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ORIGINAL PAPER

A three-tiered framework to select, prioritize, and evaluate potential wetland and stream mitigation banking sites

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Abstract Wetland and stream mitigation programs originated to offset the unavoidable impacts to wetlands and streams from activities related to development. Until recently, most mitigation in the United States and globally was done on a case-by-case basis, with site selection based on availability. Today, systematic programs that choose sites based on structural and ecological characteristics that give an indication of the feasibility of the site for wetland and stream mitigation banking are necessary. This paper outlines a three-level framework to select, prioritize, and evaluate potential wetland and stream mitigation banking sites. The framework was tested on three ten-digit hydrologic unit code watersheds in West Virginia that were in three different physiographic regions and near proposed future road construction projects. Level 1 included a Geographic Information System (GIS) based analysis of watersheds and appropriate spatial data. Level 2 was a field reconnaissance survey of sites using evaluation criteria weighted with the pairwise comparison Analytical Hierarchy Process. Level 3 was an on-site evaluation of the highly ranked sites to verify the modeling approach. Results showed successful selection of suitable sites for combined wetland and stream mitigation banking. We found the framework to be an efficient and non-subjective way to identify and prioritize wetland and stream mitigation banking sites and has direct applications for other states or regions.

Keywords Wetland and Stream Banking Site Selection · Geographic Information Systems · Prioritization Framework

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Introduction

Wetland policy in the US has evolved from encouraging the conversion of wetlands for agriculture and development activities to newer policies that encourage wetland protection and promotion. Regulations for wetlands at the federal level originated from the Clean Water Act of 1972. Section 404 of this Act protects wetlands and waters from adverse impacts when practical alternatives exist (Voigt and

Danielson 1996). The US Army Corps of Engineers handles the permitting of Section 404 regulations and evaluates submitted permits. Authorized discharges must try to avoid adverse impacts to wetlands and streams, minimize the impacts if they can't be avoided and then compensate for the unavoidable impacts that remain. Unavoidable impacts to wetlands and streams require compensatory mitigation to replace the loss of wetland and aquatic resource functions in a watershed (USEPA 2008).

Wetland and stream mitigation banking is defined as the restoration, creation, or enhancement of wetlands or streams for the sole purpose of providing compensatory mitigation in advance of authorized impacts to similar aquatic systems (Mitsch and Gosselink 2000). Mitigation banks are designed to function in advance of development impacts to compensate for unavoidable wetland losses (NRC 2001). Credits and debits are the designated units of trade (i.e., currency) used in mitigation banking (Brown and Lant 1999). Credits denote the accumulation of wetland functions at the bank; debits represent the loss of wetland functions at the impacted site. Credits are debited from the mitigation bank when they are used to offset wetland impacts. Mitigation banks must replace the chemical, physical, and biological functions of wetlands and aquatic resources that are lost due to authorized impacts.

The U.S. Army Corp of Engineers and the U.S. Environmental Protection Agency have designated mitigation banks as the preferred means of compensatory mitigation for unavoidable wetland or stream losses (USACE-USEPA 2008a). The benefits include: being a potentially more cost effective compensatory mitigation; larger wetland sites provide more ecological value; mitigation occurs before impacts to assure it is successful; and larger mitigation sites means less project review which reduces permit processing and makes regulatory agencies more effective (Voigt and Danielson 1996). Agencies such as the West Virginia Division of Highways that need to mitigate on a regular basis are setting up mitigation banks to avoid delays in permitting. Traditionally most mitigation has been conducted on a case-by-case basis as either on-site mitigation (i.e., immediately adjacent to the proposed impact) or selection of a single mitigation project at an appropriate off-site location to compensate for a particular project. Under either of these case-by-case scenarios the mitigation does not occur until after the project has been permitted and often results in relatively small wetland complexes. However, mitigation banking allows for a wetland or stream to be functioning prior to the need for mitigation and allows for the creation of a larger wetland complex. Because mitigation banks are created and functioning prior to needing them for mitigation of a particular project they are older and thus generally are functionally and structurally more similar to natural wetlands (Balcombe et al. 2005a, b).

Although many states in the United States have mitigation banking programs established, most mitigation still occurs on a case-by-case basis (Wilkinson and Thompson 2006). Some agencies have realized the need to quantitatively and qualitatively assess streams and wetlands in project areas for selecting the best mitigation sites, particularly with the new rules emphasizing banking as the preferred mitigation alternative (USACE-USEPA 2008a). To do this, they need a site selection framework that can be used to mitigate for specific projects or to develop a backlog of mitigation credit for both streams and wetlands.

In previous studies conducted to identify mitigation wetland and stream sites, the approach has been on either a site by site impact basis or on a planned project basis (e.g., developing mitigation sites for a highway prior to construction) (Bledsoe et al. 1997; Roise et al. 2004; Berman et al. 2002; Todd 2003; Sweet 2002). Because suitable sites with high potential for success (particularly wetland mitigation sites) are often difficult to find in mountainous topography such as in West Virginia, it is important to have an effective planning program to identify and study potential sites well ahead of the activities that result in the need for mitigation sites. Also for wetlands, emphasis should be on restoring rather than constructing wetlands because of the higher success rate of restoration (NRC 2001). For stream mitigation sites it is just as critical to be able to select sites that can be effectively restored to productive natural systems.

Selection of optimal sites is a crucial component of any mitigation project that involves consideration of project goals, availability of land, and scale of selection (ELI 1994; Marble and Riva 2002). A large number of wetland areas may exist, but there is a need for site evaluation to identify possible project sites. Engineering and construction issues need to be addressed, but ecological functions of restored wetlands should be a primary factor. A watershed approach to site selection that considers entire wetland and stream systems has been recommended (USACE 2002). In 2008, the Environmental Protection Agency and the US Army Corps of Engineers developed new guidelines for how to implement compensatory mitigation for the unavoidable impacts to the nation's wetlands and streams. The update has been touted as an improvement to consistency, predictability and ecological success of mitigation projects under the Clean Water Act. One of the main changes to the final rule was a clarification of the watershed approach to wetland and stream banking. Mitigation must occur within the same watershed as the impact and where most likely to replace lost functions considering habitat diversity, connectivity, land use trends, and compatibility with adjacent uses (USACE 2008). The watershed approach to mitigation also recommends the use of existing watershed plans if available or to use information on condition and needs while considering landscape position and sustainability with a suite of functions listed so that the level of information and analysis are commensurate with impacts (USACE-USEPA 2008b).

There are three main factors that have driven the selection process at a statewide extent. The first is the general *distribution* of wetland and aquatic systems in a state or region. The second is the projected occurrence of *construction activities*. And the third factor is the *ecological uniqueness* of different aquatic and wetland systems because of the physical features that caused these areas to develop. To determine the most applicable mitigation sites requires an evaluation of efforts at several levels while including these main factors while also considering other important factors such as topography, ecological placement, construction, and economic activity.

This paper outlines a systematic, hierarchical framework to identify individual mitigation and banking sites appropriate for developing credits for both wetlands and streams. A hierarchical approach that eliminates sites at different levels of analysis allows investigators to streamline the selection process and conserve time, effort, and money.

Methods

Study site selection

We conducted our research in three watersheds: South Branch Potomac River, West Fork River, and the Guyandotte Rivers in West Virginia (Fig. 1). These watersheds had digital data available that facilitated site selection for developing mitigation banks (Table 1) and were located near areas of future planned road construction.

We developed a three-level model for selecting optimal mitigation banking sites for wetlands (Fig. 2) and streams (Fig. 3). Level 1 was a coarse filter involving the analysis of Geographic Information System (GIS) and remote sensing data. Level 2 involved field reconnaissance evaluation of the sites selected in Level 1 based on ecological, design/construction, and anthropogenic factors. Level 3 was the final selection process in which sites chosen in Level 2 were subjected to on-site stream classification and wetland delineation to determine which sites would be best suited for wetland and stream restoration and mitigation.

Geographic information system analysis—Level 1

The first stage of the banking selection model required GIS and remote sensing data analysis to

Fig. 1 Locations of the 10-digit watersheds (West Fork River, South Branch Potomac, Guyandotte River) selected for the wetland and stream banking model in West Virginia

Table 1 Characteristics of the 10-digit watersheds (West Fork River 1, South Branch Potomac 3, Guyandotte River 1) selected for the wetland and stream banking model in West Virginia

Proposed		10-Digit Watershed	
		South Branch	
Parameter	West Fork River 1	Potomac River 3	Guyandotte River 1
General Location in West Virginia	Central WV	Eastern Panhandle	Southern Mountaintop Mining Region
6-Digit Hydro Basin	Monongahela River	Potomac River	Guyandotte River
Hydrophysiographic Region or Ecoregion	Pittsburgh Low Plateau	Ridge and Valley	Southern Coalfields
8-Digit Hydro Basin	West Fork	South Branch Potomac River	Upper Guyandotte River
SSURGO Soils in digital format	Yes	Yes	Yes
Active USGS Gauges	USGS Gauges	USGS Gauges	USGS Gauges
	3058020	1608500	3202750
	3058000	1608070	3202400
	3057300		
Active Watershed Association	Guardians of the West Fork	South Branch Watershed Assoc of Hampshire County	Rural Appalachian Improvement League
Public Land	Stonewall Jackson State Park	Nathaniel Mountain and Springfield WMA[a]	Horse Creek WMA and Twin Falls State Park
Water Quality Limitation (2006 303d listing)	Sand Fork, Skin Creek, Hughes Fork, Washburn Run, all aquatic life, Stone Lick, AMD[a]	Abernathy Run, Mudlick Run, Buffalo Creek, McDowell Run, Dumpling Run, all aquatic life	Marsh Fork, Sugar Run, aquatic life, Still Run, Long Branch, Joe Branch, Cabin Creek AMD[b]

[a] Wildlife Management Area

[b] Acid Mine Drainage

identify potential wetland and stream mitigation sites in each watershed (Figs. 2, 3). For wetlands, the work consisted of first using digital soil maps (NRCS 1995) at 1:20,000 to select soils that were hydric, poorly drained, or somewhat poorly drained. Added to this spatial layer were all National Wetland Inventory (NWI) 1:24,000 mapped wetlands (NRAC 2003). These potential wetland areas were then examined more closely with color infra-red 1:12,000 Digital Ortho Quarter Quads (DOQQ) aerial photos with one meter resolution flown during leaf off of 2006. The DOQQs were used to remove areas from consideration if it was evident that development or conversion to an impermeable surface had taken place. The potential wetlands that had natural land cover or permeable surface in the aerial photos were identified and mapped for the reconnaissance team to field verify and evaluate in Level 2 of the model.

To identify stream mitigation sites we first delineated watershed boundaries for each stream segment. A stream segment was defined as a 1:24,000 scale stream between confluences of tributaries. Every uninterrupted segment in the drainage structure was used to define a watershed boundary (Fig. 4). Each segment-level or sub-watershed in our study areas was then attributed with the cumulative drainage area from its associated pour point. This was done to identify the preferred streams that drained between 1 and 130 km^2.

To assess water quality impairments present within each stream, we identified streams listed on the West Virginia Department of Environmental Protection's (2006) 303d list of impaired waters. Our objective was to identify streams that were impaired biologically due to factors such as sediment, temperature, or animal waste runoff which are more easily restored with structural improvements than those impacted from acid mine drainage or acid rain. Other information attributed for each sub-watershed included the amount of barren and public land.

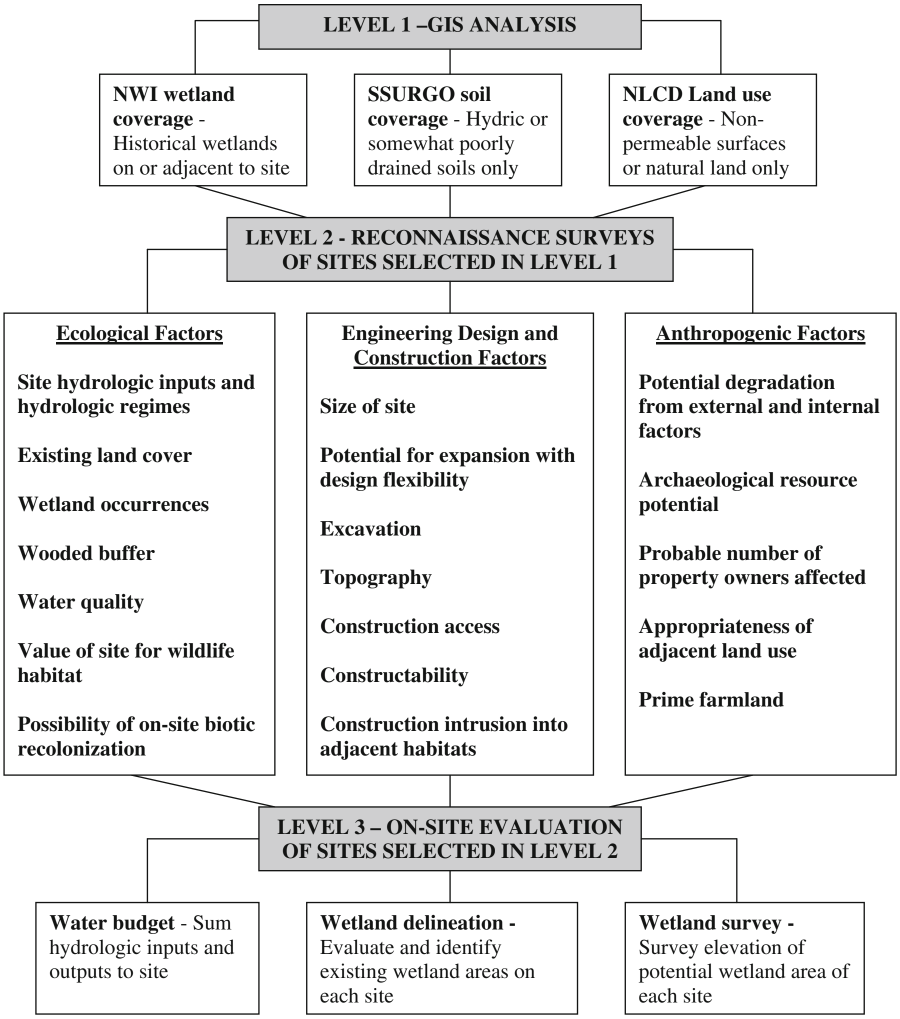

Fig. 2 Diagram of the 3 Levels of the potential wetland mitigation banking site ranking and selection model

To make this information available for the reconnaissance team, a series of maps were developed. We overlaid the potential wetlands, sub-watersheds labeled with a unique identifier and drainage area, impaired stream locations, and public land extent onto a 1:24,000 topographic map. Each potential wetland area and impacted stream segment was visited and evaluated by the reconnaissance team during Level 2 of the model.

Reconnaissance survey—Level 2

In Level 2 of the model we performed a reconnaissance survey of the potential wetland and stream mitigation sites meeting the characteristics of the requirements from Level 1. The Level 2 criteria allowed us to further narrow our list of sites for ranking. The criteria for Level 2 were derived from numerous unpublished wetland and stream design manuals and design projects that resulted in successful restorations. Fortney et al. (2001) and (KCI 1999) found the wetland criteria useful for characterizing and classifying wetlands sites for restoration while Rosgen (1996, 2001a, b) identified key stream criteria and characteristics of impaired streams when surveying sites (Figs. 2, 3). We evaluated 23 wetland criteria (Appendix A) and 15 stream criteria (Appendix B) in this step. Our list of criteria allowed for a holistic analysis by covering ecological factors, engineering design and construction factors, and

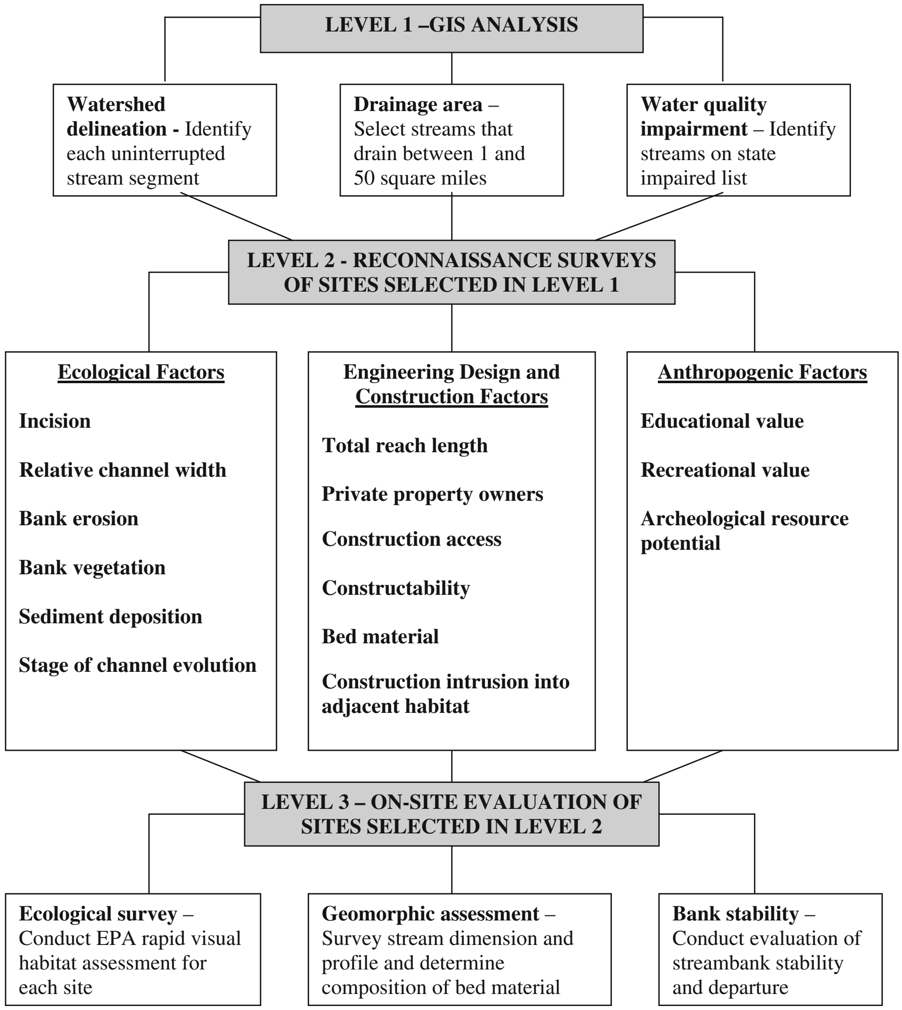

Fig. 3 Diagram of the 3 Levels of the potential stream mitigation banking site ranking and selection model

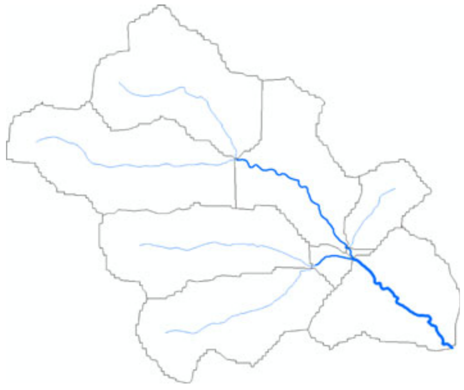

Fig. 4 An example of watershed boundaries delineated for each stream segment

anthropogenic factors. Each of these factors could be analyzed during the Level 2 reconnaissance survey and their scale of analysis also fits within the watershed approach.

We used a pairwise comparison approach—the Analytical Hierarchy Process (AHP) to derive values for criteria weights (Saaty 1980; Benjamin et al. 1992; Malczewski 1999). Using AHP, each wetland and stream mitigation scientist on our team performed a series of comparisons to create weights for each evaluation criterion. Individual pairwise tests were distributed to the project team and results were analyzed and compared using a geometric mean to develop a final stream and wetland criteria weight list

(Strager and Rosenberger 2006). Once the group representation of criteria weights was developed it was applied to the study area watersheds.

To rank potential stream and wetland sites, we implemented a multi-criteria analysis (MCA) to facilitate collaborative decision making (Munda et al. 1994; Malczewski 1999; Prato 1999). The MCA approach allows integration of preferences for attributes with objective measures of those attributes (Malczewski 1999).

Solving multi-criteria problems requires the integration of an evaluation matrix with a vector consisting of weights corresponding to the assigned priority of the criteria (Jankowski and Richard 1994; Carver 1991) (Strager and Rosenberger 2007). The evaluation matrix E and weight vector W can take the following forms:

$$E = \begin{bmatrix} f_{11} & \cdots & f_{1j} \\ \vdots & & \vdots \\ f_{il} & \cdots & f_{ij} \end{bmatrix} \quad W = (w_1, w_2, \ldots, w_i)$$

where f_{ij} is the evaluation score for each criterion, J is the set of alternatives, and I is the set of criteria. Each value is expressed with respect to the ith criterion. The basic form of the objective function can be depicted in matrix notation:

$$\begin{bmatrix} A_1 \\ \vdots \\ A_j \end{bmatrix} \text{ function of } \begin{bmatrix} f_{11} & \cdots & f_{1j} \\ \vdots & & \vdots \\ f_{il} & \cdots & f_{ij} \end{bmatrix} \text{ and } \begin{bmatrix} w_1 \\ \vdots \\ w_i \end{bmatrix}$$

where A_j is the score for alternative J.

One of the many solving algorithms in the multi-criteria literature that can be used to find a score for each site is a simple weighted linear combination (Eastman et al. 1995) noted as:

$$\text{Score} = \Sigma W_i X_i.$$

The weights were integrated with the weighted linear model to create a ranking of segment-level watersheds for wetland and stream mitigation potential. The segment-level watersheds were scored individually for wetland and stream banking opportunities by multiplying each criterion at a site by the weight determined for that criterion in the AHP comparisons. All weighted wetland criteria scores were summed to create a wetland score and all weighted stream criteria were summed to create a stream score at each site. The overall score was found by adding the wetland and stream scores at a site together. The site in each watershed with the highest value for overall score was given overall rank number one and so on. This approach allowed for a comparison of wetland and stream sites both separately and cumulatively. The sites with the three highest overall scores in each watershed were then analyzed through on-site field surveys in Level 3 of the model.

On-site evaluation survey—Level 3

The final level of analysis for the stream and wetland selection model was on-the-ground field evaluation of the highest ranked sites from the Level 2 analysis. These surveys were meant to provide a numerical description of each site, so that researchers could determine which site in each watershed was most feasible for combined wetland and stream mitigation banking. These on-site evaluations were conducted on the top three ranked sites for combined wetland and stream mitigation in each of the three major study area watersheds (Figs. 2,3).

The first step in conducting an on-site evaluation for wetland mitigation potential was to determine if any portion of the site being evaluated was already classified as wetland. We followed methods outlined in the U.S. Army Corp of Engineers Wetland Delineation Manual (USACE 1987) to delineate wetland areas on each site based on field indicators of hydrophytic vegetation, hydric soils, and wetland hydrology. The two primary axes of each wetland patch were measured and a Global Positioning System (GPS) point was taken at the center of each wetland. Area of each wetland was approximated as an ellipse and GPS locations were used to map the wetland areas at each evaluation site. Total wetland area was subtracted from the overall potential wetland restoration area that was evaluated to get an area of potential wetland restoration.

Wetland hydrology is an essential component of creating or restoring mitigation wetlands (ELI 1994). Determining hydrologic inputs to a potential wetland site is best conducted by installing observation wells and monitoring them for a year or more (Rentch et al. 2008). Unfortunately, this option was not feasible because of time and logistical constraints. Hydrologic inputs to each potential wetland site were estimated by calculating the mean annual water budget for each evaluation site. Mean annual water budget was

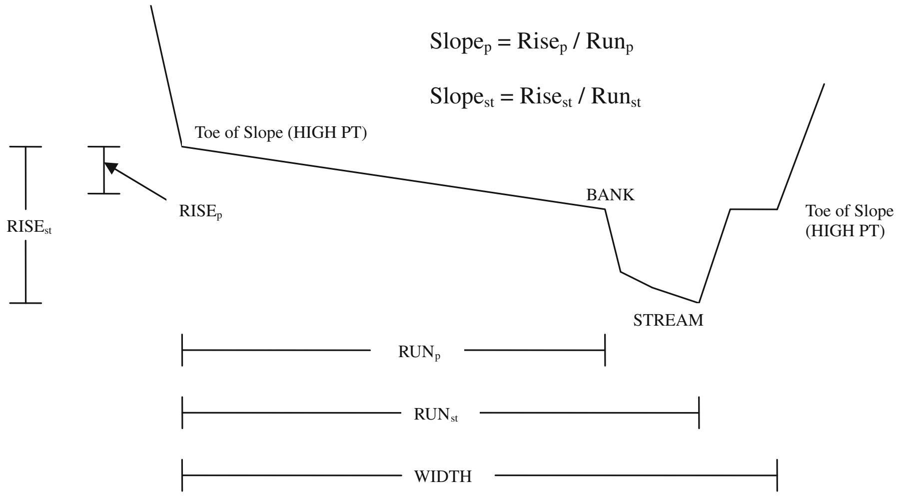

Fig. 5 Cross-sectional view of a topographic wetland survey showing the calculations of the two slope equations that were used to compare the top-ranked potential wetland mitigation sites. Width represents the width of the potential wetland site that was averaged across transects for each site

calculated by subtracting mean annual evapotranspiration from mean annual surface runoff to the site. If it was found that mean annual water budget was close to zero for a site, it was assumed that water sources other than surface runoff would be required to provide wetland hydrology to the site.

The Rational Method (RM) was used to calculate surface water runoff to each site (Fetter 2001; Gribbin 2002). For this study, we assumed that rainfall intensity was the average total precipitation per year. Based on surface area and the most common land type encompassing the majority of the study locations, the weighted runoff coefficient for unimproved land (0.20) from the American Society of Civil Engineers was used for all evaluation sites. Average annual precipitation was from the National Oceanic and Atmospheric Administration (NOAA 2003, 2004). Evapotranspiration (ET) was estimated by using data from NOAA weather stations near each watershed using standardized methods (Jensen et al. 1990; Allen 2000).

Topographic surveys were performed at each potential wetland site to determine valley slope and obtain longitudinal profile and cross-section of the area being analyzed. Contours were measured every 10 m from the primary water source to the upslope side of the potential wetland area using a laser detector on an 8.1 m rod. Readings were taken at stations 50 m apart. Average width and length of the potential wetland area were recorded during these surveys to give an approximate on-site estimate of potential restoration area. Slope across the potential wetland area from the toe of slope to the stream bank (slope$_p$) was calculated for each transect and averaged for each site (Fig. 5). The slope from the toe of slope to the stream bed (slope$_{st}$) also was calculated for each transect and averaged for each site to give an additional measure of the elevation change across the valley of each potential mitigation site (Fig. 5).

We followed the approach by Barbour et al. (1999) to quantitatively survey the ecological components of a stream and the adjacent floodplain through a series of 10 scaled parameters: epifaunal substrate, embeddedness, velocity/depth regime, sediment deposition, channel flow status, channel alteration, frequency of riffles, bank stability, vegetative protection, and riparian vegetative zone width. A full geomorphic assessment was conducted at each of the top ranked potential stream mitigation sites to quantify and compare stream dimension, pattern, and profile (Harrelson et al. 1994; Rosgen 1996). Dimension, pattern, and profile were required for proper geomorphic classification and comparison of geomorphic features among streams. For potential banking we measured cross-sections of the stream riffle every 800 m, longitudinal profile, and valley slope. The pattern of each stream was determined by measuring sinuosity, meander pattern, belt width/amplitude, radius of curvature, and dimensionless ratios for channel assessment and design (Rosgen 1996). A modified Wolman pebble count (100 pebbles) was conducted at each stream site to determine the composition of bed material in the stream (Harrelson et al. 1994). Data were analyzed to determine stream classification and condition for each of the top ranked stream reaches in each watershed (Rosgen 1996).

Streambank stability is crucial in describing the value of a stream for restoration potential (Rosgen 1996). A bank erosion hazard index (BEHI) and Pfankuch assessment of stream condition and departure were conducted on each stream to determine the potential contribution of bank sediment to the stream (Pfankuch 1975; Rosgen 2001a, b). These were relatively quick and comparable methods of determining bank erosion. An evaluation for stability and bedrock control above and below the project site was conducted using our Level 2 reconnaissance survey criteria. Several water quality parameters (temperature, pH, conductivity, specific conductance) also were measured at the downstream end of each stream and wetland evaluation site to identify if any major water quality problems existed.

Results

The soils, wetland presence, and permeable land cover data layers were combined to create a GIS coverage of potential wetland and stream mitigation banking sites. An example of a potential combined wetland and stream banking site is given in Figs. 6, 7, 8 and 9.

To maximize the area of potential wetland mitigation and length of potential stream mitigation, it was determined that all potential area along a continuous, non-branching stream reach would be combined into one potential mitigation site. Therefore, each area along a continuous non-branching stream reach was considered a potential site for evaluation in Level 2 reconnaissance surveys. Also, each combination of potential areas along a single, non-branching stream reach was combined into one potential mitigation site. All segment-level watersheds draining a single potential mitigation site, as described above, were grouped and given a unique stream code and wetland code. The grouping and selection of sites was originally performed using GIS, but some sites were re-organized due to changes in land use observed during reconnaissance surveys.

The AHP criteria weighting system was used by each individual researcher to assign importance weights to each criterion analyzed in the wetland and stream reconnaissance surveys in Level 2 of the model. The weights of each researcher for a particular criterion were averaged to come up with a single weight for each criterion in the wetland and stream surveys.

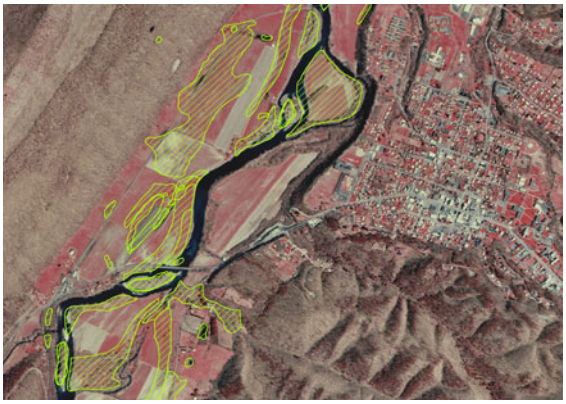

Fig. 6 The shaded areas represent potential wetland and stream mitigation banking sites for evaluation in Level 2 reconnaissance surveys. Shaded areas are a combination of SSURGO soils (NRCS 1995), National Wetland Inventory wetlands, and permeable land cover. This example is from the South Branch Potomac Watershed, West Virginia

The most optimal site in the Guyandotte River watershed was Marsh Fork, which was ranked fourth overall in the reconnaissance survey. This site had the widest, flattest, and largest valley for wetland construction. Also, Marsh Fork had the most length for stream mitigation in the Guyandotte and was adjacent to Twin Falls State Park. Moccasin Creek, the top ranked site in the reconnaissance survey, was the second most optimal site in the Guyandotte watershed. Moccasin Creek was equal to or more optimal than Marsh Fork ecologically, but Marsh Fork had significantly more area and stream length of potential area. McDonald Mill was the second highest ranked site in reconnaissance surveys and the third most optimal site for wetland and stream mitigation. The wetland area and stream banks at this site were steeper than the other two sites in the watershed, and no wetland currently exists on the McDonald Mill Creek.

In the South Branch Potomac River watershed, Mill Creek was the highest ranked site in reconnaissance surveys and the most optimal site for wetland and stream mitigation. This site was the most optimal site of the nine analyzed in Level 3 of the model because of its extensive area for wetland mitigation, gentle slope, and accessibility. The second most

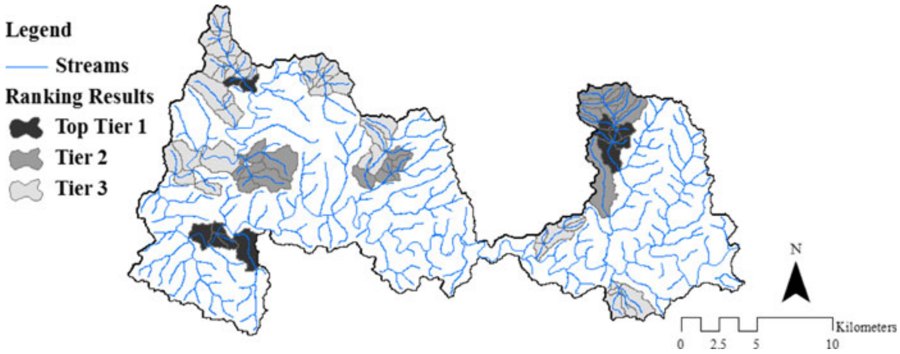

Fig. 7 Location of ranked potential wetland and stream mitigation banking sites in the Guyandotte River watershed, West Virginia

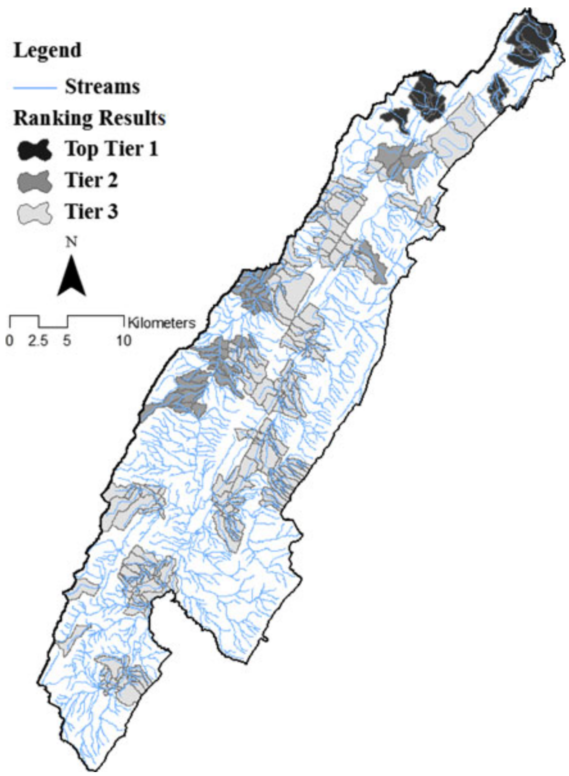

Fig. 8 Location of ranked potential wetland and stream mitigation banking sites in the South Branch Potomac watershed, West Virginia

optimal site was Stony Run, the third ranked site in Level 2 surveys. The third most optimal site in the South Branch Potomac River watershed was Tributary to Mill Creek, which ranked second in Level 2 surveys. Stony Run and Tributary to Mill Creek were well-suited for wetland and stream mitigation. Size, slope of wetland area, and stream bank slope were the only reasons these sites were considered less optimal than Mill Creek.

Wolf Fork was the third highest ranked site in reconnaissance surveys and the most optimal site for wetland and stream mitigation in the West Fork River watershed. Wolf Fork had, the most area of existing wetland, the largest area of potential wetland, and the most length of stream of any site measured in Level 3. Wolf Fork also is the only site from on-site surveys that is on public land. Linger/Buckeye Run (highest ranked in Level 2) was the second most optimal site and Straight Fork (second highest ranked in Level 2) was the third most optimal site for wetland and stream mitigation. As with the South Branch River watershed sites, Linger/Buckeye Run and Straight Fork are both viable for wetland and stream mitigation, but neither has as much area or stream length as Wolf Fork.

Discussion

There were two major outcomes of importance in this study. First, and most importantly, a convenient, non-subjective 3-level model for identifying and ranking potential wetland and stream mitigation sites was created. This model can be used in any non-coastal region that has available GIS data layers required for Level 1 site selection. The second major outcome of the project was that the model was successful in selecting and ranking specific sites in three different physiographic regions of the state that were suitable for wetland and stream mitigation. All sites analyzed in Level 3 would be feasible for wetland and stream mitigation.

The Level 3 evaluations conducted in this study were meant to validate the top ranked sites from Level 2 reconnaissance surveys and not to prepare the sites for mitigation. Much more would have to be

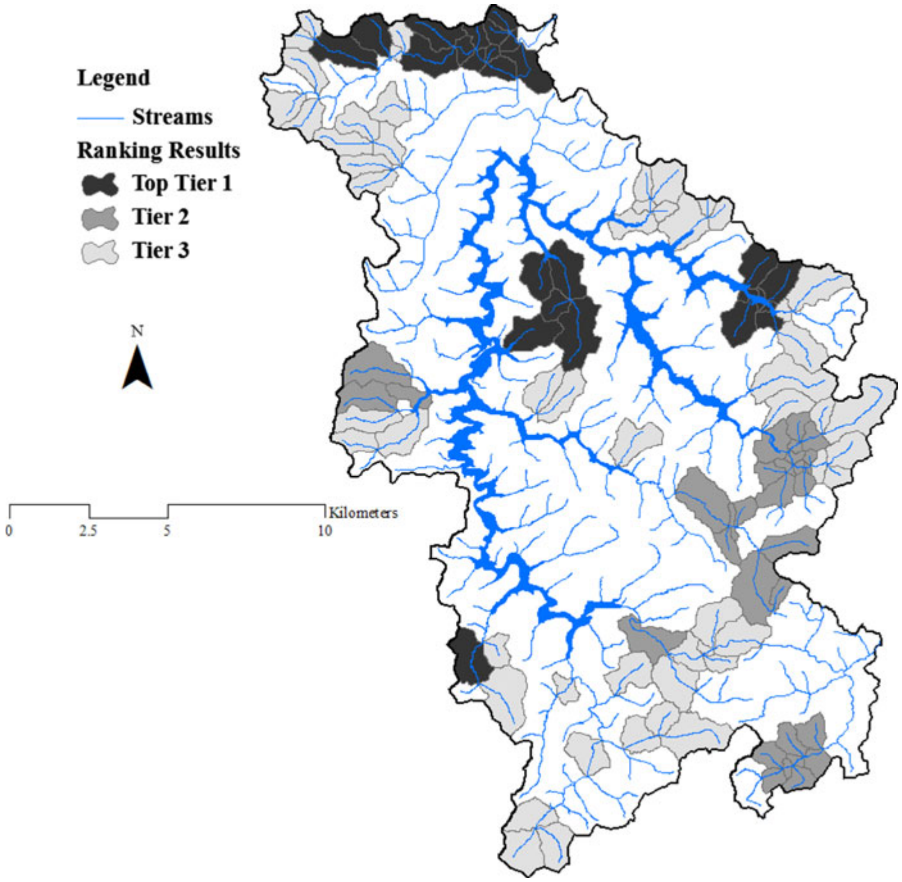

Fig. 9 Location of ranked potential wetland and stream mitigation banking sites in the West Fork River watershed, West Virginia

done on the sites before they were ready to be constructed. Landowner's permission in the form of a contract or acquisition of the land by the mitigating party would need to be established before the site could be accessed and constructed. In addition to landowner permission or land acquisition, several surveys would need to be conducted before the sites were ready for mitigation. First, wetland hydrologic inputs would need to be determined by installing observation wells and monitoring them for at least 12 months (Rentch et al. 2008). The water budget performed in Level 3 of this study gives an indication of the surface runoff to each site, but does not describe the groundwater or overbank flow of water to the site. Also, ecological surveys of wildlife and plant communities would need to be conducted to determine if any federally or state threatened or endangered species exist on the site. If so, detailed surveys of population numbers and critical habitat would need to be conducted before construction could be undertaken. A detailed topographic survey of the site by professional engineers would also need to be conducted to determine the design of the wetland and stream mitigation that would best suit the site given its physical characteristics.

It should be mentioned that Level 3 of the survey was extremely labor intensive and time consuming. If individuals using this model wish to conserve time and resources, the best recommendation would be to conduct Level 1 and 2 of the model to develop a list of ranked sites. Once this is accomplished, the user should begin to contact landowners of the top ranked sites to determine which sites will be available for potential mitigation. Acquisition and/or access permission should be established before time and resources are expended on Level 3 on-site surveys or preparing the site for wetland and stream mitigation.

Finally, we believe that there are four main implications from this work that contribute to banking at the watershed level. One, in many instances, it may be advantageous to incorporate both stream and wetlands mitigation together in one banking unit. In conjunction with efforts to develop mitigation wetlands, stream mitigation requirements can be included in some cases. Second, many wetland mitigation sites will likely be associated with streams. Using such natural stream restoration methods as those developed by Rosgen (1996), it is possible to restore stream channels to their approximate natural conditions at the same time as wetlands are being restored or constructed. Third, stream mitigation strategies may incorporate a combination of in-stream structures, bank stabilization, and channel design. This improves the economy of scale for a project and leads to an integrated project where natural interconnections between streams and wetlands can be reestablished. And fourth, this approach provided an efficient and effective means of selecting optimal wetland mitigation banking sites saving time, money, and allowing a defendable and documentable framework.

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Appendix A. Evaluation criteria used to evaluate potential wetland mitigation banking sites during Level 2 reconnaissance surveys

Ecological factors

Site hydrologic inputs and hydrologic regimes

Groundwater input

Scale	Factor
5	High probability of high seasonal groundwater table throughout the growing season
3	Moderate probability of high seasonal groundwater table during the growing season
1	High probability of high seasonal groundwater table only during winter and spring periods
0	High probability of no high seasonal groundwater table

Appendix continued

Overbank Flooding

Scale	Factor
5	High probability of a regular flooding cycle; physical evidence of flooding regime
3	High probability of regular flooding with minor construction
1	High probability of regular flooding with major construction
0	Low probability of flooding even with construction

Surface Runoff

Scale	Factor
5	High probability that adequate surface runoff occurs on the site
3	High probability of adequate surface runoff with minor construction
1	High probability of adequate surface runoff with major construction
0	Low probability of adequate surface runoff even with construction

Existing Land Cover

Scale	Factor
5	Highly disturbed (i.e. reclaimed mining land)
3	Open agricultural land (i.e. pasture, cropland, naturalized meadow)
1	Agricultural land with scattered wood lots
0	Wooded (shrub or forest) or developed land

Wetland Occurrences

Scale	Factor
5	Indicators present for historic wetlands on or adjacent to site

Appendix continued

Scale	Factor
3	Presence of wetlands on project site or on adjacent sites
0	No wetlands or evidence of historic wetlands present on-site or on adjacent sites

Wooded Buffer

Scale	Factor
5	Present and intact (>100 m) on all perimeters
3	Present and intact on more than 50% of the site perimeter
1	Present and intact on less than 50% of the site perimeter
0	Absent on all perimeters

Water Quality

Scale	Factor
5	No impairments of water sources
3	Moderately impaired water sources
0	Strongly impaired water sources

Value of site for wildlife habitat

On-site Wildlife Habitat Value

Scale	Factor
5	Disturbed (i.e. mining land)
3	Active agricultural land: cropland or pasture
1	Mixed land uses or discontinuous single natural community
0	Diverse mosaic of natural communities or continuous single natural community

Surrounding Wildlife Habitat Value

Scale	Factor
5	Multiple habitat types juxtaposed for easy movement and access by terrestrial and aquatic species
3	Single continuous natural community suitable for select species

Appendix continued

Scale	Factor
1	Fragmented patches of habitat types or fragmented single natural community creating difficult access and exposed movement corridors
0	Lack of habitat structure and variability; site dominated by open water, bare ground, or developed areas

Possibility of on-site biotic recolonization

Possibility of Hydrophytic Recolonization

Scale	Factor
5	Presence of hydrophytic vegetation on-site and on adjacent sites
3	Presence of hydrophytic vegetation adjacent to site
0	Absence of wetland vegetation in all settings

Possibility of Wildlife Recolonization

Scale	Factor
5	Presence of wetlands within 50 m of site
3	Presence of wetlands within 100 m of site
1	Presence of wetlands within 200 m of site
0	No wetlands adjacent to site

Engineering design and construction factors

Size of Site

Scale	Factor
5	Potential for site development in excess of two times the minimum size requirement
3	Potential for site development of up to two times the minimum size requirement
1	Sufficient—meets minimum size requirement
0	Inadequate—does not meet minimum size requirement

Potential for Expansion with Design Flexibility

Scale	Factor
5	Excellent flexible design capacity to support future expansion with contiguous functional wetland habitats within drainage basin

Appendix continued

Scale	Factor
3	Some flexible design capacity to support future expansion with contiguous functional wetland habitats within drainage basin
0	No flexible design capacity to support future expansion with contiguous functional wetland habitats within drainage basin

Excavation

Scale	Factor
5	No excavation required
4	<3 feet on average
3	3–6 feet on average
2	6–10 feet on average
1	10–15 feet on average
0	>15 feet on average

Topography

Scale	Factor
5	Flat
4	Gently rolling
3	Moderately rolling
2	Rolling
1	Steep
0	Very steep

Construction Access

Scale	Factor
5	Completely accessible by all equipment
4	Completely accessible by minor equipment
3	Partially accessible by all equipment
2	Partially accessible by minor equipment
1	Access can only be accomplished through major construction
0	Inaccessible

Constructability

Scale	Factor
5	High potential

Appendix continued

Scale	Factor
4	Some minor problems with construction
3	Constructible with extensive planning
2	Less constructible, greater likelihood of construction difficulties
1	Construction difficult, high risk of failure
0	Not feasible or practical

Construction Intrusion into Adjacent Habitats

Scale	Factor
5	Low potential for impacts to adjacent areas or impacts are to poor quality habitats
3	Moderate potential for impacts requiring temporary disturbance and restoration
0	High potential for impacts creating permanent disturbance to off-site areas

Anthropogenic factors

Potential Degradation due to External and Internal Factors

Scale	Factor
5	Site without intrusive adjacent land uses and impairing in situ factors
3	Site with the potential for intrusive adjacent land uses and/or impairing in situ factors
1	Site with some evidence of intrusive adjacent land uses and/or impairing in situ factors
0	Site with strong evidence of intrusive adjacent land uses and/or impairing in situ factors

Archaeological Resource Potential

Scale	Factor
5	Confirmed absence of significant archaeological site within or near mitigation site
4	Confirmed absence of significant archaeological site within site
3	Probable absence of a significant archaeological site within mitigation site
2	Probable presence of archaeological site, significance unknown

Appendix continued

Scale	Factor
1	Probable presence of a significant archaeological site within mitigation site
0	Confirmed presence of significant archaeological site within mitigation site

Probable Number of Property Owners Affected

Scale	Factor
5	Single property owner
3	Two property owners
0	More than two property owners

Appropriateness of Adjacent Land Use

Scale	Factor
5	Natural landscape with mature or developing forest cover
4	Extensive agricultural land
3	Mixed natural landscape and agricultural land
2	Mixed natural and residential land
1	Mostly residential land
0	Mostly densely developed commercial/industrial land

Prime Farmland

Scale	Factor
5	Absence of Prime Farmland soils
3	Possible presence of Prime Farmland soils
0	Presence of Prime Farmland soils

Appendix B. Evaluation criteria used to evaluate potential stream mitigation banking sites during Level 2 reconnaissance surveys

Ecological factors

Incision

Scale	Factor
5	Top of bank height/bankfull height > 2.0
4	Top of bank height/bankfull height = 1.76–2.0

Appendix continued

Scale	Factor
3	Top of bank height/bankfull height = 1.51–1.75
2	Top of bank height/bankfull height = 1.26–1.5
1	Top of bank height/bankfull height = 1.01–1.25
0	Top of bank height/bankfull height = 1.0

Relative Channel Width

Scale	Factor
5	Low flow width to toe of bank width = 0.59–0.5
4	Low flow width to toe of bank width = 0.69–0.6
3	Low flow width to toe of bank width = 0.79–0.7
2	Low flow width to toe of bank width = 0.89–0.8
1	Low flow width to toe of bank width = 0.99–0.9
0	Low flow width to toe of bank width = 1

Bank Erosion

Scale	Factor
5	Greater than 80% of channel banks are eroded
4	61–80% of channel banks are eroded
3	41–60% of channel banks are eroded
2	21–40% of channel banks are eroded
1	20% or less of channel banks are eroded
0	No erosion present on channel banks

Bank Vegetation

Scale	Factor
5	Less than 20% of banks are vegetated
4	20–39% of banks are vegetated
3	40–59% of banks are vegetated
2	60–79% of banks are vegetated
1	80–99% of banks are vegetated
0	100% of banks are vegetated

Sediment Deposition

Scale	Factor
5	Greater than 80% of bed has deposition

Appendix continued

Scale	Factor
4	61–80% of bed has deposition
3	41–60% of bed has deposition
2	21–40% of bed has deposition
1	20% or less of bed has deposition
0	No deposition present on channel bed

Stage of Channel Evolution

Scale	Factor
5	V Aggradation stage
4	IV Threshold Stage
3	III Degradation
2	II Constructed Stage
1	VI Restabilization
0	I Pre-modified Stage

Engineering design and construction factors

Total Reach Length

Scale	Factor
5	Greater than 6,000 LF
4	5000–5,900 LF
3	4,000–4,900 LF
2	3,000–3,900 LF
1	2,000–2,900 LF
0	1,000–1,900 LF

Private Property Owners

Scale	Factor
5	No private landowners along reach
4	One private landowner per 1000 LF
3	Two private landowners per 1000 LF
2	Three private landowners per 1000 LF
1	Four private landowners per 1000 LF
0	Five or more private landowners per 1000 LF

Construction Access

Scale	Factor
5	Fully accessible by all equipment
4	Partially accessible by all equipment
3	Accessible by small equipment
2	Some construction necessary
1	Access can only be accomplished through major construction
0	Inaccessible

Constructability

Scale	Factor
5	High potential for constructability
4	Some minor problems with construction
3	Constructible with extensive planning
2	Great likelihood of construction difficulties
1	Construction difficult, high risk of failure
0	Not feasible for construction

Bed Material

Scale	Factor
5	Gravel bed material (D50 = 2–64 mm)
4	Cobble bed material (D50 = 64–256 mm)
3	Sand bed material (D50 = 0.062–2 mm)
2	Silt-Clay bed material (D50 < 0.062 mm)
1	Boulder bed material (D50 = 256–2048 mm)
0	Bedrock bed material (D50 > 2048 mm)

Construction Intrusion into Adjacent Habitat

Scale	Factor
1	No functional wetlands adjacent to the site
0	Functional wetlands present adjacent to site

Anthropogenic factors

Educational Value

Scale	Factor
5	High potential for educational benefit

Appendix continued

Scale	Factor
3	Moderate potential for educational benefit
0	Low potential for educational benefit

Recreational Value

Scale	Factor
5	High potential for recreational benefit
3	Moderate potential for recreational benefit
0	Low potential for recreational benefit

Archaeological Resource Potential

Scale	Factor
5	Confirmed absence of significant archaeological site
3	Probable absence of archeological site
1	Probable presence of archaeological site
0	Confirmed presence of archaeological site

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