FINAL
FUNCTIONAL ASSESSMENT OF THE UPPER WABASH RIVER

Prepared for:

Upper Wabash River Basin Commission

February 2019

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CBBEL Project No. 17-0512.00000

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EXECUTIVE SUMMARY

This report documents the results and methodology used by Christopher B. Burke Engineering, LLC (CBBEL) and Robert Barr to identify problem areas along the Wabash River in Adams, Jay, and Wells Counties and to develop conceptual mitigation solutions.

The study reach was approximately 28 miles and extended from the Ohio-Indiana State Line to Bluffton, Indiana. The Upper Wabash River has a drainage area of approximately 532 square miles at the downstream end of the study reach.

A functional assessment of Upper Wabash River was completed by CBBEL to identify the root causes of the bank failures that have occurred, to locate problem areas that are in the greatest need of intervention, and to aide in the development of conceptual mitigation solutions. The assessment included review of previous studies and analysis of available data for the contributing watershed upstream of Bluffton, IN. The functional assessment determined that three major factors are most responsible for the current bank failure issues along the Upper Wabash River:

1. **Weak silt loam soils forming the upper bank.** Saturation of the bank causes the soils to become too heavy to support the weight of the soil above.
2. **Increased flow rates and more frequent bankfull discharges:** Higher peak flow and more frequent bankfull discharges have resulted in more frequent saturation of the soils.
3. **Location on the outside of meander bends:** Most of the problem areas are located on the outside of meander bends. The outside of meander bends frequently experience bank failures, even in stable systems, due to natural channel migration. This appears to be the least influential factor identified in the functional assessment.

The results of the assessment suggest that improvements should be made to four of the six problem areas identified. The recommended improvements include a combination of the following at the four different sites: adjusting the upper portion of the bank to provide a stable slope, installing soil lifts, installing gabion walls, utilizing live stakes to increase low-bank roughness and stability, excavating shelfs on the opposite bank, and protecting the upper slope with erosion control blanket. It is recommended that problem areas located at 305 Old Hickory Lane and 6596 State Road 116 be monitored to evaluate the need for future intervention by the homeowners, if conditions worsen and begin to threaten the homes. It is also recommended that the condition of any implemented improvements at the project areas should be monitored on an annual basis, and/or after significant flooding events to confirm that the measures are performing as expected. A summary of the location, length, and cost of the recommended improvement projects are provided in the table below.

Problem Area Address	Priority Ranking	Construction Cost	Cost of Engineering	Total Cost
6500 SR 116, Wells County	1	$201,000	$86,000	$287,000
3343 E CR 1200 S, Jay County	2	$324,000	$81,000	$405,000
270 E CR 1100 S, Adams County	3	$96,000	$64,000	$160,000
4100 E CR 1200 S, Adams County	4	$94,000	$63,000	$157,000

CHAPTER 1 PROJECT OVERVIEW

1.1 INTRODUCTION AND PROJECT PURPOSE

This report documents the results and methodology used by Christopher B. Burke Engineering, LLC (CBBEL) and Robert Barr to complete a functional assessment of the Upper Wabash River from the Ohio state line to Bluffton, Indiana. The functional assessment was commissioned by the Upper Wabash River Basin Commission (UWRBC) to identify the stressors leading to channel instability and to identify the fluvial erosion hazards along the study reach.

1.2 STUDY AREA

The study area consists of the Upper Wabash River from the Indiana-Ohio state line to Bluffton, Indiana. The drainage area of the Upper Wabash River at Bluffton is 532 square miles (mi^2). The length of the study reach is 28.0 miles (Barr, 2018). The study also included a reconnaissance of a portion of the watershed upstream of the State line to identify potential issues due to the upstream conditions. This area included the Beaver Creek Watershed and portions of Grand Lake, in Mercer County, Ohio. A map of the study area is shown in Exhibit 1.

Figure 1: Stream Bank near State Road 116

CHAPTER 2 DATA GATHERING

Existing data and previous studies, where available, were used as supporting information for the assessment. Additional data and observations were collected to provide a more comprehensive understanding of the physical processes at work near the sites and within the river system. The following sections detail the origin and use of existing datasets and applicable previous studies, as well as the type and extent of additional information gathered.

2.1 SOURCES OF DATA

Historic Aerial Photography

Aerial photography of the Upper Wabash River Watershed was obtained from multiple sources. The primary source of aerial photography information was the 2012 IndianaMap Orthophotography. Historical aerial imagery was collected from Google Earth. Additional local imagery exists; however, for watershed-wide consistency the aforementioned datasets were used.

Land Use Information

Information concerning the types and extent of land use practices in the area were necessary for a portion of the analysis. Land use information was gathered from the 2011 National Land Cover Dataset (NLCD). Aerial photography from the 2012 IndianaMap Framework Dataset was inspected to generally confirm the land uses shown in the NLCD data.

Topographic Data

The analysis of the Upper Wabash River corridor through the study area required detailed topographic information for various calculations. The 2012 IndianaMap Digital Elevation Model (DEM) was used as the source of topographic data for floodplain connectivity considerations. The IndianaMap DEM covers the entire Upper Wabash River Watershed and has a 5-foot cell resolution, which is sufficient for producing 1-foot contours. A topographic map of the Upper Wabash River Watershed is provided in Exhibit 2.

Streamflow Data

Streamflow information was obtained from the United States Geological Survey's (USGS) online portal to provide an extensive record of the hydrology for the Wabash River. The streamflow information was used to determine long-term trends in flow rates and the frequency of significant storm events.

Surficial Geology and Soils Information

Geologic composition and deposition information was obtained from the Quaternary Map of Indiana (Gray, 1989).

Soils information was obtained from the United States Department of Agriculture (USDA) Soil Survey Geographic Database (SSURGO) to provide the properties of the soils along the Upper Wabash River corridor. The characterization of channel bed and bank material at the project sites were completed using visual observations.

2.2 PREVIOUS STUDIES AND ANALYSES

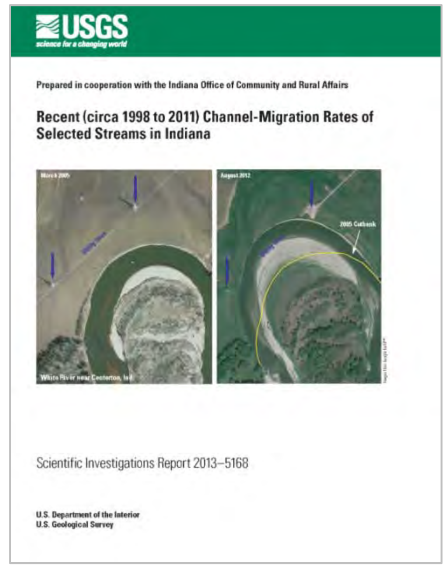
The review of previous studies in the Upper Wabash River Watershed was limited to hydrologic and hydraulic analyses, as well as a small number of other reports of significance to fluvial stability and flooding considerations.

Previous Studies

The only applicable references used were the following reports published by the United States Geologic Survey.

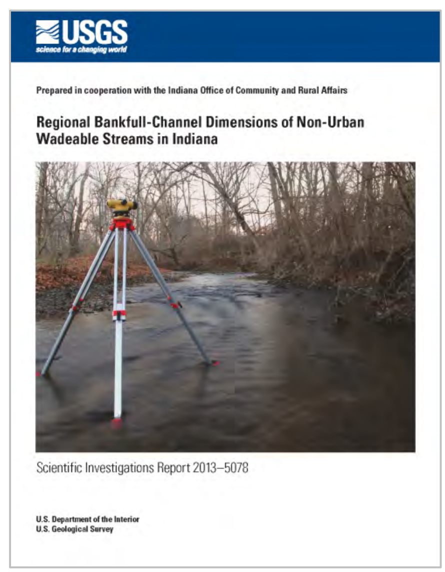
Recent (circa 1998 to 2011) Channel Migration Rates of Selected Streams in Indiana (USGS, 2013a)

A total of 42 streams in Indiana were measured to determine observed lateral migration rates of the streams, or how much a channel's banks shift relative to the surrounding land features. Lateral migration rates can be used as a surrogate for overall stream stability. The analysis completed by the USGS revealed that of the streams considered, Upper Wabash River has the 18^{h} highest lateral migration rate. The channel moves at a rate of less than 1 foot per year on average.



Regional Bankfull Channel Dimensions of Non-Urban Wadeable Streams in Indiana (USGS, 2013b)

Regionally-based relationships for channel dimensions were developed by analyzing data from streams throughout Indiana. The data was obtained from 81 streams that are non-urban, wadeable, and pristine or naturalized. The regional equations can be used to determine a channels departure from the expected dimensions as well as to aid in channel restoration design processes.



Available Models

Hydrologic and hydraulic models exist for the study reach. However, based on observations made during this assessment and the findings provided in Chapter 3 and Chapter 4 of this report, discussion of the models does not provide significant additional insight for the current study.

CHAPTER 3 FUNCTIONAL CHANNEL ASSESSMENT

3.1 INITIAL BACKGROUND ANALYSIS

An initial background analysis was completed to develop a baseline understanding of the river system prior to completing site visits and visual observation of the river corridor. The initial background analysis included evaluation of the physical basin characteristics, surficial geology and soils, the extent and composition of the riparian corridor, and the hydrologic characteristics of the contributing watershed. The majority of this information was taken from the 2018 Functional Assessment report by Robert Barr, which is included in Appendix 1.

3.1.1 Basin Physical Characteristics

The Upper Wabash River Watershed has a drainage area of approximately 532 mi^2, with nearly 260 mi^2 of that area residing in the State of Ohio. The Upper Wabash River flows from east to west through the northeast portion of the State of Indiana. The Upper Wabash River Watershed includes Berne, Geneva, and Bluffton. The predominant land use for the watershed is agricultural.

3.1.2 Surficial Geology and Soils

Surficial geology is important when considering the potential for erosion and stream stability issues. The Upper Wabash River is in the Tipton Till Plain and is composed of silty clay and clayey till materials. The surficial geology deposition type in the study area is dominated by recent alluvium, fine-textured lacustrine deposits, and Wisconsin outwash (Barr, 2018). Till refers to material that has been deposited by glaciers and is typically very hard and difficult to erode. Alluvium refers to material that has been deposited by moving water as some time in the past. The fact that the river has transported the sediment previously makes it likely that the material is still able to be moved by water, especially since the alluvial deposits are generally friable, or poorly consolidated.

The capacity of a soil to resist erosion is primarily dependent on three major factors. The first two factors are soil grain size and cohesion and often determine the importance of vegetation, the third factor. Fine-grained, low cohesion or cohesionless soils such as sands and silts have a low tolerance for erosive forces and require vegetation to remain stable over long periods of time. Clayey soils are cohesive and are much more resistant to erosion than sands and silts. Higher percentages of clay in a soil type can dramatically increase the resistance to erosion. The soils along Upper Wabash River in the study area are predominantly silty loams or clay loams (Barr, 2018). Silty loams composed of sand, silt, and a smaller amount of clay, plus organic material. They are generally friable, poorly consolidated, and easily eroded. Clay loam soils are composed of a nearly equal amount of clay, sand, and silt. They are cohesive and not easily eroded. A map of the soils present at the problem areas identified in Section 3.4 is provided in Exhibit 3.

3.1.3 Wooded Riparian Buffer Assessment

The existence of vegetation is often the most critical factor for the capacity of a soil to resist erosion. Vegetation reinforces the soil structure and serves as a buffer to reduce stress on the soil surface. Approximately 70% of the study reach was either forested or wetland areas, though the width of the buffer is quite narrow in many places. The presence of a buffer can allow for small, natural adjustments of the stream necessary to maintain stability without impairing adjacent land uses.

3.1.4 Hydrology

The response of the watershed to rainfall is a key factor in the amount of fluvial instability and flooding risk potential posed by a stream. The amount of runoff generated, and the time required for the flow to accumulate and reach the stream affect the erosive potential of the channel and determine how much flow must pass through the most restrictive sections of the channel which may or may not result in significant flooding. Increased drainage efficiency in agricultural areas and other intensive land uses frequently increase runoff and decrease infiltration. These changes often result in higher and more frequent peak flows, as well as a larger volume of runoff. The Wabash River Watershed upstream of the Indiana state line is characterized by agriculturally-modified streams and constructed drainage channels. The watershed is divided into two basins, Wabash River and Beaver Creek, a 10-mile long channelized stream. (Barr, 2018).

The Upper Wabash River Watershed upstream of the Indiana state line includes the Beaver Creek Watershed shown in Figure 2. Beaver Creek has been channelized and receives outflow for a portion of Grand Lake, 13,500-acre manmade lake. The outflow from the lake varies and appears to be unregulated based on the USGS gage. The presence of the lake also creates a severe discontinuity in sediment transport. All but the finest of the sediment that is suspended in the water column of the lake settles to the bottom of the waterbody. The significant reduction in sediment concentration in the flow leaving the lake creates a tremendous imbalance in the sediment carrying capacity and sediment supplied to the channel immediately downstream. Erosion of the channel bed and banks occurs until the sediment concentration of the flow contributed from the lake is increased to the maximum amount that the flow through the channel can carry. This is often referred to as the stream being ‘hungry’, as the bed and banks are rapidly eaten away in unarmored channels. The fluctuating discharge and reduced sediment concentration in the flow increases the potential for instability and bank erosion (Barr, 2018).

Figure 2: Upper Wabash River Watershed Upstream of Indiana State Line
(Source: USGS StreamStats)

3.2 STREAM GAGE AND PRECIPITATION ANALYSIS

An analysis of available hydrologic data was completed to determine the characteristics and trends in the watershed’s response to rainfall. The Wabash River streamflow gage at Linn Grove (USGS Gage 03322900) shows an upward trend for peak annual flow rates from 4,000 cubic feet per second (cfs) to 7,000 cfs (Barr, 2018). The increase in peak annual flow shows that large events that can cause significant channel erosion and adjustment are occurring more often.

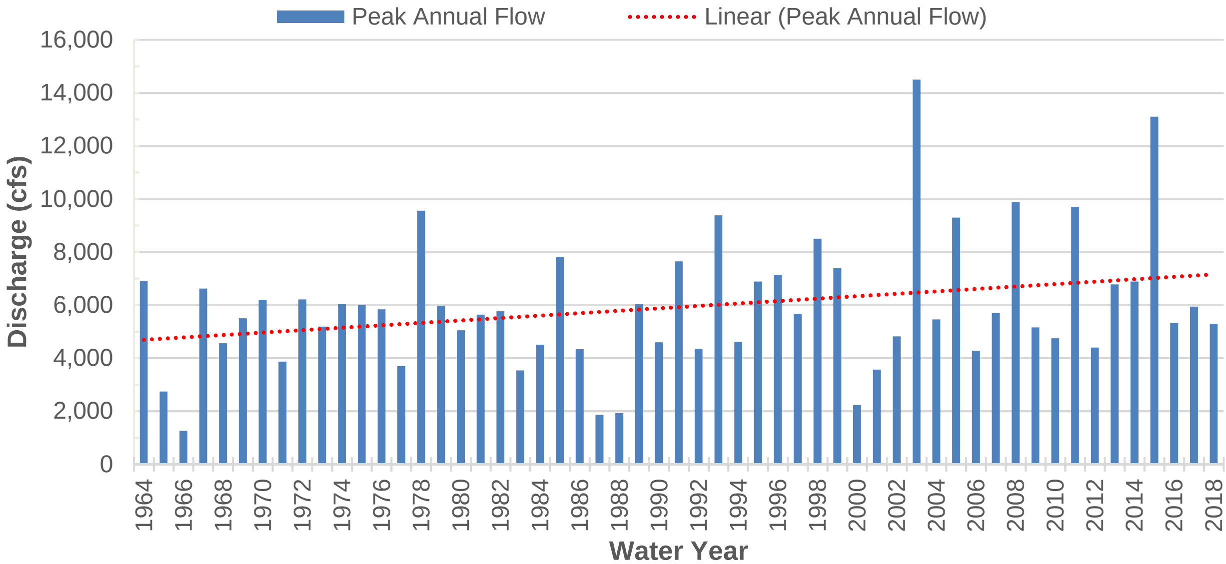


Figure 3: Peak Annual Flow Rate at USGS Gage in Linn Grove, IN

It is important to remember that erosion typically occurs in streams at any flow rate, it is simply a matter of how much erosion occurs. High flow rates obviously lead to high erosion rates; however, it is typically the bankfull flow rate that statistically moves the most sediment over time and not the high flow rates. This fact highlights the true nature of erosion in streams, a relatively slow and grinding process that is constantly reshaping the channel. For a healthy stream, the bankfull flow rate will occur for a few hours, roughly every 18 months. A statistical analysis of the Wabash River gage data suggests that the bankfull flow rate is approximately 4,770 cfs, and the average number of days at bankfull has doubled in the last 18 years (Barr, 2018).

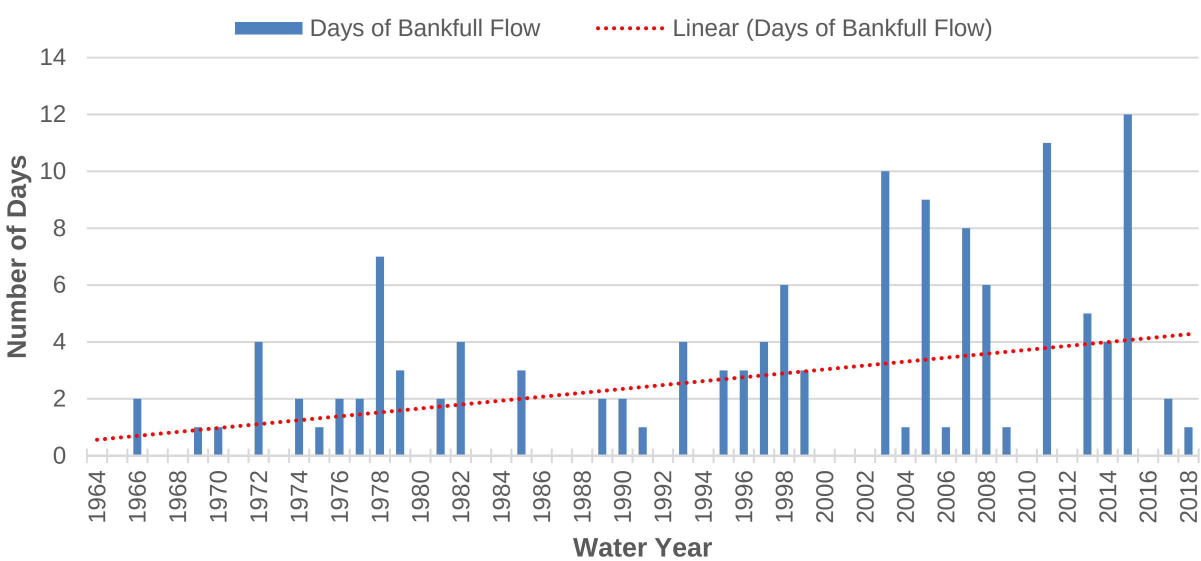


Figure 4: Frequency of Bankfull Discharge at USGS Gage in Linn Grove, IN

The average annual precipitation in Indiana is approximately 42 inches. The annual precipitation has an increasing trend over the last 120 years (IN CCIA, 2018), increasing by approximately 4 inches as shown in Figure 5.

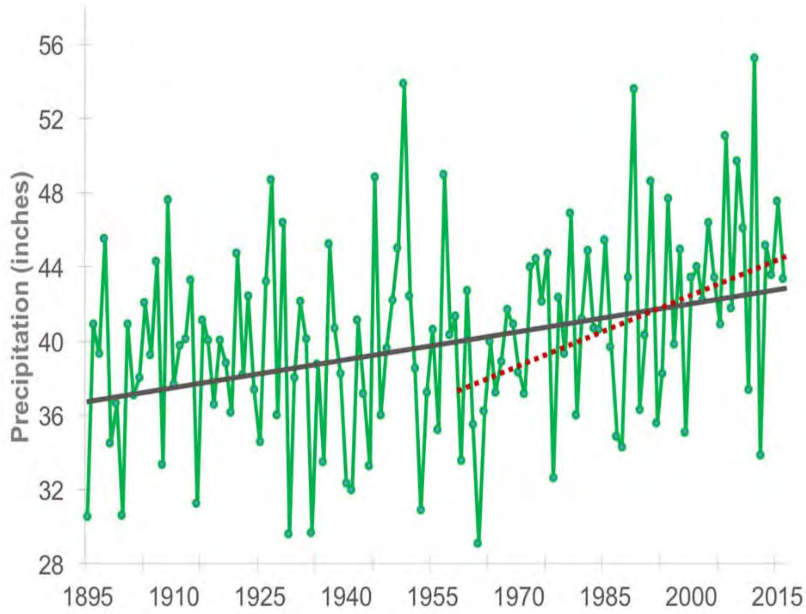


Figure 5: Indiana Annual Rainfall Depth (IN CCIA, 2018)

More relevant with regards to flooding and erosion potential than annual average precipitation is the frequency of heavy rainfall events. Previous studies of National Weather Service data from 1958 to 2016 has shown that Indiana as a whole has seen the days of extreme precipitation events increasing from 1 to 3 days since 1900 (IN CCIA, 2018), as shown in Figure 6.

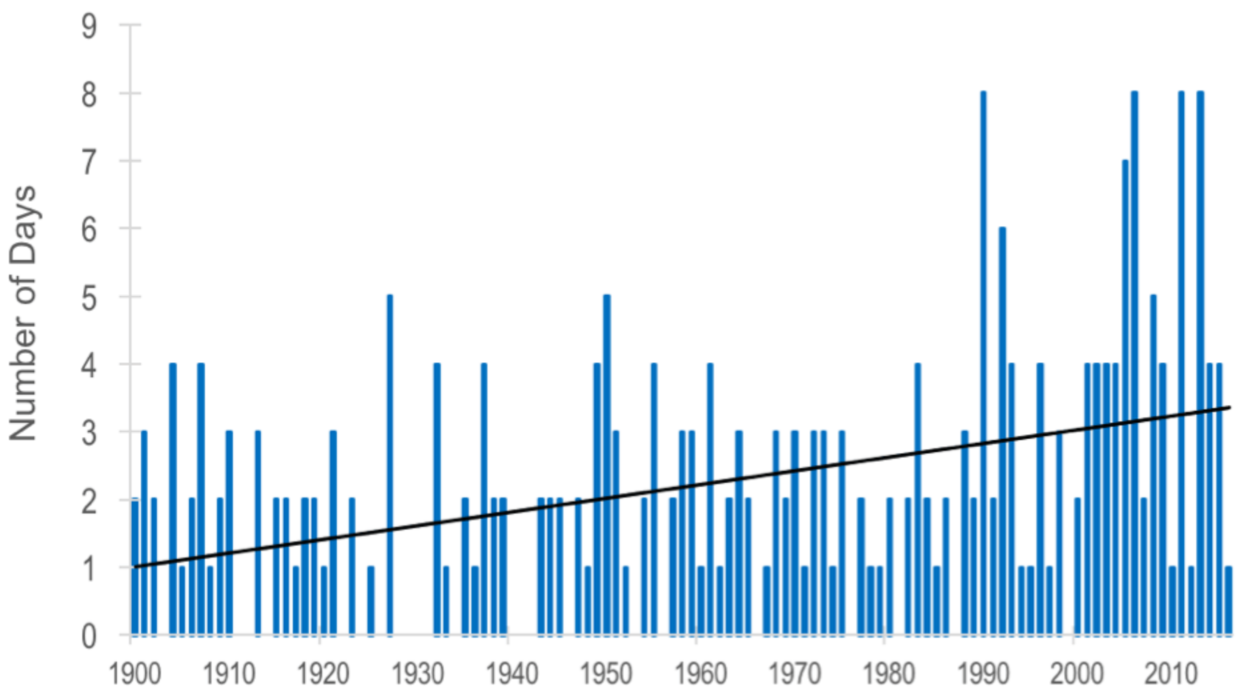


Figure 6: Change in Very Heavy Precipitation
(IN CCIA, 2018)

3.3 CURRENT GEOMORPHIC CHANNEL CHARACTERISTICS

The study reach was divided into two sections based on their channel morphology and geomorphic setting (Barr, 2018). The upstream reach, or Limberlost Reach, is from the Indiana-Ohio State line to Geneva, Indiana shown in Figure 7. The Wabash River has been channelized upstream of the State line and continues for approximately 2.5 miles into Indiana. The river becomes highly sinuous upstream of Brewster Ditch in Adams County.

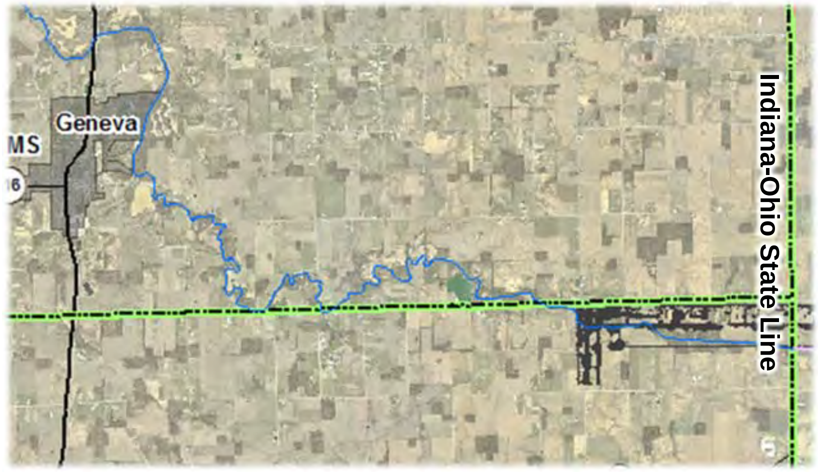


Figure 7: Limberlost Reach
(Indiana state line to Geneva, Indiana)

The downstream reach is from Geneva, Indiana to Bluffton Indiana shown in Figure 8. The sinuosity of the reach changes from 2.5 to 1.3 and the slope increases slightly. The sinuosity of the channel typically indicates lateral channel migration; however, the lateral migration rate of the Upper Wabash River is less than 1 foot (USGS, 2013). The lateral stability of the river is due to the clayey till that forms the channel bed and the lower bank. (Barr, 2018).

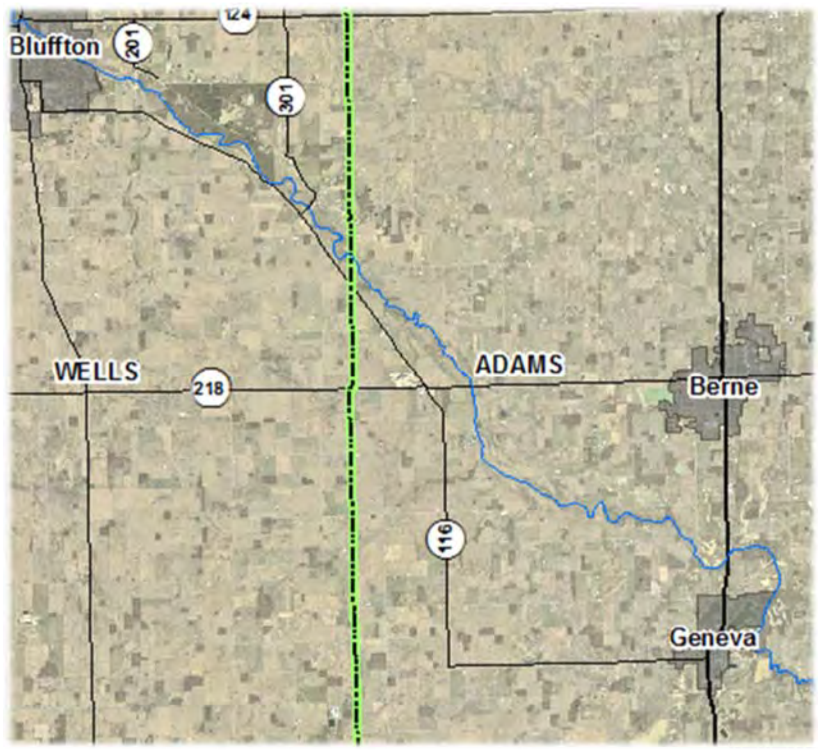


Figure 8: Downstream reach
(Geneva to Bluffton, Indiana)

Using the Rosgen stream classification system, the Limberlost Reach was classified as a C6c channel and the Wabash River downstream of Geneva was classified as a E6 channel. A C6c channel is a slightly entrenched, moderately sinuous channel made up of silt and clay. An E6 channel is a slightly entrenched, highly sinuous channel made up of silt and clay.

The study reach of the Wabash River is generally a very stable river. The main channel has eroded into the silt and clay till, which is a very resistant boundary condition (Barr, 2018) that has contributed to a stable toe-of-slope for the channel banks and low lateral migration rates.

3.4 PROBLEM AREA IDENTIFICATION

3.4.1 Initial Problem Area Identification and Verification

Several locations were identified as areas of concern by members of the UWRBC during a field visit in April 2018. UWRBC members also cited concerns about excessive sediment and tree/wood management.

The noted areas of concern, and other areas, were assessed and verified as areas of instability during a flight of the main channel of the Wabash River and additional field visits. A total of six problem areas were identified during the functional assessment. The evaluation, identification, and confirmation of problem areas was completed using the full spectrum of available data but can be summarized using the bank erosion hazard index (BEHI) and the observed extent of instability.

Bank Erosion Hazard Index

The BEHI score is used to assess the condition of channel banks and the potential for erosion by characterizing bank geometry and vegetation. As shown in Table 1, the BEHI scores ranged from 36 and 49, indicating the problem areas have a high to extreme risk of bank erosion. Calculation sheets are included in Appendix 2.

Extent of Instability

The extent of the instability present at each problem area was visually observed during site visits and confirmed using aerial photography and evaluation of the IndianaMap DEM. A summary of the length of the instability and the approximate bank height are summarized in Table 1.

3.4.2 List of Problem Areas by County

Six areas were identified as problem areas, as shown in Exhibit 4. All of the sites are experiencing slope failure. The cause of the instability appears to be more frequent saturation and for most of the site, and to a lesser degree, being located on the outside of a meander bend. A summary of the location of the problem, the BEHI score, length of instability, and bank height are provided in Table 1.

Table 1 List of Problem Areas

Location	BEHI Score	Length of Instability	Bank Height
4100 E CR 1200 S, Adams County	47	310	7
3343 E CR 1200 S, Jay County	36	480	21
270 E CR 1100 S, Adams County	47	350	17
305 Old Hickory Lane, Adams County	41	235	18
6500 SR 116, Wells County	49	430	13
6595 SR 116, Wells County	46	200	16

3.4.3 Ranking of Problem Areas

Each of the problem areas were examined to determine their rank of most critical to least critical based on perceived risk level given the anticipated detrimental impact if the area was compromised. Table 2 provides a ranking of the problem areas and the reason for the ranking.

Table 2 Ranking of Problem Areas

Problem Area	Rank	Description	Basis for Assigned Rank
6500 SR 116, Wells County	1	Road (SR 116)	Greatest potential for loss of life
3343 E CR 1200 S, Jay County	2	Road (CR 1200S)	Potential for loss of life and less room to move than 270 E CR 1100 S and 4100 E CR 1200 S
270 E CR 1100 S, Adams County	3	Road (SR 116)	Potential for loss of life
4100 E CR 1200 S, Adams County	4	Road (CR 1200S)	Potential for loss of life
305 Old Hickory Lane, Adams County	5	Residence	Less threat to the public and closer to top of slope than 6595 SR 116
6595 SR 116, Wells County	6	Residence	Less threat to the public

CHAPTER 4 CONCEPTUAL SOLUTIONS

The instabilities and issues present at each problem area are clarified in the following paragraphs to provide a context for the proposed solutions for each location. The conceptual solutions shown in Exhibit 5 through 10 and discussed in the paragraphs below are specific to the needs of the individual locations and should not be used indiscriminately along other portions along the channel to 'fix' the banks in other locations. Without a detailed and site-specific consideration of consequences, the installation of bank stabilization can result in increased erosion and instability downstream of the project that impacts adjacent properties. It must be noted that the conceptual solutions provide the general details of what might be done to reduce or eliminate the instabilities noted if corrective action is to be taken; not all the conceptual solutions have been recommended for implementation. See Chapter 5 for the list of recommended improvements.

4.1 PROBLEM AREA AT 4100 E CR 1200 S

The upstream-most problem area identified is located at 4100 East County Road 1200 South east of County Road 400 East in Adams County. The problem area instability includes slope failure along the left bank of the channel (along the road) for approximately 800 feet (Barr, 2018). The instability is caused by its location on the outside of a meander bend and more frequent saturation of soils due to increased flow rates and high-flow frequency. Emergency repairs have been made and consist of riprap placed in the channel but not along the upper portion of the slope, as shown in Figure 9.

Figure 9: Emergency Riprap Repair at 4100 E CR 1200 S

Failed, over-steepened, and undermined banks are unstable due to an inability to support the weight of the soil forming the bank. Where banks suffer from this type of geotechnical instability, a simple and cost-effective means of correcting the issue is to reduce the slope to a more stable angle, typically in the range of 3-feet horizontal to 1-foot vertical (3H:1V), or flatter.

The proposed improvements consist of regrading the slope to the more stable angle of 3H:1V in conjunction with soil lifts with live stakes. A free-draining sand and gravel drainage layer will be installed behind and below the soil lifts and below the soil lifts to help reduce the saturation of the soils. The live stakes will add protection to the soil lifts by creating more roughness along the bank which is expected to lower velocities along the near-bank. The length of the bank stabilization will be approximately 310 feet. The alignment of the bank stabilization will also create a smoother transition through the bend. The expansion of the point bar along the right bank should be expected as a result of the realignment of the outer bend. A schematic layout of the potential improvements is provided in Exhibit 5.

The cost of designing, permitting, and constructing these improvements is expected to be approximately $157,000. A detailed breakdown of the anticipated project cost is provided in Appendix 3.

4.2 PROBLEM AREA AT 3343 E CR 1200 S

The next problem area is located at 3343 East County Road 1200 South approximately 2 miles east of State Road 27, which is approximately 3,900 feet west of the first problem area. The problem area instabilities include tension cracking and slab failure along the upper left bank and slope failure along approximately 500 feet of the upper left bank. (Barr, 2018). Emergency repairs have been made and consist of riprap placed loosely along the slope, as shown in Figure 10.

Figure 10: Bank Instability and Emergency Riprap Repair (top) and Toe of Slope (bottom) at 3343 E CR 1200 S

Failed, over-steepened, and undermined banks are unstable due to an inability to support the weight of the soil forming the bank. The bank is high, over-steepened, and exhibits the same type of geotechnical instability present at the 4100 E CR 1200 S problem area.

The proposed improvements consist of installing vegetated gabion baskets along the left bank, excavating a shelf along the right bank, and regrading the slope above/behind the baskets to a 3H:1V slope using the excavated material from the shelf. The height of the bank and close proximity of the roadway make it difficult to reliably utilize softer, bioengineered stabilization methods due to the need for a more vertical solution. The length of the improvements will be approximately 480 feet. The length of the gabion wall will extend upstream a short distance to provide additional protection to the road and to reduce the risk of erosion from compromising the integrity of the upstream end of the gabion wall by flanking. The live stakes on the gabion wall increase the roughness, which will help to reduce the velocities along the wall while also improving the new riparian habitat. The excavated shelf will help to reduce the flow velocity through the improvement site and to shift the highest in-channel velocity away from the outer bank to a more central location. A schematic layout of the conceptual improvements is provided in Exhibit 6.

The cost of designing, permitting, and constructing these improvements is expected to be approximately $405,000. A detailed breakdown of the anticipated project cost is provided in Appendix 3.

4.3 PROBLEM AREA AT 270 E CR 1100 S

The problem area located at 270 East County Road 1100 South near Geneva, Indiana shows instability in the form of tension cracking, slab failure, and slope failure along the right bank. The slope failure extends for approximately 350 feet. The instability appears to be caused by more frequent saturation of the soils and its location on the outside of a very tight meander bend (Barr, 2018). Riprap has been placed in the channel and along the slope in an attempt to protect the roadway, as shown Figure 11.

Figure 11: Bank Instability and Riprap Repair at 270 E CR 1100 S

Natural, healthy streams in Indiana typically meander and gradually move back and forth across their floodplain. In certain situations, such as this one, allowing the movement of the stream can endanger infrastructure. Utilizing an armoring system on the channel banks can help to prevent the natural erosion processes that allow the channel to move.

The proposed improvements consist of regrading the right slope to the more stable angle of 3H:1V using soil lifts with live stakes, installing riprap toe protection below the filled portion of the stabilized slope, and excavating a shelf along the left bank. A drainage layer will be installed behind the riprap toe protection and below the soil. The proposed improvements will also include filling the area along the road to adjust the meander to have a more appropriate radius. This will allow for a smoother transition, decrease the velocity through the improvement site, and shift the highest-velocity flow away from the right bank. The live stakes along the right bank will also help reduce the velocities by increasing the roughness of the bank. The shelf on the left bank will provide the fill material used to fill the existing scoured area and to create the stable slope along the right bank. The length of the bank stabilization will be approximately 360 feet. A schematic layout of the potential improvements is provided in Exhibit 7.

The cost of designing, permitting, and constructing these improvements is expected to be approximately $160,000. A detailed breakdown of the anticipated project cost is provided in Appendix 3.

4.4 PROBLEM AREA AT 305 OLD HICKORY LANE

The problem area at 305 Old Hickory Lane in Adams County, Indiana, as shown in Figure 12 exhibits tension cracking and slab failure for approximately 100 feet along the left bank. The cause of the instabilities is more frequent saturation of the soils, a tall bank height, and the over-steepened nature of the bank.

Figure 12: Bank Failure (top) and Toe of Slope (bottom) at 305 Old Hickory Lane

The observations made during the functional assessment over the past year suggest that the slope is not actively unstable. The anticipated cost of intervention and the apparent stability make monitoring the most prudent measure to take at this time. The homeowner should take care to avoid undue saturation of the bank material by downspout runoff and lawn watering. Should a more proactive means of dealing with the issue be desired, or if the instability returns, the homeowner could proceed with implementing the improvements discussed below.

The proposed improvements consist of installing vegetated gabion baskets along the left bank and regrading the slope above the gabion wall to a stable slope of 3H:1V using locally sourced material. Similar to the situation at 3343 E CR 1200 S, the height of the slope and the close proximity to the home require a more vertical, structurally robust design concept. The length of the improvements will be approximately 235 feet, which includes 145 feet of a 3-block high gabion wall and 90 feet of a 4-block high wall. Live stakes will be used along the bottom of the gabion wall to increase the near-bank roughness, which will help to reduce the flow velocity along the wall. A schematic layout of the potential improvements is provided in Exhibit 8.

The cost of designing, permitting, and constructing these improvements is expected to be approximately $235,000. A detailed breakdown of the anticipated project cost is provided in Appendix 3.

4.5 PROBLEM AREA AT 6500 STATE ROAD 116

Figure 13: Bank failure (top) and Toe of Slope (bottom) at 6500 State Road 116

The problem area located at 6500 State Road 116 south of Vera Cruz, Indiana in Wells County has experienced tension cracking and slab failures along the left bank, as shown in Figure 13. Slope failure has extended approximately 700 feet along the bank and appears to be expanding (Barr 2018). The primary causes of the instabilities are more frequent saturation of the soils and the location along a meander bend.

The proposed improvements consist of regrading the upper slope to the more stable angle of 4H:1V and installing two levels of soil lifts. The lower level will be 4 lifts high and the upper level will be 3 lifts high. The upper level will be set back from the lower lift to create a shelf along the slope. The purpose of incorporating a shelf rather than a single set of 7 soil lifts is to avoid reducing the channel area and to reduce the potential of cars entering the river at this location. Additionally, a guardrail should be incorporated at the top of the slope to prevent vehicles from damaging the improvements and to reduce the potential for vehicles to enter the stream at this location. A free-draining sand and gravel drainage layer will be installed behind and below both sets of soil lifts to help reduce the saturation of the soils. The live stakes will add protection to the lower soil lifts by creating more roughness along the bank which is expected to lower near-bank flow velocity. The length of the bank stabilization will be approximately 430 feet. The proposed improvements do not address the entirety of the unstable bank in this location; it was determined that allowing the bank to go through the natural process of stabilization would be acceptable for the portion of the unstable area that is not near the roadway This helps to minimize the project cost while maintaining the integrity of the road without detrimental impact to the river. A schematic layout of the potential improvements is provided in Exhibit 9.

The cost of designing, permitting, and constructing these improvements is expected to be approximately $287,000. A detailed breakdown of the anticipated project cost is provided in Appendix 3.

4.6 PROBLEM AREA AT 6596 STATE ROAD 116

The problem area located at 6595 State Road 116, south of Vera Cruz, Indiana exhibits tension cracking and slab failure along the left bank, as shown in Figure 14. This problem area is approximately 1,000 feet west of the problem area at 6500 SR 116. Slope failure has occurred along the left bank extending approximately 500 feet and expanding in both the upstream and downstream direction. The causes of the instabilities are more frequent saturation of the soils, the location of the site along a meander bend, and the tall and over-steepened nature of the bank.

Figure 14: Bank Failure at 6596 State Road 116

As with the problem area at 305 Old Hickory Lane, the observations made over the past year suggest that the slope is not actively unstable. Preventing unnecessary saturation of the bank materials from site runoff and lawn watering, along with monitoring, is the most prudent course of action at present. The homeowner could proceed with implementing the improvements discussed below if the instability returns, or if intervention is desired.

The proposed improvements consist of installing vegetated gabion baskets along the left bank and regrading the slope above the gabion wall to a stable slope of 3H:1V using locally sourced material. Similar to the situation at 305 Old Hickory Lane, the height of the slope and the close proximity to the home require a more vertical, structurally robust design concept. The length of the improvements will be approximately 200 feet of a 3-block high gabion wall. The live stakes proposed at the base of the gabion wall increase the roughness, which will reduce the near-bank velocity along the wall. A schematic layout of the potential improvements is provided in Exhibit 10.

The cost of designing, permitting, and constructing these improvements is expected to be approximately $201,000. A detailed breakdown of the anticipated project cost is provided in Appendix 3.

4.7 IMPROVEMENT COST SUMMARY

A summary of the cost estimate for the improvements at each of the problem areas is included in Table 3. The cost estimates are arranged based on the ranking of the problems from most to least critical.

Table 3 Summary of Cost for Each Problem Area

Address	Rank	Cost of Construction	Cost of Engineering	Total Cost
6500 SR 116, Wells County	1	$201,000	$86,000	$287,000
3343 E CR 1200 S, Jay County	2	$324,000	$81,000	$405,000
270 E CR 1100 S, Adams County	3	$96,000	$64,000	$160,000
4100 E CR 1200 S, Adams County	4	$94,000	$63,000	$157,000
305 Old Hickory Lane, Adams County	5	$154,000	$81,000	$235,000
6595 SR 116, Wells County	6	$120,000	$81,000	$201,000

4.8 LIMITATIONS FOR CONCEPTUAL STRATEGIES

The proposed conceptual strategies make several key assumptions that may greatly affect the details and cost of the improvements.

Ordinary High-Water Mark Elevation

The elevation of the Ordinary High-Water Mark (OHWM) has been assumed based on the water surface elevation captured in the IndianaMap DEM. The need for environmental permits from the United States Army Corps of Engineers (USACE) and the Indiana Department of Environmental Management (IDEM) depend heavily on this information.

Location and Adequacy of Till at the Toe of Slope

The exact elevation of the till material relative to the OWHM will also be a determining factor in whether USACE and IDEM permitting will be necessary. It has been assumed that the till material extends to an elevation that is above the actual OHWM.

It has also been assumed that the till material has an erosion resistance that is sufficient to prevent undermining of the proposed improvements. The material has also been assumed to have sufficient strength to support the weight of the proposed improvements without subsidence. While the field observations made during this functional assessment tend to confirm those assumptions, geotechnical testing of the material will be necessary to provide the material properties of the till.

Environmental Permitting and Mitigation

It is anticipated that stabilizing the streambank at all of the proposed locations will require the acquisition of the following environmental permits, at a minimum:

IDNR Construction in a Floodway

IDEM Section 401 Water Quality Certification

USACE Section 404 Dredge & Fill Permit

IDEM Rule 5 Permit

4.9 ALTERNATIVE MITIGATION STRATEGY CONSIDERATIONS

Since the majority of the problem area sites are immediately adjacent to roads, relocation of the roads was considered as an alternative means of reducing the risk to the public. The evaluation was completed on a conceptual level to determine the viability of the alternative mitigation method. Ultimately, the relocation of the roads was not found to be a viable solution for the following reasons:

1. The configuration and instability at each problem area site along a road would still require some form of remedial work to stop the erosion from propagating and eventually compromising the new road location, unless the roads are moved well away from the stream. While the cost of the relocation may be less that the proposed improvements described in Section 4.1, 4.2, 4.3, and 4.5, the costs would still likely be substantial.
2. Additional cost would be incurred to purchase new property for the road to occupy.
3. There would likely be issues with the proximity of adjacent homes.

The effect of foregoing implementation of any improvements was also evaluated from a theoretical standpoint. The ‘Do Nothing’ alternative is generally expected to result in the following:

1. No up-front costs associated with making improvements would be incurred; however, it is likely that repair costs would be incurred if the bank instability compromises the actual travel lanes of the roads or the adjacent properties.
2. The potential closure of a roadway could have economic costs, in addition to the cost of erecting temporary traffic safety measures.
3. The risk to public safety would continue to increase as the erosion further compromises the adjacent public and private spaces.
4. No reduction in sediment contribution to the stream would be realized.

CHAPTER 5 CONCLUSIONS AND RECOMMENDATIONS

The results of the functional assessment described in Chapter 3 suggest that the issues at the identified problem areas can be corrected using site specific stabilization measures provided in Chapter 4. While the improvements are expected to remedy the issues at these specific locations, the improvements are not expected to meaningfully alter the stability of other areas along the river. The following paragraphs outline the improvements that are recommended for implementation based on the findings of the functional assessment and the practicability of the proposed improvements. Additional recommendations to promote the stability and sustainability of the river, as well as additional study needs for future stewardship of the river corridor are provided.

5.1 RECOMMENDED CHANNEL IMPROVEMENTS

1. **Implement Proposed Improvements at 6500 State Road 116**

   The improvements at 6500 State Road 116 are the highest priority due to the potential loss of life at this location. The proposed improvements shown in Exhibit 9 should reduce the potential for cars to enter the river, while protecting the integrity of the roadway.

   Coordination with the Indiana Department of Transportation is advisable to determine if cost-sharing opportunities exist and to establish the ability and limitations associated with implementing the work in the INDOT right-of-way.

2. **Implement Proposed Improvements at 3343 E CR 1200 S, 270 E CR 1100 S, and 4100 E CR 1200 S**

   The improvements at 3343 E CR 1200 S are the second priority due to potential loss of life. The improvements at 3343 E CR 1200 S are prioritized over 270 E CR 1100 S due the greater height of the bank and the closer proximity to the roadway. The problem areas located at 3343 E CR 1200 S and 270 E CR 1100 S are prioritized below 6500 State Road 116 due to the greater amount of traffic on a state road versus a county road.

   The improvements at 4100 E CR 1200 S (Exhibit 5) should be implemented after improvements are made to the problem areas at 6500 State Road 116 (Exhibit 9), 3343 E CR 1200 S (Exhibit 6), and 270 E CR 1100 S (Exhibit 7), and as funding allows.

3. **Monitor Bank Instability at 305 Old Hickory Lane and 6596 State Road 116**

   No improvements are recommended at 305 Old Hickory Lane (Exhibit 8) and 6596 State Road 116 (Exhibit 10). No immediate action appears to be necessary at these locations. The bank instabilities at these locations should be monitored. Should the conditions change, and a proactive approach by the homeowner(s) is desired, the homeowner(s) can implement the improvements discussed in Chapter 4 for these problem areas. To help avoid matters from getting worse, it is recommended that the homeowners avoid saturating the slopes with water from storm drainage or watering the lawns (Barr 2018).

5.2 RECOMMENDED PASSIVE MANAGEMENT PRACTICES

As discussed in Chapter 3, the observed (and projected) peak discharge increasing trends have and will continue to act as a watershed stressor, exacerbating the potential for slope failures along Wabash River. While the scope of this study did not include an examination of all the reasons for the observed and forecasted increases, based on experience with similar areas in Northern Indiana, the major factors contributing to peak discharge increases along the stream are the impacts of climate change in frequency, intensity, and depth of precipitation, increase in runoff peaks and volumes resulting from Urban development and agricultural drainage practices, and encroachment and loss of floodplain storage within the river corridor. The following passive management practices should be promoted and implemented to help reduce the impacts of watershed stressors.

5.2.1 Soil Health Practices

In agricultural areas, the health of the soil has been found to have a noticeable impact on runoff amounts. More organic material in the soil equates to an increase in soil moisture potential, or the ability of the soil to store water. Essentially, organic material in the soil is the agricultural equivalent of bioinfiltration/rain gardens in the urban setting. There are also substantial benefits for agriculture in terms of decreased energy overhead and increased drought tolerance. The set of practices that the NRCS terms "soil health" appear to be the future of sustained agriculture and have the potential to change water management in agricultural regions of the United States.


Figure 15: Cover Crop Growing in Harvested Corn Field

Current farming practices focus on tillage and clearing the land for "the crop". Soil health practices instead focus on continuing the crop and continuing to improve the soil. An example of a cover crop for improving soil health is shown in Figure 15. Soil health is a work in progress, with experiments across the country attempting to document the benefits of a soil health system. Farmers in Indiana are reporting increased drought tolerance and an increase of as much as 27,000 gallons of water per acre with a 1% increase in soil organic matter; this is approximately equal to storing 1-inch of runoff. That number will certainly vary with soil texture, antecedent conditions, and a number of other factors but the significance is that soil moisture storage can be increased – significantly.

In a watershed like the Upper Wabash River with limited natural storage, increasing the infiltration and runoff storage potential of the soil is one of the most effective ways to reduce runoff. To highlight the potential magnitude of the benefit that could be afforded by improved soil health, the total flow volume of the Upper Wabash River at the Bluffton gage was 409,300 ac-ft in 2018. If the cultivated portions of the watershed (~450 mi^2) were to increase the organic content of the soil by 1%, an additional 24,000 ac-ft of runoff could be stored in the soil. This would have reduced the volume of flow through the Upper Wabash River by approximately 5.8%.

5.2.2 Ordinance and Standards revisions

Maintaining current and strict stormwater ordinance and technical standards is critical to protecting the integrity of the stream corridor. To be effective, stormwater regulations must utilize current methods and technology, promote the use of infrastructure designs that mimic the natural / pre-development watershed, protect sensitive / critical environmental areas, and compensate for unavoidable adverse impacts to the stream system.

The analysis of the Upper Wabash River at Linn Grove stream gage data shows a clear increasing trend in flow rates despite the current level of stormwater detention requirements within the watershed. Although detention has been required in both Adams and Wells Counties, a more consistent and accurate determination of maximum allowable release rates, calculated based on calibrated watershed-wide hydrologic modeling may improve the effectiveness of peak flow control measures. Sub-watershed specific maximum 100-year and 10-year allowable release rates (cfs/acre) required for any new development and re-development within the watershed should be calculated and adopted for various developing drainage basins.

The current requirements also lack the needed control of more frequent, channel forming events and provisions for infiltrating or at least significantly delaying the Channel Protection Volume (the volume of runoff created during the 1-year, 24-hour rainfall event) to prevent further increase in flow rates.

Low Impact Development (LID) and Green Infrastructure (GI) practices should also be promoted and employed to the greatest extent practicable to reduce the amount of stormwater runoff from a developed site. These methods offer a two-fold benefit. The total volume of runoff is reduced due to use of Best Management Practices (BMPs) that allow water to infiltrate into the soil, which results in lower required detention volumes and less runoff delivered to the stream. The second benefit is the flow rate leaving a site is lower than a conventionally designed site and mimics the natural release of stormwater runoff. When implemented well, the pre-development and post-development stormwater runoff metrics are nearly identical, resulting in no changes to the hydrology of the stream.

When large areas in the watershed are planned for development or redevelopment, a holistic approach should be used to design the stormwater infrastructure for the entire development, rather than a site-by-site design. By considering how the infrastructure will function as a whole, the incremental increases in flow rate and flow volume can be more comprehensively addressed. Regional detention may serve as an acceptable method of holistic design. If a site-by-site design concept is more practicable for a given situation, tertiary stormwater infrastructure should be allowed for to act as shock absorbers prior to releasing the flow from the development area.

Environmentally sensitive areas serve a critical role in the stream system. These areas include floodplains, floodways, wetlands, and riparian areas that provide stormwater storage to reduce flow rates, flow conveyance to minimize flood elevations, energy dissipation to reduce erosion, provide habitat for the organisms at the beginning of the food chain, and process natural and manmade pollutants. Development in these areas should be discouraged and prohibited where possible. Where it is not possible or practicable to avoid these areas, compensatory mitigation should occur that will provide the same benefits. It should be noted that a 1:1 ratio for compensatory mitigation (detention/floodplain storage, wetlands, trees, etc.) may not provide the same benefit to the system due to location, quality, and/or maturity. Mitigation ratios should be established to provide equal (or greater) benefit immediately after construction and onward.

Adams and Wells Counties should update their Stormwater standards to include the above-noted more restrictive, No-Adverse-Impact requirements when new development is proposed within the County jurisdictional areas.

5.2.3 Increased Buffer Width

The buffer on the riparian corridor should be increased to reduce the detrimental impact of natural stream adjustments and to prevent incompatible land uses along the stream. While the removal of tillable land and reduced utility in urban areas has a cost, there is an economic benefit to increasing the buffer width for landowners adjacent to eroding areas. Planting crops along a bank that later fails and takes the young crop with it, caring for a lawn that sloughs into the channel, or constantly attempting to repair or stabilize the bank are all expenses that are potentially unnecessary in the end. Individual landowners typically only have a problem with erosion along a stream if they have something too close to the channel and are at risk of losing their investment. If the buffer width is adequate, the problem with the erosion (even if the erosion continues) is typically eliminated.

5.3 ADDITIONAL STUDY NEEDS

The following list provides the additional study needs relative to the proposed improvements and recommendations. The additional study needs identified in 1 and 2 below should be completed with the detailed design of the selected project(s).

1. Complete a geotechnical analysis to determine the material properties of the till material. Other geotechnical issues should also be evaluated depending on the project(s) being implemented.
2. Complete and evaluation of the selected project site(s) to determine the presence or absence of Waters of the US and confirm the jurisdictional determination with the USACE and IDEM.
3. Evaluate the stormwater ordinances and technical standards within the Upper Wabash Watershed and make revisions as required to promote sustainability and good stewardship of the river corridor through additional provisions discussed in Section 5.2.2.

5.4 NEXT STEPS

The following list provides the actions that should be taken after review of the functional assessment report:

1. Meet with CBBEL to discuss the findings and recommendations of this report.
2. Encourage the homeowners at 305 Old Hickory Lane and 6596 State Road 116 to monitor the bank conditions for significant changes to the slope.
3. Determine which project(s) are to be implemented and seek sufficient project funding. Begin detailed design after funds have been allocated.

CHAPTER 6 REFERENCES

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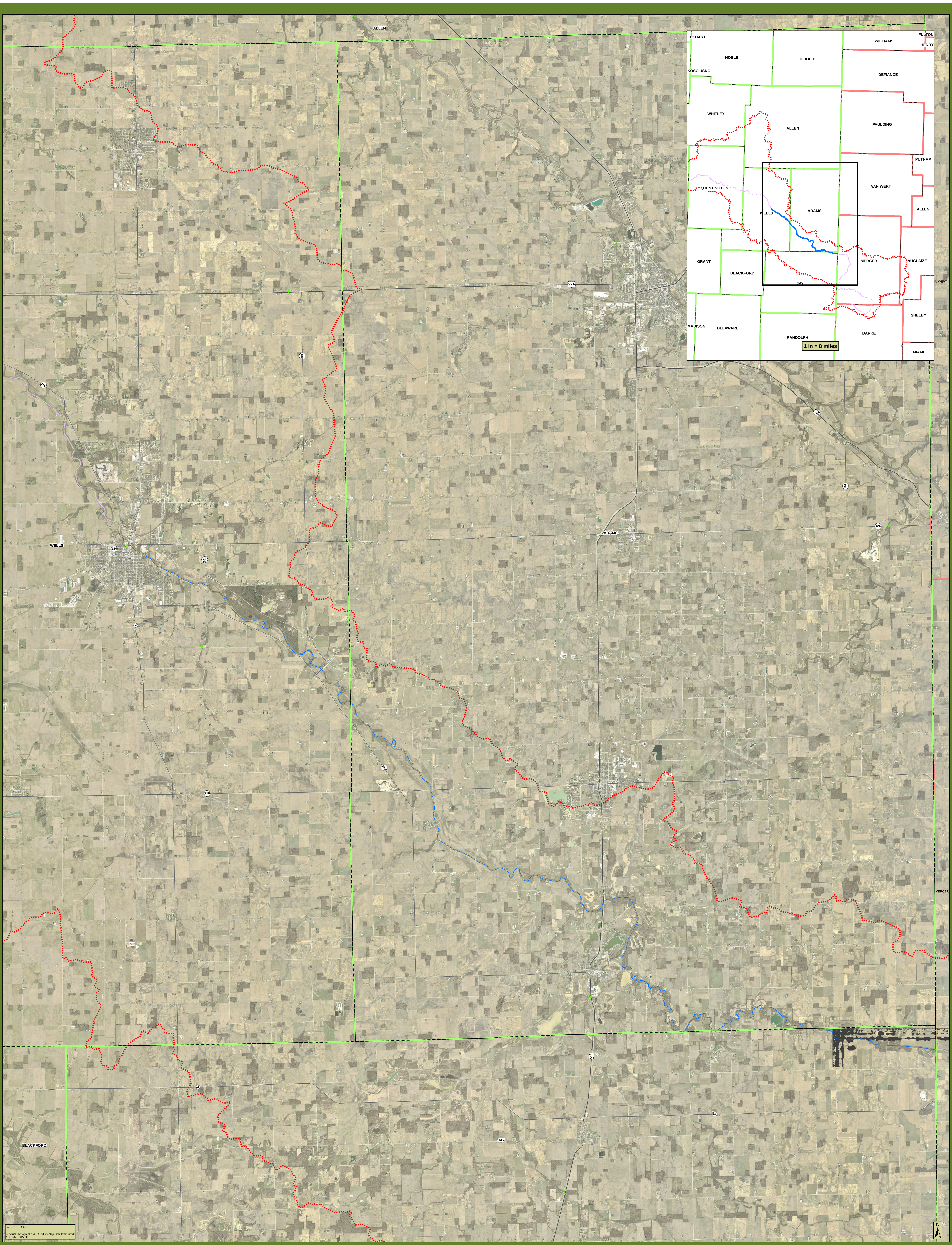
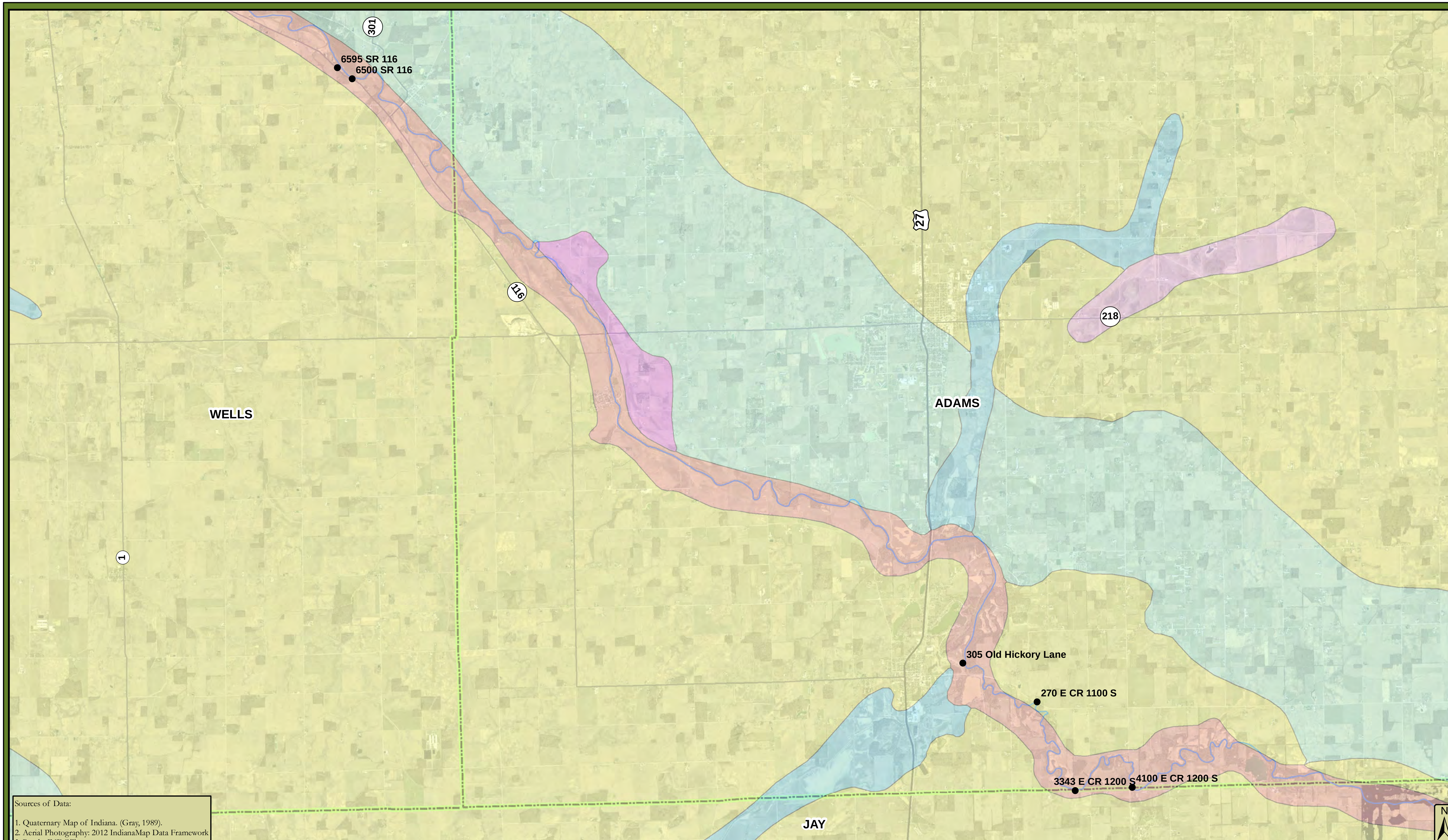
EXHIBITS



Legend

- USGS Gage Locations
- UpperWabashWatershed
- Upper Wabash River (Excluded)
- Upper Wabash River (Included)
- Indiana County Boundaries
- Ohio County Boundaries
- Interstate Hwy
- US Hwy
- State Hwy

Christopher B. Burke Engineering, LLC PNC Center, Suite 1368 South 115 West Washington Street Indianapolis, Indiana 46204 (t) 317.266.8000 (f) 317.632.3306	PROJECT: Functional Assessment of the Upper Wabash River	PROJECT NO. 17-0512	APPROX. SCALE 1"=3,500'
	TITLE: Study Area Map		DATE: 12/2018
			EXHIBIT 1



Sources of Data:

1. Quaternary Map of Indiana. (Gray, 1989).
2. Aerial Photography: 2012 IndianaMap Data Framework
3. Roads: INDOT

Legend

- Problem Areas

Quaternary

- Alluvium
- Ice-contact stratified drift
- Intensely pitted outwash deposits
- Lake
- Lake sand
- Lake silt and clay
- Limestone and dolomite
- Loam till
- Mixed drift
- Muck
- Outwash-fan deposits
- Silty clay-loam to clay-loam
- Silty clay-loam to clay-loam till
- Undifferentiated outwash
- Upper Wabash River (Excluded)
- Upper Wabash River (Included)
- Indiana County Boundaries
- Interstate Hwy
- US Hwy
- State Hwy

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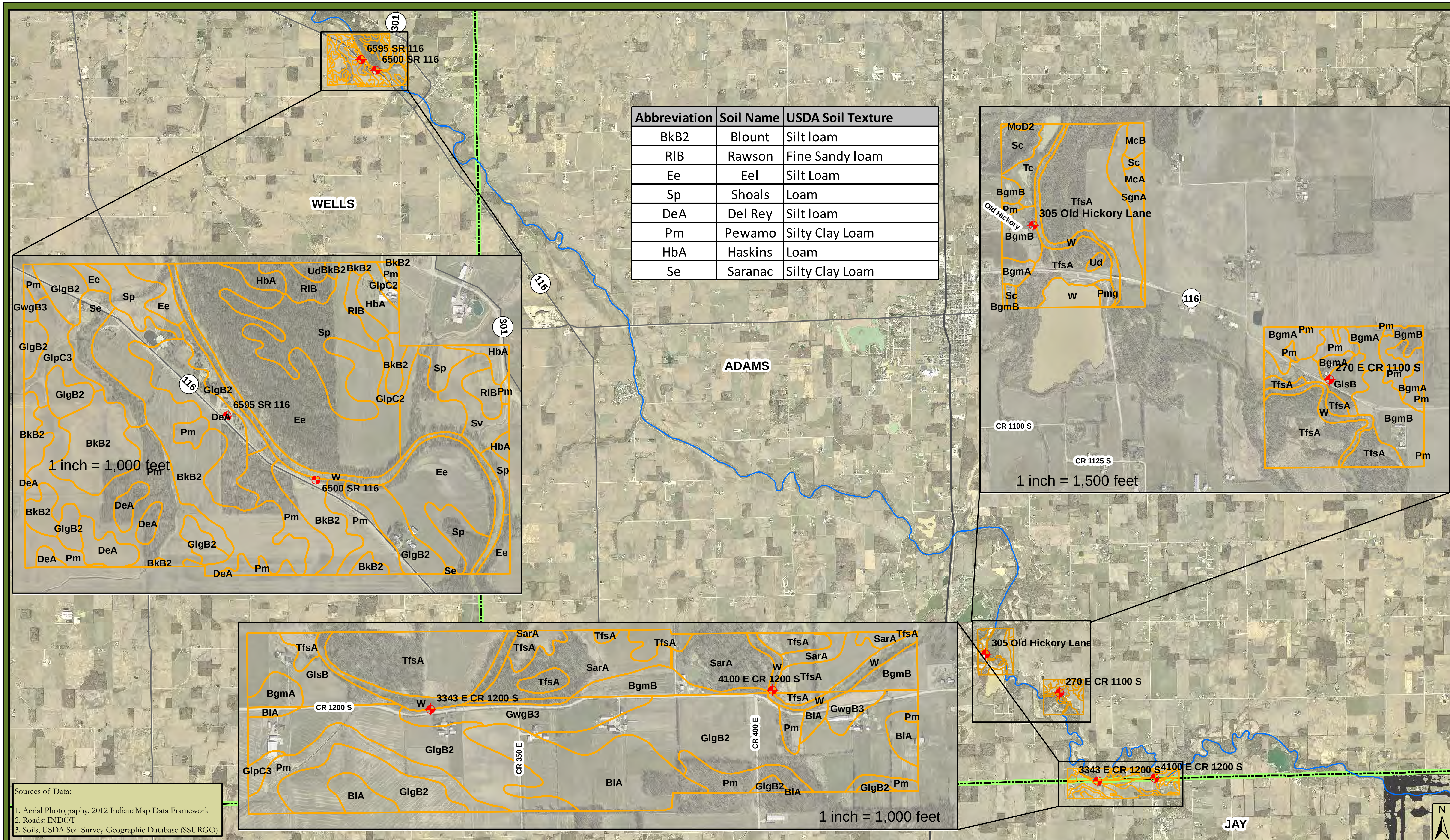
PROJECT:	Functional Assessment of the Upper Wabash River	PROJECT NO. 17-0512	APPROX. SCALE 1"=6,000'
TITLE:	Surificial (Quaternary) Geology Map		DATE: 12/2018
			EXHIBIT 2



Abbreviation	Soil Name	USDA Soil Texture
BkB2	Blount	Silt loam
RlB	Rawson	Fine Sandy loam
Ee	Eel	Silt Loam
Sp	Shoals	Loam
DeA	Del Rey	Silt loam
Pm	Pewamo	Silty Clay Loam
HbA	Haskins	Loam
Se	Saranac	Silty Clay Loam

Legend

- Problem Areas
- Soils
- Upper Wabash River (Excluded)
- Upper Wabash River (Included)
- Indiana County Boundaries
- Interstate Hwy
- US Hwy
- State Hwy

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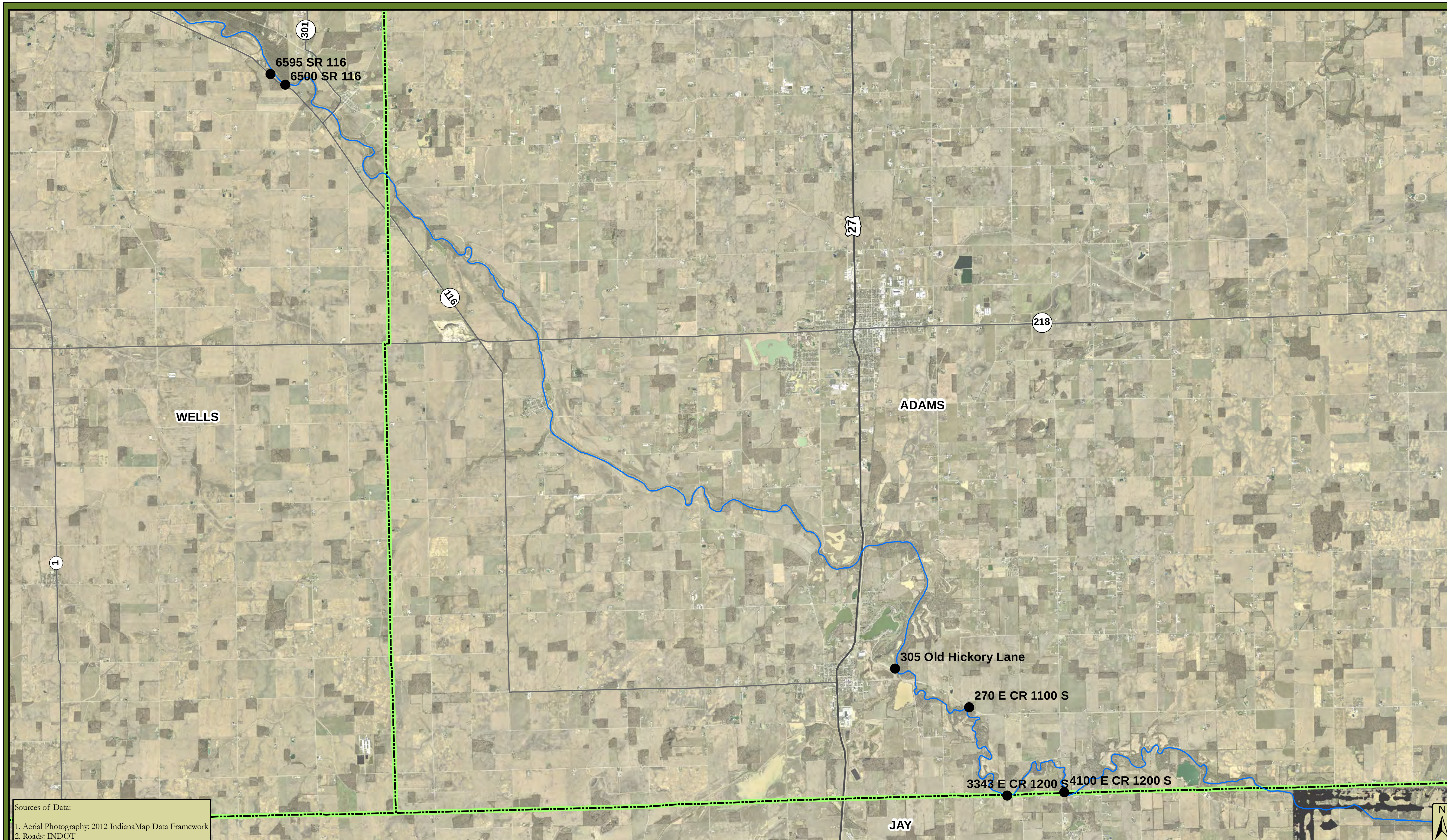
PROJECT:	Functional Assessment of the Upper Wabash River
PROJECT NO.	17-0512
APPROX. SCALE	1"=1,000'
DATE:	12/2018
TITLE:	Soils Map
EXHIBIT	3



Legend

- Problem Areas
- Indiana County Boundaries
- Upper Wabash River (Excluded)
- Upper Wabash River (Included)
- Interstate Hwy
- US Hwy
- State Hwy

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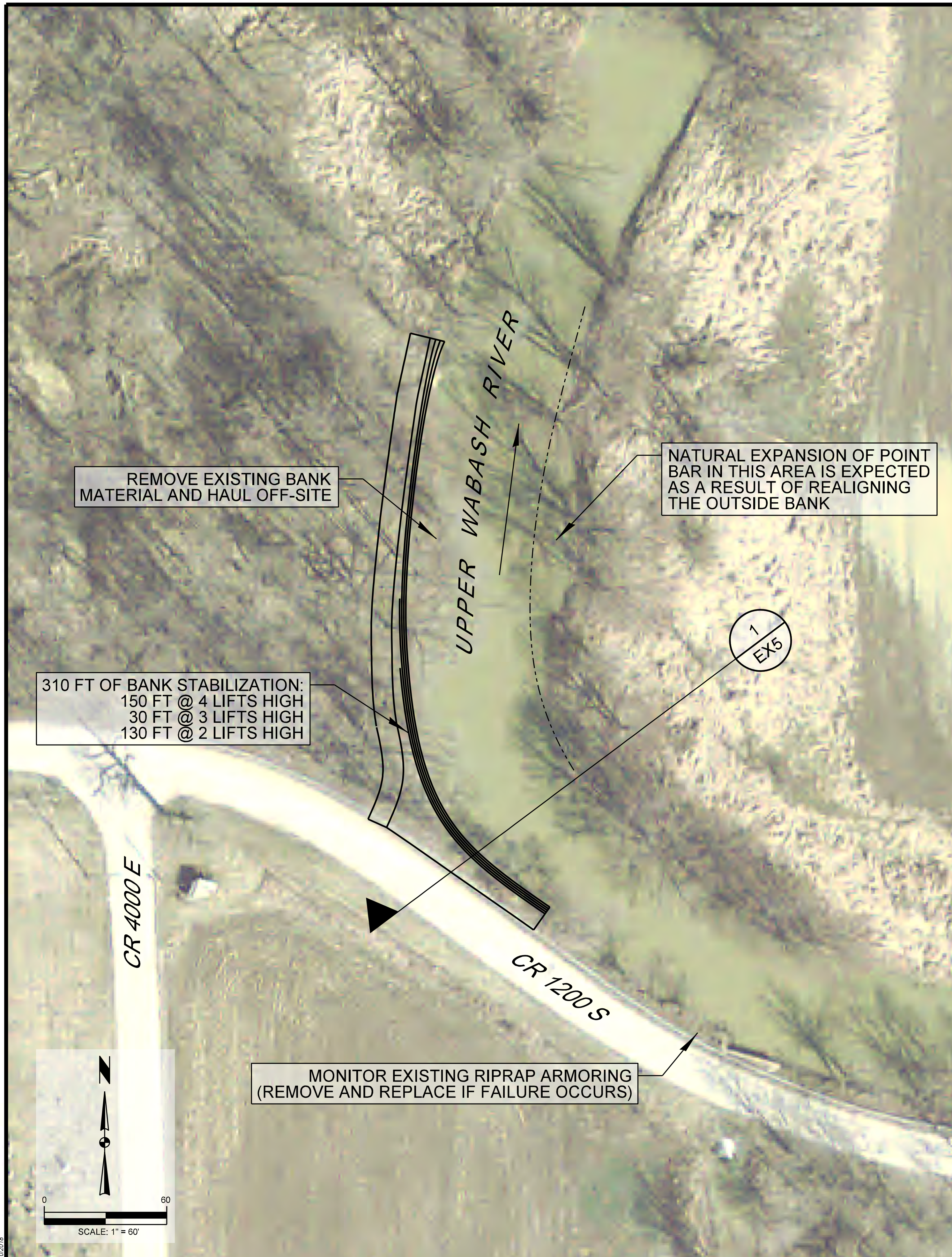
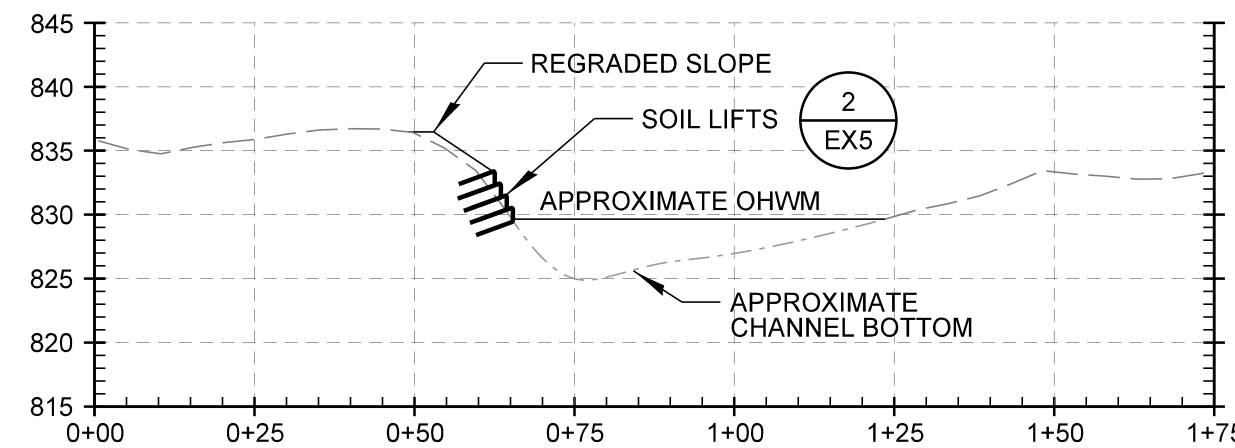
PROJECT: Functional Assessment of the Upper Wabash River	PROJECT NO. 17-0512	APPROX. SCALE 1"=6,000'
TITLE: Problem Area Map		DATE: 12/2018
		EXHIBIT 4





1 PROPOSED CHANNEL IMPROVEMENTS
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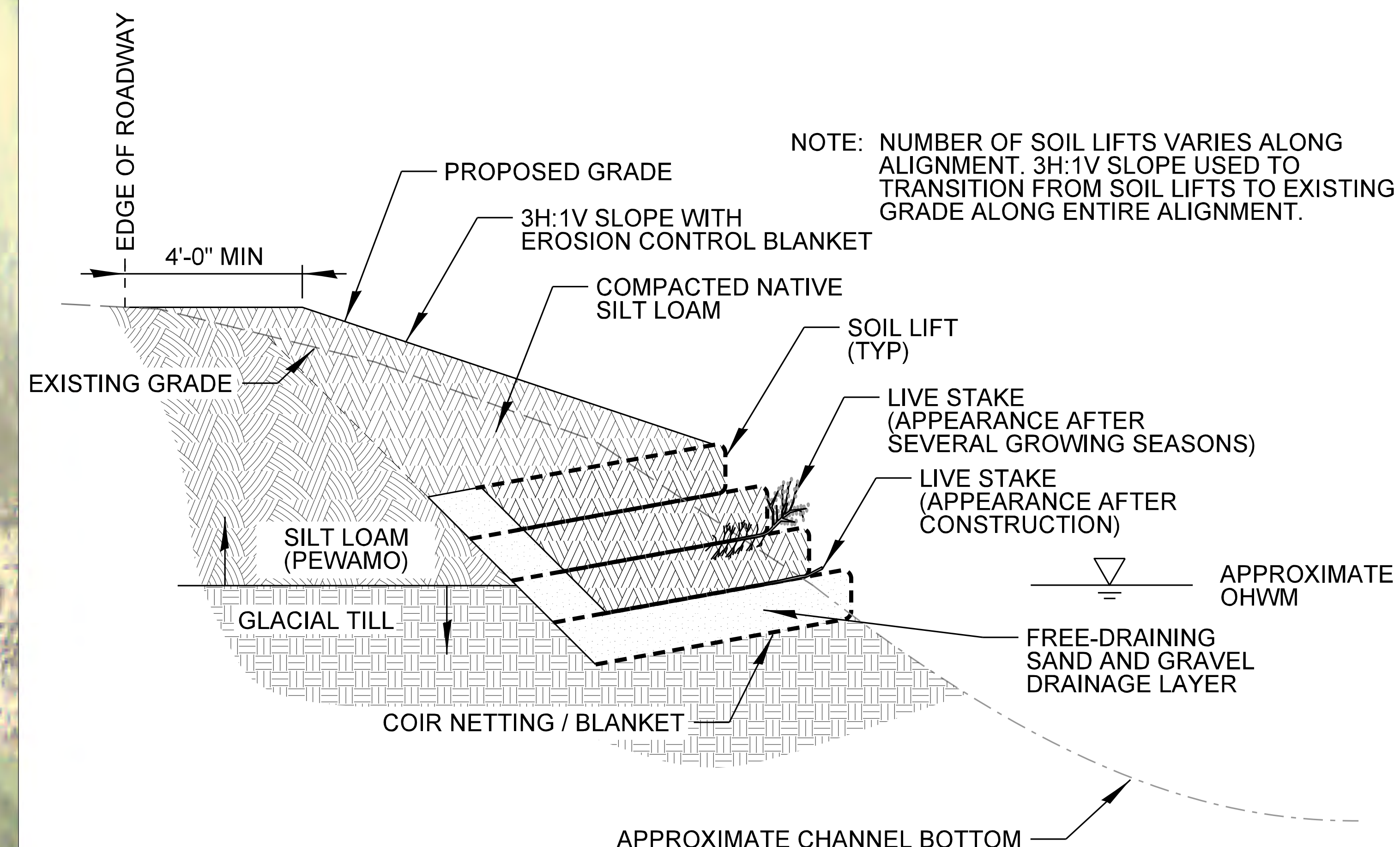
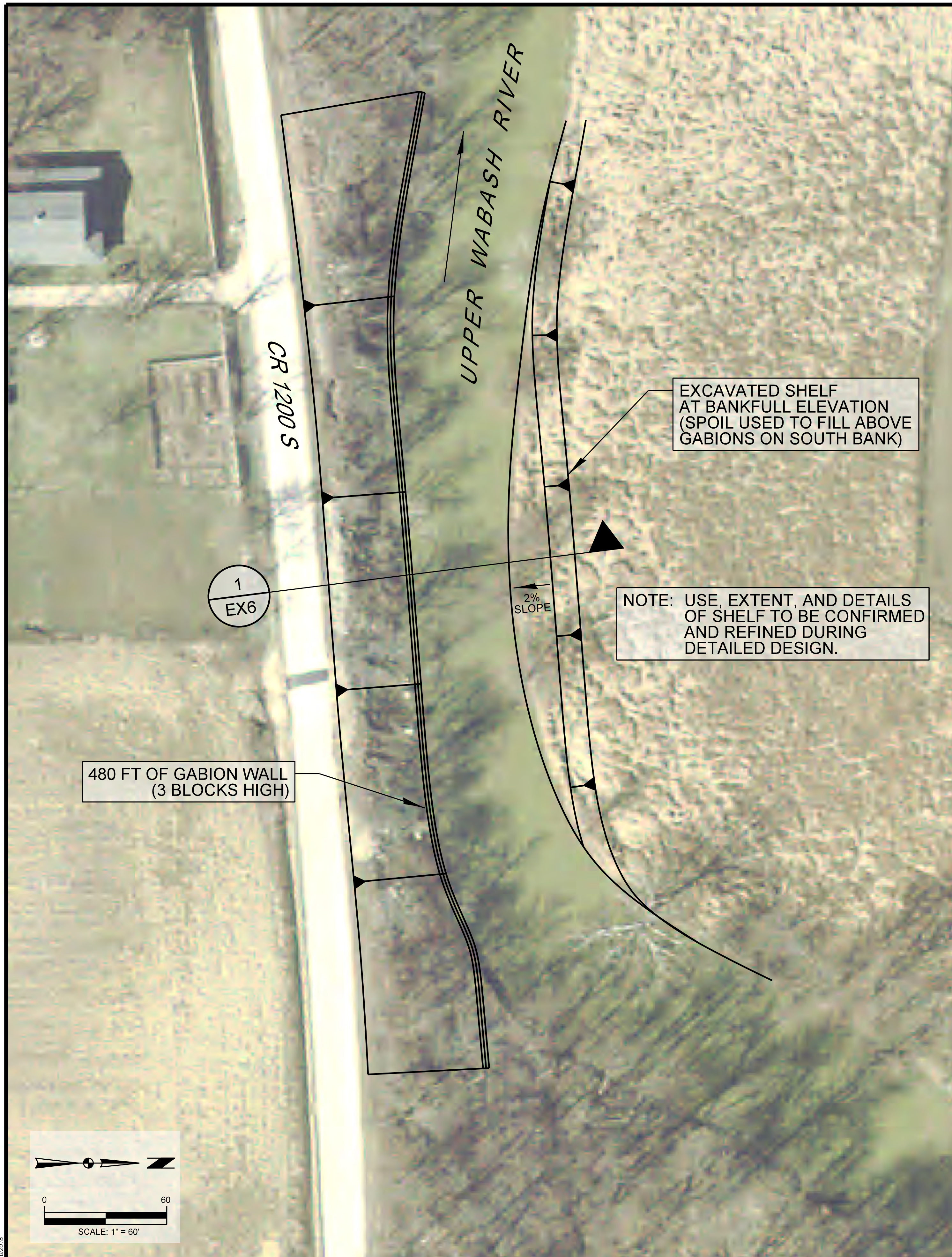
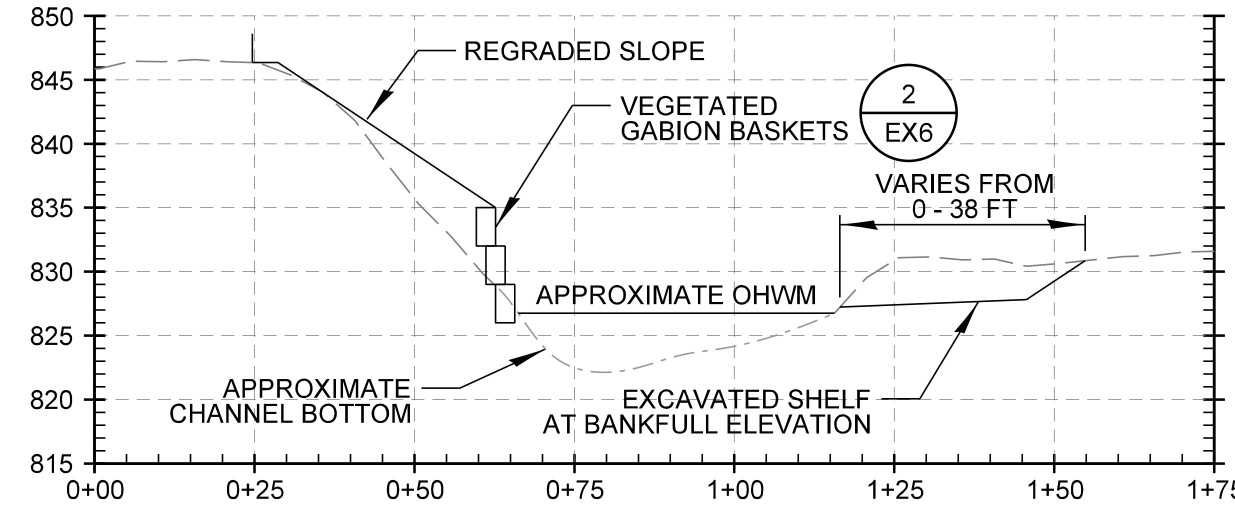


2 TYPICAL SOIL LIFT DETAIL
NOT TO SCALE

CHRISTOPHER B. BURKE ENGINEERING, LLC PNC Center, Suite 1368 South 115 West Washington Street Indianapolis, Indiana 46204 (317) 266-8000 FAX: (317) 632-3306	CERTIFIED: PRELIMINARY NOT FOR CONSTRUCTION	TITLE: PROPOSED IMPROVEMENTS AT 4100 E CR 1200 S	PROJECT NO. 19.R170512.00000 SHEET 1 OF 6	
		PROJECT: FUNCTIONAL ASSESSMENT OF THE UPPER WABASH RIVER	DRAWING NO. EX5	





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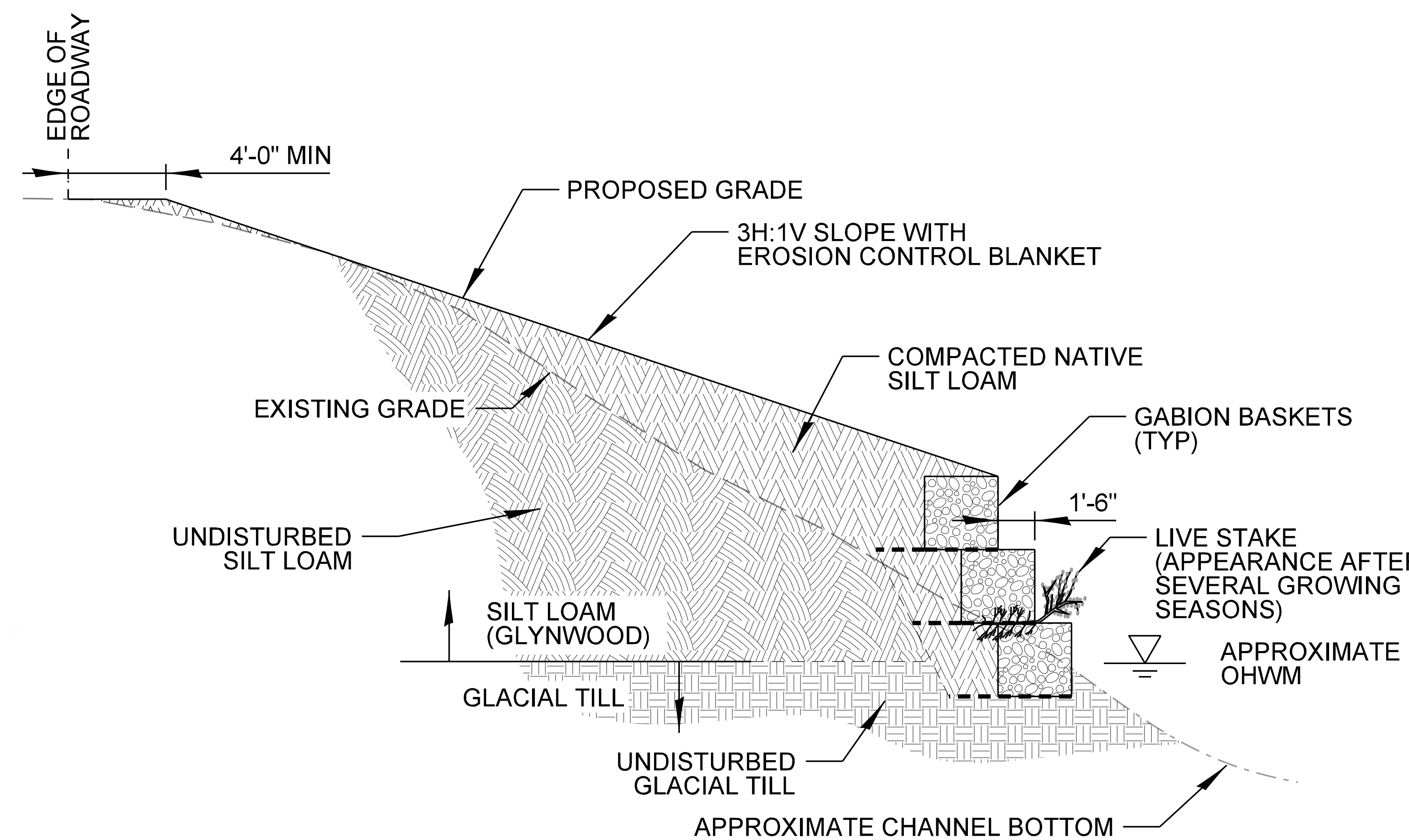

2 TYPICAL GABION WALL DETAIL
NOT TO SCALE

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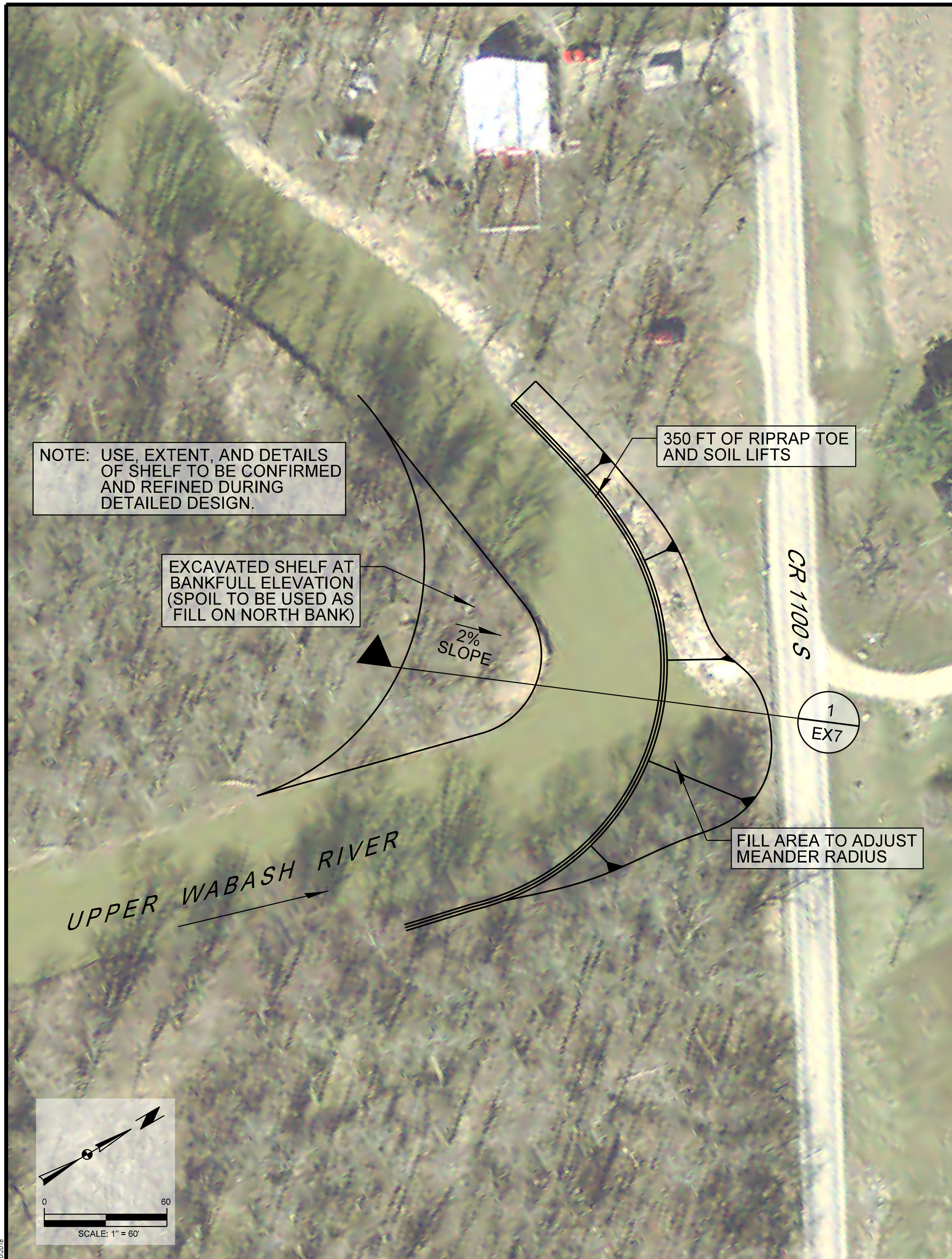
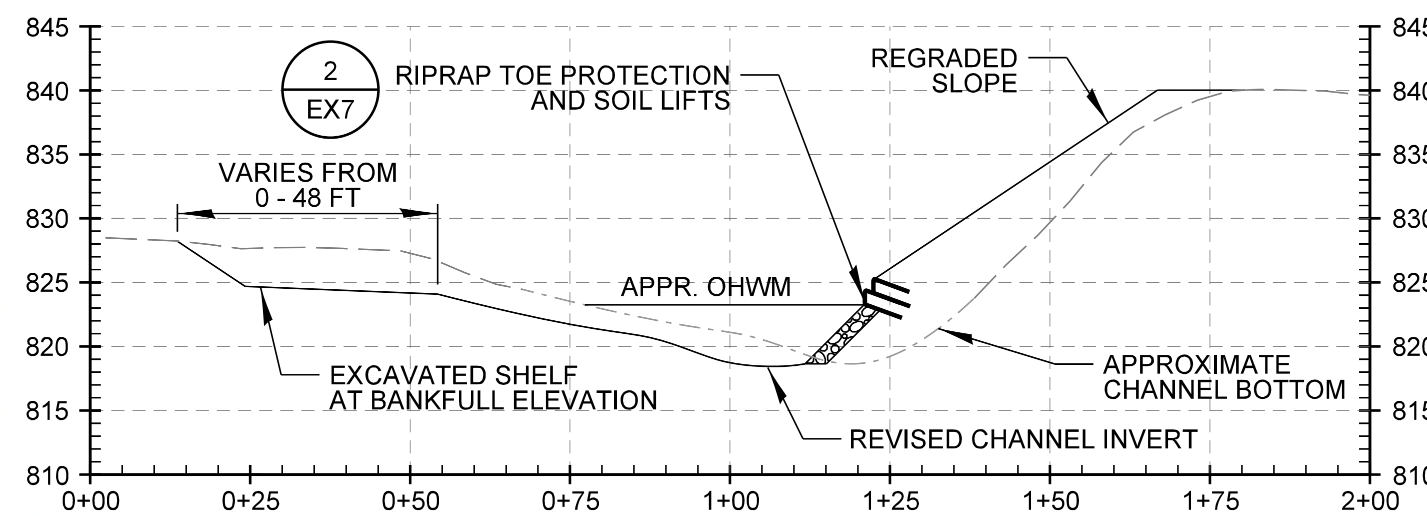
CERTIFIED: PRELIMINARY NOT FOR CONSTRUCTION

TITLE: PROPOSED IMPROVEMENTS AT 3343 E CR 1200 S

PROJECT: FUNCTIONAL ASSESSMENT OF THE UPPER WABASH RIVER

PROJECT NO. 19.R170512.00000
SHEET 2 OF 6
DRAWING NO. EX6





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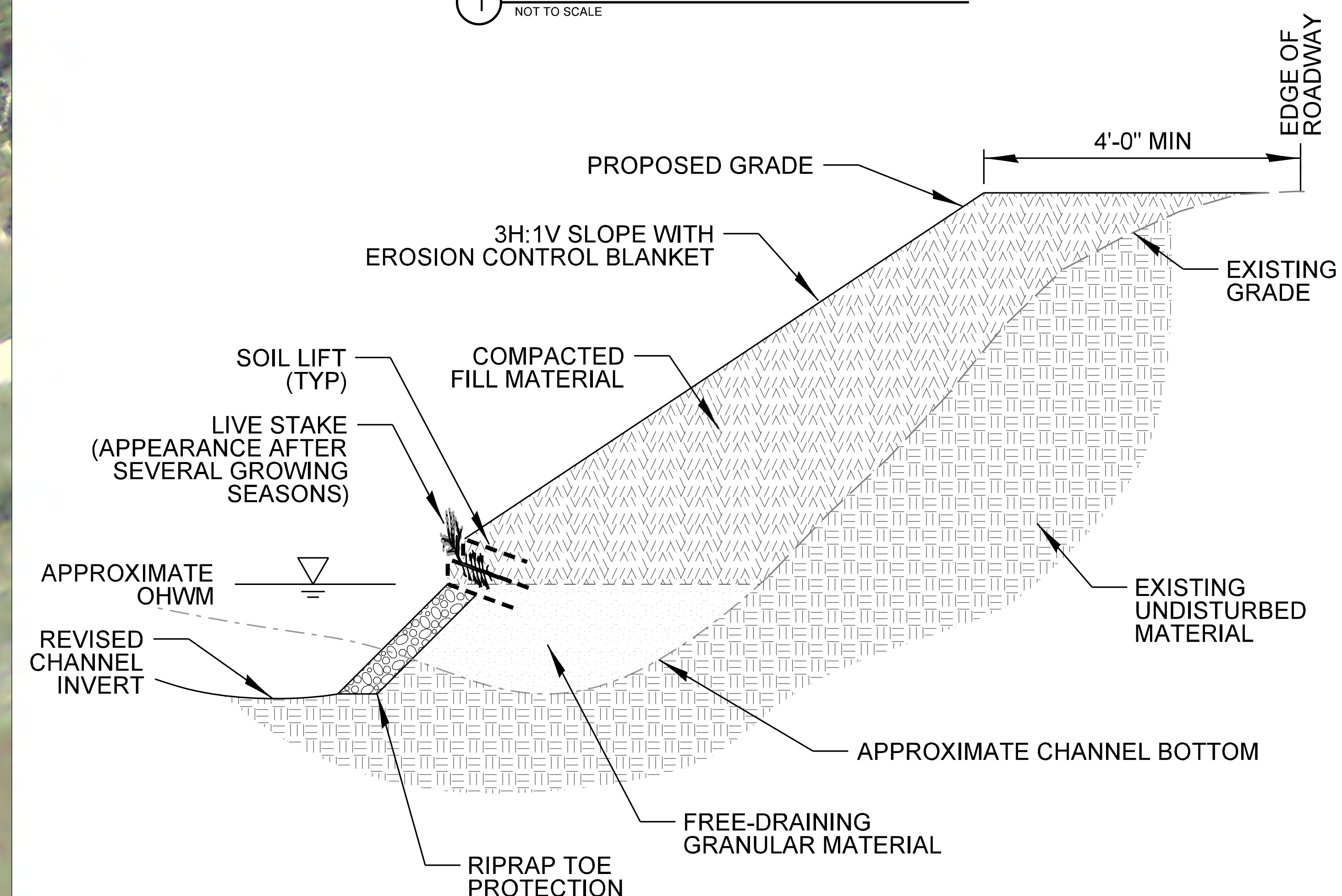

2 TYPICAL RIPRAP TOE AND SOIL LIFT DETAIL

NOT TO SCALE

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PRELIMINARY NOT FOR CONSTRUCTION	PROPOSED IMPROVEMENTS AT 270 E CR 1100 S	19.R170512.00000
		SHEET 3 OF 6
	PROJECT: FUNCTIONAL ASSESSMENT OF THE UPPER WABASH RIVER	DRAWING NO. EX7

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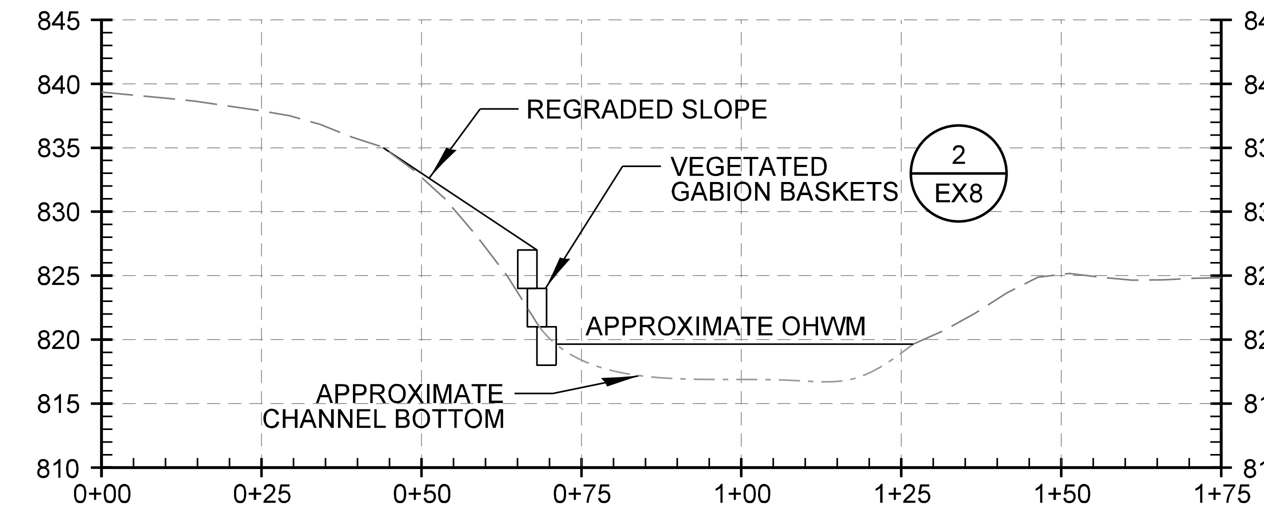
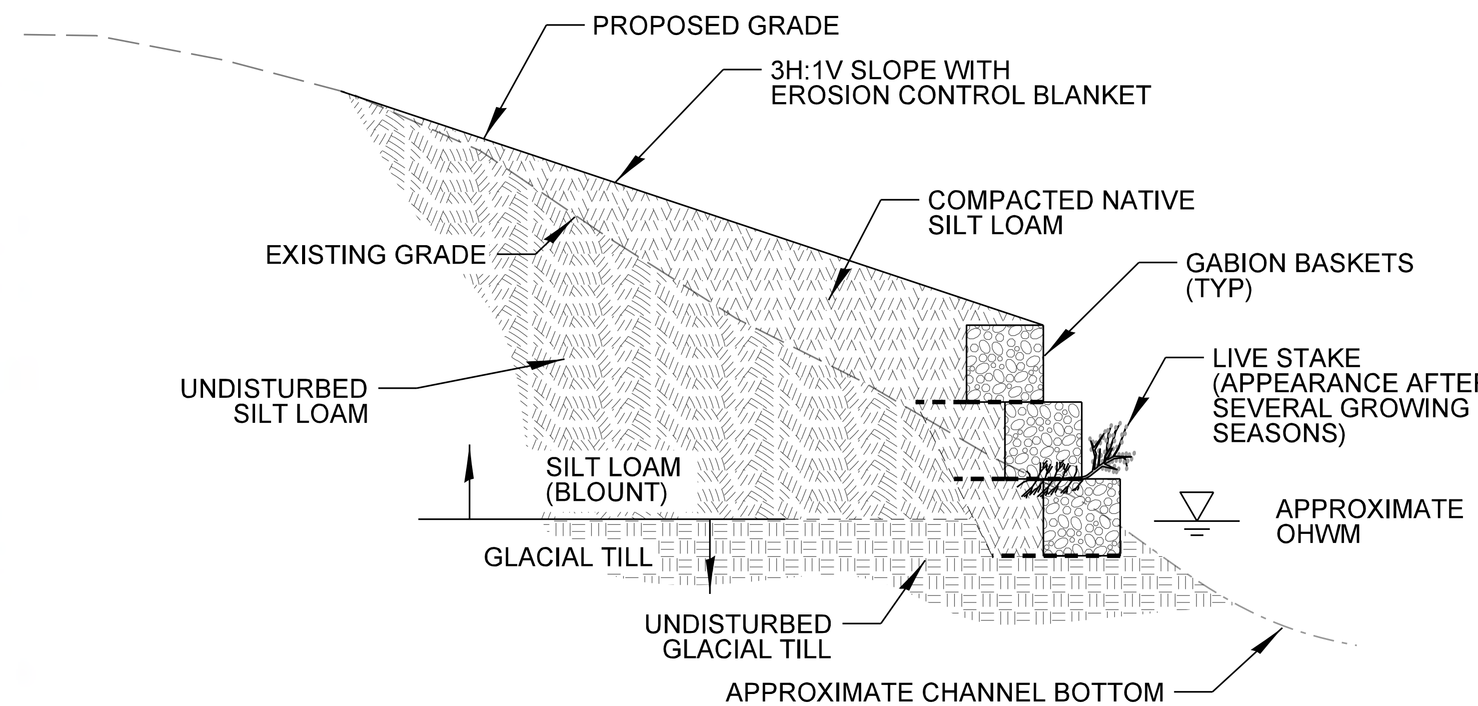
12/10/2018



1 PROPOSED CHANNEL IMPROVEMENTS
NOT TO SCALE

NOTE: SOIL LIFTS COULD BE USED AS AN ALTERNATIVE METHOD TO STABILIZE THE SLOPE; HOWEVER, THE NUMBER OF LIFTS REQUIRED RANGES FROM 6 TO 12 LIFTS AND MAY NOT BE AS COST EFFECTIVE.



2 TYPICAL GABION WALL DETAIL
NOT TO SCALE

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CERTIFIED:	TITLE:	PROJECT NO.
PRELIMINARY NOT FOR CONSTRUCTION	PROPOSED IMPROVEMENTS AT 305 OLD HICKORY LANE	19.R170512.00000
	PROJECT: FUNCTIONAL ASSESSMENT OF THE UPPER WABASH RIVER	SHEET 4 OF 6
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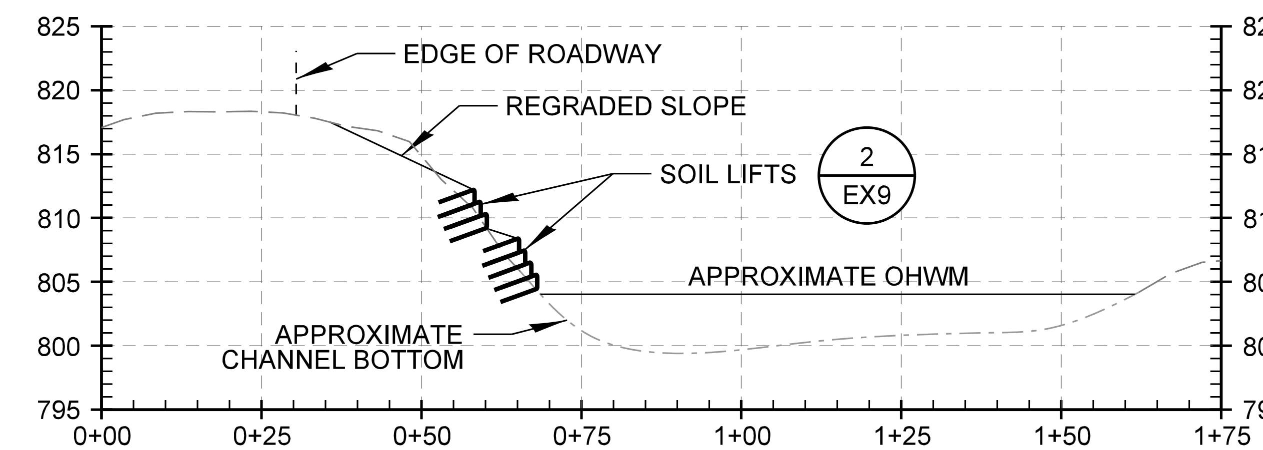

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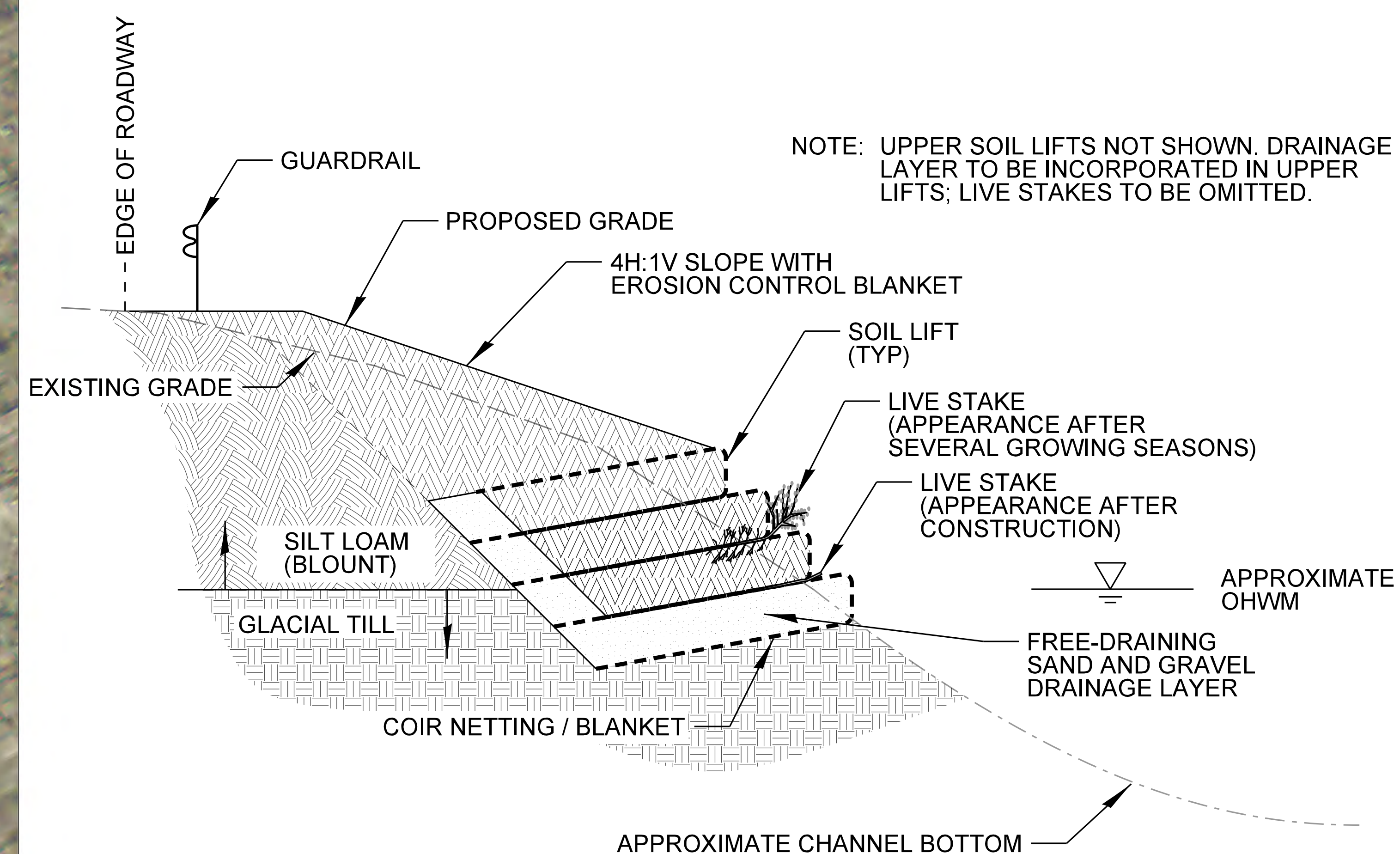

2 TYPICAL SOIL LIFT DETAIL
NOT TO SCALE

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(317) 266-8000 FAX: (317) 632-3306

CERTIFIED:
PRELIMINARY
NOT FOR CONSTRUCTION

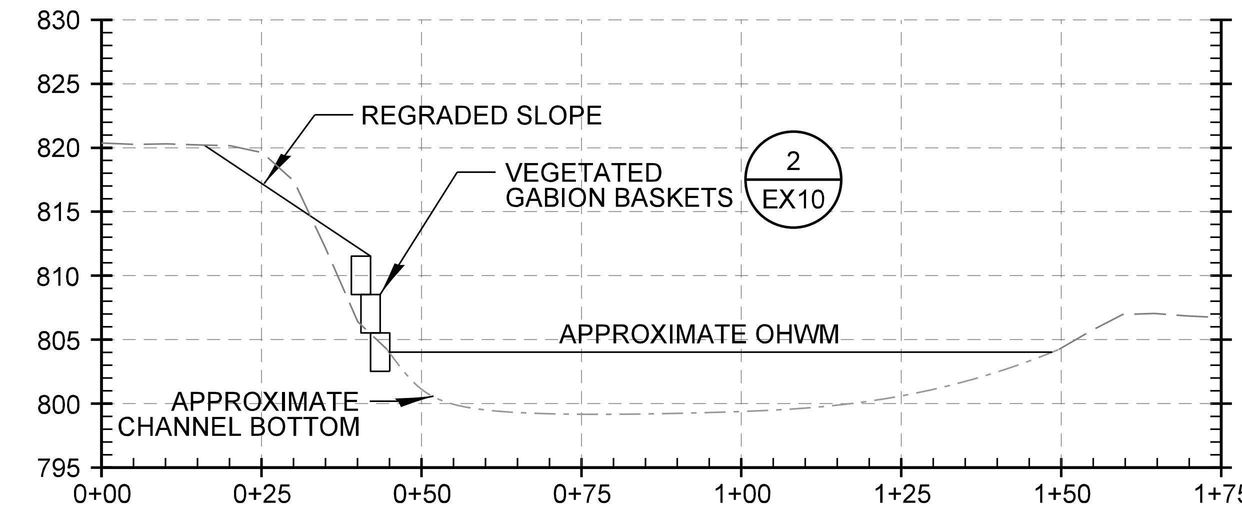
TITLE: PROPOSED IMPROVEMENTS AT 6500 STATE ROAD 116

PROJECT: FUNCTIONAL ASSESSMENT OF THE UPPER WABASH RIVER

PROJECT NO. 19.R170512.00000

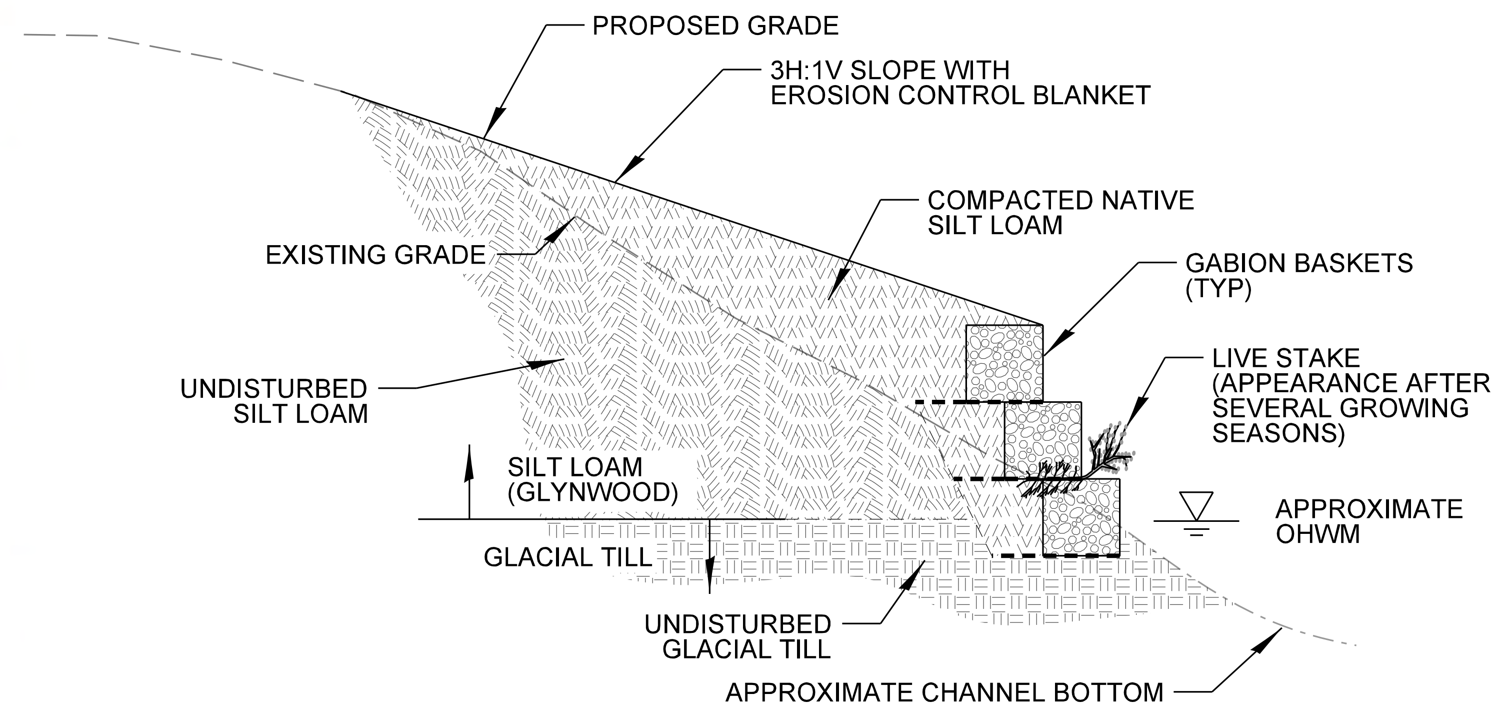
SHEET 5 OF 6

DRAWING NO. EX9



① PROPOSED CHANNEL IMPROVEMENTS
NOT TO SCALE

NOTE: SOIL LIFTS COULD BE USED AS AN ALTERNATIVE METHOD TO STABILIZE THE SLOPE; HOWEVER, THE NUMBER OF LIFTS REQUIRED RANGES FROM 6 TO 12 LIFTS AND MAY NOT BE AS COST EFFECTIVE.



② TYPICAL GABION WALL DETAIL
NOT TO SCALE

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CERTIFIED: PRELIMINARY NOT FOR CONSTRUCTION

TITLE: PROPOSED IMPROVEMENTS AT 6595 STATE ROAD 116

PROJECT: FUNCTIONAL ASSESSMENT OF THE UPPER WABASH RIVER

PROJECT NO. 19.R170512.00000

SHEET 6 OF 6

DRAWING NO. EX10

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12/10/2018

APPENDICES

Appendix 1: Geomorphic Assessment Report

Functional Assessment of a Portion of the Upper Wabash River, Adams, Jay, and Wells Counties, Indiana

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Prepared for: Christopher B. Burke Engineering, LLC
December 2018

Wabash River near Bluffton, Indiana

CBBEL Project 19. R170512.00000

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1.0 PROJECT DESCRIPTION

Conduct a functional assessment of the Upper Wabash River in Adams, Jay, and Wells Counties from the Ohio State line to Bluffton, Indiana. The initial reconnaissance will include 33 miles of the main channel of the Upper Wabash in Indiana from the Ohio State Line to Bluffton, as well as an overview of the 30 miles of the Upper Wabash in Ohio. Reconnaissance in Ohio will be limited to remote observations. Detailed assessments will be conducted on the Indiana portion of the river with a focus on identifying areas contributing to channel instability.

2.0 STUDY AREA

This report focuses on the main channel and riparian zone of the Upper Wabash River from the Indiana - Ohio state line in northeastern Jay County to Bluffton, Indiana. The overall stream length for the primary study reach is 28.0 miles. The study also included a reconnaissance of the upper headwaters of the Wabash River which originates upstream of Fort Recovery in Mercer County, Ohio. The drainage area of the Wabash River above Beaver Creek near Wabash, Ohio is 119 mi^2. The Wabash River combines with Beaver Creek approximately 1 mile west of Grand Lake St Mary's and flows west into Indiana. The drainage area of the Wabash River at the Indiana – Ohio state line is 260 mi^2 (Figure 1). Note that both drainage area and discharge are problematic because of the inclusion of a portion of Grand Lake which discharges directly into Beaver Creek through a spillway located near Celina, OH. (Figure 1). The study area watershed at Bluffton, Indiana (USGS Gage 03323000) is 532 mi^2.

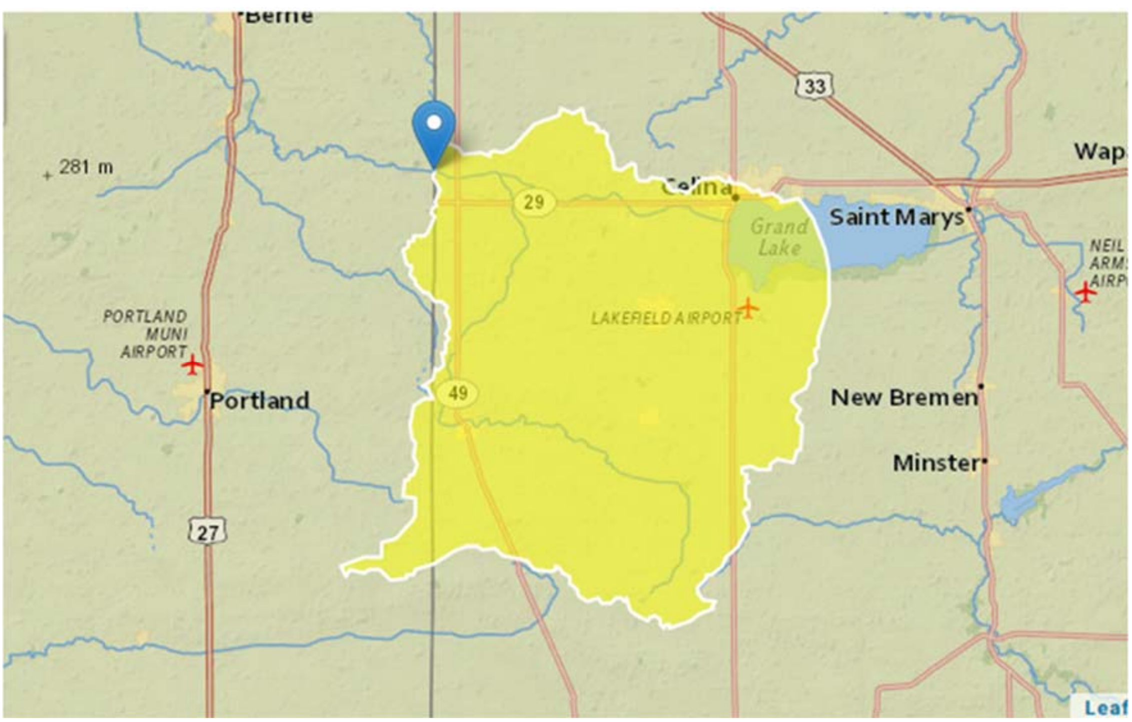

Figure 1: Wabash River watershed at the Indiana-Ohio state line (Drainage Area = 260 mi^2)
(USGS StreamStats)

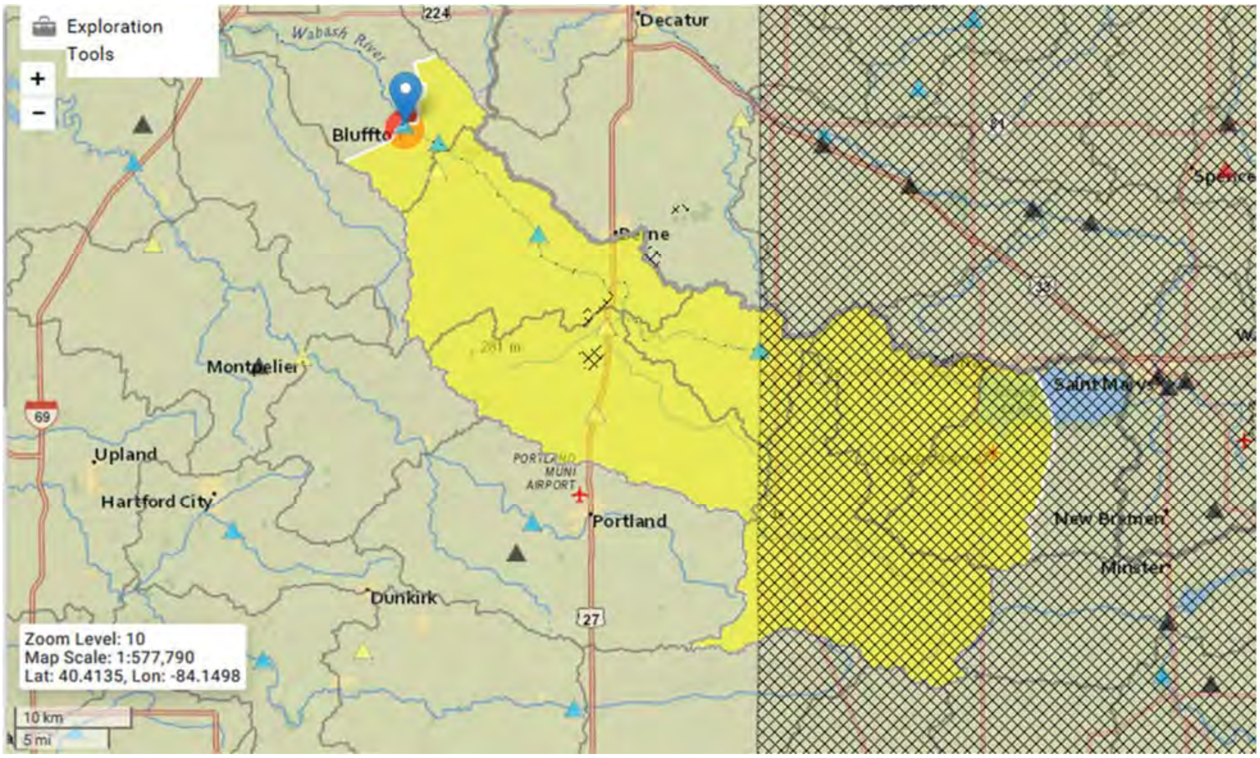

Figure 2: Wabash River at Bluffton, Indiana (Drainage area = 532 mi^2)

2.1 Study Area Surficial Geology and Soils

The Upper Wabash River in Indiana is one of four rivers in Indiana that flow along the front of a series of moraines left as the Erie Lobe retreated into the modern Lake Erie basin (Figure 3). The glacial geology is important because of the influence it has had on the form and function of the modern Wabash River. The till in study area is Largo Formation consists almost entirely of basal till. “The characteristic feature of the till units is their very fine-grained texture, which sets them apart from other till units observed during this study. The tills typically contain less than 30% sand and more than 35% clay, and some samples of the upper till contain in excess of 60 percent clay. The abundant silt and clay were derived by incorporation of lacustrine mud as the ice sheet advanced across the bed of ancestral Lake Erie..." (Fleming1994). As Figure 3 shows the primary study area is entirely within the Tipton Till Plain, and the Upper Wabash River is eroded into a valley cut into silty clay to clayey till, which as noted above can contain more than 60 percent clay. Soils in the study area have developed in this silty clay till and their texture reflects that origin. The dominant soils in the study area are classified as silty loams or clay loams (Figure 4).

Figure 3: Detail from: Quaternary geologic map of Indiana (Gray, 1989). The red arrow indicates the Wabash moraine.

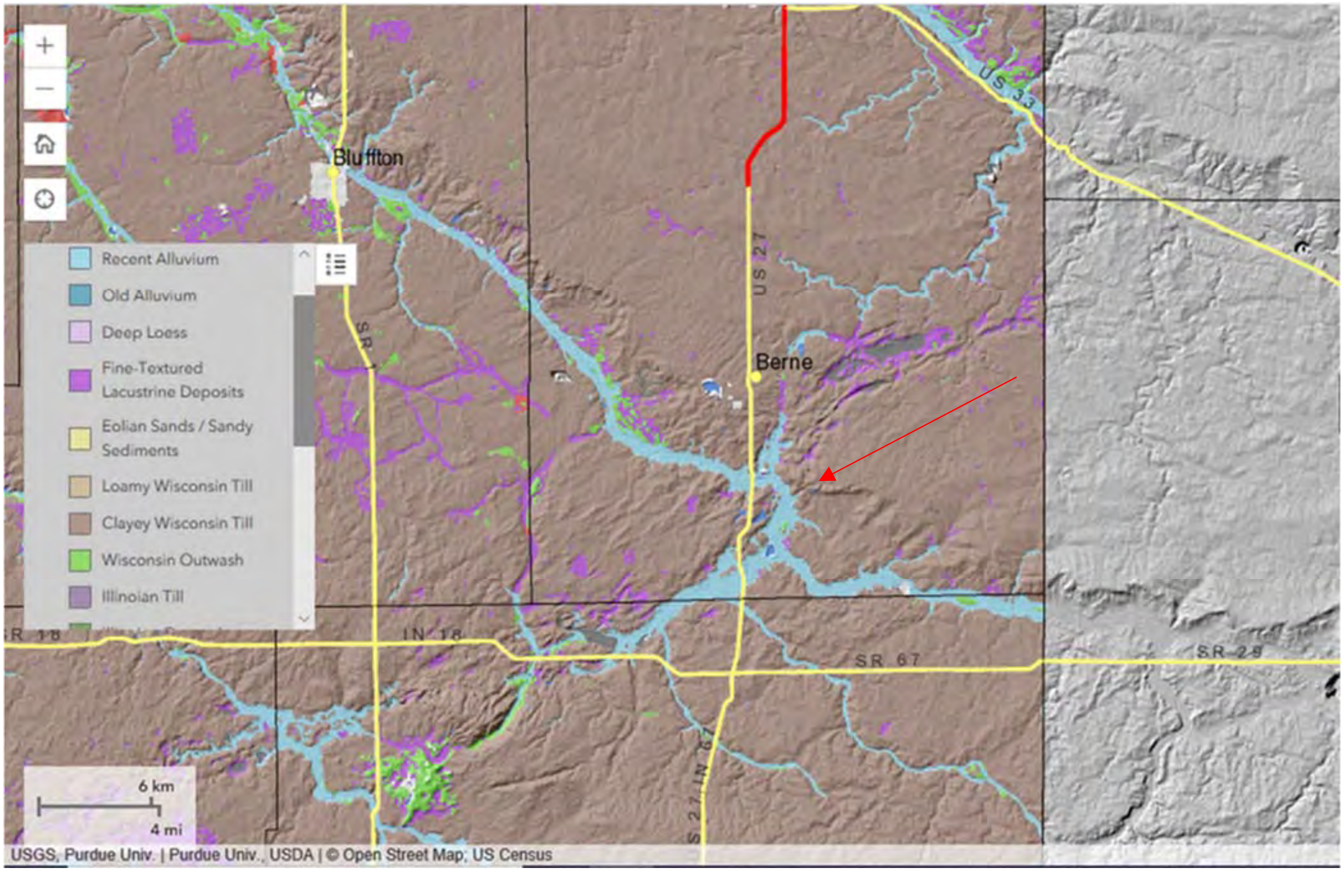

Figure 4: Parent Materials and Surficial Geology in the study area (Purdue Soil Explorer) The red arrow points to the Wabash valley.

3.0 METHODS

An initial reconnaissance of the Upper Wabash River corridor was conducted on April 5, 2018. Members of the Upper Wabash River Basin Commission (UWRBC) identified areas of concern along the main channel of the Wabash River in both Adams and Wells Counties. The UWRBC is concerned with the overall health of streams and waterways in the basin, and have concerns about wood management, bank erosion, excessive sediment, and channel instability along the Wabash River.

The main channel of the Wabash River was flown from both the upstream and downstream directions on June 24, 2018 to assess the main channel for signs of stream instability or bank erosion. Areas identified as potentially unstable were then assessed in a series of field visits. Following the June 24 flight, field visits were made to several sites identified during the flight as well as follow up visits to the sites identified during the April 5 field survey. High flows in through early Spring provided an opportunity for additional post-flood observations. The high flows also proved valuable for assessing the movement of large wood in the channel and potential areas for flood storage.

Channel conditions were assessed from the Indiana-Ohio state line to Bluffton, Indiana. The combination of high and low flow conditions during the study period allowed for observations of large wood in and around the bridge piers, and for bank assessments following high flows.

Geomorphic floodplains were determined using Web Soil Survey to map and measure alluvial soils. Floodplain connectivity was determined using a combination of field visits, Google Earth, and USGS topographic maps.

A literature review was ongoing throughout the project.

4.0 Results

The project area divides into 3 stream reaches based on channel morphology, geomorphic setting, function, and land use. Reach descriptions and results follow.

4.1 Agriculturally modified headwaters

For the purposes of this study we defined the portion of the Wabash River above the Indiana-Ohio state line as the headwaters (Figure 1). As noted in the introduction, this portion of the river, outside of Indiana, was assessed quickly to provide a basic understanding of potential issues. The headwaters are dominated by agriculturally-modified streams and constructed drainage channels and have a drainage area of 260 mi^2. The headwaters divide near Wabash, Ohio at the confluence into two separate drainage basins, Wabash River and Beaver Creek, which are shown in Figure 1.

Beaver Creek is a 10-mile long channelized stream that receives direct outflow from a spillway located on the west side of Grand Lake, a 13,500-acre manmade lake, and then flows to the west where it combines with the Wabash River. Outflow varies widely and appears to be unregulated (USGS Gage 03322485). Soils in the Beaver Creek corridor are mapped as modern alluvium suggesting that the stream was originally natural. Beaver Creek's position along the front of the moraine also suggests a modified natural channel. Our reconnaissance showed instability along several portions of the stream, and along areas that had been rocked. The widely fluctuating discharges from Grand Lake into Beaver Creek would increase the potential for instability and bank erosion, as would the "clear water" from the reservoir. There is no buffer in many sections of the stream. Figure 5 is representative of Beaver Creek.

Figure 5: A portion of Beaver Creek, Mercer County, Ohio. Upstream and Grand Lake is to the right in the image.

The Wabash River in Ohio.

The Wabash River begins upstream of Fort Recovery, flows to the west and then to the north before it combines with Beaver Creek (Figure 1). The river is highly modified, riparian buffers are primarily thin and forested, but occasionally absent. The primary land use is row crop agriculture.

4.2 The Limberlost Reach, the Wabash River from the Indiana-Ohio state line to Geneva, Indiana (11.3 miles)

The character of the Wabash River changes near the Indiana-Ohio state line as a result of both geology and land management. In Ohio the Wabash and Beaver Creek are both modified agricultural streams. Both streams have been extensively channelized. Channelization of the Wabash continues into Indiana for about 2.5 miles into Jay County. Upstream from Brewster Ditch in Adams County the river becomes highly sinuous (k=2.5) as the Wabash River flows into what was the Limberlost Swamp. The increased sinuosity continues through the area of the Limberlost Swamp and then changes above Geneva (Figure 6). Historical accounts (Snow, 1907) document that the Wabash River was straightened for approximately 2 miles from the confluence of Loblolly Creek and the Wabash downstream to the Rainbow Bridge. For the purposes of this study the changes in the planform of the river indicate potential functional changes in the river that may affect stability.

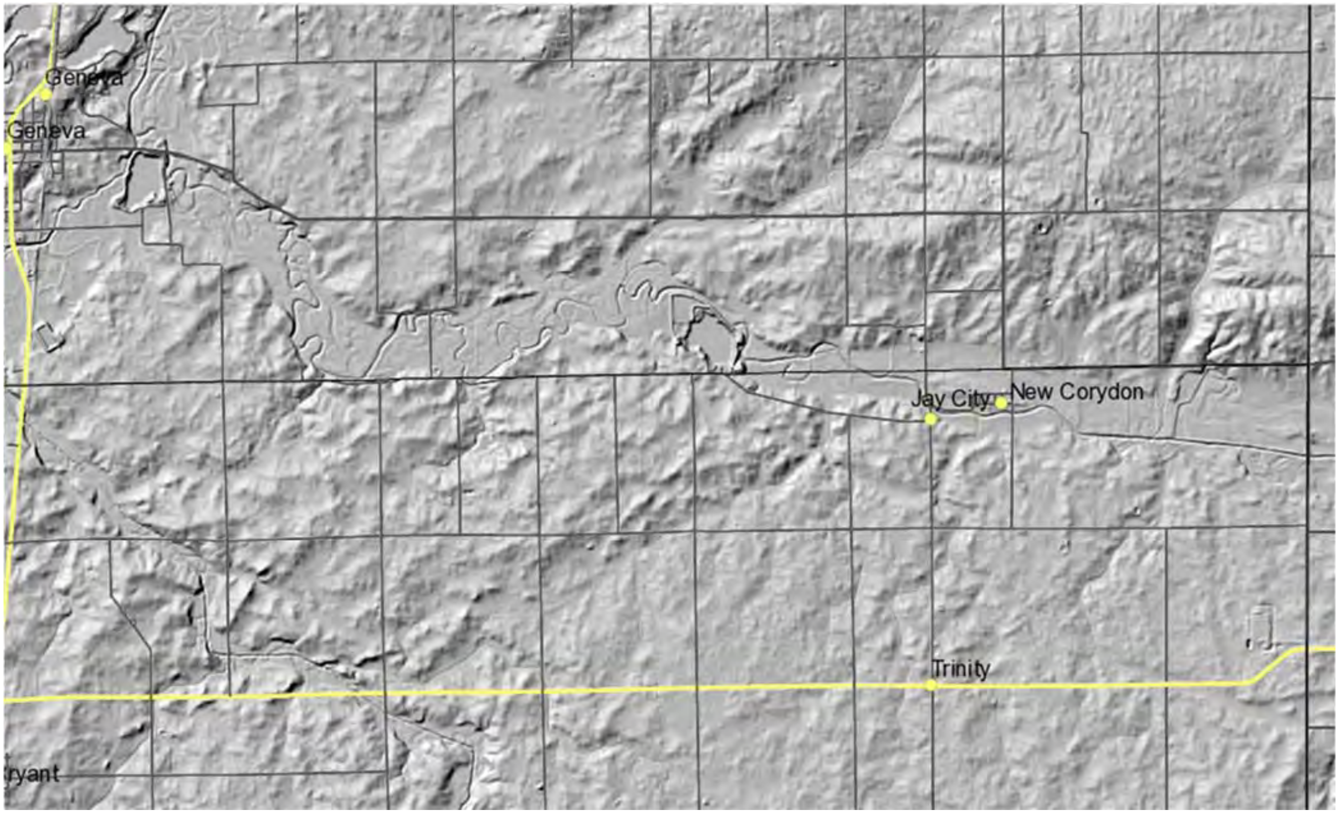

Figure 6: Wabash River from Indiana-Ohio state line to Geneva, Indiana. Note change in sinuosity near Jay City (Purdue Soil Explorer). Cut off meanders from Jay City past the confluence with Beaver Creek in Ohio show the modification of the upper Wabash.

4.3 The Wabash River from Geneva to Bluffton (17 miles)

From Geneva north to Bluffton the valley slope increases slightly and the meander pattern changes from unconfined meander scrolls to regular meanders. Sinuosity changes from 2.5 to 1.3. The consistent geology and topography of the intermorainal till plain results in similar soil types throughout the study area, but the slight change in valley slope is enough to change sinuosity. While the sinuosity of the channel indicates lateral channel migration, data from Robinson (2013b) shows the entire study section to be recently stationary. Measurements on seven meanders in Wells and Adams Counties showed a maximum measured cutbank displacement of 5-feet during the period of observation (1998-2011) for an annual channel migration rate of < 1 -foot. The lateral stability of the channel is in part a function of the clayey till that forms the bed of the channel and the lower toe portion of the bank slope.

5.0 AREAS OF CONCERN

Six areas of concern were identified during this investigation. General locations are shown in Figure 7. Two of the sites are in the Geneva to Bluffton reach and four are in the Limberlost reach. Details for the sites follow. Bank erosion hazard index worksheets for each site are located in Appendix 1

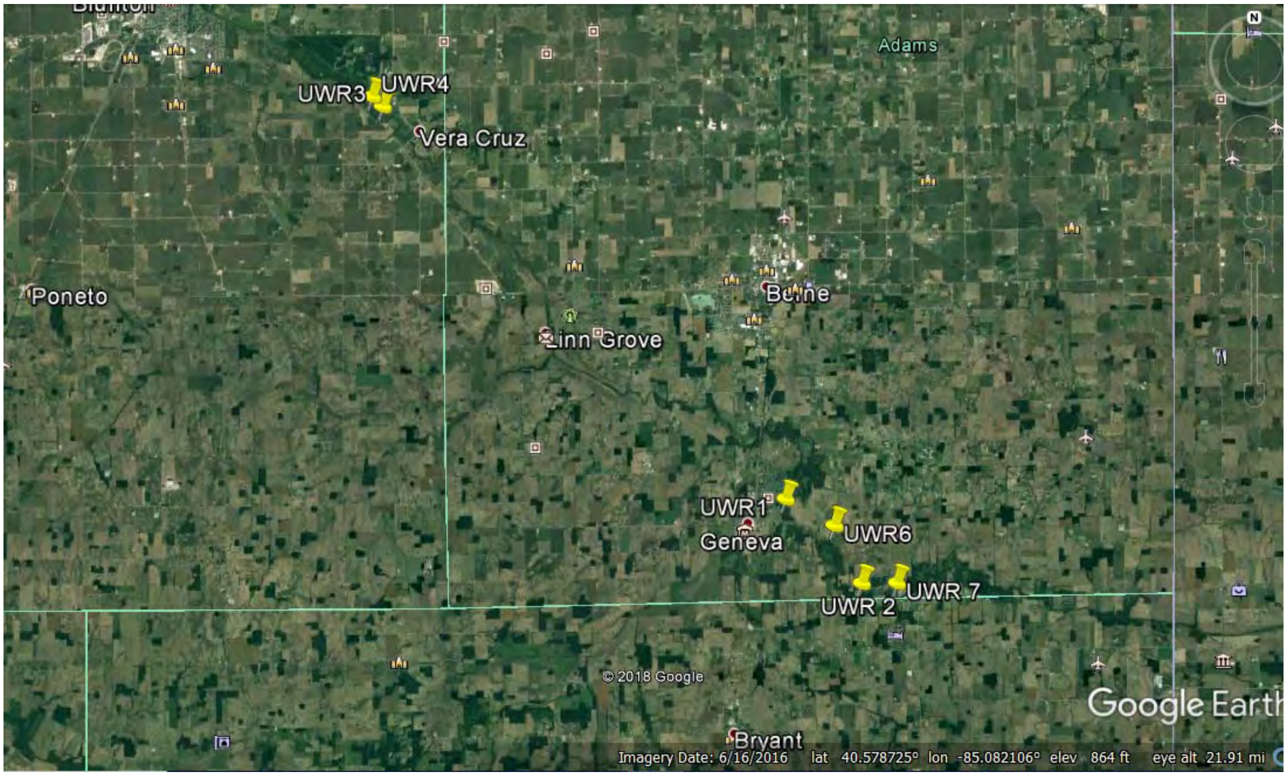

Figure 7: General location of areas of concern. Adams, Wells, and Jay Counties, Indiana.

UWRB 1 Flueckiger Site (40.5944 -84.9465) Bank Erosion Hazard Index (BEHI) = very high

This site has approximately 100-feet of the upper valley wall showing tension cracks and slab failure. No additional movement has been observed in the last 6 months. Slope failure is occurring above the left bank primarily in Blount silt loam soil. Note that the site is on the downstream portion of a meander (red arrow).

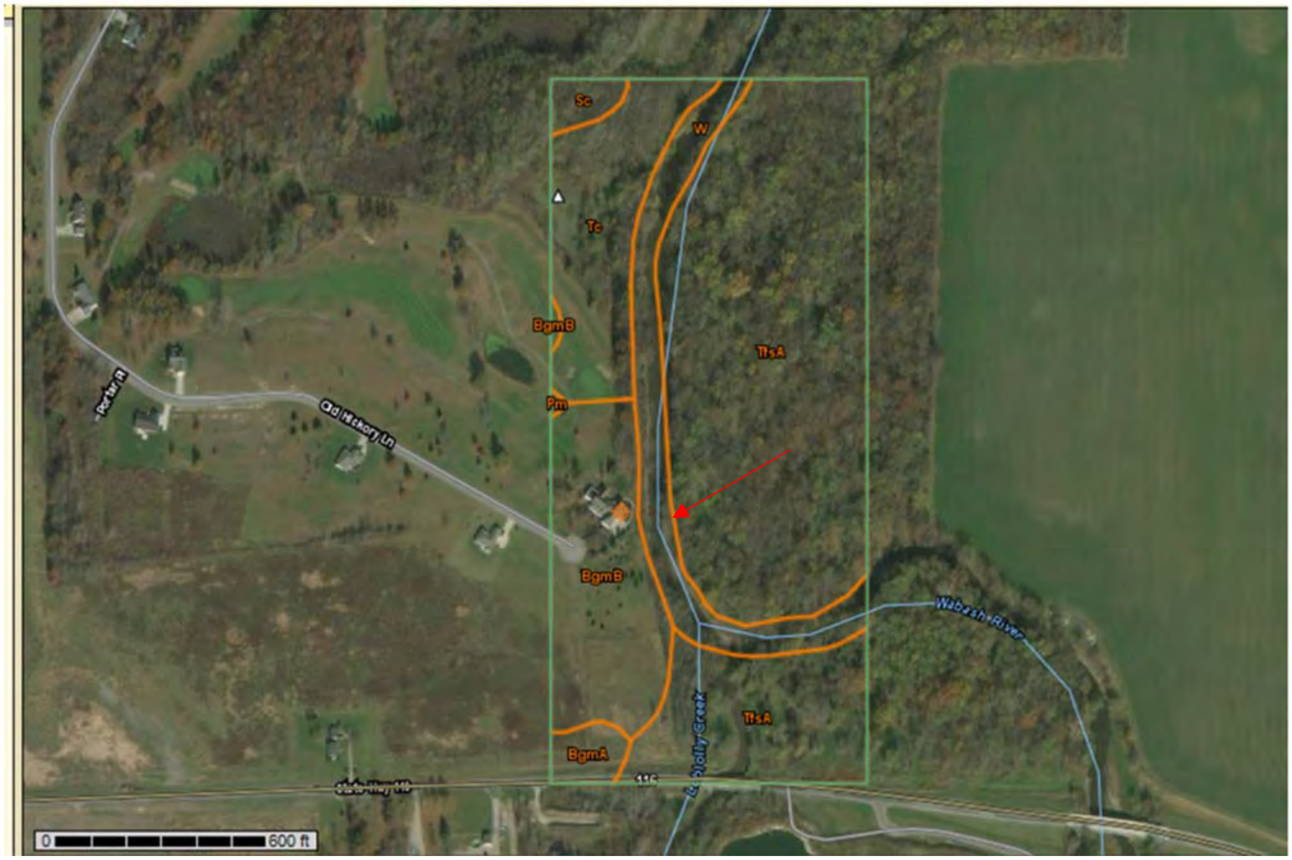

Figure 8: Detail showing soil map and soil types at UWR 1 Web Soil Survey

Figure 9: Upper slope at UWR 1

Figure 10: Lower slope at UWR 1

UWR 2, E CR 1200 S (40.5706 -84.9194) **BEHI = high**

Tension cracking and slab failure along the left upper valley wall are threatening E CR 1200 S approximately 2 miles east of SR 27. Slope failure has occurred along 500-feet of the upper valley wall (red arrow). Soil in that portion of the left bank is Glynwood-Mississinewa clay loam. Emergency repairs have been made at the site, but slope instability continues.

Figure 11: Detail showing soil map and soil types at UWR 2 Web Soil Survey


Figure 12: Initial slope repair at UWR 2


Figure 13: Slope location of UWR 2. Note slumping tree and stable toe of slope and channel.

UWR 3, South of Vera Cruz on SR 116 (40.7038 -85.0943) BEHI = extreme

Tension cracking and slab failure of the slope above the left bank. Slope failure is occurring in Blount and Del Rey silt and silty clay loam soils above the left bank. The visible slope failure extends for approximately 700 feet, but tree angle suggests that the failure area is expanding.

Figure 14: UWR 3 Site, south of Vera Cruz. Detail showing soil map and soil types. Web Soil Survey

Figure 15: Stable toe at UWR 3

Figure 16: Stable toe at UWR 3 but note tree angle on upper slope looking upstream.

UWR 4, Near private homes south of Vera Cruz near SR116 (40.7058 -85.0979) BEHI = extreme

Tension cracking and slab failure of upper valley wall above left bank of the Wabash River. Slope failure is occurring in the Glynwood silt loam soil above the left bank (red arrow). Note the dashed slope symbol on the soil map. The slope failure currently extends for about 500 feet, but it is expanding in both the upstream and downstream directions.

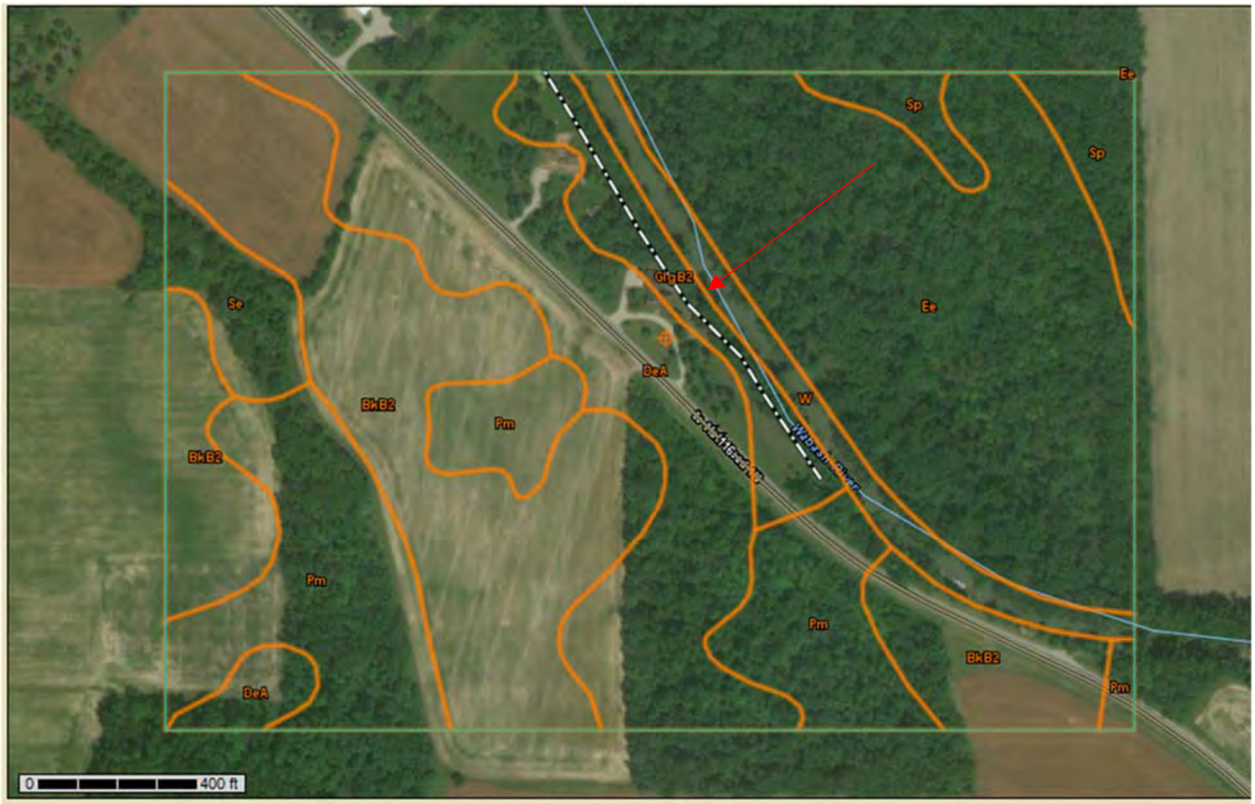

Figure 17: UWR4, South of Vera Cruz on SR 116. Detail showing soil map and soil types.   Web Soil Survey

Figure 18: Slope failure along upper slope above left bank at UWR 4. Note the elevation difference between the top of slope and the floodplain on the right bank.

UWR 6: SE of Geneva on SR 116 (E 1100 S) (40.5871, -84.9285)   BEHI = extreme

Tension cracking and slab failure along the upper valley wall above the right bank of the Wabash River (red arrow). Slope failure is occurring in Glynwood silt loam. Slope failure extends for about 350 feet in the crest of a very tight meander

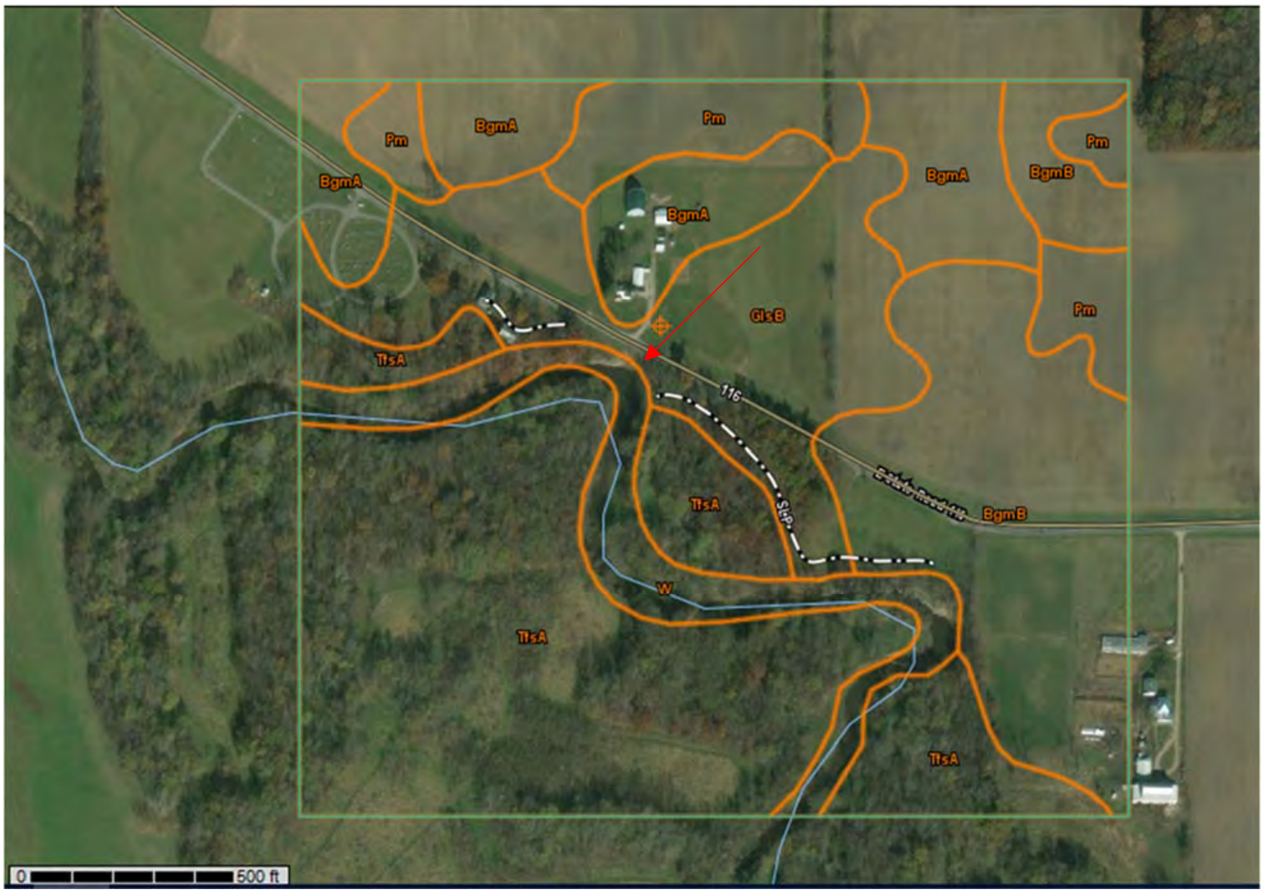

Figure 19: Site UWR 6 along SR116 south of Geneva. Detail showing soil map and soil types.   Web Soil Survey

Figure 20: Emergency stabilization at UWR 6

Figure 21: New and old stabilization at UWR 6. Note the elevation of the slope relative to the floodplain visible in the background.

Site UWR 7, East of UWR 2 on CR E 1200 S, 40.5711 -84.9055 BEHI = extreme

Slope failure along the valley wall above the left bank. Failure is occurring in Pewamo silty clay loam soil. Failure is threatening the county road for approximately 800 feet.

Figure 22: Site UWR 7 along CR 1200 S, Jay County. Detail showing soil map and soil types. Web Soil Survey

Figure 23: Looking downstream at UWR 7. Note angle of tree.

Figure 24: UWR 7, same tree as in Figure 22. Note rock repair is in channel, not on slope. New slope failure in downstream direction.

Table 1: Physical characteristics for sites of concern in the study area *note that the Indiana regional curves are not valid for the main channel of the Upper Wabash, particularly in the Limberlost reach. Please see Appendix 2 for a further explanation.

Location	**County**	**DA (mi^2)**	**W_{bkf} (ft) M ***	**s (10-85) ft/mi**	**Slope Position**	**Channel Location**	**Channel Type**	**K (SL/VL)**	**Floodplain Width (ft)**	**Valley Type**
UWR 1	Adams	405	72.0	4.4	upper	meander	B6c	2.5	1800	U-LA-LD
UWR 2	Jay	292	86.0	4.4	upper	glide	B6c	2.5	1200	U-LA-LD
UWR 3	Wells	446	70.0	3.13	upper	meander	B6c	1.5	1600	U-LA-LD
UWR 4	Wells	466	90.0	3.11	upper	meander	B6c	1.5	1400	U-LA-LD
UWR 6	Adams	293	65.0	4.54	upper	meander	B6c	2.5	1500	U-LA-LD
UWR 7	Adams	290	55.0	4.42	upper	meander	B6c	2.5	1800	U-LA-LD

6.0 Discussion

The Wabash River from the Indiana-Ohio state line is a remarkably stable river. The main channel of the Wabash is eroded into silt and clay-rich till giving it very resistant boundary condition with its floodplain. Rosgen (2018) and others have suggested that a valley confinement threshold of < 7.0 channel widths can be used to define a confined valley (floodplain width/channel bankfull width). The Wabash River floodplain in the study area far exceeds that (Table 1). The valley type in the Rosgen classification of fluvial landscapes is unconfined, Till Plain, morainal, denoted by the acronym U-GL-TP. This landscape has a slope of < 2%, and the stable river types are B, C, and E. Most of the river observed in this study is a B6c, or a low gradient meandering channel with a D_{50} in the silt and clay particle size fraction (Rosgen, 2014). The fluvial landscape is unusual because we determine the region have lacustrine or lacustrine deposition not because of the past presence of a lake in the area, but because the till into which the Upper Wabash is eroded is of lacustrine origin. The resistant lacustrine sediment forming the boundary conditions of the channel is responsible for the dimensions, pattern, and profile of the Upper Wabash. The till is also the reason for the river being primarily a wash load river with almost no bedload, which again influences it form. Wash load is the finest fraction of the sediment load, usually silt and clay. That material can be carried by the river completely in suspension, so if a river is “wash-load” dominated many of the features commonly associated with rivers, such as pools, riffles, and point bars, are absent because there is no coarse sediment to form them.

In the study area all the areas of concern have the channel moving very slowly against an upland valley wall and nonalluvial soil, usually resulting in tension cracking and slab failures. Analysis of air photographs combined with landowner observations suggest that the process is recent. An analysis of bankfull discharges in the study area indicates that the number of days that the Wabash River at Linn Grove is at bankfull stage has doubled since 2000 (Figure 24). The increase in days at bankfull stage is matched by a trend in increasing peak discharge which shows an increase in the average peak discharge from 4000 cfs to 7000 cfs (Figure 25). Since at high flows the river is against the valley wall the upland soil is now saturated on average twice as long as it was just 18 years ago. Our working hypothesis is that more frequent saturation is the main driver of the slope instability. It is important to note in the preceding images of the areas of concern that the channel does not seem to be mobile. It is primarily the upper slope that is failing.

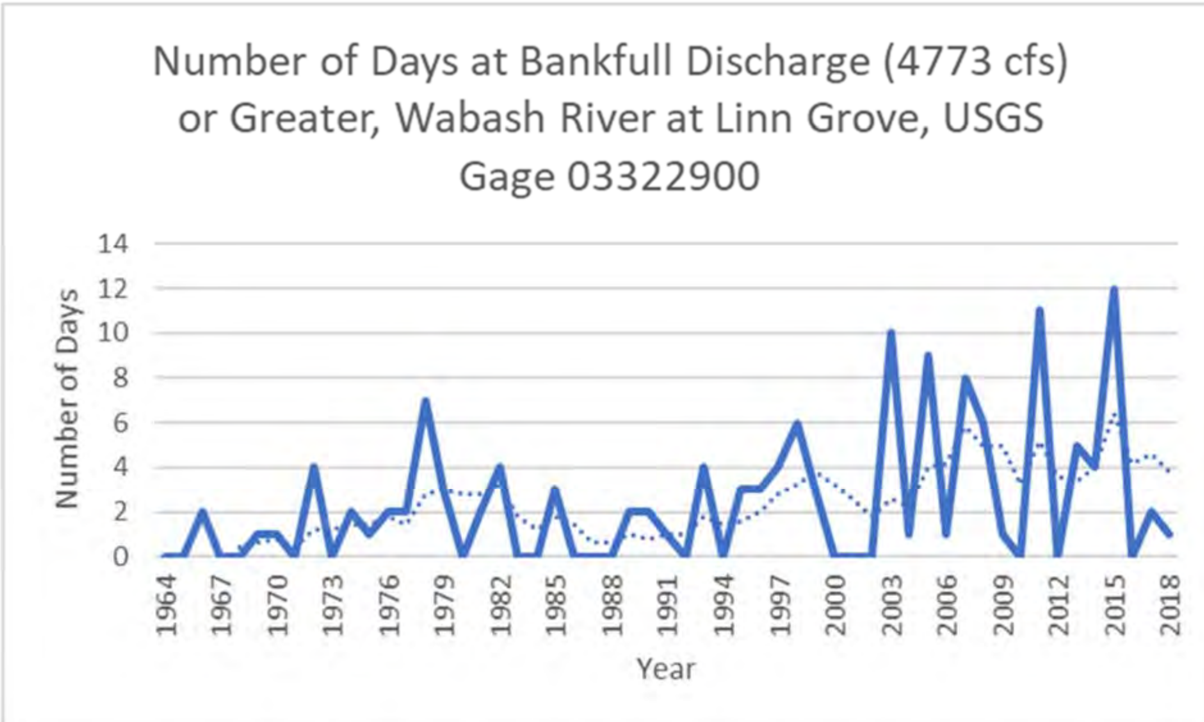

Figure 25: Number of Days at Bankfull Discharge (4773 cfs) or Greater, Wabash River at Linn Grove, USGS Gage 03322900

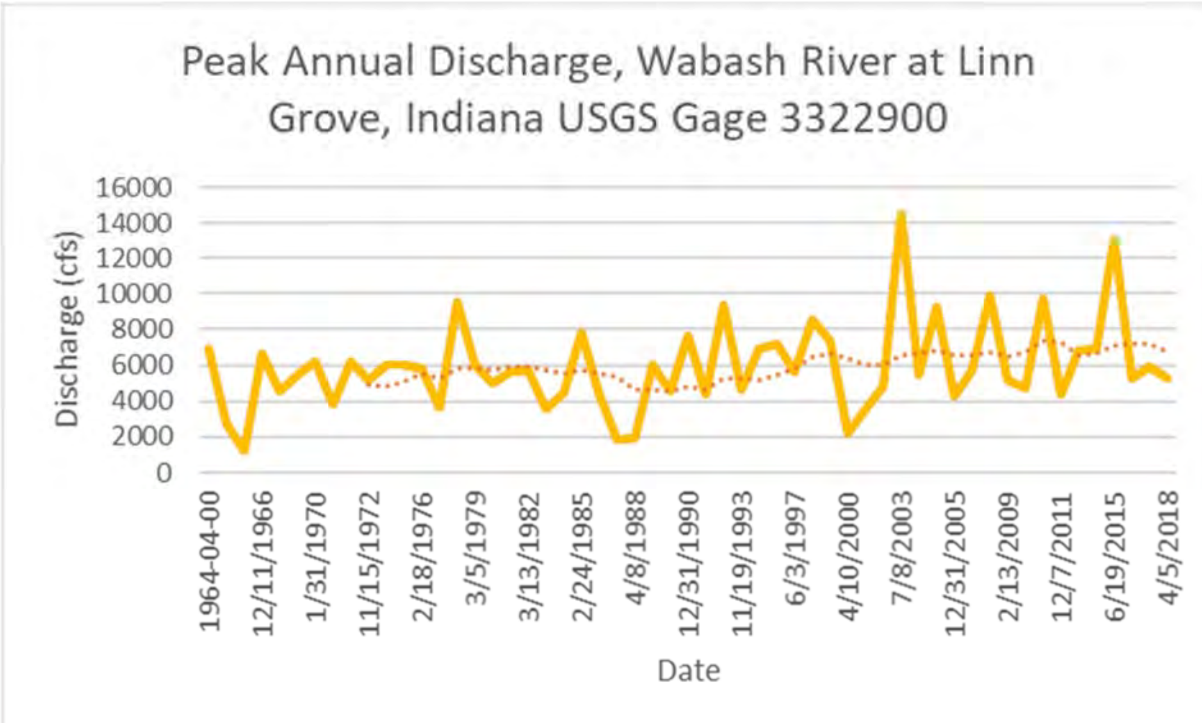

Figure 26: Peak Annual Discharge, Wabash River at Linn Grove, Indiana USGS Gage 3322900

7.0 Recommendations

1. All the recommended areas of concern are locations where slope failure is occurring. Two of the sites are areas where private homes may be threatened in the future. Both of those sites appear to be stabilizing as the slab failures adjust. We would recommend that the homeowners avoid saturating those slopes with additional water from lawn watering or storm drainage. We would also recommend installing stakes to monitor the slopes.

2. The sites where state and county roads are threatened by slope failure are dangerous and should be monitored closely.

3. All but one of the noted areas of concern are on the outside of meander bends, a channel position that is commonly unstable. The slope instability at UWR 1 is occurring on a straight reach, but also on a high bank. That may indicate that less sensitive areas are beginning to respond to the increased number of days above the bankfull stage, which would suggest that a more system-wide adjustment is beginning to occur. A systemic change will need to be managed carefully. Please contact us if you see more evidence of slope failures on straight reaches.

4. The discharge of Beaver Creek at Grand Lake should be monitored. It appears to be the dominate discharge into the upper Wabash River during lower flows. With the reported poor water quality in Grand Lake it could have a negative effect on the Wabash River. However, at higher discharges the influence of Grand Lake appears minimal. For example, the highest reported discharge for Beaver Creek near Celina (USGS gage 03322485) was 1770 cfs on June 16, 2015. On June 19, 2015 the peak discharge

at Linn Grove was 13100 cfs, indicating that the only 13% of the flow for that large event was coming from the Grand Lake portion of the watershed.

8.0 References

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Upper Wabash River Basin Commission (2016) Watershed Management Plan – Phase II January 9, 2013 – April 8, 2015 Final version: June 2016

Appendix 1: Bank Erosion Hazard Index (BEHI) Worksheets for the Areas of Concern

BEHI Worksheets for the each of the areas of concern are appended to the back of this document. It is important to note that the applicability of the BEHI to tension cracking and slope failure can be limited. The BEHI was originally designed to rank erosion hazard potential in channel banks. Here we are applying it to stream-influenced non-alluvial valley walls. The user is encouraged to use the rankings with care.

APPENDIX 2: REGIONAL CURVES AND THE MAUMEE REGION

There are two reasons for the Regional Bankfull-Channel Dimensions of Non-Urban Wadeable Streams in Indiana “Indiana regional curves” not being generally applicable in the Upper Wabash watershed:

1. The watershed of the Upper Wabash includes a portion of Grand Lake at St Mary’s, Ohio. That makes the upstream drainage area subjective at best.
2. The relationships between drainage area and at a station channel dimensions (bankfull width, depth, and cross-sectional area) for streams in similar physiographic regions and similar climates are well-documented. In Indiana the equations for the Central Till Plain were derived from data collected across that broad physiographic region. Only two sites in the Central Till Plain dataset were in the Bluffton Till Plain, a subregion of the broader Central Till Plain. A portion of the Bluffton Till Plain has the Largo formation till at the surface. “The Largo Formation consists almost entirely of basal till…The characteristic feature of the till units is their very fine-grained texture, which sets them apart from other till units observed during this study. The tills typically contain less than 30% sand and more than 35% clay, and some samples of the upper till contain in excess of 60 percent clay. The abundant silt and clay were derived by incorporation of lacustrine mud as the ice sheet advanced across the bed of ancestral Lake Erie..." (Fleming, 1994). The lacustrine clays in the Largo formation till create boundary conditions for streams in that area that are more like a lacustrine setting than most of the Indiana till plain. For that reason, we classify the fluvial setting in the Upper Wabash as unconfined-lacustrine-lacustrine deposition (U-LA-LD), despite the lack of a preexisting lake. We also classify the Indiana portion of the upper Wabash from Jay County to Bluffton as an E-type channel, a channel type heretofore only identified in the Northern Moraine and Lake region of Indiana

It should be noted that the author of the Regional Bankfull-Channel Dimensions of Non-Urban Wadeable Streams in Indiana was clear that the regional curves presented in that report were developed from a dataset that was geographically limited (Robinson, 2013a). It was suspected that there might be small regions in Indiana with enough unique characteristics that the regional curves might not be applicable. The Maumee portion of the Bluffton Till Plain appears to be that type of area but more data is needed to make a clear determination. This could be important for the long-term management of the Upper Wabash River. Without good data to support what its stable form is, there may be a tendency to try and make the Upper Wabash River into something that it is not, which would be at minimum a waste of resources, and in the worst case lead to degradation of the river.

Appendix 2: Site Assessment Data & Calculations

OWR-1

Worksheet 20. BEHI variable worksheet

Stream: Wabash	Cross Section: OWR 1	Date:	Observers: rcb / HmB

Bank Height/Max Depth Bankfull (C)

Study Bank Height (ft) 21.0 A	Bankfull Height (ft) 6.3 B	A/B = 3.3 C

Root Depth/Bank Height (E)

Root Depth (ft) 1 D	Study Bank Height (ft) 21.0 A	D/A = .05 E

Weighted Root Density (G)

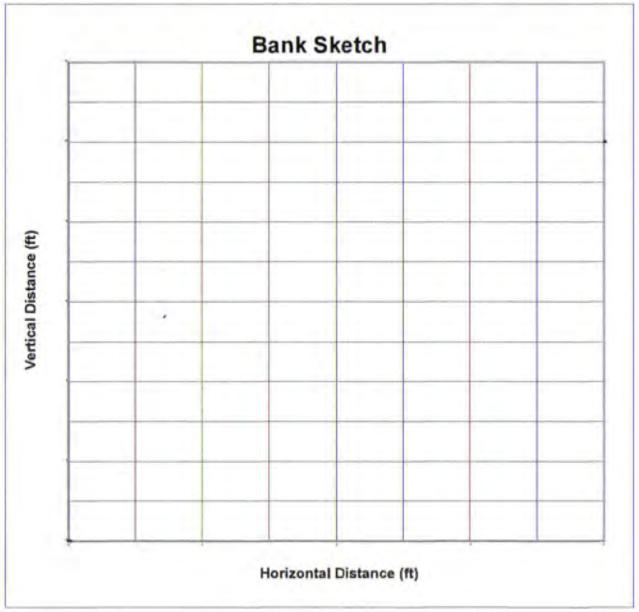
Root Density (%) 50 F	F*E = 2.5 G

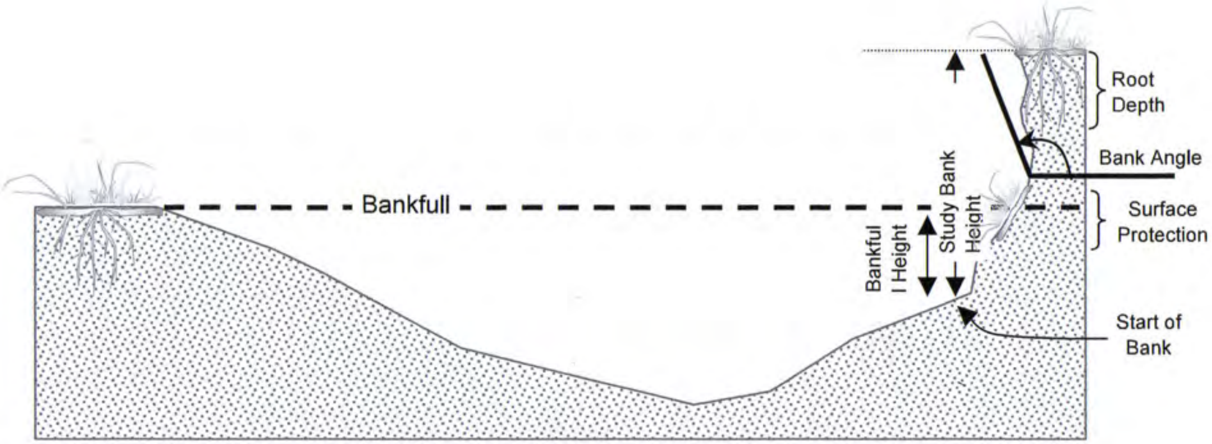
Bank Angle (H)

Bank Angle (Degrees) 60 H

Surface Protection (I)

Surface Protection % 75 I





Worksheet 21. Summary of bank erosion hazard index (BEHI)

UWR-1

Bank Erosion Potential			Bank Erosion Hazard Rating Guide				
	Stream Wabash		Reach UWR 1		Date		Crew HMKS Feb
	Bank Height (ft): Bankfull Height (ft):		Bank Height/ Bankfull Ht	Root Depth/ Bank Height	Root Density %	Bank Angle (Degrees)	Surface Protection%
	VERY LOW	Value	1.0-1.1	1.0-0.9	100-80	0-20	100-80
		Index	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9
		Choice	V: I:	V: I:	V: I:	V: I:	V: I:
	LOW	Value	1.11-1.19	0.89-0.5	79-55	21-60	79-55
		Index	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9
		Choice	V: I:	V: I:	V: I:	V: I:	V: I:
	MODERATE	Value	1.2-1.5	0.49-0.3	54-30	61-80	54-30
		Index	4.0-5.9	4.0-5.9	4.0-5.9	4.0-5.9	4.0-5.9
		Choice	V: I:	V: I:	V: I:	V: I:	V: I:
	HIGH	Value	1.6-2.0	0.29-0.15	29-15	81-90	29-15
		Index	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9
		Choice	V: I:	V: I:	V: I:	V: I:	V: I:
	VERY HIGH	Value	2.1-2.8	0.14-0.05	14-5.0	91-119	14-10
		Index	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0
		Choice	V: I:	V: I:	V: I:	V: I:	V: I:
	EXTREME	Value	>2.8	<0.05	<5	>119	<10
		Index	10	10	10	10	10
		Choice	V: I: 10	V: I: 10	V: I: 3.0	V: I: 3.5	V: I: 3.5
	V = value, I = index			SUB-TOTAL (Sum one index from each column)			

Bank Material Description:

Clayey loam – till contact at 70 in.

Bank Materials

- **Bedrock** (Bedrock banks have very low bank erosion potential)
- **Boulders** (Banks composed of boulders have low bank erosion potential)
- **Cobble** (Subtract 10 points. If sand/gravel matrix greater than 50% of bank material, then do not adjust)
- **Gravel** (Add 5-10 points depending percentage of bank material that is composed of sand)
- ~~**Sand** (Add 10 points)~~
- **Silt Clay** (+ 0: no adjustment)

BANK MATERIAL ADJUSTMENT 0

Stratification Comments:

till contact

Stratification

Add 5-10 points depending on position of unstable layers in relation to bankfull stage

STRATIFICATION ADJUSTMENT +10

VERY LOW	LOW	MODERATE	HIGH	VERY HIGH	EXTREME
5-9.5	10-19.5	20-29.5	30-39.5	40-45	46-50

Bank location description (circle one)

Straight Reach   Outside of Bend

GRAND TOTAL BEHI RATING 40.8

Worksheet 20. BEHI variable worksheet

Stream: Wabash	Cross Section: UWR 2	Date: 7.17.18	Observers: rob / HMRS

Bank Height/Max Depth Bankfull (C)

Study Bank Height (ft) 15.0 A	Bankfull Height (ft) 6.0 B	A/B = 2.5 C

Root Depth/Bank Height (E)

Root Depth (ft) 1 D	Study Bank Height (ft) 15 A	D/A = .06 E

Weighted Root Density (G)

Root Density (%) 80 F	F*E = 4.8 G

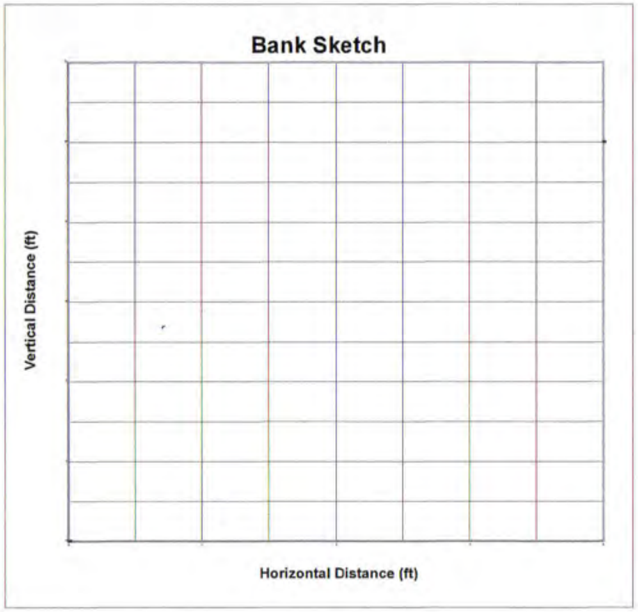
Bank Angle (H)

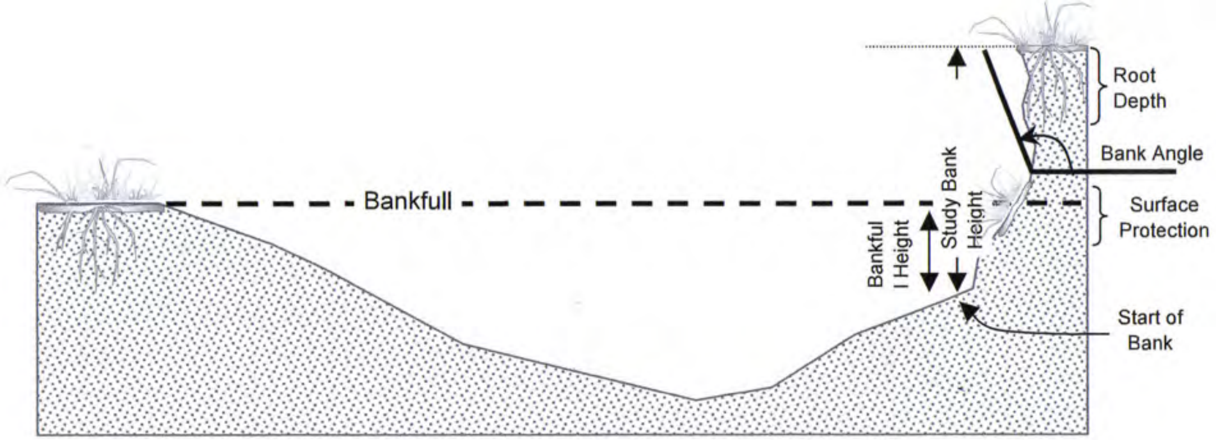
Bank Angle (Degrees) 60 H

Surface Protection (I)

Surface Protection % 50 I

(variable!)





Worksheet 21. Summary of bank erosion hazard index (BEHI)

Bank Erosion Hazard Rating Guide

Stream Wabash Reach UWR 2 Date Crew rcb

Bank Height (ft): 15.0
Bankfull Height (ft): 6.0

Bank Erosion Potential		Bank Height/ Bankfull Ht	Root Depth/ Bank Height	Root Density %	Bank Angle (Degrees)	Surface Protection%
VERY LOW	Value	1.0-1.1	1.0-0.9	100-80	0-20	100-80
	Index	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9
	Choice	V: I:	V: I:	V: I:	V: I:	V: I:
LOW	Value	1.11-1.19	0.89-0.5	79-55	21-60	79-55
	Index	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9
	Choice	V: I:	V: I:	V: I:	V: I:	V: I:
MODERATE	Value	1.2-1.5	0.49-0.3	54-30	61-80	54-30
	Index	4.0-5.9	4.0-5.9	4.0-5.9	4.0-5.9	4.0-5.9
	Choice	V: I:	V: I:	V: I:	V: I:	V: I:
HIGH	Value	1.6-2.0	0.29-0.15	29-15	81-90	29-15
	Index	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9
	Choice	V: I:	V: I:	V: I:	V: I:	V: I:
VERY HIGH	Value	2.1-2.8	0.14-0.05	14-5.0	91-119	14-10
	Index	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0
	Choice	V: I:	V: I:	V: I:	V: I:	V: I:
EXTREME	Value	>2.8	<0.05	<5	>119	<10
	Index	10	10	10	10	10
	Choice	V: I: 8.5	V: I: 8.5	V: I: 1.5	V: I: 2.5	V: I: 5.0
V = value, I = index					**SUB-TOTAL** (Sum one index from each column)	

Bank Material Description:

clay loam on fill

Bank Materials

- **Bedrock** (Bedrock banks have very low bank erosion potential)
- **Boulders** (Banks composed of boulders have low bank erosion potential)
- **Cobble** (Subtract 10 points. If sand/gravel matrix greater than 50% of bank material, then do not adjust)
- **Gravel** (Add 5-10 points depending percentage of bank material that is composed of sand)
- **Sand** (Add 10 points)
- **Silt Clay** (+ 0: no adjustment)

BANK MATERIAL ADJUSTMENT 0

Stratification Comments:

Stratification

Add 5-10 points depending on position of unstable layers in relation to bankfull stage

STRATIFICATION ADJUSTMENT 10

VERY LOW	LOW	MODERATE	HIGH	VERY HIGH	EXTREME
5-9.5	10-19.5	20-29.5	30-39.5	40-45	46-50

Bank location description (circle one)

Straight Reach Outside of Bend

GRAND TOTAL BEHI RATING 36

Worksheet 20. BEHI variable worksheet

Stream: Wabash	Cross Section: OWR 3	Date:	Observers: HMRS / rcb

Bank Height/Max Depth Bankfull (C)

Study Bank Height (ft) 15.0 A	Bankfull Height (ft) 4.25 B	A/B = 3.5 C

Root Depth/Bank Height (E)

Root Depth (ft) 0.5 D	Study Bank Height (ft) 15.0 A	D/A = .03 E

Weighted Root Density (G)

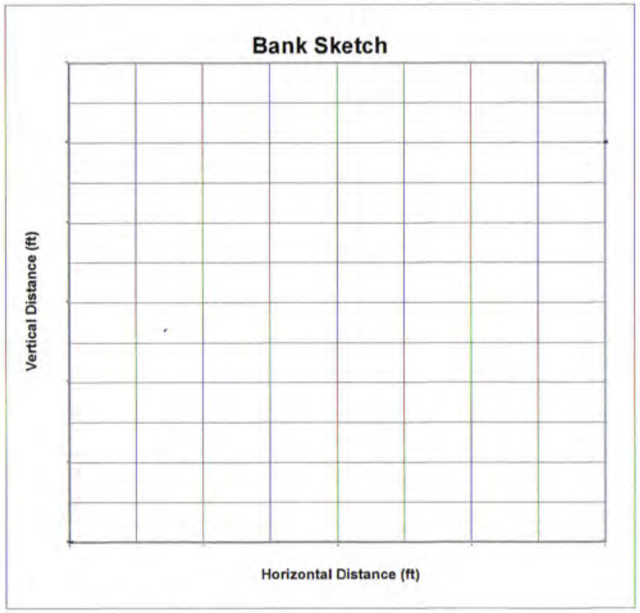
Root Density (%) 15 F	F*E = 0.45 G

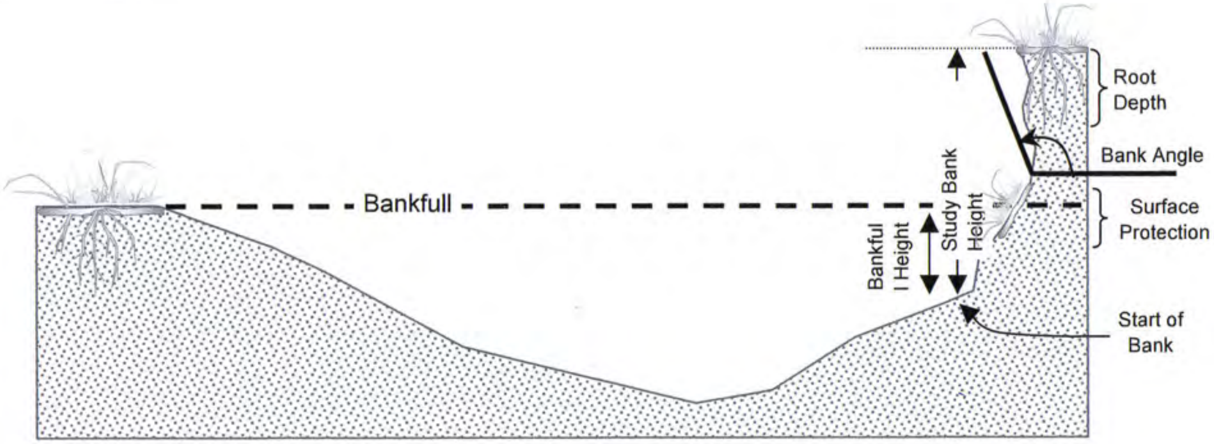
Bank Angle (H)

Bank Angle (Degrees) 45 H

Surface Protection (I)

Surface Protection % 20 I





Worksheet 21. Summary of bank erosion hazard index (BEHI)

Bank Erosion Hazard Rating Guide

Stream wabash Reach UWR 3 Date Crew HMS rcb

Bank Erosion Potential	Bank Height (ft): 4.25 Bankfull Height (ft): 15.0		Bank Height/ Bankfull Ht	Root Depth/ Bank Height	Root Density %	Bank Angle (Degrees)	Surface Protection%
	VERY LOW	Value	1.0-1.1	1.0-0.9	100-80	0-20	100-80
		Index	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9
		Choice	V: I:	V: I:	V: I:	V: I:	V: I:
	LOW	Value	1.11-1.19	0.89-0.5	79-55	21-60	79-55
		Index	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9
		Choice	V: I:	V: I:	V: I:	V: I:	V: I:
	MODERATE	Value	1.2-1.5	0.49-0.3	54-30	61-80	54-30
		Index	4.0-5.9	4.0-5.9	4.0-5.9	4.0-5.9	4.0-5.9
		Choice	V: I:	V: I:	V: I:	V: I:	V: I:
	HIGH	Value	1.6-2.0	0.29-0.15	29-15	81-90	29-15
		Index	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9
		Choice	V: I:	V: I:	V: I:	V: I:	V: I:
	VERY HIGH	Value	2.1-2.8	0.14-0.05	14-5.0	91-119	14-10
		Index	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0
		Choice	V: I:	V: I:	V: I:	V: I:	V: I:
	EXTREME	Value	>2.8	<0.05	≤5	>119	<10
		Index	10	10	10	10	10
		Choice	V: I: 10	V: I: 8.5	V: I: 10	V: I: 3	V: I: 7
	V = value, I = index				SUB-TOTAL (Sum one index from each column)		

Bank Material Description:

silty clay loam on fill

Bank Materials

- **Bedrock** (Bedrock banks have very low bank erosion potential)
- **Boulders** (Banks composed of boulders have low bank erosion potential)
- **Cobble** (Subtract 10 points. If sand/gravel matrix greater than 50% of bank material, then do not adjust)
- **Gravel** (Add 5-10 points depending percentage of bank material that is composed of sand)
- **Sand** (Add 10 points)
- **Silt Clay** (+ 0: no adjustment)

BANK MATERIAL ADJUSTMENT 0

Stratification Comments:

Stratification

Add 5-10 points depending on position of unstable layers in relation to bankfull stage

STRATIFICATION ADJUSTMENT 10

VERY LOW	LOW	MODERATE	HIGH	VERY HIGH	EXTREME
5-9.5	10-19.5	20-29.5	30-39.5	40-45	46-50

Bank location description (circle one)

Straight Reach Outside of Bend

GRAND TOTAL
BEHI RATING 48.5

Worksheet 20. BEHI variable worksheet

Stream: Wabash	Cross Section: UWR 4	Date:	Observers: rcb / HMB

Bank Height/Max Depth Bankfull (C)

Study Bank Height (ft) 10.6 A	Bankfull Height (ft) 4.25 B	A/B = 2.5 C

Root Depth/Bank Height (E)

Root Depth (ft) 0.5 D	Study Bank Height (ft) 10.6 A	D/A = .05 E

Weighted Root Density (G)

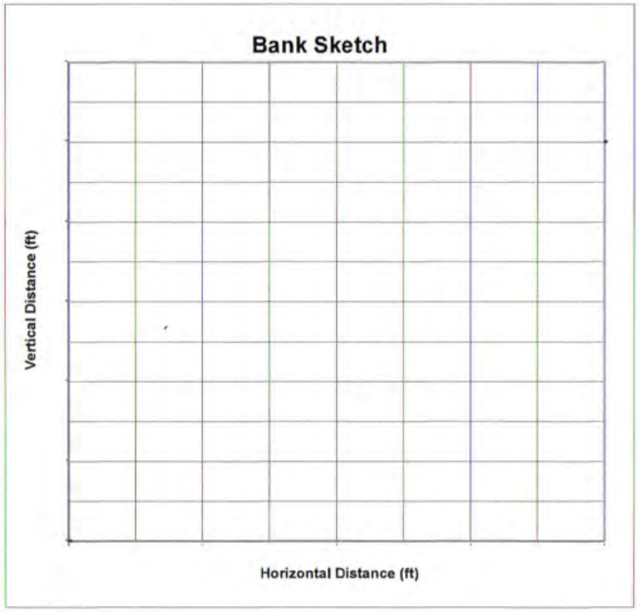
Root Density (%) 70% F	F*E = 3.5 G

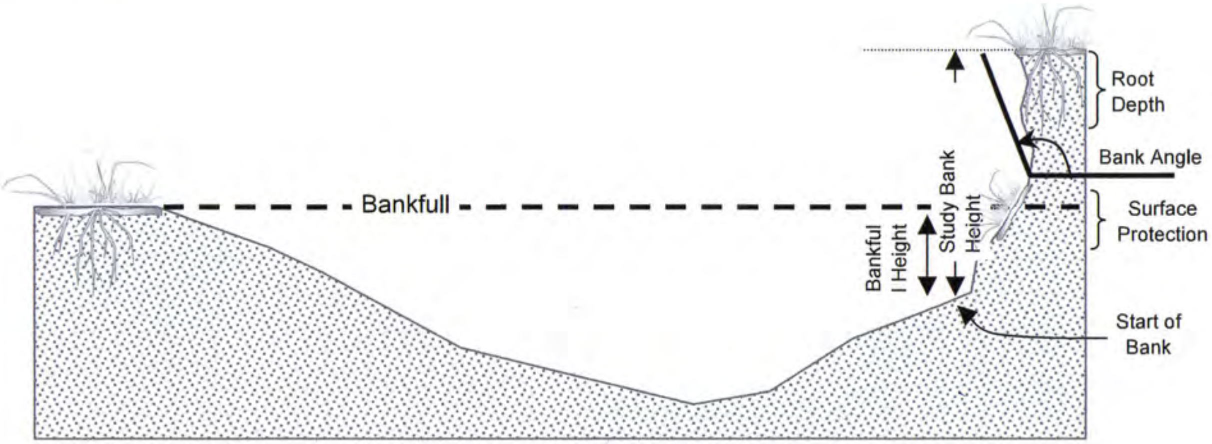
Bank Angle (H)

Bank Angle (Degrees) 90 H

Surface Protection (I)

Surface Protection % 20 I





Worksheet 21. Summary of bank erosion hazard index (BEHI)

Bank Erosion Hazard Rating Guide

Stream Wabash Reach UWR 4 Date Crew rck/Hmrs

Bank Erosion Potential	Bank Height (ft): Bankfull Height (ft):		Bank Height/ Bankfull Ht	Root Depth/ Bank Height	Root Density %	Bank Angle (Degrees)	Surface Protection%
	VERY LOW	Value	1.0-1.1	1.0-0.9	100-80	0-20	100-80
		Index	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9
		Choice	V: I:	V: I:	V: I:	V: I:	V: I:
	LOW	Value	1.11-1.19	0.89-0.5	79-55	21-60	79-55
		Index	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9
		Choice	V: I:	V: I:	V: I:	V: I:	V: I:
	MODERATE	Value	1.2-1.5	0.49-0.3	54-30	61-80	54-30
		Index	4.0-5.9	4.0-5.9	4.0-5.9	4.0-5.9	4.0-5.9
		Choice	V: I:	V: I:	V: I:	V: I:	V: I:
	HIGH	Value	1.6-2.0	0.29-0.15	29-15	81-90	29-15
		Index	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9
		Choice	V: I:	V: I:	V: I:	V: I:	V: I:
	VERY HIGH	Value	2.1-2.8	0.14-0.05	14-5.0	91-119	14-10
		Index	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0
		Choice	V: I:	V: I:	V: I:	V: I:	V: I:
	EXTREME	Value	>2.8	<0.05	<5	>119	<10
		Index	10	10	10	10	10
		Choice	V: I: 9	V: I: 8.5	V: I: 3.5	V: I: 7.5	V: I: 7.0
	V = value, I = index				**SUB-TOTAL** (Sum one index from each column)		36.3

Bank Material Description:

Silt/clay loam ~ 70" on fill

Bank Materials

- **Bedrock** (Bedrock banks have very low bank erosion potential)
- **Boulders** (Banks composed of boulders have low bank erosion potential)
- **Cobble** (Subtract 10 points. If sand/gravel matrix greater than 50% of bank material, then do not adjust)
- **Gravel** (Add 5-10 points depending percentage of bank material that is composed of sand)
- **Sand** (Add 10 points)
- **Silt Clay** (+ 0: no adjustment)

BANK MATERIAL ADJUSTMENT ~~0~~

Stratification Comments:

Stratification

Add 5-10 points depending on position of unstable layers in relation to bankfull stage

STRATIFICATION ADJUSTMENT 10

VERY LOW	LOW	MODERATE	HIGH	VERY HIGH	EXTREME
5-9.5	10-19.5	20-29.5	30-39.5	40-45	46-50

Bank location description (circle one)

Straight Reach Outside of Bend

GRAND TOTAL BEHI RATING 46.3

OWR-1

Worksheet 20. BEHI variable worksheet

Stream: Wabash	Cross Section: OWR 1	Date:	Observers: rcb / HMB

Bank Height/Max Depth Bankfull (C)

Study Bank Height (ft) 21.0 A	Bankfull Height (ft) 6.3 B	A/B = 3.3 C

Root Depth/Bank Height (E)

Root Depth (ft) 1 D	Study Bank Height (ft) 21.0 A	D/A = .05 E

Weighted Root Density (G)

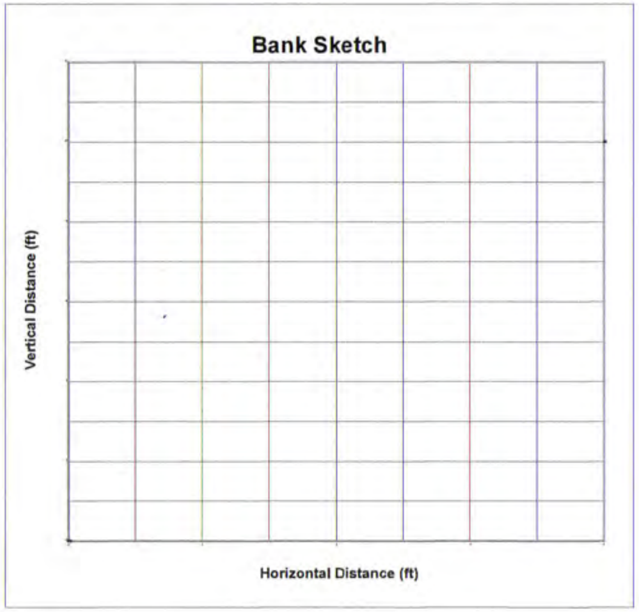
Root Density (%) 50 F	F*E = 2.5 G

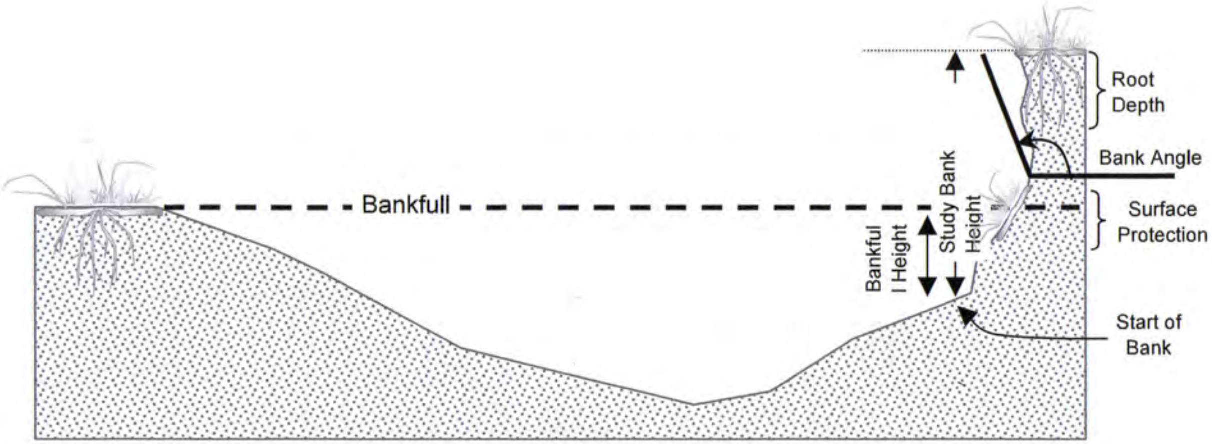
Bank Angle (H)

Bank Angle (Degrees) 60 H

Surface Protection (I)

Surface Protection % 75 I





Worksheet 20. BEHI variable worksheet

Stream: Wabash	Cross Section: UWR 2	Date: 7.17.18	Observers: rob / [illegible]

Bank Height/Max Depth Bankfull (C)

Study Bank Height (ft) 15.0 A	Bankfull Height (ft) 6.0 B	A/B = 2.5 C

Root Depth/Bank Height (E)

Root Depth (ft) 1 D	Study Bank Height (ft) 15 A	D/A = .06 E

Weighted Root Density (G)

Root Density (%) 80 F	F*E = 4.8 G

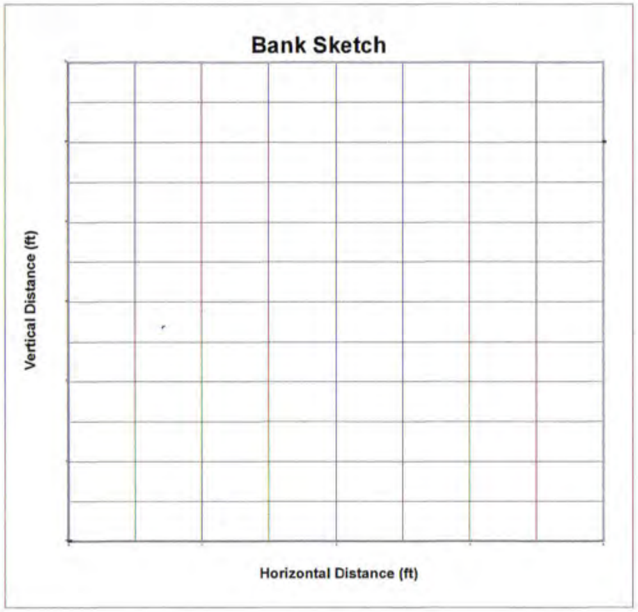
Bank Angle (H)

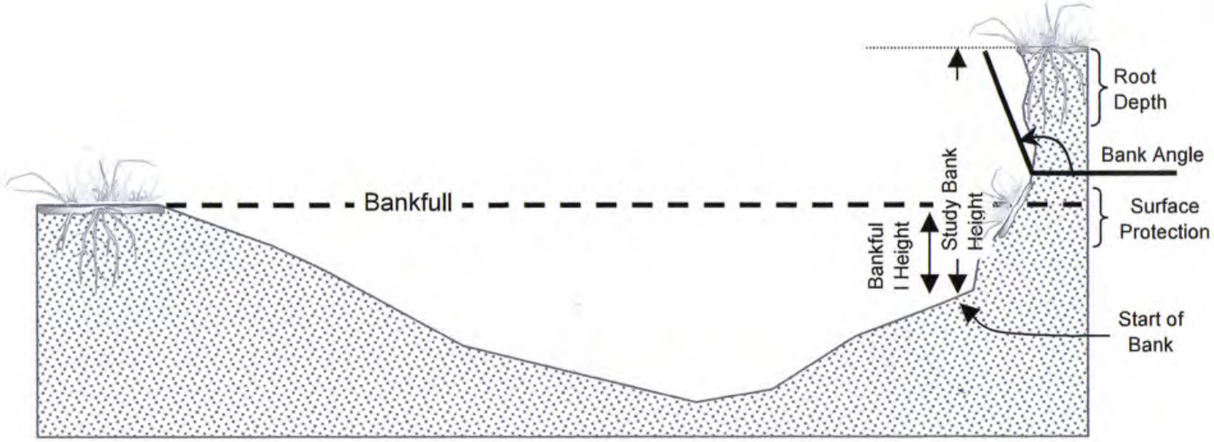
Bank Angle (Degrees) 60 H

Surface Protection (I)

Surface Protection % 50 I

(Variable!)





Worksheet 20. BEHI variable worksheet

Stream: Wabash	Cross Section: OWR 3	Date:	Observers: HMRS / rcb

Bank Height/Max Depth Bankfull (C)

Study Bank Height (ft) 15.0 A	Bankfull Height (ft) 4.25 B	A/B = 3.5 C

Root Depth/Bank Height (E)

Root Depth (ft) 0.5 D	Study Bank Height (ft) 15.0 A	D/A = .03 E

Weighted Root Density (G)

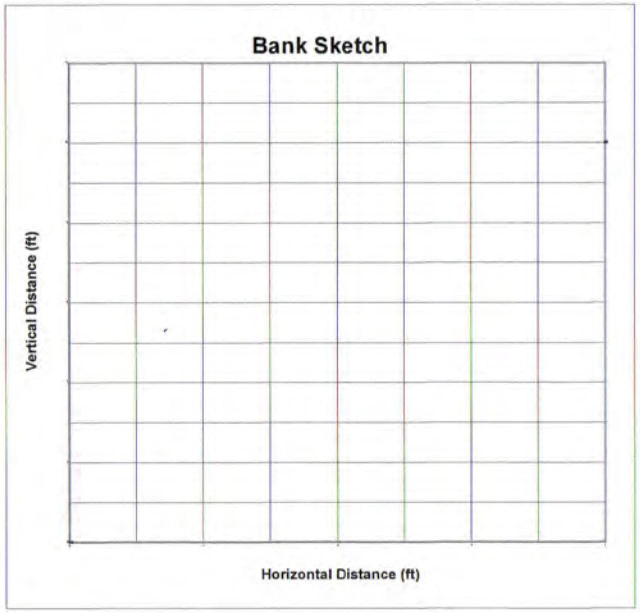
Root Density (%) 15 F	F*E = 0.45 G

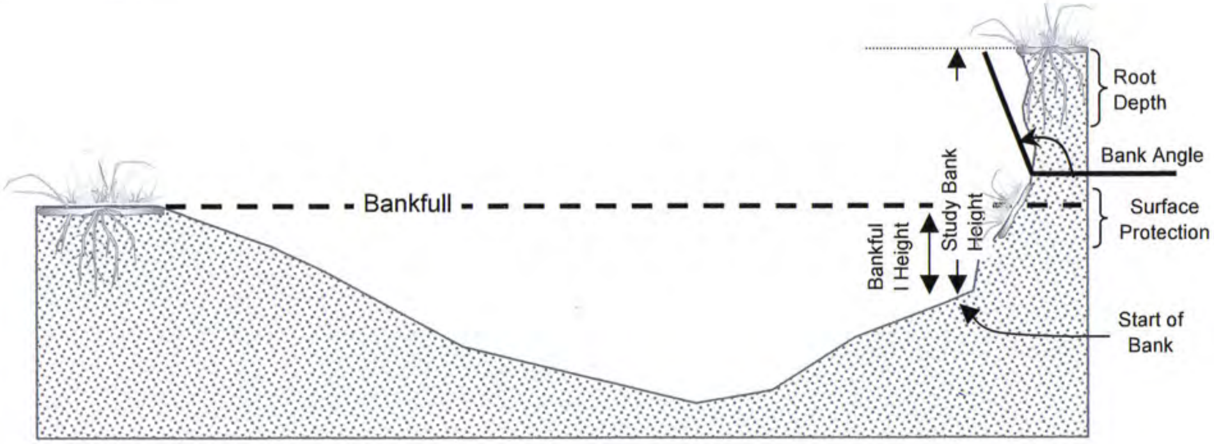
Bank Angle (H)

Bank Angle (Degrees) 45 H

Surface Protection (I)

Surface Protection % 20 I





Worksheet 20. BEHI variable worksheet

Stream: Wabash	Cross Section: UDR 4	Date:	Observers: rcb / HMB

Bank Height/Max Depth Bankfull (C)

Study Bank Height (ft) 10.6 A	Bankfull Height (ft) 4.25 B	A/B = 2.5 C

Root Depth/Bank Height (E)

Root Depth (ft) 0.5 D	Study Bank Height (ft) 10.6 A	D/A = .05 E

Weighted Root Density (G)

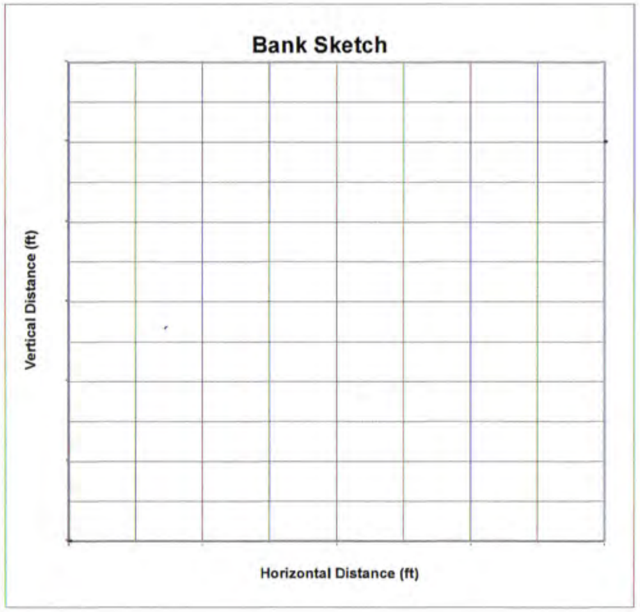
Root Density (%) 70% F	F*E = 3.5 G

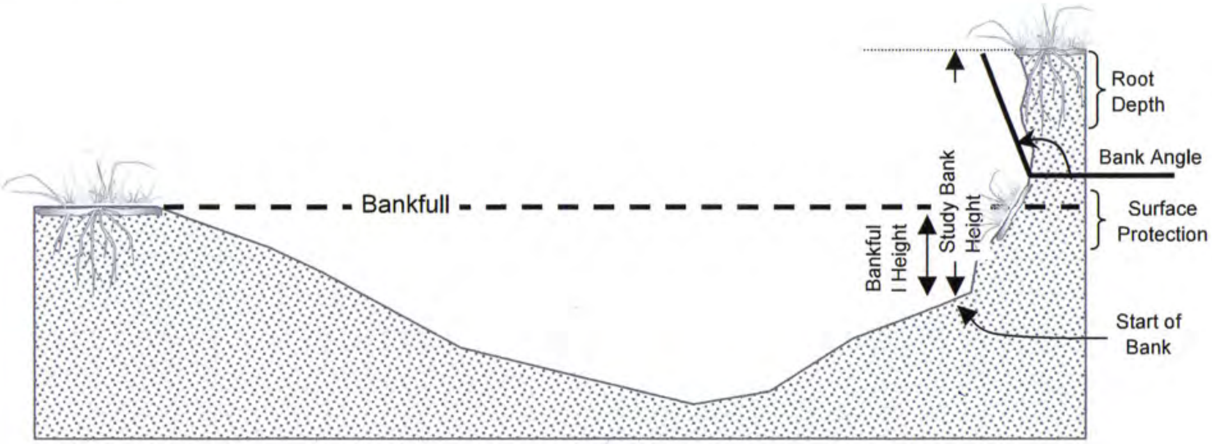
Bank Angle (H)

Bank Angle (Degrees) 90 H

Surface Protection (I)

Surface Protection % 20 I





Worksheet 20. BEHI variable worksheet

Stream: Gasaok	Cross Section: OWR6	Date:	Observers: HMB rcb

Bank Height/Max Depth Bankfull (C)

Study Bank Height (ft) 9.0 A	Bankfull Height (ft) 5.5 B	A/B = 1.6 C

Root Depth/Bank Height (E)

Root Depth (ft) 0.5 D	Study Bank Height (ft) 9.0 A	D/A = 0.05 E

Weighted Root Density (G)

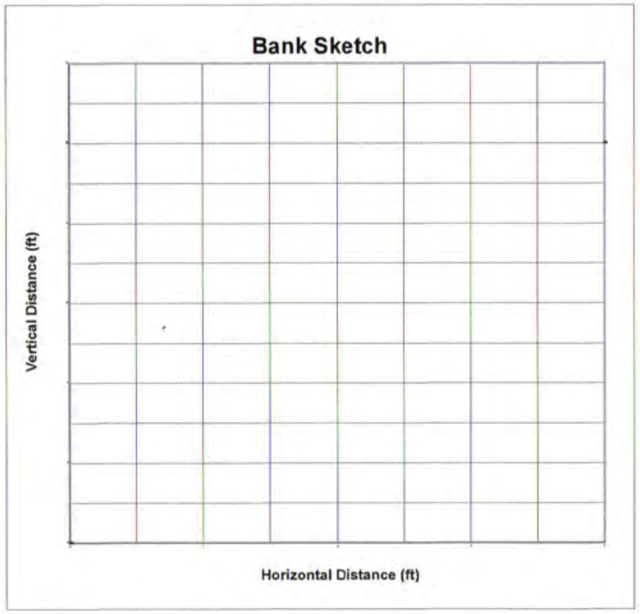
Root Density (%) 20 F	F*E = 1.0 G

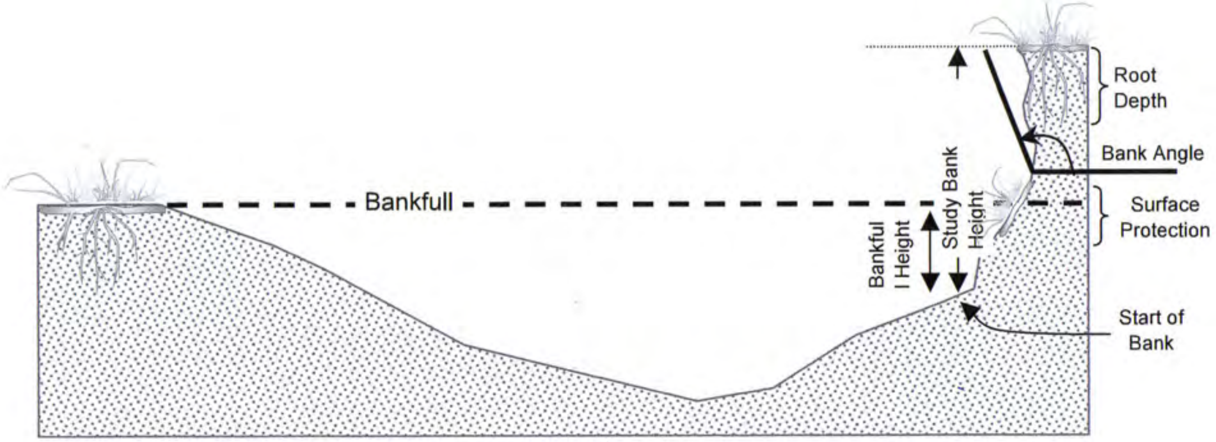
Bank Angle (H)

Bank Angle (Degrees) 90 H

Surface Protection (I)

Surface Protection % 20 I





Worksheet 20. BEHI variable worksheet

Stream: Gasaok	Cross Section: UNR6	Date:	Observers: HMB rcb

Bank Height/Max Depth Bankfull (C)

Study Bank Height (ft) 9.0 A	Bankfull Height (ft) 5.5 B	A/B = 1.6 C

Root Depth/Bank Height (E)

Root Depth (ft) 0.5 D	Study Bank Height (ft) 9.0 A	D/A = 0.05 E

Weighted Root Density (G)

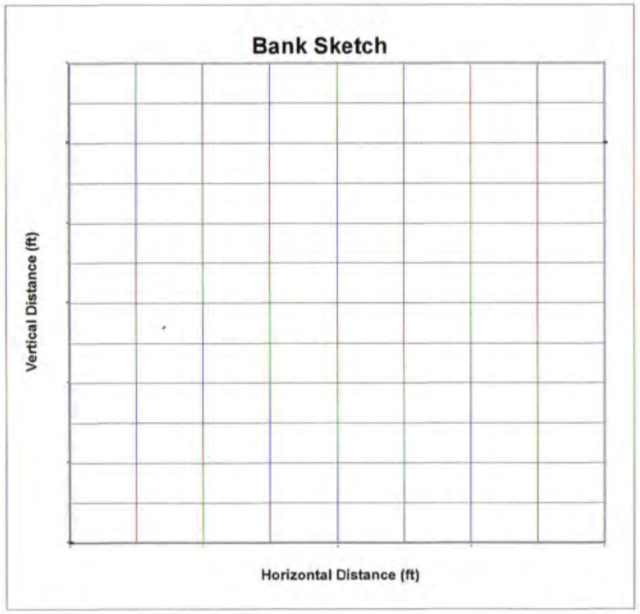
Root Density (%) 20 F	F*E = 1.0 G

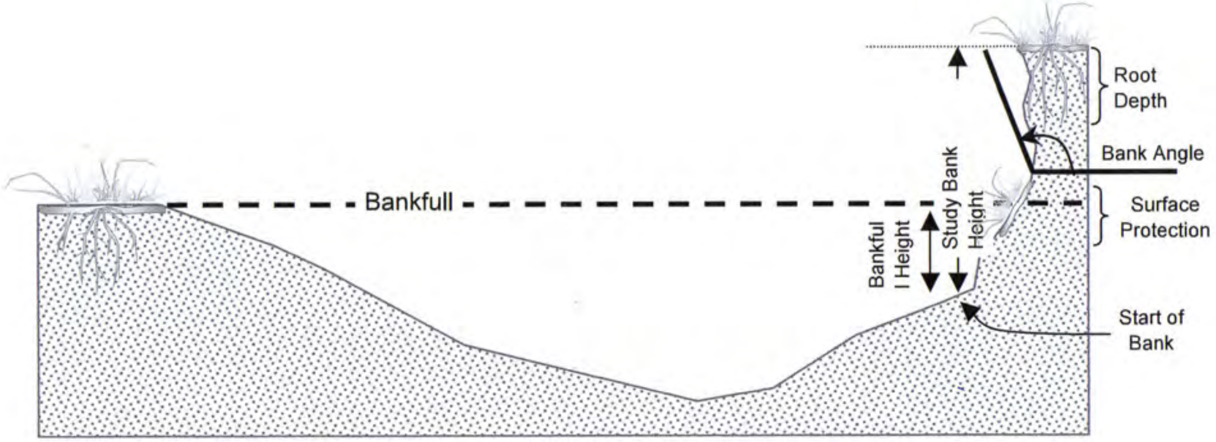
Bank Angle (H)

Bank Angle (Degrees) 90 H

Surface Protection (I)

Surface Protection % 20 I





Worksheet 21. Summary of bank erosion hazard index (BEHI)

Bank Erosion Hazard Rating Guide

Stream Reach Date Crew

Bank Erosion Potential	Bank Height (ft): 9.0 Bankfull Height (ft): 5.5		**Bank Height/ Bankfull Ht**	**Root Depth/ Bank Height**	**Root Density %**	**Bank Angle (Degrees)**	**Surface Protection%**
	VERY LOW	Value	1.0-1.1	1.0-0.9	100-80	0-20	100-80
		Index	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9
		Choice	V: I:	V: I:	V: I:	V: I:	V: I:
	LOW	Value	1.11-1.19	0.89-0.5	79-55	21-60	79-55
		Index	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9
		Choice	V: I:	V: I:	V: I:	V: I:	V: I:
	MODERATE	Value	1.2-1.5	0.49-0.3	54-30	61-80	54-30
		Index	4.0-5.9	4.0-5.9	4.0-5.9	4.0-5.9	4.0-5.9
		Choice	V: I:	V: I:	V: I:	V: I:	V: I:
	HIGH	Value	1.6-2.0	0.29-0.15	29-15	81-90	29-15
		Index	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9
		Choice	V: I:	V: I:	V: I:	V: I:	V: I:
	VERY HIGH	Value	2.1-2.8	0.14-0.05	14-5.0	91-119	14-10
		Index	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0
		Choice	V: I:	V: I:	V: I:	V: I:	V: I:
	EXTREME	Value	>2.8	<0.05	<5	>119	<10
		Index	10	10	10	10	10
		Choice	V: I: 7	V: I: 8.5	V: I: 7.0	V: I: 7.9	V: I: 7
	V = value, I = index					**SUB-TOTAL** (Sum one index from each column)	37.4

Bank Material Description:

Bank Materials

- **Bedrock** (Bedrock banks have very low bank erosion potential)
- **Boulders** (Banks composed of boulders have low bank erosion potential)
- **Cobble** (Subtract 10 points. If sand/gravel matrix greater than 50% of bank material, then do not adjust)
- **Gravel** (Add 5-10 points depending percentage of bank material that is composed of sand)
- **Sand** (Add 10 points)
- **Silt Clay** (+ 0: no adjustment)

BANK MATERIAL ADJUSTMENT 0

Stratification Comments:

Stratification

Add 5-10 points depending on position of unstable layers in relation to bankfull stage

STRATIFICATION ADJUSTMENT 10

VERY LOW	**LOW**	**MODERATE**	**HIGH**	**VERY HIGH**	**EXTREME**
5-9.5	10-19.5	20-29.5	30-39.5	40-45	46-50

Bank location description (circle one)

Straight Reach Outside of Bend

GRAND TOTAL BEHI RATING 47.4

Worksheet 20. BEHI variable worksheet

Stream: Wabash	Cross Section: OWR 7	Date:	Observers: rcb Lmb

Bank Height/Max Depth Bankfull (C)

Study Bank Height (ft) 14.0 A	Bankfull Height (ft) 6.0 B	A/B = 2.5 C

Root Depth/Bank Height (E)

Root Depth (ft) 0.5 D	Study Bank Height (ft) 14 A	D/A = .03 E

Weighted Root Density (G)

Root Density (%) 30 F	F*E = 1.0 G

Bank Angle (H)

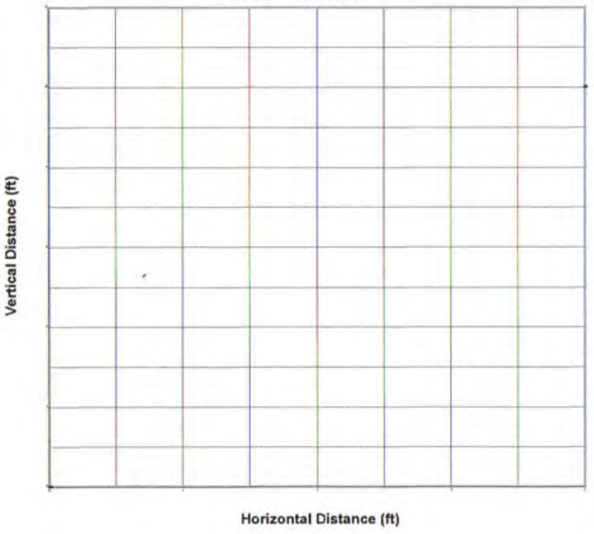
Bank Angle (Degrees) 70 H

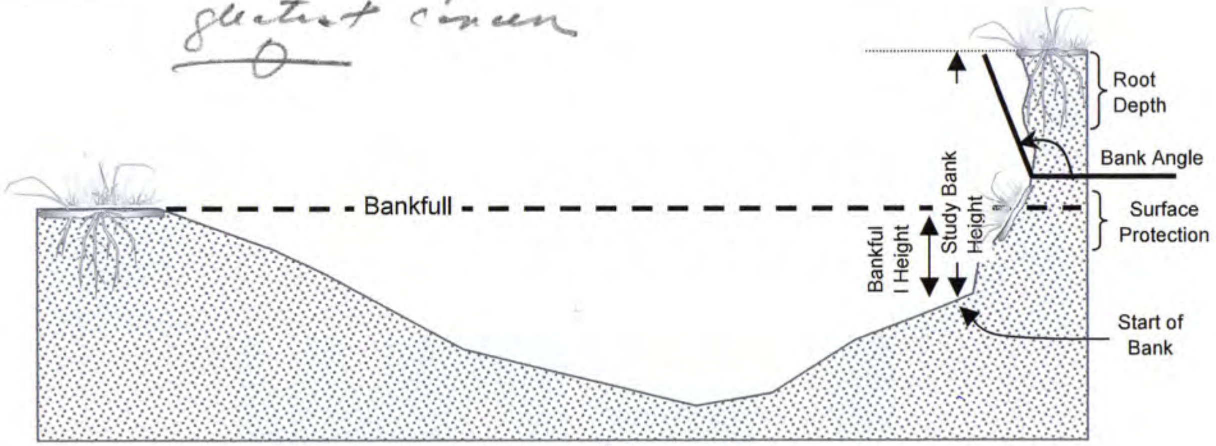
Surface Protection (I)

Surface Protection % ~~0~~ I

→ 0 – 90
in area of
greatest concern
~~0~~

Bank Sketch





Worksheet 21. Summary of bank erosion hazard index (BEHI)

Bank Erosion Hazard Rating Guide

Stream Wabash Reach UKR 7 Date 7.17.18 Crew

Bank Erosion Potential

Bank Height (ft): / Bankfull Height (ft):		Bank Height/ Bankfull Ht	Root Depth/ Bank Height	Root Density %	Bank Angle (Degrees)	Surface Protection%
VERY LOW	Value	1.0-1.1	1.0-0.9	100-80	0-20	100-80
	Index	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9
	Choice	V: I:	V: I:	V: I:	V: I:	V: I:
LOW	Value	1.11-1.19	0.89-0.5	79-55	21-60	79-55
	Index	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9
	Choice	V: I:	V: I:	V: I:	V: I:	V: I:
MODERATE	Value	1.2-1.5	0.49-0.3	54-30	61-80	54-30
	Index	4.0-5.9	4.0-5.9	4.0-5.9	4.0-5.9	4.0-5.9
	Choice	V: I:	V: I:	V: I:	V: I:	V: I:
HIGH	Value	1.6-2.0	0.29-0.15	29-15	81-90	29-15
	Index	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9
	Choice	V: I:	V: I:	V: I:	V: I:	V: I:
VERY HIGH	Value	2.1-2.8	0.14-0.05	14-5.0	91-119	14-10
	Index	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0
	Choice	V: I:	V: I:	V: I:	V: I:	V: I:
EXTREME	Value	>2.8	<0.05	<5	>119	<10
	Index	10	10	10	10	10
	Choice	V: I: 8.5	V: I: 8.5	V: I: 5	V: I: 5.0	V: I: 10
V = value, I = index					**SUB-TOTAL** (Sum one index from each column)	

Bank Material Description:

clay loam on till

Bank Materials

- **Bedrock** (Bedrock banks have very low bank erosion potential)
- **Boulders** (Banks composed of boulders have low bank erosion potential)
- **Cobble** (Subtract 10 points. If sand/gravel matrix greater than 50% of bank material, then do not adjust)
- **Gravel** (Add 5-10 points depending percentage of bank material that is composed of sand)
- **Sand** (Add 10 points)
- **Silt Clay** (+ 0: no adjustment)

BANK MATERIAL ADJUSTMENT 0

Stratification Comments:

Stratification

Add 5-10 points depending on position of unstable layers in relation to bankfull stage

STRATIFICATION ADJUSTMENT 10

VERY LOW	LOW	MODERATE	HIGH	VERY HIGH	EXTREME
5-9.5	10-19.5	20-29.5	30-39.5	40-45	46-50

Bank location description (circle one)

Straight Reach Outside of Bend

GRAND TOTAL BEHI RATING 47

Appendix 3: Cost Estimates

Opinion of Probably Cost for Functional Assessment of the Upper Wabash River

Improvements at 4100 E CR 1200 S - Adams Co

Line	Description	Estimated Quantities	Units	Unit Price	Estimated Cost (Rounded)
1	**Demolition**				
2	Strip & Stockpile Topsoil	100	CY	$ 8	$ 1,000
3	Selective Tree Clearing, Grubbing, & Hauling	0.3	AC	$ 25,000	$ 8,000
4				Estimated Demolition Cost	$ 9,000
5	**Channel Improvements**				
6	Mass Excavation & Haul Spoils	600	CY	$ 15	$ 9,000
7	Place & Compact Fill Material	200	CY	$ 8	$ 2,000
8	Install Soil Lifts	950	SF	$ 25	$ 24,000
9	Install Live Willow Stakes	950	EA	$ 3	$ 3,000
10	Topsoil Placement	500	SY	$ 5	$ 3,000
11	Finish Grading	500	SY	$ 5	$ 3,000
12	Seeding	500	SY	$ 2	$ 1,000
13	Install Erosion Control Blankets	300	SY	$ 3	$ 1,000
14				Estimated Channel Improvements Cost	$ 46,000
15	**Miscellaneous**				
16	Dewatering	1	LS	$ 2,000	$ 2,000
17	Erosion and Sediment Control	1	LS	$ 2,000	$ 2,000
18	Construction Surveying	1	LS	$ 1,000	$ 1,000
19	Construction Mobilization/Demobilization	1	LS	$ 6,000	$ 6,000
20	Project Administration & Unforeseen Additional Costs (50%)	1	LS	$ 28,000	$ 28,000
21				Estimated Miscellaneous Cost	$ 39,000
22					
23				**Total Construction Cost**	**$ 94,000**
24					
25	**Professional Services**				
26	Topographic Site Survey	1	LS	$ 3,000	$ 3,000
27	Engineering Design & Permitting	1	LS	$ 45,000	$ 45,000
28	Construction Observation	1	LS	$ 15,000	$ 15,000
29				Estimated Professional Services Cost	$ 63,000
30					
31				**Estimated Total Cost for Project**	**$ 157,000**

Notes and Assumptions

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2. All costs are in 2018 dollars.
3. Estimated costs have been rounded.
4. This estimate does not include unforeseen costs increases that may result from shortages in fuel and materials as a result of a natural or man-made disaster.
5. Costs have been estimated without the benefit of survey data, utility coordination, or design. This estimate is intended for planning level consideration, and should only be used for such purposes.
6. This estimate does not include easement, right-of-way, or land acquisition costs that may be necessary to construct the proposed alternative.
7. This estimate does not include the cost of environmental mitigation, which may be necessary as a result of project impacts

Opinion of Probably Cost for Functional Assessment of the Upper Wabash River

Improvements at 3343 E CR 1200 S - Jay Co

Line	Description	Estimated Quantities	Units	Unit Price	Estimated Cost (Rounded)
1	**Demolition**				
2	Strip & Stockpile Topsoil	300	CY	$ 7	$ 2,000
3	Selective Tree Clearing, Grubbing, & Hauling	0.6	AC	$ 25,000	$ 15,000
4			Estimated Demolition Cost		$ 17,000
5	**Channel Improvements**				
6	Mass Excavation	800	CY	$ 7	$ 6,000
7	Purchase and Haul Fill Material	500	CY	$ 15	$ 8,000
8	Place & Compact Fill Material	1,300	CY	$ 10	$ 13,000
9	Install Gabion Wall	480	CY	$ 250	$ 120,000
10	Install Live Willow Stakes	480	EA	$ 3	$ 1,000
11	Topsoil Placement	3,400	SY	$ 3	$ 10,000
12	Finish Grading	3,800	SY	$ 2	$ 8,000
13	Seeding	3,600	SY	$ 2	$ 7,000
14	Install Erosion Control Blankets	3,600	SY	$ 3	$ 11,000
15		Estimated Channel Improvements Cost			$ 184,000
16	**Miscellaneous**				
17	Dewatering	1	LS	$ 5,000	$ 5,000
18	Erosion and Sediment Control	1	LS	$ 2,000	$ 2,000
19	Construction Surveying	1	LS	$ 3,000	$ 3,000
20	Construction Mobilization/Demobilization	1	LS	$ 12,000	$ 12,000
21	Project Administration & Unforeseen Additional Costs (50%)	1	LS	$ 101,000	$ 101,000
22		Estimated Miscellaneous Cost			$ 123,000
23					
24			**Total Construction Cost**		**$ 324,000**
25					
26	**Professional Services**				
27	Topographic Site Survey	1	LS	$ 4,000	$ 4,000
28	Geotechnical Engineering Investigation	1	LS	$ 7,000	$ 7,000
29	Engineering Design & Permitting	1	LS	$ 45,000	$ 45,000
30	Construction Observation	1	LS	$ 25,000	$ 25,000
31		Estimated Professional Services Cost			$ 81,000
32					
33		**Estimated Total Cost for Project**			**$ 405,000**

Notes and Assumptions

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3. Estimated costs have been rounded.
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5. Costs have been estimated without the benefit of survey data, utility coordination, or design. This estimate is intended for planning level consideration, and should only be used for such purposes.
6. This estimate does not include easement, right-of-way, or land acquisition costs that may be necessary to construct the proposed alternative.
7. This estimate does not include the cost of environmental mitigation, which may be necessary as a result of project impacts

Opinion of Probably Cost for Functional Assessment of the Upper Wabash River

Improvements at 270 E CR 1100 S - Adams Co

Line	Description	Estimated Quantities	Units	Unit Price	Estimated Cost (Rounded)
1	**Demolition**				
2	Strip & Stockpile Topsoil	70	CY	$ 7	$ -
3	Selective Tree Clearing, Grubbing, & Hauling	0.2	AC	$ 25,000	$ 4,000
4			Estimated Demolition Cost		$ 4,000
5	**Channel Improvements**				
6	Mass Excavation	700	CY	$ 7	$ 5,000
7	Purchase and Haul Fill Material	100	CY	$ 10	$ 1,000
8	Place & Compact Fill Material	800	CY	$ 7	$ 6,000
9	Install Riprap Toe	280	TN	$ 35	$ 10,000
10	Install Soil Lifts	700	SF	$ 25	$ 18,000
11	Install Live Willow Stakes	700	EA	$ 3	$ 2,000
12	Topsoil Placement	1,100	SY	$ 3	$ 3,000
13	Finish Grading	1,100	SY	$ 2	$ 2,000
14	Seeding	1,100	SY	$ 2	$ 2,000
15	Install Erosion Control Blankets	1,100	SY	$ 3	$ 3,000
16		Estimated Channel Improvements Cost			$ 52,000
17	**Miscellaneous**				
18	Dewatering	1	LS	$ 5,000	$ 5,000
19	Erosion and Sediment Control	1	LS	$ 1,000	$ 1,000
20	Construction Surveying	1	LS	$ 1,000	$ 1,000
21	Construction Mobilization/Demobilization	1	LS	$ 5,000	$ 5,000
22	Project Administration & Unforeseen Additional Costs (50%)	1	LS	$ 28,000	$ 28,000
23		Estimated Miscellaneous Cost			$ 40,000
24					
25		**Total Construction Cost**			**$ 96,000**
26					
27	**Professional Services**				
28	Topographic Site Survey	1	LS	$ 4,000	$ 4,000
29	Engineering Design & Permitting	1	LS	$ 45,000	$ 45,000
30	Construction Observation	1	LS	$ 15,000	$ 15,000
31		Estimated Professional Services Cost			$ 64,000
32					
33		**Estimated Total Cost for Project**			**$ 160,000**

Notes and Assumptions

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2 All costs are in 2018 dollars.

3 Estimated costs have been rounded.

4 This estimate does not include unforeseen costs increases that may result from shortages in fuel and materials as a result of a natural or man-made disaster.

5 Costs have been estimated without the benefit of survey data, utility coordination, or design. This estimate is intended for planning level consideration, and should only be used for such purposes.

6 This estimate does not include easement, right-of-way, or land acquisition costs that may be necessary to construct the proposed alternative.

7 This estimate does not include the cost of environmental mitigation, which may be necessary as a result of project impacts

Opinion of Probably Cost for Functional Assessment of the Upper Wabash River

Improvements at 305 Old Hickory Ln - Adams Co

Line	Description	Estimated Quantities	Units	Unit Price	Estimated Cost (Rounded)
1	**Demolition**				
2	Strip & Stockpile Topsoil	100	CY	$ 7	$ 1,000
3	Selective Tree Clearing, Grubbing, & Hauling	1	LS	$ 10,000	$ 10,000
4			Estimated Demolition Cost		$ 11,000
5	**Channel Improvements**				
6	Purchase and Haul Fill Material	400	CY	$ 10	$ 4,000
7	Place & Compact Fill Material	400	CY	$ 10	$ 4,000
8	Install Gabion Wall	270	CY	$ 250	$ 68,000
9	Install Live Willow Stakes	235	EA	$ 3	$ 1,000
10	Topsoil Placement	600	SY	$ 3	$ 2,000
11	Finish Grading	600	SY	$ 2	$ 1,000
12	Seeding	600	SY	$ 2	$ 1,000
13	Install Erosion Control Blankets	600	SY	$ 3	$ 2,000
14		Estimated Channel Improvements Cost			$ 83,000
15	**Miscellaneous**				
16	Dewatering	1	LS	$ 2,000	$ 2,000
17	Erosion and Sediment Control	1	LS	$ 2,000	$ 2,000
18	Construction Surveying	1	LS	$ 1,000	$ 1,000
19	Construction Mobilization/Demobilization	1	LS	$ 8,000	$ 8,000
20	Project Administration & Unforeseen Additional Costs (50%)	1	LS	$ 47,000	$ 47,000
21			Estimated Miscellaneous Cost		$ 60,000
22					
23			**Total Construction Cost**		**$ 154,000**
24					
25	**Professional Services**				
26	Topographic Site Survey	1	LS	$ 4,000	$ 4,000
27	Geotechnical Engineering Investigation	1	LS	$ 7,000	$ 7,000
28	Engineering Design & Permitting	1	LS	$ 45,000	$ 45,000
29	Construction Observation	1	LS	$ 25,000	$ 25,000
30		Estimated Professional Services Cost			$ 81,000
31					
32		**Estimated Total Cost for Project**			**$ 235,000**

Notes and Assumptions

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3. Estimated costs have been rounded.
4. This estimate does not include unforeseen costs increases that may result from shortages in fuel and materials as a result of a natural or man-made disaster.
5. Costs have been estimated without the benefit of survey data, utility coordination, or design. This estimate is intended for planning level consideration, and should only be used for such purposes.
6. This estimate does not include easement, right-of-way, or land acquisition costs that may be necessary to construct the proposed alternative.
7. This estimate does not include the cost of environmental mitigation, which may be necessary as a result of project impacts

Opinion of Probably Cost for Functional Assessment of the Upper Wabash River

Improvements at 6500 SR 116 - Wells Co

Line	Description	Estimated Quantities	Units	Unit Price	Estimated Cost (Rounded)
1	**Demolition**				
2	Strip & Stockpile Topsoil	200	CY	$ 8	$ 2,000
3	Selective Tree Clearing, Grubbing, & Hauling	1.0	LS	$ 5,000	$ 5,000
4	Estimated Demolition Cost				$ 7,000
5	**Channel Improvements**				
6	Mass Excavation	300	CY	$ 15	$ 5,000
7	Install Soil Lifts	3,010	SF	$ 25	$ 75,000
8	Install Live Willow Stakes	3,010	EA	$ 3	$ 9,000
9	Topsoil Placement	1,800	SY	$ 5	$ 9,000
10	Finish Grading	1,800	SY	$ 5	$ 9,000
11	Seeding	1,800	SY	$ 2	$ 4,000
12	Install Erosion Control Blankets	1,800	SY	$ 3	$ 5,000
13	Estimated Channel Improvements Cost				$ 116,000
14	**Miscellaneous**				
15	Dewatering	1	LS	$ 2,000	$ 2,000
16	Erosion and Sediment Control	1	LS	$ 2,000	$ 2,000
17	Construction Surveying	1	LS	$ 2,000	$ 2,000
18	Construction Mobilization/Demobilization	1	LS	$ 10,000	$ 10,000
19	Project Administration & Unforeseen Additional Costs (50%)	1	LS	$ 62,000	$ 62,000
20	Estimated Miscellaneous Cost				$ 78,000
21					
22	**Total Construction Cost**				**$ 201,000**
23					
24	**Professional Services**				
25	Topographic Site Survey	1	LS	$ 4,000	$ 4,000
26	Geotechnical Engineering Investigation	1	LS	$ 7,000	$ 7,000
27	Engineering Design & Permitting	1	LS	$ 50,000	$ 50,000
28	Construction Observation	1	LS	$ 25,000	$ 25,000
29	Estimated Professional Services Cost				$ 86,000
30					
31	**Estimated Total Cost for Project**				**$ 287,000**

Notes and Assumptions

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2. All costs are in 2018 dollars.
3. Estimated costs have been rounded.
4. This estimate does not include unforeseen costs increases that may result from shortages in fuel and materials as a result of a natural or man-made disaster.
5. Costs have been estimated without the benefit of survey data, utility coordination, or design. This estimate is intended for planning level consideration, and should only be used for such purposes.
6. This estimate does not include easement, right-of-way, or land acquisition costs that may be necessary to construct the proposed alternative.
7. This estimate does not include the cost of environmental mitigation, which may be necessary as a result of project impacts

Opinion of Probably Cost for Functional Assessment of the Upper Wabash River
Improvements at 6595 SR 116 - Wells Co

Line	Description	Estimated Quantities	Units	Unit Price		Estimated Cost (Rounded)	
1	**Demolition**						
2	Strip & Stockpile Topsoil	100	CY	$	7	$	1,000
3	Selective Tree Clearing, Grubbing, & Hauling	1	LS	$	10,000	$	10,000
4			Estimated Demolition Cost			$	11,000
5	**Channel Improvements**						
6	Mass Excavation	200	CY	$	7	$	1,000
7	Place & Compact Fill Material	200	CY	$	10	$	2,000
8	Install Gabion Mattress	200	CY	$	250	$	50,000
9	Install Live Willow Stakes	200	EA	$	3	$	1,000
10	Topsoil Placement	600	SY	$	3	$	2,000
11	Finish Grading	600	SY	$	2	$	1,000
12	Seeding	600	SY	$	2	$	1,000
13	Install Erosion Control Blankets	600	SY	$	3	$	2,000
14		Estimated Channel Improvements Cost				$	60,000
15	**Miscellaneous**						
16	Dewatering	1	LS	$	2,000	$	2,000
17	Erosion and Sediment Control	1	LS	$	2,000	$	2,000
18	Construction Surveying	1	LS	$	1,000	$	1,000
19	Construction Mobilization/Demobilization	1	LS	$	8,000	$	8,000
20	Project Administration & Unforeseen Additional Costs (50%)	1	LS	$	36,000	$	36,000
21			Estimated Miscellaneous Cost			$	49,000
22							
23			**Total Construction Cost**			**$**	**120,000**
24							
25	**Professional Services**						
26	Topographic Site Survey	1	LS	$	4,000	$	4,000
27	Geotechnical Engineering Investigation	1	LS	$	7,000	$	7,000
28	Engineering Design & Permitting	1	LS	$	45,000	$	45,000
29	Construction Observation	1	LS	$	25,000	$	25,000
30		Estimated Professional Services Cost				$	81,000
31							
32		**Estimated Total Cost for Project**				**$**	**201,000**

Notes and Assumptions

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3. Estimated costs have been rounded.
4. This estimate does not include unforeseen costs increases that may result from shortages in fuel and materials as a result of a natural or man-made disaster.
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7. This estimate does not include the cost of environmental mitigation, which may be necessary as a result of project impacts