# Making Up for Losses: A Critical Analysis of Section 404 Compensatory Stream Mitigation Banking in Illinois

## SUMMARY REPORT

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### 1. PROBLEM AND RESEARCH OBJECTIVES

**Statement of Critical State Water Problem:** Illinois faces historically and geographically differentiated water quality impacts. Urbanization threatens water quality in the greater-Chicago region (Wilson and Weng 2011), widespread, intensive agriculture and tile drainage in East-Central Illinois has dramatically altered water quality as far away as the Gulf of Mexico (David et al. 2010), and coal mining poses unique challenges to water quality protection in southern Illinois (Kravits and Crelling 1981). Additionally, widespread channelization and ditching of agricultural streams is associated with conversion of wetland and prairie to farmland (Hergert 1978; McCorvie and Lant 1993), and these impacts are irreversible by natural processes alone (Urban and Rhoads 2003). While in 1820 there were 22 million acres of prairie in Illinois, this total plunged to a mere 2,300 acres by 1978 (IDNR). Thus, significant historical and contemporary land use dynamics in Illinois have degraded water quality.

Compensatory stream mitigation represents a potential means to overcome these historical and contemporary threats to water quality. The 2008 Compensatory Mitigation Rule, developed under Clean Water Act Section 404, requires that permitted unavoidable impacts to surface water are off-set by purchasing mitigation credits (Hough and Robertson 2009). Mitigation credits are produced at a mitigation bank; a segment of a stream that is restored, enhanced, or conserved to provide ecological benefit according to crediting criteria (Lave et al. 2008). Credits represent commensurable ecological value between the site of impact and site of mitigation; the goal is to achieve No Net Loss of ecological function nationally (Hough and Robertson 2009). All mitigation projects are subject to review by individual Corps[1] districts, and each of the four Corps districts in Illinois has independent crediting authority (Doyle et al. 2013). This has led to inconsistencies in crediting and credit pricing among Corps districts. Thus Corps districts in Illinois are developing a single statewide crediting guideline. The current protocol, the Illinois Stream Mitigation Method (ISMM), was published in 2010. The St. Louis Corps has organized a 24-member working group of state and federal regulators and scientists to improve the ISMM's ability to off-set losses.

The problem that Illinois faces is to come up with a way to measure "stream credits" to mitigate adverse stream impacts. The problem is twofold: 1) regulators must develop a protocol for measuring stream credits, and 2) off-sets must be ecologically comparable to impact sites (Lave et al. 2008). Addressing this problem requires attention to both social and biophysical theories. Socially, the problem is to develop a new system of measure by articulating different knowledge domains (i.e. law, economics, and science) (Espeland and Stevens 1998; Robertson 2006). Biophysically, the problem is to use ecological and stream restoration techniques at the

[1] Corps of Engineers

reach-scale to provide a comparable amount of ecosystem function to that lost elsewhere (McDonald et al. 2004; Palmer 2009; Doyle and Shields 2012). It is therefore important to determine a) if mitigation off-sets losses, and b) whether constraints to successful mitigation are ecological, political-economic, or both.

**Statement of Expected Results and Benefits:** There are two expected results from this study. First, this study will be the first of its kind to research the decision making process that occurs in developing stream mitigation credit criteria. Previous research that has traced market development in wetlands (Robertson 2004), greenhouse gases (MacKenzie 2009), and carbon crediting (McAfee and Shapiro 2010) shows the importance of this type of work. It is in the creation of the crediting protocol itself that environmental knowledge and values influence landscape outcomes. Second, this research will also be the first to directly compare the kinds of ecological functions lost at adverse impact sites with ecological functions supposedly provided by stream mitigation banks. The benefit of this study is that it will provide insight into the effectiveness of policy articulation: from the stage of policy interpretation through the stages of policy implementation and monitoring. Such a perspective will demonstrate the importance of conceptualizing environmental policy in a way that recognizes the simultaneity and inter-play, of and between, social and biophysical processes (Lave et al. 2014).

**Nature, scope and objectives of the project:** This project combines social and biophysical research. The scope of this project is the *process of compensatory stream mitigation banking in Illinois.* This research will follow the development of the crediting protocol, implementation of this protocol to assign stream credit values, and analyze the building and outcome of a stream mitigation bank. The objectives of this project are to 1) explain how adverse impacts to a stream in one location are commensurated with off-sets to a stream elsewhere, and 2) to assess, through direct biophysical comparison, if mitigation off-sets losses. The overall research question that this project addresses therefore is: *What is the translational process by which Section 404 impacts are deemed commensurate with Section 404 mitigation activities?* To answer the overall research question I will answer four sub-questions by drawing upon qualitative and quantitative methods in both the social and biophysical sciences:

**1)** How are (and what types of) ecological and geomorphic science included into the ISMM?
**2)** How do mitigation bankers decide on the location, size, and type of bank that they build?
**3)** How do regulators decide the number of stream credits lost or gained while using the ISMM?
**4)** Are the ecological functions lost at adverse impact sites off-set by mitigation at a stream mitigation bank? If so, over what temporal and spatial scales? If not, why not?

## 2. METHODOLOGY

**Social data, methods and analysis:** Questions 1, 2, and 3 will be answered using a mixed-methods approach (Ho 2009). The student researcher has IRB approval and has been granted permission by the St. Louis Corps to participate in field application of ISMM to assess the value of sites in terms of stream credits. The student researcher originally planned to also participate in discussions regarding the development of the Illinois Stream Mitigation Method. However, since the Illinois Stream Team has not met recently, the student researcher relied on secondary documents that recorded meeting procedures and discussions as well as interviews with participants of discussions. Additionally, the student researcher includes interviews with the Missouri stream assessment team members and review of the Missouri mitigation method for two reasons. First, the Illinois stream assessment team borrows the Missouri method, and therefore it is necessary to understand what decisions went into making the Missouri method to more fully capture the ecological and geomorphic science that is included in the Illinois method. Second, the student researcher includes the Missouri team to increase the sample size and to verify references that are made to the Missouri method by Illinois team members.

**Question 1)** How are (and what types of) ecological and geomorphic science included into the ISMM?

This question is answered using three methods: Semi-structured open-ended interviews, reviews of notes and correspondence during method development, and review of drafts to successive versions of the Illinois and Missouri stream mitigation methods. Semi-structured open-ended interviewing was used to question individuals involved in creating the crediting protocol about major assumptions of the protocol, the strengths and weaknesses of the protocol, what they would change about the protocol, and if they believe the protocol enables the off-setting of adverse impacts to streams. These data provide insight into individual differences of opinion and determine who has authority and ability to influence what kind of information is included in the crediting protocol. Interviews are supplemented with a review of notes taken during group meetings during method development and reviews of successive changes made to the Illinois and Missouri mitigation methods. By comparing changes made to the mitigation methods with details of discussions and debates during method creation it will be possible to further understand what constrains and enables the inclusion of best-available ecological and geomorphic science into the mitigation methods. Furthermore, reviews of successive drafts of the Illinois and Missouri methods provides evidence for the types of scientific information and data that are considered relevant when developing the Illinois and Missouri stream mitigation methods.

**Question 2)** How do mitigation bankers decide on the location, size, and type of bank that they build?

This question will be answered using semi-structured open-ended interviews with mitigation bankers (two in Illinois that sell stream credits). The student researcher will meet with mitigation bankers and ask questions pertaining to site selection and development. Meetings will be held on location at mitigation banking sites.

**Question 3)** How do regulators decide the number of stream credits lost or gained while using the ISMM?

This question is answered using a combination of three methods: Semi-structured open-ended interviews with regulators, participant observation of the use of the Illinois stream mitigation method and negotiation with Section 404 applicants during the mitigation phase of impact projects, and participant observation with mitigation practitioners while monitoring a mitigation banking site. First, the student researcher will meet and interview Corps project managers to understand how project managers interpret federal and regional guidelines and policies when implementing Section 404 compensatory mitigation regulation. Second, the student researcher will also utilize participant observation during the discussion with an applicant over what mitigation is necessary to off-set their Section 404 impacts. This participant observation includes a site visit and evaluation using the Illinois stream mitigation method. Finally, the student researcher will participate with a mitigation banker during bank monitoring and assessment.

**Question 4)** Are the ecological functions lost at adverse impact sites off-set by mitigation at a stream mitigation bank? If so, over what temporal and spatial scales? If not, why not?

Question 4 will be answered using biophysical science and methods to characterize the physical, chemical, and biological characteristics of impacted and mitigated Section 404 stream sites. The dominant biophysical factors are a combination of physical, chemical and biological processes. Utilizing a watershed approach, geomorphic characterization, and measurement of riparian corridor loss, the student researcher will characterize the physical, chemical, and biological condition of a mitigation banking site and the impacted sites that it supposedly compensates.

A widely held assumption in stream ecology is that geomorphic variability is positively correlated with biological diversity (Bartley and Rutherford 2005; Laub et al. 2012). While there are debates over the generalizability of this principle (e.g. Palmer et al. 2010), the assumption that geomorphic variability leads to diverse and positively functioning stream ecosystems is well-entrenched in the classifications used in the ISMM. For example, high "functional" value is given to streams with "natural meanders" and pool-riffle systems, while low value is given for straightened streams without visible pool-riffle systems. As such, this study assesses the overall exchange of geomorphic variability between impacted sites and the mitigation site.

Analyses include: i) channel dimension analysis, ii) channel sediment-size distribution analysis, iii) space-for-time substitution water quality analysis of impact and mitigation sites (temperature, pH, and conductivity), iv) riparian corridor and channel length change over time (before and after permit issuance) at impact and mitigation sites, v) watershed area delineation, vi) water level variation at mitigation bank.

## GEOMORPHIC CHARACTERISTICS

**i)** **Channel Dimension Analysis:** *Longitudinal Profile (i.e. thalweg) and Cross-Sectional Profile:* The longitudinal profile (i.e. thalweg) and cross-sectional profile will be measured using total station topographic survey instruments. Thalweg measurements will consist of measurements of the deepest point in the channel ~2 meters through the extent of the study reach. The line that connects the depth point measurements will constitute the thalweg, and the vertical variation of this line is the longitudinal variability. Measurement of eight to ten bankfull cross-sectional profiles ensures statistical robustness of data analysis (Bartley and Rutherford 2005). The bankfull level will be identified using appropriate indicators (minimum width-depth ratio, abrupt transition from channel to floodplain, vegetation changes). The cross-sectional profile will consist of measurements of both bankfull width and elevation data. The cross-sectional profile elevation data will be collected at all major changes in slope across the channel complemented by a regular spacing of measurement locations consistent with the channel size. Width and depth variation between sequential cross-sections constitutes cross-sectional variation.

**ii)** **Channel Sediment Size Analysis:** Channel sediment will be collected from the bed of the channel upstream and downstream of impacts in both pools and riffles. Pools, or deep and gradually sloped portions, collect the finest range of sediment in a stream. Riffles, or shallow and steeper portions, collect the largest range of sediment in a stream. Together, sampling the pools and riffles will capture the probable range of sediment in each water body. The two dominant impact activities being questioned are channel culverting and channel bank vegetation clearance. In the case of culverts, sediment will be collected upstream and downstream of culverts. In the case of vegetation clearance, sediment will be collected upstream of vegetation clearance, through the reach of cleared vegetation, and downstream of the cleared vegetation. Samples will be collected using bottom sampling grabbers. Samples will be dried, split, sieved, and weighed in the Geomorphology Soils Lab of University of Illinois, Champaign-Urbana campus to determine the particle size distribution.

**HYDROLOGICAL CHARACTERISTICS**

**iii)** **Watershed delineation:** Upstream watershed area from the downstream point of impact sites and the mitigation site were calculated using 10 meter digital elevation models (DEMs) in ArcGIS™. DEM sinks were identified and filled prior to flow direction mapping. Watershed area is a proxy for stream discharge. Comparison of watershed areas serves as a comparison for relative discharge. Watershed area is also correlated with the variability and duration of flooding events (Pociask and Matthews 2013). Watershed area therefore also serves as a proxy for the relative frequency and duration of flooding events.

**iv)** **Mitigation bank water level variation:** Water level variability in the mitigation site will be measured using a HOBO continuous-recording water level recorder. The water level recorder will capture hydrologic variability at 15-minute intervals. Data will be downloaded from the water-level recorder to produce flow a flow variability and duration curve. This data is important for understanding the connectivity between the channel and riparian corridor of the mitigation banking site.

**WATER QUALITY CHARACTERISTICS**

**v)** **Water quality analysis:** Water quality measurements will be taken at each reach using a YSI Professional ProPlus meter and hydro probes. Probes were calibrating according to YSI specificities. Measurements of temperature (℃), pH, and (specific) conductivity (µS/cm) will provide information on chemical and thermal hydrologic properties. These measurements, in turn, will be used to interpret the overall biological quality and function of the stream reaches. Data will be compared against water quality standards and historical measurements taken by the Illinois EPA.

**RIPARIAN VEGETATION**

**vi)** **Riparian vegetation loss:** Total area of riparian corridor vegetation documented in Section 404 permit documents will be compared against the total area of riparian vegetation loss at each impact site measured using Google Earth ™.

**STATISTICAL ANALYSIS**

**vii)** **Statistical Analysis:** There are a variety of statistical methods available for the analysis of variability (Bartley and Rutherford 2005; Laub et al. 2012). Bartley and Rutherford (2005) and Laub et al. (2012) each analyzed multiple metrics of geomorphic vulnerability and associated statistical analyses of variability. **Thalweg variability** will be analyzed using the "degree of wiggliness" factor (w), or the degree of vertical variation of channel depth from the mean elevation; where $w = \sqrt{n \sum(\Delta\phi_i)^2}$, and n= the number of points collected, and $\Delta\phi_i$ is the vertical deviation of each point from the mean (Bartley and Rutherford 2005). The coefficient of variation (CV) will be used to analyze the **variability in channel width and depth of the cross-section profiles** (Laub et al. 2012). CV is the ratio of the standard deviation and mean of a measurement. $\text{CV width and depth} = (\frac{\sigma}{\mu})$, where $\sigma$ is the standard deviation of cross-sectional bankfull width and depth measures, and $\mu$ is the mean width and depth of the cross-section. **Sediment variability** will be analyzed using the measurement of sediment sorting (Bartley and Rutherford 2005). Phi sorting is a measure of the standard deviation of the sediment size distribution about the mean sediment size, where $\text{Sort} = (\phi 84 - \phi 16)/2$. $\phi 84$ is a grain size that 84 percent of the sample distribution is smaller than, and $\phi 16$ is a grain size that 16 percent of the sample distribution is smaller than. The phi (ϕ) system ranges from -12 to 14, where -12 phi sizes are boulders, and 14 correlates with very fine clays. **Planform variability** will be analyzed by calculating the sinuosity of all stream sites. A stream is considered "straight" if it has a sinuosity less than 1.2, and "meandering" if it has a sinuosity greater than 1.5 (Schumm 1963; Chang 1979).

## 3. PRINCIPLE FINDINGS AND SIGNIFICANCE

### Principle findings to Question 1:

*How are (and what types of) ecological and geomorphic science included into the ISMM?*

The Illinois and Missouri stream mitigation methods were designed with similar overarching priorities and goals in mind. Both methods began with a template/pre-existing stream mitigation method (e.g. Missouri began with the 2002 Charleston, SC method; Illinois began with the 2007 Missouri method) and then modified and crafted these pre-existing methods to suit 'state-specific needs'. Neither the Illinois or Missouri team changed the overall format or calculation method of their template methods; instead changes and modifications were focused to within-document elements to encourage standard use (see Table 1 in Appendix).

The Illinois and Missouri stream mitigation method were designed to be used by non-experts. For example, in the words of one St. Louis Corps regulator: "every regulator, resource agency commenter, farmer, consultant, private citizen, developer and so on throughout the entire state that may become subject to Clean Water Act 404 regulation will need [to be capable of using the approved method]." Thus the methods in Illinois and Missouri are designed "to be done pretty quickly, pretty much office-based, and actually…[Will Jones[2]], he was going to be the only person from the Corps working on this…It wasn't like an army of minions out doing assessments. He needed something he could do in half an hour. And he might have said that in specific" (Author interview, 05/26/2015). From this perspective, the ease of completion depended significantly on the work load of an individual Corps regulator.

Scientifically-based information was only included if it was deemed simple and was recognized by state and federal authorities (e.g. could a scientific requirement be legally required of a Section 404 or 401 water quality certificate applicant?). Thus, ecological and fluvial geomorphic science was included inasmuch as it was consistent with three overriding priorities: 1) Making the method useful in the regulatory setting of each state, 2) Working closer toward achieving "in-kind" ecological goals by encouraging more in-channel work and less riparian corridor work, and 3) Ensuring that impact and mitigation credits off-set to result in "no-net loss."

A shared approach by the Missouri and Illinois stream teams was to use "activity-based" classification systems in lieu of direct functional measurements to assess the overall ecological integrity of impacts and mitigation projects. "Activity based" means that each activity (e.g. an impact activity, such as clearing vegetation or installing a culvert) is given a credit value. These activities are ranked based on two parameters: the number of functions impacted, and the spatial scale/overall physical condition (see Figure 1 below). Rather than measuring the actual functional outcome of impact activities, the Stream Assessment Teams used secondary scientific reports to get an overall sense of "expected" outcomes from different activities. This approach is "useful" to Section 404 regulators because it enables an overall assessment of stream crediting to happen by anyone in a very short time period (e.g. less than an hour). Neither Illinois nor Missouri had a formal method for determining the "net adverse impact" or "net benefit" of activities.

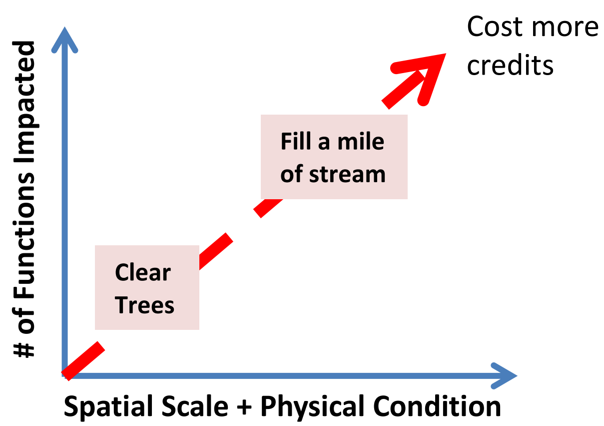


Figure 1. Schematic of the ranking of the "net degradation" caused by impact activities.

[2] All research participants have been assigned pseudonyms to ensure anonymity

The principle challenge in making this method accepted statewide is that the measurement protocol needed to reflect the working priorities and conditions of each agency that shared in the methods creation (cf. Timmerman and Berg 1997). Thus, the predominant modifications made by the Missouri team (of the Charleston, SC stream assessment protocol) and the Illinois team (of the 2007 Missouri stream assessment protocol) were to include state-recognized, legally-defensible classifications, examples of activities (impact and mitigation) that are common and accepted by state and federal agencies in each state, incorporate "user notes" and language modification to encourage more consistent and transparent use of the method, and to do so by making the method direct more desirable ecological outcomes (i.e. encourage "in-kind" work by decreasing the value of riparian buffers and increasing the credit value of in-channel restoration). Therefore, impacts and mitigation activities are considered "commensurate" by virtue of how well they meet the pre-existing working conditions of Section 404 regulatory agencies.

Therefore, ecological and geomorphic information is constrained because a) regulators resist requiring field measurements when assessing the impact and benefit of mitigation activities, b) regulators cannot require applicants to do something that exists beyond their legal authority, and c) regulators are not the only ones reviewing credit calculations. A reorganization of agency priorities is necessary to enable the inclusion of more scientific principles and methodologies that take more time, require more training, and are more site-specific.

In conclusion, at this point, the Illinois stream mitigation method is not a functional assessment protocol. Multiple things would need to occur to make this method "more functional." However, both the Illinois and Missouri methods are "living documents" and will undergo future changes. Changes will be made in response to the finalization of the Environmental Protection Agency's 2015 Waters Rule (which defines the legal scope of Section 404), as Corps districts progressively require more in-channel mitigation, and as the Illinois and Missouri stream assessment teams develop new consensuses over what types of activities are more or less commensurate with one another.

**Principle findings to Question 2:**

*How do mitigation bankers decide on the location, size, and type of bank that they build?*

There are two kinds of compensatory stream mitigation: in-channel work and riparian corridor tree plantings. While this report focuses on stream mitigation *banking* (which in Illinois consists 100% of riparian tree plantings), PRM stream work in Illinois consists of *both* in-channel work and riparian corridor tree plantings. Site selection, mitigation planning, and mitigation management and monitoring of stream mitigation banks in Illinois therefore resembles wetland mitigation rather than conventional stream mitigation projects.

*Site Selection and Planning:* Site selection and mitigation planning/goal setting are interrelated. Often mitigation practitioners have existing skills, ideals, or methods in mind when selecting a potential mitigation site. As one mitigation banker explained (who operates 2/3rd of the banks that sell stream credits in Illinois as of February 2016): "Typically I have three wetland types that I target…forested, emergent, and riparian corridor…Things that other people are doing are scrub-shrub habitat, or wet meadow, or wet prairie. But I don't do any of those" (Author interview, 05/28/2015). Because mitigation bankers utilize riparian corridor restoration and enhancement techniques (i.e. tree plantings), bank goals focus on hydrologic connectivity and the intended benefit to stream quality from converting farmland to a floodplain wetland. For example, one mitigation bank selling stream credits has goals to "reduce nutrient loading and increase nutrient fixation" and "maintain and enhance hydrologic functions and values."

From the Corps' perspective, these are positive ecological restoration goals because these are wetland types that have been historically lost in the Mississippi bottomland region and southern Illinois over the past century and a half. Joined with both the regulatory requirements and site selected, the banker and regulator formulate a site-specific plan. This plan culminates in the publication of a "Mitigation Banking Instrument." The banking instrument "is the administrative document which establishes ecological criteria for the [Corps] approval of bank credits, the financial sureties the banker must provide against site failure, the kind of ecological monitoring which is required, and other administrative details" (Robertson 2004, 363).

Riparian corridor stream mitigation bank sites are selected according to two overarching priorities: i) regulatory requirements and crediting values, and ii) mitigation practitioners' ecological goals and costs. Regulatory requirements vary district-to-district, but most requirements focus on site land use/land cover history, the presence/absence of native or non-native vegetation, and the existing tree/vegetation cover relative to the expected pre-disturbance "climax community." In the St. Louis Corps district portion of southern Illinois, mitigation bankers can only earn credits on sites that are "prior converted wetlands." Prior converted means that the land was "improved" (i.e. drained, cleared, etc.) prior to December 23, 1985 and continues to be used for agricultural purposes, among other criteria. For comparison, in Iowa (almost entirely within the Rock Island Corps district), in addition to being classified as prior converted, land must also have existing and maintained water management structures on site (e.g. tile drainage structures) to be eligible as a compensation site (Personal communication).

Regulators are not only concerned with land classifications, but also have ecological goals in mind. Therefore, when working with a mitigation banker during instrument development, they will insist or require that sites have appropriate site conditions. For riparian corridor plantings, this includes appropriate vegetation, soil, hydrology, and stream stability. Regulators first require that applicants have selected a site that is predominantly non-native vegetation. Without non-native vegetation (e.g. reed canary grass), sites are considered "already functioning" and therefore are not considered of low value to deserve crediting for improvements. If a banker selects a site that meets "Enhancement" (<50% planting) rather than "Creation" (>50% tree planting) criteria, they will need more land to increase their overall credit bank.

Mitigation bankers and regulators initially rely on soil maps when determining if a site is worth visiting to assess. However, because soil maps (e.g. county soil surveys) are at broader scale than is required for site-specific assessments, the predicted soil classification does not always match the observed soil cores. As one banker put it: "You gotta come to these sites, there's no way around it…I don't know how you just go off of the books…If you come out [ready to buy land or do work] and there isn't hydric soils [*sic*] then what do you do? You've gotta find [hydric soil]" (Author interview, 05/28/2015).

When interpreting soil hydrology, mitigation bankers do so with their overall priorities and goals in mind. Depending on the wetland type that bankers plant, their goal is to restore and jumpstart "old growth" forests with minimal ongoing mitigation management. To this end, for one mitigation banker, the key interpretive factors are the presence of hydric soils, gently sloping land, and a stable stream with a degraded riparian corridor. Stream stability is determined by visually interpreting streambank features and considering stream sinuosity. A "stable" stream is desirable because it is an indication that the riparian tree plantings will last and reach mature heights. Furthermore, sites with minimal slopes and appropriate hydrology for their target plants will require less extensive ongoing maintenance and management.

<u>The most significant hurdle to site selection is not necessarily identifying hydric conditions, but a parcel of land that meets these criteria and is also either for sale or willing to be sold or leased</u>. Cost of land is an issue, but in many cases ideal property is owned by a landowner unwilling to part with agricultural land--even if it is not highly productive. In one instance a mitigation banker identified desirable land for mitigation along a river that sat between two parcels of a park preserve. This was an ideal scenario because the banker could potentially leave the mitigation bank to the park preserve to maintain and keep out of production in perpetuity. However, the banker was concerned that the landowner would not part with the land. The banker expressed intrigue into why this farmer continued to plant in what appeared to be wet "unproductive fields."

The size of mitigation banking sites is typically larger than PRM wetland and stream mitigation projects. This is because mitigation banks are designed with the expressed purpose of offsetting multiple future impact activities, rather than single projects. Bank size depends on a combination of: a) total land area acquired, b) the potential number of credits that may be needed in the future, c) the type of credits that a banker targets (e.g. emergent wetland versus bottomland hardwood forest), and d) administrative components (e.g. level of monitoring, level of site protection). The three mitigation banks that sell stream credits in Illinois are 82.75, 62.08, and 79.04 acres in total area (RIBITS).

**Principle Findings to Question 3:**

*How do regulators decide the number of stream credits lost or gained while using the ISMM?*

**Impact Site Credit Determination:** Section 404 permit applications are reviewed using a three-level mitigation hierarchy based on the 1978 National Environmental Policy Act: avoid, minimize, and compensate impacts (Hough and Robertson 2009). Avoidance means to not take proposed actions that result in degradation of surface water quality. Minimization means to implement best-management or design practices that reduce the overall degradation caused by a development activity. Compensation, the main focus of this research project, means to replace lost or damaged resources with a substitute aquatic resource (Hough and Robertson 2009). Not all Section 404 permits require compensation. However, when an activity is deemed to require compensation, it is only determined after first considering avoidance and minimization possibilities. While very few Section 404 permits are denied by the Corps or vetoed by the Environmental Protection Agency (<1% nationwide), many are rescinded during the application process because applicants may find avoidance, minimization, and compensation requirements to be too costly and/or time consuming (Personal communication).

A key constraint on Section 404 permit review is both time and resources (Power 1977; Womble and Doyle 2012). A way to mitigate this constraint is to meet directly with applicants and clearly explain regulatory expectations and requirements. Prior to such meetings--called pre-application meetings--Corps regulators often do a “test run” of the total expected credits from what they know about a project. Corps managers typically use photographs and descriptions included in a pre-project wetland and stream delineation report, Google Earth ™, soil maps, and other data, to calculate an estimated total number of stream credits required for the proposed impact project with the ISMM. During the pre-application meeting the Corps regulator will then walk through the potential mitigation methods (e.g. channel reconstruction, riparian tree plantings, etc.) that will generate sufficient credits to meet compensation requirements. The purpose of this pre-application meeting and the pre-site credit estimation is to further streamline the permit process by walking applicants through their requirements and what flexibility is possible.

As findings to Question 1 describes above, the ISMM is designed to be a rapid-assessment protocol that does not require any background or technical experience in ecological or geomorphic sciences. However, while the ISMM is designed to be easily and consistently applied, there is no set method for determining its constituent parts. Rather than being a prescriptive method, it is mainly formal. This is most obvious in the determination of Stream Type and Existing Condition of a stream proposed to be impacted. For example, when determining the “adverse impact” of a Section 404 application, Corps regulators and/or applicants must determine the net impact in stream credits using the Adverse Impact Worksheet built into the ISMM. The Adverse Impact Worksheet contains six impact factors that, when accumulated, are intended to represent the total adverse functional impact of an adverse impact activity. Each regulator uses their best-professional judgment to determine each of the six adverse impact factors. These six are: i) Stream Type impacted, ii) Priority Water impacted, iii) Existing Condition, iv) Impact Duration, v) Activity, and vi) Cumulative Impact (a linear impact factor).

*Determination of Stream Type Impacted*: While designed to be an objectively interpreted classification, in practice, this classification is heavily determined by the best-professional judgement of each Corps regulator/applicant. Stream Type is broken into three classifications in the 2010 ISMM: a) Ephemeral/Intermittent (0.1 stream credits per impact reach), b) Intermittent with Seasonal Pools (0.4 credits), c) Perennial (0.8 credits). These classifications are defined along hydrological lines. Perennial streams are groundwater fed streams that, in a normal hydrological year, sustain base flow. Intermittent Streams with Seasonal Pools, by contrast, are only connected to groundwater in pools, and therefore may not have complete flow in a normal hydrological year. Ephemeral/Intermittent streams, by contrast, only have flow resulting from precipitation events, and therefore may be dry for most of the year or only have flowing water immediately following rain events. The implication is that, depending on the time of year, and if the Corps regulator/applicant only looks at the amount of water in the channel, they can come up with different conclusions over whether or not a stream is one classification or another.

This problem was abundantly clear during a site visit to assess the existing stream quality of a stream proposed to be partially filled and re-located. During this visit the Corps regulator, the applicant, and the engineering firm that was hired to conduct the PRM mitigation work and who also published a wetland and stream delineation assessment, collectively "assessed" an impact stream. The Corps regulator relied on the applicant and engineering firm to determine the potential boundaries of the proposed impact. Prior to this site visit, the Corps regulator had calculated a "draft" assessment of credits based on a site evaluation from the impact assessment included in the Section 404 application material and desktop methods--such as Google Earth™ or USGS StreamStats. In the field, the Corps regulator was less certain of his initial calculations. The regulator considered the impact stream to be "Intermittent" based on the fact that this waterbody has a relatively small watershed area, and therefore based on surface water alone, has a low discharge.

Walking the length of the stream with the engineering firm, the Corps regulator relied predominantly on four pieces of evidence to determine the Stream Type: i) the amount of water in the stream given recent precipitation events, ii) the engineers report that during a "dry period" the stream still had flowing water, iii) identification of aquatic species, and iv) evidence of "high" flow events, such as bent vegetation or debris encapsulating vegetation. At the time of the visit, on June 25, 2015, the stream had multiple pools with fish and other aquatic species. The Corps regulator also looked at evidence of high-flows. Feeling comfortable that he had identified a well-defined "ordinary high water mark," he then began to question his initial "Intermittent" classification.

This new evidence, coupled with the engineers' remarks that the water body was also flowing in a "relatively dry" April, made the Corps regulator more willing to switch from an Intermittent to Perennial classification. In his own words out loud while walking the stream: "I would have a hard time not calling it perennial…but this is similar to what [the engineer] saw here in April…but when was the last rainfall?...if this site had water in April--and it hadn't rained--where is the water coming from?" (Author interview, 06/25/2015)

After leaving the site, one of the applicants informed the student researcher that there was a "natural groundwater spring" upstream of the impact reach. Once the student researcher informed the regulator that the applicant informed him of this fact the regulator was even more convinced that this stream is a Perennial waterbody. Evidence of a year-round groundwater source, by the hydrological definition of Stream Types, would be enough to tip the Corp regulators' opinion that this stream was Perennial and therefore was worth 0.8 Stream Type credits. The definition of a Stream Type therefore can be a serendipitous decision that depends on what questions and evidence the regulator requests, the time of year and condition of the site during the assessment, and what evidence is put forward by others involved in permitting the activity.

*Determination of Priority Water Impacted:* Priority Water determination is much more straightforward than Stream Type determination. Priority Water is classified into Primary, Secondary, and Tertiary; ranked from more to less biological significance. Each classification is based on pre-existing ecological, water quality, and habitat rating systems and databases of relevant resource agencies involved in Section 404 permitting. For example, if a waterbody is listed on the Illinois EPA 303 (d) Impaired Water List for 'aquatic life use of indigenous aquatic life use' it is considered a Secondary Water (0.4 stream credits per reach). By contrast, Primary waters are those that are ranked as "Biologically Significant Streams" (IDNR), "Significant Mussel Beds," or other state and national biological rating lists. Tertiary waters "include all other freshwater systems not ranked as primary or secondary" (ISMM 2010, 5).

*Determination of Existing Condition of an Impacted Waterway:* Other than Stream Type, Existing Condition is perhaps the most interpretive and loosely applied adverse impact category. Existing Condition is separated into three classifications: "Fully Functional" (1.2 credits), "Moderately Functional" (0.6 credits) and "Functionally Impaired" (0.2 credits). According to the developers of the Missouri stream mitigation method, this impact factor is designed such that all streams should be assumed to be "Moderately Functional" unless it can be otherwise demonstrated with evidence supporting "Fully" or "Functionally Impaired" classification. In practice, not all assessors start from this assumption. Only in later versions (approved 2013 Missouri method; draft and in-development 2013 Illinois method) is this assumption made clearer in the document directions with the addition of "User Notes."

The Existing Condition factor is the most direct example of the way in which the Illinois (and Missouri) stream mitigation methods are rooted in physically-based assumptions of aquatic integrity and overall ecological function. Furthermore, this factor is rooted in the assumption that streams that have no direct sign of human modification (e.g. have not been channelized) are more functional than streams that do have human modifications. For example, a stream reach is "Fully Functional" if:

> it has all of the following characteristics: Has not been channelized, levied, impounded, or artificially constricted. Is not listed on the Illinois Section 303 (d) Impaired Waters List. Has no stream impact (see Activities for a list of impacts) within 0.5 mile upstream or downstream of the proposed stream impact or mitigation site. And has one of the following characteristics: Scores A or B for either Diversity or Integrity (Illinois Biological Stream Rating System). Has riparian buffer of deep-rooted native vegetation that is greater than 50 feet wide on both sides of the stream (ISMM 2010, pp. 5-6).

Corps regulators/credit assessors must therefore confidently identify whether or not the current stream condition exhibits historical evidence of human modification. Determination of Existing Condition is based primarily in physical-condition clues (e.g. are there culverts nearby? Is there visible bank erosion and sedimentation?) that are not necessarily representative of overall ecological or geomorphic function. Implicit in this assessment is the notion that an actively eroding and depositing stream is "improperly functioning."

Thus, in practice, determination of Existing Condition is based on visual, physical, and aesthetic clues (e.g. any evidence of human modification or human activities in the stream channel?). In this case, prior to the site visit, the Corps regulator had considered this stream to possibly be "moderately" or "poorly" [functionally impaired] functioning. This was based on the assumption that there was no direct evidence of channelization (i.e. the stream has likely not directly been modified), but at the same time the stream reach is surrounded by human impacts.

This particular stream reach sits in a narrow valley between a railroad embankment on one side and a coal ash fill to the other. The regulator therefore considered that, while the stream channel itself was not *directly* modified or manipulated in recent history, the construction of embankments and slopes likely alter the local hydrology and runoff in a way that introduces "external" instability into the stream system.

When the Corps regulator walked the stream, he was met with paradoxes and internal contradictions. While the stream channel itself was not manipulated, there were rock and concrete deposits that were only likely sourced from some upstream human modification. At the same time however, this waterbody was not listed as "Impaired" on any Illinois EPA Section 303 (d) database, had visual evidence of biological functionality (e.g. identification of multiple fish species), and therefore the regulator felt this may be even be a fully functional waterbody. In the end, while simultaneously re-adjusting his assessment of Stream Type, the regulator indicated that: "If I did change anything I may change it to poorly functioning [functionally impaired]…but to be honest it's got pools and riffles and it's probably functioning…I need to read the [ISMM] again" (Author interview, 06/25/2015).

*Determination of Impact Duration, Activity, and Cumulative Impact of Activity:* Impact Duration, Impact Activity, and Cumulative Impact are relatively straightforward determinations in the ISMM. Impact Duration is simply the period of time in which impact activities occur. Temporary impacts (0.05) occur in less than 180 days, Short term impacts (0.1) remain evident after 180 days and will not exist after two years, and Permanent impacts (0.3) will be greater than two years. There are nine Impact Activities: Clearing vegetation (0.05), Utility crossing/bridge footing (0.15), Below grade culvert (0.3), Armor (0.5), Detention (0.75), Morphological disturbance (1.5), Impoundment (2.0), Pipe (2.2), and Fill (2.5). The Missouri team found that in some instances applicants were incorrectly identifying activities, and therefore have added clarifying user notes to the 2013 Missouri stream mitigation method. Cumulative impact is the product of the total linear footage of stream impact per reach (as measured through the channel center line) and a cumulative impact factor of 0.0003.

**Riparian Corridor Mitigation Credit Determination:** Once a riparian corridor has been monitored, it is eligible to earn credits. For riparian corridor there are two methods in existence--the former way of doing it (area and length based) and the new way (riparian corridor crediting protocol). Prior to the 2008 Rule, the primary metric used to commensurate impact and mitigation activities were either area or length measurements. For example, one mitigation banker in southern Illinois uses 200 feet x 100 feet (20,000 $ft^2$) blocks as a "riparian credit" for two of their mitigation banking sites. Thus, if a developer impacts 40,000 $ft^2$ of riparian corridor, and they purchase stream credits from this bank, they would be purchasing 2 credits. Riparian credits are inter-changeable with "stream credits." Likewise, if a developer impacted 10,000 $ft^2$ of channel area, they could offset this by purchasing 0.5 riparian credits. This number can also be increased by adding a multiplier for being "out of kind." Hence, developers may be required to purchase as many as 1 credit (2:1 mitigation ratio) or possibly 1.5 credits (3:1 mitigation ratio) to offset their in-channel impact with riparian corridor credits purchased from this mitigation bank. Credit price is determined by the mitigation banker, and the Corps cannot request or require higher or lower credit prices.

More recently there has been a turn toward standardizing credit determination using the ISMM. Riparian credit determination in the ISMM is based on more than only total area planted and the removal of non-native species. Looking at the Riparian Corridor Worksheet (see Figure 2 in Appendix), there are three classifications of riparian corridor plantings: Creation (51-100% planting), Enhancement (10-50% planting), and Preservation (<10% planting). Creation generates the most credits per area of buffer width, with fewer credits generated for Enhancement and Preservation, respectively.

In addition to area and plant-survival-based crediting, riparian credits are also generated based on the type of waterbody that is chosen (0.05, 0.2, or 0.4 credits), whether or not buffers are created on both sides of the stream, the type of monitoring selected (0.1, 0.2, and 0.25 credits), the kind of property control that a site is placed under in perpetuity (e.g. deed restriction (0.1 credits) versus conservation easement (0.4 credits), and whether or not the mitigation work was implemented prior to, concurrent, or after impact activities. Therefore, from this new approach, riparian credits are determined on a case-by-case basis using formal requirements (the ISMM) that provide a framework/formula for calculating the total number of credits generated for riparian compensatory mitigation work.

**Principle findings to Question 4:**

*Are the ecological functions lost at adverse impact sites off-set by mitigation at a stream mitigation bank? If so, over what temporal and spatial scales? If not, why not?*

This study compares the geomorphic, hydrologic, water quality, and riparian vegetation characteristic of a mitigation banking site and the impact sites that it is intended to replace. The two primary impact activities covered by this study are 1) clearing of riparian corridor vegetation, and 2) installation of in-channel culverts for access roads. The mitigation activity is the enhancement (10-50% planting) and creation (51-100% planting) of floodplain forest. Impact activities occurred in and around August 2009. Riparian corridor credits at the mitigation banking site were approved for release (i.e. sale) by October 2008.

In total, the permitted Section 404 activity that was offset by the purchase of credits from the mitigation banking site impacted a total of 48 ephemeral, intermittent and perennial streams and rivers, as well as ephemeral water features. Of these 48, 13 stream impacts required compensation in the form of mitigation. None of these 13 are classified as perennial by the permit documentation. This study focuses on five of these streams. The impacted streams surveyed in this study were largely relatively narrow, headwater channels that varied in sediment composition. These five impacted streams had an average upstream watershed area of 1.34 miles$^2$. The upstream watershed area of these streams ranges over three orders of magnitude (from 0.05 to 5.5 miles$^2$) (see Table 2 below). Figures 3 and 4 in the appendix are photograph examples of both impact activities.

| Impact Site | Impact Activity | Drainage Area (miles$^2$) |
|---|---|---|
| 1 | Vegetation clearance | 5.516327 |
| 2 | Vegetation clearance | 0.049961 |
| 3 | Vegetation clearance and culvert for access road | 0.28305 |
| 4 | Vegetation clearance and culvert for access road | 0.403629 |
| 5 | Vegetation clearance and culvert for access road | 0.447142 |
| | Average | 1.340022 |

Table 2. Impact site upstream drainage areas (miles$^2$).

***All Sites: Overall Geology, Soils, Climate, and Land Use***

Impact site 1: Impact Site 1 is in the Karstic Northern Ozarkian River Bluffs eco-region (Woods et al. 2000). This eco-region receives 40-45 inches of rain on average annually. The average annual January low temperature is 21˚F and the average annual July high temperature is 91˚F. The stream has a mixed bedrock-alluvial bed, with well-defined pools and riffles. Bedrock is predominantly Mississippian limestone, sandstone, and siltstone in this eco-region. Impact site 1 is bounded to the west/north by a mixed Oak-Hickory forest-covered slopes (18-35 % slopes, primarily alfisols; Sonsac flaggy silt loam) and to the east/south by active farmland (0-2 % slopes, inceptisols, entisols and mollisols; Tice silty clay loam, Wakeland silt loam, Wilbur silt loam). Both forested and farmed soils developed primarily on thick loess deposits. There is evidence of sedimentation into Impact site 1 from off-site farmed topsoil erosion caused by rills formed from overland flow on sloped soil with cleared forests. Fish and turtles were observed during multiple site visits through the reach of the site. Deer and turkey were also observed at the site. Fields were most recently corn cropped.

Impact site 2: Impact Site 2 is on the eastern boundary of the Karstic Northern Ozarkian River Bluffs eco-region and the western boundary of the Southern Illinoian Till Plain eco-region (Woods et al. 2000). The Southern Illinoian Till Plain eco-region receives 39-45 inches of rain on average annually. The average annual January low temperature is 17˚F and the average annual July high temperature is 88˚F. The stream is alluvial on steep slopes. Vegetation clearance (the impact) occurred on both stream banks. The removed trees were an Oak-Hickory mix. The stream cuts through alfisols (Ruma-Ursa silt loams). The hillslopes on both sides of the stream are 18-35 %. The headwater source of impact site 2 is an actively farmed field (Bunkum silty clay loam). This field is most recently wheat cropped. Landowners note a decline in local bat populations since forest clearance in summer 2009. A rabbit carcass was found in the downstream portion of the stream.

Impact sites 3 and 4: Impact Sites 3 and 4 are parallel and adjacent stream channels, about 280 meters apart. Both sites are within the Southern Illinoian Till Plain eco-region (Woods et al. 2000). Both streams are immediately within predominantly entisol (Wakeland silt loam) soil coverage. The lateral hillslopes of both streams range from 5 to 18 % slopes, with actively farmed silty clay loam soils. Upstream of impact site 3 is a block of Oak-Hickory mixed forest. The surrounding fields were most recently corn cropped. A burrowing/ground-dwelling mammal was spotted at Site 3. Raccoon and deer tracks were identified in the channel bed. The sites flow into a wildlife habitat preserve.

Impact site 5: Impact Site 5 is within the Southern Illinoian Till Plain eco-region (Woods et al. 2000). Immediately upstream of impact site 5 is a mixed Oak-Hickory forest (~0.05 $km^2$ area). The stream cuts through Wakeland silt loam (entisol), and is bounded on both sides by cow pasture. Beyond the cow pasture are actively farmed corn fields. The actively farmed fields and pasture are additionally Bunkum, Marine, and Homen silt loam soils (alifosols). Raccoon and deer prints were identified in channel material. Cows frequented the surrounding pasture.

Mitigation site: The mitigation site is also within the Southern Illinoian Till Plain eco-region (Woods et al. 2000). The mitigation site is bounded on both sides by Belknap silt loam (inceptisol), Hurst silt loam (alfisol), and Colp silt loam (alfisol). The mitigation site is bounded on the southwest by an intact bottomland hardwood forest (mixed Oak-Hickory) and the east by active farmland (both corn and soy cropping). Deer, turtles, beavers, raccoons, snakes, and multiple fish species were observed over multiple site visits. The upstream drainage area is 174.04 $miles^2$. The watershed is heavily disturbed with corn, soy, and wheat farming.

***Impact Sites: Geomorphology, Water Quality, and Riparian Corridor Areas***

*Geomorphology: Channel Width, Depth, Slope, Sinuosity and Sediment Variability*

Channel dimension measurements were taken at sites 1, 2, 3, and 5. Average stream width varied from 1.9 m (Site 2) to 6.9 m (Site 1). The coefficient of variability (CV) of width, a metric of variance, ranged from 0.18 (Site 1) to 0.48 (Site 5). The average depth across impact sites varied from 0.43 m (Site 2) to 1.8 m (Site 5). The average of the CV of depth of all cross-sections varied from 0.14 (Site 2) to 0.31 (Site 5). Therefore, based on the CV of cross-sectional dimensions, Site 5 has the greatest channel dimension variability amongst the impact sites, Site 1 is the widest and shallowest, and Site 5 is the deepest. Table 3 summarizes these measurements.

| Impact Site | No. of cross sections | Mean Width (m) | Width CV | Mean Depth (m) | Mean Depth CV |
|---|---|---|---|---|---|
| 1 | 13 | 6.857194 | 0.184299 | 0.930955 | 0.280695 |
| 2 | 9 | 1.920875 | 0.330672 | 0.433784 | 0.140377 |
| 3 | 7 | 3.90618 | 0.311174 | 1.427581 | 0.246528 |
| 5 | 7 | 4.015851 | 0.475937 | 1.816111 | 0.310401 |

Table 3. Summary of cross-sectional measurements at impact sites 1, 2, 3, and 5.

Channel depth (thalweg) measurements were taken throughout each study reach. Thalweg graphs are provided in the appendix (Figures 5 - 8). As Table 4 shows, contrary to channel dimensions above, Site 1 has the greatest overall thalweg variability. Thalweg “wiggliness” depends on the number of samples, and therefore the difference between Site 1 (31.23, 97 samples) and Site 2 (20.65, 35 samples) could be explained by the sample size alone. As an example, if both sites had the same number of samples (e.g. 70) and their current vertical variation, Site 2 would have a higher degree of wiggliness (29.21) than Site 1 (26.53). Site 2 was not sampled further upstream because the survey prism was not visible through more dense vegetation. However, in this case, the overall wiggliness of Site 2 is likely due to its landscape position (a steep hillslope; i.e. overall vertical elevation change in the surveyed reach) rather than variability within the stream channel itself. Therefore, based on the stream channel morphology alone (and not landscape position), Site 1 had the greatest thalweg variability, mostly in the form of successive pools and riffles. Site 5 has the greatest planform variability (i.e. sinuosity).

| **Impact Site** | **Thalweg wiggliness** | **No. of samples** | **Distance Sampled (m)** | **Slope (%)** | **Reach Sinuosity** |
|---|---|---|---|---|---|
| 1 | 31.2303381 | 97 | 238.3 | 0.60999965 | 1.218786 |
| 2 | 20.65481213 | 35 | 67.6 | 2.50709205 | 1.107858 |
| 3 | 20.91432064 | 67 | 71.4 | 1.15409161 | 1.071417 |
| 5 | 17.94311383 | 79 | 98.6 | 1.19075072 | 1.392745 |

Table 4. Summary of downstream depth measurements and site slope.

Sediment was collected at Sites 2 (6 samples), 3 (4 samples), and 5 (6 samples). Although each has silt loam soils, there is a wide variability in the relative proportions of gravel, sand, and silt/clay at each site. Table 5 summarizes the mean and range of gravel, sand, and silt/clay collected at each site, as well as the sort of sediment. Site 3 has the greatest sediment sort variability of the three sites sampled. Site 2 had an abundance of gravel, while sites 3 and 5 had more sand than any other size range.

| | | **Range** | | | **Average** | | | |
|---|---|---|---|---|---|---|---|---|
| **Impact Site** | **No. of samples** | **Percent sample Gravel** | **Percent sample Sand** | **Percent sample Silt/Clay** | **Percent sample Gravel** | **Percent sample Sand** | **Percent sample Silt/Clay** | **Phi Sort Range** |
| 2 | 6 | 32.5-63.3 | 34.2-58.2 | 2.3-9.3 | 51.65232 | 44.04901 | 4.298672 | 1.8-2.875 |
| 3 | 4 | 2.1-16.4 | 39.3-82.9 | 6.8-44.3 | 7.721798 | 66.67326 | 25.60494 | 1.45-3.5 |
| 5 | 6 | 7.0-62.6 | 36.1-76.4 | 1.0-30.7 | 36.15131 | 57.3752 | 6.473488 | 1.6-2.5 |

Table 5. Impact Site sediment variability. Gravel = 31.5 mm to 2.0 mm diameter; Sand = 1.4 mm to 630 micrometers; Silt/Clay = < 630 µm; Sort 1.5 = 0.355 mm, Sort 2.5 = 0.180 mm, Sort 3.5 = 900 µm.

In summary, site 5 has the greatest overall channel variability, while site 3 had the greatest sediment variability. Sites 3 and 5 are likely still geomorphically active and will continue to widen and deepen in locations due to undercut banks. Both sites have undercut banks and exposed scarps that have formed in the past 6 years (Personal communication with landowners).

*Water Quality: Temperature, conductivity, and pH*

Water quality measurements are water-level dependent. Sites 2, 3, 4, and 5 are ephemeral and intermittent streams that have limited water depth except during precipitation events. These sites had limited or insufficient water depth during multiple sampling periods. For these reasons, temperature, conductivity, and pH measurements were only taken at impact sites 1 and 5.

Results show that vegetation clearance has a direct impact on water quality, and mainly in the form of temperature modulation. Results are inconclusive with respect to the impacts of culverting on water quality. The relationship between temperature, conductivity, and pH are well established (Girard 2005). Temperature and conductivity are directly related, while pH and conductivity generally are inversely related. Conductivity is a measure of the concentration of charged atoms present in a water body; this can be indicative of the salinity or concentration of total dissolved solids (e.g., toxic metal, H+ cations, etc.). pH is an inverse measure of H+ ion concentration; as pH increases, the concentration of H+ ions and overall conductivity decline. Conductivity is also affected by temperature; warmer water has a higher conductivity. Water bodies have a range of conductivity that reflects the overall concentration of total dissolved solids for a given water temperature and volume.

For comparison to nearby streams with similar drainage areas, Rayse Creek near Waltonville, IL (88 miles$^2$ drainage area; a disturbed watershed with agriculture), had a conductivity range from 200 to 1400 μS/cm. Lusk Creek near Eddyville, IL (42.9 miles$^2$ drainage area; an undisturbed watershed with forests) has a conductivity range from 40 to 170 μS/cm. Both of these creeks were measured between 2001 and 2003. Agriculturally-dominated watersheds therefore have high conductivity.

Impact sites 1 and 5 had detectable temperature changes due to loss of tree cover (see Figures 9-14 in appendix). As figures 9 and 12 show, temperature increased in mid-day sampling throughout the impact reaches and declined downstream of the impact reaches. On the contrary, increased downstream conductivity was only detected in the mid-day observation at Site 1 (see Figure 10 compared to Figure 13). Sites 1 and 5 had a different range of conductivity. Site 1 ranged from 498 to 553 μS/cm, while Site 5 ranged from 459 to 839 μS/cm. This difference can be explained by two factors: water depth/flow and temperature range when data was collected. Site 1 water temperature ranged 22.1-24.4˚F; Site 5 temperature ranged from 23.2 to 29. 4˚F. The water temperature difference is due to difference in water depth/flow and not air temperature; Site 1 had warmer air temperature at the time of data collection than Site 5. However, Site 1 has significantly deeper and faster flowing water than Site 5, which were mainly shallow and stagnant pools.

Impact sites 1 and 5 also had detectable pH changes; however it is unclear if it is due to loss of tree cover in both sites (figures 11 and 14). The pH of most natural surface waters ranges from 6.5 to 8.5 (Girard 2005). Natural causes for pH variability include temperature, photosynthesis, and geology (Girard 2005). pH at site 1 ranged from 6.09 to 6.22, and ranged from 5.39 to 6.39 at site 5. pH at site 1 followed a similar pattern as temperature for the mid-day measurement; pH rose throughout the impact reach and declined soon after (see Figure 11). Unlike temperature, pH also rose throughout the impact reach in morning measurements. The site 1 mid-day pH measurements ranged from 6.16 to 6.22, while the site 1 morning pH measurements ranged from 6.09 to 6.16. Therefore, site 5 is more acidic than site 1.

Based on these findings, site 5 has a considerably higher concentration of total dissolved solids than site 1 (e.g. 839 versus 553 µS/cm conductivity). Likewise, site 5 is likely more saline than site 1. Compared to the acceptable pH range for fish species, both site 1 and 5 are within the tolerable range for most fish, and predominantly in the optimum range for fish eggs (see Table 6 below). This is more significant for site 1 than site 5 because site 5 is an ephemeral water body that does not support aquatic species year round.

| **Tolerable pH range for fish species** | | |
|---|---|---|
| **Min.** | **Max.** | **Effects** |
| 3.8 | 10.0 | Fish eggs could be hatched, but deformed young are often produced |
| 4.0 | 10.1 | Limits for the most resistant fish species |
| 4.1 | 9.5 | Range tolerated by trout |
| --- | 4.3 | Carp die in five days |
| 4.5 | 9.0 | Trout eggs and larvae develop normally |
| 4.6 | 9.5 | Limits for perch |
| --- | 5.0 | Limits for stickleback fish |
| 5.0 | 9.0 | Tolerable range for most fish |
| --- | 8.7 | Upper limit for good fishing waters |
| 5.4 | 11.4 | Fish avoid waters beyond these limits |
| 6.0 | 7.2 | Optimum (best) range for fish eggs |
| --- | 1.0 | Mosquito larvae are destroyed at this pH value |
| 3.3 | 4.7 | Mosquito larvae live within this range |
| 7.5 | 8.4 | Best range for the growth of algae |

Table 6. Tolerable pH range for fish species.
Source: http://www.state.ky.us/nrepc/water/wcpph.htm, last accessed March 22, 2016.

*Riparian Vegetation Area*

This study uses a Section 404 permit as its case. The Section 404 permit documents provide a record of the total impact to streams, wetlands, and riparian corridors from the permitted activity. The permit documents also describe the compensation that was required for the permitted impacts. In this case 8 acres of riparian corridor were counted as cleared and the applicant needed to offset their impacts by providing 7.91 acres of "functioning riparian corridor". Riparian corridor counts as all trees both within 25 feet of each stream bank as well as all trees within the 150 foot right of way corridor. Using Google Earth ™, the student researcher measured approximately 50 acres of forest cover--both riparian and non-riparian--that was cleared in total for this permitted activity. Therefore, the mitigation work did not replace the total acreage lost to the permitted activity. The Section 404 applicant was not required to compensate for more riparian corridor impacts because not all impacts occurred on a waterbody that was deemed jurisdictional under Section 404.

*Summary: Overall Impacts from Culverting and Vegetation Clearance*

Culverting streams predominantly results in direct geomorphic modification of streams. Impacts include separation of sediment (fine pool upstream, coarser pool downstream) and channel widening and deepening immediately downstream of culverts. Culverts also hydrologically disconnect streams during low flows because the bottom of the culvert is above the bottom of the stream bed. Culverts also result in collection of vegetative debris on the upstream end during high flow events. All three culverts visited in this study had a collection of vegetation upstream with very little in-stream vegetation downstream.

The geomorphic impacts of culverting were obvious at both sites 3 and 5. In both cases there was scouring and widening immediately downstream of the culvert. For example, compared to upstream of the culvert, site 3 had greater width and depth variability downstream. Site 3 also had 7 times greater thalweg wiggliness downstream of the culvert as compared to upstream of the culvert. Site 3 had a separation of sediment upstream and downstream of the culvert. Immediately upstream of the culvert, site 30 channel bed sediment was 40% silt/clay. Immediately downstream of the culvert, channel bed sediment was only 6.8% silt/clay.

By contrast, vegetation clearance results in both geomorphic and water quality modifications to streams. Geomorphic impacts are primarily in the form of channel widening and deepening throughout the impacted reach. For example, site 1 is still actively widening; at least one tree has been undercut between March and June 2015 alone. Downstream of the impact reach site 1 has three times greater width variability, 2 times greater depth variability, and is five times steeper than upstream. The increased variability is attributed to increased channel erosion, bed scouring, and a large mass of sediment (i.e. a “sediment slug”) that was likely eroded and transported immediately downstream during the impact activity (i.e. when the trees were being cleared with large equipment).

Vegetation clearance also results in water quality modification, and this is primarily in the form of temperature change. Temperature increase was observed in every site throughout the impact reach. This is attributed specifically to the removal of trees that usually would shade the stream. The relationship between vegetation clearance, pH, and conductivity is more complex. While pH and conductivity dropped downstream of the site 1 impact, there was an inverse relationship downstream of the site 5 impact. It is expected for pH and conductivity to have an inverse relationship. Further study is necessary to identify why there was not an inverse relationship between pH and conductivity at site 1. A possible explanation is that conductivity is modulated more by warmer temperatures and total dissolved solids that are not detectable by pH at site 1 than at site 5. Water level is also a likely explanation; while water was continuously flowing at site 1, it was mostly stagnant during the sampling at site 5.

### *Mitigation Site: Geomorphology, Water Quality, and Riparian Corridor Area*

*Geomorphology: Channel Width, Depth, Slope, Sinuosity, Sediment Variability and Hydrology*

The mitigation banking site is on a much larger stream than the five impacted streams (on average 13 meters wider). The upstream drainage area from the downstream point of the mitigation banking site is 174.04 miles$^2$. This is 168.5 miles$^2$ greater than the largest impacted watershed area. The mitigation site therefore has a much greater discharge, with longer flood duration. While the impacted reaches had slumped banks, well defined pools and riffles, and varied sedimentology, the mitigation site is more geomorphically homogenous. The average width of the mitigation banking site is 17.8 meters, with a CV of 0.08. The mitigation site therefore has less than half the width variability as the least width-varied impact site, and has six times less width variability than impact site 5. The average maximum depth of the mitigation banking site is 3.8 meters, with an overall depth CV of 0.01. The mitigation site is therefore 14 times less depth-varied than the least depth-varied impact site, and 31 times less variable than the greatest depth-varied impact site. The slope of the mitigation site is 0.17 %, compared to the 0.61 % slope of the least steep impact site. The mitigation site is more sinuous than the impact sites (1.5 as compared to an impact site maximum of 1.39). Compared to the impact sites, the mitigation site has significantly less sediment variability. The mitigation site is predominantly sand, silt, and clay, while impact sites also have large proportions of gravel. In summary, the mitigation site is much larger than the impact sites with a larger discharge; however has more homogenous channel characteristics.

The mitigation site had one over-bank flow event between July 5 and November 5, 2015 (see Figure 19 below). This event lasted over 24 hours (approximately 28). Comparing the water level recordings between July 5 and November 5, 2015 and precipitation data at four nearby weather stations, it is likely that the site had at least four other over-bank flow events between March 5 and July 5, 2015 that lasted in total at least 5 days. June 2015 was the second wettest month on record for nearby cities (Midwest Regional Climate Center, July 2015). The frequency and magnitude of over-bank flow events at the mitigation banking site is evidence to support the claim that the riparian corridor is hydrologically connected to the stream channel. Future research is needed to understand the functional role that the riparian corridor and surrounding wetlands play in modifying in-stream water quality conditions.

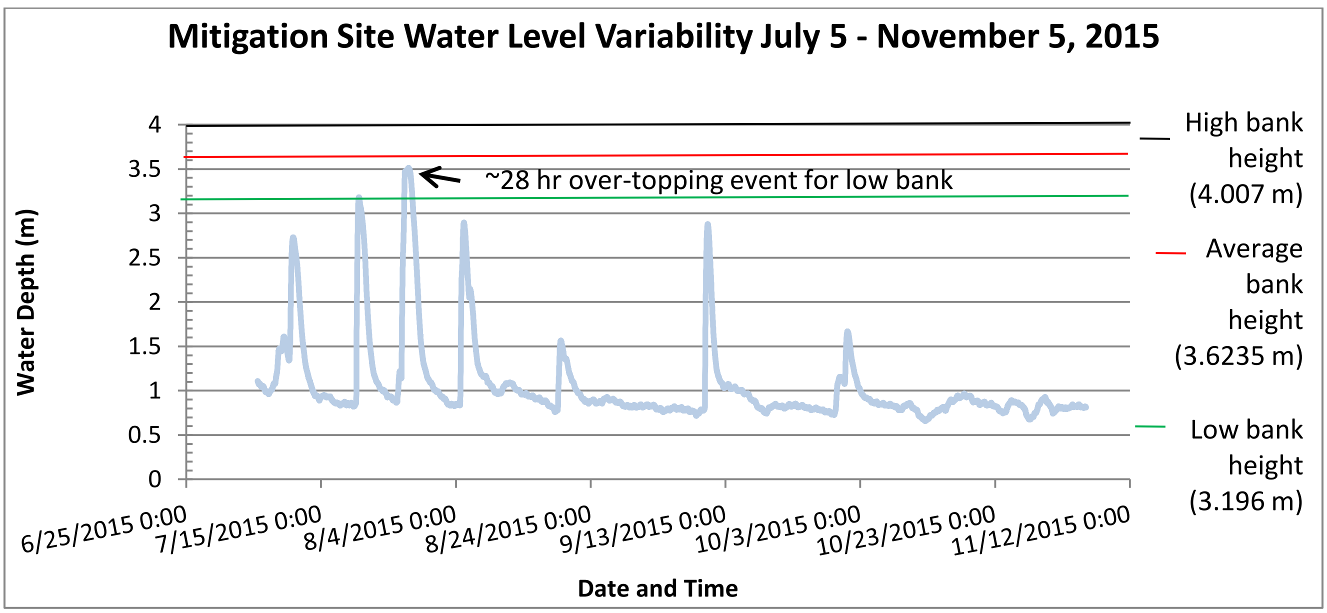


Figure 19. HOBO water level recorder data for stream mitigation banking site.

*Water Quality:* *Temperature, conductivity, and pH*

The mitigation banking site had no distinguishable impact on water level quality when compared to water level data over a 7,500 meter stream distance. Most important to note is that the overall water quality of the stream being targeted for mitigation has a pH less than 5. As table 6 above shows, pH less than 5 is beyond the tolerable range for most fish species. pH ranged from 3.99 to 4.67 for the mitigation stream. Values were consistently in this range far upstream, through the mitigation reach, and downstream of the mitigation reach. This suggests that there is an important need for watershed-scale analysis of the sources and fates of potentially toxic substance levels. The mitigation banking documentations do not refer to the existing water quality of the stream, and therefore do not have current management plants to target different pH ranges. Thus, it is fortunate that this particular waterbody was approved for a mitigation banking site.

## SUMMARY AND SUGGESTIONS

*Main Findings:*

1. *Impact Activities*

Overall, impact activities occurred in different watershed locations than where the mitigation activities were located. The average upstream watershed area of impacted streams was 1.34 $miles^2$, while the upstream watershed area of the mitigation banking site was 174.04 $miles^2$. Since watershed area is highly correlated with stream discharge, the impact and mitigation site have significantly different discharge volumes and variability. This has ecological implications. Flow variability--including duration and frequency--are some of the most important factors in ecological effectiveness and function of stream systems (Doyle et al. 2005). Therefore, the impact activities and the mitigation site perform different ecological functions.

2. *Net Loss of Functionality*

The impact sites and mitigation site serve different functions. This is primarily because a) different watershed positions, but also b) different eco-regions and channel geomorphic variability. The impact activities resulted in geomorphic, water quality, and riparian corridor changes. The mitigation activity has thus far only resulted in conversion of riparian farmland to riparian corridor. There is therefore a net less in functionality by these impact activities.

3. *Impact Sites Are Geomorphically Diverse*

A primary assumption of the newly designed mitigation method is that credits are more valuable for diverse physical forms. However, as this study shows, the impacted reaches are more geomorphically varied than the mitigation site. Impact sites have more diverse channel forms (width, depth, and sediment) and more tolerable water quality for a wider range of aquatic species (pH greater than 5).

4. *Impacts Are not Temporary and are Ongoing*

While the permit documents describe the impact activities (i.e. tree clearance and culvert placement for access roads) as temporary, the results from these activities continue to this day. Impact site 1 is a poignant example; just as recently as between March and June 2015 the stream undercut tree roots and the tree fell into the stream. The functional impacts of vegetation clearance therefore require long-term monitoring in order to sufficiently replace lost functionality.

*Suggested Modifications/Changes to Regulation Practices*

i) Continue to emphasize Avoidance and Minimization.

ii) Standardize impact site calculation and assessment: Rather than only requiring that a classification be met, guidance should suggest a specific methodology through which method users will systematically assess impact site stream type and existing condition. A possible solution would be to develop a flow chart-style methodology that directs users, step by step, to sequential data sources when making assessment decisions using the Illinois and Missouri stream mitigation methods.

iii) Incorporate more site-specific data to assess the actual function of the impact and mitigation site: Regulators may consider establishing goals--short term and long term--and progressively incorporating more complex and robust analysis techniques. For example, four short term metrics that could be incorporated immediately without changing the processing time of each application are watershed area, channel slope, channel sinuosity, and sediment type. Using USGS StreamStats, regulators can require applicants to assess the drainage area and therefore relative discharge of the impact/mitigation site. Additionally, regulators can use Google Earth ™, Soil Survey data, and stream delineation reports to gain a cursory sense of the streams slope, sinuosity, and sediment type. All of this information will be necessary when beginning to make more process-based decisions regarding stream mitigation. Long-term metrics, by contrast, would be site-specific analysis of stream power (i.e. the ability of a stream to do work given its dominant discharge and slope) and channel change over time.

iv) Impact duration is not simply a question of construction work timing: The Illinois and Missouri stream mitigation methods need to more fully acknowledge and assess the long-term impacts of development activities. Unless this is done in some way, the methods will continue to fail to replace lost aquatic functions.

v) If regulators insist on keeping the method "activity-based" instead of "function-based," they then should at least develop regionally-specific metrics for impact activities: The assumption that clearing vegetation, for instance, has equal functional impact across stream and landscape types, is not supported by this study. By developing regionally-specific (e.g. at the scale of slope, sediment, and watershed area types), the functional impact of impact activities can be better incorporated into stream crediting of impacts and mitigation activities while retaining the simplicity that regulators demand of the mitigation method.

vi) Take advantage of unique opportunities: The mitigation banking site is on a waterbody with relatively low pH; this suggests that the mitigation activities can have a potentially positive impact on water quality. Regulators should collect water quality measurements before, during, and after mitigation work to know the extent to which mitigation activities actually alter water quality. In the case of mitigation of large water bodies, it is unlikely that mitigation of only 80 acres will be sufficient to mitigate the degradation of upstream and downstream agricultural activities. In that event, regulators may consider informing other regulatory and non-regulatory water quality programs of a potential mitigation need.

*Next Steps in Research*

The following steps are necessary to continue this study in order to fully address the degree to which impacted and mitigated streams perform different functions.

1) Track the use and development of the Illinois and Missouri stream mitigation methods to further evaluate when and how methods can be made more standard and more ecologically robust.
2) Track the vegetation condition of the mitigation banking site beyond the monitoring period.
3) Conduct repeat channel geomorphology surveys to assess change over time.
4) Improve the spatial and temporal resolution of water quality measurements, including additional measurements of dissolved oxygen and turbidity.
5) Measure velocity to estimate discharge at all impact and mitigation sites to develop process-based data that can inform the overall stability of each stream.
6) Install water level recorders at impact sites to assess frequency and duration of overbank flow events.

**4. STUDENT WORKERS**

***Alex W. Peimer****, PhD student (Dept. of Geography and GIScience)*--conducted all interviews, analysis, and field work with assistance from:

***Courtney Reents****, MS student (Dept. of Geography and GIScience)*--assisted in channel surveys, water quality monitoring, water level recorder installation, and sediment collection
***Bailey Morrison****, PhD student (Program in Ecology, Evolution and Conservation Biology)*--assisted in water level recorder installation
***Dan Meyer****, PhD student (Dept. of Philosophy)*--assisted in channel surveys
***Marisa Monier****, MSW student (Dept. of Social Work)--assisted in channel surveys*
***Dora Cohen****, PhD student (Program in Ecology, Evolution and Conservation Biology)*--assisted in channel surveys and sediment collection
***Sandy Wong****, PhD student (Dept. of Geography and GIScience)*--assisted in channel surveys and sediment collection
***Rebecca Shakespeare****, PhD student (Dept. of Geography and GIScience)*--assisted in channel surveys and sediment collection

**Work that will be published based on this funding:**

1) Alex W. Peimer's Ph.D. dissertation: "Banking on Offsets: A Political Ecological and Eco-Geomorphic Analysis of Section 404 Compensatory Stream Mitigation Banking in Illinois, U.S.A."
2) Yet to be determined journal articles.

## 5. APPENDIX

| Types of Changes | MO 06[2] to MO 07[1] | MO 07[1] to MO 13[1] | MO 07[1] to IL 09[2] | IL 09[2] to IL 10[1] | IL 10[1] to IL 13[2] |
|---|---|---|---|---|---|
| Add (e.g. add reference to a new rule) | 11 | 52 | 32 | 15 | 43 |
| Remove (e.g. remove example) | 1 | 36 | 12 | 9 | 16 |
| Modify Language (e.g. changing category names) | 10 | 15 | 14 | 9 | 25 |
| Group (e.g. grouping all cumulative impacts into one scale factor) | 0 | 2 | 2 | 1 | 1 |
| Ungroup (e.g. pulling out a specific morphologic change as its own category) | 0 | 0 | 2 | 0 | 0 |
| Change number (e.g. minimum buffer distances) | 0 | 14 | 20 | 3 | *** |
| Total | 22 | 119 | 82 | 37 | 102*** |

Table 1. Summary of changes made to successive versions of the Illinois and Missouri stream mitigation methods. ***Crediting worksheet numbers were changed between the 2010 ISMM and the draft 2013 ISMM. These changes consisted of direct copies of portions of the Riparian Corridor and In-Stream Work Worksheets from the 2013 MSMM.

### A.3. RIPARIAN WORKSHEET

| | | | | |
|---|---|---|---|---|
| Priority Waters | Tertiary 0.05 | Secondary 0.2 | Primary 0.4 | |
| Net Benefit (for each side of stream | Riparian Creation, Enhancement, Restoration, and Preservation Factors (select values from Table 1) (MBW = Minimum Buffer Width = 50') | | | |
| Supplemental Buffer Credit | Condition : MBW restored or protected on both streambanks To calculate:(Buffer Credit Stream Side A + Buffer Credit Stream Side B) / 2 | | | |
| Monitoring | Level I 0.10 | Level II 0.20 | Level III 0.25 | |
| Site Protection | Deed Restriction 0.1 | | Conservation Easement / Title Transfer 0.4 | |
| Mitigation Construction Timing | Schedule 1 0 | | Schedule 2 0.1 | Schedule 3 0.3 |
| Temporal Lag (Years) | Over 20 -0.3 | 10 to 20 -0.2 | 5 to 10 -0.1 | 0 to 5 0 |
| Mitigation Factor | In HUC 12 watershed or bank service Area: 1.0 Out of kind, HUC 12 watershed, or bank service Area: 0.5 | | | |

| Factors | | Stream Reach 1 | Stream Reach 2 | Stream Reach 3 | Stream Reach 4 | Stream Reach 5 |
|---|---|---|---|---|---|---|
| Priority Area | | | | | | |
| Buffer credit | Stream Side A | | | | | |
| | Stream Side B | | | | | |
| Supplemental Buffer Credit Met (Buffer on both sides) | | | | | | |
| Monitoring | | | | | | |
| Site Protection | | | | | | |
| Mitigation Construction Timing | | | | | | |
| Temporal Lag | | | | | | |
| Sum Factors (M)= | | | | | | |
| Linear Feet of Stream Buffer (LF)= (don't count each bank separately ) | | | | | | |
| Credits ( C ) =M X LF | | | | | | |
| Mitigation Factor (MF) x (C) | | | | | | |
| **Total Credits Generated** | | | | | | |

**Total Riparian Restoration Credits Generated = ________________**

Figure 2. Riparian corridor credit worksheet (ISMM 2010).

Figure 3. Trees cleared at Site 1. Looking downstream (Photo by Alex W. Peimer).

Figure 4. Vegetation cleared and in-channel culvert installed at Site 3. Looking downstream (Photo by Alex W. Peimer).

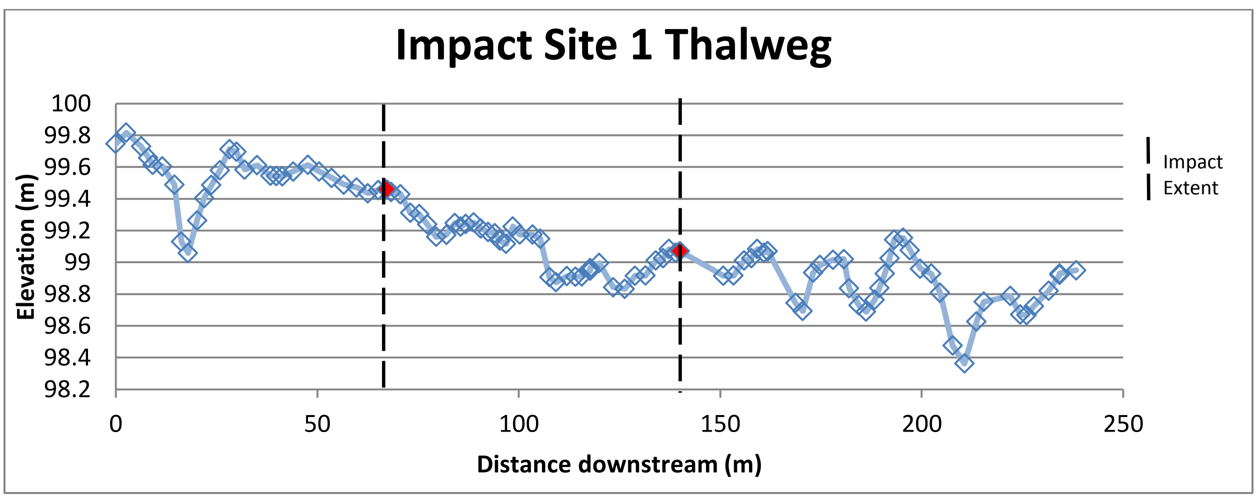


Figure 5. Impact site 1 thalweg.

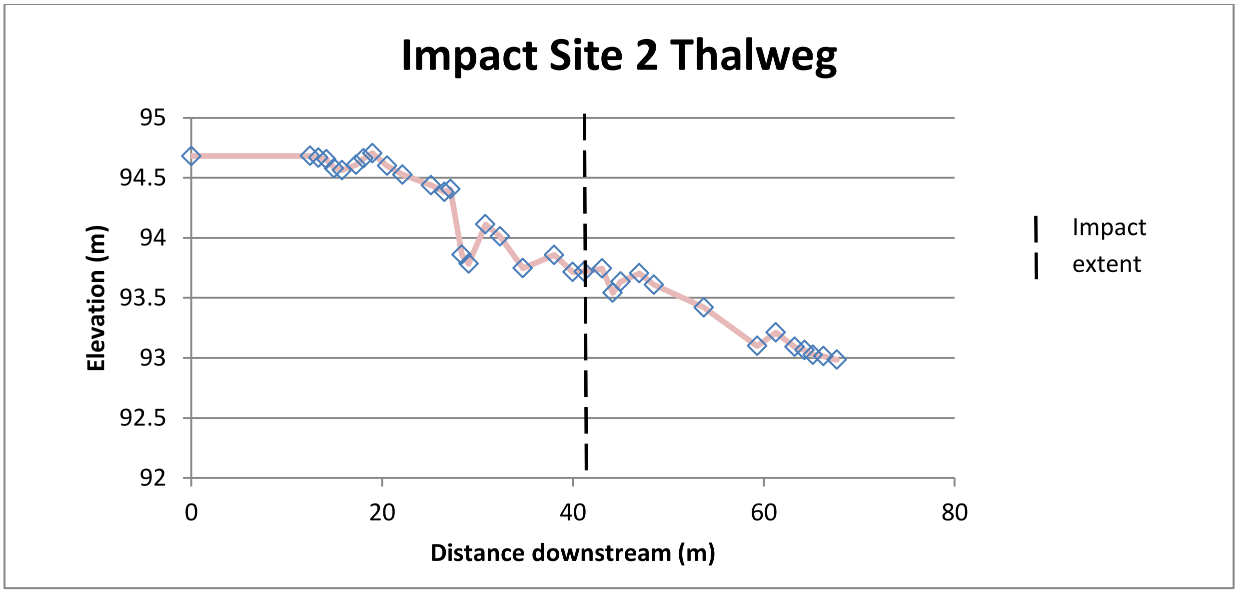


Figure 6. Impact site 2 thalweg.

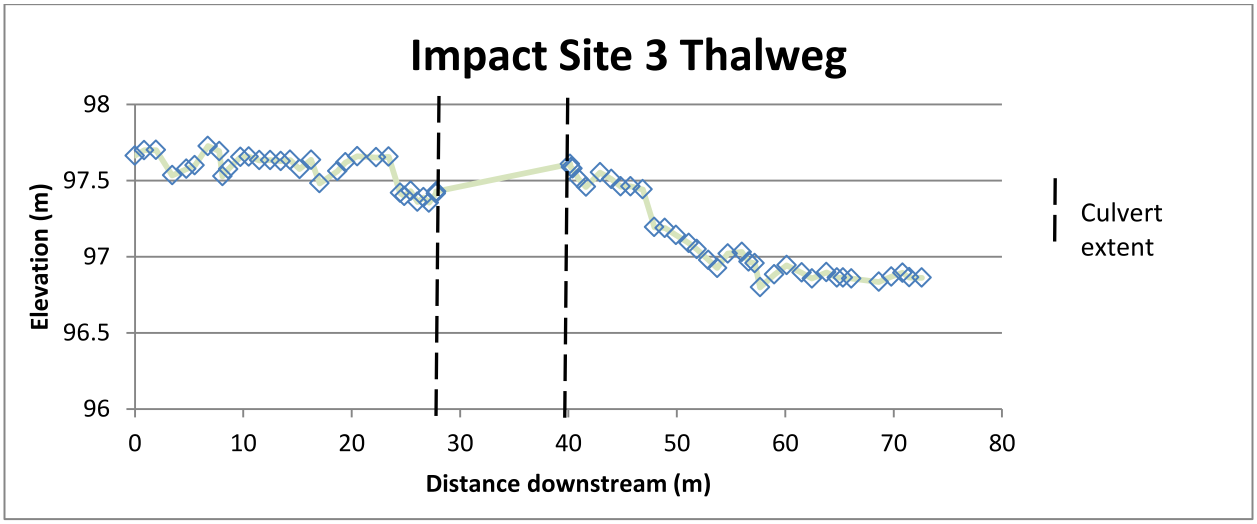


Figure 7. Impact site 3 thalweg.

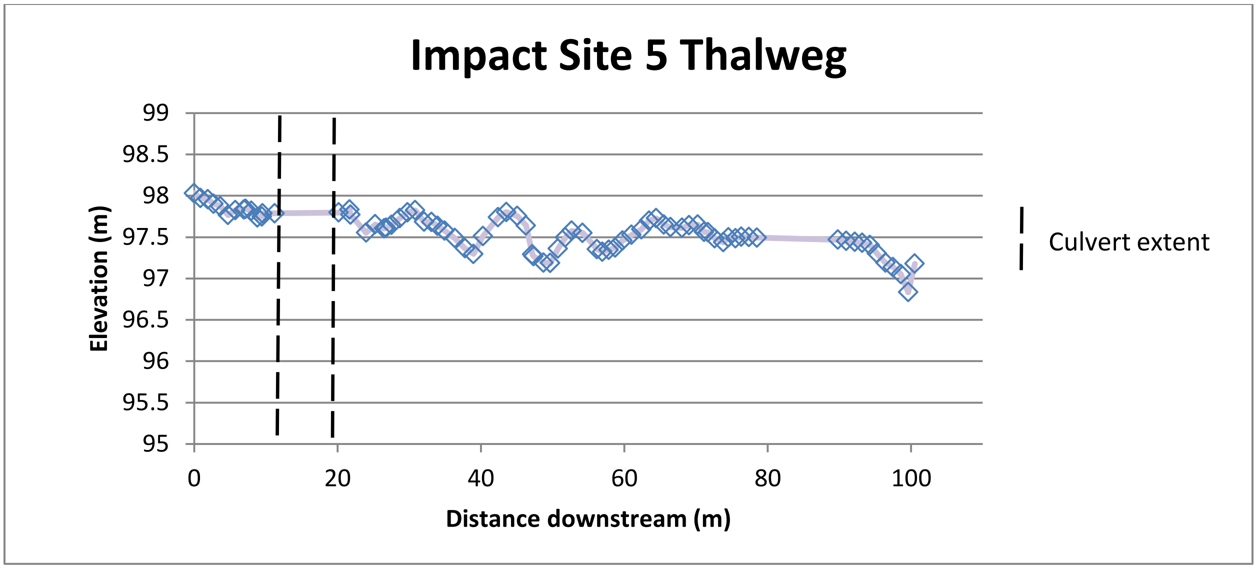


Figure 8. Impact site 5 thalweg.

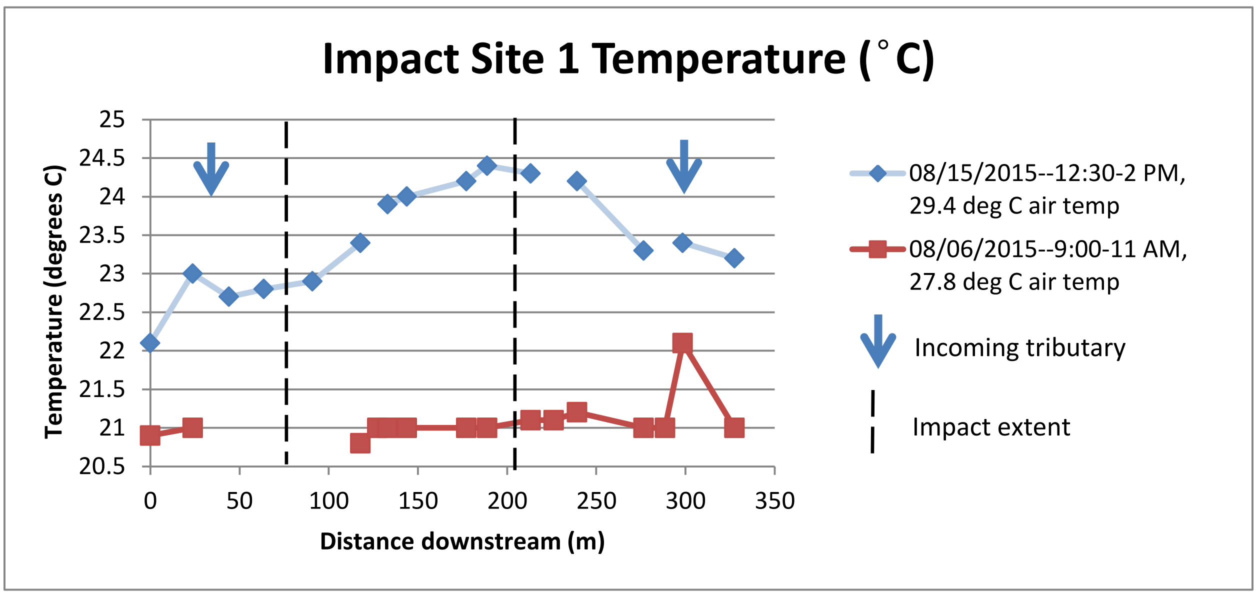


Figure 9. Impact site 1 temperature measurements.

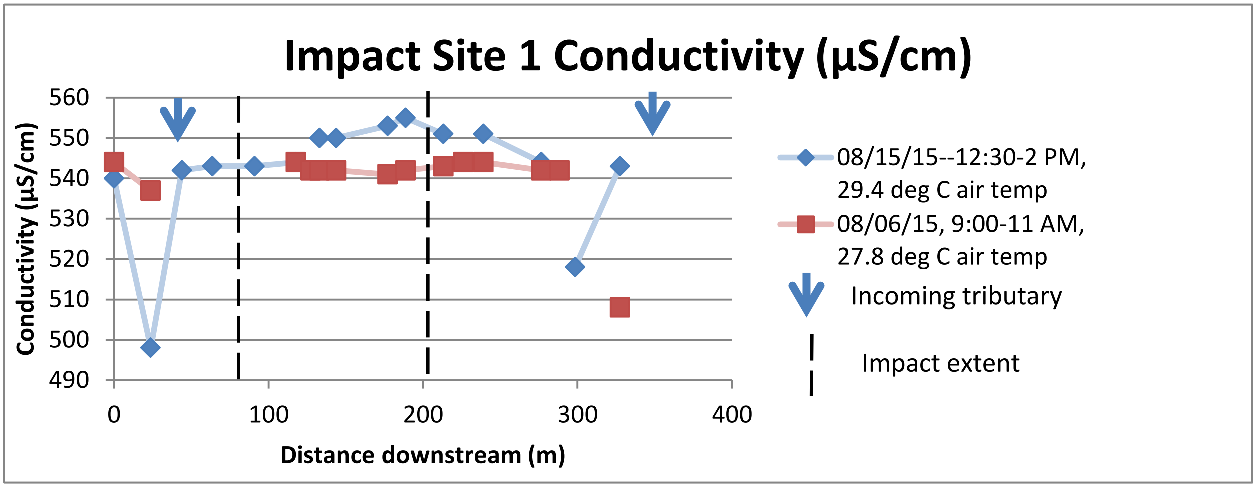


Figure 10. Impact site 1 conductivity measurements.

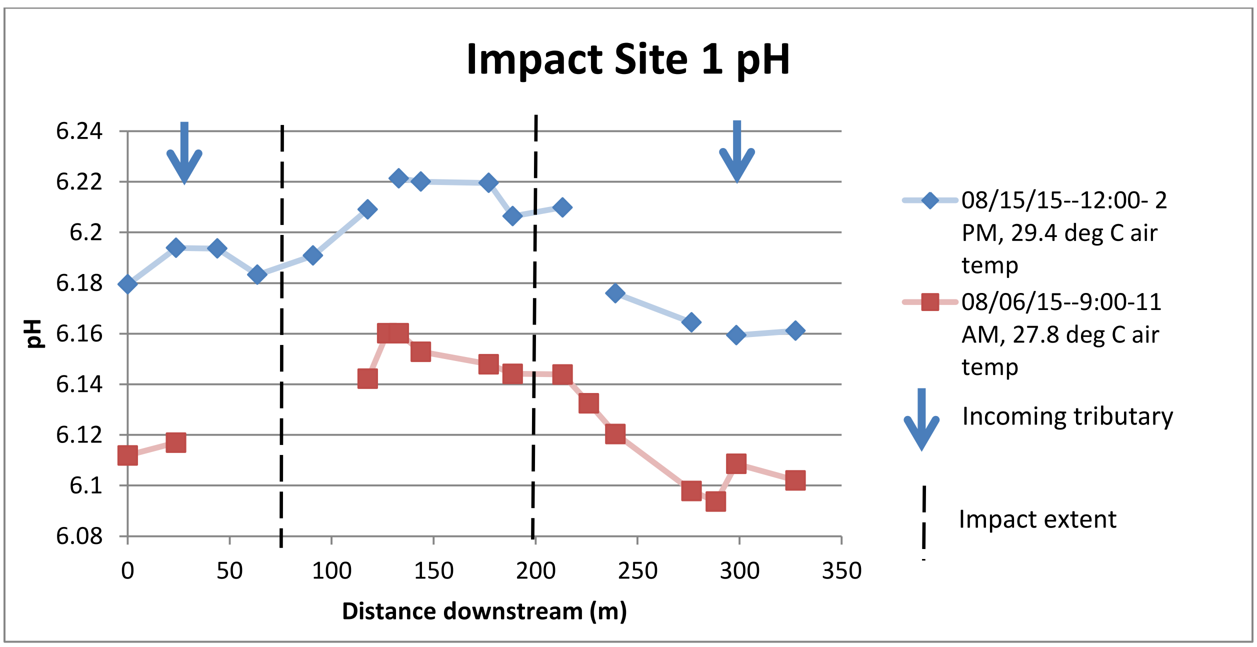


Figure 11. Impact site 1 pH measurements.

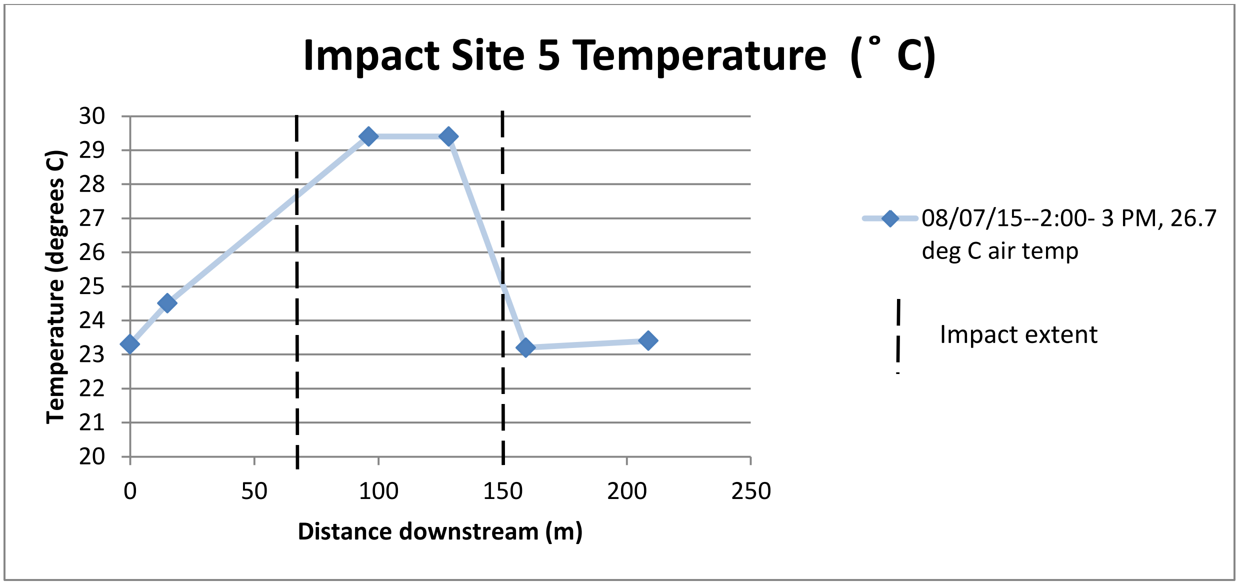


Figure 12. Impact site 5 temperature measurements.

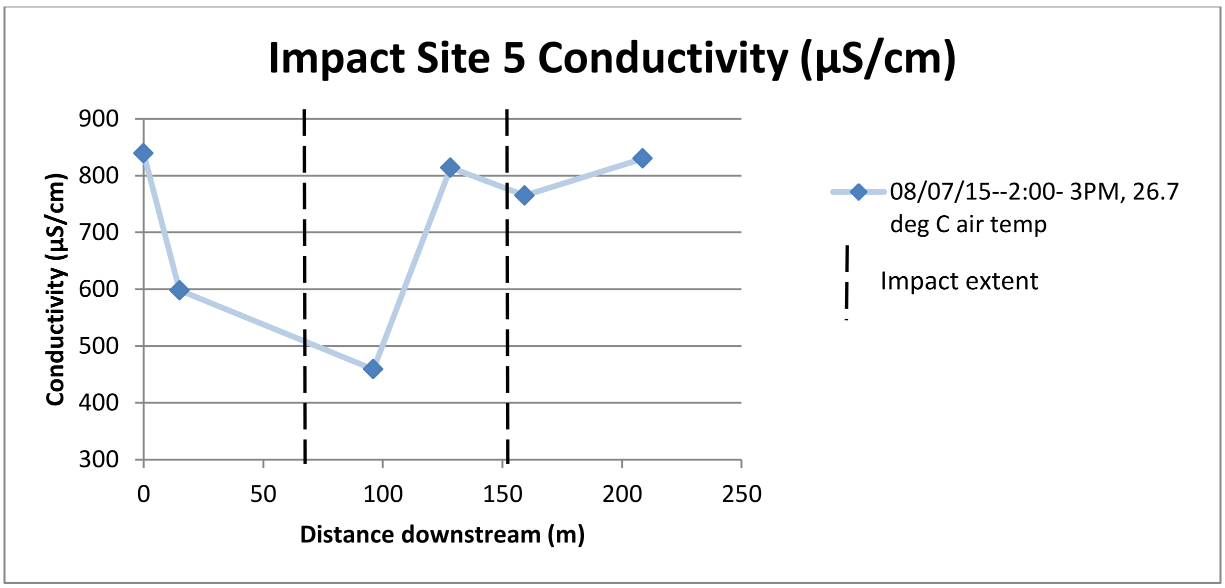


Figure 13. Impact site 5 conductivity measurements.

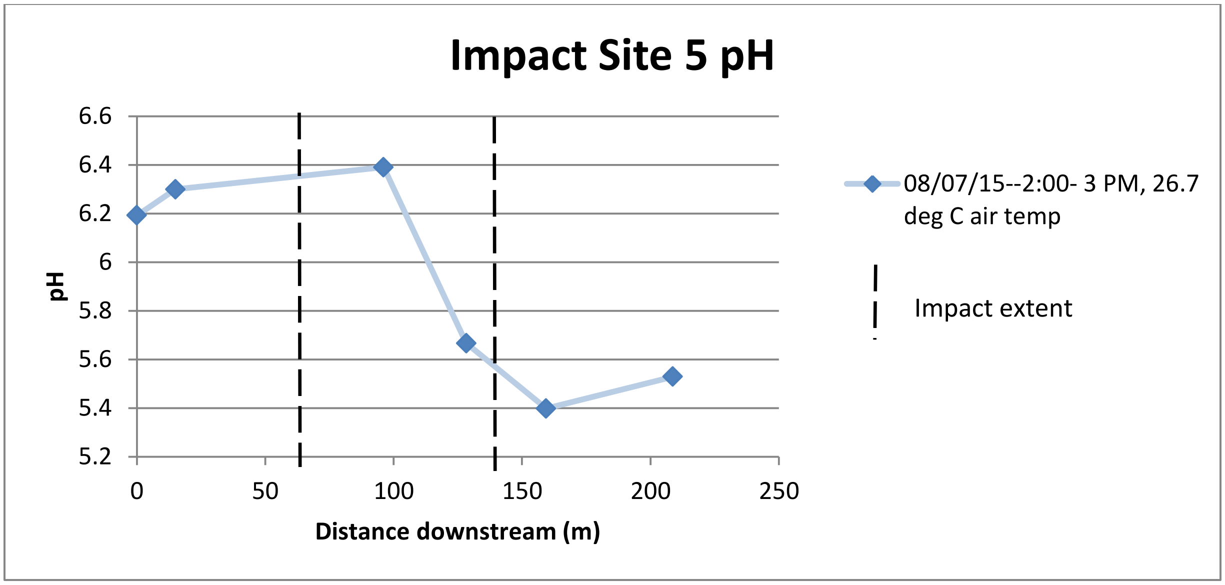


Figure 14. Impact site 5 pH measurements.

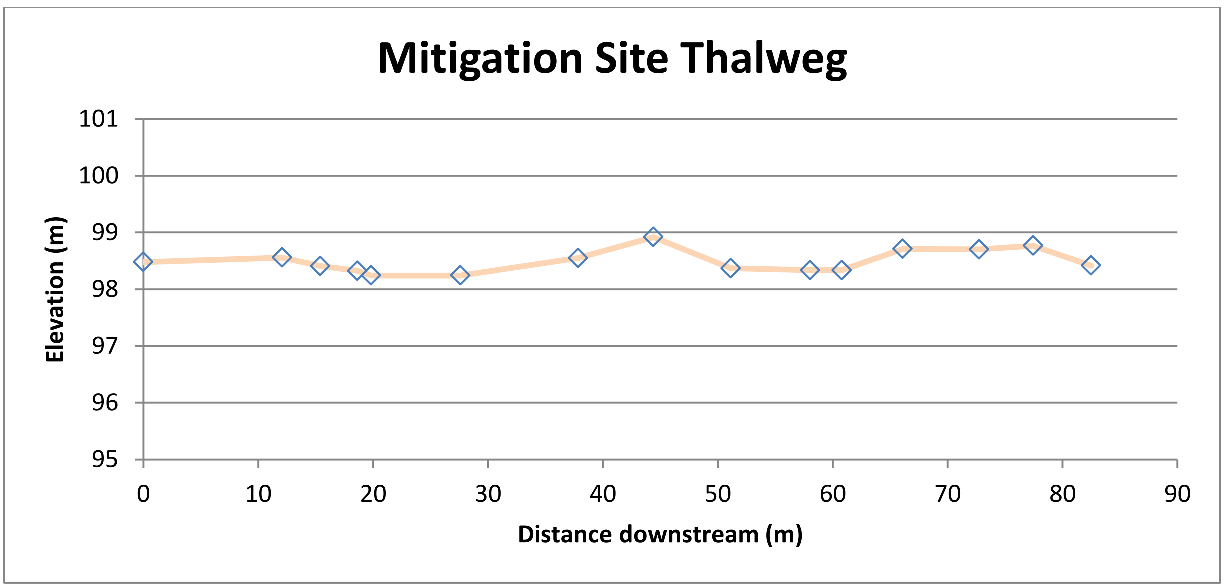


Figure 15. Mitigation site thalweg measurement.

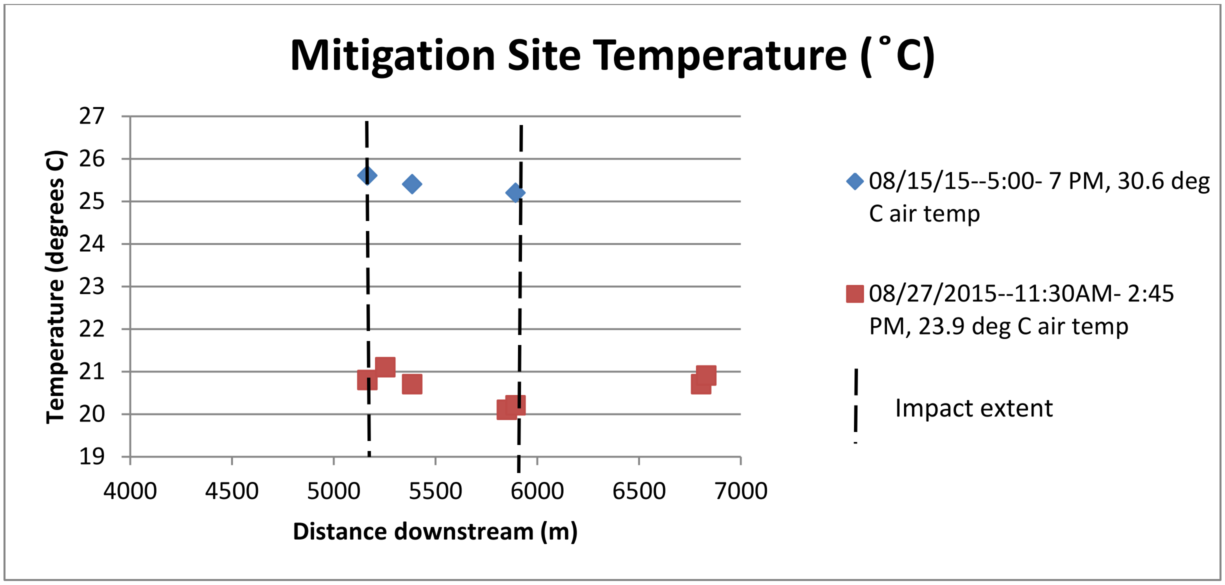


Figure 16. Mitigation site temperature measurements.

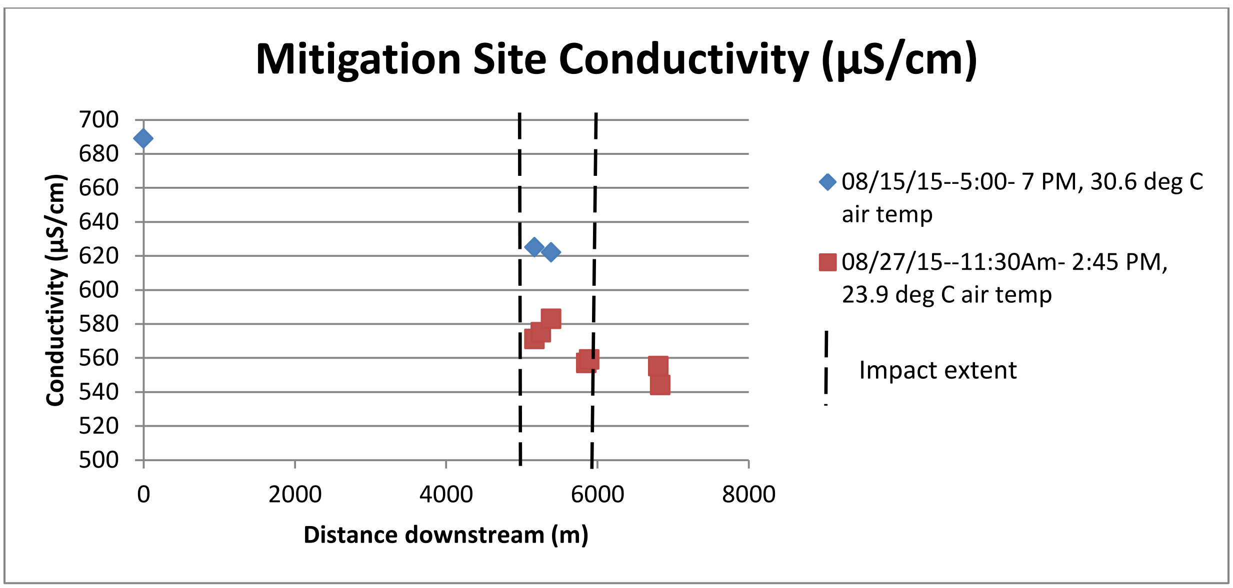


Figure 17. Mitigation site conductivity measurements.

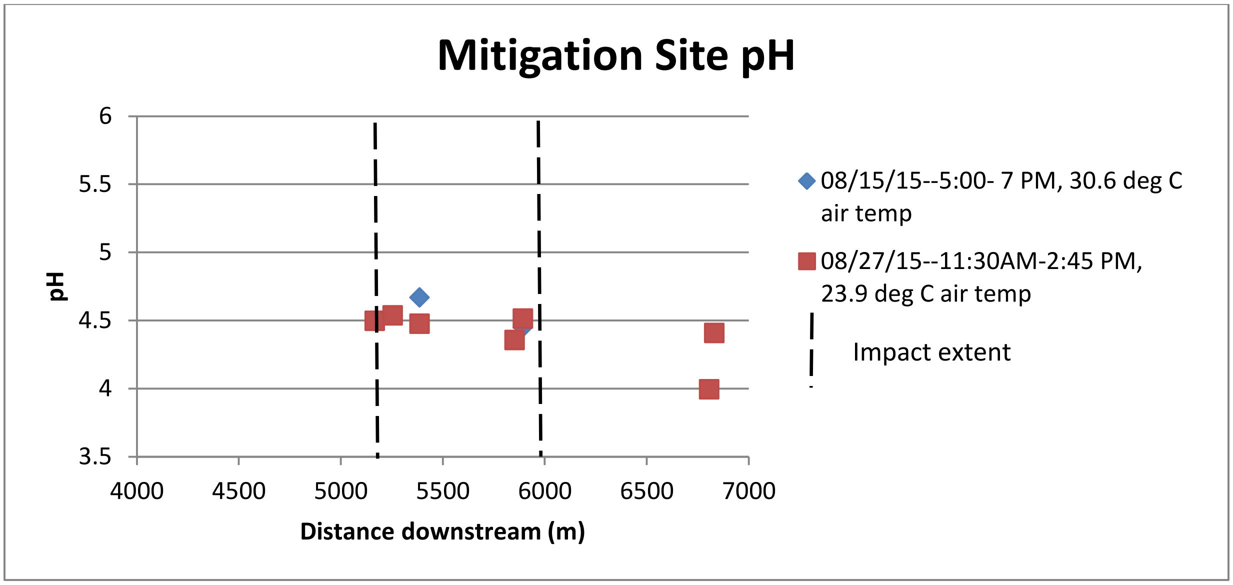


Figure 18. Mitigation site pH measurements

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