Monitoring and Management Plan

Marshville Dam Removal and Stony Creek Restoration

Shelby, Michigan

Consulting
Engineers and
Scientists

Submitted to:

WMSRDC
316 Morris Avenue, Suite 340
Muskegon, MI 49443-0387

Submitted by:

GEI Consultants of Michigan, P.C.
5225 Edgewater Drive
Allendale, Michigan 49401

September, 2025

Table of Contents

Introduction **1**

1. Project Design and Function **2**
1.1 Site Background 2
1.2 Infrastructure Installation and Removal 3
1.2.1 Culvert Removal and Three-Span Bridge Installation 3
1.2.2 Recreation and Public Access Infrastructure Improvements 5
1.2.3 Dam Remnant Removal 6
1.2.4 Abandoned Bridge Removal 8
1.3 Natural Restoration 9
1.3.1 Native Species Revegetation and Invasive Species Control 9
1.3.2 Stream Restoration 14
1.3.3 Floodplain Wetland Restoration/Creation 20
1.4 Site Construction 27

2. Site Monitoring and Assessments **28**
2.1 Overview 28
2.2 Infrastructure Monitoring 28
2.2.1 Three-Span Bridge Monitoring 28
2.2.2 Recreation and Public Access Infrastructure Monitoring 29
2.2.3 Dam Remnant Removal Monitoring 29
2.3 Natural Resources Monitoring 29
2.3.1 Vegetation Monitoring 29
2.3.2 Fish and Wildlife Monitoring 32
2.3.3 Stream Monitoring 32
2.3.4 Floodplain Monitoring 33
2.4 Public Use Impacts Monitoring 33

3. Site Management **35**
3.1 Overview 35
3.2 Infrastructure Management 36
3.2.1 Three-Span Bridge Management 36
3.2.2 Recreation and Public Access Infrastructure Management 36
3.3 Natural Resources Management 36
3.3.1 Installed Vegetation Management 36
3.3.2 Invasive Species Control 37
3.3.3 Stream Restoration Management 39
3.3.4 Floodplain Management 39
3.4 Public Use Impacts Management 39

Appendices

Appendix A: Feasibility Study
Appendix B: Project Design Plans
Appendix C: GVSU Post-Restoration Fish Monitoring
Appendix D:Representative Photos of Invasive Vegetation
Appendix E: Natural Community Abstracts

Introduction

Stony Creek is a coldwater stream located in Oceana County, Michigan, and is widely recognized as one of the premier trout streams in Lower Michigan. This project supports ongoing efforts to restore ecological function and improve habitat quality in Stony Creek by addressing the long-term impacts of a historic dam and associated infrastructure.
The project included the removal of dam remnants, an abandoned bridge south of the Marshville Dam Road crossing, and three culverts that were obstructing fish passage downstream of the dam. A new three-span bridge was installed, with the center span extending over the bankfull width of Stony Creek. Additional efforts included sediment management, native species revegetation, instream habitat enhancement, stream restoration, floodplain wetland restoration and creation, and improvements to recreational access. Key goals for fish and wildlife habitat improvement include reconnecting approximately 6.5 miles of Stony Creek for native aquatic and fish species, enhancing roughly 18 acres of wetland habitat, restoring 2,500 feet of instream habitat, and enhancing opportunities for both passive and active recreation.

The West Michigan Shoreline Regional Development Commission (WMSRDC), Conservation Resource Alliance (CRA), Oceana County, Michigan Department of Natural Resources (MDNR), and Grand Valley State Annis Water Resources Institute (AWRI) have teamed together with funding from the National Oceanic and Atmospheric Administration (NOAA), United States Fish and Wildlife Service (USFWS), MDNR, and Great Lakes Fishery Trust to develop restoration plans for the removal of the dam and restoration of an upstream reach of Stony Creek. The partnership hired GEI Consultants of Michigan, P.C. (GEI) to develop dam removal and creek restoration plans.

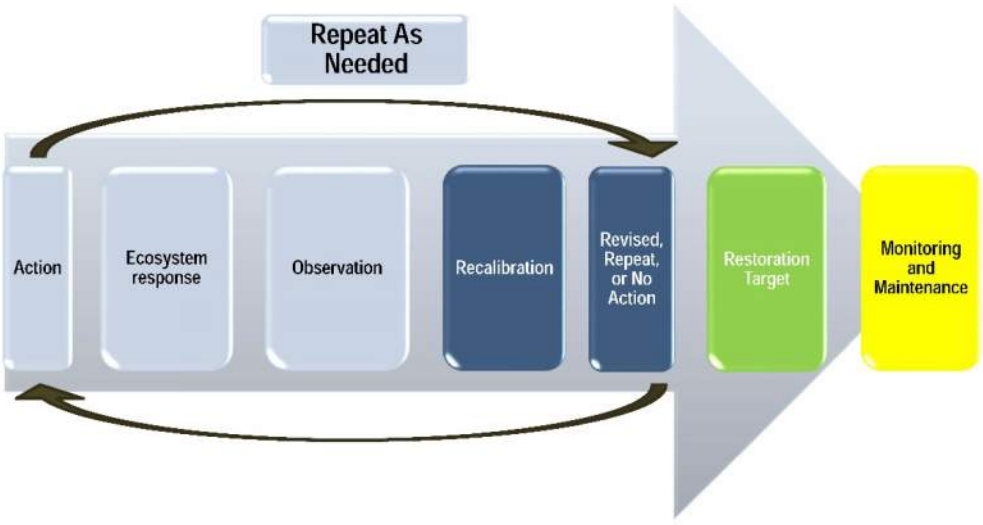


Figure 1. The ecological restoration process.

1. Project Design and Function

1.1 Site Background

Located in Oceana County, Stony Creek is a groundwater-fed coldwater stream. It has a 57-square-mile watershed that is primarily forested and undeveloped, entirely contained within the county (Tonello, 2021). The creek ultimately drains into Stony Lake and then into Lake Michigan. Stony Creek plays an important role in supporting regional water quality, providing habitat for a variety of aquatic species, and maintaining the natural flow connections between inland waters and Lake Michigan.

To restore and hydrologically reconnect Stony Creek, the project included replacement of culverts with an open span bridge, removal of a dam, creation of new floodplain, the installation of woody habitat structures, native plantings, and the installation of a boardwalk structure. The project design components and alternatives are summarized in the Feasibility Study (Appendix A) and described below.

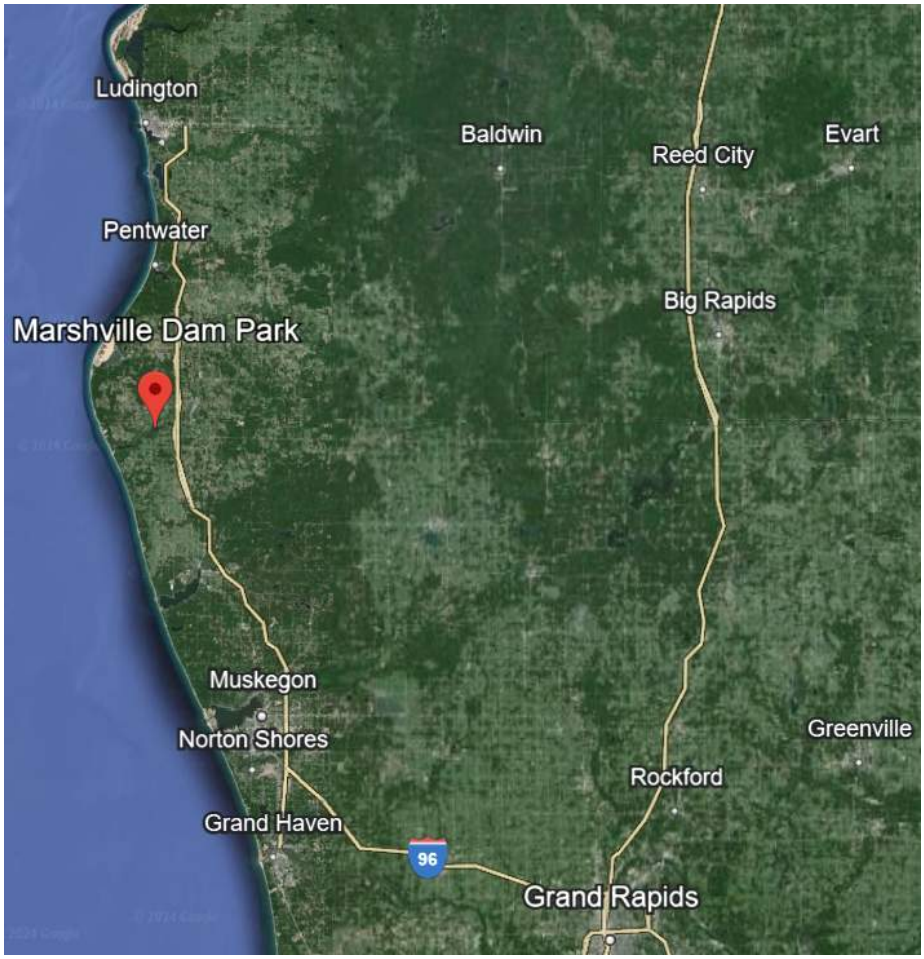


Figure 1. Project location map.

Photo 1. Project location.

1.2 Infrastructure Installation and Removal

To repair decades of ecological and structural damage at the site, obsolete structures were removed and replaced with suitable infrastructure. These efforts were extensive and essential to the restoration of the area. Removals, made for ecological, safety, or aesthetic reasons, included three undersized culverts, dam remnants, and an abandoned bridge south of the Marshville Dam Road crossing. Additions to the site included a three-span bridge as well as recreational and public access features including a ramp, boardwalk, and fishing pier. The following sections detail each of these infrastructure modifications.

1.2.1 *Culvert Removal and Three-Span Bridge Installation*

Before the new Marshville Dam Road bridge could be constructed, the three culverts beneath Marshville Dam Road spanning Stony Creek needed to be removed. Each culvert measured 65 feet in length with a diameter of 78 inches. The culverts were spaced approximately five feet apart, with about 4.25 feet of cover above them. They were rated in fair to poor condition and considered undersized. Multiple undersized culverts within a stream can cause several drawbacks and negative impacts, including:

1. Blocking of native fish and other aquatic organisms' passage. In the case of this specific site, the culverts, in addition to the dam remnants, were inhibiting fish passage, especially during times of low water. This can disrupt the life cycle of and be fatal to fish and other aquatic organisms as it does not allow them to move upstream to cooler waters and habitat needed to survive and reproduce.

2. Increased maintenance. Stream crossings with multiple culverts placed within them tend to become clogged with sediment and debris, which can cause increased velocity and increased channel scouring. Clogged culverts can also lead to structural failure.

3. Fragmentation of natural stream patterns and ecosystems. Stream crossings that do not, at a minimum, span the bottomland (i.e., lie below the ordinary high-water mark (OHWM)) can cause water to move at higher velocities. This, in turn, can cause channel erosion, such as scour holes and perched culverts, which can negatively impact habitat and disrupt migration. Fish and wildlife require continuous stretches of habitat and passageways to carry out natural processes.

4. Restriction of natural stream flows, particularly during floods, which can also increase flooding and channel and bank erosion.

Photo 2. Undersized culverts previously at the Marshville Dam Road crossing.

Once the culverts were removed, the construction of the clear span bridge began. The distance between two neighboring structural supports of a structure is known as the *span* in engineering. A clear span bridge, also known as an open span or three-span bridge, is a type of bridge that

completely spans a watercourse, does not have supporting structures located within the channel, and does not interfere with a channel's bed or banks. The Oceana County Road Commission (OCRC) designed and constructed the open span bridge. It was designed so that the center span would extend over the bankfull width of Stony Creek. Full design plans from the OCRC can be found in Appendix B on detail sheets D-2 and D-3.

More information can be found here regarding the Environment, Great Lakes, and Energy (EGLE) Water Resources Division's (WRD) stance on bridge and culvert installation, including permitting and standards.

Photo 3. Aerial photo of the three-span bridge.

1.2.2 *Recreation and Public Access Infrastructure Improvements*

One of Marshville Dam County Park and Stony Creek's most attractive qualities is the recreational opportunities, particularly fishing. Historically, the constructed ponds—both the one created because of the sawmill constructed in 1861 and the large pond constructed by volunteers in 1927—maintained a reputation for the impressive fishing it provided, earning Marshville a name throughout the state. This status was lost as the pond waters emptied and the stone riffles that attracted fishermen were covered in the 1970s. A key element of this restoration project is to improve the site's access and recreation opportunities while also healing natural stream processes and allowing for fish passage.

When planning and designing recreation and public access improvements, it was deemed essential to meet ADA standards for accessibility and provide infrastructure that allowed river

access for all. A 110-foot-long boardwalk made with treated lumber was constructed in 2025 to increase accessibility to the site. The boardwalk also includes two accessible 15-foot by 20-foot fishing platforms constructed from treated lumber. Stairs that create direct access to the creek descend from the fishing pier. Full design plans for the recreation and public access infrastructure can be found in Appendix B.

Photo 4. ADA-accessible boardwalk and fishing/viewing platforms.

1.2.3 *Dam Remnant Removal*

George Marsh—the namesake for Marshville Dam County Park and Road—first constructed a sawmill in 1861, followed by a grist mill two years later in 1863, near what is now Marshville Dam Road. During this time, a log dam and earthen berm were also built. These formed a large backwater, providing power for the operations and a route to transport logs to the mill. The dam failed in the early 1900s. Following this failure, local fishermen purchased flow millage rights, and in 1927, the Marshville Improvement Association rebuilt a concrete dam to create a pond for fishing. The earthen berm failed in 1968 when vandals created a bypass around the dam, completely emptying the pond that had once provided a spawning area for brown and brook trout. The one-lane bridge was abandoned in 1976, and a new road was built over Stony Creek. The dam has remained in a state of disrepair ever since.

Photo 5. Aerial photo of dam remnants.

Although most of the dam structure was removed prior to restoration, remnants of the dam and its impacts remained and were an impairment to the local ecology and community. In its pre-restoration condition, the dam resulted in the following impacts:

1. In its past state, the dam was relatively unattractive and a safety hazard.

2. The physical structure of the dam, as well as the adjacent road culverts, inhibited fish passage, particularly during low water conditions. In the summer of 2020, the MDNR Fisheries Division conducted an electrofishing survey of Stony Creek just upstream of the Marshville Dam. The survey showed robust numbers of resident brown trout (up to 20 inches), brook trout (up to 10 inches), and rainbow trout or steelhead (up to 12 inches)(Tonello, 2021). This project will benefit both resident salmonids and migratory salmonids (cold water species) that migrate from Lake Michigan with an emphasis on brook trout.

3. The historic construction of the dam interrupted natural stream processes that do not appear to have self-healed. A portion of the stream upstream of the dam is not in its original location. It appears over-widened, leading to a shallow stream and the formation of mid-channel sand bars and vegetative growth in the center portions of the stream. The abundance of sand is supported by MDNR's assessment (Tonello, 2021), which noted sand was "by far the primary substrate," representing 78.5% of the substrate at the Marshville Dam. Increasing substrate heterogeneity in the project area is important to protecting and improving the abundance and diversity of aquatic biota.

4. It appears that many of the trees in the impoundment were removed when the dam was constructed. Following dam construction, tree growth was either limited by the dam impoundment or, in its pre-restoration condition, was likely limited because the remaining dam structure had raised the upstream groundwater table and inhibited tree growth. As a coldwater stream, tree cover is critical because it provides shading, cooling of the water, and overhead cover from predation, which are all necessary for the fish species that use the creek and for the benthic macroinvertebrates that are major dietary items for fish. Removing the remaining dam structure and re-foresting the floodplain will restore these habitat benefits.

1.2.4 *Abandoned Bridge Removal*

The bridge, which was abandoned in 1976 after the new road was built over Stony Creek, remained in place until this project. This was a one-lane concrete bridge that had served as a stream crossing during the sawmill and grist mill operation and at the height of Marshville's fishing popularity. The abandoned bridge no longer served a purpose and was seen as a safety concern and eyesore. It was removed during the same period the culverts were removed. The aerial photo below (Photo 5) shows the abandoned bridge in the background south of Marshville Dam Road, along with the undersized culverts and remnants of the dam. This obsolete infrastructure tells a story of this area's past that no longer serves the present.

Photo 6. Aerial photo of site prior to removal of the abandoned bridge and dam.

1.3 Stream and Floodplain Restoration

The stream and floodplain restoration of the site included native planting, stream restoration, in-stream habitat enhancements, and floodplain wetland restoration/creation. These activities support the overall ecological health of the area and provide pathways to achieve goals specific to fish and wildlife habitat improvement. The restoration goals included:

1. Reconnection of approximately 6.5 miles of Stony Creek for native aquatic species and native fish species.
2. Enhancement of 18 acres of wetland habitat.
3. 2,500 feet of instream habitat restoration.
4. Enhancement of passive and active recreation.

The following sections describe the specific project designs that support each aspect of the restoration to meet the overall ecological health and/or fish and wildlife habitat improvement goals.

1.3.1 *Native Planting and Invasive Species Control*

To assess the ecological integrity of these systems to determine their health and guide management decisions, a floristic survey and a Floristic Quality Assessment (FQA) (Tables 1, 2, and 3) was conducted to compare the historical natural communities to the present-day natural communities in the impacted and surrounding areas.

Historically, the impacted area could likely be identified as a hardwood-conifer swamp (Appendix E). However, pre-restoration conditions showed that this area is now best classified as a northern wet meadow (Appendix E), although the vegetative community (Table 1) did not fit cleanly into any MNFI natural community due to the high level of disturbance. The shift in community types and the high level of disturbance were very likely anthropogenic. Cattail (*Typha* spp.), an invasive hybrid species, was the most prevalent in terms of density. Spotted touch-me-not (*Impatiens capensis*) and tussock sedge (*Carex stricta*) were also prevalent within the impacted area. 67 total species were found in this area, 55 being native, with a mean Coefficient of Conservatism (C-value) of 3.1.

The reference area used to guide restoration efforts is located south of the impacted area within the Marshville Dam/Stony Creek site. This area is comprised of hardwood-conifer swamp containing cinnamon fern (*Osmundastrum cinnamomeum*), white cedar (*Thuja occidentalis*), and tussock sedge (*Carex stricta*) and emergent wetland, with adjacent uplands of mesic northern forest (Appendix E). The reference reach has defined banks that host a variety of plants, including ostrich fern (*Matteuccia struthiopteris*), wood nettle (*Laportea canadensis*), and white cedar (*Thuja occidentalis*). This area had a mean C-value of 3.8. Out of 52 species found in this area, 47 were native (Table 3).

Revegetation activities to restore the impacted area to historical pre-disturbance conditions (hardwood-conifer swamp) included:

- Installing native trees and shrubs along the existing riverbank,
- Developing and applying a custom seed mix that is reflective of the vegetative community in the downstream reference reach (Table 6).
- Controlling invasive species.

These activities increase the overall ecological health of the impacted area while also enhancing wetland habitat and promoting instream habitat restoration.

Scientific Name	Common Name
Acer rubrum	Red maple
Acer saccharinium	Silver maple
Achillea millefolium	Common yarrow
Alder incana subsp. *rugosa*	Speckled alder
Anemonastrum canadense	Wood anemone
Arisaema triphyllum	Jack-in-the-pulpit
Asclepias syriaca	Common milkweed
*Barbarea vulgaris**	Bitter wintercress
*Berberis thunbergii**	Japanese barberry
Betula alleghaniensis	Yellow birch
Betula papirifera	Paper birch
Bidens cernua	Nodding bur-marigold
Caltha palustrus	Marsh marigold
Cardamine pensylvanica	Pennsylvania bittercress
Carex scabrata	Eastern rough sedge
Carex spp.	Sedge
Carex stricta	Tussock sedge
Cicuta bulbifera	Bulbet-bearing water hemlock
Circaea canadensis	Broad-leaved enchanter's nightshade
*Circium arvense**	Canada thistle
*Cirsium vulgare**	Bull thistle
Clematis virginiana	Virgin's bower
Cornus sericea	Red-osier dogwood
Eleochaeris obtusa	Blunt spike rush
Equisetum arvense	Field horsetail
Eupatorium perfoliatum	Common boneset
Fagus grandifolia	American beech

Fraxinus nigra	Black ash
Galium aparine	Annual bedstraw
Galium boreale	Northern bedstraw
Geranium robertianum	Lesser herbrobert
Glyceria striata	Fowl manna grass
Hypericum sp.	St. John's wort
Ilex verticilata	Common winterberry
Impatiens capensis	Spotted touch-me-not
Iris versicolor	Blue flag iris
Juncus effusus	Soft rush
Laportea canadensis	Wood nettle
Lemna minor	Common duckweed
Lonicera x *bella**	Bell's honeysuckle
Lysemachia borealis	Starflower
Matteuccia struthiopteris	Ostrich fern
Mentha spicata	Spearmint
Osmunda spectabilis	Royal fern
Osmundastrum cinnamomeum	Cinnamon fern
*Pastinaca sativa**	Wild parsnip
*Phalaris arundinacea**	Reed canary grass
Populus tremuloides	Quaking aspen
Prunus serotina	Black cherry
Pteridium aquilinium subsp. *L*	Northern bracken fern
Ranunculus hispida	Bristly buttercup
Ribes triste	Swamp red currant
*Rosa multiflora**	Multiflora rose
Rubus ideaus	Common red raspberry
*Rumex obtusifolius**	Bitter dock
Sagittaria latifolia	Broad-leaf arrowhead
*Senecio vulgaris**	Common groundsel
Sparganium eurycarpum	Giant bur-reed
Symplocarpus foetidus	Skunk cabbage
Thuja occidentalis	White cedar
Tilia americana	American basswood
Toxicodendron radicans	Eastern poison ivy
Toxicodendron vernix	Poison sumac
Tsuga canadensis	Eastern hemlock
*Typha angustifolia**	Narrowleaf cattail
Typha latifolia	Broad-leaved cattail
Typha x *glauca**	Hybrid cattail
Ulmus americana	American elm

Urtica dioica	Stinging nettle
Verbena hastata	Blue vervain
Veronica beccabunga var. *americana*	American brooklime
Vitis riparia	River-bank grape

Table 1. Impacted area species inventory.

Photo 7. Dominance of invasive cattails (*Typha* spp.) throughout the impacted area.

Scientific Name	Common Name
Acer rubrum	Red maple
Acer saccharinum	Silver maple
Acer saccharum	Sugar maple
*Allaria petiolata**	Garlic mustard
Alnus incana rugosa	Speckled alder
Anemonastrum canadense	Wood anemone
Arisaema triphyllum	Jack-in-the-pulpit
Betula alleghaniensis	Yellow birch
Bidens cernua	Nodding bur-marigold
Caltha palustris	Yellow marsh marigold
Carex canescens	Silvery sedge
Carex intumescens	Greater bladder sedge
Carex limosa	Mud sedge
Carex stricta	Tussock sedge
Cicuta bulbifera	Bulbet-bearing water hemlock
Clematis virginiana	Virgin's bower
Cornus sericea	Red-osier dogwood
Cretagus sp.	Hawthorn
*Elaeagnus umbellata**	Autumn olive
Equisetum arvense	Field horsetail
Fraxinus nigra	Black ash
Galium aparine	Annual bedstraw
Geranium robertianum	Lesser herbrobert
Geum spp.	Avens
Hesperis matronalis	Mother-of-the-evening
Ilex verticilata	Common winterberry
Impatiens capensis	Spotted touch-me-not
Iris versicolor	Larger blue flag iris
Laportea canadensis	Wood nettle
Lemna minor	Common duckweed
Menispermum canadense	Moonseed
Onoclea sensibilis	Sensitive fern
Osmundastrum cinnamomeum	Cinnamon fern
Persicaria pensylvanica	Pinkweed
*Phalaris arundinacea**	Reed canary grass
Polygonatum pubescens	Hairy solomon's-seal
Prunus serotina	Black cherry
Ranunculus hispidus	Bristly buttercup
Ranunculus recurvatum	Blisterwort

Ribes triste	Swamp red currant
Rubus ideaus	Common red raspberry
Rumex obtusifolius	Round leaved dock
Sagittaria latifolia	Broad-leaf arrowhead
Salix interior	Sandbar willow
Sparganium eurycarpum	Giant bur-reed
Symplocarpus foetidus	Skunk cabbage
Thalictrum thalictroides	Rue-anemone
Thuja occidentalis	White cedar
Tilia americana	American basswood
Toxcodendron vernix	Sumac
Toxicodendron radicans	Eastern poison ivy
Typha x *glauca**	Hybrid cattail
Ulmus americana	American elm
Urtica dioica	Stinging nettle
Vitis riparia	River-bank grape

Table 2. Reference area species inventory.

Wetland	Total Species	Native Species	Total Mean C	Native Mean C	FQI	Native FQI
Impacted Area – Northern Wet Meadow/Disturbed Hardwood Conifer Swamp	67	55	2.8	3.1	22.9	25.2
Reference Area (Hardwood Conifer Swamp)	52	47	3.4	3.8	24.5	26.1

Table 3. FQA summary.

1.3.2 *Stream Restoration*

Goals specific to stream restoration include the reconnection of approximately 6.5 miles of Stony Creek for native aquatic species and fish species and up to 2,500 feet of instream habitat restoration. Both goals, in turn, will provide numerous benefits to the local ecosystem and enhance passive and active recreation.

First, existing stream conditions had to be determined before restoration efforts could begin. A topographic survey of approximately 3,200 linear feet of the creek using a combination of ground surveys and an unmanned aerial vehicle (UAV) took place. As part of the feasibility study conducted by GEI, approximately 600 feet downstream of Marshville Dam Road and

2,600 feet upstream were surveyed. A total of 18 cross sections were recorded. The data was used to determine stream metrics for stability, habitat, floodplain connectivity, and sediment volumes. According to the feasibility study, "the existing reach of Stony Creek is classified as a C5 channel by the Rosgen Stream Classification system. This means it is characterized by being slightly entrenched (entrenchment ration of 2.2 or greater), has moderate sinuosity (1.24), a moderate width/depth ratio of 12 or greater, a relatively low bed slope (0.1%), and a sand bottom" (GEI Consultants, Inc., 2022).

As mentioned previously, the feasibility study determined that the construction of the dam had disrupted natural stream processes that never returned. The stream was not in its original location and was over-widened with limited substrate heterogeneity. This led to the formation of mid-channel sand bars and vegetative growth within the stream. Over-widening is a common impact to coldwater streams and can result in shallower, warmer waters and reduced suitable habitat for coldwater fish species and other aquatic biota.

Photo 8. Pre-restoration conditions upstream from the dam.

During the feasibility study, a reference reach of Stony Creek was also surveyed to determine the same metrics as the impacted reach of the creek and compare the conditions. The reference reach, located immediately downstream of the existing bridge south of West Marshville Dam Road, was also classified as a C5 channel by the Rosgen Stream Classification system, meaning it is "slightly entrenched, has moderate sinuosity (1.28), moderate width/depth ratio, a relatively low bed slope (0.2%), and a sand bottom" (GEI, 2022). GEI also noted that the reference reach channel has a relatively low sinuosity, which typically results in more uniform bedforms, fewer pools, and less bank cutting. In the reference reach of Stony Creek, bedform

diversity was primarily driven by in-stream wood, which was an important consideration in the design of the restored channel.

Photo 9. Conditions in the reference reach.

The addition of large woody debris (LWD) throughout the impacted area was done to mimic the reference reach, restore creek morphology, provide stability to the modified channel, and enhance instream habitat. Instream habitat enhancements and LWD are discussed more in the following section. The increase in bed form diversity was initiated by in-channel excavation. As natural processes are restored and given time to shape the creek, bedform diversity and morphology will continue to form.

In addition to installing instream LWD, the design also considered riparian vegetation as a means to increase the function of Stony Creek. Riparian vegetation is crucial to coldwater streams as it cools the water and provides shade and overhead protection from predation. All these features are necessary for the fish species and benthic macroinvertebrates that live within the creek. Revegetation plans, including plant lists, for the riparian area can be found in Section 2.3.1.

Instream Habitat Enhancements

One specific fish and wildlife habitat goal was to improve/restore up to 2,500 feet of instream habitat. This was primarily done by adding large woody debris (LWD) to the stream. Large

woody debris are dead pieces of wood at least ten centimeters in diameter and at least one meter long. According the Harman et al., LWD can have various effects on a channel, including "enhancing bedform diversity by creating scour pools and increasing depth variability, sorting sediments by altering localized water surface slopes, increasing variability in channel velocities, and trapping organic matter like leaves and sticks (2017).

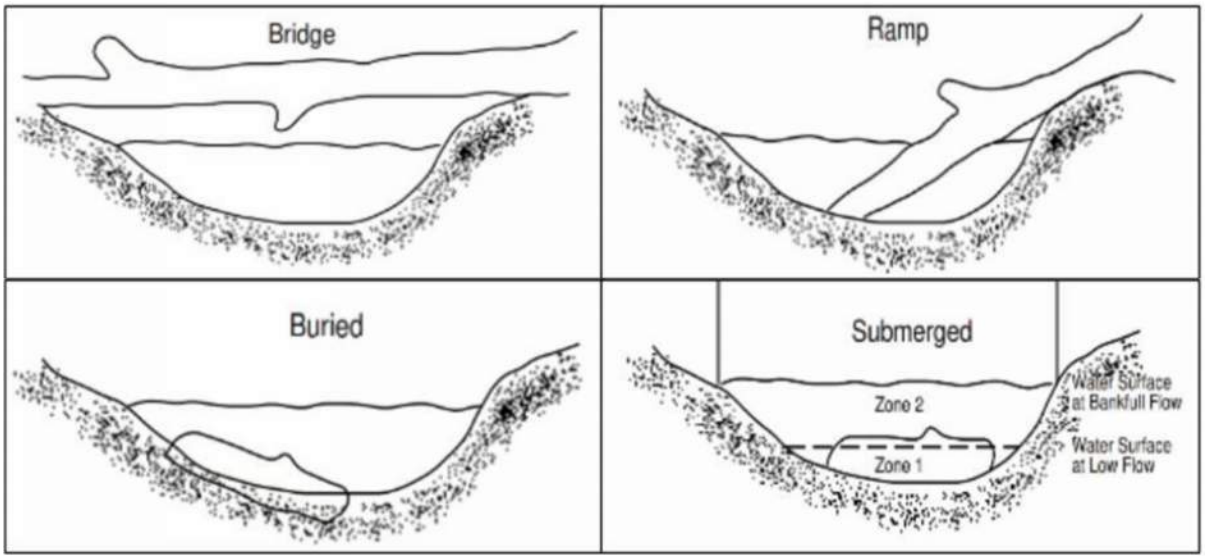


Figure 2. Types of LWD.

There are four types of LWD, according to Davis et al. (2001), which can be seen in Figure 2, including *bridge*, *ramp*, *buried*, and *submerged*. Specifications for Stony Creek call for all four types of LWD, although "bridge" wood may be eliminated due to blockage concerns. Each piece of LWD is assigned a score on a scale of one to five "based on stability and their relative influence on morphology, flow, and organic matter retention" (Davis et al., 2001) with higher scores indicating greater function (Harman et al., 2017). Table 4 shows the scores for LWD pieces. An LWD index score describes the cumulative score of all the LWD pieces within a stream or section of a stream. The existing conditions of the impacted reach had an LWD index score of 139. Design plans for this project aimed to increase the LWD index score to at least 600 in the upstream reach of Stony Creek.

Fish and other aquatic organisms use LWD in multiple ways. LWD can provide refuge and habitat for juvenile and adult fish. As water flows around LWD, scouring of the surrounding bed and banks can create pools and undercut banks, providing additional shelter and habitat for fish and other aquatic organisms. LWD can increase the substrate heterogeneity by uncovering or depositing substrate such as gravel, which is important for spawning areas for fish such as trout. Additionally, LWD can provide food for and harbor macroinvertebrates, which play a crucial role in improving water quality and being an important food source for fish. Reptiles and birds can also use exposed logs as basking and perching areas.

	Score				
	1	2	3	4	5
Pieces					
Length/Bankfull Width	0.0 to 0.4	0.4 to 0.6	0.6 to 0.8	0.8 to 1.0	> 1.0
Diameter (cm)	10 to 20	20 to 30	30 to 40	40 to 50	>50
Location	**Zone 4**		**Zone 3**	**Zone 2**	**Zone 1**
Type	Bridge		Ramp	Submersed	Buried
Structure	Plain	Plain/Int	Intermediate	Int/Sticky	Sticky
Stability	Moveable	Mov/Int	Intermediate	Int/Sec	Secured
Orientation (degrees)	0 to 20	20 to 40	40 to 60	60 to 80	80 to 90
Debris Dams					
Length (% of Bankfull Width)	0 to 20	20 to 40	40 to 60	60 to 80	80 to 100
Height (% of Bankfull Depth)	0 to 20	20 to 40	40 to 60	60 to 80	80 to 100
Structure	Coarse	Coarse/Int	Intermediate	Int/Fine	Fine
Location	Partially high flow	In high flow	Partially low flow	Mid low flow	In low flow
Stability	Moveable	Mov/Int	Intermediate	Int/Sec	Secured

Table 4. Scores for LWD pieces and debris dams.

Photo 10. Instream habitat being added to the creek.

Photo 11. Instream habitat enhancements using woody structures.

1.3.3 *Floodplain Wetland Restoration/Creation*

Floodplains, or the area adjacent to the channel that is inundated during flow events greater than the bankfull discharge, are an integral component of streams. The state of the floodplains can greatly affect the health of an adjacent stream and vice versa. The floodplains surrounding Stony Creek within the impacted area had been negatively impacted by the historical uses of the area. Due to these impairments, the floodplains and creek have experienced a decrease in ecological integrity that affects both form and function. One of the most integral components of the floodplain restoration was reforestation to reintegrate qualities of a coldwater stream. Additional components of the floodplain restoration included excavation to ensure floodplain connectivity, additional vegetation management including invasive species removal, and seeding native species representative of the desired and historic natural community. These design components are described in further detail below.

Increasing Floodplain Connectivity

Metrics related to floodplain connectivity were collected during field assessments prior to construction using the Michigan Stream Quantification Tool (MiSQT). These metrics, including the bank height ratio and entrenchment ratio, help evaluate whether stream flows can access the floodplain and the extent of the flood-prone width, and can be used to determine the vertical stability of the stream reach.

According to the Rosgen Stream Classification System, bank height ratio (BHR) measures channel incision and indicates whether flood flows can access and inundate the floodplain (2014). Bank height ratios are calculated as the ratio of the lowest bank height divided by the maximum bankfull depth. A BHR of 1.0-1.05 indicates that the bank is stable with a low risk of degradation, with higher BHRs indicating less stability. The measured BHR at the reference reach was identified as 1.0, indicating a stable bank, which informed the proposed design metric of a BHR of 1.0. However, the measured BHR at Stony Creek was determined to be 1.2, indicating that the banks in the impacted reach were moderately unstable and that the bank height is below the rooting depth of the riparian vegetation.

The entrenchment ratio (ER) is used to evaluate whether a stream has abandoned its floodplain and is measured as the ratio of the flood-prone width to the bankfull width (Rosgen, 1996). An entrenchment ratio of 2.2 or greater indicates a slightly entrenched stream, meaning that the stream is well-connected to its floodplain, with a higher ER equating to higher floodplain connectivity. The mean ER of the reference reach was determined to be 9.8, while the impacted reach of Stony Creek had an ER of 5.0.

Although these metrics showed that floodplain connectivity was determined to be "functioning," these metrics verified that design components could be implemented to increase the health and functionality of the system. The restoration design included excavation of the bankfull bench to a height and width that would allow an entrenchment ratio of at least 2.2 and a bank height ratio of 1.1, with a goal of increasing the entrenchment ratio to greater than 5 and creating a bank height ratio of 1.0.

Photo 12. Floodplain restoration in the impacted area.

Revegetation

As mentioned in Section 1.3.1, the floodplains within the impacted area were historically hardwood-conifer swamp but were converted into northern wet meadow. The reference reach used to develop restoration plans consists of hardwood-conifer swamp (Photo 12). Revegetation of native trees in the formerly impounded area is a crucial component to maintaining the coldwater habitat of Stony Creek. As discussed previously, the removal of trees during the initial installation of the dam, as well as the impacts to groundwater, have left this reach of the stream with limited shade, which can affect water temperatures and reduce protective cover for coldwater fish species. The loss of trees in the impacted area also reduces the supply of large woody debris to the stream and floodplain, reducing both aquatic and terrestrial habitat.

To promote revegetation of native species, 2,150 native shrubs and trees were installed throughout 7.75 acres of impacted floodplain. Shrub species included red-osier dogwood (*Cornus sericea*), winterberry (*Ilex verticillata*), black willow (*Salix nigra*), highbush cranberry (*Viburnum trilobum*) and spicebush (*Lindera benzoin*). The trees varied in size from two feet to four feet. The tree species selected for the floodplain include balsam fir (*Abies balsamea*), red maple (*Acer rubrum*), paper birch (*Betula papyrifera*), tamarack (*Larix laricina*), black spruce (*Picea mariana*), northern white cedar (*Thuja occidentalis*), and American basswood (*Tilia americana*). The installed vegetation lists, including seed, shrubs, and trees (Tables 6, 7, and 8 in Section 2.3.1).

Invasive species management throughout the floodplains will primarily consist of treatment and removal of narrowleaf cattail (*Typha angustifolia*) and hybrid cattail (*Typha* x *glauca*). Other invasive species are also present throughout the impacted area. This is discussed in greater detail in Section 3.3.2.

Photo 13. Reference reach of Stony Creek surrounded by hardwood-conifer swamp.

Photo 14. Post Construction Bridge and Floodplain

Photo 15. Boardwalk Structure

Photo 16. Post Construction Boardwalk and Floodplain

Photo 17. Post Construction Large Woody Debris and Floodplain

Photo 18. Post Construction Large Woody Debris and Floodplain

Photo 19. Post Construction Large Woody Debris and Floodplain

Photo 20. Post Construction Site Conditions

Photo 21. Post Construction Site Conditions

1.4 Site Construction

Construction began in May of 2024, starting with replacing the undersized culverts with a channel-spanning timber bridge. An article released by the Conservation Resource Alliance (CRA) announcing this project and providing updates can be found here. Table 5, found below, provides a timeline for the construction activities that took place during this project.

Construction Activity	Timeline
Demolition of existing road and culvert infrastructure; installation of cofferdams; installation of support pilings	May 2024
Installation of clear-span bridge complete	June, 2024
Removal of existing dam	July, 2024
Floodplain restoration	June-August, 2024
Installation of native trees and shrubs; installation of boardwalk support posts	April-May 2025
Installation of boardwalk and fishing platforms complete	June 2025

Table 5. Construction timeline.

2. Site Monitoring and Assessments

2.1 Overview

Site monitoring is broken down into different project components, including infrastructure, natural resources, and public use impacts. Naturally, these components work together as a system and can impact one another. For example, infrastructure can impact natural resources, and natural resources can affect public use. Although monitoring these different components may be carried out by different contractors or stakeholders, it is important to monitor the system as a whole and notify the appropriate organization if management is required.

2.2 Infrastructure Monitoring

The monitoring that will be necessary for infrastructure components of the project largely consists of three-span bridge monitoring as well as recreation and public access infrastructure monitoring. However, monitoring for the impacts of removed infrastructure, such as the dam remnants and culverts, should also occur. Each section below will explain the appropriate monitoring protocols, including proper reporting techniques and what organization assumes responsibility for monitoring and management if deemed necessary.

2.2.1 *Three-Span Bridge Monitoring*

The bridge is a public road that is monitored and maintained by the Oceana County Road Commission (OCRC). The Michigan Department of Transportation (MDOT) has a safety inspection program managed within the Office of Structure Preservation and Management of the Bureau of Bridges and Structures that ensures compliance with the National Bridge Inspection Standards (NBIS).

The bridge's effects on the stream should be monitored. Bridges can impact a stream in many ways, including scouring, reduced channel width, sedimentation, habitat disruption, bank erosion, and impedance to fish migration. While this bridge was designed to mitigate all these impacts, monitoring for impacts should still occur to ensure an appropriate response if impacts were to occur.

Culvert Removal Monitoring

Although monitoring for infrastructure that is no longer present may seem counterintuitive, we can still monitor the effects of removing the three undersized culverts. As discussed in Section 1.2.1, there are drawbacks to having multiple and undersized culverts within a stream. Stony Creek will continue to be restored and return to natural stream processes that will benefit fish and wildlife over time. Monitoring for this will be similar to the fish and wildlife and stream monitoring explained further below, except it should be focused within the proximity of the three-span bridge and where the culverts were previously located, both up and downstream. This is where most changes will occur in response to the removal. The culvert removal may

influence flooding and erosion frequency and severity, stream patterns, decrease or absence of stream blockages, and increase in the use of the creek by fish and other aquatic organisms for habitat and passageway.

2.2.2 *Recreation and Public Access Infrastructure Monitoring*

The lumber used for recreation and public access infrastructure, including ramps, boardwalks, and viewing decks, should be monitored for degradation which deems the infrastructure unusable or unsafe. Degradation of boards should be expected over time, especially when working alongside a creek and within a floodplain system that experiences fluctuating water levels.

2.2.3 *Dam Remnant Removal Monitoring*

The dam remnants were impacting the stream; therefore, monitoring the dam remnant removal will entail monitoring Stony Creek for restored natural processes. The dam remnants, in tandem with the undersized culverts, inhibited fish passage and interrupted natural stream form and processes. These are explained in greater detail in Section 1.2.3 but include the original stream no longer being in its original location, being over-widened, causing it to be shallow with the formation of in-channel sandbars and vegetative growth with an abundance of sand, and inhibited tree growth. These restoration activities are explained in greater detail in the following section.

2.3 Natural Resources Monitoring

Natural resources monitoring should assess the conditions of the onsite natural resources, including vegetation, fish and wildlife, instream habitat, and the floodplains. Natural resources monitoring may present an ideal opportunity for citizen science, particularly among fishermen.

2.3.1 *Vegetation Monitoring*

Vegetation is a strong indicator of the overall ecological health of a system. Michigan Flora provides information about plants found within Michigan, both native and invasive, and can serve as a valuable reference for vegetation monitoring. The vegetation onsite should be surveyed at least once yearly using a meander survey. When conducting a meander survey, the observer walks throughout the vegetated areas of the site and documents the species present. Specifically, the observer(s) should look for and document native vegetation, installed vegetation, and invasive species. The sections below describe each in greater detail.

Native Vegetation

Native vegetation refers to plant species or communities endemic to a given area. These species have developed over hundreds or thousands of years in a particular region and provide the greatest ecological benefits to the system.

Installed Vegetation

In this case, "installed vegetation" refers to native species planted as part of the restoration efforts. Monitoring should involve noting survival rates and species-specific trends, i.e., whether a specific species is experiencing above or below-average survivability. Browsing by deer and other predators is a common threat that newly installed vegetation faces that can significantly impact overall health and survival and should be monitored for. Tree cages and sunlight-transmissive shrub tubes were installed on many of the installed plants and should be maintained until the trees and shrubs have reached adequate establishment. In addition to monitoring for the success of the vegetation, it should also be determined if there are areas throughout the planted area with lower or higher survivability based on specific site conditions such as hydrology, proximity to the creek, etc. If it is determined that the survival rate of the installed trees and shrubs is below 80%, a replant may be deemed necessary. The following lists provide a complete inventory of the species installed throughout the floodplain/restored hardwood-conifer swamp.

Scientific Name	Common Name	PLS Oz/Acre
Asclepias incarnata	Swamp milkweed	4
Bidens cernua	Nodding beggar-ticks	1
Bidens frondosa	Common beggar-ticks	1
Bromus ciliatus	Fringed brome	8
Calamagrostis canadensis	Blue-joint	1
Carex crinita	Fringed sedge	4
Carex hystericina	Porcupine sedge	2
Carex lacustris	Common lake sedge	1
Carex stricta	Tussock sedge	3
Carex vulpinoidea	Fox sedge	3
Cinna arundinacea	Wood reedgrass	3
Eleocharis palustris	Great spike-rush	1
Elymus virginicus	Virginia wild-rye	48
Epilobium coloratum	Cinnamon willow-herb	1
Eupatorium perfoliatum	Common boneset	1
Glyceria striata	Fowl manna grass	4
Iris virginica	Southern blue flag iris	1
Leersia oryzoides	Rice cut grass	1
Lobelia cardinalis	Cardinal flower	0.5
Lobelia siphilitica	Great blue lobelia	0.5
Scirpus atrovirens	Dark green rush	3
Sium suave	Water-parsnip	0.5
Solidago patula	Swamp goldenrod	1
Solidago rugosa	Rough-leaved goldenrod	0.5
Symphyotrichum lanceolatum	Panicled aster	1

Symphyotrichum lateriflorum	Calico aster	1
Symphyotrichum puniceum	Swamp aster	1
Thalictrum dasycarpum	Purple meadow-rue	1
Verbena hastata	Blue vervain	2
	Total PLS Ounces Per Acre	**100.00**
	Total PLS Pounds Per Acre	**6.25**
Avena sativa	Seed oats	512
Lolium multiflorum	Annual rye	160

Table 6. Hardwood-conifer swamp seed mix.

Scientific Name	Common Name	Quantity
Cornus sericea	Red-osier dogwood	100
Ilex verticillata	Winterberry	100
Lindera benzoin	Spicebush	100
Salix nigra	Black willow	375
Viburnum trilobum	Highbush cranberry	275

Table 7. Installed shrub species and quantities.

Scientific Name	Common Name	Quantity
Abies balsamea	Balsam fir	200
Acer rubrum	Red maple	100
Betula papyrifera	Paper birch	200
Larxis laricina	Tamarack	200
Picea mariana	Black spruce	200
Thuja occidentalis	Northern white cedar	200
Tilia americana	American basswood	100

Table 8. Installed tree species and quantities.

Scientific Name	Common Name	Quantity
Asclepias incarnata	Swamp milkweed	380
Calamagrostis canadensis	Bluejoint grass	76
Carex crinita	Fringed sedge	114
Carex stricta	Tussock sedge	114
Carex vulpinodea	Fox sedge	114
Chelone glabra	White turtlehead	76
Coreopsis tripteris	Tall coreopsis	536
Eutrochium maculatum	Joe-pye weed	418
Heliopsis helianthoides	False sunflower	76
Iris virginica	Blue flag iris	190

Liatris spicata	Marsh blazing star	418
Lobelia cardinalis	Cardinal flower	574
Lobelia siphilitica	Great blue lobelia	346
Mimulus ringens	Monkeyflower	342
Packea aurea	Golden ragwort	266
Ranunculus hispidus	Bristly buttercup	190
Rudbeckia laciniata	Cutleaf coneflower	76
Scirpus atrovirens	Dark green bulrush	114
Scirpus cyperinus	Woolgrass	114
Solidago patula	Rough-leaved goldenrod	114
Sympyotrichum novae-angliae	New England aster	270
Zizea aurea	Golden Alexander	76

Table 9. Installed herbaceous plug species and quantities.

Invasive Species

Invasive species are those that are both "non-native (or alien) to the ecosystem under consideration, and whose introduction causes or is likely to cause economic or environmental harm or harm to human health" as per Executive Order 13112 (Section 1. Definitions). Invasive species can be documented in accordance with the Midwest Invasive Species Information Network's (MISIN) protocol. More information about MISIN and its protocol can be found here. Invasive species that were present are denoted by an asterisk next to the scientific name. Some of the most pervasive invasive species found within the restoration area include Japanese barberry (*Berberis thunbergii*), Canada thistle (*Cirsium arvense*), bull thistle (*Cirsium vulgare*), Bell's honeysuckle (*Lonicera* x *bella*), reed canary grass (*Phalaris arundinacea*), multiflora rose (*Rosa multiflora*), narrowleaf cattail (*Typha angustifolia*), and hybrid cattail (*Typha* x *glauca*). Monitoring for additional invasive species throughout the impacted area should be performed to inform management decisions. It should also be determined if invasive species are causing issues for the installed vegetation by outcompeting them.

2.3.2 *Fish and Wildlife Monitoring*

Fish and wildlife will be most impacted by the dam remnant and culvert removal and stream restoration. The fisheries surveys that occurred in 2020 "showed robust [and self-sustaining] populations of Brook, Brown, and Rainbow Trout, along with a few Coho Salmon" (Tonello, 2020). Over time, the health and presence of coldwater species are expected to increase as the creek returns to a healthy coldwater system. In 2025, GVSU completed post-construction monitoring of the aquatic biota in the creek (Appendix C).

2.3.3 *Stream Monitoring*

Stony Creek is groundwater-fed, which contributes to the cold stream temperatures that make this an ideal trout stream. Although the 2020 fisheries surveys determined Stony Creek to be "relatively intact and healthy" (Tonello, 2021), removal of the dam remnants and culverts,

stream restoration, and habitat improvements were strongly recommended. Now that these activities have occurred, the effects can be monitored. Because one of the goals of this restoration project was to return coldwater stream characteristics to Stony Creek, stream parameters that represent this system should be monitored. Key characteristics of coldwater streams include low water temperatures, riffle-pool sequences (alternating sections of fast-flowing water over rocks and wood and deeper, slower pools to provide diverse habitat), a shaded riparian zone, and a community of aquatic life adapted to cold water, including trout species and macroinvertebrates like stoneflies and mayflies.

Instream Habitat Monitoring

Instream habitat includes woody structures, aquatic and overhanging vegetation, rocks, and undercut banks. It also includes streambed characteristics such as the substrate, pools, runs, and riffles. Instream habitat provides areas and resources necessary for breeding, food, and protection for fish and other aquatic organisms. Most of the instream habitat monitoring in the site should occur on the large woody debris placed within the creek.

Heavy precipitation events or fluctuating water levels may displace large woody debris within the stream. The site should be monitored routinely and following inclement weather to check for displacement or premature degradation of the woody habitat structures. Monitoring should also note the use of the large woody debris by fish and wildlife and its impacts on stream characteristics, such as the creation of pools.

2.3.4 *Floodplain Monitoring*

Floodplain monitoring consists of monitoring for restored floodplain functions, success and rates of invasive species removal, and the survival of installed vegetation. Additional information for vegetation monitoring can be found in Section 2.3.1. In addition to vegetation health, monitoring connectivity to the stream channel, changes in land cover, noting areas of sediment deposition or erosion, and assessing biodiversity can help determine the system's overall health. Routine monitoring over time is crucial to identify trends and potential impacts on the floodplain. Changes can be gauged by comparing collected data to baseline data collected during the initial surveys. Monitoring can be performed using field surveys and aerial imagery through collaboration with local agencies, environmental organizations, and landowners.

2.4 Public Use Impacts Monitoring

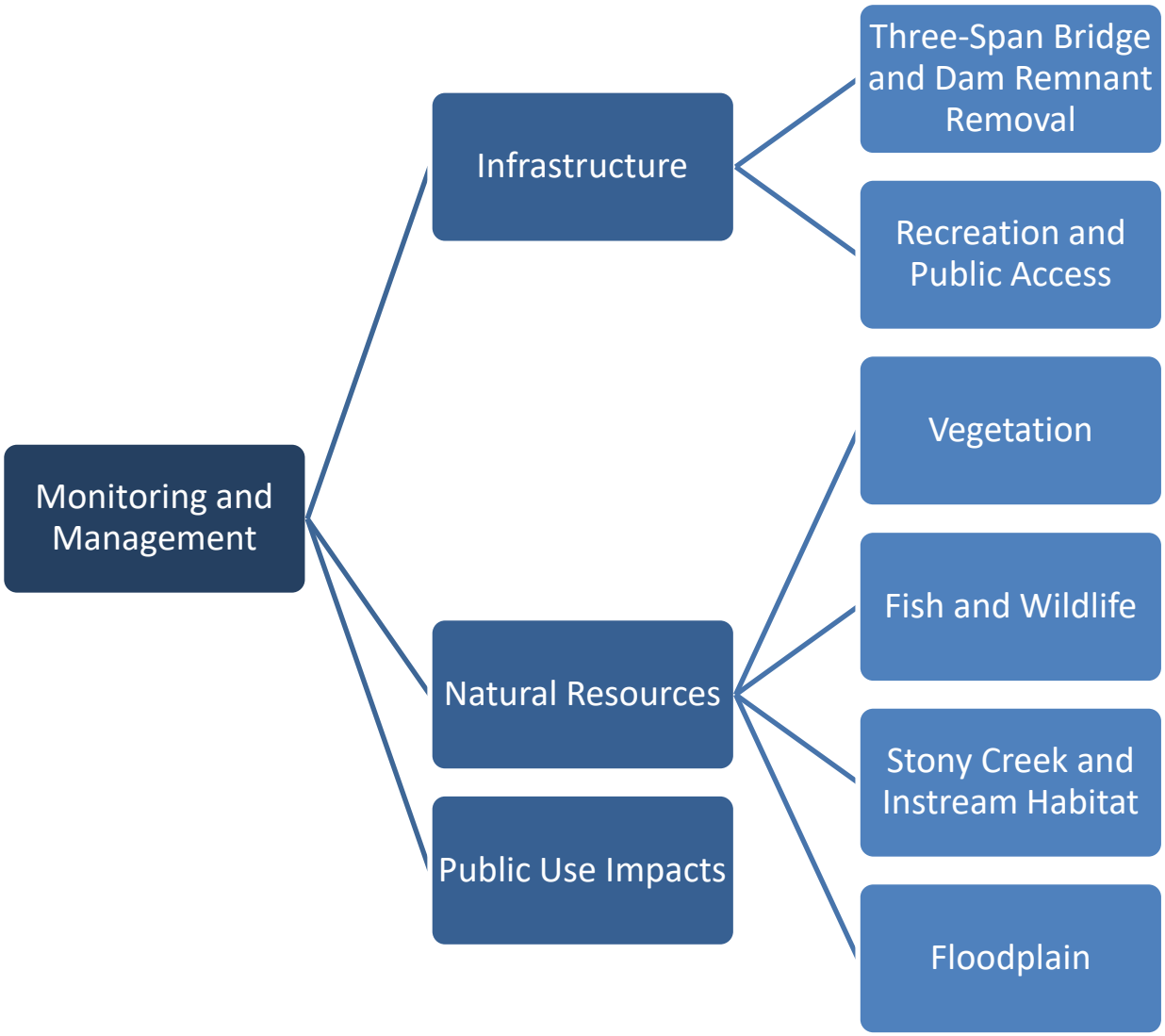
Public use is welcomed and encouraged at this site, as it occurs within a county park and has been historically utilized by the public for recreation. Naturally, public use will influence the site. Impacts from public use can be both positive and negative but should be expected over time. Public use can affect both infrastructure and natural resources, including recreation and access. Considering the site is a county park, monitoring will primarily be done by Oceana County staff. However, this site also offers a good opportunity for public monitoring and feedback.

Infrastructure can be impacted by public use, most often in the form of degradation from normal wear and tear, misuse, or intentional damage, i.e., vandalism. Monitoring for this is discussed in Section 2.2. The natural resources onsite could experience degradation by improper use, including trampling, intentional or unintentional damage to woody habitat structures, and erosion. Since this is a common fishing area, take note of the level of use, its impacts, and the type of fish being caught in this area.

Some forms of public use have the potential to affect other forms of public use. For example, high noise levels or activity from one type of recreation may take away from passive recreation, such as bird watching. It is important to maintain all forms of intended public use and keep the county park accessible for a range of recreators and visitors. Having conversations with individuals who visit and recreate within this area can be beneficial and help to inform future decisions.

3. Site Management

3.1 Overview



3.2 Infrastructure Management

Just as with infrastructure monitoring, the responsibility for the management of infrastructure will be spread among various stakeholders.

3.2.1 *Three-Span Bridge Management*

The Ocean County Road Commission (OCRC) is responsible for maintaining the bridge as it is a public road. Overseeing a bridge requires a thorough strategy that encompasses routine inspections, proactive maintenance activities such as cleaning, sealing cracks, and fixing drainage systems, keeping an eye out for structural problems, and strategizing for essential repairs or replacements according to the bridge's state and usage patterns, all while complying with safety regulations and protocols.

3.2.2 *Recreation and Public Access Infrastructure Management*

County staff may need to repair lumber on ramps, boardwalks, and viewing decks if the wood degrades. The recreation and public access infrastructure, including ramps, boardwalks, and viewing decks, was constructed using treated lumber to allow for easier maintenance by county staff. Repairing or replacing boards should be expected over time, especially when working alongside a creek and within a floodplain system that experiences fluctuating water levels.

3.3 Natural Resources Management

Extra management efforts may be necessary while the site responds to restoration activities, biotic and abiotic factors respond to new site conditions and processes, and vegetation becomes established. The focus of these efforts as it pertains to natural resources includes installed vegetation management, invasive species control, stream management (including instream habitat management), and floodplain management (which mainly entails management of installed vegetation and invasive species).

3.3.1 *Installed Vegetation Management*

One of the benefits of native vegetation is that the species are adapted to the local conditions and are, therefore, not management intensive. However, the installed vegetation may require some management during the first years following installation as they become established. If it is determined that browsing from deer and other animals is causing a decline in tree and shrub vigor, tree protection should be installed. Tree protection may include cages, tubes, or tree wrap. The type and extent of the damage should be determined to guide decisions on the type of tree protection used. Watering should not be necessary, considering the planted vegetation is within a floodplain wetland. Replanting may be necessary if there is a high mortality rate amongst the trees and shrubs. Reseeding may be necessary if there are areas of bare soil or a sparse presence of species within the seed mix after the first few years following seeding. Native species equivalent to those installed in the original plantings should be used for replanting purposes. Seed and plant materials should be obtained from a native plant nursery within the same (or an adjacent) Environmental Protection Agency Level III Ecoregion to maintain consistency in genotypes.

3.3.2 *Invasive Species Control*

Early detection and rapid response (EDRR) is the most effective method of invasive species management. Large populations of invasive plants and species that are difficult to remove by hand may be more efficiently controlled using herbicides. A glyphosate formulation approved for use in aquatic areas (such as Rodeo or AquaNeat) may be selectively applied to the foliage of target plants.

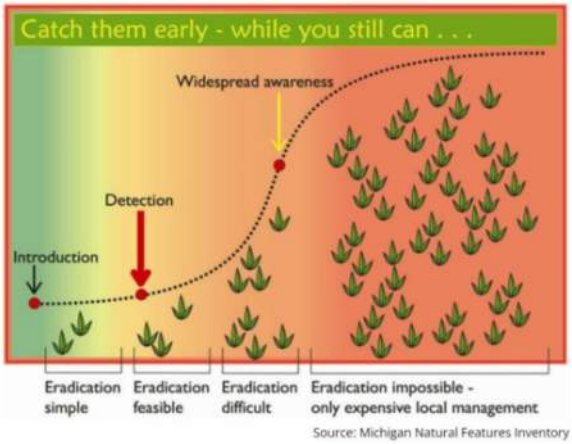


Figure 3. Invasive species EDRR.

Invasive species found throughout the impacted area during the initial species inventory are Japanese barberry (*Berberis thunbergii*), Canada thistle (*Cirsium arvense*), bull thistle (*Cirsium vulgare*), Bell's honeysuckle (*Lonicera* x *bella*), reed canary grass (*Phalaris arundinacea*), poison hemlock (*Conium maculatum*), multiflora rose (*Rosa multiflora*), narrowleaf cattail (*Typha angustifolia*), and hybrid cattail (*Typha* x *glauca*). Monitoring for additional invasive species should be performed to ensure management decisions can be informed.

Common invasive species found within wetland systems include common reed (*Phragmites australis* subsp. *australis*), purple loosestrife (*Lythrum salicaria*), cattails (*Typha* spp.), and reed canary grass (*Phalaris arundinacea*). Mix chemical in a 2% active ingredient solution with water to treat common reed, purple loosestrife, cattails, and reed canary grass. Include a wetland-safe surfactant such as Cygnet Plus in the solution at a rate of 0.6 ounces per gallon. Treatments to reed canary grass should occur in spring after emergence when most flowering herbaceous plant species have not yet emerged. Common reed (*Phragmites*) and purple loosestrife treatments should occur when most plants are blooming, which is typically July through September. Cattails, one of the most prevalent species in the impacted area, have a typical treatment window from July through September.

Japanese barberry and Bell's honeysuckle are invasive shrubs that can be treated with either glyphosate, triclopyr, or a combination. Two effective treatment methods for Japanese barberry and Bell's honeysuckle include foliar spray (2-5%) and cut-stump treatments (50%). Foliar applications can occur from early spring, when it is one of the first plants to leaf out through late summer/early fall (August/October). Cut-stump treatments can occur at any time of the year except during the spring when sap flow occurs. Multiflora rose is another aggressive invasive shrub that can form dense, impenetrable thickets. Herbicide options for multiflora rose control include glyphosate and triclopyr, which can be applied at a 2-3% solution for foliar applications or a 20-50% solution for cut-stump treatments. The treatment window for foliar applications for multiflora rose extends from early spring when it leafs out through early fall (May through October). Cut-stump treatments can be performed year-round except during spring sap flow. Mechanical removal combined with herbicide treatments often leads to better control.

Canada thistle and bull thistle are invasive biennial (bull thistle) and perennial (Canada thistle) species that spread aggressively through seeds (both) and creeping roots (Canada thistle). Effective control requires targeted herbicide treatments, timing, and follow-up to address their reproductive strategies. Glyphosate (2-3%) and triclopyr (2%) effectively combat both thistles. Foliar sprays are effective for both species. For large individual bull thistles, the plant can be cut at the base, and herbicide can be immediately applied to the surface. Hand-wicking applications can also effectively apply herbicide directly to the leaves without surrounding desirable vegetation. Canada thistle is best treated in its' pre-bloom stage when it is a rosette or bolting, typically from late spring to early summer. It can also be treated from late summer through early fall before the first frost when the plant is preparing to store nutrients in its roots, increasing herbicide absorption. Bull thistle is best treated in the rosette stage in early spring. It can also be treated before it flowers, typically late spring to early summer. Seed production can be prevented by treating or cutting before the plant bolts and flowers.

Certified pesticide applicators should perform herbicide treatments. Always follow chemical manufacturer label instructions for herbicide application. Please note that the use of herbicides in water may require an Aquatic Nuisance Control (ANC) permit from EGLE. More information can be found here.

Species	Herbicide	Timing
Bell's honeysuckle	Glyphosate or triclopyr; foliar spray (2-5%), cut-stump treatments (50%)	**Foliar applications:** late spring – early fall; **cut stump:** year-round except during spring sap flow
Bull thistle	2-3% glyphosate; 2% triclopyr	Early spring (rosette stage); late spring – early summer (prior to flowering)
Canada thistle	2-3% glyphosate; 2% triclopyr	Late spring – early summer (pre-blooming stage); late summer – early fall prior to the first frost
Cattails	2% glyphosate	July – September
Common reed (Phragmites)	2% glyphosate	August – September
Japanese barberry	Glyphosate or triclopyr; foliar spray (2-5%), cut-stump treatments (50%)	**Foliar applications:** late spring – early fall; **cut stump:** year-round except during spring sap flow
Multiflora rose	Glyphosate or triclopyr; foliar spray (2-3%), cut-stump (20-50%)	**Foliar applications:** May – October; **cut-stump:** year-round except during spring sap flow
Purple loosestrife	2% glyphosate or 2% triclopyr	July – September (when flowering)
Reed canary grass	2% glyphosate	May – September

Table 10. Invasive species treatment protocols.

3.3.3 *Stream Restoration Management*

It is important to remember that, while restoration activities to repair the stream took place, some changes will not happen immediately but rather over time as this section of the creek responds to the changes made. Form will influence function, and vice versa, as the stream continues to shape itself over time. However, if it is believed that management is required to correct a component of the stream or a factor influencing the stream, an expert should be consulted to determine the correct course of action and methods.

Instream Habitat Management

Proper maintenance should occur if woody debris has become dislodged, is prematurely degrading, or has shifted in a manner that negatively affects stream characteristics, including site hydrology and geomorphology. Maintenance may include replacing and anchoring materials that are decomposing or becoming dislodged, as well as adding materials. The structures will more likely require maintenance after high-flow or extreme weather events. Additionally, ice can adversely affect the woody debris, and extra monitoring and maintenance may be necessary following the winter season and into spring.

3.3.4 *Floodplain Management*

Management of the floodplains will primarily consist of managing vegetation, both installed and invasive species. Information on how to manage installed vegetation can be found in Section 3.3.1. Invasive species control is explained in Section 3.3.2. As mentioned in Section 3.3.3, the floodplain will naturally adjust to changing conditions over time. However, if management is deemed necessary, consult an expert to address the issue and develop the best course of action.

3.4 Public Use Impacts Management

A practical approach is to educate the public about the importance of the restoration activities that have occurred on the site and the impact that public use can have on it. This can be done through signage, outreach programs, public meetings, and other forms of community engagement. Signage and physical barriers discourage public use in sensitive areas. For example, fencing can be used to block off access to the site, or boulders can be placed in strategic locations to prevent people from entering. Working with local law enforcement to enforce any regulations, ordinances, or laws in place may be necessary. This can include issuing tickets or fines to people caught engaging in prohibited activities.

References Cited

Davis, J.C., G.W. Minshall, C.T. Robinson, and P. Landres. (2001). Large Woody Debris. In Monitoring Wilderness Stream Ecosystems. General Technical Report RMRS-GTR-70, pp. 73 - 77. US Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, Colorado.

GEI Consultants, Inc. (2022). Marshville Dam Removal and Stony Creek Restoration: Design Alternatives Feasibility Study.

Harman, W.A., T.B. Barrett, C.J. Jones, A. James, and H.M. Peel. (2017). Application of the Large Woody Debris Index: A Field User Manual Version 1. Stream Mechanics and Ecosystem Planning & Restoration, Raleigh, NC.

Tonello, M. (2021). Status of the Fishery Resource Report. Stony Creek. Michigan Dept. of Natural Resources. Report No. 2021-305

Appendix A Feasibility Study

GEI Consultants

Consulting
Engineers and
Scientists

Marshville Dam Removal and Stony Creek Restoration

Design Alternatives Feasibility Study
Shelby, Michigan

September 8, 2022

Submitted to:
Conservation Resource Alliance
10850 E Traverse Hwy #1180
Traverse City, Michigan 49684

and

West Michigan Shoreline Regional Development Commission
316 Morris Avenue # 340
Muskegon, Michigan 49440

Submitted by:
GEI Consultants, Inc.
5225 Edgewater Drive
Allendale, Michigan 49401

Brian Majka, CERP
Restoration Ecologist, Project Manager

Scott Dierks, PE
Ecological Engineer

Table of Contents

1. Project Overview 1
1.1 Problem Definition and Background 1
1.2 Project Goals 2

2. Preliminary Site Investigations 4
2.1 Depth to Refusal Survey 4
2.2 Topographic Survey 7
2.3 Reference Reach Surveys 9
2.4 Soil Disposal Location 12
2.5 Wetland Delineation 12
2.6 Floristic Quality Assessment (FQA) and Vegetation Survey 13
2.7 Sediment Volume, Characterization and Soil Disposal 18
2.8 MiSQT Assessments 19

3. Design Alternatives 22
3.1 Project-Level Design Approaches 22
3.2 Michigan Stream Quantification Tool (MiSQT) 23
3.3 Discussion and Design Recommendations 25

4. Regulatory Considerations 28

5. Opinion of Probable Cost 30

6. References Cited 31

Tables

1. Depth to Refusal Survey Results
2. Impacted Area Stream Parameters
3. Reference Reach Stream Parameters
4. Impacted Area Species Inventory
5. Reference Area Species Inventory
6. FQA Summary
7. Existing Conditions MiSQT Summary
8. Project Level Approach Pros and Const
9. Existing and Proposed MiSQT Parameters
10. LWD Index Parameters
11. Opinion of Probable Cost

Figures

1. Site Survey Summary
2. Depth to Refusal Survey
3. Topographic Survey
4. Soil Disposal Location
5. Wetland Delineation, Plant Community, and Invasive Species Mapping

Appendices

A. Floristic Quality Assessment Results
B. MNFI Hardwood Conifer Swamp Community Abstract
C. MNFI Mesic Northern Forest Community Abstract
D. In-Stream Sediment Laboratory Results
E. Michigan Stream Quantification Tool
F. Conceptual Design Drawings

1. Project Overview

1.1 Problem Definition and Background

Stony Creek is a groundwater-fed coldwater stream located in Oceana County, Michigan, and is regarded as one of the best trout streams in lower Michigan. The creek has a 57 square mile watershed that is mostly forested and undeveloped is contained entirely in Oceana County (Tonello, 2021), where the creek drains into Stony Lake and eventually into Lake Michigan. In 1861, Henry Marsh first constructed a dam in Stony Creek for a grist mill in the vicinity of what is now Marshville Dam Road. The dam, which was completed in 1861, remained in place until 1883, when the dam failed. Following this failure, the dam was re-built by the Marshville Improvement Association in 1927 to create a pond for local fisherman. The dam failed again in 1968 when vandals created a bypass around the dam. The dam has remained in a state of disrepair ever since.

Although the majority of the dam structure has been removed, the impacts of the dam remain and are an impairment to the local ecology and community. The dam in its current condition has resulted in the following impacts:

1. In its current state, the dam is relatively unattractive and is a safety hazard.

2. The physical structure of the dam, as well as the adjacent road culverts, inhibits fish passage, particularly during low water conditions. In the summer of 2020, MDNR Fisheries Division conducted an electrofishing survey of Stony Creek just upstream of the Marshville Dam. The survey showed robust numbers of resident Brown trout (to 20 inches), Brook trout (to 10 inches), and Rainbow trout or Steelhead (to 12 inches). This project will benefit both resident salmonids and migratory salmonids (cold water species) that migrate from Lake Michigan with an emphasis on Brook trout.

3. The historic construction of the dam interrupted natural stream processes that do not appear to have self-healed. A portion of the stream upstream of the dam is not in its original location and appears over-widened, leading to a shallow stream and the

formation of mid-channel sand bars and vegetative growth in the center portions of the stream. The abundance of sand is supported by MDNR's assessment (Tonello 2021), which noted sand was "by far the primary substrate", representing 78.5% of the substrate at the Marshville Dam. Increasing the heterogeneity of substrate in the project area is important to protecting and improving the abundance and diversity of aquatic biota.

4. When the dam was constructed, it appears that many of the trees in the impoundment were removed. Following dam construction, tree growth was either limited by the dam impoundment, or in its current state is likely limited because the remaining dam structure has raised the upstream groundwater table and inhibited tree growth. As a coldwater stream, tree cover is especially important because it provides shading, cooling of the water, and overhead cover from predation which are all necessary for the fish species that use the creek and for the benthic macroinvertebrates that are major dietary items for fish. Removing the remaining dam structure and re-foresting the floodplain can restore these habitat benefits.

The West Michigan Shoreline Regional Development Commission (WMSRDC), Conservation Resource Alliance (CRA), Oceana County, Michigan Department of Natural Resources (MDNR), and Grand Valley State Annis Water Resources Institute (AWRI) have teamed together together with funding from the National Oceanic and Atmospheric Administration (NOAA), United States Fish and Wildlife Service (USFWS), MDNR, and Great Lakes Fishery Trust to develop restoration plans for the removal of the dam and restoration of an upstream reach of Stony Creek. The partnership hired GEI Consultants of Michigan, P.C. (GEI) to develop plans for the dam removal and creek restoration. This feasibility study presents and discusses the preliminary site investigations and design alternatives in support of this effort.

1.2 Project Goals

The proposed project includes dam remnant removal, removal of the abandoned bridge south of the Marshville Dam Road crossing, removal of 3 culverts blocking fish passage downstream of the dam, installation of a 3-span bridge with the center span extending over the bankfull width of Stony Creek, sediment management, native species re-vegetation, stream restoration, floodplain wetland restoration/creation, in-stream habitat enhancements, and recreational access improvements. When executed, this project will provide numerous benefits to the local ecosystem and community. The specific fish and wildlife habitat improvement goals include:

1. Reconnection of approximately 6.5 miles of Stony Creek for native aquatic species and native fish species

2. Enhancement of up to 18 acres of wetland habitat

3. Up to 2,500 feet of in-stream habitat restoration

4. Enhancement of passive and active recreation.

2. Preliminary Site Investigations

To characterize the existing conditions at the site and inform the restoration designs, field surveys were completed to assess the physical and biological conditions at the site and in an adjacent reach used to establish reference conditions (Figure 1). These surveys included characterization of site soils, topography, vegetation, and stream habitat in both the proposed restoration reach and a stable reference reach. The results of these surveys are described below.

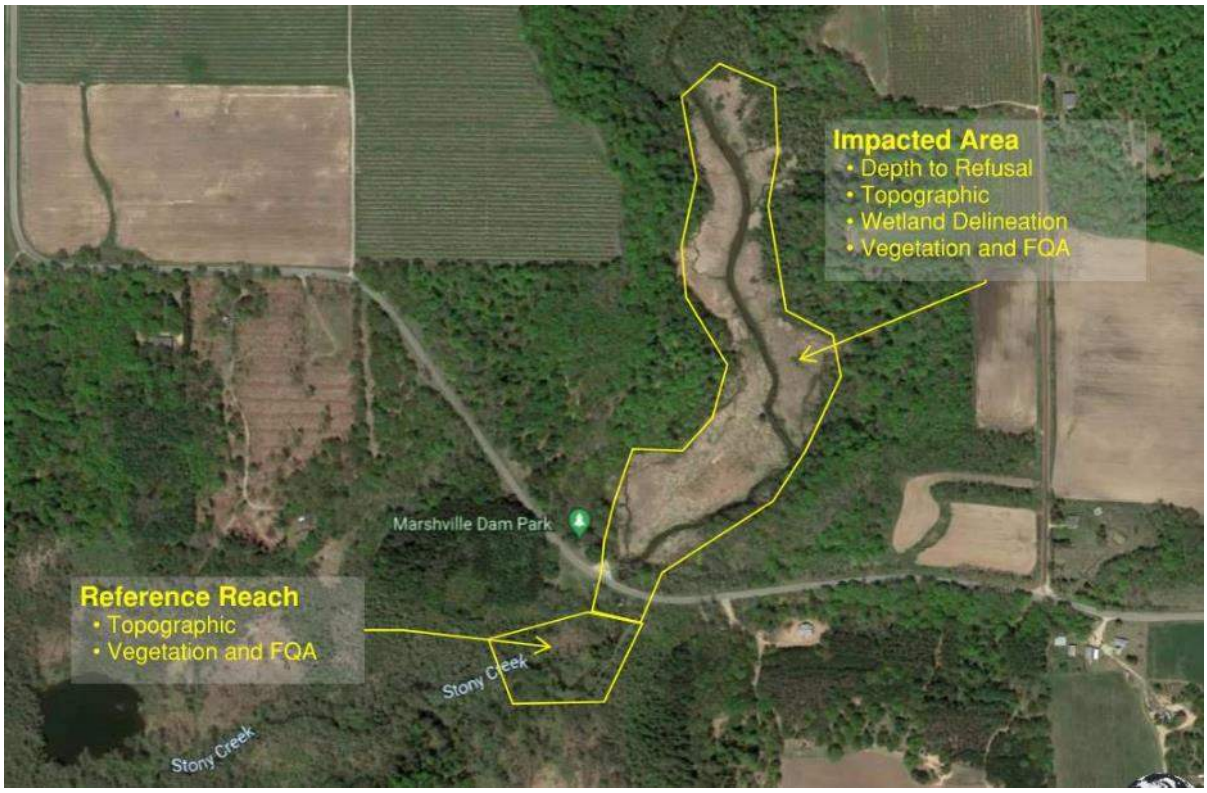


Figure 1. Site Survey Locations (Source: Google Earth)

2.1 Depth to Refusal Survey

GEI and CRA assessed subsurface soil conditions at the site by completing a depth to refusal survey, with the intent of locating the historic Stony Creek channel. The survey was completed using a tile probe with multiple extensions to sample the soils until hard refusal was reached.

Four transects were sampled across the stream valley (Figure 2), including concentrated sampling in the suspected historic channel location. A total of 43 sample points were taken throughout the site, at depths up to 11'. Notes were made when refusal or resistance was found, as many of the sample locations contained multiple points of refusal that could be penetrated with added force. This was likely due to a layering of sand and clay layers in the underlying

substrate. Figure 1 shows each point along with the corresponding elevation of the first refusal encountered, and Table 1 includes the survey results.

Depth to Refusal Survey

ID	First Refusal Depth (ft)	Second Refusal Depth (ft)	Third Refusal Depth (ft)	Notes
001	3.5	5	7.5	
002				no refusal found
003	4			no refusal found below 4.0
004	2.5	4	8.5	wood found at 8.5
005				no refusal found
006	8.5			no refusal found below 8.5
007	6			wood found at 6.0
009	6.5			no refusal found below 6.5
010	7			no refusal found below 7.0
011				no refusal found
012	5.5	10.75		no refusal found below 10.75
013	5	8.5		no refusal found below 8.5
014	4			no refusal found below 4.0
015	5	9.5		no refusal found below 9.5
016	8.5			no refusal found below 8.5
017	4	6.5	8	no refusal found below 8.0
018	4.25	6		point is in stream; no refusal found below 6.0
019	4	8		no refusal found below 6.0
020	3.5	6		no refusal found below 6.0
021	2.9	4.2	9	no refusal found below 6.0
022	6			hard refusal at 6.0
023	7.5			no refusal found below 7.5
024	3	7	8.5	no refusal found below 8.5
025	4.5	5.5	6.5	additional refusal points at 8.5 and 10.5
026	5.8	10.5		no refusal found below 10.5
027				no refusal found
028	3.5	7	8.2	additional refusal points at 11.0
029	4.5			hard refusal at 4.5
030				no refusal found
031	4.6			hard refusal at 4.6
032				no refusal found
033	4.5			no refusal found below 4.5
034	3.5	7		no refusal found below 7.0
034	1.5	5	8.7	additional refusal point at 11.0
035	3			hard refusal at 3.0
036	6.8			hard refusal at 6.8
037	3	10.5		no refusal found below 10.0
038	1.5			hard refusal, wood at 1.5
038	7.4			point located in stream, no refusal below 7.4
039	7.5	11		no refusal found below 11.0
040	4.2			hard refusal at 4.2
041				no refusal found

Table 1. Depth to Refusal Survey Results

The substrate at each sample point consisted of primarily organic substrate at the surface, followed by some combination of sand and clay below. Wood was encountered at several locations. No stone was found during the survey. Typically, when hard refusal was found it was assumed to be either wood or clay.

After analyzing the field data, it was determined that there is not a discernable pattern in underlying substrate throughout the site. Layers of sand and clay with mixed wood are present at

various depths. This data led to the conclusion that the historic stream channel cannot be located with confidence with the methods that were used.

2.2 Topographic Survey

Topographic surveys were completed of the creek, floodplain, dam, and adjacent features (Figure 3). A total of approximately 3,200 linear feet of creek were surveyed using a combination of ground surveys and unmanned aerial vehicle (UAV), including approximately 600' downstream of Marshville Dam Road and 2600' upstream. 18 total cross sections were recorded in the stream, in addition to a stream profile and planform.

The survey data was used to evaluate stream metrics for stability, habitat, floodplain connectivity, and sediment volumes, as well as for overall site planning. A summary of the analyzed metrics is included in Table 2. The existing reach of Stony Creek is classified as a C5 channel by Rosgen classification system, meaning it is characterized by being slightly entrenched (entrenchment ration of 2.2 or greater), moderate sinuousity (1.24), having moderate width/depth ratio of 12 or greater, a relatively low bedslope (0.1%), and a sand bottom.

X-SEC	STA	WSE	BKFw	BKFe	Thalweg	BKFd	W/D	Max Water Depth	Cross Sectional Area at BKF	Bank Height Ratio	Entrenchment Ratio (+)
A	0+93	600.1	27	600.8	597.1	3.7	7.3	3	72.7	1	7.4
B	2+94	599.9	31	599.7	597.5	2.2	14.1	2.4	49.6	1	8.1
C	4+96	599.9	45	600.5	597.4	3.1	14.5	2.5	95.4	1	3.6
D	7+02	599.9	45	601.1	597	4.1	11.0	2.9	106.3	1	2.4
E	9+02	599.8	39	600.4	597	3.4	11.5	2.8	74.7	1	9.2
F	11+05	599.7	41	600.6	596.7	3.9	10.5	3	91.9	1	6.1
G	13+05	599.6	28	600.1	596.3	3.8	7.4	3.3	70.5	1	11.4
H	15+06	599.5	49	600.8	596.5	4.3	11.4	3	115.7	1	6.3
I	17+14	599.3	44	599.5	596.9	2.6	16.9	2.4	83.8	1	8.4
J	19+14	599.2	28	599.5	594.5	5	5.6	4.7	63.3	1	11.1
K	21+11	598.6	48	598.7	594.9	3.8	12.6	3.7	78.2	1	6.7
L	23+12	598.5	36	598.9	594.8	4.1	8.8	3.7	66.8	1	12.5
M	25+07	597.2	22	597.1	593.5	3.6	6.1	3.7	43.9	2.8	13.6
Dam											
N	25+99	595.7	36	595.9	593.5	2.4	15.0	2.2	54.1	5.2	1.9
O	27+04	594.5	33	594.4	592.6	1.8	18.3	1.9	35.2	4.1	1.4
P	27+28	594.2	34	595.9	591.5	4.4	7.7	2.7	99.7	1.9	7.4
Q	28+58	594.2	17	594.3	590.7	3.6	4.7	3.5	33.5	1	14.1

Table 2. Impacted Area Stream Parameters

Existing Conditions Upstream from Dam

Existing Conditions Upstream from Dam

Existing Conditions Upstream from Dam

2.3 Reference Reach Surveys

On May 13, 2022 surveyors from GEI and CRA conducted topographic and geomorphological surveys throughout the identified reference reach. The reference reach is located immediately downstream of the existing bridge south of W. Marshville Dam Road (Figure 1). Surveyors used a Trimble R6 GNSS System capable of sub-meter accuracy to capture cross sectional and profile data throughout the reach.

Like the upstream reach, the reference reach of Stony Creek is classified as a C5 channel by Rosgen classification system, meaning it is characterized by being slightly entrenched, moderate sinuosity (1.28), having moderate width/depth ratio, a relatively low bedslope (0.2%), and a sand bottom. It is important to note that the channel has a relatively low sinuosity, and much the of the channel morphology and bedform diversity is driven by wood as opposed to the plan form of the stream itself. This is not uncommon in low gradient sand bed streams, and will be an important consideration in the design of the restored channel.

	STA	WSE	BKF w	BKFe	Thalweg	BKF d	W/D	Max Water Depth	Cross Sectional Area at BKF	Bank Height Ratio	Entrenchment Ratio
RR1	28+82	594	27	594.5	590.7	3.8	7.1	3.3	43.1	1	8.9
RR2	30+09	593.9	29	594.5	591.5	3	9.7	2.4	53.9	1	8.6
RR3	31+23	593.9	35	594.7	590.3	4.4	8.0	3.6	74.6	1	7.1
RR4	31+85	593.7	17	594.6	590.4	4.2	4.0	3.3	39	1	14.7

Table 3. Reference Reach Stream Parameters

Existing Conditions in Reference Reach

Existing Conditions in Reference Reach

Existing Conditions in Reference Reach

2.4 Soil Disposal Location

An undetermined volume of soil will likely be removed from the creek channel and floodplains during the restoration process to create a stable and functioning stream. Because of the potential cost savings, GEI reviewed potential local disposal locations for the potential placement of any excavated soils. There is a suitable location immediately adjacent to the project site at the corner of Marshville Dam Road and 54th Avenue (Figure 4) . This property is currently upland farm ground and is owned by John Wyns, a project partner. Mr. Wyns has indicated that he will allow soils excavated as part of this project to be placed on his property at this location, and EGLE verbally approved the use of the location during the pre-application meeting as long as the soil is placed in uplands.

2.5 Wetland Delineation

On June 1, 2022 GEI conducted a wetland delineation (Figure 5) throughout the proposed project location upstream of Marshville Dam and the reference reach. Before a site visit was conducted, GEI reviewed several resource reference maps of the two assessment areas. These included the U.S. Geologic Survey (USGS) Topographic Map Series and National Hydrography Dataset (NHD), U.S. Fish and Wildlife Service (USFWS) National Wetland Inventory (NWI), and U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Soil Survey. These maps were used to help identify potential drainage ways, wetlands, streams, and wetland soil units in the assessment areas.

GEI surveyed the two assessment areas and the surrounding lands, to determine the extent and regulatory status of any wetlands present. Wetlands were identified and delineated in accordance with the United States Army Corps of Engineers USACE Wetlands Delineation Manual and Regional Supplement to this manual for the Northcentral and Northeast Region (Version 2.0) (USACE 1987, USACE 2011).

Proposed Project Area

The Stony Creek wetlands form a wide buffer between the creek and the upland woods above. The flood plain of the creek is contained by steep upland slopes on either side which limit the wetland area to a relatively flat shelf space between the steep slopes and the edge of the creek. The wetland shelf ranges from one to 200 feet in width from the riverbank and is predominantly lacustrine emergent wetland community (Cowardin et al 1979). The community is dominated by cattails (*Typha x glauca*) and tussock sedge (*Carex stricta*). A Palustrine Forested (PFO) wetland community exists between the emergent wetland and the upland and is dominated by Eastern White Cedar (Thuja occidentalis) and speckled alder (*Alnus incana*) in the canopy layer, and cinnamon fern (*Osmundastrum cinomomeum*) in the herbaceous layer.

The signs of wetland hydrology throughout this wetland area were abundant since the wetlands were directly adjacent to Stony Creek. At wetland data point 1, the water table was recorded at

10" depth and the soil was saturated at the surface. The USDA Soil Survey classified soils in this area as Perrington Loam (USDA, 2021).

Reference Reach

The wetlands in Assessment Area B are contained between Stony Creek and upland forests in a narrow band ranging from 50 to 250 feet wide from the stream bank and is predominantly Palustrine Forested wetland community (Cowardin et al 1979). The forested wetlands are dominated by Eastern White Cedar (*Thuja occidentalis*) and Silver Maple (*Acer saccharinium*) while the herbaceous layer contains tussock sedge (Carex stricta) and Cinnamon Fern (*Osmundastrum cinnamomeum*).

At wetland data point 3 the water table was recorded at 14" depth and the soil was saturated at the surface. The soil profile observed at this data point revealed a mucky loam layer as deep as 20 inches. The USDA Soil Survey classified soils in this area as Perrington Loam (USDA, 2021).

2.6 Floristic Quality Assessment (FQA) and Vegetation Survey

In addition to the wetland delineations, GEI biologists conducted vegetation surveys throughout the Impacted Area and Reference Reach (Figure 5). The vegetative communities on site were classified by Michigan Natural Features Inventory (MNFI) named natural communities, and all plant species identified in each community were recorded. The data collected from the vegetation surveys were then used to complete a Floristic Quality Assessment (FQA) of distinct wetland units throughout the project area. Assessments followed the methodology of Herman et al. (2001) and utilized the universal FQA calculator (https://universalfqa.org/) for analysis.

In addition to the community mapping and FQA, invasive plant species located on site were mapped and are shown on Figure 5. A full list of the FQA analysis is included in Appendix A.

Impacted Area

The wetland area impacted by the dam was likely historically classified as a Hardwood Conifer Swamp (Appendix B), but would currently be classified as a Northern Wet Meadow. However, it should be noted that the current vegetative community in this area does not fit cleanly into an MNFI natural community because the site is so highly disturbed. The wetlands is surrounded by a Northern Mesic Forest (Appendix C). The wetland is dominated by cattails (*Typha sp.*), Tussock Sedge (*Carex stricta*), and Touch-Me-Nots (*Impatiens capensis*). The forested wetland contains Cinnamon Fern (*Osmundastrum cinnamomea*), Eastern White Cedar (*Thuja occidentalis*), and Tussock Sedge (*Carex stricta*). 67 total species were found in this area, with a mean C value of 3.1. A full list of species is included in Table 4.

Scientific Name	Common Name
Acer rubrum	Red Maple
Acer saccharinium	Silver Maple
Achillea millefolium	Common Yarrow
Alder incana ssp. rugosa	Speckled Alder
Anemonastrum canadense	Wood Anemone
Arisaema triphyllum	Jack-in-the-Pulpit
Asclepias syriaca	Common Milkweed
Barbarea vulgaris	Bitter Wintercress
Berberis thunbergii	Barberry
Betula alleghaniensis	Yellow Birch
Betula papirifera	Paper Birch
Bidens cernua	Nodding Bur-Marigold
Caltha palustrus	Marsh Marigold
Cardamine pensylvanica	Pennsylvania bittercress
Carex scabrata	Eastern Rough Sedge
Carex sp.	
Carex stricta	Tussock Sedge
Cicuta bulbifera	Bulbet-bearing Water Hemlock
Circaea canadensis	Broad-Leaved Enchanter's Nightshade
Circium arvense	Canada Thistle
Cirsium vulgare	Bull Thistle
Clematis virginiana	Virgin's Bower
Cornus alba	Red Osier Dogwood
Eleochaeris obtusa	Blunt Spike rush
Equisetum arvense	Field Horsetail
Eupatorium perfoliatum	Common Boneset
Fagus grandifolia	American Beech
Fraxinus nigra	Black Ash
Galium aparine	Sticky Willy
Galium boreale	Northern Bedstraw
Geranium robertianum	Lesser Herbrobert
Glyceria striata	Fowl Manna Grass
Hypericum sp.	St. John's Wart
Ilex verticilata	Common Winterberry
Impatiens capensis	Spotted Touch-Me-Not
Iris versicolor	Blue Flag Iris
Juncus effusus	Soft Rush
Laportea canadensis	Wood Nettle
Lemna minor	Common Duckweed
Lonicera x bella	Bell's Honeysuckle

Scientific Name	Common Name
Lysemachia borealis	Starflower
Matteuccia struthiopteris	Ostrich Fern
Mentha spicata	Spearmint
Osmunda spectabilis	Royal Fern
Osmundastrum cinnamomeum	Cinnamon Fern
Pastinaca sativa	Wild Parsnip
Phalaris arundinacea	Reed Canary Grass
Populus tremuloides	Quaking Aspen
Prunus serotina	Black Cherry
Pteridium aquilinium ssp. L	Northern Bracken Fern
Ranunculus hispida	Bristly Buttercup
Ribes triste	Swamp Red Currant
Rosa multiflora	Rambler Rose
Rubus ideaus	Common Red Raspberry
Rumex obtusifolius	Bitter Dock
Sagittaria latifolia	Broad-leaf Arrowhead
Senicio vulgaris	Old-Man-in-the-Spring
Sparganium eurycarpum	Giant Bur-reed
Symplocarpus foetidus	Skunk Cabbage
Thuja occidentalis	Eastern Arborvitae
Tilia americana	American Basswood
Toxicodendron radicans	Eastern Poison Ivy
Toxicodendron vernix	Poison Sumac
Tsuga canadensis	Eastern Hemlock
Typha angustifolia	Narrowleaf cattail
Typha latifolia	Broad-leaved cattail
Typha x glauca	Cattail
Ulmus americana	American Elm
Urtica dioica	Stinging Nettle
Verbena hastata	Blue vervain
Veronica americana	American-Brooklime
Vitis riparia	River-Bank Grape

Table 4. Impacted Area Species Inventory

Reference Reach

Located south of the proposed impacted area of the Marshville Dam/Stony Creek Site is a area of forested and emergent wetlands that will be used as a reference for restoration efforts. In this location, the wetland plant community is a Hardwood Conifer Swamp, and the adjacent uplands is Northern Mesic Forest . This area has defined banks that host a variety of plants including

Ostrich Fern (*Matteuccia struthiopteris*), Wood Nettles (*Laportea canadensis*), and Eastern White Cedar (*Thuja occidentalis*). Out of 52 species found in this area 47 of them were native with a mean C value of 3.8. A full list of species is included in Table 5.

Scientific Name	Common Name
Acer rubrum	Red Maple
Acer saccharinum	Silver Maple
Acer saccharum	Sugar Maple
Allaria petiolata	Garlic Mustard
Alnus incana rugosa	Speckled Alder
Anemonastrum canadense	Wood Anemone
Arisaema triphyllum	Jack-in-the-Pulpit
Betula alleghaniensis	Yellow Birch
Bidens cernua	Nodding Bur-Marigold
Caltha palustris	Yellow Marsh Marigold
Carex canescnes	Silvery Sedge
Carex intumescens	Greater Bladder Sedge
Carex limosa	Mud Sedge
Carex stricta	Tussock Sedge
Cicuta bulbifera	Bulbet-bearing Water Hemlock
Clematis virginiana	Virgin's Bower
Cornus alba	Red Osier Dogwood
Cretagus sp.	Hawthorn
Eleagnus umbellata	Autumn Olive
Equisetum arvense	Field Horsetail
Fraxinus nigra	Black Ash
Gallium aparine	Sticky-Willy
Geranium robertianum	Lesser Herbrobert
Geum	Avens
Hesperis matronalis	Mother-of-the-Evening
Ilex verticilata	Common Winterberry
Impatiens capensis	Spotted Touch-Me-Not
Iris versicolor	Larger Blue Flag Iris
Laportea canadensis	Wood Nettle
Lemna minor	Common Duckweed
Menispermum canadense	Moonseed
Onoclea sensibilis	Sensitive Fern
Osmundastrum cinnamomeum	Cinnamon Fern
Persicaria pensylvanica	Pinkweed
Phalaris arundinacea	Reed Canary Grass
Polygonatum pubescens	Hairy Solomon's-Seal

Scientific Name	Common Name
Prunus serotina	Black Cherry
Ranunculus hispidus	Bristly Buttercup
Ranunculus recurvatum	Blisterwort
Ribes triste	Swamp Red Currant
Rubus ideaus	Common Red Raspberry
Rumex obtusifolius	Round Leaved Dock
Sagittaria latifolia	Broad-leaf Arrowhead
Salix interior	Sandbar Willow
Sparganium eurycarpum	Giant Bur-reed
Symplocarpus foetidus	Skunk Cabbage
Thalictrum thalictroides	Rue-Anemone
Thuja occidentalis	Eastern Arborvitae
Tilia americana	American Basswood
Toxcodendron vernix	Sumac
Toxicodendron radicans	Eastern Poison Ivy
Typha x glauca	Cattail
Ulmus americana	American Elm
Urtica diotica	Stinging Nettle
Vitis riparia	River-Bank Grape

Table 5. Reference Area Species Inventory

Wetland	Total Species	Native Species	Total Mean C	Native Mean C	FQI	Native FQI
Impacted Area – Northern Wet Meadow/Disturbed Hardwood Conifer Swamp	67	55	2.8	3.1	22.9	25.2
Reference Area (Hardwood Conifer Swamp)	52	47	3.4	3.8	24.5	26.1

Table 6. FQA Summary

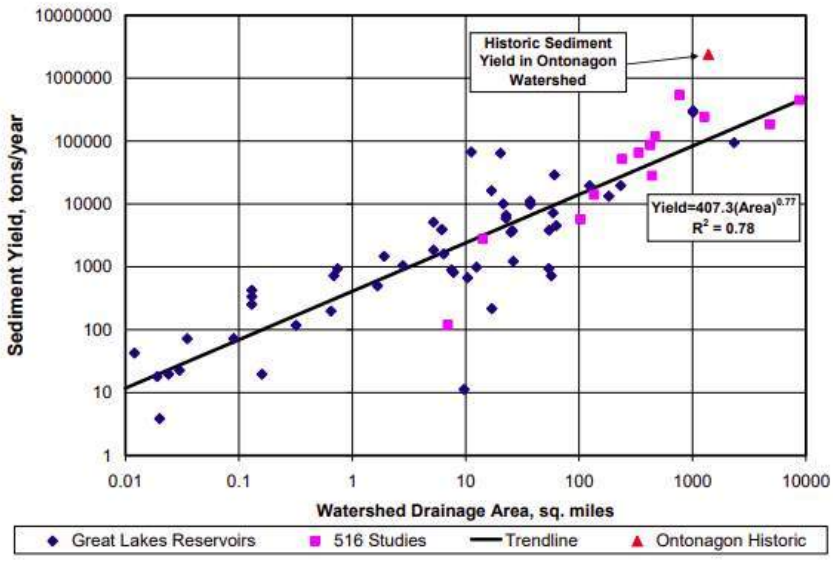
2.7 Sediment Volume, Characterization and Soil Disposal

Sediment Volume

To minimize downstream impacts, it has become customary for EGLE to require sampling of the sediments in dam impoundments prior to dam removal. In the case of the Marshville Dam, there is likely very little sediment remaining behind the dam because the weir boards have been removed, which would have effectively released the majority of the impounded sediment downstream.

EGLE typically requires sediment testing for dredge volumes greater than 2,000 cubic yards when contamination is not suspected. Additionally, EGLE has verbally indicated on previous projects that they may allow a volume of sediment up to 1-year of naturally occurring sediment load to move downstream as a result of a dam removal. Based on our preliminary assessment, we have estimated that 1,000-2,000 cubic yards of potentially mobile sediment may remain in place due to the dam. Using a sediment rating curve that has been developed for Michigan, we have estimated that an annual sediment load for Stony Creek at this location is approximately 5,900 cubic yards. Based on these considerations, we believe that at this stage it is very possible that EGLE will not require extensive sediment testing and may allow sediment to naturally move downstream following the dam removal.

Figure 15 – Annual Sediment Yield from Historic Ontonagon and other Studies



Sediment rating curve for estimation of annual sediment yield (USACE, 2010)

Sediment Characterization

The dam removal and stream restoration is likely to have an effect on in-stream sediment, which is likely to be partially mobilized following dam removal. To assess the potential for downstream impacts from the mobilization of sediment, the Michigan Department of Environment, Great Lakes, and energy (EGLE) requires that sediments be tested for metals, volatile, and semi-volatile compounds of the sediment is composed of less than 90% sand.

GEI gathered six sediment samples to determine the sand composition in the impoundment behind the dam. The samples were taken to a depth of 2' and homogenized. Samples were analyzed in a GEI geotechnical laboratory using the loss by wash method (ASTM C 117), an accepted methodology for the determination of sand composition. The laboratory analysis determined that each of the six samples contains greater than 90% sand. Using EGLE guidelines, no additional chemical testing or characterization is required in this scenario. Laboratory reports are included in Appendix D.

Soil Disposal and Additional Testing

During project design meetings, the project team determined that potentially mobilized in-stream sediment should be excavated and placed in an upland location, even though EGLE may potentially allow some mobilized sediment to be released downstream following dam removal. A potential disposal location was located immediately adjacent to the project area on the property of Mr. John Wyns (Figure 4). Mr. Wyns was presented the results of the sand gradation, and offered the option to complete additional chemical testing of the sediments. Based on his knowledge of the watershed, Mr. Wyns indicated in email correspondence pm 7/24/2022 that he did not require additional testing of the sediments if they are to be disposed of on his property.

Due to the sand characterization and input from Mr. Wyns, the project team elected to forego additional chemical characterization of the sediments. This decision was affirmed by Kirsten Fischer of EGLE during a meeting on August 4, 2022.

2.8 MiSQT Assessments

The Michigan Stream Quantification Tool (MiSQT) is a tool that has been developed to quantify existing and proposed conditions in a given Michigan stream in order to assess the potential benefits or impacts of a stream project. The tool uses physical, chemical, and biological metrics to determine the potential "lift" of stream functions.

The MiSQT was used to assess existing hydrological and geomorphological parameters in the existing impacted reach of Stony Creek, upstream from the Marshville Dam. The full MiSQT is provided in Appendix E.

Based on field assessments of current conditions, the Large Woody Debris and Bed Form Diversity parameters are currently categorized as "Not Functioning" by the tool, while Riparian Vegetation is categorized as "Functioning at Risk". The remaining parameters are categorized as "Functioning". It is important to note that geomorphic pools are noticeably absent from the impacted reach of Stony Creek, but they are commonly missing in low gradient, sand bed stream in Michigan where large woody debris typically forms pools. Metrics are summarized in Table 7.

Functional Category	Function-Based Parameters	Existing Parameter
Hydrology	Reach Runoff	0.71
Hydraulics	Floodplain Connectivity	0.86
Geomorphology	Large Woody Debris	0.07
	Lateral Migration	0.98
	Riparian Vegetation	0.35
	Bed Form Diversity	0.25

Table 7. Existing Conditions MiSQT Parameters

Reference Reach

Upstream from Dam

Reference Reach

Upstream from Dam

Reference Reach

Upstream from Dam

Comparison of Large Woody Debris in Reference Reach and Upstream from Dam

3. Design Alternatives

3.1 Project-Level Design Approaches

Multiple design paths were evaluated using the data gathered during the field surveys. Each of these elements assume complete removal of the existing dam and replacement of the culverts beneath Marshville Dam Road with a clear span bridge. Therefore, the design approaches primarily include methods to create appropriate and stable stream grades after dam removal while also restoring and/or enhancing the habitat of Stony Creek upstream from the existing dam. Table 8 is intended to describe the project-level approaches to the dam removal and stream restoration.

Design Option	Pros	Cons	Preferred
Allow sediment to naturally move downstream	1) Least costly 2) Less site impacts due to less construction activity	1) Potential downstream impacts 2) Lack of improvement to upstream habitat	N
Actively manage sediment	1) Reduces potential for downstream impacts 2) Can create bedform diversity and desired stream grade	1) Cost 2) Requires off site disposal location 3) Site and creek impacts as a result of construction access and excavation	Y
Use rock riffle structures to match stream grades upstream and downstream of dam	1) Reduce sediment movement and management costs and impacts 2) Less overall short term impact to stream	1) Bedslope and reference reach do not indicate that rock riffles are natural in Stony Creek 2) May become fish passage barrier 3) May be covered in sand due to slow creek flows	N
Extend change in stream grade through ~1500-2500' reach of stream upstream from dam	1) Provides control over stream profile	1) More costly 2) More site and creek impacts as a result of construction access and excavation	Y
Relocate channel to historic channel	1) Restoration may be more effective if the historic channel is used	1) Channel could not be located with confidence with probing 2) More refined investigation to locate historic channel would be costly 3) Significant construction cost EGLE has concerns over impacts from creation of new channel	N
Relocate channel to new channel	1) Allows construction of a channel to an exact specification for planform, cross section, and profile	1) Significant construction cost EGLE has concerns over impacts from creation of new channel	N
Modify existing channel	1) Avoids potential regulatory concerns 2) Smaller short term impact to aquatic biota 3) Less costly	1) Does not create true "restoration" 2) May not have the same ecological benefit of relocating to the original channel	Y

Table 8. Project Level Approach Pros and Cons

3.2 Michigan Stream Quantification Tool (MiSQT)

Although dam removal is not a parameter included in the tool, EGLE has verbally indicated that dam removal is naturally considered a functional lift. Using this collective information, the greatest opportunities to increase the function of Stony Creek are the addition of wood, increase in bed form diversity, and the enhancement of riparian vegetation. The tool was used to evaluate various design scenarios to increase all stream parameters to "functioning" or "functioning at risk"

With these considerations in mind, the following targets are being set to raise the stream function to a minimum of "functioning at risk" for all evaluated parameters (Table 9).

Functional Category	Function-Based Parameters	Metric	Existing Metric	Proposed Metric
Hydrology	Reach Runoff	Land Use Change Coefficient	52.96	52.96
		Concentrated Flow Points (#/1000 LF)	1	1
Hydraulics	Floodplain Connectivity	Bank Height Ratio	1.2	1
		Entrenchment Ratio	5	>5
Geomorphology	Large Woody Debris	LWD Index	139	>600
	Lateral Migration	Dominant BEHI/NBS	L/L	VL/VL
		Percent Streambank Erosion (%)	5	<5
		Percent Streambank Armoring (%)	2	0
	Riparian Vegetation	Buffer Width (ft)	200+	200+
		Average DBH (Inches)	2	2[1]
		Tree Density (#/Ac)	1	>440
		Native Shrub/Sapling Density (#/Ac)	20	>440
		Native Herbaceous Cover (%)	90	90
	Bed Form Diversity[2]	Pool Spacing Ratio	10.5	10.5
		Pool Depth Ratio	1	1.3
		Percent Riffle (%)	70	70
		Aggradation Ratio		

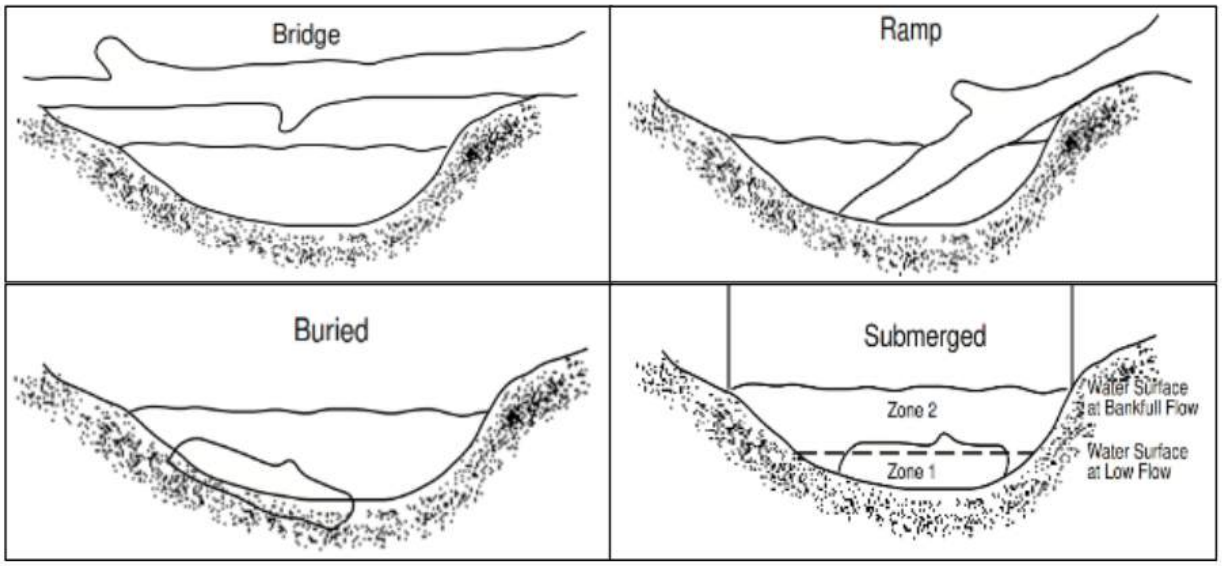
[1]Should budgets allow, larger trees may be installed along the streambed to accelerate the lift of the restoration

[2]Because bed form diversity is driven by both geomorphic and wood-based pools, the MiSQT metric for Stony Creek may not score accurately because Stony Creed is a low sinuosity, sand bed creek where bed form diversity is driven primarily by wood

Table 9. Existing and Proposed MiSQT Parameters

	Score				
	1	2	3	4	5
Pieces					
Length/Bankfull Width	0.0 to 0.4	0.4 to 0.6	0.6 to 0.8	0.8 to 1.0	> 1.0
Diameter (cm)	10 to 20	20 to 30	30 to 40	40 to 50	>50
Location	**Zone 4**		**Zone 3**	**Zone 2**	**Zone 1**
Type	Bridge		Ramp	Submersed	Buried
Structure	Plain	Plain/Int	Intermediate	Int/Sticky	Sticky
Stability	Moveable	Mov/Int	Intermediate	Int/Sec	Secured
Orientation (degrees)	0 to 20	20 to 40	40 to 60	60 to 80	80 to 90
Debris Dams					
Length (% of Bankfull Width)	0 to 20	20 to 40	40 to 60	60 to 80	80 to 100
Height (% of Bankfull Depth)	0 to 20	20 to 40	40 to 60	60 to 80	80 to 100
Structure	Coarse	Coarse/Int	Intermediate	Int/Fine	Fine
Location	Partially high flow	In high flow	Partially low flow	Mid low flow	In low flow
Stability	Moveable	Mov/Int	Intermediate	Int/Sec	Secured

Table10. LWD Index Scoring Criteria



LWD Types

3.3 Discussion and Design Recommendations

Based on the site surveys and discussions with project stakeholders, GEI proposes to remove the dam and restore the stream by modifying the existing channel by using a combination of wood and excavation. This concept is depicted in the conceptual drawings provided in Appendix F.

High densities of large woody debris were found throughout the reference reach having a significant impact on the morphology of the creek. The lack of gravel and cobble and the abundance of sand throughout the creek bed creates conditions that are highly mobile where the introduction of large woody debris can create a forced morphology that would not be expected under low woody debris loading (Montgomery, 1997). Installing wood in the impacted area will mimic these conditions and restore the creek morphology.

A summary of all site design parameters is provided below. These parameters have been preliminarily depicted in the attached conceptual design drawings and will be refined for 60% and 90% designs.

Site Level Approach

- Remove existing dam
- Install clear span bridge with footings at least 25% wider than bankfull
- Modify existing channel by adding wood, in channel excavation, floodplain excavation, and potential earth fill
- Place excavated soils on the adjacent property owned by John Wyns

Channel Morphology and Stream Considerations

- Excavate new thalweg between ~Sta 3+25 and 27+00 to change stream bedslope from 0.1% to 0.2% to account for ~3' change in elevation on the downstream end of the project that will results from the dam removal
- The new thalweg may be created by excavating a pilot channel that is+/- 10' and at the target depth,
- Selectively narrow channel in upstream reach to achieve a bankfull width averaging +/- 27. Exceptions may be made to accommodate existing in-channel wood
- As needed, excavate bankfull bench to a height and with that allows an entrenchment ration of at least 2.2 and a bank height ration of 1.1
- Use a combination of wood and bioengineering techniques to provide stability to the newly modified channel

Biological Considerations

- Add large woody debris to channel so that all upstream reaches achieves a LWD index score of at least 600. Wood should include all four types described in the LWD index (although "bridge" wood may be eliminated due to blockage concerns), and weighted toward those providing the best habitat
- Install native trees at least 1.5" DBH along the existing riverbank. Approximately 25-50% of the trees should be northern white cedar (*Thuja occidentalis*)
- Develop a custom seed mix based on the downstream reference reach
- Control invasive plant species

Social Considerations

- Install an ADA accessible ramp to allow access to the river from the parking lot
- Install up to 2 platforms not to exceed 10' x 15' near the river, at or just above the level of the floodplain
- Structures should be constructed of treated lumber to allow for easier maintenance by county staff

4. Regulatory Considerations

Two primary permits will be needed for the construction of the project:

1) Joint Permit Application from EGLE/US Army Corps of Engineers
2) Soil Erosion and Sediment Control Permit from the Oceana County Drain Commissioner

To initiate early project discussions, two pre-application meetings were held with staff from the Michigan Department of Environment, Great Lakes, and Energy (EGLE), and March 22, 2022 and August 4, 2022. Following the March meeting, EGLE provided a pre-application letter summarizing the discussion. Excerpts from that letter are provided below.

- Activities that, as currently designed, would require authorization under: Floodplain Regulatory Authority in Part 31, Water Resources Protection, of the NREPA.Section 404 of the federal Clean Water Act and/or the federal Rivers and Harbors Act from the United States Army Corps of Engineers.
- Possible alternative design options to minimize project effects on aquatic resources; specifically, alternative options to relocating 2,000 feet of Stony Creek. A robust feasible and prudent analysis will need to be provided clearly describing the proposed temporary and permanent impacts of the stream relocation as well as temporary and permanent impacts associated with the 'do nothing' approach and/or restoration of the current stream channel. Parts 301 and 303 require avoidance of regulated areas when possible, using alternative designs and locations to avoid and/or minimize impacts to resources. Permit application materials should demonstrate that impacts associated with these regulated activities and areas have been minimized to the greatest extent possible.
- If it is determined that the proposed project will impact one or more acres of regulated wetland, stream relocation of 500 feet or more, and/or result in reasonable potential for affecting federally threatened and/or endangered species or impact sites identified or proposed under the National Historic Preservation Act, the project will also be subject to federal review.
- Mitigation may be required for this project. To waive mitigation, proof of functional benefits of relocating stream and elimination/creation of wetland will be required, even if there is a net zero loss of resources.
- A monitoring plan may be required for the new stream channel and/or any wetlands created during the proposed project. Monitoring may need to be accompanied by financial assurance to guarantee compliance with permit conditions.
- In order to quantify impacts associated with the proposed project, a wetland delineation will be necessary to demarcate where the specific transition between upland and wetland occurs within the proposed project site. A wetland delineation may be conducted by EGLE's Wetland Identification Program (WIP) or a qualified wetland consultant in accordance with the United States Army Corps of Engineers Wetland Delineation Method. Please use the following link for

additional information: https://www.michigan.gov/deq/0,4561,7-135-3313_3687-24316--,00.html .

- The potential presence of state- or federally-listed threatened or endangered species on the site. We recommend review of the material available on the Michigan Department of Natural Resources' Web site at Michigan.gov/Threatened and Endangered Species.
- Potential floodplain effects. We recommend that you discuss this issue further with the WRD District Floodplain Engineer, Jacob Patin, who can be reached At PatinJ1@michigan.gov or 616-204-7176. A hydraulic analysis may be needed.
- While not mentioned during the Pre-App meeting, it is also important to note that sediment testing may be required depending on the scope of the project. More information about sediment testing may be found here - WRD-048 Sediment Testing for Dredging Projects (michigan.gov)

5. Opinion of Probable Cost

A table providing an opinion of probable cost is provided below. Costs may change based on final design decisions.

Task	Unit	Qty	Unit Cost	Total Cost
Construction Engineering	LS	1	$75,000	$75,000
Mobilization	LS	1	$25,000	$25,000
Erosion Controls (silt fence, turbidity curtain)	LS	1	$15,000	$15,000
Dam Removal	LS	1	$75,000	$75,000
Boardwalk/Platform Construction	LS	1	$90,000	$90,000
Access Construction	LS	1	$50,000	$50,000
Clearing and Grubbing	LS	1	$5,000	$5,000
Excavation (placed onsite or adjacent site)	CY	1,650	$20.00	$33,000
Coir log	LF	750	$25.00	$18,750
Woody Habitat Structures	EA	200	$250	$50,000
Erosion Control Blanket	SY	7,000	$2.50	$17,500
Native Seed	AC	10	$2,500	$25,000
Native Trees/Shrubs (Streambank)	EA	4,000	$8.00	$32,000
Native Trees (1.5" caliper)	EA	200	$450	$90,000
Site Restoration	LS	1	$20,000	$20,000
Invasive species control	AC	10	$2,500	$25,000
Floodplain reforestation plantings	EA	4,000	$10.00	$40,000
			Subtotal	$ 686,250
Total Estimate (w/20% contingency)			**Total Estimate**	**$ 745,500**

Table 11. Opinion of Probable Cost

6. References Cited

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe. 1979. Classification of Wetlands and Deepwater Habitats of the United States. U.S. Fish and Wildlife Service. FWS/OBS-79/31. Washington, DC.

Herman, K. D., L. A. Masters, M. R. Penskar, A. A. Reznicek, G. S. Wilhelm, W. W. Brodovich, and K. P. Gardiner. 2001. Floristic Quality Assessment with Wetland Categories and Examples of Computer Applications for the State of Michigan – Revised, 2nd Edition. Michigan Department of Natural Resources, Wildlife, Natural Heritage Program. Lansing, MI. 19 pp. + Appendices.

Montgomery, D. R., & Buffington, J. M. (1997). Channel-reach morphology in mountain drainage basins. Geological Society of America Bulletin, 109(5), 596-611.

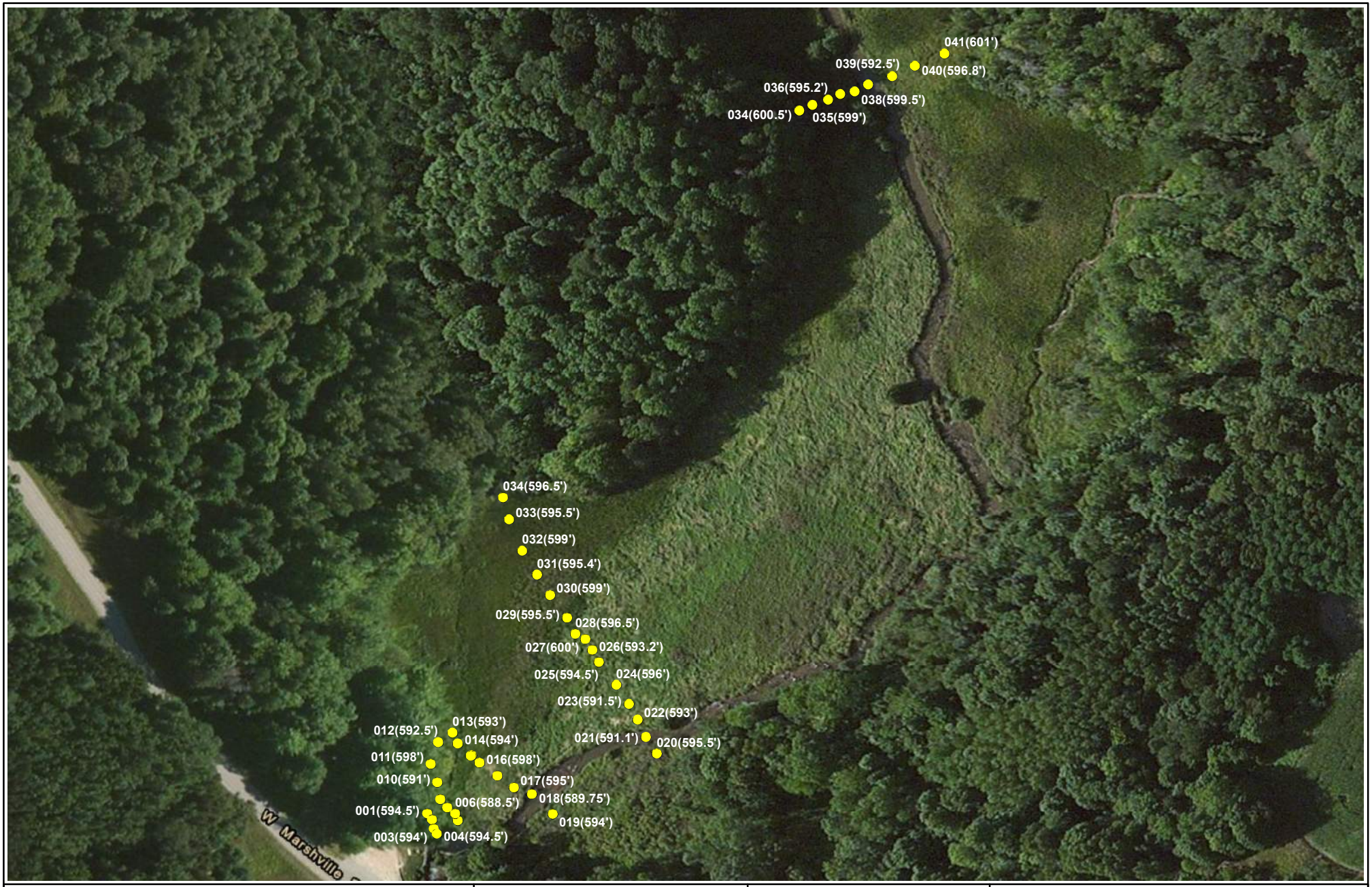
Tonello, M. 2021. Status of the Fishery Resource Report. Stony Creek. Michigan Dept. of Natural Resources. Report No. 2021-305

U.S. Department of Agriculture Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey. Available online at the following link: https://websoilsurvey.sc.egov.usda.gov/. Accessed 7/10/17.

United States Army Corps of Engineers. 1987. Wetlands Delineation Manual, Wetlands Research Program Technical Report Y-87-1. Washington, DC.

United States Army Corps of Engineers. 2011. Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Northcentral and Northeast Region (Version 2.0), ed. J.S. Wakely, R.W. Lichvar, C.V. Noble, and J.F. Berkowitz. ERDC/EL TR-12-1. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Figures



Stony Creek
Feasibility Study
Muskegon County, Michigan

West Michigan Shoreline
Regional Development Commission

0 80 160 240 Feet

1 inch = 160 feet

GEI Consultants

DEPTH TO REFUSAL SURVEY

Project: 2200272 Figure: 2

K:\WMSRDC\2200272_StonyCreek\GIS\MXD\Feasibility Study\Fig2_Depth_to_Refusal.mxd

August 2022

Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

EXISTING FEATURES LEGEND

- RIVER WATER SURFACE
- MAJOR CONTOUR
- MINOR CONTOUR
- TREELINE
- CULVERT
- EX. TREE

N

STONY CREEK

W. MARSHVILLE DAM ROAD

MARSHVILLE DAM

EX. BRIDGE

0 150' 300'

SCALE: 1" = 150'

Stony Creek Marshville Dam Road, Shelby, MI 49455	GEI Consultants	Stony Creek Overview
WMSRDC Muskegon, MI	Project 2200272	May 2022 Fig. 1

TRUITT, ASHLEY K:\WMSRDC\2200272_StonyCreek\CAD\Design\Working\20220524_Marshville Dam Overview.dwg - 5/26/2022

EXISTING FEATURES LEGEND

- RIVER WATER SURFACE
- MAJOR CONTOUR
- MINOR CONTOUR
- TREELINE
- EX. TREE

STONY CREEK

0+00 1+00 2+00 3+00 4+00 5+00 6+00 7+00 8+00 9+00

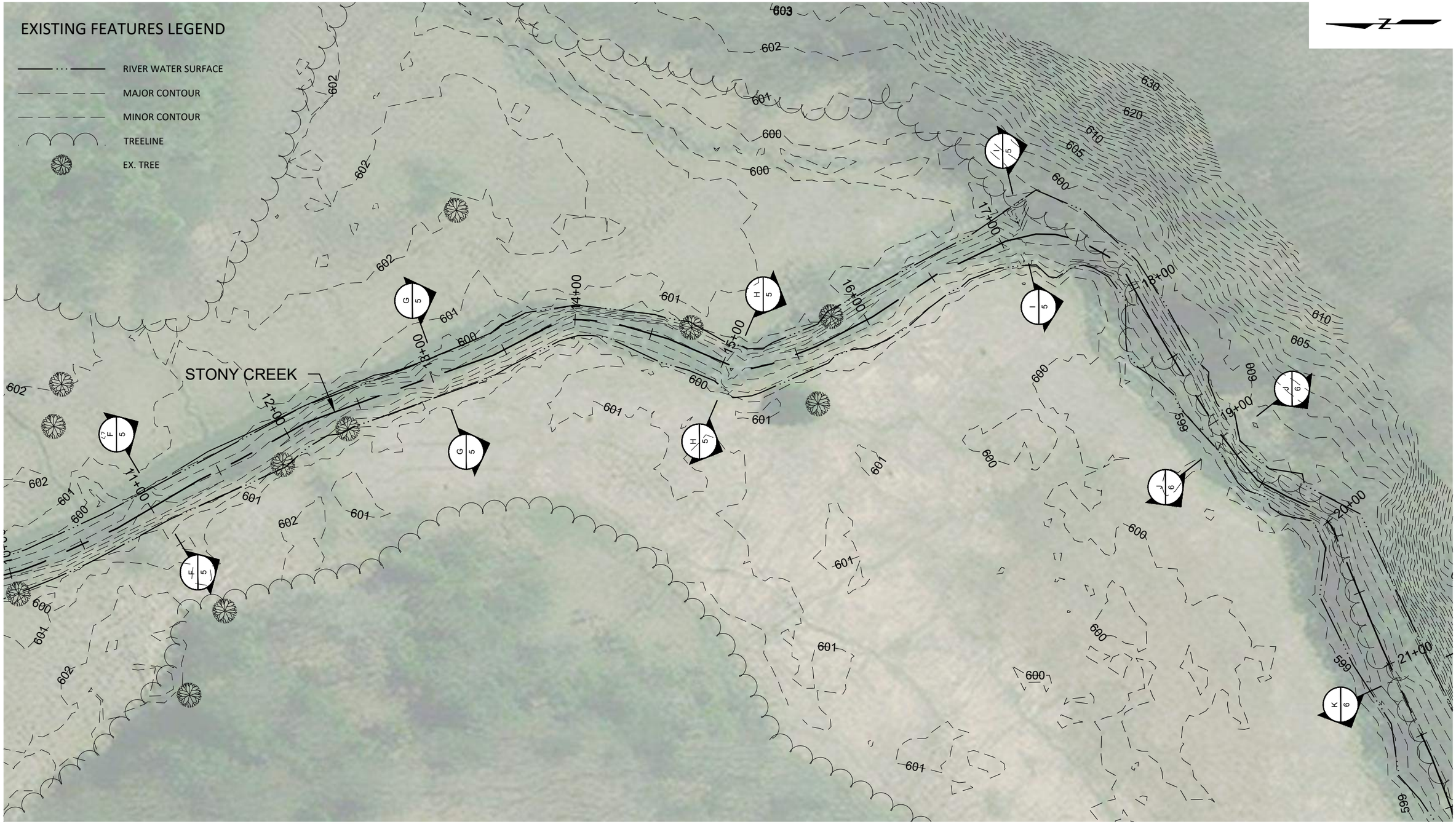
A 5 · B 5 · C 5 · D 5 · E 5

0 60 120

SCALE: 1" = 60'

Stony Creek Marshville Dam Road, Shelby, MI 49455	GEI Consultants	Stony Creek Existing Conditions 1 of 4
WMSRDC Muskegon, MI	Project 2200272	May 2022 Fig. 2

TRUITT, ASHLEY K:\WMSRDC\2200272_StonyCreek\CAD\Design\Working\20220524_MD Existing Conditions.dwg - 5/26/2022



0 60 120

SCALE: 1" = 60'

Stony Creek Marshville Dam Road, Shelby, MI 49455	GEI Consultants	Stony Creek Existing Conditions 2 of 4
WMSRDC Muskegon, MI	Project 2200272	May 2022 Fig. 3

TRUITT, ASHLEY K:\WMSRDC\2200272_StonyCreek\CAD\Design\Working\20220524_MD Existing Conditions.dwg - 5/26/2022

STONY CREEK

W. MARSHVILLE DAM ROAD

MARSHVILLE DAM

EX. BRIDGE

SEE INSET, FIG. 5

21+00

22+00

23+00

24+00

25+00

26+00

27+00

28+00

29+00

29+33

EXISTING FEATURES LEGEND

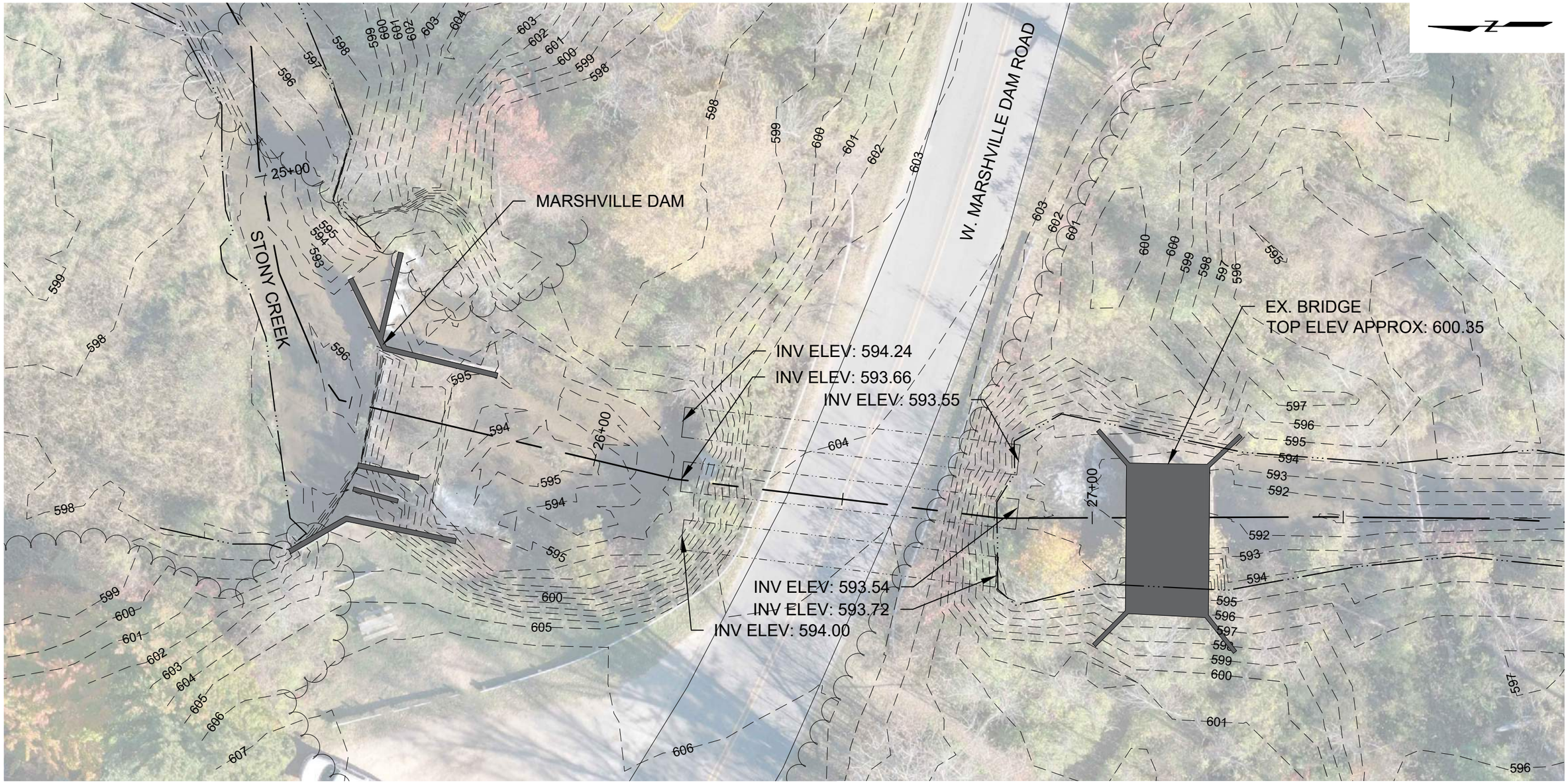
- RIVER WATER SURFACE
- MAJOR CONTOUR
- MINOR CONTOUR
- TREELINE
- CULVERT
- EX. TREE

0 60 120

SCALE: 1" = 60'

Stony Creek Marshville Dam Road, Shelby, MI 49455	GEI Consultants	Stony Creek Existing Conditions 3 of 4
WMSRDC Muskegon, MI	Project 2200272	May 2022 Fig. 4

TRUITT, ASHLEY K:\WMSRDC\2200272_StonyCreek\CAD\Design\Working\20220524_MD Existing Conditions.dwg - 5/26/2022



EXISTING FEATURES LEGEND

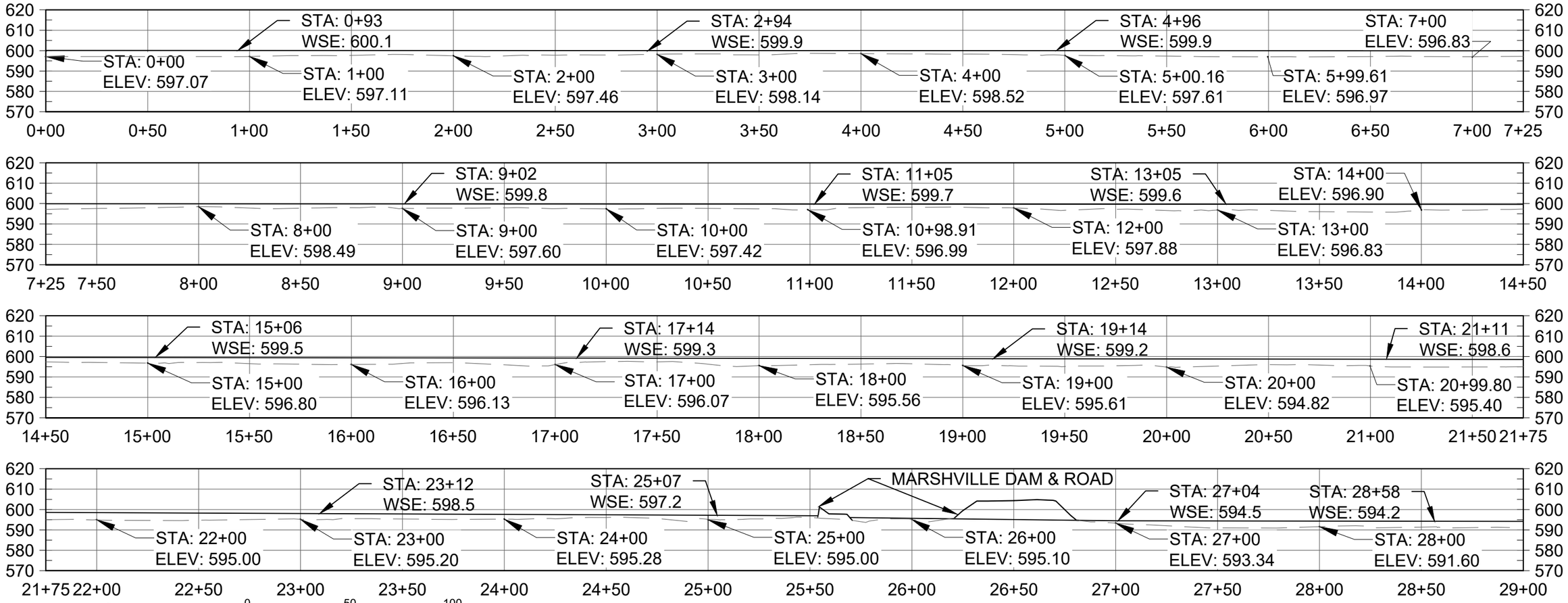
- RIVER WATER SURFACE
- MAJOR CONTOUR
- MINOR CONTOUR
- TREELINE
- CULVERT
- EX. TREE

0 20 40

SCALE: 1" = 20'

Stony Creek Marshville Dam Road, Shelby, MI 49455	GEI Consultants	Stony Creek Existing Conditions 4 of 4
WMSRDC Muskegon, MI	Project 2200272	May 2022 Fig. 5

TRUITT, ASHLEY K:\WMSRDC\2200272_StonyCreek\CAD\Design\Working\20220524_MD Existing Conditions Dam.dwg - 5/26/2022

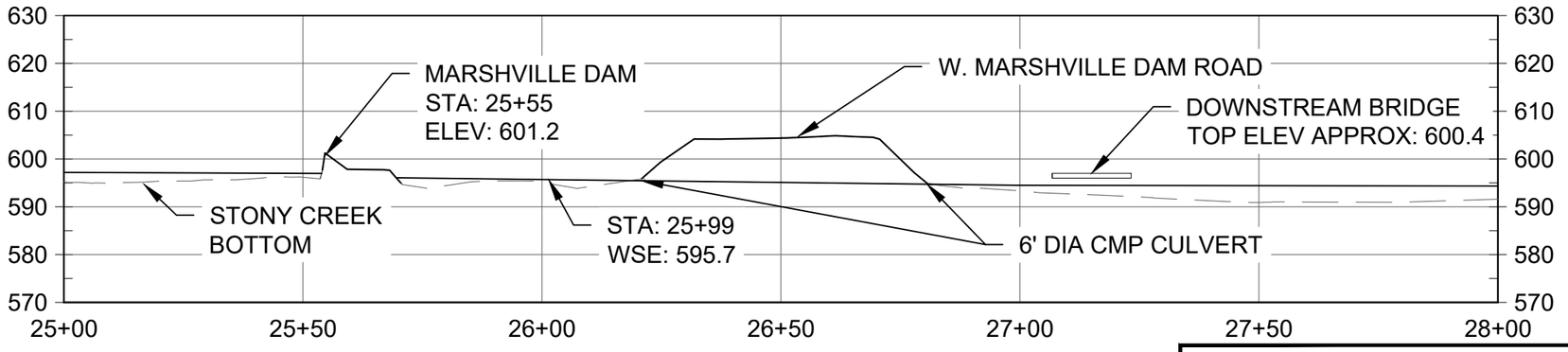


RIVER PROFILE

STA. 0+00 - STA. 29+00

0 50 100

SCALE, FEET



RIVER PROFILE

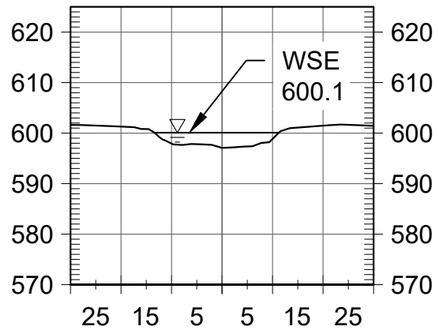
STA. 25+00 - STA. 28+00

0 30 60

SCALE, FEET

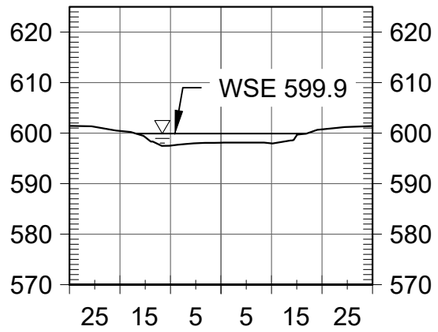
Stony Creek Marshville Dam Road, Shelby, MI 49455	GEI Consultants	Stony Creek Profile
WMSRDC Muskegon, MI	Project 2200272	May 2022 Fig. 6

TRUITT, ASHLEY K:\WMSRDC\2200272_StonyCreek\CAD\Design\Working\20220524_MD Profile.dwg - 5/26/2022



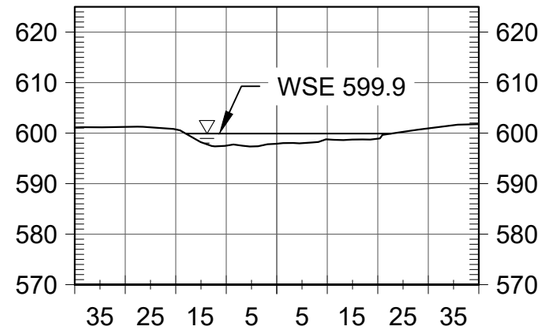
A/1 SECTION 0+93

SCALE: 1"=30'



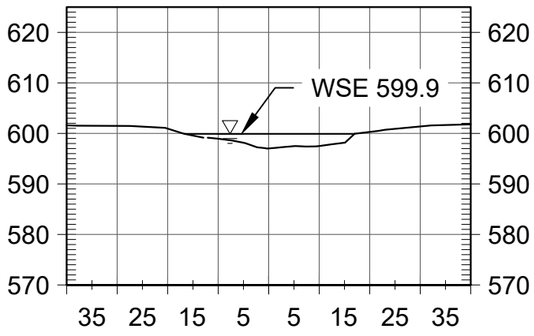
B/1 SECTION 2+94

SCALE: 1"=30'



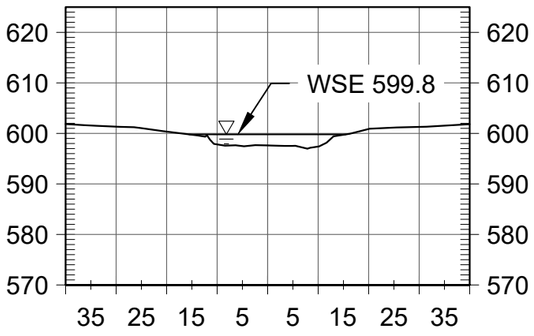
C/1 SECTION 4+96

SCALE: 1"=30'



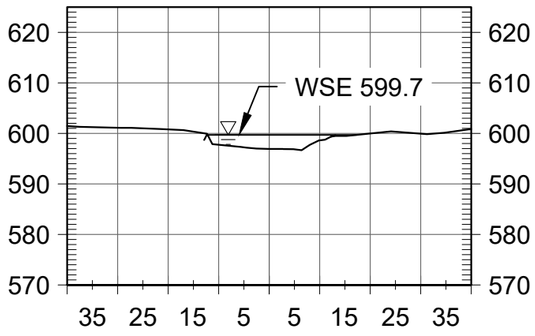
D/1 SECTION 7+02

SCALE: 1"=30'



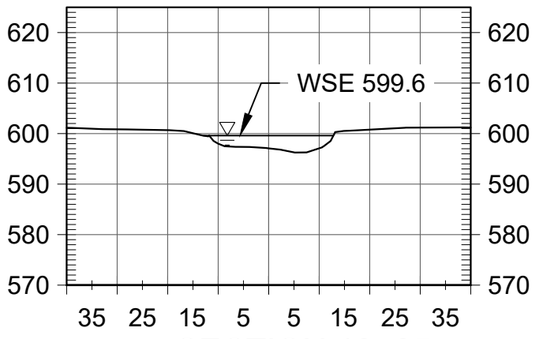
E/1 SECTION 9+02

SCALE: 1"=30'



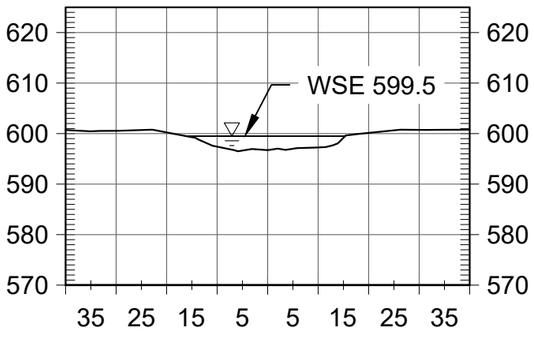
F/2 SECTION 11+05

SCALE: 1"=30'



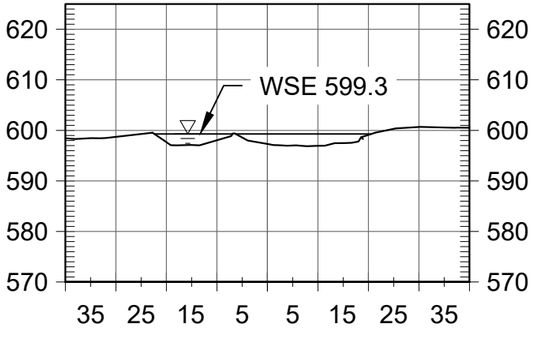
G/2 SECTION 13+05

SCALE: 1"=30'



H/2 SECTION 15+06

SCALE: 1"=30'

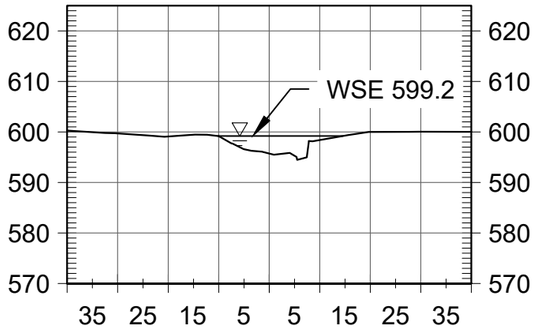


I/2 SECTION 17+14

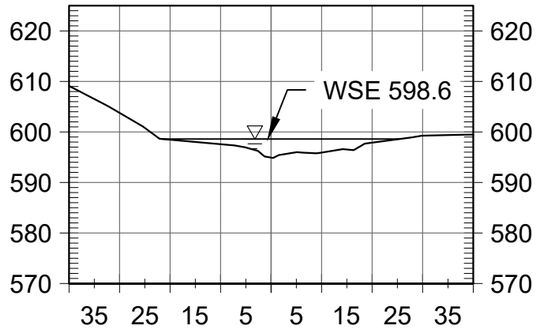
SCALE: 1"=30'

Stony Creek Marshville Dam Road, Shelby, MI 49455	GEI Consultants	Stony Creek Sections 1 of 2
WMSRDC Muskegon, MI	Project 2200272	May 2022 Fig. 7

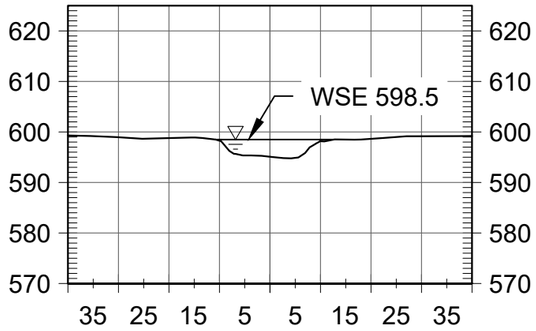
TRUITT, ASHLEY K:\WMSRDC\2200272_StonyCreek\CAD\Design\Working\20220524_MD Sections.dwg - 5/26/2022



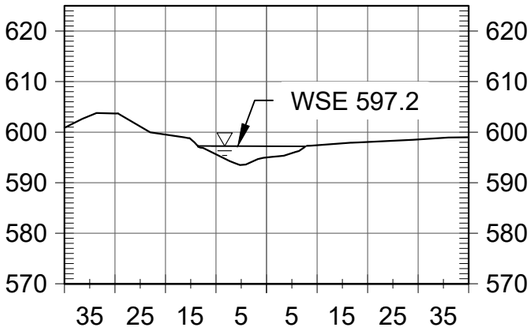
J/2 SECTION 19+14
SCALE: 1"=30'



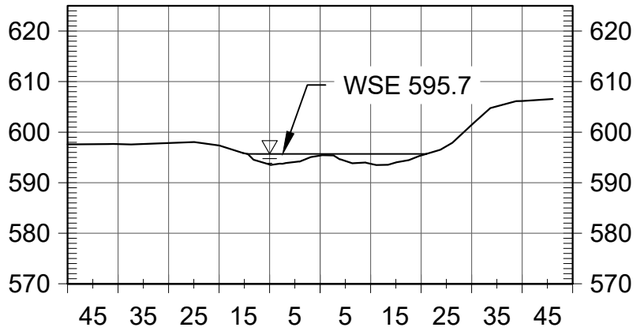
K/2 SECTION 21+11
SCALE: 1"=30'



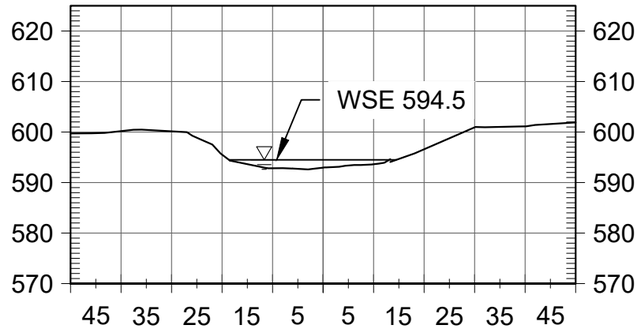
L/2 SECTION 23+12
SCALE: 1"=30'



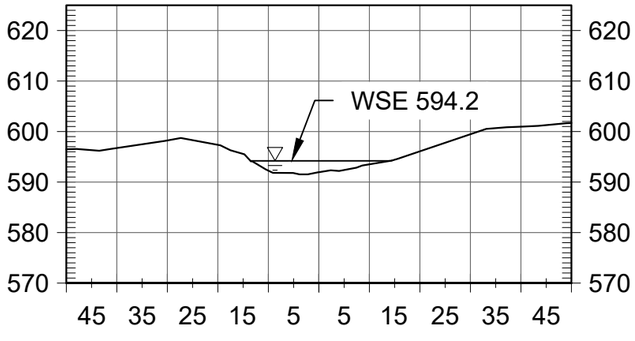
M/3 SECTION 25+07
SCALE: 1"=30'



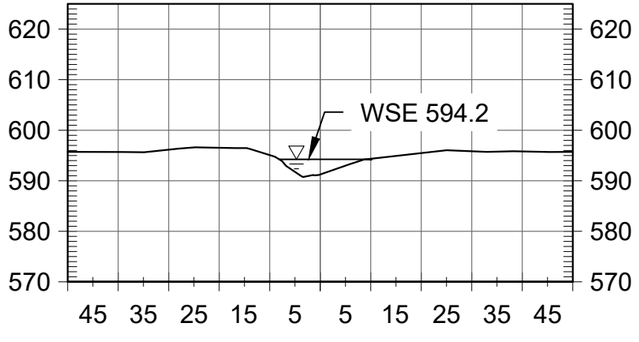
N/3 SECTION 25+99
SCALE: 1"=30'



O/3 SECTION 27+04
SCALE: 1"=30'



P/3 SECTION 27+28
SCALE: 1"=30'



Q/3 SECTION 28+58
SCALE: 1"=30'

Stony Creek Marshville Dam Road, Shelby, MI 49455	GEI Consultants	Stony Creek Sections 2 of 2
WMSRDC Muskegon, MI	Project 2200272	May 2022 Fig. 8

TRUITT, ASHLEY K:\WMSRDC\2200272_StonyCreek\CAD\Design\Working\20220524_MD Sections.dwg - 5/26/2022

Stony Creek
Feasibility Study
Muskegon County, Michigan

West Michigan Shoreline
Regional Development Commission

0 125 250 375 Feet

1 inch = 250 feet

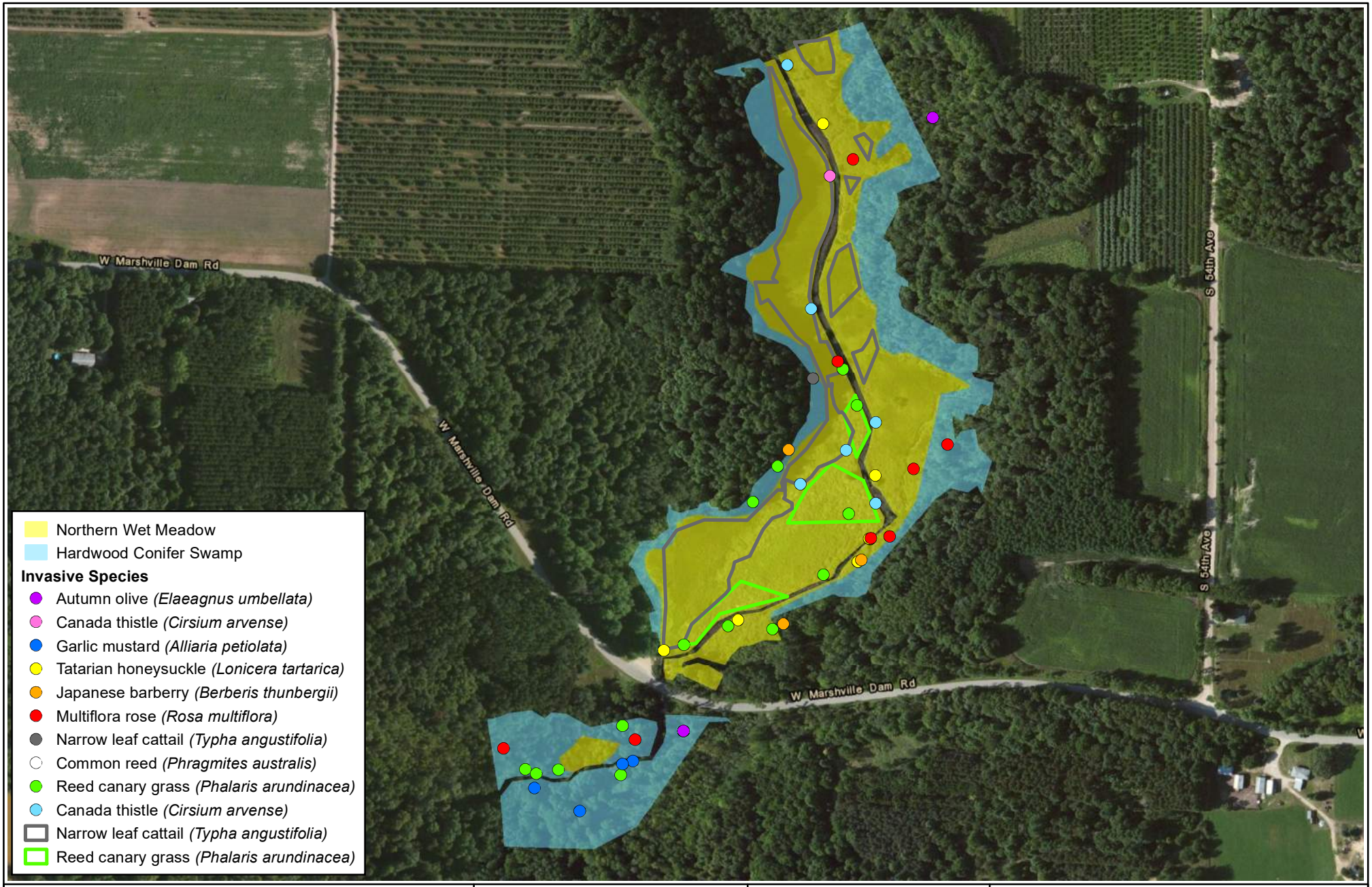
GEI Consultants

PROPOSED SOIL DISPOSAL LOCATION

Project: 2200272 Figure: 4

K:\WMSRDC\2200272_StonyCreek\GIS\MXD\220726_Fig4_Prop_Soil_Disposal.mxd
Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community, Esri, HERE, Garmin, (c) OpenStreetMap contributors

July 2022



Stony Creek
Feasibility Study
Muskegon County, Michigan

West Michigan Shoreline
Regional Development Commission

0 200 400 600 Feet

1 inch = 400 feet

GEI Consultants

WETLAND DELINEATION AND VEGETATION SURVEY

Project: 2200272 Figure: 5

K:\WMSRDC\2200272_StonyCreek\GIS\MXD\Feasibility Study\Fig5_Wetlands_Invasives.mxd

September 2022

Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Appendix A- FQA Analysis

Stony Creek - Assessment Area A

6/1/2022

Stony Creek
Benona Township
Oceana
Michigan
United States

FQA DB Region:	Michigan
FQA DB Publication Year:	2014
FQA DB Description:	Reznicek, A.A., M.R. Penskar, B.S. Walters, and B.S. Slaughter. 2014. Michigan Floristic Quality Assessment Datab
Practitioner:	Andrea Kantola
Latitude:	
Longitude:	
Weather Notes:	
Duration Notes:	
Community Type Notes:	
Other Notes:	
Private/Public:	Private

Conservatism-Based Metrics:		
Total Mean C:	2.8	
Native Mean C:	3.4	
Total FQI:	22.9	
Native FQI:	25.2	
Adjusted FQI:	30.8	
% C value 0:	23.9	
% C value 1-3:	34.3	
% C value 4-6:	38.8	
% C value 7-10:	3	
Native Tree Mean C:	3.5	
Native Shrub Mean C:	4	
Native Herbaceous Mean C:	3.3	

Species Richness:		
Total Species:	67	
Native Species:	55	82.10%
Non-native Species:	12	17.90%

Species Wetness:		
Mean Wetness:	-1.1	
Native Mean Wetness:	-1.5	

Physiognomy Metrics:		
Tree:	12	17.90%
Shrub:	8	11.90%
Vine:	3	4.50%
Forb:	34	50.70%
Grass:	2	3%
Sedge:	3	4.50%
Rush:	1	1.50%
Fern:	4	6%
Bryophyte:	0	0%

Duration Metrics:		
Annual:	6	9%
Perennial:	57	85.10%
Biennial:	4	6%
Native Annual:	5	7.50%
Native Perennial:	49	73.10%
Native Biennial:	1	1.50%

Species:

Scientific Name	Family	Acronym	Native?	C	W	Physiognor	Duration	Common Name
Acer rubrum	Sapindacea	ACERUB	native	1	0	tree	perennial	red maple
Acer saccharinum	Sapindacea	ACESAI	native	2	-3	tree	perennial	silver maple
Achillea millefolium	Asteraceae	ACHMIL	native	1	3	forb	perennial	yarrow
Alnus incana; a. rugosa	Betulaceae	ALNINC	native	5	-3	shrub	perennial	speckled alder
Anemone canadensis	Ranunculac	ANECAN	native	4	-3	forb	perennial	canada anemone
Arisaema triphyllum	Araceae	ARITRI	native	5	0	forb	perennial	jack-in-the-pulpit
Asclepias syriaca	Apocynace	ASCSYR	native	1	5	forb	perennial	common milkweed
Barbarea vulgaris	Brassicace	BARVUL	non-native	0	0	forb	biennial	yellow rocket

Berberis thunbergii	Berberidac	BERTHU	non-native	0	3	shrub	perennial	japanese barberry
Betula alleghaniensis	Betulaceae	BETALL	native	7	0	tree	perennial	yellow birch
Betula papyrifera	Betulaceae	BETPAP	native	2	3	tree	perennial	paper birch
Bidens cernua	Asteraceae	BIDCER	native	3	-5	forb	annual	nodding beggar-ticks
Caltha palustris	Ranunculac	CALPAR	native	6	-5	forb	perennial	marsh-marigold
Cardamine pensylvanica	Brassicace	CARPEN	native	1	-3	forb	biennial	pennsylvania bitter cress
Carex scabrata	Cyperaceae	CXSCAB	native	4	-5	sedge	perennial	sedge
Carex stricta	Cyperaceae	CXSTRI	native	4	-5	sedge	perennial	sedge
Circaea canadensis; c. lutetiana	Onagracea	CIRCAN	native	2	3	forb	perennial	enchanters-nightshade
Cirsium arvense	Asteraceae	CIRARV	non-native	0	3	forb	perennial	canada thistle
Cirsium vulgare	Asteraceae	CIRVUL	non-native	0	3	forb	biennial	bull thistle
Clematis virginiana	Ranunculac	CLEVIR	native	4	0	vine	perennial	virgins bower
Cornus sericea; c. stolonifera	Cornaceae	CORSER	native	2	-3	shrub	perennial	red-osier
Eleocharis obtusa	Cyperaceae	ELEOBT	native	3	-5	sedge	annual	spike-rush
Equisetum arvense	Equisetace	EQUARV	native	0	0	fern	perennial	common horsetail
Eupatorium perfoliatum	Asteraceae	EUPPER	native	4	-3	forb	perennial	boneset
Fagus grandifolia	Fagaceae	FAGGRA	native	6	3	tree	perennial	american beech
Fraxinus nigra	Oleaceae	FRANIG	native	6	-3	tree	perennial	black ash
Galium aparine	Rubiaceae	GALAPA	native	0	3	forb	annual	annual bedstraw
Galium boreale	Rubiaceae	GALBOR	native	3	0	forb	perennial	northern bedstraw
Geranium robertianum	Geraniacea	GERROB	native	3	3	forb	annual	herb robert
Glyceria striata	Poaceae	GLYSTR	native	4	-5	grass	perennial	fowl manna grass
Ilex verticillata	Aquifoliace	ILEVER	native	5	-3	shrub	perennial	michigan holly
Impatiens capensis	Balsaminac	IMPCAP	native	2	-3	forb	annual	spotted touch-me-not
Iris versicolor	Iridaceae	IRIVER	native	5	-5	forb	perennial	wild blue flag
Juncus effusus	Juncaceae	JUNEFF	native	3	-5	rush	perennial	soft-stemmed rush
Laportea canadensis	Urticaceae	LAPCAN	native	4	-3	forb	perennial	wood nettle
Lemna minor	Araceae	LEMMIN	native	5	-5	forb	perennial	common duckweed
Lonicera Ã—bella	Caprifoliac	LONBEL	non-native	0	3	shrub	perennial	hybrid honeysuckle
Matteuccia struthiopteris	Onocleace	MATSTR	native	3	0	fern	perennial	ostrich fern
Mentha spicata	Lamiaceae	MENSPI	non-native	0	-3	forb	perennial	spearmint
Osmunda cinnamomea	Osmundac	OSMCIN	native	5	-3	fern	perennial	cinnamon fern
Pastinaca sativa	Apiaceae	PASSAT	non-native	0	5	forb	biennial	wild parsnip
Phalaris arundinacea	Poaceae	PHAARU	native	0	-3	grass	perennial	reed canary grass
Populus tremuloides	Salicaceae	POPTRE	native	1	0	tree	perennial	quaking aspen
Prunus serotina	Rosaceae	PRUSER	native	2	3	tree	perennial	wild black cherry
Pteridium aquilinum	Dennstaed	PTEAQU	native	0	3	fern	perennial	bracken fern
Ranunculus hispidus	Ranunculac	RANHIS	native	5	0	forb	perennial	swamp buttercup
Rosa multiflora	Rosaceae	ROSMUL	non-native	0	3	shrub	perennial	multiflora rose
Rubus strigosus	Rosaceae	RUBSTR	native	2	0	shrub	perennial	wild red raspberry
Rumex obtusifolius	Polygonace	RUMOBT	non-native	0	0	forb	perennial	bitter dock
Sagittaria latifolia	Alismatace	SAGLAT	native	4	-5	forb	perennial	common arrowhead
Senecio vulgaris	Asteraceae	SENVUL	non-native	0	3	forb	annual	common groundsel
Sparganium eurycarpum	Typhaceae	SPAEUR	native	5	-5	forb	perennial	common bur-reed
Symplocarpus foetidus	Araceae	SYMFOE	native	6	-5	forb	perennial	skunk-cabbage
Thuja occidentalis	Cupressace	THUOCC	native	4	-3	tree	perennial	arbor vitae
Tilia americana	Malvaceae	TILAME	native	5	3	tree	perennial	basswood
Toxicodendron radicans	Anacardiac	TOXRAD	native	2	0	vine	perennial	poison-ivy
Toxicodendron vernix	Anacardiac	TOXVER	native	6	-5	shrub	perennial	poison sumac
Trientalis borealis	Myrsinacea	TRIBOR	native	5	0	forb	perennial	star-flower
Tsuga canadensis	Pinaceae	TSUCAN	native	5	3	tree	perennial	hemlock
Typha angustifolia	Typhaceae	TYPANG	non-native	0	-5	forb	perennial	narrow-leaved cat-tail
Typha latifolia	Typhaceae	TYPLAT	native	1	-5	forb	perennial	broad-leaved cat-tail
Typha Ã—glauca	Typhaceae	TYPGLA	non-native	0	-5	forb	perennial	hybrid cat-tail
Ulmus americana	Ulmaceae	ULMAME	native	1	-3	tree	perennial	american elm
Urtica dioica	Urticaceae	URTDIO	native	1	0	forb	perennial	stinging nettle
Verbena hastata	Verbenace	VERHAS	native	4	-3	forb	perennial	blue vervain
Veronica beccabunga var. americana	Plantagina	VERBEA	native	10	-5	forb	perennial	american brooklime
Vitis riparia	Vitaceae	VITRIP	native	3	0	vine	perennial	river-bank grape

Stony Creek - Assessment Area B

6/1/2022

Stony Creek
Benona Township
Oceana
Michigan
United States

FQA DB Region:	Michigan
FQA DB Publication Year:	2014
FQA DB Description:	Reznicek, A.A., M.R. Penskar, B.S. Walters, and B.S. Slaughter. 2014. Michigan Floristic Quality Assessment Databa
Practitioner:	Andrea Kantola
Latitude:	
Longitude:	
Weather Notes:	
Duration Notes:	
Community Type Notes:	
Other Notes:	
Private/Public:	Private

Conservatism-Based Metrics:		
Total Mean C:	3.4	
Native Mean C:	3.8	
Total FQI:	24.5	
Native FQI:	26.1	
Adjusted FQI:	36.1	
% C value 0:	17.3	
% C value 1-3:	28.8	
% C value 4-6:	48.1	
% C value 7-10:	5.8	
Native Tree Mean C:	3.7	
Native Shrub Mean C:	3.9	
Native Herbaceous Mean C:	3.8	

Species Richness:		
Total Species:	52	
Native Species:	47	90.40%
Non-native Species:	5	9.60%

Species Wetness:	
Mean Wetness:	-1.8
Native Mean Wetness:	-2

Physiognomy Metrics:		
Tree:	9	17.30%
Shrub:	8	15.40%
Vine:	4	7.70%
Forb:	23	44.20%
Grass:	1	1.90%
Sedge:	4	7.70%
Rush:	0	0%
Fern:	3	5.80%
Bryophyte:	0	0%

Duration Metrics:		
Annual:	5	9.60%
Perennial:	46	88.50%
Biennial:	1	1.90%
Native Annual:	5	9.60%
Native Perennial:	42	80.80%
Native Biennial:	0	0%

Species:

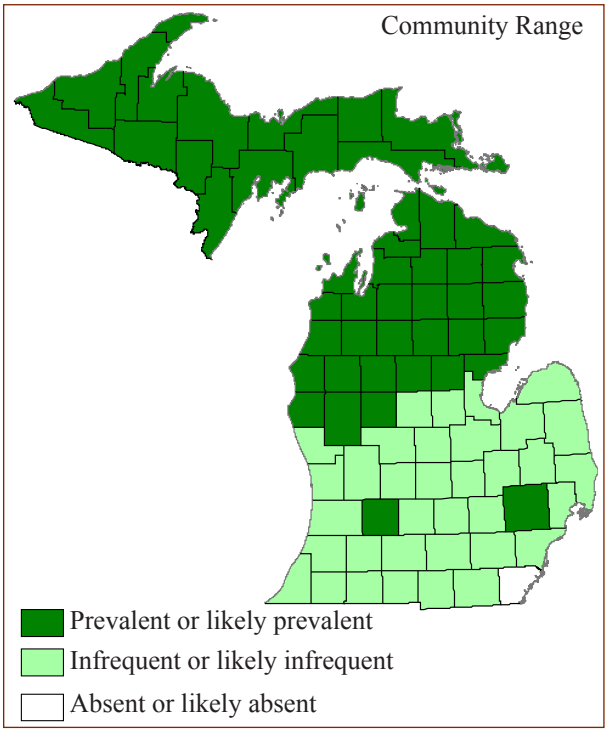
Scientific Name	Family	Acronym	Native?	C	W	Physiognor	Duration	Common Name
Acer rubrum	Sapindacea	ACERUB	native	1	0	tree	perennial	red maple
Acer saccharinum	Sapindacea	ACESAI	native	2	-3	tree	perennial	silver maple
Acer saccharum	Sapindacea	ACESAU	native	5	3	tree	perennial	sugar maple
Alliaria petiolata	Brassicace	ALLPET	non-native	0	3	forb	biennial	garlic mustard
Alnus incana; a. rugosa	Betulaceae	ALNINC	native	5	-3	shrub	perennial	speckled alder

Anemone canadensis	Ranunculac	ANECAN	native	4	-3	forb	perennial	canada anemone
Arisaema triphyllum	Araceae	ARITRI	native	5	0	forb	perennial	jack-in-the-pulpit
Betula alleghaniensis	Betulaceae	BETALL	native	7	0	tree	perennial	yellow birch
Bidens cernua	Asteraceae	BIDCER	native	3	-5	forb	annual	nodding beggar-ticks
Caltha palustris	Ranunculac	CALPAR	native	6	-5	forb	perennial	marsh-marigold
Carex canescens	Cyperaceae	CXCANE	native	8	-5	sedge	perennial	sedge
Carex intumescens	Cyperaceae	CXINTU	native	3	-3	sedge	perennial	sedge
Carex limosa	Cyperaceae	CXLIMO	native	10	-5	sedge	perennial	bog sedge
Carex stricta	Cyperaceae	CXSTRI	native	4	-5	sedge	perennial	sedge
Cicuta bulbifera	Apiaceae	CICBUL	native	5	-5	forb	perennial	water hemlock
Clematis virginiana	Ranunculac	CLEVIR	native	4	0	vine	perennial	virgins bower
Cornus sericea; c. stolonifera	Cornaceae	CORSER	native	2	-3	shrub	perennial	red-osier
Elaeagnus umbellata	Elaeagnace	ELAUMB	non-native	0	3	shrub	perennial	autumn-olive
Equisetum arvense	Equisetace	EQUARV	native	0	0	fern	perennial	common horsetail
Fraxinus nigra	Oleaceae	FRANIG	native	6	-3	tree	perennial	black ash
Galium aparine	Rubiaceae	GALAPA	native	0	3	forb	annual	annual bedstraw
Geranium robertianum	Geraniacea	GERROB	native	3	3	forb	annual	herb robert
Hesperis matronalis	Brassicace	HESMAT	non-native	0	3	forb	perennial	dames rocket
Ilex verticillata	Aquifoliace	ILEVER	native	5	-3	shrub	perennial	michigan holly
Impatiens capensis	Balsaminac	IMPCAP	native	2	-3	forb	annual	spotted touch-me-not
Iris versicolor	Iridaceae	IRIVER	native	5	-5	forb	perennial	wild blue flag
Laportea canadensis	Urticaceae	LAPCAN	native	4	-3	forb	perennial	wood nettle
Lemna minor	Araceae	LEMMIN	native	5	-5	forb	perennial	common duckweed
Menispermum canadense	Menisperm	MENCAE	native	5	0	vine	perennial	moonseed
Onoclea sensibilis	Onocleace	ONOSEN	native	2	-3	fern	perennial	sensitive fern
Osmunda cinnamomea	Osmundac	OSMCIN	native	5	-3	fern	perennial	cinnamon fern
Persicaria pensylvanica; polygonum p.	Polygonace	PERPEN	native	0	-3	forb	annual	bigseed smartweed
Phalaris arundinacea	Poaceae	PHAARU	native	0	-3	grass	perennial	reed canary grass
Polygonatum pubescens	Convallaria	POLPUB	native	5	5	forb	perennial	downy solomon seal
Prunus serotina	Rosaceae	PRUSER	native	2	3	tree	perennial	wild black cherry
Ranunculus hispidus	Ranunculac	RANHIS	native	5	0	forb	perennial	swamp buttercup
Ranunculus recurvatus	Ranunculac	RANREC	native	5	-3	forb	perennial	hooked crowfoot
Ribes triste	Grossularia	RIBTRI	native	6	-5	shrub	perennial	swamp red currant
Rubus strigosus	Rosaceae	RUBSTR	native	2	0	shrub	perennial	wild red raspberry
Rumex obtusifolius	Polygonace	RUMOBT	non-native	0	0	forb	perennial	bitter dock
Sagittaria latifolia	Alismatace	SAGLAT	native	4	-5	forb	perennial	common arrowhead
Salix exigua	Salicaceae	SALEXI	native	1	-3	shrub	perennial	sandbar willow
Sparganium eurycarpum	Typhaceae	SPAEUR	native	5	-5	forb	perennial	common bur-reed
Symplocarpus foetidus	Araceae	SYMFOE	native	6	-5	forb	perennial	skunk-cabbage
Thuja occidentalis	Cupressace	THUOCC	native	4	-3	tree	perennial	arbor vitae
Tilia americana	Malvaceae	TILAME	native	5	3	tree	perennial	basswood
Toxicodendron radicans	Anacardiac	TOXRAD	native	2	0	vine	perennial	poison-ivy
Toxicodendron vernix	Anacardiac	TOXVER	native	6	-5	shrub	perennial	poison sumac
Typha Ã—glauca	Typhaceae	TYPGLA	non-native	0	-5	forb	perennial	hybrid cat-tail
Ulmus americana	Ulmaceae	ULMAME	native	1	-3	tree	perennial	american elm
Urtica dioica	Urticaceae	URTDIO	native	1	0	forb	perennial	stinging nettle
Vitis riparia	Vitaceae	VITRIP	native	3	0	vine	perennial	river-bank grape

Appendix B- MNFI Hardwood Conifer Swamp Community Abstract

Hardwood-Conifer Swamp — Community Abstract

Photo by Joshua G. Cohen



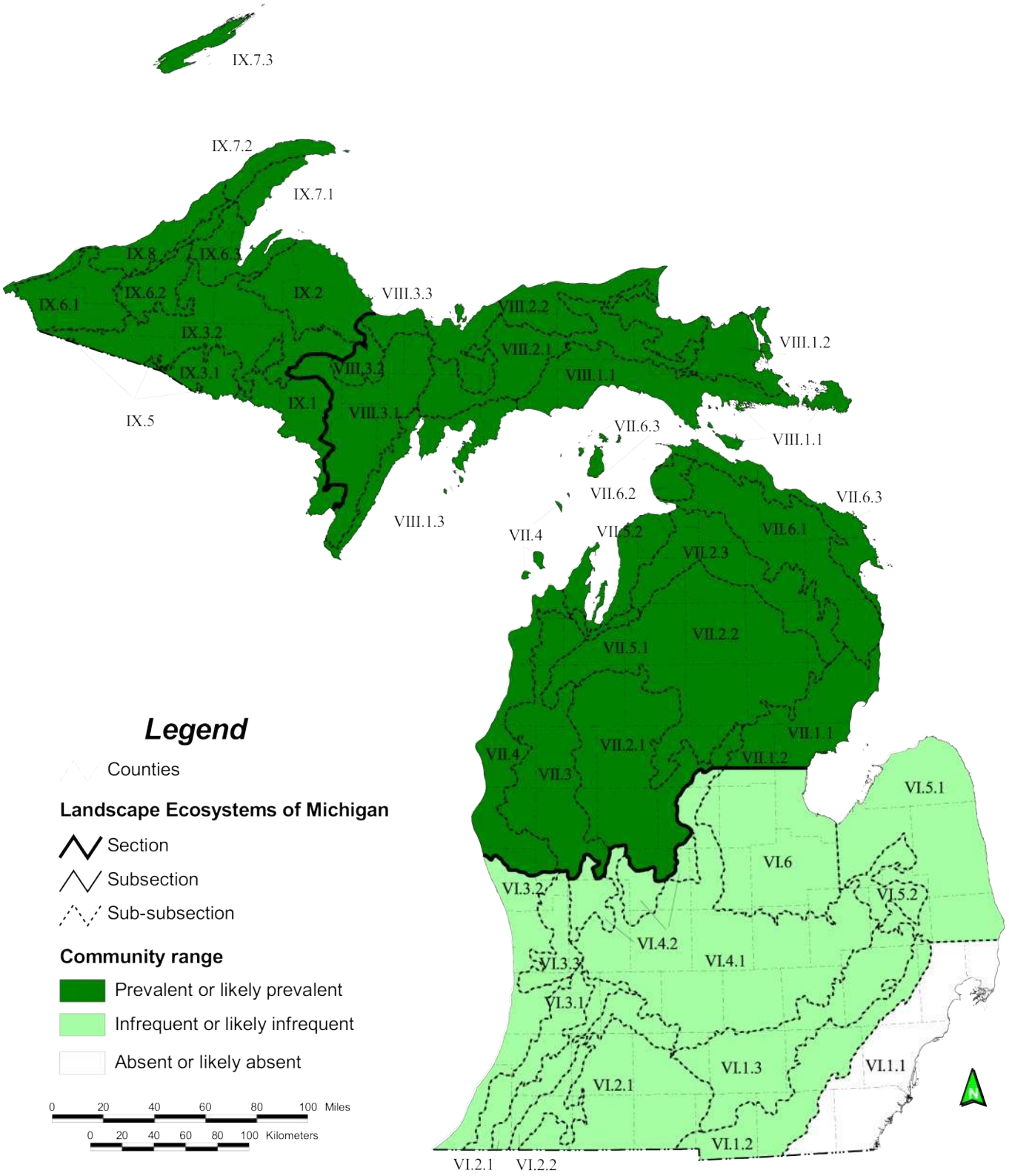
Overview: Hardwood-conifer swamp is a minerotrophic forested wetland dominated by a mixture of lowland hardwoods and conifers, occurring on organic soils and poorly drained mineral soils throughout Michigan. The community occurs on a variety of landforms, often associated with headwater streams and areas of groundwater discharge. Species composition and dominance patterns vary regionally. Windthrow and fluctuating water levels are the primary natural disturbances that structure hardwood-conifer swamp.

Global and State Rank: G4/S3

Range: Forested wetlands dominated by a mixture of hardwoods and conifers occur throughout the upper Great Lakes region, northeastern United States, and adjacent Canadian provinces (Faber-Langendoen 2001, NatureServe 2006). Species composition and dominance patterns vary across this range, which includes Minnesota, Wisconsin, Michigan, Ontario, Ohio, Pennsylvania, New Jersey, New York, Connecticut, Rhode Island, Massachusetts, Vermont, New Hampshire, Maine, New Brunswick, and Nova Scotia. In Michigan, hardwood-conifer swamp is widespread north of the climatic tension zone, with occurrences in southern Lower Michigan limited to areas within the regionally local ranges of white pine, hemlock, and northern white-cedar (Voss 1972, MNFI Biotics Database 2007).

Rank Justification: The acreage of hardwood-conifer swamp present in Michigan at the time of European settlement is difficult to determine. Analysis of General Land Office (GLO) survey notes in Michigan reveals that lowland forest dominated by a mixture of conifers and hardwoods covered approximately 290,000 acres (115,000 ha) circa 1800. Because the dominant trees in these mixed stands varied, only a fraction of this acreage likely represented hardwood-conifer swamp as it is currently defined (Kost et al. 2007). Hemlock- and white pine-dominated lowland forests, which are considered variants of hardwood-conifer swamp, covered an additional 60,000 ac (24,000 ha) and 5,000 ac (2,200 ha), respectively. The total acreage covered by mixed conifers and hardwood-, hemlock-, and white pine-dominated lowland forests (350,000 ac, or 140,000 ha) is a small fraction of the 5,600,000 ac (2,300,000 ha) covered by the broad category of conifer-dominated lowland forest circa 1800. The majority of conifer-dominated lowland forest was comprised of mixed conifers (3,000,000 ac, or 1,200,000 ha) and northern white-cedar (1,300,000 ac, or 510,000 ha), rather than the white pine, hemlock, and mixed conifer and hardwood stands characteristic of hardwood-conifer swamp. A small portion of acreage comprised of mixed

Michigan Natural Features Inventory
P.O. Box 30444 - Lansing, MI 48909-7944
Phone: 517-373-1552



Ecoregional map of Michigan (Albert 1995) depicting distribution of hardwood-conifer swamp (Albert et al. 2008)

conifers and northern white-cedar may have represented hardwood-conifer swamp, but most of this acreage likely represented other natural community types (e.g., rich conifer swamp). Historically, hardwood-conifer swamp covered less acreage than rich conifer swamp and other forested peatlands because it is typically confined to ecotones bordering uplands and more extensive wetland systems, or areas around headwater streams where groundwater seepage, rather than over-the-bank flooding, controls vegetative composition and structure.

MIRIS data (MIRIS 1978) indicated approximately 1,800,000 ac (700,000 ha) of lowland coniferous forest and about 2,300,000 ac (900,000 ha) of lowland deciduous forest occurred in Michigan as of the 1970s. The percentage of this acreage representing hardwood-conifer swamp is unknown. The current status of hardwood-conifer swamp is poorly understood because this system has not been systematically surveyed in Michigan. Currently, 30 occurrences of hardwood-conifer swamp are tracked in the MNFI statewide database, totaling over 7,000 ac (2,800 ha) (MNFI, Biotics Database 2007). Only 11 of these occurrences are estimated to be of excellent (A-rank) or good (B-rank) viability.

Following European settlement, hardwood-conifer swamp was significantly impacted by logging activities, including removal of mature seed trees, increased exposure and drying of soil, and slash fires. These disturbances resulted in a significant decline in lowland conifers, including northern white-cedar, white pine, and hemlock, throughout the region (Whitney 1987, Zhang et al. 2000, Leahy and Pregitzer 2003). In one 300,000 ac (120,000 ha) section of the Huron National Forest in northeastern Lower Michigan, for example, lowland conifers have declined to 26% of their former extent (Leahy and Pregitzer 2003). In southern Lower Michigan, where conifers characteristic of hardwood-conifer swamp were local or absent in upland communities, logging and removal of mature seed-producing trees likely eliminated seed sources and contributed to the conversion of hardwood-conifer swamp to southern hardwood swamp (Comer et al. 1995). In addition, because seedlings of conifers and yellow birch regenerate primarily on large-diameter rotting wood, such as well-decomposed logs and stumps, the removal of mature trees resulted in a reduction in suitable niches for seedling establishment (St. Hilaire and Leopold 1995, McGee 2001, Forrester et al. 2005). Following removal of conifers, shading and litterfall by hardwood species may have reduced diversity of ground layer vegetation and the suitability of the seedbed for conifer seedlings (Laidig and Zampanella 1999, Kost 2001a, 2001b). Current logging practices continue to degrade hardwood-conifer swamp throughout its range (MNFI Biotics Database 2007).

In addition to historic and recent logging pressures, acreage of hardwood-conifer swamp has been reduced by conversion of wetlands for agriculture and other human uses. Wetland acreage in Michigan is estimated to have been reduced by greater than 50% since the beginning of European settlement (Dahl 1990). The shallow organic or poorly drained mineral soils supporting hardwood-conifer swamp were easier to convert for agricultural purposes than the deep peats characteristic of rich conifer swamp and other forested peatlands, resulting in a significant reduction of hardwood-conifer swamp acreage following European settlement. Several tracked occurrences of hardwood-conifer swamp show evidence of hydrologic disturbance, including ditching and the conversion of adjacent uplands for agricultural or residential uses (MNFI Biotics Database 2007).

At the present time, excessive deer herbivory threatens the viability of hardwood-conifer swamp throughout its range. High white-tailed deer (*Odocoileus virginianus*) density is leading to considerable browse pressure on conifer seedlings and saplings throughout Michigan and the Great Lakes region (Frelich and Lorimer 1985, Mladenoff and Stearns 1993, Alverson and Waller 1997, Long et al. 1998, Rooney and Waller 1998, Rooney et al. 2002, Krueger and Peterson 2006). Deer browse also reduces frequency and cover of understory shrubs and herbs (Balgooyen and Waller 1995, Augustine and Frelich 1998, Rooney and Waller 2003, Kraft et al. 2004). The result of heavy deer browse is significant alteration of community structure consisting of impacts to all vegetative strata.

Physiographic Context: The Michigan range of hardwood-conifer swamp is statewide, falling within the following regions classified by Albert et al. (1986) and Albert (1995): Region I, Southern Lower Michigan (concentrated in the interlobate regions and near Lake Michigan), Region II, Northern Lower Michigan, Region III, Eastern Upper Michigan, and

Region IV, Western Upper Michigan. This broad area is characterized by a cool snow-forest climate with warm summers. The daily maximum temperature in July ranges from 24 to 29 °C (75 to 85 °F), the daily minimum temperature in January ranges from –21 to –9 °C (-5 to 15 °F) and the mean annual temperature is 7 °C (45 °F). The mean number of freeze-free days is between 90 and 160, and the average number of days per year with snow cover of 2.5 cm or more is between 80 and 140. The normal annual total precipitation ranges from 740 to 900 mm with a mean of 823 mm (Albert et al. 1986, Barnes 1991). The impacts of hardwood-conifer swamp on local climate are poorly known, but seasonal temperature fluctuations likely vary less in hardwood-conifer swamp relative to the surrounding landscape due to local moss cover and groundwater input (see Curtis 1959 for discussion). Moderation of climatic extremes is better understood for bog and fen peatlands with high moss cover (Heinselman 1963, McKenzie et al. 2007).

Hardwood-conifer swamp occurs on a variety of landforms, including poorly-drained outwash channels and outwash plains and depressions on medium- to coarse-textured end moraines, ground moraines, and glacial lakeplains (Kost et al. 2007). The community occupies sites influenced by groundwater seepage, usually where the water table is at or near the soil surface. Hardwood-conifer swamp occurs on gently sloping to flat topography along headwater streams or in association with relatively inactive portions of floodplains of low order streams, where it forms back swamps or occurs in meander scars (Tepley et al. 2004). Shallow kettle depressions and the margins of large forested and non-forested peatlands may also support hardwood-conifer swamp, but the community is absent from areas where significant peat accumulation isolates the rooting zone from contact with mineral-rich groundwater. Occurrences of hardwood-conifer swamp are typically narrow (<500 m, or 1,600 ft, wide), occupying outwash channels along streams and following slope contours. Large occurrences (to >250 ac, or 100 ha) are often associated with branched stream channels (MNFI Biotics Database 2007).

Hardwood-conifer swamp is bordered by a variety of natural community types. Adjacent uplands support either fire-prone systems, including oak barrens, oak openings (historically), dry-mesic southern forest, dry southern forest, dry-mesic northern forest, dry northern forest, and oak-pine barrens, or gap-phase systems, such as mesic southern forest and mesic northern forest. A variety of open to forested wetland communities may occur in adjacent lowlands, including southern wet meadow, northern wet meadow, prairie fen, northern fen, poor fen, bog, muskeg, interdunal wetland, southern shrub-carr, northern shrub thicket, southern hardwood swamp, northern hardwood swamp, rich tamarack swamp, and rich conifer swamp.

Photo by Bradford S. Slaughter

Hardwood-conifer swamp is often associated with headwater streams.

Substrate conditions are heterogeneous, and are often highly variable within a single stand. The most common condition is a thin layer of organic soil over a poorly drained mineral substrate. Organic soils are typically saturated, highly decomposed, sapric peat (i.e., muck) and frequently contain pieces of coarse wood throughout their profiles. Areas of deep (>1 m) organic deposits are common, especially in seeps. Substrate pH is also highly variable. Saturated mucks are typically of circumneutral pH, but may be acidic near the surface, especially where associated with sphagnum mosses or where coniferous needle mats accumulate. Mineral soils are often acidic. Vegetation (living and dead), depth to the water table, and groundwater movement all influence substrate alkalinity.

Natural Processes: The primary natural processes structuring hardwood-conifer swamp are small-scale windthrow and dynamics of surface water and groundwater. Patchy windthrow is the dominant natural

disturbance, creating small-scale canopy gaps (Forrester et al. 2005). Hardwood-conifer swamp often occurs on structurally weak organic soils where trees root shallowly due to anaerobic conditions and are thus particularly susceptible to windthrow. Accumulation of ice and snow in tree crowns increases the likelihood of windthrow or trunk snap, particularly for trees weakened by pests or fungal pathogens (Christensen et al. 1959). In addition to toppling and snapping trees, wind may also tip trees rooted in unstable organic soils, which produces the pit-and-mound microtopography characteristic of many forested systems (Christensen et al. 1959). Tipping is responsible for the occurrence of northern white-cedars with upward-curving boles.

Photo by Bradford S. Slaughter

Tipping associated with windthrow produces the pit-and-mound topography characteristic of hardwood-conifer swamp.

Those boles in contact with the substrate can produce vertically-growing branches that eventually form a straight line of stems, a process characteristic of cedar-dominated swamps (i.e., rich conifer swamp) called layering (Christensen et al. 1959). Plot data collected by the Minnesota Department of Natural Resources (2003) indicate curved trees are less common on firmer substrates, including mucky mineral soil or shallow peat over mineral soil, substrates that often support hardwood-conifer swamp in Michigan. Nevertheless, small-scale windthrow shapes the structure of hardwood-conifer swamp through the combined effects of tipping and snapping of its canopy trees, and this impact varies based on substrate characteristics and tree species composition.

The creation of canopy gaps and associated microtopographic heterogeneity has important consequences for the establishment and recruitment of canopy trees. Seedlings of several characteristic hardwood-conifer swamp canopy species (e.g., yellow birch, white pine, northern white-cedar, and hemlock) preferentially germinate and establish on root hummocks and/or decaying logs versus muck or litter-covered depressions (i.e., hollows) (Holcombe 1976, St. Hilaire and Leopold 1995, Rooney and Waller 1998, Allison and Ehrenfeld 1999, McGee 2001, Rooney et al. 2002). In comparison to hollows, hummocks and decaying logs have high moss cover, high moisture content, coarse substrate texture, and stable hydrology, characteristics which may favor the germination and establishment of small seeds with low nutrient reserves (Coffman 1978, St. Hilaire and Leopold 1995, McGee 2001). The degree to which hummocks differ from hollows varies depending on moss cover. Ehrenfeld (1995) found that sphagnum-covered hummocks had similar moisture content to hollows, possibly due to strong hydraulic conductivity within surficial sphagnum peat and the living mat itself. Litter-covered hummocks, in contrast, were significantly drier than hollows, and were prone to seasonal drought, leading to dessication and mortality of conifer seedlings. Studies in the Great Lakes region have illustrated a strong association of northern white-cedar and hemlock seedlings with rotting wood versus raised mounds, which may be due to differences in moss cover and the ability of rotting wood to remain moist during periods of drought (Rooney and Waller 1998, Rooney et al. 2002). Hardwood-conifer swamp tends to occur on shallow peats and mucks or poorly drained mineral soils, where conditions are not conducive to the development of a continuous moss layer, unlike the deep peats that support moss cover characteristic of rich conifer swamp (Kost 2002). Relatively low moss cover may be one factor that favors greater representation of large-seeded hardwoods in hardwood-conifer swamp versus moss-covered forested peatlands of northern white-cedar, tamarack, balsam fir, and black spruce.

Although hummocks and decaying logs are important sites for the germination and establishment of tree seedlings, these sites do not necessarily increase long-term tree survival (St. Hilaire and Leopold 1995, Rooney and Waller 1998, Rooney et al. 2002). Recruitment to the subcanopy and canopy is related to stand-scale factors, including the distribution

and size of canopy openings, and may require the establishment of mycorrhizal connections by seedlings (Rooney and Waller 1998, McGee 2001, Webster and Lorimer 2005). Canopy composition may exert a strong control on seedling recruitment. Shading and litterfall associated with hardwood-dominated canopies may reduce the suitability of the seedbed for conifer seedlings, and may reduce diversity of ground layer vegetation (Laidig and Zampanella 1999, Kost 2001a, 2001b, Simard et al. 2003). Accumulation of conifer needle litter also appears to negatively impact conifer regeneration (Simard et al. 2003). Ascertaining the relative impact of hardwood litter versus conifer litter on conifer regeneration requires additional study, but the greater surface area of hardwood leaves, in addition to complete annual turnover, suggests hardwood litter may have a more significant negative impact on conifer establishment. Despite the relatively narrow range of conditions suitable for conifer germination and establishment, replacement of wetland conifers by hardwoods may take centuries in the absence of large-scale disturbances (Zampanella et al. 1999).

The creation of canopy gaps and complex microtopography also has important impacts on ground layer diversity. Anderson and Leopold (2002) found that the degree of microtopographic variability and wetness beneath canopy gaps had more significant impacts than light variability on plant species richness. Wetland obligates (i.e., species that occur in wetlands with >99% probability) were concentrated in gaps (defined in their study as visible canopy openings), whereas hummock-dwelling species of broader ecological amplitude (i.e., species not restricted to wetlands) were concentrated in non-gaps. Paratley and Fahey (1986) noted a tendency for ground layer species to favor either mounds or depressions, and found that species richness was positively correlated with microtopographic variability, high base status (i.e., concentration of base cations, including calcium and magnesium), and magnitude of water table drawdown. The development of microsite preferences in ground layer herbs typical of hardwood-conifer swamp can be explained by the variation in substrate moisture and texture between mounds (including decaying wood) and depressions. In sum, the canopy gaps that result from windthrow promote high species diversity by increasing light availability, creating tip-up mounds, coarse woody debris, and hollows that increase microsite heterogeneity. Canopy gaps generate spatial variability in depth to the water table and seasonal periods of inundation, resulting in fine-scale spatial, seasonal, and temporal gradients in soil chemistry (Paratley and Fahey 1986, Anderson and Leopold 2002).

Photo by Bradford S. Slaughter

Windthrow is responsible for the patchy canopy characteristic of hardwood-conifer swamp. Increased light and soil moisture associated with gaps enhances plant species richness and diversity.

Although small-scale windthrow is the dominant natural process shaping hardwood-conifer swamp, stand-replacing windthrow is rare in conifer-dominated lowland forests. Estimates of return intervals range from 365 years in Minnesota to >1000 years in northern Lower Michigan (Whitney 1986, Minnesota Department of Natural Resources 2003).

Groundwater and surface water dynamics also shape hardwood-conifer swamp structure and impact succession. Significant hydrological processes impacting hardwood-conifer swamp include groundwater seepage, water table fluctuation, seasonal inundation, and flooding events. Groundwater seepage typically occurs at hydrologic breaks, such as where outwash channels bisect moraines (Amon et al. 2002). Seepages also occur away from slopes, where groundwater moves upward through breaches in otherwise impermeable deposits underlying the wetland (Amon et al. 2002). Groundwater seepages are often rich in calcium and magnesium carbonates and have high pH values, resulting from movement of groundwater through base-rich glacial deposits. In addition, water levels are more stable in groundwater seeps than in other wetland zones, in part due to the presence of most seeps at the bases of slopes that do not collect surface water (Amon et al. 2002, Bedford and

Godwin 2003). Several vascular and non-vascular plant species are concentrated in groundwater seepage zones, including many calciphiles, and add to the diversity of wetland systems (Amon et al. 2002, Bedford and Godwin 2003, Bowles et al. 2005). However, groundwater seepages and associated concentrations of calciphilic species are less characteristic of hardwood-conifer swamp than rich conifer swamp and fen communities (Faber-Langendoen 2001, Kost 2001a, 2001b, 2002, NatureServe 2006, Kost et al. 2007).

Water table fluctuation, including seasonal inundation, is characteristic outside the immediate vicinity of groundwater seepages in hardwood-conifer swamp (Paratley and Fahey 1998, Anderson and Leopold 2002). As noted above, water table fluctuation interacts with canopy gap size, such that mid- and large-sized gaps may flood quickly during rain events, presumably due to the lack of canopy to intercept precipitation and lack of transpiration by large trees (Anderson and Leopold 2002). These wet gaps create microheterogeneity within hardwood-conifer swamp that results in increased diversity of vascular plant species, including many species otherwise characteristic of open wetland types (Anderson and Leopold 2002).

Beaver flooding can also shape hardwood-conifer swamp structure and direct successional pathways. Natural community surveys in Newaygo and Luce Counties found both inactive and active beaver dams and associated flooding in several forested wetlands, including hardwood-conifer swamp (MNFI Biotics Database 2007, Slaughter et al. 2007). The areas that were inundated were typically closest to the stream or lake and lowest in elevation. Stands of dead northern white-cedar and/or tamarack were characteristic of inundated zones. Wetland margins and elevated areas within the wetlands dominated by white pine, hemlock, and hardwoods were less significantly impacted. Following beaver flooding, graminoid-dominated communities develop and sometimes persist for several decades, resisting conifer invasion (Terwilliger and Pastor 1999). In addition, the graminoid-covered substrate favors establishment of red maple, black ash, and alder (Allison and Ehrenfeld 1999), which may drive succession towards hardwood dominance or towards conversion to northern shrub thicket. The impacts of beaver on hardwood-conifer swamp succession require further study, but the primary forested communities affected by beaver dam construction are likely low-lying peatlands immediately adjacent to streams and lakes (e.g., rich conifer swamp and poor conifer swamp).

Photo by Bradford S. Slaughter

Beaver disturb hardwood-conifer swamp through dam-building activities that can flood low-lying tracts and promote shrubs and graminoids.

Changes in drainage patterns due to peat accumulation, growth of vegetation, erosion, or other disturbances can also drive succession and result in site heterogeneity, rather than uniform climax forest, over time (Paratley and Fahey 1986, Futyma and Miller 2001). The effects of watershed-scale hydrologic disturbances on forested wetlands are less well understood, and may be outweighed, at least over short time periods, by finer-scale disturbances affecting local hydrology (Laidig and Zampanella 1999).

Fire is another natural disturbance that shapes hardwood-conifer swamp. In northern Lower Michigan, Cleland et al. (2004) found historic fire rotations of 120 years for wetlands adjacent to fire-prone uplands (generally, oak- and upland conifer-dominated systems), and 684 years for wetlands adjacent to northern hardwoods. Wetlands in both landscapes were dominated by tamarack, hemlock, spruce, and balsam fir, but wetlands occurring in fire-prone landscapes had an increased proportion of fire-dependent species (e.g., pine, white birch, aspen, and oak) and very low proportions of fire-intolerant hardwoods (e.g., sugar maple, beech, elm, and basswood) (Cleland et al. 2004). Acreage of lowland hardwood-conifer cover in northern Lower Michigan at the present time is roughly split between the two fire regimes described by Cleland

et al. (2004). Despite the shorter fire return interval for forested wetlands adjacent to fire-prone uplands, broad-scale, stand-replacing fires appear to have been infrequent. For example, Whitney (1986) estimated a return interval of 3,000 years for destructive crown fires in conifer-dominated swamps in north-central Lower Michigan.

In the Great Lakes region, high densities of northern white-cedar and hemlock seedlings have been recorded on burned organic and mineral soils, often following slash fires (Curtis 1959, Rooney and Waller 1998, Rooney et al. 2002). In addition, the wind-borne samaras of red maple make it a successful invader of burned, open substrate (Allison and Ehrenfeld 1999). The relative contribution of fire to hardwood-conifer swamp structure and succession is unknown, but fire appears to provide suitable sites for the establishment of new cohorts of several canopy dominants, and may shape regional variation of structure and vegetative composition by selecting for fire-dependent canopy species and against fire-intolerant northern hardwoods and conifers (Cleland et al. 2004).

Vegetation Description: Hardwood-conifer swamp is a broadly defined natural community type, encompassing several regional, edaphic, and physiographic variants. Several vegetative associations are included within this type and are described below. In general, stands classified to this type contain at least 25% coniferous cover or basal area. Hardwoods range from dominant to uncommon or locally absent. Canopy, subcanopy, and ground layer density vary depending on species composition and local disturbance history. Throughout its range, hardwood-conifer swamp is characterized by high diversity, which can be attributed to its complex microtopography, spatially and temporally variable water table, and patchy canopy (Paratley and Fahey 1986, Vivian-Smith 1997, Anderson and Leopold 2002). The species listed below are derived from hardwood-conifer swamp occurrences tracked by MNFI (Biotics Database 2007), in addition to Curtis (1959), Brewer (1966), Voss (1972, 1985, 1996), Faber-Langendoen (2001), and NatureServe (2006). Although hardwood-conifer swamp occurs with greater frequency north of the climatic tension zone, the vegetation of occurrences south of the climatic tension zone is described first. Examples of hardwood-conifer swamp in southern Lower Michigan exhibit strong similarities in vegetative structure and composition due to the presence of only three characteristic conifers (white pine, northern white-cedar, and tamarack) in this region.

Southern Lower Michigan: In southern Lower Michigan, canopy dominance is often by red maple (*Acer rubrum*) and black ash (*Fraxinus nigra*), occasionally with high importance of yellow birch (*Betula alleghaniensis*) and white pine (*Pinus strobus*). Canopy associates include basswood (*Tilia americana*), northern white-cedar (*Thuja occidentalis*), tamarack (*Larix laricina*), and, locally, hemlock (*Tsuga canadensis*) and tulip-tree (*Liriodendron tulipifera*). Northern white-cedar often occurs in southern Lower Michigan as small patches within larger tamarack- or hardwood-dominated forested wetlands (Thompson 1953, Wenger 1975, Comer et al. 1995, Kost 2001a, Kost 2002, Slaughter and Skean 2003). Stands of significant size and of strong (>75%) northern white-cedar dominance are classified as a southern variant of rich conifer swamp (Kost 2002). Tree species typical of upland forests [e.g., red oak (*Quercus rubra*)] are sometimes present in the canopy, but are more commonly present as seedlings. American elm (*Ulmus americana*) was an important canopy tree prior to the introduction and spread of elm blight, but is now primarily an understory species, where it associates with saplings of the canopy species (Barnes 1976).

The tall shrub layer is characterized by blue-beech (*Carpinus caroliniana*), spicebush (*Lindera benzoin*), juneberries (*Amelanchier* spp.), red-osier dogwood (*Cornus stolonifera*), gray dogwood (*C. foemina*), silky dogwood (*C. amomum*), smooth highbush blueberry (*Vaccinium corymbosum*), poison sumac (*Toxicodendron vernix*), hazelnut (*Corylus americana*), Michigan holly (*Ilex verticillata*), red-berried elder (*Sambucus racemosa*), elderberry (*S. canadensis*), nannyberry (*Viburnum lentago*), wild-raisin (*V. cassinoides*), prickly-ash (*Zanthoxylum americanum*), witch-hazel (*Hamamelis virginiana*), Bebb's willow (*Salix bebbiana*), hoary willow (*S. candida*), pussy willow (*S. discolor*), slender willow (*S. petiolaris*), and autumn willow (*S. serissima*). Canada yew (*Taxus canadensis*) was once an important component of the hardwood-conifer swamp understory, but its populations have been significantly reduced and locally extirpated through deer browsing. Low shrubs include alder-leaved buckthorn (*Rhamnus alnifolia*), Canada fly honeysuckle (*Lonicera canadensis*), wild black currant (*Ribes americanum*), prickly gooseberry (*R. cynosbati*), and swamp gooseberry (*R. hirtellum*).

The ground layer, which is dense in light gaps and sparse under the shade of conifers, is characterized by the development of moss and litter-covered hummocks, interspersed with areas of level, saturated or inundated depressions. Characteristic species of hummocks and decomposing wood include wild sarsaparilla (*Aralia nudicaulis*), lady fern (*Athyrium filix-femina*), long-awned wood grass (*Brachyelytrum erectum*), goldthread (*Coptis trifolia*), crested woodfern (*Dryopteris cristata*), intermediate woodfern (*D. intermedia*), Canada mayflower (*Maianthemum canadense*), partridge berry (*Mitchella repens*), bishop's-cap (*Mitella diphylla*), naked miterwort (*Mitella nuda*), and starflower (*Trientalis borealis*). Typical species of depressions include jack-in-the-pulpit (*Arisaema triphyllum*), side-flowering aster (*Aster lateriflorus*), beggar-ticks (*Bidens* spp.), marsh marigold (*Caltha palustris*), wood reedgrass (*Cinna arundinacea*), small enchanter's-nightshade (*Circaea alpina*), honewort (*Cryptotaenia canadensis*), water horsetail (*Equisetum fluviatile*), common horsetail (*E. hyemale*), woodland horsetail (*E. sylvaticum*), purple avens (*Geum rivale*), fowl manna grass (*Glyceria striata*), spotted touch-me-not (*Impatiens capensis*), northern bugleweed (*Lycopus uniflorus*), sensitive fern (*Onoclea sensibilis*), cinnamon fern (*Osmunda cinnamomea*), royal fern (*O. regalis*), dwarf raspberry (*Rubus pubescens*), golden ragwort (*Senecio aureus*), rough goldenrod (*Solidago rugosa*), and skunk-cabbage (*Symplocarpus foetidus*), the last species a frequent ground layer dominant. Sedges are well-represented in hardwood-conifer swamp, including *Carex bromoides*, *C. crinita*, *C. disperma*, *C. gracillima*, *C. hystericina*, *C. intumescens*, *C. lacustris*, *C. lupulina*, and *C. stricta*. Species richness is generally higher in canopy gaps, where higher water tables support many wetland obligates that are absent or rare in non-gaps (Paratley and Fahey 1986, Anderson and Leopold 2002). Large canopy gaps support species typical of open wetlands and may be grass- or sedge-dominated. Species typical of large canopy gaps include swamp milkweed (*Asclepias incarnata*), bluejoint grass (*Calamagrostis canadensis*), sedges, turtlehead (*Chelone glabra*), swamp thistle (*Cirsium muticum*), joe-pye-weed (*Eupatorium maculatum*), boneset (*E. perfoliatum*), cut grass (*Leersia oryzoides*), white grass (*L. virginica*), arrow-leaved tear-thumb (*Polygonum sagittatum*), mad-dog skullcap (*Scutellaria lateriflora*), common skullcap (*S. galericulata*), common water horehound (*Lycopus americanus*), and broad-leaved cat-tail (*Typha latifolia*). Twining herbs and woody vines are also a common feature of canopy gaps, represented most commonly by hog peanut (*Amphicarpaea bracteata*), groundnut (*Apios americana*), poison-ivy (*Toxicodendron radicans*), Virginia creeper (*Parthenocissus quinquefolia*), and riverbank grape (*Vitis riparia*).

Northern Lower Michigan and Upper Peninsula: In and north of the climatic tension zone, conifers increase in importance relative to hardwoods. Hemlock, which occurs in monodominant stands or in association with yellow birch, red maple, and white pine, locally dominates shallow, poorly-drained depressions and peatland margins (Barrett et al. 1995, Comer et al. 1995, MNFI Biotics Database 2007). These sites are often referred to as hemlock or hemlock-hardwood swamps (NatureServe 2006), and are widespread in the northeastern United States and adjacent Canadian provinces. In Michigan, this type is most common in the western Upper Peninsula, where hemlock and yellow birch occur on moderately- to poorly-drained till plain, on outwash, and on lake margins in close association with upland sugar maple-hemlock forests (Frelich et al. 1993, Comer et al. 1995). In addition to hemlock, other common canopy constituents in northern Michigan hardwood-conifer swamps include balsam fir (*Abies balsamea*), black ash, northern white-cedar, tamarack, and black spruce (*Picea mariana*), with the latter two species occurring primarily on the wettest substrates.

Photo by Bradford S. Slaughter

Rotting, moss-covered wood provides a suitable substrate for conifer seedlings and a variety of ferns and forbs.

Paper birch (*Betula papyrifera*), quaking aspen (*Populus tremuloides*), and balsam poplar (*Populus balsamifera*) can be common canopy and subcanopy species, especially in stands with recent disturbance history (Braun 1950). In addition, white spruce (*Picea glauca*) is occasionally present as scattered overstory individuals. In general, stands in northern Michigan have greater presence of boreal conifers and hardwoods than stands in southern Lower Michigan, but the majority of species are common to both regions. Continued inventory and research is necessary to identify additional variants.

Photo by Bradford S. Slaughter

Yellow birch (left) and hemlock (right) are characteristic trees, often found in close association.

Common small tree and shrub species in addition to those found in southern Lower Michigan include mountain maple (*Acer spicatum*), striped maple (*A. pensylvanicum*), blueberry (*Vaccinium angustifolium*), swamp red currant (*Ribes triste*), and Labrador-tea (*Ledum groenlandicum*). Smooth highbush blueberry and spicebush are generally absent, except in the tension zone. Tag alder (*Alnus rugosa*) often forms dense colonies at the lowland margin of hardwood-conifer swamps, as along streams, and also occupies canopy gaps within forested wetlands. Small individuals of canopy species are prevalent in the understory.

Northern white-cedar and hemlock are characteristic in the understories of sites with low deer densities, including areas characterized by high snowfall, and where large-diameter coarse woody debris provides ample microsites for seedling establishment.

The ground layer includes many of the same species found in southern Lower Michigan. Species occurring with greater frequency in northern Michigan include bluebead lily (*Clintonia borealis*), bunchberry (*Cornus canadensis*), oak fern (*Gymnocarpium dryopteris*), Indian cucumber root (*Medeola virginiana*), gaywings (*Polygala paucifolia*), large-leaved shinleaf (*Pyrola elliptica*), interrupted fern (*Osmunda claytoniana*), creeping snowberry (*Gaultheria hispidula*), twinflower (*Linnaea borealis*), and northern wood-sorrel (*Oxalis acetosella*). Golden saxifrage (*Chrysosplenium americanum*) is locally common on exposed muck. Skunk-cabbage is sporadic north of the tension zone, whereas it frequently dominates the ground layer in southern Lower Michigan (Voss 1972, MNFI Biotics Database 2007).

The bryophyte community of hardwood-conifer swamps is poorly understood. Holcombe (1976) documented 72 species in a northern Michigan rich conifer swamp (cedar swamp), including 50 mosses and 22 liverworts. Mat-forming mosses, including *Heterophyllium haldanianum* and *Pleurozium schreberi*, dominated decomposing logs. Sphagnum mosses are also occasional dominants in rich conifer swamp (Kost 2002). The presence of pronounced hummock-hollow development, in which hollows are often inundated, concentrates moss development in hardwood-conifer swamp to the hummocks, and a continuous moss layer is generally not characteristic of these systems (NatureServe 2006).

Noteworthy Animal Species: Through flooding and herbivory, beaver can cause tree mortality and the conversion of hardwood-conifer swamp to open wetlands such as shallow ponds, emergent marsh, wet meadows, or fens. Insect outbreaks and plant parasites can set back or kill conifers, altering community composition and structure. Pests of potentially significant impact include the hemlock woolly adelgid (*Adelges tsugae*), which has the potential to cause hemlock mortality if it establishes in Michigan, and the emerald ash borer (*Agrilus planipennis*), which has already decimated the ash population in southeastern

Michigan (Haack et al. 2002, McCullough and Roberts 2002, MacFarlane and Meyer 2005). Other insects affecting conifers include larch sawfly (*Pristophora erichsonii*) and larch casebearer (*Coleophora laricella*), which can repeatedly defoliate and kill tamarack, and spruce budworm (*Choristoneura fumiferana*), which defoliates black spruce and balsam fir. Because tamarack, black spruce, and balsam fir are rarely dominant trees in hardwood-conifer swamp, impacts of the latter three insects on this natural community type are generally modest.

Conservation and Biodiversity Management: Conservation and management of hardwood-conifer swamp should focus on the following key areas: preservation of the coarse woody debris resource, protection of mature seed-bearing trees, maintenance of canopy gap structure, protection of groundwater and surface water hydrology, reduction of deer browse pressure, and control and monitoring of invasive species, including plants, animals, and pathogens.

Regeneration of hardwood-conifer swamp canopy trees, particularly of conifers, relies on the presence of suitable sites for germination and establishment within the stand. Management should focus on protecting large-diameter decaying logs and hummocks that are favored germination sites for yellow birch, white pine, northern white-cedar, and hemlock (Holcombe 1976, St. Hiliare and Leopold 1995, Rooney and Waller 1998, Allison and Ehrenfeld 1999, McGee 2001, Rooney et al. 2002). Maintaining mature, senescent, and dead canopy trees within hardwood-conifer swamp stands ensures a continuing source of the large-diameter coarse woody debris important for seedling germination and survival. In addition to providing suitable germination sites for tree seedlings, coarse woody debris and snags create microtopographic variability on the forest floor that is associated with high species richness and diversity (Paratley and Fahey 1986, Anderson and Leopold 2002). Removal of coarse woody debris or senesced trees from hardwood-conifer swamps should be avoided to ensure the continued viability of the system.

Protection of mature, seed-bearing trees is necessary for the continued viability of hardwood-conifer swamp occurrences. Historic logging activities significantly reduced the acreage of lowland and upland conifers throughout Michigan, through direct mortality and reduction of regeneration capacity (Whitney 1987, Zhang et al. 2000, Leahy and Pregitzer 2003). Where conifers are absent in the uplands, removal of mature seed-bearing conifers occurring in the wetlands can convert the affected stands to hardwood-dominated systems (e.g., southern hardwood swamp). Mature, seed-bearing conifers in wetlands also serve as potential seed sources for the regeneration of conifers in adjacent upland forests, and wetland systems provide a refuge for hemlock during climatically dry periods (Mladenoff and Stearns 1993). Removal of mature conifers from hardwood-conifer swamps should be carefully managed to ensure the continued presence of seed sources within the wetland.

Expansion of red maple in some stands, often following logging or hydrologic disturbance, limits conifer seedling establishment and recruitment by reducing light availability at the ground level. An increase in deciduous canopy trees leads to an increase in deciduous leaf litter, which creates an unfavorable seed bed for conifers (Mladenoff and Stearns 1993). Harvest in closed-canopy, hardwood-dominated stands that formerly supported hardwood-conifer swamp should focus on creating canopy gaps suitable for colonization and establishment of species intolerant of dense shade, such as yellow birch (Webster and Lorimer 2005). Conifers, preferably from a native, local seed source, can be established in these stands by underplanting of appropriate species in light gaps and protecting them from deer browse.

Protection of groundwater and surface water hydrology is critical to maintaining the integrity of the hardwood-conifer swamp community. Hydrologic disturbances, including road construction and ditching, cause peat subsidence and decomposition and alter water tables by draining water or blocking its flow (Bradof 1992, Hillman 1997, Amon et al. 2002). Logging and hydrologic disturbances associated with logging roads and railroads in the late 19th and early 20th centuries converted many conifer-dominated stands to hardwood stands. Urban development also degrades water quality and disrupts hydrology, but the effects of urbanization may be unpredictable for any given site (Ehrenfeld and Schneider 1993). The degree to which forested wetland vegetation is impacted by hydrologic disturbance may be related to characteristics of the pit-and-mound microtopography (Ehrenfeld and Schneider 1993). Natural hydrologic disturbances, including flooding associated with beaver dams, also profoundly impact

Rare Plants Associated with Southern Hardwood Swamp (E, Endangered; T, Threatened; SC, species of special concern).

Scientific Name	Common Name	State Status
Berula erecta	cut-leaved water-parsnip	T
Calypso bulbosa	calypso of fairy-slipper	T
Carex seorsa	sedge	T
Cypripedium arietinum	ram's head lady's-slipper	SC
Dentaria maxima	large toothwort	T
Hydrastis canadensis	goldenseal	T
Lonicera involucrata	black twinberry	T
Mimulus glabratus var. *michiganensis*	Michigan monkey flower	E
Poa paludigena	bog bluegrass	T
Trillium undulatum	painted trillium	E

Rare Animals Associated with Southern Hardwood Swamp (E, Endangered; T, Threatened; SC, species of special concern).

Scientific Name	Common Name	State Status
Accipiter gentilis	northern goshawk	SC
Alces americanus	moose	SC
Appalachina sayanus	spike-lip crater	SC
Ardea herodias rookery	great blue heron rookery	*
Asio otus	long-eared owl	T
Buteo lineatus	red-shouldered hawk	T
Canis lupus	gray wolf	T
Emydoidea blandingii	Blanding's turtle	SC
Glyptemys insculpta	wood turtle	SC
Gomphus quadricolor	rapids clubtail	SC
Haliaeetus leucocephalus	bald eagle	SC
Incisalia henrici	Henry's elfin	T
Pachypolia atricornis	three-horned moth	SC
Pandion haliaetus	osprey	SC
Planogyra asteriscus	eastern flat-whorl	SC
Sistrurus c. catenatus	eastern massasauga	SC
Tachopteryx thoreyi	grey petaltail	SC
Terrapene c. carolina	eastern box turtle	SC
Williamsonia fletcheri	ebony boghaunter	SC

*Protected by the Migratory Bird Treaty Act of 1918.

Hardwood-conifer swamp, Luce County, Michigan. Photo by Joshua G. Cohen.

hardwood-conifer swamp structure (see Natural Processes). Bradof (1992) notes that drainage projects involving the creation of ditches facilitate beaver colonization of large areas of previously uncolonized wetlands, causing widespread flooding and tree-kill. Several measures can be taken to protect the integrity of hardwood-conifer swamp hydrology. A relatively wide upland buffer zone can be established to prevent surface water run-off and protect groundwater seepage zones. Construction of new ditches should be avoided, as should new road construction and stream maintenance projects (e.g., dredging, straightening, and removal of fallen wood). Tree harvest should take place in winter to avoid significant degradation of organic soils. Trapping and removal of beaver may be necessary in isolated nature preserves where the maintenance of hardwood-conifer swamp is a conservation priority, and where flooding is likely to eliminate species of conservation concern.

High white-tailed deer density has led to significant browse pressure on conifer seedlings and saplings throughout Michigan and the Great Lakes region (Frelich and Lorimer 1985, Mladenoff and Stearns 1993, Alverson and Waller 1997, Long et al. 1998, Rooney and Waller 1998, Rooney et al. 2002, Krueger and Peterson 2006). In addition, deer browse reduces frequency and cover of understory shrubs and herbs, altering structure of all strata and producing a cascade of effects extending to pollinators of affected plant species (Balgooyen and Waller 1995, Augustine and Frelich 1998, Rooney and Waller 2003, Kraft et al. 2004). In forests impacted by high deer densities, microsites, including treefall mounds, may serve as refugia for deer-favored species such as hemlock (Krueger and Peterson 2006). Protection of the coarse woody debris resource is an important component of any strategy to promote conifer regeneration, particularly in landscapes characterized by high deer density. Salvage logging of blowdowns should be avoided, as piles of toppled trees create physical barriers to deer and thus promote conifer recruitment.

In addition, hemlock recruitment appears to be facilitated by balsam fir, a relatively unpalatable conifer that grows in dense patches and restricts access by deer (Borgmann et al. 1999). Therefore, maintaining high balsam fir cover in managed forest stands should be considered along with protecting the coarse woody debris resource to promote hemlock regeneration. At the landscape scale, reduction of deer densities will promote recovery of tree seedling, shrub, and herb populations. In areas where reducing the number of deer is not feasible, or in small, isolated stands of high-quality hardwood-conifer swamp, deer exclosures should be considered in order to promote conifer regeneration and recruitment.

Photo by Bradford S. Slaughter

Blowdowns serve as refugia for conifer seedlings and saplings in sites impacted by high deer density.

Invasive plant species can establish within hardwood-conifer swamps in canopy gaps and in openings along streams. Species of particular concern include reed canary grass (*Phalaris arundinacea*), common reed (*Phragmites australis*), purple loosestrife (*Lythrum salicaria*), autumn-olive (*Elaeagnus umbellata*), and glossy buckthorn (*Rhamnus frangula*), although many other non-native plant species of lesser impact are of frequent occurrence (MNFI Biotics Database 2007). Fragmentation and isolation of hardwood-conifer swamp occurrences by residential, commercial, and industrial development, particularly in southern Lower Michigan, locally threatens this natural community type by restricting dispersal of native species and increasing the propagule pressure of commonly planted non-native trees, shrubs, and herbs. Hydrologic disturbances, including flooding and nutrient loading via surface water run-off, facilitate invasion of otherwise intact systems (Zedler and Kercher 2004). Monitoring and removal of invasive species should focus on those species which threaten to alter community composition and structure (e.g., glossy buckthorn and purple loosetrife). Management activities should avoid soil and hydrologic disturbances that favor spread of invasive plant species.

Other pests of potentially significant impact include the hemlock woolly adelgid (*Adelges tsugae*), which has the potential to cause significant hemlock mortality if it establishes in Michigan, and the emerald ash borer (*Agrilus planipennis*), which has already decimated the ash population in southeastern Michigan (Haack et al. 2002, McCullough and Roberts 2002, MacFarlane and Meyer 2005). Urgent measures must be taken to restrict the access of these species to unaffected swamps.

Research Needs: Hardwood-conifer swamp is a relatively poorly studied wetland type in Michigan and across its range, as the majority of research on lowland forests has been conducted in peatlands (e.g., rich conifer swamp, poor conifer swamp) and hardwood-dominated floodplain forests. A systematic survey for hardwood-conifer swamp in Michigan, including the collection of plot data, is necessary to assess the statewide and ecoregional conservation status of this natural community type, and to determine if any of the above described variants warrant splitting as separate natural community types. Additional inventory for hardwood-conifer swamp in northern Michigan is required, as few occurrences have been documented despite the community's widespread distribution in that region (MNFI Biotics Database 2007). Additional research is necessary to study the edaphic and climatic characteristics and successional pathways associated with hardwood-conifer swamp. The impacts of fire, windthrow, and beaver flooding on hardwood-conifer swamp in Michigan are poorly understood and should be investigated. Deer browse is a significant disturbance, but its impacts on hardwood species, shrubs, and ground layer species typical of hardwood-conifer swamp require further research. The most effective means of limiting the impacts of deer herbivory in this system must also be determined. The potential impacts of emerald ash borer and hemlock woolly adelgid on hardwood-conifer swamp should be studied and modeled. The interaction of natural and anthropogenic disturbances, and their impacts on hardwood-conifer swamp should also be elucidated. For example, the impacts of beaver in anthropogenically disturbed versus undisturbed forested wetlands should be studied to help improve land management and protection strategies. Additional research on conifer regeneration in hardwood-conifer swamp will improve management techniques and conservation strategies for this natural community type.

Similar Communities: *Rich tamarack swamp* is a tamarack-dominated peatland located primarily in the interlobate regions of southern Lower Michigan, where it was the most common forested wetland type circa 1800 (Kost 2001a). *Rich conifer swamp* is a northern white-cedar – dominated peatland, with tamarack, black spruce, and balsam fir as common associates. Lowland hardwoods are of low importance in rich conifer swamp. This system occurs primarily in cool regions of the state where climate limits peat decomposition, although isolated stands of rich conifer swamp, typically associated with tamarack and lowland hardwoods, are documented from southern Lower Michigan (Kost 2002). *Poor conifer swamp* is an oligotrophic forested wetland dominated by black spruce and tamarack on deep sphagnum peats (Cohen 2006). *Southern hardwood swamp* is dominated by hardwood species tolerant of seasonal hydrologic fluctuation (e.g., silver maple and green ash), and typically occurs on shallow muck or seasonally inundated mineral soils south of the climatic tension zone. Conifers are generally absent or of limited occurrence (Kost et al. 2007). *Northern hardwood swamp* is a black ash-dominated community on shallow muck or seasonally inundated mineral soils north of the tension zone (Weber et al. 2007). *Floodplain forest* is a broadly defined community occurring on third order or greater streams; hardwood-conifer swamps sometimes occur within floodplain forests in meander scars no longer subject to over-the-bank flooding (Tepley et al. 2004). Hardwood-conifer swamp can also occur as a zone in *wooded dune and swale complexes*.

Other Classifications:

Michigan Department of Natural Resources (MDNR): Q – Mixed Swamp Conifers; E – Swamp Hardwoods; C – Northern White Cedar; H – Hemlock

Michigan Resource Information Systems (MIRIS): 423 (conifer swamp): 4237 (hemlock, yellow birch), 4238 (hemlock), 4239 (white pine); 432 (lowland hardwoods & conifer): 4322 (white pine, tamarack, red maple, yellow birch, black ash, cedar, [&/or hemlock]), 4322 (hemlock, yellow birch)

The Nature Conservancy U.S. National Vegetation Classification and International Classification of Ecological Communities (Faber-Langendoen 2001, NatureServe 2006):

CODE; ALLIANCE; ASSOCIATION; COMMON NAME

I.A.8.N.g; *Tsuga canadensis* Saturated Forest Alliance; *Tsuga canadensis - Betula alleghaniensis / Ilex verticillata / Sphagnum* spp. Forest; Eastern Hemlock - Yellow Birch / Common Winterberry / Peatmoss species Forest; Hemlock – Hardwood Swamp

I.B.2.N.g; *Fraxinus nigra - Acer rubrum* Saturated Forest Alliance; *Acer rubrum - Fraxinus nigra - (Tsuga canadensis) / Tiarella cordifolia* Forest; Red Maple - Black Ash - (Eastern Hemlock) / Heartleaf Foamflower Forest; Northern Hardwood – Hemlock Seepage Swamp

I.B.2.N.g; *Fraxinus nigra - Acer rubrum* Saturated Forest Alliance; *Acer rubrum - Fraxinus* spp. - *Betula papyrifera / Cornus canadensis* Forest; Red Maple - Ash species - Paper Birch / Canadian Bunchberry Forest; Red Maple – Ash – Birch Swamp Forest

I.B.2.N.g; *Fraxinus nigra - Acer rubrum* Saturated Forest Alliance; *Fraxinus nigra* - Mixed Hardwoods - Conifers */ Cornus sericea / Carex* spp. Forest; Black Ash - Mixed Hardwoods - Conifers / Red-osier Dogwood / Sedge species Forest; Black Ash – Mixed Hardwood Swamp

I.C.3.N.d; *Pinus strobus - (Acer rubrum)* Saturated Forest Alliance; *Pinus strobus - (Acer rubrum) / Osmunda* spp. Forest; Eastern White Pine - (Red Maple) / Royal Fern species Forest; White Pine – Red Maple Swamp

I.C.3.N.d; *Tsuga canadensis - Acer rubrum* Saturated Forest Alliance; *Betula alleghaniensis - Acer rubrum - (Tsuga canadensis, Abies balsamea) / Osmunda cinnamomea* Forest; Yellow Birch - Red Maple - (Eastern Hemlock, Balsam Fir) / Cinnamon Fern Forest; Hardwood – Conifer Seepage Forest

I.C.3.N.d; *Thuja occidentalis - Acer rubrum* Saturated Forest Alliance; *Thuja occidentalis - Fraxinus nigra* Forest; Northern White-cedar - Black Ash Forest; White-cedar – Black Ash Swamp

Other states and Canadian provinces (natural community types with significant overlap with Michigan hardwood-conifer swamp indicated in *italics*):

MN: Northern wet cedar forest; Northern wet ash swamp; Northern very wet ash swamp (Minnesota Department of Natural Resources 2003)

WI: *White pine – red maple swamp* (Epstein et al. 2002)

ON: *White pine – hemlock mineral coniferous swamp ecosite*; White cedar mineral coniferous swamp ecosite; White cedar mineral mixed swamp ecosite; Maple mineral mixed swamp ecosite; Birch – poplar mineral mixed swamp ecosite; White cedar organic mixed swamp ecosite; Maple organic mixed swamp ecosite; Birch – poplar organic mixed swamp ecosite; *Fresh – moist hemlock coniferous forest ecosite*; *Fresh – moist hemlock mixed forest ecosite*; *Fresh – moist white cedar coniferous forest ecosite*; *Fresh – moist white cedar – hardwood mixed forest ecosite*; Fresh – moist poplar – white birch mixed forest ecosite (Lee et al. 1998)

OH: *Hemlock – hardwood swamp* (Schneider and Cochrane 1998)

PA: *Hemlock palustrine forest*; *Hemlock – mixed hardwood palustrine forest*; Red maple – highbush blueberry palustrine woodland; Red maple – sedge palustrine woodland; red maple – mixed shrub palustrine woodland (Fike 1999)

NY: *Hemlock – hardwood swamp*; *Rich hemlock – hardwood peat swamp* (Edinger et al. 2002)

MA: *Hemlock – hardwood swamp*; Red maple swamp; Black ash swamp (Swain and Kearsley 2001)

VT: *Red maple – white pine – huckleberry swamp*; Spruce – fir – tamarack swamp; *Hemlock swamp*; *Hemlock – hardwood swamp*; Red maple – black ash swamp;

Red maple – northern white cedar swamp; (Thompson and Sorenson 2000)

NH: *Northern hardwood – black ash – conifer swamp*; *Northern white cedar – hemlock swamp*; *Hemlock – cinnamon fern forest* (Sperduto and Nichols 2004)

ME: *Hemlock – hardwood pocket swamp*; Hardwood seepage forest; Red maple – sensitive fern swamp (Gawler and Cutko 2004)

Related Abstracts: rich conifer swamp, rich tamarack swamp, poor conifer swamp, northern hardwood swamp, floodplain forest, wooded dune and swale complex, Cooper's hawk, northern goshawk, spike-lip crater, red-shouldered hawk, Blanding's turtle, wood turtle, rapids clubtail, eastern massasauga, osprey, eastern box turtle, great blue heron rookery, goldenseal, Michigan monkey-flower, painted trillium, large toothwort, calypso, ram's head lady's-slipper.

Photo by Bradford S. Slaughter

White pine and red maple dominate a hardwood-conifer swamp in Newaygo County.

References:

Albert, D.A. 1995. Regional landscape ecosystems of Michigan, Minnesota, and Wisconsin: A working map and classification. Gen. Tech. Rep. NC-178. St. Paul, MN: USDA, Forest Service, North Central Forest Experiment Station, St. Paul, MN. http://nrs.fs.fed.us/pubs/242 (Version 03JUN1998). 250 pp.

Albert, D.A., J.G. Cohen, M.A. Kost, B.S. Slaughter, and H.D. Enander. 2008. Distribution maps of Michigan's Natural Communities. Michigan Natural Features Inventory, Report No. 2008-01, Lansing, MI. 174 pp.

Albert, D.A., S.R. Denton, and B.V. Barnes. 1986. Regional landscape ecosystems of Michigan. Ann Arbor, MI: University of Michigan, School of Natural Resources. 32 pp. & map.

Allison, S.K., and J.G. Ehrenfeld. 1999. The influence of microhabitat variations on seedling recruitment of *Chamaecyparis thyoides* and *Acer rubrum*. Wetlands 19: 383-393.

Alverson, W.S., and D.M. Waller. 1997. Deer populations and the widespread failure of hemlock regeneration in northern forests. Pp. 280-297 *in* W.J. McShea, H.B. Underwood, and J.H. Rappole (eds.). The Science of Overabundance: Deer Ecology and Population Management. Smithsonian Institution Press, Washington, D.C.

Amon, J.P., C.A. Thompson, Q.J. Carpenter, and J. Miner. 2002. Temperate zone fens of the glaciated Midwestern USA. Wetlands 22: 301-317.

Anderson, K.L., and D.J. Leopold. 2002. The role of canopy gaps in maintaining vascular plant diversity at a forested wetland in New York State. Journal of the Torrey Botanical Society 129: 238-250.

Augustine, D.J., and L.E. Frelich. 1998. Effects of white-tailed deer on populations of an understory forb in fragmented deciduous forests. Conservation Biology 12: 995-1004.

Balgooyen, C.P., and D.M. Waller. 1995. The use of *Clintonia borealis* and other indicators to gauge impacts of white-tailed deer on plant communities in northern Wisconsin, USA. Natural Areas Journal 15: 308-318.

Barnes, B.V. 1976. Succession in deciduous swamp communities of southeastern Michigan formerly dominated by American elm. Canadian Journal of Botany. 54:19-24.

Barnes, B.V. 1991. Deciduous forest of North America. Pp. 229-344 *in* E. Röhrig and B. Ulrich, eds., Ecosystems of the World 7: Temperate Deciduous Forests. Elsevier Publishing, New York.

Barrett, L.R., J. Liebens, D.G. Brown, R.J. Schaetzl, P. Zuwerink, T.W. Cate, and D.S. Nolan. 1995. Relationships between soils and presettlement forests in Baraga County, Michigan. American Midland Naturalist 134: 264-285.

Bedford, B.L., and K.S. Godwin. 2003. Fens of the United States: Distribution, characteristics, and scientific connection versus legal isolation. Wetlands 23: 608-629.

Borgmann, K.L., D.M. Waller, and T.P. Rooney. 1999. Does balsam fir (*Abies balsamea*) facilitate the recruitment of eastern hemlock (*Tsuga canadensis*)? American Midland Naturalist 141: 391-397.

Bowles, M.L., P.D. Kelsey, and J.L. McBride. 2005. Relationships among environmental factors, vegetation zones, and species richness in a North American calcareous prairie fen. Wetlands 25: 685-696.

Bradof, K.L. 1992. Impact of ditching and road construction on Red Lake Peatland. Pp. 173-186 *in* H.E. Wright, Jr., B.A. Coffin, and N.E. Aaseng, eds. The Patterned Peatlands of Minnesota. University of Minnesota Press, Minneapolis.

Braun, E.L. 1950. Deciduous forests of eastern North America. McGraw-Hill, New York.

Brewer, R. 1966. Vegetation of two bogs in southwestern Michigan. Michigan Botanist 5: 36-46.

Christensen, E.M., J.J. (Jones) Clausen, and J.T. Curtis. 1959. Phytosociology of the lowland forests of northern Wisconsin. American Midland Naturalist 62: 232-247.

Cleland, D.T., T.R. Crow, S.C. Saunders, D.I. Dickmann, A.L. Maclean, J.K. Jordan, R.L. Watson, A.M. Sloan, and K.D. Brosofske. 2004. Characterizing historical and modern fire regimes in Michigan (USA): A landscape ecosystem approach. Landscape Ecology 19: 311-325.

Coffman, M.S. 1978. Eastern hemlock germination influenced by light, germination media, and moisture content. Michigan Botanist 17: 99-103.

Cohen, J.G. 2006. Natural community abstract for poor conifer swamp. Michigan Natural Features Inventory, Lansing, MI. 22 pp.

Comer, P.J., D.A. Albert, H.A. Wells, B.L. Hart, J.B. Raab, D.L. Price, D.M. Kashian, R.A. Corner, and D.W. Schuen. 1995. Michigan's presettlement vegetation, as interpreted from the General Land Office Surveys 1816-1856. Michigan Natural Features Inventory, Lansing, MI. Digital map.

Curtis, J.T. 1959. The Vegetation of Wisconsin: An Ordination of Plant Communities. The University of Wisconsin Press, Madison, WI. 657 pp.

Dahl, T.E. 1990. Wetlands – Losses in the United States, 1780s to 1980s.Washington, D.C., U.S. Fish and Wildlife Service Report to Congress, 13 pp.

Edinger, G.J., D.J. Evans, S. Gebauer, T.G. Howard, D.M. Hunt, and A.M. Olivero (editors). 2002. Ecological communities of New York State. Second Edition. A revised and expanded edition of Carol Reschke's Ecological communities of New York State. (Draft for review). New York Natural Heritage Program, New York Department of Environmental Conservation, Albany, NY.

Ehrenfeld, J.G., and J.P. Schneider. 1993. Responses of forested wetland vegetation to perturbations of water chemistry and hydrology. Wetlands 13: 122-129.

Ehrenfeld, J.G. 1995. Microsite differences in surface substrate characteristics in *Chamaecyparis* swamps of the New Jersey Pinelands. Wetlands 15: 183-189.

Epstein, E., E. Judziewicz, and E. Spencer. 2002. Wisconsin Natural Heritage Inventory (NHI) recognized natural communities – working document. September 2002 revision. Wisconsin Natural Heritage Inventory, Madison, WI.

Faber-Langendoen, D., ed. 2001. Plant communities of the Midwest: Classification in an ecological context. NatureServe, Arlington, VA.

Fike, J. 1999. Terrestrial and palustrine plant communities of Pennsylvania. Pennsylvania Department of Conservation and Natural Resources, Bureau of Forestry, Harrisburg, PA.

Forrester, J.A., T.E. Yorks, and D.J. Leopold. 2005. Arboreal vegetation, coarse woody debris, and disturbance history of mature and old-growth stands in a coniferous forested wetland. Journal of the Torrey Botanical Society 132: 252-261.

Frelich, L.E., and C.G. Lorimer. 1985. Current and predicted long-term effects of deer browsing in hemlock forests in Michigan, USA. Biological Conservation 34: 99-120.

Frelich, L.E., R.R. Calcote, M.B. Davis, and J. Pastor. 1993. Patch formation and maintenance in an old-growth hemlock-hardwood forest. Ecology 74: 513-527.

Futyma, R.P., and N.G. Miller. 2001. Postglacial history of a marl fen: Vegetational stability at Byron-Bergen Swamp, New York. Canadian Journal of Botany 79: 1425-1438.

Gawler, S.C., and A.R. Cutko. 2004. Natural landscapes of Maine: A classification of vegetated natural communities and ecosystems. Maine Natural Areas Program, Department of Conservation, Augusta, ME.

Haack, R.A., E. Jendek, H. Liu, K.R. Marchant, T.R. Petrice, T.M. Poland, and H. Ye. 2002. The emerald ash borer: A new exotic pest in North America. Michigan Entomological Society Newsletter 47: 1-5.

Heinselman, M.L. 1963. Forest sites, bog processes, and peatland types in the Glacial Lake Agassiz Region, Minnesota. Ecological Monographs 33: 327-374.

Hillman, G.R. 1997. Effects of engineered drainage on water tables and peat subsidence in an Alberta treed fen. Pp. 253-272 *in* C.C. Trettin, M.F. Jurgensen, D.F. Grigal, M.R. Gale, and J.K. Jeglum, eds. Northern Forested Wetlands: Ecology and Management. Lewis Publishers, Boca Raton, FL.

Holcombe, J.W. 1976. The bryophyte flora of *Thuja* seedbed logs in a northern white-cedar swamp. Michigan Botanist 15: 173-181.

Kost, M.A. 2001a. Natural community abstract for relict conifer swamp. Michigan Natural Features Inventory, Lansing, MI. 6 pp.

Kost, M.A. 2001b. Potential indicators for assessing biological integrity of forested, depressional wetlands in southern Michigan. Michigan Natural Features Inventory, Lansing, MI. 69 pp.

Kost, M.A. 2002. Natural community abstract for rich conifer swamp. Michigan Natural Features Inventory, Lansing, MI. 9 pp.

Kost, M.A., D.A. Albert, J.G. Cohen, B.S. Slaughter, R.K. Schillo, C.R. Weber, and K.A. Chapman. 2007. Natural communities of Michigan: Classification and description. Michigan Natural Features Inventory, Report Number 2007-21, Lansing, MI. 314 pp.

Kraft L.S., T.R. Crow, D.S. Buckley, E.A. Nauertz, and J.C. Zasada. 2004. Effects of harvesting and deer browsing on attributes of understory plants in northern hardwood forests, Upper Michigan, USA. Forest Ecology and Management 199: 219-230.

Krueger, L.M., and C.J. Peterson. 2006. Effects of white-tailed deer on *Tsuga canadensis* regeneration: Evidence of microsites as refugia from browsing. American Midland Naturalist 156: 353-362.

Laidig, K.L., and R.A. Zampanella. 1999. Community attributes of Atlantic white cedar (*Chamaecyparis thyoides*) swamps in disturbed and undisturbed Pinelands watersheds. Wetlands 19: 35-49.

Leahy, M.J., and K.S. Pregitzer. 2003. A comparison of presettlement and present-day forests in northeastern Lower Michigan. American Midland Naturalist 149: 71-89.

Lee, H.T., W.D. Bakowsky, J. Riley, J. Bowles, M. Puddister, P. Uhlig, and S. McMurray. 1998. Ecological land classification for southern Ontario: First approximation and its application. Ontario Ministry of Natural Resources, Southcentral Science Section, Science Development and Transfer Branch. SCSS Field Guide FG-02.

Long, Z.T., W.P. Carson, and C.J. Peterson. 1998. Can disturbance create refugia from herbivores: An example with hemlock regeneration on treefall mounds. Journal of the Torrey Botanical Society 125: 165-168.

MacFarlane, D.W., and S.P. Meyer. 2005. Characteristics and distribution of potential ash tree hosts for emerald ash borer. Forest Ecology and Management 213: 15-24.

McCullough, D.G., and D.L. Roberts. 2002. Emerald ash borer. USDA Forest Service, Northeast Area, State and Private Forests, Pest Alert NA-PR-07-02.

McGee, G.G. 2001. Stand-level effects on the role of decaying logs as vascular plant habitat in Adirondack northern hardwood forests. Journal of the Torrey Botanical Society 128: 370-380.

McKenzie, J.M., D.I. Siegel, D.O. Rosenberry, P.H. Glaser, and C.I. Voss. 2007. Heat transport in the Red Lake Bog, Glacial Lake Agassiz Peatlands. Hydrological Processes 21: 369-378.

Michigan Natural Features Inventory (MNFI). 2007. Biotics Database. Michigan Natural Features Inventory, Lansing, MI.

Minnesota Department of Natural Resources. 2003. Field guide to the native plant communities of Minnesota: The Laurentian Mixed Forest Province. Ecological Land Classification Program, Minnesota County Biological Survey, and Natural Heritage and Nongame Research Program. MNDNR, St. Paul, MN.

MIRIS. 1978. MIRIS Landcover 1978. Michigan Department of Natural Resources, Lansing, MI. Digital dataset.

Mladenoff, D.J., and F. Stearns. 1993. Eastern hemlock regeneration and deer browsing in the northern Great Lakes region: A re-examination and model simulation. Conservation Biology 7: 889-900.

NatureServe. 2006. NatureServe Explorer: An online encyclopedia of life [web application]. Version 6.1. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. (Accessed: November 30, 2006).

Paratley, R.D., and T.J. Fahey. 1986. Vegetation – environment relations in a conifer swamp in central New York. Bulletin of the Torrey Botanical Club 113: 357-371.

Rooney, T.P., and D.M. Waller. 1998. Local and regional variation in hemlock seedling establishment in forests of the upper Great Lakes region, USA. Forest Ecology and Management 111: 211-224.

Rooney, T.P., and D.M. Waller. 2003. Direct and indirect effects of white-tailed deer in forest ecosystems. Forest Ecology and Management 181: 165-176.

Rooney, T.P., S.L. Solheim, and D.M. Waller. 2002. Factors affecting the regeneration of northern white-cedar in lowland forests of the Upper Great Lakes region, USA. Forest Ecology and Management 163: 119-130.

Schneider, G.J., and K.E. Cochrane. 1998. Plant community survey of the Lake Erie Drainage. Ohio Department of Natural Resources, Division of Natural Areas and Preserves, Columbus, OH.

Simard, M.-J., Y. Bergeron, and L. Sirois. 2003. Substrate and litterfall effects on conifer seedling survivorship in southern boreal stands of Canada. Canadian Journal of Forest Research 33: 672-681.

Slaughter, B.S., and J.D. Skean, Jr. 2003. Comparison of cedar and tamarack stands in a relict conifer swamp at Pierce Cedar Creek Institute, Barry County, Michigan. Michigan Botanist 42: 111-126.

Slaughter, B.S., B.S. Walters, and E.H. Schools. 2007. A natural features inventory of Newaygo County, Michigan. Report No. 2007-01. Michigan Natural Features Inventory, Lansing, MI. 55 pp.

Sperduto, D.D., and W.F. Nichols. 2004. Natural communities of New Hampshire. The New Hampshire Natural Heritage Bureau, Concord, NH. UNH Cooperative Extension, Durham, NH.

St. Hilaire, L.R., and D.J. Leopold. 1995. Conifer seedling distribution in relation to microsite conditions in a central New York forested minerotrophic peatland. Canadian Journal of Forest Research 25: 261-269.

Swain, P.C., and J.B. Kearsley. 2001. Classification of the Natural Communities of Massachusetts. Version 1.3. Natural Heritage and Endangered Species Program, Division of Fisheries and Wildlife. Westborough, MA.

Tepley, A.J., J.G. Cohen, and L. Huberty. 2004. Natural community abstract for southern floodplain forest. Michigan Natural Features Inventory, Lansing, MI. 14 pp.

Terwilliger, J., and J. Pastor. 1999. Small mammals, ectomycorrhizae, and conifer succession in beaver meadows. Oikos 85: 83-94.

Thompson, P.W. 1953. Vegetation of Haven Hill, Michigan. American Midland Naturalist 50: 218-223.

Thompson, E.H., and E.R. Sorenson. 2000. Wetland, Woodland, Wildland: A guide to the natural communities of Vermont. Vermont Department of Wildlife and The Nature Conservancy. University Press of New England, Hanover, NH.

Vivian-Smith, G. 1997. Microtopographic heterogeneity and floristic diversity in experimental wetland communities. Journal of Ecology 85: 71-82.

Voss, E.G. 1972. Michigan Flora. Part I: Gymnosperms and Monocots. Bull. Cranbrook Inst. Sci. 55 and Univ. Michigan Herbarium, Ann Arbor, MI. 488 pp.

Voss, E.G. 1985. Michigan Flora. Part II: Dicots (Saururaceae—Cornaceae). Bull. Cranbrook. Inst. Sci. 59 and Univ. Michigan Herbarium, Ann Arbor, MI. 724 pp.

Voss, E.G. 1996. Michigan Flora. Part III: Dicots (Pyrolaceae—Compositae). Bull. Cranbrook Inst. Sci. 61 and Univ. Michigan Herbarium, Ann Arbor, MI. 622 pp.

Weber, C.R., J.G. Cohen, and M.A. Kost. 2007. Natural community abstract for northern hardwood swamp. Michigan Natural Features Inventory, Lansing, MI. 8 pp.

Webster, C.R., and C.G. Lorimer. 2005. Minimum opening sizes for canopy recruitment of midtolerant tree species: A retrospective approach. Ecological Applications 15: 1245-1262.

Wenger, J.D. 1975. The vegetation of a white-cedar swamp in southwestern Michigan. Michigan Botanist 14: 124-130.

Whitney, G.G. 1986. Relation of Michigan's presettlement pine forests to substrate and disturbance history. Ecology 67: 1548-1559.

Whitney, G.G. 1987. An ecological history of the Great Lakes Forest of Michigan. Journal of Ecology 75: 667-684.

Zampanella, R.A., K.J. Landig, R.G. Lathrop, and J.A. Bognar. 1999. Size-class structure and hardwood recruitment in Atlantic white cedar swamps of the New Jersey pinelands. Journal of the Torrey Botanical Society 126: 268-275.

Zedler, J.B., and S. Kercher. 2004. Causes and consequences of invasive plants in wetlands: Opportunities, opportunists, and outcomes. Critical Reviews in Plant Sciences 23: 431-452.

Zhang, Q., K.S. Pregitzer, and D.D. Reed. 2000. Historical changes in the forests of the Luce District of the Upper Peninsula of Michigan. American Midland Naturalist 143: 94-110.

Abstract Citation:

Slaughter, B.S., J.G. Cohen, and M.A. Kost. 2007. Natural community abstract for hardwood-conifer swamp. Michigan Natural Features Inventory, Lansing, MI. 20 pp.

Updated June 2010.

Copyright 2007 Michigan State University Board of Trustees. Michigan State University is an affirmative-action, equal-opportunity organization.

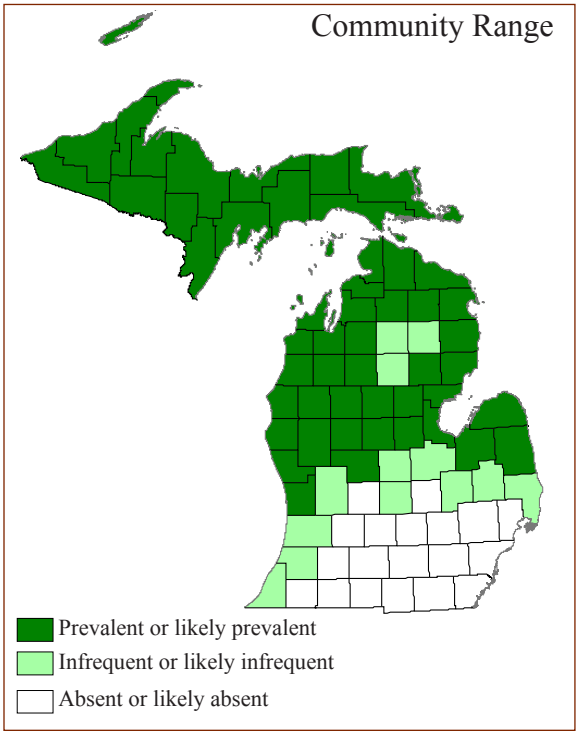
Funding for abstract provided by Michigan Department of Natural Resources Forest, Mineral and Fire Management Division and Wildlife Division.

Hardwood-conifer swamp, Baraga County, Michigan. Photo by Joshua G. Cohen.

Appendix C- MNFI Mesic Northern Forest Community Abstract

Mesic Northern Forest — Community Abstract

Photo by Joshua G. Cohen



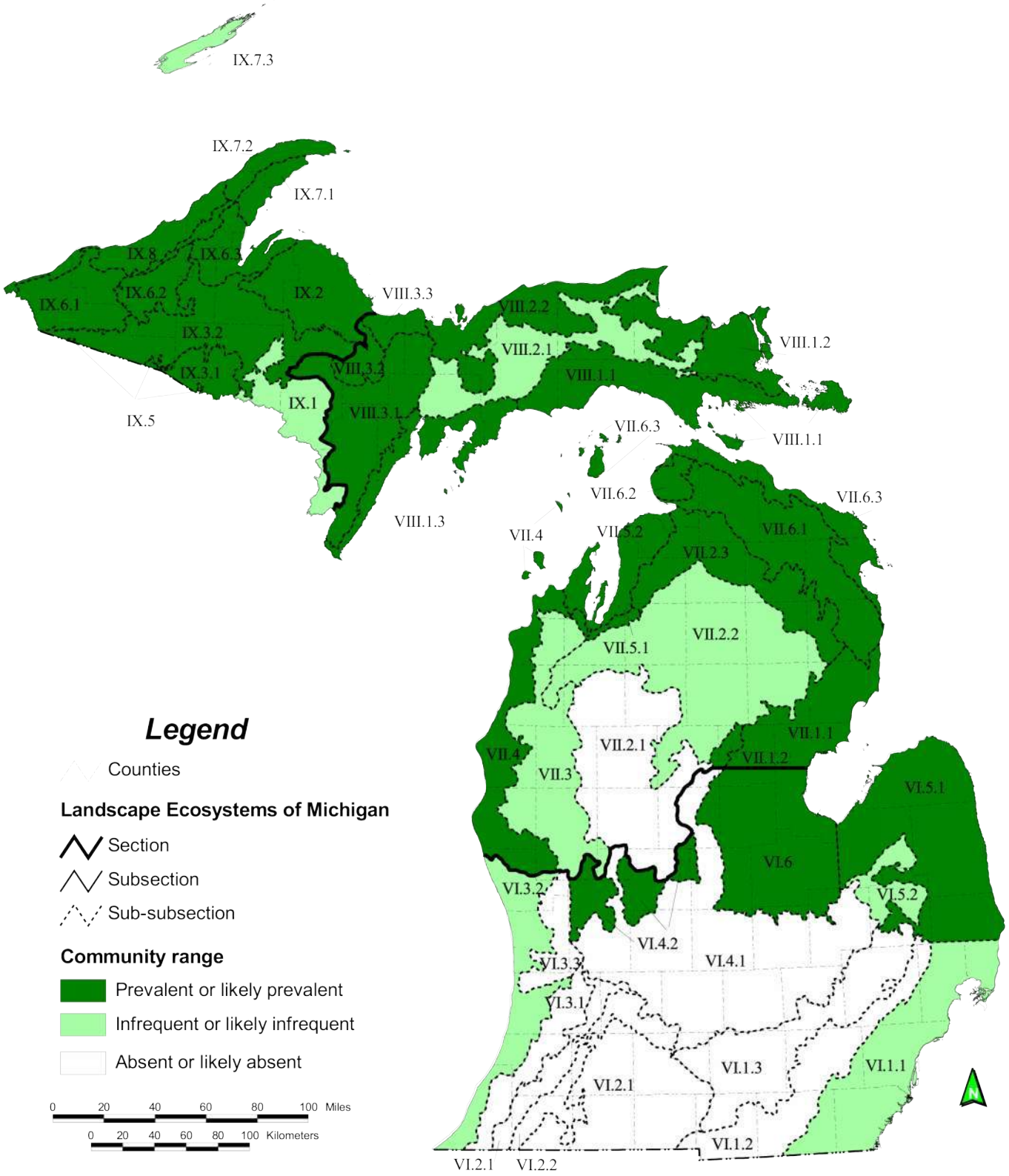
Global and State Rank: G4/S3

Range: The mesic northern forest community has existed as a dominant assemblage for approximately 2,000 years (Davis, 1981) extending from southeastern Manitoba and northern Minnesota east across the northern U.S. and southern Canada to Maine and Nova Scotia (Barnes, 1991). Within Michigan, this forest type is predominantly found throughout the Upper Peninsula and in the northern half of the Lower Peninsula above the transition zone. This community also sporadically occurs below the transition zone along the Great Lakes shores of the Lower Peninsula.

Rank Justification: Widespread selective logging of white pine and hemlock at the end of the 19th century and the beginning of the 20th century followed by extensive slash fires greatly diminished the role of conifers as a widespread component of the mesic northern forest. In the Great Lakes region more than 99% of the mature hemlock-hardwood forest has been eliminated (Noss et al., 1995) and hemlock has been reduced from its former position as a regional dominant to where it now occupies only 0.5% of the landscape (Mladenoff and Stearns, 1993). Hemlock regeneration has diminished with this drastic reduction in seed source, the rise of winter browse pressure from the increasing deer population (Alverson et al., 1988) and the paucity of suitable establishment substrate such as decaying logs (nurse logs) and tip up mounds, features associated with old growth stands and also necessary for yellow birch establishment (Curtis, 1959). Logging, with a shift in focus from conifers to hardwoods, has continued as the primary disturbance in this forest (Frelich and Lorimer, 1991; Metzger and Schultz, 1984). Gaps generated by selective logging tend to be filled by sugar maple (Curtis, 1959), the seedlings of which often saturate the shaded understory of mesic northern forests (Barnes, 1991). Sustained and ubiquitous harvesting has reduced the structural and compositional complexity of this community. Old growth forest has dwindled from 68.0% to 5.2-8.3% of the Great Lakes landscape (Frelich, 1995). Remnants of northern hemlock-hardwood forests unscathed by logging are among the rarest vegetation types in the lake states, with just 0.6% remaining (Frelich and Reich, 1996). According to Noss et al. (1995), old growth eastern deciduous forest is among the 21 most endangered ecosystems in the United States.

In Michigan, 5.8% of the northern hardwood commercial forest is old growth (Frelich, 1995). In the 1800s, approximately 32.0% (over 12 million acres) of Michigan was mesic northern forest (Comer et al., 1995). Just over 0.4% of mesic northern forest in presettlement condition remains in Michigan. Large tracts of primary old growth forest remain in the Upper Peninsula in the Porcupine Mountains (31,000 acres), the Sylvania Wilderness (17,950 acres) and the Huron Mountains (4,000 acres). Currently there are 81 documented occurrences of the mesic northern forest community. Thirty-seven of those occurrences, constituting just over 84,000 acres, are high quality representations of this type.

Michigan Natural Features Inventory
P.O. Box 30444 - Lansing, MI 48909-7944
Phone: 517-373-1552



Ecoregional map of Michigan (Albert 1995) depicting distribution of mesic northern forest (Albert et al. 2008)

Michigan Natural Features Inventory
P.O. Box 30444 - Lansing, MI 48909-7944
Phone: 517-373-1552

Landscape, Abiotic and Historical Context: Mesic northern forest occurs on a wide variety of soils, typically on loamy sand to sandy loam and occasionally on sand, loam and clay. Soils range widely in pH from extremely acid to moderately alkaline but are more commonly extremely acid to medium acid. According to the Köppen classification, the Northern Hardwood-Conifer region has a cool snow-forest climate with warm summers. The daily maximum temperature in July ranges from 24 to 29 °C (75 to 85 °F) and the daily minimum temperature in January ranges from –21 to –9 °C (-5 to 15 °F). The mean length of freeze-free days is between 90 to 160 days and the average number of days per year with snow cover of 2.5 cm or more is between 80 and 140 days. The normal annual total precipitation ranges from 610 to 1270 mm (Albert et al., 1986; Barnes, 1991).

A forest type of moist to dry-mesic sites lying predominantly north of the tension zone, mesic northern forest is found chiefly on coarse-textured ground and end moraines, but also occurs commonly on silty/clayey lake plains, thin glacial till over bedrock and medium-textured moraines. It also occurs locally on kettle-kame topography, moderately well-drained to well-drained sandy lake plain and sand dunes (Kost et al. 2007).

Presettlement forests of eastern hemlock and yellow birch were frequent on moderate to poorly drained till plains and outwash plains, especially in the western Upper Peninsula. This assemblage was predominantly found around lake and bog margins and in complex mosaics with sugar maple-hemlock forest on the surrounding better- drained soils. Beech-sugar maple-hemlock forests, which dominated nearly 17% of the state's surface in the 1800s, were mostly found on large expanses of rolling moraines in the northern Lower Peninsula and eastern Upper Peninsula. This species mix was also found on the clay lakeplain along Saginaw Bay. Eastern hemlock and white pine were the conifers most commonly occurring in mixed stands with hardwoods. Eastern hemlock and American beech were occasionally co-dominant, most commonly on moderately drained sand plains. Assemblages dominated by hemlock and white pine were prevalent in the 1800's on moderately drained lake plain and outwash plain extending from Saginaw Bay through the Upper Peninsula. Large areas of hemlock–dominated forest grew on the clay plain of Huron and Sanilac counties. Extensive tracts of sugar maple and white cedar located in dunes or over calcareous bedrock were known from the surveyor's notes and are found today locally in dunes and on the drumlin fields of Menominee County (Comer et al., 1995).

Natural Processes: The natural disturbance regime in mesic northern forests is dominated by wind (Frelich et al., 1993). The Great Lakes region is one of the most active weather zones in the northern hemisphere with polar jet streams positioned overhead much of the year. More cyclones pass over this area than any other area in the continental U.S (Frelich and Lorimer, 1991). Severe low-pressure systems are a significant source of small-scale canopy gaps, which generate diversity of age structure in these stands (Canham and Loucks, 1984). In a study in the western Upper Peninsula, Frelich and Lorimer (1991) found that 60% of the canopy trees attained their canopy ascendance as the result of periodic small-gap formation. Because of the ability of shade tolerant species to remain in a suppressed understory state for prolonged periods of time, small canopy gaps are filled by advanced regeneration (Runkle, 1982). Sugar maple seedlings often survive in the shaded understory for over 30 years (Marks and Gardescu, 1998) and suppressed hemlock seedlings can live over 100 years (Davis et al., 1996).

Photo by Joshua G. Cohen

Small canopy gaps allow for regeneration of shade-tolerant tree species.

Catastrophic windthrow is an important yet infrequent component of the disturbance regime of the mesic northern forests. Canham and Loucks (1984) estimated that the return time for large-scale windthrow (> 1.0 ha) to be 1,210 years in forests of northern Wisconsin. This return time is remarkably similar to Whitney's (1986) estimated windthrow recurrence interval of 1,220 years in hemlock-white pine-northern hardwood forests of the northern Lower Peninsula. Investigating primary hemlock-hardwood forests of the Upper Peninsula, Frelich and Lorimer (1991) estimated that the rotation period of wind disturbance which leveled greater than 60% of the canopy on a given site to be more than 1500 years. The principal mechanisms for large-scale windthrow are tornadoes and downbursts from thunderstorms. Downbursts are parcels of air in down drafts that shoot out from the base of

The dense, shade-tolerant canopy of mesic northern forest is periodically and patchily opened by small-scale windthrow events that generate canopy gaps critical for tree regeneration. Photos by Joshua G. Cohen.

thunderstorms and splatter in all directions upon impact with the earth (Frelich and Reich, 1996). Frelich et al. (1993) proposed that unless followed by catastrophic fire, catastrophic windthrow would cause little change in species composition because of the prevalence of advanced regeneration of shade-tolerant species. Using 19th-century land-survey evidence, Whitney (1986) estimated a fire rotation of 1,400 years in hemlock-hardwood forests of northern Lower Michigan. Catastrophic fire in the wake of windthrow would result in the following successional sequence: invasion by shade intolerant species such as aspen and paper birch followed by the encroachment into the disturbed stand by white pine and ending with replacement by shade tolerant species. Evidence of charcoal in the forest floor and fire scars on canopy dominants indicates that stands dominated by hemlock in the overstory are often the result of crown fires (Hix and Barnes, 1984; Simpson et al., 1990). However, the infrequency of fire historically in northern mesic forests is manifest by the paucity of successional species in land survey evidence: less than 5% of the presettlement northern hardwood forest was composed of pioneer species (Frelich and Lorimer, 1991).

Because of the long rotation period of large-scale disturbance in this community type, several generations of trees can pass between catastrophes. As a result, mesic northern forests tend to be multi-generational, with old-growth conditions lasting several centuries in the absence of anthropogenic disturbance (Frelich, 1995). In addition, the high degree of compositional stability of this forest type (Curtis, 1959) allows for ample opportunity for competitive interactions between dominant species to influence the patch structure of the landscape (Frelich et al., 1993). Studying old-growth hemlock-hardwood forest in the Sylvania Wilderness of the western Upper Peninsula, Frelich et al. (1993) concluded that hemlock and sugar maple exhibit strong positive self-association and negative reciprocal association. Each species alters their local environment, creating conditions in their immediate vicinity that favors self-recruitment and discourages establishment of seedlings of the other dominant. Sugar maple is disadvantaged by the dense shade and low nutrient conditions in the podzolized understory of hemlock-dominated stands. In sugar maple-dominated stands, hemlock seedlings are unable to penetrate the thick coarse duff and are often smothered by the ubiquitous leaf fall of sugar maple.

Vegetation Description: The mesic northern forest is a broadly defined community type with numerous regional, physiographic and edaphic variations. The following tolerant trees can dominate or co-dominate the canopy of this community*: Acer saccharum* (sugar maple), *Tsuga canadensis* (eastern hemlock), *Fagus grandifolia* (American beech) and *Betula alleghaniensis* (yellow birch). Other important components of the canopy include: *Tilia americana* (American basswood), *Pinus strobus* (white pine), *Quercus rubra* (red oak), *Thuja occidentalis* (white cedar*), Acer rubrum* (red maple), *Betula papyrifera* (paper or white birch) and *Fraxinus americana* (white ash). Tree species associated with this community but most commonly found in the sub-canopy include: *Ostrya virginiana* (ironwood or hop-hornbeam), *Ulmus americana* (American elm) and *Abies balsamea* (balsam fir).

In terms of their relative importance as arboreal components in the mesic northern forest, these trees differ greatly among themselves in different parts of the region and locally within the same region (Nichols, 1935). Significant variation in composition of communities is proportional to marked differences in local topography, soil, disturbance factors, geographic context (Barnes, 1991) and biotic factors such as competitive interactions (Frelich et al., 1993) and browsing pressure (Alverson et al., 1988).

The leading dominant of this community is sugar maple (Curtis, 1959) which thrives on moderately well drained to excessively drained deep soils (Pregitzer, 1981). Sugar maple is typically found in association with beech, basswood, yellow birch, and red oak. Basswood, characteristic on nutrient rich sites, is most prevalent in mixed-hardwood stands in the western Upper Peninsula. In a study in the McCormick Experimental Forest in the western Upper Peninsula, Pregitzer (1981) found that when ground water or bedrock influences the rooting zone, the proportion of conifers and hardwoods other than sugar maple increases. In the northern Lower Peninsula and in the eastern Upper Peninsula, sugar maple and beech occur commonly as co-dominants, frequently thriving on heavy-textured soils such as silt loam and clay loam. The absence of beech in the western Upper Peninsula is probably due to the increased dryness, shorter growing seasons and extreme minimum winter temperatures of this region (Barnes, 1991).

Conifer-dominated mesic northern forests usually have hemlock and yellow birch as the primary canopy components. Often present in these stands are white cedar and large, but widely spaced white pine, relicts of an earlier successional stage generated by forest fire and/or windthrow (Nichols, 1935). The conifer-dominated stands are generally found on moist or poorly drained sites. Mixed stands of hemlock and yellow birch or pure stands of yellow birch occur primarily in depressions or sites adjacent to swamps (Barnes, 1991).

The ground and shrub layer of mesic northern forests, like the overstory, is diverse in compositional variation. Communities of beech and sugar maple have relatively few shrubs but do support many spring ephemerals and perennial herbs. Stands composed of mixed hardwoods tend to have a well-developed shrub layer and a fairly diverse groundlayer. A plethora of spring ephemeral herbs in these assemblages can be attributed to the development of moisture holding and nutrient-rich soils. Sugar maple, yellow birch and basswood enhance the soil with their nutrient rich leaf-fall. In contrast, in hemlock-dominated stands, groundlayer diversity is low due to the nutrient-poor and acidic mor humus as well as the low understory light intensity caused by the perpetually dense hemlock canopy (Curtis, 1959).

Photo by Joshua G. Cohen

Nurse logs provide critical substrate for seedling establishment.

Prevalent herbs of the mesic northern forest include: *Actaea pachypoda* (white baneberry), *Actaea rubra* (red baneberry), *Allium tricoccum* (wild leek), *Aralia nudicaulis* (wild sarsaparilla), *Aralia racemosa* (spikenard), *Arisaema triphyllum* (jack-in-the-pulpit), *Carex deweyana, Carex hirtifolia, Carex leptonervia, Carex plantaginea, Carex woodii, Caulophyllum thalictroides* (blue cohosh), *Circaea alpina* (enchanter's nightshade), *Circaea lutetiana* (enchanter's nightshade), *Clintonia borealis* (blue-bead lily), *Cornus canadensis* (bunchberry), *Galium triflorum* (bedstraw), *Maianthemum canadense* (Canada mayflower), *Mitchella repens* (partridge berry), *Osmorhiza claytoni* (sweet cicely), *Polygonatum pubescens* (Solomon's seal), *Smilacina racemosa* (false spikenard), *Streptopus roseus* (twisted stalk), *Uvularia grandiflora* (bellwort), *Trientalis borealis* (star flower), *Trillium cernuum* (nodding trillium) and *Trillium grandiflorum* (common trillium).

Common ferns and clubmosses of this community include: *Adiantum pedatum* (maidenhair fern), *Athyrium filix-femina* (lady fern), *Athyrium thelypteroides* (silvery spleenwort), *Botrychium virginianum* (rattlesnake fern), *Dryopteris spinulosa* (spinulose woodfern), *Lycopodium annotinum* (stiff clubmoss), *Lycopodium lucidulum* (shining clubmoss) and *Lycopodium obscurum* (groundpine).

Characteristic shrubs include: *Acer pensylvanicum* (striped maple), *Acer spicatum* (mountain maple or moosewood), *Cornus alternifolia* (alternate-leaved dogwood), *Corylus cornuta* (beaked hazelnut), *Dirca palustris* (leatherwood), *Lonicera canadensis* (fly honeysuckle), *Ribes cynosbati* (wild gooseberry), *Sambucus pubens* (red elderberry), *Taxus canadensis* (Canada yew) and *Viburnum acerifolium* (maple-leaf viburnum). (Above species lists compiled from MNFI database and from Curtis, 1959; Gleason and Cronquist, 1964; and Nichols, 1935.)

A unique feature of this forest type is the presence of chlorophyll-free, parasitic and saprophytic seed plants such as: Indian pipes (*Monotropa* spp.), coral root orchids (*Corallorhiza* spp.) and beech drops (*Epifagus virginiana*) when beech is a component of the forest. These saprophytes are fed by the thick organic matter in the humus layer of the soil and are further benefited by the constant moisture supply (Curtis, 1959).

Michigan indicator species: *Aralia nudicaulis* (wild sarsaparilla), *Betula alleghaniensis* (yellow birch), *Botrychium virginianum* (rattlesnake fern), *Carex hirtifolia, Caulophyllum thalictroides* (blue cohosh), *Circaea alpina* (enchanter's nightshade), *Corylus cornuta* (beaked hazelnut), *Dirca palustris* (leatherwood), *Smilacina racemosa* (false spikenard), *Taxus canadensis* (Canada yew) and *Tsuga canadensis* (hemlock).

Other noteworthy species: Rare plants associated with mesic northern forests include: *Asplenium rhizophyllum* (walking fern, state threatened), *Asplenium scolopendrium* var. *americanum* (Hart's-tongue fern, state endangered), *Asplenium trichomanes-ramosum* (green spleenwort, state special concern), *Botrychium mormo* (goblin moonwort, state threatened), *Carex assiniboinensis* (Assiniboia sedge, state threatened), *Cystopteris laurentiana* (Laurentian fragile fern, state special concern), *Cystopteris tennesseensis* (Tennessee bladder fern, state threatened), *Dryopteris filix-mas* (male fern, state special concern), *Galium kamtschaticum* (bedstraw, state endangered), *Panax quinquefolius* (ginseng, state threatened), *Prosartes hookeri* (fairy bells, state), *Tipularia discolor* (cranefly orchid, state endangered), *Triphora trianthophora* (three-birds orchid, state threatened), and *Viola novae-angliae* (New England violet, state threatened).

Two rare raptor species frequently nest in mesic northern forests: *Buteo lineatus* (red-shouldered hawk, state threatened) and *Accipiter gentilis* (Northern goshawk, state special concern). Extensive tracts of mesic northern forest provide habitat for large mammals such as *Alces americanus* (moose, state special concern), *Canis lupus* (wolf, state threatened) and marten. This community provides summer nesting habitat for many neotropical migrants, especially interior forest obligates such as *Dendroica caerulescens* (black-throated blue warbler), *Dendroica cerulea* (cerulean warbler, state threatened), *Dendroica virens* (black-throated green warbler), *Piranga olivacea* (scarlet tanager) and *Seiurus aurocappilus* (ovenbird). Rapids clubtail (*Gomphus quadricolor*, state special concern) is a rare dragonfly that utilizes quiet water pools and cool rapid streams that flow through mesic northern forests.

Conservation/management: When the primary conservation objective is to maintain biodiversity in mesic northern forests, the best management is to leave large tracts unharvested and to allow natural processes (growth, senescence, windthrow, fire, disease, insect infestation, etc.) to operate unhindered. Lorimer and Frelich (1991) estimated the maximum size of an individual downburst in the Great Lakes region to be 3,785 ha. Given the large-scale of the catastrophic disturbance to the landscape, recovery from perturbation requires protection of substantial area of forest. Johnson and Van Wagner (1985) suggest that a landscape should be at least twice the size of the largest disturbance event.

When tracts of mesic northern forest are being managed for timber harvest, care should be taken to minimize fragmentation, preserve as much area as possible in a forested matrix and maintain a range of canopy closure comparable to pre-harvest closure. Animal species associated with vernal pools and the groundlayer plant community would benefit from winter harvests. Presently, commercial timber harvest is the most common disturbance occurring in this community. Given time to recuperate, mesic northern forests have shown a high degree of resilience following logging disturbance. Metzger and Schultz (1984) and Albert and Barnes (1987) found that 50 years after logging a well-developed herb layer persisted in the understory of harvested stands. Timber management practices that maintain or enhance characteristics of mature structure will help protect the biodiversity value of managed stands. Components of mature structure include: standing snags and dead and down woody material in various stages of decomposition and representing a diversity of species and diameter classes, a diversity of living tree species and an overstory dominated by large diameter trees but including individuals of all age classes.

Research needs: In 1931 George McIntire wrote the following: "Northern Hardwoods as a type has been considered justified because of long, wide and consistent use. This term certainly has been long and widely used but the most consistent thing about it has been the indefiniteness of its application. It is a convenient term but it means little unless accompanied by explicit description." McIntire's turn of the century criticism is still pertinent today and is applicable to the use of the phrase mesic northern forest. Misunderstanding and misuse of the term can be alleviated by the continued refinement of regional classifications that correlate species composition and landscape context.

Given the historical importance of catastrophic windthrow in this system, an important research question to be addressed is how the disturbance regime and species composition of this community will change as the Great Lakes region becomes increasingly fragmented. The prevalence of timber activity in this community demands increased post-harvest monitoring of rare species that depend on this forest and/or old growth conditions. Factors limiting hemlock and yellow birch regeneration need to be continually assessed and techniques for enhancing their regeneration need to be further explored.

Similar communities: mesic southern forest, dry-mesic northern forest, dry northern forest, hardwood-conifer swamp.

Other Classifications:

Michigan Natural Features Inventory Pre-settlement Vegetation (MNFI):
Beech-Sugar Maple-Hemlock, Hemlock-White Pine, Hemlock-Yellow Birch

Michigan Department of Natural Resources (MDNR): M-Northern Hardwoods, H-Hemlock

Michigan Resource Information Systems (MIRIS): 411 (Northern Hardwood), 41101-411109 (Undifferentiated Northern Hardwood), 41111-411119 (Sugar Maple), 41143-41149 (Beech), 41115 (Yellow Birch), 41179 (Basswood), 42 (Coniferous Forest),

The Nature Conservancy National Classification:
CODE; ALLIANCE; ASSOCIATION;
COMMON NAME

I.C.3.N.a; *Tsuga Canadensis-Betula alleghaniensis* Forest Alliance; *Tsuga canadensis-Acer saccahrum-Betula alleghaniensis* Forest; North Central Hemlock-Hardwood Forest.

I.C.3.N.a; *Tsuga Canadensis-Betula alleghaniensis* Forest Alliance; *Tsuga canadensis-Fagus grandifolia-(Acer saccharum)* Great Lakes Forest; Great Lakes Hemlock-Beech-Hardwood Forest.

I.A.8.N.c; *Tsuga Canadensis* Forest Alliance; *Tsuga Canadensis-(Betula alleghaniensis*) Forest; Hemlock Mesic Forest.

I.A.8.N.b; *Pinus strobus-Tsuga canadensis* Forest Alliance; *Pinus strobus-Tsuga canadensis* Great Lakes Forest; Great Lakes White Pine-Hemlock Forest.

I.B.2.N.a; *Acer saccharum-Betula alleghaniensis-(Fagus grandifolia)* Forest Alliance; *Acer saccharum-Betula alleghaniensis-(Tilia americana)* Forest; Maple-Yellow Birch Northern Hardwoods.

I.B.2.N.a; *Acer saccharum-Betula alleghaniensis-(Fagus grandifolia)* Forest Alliance; *Acer saccharum-Fagus grandifoli-Betula spp./Maianthemum canadense* Forest, Beech-Maple-Northern Hardwood Forest.

Related Abstracts: Assiniboia sedge, fairy bells, ginseng, goblin moonwort, Northern goshawk, rapids clubtail, red-shouldered hawk, mesic southern forest, dry-mesic northern forest, dry northern forest, hardwood-conifer swamp.

Selected References:

Albert, D.A. 1995. Regional landscape ecosystems of Michigan, Minnesota, and Wisconsin: A working map and classification. Gen. Tech. Rep. NC-178. St. Paul, MN: USDA, Forest Service, North Central Forest Experiment Station, St. Paul, MN. http://nrs.fs.fed.us/pubs/242 (Version 03JUN1998). 250 pp.

Albert, D.A., J.G. Cohen, M.A. Kost, B.S. Slaughter, and H.D. Enander. 2008. Distribution maps of Michigan's Natural Communities. Michigan Natural Features Inventory, Report No. 2008-01, Lansing, MI. 174 pp.

Albert, D.A. and B.V. Barnes. 1987. Effects of clearcutting on the vegetation and soil of a sugar maple-dominated ecosystem, Western Upper Michigan. Forest Ecology and Management 18: 283-298.

Albert, D.A., S.R. Denton and B.V. Barnes. 1986. Regional landscape ecosystems of Michigan. Ann Arbor, MI: University of Michigan, School of Natural Resources. 32pp & map.

Alverson, S. A., D.M. Waller and S.L. Solheim. 1988. Forests too deer: edge effects in Northern Wisconsin. Conservation Biology 2(4): 348-358.

Barnes, B.V. 1991. Deciduous forests of North America. Pp 219-344 in E. Röhrig and B. Ulrich (eds.) Ecosystems of the World 7: Temperate Deciduous Forests. Elsevier, Amsterdam.

Barnes, B.V., K.S. Pregitzer, T.A. Spies and V. H. Spooner. 1982. Ecological forest site classification. Journal of Forestry 80(8): 493-498.

Canham, C.D. and O.L. Loucks. 1984. Catastrophic windthrow in the presettlement forests of Wisconsin. Ecology 65(3): 803-809.

Comer, P.J., D.A. Albert, H.A. Wells, B.L. Hart, J.B. Raab, D.L. Price, D.M. Kashian, R.A. Corner and D.W. Schuen. 1995. Michigan's Presettlement Vegetation, as Interpreted from the General Land Office Surveys 1816-1856. Michigan Natural Features Inventory, Lansing MI. (digital map)

Curtis, J.T. 1959. Vegetation of Wisconsin: An Ordination of Plant Communities. University. of Wisconsin Press, Madison, WI. 657 pp.

Davis, M.B. 1981. Quaternary history and the stability of forest communities. Pp. 132-153 in D.C. West, H.H. Shugart and D.B. Botkin (eds.) Forest Succession. Springer-Verlag, New York.

Frelich, L.E. 1995. Old forests in the Lake States today and before European settlement. Natural Areas Journal 15(2): 157-167.

Frelich, L.E., R.R. Calcote, M.B. Davis and J. Pastor. 1993. Patch formation and maintenance in an old-growth hemlock-hardwood forest. Ecology 4(2): 513-527.

Frelich, L.E. and C.G. Lorimer. 1991. Natural disturbance regimes in hemlock-hardwood forests of the Upper Great Lakes region. Ecological Monographs 61(2): 145-164.

Gleason, H.A and A. Cronquist. 1964. The natural geography of plants. Columbia University Press, New York. 416 pp.

Graham, S.A. 1941. Climax forests of the Upper Peninsula of Michigan. Ecology 22(4): 355-362.2265 and 42268-42269 (Hemlock).

Hix, D.M. and B.V. Barnes. 1984. Effects of clear-cutting on the vegetation and soil of an eastern hemlock dominated ecosystem, western Upper Michigan. Canadian Journal of Forest Research 14: 914-923.

Johnson, E.A. and C.E. Van Wagner. 1985. The theory and use of two fire history models. Canadian Journal of Forest Research 15: 214-220.

Kost, M.A., D.A. Albert, J.G. Cohen, B.S. Slaughter, R.K. Schillo, C.R. Weber, and K.A. Chapman. 2007. Natural communities of Michigan: Classification and Description. Michigan Natural Features Inventory, Report Number 2007-21, Lansing, MI. 314 pp.

Marks, P.L. and S. Gardescu. 1998. A case study of sugar maple (*Acer saccharum*) as a forest seedling bank species. Journal of the Torrey Botanical Society 125(4): 287-296.

McIntire, G.S. 1931. Theory and practice of forest typing with special relation to the hardwood and hemlock association of Northern Michigan. Michigan Academy of Science Arts and Letters 15: 239-251.

Metzger, F. and J. Schultz. 1984. Understory response to 50 years of management of a northern hardwood forest in Upper Michigan. American Midland Naturalist 112(2): 209-223.

Minnesota DNR- Natural Heritage Program (MNDNR). 1993. Minnesota's native vegetation: a key to natural communities, Version 1.5. St. Paul, MN. 110 pp.

Mladenoff, D.J. and F. Stearns. 1993. Eastern hemlock regeneration and deer browsing in the Northern Great Lakes region: a re-examination and model simulation. Conservation Biology 7(4): 889-900.

Nichols, G.E. 1935. The hemlock-white pine-northern hardwood region of Eastern North America. Ecology 6: 403-422.

Noss, R.F., E.T.L. LaRoe and J.M. Scott. 1995. Endangered ecosystems of the United States: A preliminary assessment of loss and degradation. Washington, DC, National Biological Service, U.S. Dept. of the Interior.

Pregitzer, K.S. 1981. Relationships among physiography, soils and vegetation of the McCormick experimental forest, Upper Michigan Ann Arbor, MI: University of Michigan. 205 pp. Ph.D. dissertation.

Rogers, R. S. 1978. Forests dominated by hemlock (Tsuga canadensis): distribution as related to site and postsettlement history. Can. J. Bot. 56: 843-854.

Rooney, T.P. and D.M. Waller. 1998. Local and regional variation in hemlock seedling establishment in forests of the upper Great Lakes region, USA. Forest Ecology and Management 111; 211-224.

Runkle, J. R. 1982. Patterns of disturbance in some old-growth mesic forests of Eastern North America. Ecology 63(5): 1533-1546.

Stearns, F.W. 1949. Ninety years change in a northern hardwood forest in Wisconsin. Ecology 30(3): 350-358.

Simpson, T.B., P.E. Stuart and B.V. Barnes. 1990. Landscape ecosystems and cover types of the reserve area and adjacent lands of the Huron Mountain Club. Occasional papers of the Huron Mountain Wildlife Foundation 4: 128.

Spies, T.A. and B.V. Barnes. 1985. A multifactor ecological classification of the northern hardwood and conifer ecosystems of Sylvania Recreation Area, Upper Peninsula , Michigan. Canadian Journal of Forest Research 15: 949-960.

Waller, D.M., W.S. Alverson and S. Solheim. Local and regional factors influencing the regeneration of eastern hemlock. Hemlock Symposium Proceedings. 73-90.

Whitney, G.C. 1986. Relation of Michigan's presettlement pine forest to substrate and disturbance history. Ecology 67(6): 1548-1559.

Whitney, G. C. 1987. An ecological history of the Great Lakes forest of Michigan. Journal of Ecology 75: 667-684.

Zhang, Q., Pregitzer K.S. and D.D. Reed. 2000. Historical changes in the forests of the Luce district of the Upper Peninsula of Michigan. Am. Midl. Nat. 143: 94-110.

Abstract Citation:

Cohen, J.G. 2000. Natural community abstract for mesic northern forest. Michigan Natural Features Inventory, Lansing, MI. 9 pp.

Photo by Michael A. Kost

Old-growth mesic northern forest, Porcupine Mountains.

Update June 2010.

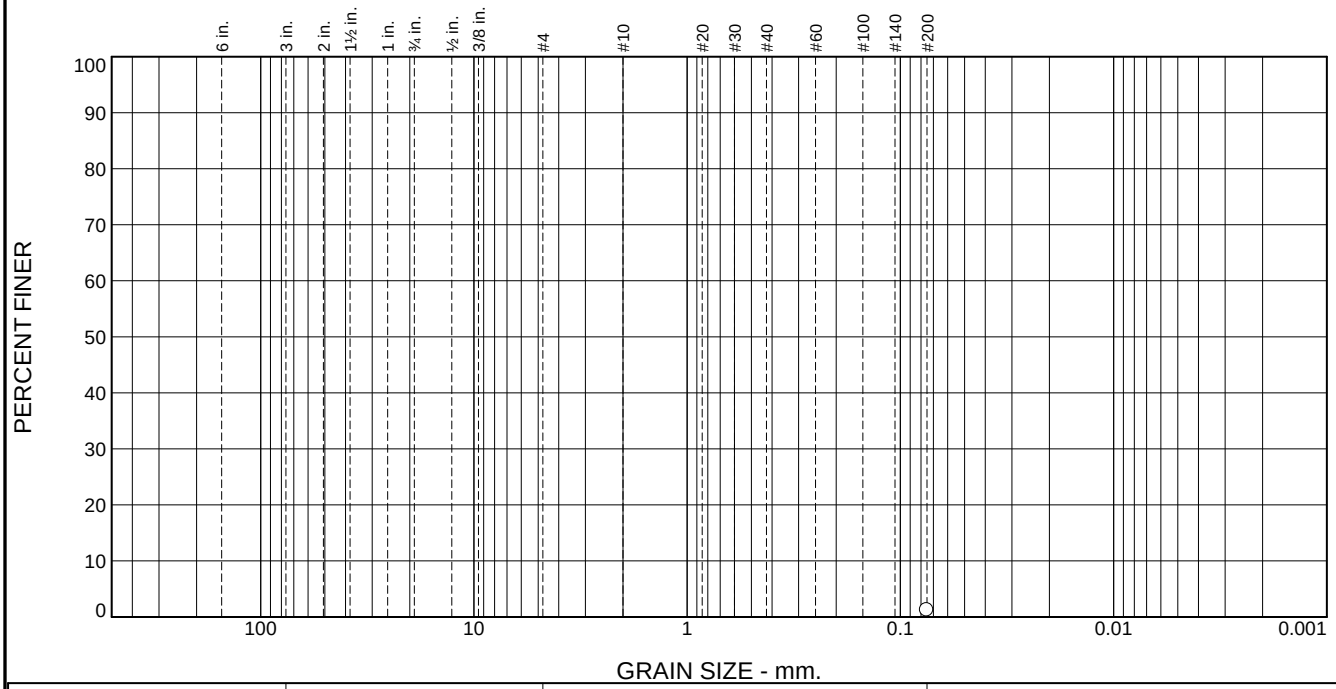
Copyright 2004 Michigan State University Board of Trustees.

Michigan State University is an affirmative-action, equal-opportunity organization.

Funding for abstract provided by Michigan Department of Natural Resources-Forest Management Division and Wildlife Division.

Appendix D- Sediment Analysis Laboratory Results

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						1	

TEST RESULTS

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
#200	1.2		

* (no specification provided)

Material Description

Sediment 1

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= SP **AASHTO (M 145)=** NA

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Remarks

Performed loss by wash (ASTM C117).
Moisture content: 31.3%
Sand content is greater than 90%.

Date Received: 7/7/2022 **Date Tested:** 7/20/2022

Tested By: Sarah Synnestvedt

Checked By: Chris Abraham, PE

Title: QA Manager

Location: On Site
Sample Number: S-1 **Depth:** -

Date Sampled: 7/7/2022

GEI Consultants of Michigan, P.C.

Marquette, Michigan

Client: West Michigan Shoreline Regional Development Commission
Project: Stony Creek

Project No: 2200483 **Figure**

GRAIN SIZE DISTRIBUTION TEST DATA

7/21/2022

Client: West Michigan Shoreline Regional Development Commission
Project: Stony Creek
Project Number: 2200483
Location: On Site
Depth: -
Sample Number: S-1
Material Description: Sediment 1
Sample Date: 7/7/2022
Date Received: 7/7/2022 **PL:** NP **LL:** NV **PI:** NP
USCS Classification: SP **AASHTO Classification:** NA
#200 Wash Method: ASTM C 117
Testing Remarks: Performed loss by wash (ASTM C117).
Moisture content: 31.3%
Sand content is greater than 90%.
Tested By: Sarah Synnestvedt **Test Date:** 7/20/2022
Checked By: Chris Abraham, PE **Title:** QA Manager

Sieve Test Data

Post #200 Wash Test Weights (grams): **Dry Sample and Tare =** 805.60
Tare Wt. = 385.30
Minus #200 from wash = 1.2%

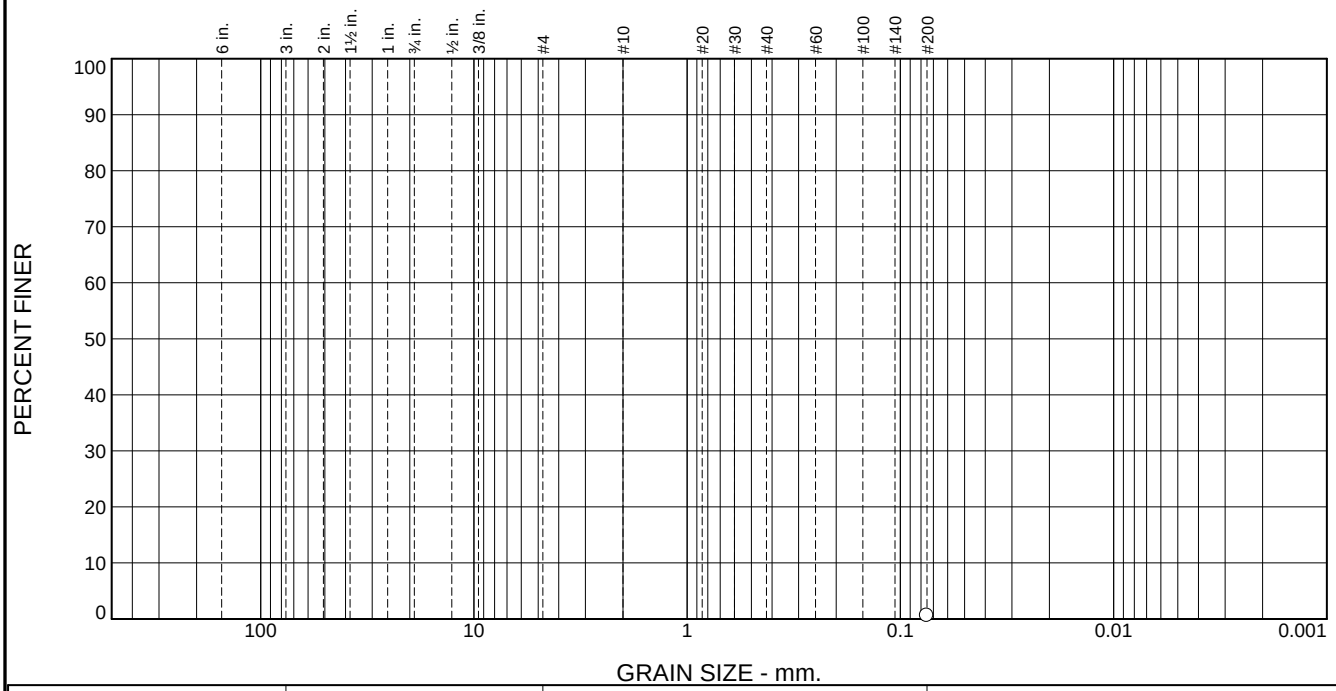
Dry Sample and Tare (grams)	Tare (grams)	Sieve Opening Size	Weight Retained (grams)	Sieve Weight (grams)	Percent Finer
810.80	385.30				

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
										1

D_5	D_{10}	D_{15}	D_{20}	D_{30}	D_{40}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						1	

TEST RESULTS

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
#200	0.6		

* (no specification provided)

Material Description

Sediment 2

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= SP **AASHTO (M 145)=** NA

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Remarks

Performed loss by wash (ASTM C117).
Moisture content: 28.4%
Sand content is greater than 90%.

Date Received: 7/7/2022 **Date Tested:** 7/20/2022

Tested By: Sarah Synnestvedt

Checked By: Chris Abraham, PE

Title: QA Manager

Location: On Site **Date Sampled:** 7/7/2022
Sample Number: S-2 **Depth:** -

GEI Consultants of Michigan, P.C.

Marquette, Michigan

Client: West Michigan Shoreline Regional Development Commission
Project: Stony Creek

Project No: 2200483 **Figure**

GRAIN SIZE DISTRIBUTION TEST DATA

7/21/2022

Client: West Michigan Shoreline Regional Development Commission
Project: Stony Creek
Project Number: 2200483
Location: On Site
Depth: -
Sample Number: S-2
Material Description: Sediment 2
Sample Date: 7/7/2022
Date Received: 7/7/2022 **PL:** NP **LL:** NV **PI:** NP
USCS Classification: SP **AASHTO Classification:** NA
#200 Wash Method: ASTM C 117
Testing Remarks: Performed loss by wash (ASTM C117).
Moisture content: 28.4%
Sand content is greater than 90%.
Tested By: Sarah Synnestvedt **Test Date:** 7/20/2022
Checked By: Chris Abraham, PE **Title:** QA Manager

Sieve Test Data

Post #200 Wash Test Weights (grams): **Dry Sample and Tare =** 831.50
Tare Wt. = 369.90
Minus #200 from wash = 0.6%

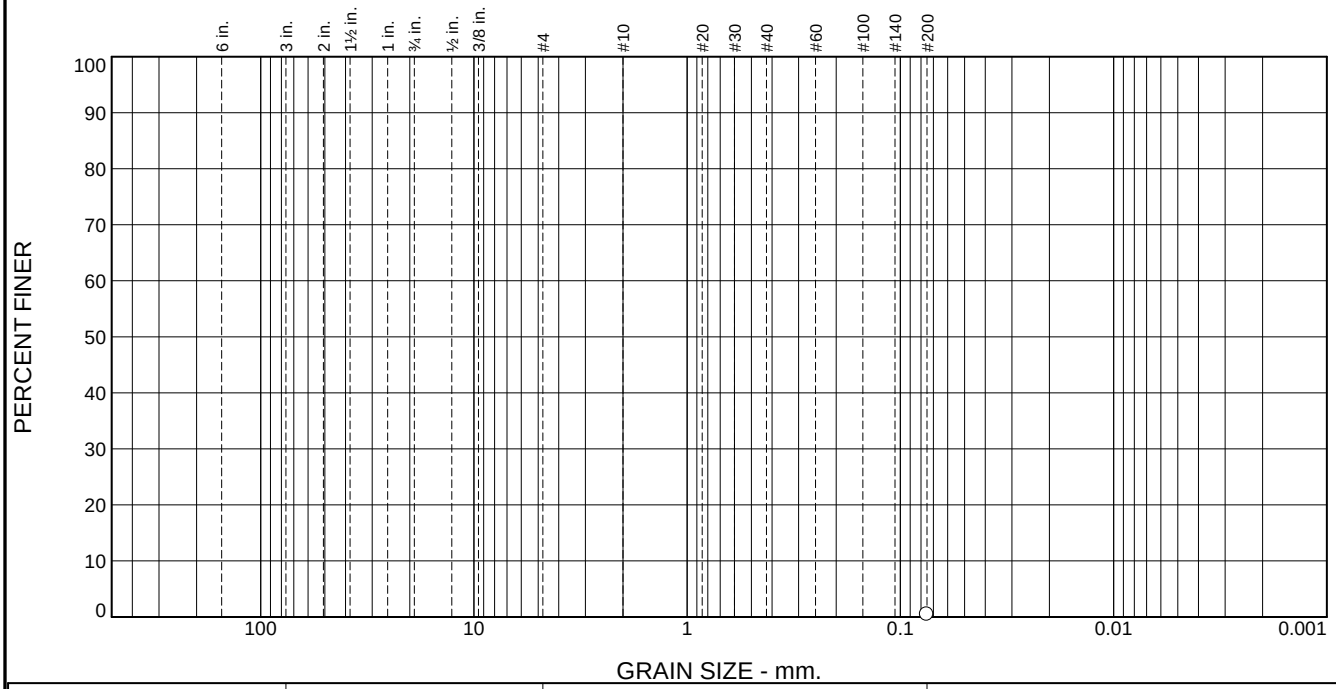
Dry Sample and Tare (grams)	Tare (grams)	Sieve Opening Size	Weight Retained (grams)	Sieve Weight (grams)	Percent Finer
834.30	369.90				

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
										1

D_5	D_{10}	D_{15}	D_{20}	D_{30}	D_{40}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						0	

TEST RESULTS

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
#200	0.5		

* (no specification provided)

Material Description

Sediment 3

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= SP **AASHTO (M 145)=** NA

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Remarks

Performed loss by wash (ASTM C117)
Moisture content: 25.7%
Sand content is greater than 90%.

Date Received: 7/7/2022 **Date Tested:** 7/20/2022

Tested By: Sarah Synnestvedt

Checked By: Chris Abraham, PE

Title: QA Manager

Location: On Site
Sample Number: S-3 **Depth:** -

Date Sampled: 7/7/2022

GEI Consultants of Michigan, P.C.

Marquette, Michigan

Client: West Michigan Shoreline Regional Development Commission
Project: Stony Creek

Project No: 2200483 **Figure**

GRAIN SIZE DISTRIBUTION TEST DATA

7/21/2022

Client: West Michigan Shoreline Regional Development Commission
Project: Stony Creek
Project Number: 2200483
Location: On Site
Depth: -
Sample Number: S-3
Material Description: Sediment 3
Sample Date: 7/7/2022
Date Received: 7/7/2022 **PL:** NP **LL:** NV **PI:** NP
USCS Classification: SP **AASHTO Classification:** NA
#200 Wash Method: ASTM C 117
Testing Remarks: Performed loss by wash (ASTM C117)
Moisture content: 25.7%
Sand content is greater than 90%.
Tested By: Sarah Synnestvedt **Test Date:** 7/20/2022
Checked By: Chris Abraham, PE **Title:** QA Manager

Sieve Test Data

Post #200 Wash Test Weights (grams): **Dry Sample and Tare =** 827.20
Tare Wt. = 384.80
Minus #200 from wash = 0.5%

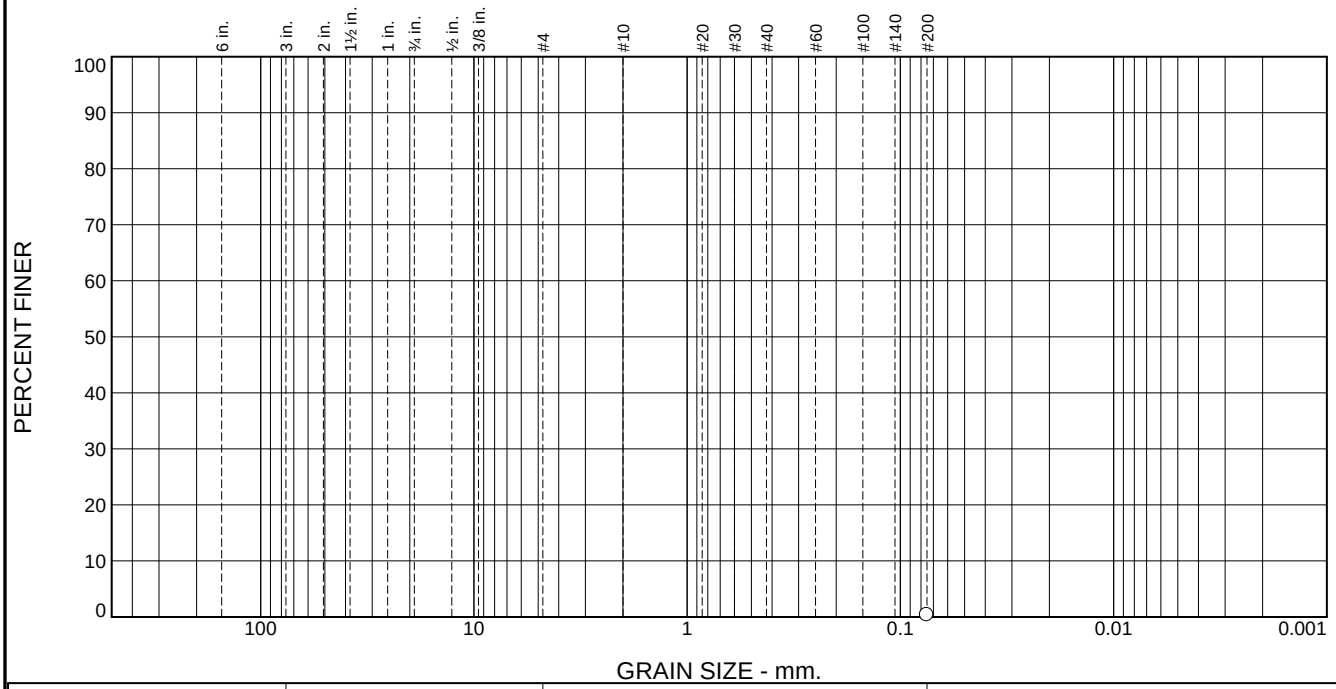
Dry Sample and Tare (grams)	Tare (grams)	Sieve Opening Size	Weight Retained (grams)	Sieve Weight (grams)	Percent Finer
829.20	384.80				

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
										0

D_5	D_{10}	D_{15}	D_{20}	D_{30}	D_{40}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						0	

TEST RESULTS

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
#200	0.3		

* (no specification provided)

Material Description

Sediment 4

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= SP **AASHTO (M 145)=** NA

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Remarks

Performed loss by wash (ASTM C117).
Moisture content: 25.2%
Sand content is greater than 90%.

Date Received: 7/7/2022 **Date Tested:** 7/20/2022

Tested By: Sarah Synnestvedt

Checked By: Chris Abraham, PE

Title: QA Manager

Location: On Site
Sample Number: S-4 **Depth:** -

Date Sampled: 7/7/2022

GEI Consultants of Michigan, P.C.

Marquette, Michigan

Client: West Michigan Shoreline Regional Development Commission
Project: Stony Creek

Project No: 2200483 **Figure**

GRAIN SIZE DISTRIBUTION TEST DATA

7/21/2022

Client: West Michigan Shoreline Regional Development Commission
Project: Stony Creek
Project Number: 2200483
Location: On Site
Depth: -
Sample Number: S-4
Material Description: Sediment 4
Sample Date: 7/7/2022
Date Received: 7/7/2022 **PL:** NP **LL:** NV **PI:** NP
USCS Classification: SP **AASHTO Classification:** NA
#200 Wash Method: ASTM C 117
Testing Remarks: Performed loss by wash (ASTM C117).
Moisture content: 25.2%
Sand content is greater than 90%.
Tested By: Sarah Synnestvedt **Test Date:** 7/20/2022
Checked By: Chris Abraham, PE **Title:** QA Manager

Sieve Test Data

Post #200 Wash Test Weights (grams): **Dry Sample and Tare =** 836.20
Tare Wt. = 384.40
Minus #200 from wash = 0.3%

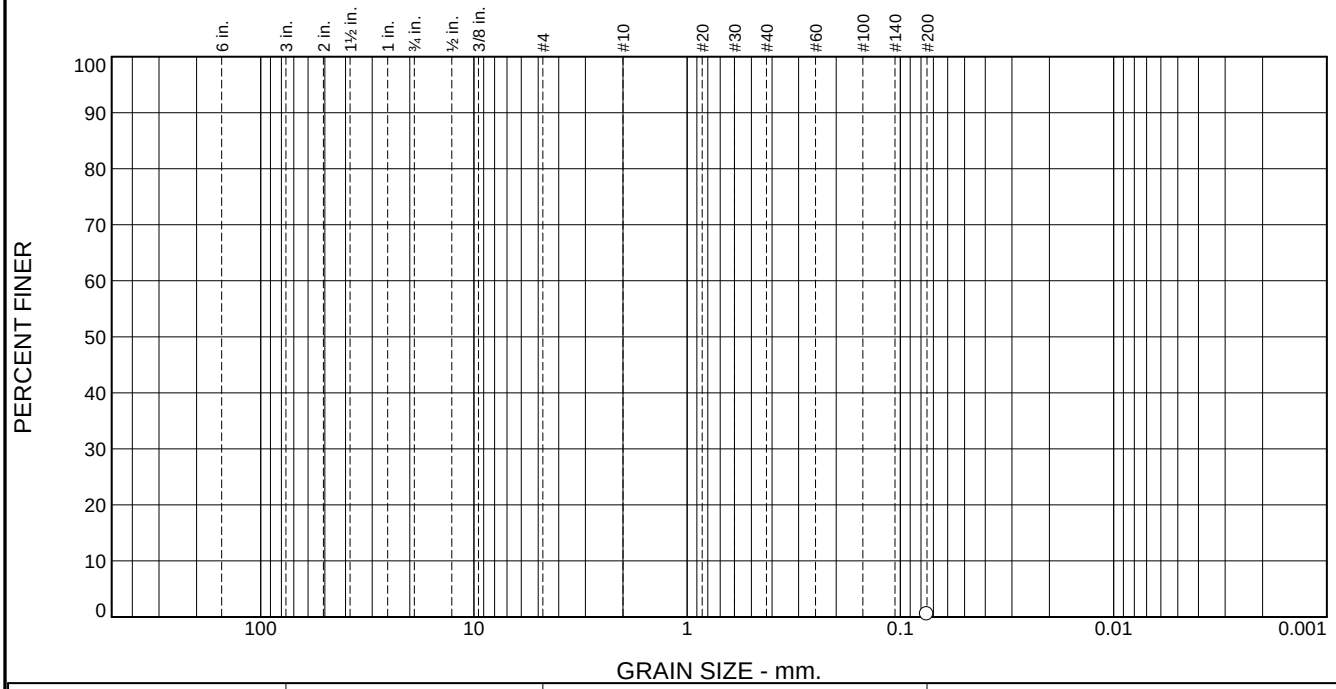
Dry Sample and Tare (grams)	Tare (grams)	Sieve Opening Size	Weight Retained (grams)	Sieve Weight (grams)	Percent Finer
837.70	384.40				

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
										0

D_5	D_{10}	D_{15}	D_{20}	D_{30}	D_{40}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						0	

TEST RESULTS

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
#200	0.5		

* (no specification provided)

Material Description

Sediment 5

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= SP **AASHTO (M 145)=** NA

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Remarks

Performed loss by wash (ASTM C117).
Moisture content: 24.3%
Sand content is greater than 90%.

Date Received: 7/7/2022 **Date Tested:** 7/20/2022

Tested By: Sarah Synnestvedt

Checked By: Chris Abraham, PE

Title: QA Manager

Location: On Site
Sample Number: S-5 **Depth:** -

Date Sampled: 7/7/2022

GEI Consultants of Michigan, P.C.

Marquette, Michigan

Client: West Michigan Shoreline Regional Development Commission
Project: Stony Creek

Project No: 2200483 **Figure**

GRAIN SIZE DISTRIBUTION TEST DATA

7/21/2022

Client: West Michigan Shoreline Regional Development Commission
Project: Stony Creek
Project Number: 2200483
Location: On Site
Depth: -
Sample Number: S-5
Material Description: Sediment 5
Sample Date: 7/7/2022
Date Received: 7/7/2022 **PL:** NP **LL:** NV **PI:** NP
USCS Classification: SP **AASHTO Classification:** NA
#200 Wash Method: ASTM C 117
Testing Remarks: Performed loss by wash (ASTM C117).
Moisture content: 24.3%
Sand content is greater than 90%.
Tested By: Sarah Synnestvedt **Test Date:** 7/20/2022
Checked By: Chris Abraham, PE **Title:** QA Manager

Sieve Test Data

Post #200 Wash Test Weights (grams): **Dry Sample and Tare =** 856.70
Tare Wt. = 370.90
Minus #200 from wash = 0.5%

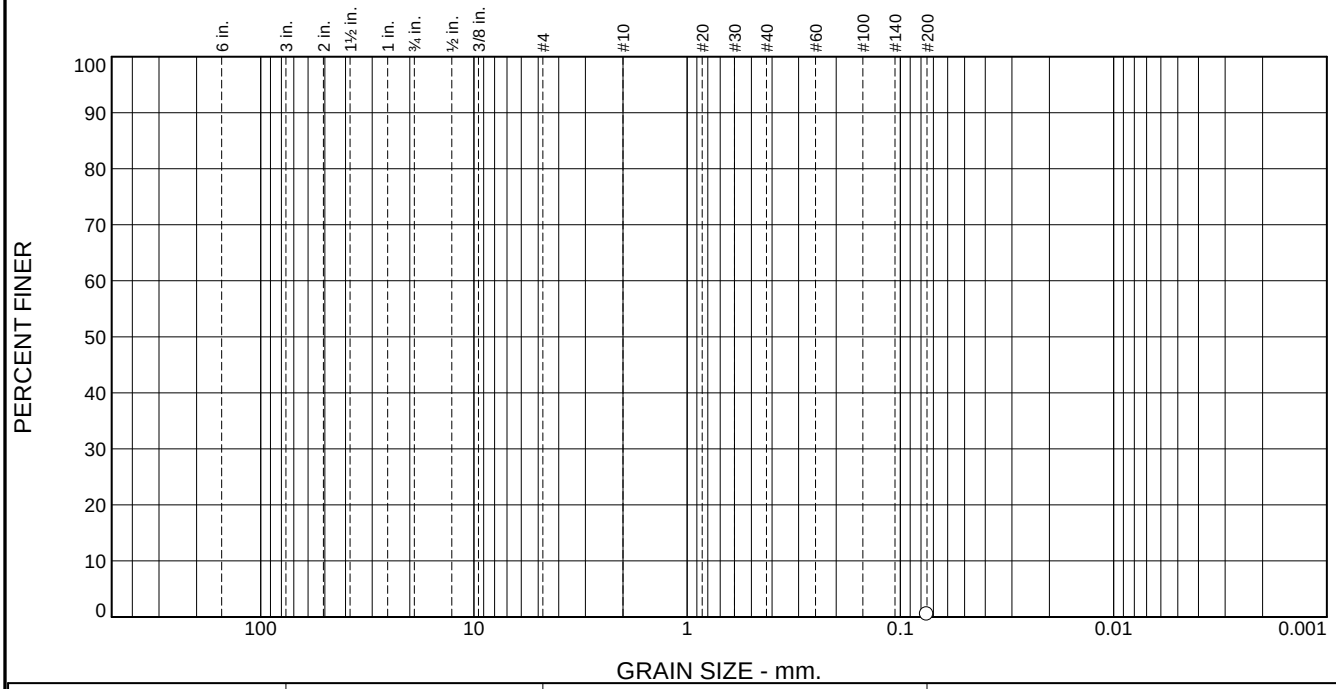
Dry Sample and Tare (grams)	Tare (grams)	Sieve Opening Size	Weight Retained (grams)	Sieve Weight (grams)	Percent Finer
859.00	370.90				

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
										0

D_5	D_{10}	D_{15}	D_{20}	D_{30}	D_{40}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						0	

TEST RESULTS

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
#200	0.5		

* (no specification provided)

Material Description

Sediment 6

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= SP **AASHTO (M 145)=** NA

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Remarks

Performed loss by wash (ASTM C117).
Moisture content: 29.9%
Sand content is greater than 90%.

Date Received: 7/7/2022 **Date Tested:** 7/20/2022

Tested By: Sarah Synnestvedt

Checked By: Chris Abraham, PE

Title: QA Manager

Location: On Site **Date Sampled:** 7/7/2022
Sample Number: S-6 **Depth:** -

GEI Consultants of Michigan, P.C.

Marquette, Michigan

Client: West Michigan Shoreline Regional Development Commission
Project: Stony Creek

Project No: 2200483 **Figure**

GRAIN SIZE DISTRIBUTION TEST DATA

7/21/2022

Client: West Michigan Shoreline Regional Development Commission
Project: Stony Creek
Project Number: 2200483
Location: On Site
Depth: -
Sample Number: S-6
Material Description: Sediment 6
Sample Date: 7/7/2022
Date Received: 7/7/2022 **PL:** NP **LL:** NV **PI:** NP
USCS Classification: SP **AASHTO Classification:** NA
#200 Wash Method: ASTM C 117
Testing Remarks: Performed loss by wash (ASTM C117).
Moisture content: 29.9%
Sand content is greater than 90%.
Tested By: Sarah Synnestvedt **Test Date:** 7/20/2022
Checked By: Chris Abraham, PE **Title:** QA Manager

Sieve Test Data

Post #200 Wash Test Weights (grams): **Dry Sample and Tare =** 852.50
Tare Wt. = 383.80
Minus #200 from wash = 0.5%

Dry Sample and Tare (grams)	Tare (grams)	Sieve Opening Size	Weight Retained (grams)	Sieve Weight (grams)	Percent Finer
854.70	383.80				

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
										0

D_5	D_{10}	D_{15}	D_{20}	D_{30}	D_{40}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}

Appendix E- MiSQT Analysis

Version 1
Version Last Updated 18-Dec-20

Programmatic Goals

Select: Restoration

Reach Description

Project Name:	Stony Creek Dam Removal and Restoration
Reference No:	
Reach ID:	
Township:	Benona/14N
Range:	18W
Section:	26
Latitude (decimal degrees):	
Longitude (decimal degrees):	

Describe this reach and reach break criteria: The proposed reach includes the stretch of Stony Creek that extends approximately 2,500' upstream from Marshville Dam Road.

Stream Succession Scenario

Describe the rationale used to select the stream succession scenario and which stage of the scenario the reach is currently in:

Restoration Approach

Expand on the programmatic goals of this project (For example, if the programmatic goal is to offset on-site impacts by generating mitigation credits, then provide the type and number of credits needed): The project is funded with federal and state dollars with the intent of removing the existing Marshville Dam and restoring the upstream portion of Stony Creek.

Explain the restoration potential of this project based on the programmatic goals: The proejct has high restoration potential due to the available funding and existing condition of impacted creek.

Explain the goals and objectives for this project:

Goals: 1. Remove dam. 2) Restore approximately 2,500' of Stony Creek

Objectives:

Insert Aerial Photo of Project Reach

CATCHMENT ASSESSMENT FORM

Reach ID(s):

Overall Catchment Condition	**Good (G)**
Restoration Potential	**Partial Restoration**

Purpose: This form is used to determine the project's restoration potential.

CATCHMENT ASSESSMENT

	Categories	Description of Catchment Condition			Rating (P/F/G)
		Poor	Fair	Good	
1	Concentrated Flow (Hydrology)	Potential for concentrated flow/impairments immediately upstream of the project and no treatments are in place.	Some potential for concentrated flow/impairments to reach restoration site, however, measures are in place to protect resources.	No potential for concentrated flow/impairments from adjacent land use.	F
2	Impervious cover (Hydrology)	Greater than 25%	Between 10% and 25%	Less than 10%	G
3	Land Use Change (Hydrology)	Rapidly urbanizing/urban	Single family homes/suburban	Rural communities/slow growth or primarily forested	G
4	Distance to Roads (Hydrology)	Roads located in or adjacent to project reach and/or road expansion proposed in 10 year plans.	No roads in or adjacent to project reach. No more than one road expansion proposed in 10 year plans.	No roads in or adjacent to project reach. No proposed road expansion in 10 year plans.	P
5	Percent Forested (Hydrology)	≤ 20%	>20% and <70%	≥ 70%	F
6	Flashiness Index (Hydrology)	RBI <25% quartile value or >75% quartile value.	RBI declining over time and approaching 25% quartile value, or increasing and approaching the 75% quartile value.	RBI ≥ 25% quartile value and ≤75% quartile value.	G
7	Riparian Vegetation (Geomorphology)	<50% of contributing stream length has >25 ft corridor width.	50-80% of contributing stream length has >25 ft corridor width.	>80% of contributing stream length has >25 ft corridor width.	G
8	Sediment Supply (Geomorphology)	High sediment supply from upstream bank erosion and surface runoff.	Moderate sediment supply from upstream bank erosion and surface runoff.	Low sediment supply. Upstream bank erosion and surface runoff is minimal.	G
9	Michigan Integrated Report (305(b) and 303(d)) designated use support status *(Note: impairments with atmospheric deposition as a source should be excluded*)*	On or immediately upstream or downstream of a waterbody in Category 5 OR in Category 4c (i.e., designated use impairment not actively being mitigated).	On or immediately upstream or downstream of a waterbody in Category 4a or 4b (i.e., active mitigation of designated use impairment through approved TMDL or other control mechanisms).	No adjacent waterbodies listed as not supporting a designated use (i.e., all designated uses either unassessed or in Category 1, 2, or 3).	G
10	Agricultural Land Use (Physicochemical)	Livestock access to stream and/or intensive cropland immediately upstream of project reach.	Livestock access to stream and/or intensive cropland upstream of project reach. A sufficient reach of stream is between Ag. land use and project reach.	There is little to no agricultural land uses or the livestock or cropland is far enough away from project reach to cause no impact to water quality or biology.	G
11	Inline Watershed Impoundments (Biology)	Impoundment(s) has a negative effect on project area and fish passage	Impoundment(s) might/suspected to have a negative effect on project area and fish passage.	No impoundment upstream or downstream of project area.	P
12	Organism Recruitment (Biology)	Channel immediately upstream or downstream of project reach is concrete, piped, or hardened.	Channel immediately upstream or downstream of project reach has native bed and bank material, but is impaired.	Channel immediately upstream or downstream of project reach has native bed and bank material.	E
13	Other				

** Refer to user manual for more detail on atmospheric sources of impairment.*

Site Information and Reference Standard Stratification	
Project Name:	hy Creek Dam Removal and Restoration
Reach ID:	0
Restoration Potential:	Partial Restoration
Existing Stream Length (ft):	2800
Proposed Stream Length (ft):	2800
Existing Stream Type:	C
Proposed/ Reference Stream Type:	C
Valley Type:	Unconfined Alluvial
Drainage Area (sq. mi.):	
Strahler Stream Order:	
Flow Type:	Perennial
Ecoregion:	Southern Michigan/Northern Indiana Drift Plains
Bed Material:	Sand
Stream Slope (%):	0.1
Stream Temperature:	Coldwater
Wadeable/Non-wadeable:	Wadeable
Reference Vegetation Community:	Forested

Notes
1. Users input values that are highlighted based on restoration potential
2. Users select values from a pull-down menu
3. Leave values blank for field values that were not measured and/or autopopulate

FUNCTIONAL CHANGE SUMMARY	
Existing Condition Score (ECS)	0.40
Proposed Condition Score (PCS)	0.46
Change in Functional Condition (PCS - ECS)	0.06
Percent Condition Change	15%
Existing Stream Length (ft)	2800
Proposed Stream Length (ft)	2800
Additional Stream Length (ft)	0
Existing Functional Foot Score (FFS)	1120
Proposed Functional Foot Score (FFS)	1288
Proposed FFS - Existing FFS (ΔFF)	**168 PFALSE**
Yield (ΔFF/Proposed LF)	0.06

BMP FUNCTIONAL CHANGE SUMMARY	
Existing BMP Functional Feet Score (FFS)	0
Proposed BMP Functional Feet Score (FFS)	0
Proposed BMP FFS - Existing BMP FFS	0

FUNCTIONAL FEET (FF) SUMMARY	
Existing Stream FFS + Existing BMP FFS	1120
Proposed Stream FFS + Proposed BMP FFS	1288
Total Proposed FFS - Total Existing FFS	168
Yield (ΔFF/Proposed LF)	0.06

FUNCTION-BASED PARAMETER SUMMARY			
Functional Category	**Function-Based Parameters**	**Existing Parameter**	**Proposed Parameter**
Hydrology	Reach Runoff	0.71	0.71
Hydraulics	Floodplain Connectivity	0.86	1.00
Geomorphology	Large Woody Debris	0.07	0.31
	Lateral Migration	0.98	1.00
	Riparian Vegetation	0.35	0.67
	Bed Form Diversity	0.25	0.30
Physicochemical	Temperature		
	Bacteria		
	Nutrients		
	Dissolved Oxygen		
Biology	Macroinvertebrates		
	Fish		

FUNCTIONAL CATEGORY REPORT CARD			
Functional Category	**ECS**	**PCS**	**Functional Change**
Hydrology	0.71	0.71	0.00
Hydraulics	0.86	1.00	0.14
Geomorphology	0.41	0.57	0.16
Physicochemical			
Biology			

MiSQT v1
Quantification Tool

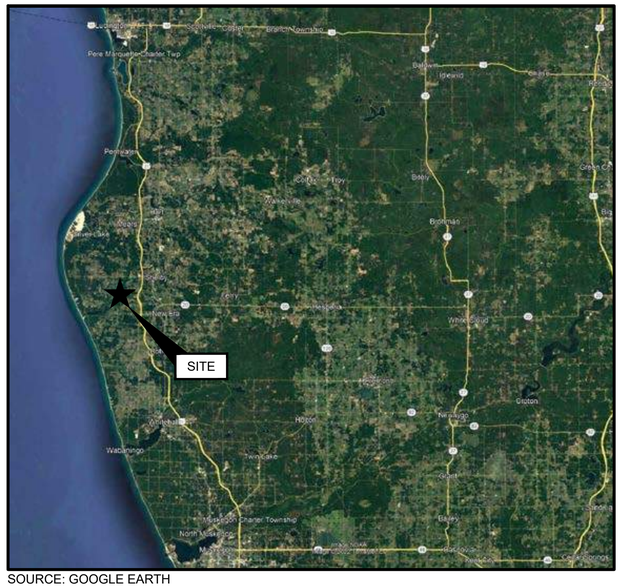
EXISTING CONDITION ASSESSMENT					Roll Up Scoring			
Functional Category	**Function-Based Parameters**	**Metric**	**Field Value**	**Index Value**	**Parameter**	**Category**	**Category**	**Overall**
Hydrology	Reach Runoff	Land Use Change Coefficient	52.96	0.72	0.71	0.71	Functioning	0.40
		Concentrated Flow Points (#/1000 LF)	1	0.70				
Hydraulics	Floodplain Connectivity	Bank Height Ratio	1.2	0.72	0.86	0.86	Functioning	
		Entrenchment Ratio	5	1.00				
Geomorphology	Large Woody Debris	LWD Index	139	0.07	0.07	0.41	Functioning At Risk	
	Lateral Migration	Dominant BEHI/NBS	L/L	1.00	0.98			
		Percent Streambank Erosion (%)	5	1.00				
		Percent Streambank Armoring (%)	2	0.93				
	Riparian Vegetation	Buffer Width (ft)	200	1.00	0.35			
		Average DBH (Inches)	2	0.17				
		Tree Density (#/Ac)	1	0.01				
		Native Shrub/Sapling Density (#/Ac)	20	0.20				
		Native Herbaceous Cover (%)	90	FALSE				
	Bed Form Diversity	Pool Spacing Ratio	10.5	0.00	0.25			
		Pool Depth Ratio	1	0.00				
		Percent Riffle (%)	70	0.75				
		Aggradation Ratio						
Physicochemical	Temperature	July Mean Temperature (°F)						
	Bacteria	E. Coli (cfu/100 ml)						
	Nutrients	Total Phosphorus (mcg/L)						
	Dissolved Oxygen	DO Concentration (mg/L)						
Biology	Macroinvertebrates	Macroinvertebrate P51 Index Score						
		Macroinvertebrate P22 Index Score						
	Fish	Fish P51 Index Score						

PROPOSED CONDITION ASSESSMENT					Roll Up Scoring			
Functional Category	**Function-Based Parameters**	**Metric**	**Field Value**	**Index Value**	**Parameter**	**Category**	**Category**	**Overall**
Hydrology	Reach Runoff	Land Use Change Coefficient	52.96	0.72	0.71	0.71	Functioning	0.46
		Concentrated Flow Points (#/1000 LF)	1	0.70				
Hydraulics	Floodplain Connectivity	Bank Height Ratio	1	1.00	1.00	1.00	Functioning	
		Entrenchment Ratio	5	1.00				
Geomorphology	Large Woody Debris	LWD Index	600	0.31	0.31	0.57	Functioning At Risk	
	Lateral Migration	Dominant BEHI/NBS	VL/VL	1.00	1.00			
		Percent Streambank Erosion (%)	0	1.00				
		Percent Streambank Armoring (%)	0	1.00				
	Riparian Vegetation	Buffer Width (ft)	200	1.00	0.67			
		Average DBH (Inches)	2	0.17				
		Tree Density (#/Ac)	440	0.50				
		Native Shrub/Sapling Density (#/Ac)	440	1.00				
		Native Herbaceous Cover (%)	90	FALSE				
	Bed Form Diversity	Pool Spacing Ratio	10.5	0.00	0.30			
		Pool Depth Ratio	1.3	0.15				
		Percent Riffle (%)	70	0.75				
		Aggradation Ratio						
Physicochemical	Temperature	July Mean Temperature (°F)						
	Bacteria	E. Coli (cfu/100 ml)						
	Nutrients	Total Phosphorus (mcg/L)						
	Dissolved Oxygen	DO Concentration (mg/L)						
Biology	Macroinvertebrates	Macroinvertebrate P51 Index Score						
		Macroinvertebrate P22 Index Score						
	Fish	Fish P51 Index Score						

Appendix F- 30% Design Set

MARSHVILLE DAM REMOVAL & STONY CREEK RESTORATION

30% Design
July, 2022



SOURCE: GOOGLE EARTH

VICINITY MAP
(NOT TO SCALE)

SOURCE: GOOGLE EARTH

LOCATION MAP
(NOT TO SCALE)

SHEET INDEX

SHEET NO.	DRAWING NO.	TITLE
1	G-1	COVER SHEET
2	C-1	EXISTING CONDITIONS
3	C-2	EXISTING CONDITIONS
4	C-3	EXISTING CONDITIONS
5	C-4	EXISTING CONDITIONS
6	C-5	EXISTING CONDITIONS
7	C-6	PROFILE
8	C-7	SECTIONS
9	C-8	SECTIONS
10	C-9	PROPOSED PLAN
11	C-10	PROPOSED PLAN
12	C-12	PROPOSED PLAN
13	C-13	PROPOSED PLAN: FISHING PIER
14	C-14	PROPOSED PROFILE
15	C-15	PROPOSED SECTIONS
16	D-1	DETAILS
17	D-2	OPEN SPAN BRIDGE DETAILS
18	D-3	OPEN SPAN BRIDGE DETAILS

PREPARED FOR:

West Michigan Shoreline Regional
Development Commission
316 Morris Avenue
Suite 340
Muskegon, MI 49440
(231)722-7878

Conservation Resource Alliance
10850 E Traverse Hwy #1180
Traverse City, MI 49684
(231) 948-6817

PREPARED BY:

GEI CONSULTANTS OF MICHIGAN, P.C.
5225 EDGEWATER DRIVE
ALLENDALE, MI 49401
(616)384-2710

GEI Consultants

30% DESIGN

THIS DOCUMENT, AND THE IDEAS AND DESIGNS INCORPORATED HEREIN, IS AN INSTRUMENT OF PROFESSIONAL SERVICE, IS THE PROPERTY OF GEI CONSULTANTS AND IS NOT TO BE USED, IN WHOLE OR IN PART, FOR ANY OTHER PROJECT WITHOUT THE WRITTEN AUTHORIZATION OF GEI CONSULTANTS.

GEI PROJECT NO. 2200272

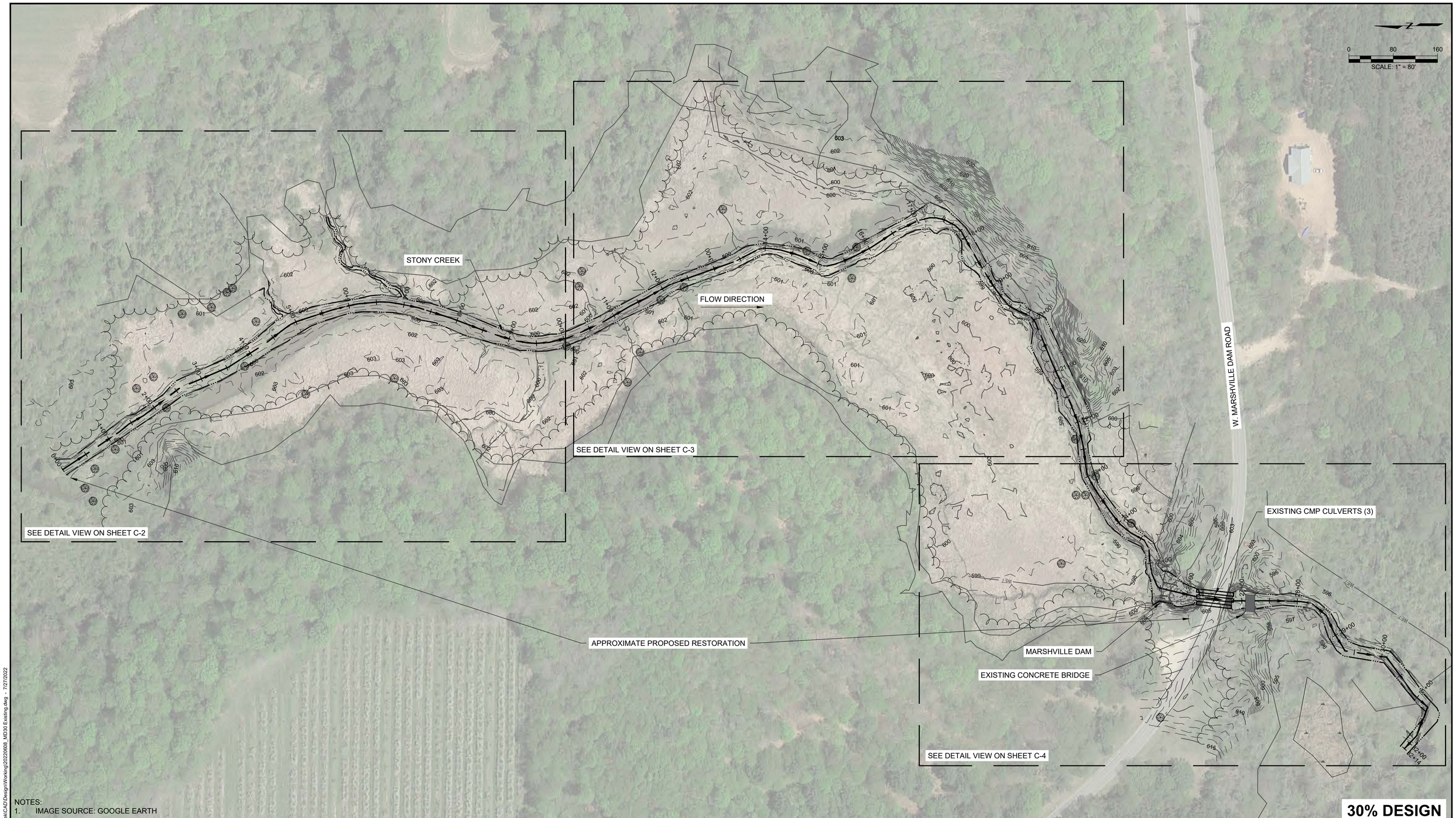
NO.	DATE	ISSUE/REVISION	APP
1	7/20/2022	30% DESIGN SET	BM

DRAFT

DWG. NO. G-1

SHEET NO. 1 OF 18

TRUITT, ASHLEY K:\WMSRDC\2200272_StonyCreek\CAD\Design\Working\20220608_MD30 Cover.dwg - 7/27/2022



NOTES:
1. IMAGE SOURCE: GOOGLE EARTH

30% DESIGN

EXISTING FEATURES LEGEND

- RIVER WATER SURFACE
- MAJOR CONTOUR
- MINOR CONTOUR
- TREELINE
- WETLAND DELINEATION
- WETLAND AREA
- EX. TREE

Attention:
0 1"
If this scale bar does not measure 1" then drawing is not original scale.

DRAFT

Designed:	DSN_BY
Drawn:	DRWN_BY
Checked:	CHK_BY
Approved:	APP_BY
P.E. No:	PE#
GEI Project	VALUE

GEI Consultants

WMSRDC
316 Morris Avenue
Suite 340
Muskegon, MI 49440

MARSHVILLE DAM REMOVAL & STONY CREEK RESTORATION

STONY CREEK
MARSHVILLE DAM ROAD
SHELBY, MI 49455

NO	DATE	ISSUE/REVISION	APP
1	7/20/2022	30% DESIGN SET	BM

SHEET NAME
EXISTING CONDITIONS

DWG. NO.
C-1

SHEET NO.
2 of 18

TRUITT, ASHLEY K:\WMSRDC\22302\72_StonyCreek\CAD\Design\Working\20220608_MD30 Existing.dwg - 7/27/2022

NOTES:
1. IMAGE SOURCE: GOOGLE EARTH

30% DESIGN

EXISTING FEATURES LEGEND

- RIVER WATER SURFACE
- MAJOR CONTOUR
- MINOR CONTOUR
- TREELINE
- WETLAND DELINEATION
- EX. TREE

Attention:
0 1"
If this scale bar does not measure 1" then drawing is not original scale.

DRAFT

Designed:	DSN_BY
Drawn:	DRWN_BY
Checked:	CHK_BY
Approved:	APP_BY
P.E. No:	PE#
GEI Project	VALUE

GEI Consultants

WMSRDC
316 Morris Avenue
Suite 340
Muskegon, MI 49440

MARSHVILLE DAM REMOVAL & STONY CREEK RESTORATION

STONY CREEK
MARSHVILLE DAM ROAD
SHELBY, MI 49455

NO	DATE	ISSUE/REVISION	APP
1	7/20/2022	30% DESIGN SET	BM

SHEET NAME
EXISTING CONDITIONS

DWG. NO.
C-2

SHEET NO.
3 of 18

TRUITT, ASHLEY K:\WMSRDC\2200272_StonyCreek\CAD\Design\Working\20220608_MD30 Existing.dwg - 7/27/2022

KEY PLAN

N

0 30 60
SCALE: 1" = 30'

STONY CREEK

FLOW DIRECTION

NOTES:
1. IMAGE SOURCE: GOOGLE EARTH

30% DESIGN

EXISTING FEATURES LEGEND

- RIVER WATER SURFACE
- MAJOR CONTOUR
- MINOR CONTOUR
- TREELINE
- WETLAND DELINEATION
- EX. TREE

Attention:
0 1"
If this scale bar does not measure 1" then drawing is not original scale.

DRAFT

Designed:	DSN_BY
Drawn:	DRWN_BY
Checked:	CHK_BY
Approved:	APP_BY
P.E. No:	PE#
GEI Project	VALUE

GEI Consultants

WMSRDC
316 Morris Avenue
Suite 340
Muskegon, MI 49440

MARSHVILLE DAM REMOVAL & STONY CREEK RESTORATION

STONY CREEK
MARSHVILLE DAM ROAD
SHELBY, MI 49455

NO	DATE	ISSUE/REVISION	APP
1	7/20/2022	30% DESIGN SET	BM

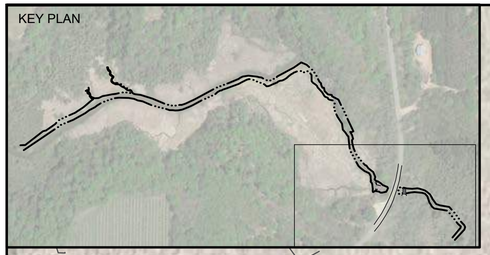
SHEET NAME
EXISTING CONDITIONS

DWG. NO.
C-3

SHEET NO.
4 of 18

TRUITT, ASHLEY K:\WMSRDC\2220072_StonyCreek\CAD\Design\Working\20220608_MD30 Existing.dwg - 7/27/2022

KEY PLAN



N

0 30 60

SCALE: 1" = 30'

STONY CREEK

MARSHVILLE DAM

SEE DETAIL VIEW ON SHEET C-5

EX. CONCRETE BRIDGE

FLOW DIRECTION

L C-7

L' C-7

M C-8

N C-8

O C-8

P C-8

Q C-8

R C-8

M' C-8

N' C-8

O' C-8

P' C-8

Q' C-8

R' C-8

S C-8

S' C-8

T C-8

T' C-8

U C-8

U' C-8

23+00 24+00 25+00 26+00 27+00 28+00 29+00 30+00 31+00 32+00 32+30 32+74

598 599 600 603 604 605 606 608 610 615

WET

NOTES:
1. IMAGE SOURCE: GOOGLE EARTH

EXISTING FEATURES LEGEND

- RIVER WATER SURFACE
- MAJOR CONTOUR
- MINOR CONTOUR
- TREELINE
- WETLAND DELINEATION
- WETLAND AREA
- EX. TREE

Attention:

0 1"

If this scale bar does not measure 1" then drawing is not original scale.

DRAFT

Designed:	DSN_BY
Drawn:	DRWN_BY
Checked:	CHK_BY
Approved:	APP_BY
P.E. No:	PE#
GEI Project	VALUE

GEI Consultants

WMSRDC
316 Morris Avenue
Suite 340
Muskegon, MI 49440

MARSHVILLE DAM REMOVAL & STONY CREEK RESTORATION

STONY CREEK
MARSHVILLE DAM ROAD
SHELBY, MI 49455

NO	DATE	ISSUE/REVISION	APP
1	7/20/2022	30% DESIGN SET	BM

SHEET NAME

EXISTING CONDITIONS

DWG. NO.

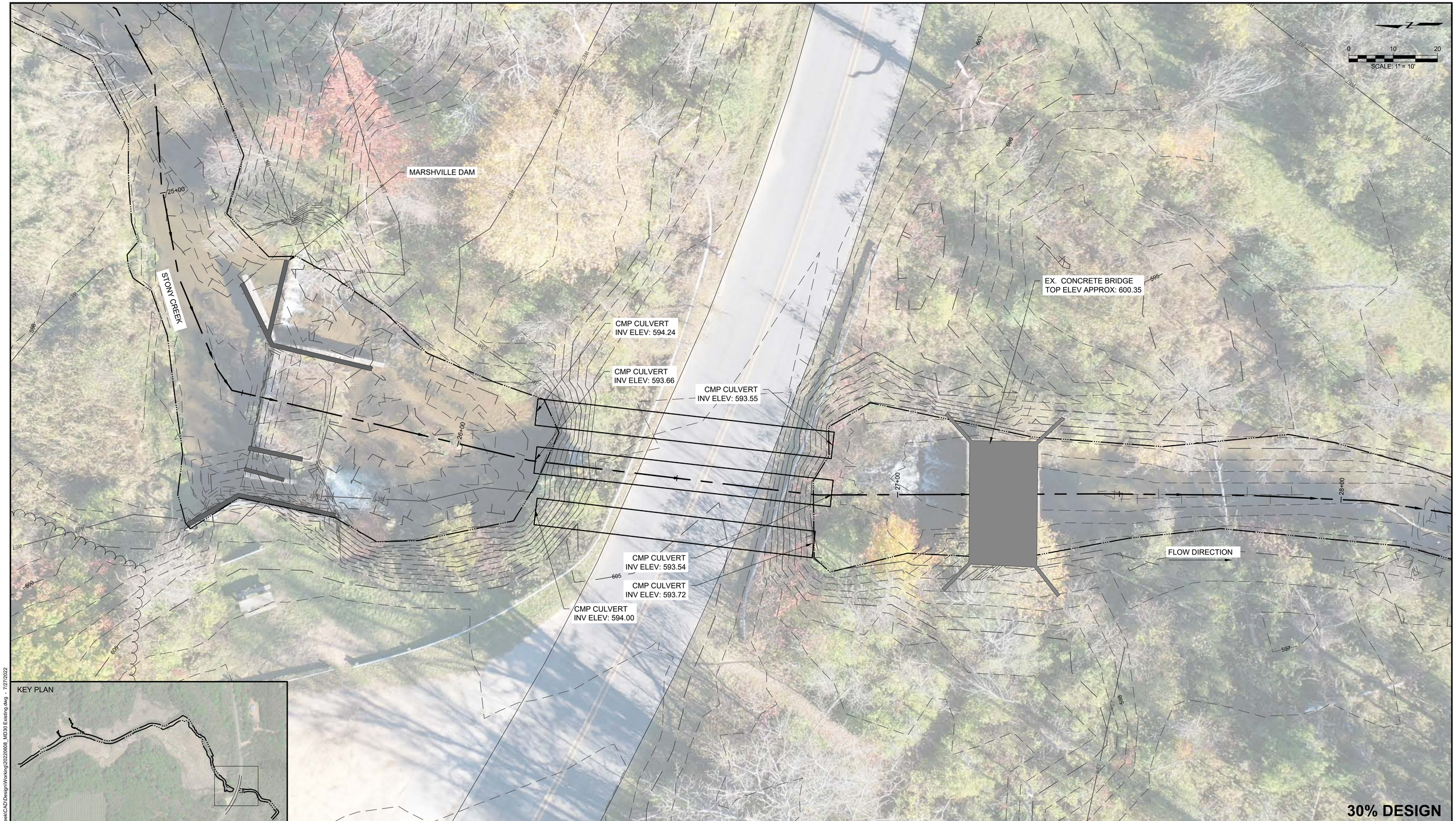
C-4

SHEET NO.

5 of 18

30% DESIGN

TRUITT, ASHLEY K:\WMSRDC\22\20272_StonyCreek\CAD\Design\Working\20220608_MD30 Existing.dwg - 7/27/2022



EXISTING FEATURES LEGEND

- RIVER WATER SURFACE
- MAJOR CONTOUR
- MINOR CONTOUR
- TREELINE
- WETLAND DELINEATION
- WETLAND AREA
- EX. TREE

Attention:

0 1"

If this scale bar does not measure 1" then drawing is not original scale.

DRAFT

Designed:	DSN_BY
Drawn:	DRWN_BY
Checked:	CHK_BY
Approved:	APP_BY
P.E. No:	PE#
GEI Project	VALUE

GEI Consultants

WMSRDC
316 Morris Avenue
Suite 340
Muskegon, MI 49440

MARSHVILLE DAM REMOVAL & STONY CREEK RESTORATION

STONY CREEK
MARSHVILLE DAM ROAD
SHELBY, MI 49455

NO	DATE	ISSUE/REVISION	APP
1	7/20/2022	30% DESIGN SET	BM

SHEET NAME

EXISTING CONDITIONS

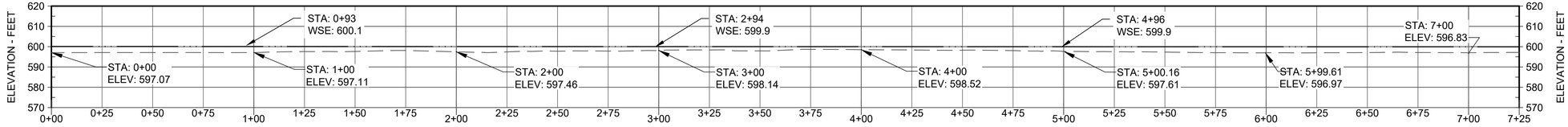
DWG. NO.

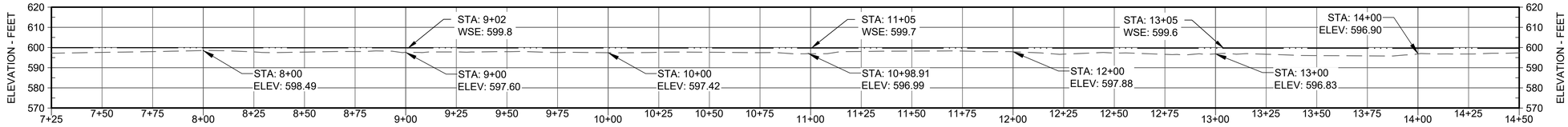
C-5

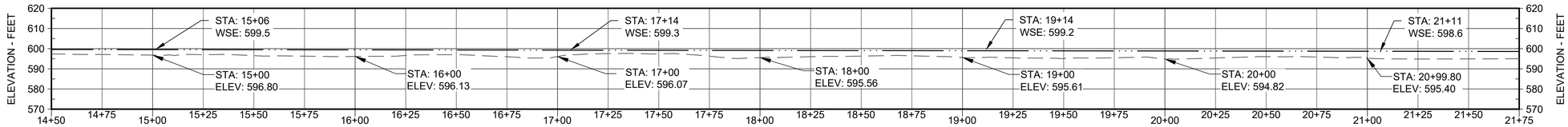
SHEET NO.

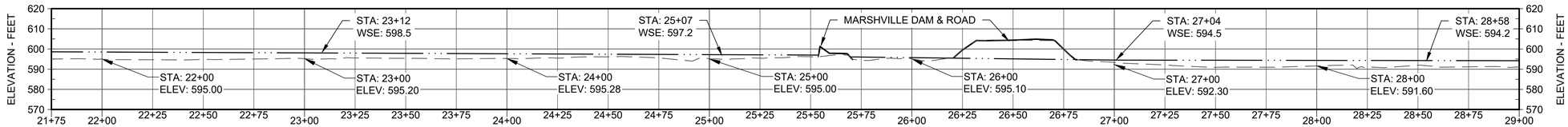
6 of 18

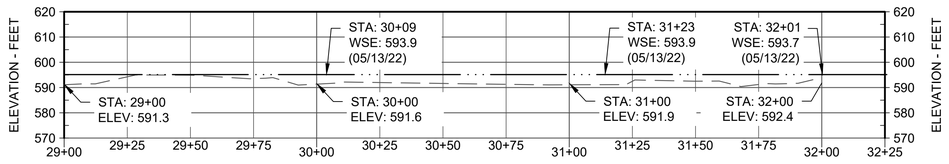
TRUITT_ASHLEY K:\WMSRDC\220272_StonyCreek\CAD\Design\Working\20220608_MD3\Existing.dwg - 7/27/2022







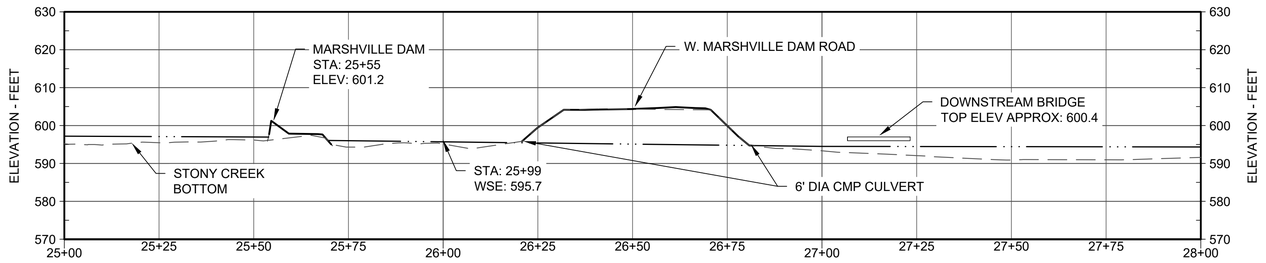




CREEK PROFILE

STA. 0+00 - STA. 32+25

SCALE, FEET: 0, 30, 60



CREEK PROFILE

STA. 25+00 - STA. 28+00

SCALE, FEET: 0, 20, 40

WATER SURFACE ELEVATION

EXISTING CREEK BEDLINE

30% DESIGN

Attention:

0 1"

If this scale bar does not measure 1" then drawing is not original scale.

DRAFT

Designed:	DSN_BY
Drawn:	DRWN_BY
Checked:	CHK_BY
Approved:	APP_BY
P.E. No:	PE#
GEI Project	VALUE

GEI Consultants

WMSRDC
316 Morris Avenue
Suite 340
Muskegon, MI 49440

MARSHVILLE DAM REMOVAL & STONY CREEK RESTORATION

STONY CREEK
MARSHVILLE DAM ROAD
SHELBY, MI 49455

NO	DATE	ISSUE/REVISION	
1	7/20/2022	30% DESIGN SET	BM

SHEET NAME

PROFILE

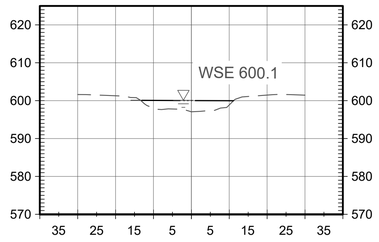
DWG NO.

C-6

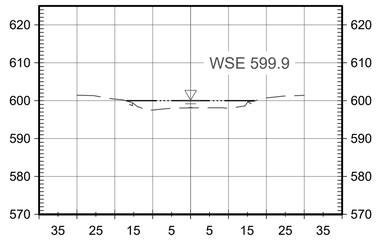
SHEET NO.

7 of 18

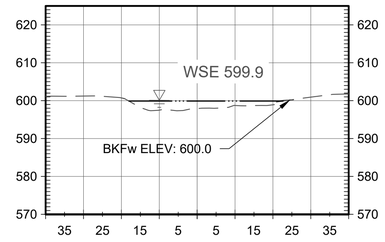
TRUITT, ASHLEY K:\WMSRDC\2200272_StonyCreekCAD\Design\Working\20220608_MD30 Profile.dwg - 7/27/2022



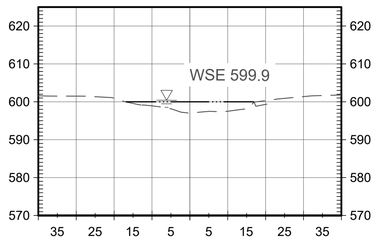
A C-2 SECTION 0+93
SCALE: 1"=20'



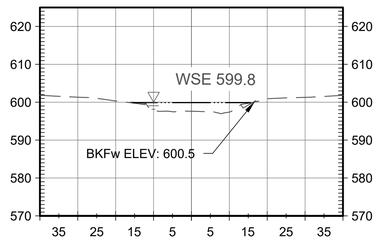
B C-2 SECTION 2+94
SCALE: 1"=20'



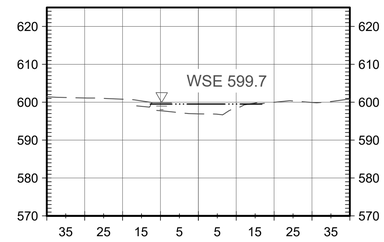
C C-2 SECTION 4+96
SCALE: 1"=20'



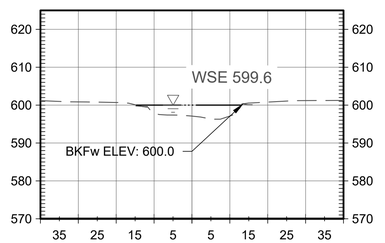
D C-2 SECTION 7+02
SCALE: 1"=20'



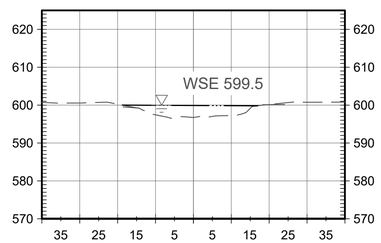
E C-2 SECTION 9+02
SCALE: 1"=20'



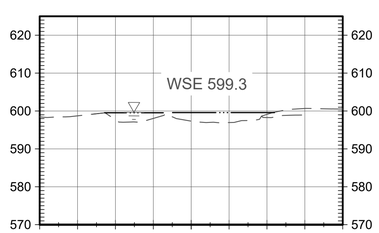
F C-3 SECTION 11+05
SCALE: 1"=20'



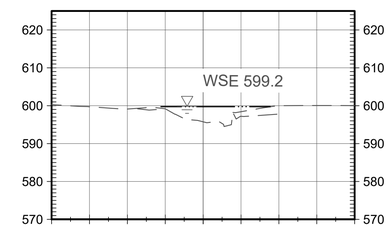
G C-3 SECTION 13+05
SCALE: 1"=20'



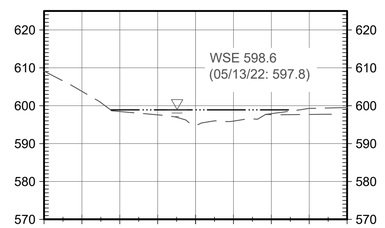
H C-3 SECTION 15+06
SCALE: 1"=20'



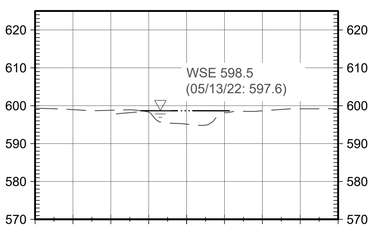
I C-3 SECTION 17+14
SCALE: 1"=20'



J C-3 SECTION 19+14
SCALE: 1"=20'



K C-3 SECTION 21+11
SCALE: 1"=20'



L C-4 SECTION 23+12
SCALE: 1"=20'

PROPOSED WATER SURFACE ELEVATION
EXISTING CREEK BEDLINE

30% DESIGN

Attention:
0 1"
If this scale bar does not measure 1" then drawing is not original scale.

DRAFT

Designed:	DSN_BY
Drawn:	DRWN_BY
Checked:	CHK_BY
Approved:	APP_BY
P.E. No:	PE#
GEI Project	VALUE

GEI Consultants

WMSRDC
316 Morris Avenue
Suite 340
Muskegon, MI 49440

MARSHVILLE DAM REMOVAL & STONY CREEK RESTORATION

STONY CREEK
MARSHVILLE DAM ROAD
SHELBY, MI 49455

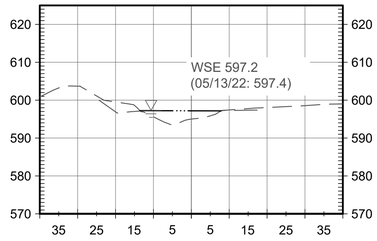
NO	DATE	ISSUE/REVISION	APP
1	7/20/2022	30% DESIGN SET	BM

SHEET NAME
SECTIONS

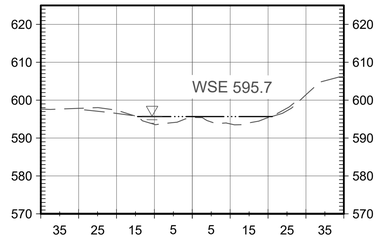
DWG NO.
C-7

SHEET NO.
8 of 18

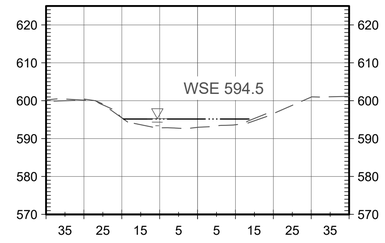
TRUITT, ASHLEY K:\WMSRDC\2200272_StonyCreek\CAD\Design\Working\20220608_MD30 SECTIONS.dwg - 7/27/2022



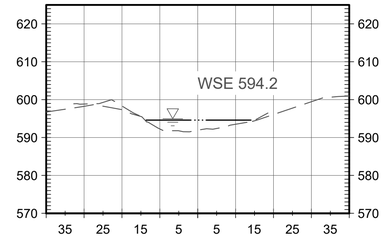
M C-4 SECTION 25+07
SCALE: 1"=20'



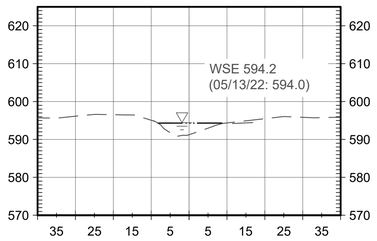
N C-4 SECTION 25+99
SCALE: 1"=20'



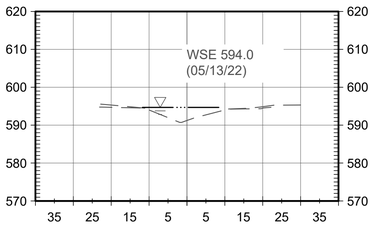
O C-4 SECTION 27+04
SCALE: 1"=20'



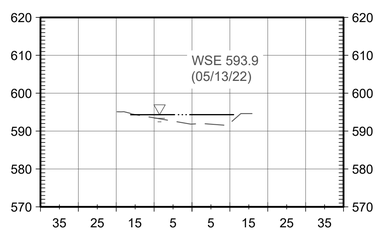
P C-4 SECTION 27+28
SCALE: 1"=20'



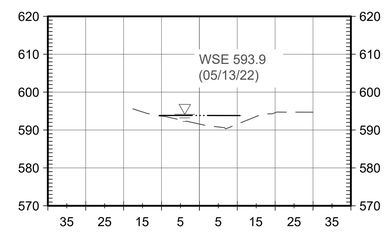
Q C-4 SECTION 28+58
SCALE: 1"=20'



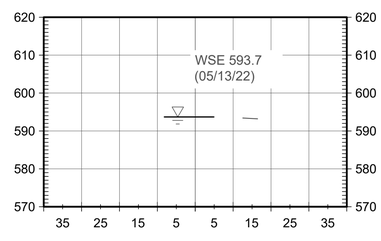
R C-4 SECTION 28+82
SCALE: 1"=20'



S C-4 SECTION 30+09
SCALE: 1"=20'



T C-4 SECTION 31+23
SCALE: 1"=20'



U C-4 SECTION 32+01
SCALE: 1"=20'

REFERENCE REACH SECTIONS

PROPOSED WATER SURFACE ELEVATION
EXISTING CREEK BEDLINE

30% DESIGN

Attention:
0 1"
If this scale bar does not measure 1" then drawing is not original scale.

DRAFT

Designed:	DSN_BY
Drawn:	DRWN_BY
Checked:	CHK_BY
Approved:	APP_BY
P.E. No:	PE#
GEI Project	VALUE

GEI Consultants

WMSRDC
316 Morris Avenue
Suite 340
Muskegon, MI 49440

MARSHVILLE DAM REMOVAL & STONY CREEK RESTORATION

STONY CREEK
MARSHVILLE DAM ROAD
SHELBY, MI 49455

NO	DATE	ISSUE/REVISION	APP
1	7/20/2022	30% DESIGN SET	BM

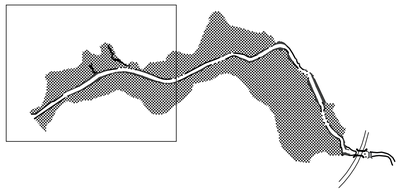
SHEET NAME
SECTIONS

DWG NO.
C-8

SHEET NO.
9 of 18

TRUITT, ASHLEY K:\WMSRDC\2200272_StonyCreekCAD\Design\Working\20220608_MD30 SECTIONS.dwg - 7/27/2022

KEY PLAN



N

0 30 60

SCALE: 1" = 30'

ADD LARGE WOODY DEBRIS TO STREAM CHANNEL TO ACHIEVE MINIMUM LWDI SCORE OF 600

STONY CREEK

CREATE POOLS AS NEEDED TO ACHIEVE MINIMUM POOL DEPTH RATIO OF 1:3

EXCAVATE AND SHAPE CHANNEL AS NEEDED TO MEET PROPOSED DIMENSIONS. SEE SHEET C-13 AND C-14

A C-14

A' C-14

0+00 1+00 2+00 3+00 4+00 5+00 6+00 7+00 8+00 9+00 10+00

600 605 610 615 620 625 630 635 640 645 650 655 660 665 670 675 680 685

PROPOSED FEATURES LEGEND

- RIVER WATER SURFACE
- MAJOR CONTOUR
- MINOR CONTOUR
- TREELINE
- EX. TREE
- NATIVE VEGETATION PLANTING
- REDUCE CHANNEL WIDTH USING WOOD AND/OR FILL

30% DESIGN

Attention:

0 1"

If this scale bar does not measure 1" then drawing is not original scale.

DRAFT

Designed:	DSN_BY
Drawn:	DRWN_BY
Checked:	CHK_BY
Approved:	APP_BY
P.E. No:	PE#
GEI Project	2200272

GEI Consultants

WMSRDC
316 Morris Avenue
Suite 340
Muskegon, MI 49440

MARSHVILLE DAM REMOVAL & STONY CREEK RESTORATION

STONY CREEK
MARSHVILLE DAM ROAD
SHELBY, MI 49455

NO	DATE	ISSUE/REVISION	APP
1	7/20/2022	30% DESIGN SET	BM

SHEET NAME

PROPOSED PLAN

DWG. NO.

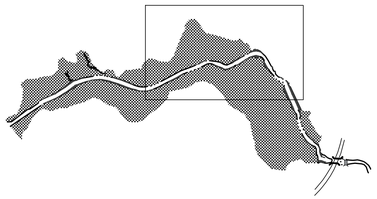
C-9

SHEET NO.

10 of 18

TRUITT, ASHLEY K:\WMSRDC\2200272_StonyCreek\CAD\Design\Working\20220608_MD30 Proposed.dwg - 7/27/2022

KEY PLAN



ADD LARGE WOODY DEBRIS TO STREAM CHANNEL TO ACHIEVE MINIMUM LWDI SCORE OF 600

CREATE POOLS AS NEEDED TO ACHIEVE MINIMUM POOL DEPTH RATIO OF 1:3

EXCAVATE AND SHAPE CHANNEL AS NEEDED TO MEET PROPOSED DIMENSIONS. SEE SHEET C-13 AND C-14

STONY CREEK

N

0 30 60

SCALE: 1" = 30'

B C-14

B' C-14

C C-14

C' C-14

30% DESIGN

PROPOSED FEATURES LEGEND

- RIVER WATER SURFACE
- MAJOR CONTOUR
- MINOR CONTOUR
- TREELINE
- EX. TREE
- NATIVE VEGETATION PLANTING
- REDUCE CHANNEL WIDTH USING WOOD AND/OR FILL

Attention:

0 1"

If this scale bar does not measure 1" then drawing is not original scale.

DRAFT

Designed:	DSN_BY
Drawn:	DRWN_BY
Checked:	CHK_BY
Approved:	APP_BY
P.E. No:	PE#
GEI Project	2200272

GEI Consultants

WMSRDC
316 Morris Avenue
Suite 340
Muskegon, MI 49440

MARSHVILLE DAM REMOVAL & STONY CREEK RESTORATION

STONY CREEK
MARSHVILLE DAM ROAD
SHELBY, MI 49455

NO	DATE	ISSUE/REVISION	APP
1	7/20/2022	30% DESIGN SET	BM

SHEET NAME

PROPOSED PLAN

DWG. NO.

C-10

SHEET NO.

11 of 18

TRUITT, ASHLEY K:\WMSRDC\2200272_StonyCreek\CAD\Design\Working\20220608_MD30 Proposed.dwg - 7/27/2022

ADD LARGE WOODY DEBRIS TO STREAM CHANNEL TO ACHIEVE MINIMUM LWDI SCORE OF 600

CREATE POOLS AS NEEDED TO ACHIEVE MINIMUM POOL DEPTH RATIO OF 1:3

MANAGE INVASIVE SPECIES AND RE-PLANT WITH NATIVE VEGETATION

EXCAVATE AND SHAPE CHANNEL AS NEEDED TO MEET PROPOSED DIMENSIONS. SEE SHEET C-13 AND C-14

STONY CREEK

W. MARSHVILLE DAM ROAD

REMOVE EXISTING DAM

CULVERTS TO BE REPLACED WITH OPEN SPAN BRIDGE (TO BE DESIGNED AND CONSTRUCTED BY OCEANA COUNTY ROAD COMMISSION, SEE DETAIL SHEETS D2-D3)

REMOVE CONCRETE BRIDGE

REDUCE CREEK CHANNEL USING WOOD AND FILL SEE DETAIL SHEET D-1

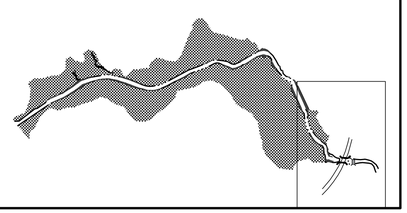
PUBLIC ACCESS TO CREEK SEE DETAIL VIEW SHEET C-12

N

0 30 60

SCALE: 1" = 30'

KEY PLAN



PROPOSED FEATURES LEGEND

- RIVER WATER SURFACE
- MAJOR CONTOUR
- MINOR CONTOUR
- TREELINE
- EX. TREE
- NATIVE VEGETATION PLANTING
- REDUCE CHANNEL WIDTH USING WOOD AND/OR FILL

Attention:

0 1"

If this scale bar does not measure 1" then drawing is not original scale.

DRAFT

Designed:	DSN_BY
Drawn:	DRWN_BY
Checked:	CHK_BY
Approved:	APP_BY
P.E. No:	PE#
GEI Project	2200272

GEI Consultants

WMSRDC
316 Morris Avenue
Suite 340
Muskegon, MI 49440

MARSHVILLE DAM REMOVAL & STONY CREEK RESTORATION

STONY CREEK
MARSHVILLE DAM ROAD
SHELBY, MI 49455

NO	DATE	ISSUE/REVISION	APP
1	7/20/2022	30% DESIGN SET	BM

SHEET NAME

PROPOSED PLAN

DWG. NO.

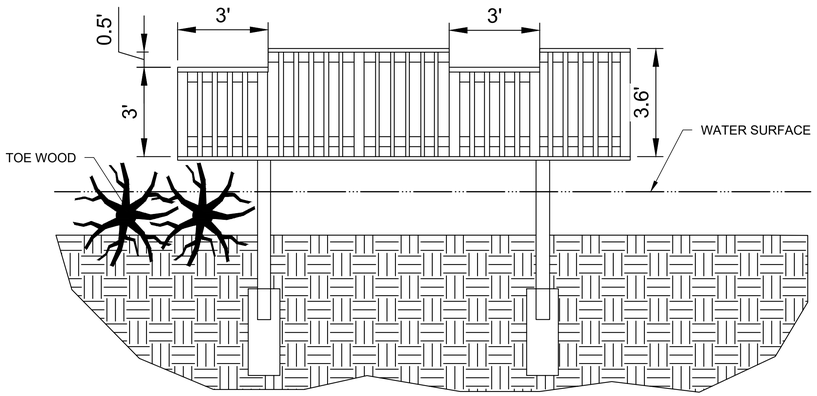
C-11

SHEET NO.

12 of 18

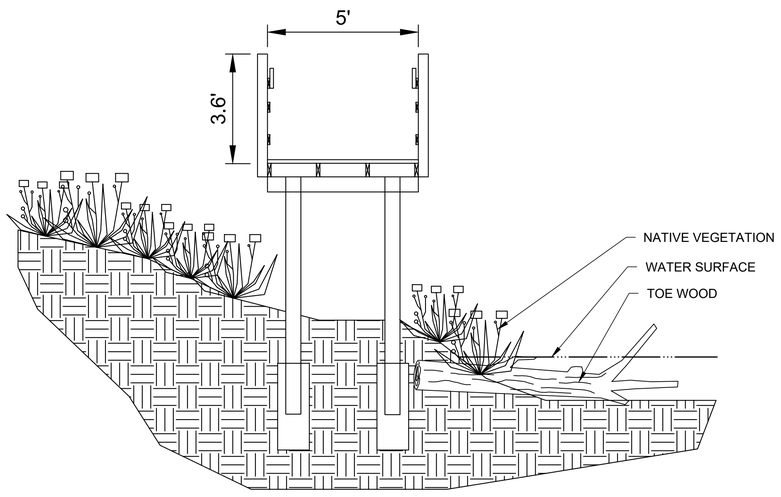
30% DESIGN

TRUITT, ASHLEY K:\WMSRDC\2200272_StonyCreek\CAD\Design\Working\20220608_MD30 Proposed.dwg - 7/27/2022



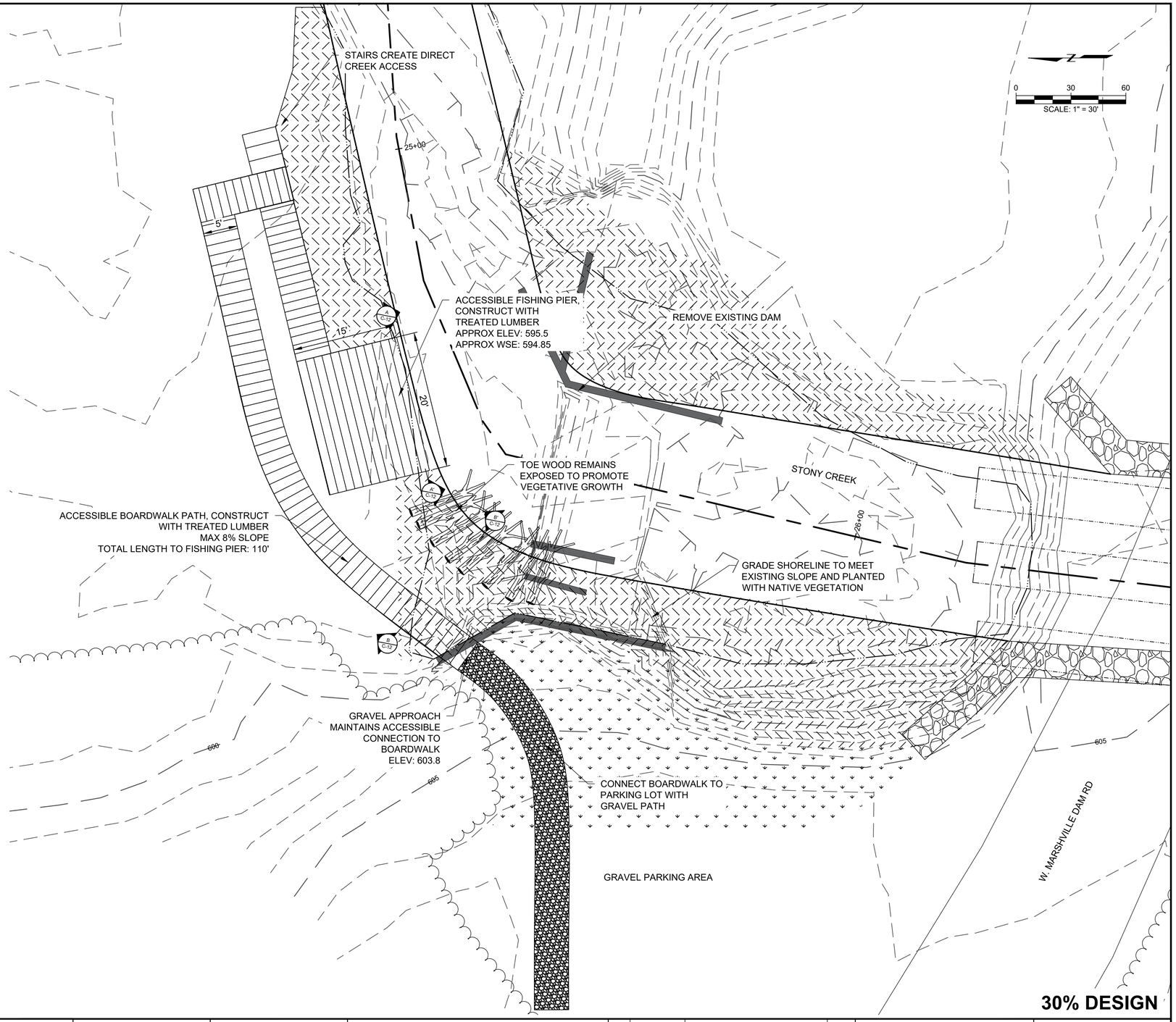
A C-12 ACCESSIBLE FISHING PIER

SCALE: NOT TO SCALE



B C-12 ACCESSIBLE BOARDWALK

SCALE: NOT TO SCALE



30% DESIGN

PROPOSED FEATURES LEGEND

- RIVER WATER SURFACE
- MAJOR CONTOUR
- MINOR CONTOUR
- TREELINE
- LAWN
- GRAVEL PATH
- NATIVE VEGETATION PLANTING ON BANKS

Attention:

0 1"

If this scale bar does not measure 1" then drawing is not original scale.

DRAFT

Designed:	DSN_BY
Drawn:	DRWN_BY
Checked:	CHK_BY
Approved:	APP_BY
P.E. No:	PE#
GEI Project	2200272

GEI Consultants

WMSRDC
316 Morris Avenue
Suite 340
Muskegon, MI 49440

MARSHVILLE DAM REMOVAL & STONY CREEK RESTORATION

STONY CREEK
MARSHVILLE DAM ROAD
SHELBY, MI 49455

NO	DATE	ISSUE/REVISION	APP
1	7/20/2022	30% DESIGN SET	BM

SHEET NAME

PROPOSED PLAN: FISHING PIER

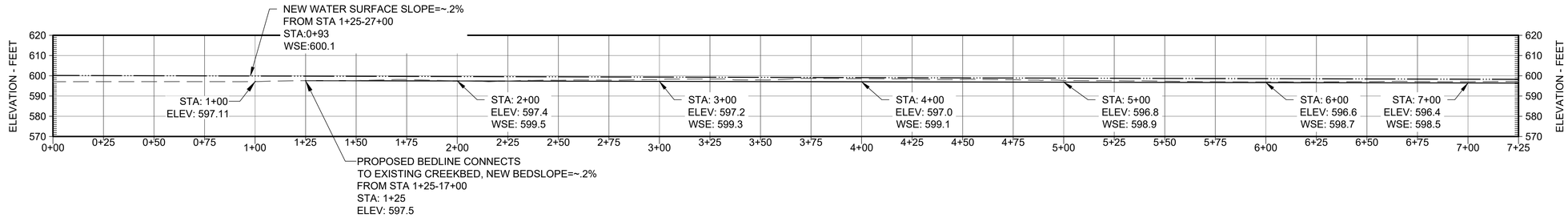
DWG. NO.

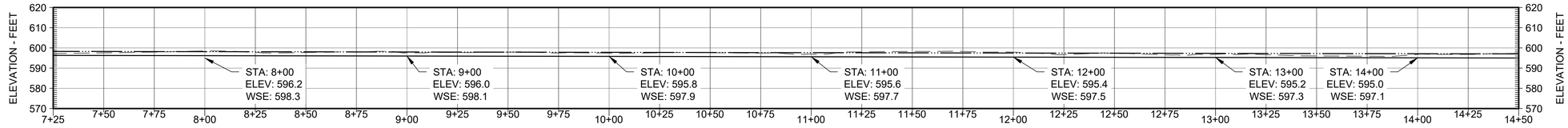
C-12

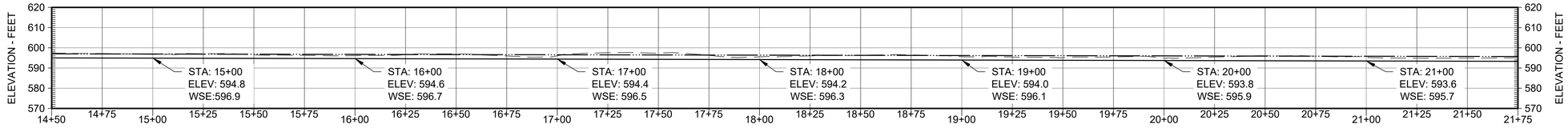
SHEET NO.

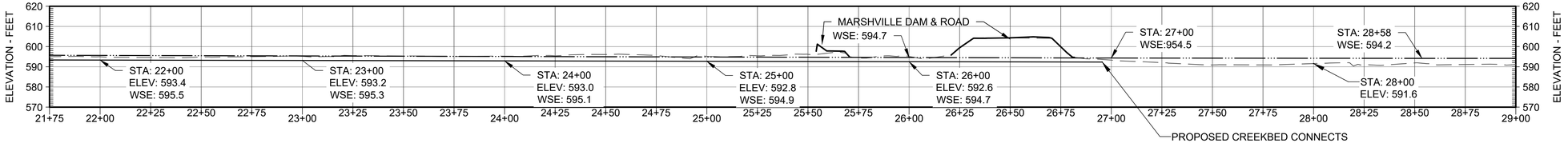
13 of 18

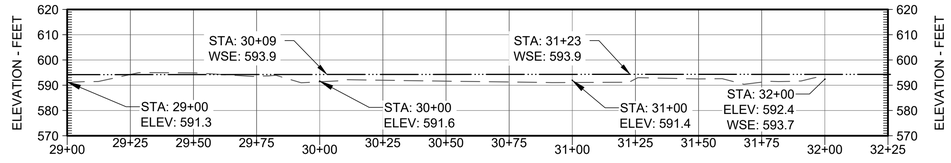
TRUITT, ASHLEY K:\WMSRDC\2200272_StonyCreek\CAD\Design\Working\20220608_MD30 Proposed.dwg, - 7/27/2022











CREEK PROFILE

STA. 0+00 - STA. 32+25

0 30 60

SCALE: 1" = 30'

PROPOSED WATER SURFACE ELEVATION
PROPOSED CREEKBED
EXISTING CREEKBED

30% DESIGN

Attention:

0 1"

If this scale bar does not measure 1" then drawing is not original scale.

DRAFT

Designed:	DSN_BY
Drawn:	DRWN_BY
Checked:	CHK_BY
Approved:	APP_BY
P.E. No:	PE#
GEI Project	VALUE

GEI Consultants

WMSRDC
316 Morris Avenue
Suite 340
Muskegon, MI 49440

MARSHVILLE DAM REMOVAL & STONY CREEK RESTORATION

STONY CREEK
MARSHVILLE DAM ROAD
SHELBY, MI 49455

NO	DATE	ISSUE/REVISION	APP
1	7/20/2022	30% DESIGN SET	BM

SHEET NAME

PROPOSED PROFILE

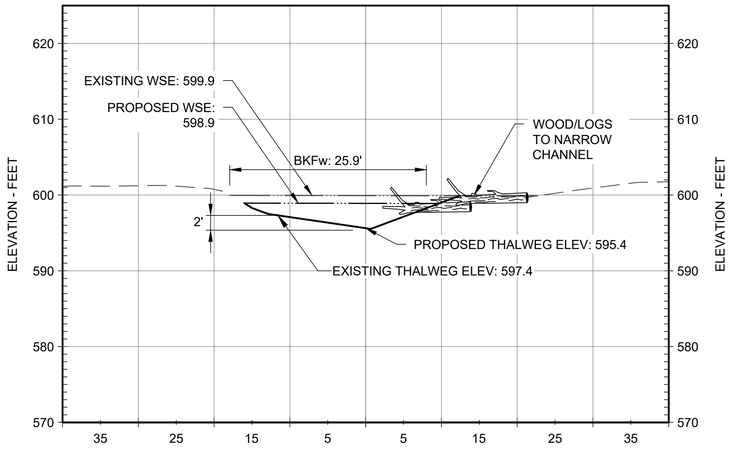
DWG. NO.

C-13

SHEET NO.

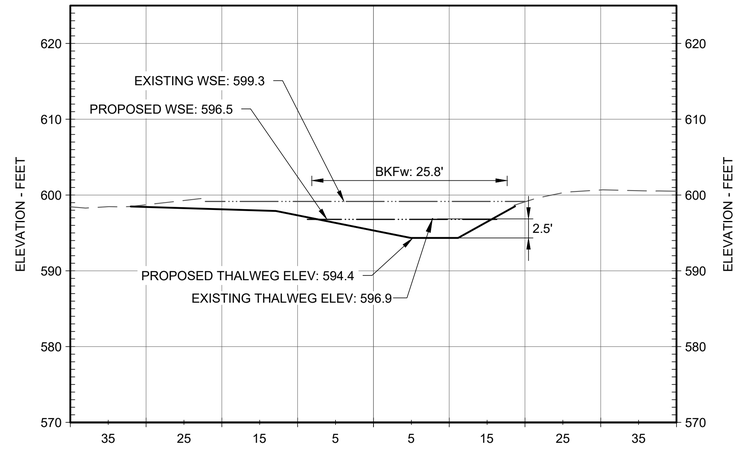
14 of 18

TRUITT, ASHLEY K:\WMSRDC\2200272_StonyCreekCAD\Design\Working\20220608_MD30 Proposed.dwg - 7/27/2022



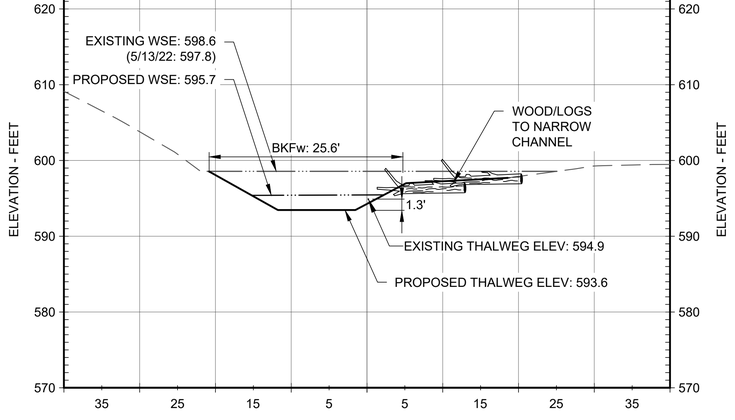
A C-9 SECTION 4+96

SCALE: SCALE: 1"=10'



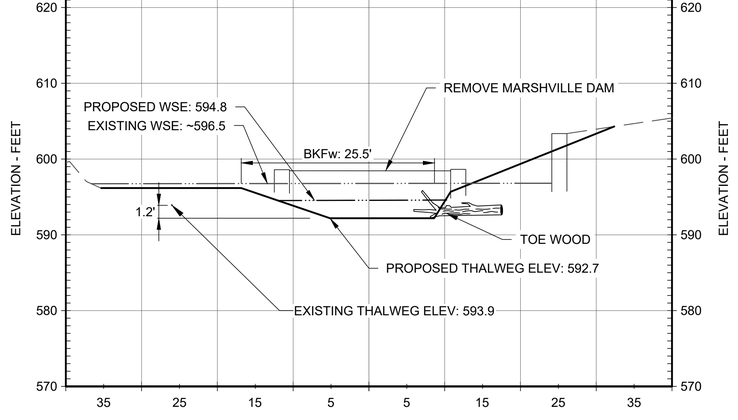
B C-10 SECTION 17+14

SCALE: SCALE: 1"=10'



C C-10 SECTION 21+11

SCALE: SCALE: 1"=10'



D C-11 SECTION 25+65

SCALE: SCALE: 1"=10'

PROPOSED WATER SURFACE
EXISTING WATER SURFACE
PROPOSED CREEKBED
EXISTING CREEKBED

30% DESIGN

Attention:
0 1"
If this scale bar does not measure 1" then drawing is not original scale.

DRAFT

Designed:	DSN_BY
Drawn:	DRWN_BY
Checked:	CHK_BY
Approved:	APP_BY
P.E. No:	PE#
GEI Project	VALUE

GEI Consultants

WMSRDC
316 Morris Avenue
Suite 340
Muskegon, MI 49440

MARSHVILLE DAM REMOVAL & STONY CREEK RESTORATION

STONY CREEK
MARSHVILLE DAM ROAD
SHELBY, MI 49455

NO	DATE	ISSUE/REVISION	APP
1	7/20/2022	30% DESIGN SET	BM

SHEET NAME

PROPOSED SECTIONS

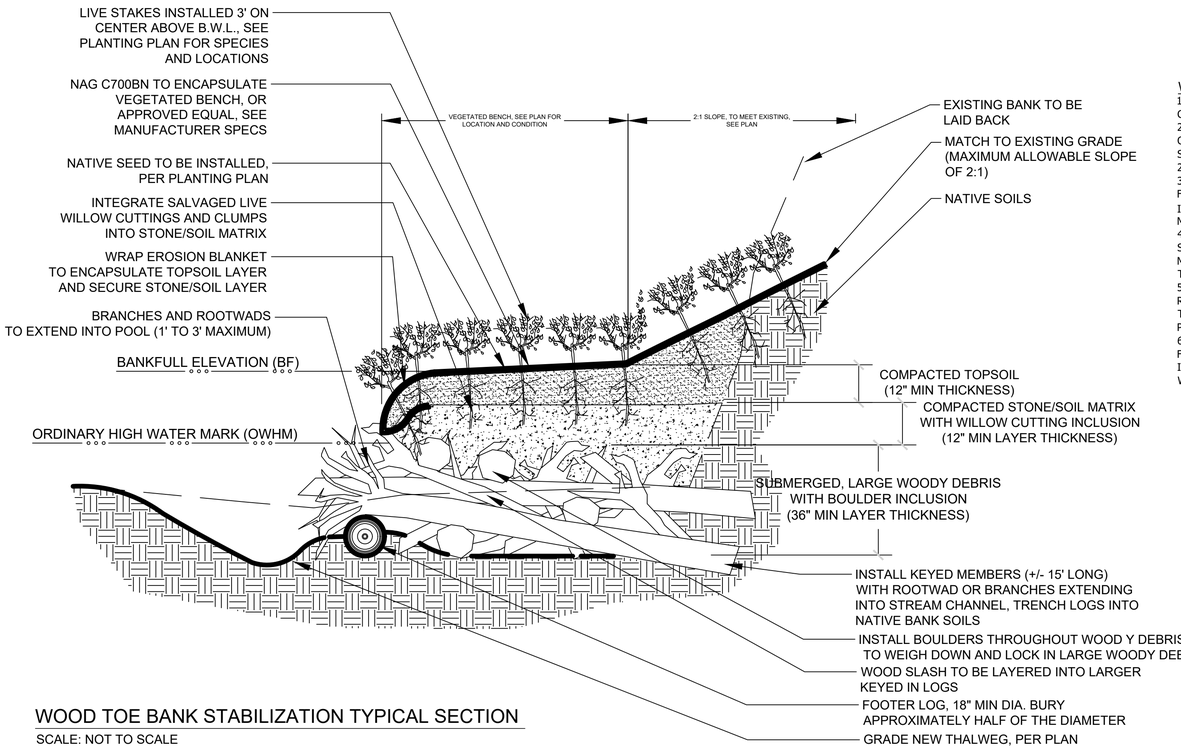
DWG. NO.

C-14

SHEET NO.

15 of 18

TRUITT, ASHLEY K:\WMSRDC\2220272_StonyCreek\CAD\Design\Working\20220608_MD30 Proposed.dwg - 7/27/2022

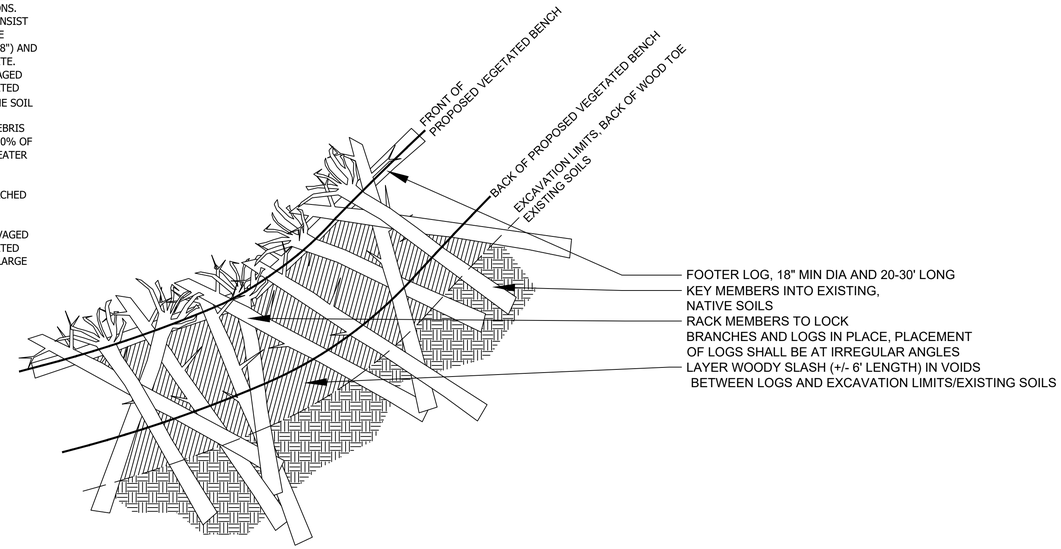


WOOD TOE BANK STABILIZATION TYPICAL SECTION

SCALE: NOT TO SCALE

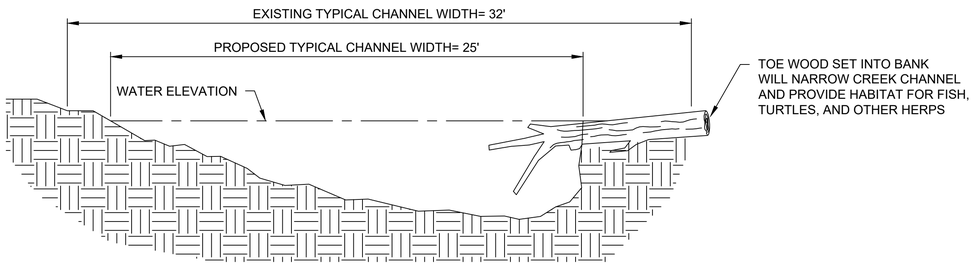
WOOD TOE NOTES:

1. TOPSOIL SPECIFICATIONS SHALL COMPLY WITH SPECIAL PROVISIONS.
2. STONE SOIL MATRIX SHALL CONSIST OF 80% NATIVE BANK RUN STONE SALVAGED FROM SITE (MAX DIA. 8") AND 20" SOIL FILL SALVAGED FROM SITE.
3. LIVE WILLOW CUTTINGS SALVAGED FROM SITE SHALL BE INCORPORATED INTO THE FRONT ⅓ OF THE STONE SOIL MATRIX.
4. SUBMERGED LARGE WOODY DEBRIS SHALL CONTAIN A MINIMUM OF 50% OF MATERIAL WITH A DIAMETER GREATER THAN OR EQUAL TO 6".
5. ROOTWADS CAN AND ARE RECOMMENDED TO REMAIN ATTACHED TO LARGE WOODY DEBRIS FOR PLACEMENT.
6. BOULDERS (MIN DIA. 18") SALVAGED FROM SITE SHALL BE INCORPORATED INTO 10%-15% OF SUBMERGED LARGE WOODY DEBRIS LAYER.



WOOD TOE BANK STABILIZATION TYPICAL PLAN

SCALE: NOT TO SCALE



TYPICAL CREEK CROSS SECTION

SCALE: NOT TO SCALE

30% DESIGN

Attention: 0 — 1"
If this scale bar does not measure 1" then drawing is not original scale.

DRAFT

Designed:	DSN_BY
Drawn:	DRWN_BY
Checked:	CHK_BY
Approved:	APP_BY
P.E. No:	PE#
GEI Project	VALUE

GEI Consultants

WMSRDC
316 Morris Avenue
Suite 340
Muskegon, MI 49440

MARSHVILLE DAM REMOVAL & STONY CREEK RESTORATION

STONY CREEK
MARSHVILLE DAM ROAD
SHELBY, MI 49455

NO	DATE	ISSUE/REVISION	APP
1	7/20/2022	30% DESIGN SET	BM

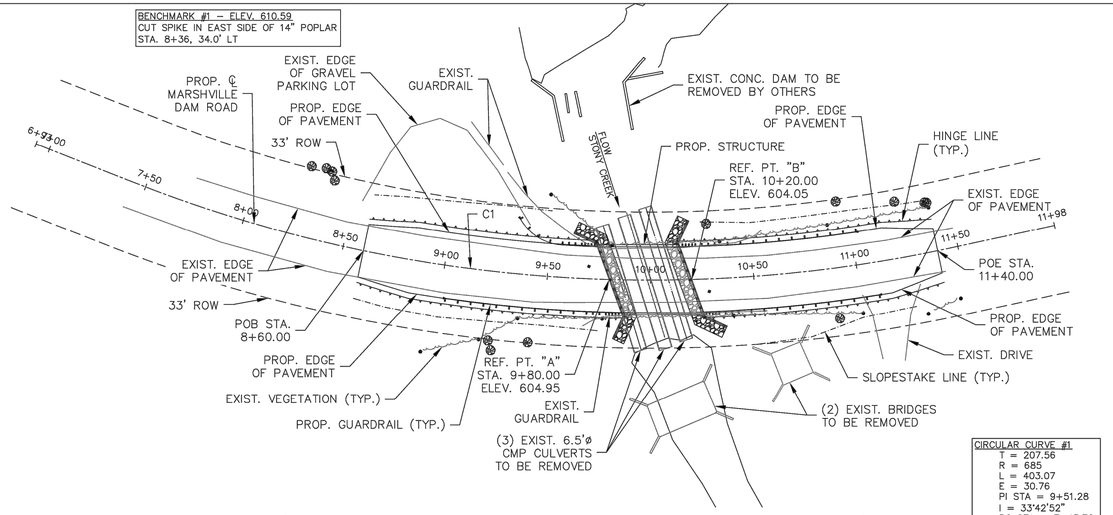
SHEET NAME: **DETAILS**

DWG. NO.: **D-1**

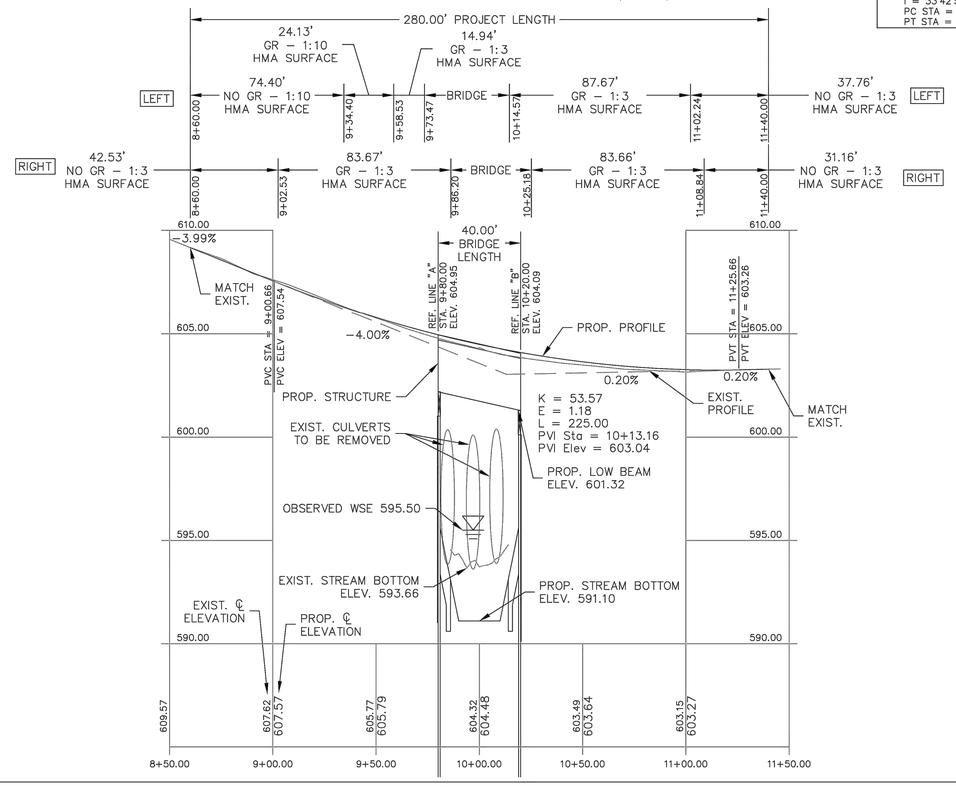
SHEET NO.: **16 of 18**

TRUITT, ASHLEY K:\WMSRDC\22020272_StonyCreek\CAD\Design\Working\20220608_MD30 Proposed.dwg - 7/27/2022

NOT TO SCALE



CIRCULAR CURVE #1
T = 207.56
R = 685
L = 403.07
E = 30.76
PI STA = 9+51.28
I = 33°42'52"
PC STA = 7+43.72
PT STA = 11+46.79



GENERAL NOTES

THE WORK COVERED BY THESE PLANS INCLUDES: MAINTAINING TRAFFIC, REMOVAL OF THE EXISTING STRUCTURES, CONSTRUCTION OF THE PROPOSED BRIDGE, GUARDRAIL REPLACEMENT, SLOPE PROTECTION, SCOUR COUNTERMEASURES AND RIPRAP, AND APPROACH WORK TO THE LIMITS SHOWN.

LOCATE ALL ACTIVE UNDERGROUND UTILITIES PRIOR TO STARTING WORK AND CONDUCT OPERATIONS IN SUCH A MANNER AS TO ENSURE THAT THOSE UTILITIES NOT REQUIRING RELOCATION WILL NOT BE DISTURBED.

DETOUR VEHICLE TRAFFIC OVER OTHER EXISTING ROADS.

IMPLEMENT MEASURES TO PREVENT DEBRIS FROM FALLING FROM THE STRUCTURE. IF DEBRIS FALLS INTO THE WATERWAY, REMOVE IT WITHIN 24 HOURS. SINCE DISTURBANCE OF THE WATERWAY BOTTOM MAY BE AS HARMFUL AS THE DEBRIS ITSELF, THE PREVENTATIVE MEASURES MUST BE EFFECTIVE.

THE CONTRIBUTING DRAINAGE AREA TO THIS CROSSING IS 21.5 SQUARE MILES. THE 1% AND 2% CHANCE FLOODS ARE ESTIMATED TO BE 650 CUBIC FEET PER SECOND (CFS) AND 500 CFS RESPECTIVELY, AS DETERMINED BY THE MICHIGAN DEPARTMENT OF ENVIRONMENT, GREAT LAKES AND ENERGY.

THE WATER LEVEL OF STONY CREEK IS SUBJECT TO CHANGE. MAKE A DETERMINATION OF WATER LEVELS THAT MAY EXIST DURING CONSTRUCTION.

DATUM REFERS TO NAVD 88 DATUM.

DO NOT ALLOW TEMPORARILY STORED EXCAVATED MATERIAL TO ERODE INTO THE WATERCOURSE.

REMOVAL NOTES:

REMOVE TOPO ITEMS SHOWN WITH AN ASTERISK (*). PAYMENT FOR REMOVAL SHALL BE INCLUDED IN THE RESPECTIVE REMOVAL ITEMS. ALL OTHERS SHALL REMAIN IN PLACE.

EXISTING TREES MARKED FOR REMOVAL WILL BE DOWNED BY OCEANA COUNTY ROAD COMMISSION PRIOR TO THE START OF THE PROJECT. REMOVAL OF ANY TREE DEBRIS LEFT INSIDE THE ROW WILL BE PAID AS "CLEARING, MODIFIED". REMOVAL OF STUMPS WILL BE INCLUDED IN THE RESPECTIVE STUMP REMOVAL ITEMS.

UTILITY NOTES:

UPDATE

EXISTING STRUCTURE NOTES:
EXISTING STRUCTURE CONSISTS OF (3) 65' LONG 78"ø CMP CULVERTS RATED IN FAIR TO POOR CONDITION, WITH 5'± BETWEEN BARRELS 4.25'± COVER OVER BARRELS.

OCEANA COUNTY
ROAD COMMISSION

GENERAL PLAN OF SITE
MARSHVILLE DAM ROAD
OVER STONY CREEK

SCECO
SCOTT CIVIL ENGINEERING COMPANY
GRAND RAPIDS, MICHIGAN

DRAWN	RCM	CHECKED	~~~	DATE	7/15/22

1
2

JOB NO. XXXXXX SN 8380

30% DESIGN

NOTES:
BRIDE DESIGN BY SCOTT CIVIL ENGINEERING COMPANY

Attention:
0 1"
If this scale bar does not measure 1" then drawing is not original scale.

DRAFT

Designed:	DSN_BY
Drawn:	DRWN_BY
Checked:	CHK_BY
Approved:	APP_BY
P.E. No:	PE#
GEI Project	VALUE

GEI Consultants

WMSRDC
316 Morris Avenue
Suite 340
Muskegon, MI 49440

MARSHVILLE DAM REMOVAL & STONY CREEK RESTORATION

STONY CREEK
MARSHVILLE DAM ROAD
SHELBY, MI 49455

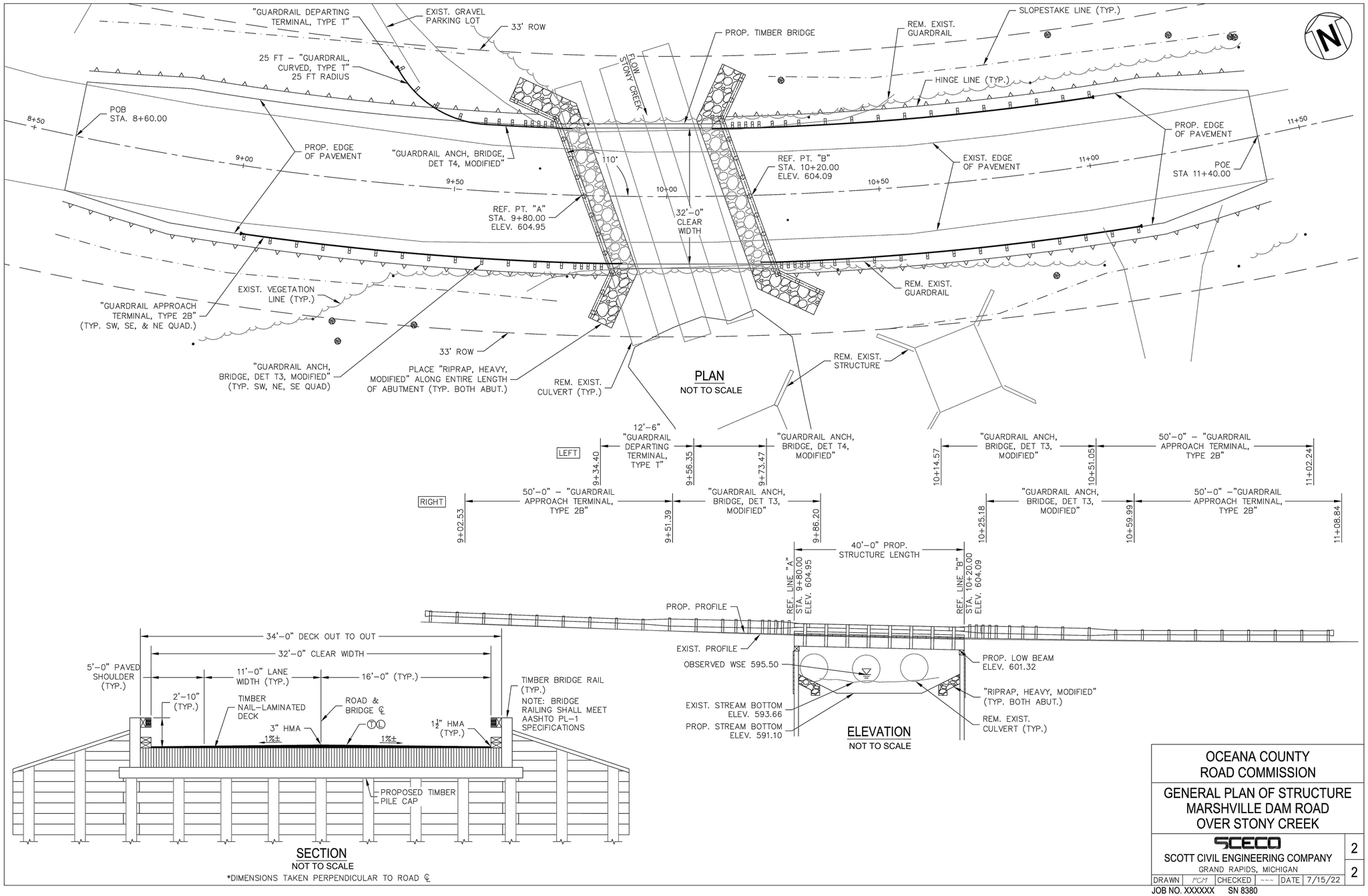
NO	DATE	ISSUE/REVISION	APP
1	7/20/2022	30% DESIGN SET	BM

SHEET NAME
OPEN SPAN BRIDGE DETAILS

DWG. NO.
D-2

SHEET NO.
17 of 18

TRUITT, ASHLEY K:\WMSRDC\22020272_StonyCreek\CAD\Design\Working\20220608_MD30 Proposed.dwg - 7/27/2022



OCEANA COUNTY
ROAD COMMISSION

GENERAL PLAN OF STRUCTURE
MARSHVILLE DAM ROAD
OVER STONY CREEK

SCECO
SCOTT CIVIL ENGINEERING COMPANY
GRAND RAPIDS, MICHIGAN

DRAWN	FCM	CHECKED	~~~	DATE	7/15/22

2
2

JOB NO. XXXXXX SN 8380

30% DESIGN

NOTES:
BRIDE DESIGN BY SCOTT CIVIL ENGINEERING COMPANY

Attention:
0 1"
If this scale bar does not measure 1" then drawing is not original scale.

DRAFT

Designed:	DSN_BY
Drawn:	DRWN_BY
Checked:	CHK_BY
Approved:	APP_BY
P.E. No:	PE#
GEI Project	VALUE

GEI Consultants

WMSRDC
316 Morris Avenue
Suite 340
Muskegon, MI 49440

MARSHVILLE DAM REMOVAL & STONY CREEK RESTORATION

STONY CREEK
MARSHVILLE DAM ROAD
SHELBY, MI 49455

NO	DATE	ISSUE/REVISION	APP
1	7/20/2022	30% DESIGN SET	BM

SHEET NAME

OPEN SPAN BRIDGE DETAILS

DWG. NO.
D-3

SHEET NO.
18 of 18

TRUITT, ASHLEY K:\WMSRDC\2200272_StonyCreek\CAD\Design\Working\20220608_MD30 Proposed.dwg - 7/27/2022

Appendix B Design Plans

MARSHVILLE DAM REMOVAL & STONY CREEK RESTORATION

CONSTRUCTION DRAWINGS
MAY 31, 2023

MICHIGAN STATE MAP
(NOT TO SCALE)

SOURCE: GOOGLE EARTH

PROJECT AREA
(NOT TO SCALE)

SHEET INDEX

SHEET NO.	DRAWING NO.	TITLE
1	G-1	COVER SHEET
2	C-1	EXISTING CONDITIONS OVERVIEW
3	C-2	EXISTING CONDITIONS DETAIL VIEW
4	C-3	EXISTING CONDITIONS DETAIL VIEW
5	C-4	EXISTING CONDTIONS DETAIL VIEW
6	C-5	EXISTING CONDITIONS DAM DETAIL VIEW
7	C-6	EXISTING CONDITIONS PROFILE
8	C-7	EXISTING CONDITIONS SECTIONS 1
9	C-8	EXISTING CONDITIONS SECTIONS 2
10	C-9	EXISTING CONDITIONS SECTIONS 3
11	C-10	ACCESS AND STAGING
12	C-11	PROJECT SEQUENCING
13	C-12	DAM REMOVAL PLAN AND SECTIONS
14	C-13	DRAWDOWN
15	C-14	PROPOSED CONDITIONS 1
16	C-15	PROPOSED CONDITIONS 2
17	C-16	PROPOSED CONDITIONS 3
18	C-17	FISHING PIER AND BOARDWALK DESIGN
19	C-18	FISHING PIER IMPACTS
20	C-19	PROPOSED PROFILE
21	C-20	PROPOSED SECTIONS 1
22	C-21	PROPOSED SECTIONS 2
23	D-1	STREAM PARAMETERS
24	D-2	SITE DETAILS
25	D-3	RESTORATION DETAILS
26	D-4	TRIBUTARY GRADE CONTROL DETAILS
27	D-5	PLANTING DETAILS AND PLANT LISTS

PREPARED FOR:

West Michigan Shoreline Regional
Development Commission
316 Morris Avenue
Suite 340
Muskegon, MI 49440
(231)722-7878

Conservation Resource Alliance
10850 E Traverse Hwy #1180
Traverse City, MI 49684
(231) 948-6817

PREPARED BY:

GEI CONSULTANTS OF MICHIGAN, P.C.
5225 EDGEWATER DRIVE
ALLENDALE, MI 49401
(616)384-2710

GEI Consultants

Conservation Resource Alliance

WMSRDC
WEST MICHIGAN SHORELINE
REGIONAL DEVELOPMENT COMMISSION

THIS DOCUMENT, AND THE IDEAS AND DESIGNS INCORPORATED HEREIN, IS AN INSTRUMENT OF PROFESSIONAL SERVICE, IS THE PROPERTY OF GEI CONSULTANTS AND IS NOT TO BE USED, IN WHOLE OR IN PART, FOR ANY OTHER PROJECT WITHOUT THE WRITTEN AUTHORIZATION OF GEI CONSULTANTS.

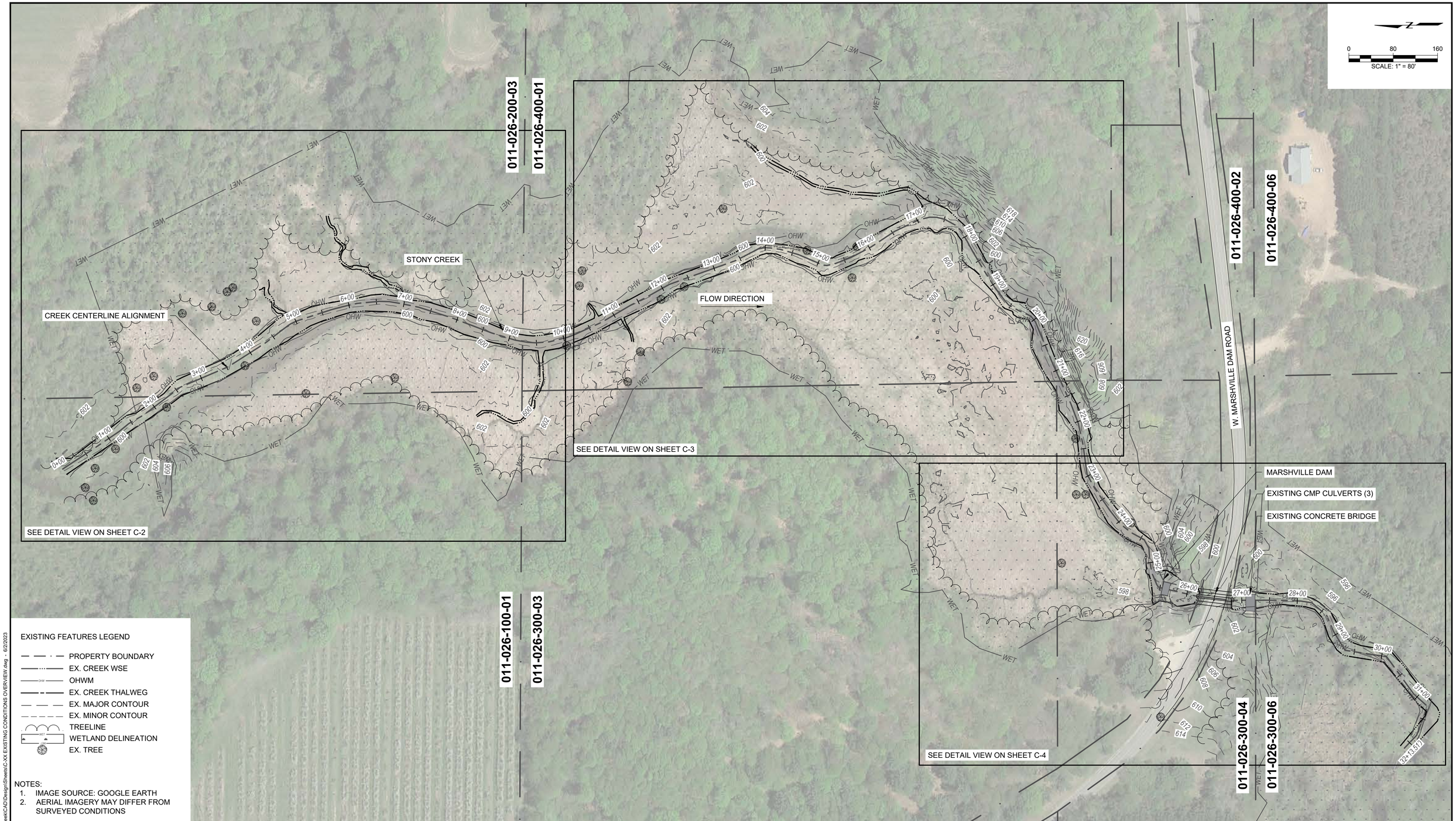
GEI PROJECT NO. 2200272

NO.	DATE	ISSUE/REVISION	APP
5	5/31/2023	CONSTRUCTION DRAWINGS	BM
4	3/22/2023	FOR PERMIT	BM
3	1/23/2023	FOR PERMIT	BM
2	12/22/2022	60% DESIGN SET	BM
1	7/20/2022	30% DESIGN SET	BM

DWG. NO.
G-1

SHEET NO.
1 OF 27

TRUITT_ASHLEY K:\WMSRDC\2200272_StonyCreek\CAD\Design\Sheets\G-01 COVER.dwg - 6/2/2023



EXISTING FEATURES LEGEND

- PROPERTY BOUNDARY
- EX. CREEK WSE
- OHWM
- EX. CREEK THALWEG
- EX. MAJOR CONTOUR
- EX. MINOR CONTOUR
- TREELINE
- WETLAND DELINEATION
- EX. TREE

NOTES:
1. IMAGE SOURCE: GOOGLE EARTH
2. AERIAL IMAGERY MAY DIFFER FROM SURVEYED CONDITIONS

Attention:
0 1"
If this scale bar does not measure 1" then drawing is not original scale.

MISS DIG System, Inc. 1-800-482-7171 www.missdig.org

STATE OF MICHIGAN SCOTT B. DIERKS ENGINEER No. 44371 PROFESSIONAL ENGINEER

Designed:	BM
Drawn:	AT
Checked:	
Approved:	BM
P.E. No:	44371
GEI Project	2200272

GEI Consultants

WMSRDC
316 MORRIS AVENUE
SUITE 340
MUSKEGON, MI 49440

MARSHVILLE DAM REMOVAL & STONY CREEK RESTORATION

STONY CREEK
MARSHVILLE DAM ROAD
SHELBY, MI 49455

NO	DATE	ISSUE/REVISION	APP
5	5/31/2023	CONSTRUCTION DRAWINGS	BM
4	3/22/2023	FOR PERMIT	BM
3	1/23/2023	FOR PERMIT	BM
2	12/22/2022	60% DESIGN SET	BM
1	7/20/2022	30% DESIGN SET	BM

SHEET NAME

EXISTING CONDITIONS OVERVIEW

DWG. NO.

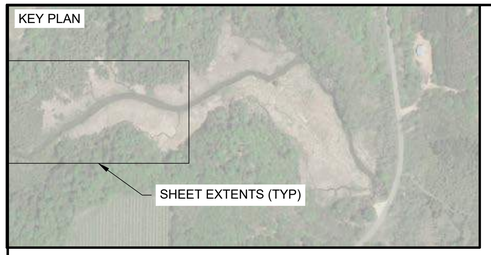
C-1

SHEET NO.

2 of 27

TRUITT, ASHLEY K:\WMSRDC\2200272_StonyCreek\CAD\Design\Sheets\C-XX EXISTING CONDITIONS OVERVIEW.dwg - 6/2/2023

KEY PLAN



NOTES:
1. IMAGE SOURCE: GOOGLE EARTH. AERIAL IMAGERY MAY DIFFER FROM SURVEYED CONDITIONS

EXISTING FEATURES LEGEND

- PROPERTY BOUNDARY
- EX. CREEK WSE
- OHWM
- EX. CREEK THALWEG
- EX. MAJOR CONTOUR
- EX. MINOR CONTOUR
- TREELINE
- WETLAND DELINEATION
- EX. TREE

N

0 30 60

SCALE: 1" = 30'

011-026-200-03

011-026-400-01

EXISTING TRIBUTARY

STONY CREEK

FLOW DIRECTION

EXISTING TRIBUTARY

EXISTING TRIBUTARY

011-026-100-01

011-026-300-03

A C-7 / A' C-7

B C-7 / B' C-7

C C-7 / C' C-7

D C-7 / D' C-7

E C-7 / E' C-7

0+00 1+00 2+00 3+00 4+00 5+00 6+00 7+00 8+00 9+00 10+00

600 601 602 603 604 605 606 607 608 609 610 612

OHW WET

Attention:

0 1"

If this scale bar does not measure 1" then drawing is not original scale.

MISS DIG System, Inc. 811 www.missdig.org 1-800-482-7171

SCOTT B. DIERKS ENGINEER NO. 44371 STATE OF MICHIGAN PROFESSIONAL ENGINEER

Designed:	BM
Drawn:	AT
Checked:	
Approved:	BM
P.E. No:	44371
GEI Project	2200272

GEI Consultants

WMSRDC
316 MORRIS AVENUE
SUITE 340
MUSKEGON, MI 49440

MARSHVILLE DAM REMOVAL & STONY CREEK RESTORATION

STONY CREEK
MARSHVILLE DAM ROAD
SHELBY, MI 49455

NO	DATE	ISSUE/REVISION	APP
5	5/31/2023	CONSTRUCTION DRAWINGS	BM
4	3/22/2023	FOR PERMIT	BM
3	1/23/2023	FOR PERMIT	BM
2	12/22/2022	60% DESIGN SET	BM
1	7/20/2022	30% DESIGN SET	BM

SHEET NAME

EXISTING CONDITIONS DETAIL VIEW

DWG. NO.

C-2

SHEET NO.

3 of 27

TRUITT, ASHLEY K:\WMSRDC\2200272_StonyCreek\CAD\Design\Sheets\C-XX EXISTING CONDITIONS DETAIL VIEW.dwg - 6/2/2023

KEY PLAN

NOTES:
1. IMAGE SOURCE: GOOGLE EARTH. AERIAL IMAGERY MAY DIFFER FROM SURVEYED CONDITIONS

EXISTING FEATURES LEGEND

- PROPERTY BOUNDARY
- EX. CREEK WSE
- OHWM
- EX. CREEK THALWEG
- EX. MAJOR CONTOUR
- EX. MINOR CONTOUR
- TREELINE
- WETLAND DELINEATION
- EX. TREE

N

0 30 60

SCALE: 1" = 30'

STONY CREEK

FLOW DIRECTION

EXISTING TRIBUTARY

EXISTING TRIBUTARY

EXISTING TRIBUTARY

011-026-400-01

011-026-300-03

TRUITT, ASHLEY K:\WMSRDC\2200272_StonyCreek\CAD\Design\Sheets\C-XX EXISTING CONDITIONS DETAIL VIEW.dwg - 6/2/2023

MISS DIG System, Inc. 811 www.missdig.org 1-800-482-7171

Attention:
0 1"
If this scale bar does not measure 1" then drawing is not original scale.

STATE OF MICHIGAN SCOTT B. DIERKS ENGINEER No. 44371 PROFESSIONAL ENGINEER

Designed:	BM
Drawn:	AT
Checked:	
Approved:	BM
P.E. No:	44371
GEI Project	2200272

GEI Consultants

WMSRDC
316 MORRIS AVENUE
SUITE 340
MUSKEGON, MI 49440

MARSHVILLE DAM REMOVAL & STONY CREEK RESTORATION

STONY CREEK
MARSHVILLE DAM ROAD
SHELBY, MI 49455

NO	DATE	ISSUE/REVISION	APP
5	5/31/2023	CONSTRUCTION DRAWINGS	BM
4	3/22/2023	FOR PERMIT	BM
3	1/23/2023	FOR PERMIT	BM
2	12/22/2022	60% DESIGN SET	BM
1	7/20/2022	30% DESIGN SET	BM

SHEET NAME

EXISTING CONDITIONS DETAIL VIEW

DWG. NO.

C-3

SHEET NO.

4 of 27

KEY PLAN

NOTES:
1. IMAGE SOURCE: GOOGLE EARTH. AERIAL IMAGERY MAY DIFFER FROM SURVEYED CONDITIONS

EXISTING FEATURES LEGEND

- PROPERTY BOUNDARY
- EX. CREEK WSE
- OHWM
- EX. CREEK THALWEG
- EX. MAJOR CONTOUR
- EX. MINOR CONTOUR
- TREELINE
- WETLAND DELINEATION
- EX. TREE

N

0 30 60
SCALE: 1" = 30'

W. MARSHVILLE DAM ROAD

STONY CREEK

TRIBUTARY

MARSHVILLE DAM

EX. PARKING AREA

SEE DETAIL VIEW ON SHEETC-5

EX. CONCRETE BRIDGE

FLOW DIRECTION

011-026-300-03

011-026-300-04

011-026-300-06

TRUITT, ASHLEY K:\WMSRDC\2200272_StonyCreek\CAD\Design\Sheets\C-XX EXISTING CONDITIONS DETAIL VIEW.dwg - 6/2/2023

MISS DIG System, Inc. 811 www.missdig.org 1-800-482-7171

Attention:
0 1"
If this scale bar does not measure 1" then drawing is not original scale.

SCOTT S. DIERKS ENGINEER No. 44371 STATE OF MICHIGAN PROFESSIONAL ENGINEER

Designed:	BM
Drawn:	AT
Checked:	
Approved:	BM
P.E. No:	44371
GEI Project	2200272

GEI Consultants

WMSRDC
316 MORRIS AVENUE
SUITE 340
MUSKEGON, MI 49440

MARSHVILLE DAM REMOVAL & STONY CREEK RESTORATION

STONY CREEK
MARSHVILLE DAM ROAD
SHELBY, MI 49455

NO	DATE	ISSUE/REVISION	APP
5	5/31/2023	CONSTRUCTION DRAWINGS	BM
4	3/22/2023	FOR PERMIT	BM
3	1/23/2023	FOR PERMIT	BM
2	12/22/2022	60% DESIGN SET	BM
1	7/20/2022	30% DESIGN SET	BM

SHEET NAME

EXISTING CONDTIONS DETAIL VIEW

DWG. NO.

C-4

SHEET NO.

5 of 27

KEY PLAN

N

0 10 20

SCALE: 1" = 10'

MARSHVILLE DAM

STONY CREEK

W. MARSHVILLE DAM ROAD

6.5' DIA. CMP CULVERT
INV ELEV: 594.24'

6.5' DIA. CMP CULVERT
INV ELEV: 593.66'

6.5' DIA. CMP CULVERT
INV ELEV: 594.00'

EX. CONCRETE BRIDGE
TOP ELEV APPROX: 600.35

6.5' DIA. CMP CULVERT
INV ELEV: 593.55'

6.5' DIA. CMP CULVERT
INV ELEV: 593.54'

6.5' DIA. CMP CULVERT
INV ELEV: 593.72'

FLOW DIRECTION

011-026-300-04

011-026-300-06

EXISTING FEATURES LEGEND

- PROPERTY BOUNDARY
- EX. CREEK WSE
- OHWM
- EX. CREEK THALWEG
- EX. MAJOR CONTOUR
- EX. MINOR CONTOUR
- TREELINE
- WETLAND DELINEATION
- EX. TREE

NOTES:

1. IMAGE SOURCE: GEI CONSULTANTS
2. AERIAL IMAGERY MAY DIFFER FROM SURVEYED CONDITIONS

Attention:

0 1"

If this scale bar does not measure 1" then drawing is not original scale.

STATE OF MICHIGAN · SCOTT B. DIERKS · ENGINEER · No. 44371 · PROFESSIONAL ENGINEER

Designed:	BM
Drawn:	AT
Checked:	
Approved:	BM
P.E. No:	44371
GEI Project	2200272

GEI Consultants

WMSRDC
316 MORRIS AVENUE
SUITE 340
MUSKEGON, MI 49440

MARSHVILLE DAM REMOVAL & STONY CREEK RESTORATION

STONY CREEK
MARSHVILLE DAM ROAD
SHELBY, MI 49455

NO	DATE	ISSUE/REVISION	APP
5	5/31/2023	CONSTRUCTION DRAWINGS	BM
4	3/22/2023	FOR PERMIT	BM
3	1/23/2023	FOR PERMIT	BM
2	12/22/2022	60% DESIGN SET	BM
1	7/20/2022	30% DESIGN SET	BM

SHEET NAME

EXISTING CONDITIONS DAM DETAIL VIEW

DWG. NO.

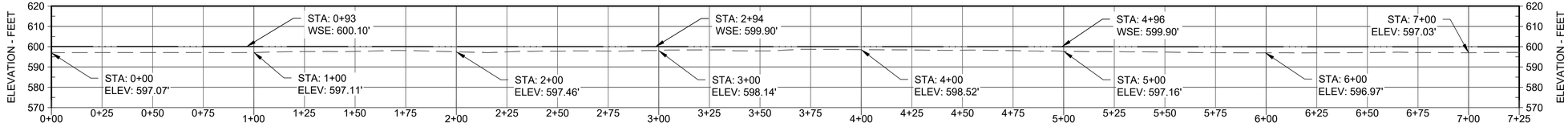
C-5

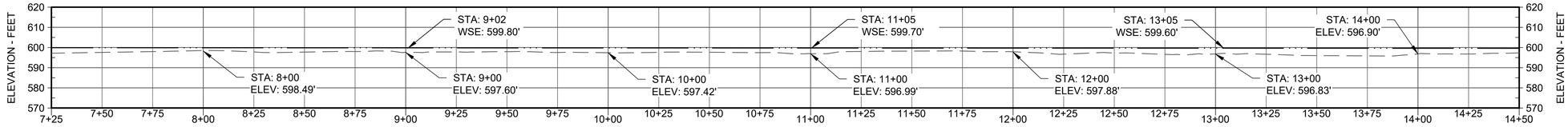
SHEET NO.

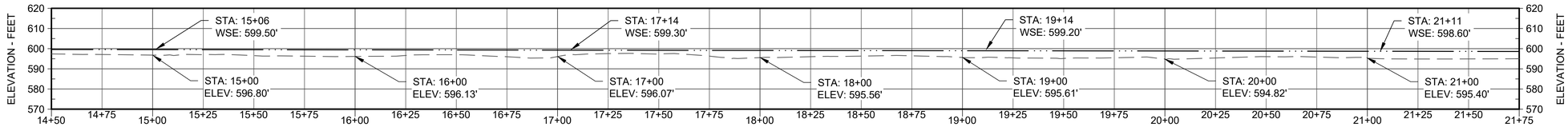
6 of 27

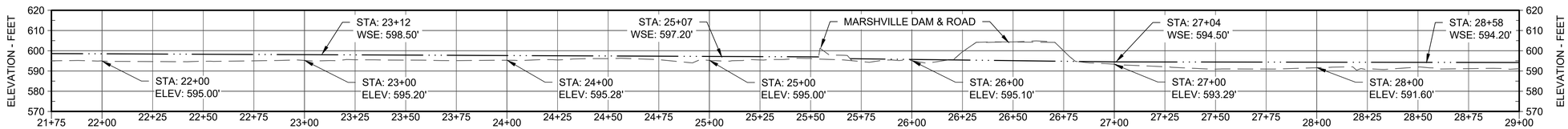
MISS DIG System, Inc. 811 www.missdig.org 1-800-482-7171

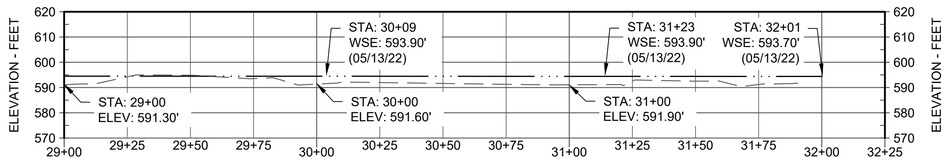
TRUITT, ASHLEY K:\WMSRDC\2200272_StonyCreek\CAD\DesignSheets\C-XX EXISTING CONDITIONS DAM DETAIL VIEW.dwg - 6/2/2023







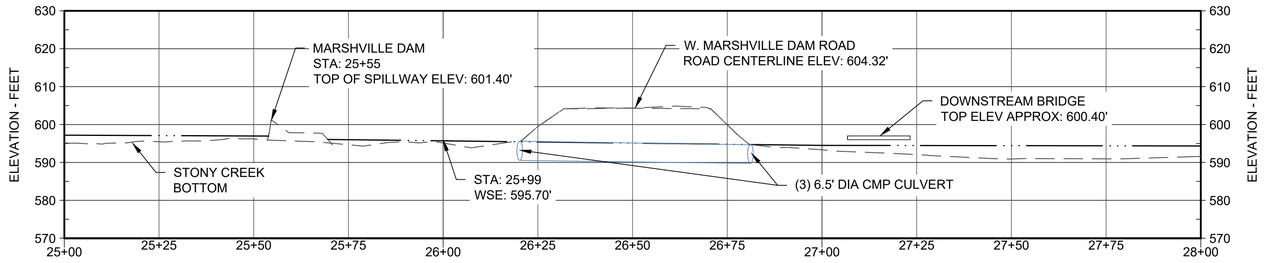




CREEK PROFILE

STA. 0+00 - STA. 32+25

SCALE, FEET: 0, 30, 60



CREEK PROFILE

STA. 25+00 - STA. 28+00

SCALE, FEET: 0, 20, 40

SURVEYED WATER SURFACE ELEVATION

EXISTING CREEK BATHYMETRY AND SURROUNDING TOPOGRAPHY

Attention:

0 1"

If this scale bar does not measure 1" then drawing is not original scale.

STATE OF MICHIGAN SCOTT S. DIERKS ENGINEER NO. 44371 PROFESSIONAL ENGINEER

Designed:	BM
Drawn:	AT
Checked:	
Approved:	BM
P.E. No:	44371
GEI Project	2200272

GEI Consultants

WMSRDC
316 MORRIS AVENUE
SUITE 340
MUSKEGON, MI 49440

MARSHVILLE DAM REMOVAL & STONY CREEK RESTORATION

STONY CREEK
MARSHVILLE DAM ROAD
SHELBY, MI 49455

NO	DATE	ISSUE/REVISION	APP
5	5/31/2023	CONSTRUCTION DRAWINGS	BM
4	3/22/2023	FOR PERMIT	BM
3	1/23/2023	FOR PERMIT	BM
2	12/22/2022	60% DESIGN SET	BM
1	7/20/2022	30% DESIGN SET	BM

SHEET NAME

EXISTING CONDITIONS PROFILE

DWG. NO.

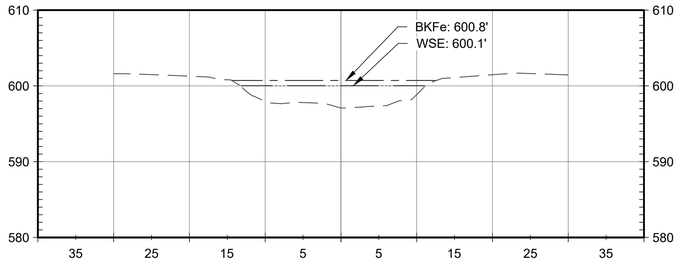
C-6

SHEET NO.

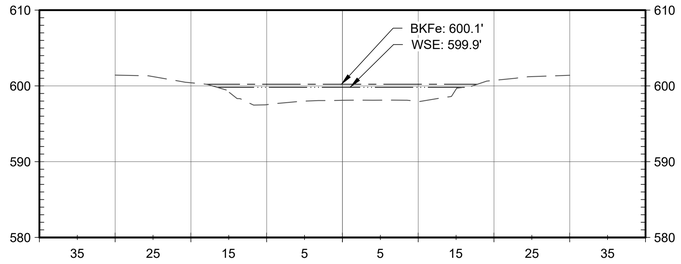
7 of 27

MISS DIG System, Inc. www.missdig.org 1-800-482-7171

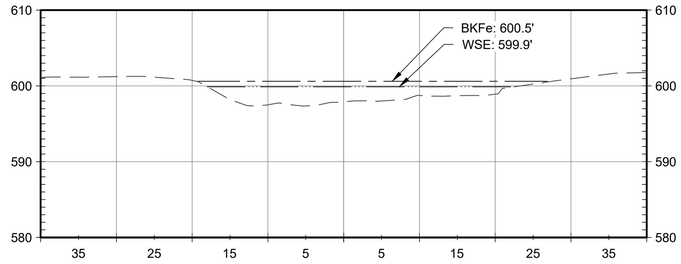
TRUITT, ASHLEY K:\WMSRDC\2200272_StonyCreek\CAD\Design\Sheets\C-XX PROFILE.dwg - 6/2/2023



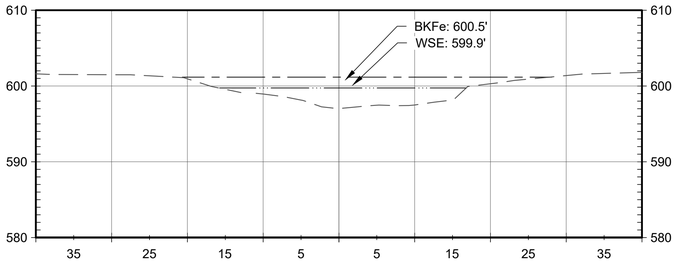
A C-2 SECTION 0+93
SCALE: 1" = 10'



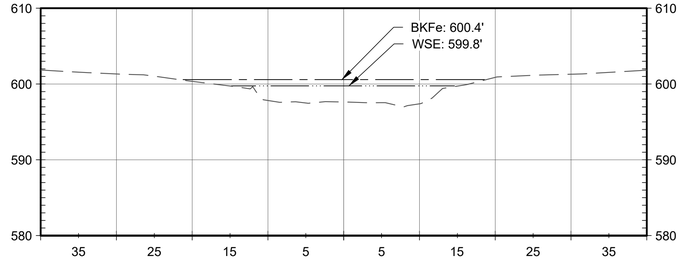
B C-2 SECTION 2+94
SCALE: 1" = 10'



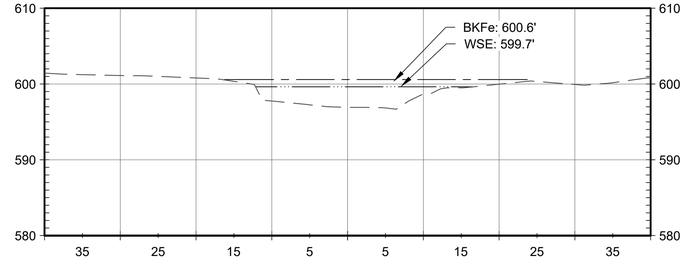
C C-2 SECTION 4+96
SCALE: 1"=20'



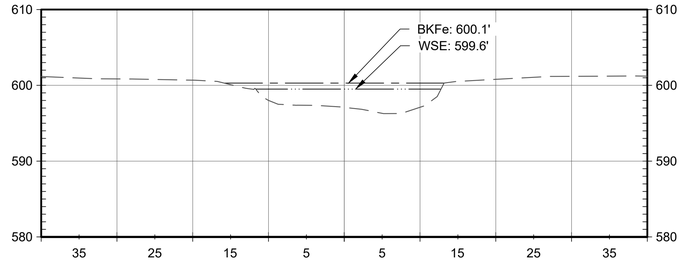
D C-2 SECTION 7+02
SCALE: 1"=20'



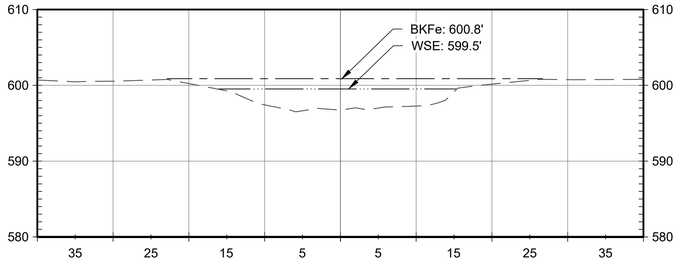
E C-2 SECTION 9+02
SCALE: 1" = 10'



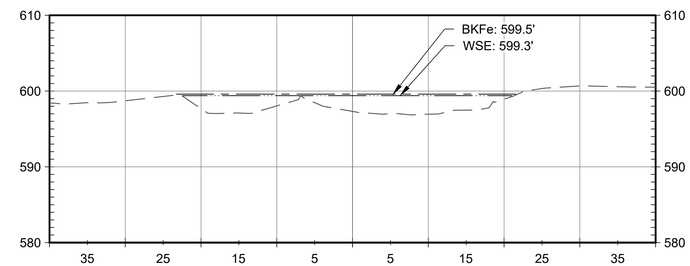
F C-3 SECTION 11+05
SCALE: 1" = 10'



G C-3 SECTION 13+05
SCALE: 1"=20'



H C-3 SECTION 15+06
SCALE: 1"=20'



I C-3 SECTION 17+14
SCALE: 1"=20'

SURVEYED WATER SURFACE ELEVATION
SURVEYED BANKFUL ELEVATION
EXISTING CREEK BATHYMETRY AND SURROUNDING TOPOGRAPHY

0 10 20
SCALE: 1" = 10'

TRUITT, ASHLEY K:\WMSRDC\2200272_StonyCreek\CAD\Design\Sheets\C-XX SECTIONS.dwg - 6/2/2023

MISS DIG System, Inc. 811 www.missdig.org 1-800-482-7171

Attention:
0 1"
If this scale bar does not measure 1" then drawing is not original scale.

STATE OF MICHIGAN SCOTT B. DIERKS ENGINEER NO. 44371 PROFESSIONAL ENGINEER

Designed:	BM
Drawn:	AT
Checked:	
Approved:	BM
P.E. No:	44371
GEI Project	2200272

GEI Consultants

WMSRDC
316 MORRIS AVENUE
SUITE 340
MUSKEGON, MI 49440

MARSHVILLE DAM REMOVAL & STONY CREEK RESTORATION

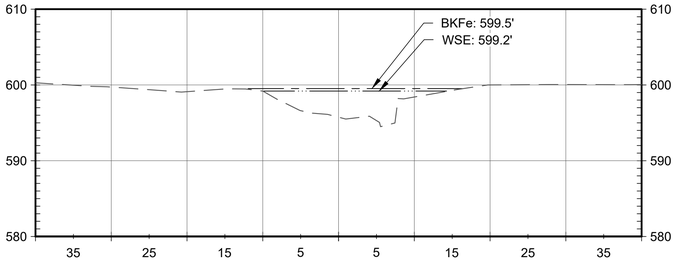
STONY CREEK
MARSHVILLE DAM ROAD
SHELBY, MI 49455

NO	DATE	ISSUE/REVISION	APP
5	5/31/2023	CONSTRUCTION DRAWINGS	BM
4	3/22/2023	FOR PERMIT	BM
3	1/23/2023	FOR PERMIT	BM
2	12/22/2022	60% DESIGN SET	BM
1	7/20/2022	30% DESIGN SET	BM

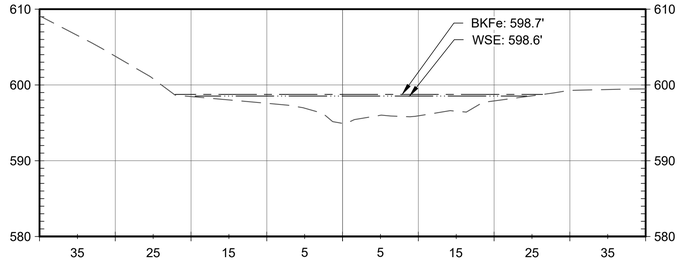
SHEET NAME
EXISTING CONDITIONS SECTIONS

DWG. NO.
C-7

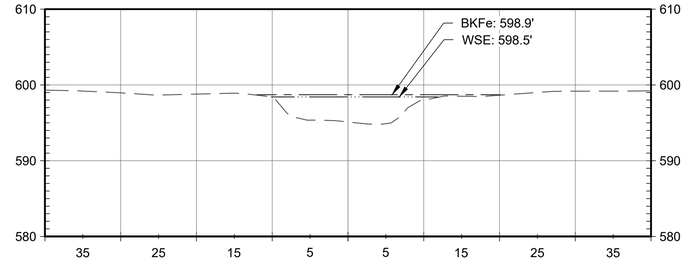
SHEET NO.
8 of 27



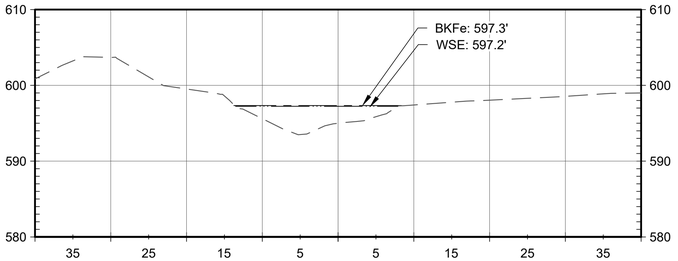
J / C-3 SECTION 19+14
SCALE: 1"=20'



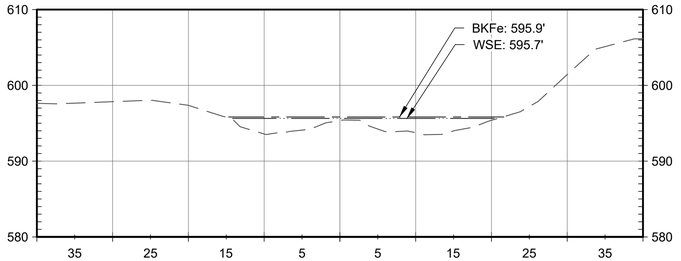
K / C-3 SECTION 21+11
SCALE: 1"=20'



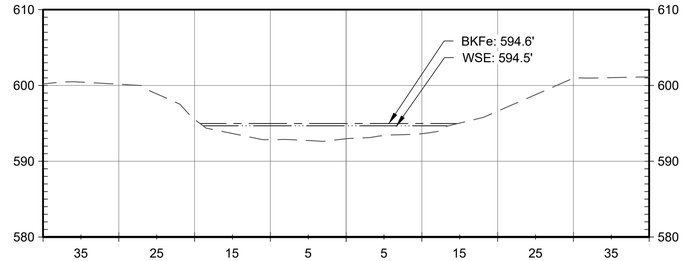
L / C-4 SECTION 23+12
SCALE: 1"=20'



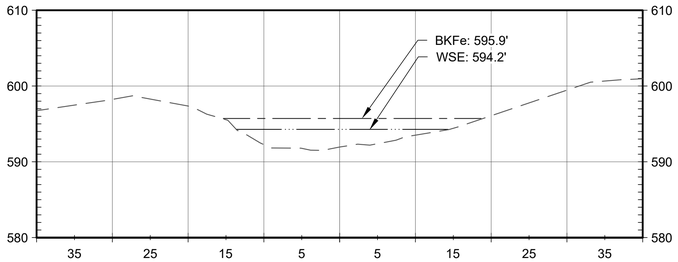
M / C-4 SECTION 25+07
SCALE: 1"=20'



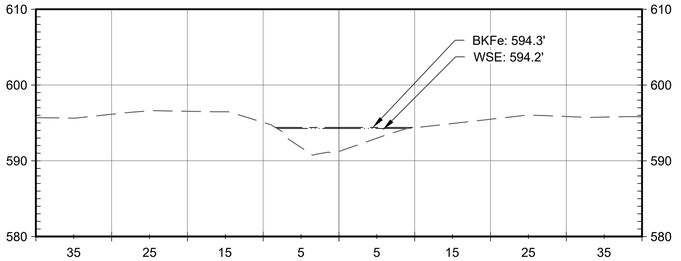
N / C-4 SECTION 25+99
SCALE: 1"=20'



O / C-4 SECTION 27+04
SCALE: 1"=20'



P / C-4 SECTION 27+28
SCALE: 1"=20'



Q / C-4 SECTION 28+58
SCALE: 1"=20'

REFERENCE REACH SECTIONS

SURVEYED WATER SURFACE ELEVATION
SURVEYED BANKFUL ELEVATION
EXISTING CREEK BATHYMETRY AND SURROUNDING TOPOGRAPHY

0 10 20
SCALE: 1" = 10'

Attention:
0 1"
If this scale bar does not measure 1" then drawing is not original scale.

MISS DIG System, Inc. 811 www.missdig.org 1-800-482-7171

SCOTT S. DIERKS ENGINEER NO. 44371 STATE OF MICHIGAN PROFESSIONAL ENGINEER

Designed:	BM
Drawn:	AT
Checked:	
Approved:	BM
P.E. No:	44371
GEI Project	2200272

GEI Consultants

WMSRDC
316 MORRIS AVENUE
SUITE 340
MUSKEGON, MI 49440

MARSHVILLE DAM REMOVAL & STONY CREEK RESTORATION

STONY CREEK
MARSHVILLE DAM ROAD
SHELBY, MI 49455

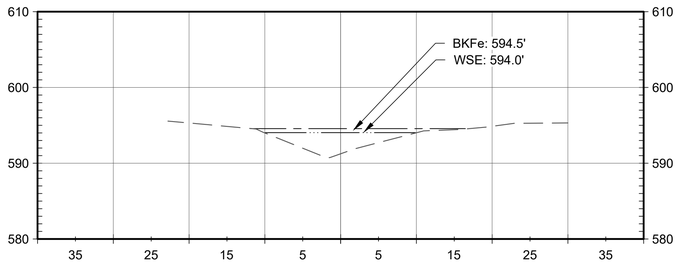
NO	DATE	ISSUE/REVISION	APP
5	5/31/2023	CONSTRUCTION DRAWINGS	BM
4	3/22/2023	FOR PERMIT	BM
3	1/23/2023	FOR PERMIT	BM
2	12/22/2022	60% DESIGN SET	BM
1	7/20/2022	30% DESIGN SET	BM

SHEET NAME
EXISTING CONDITIONS SECTIONS

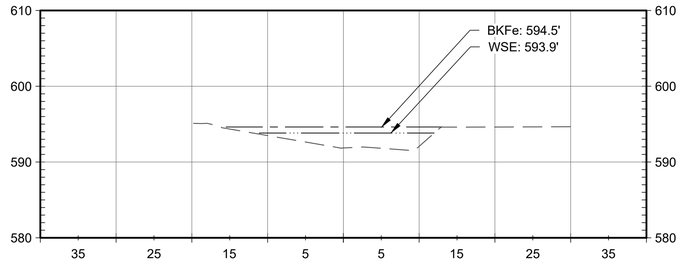
DWG. NO.
C-8

SHEET NO.
9 of 27

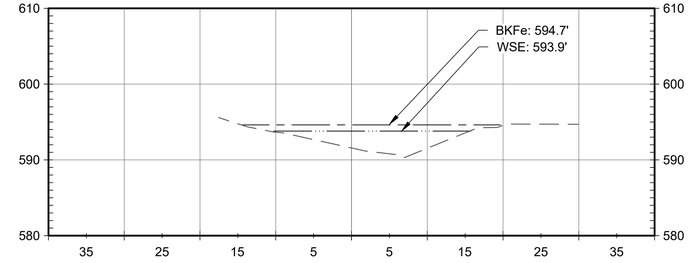
TRUITT, ASHLEY K:\WMSRDC\2200272_StonyCreek\CAD\Design\Sheets\C-XX SECTIONS.dwg - 6/2/2023



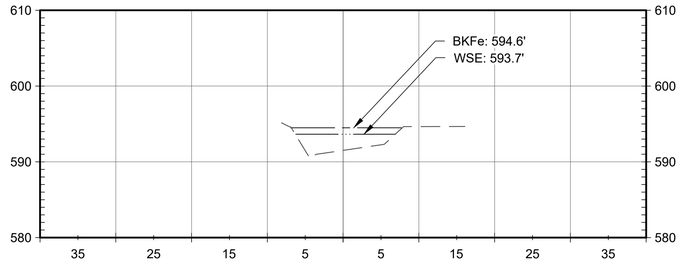
R C-4 SECTION 28+82
SCALE: 1"=20'



S C-4 SECTION 30+09
SCALE: 1"=20'



T C-4 SECTION 31+23
SCALE: 1"=20'



U C-4 SECTION 31+85
SCALE: 1"=20'

REFERENCE REACH SECTIONS

SURVEYED WATER SURFACE ELEVATION
SURVEYED BANKFUL ELEVATION
EXISTING CREEK BATHYMETRY AND SURROUNDING TOPOGRAPHY

0 10 20
SCALE: 1" = 10'

Attention:
0 1"
If this scale bar does not measure 1" then drawing is not original scale.

MISS DIG System, Inc. 811 www.missdig.org 1-800-482-7171

SCOTT B. DIERKS ENGINEER NO. 44371 STATE OF MICHIGAN PROFESSIONAL ENGINEER

Designed:	BM
Drawn:	AT
Checked:	
Approved:	BM
P.E. No:	44371
GEI Project	2200272

GEI Consultants

WMSRDC
316 MORRIS AVENUE
SUITE 340
MUSKEGON, MI 49440

MARSHVILLE DAM REMOVAL & STONY CREEK RESTORATION

STONY CREEK
MARSHVILLE DAM ROAD
SHELBY, MI 49455

NO	DATE	ISSUE/REVISION	APP
5	5/31/2023	CONSTRUCTION DRAWINGS	BM
4	3/22/2023	FOR PERMIT	BM
3	1/23/2023	FOR PERMIT	BM
2	12/22/2022	60% DESIGN SET	BM
1	7/20/2022	30% DESIGN SET	BM

SHEET NAME
EXISTING CONDITIONS SECTIONS: REFERENCE REACH

DWG. NO.
C-9

SHEET NO.
10 of 27

TRUITT, ASHLEY K:\WMSRDC\2200272_StonyCreek\CAD\Design\Sheets\C-XX SECTIONS.dwg - 6/2/2023

S. 48TH AVE

011-026-100-01

011-026-300-03

011-026-200-03

011-026-400-01

W. MARSHVILLE DAM ROAD

S. 54TH AVE

WORK AREA ACCESS
CONSTRUCT ACCESS ROAD. CONTRACTOR TO MAINTAIN AS NEEDED AND RESTORE TO PRE-CONSTRUCTION CONDITION OR BETTER AFTER USE.
TEMPORARY WETLAND IMPACTS: 56,490-SF

TEMPORARY WETLAND IMPACTS: 19,380-SF

APPROX. LIMITS OF ROAD CLOSURE (TO BE IMPLEMENTED AND MANAGED BY OCEANA COUNTY ROAD COMMISSION)

SITE ACCESS
SITE ACCESS FROM MARSHVILLE DAM ROAD.

011-026-300-04

011-026-400-02

011-026-300-06

011-026-400-06

STAGING AREA
EXISTING PARKING AREA TO SERVE AS ACCESS AND STAGING AREA FOR THIS PROJECT.

AVAILABLE ACCESS ROUTE
ROUTE TO BE DETERMINED BASED ON EXISTING LOGGING ROADS AND PROPERTY OWNER APPROVAL.

NO DISTURBANCE OR SOIL PLACEMENT IN THIS AREA

STAGING AND SPOILS DISPOSAL LOCATION

N

0 75' 150' 300'
SCALE, FEET

EXISTING FEATURES LEGEND

- PROPERTY BOUNDARY
- EX. CREEK WSE
- OHWM
- EX. CREEK THALWEG
- EX. MAJOR CONTOUR
- EX. MINOR CONTOUR
- TREELINE
- WETLAND DELINEATION
- EX. TREE

NOTES:
1. IMAGE SOURCE: MICROSOFT. AERIAL IMAGERY MAY DIFFER FROM SURVEYED CONDITIONS

Attention:
0 1"
If this scale bar does not measure 1" then drawing is not original scale.

STATE OF MICHIGAN · SCOTT B. DIERKS · ENGINEER · No. 44371 · PROFESSIONAL ENGINEER

Designed:	BM
Drawn:	AT
Checked:	
Approved:	BM
P.E. No:	44371
GEI Project	2200272

GEI Consultants

WMSRDC
316 MORRIS AVENUE
SUITE 340
MUSKEGON, MI 49440

MARSHVILLE DAM REMOVAL & STONY CREEK RESTORATION

STONY CREEK
MARSHVILLE DAM ROAD
SHELBY, MI 49455

NO	DATE	ISSUE/REVISION	APP
5	5/31/2023	CONSTRUCTION DRAWINGS	BM
4	3/22/2023	FOR PERMIT	BM
3	1/23/2023	FOR PERMIT	BM
2	12/22/2022	60% DESIGN SET	BM
1	7/20/2022	30% DESIGN SET	BM

SHEET NAME

ACCESS AND STAGING

DWG. NO.

C-10

SHEET NO.

11 of 27

MISS DIG System, Inc. www.missdig.org 1-800-482-7171

TRUITT, ASHLEY K:\WMSRDC\2200272_StonyCreek\CAD\Design\Sheets\C-XX ACCESS PLAN.dwg - 6/2/2023

PROPOSED PROJECT TASKS AND SCHEDULE

		2023																2024																			
		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC		JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV	
TASK	**RESPONSIBILITY**	1	15	1	15	1	15	1	15	1	15	1	15	1	15	1	15	1	15	1	15	1	15	1	15	1	15	1	15	1	15	1	15	1	15	1	15
Advertise For Bids/Acquire Contracts	OCRC/WMSRDC/CRA																																				
Order Bridge Materials (4 Month Lead Time)	OCRC																																				
Road Closure	OCRC																																				
Construct Staging Area	OCRC/sub																																				
Remove Downstream Bridge	OCRC/sub																																				
Remove Existing Culverts	OCRC/sub																																				
Excavate Stream Channel Below Road to Grade	OCRC/sub																																				
Install New Bridge Abutments and Piers	OCRC/sub																																				
Install Timber Bridge	OCRC																																				
Construct Roadway Approaches	OCRC																																				
Pave Roadway	OCRC/sub																																				
Install Guardrail	OCRC/sub																																				
Excavate Stream Channel Upstream from Dam	WMSRDC/CRA																																				
Excavate Stream Channel Downstream from Dam to Meet Road	WMSRDC/CRA																																				
Dam Drawdown	WMSRDC/CRA																																				
Dam Removal	WMSRDC/CRA																																				
Excavate Floodplain	WMSRDC/CRA																																				
Stage Material for Bank Stabilization	WMSRDC/CRA																																				
Install Bank Stabilization Measures	WMSRDC/CRA																																				
Remove and Repair Construction Access Roads	WMSRDC/CRA																																				
Install New Boardwalk and Viewing Platform	OCRC/CRA																																				
Final Site Repairs and Restoration	OCRC/WMSRDC/CRA																																				
Invasive Species Control	WMSRDC/CRA																																				
Install Native Seed and Trees	WMSRDC/CRA																																				

PROPOSED PROJECT SEQUENCING NOTES

TASK	RESPONSIBILITY	DURATION
Close Road for Construction	OCRC	14 Weeks
Mobilization/Construct Construction Staging	OCRC	1 Week
Install Temporary Erosion Controls (Turbidity Curtain and Silt Fence)	OCRC/WMSRDC/CRA	1 Week
Remove Downstream Bridge	OCRC	2 Weeks
Remove Existing Culverts	OCRC	2 Weeks
Construct New Stream Channel in Current Location of Culverts	OCRC	2 Weeks
Install Bridge Abutments and Piers	OCRC	2 Weeks
Install New Timber Bridge	OCRC	2 Weeks
Construct Roadway Approaches	OCRC	1 Week
Pave Roadway	OCRC	1 Week
Install Guardrail	OCRC	1 Week
Excavate Pilot Channel Upstream of Dam at Elevation of New River Thalweg	WMSRDC/CRA	2 Weeks
Excavate Stream Channel Downstream from Dam to Meet Road	WMSRDC/CRA	1 Week
Dam Drawdown (0.5' per day)	WMSRDC/CRA	1 Week
Remove Existing Dam	WMSRDC/CRA	2 Weeks
Excavate Floodplain	WMSRDC/CRA	2 Weeks
Install Bank Stabilization Measures and Permanent Erosion Controls	WMSRDC/CRA	3 Weeks
Remove and Repair Access Roads	WMSRDC/CRA	1 Week
Install Boardwalk and Viewing Platforms	WMSRDC/CRA	3 Weeks
Install Native Trees and Shrubs	WMSRDC/CRA	1 Week
Final Repair and Restoration	WMSRDC/CRA	1 Week

TRUITT, ASHLEY K:\WMSRDC\2200272_StonyCreek\CAD\Design\Sheets\C-XX ACCESS PLAN.dwg - 6/2/2023

MISS DIG System, Inc. www.missdig.org 1-800-482-7171

Attention:
0 1"
If this scale bar does not measure 1" then drawing is not original scale.

STATE OF MICHIGAN SCOTT B. DIERKS ENGINEER No. 44371 PROFESSIONAL ENGINEER

Designed:	BM
Drawn:	AT
Checked:	
Approved:	BM
P.E. No:	44371
GEI Project	2200272

GEI Consultants

WMSRDC
316 MORRIS AVENUE
SUITE 340
MUSKEGON, MI 49440

MARSHVILLE DAM REMOVAL & STONY CREEK RESTORATION

STONY CREEK
MARSHVILLE DAM ROAD
SHELBY, MI 49455

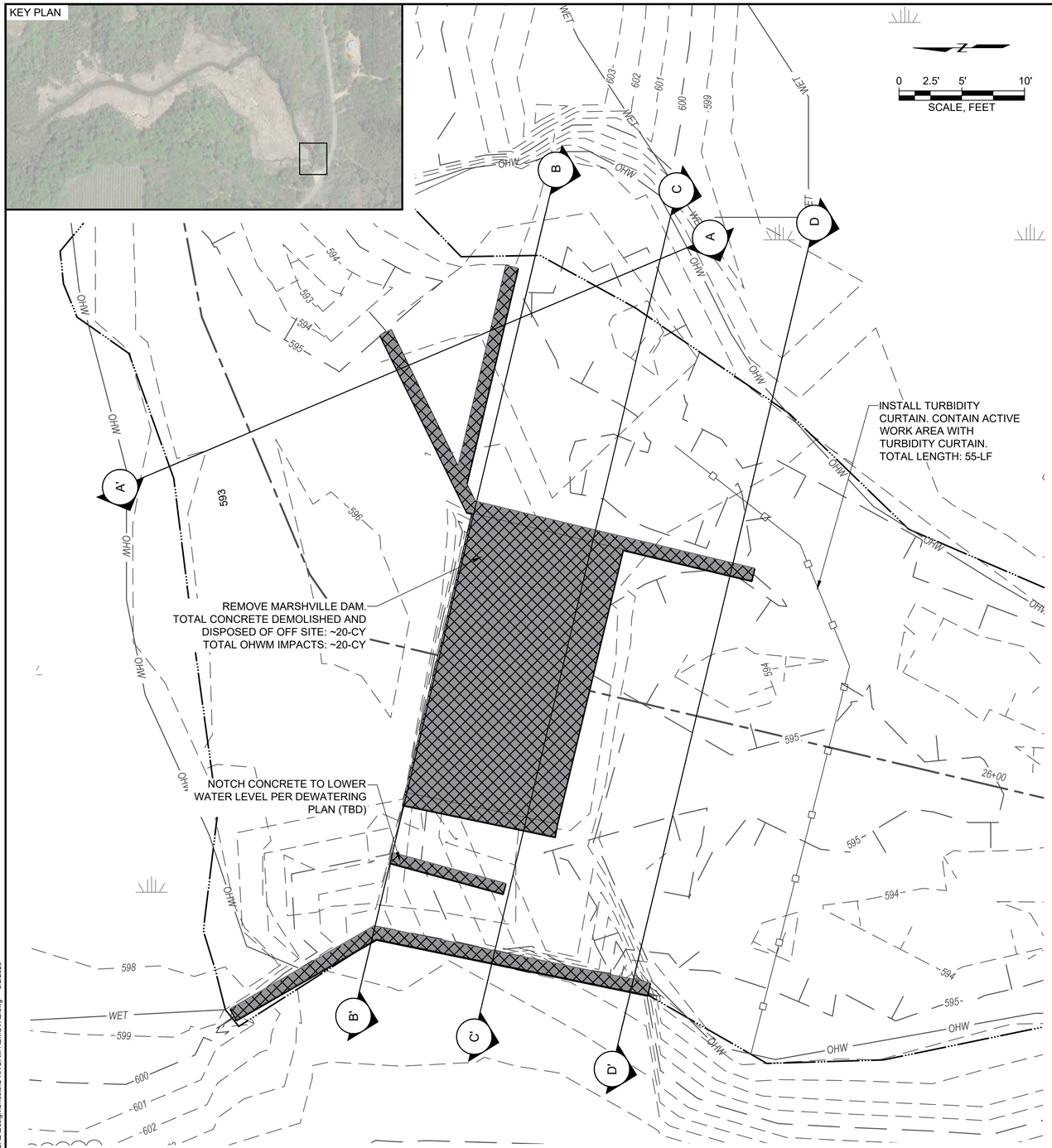
NO	DATE	ISSUE/REVISION	APP
5	5/31/2023	CONSTRUCTION DRAWINGS	BM
4	3/22/2023	FOR PERMIT	BM
3	1/23/2023	FOR PERMIT	BM
2	12/22/2022	60% DESIGN SET	BM
1	7/20/2022	30% DESIGN SET	BM

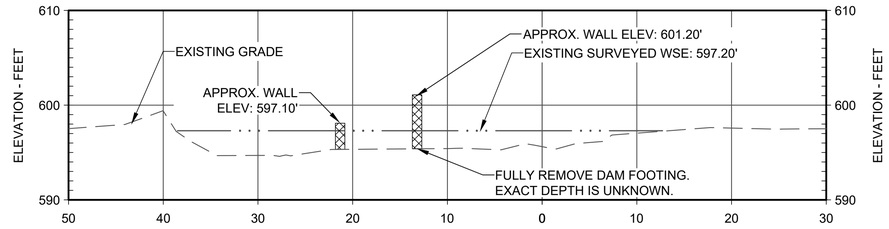
SHEET NAME
PROJECT SEQUENCING

DWG. NO.
C-11

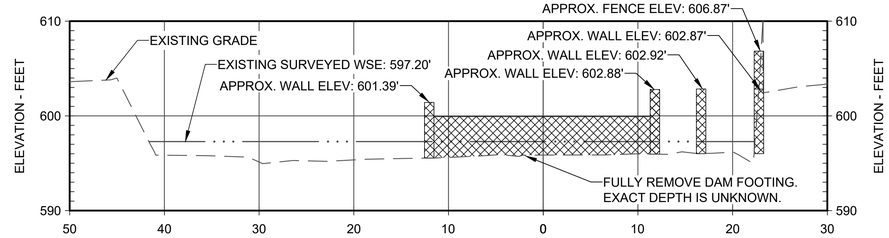
SHEET NO.
12 of 27

KEY PLAN

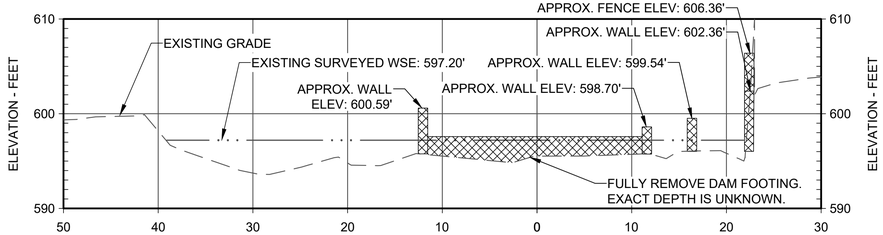




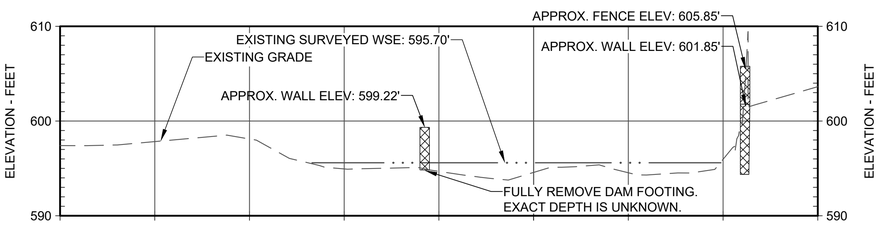
SECTION A-A'
STATION 25+29 SCALE: 1"=8'



SECTION B-B'
STATION 25+55 SCALE: 1"=8'



SECTION C-C'
STATION 25+64 SCALE: 1"=8'



SECTION D-D'
STATION 25+76 SCALE: 1"=8'

EXISTING FEATURES LEGEND

- EX. CREEK WSE
- OHWM
- EX. CREEK THALWEG
- EX. MAJOR CONTOUR
- EX. MINOR CONTOUR
- TREELINE
- WETLAND DELINEATION
- EX. TREE

MISS DIG System, Inc. 811 www.missdig.org 1-800-482-7171

Attention:
0 1"
If this scale bar does not measure 1" then drawing is not original scale.

STATE OF MICHIGAN SCOTT B. DIERKS ENGINEER No. 44371 PROFESSIONAL ENGINEER

Designed:	BM
Drawn:	AT
Checked:	
Approved:	BM
P.E. No:	44371
GEI Project	2200272

GEI Consultants

WMSRDC
316 MORRIS AVENUE
SUITE 340
MUSKEGON, MI 49440

MARSHVILLE DAM REMOVAL & STONY CREEK RESTORATION

STONY CREEK
MARSHVILLE DAM ROAD
SHELBY, MI 49455

NO	DATE	ISSUE/REVISION	APP
5	5/31/2023	CONSTRUCTION DRAWINGS	BM
4	3/22/2023	FOR PERMIT	BM
3	1/23/2023	FOR PERMIT	BM
2	12/22/2022	60% DESIGN SET	BM
1	7/20/2022	30% DESIGN SET	BM

SHEET NAME
DAM REMOVAL PLAN AND SECTIONS

DWG. NO.
C-12

SHEET NO.
13 of 27

TRUITT, ASHLEY K:\WMSRDC\2200272_StonyCreekCAD\Design\Sheets\C-XX DAM REMOVAL.dwg - 6/2/2023

KEY PLAN

EXISTING FEATURES LEGEND

- EX. CREEK WSE
- OHWM
- EX. CREEK THALWEG
- EX. MAJOR CONTOUR
- EX. MINOR CONTOUR
- WETLAND DELINEATION

PROPOSED FEATURES LEGEND

- PR. CREEK WSE
- PR. CREEK THALWEG
- PR. MAJOR CONTOUR
- PR. MINOR CONTOUR
- DRAWDOWN AREA

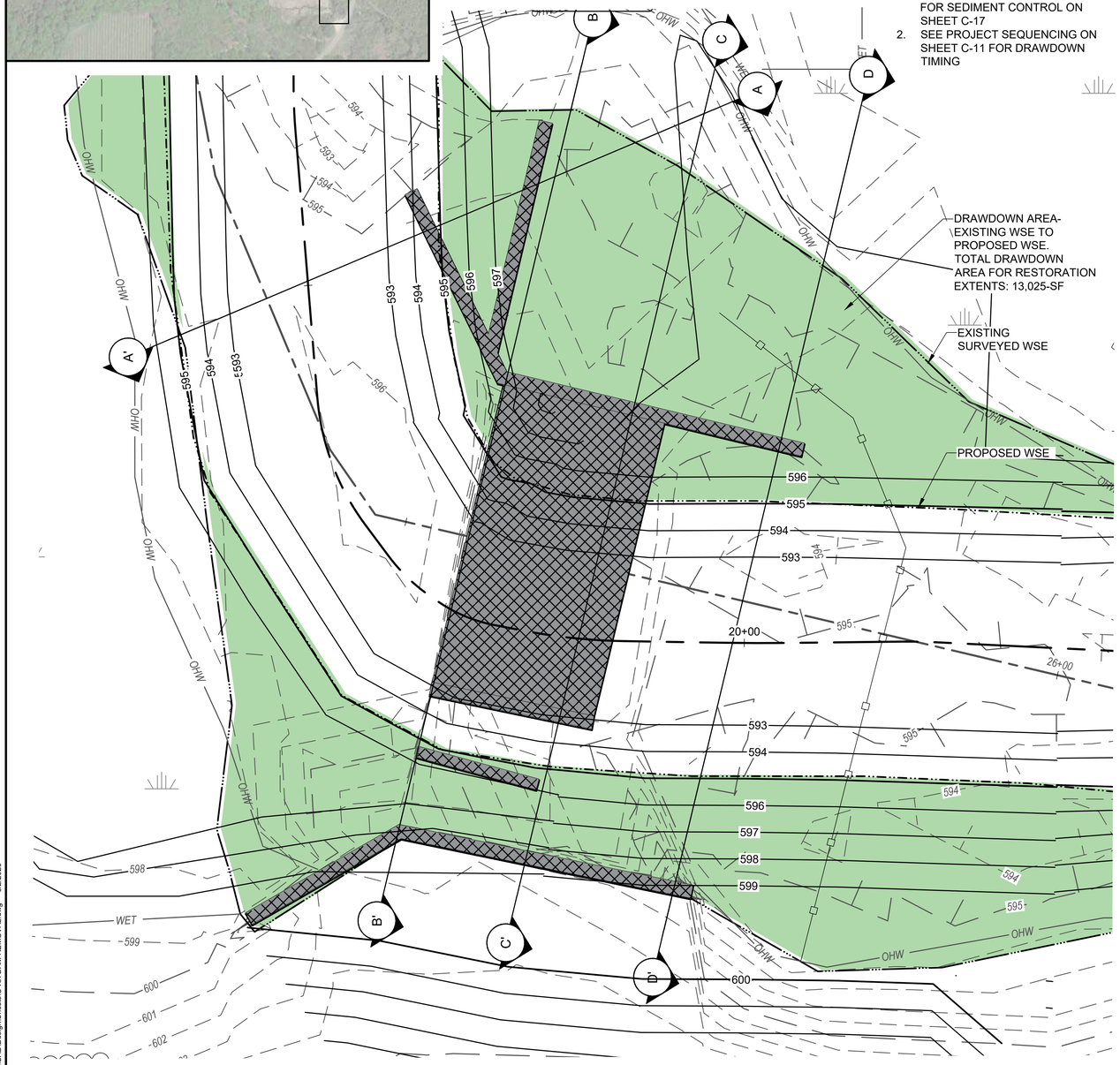
N

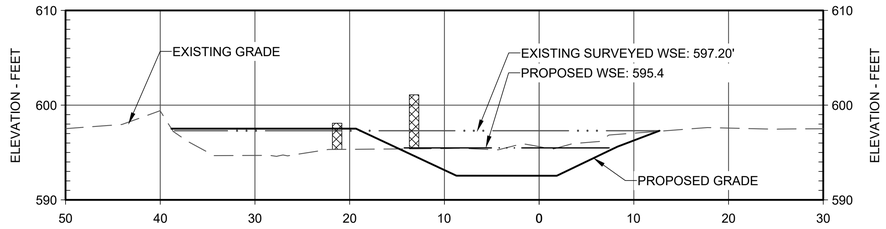
0 2.5' 5' 10'

SCALE, FEET

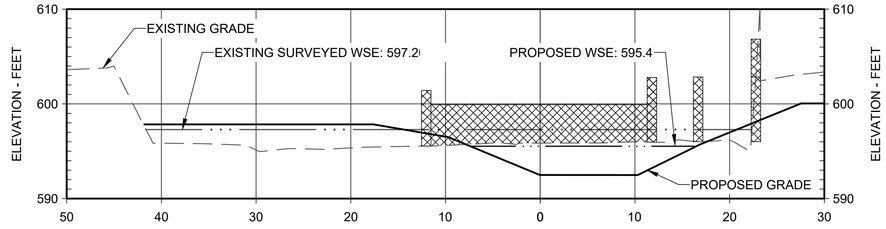
NOTES:

1. SEE PILOT CHANNEL DREDGING FOR SEDIMENT CONTROL ON SHEET C-17
2. SEE PROJECT SEQUENCING ON SHEET C-11 FOR DRAWDOWN TIMING

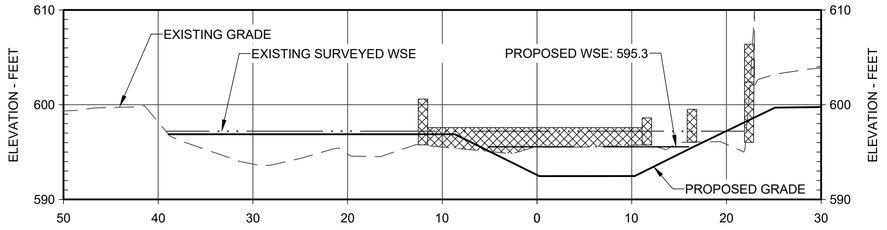




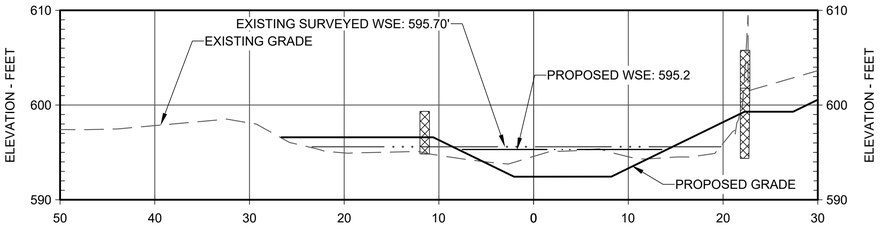
SECTION A-A'
STATION 25+29
SCALE: 1"=8'



SECTION B-B'
STATION 25+55
SCALE: 1"=8'



SECTION C-C'
STATION 25+64
SCALE: 1"=8'



SECTION D-D'
STATION 25+76
SCALE: 1"=8'

Attention:

0 1"

If this scale bar does not measure 1" then drawing is not original scale.

STATE OF MICHIGAN SCOTT B. DIERKS ENGINEER No. 44371 LICENSED PROFESSIONAL ENGINEER

Designed:	BM
Drawn:	AT
Checked:	
Approved:	BM
P.E. No:	44371
GEI Project	2200272

GEI Consultants

WMSRDC
316 MORRIS AVENUE
SUITE 340
MUSKEGON, MI 49440

MARSHVILLE DAM REMOVAL & STONY CREEK RESTORATION

STONY CREEK
MARSHVILLE DAM ROAD
SHELBY, MI 49455

NO	DATE	ISSUE/REVISION	APP
5	5/31/2023	CONSTRUCTION DRAWINGS	BM
4	3/22/2023	FOR PERMIT	BM
3	1/23/2023	FOR PERMIT	BM
2	12/22/2022	60% DESIGN SET	BM
1	7/20/2022	30% DESIGN SET	BM

SHEET NAME

DRAWDOWN

DWG. NO.

C-13

SHEET NO.

14 of 27

TRUITT, ASHLEY K:\WMSRDC\2200272_StonyCreek\CAD\Design\Sheets\C-XX DAM REMOVAL.dwg - 6/2/2023

KEY PLAN

OVERALL PROJECT EARTHWORK

	VOL (CY)	AREA (SF)
CUT	4,120	67,890
EARTH FILL	250	9,500
WOOD FILL	110	3,500
STONE FILL	0	0
TOTAL FILL	360	13,000
NET EARTHWORK	3,760 CUT	80,890

OVERALL PROJECT OHWM IMPACTS

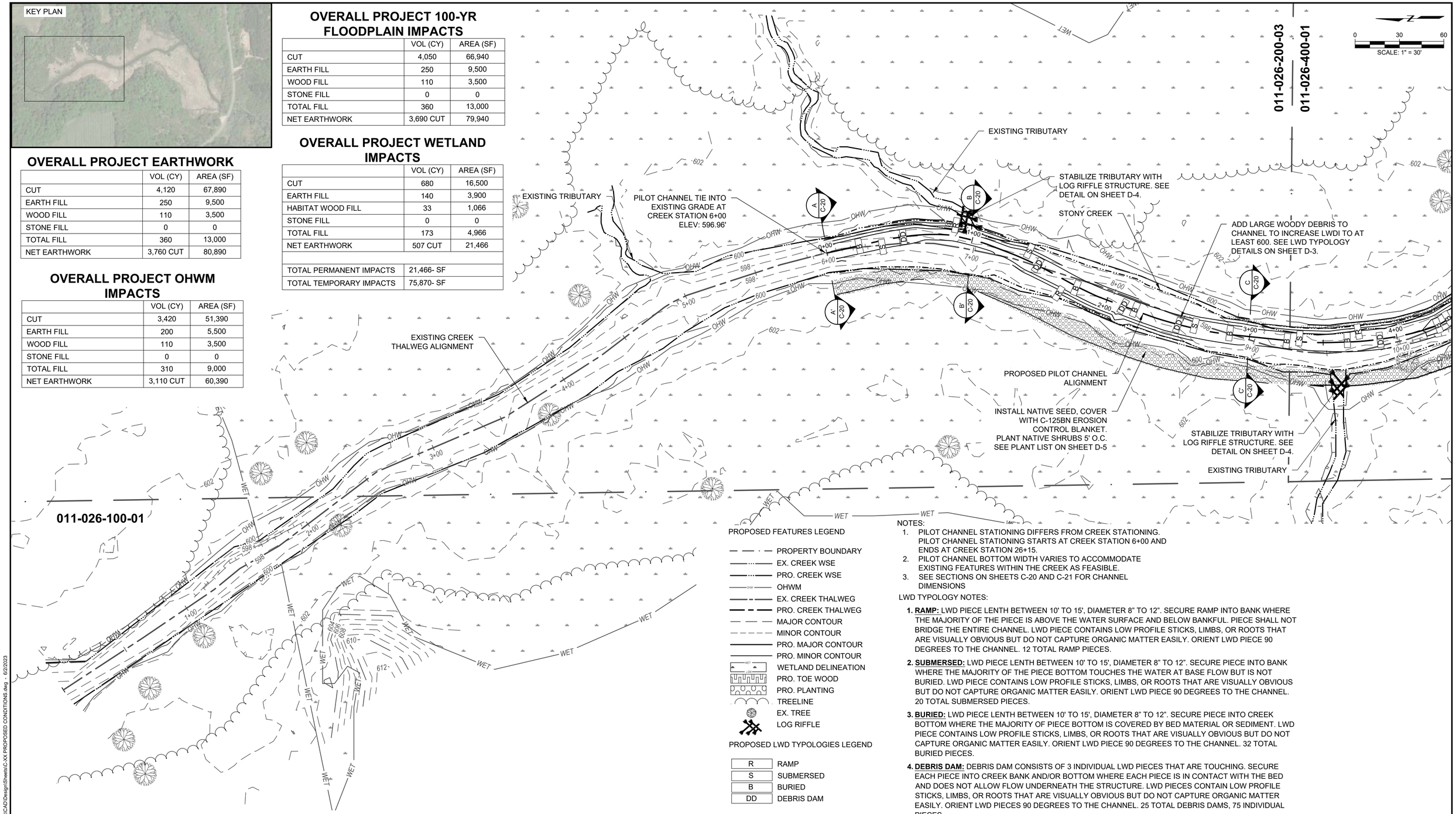
	VOL (CY)	AREA (SF)
CUT	3,420	51,390
EARTH FILL	200	5,500
WOOD FILL	110	3,500
STONE FILL	0	0
TOTAL FILL	310	9,000
NET EARTHWORK	3,110 CUT	60,390

OVERALL PROJECT 100-YR FLOODPLAIN IMPACTS

	VOL (CY)	AREA (SF)
CUT	4,050	66,940
EARTH FILL	250	9,500
WOOD FILL	110	3,500
STONE FILL	0	0
TOTAL FILL	360	13,000
NET EARTHWORK	3,690 CUT	79,940

OVERALL PROJECT WETLAND IMPACTS

	VOL (CY)	AREA (SF)
CUT	680	16,500
EARTH FILL	140	3,900
HABITAT WOOD FILL	33	1,066
STONE FILL	0	0
TOTAL FILL	173	4,966
NET EARTHWORK	507 CUT	21,466
TOTAL PERMANENT IMPACTS	21,466- SF	
TOTAL TEMPORARY IMPACTS	75,870- SF	



PROPOSED FEATURES LEGEND

- PROPERTY BOUNDARY
- EX. CREEK WSE
- PRO. CREEK WSE
- OHWM
- EX. CREEK THALWEG
- PRO. CREEK THALWEG
- MAJOR CONTOUR
- MINOR CONTOUR
- PRO. MAJOR CONTOUR
- PRO. MINOR CONTOUR
- WETLAND DELINEATION
- PRO. TOE WOOD
- PRO. PLANTING
- TREELINE
- EX. TREE
- LOG RIFFLE

PROPOSED LWD TYPOLOGIES LEGEND

R	RAMP
S	SUBMERSED
B	BURIED
DD	DEBRIS DAM

NOTES:

1. PILOT CHANNEL STATIONING DIFFERS FROM CREEK STATIONING. PILOT CHANNEL STATIONING STARTS AT CREEK STATION 6+00 AND ENDS AT CREEK STATION 26+15.
2. PILOT CHANNEL BOTTOM WIDTH VARIES TO ACCOMMODATE EXISTING FEATURES WITHIN THE CREEK AS FEASIBLE.
3. SEE SECTIONS ON SHEETS C-20 AND C-21 FOR CHANNEL DIMENSIONS

LWD TYPOLOGY NOTES:

1. **RAMP:** LWD PIECE LENTH BETWEEN 10' TO 15', DIAMETER 8" TO 12". SECURE RAMP INTO BANK WHERE THE MAJORITY OF THE PIECE IS ABOVE THE WATER SURFACE AND BELOW BANKFUL. PIECE SHALL NOT BRIDGE THE ENTIRE CHANNEL. LWD PIECE CONTAINS LOW PROFILE STICKS, LIMBS, OR ROOTS THAT ARE VISUALLY OBVIOUS BUT DO NOT CAPTURE ORGANIC MATTER EASILY. ORIENT LWD PIECE 90 DEGREES TO THE CHANNEL. 12 TOTAL RAMP PIECES.
2. **SUBMERSED:** LWD PIECE LENTH BETWEEN 10' TO 15', DIAMETER 8" TO 12". SECURE PIECE INTO BANK WHERE THE MAJORITY OF THE PIECE BOTTOM TOUCHES THE WATER AT BASE FLOW BUT IS NOT BURIED. LWD PIECE CONTAINS LOW PROFILE STICKS, LIMBS, OR ROOTS THAT ARE VISUALLY OBVIOUS BUT DO NOT CAPTURE ORGANIC MATTER EASILY. ORIENT LWD PIECE 90 DEGREES TO THE CHANNEL. 20 TOTAL SUBMERSED PIECES.
3. **BURIED:** LWD PIECE LENTH BETWEEN 10' TO 15', DIAMETER 8" TO 12". SECURE PIECE INTO CREEK BOTTOM WHERE THE MAJORITY OF PIECE BOTTOM IS COVERED BY BED MATERIAL OR SEDIMENT. LWD PIECE CONTAINS LOW PROFILE STICKS, LIMBS, OR ROOTS THAT ARE VISUALLY OBVIOUS BUT DO NOT CAPTURE ORGANIC MATTER EASILY. ORIENT LWD PIECE 90 DEGREES TO THE CHANNEL. 32 TOTAL BURIED PIECES.
4. **DEBRIS DAM:** DEBRIS DAM CONSISTS OF 3 INDIVIDUAL LWD PIECES THAT ARE TOUCHING. SECURE EACH PIECE INTO CREEK BANK AND/OR BOTTOM WHERE EACH PIECE IS IN CONTACT WITH THE BED AND DOES NOT ALLOW FLOW UNDERNEATH THE STRUCTURE. LWD PIECES CONTAIN LOW PROFILE STICKS, LIMBS, OR ROOTS THAT ARE VISUALLY OBVIOUS BUT DO NOT CAPTURE ORGANIC MATTER EASILY. ORIENT LWD PIECES 90 DEGREES TO THE CHANNEL. 25 TOTAL DEBRIS DAMS, 75 INDIVIDUAL PIECES.

Attention:

0 1"

If this scale bar does not measure 1" then drawing is not original scale.

MISS DIG System, Inc. www.missdig.org 1-800-482-7171

STATE OF MICHIGAN SCOTT B. DIERKS ENGINEER No. 44371 PROFESSIONAL ENGINEER

Designed:	BM
Drawn:	AT
Checked:	
Approved:	BM
P.E. No:	44371
GEI Project	2200272

GEI Consultants

WMSRDC
316 MORRIS AVENUE
SUITE 340
MUSKEGON, MI 49440

MARSHVILLE DAM REMOVAL & STONY CREEK RESTORATION

STONY CREEK
MARSHVILLE DAM ROAD
SHELBY, MI 49455

NO	DATE	ISSUE/REVISION	APP
5	5/31/2023	CONSTRUCTION DRAWINGS	BM
4	3/22/2023	FOR PERMIT	BM
3	1/23/2023	FOR PERMIT	BM
2	12/22/2022	60% DESIGN SET	BM
1	7/20/2022	30% DESIGN SET	BM

SHEET NAME

PROPOSED CONDITIONS

DWG. NO.

C-14

SHEET NO.

15 of 27

TRUITT, ASHLEY K:\WMSRDC\2200272_StonyCreek\CAD\Design\Sheets\C-XX PROPOSED CONDITIONS.dwg - 6/2/2023

EXISTING TRIBUTARY
STABILIZE TRIBUTARY WITH LOG RIFFLE STRUCTURE. SEE DETAIL ON SHEET D-4.

INSTALL TOE WOOD
SEE DETAIL ON SHEET D-3

ADD LARGE WOODY DEBRIS TO CHANNEL TO INCREASE LWDI TO AT LEAST 600. SEE LWD TYPOLOGY DETAILS ON SHEET D-3.

PROPOSED PILOT CHANNEL ALIGNMENT

STONY CREEK

EXISTING TRIBUTARY
STABILIZE TRIBUTARY WITH LOG RIFFLE STRUCTURE. SEE DETAIL ON SHEET D-4.

EXISTING CREEK THALWEG ALIGNMENT

INSTALL NATIVE SEED, COVER WITH C-125BN EROSION CONTROL BLANKET. PLANT NATIVE SHRUBS 5' O.C. SEE PLANT LIST ON SHEET D-5

STABILIZE TRIBUTARY WITH LOG RIFFLE STRUCTURE. SEE DETAIL ON SHEET D-4.

EXISTING TRIBUTARY

011-026-400-01

011-026-300-03

0 30 60
SCALE: 1" = 30'

PROPOSED FEATURES LEGEND

- PROPERTY BOUNDARY
- EX. CREEK WSE
- PRO. CREEK WSE
- OHWM
- EX. CREEK THALWEG
- PRO. CREEK THALWEG
- MAJOR CONTOUR
- MINOR CONTOUR
- PRO. MAJOR CONTOUR
- PRO. MINOR CONTOUR
- WETLAND DELINEATION
- PRO. TOE WOOD
- PRO. PLANTING
- TREELINE
- EX. TREE
- LOG RIFFLE

PROPOSED LWD TYPOLOGIES LEGEND

R	RAMP
S	SUBMERSED
B	BURIED
DD	DEBRIS DAM

GENERAL NOTES:

1. PILOT CHANNEL STATIONING DIFFERS FROM CREEK STATIONING. PILOT CHANNEL STATIONING STARTS AT CREEK STATION 6+00 AND ENDS AT CREEK STATION 26+15.
2. PILOT CHANNEL BOTTOM WIDTH VARIES TO ACCOMMODATE EXISTING FEATURES WITHIN THE CREEK.
3. SEE SECTIONS ON SHEETS C-20 AND C-21 FOR CHANNEL DIMENSIONS

LWD TYPOLOGY NOTES:

1. **RAMP:** LWD PIECE LENTH BETWEEN 10' TO 15', DIAMETER 8" TO 12". SECURE RAMP INTO BANK WHERE THE MAJORITY OF THE PIECE IS ABOVE THE WATER SURFACE AND BELOW BANKFUL. PIECE SHALL NOT BRIDGE THE ENTIRE CHANNEL. LWD PIECE CONTAINS LOW PROFILE STICKS, LIMBS, OR ROOTS THAT ARE VISUALLY OBVIOUS BUT DO NOT CAPTURE ORGANIC MATTER EASILY. ORIENT LWD PIECE 90 DEGREES TO THE CHANNEL. 12 TOTAL RAMP PIECES.
2. **SUBMERSED:** LWD PIECE LENTH BETWEEN 10' TO 15', DIAMETER 8" TO 12". SECURE PIECE INTO BANK WHERE THE MAJORITY OF THE PIECE BOTTOM TOUCHES THE WATER AT BASE FLOW BUT IS NOT BURIED. LWD PIECE CONTAINS LOW PROFILE STICKS, LIMBS, OR ROOTS THAT ARE VISUALLY OBVIOUS BUT DO NOT CAPTURE ORGANIC MATTER EASILY. ORIENT LWD PIECE 90 DEGREES TO THE CHANNEL. 20 TOTAL SUBMERSED PIECES.
3. **BURIED:** LWD PIECE LENTH BETWEEN 10' TO 15', DIAMETER 8" TO 12". SECURE PIECE INTO CREEK BOTTOM WHERE THE MAJORITY OF PIECE BOTTOM IS COVERED BY BED MATERIAL OR SEDIMENT. LWD PIECE CONTAINS LOW PROFILE STICKS, LIMBS, OR ROOTS THAT ARE VISUALLY OBVIOUS BUT DO NOT CAPTURE ORGANIC MATTER EASILY. ORIENT LWD PIECE 90 DEGREES TO THE CHANNEL. 32 TOTAL BURIED PIECES.
4. **DEBRIS DAM:** DEBRIS DAM CONSISTS OF 3 INDIVIDUAL LWD PIECES THAT ARE TOUCHING. SECURE EACH PIECE INTO CREEK BANK AND/OR BOTTOM WHERE EACH PIECE IS IN CONTACT WITH THE BED AND DOES NOT ALLOW FLOW UNDERNEATH THE STRUCTURE. LWD PIECES CONTAIN LOW PROFILE STICKS, LIMBS, OR ROOTS THAT ARE VISUALLY OBVIOUS BUT DO NOT CAPTURE ORGANIC MATTER EASILY. ORIENT LWD PIECES 90 DEGREES TO THE CHANNEL. 25 TOTAL DEBRIS DAMS, 75 INDIVIDUAL PIECES.

Attention:
0 1"
If this scale bar does not measure 1" then drawing is not original scale.

SCOTT B. DIERKS ENGINEER No. 44371 STATE OF MICHIGAN

Designed:	BM
Drawn:	AT
Checked:	
Approved:	BM
P.E. No:	44371
GEI Project	2200272

GEI Consultants

WMSRDC
316 MORRIS AVENUE
SUITE 340
MUSKEGON, MI 49440

MARSHVILLE DAM REMOVAL & STONY CREEK RESTORATION

STONY CREEK
MARSHVILLE DAM ROAD
SHELBY, MI 49455

NO	DATE	ISSUE/REVISION	APP
5	5/31/2023	CONSTRUCTION DRAWINGS	BM
4	3/22/2023	FOR PERMIT	BM
3	1/23/2023	FOR PERMIT	BM
2	12/22/2022	60% DESIGN SET	BM
1	7/20/2022	30% DESIGN SET	BM

SHEET NAME
PROPOSED CONDITIONS

DWG. NO.
C-15

SHEET NO.
16 of 27

MISS DIG System, Inc. www.missdig.org 1-800-482-7171

TRUITT, ASHLEY K:\WMSRDC\2200272_StonyCreek\CAD\DesignSheets\C-XX PROPOSED CONDITIONS.dwg - 6/2/2023

PROJECT QUANTITY SUMMARY

LWD RAMP TREATMENT	12 PIECES
LWD SUMBERSED TREATMENT	20 PIECES
LWD BURIED TREATMENT	32 PIECES
LWD DEBRIS DAM TREATMENT	75 PIECES
TOEWOOD TREATMENT	230-LF
ROLANKA BIO-D 12-300 SOIL LIFT	230-LF
TURBIDITY CURTAIN	55-LF
C-125BN EROSION CONTROL BLANKET	4,350-SY
HARDWOOD CONIFER SWAMP UNDERSTORY SEED MIX	0.9-AC
1.5" CALIPER TREES	170 EACH
STREAM BANK BARE ROOT SHRUBS	2,260 EACH
2'-3' BARE ROOT FLOODPLAIN PLANTINGS	2,000 EACH
3'-4' BARE ROOT FLOODPLAIN PLANTINGS	1,520 EACH

LWD TYPOLOGY NOTES:

1. **RAMP:** LWD PIECE LENTH BETWEEN 10' TO 15', DIAMETER 8" TO 12". SECURE RAMP INTO BANK WHERE THE MAJORITY OF THE PIECE IS ABOVE THE WATER SURFACE AND BELOW BANKFUL. PIECE SHALL NOT BRIDGE THE ENTIRE CHANNEL. LWD PIECE CONTAINS LOW PROFILE STICKS, LIMBS, OR ROOTS THAT ARE VISUALLY OBVIOUS BUT DO NOT CAPTURE ORGANIC MATTER EASILY. ORIENT LWD PIECE 90 DEGREES TO THE CHANNEL. 12 TOTAL RAMP PIECES.
2. **SUBMERSED:** LWD PIECE LENTH BETWEEN 10' TO 15', DIAMETER 8" TO 12". SECURE PIECE INTO BANK WHERE THE MAJORITY OF THE PIECE BOTTOM TOUCHES THE WATER AT BASE FLOW BUT IS NOT BURIED. LWD PIECE CONTAINS LOW PROFILE STICKS, LIMBS, OR ROOTS THAT ARE VISUALLY OBVIOUS BUT DO NOT CAPTURE ORGANIC MATTER EASILY. ORIENT LWD PIECE 90 DEGREES TO THE CHANNEL. 20 TOTAL SUBMERSED PIECES.
3. **BURIED:** LWD PIECE LENTH BETWEEN 10' TO 15', DIAMETER 8" TO 12". SECURE PIECE INTO CREEK BOTTOM WHERE THE MAJORITY OF PIECE BOTTOM IS COVERED BY BED MATERIAL OR SEDIMENT. LWD PIECE CONTAINS LOW PROFILE STICKS, LIMBS, OR ROOTS THAT ARE VISUALLY OBVIOUS BUT DO NOT CAPTURE ORGANIC MATTER EASILY. ORIENT LWD PIECE 90 DEGREES TO THE CHANNEL. 32 TOTAL BURIED PIECES.
4. **DEBRIS DAM:** DEBRIS DAM CONSISTS OF 3 INDIVIDUAL LWD PIECES THAT ARE TOUCHING. SECURE EACH PIECE INTO CREEK BANK AND/OR BOTTOM WHERE EACH PIECE IS IN CONTACT WITH THE BED AND DOES NOT ALLOW FLOW UNDERNEATH THE STRUCTURE. LWD PIECES CONTAIN LOW PROFILE STICKS, LIMBS, OR ROOTS THAT ARE VISUALLY OBVIOUS BUT DO NOT CAPTURE ORGANIC MATTER EASILY. ORIENT LWD PIECES 90 DEGREES TO THE CHANNEL. 25 TOTAL DEBRIS DAMS, 75 INDIVIDUAL PIECES.

PROPOSED FEATURES LEGEND

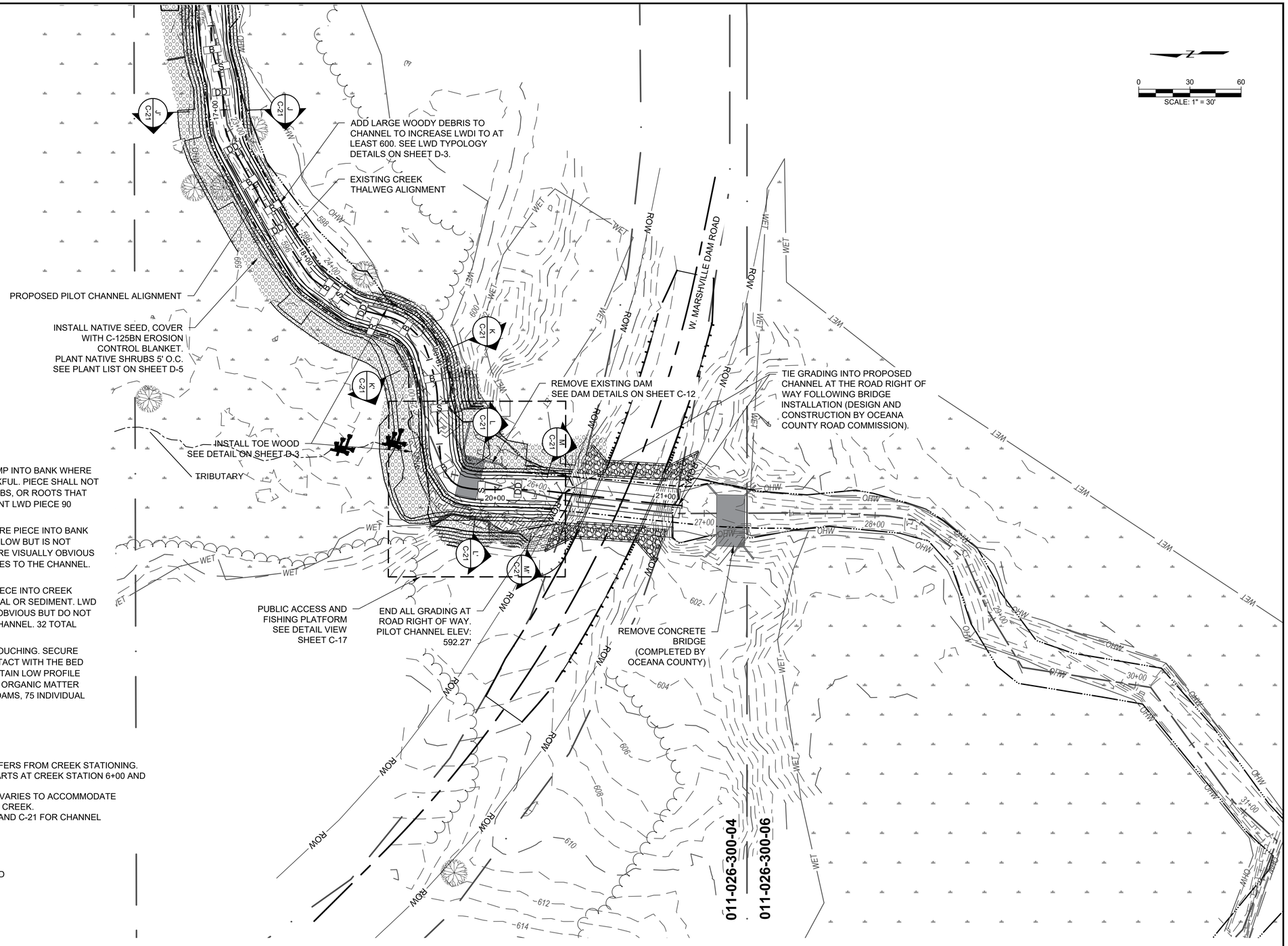
- PROPERTY BOUNDARY
- EX. CREEK WSE
- PRO. CREEK WSE
- OHWM
- EX. CREEK THALWEG
- PRO. CREEK THALWEG
- MAJOR CONTOUR
- MINOR CONTOUR
- PRO. MAJOR CONTOUR
- PRO. MINOR CONTOUR
- WETLAND DELINEATION
- PRO. TOE WOOD
- PRO. PLANTING
- TREELINE
- EX. TREE

GENERAL NOTES:

1. PILOT CHANNEL STATIONING DIFFERS FROM CREEK STATIONING. PILOT CHANNEL STATIONING STARTS AT CREEK STATION 6+00 AND ENDS AT CREEK STATION 26+15.
2. PILOT CHANNEL BOTTOM WIDTH VARIES TO ACCOMMODATE EXISTING FEATURES WITHIN THE CREEK.
3. SEE SECTIONS ON SHEETS C-20 AND C-21 FOR CHANNEL DIMENSIONS

PROPOSED LWD TYPOLOGIES LEGEND

R	RAMP
S	SUBMERSED
B	BURIED
DD	DEBRIS DAM



TRUITT, ASHLEY K:\WMSRDC\2200272_StonyCreek\CAD\Design\Sheets\C-XX PROPOSED CONDITIONS.dwg - 6/2/2023

Attention:
0 1"
If this scale bar does not measure 1" then drawing is not original scale.

MISS DIG System, Inc. www.missdig.org 1-800-482-7171

STATE OF MICHIGAN SCOTT B. DIERKS ENGINEER No. 44371 PROFESSIONAL ENGINEER

Designed:	BM
Drawn:	AT
Checked:	
Approved:	BM
P.E. No:	44371
GEI Project	2200272

GEI Consultants

WMSRDC
316 MORRIS AVENUE
SUITE 340
MUSKEGON, MI 49440

MARSHVILLE DAM REMOVAL & STONY CREEK RESTORATION

STONY CREEK
MARSHVILLE DAM ROAD
SHELBY, MI 49455

NO	DATE	ISSUE/REVISION	APP
5	5/31/2023	CONSTRUCTION DRAWINGS	BM
4	3/22/2023	FOR PERMIT	BM
3	1/23/2023	FOR PERMIT	BM
2	12/22/2022	60% DESIGN SET	BM
1	7/20/2022	30% DESIGN SET	BM

SHEET NAME
PROPOSED CONDITIONS

DWG. NO.
C-16

SHEET NO.
17 of 27

KEY PLAN

0 7.5 15 30
SCALE, FEET

N

PROPOSED PILOT CHANNEL ALIGNMENT

ACCESSIBLE BOARDWALK
MAXIMUM SLOPE OF 5% TO
MEET ADA STANDARDS
SEE DETAIL SHEET D-2

ACCESSIBLE FISHING PIERS (TYP) NOT TO EXCEED
120-SQ FT
TOE BOARD NOT TO EXCEED 4" FROM TOP OF DECK
PLATFORM
DECK HEIGHT MAXIMUM OF 24" FROM AVERAGE
DAILY WATER SURFACE ELEVATION
SEE DETAIL SHEET D-2

BOARDWALK AND FISHING PIERS TO BE CONSTRUCTED BY OTHERS UNDER A SEPARATE CONTRACT.

EXISTING TREE (TYP)

GRAVEL PATH FROM PARKING LOT
MAINTAINS AN ACCESSIBLE CONNECTION
TO THE BOARDWALK AND FISHING PIERS

GRAVEL PARKING LOT
5 PARKING SPACES

EXISTING CREEK
THALWEG ALIGNMENT

ADD LARGE WOODY DEBRIS TO
CHANNEL TO INCREASE LWDI TO AT
LEAST 600. SEE LWD TYPOLOGY
DETAILS ON SHEET D-3.

INSTALL TOE WOOD INTO BANKS. SEE
DETAIL ON SHEET D-3

GRADE SHORELINE TO MEET EXISTING GRADE
SLOPE SHALL NOT EXCEED 3H:1V.
INSTALL C-125-BN EROSION CONTROL BLANKET
INSTALL NATIVE SEEDMIX
PLANT NATIVE SHRUBS 5' O.C.
SEE PLANT LIST ON SHEET

TIE GRADING INTO PROPOSED
CHANNEL AT THE ROAD RIGHT OF
WAY FOLLOWING BRIDGE
INSTALLATION (DESIGN AND
CONSTRUCTION BY OCEANA
COUNTY ROAD COMMISSION).

PROPOSED FEATURES LEGEND

- PROPERTY BOUNDARY
- EX. CREEK WSE
- PRO. CREEK WSE
- OHWM
- EX. CREEK THALWEG
- PRO. CREEK THALWEG
- MAJOR CONTOUR
- MINOR CONTOUR
- PRO. MAJOR CONTOUR
- PRO. MINOR CONTOUR
- WETLAND DELINEATION
- PRO. PLANTING
- TREELINE
- EX. TREE

OVERALL BOARDWALK AND PIER FILL

	VOL (CY)	AREA (SF)
TOTAL	20	1,570
OHWM IMPACTS	18	95
WETLAND IMPACTS	15	1,285

Attention:
0 1"
If this scale bar does not measure 1" then drawing is not original scale.

SCOTT S. DIERKS ENGINEER No. 44371 STATE OF MICHIGAN PROFESSIONAL ENGINEER

Designed:	BM
Drawn:	AT
Checked:	
Approved:	BM
P.E. No:	44371
GEI Project	2200272

GEI Consultants

WMSRDC
316 MORRIS AVENUE
SUITE 340
MUSKEGON, MI 49440

MARSHVILLE DAM REMOVAL & STONY CREEK RESTORATION

STONY CREEK
MARSHVILLE DAM ROAD
SHELBY, MI 49455

NO	DATE	ISSUE/REVISION	APP
5	5/31/2023	CONSTRUCTION DRAWINGS	BM
4	3/22/2023	FOR PERMIT	BM
3	1/23/2023	FOR PERMIT	BM
2	12/22/2022	60% DESIGN SET	BM
1	7/20/2022	30% DESIGN SET	BM

SHEET NAME

FISHING PIER AND BOARDWALK

DWG. NO.
C-17

SHEET NO.
18 of 27

MISS DIG System, Inc. 811 www.missdig.org 1-800-482-7171

TRUITT, ASHLEY K:\WMSRDC\2200272_StonyCreek\CAD\Design\Sheets\C-14 FISHING PIER DESIGN 2.dwg - 6/2/2023

KEY PLAN

0 7.5 15 30
SCALE, FEET

N

PROPOSED PILOT CHANNEL ALIGNMENT

OHWM

EXISTING CREEK
THALWEG ALIGNMENT

BOARDWALK AND FISHING PIER
OHWM IMPACTS
TOTAL CREEK SHADING/COVER
IMPACTS: 95-SF

18+00
19+00
20+00
21+00
24+00
25+00
26+00

600.19
596.84
596.67
596.48
605.89

PROPOSED FEATURES LEGEND

- PROPERTY BOUNDARY
- EX. CREEK WSE
- PRO. CREEK WSE
- OHWM
- EX. CREEK THALWEG
- PRO. CREEK THALWEG
- MAJOR CONTOUR
- MINOR CONTOUR
- PRO. MAJOR CONTOUR
- PRO. MINOR CONTOUR
- WETLAND DELINEATION
- OHWM IMPACTS
- TREELINE
- EX. TREE

OVERALL BOARDWALK AND PIER FILL

	VOL (CY)	AREA (SF)
TOTAL	20	1,570
OHWM IMPACTS	18	95
WETLAND IMPACTS	15	1,285

Attention:
0 1"
If this scale bar does not measure 1" then drawing is not original scale.

MISS DIG System, Inc.
811
www.missdig.org
1-800-482-7171

STATE OF MICHIGAN
SCOTT B. DIERKS
ENGINEER
No. 44371
PROFESSIONAL ENGINEER

Designed:	BM
Drawn:	AT
Checked:	
Approved:	BM
P.E. No:	44371
GEI Project	2200272

GEI Consultants

WMSRDC
316 MORRIS AVENUE
SUITE 340
MUSKEGON, MI 49440

MARSHVILLE DAM REMOVAL & STONY CREEK RESTORATION

STONY CREEK
MARSHVILLE DAM ROAD
SHELBY, MI 49455

NO	DATE	ISSUE/REVISION	APP
5	5/31/2023	CONSTRUCTION DRAWINGS	BM
4	3/22/2023	FOR PERMIT	BM
3	1/23/2023	FOR PERMIT	BM
2	12/22/2022	60% DESIGN SET	BM
1	7/20/2022	30% DESIGN SET	BM

SHEET NAME

FISHING PIER AND BOARDWALK OHWM IMPACTS

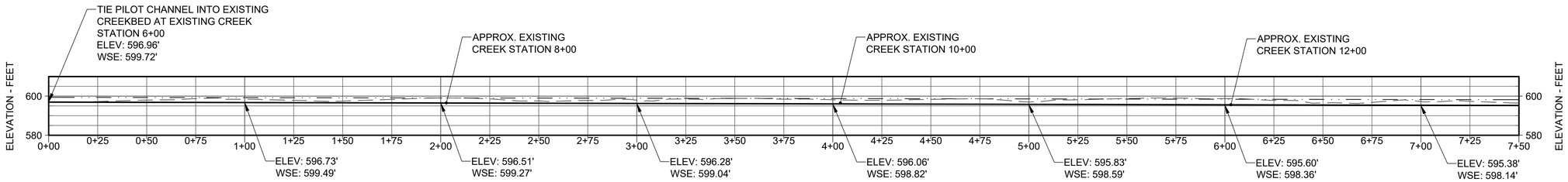
DWG. NO.

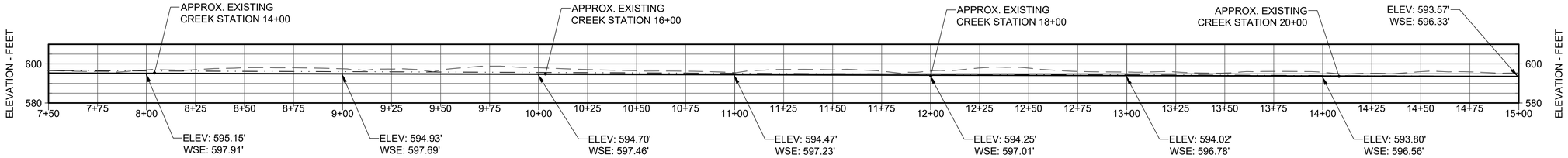
C-18

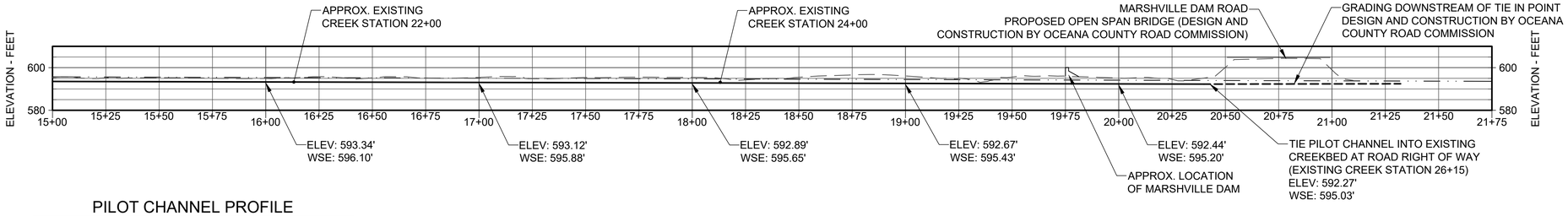
SHEET NO.

19 of 27

TRUITT, ASHLEY K:\WMSRDC\2200272_StonyCreek\CAD\Design\Sheets\C-14 FISHING PIER DESIGN 2.dwg - 6/2/2023







PILOT CHANNEL PROFILE

SCALE: 1"=30'

0 30 60
SCALE, FEET

PROPOSED PILOT CHANNEL
EXISTING CREEKBED
PROPOSED WATER SURFACE ELEVATION

NOTE:
PILOT CHANNEL STATIONING DIFFERS FROM CREEK STATIONING.
PILOT CHANNEL STATIONING STARTS AT CREEK STATION 6+00 AND ENDS AT CREEK STATION 26+15
CREEKBED SLOPE: 0.23%
WATER SURFACE SLOPE: 0.23%

TRUITT, ASHLEY K:\WMSRDC\2200272_StonyCreek\CAD\Design\Sheets\C-15 PROPOSED PROFILE.dwg - 6/2/2023

MISS DIG System, Inc.

Attention:
0 1"
If this scale bar does not measure 1" then drawing is not original scale.

STATE OF MICHIGAN SCOTT S. DIERKS ENGINEER No. 44371

Designed:	BM
Drawn:	AT
Checked:	
Approved:	BM
P.E. No:	44371
GEI Project	2200272

GEI Consultants

WMSRDC
316 MORRIS AVENUE
SUITE 340
MUSKEGON, MI 49440

MARSHVILLE DAM REMOVAL & STONY CREEK RESTORATION

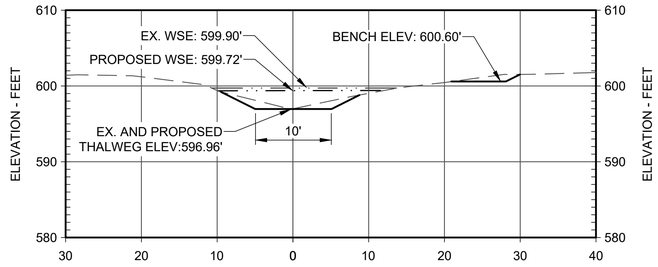
STONY CREEK
MARSHVILLE DAM ROAD
SHELBY, MI 49455

NO	DATE	ISSUE/REVISION	APP
5	5/31/2023	CONSTRUCTION DRAWINGS	BM
4	3/22/2023	FOR PERMIT	BM
3	1/23/2023	FOR PERMIT	BM
2	12/22/2022	60% DESIGN SET	BM
1	7/20/2022	30% DESIGN SET	BM

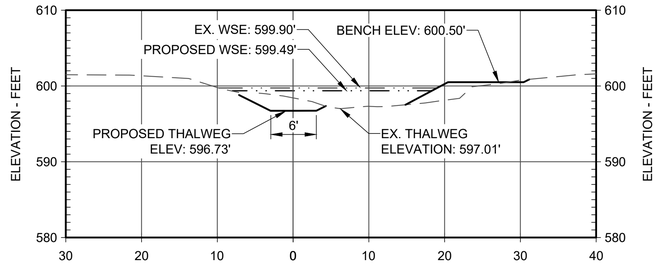
SHEET NAME
PROPOSED PROFILE

DWG. NO.
C-19

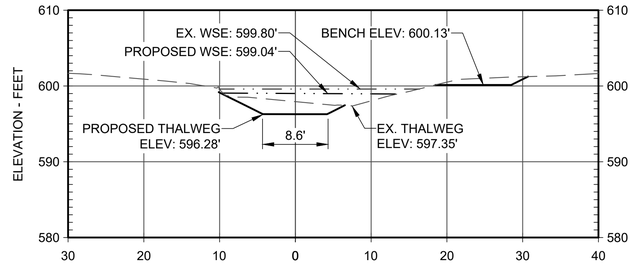
SHEET NO.
20 of 27



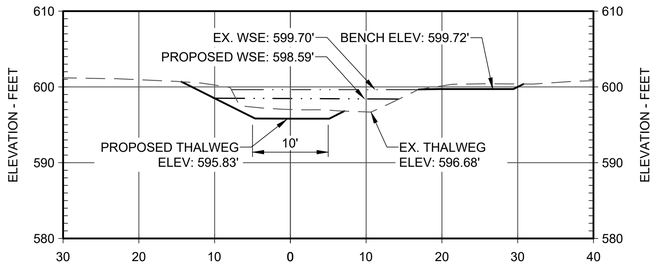
A C-14 SECTION 0+00
SCALE: 1"=10'



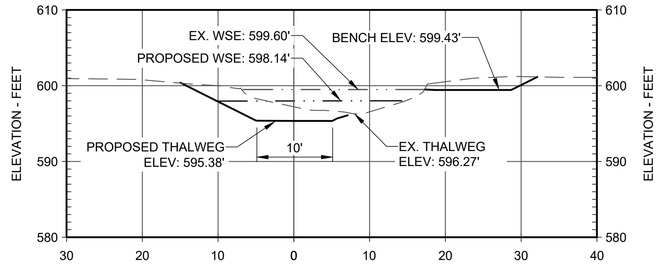
B C-14 SECTION 1+00
SCALE: 1"=10'



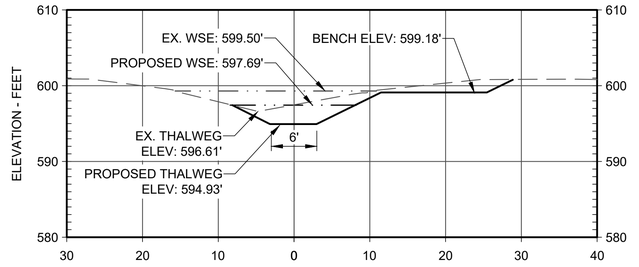
C C-14 SECTION 3+00
SCALE: 1"=10'



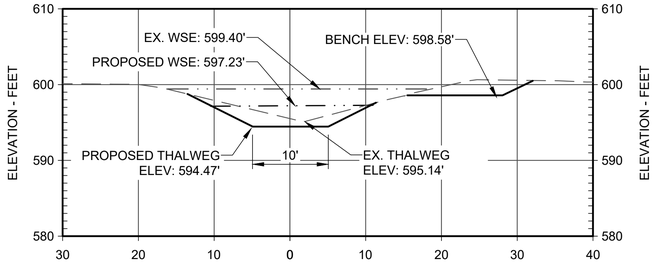
D C-15 SECTION 5+00
SCALE: 1"=10'



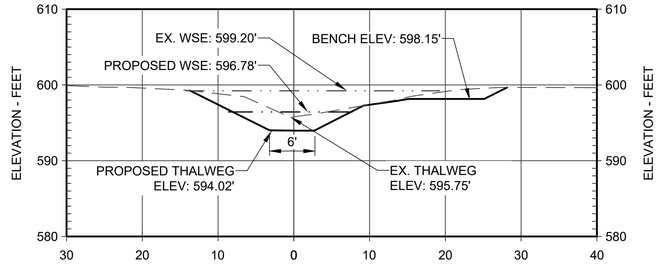
E C-15 SECTION 7+00
SCALE: 1"=10'



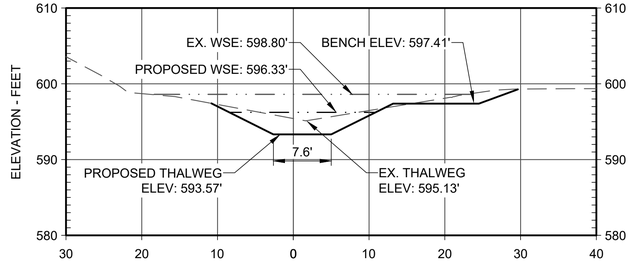
F C-15 SECTION 9+00
SCALE: 1"=10'



G C-15 SECTION 11+00
SCALE: 1"=10'



H C-15 SECTION 13+00
SCALE: 1"=10'



I C-15 SECTION 15+00
SCALE: 1"=10'

NOTE:
PILOT CHANNEL STATIONING DIFFERS FROM CREEK STATIONING.
PILOT CHANNEL STATIONING STARTS AT CREEK STATION 6+00 AND ENDS AT CREEK STATION 26+15

Miss Dig System, Inc. 811 www.missdig.org 1-800-482-7171

Attention:
0 1"
If this scale bar does not measure 1" then drawing is not original scale.

STATE OF MICHIGAN SCOTT S. DIERKS ENGINEER NO. 44371 PROFESSIONAL ENGINEER

Designed:	BM
Drawn:	AT
Checked:	
Approved:	BM
P.E. No:	44371
GEI Project	2200272

GEI Consultants

WMSRDC
316 MORRIS AVENUE
SUITE 340
MUSKEGON, MI 49440

MARSHVILLE DAM REMOVAL & STONY CREEK RESTORATION

STONY CREEK
MARSHVILLE DAM ROAD
SHELBY, MI 49455

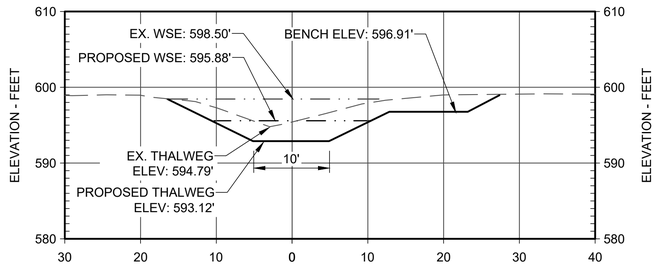
NO	DATE	ISSUE/REVISION	APP
5	5/31/2023	CONSTRUCTION DRAWINGS	BM
4	3/22/2023	FOR PERMIT	BM
3	1/23/2023	FOR PERMIT	BM
2	12/22/2022	60% DESIGN SET	BM
1	7/20/2022	30% DESIGN SET	BM

SHEET NAME
PROPOSED SECTIONS

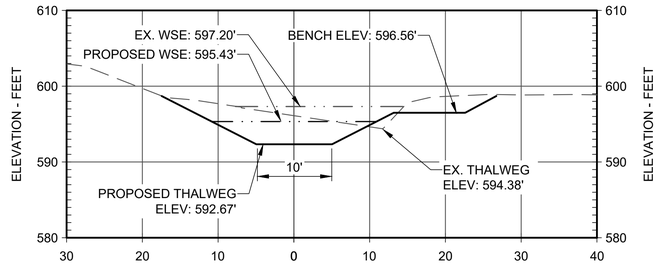
DWG. NO.
C-20

SHEET NO.
21 of 27

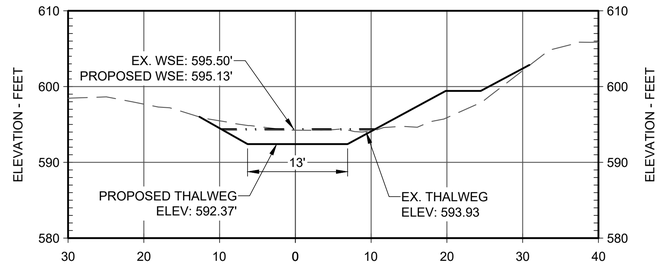
TRUITT, ASHLEY K:\WMSRDC\2200272_StonyCreek\CAD\Design\Sheets\C-XX PROPOSED SECTIONS.dwg - 6/2/2023



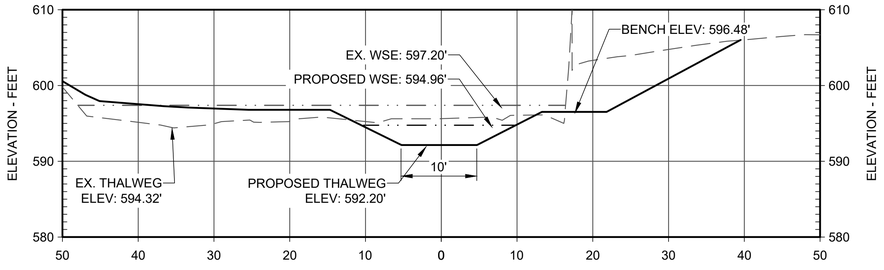
J C-16 SECTION 17+00
SCALE: 1"=10'



K C-16 SECTION 19+00
SCALE: 1"=10'



M C-16 SECTION 20+30
SCALE: 1"=10'



L C-16 SECTION 19+85 (AT DAM)
SCALE: 1"=10'

0 10 20
SCALE, FEET

PROPOSED GRADE
EXISTING CREEKBED
PROPOSED WSE
EXISTING WSE

NOTE:
PILOT CHANNEL STATIONING DIFFERS FROM CREEK STATIONING.
PILOT CHANNEL STATIONING STARTS AT CREEK STATION 6+00 AND ENDS AT CREEK STATION 26+15

MISS DIG System, Inc.
811
www.missdig.org 1-800-482-7171

Attention:
0 1"
If this scale bar does not measure 1" then drawing is not original scale.

STATE OF MICHIGAN
SCOTT S. DIERKS
ENGINEER
No. 44371
PROFESSIONAL ENGINEER

Designed:	BM
Drawn:	AT
Checked:	
Approved:	BM
P.E. No:	44371
GEI Project	2200272

GEI Consultants

WMSRDC
316 MORRIS AVENUE
SUITE 340
MUSKEGON, MI 49440

MARSHVILLE DAM REMOVAL & STONY CREEK RESTORATION

STONY CREEK
MARSHVILLE DAM ROAD
SHELBY, MI 49455

NO	DATE	ISSUE/REVISION	APP
5	5/31/2023	CONSTRUCTION DRAWINGS	BM
4	3/22/2023	FOR PERMIT	BM
3	1/23/2023	FOR PERMIT	BM
2	12/22/2022	60% DESIGN SET	BM
1	7/20/2022	30% DESIGN SET	BM

SHEET NAME
PROPOSED SECTIONS

DWG. NO.
C-21

SHEET NO.
22 of 27

TRUITT, ASHLEY K:\WMSRDC\2200272_StonyCreek\CAD\Design\Sheets\C-XX PROPOSED SECTIONS.dwg - 6/2/2023

Cross Section	Station	Thalweg Elev.	Water Surface Elev.	Bankfull Elev.	Bankfull Width (FT)	Bankfull Depth (FT)	Width/ Depth	Cross Sectional Area at Bankfull (SQ FT)	Bank Height Ratio	Floodprone Depth (FT)	Floodprone Width (FT)	Entrenchment Ratio
A	0+93	597.1	600.1	600.8	27	3.7	7.3	72.7	1	7.4	200	7.4
B	2+94	597.5	599.9	599.7	31	2.2	14.1	49.6	1	4.4	250	8.1
C	4+96	597.4	599.9	600.5	45	3.1	14.5	95.4	1	6.2	160	3.6
D	7+02	597.0	599.9	601.1	45	4.1	11.0	106.3	1	8.2	110	2.4
E	9+02	597.0	599.8	600.4	39	3.4	11.5	74.7	1	6.8	360	9.2
F	11+05	596.7	599.7	600.6	41	3.9	10.5	91.9	1	7.8	250	6.1
G	13+05	596.3	599.6	600.1	28	3.8	7.4	70.5	1	7.6	320	11.4
H	15+06	596.5	599.5	600.8	49	4.3	11.4	115.7	1	8.6	310	6.3
I	17+14	596.9	599.3	599.5	44	2.6	16.9	83.8	1	5.2	370	8.4
J	19+14	594.5	599.2	599.5	28	5.0	5.6	63.3	1	10.0	310	11.1
K	21+11	594.9	598.6	598.7	48	3.8	12.6	78.2	1	7.6	320	6.7
L	23+12	594.8	598.5	598.9	36	4.1	8.8	66.8	1	8.2	450	12.5
M	25+07	593.5	597.2	597.1	22	3.6	6.1	43.9	1	7.2	300	13.6
Marshville Dam												
N	25+99	593.5	595.7	595.9	36	2.4	15.0	54.1	5.2	4.8	70	1.9
O	27+04	592.6	594.5	594.4	33	1.8	18.3	35.2	4.1	3.6	45	1.4
P	27+28	591.5	594.2	595.9	34	4.4	7.7	99.7	1.9	8.8	250	7.4
Q	28+58	590.7	594.2	594.3	17	3.6	4.7	33.5	1	7.2	240	14.1
Reference Reach												
R	28+82	590.7	594.0	594.5	27	3.8	7.1	43.1	1	7.6	240	8.9
S	30+09	591.5	593.9	594.5	29	3.0	9.7	53.9	1	6.0	250	8.6
T	31+23	590.3	593.9	594.7	35	4.4	8.0	74.6	1	8.8	250	7.1
U	31+85	590.4	593.7	594.6	17	4.2	4.0	39.0	1	8.4	250	14.7

EXISTING CONDITIONS STREAM PARAMETERS

Cross Section	Station	Thalweg Elev.	Water Surface Elev.	Bankfull Elev.	Bankfull Width(FT)	Bankfull Depth (FT)	Width/ Depth	Cross Sectional Area at Bankfull (SQ FT)	Bank Height Ratio	Floodprone Depth (FT)	Floodprone Width (FT)	Entrenchment Ratio
A	0+00	597.0	599.7	600.6	35	3.6	9.7	69.2	1	7.2	180	5.1
B	1+00	596.7	599.5	600.5	32	3.8	8.4	84.3	1	7.6	180	5.6
C	3+00	596.3	599.0	600.1	30	3.8	7.8	70.9	1	7.7	320	10.7
D	5+00	595.8	598.6	599.7	29	3.9	7.4	79.5	1	7.8	210	7.2
E	7+00	595.4	598.1	599.4	31	4.0	7.7	90.7	1	8.1	250	8.1
F	9+00	594.9	597.7	599.2	28	4.3	6.5	67.4	1	8.6	350	12.5
G	11+00	594.5	597.2	598.6	28	4.1	6.9	80.9	1	8.2	500	17.9
H	13+00	594.0	596.8	598.2	27	4.2	6.5	64.3	1	8.3	380	14.1
I	15+00	593.6	596.3	597.4	24	3.8	6.3	64.9	1	7.6	260	10.8
J	17+00	593.1	595.9	596.9	26	3.8	6.8	69.1	1	7.6	400	15.4
K	19+00	592.7	595.4	596.6	26	3.9	6.7	74.6	1	7.7	300	11.5
Marshville Dam												
L	19+85	592.5	595.2	596.5	28	4.0	7.0	88.4	1	8.0	76	2.7
M	20+30	592.4	595.1	596.4	26	4.0	6.5	64.4	1	8.0	150	5.8

PROPOSED CONDITIONS STREAM PARAMETERS

NOTE:
PILOT CHANNEL STATIONING DIFFERS FROM CREEK STATIONING.
PILOT CHANNEL STATIONING STARTS AT EXISTING CREEK STATION 6+00
AND ENDS AT EXISTING CREEK STATION 26+15

TRUITT, ASHLEY K:\WMSRDC\2200272_StonyCreek\CAD\Design\Sheets\D-XX DETAILS.dwg - 6/2/2023

Attention:
0 1"
If this scale bar does not measure 1" then drawing is not original scale.

MISS DIG System, Inc. 811 www.missdig.org 1-800-482-7171

STATE OF MICHIGAN SCOTT S. DIERKS ENGINEER No. 44371 PROFESSIONAL ENGINEER

Designed:	BM
Drawn:	AT
Checked:	
Approved:	BM
P.E. No:	44371
GEI Project	2200272

GEI Consultants

WMSRDC
316 MORRIS AVENUE
SUITE 340
MUSKEGON, MI 49440

MARSHVILLE DAM REMOVAL & STONY CREEK RESTORATION

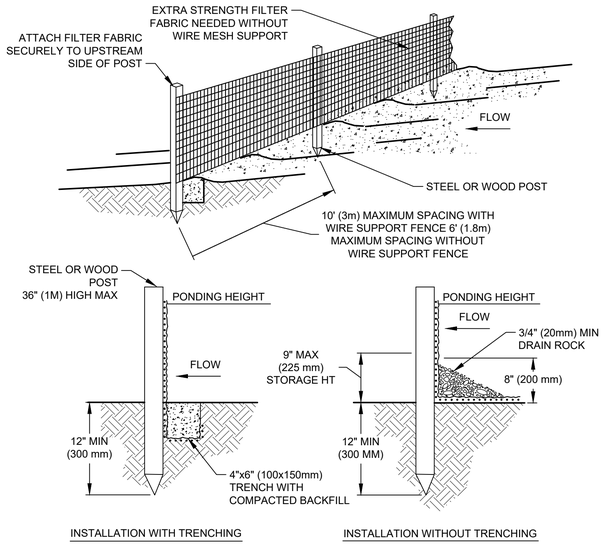
STONY CREEK
MARSHVILLE DAM ROAD
SHELBY, MI 49455

NO	DATE	ISSUE/REVISION	APP
5	5/31/2023	CONSTRUCTION DRAWINGS	BM
4	3/22/2023	FOR PERMIT	BM
3	1/23/2023	FOR PERMIT	BM
2	12/22/2022	60% DESIGN SET	BM
1	7/20/2022	30% DESIGN SET	BM

SHEET NAME
STREAM PARAMETERS

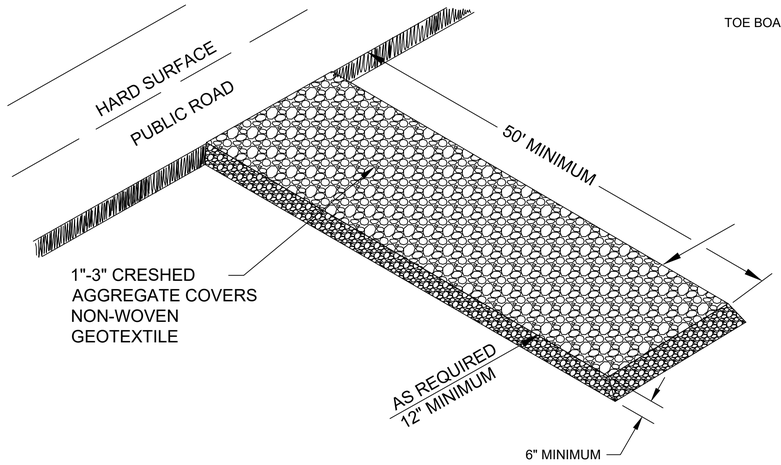
DWG. NO.
D-1

SHEET NO.
23 of 27

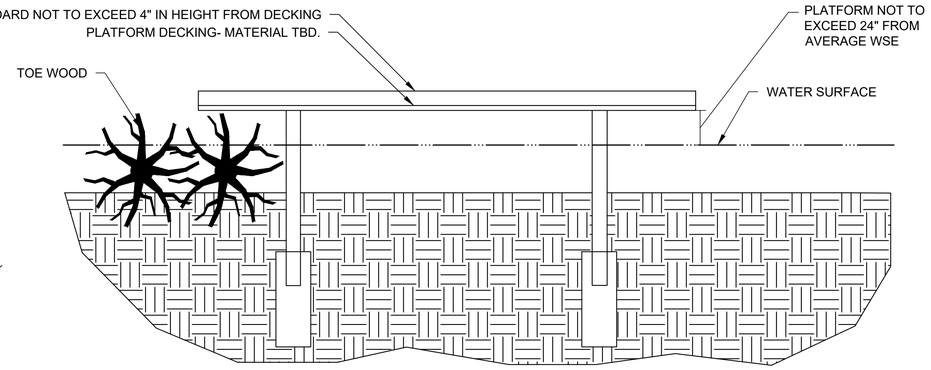


NOTES:
1. SILT FENCE SHALL BE PLACED ON SLOPE CONTOURS TO MAXIMIZE PONDING EFFICIENCY.
2. INSPECT AND REPAIR FENCE AFTER EACH STORM EVENT AND REMOVE SEDIMENT WHEN NECESSARY. 9" (225mm) MAXIMUM RECOMMENDED STORAGE HEIGHT.
3. REMOVED SEDIMENT SHALL BE DEPOSITED TO AN AREA THAT WILL NOT CONTRIBUTE SEDIMENT OFF-SITE AND CAN BE PERMANENTLY STABILIZED.

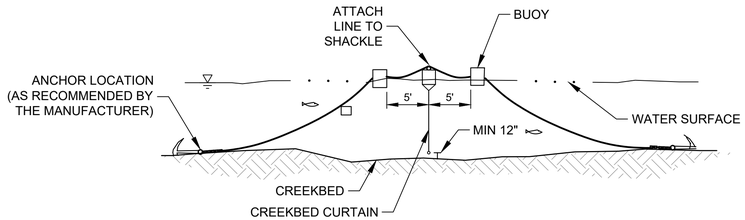
SILT FENCE INSTALLATION
SCALE: NOT TO SCALE



GRAVEL CONSTRUCTION ENTRANCE
SCALE: NOT TO SCALE

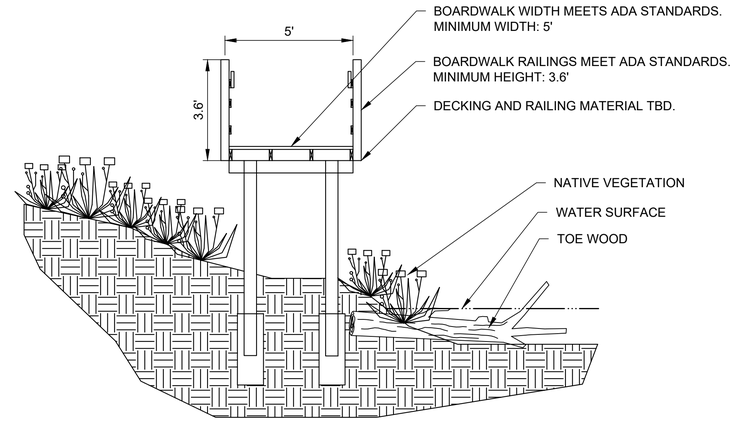


ACCESSIBLE FISHING PIER- CONCEPT DESIGN
SCALE: NOT TO SCALE



NOTES:
1. FLOATING TURBIDITY BARRIER CONSTRUCTION SHALL CONFORM WITH RELEVANT LOCAL AND STATE STANDARDS FOR SOIL EROSION AND SEDIMENT CONTROL.
2. FLOATING TURBIDITY BARRIER WILL BE INSPECTED AND MAINTAINED DAILY.

TURBIDITY CURTAIN
SCALE: NOT TO SCALE



ACCESSIBLE BOARDWALK- CONCEPT DESIGN
SCALE: NOT TO SCALE

TRUITT, ASHLEY K:\WMSRDC\2200272_StonyCreek\CAD\Design\Sheets\D-XX DETAILS.dwg - 6/2/2023

MISS DIG System, Inc. 811 www.missdig.org 1-800-482-7171

Attention:
0 1"
If this scale bar does not measure 1" then drawing is not original scale.

SCOTT D. DIERKS ENGINEER NO. 44371 STATE OF MICHIGAN PROFESSIONAL ENGINEER

Designed:	BM
Drawn:	AT
Checked:	
Approved:	BM
P.E. No:	44371
GEI Project	2200272

GEI Consultants

WMSRDC
316 MORRIS AVENUE
SUITE 340
MUSKEGON, MI 49440

MARSHVILLE DAM REMOVAL & STONY CREEK RESTORATION

STONY CREEK
MARSHVILLE DAM ROAD
SHELBY, MI 49455

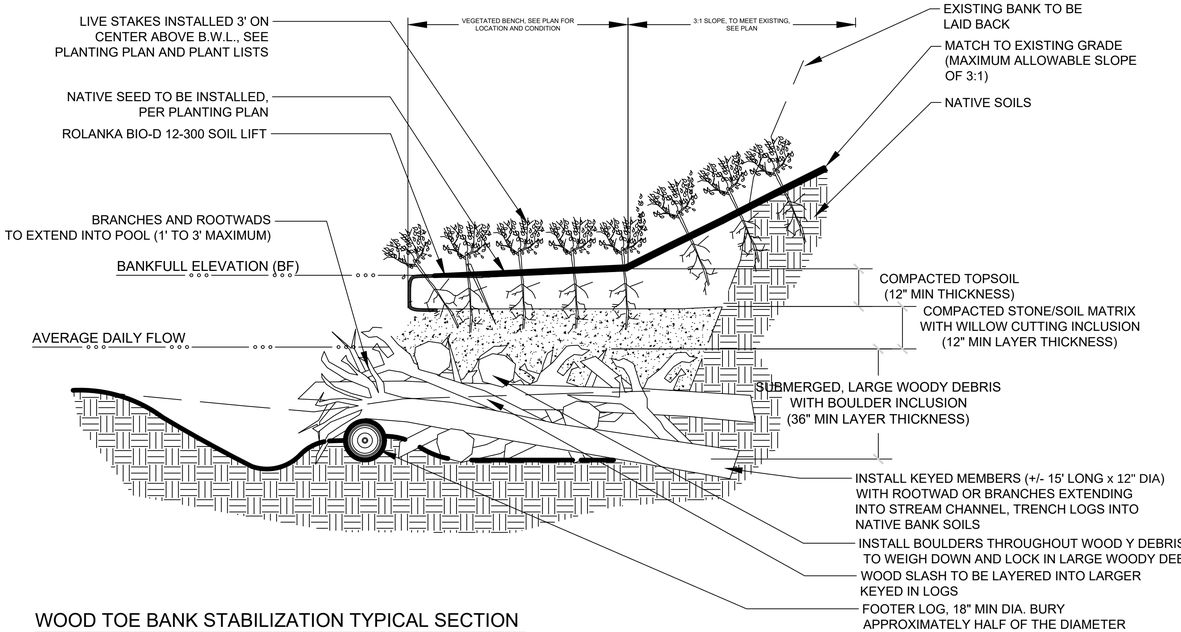
NO	DATE	ISSUE/REVISION	APP
5	5/31/2023	CONSTRUCTION DRAWINGS	BM
4	3/22/2023	FOR PERMIT	BM
3	1/23/2023	FOR PERMIT	BM
2	12/22/2022	60% DESIGN SET	BM
1	7/20/2022	30% DESIGN SET	BM

SHEET NAME
SITE DETAILS

DWG. NO.
D-2

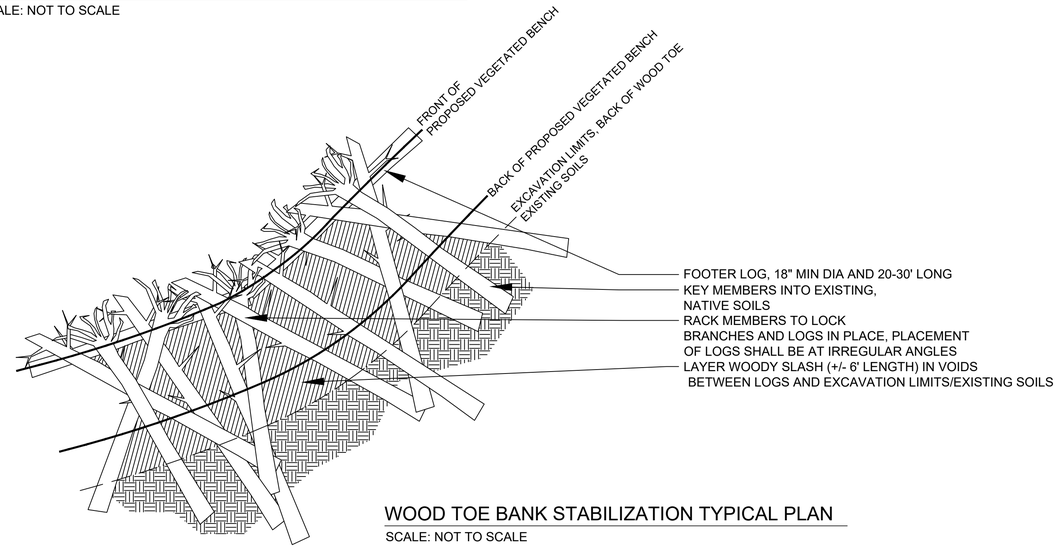
SHEET NO.
24 of 27

WOOD TOE NOTES
1.TOPSOIL SPECIFICATIONS SHALL COMPLY WITH SPECIAL PROVISIONS:
2.STONE SOIL MATRIX SHALL CONSIST OF 80% NATIVE BANK RUN STONE (MAX DIA 8") SALVAGED FROM SITE AND 20" SOIL FILL SALVAGED FROM SITE
3.SUBMERGED LARGE WOODY DEBRIS SHALL CONTAIN A MINIMUM OF 50% OF MATERIAL WITH A DIAMETER GREATER THAN OR EQUAL TO 6"
4.ROOTWADS CAN AND ARE RECOMMENDED TO REMAIN ATTACHED TO LARGE WOODY DEBRIS FOR PLACEMENT
5. BOULDERS (MIN 24" DIA) SALVAGED FROM SITE SHALL BE INCORPORATED INTO 10-15% OF SUBMERGED LARGE WOODY DEBRIS LAYER



WOOD TOE BANK STABILIZATION TYPICAL SECTION

SCALE: NOT TO SCALE



WOOD TOE BANK STABILIZATION TYPICAL PLAN

SCALE: NOT TO SCALE

LARGE WOODY DEBRIS RAMP NOTES
1.WOOD AND ASSOCIATED BALLAST SHALL BE COMPRISED OF ONE OF THE FOLLOWING COMBINATIONS:
a.WOOD SHALL BE MIN 3" AND MAX 6" IN DIAMETER AND 12' LONG. WOOD SHALL BE BURIED A MINIUM OF 6' INTO THE BANK WITH 2' OF COVER OVER TOP or 1.5' OF COVER WITH AT LEAST 1 12" ANCHOR STONE
b.OR WOOD SHALL BE MAX 12" IN DIAMETER AND 12' LONG. WOOD SHALL BE BURIED A MINIUM OF 6' INTO THE BANK WITH 2' OF COVER OVER TOP WITH AT LEAST 1 24" ANCHOR STONES
c.OR WOOD SHALL BE MAX 18" IN DIAMETER AND 12' LONG. WOOD SHALL BE BURIED A MINIUM OF 8' INTO THE BANK WITH 2' OF COVER OVER TOP WITH AT LEAST 2 24" ANCHOR STONES

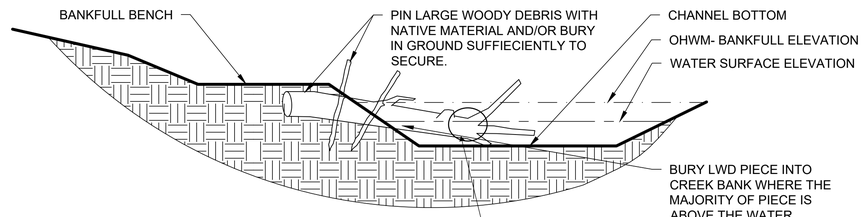
LARGE WOODY DEBRIS SUBMERSED NOTES
1.WOOD AND ASSOCIATED BALLAST SHALL BE COMPRISED OF ONE OF THE FOLLOWING COMBINATIONS:
a.WOOD SHALL BE MIN 3" AND MAX 6" IN DIAMETER AND 12' LONG. WOOD SHALL BE BURIED A MINIUM OF 6' INTO THE BANK WITH 2' OF COVER OVER TOP or 1.5' OF COVER WITH AT LEAST 1 12" ANCHOR STONE
b.OR WOOD SHALL BE MAX 12" IN DIAMETER AND 12' LONG. WOOD SHALL BE BURIED A MINIUM OF 6' INTO THE BANK WITH 2' OF COVER OVER TOP WITH AT LEAST 1 24" ANCHOR STONES
c.OR WOOD SHALL BE MAX 18" IN DIAMETER AND 12' LONG. WOOD SHALL BE BURIED A MINIUM OF 8' INTO THE BANK WITH 2' OF COVER OVER TOP WITH AT LEAST 2 24" ANCHOR STONES

LARGE WOODY DEBRIS BURIED NOTES
1.WOOD AND ASSOCIATED BALLAST SHALL BE COMPRISED OF ONE OF THE FOLLOWING COMBINATIONS:
a.WOOD SHALL BE MIN 3" AND MAX 6" IN DIAMETER AND 12' LONG. WOOD SHALL BE BURIED A MINIUM OF 8' INTO THE BANK WITH 2' OF COVER OVER TOP or 1.5' OF COVER WITH AT LEAST 1 12" ANCHOR STONE
b.OR WOOD SHALL BE MAX 12" IN DIAMETER AND 12' LONG. WOOD SHALL BE BURIED A MINIUM OF 8' INTO THE BANK WITH 2' OF COVER OVER TOP WITH AT LEAST 1 24" OR 2 18" ANCHOR STONES
c.OR WOOD SHALL BE MAX 18" IN DIAMETER AND 12' LONG. WOOD SHALL BE BURIED A MINIUM OF 8' INTO THE BANK WITH 2' OF COVER OVER TOP WITH AT LEAST 2 24" ANCHOR STONES
.

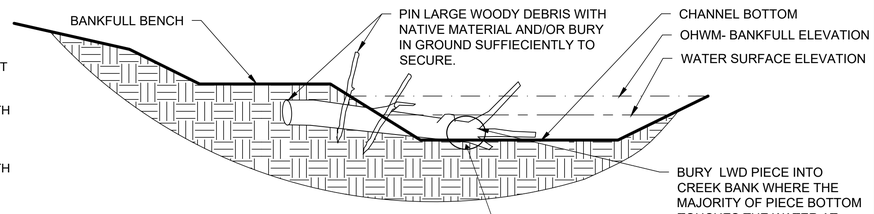
LARGE WOODY DEBRIS DAM NOTES
1.WOOD AND ASSOCIATED BALLAST SHALL BE COMPRISED OF ONE OF THE FOLLOWING COMBINATIONS:
a.WOOD SHALL BE MIN 3" AND MAX 6" IN DIAMETER AND 12' LONG. WOOD SHALL BE BURIED A MINIUM OF 8' INTO THE BANK WITH 2' OF COVER OVER TOP or 1.5' OF COVER WITH AT LEAST 1 12" ANCHOR STONE
b.OR WOOD SHALL BE MAX 12" IN DIAMETER AND 12' LONG. WOOD SHALL BE BURIED A MINIUM OF 8' INTO THE BANK WITH 2' OF COVER OVER TOP WITH AT LEAST 1 24" OR 2 18" ANCHOR STONES
c.OR WOOD SHALL BE MAX 18" IN DIAMETER AND 12' LONG. WOOD SHALL BE BURIED A MINIUM OF 8' INTO THE BANK WITH 2' OF COVER OVER TOP WITH AT LEAST 2 24" ANCHOR STONES
.

LARGE WOODY DEBRIS TYPOLOGIES

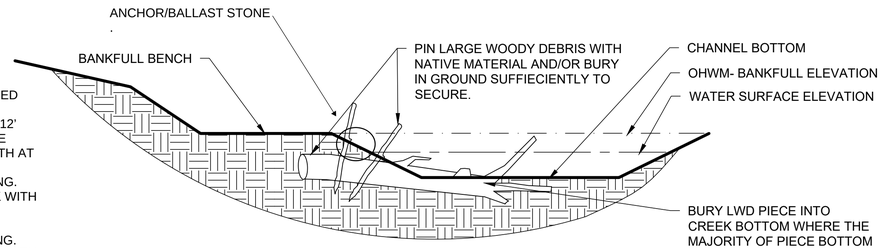
SCALE: NOT TO SCALE



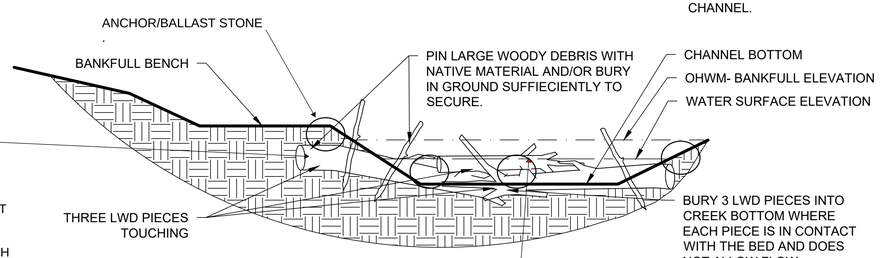
TYPICAL RAMP SECTION



TYPICAL SUBMERSED SECTION



TYPICAL BURIED SECTION



TYPICAL DEBRIS DAM SECTION

LARGE WOODY DEBRIS DAM NOTES (CENTER CHANNEL)
1.WOOD AND ASSOCIATED BALLAST SHALL BE COMPRISED OF ONE OF THE FOLLOWING COMBINATIONS:
a.WOOD SHALL BE MIN 3" AND MAX 6" IN DIAMETER AND 12' LONG. WOOD BE ANCHORED WITH 2 12" ANCHOR STONES
b.OR WOOD SHALL BE MAX 12" IN DIAMETER AND 12' LONG. WOOD SHALL BE ANCHORED WITH AT LEAST 1 24" OR 2 18" ANCHOR STONES
c.OR WOOD SHALL BE MAX 18" IN DIAMETER AND 12' LONG. WOOD SHALL BE ANCHORED WITH AT LEAST 2 24" ANCHOR STONES
.

Attention:
0 1"
If this scale bar does not measure 1" then drawing is not original scale.

STATE OF MICHIGAN SCOTT B. DIERKS ENGINEER No. 44371 PROFESSIONAL ENGINEER

Designed:	BM
Drawn:	AT
Checked:	
Approved:	BM
P.E. No:	44371
GEI Project	2200272

GEI Consultants

WMSRDC
316 MORRIS AVENUE
SUITE 340
MUSKEGON, MI 49440

MARSHVILLE DAM REMOVAL & STONY CREEK RESTORATION

STONY CREEK
MARSHVILLE DAM ROAD
SHELBY, MI 49455

NO	DATE	ISSUE/REVISION	APP
5	5/31/2023	CONSTRUCTION DRAWINGS	BM
4	3/22/2023	FOR PERMIT	BM
3	1/23/2023	FOR PERMIT	BM
2	12/22/2022	60% DESIGN SET	BM
1	7/20/2022	30% DESIGN SET	BM

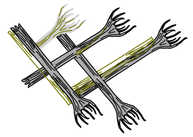
SHEET NAME
RESTORATION DETAILS

DWG. NO.
D-3

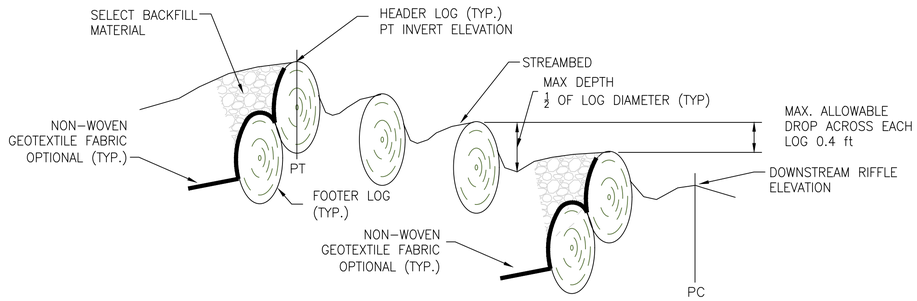
SHEET NO.
25 of 27

MISS DIG System, Inc. www.missdig.org 1-800-482-7171

TRUITT_ASHLEY K:\WMSRDC\2200272_StonyCreek\CAD\Design\Sheet\D-XX DETAILS.dwg - 6/2/2023

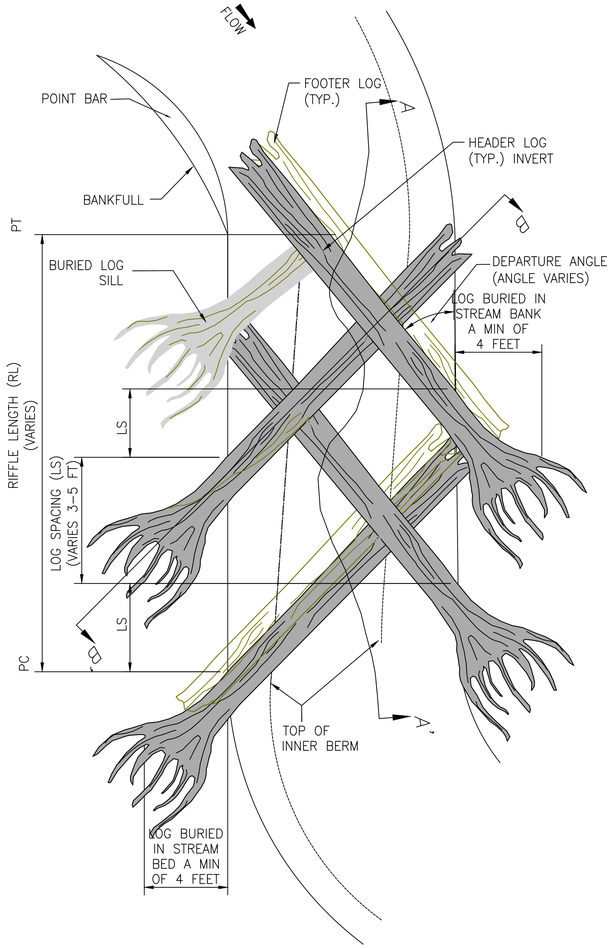


PLAN–SYMBOL

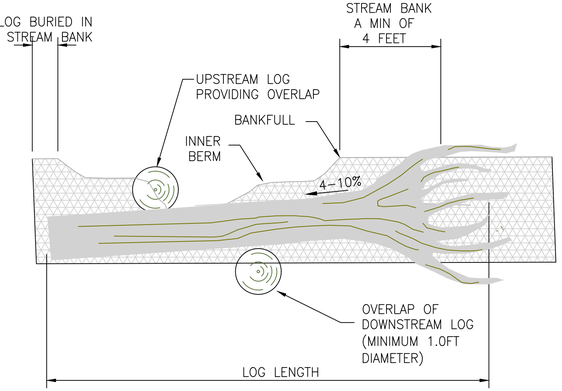


PROFILE A–A'

NOT TO SCALE



PLANVIEW



SECTION
B–B'

TRUITT, ASHLEY K:\WMSRDC\2200272_StonyCreek\CAD\Design\Sheets\D-XX DETAILS.dwg - 6/2/2023

Attention:

0 1"

If this scale bar does not measure 1" then drawing is not original scale.

NOT TO SCALE

Designed:	BM
Drawn:	AT
Checked:	
Approved:	BM
P.E. No:	44371
GEI Project	2200272

GEI Consultants

WMSRDC
316 MORRIS AVENUE
SUITE 340
MUSKEGON, MI 49440

MARSHVILLE DAM REMOVAL & STONY CREEK RESTORATION

STONY CREEK
MARSHVILLE DAM ROAD
SHELBY, MI 49455

NO	DATE	ISSUE/REVISION	APP
5	5/31/2023	CONSTRUCTION DRAWINGS	BM
4	3/22/2023	FOR PERMIT	BM
3	1/23/2023	FOR PERMIT	BM
2	12/22/2022	60% DESIGN SET	BM
1	7/20/2022	30% DESIGN SET	BM

SHEET NAME

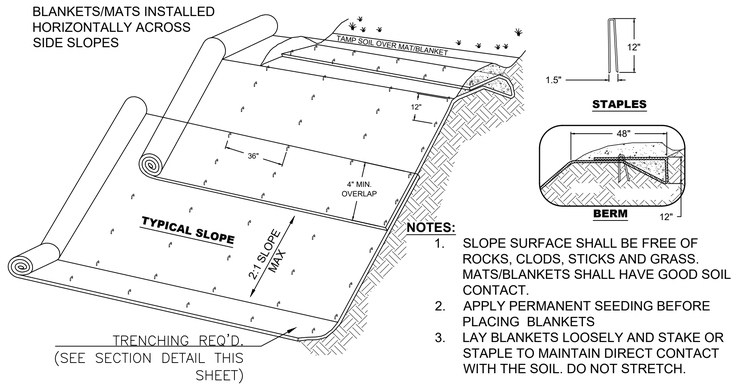
LOG RIFFLE/ TRIBUTARY GRADE CONTROL DETAILS

DWG. NO.

D-4

SHEET NO.

26 of 27

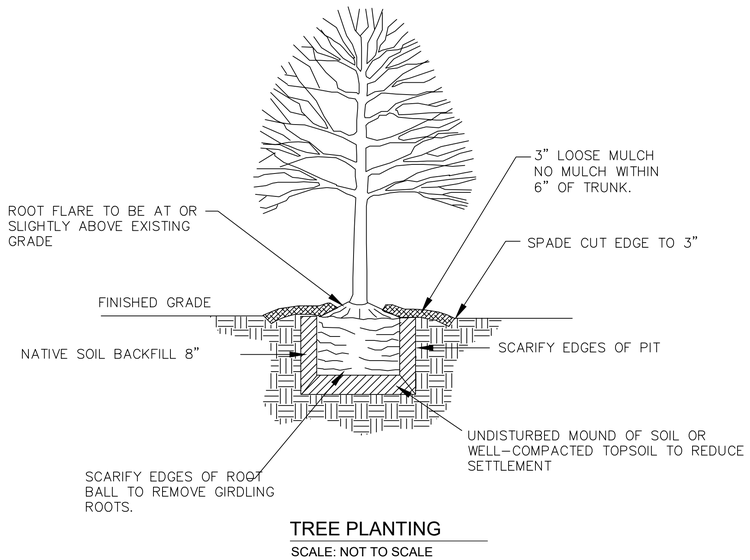


NOTES:

1. SLOPE SURFACE SHALL BE FREE OF ROCKS, CLODS, STICKS AND GRASS. MATS/BLANKETS SHALL HAVE GOOD SOIL CONTACT.
2. APPLY PERMANENT SEEDING BEFORE PLACING BLANKETS
3. LAY BLANKETS LOOSELY AND STAKE OR STAPLE TO MAINTAIN DIRECT CONTACT WITH THE SOIL. DO NOT STRETCH.

EROSION CONTROL BLANKET

SCALE: NOT TO SCALE



TREE PLANTING

SCALE: NOT TO SCALE

HARDWOOD CONIFER SWAMP PLANT LISTS

UNDERSTORY SEED MIX

Scientific Name	Common Name	Per Acre
Asclepias incarnata	Swamp milkweed	4
Bidens cernua	Nodding beggar ticks	1
Bidens frondosa	Common beggar ticks	1
Bromus ciliatus	Fringed brome	8
Calamagrostis canadensis	Blue-joint	1
Carex crinita	Fringed sedge	4
Carex hystericina	Porcupine sedge	2
Carex lacustris	Common lake sedge	1
Carex stricta	Common tussock sedge	3
Carex vulpinoidea	Brown fox sedge	3
Cinna arundinacea	Wood reedgrass/ common wood reed	3
Eleocharis palustris	Great spike rush	1
Elymus virginicus	Virginia wild rye	48
Epilobium coloratum	Cinnamon willow herb	1
Eupatorium perfoliatum	Common boneset	1
Glyceria striata	Fowl manna grass	4
Iris virginica	Southern blue flag/ blue flag iris	1
Leersia oryzoides	Cut grass/ rice cut grass	1
Lobelia cardinalis	Red lobelia/ cardinal flower	0.50
Lobelia siphilitica	Great blue lobelia	0.50
Scirpus atrovirens	Dark green rush	3
Sium suave	Tall water parsnip	0.50
Solidago patula	Swamp goldenrod/ roough-leaved goldenrod	1
Solidago rugosa	Rough goldenrod	0.50
Symphyotrichum lanceolatum	Panicled aster	1
Symphyotrichum lateriflorum	Calico aster/ side-flowering aster	1
Symphyotrichum puniceum	Swamp aster/ bristly aster	1
Thalictrum dasycarpum	Purple meadow rue	1
Verbena hastata	Blue vervain	2
	Total PLS Ounces Per Acre	**100.00**
	Total PLS Pounds Per Acre	**6.25**
Avena sativa	Seed oats	512
Lolium multiflorum	Annual rye	160

SHRUB LIST

Scientific Name	Common Name
Alnus incana	Tag alder
Cornus sericea	Red-Osier dogwood
Ilex verticillata	Winterberry
Lindera benzoin	Spicebush

TREE LIST

Scientific Name	Common Name
Abies balsamea	Balsam fir
Acer rubrum	Red maple
Betula alleghaniensis	Yellow birch
Betula papyrifera	Paper birch
Larxis laricina	Tamarack
Picea mariana	Black spruce
Thuja occidentalis	Northern white cedar
Tilia americana	Basswood
Tsuga canadensis	Hemlock

TRUITT, ASHLEY K:\WMSRDC\2200272_StonyCreek\CAD\DesignSheets\D-XX DETAILS.dwg - 6/2/2023

MISS DIG System, Inc.

Attention: 0 1" — If this scale bar does not measure 1" then drawing is not original scale.

SCOTT B. DIERKS, STATE OF MICHIGAN, ENGINEER, No. 44371

Designed:	BM
Drawn:	AT
Checked:	
Approved:	BM
P.E. No:	44371
GEI Project	2200272

GEI Consultants

WMSRDC
316 MORRIS AVENUE
SUITE 340
MUSKEGON, MI 49440

MARSHVILLE DAM REMOVAL & STONY CREEK RESTORATION

STONY CREEK
MARSHVILLE DAM ROAD
SHELBY, MI 49455

NO	DATE	ISSUE/REVISION	APP
5	5/31/2023	CONSTRUCTION DRAWINGS	BM
4	3/22/2023	FOR PERMIT	BM
3	1/23/2023	FOR PERMIT	BM
2	12/22/2022	60% DESIGN SET	BM
1	7/20/2022	30% DESIGN SET	BM

SHEET NAME: **PLANTING DETAILS AND PLANT LISTS**

DWG. NO. **D-5**

SHEET NO. **27 of 27**

STONY CREEK FISHING PLATFORMS AND BOARDWALK DESIGN

FOR CONSTRUCTION

MAY 14, 2024

MICHIGAN STATE MAP

(NOT TO SCALE)

SOURCE: GOOGLE EARTH

PROJECT AREA

(NOT TO SCALE)

SHEET INDEX

Sheet Number	DWG Number	Sheet Title
1	G-01	Cover Sheet
2	C-01	Boardwalk Design Plan
3	C-02	Boardwalk Design Sections
4	D-01	Construction Details

PREPARED FOR:

West Michigan Shoreline Regional
Development Commission
316 Morris Avenue
Suite 340
Muskegon, MI 49440
(231)722-7878
and
Conservation Resource Alliance (CRA)
10850 E Traverse Hwy #1180
Traverse City, MI 49684
(231) 948-6817

PREPARED BY:

GEI CONSULTANTS OF MICHIGAN, P.C.
5225 EDGEWATER DRIVE
ALLENDALE, MI 49401
(616)384-2710

GEI Consultants

Conservation Resource Alliance (CRA)

WMSRDC
WEST MICHIGAN SHORELINE
REGIONAL DEVELOPMENT COMMISSION

THIS DOCUMENT, AND THE IDEAS AND DESIGNS INCORPORATED HEREIN, IS AN INSTRUMENT OF PROFESSIONAL SERVICE, IS THE PROPERTY OF GEI CONSULTANTS AND IS NOT TO BE USED, IN WHOLE OR IN PART, FOR ANY OTHER PROJECT WITHOUT THE WRITTEN AUTHORIZATION OF GEI CONSULTANTS.

MISS DIG System, Inc.

GEI PROJECT NO. 2200534

NO.	DATE	ISSUE/REVISION	APP
2	5/14/2024	FOR CONSTRUCTION	BM
1	3/4/2024	90% DESIGN	BM

DRAFT

DWG. NO. G-01

SHEET NO. 1 OF 4

PRODEHL_DREW B:\Working\WEST MICHIGAN SHORELINE REGIONAL DEVELOPMENT COMMISSION\2200483 Stony Creek\CAD\Design\Sheets\Boardwalk\G-01 COVER.dwg - 5/14/2024

CONSTRUCTION NOTES:

1. CHANNEL AND BANK GRADING SHALL BE COMPLETED PRIOR TO BOARDWALK INSTALLATION.
2. PARKING AREA AND ADA STALLS SHALL BE COMPLETED UNDER A SEPARATE CONTRACT.
3. CONTRACTOR SHALL FIELD VERIFY ELEVATIONS OF BOARDWALK DECKING AT LOCATIONS NOTED ON SHEET C-01.
4. BOARDWALK SLOPE IS CONSTANT BETWEEN SPOT ELEVATIONS.
5. ALL BOARDWALK CORNERS ARE LEVEL IN ALL DIRECTIONS

0 2.5 5 10
SCALE, FEET

OVERALL PROJECT QUANTITIES

DOWNSTREAM BOARDWALK AND FISHING PLATFORM AREA	1,210-SF
DOWNSTREAM BOARDWALK AND FISHING PLATFORM LENGTH	230-LF
HELICAL PILES	68-EA
ALTERNATE BOARDWALK AND FISHING PLATFORM AREA	295-SF
ALTERNATE BOARDWALK AND FISHING PLATFORM LENGTH	50-LF
ALTERNATE HELICAL PILES	15-EA

BOARDWALK LANDING
TOP OF BOARDWALK DECKING ELEVATION, TYP.
BOARDWALK LANDING
SEE DETAILS ON SHEET D-01 FOR BOARDWALK CONSTRUCTION
INSTALL 5'X8'X6" CONCRETE PAD ON GRADE, SEE DETAIL ON SHEET D-1
START OF ELEVATED BOARDWALK
CHANNEL AND BANK GRADING COMPLETED PRIOR TO BOARDWALK CONSTRUCTION UNDER SEPARATE CONTRACT
PARKING AREA INCLUDING ADA STALLS NOT INCLUDED IN THIS CONTRACT
BOARDWALK LANDING
DOWNSTREAM FISHING PLATFORM TOP OF DECKING 1.98' ABOVE AVERAGE WATER SURFACE ELEVATION
ALTERNATE BOARDWALK AND ALTERNATE FISHING PLATFORM AREA
ALTERNATE UPSTREAM FISHING PLATFORM TOP OF DECKING 1.88' ABOVE AVERAGE WATER SURFACE ELEVATION
8.0' TYP.
5.0' TYP.
15.0' TYP.

FOR CONSTRUCTION

Attention:
0 1"
If this scale bar does not measure 1" then drawing is not original scale.

STATE OF MICHIGAN STEVEN A. ELVER ENGINEER No. 40446 LICENSED PROFESSIONAL ENGINEER

Designed:	AT
Drawn:	AT
Checked:	BM
Approved:	
P.E. No:	40446
GEI Project	2200534

GEI Consultants
GEI CONSULTANTS OF MICHIGAN, P.C.
5225 EDGEWATER DRIVE
ALLENDALE, MI 49401
(616)384-2710

CRA
10850 E TRAVERSE HWY #1180
GARFIELD TWP, MI 49684

STONY CREEK FISHING PLATFORMS AND BOARDWALK DESIGN

STONY CREEK
MARSHVILLE DAM ROAD
SHELBY, MI 49455

NO	DATE	ISSUE/REVISION	APP
2	5/14/2024	FOR CONSTRUCTION	BM
1	3/4/2024	90% DESIGN	BM

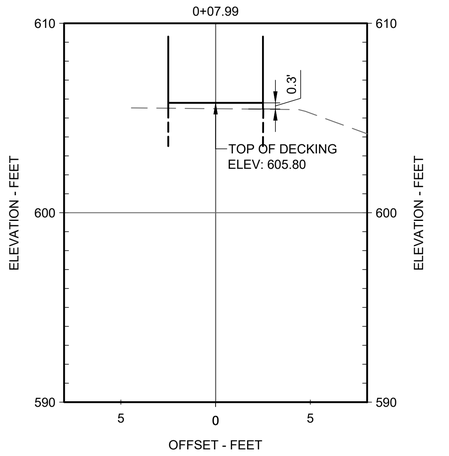
SHEET NAME
Boardwalk Design Plan

DWG. NO.
C-01

SHEET NO.
2 of 4

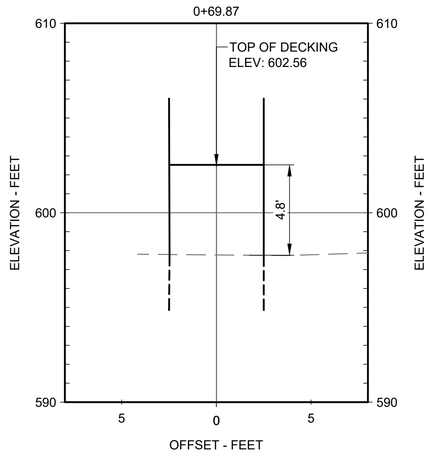
MISS DIG System, Inc. 811 www.missdig.org 1-800-482-7171

PRODEH... DREW B:\Working\WEST MICHIGAN SHORELINE REGIONAL DEVELOPMENT COMMISSION\2200483 Stony Creek\CAD\Design\Sheets\Boardwalk\C-01 Boardwalk Design Plan.dwg - 5/14/2024



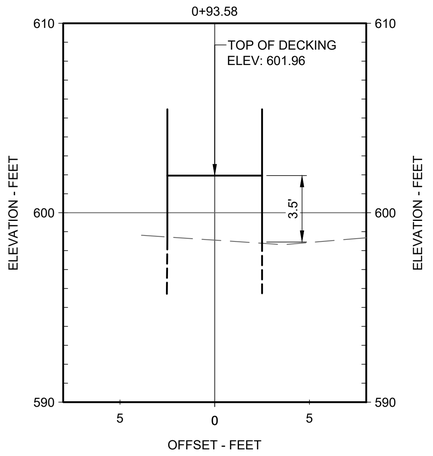
SECTION A-A'

SCALE: 1" = 4'



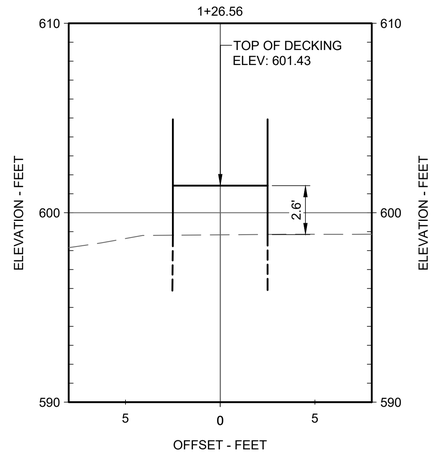
SECTION B-B'

SCALE: 1" = 4'



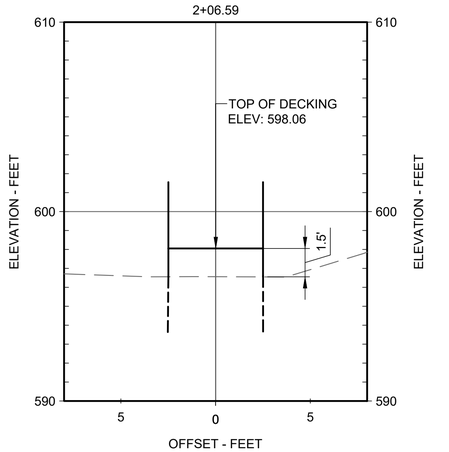
SECTION C-C'

SCALE: 1" = 4'



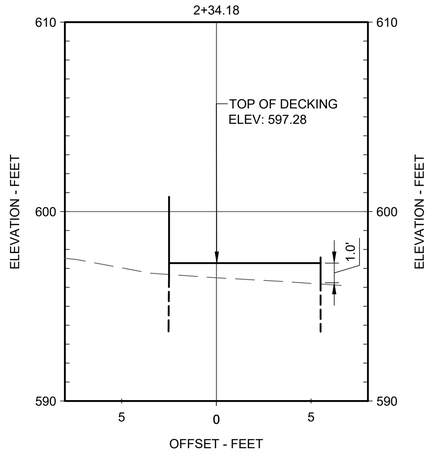
SECTION D-D'

SCALE: 1" = 4'



SECTION E-E'

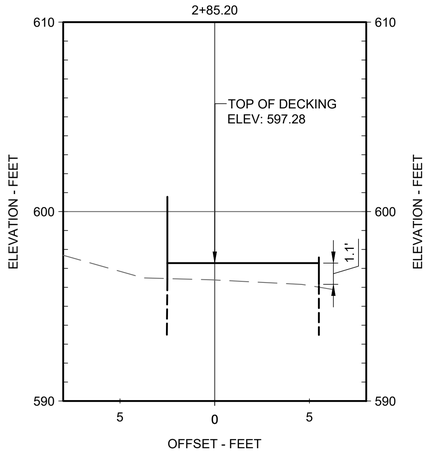
SCALE: 1" = 4'



SECTION F-F'

DOWNSTREAM FISHING PLATFORM

SCALE: 1" = 4'



SECTION G-G'

UPSTREAM FISHING PLATFORM - ALTERNATE

SCALE: 1" = 4'

CONSTRUCTION NOTES:

1. SEE CONSTRUCTION NOTES ON SHEET C-01

FOR CONSTRUCTION

PRODEHL_DREW B:\Working\WEST MICHIGAN SHORELINE REGIONAL DEVELOPMENT COMMISSION\2200483 Stony Creek\CAD\Design\Sheets\Boardwalk\C-02 Boardwalk Design Sections.dwg - 5/14/2024

MISS DIG System, Inc.
811
www.missdig.org
1.800.482.7171

0 2.5' 5' 10'
SCALE, FEET

Attention:
0 1"
If this scale bar does not measure 1" then drawing is not original scale.

STATE OF MICHIGAN
STEVEN A. ELVER
ENGINEER
No. 40446
LICENSED PROFESSIONAL ENGINEER

Designed:	AT
Drawn:	AT
Checked:	BM
Approved:	SE
P.E. No:	40446
GEI Project	2200534

GEI Consultants
GEI CONSULTANTS OF MICHIGAN, P.C.
5225 EDGEWATER DRIVE
ALLENDALE, MI 49401
(616)384-2710

CRA
10850 E TRAVERSE
HWY #1180
GARFIELD TWP, MI
49684

STONY CREEK FISHING PLATFORMS AND BOARDWALK DESIGN

STONY CREEK
MARSHVILLE DAM ROAD
SHELBY, MI 49455

NO	DATE	ISSUE/REVISION	APP
2	5/14/2024	FOR CONSTRUCTION	BM
1	3/4/2024	90% DESIGN	BM

SHEET NAME

Boardwalk Design Sections

DWG. NO.

C-02

SHEET NO.

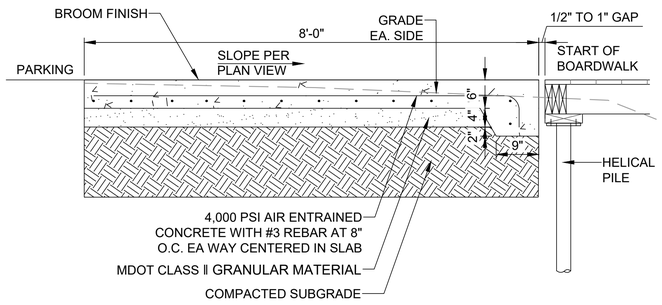
3 of 4

CONSTRUCTION NOTES:

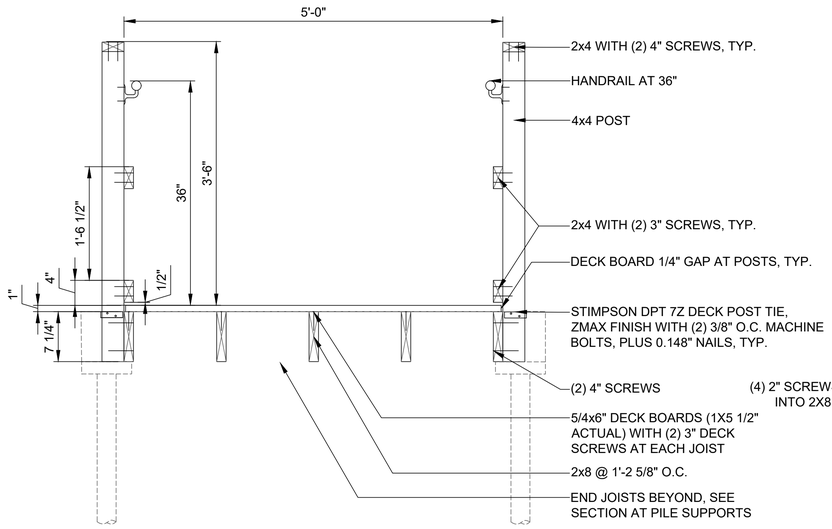
1. ALL BOARDWALK MATERIALS AND FASTENERS SHALL BE AS AS SPECIFIED ON SHEET D-01 AND CONTRACT DOCUMENTS.
2. ALL BOLTS AND CONNECTION HARDWARE SHALL FOLLOW ASTM A307 AND A153 RESPECTIVELY.
3. TREATED LUMBER SHALL BE IN ACCORDANCE WITH AWPA STANDARDS C2 AND C9. WATERBORNE PRESERVATIVES SHALL HAVE A RETENTION OF 0.40 LB./CU.FT. FOR WOOD IN CONTACT WITH THE GROUND.
4. ALL LUMBER SHALL HAVE A GRADE STAMP RECOGNIZED BY THE NATIONAL DESIGN SPECIFICATION FOR WOOD CONSTRUCTION OR THE AMERICAN PLYWOOD ASSOCIATION.

CONCRETE NOTES:

1. ALL REINFORCING STEEL SHALL CONFORM TO ASTM A615, GRADE 60.
2. CONCRETE SHALL CONFORM TO ACI 301: SPECIFICATIONS FOR STRUCTURAL CONCRETE, ACI 305: HOT WEATHER CONCRETING, AND ACL 306: COLD WEATHER CONCRETING
3. REBAR SHOP DRAWINGS SHALL BE SUBMITTED TO THE ENGINEER FOR APPROVAL PRIOR TO FABRICATION.
4. ALL EXPOSED EDGES OF CONCRETE SHALL BE CHAMFERED 3/4".



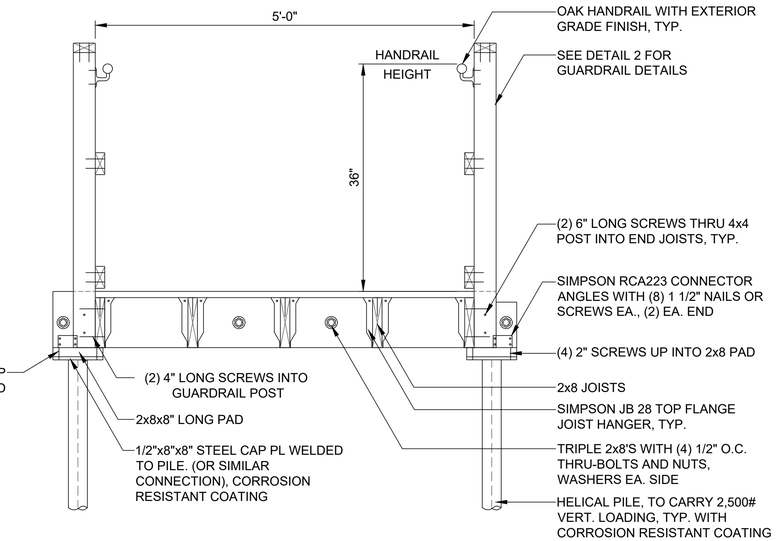
1 CONCRETE PAD
AT START OF BOARDWALK
SCALE: 3/4"=1'-0"



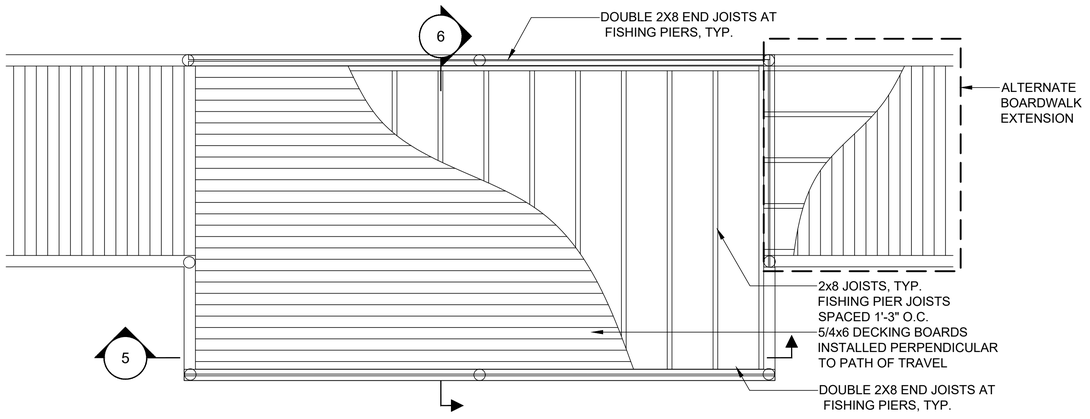
NOTES:

1. ALL WOOD TO BE "GROUND CONTACT" TREATED.
2. FASTENERS TO BE CORROSION RESISTANT FOR TREATED WOOD.

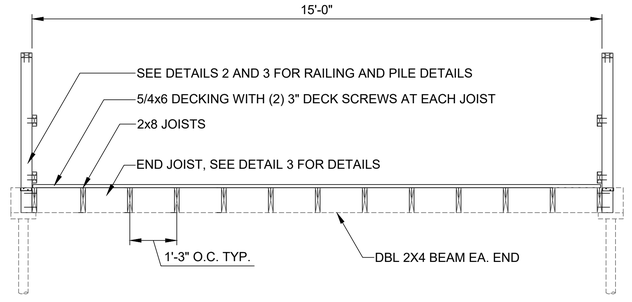
2 BOARDWALK CROSS SECTION
MIDWAY BETWEEN SUPPORTS
SCALE: 1"=1'-0"



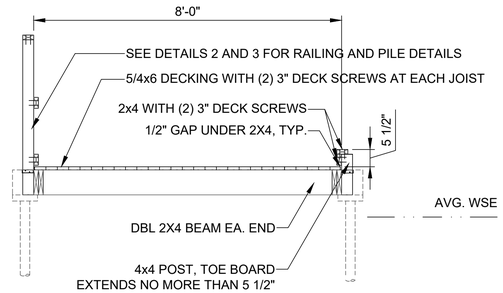
3 BOARDWALK CROSS SECTION
AT PILE SUPPORTS
SCALE: 1"=1'-0"



4 DECKING PLAN
AT DOWNSTREAM FISHING PIER AND BOARDWALK CONNECTION
SCALE: 1/2" = 1'-0"



5 FISHING PIER CROSS SECTION
ALONG LENGTH OF PIER
SCALE: 1/2" = 1'-0"



6 FISHING PIER CROSS SECTION
ALONG WIDTH OF PIER
SCALE: 1/2" = 1'-0"

FOR CONSTRUCTION

Attention:
0 1"
If this scale bar does not measure 1" then drawing is not original scale.

STATE OF MICHIGAN
STEVEN A. ELVER
ENGINEER
No. 40446
LICENSED PROFESSIONAL ENGINEER

Designed:	AT
Drawn:	AT
Checked:	BM
Approved:	SE
P.E. No:	40446
GEI Project	2200534

GEI Consultants
GEI CONSULTANTS OF MICHIGAN, P.C.
5225 EDGEWATER DRIVE
ALLENDALE, MI 49401
(616)384-2710

CRA
10850 E TRAVERSE
HWY #1180
GARFIELD TWP, MI
49684

STONY CREEK FISHING PLATFORMS AND BOARDWALK DESIGN

STONY CREEK
MARSHVILLE DAM ROAD
SHELBY, MI 49455

NO	DATE	ISSUE/REVISION	APP
2	5/14/2024	FOR CONSTRUCTION	BM
1	3/4/2024	90% DESIGN	BM

SHEET NAME
Construction Details

DWG. NO.
D-01

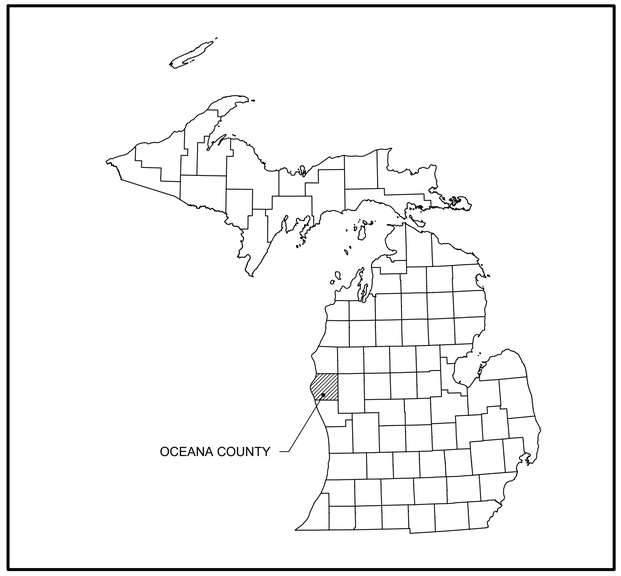
SHEET NO.
4 of 4

MISS DIG System, Inc.
www.missdig.org 1.800.482.7171

PRODEHL_DREW B:\Working\WEST MICHIGAN SHORELINE REGIONAL DEVELOPMENT COMMISSION\2200483 Stony Creek\CAD\Design\Sheets\Boardwalk\D-01 Boardwalk Details.dwg - 5/14/2024

STONY CREEK RESTORATION PLANTING PROJECT

FOR BIDDING
JANUARY 14, 2025



MICHIGAN STATE MAP
(NOT TO SCALE)

SOURCE: GOOGLE EARTH

PROJECT AREA
(NOT TO SCALE)

Sheet List Table

Sheet Number	Sheet Description	Sheet Title
1	G-1	Cover
2	C-1	Planting Plan
3	C-2	Plant Lists and Specifications

PREPARED FOR:

Conservation Resource Alliance
10850 E Traverse Hwy #1180
Traverse City, MI 49684
(231) 948-6817

PREPARED BY:

GEI CONSULTANTS OF MICHIGAN, P.C.
5225 EDGEWATER DRIVE
ALLENDALE, MI 49401
(616)384-2710

GEI Consultants

THIS DOCUMENT, AND THE IDEAS AND DESIGNS INCORPORATED HEREIN, IS AN INSTRUMENT OF PROFESSIONAL SERVICE, IS THE PROPERTY OF GEI CONSULTANTS AND IS NOT TO BE USED, IN WHOLE OR IN PART, FOR ANY OTHER PROJECT WITHOUT THE WRITTEN AUTHORIZATION OF GEI CONSULTANTS.

MISS DIG System, Inc.
www.missdig.org 1-800-482-7171

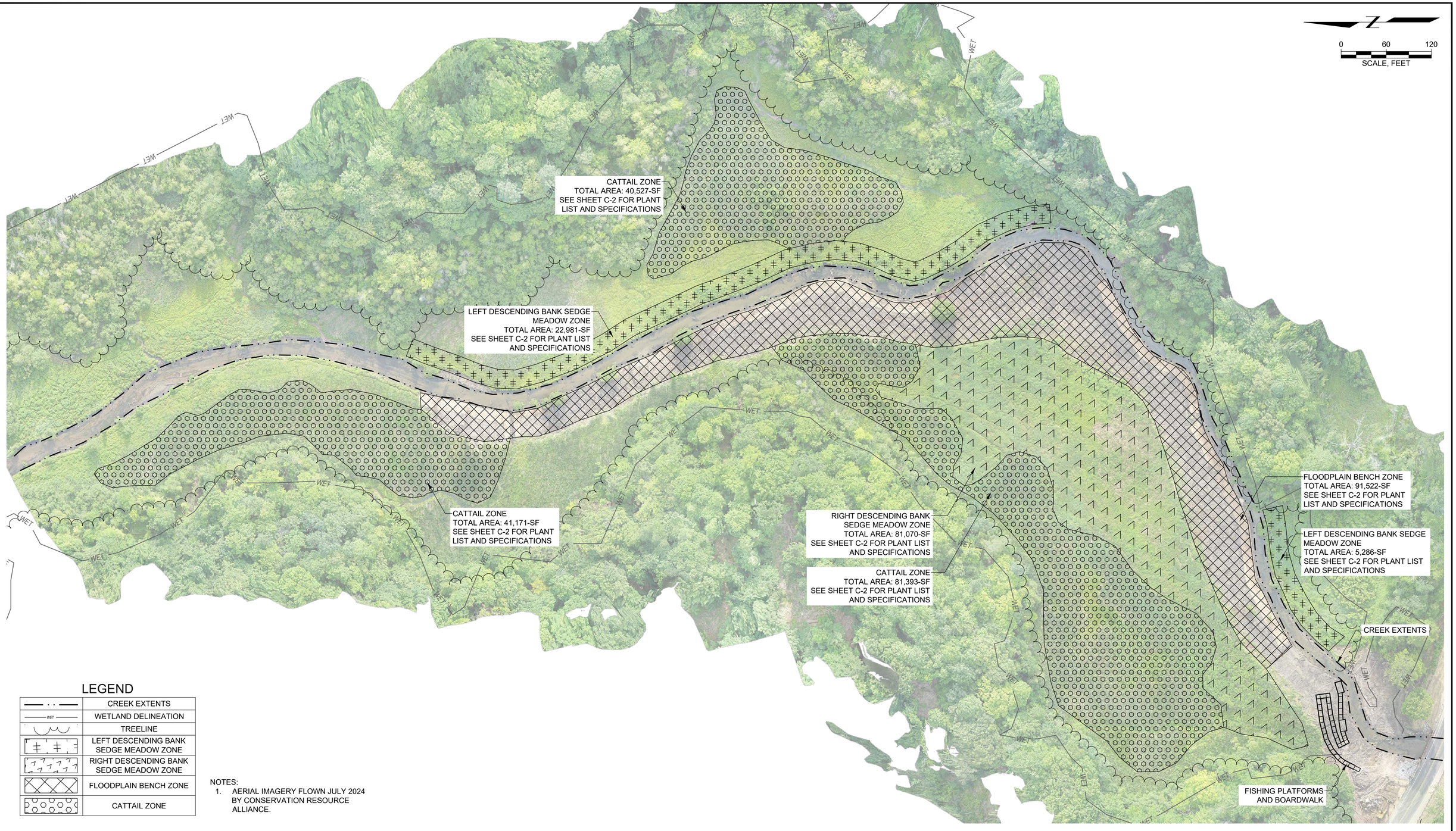
GEI PROJECT NO. 2200272

NO.	DATE	ISSUE/REVISION	APP
2	1/14/2025	FOR BIDDING	BM
1	12/9/2024	PRELIMINARY	BM

DWG. NO.
G-1

SHEET NO.
1 OF 3

TRUITT, ASHLEY B:\Working\WEST MICHIGAN SHORELINE REGIONAL DEVELOPMENT COMMISSION\2200483 Stony Creek\CAD\Design\Sheets\20250109_PLANTING PLAN COVER.dwg - 1/20/2025



LEGEND

	CREEK EXTENTS
WET	WETLAND DELINEATION
	TREELINE
	LEFT DESCENDING BANK SEDGE MEADOW ZONE
	RIGHT DESCENDING BANK SEDGE MEADOW ZONE
	FLOODPLAIN BENCH ZONE
	CATTAIL ZONE

NOTES:
1. AERIAL IMAGERY FLOWN JULY 2024 BY CONSERVATION RESOURCE ALLIANCE.

MISS DIG System, Inc.
www.missdig.org 1-800-482-7171

Attention:
0 1"
If this scale bar does not measure 1" then drawing is not original scale.

Designed:
Drawn:
Checked:
Approved:
P.E. No:
GEI Project 2200272

GEI Consultants
GEI CONSULTANTS OF MICHIGAN, P.C.
5225 EDGEWATER DRIVE
ALLENDALE, MI 49401
(616)384-2710

CRA
10850 E. TRAVERSE HWY #1180
TRAVERSE CITY, MI 49684
(231) 948-6817

STONY CREEK RESTORATION PLANTING PROJECT

STONY CREEK
MARSHVILLE DAM ROAD
SHELBY, MI 49455

NO	DATE	ISSUE/REVISION	APP
2	1/14/2025	FOR BIDDING	BM
1	12/9/2024	PRELIMINARY	BM

SHEET NAME
PLANTING PLAN

DWG. NO.
C-1

SHEET NO.
2

TRUITT, ASHLEY B:\Working\WEST MICHIGAN SHORELINE REGIONAL DEVELOPMENT COMMISSION\2200483 Stony Creek\CAD\Design\Sheets\20241018_Planting Plan.dwg - 1/20/2025

FLOODPLAIN BENCH ZONE

SCIENTIFIC NAME	COMMON NAME	QUANTITY	WILDLIFE BROWSE PROTECTION
Abies balsamea	Balsam Fir	119	NONE
Acer rubrum	Red Maple	59	5-FT TALL TREE-PRO TREE TUBE
Betula papyrifera	Paper Birch	100	5-FT TALL TREE-PRO TREE TUBE
Cornus sericea	Red-Osier Dogwood	75	3-FT TALL TREE-PRO TREE TUBE
Ilix verticillata	Winterberry	63	3-FT TALL TREE-PRO TREE TUBE
Larix laricina	Tamarack	119	NONE
Lindera benzoin	Spicebush	63	3-FT TALL TREE-PRO TREE TUBE
Picea mariana	Black Spruce	119	NONE
Thuja occidentalis	Northern White Cedar	119	5-FT TALL WIRE CAGE, 18-IN DIAMETER
Tilia americana	American Basswood	59	5-FT TALL TREE-PRO TREE TUBE
Viburnum trilobum	Highbush Cranberry	63	3-FT TALL TREE-PRO TREE TUBE

* REMOVE 1.5-FT RADIUS SOD AROUND EACH SEEDLING
* INSTALL 30-IN DIAMETER COCONUT COIR OR EQUIVALENT AROUND EACH SEEDLING
* INSTALL PLANTS AT APPROXIMATELY 12-FT ON CENTER, SOME VARIABILITY IN SPACING IS DESIRED AND SUBJECT TO CONTRACTORS DISCRETION

LEFT DESCENDING BANK SEDGE MEADOW ZONE

SCIENTIFIC NAME	COMMON NAME	QUANTITY	WILDLIFE BROWSE PROTECTION
Abies balsamea	Balsam Fir	33	NONE
Acer rubrum	Red Maple	17	5-FT TALL TREE-PRO TREE TUBE
Betula papyrifera	Paper Birch	50	5-FT TALL TREE-PRO TREE TUBE
Larix laricina	Tamarack	33	NONE
Picea mariana	Black Spruce	33	NONE
Thuja occidentalis	Northern White Cedar	33	5-FT TALL WIRE CAGE, 18-IN DIAMETER
Tilia americana	American Basswood	17	5-FT TALL TREE-PRO TREE TUBE

* REMOVE 1.5-FT RADIUS SOD AROUND EACH SEEDLING
* INSTALL 30-IN DIAMETER COCONUT COIR OR EQUIVALENT AROUND EACH SEEDLING
* INSTALL PLANTS AT APPROXIMATELY 10-FT ON CENTER, SOME VARIABILITY IN SPACING IS DESIRED AND SUBJECT TO CONTRACTORS DISCRETION

RIGHT DESCENDING BANK SEDGE MEADOW ZONE

SCIENTIFIC NAME	COMMON NAME	QUANTITY	WILDLIFE BROWSE PROTECTION
Abies balsamea	Balsam Fir	48	NONE
Acer rubrum	Red Maple	24	5-FT TALL TREE-PRO TREE TUBE
Betula papyrifera	Paper Birch	50	5-FT TALL TREE-PRO TREE TUBE
Cornus sericea	Red-Osier Dogwood	25	3-FT TALL TREE-PRO TREE TUBE
Ilix verticillata	Winterberry	37	3-FT TALL TREE-PRO TREE TUBE
Larix laricina	Tamarack	48	NONE
Lindera benzoin	Spicebush	37	3-FT TALL TREE-PRO TREE TUBE
Picea mariana	Black Spruce	48	NONE
Thuja occidentalis	Northern White Cedar	48	5-FT TALL WIRE CAGE, 18-IN DIAMETER
Tilia americana	American Basswood	24	5-FT TALL TREE-PRO TREE TUBE
Viburnum trilobum	Highbush Cranberry	27	3-FT TALL TREE-PRO TREE TUBE

* REMOVE 1.5-FT RADIUS SOD AROUND EACH SEEDLING
* INSTALL 30-IN DIAMETER COCONUT COIR OR EQUIVALENT AROUND EACH SEEDLING
* INSTALL PLANTS AT APPROXIMATELY 12-FT ON CENTER, SOME VARIABILITY IN SPACING IS DESIRED AND SUBJECT TO CONTRACTORS DISCRETION

CATTAIL ZONE

SCIENTIFIC NAME	COMMON NAME	QUANTITY	WILDLIFE BROWSE PROTECTION
Salix nigra	Black Willow- Rooted Cutting	375	NONE
Viburnum trilobum	Highbush Cranberry	185	NONE

* SITE PREPARATION IS NOT REQUIRED IN THE CATTAIL ZONE
* MULCHING IS NOT REQUIRED IN THE CATTAIL ZONE
* INSTALL PLANTS AT APPROXIMATELY 17-FT ON CENTER, SOME VARIABILITY IN SPACING IS DESIRED AND SUBJECT TO CONTRACTORS DISCRETION

GENERAL TECHNICAL SPECIFICATIONS:

1. Equipment Cleaning - To prevent the spread of non-native invasive species, CONTRACTOR's equipment will be inspected prior to starting work. All equipment must be cleaned and free of brush, debris, mud, dirt, and plant parts including roots and seed prior to entering the site. Methods of equipment cleaning may include, but are not limited to steam-cleaning, running through a car wash, or compressed air cleaning. CRA will inspect equipment upon being brought onto job site for the first time, or subsequent times if the equipment is taken off site and returned.

2. Treatment Areas -Treatment activities will only occur within the job area boundary. Contact CRA if there are any questions about job area boundaries.

3. Personal Protective Equipment - Personal protective equipment (PPE) will be worn at all times while in the job area. Unsafe work practices could result in a 'Stop Work' order being issued or further penalties.

SPECIFIC TECHNICAL SPECIFICATIONS:

1. The selected CONTRACTOR shall coordinate with CRA and each of the seedling nurseries to arrange for the contractor's preferred pickup date or delivery details (subject to the seedling nursery approval).

2. The CONTRACTOR shall take responsibility of the plant material upon delivery to the CONTRACTOR'S preferred location or pickup from the nursery. The CONTRACTOR shall notify CRA in writing within 48 hours of delivery if plant material is of poor quality, is not true to species, or does not meet the project specification for species, size, or quantity.

3. If the CONTRACTOR does not provide written notification of plant deficiencies, it shall be assumed that the contractor has accepted the material and will meet plant survival guarantees described in the specifications.

4. Upon receipt of the seedlings, the CONTRACTOR, at all times until the seedlings are planted, shall strictly adhere the guidance outlined in the care of seedlings section of the document entitled *Tree /Shrub Establishment Michigan Guidance Document,* Attachment 3.

5. The CONTRACTOR shall notify CRA at least 48 hours prior to the start of planting, and either CRA or GEI will inspect plant material prior to installation. If plant material is deemed unacceptable due to mortality, desiccation, dry roots, or other condition that may jeopardize the success of the planting, the CONTRACTOR will be required to replace material at his or her own cost.

6. The CONTRACTOR shall plant the seedlings within the designated planting zones shown on the Stony Creek Restoration Planting Project Plan. Tree species shall be planted roughly 12 feet (not less than 8 feet and not more than 16 feet) on center. Shrub species can be grouped in clusters containing up to 10 shrubs spaced 5 feet on center. Space clusters of shrubs throughout the designated planting zones.

7. Site preparation and planting will be completed manually using hand tools including hand augers and small rototillers. The CONTRACTOR will perform the following for all planted shrubs/trees:

   7.1. With the exception of the Cattail Zones, all planting locations will require site preparation in the form of scalping the top layer of sod no more than 4- inches deep and no less than 1.5 feet in radius around the native tree to be planted followed by installation of a 30 inch diameter vegetation suppression mat (erosion control coconut coir or approved equivalent) once the seedling is installed.
   7.2. Dig planting hole slightly larger than the root size of the tree. Hole will consist of primarily mineral soil and be free of debris, foreign material, or excessive organic material. For seedlings with smaller root wads and willow stakes, a planting bar/dibble can be used instead of digging a hole.
   7.3. Gently remove tree from bundle and trim any exceptionally long roots that may result in root binding or J-rooting (no more than 25% of the root mass).
   7.4. Place tree into the hole and firmly pack soil around roots removing any air pockets. Trees will be planted so the root flare is slightly above or at the soil surface.
   7.5. Soil amendments for water retention (terasorb or similar) shall also be a component of each installation except for the seedlings being installed within the Cattail Zones, which can be added during tree planting.

8. At the time of planting, the CONTRACTOR will install deer browse protection and mulch measure as specified.

9. Site prep, planting, and installation of browse protection will occur between February 28, 2025 and April 25, 2025. Individual sites must be completed during a single-entry period.

TRUITT, ASHLEY B:\Working\WEST MICHIGAN SHORELINE REGIONAL DEVELOPMENT COMMISSION\2200483 Stony Creek\CAD\Design\Sheets\20241018_Planting Plan.dwg - 1/20/2025

MISS DIG System, Inc.
www.missdig.org 1-800-482-7171

Attention:
0 1"
If this scale bar does not measure 1" then drawing is not original scale.

Designed:
Drawn:
Checked:
Approved:
P.E. No:
GEI Project 2200272

GEI Consultants
GEI CONSULTANTS OF MICHIGAN, P.C.
5225 EDGEWATER DRIVE
ALLENDALE, MI 49401
(616)384-2710

CRA
10850 E. TRAVERSE HWY #1180
TRAVERSE CITY, MI 49684
(231) 948-6817

STONY CREEK RESTORATION PLANTING PROJECT

STONY CREEK
MARSHVILLE DAM ROAD
SHELBY, MI 49455

NO	DATE	ISSUE/REVISION	APP
2	1/14/2025	FOR BIDDING	BM
1	12/9/2024	PRELIMINARY	BM

SHEET NAME
PLANT LISTS AND SPECIFICATIONS

DWG. NO.
C-2

SHEET NO.
3

Appendix C GVSU Post-Restoration Fish Monitoring

Stony Creek Fish Passage Improvement: Post-Construction Fish Monitoring

Carl R. Ruetz III[1]

Annis Water Resources Institute

Grand Valley State University

740 W. Shoreline Drive

Muskegon, MI, 49431

A Final Report to

West Michigan Shoreline Regional Development Commission

Project # 756423

5 September 2025

[1] e-mail: ruetzc@gvsu.edu, office: 616-331-3946

Introduction

Road-stream crossings often cause spatial fragmentation in watersheds, limiting the ability of fishes to move upstream of barriers (Januchowski-Hartley et al. 2013; McKay et al. 2020). Conservation efforts to remove barriers and restore stream connectivity have been shown to positively benefit fish populations and communities (Warren and Pardew 1998; Nislow et al. 2011). Pre- and post-assessment monitoring is a key component of measuring river restoration success (Palmer et al. 2005). Although much effort (e.g., financial resources) is spent on river restoration, reporting on measurements of ecological outcomes is often lacking, which provide a valuable opportunity to learn from both successes and failures of restoration activities (Bernhardt et al. 2005; Palmer et al. 2005).

The goal of this ecological monitoring effort was to compare pre- and post-assessment observations on a road-stream crossing (located on Stony Creek, Oceana County, Michigan) that was improved and habitat enhanced. In addition to the road-stream crossing at Marshville Dam Road, remnants of a failed dam (Figure 1a) immediately upstream of the road were removed and habitat was improved in a section of stream that was previously a mill pond prior to the failure of the dam. This report provides a summary of the pre-assessment and post-assessment stream conditions at the restoration site and provides a basis for interpreting the ecological success of the construction project.

Methods

Study sites.—Stony Creek is a tributary to Lake Michigan located in Oceana County, Michigan. Stony Creek flows into Stony Lake (a drowned river mouth lake) that then drains directly into Lake Michigan via lower Stony Creek (Mader et al. 2023). The watershed encompasses approximately 57 square miles, containing six named tributaries, nine unnamed tributaries, and countless points of groundwater infiltration (Tonello 2021). Stony Creek is designated as a cold-water trout stream and is known to contain a healthy fishery of Brook Trout *Salvelinus fontinalis*, Brown Trout *Salmo trutta*, and Rainbow Trout *Oncorhynchus mykiss* that is supported by natural reproduction (O'Neal 1999; Tonello 2021). The stream is also known to support runs of adult Rainbow Trout (Steelhead), Coho Salmon *O. kisutch*, and Chinook Salmon *O. tshawytscha* from Lake Michigan (Tonello 2021).

Environmental monitoring was conducted at two sites on Stony Creek. Sites were located at Marshville Dam Road and Shelby Road (Appendix A). Monitoring was conducted both upstream and downstream of the road-stream crossing at Marshville Dam, and upstream of the road-stream crossing at Shelby Road, which served as a control reach (i.e., no habitat improvements were associated with this reach). The upstream reach at Marshville Dam Road was upstream of remnants of the previously failed dam. Locations of the upstream and downstream terminus of each reach were recorded at the time of sampling (Appendix B).

Environmental monitoring.—Fish sampling was performed following Michigan's Procedure 51 via backpack electrofishing unit (MDEQ 2008). The sampling goal of Procedure 51 was to capture at least 100 fish in a reach, which should generally require approximately 30 minutes of electrofishing effort per reach. If the number of fish was less than 100 fish, then electrofishing continued until the total elapsed time was about 45 minutes. Sampling was conducted in an upstream direction using two backpack electrofishing units (AbP-3 and AbP-4 pulsed DC

backpack electrofisher [220 V, duty cycle: 10%, pulse rate: 50 pulses/s; ETS Electrofishing, Verona, Wisconsin]) accompanied by additional netters. All fish captured were identified to species, measured for total length, and then released within the reach from which they were captured. Pre-construction fish monitoring was conducted on 25-26 July 2022. Post-construction fish monitoring was conducted on 25 June 2025. Stream discharge was visibly stable at the time of sampling.

For each reach, the reach length and GPS coordinates for the upstream and downstream ends were recorded. Three measurements were made at each reach (upstream, middle, and downstream within the reach) of water temperature, dissolved oxygen concentration, specific conductivity, and turbidity with a YSI sonde. The width of each stream reach was measured at five locations within the reach. At each location where width was measured, mean water-column velocity and depth were measured along a transect (10 equidistant measurements/transect). Additionally, we measured water velocity and depth within each culvert and the jump height (distance from bottom of culvert to surface of water at the downstream side of the road-stream crossing) at the time of sampling during pre-construction monitoring.

Results

A total of 610 fish representing eight species were captured during pre- and post-construction surveys at three stream reaches in Stony Creek. During pre-construction surveys, 354 fish representing seven species were captured, and 256 fish representing five species were captured during post-constructions surveys in the same reaches (Table 1). The catch at both Marshville Dam Road and Shelby Road was dominated by sculpins followed by Brown Trout, Rainbow Trout, and Brook Trout. Initially, all sculpins were identified as Mottled Sculpin *Cottus bairdii* during pre-construction surveys; however, a subset of individuals identified in the laboratory during post-construction surveys suggested the presence of both Slimy Sculpin *Cottus cognatus* and Mottled Sculpin. Although catch per unit effort was somewhat lower during post-construction surveys compared with pre-construction surveys (Table 2), the fish assemblage appeared relatively consistent between the two sampling events (Table 1).

There were three culverts at Marshville Dam Road (Figure 2) that were replaced with a bridge (Figure 3a). During pre-construction surveys, the mean widest width of each culvert was 202 cm and height was about 191 cm. Mean wetted width inside the culvert was a 179 cm, while mean water depth was 42.9 cm at the upstream end and 37.0 cm at the downstream end of the culvert. Jump height was 0 cm for all culverts because none of the culverts were perched. Mean water velocity in the culverts was 0.50 m/s at the upstream end and 0.77 m/s at the downstream end of the culvert, which was about 2× greater than the mean water velocity of 0.31 m/s measured in the upstream and downstream reaches (n = 100) during pre-construction surveys. The mean water velocity (0.29 m/s) in the upstream and downstream reaches at Marshville Dam Road during post-construction surveys (n = 100) was similar to observations made during pre-construction surveys, suggesting that the replacement of the culverts with a bridge should increase fish passage. No culvert existed at Shelby Road.

Most environmental variables showed minimal differences among reaches and between pre- vs. post-construction surveys (Tables 2 and 3). An exception to this generalization was that the upstream reach at Marshville Dame Road was about 29% narrower during post-construction surveys (Table 2; Figure 3).

Discussion

Fish assemblages were similar among the three stream reaches of Stony Creek. Most of the species (i.e., Brook Trout, Brown Trout, and sculpins) captured in Stony Creek are classified as coldwater species (Wehrly et al. 2003). Thus, the fish assemblages corresponded with a coldwater stream, which agreed with the point estimates of water temperature measured at the time of sampling (Table 3). The observations summarized here on the fish assemblage were reflective of past surveys (Table 4).

We captured three species (i.e., Brown Trout, Rainbow Trout, and Brook Trout) of trout in Stony Creek (Table 1). These trout species were all observed in past surveys (Table 4). Trout populations in Stony Creek are naturally reproducing; stocking records show that no stocking has occurred since 1976 (Tonello 2021, MDNR 2022). Rainbow Trout, Brown Trout, and (to a greater extent) Brook Trout all require cold (mean July water temperature < 19°C) water temperatures (Wehrly et al. 2003). Thorough monitoring of water temperatures at Marshville Dam Road showed a mean July water temperature of 13.7°C in 2019 (Tonello 2021), well within the range of the coldwater (< 19°C) thermal classification for Michigan streams (Wehrly et al. 2003) and similar to the daytime point estimates of water temperature reported here (Table 3).

The habitat improvements at the road-stream crossing at Marshville Dam Road improved fish passage and stream connectivity. For instance, culverts (Figure 2) were removed and replaced with a bridge (Figure 3a). Moreover, a remnant dam (Figure 1a) was removed, and the stream channel was restored to more natural condition (Figure 3b-c), which should provide better habitat for fish. Although I did not detect major changes in the fish assemblage as a result of the habitat improvements, these surveys provide valuable observations on the ecological conditions of Stony Creek and were consistent with a healthy coldwater stream (e.g., Wehrly et al. 2003).

Acknowledgements

I thank numerous GVSU students and technicians for their assistance in conducting field surveys and data entry. Grayson Kosak was the field crew leader for the pre-construction monitoring and the first author on the pre-construction monitoring report for which this report adds the post-construction monitoring results. Ruby Johnson assisted with summarizing post-construction data. Mark Tonello provided agency reports of previous fish surveys conducted in Stony Creek as well as advice on selecting our upstream control reach. This project would not have been possible without assistance from Fallon Chabala, Gale Nobes, and Brian Majka. Fish sampling for this research was approved by GVSU's Institutional Animal Care and Use Committee (Protocol No. 22-10-A and 25-14-A). Funding for this project was provided to GVSU from the National Oceanic and Atmospheric Administration with a contract from the West Michigan Shoreline Regional Development Commission.

References

Bernhardt, E.S., M.A. Palmer, J.D. Allan, and 22 coauthors. 2005. Synthesizing U.S. river restoration efforts. Science 308:636-637.

Januchowski-Hartley, S.R., P.B. McIntyre, M. Diebel, P.J. Doran, D.M. Infante, C. Joseph, and J.D. Allan. 2013. Restoring aquatic ecosystem connectivity requires expanding

inventories of both dams and road crossings. Frontiers in Ecology and Environment 11:211-217.
O'Neal, R. P. 1999. Fisheries Survey Report: Stony Creek, Oceana County. Michigan Department of Natural Resources, Cadillac.
Mader, M.M., C.R. Ruetz III, S.A. Woznicki, and A.D. Steinman. 2023. Land cover and water quality of drowned river mouths: evidence of an environmental gradient along the eastern Lake Michigan shoreline. Journal of Great Lakes Research 49:102237.
McKay, S.K., E.H. Martin, P.B. McIntyre, A.W. Milt, A.T. Moody, and T.M. Neeson. 2020. A comparison of approaches for prioritizing removal and repair of barriers to stream connectivity. River Research and Application 36:1754-1761.
Michigan Department of Environmental Quality (MDEQ). 2008. Qualitative biological and habitat survey protocols for wadeable streams and rivers. Water Bureau: Policy and Procedure, WB-SWAS-051.
Michigan Department of Natural Resources (MDNR). 2025. Fishing stocking database (www2.dnr.state.mi.us/fishstock). Accessed 15 August 2025.
Nislow, K.H., M. Hudy, B.H. Letcher, and E.P. Smith. 2011. Variation in local abundance and species richness of stream fishes in relation to dispersal barriers: implications for management and conservation. Freshwater Biology 56:2135-2144.
Palmer, M.A., E.S. Bernhardt, J.D. Allan, and 19 coauthors. 2005. Standards for ecologically successful river restoration. Journal of Applied Ecology 42:208-217.
Tonello, M. 2021. Status of the Fishery Resource Report. Stony Creek. Michigan Dept. of Natural Resources. Report No. 2021-305.
Warren, Jr., M.L., and M.G. Pardew. 1998. Road crossings as barriers to small-stream fish movement. Transactions of the American Fisheries Society 127:637-644.
Wehrly, K.E., M.J. Wiley, and P.W. Seelbach. 2003. Classifying regional variation in thermal regime based on stream fish community patterns. Transactions of the American Fisheries Society 132:18-38.

Table 1. Catch (total number) and total length (cm, reported as mean; range) of fishes in Stony Creek at two road-stream crossing (Marshville Dam Road and Shelby Road) in Oceana County. Backpack electrofishing surveys were conducted upstream (Up) and downstream (Down) of the road-stream crossing at Marshville Dam Road and upstream of the crossing at Shelby Road. Pre-construction surveys were conducted during July 2022, and post-construction surveys were conducted June 2025.

		Marshville Dam				Shelby		
		Pre-Construction		Post-Construction		Pre-Construction	Post-Construction	
Common Name	Scientific Name[a]	Down	Up	Down	Up	Up	Up	TOTAL
American Brook Lamprey	*Lampetra appendix*	0	0	0	0	0	5 (15.0; 11.6-18.0)	5
Brook Trout	*Salvelinus fontinalis*	0	4 (17.5; 14.7-23.2)	5 (19.1; 16.6-22.2)	0	4 (14.5; 7.6-17.7)	6 (15.9; 11.7-21.7)	19
Brown Trout	*Salmo trutta*	16 (27.2; 15.1-38.4)	9 (24.4; 14.6-35.5)	21 (23.0; 13.9-36.6)	6 (24.6; 14.4-37.5)	10 (22.4; 6.5-31.7)	1 (13.4)	63
Rainbow Trout	*Oncorhynchus mykiss*	9 (18.6; 13.0-24.9)	12 (15.4; 6.3-22.5)	6 (17.1; 13-21.1)	5 (15.6; 14.5-16.4)	8 (18.0; 13.5-26.0)	5 (14.9; 12.7-16.6)	45
Sculpins	*Cottus* spp.	76 (6.0; 2.1-10.5)	103 (5.9; 2.0-11.8)	60 (7.0; 1.5-9.9)	60 (7.8; 1.9-10.7)	97 (5.6; 1.7-9.6)	76 (5.8; 1.6-9.0)	472
Central Mudminnow	*Umbra limi*	0	2 (8.7; 8.2-9.2)	0	0	0	0	2
Pumpkinseed	*Lepomis gibbosus*	1 (4.9)	0	0	0	0	0	1
Rock Bass	*Ambloplites rupestris*	3 (14.0; 11.6-15.6)	0	0	0	0	0	3
	TOTAL	105	130	92	71	119	93	

[a]Names are based on Bailey et al. (2004).

Table 2. Total catch of fish, electrofishing effort, reach length, mean (1 standard deviation) width (n = 5), depth (n = 50), and velocitry (n = 50) in Stony Creek (Marshville Dam Road and Shelby Road). Means and standard deviation were calculated based on 5 transects in a reach and 10 observations of depth and velocity per transect.

Site	Reach	Construction	Catch (no.)	Effort (min)	Reach Length (m)	Width (m)	Depth (m)	Velocity (m/s)
Marshville Dam	Downstream	Pre	105	30.8	91.4	7.67 (0.88)	0.43 (0.21)	0.41 (0.26)
Marshville Dam	Downstream	Post	92	45.0	150.0	7.18 (1.33)	0.46 (0.21)	0.26 (0.22)
Marshville Dam	Upstream	Pre	130	39.4	91.4	8.03 (1.38)	0.51 (0.26)	0.22 (0.14)
Marshville Dam	Upstream	Post	71	45.0	150.0	5.74 (1.01)	0.48 (0.25)	0.32 (0.22)
Shelby	Upstream	Pre	119	40.7	118.2	5.97 (0.45)	0.42 (0.16)	0.28 (0.14)
Shelby	Upstream	Post	93	45.0	150.0	5.70 (0.31)	0.40 (0.18)	0.25 (0.18)

Table 3. Mean (1 standard deviation) of water temperature (Temp), specific conductivity (SPC), dissolved oxygen (DO) concentration and saturation, and turbidity (n =3) in Stony Creek (Marshville Dam Road and Shelby Road). Pre-construction observations were made during July 2022, and post-construction obervations were made during July 2025.

Site	Reach	Construction	Temp (°C)	SPC (µS/cm)	DO (mg/L)	DO (%)	Turbidity (NTU)
Marshville Dam	Downstream	Pre	13.1 (0.03)	442 (0.6)	10.4 (0.13)	99.0 (1.38)	6.7 (0.26)
Marshville Dam	Downstream	Post	13.0 (0.06)	437 (0.3)	11.1 (0.02)	105.2 (0.57)	2.7 (0.62)
Marshville Dam	Upstream	Pre	12.2 (0.01)	451 (0.0)	10.5 (0.12)	97.9 (1.08)	5.2 (1.50)
Marshville Dam	Upstream	Post	13.3 (0.21)	436 (0.4)	11.1 (0.04)	106.6 (0.89)	3.0 (0.92)
Shelby	Upstream	Pre	12.8 (0.02)	450 (0.6)	10.1 (0.10)	95.5 (0.97)	1.8 (0.10)
Shelby	Upstream	Post	11.5 (0.01)	436 (0.4)	9.8 (0.03)	90.0 (0.26)	2.2 (0.66)

Table 4. Current and historical catches of fishes from electrofishing surveys at Marshville Dam Road and Shelby Road on Stony Creek, Oceana County, Michigan.

		Catch at Marshville Dam Road								Catch at Shelby Road							
		1999[b]		2020[c]		2022[d]		2025[d]		1999[e]		2020[f]		2022[d]		2025[d]	
Common Name	Scientific Name[a]	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
American Brook Lamprey	Lampetra appendix	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	5.4
Brook Trout	*Salvelinus fontinalis*	23	48.9	24	7.6	4	1.7	5	3.1	6	42.9	11	8.1	4	3.4	6	6.5
Brown Trout	*Salmo trutta*	4	8.5	20	6.3	25	10.6	27	16.6	3	21.4	14	10.4	10	8.4	1	1.1
Rainbow Trout	*Oncorhynchus mykiss*	19	40.4	20	6.3	21	8.9	11	6.7	4	28.6	42	31.1	8	6.7	5	5.4
Coho Salmon	*Oncorhynchus kisutch*	0	0	1	0.3	0	0	0	0	0	0	3	2.2	0	0	0	0
Central Mudminnow	*Umbra limi*	0	0	3	1.0	2	0.9	0	0	0	0	0	0	0	0	0	0
Sculpins	*Cottus* spp.	0	0	246	78.1	179	76.2	120	73.6	0	0	65	48.1	97	81.5	76	81.7
Rock Bass	*Ambloplites rupestris*	0	0	0	0	3	1.3	0	0	0	0	0	0	0	0	0	0
Pumpkinseed	*Lepomis gibbosus*	1	2.1	0	0	1	0.4	0	0	1	7.1	0	0	0	0	0	0
Goldfish	*Carassius auratus*	0	0	1	0.3	0	0	0	0	0	0	0	0	0	0	0	0
	TOTAL	47		315		235		163		14		135		119		93	

[a]Names based on Bailey et al (2004).

[b]Surveyed a total of 152.9 m upstream of Marshville Dam Road on 20 July 1999 and recorded a water temperature of 13.3°C (O'Neal 1999).

[c]Surveyed a total of 243.8 m upstream of Marshville Dam Road on 27 July 2020 (Tonello 2021).

[d]Present Study.

[e]Surveyed a total of 91.7m upstream of Shelby Road on 4 August 1999 and recorded a water temperature of 11.5°C (O'Neal 1999).

[f]Surveyed a total of 213.4 m upstream of Shelby Road on 16 September 2020 (Tonello 2021).

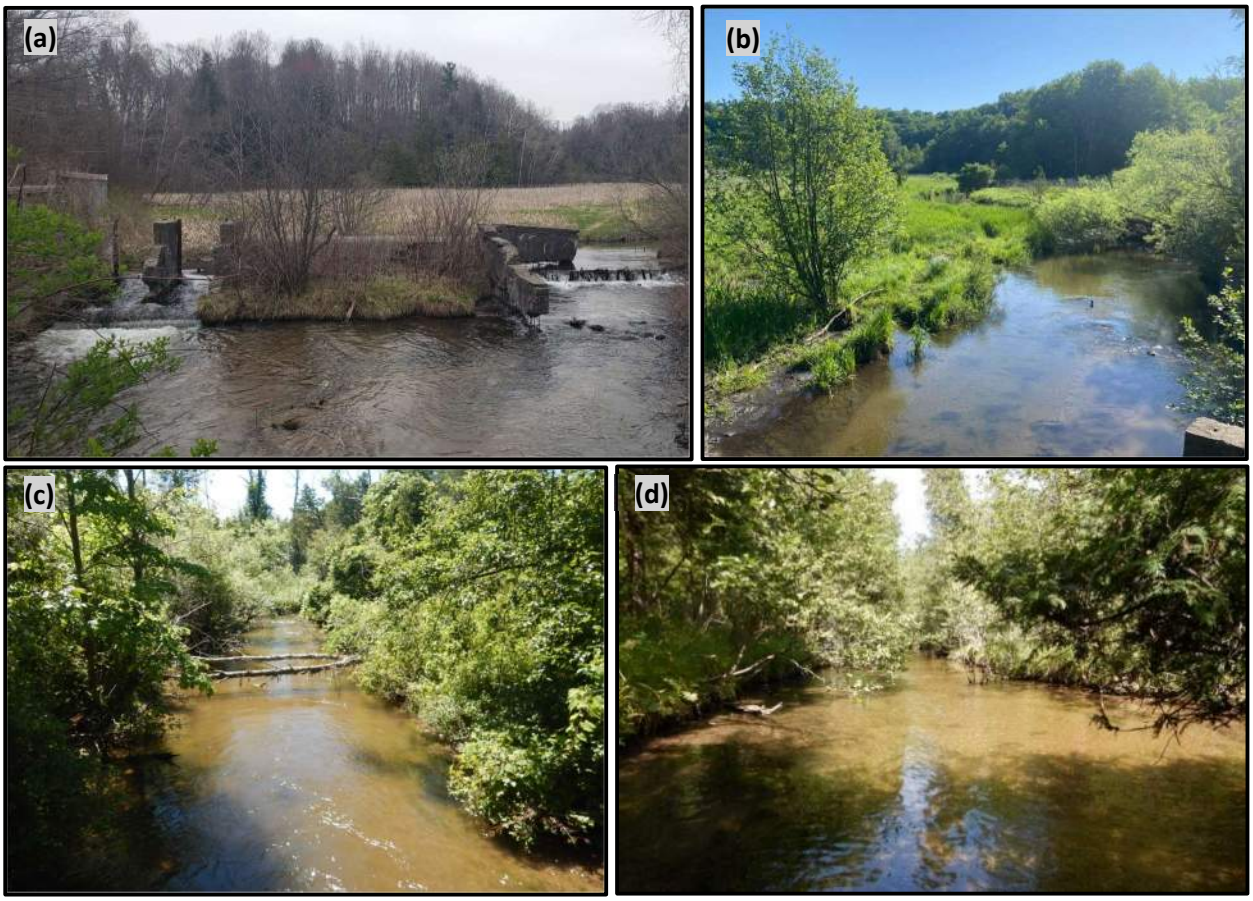


Figure 1. (**a**) Marshville Dam remnant structure (photo taken looking upstream from the road-stream crossing at Marshville Dam Road), (**b**) upstream reach above old dam structure (small portion of dam can be seen in lower-right of picture), (**c**) downstream reach at Marshville Dam Road (photo taken looking downstream from old bridge structure), (**d**) upstream reach at Shelby Road (Oceana County, Michigan). Photos taken on: (**a**) 5 May 2022, (**b**) 3 June 2022, (**c**) 25 July 2022, and (**d**) 26 July 2022, where the letter corresponds to the picture.

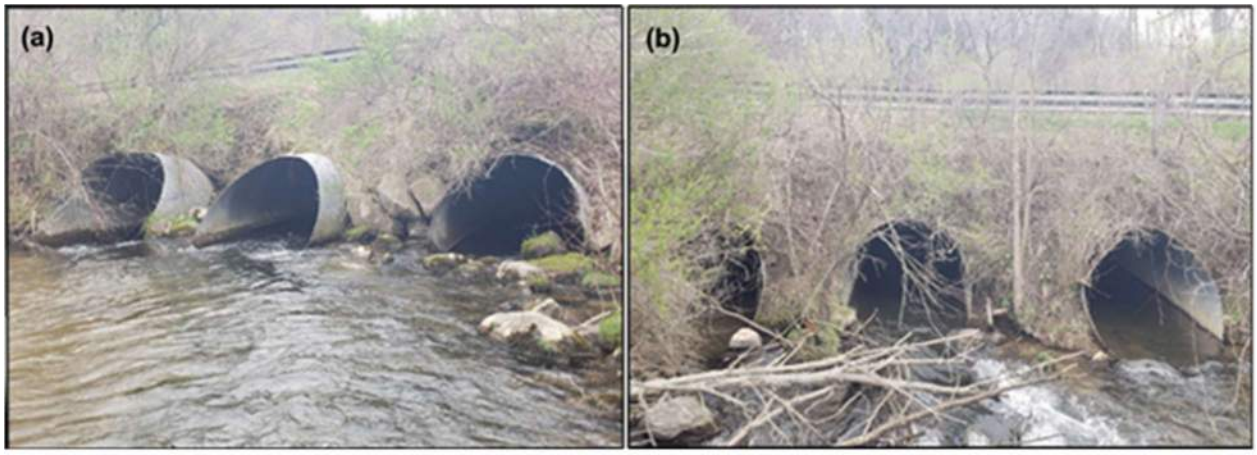
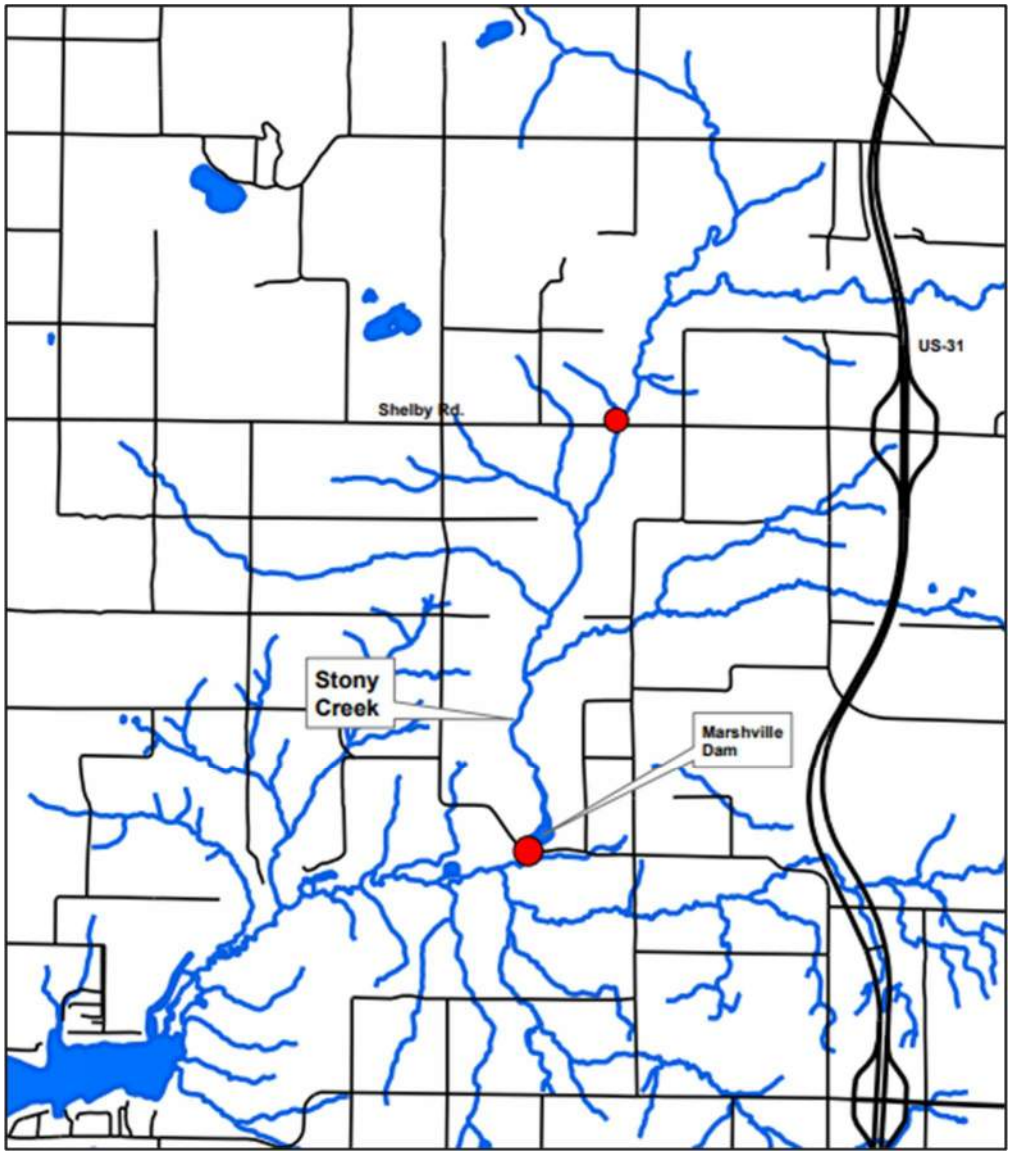


Figure 2. The (**a**) upstream and (**b**) downstream views of three culverts in Stony Creek at Marshville Dam Road (Oceana County, Michigan). Photos taken on 5 May 2022.

Figure 3. (**a**) The bridge that replaced the culverts at the road-stream crossing at Marshville Dam Road and Stony Creek (Oceana County). (**b**) Upstream view from Marshville Dam Road, including new observation deck/fish access along Stony Creek at Marshville Dam County Park. (**c**) Upstream view from observation deck at Marshville Dam County Park; view of historic mill pond. Photos taken on 13 June 2025.



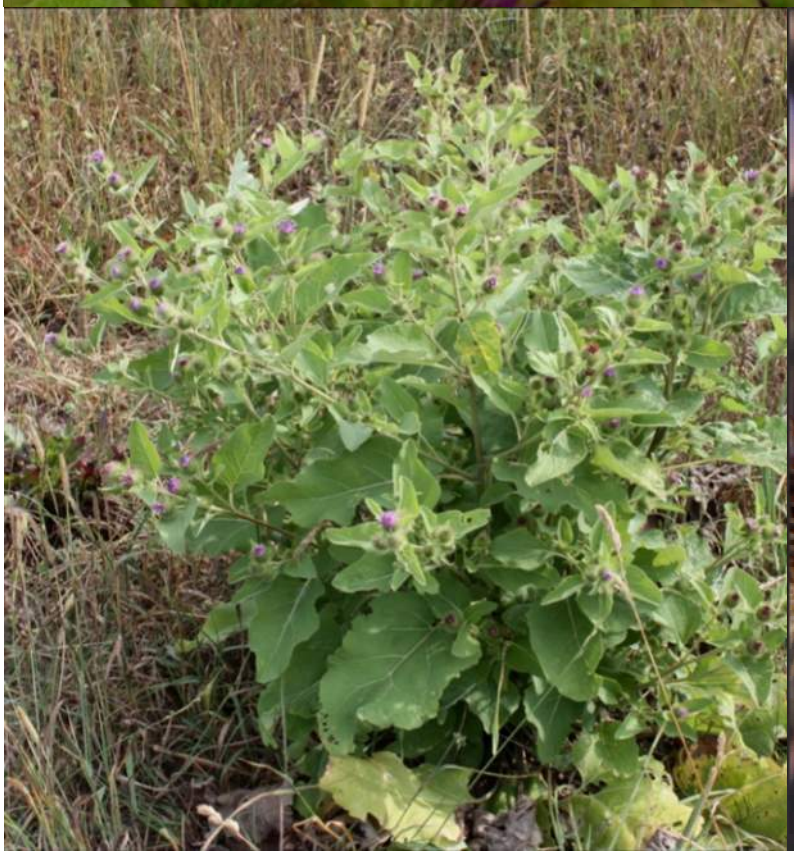
Appendix A. Map of sampling sites (represented by red circles) located at road-stream crossings at Marshville Dam Road and Shelby Road on Stony Creek, Oceana County, Michigan.

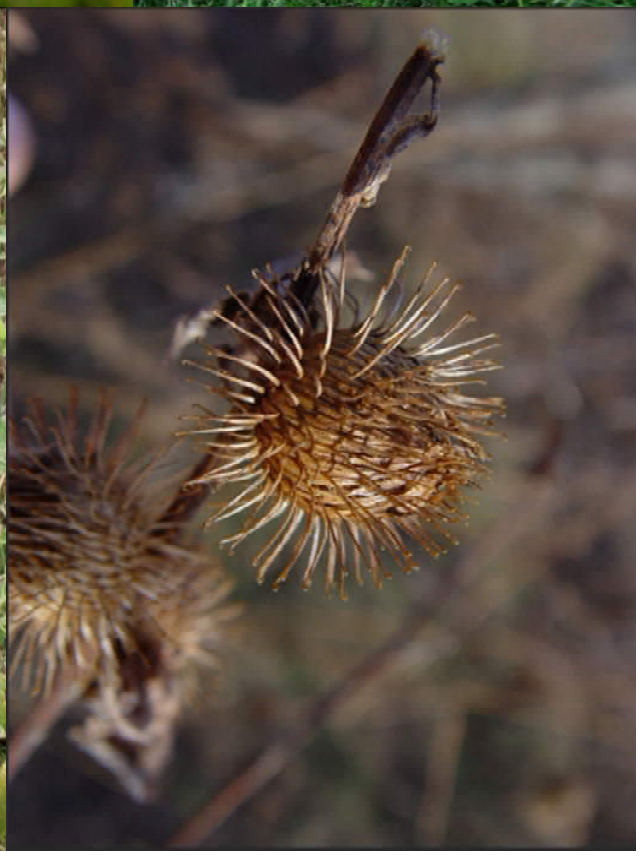
Appendix B. Latitude (°) and longitude (°) for the upstream and downstream terminus of each sampling reach at two sites in Stony Creek (Oceana County, Michigan).

			Downstream Terminus		Upstream Terminus	
Site	Reach	Construction	Latitude (N)	Longitude (W)	Latitude (N)	Longitude (W)
Marshville Dam Road	Downstream	Pre	43.57656	86.42970	43.57730	86.42937
Marshville Dam Road	Downstream	Post	43.57660	86.42977	43.57729	86.42937
Marshville Dam Road	Upstream	Pre	43.57805	86.42941	43.57805	86.42854
Marshville Dam Road	Upstream	Post	43.57748	86.42940	43.57809	86.42815
Shelby Road	Upstream	Pre	43.60996	86.41966	43.61088	86.41911
Shelby Road	Upstream	Post	43.60986	86.41975	43.60163	86.41944

Appendix D Representative Photos of Invasive Plant Species

Garlic mustard (*Alliaria petiolata*)





Common burdock (*Arctium minus*)

Spotted knapweed (*Centaurea stoebe)*

Bull thistle (*Cirsium vulgare*)

GEI Consultants

Geotechnical
Environmental
Water Resources
Engineering

Invasive Species Photographs

Bittersweet (*Celastrus orbiculatus*)

Japanese knotweed (*Fallopia japonica*)

Honeysuckle (*Lonicera spp)*

Birdsfoot trefoil (*Lotus corniculatus*)

Purple loosestrife (*Lythrum salicaria*)

White Sweet Clover (*Melilotus alba)*

Reed canary grass (*Phalaris arundinacea*)

GEI Consultants

Geotechnical
Environmental
Water Resources
Engineering

Invasive Species Photographs

Common reed (*Phragmites australis var. australis*)

GEI Consultants

Geotechnical
Environmental
Water Resources
Engineering

Invasive Species Photographs

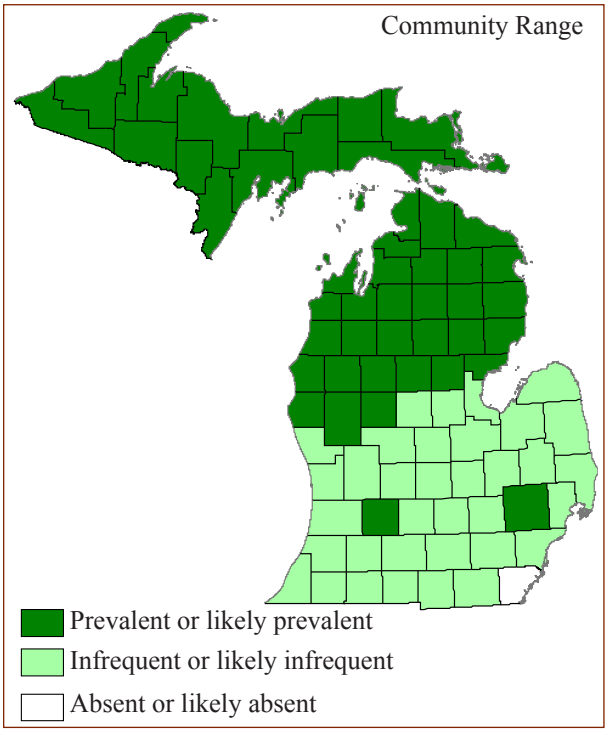
Black locust (*Robinia pseudoacacia*)

Narrow-leaved cattail (*Typha angustifolia*) / Cattail hybrid (*Typha x glauca*)

Appendix E Natural Community Abstracts

Hardwood-Conifer Swamp — Community Abstract

Photo by Joshua G. Cohen



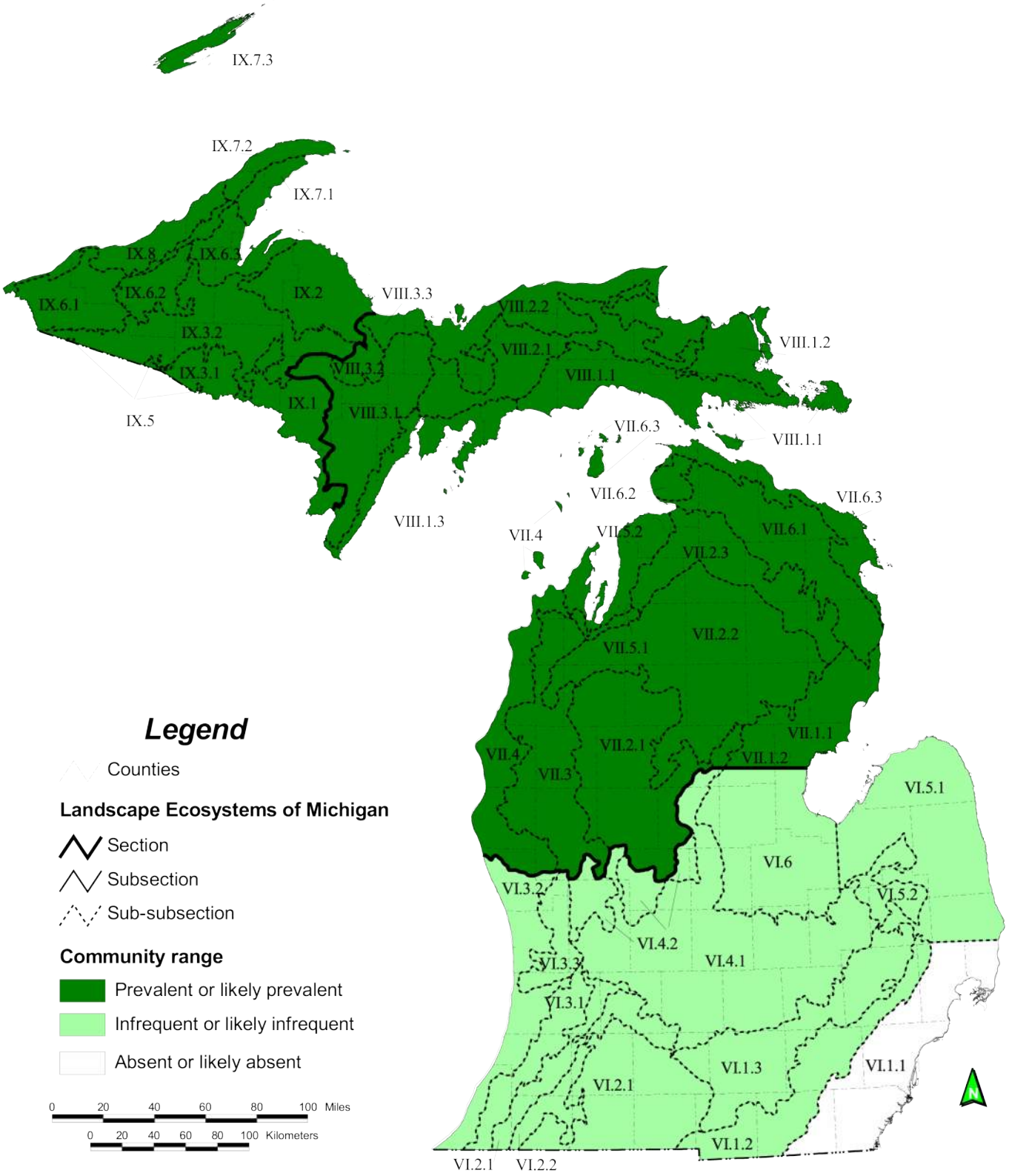
Overview: Hardwood-conifer swamp is a minerotrophic forested wetland dominated by a mixture of lowland hardwoods and conifers, occurring on organic soils and poorly drained mineral soils throughout Michigan. The community occurs on a variety of landforms, often associated with headwater streams and areas of groundwater discharge. Species composition and dominance patterns vary regionally. Windthrow and fluctuating water levels are the primary natural disturbances that structure hardwood-conifer swamp.

Global and State Rank: G4/S3

Range: Forested wetlands dominated by a mixture of hardwoods and conifers occur throughout the upper Great Lakes region, northeastern United States, and adjacent Canadian provinces (Faber-Langendoen 2001, NatureServe 2006). Species composition and dominance patterns vary across this range, which includes Minnesota, Wisconsin, Michigan, Ontario, Ohio, Pennsylvania, New Jersey, New York, Connecticut, Rhode Island, Massachusetts, Vermont, New Hampshire, Maine, New Brunswick, and Nova Scotia. In Michigan, hardwood-conifer swamp is widespread north of the climatic tension zone, with occurrences in southern Lower Michigan limited to areas within the regionally local ranges of white pine, hemlock, and northern white-cedar (Voss 1972, MNFI Biotics Database 2007).

Rank Justification: The acreage of hardwood-conifer swamp present in Michigan at the time of European settlement is difficult to determine. Analysis of General Land Office (GLO) survey notes in Michigan reveals that lowland forest dominated by a mixture of conifers and hardwoods covered approximately 290,000 acres (115,000 ha) circa 1800. Because the dominant trees in these mixed stands varied, only a fraction of this acreage likely represented hardwood-conifer swamp as it is currently defined (Kost et al. 2007). Hemlock- and white pine-dominated lowland forests, which are considered variants of hardwood-conifer swamp, covered an additional 60,000 ac (24,000 ha) and 5,000 ac (2,200 ha), respectively. The total acreage covered by mixed conifers and hardwood-, hemlock-, and white pine-dominated lowland forests (350,000 ac, or 140,000 ha) is a small fraction of the 5,600,000 ac (2,300,000 ha) covered by the broad category of conifer-dominated lowland forest circa 1800. The majority of conifer-dominated lowland forest was comprised of mixed conifers (3,000,000 ac, or 1,200,000 ha) and northern white-cedar (1,300,000 ac, or 510,000 ha), rather than the white pine, hemlock, and mixed conifer and hardwood stands characteristic of hardwood-conifer swamp. A small portion of acreage comprised of mixed

Michigan Natural Features Inventory
P.O. Box 30444 - Lansing, MI 48909-7944
Phone: 517-373-1552



Ecoregional map of Michigan (Albert 1995) depicting distribution of hardwood-conifer swamp (Albert et al. 2008)

conifers and northern white-cedar may have represented hardwood-conifer swamp, but most of this acreage likely represented other natural community types (e.g., rich conifer swamp). Historically, hardwood-conifer swamp covered less acreage than rich conifer swamp and other forested peatlands because it is typically confined to ecotones bordering uplands and more extensive wetland systems, or areas around headwater streams where groundwater seepage, rather than over-the-bank flooding, controls vegetative composition and structure.

MIRIS data (MIRIS 1978) indicated approximately 1,800,000 ac (700,000 ha) of lowland coniferous forest and about 2,300,000 ac (900,000 ha) of lowland deciduous forest occurred in Michigan as of the 1970s. The percentage of this acreage representing hardwood-conifer swamp is unknown. The current status of hardwood-conifer swamp is poorly understood because this system has not been systematically surveyed in Michigan. Currently, 30 occurrences of hardwood-conifer swamp are tracked in the MNFI statewide database, totaling over 7,000 ac (2,800 ha) (MNFI, Biotics Database 2007). Only 11 of these occurrences are estimated to be of excellent (A-rank) or good (B-rank) viability.

Following European settlement, hardwood-conifer swamp was significantly impacted by logging activities, including removal of mature seed trees, increased exposure and drying of soil, and slash fires. These disturbances resulted in a significant decline in lowland conifers, including northern white-cedar, white pine, and hemlock, throughout the region (Whitney 1987, Zhang et al. 2000, Leahy and Pregitzer 2003). In one 300,000 ac (120,000 ha) section of the Huron National Forest in northeastern Lower Michigan, for example, lowland conifers have declined to 26% of their former extent (Leahy and Pregitzer 2003). In southern Lower Michigan, where conifers characteristic of hardwood-conifer swamp were local or absent in upland communities, logging and removal of mature seed-producing trees likely eliminated seed sources and contributed to the conversion of hardwood-conifer swamp to southern hardwood swamp (Comer et al. 1995). In addition, because seedlings of conifers and yellow birch regenerate primarily on large-diameter rotting wood, such as well-decomposed logs and stumps, the removal of mature trees resulted in a reduction in suitable niches for seedling establishment (St. Hilaire and Leopold 1995, McGee 2001, Forrester et al. 2005). Following removal of conifers, shading and litterfall by hardwood species may have reduced diversity of ground layer vegetation and the suitability of the seedbed for conifer seedlings (Laidig and Zampanella 1999, Kost 2001a, 2001b). Current logging practices continue to degrade hardwood-conifer swamp throughout its range (MNFI Biotics Database 2007).

In addition to historic and recent logging pressures, acreage of hardwood-conifer swamp has been reduced by conversion of wetlands for agriculture and other human uses. Wetland acreage in Michigan is estimated to have been reduced by greater than 50% since the beginning of European settlement (Dahl 1990). The shallow organic or poorly drained mineral soils supporting hardwood-conifer swamp were easier to convert for agricultural purposes than the deep peats characteristic of rich conifer swamp and other forested peatlands, resulting in a significant reduction of hardwood-conifer swamp acreage following European settlement. Several tracked occurrences of hardwood-conifer swamp show evidence of hydrologic disturbance, including ditching and the conversion of adjacent uplands for agricultural or residential uses (MNFI Biotics Database 2007).

At the present time, excessive deer herbivory threatens the viability of hardwood-conifer swamp throughout its range. High white-tailed deer (*Odocoileus virginianus*) density is leading to considerable browse pressure on conifer seedlings and saplings throughout Michigan and the Great Lakes region (Frelich and Lorimer 1985, Mladenoff and Stearns 1993, Alverson and Waller 1997, Long et al. 1998, Rooney and Waller 1998, Rooney et al. 2002, Krueger and Peterson 2006). Deer browse also reduces frequency and cover of understory shrubs and herbs (Balgooyen and Waller 1995, Augustine and Frelich 1998, Rooney and Waller 2003, Kraft et al. 2004). The result of heavy deer browse is significant alteration of community structure consisting of impacts to all vegetative strata.

Physiographic Context: The Michigan range of hardwood-conifer swamp is statewide, falling within the following regions classified by Albert et al. (1986) and Albert (1995): Region I, Southern Lower Michigan (concentrated in the interlobate regions and near Lake Michigan), Region II, Northern Lower Michigan, Region III, Eastern Upper Michigan, and

Region IV, Western Upper Michigan. This broad area is characterized by a cool snow-forest climate with warm summers. The daily maximum temperature in July ranges from 24 to 29 °C (75 to 85 °F), the daily minimum temperature in January ranges from –21 to –9 °C (-5 to 15 °F) and the mean annual temperature is 7 °C (45 °F). The mean number of freeze-free days is between 90 and 160, and the average number of days per year with snow cover of 2.5 cm or more is between 80 and 140. The normal annual total precipitation ranges from 740 to 900 mm with a mean of 823 mm (Albert et al. 1986, Barnes 1991). The impacts of hardwood-conifer swamp on local climate are poorly known, but seasonal temperature fluctuations likely vary less in hardwood-conifer swamp relative to the surrounding landscape due to local moss cover and groundwater input (see Curtis 1959 for discussion). Moderation of climatic extremes is better understood for bog and fen peatlands with high moss cover (Heinselman 1963, McKenzie et al. 2007).

Hardwood-conifer swamp occurs on a variety of landforms, including poorly-drained outwash channels and outwash plains and depressions on medium- to coarse-textured end moraines, ground moraines, and glacial lakeplains (Kost et al. 2007). The community occupies sites influenced by groundwater seepage, usually where the water table is at or near the soil surface. Hardwood-conifer swamp occurs on gently sloping to flat topography along headwater streams or in association with relatively inactive portions of floodplains of low order streams, where it forms back swamps or occurs in meander scars (Tepley et al. 2004). Shallow kettle depressions and the margins of large forested and non-forested peatlands may also support hardwood-conifer swamp, but the community is absent from areas where significant peat accumulation isolates the rooting zone from contact with mineral-rich groundwater. Occurrences of hardwood-conifer swamp are typically narrow (<500 m, or 1,600 ft, wide), occupying outwash channels along streams and following slope contours. Large occurrences (to >250 ac, or 100 ha) are often associated with branched stream channels (MNFI Biotics Database 2007).

Hardwood-conifer swamp is bordered by a variety of natural community types. Adjacent uplands support either fire-prone systems, including oak barrens, oak openings (historically), dry-mesic southern forest, dry southern forest, dry-mesic northern forest, dry northern forest, and oak-pine barrens, or gap-phase systems, such as mesic southern forest and mesic northern forest. A variety of open to forested wetland communities may occur in adjacent lowlands, including southern wet meadow, northern wet meadow, prairie fen, northern fen, poor fen, bog, muskeg, interdunal wetland, southern shrub-carr, northern shrub thicket, southern hardwood swamp, northern hardwood swamp, rich tamarack swamp, and rich conifer swamp.

Photo by Bradford S. Slaughter

Hardwood-conifer swamp is often associated with headwater streams.

Substrate conditions are heterogeneous, and are often highly variable within a single stand. The most common condition is a thin layer of organic soil over a poorly drained mineral substrate. Organic soils are typically saturated, highly decomposed, sapric peat (i.e., muck) and frequently contain pieces of coarse wood throughout their profiles. Areas of deep (>1 m) organic deposits are common, especially in seeps. Substrate pH is also highly variable. Saturated mucks are typically of circumneutral pH, but may be acidic near the surface, especially where associated with sphagnum mosses or where coniferous needle mats accumulate. Mineral soils are often acidic. Vegetation (living and dead), depth to the water table, and groundwater movement all influence substrate alkalinity.

Natural Processes: The primary natural processes structuring hardwood-conifer swamp are small-scale windthrow and dynamics of surface water and groundwater. Patchy windthrow is the dominant natural

disturbance, creating small-scale canopy gaps (Forrester et al. 2005). Hardwood-conifer swamp often occurs on structurally weak organic soils where trees root shallowly due to anaerobic conditions and are thus particularly susceptible to windthrow. Accumulation of ice and snow in tree crowns increases the likelihood of windthrow or trunk snap, particularly for trees weakened by pests or fungal pathogens (Christensen et al. 1959). In addition to toppling and snapping trees, wind may also tip trees rooted in unstable organic soils, which produces the pit-and-mound microtopography characteristic of many forested systems (Christensen et al. 1959). Tipping is responsible for the occurrence of northern white-cedars with upward-curving boles.

Photo by Bradford S. Slaughter

Tipping associated with windthrow produces the pit-and-mound topography characteristic of hardwood-conifer swamp.

Those boles in contact with the substrate can produce vertically-growing branches that eventually form a straight line of stems, a process characteristic of cedar-dominated swamps (i.e., rich conifer swamp) called layering (Christensen et al. 1959). Plot data collected by the Minnesota Department of Natural Resources (2003) indicate curved trees are less common on firmer substrates, including mucky mineral soil or shallow peat over mineral soil, substrates that often support hardwood-conifer swamp in Michigan. Nevertheless, small-scale windthrow shapes the structure of hardwood-conifer swamp through the combined effects of tipping and snapping of its canopy trees, and this impact varies based on substrate characteristics and tree species composition.

The creation of canopy gaps and associated microtopographic heterogeneity has important consequences for the establishment and recruitment of canopy trees. Seedlings of several characteristic hardwood-conifer swamp canopy species (e.g., yellow birch, white pine, northern white-cedar, and hemlock) preferentially germinate and establish on root hummocks and/or decaying logs versus muck or litter-covered depressions (i.e., hollows) (Holcombe 1976, St. Hilaire and Leopold 1995, Rooney and Waller 1998, Allison and Ehrenfeld 1999, McGee 2001, Rooney et al. 2002). In comparison to hollows, hummocks and decaying logs have high moss cover, high moisture content, coarse substrate texture, and stable hydrology, characteristics which may favor the germination and establishment of small seeds with low nutrient reserves (Coffman 1978, St. Hilaire and Leopold 1995, McGee 2001). The degree to which hummocks differ from hollows varies depending on moss cover. Ehrenfeld (1995) found that sphagnum-covered hummocks had similar moisture content to hollows, possibly due to strong hydraulic conductivity within surficial sphagnum peat and the living mat itself. Litter-covered hummocks, in contrast, were significantly drier than hollows, and were prone to seasonal drought, leading to dessication and mortality of conifer seedlings. Studies in the Great Lakes region have illustrated a strong association of northern white-cedar and hemlock seedlings with rotting wood versus raised mounds, which may be due to differences in moss cover and the ability of rotting wood to remain moist during periods of drought (Rooney and Waller 1998, Rooney et al. 2002). Hardwood-conifer swamp tends to occur on shallow peats and mucks or poorly drained mineral soils, where conditions are not conducive to the development of a continuous moss layer, unlike the deep peats that support moss cover characteristic of rich conifer swamp (Kost 2002). Relatively low moss cover may be one factor that favors greater representation of large-seeded hardwoods in hardwood-conifer swamp versus moss-covered forested peatlands of northern white-cedar, tamarack, balsam fir, and black spruce.

Although hummocks and decaying logs are important sites for the germination and establishment of tree seedlings, these sites do not necessarily increase long-term tree survival (St. Hilaire and Leopold 1995, Rooney and Waller 1998, Rooney et al. 2002). Recruitment to the subcanopy and canopy is related to stand-scale factors, including the distribution

and size of canopy openings, and may require the establishment of mycorrhizal connections by seedlings (Rooney and Waller 1998, McGee 2001, Webster and Lorimer 2005). Canopy composition may exert a strong control on seedling recruitment. Shading and litterfall associated with hardwood-dominated canopies may reduce the suitability of the seedbed for conifer seedlings, and may reduce diversity of ground layer vegetation (Laidig and Zampanella 1999, Kost 2001a, 2001b, Simard et al. 2003). Accumulation of conifer needle litter also appears to negatively impact conifer regeneration (Simard et al. 2003). Ascertaining the relative impact of hardwood litter versus conifer litter on conifer regeneration requires additional study, but the greater surface area of hardwood leaves, in addition to complete annual turnover, suggests hardwood litter may have a more significant negative impact on conifer establishment. Despite the relatively narrow range of conditions suitable for conifer germination and establishment, replacement of wetland conifers by hardwoods may take centuries in the absence of large-scale disturbances (Zampanella et al. 1999).

The creation of canopy gaps and complex microtopography also has important impacts on ground layer diversity. Anderson and Leopold (2002) found that the degree of microtopographic variability and wetness beneath canopy gaps had more significant impacts than light variability on plant species richness. Wetland obligates (i.e., species that occur in wetlands with >99% probability) were concentrated in gaps (defined in their study as visible canopy openings), whereas hummock-dwelling species of broader ecological amplitude (i.e., species not restricted to wetlands) were concentrated in non-gaps. Paratley and Fahey (1986) noted a tendency for ground layer species to favor either mounds or depressions, and found that species richness was positively correlated with microtopographic variability, high base status (i.e., concentration of base cations, including calcium and magnesium), and magnitude of water table drawdown. The development of microsite preferences in ground layer herbs typical of hardwood-conifer swamp can be explained by the variation in substrate moisture and texture between mounds (including decaying wood) and depressions. In sum, the canopy gaps that result from windthrow promote high species diversity by increasing light availability, creating tip-up mounds, coarse woody debris, and hollows that increase microsite heterogeneity. Canopy gaps generate spatial variability in depth to the water table and seasonal periods of inundation, resulting in fine-scale spatial, seasonal, and temporal gradients in soil chemistry (Paratley and Fahey 1986, Anderson and Leopold 2002).

Photo by Bradford S. Slaughter

Windthrow is responsible for the patchy canopy characteristic of hardwood-conifer swamp. Increased light and soil moisture associated with gaps enhances plant species richness and diversity.

Although small-scale windthrow is the dominant natural process shaping hardwood-conifer swamp, stand-replacing windthrow is rare in conifer-dominated lowland forests. Estimates of return intervals range from 365 years in Minnesota to >1000 years in northern Lower Michigan (Whitney 1986, Minnesota Department of Natural Resources 2003).

Groundwater and surface water dynamics also shape hardwood-conifer swamp structure and impact succession. Significant hydrological processes impacting hardwood-conifer swamp include groundwater seepage, water table fluctuation, seasonal inundation, and flooding events. Groundwater seepage typically occurs at hydrologic breaks, such as where outwash channels bisect moraines (Amon et al. 2002). Seepages also occur away from slopes, where groundwater moves upward through breaches in otherwise impermeable deposits underlying the wetland (Amon et al. 2002). Groundwater seepages are often rich in calcium and magnesium carbonates and have high pH values, resulting from movement of groundwater through base-rich glacial deposits. In addition, water levels are more stable in groundwater seeps than in other wetland zones, in part due to the presence of most seeps at the bases of slopes that do not collect surface water (Amon et al. 2002, Bedford and

Godwin 2003). Several vascular and non-vascular plant species are concentrated in groundwater seepage zones, including many calciphiles, and add to the diversity of wetland systems (Amon et al. 2002, Bedford and Godwin 2003, Bowles et al. 2005). However, groundwater seepages and associated concentrations of calciphilic species are less characteristic of hardwood-conifer swamp than rich conifer swamp and fen communities (Faber-Langendoen 2001, Kost 2001a, 2001b, 2002, NatureServe 2006, Kost et al. 2007).

Water table fluctuation, including seasonal inundation, is characteristic outside the immediate vicinity of groundwater seepages in hardwood-conifer swamp (Paratley and Fahey 1998, Anderson and Leopold 2002). As noted above, water table fluctuation interacts with canopy gap size, such that mid- and large-sized gaps may flood quickly during rain events, presumably due to the lack of canopy to intercept precipitation and lack of transpiration by large trees (Anderson and Leopold 2002). These wet gaps create microheterogeneity within hardwood-conifer swamp that results in increased diversity of vascular plant species, including many species otherwise characteristic of open wetland types (Anderson and Leopold 2002).

Beaver flooding can also shape hardwood-conifer swamp structure and direct successional pathways. Natural community surveys in Newaygo and Luce Counties found both inactive and active beaver dams and associated flooding in several forested wetlands, including hardwood-conifer swamp (MNFI Biotics Database 2007, Slaughter et al. 2007). The areas that were inundated were typically closest to the stream or lake and lowest in elevation. Stands of dead northern white-cedar and/or tamarack were characteristic of inundated zones. Wetland margins and elevated areas within the wetlands dominated by white pine, hemlock, and hardwoods were less significantly impacted. Following beaver flooding, graminoid-dominated communities develop and sometimes persist for several decades, resisting conifer invasion (Terwilliger and Pastor 1999). In addition, the graminoid-covered substrate favors establishment of red maple, black ash, and alder (Allison and Ehrenfeld 1999), which may drive succession towards hardwood dominance or towards conversion to northern shrub thicket. The impacts of beaver on hardwood-conifer swamp succession require further study, but the primary forested communities affected by beaver dam construction are likely low-lying peatlands immediately adjacent to streams and lakes (e.g., rich conifer swamp and poor conifer swamp).

Photo by Bradford S. Slaughter

Beaver disturb hardwood-conifer swamp through dam-building activities that can flood low-lying tracts and promote shrubs and graminoids.

Changes in drainage patterns due to peat accumulation, growth of vegetation, erosion, or other disturbances can also drive succession and result in site heterogeneity, rather than uniform climax forest, over time (Paratley and Fahey 1986, Futyma and Miller 2001). The effects of watershed-scale hydrologic disturbances on forested wetlands are less well understood, and may be outweighed, at least over short time periods, by finer-scale disturbances affecting local hydrology (Laidig and Zampanella 1999).

Fire is another natural disturbance that shapes hardwood-conifer swamp. In northern Lower Michigan, Cleland et al. (2004) found historic fire rotations of 120 years for wetlands adjacent to fire-prone uplands (generally, oak- and upland conifer-dominated systems), and 684 years for wetlands adjacent to northern hardwoods. Wetlands in both landscapes were dominated by tamarack, hemlock, spruce, and balsam fir, but wetlands occurring in fire-prone landscapes had an increased proportion of fire-dependent species (e.g., pine, white birch, aspen, and oak) and very low proportions of fire-intolerant hardwoods (e.g., sugar maple, beech, elm, and basswood) (Cleland et al. 2004). Acreage of lowland hardwood-conifer cover in northern Lower Michigan at the present time is roughly split between the two fire regimes described by Cleland

et al. (2004). Despite the shorter fire return interval for forested wetlands adjacent to fire-prone uplands, broad-scale, stand-replacing fires appear to have been infrequent. For example, Whitney (1986) estimated a return interval of 3,000 years for destructive crown fires in conifer-dominated swamps in north-central Lower Michigan.

In the Great Lakes region, high densities of northern white-cedar and hemlock seedlings have been recorded on burned organic and mineral soils, often following slash fires (Curtis 1959, Rooney and Waller 1998, Rooney et al. 2002). In addition, the wind-borne samaras of red maple make it a successful invader of burned, open substrate (Allison and Ehrenfeld 1999). The relative contribution of fire to hardwood-conifer swamp structure and succession is unknown, but fire appears to provide suitable sites for the establishment of new cohorts of several canopy dominants, and may shape regional variation of structure and vegetative composition by selecting for fire-dependent canopy species and against fire-intolerant northern hardwoods and conifers (Cleland et al. 2004).

Vegetation Description: Hardwood-conifer swamp is a broadly defined natural community type, encompassing several regional, edaphic, and physiographic variants. Several vegetative associations are included within this type and are described below. In general, stands classified to this type contain at least 25% coniferous cover or basal area. Hardwoods range from dominant to uncommon or locally absent. Canopy, subcanopy, and ground layer density vary depending on species composition and local disturbance history. Throughout its range, hardwood-conifer swamp is characterized by high diversity, which can be attributed to its complex microtopography, spatially and temporally variable water table, and patchy canopy (Paratley and Fahey 1986, Vivian-Smith 1997, Anderson and Leopold 2002). The species listed below are derived from hardwood-conifer swamp occurrences tracked by MNFI (Biotics Database 2007), in addition to Curtis (1959), Brewer (1966), Voss (1972, 1985, 1996), Faber-Langendoen (2001), and NatureServe (2006). Although hardwood-conifer swamp occurs with greater frequency north of the climatic tension zone, the vegetation of occurrences south of the climatic tension zone is described first. Examples of hardwood-conifer swamp in southern Lower Michigan exhibit strong similarities in vegetative structure and composition due to the presence of only three characteristic conifers (white pine, northern white-cedar, and tamarack) in this region.

Southern Lower Michigan: In southern Lower Michigan, canopy dominance is often by red maple (*Acer rubrum*) and black ash (*Fraxinus nigra*), occasionally with high importance of yellow birch (*Betula alleghaniensis*) and white pine (*Pinus strobus*). Canopy associates include basswood (*Tilia americana*), northern white-cedar (*Thuja occidentalis*), tamarack (*Larix laricina*), and, locally, hemlock (*Tsuga canadensis*) and tulip-tree (*Liriodendron tulipifera*). Northern white-cedar often occurs in southern Lower Michigan as small patches within larger tamarack- or hardwood-dominated forested wetlands (Thompson 1953, Wenger 1975, Comer et al. 1995, Kost 2001a, Kost 2002, Slaughter and Skean 2003). Stands of significant size and of strong (>75%) northern white-cedar dominance are classified as a southern variant of rich conifer swamp (Kost 2002). Tree species typical of upland forests [e.g., red oak (*Quercus rubra*)] are sometimes present in the canopy, but are more commonly present as seedlings. American elm (*Ulmus americana*) was an important canopy tree prior to the introduction and spread of elm blight, but is now primarily an understory species, where it associates with saplings of the canopy species (Barnes 1976).

The tall shrub layer is characterized by blue-beech (*Carpinus caroliniana*), spicebush (*Lindera benzoin*), juneberries (*Amelanchier* spp.), red-osier dogwood (*Cornus stolonifera*), gray dogwood (*C. foemina*), silky dogwood (*C. amomum*), smooth highbush blueberry (*Vaccinium corymbosum*), poison sumac (*Toxicodendron vernix*), hazelnut (*Corylus americana*), Michigan holly (*Ilex verticillata*), red-berried elder (*Sambucus racemosa*), elderberry (*S. canadensis*), nannyberry (*Viburnum lentago*), wild-raisin (*V. cassinoides*), prickly-ash (*Zanthoxylum americanum*), witch-hazel (*Hamamelis virginiana*), Bebb's willow (*Salix bebbiana*), hoary willow (*S. candida*), pussy willow (*S. discolor*), slender willow (*S. petiolaris*), and autumn willow (*S. serissima*). Canada yew (*Taxus canadensis*) was once an important component of the hardwood-conifer swamp understory, but its populations have been significantly reduced and locally extirpated through deer browsing. Low shrubs include alder-leaved buckthorn (*Rhamnus alnifolia*), Canada fly honeysuckle (*Lonicera canadensis*), wild black currant (*Ribes americanum*), prickly gooseberry (*R. cynosbati*), and swamp gooseberry (*R. hirtellum*).

The ground layer, which is dense in light gaps and sparse under the shade of conifers, is characterized by the development of moss and litter-covered hummocks, interspersed with areas of level, saturated or inundated depressions. Characteristic species of hummocks and decomposing wood include wild sarsaparilla (*Aralia nudicaulis*), lady fern (*Athyrium filix-femina*), long-awned wood grass (*Brachyelytrum erectum*), goldthread (*Coptis trifolia*), crested woodfern (*Dryopteris cristata*), intermediate woodfern (*D. intermedia*), Canada mayflower (*Maianthemum canadense*), partridge berry (*Mitchella repens*), bishop's-cap (*Mitella diphylla*), naked miterwort (*Mitella nuda*), and starflower (*Trientalis borealis*). Typical species of depressions include jack-in-the-pulpit (*Arisaema triphyllum*), side-flowering aster (*Aster lateriflorus*), beggar-ticks (*Bidens* spp.), marsh marigold (*Caltha palustris*), wood reedgrass (*Cinna arundinacea*), small enchanter's-nightshade (*Circaea alpina*), honewort (*Cryptotaenia canadensis*), water horsetail (*Equisetum fluviatile*), common horsetail (*E. hyemale*), woodland horsetail (*E. sylvaticum*), purple avens (*Geum rivale*), fowl manna grass (*Glyceria striata*), spotted touch-me-not (*Impatiens capensis*), northern bugleweed (*Lycopus uniflorus*), sensitive fern (*Onoclea sensibilis*), cinnamon fern (*Osmunda cinnamomea*), royal fern (*O. regalis*), dwarf raspberry (*Rubus pubescens*), golden ragwort (*Senecio aureus*), rough goldenrod (*Solidago rugosa*), and skunk-cabbage (*Symplocarpus foetidus*), the last species a frequent ground layer dominant. Sedges are well-represented in hardwood-conifer swamp, including *Carex bromoides*, *C. crinita*, *C. disperma*, *C. gracillima*, *C. hystericina*, *C. intumescens*, *C. lacustris*, *C. lupulina*, and *C. stricta*. Species richness is generally higher in canopy gaps, where higher water tables support many wetland obligates that are absent or rare in non-gaps (Paratley and Fahey 1986, Anderson and Leopold 2002). Large canopy gaps support species typical of open wetlands and may be grass- or sedge-dominated. Species typical of large canopy gaps include swamp milkweed (*Asclepias incarnata*), bluejoint grass (*Calamagrostis canadensis*), sedges, turtlehead (*Chelone glabra*), swamp thistle (*Cirsium muticum*), joe-pye-weed (*Eupatorium maculatum*), boneset (*E. perfoliatum*), cut grass (*Leersia oryzoides*), white grass (*L. virginica*), arrow-leaved tear-thumb (*Polygonum sagittatum*), mad-dog skullcap (*Scutellaria lateriflora*), common skullcap (*S. galericulata*), common water horehound (*Lycopus americanus*), and broad-leaved cat-tail (*Typha latifolia*). Twining herbs and woody vines are also a common feature of canopy gaps, represented most commonly by hog peanut (*Amphicarpaea bracteata*), groundnut (*Apios americana*), poison-ivy (*Toxicodendron radicans*), Virginia creeper (*Parthenocissus quinquefolia*), and riverbank grape (*Vitis riparia*).

Northern Lower Michigan and Upper Peninsula: In and north of the climatic tension zone, conifers increase in importance relative to hardwoods. Hemlock, which occurs in monodominant stands or in association with yellow birch, red maple, and white pine, locally dominates shallow, poorly-drained depressions and peatland margins (Barrett et al. 1995, Comer et al. 1995, MNFI Biotics Database 2007). These sites are often referred to as hemlock or hemlock-hardwood swamps (NatureServe 2006), and are widespread in the northeastern United States and adjacent Canadian provinces. In Michigan, this type is most common in the western Upper Peninsula, where hemlock and yellow birch occur on moderately- to poorly-drained till plain, on outwash, and on lake margins in close association with upland sugar maple-hemlock forests (Frelich et al. 1993, Comer et al. 1995). In addition to hemlock, other common canopy constituents in northern Michigan hardwood-conifer swamps include balsam fir (*Abies balsamea*), black ash, northern white-cedar, tamarack, and black spruce (*Picea mariana*), with the latter two species occurring primarily on the wettest substrates.

Photo by Bradford S. Slaughter

Rotting, moss-covered wood provides a suitable substrate for conifer seedlings and a variety of ferns and forbs.

Paper birch (*Betula papyrifera*), quaking aspen (*Populus tremuloides*), and balsam poplar (*Populus balsamifera*) can be common canopy and subcanopy species, especially in stands with recent disturbance history (Braun 1950). In addition, white spruce (*Picea glauca*) is occasionally present as scattered overstory individuals. In general, stands in northern Michigan have greater presence of boreal conifers and hardwoods than stands in southern Lower Michigan, but the majority of species are common to both regions. Continued inventory and research is necessary to identify additional variants.

Photo by Bradford S. Slaughter

Yellow birch (left) and hemlock (right) are characteristic trees, often found in close association.

Common small tree and shrub species in addition to those found in southern Lower Michigan include mountain maple (*Acer spicatum*), striped maple (*A. pensylvanicum*), blueberry (*Vaccinium angustifolium*), swamp red currant (*Ribes triste*), and Labrador-tea (*Ledum groenlandicum*). Smooth highbush blueberry and spicebush are generally absent, except in the tension zone. Tag alder (*Alnus rugosa*) often forms dense colonies at the lowland margin of hardwood-conifer swamps, as along streams, and also occupies canopy gaps within forested wetlands. Small individuals of canopy species are prevalent in the understory.

Northern white-cedar and hemlock are characteristic in the understories of sites with low deer densities, including areas characterized by high snowfall, and where large-diameter coarse woody debris provides ample microsites for seedling establishment.

The ground layer includes many of the same species found in southern Lower Michigan. Species occurring with greater frequency in northern Michigan include bluebead lily (*Clintonia borealis*), bunchberry (*Cornus canadensis*), oak fern (*Gymnocarpium dryopteris*), Indian cucumber root (*Medeola virginiana*), gaywings (*Polygala paucifolia*), large-leaved shinleaf (*Pyrola elliptica*), interrupted fern (*Osmunda claytoniana*), creeping snowberry (*Gaultheria hispidula*), twinflower (*Linnaea borealis*), and northern wood-sorrel (*Oxalis acetosella*). Golden saxifrage (*Chrysosplenium americanum*) is locally common on exposed muck. Skunk-cabbage is sporadic north of the tension zone, whereas it frequently dominates the ground layer in southern Lower Michigan (Voss 1972, MNFI Biotics Database 2007).

The bryophyte community of hardwood-conifer swamps is poorly understood. Holcombe (1976) documented 72 species in a northern Michigan rich conifer swamp (cedar swamp), including 50 mosses and 22 liverworts. Mat-forming mosses, including *Heterophyllium haldanianum* and *Pleurozium schreberi*, dominated decomposing logs. Sphagnum mosses are also occasional dominants in rich conifer swamp (Kost 2002). The presence of pronounced hummock-hollow development, in which hollows are often inundated, concentrates moss development in hardwood-conifer swamp to the hummocks, and a continuous moss layer is generally not characteristic of these systems (NatureServe 2006).

Noteworthy Animal Species: Through flooding and herbivory, beaver can cause tree mortality and the conversion of hardwood-conifer swamp to open wetlands such as shallow ponds, emergent marsh, wet meadows, or fens. Insect outbreaks and plant parasites can set back or kill conifers, altering community composition and structure. Pests of potentially significant impact include the hemlock woolly adelgid (*Adelges tsugae*), which has the potential to cause hemlock mortality if it establishes in Michigan, and the emerald ash borer (*Agrilus planipennis*), which has already decimated the ash population in southeastern

Michigan (Haack et al. 2002, McCullough and Roberts 2002, MacFarlane and Meyer 2005). Other insects affecting conifers include larch sawfly (*Pristophora erichsonii*) and larch casebearer (*Coleophora laricella*), which can repeatedly defoliate and kill tamarack, and spruce budworm (*Choristoneura fumiferana*), which defoliates black spruce and balsam fir. Because tamarack, black spruce, and balsam fir are rarely dominant trees in hardwood-conifer swamp, impacts of the latter three insects on this natural community type are generally modest.

Conservation and Biodiversity Management: Conservation and management of hardwood-conifer swamp should focus on the following key areas: preservation of the coarse woody debris resource, protection of mature seed-bearing trees, maintenance of canopy gap structure, protection of groundwater and surface water hydrology, reduction of deer browse pressure, and control and monitoring of invasive species, including plants, animals, and pathogens.

Regeneration of hardwood-conifer swamp canopy trees, particularly of conifers, relies on the presence of suitable sites for germination and establishment within the stand. Management should focus on protecting large-diameter decaying logs and hummocks that are favored germination sites for yellow birch, white pine, northern white-cedar, and hemlock (Holcombe 1976, St. Hiliare and Leopold 1995, Rooney and Waller 1998, Allison and Ehrenfeld 1999, McGee 2001, Rooney et al. 2002). Maintaining mature, senescent, and dead canopy trees within hardwood-conifer swamp stands ensures a continuing source of the large-diameter coarse woody debris important for seedling germination and survival. In addition to providing suitable germination sites for tree seedlings, coarse woody debris and snags create microtopographic variability on the forest floor that is associated with high species richness and diversity (Paratley and Fahey 1986, Anderson and Leopold 2002). Removal of coarse woody debris or senesced trees from hardwood-conifer swamps should be avoided to ensure the continued viability of the system.

Protection of mature, seed-bearing trees is necessary for the continued viability of hardwood-conifer swamp occurrences. Historic logging activities significantly reduced the acreage of lowland and upland conifers throughout Michigan, through direct mortality and reduction of regeneration capacity (Whitney 1987, Zhang et al. 2000, Leahy and Pregitzer 2003). Where conifers are absent in the uplands, removal of mature seed-bearing conifers occurring in the wetlands can convert the affected stands to hardwood-dominated systems (e.g., southern hardwood swamp). Mature, seed-bearing conifers in wetlands also serve as potential seed sources for the regeneration of conifers in adjacent upland forests, and wetland systems provide a refuge for hemlock during climatically dry periods (Mladenoff and Stearns 1993). Removal of mature conifers from hardwood-conifer swamps should be carefully managed to ensure the continued presence of seed sources within the wetland.

Expansion of red maple in some stands, often following logging or hydrologic disturbance, limits conifer seedling establishment and recruitment by reducing light availability at the ground level. An increase in deciduous canopy trees leads to an increase in deciduous leaf litter, which creates an unfavorable seed bed for conifers (Mladenoff and Stearns 1993). Harvest in closed-canopy, hardwood-dominated stands that formerly supported hardwood-conifer swamp should focus on creating canopy gaps suitable for colonization and establishment of species intolerant of dense shade, such as yellow birch (Webster and Lorimer 2005). Conifers, preferably from a native, local seed source, can be established in these stands by underplanting of appropriate species in light gaps and protecting them from deer browse.

Protection of groundwater and surface water hydrology is critical to maintaining the integrity of the hardwood-conifer swamp community. Hydrologic disturbances, including road construction and ditching, cause peat subsidence and decomposition and alter water tables by draining water or blocking its flow (Bradof 1992, Hillman 1997, Amon et al. 2002). Logging and hydrologic disturbances associated with logging roads and railroads in the late 19th and early 20th centuries converted many conifer-dominated stands to hardwood stands. Urban development also degrades water quality and disrupts hydrology, but the effects of urbanization may be unpredictable for any given site (Ehrenfeld and Schneider 1993). The degree to which forested wetland vegetation is impacted by hydrologic disturbance may be related to characteristics of the pit-and-mound microtopography (Ehrenfeld and Schneider 1993). Natural hydrologic disturbances, including flooding associated with beaver dams, also profoundly impact

Rare Plants Associated with Southern Hardwood Swamp (E, Endangered; T, Threatened; SC, species of special concern).

Scientific Name	Common Name	State Status
Berula erecta	cut-leaved water-parsnip	T
Calypso bulbosa	calypso of fairy-slipper	T
Carex seorsa	sedge	T
Cypripedium arietinum	ram's head lady's-slipper	SC
Dentaria maxima	large toothwort	T
Hydrastis canadensis	goldenseal	T
Lonicera involucrata	black twinberry	T
Mimulus glabratus var. *michiganensis*	Michigan monkey flower	E
Poa paludigena	bog bluegrass	T
Trillium undulatum	painted trillium	E

Rare Animals Associated with Southern Hardwood Swamp (E, Endangered; T, Threatened; SC, species of special concern).

Scientific Name	Common Name	State Status
Accipiter gentilis	northern goshawk	SC
Alces americanus	moose	SC
Appalachina sayanus	spike-lip crater	SC
Ardea herodias rookery	great blue heron rookery	*
Asio otus	long-eared owl	T
Buteo lineatus	red-shouldered hawk	T
Canis lupus	gray wolf	T
Emydoidea blandingii	Blanding's turtle	SC
Glyptemys insculpta	wood turtle	SC
Gomphus quadricolor	rapids clubtail	SC
Haliaeetus leucocephalus	bald eagle	SC
Incisalia henrici	Henry's elfin	T
Pachypolia atricornis	three-horned moth	SC
Pandion haliaetus	osprey	SC
Planogyra asteriscus	eastern flat-whorl	SC
Sistrurus c. catenatus	eastern massasauga	SC
Tachopteryx thoreyi	grey petaltail	SC
Terrapene c. carolina	eastern box turtle	SC
Williamsonia fletcheri	ebony boghaunter	SC

*Protected by the Migratory Bird Treaty Act of 1918.

Hardwood-conifer swamp, Luce County, Michigan. Photo by Joshua G. Cohen.

hardwood-conifer swamp structure (see Natural Processes). Bradof (1992) notes that drainage projects involving the creation of ditches facilitate beaver colonization of large areas of previously uncolonized wetlands, causing widespread flooding and tree-kill. Several measures can be taken to protect the integrity of hardwood-conifer swamp hydrology. A relatively wide upland buffer zone can be established to prevent surface water run-off and protect groundwater seepage zones. Construction of new ditches should be avoided, as should new road construction and stream maintenance projects (e.g., dredging, straightening, and removal of fallen wood). Tree harvest should take place in winter to avoid significant degradation of organic soils. Trapping and removal of beaver may be necessary in isolated nature preserves where the maintenance of hardwood-conifer swamp is a conservation priority, and where flooding is likely to eliminate species of conservation concern.

High white-tailed deer density has led to significant browse pressure on conifer seedlings and saplings throughout Michigan and the Great Lakes region (Frelich and Lorimer 1985, Mladenoff and Stearns 1993, Alverson and Waller 1997, Long et al. 1998, Rooney and Waller 1998, Rooney et al. 2002, Krueger and Peterson 2006). In addition, deer browse reduces frequency and cover of understory shrubs and herbs, altering structure of all strata and producing a cascade of effects extending to pollinators of affected plant species (Balgooyen and Waller 1995, Augustine and Frelich 1998, Rooney and Waller 2003, Kraft et al. 2004). In forests impacted by high deer densities, microsites, including treefall mounds, may serve as refugia for deer-favored species such as hemlock (Krueger and Peterson 2006). Protection of the coarse woody debris resource is an important component of any strategy to promote conifer regeneration, particularly in landscapes characterized by high deer density. Salvage logging of blowdowns should be avoided, as piles of toppled trees create physical barriers to deer and thus promote conifer recruitment.

In addition, hemlock recruitment appears to be facilitated by balsam fir, a relatively unpalatable conifer that grows in dense patches and restricts access by deer (Borgmann et al. 1999). Therefore, maintaining high balsam fir cover in managed forest stands should be considered along with protecting the coarse woody debris resource to promote hemlock regeneration. At the landscape scale, reduction of deer densities will promote recovery of tree seedling, shrub, and herb populations. In areas where reducing the number of deer is not feasible, or in small, isolated stands of high-quality hardwood-conifer swamp, deer exclosures should be considered in order to promote conifer regeneration and recruitment.

Photo by Bradford S. Slaughter

Blowdowns serve as refugia for conifer seedlings and saplings in sites impacted by high deer density.

Invasive plant species can establish within hardwood-conifer swamps in canopy gaps and in openings along streams. Species of particular concern include reed canary grass (*Phalaris arundinacea*), common reed (*Phragmites australis*), purple loosestrife (*Lythrum salicaria*), autumn-olive (*Elaeagnus umbellata*), and glossy buckthorn (*Rhamnus frangula*), although many other non-native plant species of lesser impact are of frequent occurrence (MNFI Biotics Database 2007). Fragmentation and isolation of hardwood-conifer swamp occurrences by residential, commercial, and industrial development, particularly in southern Lower Michigan, locally threatens this natural community type by restricting dispersal of native species and increasing the propagule pressure of commonly planted non-native trees, shrubs, and herbs. Hydrologic disturbances, including flooding and nutrient loading via surface water run-off, facilitate invasion of otherwise intact systems (Zedler and Kercher 2004). Monitoring and removal of invasive species should focus on those species which threaten to alter community composition and structure (e.g., glossy buckthorn and purple loosetrife). Management activities should avoid soil and hydrologic disturbances that favor spread of invasive plant species.

Other pests of potentially significant impact include the hemlock woolly adelgid (*Adelges tsugae*), which has the potential to cause significant hemlock mortality if it establishes in Michigan, and the emerald ash borer (*Agrilus planipennis*), which has already decimated the ash population in southeastern Michigan (Haack et al. 2002, McCullough and Roberts 2002, MacFarlane and Meyer 2005). Urgent measures must be taken to restrict the access of these species to unaffected swamps.

Research Needs: Hardwood-conifer swamp is a relatively poorly studied wetland type in Michigan and across its range, as the majority of research on lowland forests has been conducted in peatlands (e.g., rich conifer swamp, poor conifer swamp) and hardwood-dominated floodplain forests. A systematic survey for hardwood-conifer swamp in Michigan, including the collection of plot data, is necessary to assess the statewide and ecoregional conservation status of this natural community type, and to determine if any of the above described variants warrant splitting as separate natural community types. Additional inventory for hardwood-conifer swamp in northern Michigan is required, as few occurrences have been documented despite the community's widespread distribution in that region (MNFI Biotics Database 2007). Additional research is necessary to study the edaphic and climatic characteristics and successional pathways associated with hardwood-conifer swamp. The impacts of fire, windthrow, and beaver flooding on hardwood-conifer swamp in Michigan are poorly understood and should be investigated. Deer browse is a significant disturbance, but its impacts on hardwood species, shrubs, and ground layer species typical of hardwood-conifer swamp require further research. The most effective means of limiting the impacts of deer herbivory in this system must also be determined. The potential impacts of emerald ash borer and hemlock woolly adelgid on hardwood-conifer swamp should be studied and modeled. The interaction of natural and anthropogenic disturbances, and their impacts on hardwood-conifer swamp should also be elucidated. For example, the impacts of beaver in anthropogenically disturbed versus undisturbed forested wetlands should be studied to help improve land management and protection strategies. Additional research on conifer regeneration in hardwood-conifer swamp will improve management techniques and conservation strategies for this natural community type.

Similar Communities: *Rich tamarack swamp* is a tamarack-dominated peatland located primarily in the interlobate regions of southern Lower Michigan, where it was the most common forested wetland type circa 1800 (Kost 2001a). *Rich conifer swamp* is a northern white-cedar – dominated peatland, with tamarack, black spruce, and balsam fir as common associates. Lowland hardwoods are of low importance in rich conifer swamp. This system occurs primarily in cool regions of the state where climate limits peat decomposition, although isolated stands of rich conifer swamp, typically associated with tamarack and lowland hardwoods, are documented from southern Lower Michigan (Kost 2002). *Poor conifer swamp* is an oligotrophic forested wetland dominated by black spruce and tamarack on deep sphagnum peats (Cohen 2006). *Southern hardwood swamp* is dominated by hardwood species tolerant of seasonal hydrologic fluctuation (e.g., silver maple and green ash), and typically occurs on shallow muck or seasonally inundated mineral soils south of the climatic tension zone. Conifers are generally absent or of limited occurrence (Kost et al. 2007). *Northern hardwood swamp* is a black ash-dominated community on shallow muck or seasonally inundated mineral soils north of the tension zone (Weber et al. 2007). *Floodplain forest* is a broadly defined community occurring on third order or greater streams; hardwood-conifer swamps sometimes occur within floodplain forests in meander scars no longer subject to over-the-bank flooding (Tepley et al. 2004). Hardwood-conifer swamp can also occur as a zone in *wooded dune and swale complexes*.

Other Classifications:

Michigan Department of Natural Resources (MDNR): Q – Mixed Swamp Conifers; E – Swamp Hardwoods; C – Northern White Cedar; H – Hemlock

Michigan Resource Information Systems (MIRIS): 423 (conifer swamp): 4237 (hemlock, yellow birch), 4238 (hemlock), 4239 (white pine); 432 (lowland hardwoods & conifer): 4322 (white pine, tamarack, red maple, yellow birch, black ash, cedar, [&/or hemlock]), 4322 (hemlock, yellow birch)

The Nature Conservancy U.S. National Vegetation Classification and International Classification of Ecological Communities (Faber-Langendoen 2001, NatureServe 2006):

CODE; ALLIANCE; ASSOCIATION; COMMON NAME

I.A.8.N.g; *Tsuga canadensis* Saturated Forest Alliance; *Tsuga canadensis - Betula alleghaniensis / Ilex verticillata / Sphagnum* spp. Forest; Eastern Hemlock - Yellow Birch / Common Winterberry / Peatmoss species Forest; Hemlock – Hardwood Swamp

I.B.2.N.g; *Fraxinus nigra - Acer rubrum* Saturated Forest Alliance; *Acer rubrum - Fraxinus nigra - (Tsuga canadensis) / Tiarella cordifolia* Forest; Red Maple - Black Ash - (Eastern Hemlock) / Heartleaf Foamflower Forest; Northern Hardwood – Hemlock Seepage Swamp

I.B.2.N.g; *Fraxinus nigra - Acer rubrum* Saturated Forest Alliance; *Acer rubrum - Fraxinus* spp. - *Betula papyrifera / Cornus canadensis* Forest; Red Maple - Ash species - Paper Birch / Canadian Bunchberry Forest; Red Maple – Ash – Birch Swamp Forest

I.B.2.N.g; *Fraxinus nigra - Acer rubrum* Saturated Forest Alliance; *Fraxinus nigra* - Mixed Hardwoods - Conifers */ Cornus sericea / Carex* spp. Forest; Black Ash - Mixed Hardwoods - Conifers / Red-osier Dogwood / Sedge species Forest; Black Ash – Mixed Hardwood Swamp

I.C.3.N.d; *Pinus strobus - (Acer rubrum)* Saturated Forest Alliance; *Pinus strobus - (Acer rubrum) / Osmunda* spp. Forest; Eastern White Pine - (Red Maple) / Royal Fern species Forest; White Pine – Red Maple Swamp

I.C.3.N.d; *Tsuga canadensis - Acer rubrum* Saturated Forest Alliance; *Betula alleghaniensis - Acer rubrum - (Tsuga canadensis, Abies balsamea) / Osmunda cinnamomea* Forest; Yellow Birch - Red Maple - (Eastern Hemlock, Balsam Fir) / Cinnamon Fern Forest; Hardwood – Conifer Seepage Forest

I.C.3.N.d; *Thuja occidentalis - Acer rubrum* Saturated Forest Alliance; *Thuja occidentalis - Fraxinus nigra* Forest; Northern White-cedar - Black Ash Forest; White-cedar – Black Ash Swamp

Other states and Canadian provinces (natural community types with significant overlap with Michigan hardwood-conifer swamp indicated in *italics*):

MN: Northern wet cedar forest; Northern wet ash swamp; Northern very wet ash swamp (Minnesota Department of Natural Resources 2003)

WI: *White pine – red maple swamp* (Epstein et al. 2002)

ON: *White pine – hemlock mineral coniferous swamp ecosite*; White cedar mineral coniferous swamp ecosite; White cedar mineral mixed swamp ecosite; Maple mineral mixed swamp ecosite; Birch – poplar mineral mixed swamp ecosite; White cedar organic mixed swamp ecosite; Maple organic mixed swamp ecosite; Birch – poplar organic mixed swamp ecosite; *Fresh – moist hemlock coniferous forest ecosite*; *Fresh – moist hemlock mixed forest ecosite*; *Fresh – moist white cedar coniferous forest ecosite*; *Fresh – moist white cedar – hardwood mixed forest ecosite*; Fresh – moist poplar – white birch mixed forest ecosite (Lee et al. 1998)

OH: *Hemlock – hardwood swamp* (Schneider and Cochrane 1998)

PA: *Hemlock palustrine forest*; *Hemlock – mixed hardwood palustrine forest*; Red maple – highbush blueberry palustrine woodland; Red maple – sedge palustrine woodland; red maple – mixed shrub palustrine woodland (Fike 1999)

NY: *Hemlock – hardwood swamp*; *Rich hemlock – hardwood peat swamp* (Edinger et al. 2002)

MA: *Hemlock – hardwood swamp*; Red maple swamp; Black ash swamp (Swain and Kearsley 2001)

VT: *Red maple – white pine – huckleberry swamp*; Spruce – fir – tamarack swamp; *Hemlock swamp*; *Hemlock – hardwood swamp*; Red maple – black ash swamp;

Red maple – northern white cedar swamp; (Thompson and Sorenson 2000)

NH: *Northern hardwood – black ash – conifer swamp*; *Northern white cedar – hemlock swamp*; *Hemlock – cinnamon fern forest* (Sperduto and Nichols 2004)

ME: *Hemlock – hardwood pocket swamp*; Hardwood seepage forest; Red maple – sensitive fern swamp (Gawler and Cutko 2004)

Related Abstracts: rich conifer swamp, rich tamarack swamp, poor conifer swamp, northern hardwood swamp, floodplain forest, wooded dune and swale complex, Cooper's hawk, northern goshawk, spike-lip crater, red-shouldered hawk, Blanding's turtle, wood turtle, rapids clubtail, eastern massasauga, osprey, eastern box turtle, great blue heron rookery, goldenseal, Michigan monkey-flower, painted trillium, large toothwort, calypso, ram's head lady's-slipper.

Photo by Bradford S. Slaughter

White pine and red maple dominate a hardwood-conifer swamp in Newaygo County.

References:

Albert, D.A. 1995. Regional landscape ecosystems of Michigan, Minnesota, and Wisconsin: A working map and classification. Gen. Tech. Rep. NC-178. St. Paul, MN: USDA, Forest Service, North Central Forest Experiment Station, St. Paul, MN. http://nrs.fs.fed.us/pubs/242 (Version 03JUN1998). 250 pp.

Albert, D.A., J.G. Cohen, M.A. Kost, B.S. Slaughter, and H.D. Enander. 2008. Distribution maps of Michigan's Natural Communities. Michigan Natural Features Inventory, Report No. 2008-01, Lansing, MI. 174 pp.

Albert, D.A., S.R. Denton, and B.V. Barnes. 1986. Regional landscape ecosystems of Michigan. Ann Arbor, MI: University of Michigan, School of Natural Resources. 32 pp. & map.

Allison, S.K., and J.G. Ehrenfeld. 1999. The influence of microhabitat variations on seedling recruitment of *Chamaecyparis thyoides* and *Acer rubrum*. Wetlands 19: 383-393.

Alverson, W.S., and D.M. Waller. 1997. Deer populations and the widespread failure of hemlock regeneration in northern forests. Pp. 280-297 *in* W.J. McShea, H.B. Underwood, and J.H. Rappole (eds.). The Science of Overabundance: Deer Ecology and Population Management. Smithsonian Institution Press, Washington, D.C.

Amon, J.P., C.A. Thompson, Q.J. Carpenter, and J. Miner. 2002. Temperate zone fens of the glaciated Midwestern USA. Wetlands 22: 301-317.

Anderson, K.L., and D.J. Leopold. 2002. The role of canopy gaps in maintaining vascular plant diversity at a forested wetland in New York State. Journal of the Torrey Botanical Society 129: 238-250.

Augustine, D.J., and L.E. Frelich. 1998. Effects of white-tailed deer on populations of an understory forb in fragmented deciduous forests. Conservation Biology 12: 995-1004.

Balgooyen, C.P., and D.M. Waller. 1995. The use of *Clintonia borealis* and other indicators to gauge impacts of white-tailed deer on plant communities in northern Wisconsin, USA. Natural Areas Journal 15: 308-318.

Barnes, B.V. 1976. Succession in deciduous swamp communities of southeastern Michigan formerly dominated by American elm. Canadian Journal of Botany. 54:19-24.

Barnes, B.V. 1991. Deciduous forest of North America. Pp. 229-344 *in* E. Röhrig and B. Ulrich, eds., Ecosystems of the World 7: Temperate Deciduous Forests. Elsevier Publishing, New York.

Barrett, L.R., J. Liebens, D.G. Brown, R.J. Schaetzl, P. Zuwerink, T.W. Cate, and D.S. Nolan. 1995. Relationships between soils and presettlement forests in Baraga County, Michigan. American Midland Naturalist 134: 264-285.

Bedford, B.L., and K.S. Godwin. 2003. Fens of the United States: Distribution, characteristics, and scientific connection versus legal isolation. Wetlands 23: 608-629.

Borgmann, K.L., D.M. Waller, and T.P. Rooney. 1999. Does balsam fir (*Abies balsamea*) facilitate the recruitment of eastern hemlock (*Tsuga canadensis*)? American Midland Naturalist 141: 391-397.

Bowles, M.L., P.D. Kelsey, and J.L. McBride. 2005. Relationships among environmental factors, vegetation zones, and species richness in a North American calcareous prairie fen. Wetlands 25: 685-696.

Bradof, K.L. 1992. Impact of ditching and road construction on Red Lake Peatland. Pp. 173-186 *in* H.E. Wright, Jr., B.A. Coffin, and N.E. Aaseng, eds. The Patterned Peatlands of Minnesota. University of Minnesota Press, Minneapolis.

Braun, E.L. 1950. Deciduous forests of eastern North America. McGraw-Hill, New York.

Brewer, R. 1966. Vegetation of two bogs in southwestern Michigan. Michigan Botanist 5: 36-46.

Christensen, E.M., J.J. (Jones) Clausen, and J.T. Curtis. 1959. Phytosociology of the lowland forests of northern Wisconsin. American Midland Naturalist 62: 232-247.

Cleland, D.T., T.R. Crow, S.C. Saunders, D.I. Dickmann, A.L. Maclean, J.K. Jordan, R.L. Watson, A.M. Sloan, and K.D. Brosofske. 2004. Characterizing historical and modern fire regimes in Michigan (USA): A landscape ecosystem approach. Landscape Ecology 19: 311-325.

Coffman, M.S. 1978. Eastern hemlock germination influenced by light, germination media, and moisture content. Michigan Botanist 17: 99-103.

Cohen, J.G. 2006. Natural community abstract for poor conifer swamp. Michigan Natural Features Inventory, Lansing, MI. 22 pp.

Comer, P.J., D.A. Albert, H.A. Wells, B.L. Hart, J.B. Raab, D.L. Price, D.M. Kashian, R.A. Corner, and D.W. Schuen. 1995. Michigan's presettlement vegetation, as interpreted from the General Land Office Surveys 1816-1856. Michigan Natural Features Inventory, Lansing, MI. Digital map.

Curtis, J.T. 1959. The Vegetation of Wisconsin: An Ordination of Plant Communities. The University of Wisconsin Press, Madison, WI. 657 pp.

Dahl, T.E. 1990. Wetlands – Losses in the United States, 1780s to 1980s.Washington, D.C., U.S. Fish and Wildlife Service Report to Congress, 13 pp.

Edinger, G.J., D.J. Evans, S. Gebauer, T.G. Howard, D.M. Hunt, and A.M. Olivero (editors). 2002. Ecological communities of New York State. Second Edition. A revised and expanded edition of Carol Reschke's Ecological communities of New York State. (Draft for review). New York Natural Heritage Program, New York Department of Environmental Conservation, Albany, NY.

Ehrenfeld, J.G., and J.P. Schneider. 1993. Responses of forested wetland vegetation to perturbations of water chemistry and hydrology. Wetlands 13: 122-129.

Ehrenfeld, J.G. 1995. Microsite differences in surface substrate characteristics in *Chamaecyparis* swamps of the New Jersey Pinelands. Wetlands 15: 183-189.

Epstein, E., E. Judziewicz, and E. Spencer. 2002. Wisconsin Natural Heritage Inventory (NHI) recognized natural communities – working document. September 2002 revision. Wisconsin Natural Heritage Inventory, Madison, WI.

Faber-Langendoen, D., ed. 2001. Plant communities of the Midwest: Classification in an ecological context. NatureServe, Arlington, VA.

Fike, J. 1999. Terrestrial and palustrine plant communities of Pennsylvania. Pennsylvania Department of Conservation and Natural Resources, Bureau of Forestry, Harrisburg, PA.

Forrester, J.A., T.E. Yorks, and D.J. Leopold. 2005. Arboreal vegetation, coarse woody debris, and disturbance history of mature and old-growth stands in a coniferous forested wetland. Journal of the Torrey Botanical Society 132: 252-261.

Frelich, L.E., and C.G. Lorimer. 1985. Current and predicted long-term effects of deer browsing in hemlock forests in Michigan, USA. Biological Conservation 34: 99-120.

Frelich, L.E., R.R. Calcote, M.B. Davis, and J. Pastor. 1993. Patch formation and maintenance in an old-growth hemlock-hardwood forest. Ecology 74: 513-527.

Futyma, R.P., and N.G. Miller. 2001. Postglacial history of a marl fen: Vegetational stability at Byron-Bergen Swamp, New York. Canadian Journal of Botany 79: 1425-1438.

Gawler, S.C., and A.R. Cutko. 2004. Natural landscapes of Maine: A classification of vegetated natural communities and ecosystems. Maine Natural Areas Program, Department of Conservation, Augusta, ME.

Haack, R.A., E. Jendek, H. Liu, K.R. Marchant, T.R. Petrice, T.M. Poland, and H. Ye. 2002. The emerald ash borer: A new exotic pest in North America. Michigan Entomological Society Newsletter 47: 1-5.

Heinselman, M.L. 1963. Forest sites, bog processes, and peatland types in the Glacial Lake Agassiz Region, Minnesota. Ecological Monographs 33: 327-374.

Hillman, G.R. 1997. Effects of engineered drainage on water tables and peat subsidence in an Alberta treed fen. Pp. 253-272 *in* C.C. Trettin, M.F. Jurgensen, D.F. Grigal, M.R. Gale, and J.K. Jeglum, eds. Northern Forested Wetlands: Ecology and Management. Lewis Publishers, Boca Raton, FL.

Holcombe, J.W. 1976. The bryophyte flora of *Thuja* seedbed logs in a northern white-cedar swamp. Michigan Botanist 15: 173-181.

Kost, M.A. 2001a. Natural community abstract for relict conifer swamp. Michigan Natural Features Inventory, Lansing, MI. 6 pp.

Kost, M.A. 2001b. Potential indicators for assessing biological integrity of forested, depressional wetlands in southern Michigan. Michigan Natural Features Inventory, Lansing, MI. 69 pp.

Kost, M.A. 2002. Natural community abstract for rich conifer swamp. Michigan Natural Features Inventory, Lansing, MI. 9 pp.

Kost, M.A., D.A. Albert, J.G. Cohen, B.S. Slaughter, R.K. Schillo, C.R. Weber, and K.A. Chapman. 2007. Natural communities of Michigan: Classification and description. Michigan Natural Features Inventory, Report Number 2007-21, Lansing, MI. 314 pp.

Kraft L.S., T.R. Crow, D.S. Buckley, E.A. Nauertz, and J.C. Zasada. 2004. Effects of harvesting and deer browsing on attributes of understory plants in northern hardwood forests, Upper Michigan, USA. Forest Ecology and Management 199: 219-230.

Krueger, L.M., and C.J. Peterson. 2006. Effects of white-tailed deer on *Tsuga canadensis* regeneration: Evidence of microsites as refugia from browsing. American Midland Naturalist 156: 353-362.

Laidig, K.L., and R.A. Zampanella. 1999. Community attributes of Atlantic white cedar (*Chamaecyparis thyoides*) swamps in disturbed and undisturbed Pinelands watersheds. Wetlands 19: 35-49.

Leahy, M.J., and K.S. Pregitzer. 2003. A comparison of presettlement and present-day forests in northeastern Lower Michigan. American Midland Naturalist 149: 71-89.

Lee, H.T., W.D. Bakowsky, J. Riley, J. Bowles, M. Puddister, P. Uhlig, and S. McMurray. 1998. Ecological land classification for southern Ontario: First approximation and its application. Ontario Ministry of Natural Resources, Southcentral Science Section, Science Development and Transfer Branch. SCSS Field Guide FG-02.

Long, Z.T., W.P. Carson, and C.J. Peterson. 1998. Can disturbance create refugia from herbivores: An example with hemlock regeneration on treefall mounds. Journal of the Torrey Botanical Society 125: 165-168.

MacFarlane, D.W., and S.P. Meyer. 2005. Characteristics and distribution of potential ash tree hosts for emerald ash borer. Forest Ecology and Management 213: 15-24.

McCullough, D.G., and D.L. Roberts. 2002. Emerald ash borer. USDA Forest Service, Northeast Area, State and Private Forests, Pest Alert NA-PR-07-02.

McGee, G.G. 2001. Stand-level effects on the role of decaying logs as vascular plant habitat in Adirondack northern hardwood forests. Journal of the Torrey Botanical Society 128: 370-380.

McKenzie, J.M., D.I. Siegel, D.O. Rosenberry, P.H. Glaser, and C.I. Voss. 2007. Heat transport in the Red Lake Bog, Glacial Lake Agassiz Peatlands. Hydrological Processes 21: 369-378.

Michigan Natural Features Inventory (MNFI). 2007. Biotics Database. Michigan Natural Features Inventory, Lansing, MI.

Minnesota Department of Natural Resources. 2003. Field guide to the native plant communities of Minnesota: The Laurentian Mixed Forest Province. Ecological Land Classification Program, Minnesota County Biological Survey, and Natural Heritage and Nongame Research Program. MNDNR, St. Paul, MN.

MIRIS. 1978. MIRIS Landcover 1978. Michigan Department of Natural Resources, Lansing, MI. Digital dataset.

Mladenoff, D.J., and F. Stearns. 1993. Eastern hemlock regeneration and deer browsing in the northern Great Lakes region: A re-examination and model simulation. Conservation Biology 7: 889-900.

NatureServe. 2006. NatureServe Explorer: An online encyclopedia of life [web application]. Version 6.1. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. (Accessed: November 30, 2006).

Paratley, R.D., and T.J. Fahey. 1986. Vegetation – environment relations in a conifer swamp in central New York. Bulletin of the Torrey Botanical Club 113: 357-371.

Rooney, T.P., and D.M. Waller. 1998. Local and regional variation in hemlock seedling establishment in forests of the upper Great Lakes region, USA. Forest Ecology and Management 111: 211-224.

Rooney, T.P., and D.M. Waller. 2003. Direct and indirect effects of white-tailed deer in forest ecosystems. Forest Ecology and Management 181: 165-176.

Rooney, T.P., S.L. Solheim, and D.M. Waller. 2002. Factors affecting the regeneration of northern white-cedar in lowland forests of the Upper Great Lakes region, USA. Forest Ecology and Management 163: 119-130.

Schneider, G.J., and K.E. Cochrane. 1998. Plant community survey of the Lake Erie Drainage. Ohio Department of Natural Resources, Division of Natural Areas and Preserves, Columbus, OH.

Simard, M.-J., Y. Bergeron, and L. Sirois. 2003. Substrate and litterfall effects on conifer seedling survivorship in southern boreal stands of Canada. Canadian Journal of Forest Research 33: 672-681.

Slaughter, B.S., and J.D. Skean, Jr. 2003. Comparison of cedar and tamarack stands in a relict conifer swamp at Pierce Cedar Creek Institute, Barry County, Michigan. Michigan Botanist 42: 111-126.

Slaughter, B.S., B.S. Walters, and E.H. Schools. 2007. A natural features inventory of Newaygo County, Michigan. Report No. 2007-01. Michigan Natural Features Inventory, Lansing, MI. 55 pp.

Sperduto, D.D., and W.F. Nichols. 2004. Natural communities of New Hampshire. The New Hampshire Natural Heritage Bureau, Concord, NH. UNH Cooperative Extension, Durham, NH.

St. Hilaire, L.R., and D.J. Leopold. 1995. Conifer seedling distribution in relation to microsite conditions in a central New York forested minerotrophic peatland. Canadian Journal of Forest Research 25: 261-269.

Swain, P.C., and J.B. Kearsley. 2001. Classification of the Natural Communities of Massachusetts. Version 1.3. Natural Heritage and Endangered Species Program, Division of Fisheries and Wildlife. Westborough, MA.

Tepley, A.J., J.G. Cohen, and L. Huberty. 2004. Natural community abstract for southern floodplain forest. Michigan Natural Features Inventory, Lansing, MI. 14 pp.

Terwilliger, J., and J. Pastor. 1999. Small mammals, ectomycorrhizae, and conifer succession in beaver meadows. Oikos 85: 83-94.

Thompson, P.W. 1953. Vegetation of Haven Hill, Michigan. American Midland Naturalist 50: 218-223.

Thompson, E.H., and E.R. Sorenson. 2000. Wetland, Woodland, Wildland: A guide to the natural communities of Vermont. Vermont Department of Wildlife and The Nature Conservancy. University Press of New England, Hanover, NH.

Vivian-Smith, G. 1997. Microtopographic heterogeneity and floristic diversity in experimental wetland communities. Journal of Ecology 85: 71-82.

Voss, E.G. 1972. Michigan Flora. Part I: Gymnosperms and Monocots. Bull. Cranbrook Inst. Sci. 55 and Univ. Michigan Herbarium, Ann Arbor, MI. 488 pp.

Voss, E.G. 1985. Michigan Flora. Part II: Dicots (Saururaceae—Cornaceae). Bull. Cranbrook. Inst. Sci. 59 and Univ. Michigan Herbarium, Ann Arbor, MI. 724 pp.

Voss, E.G. 1996. Michigan Flora. Part III: Dicots (Pyrolaceae—Compositae). Bull. Cranbrook Inst. Sci. 61 and Univ. Michigan Herbarium, Ann Arbor, MI. 622 pp.

Weber, C.R., J.G. Cohen, and M.A. Kost. 2007. Natural community abstract for northern hardwood swamp. Michigan Natural Features Inventory, Lansing, MI. 8 pp.

Webster, C.R., and C.G. Lorimer. 2005. Minimum opening sizes for canopy recruitment of midtolerant tree species: A retrospective approach. Ecological Applications 15: 1245-1262.

Wenger, J.D. 1975. The vegetation of a white-cedar swamp in southwestern Michigan. Michigan Botanist 14: 124-130.

Whitney, G.G. 1986. Relation of Michigan's presettlement pine forests to substrate and disturbance history. Ecology 67: 1548-1559.

Whitney, G.G. 1987. An ecological history of the Great Lakes Forest of Michigan. Journal of Ecology 75: 667-684.

Zampanella, R.A., K.J. Landig, R.G. Lathrop, and J.A. Bognar. 1999. Size-class structure and hardwood recruitment in Atlantic white cedar swamps of the New Jersey pinelands. Journal of the Torrey Botanical Society 126: 268-275.

Zedler, J.B., and S. Kercher. 2004. Causes and consequences of invasive plants in wetlands: Opportunities, opportunists, and outcomes. Critical Reviews in Plant Sciences 23: 431-452.

Zhang, Q., K.S. Pregitzer, and D.D. Reed. 2000. Historical changes in the forests of the Luce District of the Upper Peninsula of Michigan. American Midland Naturalist 143: 94-110.

Abstract Citation:

Slaughter, B.S., J.G. Cohen, and M.A. Kost. 2007. Natural community abstract for hardwood-conifer swamp. Michigan Natural Features Inventory, Lansing, MI. 20 pp.

Updated June 2010.

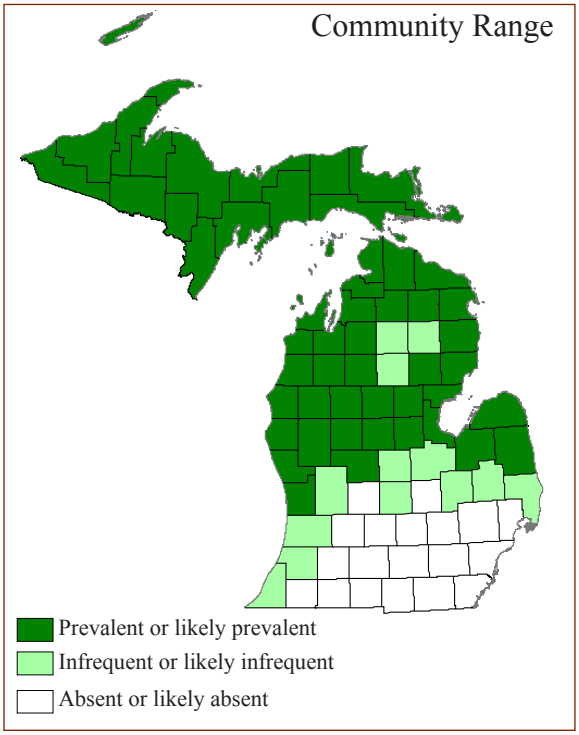
Copyright 2007 Michigan State University Board of Trustees. Michigan State University is an affirmative-action, equal-opportunity organization.

Funding for abstract provided by Michigan Department of Natural Resources Forest, Mineral and Fire Management Division and Wildlife Division.

Hardwood-conifer swamp, Baraga County, Michigan. Photo by Joshua G. Cohen.

Mesic Northern Forest — Community Abstract

Photo by Joshua G. Cohen



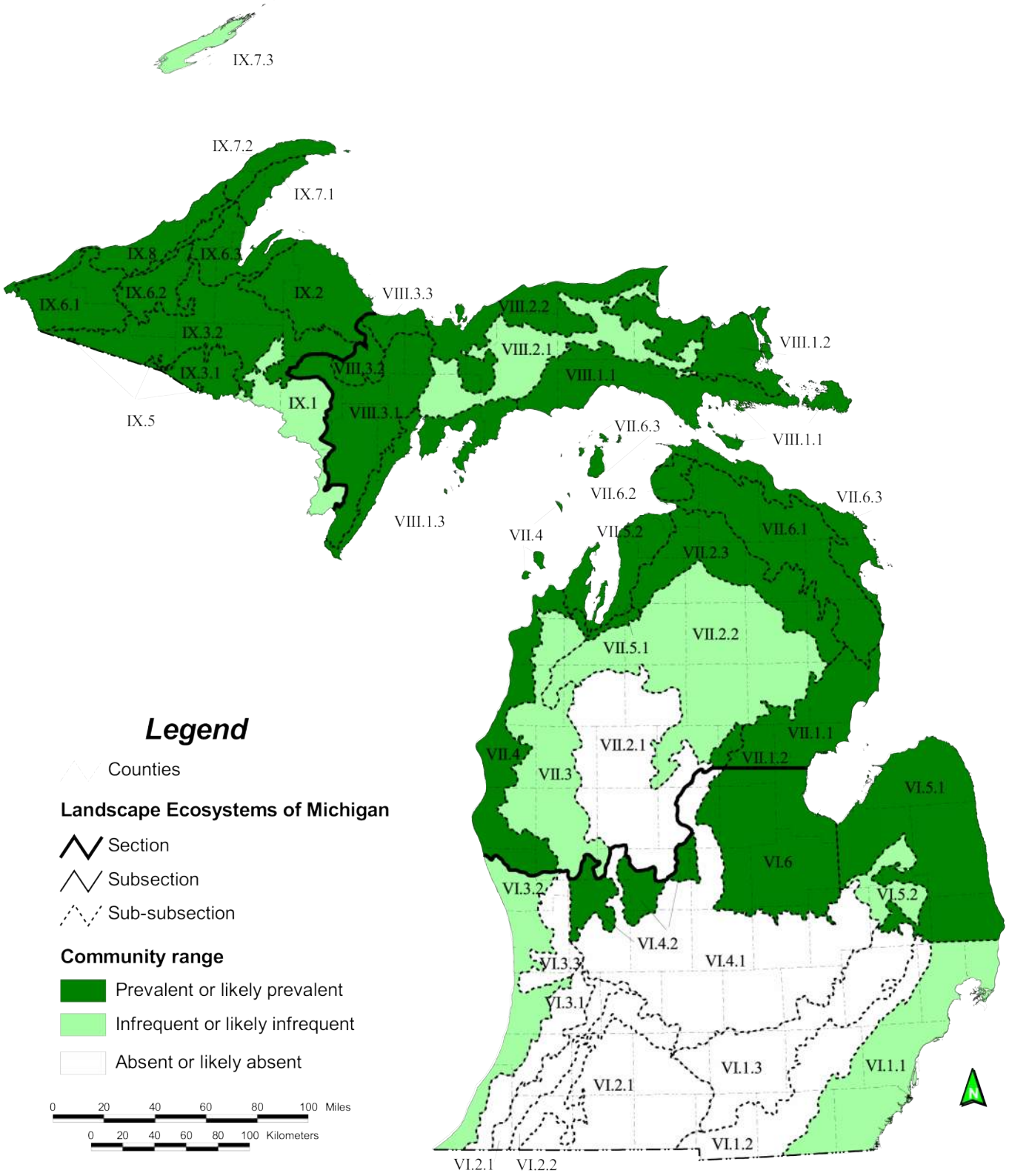
Global and State Rank: G4/S3

Range: The mesic northern forest community has existed as a dominant assemblage for approximately 2,000 years (Davis, 1981) extending from southeastern Manitoba and northern Minnesota east across the northern U.S. and southern Canada to Maine and Nova Scotia (Barnes, 1991). Within Michigan, this forest type is predominantly found throughout the Upper Peninsula and in the northern half of the Lower Peninsula above the transition zone. This community also sporadically occurs below the transition zone along the Great Lakes shores of the Lower Peninsula.

Rank Justification: Widespread selective logging of white pine and hemlock at the end of the 19th century and the beginning of the 20th century followed by extensive slash fires greatly diminished the role of conifers as a widespread component of the mesic northern forest. In the Great Lakes region more than 99% of the mature hemlock-hardwood forest has been eliminated (Noss et al., 1995) and hemlock has been reduced from its former position as a regional dominant to where it now occupies only 0.5% of the landscape (Mladenoff and Stearns, 1993). Hemlock regeneration has diminished with this drastic reduction in seed source, the rise of winter browse pressure from the increasing deer population (Alverson et al., 1988) and the paucity of suitable establishment substrate such as decaying logs (nurse logs) and tip up mounds, features associated with old growth stands and also necessary for yellow birch establishment (Curtis, 1959). Logging, with a shift in focus from conifers to hardwoods, has continued as the primary disturbance in this forest (Frelich and Lorimer, 1991; Metzger and Schultz, 1984). Gaps generated by selective logging tend to be filled by sugar maple (Curtis, 1959), the seedlings of which often saturate the shaded understory of mesic northern forests (Barnes, 1991). Sustained and ubiquitous harvesting has reduced the structural and compositional complexity of this community. Old growth forest has dwindled from 68.0% to 5.2-8.3% of the Great Lakes landscape (Frelich, 1995). Remnants of northern hemlock-hardwood forests unscathed by logging are among the rarest vegetation types in the lake states, with just 0.6% remaining (Frelich and Reich, 1996). According to Noss et al. (1995), old growth eastern deciduous forest is among the 21 most endangered ecosystems in the United States.

In Michigan, 5.8% of the northern hardwood commercial forest is old growth (Frelich, 1995). In the 1800s, approximately 32.0% (over 12 million acres) of Michigan was mesic northern forest (Comer et al., 1995). Just over 0.4% of mesic northern forest in presettlement condition remains in Michigan. Large tracts of primary old growth forest remain in the Upper Peninsula in the Porcupine Mountains (31,000 acres), the Sylvania Wilderness (17,950 acres) and the Huron Mountains (4,000 acres). Currently there are 81 documented occurrences of the mesic northern forest community. Thirty-seven of those occurrences, constituting just over 84,000 acres, are high quality representations of this type.

Michigan Natural Features Inventory
P.O. Box 30444 - Lansing, MI 48909-7944
Phone: 517-373-1552



Ecoregional map of Michigan (Albert 1995) depicting distribution of mesic northern forest (Albert et al. 2008)

Michigan Natural Features Inventory
P.O. Box 30444 - Lansing, MI 48909-7944
Phone: 517-373-1552

Landscape, Abiotic and Historical Context: Mesic northern forest occurs on a wide variety of soils, typically on loamy sand to sandy loam and occasionally on sand, loam and clay. Soils range widely in pH from extremely acid to moderately alkaline but are more commonly extremely acid to medium acid. According to the Köppen classification, the Northern Hardwood-Conifer region has a cool snow-forest climate with warm summers. The daily maximum temperature in July ranges from 24 to 29 °C (75 to 85 °F) and the daily minimum temperature in January ranges from –21 to –9 °C (-5 to 15 °F). The mean length of freeze-free days is between 90 to 160 days and the average number of days per year with snow cover of 2.5 cm or more is between 80 and 140 days. The normal annual total precipitation ranges from 610 to 1270 mm (Albert et al., 1986; Barnes, 1991).

A forest type of moist to dry-mesic sites lying predominantly north of the tension zone, mesic northern forest is found chiefly on coarse-textured ground and end moraines, but also occurs commonly on silty/clayey lake plains, thin glacial till over bedrock and medium-textured moraines. It also occurs locally on kettle-kame topography, moderately well-drained to well-drained sandy lake plain and sand dunes (Kost et al. 2007).

Presettlement forests of eastern hemlock and yellow birch were frequent on moderate to poorly drained till plains and outwash plains, especially in the western Upper Peninsula. This assemblage was predominantly found around lake and bog margins and in complex mosaics with sugar maple-hemlock forest on the surrounding better- drained soils. Beech-sugar maple-hemlock forests, which dominated nearly 17% of the state's surface in the 1800s, were mostly found on large expanses of rolling moraines in the northern Lower Peninsula and eastern Upper Peninsula. This species mix was also found on the clay lakeplain along Saginaw Bay. Eastern hemlock and white pine were the conifers most commonly occurring in mixed stands with hardwoods. Eastern hemlock and American beech were occasionally co-dominant, most commonly on moderately drained sand plains. Assemblages dominated by hemlock and white pine were prevalent in the 1800's on moderately drained lake plain and outwash plain extending from Saginaw Bay through the Upper Peninsula. Large areas of hemlock–dominated forest grew on the clay plain of Huron and Sanilac counties. Extensive tracts of sugar maple and white cedar located in dunes or over calcareous bedrock were known from the surveyor's notes and are found today locally in dunes and on the drumlin fields of Menominee County (Comer et al., 1995).

Natural Processes: The natural disturbance regime in mesic northern forests is dominated by wind (Frelich et al., 1993). The Great Lakes region is one of the most active weather zones in the northern hemisphere with polar jet streams positioned overhead much of the year. More cyclones pass over this area than any other area in the continental U.S (Frelich and Lorimer, 1991). Severe low-pressure systems are a significant source of small-scale canopy gaps, which generate diversity of age structure in these stands (Canham and Loucks, 1984). In a study in the western Upper Peninsula, Frelich and Lorimer (1991) found that 60% of the canopy trees attained their canopy ascendance as the result of periodic small-gap formation. Because of the ability of shade tolerant species to remain in a suppressed understory state for prolonged periods of time, small canopy gaps are filled by advanced regeneration (Runkle, 1982). Sugar maple seedlings often survive in the shaded understory for over 30 years (Marks and Gardescu, 1998) and suppressed hemlock seedlings can live over 100 years (Davis et al., 1996).

Photo by Joshua G. Cohen

Small canopy gaps allow for regeneration of shade-tolerant tree species.

Catastrophic windthrow is an important yet infrequent component of the disturbance regime of the mesic northern forests. Canham and Loucks (1984) estimated that the return time for large-scale windthrow (> 1.0 ha) to be 1,210 years in forests of northern Wisconsin. This return time is remarkably similar to Whitney's (1986) estimated windthrow recurrence interval of 1,220 years in hemlock-white pine-northern hardwood forests of the northern Lower Peninsula. Investigating primary hemlock-hardwood forests of the Upper Peninsula, Frelich and Lorimer (1991) estimated that the rotation period of wind disturbance which leveled greater than 60% of the canopy on a given site to be more than 1500 years. The principal mechanisms for large-scale windthrow are tornadoes and downbursts from thunderstorms. Downbursts are parcels of air in down drafts that shoot out from the base of

The dense, shade-tolerant canopy of mesic northern forest is periodically and patchily opened by small-scale windthrow events that generate canopy gaps critical for tree regeneration. Photos by Joshua G. Cohen.

thunderstorms and splatter in all directions upon impact with the earth (Frelich and Reich, 1996). Frelich et al. (1993) proposed that unless followed by catastrophic fire, catastrophic windthrow would cause little change in species composition because of the prevalence of advanced regeneration of shade-tolerant species. Using 19th-century land-survey evidence, Whitney (1986) estimated a fire rotation of 1,400 years in hemlock-hardwood forests of northern Lower Michigan. Catastrophic fire in the wake of windthrow would result in the following successional sequence: invasion by shade intolerant species such as aspen and paper birch followed by the encroachment into the disturbed stand by white pine and ending with replacement by shade tolerant species. Evidence of charcoal in the forest floor and fire scars on canopy dominants indicates that stands dominated by hemlock in the overstory are often the result of crown fires (Hix and Barnes, 1984; Simpson et al., 1990). However, the infrequency of fire historically in northern mesic forests is manifest by the paucity of successional species in land survey evidence: less than 5% of the presettlement northern hardwood forest was composed of pioneer species (Frelich and Lorimer, 1991).

Because of the long rotation period of large-scale disturbance in this community type, several generations of trees can pass between catastrophes. As a result, mesic northern forests tend to be multi-generational, with old-growth conditions lasting several centuries in the absence of anthropogenic disturbance (Frelich, 1995). In addition, the high degree of compositional stability of this forest type (Curtis, 1959) allows for ample opportunity for competitive interactions between dominant species to influence the patch structure of the landscape (Frelich et al., 1993). Studying old-growth hemlock-hardwood forest in the Sylvania Wilderness of the western Upper Peninsula, Frelich et al. (1993) concluded that hemlock and sugar maple exhibit strong positive self-association and negative reciprocal association. Each species alters their local environment, creating conditions in their immediate vicinity that favors self-recruitment and discourages establishment of seedlings of the other dominant. Sugar maple is disadvantaged by the dense shade and low nutrient conditions in the podzolized understory of hemlock-dominated stands. In sugar maple-dominated stands, hemlock seedlings are unable to penetrate the thick coarse duff and are often smothered by the ubiquitous leaf fall of sugar maple.

Vegetation Description: The mesic northern forest is a broadly defined community type with numerous regional, physiographic and edaphic variations. The following tolerant trees can dominate or co-dominate the canopy of this community*: Acer saccharum* (sugar maple), *Tsuga canadensis* (eastern hemlock), *Fagus grandifolia* (American beech) and *Betula alleghaniensis* (yellow birch). Other important components of the canopy include: *Tilia americana* (American basswood), *Pinus strobus* (white pine), *Quercus rubra* (red oak), *Thuja occidentalis* (white cedar*), Acer rubrum* (red maple), *Betula papyrifera* (paper or white birch) and *Fraxinus americana* (white ash). Tree species associated with this community but most commonly found in the sub-canopy include: *Ostrya virginiana* (ironwood or hop-hornbeam), *Ulmus americana* (American elm) and *Abies balsamea* (balsam fir).

In terms of their relative importance as arboreal components in the mesic northern forest, these trees differ greatly among themselves in different parts of the region and locally within the same region (Nichols, 1935). Significant variation in composition of communities is proportional to marked differences in local topography, soil, disturbance factors, geographic context (Barnes, 1991) and biotic factors such as competitive interactions (Frelich et al., 1993) and browsing pressure (Alverson et al., 1988).

The leading dominant of this community is sugar maple (Curtis, 1959) which thrives on moderately well drained to excessively drained deep soils (Pregitzer, 1981). Sugar maple is typically found in association with beech, basswood, yellow birch, and red oak. Basswood, characteristic on nutrient rich sites, is most prevalent in mixed-hardwood stands in the western Upper Peninsula. In a study in the McCormick Experimental Forest in the western Upper Peninsula, Pregitzer (1981) found that when ground water or bedrock influences the rooting zone, the proportion of conifers and hardwoods other than sugar maple increases. In the northern Lower Peninsula and in the eastern Upper Peninsula, sugar maple and beech occur commonly as co-dominants, frequently thriving on heavy-textured soils such as silt loam and clay loam. The absence of beech in the western Upper Peninsula is probably due to the increased dryness, shorter growing seasons and extreme minimum winter temperatures of this region (Barnes, 1991).

Conifer-dominated mesic northern forests usually have hemlock and yellow birch as the primary canopy components. Often present in these stands are white cedar and large, but widely spaced white pine, relicts of an earlier successional stage generated by forest fire and/or windthrow (Nichols, 1935). The conifer-dominated stands are generally found on moist or poorly drained sites. Mixed stands of hemlock and yellow birch or pure stands of yellow birch occur primarily in depressions or sites adjacent to swamps (Barnes, 1991).

The ground and shrub layer of mesic northern forests, like the overstory, is diverse in compositional variation. Communities of beech and sugar maple have relatively few shrubs but do support many spring ephemerals and perennial herbs. Stands composed of mixed hardwoods tend to have a well-developed shrub layer and a fairly diverse groundlayer. A plethora of spring ephemeral herbs in these assemblages can be attributed to the development of moisture holding and nutrient-rich soils. Sugar maple, yellow birch and basswood enhance the soil with their nutrient rich leaf-fall. In contrast, in hemlock-dominated stands, groundlayer diversity is low due to the nutrient-poor and acidic mor humus as well as the low understory light intensity caused by the perpetually dense hemlock canopy (Curtis, 1959).

Photo by Joshua G. Cohen

Nurse logs provide critical substrate for seedling establishment.

Prevalent herbs of the mesic northern forest include: *Actaea pachypoda* (white baneberry), *Actaea rubra* (red baneberry), *Allium tricoccum* (wild leek), *Aralia nudicaulis* (wild sarsaparilla), *Aralia racemosa* (spikenard), *Arisaema triphyllum* (jack-in-the-pulpit), *Carex deweyana, Carex hirtifolia, Carex leptonervia, Carex plantaginea, Carex woodii, Caulophyllum thalictroides* (blue cohosh), *Circaea alpina* (enchanter's nightshade), *Circaea lutetiana* (enchanter's nightshade), *Clintonia borealis* (blue-bead lily), *Cornus canadensis* (bunchberry), *Galium triflorum* (bedstraw), *Maianthemum canadense* (Canada mayflower), *Mitchella repens* (partridge berry), *Osmorhiza claytoni* (sweet cicely), *Polygonatum pubescens* (Solomon's seal), *Smilacina racemosa* (false spikenard), *Streptopus roseus* (twisted stalk), *Uvularia grandiflora* (bellwort), *Trientalis borealis* (star flower), *Trillium cernuum* (nodding trillium) and *Trillium grandiflorum* (common trillium).

Common ferns and clubmosses of this community include: *Adiantum pedatum* (maidenhair fern), *Athyrium filix-femina* (lady fern), *Athyrium thelypteroides* (silvery spleenwort), *Botrychium virginianum* (rattlesnake fern), *Dryopteris spinulosa* (spinulose woodfern), *Lycopodium annotinum* (stiff clubmoss), *Lycopodium lucidulum* (shining clubmoss) and *Lycopodium obscurum* (groundpine).

Characteristic shrubs include: *Acer pensylvanicum* (striped maple), *Acer spicatum* (mountain maple or moosewood), *Cornus alternifolia* (alternate-leaved dogwood), *Corylus cornuta* (beaked hazelnut), *Dirca palustris* (leatherwood), *Lonicera canadensis* (fly honeysuckle), *Ribes cynosbati* (wild gooseberry), *Sambucus pubens* (red elderberry), *Taxus canadensis* (Canada yew) and *Viburnum acerifolium* (maple-leaf viburnum). (Above species lists compiled from MNFI database and from Curtis, 1959; Gleason and Cronquist, 1964; and Nichols, 1935.)

A unique feature of this forest type is the presence of chlorophyll-free, parasitic and saprophytic seed plants such as: Indian pipes (*Monotropa* spp.), coral root orchids (*Corallorhiza* spp.) and beech drops (*Epifagus virginiana*) when beech is a component of the forest. These saprophytes are fed by the thick organic matter in the humus layer of the soil and are further benefited by the constant moisture supply (Curtis, 1959).

Michigan indicator species: *Aralia nudicaulis* (wild sarsaparilla), *Betula alleghaniensis* (yellow birch), *Botrychium virginianum* (rattlesnake fern), *Carex hirtifolia, Caulophyllum thalictroides* (blue cohosh), *Circaea alpina* (enchanter's nightshade), *Corylus cornuta* (beaked hazelnut), *Dirca palustris* (leatherwood), *Smilacina racemosa* (false spikenard), *Taxus canadensis* (Canada yew) and *Tsuga canadensis* (hemlock).

Other noteworthy species: Rare plants associated with mesic northern forests include: *Asplenium rhizophyllum* (walking fern, state threatened), *Asplenium scolopendrium* var. *americanum* (Hart's-tongue fern, state endangered), *Asplenium trichomanes-ramosum* (green spleenwort, state special concern), *Botrychium mormo* (goblin moonwort, state threatened), *Carex assiniboinensis* (Assiniboia sedge, state threatened), *Cystopteris laurentiana* (Laurentian fragile fern, state special concern), *Cystopteris tennesseensis* (Tennessee bladder fern, state threatened), *Dryopteris filix-mas* (male fern, state special concern), *Galium kamtschaticum* (bedstraw, state endangered), *Panax quinquefolius* (ginseng, state threatened), *Prosartes hookeri* (fairy bells, state), *Tipularia discolor* (cranefly orchid, state endangered), *Triphora trianthophora* (three-birds orchid, state threatened), and *Viola novae-angliae* (New England violet, state threatened).

Two rare raptor species frequently nest in mesic northern forests: *Buteo lineatus* (red-shouldered hawk, state threatened) and *Accipiter gentilis* (Northern goshawk, state special concern). Extensive tracts of mesic northern forest provide habitat for large mammals such as *Alces americanus* (moose, state special concern), *Canis lupus* (wolf, state threatened) and marten. This community provides summer nesting habitat for many neotropical migrants, especially interior forest obligates such as *Dendroica caerulescens* (black-throated blue warbler), *Dendroica cerulea* (cerulean warbler, state threatened), *Dendroica virens* (black-throated green warbler), *Piranga olivacea* (scarlet tanager) and *Seiurus aurocappilus* (ovenbird). Rapids clubtail (*Gomphus quadricolor*, state special concern) is a rare dragonfly that utilizes quiet water pools and cool rapid streams that flow through mesic northern forests.

Conservation/management: When the primary conservation objective is to maintain biodiversity in mesic northern forests, the best management is to leave large tracts unharvested and to allow natural processes (growth, senescence, windthrow, fire, disease, insect infestation, etc.) to operate unhindered. Lorimer and Frelich (1991) estimated the maximum size of an individual downburst in the Great Lakes region to be 3,785 ha. Given the large-scale of the catastrophic disturbance to the landscape, recovery from perturbation requires protection of substantial area of forest. Johnson and Van Wagner (1985) suggest that a landscape should be at least twice the size of the largest disturbance event.

When tracts of mesic northern forest are being managed for timber harvest, care should be taken to minimize fragmentation, preserve as much area as possible in a forested matrix and maintain a range of canopy closure comparable to pre-harvest closure. Animal species associated with vernal pools and the groundlayer plant community would benefit from winter harvests. Presently, commercial timber harvest is the most common disturbance occurring in this community. Given time to recuperate, mesic northern forests have shown a high degree of resilience following logging disturbance. Metzger and Schultz (1984) and Albert and Barnes (1987) found that 50 years after logging a well-developed herb layer persisted in the understory of harvested stands. Timber management practices that maintain or enhance characteristics of mature structure will help protect the biodiversity value of managed stands. Components of mature structure include: standing snags and dead and down woody material in various stages of decomposition and representing a diversity of species and diameter classes, a diversity of living tree species and an overstory dominated by large diameter trees but including individuals of all age classes.

Research needs: In 1931 George McIntire wrote the following: "Northern Hardwoods as a type has been considered justified because of long, wide and consistent use. This term certainly has been long and widely used but the most consistent thing about it has been the indefiniteness of its application. It is a convenient term but it means little unless accompanied by explicit description." McIntire's turn of the century criticism is still pertinent today and is applicable to the use of the phrase mesic northern forest. Misunderstanding and misuse of the term can be alleviated by the continued refinement of regional classifications that correlate species composition and landscape context.

Given the historical importance of catastrophic windthrow in this system, an important research question to be addressed is how the disturbance regime and species composition of this community will change as the Great Lakes region becomes increasingly fragmented. The prevalence of timber activity in this community demands increased post-harvest monitoring of rare species that depend on this forest and/or old growth conditions. Factors limiting hemlock and yellow birch regeneration need to be continually assessed and techniques for enhancing their regeneration need to be further explored.

Similar communities: mesic southern forest, dry-mesic northern forest, dry northern forest, hardwood-conifer swamp.

Other Classifications:

Michigan Natural Features Inventory Pre-settlement Vegetation (MNFI):
Beech-Sugar Maple-Hemlock, Hemlock-White Pine, Hemlock-Yellow Birch

Michigan Department of Natural Resources (MDNR): M-Northern Hardwoods, H-Hemlock

Michigan Resource Information Systems (MIRIS): 411 (Northern Hardwood), 41101-411109 (Undifferentiated Northern Hardwood), 41111-411119 (Sugar Maple), 41143-41149 (Beech), 41115 (Yellow Birch), 41179 (Basswood), 42 (Coniferous Forest),

The Nature Conservancy National Classification:
CODE; ALLIANCE; ASSOCIATION;
COMMON NAME

I.C.3.N.a; *Tsuga Canadensis-Betula alleghaniensis* Forest Alliance; *Tsuga canadensis-Acer saccahrum-Betula alleghaniensis* Forest; North Central Hemlock-Hardwood Forest.

I.C.3.N.a; *Tsuga Canadensis-Betula alleghaniensis* Forest Alliance; *Tsuga canadensis-Fagus grandifolia-(Acer saccharum)* Great Lakes Forest; Great Lakes Hemlock-Beech-Hardwood Forest.

I.A.8.N.c; *Tsuga Canadensis* Forest Alliance; *Tsuga Canadensis-(Betula alleghaniensis*) Forest; Hemlock Mesic Forest.

I.A.8.N.b; *Pinus strobus-Tsuga canadensis* Forest Alliance; *Pinus strobus-Tsuga canadensis* Great Lakes Forest; Great Lakes White Pine-Hemlock Forest.

I.B.2.N.a; *Acer saccharum-Betula alleghaniensis-(Fagus grandifolia)* Forest Alliance; *Acer saccharum-Betula alleghaniensis-(Tilia americana)* Forest; Maple-Yellow Birch Northern Hardwoods.

I.B.2.N.a; *Acer saccharum-Betula alleghaniensis-(Fagus grandifolia)* Forest Alliance; *Acer saccharum-Fagus grandifoli-Betula spp./Maianthemum canadense* Forest, Beech-Maple-Northern Hardwood Forest.

Related Abstracts: Assiniboia sedge, fairy bells, ginseng, goblin moonwort, Northern goshawk, rapids clubtail, red-shouldered hawk, mesic southern forest, dry-mesic northern forest, dry northern forest, hardwood-conifer swamp.

Selected References:

Albert, D.A. 1995. Regional landscape ecosystems of Michigan, Minnesota, and Wisconsin: A working map and classification. Gen. Tech. Rep. NC-178. St. Paul, MN: USDA, Forest Service, North Central Forest Experiment Station, St. Paul, MN. http://nrs.fs.fed.us/pubs/242 (Version 03JUN1998). 250 pp.

Albert, D.A., J.G. Cohen, M.A. Kost, B.S. Slaughter, and H.D. Enander. 2008. Distribution maps of Michigan's Natural Communities. Michigan Natural Features Inventory, Report No. 2008-01, Lansing, MI. 174 pp.

Albert, D.A. and B.V. Barnes. 1987. Effects of clearcutting on the vegetation and soil of a sugar maple-dominated ecosystem, Western Upper Michigan. Forest Ecology and Management 18: 283-298.

Albert, D.A., S.R. Denton and B.V. Barnes. 1986. Regional landscape ecosystems of Michigan. Ann Arbor, MI: University of Michigan, School of Natural Resources. 32pp & map.

Alverson, S. A., D.M. Waller and S.L. Solheim. 1988. Forests too deer: edge effects in Northern Wisconsin. Conservation Biology 2(4): 348-358.

Barnes, B.V. 1991. Deciduous forests of North America. Pp 219-344 in E. Röhrig and B. Ulrich (eds.) Ecosystems of the World 7: Temperate Deciduous Forests. Elsevier, Amsterdam.

Barnes, B.V., K.S. Pregitzer, T.A. Spies and V. H. Spooner. 1982. Ecological forest site classification. Journal of Forestry 80(8): 493-498.

Canham, C.D. and O.L. Loucks. 1984. Catastrophic windthrow in the presettlement forests of Wisconsin. Ecology 65(3): 803-809.

Comer, P.J., D.A. Albert, H.A. Wells, B.L. Hart, J.B. Raab, D.L. Price, D.M. Kashian, R.A. Corner and D.W. Schuen. 1995. Michigan's Presettlement Vegetation, as Interpreted from the General Land Office Surveys 1816-1856. Michigan Natural Features Inventory, Lansing MI. (digital map)

Curtis, J.T. 1959. Vegetation of Wisconsin: An Ordination of Plant Communities. University. of Wisconsin Press, Madison, WI. 657 pp.

Davis, M.B. 1981. Quaternary history and the stability of forest communities. Pp. 132-153 in D.C. West, H.H. Shugart and D.B. Botkin (eds.) Forest Succession. Springer-Verlag, New York.

Frelich, L.E. 1995. Old forests in the Lake States today and before European settlement. Natural Areas Journal 15(2): 157-167.

Frelich, L.E., R.R. Calcote, M.B. Davis and J. Pastor. 1993. Patch formation and maintenance in an old-growth hemlock-hardwood forest. Ecology 4(2): 513-527.

Frelich, L.E. and C.G. Lorimer. 1991. Natural disturbance regimes in hemlock-hardwood forests of the Upper Great Lakes region. Ecological Monographs 61(2): 145-164.

Gleason, H.A and A. Cronquist. 1964. The natural geography of plants. Columbia University Press, New York. 416 pp.

Graham, S.A. 1941. Climax forests of the Upper Peninsula of Michigan. Ecology 22(4): 355-362.2265 and 42268-42269 (Hemlock).

Hix, D.M. and B.V. Barnes. 1984. Effects of clear-cutting on the vegetation and soil of an eastern hemlock dominated ecosystem, western Upper Michigan. Canadian Journal of Forest Research 14: 914-923.

Johnson, E.A. and C.E. Van Wagner. 1985. The theory and use of two fire history models. Canadian Journal of Forest Research 15: 214-220.

Kost, M.A., D.A. Albert, J.G. Cohen, B.S. Slaughter, R.K. Schillo, C.R. Weber, and K.A. Chapman. 2007. Natural communities of Michigan: Classification and Description. Michigan Natural Features Inventory, Report Number 2007-21, Lansing, MI. 314 pp.

Marks, P.L. and S. Gardescu. 1998. A case study of sugar maple (*Acer saccharum*) as a forest seedling bank species. Journal of the Torrey Botanical Society 125(4): 287-296.

McIntire, G.S. 1931. Theory and practice of forest typing with special relation to the hardwood and hemlock association of Northern Michigan. Michigan Academy of Science Arts and Letters 15: 239-251.

Metzger, F. and J. Schultz. 1984. Understory response to 50 years of management of a northern hardwood forest in Upper Michigan. American Midland Naturalist 112(2): 209-223.

Minnesota DNR- Natural Heritage Program (MNDNR). 1993. Minnesota's native vegetation: a key to natural communities, Version 1.5. St. Paul, MN. 110 pp.

Mladenoff, D.J. and F. Stearns. 1993. Eastern hemlock regeneration and deer browsing in the Northern Great Lakes region: a re-examination and model simulation. Conservation Biology 7(4): 889-900.

Nichols, G.E. 1935. The hemlock-white pine-northern hardwood region of Eastern North America. Ecology 6: 403-422.

Noss, R.F., E.T.L. LaRoe and J.M. Scott. 1995. Endangered ecosystems of the United States: A preliminary assessment of loss and degradation. Washington, DC, National Biological Service, U.S. Dept. of the Interior.

Pregitzer, K.S. 1981. Relationships among physiography, soils and vegetation of the McCormick experimental forest, Upper Michigan Ann Arbor, MI: University of Michigan. 205 pp. Ph.D. dissertation.

Rogers, R. S. 1978. Forests dominated by hemlock (Tsuga canadensis): distribution as related to site and postsettlement history. Can. J. Bot. 56: 843-854.

Rooney, T.P. and D.M. Waller. 1998. Local and regional variation in hemlock seedling establishment in forests of the upper Great Lakes region, USA. Forest Ecology and Management 111; 211-224.

Runkle, J. R. 1982. Patterns of disturbance in some old-growth mesic forests of Eastern North America. Ecology 63(5): 1533-1546.

Stearns, F.W. 1949. Ninety years change in a northern hardwood forest in Wisconsin. Ecology 30(3): 350-358.

Simpson, T.B., P.E. Stuart and B.V. Barnes. 1990. Landscape ecosystems and cover types of the reserve area and adjacent lands of the Huron Mountain Club. Occasional papers of the Huron Mountain Wildlife Foundation 4: 128.

Spies, T.A. and B.V. Barnes. 1985. A multifactor ecological classification of the northern hardwood and conifer ecosystems of Sylvania Recreation Area, Upper Peninsula , Michigan. Canadian Journal of Forest Research 15: 949-960.

Waller, D.M., W.S. Alverson and S. Solheim. Local and regional factors influencing the regeneration of eastern hemlock. Hemlock Symposium Proceedings. 73-90.

Whitney, G.C. 1986. Relation of Michigan's presettlement pine forest to substrate and disturbance history. Ecology 67(6): 1548-1559.

Whitney, G. C. 1987. An ecological history of the Great Lakes forest of Michigan. Journal of Ecology 75: 667-684.

Zhang, Q., Pregitzer K.S. and D.D. Reed. 2000. Historical changes in the forests of the Luce district of the Upper Peninsula of Michigan. Am. Midl. Nat. 143: 94-110.

Abstract Citation:

Cohen, J.G. 2000. Natural community abstract for mesic northern forest. Michigan Natural Features Inventory, Lansing, MI. 9 pp.

Photo by Michael A. Kost

Old-growth mesic northern forest, Porcupine Mountains.

Update June 2010.

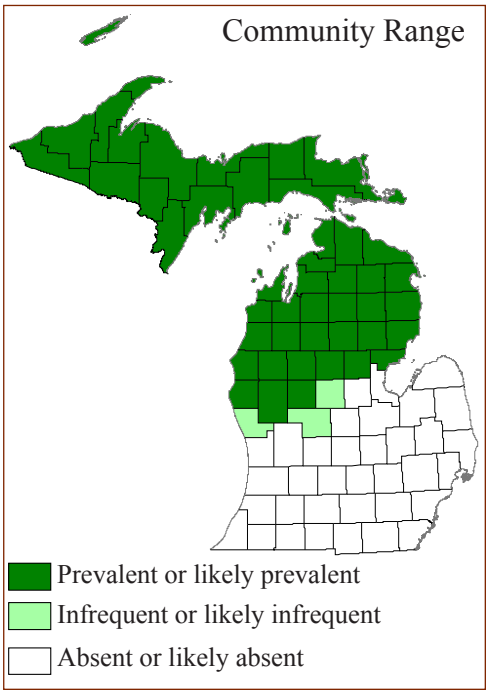
Copyright 2004 Michigan State University Board of Trustees.

Michigan State University is an affirmative-action, equal-opportunity organization.

Funding for abstract provided by Michigan Department of Natural Resources-Forest Management Division and Wildlife Division.

Northern Wet Meadow — Community Abstract

Photo by Joshua G. Cohen



Overview: Northern wet meadow is an open, groundwater-influenced, sedge- and grass-dominated wetland that occurs in the northern Lower and Upper Peninsulas and typically borders streams but is also found on pond and lake margins and above beaver dams. Soils are nearly always sapric peat and range from strongly acid to neutral pH. Open conditions are maintained by seasonal flooding, beaver-induced flooding, and fire.

Global and State Rank: G4G5/S4

Range: Northern wet meadow, which is commonly referred to as sedge meadow, occurs in Michigan, Minnesota, North Dakota, Wisconsin, and Ontario. In Michigan, northern wet meadow is thought to occur in the northern half of the Lower Peninsula above the climatic transition zone and throughout the Upper Peninsula and to differ from sedge meadows in southern Michigan (Kost 2001). However, no detailed study of the differences between northern and southern types has been undertaken in Michigan. Curtis (1959) studied sedge meadows in northern and southern Wisconsin and found them to be floristically similar but concluded that northern meadows had consistently lower soil pH values and were frequently wetter and smaller than many southern wet meadows. In Michigan, southern wet meadows are dominated primarily by *Carex stricta* (tussock sedge) while northern wet meadows can be dominated or co-dominated by several additional sedges and/or *Calamagrostis canadensis* (blue-joint grass) (Faber-Langendoen 2001, NatureServe 2006, Kost et al. 2007). Another sedge-dominated natural community, poor fen, also occurs in Michigan but differs markedly from sedge meadow because of its acidic, organic soils, and the prevalence of *Carex oligosperma* (few-seed sedge) and other open bog species (Kost and Cohen 2005, Kost et al. 2007).

Rank Justification: Because northern wet meadow often occurs as a zone within large wetland complexes, information on its historical extent and present acreage is not readily available. However, in Wisconsin, where 459,000 ha (1,130,000 acres) of sedge meadow are thought to have existed circa 1800 (Curtis 1959), it is estimated that less than one percent remain intact (Reuter 1986). It is likely that wet meadow acreage has declined similarly in other Midwest states, such as Michigan, where similar agricultural methods have been practiced. Northern wet meadows have fared slightly better than southern wet meadows because agriculture and development have been less extensive north of the climatic tension zone (Hoffman 2002).

Northern wet meadows have been extensively utilized for agriculture. Prior to the 1950s, mowing for marsh hay was widely practiced (Stout 1914, Curtis 1959, Eggers and Reed 1997). Wet meadows were frequently tiled, ditched, drained, and converted to pasture and row crops or mined for peat or muck (Costello

Michigan Natural Features Inventory
P.O. Box 30444 - Lansing, MI 48909-7944
Phone: 517-373-1552

Ecoregional map of Michigan (Albert 1995) depicting distribution of northern wet meadow (Albert et al. 2008)

Michigan Natural Features Inventory
P.O. Box 30444 - Lansing, MI 48909-7944
Phone: 517-373-1552

1936, Curtis 1959, Reuter 1986, Eggers and Reed 1997). The hydrology of these systems is currently threatened by the reduction and diversion of surface runoff, channelization of stream flow, lowering local groundwater discharge, and deterioration of water quality (Reuter 1986). Lowering of the water table has caused the conversion of many sedge meadows to shrub thickets (Curtis 1959, Reuter 1986, Eggers and Reed 1997). In addition, fire suppression has allowed shrub encroachment with many sedge meadows converting to shrub thicket within ten to twenty years (Curtis 1959, White 1965, Davis 1979, Reuter 1986, Jean and Bouchard 1991). This is especially evident where the water table has been lowered through tiling or ditching and where the practice of mowing for marsh hay has been abandoned (White 1965, Eggers and Reed 1997). Drastic reductions in beaver populations following the fur-trading era significantly altered the hydrologic regimes of wetland ecosystems across the Great Lakes. In the absence of periodic long-term flooding by beaver, many streamside northern wet meadows have gradually converted to northern shrub thickets. Alteration of the fire and hydrologic regimes has allowed for the invasion of sedge meadows by pernicious non-native species, especially *Lythrum salicaria* (purple loosestrife), *Rhamnus cathartica* (common buckthorn), and *Rhamnus frangula* (glossy buckthorn) (Reuter 1986).

Photo by Joshua G. Cohen

Lowering of the water table or fire suppression can result in the conversion of northern wet meadow to northern shrub thicket.

Landscape and Abiotic Context: Northern wet meadow occurs on glacial lakebeds, in channels of glacial outwash, and in depressions on glacial outwash and moraines (Curtis 1959, Reuter 1986, Faber-Langendoen 2001, Hoffman 2002, NatureServe 2005, NatureServe 2006). The community frequently occurs along the margins of lakes, ponds, and streams where seasonal flooding or beaver-induced flooding is common (Curtis 1959, Reuter 1986, Hoffman 2002).

Northern wet meadow typically occurs on organic soils such as well-decomposed sapric peat (Curtis 1959), but saturated mineral soil may also support the community (Costello 1936, Curtis 1959, Faber-Langendoen 2001, NatureServe 2006). Because of the calcareous nature of the glacial drift in many of the regions occupied by wet meadow, its wet soils can contain high levels of dissolved minerals such as calcium and magnesium and occasionally the soil profile may include a layer of marl, a whitish, calcium carbonate precipitate that forms in shallow water rich in calcium- and magnesium carbonates. Northern wet meadow soils range from strongly acid to neutral (pH 5.1 to 7.3). However, the organic soils near the surface of northern wet meadow are typically more acidic than soils occurring in southern wet meadow, which is found on neutral to strongly alkaline soils (Costello 1939, Curtis 1959, Warners 1993).

Northern wet meadow is found adjacent to other wetland communities, often in large wetland complexes. Along streams, northern wet meadow typically borders northern shrub thicket and swamp forest (Curtis 1959).

Photo by Joshua G. Cohen

Northern wet meadow often occurs in large wetland complexes and grades into northern shrub thicket.

Michigan Natural Features Inventory
P.O. Box 30444 - Lansing, MI 48909-7944
Phone: 517-373-1552

On the edges of inland lakes, northern wet meadow often borders emergent marsh and less frequently northern fen. It may also occur along the margins of patterned peatlands and within extensive areas of Great Lakes marsh along the Great Lakes shoreline.

The Michigan range of northern wet meadow falls within the area classified by Braun (1950) as the Northern Hardwood-Conifer Region (Hemlock/White Pine/ Northern Hardwoods Region) and within the following regions classified by Albert et al. (1986) and Albert (1995): Region II, Northern Lower Michigan; Region III, Eastern Upper Michigan; and Region IV, Western Upper Michigan. The Northern Hardwood-Conifer Region has a cool snow-forest climate with short, warm summers, cold winters, and a large number of cloudy days. The daily maximum temperature in July ranges from 24 to 29 °C (75 to 85 °F), the daily minimum temperature in January ranges from -21 to -9 °C (-5 to 15 °F) and the mean annual temperature is 7 °C (45 °F). The mean number of freeze-free days is between 90 and 160, and the average number of days per year with snow cover of 2.5 cm (1 in) or more is between 80 and 140. The normal annual total precipitation ranges from 740 to 900 mm (30 to 35 in) with a mean of 823 mm (32 in) (Albert et al. 1986, Barnes 1991, Albert 1995). Northern wet meadows are characterized by local climates with lower temperatures and evaporation rates and shorter growing seasons than the surrounding uplands (Curtis 1959).

Natural Processes: Northern wet meadow is a groundwater-dependent, graminoid-dominated, wetland community. Water levels in northern wet meadow fluctuate seasonally, reaching their peaks in spring and lows in late summer (Costello 1936, Warners 1993). However, water levels typically remain at or near the soil's surface throughout the year (Costello 1936, Curtis 1959, Warners 1993, Eggers and Reed 1997). The community's structure may depend on the maintenance of a consistently high water table. Costello (1936) stated that the *Carex stricta* tussocks disappeared within ten years from a meadow where the water levels were reduced to two to four feet below the surface as a result of tiling. In addition to seasonal flooding, beaver-induced flooding may also play an important role in maintaining the community by occasionally raising water levels and killing encroaching trees and shrubs. Beaver can also help create new northern wet meadows by flooding swamp forests and northern shrub thickets and thus creating suitable habitat for the growth of shade-intolerant wet meadow species.

Photo by Joshua G. Cohen

Beaver flooding along streams can create and maintain northern wet meadow.

Photo by Joshua G. Cohen

Evidence from wetland peat cores and circa 1800 vegetation maps indicate fire is also an important disturbance factor within northern wet meadow (Curtis 1959, Davis 1979). Analysis of wetland peat cores shows that charcoal fragments are consistently associated with sedge and grass pollen (Davis 1979). Conversely, charcoal fragments are lacking from sections of peat cores dominated by shrub pollen. Fires typically occur in sedge meadows during dry conditions of early spring or late fall (White 1965). By reducing leaf litter and allowing light to reach the soil surface and

stimulate seed germination, fire can play an important role in maintaining wet meadow seed banks and species diversity (Warners 1997, Kost and De Steven 2000). Fire also plays a critical role in maintaining species richness in many community types by creating micro-niches for small species and temporarily reducing competition from robust perennials (Leach and Givnish 1996). In the absence of fire, a thick layer of leaf litter can develop that stifles seed germination and seedling establishment. Another critically important attribute of fire for maintaining open sedge meadow is its ability to temporarily reduce shrub cover (White 1965, Reuter 1986, Hoffman 2002). In the absence of fire or flooding, all but the wettest sedge meadows typically convert to shrub thicket and eventually swamp forest (Curtis 1959). Because many of the species that inhabit wet meadow are shade-intolerant, species richness usually declines following shrub and tree invasion (Curtis 1959, White 1965, Reuter 1986).

Vegetation Description: Northern wet meadow is a sedge-dominated system that typically has 100% vegetative cover in the ground layer (Curtis 1959, Eggers and Reed 1997) and is often dominated by *Carex stricta* (tussock sedge) (Stout 1914, Costello 1936, Curtis 1959, Warners 1997, Kost and De Steven 2000). Because the roots of *Carex stricta* form large hummocks or tussocks, the species is often responsible for the community's hummock and hollow structure. Individual culms of *Carex stricta* grow from the tussocks, which may reach more than one meter in height and half a meter in diameter and live for more than 50 years (Costello 1936). The *Carex stricta* tussocks can occur at very high densities (1 to 4 per m^2) and occupy more than 40% of a meadow's area (Costello 1936). Because the shaded areas between tussocks are often covered with standing water and leaf litter, many of the shorter species inhabiting sedge meadows grow almost exclusively from the sides or tops of *Carex stricta* tussocks.

Other sedges that commonly occur in northern wet meadow include: *Carex aquatilis* (water sedge), *C. bebbii* (Bebb's sedge), *C. buxbaumii* (Buxbaum's sedge), *C. comosa* (long-hair sedge), *C. hystericina* (bottlebrush sedge), *C. lacustris* (lake or hairy sedge), *C. lasiocarpa* (wiregrass sedge), *C. pellita* (woolly sedge), *C. rostrata* (beaked sedge), *C. stipata* (saw-beak sedge), *C. vesicaria* (blister sedge), and *C. vulpinoidea* (fox sedge). Although most of the associated sedge species tend to be randomly interspersed, *Carex lacustris*, *C. lasiocarpa*, *C. rostrata*, and *C. vesicaria* can often occur as dominants or co-dominants.

The most dominant grass species in northern wet meadow is *Calamagrostis canadensis* (blue-joint grass) (Stout 1914, Kost and De Steven 2000). Other common grasses include: *Bromus ciliatus* (fringed brome), *Glyceria canadensis* (manna grass), *G. striata* (fowl manna grass), *Muhlenbergia glomerata* (marsh wild timothy), *M. mexicana* (leafy satin grass), and *Poa palustris* (fowl meadow grass). *Eleocharis erythropoda* (bald spike-rush), *Typha latifolia* (broad-leaved cat-tail), *Cladium marisicoides* (twig-rush), and *Scirpus atrovirens* (green bulrush) are also common graminoids. Sedge meadows disturbed by agricultural use, grazing, drainage, and/or filling are frequently dominated by *Phalaris arundinaceae* (reed canary grass), an extremely aggressive grass that forms persistent, monotypic stands (Eggers and Reed 1997).

A wide variety of wetland forbs occur scattered in northern wet meadow. Due to the high moisture conditions during the spring, many of the forbs bloom in the summer and fall (Curtis 1959, Hoffman 2002). The following are some of the more common species: *Anemone canadensis* (Canada anemone), *Asclepias incarnata* (swamp milkweed), *Aster lanceolatus* (eastern-line aster), *A. lateriflorus* (side-flowering aster), *A. puniceus* (swamp aster), *A. umbellatus* (flat-topped white aster), *Campanula aparinoides* (marsh bellflower), *Cicuta bulbifera* (water-hemlock), *C. maculata* (water-hemlock), *Cirsium muticum* (swamp thistle), *Epilobium strictum* (downy willowherb), *Eupatorium maculatum* (joe-pye-weed), *E. perfoliatum* (common boneset), *Euthamia graminifolia* (grass-leaved goldenrod), *Galium asprellum* (rough bedstraw), *G. trifidum* (small bedstraw), *Impatiens capensis* (jewelweed), *Iris versicolor* (wild blue flag), *Lathyrus palustris* (marsh pea), *Lycopus americanus* (American water-horehound), *L. uniflorus* (northern bugleweed), *Lysimachia thyrsifolia* (tufted loosestrife), *Mentha arvensis* (wild mint), *Polygonum amphibium* (water smartweed), *Potentilla palustris* (marsh cinquefoil), *Rumex orbiculatus* (greater water dock), *Sagittaria latifolia* (common arrowhead), *Scutellaria galericulata* (common skullcap), *Solidago canadensis* (Canada goldenrod), *S. gigantea* (late goldenrod), *S. patula* (swamp goldenrod), *Thalictrum dasycarpum* (purple meadow rue), *Triadenum fraseri* (marsh St. John's-

Meandering streams, sedge tussocks, and scattered trees and shrubs are prevalent structural attributes of northern wet meadows that influence floristic and faunal composition. Top photo by Michael A. Kost. Bottom photo by Joshua G. Cohen.

wort), *Verbena hastata* (blue vervain), and *Viola cucullata* (marsh violet). Characteristic fern or fern allies include *Dryopteris cristata* (crested woodfern), *Equisetum arvense* (common horsetail), *E. fluviatile* (water horsetail), *Onoclea sensibilis* (sensitive fern), and *Thelypteris palustris* (marsh fern).

Northern wet meadow can also contain numerous, scattered shrub and tree species. Shrub and tree encroachment is especially pronounced in sites that have altered flooding or fire regimes. Prevalent shrubs include *Alnus rugosa* (tag alder or speckled alder), *Betula pumila* (bog birch), *Cornus stolonifera* (red-osier dogwood), *Potentilla fruticosa* (shrubby cinquefoil), *Salix* spp. (willows), *Spiraea alba* (meadowsweet), and *S. tomentosa* (steeplebush). Scattered trees and tree saplings are often found invading northern wet meadow. Typical tree species include *Acer rubrum* (red maple), *Fraxinus nigra* (black ash), *Larix laricina* (tamarack), *Populus balsamifera* (balsam poplar), *P. tremuloides* (quaking aspen), and *Thuja occidentalis* (northern white-cedar). (Above species lists compiled from Michigan Natural Features Inventory database, Curtis 1959, Reuter 1986, Eggers and Reed 1997, Faber-Langendoen 2001, Hoffman 2002, NatureServe 2006)

Michigan Indicator Species: blue-joint grass, common boneset, greater water dock, joe-pye-weed, lake sedge, marsh bellflower, northern bugleweed, swamp aster, tussock sedge, and tufted loosestrife.

Other Noteworthy Species: Several rare plants can be found in northern wet meadow and associated open wetlands including *Cacalia plantaginea* (prairie indian-plantain, state special concern), *Carex wiegandii* (Wiegand's sedge, state special concern), *Gentiana linearis* (narrow-leaved gentian, state threatened), *Parnassia palustris* (marsh grass-of-Parnassus, state threatened), *Petasites sagittatus* (sweet coltsfoot, state threatened), *Silene nivea* (evening campion, state endangered), and *Vaccinium cespitosum* (dwarf bilberry, state threatened), which is the host plant for *Lycaeides idas nabokovi* (northern blue butterfly, state threatened).

Northern wet meadow provides habitat for numerous herptiles such as *Clemmys guttata* (spotted turtle, state threatened), *Emydoidea blandingii* (Blanding's turtle, state special concern), *Glyptemys insculpta* (wood turtle, state special concern), *Pseudacris triseriata maculata* (boreal chorus frog, state special concern), and *Sistrurus catenatus catenatus* (eastern massasauga, state special concern, federal candidate species). The late-blooming composites found in sedge meadows supply an important food source for insects, which in turn support songbirds. The hummock -hollow microtopography provides excellent nesting habitat for wetlands birds (Eggers and Reed 1997). Rare birds that utilize these wetlands include *Asio flammeus* (short-eared owl, state endangered), *Botaurus lentiginosus* (American bittern, state special concern), *Chlidonias niger* (black tern, state special concern), *Circus cyaneus* (northern harrier, state special concern), *Cistothorus palustris* (marsh wren, state special concern), *Coturnicops noveboracensis* (yellow rail, state threatened), *Gallinula chloropus* (common moorhen, state threatened), *Ixobrychus exilis* (least bittern, state threatened), *Phalaropus tricolor* (Wilson's phalarope, state special concern), *Rallus elegans* (king rail, state endangered), and *Sterna forsteri* (Forster's tern, state threatened). *Alces americanus* (moose, state special concern), *Canis lupus* (gray wolf, state threatened), and *Lynx canadensis* (lynx, state endangered) utilize sedge meadow habitat. *Oncocnemis piffardi* (three-striped oncocnemis, state special concern moth) utilizes northern wet meadows, especially where its host plant meadowsweet is prevalent.

Photo by Joshua G. Cohen

Northern wet meadows contribute significantly to the overall biodiversity of northern Michigan and also provide important ecosystem services.

Conservation and Biodiversity Management: Northern wet meadows contribute significantly to the overall biodiversity of northern Michigan by providing habitat to a wide variety of plant and animal species including numerous rare species. In addition, sedge meadows provide ecosystem services, protecting water

quality by assimilating nutrients, trapping sediment, and retaining storm and floodwater (Eggers and Reed 1997). Protecting the hydrology of northern wet meadow is imperative for the community's continued existence and includes avoiding surface water inputs to meadows from drainage ditches, agricultural fields, road construction, and logging in the adjacent uplands, and protecting groundwater recharge areas by maintaining native vegetation types in the uplands surrounding the community. Resource managers operating in uplands adjacent to sedge meadows should take care to minimize the impacts of management to hydrologic regimes, especially increased surface flow. This can be accomplished by establishing no-cut buffers around wet meadows and avoiding road construction and complete canopy removal in stands immediately adjacent to wetlands.

Photo by Joshua G. Cohen

Protecting the hydrology of northern wet meadow is critical for the community's ecological integrity and persistence.

In fire-prone landscapes, management for wet meadow should include the use of prescribed fire (Curtis 1959, White 1965). Prescribed fire can help reduce litter, stimulate seed germination, promote seedling establishment, and bolster grass, sedge, and perennial and annual forb cover (Bowles et al. 1996, Warners 1997, Kost and De Steven 2000). While prescribed fire can be an important tool for rejuvenating wet meadow seed banks, it can also help ensure that the community remains in an open condition by temporarily setting back invading woody species (Reuter 1986). Using prescribed fire to control shrub invasion in sedge meadows has also been shown to be 85% less expensive to implement than manual cutting (Reuter 1986). Prescribed fire should not be utilized during periods of drought to avoid igniting the community's organic soils (Curtis 1959, Vogl 1969). Burning in the early spring while the soil moisture is high reduces the chances of destroying the organic soils (Reuter 1986), however, growing season burns can be more effective at reducing aggressive woody vegetation (Bowles et al. 1996). If prescribed burning is not feasible, mowing can be used to temporarily reduce woody plant cover but should be restricted to the winter, when ground frost will reduce disturbance to soils, herbaceous plants, and hydrology, or late summer and fall when the meadows are dry (White 1965, Reuter 1986). In situations where shrub encroachment is severe, resource managers may need to cut invading shrubs and herbicide the cut stumps, especially for shrub species that are capable of resprouting, like *Alnus rugosa* (tag alder or speckled alder) or *Rhamnus frangula* (glossy buckthorn) (Heidorn 1991).

Invasive species that can occur in northern wet meadow include glossy buckthorn, common buckthorn, purple loosestrife, reed canary grass, *Typha angustifolia* (narrow-leaved cat-tail), *Typha* x*glauca* (hybrid cat-tail), *Rosa multiflora* (multiflora rose), and *Phragmites australis* (reed). Each of these species is capable of significantly altering northern wet meadow community structure and dramatically reducing species richness. Management should strive to prevent the establishment and spread of these invasive. Establishment of invasive species can be prevented by maintaining the hydrologic and fire disturbance regimes and avoiding grazing (Reuter 1986).

Restoration of degraded northern wet meadows depends on the occurrence of water-saturated peat and muck soils, maintenence of waters levels very near the soil surface throughout the year, protection from shrub encroachment and invasive species, and the availability of appropriate seed stock (Reuter 1986). Finding viable seed for sedges, the plant group responsible for the overall structure of wet meadow, may be a difficult task. Costello (1936) reports that in more than six years of studying *Carex stricta*–dominated sedge meadows he did not find a single seedling of the species. Because of the difficulty of restoring wet meadow in the absence of favorable hydrology and intact organic soils, conservation efforts should focus on protecting the remaining community occurrences (Reuter 1986).

Research Needs: Further work on community classification is needed to elucidate differences among sedge meadow types both within and among ecoregions (Reuter 1986). More studies need to focus on the flooding and fire regimes of northern wet meadow and the interaction of disturbance factors. As noted by Hammerson (1994), beaver significantly alter the ecosystems they occupy. An important research question to examine is how the wetland ecosystems of the Great Lakes have been and continue to be affected by the fluctuating beaver population. Experimentation is needed to determine how best to prevent shrub encroachment of open wetlands that are threatened by conversion to northern shrub thicket (Reuter 1986). The examination of non-native plant establishment in northern wet meadows and means of controlling invasive species is critical. In addition, scientists should gain an understanding of plant and animal community responses to the frequency and seasonal timing of prescribed burning and anthropogenic flooding. Effects of management within northern wet meadow need to be monitored to allow for assessment and refinement of management techniques. Conservation and management of northern wet meadow will be stimulated by research on the importance of the community for maintaining rare species and regional biodiversity.

Photo by Joshua G. Cohen

Important research needs include ascertaining how flooding and fire interact at both the landscape and local scales to influence northern wet meadows and associated wetlands.

Similar Communities: emergent marsh, Great Lakes marsh, intermittent wetland, southern wet meadow, northern fen, northern shrub thicket, patterned fen, poor fen, wet-mesic sand prairie, and wet prairie.

Other Classifications:

Michigan Natural Feature Inventory (MNFI) Circa 1800 Vegetation: Wet Meadow (6224), Emergent Marsh or Shrub Swamp (6221)

Michigan Department of Natural Resources (MDNR): L-lowland brush, N-marsh, V-bog

Michigan Resource Information Systems (MIRIS): 622 (emergent wetland)

Integrated Forest Monitoring, Assessment, and Prescription (IFMAP): Emergent Wetland (623), Mixed Non-Forest Wetland (629)

The Nature Conservancy National Classification: CODE; ALLIANCE; ASSOCIATION; COMMON NAME

V.A.5.N.k; *Calamagrostis canadensis* Seasonally Flooded Herbaceous Alliance; *Calamagrostis canadensis – Phalaris arundinacea* Herbaceous Vegetation; Bluejoint – Reed Canary Grass Herbaceous Vegetation; Bluejoint Wet Meadow.

V.A.5.N.k; *Carex aquatilis* Seasonally Flooded Herbaceous Alliance; *Carex aquatilis – Carex* spp. Herbaceous Vegetation; Aquatic Sedge – Sedge Species Herbaceous Vegetation; Water Sedge Wet Meadow.

V.A.5.N.k; *Carex lacustris* Seasonally Flooded Herbaceous Alliance; *Carex lacustris* Herbaceous Vegetation; Lake Sedge Herbaceous Vegetation; Lake Sedge Wet Meadow.

V.A.5.N.k; *Carex* (*rostrata, urticulata*) Seasonally Flooded Herbaceous Alliance; *Carex rostrata – Carex lacustris* – (*Carex vesicaria*) Herbaceous Vegetation; Swollen-Beak Sedge – Lake Sedge – (Inflated Sedge) Herbaceous Vegetation; Northern Sedge Wet Meadow.

V.A.5.N.k; *Carex stricta* Seasonally Flooded Herbaceous Alliance; *Carex stricta – Carex* spp. Herbaceous Vegetation; Tussock Sedge – Sedge Species Herbaceous Vegetation; Tussock Sedge Wet Meadow.

NatureServe Ecological Systems Classification:

CES201.582: Laurentian-Acadian Wet Meadow Shrub Swamp

CES202.701: North-Central Interior Wet Meadow-Shrub Swamp

Related Abstracts: American bittern, black tern, Blanding's turtle, dwarf bilberry, eastern massasauga, floodplain forest, Forster's tern, Great Lakes marsh, prairie Indian-plantain, intermittent wetland, king rail, least bittern, marsh grass-of-Parnassus, northern blue butterfly, northern fen, northern harrier, northern shrub thicket, poor fen, short-eared owl, southern wet meadow, spotted turtle, sweet coltsfoot, wood turtle, and yellow rail.

References:

Albert, D.A. 1995. Regional landscape ecosystems of Michigan, Minnesota, and Wisconsin: A working map and classification. Gen. Tech. Rep. NC-178. St. Paul, MN: USDA, Forest Service, North Central Forest Experiment Station, St. Paul, MN. http://nrs.fs.fed.us/pubs/242 (Version 03JUN1998). 250 pp.

Albert, D.A., J.G. Cohen, M.A. Kost, B.S. Slaughter, and H.D. Enander. 2008. Distribution maps of Michigan's Natural Communities. Michigan Natural Features Inventory, Report No. 2008-01, Lansing, MI. 174 pp.

Albert, D.A., S.R. Denton, and B.V. Barnes. 1986. Regional landscape ecosystems of Michigan. Ann Arbor, MI: University of Michigan, School of Natural Resources. 32 pp. & map.

Barnes, B.V. 1991. Deciduous forest of North America. Pp 219-344 *in* E. Röhrig and B. Ulrich, eds., Temperate Deciduous Forests. Elsevier, Amsterdam. 635 pp.

Braun, E.L. 1950. Deciduous Forests of Eastern North America. Hafner Press, New York, NY. 596 pp.

Bowles, M., J. McBride, N. Stynoff, and K. Johnson. 1996. Temporal changes in vegetation composition and structure in a fire-managed prairie fen. Natural Areas Journal 16: 275-278.

Comer, P., D. Faber-Langendoen, R. Evans, S. Gawler, C. Josse, G. Kittel, S. Menard, M. Pyne, M. Reid, K. Schulz, K. Snow, and J. Teague. 2003. Ecological Systems of the United States: A Working Classification of U.S. Terrestrial Systems. NatureServe, Arlington, Virginia.

Costello, D.F. 1936. Tussock meadows in southeastern Wisconsin. Botanical Gazette 97: 610-48.

Curtis, J.T. 1959. Vegetation of Wisconsin: An Ordination of Plant Communities. University of Wisconsin Press, Madison, WI. 657 pp.

Davis, A. M. 1979. Wetland succession, fire and the pollen record: A Midwestern example. American Midland Naturalist 102: 86-94.

Eggers, S.D., and D.M. Reed. 1997. Wetland plants and plant communities of Minnesota and Wisconsin. U.S. Army Corps of Engineers, St Paul, Minnesota. 263 pp.

Faber-Langendoen, D. (editor). 2001. Plant communities of the Midwest: Classification in an ecological context. Association for Biodiversity Information, Arlington, VA. 61 pp. + appendix (705 pp.).

Hammerson, G. 1994. Beaver (*Castor canadensis*): Ecosystem alterations, management, and monitoring. Natural Areas Journal 14(1): 44-57.

Heidorn 1991. Vegetation management guidelines: Buckthorns. Natural Areas Journal 11: 216-217

Hoffman, R. 2002. Wisconsin's Natural Communities. How to recognize them, where to find them. The University of Wisconsin Press, Madison, WI. 375 pp.

Leach, M.K. and T.J. Givnish. 1996. Ecological determinants of species loss in remnant prairies. Science 273: 1555-1558.

Jean, M., and A. Bouchard. 1991. Temporal changes in wetland landscapes of a section of the St. Lawrence River, Canada. Environmental Management 15(2): 241-250.

Kost, M.A. 2001. Natural community abstract for southern wet meadow. Michigan Natural Features Inventory, Lansing, MI. 5 pp.

Kost, M.A., D.A. Albert, J.G. Cohen, B.S. Slaughter, R.K. Schillo, C.R. Weber, and K.A. Chapman. 2007. Natural communities of Michigan: Classification and description. Michigan Natural Features Inventory, Report Number 2007-21, Lansing MI. 314 pp.

Kost, M.A., and D. De Steven. 2000. Plant community responses to prescribed burning in Wisconsin sedge meadows. Natural Areas Journal 20: 36-49.

Kost, M.A., and J.G. Cohen. 2005. A Reassessment of High Quality Natural Communities on Camp Grayling. Report for Michigan Dept. of Military and Veterans Affairs, Camp Grayling, MI. Michigan Natural Features Inventory report number 2005-11. 124pp.

NatureServe. 2005. International Ecological Classification Standard: Terrestrial Ecological Classifications. NatureServe Central Databases. Arlington, VA. U.S.A. Data current as of January 13, 2005.

NatureServe. 2006. NatureServe Explorer: An online encyclopedia of life [web application]. Version 4.2. NatureServe, Arlington, Virginia. Available: http://www.natureserve.org/explorer. (Accessed: March 03, 2005.)

Reuter, D.D. 1986. Sedge meadows of the upper Midwest: A stewardship summary. Natural Areas Journal 6(4): 27-34.

Stout, A.B. 1914. A biological and statistical analysis of the vegetation of a typical wild hay meadow. Transactions of the Wisconsin Academy of Sciences, Arts, and Letters 17: 405-57.

Vogl, R.J. 1969. One hundred and thirty years of plant succession in a Southeastern Wisconsin lowland. Ecology 50: 248-55.

Warners, D.P. 1993. Species diversity in southern Michigan sedge meadows. Unpublished report to The Nature Conservancy, Michigan Chapter, East Lansing, MI 35 pp.

Warners, D.P. 1997. Plant diversity in sedge meadows: Effects of groundwater and fire. Ph.D. dissertation, University of Michigan, Ann Arbor, MI. 231 pp.

White, K.L. 1965. Shrub-carrs of southeastern Wisconsin. Ecology 46: 286-304.

Abstract Citation:

Cohen, J.G., and M.A. Kost. 2007. Natural community abstract for northern wet meadow. Michigan Natural Features Inventory, Lansing, MI. 11 pp.

Updated June 2010.

Copyright 2007 Michigan State University Board of Trustees.

Michigan State University Extension is an affirmative-action, equal-opportunity organization.

Funding for abstract provided by Michigan Department of Military and Veterans Affairs.

Northern wet meadow adjacent to granite bedrock glade, Marquette County. Photo by Joshua G. Cohen.