Dowagiac River Restoration

Final Assessment Report

June 27, 2013

Prepared for:

Pokagon Band of Potawatomi
58620 Sink Road
Dowagiac, MI 49047

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TABLE OF CONTENTS

INTRODUCTION

The Pokagon Band of Potawatomi Indians are one of the only native american tribes within the midwest that reside on their ancestral lands. Though many of the Potawatomi people were subjected to the forced removal policy of the US government and moved to reservations in the west, a small band under the direction of Chief Leopold Pokagon were able to remain. Silver Creek and Pokagon Townships within Cass County encompass most of the current land holdings of the tribe. The Dowagiac River flows through these townships and within tribal lands. True to the tribal culture of respect for Mother Earth, the band has endeavored to heal historic impacts created by the channelization of the Dowagiac.

The management of waterways has evolved across the nation as science has illuminated the correlation between healthy river corridors and clean drinking water, flood abatement, and nutrient processing among a multitude of other beneficial relationships. No longer are the goals of development (primarily agriculture here) and healthy rivers in opposition, with techniques to successfully accomplish both well understood and proven. Benefits of healthy river systems for fishing, hunting, paddling, and the general aesthetics of a natural system are valued in both urban and rural communities. For these reasons many local stakeholders are seeking river revitalization as both an economic and ecological positive for the community.

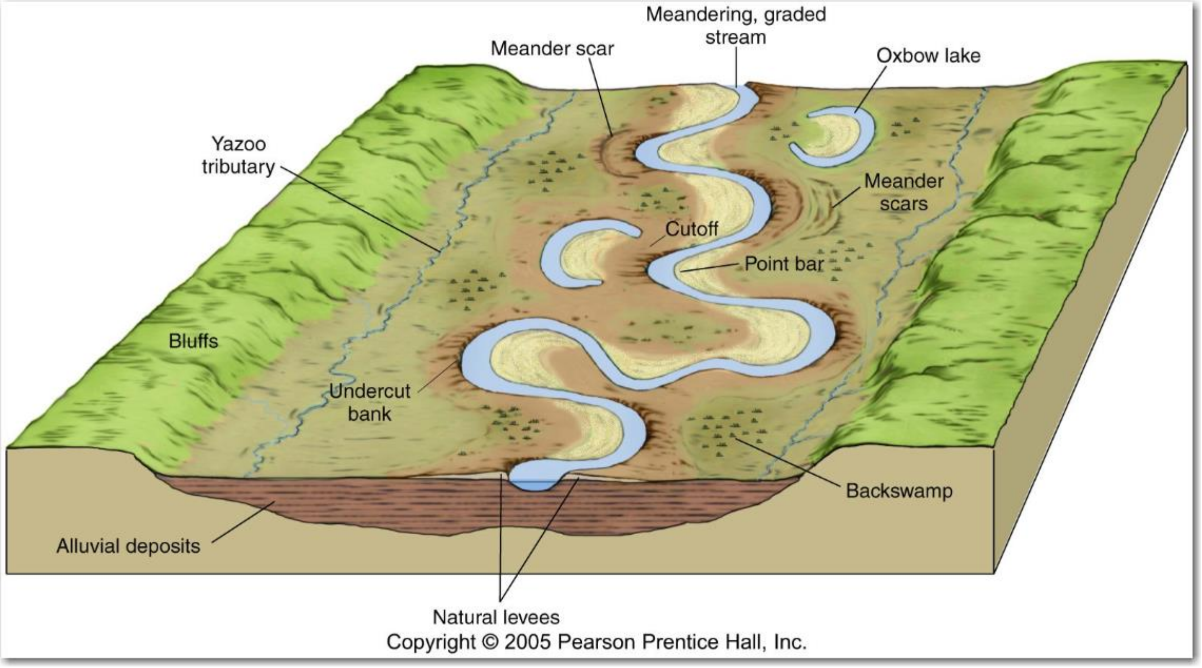

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Figure 1. The valley of the historic Dowagiac River is very similar to this drawing. Channelization in the early 1900s cut a straight channel through the valley, restoration seeks to return to this more natural condition, depicted here.

PROJECT GOALS

The boundaries for this restoration project run approximately from Peavine Street to just above Crystal Springs Street at the tribal property boundary. Discussions with tribal biologists have outlined a set of *Project Goals* that are used to inform and guide the design approach. Goals were developed specific to the two major elements of the river corridor, the river channel itself, and the floodplain on either side of the channel (Figure

2). Project goals have been discussed with the tribe and categorized into goals related to the channel proper and the adjacent floodplain of the system.

Dowagic River Channel

- Increase frequency of pool habitat and riffle habitat (if appropriate)
- Restore sinuosity and meanders to near pre-channelization conditions
- Re-establish more natural patterns of scour and deposition to create bed heterogeneity
- Increase the frequency of large wood habitat, both single logs and jams
- Maintain recreational passage through the channel
- Eliminate or minimize flood profile changes upstream that may impact adjacent neighbors

Dowagic River Floodplain

- Increase the frequency and extent of floodwater accessing the floodplain
- Breach or remove levee spoils placed during channelization in the early 1900s
- Preserve and increase microtopographic features that develop complex habitat types on the floodplain
- Re-establish or maintain tribally significant vegetation within the floodplain

Ecological goals will be accomplished through a return to the pre-disturbance channel. This report centers on the understanding of historic phases of manipulation to the watershed and the river corridor itself that resulted in todays Dowagiac River system. By understanding the "layers of impact," restoration can begin to peel back those layers and return the system to a more functional condition. Restoration must occur however within the contemporary watershed constraints which have developed over nearly 100 years.

Roads, bridges, and homes have been built within the corridor. Agriculture thrives within the historic swamp lands of the headwaters near Decatur. Restoration goals must be accomplished only to the extent that changes to these existing uses are understood in detail and demmed acceptable. Often termed a "good neighbor policy" it is common for river projects to define changes not only within the project area but above and below as well, ensuring that these changes are acceptable to adjacent landowners.

Figure 2. This house upstream of Peavine St. is sited very near the Dowagiac floodplain

CRITICAL ELEMENTS IN THIS REPORT

This report is a synopsis of the data collection phase of the project. Data collection focused on two areas, the collection of field information (surveys, photographs, cores of sediments, probing the existing river etc) as well as the collection and review of existing, published information (DNR reports, bridge information, historic documents, landownership records etc.). Several critical elements of the project were identified at the outset of the project and the data here is intended to shed light on these areas.

#1 – Changes to Sediment Transport – Rivers move water and sediment downstream, this is their basic physical purpose dictating all other functions. This is how the Dowagiac valley was formed, as the river cut vertically and horizontally into the landscape eroding sediment over time down to the St Joseph River. Several changes occurred to natural rates of sediment and water transport. First, the watershed was likely clearcut in the mid-1800s for agriculture and timber harvest. This essentially removed the protective "blanket" of vegetation throughout the watershed and opened bare ground to erosion by rainfall – delivering more sediment to the river than normal. Over the last several decades the watershed has likely reduced the delivery of sediment to the channel as soil conservation practices, re-vegetation, and paving of roads have all reduced erosion. Whether this reduction is a return to more "natural" levels of the early 1800s is unknown. The second change was the channelization itself in the early 1900s which increased the slope and energy of the channel to transport sediment and increased the velocity and speed with which water could flow downstream. In essence the channel appears to have been very efficient over the last 100 years at moving both water and sediment along a near constant bed slope established by the channelization project. This has been to the detriment of the health of the river. Putting the river back into its historic channel will create an anomaly within this efficient corridor, creating +/- 5 miles of new channel where currently only +/- 3 miles of straight channel exist. This section will have a flatter bed slope and water will be allowed to flood laterally out onto the floodplain. If the upstream watershed is delivering a large load of sediment through the channel, once this load encounters our project reach, it may deposit within the lower slope section of the project. If the

sediment load from upstream is small, it will likely pass through the restoration section without causing significant changes.

#2 – *Presence of Riffles* – The document "Feasibility Assessment for Rehabilitating the Dowagiac River System in Southwestern Michigan - A Watershed Analysis of Potential Changes to the Ecology and Community" (Clarke et al., 1998) includes a well- researched and thorough account of the watershed and the potential for restoration. Within this report, the restoration of the channel calls for the establishment of riffles and pools within the channel. The character of a river varies along its length, occasionally quite abruptly. It is not uncommon to find wetland sections of river channel where the bed slope is relatively flat, the channel narrow and deep, and a bed composed of sand or organic material, though coarse gravel can be encountered as well. Other sections feature a steeper bed slope with a well-defined channel and gravel bed. Water depth varies from deep in pools to shallow in riffle areas. Rock riffles occur with regularity between meander pools in this type of river. The latter form appears to be intact within the vicinity of Kinzie Road on the Dowagiac, though was not investigated in detail. The former, more wetland-like channel section is apparent in the upper sections of the river near Decatur. In between these two areas the river likely transitioned between wetland sections and pool/riffle sections prior to channelization. Whether the project area was located in a more wetland type channel section or a pool / riffle channel section is an area the assessment attempted to shed light on. This information aids in understanding the habitat types that might re-develop in the project area, and the expected fauna that would occupy such habitats.

#3 – *Hydraulic Changes and Bed Elevations* – Upon channelization, the historic channel was deepened below the bed elevation of the meandering channel. Placing water back into the old channel at a higher bed elevation may induce changes to the elevation of the water surface under a variety of flow conditions. Typically an increase in water elevation is evident at normal flows and diminishes at floods. Bridge crossings at Peavine, Sink, and Crystal Springs also induce a hydraulic control at a certain flood event, essentially reducing the volume of water that can pass through the opening and causing a backup upstream. Understanding the hydraulic implications of the project is paramount to communicating the potential changes to upstream landowners. A prominent "lesson learned" from the MEANDRS group with the Dodd Park restoration was a need to better anticipate and communicate these changes, as the reoccupation of the old meander raised the water surface elevation at normal flows upstream of the project.

WATERSHED OVERVIEW

GENERAL

The Dowagiac River drains approximately 285 mi^2 of the southwest corner of Michigan's Lower Peninsula. It originates in Decatur Township, Van Buren County, and terminates approximately 31 miles downstream at its confluence with the St. Joseph River in Berrien County, near the town of Niles, MI (Figure 3). The river has two major branches, the Dowagiac River (west) and Dowagiac Creek (east). A northeast-southwest trending glacial moraine, the Inner Kalamazoo Moraine, separates the two branches which come together west of Dowagiac, MI. Above the confluence, the Dowagiac River has a relatively low gradient and primarily drains swampland. It was straightened along most of its length at the turn of the 19th century to improve drainage efficiency. Conversely, Dowagiac Creek is a steeper, faster-flowing stream, although large segments have been impounded, especially through the town of Dowagiac.

Southwestern Michigan was covered by glaciers until around 15,000 years ago, and the landforms, soils, and surface geology are the result of the retreat of the most recent glaciation. Thick, complex deposits of glacial sands and gravels blanket the region. The watershed is generally flat to gently rolling with an elevation range between 680 feet and 895 feet above sea level; however, moraines, kettles, kames, eskers, and outwash plains associated with past glacial activity provide topographic variability (Kirby and Hampton, 1998).

The climate of the watershed is characterized by relatively high precipitation and moderate temperatures, largely controlled by nearby Lake Michigan. Total annual precipitation at Dowagiac, MI, is 22 inches. Most of the rainfall and snowmelt water drains to the Dowagiac River and its tributaries as groundwater. The glacial materials associated with the outwash plains and moraines are relatively permeable, allowing precipitation to infiltrate and travel in subsurface pathways through the deposits rather than across the ground surface as runoff. The coarse glacial material of the watershed is responsible for storing tremendous volumes of cold groundwater which maintain the Dowagiac River flow, even in the heat of summer, as a cold water river system.

Historically, oak savanna and oak-hickory forests dominated the upland areas of the watershed, although maple-beech forests were likely not uncommon. Along the Dowagiac River, the floodplains were dominated by wet hardwood forests, often featuring black ash, a significant species for the tribe. A variety of wetland types could also be found along the river. Today, agriculture dominates the watershed, comprising 55% of the total acreage. The uplands are primarily used for crops, especially corn, but hogs and other livestock are also raised in portions of the watershed.

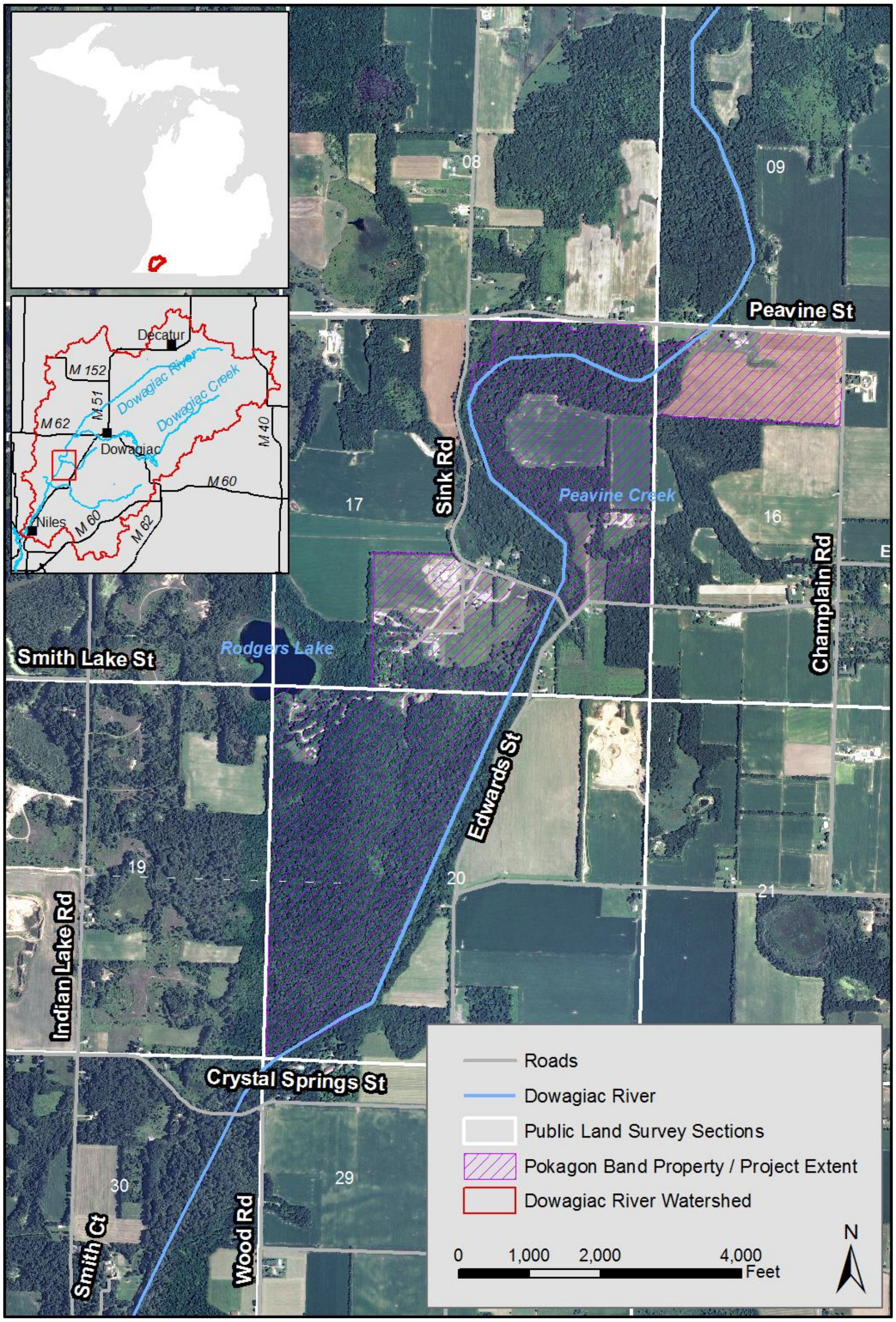


Figure 3. Location Map for the Dowagiac River Project Reach.

HISTORIC IMPACTS

The first settlement in Cass County was in 1825 and rapid settlement followed in the 1830s (Rogers, 1875). The township of Pokagon was settled in 1858. Pioneers voiced concerns over diseases such as typhoid fever that they attributed to the presence of the swamps. Prospectors and settlers were also interested in reclaiming land from the wetlands to increase property values. As early as 1875 the Dowagiac River drainage was discussed as an improvement project amongst representatives from Cass and Van Buren County (Hamper, 1996). Almost 25 years later, the Dowagiac River was straightened, lowered, and channelized between 1901 and 1928 to drain the surrounding swamp making land more suitable for agriculture.

The drainage project was built in two phases. The first phase began at the railroad bridge south of Decatur Township and ended at the south line of Section 9 in Pokagon Township, the location of the current Peavine St. Bridge, and the upstream end of our project reach. Excavation commenced in July 1901 and was completed two years later in the spring of 1903 (Hamper, 1996). The contractor used a dredge barge that worked day and night at a rate of one mile every 15 days to remove soil from the newly excavated channel (per unreferenced notes filed at the Cass County Historic Library). Excavated spoils were to be placed "3 feet from the edge of the excavation, not higher than 4 feet on each side and balanced between each bank" (Records of the Cass Co Drainage Commission). These levees are still evident today.

The existing Dowagiac River which "was only about two feet deep and 40-50 feet wide…was dredged to a depth of four feet" (per unreferenced notes filed at the Cass County Historic Library). Channel dimensions as documented by Hamper (1996) described the drain dimensions as "25-30 feet in width and 4 feet in depth." Phase I of the drainage project diverted 30 miles of the meandering river into 14 miles of straightened, channelized ditch by "removing the kinks". The project resulted in the loss of 16 miles of river length, increased channel gradient, lowered bed elevation and a disconnection of the river to its floodplain. This work effectively doubled the slope of channel by removing over half of its length.

The first phase of the project was considered too short and too shallow to adequately drain the area. A second phase of construction was proposed, including dredging both upstream and downstream of the initial reach to an eight foot depth (per unreferenced notes filed at the Cass County Historic Library). Dredging was to begin at the upper end of the Dowagiac River southeast of Decatur, near Pickerel Lake, and continue approximately twenty-five miles south ending north of Niles township in Berrien County, just upstream of present day Kenzie Rd. (Hamper, 1996; Figure 4). The dredge barge for Phase 2 was recorded as 75 feet long and 20 feet wide with a 60 foot long boom and a four foot draft.

Construction of the second phase of the drainage project was not nearly as efficient as the first. Unpredictable soils (quicksand), equipment shortages and failures, landowner lawsuits, bridge concerns and a distracted and financially negligent contractor, created numerous delays. Construction of the upstream portion of the river – including the re-dredging of the initial reach - began in June 1917 and was halted in the spring of 1919. It was not until December 1920 that the contractor reached the Peavine St. Bridge. Due to litigation, the drainage project was not completed until 1928. At the end of both phases, the drainage project was accredited with reclaiming between 15,000 and 20,000 acres of "marginal and swamp land" (per unreferenced sources in Dowagiac River Drain notes in Cass County Historical library files).

Historic documents indicate an abundance of springs in the area. One particularly active spring was described in Pokagon Township Section 8, just north of Peavine St. near the current project (Figure 5, north of station 22000). Two prospectors envisioned a waterfront town excavated from the springs and connected to the Dowagiac River via a dredged channel. Accounts from 1875 describe a large spring – Toponnebee – that was "strong and high enough to furnish ample supply for two thirds of the town" (Rogers, 1875). The paper Town of Shakespeare was never realized and consists of agricultural fields today. We noted evidence of substantial groundwater seepage in this part of the project site during field reconnaissance.

Crystal Springs was a large spring noted at the downstream end of the project site (Figure 5, station 10000). The area was developed by the Methodist Church as a campground which held its first meeting in 1860 (Barbara Wood Hunzcher, Cass County Historic Library, personal communication).

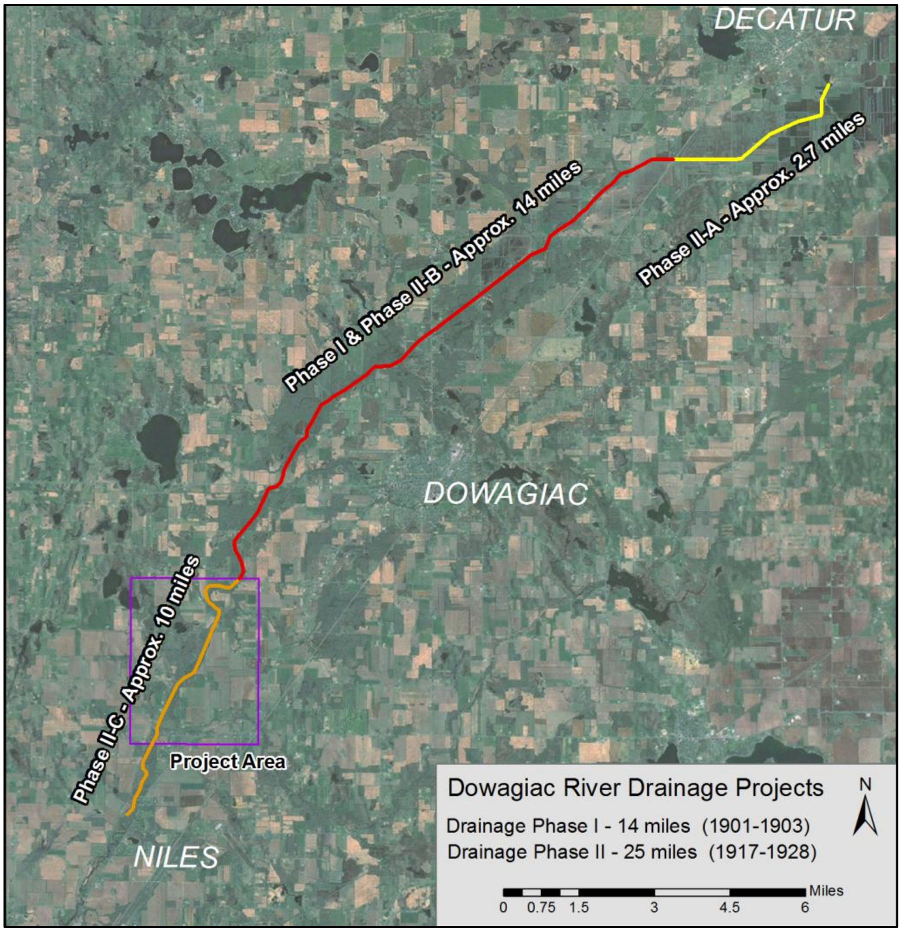


Figure 4. Dowagiac River Drainage Project Phases.

The Crystal Springs Campground is still in use today; however, the spring for which it was named is now gone. Per historical accounts, "the spring is situated about twenty-five rods (412 feet) south of the Dowagiac Creek, at the head of a ravine covered with a natural growth of timber…The volume discharged by the spring is estimated to be six hundred barrels per hour" (Rogers, 1875; p200). In 1873 the site was slated to become a State Fish Hatchery for rearing "California salmon trout and white fish" (Rogers, 1875; p200). Due to "impurity of the water and uneven temperatures" the fishery was discontinued in 1881 (from an undated Crystal Springs Campgrounds document submitted by Donna Kowalewski, Historical Project Coordinator in Cass County Historical Library). Dredging of the Dowagiac River dried up the spring. In a Chapter titled "Crystal Springs" in an undocumented source filed in Cass County Historical library, "the effect of the dredging was gradual, but final."

One mill dam is recorded within the project area in Section 17 of Pokagon Township and is located on the Pokagon Township map in the Atlas of Cass County Michigan, 1873. Per Hamper (1996), the mill was located along the North-South quarter line of section 17 "on the Smith Lake outlet to Dowagiac Creek" (Figure 5, station 20000). The hydraulic head at the dam was fourteen feet and the mill was powered by one overshot wheel. An impounded pond is evident in the 1872 map on the west side of Sink Road. The mill was constructed in the 1850s for the purpose of making fence caps for lumber rail fences. It was discontinued when timber in the area was overharvested. According to Hamper (1996), there are no remains of the mill at the site.

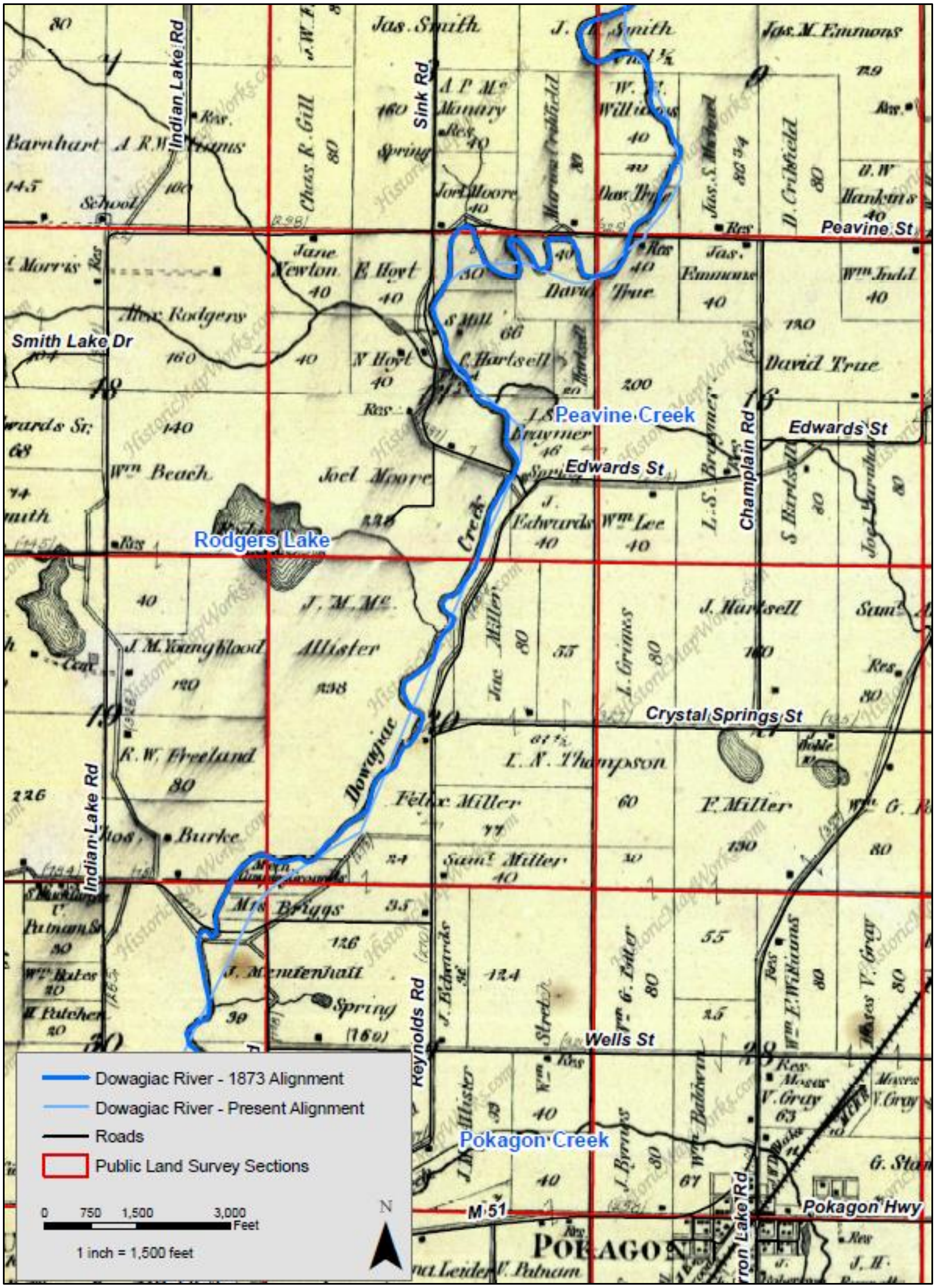


Figure 5. Section of 1873 atlas map of Pokagon Township, MI. Map provides approximate river alignment, parcel ownership, and important features along the channel such as springs and mills.

GEOLOGIC HISTORY

A river is a product of the forces which created and shaped its watershed. A thorough understanding of the geology of the watershed can provide important information related to the movement of water and sediment within the landscape that govern most functions in the river.

BEDROCK GEOLOGY

The bedrock underlying the Dowagiac River Watershed consists of Late Devonian to Mississippian age (320-380 million years ago) rock formations (Figure 6) representing a period where southwestern Michigan was part of an offshore marine environment (Dorr and Eschman, 2001). The gray Ellsworth Shale underlies the western third of the Dowagiac Watershed. It comprises a mixture of green and gray muds from the Wisconsin Highlands to the west and black muds from the Appalachian Region to the east. The younger Coldwater Shale underlies the eastern two-thirds of the watershed and consists of black to gray, silty shale with thin layers of limestone, dolomite, and sandstone. The Ellsworth and Coldwater Formation rocks are relatively flat-lying units, although they are eroded in areas exposed when the adjacent sea receded toward the end of the Mississippian period. Because the Pleistocene age glacial drift is so thick, covering the bedrock with 100-600 feet of material (Rieck and Winters, 1993), there is almost no correlation between the bedrock geology and the surface topography within the Dowagiac Watershed, including stream courses. However, relatively thin areas in glacial drift thickness may roughly correspond with topographic highs or ridges in the bedrock surface.

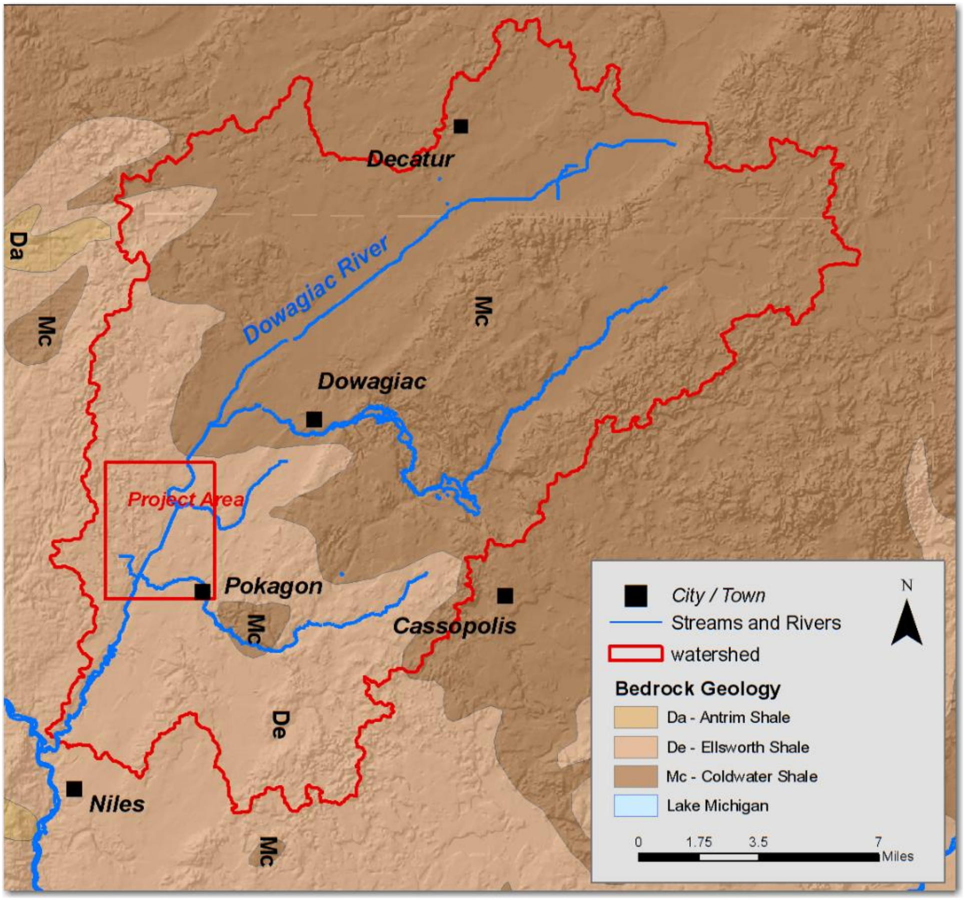


Figure 6. Bedrock geology for the region surrounding the Dowagiac River Project Reach (red box).

GLACIAL GEOLOGY

The surficial, or visible, geology within the Dowagiac Watershed consists almost entirely of Pleistocene glacial deposits, along with limited post-glacial stream deposits (

Figure 8). The glacial deposits resulted from the advance, temporary halt, and then retreat of the glaciers during the Wisconsinan age (75,000 – 10,000 years ago), which was the last glacial period of the Pleistocene. The Dowagiac watershed lies in an area where the Michigan Lobe of the Wisconsin Glacier expanded and contracted over time. The watershed material includes moraines deposited while the ice front was relatively stationary, as well as material carried away from the ice by meltwater flow and deposited in channels, sheets, and deltas. Glacial sediments within the watershed consist of outwash sand and gravel, ice contact outwash sand and gravel, end moraines of coarse textured till, coarse textured till, and glacial lake deposits (Kincare, 2010).

Moraines

A moraine marks the edge of the glacier. A moraine is primarily a pile or ridge of unconsolidated rock and sand deposited at the edge of a glacier when the glacier is at equilibrium (i.e., where the rate of ice advance is balanced by the rate of melting and there is no considerable advance or retreat). The moving ice in a glacier acts much like a conveyor belt, carrying debris from upstream within the glacier to the margins of the ice, and sometimes along the margins as well. Therefore, the longer the terminus of the glacier stays in one place the more debris will accumulate in the moraine. In continental glacial systems, sets of moraines often run parallel to one another, forming where the ice front is stationary for a period, marking its edge, before climate conditions change and the glacier begins retreating to its next stable position. This latter process corresponds to the moraines along the Dowagiac River and other moraines in southwest Michigan.

The Michigan Lobe of the Wisconsin Glaciation advanced south, along what is now Lake Michigan, into Illinois and Indiana. The Kalamazoo Moraine and the Valparaiso Moraine demarcate the eastern flanks of the Michigan Lobe over subsequent time periods as the ice retreated at the end of the Wisconsin period (Kincare, 2010;

Figure 8). The Dowagiac River flows between the two moraines. The east half of the Dowagiac River Watershed is comprised of the Kalamazoo Moraine system. This system is defined by two ridges separated by a nearly continuous but narrow gravel plain that can be traced from north of Kalamazoo, MI, to South Bend, IN. The western, inner, ridge separates the north branch of the Dowagiac River from Dowagiac Creek. The Valparaiso Moraine is located on the western side of the Dowagiac Watershed (Figure 7,

Figure 8). It is lower, flatter, and wider than the Kalamazoo system and formed after the ice retreated from the Kalamazoo System position. Both moraines are constructed of shingled, fluvio-deltaic complexes that were built out into glacial lakes (Stone et al., 2003). In the case of the Valparaiso System, the deltas were built into Glacial Lake Dowagiac. Both moraines are characterized by a complex arrangement of knolls, basins, and ridges formed by the overlapping deltas and subsequent sediment collapse associated with melting ice blocks along the ice front. The upper moraine deposits are coarse grained, locally containing boulders and lenses of poorly sorted till, but they grade to sands at depth and to the east (Kincare, 2010).

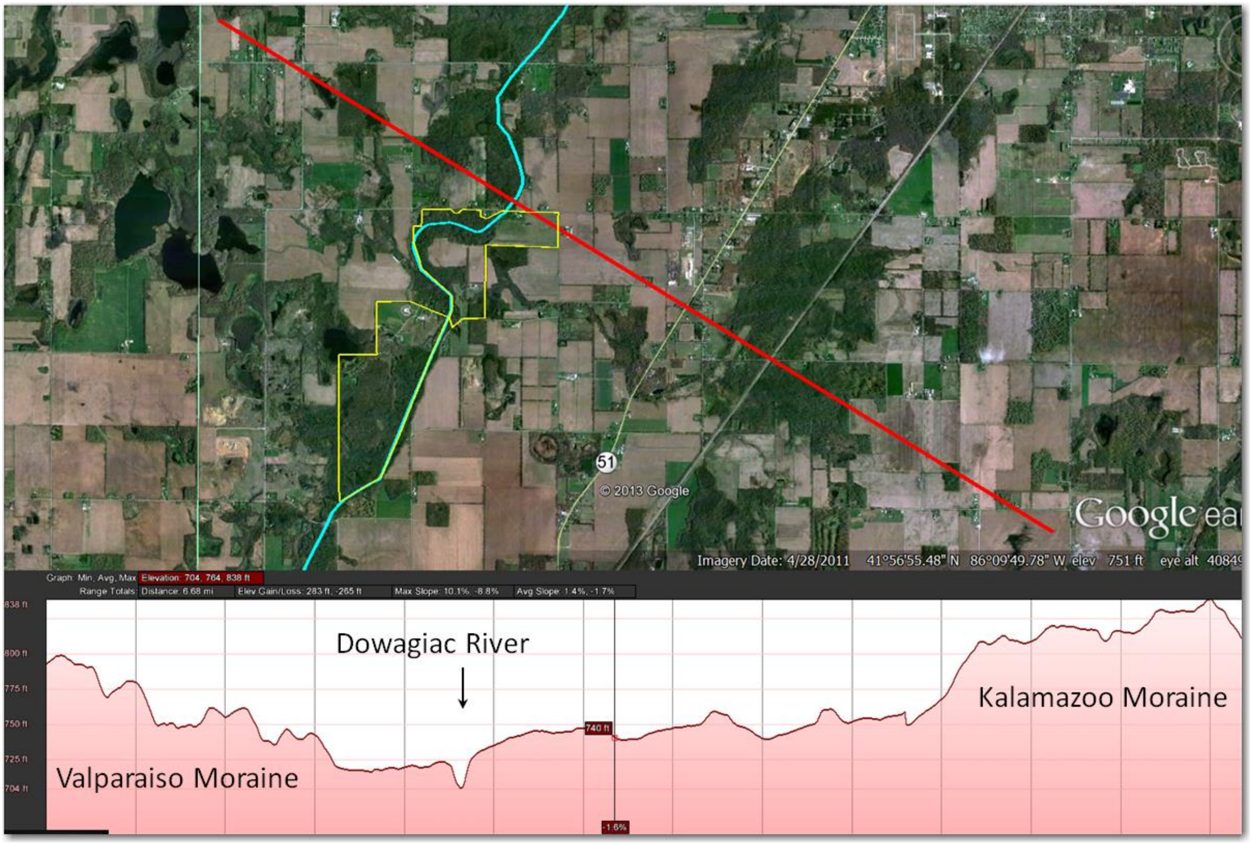


Figure 7. Generalized cross section of the Dowagiac River valley at the upstream end of the project reach. The overall valley is defined by the Valparaiso Moraine to the west (left) and the Kalamazoo Moraine to the east (right) – the red line (cross section) is about 6.5 miles wide.

Glacial Lake Deposits

Temporary lakes are often created in the areas between the leading edge of a glacier and the moraine formed at the previous stable ice front position. The moraines act as dams, impounding melt water and rearranging drainage courses as water levels rise and fall. The "bed" of the lake is similar to modern lakes with a relatively flat, level surface. When the lakes dry up or drain via spillways, these flat lake beds remain. Similarly, Glacial Lake Dowagiac ponded behind a ridge deposited between the Kalamazoo Moraine and the Valparaiso moraine as the Michigan Lobe retreated to the west (Kincare 2010;

Figure 8). The lake was about 10 miles across and extended from Grand Rapids, MI, to South Bend, IN where it spilled south into the Kankakee River system. It expanded to the west as the ice retreated and continued to be functional until the ice had receded sufficiently to permit meltwater to discharge down the Paw Paw and St. Joseph River Valleys. The Dowagiac Swamp and the low flat plain occupying much of Pokagan and Silver Creek Townships in Cass County, which contain the project reach, are the remnants of this lake (Leverett and Taylor, 1915). The relatively flat valley gradient created by the lake bed is also expressed in the low gradients of the Dowagiac River and the river's associated riparian wetlands upstream of Sumnerville, MI.

Outwash and Other Deposits

While ice covered the modern Dowagiac River valley and was producing the Kalamazoo moraine, drainage probably overflowed south toward the Wabash River drainage basin in Indiana. Retreat from the Kalamazoo Moraine to the Valparaiso Moraine, about 17,500 years ago, redirected flow to the Kankakee River system (Ekblaw and Athy, 1925). Glacial Lake Dowagiac formed between the moraines (Figure 8), overflowing to the Kankakee near South Bend (Kincare, 2010; Leverett and Taylor, 1915). The Lake and its associated waterways formed a glacial spillway which conveyed meltwater and sediment to the south. Rivers and creeks in the watershed generally flow along the remnants of the spillway and form most of the valley floor. The outwash plain is 5-7 miles wide at the city of Dowagiac, and contains a high percentage of sand and gravel, mostly as part of delta deposits formed along the spillway. Modern day alluvium (sediment transported by the modern river), consisting of sands and gravels reworked from glacial outwash, is found along the modern stream system throughout the watershed (Hamper, 1996).

Figure 8. Photo of the channelized portion of the Dowagiac River near Decatur. One can imagine a lake bed here, bounded between the two moraines on the left and right.

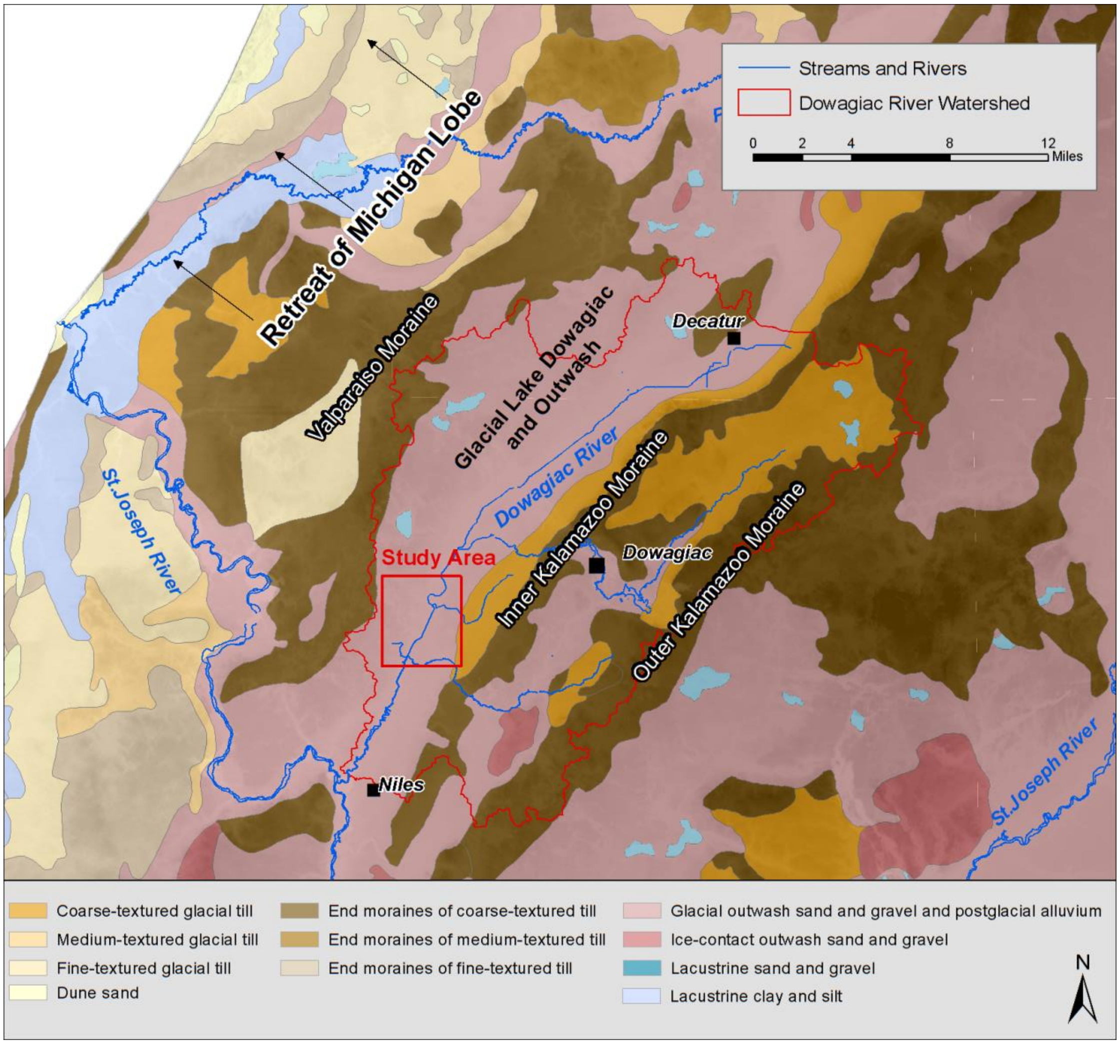


Figure 9. Glacial geology of the region surrounding the Dowagiac River project area (red box). The river flows between two end moraines associated with the Michigan Lobe of the Wisconsin continental glaciation. Glacial retreat from the Kalamazoo Moraine system to the Valparaiso Moraine system established a southwest trending meltwater spillway dominated by Glacial Lake Dowagiac. The spillway is largely filled with gravelly, sandy delta deposits from upstream (north) and off of the Valparaiso Moraine.

SOILS AND WETLANDS

Most soils in the Dowagiac River watershed are well drained sandy and loamy soils representing the relatively coarse glacial deposits found in the basin. These sandy, loamy soils allow water to infiltrate into the ground, thereby recharging the groundwater and contributing to the groundwater flow in the Dowagiac River and its tributaries (Cass County Conservation District, 2002). The main upland soil units along the channel in the study area are the Kalamazoo Loam and the Oshtemo and Brady Sandy Loams (Figure 10).

The main soil associations for the outwash plains and moraine deposits are listed below:

- **Coloma-Spinks-Oshtemo:** Deep, nearly level to strongly sloping, well-drained, coarse textured and moderately coarse textured soils on outwash plains and terraces.
- **Oshtemo-Kalamazoo-Houghton:** Nearly level to strongly sloping, well-drained, moderately coarse textured and coarse textured soils, some are deep and some are moderately deep over sand and gravel, on outwash plains and moraines.
- **Riddles-Crosier-Oshtemo:** Deep, nearly level to strongly sloping, well-drained and somewhat poorly drained, medium textured and moderately fine textured soils on till plains.
- **Schoolcraft-Kalamazoo-Elston:** Nearly level to rolling, well drained soils that have loamy or loamy and sandy subsoil; formed in glacial outwash.

The soils adjacent to the Dowagiac River, especially upstream of the Peavine Creek-Dowagiac River confluence, consist of mucky, poorly developed, and very poorly drained soils including the Glendora Muck, the Houghton Muck, and to a lesser degree, the Adrain Muck. Muck soils are those with a high organic component, formed partly or almost completely by the decomposed remains of woody or herbaceous vegetation. These soils are likely closely associated with Glacial Lake Dowagiac's flat lake bed and the river's original (pre-1900) floodplain and broad riparian wetlands. The organic soils are important components of many wetland communities present in this region. Outwash plain deposits underlie the floodplain soils, and therefore the muck does not impede delivery of groundwater to the river. However, their poorly drained nature prevents infiltration and artificial drainage is required where the soils are used for agriculture (Cass County Conservation District, 2002). Draining the Glendora Muck near Decatur, MI, upstream of the study site, was the primary impetus for channelizing the Dowagiac River.

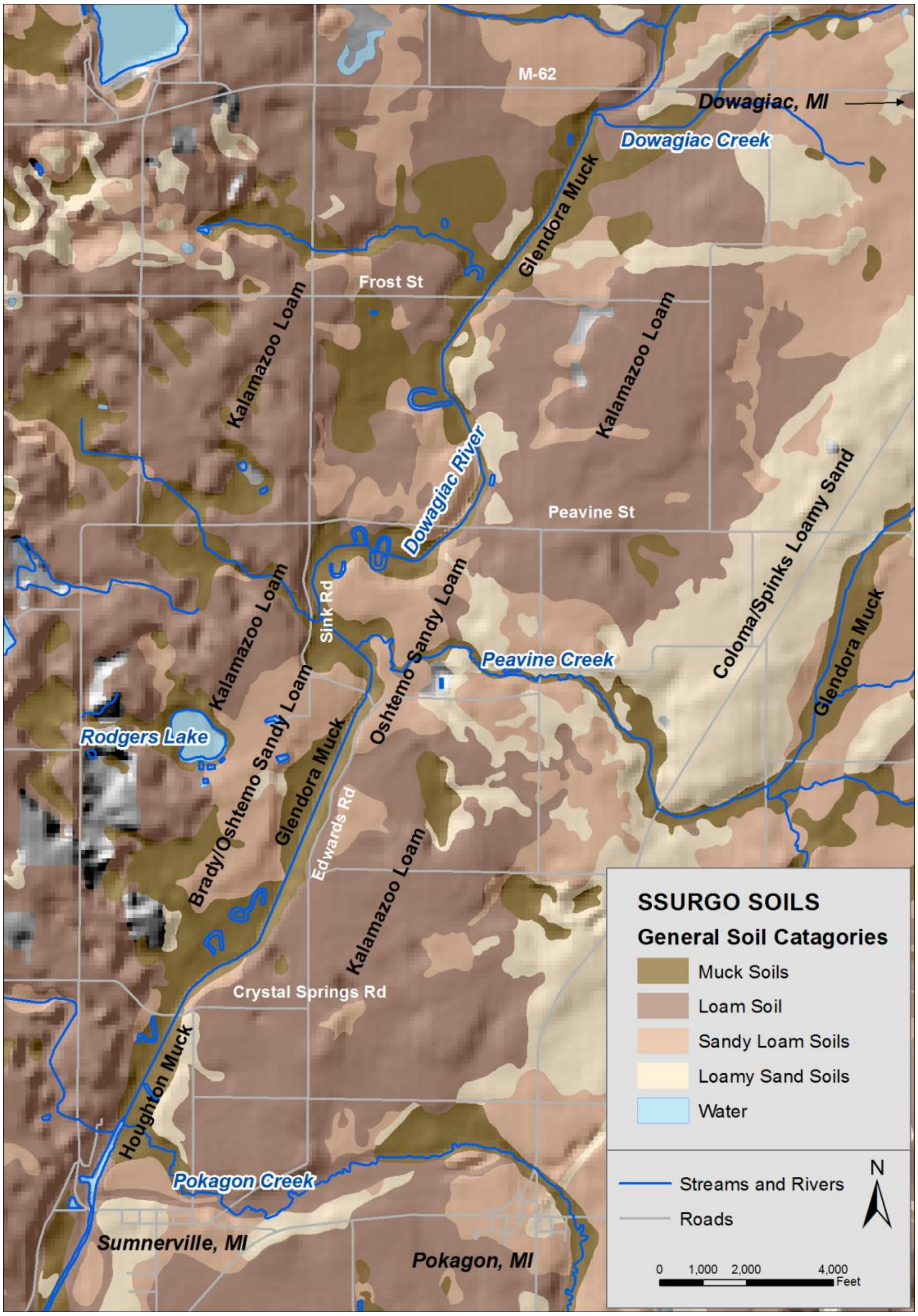


Figure 10. Soil Survey Geographic database (SSURGO) map of the soils along the project reach of the Dowagiac River. The floodplain soils are primarily organic rich Glendora and Houghton Muck Soils. The uplands are dominated by sandy loams and loams, especially the Oshtemo and Kalamazoo soil types.

FLORA AND FAUNA

The report by Clarke et al (1998) - Section 2.4.3 *Biological Profiles* includes an excellent description of the historic and contemporary faunal assemblage of the Dowagiac. Here we touch on data collected since that report, as well as observations associated with the Dodd Park restoration project.

A 1997 Michigan Natural Features Inventory by P.J. Comer and D.A. Albert is an interpretation of the 1800 General Land Office surveys (Figure 11). Per the interpretation, the dominant vegetation type west of the Dowagiac River is a Beech/Sugar Maple forest with islands of cedar swamp and pockets of shrub swamp and emergent marsh. Pockets of black ash swamp are noted north of Peavine St. The landscape to the east of the river is predominantly mixed oak savannah with prairie grasslands and lowland emergent marsh pockets. Trees that were noted by the surveyor in 1830 include: White oak, beech, red oak, yellow oak, elm and tamarack.

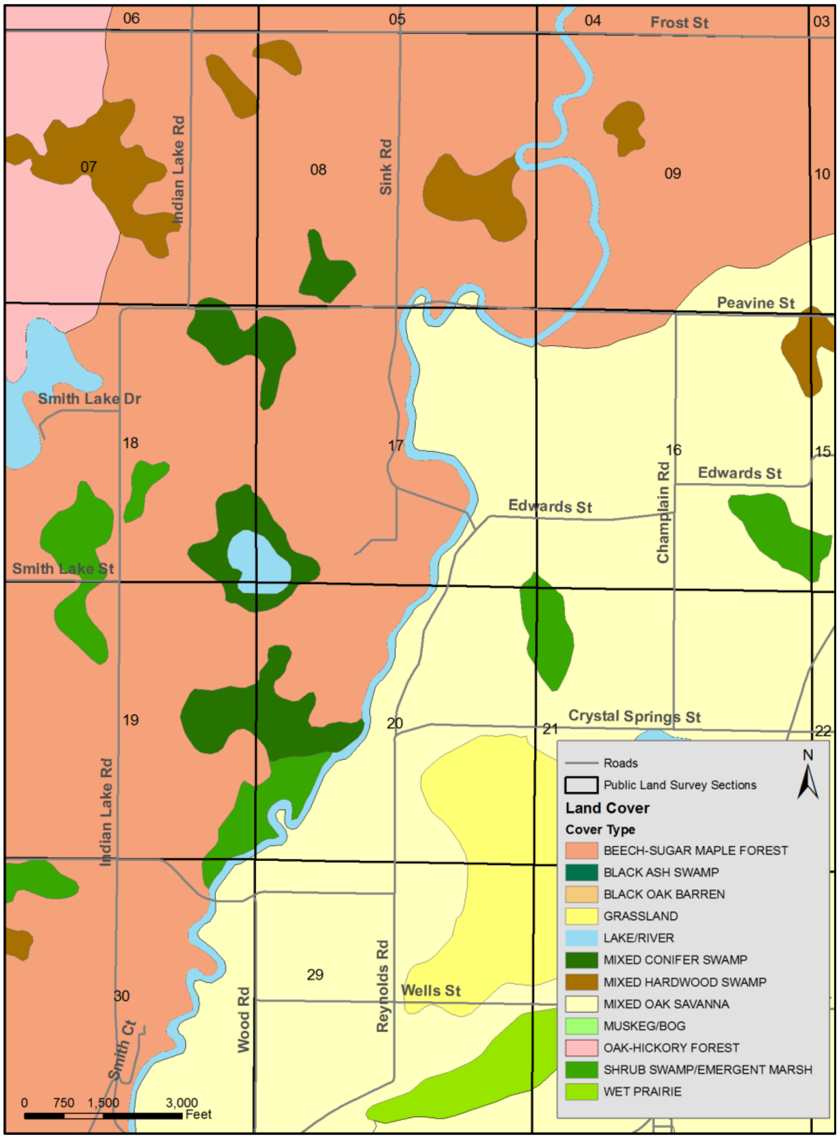


Figure 11. Historic vegetation adjacent to the Dowagiac River based on the 1800's GLO surveys (Comer et al., 1997).

The vegetation assessment and tree survey showed the dominant community within the study area to be floodplain forest dominated by silver maple, sycamore, green ash, hackberry and American elm. Several areas of shrub swamp and emergent marsh were also observed throughout the study area, especially along the eastern river bank. Overall, the vegetation community types observed in the field did not match those of the historic mapping. This is likely based on the scale the historic mapping data was collected and post settlement land activities such as logging, farming (including dredging). Based on the vegetation, topography and hydrology observed in the field, it is apparent that the historic mapping did not accurately identify the vast bottomlands associated with river in this area.

The vegetation assessment conducted during the March field work identified 93 woody and herbaceous species within the study area. Trees were surveyed along the existing spoils areas within the project area. Species and diameter were noted. Observations of additional fauna were made within this area as they were encountered. Observations were compared with the vegetation survey completed by Wilhelm in 2012. The comparison showed that 51 of the original 111 species (June 2012) were observed in 2013. It should be noted that the vegetation assessment was conducted in late spring (March 19-20, 2013) and is in no way a complete survey or assessment since many of the herbaceous plants were not present or were unable to be identified. Additionally, 37 species were added to the 2012 list, including 27 native species and 10 adventive species (Appendix). Some of these adventive species are species that can be potentially invasive (PI) and the spread of these plants should be minimized especially when performing any earth moving activities such as channel realignment.

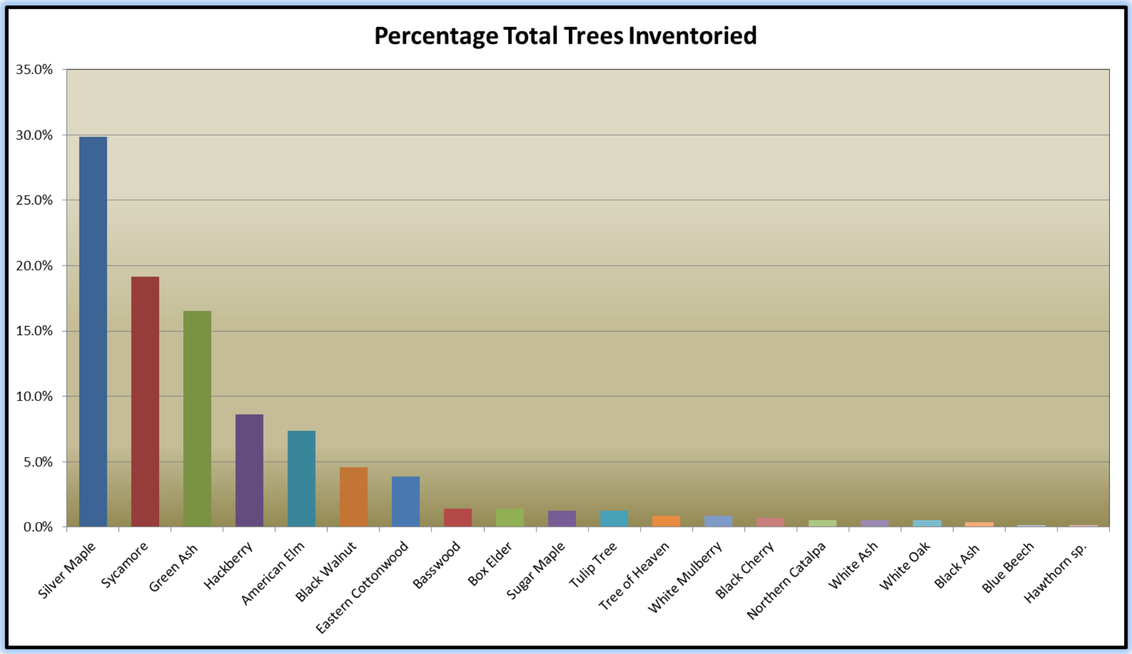


Figure 12: Species and relative abundance of trees within the spoils areas available for harvest and use for restoration.

Aquatic sampling has been conducted by the MDEQ and MDNR within the watershed and tributaries. The following general observations are consistent within the mainstem. Habitat is depressed throughout the mainstem river for reasons discussed elsewhere in this report.

Fish – Fish species above the Pucker Street dam are consistent with a cold water fishery. Assessments in the mainstem included a total of 37 species, with Brown Trout being the most numerous species. Brown trout have been stocked by MDNR in the Dowagiac. Although the species diversity was considered good in a report by Wesley and Duffy (2003), it was noted that habitat was lacking. Discussions with landowners during the March 2013 field work indicated some brook trout have been observed in the Dowagiac, a native trout species (brown trout are introduced) but these fish have not been found in the MDNR surveys. The dam at Pucker Street prevents fish passage and connection with the larger St Joseph River. Species from Lake Michigan did historically migrate to the river. Lake Sturgeon were noted to ascend the Dowagiac historically and Lake trout were noted to spawn in the river above Niles (Ballard, 1948).

Macroinvertabrates – Between 22 and 32 taxa were identified in the 2012 survey. Assemblages of mayflies, stoneflies, and caddisflies were present, consistent with a cold water system and indicative of good water quality. The number of taxa generally increases in the upstream direction. The increase of taxa does not result in an increase in the quality of the community however. The Dodd Park site, which included a river wide high of 37 taxa – was the result of restoration work completed to expose coarse substrate in the old meander. Given the results from the Dodd Park site, located in the lower part of the river, habitat would appear to be the more limiting factor over water quality in the development of a healthy macroinvertabrate community.

FIELD ASSESSMENT RESULTS

GEOMORPHIC ANALYSIS

UPPER WATERSHED CONDITION

A windshield survey of the upper Dowagaic watershed was performed in an effort to understand the potential sediment load carried by the river into our project reach. Photos were collected at each stop and geo-referenced into Google Earth to provide a record. To determine sediment load in a qualitative sense there were three components of note. First was sediment delivery to the channel – signs of erosion on the landscape and tributary channels with systemic erosion and instability signal a high level of active delivery may be ocurring. The second observation is within the channel itself. Signs of deposition associated with mid channel bars indicate the load to the channel is significant. Corresponding sign of erosion indicate that the channel itself is providing sediment from its banks and bed. The final observation was the nature of the material itself. Fine material typically moves in suspension and is less sensitive to slope changes associated with our project. Sand and gravel however are heavier and tend to move along the bed of the channel, and may be affected by a change in slope with the project. Within this context the upper watershed was assessed.

At Old Swamp Rd., Near Decatur – A small tributary enters along the road showing some signs of erosion, the channel is extremely low gradient with little capacity to transport sediment that gets into the channel. This location is just below Pickeral Lake, noted as the area where the historic dredging project occurred.

Figure 13: Tributary showing some erosion and sediment delivery to the Dowagiac River

Figure 14: The Dowagiac looking downstream at Old Swamp Rd.

46th Street Bridge – A continued low gradient channel, evidence of some frequent dredging of the channel exists. The channel itself is stable and not contributing sediment from the banks

Figure 15: Looking upstream from 46th street

CR 215 / Glenwood Rd. Bridge – Trees are more prolific along the channel here, but the general cross section is maintained. Bed material appears to be sand and fine material, consistent with a wetland channel.

Figure 16: Dowagiac River at CR 215

Twin Lakes Rd. Bridge – Trees continue in this section, the channel appears to gain some width here and the adjacent landscape indicates a transition out of the swamps of the upper watershed. The bed is largely sand and fines with no gravels apparent. Bank height begins to increase slightly.

Figure 17: Twin Lakes Rd. - trees and banks indicate a stable channel section. Periodic dredging may still occur here, evidenced by the lack of trees along the right bank in the photo

At Dewey Lake Rd. Bridge – A slight floodplain is evident here in the photograph as well as a slight bend – may indicate a location where the old channel and the excavated channel were coincident. Overall similar observations, stable channel, a bed of sands and fines. If there were significant sediment coming in from upstream a small deposit might be expected along the right bank in the photo below.

Figure 18: Dowagiac River at Dewey Lake Rd.

Tributary below Dewey Lake Rd. Bridge – A tributary enters the river below Dewey Lake Rd. and crosses Dewey Lake Rd. just west of the Dowagiac. The channel of the tributary appears to be stable at this location and is contributing a sand load to the channel of the Dowagiac. Investigation of the tributary upstream of this location was not performed but based on observations at this location, rates of sediment delivery might be considered normal, as little evidence of deposition is apparent.

Figure 19: Dowagiac tributary at Dewey Lake Road

At Rudy Rd. – The river here begins to take the form noted within the project area with significant spoils piles on each side of the straight channel. Trees along the banks are leaning slightly and some exposed roots are evident, indicating some erosion is occurring but at very slow rates. The bed is composed of sands and fines here and some deposition is apparent in the photo below on the right bank.

Figure 20: Dowagiac River at Rudy Rd.

At Middle Crossing Rd. – This sections appears to be slightly more active than others, although it must be noted that this observation is specific to the area around the bridge. Trees are more common in the channel and the dimensions appear consistent with what was observed upstream. Some bank erosion is noted in the right of the photo, the first significant erosion noted, but localized and likely due to scour from trees. The levees on either side persist, though have been removed by landowners where houses are present. A small tributary enters here from the west, draining cultivated land. In the photos the contribution of sediment from this tributary is higher than normal, but this scenario appears to be infrequent within the watershed.

Figure 21: Dowagiac mainstem at Indian Lake Rd.

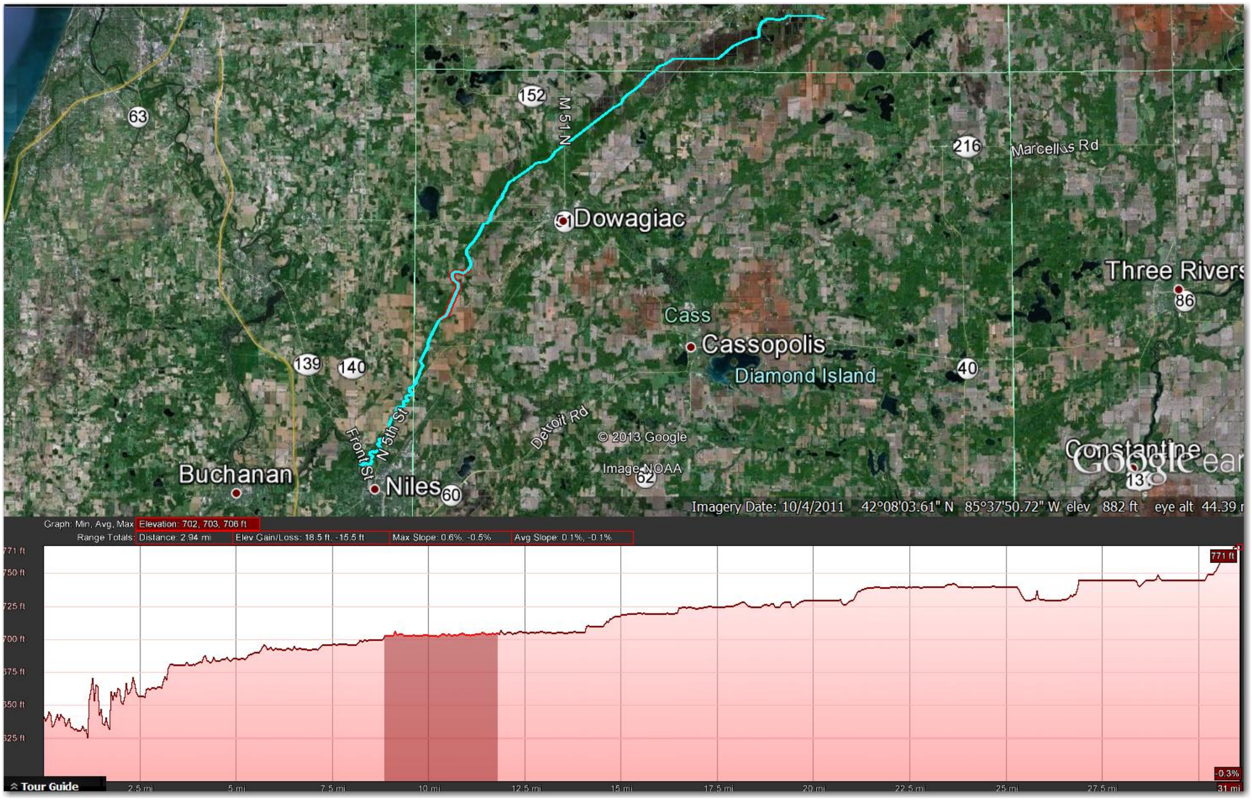
Figure 22: A small tributary along Middle Crossing Rd., just west of the Dowagiac. Sand is present in the channel and during runoff events, it is likely topsoil is being mobilized into the channel as well given the lack of buffer

At M-62 – Very similar to upstream sections and to our project area. This is the last stop prior to the confluence with Dowagiac Creek, one of the larger tributaries to the Dowagiac. The creek includes a mill dam that arrests most sediment delivery its upper watershed before it can get to the mainstem Dowagiac. Sand is noted in the bed.

Figure 23: Dowagiac Creek at M-62. The sand bed is prevalent in the photo

Figure 24: Looking downstream from M-62 at the Dowagiac

Based on the observations in the upper watershed, the Dowagiac appears to gain some sediment from tributaries within the area above Twin Lakes Rd., but the material cannot be transported easily by the low gradient channel in this reach unless it is fine material that can be moved in suspension. Below Twin Lakes Rd. where the landscape gains some topography sediment is gained from the tributaries as well and to a lesser extent from the channel itself that can be mobilized by the channel. An exhaustive investigation of the river was not performed, but it appears that sand comprises the majority of the sediment load within the river. Sand moves nearly continuously within the Dowagiac system and is likely being delivered to the project reach. The volume of this material, in qualitative sense, does not appear to be excessive, evidenced by a lack of bar formation or an aggraded bed.



Graph: Min, Avg, Max | Elevation: 702, 703, 706 ft

Range Totals: Distance: 2.94 mi | Elev Gain/Loss: 18.5 ft, -15.5 ft | Max Slope: 0.6%, -0.5% | Avg Slope: 0.1%, -0.1%

Imagery Date: 10/4/2011 42°08'03.61" N 85°37'50.72" W elev 882 ft eye alt 44.39

Figure 25: A long profile from Google Earth - the project area is highlighted in the profile

A helpful tool in understanding the movement of sediment and water as well as the energy of a river system is the long profile. The profile is an elevation, typically of the bed of the channel from its headwaters to its confluence with a larger river. The specific elevations in Figure 25 are not important, but the overall shape of various segments of the profile are. Beginning in the headwaters, the flat, wetland swamp is apparent with a few short steeper transitions down to additional flat areas. As water leaves the wetland area the slope increases slightly and channel picks up energy. Through the project area the slope is gradual until just below, likely near the Dodd Park area where the river begins to steepen on its way down to the St Joseph River valley. The steepest section includes the Pucker Street Dam – to take advantage of the high energy of the river here. The steepness of the slope dictates the type of river patterns at various locations along the 30 mile length, with the wetland sections in the headwaters, transitions between wetland and pool/riffle sections in the middle, and finally a steeper channel with coarse cobbles and gravels and mild rapids making the transition down into the St Joe Valley.

EXISTING PROJECT REACH CONDITIONS

The Dowagiac River, from Peavine St. to the southern extent of the property owned by the Pokagon Band of the Potawatomi, currently flows approximately 2.9 miles through forested riparian wetland. The River was channelized along almost its entire length (18.6 miles), including the project reach, and is now almost completely straight with a sinuosity (channel length/valley length) in the study area of 1.07 (Table 1; Figure 28). The dredge spoils were piled along the channel, usually around 4 feet or more above the existing floodplain, and have been overgrown and stabilized by trees and brush. Despite the time that has passed since the channel was dredged, the river is still relatively homogeneous through the project reach. Channel bed elevations do not vary significantly and the gradient is relatively consistent (0.0004; Figure 29). Pools are often deep, but infrequent. When they occur, they are often the direct result of obstructions, such as bridge abutments and woody debris. Channel widths are also strikingly consistent. They range from 40 to 70 feet, but are most often around 50 to 60 feet wide and depths at a 1.5-year recurrence interval flood, used as an approximate surrogate for bankfull, is approximately 7.5 feet (Table 1). Overall, the channel is an artificial, straightened G channel (Rosgen, 1996).

In artificially straightened and entrenched systems, channels will usually follow a general pattern of recovery or adjustment (Schumm, 1977). They will often incise, which in turn, causes over-steepening and destabilization along the banks. The banks then begin to erode and the channel widens. Over time, the channel equilibrates and will form a new set of bars and meanders within the enlarged space it carved for itself during its adjustment period. In the case of the Dowagiac River, the channel will eventually begin to erode its banks, undercut the existing spoils berm, and re-establish its meandering form within its floodplain. This process on the Dowagiac is slow, governed mainly by the low slope and stream power of the system, and the presence of well-established vegetation along the margins that resist erosion. There is evidence that the channel is beginning to adjust. Some trees have been undercut by the river eroding the toe of the banks. Erosion is also evident where woody debris deflects flow into adjacent channel banks. The process could initiate further meandering and adjustment, but new vegetation along the berm and in the floodplain will prolong any significant recovery.

Table 1. Existing and proposed river characteristics and Rosgen stream and valley types.

Channel Characteristic	Existing	Proposed
Length (feet)	15445	25442
Gradient	0.0004	0.0002
Sinuosity	1.1	1.8
Width:Depth	8.0	10.8
Entrenchment	1.3	15.0
Stream Type	G5c	C5c-
Valley Type	VIIIc	VIIIc

Figure 26. The Dowagiac River features long, straight, homogeneous channel reaches bordered by vegetated berms (dredge spoils).

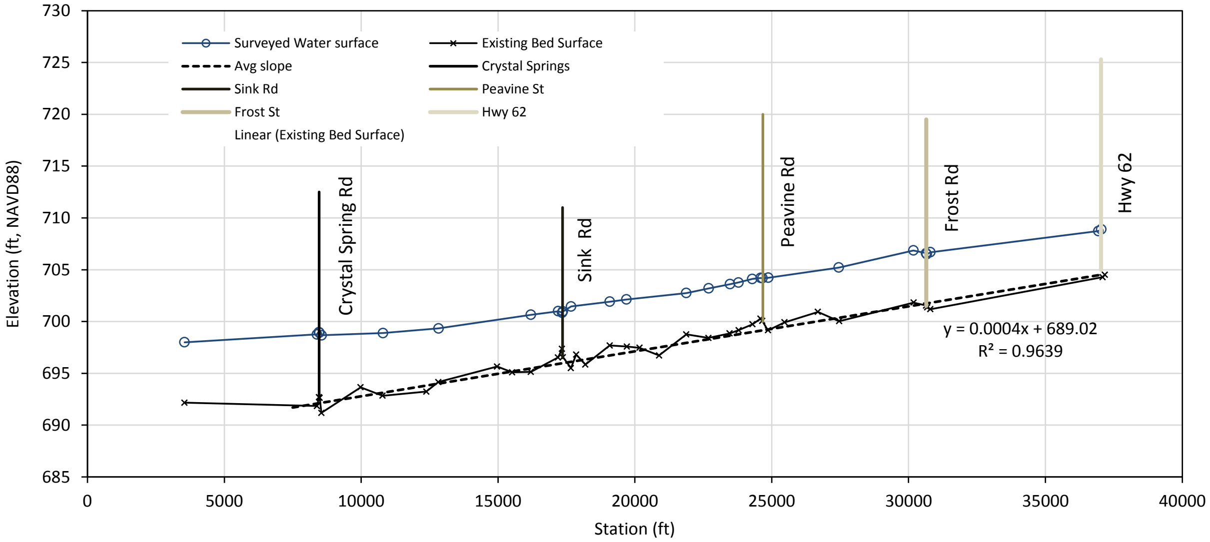


Figure 27. Long profile through the Dowagiac River Project Reach. The bed has a relatively consistent slope throughout (0.0004 feet/feet) and little variability in bed elevation.

Figure 28. Typical erosion and woody debris along the Dowagiac River banks.

The floodplain is largely forested, although local grassy wetlands and bog areas are common, especially along stretches of abandoned channel. The floodplain includes valuable microtopography comprising small ridges, berms, and depressions associated with past channel migration, and many of the depressions are filled with standing water. These ponded areas often support new trees (saplings). Additionally, small tributary channels drain groundwater seeps along the valley wall and bottom, providing cold water habitats within the floodplain. Many of these channels flow to depressions or are effectively dammed at the river by the spoils berm, adding to the ponded area (Figure 32).

Bed material along the project reach is primarily sand, although gravel patches have formed locally where the channel abuts the valley walls, where tributaries have deposited coarser material in the mainstem, and where the channel has likely cut through lenses of gravel within the outwash deposits or the dredged material. Exposed bank material and spoils along the channel reveal that most of the margins are sandy with an inconsistent gravel layer often appearing between the organic soil layer and the sand below. Gravel seems to be more common downstream of the project reach where gradients begin to increase. For instance, a significant gravel layer was unearthed as part of the Dodd Park Project at Sumnerville, MI. Additionally, depth-of-refusal (DOR) data suggests the floodplain in the project reach primarily includes a layer of fine sediment and organics overlying a layer of medium and coarse sands. Gravel and cobbles were located with the DOR rod, but they were mostly localized deposits. Examples include a gravel/cobble layer roughly 2 feet below ground surface immediately downstream of Peavine St., and another layer at the surface along Edwards Road.

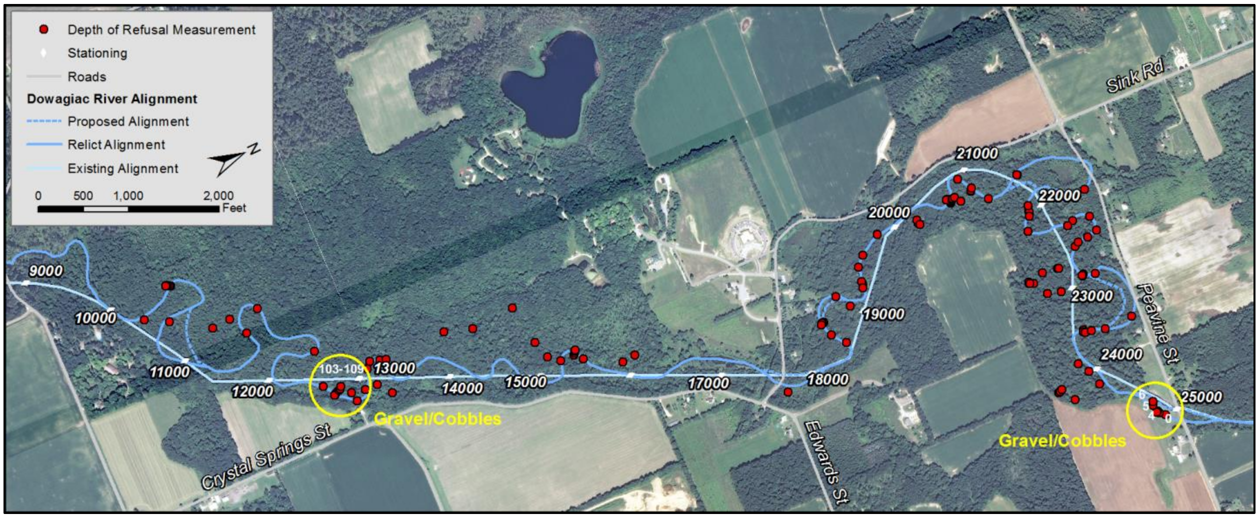


Figure 29. Plan form map of the depth of refusal (DOR) survey locations. The DOR measurements were collected along relict channel positions. Refusal generally occurred in sand, although localized gravel deposits were encountered downstream of Peavine St. and along Edwards Street (yellow circles)

Figure 30. Forested floodplain south of Peavine St. (Location 12). The photograph also exhibits hummocky topography related to meander scroll bars and standing water associated with the latest channel position in the bend.

Figure 31. Grassy, muddy wetland along the old channel alignment at photo location 34.

Figure 32. Standing water supporting numerous tree saplings at photo location 29.

Figure 33. Coldwater tributary draining upstream spring and nearby groundwater seeps at photo location 22.

HISTORIC CONDITIONS

Although the existing condition of the Dowagiac River is straight and relatively homogeneous, historic documents, sequential aerial photography, and airborne LiDAR (Light Detection and Ranging) survey data suggest the channel and valley wetlands were much more active in the past. Prior to dredging and/or possible additional impacts (e.g., agricultural erosion and subsequent channel deposition), the river appears to have meandered throughout its wider valley sections. The LiDAR data, and to some degree the aerial photographs, clearly show numerous abandoned meander bends along the floodplain, especially between stations 25000 and 20000 (Figure 35), and upstream and downstream of the project reach (Figure 356).

The observable relict channels range in width from 50 to 100 feet wide, with most measurements between 60 and 80 feet and a mean around 65 feet. They display clear signs of past activity, such as remnant scroll bars associated with channel migration, and channel cutoffs at narrow meander bend necks (Figure 345). The past activity likely accounts for the quality of the microhabitat observed along the valley floor. The channel was likely acting as a meandering C-type channel (Rosgen, 1996; Table 1) – eroding the banks at the outside of bends and depositing material on the point bars formed at the inside of the bends – and the evidence has been preserved by locking the channel in its present position.

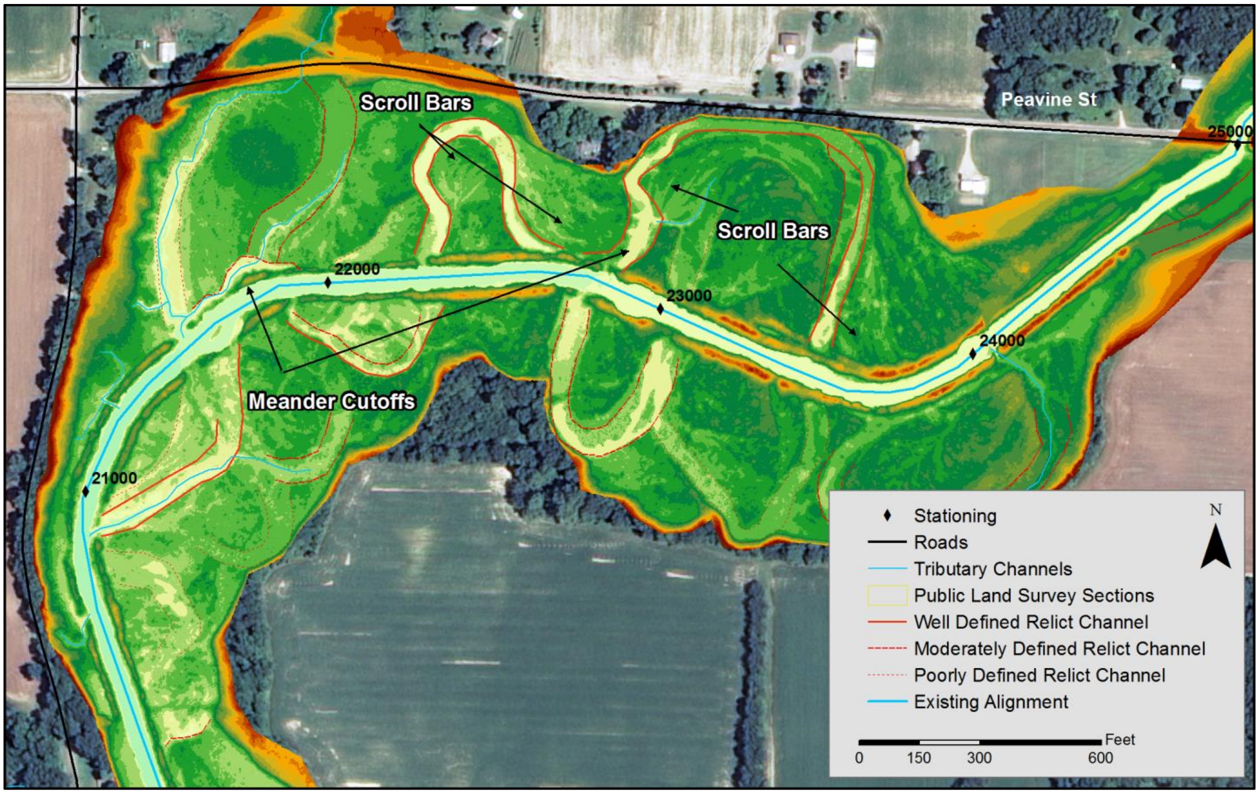


Figure 34. Preserved scroll bars and relict meander bends along the Dowagiac River in the upstream end of the project.

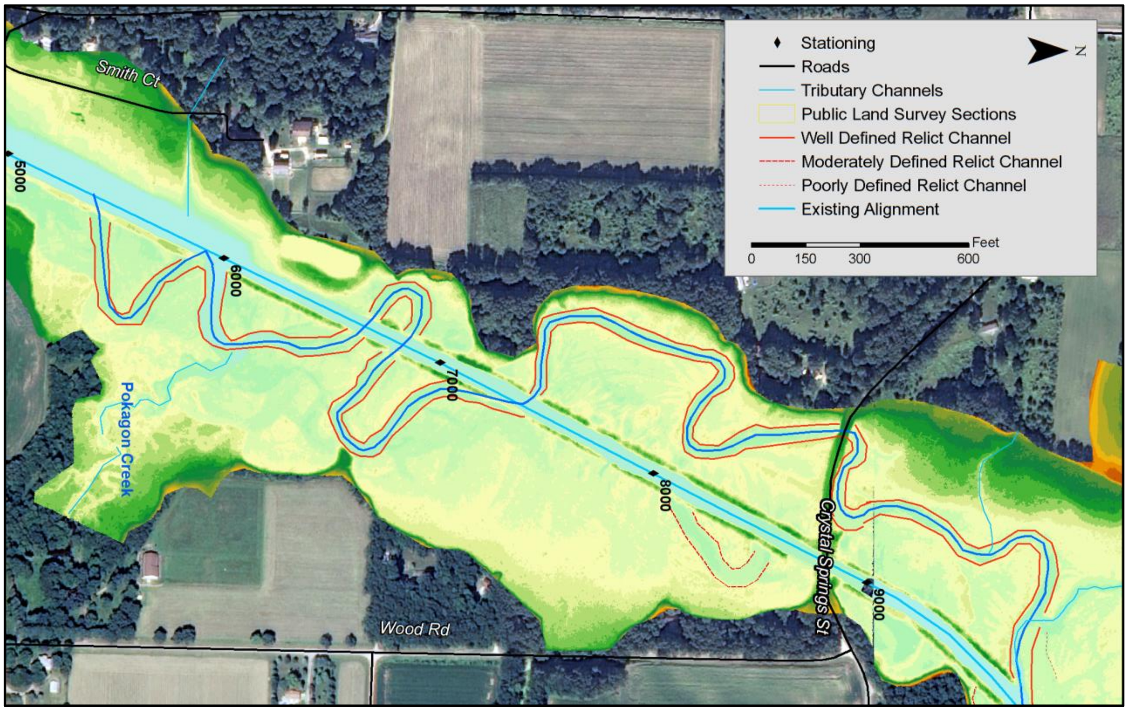


Figure 35. Well preserved meander bends along the Dowagiac River downstream of the project reach and Crystal Springs St.

It remains unclear when each of the individual abandoned bends were active within the project reach. Some bends, such as the two to the north of the channel, between stations 23000 and 22000, appear to be relatively young. These meanders exhibit a distinct plan form and topographic shape. Other bends include sections that appear to be well preserved, but adjacent sections appear filled, well vegetated, and occur at higher elevations. Additionally, the valley between sections 13000 and 10000 appears to be relatively wide and conducive to meandering, but the LiDAR and other data do not provide a definitive historic channel pattern. Reaches upstream and downstream of the project reach, however, exhibit relatively well persevered historic plan forms, presumably active just prior to dredging. These channels indicate the Dowagiac River was considerably more sinuous (channel length/valley length > 1.7), especially in the wider sections (Figure 36).

With the assistance of Jonathan Wuepper at the Cass County Historic Library in Cassopolis, MI, we were able to locate microfiche copies of the original General Land Office (GLO) Public Land Survey System (PLSS) maps and notes. The current project area is located within Township 6 South, Range 16 West in Pokagon Township of Cass County, Michigan. The project falls within Sections 16, 17, 19, and 20 of Pokagon Township, which was surveyed by William Brookfield in 1830. Mr. Brookfield walked the section lines and made note of the vegetation and landscape (mostly for its suitability for settlement) as well as noting where landscape changes occurred. Of particular relevance are the notes describing where and how often the surveyor crossed a water feature and any accounts of the feature's character or width. He also provided a sketch map of his measured and general observations (Figure 367). In general, the surveyor's notes are fairly consistent with the map in the 1872 Atlas of Cass County – Pokagon Township. The mapped channel features three bends west of the Peavine St. crossing, followed by a relatively long straight reach, where the river is not observable from the section lines, and then it finally begins to meander again at the downstream end of the project reach, at Crystal Springs Street.

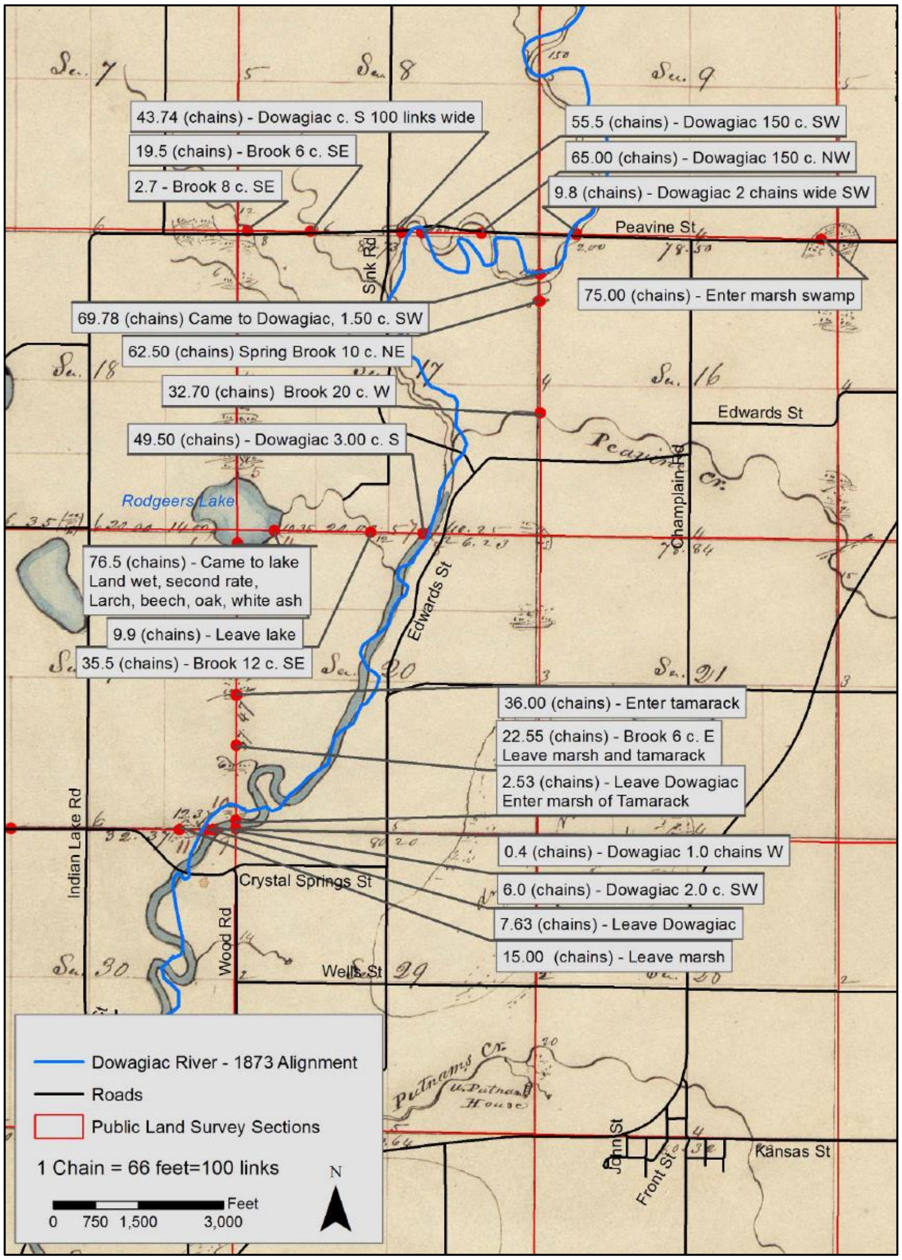


Figure 36. Historic map developed for the General Land Office Public Land Survey System. Callouts indicate channel widths and tree species encountered as the surveyor traversed the Dowagiac River.

Notes from surveyor in the direction he was walking the line between sections are transcribed from the microfiche notes in the Appendix. The Pokagon Township map of 1873 illustrates six meander bends at the upstream end of the project between sections 8 and 17. In his walk east between sections 8 and 17 (Peavine St.) the surveyor notes four instances of meeting the Dowagiac River. He notes the width between 100 to 150 links wide or roughly 66 – 100 feet. The land in this section was described as "level and rich with white, red, yellow oak and beech etc." The surveyor also noted two spring brooks west of the river along the section line. The south end of the project is described as a marsh landscape with cedar and tamarack trees. The surveyor notes entering and leaving the river in these sections, although he likely did not cross the channel perpendicular to flow and therefore some of the measurements are wider than expected. Additionally, he may have been walking through partial wetland area adjacent to the channel. The river is noted as 1.63 chains wide

(107 feet) walking west between Section 19 and 30, and 2.13 chains wide (140 feet) walking north between Section 19 and 20. This reach of the river is just downstream of Crystal Springs. The land in this area is described as "wet, second rate, with beech, white oak, and white ash."

An 1873 survey map of the channel, which was completed prior to the major dredging effort along the Dowagiac River, suggests the channel was relatively straight even before channelization. The mapped channel does not follow the patterns seen on the LiDAR exactly, but it does follow the general pattern of relict meandering at the upstream end of the project reach (stations 25000 to 22000) and to some degree, downstream of the reach. If the river alignment on the 1873 map is inaccurate, it is unclear whether the channel was naturally straight in this section, if it had already been straightened in sections, or if some change in the hydrology or sediment load had occurred in the system, prompting this straightened condition. In the latter case, the channel may have become straighter in response to increased sediment inputs related to adjacent agricultural practices. Sediment may have choked the longer bends, forcing flow across, and through, the meander necks, thus cutting off the bends. Currently, there is little evidence to support or refute any of these possibilities.

The remainder of the historic data represents the time period after the Dowagiac River channel had been dredged. The 1938 air photos show the straightened channel in the same position as it is today. The berm even appears to be vegetated already, especially upstream of Sink Rd. The main difference between the 1938 images and more recent photos is the forested cover within the floodplain and along the adjacent uplands. There are numerous areas along the channel that had either been cleared to the channel margin or supported a different vegetation type prior to 1938. For example, the area at station 14000 and 13000 was cleared of vegetation on the east bank, and the floodplain between stations 24000 and 21000 featured numerous patches that may have been open wetland habitats. Additionally, a large area of land south and east of Rodgers Lake, which appeared to be pasture in 1938, is now forested. Over time, reduced flooding (i.e., loss of channel – floodplain connectivity) and abandonment of adjacent agricultural fields has likely allowed forests to recover and expand. This activity has likely reduced sediment loads to the river.

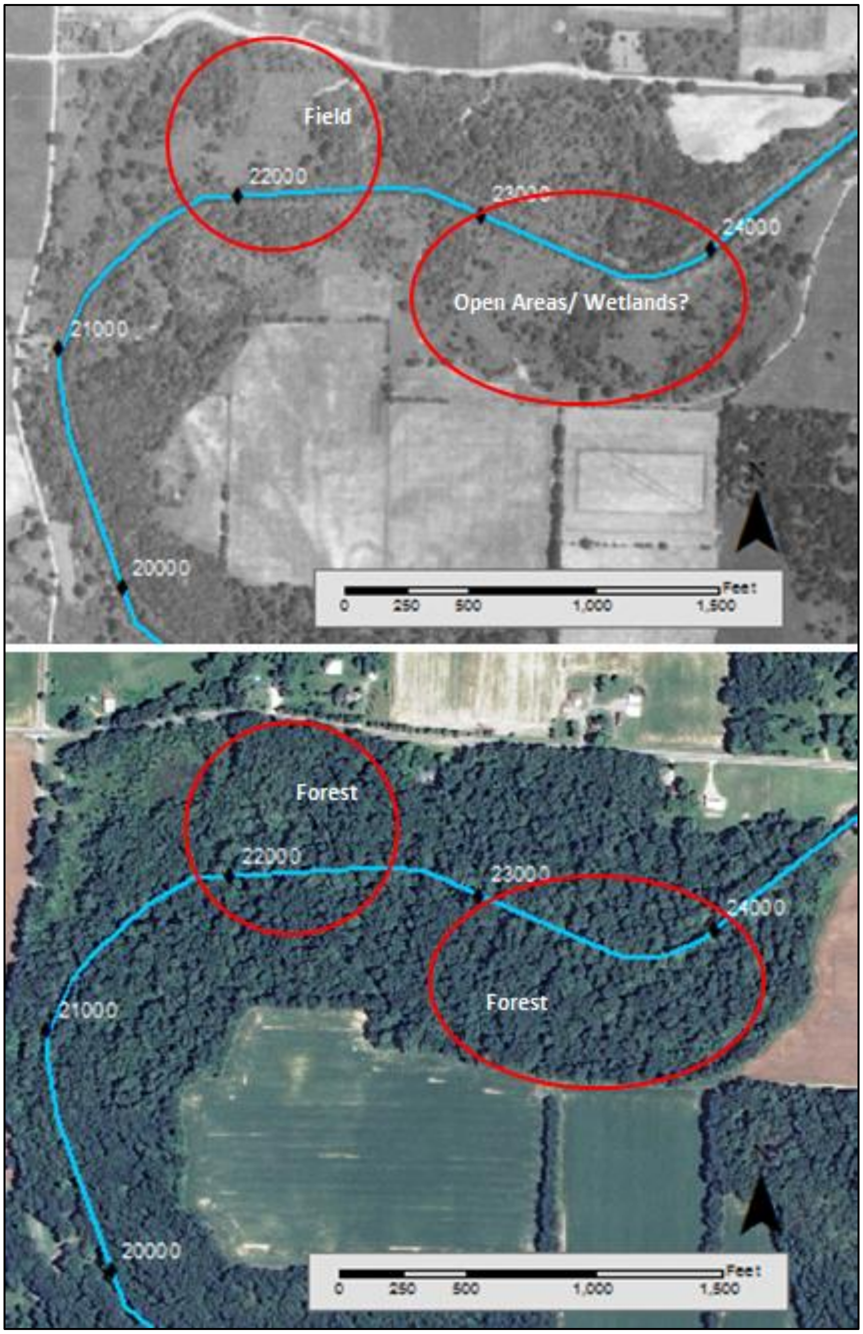


Figure 37. Comparison between 1938 and more recent air photos. The 1938 photos include less forested cover within the floodplain and along the adjacent uplands. There are numerous areas along the channel that had either been cleared up to the channel or supported a different vegetation type prior to 1938 than now.

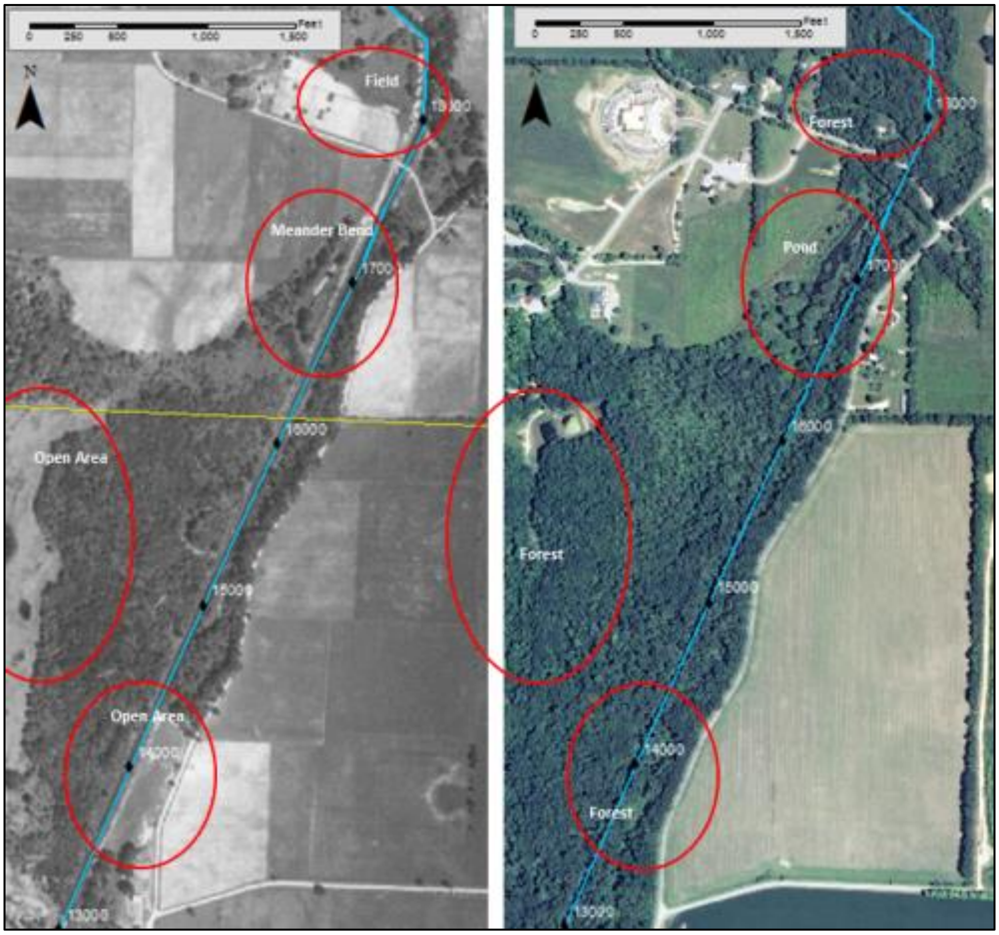


Figure 38. Comparisons between 1938 and more recent air photos. The 1938 photos include less forested cover within the floodplain and along the adjacent uplands. There are numerous areas along the channel that had either been cleared up to the channel or supported a different vegetation type prior to 1938 than now.

SEDIMENTATION

DEPTH OF REFUSAL SURVEY

In order to determine past channel shape and possible cut material, we incorporated a Depth-of-Refusal (DOR) survey into our channel and floodplain characterization. A DOR survey involves pushing a long, narrow rod (i.e., chimney cleaning rod) through the floodplain and channel material and noting the general sediment sizes and the depths at which the sediment changes. DOR measurements were made at relict channel locations throughout the floodplain and relict channel. Sediment cores were also collected to confirm the DOR data.

In general, the DOR measurements and cores provided useful information on the makeup of the floodplain deposits. The surface material usually consists of 1 to 9 feet (mean = 3.3 feet) of dark mixed silt, fine sand, and organic material. A layer of fine to medium sand underlies the organic layer. It is usually between 0 and 7 feet thick (mean = 3.2 feet) and can be layered with medium and coarse sands or homogenous. Final refusal was generally within a layer of coarser sand. Exceptions to this general pattern of layering existed within the project area, however. Gravel and cobbles were found near the surface at station 25000 and 13000, and gravel was often found near many of the tributary channels. A clay layer was noted at a few locations south of station 22000. Sand appears to have been the dominant bed material, and well sorted medium sand is spread throughout the floodplain, consistent with the overall composition of the watershed.

Figure 39. Gravel noted in the spoils along the existing channel near station 22000

Figure 40. Gravel in the bank of the existing channel just below Peavine St.

The elevations and depths of first refusal were variable along the proposed alignment (**Error! Reference source not found.**44). Near Peavine St., at the upstream end of the project reach, the DOR was more than 6 feet above the existing channel, whereas within the abandoned channel north of station 22000, DOR was more than 2 feet below the existing channel cut. Overall, the values fluctuated 2 to 6 feet along the profile, but suggest the previous channel was around 4 feet higher than the bed elevation of the current channel. This corroborates the anecdotal evidence indicating that the dredge cut was 4 feet deeper than the original channel. Gravel areas, represented with black circles in **Error! Reference source not found.**44, are primarily located where the channel flowed against the valley wall and may have represented former riffles. Gravel at the upstream end of the project reach (i.e, Peavine St.) may be related to the narrower upstream valley. The gravel could be deposited as the energy dissipates in the transition between the narrower, steeper valley segment and the wider, flatter downstream segment. The rest of the relict channel is relatively flat (i.e., lower gradient), although the slope appears to increase in the narrow segment downstream of Sink Rd. The downstream third of the project area (downstream of DOR 109; **Error! Reference source not found.**44), which featured relatively large areas of standing water at the time of the survey, appears to be exceptionally flat. Additional data is needed to better define the channel in this segment. Most of the variability seen in the DOR data can likely be attributed to variability in sampling location (i.e., what part of the abandoned channel section was probed) and variability in channel position and form over time.

Figure 41. Coarse sand under organics within a DOR core at photo location 31. The sand is relatively coarse with both sediment units including penny-sized chunks of wood.

Figure 42. Sand within a DOR core at photo location 14. The sand is fine to coarse with bivalve shells throughout.

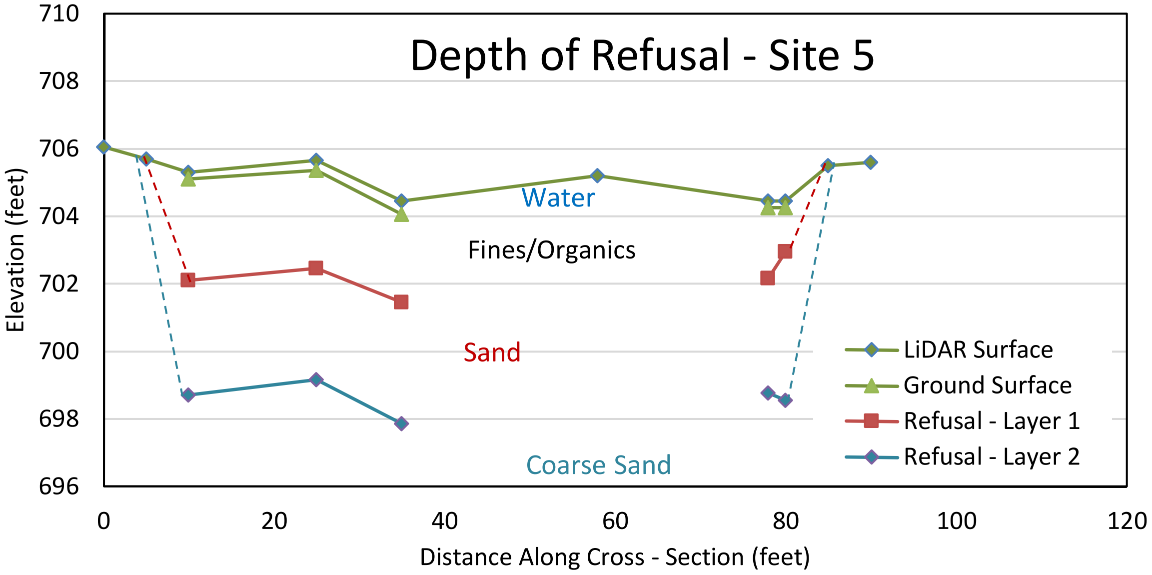


Figure 43. Depth of refusal survey data at a DOR cross section. The former channel bed is likely represented by refusal at Layer 1 (top of the sand layer).

The sedimentation history of the channel is challenging to interpret with the data collected data. As area settlement increased in the mid-1800s, it seems likely that vegetation was cleared for agriculture, roads, and residential areas. In other regions of the United States, similar changes in land use had major impacts to the sediment load and hydrologic regime of rivers and streams which translated into significant shifts in stream geomorphic characteristics (Jacobson and Primm, 1997; Knox, 1977; Phillips, 1991; Trimble, 1982). Depending on the geologic, atmospheric, and vegetation characteristics of a watershed, rivers and streams can have drastically different responses to land use changes. Depending on the context, channels may either widen or contract, beds may incise or aggrade, floodplains may aggrade or be abandoned, or channels may straighten or meander.

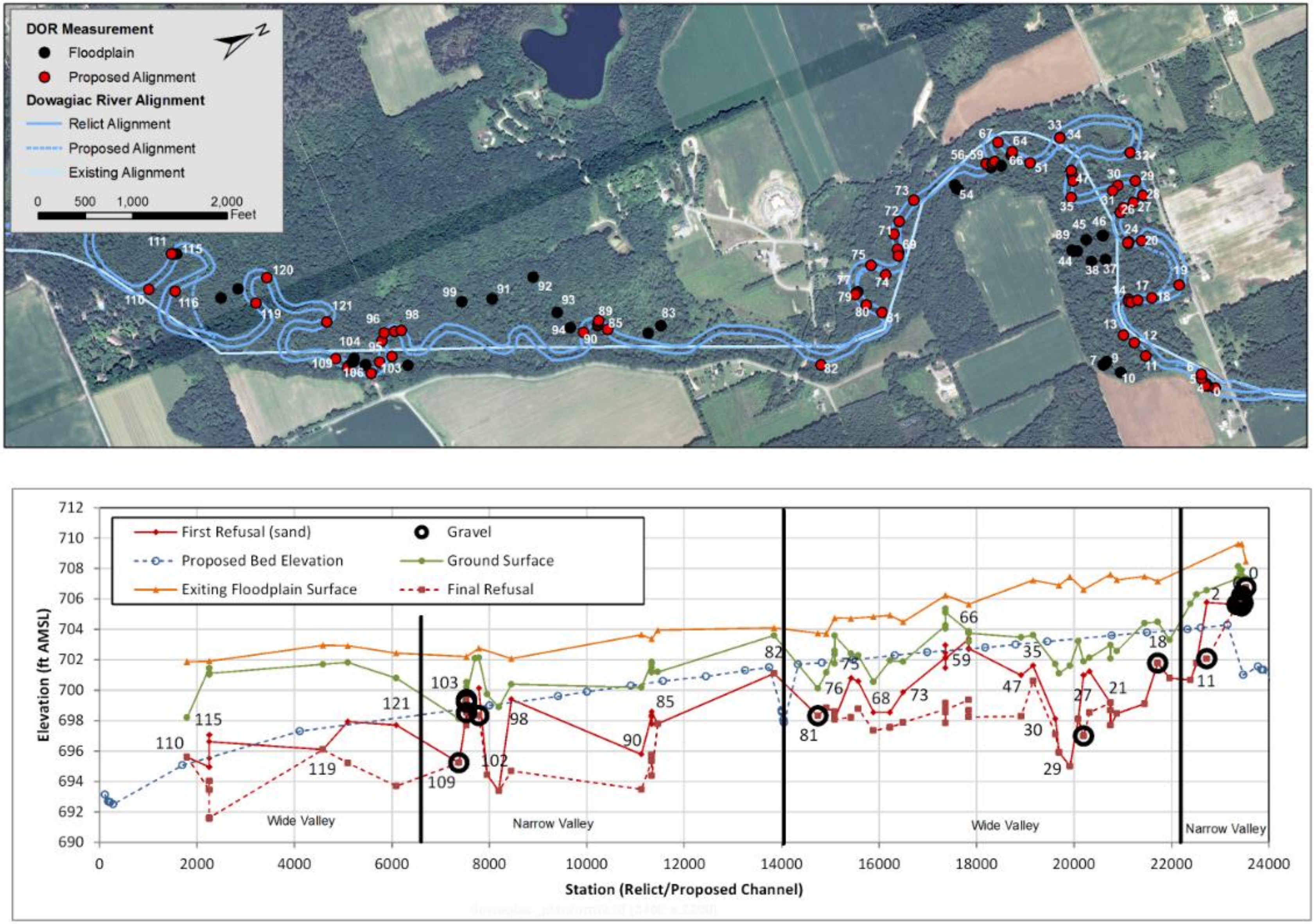


Figure 44. Depth of refusal profile along the proposed alignment.

The sand found in the abandoned channels during the DOR survey appears to be widespread. DOR probing upstream of Frost St., north of the project reach,(recall Peavine St. was the boundary between different phases of dredging) found floodplain and abandoned channel sediment conditions similar to those in the project reach (recall Peavine St. was the northern extent of the proposed project and the boundary between different phases of dredging). At the seven upstream DOR survey locations (i.e., upstream of Frost St.), the organic layer ranged between 1 and 5 feet thick (mean = 3.5 feet), and the underlying sand layer ranged from 2 to 5.5 feet thick (mean = 3.7 feet). Final rod refusal was in coarse sand at 7.3 feet, on average. The results, which are similar to the DOR results in the project area, indicate the sand is likely a consistent part of the valley sediment. It was likely left behind as the channel meandered its way back and forth across the floodplain.

Current and historic data defining sediment transport in the Dowagiac River is limited. The Pucker Street Dam is the only main stem barrier that traps sediment. It is located approximately three miles upstream of the Dowagiac River confluence with the St. Joseph River in Niles Township, Berrien County. As of 2008, the impoundment at full head (20 feet) creates a narrow 60 acre pond with an average water depth of three feet. Pucker Street Dam was originally a wooden dam constructed in 1897 to power a mill. The existing concrete dam was built about 100 feet downstream of the wooden dam in 1928, contiguous with dredging upstream.

In 1940, just 12 years later, enough sand and silt had settled behind the dam that it had to be dredged. This activity pre-dates the earliest aerial photographs. The 1938 photographs (Figure 4545) depict delta formation at the upstream end of the impoundment, indicating continued filling. By 1999, a significant delta had formed over the upper third of the reservoir, leaving low lying vegetated islands and bars of fine material (Figure 4545). The wedge of sediment formed despite at least one dredging event and multiple accidental and maintenance related sediment releases. The reservoir was drawn down in the early 2000s, and the corresponding air photos show exposed deposition throughout the former pond. The dam has essentially been abandoned with three gates permanently left open. Monitoring of the sediment up- and downstream of the dam allowed for bedload transport rate estimates of 3 tons/day and 1 ton/day in the fall of 2001 and 2002, respectively (Wesley, 2008), which presumably represent normal rates of transport through the dam reach.

1938

1999

Figure 45. Comparison of the 1999 air photo and 1938 air photo at the Pucker Street Dam impoundment. A sizeable delta formed over the northern (top of figure) third of the reach.

RODGERS POND

Rodgers Pond is a small impoundment on the Rodgers Lake Outlet Channel located just upstream of the All Seasons Resort Road. The Band is interested in replacing the culvert and restoring the pond to a natural stream corridor. Several iterations of manipulation to the outlet channel are evident, both modern and historic strcutures and crossings abound. We completed a topographic/bathymetric survey of the site along with a depth of refusal (DOR) survey in the pond. Survey data from March, 2013 were compiled into AutoCAD Civil3D along with LiDAR data collected in April, 2013. Surface models were developed for the topographic/bathymetric data, DOR data, and LiDAR.

The maximum depth in the pond is about 6 feet and reduces to just a few inches about 325 feet upstream of the culvert at All Seasons Resort Road, near the defunct walking bridge. Refusal depths average 2.8 feet below the bed elevation of the pond. A profile of the surfaces along the thalweg of the Rodgers Lake Outlet Channel indicates a discontinuity in the profile (Figure 477, black dashed line). This information indicates that the road embankment material was excavated from the pond, essentially removing the historic stream and floodplain corridor. Typically the DOR data indicates the former surface of the channel and floodplain. Here it is likely indicative of a surface has little bearing on the overall restoration of the stream corridor.

Upstream from Rodgers Pond, a beaver dam was present about 1,500 feet upstream and 200 feet downstream of Rodgers Lake. The beaver dam helps provide vertical stability for the lake and the channel. Without the beaver dam, water levels would drop in Rodgers Lake. A relic crossing is evident below the dam, likely an old farm or logging crossing, identifed by two old culverts in the bed of the channel. Below the dam, another old crossing exists with a dilapidated culvert that is easily removed. Downstream the channel was re-routed to the north for unknown reasons and enters the Dowagiac River just below Sink Rd. The historic alignment is still evident on site.

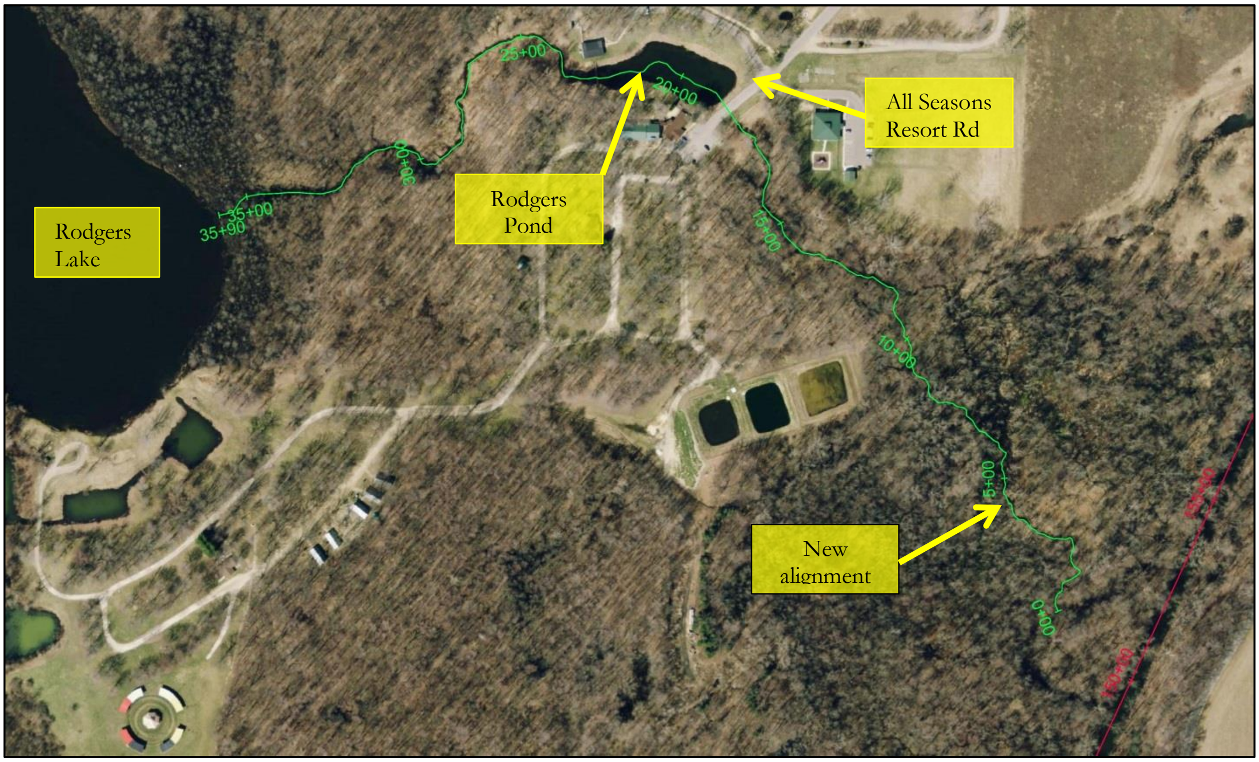


Figure 46. Location of the Rodgers Lake Outlet Channel and Pond. The channel will be re-aligned to its historic location. The current outlet to the Dowagiac River is at station 122+00.

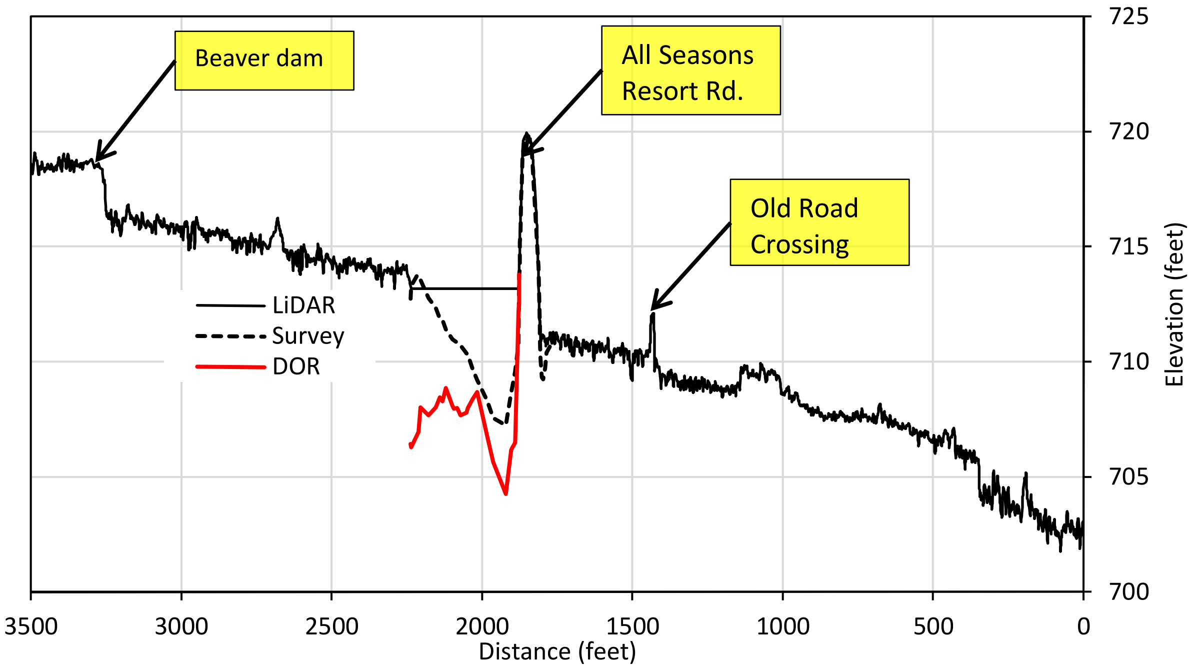


Figure 47. Rodgers Lake Outlet Channel profile for the proposed alignment shown in Figure 46. Note the discontinuity in the profile indicating the pond has been dredged.

Figure 48. Beaver dam just below Rodgers Lake

Figure 49. Typical view of the upstream section of channel above Rodgers Pond

Figure 50. The old crossing above the pond - note the two old pipes in the bed

Figure 51. Looking downstream at the Rodgers Pond toward the road

Figure 52: Looking downstream from All Seasons Rd. during the January flood

HYDROLOGIC ANALYSIS

The Dowagiac is a unique river. Few rivers and streams are capable of supporting a cold water fishery in southern Lower Michigan, especially rivers with top widths near 60 feet that are susceptible to heating from the sun. The cold water is the result of extensive coarse-textured surficial sediments deposited by recent glaciations (see geologic discussion above). These sediments are highly permeable and induce significant infiltration of precipitation into the ground which subsequently discharges to the Dowagiac River as base flow. This groundwater-derived base flow is significantly cooler than water derived from surface runoff.

The project reach is located downstream of the confluence with Dowagiac Creek which contains a large portion of the upstream drainage area (55%). Within the project reach, there are three tributaries that provide a significant source of flow: (1) an unnamed tributary 2,300 feet upstream of Sink Rd. to the west of the river, (2) Peavine Creek located 1,200 feet upstream of Sink Rd. to the east of the river, and (3) the Rodgers Lake Outlet Channel located 1,200 feet downstream of Sink Rd. to the west of the river.

Figure 53. Locations of the Sumnerville (04101800) and State Highway 51 (04101535) USGS flow gaging stations relative to the project reach. The red polyline indicate the project reaches on the Dowagiac Creek and the Rodgers Lake Outlet Channel.

To better understand the flow regime of the Dowagiac River, we utilized the US Geological Survey (USGS) flow gage at Sumnerville (04101800) to estimate peak flood magnitudes and the duration and frequency of base flows. The Sumnerville Gage includes a period of record from 1961 to 2012. An additional flow gage was installed by the USGS at State Highway 51 (04101535) in February, 2013, but the short record of this gage prevented us from utilizing the data for historic analysis. This gage was useful for scaling discharges required for the hydraulic model calibration.

The following sections focus on the estimation of flood flows, a characterization of base flow within the system, and finally a discussion on the changes to watershed hydrology over the period encompassing European settlement to present.

FLOOD MAGNITUDES

Dowagiac River

To estimate flood magnitudes, a Log-Pearson Type III (LP3) probability distribution was fit to the Sumnerville flow gaging station data on the Dowagiac River (USGS gage 04101800) (IACWD, 1983). This gage is located 1.2 miles downstream of the project site (Figure 53) and has a drainage area of 255 mi^2 compared with 219 mi^2 at the downstream end of the project area. The flow gaging station at State Highway 51 (USGS gage 04101535) was not utilized for flood magnitude analysis given its short period of record.

The gage record at Sumnerville included 52 years of data; however, analysis of the annual peak flood plot (Figure 54) suggests peak flood magnitudes have an increasing trend over the period of record. Given the importance of flood hydrology to the project, the data was parsed to examine the potential effect of this trend on predicted discharge. Three component sets were analyzed. First, the 1983 through 2013 data set was used because it includes inter-decadal climate cycles that have been shown to persist within the Lake Michigan region (Thompson and Baedke, 1997; Hanrahan, 2009; Wang et al., 2012). This 30 year data record (31 floods were recorded, but one was omitted from the analysis as it was an outlier) provided a sufficient time period to complete the LP3 analysis (a minimum of 10 years is recommended for analysis [IACWD, 1983]). The second period of analysis focused only on the data record over the last 10 years (11 floods were recorded, but one was omitted from the analysis as it was an outlier); the shortest period of time recommended for analysis. The final data set included the entire 52 year period.

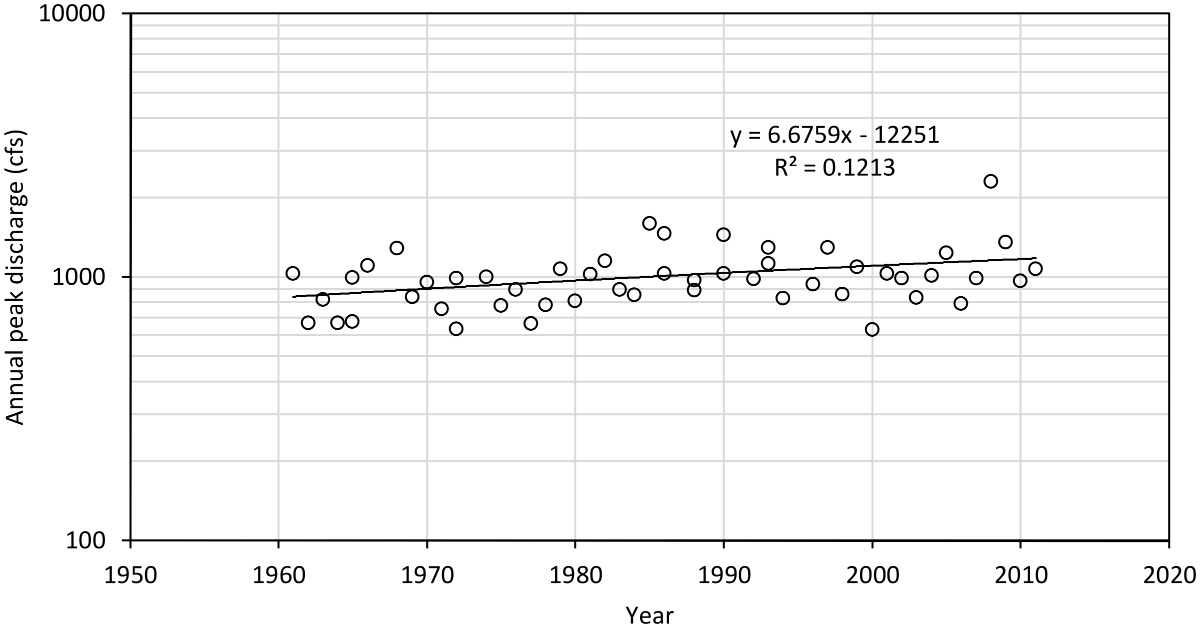


Figure 54. Annual instantaneous peak discharges for the Dowagiac River gaging station at Sumnerville (USGS 04101800). One high outlier was detected in 2008 and removed from the flood quantile estimation procedure. The solid black line represents a linear trendline through the data. There is a general increase in annual peak flood magnitude.

The application of the LP3 method for determining flood magnitudes required calculating first, second and third moments of logarithms of the annual maximum peak discharges at the USGS Dowagiac River gaging station at Sumnerville (04101800). For the third moment (i.e., skew coefficient), we used a generalized value that combined the gaging record with a regional average value as flood quantiles are relatively sensitive to the value (IACWD, 1983). With the entire gage record data, the skew was 0.085 while the regional average skew was 0.081 (Croskey and Holtschlag, 1983). The similarity between the two values confirms that the Sumnerville gage reflects regional climate and runoff regimes. Combining the two values resulted in a generalized value of 0.083. For the parsed data, the sample skew coefficient was 0.17 and 0.28 for the 30- and 10-year gaging records, respectively. The higher skews indicate larger magnitude floods in recent years.

Flood magnitude estimation also involved testing for outliers in the data. One high outlier of 2,300 cfs from 2008 was detected in all three gaging period analyses and was omitted from the analysis. No low outliers were found. Transformation of the LP3 results to the project area were based on the results of regional regression equation estimates at the project site and the gaging station. The regression equations relate various physiographic and climatic characteristics to estimated peak floods (Holtschlag and Croskey, 1984). For the southern region of Michigan, floods were found to correlate with drainage area, storage area, slenderness ratios (length of channel squared divided by the drainage area), precipitation intensity, and the types of surficial geologic material. To utilize the regression equations, we multiplied the LP3 estimated flood magnitudes at the Sumnerville Gage by the ratio of regression equation estimates for the corresponding recurrence interval at the project site and the Sumnerville Gage with the following equation:

$$Q_{site} = Q_{SMN,LP3}\left(\frac{Q_{site,reg}}{Q_{SMN,reg}}\right)$$

Q_{site} was the predicted discharge at the site of interest, $Q_{SMN,LP3}$ was the estimated flood magnitude at the Sumnerville gage using the IACWD (1982) method, $Q_{site,reg}$ was the flood magnitude predicted by the regression equation at the site of interest, and $Q_{SMN,reg}$ was the flood magnitude predicted by the regression equation at the Sumnerville gage. The results of this analysis are shown in Table 2.

Predicted flood magnitudes at the project site were smaller than magnitudes obtained by simply scaling drainage areas. This adjustment makes sense as the floodplains along the Dowagiac River have the ability to attenuate flows when floods overtop the channel banks.

Table 2. Peak flood magnitude estimates at the USGS gage (04101800) using the full, 30-year, and 10-year data records. The 30-year record predicted the highest discharges and was used to provide a more conservative approach for hydraulic modeling.

Recurrence Interval (years)	Discharge (cfs) for various gaging record lengths		
	Full record	30-year	10-year
1.43	901	911	897
2	952	1017	991
5	1149	1218	1166
10	1269	1341	1271
25	1314	1488	1394
50	1517	1593	1480
100	1617	1695	1562

The flood magnitudes for the 30-year gage record resulted in the largest estimates while the full record had the second highest estimates and the 10-year record had the lowest estimates. We applied the 30-year gaging data for the hydraulic model as it provided more conservative results by producing higher estimated water surface elevations and larger shear stresses.

Table 3. Predicted flood magnitudes at Peavine St., Sink Rd., and Crystal Springs St. based on the 30-year Sumnerville Gage data record and the regression equation transformation.

Recurrence Interval (years)	Discharge (cfs)		
	Peavine	Sink	Crystal Springs
1.43	753	803	809
2	841	897	903
5	1008	1075	1083
10	1110	1184	1193
25	1233	1314	1324
50	1320	1408	1418
100	1405	1498	1509

Rodgers Lake Outlet Channel

Peak flows in the Rodgers Lake Outlet Channel were estimated using regional regression equations (Holtschlag and Croskey, 1984) and corroborated with flow gaging data. The same regression equations that were used for the Dowagiac River gage transfer were applied to the 1.03 mi^2 drainage area for the Rodgers Lake Outlet Channel. Variables used for the equations included: surficial geology (100% glacial outwash), channel slope (19 feet/mile), the percentage of the channel running through lakes and swamps (47%), and the slenderness ratio (2.38). The resulting discharges are listed in Table 4. The ratio of 100-year flood magnitude to 5-year flood magnitude is quite small at only 2. This result is due to the large attenuation capacity available at Rodgers Lake and the upstream wetlands for storing precipitation runoff and slowly releasing the water downstream. Thus, flows are relatively stable during floods.

Confirmation of the estimated flood magnitudes was provided by discharge measurements on January 31, 2013 during an estimated 1.3-year flood on the Dowagiac River. Projecting the regression results using a logarithmic trendline, the estimated discharge was 6 cfs for a 1.3-year flood. The discharge was not measured directly on the day of the flood, but a nearby stream discharge was measured at 2 cfs and was visually estiamted to have a similar magnitude as the Rodgers Lake Outlet Channel. Provided that the visual estimate produced a ±100% error, the regression equation results provide a conservative estimate of peak flood magnitudes.

Table 4. Estimated flood magnitudes in the Rodgers Lake Outlet Channel at the All Seasons Resort Road.

Recurrence Interval (years)	Discharge (cfs)
5	12
10	14
25	18
50	21
100	24

BASE FLOWS

Base flow is the portion of the river discharge that results from groundwater. Surface water runoff when added to base flow, induces floods of various magnitudes. It is important to note the base flow, although constant, does vary in magnitude with the season and the associated amount of precipitation in a given year. This groundwater contribution is important to the Dowagiac River, providing a stable source of cold water that makes it suitable habitat for cold water species.

To investigate base flow in the Dowagiac, a plot of the average daily discharge can be useful. Average daily discharge should factor out major flood events over time and provide an understanding of the average flow on any day of the year in the Dowagiac. This average would represent base flow. A plot of this average daily discharge in included in Figure 55 below. Looking closer at this plot, the seasonality of flow on the Dowagiac is apparent, with higher flows in the spring, gradually trending lower into summer then increasing in late fall and winter with rainfall and lake effect snow events.

To understand the changes between wet years and dry years in the magnitude of base flow, the exceedance probability is useful. The exceedance is best understood by filling in the values to the following sentence – "Over the period of record (1961-present) on this day, flow exceeded X cfs only X% of the time." The driest of years would be indicated by the 100% exceedance value. In other words, flow has never been below this value during the period of record. Base flow during wet years is difficult to interpret as the lower flow exceedance values begin to incorporate some element of the flood signature. In Figure 55 below we used the 10% value to indicate base flow in extremely wet years.

Table 5. Low flow statistics at the Sumnerville gage and at Crystal Springs St. and Peavine St.

% Time Exceeded	Discharge (cfs)		
	Sumnerville Gage	Crystal Springs St.	Peavine St.
1	777	670	528
5	541	467	368
10	458	395	311
50	276	238	188
75	205	177	139
90	162	140	110

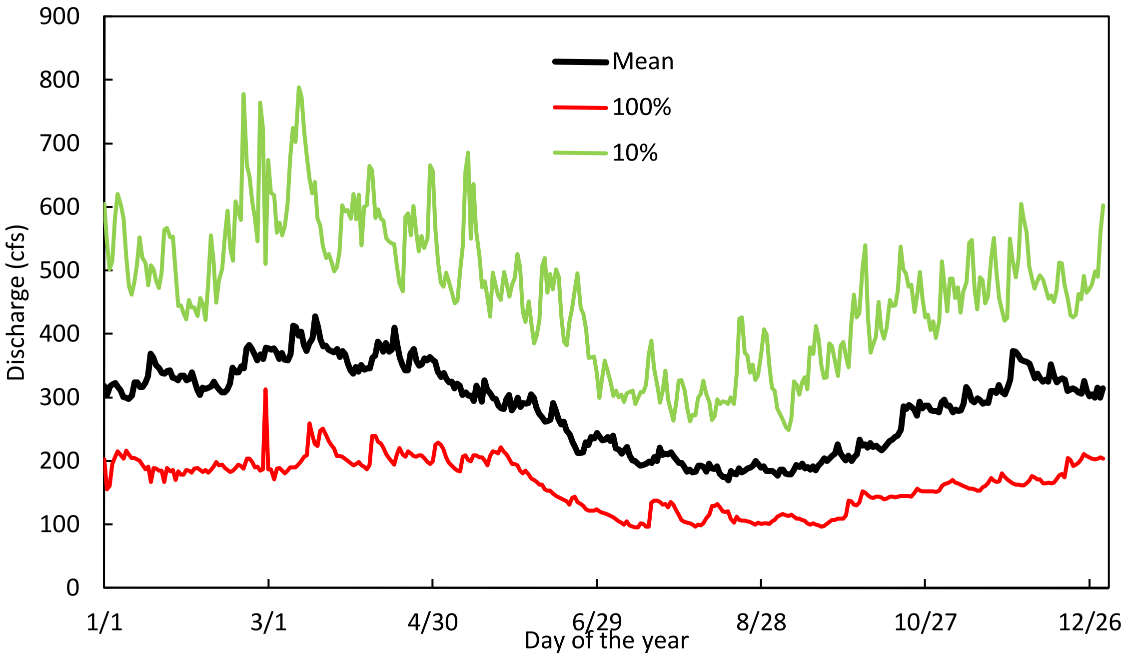


Figure 55. Probability of flows exceeded for each day of the year at the Sumnerville gage. The black line is the average flow magnitude for each day averaged for the gage record since 1980, while the green and red lines relate to flows exceeded 10% and 100% of the time, respectively, for each day of the year.

CHANGES TO WATERSHED HYDROLOGY

The current hydrologic regime of the Dowagiac River has changed since the arrival of Europeans in the watershed. The magnitude of this change is important for the design of the Dowagiac River Restoration Project as historic channel locations may have existing under a different flood regime, responsible for shaping the channel. Investigating the magnitude of the changes in both peak discharge and base flow can provide context for the geometry of the old channels within the project area.

Peak Flow Changes

In the Dowagiac River, the average and variability of peak floods have increased based on the gage record (1961-2012). Visual assessment of the annual peak flood data (Figure 54) suggests that the mean and variance of peak discharges have both increased since 1961 when flow gaging began. This is confirmed by the fitted trend line to the data. Another analysis tool that determines hydrologic regime change is a flashiness index. As watershed or atmospheric conditions change through time, the precipitation runoff response of a watershed and river also changes. Analysis of flood hydrographs can reveal these changes as the time to peak discharge and the recession back to base flow will change with different atmospheric or watershed conditions. Baker et al. (2004) developed a flashiness index (Richards-Baker Flashiness Index) that was based on the differences in average daily discharge between successive days at a gaging station. An increase in flashiness value for a year indicates that the differences between average daily flows were larger in that given year. In other words, the time decreases for a river to rise from base flow to the maximum discharge during a flood. Similarly, the time required for the flood to recede back to base flow from peak discharge will also decrease.

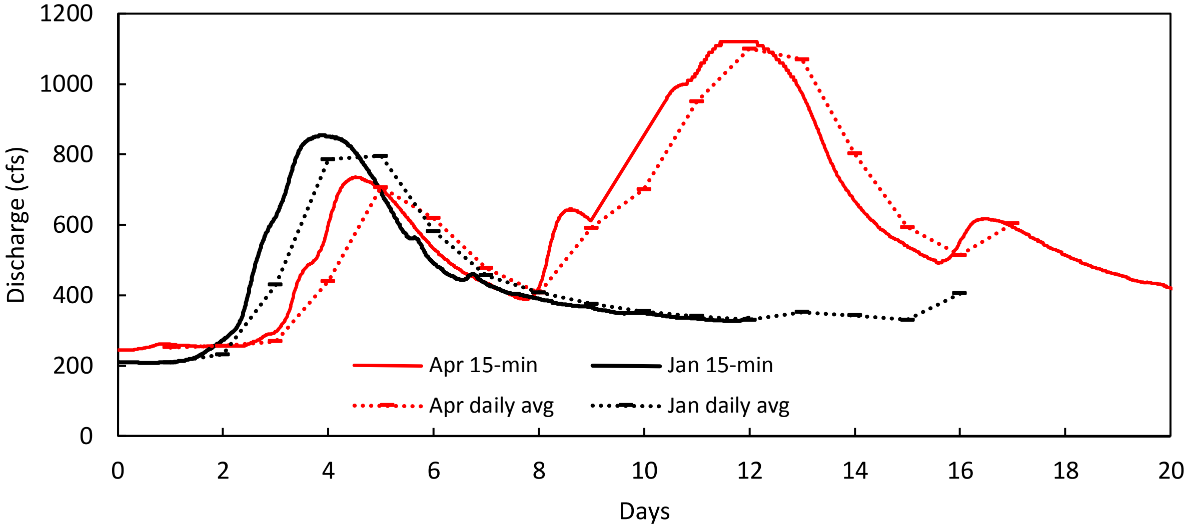


Figure 56. Typical hydrographs at the Sumnerville flow gage using 15-min and daily average data. Separate flood events from January and April, 2013 are shown with a common daily x-axis scale. Note that the rising limbs and time from base flow to peak discharge is about the same for each event despite one occurring with rain on snow in the winter and the other occurring in April due to rain alone. The differences between average daily discharges on successive days form the basis of the Richards-Baker Flashiness Index.

Fongers et al. (2012) applied the Richards-Baker Flashiness Index to the Dowagiac River gage at Sumnerville (Figure 57). They calculated the index for each year of the gaging record then estimated the trend of the data. Between 1961 and 1972 there appeared to be a decreasing trend with the R-B Index values, though there was some scatter. Fongers et al. (2012) did not calculate trend statistics for this time period. Nevertheless, the decreasing trend is apparent in the data. It is not known, however, what caused the decrease in flashiness. One possible scenario could be the increase in forested areas and the maturing of existing forests within the watershed.

From 1973 through 2011 there was a significant (p-value 0.00) increase in flashiness. Common causes of increased flashiness include urbanization, channelization (straightening), drain tile installation, or deforestation. In the Dowagiac River, the major changes are likely related to continued alteration of hydrology for drainage purposes. This assessment follows a simple process of elimination as the population of the watershed has not increased markedly, forestation within the watershed has likely increased based on limited aerial photo interpretation, and the channelization of the main stem Dowagiac already occurred well before gage recording began.

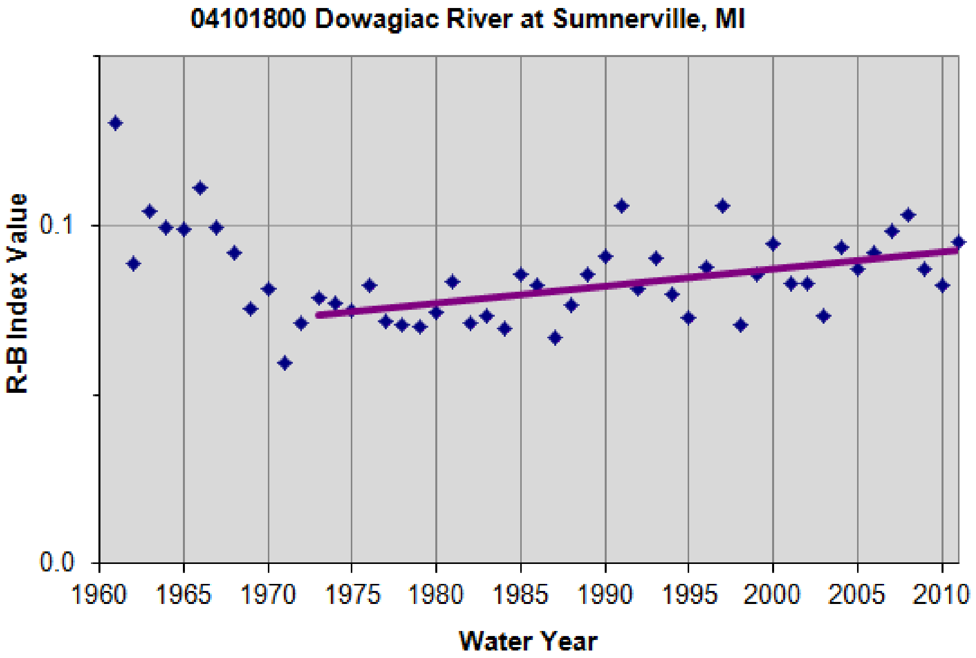


Figure 57. Richards-Baker Flashiness Index results from the Sumnerville gage (Fongers et al., 2012). After 1972 there was a significant increase in flashiness.

An increase in peak flows, flashiness and variability were evident in the Dowagiac River gage data over the last 40 years; however, flow records were not available between pre-European settlement (early 1800s) and current hydrologic conditions. As a surrogate for pre-gaging record peak flood analysis, we estimated bankfull flows for the relict channel to compare with current peak flood estimates. This analysis is based on evidence that most dynamically stable rivers with low gradients in agricultural watersheds have bankfull channels that are adjusted to convey a peak flood between the 1.0-1.5-year recurrence interval (Williams, 1978; Powell et al., 2006). The 1.0-1.5-year recurrence interval is a flood that is, on average, estimated to occur once every year (based on the annual flood series).

To estimate the bankfull discharge of the relict channels, we first estimated an average 65 foot channel top width from the LiDAR data, confirmed by DOR probing. An average bankfull depth of 5 feet was estimated between the DOR survey elevations and the current floodplain elevations. The reach average slope was determined by dividing the current drop in elevation through the valley by the plan form length of the old channel to obtain a grade of 0.00037 (for comparison, the current, channelized slope is about 0.00043). Finally, 1:1 (horizontal:vertical) bank slopes were specified and the roughness values were subjectively increased to 0.055 from 0.05 to account for additional large woody debris likely present in the relict channel. The resultant discharge was 420 cfs.

We also tested the sensitivity of this analysis to various channel configurations as the historic river likely varied from steeper to milder grades and there is likely some scatter around the measured DOR. To begin, we tested the sensitivity to slope by increasing, then decreasing the drop in channel bed elevation by 2 feet while the plan form alignment remained the same. This exercise assumes all other channel dimensions noted above are constant. The results indicate that the bankfull discharges vary between 340 and 460 cfs (Table 6).

As slopes change, bank heights also typically change. Accordingly, we tested the change in bankfull discharge with an increase and decrease in bankfull depth by 1 feet. The slope was specified as 0.00037 for all three scenarios. The results indicate that the bankfull discharge varies between 300 and 550 cfs.

Table 6. Estimated bankfull discharges for the relict channel with various slopes. Bankfull depths were held constant at 5 feet. The slopes were determined by increasing and decreasing the drop in elevation along the plan form alignment by 2 feet. Note that the maximum discharge of 460 cfs is still much less than the current 1.05-year flood discharge of 639 cfs.

Slope	Q (cfs)
0.00026	340
0.00037	420
0.00043	460

Table 7. Estimated bankfull discharges for the relict channel with various bankfull depths. The channel slope was held constant at 0.00037. The depths represent the range of potential depths found in the DOR survey. Note that the maximum discharge of 550 cfs is still much less than the current 1.05-year flood discharge of 639 cfs.

Bankfull depth (feet)	Q (cfs)
4	300
5	420
6	550

Comparison with the current estimated 1.05 and 1.43 year peak floods (1.05- and 1.43-year recurrence intervals are used because they are the reciprocals of the 0.95 and 0.7 probabilities for which frequency factors are readily available [Chow et al., 1988]) of 639 cfs and 803 cfs, respectively, suggests that annual flood magnitudes have increased substantially since European settlement.

Although annual floods (1-1.5-year recurrence) appear to have increased significantly, it is important to be aware that the historic channels within the project area were still active until 1910 when channelization occurred. By 1910 the watershed experienced large scale deforestation and conversion to agriculture. The historic channel, currently present in the floodplain, therefore, would have adjusted or been adjusting to hydrologic and sediment transport regimes that were different than pre-settlement conditions. For the relict channel to arrive at the form we encountered in the floodplain, multiple channel evolution processes are possible. Channel widening and incision may have occurred as precipitation runoff increased due to the lack of canopy interception of rainfall, the channeling of water down row crops in fields, the lack of roughness on the land to impede runoff, and the absence of large woody debris in the channel to attenuate floods. Conversely, the conversion to agriculture and the reduction of riparian forests could have increased sediment supply to the river, filling up the channel cross section to reduce depths and induce excessive overbank deposition. To delineate precise historic channel geometries, it would be necessary to date sedimentation layers and/or radiocarbon date organic matter, an effort well beyond the scope of this project. Nevertheless, the results indicate that peak floods were likely different in 1910 than they are today.

Other methods were also investigated to attempt to understand the magnitude of change in hydrologic regime since settlement of the watershed. The Nature Conservancy's Indicators of Hydrologic Alteration was investigated for applicability (The Nature Conservancy, 2009). This program, however, analyzes existing flow gage data to develop environmental flow standards. The results of the method are directed towards determining flow requirements for various riverine and riparian bugs, fishes and plants. It does not predict changes in flow regime due to changes in land use. Additionally, the program relies on existing gage data rather than allowing us to predict pre-settlement conditions long before a gage was present on the river.

The US Geological Survey National Hydrologic Assessment Tool (NATHAT) (Cade, 2009) was also investigated, but was found to provide similar results as The Nature Conservancy's program. NATHAT relies on existing gage data to detect changes in hydrologic regime. Although we know changes have occurred in the watershed since the Sumnerville gage began operation in 1960, the bulk of the hydrologic alteration occurred previous to 1960. As noted above, the flashiness index provides evidence that the watershed continues to change; however, these likely pale in magnitude to the changes induced between the mid 1800's and 1920's.

Base Flow Changes

The base flow regime has changed slightly over the gaging record at Sumnerville. Discharges during the winter months have increased in the period between 1983 and 2012 compared with the 1961 through 1982 period. It is unknown what caused the increase in winter flows, but some potential causes may include: warmer winter temperatures allowing for additional groundwater recharge, or increased drain tiling intercepting the groundwater table and discharging to the river. In the summer, base flows appear to have remained stable throughout the gaging record.

Base flow changes since before European settlement could not be determined as flow gaging data was not available. Regime changes could be determined by constructing a calibrated hydrologic model of the watershed. This analysis was beyond the scope of our work.

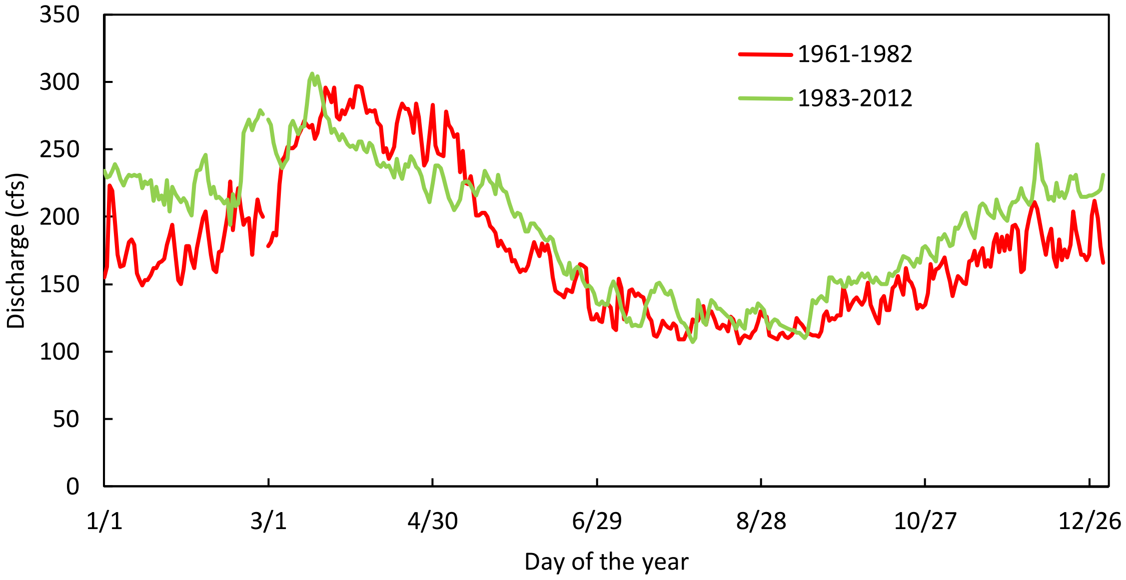


Figure 58. Daily discharges exceeded 90% of the time at the Sumnerville Gage. Base flows in the 1983-2012 time period have increased during the winter and remained steady in the summer compared with the 1961-1982 time period.

HYDRAULIC ANALYSIS

Hydraulic modeling was performed using the one-dimensional program HEC-RAS. Although the model does not account for horizontal or vertical variations in velocity, it is appropriate for most river systems that do not have lateral flow directions on floodplains. The geometry for the existing conditions model was provided by the topographic/bathymetric survey completed in March, 2013 and LiDAR data collected in April, 2013. Cross section locations and configurations were altered from the original model to determine the effects of various restoration scenarios on hydraulic characteristics. The peak and base flow magnitudes from the hydrologic analysis were applied for the steady flow component in HEC-RAS.

Two models were created for this analysis. The first was a model of existing conditions calibrated to conditions observed on the site. The second model was a proposed conditions model, intended to predict the hydraulic conditions associated with placing the Dowagiac back into its old channel under a restored condition. Both model iterations are discussed in detail below.

EXISTING CONDITIONS

Model Construction

The geometric data for the existing conditions HEC-RAS model were synthesized in AutoCAD Civil3D from the March, 2013 survey data and the April, 2013 LiDAR. In AutoCAD, points from the topographic survey were integrated into a land surface model. Separate surfaces were setup for the survey and LiDAR data. An alignment representing the existing thalwegs (the deepest part of the channel cross section) was drawn through the surface models to define reach lengths between cross sections. Hydraulic cross sections were overlaid onto surveyed cross sections. Overbank flow path lengths between cross sections were estimated from the difference between centroids of the flow areas in the left and right floodplains. Finally, the geometry established in AutoCAD was exported to HEC-RAS for further model development.

Bridge data was setup in HEC-RAS by measuring distances and elevations in the survey points in AutoCAD. An energy equation approach was specified for all bridges. Contraction and expansion ratios were specified to be 0.3 and 0.5 at the adjacent upstream and downstream cross sections to the bridges, respectively. Ineffective flow areas were established at the cross sections adjacent to the bridges to block off areas that would not actively convey water during floods but would remain wetted. We assumed a 1:1 contraction ratio angle immediately upstream of the bridges and a 2:1 expansion ratio as flows exit the bridges.

Ineffective flow areas were established in the floodplains of cross sections where levees were present. The levees were formed during the excavation of the straightened channel and aligned parallel the river. There are low saddle points in the levees, however, that allow water to spill laterally onto the floodplain. We estimated an elevation about 0.5 feet higher than the low spots in the levees as the threshold where water conveyance begins on the floodplain. Water surfaces below this threshold were assumed to have minimal flow conveyance in the floodplain areas.

Model Calibration

To calibrate the hydraulic model, we adjusted roughness values until modeled water surface elevations matched observed elevations during two high flow events. On January 31, 2013, we surveyed water surface elevations while the average discharge at the Sumnerville Gage was 843 cfs. The corresponding recurrence interval for the flood was approximately 1.3 years. To utilize the data in the hydraulic model, we linearly interpolated data between the Sumnerville and Highway 51 Gage based on drainage area with the following equation:

$$Q_l = Q_{51} + (DA_l - DA_{51})\left(\frac{Q_S - Q_{51}}{DA_S - DA_{51}}\right)$$

where Q_l is the discharge at the desired location, DA_l is the drainage area at the desired location, DA_{51} is the drainage area at the Highway 51 gage, DA_S is the drainage area at the Sumnerville gage, Q_S is the measured discharge at the Sumnerville gage, and $Q_{51}$is the measured discharge at the Highway 51 gage. The estimated discharges using this interpolation method resulted in magnitudes that were within 2-4% of the scaling method utilized for the peak flow analysis.

Flow magnitudes were derived for the bridge crossings at Highway 62, Frost St., Peavine St., Sink Rd., and Crystal Springs St., which were all included in the model. The calibrated Manning's n values varied from 0.054 in the channel downstream of Sink Rd. to 0.045 in portions of the channel just downstream from Peavine St. The floodplain values were all specified to be 0.1 as estimated using roughness partitioning methods suggested by Arcement and Schneider (1989). The differences between the observed and modeled water surfaces were all within 0.10 feet for the January 30 discharge (Table 8), indicating good model agreement.

On April 19, 2013, water surface elevations were measured by Robert Frank and Grant Poole of the Pokagon Band of Potawatomi during a 1,120 cfs flow event at the Sumnerville Gage. The discharge magnitude corresponds to approximately a 3.5-year flood. Measured water surface elevations were referenced to bridge low chord elevations that were previously surveyed in March, 2013 (Figure 6060). Some error was inherent with this methodology as it was difficult to survey bridge low chord elevations exactly while standing on top of the bridge deck (estimated error about 0.10 feet). Additional error was involved with measuring down from the low chord to the water surface elevation during the flood (additional estimated error about 0.10 feet). Nevertheless, measured water surface elevations were 0.16 feet higher than those predicted by the model at Sink Rd., 0.00 feet at Peavine St., and 0.01 feet lower at Frost St. These errors were based on maintaining the same roughness values established for the January 31, 2013 calibration.

Finally, we surveyed one high water mark from the September, 2008 flood in Paul Hinsey's shed along Sink Rd., about 2,600 feet upstream of the Sink Rd. bridge (elevation 710.21 feet). The flood had a magnitude of 2,300 cfs which was larger than the predicted 500-year recurrence interval flood. At this stage, there was significant flow conveyance on the floodplain. The model predicted water surface elevation at this discharge was 0.45 feet higher than the measured elevation. This error is relatively large, however, it confirms that the hydraulic model is conservative with predicting flood water surface elevations. Roughness values were left the same, though extensive research indicates flow roughness decreases with stage (Shields and Gippel, 1995; Dudley et al., 1998). If we lowered the roughness values, the resulting water surface elevation predicted by the model would decrease. In other words, we are very confident that the actual water surface elevations for large floods (25-500+ year recurrence interval) will be at or lower than the predicted elevations in the model.

Table 8. Differences between measured and modeled water surface elevations during the January and April, 2013 flood events.

Modeled vs. measured water surface differences (feet)		
January 31, 2013 (843 cfs)	April 19, 2013 (1006 cfs)	September 15, 2008
0.04	-0.02	-0.45
0.07	0.16	
0.07	-0.02	
-0.04	-0.01	
-0.05		
-0.09		
0.09		
0.06	0.05	-0.45

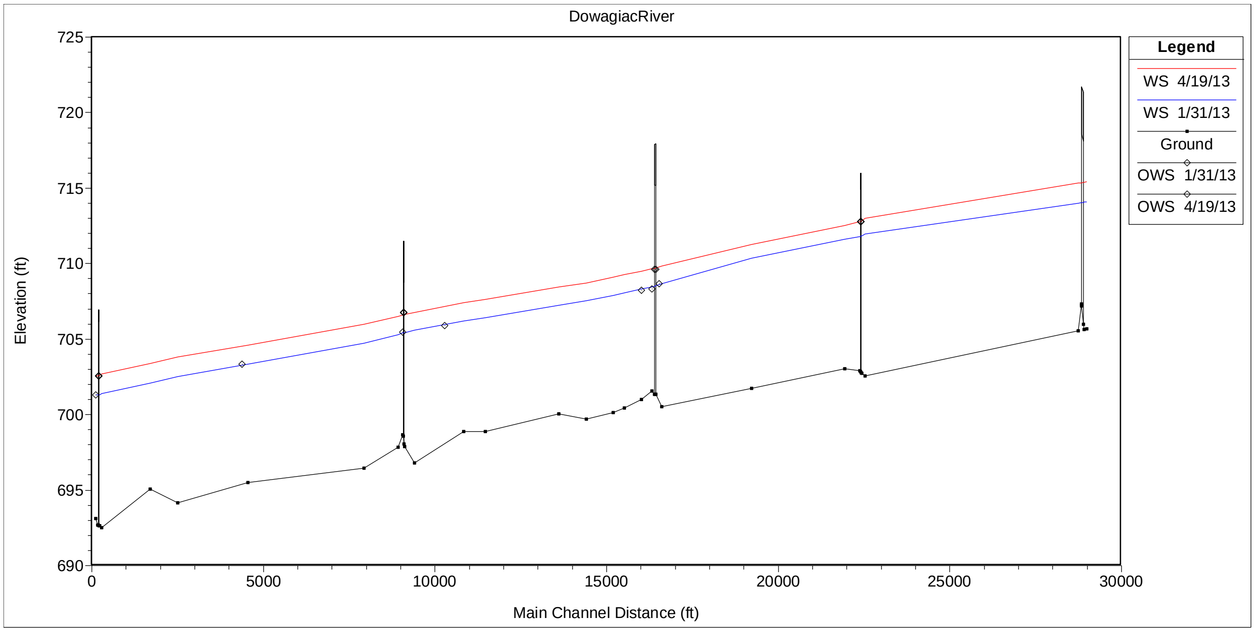


Figure 59. Modeled and observed (black diamonds) water surface elevations on January 31, 2013 (blue line) and April 19, 2013 (red line). Matching these elevations created a calibrated model with errors less than 0.10 feet.

Figure 60. Example of how water surface elevations were measured with reference to the low chords of the bridges during the April, 2013 flood. This is at Sink Rd. (photo provided by Robert Frank).

Downstream boundary conditions were specified as a known water surface for the calibrated model, but were set to normal depth for the existing and conditions models. We calibrated the normal depth slope until modeled and observed water surfaces during the two 2013 high flow events matched the known water surface elevations at the downstream end of the model. The resultant slope was 0.00037 which is milder than the channel grades upstream. This is consistent because the downstream end of the modeled reach is influenced by backwater from raising the channel bed 4 feet at the Dodd Park re-meander project (Cass County Conservation District, 2007).

PROPOSED CONDITIONS

Model Construction

As part of this investigation, we completed a preliminary analysis of changes to hydraulic conditions with the proposed project in place. Since we have not finished the final design stage of the project, we bracketed a range of potential proposed channel geometries for analysis. A preliminary channel alignment was determined based on historic maps, LiDAR data, and field reconnaissance observations (see section Plan Form Alignment of Dowagiac Channel). The proposed bankfull channel width was specified to be 60 feet as this is the lower end of the range of possibilities (60-80 feet; see Table 9). The smaller top width provided a more conservative model as it created higher predicted water surface elevations, creating a worst case scenario. This was critical to understand the potential impact of floods on nearby homes due to the project. The bankfull channel depth was set to 6 feet so that the 1.05-year flood would be just contained within the bank tops at a slope of 0.00037 (see discussion below). The 0.00037 slope was determined by subtracting the elevation of the channel bed at Peavine St. from Crystal Springs St., then dividing by the plan form length of the proposed channel. As the DOR in the old channel to be re-occupied indicates, there was likely some variability in channel grades within the project reach. Therefore, the minimum and maximum values in Table 9 indicate a range that the proposed design should contain.

Table 9. Proposed bankfull channel geometry compared with the existing geometry. We bracketed a minimum and maximum range of probable proposed channel geometries. The final configuration will be determined during the final design stage.

Channel characteristic	Existing channel	Proposed channel	
		Minimum	Maximum
Bankfull width	80 feet	60	80
Bankfull depth	10 feet	5	7
Sinuosity	1.00	1.53	1.53
Slope	0.00043	0.00026	0.00043

The elevation of the proposed channel bed was raised 3 feet above the existing channel bed so that the top of the proposed 6 foot tall banks would approximately match the existing floodplain elevation. Once water levels overtop the banks at the 1.05-year flood, therefore, most of the valley will become inundated. Reconnection of the floodplain was one goal for this project.

The old channel and spoil piles adjacent to the river were graded flat in the model. We assumed that the material to be cut from the spoils would exactly offset the fill in the channel. Although areas of the current channel may not be filled in with the project, this geometry is valid in HEC-RAS as these areas will not actively convey flood flows. All bridge geometries and cross sections immediately upstream and downstream of the bridges were unaltered for the proposed conditions model.

Proposed cross sections were laid out between the existing bridge locations with an average spacing around 1,000 feet. This spacing is denser than the 2,100 feet required by Samuels (1989) based on a slope of 0.00037 and a bankfull channel depth of 6 feet. The sections were located in areas where the bankfull channel's flow direction was the same as the direction of overbank flow (middle of meander bends). This layout prevented having cross sections in areas where flow may not be one-dimensional or directed down-valley. Bankfull channel reach lengths were delineated using the proposed channel alignment. Overbank flow area reach lengths were measured between the distances between centroids of flow area at each cross section. The centroid of flow area was defined as one third of the distance from the bankfull channel top to the edge of the floodplain valley. Roughness values were increased to 0.055 in the bankfull channel throughout the project area to reflect increased densities of large woody debris that will likely be placed. This increase reflects suggestions by Arcement and Schneider (1989) for large woody debris occupying about 15% of the flow area in the proposed channel. Floodplain roughness remained unchanged from existing conditions.

PROJECT-RELATED CHANGES

Flood and Base Flow Changes

Three homes were identified within and upstream of the project area that may be susceptible to flooding under existing and proposed conditions. To analyze potential impacts, we integrated the HEC-RAS hydraulic model with the LiDAR land surface model to develop maps of inundation areas before and after the proposed project. As the project will likely raise the channel bed about 3 feet and increase sinuosity, the water surface elevations during most flow conditions will rise. Increased water elevation will be greatest during normal flows and gradually decrease as the flow, or flood magnitude increases. During these large flood events, water surface elevations will be smaller as the floodplain conveys the majority of the water and the floodplains will not be altered with the project.

Table 10. Water surface elevation increase due to the proposed project for various flood recurrence intervals and the September 15, 2008 flood (greater than 500-year recurrence interval).

RI	Sink Rd.	Peavine St.	Frost St.
1.05	3.16	2.46	0.48
1.43	2.86	1.90	0.2
1.67	2.78	1.80	0.16
2	2.69	1.68	0.12
5	2.38	1.29	0.03
10	2.20	1.07	0
25	1.99	0.83	0
50	2.06	0.71	0
100	1.94	0.56	0
500	1.71	0.24	0
Sept. 15, 2008	1.40	0.15	0

To analyze the potential impacts to nearby homes (Figure 61), we compared existing and proposed conditions during the 100-year flood event. This flood has a one-percent chance of occurring each year. It is used by the National Flood Insurance Program and all other Federal agencies to determine whether flood insurance should be purchased (French and Associates, 1998).

During average base flow conditions, water surface elevations will rise about 3 feet within the project reach. Nevertheless, the character of the river should not change drastically after project completion as river depths will remain approximately the same. Depths will likely vary between 3.5 and 4.0 feet at most cross sections with some deeper and shallower sections. In general, the depths will vary more than the existing channel as pools and riffle areas will be created. The increased complexity reflects more natural conditions of healthy river systems and will create better habitat for aquatic bugs and fishes.

Upstream of the project area, greater channel depths and water surface elevations are expected. As the downstream bed elevation increases while the upstream bed remains the same, backwater will create slower velocities and deeper water. Nevertheless, the river will remain within the channel banks (levees) as it does now. Immediately upstream of Peavine St. there will still be approximately 2 vertical feet of bank exposed. At Frost St., the channel is already in an incised condition and there will be little change in the water surface elevation during base flows. The water surface here will increase about 1 foot during average flows compared to existing conditions.

Downstream of the project area, no rise in water surfaces will occur. Here, the river is controlled by downstream hydraulics due to the low gradient.

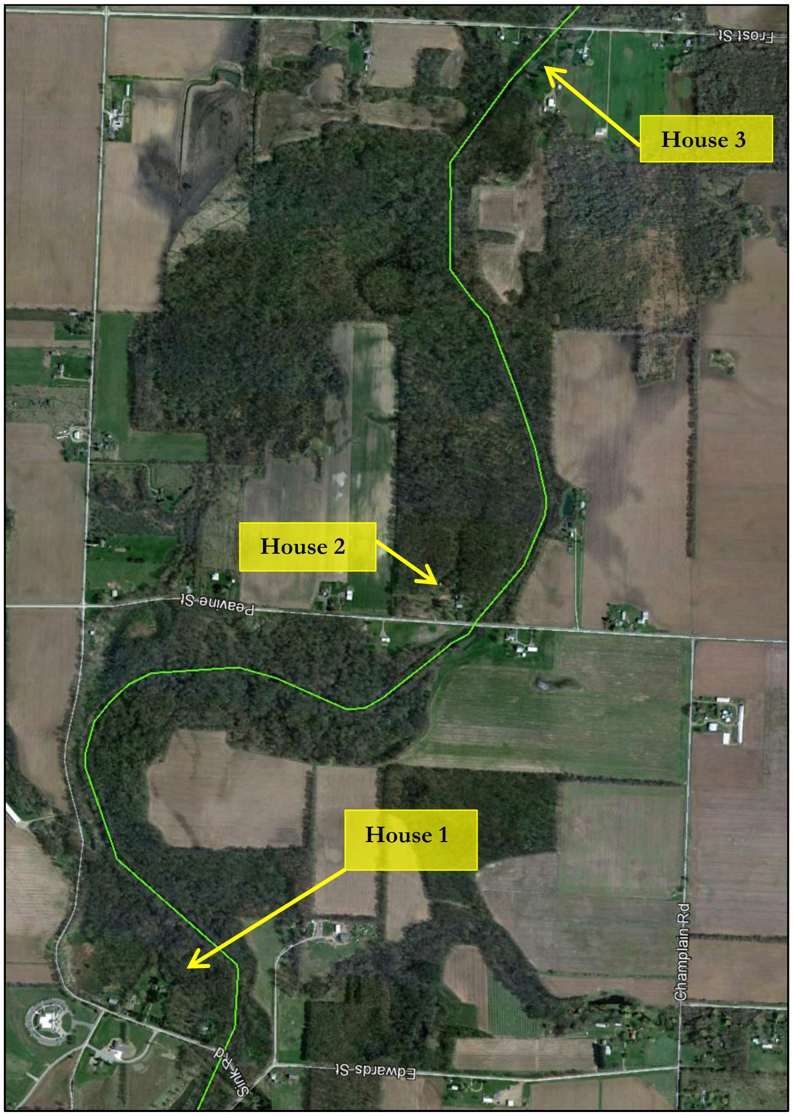


Figure 61. Map of the homes that were analyzed for potential flood impacts with the project.

Home #1 – (Parcel 14-110-017-296-30)

One of the homes situated near the proposed channel is located about 1,000 feet upstream of Sink Rd. on the west of the historic river valley. The river may be raised and shifted laterally about 400 feet closer to the home under the proposed restoration alignment. At the 100-year flood, water surfaces rise 2.04 feet along the cross section of the valley that includes the home (Figure 6361). The existing water surface is currently estimated at 708.11 feet while the proposed conditions would increase the elevation to 710.15 feet for the same flood event. The ground surface adjacent to the home was measured at 710.62 feet using the LiDAR data, providing about 0.5 feet of freeboard. Laterally, this pushes the edge of the water surface moves closer to the home about 30 feet.

At base flow conditions, water surfaces will increase up to 3.65 feet, though the channel depth will remain approximately the same as the existing river. This increase should produce wetter ground conditions around the home, likely returning some of the vegetation community to wetlands.

Figure 62. Photo (looking upstream) of the relict channel that may be re-occupied near the home approximately 1,000 feet upstream of Sink Rd. on the west side of the valley.

Table 11. Water surface elevation changes at the home approximately 1,000 feet upstream of Sink Rd. on the west side of the valley.

RI	EG	PR	Change
Base flow	701.03	704.68	+3.65
1.43	705.72	708.64	+2.92
100	708.11	710.15	+2.04
500	708.69	710.50	+1.81

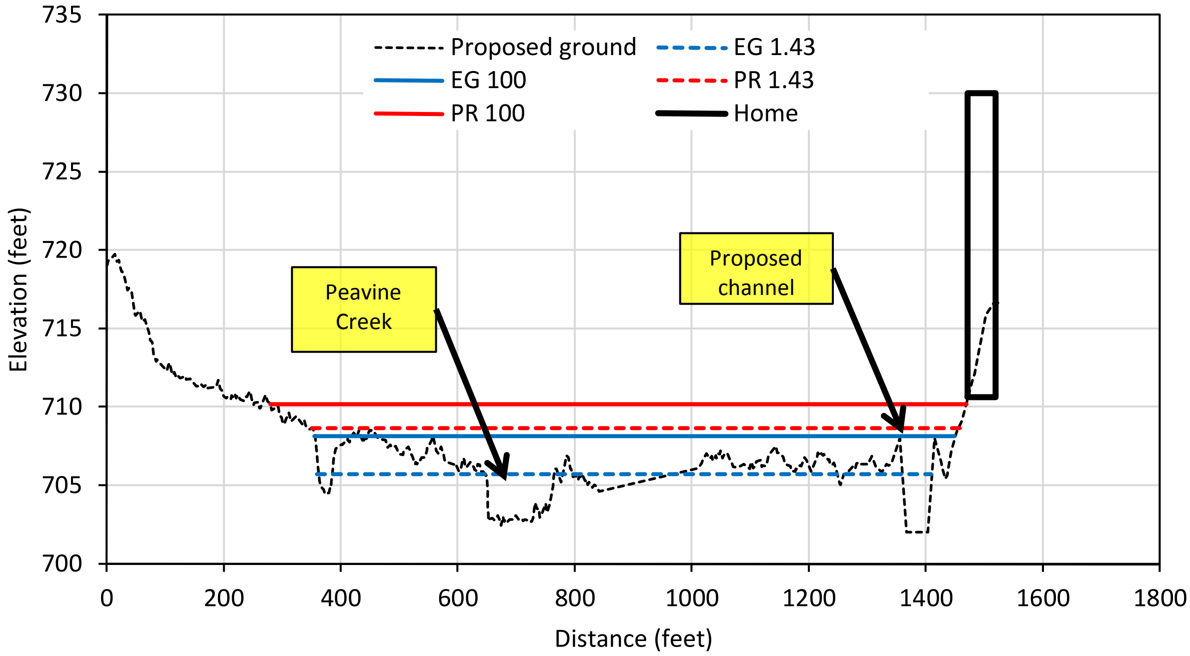


Figure 63. Valley wide cross section at House #1 - 1,000 feet upstream of Sink Rd. Existing (EG) and proposed (PR) water surface elevations are shown for the 1.43- and 100-year floods. Note that water surfaces rise with the proposed restoration; however, the house is not impacted.

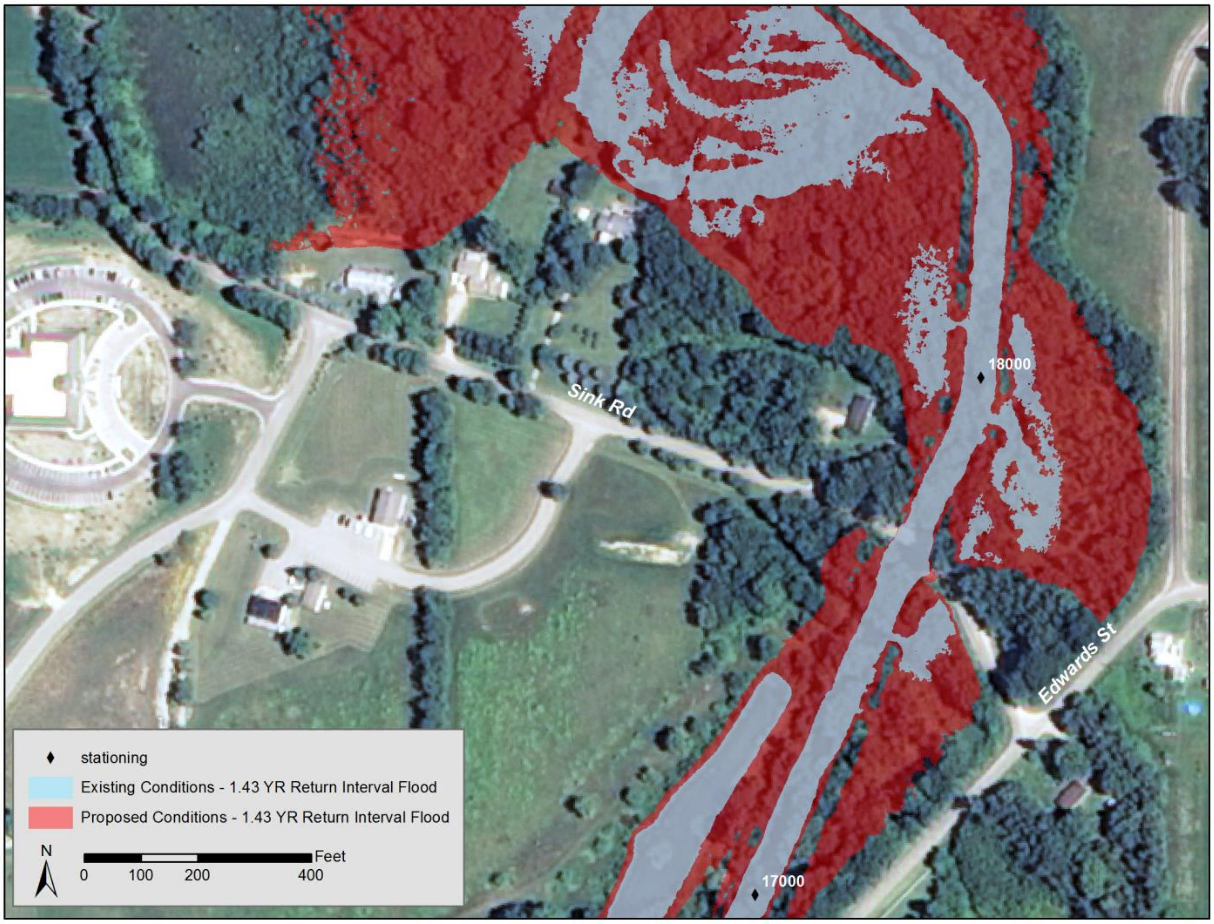


Figure 64. Plan view of the water surface extents around Sink Rd. at the 100-year flood. The proposed (red polygon) water surface rises and covers a larger area than the existing (blue hatched polygon) area.

Home #2 – (Parcel 14-110-009-172-00)

The second home is located just upstream of Peavine St. on the west side of the river. Although the river upstream of Peavine St. will not be re-routed with the project, the increased bed elevations downstream will induce some backwater that could impact upstream homes. Nevertheless, after the project, water surfaces during the 100 year flood are not expected to impact the home despite the 0.56 foot rise from 711.53 feet to 712.09 feet. The 712.09 foot elevation is still 3 feet lower than the elevation of the ground surface at the home. This translates into a 35 foot buffer of dry land at the 100 year flood.

Base flow water surface elevations will rise and create deeper water adjacent to the home. The estimated increase is 2.93 feet. The increase will still remain below channel bank tops here. A significant rise in groundwater elevations is not expected as there should still be about 3 foot depths to the groundwater surface.

Figure 65. Photo looking west from the river at the home just upstream of Peavine St. There is little freeboard for the house in the background.

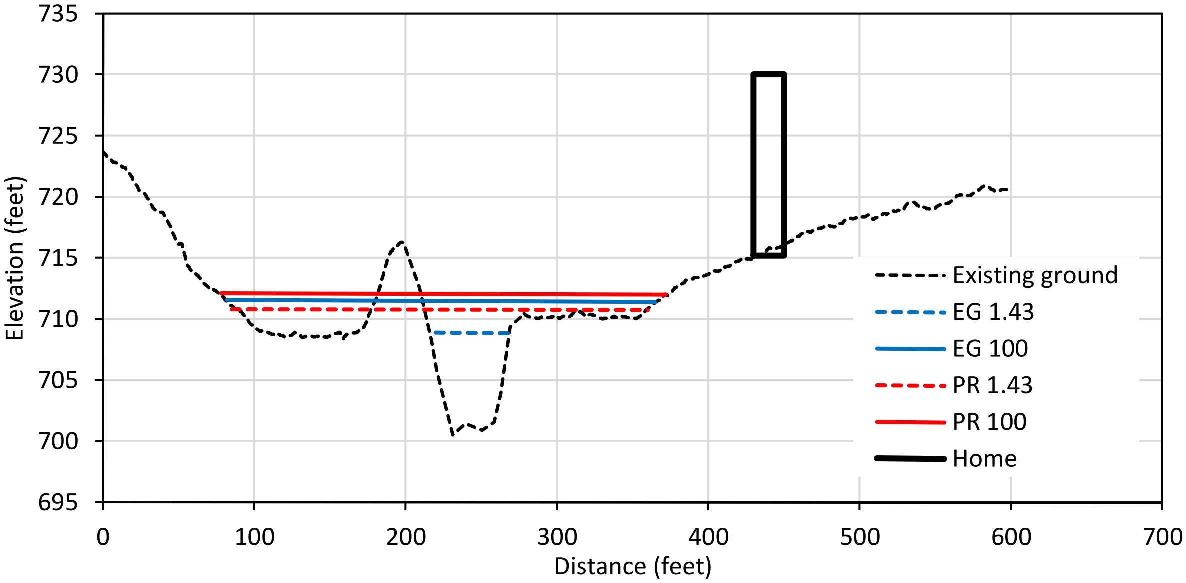


Figure 66. Valley wide cross section at the home just upstream from Peavine St. Existing (EG) and proposed (PR) water surface elevations are shown for the 1.43- and 100-year flood. Note that water surfaces rise with the proposed restoration; however, the house is not impacted.

Table 12. Water surface elevation changes at the home just upstream of Peavine St.

RI	EG	PR	Change
Base flow	704.24	707.17	+2.93
1.43	708.86	710.76	+1.90
100	711.53	712.09	+0.56
500	712.18	712.42	+0.24

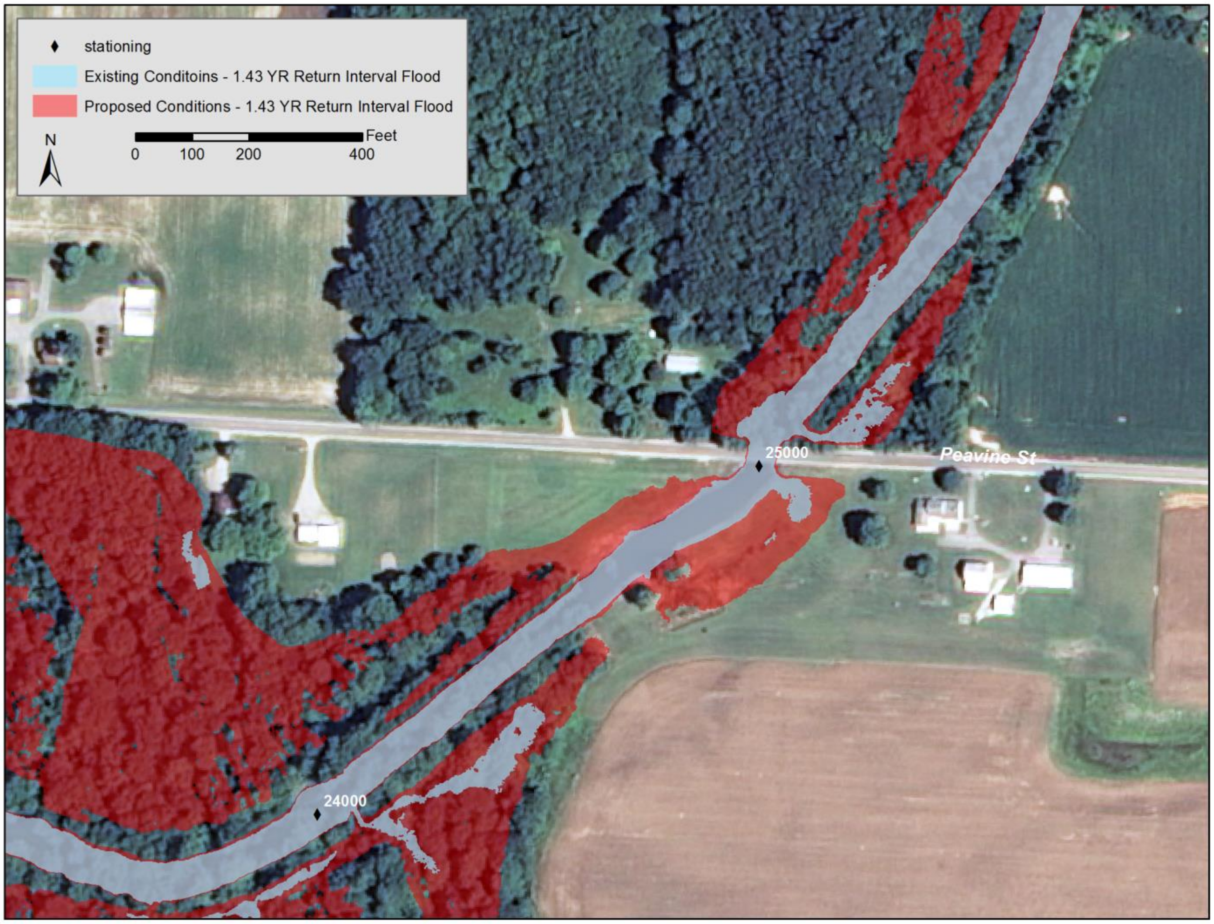


Figure 67. Plan view of the water surface extents around Peavine St. at the 100-year flood. The proposed (red polygon) water surface rises and covers a larger area than the existing (blue hatched polygon) area.

Home #3 – (Parcel 14-110-009-167-01)

At Frost Road, flood impacts will be smaller with the proposed project as it is located about 6,000 feet upstream of any channel grading work. Still, given the extremely mild slope of the river, some changes will occur in this area. About 450 feet downstream from the Frost St. Bridge is a home on the east side of the river that is relatively close to the water. From the LiDAR data, it appears that the home was placed on fill to raise the building to a higher elevation than the surrounding floodplain elevation. With the proposed project, the 100-year flood elevation is not expected to change. The 100-year flood elevation is 713.55 feet and the home is at an elevation of about 715.35 feet as measured by the ground with the LiDAR data. This provides a 1.8 foot vertical buffer between the water surface and the foundation of the home. During base flow conditions, there will be a rise in water surface elevation. An increase of about 0.93 feet will create deeper water.

Table 13. Water surface elevation changes with the proposed project at the home about 450 feet downstream from Frost St. on the east side of the river.

RI	EG	PR	Change
Base flow	706.72	707.65	+0.93
1.43	711.83	712.03	+0.20
100	713.66	713.61	+0.00
500	714.01	713.96	+0.00

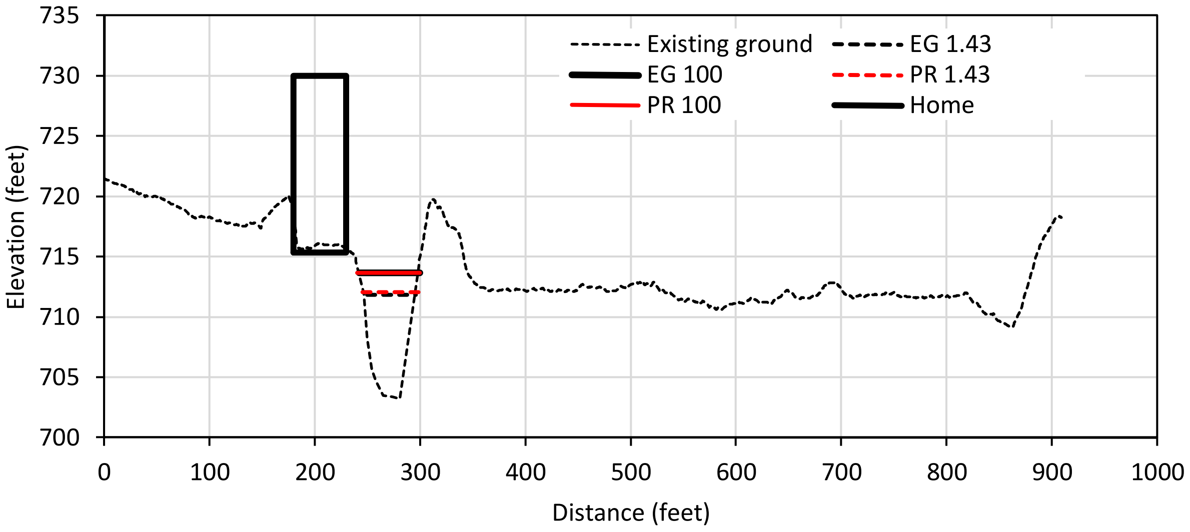


Figure 68. Valley wide cross section at the home about 450 feet downstream from Frost St. on the river left. Existing (EG) and proposed (PR) water surface are shown for the 1.43- and 100-year flood. Note that water surfaces rise with the proposed restoration; however, the house is not impacted.

Figure 69. Plan view of the water surface extents around Frost St. at the 100-year flood quantile. The proposed (red polygon) water surface rises and covers a larger area than the existing (blue hatched polygon) area.

Summary of Hydraulic Impacts to Homes

The hydraulic analysis indicates that although normal, or seasonal base flow, will be elevated, 100-year flood flows should not impact homes above Peavine St. The home just upstream of Sink Rd. has the least free board at about 0.5 feet. at the 100-year flood, suggesting there may be some impact. However, given that the modeled roughness values and channel dimensions were conservative, we are confident that the home will not be impacted during this flood event.

The hydraulic model used is as accurate as the information utilized in its calibration. The two flows used for calibration were much lower than a 100-year event, but as discussed, we have left roughness values consistent with these floods to evaluate impacts at the 100-year event, although they should in fact decrease. Given the size of the floodplain available within the Dowagiac, an increase of nearly 60 cfs would be required to raise the water surface elevation 0.1 feet at the home just above Sink Rd. With 0.5 feet of freeboard here, this would require an additional 300 cfs discharge to begin flooding the home. This information is useful in understanding how robust the model predictions are.

If these projected impacts to nearby homes are deemed unacceptable, there are alternatives for the proposed channel that will reduce these threats. First, the proposed channel bed could be lowered. This would result in larger flows being contained within the bankfull before spilling onto the floodplain. A second alternative is widening the proposed channel. Our analysis of the relict channel indicates a width of 65 feet rather than the 60 foot modeled width. This will decrease predicted water surface elevations slightly. Greater widths, however, are not suggested as the power of the channel available to transport sediments will be reduced if it is over-widened. Eventually, the channel will fill up with sediments again and have self-organize into a channel with a smaller top width. A third alternative would be to keep the channel as proposed, but construct levees around the homes that may be impacted. These levees would only need to be about 2-3 foot tall berms to prevent water from approaching the home near Sink Rd. during the 100-500-year flood events.

We have purposely utilized a conservative approach in analyzing the flood effects, making certain that landowners are aware of the changes and have all of the information necessary to fully understand the project and the potential changes within their property. Living along a river always involves risk of flooding, but the goal of this project is to follow a good neighbor policy and be certain these issues are discussed at length.

Groundwater and Wetland Changes

As water surface elevations rise within and upstream of the project reach for most flows, groundwater table elevations are also expected to rise. The resulting depth from the ground surface to the groundwater table will be shallower with the project, likely expanding existing wetlands and creating new ones. Clarke et al. (1998) also indicated that areas upstream of Dodd Park will be sensitive to increases in groundwater elevation. Most of these impacted areas will be contained within the historic Dowagiac River floodplain. Whether the springs – noted in historic accounts to have dried up will return with the restoration of the former bed elevation is unknown.

DESIGN RECOMMENDATIONS

PLAN FORM ALIGNMENT OF DOWAGIAC CHANNEL

Appendix A includes detailed maps of the plan form alignment for initial design purposes. The proposed alignment (relict alignment) maximizes the channel length through the reach by taking advantage of most of the abandoned bends within the floodplain. In the upstream section of the project reach (station 25000 to 21000), the proposed alignment follows the route suggested by the 1873 historic atlas map. Downstream of station 21000 here, the proposed alignment follows relict meander bends based on degree of definition as seen in the field and on the LiDAR maps. Where channel definition was lacking, floodplain patterns and probable pathways based on upstream and downstream channel alignment were used as guides. The existing channel will be utilized where the proposed and current plan form are coincident, at crossings, and where the channel should likely be kept away from nearby infrastructure. Additionally, proposed/historic alignments have been adjusted in some meander bends to protect homes along the original channel. For instance, the inactive bend at station 19000 is currently within 100 feet of a residence, and, therefore, pulling the proposed bend north might be prudent (Figure 7070). Or, in the case of the large meander north of station 22500, the cutoff channel should be occupied to maintain cold water tributary habitat along the westerly arm of the abandoned meander, and to avoid restoring the channel adjacent to Peavine St. (Figure 44). In most of these cases, the channel was aligned through scroll bars along the inside of the abandoned bend.

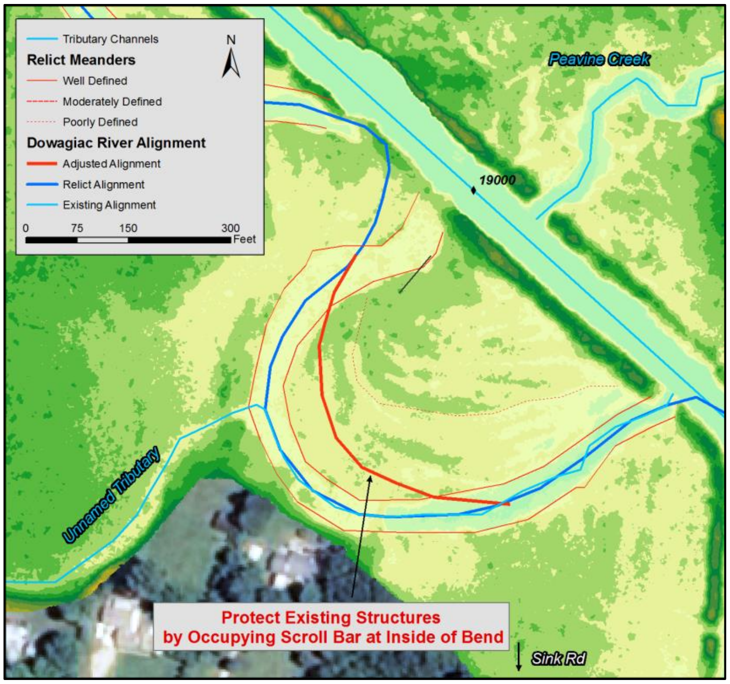


Figure 70. Large meander southwest of station 19000. A chute channel within the scroll bars on the inside bend should be occupied to protect the structures along the bend.

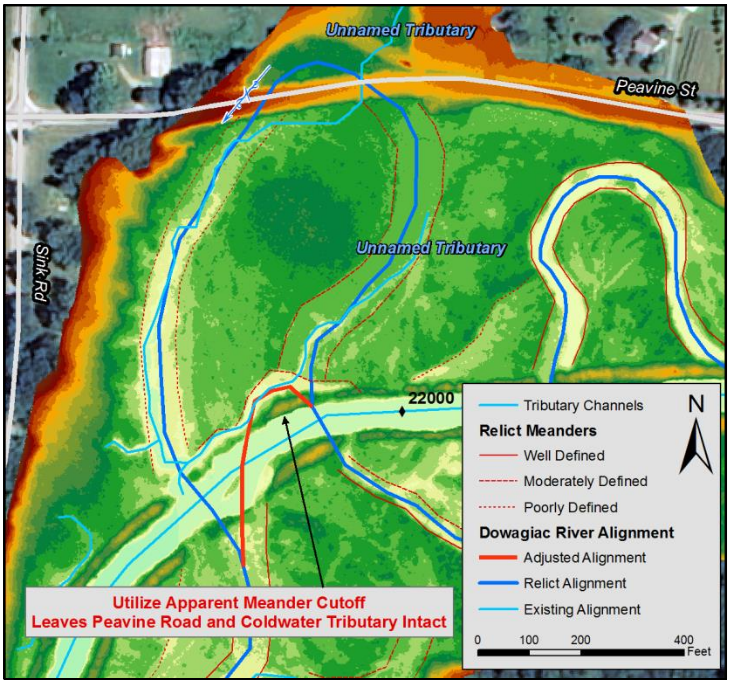


Figure 71. Large meander north of station 22500. The cutoff channel should be occupied to maintain coldwater tributary habitat along the westerly arm of the abandoned meander, and to avoid Peavine St.

Although it is likely that the meander bends comprising the proposed alignment were not all active at the same time, and the channel south of Sink Rd. may have been relatively straight immediately prior to dredging, maximizing the number of bends and the sinuosity will help meet many of the design goals. The meanders will deliver water throughout the floodplain, even in the wider sections, thereby helping increase wetland function and habitat. Additionally, re-establishing bends will also likely re-establish scour and deposition in the channel and floodplain. Once these processes are reinstated, they will provide more heterogeneous velocities and diverse bathymetry and topography along the meander sequences, thereby creating more complex aquatic and riparian habitats. A host of additional processes related to nutrient cycling, flood storage, and biotic exchange between the floodplain and channel will be renewed by the restoration of a natural flooding regime to the reach. There are few potential impacts to infrastructure due to normal channel adjustment within the reach, so once meandering is re-established, allowing the channel to adjust its sinuosity should not be an issue

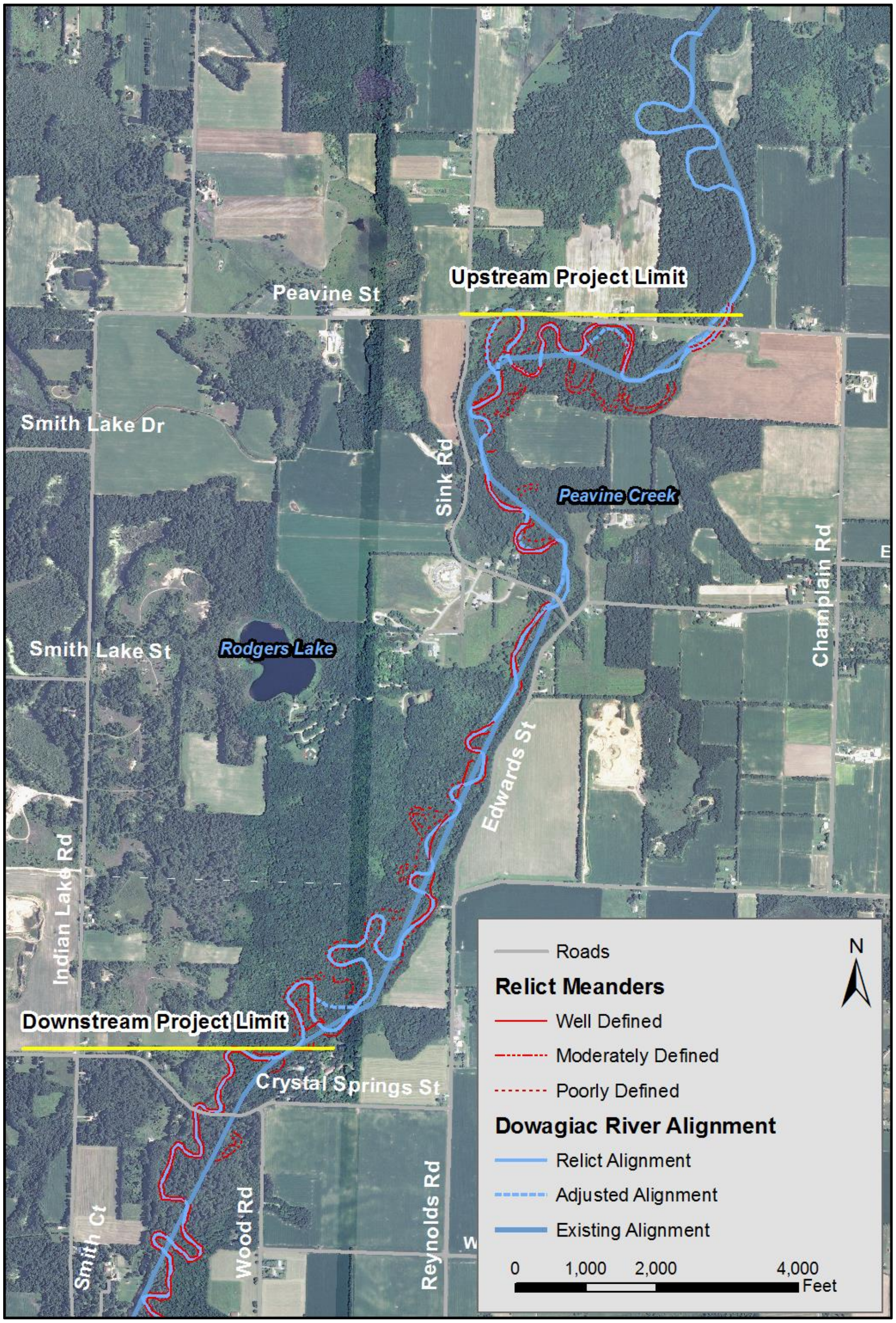


Figure 72. Overview of the proposed Dowagiac River plan form alignment (see Appendix for details).

DOWAGIAC CROSS SECTIONAL GEOMETRY

Descriptions of the Dowagiac River's width prior to dredging vary depending on the source. An unknown observer remarked that the river was "only about two feet deep and 40-50 feet wide" (unreferenced notes filed at the Cass County Historic Library), whereas the General Land Office surveyor measured eight channel crossings between 60 to 120 feet, with an average of 99 feet. The 40-50 foot width estimates were likely related to the first phase of dredging, which took place upstream of the project reach. Channel cross sections usually increase in the downstream direction, and therefore, these values are likely too low for the project reach. They also likely correspond to general water levels, not bankfull conditions. With respect to the surveyor notes, width measurements were often taken along section lines, which often crossed the channels at an angle (i.e., not perpendicular to flow), thereby biasing the widths towards higher magnitudes. For instance, the channel is estimated to be about 108 feet wide (1.63 chains) along the section line dividing sections 19 and 30, but just north of there, along the line between sections 19 and 20, the channel was noted as 66 feet wide (1 chain). The difference being that the channel measurement at the second location was more perpendicular to flow. A perpendicular measurement in the first case would have provided a width of approximately 70 feet. Additionally, many of the measurements were taken across meander bends. In general, bends tend to feature wider channel sections than straighter channel sections, and therefore, these measurements also likely over-estimate channel width.

In addition to the historical data, the LiDAR survey data provided valuable information for defining channel widths prior to dredging. In many floodplain areas, the pre-dredging channel appeared to be relatively well preserved and channel widths were directly measured within the GIS. Using this method, random channel width measurements ranged from 50 to 100 feet. Where the channel was well defined, the widths were consistently around 65 feet, with wider sections located in bends.

Finally, regression equations based on channel dimensions measured throughout southern Michigan (Rachol and Borley-Morse, 2009) predicted a channel width at 87 feet for the contributing Dowagiac River watershed at Sink Rd. It is important to note, however, that these rating curves were not organized by geomorphic stream type which can aid in tightening predicted dimensions and the R^2 value was 0.69.

Except for the overly-shallow estimate of 2 feet mentioned previously, there was no description of channel depth for the project reach in the reviewed historic documents. Therefore, estimates of depth for the historic channel were based primarily on field observations. Defined abandoned channels were often delineated by 2 foot high banks lined by vegetation with exposed roots (Figure 73). We assumed the top of these banks were the historic top-of-bank at bankfull conditions, and then added the average DOR for the organic-sand interface (i.e., 3.3 feet), providing an overall channel depth of 5.3 feet. This depth was rounded up to 6 feet since this provided sufficient capacity to contain the 1.05-year flood magnitude (see Proposed Conditions Model Construction). The increased depth relative to the DOR results and the anecdotal evidence from pre-settlement conditions makes sense as channels typically have a larger bankfull area as peak flows increase. Conversely, the regression equations for southwestern Michigan rivers and streams (Rachol and Borley-Morse, 2009) suggested a depth of 3 feet for the Dowagiac River channel. This value would create a bankfull channel that would be overtopped multiple times per year.

Figure 73. Bank along an abandoned channel as indicated by: (1) a break in slope from the floodplain surface down to the water, and (2) the exposed roots facing the channel.

HABITAT ELEMENTS OF RESTORED DOWAGIAC CHANNEL

As noted in the discussion of design goals above, the habitat potential for the project lies largely within two realms, the in-channel habitat and the floodplain habitat. The overall goal for any habitat project is to increase complexity of habitats, which in turn increases the types and abundance of species that utilize such areas. A brief discussion of the expected project based on the data gathered is below.

FLOODPLAIN HABITAT

The existing levee (excavation spoils) runs along the entire length of the project. This levee represents the volume of material removed from the excavation of the new channel in the early 1900s. Putting the channel back into a meandering alignment will effectively breach this levee – allowing water that follows the meandering channel to spill freely onto the floodplain during flood events and inundating areas seasonally. Topography – microtopogrpahy in fact – defines habitat complexity in a floodplain. Areas only a few inches lower or higher than the average elevation of the floodplain can include a different vegetation community which in turn dictates a different faunal community as well.

Figure 74: A great example of the role microtopography plays on the floodplain. The photo indicates varies areas of inundation on the existing Dowagiac floodplain

Although the existing floodplain is intact, complete with this microtopograpy, the project will include shallow wetland scrapes as well as shallow deposits of fill to augment the existing topographic variation. This work will be constructed in disturbance areas necessary to gain access for construction and confined largely to the corridor of the existing straight channel where the spoils from excavation of the meandering channel will be placed. Upon completion of the project, the current channel will become part of the floodplain as well. Here we intend to preserve portions of the existing channel as open water wetlands within the floodplain and fill other portions along the corridor to the grade of the adjacent floodplain or above creating at least 3 different elevations for developing various types of communities.

IN-CHANNEL HABITAT

Large Wood

Habitat within the newly created meandering channel will be augmented by the construction of large wood complexes and single log pieces. Analogs of these exist within the current channel as well (Figures 75 and 76 below). A complex of large wood provides important habitat for young of the year species, by creating a complex of small branches within which to hide from predation. These complex also induces deposition within the channel, creating areas within and downstream of the complex that are more shallow but in turn typically deepening areas adjacent to the complex as well. Often noted as log jams – this connotation is avoided here because these will be constructed with recreational passage in mind. Thus they will not span the channel and afford easy pass through for canoes. These will still require periodic maintenance overtime to ensure wood captured from upstream does not completely block the channel. These complexes can be constructed within the restored channel utilizing trees from the existing levee.

Figure 75: This complex of wood affords excellent habitat for young fish. The deposition of sand behind the wood can be seen in the photo, with a deep hole to the left. This jam is wider than necessary but affords an understanding of the type of habitat that will develop in the restored channel of the Dowagiac.

Single log structures are a second type of habitat that will be created within the restored channel. These are typically composed of a single tree, or perhaps 2 trees, and are intended to induce scour pools, typically creating habitat for larger adult fish, such as trout. Trees are anchored into the bank and typically placed below the water to slow the natural breakdown process.

Figure 76: A good example of single log habitat. A floating log on the left in the foreground and a second tree below the waterline at right.

Channel Banks

In most areas, the old channel will be reactivated with active flow. The existing banks and associated mature trees along those banks will be preserved creating an instant channel bank which can resist erosion. Overtime undercut banks will develop and the root mass of trees will become exposed providing refuge along this interface (Figure 77). New banks (flow barrier) will need to be constructed wherever the existing channel needs to be cut off from the restored channel. In all instances this will be required on the upstream side of the existing channel. This bank will be constructed using a bioengineering approach. Two components to this design include the lower bank, or the toe of the bank, beginning just above the water line and extending down to the bed of the channel, and the upper bank (Figures 78 and 79). The lower bank or toe will receive a treatment that will likely include a mixture of rock and trees (often called toe wood) to ensure the river cannot erode through the bank at this location. This toe protection also affords a level of habitat as well when wood is incorporated properly. The upper bank will be composed of fabric encapsulated soil lifts. The fabric provides short term protection from erosion until the vegetation planted or seeded within the soil can become established and take over the long term stabilization of the bank. This approach will not only provide a stable barrier, keeping flow from re-occupying the existing channel, but will likely provide some quasi-upland habitat within the floodplain as well.

Figure 77: A relic channel illustrating the mature trees along the old banks of the channel that would be preserved and remain once active flow is restored to this channel again.

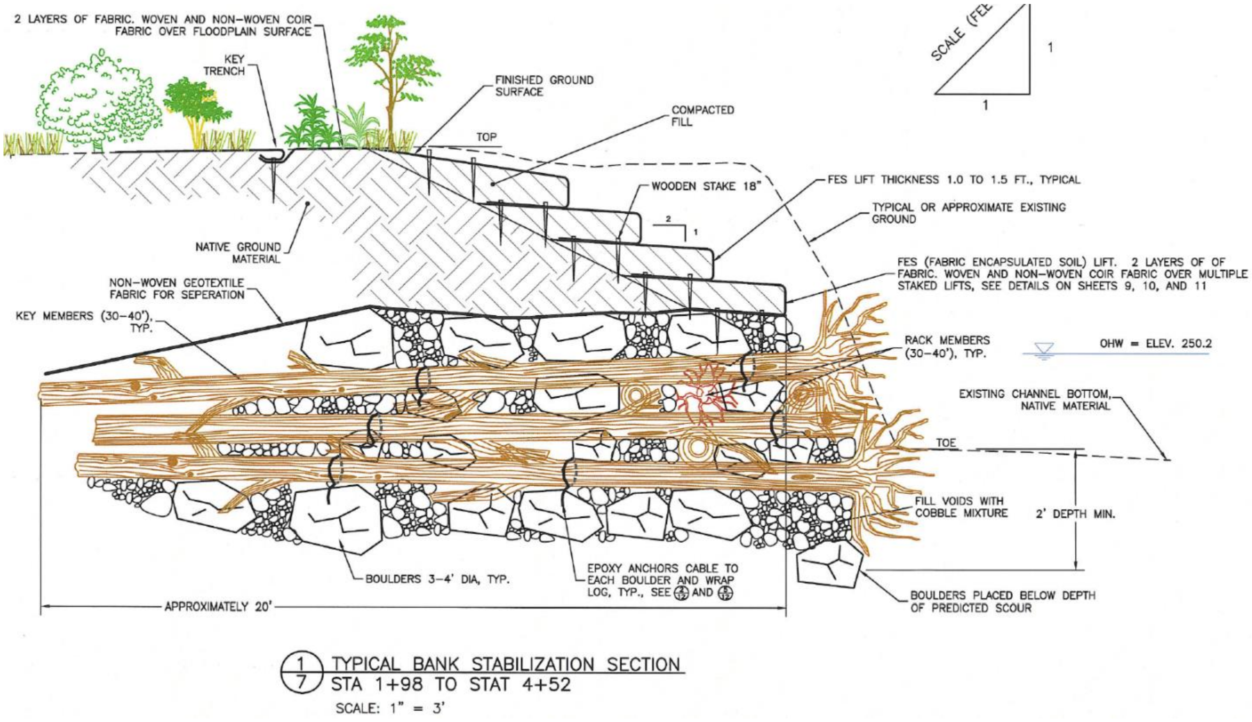


Figure 78: Example of the type of bank constructed where the existing straight channel would be cut off from flow.

Figure 79: Photo of the above design following construction

Figure 80: Mature trees are in ready supply along the spoil piles (levees) on either side of the existing channel.

Pool and Riffle Habitat

It is clear based on probing that, at a minimum, lenses of gravel and perhaps cobble exist within the valley bottom of the Dowagiac in the project area. Where encountered, we expect at a minimum coarse material to be exposed, whether a riffle develops (defined as a shallow flow section with a slightly higher gradient) is still being determined. Pools will develop in two places, on the outside of meander bends and in association with scour from obstructions, typically wood, encountered in the channel. Pools on meander bends are often a product of sediment deposited on the inside of the bend, often called the point bar. Based on field observations in the project area at the only bend in the existing channel (downstream of station 7000), this process persists and will be magnified when the channel is re-meandered with a multitude of bends.

Figure 81: Below station 7000, a slight bend in the channel exhibits a weak point bar (covered in snow on left) and deeper pool on the outside of the bend.

Channel Migration

It is clear from the LiDAR data that the Dowagiac channel is an active channel, moving around on within its valley bottom with some frequency. Carbon dating would be the only way to determine the ages of the various channels encountered at the site to determine the rates of channel migration. A meander may develop and migrate toward a critical radius over a period of years of centuries before it is cut off and abandoned by the river (refer to Figure 1 in the beginning of this report). We can assume that the vegetation, in this case floodplain forest, will provide the natural check to balance the erosive forces of the river. Thus whatever migration develops will be a part of the natural function of the river in developing diverse habitats.

Figure 82: Sand is depositing on a point bar within the Dodd Park remeander site as would be expected to occur within this project.

RODGERS LAKE OUTLET

The restoration of Rodgers Pond back to a stream system will focus on the nature of the crossing at All Seasons Road. It is clear that the road holds the volume of material necessary to rebuild the bed elevation of the pond to match the stream grades above and below the road crossing. However, removal of this material would require the road grade to include a significant dip in the driving surface that may not be desirable. Ample fill material will be available from the mainstem construction and could be imported to the site to compose the volume necessary to rebuild the stream AND maintain the road in its current configuration.

Figure 83. A bottomless arch bridge (left) and a buried concrete box (right) that can be used to replace the existing structure at All Seasons Rd.

The crossing under the road will be replaced and could become a small bridge, perhaps a timber frame structure if the fill elevation were reduced. If the road maintains its current configuration, a buried box culvert can be used to provide passage for both fish and other aquatic species through the culvert. Inter-Fluve has constructed similar configurations elsewhere (Figure 83).

The stream will be constructed in a manner similar to what exists immediately upstream and downstream of the crossing. The gradient and the valley type indicate a stream with tight sinuosity. Pools develop as steps, often in response to a log control or weir in the channel and riffles develop between subtle meanders. Excavation will be necessary in the upper end of the existing pond to remove material and expose the pre-dam stream bed in all other areas fill will be required. The floodplain will be replanted with floodplain forest species consistent with assemblage above and below the crossing.

Further discussion with the tribe regarding the use and expectation of this area will allow preferred restoration options to be dialed in.

CONSTRUCTABILITY AND COSTS

Both the Dowagiac mainstem and Rodgers Lake afford excellent access, assuming landowner cooperation, for equipment and ample space within which to manage materials and construct the project. Other than the challenges inherent in working within an active river corridor, largely related to management of water, both flood and groundwater, and challenging soil conditions for access, the sites lend themselves well to the projects at hand. A couple of insights are useful to mention at this early stage as the logistics of construction begin to take form.

Single Pass Construction – key to limiting the disturbance areas on a site, in particular a wet site, is managing access. On the mainstem Dowagiac, the only areas that appear necessary for disturbance lie within the existing channel corridor, defined laterally by the extents of the spoils, and the proposed channel corridor. In utilizing a technique we call single pass construction, the haul road will be the proposed channel. In this manner, much of the adjacent, intact floodplain can be left relatively undisturbed. Access within areas of this channel may be challenging and require haul roads of mats to be constructed and low ground pressure equipment will be required.

Phasing - given the spatial extent of the project and the potential funding cycles for construction, the project will have to be phased. A myriad of options exist for phasing construction and could be as simple as completing single meander bends on an annual basis or taking large lengths on for a whole construction season. All work in the new channel can be performed off-line until the very end when material can be placed in the existing channel to direct flow into the newly excavated one. Phasing is less opportunistic at Rodgers Pond, where access and traffic management will be the keys during construction.

Inter-Fluve has found costs for restoration projects vary by orders of magnitude, even among contractors bidding on the same documents. A recent large scale project north of Cadillac included a range of $3M - $12M among a suite of 4 contractors bidding the project. This is typical, as restoration work is often a foreign experience for many companies. The major components of the Dowagiac Mainstem and Rodgers Pond construction are noted below, with associated quantities. Minor components, such as excavation of wetland scrapes and fill work around the existing channel are considered to be included within the major work item "Channel Excavation," though not specifically called out. These costs and quantities are decidedly conservative at this pre-design phase of the project. Costs assume local contractors will perform the work and have not been regionalized to the Dowagiac area. A 30% contingency has been added to all totals to reflect the level of design.

DOWAGIAC MAINSTEM

Item	Quantity	Unit	Unit Cost	Total Cost	Notes
Bank Treatment - FES Lift and Log/ Rock Toe	30	100 LF	$ 25,000	$ 750,000	Each flow barrier is 100 LF to construct Above Sink Rd = 8-16 Below Sink Rd = 10-20
Habitat- Log Jams / Single Logs	250	EA	$ 2,800	$ 700,000	Composed of 8-10 Trees Each $350/Log = $2800/Jam 10 Jams/Single Logs / 1000' Channel 25000 Total LF
Channel Excavation and Access	170,000	CY	$ 15	$ 2,550,000	25,500 LF Total, Average Depth 3' Width 65" Above Sink Rd +/- 76,100 CY Below Sink Rd = +/- 90,100 CY
			Subtotal	$ 4,000,000	
			Concept Level Contingency (30%)	$ 1,200,000	
			Total	**$ 5,200,000**	

RODGERS POND

Item	Quantity	Unit	Unit Cost	Total Cost	Notes
Stream Construction	460	LF	$ 250	$ 115,000	Includes bank treatment, Wood etc +/- 460 ft
New Crossing Structure	1	EA	$ 80,000	$ 80,000	Range $60-$100K depending on structure
Fill For Stream Bed	3,000	CY	$ 10	$ 30,000	+/- 3000 CY
			Subtotal	$ 225,000	
			Concept Level Contingency (30%)	$ 67,500	
			Total	**$ 292,500**	

In looking at the costs, particularly for the mainstem Dowagiac, it becomes apparent that the tribe may be able to purchase equipment and self-perform much of the construction work with staff who are experienced with such projects. Given the size and scale of the work, phases over several years may be necessary to complete the project. The equipment required would likely be limited to a few excavators and dump trucks as much of the work is earth moving in nature. All of the excavation, even if performed in the wet, can be done mechanically.

CHALLENGES AND FURTHER INVESTIGATION FOR FINAL DESIGN

This report is a step in the process toward restoration of the Dowagiac River and Rodgers Pond. Field investigation, processing and modeling of this data have allowed us to become familiar with the challenges and advantages provided by the site and to begin to rough in a plan for the work. Additional investigations are required to take the project through the Final Design phase. A few are noted below.

Hydraulic Implications – it is clear that restoration will include changes to the hydraulics, a benefit to the system, but changes that will affect landowners within and above the project area. Additional modeling and discussion will be key to fully vetting this issue

Transitions from New to Old Channel – If phased, a discontinuity will be present where the new channel and old channel coincide, perhaps up to 3'. On the upstream end, where water leaves the existing channel and moves into the new channel, this transition may not require attention. On the downstream end however, the potential exists for headcutting to occur at this location and may require various techniques for stabilization. The reality of this scenario will have to be investigated during Final Design.

Additional Data Collection – A tremendous amount of information has been gathered to date. Several pieces of information related to subsurface conditions will further detail the situation. The first is a more detailed DOR survey along the chosen alignment, defining what might be considered the microtopography of the excavated channel, important for estimating quantities. The second is a series of test pits within areas intended to be excavated. By digging below grade, we can confirm the nature of the material to be encountered and provide a level of assurance to contractors on the nature of the material at the site.

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APPENDIX A – MAPS

APPENDIX B – RESULTS OF TREE SURVEY

APPENDIX C – PHOTO LOG