Berrien County
Drain Commissioner

Galien River Watershed

Hydrologic and Hydraulic Study

Project No. G01338

fishbeck, thompson, carr & huber
engineers • scientists • architects

GALIEN RIVER WATERSHED

HYDROLOGIC AND HYDRAULIC STUDY

JULY 2003
PROJECT NO. G01338

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TABLE OF CONTENTS

LIST OF PHOTOGRAPHS

TABLE OF CONTENTS

LIST OF GRAPHS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

INTRODUCTION

The Galien River Watershed Steering Committee (Steering Committee) was formed to guide a watershed management planning process for the Galien River Watershed (Watershed), Figure 1. This Hydrologic and Hydraulic (H&H) study is a component of the Galien River Watershed Management Plan (WMP).

The Watershed is scattered with small farms and healthy forests, as well as a thriving seasonal Lake Michigan shoreline community. Water quality is a concern in this Watershed, which has problems with sediment, *E. coli*, and extreme flows, which flood valuable crops and structures.

Many Best Management Practices (BMPs) designed to address water quality problems in a watershed will also have an effect on the hydrology of the stream. A stream has hydrologic stability when the drainage area maintains an identical response to an identical rainfall over a long period of time. Identical response is expected if land uses, soils, and drainage characteristics within the watershed are not changing. Hydrologic changes occur when forests are cleared, artificial drainage is expanded, or impervious cover is increased, which increases the rate and duration of these flows. Changes can cause the stream to become unstable. This instability can manifest itself as streambank erosion, streambed scour, and other changes in geomorphology, including sinuosity. The more frequently occurring flows, those with a 1.5- to 2-year recurrence interval, are generally the dominant channel-forming flows in stable, natural streams.

STUDY AREA

The Watershed, located in the southwest corner of Michigan and northern Indiana, encompasses about 112,000 acres of agricultural, urban, and forested land, Figure 1. The Michigan portion, about 82,000 acres, flows through several southwestern townships of Berrien County and flows into Lake Michigan at the City of New Buffalo.

The stream pattern of the Watershed includes many stream branches and tributaries with a meandering main channel. The Galien River (River) has been channelized and drained in the Elm Valley region, which is the southern, central portion of the Watershed. This stretch of the River is in silty and loamy soils, which are naturally poorly drained soils and have seasonal high water tables. The area was mixed, hardwood swamp during presettlement times and were later artificially drained to allow farming.

BACKGROUND AND PROBLEM AREAS

Both the Michigan Department of Environmental Quality (MDEQ) and the Steering Committee are concerned about the stability of water courses in the Watershed. An assessment of stream stability was included in this study to ensure a longer design life for proposed in-stream measures and to select appropriate BMPs that address the cause of the instability and do not move the problem to another location. Streams experiencing excessive instability contribute sediment to the water column, increasing turbidity, and impairing the designated uses of a stream. Changes in hydrology and flow regime, due to changing land uses and drainage patterns within the Watershed, may make streams unstable.

The region of Elm Valley is a particular concern to the Steering Committee. This area is located in the south central part of the Watershed, where previously existing wetlands have been heavily drained and channelized. Streambeds tend to be very sandy in this region, as noted in the MDEQ road stream crossing survey, and sediment is a serious concern. This area has undergone significant drain maintenance activities in recent decades. Problems include accelerated meandering, streambank erosion, and loss of trees due to channel bank undercutting. This H&H analysis includes the stretch of the River in Elm Valley and its major contributors, the Blue Jay Drain and Dowling Creek. Most of these drains were constructed while settlement was occurring in the early 1900s. Less than 20% of the drains were established after the start of World War II.

The Steering Committee is also concerned about the effects of log jams on flood levels and soil erosion. Conveyance capacities of road crossings and open channels in upper reaches of the Watershed are concerns of the Berrien County Road Commission (BCRC) and the Berrien County Drain Commissioner (BCDC). The BCDC has removed log jams from the River upstream of Minnich Road where it is a designated county drain. In 1998, the U.S. Army Corps of Engineers (ACOE) conducted a study to evaluate the effects of log jam removal downstream from Minnich Road. They have concluded the water surface elevation at Minnich Road is raised by 0.5 to 1 foot during most storms because of the presence of log jams (Appendix 1). However, they noted this increase in water surface elevation does not affect valuable farmland or structures. The backwater effects upstream of Minnich Road were not studied by the ACOE. Flooding of structures and valuable farmland occurs much further upstream in the Watershed as shown in Figure 2. Much of the floodplain along the River in the Elm Valley region upstream from the confluence with the East Branch of the River experiences flooding. Additional areas, located on upstream tributaries, are also flooded regularly, and some of the more frequently flooded areas are shown in Figure 2.

HYDROLOGY AND MORPHOLOGY

METHODS OF EVALUATION

A morphological assessment was performed using the Rosgen Level II classification system to assess the stability of the River system. Four locations in the Watershed were selected for the assessment. The parameters of the channel measured for the assessment included entrenchment ratio, width/depth ratio, sinuosity, channel slope, and channel materials.

A field inventory conducted in the fall of 2001 revealed the most commonly identified problems as streambank erosion, log jams, and erosion at road crossings. The investigators visited every region of the River and its tributaries that was accessible from road crossings. The lower portion of the River was inventoried more thoroughly by kayak. Additional information including regions of flooding and typical duration of high water was gained from landowners, some of whom provided pictures.

A Geographic Information System (GIS) was used to study 1978 Michigan Resource Information System (MIRIS) presettlement vegetation, which is available from the Michigan Center for Geographic Information.

County drain information was made available by the BCDC (Appendix 2). Frequent maintenance on a stream may indicate that the reach is unstable. It is not uncommon for trees to fall into the stream at the bank. The frequency of this occurrence varies widely, depending on soil type, topography, vegetation type, and flow rates. A fallen tree will cause the stream to change flow paths, but normally the stream will maintain the channel with slight alteration of the banks. It may scour the streambed below and the banks around the obstacle, creating an increased sediment load in the River (Photographs 1 and 2). This sediment load may be deposited downstream in the form of a sandbar. It may also alter a fast flowing channelized system into a slower meandering system with riffles, pools, and snags, which provide fish habitat. Major changes to flow paths and heavy sediment load are causes for concern.

Photograph 1: Fallen Tree Diverting Flow

Photograph 2: Erosion from Diverted Flow at Root Mass

Past changes in the land use and of the River and stream channels were examined through the USDA Farm Service Agency aerial photographs from 1981 and 1993. Digital orthophotographs with 2-meter resolution from 1996 were studied as well. Changes in land cover, such as forest clearing, wetland loss, and increased imperviousness were identified. Channel alterations, including movement of meanders, straightening, and state of bank vegetation were also noted.

EVALUATION OF EXISTING HYDROLOGY AND MORPHOLOGY

STABILITY OF THE GALIEN RIVER SYSTEM

An assessment of the morphological stability of a river system is an important step in selecting remediation techniques for water quality impairments. The Rosgen Level II classification system uses five morphological measurements for assessing a stream reach: entrenchment ratio, width/depth ratio, sinuosity, channel slope, and channel materials. The resulting classification identifies the stability of the reach of the stream, which is important to recognize whether an erosion problem is localized or systemic.

CONCEPTS OF STREAM STABILITY

A stream is considered stable when allowed to develop a stable dimension, pattern and profile, which are maintained over time, with the stream system neither aggrading or degrading (Rosgen, 1996). A stable stream is able to transport its sediment load through local deposition and scour. Channel instability occurs when the excessive deposition leads to aggradation or excessive scour leads to degradation. A stream is considered "active" or "dynamic" when it laterally migrates but maintains its bankfull width/depth ratio.

ASSESSMENT OF THE GALIEN RIVER SYSTEM

The bankfull discharge was used in the assessment to represent the stream forming discharge or channel forming flow. Four reaches of the stream were selected according to the criteria by Rosgen, and the morphological measurements were calculated from available information. The first site selected was near the mouth of the River, where it flows into Lake Michigan at New Buffalo. The reach is in Sections 2 and 3 of New Buffalo Township. The second area selected was also a reach of the River, near New Troy, at Minnich Road. The Blue Jay Drain, a tributary of the River, was selected as the third site, in Sections 21 and 28 of Weesaw Township. Dowling Creek, another tributary to the River, was the fourth site selected, in Section 8 of Galien Township. The data and calculations to determine the classifications are included in Appendix 3.

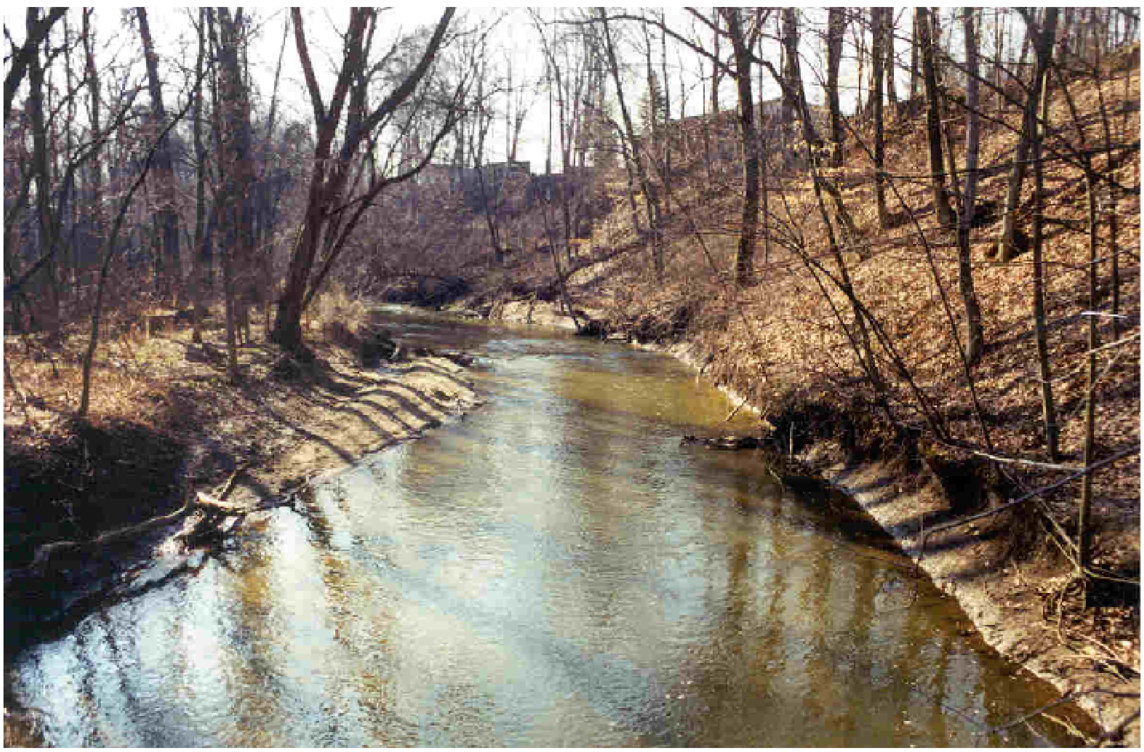
REACH 1 - GALIEN RIVER BETWEEN LAKE MICHIGAN CHANNEL AND RED ARROW HIGHWAY

This reach of the River was classified as E6 (Photograph 3). An E classification represents the developmental "end-point" of channel stability and fluvial process efficiency for certain alluvial streams undergoing a natural dynamic sequence of system evolution (Rosgen, 1996). The E stream types are typically slightly entrenched (>2.2), exhibit very low channel width/depth ratios (<12), and display very high channel sinuosity (>1.5). This reach is very slightly entrenched (22), since it is mostly a low marshy area and forested floodplain. The width/depth ratio is 9.6, indicating a wide, relatively deep river. The sinuosity is not as high as a typical type E stream, calculated at 1.3, but the number does indicate meandering, which is evident in the historical photographs. The slope (0.0012) and channel materials (Aquents and Histosols) identify the stream as E6. The relatively deep channels maintain a high resistance to change, resulting in channel stability. The stability can be compromised, however, when streambanks are disturbed or significant changes occur in the sediment loads or flows.

Photograph 3: Galien River Between Lake Michigan Channel and Red Arrow Highway

REACH 2 - GALIEN RIVER AT MINNICH ROAD

This reach of the River was also classified as E6 (Photograph 4). The E stream types are typically slightly entrenched (>2.2), exhibit very low channel width/depth ratios (<12), and display very high channel sinuosity (>1.5). The entrenchment ratio of 25 for a single stream indicates either a type C or E stream. The width/depth ratio of 8 indicates a wide, relatively deep river, resulting in an E classification. The sinuosity (1.4), slope, (0.0023) and channel material (Cohoctah sandy loam) yields a classification of E6. The relatively deep channels maintain a high resistance to change, resulting in channel stability. The stability can be compromised, however, when streambanks are disturbed or significant changes occur in the sediment loads or flows.



Photograph 4: Galien River at Minnich Road

REACH 3 - BLUE JAY DRAIN BETWEEN HOLDEN ROAD AND PARDEE ROAD

The Blue Jay Drain was also classified as E6 (Photograph 5). The E stream types are typically slightly entrenched (>2.2), exhibit very low channel width/depth ratios (<12), and display very high channel sinuosity (>1.5). The entrenchment of this reach is slight (6), as it is located in an area that was a Black Ash swamp in presettlement days. The channel width/depth ratio is very low (5.8), indicating that the narrow and relatively deep channels maintain a high resistance to change, which results in channel stability, unless streambanks are disturbed and significant changes in the sediment loads or flows occur. A tributary to this reach had maintenance performed in 1996, which could have added a large sediment load and increased flows to the stream, thus creating an unstable condition. The reach has moderate sinuosity (1.2). The slope (0.0009) and channel materials (silt loam) are indicative of the E6 classification.

Photograph 5: Blue Jay Drain Between Holden and Pardee Roads

REACH 4 - DOWLING CREEK EAST OF HAMPTON ROAD

Dowling Creek is classified as C5 (Photograph 6). The C stream types have a well developed floodplain, are relatively sinuous, and have a low relief channel (Rosgen, 1996). Channels of these types of streams can be significantly altered when the effects of changes in bank stability, watershed condition, or flow regime are combined to cause an exceedance of the channel stability threshold. Dowling Creek is very slightly entrenched (3.3), located in the Elm Valley area of glacial outwash in the Watershed. The channel has a moderately high width/depth ratio (14) and a high sinuosity (1.21), indicative of the depositional characteristics of the stream bed and the active meandering. The slope of the channel (0.0018) identifies the reach as C5. This stream type is susceptible to shifts of stability caused by direct channel disturbance and changes in the flow and sediment regimes of the contributing watershed, but is able to recover quickly if no further disturbances occur.

Photograph 6: Dowling Creek East of Hampton Road

FINDINGS

The reaches analyzed in this study represent different areas of the Watershed that have specific land uses and various degrees of stream channel modifications. The difficulty with this analysis, however, is that significant alterations have been made to many of these areas, which are designated county drains, thus the classifications do not always fit the actual conditions. Generally, streams classified in the E category tend to be the most stable. Table 1 summarizes the findings of the assessment, which indicate that the River appears to be fairly stable in the lower reaches, but susceptible to streambank erosion in the upper reaches and tributaries where the channels have been altered for agricultural use.

Table 1 - Results of Rosgen's Level II Classification Assessment of the Galien River System

Location	Galien River Between Lake Michigan Channel and Red Arrow Highway	Galien River at Minnich Road	Blue Jay Drain Between Holden and Pardee Roads	Dowling Creek East of Hampton Road
Entrenchment Ratio	22	25	6.0	3.3
Width/Depth	9.6	8	5.8	14
Sinuosity	1.3	1.4	1.2	1.21
Slope	0.0012	.0023	.0009	.0018
Channel Materials	Silt/clay	Sandy Loam	Silt	Sand
Classification	E6	E6	E6	C5
Characteristic	Very stable unless streambanks are disturbed or changes in sediment supply occur.	Very stable unless streambanks are disturbed or changes in sediment supply occur.	Very stable unless streambanks are disturbed or changes in sediment supply occur.	Susceptible to shifts in stability caused by channel disturbances and changes in flow and sediment regimes of the contributing watershed.

The Watershed inventory found many areas with streambank erosion caused by increased flows or obstructions diverting the natural flow path. Although many obstructions were observed in the lower reaches of the River, few areas of erosion were found, which indicates the stability of the River near the mouth.

Streambank erosion was present in the areas around New Troy, an area, which also had significant numbers of obstructions and was determined to be susceptible to streambank erosion if disturbed.

Upstream areas and tributaries are susceptible to streambank erosion if flows increase from drain maintenance activities or increased development.

RECOMMENDATIONS

? Streambank restoration work upstream of the Warren Woods Preserve (Preserve) should be selectively and carefully completed so flows or increase sediment downstream are not altered.

? Restoring wetlands in the areas where presettlement wetlands existed, in northern Galien Township and southern Weesaw Township, would reduce the volume and velocity of flows.

? New developments, in and upstream of Elm Valley, should be required to have onsite detention or retention of storm water.

QUALITATIVE EVALUATION

GALIEN RIVER

A qualitative evaluation was performed on the Watershed using various sources to determine changes in the Watershed, including flow paths, geomorphology, channelization, land cover, vegetation type, canopy, imperviousness, and exposed soil. The following tasks were part of the evaluation:

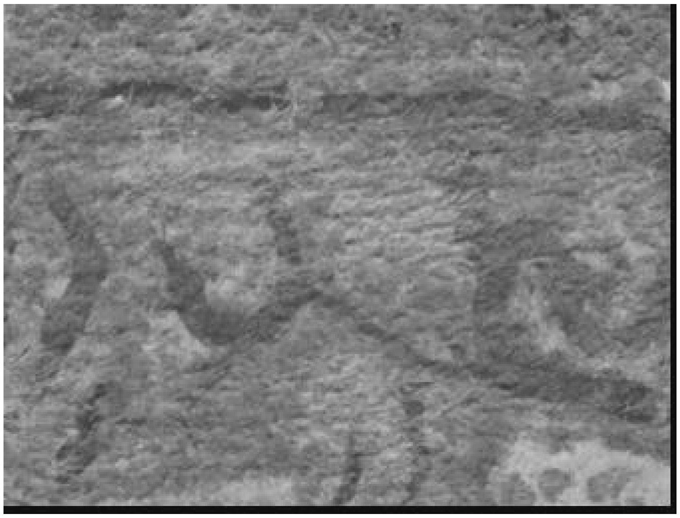
? Examine survey information, including topography, land use, soils, wetlands, and presettlement vegetation, and other data available to determine geomorphologic characteristics of the Watershed.

? Analyze the drainage system and review the maintenance activities performed on the county drains.

? Examine aerial photographs for changes in land cover over an approximately 15-year period, using 1981 and 1993 Farm Service Agency aerial photographs and 1996 Berrien County GIS Department digital orthophotographs.

? Examine aerial photographs for changes in stream channel and movement of meanders over a 15-year period, using 1981 and 1993 Farm Service Agency aerial photographs and 1996 Berrien County GIS Department digital orthophotographs.

The River, through most of its course, is highly meandering and equi-width from bank to bank. Though it has been channelized in Elm Valley, the River is regaining its sinuosity in regions that are not actively managed. In forested areas, evidence of past meanders can be found, which form crescent shaped ponds and marshes adjacent to the River (Photograph 7).

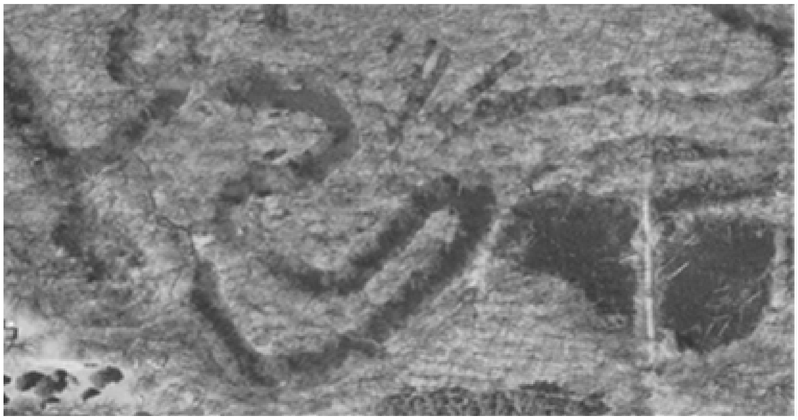


Photograph 7: Past Meanders on the Galien River

Continual maintenance of the designated drains in the upper portion of the Watershed has occurred over the past decade, mainly in the form of brush removal or channel clean out. Of the 239 drains, shown by township in Appendix 2, 161 or 67% have had improvements since 1981, with many requiring future additional work in the coming years.

The lower portion of the River, downstream of Minnich Road, has been left in a more natural state with large meanders and broad forested floodplains. The River passes through the Preserve, which includes very unique southern floodplain forest and old growth upland forest. It is the only southern floodplain forest found north of southern Indiana. Even in the southeastern United States, where they are most commonly found, southern floodplain forests comprise only 17% of all forests, and an estimated 69% of southern floodplain forests have been lost since European settlement. Southern floodplain forests consist of bottomland hardwood stands and deep, alluvial swamps with natural levees created by the deposition of sand and organic debris during flooding. The constantly replenished organic matter boosts biological productivity. Steadily shifting stream migration, soil erosion, and deposition are inherent to southern floodplain forests and create areas of variable topography, soil texture, and organic content. Swamps and oxbow lakes are interspersed with forest. These factors create areas of ecosystem overlap, where biodiversity of both plants and animals is very high. Other important components are the predominance of woody vegetation for cover, the presence of surface water and soil moisture for greater food availability, and the presence of riparian forests that provide travel corridors for migration and dispersion. The relative stability of water levels and lack of fire in the Preserve has also allowed the formation of a climax of old growth upland forest in the low rises. The Preserve is a highly valued resource.

The River, in this lower area of the Watershed, has a wide floodplain and the pattern of its sinuosity has shifted over time. It is a constantly changing river with meanders that slowly move as trees fall in at the banks. Its history can be seen in the convoluted meanders and oxbow lakes (Photograph 8). Flow through the meanders slowly erodes the outer bank, eventually causing the trees to fall in on the outer bank. It is a process, whereby flow may be diverted back toward the center of the channel or lead to the formation of more meanders and oxbow lakes. Reducing the roughness of banks and straightening the River through drain maintenance may increase the rate of meander wandering and erosion downstream.



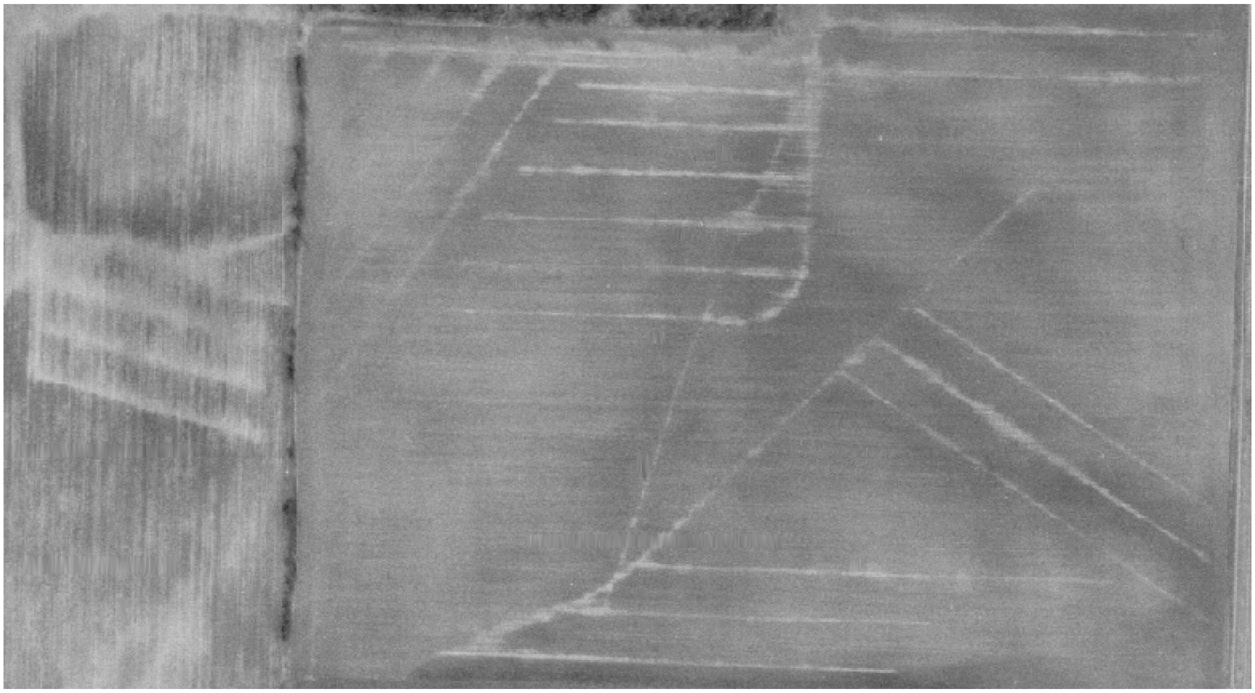
Photograph 8: Log Jams on the Galien River

Some movement of meanders appears to be occurring at a slow rate, barely visible over the 15-year period. The meander in the southwest quarter of Section 13 in Chikaming Township appears to be moving toward Flynn Road. Meanders in the southwest quarter of Section 7 in Weesaw Township are decreasing (Photograph 9).

Photograph 9: Decreasing Meander of the Galien River

TRIBUTARIES

The most significant change in the natural hydrology of the Watershed was the loss of a 5-square-mile wetland in Elm Valley, located in the southern central portion of the Watershed around Avery Road (Figure 3). This wooded wetland system not only stored water, but through evapotranspiration and infiltration, prevented much of the runoff from entering the stream system. Artificial drainage in the form of tiles in fields and trenched open drains has converted this wetland into cropland (Photograph 10). The major wetlands that were drained were in Galien Township, Sections 5, 6, 7, and 8, as well as Weesaw Township, Sections 31 and 32. Restoring wetlands in these areas would reduce the volume and velocity of flows. The more water stored in this region, the less flooding will occur in Elm Valley. There are some large tracts of land that may be available to enroll in the Wetlands Reserve Program, but even small wetlands will reduce flooding. An alternative to restoring the wetlands is to reduce drainage and grow specialty crops that require or can withstand greater moisture. New developments in and upstream of Elm Valley should be required to have onsite retention and detention of storm water.



Photograph 10: Tile Network Draining Wetland of Elm Valley

Potential problems exist in Weesaw Township, Section 21, where a wetland appears to have been drained just north of the Blue Jay Drain. Near Dowling Creek, in the northwest quarter of Galien Township, Section 5, vegetation was removed and drainage added between 1981 and 1993. Gullies in the field are apparent in the 1996 photographs.

HYDRAULIC ANALYSIS

The hydraulic analysis studied both extreme and more frequent flows to assess the conveyance capacities of the Galien River and its major tributaries.

GALIEN RIVER

A hydraulic model was developed to determine the bankfull conveyance capacity of a critical portion of the River. The ACOE HEC-RAS 3.0 computer program (HEC-RAS) was used. The HEC-RAS was selected due to its universal use, availability, and acceptance as a hydraulic modeling tool. The model was used to calculate both stage and velocity of the 2-year event and larger flows for the length of the River approximately 2 miles upstream and downstream of the area of New Troy. It was also used to evaluate the backwater effects and the impacts of log jams not included in the ACOE analysis. Figure 2 shows the extent of this model, indicated as the Obstruction Study Area.

METHODOLOGY

The HEC-RAS model required the following inputs:

? Discharges: Flood frequency discharges were provided by the MDEQ (Appendix 4). The 50%, 20%, 10%, 2%, 1%, and 0.2% annual storm water discharges were estimated for the River at confluences with major contributing subbasins and at locations of potential channel instability and flooding.

? Starting water surface elevation: A rating curve from the USGS stream gauge located at Minnich Road was used to determine starting water surface elevations for the hydraulic model (Appendix 5). The starting water surface elevation at Minnich Road was lowered by 1 foot to represent the effects of log jam removal. The 1-foot drop is based on the ACOE determination that log jam removal would lower the water surface elevation by 0.7 feet. This was rounded to the closest foot because of the accuracy of the ACOE study. The ACOE did not conduct a survey of the River, but relied on 10-foot interval USGS quadrangle maps.

? River geometric characteristics: Surveyors collected cross sectional data at six locations on the River; the upstream side of Minnich Road, 1,150 feet upstream of the confluence with the East Branch of the River, just downstream of Kaiser Road, and two locations downstream of Warren Woods Road. USGS quadrangle maps were used to extend the channel cross sections to a sufficient width. The effects of bridges on the stage of the River were assumed insignificant to simplify the model. The low flow comparison confirmed this assumption (Appendix 6).

? River hydraulic characteristics: The roughness coefficient for the channel and the floodplain were estimated from floodplain photographs.

? River slope: The slope of the channel was determined from the survey data and USGS topographic maps.

RESULTS

The 1-year water surface elevations in the Galien River from Warren Woods Road to Mill Road (Locations 2, 3, and 4) correlate with bankfull conditions (Figure 4). The 2-year water surface elevation at Minnich Road (Location 1) exceeds the top of bank by 3.5 feet. This indicates a section of the River that may be in the process of stabilizing, although no bank erosion was reported at this location. Often, the 2-year flow is generalized as an approximation for the channel-forming flow and bankfull discharge, but in the Watershed, these flows apparently occur every one to two years. The peak water depths and velocities associated with the 2-year storm event at locations 1 through 4 are listed in Table 2 and shown in Figure 4. The selection and placement of instream habitat structures, however, should be based on computed peak flows and velocities for the 10-year storm (Schueler, 2000).

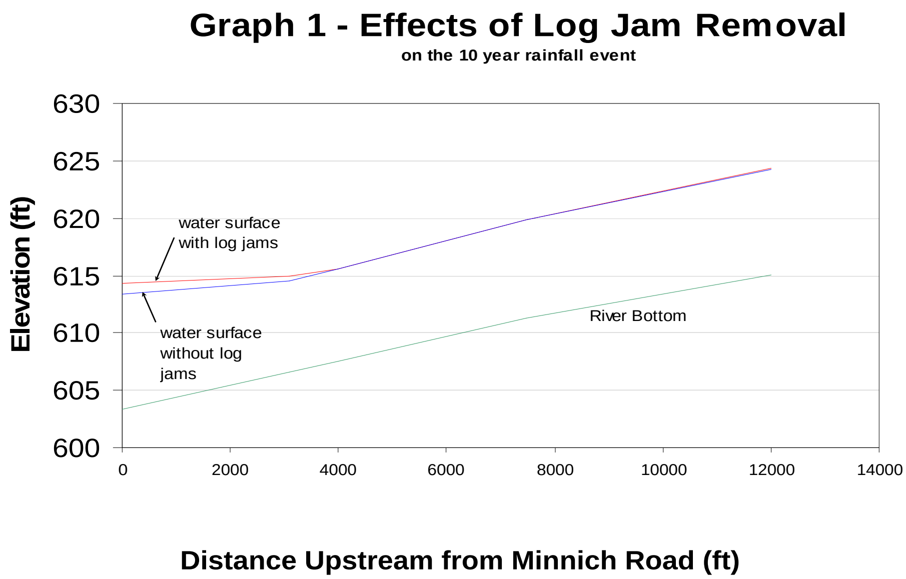
The backwater effects of removing log jams downstream from Minnich Road reduced water surface elevations for about 4,000 feet upstream of Carpenter Road for the 2-, 5-, 10-, 50-, and 100-year precipitation events. Graph 1 shows the backwater impacts of log jam removal in the profile view for the 10-year storm event. The floodplain east of Minnich Road, however, is undeveloped forest, where structural or crop flooding damage is not a concern. These results agree with the conclusions in the ACOE analysis conclusions.

Log jam removal upstream from Minnich Road was completed in 1997. Landowners have reported shorter sustained flooding since the log jams have been removed, which confirms the model results.

Table 2 - Depth and Velocity of Two-Year Rainfall Event Discharges

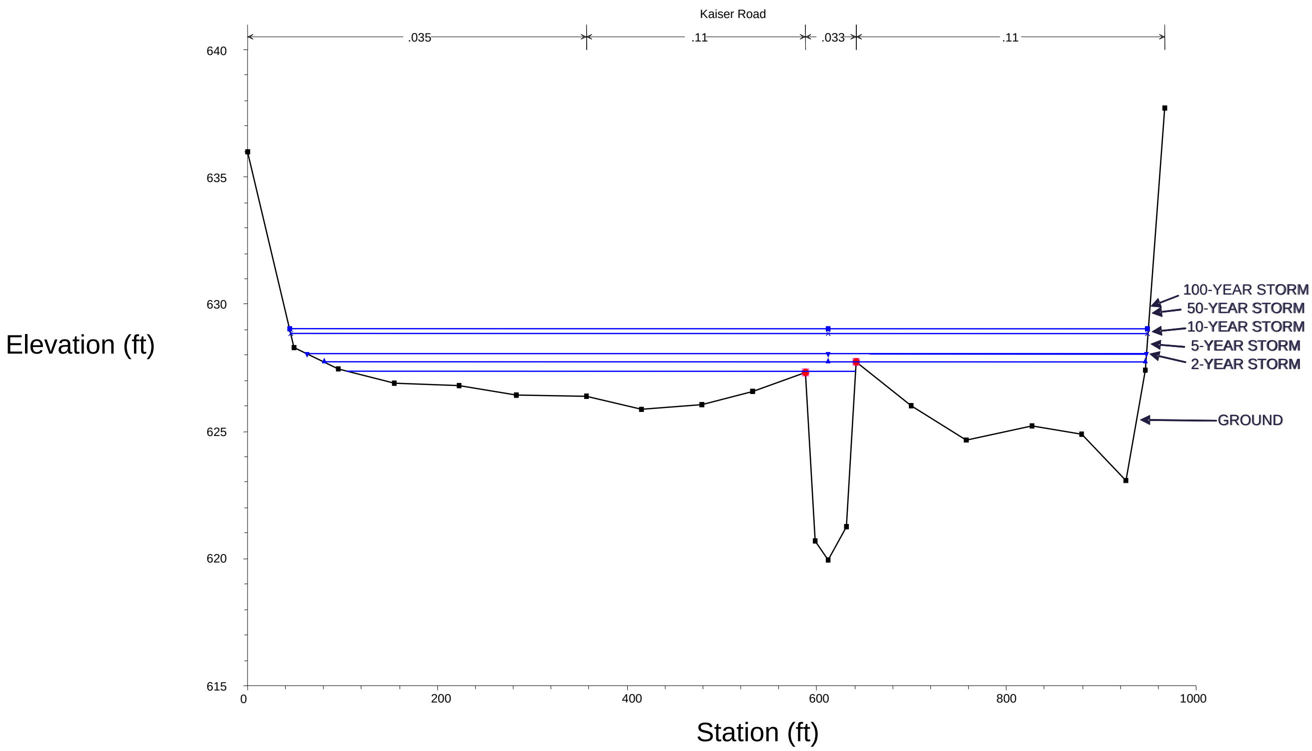
Location No.	Peak 2-year Flow (cfs)	Actual Bankfull Height (ft)	Peak 2-year Flow Depth (ft)	Peak 2-year Flow Velocity (fps)
1	1,500	6.5	10.0	1.3
2	1,500	4.0	4.0	3.1
3	1,100	7.5	7.5	2.4
4	850	10.5	10.5	1.0
5	250	10.0	4.0	2.6
6	70	8.0	4.7	1.0
7	70	10.0	3.0	2.1
8	70	10.5	1.9	3.8
9	70	5.0	2.9	1.7
10	70	5.0	5.4	0.6
11	30	NA	NA	NA
12	30	5.0	2.0	1.5
13	30	7.0	1.5	2.5
14	30	8.0	0.8	3.1
15	30	10.0	1.8	2.3
16	130	14.0	3.2	2.0
17	130	7.0	2.7	1.9
18	50	7.0	3.4	1.2
19	50	8.0	2.8	1.9
20	50	10.5	2.8	1.9
21	50	9.0	3.3	1.4
22	50	9.0	2.8	1.9
23	70	10.0	2.7	2.0
24	70	2.5	1.3	2.9
25	90	6.0	1.8	1.9

Locations 1 through 4 are modeled in HEC-RAS
All other locations modeled using the Principles of Hydraulic Design Series No. 5, Hydraulic Design of Highway Culverts (1985) as prepared for the U.S. Federal Highway Administration
NA = Not applicable



A channel cross section of the River at Kaiser Road (Location 3) shows the water surface elevation for various storm events (Graph 2). Much of the Elm Valley upstream from the confluence of the River and the East Branch of the River is farmed in the 2- to 5-year floodplain. Private drainage systems can be maintained to expedite the conveyance of water from the fields to the River once its level has gone down. Photograph 11 shows a blocked culvert that prevents drainage of water into the channel on the other side. Water will back up in the fields and overtop the driveway, causing both flooding conditions and erosion of the driveway.

Graph 2: Cross Section of Galien River at Kaiser Road (Location 3)



Photograph 11: Blocked Driveway Culvert

TRIBUTARIES TO THE GALIEN RIVER

METHODOLOGY

Weesaw and Galien Townships have experienced historical flooding. *The Principles of Hydraulic Design Series No. 5, Hydraulic Design of Highway Culverts* (1985) as prepared for the U.S. Federal Highway Administration was used to evaluate the crossings. Channel conveyance was evaluated using Manning's formula. Twenty-five crossing locations were evaluated (Figure 4).

The evaluation of upstream crossings includes the following data inputs:

? Peak discharges for the 2-, 5-, and 10-year rainfall events used in the hydrologic analysis are provided by the MDEQ. Appendix 4 details the estimates of the flood frequency discharges.

? Crossing and channel geometry are based on BCDC record drawings and BCRC culvert and bridge assessment information. FTC&H staff conducted field visits to confirm geometry and to photograph each road crossing.

? The roughness coefficients are based on channel and floodplain photographs.

? The slope of the channel is from record drawings and USGS topographical maps.

The evaluation was conducted to determine if current 2-year peak flow conditions exceed bankfull conveyance capacities along tributaries to the River and the present level of flood protection.

RESULTS

Twenty-five sites on tributaries in the upper reaches of the River were evaluated for conveyance capacity (Figure 4). All but two of the evaluated locations convey the 2-year event at less than bankfull conditions (Table 2). Many of the channels are much deeper than the depth that water flows during a 2-year storm. On average, the depth of flow during a 2-year event was 4 feet lower than the top of bank or about 50% of the actual channel depth. These tributaries have been formed by excavation to convey 5- to 10-year storm events. Two-year event peak velocities are reported in Table 2.

All but two of the crossings evaluated provide conveyance for the 5-year storm, or greater. Locations 2 and 11, shown in Figure 4, provided enough conveyance for only the 2-year storm event. Locations 3, 5, 10, 12, 13, 18, 22, and 24 provided conveyance for the 5-year storm, while all other locations provide conveyance for the 10-year storm or greater (Table 3). Five- and ten-year conveyances are common levels of protection used in agricultural drainage.

Table 3 - Upper Galien Crossing Capacity Analysis

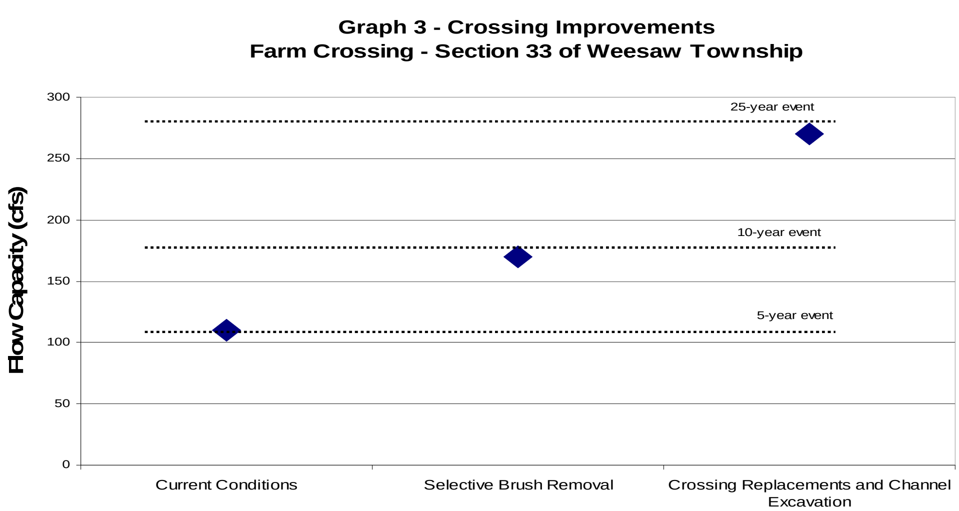
Location No.	Peak 2-Year Flow (cfs)	Peak 5-Year Flow (cfs)	Peak 10-Year Flow (cfs)	Capacity* (cfs)	Structure Description
1	1,500	2,200	2,700	NC	Bridge
2	1,500	2,200	2,700	1,700*	Bridge
3	1,100	1,600	2,000	1,656*	Bridge
5	250	400	500	400	16’x9.5’ multi-plate CMP
6	70	180	280	280	16'x8.5' bridge opening
7	70	180	280	>280	12'x8.5' bridge opening
8	70	180	280	>280	8"x6' CMP Arch
9	70	180	280	280	12'x6' bridge opening
10	70	160	270	160	6'x10' elliptical CMP half full of sediment
11	30	80	140	30	1580' LF of 36" concrete pipe
12	30	80	140	80	48" conc. with 1' of sediment + 15" PVC
13	30	80	140	80	150 LF of 36" concrete pipe
14	30	80	140	>140	6' CMP
15	30	80	140	>140	5'x5' concrete box culvert
16	130	300	470	>470	Twin 19'-3" span x 12'-4" rise steel plate
17	130	300	470	470	3 wood 8'x7' box culverts
18	50	110	170	110	7' steel structural plate culvert
19	50	110	170	170	7' steel structural plate culvert
20	50	110	170	170	7' steel structural plate culvert
21	50	110	170	170	7' steel structural plate culvert
22	50	110	170	110	7' steel structural plate culvert
23	70	180	280	>280	13.8'x7.5' Concrete Box
24	70	160	260	160	14'x6.5' Concrete Bridge
25	90	140	230	>230	13.8'x7.5' Concrete Box

* = Capacity calculations account for tail water control of the downstream channel and crossing hydraulics.
** = According to design calculations by design engineer.
NC = Not calculated because flooding was not reported in these areas or not enough information was available.
CMP = Corrugated Metal Pipe.
Location No. 4 was not analyzed.

Photograph 12: Thick Brush on Banks

Flooding problems have been reported at Locations 18 and 24. Photographs of Location 18 show thick brush on the channel banks (Photograph 12). Graph 3 shows the effects on flow capacity from different channel modifications at Location 18. Channel conveyance will approach the 10-year storm event at this location with selective brush removal. Replacing the crossing and excavating additional channel will increase this location's conveyance capacity to the 25-year event. A channel's flow capacity is related to the channel roughness. Decreasing channel roughness often results in an increase of the channel's capacity. Selective brush removal within the channel can reduce a channel's roughness and increase the channel's capacity. Proper selective brush removal can also maintain the streambank vegetative cover, which benefits the stream by both shading the stream to maintain temperatures and stabilizing the streambank from possible erosion.

Channel excavation changes both channel roughness and flow area, usually increasing the channel's capacity. An increase in channel and culvert capacity can create or increase downstream channel instability, often causing excessive streambank erosion. These measures to increase flow capacity should always be fully studied to ensure that the erosion and water quantity problems are not just moving downstream from the site of where improvements are made. Maintaining vegetated streambank cover downstream of stream improvement efforts lessens erosive effects that can result from these changes to the hydraulics of the stream.



At location 11, on a tributary to the Blue Jay Drain at Holden Road shown in Figure 4, the capacity of the 1,580 linear feet of 36-inch storm sewer limits conveyance to the 2-year event. Replacement of the 36-inch pipe with a larger diameter storm sewer or open channel could increase conveyance to the 5- or 10-year event.

CONCLUSIONS

The following conclusions are based on the results of the hydrologic study and hydraulic modeling:

? Restoring wetlands in the upper reaches of Dowling Creek, the Blue Jay Drain, and the River will retain water and reduce flooding in Elm Valley. Target areas to restore wetlands are Galien Township, Sections 5, 6, 7, and 8, as well as Weesaw Township, Sections 31 and 32. These areas are agricultural and eligible for many of the wetland restoration programs.

? Streambank restoration work upstream of the Preserve should be selectively and carefully completed so as to not alter flows or increase sediment downstream.

? Onsite retention or detention should be required for developments within or upstream of Elm Valley, based on stream protection volumes and flood control volumes.

? The River appears to be fairly stable in the lower reaches and the main tributaries. The instability of the River appears to be within and downstream of the agricultural areas in the western part of Galien Township and the eastern part of Three Oaks Township, where the natural hydrology of the system has been altered for agricultural drainage and the River is disconnected from the floodplain.

? Rosgen's stream classification assessment should be used when determining the types of remediation efforts to solve streambank erosion problems in the Watershed.

? Peak water surface elevations in flooded areas upstream of the confluence of the River and Kirktown Creek will not be lowered by removing log jams in the River downstream from Minnich Road.

? Flooding in the 2- to 5-year floodplain of the River is to be expected. Private drainage systems can be maintained to decrease flood damage and provide drainage once the River stage decreases.

? Most of the crossings and channels in the upper reaches of the River provide conveyance for the 5-year event or greater. Conveyance improvements can be made by selectively removing obstructions and replacing culverts, although the effects that these improvements may have on streambank erosion and flooding downstream must be thoroughly evaluated.

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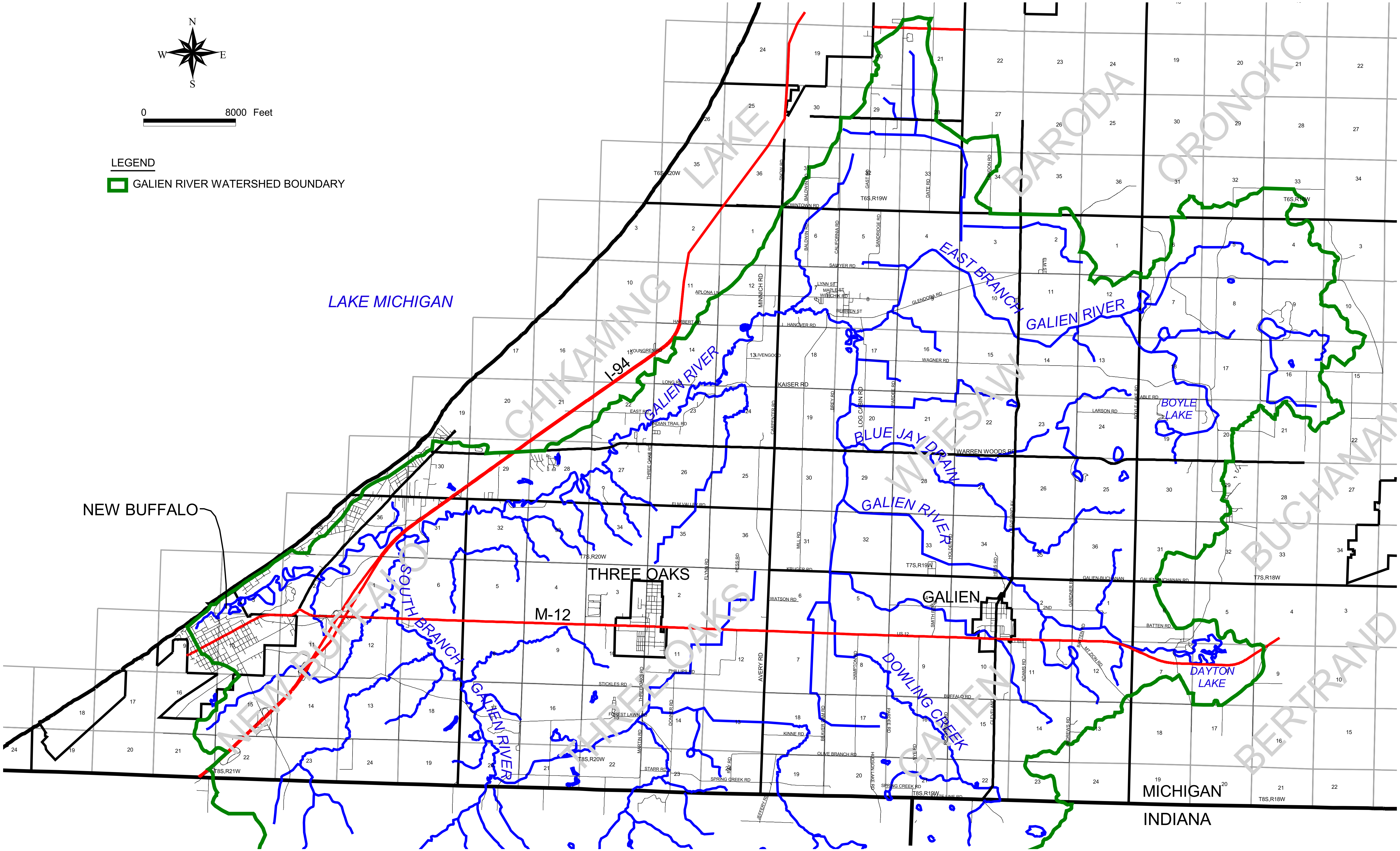
Schueler, Thomas and Heather Holland. 2000. *The Practice of Watershed Protection. Article #148, Technical Note #46 from Watershed Protection Techniques. 1(4): 182-183.* The Center for Watershed Protection, Ellicott City, Maryland.



DATA SOURCES: BASE MAP, BERRIEN LAND INFORMATION SYSTEM, 2001, SPCS NAD 83, INTERNATIONAL FEET.
RIVERS, US EPA REACH FILES VERSION 3.0.
WATERSHED DELINEATION, MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY GIS, DIGITAL SHEDS, 2001.

D:\WORK\01338\PROJECT\GALIEN_EXHIBITS.APR\HHFIG1 BASE MAP DATE: 9-10-2002 USER: MCL

BASE MAP

Fishbeck, Thompson, Carr & Huber
Engineers ● Scientists ● Architects
Grand Rapids, Michigan
ftc&h

Berrien County Drain Commissioner
Berrien County, Michigan

Galien River Hydraulic and Hydrologic Study

PROJECT NO.
G01338

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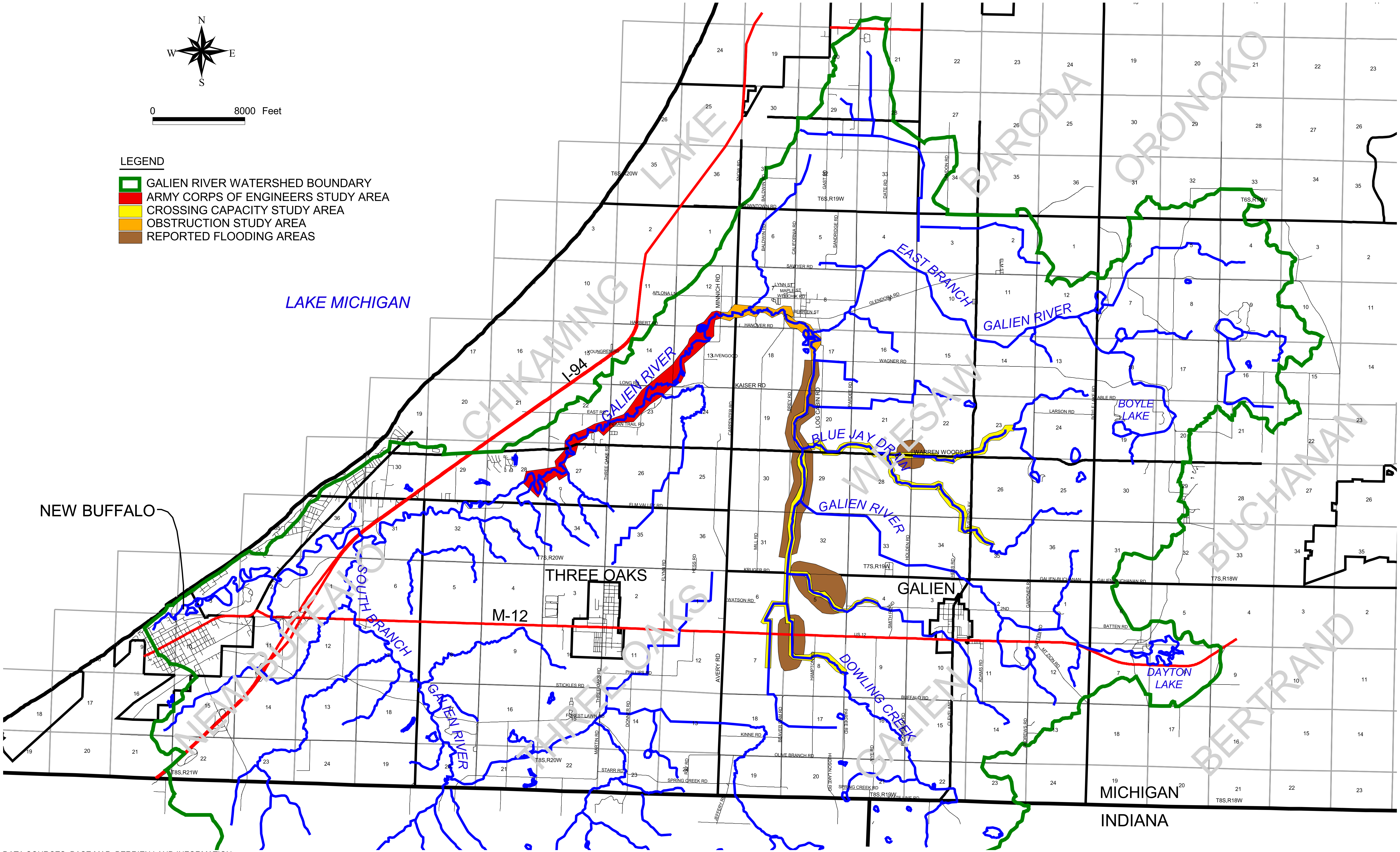


DATA SOURCES: BASE MAP, BERRIEN LAND INFORMATION SYSTEM, 2001, SPCS NAD 83, INTERNATIONAL FEET.
FLOOD AREAS, USDA NRCS AND THE BERRIEN COUNTY DRAIN COMMISSIONER.
RIVERS, US EPA REACH FILES VERSION 3.0.
WATERSHED DELINEATION, MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY GIS, DIGITAL SHEDS, 2001.

D:\WORK\01338\PROJECT\GALIEN_EXHIBITS.APR\HHFIG 2 FLOOD AREAS DATE: 9-10-2002 USER: MCL

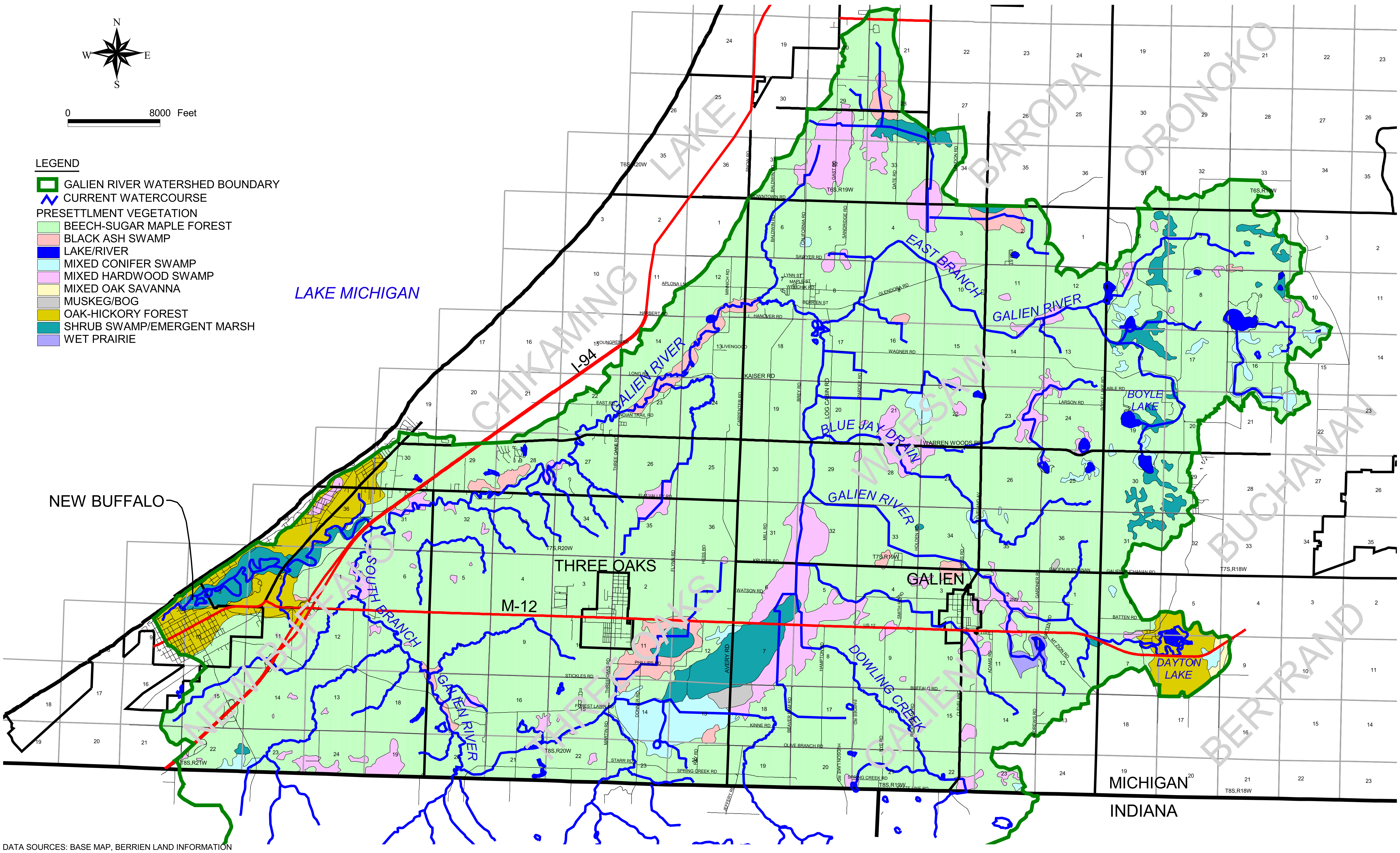
FLOODING STUDY SITES

Fishbeck, Thompson, Carr & Huber
Engineers ● Scientists ● Architects
Grand Rapids, Michigan
ftc&h

Berrien County Drain Commissioner
Berrien County, Michigan
Galien River Hydraulic and Hydrologic Study

PROJECT NO.
G01338

2



DATA SOURCES: BASE MAP, BERRIEN LAND INFORMATION SYSTEM, 2001, SPCS NAD 83, INTERNATIONAL FEET.
RIVERS, US EPA REACH FILES VERSION 3.0.
PRESETTLEMENT VEGETATION, MICHIGAN DEPARTMENT OF NATURAL RESOURCES SPATIAL DATA LIBRARY, LAND COVER CIRCA 1800, MIRIS 1978.
WATERSHED DELINEATION, MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY GIS, DIGITAL SHEDS, 2001.

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PRESETTLEMENT VEGETATION

Fishbeck, Thompson, Carr & Huber
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Grand Rapids, Michigan

ftc&h

Berrien County Drain Commissioner
Berrien County, Michigan

Galien River Hydraulic and Hydrologic Study

PROJECT NO.
G01338

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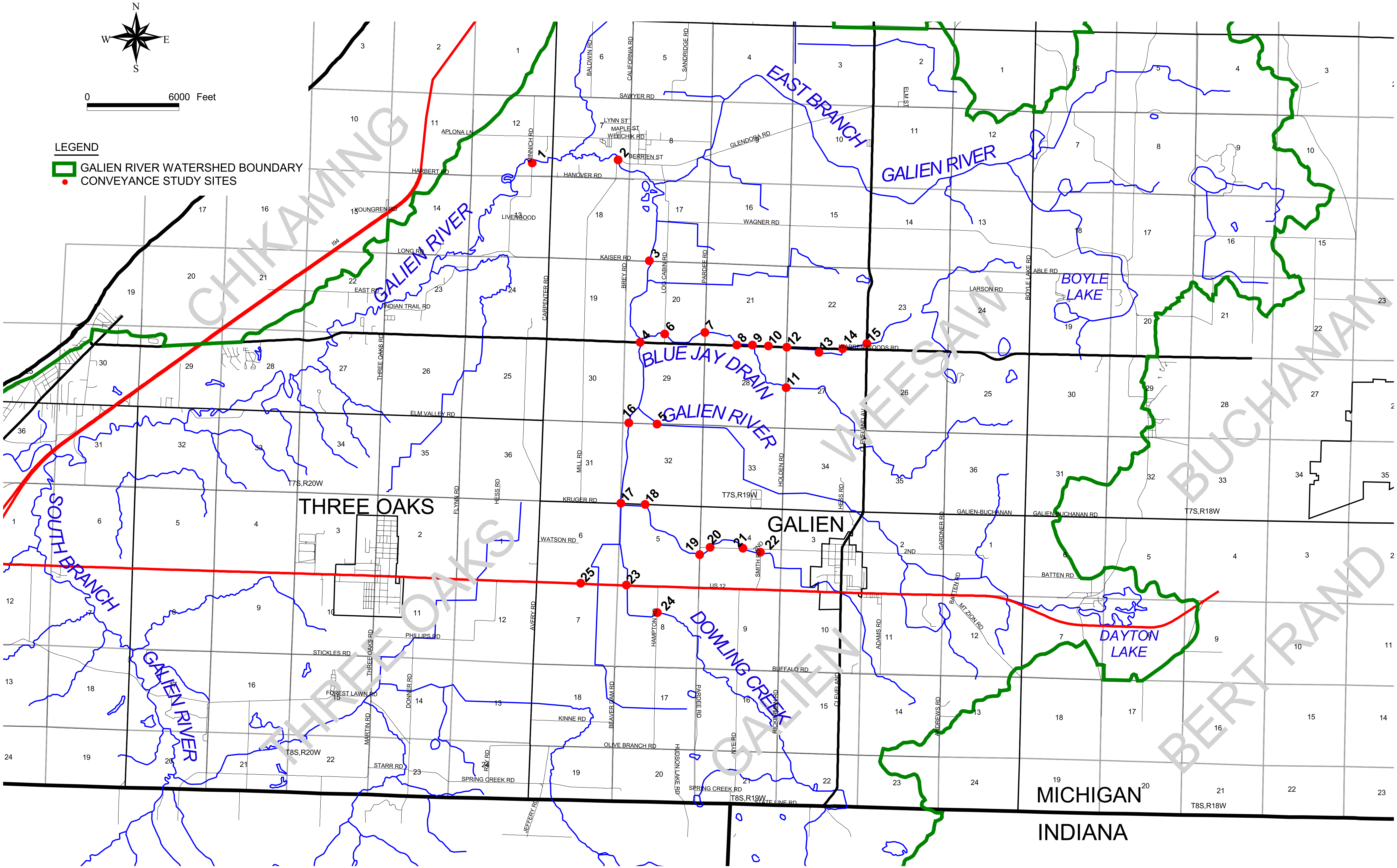

DATA SOURCES: BASE MAP, BERRIEN LAND INFORMATION SYSTEM, 2001, SPCS NAD 83, INTERNATIONAL FEET.
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WATERSHED DELINEATION, MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY GIS, DIGITAL SHEDS, 2001.

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CONVEYANCE STUDY SITES

Fishbeck, Thompson, Carr & Huber
Engineers • Scientists • Architects
Grand Rapids, Michigan

Berrien County Drain Commissioner
Berrien County, Michigan

Galien River Hydraulic and Hydrologic Study

PROJECT NO.
G01338

4

GALEN RIVER, BERRIED COUNTY, MICHIGAN
SECTION 208 STUDY

APPENDIX A

HYDROLOGY AND HYDRAULICS ANALYSIS

U.S. ARMY CORPS OF ENGINEERS
DETROIT DISTRICT

SEPTEMBER 1998

GALIEN RIVER, BERRIEN COUNTY, MICHIGAN
SECTION 208 STUDY

APPENDIX A

HYDROLOGY AND HYDRAULICS ANALYSIS

TABLE OF CONTENTS

SUPPLEMENT TO CELRE-EP-HE
20 APRIL 1998 MEMORANDUM

CELRE-EP-HE 27 JULY 1998

MEMORANDUM FOR Chief, Planning Branch

SUBJECT: Galien River through Berrien County, Section 208 Clearing and Snagging

1. Background:

A) In previous memos (3 October 1997, and 20 April 1998), The Great Lakes Hydraulics and Hydrology Branch summarized its findings regarding flooding problems along the Galien River through Berrien County.

B) Hydrologic analysis of a similarly sized, gaged watershed with similar soil horizons suggests that the 2600 cfs peak discharge recorded on May 10, 1996 was indeed a 100-yr discharge. This seems to be corroborated by reported damage to specific properties along West Glendora and Indian Trail Roads in Chikaming Township.

C) Hydraulic modeling efforts indicate that the Galien River, in many locations, overflows its banks when the discharge exceeds the 5-yr return period event. However, a number of site visits to the area revealed a broad, deeply incised, and heavily forested floodplain extending ~8 miles downstream from Minnich Road to the I-94 bridge. All agricultural, commercial and residential development appears to be located significantly *above* the Galien River floodplain.

D) The GLH&H Branch assessed the potential reduction in water surface profiles that might result from clearing specific lengths of the Galien River through Chikaming Township. If significant reductions in the water surface had materialized, the analysis would have continued further upstream. Although not specifically stated in the Branch's 20 April memo, the reductions observed were not large enough to warrant further analysis.

2. Subsequent Analysis:

A) The peak water surface elevation associated with the May 10, 1996 flood event as recorded at the Minnich Road USGS stream gage was 623.4 ft NGVD. This elevation was determined from the rating curve supplied by the USGS at our request. The USGS made several flow measurements of the Galien River in the vicinity of this gage as the flood was occurring.

B) In the vicinity of this gage, the table of land on which the town of New Troy and all its adjacent farmland and home sites are found is at a minimum elevation of 635.0 ft NGVD or higher.

C) Recorded peak daily discharges for the Minnich Road gage for this flood event were as follows; May 8 = 62cfs, May 9 = 107cfs, May 10 = 2640cfs, May 11 = 1890cfs, and May 12 = 991cfs. The water surface elevations (ft NGVD) associated with these discharges are; 616.2, 617.0, 623.4, 622.5, and 621.1. Galien River discharges returned to their normal seasonal levels by the end of June.

D) The relatively rapid rise and fall of the Galien River during this flood event is noteworthy. Sustained flooding, when caused by rivers escaping their banks, is characterized by river levels that rise *and then remain high for extended periods of time* -- often weeks.

3. Conclusions:

A) Roads across the Galien River were most certainly overtopped and damaged by this flood event. The list of flood-damaged properties was studied in an effort to locate homes and businesses adjacent to river crossings, as well as those "stream side" of roads paralleling the river. With possibly two or three exceptions in Chikaming Township, the bulk of damages occurred to properties well removed from the influences of the Galien River.

B) Extensive agricultural damages *due to flooding from the river* would require that the flood stage remain at its peak for *at least* 48 to 72 hours. From the information available, all agricultural land appears to be at an elevation well above the influence of the river.

C) Careful consideration has been given both to the information provided by the Berrien County Drain Commissioner's Office, as well as data and analyses developed in-house.

D) As well as can be determined, all of the agricultural damages and in excess of 90% of the residential and commercial damages must have been the result of upstream drainage problems *unrelated* to conditions on the Galien River.

E) It is the opinion of the Great Lakes Hydraulics and Hydrology Branch that removing debris and snags from the Galien River would do nothing to prevent the damages which occurred during the May 10 1996 hydrologic event.

F) The POC for this project is Mr Christopher Purzer @ 6-6791.

for David L. Schweiger, P.E.
Chief, Great Lakes Hydraulics and
Hydrology Branch

CELRE-EP-HE 20 APRIL 1998

MEMORANDUM FOR: Chief, Planning Branch

SUBJECT: Section 1135 Project, Berrien County, Galien River Clearing and Snagging Investigation

1. The Great Lakes Hydraulics and Hydrology Branch performed a series of analyses to investigate the potential effect of clearing fallen trees and large debris from the Galien River. The information presented in this memorandum was specifically requested in order to develop an economic analysis.

2. Estimating the Return Period of the May 1996 Flood Event:

Based on a listing of damaged homes and businesses, addresses located along roads near the Galien River were located. This was accomplished through "Map Quest" services on the Internet. "Map Quest" provides street addresses on a block by block basis as pin-pointed by the cursor's position on an on-line map. In this way, four residences were located;

6802 W. Warren Woods Road	Chikaming Township
5802 W. Indian Trail	Chikaming Township
3763 W. Glendora Road	Weesaw Township
3333 W. Glendora Road	Weesaw Township

The proximity of the two Chikaming addresses relative to the 100-year flood boundary (Chikaming Township Flood Insurance Study) suggests that the May 1996 event was at least a 100-year flood. The two Weesaw Township addresses are located far enough away from the Galien River that *overland drainage from this extreme rain event*, rather than rising river waters, was probably responsible for flooding damage.

3. Establishing Damage Reaches and Representative Water Surface Elevations:

Approximately three miles of the Galien River between Three Oaks Road and Minnich Road was modeled using HEC-2 and divided into four damage reaches--two upstream, and two downstream of Flynn Road. The physical limits of each damage reach are illustrated in figure 1. The numbers 2.07, 3.05, 7.00, and 10.09 correspond to the HEC-2 model section identifiers selected as representative of the damage reaches. For each of these four cross sections stage - frequency curves, representative of the damage reaches under existing conditions, were created as Figure A-2. With reference to Figure A-2, reach #1 corresponds to HEC-2 section identifier 2.07 from Figure A-1; reach #2 corresponds to section identifier 3.05 from Figure A-2, and so forth.

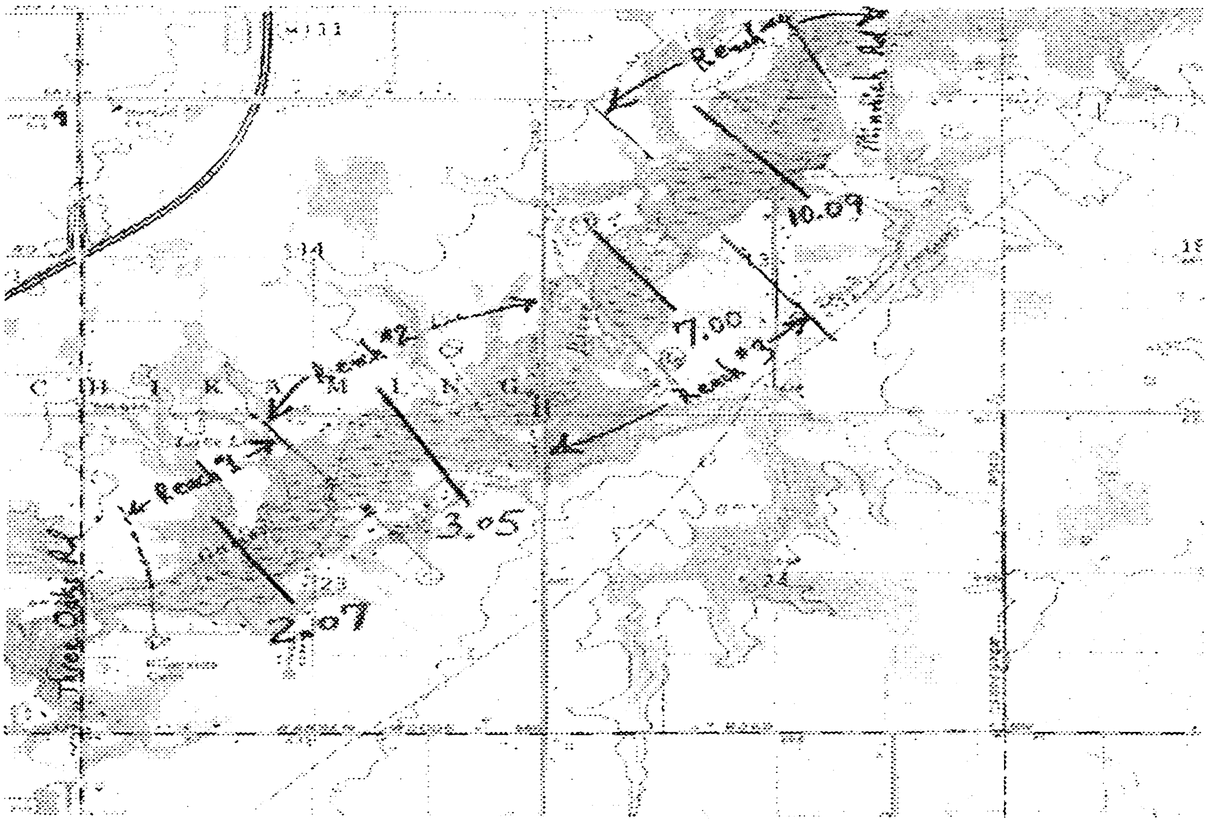


Figure A-1. Approximate Reach Lengths along the Galien River. River flow is diagonally from right to left. "Damage Reach" lengths are identified in black; HEC-2 section identifiers are noted in orange.

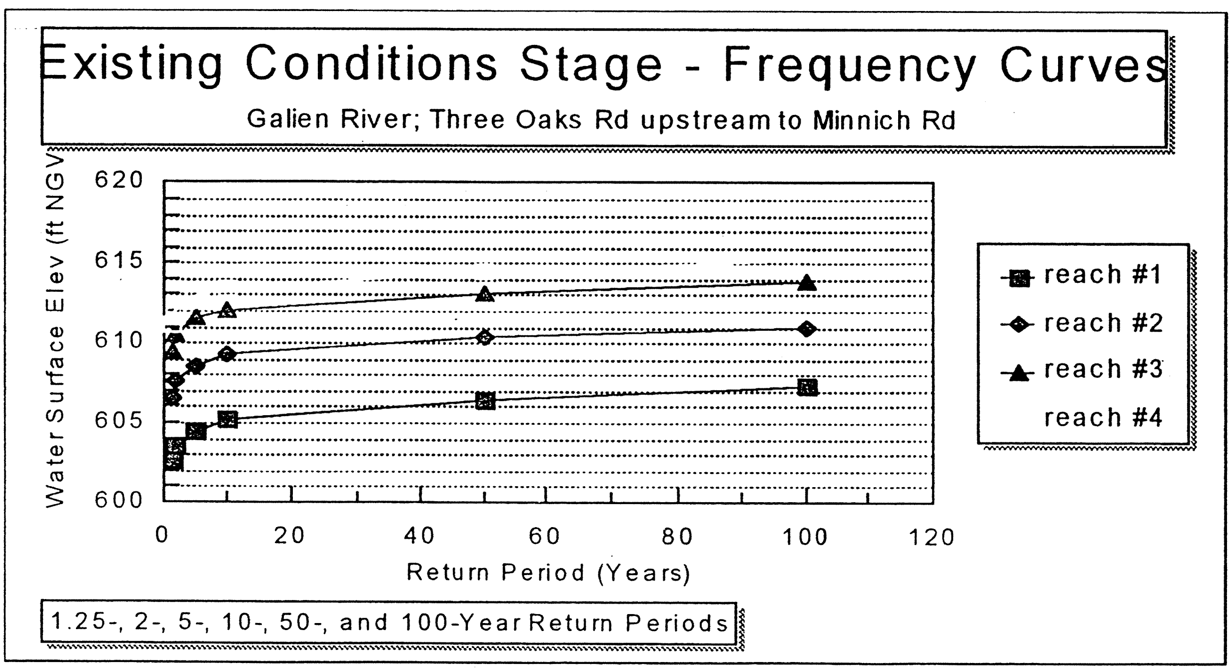


Figure A-2. Stage - Frequency Curves for the Galien River through Chikaming Township, Berrien County. Data points correspond to the six stated return periods..

4. Modeling the Effects of Clearing and Snagging:

For the existing conditions HEC-2 model, Manning's roughness coefficients for the study area were assumed to be 0.11 across the overbank regions and 0.045 through the channel. The channel roughness coefficient was decreased from 0.045 to 0.033 to model the impact of removing logs and sandbars from a section of river. Overbank roughness coefficients remained unchanged. Clearing this three mile stretch of river was investigated as a percentage of the study reach as illustrated in Figure 3 "100%" implies 100% of the river channel was cleared from Three Oaks Road to Minnich Road, while "50%" implies the river channel was cleared from Flynn Road to Minnich Road.

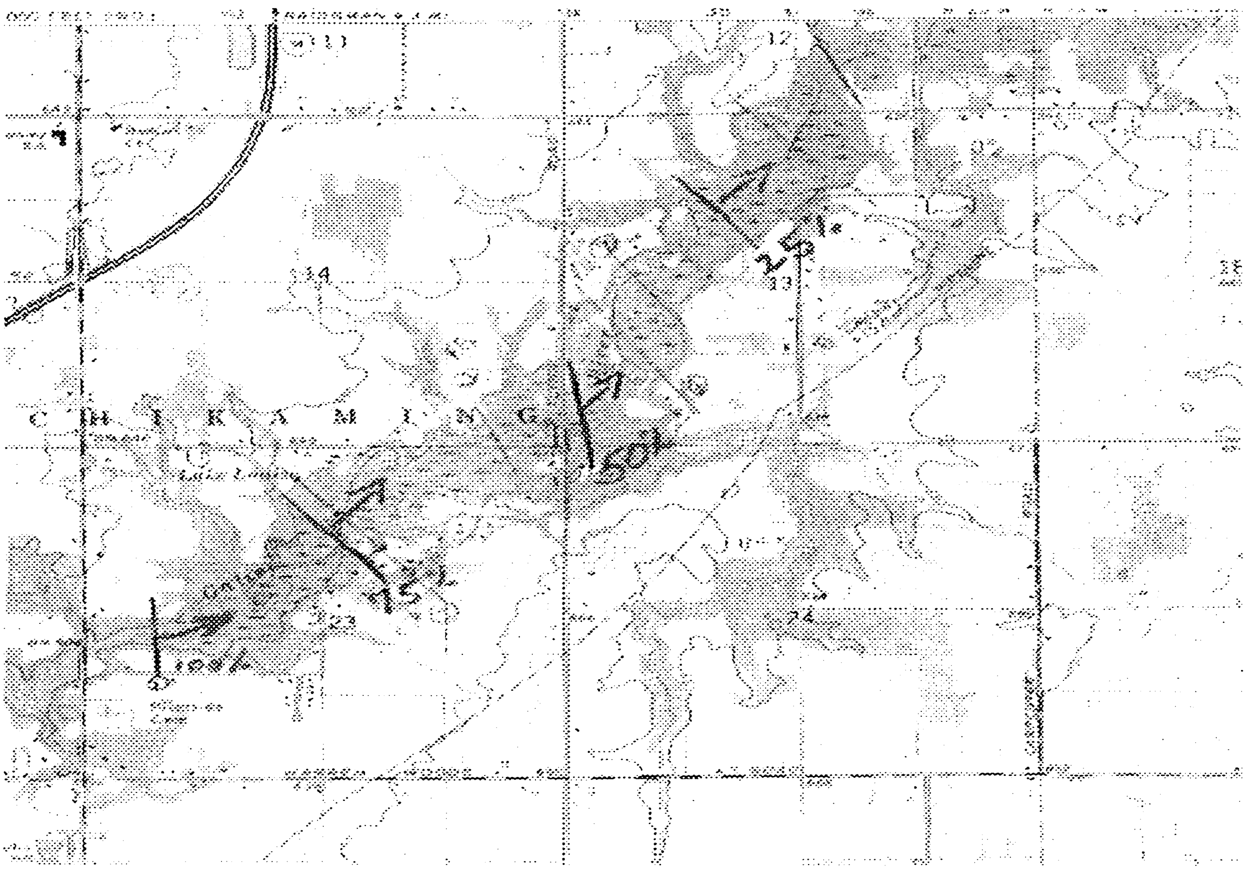


Figure A-3. Overview of incrementally clearing the Galien River channel. "25%" corresponds to clearing the channel of damage reach #4, while "50%" corresponds to clearing the channel of *both* damage reach #4 and damage reach #3. Arrows are located approximately at the downstream limits of previously identified damage reaches and point *upstream*. Refer back to Figure A-1 for damage reach designations and road names.

Table A-1 summarizes the water surface elevations generated by clearing the river channel as previously described, for each of six return period flood events (1.25, 2, 5, 10, 50, and 100 years). Quantities in parentheses are the depth the water surface *dropped* relative to the existing conditions river model. A zero in parentheses implies that all clearing in the river took place *upstream* and would therefore have no impact on the water surface through that particular damage reach.

Table A-1 Summary of Approximate Water Surface Elevations Resulting from Channel Clearing				
100% of study area channel is cleared of snags and sand bars (Damage Reaches 1,2,3, and 4)				
Return Period	Reach #1	Reach #2	Reach #3	Reach #4
1.25 yr	601.84 (0.67)	605.91 (0.66)	608.73 (0.72)	610.55 (0.56)
2	602.70 (0.77)	606.80 (0.76)	609.69 (0.84)	611.33 (0.66)
5	603.58 (0.83)	607.70 (0.85)	610.68 (0.83)	612.15 (0.70)
10	604.24 (0.87)	608.38 (0.87)	611.38 (0.69)	612.76 (0.65)
50	~605.7 (0.7)	609.62 (0.69)	612.42 (0.62)	613.77 (0.64)
100	~606.7 (0.6)	610.37 (0.60)	613.14 (0.63)	614.49 (0.65)
75% of study area channel is cleared of snags and sand bars (Damage Reaches 2,3, and 4)				
Return Period	Reach #1	Reach #2	Reach #3	Reach #4
1.25 yr	602.51 (0)	605.95 (0.62)	608.73 (0.72)	610.55 (0.56)
2	603.47 (0)	606.87 (0.69)	609.70 (0.83)	611.33 (0.66)
5	604.41 (0)	607.81 (0.74)	610.69 (0.82)	612.16 (0.69)
10	605.11 (0)	608.51 (0.74)	611.40 (0.67)	612.77 (0.64)
50	606.40 (0)	609.76 (0.55)	612.43 (0.61)	613.78 (0.63)
100	607.34 (0)	610.52 (0.45)	613.17 (0.60)	614.50 (0.64)
50% of study area channel is cleared of snags and sand bars (Damage Reaches 3 and 4)				
Return Period	Reach #1	Reach #2	Reach #3	Reach #4
1.25 yr	602.51 (0)	606.57 (0)	608.91 (0.54)	610.57 (0.54)
2	603.47 (0)	607.56 (0)	609.96 (0.57)	611.39 (0.60)
5	604.41 (0)	608.55 (0)	610.97 (0.54)	612.25 (0.60)
10	605.11 (0)	609.25 (0)	611.62 (0.45)	612.85 (0.56)
50	606.40 (0)	610.31 (0)	612.65 (0.39)	613.86 (0.55)
100	607.34 (0)	610.97 (0)	613.41 (0.36)	614.60 (0.54)
25% of study area channel is cleared of snags and sand bars (Damage Reach 4 only)				
Return Period	Reach #1	Reach #2	Reach #3	Reach #4
1.25 yr	602.51 (0)	606.57 (0)	609.45 (0)	610.91 (0.20)
2	603.47 (0)	607.56 (0)	610.53 (0)	611.82 (0.17)
5	604.41 (0)	608.55 (0)	611.51 (0)	612.68 (0.17)
10	605.11 (0)	609.25 (0)	612.07 (0)	613.24 (0.17)
50	606.40 (0)	610.31 (0)	613.04 (0)	614.23 (0.18)
100	607.34 (0)	610.97 (0)	613.77 (0)	614.95 (0.19)

5. Estimating Minimum Riverbank Elevations:

Photographs and field notes of this entire study area along the Galien River were assembled by Corps survey personnel. Because of the reported surface speed and depth of the river, and due to the fact that all the photos show the river flowing within its low and shallow banks, the Galien River was assumed photographed at its average annual discharge. Based on this assumption, the photographs through each of the four damage reaches were examined for low bank locations and these bank elevations estimated based on an assumed height above the HEC-2 computed water surface from the existing condition model.

USGS gage infomation for flows on the Galien River (near Sawyer, MI) for the period during which the photographs were taken will not be available until the middle of May.

Estimated minimum riverbank elevations are as follows (ft NGVD):

Damage Reach #1 = 603.1
Damage Reach #2 = 606.5
Damage Reach #3 = 610.3
Damage Reach #4 = 612.1

6. Modeling Limitations and Comments:

The HEC-2 model assembled for this analysis was created without any survey information. The entire modeling effort relied on 10 ft topographic quadrangle maps (ft NGVD) to provide elevation and distance measurements at the 600, 610, 620, 630, and 640 contours. All other elevations and distances were the result of interpretation and imagination. The channel slope is, *perhaps*, reasonably accurate because it was measured from the topographic map.

Without survey data, no reasonable attempt could be made to model the road crossings. This may or may not be problematic. Bridges built or modified since 1968, by MDOT requirements, cause no more than a 0.10 ft rise in 100 year flood events. If the bridges at Three Oaks Road and Flynn Road were built before 1968, there is the possibility they could significantly raise the water surface associated with the 50 or 100 year flood events.

Assuming reasonable estimates of Manning's roughness, an accurate channel slope is more important than accurate cross sectional shapes for the 50 and 100 year return period events. Assigning lesser importance to channel shape is warranted in these two situations because so much land is covered with water during these flood events. As the flood event return period decreases, the water recedes back into the channel, and the channel *shape* between *the bank stations* becomes as important as the channel slope. Acknowledging that all the cross section data is essentially ficticious, the 100 year return period results are more reliable than the 1.25 year return period results.

Regarding Table A-1 results, the data presented for clearing *all four* damage reaches might only materialize if; (1) the bridges at Three Oaks Road and Flynn Road are built in accordance with 1968 MDOT requirements, and (2) as much as 0.5 to 0.75 miles of river *downstream* of Three Oaks Road are also cleaned. The river would need approximately this much length to work itself *out* of the backwater effects induced by channel debris *downstream*.

7. The POC for this project is Mr Christopher Purzer @ 6-6791

David L. Schweiger, P.E.
Chief, Great Lakes Hydraulics and
Hydrology Branch

County Drains in the Galien River Watershed

DRAIN NAME	TOWNSHIP	DATE OF ESTABLISHMENT	LENGTH	DATE OF MOST RECENT IMPROVEMENT	DATE OF FUTURE IMPROVEMENTS	ADDITIONAL COMMENTS
Anderson & Tibbles	Weesaw	1938	2345'	-		
Babcock	Weesaw	1927	4372'	1996		
Blue Jay	Weesaw				Next couple of years	
Blue Jay-North Branch	Weesaw	1922	15,788'	1996	Next couple of years	
Bowers & Penwell	Weesaw	1903	2465'	1967		
Carpenter & Ferry	Weesaw	1906	13199'	1997		
Carpenter & Holden	Weesaw	1911	6126'	1994		
Charles Orris	Weesaw	1916	6875'	1993		
Clark & Bowers - W. Br.	Weesaw	1985	Not listed	1987		
Clark & Bowers	Weesaw	1917	7474'	1996		
Clark & Bowers - E. Br.	Weesaw	1922	1300'	1984		
Clark & Goodell	Weesaw	1903	3720'	1997		
Close	Weesaw	1891	34,400'	1996	Next couple of years	
Dempsey	Weesaw	1915	6000'	1997		
Dinges	Weesaw	1921	1310'	1995		
Fowler	Weesaw	1907	20,900'	1993		
Galien River	Weesaw	1890	Not listed	1955		
Galien River - S. Br. Ext.	Weesaw	1930	Not listed	1934		
Galien River - S. Br.	Weesaw	1908	19148'	1991	Next couple of years	Especially along Elm Valley
Gardner	Weesaw	1885	5222'	1993		
Garfield Ave	Weesaw	1887	8875'	1993		
Gifford	Weesaw	1906	10,482'	1993		
Gifford Ext.	Weesaw	1952	15,321'	1993		
Gifford Ext. Partial	Weesaw					
Glaske & Krieger	Weesaw	1911	2157'	1995		
Hall & Potter	Weesaw	1899	5443'	1996		
Hanover	Weesaw	1917	7957'	1991		
Hanover S. Br.	Weesaw	1917	2472'	1994		
Haskins #15	Weesaw	1899	3620'	1941		
Hess	Weesaw	1897	3054'	1997		
Hickory Cr. - Ext. & Outlet	Weesaw	1903	Not listed	1961		
Hickory Creek	Weesaw	1894	43,246	1997		
Hickory Creek Partial	Weesaw	1985	Not listed	-		
Hickory Creek Partial - 1994	Weesaw	1994	Not listed	-		
Holden & Smith	Weesaw	1917	4800'	1997		
Holden & Smith - Partial	Weesaw	1996	Not listed	1996		
John English	Weesaw	1903	6550'	1995		
Judy Lake	Weesaw	1898	26015'	2000		

DRAIN NAME	TOWNSHIP	DATE OF ESTABLISHMENT	LENGTH	DATE OF MOST RECENT IMPROVEMENT	DATE OF FUTURE IMPROVEMENTS	ADDITIONAL COMMENTS
Lake & Weesaw Twp Line	Weesaw	1922	3340'	1984		
Lintner, Allen & Ren Barger	Weesaw	1909	6926'	1997		
Log Cabin Road	Weesaw	1994	Not listed	1997		
Ludlam	Weesaw	1917	1900'	1993		
Luther	Weesaw	1917	3340'	1995		
Mc Donald	Weesaw	1927	2116'	1996		
Miller & Ristoff	Weesaw	1952	5260'	1982		
Minnich Road	Weesaw					No card
Moore, Klassner & Hess	Weesaw	1883	2380'	1994		
Moore, Klassner & Hess - old	Weesaw	1967	Not listed	1997		
Mud Hollow	Weesaw	1898	2772'	1994		
Murdock & Beeson	Weesaw	1896	5460'	1993		
New Troy Village	Weesaw	1950	2484'	1993		
New Troy Village - Detroit St.	Weesaw	1981	848'	1981		
Nimtz & Rantz	Weesaw	1918	4080'	1997		
Norris Lake	Weesaw	1902	17,340'	1993		
Norris Lake	Weesaw				Next couple of years	
Nowlan ?	Weesaw					No card
Orris & Weaver	Weesaw	1916	5660'	1990		
Ott & Krieger	Weesaw					
Painter & Weatherwax	Weesaw	1901	4800'	1997		
Painter & Weatherwax-Wagne	Weesaw	1996	Not listed	1997		
Pardee, McDonald & Clark	Weesaw					No card
Penwell	Weesaw	1937	2310'	1996		
Pierce, Lewin & Jennings	Weesaw	1896	4892'	1996		
Prenkert & Murdock	Weesaw	1914	7876'	1993		Not found
Priebe	Weesaw	1922	1758'	1993		
Pufall	Weesaw	1928	2900'	1993		
Reese	Weesaw	1915	4600'	1993		
Robbins	Weesaw	1916	1710'	1996		
Rug Lake	Weesaw	1921	3482'	1991		
Shields	Weesaw	1898	4020'	1995		
Smith & Nowlen	Weesaw	1885	10,724'	1996		
Sober & Becker	Weesaw	1906	21,900'	1993		
Sober & Becker Ext.	Weesaw	1937	4930'	1987		
Sober & Becker So. Br.	Weesaw	1931	9220'	1985		
Sober & Becker So. Br. Partia	Weesaw					
Stevens	Weesaw	1916	1650'	1992		
Troy	Weesaw	1901	1454'	1993		
Troy Meadow	Weesaw	1897	8267'	1994		
Troy Meadow Outlet	Weesaw	1935	6760'	1995		

DRAIN NAME	TOWNSHIP	DATE OF ESTABLISHMENT	LENGTH	DATE OF MOST RECENT IMPROVEMENT	DATE OF FUTURE IMPROVEMENTS	ADDITIONAL COMMENTS
Washburn	Weesaw	1917	1828	1996		
Weaver & Haroff	Weesaw	1913	22,675'	1995		
William Morley	Weesaw	1918	3035'	1945		
Williams & Essig	Weesaw	1910	2400'	1994		
Wolf Creek	Weesaw	1934	10,626	1993		
Bethany Beach	Chikaming					Not in watershed
Close	Chikaming				Next couple of years	
Edinger	Chikaming					Not in watershed
Gifford	Chikaming	1906	10,482'	1993		
Gifford Ext.	Chikaming	1953	15,321' total	1993		
Gifford Ext. Partial	Chikaming	1980	-	-		
Hellinga	Chikaming	1914	15,032'	1993		
Indian Trails Estates	Chikaming	1976	2832'	1977		
John Morley Br.	Chikaming	1925	2550'	1941		
Minnich Road	Chikaming					No card
Streed	Chikaming	1931	8828'	1986		
Streed Ext.	Chikaming	1938	7346'	1981		
Streed Relief	Chikaming	1961	1370'	1986		
Union Pier	Chikaming	1909	6871'	1995	Next couple of years	
Bain	Lake	1898	1115'	1978		
Barfelz	Lake	1928	2150'	1993		
Becker	Lake	1885	12292'	1983		
Becker N. Br.	Lake	1983	Not listed	1983		
Becker S. Br.	Lake					No card
Clark & Duart	Lake	1898	6303'	1994		
Clark & Duart Ext.	Lake	1936	2472'	1980		
Galien River	Lake	1890	Not listed	1951	Next couple of years	
Gaul	Lake	1890	4366'	1994		
Grande Mere Lake	Lake	1931	Not listed	1997		
Hauser & Hendrix W. Ext	Lake					No card
Hauser & Hendrix	Lake	1903	Not listed	1997		
Hickory Creek Ext.	Lake	1903	Not listed	1961		
Hickory Creek	Lake	1894	43246'	1997		
Hickory Creek Partial	Lake	1985	-	-		
Hickory Crrek Partial 1994	Lake	1994	-	-		
James	Lake	1914	7060'	1997		
James Partial	Lake					No card
Johns	Lake	1899	14834'	1995		
Kill	Lake	1908	9635'			
Kill Bowling Green	Lake	1996	Not listed	1997		
Kill Clark & Duart Contribution	Lake	1996	Not listed	1996		

DRAIN NAME	TOWNSHIP	DATE OF ESTABLISHMENT	LENGTH	DATE OF MOST RECENT IMPROVEMENT	DATE OF FUTURE IMPROVEMENTS	ADDITIONAL COMMENTS
Kill East Br.	Lake	1996	Not listed	1997		
Kill Partial A	Lake	1983	-	-		
Kill Partial B	Lake	1983	-	-		
Livengood	Lake					
McDaneld	Lake	1927	2116'	1996		
Merklin	Lake	1965	707.5'	1990		
Miller & Ristoff	Lake	1952	5260'	1982		
Nazke & Smikel	Lake	1917	1000'	1993		
Price	Lake					
Smith & Nowlan	Lake	1885	10,724'	1996		
Smith & Nowlan Ext.	Lake	1955	1678'	1993		
Smith & Nowlan Partial	Lake	1976				
Sober & Becker	Lake	1906	2190'	1993		
Sober & Becker Ext.	Lake	1937	4930'	1987		
Sober & Becker So. Br. Partia	Lake					Project failed
Sober & Becker So. Br.	Lake	1931	9220'	1985		
Woodridge Estates	Lake					No card
Johns	Baroda	1899	14,834'	1995		
Nixon & Landon	Baroda	1917	2508'	1974		
Schutze & Br.	Baroda	1919	2285'	1993		
Sober & Becker	Baroda	1906	31,120'	1993		
Chaimberland & Ext.	Three Oaks	1887	29,097'	1993		
Chestnut	Three Oaks	1977	3040'	1977		
Close	Three Oaks	1891	34,400'	1996	Next couple of years	
Close Partial A & B	Three Oaks					1936 deemed unnecessary
Deer Creek Br.	Three Oaks	1934	1238'	1995		
Deer Creek Br. Partial	Three Oaks	1980	2224'	1995		
Forest Lawn	Three Oaks	1992	1030'			Maintained by Forest Lawn Land Fill
Gale Wilson	Three Oaks	1954	Not listed	1982		
Galien River	Three Oaks	1890	Not listed	1951		
Gifford	Three Oaks	1906	10482'	1993		
Gifford Ext.	Three Oaks	1953	15321' total	1993		
Hellenga	Three Oaks	1914	15032'	1993		
Payne & Donner	Three Oaks	1928	5331'	1993		
Schwark	Three Oaks	1972	2816'	1993		No card
Wild Rose	Three Oaks	1908	21,667'	1995	Next couple of years	
Baker Town	Buchanan	1894	19,014'	1995		
Blue Jay	Buchanan	1902	21,180'	1990	Next couple of years	
Cassler	Buchanan	1908	4633'	1990		

DRAIN NAME	TOWNSHIP	DATE OF ESTABLISHMENT	LENGTH	DATE OF MOST RECENT IMPROVEMENT	DATE OF FUTURE IMPROVEMENTS	ADDITIONAL COMMENTS
Chippewa - Walnut	Buchanan					No card
Clear Lake	Buchanan	1997	Not listed	1997		not in watershed
Close	Buchanan	1891	34,400'	1996	Next couple of years	
Coveney Lake	Buchanan	1918	4300'	1993		
Cresent View	Buchanan					Not in watershed
Cresent View South	Buchanan					Not in watershed
Fuller & Nutt	Buchanan					Outside watershed
Galien River	Buchanan	1890	Not listed	1951		
Galien River South Br. Ext.	Buchanan	1930	Not listed	1934		
Galien River South Br.	Buchanan	1908	19,148'	1991	Next couple of years	
Gray's Run South Br.	Buchanan					Outside watershed
Haskins #15	Buchanan	1899	3620'	1941		
Hickory Creek Ext. Outlet	Buchanan	1903	Not listed	1961		
Hickory Creek	Buchanan	1894	43,246'	1997		
Hickory Creek Partial	Buchanan	1985	Not listed	-		
Hickory Creek 1994	Buchanan	1994	Not listed			
Judy Lake	Buchanan	1898	26,015'	2000		
Lake & Creek	Buchanan					Outside watershed
Lutz	Buchanan	1947	2330'	1947		
Madron Lake #4 or North Bra	Buchanan	1898	6204'	1990		
Madron Lake South	Buchanan	1904	10,183	1997		
Madron Lake #2 Full District	Buchanan	1934	4633'	1995		
Mutchler & Sabin	Buchanan	1898	1848'	1898		
Powers & Miller	Buchanan	1961	6000'	1993		
Snedker	Buchanan	1921	2384'	1956		
Spaulding	Buchanan	1909	6389'	1990		
Spaulding Partial	Buchanan	1971	Not listed	1990		
Wagner Lake	Buchanan	1899	15,378'	1899		
Weaver & Harroff	Buchanan	1913	22,675'	1995		
Weaver & Harroff - Partial	Buchanan	1976	Not listed	1995		
Wilson & Marble	Buchanan	1938	13,854'	1993		
Blakeslee & Glover	Galien					Not cty drain 3/4/88
Chamberlain & Ext.	Galien	1887	29,097' total	1993		
Clark & Swark	Galien	1918	5000'	1996		
Close	Galien	1891	34,400'	1996	Next couple of years	
Close Part A	Galien					Deemed not necessary
Close Part B	Galien					Deemed not necessary
Critchet, Allen & Huston	Galien	1903	Not listed	1996		
Cuthbert & Imhoff	Galien	1909	8786'	1993		
Dayton Lake	Galien	prior to 1958	Not listed			
Denison & Roundy	Galien					Not cty drain 11/15/88

DRAIN NAME	TOWNSHIP	DATE OF ESTABLISHMENT	LENGTH	DATE OF MOST RECENT IMPROVEMENT	DATE OF FUTURE IMPROVEMENTS	ADDITIONAL COMMENTS
Dowling Creek	Galien	1950	2970'	1994		
Galien River	Galien	1890	Not listed	1951		
Galien River South Br.	Galien	1908	19,148'	1991	Next couple of years	
Galien River South Br. Ext.	Galien	1930	not listed	1934		
Galien Village	Galien	1918	3960	1993		
Geminder & Ext.	Galien	1909	6490	1997		
Geminder Ext. & Partial	Galien	1939	1510'	1992		
Hall & Potter	Galien	1899	5443'	1996		
Horine, Thompson & Jerue	Galien					Not cty drain 3/4/88
James & Grooms	Galien	1925	12,919	1993		
J S Ingles	Galien					Not cty drain 11/3/88
Jerue & Goodenough	Galien	1914	3883	1997		
Lintner, Allen & Renbarger	Galien	1909	6926'	1997		
Luther & Doehrer	Galien	1921	2690'	1995		
Moore, Klassner & Hess	Galien	1929	2380'	1994		
Moore, Klassner & Hess East	Galien	1919	Not listed	1994		
Moore, Klassner & Hess Old	Galien	1967	Not listed	1997		
Partridge & Heimert	Galien	1913	2950'	1993		
Storm & Cowell	Galien	1903	4255'	1993		
Storms	Galien	1918	2860'	1994		
Toland, Bryant & Davidson	Galien	1933	3828	1996		
Wild Rose	Galien	1908	21,667'	1995	Next couple of years	
Wilson & Marble	Galien	1938	13,854'	1993		
Wolf, Artus & Heimert	Galien	1906	1882'	1994		
Zaring & Russ	Galien	1908	15,040'	1993		
Zaring & Russ Ext.	Galien	1994	Not listed	1994		
Mud Hollow	Bertrand	1898	2772'	1994		
Close	Bertrand				Next couple of years	
Galien South Branch	Bertrand				Next couple of years	
Blood Run	New Buffalo	1883	11,823'	1997		
Lake Shore	New Buffalo	1885	5724'	1996		
Squaw Creek	New Buffalo	1883	4950'	1993		
Squaw Creek Holiday Dr. Ext.	New Buffalo					No card
State Line	New Buffalo					Not a county drain
Timber Lane	New Buffalo	1995	Not listed	1995		
Union Pier	New Buffalo	1909	6871'	1995	Next couple of years	

Location #1: Galien River at Red Arrow Highway
Worksheet for Irregular Channel

Project Description	
Worksheet	Galien River near Red Arrow
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Slope	001200	ft/ft
Discharg	,200.00	cfs

Options	
Current Roughness Meth	oved Lotter's Method
Open Channel Weighting	oved Lotter's Method
Closed Channel Weightin	Horton's Method

Results		
Mannings Coefficie	0.069	
Water Surface Elev	582.03	ft
Elevation Range	2.10 to 600.00	
Flow Area	2,380.1	ft²
Wetted Perimeter	1,742.09	ft
Top Width	1,738.56	ft
Actual Depth	9.93	ft
Critical Elevation	577.52	ft
Critical Slope	0.048029	ft/ft
Velocity	0.92	ft/s
Velocity Head	0.01	ft
Specific Energy	582.04	ft
Froude Number	0.14	
Flow Type	Subcritical	

Calculation Messages:
Flow is divided.

Roughness Segments

Start Station	End Station	Mannings Coefficient
1+00	2+60	0.100
2+60	3+50	0.035
3+50	4+00	0.100
4+00	23+08	0.070
23+08	23+89	0.100
23+89	24+35	0.050

Natural Channel Points

Station (ft)	Elevation (ft)
1+00	599.30
1+95	591.90
2+45	593.80
2+60	579.80
2+70	577.40

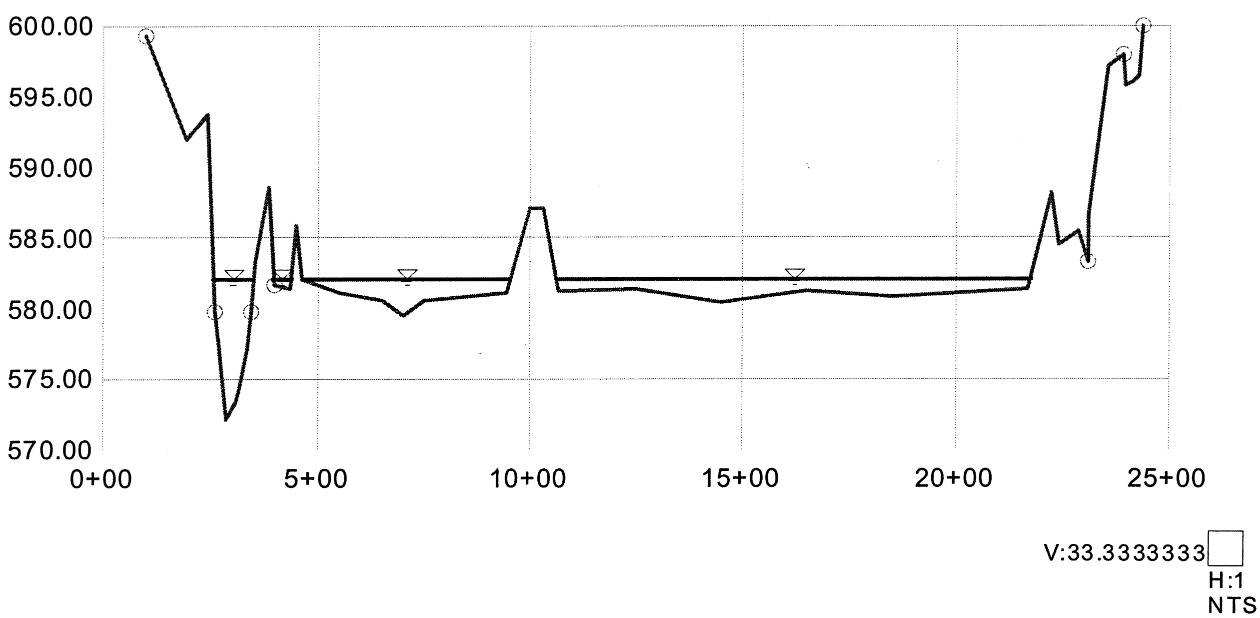
Location #1: Galien River at Red Arrow Highway
Worksheet for Irregular Channel

Natural Channel Points	
Station (ft)	Elevation (ft)
2+90	572.10
3+10	573.40
3+20	574.50
3+40	577.10
3+50	579.80
3+56	583.30
3+88	588.60
4+00	581.70
4+40	581.30
4+50	585.80
4+65	582.00
5+50	581.10
6+50	580.50
7+00	579.50
7+50	580.60
9+45	581.10
10+00	587.10
10+30	587.10
10+70	581.20
10+85	581.20
12+50	581.30
14+50	580.40
16+50	581.20
18+50	580.80
21+70	581.30
22+25	588.10
22+40	584.50
22+87	585.40
23+08	583.30
23+10	586.50
23+55	597.10
23+89	597.90
23+97	595.80
24+12	596.00
24+29	596.40
24+35	600.00

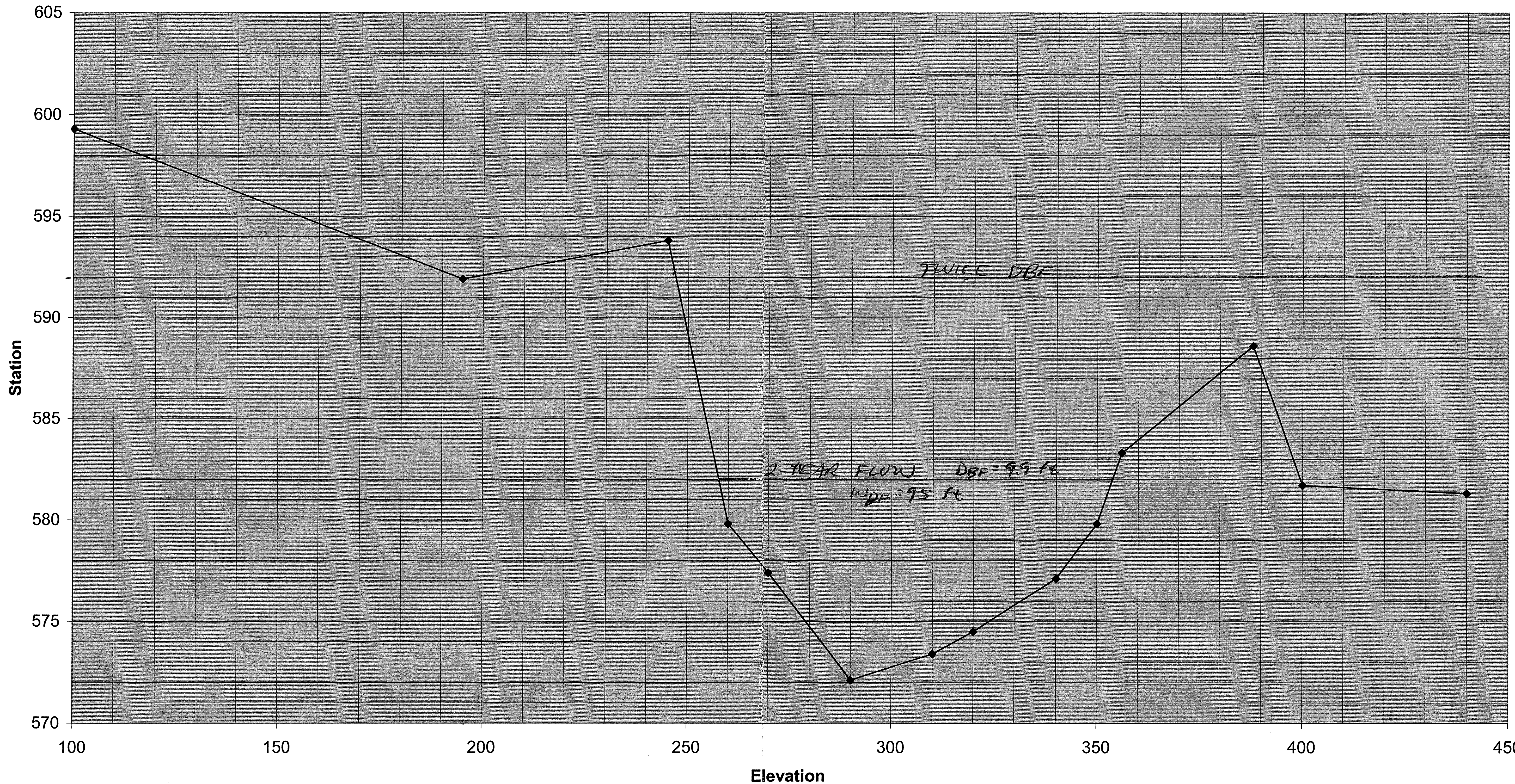
Cross Section
Cross Section for Irregular Channel

Project Description	
Worksheet	Galien River near Red Arrow Highway
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

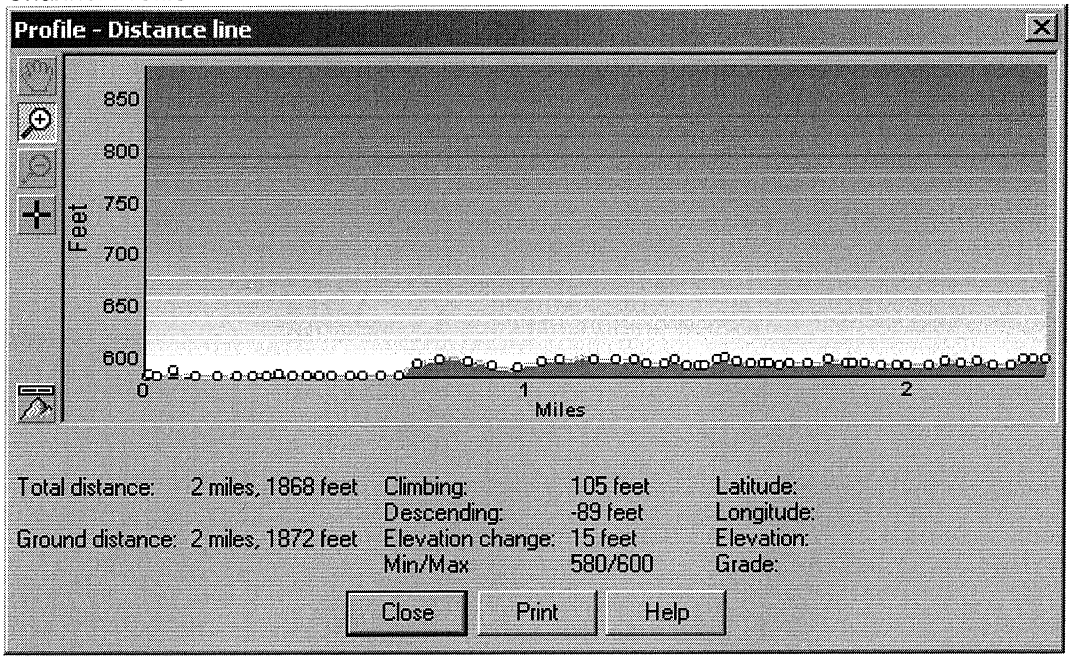
Section Data		
Mannings Coefficient	0.069	
Slope	0.001200	ft/ft
Water Surface Elevation	582.03	ft
Elevation Range	572.10 to 600.00	
Discharge	2,200.00	cfs



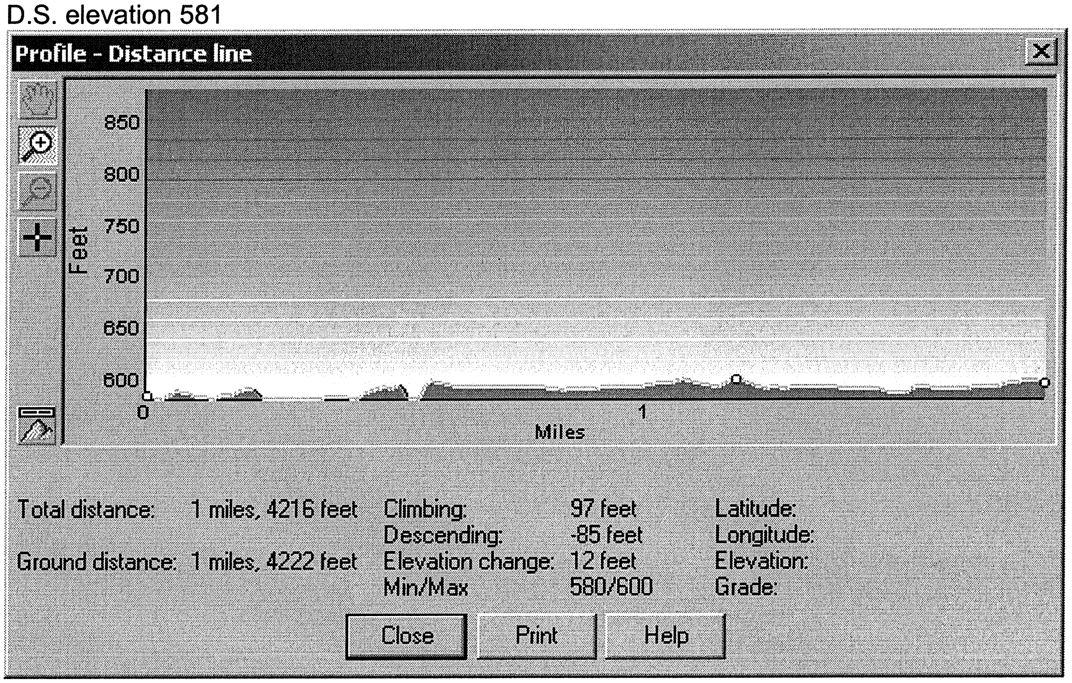
Galien River Cross Section D



New Buffalo
Between Lake Michigan Channel and Red Arrow Highway
Channel Profile



Valley Profile
U.S. elevation 596
D.S. elevation 581



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SUBJECT BCDC/GALIEN RIVER 319
PROJECT NO. G01338
SHEET NO. ____ OF ____
COMP. BY ____ DATE ____
CHKD. BY ____ DATE ____

(1/4")

LEVEL II RIVER MORPHOLOGICAL DESCRIPTION

LOCATION #1: GALIEN RIVER BETWEEN LAKE MICHIGAN CHANNEL AND RED ARROW HIGHWAY

① ENTRENCHMENT RATIO

2 YEAR FLOOD ELEVATION	582.03 ft
CHANNEL BOTTOM	572.10 ft
DEPTH	9.93 ft Dbf
WIDTH	95 ft
TWICE Dbf	19.86
ELEVATION at 2·DBF	592. ft
WIDTH @ 2·DBF	2100 ft

ENTRENCHMENT $= \frac{2100}{95} = 22 > 2.2$

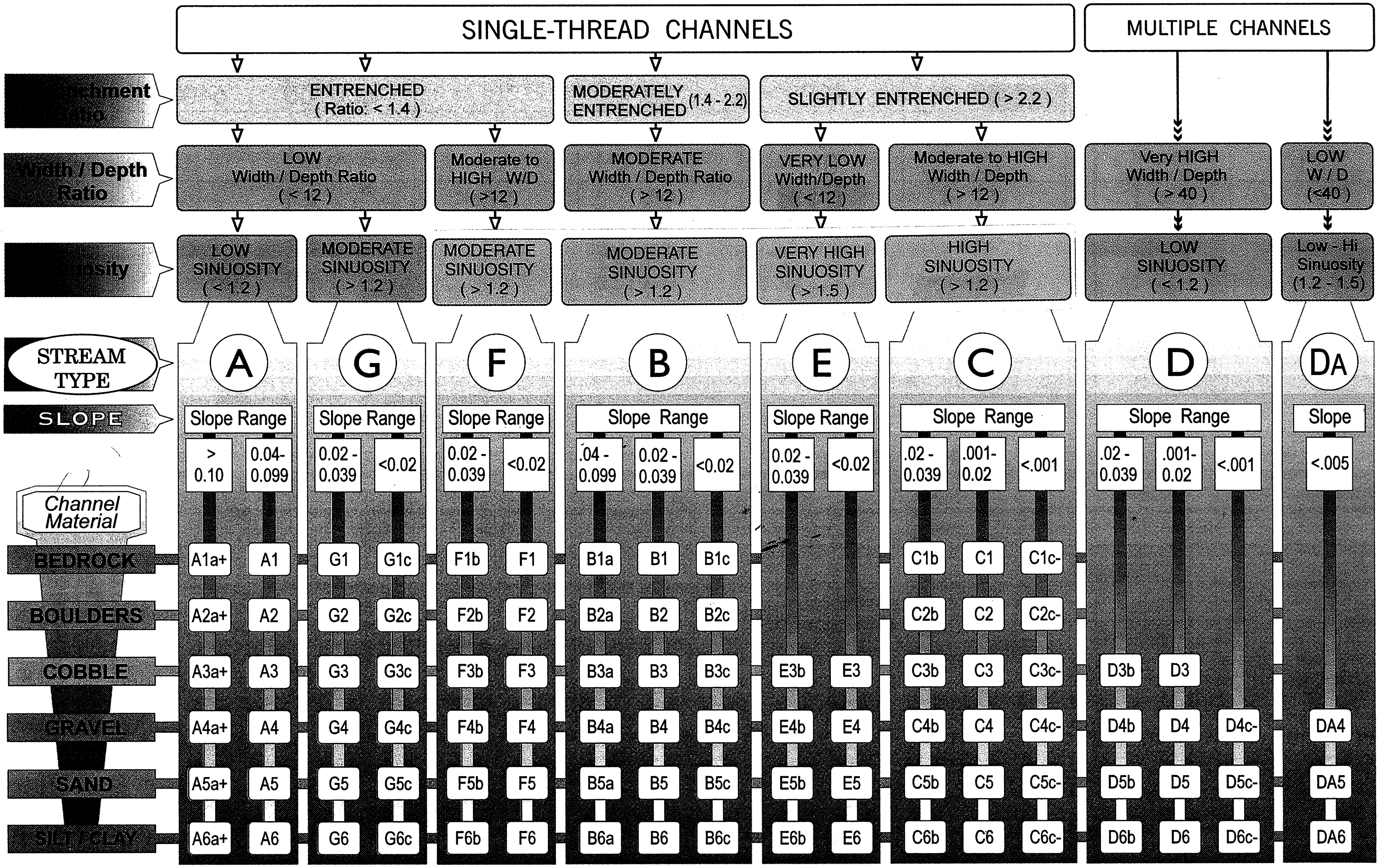
② WIDTH/DEPTH $= 95/9.93 = 9.6 < 12$

③ SINUOSITY $= \frac{2(5280) + 1872}{(5280) + 4222} = 1.30 > 1.2$

④ SLOPE $= \frac{596-585}{2(5280) + 1872} = .0012 < .02$

⑤ CHANNEL MATERIAL: AQUENTS & HISTOSOLS

E6

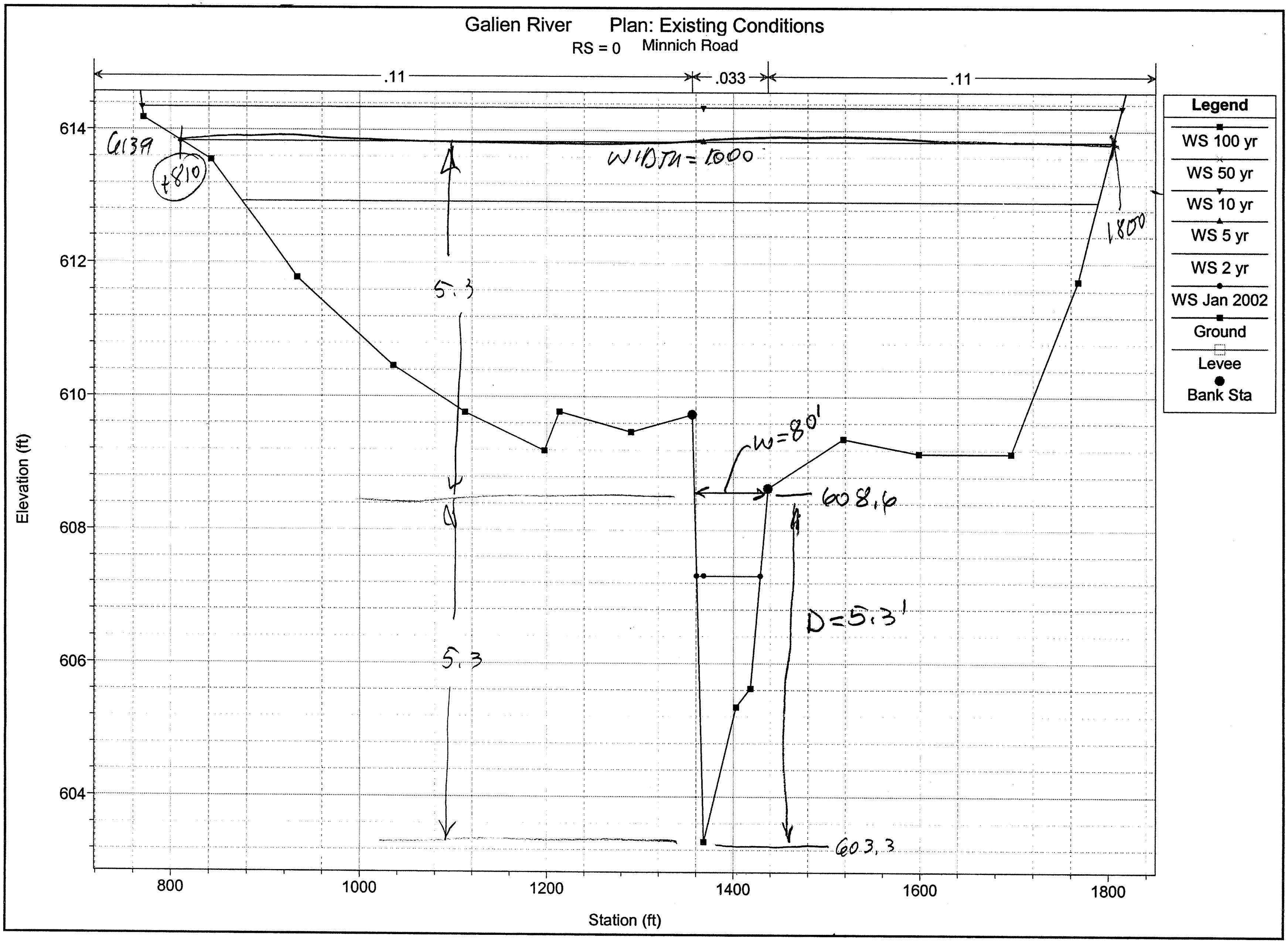


KEY to the *ROSGEN* CLASSIFICATION of NATURAL RIVERS. As a function of the "*continuum of physical variables*" within stream reaches, values of ***Entrenchment*** and ***Sinuosity*** ratios can vary by +/- 0.2 units; while values for ***Width / Depth*** ratios can vary by +/- 2.0 units.

FIGURE 5-3. Classification key for natural rivers.

Revised: 07/07/2003

Location # 2: Galien River at Minnich Road



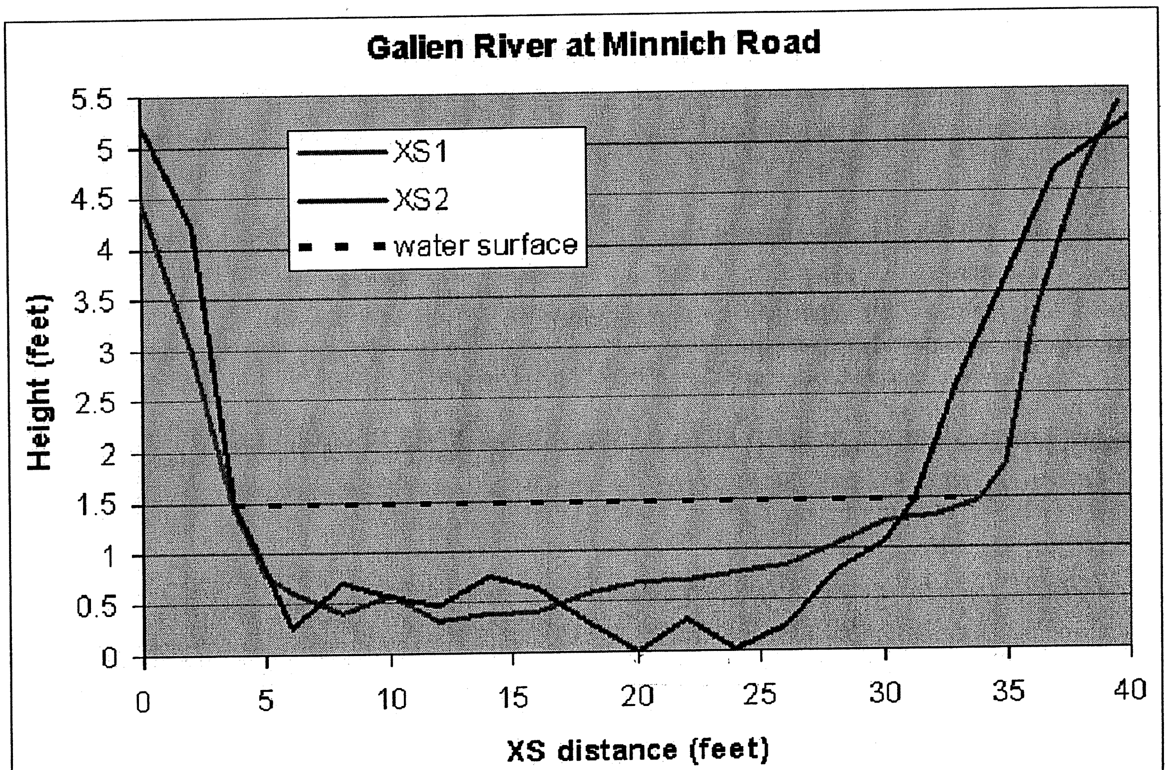
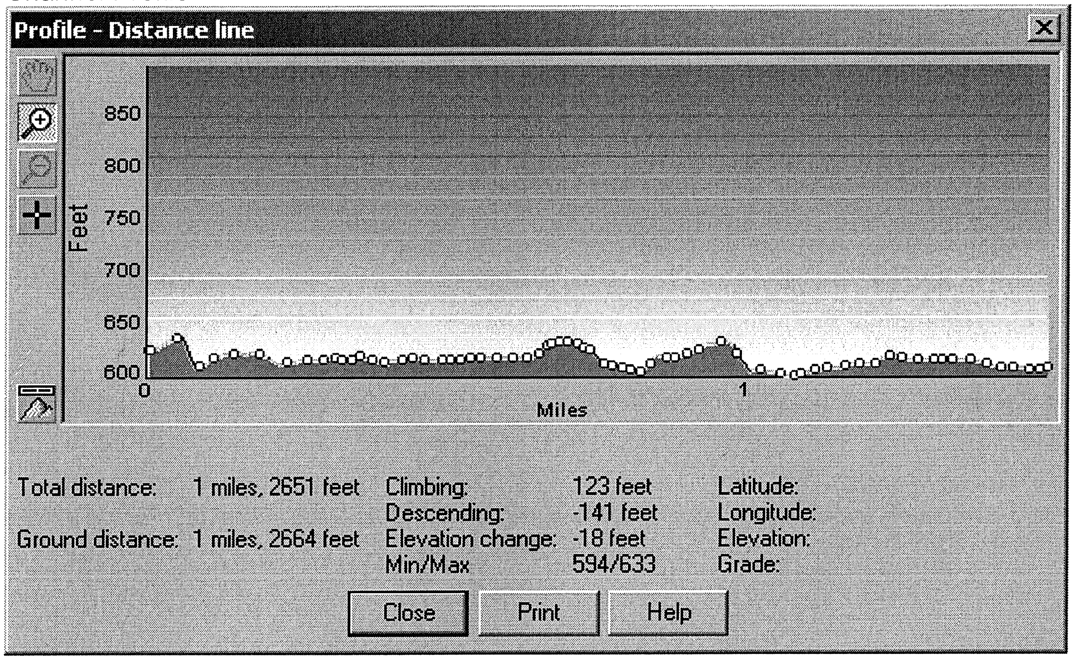


Figure 1: Surveyed cross-sections

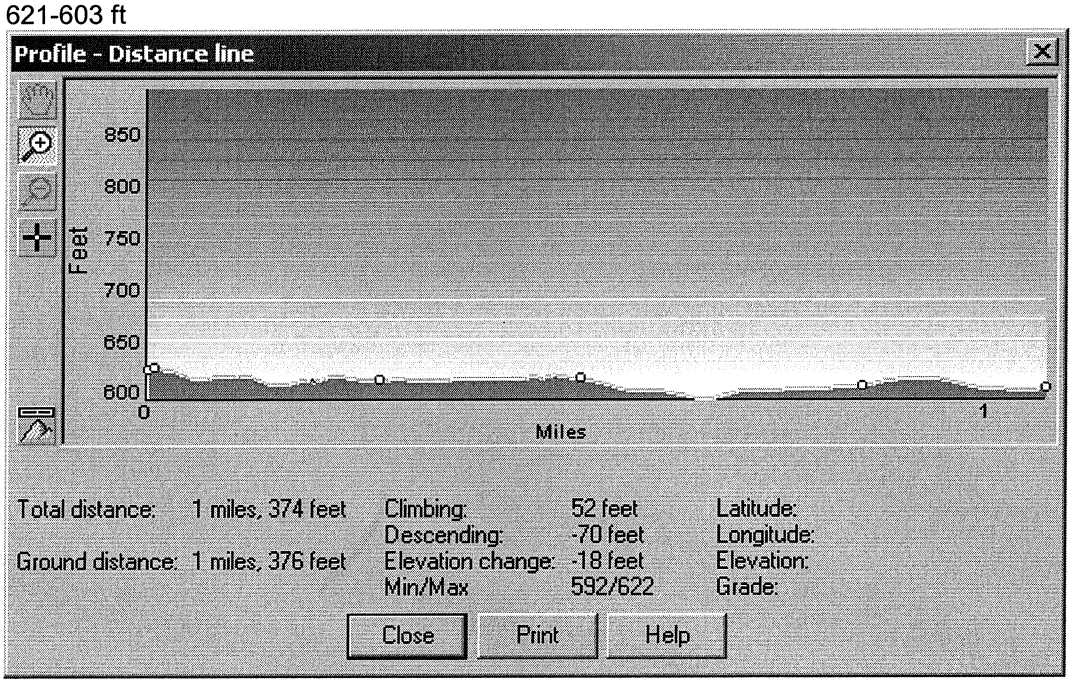
Plan: Existing galien 1 RS: 0 Profile: 2 yr

E.G. Elev (ft)	612.95	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.02	Wt. n-Val.	0.110	0.033	0.110
W.S. Elev (ft)	612.93	Reach Len. (ft)			
Crit W.S. (ft)	607.49	Flow Area (sq ft)	1255.42	600.11	1170.81
E.G. Slope (ft/ft)	0.000079	Area (sq ft)	1255.42	600.11	1170.81
Q Total (cfs)	1500.00	Flow (cfs)	286.12	899.81	314.07
Top Width (ft)	914.26	Top Width (ft)	481.52	81.13	351.61
Vel Total (ft/s)	0.50	Avg. Vel. (ft/s)	0.23	1.50	0.27
Max Chl Dpth (ft)	9.61	Hydr. Depth (ft)	2.61	7.40	3.33
Conv. Total (cfs)	168408.9	Conv. (cfs)	32123.1	101024.1	35261.6
Length Wtd. (ft)		Wetted Per. (ft)	481.56	83.02	351.69
Min Ch El (ft)	603.32	Shear (lb/sq ft)	0.01	0.04	0.02
Alpha	5.59	Stream Power (lb/ft s)	0.00	0.05	0.00
Frctn Loss (ft)		Cum Volume (acre-ft)			
C & E Loss (ft)		Cum SA (acres)			

Minich Road to Avery Road
Channel Profile



Valley Profile
621-603 ft



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SUBJECT BCDC/GALIEN RIVER 319

PROJECT NO. G01338
SHEET NO. 1 OF
COMP. BY ______ DATE ______
CHKD. BY ______ DATE ______

(1/4")

LEVEL II RIVER MORPHALOGICAL DESCRIPTION

LOCATION #2: GALIEN RIVER ~~BETWEEN~~ AT MINNICH ~~AND~~ ROAD ~~AVERY RD~~ ~~CARPENTER~~

① ENTRENCHMENT RATIO

USING MINNICH RD X-SECTION

2-YR FLOW DEPTH at MINNICH RD BY HEC-RAS MODELING		612.93	
CHANNEL BOTTOM ELEVATION		603.32	
BANKFULL DEPTH	5.3 5	9.61	Dbf
BANKFULL WIDTH	80 40	914. ft	Wbf
TWICE Dbf	10.6	19.22	
WIDTH at 2 Dbf	~~2000~~ ~~1000~~ 1000	1200 ft	

ENTRENCHMENT = $\frac{1200}{914}$ = 1.3 $\frac{1000}{40}$ = 25 $\frac{1000}{80}$ = 12.5

(TYPE A, G, OR F) E, C

② WIDTH / DEPTH = 914/9.61 C = 95 $\frac{80}{5.3}$ = 15 40/5 = 8

(TYPE F) C or (E)

3. SINUOSITY = $\frac{5280 + 2664}{5280 + 376?}$ = 1.4

(TYPE F) E6

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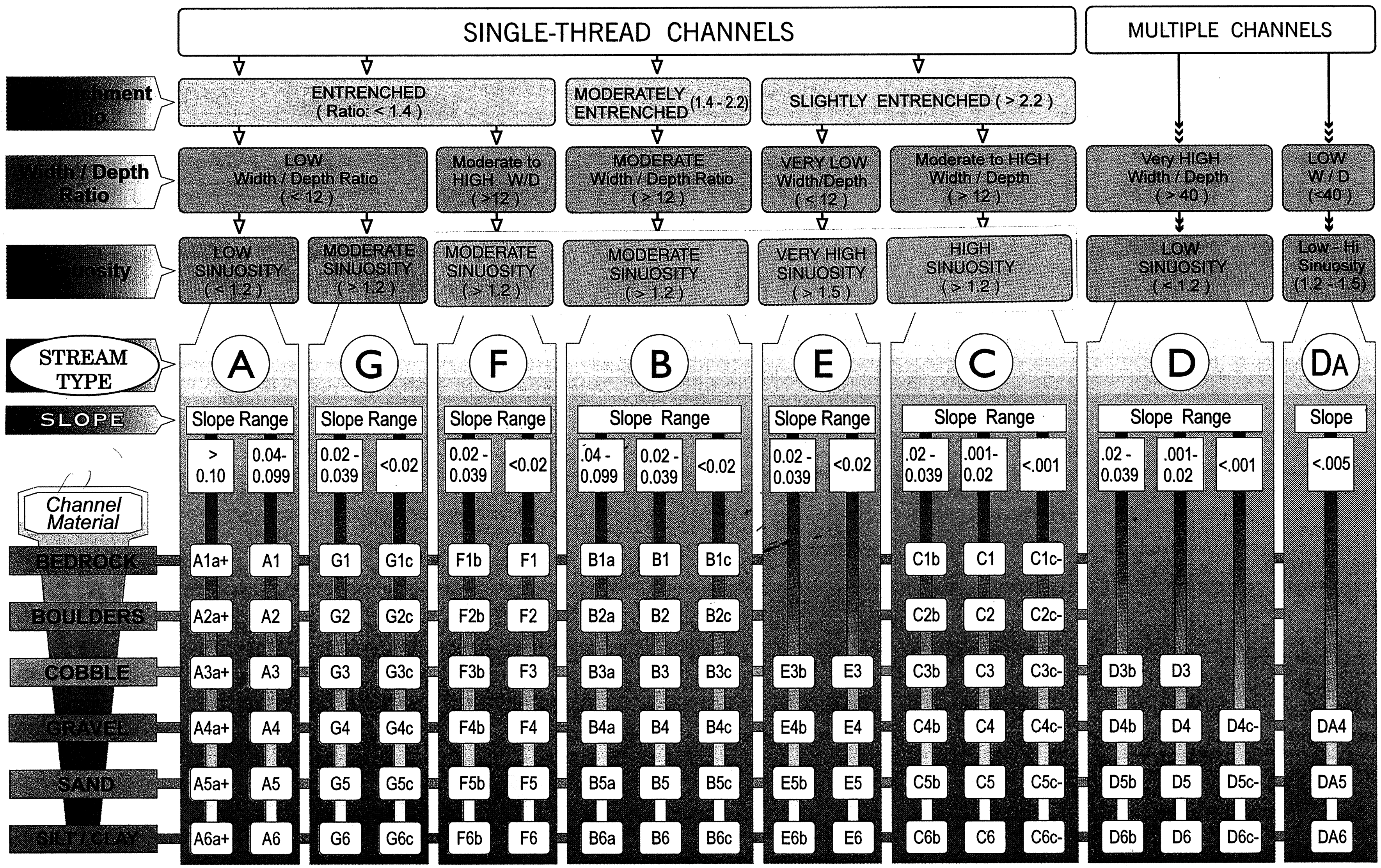
(4) SLOPE = $\frac{621-603}{5280+2664}$ = ,0023 <.02

(5) CHANNEL MATERIAL

29 - Cohoctah Sandy Loam

CLASSIFICATION (F5)



KEY to the *ROSGEN* CLASSIFICATION of NATURAL RIVERS. As a function of the "*continuum of physical variables*" within stream reaches, values of ***Entrenchment*** and ***Sinuosity*** ratios can vary by +/- 0.2 units; while values for ***Width / Depth*** ratios can vary by +/- 2.0 units.

FIGURE 5-3. Classification key for natural rivers.

Location #3: Blue Jay Drain
Worksheet for Irregular Channel

Project Description	
Worksheet	Blue Jay Drain
Flow Element	Irregular Chan
Method	Manning's Forr
Solve For	Channel Depth

Input Data		
Slope	000900	ft/ft
Discharg	70.00	cfs

Options	
Current Roughness Methc	oved Lotter's Method
Open Channel Weighting	oved Lotter's Method
Closed Channel Weightin	Horton's Method

Results		
Mannings Coefficie	0.043	
Water Surface Elev	-2.66	ft
Elevation Range	6.00 to -1.00	
Flow Area	42.3	ft²
Wetted Perimeter	20.97	ft
Top Width	19.35	ft
Actual Depth	3.34	ft
Critical Elevation	-4.62	ft
Critical Slope	0.028572	ft/ft
Velocity	1.66	ft/s
Velocity Head	0.04	ft
Specific Energy	-2.62	ft
Froude Number	0.20	
Flow Type	Subcritical	

Roughness Segments

Start Station	End Station	Mannings Coefficient
0+00	0+50	0.033
0+50	0+62	0.050
0+62	0+68	0.033
0+68	0+76	0.050
0+76	1+20	0.035

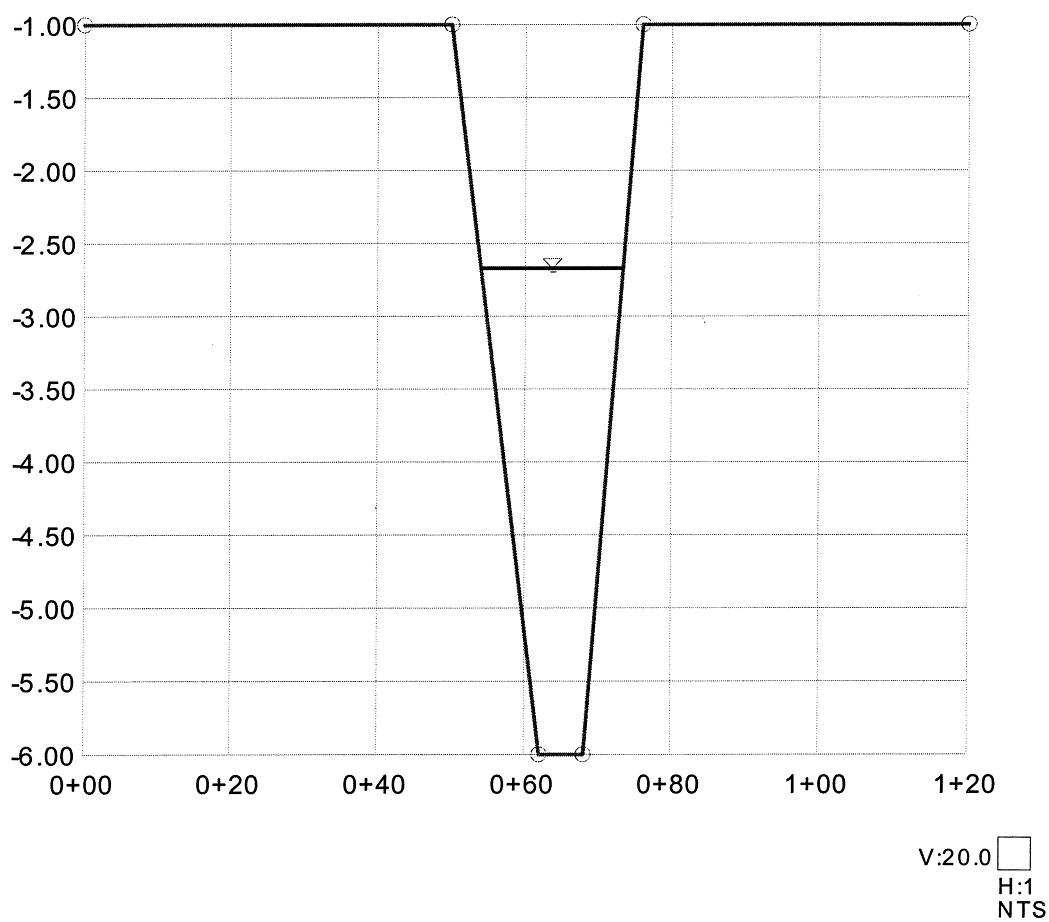
Natural Channel Points

Station (ft)	Elevation (ft)
0+00	-1.00
0+50	-1.00
0+62	-6.00
0+68	-6.00
0+76	-1.00
1+20	-1.00

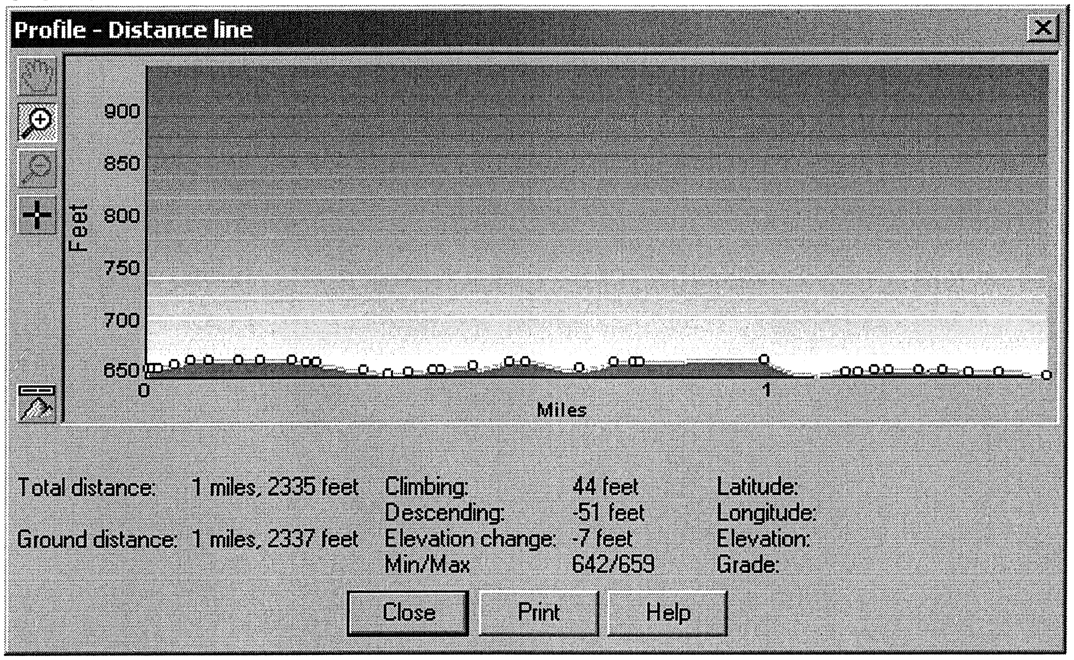
Cross Section
Cross Section for Irregular Channel

Project Description	
Worksheet	Blue Jay Drain
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

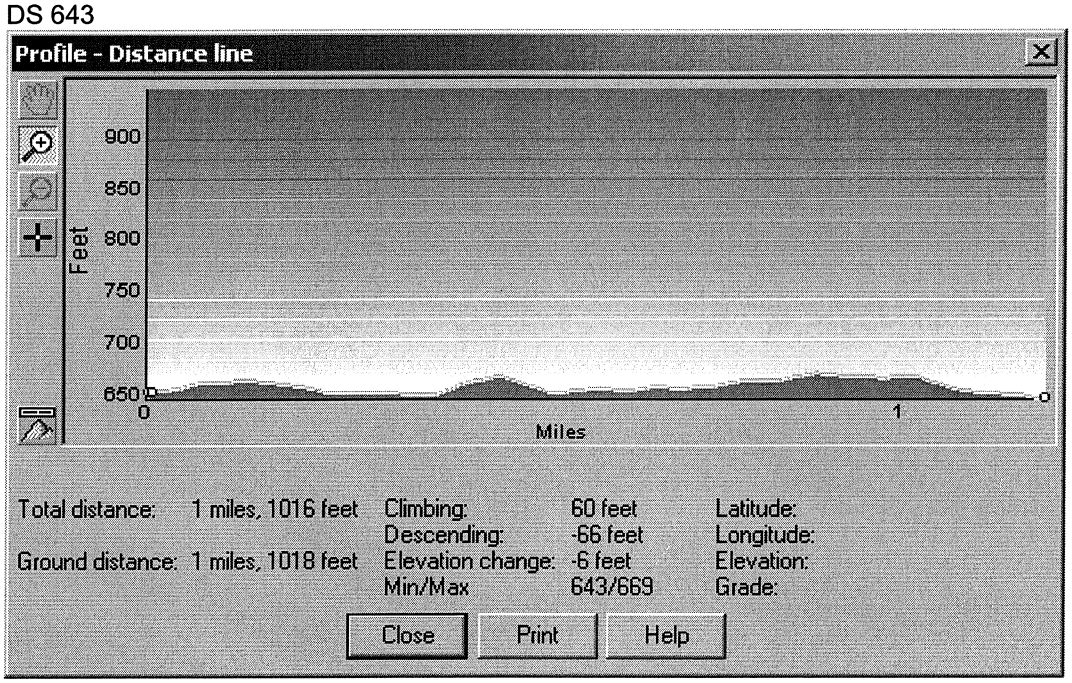
Section Data		
Mannings Coefficient	0.043	
Slope	0.000900	ft/ft
Water Surface Elevation	-2.66	ft
Elevation Range	-6.00 to -1.00	
Discharge	70.00	cfs



Blue Jay Drain from Holden Rd to Pardee Rd
Channel



Valley
US 650
DS 643



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SUBJECT BCDC/GALIEN RIVER 319

PROJECT NO. G01338
SHEET NO. ____ OF ____
COMP. BY ____ DATE ____
CHKD. BY ____ DATE ____

(1/4")

LEVEL II RIVER MORPHOLOGICAL DESCRIPTION

LOCATION #3: BLUE JAY CREEK BETWEEN HOLDEN AND PARDEE ROADS

① ENTRENCHMENT RATIO

2 YR FLOW DEPTH	3.34 ft	Dbf
2 YR FLOW WIDTH	19.35 ft	Wbf
TWICE Dbf	6.68 ft	
WIDTH @ 2 X Dbf	?. 120 MIN	*

ENTRENCHMENT RATIO $\frac{120}{20}$ = 6 > 2.2

TYPE E OR C

② WIDTH/DEPTH = 19.35/3.34 = 5.8 < 12

Type E

③ SINUOSITY = $\frac{5280 + 2337}{5280 + 1018}$ = 1.2

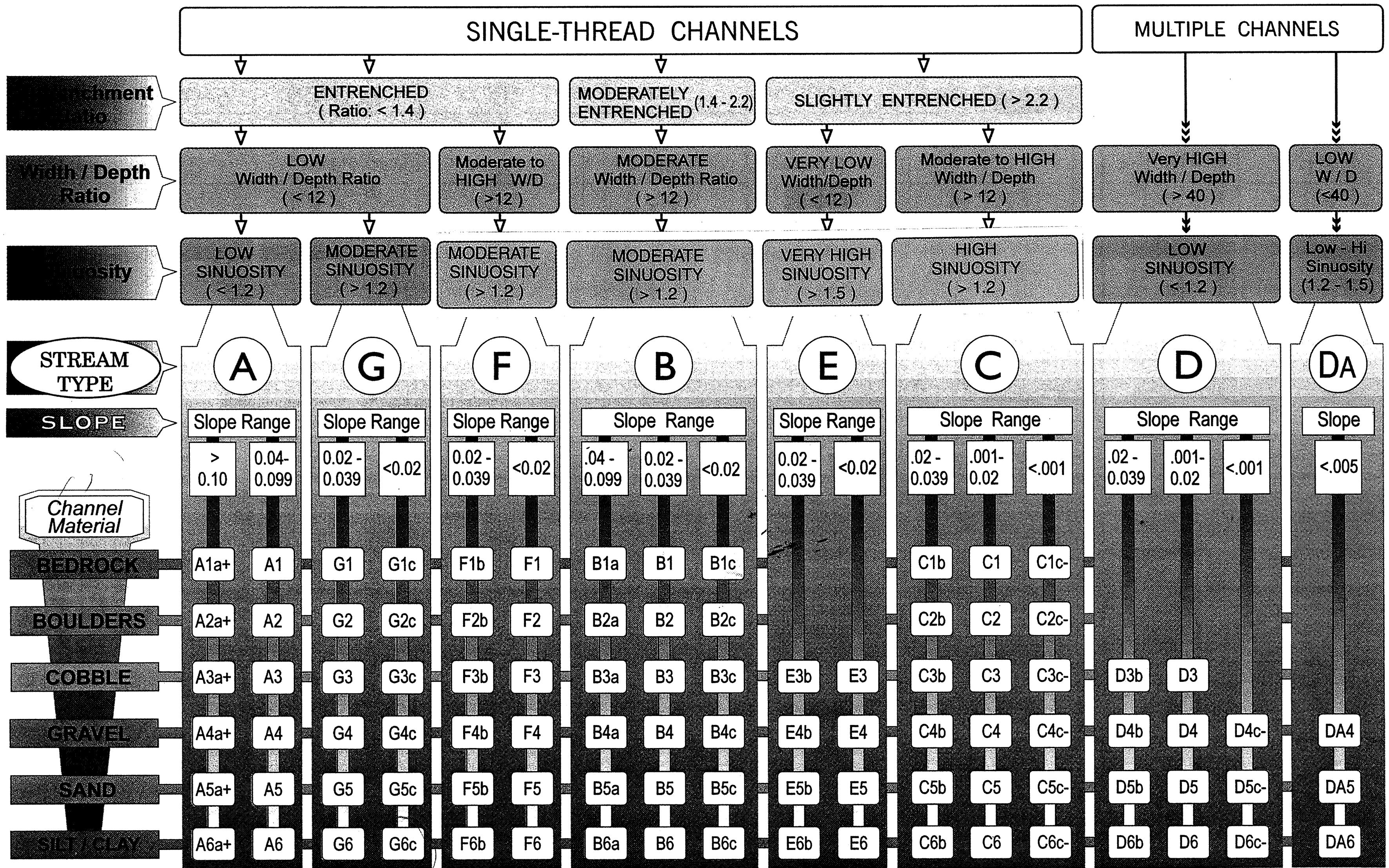
④ SLOPE = $\frac{650 - 643}{5280 + 2337}$ = .0009 < .02

⑤ CHANNEL MATERIAL

67A: SHOALS SILT LOAM

E6

BLUE JAY CREEK



KEY to the ROSGEN CLASSIFICATION of NATURAL RIVERS. As a function of the "*continuum of physical variables*" within stream reaches, values of ***Entrenchment*** and ***Sinuosity*** ratios can vary by +/- 0.2 units; while values for ***Width / Depth*** ratios can vary by +/- 2.0 units.

FIGURE 5-3. Classification key for natural rivers.

Location #4: Dowling Creek East of Hampton Road
Worksheet for Irregular Channel

Project Description	
Worksheet	Dowling Creek at Hampt
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Slope	001900	ft/ft
Discharg	70.00	cfs

Options	
Current Roughness Methc	›ved Lotter's Method
Open Channel Weighting	›ved Lotter's Method
Closed Channel Weightin	Horton's Method

Results		
Mannings Coefficie	0.035	
Water Surface Elev	-4.82	ft
Elevation Range	3.50 to -2.00	
Flow Area	32.1	ft²
Wetted Perimeter	24.77	ft
Top Width	24.23	ft
Actual Depth	1.68	ft
Critical Elevation	-5.64	ft
Critical Slope	0.020444	ft/ft
Velocity	2.18	ft/s
Velocity Head	0.07	ft
Specific Energy	-4.75	ft
Froude Number	0.33	
Flow Type	Subcritical	

Roughness Segments

Start Station	End Station	Mannings Coefficient
0+00	0+50	0.035
0+50	0+58	0.100
0+58	0+72	0.033
0+72	0+85	0.100
0+85	1+30	0.035

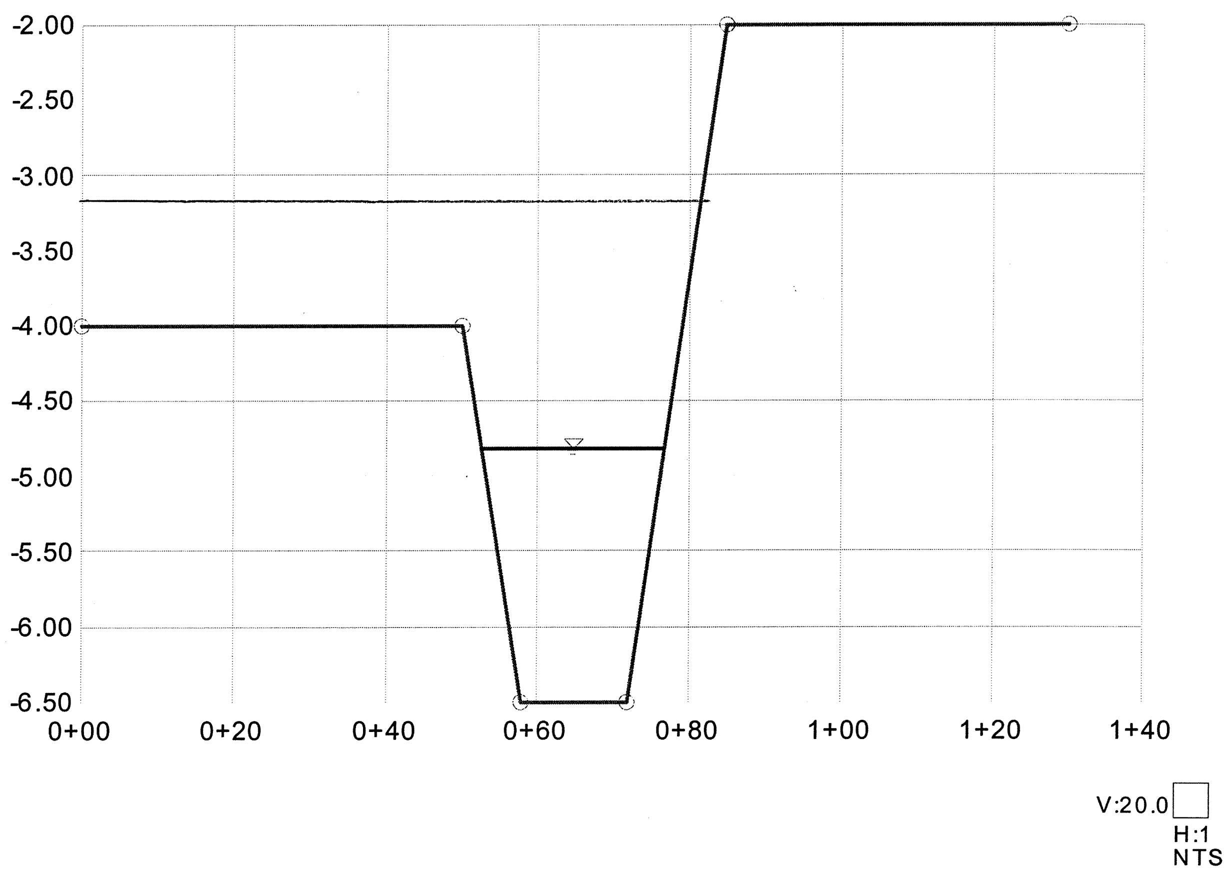
Natural Channel Points

Station (ft)	Elevation (ft)
0+00	-4.00
0+50	-4.00
0+58	-6.50
0+72	-6.50
0+85	-2.00
1+30	-2.00

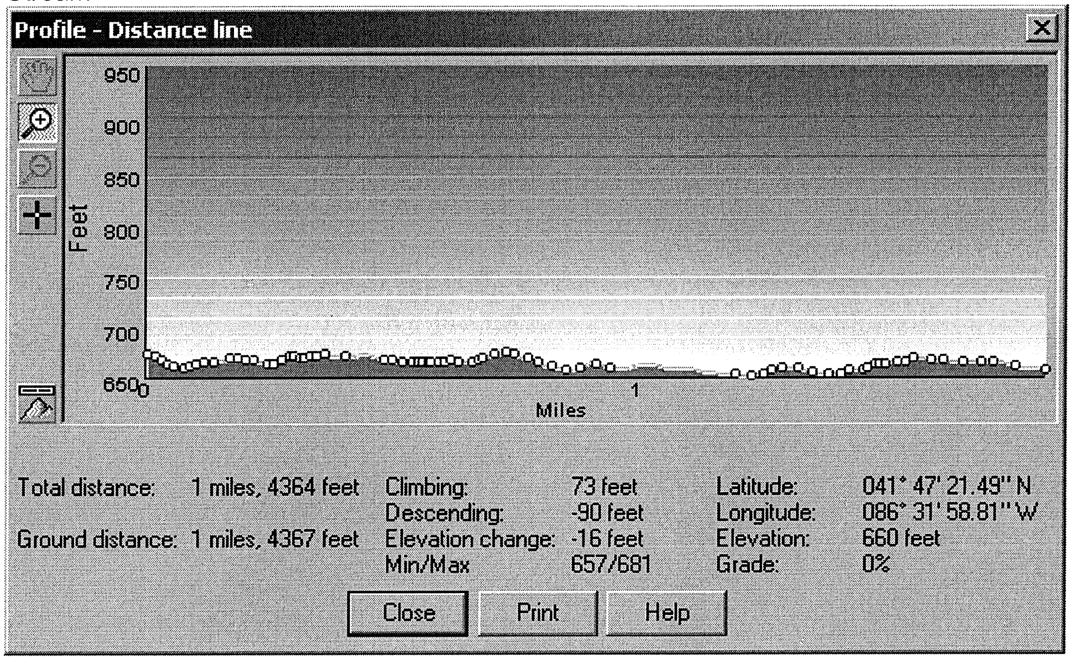
Cross Section
Cross Section for Irregular Channel

Project Description	
Worksheet	Dowling Creek at Hampton Roa
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

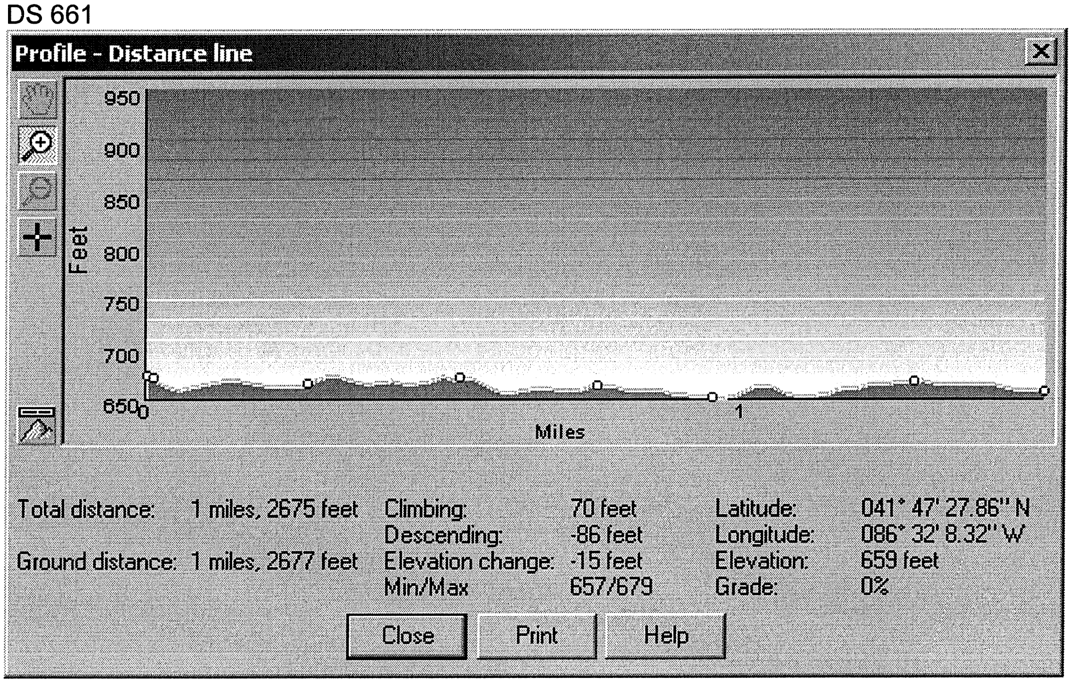
Section Data		
Mannings Coefficient	0.035	
Slope	0.001900	ft/ft
Water Surface Elevation	-4.82	ft
Elevation Range	-6.50 to -2.00	
Discharge	70.00	cfs



Dowling Creek
Nye Road to Hampton Road
Stream



Valley
US 679
DS 661



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SUBJECT BCDC/GALIEN RIVER 319

PROJECT NO. G01338
SHEET NO. ______ OF ______
COMP. BY ______ DATE ______
CHKD. BY ______ DATE ______

(1/4")

LEVEL II RIVER MORPHOLOGICAL DESCRIPTION

LOCATION #4: DOWLING CREEK EAST OF HAMPTON RD.

① ENTRENCHMENT RATIO

2 YR FLOW DEPTH BY FLOW MASTER	1.68 ft Dbf
2 YR FLOW WIDTH	24.2 ft Wbf
TWICE Dbf	3.36 ft
WIDTH @ 2 Dbf	80 ft MIN
ENT RATIO $\frac{80}{24}$ =	3.3

TYPE E OR C

② WIDTH/DEPTH = $\frac{24.2}{1.68}$ = 14

TYPE C

3. SINUOSITY = $\frac{5280 + 4367}{5280 + 2677}$ = 1.21

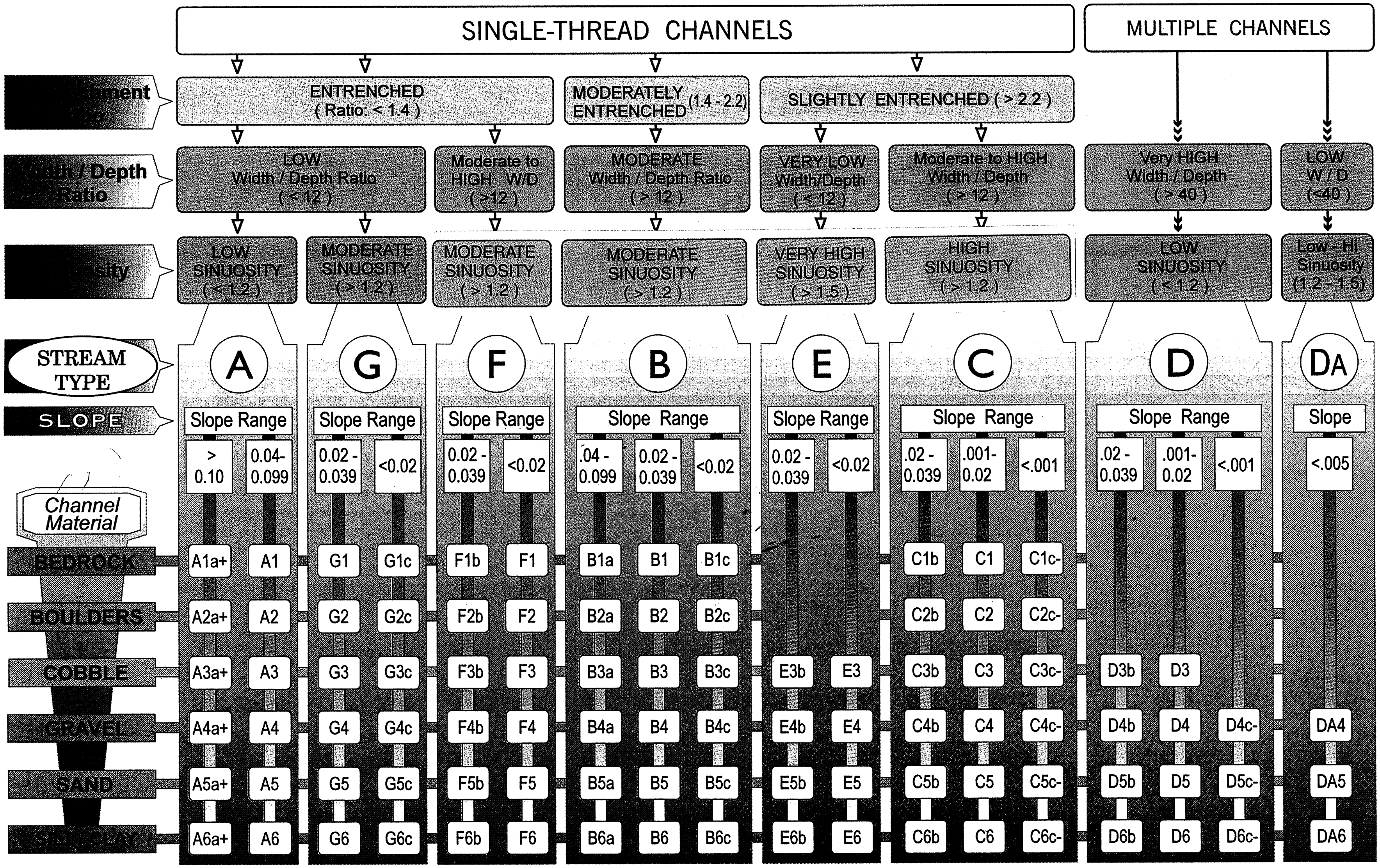
TYPE C

4. SLOPE $\frac{679 - 661}{5280 + 4367}$ = .0018
< .001

5. CHANNEL MATERIAL
61A WHITAKER LOAM (SANDY LOAM @ 60")

C5

DOWLING CREEK @ HAMPTON ROAD



KEY to the ROSGEN CLASSIFICATION of NATURAL RIVERS. As a function of the "*continuum of physical variables*" within stream reaches, values of ***Entrenchment*** and ***Sinuosity*** ratios can vary by +/- 0.2 units; while values for ***Width / Depth*** ratios can vary by +/- 2.0 units.

FIGURE 5-3. Classification key for natural rivers.

STATE OF MICHIGAN

JOHN ENGLER, Governor

DEPARTMENT OF ENVIRONMENTAL QUALITY

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INTERNET: www.deq.state.mi.us

RUSSELL J. HARDING, Director

REPLY TO:

LAND & WATER MANAGEMENT DIVISION
PO BOX 30458
LANSING MI 48909-7958

November 2, 2001

Mr. Michael Townley
Fishbeck, Thompson, Carr & Huber, Inc.
161 East Michigan Avenue, Suite 615
Kalamazoo, MI 49007

Dear Mr. Townley:

We have estimated the flood frequency discharges requested in your transmittal of October 11, 2001 (Process No. 20010593), as follows.

1. Galien River at Red Arrow Highway, Section 2, T8S, R21W, New Buffalo Township, Berrien County, has a total drainage area of 173 square miles and a contributing drainage area of 169 square miles. The 50%, 20%, 10%, 4%, 2%, 1%, 0.5%, and 0.2% chance peak flows are estimated to be 2200 cubic feet per second (cfs), 3200 cfs, 3900 cfs, 4800 cfs, 5600 cfs, 6000 cfs, 6500 cfs, and 6800 cfs, respectively. (Watershed Basin No. 34L St. Joseph (Lake)/Quad W16SW).

2. Galien River at I-94, Section 36, T7S, R21W, New Buffalo Township, Berrien County, has a total drainage area of 170 square miles and a contributing drainage area of 167 square miles. The 50%, 20%, 10%, 4%, 2%, 1%, 0.5%, and 0.2% chance peak flows are estimated to be 2100 cfs, 3100 cfs, 3800 cfs, 4700 cfs, 5500 cfs, 5900 cfs, 6400 cfs, and 6700 cfs, respectively. (Watershed Basin No. 34L St. Joseph (Lake)/Quad W16SW).

3. Galien River, 1200 feet downstream of Elm Valley Road, Section 32, T7S, R20W, Three Oaks Township, Berrien County, has a total drainage area of 93.6 square miles and a contributing drainage area of 90.1 square miles. The 50%, 20%, 10%, 4%, 2%, 1%, 0.5%, and 0.2% chance peak flows are estimated to be 1500 cfs, 2000 cfs, 2400 cfs, 2900 cfs, 3300 cfs, 3500 cfs, 3700 cfs, and 3900 cfs, respectively. (Watershed Basin No. 34L St. Joseph (Lake)/Quad W16SW).

4. Galien River, 1900 feet south of Warren Woods Road, 6700 feet west of Three Oaks Road, Section 28, T7S, R20W, Chikaming Township, Berrien County, has a total drainage area of 91.4 square miles and a contributing drainage area of 87.8 square miles. The 50%, 20%, 10%, 4%, 2%, 1%, 0.5%, and 0.2% chance peak flows are estimated to be 1500 cfs, 2100 cfs, 2500 cfs, 3000 cfs, 3400 cfs, 3700 cfs, 3900 cfs, and 4100 cfs, respectively. (Watershed Basin No. 34L St. Joseph (Lake)/Quad W16SW).

5. Galien River, 4100 feet upstream of Three Oaks Road, Section 23, T7S, R20W, Chikaming Township, Berrien County, has a total drainage area of 86.3 square miles and a contributing drainage area of 82.8 square miles. The 50%, 20%, 10%, 4%, 2%, 1%, 0.5%, and 0.2% chance peak flows are estimated to be 1500 cfs, 2100 cfs, 2600 cfs, 3200 cfs, 3700 cfs, 4100 cfs, 4300 cfs, and 4500 cfs, respectively. (Watershed Basin No. 34L St. Joseph (Lake)/Quad W16SE).

6. Galien River, 3080 feet upstream of Minnich Road, between tributaries from the south and the north, Section 7, T7S, R19W, Weesaw Township, Berrien County, has a total drainage area of 80.1 square miles and a contributing drainage area of 76.5 square miles. The 50%, 20%, 10%, 4%, 2%, 1%, 0.5%, and 0.2% chance peak flows are estimated to be 1500 cfs, 2200 cfs, 2700 cfs, 3400 cfs, 4100 cfs, 4500 cfs, 4900 cfs, and 5100 cfs, respectively. (Watershed Basin No. 34L St. Joseph (Lake)/Quad W16NE).

7. Galien River, 3000 feet upstream of Glendora Road, 820 feet west of Log Cabin Road, Section 17, T7S, R19W, Weesaw Township, Berrien County, has a total drainage area of 76.0 square miles and a contributing drainage area of 72.4 square miles. The 50%, 20%, 10%, 4%, 2%, 1%, 0.5%, and 0.2% chance peak flows are estimated to be 1500 cfs, 2200 cfs, 2700 cfs, 3600 cfs, 4400 cfs, 4800 cfs, 5200 cfs, and 5400 cfs, respectively. (Watershed Basin No. 34L St. Joseph (Lake)/Quad W16SE).

8. Galien River at Kaiser Road, Section 20, T7S, R19W, Weesaw Township, Berrien County, has a drainage area of 44.3 square miles. The 50%, 20%, 10%, 4%, 2%, 1%, 0.5%, and 0.2% chance peak flows are estimated to be 1100 cfs, 1600 cfs, 2000 cfs, 2600 cfs, 3100 cfs, 3400 cfs, 3700 cfs, and 3900 cfs, respectively. (Watershed Basin No. 34L St. Joseph (Lake)/Quad W16SE).

9. Galien River, 450 feet downstream of Warren Woods Road, dowstream of Blue Jay Creek, Section 20, T7S, R19W, Weesaw Township, Berrien County, has a drainage area of 41.6 square miles. The 50%, 20%, 10%, 4%, 2%, 1%, 0.5%, and 0.2% chance peak flows are estimated to be 850 cfs, 1400 cfs, 1800 cfs, 2400 cfs, 2900 cfs, 3200 cfs, 3500 cfs, and 3600 cfs, respectively. (Watershed Basin No. 34L St. Joseph (Lake)/Quad W16SE).

10. Galien River, 1900 feet downstream of Elm Valley Road, Section 29, T7S, R19W, Weesaw Township, Berrien County, has a drainage area of 31.6 square miles. The 50%, 20%, 10%, 4%, 2%, 1%, 0.5%, and 0.2% chance peak flows are estimated to be 700 cfs, 1100 cfs, 1400 cfs, 1900 cfs, 2300 cfs, 2500 cfs, 2700 cfs, and 2900 cfs, respectively. (Watershed Basin No. 34L St. Joseph (Lake)/Quad W16SE).

11. Galien River, 700 feet upstream of 2nd Street and downstream of the tributary from the south, Section 2, T8S, R19W, Galien Township, Berrien County, has a drainage area of 6.6 square miles. The 50%, 20%, 10%, 4%, 2%, 1%, 0.5%, and 0.2% chance peak flows are estimated to be 180 cfs, 280 cfs, 360 cfs, 470 cfs, 550 cfs, 650 cfs, 700 cfs, and 750 cfs, respectively. (Watershed Basin No. 34L St. Joseph (Lake)/Quad W17SW).

Please include a copy of this letter with your application for permit. These estimates should be confirmed by our office if an application is not submitted within one year. If you have any questions concerning the discharge estimates, please contact Mr. Arthur Armour, Hydrologic Studies Unit, at 517-335-3177, or by e-mail at: armoura@state.mi.us. Any questions concerning the hydraulics or the proper procedure for filing for a permit should be directed to Mr. Matthew Occhipinti, Land and Water Management Division, Kalamazoo District Office, at 616-567-3564.

Sincerely,

Richard C. Sorrell, P.E., Chief
Hydrologic Studies Unit
Land and Water Management Division
517-335-3176

RCS:AA:BW

cc: Mr. Matthew Occhipinti, DEQ

STATE OF MICHIGAN

JOHN ENGLER, Governor

DEPARTMENT OF ENVIRONMENTAL QUALITY

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CONSTITUTION HALL, 525 WEST ALLEGAN, PO BOX 30473, LANSING MI 48909-7973

INTERNET: www.deq.state.mi.us

RUSSELL J. HARDING, Director

REPLY TO:

LAND & WATER MANAGEMENT DIVISION
PO BOX 30458
LANSING MI 48909-7958

January 4, 2002

Mr. Michael Townley, P.E.
Fishbeck, Thompson, Carr & Huber, Inc.
161 E. Michigan Avenue
Suite 615
Kalamazoo, MI 49007

Dear Mr. Townley:

We have estimated the flood frequency discharges requested in your December 19, 2001 transmittal (Process No. 20010737), as follows.

1. Tributary to Blue Jay Creek at Holden Road, Section 27, T7S, R19W, Weesaw Township, Berrien County, has a drainage area of 3.4 square miles. The 50%, 20%, 10%, 4%, 2%, 1%, 0.5%, and 0.2% chance peak flows are estimated to be 30 cubic feet per second (cfs), 80 cfs, 140 cfs, 220 cfs, 310 cfs, 420 cfs, 550 cfs, and 750 cfs, respectively. (Watershed Basin No. 34L St. Joseph (Lake)/Quad W16SE).

2. Blue Jay Creek at Warren Woods Road, Section 28, T7S, R19W, Weesaw Township, Berrien County, has a drainage area of 7.8 square miles. The 50%, 20%, 10%, 4%, 2%, 1%, 0.5%, and 0.2% chance peak flows are estimated to be 70 cfs, 160 cfs, 270 cfs, 440 cfs, 600 cfs, 850 cfs, 1100 cfs, and 1500 cfs, respectively. (Watershed Basin No. 34L St. Joseph (Lake)/Quad W16SE).

3. Tributary to Dowling Creek at Pardee Road, Section 4, T8S, R19W, Galien Township, Berrien County, has a drainage area of 3.5 square miles. The 50%, 20%, 10%, 4%, 2%, 1%, 0.5%, and 0.2% chance peak flows are estimated to be 50 cfs, 110 cfs, 170 cfs, 280 cfs, 380 cfs, 500 cfs, 650 cfs, and 900 cfs, respectively. (Watershed Basin No. 34L St. Joseph (Lake)/Quad W16SE).

4. Dowling Creek at US-12, Section 8, T8S, R19W, Galien Township, Berrien County, has a drainage area of 9.5 square miles. The 50%, 20%, 10%, 4%, 2%, 1%, 0.5%, and 0.2% chance peak flows are estimated to be 70 cfs, 180 cfs, 280 cfs, 450 cfs, 600 cfs, 850 cfs, 1100 cfs, and 1500 cfs, respectively. (Watershed Basin No. 34L St. Joseph (Lake)/Quad W16SE).

5. Dowling Creek at Hampton Road, Section 8, T8S, R19W, Galien Township, Berrien County, has a drainage area of 8.8 square miles. The 50%, 20%, 10%, 4%, 2%, 1%, 0.5%, and 0.2% chance peak flows are estimated to be 70 cfs, 160 cfs, 260 cfs, 420 cfs, 600 cfs, 800 cfs, 1000 cfs, and 1400 cfs, respectively. (Watershed Basin No. 34L St. Joseph (Lake)/Quad W16SE).

6. Beaverdam Creek at US-12, Section 5, T8S, R19W, Galien Township, Berrien County, has a drainage area of less than two square miles. (Watershed Basin No. 34L St. Joseph (Lake)/Quad W16SE). Since the drainage area is less than two square miles, a permit is not required under the provisions of the Floodplain Regulatory Authority found in Part 31, Water Resources Protection, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended (NREPA). A permit may be required under Part 301, Inland Lakes and Streams, of the NREPA.

7. Dowling Creek at Kruger Road, Section 8, T8S, R19W, Galien Township, Berrien County, has a drainage area of 18.0 square miles. The 50%, 20%, 10%, 4%, 2%, 1%, 0.5%, and 0.2% chance peak flows are estimated to be 130 cfs, 300 cfs, 470 cfs, 750 cfs, 1000 cfs, 1400 cfs, 1800 cfs, and 2500 cfs, respectively. (Watershed Basin No. 34L St. Joseph (Lake)/Quad W16SE).

8. Beaverdam Creek (Close Drain) at Penn Central Railroad, Section 7, T8S, R19W, Galien Township, Berrien County, has a drainage area of 2.9 square miles. The 50%, 20%, 10%, 4%, 2%, 1%, 0.5%, and 0.2% chance peak flows are estimated to be 40 cfs, 90 cfs, 140 cfs, 230 cfs, 310 cfs, 410 cfs, 550 cfs, and 700 cfs, respectively. (Watershed Basin No. 34L St. Joseph (Lake)/Quad W16SE).

9. Galien River at Pardee Road, Section 32, T7S, R19W, Weesaw Township, Berrien County, has a drainage area of 9.9 square miles. The 50%, 20%, 10%, 4%, 2%, 1%, 0.5%, and 0.2% chance peak flows are estimated to be 250 cfs, 400 cfs, 500 cfs, 650 cfs, 800 cfs, 900 cfs, 1000 cfs, and 1100 cfs, respectively. (Watershed Basin No. 34L St. Joseph (Lake)/Quad W16SE).

10. Blue Jay Creek at Pardee Road, Section 21, T7S, R19W, Weesaw Township, Berrien County, has a drainage area of 8.5 square miles. The 50%, 20%, 10%, 4%, 2%, 1%, 0.5%, and 0.2% chance peak flows are estimated to be 70 cfs, 180 cfs, 280 cfs, 470 cfs, 650 cfs, 900 cfs, 1100 cfs, and 1600 cfs, respectively. (Watershed Basin No. 34L St. Joseph (Lake)/Quad W16SE).

Please include a copy of this letter with your application for permit. These estimates should be confirmed by our office if an application is not submitted within one year. If you have any questions concerning the discharge estimates, please contact Mr. Arthur Armour, Hydrologic Studies Unit, at 517-335-3177, or by email at: armoura@michigan.gov. Any questions concerning the hydraulics or the proper procedure for filing for a permit should be directed to Mr. Matthew Occhipinti, Land and Water Management Division, Kalamazoo District Office, at 616-567-3564.

Sincerely,

Ric Sorrell

Richard C. Sorrell, P.E., Chief
Hydrologic Studies Unit
Land and Water Management Division
517-335-3176

RCS:AA:BW
cc: Mr. Matthew Occhipinti, DEQ
Mr. Arthur Armour, DEQ

UNITED STATES DEPARTMENT OF INTERIOR - GEOLCGICAL SURVEY - WATER RESOURCES DIVISION

EXPANDED RATING TABLE

TYPE: LOG

04096015

DATE PROCESSED: 11-26-2001 @ 11:03 BY rlleuvoy

GALIEN RIVER NEAR SAWYER, MI

DD: 1 TYPE: 001 RATING NO: 2.0

OFFSET: 4.00

START DATE/TIME: 10-01-1999 (0015)

BASED ON _______ DISCHARGE MEASUREMENTS, NOS ________, AND ________, AND IS ______ WELL DEFINED BETWEEN ______ AND ______ CFS

COMP BY _____ DATE ________ CHK. BY _____ DATE ________

SAME AS RATING NO. 1 ABOVE 9.2 FT

GAGE HEIGHT (FEET)	DISCHARGE IN CUBIC FEET PER SECOND					(EXPANDED PRECISION)					DIFF IN Q PER TENTH FT
	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	
4.90	11.30*	11.65	12.00	12.37	12.74	13.11	13.50	13.89	14.28	14.69	3.800
5.00	15.10*	15.46	15.82	16.19	16.56	16.94	17.32	17.71	18.10	18.50	3.800
5.10	18.90*	19.26	19.63	20.00	20.38	20.75	21.14	21.52	21.91	22.30	3.800
5.20	22.70*	23.07	23.44	23.81	24.19	24.56	24.95	25.33	25.72	26.11	3.800
5.30	26.50*	26.87	27.24	27.62	27.99	28.37	28.75	29.14	29.52	29.91	3.800
5.40	30.30*	30.67	31.05	31.42	31.80	32.18	32.56	32.94	33.33	33.71	3.800
5.50	34.10*	34.48	34.85	35.23	35.61	36.00	36.38	36.77	37.15	37.54	3.830
5.60	37.93	38.32	38.72	39.11	39.51	39.91	40.31	40.71	41.11	41.52	3.990
5.70	41.92	42.33	42.74	43.15	43.56	43.97	44.39	44.81	45.23	45.65	4.150
5.80	46.07	46.49	46.91	47.34	47.77	48.20	48.63	49.06	49.49	49.93	4.300
5.90	50.37	50.80	51.24	51.68	52.13	52.57	53.02	53.46	53.91	54.36	4.440
6.00	54.81	55.27	55.72	56.18	56.63	57.09	57.55	58.01	58.48	58.94	4.600
6.10	59.41	59.87	60.34	60.81	61.29	61.76	62.23	62.71	63.19	63.67	4.740
6.20	64.15	64.63	65.11	65.60	66.08	66.57	67.06	67.55	68.04	68.53	4.880
6.30	69.03	69.52	70.02	70.52	71.02	71.52	72.02	72.53	73.03	73.54	5.020
6.40	74.05	74.56	75.07	75.58	76.10	76.61	77.13	77.65	78.16	78.69	5.160
6.50	79.21	79.73	80.26	80.78	81.31	81.84	82.37	82.90	83.43	83.97	5.290
6.60	84.50	85.04	85.58	86.12	86.66	87.20	87.74	88.29	88.83	89.38	5.430
6.70	89.93	90.48	91.03	91.59	92.14	92.70	93.25	93.81	94.37	94.93	5.560
6.80	95.49	96.06	96.62	97.19	97.75	98.32	98.89	99.46	100.0	100.6	5.710
6.90	101.2	101.8	102.3	102.9	103.5	104.1	104.7	105.2	105.8	106.4	5.800
7.00	107.0	107.6	108.2	108.8	109.4	110.0	110.6	111.2	111.8	112.4	6.000
7.10	113.0	113.6	114.2	114.8	115.4	116.0	116.6	117.2	117.8	118.4	6.000
7.20	119.0	119.6	120.3	120.9	121.5	122.1	122.7	123.4	124.0	124.6	6.200
7.30	125.2	125.9	126.5	127.1	127.7	128.4	129.0	129.6	130.3	130.9	6.300
7.40	131.5	132.2	132.8	133.5	134.1	134.8	135.4	136.0	136.7	137.3	6.500
7.50	138.0	138.6	139.3	139.9	140.6	141.3	141.9	142.6	143.2	143.9	6.600
7.60	144.6	145.2	145.9	146.5	147.2	147.9	148.6	149.2	149.9	150.6	6.600
7.70	151.2	151.9	152.6	153.3	153.9	154.6	155.3	156.0	156.7	157.4	6.800
7.80	158.0	158.7	159.4	160.1	160.8	161.5	162.2	162.9	163.6	164.3	7.000
7.90	165.0	165.7	166.4	167.1	167.8	168.5	169.2	169.9	170.6	171.3	7.000
8.00	172.0*	172.8	173.6	174.4	175.2	176.0	176.8	177.6	178.4	179.2	8.000
8.10	180.0*	180.9	181.8	182.7	183.6	184.5	185.4	186.3	187.2	188.1	9.000
8.20	189.0*	190.1	191.2	192.3	193.4	194.5	195.6	196.7	197.8	198.9	11.00
8.30	200.0*	201.3	202.6	203.8	205.1	206.4	207.7	209.0	210.4	211.7	13.00
8.40	213.0*	214.4	215.8	217.1	218.5	219.9	221.3	222.7	224.2	225.6	14.00
8.50	227.0*	228.5	229.9	231.4	232.9	234.4	235.9	237.4	238.9	240.5	15.00

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION

EXPANDED RATING TABLE TYPE: LOG

04096015 DATE PROCESSED: 11-26-2001 @ 11:03 BY rlleuvoy

GALIEN RIVER NEAR SAWYER, MI DD: 1 TYPE: 001 RATING NO: 2.0

OFFSET: 4.00 START DATE/TIME: 10-01-1999 (0015)

SAME AS RATING NO. 1 ABOVE 9.2 FT

GAGE HEIGHT (FEET)	DISCHARGE IN CUBIC FEET PER SECOND					(EXPANDED PRECISION)					DIFF IN Q PER TENTH FT
	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	
8.60	242.0*	243.6	245.1	246.7	248.3	249.9	251.5	253.1	254.7	256.4	16.00
8.70	258.0*	259.7	261.3	263.0	264.7	266.4	268.1	269.8	271.5	273.3	17.00
8.80	275.0*	276.8	278.5	280.3	282.1	283.9	285.7	287.5	289.3	291.2	18.00
8.90	293.0*	294.9	296.7	298.6	300.5	302.4	304.3	306.2	308.1	310.1	19.00
9.00	312.0*	314.0	315.9	317.9	319.9	321.9	323.9	325.9	327.9	330.0	20.00
9.10	332.0*	334.1	336.1	338.2	340.3	342.4	344.5	346.6	348.7	350.9	21.00
9.20	353.0*	355.2	357.5	359.8	362.0	364.3	366.6	368.9	371.2	373.5	22.90
9.30	375.9	378.2	380.6	382.9	385.3	387.7	390.1	392.5	394.9	397.3	23.80
9.40	399.7	402.2	404.6	407.1	409.6	412.1	414.6	417.1	419.6	422.1	25.00
9.50	424.7	427.2	429.8	432.3	434.9	437.5	440.1	442.7	445.3	448.0	25.90
9.60	450.6	453.3	456.0	458.6	461.3	464.0	466.7	469.5	472.2	474.9	27.10
9.70	477.7	480.5	483.2	486.0	488.8	491.6	494.5	497.3	500.1	503.0	28.20
9.80	505.9	508.7	511.6	514.5	517.5	520.4	523.3	526.3	529.2	532.2	29.30
9.90	535.2	538.2	541.2	544.2	547.2	550.3	553.3	556.4	559.5	562.5	30.40
10.00	565.6	568.8	571.9	575.0	578.2	581.3	584.5	587.7	590.9	594.1	31.70
10.10	597.3	600.5	603.8	607.0	610.3	613.6	616.9	620.2	623.5	626.8	32.90
10.20	630.2	633.5	636.9	640.3	643.7	647.1	650.5	653.9	657.4	660.8	34.10
10.30	664.3	667.8	671.3	674.8	678.3	681.8	685.4	688.9	692.5	696.1	35.40
10.40	699.7	703.3	706.9	710.5	714.2	717.8	721.5	725.2	728.9	732.6	36.60
10.50	736.3	740.1	743.8	747.6	751.4	755.2	759.0	762.8	766.6	770.5	38.00
10.60	774.3	778.2	782.1	786.0	789.9	793.8	797.8	801.7	805.7	809.7	39.40
10.70	813.7	817.7	821.7	825.7	829.8	833.8	837.9	842.0	846.1	850.2	40.70
10.80	854.4	858.5	862.7	866.9	871.0	875.2	879.5	883.7	887.9	892.2	42.10
10.90	896.5	900.8	905.1	909.4	913.7	918.1	922.4	926.8	931.2	935.6	43.50
11.00	940.0*	944.4	948.9	953.3	957.8	962.3	966.8	971.3	975.9	980.4	45.00
11.10	985.0*	989.6	994.3	998.9	1004	1008	1013	1018	1022	1027	47.00
11.20	1032*	1037	1042	1047	1052	1057	1063	1068	1073	1078	51.00
11.30	1083	1089	1094	1099	1105	1110	1115	1121	1126	1131	54.00
11.40	1137	1142	1148	1153	1159	1164	1170	1175	1181	1186	55.00
11.50	1192	1197	1203	1209	1214	1220	1226	1231	1237	1243	57.00
11.60	1249	1255	1260	1266	1272	1278	1284	1290	1296	1302	59.00
11.70	1308	1314	1320	1326	1332	1338	1344	1350	1356	1362	61.00
11.80	1369	1375	1381	1387	1394	1400	1406	1412	1419	1425	62.00
11.90	1431	1438	1444	1451	1457	1464	1470	1477	1483	1490	65.00
12.00	1496	1503	1510	1516	1523	1530	1536	1543	1550	1557	67.00
12.10	1563	1570	1577	1584	1591	1598	1605	1612	1619	1626	70.00
12.20	1633	1640	1647	1654	1661	1668	1675	1682	1689	1697	71.00
12.30	1704	1711	1718	1726	1733	1740	1748	1755	1763	1770	73.00

EXPANDED RATING TABLE TYPE: LOG

04096015 DATE PROCESSED: 11-26-2001 @ 11:03 BY rlleuvoy

GALIEN RIVER NEAR SAWYER, MI DD: 1 TYPE: 001 RATING NO: 2.0

OFFSET: 4.00 START DATE/TIME: 10-01-1999 (0015)

SAME AS RATING NO. 1 ABOVE 9.2 FT

GAGE HEIGHT (FEET)	DISCHARGE IN CUBIC FEET PER SECOND (EXPANDED PRECISION) .00	.01	.02	.03	.04	.05	.06	.07	.08	.09	DIFF IN Q PER TENTH FT
12.40	1777	1785	1792	1800	1807	1815	1823	1830	1838	1845	76.00
12.50	1853	1861	1869	1876	1884	1892	1900	1908	1915	1923	78.00
12.60	1931	1939	1947	1955	1963	1971	1979	1987	1995	2003	81.00
12.70	2012	2020	2028	2036	2044	2053	2061	2069	2078	2086	82.00
12.80	2094	2103	2111	2120	2128	2137	2145	2154	2162	2171	85.00
12.90	2179	2188	2197	2205	2214	2223	2232	2240	2249	2258	88.00
13.00	2267	2276	2285	2294	2303	2312	2321	2330	2339	2348	90.00
13.10	2357	2366	2375	2385	2394	2403	2412	2422	2431	2440	93.00
13.20	2450	2459	2469	2478	2488	2497	2507	2516	2526	2535	95.00
13.30	2545	2555	2564	2574	2584	2594	2603	2613	2623	2633	98.00
13.40	2643	2653	2663	2673	2683	2693	2703	2713	2723	2733	100.0
13.50	2743	2753	2764	2774	2784	2795	2805	2815	2826	2836	103.0
13.60	2846	2857	2867	2878	2889	2899	2910	2920	2931	2942	106.0
13.70	2952	2963	2974	2985	2996	3006	3017	3028	3039	3050	109.0
13.80	3061	3072	3083	3094	3105	3117	3128	3139	3150	3161	112.0
13.90	3173	3184	3195	3207	3218	3230	3241	3253	3264	3276	114.0
14.00	3287	3299	3310	3322	3334	3346	3357	3369	3381	3393	118.0
14.10	3405	3417	3428	3440	3452	3464	3476	3489	3501	3513	120.0*
14.20	3525*										

Project: BCDC/Galien River
Project No.: G01338
Date: 4/26/2002
By: MOT

FTC&H
1515 Arboretum Drive, SE
Grand Rapids, MI 49546
616-575-3824

LOW FLOW COMPARISONS					
River Station	Location	Jan-02 Flow (cfs)	Surveyed W.S.E. (ft)	Modeled W.S.E. (ft)	Percent Error
25475	Warren Woods Road	35			
25188	Trib. at Warren Woods Road	43	624.11	624.54	0.07%
18858	Kaiser Road	55	621.43	621.80	0.06%
13145	Near Log Cabin Road	55	617.90	618.63	0.12%
11998	East Branch Inlet	75			
7466	Avery Mill Road	75	613.65	614.05	0.07%
3080	Tributary	75			
0	Minnich Road	75	607.33	607.31	0.00%