owner exposure to contaminants ▸ Mitigation measures included covering exposed soils, house cleaning, and monitoring, maintenance, and restoration of mitigated areas	Dow Chemical, 2007b
2003-2004	Imerman Park IRAs to reduce public exposure to surface soils and address erosion along the river bank ▸ Stabilize riverbank near the pavilion and floating dock to prevent erosion ▸ Covering walking trails with wood chips ▸ Revegetation in areas with bare soil ▸ Graveled boat ramp ▸ Fertilize grassy areas to promote good spring growth ▸ Continued hand washing station service ▸ Power washing of affected hard surfaces	Dow Chemical, 2003c

Table 3.1. Summary of historic remedial actions, interim response actions (IRAs), and CERCLA removal actions conducted in the TRSAA (cont.)

Date	Actions	Reference
	IRAs (cont.)	
2003-2004	Freeland Festival Park IRAs to reduce public exposure to surface soils within the floodplain ▸ Installation of a stone wall along the riverbank to limit access to the river ▸ Construction of a two tier deck to allow boat and canoe access while minimizing contact with river sediments ▸ New topsoil and appropriate ground cover vegetation in select areas to improve ground cover and eliminate exposed soil ▸ Continued hand washing station service ▸ Power washing of affected hard surfaces	Dow Chemical, 2003b
	Leonard Boers III boat launch prevention measures for potential track out of flood deposited sediments ▸ New topsoil and seeding in ¼ acre corner of boat launch parking lot ▸ Graveled boat ramp ▸ Sediment and silt removal and off-site disposal ▸ Power washing of affected roadways	Dow Chemical, 2003a
	West Michigan Park IRAs to reduce public exposure to surface soils within the floodplain ▸ Boat launch bank erosion control and exposed soil coverage ▸ Fertilize grassy areas to promote good spring growth ▸ Removed and replaced sand under children's play areas ▸ Continued hand washing station service	Dow Chemical, 2003d
	Removal actions	
July 2007	Administrative order on consent for immediate removal of Tittabawassee River Reach D sediments	U.S. EPA, 2007b
August 2007	Administrative order on consent for immediate removal of Tittabawassee River Reach J-K sediments	U.S. EPA, 2007c
August 2007	Administrative order on consent for immediate removal of Tittabawassee River Reach O sediments	U.S. EPA, 2007d
November 2007	Administrative order on consent for immediate removal of Saginaw River Wickes Park sediments	U.S. EPA, 2007e

In 1988 a second "final order of abatement" was issued (MDNR, 1988b). Similar to the 1984 order, effluent limitations and monitoring requirements were established in addition to new remedial actions.

In the mid-1990s, Dow's T-ponds were the subject of civil and criminal law suits stemming from NPDES violations for phosphorus, 2,4-D, and 2,4,6-trichlorophenol (Gold, 1998). As a result of a 1996 court-ordered consent decree, Dow began to remove historically accumulated solids from its tertiary treatment ponds. They installed a filter press and a dryer to handle waste solids from its secondary clarifiers, and they installed a trace organics removal system at the site. Mismanagement of these activities resulted in a consent order in 1998 to address illegal releases of hazardous waste from the T-Pond solids removal project. A consent order in 2002 required Dow to pay penalties and costs associated with the solids removal project and improperly stored wastes. A criminal case against a Dow subcontractor involved in the solids removal project was dismissed after the company agreed to settle the case with the State for approximately $500,000 (MDEQ, 2003d).

With issuance of MDEQ's 2003 "Hazardous Waste Management Facility Operating License" (License), Dow is required to implement corrective actions for all releases of a contaminant from any waste management unit(s) at the facility and beyond the facility boundary if that release has or may have migrated or has or may have been emitted, beyond the facility boundary[4] (MDEQ, 2004a, 2006e, Conditions XI.A.1 and XI.B.1). Also pursuant to the License, IRAs have included exposure controls at a number of public and private properties in the Tittabawassee River floodplain and educational outreach to potentially exposed residents. Table 3.1 summarizes remedial actions, IRAs, and CERCLA removal actions conducted in the TRSAA.

As a part of this process, the License requires the preparation of "Remedial Investigation Workplans" for areas affected by contaminant release(s), including Midland area soils, the Tittabawassee River and floodplain, the Saginaw River and floodplain, and Saginaw Bay. RIs are conducted to collect information on the nature and extent of the contamination. Dow's 2003 License specifically states the minimum requirements and submittal timeframe for RI reports (Conditions XI.F.1 through XI.F.7 in MDEQ, 2006e). Table 3.2 summarizes relevant documents that have been reviewed by MDEQ as part of the RI and corrective action process.

4. While dioxins and furans have been the main focus of past remedial and IRAs, recent sampling efforts in the TRSAA have identified dozens of additional contaminants (ATS, 2007).

Table 3.2. Summary of Dow's remedial investigation site characterization documents

Document (date)	Document title and description	Status
Dow Chemical, 2005a (12/29/2005)	Midland Area Soils Remedial Investigation Work Plan	Notice of deficiency dated 4/13/2006 (MDEQ, 2006d)
Dow Chemical, 2005b (12/29/2005)	Tittabawassee River and Floodplain Remedial Investigation Work Plan (Final Report)	Notice of deficiency dated 3/2/2006 (MDEQ, 2006c)
ENTRIX, 2006b (1/2006)	Revised Draft Screening Level Ecological Risk Assessment Work Plan for the Tittabawassee River and Associated Floodplains ▸ Provides the framework for conducting a Screening Level Ecological Risk Assessments (SLERA) ▸ Identifies how other contaminants of potential ecological concern than dioxins and furans in the Tittabawassee River sediments and floodplain soils will be identified	Document currently under MDEQ review, but work has started
ENTRIX, 2006a (1/2006)	Revised Draft Baseline Ecological Risk Assessment Work Plan for Polychlorinated Dibenzo-p-Dioxins (PCDDs) and Dibenzofurans (PCDFs) in the Tittabawassee River and Associated Floodplains ▸ Work plan to conduct a baseline ecological risk assessment (BERA) ▸ Evaluation of evidence and data that are needed to evaluate risks to ecological receptors	Document currently under MDEQ review, but work has started
Dow Chemical, 2006 (7/2006)	Sampling and Analysis Plan in Support of Bioavailability Study, Midland Area Soils ▸ Describes methods for characterizing the distribution of physical and chemical parameters in soils in the vicinity of the Dow plant	Document currently under MDEQ review
ATS, 2006a (7/7/2006)	GeoMorph® Sampling and Analysis Plan: Upper Tittabawassee River Midland Michigan ▸ Documents how the GeoMorph® approach will address investigation of contaminated sediments in the upper Tittabawassee River (UTR)	Approved by MDEQ on 7/12/2006 (MDEQ, 2006b)
ENVIRON, 2006a, 2006b (10/16/2006)	Sediment Trap Sampling and Analysis Plans ▸ Pilot studies investigating the use of sediment traps to capture and remove sediments and associated dioxin and furans in the Saginaw River ▸ Study 1 – Characterization of Sediments in the Ojibway Turning Basin; Study 2 – Sediment Trap Performance and Feasibility Study at Sixth Street Turning Basin	Documents currently under MDEQ review

Table 3.2. Summary of Dow's remedial investigation site characterization documents (cont.)

Document (date)	Document title and description	Status
Dow Chemical, 2005a (12/29/2005)	Midland Area Soils Remedial Investigation: Work Plan ▸ Defines the approach and sequence of activities to streamline the corrective action process by controlling risks to human health and the environment from exposure to contaminated soils ▸ Phased, results-based approach	Partial approval with compliance schedule modification by MDEQ on 7/24/2007 (MDEQ, 2007a); revised work plan (Dow Chemical, 2007b)
ATS, 2006b (12/1/2006)	Remedial Investigation Work Plan: Tittabawassee River and Upper Saginaw River and Floodplain Soils – Volumes 1 and 2 ▸ Describes work to be performed in offsite areas identified under Conditions X.I.B.2 and XI.B.6 of the operating license, which require corrective action ▸ Describes the IRA/Pilot Corrective Action Plan Decision Tree Process for the implementation of IRA Pilot Corrective Action Plans during the RI process	Partial approval with compliance schedule modification by MDEQ on 7/24/2007 (MDEQ, 2007a)
ATS, 2006c (12/20/2006)	Upper Tittabawassee River Reach O Plan and Pilot Corrective Action Plan[a] ▸ Outlines the objectives, approach, and schedule for a focused Pilot Corrective Action Plan ▸ Developed in response to finding very high levels of dioxin and furan concentrations in UTR sediments	MDEQ documented the events that led to the discovery of the highly contaminated sediments, regulatory authority, and scheduling requirements (MDEQ, 2006f)
ATS, 2007 (2/1/2007)	GeoMorph® Pilot Site Characterization Report – Upper Tittabawassee River and Floodplain Soils, Midland, Michigan ▸ Report summarizes sediment contamination in river channels and floodplains of the upper 6.4 miles of Tittabawassee River downstream of the confluence with the Chippewa River	Approval to use GeoMorph® process for Middle and Lower Tittabawassee River/Upper Saginaw River site characterization on 5/3/2007 (MDEQ, 2007c)
ENVIRON, 2007b (7/13/2007)	Remedial Investigation Scope of Work for the Saginaw River and Saginaw Bay, Michigan	Notice of Deficiency on 8/29/2007 (MDEQ, 2007d)
ENVIRON, 2007c (10/15/2007)	Revised Remedial Investigation Scope of Work for the Saginaw River and Saginaw Bay, Michigan	Approved with modifications on 2/1/2008 (MDEQ, 2008)
ENVIRON, 2007a (9/14/2007)	Draft Current Conditions Report for the Saginaw River, Floodplain, and Bay ▸ Summarizes environmental information for Saginaw River and Bay and associated 100-year floodplain	Document currently under MDEQ review

Table 3.2. Summary of Dow's remedial investigation site characterization documents (cont.)

Document (date)	Document title and description	Status
Dow Chemical, 2007a (10/15/2007)	Direct Contact Criteria Report: Midland Area Soils, Midland, Michigan ▸ Report to investigate a site-specific residential soil direct contact criterion for TCDD ▸ Part of the Human Health Risk Assessment for Midland Area Soils	State review found that the report is incomplete, deficient, and contains substantial inaccuracies (MDEQ, 2007b)

a. The Upper Tittabawassee River Reach O Plan and Pilot Corrective Action Plan (ATS, 2006c) was superseded by EPA Region 5 CERCLA administrative order on consent for immediate removal of highly contaminated sediments.

3.2.2 Removal actions

In addition to the interim remedial actions, Dow has conducted removal actions downstream of its Midland plant (Table 3.1). These actions were initiated with the discovery of extremely high concentrations of dioxins and furans at locations downstream of the Dow plant, including a measured concentration of 87,000 parts per trillion (pptr) toxicity equivalents (TEQ)[5] within a buried in-channel sediment deposit in Tittabawassee River Reach O, and high concentrations at Reach D and Reaches J-K (ATS, 2007). Elevated concentrations of other substances, including chlorobenzenes, were also the focus at Reach D. In the spring of 2007, Dow submitted to MDEQ permit applications for three Pilot Corrective Actions for three sites in the UTR located in reaches D, J-K, and O. However, as related below, removal actions instead occurred under EPA authority, pursuant to CERCLA.

In June 2007, EPA notified Dow that it must begin cleanup of areas in Reach D, J-K, and O. Immediately following a brief negotiation, three "administrative orders on consent" (orders) were drafted requiring cleanup under CERCLA (U.S. EPA, 2007f). On July 18, 2007, EPA released an "enforcement action memorandum." This memorandum summarized EPA's determination that the cleanup sites were an "imminent and substantial threat to public health and the environment" (Augustyn, 2007). On July 12, 2007, EPA and Dow entered into three separate administrative agreements and orders for Reach D (U.S. EPA, 2007b), Reach J-K (U.S. EPA, 2007c), and Reach O (U.S. EPA, 2007d).

5. The concentration of mixtures of individual dioxins, furans, and dioxin-like PCB compounds can be expressed as the amount of TCDD that has the equivalent toxicity as the mixture. Unless specified otherwise in this report, TEQs represent the toxicity of the mixture of dioxins and furans in a given sample.

Reach D is located in the vicinity of a historic flume situated along the northeast bank of the Tittabawassee River, within the Midland plant property. The Reach J-K cleanup area is located in over-bank areas on the northeast side of the Tittabawassee River, approximately 3.6 miles downstream of the confluence of the Chippewa and Tittabawassee rivers within Dow's property. Reach O is approximately 6.1 miles downstream of the confluence of the Chippewa and Tittabawassee rivers and is also located within and immediately adjacent to Dow's property. The cleanup actions vary by reach and are summarized below.

At Reach D, Dow was ordered to remove the historical flume sheet piling and contaminated bottom deposits and sediments in the immediate area around the historical flume. At Reach J-K, Dow was ordered to remove a highly contaminated naturally occurring levee, cap one contaminated upland area, and fence off another contaminated wetland area. At Reach O, Dow was ordered to remove contaminated sediments in designated locations of a 1,300-foot long point bar that extended approximately 50 to 100 feet into the Tittabawassee River, parallel to the northwest bank. Dow initiated the removal action at Reach D on July 9, 2007, at Reach J-K on August 6, 2007, and at Reach O on August 24, 2007. As of February 2008, EPA reports that removal actions at Reaches J-K and O have been completed except for monitoring activities, and Reach D cleanup is still being implemented (U.S. EPA, 2008).

In addition to Tittabawassee River sites, discovery of a dioxin and furan hotspot in the upper Saginaw River spurred an additional cleanup action. On November 9, 2007, Dow notified EPA that Saginaw River sediments sampled adjacent to Wickes Park in the City of Saginaw, approximately 0.5 miles downstream of the Tittabawassee River confluence (Figure 2.2), contained extremely high dioxin and furan concentrations (U.S. EPA, 2007e). Preliminary results showed dioxin and furan concentrations up to 1,640,000 pptr TEQ. This is likely the highest reported concentration of dioxins and furans ever found in the Great Lakes region (U.S. EPA, 2007g). On November 15, 2007, an order was signed beginning a removal action in the Saginaw River hot spot. The order required Dow to begin fieldwork immediately, with the dredging to be completed by December 15, 2007 (U.S. EPA, 2007a). On December 18, 2007, dredging was completed. The staging and treatment area at Wickes Park was cleared and secured from public access until restoration work can be completed in the spring of 2008.

3.2.3 Ecological risk assessments

In addition to site characterization studies outlined above, a State-supported ecological risk assessment (ERA) was completed. This assessment, produced by Galbraith Environmental Services, focused on the effects of dioxins and furans, and is summarized below. Similarly, Dow was required to perform a SLERA and BERA, and these assessment are underway. Michigan State University and Dow's consultants are pursuing field studies to collect data for the SLERA and BERA. A summary of field studies conducted by Dow, Michigan State University, and ENTRIX follows a summary of the Galbraith Environmental Services ERA, below.

Galbraith ERA

The Galbraith ERA concluded that birds and mammals in the Tittabawassee River and floodplain are at risk from adverse effects of dioxins and furan exposure (Galbraith Environmental Services, 2003). Risks were evaluated using site-specific contaminant data for sediment, water, and fish from Tittabawassee River, bird eggs from the Shiawassee NWR, and comparison to information from the scientific literature. Based on a review of the scientific literature, dietary concentrations that would result in toxicity to exposed piscivorous (fish-eating) mammalian species [such as river otter (*Lutra canadensis*) and mink (*Neovison vison*)] and piscivorous birds were identified. Measured concentrations in fish tissue collected in the Tittabawassee River were then compared to the literature values. Based on this comparison, mammalian and avian piscivorous species were reported to be at risk to the adverse effects of dioxins and furans. Dioxin and furan concentrations in migratory waterfowl [wood ducks (*Aix sponsa*) and hooded mergansers (*Lophodytes cucullatus*)] eggs collected in the Shiawassee NWR were also measured and compared to literature values, and results were reported to indicate that these species are also at risk of adverse effects.

Studies by Dow, Michigan State University, and ENTRIX

Dow is actively assessing biological and ecological risk in the Tittabawassee River and floodplain. In general, Dow is focusing on population-level effects that could be caused by a subset of dioxins and furans found in Tittabawassee River and floodplain sediments and soils on a variety of biota that reside in or near the river.

Dow is funding field studies to examine the effects of dioxins and furans on wildlife in the Tittabawassee River floodplain. The studies were initiated in 2003, with the bulk of the work to be completed by the end of 2008 (ENTRIX, 2006a). Dow has indicated that some or all of the study results will be used in the BERA (ENTRIX, 2006a). Field study work plans are included as appendices to the BERA work plan. According to the Dow BERA and SLERA work plans (ENTRIX, 2006a, 2006b), the studies are investigating site- and congener-specific exposure (exposure studies) and population-level health (effects studies) for selected species from the Tittabawassee River floodplain.

To date, results of the field studies have been presented as conference abstracts and presentations (SETAC, 2005, 2006, 2007). Five manuscripts related to mink exposure and dietary studies have been prepared [Blankenship et al., 2008; Zwiernik et al., In press (a, b, c, d)].

Exposure studies

According to the BERA work plan (ENTRIX, 2006a), the main goal of the exposure study field work is to collect data on the levels of dioxins and furans in the diet and tissues of the species under study. These levels will then be compared to samples collected from reference areas, and to literature-based toxicity reference values (TRVs).

The species under study are mink, shrew (Soricidae), tree swallow (*Tachycineta bicolor*), eastern bluebird (*Sialia sialis*), house wren (*Troglodytes aedon*), robin (*Turdus migratorius*), great horned owl (*Bubo virginianus*), great blue heron (*Ardea herodias*), and belted kingfisher (*Megaceryle alcyon*). According to the BERA work plan (ENTRIX, 2006a), these species were selected according to EPA ERA guidelines (U.S. EPA, 1998), including their relevance to the wildlife in the TRSAA.

The following is a summary of the exposure work, known to be underway:

- Site-specific data are or will be available for 17 dioxin and furan congeners in dietary items, including sediments and soils, aquatic plants, crayfish, benthic and emergent invertebrates, soil, terrestrial plants, worms, terrestrial invertebrates, and small mammals.
- Dietary composition of receptors are being or will be analyzed, including analyses of stomach contents, to develop frequencies and proportions of different dietary items that are consumed by the species under study.
- Site-specific dietary exposures for each receptor are being or will be calculated using likely concentrations in dietary items and their intake frequencies. Other exposure routes, including direct contact and inhalation, will be modeled and such exposures will be incorporated into estimated potential average daily doses (ENTRIX, 2006a).
- Dietary doses and receptor tissue concentrations will be compared to reference sites and literature-based dietary TRVs.

Effects studies

According to Dow, the purpose of the effects studies is to evaluate the population-level reproductive health of the species under study (ENTRIX, 2006a). The assessment endpoints for the exposure and effects studies are summarized in Tables 3.3 and 3.4. In addition to these measurements, habitat suitability, relative abundance, individual health (morphological and histological endpoints for trapped mink), and productivity potential (placental scars for trapped mink) are also being investigated, as well as separate studies to address organism contaminant uptake kinetics and dose responses related to specific stressors.

Table 3.3. Summary of exposure and effects endpoints to be measured in the field studies funded by Dow

	Exposure studies		Effects studies		
Species	**Dietary-based exposure**	**Receptor tissue concentrations[b]**	**Return rates/survival estimates**	**Screening for deformities/ birth defects**	**Foraging range**
Shrew	X	X			
Mink[a]	X	X			
Tree swallow	X	X	X	X	
Eastern bluebird	X	X	X	X	
House wren	X	X	X	X	
American robin	X	X			
Great horned owl	X	X	X	X	X
Great blue heron	X	X	X	X	X
Belted kingfisher	X	X	X	X	X

a. Additional individual and population level health effects listed in the text.
b. Tissues samples in birds include adults, nestlings, fresh and addled eggs, adult plasma, nestling blood, and/or salvaged nestlings.

Table 3.4. Summary of productivity endpoints to be measured in the field studies funded by Dow

Species	Box occupancy	Egg masses	Clutch size	Hatching success	Nestling growth curves	Fledging success	Nest attentiveness (adult)	Depredation rates	Nest occupancy	Nestling sex ratio
Tree swallow	X	X	X	X	X	X	X	X		
Eastern bluebird	X	X	X	X	X	X	X	X		
House wren	X	X	X	X	X	X	X	X		
Great horned owl	X	X	X	X	X	X	X	X		
Great blue heron			X	X		X			X	
Belted kingfisher			X	X	X	X		X		X

4. Confirmation of Exposure

This chapter presents data confirming that natural resources of the TRSAA have been exposed to hazardous substances released from the Dow plant.

Federal regulations state that an assessment plan should confirm that:

> at least one of the natural resources identified as potentially injured in the preassessment screen has in fact been exposed to the released substance [43 CFR § 11.37(a)].

A natural resource has been exposed to hazardous substances and/or petroleum products if "all or part of [it] is, or has been, in physical contact with . . . a hazardous substance, or with media containing the . . . hazardous substance" [43 CFR § 11.14(q)]. Federal regulations also state that, "whenever possible, exposure shall be confirmed using existing data" from previous studies of the assessment area [43 CFR § 11.37(b)(1)].

Hazardous substances released from the Dow plant include dioxins and furans, and a broad range of other organic contaminants and metals (see Chapter 3). The following sections provide confirmation of exposure through summaries of readily available information about hazardous substances in the assessment area, including advisory information and data for surface water resources (including sediments), groundwater resources, geological resources (soils), and biological resources such as birds and fish.

4.1 Study Area Advisories

An unusually large and extensive body of advisories exists for the TRSAA, including for fish consumption, wild game consumption, and soil contact. This section of the Assessment Plan presents a summary of these advisories with respect to hazardous substances released by Dow. In later sections, we identify aspects of the advisories that are key to the NRDA and provide a methodology on how advisories could be used as measures of injuries, services, and damages.

According to federal regulations, an injury to biological resources has resulted from the release of a hazardous substance if the concentration of the substance is sufficient to:

> exceed levels for which an appropriate state health agency has issued directives to limit or ban the consumption of such organism [43 CFR §11.62(f)(1)(iii)].

Federal regulations also specify that an injury to biological resources can be defined by an exceedence of action or tolerance levels established under Section 402 of the Food, Drug and Cosmetic Act [21 USC § 342] in edible portions of organisms [43 CFR § 11.62(f)(1)(ii)]. This section focuses on consumption advisories; however, the Trustees may also evaluate injury as concentrations that exceed action or tolerance levels, regardless of advisories.

4.1.1 Fish consumption advisories

The State of Michigan began advising that people restrict their consumption of contaminated sport-caught fish in the 1970s. Fish consumption advisories (FCAs) have changed over time to reflect contemporaneous data on fish contaminant levels and contaminant toxicity, and new methodologies for establishing and issuing advisories. Until 1980, Michigan issued FCAs based on the U.S. Food and Drug Administration's guidelines. In 1981, Michigan began to apply risk assessment methodologies to determine trigger levels for certain contaminants. Trigger levels have changed over the years, mainly based on refinements in knowledge of the contaminants. For example, in 1986 the Michigan Department of Community Health (MDCH) evaluated the dioxin trigger level of 25 pptr and adopted a lower trigger value of 10 pptr. The details of the advisories for the TRSAA are provided in Attachment D (MDNR, 1977, 1978a, 1978b, 1979, 1980, 1981a, 1982, 1983a, 1984a, 1985, 1986, 1987, 1988a, 1989, 1990a, 1991a, 1992, 1993a, 1994a, 1994c, 1995, 1996, 1997; MDCH, 1998, 1999, 2000, 2001, 2002, 2003, 2004a, 2007).

Tittabawassee River

The specific details of the advisories in the Tittabawassee River are presented in Tables D.1-D.4 of Attachment D and are summarized as follows:

- **1981**: The first advisory recommended "against eating any fish" for all human population groups, based on polybrominated biphenyls (PBBs) and dioxin.

- **1982-1988**: "Do not eat any fish" advisories were issued for all fish species for all human population groups; from 1986 to 1988, the FCAs specified carp and catfish. The contaminants responsible for the advisories during these years were not specified. For some of the years, the advisory was issued with a list of possible contaminants that may have caused the advisory; for others, no contaminants were listed. However, for years prior to and after this time span, the FCAs were based on only three contaminants: PBBs, PCBs, and dioxin. Hence, it is likely that either one or some combination of the three was also responsible for the advisories issued between 1982 and 1988.

- **1989-1996**: The FCAs stipulated "do not eat" carp and catfish for all human population groups; PCBs and dioxin were specified as the contaminants responsible for the consumption advisory. A new advisory was issued for "all other species" for dioxin and

PCBs: 1 meal/month for women and children subpopulations and restricted consumption for the general population (though a meal frequency was not specified).

- **1997-2000**: In addition to advisories to the general population for PCBs and dioxin in catfish, carp, and "all other species," advisories to subpopulations were issued for PCBs in white bass, white sucker, and walleye.

- **2001-present**: The catfish and carp advisories remain in place, and the "all other species" advisory further specifies 1 meal/week for the general population, and 1 meal/month for subpopulations. The advisory to the general population for PCBs and dioxin in white bass was extended to "do not eat." The advisories specific to walleye and white sucker were removed (these species are now included under the "all other species" advisory), and a new advisory was issued for PCBs and dioxin in smallmouth bass.

Changes have also occurred regarding fish size specifications within the advisories. Generally, the earlier advisories did not specify fish sizes, but later advisories specified applicable lengths. For example, the advisories for carp and catfish did not specify a size until 1997 when the advisories were specifically issued for fish over 6 inches in length. A similar trend occurred in the Saginaw River and Bay advisories. Advisories for children and for women are generally more stringent than the advisories for the general population because of the concern that certain chemicals may have adverse reproductive effects.

Saginaw River

Advisories for the Saginaw River were first issued in 1979. The advisories followed a similar pattern to those issued for the Tittabawassee River, both in terms of fish species affected and contaminants, with dioxin and PCBs being the dominant cause of advisories. The exact definition of the geographic extent of the advisories also changed over time, though they generally applied to the full length of the Saginaw River, from its confluence with the Tittabawassee and Shiawassee rivers, to its mouth at Saginaw Bay. The specific details of the advisories are presented in Tables D.1-D.4 of Attachment D and are summarized below:

- **1979-1981**: The first advisories recommended "against eating any fish" for all human population groups, based on PBBs and dioxin.

- **1982-1988**: "Do not eat any fish" advisories were issued for all fish species for all human population groups from 1982 to 1985. In 1986, the advisory was for carp, with one meal/week advised for the general population, and no consumption advised for women and children. From 1986 to 1988, FCAs were issued for catfish in addition to carp, and the FCA again stipulated "do not eat" for all populations. The contaminants responsible for the advisories during these years were not specified. For some of the years, the advisory was issued with a list of possible contaminants; for others, no contaminants were listed. However, for years prior to and after this time span, the FCAs were issued based on PBBs, PCBs, and dioxin. Hence, it is likely that either one or some combination of the three was also responsible for the advisories issued between 1982 and 1988.

- **1989-1996**: The FCAs recommended that all human population groups "do not eat" carp and catfish because of PCBs and dioxin. A new advisory was issued for PCBs and dioxin in "all other species": 1 meal/month for women and children subpopulations, and restricted consumption for the general population (meal frequency was not specified).

- **1997-present**: The catfish and carp advisories remain in place, but the "all other species" advisory was further specified to indicate 1 meal/week for the general population and 1 meal/month for subpopulations. An advisory for white bass for PCBs was introduced, first as 1 meal/week for the general population and "do not eat" for woman and children subpopulations, then revised in 1998 for the subpopulations to 6 meals/year. The history and pattern of FCAs for the Saginaw River is similar to those of the Tittabawassee River. Advisories were continuous from 1979 to the present for the length of the river. The FCAs included all species, with "do not eat" advisories for numerous species targeted by anglers. PCBs and dioxin were the dominant contaminants identified in the issuance of the advisories, but dioxin was listed as a contaminant only in combination with PCBs, never independently.

Saginaw Bay

Advisories were first issued in the Saginaw Bay in 1977. From 1977 to the present, consumption advisories have been issued for 20 species of fish in the Bay (Tables D.1-D.4 of Attachment D). The basis for the advisories has changed over time. For example, between 1977 and 1992, only PCBs triggered advisories, except during 1988-1992, when FCAs did not specify a contaminant. Dioxin first appeared in FCAs for the Bay in 1994, and between 1994 and the present, dioxin advisories included lake trout, rainbow trout, whitefish, carp, and catfish. The geographic details of the advisories over time are summarized in Table D.5 of Attachment D.

4.1.2 Wild game advisories

This section summarizes the wild game consumption advisory that was issued in September 2004 by the MDCH (2004c). In a study conducted by Dow Chemical and reviewed by Michigan health assessors, dioxin levels in deer, turkeys, and squirrels were 2 to 120 times higher in the floodplain downstream of Midland than a location upstream of Midland (MDEQ, 2004b). State of Michigan health assessors concluded that eating deer, turkeys, or squirrels harvested at the levels found in the Dow study could result in adverse health effects. In September 2004, the

MDCH issued an advisory to not consume deer liver or turkey, and to limit consumption of deer muscle and squirrels, harvested in the floodplain downstream of Midland. The advisory was issued for areas adjacent to the Tittabawassee River from Midland to the confluence with the Saginaw River, but included a statement that the areas of concern could not be defined precisely due to the movement of animals (MDEQ, 2004b, 2004c). MDCH recognized that people may still eat deer and turkey from the advisory area, so the advisory made the additional recommendations that included trimming visible fat from the meat before cooking, and to not consume organ meats such as liver and brains or the skin of harvested animals. Table D.6 of Attachment D summarizes the wild game consumption advisory issued in 2004 (MDCH, 2004c).

4.1.3 Soil advisories

High levels of dioxins and furans were first found in the Tittabawassee River floodplain during a wetland mitigation project in 2000. Results of soil samples showed dioxin concentrations as high as 2,200 pptr TEQs, nearly 25 times the residential direct contact criterion established in provisions of Part 201 ("Environmental Remediation") of Michigan's NREPA (MDEQ, 2003b). This prompted the Michigan Department of Agriculture (MDA) to issue a food and gardening guidance document in 2002 (MDA, 2002), and conduct a soil sampling and assessment program in the Tittabawassee floodplain (MDEQ, 2003b, 2003f). Soil and sediment sample results identified dioxin concentrations as high as 7,300 pptr TEQs. Given these results, the MDEQ, MDCH, and MDA issued the 2003 soil movement advisory (MDEQ, 2003e), which was later revised in July 2005 (MDEQ, 2005).

The contents of the 2003 advisory are summarized in Tables D.7 and D.8 of Attachment D (MDEQ, 2003e). The area of concern, as described in the 2003 advisory, is the Tittabawassee River 100-year floodplain downstream of Midland. This area is generally bordered to the southwest by River Road and Stroebel Road. Downstream of Midland, the 100-year floodplain borders Midland Road, St. Andrews Road, and Michigan Avenue to the northeast (MDEQ, 2003e).

The 2005 revised advisory refined the areas covered by the advisory areas downstream of the City of Midland that are flooded by the river every 7 to 10 years. In addition, the 2005 revised advisory also includes properties in the City of Midland that are close to and downwind of the Dow Midland plant, which exceed residential soil direct contact for dioxins and furans, based on soil sampling conducted by the MDEQ, Dow, and EPA (MDEQ, 2005). The purpose of the soil advisory is to avoid problems that can result from disturbing, moving, and redistributing contaminated floodplain soil and river sediments. The advisory applies to minor and major movement of household soil and commercial movement of soil, including sediment dredging and farming, with the premise that all movement of soil and sediment increases exposure risk. Below is a summary of the advisories for soil activities related to household activities (construction of ponds, berms, and home footings; gardening; lawn work; electrical and plumbing conduit trenching; and the installation of septic tanks and tile fields) and to commercial activities (sand mining; construction or repair of roads, bridges, sewer lines, water lines, and utility lines; boat launch maintenance; marina maintenance; and installation or removal of pilings).

The household soil advisory makes these recommendations:

- Minimize or eliminate soil displacement and movement activities on property located within the floodplain
- Prevent children from playing in soils
- Do not eat unwashed foods
- Store all gardening clothes outdoors
- Avoid activities that may introduce soils to the mouth
- Keep soil moist to avoid dust
- Avoid placement of outbuildings and homes within the floodplain.

Commercial soil movement and dredging activities included additional precautions for commercial soil movement (including the analytical testing of soils at depth) and soil erosion prevention (including covering soil piles with plastic sheeting). In addition to human health recommendations, the advisories also provide guidance on avoiding potential liability issues associated this contaminated soil movement:

- Minimizing or eliminating soil displacement and movement activities on property located within the floodplain
- Disposing of any removed soil at a licensed landfill
- Using only clean fill or topsoil to re-grade areas
- Not moving soil from low-lying, more potentially contaminated areas to higher, potentially uncontaminated or less contaminated areas
- Immediately enacting measures to prevent wind and rain erosion of soil
- Utilizing minimum tillage and dust reduction practices and following the personal risk reduction strategies for gardening.

4.2 Other Data Confirming Exposure of Natural Resources

Many data are available to confirm the exposure of natural resources to hazardous substances within the TRSAA. Attachment E lists sources of relevant data from the Tittabawassee River, the Saginaw River, and Saginaw Bay. The data sources are organized according to media (surface water, sediment, biota, and groundwater), and are separated into four specific time periods: pre-1980, 1980-1989, 1990-1999, and 2000-present.

For the Tittabawassee River, surface water, sediment, and fish tissue data are available for each time segment. Bioassay (toxicity testing, bioaccumulation, and caged fish studies) and macroinvertebrate survey data are available for pre-1980 through 2004. Additional Tittabawassee River data are available for air emissions, Dow discharges, fish surveys, bird tissues, bird eggs, benthic invertebrates, periphyton/phytoplankton, groundwater, and soils. In the Saginaw River, sediment data are available for each year category. In addition, Saginaw River data are available for surface water, fish tissue, and benthic invertebrate surveys for many years. Surface water, sediment, fish tissue, bird survey, and benthic invertebrate survey data are available for the Saginaw Bay for many years. Below, major categories of natural resources that have potentially been injured are defined, including surface water and sediments, biological resources, groundwater, and geologic resources.

4.3 Surface Water and Sediment Resources

4.3.1 Definition

Surface water resources are defined as the waters of the United States, including the sediments suspended in water or lying on the bank, bed, or shoreline and sediments in or transported through coastal and marine areas. This term does not include groundwater or water or sediments in ponds, lakes, or reservoirs designed for waste treatment under the RCRA [42 USC §§ 6901-6992] or the CWA, and applicable regulations [43 CFR § 11.14(pp)].

4.3.2 Exposed surface water and sediment resources

In the assessment area, exposed surface water and associated sediments include, but are not limited to the:

- Tittabawassee River from the Dow plant to the confluence with the Saginaw River
- Tittabawassee River floodplain
- Saginaw River downstream of the confluence with the Tittabawassee River
- Saginaw River floodplain
- Saginaw Bay.

These resources provide ecological services such as habitat for aquatic biota and a water supply for riparian vegetation habitat. In addition, the surface water is a likely transport pathway for carrying contaminants downstream of the plant.

4.4 Biological Resources

4.4.1 Definition

Biological resources are defined as those natural resources referred to in Section 101(16) of CERCLA as fish and wildlife and other biota. Fish and wildlife include aquatic and terrestrial species; game, nongame, and commercial species; and threatened, endangered, and state sensitive species. Other biota encompass shellfish, terrestrial and aquatic plants, and other living organisms not otherwise listed in this definition [43 CFR § 11.14(f)].

4.4.2 Exposed biological resources

The Tittabawassee River and floodplain habitats support a wide variety of biota potentially exposed to hazardous substance releases from the plant. Potentially injured biological resources may include, but are not limited to:

- Riverine, wetland, and floodplain fish and wildlife habitats
- Mammalian and avian species
- Fish of various species
- Reptiles and amphibians
- Aquatic benthic macroinvertebrates
- Other aquatic flora and fauna
- Vegetation
- Threatened or endangered species.

4.5 Groundwater Resources

4.5.1 Definition

Groundwater is defined as water in a saturated zone or stratum beneath the surface of land or water and the rocks or sediments through which groundwater moves. It includes groundwater resources that meet the definition of drinking water supplies [43 CFR § 11.14(t)].

4.5.2 Exposed groundwater resources

Groundwater that is collected at the Dow plant by the RGIS is sampled and analyzed on a regular basis (Dow Chemical, 1984; ATS, 2006b), and these data will be compiled and reviewed by the Trustees as a part of the assessment of injuries to groundwater in the TRSAA.

4.6 Geologic Resources

4.6.1 Definition

Geologic resources are defined as those elements of the Earth's crust such as soils, sediments, rocks, and minerals, including petroleum and natural gas, that are not included in the definitions of groundwater and surface water resources [43 CFR § 11.14(s)].

4.6.2 Exposed geologic resources

Geologic resources of the TRSAA include soils exposed to hazardous substances by foot traffic and wind. In addition, soils within the Tittabawassee and Saginaw River floodplains are potentially exposed by flooding. These soils are important in providing a medium for vegetation, invertebrates, microbes, and other biota. Under flooding conditions, contaminated floodplain soils can expose aquatic biota and/or surface water resources to hazardous substances. In addition, soils can serve as a pathway to groundwater via percolation of hazardous substances from contaminated surface soils to the underlying aquifer.

5. Assessment Approach

Chapter 4 summarized data confirming that natural resources in the TRSAA have been exposed to hazardous substances. Natural resources, including surface water, sediments, groundwater, floodplain soils, riparian vegetation, aquatic biota, and terrestrial wildlife resources, may be injured as a result of this exposure. The Trustees will conduct an assessment to determine the nature and extent of injuries to these resources, the restoration opportunities that could offset the losses caused by injuries, and the appropriate amount of restoration to make the public whole. The Trustees may use a combination of metrics that address either the natural resources themselves, the ecological and human services that the natural resources provide, or the human values associated with the natural resources and their services.[1] Generally, the purpose of the injury assessment is to determine whether injuries to natural resources have occurred [43 CFR § 11.62], to identify the environmental pathways through which injured resources have been exposed to hazardous substances [43 CFR § 11.63], and to quantify the degree and extent (spatial and temporal) of injury losses and potential restoration gains compared with baseline conditions [43 CFR § 11.70].

This chapter provides an overview of potential injuries to, and restoration of, natural resources that will be assessed by the Trustees, including potential methods to scale restoration gains to injury losses. Specifically, this chapter addresses the Trustees' proposed approaches for injury determination, determination of restoration alternatives, and quantification of the link between them as damage determination.

5.1 Overall Approach

To assess damages at the TRSAA, the Trustees intend to follow federal regulations at 43 CFR Part 11 (see Section 1.3 of this Assessment Plan), to the extent practical. Consistent with the regulations, injury determination, restoration alternatives, and quantification will be evaluated for all relevant categories of natural resources. However, natural resources are interdependent. For example, surface water; bed, bank, and suspended sediments; floodplain soils; and riparian vegetation together provide habitat – and lateral and longitudinal connectivity between habitats – for aquatic biota, semi-aquatic biota, and upland biota. Hence, injuries to individual natural resources may cause ecosystem-level losses and restoration of habitats may allow ecosystem-

1. Often, injury determination targets impacts caused by hazardous substances on the quantity and quality of the natural resources themselves. However, in some cases, measurement of services or values can provide highly relevant information for quantification of injuries or the injury-damage nexus.

level gains. The Trustees will consider these interdependent ecosystem-level losses and gains when conducting their assessment.

In addition, the Trustees will evaluate whether any specific natural resources and services are impacted, and determine their importance to the public. For instance, the Tittabawassee River and its floodplain have required an unusually large number of advisories that may significantly impact the public's recreational uses and appreciation of natural resources.

5.1.1 Iterative assessment planning and assessment determination

The Trustees will use the extensive body of existing data in the assessment. Key sources of existing data are described in Chapter 4 of this Assessment Plan. The Trustees will compile and review existing site-specific data. The results of any ongoing data collection and monitoring programs, including those associated with response activities, will also be examined.

Following this review, the Trustees may determine that additional data are required in order to assess the site. In such cases, the Trustees may issue subsequent assessment plan addenda, study plans, or SOPs for the public to view. The Trustees will also determine whether targeted assessment studies should be conducted cooperatively with the Trustees as the lead, cooperatively with Dow as the lead, or independently by the Trustees (see Section 5.1.2, below). Any assessment studies will be designed to provide additional data relevant to assessing injury and losses, determining potential gains from restoration, and/or for scaling restoration to the losses.

5.1.2 Cooperative assessment with Dow

The Trustees have entered a funding and participation agreement with Dow to facilitate assessment activities (USFWS, 2007a). The agreement allows for Trustee-implemented cooperative studies and related activities, Dow-implemented cooperative studies and related activities, and independent studies. Cooperative elements of the assessment will either be funded by Dow or led by Dow under Trustee oversight.

The cooperative approach also permits the Trustees and Dow to capitalize on the shared experience of the respective parties. The Trustees have formed three technical workgroups with Dow to evaluate the need for additional assessment studies in the TRSAA that could be conducted cooperatively. The workgroups include a human services workgroup, an ecological workgroup, and a restoration workgroup.

5.2 Injury and Pathway Determination

The Trustees will determine whether an injury to one or more natural resources has occurred as a result of releases of hazardous substances [43 CFR § 11.62]. This determination will include the following two steps:

1. **Determination that injury has occurred.** In this first step, the Trustees will determine whether injuries, such as those that meet the definitions of injury in 43 CFR § 11.62, have occurred for surface water, sediment, groundwater, geologic, and biological resources (see Section 5.2.1).

2. **Pathway determination.** The Trustees will determine whether sufficient exposure pathways exist or have existed by which hazardous substances are transported in the environment and natural resources are exposed to those substances [43 CFR § 11.63]. Pathways will be determined using a combination of information about the nature and transport mechanisms of the hazardous substances, potential pathways, and data documenting the presence of the hazardous substance in the pathway resource(s).

The rest of Section 5.2 describes methods proposed by the Trustees to determine injuries to specific natural resources. Definitions of injury for each natural resource category are presented, followed by proposed approaches to determine if the resources have been injured. Methods proposed by the Trustees to determine pathways are also described.

5.2.1 Definitions of injury

Based on an initial review of existing data, the relevant NRDA regulatory definitions for the evaluation of injuries to natural resources of the TRSAA include the following:

Biota

- Concentrations of a hazardous substance sufficient to cause the biological resource or its offspring to have undergone at least one of the following changes in viability: death, disease, behavioral abnormalities, cancer, physiological malfunctions (including malfunctions in reproduction), or physical deformations [43 CFR § 11.62(f)(1)(i)].

- According to federal regulations, an injury to biological resources has resulted from the release of a hazardous substance if the concentration of the substance is sufficient to "exceed levels for which an appropriate State health agency has issued directives to limit or ban the consumption of such organism" [43 CFR §11.62(f)(1)(iii)]. Federal regulations also specify that an injury to biological resources can be defined by an exceedence of action or tolerance levels established under Section 402 of the Food, Drug and Cosmetic Act in edible portions of organisms [43 CFR § 11.62(f)(1)(ii)].

Surface water

- Concentrations and durations of hazardous substances in excess of drinking water standards as established by Sections 1411-1416 of the Safe Drinking Water Act (SDWA), or by other federal or state laws or regulations that establish such standards for drinking water, in surface water that was potable before the release [43 CFR § 11.62(b)(1)(i)]

- Concentrations and duration of hazardous substances in excess of applicable water quality criteria established by Section 304(a)(1) of the CWA, or by other federal or state laws or regulations that establish such criteria, in surface water that before the release met the criteria and is committed use as habitat for aquatic life, water supply, or recreation [43 CFR § 11.62(b)(1)(iii)]

- Concentrations and duration of hazardous substances sufficient to have caused injury to groundwater, air, geologic, or biological resources, when exposed to surface water [43 CFR § 11.62(b)(1)(v)].

Sediment

- Concentrations and duration of hazardous substances sufficient to cause injury to biological resources, groundwater, or surface water resources that are exposed to sediments [43 CFR § 11.62(b)(v); 11.62(e)(11)].

Groundwater

- Concentrations and duration of hazardous substances in excess of drinking water standards as established by Sections 1411-1416 of the SDWA, or by other federal or state laws or regulations that establish such standards for drinking water, in groundwater that was potable before the release [43 CFR § 11.62(c)(1)(i)]

- Concentrations and duration of hazardous substances sufficient to have caused injury to surface water, when exposed to groundwater [43 CFR § 11.62(c)(1)(iv)].

Geologic resources

- Concentrations of substances sufficient to cause a toxic response to soil invertebrates [43 CFR § 11.62(e)(9)]
- Concentrations of substances sufficient to cause a phytotoxic response such as retardation of plant growth [43 CFR § 11.62(e)(10)]
- Concentrations of substances sufficient to have caused injury to surface water, groundwater, air, or biological resources, when exposed to geologic resources [43 CFR § 11.62(e)(11)].

5.2.2 Injury determination approaches

The injury definitions described in Section 5.2.1 consist of several components. These components are presented in Table 5.1, along with approaches that may be undertaken to determine whether the conditions of the injury definition are met.

In addition to the injury categories listed in Table 5.1, the Trustees will assess injuries caused by cleanup activities and corrective actions required by the response agencies to protect public welfare and the environment. In many case, necessary cleanup, such as dredging, soil removal, and capping can impact natural resources and habitats. Natural resource restoration will be used to compensate for these losses, as well as the losses caused directly by hazardous substances themselves.

5.2.3 Pathway determination approach

A pathway is the "route or medium through which . . . a hazardous substance is or was transported from the source of the discharge or release to the injured resource" [43 CFR § 11.14(dd)]. The regulations specify pathways through surface water [43 CFR § 11.63(b)], groundwater [43 CFR § 11.63(c)], air [43 CFR § 11.63(d)], geologic resources [43 CFR § 11.63(e)], and biological resources [43 CFR § 11.63(f)]. For example, a hazardous substance might move from a point of release to surface water, through groundwater, into the soil, and into a plant or the food web.

Pathways can be determined using a combination of information about the nature and transport mechanisms of the hazardous substances, potential pathways, and data documenting the presence of the hazardous substance in the pathway resource. Figure 5.1 shows the relationships between important pathways of exposure and ecological receptors in an aquatic food web.

Table 5.1. Components of selected injury definitions and evaluation approaches

Injury definition	Definition components	Potential determination approach
	Biota	
Cause the biological resource or its offspring to have undergone adverse changes in viability [43 CFR 11.62(f)(1)(i)]	Aquatic and terrestrial biota resources are injured when concentrations of hazardous substances are sufficient to cause changes in viability such as death, disease, behavioral abnormalities, physiological malfunctions, or physical deformation.	Compare surface water concentrations to criteria for the protection of aquatic life. Compare surface sediment concentrations to consensus-based sediment effect concentrations for benthic invertebrates. Evaluate population survey data to determine the degree of impairment of biotic communities using community indices, such as diversity, abundance, biomass, and pollution tolerance indices. Evaluate results of site-specific toxicity tests on biota exposed to assessment area surface water, sediment, soils, and/or diet. Evaluate dietary and tissue concentrations relative to concentrations known to cause death, disease, behavioral abnormalities, physiological malformations, or physical deformities.
	Vegetation resources are injured when concentrations of hazardous substances are sufficient to cause changes in viability such as death, disease, physiological malfunctions, or physical deformation.	Compare concentrations of hazardous substances in floodplain soils to thresholds for phytotoxic effects in terrestrial plants. Evaluate field vegetation survey data and aerial photographs to determine the degree of impairment of riparian vegetation.
Consumption advisories [43 CFR 11.62(f)(1)(ii) and (iii)]	Consumption advisories issued or exceed action or tolerance levels.	Evaluate basis of advisories; compare concentrations in organisms with action or tolerance levels.

Table 5.1. Components of selected injury definitions and evaluation approaches (cont.)

Injury definition	Definition components	Potential determination approach
	Surface water	
Water quality criteria exceedences [43 CFR 11.62(b)(1)(iii)]	Surface waters are a committed use as aquatic life habitat, water supply, or recreation.	Determine whether assessment area water bodies have or had committed uses. Committed use means either a current public use, or a planned public use of a natural resource for which there is a documented legal, administrative, budgetary, or financial commitment established before the release of a hazardous substance is detected.
	Concentrations and duration of hazardous substances are in excess of applicable water quality criteria.	Compare surface water concentrations to state, tribal, and federal water quality criteria. Consider spatial extent of exceedences, and temporal patterns of exceedences for use in evaluating potential service loss associated with exceedences.
	Criteria were not exceeded before release.	Compare conditions before the release, if data are available, or compare conditions at a carefully selected reference site, to state, tribal, and federal water quality criteria or standards, to determine whether exceedences of criteria measured since the release are a result of the release.
Drinking water standards exceedences [43 CFR 11.62(b)(1)(i)]	Concentrations and duration of hazardous substances are in excess of applicable drinking water standards.	Compare surface water concentrations to state, tribal, and federal water quality criteria and standards. Consider spatial extent of exceedences, and temporal patterns of exceedences for use in evaluating potential service loss associated with exceedences.
	Water was potable before release.	Compare conditions before the release, if data are available, or compare conditions at a carefully selected reference site to drinking water standards to determine whether exceedences of standards measured since the release are a result of the release.

Table 5.1. Components of selected injury definitions and evaluation approaches (cont.)

Injury definition	Definition components	Potential determination approach
Biological resources injured when exposed to surface water [43 CFR 11.62(b)(1)(v)]	Biological resources are injured when exposed to surface water.	Determine whether biological resources have been injured as a result of exposure to surface water. For example, examine individual, population, and community level indicators for health of aquatic biota (e.g., abundance and diversity of fish or benthic invertebrates); consider potential effects on waterbirds and aquatic mammals.
Sediment (defined as a surface water resource)		
Biological resources injured when exposed to sediments [43 CFR 11.62(b)(v); 11.62(e)(11)]	Biological resources are injured when exposed to sediments.	Compare sediment concentrations to consensus probable effect concentrations and consensus threshold effect concentrations to determine whether biological resources exposed to the sediments are likely to be adversely affected.
		Determine whether sediment concentrations have caused an adverse change in benthic invertebrate communities. Compare indices such as benthic invertebrate diversity, abundance, and biomass to evaluate whether contaminants have altered baseline conditions.
Contact advisories [analogous to 43 CFR 11.62(f)(1)(ii) and (iii)]	Contact advisories issued.	Evaluate basis of advisories.

Table 5.1. Components of selected injury definitions and evaluation approaches (cont.)

Injury definition	Definition components	Potential determination approach
	Groundwater	
Drinking water standards exceedences [43 CFR 11.62(c)(1)(i)]	Concentrations and duration of hazardous substances are in excess of applicable drinking water standards.	Compare groundwater concentrations to state, tribal, and federal standards. Consider spatial extent of exceedences for injury quantification.
	Water was potable before release.	Compare conditions before the release, upgradient of the release, or conditions in a carefully selected reference site, to drinking water standards to determine whether the water met standards before the release.
Other resources injured when exposed to groundwater [43 CFR 11.62(c)(1)(iv)]	Surface water resources are injured when exposed to groundwater.	Determine whether surface water has been injured as a result of exposure to groundwater. Measure surface water concentrations at seeps, springs, and gaining sections of streams and compare to surface water quality criteria and Michigan's groundwater/surface water interface standards.
	Geologic resources	
Soil invertebrates injured when exposed to soil [43 CFR 11.62(e)(9)]	Soil invertebrates are injured when exposed to soil.	Compare concentrations in soils to thresholds for effects in soil invertebrates.
Biological resources injured when exposed to soil [43 CFR 11.62(e)(11)]	Biological resources are injured when exposed to soil.	Compare concentrations in soils to thresholds for effects in biota.
Surface water and groundwater resources injured when exposed to soil [43 CFR 11.62(e)(11)]	Surface water and groundwater standards or criteria are exceeded (as described above).	Compare concentrations in surface water and groundwater to applicable standards and criteria (as described above).
Phytotoxic response when exposed to soil [43 CFR 11.62(e)(10)]	Plant survival or growth retarded when exposed to soil.	Compare concentrations of hazardous substances in soils to thresholds for effects in terrestrial plants. Compare vegetation community characteristics between assessment area and reference area.
Contact advisories [analogous to 43 CFR 11.62(f)(1)(ii) and (iii)]	Contact advisories issued.	Evaluate basis of advisories.

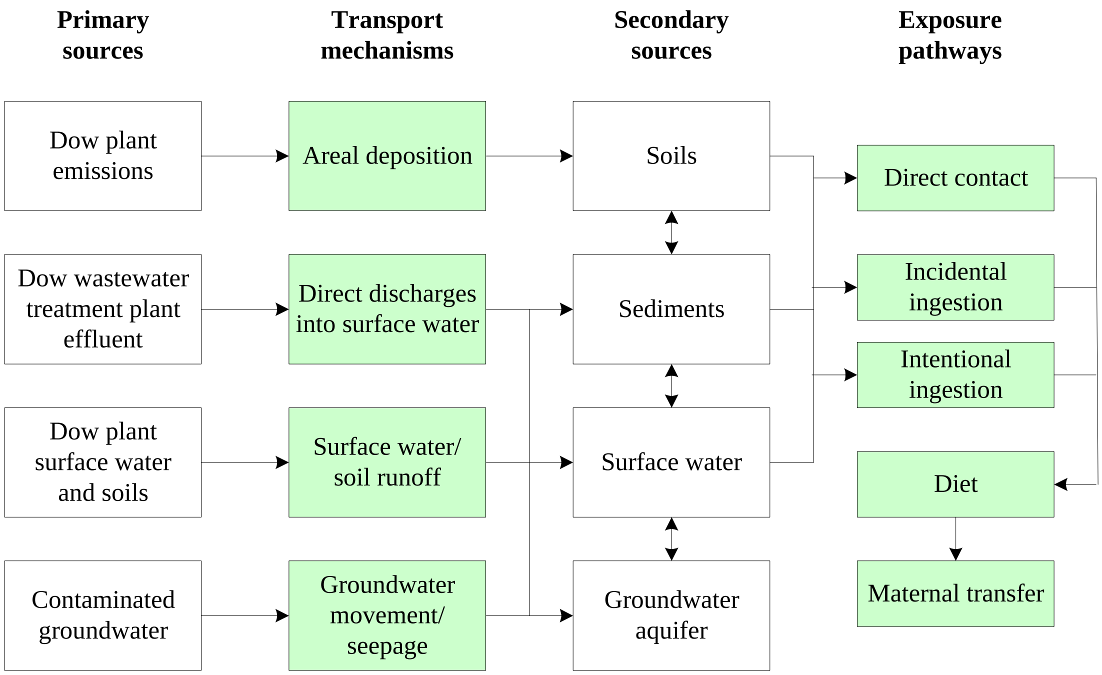

Figure 5.1. Partial ecological conceptual model identifying primary and secondary sources of contamination in the lower Tittabawassee River and floodplain with respective exposure routes to ecological receptors.

5.2.4 Quantification of spatial and temporal extent of injuries

Quantification of injuries will include an evaluation of the spatial extent, the temporal extent (past, present, and expected future), and the degree of injuries throughout the assessment area. To do so, the Trustees will evaluate contaminant data, historical records, and human use and enjoyment information. Spatial extent will be evaluated by considering the available information on injuries using a spatial analysis tool such as a geographic information system. Spatial extent may also include three-dimensional estimates of the extent of injuries in groundwater, based on available information on the volume of affected groundwater.

The degree of injuries will be evaluated by considering the degree of exceedence of criteria or other thresholds that are protective of natural resources. Other indicators of injury such as changes in ecological health and viability may also be relied upon in determining the degree of injury.

5.2.5 Determination of baseline

Baseline refers to the conditions that would have existed had the releases of hazardous substances not occurred [43 CFR § 11.72(b)(1)]. The condition of the injured resources, or the services or values provided by the injured resources, will be compared to baseline conditions to estimate the amount of restoration, service replacement, or the value of offsets required. The regulations suggest using historical data to evaluate baseline conditions, if they are available [43 CFR § 11.72(c)]. Data from control areas may also be used [43 CFR § 11.72(d)]. Because baseline services can be affected by conditions and activities that are not related to the release (e.g., roads, construction, permitted land uses), control areas may be evaluated to ensure that they are appropriate in terms of relevant physical, chemical, biological, or socioeconomic conditions.

5.2.6 Estimation of losses

The difference between natural resources, services, or values provided under baseline conditions versus injured conditions can be used to calculate the natural resource damages incurred by the public. The Trustees will quantify losses by evaluating how natural resources, services, or values that are normally available under baseline conditions have been or will be disrupted by the release [43 CFR § 11.71(b)].

5.2.7 Estimation of recovery to baseline

The Trustees will estimate the time needed for recovery of injured resources, services, or values to baseline levels. This evaluation will include an estimate of recovery time if no actions beyond response actions are taken, and estimates of recovery time for possible alternatives for restoration, rehabilitation, replacement, and/or acquisition of equivalent resources [43 CFR § 11.73].

5.3 Determining Restoration Opportunities and Benefits

The natural resource trustees have developed a proposed list of criteria for evaluating potential restoration ideas and projects for the NRDA restoration planning process for the TRSAA. These criteria are based on those identified in federal regulations at 43 CFR § 11.82, 15 CFR §§ 990.54 and 990.55, as well as relevant criteria developed as part of NRDAs conducted at other sites such as Bunker Hill, Idaho; Pecos Mine, New Mexico; New Bedford Harbor, Massachusetts; Green Bay, Wisconsin and Michigan; and Kalamazoo River, Michigan.

5.3.1 Categories of evaluation criteria

The criteria have been grouped into four evaluation categories: eligibility, focus, implementability, and benefits. These categories are intended to provide a framework to use when evaluating potential projects. Initially, the eligibility criteria will be used to screen out projects that do not meet the minimum standards described in federal regulations. Following the initial screening, the remaining projects will be evaluated in more detail using the focus, implementability, and benefits criteria. A brief description of each criteria category follows:

Eligibility: Criteria that relate to whether a proposed project meets minimum standards of relevance to injured resources and/or services, achieves a beneficial outcome, and complies with applicable and relevant laws including the ability to obtain any necessary regulatory permits. A project must meet each of these criteria to be considered further.

Focus: Criteria that relate to achieving the documented goals and objectives of the Trustees for the restoration of the TRSAA.

Implementability: Criteria that relate to project implementability, feasibility, and cost-effectiveness.

Benefits: Criteria that relate to the types, timing, and permanence of benefits provided by a project.

5.3.2 Evaluation criteria and their interpretation

Tables 5.2-5.5 provide specific criteria under each evaluation category. A brief interpretation is provided for each criterion to make clear how each will be used in the evaluation process.

Table 5.2. Eligibility criteria for restoration planning

Priority	Criteria	Interpretation
Pass/fail	E1: Complies with applicable/relevant federal, state, local, and tribal laws and regulations.	Project must be legal, able to be permitted, and must not jeopardize public health and safety.
Pass/fail	E2: Benefits natural resources injured by hazardous substances released to the Tittabawassee River system, or natural resource services[a] lost because of injuries.	Projects will be evaluated as to whether they restore, rehabilitate, replace, or acquire the equivalent of injured natural resources and services.
Pass/fail	E3: Is technically feasible.	Projects must have a high likelihood of success.

a. The term “services” includes ecological and active and passive public use services.

Table 5.3. Focus criteria for restoration planning

Priority	Criteria	Interpretation
Higher	F1: Restores, rehabilitates, replaces, or acquires the equivalent of injured natural resources.	Restoration/rehabilitation is preferred. Projects that benefit natural resources on site (within or adjacent to the Tittabawassee River system) are preferred. Acquisition of the equivalent is least preferred.
Medium	F2: Addresses/incorporates restoration of targeted natural resources and services as documented by Trustee mandates and priorities.	Priorities will be based on the resource types injured and degree of injury. Targeted resources include fish and wildlife and their habitats with emphasis on dynamic floodplain/riverine habitats, habitat continuity, water quality, soil and sediment quality, public game/wildlife/recreation areas, threatened and endangered species, native species, important food-web species, recreationally significant species, and culturally significant resources.
Lower	F3: Targets resources or services that are unable to recover to baseline[a] without restoration action, or that will require a long time to recover naturally (e.g., > 25 years).	Projects that target resources/services that will be slow to recover will be favored over projects that target resources/services that will recover quickly naturally.

a. Baseline is the state of natural resources and services that would exist if hazardous substances being addressed in this assessment had never been released.

Table 5.4 Implementation criteria for restoration planning

Priority	Criteria	Interpretation
High	I1: Is cost-effective, including planning, implementation, and long-term operation, maintenance, and monitoring activities.	Projects are preferred that have a high ratio of expected benefits to expected cost. Projects will be evaluated relative to other projects that benefit the same resource. Cost-sharing, e.g., for monitoring or maintenance, will be considered in evaluating expected costs.
High	I2: Benefits can be measured for success by evaluation/comparison to baseline, and can be scaled to the appropriate level of resource injury or loss.	Projects will be evaluated in terms of whether the benefits can be quantified and the success of the project determined. Projects can be scaled to provide restoration of appropriate magnitude. Small projects that provide only minimal benefit relative to lost injury/service or larger projects that cannot be appropriately reduced in scope are less favored.
Medium	I3: Uses established, reliable methods/technologies known to have a high probability of success.	Projects will be evaluated for their likelihood of success given the proposed methods. Factors that will be considered include whether the proposed technique is appropriate to the project, whether it has been used before, and whether it has been successful. Projects incorporating experimental methods, research, or unproven technologies will be given lower priority.

Table 5.4 Implementation criteria for restoration planning (cont.)

Priority	Criteria	Interpretation
Medium	I4: Takes into account completed, planned, or anticipated response actions.	Projects that restore or enhance habitat impacted by response actions will be preferred over those not associated with response actions. Projects proposed in areas likely to be impacted by response actions must be coordinated with response actions to provide cost savings and to take advantage of the availability of mobilized equipment on site during response actions, if possible, and to avoid damage to the restoration project by any subsequent response actions.
Medium	I5: If the project involves source control, it reduces exposure of natural resources to hazardous substances, including reduction of the volume, mobility, and/or toxicity.	Projects that address source control will be evaluated in terms of the extent to which they reduce exposure to hazardous substances, including by reducing volume, mobility, and/or toxicity.
Lower	I6: Is consistent with regional planning.	Project will be evaluated for consistency with regional planning, especially planning that has been publicly reviewed and/or formally adopted. Examples of relevant regional plans include species recovery plans and fish and wildlife management plans.

Table 5.5. Benefit criteria for restoration planning

Priority	Criteria	Interpretation
Higher	B1: Provides the greatest scope of ecological, cultural, and economic benefits to the largest area or population.	Projects that benefit more than one injured resource or service will be given priority. Projects that avoid or minimize additional natural resource injury, service loss, or environmental degradation will be given priority.
Higher	B2: Provides benefits not being provided by other restoration projects being implemented/funded under other programs.	Preference is given to projects that are not already being implemented or have no planned funding under other programs. Although the Trustees will use restoration-planning efforts by other programs, preference is given to projects that would not otherwise be implemented without NRDA restoration funds.
Medium	B3: Aims to achieve environmental equity and environmental justice.	A restoration program should benefit low-income and ethnic populations (including Native Americans) in proportion to the impacts to these populations. A restoration program should not have disproportionate high costs or low benefits to low-income or ethnic populations. Further, where there are specific service injuries to these populations, such as impacts on subsistence fishing, restoration programs should target benefits to these populations.
Lower	B4: Maximizes the time over which benefits accrue.	Projects that provide benefits sooner are preferred. Projects that provide longer-term benefits are preferred.

5.3.3 Restoration opportunities

The natural resource trustees are developing a list of potential restoration ideas and projects within the TRSAA. Examples of the types of projects that have been identified to date include wetland restoration/enhancement, species restoration, and fish passage/dam removal projects. Public input is solicited, and may be provided to the Trustees using the contact information provided in Section 1.6.

5.4 Scaling Restoration Gains to Losses Caused by Injuries

A damage determination is intended to "establish the amount of money to be sought in compensation for injuries to natural resources resulting from a . . . release of a hazardous substance" [43 CFR § 11.80(b)]. Damages are defined as ". . . the amount of money sought by the natural resource trustee as compensation for injury, destruction, or loss of natural resources as set forth in Section 107(a) or 111(b) of CERCLA" [43 CFR § 11.14(l)]. Generally damages include:

- The cost or value of sufficient restoration to accelerate the return to baseline
- The cost or value of restoration to offset losses between the time of release and the time when baseline conditions are restored ("compensable value")
- The cost to undertake the assessment process.

Compensable values of the injuries to natural resources and services lost to the public accrue from the time of discharge or release until the attainment of the restoration, replacement, and/or acquisition of the equivalent of the resources and their services to baseline. *Past damages* are those that accrue from the earliest point that injuries from releases can be determined, or authorization of the statute (1976 for the CWA and December 1980 for CERCLA), up to the present. However, recovery of past damages may be subject to certain limitations, including the history of data collection at the site. *Current and future damages* are those that accrue from the present until the resource and its services return or are restored to baseline conditions. Future damages can include *interim damages* (from the present until restoration actions are completed), and *residual damages* (ongoing damages that accrue after restoration activities have ceased if restoration did not fully restore natural resources services to baseline levels).

Figure 5.2 depicts how injuries (and lost services and values) accumulate over time for a hypothetical scenario. Losses accrue for as long as natural resources and services remain below baseline conditions. Thus, in Figure 5.2, the total losses are quantified as the present value of the sum of Areas A, B, C, D, and E. Area A represents unmitigated natural resource injuries that are

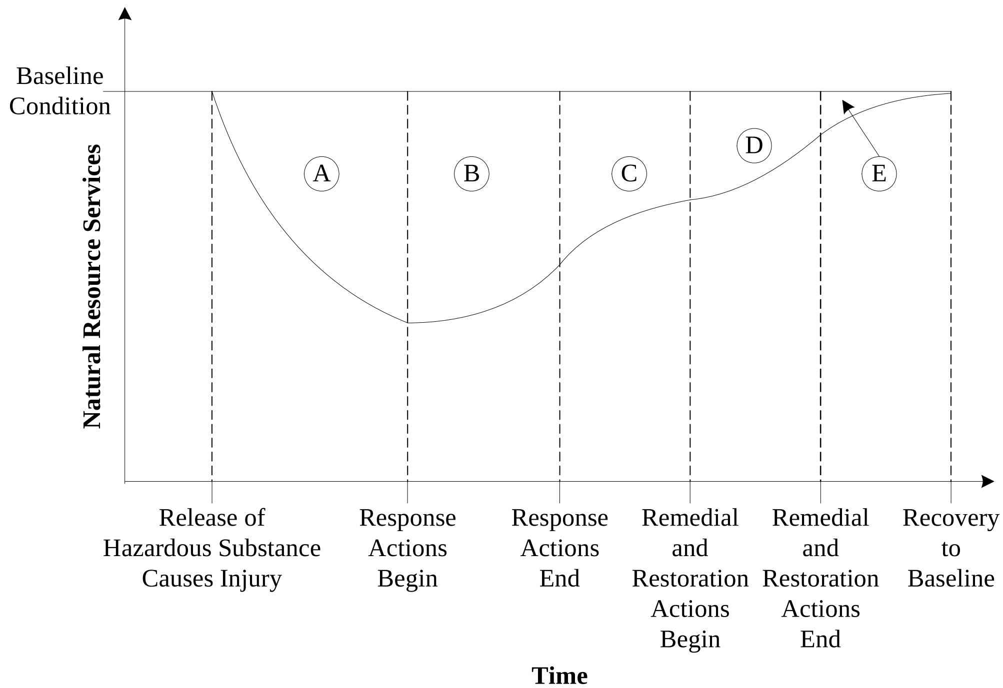

Figure 5.2. Timeline of injuries and damages.

getting worse over time. Then, response actions that may be focused on reducing human health risk, continuing injuries, and damages are represented by Areas B and C. Subsequently, remediation and restoration activities can further reduce injuries and damages, and close the gap between the injured level of services and baseline services (Area D). Finally, Area E represents any residual losses that may exist after remediation and restoration.

Trustees can consider a variety of methods that determine the amount of restoration, the cost of restoration, or the value of restoration needed to return resources and services to baseline conditions and compensate the public for interim losses. The Trustees' damage determination will quantify the link between the injury and pathway determination and the restoration evaluation described previously in this plan. There are several methods of determining damages, including:

- The cost of sufficient restoration based on resource-to-resource scaling
- The cost of sufficient restoration based on habitat-to-habitat scaling
- The value of losses caused by injuries to natural resources
- The value of gains caused by sufficient restoration to offset losses.

5.5 Development of the Restoration and Compensation Determination Plan

Federal regulations at 43 CFR § 11.81 provide that the Trustees should prepare an RCDP. The RCDP:

- Lists a reasonable number of alternatives for restoration, rehabilitation, replacement, or acquisition of equivalent resources and the related services lost to the public associated with each
- Selects one of the alternatives (a single "alternative" can include a combination of projects or project types)
- Gives the rationale for selecting that alternative
- Identifies methods to be used to determine the cost of the selected alternative and the compensable value of services lost to the public.

An RCDP contains both assessment results (i.e., Trustee determinations about restoration alternatives) and assessment planning elements (i.e., identification of compensable valuation methods). Therefore, though the regulations identify the RCDP as part of the Assessment Plan, Trustees often do not publish an RCDP until after the injury determination and quantification phases of the assessment are complete. In some cases, both an initial RCDP and a final RCDP are published to allow assessment-planning elements of the RCDP to precede assessment result elements of the RCDP. This plan will contain elements of an initial RCDP (this section and Section 5.3); however, determination of a preferred alternative for the final RCDP will be published after sufficient pathway, injury, restoration planning, and restoration-scaling determinations have been completed by the Trustees.

5.6 New TRSAA-Specific Assessment Studies Being Considered by the Trustees

This section proposes initial studies for the NRDA. Before initiating any data collections at the TRSAA, relevant existing data will be thoroughly reviewed.

5.6.1 Restoration planning

The Trustees have developed restoration criteria, pursuant to federal regulations at 43 CFR Part 11, as described in Section 5.3. The Trustees are working cooperatively with Dow to identify natural resource restoration opportunities in the TRSAA that could be used to address natural resources damages, which are also consistent with the mandates and priorities of the Trustees natural resource management authorities. The criteria described in Section 5.3 will be applied to the collected restoration projects and ideas. Furthermore, the Trustees intend to categorize and prioritize relevant restoration opportunities, including identifying methods to compare the benefits of different categories, and of different projects within a given category.

5.6.2 Biological and ecological injuries

Analysis of ongoing biological injury studies led by Dow

The Trustees intend to evaluate ongoing work already being led by Dow to determine its relevance for determining current pathways and current biological injuries, particularly as caused by dioxins and furans released by Dow. The Trustees expect that some of the data will be relevant to the assessment of damages within the TRSAA. The Trustees intend to work cooperatively with Dow to ensure that the ongoing studies maximize their relevance to the assessment. For example, the Trustees are currently proposing a cooperative study to extend some of the biological work that Dow has conducted on passerine bird return rates at nest boxes within the Tittabawassee River floodplain. The extension of the study will help Trustees develop a better understanding of longer-term trends in bird return rates. The Trustees also intend to analyze data and results in the context of current pathways and injuries within the TRSAA caused by dioxins and furans released by Dow. Finally, the Trustees intend to determine whether additional studies should be conducted to address key questions about current pathways and biological injuries caused by dioxins and furans released by Dow. For example, the Dow studies are focused on population-level endpoints. The Trustees are currently evaluating the need for studies that address more sensitive endpoints, such as cardiac malformations in birds, which may indicate biological injury that would otherwise not be captured by the Dow studies. The Trustees also intend to carefully review the data that have been collected to date on mink, and determine if additional studies are warranted to address the level of uncertainty that remains unresolved with regards to whether mink of the Tittabawassee floodplain have suffered injuries as a result of exposure to dioxins and furans.

5.6.3 Analysis of past injuries and future trajectories of injuries

The Trustees intend to evaluate past pathways and injuries caused by hazardous substances (including, but not limited to, dioxins and furans) released from the Dow Midland plant to the TRSAA. This analysis may be done cooperatively or independently. The purpose of this analysis will be to help determine past natural resource damages that occurred from 1976 (which is when the NRDA provisions of the CWA were enacted) or December 1980 (which is when CERCLA was enacted) until the present, and to help determine future trajectories of ongoing injuries.

The Trustees expect to use three primary kinds of information to conduct this analysis: information about the history of chemical production and waste management at the Midland plant; information about the physical dynamics of the TRSAA (e.g., the hydrodynamics of the Tittabawassee River); and relevant and reliable chemical concentration data from all relevant time periods and in all relevant media. The Trustees will be examining existing datasets for those best suited to form the basis of long-term monitoring of exposure, injury, and recovery and working with others to ensure that these monitoring efforts are continued. Data from the studies described above will be included if they are available, relevant, and reliable. The Trustees may also evaluate historical benthic invertebrate survey data, and consider conducting a new survey if necessary, to aid in the evaluation of injuries caused by hazardous substances in the TRSAA.

5.6.4 Determining the scope of economic studies to measure damages related to advisories

Analysis of the geographical extent of potential economics studies

The Trustees intend to analyze the geographical scope for potential economic studies of damages related to advisories. This analysis will address all types of advisories (fish consumption, wildlife consumption, and soil contact) in the Tittabawassee River and floodplain, Saginaw River and floodplain, and Saginaw Bay. If conducted cooperatively, pursuant to the funding and participation agreement, the Trustees intend to identify and assimilate relevant information and to determine the methods of analyses in cooperation with Dow. If not approved as a cooperative study, the Trustees intend to conduct this analysis independently.

Analysis of whether potential economics studies should focus on recreational use or total values

The Trustees intend to propose to Dow a cooperative study to analyze whether damages related to advisories in the TRSAA should be measured as recreational use values or total values. This analysis will also evaluate whether economic studies should use dollars, restoration actions, or both as metrics. If approved as a cooperative study, pursuant to the funding and participation agreement, the Trustees intend to identify and assimilate relevant information and to determine the methods of analyses in cooperation with Dow. If not approved as a cooperative study, the Trustees intend to conduct this analysis independently.

5.6.5 Economic study to measure damages related to advisories

The Trustees intend to propose to Dow a cooperative study to measure economic damages resulting from advisories caused by releases of dioxins and furans by Dow. The study approach is in part based on, and is consistent with, discussions of the human services technical workgroup, which includes representation from the Trustees and Dow. The study will address the losses to area residents and visitors due to FCAs, wild game consumption advisories, and soil advisories issued by the State of Michigan in response to hazardous substances, including those released by Dow.

The proposed tasks will take into consideration the breadth of activities affected by the advisories and the potentially significant losses associated with their impacts on the public's use of natural resources. Preliminary data indicate that a substantial number of fishing and hunting trips have potentially been affected and may continue to be affected by the presence of consumption advisories. In addition, dioxin and furan contamination from the Dow facility may affect visits to local parks and other recreation access areas, as well as backyard activities for local residents. Previous studies indicate that many members of the public who engage in outdoor activities choose to avoid areas where they may be exposed to environmental contaminants, or make other changes in their use of resources to minimize their potential exposure. These changes in behavior correspond to a loss in human services provided by the natural resources and a loss in public value, which have been found to be significant in many previous assessments.

The proposed tasks will furthermore take into consideration the limited availability of existing data sources that specifically address the circumstances of the TRSAA assessment. In particular, impacts to hunting from toxic contamination in wild game and impacts to outdoor recreation and backyard use due to soil contamination have not previously been addressed in valuation studies at other sites. While lost value to fishing from consumption advisories has been studied, an evaluation of fishing losses based solely on previous analyses at other sites would involve uncertainties that could be significant if the magnitude of losses is large. In addition, an assessment based solely on studies conducted at other sites would not specifically assist with restoration planning or the development of a restoration-based claim for this site.

This proposed study of lost value from fishing, hunting, and soil advisories in the TRSAA would be based on a survey and include a "revealed-preference" component based on the site-choice and trip-frequency decisions of participants in outdoor recreation throughout the region. It would also include a "stated-preference" component to specifically elicit from members of the public their values and preferences regarding contamination in the affected area. The use of these complementary data sources allows for rigorous analysis of values derived from economic behavior while using researcher-designed choice scenarios to overcome the limitations in the precision and scope of a solely behavior-based study.

6. Quality Assurance Project Plan

This QAPP has been developed to support studies that may be performed as part of the TRSAA NRDA. Under the NRDA regulations [43 CFR § 11.31], the QAPP is required to develop procedures to ensure data quality and reliability. This QAPP is intended to provide quality assurance/quality control (QA/QC) procedures, guidance, and targets for use in future studies that may be conducted for the NRDA. It is not intended to provide a rigid set of predetermined steps with which all studies must conform or against which data quality is measured, nor is it intended that data available from other sources for use in the NRDA must adhere to each of the elements presented in this QAPP. Ultimately, the quality and usability of data are based on methods employed in conducting studies, the expertise of study investigators, and the intended uses of the data. The QAPP has been designed to be consistent with the NCP and EPA's Guidelines and Specifications for Preparing Quality Assurance Project Plans (U.S. EPA, 1998).

The elements outlined in this plan are designed to:

- Provide procedures and criteria for maintaining and documenting custody and traceability of environmental samples
- Provide procedures and outline QA/QC practices for the sampling, collection, and transporting of samples
- Outline data quality objectives (DQOs) and data quality indicators
- Provide a consistent and documented set of QA/QC procedures for the preparation and analysis of samples
- Help ensure that data are sufficiently complete, comparable, representative, unbiased, and precise so as to be suitable for their intended uses.

Before the implementation of NRDA studies, study-specific sampling and analysis plans (SAPs) providing descriptions of study objectives, sampling methods, and QA/QC measures will be developed. To provide an ongoing record of methods and procedures employed in the assessment, developed SAPs will be appended to this QAPP. SAPs will be developed and updated as methods and procedures are reviewed and accepted for use.

6.1 Project Organization and Responsibility

An example of project QA organization, including positions with responsibility for supervising or implementing QA activities, is shown in Figure 6.1, with key positions and lines of communication and coordination indicated. Defining project organization, roles, and responsibilities helps ensure that individuals are aware of specific areas of responsibility that contribute to data quality. However, fixed organizational roles and responsibilities are not necessary and may vary by study or task. Descriptions of specific QA responsibilities of key project staff are included below. Only the project positions related directly to QA/QC are described; other positions may be described in associated project plans. Specific individuals and laboratories selected to work on an investigation will be summarized and appended to this QAPP or included in study-specific SAPs when they are established.

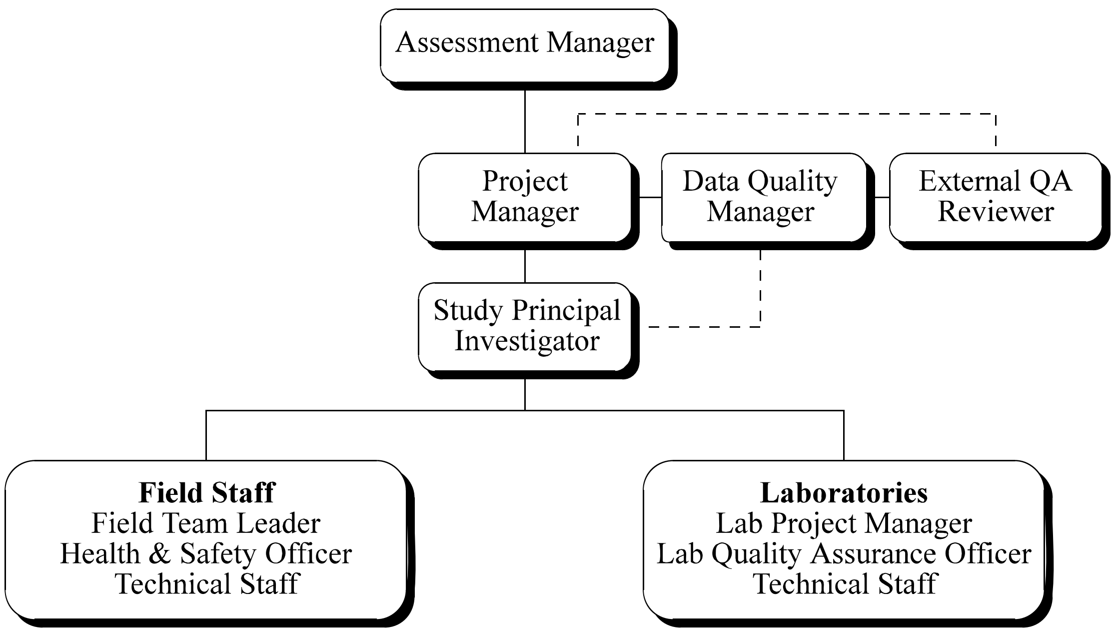

Figure 6.1. Example of project quality assurance organization.

6.1.1 Assessment Manager and Project Manager

The Assessment Manager (AM) is responsible for all technical, financial, and administrative aspects of the project. The Project Manager (PM) supports the AM and is responsible for producing quality data and work products for this project within allotted schedules and budgets. Duties of both include executing all phases of the project and efficiently applying the full resources of the project team in accordance with the project plans. Specific QA-related duties of the AM and the PM can include:

- Coordinating the development of a project scope, project plans, and DQOs
- Ensuring that written instructions in the form of SOPs and/or associated SAPs are available for activities that affect data quality
- Monitoring investigative tasks for their compliance with plans, written procedures, and QC criteria
- Monitoring the performance of subcontractors in regard to technical performance and specifications, administrative requirements, and budgetary controls
- Participating in performance and/or systems audits and monitoring the implementation of corrective actions
- Reviewing, evaluating, and interpreting data collected as part of this investigation
- Supervising the preparation of project documents, deliverables, and reports
- Verifying that all key conclusions, recommendations, and project documents are subjected to independent technical review, as scheduled in the project plans.

6.1.2 Data Quality Manager

A Data Quality Manager can be assigned to be responsible for the overall implementation of the QAPP. General duties include conducting activities to ensure compliance with the QAPP, reviewing final QA reports, training field staff in QA procedures, providing technical QA assistance, preparing and submitting QA project reports to the AM and PM, conducting and approving corrective actions, and conducting audits, as necessary. Specific tasks may include:

- Assisting the project team with the development of DQOs
- Managing the preparation of and reviewing data validation reports
- Submitting QA reports and corrective actions to the PM
- Ensuring that data quality, data validation, and QA information are complete and are reported in the required deliverable format
- Communicating and documenting corrective actions
- Maintaining a copy of the QAPP
- Supervising laboratory audits and surveillance
- Ensuring that written instructions in the SOPs and SAPs are available for activities that affect data quality
- Monitoring investigative tasks for their compliance with plans, written procedures, and QC criteria
- Monitoring the performance of subcontractors in regard to technical performance and specifications, administrative requirements, and budgetary controls
- Reviewing, evaluating, and interpreting data collected as part of this investigation.

6.1.3 External QA Reviewer

If needed, external QA Reviewers can be assigned to review QA documentation and procedures, perform data validation, and perform field and laboratory audits.

6.1.4 Principal Investigator

Study-specific Principal Investigators (PIs) ensure that QA guidance and requirements are followed. The PI or the designee will note significant deviations from the QAPP for the study. Significant deviations will be recorded and promptly reported to the PM and Data Quality Manager. In addition, the PI typically is responsible for reviewing and interpreting study data and preparing reports.

6.1.5 Field Team Leader

The Field Team Leader (FTL) supervises sample collection, field observations, field measurements, and other day-to-day field investigation tasks. The FTL generally is responsible for all field QA procedures defined in the QAPP, and in associated SAPs and SOPs. Specific responsibilities may include:

- Implementing the field investigation in accordance with project plans
- Supervising field staff and subcontractors to monitor that appropriate sampling, testing, measurement, and recordkeeping procedures are followed
- Ensuring the proper use of SOPs associated with data collection and equipment operation
- Monitoring the collection, transport, handling, and custody of all field samples, including field QA/QC samples
- Coordinating the transfer of field data, including field sampling records, chain of custody (COC) records, and field logbooks
- Informing the PI and Data Quality Manager when problems occur, and communicating and documenting any corrective actions that are taken.

6.1.6 Laboratory Project Manager

A Laboratory Project Manager can be responsible for monitoring and documenting the quality of laboratory work. Duties may include:

- Ensuring that the staff and resources required to produce quality results in a timely manner are committed to the project
- Ensuring that the staff are adequately trained in the procedures that they are using so that they are capable of producing high quality results and detecting situations not within the QA limits of the project
- Ensuring that the stated analytical methods and laboratory procedures are followed and the laboratory’s compliance is documented
- Maintaining a laboratory QA manual and documenting that its procedures are followed
- Ensuring that laboratory reports are complete and reported in the required deliverable format

- Communicating, managing, and documenting all corrective actions initiated at the laboratory

- Notifying the Data Quality Manager, within one working day of discovery at the laboratory, of any situations that will potentially result in qualification of analytical data.

6.1.7 Technical staff

Technical staff should have adequate education, training, and specific experience to perform individual tasks as assigned. They are required to read and understand any documents describing the technical procedures and plans that they are responsible for implementing.

6.2 Quality Assurance Objectives for Measurement Data

6.2.1 Overview

QA objectives are qualitative and quantitative statements that aid in specifying the overall quality of data required to support various data uses. These objectives often are expressed in terms of accuracy, precision, completeness, comparability, representativeness, and sensitivity. Laboratories involved with the analysis of samples collected in support of this NRDA will make use of various QC samples such as standard reference materials (SRMs), matrix spikes, and replicates to assess adherence to the QA objectives discussed in the following sections and in specific laboratory QA/QC plans. The overall QA objectives are to help ensure that the data collected are of known and acceptable quality for their intended uses. Field and laboratory QC targets for chemical analyses, frequency, applicable matrices, and acceptance criteria are listed in Table 6.1.

Numeric QC criteria are specific to a study, method, or laboratory, and hence criteria are not included in this QAPP. When appropriate, criteria can be established when study and method procedures are approved; such criteria will be appended to this QAPP or included in study-specific SAPs. Criteria will be determined based on factors that may include:

- Specific analytical methods and accepted industry standards of practice
- Matrix-specific control limits for acceptable sample recovery, accuracy, or precision
- Historical laboratory performance of selected analytical methods
- Intended uses of the data.

Table 6.1. Laboratory and field quality control sample targets for chemical analyses

QC element	Target frequency	Applicable matrices	Target acceptance criteria
Method blank	1 in 20 samples	S, SW, T	Method dependent
Laboratory duplicate	1 in 20 samples	S, SW, T	Method dependent
Matrix spike	1 in 20 samples	S, SW, T	Method dependent
Standard reference material	1 in 20 samples	S, SW, T	Method dependent
Equipment blank	1 in 20 samples	SW	Study dependent
Field duplicate	1 in 20 samples	S, SW, T	Study dependent
Surrogates	All samples for organics analysis	S, SW, T	Method dependent
Laboratory control sample	1 in 20 samples	S, SW, T	Method dependent

S = sediment; SW = surface water; T = tissue.

Where statistically generated or accepted industry standards of practice are not available, QC criteria may be defined by the Data Quality Manager working with the Laboratory QA Officer and PIs.

6.2.2 Quality control metrics

Accuracy

Accuracy is a quantitative measure of how close a measured value lies to the actual or "known" value. Sampling accuracy is partially evaluated by analyzing field QC samples such as field blanks, trip blanks, and rinsates (or equipment blanks). In these cases, the "true" concentration is assumed to be not detectable, and any detected analytes may indicate a positive bias in associated environmental sample data.

Laboratory accuracy is assessed using sample (matrix) spikes and other QC samples. For example, a sample (or blank) may be spiked with an inorganic compound of known concentration and the average percent recovery (%R) calculated as a measurement of accuracy. A second procedure is to analyze a standard (e.g., SRMs or other certified reference materials) and calculate the %R for that known standard. As an additional, independent check on laboratory accuracy, blind SRMs submitted as field samples may be used.

Accuracy criteria are established statistically from historical performance data, and often are based on confidence intervals set about the mean. Where historical data are not adequate for statistical calculations, criteria may be set by the Laboratory Project Manager, Data Quality Manager, and PIs. Accuracy criteria will be appended to this QAPP or included in study-specific SAPs when established. Accuracy may be assessed during the data validation or data quality assessment stage of these investigations.

Precision

Precision is a measure of the reproducibility of analytical results under a given set of conditions. The overall precision of a set of measurements is determined by both sampling and laboratory variables. Reproducibility is affected by sample collection procedures, matrix variations, the extraction procedure, and the analytical method.

Field precision typically is evaluated using sample replicates, which are usually duplicate or triplicate samples. Sample replicates may be generated by homogenizing the sample, splitting the sample into several containers, and initiating a blind submittal to the laboratory with unique sample numbers. For a duplicate sample, precision of the measurement process (sampling and analysis) is expressed as:

$$\text{Relative Percent Difference (RPD)} = \frac{2(\text{Duplicate Sample Result - Sample Result})}{(\text{Duplicate Sample Result + Sample Result})} \text{ x } 100.$$

For a triplicate analysis, precision of the sampling and analysis process is expressed as:

$$\text{Percent Relative Standard Deviation (\% RSD)} = \frac{\sigma_{\text{n-1}}}{\text{Mean}} \text{ x } 100,$$

where σ_{n-1} is the standard deviation of the three measurements.

Laboratory precision typically is evaluated using laboratory duplicates, matrix spike duplicates, or laboratory control sample or SRM duplicate sample analysis. Duplicates prepared in the laboratory are generated before sample digestion. Laboratory precision is also expressed as the RPD between a sample and its duplicate, or as the %RSD for three values.

Precision criteria are established statistically from historical performance data, and are usually based on the upper confidence interval set at two standard deviations above the mean. Where historical data are not adequate for statistical calculations, criteria may be set by the Laboratory

Project Manager, Data Quality Manager, and PIs. Precision criteria will be appended to this QAPP or included in study-specific SAPs, when established.

Completeness

Completeness is defined as the percentage of measurement data that remain valid after discarding any invalid data during the field or laboratory QC review process. A completeness check may be performed following a data validation process. Analytical completeness goals may vary depending on study type, methods, and intended uses of the data.

Analytical data completeness will be calculated by analyte. The percent of valid data is 100 times the number of sample results not qualified as unusable divided by the total number of samples analyzed. Data qualified as estimated because of minor QC deviations (e.g., laboratory duplicate RPD exceeded) will be considered valid.

Comparability

Comparability is a qualitative parameter expressing the confidence with which one dataset can be compared to another. Comparability is facilitated by use of consistent sampling procedures, standardized analytical methods, and consistent reporting limits and units. Data comparability is evaluated using professional judgment.

Representativeness

Representativeness expresses the degree to which data accurately and precisely represent a defined or particular characteristic of a population, parameter variations at a sampling point, a processed condition, or an environmental condition. Representativeness is a qualitative parameter that is dependent on the proper design of the sampling program and proper laboratory protocol. Sampling designs for this investigation will be intended to provide data representative of sampled conditions. During development of SAPs and SOPs, consideration will be given to existing analytical data, environmental setting, and potential industrial sources. Representativeness will be satisfied by ensuring that the sampling plan is followed.

Sensitivity

Detection limit targets for each analyte and matrix will be appended to this QAPP or included in study-specific SAPs as they are established.

6.3 Sampling Procedures

6.3.1 Sample collection

Samples are collected and handled in accordance with the procedures contained in SOPs or associated SAPs. These documents describe sample collection, handling, and documentation procedures to be used during field activities. As appropriate, SOPs and SAPs may cover the following topics:

- Procedures for selecting exact sample locations and frequency of collection
- Sampling equipment operation, decontamination, and maintenance
- Sample collection and processing, which includes sample collection order and homogenization procedures, sample containers, and volume required
- Field QC sample and frequency criteria
- Sample documentation, including COC and field documentation forms and procedures
- Sample packaging, tracking, storage, and shipment procedures.

6.3.2 Sample containers, preservation, and holding times

Containers will be prepared using EPA specified or other professionally accepted cleaning procedures. Analysis statements for containers prepared by third-party vendors will be included in the project file. Since the investigations involved with this NRDA may involve samples not amenable to typical environmental sample containers (such as whole body tissue samples), multiple types of containers may be required. Sample containers may include aluminum foil and watertight plastic bags for tissue samples and whole body samples.

When appropriate, sample coolers will contain refrigerant in sufficient quantity to maintain samples at the required temperatures until receipt at the laboratories.

6.3.3 Sample identification and labeling procedures

Before transportation, samples should be properly identified with labels, tags, or markings. Identification and labeling typically includes, but need not be limited to, the following information:

- Project identification
- Place of collection
- Sample identification
- Analysis request
- Preservative
- Date and time of collection
- Name of sampler (initials)
- Number of containers associated with the sample.

6.3.4 Field sampling forms

Field sampling forms should be described in the appropriate SOP or associated SAP, and be designed for ease of use in the field and for completeness of documentation. Forms typically must be completed in the field at the same time as the sample label. At a minimum, date, time, sampler's initials, location, and other specific field observations should be completed at the time of sampling. The FTL should review the field sampling forms, make any necessary corrections, and initial them as approved.

6.3.5 Sample storage and tracking

In the field, samples may be stored temporarily in coolers with wet or dry ice (as appropriate). Security should be maintained and proper storage should be documented in the project field notebook. Samples stored temporarily in coolers should be transported to a storage facility as soon as logistically possible. When possible, samples will be shipped directly to the appropriate laboratories from the field.

Samples will be stored under appropriate conditions at the storage facility or laboratory (refrigerator or freezer) before analysis. Security should be maintained at all times. A log book or inventory record typically is maintained for each sample storage facility refrigerator or freezer. The log books or inventory records are used to document sample movement in and out of the facility. In general, samples will be placed into a freezer and information regarding sample identification, matrix, and study will be recorded. Additional information in the record for each sample may include the date of the initial storage, subsequent removal/return events with associated dates, and initials of the person(s) handling the samples. Additional information may also include study name and special comments. If required, unused samples or extra samples will be archived in a secure location under appropriate holding conditions to ensure that sample integrity is maintained.

Documentation should allow for unambiguous tracking of the samples from the time of collection until shipment to the laboratory. The tracking system should include a record of all sample movement and provide identification and verification (initials) of the individuals responsible for the movement.

6.3.6 Geographic data collection

The usefulness of field data is often greatly enhanced by the collection of geographic data for each sample location. Sample locations should all be given distinct names and documented. If possible, a global positioning system (GPS) will be used to document the exact coordinates of each sample location. Field personnel should be trained on how to properly use the GPS and record necessary supplemental information such as the datum and units of measurement.

6.4 Sample Custody

COC procedures are adopted for samples throughout the field collection, handling, storage, and shipment process. Each sample will be assigned a unique identification label and have a separate entry on a COC record. A COC record should accompany every sample and every shipment to document sample possession from the time of collection through final disposal.

6.4.1 Definition of custody

A sample is defined as being in a person's custody if one of the following conditions applies:

- The sample is in the person's actual possession or view
- The sample was in the person's possession and then was locked in a secure area with restricted access
- The person placed it in a container and sealed the container with a custody seal in such a way that it cannot be opened without breaking the seal.

6.4.2 Procedures

The following information typically will be included on COC forms:

- Place of collection
- Laboratory name and address
- Sample receipt information (total number of containers, whether COC seals are intact, whether sample containers are intact, and whether the samples are cold when received)
- Signature block with sufficient room for “relinquished by” and “received by” signatures for at least three groups (i.e., field sampler, intermediate handler, and laboratory)
- Sample information (e.g., field sample identifier, date, time, matrix, laboratory sample identifier, and number of containers for that sample identifier)
- Name of the sampler
- Airbill number of overnight carrier (if applicable)
- Disposal information (to track sample from “cradle to grave”)
- Block for special instructions
- Analysis request information.

The sample identification, date and time of collection, and request for analysis on the sample label should correspond to the entries on the COC form and in associated field log books or sampling forms.

Responsibility for reviewing the completed COC forms lies with the Data Quality Manager or designated representative. Any inconsistencies, inaccuracies, or incompleteness in the forms must be brought to the attention of the field staff completing the form. Corrective action should be taken and documented if the problem is significant. Depending on the problem, this may involve informing the laboratory that a sample ID or analysis request needs to be changed, or notifying the FTL that retraining of field staff in COC procedures is indicated. The corrective action and its outcome should be documented.

6.5 Analytical Procedures

Analytical methods will be consistent with, or equivalent to, EPA methods or some other commonly accepted or approved method, as approved by the Data Quality Manager. All laboratory equipment and instruments will be operated, maintained, calibrated, and standardized in accordance with EPA-accepted or manufacturer's practices.

Laboratory method detection limit (MDL) studies should be conducted for each matrix per analytical method, according to specifications described in 40 CFR Part 136 or other comparable professionally accepted standards. The MDL is a statistically derived, empirical value that may vary.

Laboratory QC samples, which include a method blank, replicate (matrix spike or duplicate) analyses, laboratory control sample, and SRM, will be performed at a target frequency of 1 per 20 samples per matrix per analytical batch. Method blanks should be free of contamination of target analytes at concentrations greater than or equal to the MDL, or associated sample concentrations should be greater than 10 times the method blank values. The matrix spike/matrix spike duplicate and laboratory control sample analyses should meet the specific accuracy and precision goals for each matrix and analytical method.

6.6 Calibration Procedures and Frequency

This section provides information on general calibration guidelines for laboratory and field methods.

6.6.1 Laboratory equipment

All equipment and instruments used for laboratory analyses will be operated and maintained according to the manufacturer's recommendations, as well as by criteria defined in the laboratory's SOPs. Operation, maintenance, and calibration should be performed by personnel properly trained in these procedures. Documentation of all routine and special maintenance and calibration should be recorded in appropriate log books and reference files.

Calibration curve requirements for all analytes and surrogate compounds should be met before sample analysis. Calibration verification standards, which should include the analytes that are expected to be in the samples and the surrogate compounds, should be analyzed at a specified frequency and should be within a percent difference or percent drift criterion.

6.6.2 Field equipment

All equipment and instruments used to collect field measurements will be operated, maintained, and calibrated according to the manufacturer's recommendations and by criteria defined in individual SOPs. Operation, calibration, and maintenance should be performed by personnel properly trained in these procedures. Documentation of all routine and special maintenance and calibration should be recorded in appropriate log books or reference files. Field instruments that may be used include thermometers/temperature probes, scales, pH meters, dissolved oxygen meters, and GPS units.

6.7 Data Validation and Reporting

6.7.1 General approach

Data generated by the laboratory and during field measurements may undergo data review and validation by an External QA Reviewer. Laboratory data may be evaluated for compliance with DQOs, with functional guidelines for data validation, and with procedural requirements contained in this QAPP.

6.7.2 Data reporting

Laboratories should provide sufficient information to allow for independent validation of the sample identity and integrity, the laboratory measurement system, the resulting quantitative and qualitative raw data, and all information relating to standards and sample preparation. Laboratories should provide a usable electronic version of their results in a common database format.

6.7.3 Data review and validation of chemistry data

Data review is an internal laboratory process in which data are reviewed and evaluated by a laboratory supervisor or QA personnel. Data validation is an independent review process conducted by personnel not associated with data collection and generation activities. External and independent data validation may be performed for selected sample sets as determined by the PM and Data Quality Manager. Each data package chosen for review will be assessed to determine whether the required documentation is of known and documented quality. This includes evaluating whether:

- Field COC or project catalog records are present, complete, signed, and dated
- The laboratory data report contains required deliverables to document procedures.

Two levels of data validation may be performed: full or cursory validation. Initial data packages received for each sample matrix may receive full validation. This consists of a review of the entire data package for compliance with documentation and QC criteria for the following:

- Analytical holding times
- Data package completeness
- Preparation and calibration blank contamination
- Initial and continuing calibration verifications
- Internal standards
- Instrument tuning standards
- Analytical accuracy (matrix spike recoveries and laboratory control sample recoveries)
- Analytical precision (comparison of replicate sample results)
- Reported detection limits and compound quantitation
- Review of raw data and other aspects of instrument performance
- Review of preparation and analysis bench sheets and run logs.

Cursory validation may be performed on a subset of the data packages at the discretion of the PM and Data Quality Manager. Cursory review includes the comparison of laboratory summarized QC and instrument performance standard results to the required control limits, including:

- Analytical holding times
- Data package completeness
- Preparation and calibration blank contamination
- Analytical accuracy (matrix spike recoveries and laboratory control sample recoveries)
- Analytical precision (comparison of replicate sample results).

Both the full and the cursory validation will follow documented QC and review procedures as outlined in the guidelines for data validation (U.S. EPA, 1998) and documented in validation and method SOPs. Various qualifiers, comments, or narratives may be applied to data during the validation process. These qualifier codes may be assigned to individual data points to explain deviations from QC criteria and will not replace qualifiers or footnotes provided by the laboratory. Data validation reports summarizing findings will be submitted to the Data Quality Manager for review and approval.

Laboratory data will be evaluated for compliance with DQOs. Data usability, from an analytical standpoint, may be evaluated during the data evaluation. The data users (the PI, PM, and AM) will determine the ultimate usability of the data.

6.8 Performance and System Audits

A Data Quality Manager or designee will be responsible for coordinating and implementing any QA audits that may be performed. Checklists may be prepared that reflect the system or components being audited, with references to source of questions or items on the checklist. Records of all audits and corrective actions should be maintained in the project files.

6.8.1 Technical system audits

Technical System Audits (TSAs) are qualitative evaluations of components of field and laboratory measurement systems, including QC procedures, technical personnel, and QA management. TSAs involve a comparison of the activities described in the SAP and SOPs with those actually scheduled or performed. Coordination and implementation of any TSAs will be the responsibility of the Data Quality Manager or designee. TSAs determine if the measurement systems are being used appropriately. TSAs are normally performed before or shortly after measurement systems are operational, and during the program on a regularly scheduled basis.

Analytical data generation (laboratory audit)

Laboratory audits may be performed to evaluate if the laboratory is generating data according to all processes and procedures documented in the associated SAPs, QAPP, SOPs, and analytical methods. Laboratory audits may be performed by an External QA Reviewer, a Data Quality Manager, or their designee.

Field audits

Field audits may be performed to determine whether field operations and sample collection are being performed according to processes and procedures documented in the SAP, QAPP, and SOPs.

6.8.2 Performance evaluation audits

Performance evaluation audits are quantitative evaluations of the measurement systems of a program. Performance evaluation audits involve testing measurement systems with samples of known composition or behavior to evaluate precision and accuracy, typically through the analysis of SRMs. These may be conducted before selecting an analytical laboratory.

6.9 Preventative Maintenance Procedures and Schedules

Preventative maintenance typically is implemented on a scheduled basis to minimize equipment failure and poor performance. In addition to the scheduled calibration procedures described above, the following procedures may be followed:

- Thoroughly clean field equipment before returning to the office. The equipment generally should be stored clean and dry.
- Replaceable components such as pH electrodes and dissolved oxygen membranes should be inspected after and before each use, and replaced as needed to maintain acceptable performance.
- Equipment that is malfunctioning or out of calibration will be removed from operation until repaired or recalibrated.

6.10 Procedures Used to Assess Data Usability

Data usability is a function of study methods, investigator expertise and competence, and intended uses. QA/QC procedures are designed to help ensure data usability but, in themselves, neither ensure data usability nor – if not implemented – indicate that data are not useable or valid. Data validity and usability will ultimately be determined by the PI, PM, and AM using their best professional judgment. Independent data validation, consultations with Data Quality Managers, and review of project-wide databases for data compatibility and consistency can be used to support usability evaluations. The usability and validity of existing and historical data, which were not collected pursuant to the QAPP presented in this Assessment Plan, will be determined by the AM, PM, PIs, and Trustee technical staff using their best professional judgment.

6.11 Corrective Actions

6.11.1 Definition

Corrective actions consist of the procedures and processes necessary to correct and/or document situations where data quality and/or QA procedures fall outside of acceptance criteria or targets. [These criteria/targets may be numeric goals such as those discussed in Section 6.2, or procedural requirements such as those presented throughout the QAPP and other project documents (e.g., SAPs and SOPs)].

The goal of corrective action is to identify as early as possible a data quality problem and to eliminate or limit its impact on data quality. The corrective action information typically is provided to a Data Quality Manager for use in data assessment and long-term quality management. Corrective action typically involves the following sequential steps:

- Discovering any nonconformance or deviations from DQOs or the plan
- Identifying the party with authority to correct the problem
- Planning and scheduling an appropriate corrective action
- Confirming that the corrective action produced the desired result
- Documenting the corrective action.

6.11.2 Discovery of nonconformance

The field personnel and bench-level analysts are responsible for initial identification of nonconformance with procedures and QC criteria. Performance and system audits are also designed to detect these problems. However, anyone who identifies a problem or potential problem should initiate the corrective action process by, at the least, notifying a PI or Data Quality Manager of his or her concern.

Deviations from SAP, QAPP, and SOP procedures are sometimes required and appropriate because of field or sample conditions. Such deviations should be noted in field or laboratory logbooks and their effect on data quality evaluated by a PI and Data Quality Manager. Occasionally, procedural changes are made during an investigation because method improvements are identified and implemented. Even though these procedural improvements are not initiated because of nonconformance, they are procedural deviations and typically should be documented.

6.11.3 Planning, scheduling, and implementing of corrective action

Appropriate corrective actions for routine problems may range from documentation of the problem to resampling and reanalysis to the development of new methods, and depends on the particular situation. When the corrective action is within the scope of these potential actions, the bench-level analyst or the field staff can identify the appropriate corrective action and implement it. Otherwise, the corrective action should be identified and selected by the PM, the FTL, the Laboratory Manager, or the Data Quality Manager.

6.11.4 Confirmation of the result

While a corrective action is being implemented, additional work dependent on the nonconforming data should not be performed. When the corrective action is complete, the situation should be evaluated to determine if the problem was corrected. If not, new corrective actions should be taken until no further action is warranted, either because the problem is now corrected or because no successful corrective action has been found.

6.11.5 Documentation and reporting

Corrective action documentation may consist of the following reports or forms:

- Corrective action forms initiated by project staff that will be collected, evaluated, and filed by the Data Quality Manager
- Corrective action log maintained by the Data Quality Manager to track the types of nonconformance problems encountered and successful completion of corrective actions
- Corrective action plans, if needed, to address major nonconformance issues
- Performance and systems audit reports, if such audits are performed
- Corrective action narratives included as part of data reports from independent laboratories
- Corrective action forms initiated by laboratory staff and summarized in the report narrative.

6.11.6 Laboratory-specific corrective action

The need for corrective action in the analytical laboratory may originate from several sources: equipment malfunction, failure of internal QA/QC checks, method blank contamination, failure of performance or system audits, and/or noncompliance with QA requirements. When measurement equipment or analytical methods fail QA/QC checks, the problem should immediately be brought to the attention of the appropriate laboratory supervisor in accordance with the laboratory's SOP or Quality Assurance Manual. If the failure is due to equipment malfunction, the equipment should be repaired, the precision and accuracy should be reassessed, and the analysis rerun.

All incidents of QA failure and the corrective action tasks should be documented, and reports should be placed in the appropriate project file. Corrective action should also be taken promptly for deficiencies noted during spot checks of raw data. As soon as sufficient time has elapsed for a corrective action to be implemented, evidence of correction of deficiencies should be presented to a Data Quality Manager or PI.

Laboratory corrective actions may include, but are not limited to:

- Reanalyzing the samples, if holding time criteria permit and if sample volume is available
- Resampling and analyzing
- Evaluating and amending sampling analytical procedures
- Accepting data and acknowledging the level of uncertainty.

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