STATE OF MICHIGAN
DEPARTMENT OF ENVIRONMENTAL QUALITY
WATER RESOURCES DIVISION

In the matter of:

ACO-000235
Date Entered:

City of Traverse City
400 Boardman Avenue
Traverse City, Michigan 49684
______________________________/

ADMINISTRATIVE CONSENT ORDER

This document results from allegations by the Department of Environmental Quality (DEQ), Water Resources Division (WRD). The DEQ alleges the City of Traverse City (City) with offices located at 400 Boardman Avenue, Traverse City, Michigan, Grand Traverse County, is in violation of Part 31, Water Resources Protection, MCL 324.3101 *et seq.*; Part 301, Inland Lakes and Streams, MCL 324.30101 *et seq.*; Part 303, Wetlands Protection, MCL 324.30301 *et seq.;* and Part 315, Dam Safety, MCL 324.31501 *et seq.*, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended (NREPA). The City is a person, as defined by Section 301 of the NREPA. The City and the DEQ agree to resolve the violations set forth herein through entry of this Administrative Consent Order (Consent Order).

I. STIPULATIONS

The City and the DEQ stipulate as follows:

1.1 The NREPA, MCL 324.101 *et seq.*, is an act that controls pollution to protect the environment and natural resources in the state.

1.2 Pollution Control, Part 31, Water Resources Protection, of the NREPA (Part 31), MCL 324.3101 *et seq.*, and the rules promulgated pursuant thereto, provides for the protection, conservation, and the control of pollution of the water resources of the state.

1.3 Part 301, Inland Lakes and Streams, of the NREPA (Part 301), MCL 324.30101 *et seq.*, and the rules promulgated thereto, provides in part that a person shall not fill bottomland, diminish, or structurally interfere with the natural flow of an inland lake or stream without obtaining a permit from the department.

1.4 Part 303, Wetlands Protection, of the NREPA (Part 303), MCL 324.30301 *et seq.*, and the rules promulgated thereto, provides that a person shall not deposit fill or dredge or drain regulated wetlands or maintain a use or development within a regulated wetland without a permit from the department.

1.5 Part 315, Dam Safety, of the NREPA (Part 315), MCL 324.31501 *et seq.*, and the rules promulgated thereto, provides, in part, that a person shall not construct, repair, alter, or remove a dam without a permit from the department.

1.6 The DEQ is authorized by Section 3112(4) of Part 31; Section 30112(1) of Part 301; Section 30315 of 303; and Section 315254 of Part 315, of the NREPA, to enter orders requiring persons to abate pollution, or otherwise cease or correct activities in violation of a specific part. The director of the DEQ may delegate this authority to a designee under Section 301(b) of the NREPA, MCL 324.301(b).

1.7 The City consents to the issuance and entry of this Consent Order and stipulates that the entry of this Consent Order constitutes a final order of the DEQ and is enforceable as such under Section 3112(4) of Part 31; Section 30112 of Part 301; Section 30315 of Part 303; and Section 31524 of Part 315. The City agrees not to contest the issuance of this Consent Order, and further agrees that the resolution of this matter by entry of this Consent Order is appropriate and acceptable. It is also agreed that this Consent Order shall become effective on the date it is signed by the chief of the WRD, delegate of the director, pursuant to Section 301(b) of the NREPA.

1.8 The City and the DEQ agree that the signing of this Consent Order is for settlement purposes only and does not constitute an admission by the City that any law has been violated.

1.9 The signatory to this Consent Order certifies that he is fully authorized by the City to enter into the terms and conditions of this Consent Order and to execute and legally bind the City to this document. The City hereby agrees to comply with the requirements of this

Consent Order to resolve the violations alleged in Section II of this Consent Order and agrees to achieve compliance with the NREPA and associated permits by fulfilling the terms of Section III of this Consent Order.

II. FINDINGS

2.1 The City owns the property on which the former Brown Bridge Dam and impoundment of the Boardman River was located within Grand Traverse County's East Bay Township located at T26N, R10W, Sections 14/15.

2.2 On August 8, 2012, the DEQ, WRD, issued Permit No. 12-28-0011-P under Parts 31, 301, 303, and 315, of the NREPA, to the City for the final draw down of the Brown Bridge Impoundment and removal of the Brown Bridge Dam infrastructure.

2.3 On October 6, 2012, at approximately 10:00 a.m., the City, through its contractor AMEC Environment & Infrastructure, Inc., a Nevada corporation, and AMEC's subcontractor Molon Excavating, Inc., a Michigan corporation, continued the drawdown process, which had commenced under terms of a previous permit, through a temporary dewatering structure (TDS) constructed adjacent to the Brown Bridge Dam. At approximately 10:20 a.m., AMEC called the county emergency management telephone number and informed emergency management personnel that the TDS had failed, which ultimately resulted in a breach of the dam's earthen embankment and rapid release of water from the impoundment. The uncontrolled discharge of impounded water and sediment into the Boardman River resulted in scouring and deposits of sediment within the river and adjacent wetlands and floodplains and damages to natural resources, including the loss of fish. County emergency management officials issued an evacuation order for residents living downstream of the failure because the high flow and velocity of water from the uncontrolled discharge posed a threat of substantial endangerment to the public.

2.4 The uncontrolled discharge of impounded water and sediment, breach of the embankment of the Boardman Dam, related scouring and fill, and damages to natural resources were not authorized by DEQ Permit No. 12-28-0011-P, issued to the City under the authorities of Parts 31, 301, 303, and 315, or consistent with project plans prepared by consultants employed by the City.

2.5 WRD staff conducted investigations of this incident to assess downstream impacts to natural resources. Starting on Monday, October 8, 2012, and on various dates thereafter, WRD staff were on-site to observe, monitor and/or sample the river water and evaluate resource impacts to downstream wetland, floodplain and stream channel areas. Photos, observations, and samples were collected at specific locations to document turbidity and sediment deposition. Sand and other soil material was deposited downstream of the TDS with much of the deposition occurring within wetlands, floodplains, and the stream channel between the TDS and Brown Bridge Road.

2.6 Violation Notice (VN) No. VN-005441/12-28-0035-V was sent from the WRD, Cadillac District Office, to the City on November 9, 2012, citing violations of Parts 31, 301, and 303, for the breach of the Brown Bridge Dam's temporary dewatering structure resulting in a high rate and volume of water discharge and sediment release downstream into the Boardman River and associated wetlands and floodplain areas. The WRD required restoration of a section of the Boardman River that had accumulated a significant portion of the sediment released (between the TDS and Brown Bridge Road). WRD staff conducted an on-site compliance inspection on December 14, 2012, and the restoration required under the November 9, 2012, VN was determined to be adequate. This restoration area, including the stream, wetlands, and floodplain, received the majority of the coarse sediment from the discharge. The VN did not address potential violations of Part 315. The WRD's Hydrologic Studies and Dam Safety Unit continued to investigate the root cause of the failure of the TDS.

2.7 On December 21, 2012, the City submitted to the WRD a response prepared by AMEC to the VN. The response identified additional areas for restoration where coarse material was deposited. WRD Water Resources Program staff continued to identify impacted locations and worked with the City, AMEC, affected property owners, and other interested parties to develop prudent restoration plans. The City and the DEQ have worked cooperatively toward a mutual goal of site restoration.

2.8 The City's December 21, 2012, response states that 140,000 cubic yards of sediment was removed from the impoundment area prior to the release on October 6, 2012. The City estimated that 5,700-7,500 cubic yards of sediment was deposited downstream as a result of the TDS failure. Per the response to the VN, the restoration work performed in November and early December 2012 reclaimed an estimated 3,500 - 4,500 cubic yards.

2.9 On Friday, December 14, 2012, WRD staff inspected the Boardman River Dam site and evaluated downstream resource impacts and the City's efforts to restore downstream wetland, floodplain and stream channel areas. WRD staff reported completion of removal of the Boardman Dam infrastructure and further observed continued restoration efforts underway to remove sand and other soil material deposited within downstream areas.

2.10 In June 2014, the WRD completed its investigation and issued the "Brown Bridge Dam-Temporary Dewatering Structure Root Cause Analysis of the October 6, 2012, Failure Incident." The WRD determined that the most likely failure mode of the TDS was internal erosion of the foundation material from underneath the water control structure within the TDS. Unsuitable subsurface soil conditions and inadequate site preparation for the TDS appear to have likely led to the failure.

2.11 In September 2014, the WRD requested that the City evaluate the need to further restore stream habitat diversity and channel stability within the "Impacted Reach" of the Boardman River, identified by the WRD as the Boardman River as it flows through the former Brown Bridge Impoundment downstream to the railroad bridge at 1400 East River Road. Although the City was not required to do so pursuant to a prior Administrative Consent Order, the City provided the WRD with a proposed Scope of Work detailing how such an evaluation would be conducted. For the purposes of this Order, "Impacted Reach" means the section of the Boardman River identified in this paragraph. The WRD approved a revised Scope of Work on January 29, 2015. The approved Scope of Work, dated January 19, 2015 by Stream Mechanics, PLLC, is appended to this Consent Order as Exhibit A.

2.12 After the City implemented the approved Scope of Work, it submitted a Boardman River

Assessment Report on March 18, 2015 containing the results of its evaluation. In the report, the City concluded that, among other things, the Impacted Reach is recovering from the TDS failure and that further restoration of stream habitat diversity and channel stability within the Impacted Reach is not needed. In a letter dated April 16, 2015, the WRD concurred with the conclusions of the report. The Boardman River Assessment Report is appended as Exhibit B.

2.13 In a draft Consent Order the WRD requested that the City "conduct annual surveys within the Impacted Reach and appropriate reference locations to monitor trends in fish and benthic macroinvertebrate community structure and habitat through the summer months of 2017" and that the DEQ's Policy and Procedure No. WRD-SWAS-051, Qualitative Biological and Habitat Survey Protocols for Wadeable Streams and Rivers (P-51) shall be used. Although the City was not required to do so pursuant to a prior Administrative Consent Order, the City provided the WRD with a proposed Scope of Work detailing how such an evaluation would be conducted. The WRD approved the City's proposal for the P-51 surveys and the City submitted the 2015 P-51 study to the WRD on September 28, 2015.

III. COMPLIANCE PROGRAM

IT IS THEREFORE AGREED AND ORDERED THAT the City shall take the following actions to prevent further violations of Part 31, 301, 303 and 315:

3.1 The City shall conduct annual surveys within the Impacted Reach and appropriate reference locations to monitor trends in fish and benthic macroinvertebrate community structure and habitat through the summer months of 2017. The City shall use DEQ's Policy and Procedure No. WRD-SWAS-051, Qualitative Biological and Habitat Survey Protocols for Wadeable Streams and Rivers (P-51), to conduct the annual surveys. The annual survey results (including the data collected and conclusions reached) shall be submitted in writing for DEQ review not later than each of the following dates:

October 1, 2016
October 1, 2017

The City's proposal for conducting the annual surveys (including the specific locations within the Impacted Reach for the surveys) prepared by the City's contractor Advanced Ecological Management has been accepted by the WRD and is attached as Exhibit C.

3.2 The City shall submit the annual survey results required by this section to the Cadillac District Supervisor, WRD, DEQ, 120 West Chapin Street, Cadillac, Michigan 49601-2158. The cover letter with each submittal shall identify the specific paragraph and requirement of this Consent Order that the submittal is intended to satisfy.

IV. EXTENSIONS

4.1 The City and the DEQ agree that the DEQ may grant the City a reasonable extension of the specified deadlines set forth in this Consent Order. Any extension shall be preceded by a written request in duplicate to the DEQ, WRD, Enforcement Unit Chief, P.O. Box 30458, Lansing, Michigan 48909-7958, and the Cadillac District Supervisor at the address in paragraph 3.2, no later than ten business days prior to the pertinent deadline, and shall include:

a. Identification of the specific deadline(s) of this Consent Order that will not be met.
b. A detailed description of the circumstances that will prevent the City from meeting the deadline(s).
c. A description of the measures the City has taken and/or intends to take to meet the required deadline.
d. The length of the extension requested and the specific date on which the obligation will be met.

The district supervisor, in consultation with the Enforcement Unit Chief, shall respond in writing to such requests. No change or modification to this Consent Order shall be valid unless in writing from the DEQ, and if applicable, signed by both parties.

V. REPORTING

5.1 The City shall verbally report any violation(s) of the terms and conditions of this Consent Order to the WRD Cadillac District Supervisor by no later than the close of the next business day following detection of such violation(s) and shall follow such notification with a written report within five business days following detection of such violation(s). The written report shall include a detailed description of the violation(s), as well as a description of any actions proposed or taken to correct the violation(s). The City shall report any anticipated violation(s) of this Consent Order to the above-referenced individual in advance of the relevant deadlines whenever possible.

VI. RETENTION OF RECORDS

6.1 Upon request by an authorized representative of the DEQ, the City shall make available to the DEQ all records, plans, logs, and other documents required to be maintained under this Consent Order or pursuant to Part 31 or its rules. All such documents shall be retained by the City for at least a period of three years from the date of generation of the record unless a longer period of record retention is required by Part 31 or its rules.

VII. RIGHT OF ENTRY

7.1 The City shall allow any authorized representative or contractor of the DEQ, upon presentation of proper credentials, to enter any area of the Boardman River and adjacent properties owned or controlled by the City at all reasonable times for the purpose of monitoring compliance with the provisions of this Consent Order. This paragraph in no way limits the authority of the DEQ to conduct tests and inspections pursuant to the NREPA and the rules promulgated thereunder, or any other applicable statutory provision.

VIII. SUPPLEMENTAL ENVIRONMENTAL PROJECT

8.1 The City shall implement the Supplemental Environmental Project (SEP) described in Exhibit D, which is attached, incorporated by reference, and enforceable under this Consent Order.

8.2 The City shall obtain any permits required by law to implement the SEP.

8.3 The City's total expenditures to implement the SEP shall not be less than $111,250.00. These costs include planning, engineering, permitting, contractor fees and all other reasonable costs incurred to implement the SEP. All costs of the SEP shall be the responsibility of the City.

8.4 If the City's actual expenditures to implement the SEP are less than $111,250.00, then the City shall pay to the DEQ as a civil fine, within thirty (30) days after submission of the SEP Completion Report required pursuant to paragraph 8.6 below, the difference between $111,250.00 and the City's actual expenditures. The City's payment shall be made in accordance with paragraph 9.4.

8.5 With regard to the SEP, the City certifies the truth and accuracy of each of the following:

a. that the City is not required to develop or implement the SEP by any local, state, or federal statute, regulation, rule, or permit.

b. that the City has not received, and is not presently negotiating to receive, a credit for the SEP as part of any other enforcement action with Michigan, the U.S. Environmental Protection Agency or any other entity.

c. that the City has not received, and is not presently negotiating to receive, any state or federal financial assistance to fund the SEP.

d. that the SEP is not a project that has any direct financial benefit to the City.

8.6 Within 30 days after the date scheduled for completion of the SEP, the City shall submit a SEP Completion Report to the DEQ, WRD, Enforcement Unit Chief, P.O. Box 30458, Lansing, Michigan 48909-7958, and the Cadillac District Supervisor at the address in paragraph 3.2. The SEP Completion Report shall contain the following information:

a. a detailed description of the SEP as implemented;

b. a description of any problems encountered in completing the SEP and the solutions thereto;

c. an itemized list of all eligible SEP costs expended; and

d. a certification that the SEP has been fully implemented pursuant to the provisions of this Consent Order.

8.7 After receiving the SEP Completion Report, DEQ shall notify the City whether it has satisfactorily completed the SEP. If the City has not completed the SEP in accordance with this Consent Order, then the DEQ may assess stipulated penalties under Section IX.

8.8 Any public statement made by the City making reference to the SEP under this Consent Order shall include the following language: "This project was undertaken in connection with the settlement of an enforcement action taken by the Michigan Department of Environmental Quality for violations of water resource protection laws."

IX. PENALTIES

9.1 Within 30 days after the effective date of this Consent Order, the City shall pay to the State of Michigan a civil fine of $18,750.00 for the violations alleged within Section II of this Consent Order.

9.2 If the City fails to implement the SEP in accordance with Section VIII of this Consent Order, or abandons works on the SEP, the City shall pay a stipulated penalty of $111,125.00. The penalty under this paragraph shall accrue as of the date specified for completing the SEP or the date performance ceases, whichever is earlier.

9.3 For each failure to comply with a provision of this Consent Order, the City shall pay stipulated penalties of up to **$200** per violation per day for each day of violation. For the purposes of this Consent Order, each day a deadline is missed, including deadlines for the SEP set forth in Exhibit D, constitutes a separate day of violation. The amount of the stipulated penalties imposed pursuant to this paragraph shall be within the discretion of the DEQ. The City shall submit stipulated penalties within 30 days of a written demand by DEQ.

9.4 The City agrees to pay all funds due pursuant to this agreement by check made payable to the State of Michigan and delivered to the Accounting Services Division, Cashier's Office for DEQ, P.O. Box 30657, Lansing, Michigan 48909-8157; or hand delivered to the Accounting Services Division, Cashier's Office for DEQ, 425 West Ottawa Street, Lansing, Michigan 48933. To ensure proper credit, all payments made pursuant to this Consent Order must include the **Payment Identification No. WRD50004**.

9.5 The City agrees not to contest the legality of the settlement amount paid pursuant to paragraph 9.1, above. The City further agrees not to contest the legality of any stipulated penalties assessed pursuant to paragraph 9.2 or 9.3, above, but reserves the right to dispute the factual basis upon which a demand by the DEQ for stipulated penalties or interest penalties is made.

9.6 The DEQ reserves its rights to seek interest on any unpaid sums due pursuant to the terms of the Consent Order. Subject to the other provisions of this Section IX, the DEQ may waive, in its unreviewable discretion, any portion of stipulated penalties and interest that has accrued pursuant to this Consent Order. This interest penalty shall be based on the rate set forth at MCL 600.6013(8), using the full increment of amount due as principal, and calculated from the due date for the payment until the delinquent payment is finally made in full.

X. FORCE MAJEURE

10.1 The City shall perform the requirements of this Consent Order within the time limits established herein, unless performance is prevented or delayed by events that constitute a "Force Majeure." Any delay in the performance attributable to a "Force Majeure" shall not be deemed a violation of the City's obligations under this Consent Order in accordance with this section.

10.2 For the purpose of this Consent Order, "Force Majeure" means an occurrence or nonoccurrence arising from causes not foreseeable, beyond the control of, and without the fault of the City, such as: an Act of God, untimely review of permit applications or submissions by the DEQ or other applicable authority, and acts or omissions of third parties that could not have been avoided or overcome by the City's diligence and that delay the performance of an obligation under this Consent Order. "Force Majeure" does not include, among other things, unanticipated or increased costs, changed financial circumstances, or failure to obtain a permit or license as a result of the City's actions or omissions.

10.3 The City shall notify the DEQ, by telephone, within 48 hours of discovering any event that causes a delay in its compliance with any provision of this Consent Order. Verbal notice shall be followed by written notice within ten calendar days and shall describe, in detail, the anticipated length of delay, the precise cause or causes of delay, the measures taken by the City to prevent or minimize the delay, and the timetable by which those measures shall be implemented. The City shall adopt all reasonable measures to avoid or minimize any such delay. The City shall provide verbal notice and written notice pursuant to this paragraph to the Cadillac District Supervisor, 120 West Chapin Street, Cadillac, Michigan 49601-2158, (231) 775-3960.

10.4 Failure of the City to comply with the notice requirements and time provisions under paragraph 10.3 shall render this Section X void and of no force and effect as to the particular incident involved. The DEQ may, at its sole discretion and in appropriate circumstances, waive in writing the notice requirements of paragraph 10.3, above.

10.5 If the parties agree that the delay or anticipated delay was beyond the control of the City, this may be so stipulated, and the parties to this Consent Order may agree upon an appropriate modification of this Consent Order. However, the DEQ is the final decisionmaker on whether or not the matter at issue constitutes a force majeure. The burden of proving that any delay was beyond the reasonable control of the City, and that all the requirements of this Section X have been met by the City, rests with the City.

10.6 An extension of one compliance date based upon a particular incident does not necessarily mean that the City qualifies for an extension of a subsequent compliance date without providing proof regarding each incremental step or other requirement for which an extension is sought.

XI. GENERAL PROVISIONS

11.1 With respect to any violations not specifically addressed and resolved by this Consent Order, the DEQ reserves the right to pursue any other remedies to which it is entitled for any failure on the part of the City to comply with the requirements of the NREPA and its rules.

11.2 The DEQ and the City consent to enforcement of this Consent Order in the same manner and by the same procedures for all final orders entered pursuant to Parts 31, 301, 303, and 315 of the NREPA.

11.3 This Consent Order in no way affects the City's responsibility to comply with any other applicable state, federal, or local laws or regulations.

11.4 The DEQ reserves its right to pursue appropriate action, including injunctive relief to enforce the provisions of this Consent Order, and at its discretion, may also seek stipulated fines or statutory fines for any violation of this Consent Order. However, the DEQ is precluded from seeking both a stipulated fine under this Consent Order and a statutory fine for the same violation.

11.5 The parties agree to diligently and in good faith pursue informal negotiations to resolve any disputes arising out of this Consent Order prior to resorting to judicial enforcement. Such negotiations shall proceed in a timely manner.

11.6 The provisions of this Consent Order shall apply to and be binding upon the parties to this action, and their successors and assigns.

11.7 This Consent Order constitutes a civil settlement and satisfaction as to the resolution of the violations specifically addressed herein, including any claim for Natural Resources Damages that was or could have been asserted as a result of the alleged violations; however, it does not resolve any criminal action that may result from these same violations.

11.8 The effective date of this Consent Order is the date it is signed by the WRD Chief.

XII. TERMINATION

12.1 This Consent Order shall remain in full force and effect until terminated by a written Termination Notice (TN) issued by the DEQ. Prior to issuance of a written TN, the City shall submit a request consisting of a written certification that the City has fully complied with the requirements of this Consent Order and has made payment of any fines, including stipulated penalties, required in this Consent Order. Specifically, this certification shall include:

a. The date of compliance with each provision of the compliance program in Section III, and the date any fines or penalties were paid.
b. A statement that all required information has been reported to the district supervisor.
c. Confirmation that all records required to be maintained pursuant to this Consent Order are being maintained at the facility.

The DEQ may also request additional relevant information. The DEQ shall not unreasonably withhold issuance of a TN.

Signatories

The undersigned CERTIFY they are fully authorized by the party they represent to enter into this Consent Order to comply by consent and to EXECUTE and LEGALLY BIND that party to it.

DEPARTMENT OF ENVIRONMENTAL QUALITY

Peter Ostlund, Interim Chief
Water Resources Division

5-2-2016
Date

CITY OF TRAVERSE CITY

James C. Carruthers, Mayor

4-20-2016
Date

Benjamin C. Marentette, City Clerk

4/20/16
Date

APPROVED AS TO SUBSTANCE:

Martin A. Colburn, City Manager

4-19-2016
Date

APPROVED AS TO FORM:

Lauren Trible-Laucht, City Attorney

4/19/16
Date

APPROVED AS TO FORM:

By: Neil D. Gordon, Assistant Attorney General
For: S. Peter Manning, Chief
Environment, Natural Resources, and Agriculture Division
Michigan Department of Attorney General

May 2, 2016
Date

Exhibit A

StreamMechanics
Restoring Stream Ecosystems

Boardman River Assessment Report
Scope of Work
January 19, 2015

Stream Mechanics, PLLC (SM) is pleased to provide the following scope of work to Foley, Baron, Metzger, and Juip, PLLC (FBMJ). The purpose of this project is to prepare a technical report about the hydraulic and geomorphic assessments that were completed in 2013 and 2014 to evaluate the impact of the Brown Bridge Pond dam breach. In addition, assessment results completed by others that evaluated stream temperature, macroinvertebrates, and fish communities before and after dam removal will be summarized and related to this study. The final product will include an evaluation and, if appropriate, a set of recommendations regarding the need for river restoration as a result of the dam breach in general accordance with the outline of the draft administrative consent order provided by Michigan Department of Environmental Quality on September 26, 2014.

Background

Stream Mechanics worked with members of the Implementation Team (IT) in December 2013 and July 2014 to perform geomorphic assessments along the Boardman River. The 2013 assessment included bed stability measurements at Brown Bridge Road and upstream of the Shumsky Road access to quantify impacts from the dam breach by comparing the results to data collected before the dam breach. Bed stability measurements were taken at the same location as pre-dam removal surveys. The 2014 assessment repeated many of the 2013 measurements and added more, including: bed form mapping, grain-size distributions, and a large woody debris assessment.

The 2014 study also monitored these parameters at the Forks Campground to provide data upstream of the former Brown Bridge Pond. Two additional sites were selected upstream of the former impoundment as well. The first addition was a reach downstream of Forks Campground. This site was selected because it appeared to be one of the sandiest reaches anywhere in the Boardman River Watershed, even though it is located upstream of the former impoundment. A pebble count was completed in this reach to quantify the percent of sand and compare it to the other reaches. The second addition was a large woody debris reference site that is not managed for recreational paddling, unlike areas on the Boardman downstream of the former impoundment. This reach included large woody debris jams that spanned the channel. The large woody debris index was the only assessment completed at this site. Appendix 1 includes a table listing the parameters described above and their purpose in the assessment, the method used, and the source of the methodology (reference).

Scope of Work and Report Outline

Under this scope of work, a technical report will be prepared that presents the study objectives, methods, and results from these two past assessments (2013 and 2014). The results will include bed form diversity maps, grain size distributions, depth variability graphs, and large woody debris results. Comparisons will be made between upstream (reference) and downstream (impacted) reaches of the former impoundment.

The results from a macroinvertebrate assessment report by the Au Sable Institute and temperature results from the Grand Traverse Conservation District will be included in this study. Fish population data from the Michigan

Department of Natural Resources (DNR) will also be included, assuming that a final report is released before this report is prepared. If other temperature and biological data are available from state, federal, or local agencies, they will also be summarized and included.

A report outline is provided below.

I. Introduction and Purpose – A brief description about why the assessments were completed and the purpose of the study, i.e., to evaluate the geomorphological impacts of the dam breach and determine if restoration/enhancement efforts are needed.

II. Background—A brief description of the dam removal and stream restoration project, dam breach, and enforcement action.

III. Site Selection –Site selection process, parameters measured, and a map showing the assessment locations.

IV. Study Methods – Data collection and analysis methods, including type of equipment and software (See Appendix 1).

V. Results – Data results from the geomorphic assessment will be organized from upstream to downstream of the former impoundment. The geomorphic assessment results will focus on floodplain connectivity, bed form diversity (depth variability), substrate composition, bed elevation changes (downstream of former dam only, before and after breach), and large woody debris. Photographs and underwater video of bedforms will also be provided. Graphs, depth variability maps, and bed form maps will be provided. Supporting studies of macroinvertebrates, fish, and temperature will be summarized and related to the study.

The Stream Functions Pyramid Framework by Harman et al. (2012)[1] will be used to organize the above parameters into functional categories, e.g., hydraulics, geomorphology, physicochemical, and biology. The parameter is matched to the functional category in Appendix 1. For each parameter, a designation of Functioning, Functioning-At-Risk, or Not Functioning will be determined based on guidance from Harman et al. (2012), data collected from the reference reaches, and best professional judgment. The results will be shown in a table that compares the functionality of the upstream reaches (reference) to the downstream reaches (Impacted Reaches).

VI. Discussion and Recommendations – Discussion about what the above assessment results mean for overall river health and management. Existing restoration/enhancement efforts will be described. A recommendation will be made about the need for further restoration/enhancement efforts in the DEQ identified "Impacted Reach" based on the results of the assessment. The determination will be made by comparing the Functioning, Functioning-At-Risk, and Not Functioning results by parameter of the reference condition to the Impacted Reach condition. The vertical stability surveys, presence of sand, and bed form diversity data will primarily be used to determine if the dam breach caused the differences in functionality to the Impacted Reach. For example, impacts caused by a sudden release of a large quantity of sediment would include bed aggradation, mid-channel

[1] Harman, W, R. Starr, M. Carter, K. Tweedy, M. Clemmons, K. Suggs, C. Miller. 2012. A Function-Based Framework for Stream Assessment and Restoration Projects. US Environmental Protection Agency, Office of Wetlands, Oceans, and Watersheds, Washington, DC. EPA 843-K-12-006.

bar formations, filling of pools with sand, and a reduction in depth variability. If bed aggradation is not quantitatively and qualitatively observed, mid-channel bars are not prevalent, pool depths are maintained with gravel beds, then it is unlikely that the breach caused sediment impacts to the river system that lead to a Functioning-At-Risk or Not Functioning condition. In addition, overall river management recommendations, unrelated to the dam breach, will be provided to show how function-based parameters can be improved from a Not-Functioning or Functioning-At-Risk category to a Functioning category.

Evaluation of Stream Reach through Former Impoundment

The DEQ response letter dated December 23, 2014 requested an assessment of the Impact Reach through the former impoundment. The detailed request was provided in Item A of the letter. Per a phone conference with Sandra Sroonian (Project Manager with AMEC) on January 19th, it is our understanding that AMEC and Inter-fluve completed an as-built survey of the restored channel and are finishing a closeout report showing that the project met the permit conditions. Therefore, further assessments are not proposed as part of this scope of work.

Project Management, Schedule, and Sub-Consultants

Will Harman, PG will serve as the Project Manager and lead investigator for this project. Engineers and scientist from Ecosystem Planning and Restoration will assist with preparing maps, figures, and data analysis. A report will be released for submittal by counsel by March 16, 2015.

Submitted By:

Will A Harman

Will Harman, PG
Principal

Appendix 1
2013 Parameters

Metric (Functional Category)	Purpose	Method	Reference
I. 2013 Floodplain Connectivity (Hydraulics)	Evaluate degree of channel incision and entrenchment to determine floodplain inundation frequency and extent.	Methods are shown below for longitudinal profile and cross section. A survey-grade GPS is used to complete the floodplain connectivity and vertical stability measurements. The GPS is tied to local control points and a base station.	
Ia. Longitudinal Profile	Used to calculate vertical incision throughout the reach. Low incision equals good floodplain connectivity.	The bank height ratio (channel depth/bankfull depth) is calculated at each riffle. Adapted from Rosgen (2014)	Rosgen, D. 2014. River Stability Field Guide (Second Edition). Wildland Hydrology, Fort Collins, CO.
Ib. Riffle Cross Section	Used to calculate bankfull dimensions and entrenchment ratio. High entrenchment ratio equals good floodplain connectivity.	The entrenchment ratio (floodprone width/bankfull width) is calculated at the riffle cross section. It is estimated for sites with wide floodplains.	Rosgen, D. 2014. River Stability Field Guide (Second Edition). Wildland Hydrology, Fort Collins, CO.
II. 2013 Vertical Stability (Geomorphology)	Used to determine if the streambed has aggraded or degraded as a result of the dam breach	Methods are shown below for bed elevations and depth of refusal.	
IIa. Bed elevations	Used to measure degradation and aggradation of the stream bed.	The GPS was used to survey thalweg bed points that had been surveyed before the breach. This was surveyed as a stakeout, where the point was located and then resurveyed.	All points based on Michigan Central Geometric Coordinate System.
IIb. Depth of refusal	Used to estimate the depth of "soft" sediments, e.g., sand over gravel.	A steel rod, graduated with 0.1 ft increments was inserted into the bed until it could no longer penetrate the sediments. The depth of penetration was measured at same location as bed elevation survey.	

Appendix 1
2014 Metrics

Metric (Functional Category)	Purpose	Method	Reference
III. 2014 Floodplain Connectivity (Hydraulics)	The 2013 Floodplain Connectivity Measurements were repeated in 2014		
IV. 2014 Vertical Stability (Geomorphology)	The 2013 Vertical Stability Measurements were repeated in 2014		
V. 2014 Bed Form Diversity (Geomorphology)	Used to show channel complexity upstream and downstream of the former impoundment.	A survey-grade GPS or Total Station was used to create a detailed topographic map of the study reach. The GPS is tied to local control points and a base station.	
Va. Bed form mapping	Used to show a plan view map of riffles, pools, point bars, and location of large wood.	Survey-grade GPS or Total Station survey.	
Vb. Depth Variability	Used to show the variability of depth in the study reach.	Transects were created from the topographic map to measure bankfull depths proportionally in the riffles and pools. Box plots and scatter graphs are used to show variability. This method is adapted from Laub et al. (2012)	Laub, B. D. Baker, B. Bledsoe, M. Palmer. 2012. Range of variability of channel complexity in urban, restored, and forested reference streams. Freshwater Biology. 57, 1076-1095.
Vc. Bed Form Video	Used to provide video examples of underwater sand deposits and transport, effects of large woody debris on bed material sorting and pool formation, and visual comparison/support to the bed form mapping measurement method.	A Go Pro was used to video the study reach by walking the channel. Underwater video was taken at sample locations.	

Appendix 1
2014 Metrics

VI. Bed Material Characterization (Geomorphology)	Used to show spatial distribution of riffle and pool bed forms (facies mapping) and the distribution of particle sizes by percent silt, sand, gravel, and cobble at sites upstream and downstream of former impoundment.	Facies mapping and grain size distributions as described below.	
VIa. Facies Mapping	Used to show the aerial distribution of sand and gravel. Used to determine if the thalweg is coarse (gravel).	Shown on the Bed form map. Map shows areas that are dominated by gravel and sand, overlaid with bed forms (riffles, pools, point bars).	
VIb. Grain Size Distributions	Used to compare the percent silt, sand, gravel and cobble between sites upstream and downstream of the former impoundment. Used to determine if sand is common throughout the watershed.	Wolman pebble count procedure, stratified by riffle, pool, and point bar.	Bunte, K. and S. Abt. 2001. Sampling Surface and Subsurface Particle-Size Distributions in Wadable Gravel- and Cobble-Bed Streams for Analyses in Sediment Transport, Hydraulics, and Streambed Monitoring. USDA Forest Service, Rocky Mountain Research Station. GTR-RMRS-GTR-74.
VII. Large Woody Debris (Geomorphology)	Used to evaluate the differences in the amount and location of large wood upstream and downstream of the former impoundment.	Large Woody Debris Index	Davis, Jeffrey, G. Mishall, C. Robinsion, P. Landres. 2001. Monitoring Wilderness Stream Ecosystems. USDA Forest Service, Rocky Mountain Research Station. GTR-RMRS-GTR-70.

Exhibit B

BOARDMAN RIVER ASSESSMENT

Prepared By:
Will Harman, PG
March, 2015

StreamMechanics

Table of Contents

List of Figures

List of Tables

List of Abbreviations and Acronyms

City	City of Traverse City
EA	Environmental Assessment
EPR	Ecosystem Planning and Restoration
GPS	Global Positioning System
GTB	Grand Traverse Band of Ottawa and Chippewa Indians
GTCD	Grand Traverse Conservation District
IT	Implementation Team
LWD	Large Woody Debris
LWDI	Large Woody Debris Index
MDEQ	Michigan Department of Environmental Quality
MDNR	Michigan Department of Natural Resources
NOV	Notice of Violation
NRCS	Natural Resources Conservation Service
SFPF	Stream Functions Pyramid Framework
SM	Stream Mechanics
SOW	Scope of Work
TDS	Temporary Dewatering Structure

Appendices

Acknowledgements

This document was authored by Will Harman with Stream Mechanics, PLLC. Harman is the owner of Stream Mechanics and a licensed geologist with 24 years of experience in stream assessment and restoration. His work with Stream Mechanics focuses on stream restoration training, applied research, and demonstration projects. More information about Harman and Stream Mechanics is available at www.stream-mechanics.com. Ecosystem Planning and Restoration, LLC (EPR) is an engineering firm that focuses on stream and wetland restoration design, as well as stream and wetland assessments. EPR is owned by Harman, Sonny Kaiser and Kevin Tweedy. Erin Bennett, Emmett Perdue, Matt Koon, Sonny Kaiser, and Kevin Tweedy, all with EPR, provided assistance with data analysis, feature/topographic mapping, flood frequency calculations, and report formatting. More information about EPR can be found at www.epr.net.

This work would not have been possible without the assistance of members of the Implementation Team. Specifically, Frank Dituri with the GTB was instrumental in making the assessment work happen by providing survey equipment, logistical coordination, hospitality, and historical perspective. Special thanks to the following IT members who helped with data collection: Brett Fessell with the GTB, Nate Winkler with Conservation Resources Alliance, D.J. Shook with the NRCS/GTCD, and Steve Largent with the GTCD.

BOARDMAN RIVER ASSESSMENT REPORT

1.0 INTRODUCTION, BACKGROUND, AND PURPOSE

The Boardman River originates in Kalkaska County, flowing southwest into Grand Traverse County, and ultimately discharging into West Grand Traverse Bay of Lake Michigan in Traverse City, Michigan. The total drainage area is approximately 291 square miles and includes 12 natural lakes (See **Figure 1**). The river is designated a State of Michigan Natural River with 36 miles of Blue Ribbon Trout Stream (US ACE, 2009, Hettinger, 2013).

Until 2012, four dams were located along the main stem of the river. From upstream to downstream, they include: Brown Bridge Dam, Boardman Dam, Sabin Dam, and Union Street Dam. Brown Bridge Dam was removed during the final quarter of 2012. Two out of the three remaining dams (Sabin and Boardman) are scheduled to be removed (Hettinger, 2013). The Brown Bridge Dam removal project also included a river restoration project within the former impoundment. The purpose was to provide fish passage and restore riverine habitat by re-establishing the river alignment to its pre-dam location. Large wood and vegetation were included to provide bank stabilization. More detail about the restoration project is included in the Brown Bridge Dam Removal Environmental Assessment (US FWS, 2012).

On October 6, 2012, during the Brown Bridge Dam removal, the temporary dewatering structure (TDS) failed causing the reservoir level to drop approximately 14 feet in six hours. The resulting flood damaged numerous homes and transported a large quantity of sediment that had accumulated within the impoundment to downstream portions of the river. The Michigan Department of Environmental Quality (DEQ) issued a Notice of Violation (NOV) to the City of Traverse City (City) on November 9, 2012 stating that the TDS failure violated several permits. The City is the project owner and permit applicant; however, the dam removal design and construction was completed by contractors. On August 26, 2015, MDEQ submitted an enforcement notice to the City. Among other things, the enforcement notice required the City to evaluate the need to further restore stream habitat diversity and channel stability within the "Impacted Reach," which is defined as the stream length from the upstream limit of the former Brown Bridge Pond (restored reach now) and downstream to the railroad bridge at 1400 East River Road (See **Figure 1**). In response to the enforcement notice, the City worked with Stream Mechanics (SM) to develop a Scope of Work (SOW). The SOW provides a method to evaluate a portion of the Boardman River (including the Impacted Reach) following the failure of the Temporary Dewatering Structure (TDS). The final SOW is attached as Appendix 1.

The purpose of this report is to meet the deliverable requirement of the SOW by providing river assessment results and recommendations about the need for restoration efforts within the Impacted Reach. The report includes channel stability and function-based assessments performed by SM in 2013 and 2014 in response to the TDS failure; as well as, studies performed by the Grand Traverse Conservation District (GTCD), Au Sable Institute, Michigan Department of Natural Resources (MDNR), and the Grand Traverse Band of Ottawa and Chippewa Indians, Natural Resources Department (GTB). The next section provides background information on the Stream Functions Pyramid Framework (SFPF) developed by Harman et al. (2012). This framework was used to design the function-based assessment methodology and to evaluate if restoration activities are needed in the Impacted Reach. The Methodology and Results Sections are organized using the SFPF.

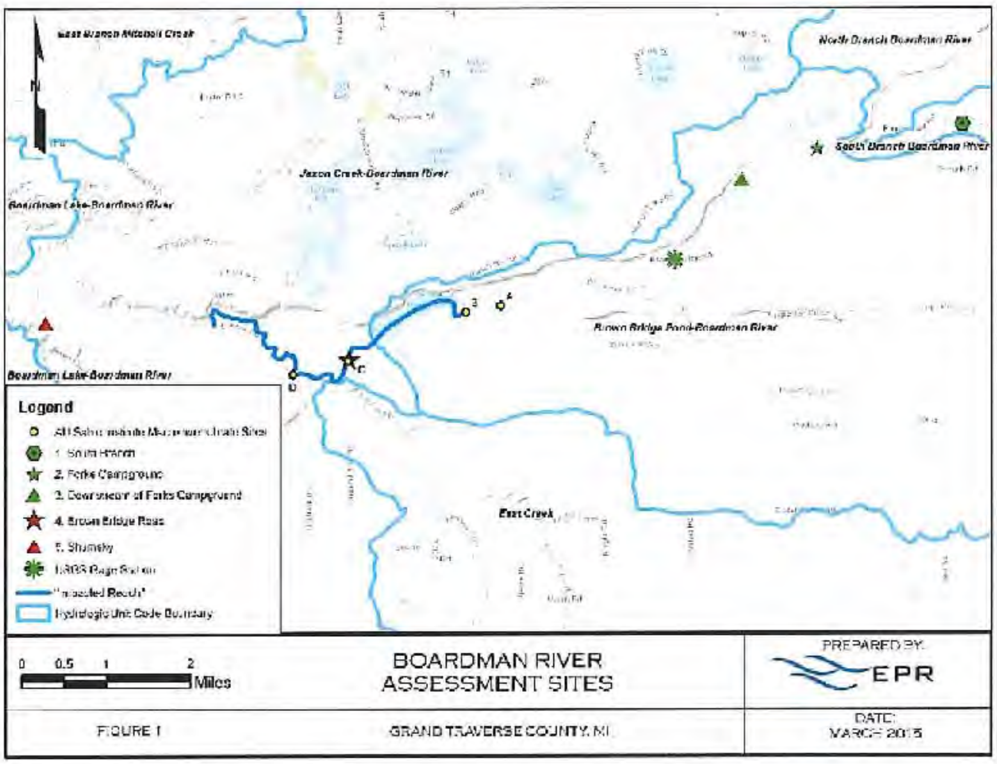


Figure 1. Boardman River Assessment Sites

2.0 STREAM FUNCTIONS PYRAMID FRAMEWORK

The Stream Functions Pyramid Framework (SFPF) is described in detail in *A Function-Based Framework for Stream Assessment and Restoration Projects* (Harman et al, 2012), published by the US Environmental Protection Agency and the US Fish and Wildlife Service. The Stream Functions Pyramid, shown below in **Figure 2**, includes five functional categories: Level 1 = Hydrology, Level 2 = Hydraulics, Level 3 = Geomorphology, Level 4 = Physicochemical and Level 5 = Biology. The Pyramid is based on the premise that lower-level functions support higher-level functions and that they are all influenced by local geology and climate. Each functional category is defined by a functional statement. For example, the functional statement for Level 1, Hydrology is "the transport of water from the watershed to the channel," which supports all other aquatic functions.

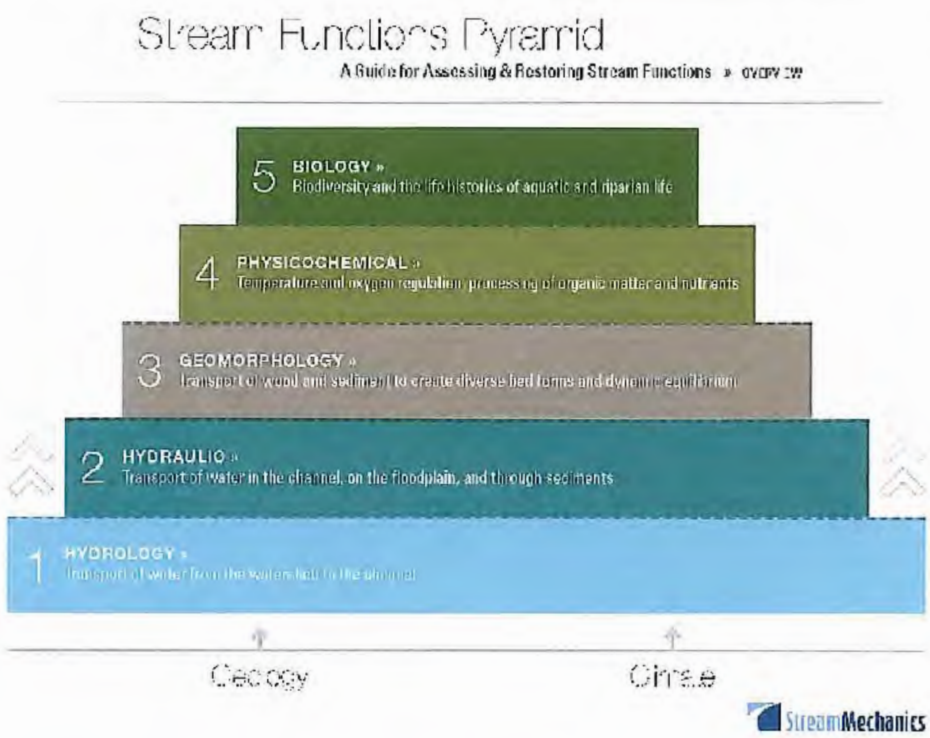


Figure 2. Stream Functions Pyramid

The Stream Functions Pyramid *alone* (**Figure 2**) is a hierarchy of stream functions and does not provide a specific mechanism for addressing functional capacity, establishing performance standards, or communicating functional loss or lift. The diagram in **Figure 3** expands the Pyramid concept into a more detailed Framework. The Framework is a "drilling down" approach that provides additional forms of analysis and quantification of functions. The Function-Based Parameters describe and support the functional statements within each functional category. The Measurement Methods are specific tools, equations, assessment methods, etc. that are used to quantify the Function-Based Parameter. There can be more than one Measurement Method for a single Function-Based Parameter. An example is shown below in **Table 1** for Floodplain Connectivity, a Function-Based Parameter. In this example, three Measurement Methods are used to quantify one Function-Based Parameter.

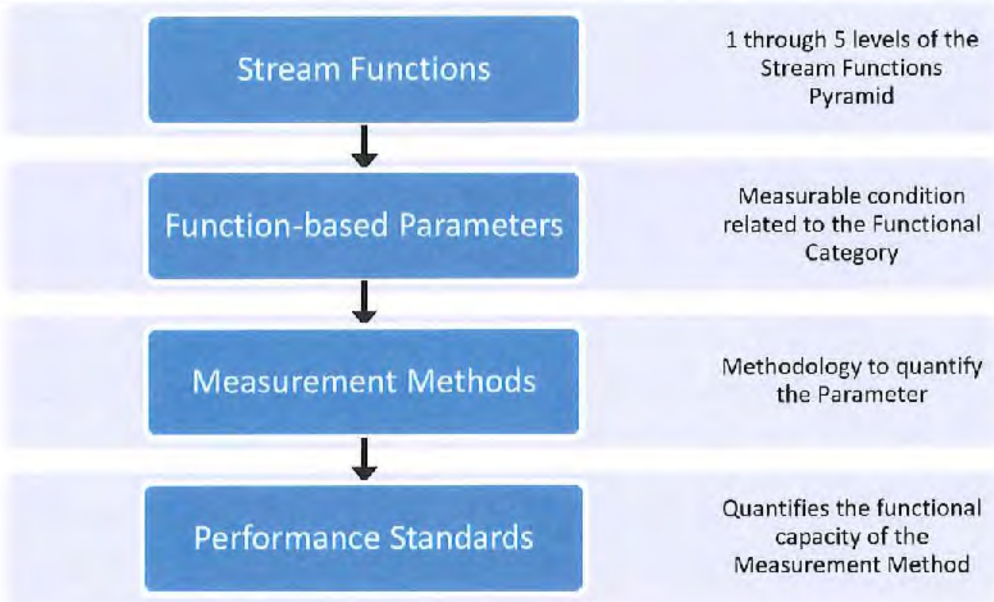


Figure 3. Stream Functions Pyramid Framework

Table 1. Example Measurement Methods to quantify the Function-Based Parameter of Floodplain Connectivity.

Functional Category	Function-Based Parameter	Measurement Method (Examples)
Level 2: Hydraulics	Floodplain Connectivity	Bank Height Ratio
		Entrenchment Ratio

Note: There are two Measurement Methods used to quantify the Parameter. This parameter and the measurement methods are further described under the Methodology Section and Hydraulic sub-section.

Performance Standards are used to determine functional capacity at the Measurement Method level and are stratified by Functioning, Functioning-At-Risk, and Not Functioning. Using the example from **Table 1**, Performance Standards are added to the three Measurement Methods and shown in **Table 2**.

Table 2. Example Performance Standards for two Measurement Methods used to quantify Floodplain Connectivity.

Functional Category	Function-Based Parameter	Measurement Method	Functional Capacity Performance Standard		
			F	FAR	NF
Level 2: Hydraulics	Floodplain Connectivity	Bank Height Ratio	1.0 to 1.2	1.3 to 1.5	>1.5
		Entrenchment Ratio	>2.2	2.0 to 2.2	<2.0

Note: F = Functioning, FAR = Functioning-At-Risk, and NF = Not Functioning.

Definitions for Functioning, Functioning-At-Risk, and Not Functioning are provided below:

- Functioning – A Functioning score means that the Measurement Method is quantifying the functional capacity of one aspect of a Function-based Parameter in a way that **does support** a healthy aquatic ecosystem. A single Functioning Measurement Method, out of several Measurement Methods, may not mean that the Function-based Parameter is Functioning. Therefore, functional capacity is "rolled up" to the parameter level and not determined at the measurement method level.
- Functioning-At-Risk –A Functioning-At-Risk score means that the Measurement Method is quantifying or describing one aspect of a Function-based Parameter in a way that **can support** a healthy aquatic ecosystem. In many cases, this indicates the Function-based Parameter is adjusting in response to changes in the reach or the watershed. The trend may be towards lower or higher function. A Functioning-At-Risk score implies that the aspect of the Function-based Parameter, described by the Measurement Method, is between Functioning and Not Functioning.
- Not Functioning - A Not Functioning score means that the measurement method is quantifying or describing one aspect of a function-based parameter in a way that **does not support** a healthy aquatic ecosystem. A single Not Functioning Measurement Method, out of several Measurement Methods, also may not mean that the function-based parameter is not functioning.

3.0 SITE SELECTION

The stream reaches assessed in December 2013 and July 2014 by SM are shown on **Figure 1**. The December 2013 sites included two reaches, one at the Brown Bridge Road crossing and the second upstream of the Shumsky Road river access. Both sites included pre-dam removal bed elevation data collected by the Implementation Team (IT) in 2012 (data provided by GTB). Additionally, the Brown Bridge Road site represents a reach within close proximity to the former Brown Bridge Pond dam and within the MDEQ defined Impacted Reach. The assumption in selecting this site is that stream bed aggradation or degradation, resulting from the TDS failure, would be most prevalent close to the dam.

The Shumsky Road site was selected by SM as the farthermost downstream site from the former dam, while still having pre-dam removal bed elevation data and site access. It is also upstream of the next closest dam, the Boardman dam. This site is downstream of the Impacted Reach and was selected before the MDEQ defined the Impacted Reach limits. The points surveyed during the 2013 assessment are shown below in **Figure 4** and **Figure 5**.

Figure 4. Shumsky Road Reach (Site 5)

Figure 5. Brown Bridge Road Reach (Site 4)

For the Brown Bridge Road reach, additional points were surveyed in 2014 downstream of Garfield Road to the first riffle past Old Garfield Road. The reason for this selection is discussed in the Results section.

The Brown Bridge Road and Shumsky Road reaches were re-assessed in July 2014 and additional information was collected (See Methodology Section). Additional sites were added upstream of the former Brown Bridge Pond as a comparison to downstream sites. From upstream to downstream, these sites included: South Branch Boardman River, Forks Campground, and Downstream of Forks Campground (Refer to **Figure 1** for locations). The South Branch of the Boardman River represents a reach where wood removal does not routinely occur (See **Figure 6**). This site was used as a reference reach for the Large Woody Debris (LWD) assessment. Forks Campground was selected as a representative stream reach, well upstream of the former impoundment. The actual study reach was located immediately downstream of the camping area to avoid streambank impacts caused by swimmers and fisherman. The reach limits are shown below on **Figure 7**. Another site was selected approximately 1.4 miles downstream to represent a sand-bed channel upstream of the former impoundment. This reach was observed to be one of the sandiest reaches between Shumsky Road and the North and South Branch's confluence with the Boardman River. The survey reach is shown on **Figure 8**. The final list of sampling sites assessed by SM, listed from upstream to downstream, include: 1, South Branch (wood reference); 2, Forks Campground (Upstream of former pond reference); 3, Downstream of Forks (sandy reach above pond); 4, Brown Bridge Road (Impacted Reach); and 5, Shumsky Road (farthest downstream site). The site number and name are used for reference throughout the remainder of the assessment report.

Figure 6. Site 1, South Branch of Boardman River.

Figure 7. Site 2, Forks Campground Reach

4.0 STUDY METHODOLOGY

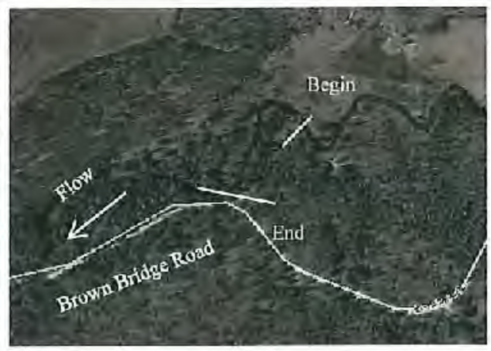


Figure 8. Site 3, Downstream of Forks Campground. Sandy reach.

A detailed study methodology is provided for the vertical stability and function-based assessments. The assessments were led by SM with support from the IT. In addition, a general overview of the macroinvertebrate, fish, and temperature methodologies, conducted by others, is provided along with references to the original reports. The vertical stability assessment is described first and is sub-divided into the bed point surveys and bed sediment depth measurements. The methodology for the function-based assessment follows and is organized by functional category (e.g., hydrology, hydraulics, geomorphology, physicochemical, and biology).

4.1 VERTICAL STABILITY STUDY METHODS

The SM assessments were conducted in December 2013 and July 2014. The assessments included bed point surveys and sediment depth measurements at site 4, Brown Bridge Road and site 5, Shumsky Road to determine vertical stability of the streambed by comparing pre-dam-removal data to post-TDS failure data. The primary purpose of re-surveying points is to determine if the streambed aggraded (filled) or degraded (eroded) due to the TDS failure. A mixture of riffle and pool bedforms were included in the survey.

4.1.1 Bed Point Survey

The bed was surveyed at discrete points using a survey-grade Global Positioning System (GPS) tied to state plane control points and a portable base station. The GPS accuracy is typically 0.08 feet with a max error tolerance of 0.16 feet. The survey points from the 2012 pre-dam-removal survey were loaded into the electronic data recorder and a stakeout function was used to relocate these points. A new location (northing and easting) and elevation were recorded. In addition to the max error tolerance of 0.16 feet, there is error in the placement of the rod on the bed material. For example, one survey may record elevation at the top of a rock (e.g., cobble) and the next survey may record a lower elevation beside the cobble. Therefore, the total error was assumed to be approximately 0.4 feet. This approach was used to compare before and after bed elevations instead of a longitudinal profile to better show bed elevation changes. Longitudinal profiles often show variability in bed elevations simply because the bed is surveyed at different locations. A plan view of the sampling points is shown on **Figure 4** and **Figure 5**.

The same points were re-surveyed in July 2013 with additional downstream points at site 4, Brown Bridge Road. Eight new points were added between Garfield Road and the riffle downstream of Old Garfield Road. These points were added after reviewing the results from the 2012 data and noticing bed scour that likely was caused by flow constriction under the Garfield Road Bridge. This is discussed in more detail in the Results Section.

In addition to the data SM collected in December 2013 and July 2014, an existing data set collected by the IT on November 16^{th} 2012, soon after the TDS failure, was included at site 4, Brown Bridge Road. Again, the same survey points were used for comparison. All of the survey data were graphically overlaid to determine if the bed aggraded or degraded from before the TDS failure to approximately six weeks (Site 4, Brown Bridge only), 14 months, and 21 months after TDS failure.

4.1.2 Bed Sediment Depth

Bed sediment depth was measured at the same location as each bed survey measurement described above and shown on **Figure 4** and **Figure 5** during the 2012 and 2013 sampling events. Sediment depth was measured using a steel or fiberglass rod graduated in 0.1 foot increments. The rod was placed on the bed and the water surface depth was determined. The rod was then firmly pushed through the bed sediments. Upon refusal, the water depth was measured again. The difference between the two depths was recorded as the depth of soft-bed sediments. It was noted if the sediments were mostly sand or gravel. Graphs were created overlaying the 2013 and 2014 data.

4.2 Function-Based Assessment Study Methods

The 2014 assessment also was completed by SM and repeated the measurements from the 2013 assessment. Additional metrics were included to provide a function-based assessment of the Boardman River upstream and downstream of the former Brown Bridge Pond to determine if the TDS failure caused functional loss to the Impacted Reach. Site 2, Forks Campground was added as a representative reach upstream of the former impoundment and compared to sites 4, Brown Bridge Road Reach and 5, Shumsky Reach. The SFPF (Harman et al., 2012) was used to organize the metrics into functional categories and as an aid in determining if restoration work is needed within the Impacted Reach. A summary of the 2013 and 2014 assessment parameters is provided below in **Table 3**.

Table 3. Summary of primary parameters measured in 2013 and 2014 by project reach (site).

Site (From Upstream to Downstream)	2013 Parameters	2014 Parameters
1. South Branch Boardman River	None	Large Woody Debris
2. Forks Campground	None	Floodplain Connectivity, Bedform Diversity, Bed Material Characterization, Large Woody Debris
3. Downstream of Forks Campground	None	Bed Material Characterization
4. Brown Bridge Road	Vertical Stability	Vertical Stability, Floodplain Connectivity, Bedform Diversity, Bed Material Characterization, Large Woody Debris
5. Shumsky Road	Vertical Stability	Vertical Stability, Floodplain Connectivity, Bedform Diversity, Bed Material Characterization, Large Woody Debris

Note: Lateral stability and riparian vegetation parameters also are discussed in the function-based assessment; however, they are included as visual observations and not as measured parameters. Lateral stability and riparian vegetation were included because they support many higher order functions and are recommended by Harman et al., (2012) in all assessments. They were not quantitatively assessed because they are not as directly relatable to the TDS failure as parameters like vertical stability, bed form diversity, and bed material characterizations.

4.2.1 Hydrology Functions

Hydrology functions transport water from the watershed to the channel and include parameters like rainfall/runoff relationships, flood frequency, and bankfull discharge (Harman et al., 2012). Hydrology functions in the Boardman River Watershed are dominated by groundwater flow through glacial deposits of sand and gravel. This is visually evident by the presence of tannins observed during baseflow conditions. The result is a watershed that is "not flashy", meaning that flood stage does not increase quickly with precipitation. Rather, a large portion of the precipitation soaks into the ground and slowly moves toward the channel as subsurface flow.

Hydrology functions were not directly measured during the SM assessment. However, the gage station at Brown Bridge Road, near Ranch Rudolph was used to calibrate the bankfull stage, perform hydraulic geometry calculations, and to evaluate flow conditions between the 2013 and 2014 sampling events. Each method is described below.

Bankfull Verification

Bankfull discharge is the flow that shapes and maintains channel size (Inglis, 1947). Bankfull area, width, and mean depth are measurements of the riffle cross section that are created by the bankfull discharge. These measurements are taken by identifying bankfull indicators in the field. In the Boardman River, the bankfull indicator was almost always the top of the streambank or first major break in slope. An example of the bankfull stage, representing the breakpoint between the channel and floodplain is shown below in **Figure 9**

Figure 9. A bankfull feature (top of bank) being surveyed at site 5, Shumsky Road Reach.

The bankfull indicator was verified by performing a gage station survey and analysis. The procedure included identifying the bankfull indicator at the gage station and performing a cross sectional survey at a representative riffle to calculate the bankfull area, width, and mean depth. Next, the bankfull indicator was related to a stage at the gage station. Members of the IT performed this survey and identified the bankfull stage to equal 4.1 feet on the gage. Once the stage was determined, the bankfull discharge was calculated by SM using the stage versus discharge relationship developed by USGS and shown on **Figure 10.** The bankfull discharge is 229 cfs.

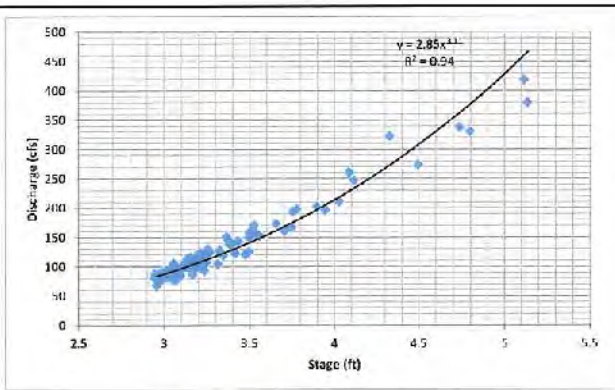


Figure 10. Discharge versus stage for gage station.

Table 4. Flood Frequency at Brown Bridge Gage Station

Return Period (years)	Discharge Q (cfs)
1.01	163
2	317
5	409
10	469
25	543
50	597
100	651
200	706

Next, Ecosystem Planning and Restoration (EPR) used the peak discharge data and Bulletin 17b to develop a flood frequency relationship (USGS, 1981). Bulletin 17b is the methodology used throughout the United States to estimate flood flow return intervals, e.g., 2-year and 100-year. Results from this approach are often entered into hydraulic models, like the Hydrologic Engineering Centers River Analysis System (HEC-RAS) to estimate flood depths and other characteristics associated with each flood flow. Hydrology models and HEC-RAS were not used in this study because a stage versus discharge curve was available at the Ranch Rudolph gage station, along with annual peak flood flows. The results are shown in **Table 4**. Comparing the bankfull discharge of 229 cfs to the flood frequency table shows that the bankfull return interval is between 1 and 2 years. This provides confidence that the correct bankfull indicator was selected for the following reasons:

1. The range of bankfull return intervals is typically between 1.0 and 2.0 years. The national average is 1.5 years (Leopold 1994 and Rosgen 2014). The top of bank indicator is well within the typical range.
2. There are no consistent indicators higher, so bankfull can't have a larger return interval.
3. There are no consistent indicators located below the top of bank, so bankfull can't have a lower return interval.

Hydraulic Geometry

To further quantify bankfull characteristics at the gage station, previous cross sectional measurements by USGS were plotted versus stage. These hydraulic geometry plots are shown below on **Figure 11** for area and width, and **Figure 12** for mean depth and velocity. The results for bankfull area, width, and depth, along with the resulting W/D ratio are provided in **Table 5**. The results show that the IT survey matches well with the USGS curve data.

The velocity curve is also shown in **Figure 12**, yielding a bankfull velocity of 2.5 ft/s. This is much lower than the national average of 4.0 ft/s (Leopold, 1994), which is not surprising due to the low slope, coarse bed, well-vegetated banks, and moderate width/depth ratio that lower the average velocity. In fact, the 2.5 ft/s is almost exactly the same as the Michigan regional curve for a watershed of the same size (145 mi^2). To make this comparison the regional curve discharge was divided by the area, yielding a velocity of 2.6 ft/s (Rachol and Boley-Morse, 2009). Overall, the hydraulic geometry data show that bankfull is at or near the top of the streambank and the Boardman River is a low-gradient river with a moderate bankfull W/D ratio and low average velocity. These results are typical of streams in wide alluvial valleys that support meandering single-thread channels as well as anastomosed stream/wetland complexes. This information is used throughout the assessment as a guide for identifying bankfull in ungauged reaches.

Table 5. Comparison of IT-surveyed cross section with USGS measurement data taken from the curves in Figures 11 and 12.

Parameter	Area (ft^2)	Width (ft)	Mean Depth (ft)	W/D
IT Cross Section	92.8	41.1	2.3	17.9
USGS Measurements	92.0	41.6	2.2	18.9

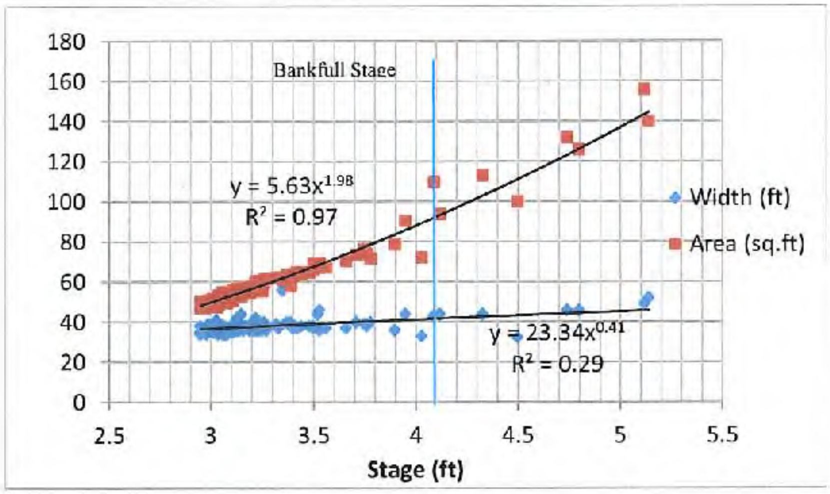


Figure 11. Hydraulic geometry showing bankfull width and area versus stage for the USGS Gage Station at Ranch Rudolph.

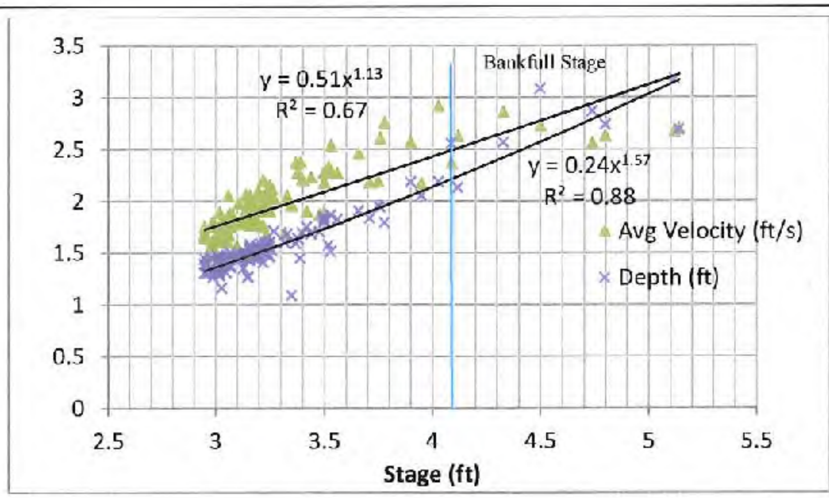


Figure 12. Hydraulic geometry showing bankfull mean depth and velocity versus stage for the USGS Gage Station at Ranch Rudolph.

2014 Flood Event

Between the December 2013 and July 2014 assessments, a large flood occurred in the Boardman River Watershed due to a rain on snow event. A hydrograph was created from the USGS gage station data showing mean daily flows between the two assessments. **Figure 13** shows that the flood occurred in April 2014 and **Figure 14** shows that the peak discharge for the April event was approximately 624 cfs. Using the flood frequency table in **Table 4**, the estimated return interval is just under a 100 year-event. The 100-year flood event means that there is a 1% probability of seeing a flood of that size each year. **Figure 14** also shows that this is the largest flood to occur since at least 1998 and that the 1998 flood was considerably smaller at 449 cfs. This is important to the assessment results because large floods can create large changes in channel geometry if there are vertical or lateral instability problems. In other words, this flood is a good test to see if the TDS failure/dam removal and associated sedimentation caused negative changes to channel geometry at sites 4, Brown Bridge or 5, Shumsky (See vertical stability results).

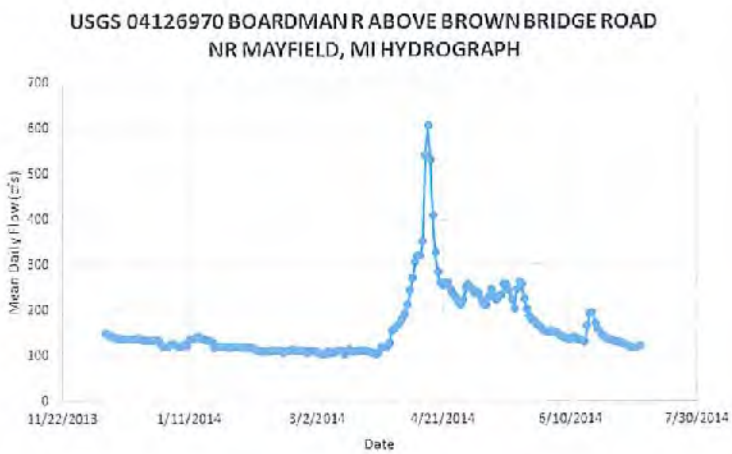


Figure 13. Hydrograph of mean daily flow from November 2013 through July 2014

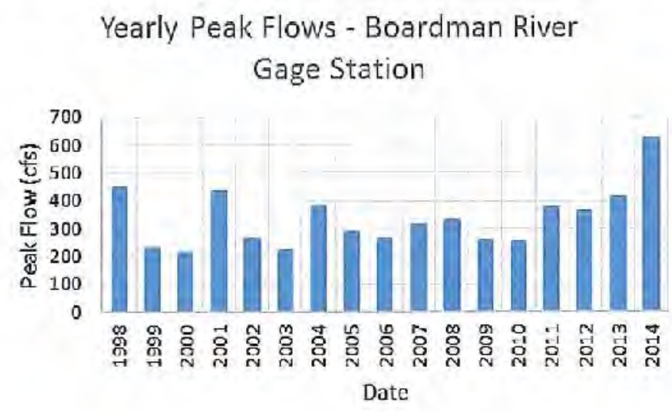


Figure 14. Peak Discharge data from 1998 to 2014

4.2.2 Hydraulic Functions

Hydraulic functions transport water in the channel, on the floodplain, and through sediments. Floodplain Connectivity was selected as the function-based parameter to describe the relationship between water flowing in the channel and on the floodplain. More specifically, floodplain connectivity is used to quantify the frequency of floodplain inundation (Harman et al., 2012). The bank height ratio and entrenchment ratio were used to measure floodplain connectivity. The bank height ratio is calculated by dividing the maximum channel depth by the maximum bankfull depth (Rosgen, 2014). If the ratio is equal to 1.0, all flows greater than bankfull spread onto the adjacent floodplain and the stream is considered well-connected to the floodplain. Based on the Boardman River gage data, the bankfull return interval is approximately 1.4 years when the bank height ratio is 1.0. The entrenchment ratio is calculated as the floodprone area width divided by the bankfull width. And the floodprone area width is calculated as the maximum ground width measured at an elevation equal to two times the bankfull max depth. Detailed descriptions of these measurement methods are provided in Rosgen (2014).

For this study, the bank height ratio was measured using a combination of methods, including: longitudinal profiles of the thalweg (main thread and generally deepest part of river) and bankfull, riffle cross sections, and a topographic survey of the streambed and floodplain. Rapid methods of comparing the water surface with bankfull stage also were used to verify that the bankfull indicator was consistent throughout the study reach. The entrenchment ratio was measured from a riffle cross section surveyed within the study reach. In most cases, the floodprone width extended well past the surveyed cross section, indicating a wide floodplain. In these cases, the entrenchment ratio was reported as greater than 2.2, a threshold for determining Rosgen stream type (Rosgen, 2014).

4.2.3 Geomorphology Functions

Geomorphology functions transport and store wood and sediment to create diverse bed forms and provide dynamic equilibrium. There are many function-based parameters and measurement methods provided by Harman et al., (2012), but the ones selected for this study include bed form diversity, bed material characterization, and large woody debris. Visual observations also were included for lateral stability and riparian vegetation and used in the Function-Based Assessment Results.

Bedform Diversity

The primary concern regarding the sudden release of sediment from the TDS failure is the negative affect it may have on sediment transport processes. Lane (1955) shows that sediment supply and size are proportional to water discharge and slope. The TDS failure released a large quantity of historically-accumulated sediment and water; however, the most common affect from this type of flood is bed aggradation. Aggradation can be qualitatively observed through bar formations, e.g. lateral and mid-channel bars. When assessing channel stability, mid-channel bars are worse than lateral bars because they indicate that the thalweg is aggrading through a reduction in sediment transport capacity. Mid-channel bars often lead to bank erosion and negative changes to channel pattern. Lateral bars show that the stream is transporting sediment along the thalweg and storing sediment in the channel margins, which is indicative of effective sediment transport processes. Point bars are a natural depositional area along the inside of a meander bend. They are neither good nor bad from a sediment transport perspective, and are common in stream systems with a moderate width/depth ratio and sediment supply like the Boardman.

Measuring sediment transport is extremely difficult and fraught with error. Therefore, bed form diversity metrics are typically used as a surrogate. The assumption is that a reach with deep pools and shallow, coarse riffles has sediment transport processes that are "functioning," because pool depths are being maintained and the riffles are not inundated with sand. A reach where the pools have filled with sediment is "not functioning" in terms of sediment transport.

Bedform diversity was assessed by measuring the depth variability between riffles and pools. A common method for comparing pool depth to riffle depth is to calculate a pool depth ratio using the Rosgen (2014) method. The pool depth ratio is calculated from a longitudinal profile by dividing the max pool depth by the mean riffle depth, both measured from the thalweg. This method was not used in the SM study due to concerns about aggradation across the channel width, i.e., depth variability in the thalweg *and* the channel margins. Depth variability was assessed by measuring bankfull depths across the channel by modifying a methodology by Laub et al. (2012). For each study reach, six cross sections were measured in a pool and six in a riffle. Five bankfull depths were measured at each cross section for a total of 60 depth measurements per reach. One point was measured at the thalweg, one was measured at each edge of channel (left and right), and the remaining two were measured between the thalweg and edge of channel.

A plan view of the sampling methodology is shown for site 4, Brown Bridge Road Reach in **Figure 15** to illustrate where points are sampled.

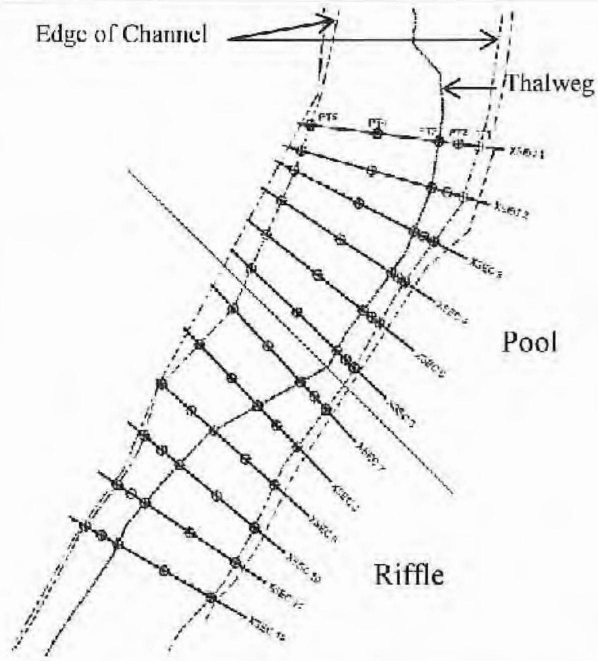


Figure 15. Depth variability measurements to assess bed form diversity

These points were plotted using a scatter graph to compare the variability in bankfull depth. The variability in the upstream reach (Site 2, Forks) is compared to the variability in the downstream reaches (4, Brown Bridge and 5, Shumsky) using the coefficient of variation (CV), which is the standard deviation divided by the mean depth. The CV is then multiplied by 100 to present the result as a percent of variability. The CV is a way to interpret the magnitude of the standard deviation and to compare variability between sites. Other descriptive statistics are provided as well.

Bed form diversity also was assessed by creating a topographic map of each study reach. Site 2, Forks was upstream of the GPS control points so it was surveyed using a robotic total station and arbitrary control points. Site 4, Brown Bridge was surveyed using a robotic total station and 5, Shumsky was surveyed using the survey-grade GPS, and both were tied to a local control network. The survey was used to create a topographic map of the floodplain and channel. A coordinate plane was created from the bankfull survey points and used to calculate depths greater than and less than the bankfull stage. Floodplain depths (greater than bankfull) are shown as positive numbers and depths below bankfull are negative numbers. The map is used to show pools as dark blue areas and shallower areas, like riffles, as light blue. These colors can then be compared to the channel geometry and location of LWD to see if pools are forming in the meander bends and near LWD and to determine if straight reaches between meander bends are riffles. A second map was created from the topographic survey to show the bed features (riffles and pools), the location of LWD, and whether the thalweg is dominated by sand or gravel.

Bed Material Characterization

Bed material was sampled at the following sites: 2, Forks Campground; 3, Downstream of Forks; 4, Brown Bridge Road; and, 5, Shumsky Road. The site 3, Downstream of Forks was added to quantify the percent of sand and gravel in one of the sandiest reaches along the Boardman River. No other measurements were made at this reach. Bed material was sampled using a Wolman pebble count procedure stratified by riffles, pools, and point bars (Bunte and Abt, 2001). The riffle pebble count included 100 samples from the channel bed, sampled in a zig-zag pattern from edge of channel to edge of channel (Bevenger and King, 1995) throughout the length of the feature. The intermediate axis of the particle was measured and categorized as silt, sand, gravel, cobble, or boulder. The data were entered into the Reference Reach Survey spreadsheet developed by the Ohio Department of Natural Resources. The categories are shown below in **Table 6**. Pools were sampled in a similar way except the point bar was excluded from the sample to avoid including sand deposits. By removing the point bar feature from each site, a better representation of the thalweg bed material was provided. However, the point bar was not omitted, just sampled separately from the pool. The percent silt, sand, gravel, and cobble was calculated for each reach and plotted as stacked columns.

The bed material data set is used with the depth variability data to provide a more complete assessment of bed form diversity. In a healthy gravel bed river, the thalweg through the riffles and pools should remain coarse. Sand loads should be deposited along the channel margins, point bars, and the floodplain. Bed material samples are used with the depth variability information to determine if reaches downstream of the former impoundment are sandier than upstream.

Table 6. Categories used to determine percent silt, sand, gravel, and cobble.

Material	Size Range (mm)
Silt/Clay	0 – 0.062
Sand	0.062 – 2
Gravel	2 - 64
Cobble	64 - 256
Boulder	256 - 4096

Large Woody Debris

Large woody debris (LWD) includes individual pieces of wood located from the streambed to the top of the bank that are at least 10cm in diameter at the basal end and 1 meter long. LWD alone is not a function; however, depending on its size and location, it does affect many hydraulic and geomorphic functions, as well as support higher order physicochemical and biological functions. For example, LWD can create downstream scour pools and habitat for fish. LWD also creates heterogeneity of the bed material, by storing fine grained sediments on the upstream side and coarser sediments downstream (Wohl, 2011).

The large woody debris index (LWDI), developed by the US Forest Services (Davis et al., 2001) was used to assess LWD at sites 2, Forks Campground; 4, Brown Bridge Road; and, 5, Shumsky Road. Since wood is routinely removed from site 2, Forks Campground, it could not be used as the upstream reference. An additional reference site was therefore added along the South Branch (Site 1) of the Boardman River to represent a condition where wood is not routinely removed from the river. The LWDI includes measurements of individual pieces of wood and debris jams, defined as three or more touching pieces. The sample reach length is 100 meters and located within the study reach. Individual piece assessments include measurements of wood length, diameter, location, structure, stability, and orientation. Jam assessment includes measurements of jam length, height, orientation, structure, location, and stability. The measurements are weighted and tallied to create an overall score.

4.2.4 Physicochemical Functions

Physicochemical functions include temperature regulation and the processing of organic matter and nutrients (Harman et al., 2012). There are many parameters that can be used to assess physicochemical functions including pH, specific conductance, temperature, dissolved oxygen, organic matter, and nutrients. None of these parameters were measured as part of the SM assessment. However, the GTCD has measured water temperatures upstream and downstream of the former impoundment for several years. The data were assessed in a 2013 report by the Au Sable Institute and a separate report by MIDNR. Results from these reports are included to determine if dam removal is having a beneficial effect on river temperatures.

4.2.5 Biological Functions

Biological functions include the life histories of aquatic and riparian life. Typical parameters with river assessments include macroinvertebrate and fish communities (Harman et al., 2012). Note that biological functions do not include habitat. Habitat is included in lower order functional categories like Geomorphology. For example, riffles and pools are habitat for macroinvertebrates and fish and assessed as part of the geomorphology functions. Macroinvertebrates and fish were not assessed as part of the SM assessment; however, results from the Au Sable Institute and Michigan DNR, respectively, are summarized and used to evaluate overall river health.

Macroinvertebrate Communities

Two studies prepared by the Au Sable Institute are most complimentary to this study. The first, and most applicable, is by Guebert and Mahan (2014). This study includes four monitoring sites upstream and downstream of the former Brown Bridge Pond. Site A is a control or reference site located upstream of the reservoir influence. Site B is near the upstream limit of the impoundment effect. Sites C and D are downstream of the former impoundment, with site C located within the site 4, Brown Bridge reach of this study. Site D is farther downstream near the end of the Impacted Reach. These locations are shown on **Figure 1**. The study provides results from 2011 to 2014 with a detailed focus of organism change between 2013 and 2014.

The second study is by Scheeres and Mahan (2014), which includes data for site 5, Shumsky reach; however, it's not clear if their sampling location matched the SM sampling location. This paper is not as applicable because Shumsky is used as an upstream control for evaluating downstream changes anticipated by the Boardman Dam removal and associated Keystone Reservoir drawdown. Nevertheless, the results are used to help determine macroinvertebrate health at the Shumsky reach.

These two papers are part of a larger report by the Au Sable Institute that was released in 2014. Other studies discuss macroinvertebrate trends between sites 4, Brown Bridge and 5, Shumsky and within the newly created stream channel (restoration site within the former Brown Bridge Pond). The results from all studies are used to determine overall trends in macroinvertebrate health.

Fish Communities

There were two letter reports provided by Heather Hettinger with the MDNR about fish populations in the Boardman River after dam removal. The first report summarized fish samples taken on May 29, 2013 from within the former Brown Bridge Impoundment. The second report was provided in 2012 and included data from Beitner Road, which is several miles downstream from site 5, Shumsky. This study was not included in the results since it does not represent the study reach or Impacted Reach. In addition to these letter reports, the EA (US FWS, 2012) includes a summary of coldwater fish abundance upstream and downstream of Brown Bridge Pond. A summary of this data set is provided in the function-based assessment to determine the pre-dam removal functional capacity (Functioning, Functioning-At-Risk, or Not Functioning).

5.0 RESULTS

The results from the 2013 and 2014 SM assessments are provided below, starting with the vertical stability assessment and followed by the function-based assessment that includes results by others.

5.1 VERTICAL STABILITY ASSESSMENT

5.1.1 Site 4, Brown Bridge Road Reach

Figure 16 shows bed elevation comparisons from the pre-TDS failure condition and the post-failure condition at site 4, Brown Bridge Road. The bars represent the bed elevation of the pre-dam condition. Generally, the higher elevation bars represent riffles and the lower elevation bars are pools. The points represent the post-TDS failure condition. The graph shows that aggradation of the bed occurred after the failure, with the most aggradation represented by the November 16, 2012 IT survey, which was measured almost six weeks after the October 6, 2012 TDS failure. Bed aggradation extended from point number 1 (upstream starting point) to point number 14, which is a distance of approximately 2,450 feet. The 2013 data show that most bed elevations decreased during the thirteen months between sampling, but were still above the pre-dam elevations in most cases. The graph also shows that the pools filled more than the riffles (see points 1, 3, 5, and 7). However, in some cases, the riffle elevations in 2013 were back to the pre-dam condition (see points 2, 4 and 6).

Oddly, point number 10 showed aggradation in 2012 and degradation during the 2013 and 2014 assessments. This point is located immediately upstream of Garfield Road and is likely influenced by bridge hydraulics, which can create scour through flow contraction during storm events. Therefore, the 2014 assessment added points downstream of Garfield Road. The 2014 data shows that for every point between 1 and 10, the bed elevation remained almost the same as 2013 or moved towards the pre-dam condition, despite the large flood event that occurred in April 2014 (See Hydrology Methodology). The 2014 data downstream of Garfield Road shows aggradation at points 11 through 13, bed equilibrium at points 14 and 15, and minor degradation at points 16-18. East Creek flows into the Boardman downstream of point 18 so no additional points were surveyed.

To better understand the magnitude of bed aggradation and degradation, a graph was created showing the post-TDS failure elevation minus the pre-TDS failure elevation for each site. The results are shown on **Figure 17** and clearly show a sediment wedge with maximum aggradation near the beginning of site 4, Brown Bridge Road and decreasing through Garfield Road. The aggradation wedge ends at point 14. The maximum aggradation was 2.9 feet at point number 1, surveyed approximately six weeks after the TDS failure (November 16, 2012). The max aggradation during the 2013 and 2014 survey was 2.3 feet.

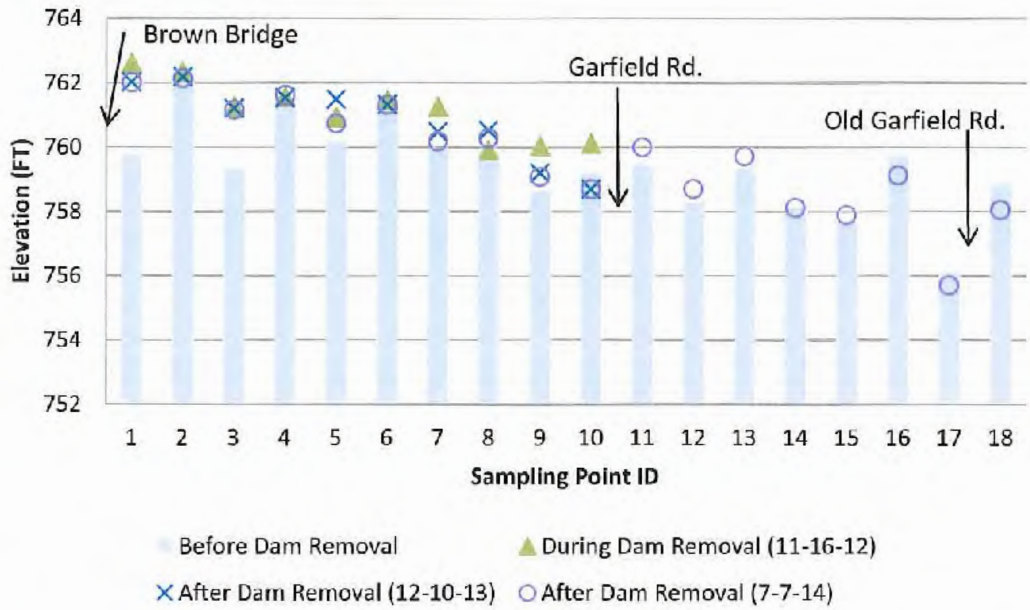


Figure 16. Before and after dam-breach bed elevations at site 4, Brown Bridge Road Reach

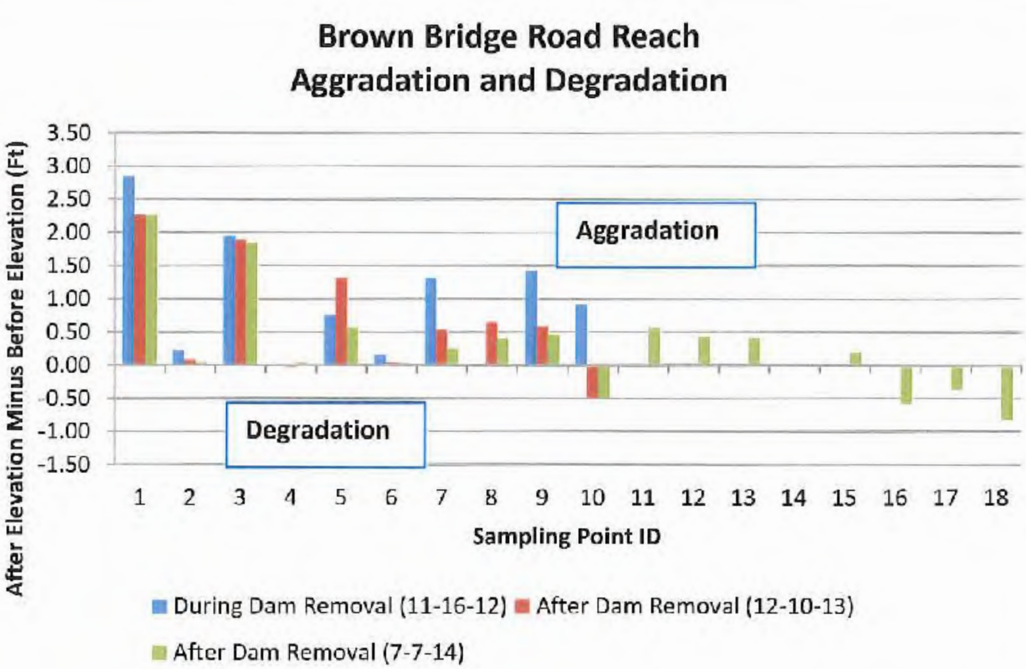


Figure 17. Before and after dam-breach aggradation and degradation at site 4, Brown Bridge Road Reach

Figure 18 shows the depth of refusal results for site 4, Brown Bridge Road. The zero depth on the graph represents the streambed elevation and the negative numbers show how far the steel/fiberglass graduated rod penetrated the bed sediments. Generally, the bar penetrated "soft" material like sand and small gravel that is scoured and filled during storm events. Coarse gravel is located below the refusal depth. The graph shows the depth of refusal generally decreasing in a downstream direction with the exception of points 9 and 10. These points are most likely influenced by scour and fill processes created by Garfield Road. Soft sediments are minimal downstream of Garfield Road with the exception of point 17, which is a deep pool near old Garfield Road.

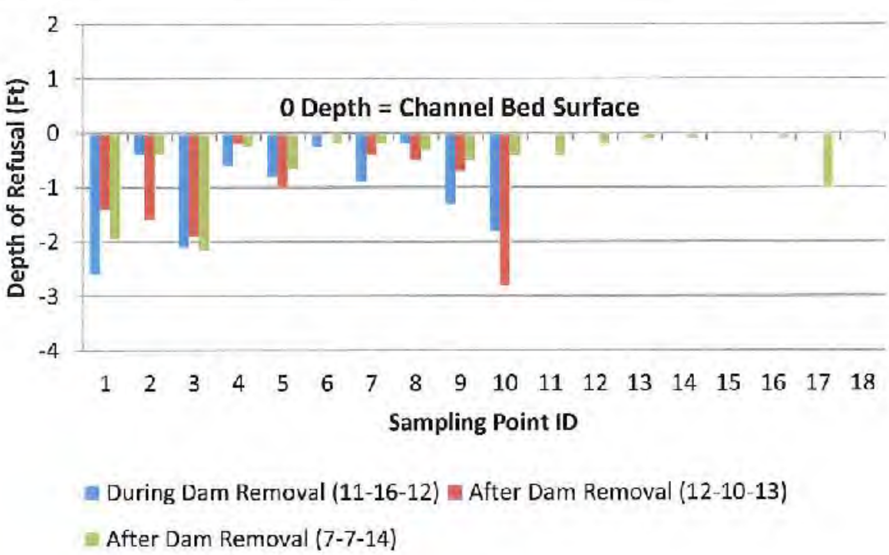


Figure 18. Depth of refusal at site 4, Brown Bridge Road Reach

5.1.2 Site 5, Shumsky Road Reach

Figure 19 shows the bed elevation survey results for site 5, Shumsky Road. This graph shows very little bed elevation change from the pre-TDS failure condition to the post-TDS failure condition. There is no obvious sediment wedge; however, there are individual points that show minor increases and decreases in elevation. Points 15 and 16 show the largest elevation increases. The amount of aggradation and degradation is shown in **Figure 20**. Points 15 and 16 have aggradation rates ranging from 0.1 to 0.7 feet. The majority of the change is less than 0.4 feet, which is approximately the accuracy of the sampling method. Therefore, based on the sampling accuracy and lack of a sediment wedge, this reach is considered within the range of natural variability for streambed elevation fluctuation, i.e., it is vertically stable.

Figure 21 shows the depth refusal data and matches well with **Figure 20**. For most points, it was very difficult to drive the steel rod into the bed. Point number 6 was the only place where the rod could penetrate more than one foot. Points with apparently no data are locations where the depth of refusal was zero, i.e., no bed penetration. It was noted during sampling that the Shumsky streambed was much "harder" than the streambed at Brown Bridge Road.

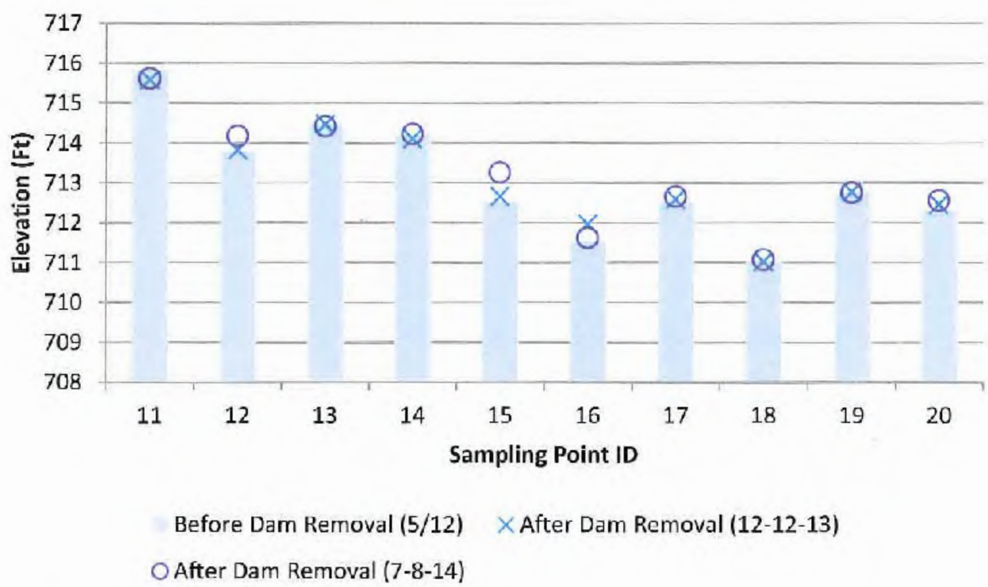


Figure 19. Before and after dam breach elevation data at site 5, Shumsky Road

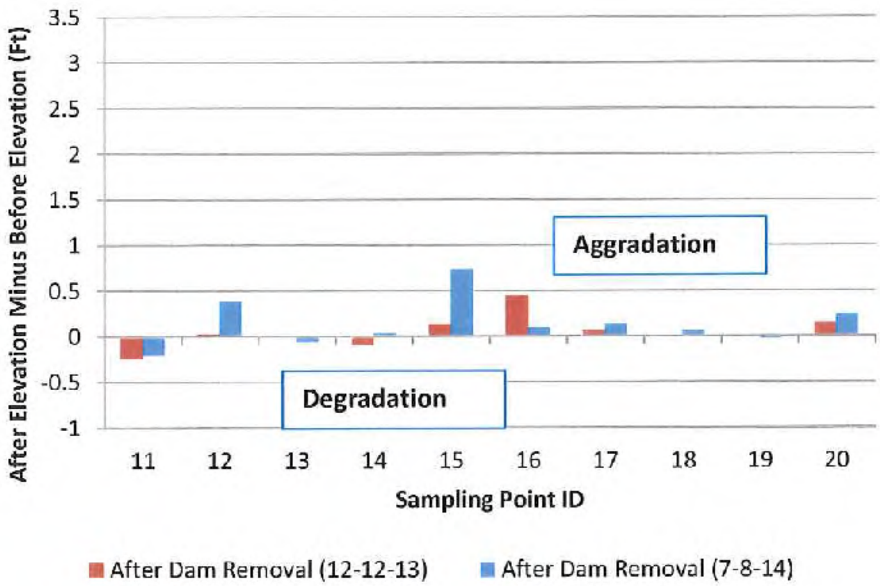


Figure 20. Before and after dam-breach aggradation and degradation at site 5, Shumsky Road

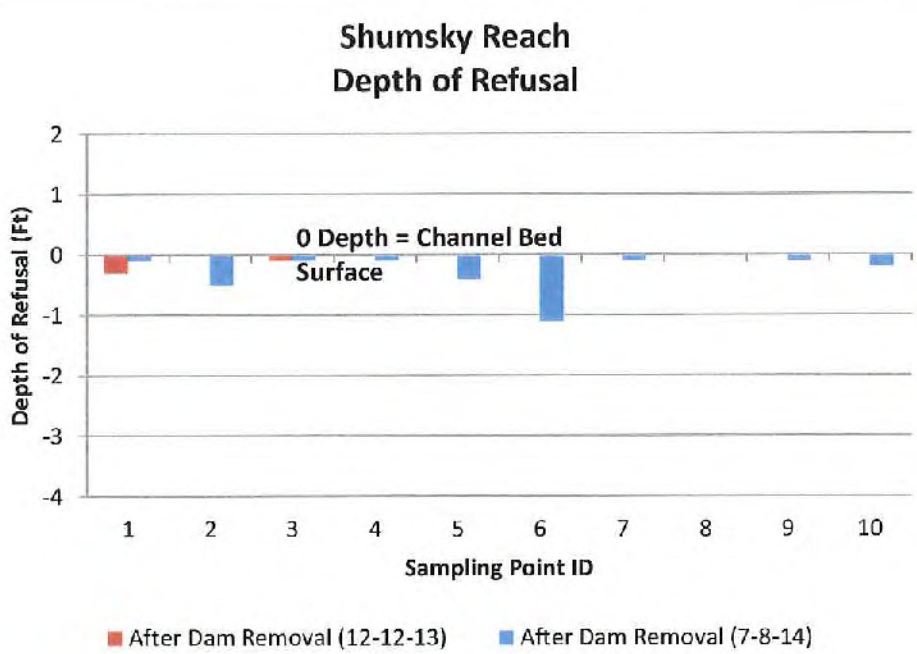


Figure 21. Depth of refusal at site 4, Brown Bridge Road

5.2 Function-Based Assessment

5.2.1. Hydrology Functions

Hydrology functions were not assessed as part of a pre- and post-TDS failure assessment. However, the USGS gage station at Ranch Rudolph was used to calibrate the bankfull indicators, characterize hydraulic geometry, and determine the return interval of the bankfull discharge and April 2014 flood. See the Hydrology discussion under the Methodology Section for details. The bankfull calibration and hydraulic geometry were used to help evaluate floodplain connectivity, which is described in the following section.

5.2.2 Hydraulic Functions

Floodplain connectivity was assessed by measuring the bank height ratio and entrenchment ratio. These ratios are shown in **Table 7** for sites 2, Forks Campground; 4, Brown Bridge Road; and, 5, Shumsky Road. In addition, the bankfull riffle dimensions from representative riffle cross sections are shown. The results show that each site is well-connected to the floodplain with bank height ratios near 1.0 and entrenchment ratios greater than 2.2. There were short sections of each reach where the bank height ratio exceeded 1.0, if the stream meandered into a terrace or hillslope for example. However, each reach consistently inundated the floodplain at the bankfull stage.

The riffle width/depth (W/D) ratio is considerably higher at sites 4, Brown Bridge and 5, Shumsky than 2, Forks (See **Table 7**). And 2, Forks is very similar to the USGS gage station, which is 19 and 18 respectively. These similarities could be caused by their close proximity to each other. Likewise, sites 4, Brown Bridge and 5, Shumsky could have higher W/D ratios because they are much farther downstream and are more affected by wood removal. However, it could also be caused by a higher sediment load, variations in the bankfull determination, and other factors. It is also interesting that site 5, Shumsky Road is almost the same size channel (see Area below) as 4, Brown Bridge. This could be caused by sedimentation at Brown Bridge, but also from slight differences in the bankfull identification.

Table 7. Bankfull dimensions

Site	Drainage Area (mi^2)	Area (ft^2)	Width (ft)	Depth (ft)	Max Depth (ft)	Width/Depth (ft/ft)	Bank Height Ratio (ft/ft)	Entrenchment Ratio (ft/ft)
Forks Campground	121	81	39	2.1	2.4	19	1.0	>2.2
Brown Bridge Road	151	179	68	2.6	3.1	26	1.0	>2.2
Shumsky Road	207	180	68	2.7	3.6	26	1.0	>2.2

5.2.3 Geomorphology Functions

Quantitative results from the geomorphology assessment are provided for bed form diversity, bed material characterization, and large woody debris. In addition, qualitative observations are provided for lateral stability and riparian vegetation. Links to underwater and above-water videos are also provided.

Bedform Diversity

Results from the bed form diversity assessment include the stream features mapping, detailed topography map, and depth variability plots. The stream feature maps are shown for sites 2, Forks Campground; 4, Brown Bridge Road; and, 5, Shumsky Road on **Figure 22**, **Figure 23**, **Figure 24**, respectively. Full-page versions of these maps are included in Appendix 2. The feature maps all show similar patterns; the streambed is primarily comprised of gravel material throughout the thalweg, both in riffle and pool habitats. Sand dominates the inside of the meander bends forming well-developed point bars. Sand also accumulates along the channel margins if LWD is present. This is typical of healthy rivers. Point bars are depositional areas due to centrifugal and other forces that occur in meander bends. The point bar is a low energy habitat. The LWD creates boundary roughness and encourages sand deposition within the wood structure. The thalweg remained free of excessive deposition in all three study reaches, with one exception, indicating that sediment transport processes are working. The one exception is at site 4, Brown Bridge Road where there is a mid-channel bar located downstream of the road crossing. It is labeled on the map and shown below in **Figure 25**. This bar was not present prior to the TDS failure (personal communication with Frank Dituri and Steve Largent) and probably formed due to extreme velocities exiting the culvert during the TDS-failure flood. There is a very deep scour pool just downstream of the culvert, which is likely the source area for the deposited material. The mid-channel bar is located in the area of max aggradation shown on **Figure 17**. Other than this bar, there is no major difference in the character of stream features between the upstream site at 2, Forks Campground and the downstream sites (4, Brown Bridge and 5, Shumsky).

Minor differences include variations in the location of sand based on geometry differences and the location of LWD. Site 2, Forks has more sand in the pool and less sand in the riffle margins than the downstream sites. This is likely caused by a LWD jam and channel constriction near the lower end of the reach. These jams will create backwater conditions during higher flows, and in this case backs up water into the meander bend. This causes the point bar to merge with a lateral bar. There is less sand in the riffle margins than sites 4, Brown Bridge and 5, Shumsky because there is less wood in the margins. From a stream function perspective, the important points are: 1) sand deposits are located upstream and downstream of the former impoundment, 2) sand is depositing on point bars and between LWD pieces and within jams, and 3) there is a gravel thalweg throughout the riffle and pool habitats. These are all indicators that sediment transport processes are functioning like a healthy river.

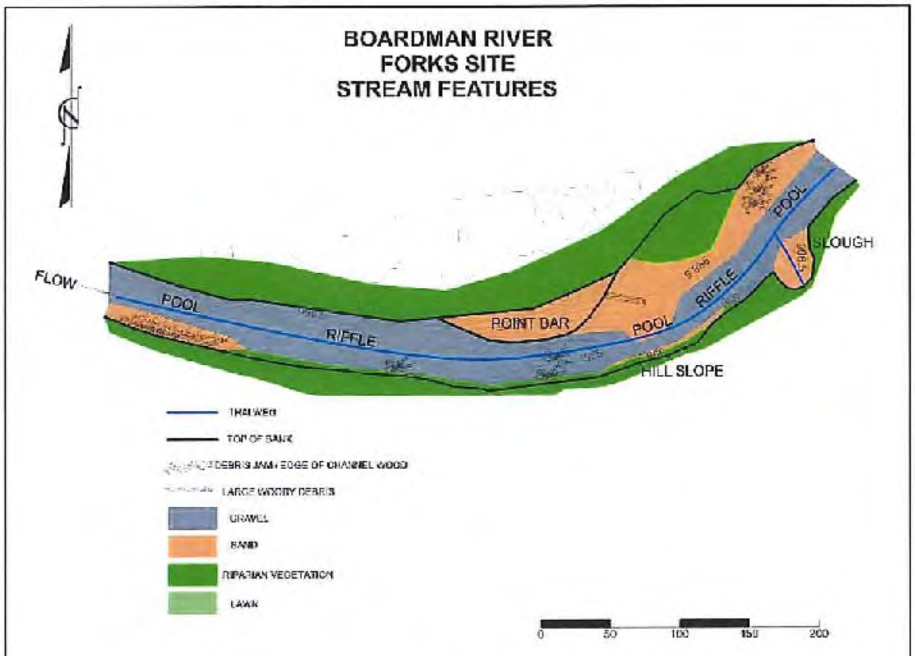


Figure 22. Stream Feature Map at 2, Forks Campground Reach

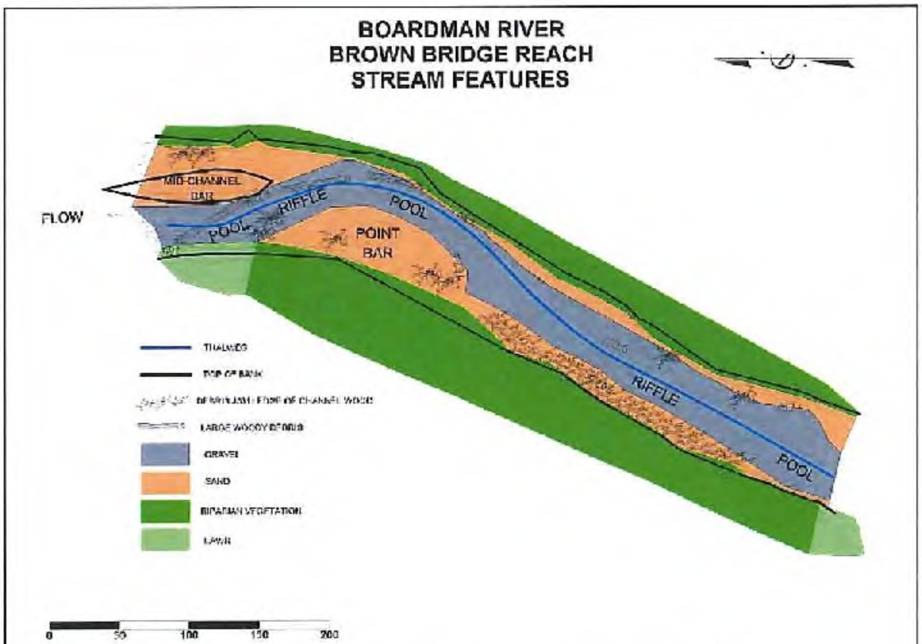


Figure 23. Stream Feature Map at 4, Brown Bridge Reach

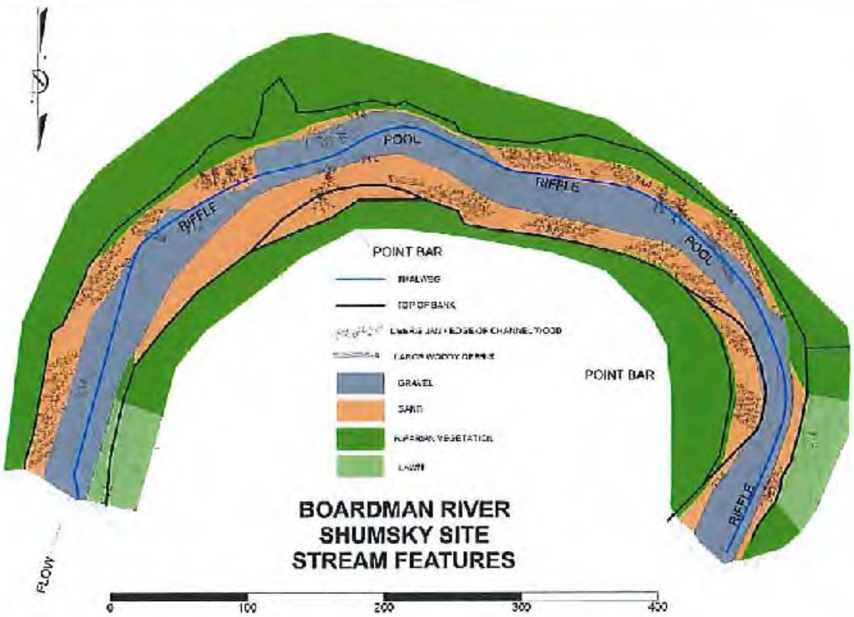


Figure 24. Stream Feature Map at 5, Shumsky Road Reach

Figure 25. Mid-channel bar downstream of 4, Brown Bridge Road.

These results are further verified with the detailed topographic map of the channel bed and banks and its contrast with the floodplain; a river bathymetric map. These results are shown for sites 2, Forks; 4, Brown Bridge; and, 5, Shumsky on **Figure 26**, **Figure 27**, and **Figure 28**, respectively.

Full-page versions of these maps along with representative photos are provided in Appendix 2. The solid black line represents the bankfull stage, which in most cases is the top of the streambank or lowest break in slope. The bankfull stage is shown as 0 feet with a brown color representing bankfull plus or minus 1 foot. The blue shading and negative numbers represent channel depths and the green numbers and positive numbers represent depth above bankfull. The deep blue areas are pools and the light blue areas are riffles and shallow areas. Results are similar for all three sites regarding the location of pools. Deep pools form along the outside of the meander bends and downstream of LWD. Pools are generally deeper in the meander bends than downstream of the LWD.

Site 4, Brown Bridge Road reach is particularly interesting. As discussed in the vertical stability assessment and stream mapping results, there are signs of aggradation in this reach. However, **Figure 267** shows that the aggradation is not having a negative impact on pool depth. There are deep pools along the outside meander bends and a thalweg has formed along the right side of the mid-channel bar. There are several pieces of LWD in this location, so a pool has formed as well.

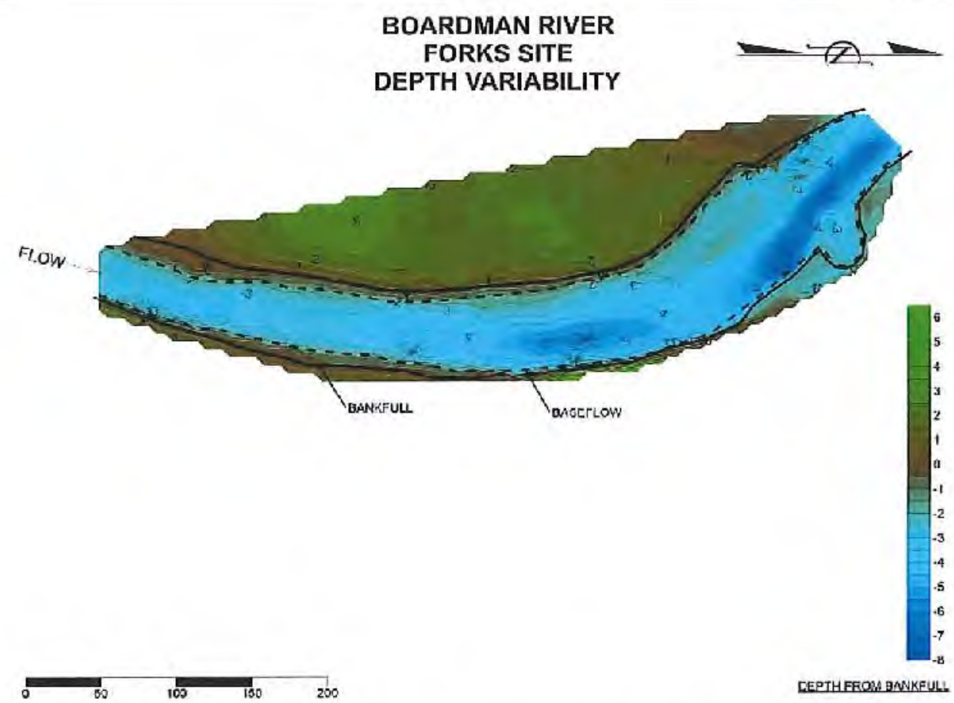


Figure 26. Depth (feet) variability map at 2, Forks Campround Reach.

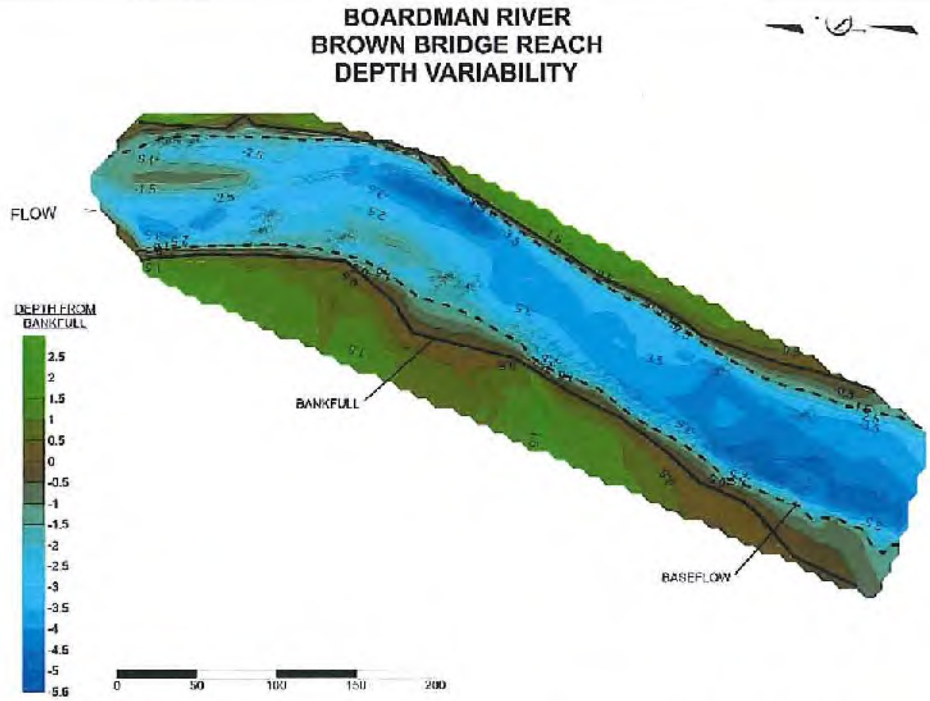


Figure 27. Depth (feet) variability map at 4, Brown Bridge Road Reach.

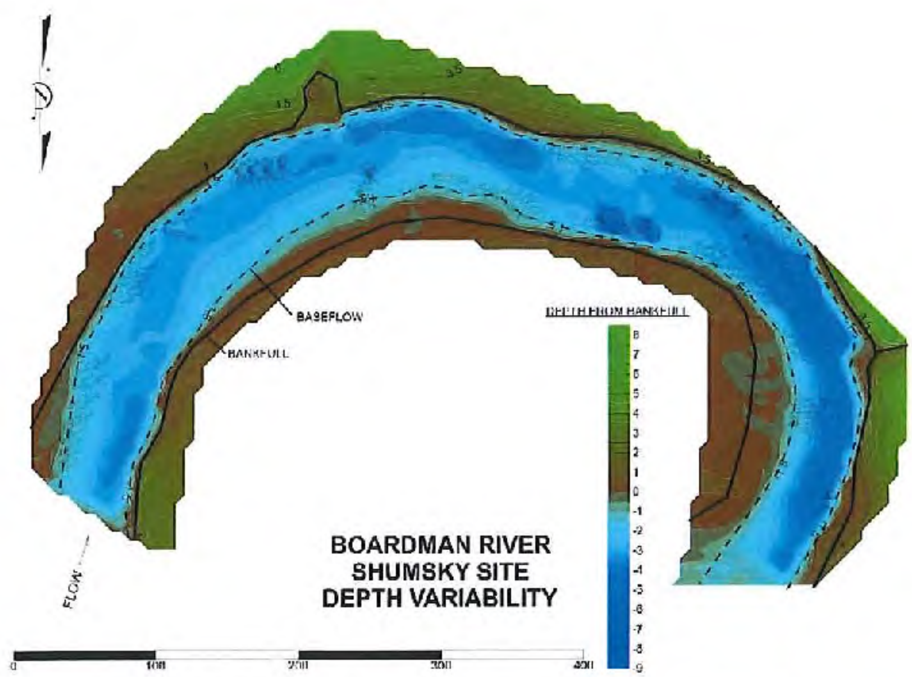


Figure 28. Depth (feet) variability map at 5, Shumsky Road Reach.

The final result from the bedform diversity assessment is the depth variability scatter plots. These plots are created from the same data set used to create the topographic maps. The result is shown in **Figure 29**. The black points are individual bankfull depths, the red line is the median, and the red plus sign is the mean. As expected, the mean/median and baseflow depth increase in a downstream direction due to increases in drainage area and flow. The max depth for site 2, Forks is almost the same as site 5, Shumsky, the farthest downstream reach. This is probably due to the flow contraction that occurs from the meander bend and LWD jam at 2, Forks. However, the distribution of depth is similar between the three sites. In other words, no site is mostly shallow or mostly deep.

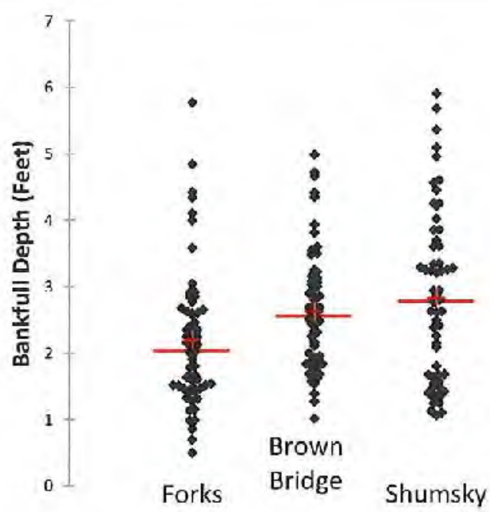


Figure 29 Scatter plot of bankfull depths

A statistical summary of the depth data is provided below in **Table 8**. The range and coefficient of variation are used to assess depth variability. The range (difference between max and min depths) is greatest for site 2, Forks Campground (5.3) and least for site 4, Brown Bridge (4.0). The coefficient of variation (CV, which is the standard deviation divided by the mean) shows a similar result. Site 4, Brown Bridge has a CV of 35%, which is less variability than site 2, Forks with a CV of 45%. Site 5, Shumsky has the same CV as 2, Forks. The lower variability at 4, Brown Bridge Road is likely caused by the aggradation resulting from the TDS failure. However, there is variation in depth between the pools and riffles, which is characteristic of a healthy stream. In other words, the aggradation does not appear to be causing excessive impacts that lead to a loss in pool habitat or a loss in sediment transport capacity.

Table 8. Summary statistics for bankfull depth data.

Variables	**2. Forks Campground**	**4. Brown Bridge**	**5. Shumsky Road**
Count	60	60	60
Mean	2.2	2.6	2.8
Median	2.0	2.6	2.8
Min (Feet)	0.5	1.0	1.1
Max (Feet)	5.8	5.0	5.9
Range	5.3	4.0	4.8
Standard Deviation	1.0	0.9	1.3
Coefficient of Variation (%)	45	35	46

Bed Material Characterization

Results for the bed material data are divided by riffles, pool, and point bar bed features. The riffle results are shown on **Figure 30** and include sites 2, Forks; 3, Downstream of Forks; 4, Brown Bridge; and, 5, Shumsky. A full-page version of Figures 30 and 31 along with representative photos is included in Appendix 2. The riffles at sites 2, Forks, 4, Brown Bridge, and 5, Shumsky are mostly gravel at 82%, 72%, and 60%, respectively. It is typical that the percent gravel will decrease in a downstream direction (Knighton, 1998). There also is sand in the riffles, located along the channel margin as shown in the feature maps. The sand percentages for each site are: 2, Forks (13%); 4, Brown Bridge (21%); and, 5, Shumsky (25%). As discussed in the methodology section, the site 3, Downstream of Forks was selected because it appeared to be one of the sandiest reaches in the watershed. The pebble count data quantify this observation. The riffle here is 44% sand and 37% gravel, with 16% silt, this is twice as much as site 5, Shumsky. It is unknown why this site is so sandy, but this site along with visual observations, shows that there is a sand load throughout the Boardman River Watershed, not just downstream of the former Brown Bridge Pond.

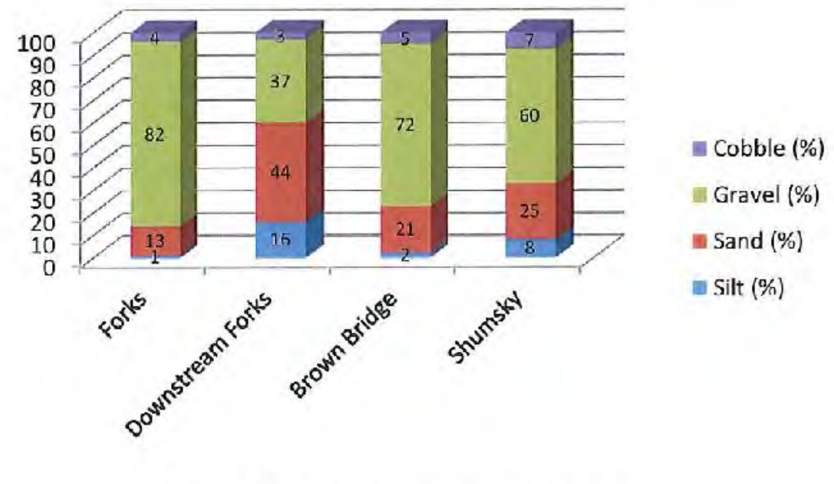


Figure 30. Riffle bed material characterization

The pool bed material composition is shown in **Figure 31**. This graph shows that the pools also are dominated by gravel, both upstream and downstream of the former Brown Bridge Impoundment. Site 2, Forks Campground has the highest percentage of sand within the pool at 35%. Pools at sites 4, Brown Bridge and 5, Shumsky are 22% and 10% sand, respectively. If the TDS failure / dam removal were causing excessive sedimentation, the pools would likely have more sand than gravel. When comparing the pools to the riffles, the pools do have a higher percentage of sand, but it is not excessive. Combining this information with the depth data shows that the pools are well-formed. They are deep with coarse thalwegs; whereas, a reach impacted by sediment loading would have shallow pools filled with sand.

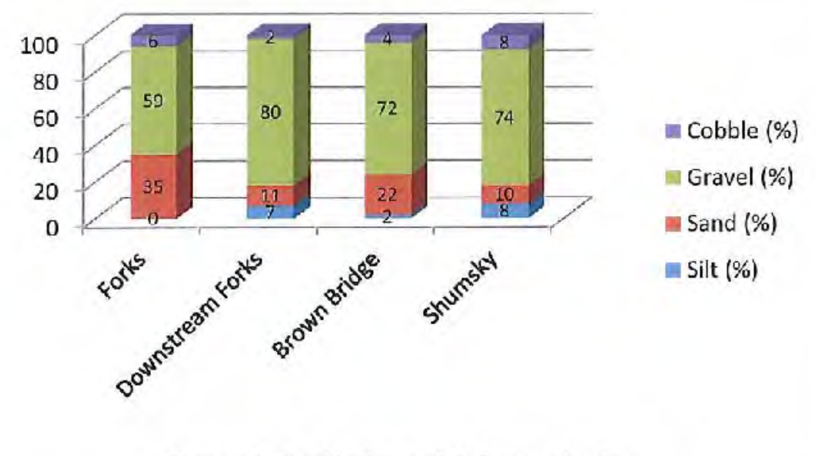


Figure 31. Pool bed material characterization

The bed material composition of representative point bars also was sampled and the results are shown in **Figure 32**. This graph is less important than the riffle and pool graphs, but it does quantify the distribution of silt, sand, gravel, and cobble that is deposited on point bars. The distributions are fairly similar across sites in that the point bars are dominated by sand. Site 2, Forks Campground has the highest percentage of silt and gravel, which probably is caused by the shape of the pool and point bar. The point bar at site 2, Forks was not as well formed as the other point bars.

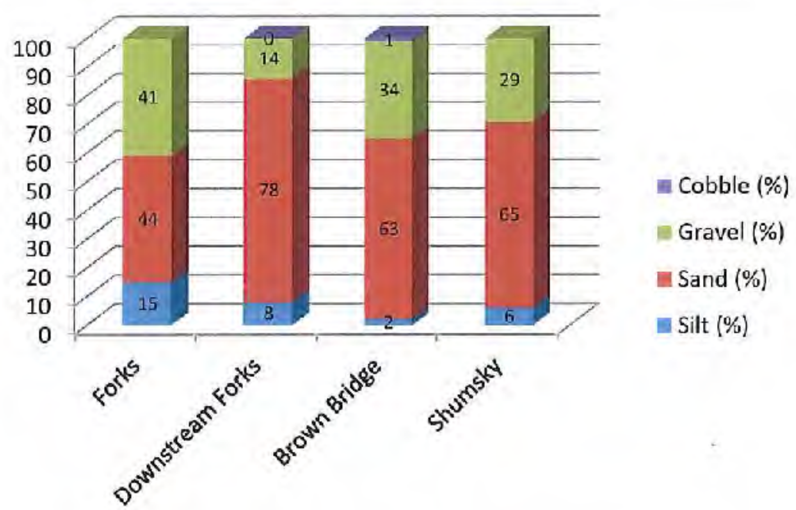


Figure 32. Point bar bed material characterization.

Large Woody Debris

Results from the LWD assessment are provided in **Figure 33**. The LWDI was calculated at site1, South Branch (un-managed) to represent a reach where wood is not routinely removed from the river. All other sites (2, Forks; 4, Brown Bridge; and, 5, Shumsky) have wood routinely removed to support water-based recreation like canoeing. Therefore, the comparison between managed and un-managed is more relevant than whether the site is upstream or downstream of the former Brown Bridge Pond. The difference is large. There is much more wood in the un-managed reach than the managed reaches, which is most of the main-stem of the Boardman River. The site closest to the un-managed LWDI is site 4, Brown Bridge, which is still 1,103 points less than the managed site (1, South Branch). A photo of the un-managed reach is provided below in **Figure 34**. This reach would be impossible to canoe, so it's understandable why wood removal is common.

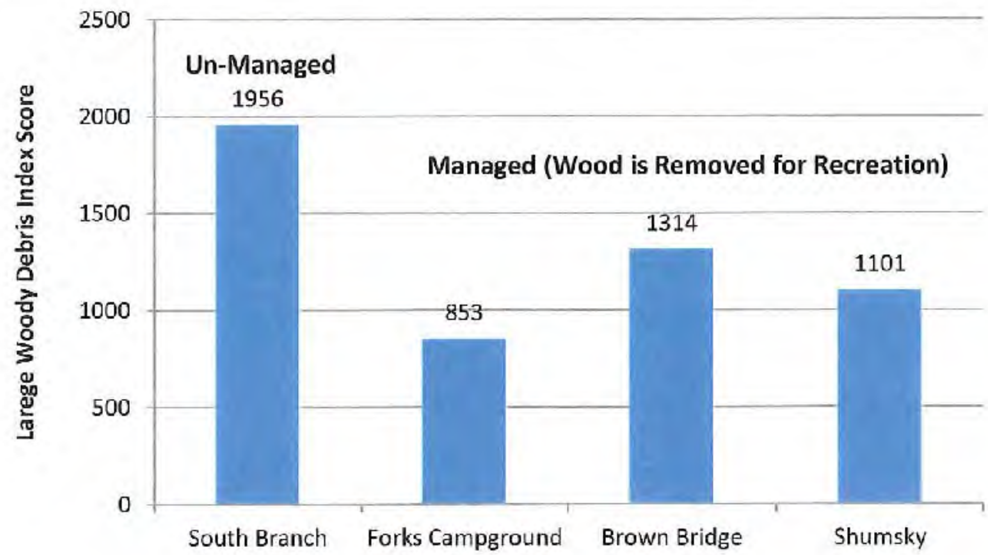


Figure 33. Large Woody Debris Index Scores

Figure 34. Large woody debris jam in the un-managed reach (Site 1, South Branch)

Qualitative Observations of Lateral Stability and Riparian Vegetation

All reaches assessed were laterally stable, meaning that bank erosion did not appear to be excessive or beyond what would be observed in a reference condition. The primary reasons include the following: 1) the stream reaches were well-connected to the floodplain, bank height ratios were low and entrenchment ratios were high; 2) the watershed is not flashy and the gradient is low, which minimizes erosive forces against the bank, 3) bank and floodplain vegetation is well established except for sporadic lawns, which provides resistance against erosive forces. There were minor areas of bank erosion, typically in areas where the river had meandered into a hillslope or terrace; however, the rates were not causing overwidening of the channel, downvalley migration of meander bends, or mid-channel bar formations.

Riparian vegetation was well-established throughout each reach and the majority of the watershed. The streambanks were vegetated with a mixture of herbaceous, shrub/scrub and large woody vegetation. The floodplains also were a mixture of herbaceous and woody vegetation, and often included LWD. There were exceptions. Sites 4, Brown Bridge and 5, Shumsky Reaches had short sections of bank and floodplain where woody vegetation had been removed. Herbaceous vegetation was present and in most cases mowed to provide a lawn. Site 2, Forks was well-vegetated in the study reach; however, there was a campground immediately upstream with a parking area and camp sites. At site 5, Shumsky, bank stabilization work was apparent near the beginning of the reach. However, in each case, the removal of vegetation did not create excessive bank erosion or lateral stability problems. It's also unlikely that the vegetation removal would have a negative impact on stream temperature due to the small areas of vegetation removal and dominance of groundwater discharge.

Videos

Videos from sites 2, Forks Campground; 3, Downstream from Forks Campground; 4, Brown Bridge; and, 5, Shumsky Reaches are provided on a Stream Mechanic's file transfer page and a CD provided to MDEQ with this report. Hyperlinks to the files and descriptions are provided below and will allow access to the files for the remainder of 2015.

Overall, the videos support the geomorphology data provided above; primarily that the Boardman is a gravel-bed river with a large sand load. The thalweg in the riffles and pools are dominated with gravel. Sand is deposited along the channel margins, and most prevalent if wood also is located along the channel margin.

Site 2, Forks Campground:

1. Forks Reach Riffle LWD — Shows gravel in the riffle thalweg. Video focuses on sand and silt that has accumulated around the LWD and channel edge. https://streammechanics.egnyte.com/dl/lAXiCFWlB0

2. Forks Reach Riffle — Shows the bed material of the study riffle moving from right edge of channel to left edge. The video shows sand along the edge of the channel and a well-developed, gravel thalweg. https://streammechanics.egnyte.com/dl/a4JBaHyOIW

3. Forks Pool and Pt Bar — Shows a portion of the study pool and point bar to the left. The thalweg has gravel material and the point bar is mostly sand. https://streammechanics.egnyte.com/dl/4Cqp8DHavG

4. Reach video — Shows the study reach from upstream to downstream, shot walking in the channel. This video has a very large file size and is only included on CD.

Site 3, Downstream of Forks Campground:

1. Downstream of Forks Riffle — Shows the riffle moving from river left to right and then back to the left. This riffle does have gravel; however, it has more sand in along the channel margin and in the thalweg than other reaches. https://streammechanics.egnyte.com/dl/wkMG0yTrYw

2. Downstream of Forks Pool — Shows the study pool moving from river left to right, starting upstream and ending downstream. The pool and point bar was mostly sand. https://streammechanics.egnyte.com/dl/m15AtJRz8g

Site 4, Brown Bridge:

1. Brown Bridge Riffle — Shows riffle moving downstream from right to left and gravel material in the thalweg. https://streammechanics.egnyte.com/dl/Kb7kAUTOdB

2. Brown Bridge Pool and Pt Bar — Shows that pool thalweg material is similar to riffle thalweg material; sand is located on the point bar. streammechanics.egnyte.com/dl/7r5zIQg9gf

3. Brown Bridge Reach LWD — Shows sand and silt that has accumulated around LWD in the study riffle. https://streammechanics.egnyte.com/dl/xpyGqnqfxf

4. Reach video — Shows the study reach from upstream to downstream, shot walking in the channel. This video has a very large file size and is only included on CD.

Site 5, Shumsky:

1. Shumsky Riffle 2 Shows gravel in study riffle. streammechanics.egnyte.com/dl/CCalPVBDRI

2. Shumsky Pool and Pt Bar — Shows a small portion of the pool and point bar. This video was difficult to shoot due to the pool depth and velocity between the LWD and point bar. https://streammechanics.egnyte.com/dl/XzEtfj3hWM

3. Shumsky LWD — This is one of the larger trees that was left in the river. The video shows the bed sediments around the tree. The sediments are mostly gravel because the tree is "coarse," meaning that water easily flows through the structure, preventing sand accumulation. https://streammechanics.egnyte.com/dl/hfGQiN956f

4. Reach video — Shows the study reach from upstream to downstream, shot walking in the channel. This video has a very large file size and is only included on CD.

5.2.4 Physicochemical Functions

Results from a temperature study are provided in a report by the Au Sable Institute (Petry, 2013) and include data collected by the GTCD from 2011 to 2013. Results show that the dam had a negative impact on thermal regulation by increasing summer water temperature downstream of the dam by approximately 3°C. After dam removal, the July 2013 downstream temperature was slightly lower than the upstream temperature. Conversely, in the winter of 2012-2013, the downstream temperature was slightly warmer than the upstream temperature. Using the 2013 data set, Hettinger (2013) reported that water temperature cooled during the summer months by approximately 10°F and warmed during the winter months by approximately 10°F. Hettinger attributes the cooler summer temperatures to an increase in groundwater discharge to the river within the former impoundment and a decrease in surface water warming when the dam was in place. The warmer winter temperatures are attributed to an increase in groundwater discharge as well. Hettinger also notes that these changes are highly beneficial to cold water fish species, such as trout.

5.2.5 Biological Functions

Macroinvertebrate sampling results are provided in several reports by the Au Sable Institute. A paper by Guebert and Mahan (2014) provides results from samples taken upstream and downstream of the former Brown Bridge Pond. Their study documents that the dam breach/removal had negative impacts to macroinvertebrate communities downstream of the dam during the first year after removal. The 2013 data showed a reduction in organism numbers, diversity, percent EPT, which is an acronym for Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies), EPT/C ratio, and sensitive/tolerant ratio at site 4, Brown Bridge Road (their site C) and Garfield Road (site D). However, the 2014 data show strong recovery in macroinvertebrate health despite the large spring flood event. Site C's total organisms are still low in comparison to A (upstream reference) and D; however, percent EPT and organism tolerance ratios at site C are similar to A and D. In addition, the index of similarity increased from 72% to 80% between 2013 and 2014. Diversity and ENS values in 2014 more than doubled, and percent EPT increased at sites C and D. The four-year study concludes that the 2013 decline is likely a result of the dam removal and the 2014 data reflects recovery.

Scheeres and Mahan (2014) provide macroinvertebrate results for site 5, Shumsky reach, which was used as an upstream control for their study of the Boardman dam/Keystone Pond removal and drawdown. Shumsky showed below average numbers for the past two years in comparison with the last six years. In 2014, the observed percentages of both sensitive and tolerant macroinvertebrate families decreased; however, the percent EPT and EPT/C ratios increased, indicating an improvement in water quality. However, these increases were not statistically significant. The total number of organisms has declined since 2012; however, the diversity remained constant.

The authors do not draw specific conclusions about Shumsky because it was used as an upstream control for Lone Pine, which is near the beginning of Keystone Pond. However, in a summary report of all the 2014 data, Mahan (2014) concludes that the overall trend in the Impacted Reach is macroinvertebrate recovery. He notes that the only site not currently recovering is site B (upstream of restored channel in former Brown Bridge Pond) because the channel is still adjusting to the river's new base level.

The MDNR is monitoring fish communities; however, a detailed report of their finding is not yet available. The two letter reports described under the Methodology section do not include results for the sites assessed in this study. The Hettinger (2013) report about fish populations in the restored reach (former impoundment) shows signs of brook and brown trout recovery after 10 months of habitat conversion from a pond back to a river. This is a positive sign, but there is not enough information to draw conclusions about the Impacted Reach. This recovery is a function of beneficial habitat changes from a warm water to cold water fishery following removal of the Brown Bridge dam. The EA (US FWS, 2012) shows that the number of brown trout, brook trout, and slimy sculpin become less abundant downstream of Brown Bridge dam compared to upstream of Brown Bridge Pond, when the dam was in place. The EA predicts that downstream fish communities will become more similar to upstream communities after the dam has been removed and the restoration project is established.

5.2.6 Function-Based Assessment Results

Results from the function-based assessment are included in **Figure 35**. The rationale for selecting a Functioning, Functioning-At-Risk, or Not Functioning result is provided in **Table 9**. These results are meant to be a synthesis of all the above information, including quantitative and qualitative assessments. The information is used in the discussion and recommendations section as an aide in determining if restoration activities are needed for the Impacted Reach.

Figure 35 includes pre-dam removal and 2014 results for sites 4, Brown Bridge and 5, Shumsky. The results are organized by function-based parameter and tied to a functional category. Site 4, Brown Bridge reach shows functional improvement from the pre-dam condition to the 2014 assessment. The only parameter that was not shown as an improvement was LWD because it was assumed that wood management occurred before and after dam removal. Overall, site 4, Brown Bridge Reach is classified as Functioning-At-Risk trending towards Functioning. To achieve an overall Functioning rating, the reach would need significantly more wood, which is probably not desirable from a recreational perspective. For function-based parameters like vertical stability, temperature, and macroinvertebrate communities, the trend should continue towards Functioning as discussed in the bed form diversity, physicochemical and biological sections. The riparian vegetation rating will not change unless landowners start planting woody vegetation. Since the fish assessment reports have not been prepared, the functional trend is unknown.

Site 5, Shumsky Reach is similar to site 4, Brown Bridge Reach with the exception of vertical stability. Site 5, Shumsky Reach was vertically stable before and after dam removal, and therefore received a Functioning rating for both assessments. Temperature and fish data were not available for Shumsky, so ratings were not provided. The overall rating is still Functioning-At-Risk trending towards Functioning for the same reasons listed for site 4, Brown Bridge Reach.

Functional Category	Parameter	Brown Bridge Pre-dam Removal	Brown Bridge 2014	Shumsky Pre-dam Removal	Shumsky 2014
Hydrology	Runoff	Functioning-At-Risk (FAR)	Functioning (F)	Functioning-At-Risk (FAR)	Functioning (F)
Hydraulics	Floodplain Connectivity	Functioning (F)	Functioning (F)	Functioning (F)	Functioning (F)
Geomorphology	Vertical Stability	Functioning-At-Risk (FAR)	FAR trending towards F	Functioning (F)	Functioning (F)
	Bed Form Diversity	No Data	Functioning (F)	No Data	Functioning (F)
	Bed Material Characterization	No Data	Functioning (F)	No Data	Functioning (F)
	Large Woody Debris	Functioning-At-Risk (FAR)	Functioning-At-Risk (FAR)	Functioning-At-Risk (FAR)	Functioning-At-Risk (FAR)
	Lateral Stability	Functioning (F)	Functioning (F)	Functioning (F)	Functioning (F)
	Riparian Vegetation	FAR trending towards F	FAR trending towards F	FAR trending towards F	FAR trending towards F
Physicochemical	Temperature	Not Functioning (NF)	FAR trending towards F	No Data	No Data
Biology	Macroinvetebrate Communities	Functioning-At-Risk (FAR)	FAR trending towards F	Functioning-At-Risk (FAR)	Functioning-At-Risk (FAR)
	Fish Communities	Functioning-At-Risk (FAR)	No Data	No Data	No Data

Legend:

Colour	Rating
White	No Data
Red	Not Functioning (NF)
Yellow	Functioning-At-Risk (FAR)
Light green	FAR trending towards **F**
Dark green	Functioning (F)

Figure 35. Results from Function-Based Assessment

Table 9. Rationale for Selecting Functioning (F), Functioning-At-Risk (FAR), or Not Functioning (NF).

Functional Category	**Function-Based Parameter**	**Rationale for Selecting F, FAR, or NF**
Hydrology	Runoff	Pre-dam removal is FAR because dams alter the natural hydrology of a watershed and the F, FAR, and NF determination is based on reference condition. Post dam-removal is F because the dam has been removed and the watershed is dominated by groundwater discharge (non-flashy).
Hydraulics	Floodplain Connectivity	The Boardman is well-connected to the floodplain throughout the watershed.
Geomorphology	Vertical Stability	FAR was selected for pre-dam-removal condition at Brown Bridge because sediment supply was cut off from the reach, potentially causing riffle erosion. Brown Bridge data shows aggradation after TDS-failure, but little change after the 2014 flood. The trend appears to be towards vertical stability. Shumsky showed no signs of vertical change before or after breach.
	Bed Form Diversity	There was not enough pre-dam removal data to determine F, FAR, or NF. Post dam-removal data suggest that depth variability and riffle-pool sequences at Brown Bridge and Shumsky are similar to upstream conditions (Forks) and represent a healthy river system.
	Bed Material Characterization	There was not enough pre-dam removal data to determine F, FAR, or NF. Post dam-removal data suggest that bed material composition at Brown Bridge and Shumsky are similar to upstream conditions (Forks) and represent a gravel bed river with a large sand load.
	Large Woody Debris	FAR was selected for both reaches and for the pre- and post-dam-removal condition because wood is removed from the river and the LWDI is much lower than the reference condition. The reaches were not scored NF because there was LWD in the channel margin, creating sediment storage areas and downstream scour pools.
	Lateral Stability	F was selected for both reaches and for the pre- and post-dam-removal condition due to similar bank stability conditions upstream and downstream of the former Brown Bridge impoundment. Minor bank erosion was noted along the outside meander bend at Shumsky; however, not at excessive rates.
	Riparian Vegetation	FAR was selected because both reaches had a combination of lawns and well-established riparian vegetation. FAR trending towards F was used because the majority of the river corridor is well-established with woody vegetation. And temperature regulation is controlled by groundwater discharge and therefore less effected by the low percentage of lawns.
Physicochemical	Temperature	NF score was selected for the pre-dam removal condition based on data from the GTCD and analysis by the Au Sable Institute and DNR report. The data show improving trends after dam removal. A FAR trending towards F was selected to acknowledge that thermal regulation may continue to improve as the riparian vegetation becomes more established within the restored reach.
Biology	Macroinvertebrate Communities	For Brown Bridge, FAR was selected for pre-dam condition and FAR trending towards F was selected for 2014 because the 2014 data set is more similar to the upstream reference. Shumsky was left as FAR for both dates due to uncertainty in interpreting the results. One study reported declines, but the overall report was positive.
	Fish Communities	There was not enough data provided within the study reach to make a determination about post-dam removal fish health. Before is assessed as FAR because abundance numbers were lower than upstream reaches.

6.0 Conclusions and Recommendations

The primary purpose of this report is to determine if there were negative impacts to the river resulting from the October 6, 2012 TDS failure, and if there were, to propose recommendations regarding the need for stream restoration efforts. The MDEQ defined the Impacted Reach to include the restored section of channel within the former Brown Bridge Pond downstream to 1400 East River Road.

The assessment revealed that aggradation did occur at site 4, Brown Bridge Reach as a result of the TDS failure. The data show that aggradation was highest at the upstream end of the study reach, creating a mid-channel bar, and decreased in a downstream direction. Aggradation ended near Old Garfield Road, approximately 2,450 feet downstream from Brown Bridge Road. While it is obvious that aggradation was caused by the TDS failure, it is not obvious that the result is negative from a geomorphology perspective. First, it is likely that the reach experienced degradation while the dam was in place, probably through riffle erosion because the dam stopped the natural transport of sediment to downstream reaches (US FWS, 2012). Second, the aggradation probably would have occurred as part of the dam removal, regardless of the TDS failure. Dam removal restored the natural transport rate of sand and gravel, thus re-building riffles. Support for this is provided by comparing the 2013 and 2014 vertical stability data. As noted in the Results section, the bed had minimal change even though the largest flood in over 16 years passed through the reach. This indicates that the bed has mostly equilibrated to the new flow regime. The depth variability and bed material composition data also support the conclusion that aggradation has not caused a negative impact on the reach. The pools are deep and the thalweg is coarse throughout the reach. A negative response would include shallow pools dominated with sand and possibly more mid-channel bars in the riffles.

Site 5, Shumsky Reach showed no signs of vertical instability as a result of the TDS failure. The pre- and post-bed elevations were very similar, and there were no signs of widespread aggradation, only localized fluctuation that was within the range of natural variability. Bed form diversity and depth variability at 5, Shumsky was similar to 4, Brown Bridge and 2, Forks (the upstream control).

Throughout all study sites, pools were located along the outside of meander bends and downstream of LWD. The thalweg was predominantly gravel, but there was a high sand load that was often stored along the channel margins (if LWD was present) and on point bars. In short, the Boardman is a gravel bed river with a large sand load. This fact is not caused by the dam removal process, but is likely a result from past agricultural and silvicultural land use practices that eroded glacial deposits of sand into the river. The Boardman River will transport and store this sand for a very long time.

The transport and storage of LWD is critical to supporting geomorphology, physicochemical, and biological functions in the Boardman River. The SM study showed that there is much less wood in routinely managed sections of the river as compared to reaches that are not routinely managed. The removal of wood from the river does have a negative effect on stream functions. The presence of wood, and especially jams, creates heterogeneity of localized water surface slope, velocity, and bed material sorting. This creates a more complex habitat that is more suitable to native fish populations than consistent bed material sizes, near-constant velocities, and less depth variability. Furthermore, LWD retains organic matter that is an energy source for macroinvertebrates and other organisms. Future trends in LWD are dependent on river management decisions.

The Physicochemical results showed an improvement in temperature after the dam was removed. Summer peaks were lowered to a range that will support native fish populations. Preliminary data showed that native brook trout populations are already responding positively in the restored channel (former impoundment). Macroinvertebrate populations were negatively impacted in 2013 by the dam removal process, probably because the bed aggraded and changed their habitat. However, the 2014 showed strong recovery and the trajectory is towards functioning in the Impacted Reach like the reach above the former Brown Bridge Pond. This is supported by the bed form diversity results showing that the bed aggraded but then stabilized, i.e., stable riffles will help support the macroinvertebrate community.

Overall, the Impacted Reach is trending towards a functioning stream system, as compared to the reaches above the former impoundment. Based on all of the assessment data, the following recommendations are proposed.

1. Do not dredge the river! Earlier reports seemed to indicate that dredging and using sand traps should be a reclamation activity. This approach would be ineffective due to the amount of sand that is distributed throughout the entire watershed.
2. The bed form diversity, grain size distributions, temperature, and macroinvertebrate data show that the Impacted Reach is recovering from the TDS failure and dam removal. Therefore, no restoration/reclamation work is proposed within the Impacted Reach that is downstream of the former impoundment. More detail is provided below this list.
3. Temperature, macroinvertebrate, and fish community studies by the Au Sable Institute and MDNR should continue to verify the trend that the stream is recovering. Additional vertical stability and bed form diversity monitoring is not necessary because there are no other significant anthropogenic stressors that would cause a negative change. And the bedform diversity data showed good results even though a large flood occurred in 2014.
4. The NRCS provided grant funding to GTB to add more LWD to the restored reach. The efforts are focusing on easy-to-access sections and not the entire restored length due to funding limitations. Additional grant efforts are encouraged to add more wood to the restored reach. This will provide greater bed form diversity and channel complexity, which is especially important because the floodplain vegetation is not mature. Work within the restored reach is not recommended as a result of this report because it is

unlikely that the TDS failure caused functional problems to upstream reaches like the restored reach.

5. River management should continue to allow more LWD to accumulate in the channel while still allowing for water-based recreation like canoeing. This means leaving more large trees intact when one falls into the river, and only cutting small sections near the thalweg to allow passage. From personal conversations with the GTCD, NRCS, GTB and IT, it seems like this approach has already started, at least in some areas. The management of LWD is a policy/management process with varying viewpoints from many stakeholders. Those decisions are being made by the local community and perhaps will be influenced, but are not able to be controlled, by this report.

The recommendations do not include heavy equipment access to the Impacted Reach for the purpose of restoration/reclamation. It is likely that more harm than good would come from such activities because riparian vegetation would have to be removed and the banks disturbed. Mechanical approaches are sometimes warranted if the channel is unstable and will remain in disequilibrium for many years. That is not the case in the Boardman. The Impacted Reach has a channel form that already is similar to upstream conditions. There is the issue of the mid-channel bar at the Brown Bridge Reach; however, it is slowly merging with a point bar. A pool is forming along the outside bend, and it is not causing stability problems. Fishermen are using the bar to catch fish from the pool. Restoration activities should continue in the restored reach through grant programs and other efforts. Therefore, there is no need for the City to fund a restoration program because of the TDS failure.

7.0 REFERENCES

Bevenger, G.S., and R.M. King, 1995. A Pebble Count Procedure for Assessing Watershed Cumulative Effects. US Department of Agriculture Forest Service Research Paper RM-RP-319. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

Bunte, K. and S.R. Abt, 2001. Sampling Surface and Subsurface Particle-Size Distributions in Wadeable Gravel- and Cobble-Bed Streams for Analyses in Sediment Transport, Hydraulics, and Stream-Bed Monitoring. General Technical Report RMRS-GTR-74, US Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, Colorado.

Davis, J.C., G. W. Minshall, C.T. Robinsion, and P. Landres, 2001. Monitoring Wilderness Stream Ecosystems. US Department of Agriculture Forest Service, Rocky Mountain Research Station. General Technical Report RMRS-GTR-70. January, 2001.

Guebert, D.A., D.C. Mahan,2014. Macroinvertebrate rates of recovery after dam removal on the Boardman River. Au Sable Institute of Environmental Studies. Mancelona, MI.

Harman, W., R. Starr, M. Carter, K. Tweedy, M. Clemmons, K. Suggs, C. Miller. 2012. *A Function-Based Framework for Stream Assessment and Restoration Projects.* US Environmental Protection Agency, Office of Wetlands, Oceans, and Watersheds, Washington, DC EPA 843-K-12-006.

Hettinger, Heather, 2013. Boardman River in the Former Brown Bridge Pond, 2013 Fisheries Survey. Michigan Department of Natural Resources, Ann Arbor, MI.

Inglis, C.C., 1947. Meanders and their Bearing on River Training. Institution of Civil Engineers, Maritime and Waterways Engineering Division, Paper No. 7, London, England.

Knighton, David, 1998. Fluvial Forms and Processes: A New Perspective. Oxford University Press Inc. New York, NY.

Lane, E.W., 1955. Design of Stable Channels. Transactions of the American Society of Civil Engineers Paper No. 2776:1234-1279.

Laub, B.G., D.W. Baker, B.P. Bledsoe, and M.A. Palmer, 2012. Range of variability of channel complexity in urban, restored and forested reference streams. *Freshwater Biology* (2012) 57, 1076-1095.

Leopold, Luna, 1994. A View of a River. Harvard University Press, Cambridge, MA.

Mahan, Dave, 2014. Report to Conservation Resources Alliance Macroinvertebrate Survey by Au Sable Institute, Summer 2014 in support of the project, "The Boardman: A River Reborn." Au Sable Institute of Environmental Studies. Mancelona, MI.

Rachol, C. M., and K. Boley-Morse, 2009. Estimated Bankfull Discharge for Selected Michigan Rivers and Regional Hydraulic Geomoetry Curves for Estimating Bankfull Characteristics in Southern Michigan Rivers. U.S. Geological Survey, Scientific Investigations Report 2009-5133. Reston, VA.

Rosgen, Dave, 2014. River Stability Field Guide (Second Edition). Wildland Hydrology. Fort Collins, CO.

Scheeres, A. E., and D.C. Mahan, 2014. Effects of reservoir drawdown on benthic riffle macroinvertebrate communities. Au Sable Institute of Environmental Studies. Mancelona, MI.

US Army Corps of Engineers, 2009. Boardman River SIAM Modeling Base-case Scenario. Prepared by: NTH Consultants, Ltd and Baird Associates Ltd. US Army Corps of Engineers, Detroit District.

US Fish and Wildlife Service, 2012. Final Brown Bridge Dam Removal Environmental Assessment. US Fish and Wildlife Service, Green Bay Fish and Wildlife Conservation Office, Elmira, MI.

US Geological Survey (USGS), 1981. Guidelines for Determining Flood Flow Frequency, Bulletin 17b of the Hydrology Subcommittee. US Geological Survey, Reston, Virginia.

Wohl, E., L.E. Polvi, and D. Cadol, 2011. Wood distribution along streams draining old-growth floodplain forests in Congaree National Park, South Carolina, USA. *Geomorphology* 126 (2011) 108-120.

Appendix 1
Boardman River Assessment Report, Scope of Work

StreamMechanics
Restoring Stream Ecosystems

Boardman River Assessment Report
Scope of Work
January 19, 2015

Stream Mechanics, PLLC (SM) is pleased to provide the following scope of work to Foley, Baron, Metzger, and Juip, PLLC (FBMJ). The purpose of this project is to prepare a technical report about the hydraulic and geomorphic assessments that were completed in 2013 and 2014 to evaluate the impact of the Brown Bridge Pond dam breach. In addition, assessment results completed by others that evaluated stream temperature, macroinvertebrates, and fish communities before and after dam removal will be summarized and related to this study. The final product will include an evaluation and, if appropriate, a set of recommendations regarding the need for river restoration as a result of the dam breach in general accordance with the outline of the draft administrative consent order provided by Michigan Department of Environmental Quality on September 26, 2014.

Background

Stream Mechanics worked with members of the Implementation Team (IT) in December 2013 and July 2014 to perform geomorphic assessments along the Boardman River. The 2013 assessment included bed stability measurements at Brown Bridge Road and upstream of the Shumsky Road access to quantify impacts from the dam breach by comparing the results to data collected before the dam breach. Bed stability measurements were taken at the same location as pre-dam removal surveys. The 2014 assessment repeated many of the 2013 measurements and added more, including: bed form mapping, grain-size distributions, and a large woody debris assessment.

The 2014 study also monitored these parameters at the Forks Campground to provide data upstream of the former Brown Bridge Pond. Two additional sites were selected upstream of the former impoundment as well. The first addition was a reach downstream of Forks Campground. This site was selected because it appeared to be one of the sandiest reaches anywhere in the Boardman River Watershed, even though it is located upstream of the former impoundment. A pebble count was completed in this reach to quantify the percent of sand and compare it to the other reaches. The second addition was a large woody debris reference site that is not managed for recreational paddling, unlike areas on the Boardman downstream of the former impoundment. This reach included large woody debris jams that spanned the channel. The large woody debris index was the only assessment completed at this site. Appendix 1 includes a table listing the parameters described above and their purpose in the assessment, the method used, and the source of the methodology (reference).

Scope of Work and Report Outline

Under this scope of work, a technical report will be prepared that presents the study objectives, methods, and results from these two past assessments (2013 and 2014). The results will include bed form diversity maps, grain size distributions, depth variability graphs, and large woody debris results. Comparisons will be made between upstream (reference) and downstream (Impacted) reaches of the former impoundment.

The results from a macroinvertebrate assessment report by the Au Sable Institute and temperature results from the Grand Traverse Conservation District will be included in this study. Fish population data from the Michigan

Department of Natural Resources (DNR) will also be included, assuming that a final report is released before this report is prepared. If other temperature and biological data are available from state, federal, or local agencies, they will also be summarized and included.

A report outline is provided below.

I. Introduction and Purpose – A brief description about why the assessments were completed and the purpose of the study, i.e., to evaluate the geomorphological impacts of the dam breach and determine if restoration/enhancement efforts are needed.

II. Background—A brief description of the dam removal and stream restoration project, dam breach, and enforcement action.

III. Site Selection –Site selection process, parameters measured, and a map showing the assessment locations.

IV. Study Methods – Data collection and analysis methods, including type of equipment and software (See Appendix 1).

V. Results – Data results from the geomorphic assessment will be organized from upstream to downstream of the former impoundment. The geomorphic assessment results will focus on floodplain connectivity, bed form diversity (depth variability), substrate composition, bed elevation changes (downstream of former dam only, before and after breach), and large woody debris. Photographs and underwater video of bedforms will also be provided. Graphs, depth variability maps, and bed form maps will be provided. Supporting studies of macroinvertebrates, fish, and temperature will be summarized and related to the study.

The Stream Functions Pyramid Framework by Harman et al. (2012)[1] will be used to organize the above parameters into functional categories, e.g., hydraulics, geomorphology, physicochemical, and biology. The parameter is matched to the functional category in Appendix 1. For each parameter, a designation of Functioning, Functioning-At-Risk, or Not Functioning will be determined based on guidance from Harman et al. (2012), data collected from the reference reaches, and best professional judgment. The results will be shown in a table that compares the functionality of the upstream reaches (reference) to the downstream reaches (Impacted Reaches).

VI. Discussion and Recommendations – Discussion about what the above assessment results mean for overall river health and management. Existing restoration/enhancement efforts will be described. A recommendation will be made about the need for further restoration/enhancement efforts in the DEQ identified "Impacted Reach" based on the results of the assessment. The determination will be made by comparing the Functioning, Functioning-At-Risk, and Not Functioning results by parameter of the reference condition to the Impacted Reach condition. The vertical stability surveys, presence of sand, and bed form diversity data will primarily be used to determine if the dam breach caused the differences in functionality to the Impacted Reach. For example, impacts caused by a sudden release of a large quantity of sediment would include bed aggradation, mid-channel

[1] Harman, W, R. Starr, M. Carter, K. Tweedy, M. Clemmons, K. Suggs, C. Miller. 2012. A Function-Based Framework for Stream Assessment and Restoration Projects. US Environmental Protection Agency, Office of Wetlands, Oceans, and Watersheds, Washington, DC. EPA 843-K-12-006.

bar formations, filling of pools with sand, and a reduction in depth variability. If bed aggradation is not quantitatively and qualitatively observed, mid-channel bars are not prevalent, pool depths are maintained with gravel beds, then it is unlikely that the breach caused sediment impacts to the river system that lead to a Functioning-At-Risk or Not Functioning condition. In addition, overall river management recommendations, unrelated to the dam breach, will be provided to show how function-based parameters can be improved from a Not-Functioning or Functioning-At-Risk category to a Functioning category.

Evaluation of Stream Reach through Former Impoundment

The DEQ response letter dated December 23, 2014 requested an assessment of the Impact Reach through the former impoundment. The detailed request was provided in Item A of the letter. Per a phone conference with Sandra Sroonian (Project Manager with AMEC) on January 19th, it is our understanding that AMEC and Inter-fluve completed an as-built survey of the restored channel and are finishing a closeout report showing that the project met the permit conditions. Therefore, further assessments are not proposed as part of this scope of work.

Project Management, Schedule, and Sub-Consultants

Will Harman, PG will serve as the Project Manager and lead investigator for this project. Engineers and scientist from Ecosystem Planning and Restoration will assist with preparing maps, figures, and data analysis. A report will be released for submittal by counsel by March 16, 2015.

Submitted By:

William A Harman

Will Harman, PG
Principal

Appendix 1
2013 Parameters

Metric (Functional Category)	Purpose	Method	Reference
I. 2013 Floodplain Connectivity (Hydraulics)	Evaluate degree of channel incision and entrenchment to determine floodplain inundation frequency and extent.	Methods are shown below for longitudinal profile and cross section. A survey-grade GPS is used to complete the floodplain connectivity and vertical stability measurements. The GPS is tied to local control points and a base station.	
Ia. Longitudinal Profile	Used to calculate vertical incision throughout the reach. Low incision equals good floodplain connectivity.	The bank height ratio (channel depth/bankfull depth) is calculated at each riffle. Adapted from Rosgen (2014)	Rosgen, D. 2014. River Stability Field Guide (Second Edition). Wildland Hydrology, Fort Collins, CO.
Ib. Riffle Cross Section	Used to calculate bankfull dimensions and entrenchment ratio. High entrenchment ratio equals good floodplain connectivity.	The entrenchment ratio (floodprone width/bankfull width) is calculated at the riffle cross section. It is estimated for sites with wide floodplains.	Rosgen, D. 2014. River Stability Field Guide (Second Edition). Wildland Hydrology, Fort Collins, CO.
II. 2013 Vertical Stability (Geomorphology)	Used to determine if the streambed has aggraded or degraded as a result of the dam breach	Methods are shown below for bed elevations and depth of refusal.	
IIa. Bed elevations	Used to measure degradation and aggradation of the stream bed.	The GPS was used to survey thalweg bed points that had been surveyed before the breach. This was surveyed as a stakeout, where the point was located and then resurveyed.	All points based on Michigan Central Geometric Coordinate System.
IIb. Depth of refusal	Used to estimate the depth of "soft" sediments, e.g., sand over gravel.	A steel rod, graduated with 0.1 ft increments was inserted into the bed until it could no longer penetrate the sediments. The depth of penetration was measured at same location as bed elevation survey.	

Appendix 1
2014 Metrics

Metric (Functional Category)	Purpose	Method	Reference
III. 2014 Floodplain Connectivity (Hydraulics)	The 2013 Floodplain Connectivity Measurements were repeated in 2014		
IV. 2014 Vertical Stability (Geomorphology)	The 2013 Vertical Stability Measurements were repeated in 2014		
V. 2014 Bed Form Diversity (Geomorphology)	Used to show channel complexity upstream and downstream of the former impoundment.	A survey-grade GPS or Total Station was used to create a detailed topographic map of the study reach. The GPS is tied to local control points and a base station.	
Va. Bed form mapping	Used to show a plan view map of riffles, pools, point bars, and location of large wood.	Survey-grade GPS or Total Station survey.	
Vb. Depth Variability	Used to show the variability of depth in the study reach.	Transects were created from the topographic map to measure bankfull depths proportionally in the riffles and pools. Box plots and scatter graphs are used to show variability. This method is adapted from Laub et al. (2012)	Laub, B. D. Baker, B. Bledsoe, M. Palmer. 2012. Range of variability of channel complexity in urban, restored, and forested reference streams. Freshwater Biology. 57, 1076-1095.
Vc. Bed Form Video	Used to provide video examples of underwater sand deposits and transport, effects of large woody debris on bed material sorting and pool formation, and visual comparison/support to the bed form mapping measurement method.	A Go Pro was used to video the study reach by walking the channel. Underwater video was taken at sample locations.	

Appendix 1
2014 Metrics

VI. Bed Material Characterization (Geomorphology)	Used to show spatial distribution of riffle and pool bed forms (facies mapping) and the distribution of particle sizes by percent silt, sand, gravel, and cobble at sites upstream and downstream of former impoundment.	Facies mapping and grain size distributions as described below.	
VIa. Facies Mapping	Used to show the aerial distribution of sand and gravel. Used to determine if the thalweg is coarse (gravel).	Shown on the Bed form map. Map shows areas that are dominated by gravel and sand, overlaid with bed forms (riffles, pools, point bars).	
VIb. Grain Size Distributions	Used to compare the percent silt, sand, gravel and cobble between sites upstream and downstream of the former impoundment. Used to determine if sand is common throughout the watershed.	Wolman pebble count procedure, stratified by riffle, pool, and point bar.	Bunte, K. and S. Abt. 2001. Sampling Surface and Subsurface Particle-Size Distributions in Wadable Gravel- and Cobble-Bed Streams for Analyses in Sediment Transport, Hydraulics, and Streambed Monitoring. USDA Forest Service, Rocky Mountain Research Station. GTR-RMRS-GTR-74.
VII. Large Woody Debris (Geomorphology)	Used to evaluate the differences in the amount and location of large wood upstream and downstream of the former impoundment.	Large Woody Debris Index	Davis, Jeffrey, G. Mishall, C. Robinsion, P. Landres. 2001. Monitoring Wilderness Stream Ecosystems. USDA Forest Service, Rocky Mountain Research Station. GTR-RMRS-GTR-70.

STATE OF MICHIGAN
DEPARTMENT OF ENVIRONMENTAL QUALITY
LANSING

RICK SNYDER
GOVERNOR

DAN WYANT
DIRECTOR

January 29, 2015

VIA E-MAIL

Mr. Jered Ottenwess, City Manager
City of Traverse City
400 Boardman Avenue
Traverse City, Michigan 49684

Dear Mr. Ottenwess:

SUBJECT: Revised Scope of Work for Boardman River Assessment Report

On January 20, 2015, Mr. Richard Baron, provided a "Boardman River Assessment Report Scope of Work January 19, 2015" (the Scope of Work) to me, via e-mail. Department of Environmental Quality (DEQ), Water Resources Division (WRD) staff reviewed the revised Scope of Work, as prepared by Mr. Will Harmon of Stream Mechanics, to determine whether the revised Scope of Work now meets the intent of the requirement set forth within Paragraph 3.1 of the draft Administrative Consent Order (ACO) shared with the City of Traverse City (City) in August 2014 through the incorporation of comments provided by the WRD in a letter dated December 23, 2014.

The WRD accepts the January 19, 2015, revised Scope of Work as meeting the intent of the draft ACO and looks forward to reviewing the report, which should be submitted not later than March 20, 2015. We also await comments from Mr. Baron on the draft ACO.

Despite our acceptance, two concerns with the revised Scope of Work should be noted by the City and acknowledged within the report:

1. Recommendations on the need for further restoration/enhancement efforts within the Impacted Reach should also include implementation schedules for any recommended activities.
2. We are unsure of the City's intentions for the inclusion of "overall river management recommendations, unrelated to the dam breach," but are willing to review Mr. Harmon's conclusions.

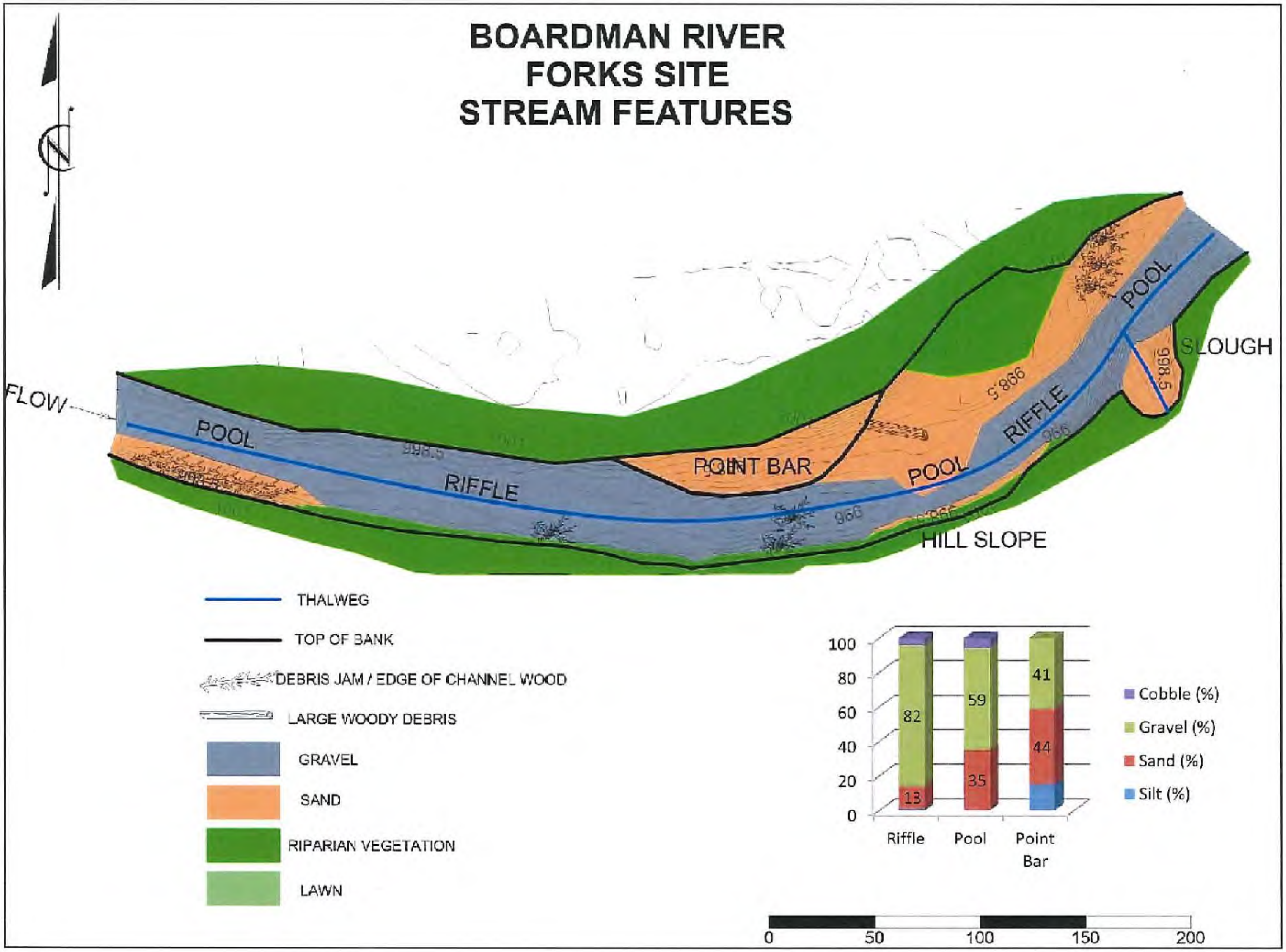
If you have any questions, please contact me at 517-256-1280; zachardan@michigan.gov; or DEQ, P.O. Box 30458, Lansing, Michigan 48909-7958.

Sincerely,

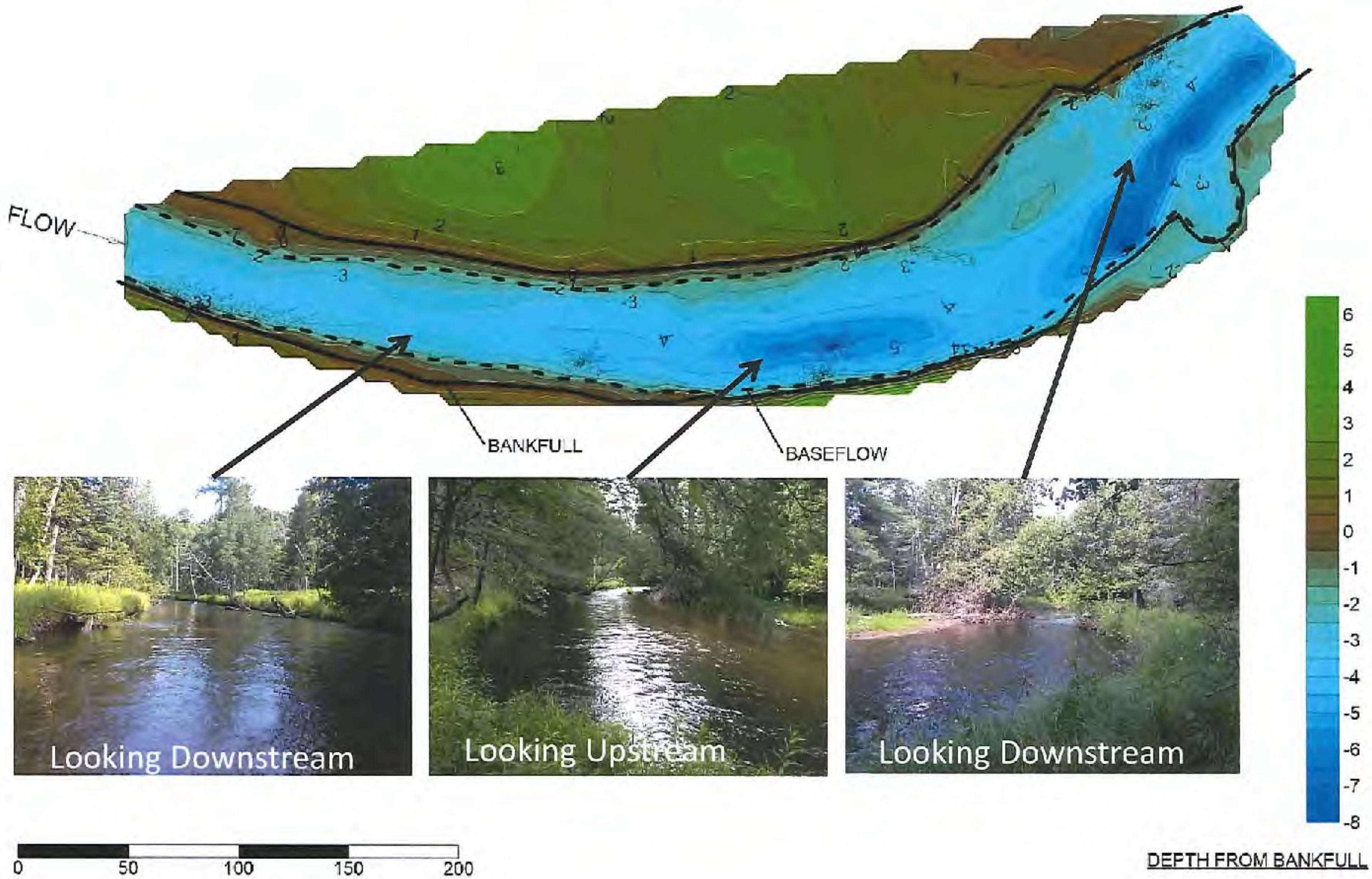
Nicole M. Zacharda, Enforcement Specialist
Water Enforcement Unit
Water Resources Division

cc: Ms. Lauren Trible-Laucht, City of Traverse City
Mr. Richard Baron, Foley, Baron, Metzger & Juip, PLLC
Mr. Neil Gordon, Department of Attorney General
Mr. Mike Masterson, DEQ
Mr. William Larsen, DEQ
Mr. Brian Jankowski, DEQ
Mr. Ralph Reznick, DEQ

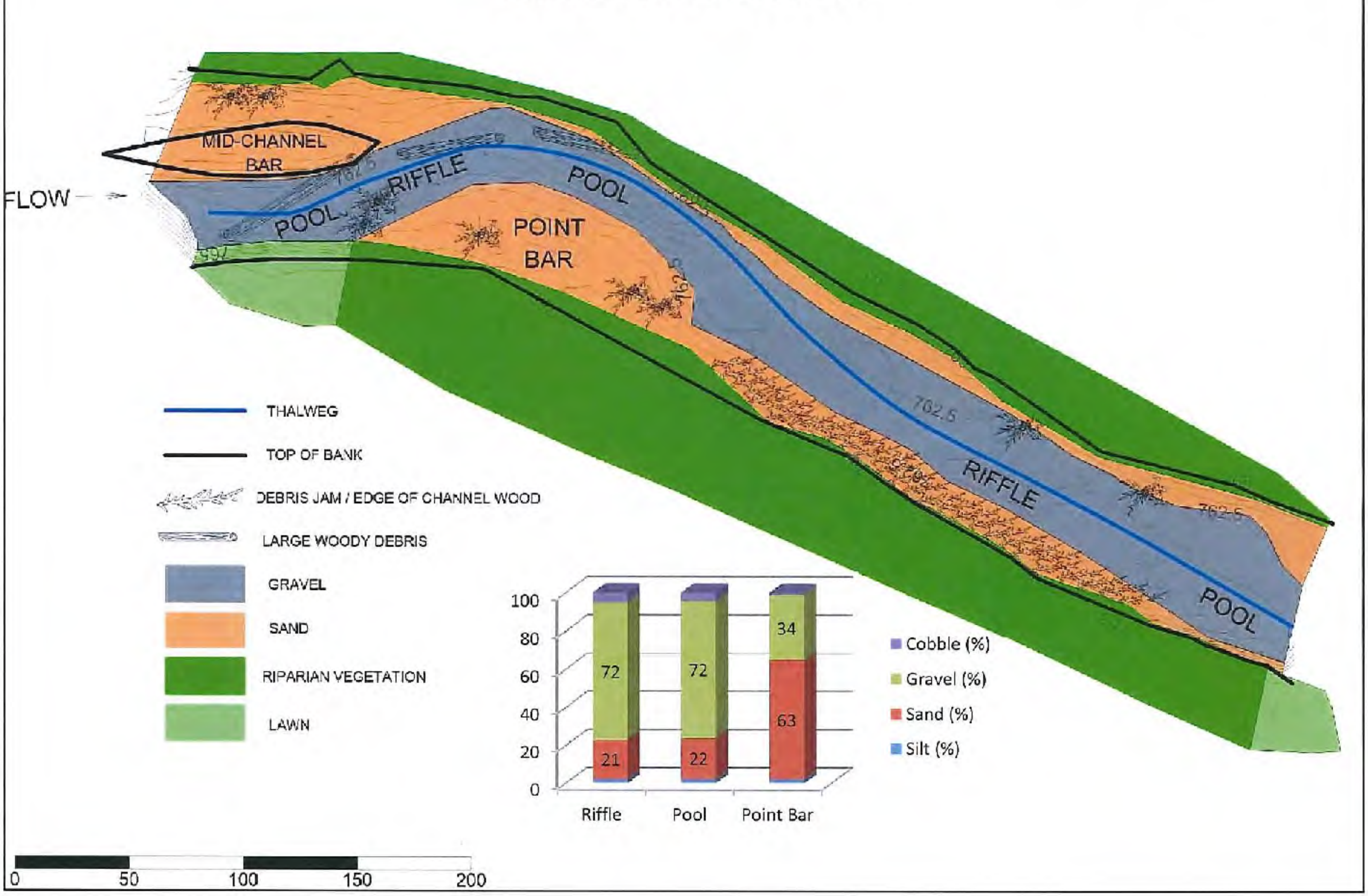
Appendix 2
Steam Feature Maps and Grain Size Distributions for Riffles and Pools


BOARDMAN RIVER
FORKS SITE
STREAM FEATURES
FLOW
POOL
RIFFLE
POINT BAR
POOL
RIFFLE
POOL
SLOUGH
HILL SLOPE
998.5
996
THALWEG
TOP OF BANK
DEBRIS JAM / EDGE OF CHANNEL WOOD
LARGE WOODY DEBRIS
GRAVEL
SAND
RIPARIAN VEGETATION
LAWN
Cobble (%)
Gravel (%)
Sand (%)
Silt (%)
Riffle
Pool
Point Bar
82
13
59
35
41
44
0 20 40 60 80 100
0 50 100 150 200

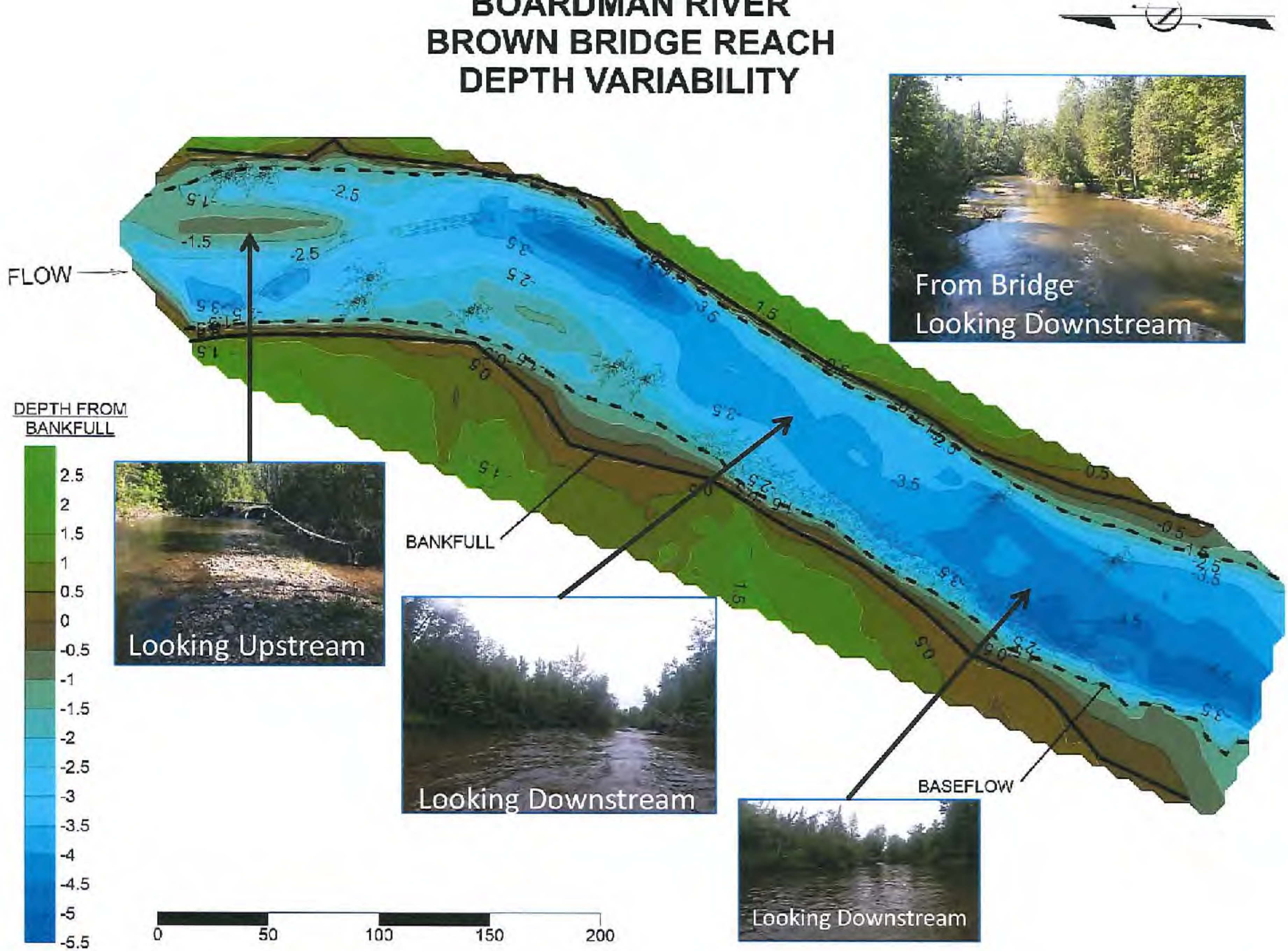
BOARDMAN RIVER
FORKS SITE
DEPTH VARIABILITY

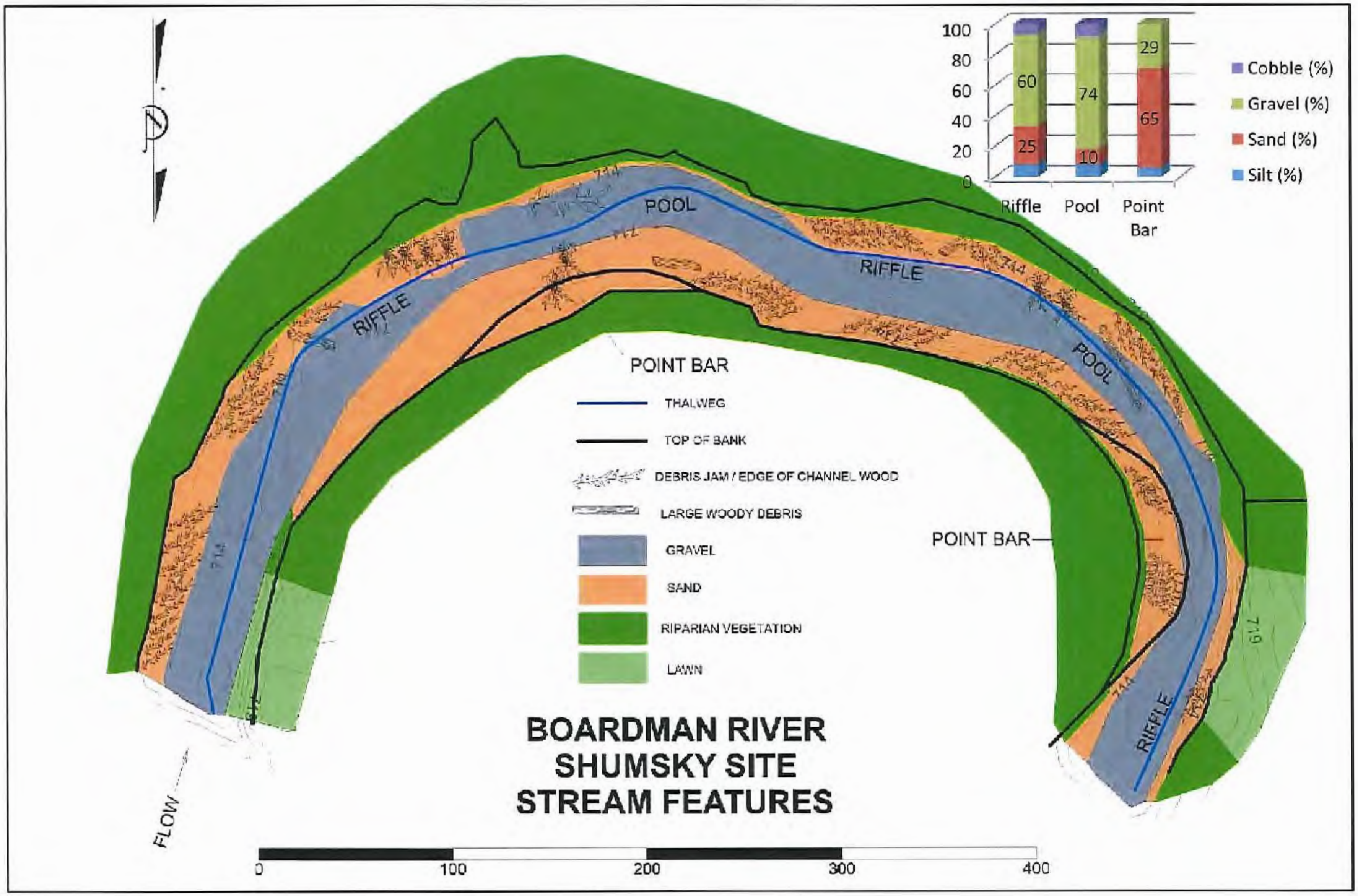


BOARDMAN RIVER
BROWN BRIDGE REACH
STREAM FEATURES

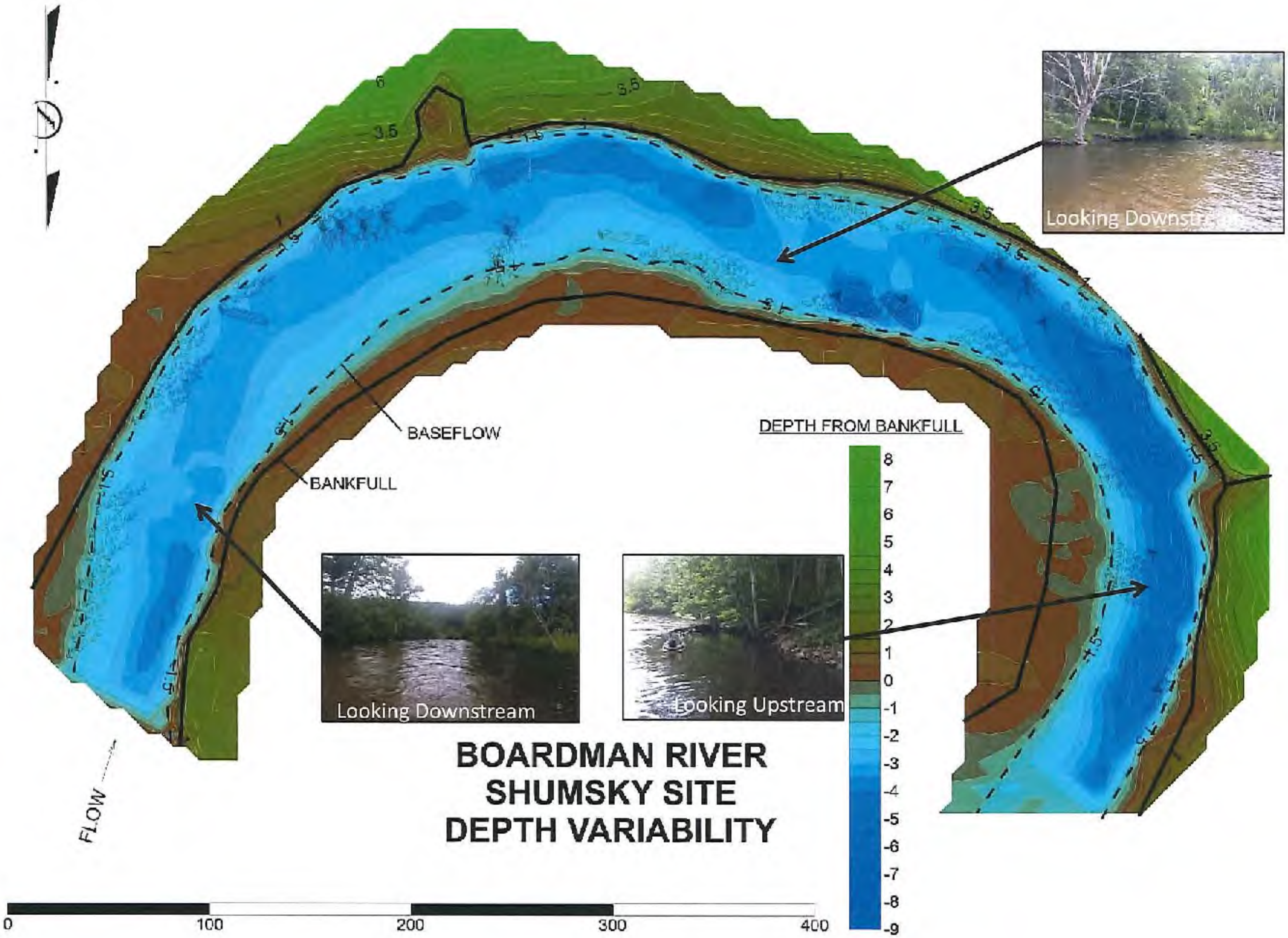


BOARDMAN RIVER
BROWN BRIDGE REACH
DEPTH VARIABILITY



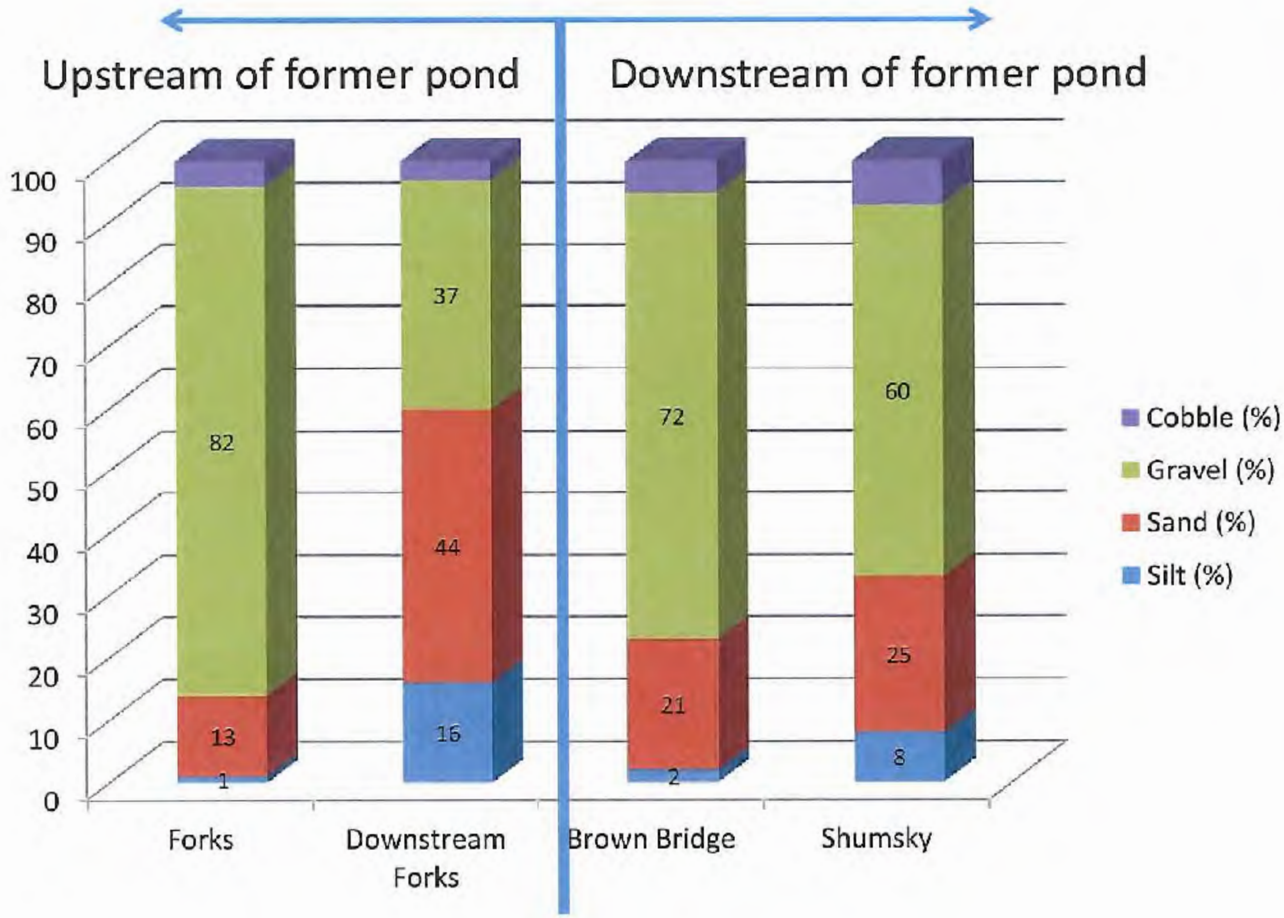


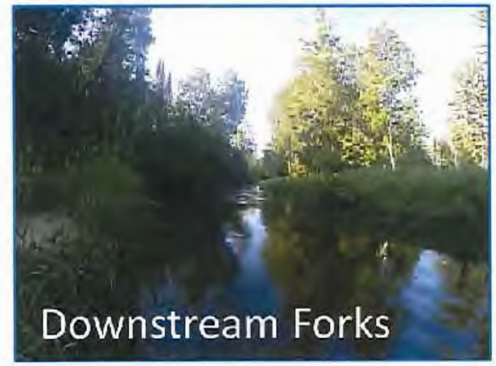
100
80
60
40
20
0
60
25
74
10
29
65
Riffle
Pool
Point Bar
Cobble (%)
Gravel (%)
Sand (%)
Silt (%)
POOL
RIFFLE
RIFFLE
POOL
POINT BAR
POINT BAR
RIFFLE
THALWEG
TOP OF BANK
DEBRIS JAM / EDGE OF CHANNEL WOOD
LARGE WOODY DEBRIS
GRAVEL
SAND
RIPARIAN VEGETATION
LAWN
BOARDMAN RIVER
SHUMSKY SITE
STREAM FEATURES
FLOW
0
100
200
300
400

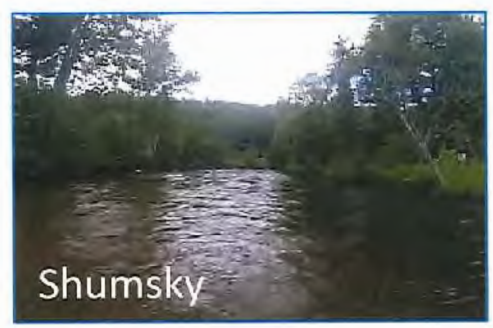


BOARDMAN RIVER
SHUMSKY SITE
DEPTH VARIABILITY

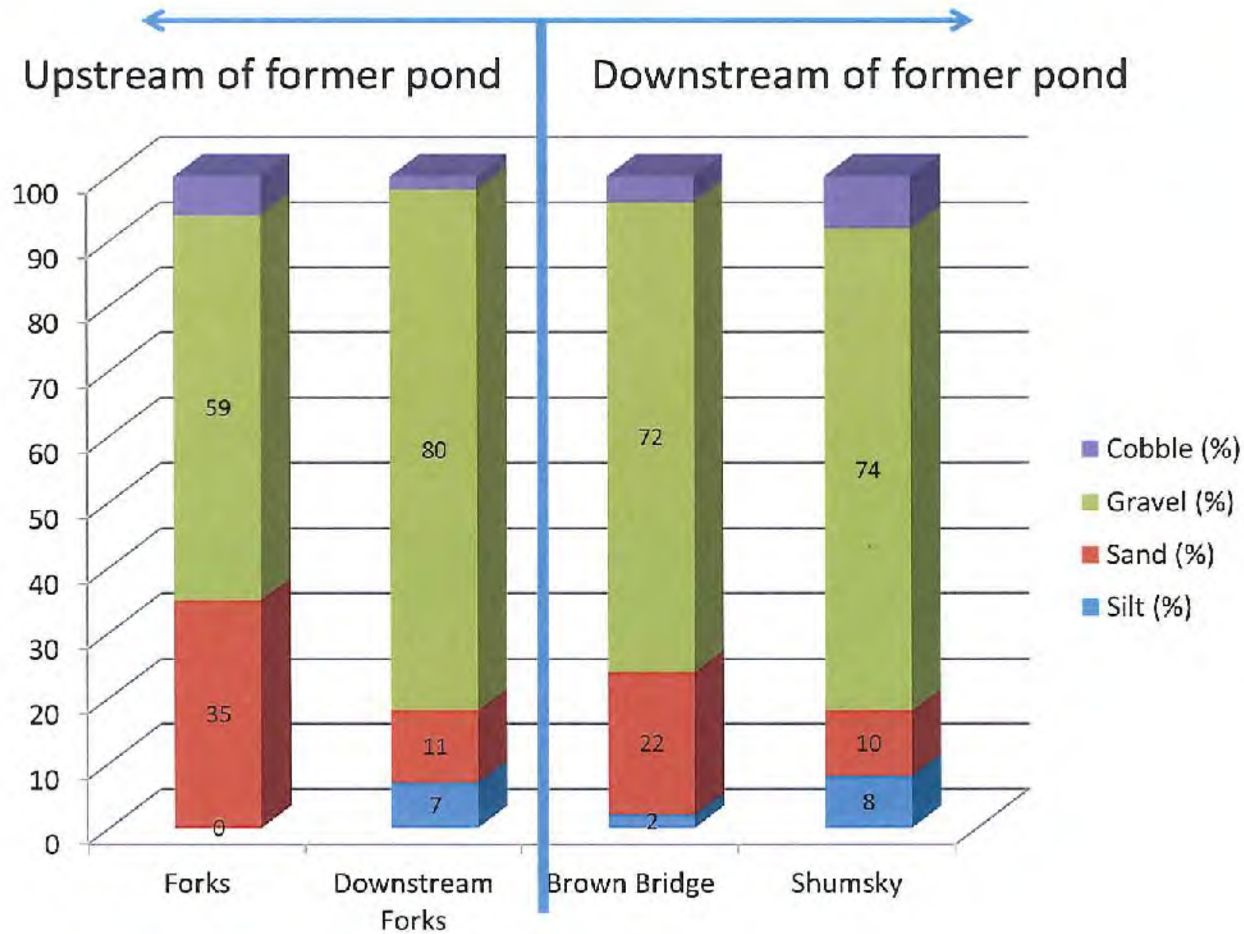
Riffle
Bed Material Composition

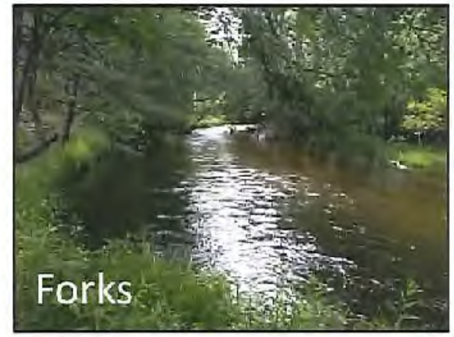


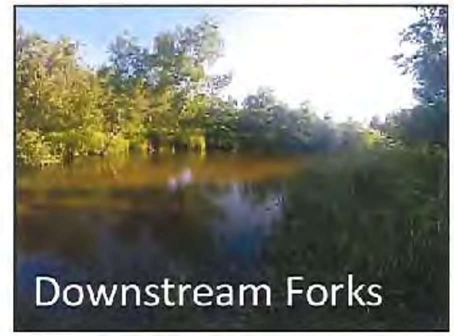




Pool
Bed Material Composition







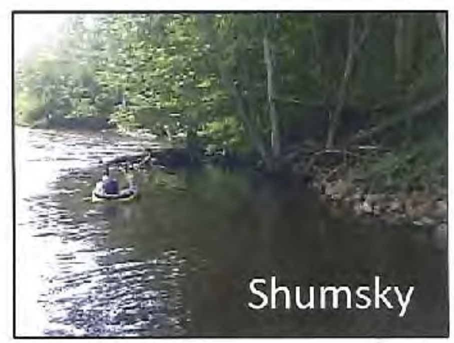


Exhibit C

AeM ADVANCED ECOLOGICAL MANAGEMENT

22071 7 Mile Road
Reed City, MI 49677
Office: 231.832.3200
Mobile: 231.912.0506

To: Richard Baron; Foley, Baron, Metzger & Juip, PLLC

From: Doug Workman

Date: June 16, 2015

Re: Proposal – Board River Procedure 51

Dear Mr. Baron:

Thank you for the opportunity for Advanced Ecological Management, LLC (AEM), to submit the following proposal for professional services regarding Procedure No. WRD-SWAS-051, Qualitative Biological and Habitat Survey Protocols for Wadeable Streams and Rivers (Procedure 51). It is AEM's understanding that a P-51 survey is required within the reach of the Boardman River that was impacted by the failure of the temporary dewatering structure and within a suitable reference reach that was not impacted by the failure to monitor trends in fish, benthic macroinvertebrates, and stream habitat.

BASIC SERVICES

AEM is proposing to conduct a P-51 in one 1,000 foot-long survey station within the Impacted Reach and one 1,000 foot-long survey station to represent a reference reach of the Boardman River. The extent of the Impacted Reach survey would begin immediately downstream of Brown Bridge and continue downstream for 1,000 feet (Figure 1). The reference reach is proposed to be located approximately 3.6 miles upstream of the Impacted Reach survey station and would begin at the Brown Bridge Road crossing and continue downstream for 1,000 feet (Figure 1).

Fish

P-51 Surveys involve collection of fish, benthic macroinvertebrates, and habitat data. Fish surveys are typically conducted first and are conducted in an upstream direction beginning at the downstream extent of the survey reach. Fish collection is expected to involve deploying electricity into the water where fish will be temporarily stunned, and subsequently collected via dip nets and placed into temporary holding tanks. Because of the larger size of the Boardman River (stream width ranging from approximately 40 to 68 feet within the Impacted Reach), a backpack electroshocker cannot generate a large enough electrical field to adequately capture fish and is not an appropriate device to use in this portion of the river system. AEM intends to use a tote-barge electroshocker to collect the fish and will temporarily keep all collected fish in tubs filled with aerated water. Following collection, AEM will identify each fish, collect length and weight data, and release each fish back into the river following identification and enumeration. AEM anticipates a crew of four persons to operate the tote-barge electroshocker, and one of the crew persons will possess a valid State of Michigan Scientific Collector's Permit to conduct the electrofishing portion of the survey.

Macroinvertebrates

Sampling of aquatic macroinvertebrates, including mussels and crayfish (Decapoda), will be conducted following the electrofishing survey according to the P-51 protocol. Macroinvertebrates will be collected within each survey station using D-framed kick-nets. Survey stations will be sampled for 45 minutes using two kick-nets (total sample time = 1.5 hours) and samples will be collected in all habitat types within each station to characterize the macroinvertebrate community. Consistent with P-51 protocol, AEM will attempt to collect a total of 300 +/- 60 organisms. Collected specimens will be stored in 250 ml plastic wide-mouth jars containing 70% ethanol, and will be identified to the lowest possible taxonomic level that is consistent with Appendix H of the P-51 protocol.

Habitat

Riparian and in-stream habitats will be qualitatively described for each survey station. A description of stream morphology including run/riffle/pool/shallow pool configurations, substrate, substrate embeddedness, in-stream cover, vegetation, flow stability, and bank stability will be completed during the P-51. Stream habitat will be rated as excellent, good, marginal, or poor based on P-51 scores interpreted from 10 habitat metrics.

Habitat conditions, water quality, and stream dimensions will also be documented during the aquatic survey. Photographs will be collected at each station to illustrate the conditions during the sampling period. Because water quality is an important component of aquatic habitat, water temperature, dissolved oxygen, pH, and conductivity will be measured as part of the stream habitat evaluation. These water quality parameters will be measured using a Yellow Springs Instrument Professional Plus water quality meter.

Report

Following data collection, AEM will prepare a report describing the fish and macroinvertebrate communities, and provide a description of the stream habitat conditions within the survey stations at the time of the survey. AEM will also interpret the P-51 metrics according the P-51 methodology and provide ratings for fish, macroinvertebrates, and habitat based on survey data.

AEM understands that the Michigan Department of Environmental Quality (MDEQ) has requested the report by October 1 for review. To comply with MDEQ requirements, AEM would complete the draft report for client review by September 1 to allow for edits prior to report submittal to the MDEQ.

This work described in this proposal would be conducted once during 2015 and repeated once again in 2016 and 2017. AEM would attempt to conduct the survey at similar times each year in an attempt to maintain data comparability among years.

To summarize, the project deliverables are as follows:

- Conduct a P-51 survey in two 1,000-foot survey stations within the Boardman River.
    - Fish will be surveyed using a tote-barge electroshocker.
    - Aquatic macroinvertebrates will be collected immediately following the fish survey.
    - Collect habitat data according to P-51 metrics and collect additional supplemental habitat data as previously described.
- Provide a report describing survey findings and P-51 ratings.

Please contact me if you have any questions or concerns regarding the proposal.

Sincerely,

R. Douglas Workman
Advanced Ecological Management

Figure 1. Boardman River proposed Procedure 51 survey locations.

Exhibit D

Exhibit D

Supplemental Environmental Project

Boardman River Bank Stabilization and Floodplain Reconnection

Project Description

This project will occur along a reach of the Boardman River that extends approximately 1200-feet upstream from the former impoundment of the Brown Bridge Dam. The project involves stabilizing steep river banks and restoring the connection between the river and its floodplain. More specifically, the project involves (1) reducing the height of the river banks to bankfull-stage elevation; (2) constructing bankfull benches that extend 20 to 25-feet from the banks; and (3) constructing and vegetating the banks, benches, terrace slopes and terraces.

Bank stabilization is expected to reduce erosion into the Boardman River, resulting in decreased sedimentation and habitat improvement. Restoring floodplain connectivity is expected to improve flood and erosion control and reduce bank erosion. In addition, planting of native vegetation is expected to improve habitat and the aesthetics of the river corridor.

Project Reach and Existing Conditions

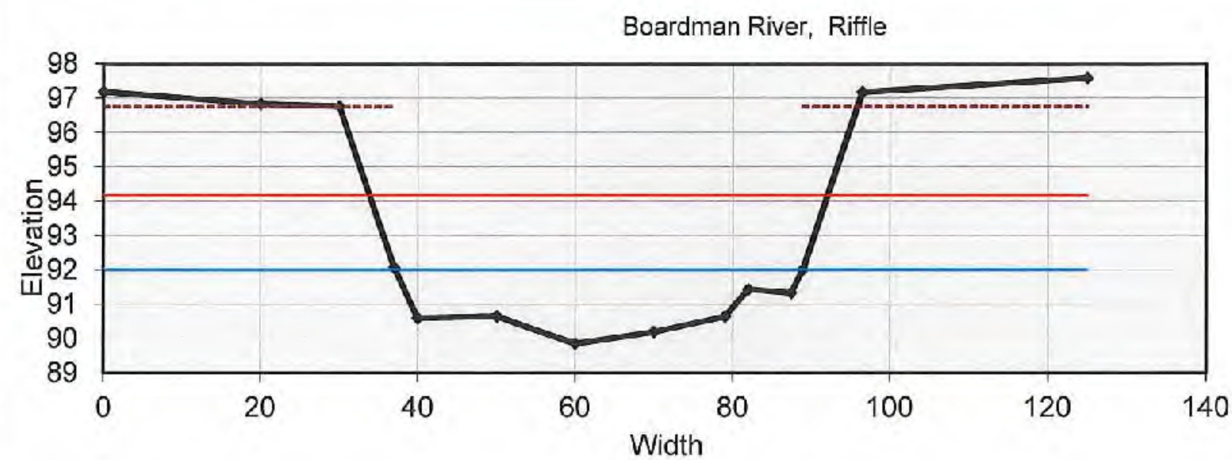
The project reach starts at the upstream terminus of the former impoundment and extends approximately 1200 feet upstream. Figure 1 shows the approximate location and limits of the project reach. The cross sections (SEP XSec1 and SEP XSec2) were surveyed by the Grand Traverse Band of

Figure 1: Project Reach

Ottawa and Chippewa Indians, Natural Resources Department (Tribe). The float visit stop shows where the Tribe staff stopped with DEQ staff on a float trip in the summer of 2015.

Cross sections 1 and 2 are provided below in Figures 2 and 3. The blue line represents the bankfull stage, the red line is the floodprone area width, and the dotted line is the low bank elevation. The bankfull and flood dimensions are shown below the graphs. The cross sections show that this reach is incised (bank height ratios of 3.2 and 2.7) and entrenched (entrenchment ratio of 1.1 for both cross sections). The Rosgen Stream Type is an unstable F4 channel. Using the Stream Functions Pyramid Framework, this reach would score a "Not Functioning" for floodplain connectivity.

Figure 2: Cross Section 1



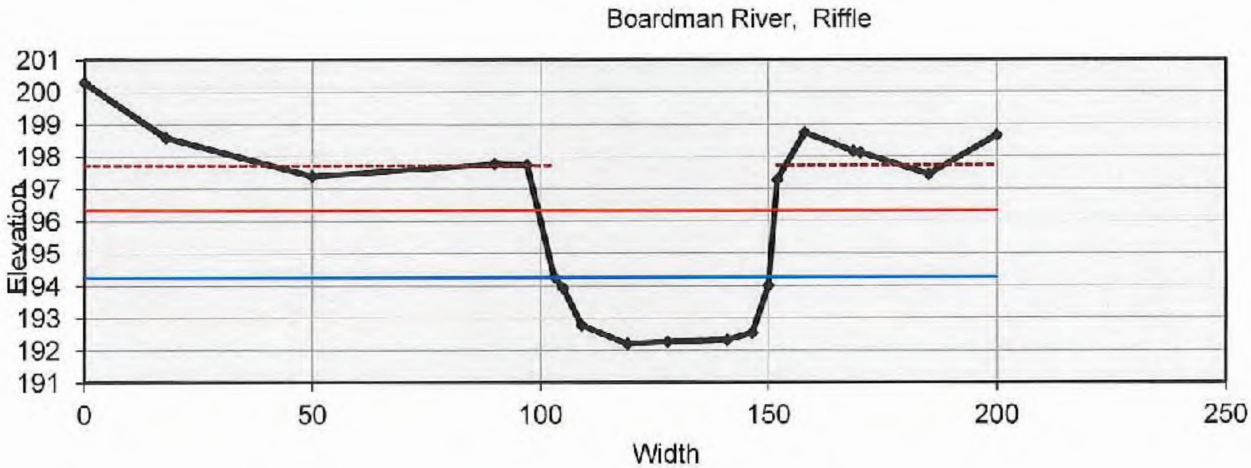
Bankfull Dimensions	
74.7	x-section area (ft.sq.)
51.9	width (ft)
1.4	mean depth (ft)
2.2	max depth (ft)
52.5	wetted parimeter (ft)
1.4	hyd radi (ft)
36.1	width-depth ratio

Flood Dimensions	
58.3	W flood prone area (ft)
1.1	entrenchment ratio
6.9	low bank height (ft)
3.2	low bank height ratio

Materials	
---	D50 (mm)
---	D84 (mm)
---	threshold grain size (mm):

Photographs taken along the project reach are shown in Figure 4. Bank erosion is prevalent along both sides of the channel, which is very common when streams are disconnected from their floodplain, e.g., as shown with the high bank height ratio. This condition is prevalent throughout the project reach and it is unlikely that the banks will stabilize on their own in a short period of time.

Figure 3: Cross Section 2.



Bankfull Dimensions		Flood Dimensions		Materials	
79.7	x-section area (ft.sq.)	52.0	W flood prone area (ft)	---	D50 (mm)
47.2	width (ft)	1.1	entrenchment ratio	---	D84 (mm)
1.7	mean depth (ft)	5.5	low bank height (ft)	---	threshold grain size (mm):
2.1	max depth (ft)	2.7	low bank height ratio		
47.8	wetted parimeter (ft)				
1.7	hyd radi (ft)				
27.9	width-depth ratio				

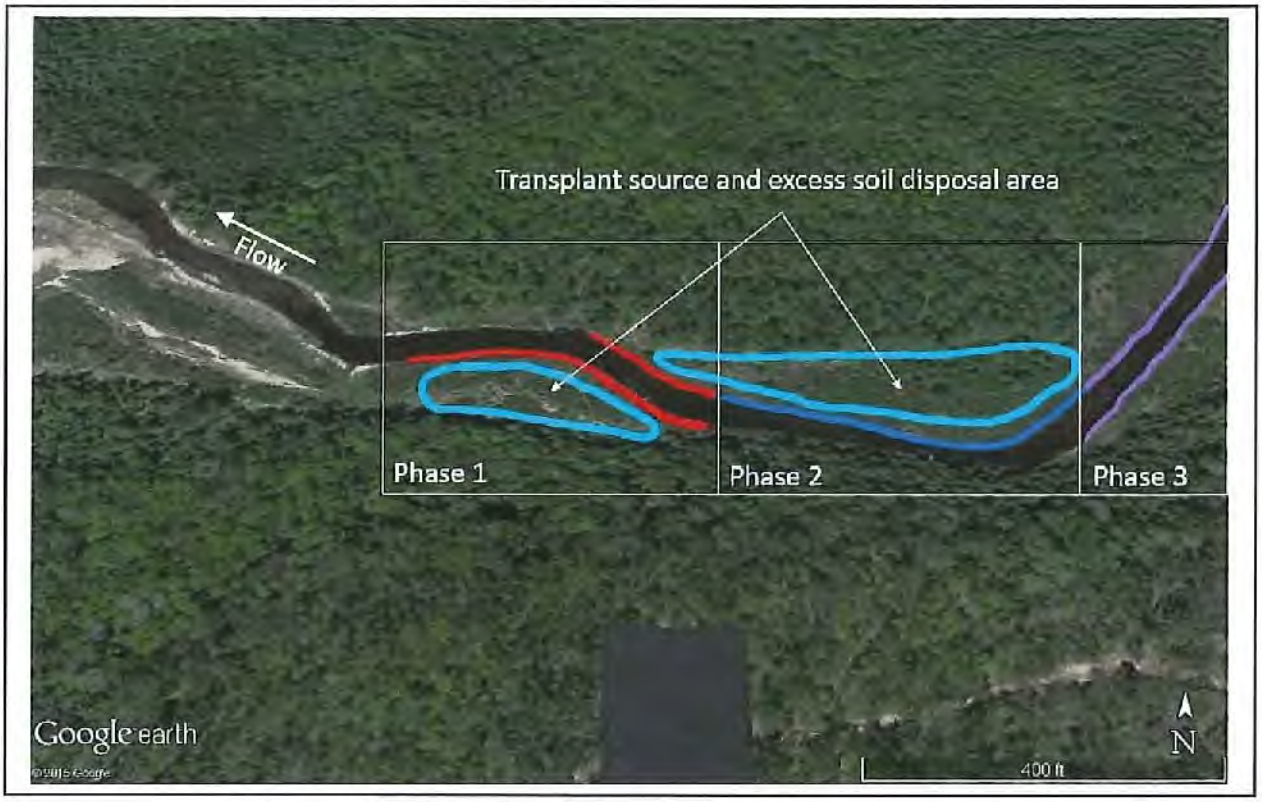
Figure 4: Photos of Project Reach

Design and Construction

Design Approach

A conceptual design is provided below in Figures 5 and 6. Figure 5 shows three phases of construction. Phase 1 is the downstream most reach and will be completed first. A bankfull bench will be constructed along the approximate length of the red lines. A typical design cross section is provided in Figure 6. The purpose of the bankfull bench is to reduce streambank

Figure 5: Project Reach and Phases of Construction

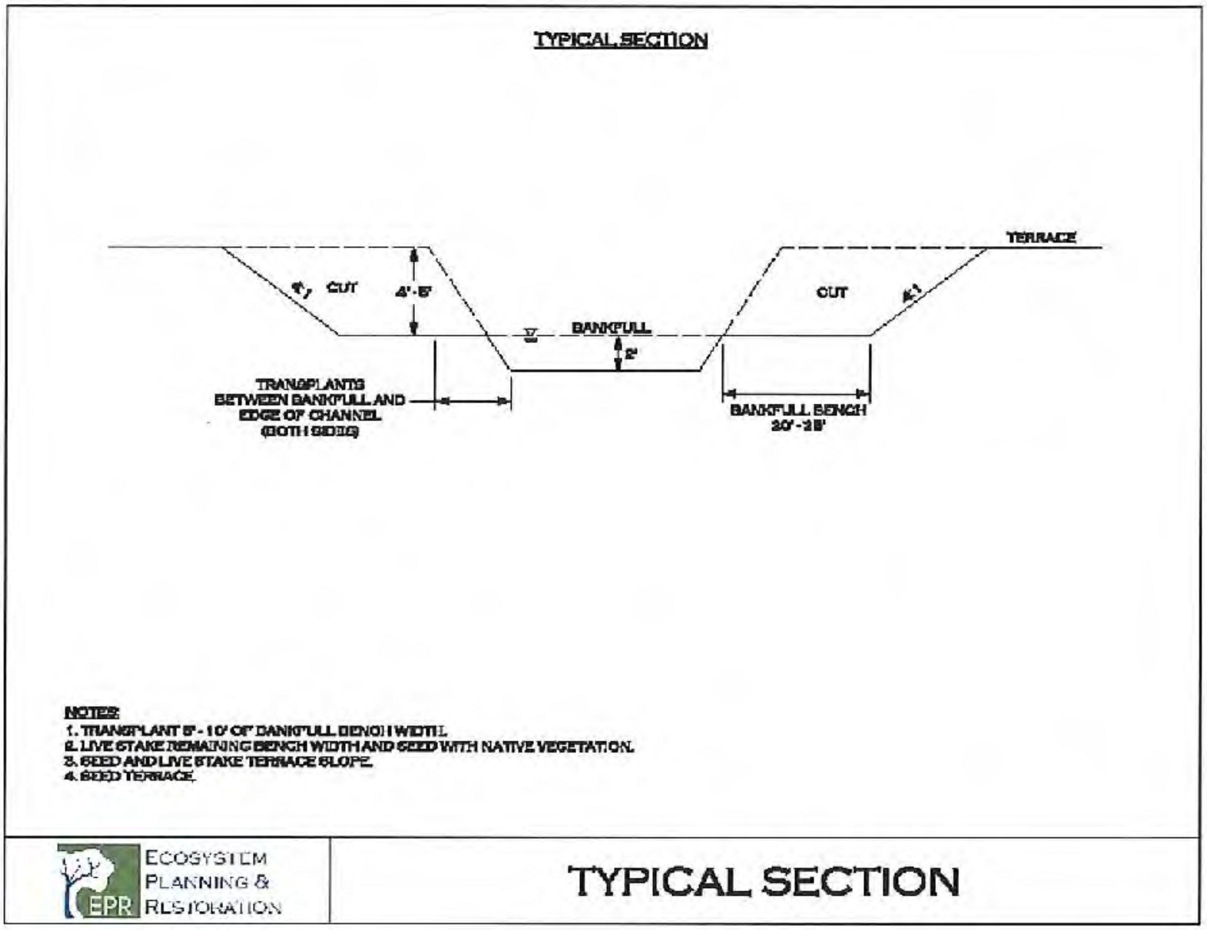


heights and increase the width of the active floodplain. Transplanted vegetation will be removed from source areas and used to stabilize the streambanks and a portion of the bankfull bench as shown in Figure 6. Live stakes and native seed will be used to stabilize the remainder of the bankfull bench and terrace slope. Excavated material from the banks and bankfull bench will be placed on the terrace where transplants were removed and the area re-seeded and planted with native vegetation.

Currently, a portion of the right bank in Phase 1 (looking downstream) is not proposed for treatment (no red line). This portion is close to the hillslope making it difficult for equipment to work from the bank. Excavated material might have to be transported across the channel to the disposal area. This section will be re-assessed before construction starts. If it is determined that the banks are unstable and construction is easier than expected, the section will be added to the project.

After Phase 1 has been completely stabilized, including the banks, bankfull bench, and terrace, work in Phase 2 will begin. Since funding is limited and there is uncertainty about how much stream length can be treated, completing one phase before starting another will prevent the project from running out of funds before work has been stabilized. Phase 2 will start at the downstream end and progress upstream.

Figure 6 shows a typical cross section of the design approach.



The left streambank of Phase 2 is almost against the existing hillslope and has large woody debris along the toe of the bank. No work is proposed for this section of Phase 2 because lateral migration will be prevented by the hillslope. In addition, woody debris along the toe is providing aquatic habitat and some toe stability. However, the entire right bank (blue line on Figure 5) will be re-graded and transplanted using the same methods as Phase 1.

It is unlikely that funds will be sufficient to start Phase 3. However, if funds are available, the same approach used in Phases 1 and 2 will be applied to Phase 3. Transplants from Phase 2 will be used for as long as supplies last. If needed, new transplant source areas and soil disposal areas will be located along the Phase 3 terrace.

Construction Approach

Construction access is limited and equipment must be tracked in from the former Brown Bridge Pond Stream Stabilization Project. An existing construction access road can be used or a portion of the distance through the former Stabilization project. Once the road ends, equipment will need to track upstream within the channel to reach the project site. This method will prevent construction equipment from damaging the recently planted floodplain vegetation. Once equipment reaches the project site, most of the work will be completed from the streambank.

The general construction sequence includes the following steps for each reach.

1. Excavate existing streambank material from the edge of channel to top of bank and away from the channel for a distance of five to ten feet. A track hoe will be used to excavate this material.
2. Remove transplants from source area using another track hoe and off-road dump or a wheel-loader (most likely will use a wheel-loader). Re-build streambank with transplants as shown in Figure 7 up to the bankfull stage. This will also create a portion of the bankfull bench.
3. Excavate the remainder of the bankfull bench with widths varying from 20 to 25 feet in most places. Bench width will taper to meet untreated reaches and may be narrower in some places to save larger trees or to blend with existing landscape.
4. Live stake the remainder of the bankfull bench and terrace slope. Seed with native herbaceous cover. Note, live stakes may be done at a later time with volunteers.
5. Dispose of excess soil material along terrace and as close to hillslope (away from channel) as is feasible. Once grading is completed, seed all disturbed areas before moving to next phase.

Permitting

A Joint Permit Application, including the relevant permit application fees, will be submitted to the DEQ to obtain the applicable authorizations for this project. Site specific plans and details will be developed and included with the Joint Permit Application. All other applicable local authorizations, including a sediment and soil erosion control permit, will be obtained.

Schedule

The Joint Permit Application will be submitted to the DEQ within 90 days after the effective date of Administrative Consent Order ACO-000235, to which this Exhibit D is attached. The project will be completed by December 31, 2016.