Implementing a long-term monitoring system on the restored Conococheague Creek following removal of Birch Run Dam

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ABSTRACT

The removal of Birch Run Dam (Adams County, Pennsylvania) in 2005 was one of more than 700 dam removals in the United States over the last ten years. The restored portion of Conococheague Creek did not receive any post-project assessments, thus it presents an excellent opportunity to study the long-term geomorphologic effects following the removal of a medium-sized dam. This work designed and implemented a long-term monitoring system (based on commonly used methods at similar sites) to better understand the evolution of the stream channel. In so doing it is hoped that lessons from this research will be readily transferrable. The original goal of the Birch Run Dam removal project was to restore the Conococheague Creek to a stable form. This monitoring system is thus, focused on characterizing the stability of the stream channel. Thorne's (1998) reconnaissance record sheets were used to guide field investigations and standardize the record. This methodology provided the necessary balance of high-quality data and efficient collection procedures. Contrary to many rapid geomorphic assessments (RGAs), this technique records raw data prior to interpretation. RGAs frequently require the user to interpret results in order to calculate a stability index. Future analysis from this monitoring system will be less vulnerable to the subjectivity of past users. Repeated measurements and observations over successive field visits should thus be comparable regardless of who performs each successive round of study.

Two study reaches were chosen to represent lengths of stream channel with distinctly different histories. The first reach was inundated by water during the life of the reservoir and then dredged and stabilized during the restoration process. The second study reach was alternately flooded and exposed; subject to deltaic deposition; and then untouched during the restoration process. Preliminary results indicate that the actively restored reach appears nearer to a stable form representing dynamic equilibrium. Extensive undercutting of the left bank may prove otherwise. The reach in the former delta is completely disconnected from the floodplain and the channel form appears to be progressing similar to that of an incised channel.

Introduction

The waterways of the United States have been fragmented and fundamentally altered during over 300 years of dam construction (Graf 1999). The physical and biological impacts of more than 80,000 dams spread across nearly every major watershed took decades to understand (Graf 1999). Although new dams are still being built (U.S. ACE 2008), older dams are more frequently being decommissioned. Potential safety hazards, negative physical and biological impacts and expired licenses are some of the most common reasons prompting dam removals (Graf 2001, 2005; Heinz Center 2002). More than 700 dams in the United States were removed between 1999 and 2006 (American Rivers 2007), suggesting that dam removal has become an important part of efforts to restore the nation's streams and rivers.

Dam removal is part of a larger stream restoration industry that has grown to $1 billion annually in the United States since 1990 (Bernhardt et al. 2005, NRRSS 2008). An assessment of the National River Restoration Science Synthesis (NRRSS) database revealed that only 10% of the restoration projects included any systematic assessment of the results of the project (Bernhardt et al. 2005). With such a low assessment rate, future project planners have relatively few opportunities to learn from previous work (Downs and Kondolf 2002; Wohl et al. 2005). Stream restoration projects which include dam removal share in this deficiency of post-project analyses (Kondolf and Micheli 1995; Tompkins and Kondolf 2007; O'Donnell and Galat 2008).

Pennsylvania, where more than 300 dams have been removed since 1999, is one of few states that are aggressively removing dams (America Rivers 2007). There is clearly an opportunity to learn from dam removal projects in Pennsylvania, yet remarkably few projects receive post-project monitoring or disseminate findings beyond those people related directly to the project (NRRSS 2008). Dam removal will likely continue in the Commonwealth as all but one of the hydroelectric dams in the Susquehanna River Basin require re-licensing before 2014 (Brownell 2008). A greater understanding of why dam removal projects succeed and fail is necessary if these types of projects are to be successful in the future. Long-term monitoring of dam removal projects will help to determine why a project succeeds or fails.

Dam removal projects are assumed to be inherently beneficial to local ecosystems (ICF 2005). They can have adverse impacts on an ecosystem by mobilizing sediment harmful to downstream fauna and flora (Stanley and Doyle 2002; ICF 2005; Cantelli et al. 2007) and fostering the colonization of invasive species (Nislow et al. 2002; Shafroth et al. 2002; Orr and Koenig 2006; Auble et al. 2007). The long-term impacts of these changes to the ecosystem are not yet understood. Restored streams require long-term monitoring covering a wide variety of discharge events (USGS 2005). The fluvial processes acting on streams occur over years, decades and centuries; therefore the long-term impacts of a dam removal cannot be observed within a single snapshot of time (Knighton 1998; Pizzuto 2002). If a permanent reference site is established, change over time and after significant events can be directly compared (Harrelson et al. 1994).

The removal of Birch Run Dam (Adams County, Pennsylvania) in 2005 prompted the restoration of over 1,000 meters of the Conococheague Creek. The goal of the stream restoration was to produce a stable channel that would not mobilize large volumes of sediment downstream. The project did not include any post-project assessment. This site is therefore, an excellent opportunity to begin to study the evolution of a restored stream channel in a former impoundment following the removal of a dam.

Purpose

Despite the widespread practice of dam removal, little data on the effects of these actions on stream recovery have been collected. This study attempts to design and implement a long-term monitoring system at a recently removed dam site. Observing and recording the stream channel form in a reproducible format will begin what is hoped to be a long-term monitoring program. Over time these data will provide valuable information on the evolution of a restored stream through a former reservoir following dam removal. This research seeks to answer the following question:

How should a post-restoration monitoring system be designed for long-term study of the Conococheague Creek at the former Birch Run Dam?

Objectives

I. Identify and construct monumented reference sites for long-term study on the restored Conococheague Creek.

II. Identify and collect the necessary information to describe the stability of the stream channel. Long-term monitoring protocols must be designed to produce results that can be replicated. Techniques should provide high quality data in an efficient fashion.

III. Report on any changes to the study reaches of the Conococheague Creek over the first four-month period of study.

IV. Disseminate the results of a dam removal stream restoration in order to encourage the spread of information regarding dam removal sites.

Literature Review

Stream Channel Stability

A dynamic equilibrium is said to exist for all streams where the processes of erosion and deposition are balanced over short and medium timescales, $10^1 – 10^2$ and $10^3 - 10^4$ years, respectively (Knighton 1998; Ritter et al. 2002). Stream channel form is not static, but varies over these time scales. (Confined channels in bedrock may appear static in the short term due to the longer time periods necessary for erosion to occur.) When stream stability is defined over a graded timescale ($10^1 – 10^2$), stable stream form will vary within a particular range (Knighton 1998).

Geomorphology defines a stream as unstable or out of equilibrium when it has changed to such an extent that it has passed a threshold where it will not return to its previous condition (Knighton 1998). Upon breaching that threshold, the previous balance between erosion and deposition is lost and one of the processes dominates. After having passed such a threshold, the stream is expected to eventually develop into a new dynamic equilibrium that reflects the new hydrologic regime, sediment supply and form (Simon and Darby 1999). Under the new physical conditions and balance of processes, stability can be re-established quite rapidly or require many years.

Stability in a stream channel depends on a system-wide balance between a multitude of factors, such as the volume/timing of the water supply; slope gradient of the channel; and sediment supply (Simon and Darby 1999). Erosion and deposition are normal, even necessary, processes in a stream channel (Leopold et al. 1964; Simon and Darby 1999; Florscheim et al. 2002; Downs and Gregory 2004). A stable meandering stream, for example, erodes material along the cut bank while material is deposited along a point bar. After enough time has elapsed, the channel will no longer be in the same location, yet the cross-sectional area of the channel is relatively unchanged. The overall planform of the stream changed in an otherwise stable system.

Relatively small, localized events that change the shape of a particular reach and thus the local balance of sediment movement can be important components of a stable fluvial system. Along forested streams, tree-falls are recognized as important elements of the channel (Dahlstrōm and Nilsson 2004). Large woody debris dissipates stream flow, can induce deposition upstream, create scour pools downstream, and provide habitat. The steady-state equilibrium experienced by these streams depends on a supply of trees without which the system would operate differently (Dahlstrōm and Nilsson 2004). The tree-fall will cause a local change to the channel (deposition and/or local scour); however when viewed over graded timescales and the entire watershed, the system remains in a dynamic equilibrium. Compared to the local effects of a tree-fall, the impact of a medium or large dam removal may be felt throughout the watershed.

Much is unknown about the stability of a stream channel following dam removal, however initial responses mimic those of incised channels (Doyle et al. 2002). The dam removal causes a base level lowering which mobilizes sediment stored in the reservoir through a process of head cut (or knickpoint) migration upstream from the former dam (Doyle et al. 2002; Pizzuto 2002). The migration of the head cut can continue upstream until resistant materials halt the migration (e.g. bedrock, another dam) or until the knickpoint has traveled up all of the tributaries (Simon and Darby 1999). Observations of two dam removals in Wisconsin found that those reaches upstream of the head cut were wide and shallow, while those stream channels where the head cut had passed were narrow, deep and had steep bank angles (Doyle et al. 2002). This pattern of incision has been observed elsewhere (Wildman and MacBroom 2005; Cantelli et al. 2007), however knowledge of the channel evolution five and ten years beyond the initial incision is still lacking (Graf 2005). Until long term measurements of channels in former reservoirs are performed and published, understanding channel adjustments through former reservoirs is aided by current knowledge on the evolution of incised channels (Doyle et al. 2002; Pizzuto 2002; Wildman and MacBroom 2005).

Channel evolution models (CEMs) were developed in an effort to understand incised stream channel forms and processes (Simon and Hupp 1986; Simon and Rinaldi 2000; Doyle et al. 2002; Wildman and MacBroom 2005). CEMs provide a general interpretation of the processes that produce certain channel forms in an unstable fluvial system. Incised streams and rivers of varying sizes will not always fit perfectly into the exact categories; however CEMs are useful tools to compare study sites. Observers of the Anaconda and Union City Dam removals in Connecticut, for example, used a CEM to track the changing channel morphology for four years following the respective dam removals (Wildman and MacBroom 2005). The channel forms were observed in an effort to understand the processes causing the evolving channel form. The CEM provided a context for describing the evolution of the channels in a manner that can be compared to past and future sites.

There are subtle differences between CEMs developed by Schumm and his colleagues (1984) and those of Simon and Hupp (1986). Both agree on the general evolution from incised channel to new stable channel. Incision of the channel bed leads to increased bank heights which serve to disconnect the channel from the floodplain. Rather than dissipate the erosive energy of the flowing water onto the floodplain, flood flows are contained in the channel which leads to further bed and bank erosion. The incised channel is then predicted to widen due to mass failures along the steep channel banks (Simon and Rinaldi 2000). When an over-widened channel results from the failure of the channel banks, the increased width-to-depth ratio of the channel slows the velocity of the water and thus the capacity of the water to transport sediment (Leopold et al. 1964; Knighton 1998). As material is deposited in the channel, a channel approaching a new dynamic equilibrium form will begin to establish alternate bars and a meandering thalweg. Following all of these adjustments, the new, stable channel will have a new 'proto-floodplain' within the over-widened channel and the former floodplain will act as a terrace (Simon and Rinaldi 2000). While many channels will progress through the model as predicted, many will not, due to unique circumstances that could not have been predicted by a single model (Simon et al. 2007).

Channel evolution models attempt to describe the evolution of incised channels across virtually every physiographic province (Leopold et al. 1964; Knighton 1998; Simon and Rinaldi 2000). The collective knowledge contained within the models was gained through years of observation and measurement of fluvial systems. The rise in stream restoration projects due to dam removals presents a new challenge in understanding the evolution of fluvial systems. It can take decades for a stream to progress from incised channels to stable channel (Doyle et al. 2002). Without direct observation of the forms and processes, CEMs provide a means of framing instability induced by dam removal through the lens of current knowledge (Doyle et al. 2002, 2003; Pizzuto 2002).

Reference Reaches in Stream Restoration

Stream channel form is the easiest and most readily available stream channel characteristic to study (Simon et al. 2007). Accordingly, popular stream restoration practices use evidence from similar streams to guide designs of new channels at restoration sites (Rosgen 1994; Hey 2006). The practice assumes that if the form of a stable reference stream can be replicated at the restoration site, then a stable, acceptable stream channel will result. This common practice, which focuses on form rather than process, can fail to account for new geomorphologic conditions that might be acting on the new stream channel (Simon et al. 2007). For example, a stream restoration project that does not account for altered discharge and/or sediment supply regimes can, despite efforts to control channel form, unwittingly create conditions that continue to be vulnerable to unstable erosion and geotechnical failures. Successful restoration projects that retain the designed form will also account for the changed inputs to the system, both direct and indirect (Shields et al. 2003).

The identification of a suitable reference reach for a restoration project within a former reservoir can be complicated by the new sediment regime. The new material forming the bed and banks is likely different than the materials that comprise the bed and banks of potential nearby reference reaches. The sediment deposited in the reservoir is typically well sorted based on the size of the particle and the velocity of the water. Coarse materials are generally deposited in a deltaic fashion and fine materials settle in slow-moving water (Morris and Fan 1997; Shotbolt et al. 2005).

Stream channels coursing through a former reservoir with stratified deposits will respond to stream energy differently than stream channels without lacustrine deposition. In an experimental flume study on the evolution of a stream channel through coarse material following a dam removal, Cantelli and colleagues (2007) observed significant incision of the channel bed followed by widening of the channel. The differences in bed and bank material between a reference reach and a project reach can be the difference between a successful and failed stream restoration (Simon et al. 2007). Stream restoration projects at dam removal sites thus need to rely on analysis of the current and anticipated controls on the new stream system.

Trends in Stream Restoration

Since 1990 a billion dollars have been spent annually on river and stream restoration projects in the United States, yet few projects are subject to post-project monitoring (Thorne 1998; USGS 2005; Wohl et al. 2005; Alexander and Allan 2006, 2007). Only the largest projects seem to include post-monitoring and large projects represent a small fraction of the total number of projects and river miles impacted (Bernhardt et al. 2005). In a review of stream restoration projects in the Mid-western United States, some sort of assessment or post-monitoring occurred on most of the projects (Alexander and Allan 2007). Where monitoring occurred, however, there was seldom pre-restoration information or stated goals to compare with the post-restoration results. Defining successful projects thus became blurred between what the public perceived as a success and the physical outcomes (Alexander and Allan 2007).

Kondolf and Micheli (1995) offer a variety of reasons for the lack of post-project evaluations, but concede that a lack of resources is frequently to blame. River managers and engineering firms are often unwilling to allocate scarce resources on a project after construction is complete (Graf 2005). Monitoring efforts are thus frequently dependent on the will of the river manager and his/her ability to make time for monitoring (Alexander and Allan 2007). Further limiting the advancement of knowledge in the field is the lack of public information on failed attempts at restoration. Indeed, the engineers and contractors of failed projects are typically unwilling to share their results. According to O'Donnell and Galat (2008), the lack of scholarship on project outcomes results in repeated project failures.

Post-project assessments (PPAs) that use 'adaptive management' techniques are well suited to the management of stream restoration projects because of the dynamic nature of fluvial systems (Downs and Kondolf 2002). 'Adaptive management' calls for a project site to be actively monitored before, during and after a project's implementation. This allows personnel to respond to immediate concerns as they occur and learn from the short-term results of the project (Downs and Kondolf 2002). The ultimate goal of PPAs is to learn lessons from a project over the short- and long-term. A failure to continue to evaluate past projects can result in lost lessons regarding the long-term changes to the stream (Tompkins and Kondolf 2007). Many researchers (Downs and Kondolf 2002; Wohl et al. 2005; Tompkins and Kondolf 2007) argue that projects without PPAs are inherently unsuccessful projects because the stream restoration field desperately needs results from projects over a variety of time scales and geographic settings.

Stream Monitoring Techniques

Resources for long-term monitoring are often scarce (Mosley 1987; Kondolf and Micheli 1995; Wohl et al. 2005). Choosing a monitoring scheme requires a trade-off between resources and the value of the information collected (Darby and Sear 2008). Repeated topographic surveys, for example, will provide high-value data with minimal uncertainty at a high cost. Conversely, repeated ground photos are inexpensive and efficient, yet yield lower value scientific information (Darby and Sear 2008).

Monitoring systems record a combination of ecological, biological, hydrological, and geomorphic-related variables. The specific variables that are observed and recorded are dictated by the goals of the project (Downs and Thorne 1996; Alexander and Allan 2006; Klein et al. 2007). The post-monitoring of a stream restoration project that seeks to increase the local fish population, for example, will count fish to measure success, but not sample macro-invertebrate diversity.

Channel geometry is one of the most common characteristics collected in studies of streams and rivers, often through the mapping of channel cross-sections (Table 1; e.g. Harrelson et al. 1994; Collins et al. 2007). Aerial imagery has been used to study stream planform (Gregory et al. 1992; Evans et al. 2007). Trees and bridges often block the view of the channel boundary, thus limiting the quality of the data collected, particularly on small streams. Aerial imagery can provide substantial information regarding fluvial systems; however, they cannot replace field-collected data in monitoring a stream or river (Hughes et al. 2006).

Stream restoration projects with biodiversity goals often measure channel geometry in addition to other biologic indicators (Table 1). The quality of habitat created by a restoration can be measured in the stream and the riparian zone (Klein et al. 2007). Water chemistry and macroinvertebrate populations offer evidence of in-stream changes (Schueler 1994). Surveys of riparian vegetation describe the habitat, and thus whether native plant assemblages are colonizing the restored habitat. The types of colonizing plants can provide clues to the water table depth. Peizometers can also be installed to directly monitor the water table depth (Klein et al. 2007). The best monitoring systems collect a variety of data types in order to thoroughly characterize the condition of the channel. River channel reconnaissance surveys provide a balance between cost, time and high value data in order to be effective at monitoring a stream (Downs and Thorne 1996; Johnson et al. 1999; Downs and Gregory 2004; U.S. DOT 2006).

Table 1. Stream monitoring techniques used at dam removal and stream restoration sites.

Study	**Ambers 2007**	**Bushaw-Newton et al. 2002**	**Chaplin et al. 2005**	**Collins et al. 2007**	**Doyle et al. 2002**	**Evans et al. 2007**	**Harrelson et al. 1994**	**Klein et al. 2007**	**Kondolf and Micheli 1995**	**Rosgen 1994**	**Simon and Rinaldi 2000**	**Tompkins and Kondolf 2007**
Primary Purpose	Dam Removal	Dam Removal	Dam Removal	Dam Removal	Dam Removal	Dam Removal	Stream Restoration	Stream Restoration	Stream Restoration	Stream Restoration	Stream Restoration	Stream Restoration
Cross-Sections	X	X	X	X			X	X	X	X	X	X
Longitudinal Profile		X	X	X	X		X	X	X	X	X	X
Mapping with Aerial Imagery						X		X			X	X
Bed Material	X	X	X	X		X	X	X	X	X		X
Bank Material	X	X		X			X	X				
Water Chemistry	X	X	X	X					X			
Water Table Depth								X	X			
Riparian Habitat	X	X	X	X			X	X	X	X		X
Fish Count	X	X	X					X	X			
Macro-invertebrate Populations	X	X	X	X				X				
RGA Rating System										X		X
CEM Stage					X						X	
Hydrologic Modeling								X	X		X	X

Rapid geomorphic assessments (RGAs) and geomorphologic classification systems were developed to provide quick and simple quantification of stream stability (Thorne et al. 1996). The original purpose of RGAs was focused on potential hazards associated with bridges and other human infrastructure built adjacent to rivers and streams (Thorne et al.

1996; Johnson et al. 1999). There are a variety of formats for the completion of RGAs (Kellerhals 1976; Thorne et al. 1996; Simon et al. 2007). RGAs, like Rosgen's (1994) popular 'Natural Channel Design' classification system, produce a stability index. These indexes weight the importance of different channel features such as bank material and angle (Simon et al. 2007). The summed scores provide the user a stability rating. These systems are useful for analyzing regional data, such as the Simon and Downs (1995) RGA that can be inputted into a GIS, however; they do not create a high-value record for long-term monitoring.

Classification systems seek to classify homogeneous units within a watershed based on a matrix of physical descriptions (Mosley 1987). Many of the variables used, such as sediment load/type, width/depth ratio, and slope, are forced into classes despite the fact that they exist along a continuum (Mosley 1987; Simon et al. 2007). While these systems are convenient for discussion, they can skew observations by leading the investigator to mis-categorize a channel based on an expected form (Simon et al. 2007). RGAs that record channel information without relying on interpretation are better for long-term monitoring because they produce objective, reproducible results. Interpreted results in the Thorne (1998) technique, for example, are accompanied by a record of the observer's confidence.

Thorne (1998) developed an RGA based on reconnaissance record sheets. The use of a standard form minimizes the discrepancy caused by repeat observations by different persons (Mosley 1987; Gregory et al. 1992; Downs and Thorne 1996). The form is flexible enough to work nearly everywhere if used carefully. Inherent to this quality is the potential for confusion where sections of the record sheets are not applicable to a study site (Thorne 1998). The Thorne technique was refined on multiple occasions to provide rapid assessment of bridges in the Mid-Atlantic region (Johnson et al. 1999) and later expanded for use in all physiographic provinces in the United States (U.S. DOT 2006). These record sheets simplify Thorne's 8-page form to 3 pages of observations solely at the bridge crossing (U.S. DOT 2006). The framework produced by Thorne (1998) succinctly balances the need to be thorough and efficient.

The dynamism of fluvial systems necessitates that investigations of a potential instability occur up- and downstream of the study site (Simon et al. 2007). The assessment thus needs to be broad enough to capture trends in the entire system, but narrow enough to identify locations requiring further investigation (Downs and Thorne 1996). The holistic nature of the reconnaissance means it cannot replace geotechnical or hydraulic studies by specialists; the assessment should, in fact, be used to identify the need for these more resource-intense investigations (Downs and Thorne 1996; Downs and Gregory 2004).

Examples of Stream Restoration Monitoring

Restoration of a wet meadow along the Lower Red River in Idaho sought to stabilize two kilometers of stream channel, restore the floodplain and riparian habitat, and increase trout and salmon populations (Klein 2004). These goals are reflected in the data collected in the long-term monitoring plan: cross-sectional dimensions, channel slope and planform, groundwater depth, summer water temperatures, vegetation recovery of the meadow, and fish populations (Klein 2004; Klein et al. 2007). The width-to-depth ratio, for example, was identified as one of 17 parameters important to the restoration project, thus the monitoring system was designed to track the cross-sectional geometry and thalweg depth of the channel (Klein 2004).

Reference reaches could not be established in the Red River due to pervasive human influence, therefore a suite of performance criteria were created for the Lower Red River Restoration Project based on ecological concepts, historical records, and hydrological data (Klein et al. 2007). Many of the changes observed between the pre- and post-restoration conditions were analyzed for statistical significance. This proved mildly useful because statistical significance was found where performance indicators had or had not been met (e.g. high and low-flow water depths). The planted willow trees, for example, are expected to cool the water temperature by shading the stream. The trees have not reached maturity, thus the water temperature has not fallen. The increase in water temperature over the three years since the restoration is not considered a failure because not enough time has elapsed since implementation. Similarly, the lack of a strong return of salmonid populations is dependent on the vegetative maturation in order to complete the necessary habitat recovery (Klein et al. 2007).

The Lower Red River Restoration Project, like many restoration projects, has a goal of a self-sustaining system (Palmer et al. 2005; Klein et al. 2007). Klein and colleagues (2007) recognized that three years of monitoring was not enough time to determine the overall success of the project. In addition to pursuing future funding to continue long-term monitoring, the final report is provided on-line (http://www.redriver.uidaho.edu) with extensive contact information for potential future investigators.

The removals of the Manatawny Dam and Good Hope Dam, in southeast and central Pennsylvania respectively, represent examples of dam removal projects that received exhaustive monitoring before and immediately following the dam removal (Bushaw-Newton et al. 2002; Chaplin et al. 2005). Neither dam impounded water beyond the banks of the stream channel. Like many small dams, the Good Hope Dam did not store a significant volume of sediment behind the barrier (Chaplin et al. 2005). Monitoring for both sites included: cross sections, longitudinal profiles, sediment grain size estimates, water chemistry analysis, surveys of benthic macroinvertebrates and fish counts (Bushaw-Newton et al. 2002; Chaplin et al. 2005). The dam removals were performed largely for habitat restoration purposes, thus the performance indicators that were measured were focused on habitat quality. At the Manatawny Dam geomorphologic parameters were only measured during the multi-stage removal process; benthic and algal surveys continued for one year following the dam removal (Thomson et al. 2005). Sediment surveys three years after the Manatawny Dam removal are cited by Thomson and colleagues (2005) based on an oral communication with a former collaborator.

These dam removal projects provide valuable insight into the immediate and short-term channel responses to small dam removals. Channel morphology was measured at five locations up to 23 months following the removal of Good Hope Dam with minimal change reported (Chaplin et al. 2005). The results remain preliminary in looking at the long-term effects of dam removal because of a study period dominated by low-flow conditions (Chaplin et al. 2005). The sediment surveys following the Manatawnay Dam removal are also said to reveal little change in the grain size of the channel bed (Thomson et al. 2005). The researchers from the Manatawny Dam removal caution that their results are tentative pending longer periods of monitoring (Thomson et al. 2005). Much like the previously discussed Lower Red River Restoration, the results of these post-project assessments reflect only the short-term responses of dynamic fluvial systems that will take many years to respond to recent changes in the hydrologic regime.

The Need for Long-Term Monitoring

Long-term monitoring of streams is not a new endeavor. A single snap shot of a stream channel provides limited information. Fluctuations in inter-annual precipitation, such as observed at the Good Hope Dam removal project, can cause low-flow or high-flow conditions for successive years prior to a return to climatic averages (Leopold et al. 1964). Studying streams over long timescales allows researchers to rule out potential causes to channel change such as weather or land use (Osterkamp and Emmett 1992). The development of CEMs was based on decades of observations and measurements of incised channels because the stream stabilization process can take decades to occur (Simon and Rinaldi 2000; Doyle et al. 2002). A thorough understanding of how streams flowing through former reservoirs evolve will also require a long-term approach.

No consensus exists regarding the size of the storm event that does the most to determine the shape of a channel (Leopold et al. 1964; Knighton 1998). The bankfull event is often used as a pivotal discharge value in stream restoration (Rosgen 1994; Hey 2006). This approach has seen quite a few failures following storms with recurrence intervals less than ten years (Simon et al. 2007). Calculations to determine the exact storm recurrence interval that will move the most sediment can be quite data intensive (Shields et al. 2003) and beyond the resources of river managers. Long-term monitoring should continue for at least ten years longer if few flood events take place (Simon and Darby 199; Tompkins and Kondolf 2007).

Archives such as the Vigil Network provide a means of storing long-term geomorphological records for future analysis. In 1962, the Vigil Network was established in order to facilitate the collection of data capable of observing long-term geomorphologic changes (Osterkamp and Emmett 1992). Two of the primary goals of the program were to facilitate long-term observations of hydrologic and geomorphologic landscape features and preserve the measured results for future generations (Osterkamp and Emmett 1992). Scientists from across the globe were invited to submit the results from their independent, stream-related research. The database currently contains geomorphic data from 83 study sites representing streams and small basins in the United States, Sweden, Israel, Botswana, and Puerto Rico (USGS 2008c). The Vigil Network database has grown slowly since its first ten years (Osterkamp and Emmett 1992), however, publication of the records on-line in 1999 may encourage expansion of the database.

In addition to the Vigil Network, there are a variety of Internet databases of stream, river and dam-related information. The Clearinghouse for Dam Removal Information

(CDRI) is a collection of dam removal-related information administered by the Water Resources Center Archive at the University of California (CDRI 2009). American Rivers (2007) maintains an on-going list of past and potential dam removal projects. The National River Restoration Science Synthesis (NRRSS 2008) was a short-term project which created a collection of information on restoration projects across the country. All of the study sites in these archives contain spatial data, yet the types of data collected by these disparate archives vary. The data types included in the Vigil Network, for example, include at least two channel cross sections from 72 of the 83 study sites (USGS 2008c). CDRI lists over 900 records from dams across the country with some dam projects limited to a single file with a date and photo (e.g. Nestle Dam in Pennsylvania) while other projects include 35 files with detailed records such as the modeling of sediment transport (e.g. Marmot Dam in Oregon). While standardization of data records would be ideal, these archives begin to collectively fill the need for publicly available information from past stream restoration and dam removal projects.

The use of long-term geomorphologic data has enabled a greater understanding of stream channel geomorphology. Fluvial systems subject to the impacts from a dam removal will require similar long-term study (Graf 2005). The use of on-line archives will aid in the collection and dissemination of long-term geomorphological data at a time when long-term monitoring is again being advocated by stream and river scientists (Kondolf and Micheli 1995; Downs and Thorne 1996; Graf 2001; Downs and Gregory 2004; Darby and Sear 2008). It took years to understand the impacts from the construction of medium to large dams; it will likely take many more years to understand the impacts of dam removal projects (Pizzuto 2002; Doyle et al. 2003b; Graf 2005).

Dam Inventory

There are over 80,000 dams listed in the Army Corps of Engineers' (2008) National Inventory of Dams (NID). Dams included in the database must meet at least one of two criteria: 15.2 meters (50 feet) tall with a storage capacity of 6.2×10^6 m^3 (5,000 acre-feet) or a dam reservoir with a storage capacity greater than 3.1×10^7 m^3 (25,000 acre-feet), regardless of height (U.S. ACE 2008). Based on the Graf/Heinz Center classification of dams, more than half of the listed dams (45,752) are considered medium-sized, like the former Birch Run Dam (Table 2, Heinz Center 2002; Graf 2005). Many of these dams are in physiographic settings that make their removal dramatically different from Birch Run Dam (such as Oregon's Marmot Dam, Majors et al. 2008). Based on a publicly available sub-set of the NID, there are 103 medium-sized dams and 21 large dams within the Blue Ridge Mountains (U.S. ACE 2008).

Table 2. A sample of the number of dams in the Blue Ridge Mountains and adjacent physiographic provinces based on size (dam data from U.S. ACE 2008; physiographic province extents from USGS 2008b). The number of dams represents a publicly available sub-set of the U.S. Army Corps of Engineers' database of dams. The Graf/Heinz Center classification of dams is based on the normal storage of the reservoir. The corresponding volumes between units of measure are intentionally approximated by the original author (Heinz Center 2002; Graf 2005).

Dam Size Category	**Reservoir Storage acre-feet (meters³)**	**Number of Dams from Sample (Percent)**	**Appalachian Plateau**	**Ridge and Valley**	**Blue Ridge**	**Piedmont**
Small	< 10^2 (< 10^5)	200 (12.4%)	73	11	41	75
Medium	10^2 - 10^4 (10^5 - 10^7)	989 (61.1%)	406	227	103	253
Large	10^4 - 10^6 (10^7 - 10^9)	396 (24.5%)	187	63	21	125
Extra Large	> 10^6 (> 10^9)	33 (2.0%)	3	18	5	7
Total		1,618	669	319	170	460

The majority of dams in the Appalachian Plateau, Ridge and Valley, Blue Ridge, and Piedmont are medium-sized based on the sub-set (61.1%; Table 2). The sub-set of the NID represents 10% of the total NID (8,121 dams). The former Birch Run Dam and the upstream catchment are located within the Blue Ridge physiographic province (USGS 2008b). The Blue Ridge is distinguished by metamorphic and igneous rocks forming medium-relief (50-250 meters) rugged terrain (Thornbury 1967). Low rates of uplift, low-moderate relief and crystalline bedrock contribute to low denudation rates in the central Appalachian region (McLennan 1993). The rate of sedimentation in reservoirs is thus expected to be less severe as compared to areas experiencing greater denudation (such as in the Coast Mountains of British Columbia, Campbell and Church 2003). Birch Run Dam is, thus, typical of many such medium-sized dams of the central Appalachians.

Dam Removal

Many scientists (Graf 1999, 2001, 2005; Babbitt 2002; Heinz Center 2002; Pizzuto 2002; Walter and Merritts 2008) have called for greater research on a host of different dam removal-related issues. Examples of specific research needs include the role of dam removal in floodplain communities and the response of vegetation (Nislow et al. 2002; Shafroth et al. 2002), channel capacity downstream of the removed dam (Chin et al. 2002), and the potential erosion of the deltaic deposit upstream of the dam's reservoir (Cantelli et al. 2007). The fate of the sediment that accumulated behind the dam is of great concern to researchers, river managers, and the public (Heinz Center 2002; Cantelli et al. 2007; Cheng and Granata 2007; Evans et al. 2007). Analogies, such as a channel's response to base level lowering, have been used to predict a stream channel's response to dam removal (Doyle et al. 2002, see also the discussion Thornton 2003; Doyle et al. 2003; Pizzuto 2002).

Construction of new dams has all but ceased, while dam removals are on the rise (Graf 2001; Chin et al. 2002; U.S. ACE 2008). There are an approximated two million small dams in the United States (Poff and Hart 2002), of which over 5,000 are in Pennsylvania (Walter and Merritts 2008). Given these numbers it is no surprise that the majority of dams that are removed or breached are small, run-of-the-river type dams (Poff and Hart 2002). Of the more than 300 dams removed in Pennsylvania since 1999, only twelve were at least ten meters tall (American Rivers, 2007). The removal of Birch Run Dam was thus unusual for Pennsylvania, where medium and large dam removals are relatively rare.

The lack of post-project monitoring at the Birch Run Dam removal project is not unusual. The National River Restoration Science Synthesis cites Pennsylvania as an example of a state with aggressive dam removal and stream restoration practices, yet poor post-project monitoring data collection (NRRSS 2008). Medium to large-sized dam removals are less frequent, however, they have the greatest risk of failure due to the large volumes of stored sediment (Fan and Morris 1997; Doyle et al. 2005). Such projects present critical opportunities for evaluating dam removal techniques. The successful completion of future medium to large-sized dam removals depends on learning from past projects.

Summary

Streams are part of dynamic systems that cannot be thoroughly understood with a single snapshot. Conclusions regarding the stability of a channel cannot be made without investigating the forms and processes occurring up- and downstream of the subject reach. Changes in the form of a stream reach may be within the range of stable forms for the channel or the change in form may be indicative of a change to the system leading to instability (e.g. paving the catchment). Fluvial geomorphology is studied at differing scales, time and space, in order to understand how changes to local form fit into the context of the entire system (Knighton 1998; Ritter et al. 2002). Successful stream restoration projects use knowledge of the entire fluvial system in question. Viewing a stream channel without the context of the entire fluvial system can lead to false conclusions.

Despite the best efforts of stream scientists, restoration projects are not always successful (Bernhardt et al. 2007). Projects that have failed to meet the intended outcomes are seldom publicized and the reasons for the respective failures often go unreported due to a lack of post-project analysis (Wohl et al. 2005). Stream and river restoration projects are taking place in every physiographic province in the United States, thus lessons from project sites are not directly transferable to every other project. The paucity of sites with post-project monitoring combined with the wide variety of geomorphologic conditions translates into too few opportunities to learn from past experiences (O'Donnell and Galat 2008). Our accumulated knowledge regarding channel evolution models (Simon and Rinaldi 2000) was gathered over repeated, long-term observations of study reaches. Stream restoration projects, especially those including dam removal, that do not include a system of long-term monitoring are depriving future restoration practitioners of potential learning opportunities (Kondolf and Micheli 1995).

The designed removal of dams in the United States is a relatively new undertaking (Pizzuto 2002). Given aging infrastructure and an increasing understanding of the biological impacts caused by dams, the moderate pace of dam removals is likely to continue (Poff and Hart 2002; Graf 2005). There is limited knowledge of how a system will respond immediately following dam removal and no information on dam removals over the time scales needed to identify dynamic equilibrium (Pizzuto 2002; Graf 2005; Evans et al. 2007). Dam removal and base-level lowering have analogies in fluvial geomorphology (Doyle et al. 2002), yet requires empirical, long-term study in order to understand the overall impacts.

Study Area

The former Birch Run Dam and Chambersburg Reservoir in Adams County, Pennsylvania were chosen for this research because the dam was recently removed (2005); the site is accessible for study; and the project has not received post-project monitoring or assessment (Johnston, T.W.[1], personal communication). The former Chambersburg Reservoir was filled by in-flow from the Conococheague Creek (39° 55′ 08″ North, 77° 27′ 16″ West; Figure 1). The Conococheague Creek receives in-flow upstream of the reservoir from Birch Run and Long Pine Run. The total catchment upstream of the former dam is 35.7 km^2 (13.8 $mile^2$); 55% (19.8 km^2) of the catchment area is upstream of the Long Pine Dam (Figure 1). The watershed above the former dam is largely covered by hardwood forests in the Michaux State Forest with a small fraction of land cover devoted to roads and private residents.

The watershed is located within South Mountain in the Blue Ridge physiographic province of south-central Pennsylvania (Thornbury 1967). The linear ridges largely consist of early Cambrian-aged Weverton quartzite with slopes and valleys underlain by the Harpers Formation, also of early Cambrian age (Fauth 1968). At the surface, the Harpers Formation appears as coarse sandstone that weathers to a pale orange color. The valley floor is covered with alluvial deposits (Fauth 1968).

The region receives 1,118 mm (44.0 inches) of precipitation annually and the Conococheague Creek has an average discharge of 0.207 cms (7.3 cfs) or 6.5×10^6 m^3yr^{-1} (1.7 billion gallons) as measured at the Chambersburg Water Authority's raw water in-take 1.3 km downstream of Birch Run Dam. The Chambersburg Reservoir behind Birch Run Dam served as a water supply for the residents of Chambersburg, Pennsylvania from 1933 until it was drained in 2005 (Johnston et al. 2005). The Birch Run Dam was 213.3 meters (700 feet) across and 19.8 meters (65 feet) tall. The earthen-fill dam held back a reservoir covering 22 ha (54 acres) with 6.8 x 106 m^3 (508 million gallons) of water (PA DEP Inspection Reports dated, 15.October.1998 and 31.October.2003).

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[1] The Chambersburg Water Authority retained Gannett Fleming, Inc. as the engineer for the maintenance and eventual removal of Birch Run Dam. Johnston, Timothy W. was the lead engineer on the removal project.

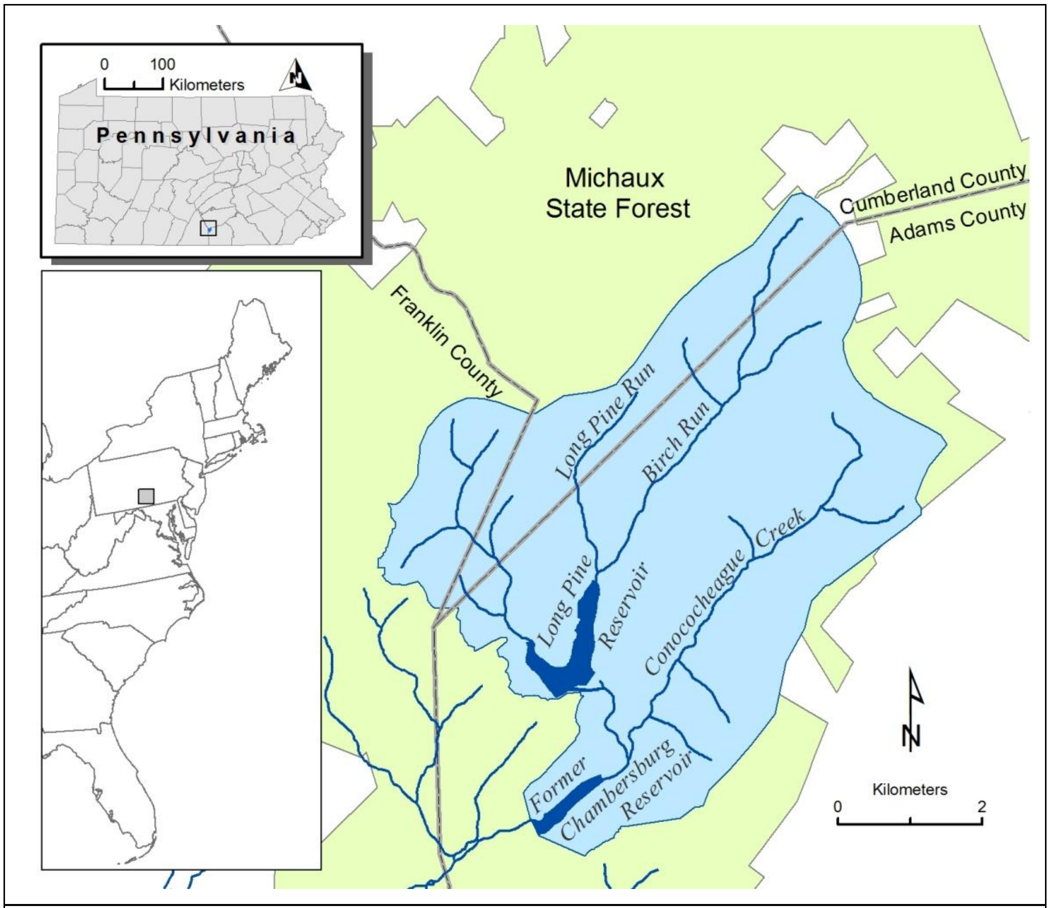

Figure 1. The Conococheague Creek and the catchment for the former Chambersburg Reservoir in Michaux State Forest (Adams County, Pennsylvania). (Hydrologic units from USGS 2008; Forest boundary from ERRI 1998; political boundaries from PA DOT 2008.)

Reasons for Dam Removal

Beginning in the late 1970's, the U.S. Army Corps of Engineers identified safety concerns including uncontrolled seepage of water through the dam and inadequate spillway capacity (Johnston et al. 2005). In 1982 monitoring peizometers were installed to track the volume of water flowing through the dam as well as drainage facilities to channel water from known seepage areas to the Conococheague Creek downstream (Table 3). These measures did not seek to stop or slow the movement of water through the dam (Johnston et al. 2005). Inspections by the Pennsylvania Department of Environmental Protection (PA DEP) Bureau of Dam Safety also cited spalling of the pump tower and the spillway cement walls and floor as safety concerns (PA DEP Dam Inspection Report dated, December 1997).

Table 3. Timeline for the former Birch Run Dam and Chambersburg Reservoir in Adams County, Pennsylvania.

Date	**Event**
1933	Construction begins on Birch Run Dam. A large storm washes out construction and construction begins anew (Alternatives Report, 2000).
September 1960 - March 1981	USGS operates stream gage upstream of damn, near Fayetteville, site no. 01614090 (Feasibility Report, 2001).
1982	DEP installs peizometers to monitor the movement of water within the dam and begins monitoring uncontrolled seepage through constructed drainage weirs (Johnston et al. 2005).
Late 1980's	DEP requests a draw down while the Chambersburg Water Authority debates alternative options (letter from Borough dated, 29.January.1999).
15.October. 1998	Annual DEP inspection notes that the reservoir water level was reduced 3.7 m (12 ft) below the capacity elevation of 332.2 m (1090 ft).
30.June.2000	Temporary draw down at a rate of 7.6 – 15.2 cm per day in order to reduce the water elevation by 7.6 m (25 ft). Severe vibration in outlet works and flushing of reservoir sediment slows draw down rate (letter from Gannett Fleming dated, 04.August.2000).
01.July.2002	DEP orders approval to proceed with plans to breach Birch Run Dam (letter from DEP Division of Dam Safety dated, 01.July.2002).
Summer 2004	Chambersburg Reservoir behind Birch Run Dam drained after DEP dam inspection (dated, 18.June2009).
17.September. 2004	Hurricane Ivan drops 63.5 mm (4.5 in) of rain on the watershed causing a significant rise in an otherwise empty basin while the 30-inch outlet pipe was 100% open (Contract Document prepared by Gannett Fleming, February 2005).
17.August. 2005	Inspection by DEP (dated the same) notes the breach in the dam is completed, "No work on the dam or the historic channel was being done." Photos (dated the same) show the stream diverted into the outlet pipe and ponding upstream of coffer dam at breach.
31.October. 2005	DEP inspection (dated the same) notes construction complete except for erosion problems relating to the dam embankment and spillway approach area—these issues delayed the "Final Report."
01.February. 2006	The "Dam Breach Completion Certificate" is signed. No further assessment or oversight occurred at the site by DEP, the contractor or the engineering company (Johnston, T.W., personal communication).

Pennsylvania DEP encouraged the Chambersburg Water Authority to reduce the water level in order to allow for research into alternatives and to potentially reduce the water pressure that was suspected of forcing water through the drainage works (PA DEP letter dated, 7.September.1999). As early as 1998 the Borough agreed to maintain the Chambersburg Reservoir 4.6 m (15 ft) below capacity with the understanding that the reservoir was prone to filling rapidly during/after storm events (Borough letter to PA DEP dated, 29.January.1999). Inspections in the fall of 1999 indicated that the water level had not been reduced more than 1.0 meter (PA DEP letter dated, 7.September.1999).

In 2002 DEP approved plans to remove Birch Run Dam at the end of summer in 2003. The final draw down approval from the PA Fish and Boat Commission took place on 16.August.2004 (PA Fish and Boat Commission permit, 2004). The reservoir was drained in 2004 by reducing the water elevation by 15 – 30 cm per day (Contract Document, prepared by Gannett Fleming February 2005). The draw down rate was previously approved by the PA Fish and Boat Commission during prior draw downs to avoid harming the fish populations downstream (e-mail from Gannett Fleming dated, 18.May.2000). Previous attempts to draw down the reservoir resulted in uncontrolled vibrations of the pump tower when the outlet works were open 30-40% of capacity (Gannett Fleming letter to DEP, dated 18.May.2000). After the reservoir was drained, the Conococheague Creek was routed to the outlet works with an in-stream diversion 190 meters upstream from the dam (Figure 2).

Stream Channel History

Over the nearly 70-year history of the reservoir, the elevation of the water regularly changed due to variations in precipitation, especially drought. The depositional environments for the former (and future) channel were dramatically different along the 1,193 meters of inundated valley (at the normal reservoir depth, 332.8 m). Those reaches nearest the dam were below the slowest-moving water and thus largely experienced the deposition of fine-grained material. The upstream reaches, however, were subject to the deposition of sands and coarse grained materials (Figure 3), much like a deltaic environment (Ritter et al. 2002; Cantelli et al. 2004; Shotbolt et al. 2005).

During the life of the reservoir, the reach passing through the sandy delta appears to have been conveying water into the reservoir as a stream mouth or stream channel. When the reservoir was at or near capacity, the water slowed down enough to deposit sands. During periods of low water elevation (i.e. drought or draw downs) this reach was an active stream channel. As the water level of a lake rises and drops, there is a sloshing or mixing action that can churn non-cohesive sediment at the shorelines (Shotbolt et al. 2005). Erosion and mixing of the deltaic deposits likely occurred along the shorelines of the reservoir.

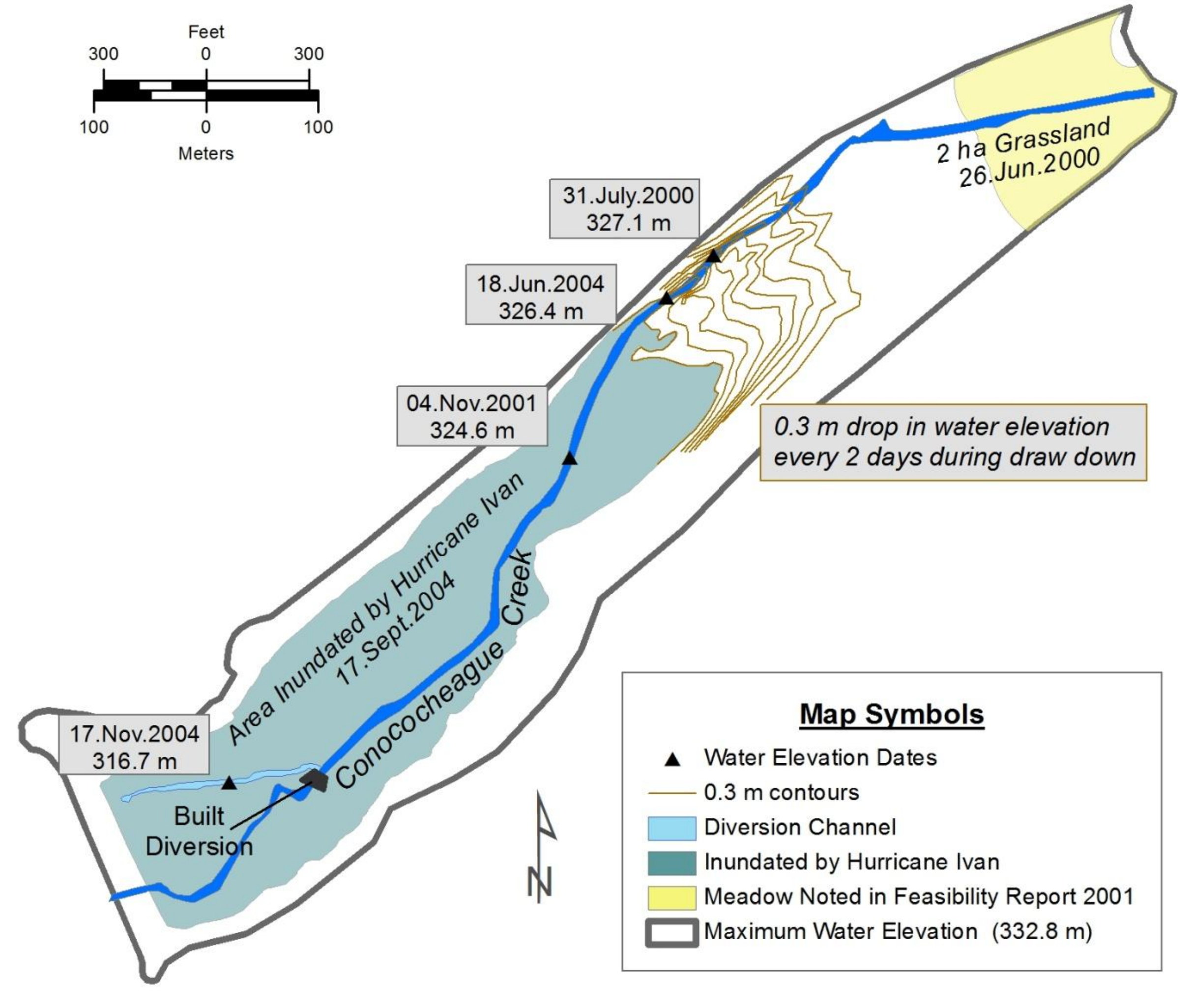

Figure 2. A graphic illustration of the different events that altered the deposition and erosion of the Conococheague channel. The uppermost reach of the stream, in the area of deltaic deposits, was observed as a sandy grassland during a DEP inspection (dated, 26.June.2000). The incremental exposure of the valley and stream channel during the draw down is illustrated with contours representing the changing waterline every two days. Individual measurements of the reservoir depth (DEP inspections, as dated) describe the varying lengths of the channel exposed over the lifespan of the Chambersburg Reservoir. The length of stream channel upstream of the diversion was exposed to a ten-year storm (Hurricane Ivan) and partially inundated.

The reach of the Conococheague Creek entering the reservoir was exposed to the erosive action of flowing water over greater periods of time than the remaining reaches within the former impoundment. In 2000 PA DEP inspectors found approximately 2 ha of exposed, sandy soil with grasses at the uppermost end of the reservoir during a six-meter draw down (DEP inspection dated, 26.June.2000; Figure 2). As the reservoir was drained in 2004 prior to the decommissioning of Birch Run Dam, new sections of the channel were incrementally exposed and subject to erosion and deposition. Based on a mean valley slope of 0.013 (based on a Digital Elevation Model, USGS 2004), approximately 23.4 linear meters (76.9 ft) of stream channel and valley floor were exposed with every drop of 30 cm in water elevation (Figure 2).

Figure 3. An example of the material deposited near the upstream extent of the former Chambersburg Reservoir behind Birch Run Dam. The image is looking upstream along the right bank of the Conococheague Creek (author's image dated, 07.May.2009).

After the reservoir was drained, the stream was diverted away from its current path and through the outlet works of the dam (Figure 2). During the period between the draw down in 2004 and the channel activation in 2005, the length of stream channel from the diversion to the breach did not experience the same variety of discharge events as the remainder of the stream. On 17.September.2004 the remnants of Hurricane Ivan passed over the watershed and dropped 63.5 mm (4.5 in) of rain in 24 hours (a storm with a ten-year recurrence interval; National Weather Service 2009; Pennsylvania State Climatologist 2009). Although the outlet pipes in Birch Run Dam remained completely open, the water elevation rose to approximately 327 m, nearly 9 m (30 ft) behind the dam (Chambersburg

Water Authority Meeting minutes dated, 27.September.2004; Contract Documents composed by Gannett Fleming, February.2005). Only the 1,062 meters of stream channel upstream of the diversion were subject to the erosive forces of this event. The constructed reach has had a distinctly different formative history than the remaining reaches within the former impoundment, before and after the Chambersburg Reservoir was drained.

Figure 4. Image of the re-constructed Conococheague Creek channel after activation (DEP file photo dated, 1.February.2006). This image was used as photographic evidence of as-built conditions in order to submit a "Dam Breach Completion Certification" to DEP.

The primary goal of the stream restoration was a stable stream channel (Johnston et al. 2005). Project documents indicate that a stable stream is one that does not entrain significant enough sediment to cause environmental degradation or structural damage downstream. The raw water intake for the Chambersburg Water Authority operates less than a mile downstream of the former dam. Restoration of habitat for native plants and animals does not appear to have been a significant concern to the engineers (Contract Documents composed by Gannett Fleming, February 2005). The stream channel was dredged and stabilized from the diversion to the breach in the dam. The channel was designed to have a bed width of 4.9 m (16 feet) based on downstream reaches and the streambank slope gradient ratios were not to exceed 2.0H:1.0V (Figure 4; Contract Documents, February 2005). Constructed stream banks were stabilized with grass seed prior to activation (Johnston et al. 2005).

Summary

Mounting safety concerns prompted the decommissioning of the Birch Run Dam in 2005. The long history of monitoring at the site promptly ceased when the safety threat was relieved with the breaching of the dam. The engineers on the project met their legal responsibilities by restoring the Conococheague Creek and have not returned to the site. As one of the few medium or large sized dams to be removed in the eastern United States, the site presents an excellent opportunity to study the evolution of a stream through a formerly inundated valley. Scientific investigations seek to control the variation amongst parameters not specifically under study. Despite the presence of a dam upstream, this site may be considered a virtual 'control site' to be compared against future research due to the largely forested upstream catchment.

The un-restored reaches of the stream provide an opportunity to study the evolution of channel form without restoration activities. Long-term study will detail whether streams forming in deltaic deposits evolve in a similar fashion to incised channels or follow a different pattern. The stream channel between the diversion and the former dam had a completely different depositional history than the upstream reaches, furthermore; it was dredged to a specific size and then stabilized. The restoration can be considered a success if the reach remains stable without mobilizing high volumes of sediment. The long-term evolution of this channel will provide future practitioners a learning opportunity that can aid in the successful restoration of future streams following dam removal.

Methods

The long-term study of a site is rarely done by a single person, thus the data collection require common methodologies that are easily replicated by a variety of different investigators (Harrelson et al. 1994; Kondolf and Micheli 1995; Thorne 1998; Downs and Kondolf 2002; USGS 2005; U.S. DOT 2006). The present research sought to use standard techniques. In meeting Objective II., the collected information for the monitoring system is focused on stream stability. Upon mapping the planform of the Conococheague Creek through the former Chambersburg Reservoir, study reaches were identified for long-term study. An adapted version of the Thorne (1998) format for recording the observations and measurements was used to standardize the records. The methods for collecting these data are discussed individually here.

Stream Planform

Stream planform was mapped in the fall of 2008 based on point-location data collected with a TopCon GTS 211-D total station. The National Geodetic Survey benchmark previously located on the Birch Run Dam no longer exists, therefore a virtual benchmark was established on a boulder within the breach of the former dam with a global positioning system (GPS) receiver with antenna (Trimble GeoXM 2005-Series). The study area is too long to be mapped from a single benchmark. Five temporary benchmarks were established with a GPS receiver along the length of the valley (Figure 5). These exact locations were later occupied with a total station in order to achieve complete visual coverage of the area and to map elevation along the entire length of stream in the former reservoir.

Five additional control points were established along the stream with a GPS receiver (Figure 5). The points were positioned in between the temporary benchmarks and marked the overlap in coverage between total stations. Redundancy was thus achieved between data collected from a total station and GPS. Each of the five total station locations were linked based on the backsight point-location data and a control point. The control points in the middle of the study site therefore had three sources of point-location data: GPS-acquired and two different total station-gathered points. This quality control procedure was performed in order to reduce error while the elevations were carried upstream.

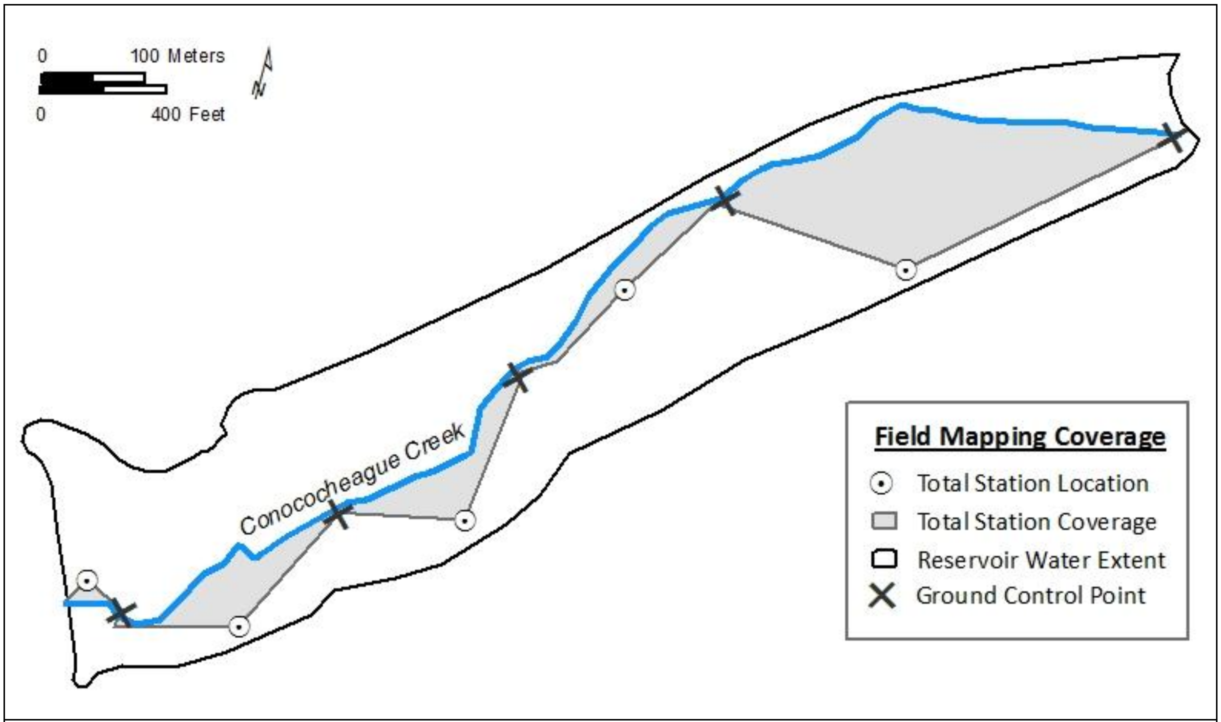

Figure 5. A graphic display of the methods employed to map the planform of the Conococheague Creek. Total station locations were mapped first with a GPS receiver then from the next nearest total station location. The ground control points were distributed to provide overlap between total station locations in an effort to minimize error.

The collected data were used to map the stream channel in a GIS environment (ArcGIS 9.2). The resulting stream path length (Figure 6) was used to calculate sinuosity with Equation 1 (Harrelson et al. 1994). Sinuosity is used to quantify how straight the path of a stream channel is through a valley; a value of 1.0 is considered to be straight.

$$\text{Sinuosity} = \frac{\text{Stream Length}}{\text{Valley Length}} \qquad \text{Equation 1)}$$

The mapped location of the stream was compared with two aerial photographs: one taken in 2005 (USDA 2005) after the reservoir was drained but before the dam was breached and the second after all restoration practices were complete in April 2007 (PA DCNR 2008). Point-location data obtained in the mapping of the stream channel were used to calculate the slope of the valley and stream channel. The slope of the valley within the former reservoir was compared to published elevation data of the valley up and downstream of the study site; these data were analyzed in ArcGIS 9.2.

Identification of Suitable Study Reaches

Preliminary fieldwork at the site was performed in order to identify suitable locations for permanent study reaches. The entire impoundment site was walked at length in order to complete a mapping project as part of a field techniques course in the summer of 2008. Research in this course provided an estimation of the extent and depth of silt deposition in the former reservoir. The results of this preliminary work suggested that the thickest deposits of silt were within the first 100 meters upstream of the former dam (Manuel forthcoming). This illustrated that the channel bank material is likely different depending on the location within the impoundment. The different channel forming histories between the reaches up- and downstream of the diversion divides the study area (Figure 2). Knowledge gained from these investigations was used to identify two distinctly different locations where observations of the stream could be repeated.

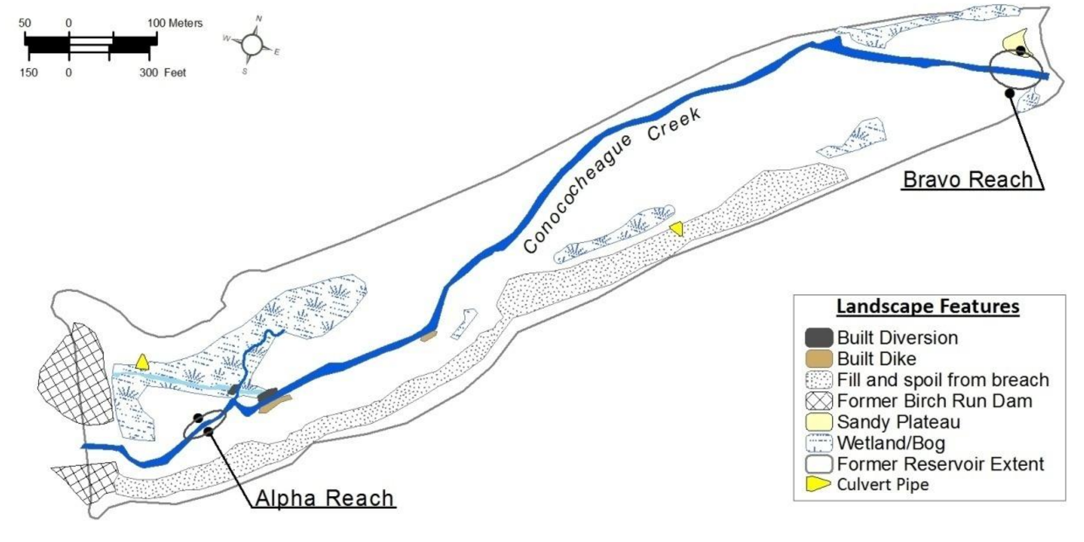

Figure 6. The location of the study reaches on the Conococheague Creek within the former Chambersburg Reservoir including prominent landforms. The route of the Conococheague Creek is from the data produced in this research and other landscape features are approximated based on field notes and aerial imagery (USDA 2005; PA DCNR 2008).

Two reaches along the Conococheague Creek in the former Chambersburg Reservoir impoundment were identified for long-term, intensive study. It was decided to intensively investigate two reaches in order to build a thorough baseline of information, rather than establish numerous study reaches with less data collected for each. Limited time and resources ultimately prevented the establishment of more study reaches. The sites were chosen to be along fairly straight stretches of stream channel between meanders where there is not a distinct change exists in channel shape, slope or channel characteristics so that the collected data, both quantitative and qualitative, describes one homogeneous unit (Harrelson et al. 1994).

The first study reach, *Alpha*, represents the channel between the diversion and the former Birch Run Dam in order to observe the evolution of the constructed channel (Figure 6). Based on prior investigations, this area was estimated to have been deposited with at least 25 cm of silt during the period of inundation (Manuel forthcoming). The second study reach, *Bravo*, is located in the sandy deltaic environment near the furthest upstream extent of the former reservoir (Figure 6). These two sites were chosen because they represent areas with two distinctly different histories since the construction of Birch Run Dam in the 1930's.

Reconnaissance Record Sheets

An amended version of Thorne's (1998) stream reconnaissance record sheets was used to guide and record field observations and lab calculations. This format provides a systematic record that can be compared with future surveys of the sites (Johnson et al. 1999; U.S. DOT 2006). Thorne's system is more comprehensive than a simple, rapid geomorphic assessment (Thorne et al. 1996; Simon et al. 2007) and thus meets the goals of this project in creating a thorough baseline of information. The reconnaissance form is comprised of five sections (see Appendix I. for a detailed discussion of the completion of the reconnaissance record sheets and Appendix III for a record of the sheets used in the field for this research). The first section covers the scope, purpose and logistics of the reconnaissance trip; regional and valley information are recorded in Section 2; the stream channel is described in Section 3; and the left and right stream banks are described in Sections 4 and 5, respectively. Two reconnaissance trips were performed for each reference site on 4-5.March.2009 and 29.May.2009. The record sheets were edited between site visits to facilitate data collection in the field.

Valley and Channel Information

The regional and valley information for Section 2 were derived and from published sources from repeated field visits prior to the two formal reconnaissance visits. Geologic information was collected from published maps (Fauth 1968). Valley characteristics were obtained from a USGS (1984) orthoquad and aerial photographs (USDA 2005; PA DCNR 2008). Unpublished reports were collected from the Dam Safety Office of PA DEP Bureau of Waterways Engineering which included: Alternatives Reports; Dam Inspection Reports; and correspondence with the owner (Chambersburg Borough Water Authority) and the contractor (Gannett Fleming, Inc.). Manning's n roughness values were recorded. The values were not used for any other calculations. They are recorded for potential use in future hydrologic modeling (Shields et al. 2003).

Important details regarding the landscape cannot be captured by a topographic map, nor can processes be mapped (Kellerhals 1976). Geomorphologic mapping provides an understanding of the constructive and destructive processes that caused the current landform (Cooke and Doornkamp 1974). Sketches of the studied reaches are included in the reconnaissance record sheets (Section 3) to record the types of materials and the processes responsible for landforms (e.g. point bar, dike). Information from Section 2 and these sketches were used to produce the generalized land form map of the valley (Figure 2).

Channel Cross-Section

Channel cross sections are a standard component of stream and river studies (Harrelson et al. 1994; Hadley and Emmett 1998; U.S. DOT 2006; Klein et al. 2007; USGS 2008c). The Thorne (1998) record sheets call for channel geometry information, but not specifically a channel cross-section. Cross-sections were considered integral to the establishment of a baseline of information (Section 3). The channel cross-section at each reference site was surveyed following the procedures described by Harrelson and others (1994) with a TopCon automatic level. The automatic level was located along the channel at a distance that allowed the clearest line of site along the transect and at a similar distance from each endpoint of the transect. The persons carrying the stadia rods were instructed to stop at regular intervals along the transect (every 0.3 m in the stream channel and 1.5 m on the floodplain), in addition to stopping at distinct changes in slope gradient (e.g. banktop edge, bank toe).

The point location data for the end-points of each transect were gathered with a GPS receiver (with antennae) at a one-second logging interval. Positions could have a maximum 'positional diffusion of precision' (PDOP) value of 4.0. PDOP calculations are used as an indicator of the diversity of geometries amongst the satellites a GPS receiver is communicating with at the time. Ideal satellite geometry occurs when the satellites are equally distributed around the horizon; the result is a 1.0 PDOP value. A minimum of 200 positions were collected in order to derive each point (Drzyzga 2007). Post-processing was performed with GPS Pathfinder Office software. The collected positions were differentially corrected based on the nearest base station, Hagerstown 6 CORS base station (46 km from the study site) to establish the coordinates of the cross-section end-points (North American Datum 1983).

Stream Discharge

The volume and velocity of water was measured following standard USGS (1982) procedures along each transect with a top-setting wading rod and pygmy current meter. Depths were less than 0.8 meters (2.5 feet), thus the six-tenths depth method was performed (USGS 1982; Harrelson et al. 1994). The water width was divided into 20 lengths of approximately equal flow. Along the *Bravo* reach no transects could be identified that avoided a rock exposure at the surface during the March field visit, thus the length of a boulder in the cross-section was accounted for and 20 other sections were identified. The meter rod was placed at the center of the length for each respective measurement (USGS 1982). In a Microsoft Excel spreadsheet the 20 lengths and depths were used to calculate the 20 respective partial average areas. Discharge was calculated based on the velocity of each respective area with Equation 2. The summation of the partial average discharge values provided a total stream discharge value (Harrelson et al. 1994).

$$\text{Area (m}^{2}\text{) x Velocity (m sec}^{-1}\text{)} \quad = \quad \text{Discharge (m}^{3}\text{s}^{-1}\text{)} \qquad \text{Equation 2)}$$

Channel Bank Observations

The left and right banks were investigated individually to complete Sections 4 and 5, respectively, of Thorne's reconnaissance record sheets. The results from the cross-section measurements (discussed below) were used to measure bank heights. The bank angles or slope gradients were measured with a Brunton compass. The bank material was characterized in the field based on material size and distribution along the bank height. Changes in the types of material (e.g. cohesive, non-cohesive, gravel, or cobbles) along the bank were observed and recorded for each bank. The banks were not coarse enough for a pebble count; therefore a 'texture by feel' technique was used to describe the bank material (Brady and Weil 2002; Klein et al. 2007). Primary to the investigation of the bank material was the presence or absence of cohesive material because overlapping layers of non-cohesive material may be an indication of a future instability (Thorne 1998; Walter and Merritts 2008). Where necessary, the material in the bank below the water line was described. A record of any distinct changes in the color of the soil material was noted, particularly oranges or grays. Signs of oxidation may indicate the duration of inundation and water depth trends.

The presence, type and health of bank vegetation will change the erosion potential for the banks (Knighton 1998; Bedient et al. 2008). Vegetation types along the banks were recorded (Parts 12 and 17) and noted in the channel sketch maps for the left and right banks (Sections 4 and 5, respectively). The distribution, age, extent and orientation of any trees were recorded. The health of the trees was checked, including any protective planting tubes that were used to establish trees in the area.

Physical evidence of overbank flows was identified along each study reach and the greatest height above the banks recorded (Harrelson et al. 1994). Types of evidence include sand deposited on the floodplain and dead leaves deposited behind vegetation stems/trunks and stumps. Evidence that could indicate the bankfull stage of the channel was sought and observed in the field where present (Rosgen 1994; Thorne 1998). Characteristics that were sought included undercuts in banks, the height of depositional features, changes in bank materials in depositional areas, stain lines and changes in vegetation (Harrelson et al. 1994).

Erosional features, where present, were recorded based on their location and present status (Thorne 1998). These interpretive observations were accompanied with a recording of the confidence in the answers recorded in the reconnaissance record sheets so as to allow future users to best understand the notes recorded by the user (Thorne 1998). The location of the erosional feature will provide evidence for the potential migration and/or instability of the stream (Johnson et al. 1999; Downs and Thorne 1996; U.S. DOT 2006). Where a variety of erosional locations were observed, they were noted with their associated process as interpreted by the physical evidence (Thorne 1998). The present status of the activity was also noted for each process. A lack of accumulation of material at the toe was noted as evidence of active erosion. Dormant erosional features were expected to display a collection of material and/or colonizing vegetation (Leopold et al. 1964; U.S. DOT 2006).

The left and right banks were investigated for geotechnical failures independent of erosional features (Parts 14 and 19). Geotechnical failures can be associated with erosional features however they are not inherently linked (Simon and Darby 2008). Failures of the bank may be indicative of serious instabilities (Leopold et al. 1964; Thorne 1998; Bedient et al. 2008). The locations of any bank failures, such as scars or scallops, were noted in the context of the entire reach (e.g. relative to any bars, height of the bank). Neither of the study reaches include any man-made structures, however both include previously buried root balls. Failures near these features were noted where necessary. Failures were interpreted to be active or dormant based on the colonization of vegetation and the mobilization of material.

The accumulation of sediment at the toe of the bank was reported in Part 15 and Part 20 for the left and right bank, respectively. This describes the balance of soil accumulation and sediment transport in the channel (Leopold et al. 1964; Simon and Rinaldi 2000). Sediment stored at the toe is subject to entrainment during high flows and thus a greater accumulation can provide insight into the connectivity of the channel and its banks. Similar to the erosion section above, vegetation that colonized the accumulating sediment was interpreted to estimate the age of the feature (e.g. mature trees).

Bed Material

Surface bed material was assessed via Wolman's (1954) pebble count method (Part 10). The reproducible nature of this technique and its widespread use will allow for direct comparison of future reconnaissance trips to the site and potential transfer of results to similar sites (Kondolf and Li 1992). This method involves walking from bank-to-bank and picking up the bed material that is against/below the observer's big toe while averting his/her gaze (Wolman 1954). Each piece of bed material was measured along the median axis with a ruler. The results were tabulated by size classes. The data were plotted by size class and frequency on a logarithmic scale (base 10) to determine distributions (16%, 50%, and 84%; Wolman 1954).

The channel is approximately five meters wide; therefore 100 samples would not have been reasonable for a single walk along the cross-section. Ten transects were walked perpendicular to the channel in order to obtain a sample that is representative of the entire reach. Collection and measurement of pebbles began along the original transect. After taking one step upstream, collection of pebbles continued along a new transect parallel to the original transect. This was repeated five times on either side of the original transect in order to obtain at least 100 samples.

Photo Stations

Photographs are a low-cost method of recording geomorphologic information (Collins et al. 2007; Darby and Sear 2008). When performed in a standardized format, photographs can be used to track physical changes to the stream channel and vegetation distribution. Photo stations were set-up on the right bank for each study reach. The photos were taken with a Nikon D100 camera with a 35mm lens at a height of 1.7 meters. Photographs were taken during the March and May 2009 reconnaissance trips at known locations and azimuths (Figure 7; see Appendix IV for a complete record of the images and locations). Azimuth data were collected in the field with a Brunton compass.

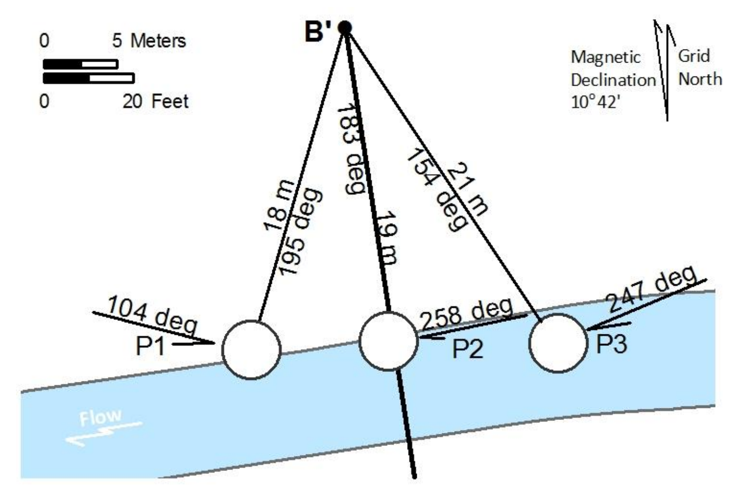

Figure 7. Schematic used to describe the location of the photo stations at the *Bravo* reach.

Lack of Baseline Data

Without pre-project data, the efficacy of post-project monitoring is limited (Downs and Kondolf 2002). No documentation exists regarding the geomorphologic condition of the Conococheague Creek prior to the construction of Birch Run Dam and subsequent filling of Chambersburg Reservoir in the early 1930's. Information from that period would be of negligible use given the more than 180,000 metric tonnes of silt deposited behind the dam as a result of the lacustrine environment (Manuel forthcoming).

Similarly, another pitfall for monitoring systems is the potential difference between engineer's drawings for a stream restoration project and the actual results of the contractor's work (Darby and Sear 2008). The engineer's drawings indicate a designed channel 4.9 m (16 feet) wide with streambank slope gradient ratios not to exceed 2.0H:1.0V downstream of the installed diversion (unpublished PA DEP report, 2004). Despite the lead engineer's indication that these specifications were met (Johnston, personal communication 2008), the present study lacks as-built information other than a single photograph (Figure 4). Field evidence indicates that the contractor dug the channel from the diversion to the breach. Photographs taken by DEP indicate that the banks were stabilized with grasses prior to activation. Fortunately, those short-term fluctuations in channel evolution are of little concern to long-term studies such as this one.

Summary

Field methods for this study were chosen to balance high quality with maximum collection efficiency. Field studies have finite resources; likewise there is no way of knowing what resources will be available to future researchers at the site. Use of expensive technology was kept to a minimum in order to encourage the opportunity for repeat field visits to replicate the procedures herein. A modified version of Thorne's (1998) reconnaissance record sheets was used to organize the field visits. This will facilitate and standardize the collection of information during future reconnaissance missions, thus making the collected information comparable to all past and future investigations.

Results

This chapter presents the results of two field reconnaissance trips (dated March 4-5, 2009 and 29.May.2009) to reaches of the Conococheague Creek within the former impoundment behind the recently decommissioned Birch Run Dam. The two subject reaches represent two portions of the stream with distinctly different histories. Measurements and observations in the field were performed based on the methods described in the Methods Chapter and Appendix I. The three-dimensional planform of the stream through the former impoundment and measured discharge values are reported here first. The results from both of the study reaches, *Alpha* and *Bravo*, are then reported individually. Precipitation and modeled discharge data are reported for the entire study area. Regional and valley information (associated with Sections 1 and 2 of the reconnaissance record sheets) can be found in the Study Area Chapter.

Stream Planform

On 05.September.2008 the banks of the Conococheague Creek were mapped following the methods described in the Methods Section. The collection of three-dimensional point location data at 170 locations along the left and right banks were used to characterize the route of the stream channel through the former impoundment (Figure 8). Stream length as measured up the center of the channel was 1,312.5 meters. The valley length from the relict shoreline where the stream channel enters the former impoundment to the upstream face of the breach was measured to be 1,193.0 meters. Using Equation 1, the Conococheague Creek has a sinuosity value of 1.1 through the former impoundment.

$$\text{Sinuosity} = \frac{\text{Stream Length}}{\text{Valley Length}} \qquad \text{Equation 1)}$$

A sinuosity value of 1.0 describes a straight channel, thus suggesting that the Conococheague Creek has a relatively straight channel with no significant meanders. The stream path did not appear to have shifted course appreciably (Figure 8) when the mapped stream boundaries were compared with recent aerial images from 2005 and 2006 (USDA 2005; PA DCNR 2008).

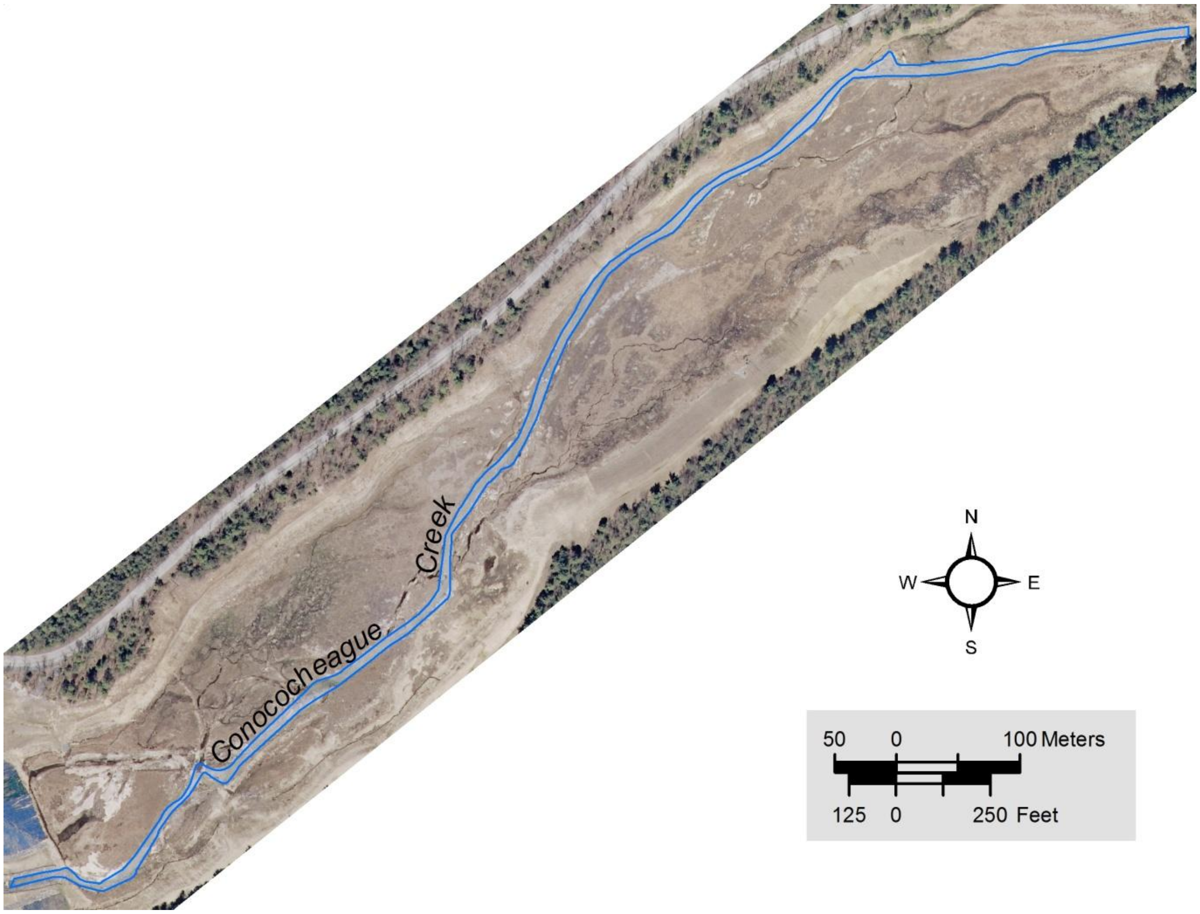

Figure 8. Stream planform of the Conococheague Creek through the former impoundment behind Birch Run Dam. Channel boundaries were mapped in the fall of 2008. There is no change to the channel planform compared to an aerial image taken in 2005 (PA DCNR 2008).

Stream Discharge

Partial stream depth and velocity data were collected following the protocol described in the Methods Section at the *Alpha* and *Bravo* reaches. Evidence in the field indicated that the field reconnaissance on 04.March.2009 was during a winter thaw. Both banks were lined with ice at the beginning of the day with little bank ice remaining 24 hours later. Despite the occasional piece of ice floating downstream, average stream velocity and discharge values were collected on 04.March.2009 (Table 4).

Stream discharge and velocity data were again collected at the *Alpha* and *Bravo* reaches of the Conococheague Creek on 29.May.2009 (Table 4). Field notes indicate a thunderstorm delayed set-up of field observations at the *Bravo* reach following the *Alpha* field reconnaissance (Appendix III, *Bravo* reconnaissance sheets). The Biglerville COOP station indicates that 4.1 cm (1.6 in) of rain fell over the entirety of 29.May.2009 (Pennsylvania State Climatologist 2009). These weather-related issues make comparison of discharge values across the site inappropriate, however the data are of use in understanding the capacity of the channel to convey water downstream.

Table 4. Stream discharge results from each of the two cross-sections on two different field visits. The site visit on 04.March.2009 was during a spring thaw; ice was present along the banks of the stream. Measurements on 29.May.2009 were separated by a thunderstorm that passed over the study area between collection times.

	Discharge (cubic meters per second)		**Velocity (meters per second)**	
Reach	**4.March.2009**	**29.May.2009**	**4.March.2009**	**29.May.2009**
Alpha	0.39	0.53	0.82	0.70
Bravo	0.21	0.66	0.49	0.56

Alpha Reach

Transect Coordinates

The point-location data for the end-points of the *Alpha* transects were obtained with a GPS receiver (with antennae). Over 900 positions were collected at each of the *Alpha* cross-section end-points in order to derive the three-dimensional location (Table 5). Upon following the established quality control protocol, 1,405 of the 1,705 (82.4%) collected points for the *Alpha* left bank were retained.

Table 5. Statistics describing the collection of location data for the end-points of the *Alpha* reach cross-section. Location coordinates and elevation are based on the North American Datum 1983 (NAD83).

Location	**Collected Positions**	**Retained Positions**	**Standard Deviation**	**Latitude** **Longitude**	**Elevation (meters)**
***Alpha*-Left**	1,706	1,405 (82.4%)	0.6 m	39° 55' 8.4864" -77° 27' 9.8166"	318.52
***Alpha*-Right**	934	879 (94.1%)	0.6 m	39° 55' 8.8638" -77° 27' 10.4724"	318.37

Establishment of the right bank end-point utilized 879 of the 934 (94.1%) positions collected. All of the discarded positions from both locations were due to high dilution of precision (DOP) values. The remaining array of positions for both end-points were differentially corrected in order to establish the respective end-points.

Channel Cross-Section

There is a small terrace along the right bank of the *Alpha* channel before the right bank rises to the floodplain (Figure 9). The small terrace and upper bank are 0.55 and 1.01 meters above the stream bed, respectively (Table 6). The channel widens from approximately 5.27 m at the lower bank (elevation 317.9 m) to 8.65 m at the upper bank (elevation 318.4 m). Average water depth was 0.21 m and 0.37 m during the March and May observations, respectively. The water width of the *Alpha* reach increased less than 3% (13 cm) between site visits when the water depth increased 76%, 16 cm depth (Table 6).

Table 6. Channel dimensions of the *Alpha* cross-section as measured during two separate field reconnaissance visits. No significant changes to the channel dimensions occurred in between site visits; slight differences in the geometry are likely due to identification of the top of the bank. The slope value listed for the March field visit (*) was determined based on data collected during the planform mapping.

Dimension	**Location**	***04.March.2009***	***29.May.2009***
Bank-top Width	**Upper**	8.77	8.53
	Lower	4.89	5.64
Water Width		4.57	4.70
Channel Depth	**Upper**	1.01	1.01
	Lower	0.55	0.55
Channel Width: Depth Ratio	**Upper**	8.68	8.45
	Lower	8.89	10.3
Average Water Depth		0.21	0.37
Average Discharge (m^3 s^{-1})		0.39	0.53
Cross-Sectional Area (m^2)	**Upper**	2.90	2.94
	Lower	0.82	1.31
Slope		0.01*	0.02

The cross-sectional area of the *Alpha* reach was calculated with the same 'average area' procedure used in calculating area as described for discharge measurements (USGS

1982). Data for the cross-section area were derived from the automatic level mapping procedure. The *Alpha* reach is reported to have an increased cross-sectional area between the March and May site visits for both the Lower and Upper areas (Table 6). When graphed together, the cross-section appears to have changed little between site visits (Figure 9). Field notes (Appendix III) from the respective reconnaissance trips agree that there was not a significant visual change in cross-section shape between site visits. The identification of the bank-top of a stream channel is subject to some ambiguity (Harrelson et al. 1994; Simon et al. 2007). Discrepancies in the channel widths are likely due to slight differences in the identification of the 'bank-top' in the field.

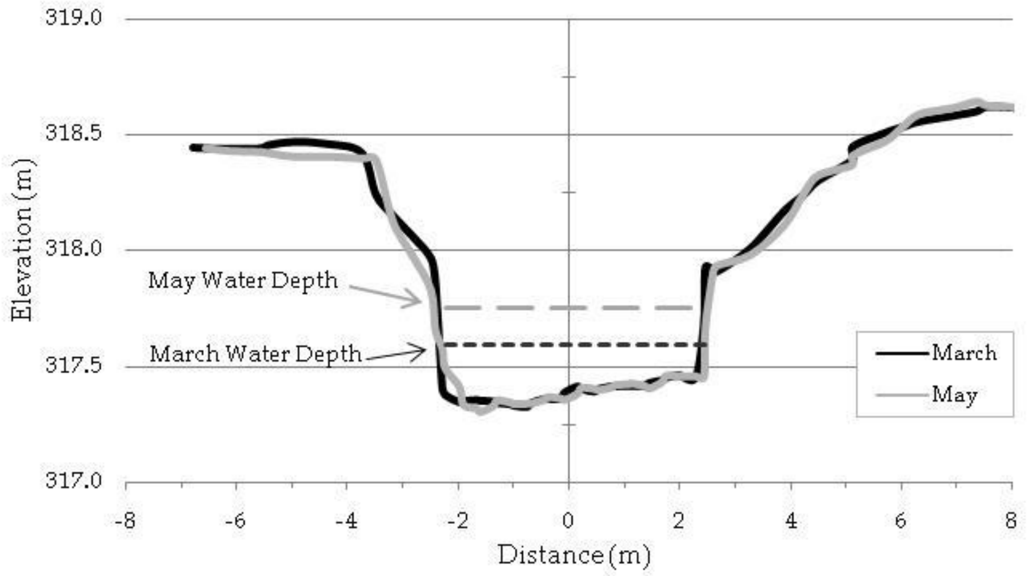

Figure 9. Comparison of the channel cross-sections observed during two field visits (March and May 2009) to the *Alpha* study reach along the Conococheague Creek.

Bank Material and Vegetation

Samples of the bank material along the *Alpha* reach were tested in the field using the 'texture by feel' method (Methods Chapter). Changes in the distribution of material type and texture were noted. Both banks along the *Alpha* reach were comprised of cohesive material throughout the entire bank (above and below the water line). The texture of the material was identified as a silty clay loam. During the March field visit the right bank had an orange line in the soil at the water line. This line was absent during the May field visit.

The type and distribution of vegetation along the *Alpha* reach were described relative to the channel banks. Field notes indicate that the visit in March was prior to the leaf-on season. The banks between the upper and lower limits were covered with healthy grass (+/- 30 cm tall) and the occasional tree sapling. Based on the dominance of grasses, the Manning's n value was estimated to be 0.035 and 0.040 during the winter and summer seasons respectively (Appendix III). The riparian zone on both sides of the channel has individual stands of deciduous trees; the stands of trees along the left bank appear to be more densely populated than the right bank (Figure 10). The trees have diameters of approximately 3 cm and stand 3-4 m tall. None of the trees appear to be leaning, which could otherwise be evidence of potential instabilities (Thorne 1998). Extensive moss is growing along the lower bank on the north-facing, left bank; the right bank has less moss on the nearly vertical lower bank face.

Figure 10. Image of the vegetation on the left bank of the *Alpha* reach. The left side of the channel has a far denser distribution of trees as compared to the right side (author’s image dated, 7.May.2009).

Field reconnaissance on 29.May.2009 noted evidence of overbank material (medium sand) along the *Alpha* reach on the lower bank. There appeared to be a greater quantity of material deposited on the lower, flatter right bank than the steeper left bank. Relict trash lines, consisting entirely of dead grasses, were observed at the base of tree sapling stems on both sides of the floodplain, approximately one meter above the *Alpha* channel bottom.

Bank Survey -- Erosion and Undercutting

The left and right banks within the *Alpha* reach were investigated individually for evidence of erosion and/or geotechnical failures. The right bank experienced no major changes between site visits. There was a distinct change in the size of a cut in the left bank of the *Alpha* reach upstream of the measured cross-section. During the March 2009 field visit the notch in the bank was approximately one meter in length and less than half of one meter in depth. The May 2009 field reconnaissance found the notch to be at least one meter in length, but having grown to at least one meter in depth as well. A formerly buried stump is exposed at the downstream extent of the notch and sand has been deposited at the foot of this new bank.

In addition to the expansion of the notch, undercutting of the left bank has increased along the *Alpha* reach. During the March field visit the undercutting was non-continuous and at maximum of 0.3 meters into the bank. The undercutting appeared continuously greater than 0.3 meters in May with individual sections measuring greater than 0.5 meters deep. The right bank has moderate undercutting that appeared largely unchanged over the period of observation.

Bed Material

The Wolman (1954) pebble count method of quantifying channel bed material was performed during the March and May field visits. Bed material size along the *Alpha* reach changed slightly over the two field visits (Table 7). The 16% and 50% majority diameter sizes each increased. The D16 pebble size was 8-11 mm in March and 16-22 mm during the May visit. The D50 pebble size increased from the 32-45 mm class to the 45-64 mm class over the two site visits. The D84 pebble size class remained at the 90-128 mm class. When graphed in logarithmic scale (base 10), the results from the May pebble count are slightly coarser, yet follow the same general distribution trend (Figure 11).

Table 7. Pebble count results for the channel bed of the *Alpha* and *Bravo* study reaches along the Conococheague Creek in March and May of 2009. The data were aggregated into size classes (mm) and graphed on a $\log_2$ scale graph (Figure 11) in order to identify the percent of the total bed material percentages.

	Alpha		***Bravo***	
Majority Pebble Size	**5.March.2009**	**24.May.2009**	**5.March.2009**	**24.May.2009**
D16	8-11	16-22	8-11	8-11
D50	32-45	45-64	45-64	64-90
D84	90-128	90-128	128-180	180-256

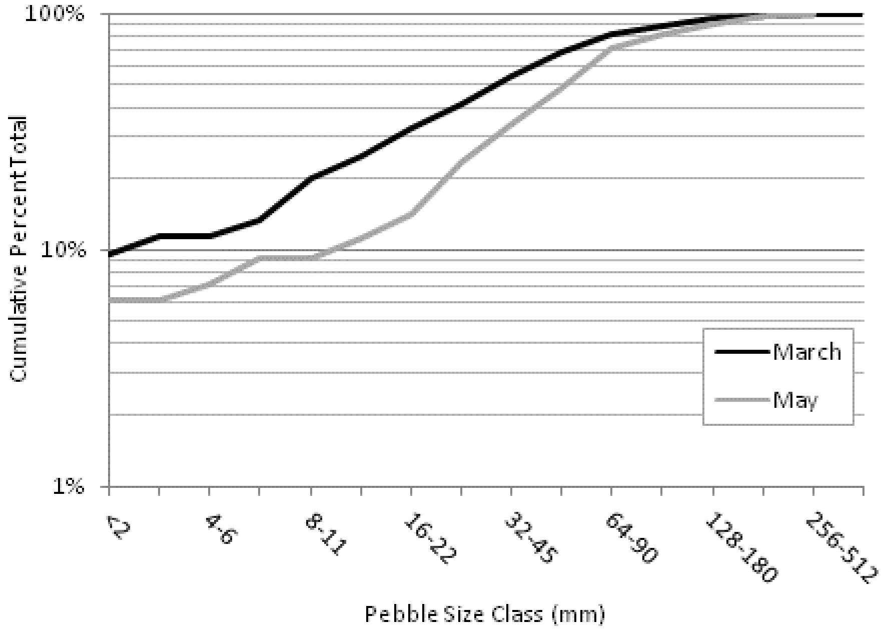

Figure 11. The results of two pebble counts on the channel bed of the Conococheague Creek (*Alpha* reach) are graphed in a logarithmic format. The bed material of the *Alpha* reach was quantified based on a pebble count (Wolman 1954).

Bravo Reach

Transect Coordinates

The locations of the end-points of the *Bravo* reach cross-section were obtained in the field with a Trimble GPS receiver (with antennae). The array of satellites available for mapping at the time of collection provided positions with greater accuracy while at the *Bravo* reach than at the *Alpha* reach. Between the left and right end-points, 1,252 positions were collected and only one position was omitted during quality control procedures (Table 8). The remaining positions were differentially corrected in order to obtain the three-dimensional point location data for each end-point.

Table 8. Statistics describing the collection of location data for the end-points of the *Bravo* reach cross-section. Location coordinates and elevation data are based on the North American Datum 1983 (NAD83).

Location	Collected Positions	Retained Positions	Standard Deviation	Latitude Longitude	Elevation (meters)
***Bravo*-Left**	700	700 (100%)	0.2 m	39° 55' 28.8912" -77° 26' 37.6656"	334.39
***Bravo*-Right**	552	551 (99.8%)	0.4 m	39° 55' 30.5034" -77° 26' 37.7406"	334.71

Channel Cross-Section

The channel cross-section was measured with an automatic level as described in the Methods Chapter. During both field visits the automatic level was located on the flood plain above the right bank, downstream of the cross-section. The channel cross-section in the *Bravo* reach was approximately 9.4 m wide at the lower bank height (elevation 332.6 m) and 20.2 m wide at the top bank (elevation 333.8 m; Figure 12). The lower and upper banks were 0.5 m and 1.7 m above the channel bottom respectively. Water depth increased during the May field visit by 80% as compared to the March measurements, while the water width remained 8.4 m during both field visits (Table 9).

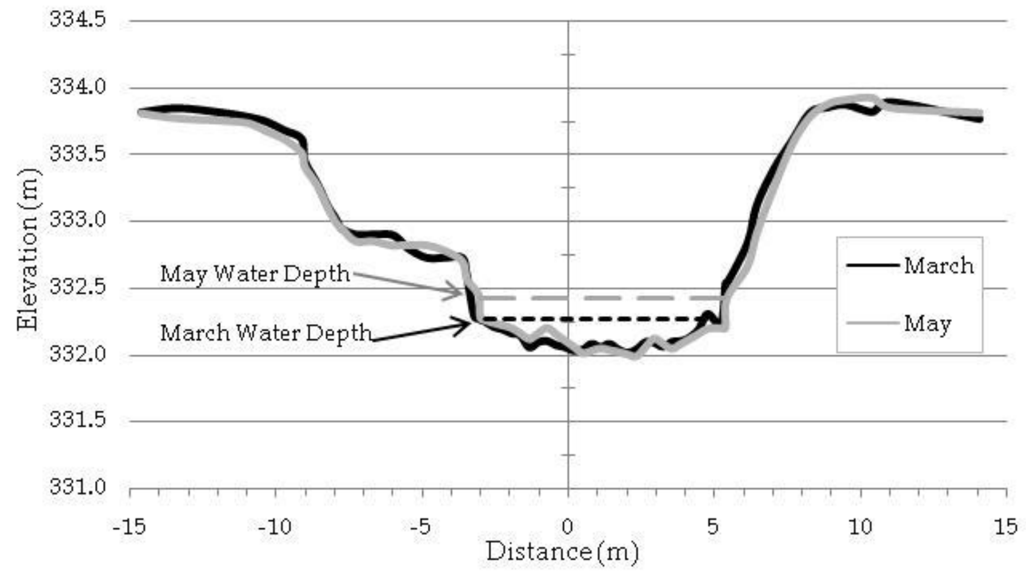

Figure 12. Comparison of the Bravo channel cross-sections observed during two field visits (March and May 2009) to the Conococheague Creek.

Table 9. Channel dimensions of the *Bravo* cross-section as observed in March and May 2009. No discernible changes to the channel dimensions occurred in between site visits. The slope value listed for the March field (*) visit was determined based on data collected during the planform mapping.

Dimension	**Location**	***04.March.2009***	***29.May.2009***
Bank-top Width	**Upper**	20.11	20.25
	Lower	9.23	9.61
Water Width		8.40	8.40
Channel Depth	**Upper**	1.72	1.63
	Lower	0.49	0.58
Channel Width:Depth Ratio	**Upper**	11.7	12.4
	Lower	18.8	16.6
Average Water Depth		0.17	0.31
Average Discharge (m^3 s^{-1})		0.21	0.66
Cross-Sectional Area (m^2)	**Upper**	11.03	10.48
	Lower	1.41	2.46
Slope		0.01*	0.02

Bank Material and Vegetation

The materials comprising the banks of the *Bravo* reach were investigated in the field for material size and texture as described in the Methods Chapter. The distribution of material and vegetation is noted relative to the banks. The left bank of the *Bravo* reach was comprised of sand and gravel with the occasional boulder armoring the toe. The sand appeared finer on the mid- and upper-banks as compared to the sand present along the toe. Vegetation of the left bank is dominated by grasses; the wide bench has a dense thicket of shrubs near the toe of the upper bank (Figure 13). The occasional planted tree that continues to survive is rarely taller than their protective plastic tubes. Most of the surviving seedlings are along the bench rather than on the wider floodplain above. No overbank deposits were observed along the left bank of the *Bravo* reach.

Figure 13. Image of the vegetation along the left bank of the *Bravo* reach. Note the slight change to shrubs at the toe of the upper bank and then returning to grass on the flood plain (author's image dated, 29.May.2009).

The right bank of the *Bravo* reach is largely armored along the toe with cobbles and the occasional boulder (Figure 14). The remainder of the bank (above the lowest 30 cm of the right bank) is non-cohesive and comprised of sands of varying sizes and colors. Grasses and sparse shrubs dominate the entire bank and floodplain. None of the planted trees appear to have survived on the floodplain. There were no overbank deposits observed along the right bank.

Figure 14. Image of the cobble-sized armoring along the right bank of the *Bravo* channel. Grasses are dominant cover along the majority of the bank (author's image dated, 05.March.2009).

Bank Survey – Erosion and Failure

Both banks of the *Bravo* reach were investigated for erosional features, active or dormant, and signs of geotechnical failures. Active erosion due to parallel flow appears to be moderate-to-insignificant along the left bank. Cobbles are exposed along the toe near boulders that appear to be causing local scour. Minor slides of material may be occurring on the lower bank with no accumulation at the toe. This localized process appears to only be located near boulders along the bank.

General erosion along the toe of the right bank appears to be a minor process on this bank due to the cobble armoring. New and old scars appear along the right bank with cobbles armoring the toe below previous failures. Old scars were identified where grasses were growing in a concave depression (known as a scallop). The material that failed at these scars has since been transported away from the immediate area of the failure. The only accumulating sediment is behind boulders that are locally slowing the stream flow near the toe.

Bed Material

Based on the Wolman (1954) pebble count methodology, the bed material along the *Bravo* reach was dominated by coarse gravels and small cobbles (Table 7). The D16 pebble class, 8-11 mm, did not change over the two field visits. The D50 pebble class increased from the 45-64 mm to the 64-90 mm class. The D84 pebble class size increased from 128-180 mm to the 180-256 mm pebble class size. The overall character of the bed material appears to have changed little over the period of observation (Figure 15).

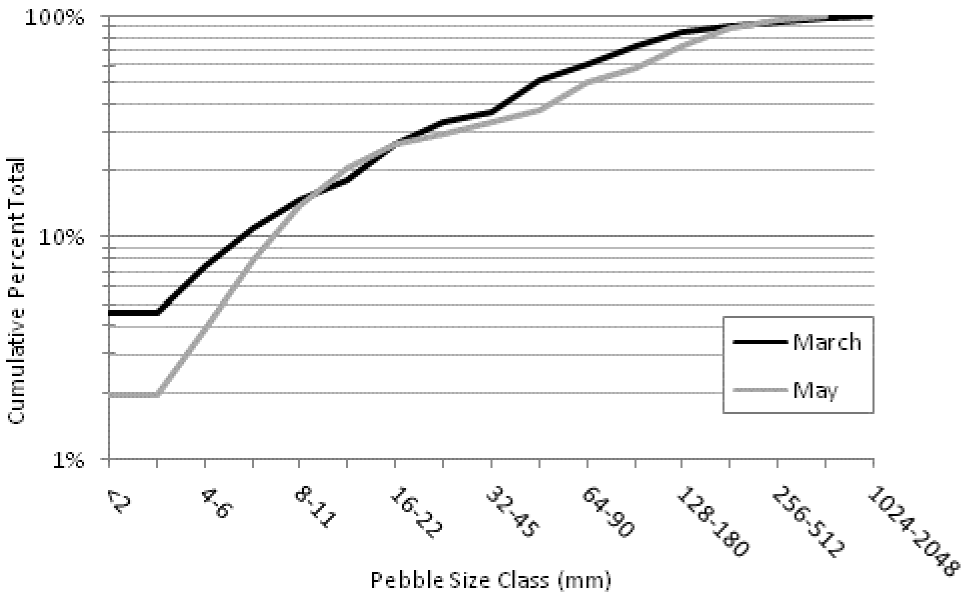

Figure 15. The results of two pebble counts on the channel bed of the Conococheague Creek (*Bravo* reach) are graphed in a logarithmic format. The bed material of the *Bravo* reach was quantified based on a pebble count (Wolman 1954).

Discussion

The locations of the two study reaches along the Conococheague Creek were chosen because of their different formative histories since the construction of Birch Run Dam in the early 1930's. The *Alpha* reach has a constructed channel and was subject to the deposit of fine, lacustrine material. The *Bravo* reach was alternately submerged by slow-moving, shallow water or an active stream channel delta. The qualitative and quantitative differences between the reaches, discussed here, reflect these differences. Simon and Hupp's (1986) channel evolution model (CEM) is used to describe and estimate the evolution of both study reaches. The use of a CEM facilitates estimates for the evolution of the channel form in a context that can be compared to past and future studies (Simon and Rinaldi 2000). The methods for collecting field data for a long-term monitoring program are reviewed in the context of balancing the need to make accurate measurements with available tools. Finally, this chapter commences with an explanation of how this research will be disseminated in order to meet the fourth objective.

Long-term Monitoring Design

A system of monitoring a fluvial system over medium or long time scales requires future investigators to be able to replicate the original study to the best of their ability. The collection of observations should be standardized in order for repeat surveys to be comparable to each other (Johnson et al. 1999). The use of a standard format encourages future users to systematically observe and record the status of the stream channel (Mosley 1987; Simon and Downs 1995; Thorne et al. 1996). A balance must be struck between resource allocation (i.e. time and technology) and allowable uncertainty in the data collection techniques (Darby and Sear 2008).

Finite resources like time and money mean that methods need to be efficient and the necessary technology needs to be available (Thorne et al. 1996). The Thorne (1998) technique works for the former Birch Run Dam sites because it balances the need to be thorough and efficient. A student with a background in geomorphology could feasibly complete a rudimentary reconnaissance survey with little more than the reconnaissance record sheets, a compass and a tape measure. Where that student has the help of fellow students and additional tools, such as an automatic level, the quality and comparability of the investigation are enhanced.

The cross-sections were measured with an automatic level atop a tripod (Methods Chapter). The use of a total station in mapping the cross-sections was considered to be unnecessary. The quality of the results provided by using an automatic level are acceptable for this baseline survey because the automatic level methodology is efficient and accurate (Harrelson et al. 1994). If future investigators do not have access to a tripod and automatic level, hand-leveling mapping techniques can produce results comparable to those gathered here.

The three-dimensional locations of the banks of the Conococheague Creek were mapped with a total station and four volunteers. This was deemed the most accurate means of collecting these data with the resources available. Mapping the length of the subject stream required five people to invest eight hours in the field. The future availability of volunteers and a functioning total station is not certain, therefore completion of future reconnaissance surveys are not critical to successfully completing future reconnaissance field visits. These data were collected in order to provide baseline information for future study. This is not to discourage future mapping activities at the site if warranted. Future investigators will be able to analyze the planform data in order to base future analysis on the known location of the stream in the fall of 2008.

Photo stations are a cost effective way to record the conditions at a study site (Darby and Sear 2008). This baseline survey utilized the efficient collection of information with digital photography because of the value that can be derived from the images and the ubiquity of digital cameras today. Digital imagery allows the observed conditions to be shared with persons not present at the investigation for further insight and analysis. Photographs provide an effective means of documenting the status of a restoration site for all variety of stakeholders (Collins et al. 2007).

Study Reaches Compared

Substantial differences exist in the sizes of the respective subject channels. Measurements revealed that the *Bravo* channel cross-sectional area (10.76 m^2) is more than 300% larger than that of the *Alpha* channel (2.92 m^2). The lower banks of both channels are approximately 0.5 m high. The *Bravo* reach, however, is nearly twice as wide (9.43 m) at the lower bank height compared to the width of the *Alpha* cross-section (5.27 m) at the same relative height (Figure 16). These differences can, in part, be attributed to the differing materials that comprise the banks.

Evidence of undercutting and slope failure at the *Alpha* and *Bravo* reaches, respectively, indicate differing bank responses to high flow events. The banks of the *Alpha* reach are comprised of cohesive material, thus the entire bank does not fail in response to erosive action (parallel or impinging flow). The *Alpha* bank is undercut which displays exposed tree sapling roots in the riparian zone and previously buried stumps. If the entire undercut area of the *Alpha* left bank fails, the channel width could increase by 0.5 m (10%). The increased cross-sectional area could have dramatic impacts on the connectivity of the channel with the flood plain. The cohesive clays that comprise the banks, in addition to the sapling roots, are currently preventing collapse.

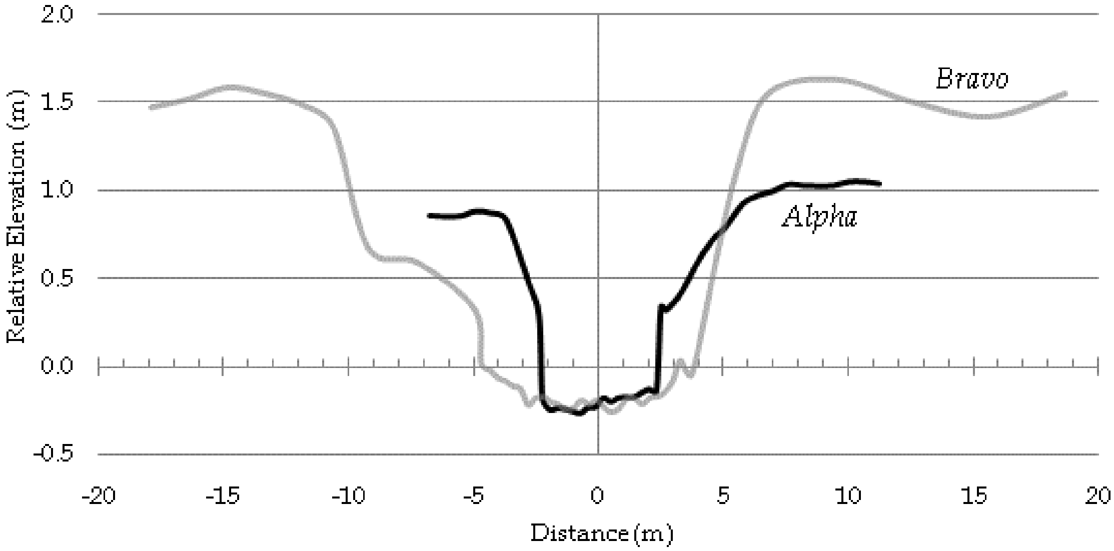

Figure 16. Comparison of studied cross-sections along the Conococheague Creek upstream of the former Birch Run Reservoir. Data are from the March field reconnaissance. The water line on the day of observation is represented by the zero elevation mark.

The non-cohesive materials along the *Bravo* reach are more vulnerable to erosional and geotechnical failures than the silty clays found at the *Alpha* reach. Scallops along the length of the channel provide evidence of past bank failures. These failures occur when shear stress is greater than shear strength (Ritter et al. 2002). Two potential mechanisms for high shear stress values in the *Bravo* reach are steep bank angles and the removal of underlying support. The 75 degree angle of the right bank (Appendix III) combined with the coarse sands comprising the bank raise the likelihood that the summed shear stresses will outweigh the shear strength of the bank. Parallel flow erosion likely mobilized the bank material that was supporting the weight of the bank. The removal of the bank support increases the shear stress on the bank material, thus making the bank vulnerable to a minor failure.

The *Bravo* reach has been exposed to stream flow throughout the entire history of the former Chambersburg Reservoir. As the reservoir delta, the reach was alternately subject to erosion and deposition of material (Morris and Fan 1997; Shotbolt et al. 2005). When the reservoir was at (or near) capacity, the channel behaved like a river delta, subject to the deposition of material from bed load and suspended load of the Conococheague Creek. With every drop in the water elevation, the newly deposited materials near the water line were vulnerable to mixing due to wave action. Materials that were deposited when flow in the channel was slowed by the reservoir could then be entrained by the increased velocity of the in-flowing stream. Together, the coarse material and the variety of mechanisms for mobilizing that material played a crucial role in the evolution of the *Bravo* channel geometry.

Channel Capacity

The current cross-sectional areas of the two channels indicate that the *Bravo* channel is able to convey a far greater volume of water without spilling over the banks as compared to the *Alpha* channel. Given the same volume of water, the *Bravo* reach will flood its lower banks shortly before the *Alpha* channel over-tops its upper banks (Figure 17). The greater connectivity between the *Alpha* channel and the floodplain is evidenced by the overbank material found along the lower banks. Overbank flow was observed along the lower banks of the *Alpha* channel and not the *Bravo* reach on 07.May.2009 following 7.9 cm of rain over five days, 2.7 cm on the observed date (Pennsylvania State Climatologist 2009). The benefit of overbank flow for the *Alpha* reach is the dissipation of energy from the flowing water onto the floodplain.

The *Bravo* reach appears to be channelized and entirely disconnected from the floodplain. The lack of overbank flow along the *Bravo* reach perpetuates incision of the channel. Energy from the flowing water is unable to dissipate over the floodplain; instead, the potential energy of the flowing water is contained in the channel. The result of the contained flow is erosion of the stream bed and/or bank (Schueler 1994; Knighton 1998).

Incision of a channel often drops the water table to a depth too deep for most saplings to access. The low survival rate of the planted trees on the floodplain seems to indicate the same. In order to understand the processes of bed incision and bank failure that appear to be occurring along the *Bravo* reach, it is useful to compare the channel to a CEM.

Figure 17. Image of the *Alpha* reach flowing slightly above the lower bank following 7.9 cm of rain over five days. The location of the lower bank edge is approximated by the dashed line (author's image dated, 07.May.2009).

Channel Evolution

The six-stage CEM offered by Simon and Hupp (1986) predicts that channelized streams will first incise the stream bed. The steep banks that result are susceptible to mass wasting, which eventually widens the channel. When the channel reaches a sufficient width, the velocity of the water is expected to slow, thereby inducing aggradation of material at the site (Simon and Rinaldi 2000). Evidence of a re-stabilizing stream channel are the deposition of alternate bars; vegetation on the recently deposited material in the channel; and the establishment of a meandering thalweg.

The *Bravo* reach appears to be shifting from the 'Degradation Stage' (Stage III) to the 'Threshold' Stage (Stage IV) of the Simon and Hupp (1986) CEM. Stage III is characterized by taller/steeper banks; pop-out failures, and a lack of alternate bars. Stage IV is dominated by mass wasting, while bed erosion may still continue. All of these conditions appear to be

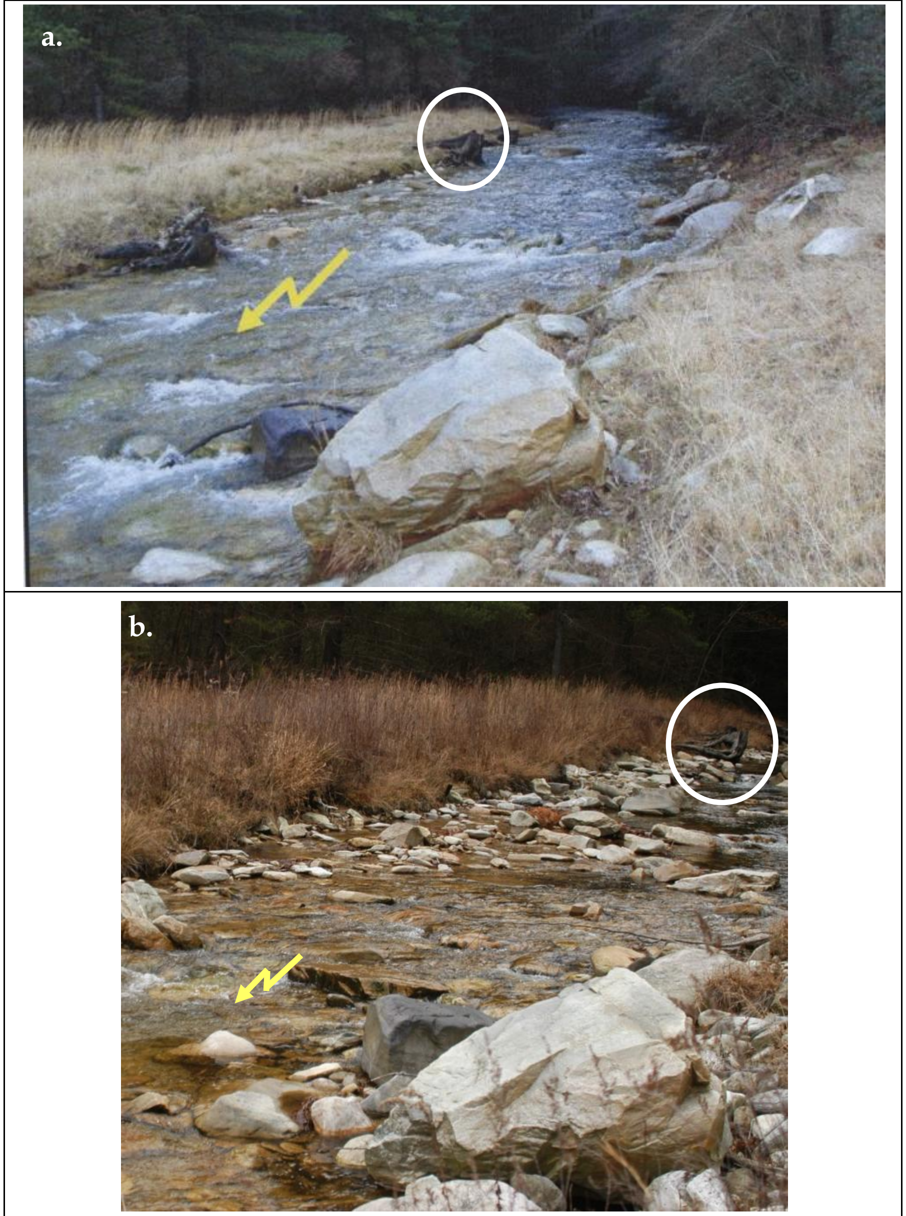

Figure 18a. PA DEP file image of the *Bravo* reach taken in 2005 during a Phase I assessment of the adjacent wetland.
Figure 18b. An image of the *Bravo* channel on 04.March.2009 (author's image). The opposite bank appears to be taller in 2009 when compared to the previous image. The same stump on the right bank is circled for reference.

present along the *Bravo* reach. A photograph of the *Bravo* reach (Figure 18a; PA DEP file photo dated, 13.January.2005) taken during a Phase I assessment of an adjacent wetland provides insight into the evolution of the stream channel over the last four years. The right bank observed in 2009 appears to be heightened and steeper compared to the right bank in

2005 (Figure 18b). The left bank also appears to be eroded around the boulder. Given the angle of the 2005 photo, it remains speculative to conclude that the left bank is significantly eroding around the boulder. Current photographs will enable future comparison to the potential widening of the *Bravo* channel.

The lack of alternate bars along the *Bravo* stream channel is important to recognize. Substantial deposits would indicate an over-widened channel (Stage V). In the few and minor locations where material is aggrading, the material is below the water line and not vegetated. Based on the two more popular CEMs (Schumm et al. 1984; Simon and Hupp 1986), mass wasting will continue to be the dominant process along this reach; the *Bravo* reach will erode more material than it aggrades. It should be noted, however, that there is one location where small gravels are being deposited in the *Bravo* channel (Figure 19). The area is approximately 1 m^2 behind an in-stream boulder near the left bank. This deposit remains below the water line; however future growth of this deposit may reflect early signs of an increasingly stable channel form.

Figure 19. Image of sand and gravel deposited along the left bank of the *Bravo* reach. Future growth and established permanence of this deposit may indicate an increasingly stable channel form (author's image dated, 5.March.2009).

Changes in the stream channel, such as alternate bars or colonizing vegetation, need to be viewed in the context of the entire system. Low flows due to a below-normal precipitation year could easily expose material such as the small deposits behind boulders along the banks. Fifty-five percent of the upstream catchment is subject to the operation of the Chambersburg Reservoir behind Long Pine Dam. During the dry months of the year, the Long Pine Dam attenuates the high flow effects of storm events (Figure 20). The colonization of vegetation within the stream channel during a prolonged drought could trigger the false positive of a stable channel. The establishment of alternate bars (with or without vegetation) will have to survive multiple years and formative storm events in order to be considered evidence of a stabilizing stream channel. Repeated, long-term observations will be necessary prior to any conclusions regarding the evolution of the channel.

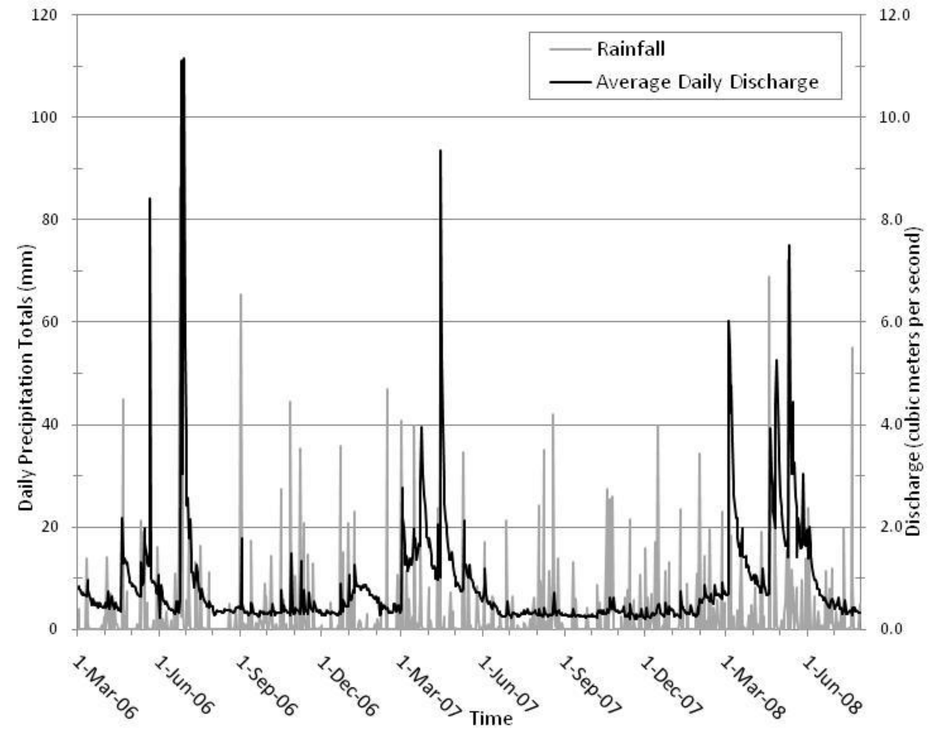

Figure 20. A comparison of the discharge of Conococheague Creek and precipitation between March 2006 and July 2008. Only during spring rains when the Long Pine Reservoir is most likely to be at capacity does the discharge of directly reflect precipitation events (discharge data from the Chambersburg Water Authority; precipitation data from Pennsylvania State Climatologist 2009).

The *Alpha* reach does not fit neatly into the typical CEM because it does not appear to be as greatly incised as the *Bravo* reach. Simon and Hupp (1986) describe a 'Pre-modified' channel (Stage I) as stable with a 'flow line high relative to top bank' and a convex bank shape. The right bank of the *Alpha* reach is convex between the lower and upper banks (Figures 9 and 16); however the left bank is increasingly undercut. None of the saplings on either bank appear to be tilted towards the channel as evidence of imminent failure. A point bar is forming downstream of the reach with colonizing grasses (Figure 21), however, no other material is being deposited along the *Alpha* reach.

Figure 21. Image of point-bar development downstream of the Alpha reach of the Conococheague Creek. Note the colonization of vegetation on the point bar (author's image dated, 9.July.2009).

Two field visits within four months are not adequate time to determine whether the *Alpha* channel will continue to widen due to bank erosion or is in the process of a stable meander cut. The thalweg of the reaches were not mapped, however the *Alpha* cross-section indicates that the thalweg passes near the left bank (Figure 9). Based on this and photographic evidence of the site (Figure 21), it appears that the stream is meandering towards the left bank through the *Alpha* reach. The establishment of a point bar opposite of the undercut channel bank would provide strong evidence that the *Alpha* reach has attained a new equilibrium. The undercutting and eroded notch along the left bank of the *Alpha* reach will need to continue to be studied over a longer time period.

Dissemination

In order to meet the fourth objective of this research, the baseline results that were obtained and analyzed herein need to be shared with the wider public. Future Shippensburg University students will have access to these results through the library and the Geography-Earth Science Department. Additionally, two on-line databases have been identified as repositories of the research: the Clearinghouse of Dam Removal Information (CDRI) and the Vigil Network. The CDRI is an on-line archive that stores information related to all aspects of dam removal (University of California 2009). The Vigil Network (discussed previously in the Literature Review Chapter) is co-managed by one of the original creators, Dr. Waite R. Osterkamp, through a site housed by the USGS (2008c). Administrators from both archives have expressed an interest in storing and sharing information from this research.

On-line archives allow an open exchange of information that would otherwise be unavailable to future practitioners. The National River Restoration Science Synthesis (NRRSS 2009) is an example of an archive of stream restoration that is publicly available on the internet. The NRRSS was used to understand regional and national trends in stream restoration (Kondolf and Micheli 1995; Bernhardt et al. 2005; Wohl et al. 2005). The Vigil Network and CDRI are organized in a way that allows future researchers to not just view the results, but to build on the research as well (Osterkamp and Emmett 1992; University of California 2009). Storing this research on the Conococheague Creek with these archives provides public access to the raw data that are necessary for a long-term study. The location and geometry of stream cross-sections, for example, are available for direct replication by future users without the cumbersome process of contacting past researchers. Sharing this research through these outlets will increase accessibility to the research in order to expedite future learning opportunities.

Conclusion

Dams across the United States are being removed for a variety of reasons not limited to expiring licenses and habitat restoration. As a stream restoration technique, dam removal shows great promise. Unfortunately, the popularity in performing stream restoration projects has not been met with similar enthusiasm towards assessing the outcomes from the projects. In order to advance the science of stream restoration, post-project assessments need to be performed on projects in a variety of physiographic provinces and on sites utilizing a range of restoration techniques. Stream restoration due to dam removal presents a new set of circumstances that to this point, fluvial geomorphologists have not yet had the opportunity to study in sufficient detail. Current knowledge of the processes that control stream channel form is the result of decades of investigation. The long-term study of restored stream channels following dam removal will help to fill the current void in stream restoration science.

The former Birch Run Dam in Michaux State Forest was removed and the Conococheague Creek restored in 2005. In the absence of any other post-project assessments at the site, this research seeks to establish a long-term monitoring system of the Conococheague Creek within the former Chambersburg Reservoir. As one of the few medium-sized dams to be removed in Pennsylvania, the project is an excellent opportunity to learn from a completed restoration site with a largely static upstream catchment.

Objective I.

Identify and construct monumented reference sites for long-term study on the restored Conococheague Creek.

Two study reaches were chosen to represent two entirely different reaches. The *Alpha* reach was inundated by water during the life of the reservoir and then dredged and stabilized during the restoration process. The *Bravo* reach was the exact opposite: alternately flooded and exposed; subject to deltaic deposition; and then untouched during the restoration process. Two field reconnaissance visits to both study reaches indicate that the forms of the two subject reaches are evolving differently than one another.

Objective II.

Identify and collect the necessary information to describe the stability of the stream channel. Long-term monitoring protocols must be designed to produce results that can be replicated.

The original goal of the Birch Run Dam removal project was to restore the Conococheague Creek to a stable form. This monitoring system is thus, focused on characterizing the stability of the stream channel. Common field techniques (Harrelson et al. 1994) were used in order to facilitate future site visits. The Thorne (1998) technique of collecting and recording information was used. Contrary to many rapid geomorphic assessments (RGAs), this technique records raw data prior to interpretation. RGAs frequently require the user to interpret results in order to calculate a stability index. Future analysis from this monitoring system will be less vulnerable to the subjectivity of past users. As a result, the repeated measurements and observations over successive field visits should be comparable regardless of who performs the studies.

Channel geometry is important to studying a stream, however; had cross-sections alone been used to study the reaches, the expansion of the erosional features along the *Alpha* reach may have been overlooked. Likewise, many of the geotechnical failures along the *Bravo* reach were colonized by vegetation, thus they could have been missed with a less systematic format for data collection. Cross-sections can provide valuable information regarding a stream channel; indeed, expanded study of this site may require more cross-sections to be measured in the future. For the purposes of this study, the Thorne (1998) record sheets created a checklist of tasks that helped to prevent critical omissions such as slope failures. Future investigations of these channels will benefit from the step-wise format for studying the reaches.

Repeated field reconnaissance visits to the subject reaches will serve to supplement the baseline results produced in this research. Previous stream monitoring efforts at other sites were only able to provide tentative results due to low-flow conditions (Bushaw-Newton et al. 2002; Chaplin et al. 2005); likewise, this study site needs to be monitored following discharge events with a variety of return intervals. Other reasons that should prompt further field visits include high sediment loads downstream, changes to the stream path, and reports of slope failures along the hillside.

Objective III.

Report on any changes to the study reaches of the Conococheague Creek over the first four-month period of study.

Evidence of a point bar downstream of the *Alpha* reach and possible development of a thalweg indicate that the *Alpha* reach may be approaching a stable channel form. It is yet unknown whether undercutting along the left bank is a natural meander progression or the early signs of uncontrolled channel widening. The evolution of the *Bravo* reach may be following the same trajectory predicted by Simon and Hupp's (1986) channel evolution model. The channel is disconnected from the flood plain and non-cohesive materials comprising the banks of the *Bravo* reach have yielded a cross-sectional area twice the size of the *Alpha* reach.

The engineers and contractors of the stream restoration likely considered the project a success when Pennsylvania Department of Environmental Protection approved the completion of the project on 1.February.2006 (Table 3). Likewise, the Chambersburg Municipal Water Authority may consider the restoration a success because, to this point, they have not experienced sediment loads high enough at the raw water in-take to cause a disruption to the water supply. Evidence from this research supports the conclusion of a successful stream restoration. There is no evidence at the site that suggests a migrating knickpoint caused significant incision of the stream channel. The stabilized channel, characterized by the *Alpha* reach, currently shows no evidence of an incising channel that would lead to the transport of large volumes of sediment. Interestingly, the re-filling of the reservoir prior to the removal of the dam may have been the perfect accidental sediment management procedure.

Objective IV.

Disseminate the results of a dam removal stream restoration in order to encourage the spread of information regarding dam removal sites.

The collected data and results will be stored at two Internet archives: The Clearinghouse of Dam Removal Information and the Vigil Network. In so doing, the outcomes from this restoration will set an example for similar projects. Dam removal and stream restoration science are plagued by a lack of post-project assessment (Heinz Center 2002; Bernhardt et al. 2005). This research begins to fill that void by establishing a long-term monitoring system on a restored stream following the removal of a medium-sized dam.

Further Research

Where this research begins to provide a greater understanding of how stream channels evolve following dam removal, many other questions can be answered at this study site. Differences in water quality across the site may yield further information regarding the newly formed stream and its relationship to the wetlands in the valley. Other potential research opportunities at this site include biological surveys in the riparian zone and in the water. The author can only speak anecdotally of fish and macroinvertebrates in the stream, however systematic inquiry of the aquatic life could measure the success of the overall habitat recovery. Whether future investigators choose to repeat the procedures established herein, or expand the inquiry, this site remains a dynamic system with many more lessons to be learned.

An investigation of the sand deposits behind the former dam will help to determine the timing of their deposition. The material, in some places greater than a meter in depth, was not present directly following the drainage of the reservoir (Johnston, T.W., personal communication). It would seem that the high-flow event that partially re-filled the reservoir on 17.September 2004, Hurricane Ivan (Table 3; Figure 2), scoured the channel and re-deposited the material behind the former dam. If so, the removal of the material from the channel without harm to downstream habitat or infrastructure can be considered a success. Use of the stream's power to move the lacustrine material rather than dredging with heavy machinery is not an entirely new idea (Majors et al. 2008); the success here could be evidence for a sediment management alternative to be used on future sites. This is the type of lesson that cannot be predicted through analogous scenarios; it is through the study of current projects that we can understand the many facets of post-dam removal stream restoration.

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Appendix I.

Directions for completing the Reconnaissance Record Sheets

The reconnaissance record sheets are designed to facilitate data collection in the field and to ensure all of the necessary data are collected (Thorne 1998). The record sheets that guide this work are organized to focus the investigation from the entire watershed (Sections 1 and 2) to individual failure locations on the left and right banks (Parts 14 and 19, respectively). Section 1 includes the purpose of the reconnaissance, date, location, weather, persons, and other general notes. Section 2 is used to describe the entire catchment and valley (e.g. geology and vegetation). Section 3 begins the description of the subject reach. Data from the channel cross section (Part 6) will be used to complete a list of questions in the channel bed and bank sections. The left and right banks are described individually in Sections 4 and 5, respectively. Based on convention, identification of the left and right bank is done by looking downstream with the water traveling away from the observer. The steps described for Section 4 (the left bank) below should be replicated in order to complete Section 5 (the right bank).

Throughout the data collection process the user will need to interpret the status of a variety of features. These *Interpretative Observations* require the user to judge the adjustment and stability of physical features that may impact the fluvial system. For example, in Part 4 the relationship between the stream channel and the valley is interpreted to be adjusted, incised, or aggraded. These interpretations are to be based on the entire collection of observations and measurements made before and during the current reconnaissance trip. It is important, however, that the interpretations of the left bank not directly impact the interpretations of the right bank (Thorne 1998). The user is expected to have some knowledge of hydrologic, erosional and depositional processes. Regardless of the user's experience, a record of confidence should always be noted (for an example, see Part 4). The record of confidence gives the user a means of recording how sure they are of their assessment of the situation. This record provides future users an indicator of the reliability of prior observations. If, for example, a previous reconnaissance record sheet notes an active failure with a confidence of 40 percent, then subsequent observations of a dormant slope failure can still be made confidently given other physical evidence.

Section 1. Scope and Purpose

The first section of the reconnaissance sheets provides context for the remainder of the field visit. The *Problem Statement* and *Purpose* boxes should be used to describe why the site is being studied and what prompted the current site investigation. The original problem statement was the lack of post-project monitoring following a dam removal and stream restoration. If a new problem has been identified at the site such as heavy sediment loads at the Chambersburg Water Authority's raw water intake, then it should be stated here. The original purpose was to establish a baseline of information for long-term monitoring of a stream restoration post-dam removal. Future investigators should explain if the reconnaissance was performed as part of a regular monitoring program, or if an event prompted the visit to the site. If the trip is in response to a large storm event, then the storm event should be described, including any discharge data obtained from downstream sources (e.g. Chambersburg Water Authority).

Section 1 includes the basic information one can expect to find at the beginning of a typical fieldbook entry. This sheet will cover the basic logistics of the effort including who performed the reconnaissance; when it was performed (date and time); and where it took place. The weather on the day(s) of the investigation should be noted in addition to recent weather trends (e.g. drought, blizzard, or heavy rains) in the *General Notes* box. A different set of reconnaissance record sheets must be used for each of the reaches at the former Birch Run Dam, thus it is important to note next to *Location* which reach, *Alpha* or *Bravo*, is the subject of the investigation.

Section 2. Region and Valley Description

Supplies:

- Previous reconnaissance record sheet(s)
- Topographic maps
- Geologic maps
- Tripod
- Automatic level
- Stadia rod
- Tape measure

Section 2 provides a physical description of the catchment and river valley. Where possible, this task should be performed prior to the site visit in order to provide the observer a holistic understanding of the catchment (Johnson et al. 1999). Much of this information should be derived from a combination of recent aerial images, topographic maps, geologic maps, and visits to the catchment. Part 1 describes the entire catchment. The terrain, surface geology and rock type in Part 1 are not likely to have changed. The drainage pattern of the catchment is unlikely to have changed, but should be reviewed based on recent maps (i.e. topographic and/or hydrologic unit maps). Land use change can be estimated based on recent aerial imagery, published maps and field visits. Any significant changes to the land use based on published imagery should be confirmed during a field visit. Much of the catchment is located within the Michaux State Forest therefore intensive development is not likely to occur. Where possible, it is useful to drive through the catchment to look for signs of changes to the vegetation. Potential sources of recent change that will not appear on published maps include forest fires, blight, and pests.

The use of past reconnaissance record sheets to fill-in this information should be done with caution if the investigator is unfamiliar with the study area. The quartzitic ridges that dominate the study site are, for example, largely resistant to chemical weathering in the current climate, thus the user needs to understand the implications of this lithology on drainage pattern and sediment supply.

Stream channel form is the result of a multitude of contributing factors, thus only by with an understanding of the entire system can the investigator begin to identify how the current form resulted (Leopold et al. 1964; Knighton 1998; Ritter et al. 2002). Changes to the land use and vegetation of the catchment may provide a system-wide explanation for a change to a stream reach that would otherwise not be observable at the reach scale (Simon et al. 2007). Simply copying previous reconnaissance sheets may encourage the future user to overlook subtle changes that may be impacting the site. This section provides the investigator with an opportunity to identify changes to the landscape prior to visiting the subject reaches.

Part 2 describes the ridges of the valley and their relationship with the stream. The location of the stream is an old lake bed. The valley shape and the valley height are not expected to have changed substantially, or at all, since the baseline data were collected. The left side of the valley of the former impoundment was used for spoil during the decommissioning of the dam, opening the possibility of unstable slopes (Figure 6, Study Area map). Changes to the angle of the valley sides and/or observations of failures can impact the stream, particularly along the *Alpha* reach. These areas should be viewed anew during each field visit. The right side of the valley should not be overlooked for failures because the Conococheague Creek meanders next to the right side in between the two study reaches. A walk between the reaches may yield evidence of a failure within the former reservoir. Particular attention should be paid to the remaining portions of the Birch Run Dam and the areas used to deposit spoil from the breaching process. Any such failures should be noted in Part 2 of the closest reach record sheet and, if substantial, in the *General Notes* box of Section 1.

Part 3 describes the valley floor including the former reservoir and the upstream valley floor. The valley floor type and width indicates the vulnerability of the channel to be directly impacted by valley slope failures (Thorne 1998). The surface geology information is not expected to change in a short time frame. The valley floor has been mapped as alluvium beginning approximately 1.5 km upstream of the former reservoir (Fauth 1968). Changes to the dominant vegetation and land use will have an impact on the *Overbank Manning's n* values (Chow 1959; USGS 1990). Tables of these values can be found in many hydrology textbooks (Table 1a; Bedient et al. 2008). Manning's *n* values are estimates of the surface roughness which will affect the speed that water passes over the surface (Bedient et al. 2008). Differences in *n* are crucial in hydraulic modeling; therefore they could be useful in the event of future hydrologic or hydraulic modeling of the system. The description of a riparian buffer is typically more pertinent in urbanized locations, however here it is recorded as a reminder of the spatial distribution of the vegetation on the valley floor. Trees were planted by the Pennsylvania Department of the Conservation of Natural Resources (DCNR) in the former reservoir as part of the habitat restoration (Johnston et al. 2005). The survival of the trees in different locations may be indicative of water-table depth and the availability of water in the riparian zone (Klein 2004).

Part 4 is designed to describe a channel's relationship with the floodplain. Terraces, trash lines, overbank deposits, and levees all form during flood events when flow is beyond the banks of the channel. Time needs to be devoted to walking the floodplain of the reach to identify any overbank material or trash lines. If working in groups, persons should identify different deposits and discussion should be used to confirm the nature of the deposit and the probable height of the deposit above the floodplain (Harrelson et al. 1994). The *Alpha* reach (nearest the former dam) lacked natural terraces or levees. The levee directly upstream of the *Alpha* reach, opposite the diversion, appears to be a man-made structure (although it is absent from the engineer's drawings). The status of these features should be recorded in the interpretative observations section of Part 5.

The lateral relationship of the channel with the valley (Part 5) should be observed in the field with help from recent aerial imagery, when possible. Lateral activity and floodplain features can only be observed by walking the study site, especially along the length between the study reaches. The stream planform was mapped in the fall of 2008 with a total station (TopCon 200-series). This is not necessary for subsequent investigations due to the significant time and labor required to complete this task. Mapping of the channel is, however, encouraged if significant changes appear to have occurred. If planform mapping does not take place, the users should take the time to view the valley from the former dam and the constructed bench along the left valley slope. The broader perspective from elevation should aid the interpretation of the channel-valley relationship. The interpretative observations section is used to describe the width of the channel. This is important because if the channel is accumulating more material than it can move, it is likely to be considered too wide. Conversely, if it is incising into the bed, then the channel may be too narrow (Thorne 1998; Downs and Kondolf 2002).

Mapping of the channel cross-section (Part 6) is crucial to completion of the reconnaissance field visit. This will provide data for the remaining sections such as the slope and the height of banks, along with the average depth of channel. The tasks performed by each person should be recorded on the Recording Sheet. This task is best completed with an automatic level and a stadia rod (Harrelson et al. 1994); however, hand leveling techniques will provide comparable results. The automatic level should be located approximately equidistant from both of the channel banks. If vegetation prevents this set-up, the location that provides the greatest vision of the channel should be used. Locations of distinct change in the slope gradient are good locations to collect relative elevation data. Regular intervals of one-foot distance within the stream and one to 10-foot intervals should be used on the flood plain depending on the homogeneity of the surface. The person with the stadia rod should identify to the note-taker which locations are in water, at the toe of the bank, and at the top of the channel banks, regardless of the spacing interval. The *Alpha* and *Bravo* channels each appeared to have an upper and lower bank top. The record of heights should note these points and any others of significance (e.g. islands, location of the water).

Slope should be measured during this mapping activity if overall stream planform mapping is not included in the overall investigation. The distance between two points within the channel representing the up- and downstream extent of the reach needs to be measured. With the automatic level, capture the relative elevation of those two points. The change in relief divided by the distance is the slope of the reach. This process should be repeated multiple times and the resulting slope values averaged. Locating one of the stadia rods in a pool or the thalweg will skew the results, thus by averaging the results an overall descriptive value is recorded (Part 7, Section 3).

Section 3. Channel Description

Supplies:

Stream Discharge:

- Tape measure
- Tape (for partitioning the channel)
- Wading rod
- Gage (pygmy)
- Current meter (or headphone)
- Previous reconnaissance record sheet(s)
- Ruler or gravelometer

The overall channel description is recorded in Section 3. The channel dimension information for Part 7 is derived from the results of the cross-section mapping in Part 6. Average water depth and mean velocity of flow will be measured in Part 9 during the measurements of discharge. Drawing the tape across the channel for the discharge measurement will provide supplemental width data. The flow type record provides a qualitative description of the stream that further describes the discharge measurement. Changes to the flow type for comparable flows may be indicative of changes to the channel geometry (Thorne 1998).

Bed and width controls in the channel should be counted for the number of different types occurring in the reach and a note on their frequency. This provides an indication of the likelihood and amount of channel migration. Changes to the frequency of gravel, cobble, and/or boulder controls may indicate substantial movement of material from upstream or recent exposures of new controls due to erosion.

Bed material (Part 8) is first described qualitatively and then quantified based on the results from Part 10. The *Surface Size Data* (D50, D84, and D16) are obtained by plotting the results of the pebble count (Part 10) on a $\log_2$ scale. This graph provides the estimated distribution of sediment sizes on the channel bed. Measurement of the sediment depth can be performed with a ruler in sandy deposits; in coarser material this is easier to perform with a rod. Sediment depth should be measured in order to identify the active layer of the bed. In the presence of bedrock this is unnecessary. The size of the substrate can be qualitative, but needs to be reported in order to understand the vulnerability/frequency of entrainment (Thorne 1998).

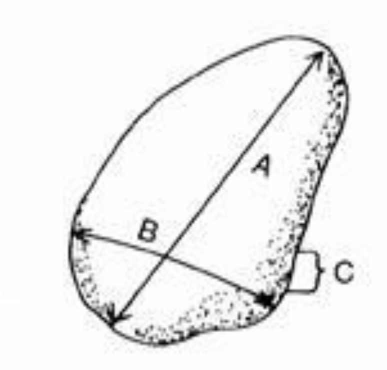
Particular attention should be paid to any bars that exist within the reach. Their spatial distribution throughout the reach should be noted in the Channel Sketch Map below Part 8. The size of the material forming any bars can be estimated, or a random sampling procedure similar to the Wolman pebble count method (1954) can be used if it is largely comprised of cobbles. If the majority of the bar(s) is comprised of sands/fines, a representative sample near mid-bar should be sampled via sieve-by-weight procedures. Any spatial trends in the distribution of particle sizes should be noted in the channel sketch map as it can provide an indicator of bankfull depth and velocity (Harrelson et al. 1994).

The channel sketch map is an opportunity to map the location of different features throughout the study reach. The orientation of the sketch and the flow of water should be noted. The distribution of differing vegetation types should be graphically displayed. Any in-stream features such as bars or islands and their relative sizes should be included in the sketch. The only man-made features likely to be present on these sketches will be the transects across each subject reach. The transect should be noted so that features can be compared relative to their location during previous field visits. The location of any sediment samples should be noted on the map. The channel sketch map can be used for the documentation of the photo stations as well.

A series of photographs should be taken from the locations identified in the photo record (Appendix IV). The orientation of the original photograph is listed on the photo record sheets for future replication. Additional photo stations can be added as necessary. Where new stations are created, the location and orientation of the camera should be reported either in the channel sketch map or on a fresh sketch of the study reach.

The discharge of the stream (Part 9) is measured along the established transect following standard USGS (1982) procedures with a wading rod and current meter. The water width should be divided into 20 segments of equal velocity. If boulders are too numerous to avoid along the transect, the segment associated with the boulder does not count towards the 20 segments. Where water depths are less than 0.8 meters (2.5 feet), the six-tenths depth method should be used. In greater depths, a measurement needs to be obtained at two-tenths and eight-tenths depth of the water column. Sampling periods should be at least 40 seconds. Use the form in Part 9 to record the beginning/end distance for each segment; the depth of measurement (in inches/feet); the duration of sampling (seconds); number of rotations; and velocity. Recording all of these data will enable a more effective investigation in the case of anomalous calculations.

The *Surface Size Data* are measured following the Wolman pebble count method (1954) and are recorded in Part 10. This method involves walking from bank-to-bank and picking up the bed material (granule, pebble, cobble, etc.) that is against/below the observer's big toe. The channels along the Conococheague Creek are approximately 5 meters wide, thus 100 samples are not reasonable for one walk along the transect. At least ten transects should be walked perpendicular to the channel in order to obtain a sample that is representative of the entire reach. Begin by collecting and measuring pebbles along the original transect then take one step downstream and collect pebbles along a new transect parallel to the original transect. Repeat this procedure five times on either side of the original transect.



A = Longest axis (length)

B = Intermediate axis (width)

C = Shortest axis (thickness)

Figure 1a. The intermediate axis of a pebble to be measured when performing the Wolman (1954) pebble count methodology. If using a gravelometer, this will be the width that prevents the pebble from passing through one of the squares. (Graphic from Harrelson et al. 1994.)

The pebble or cobble is measured along the intermediate axis (Figure 1a). The intermediate axis can be considered the side of a pebble that will prevent it from fitting through a small hole. Where the pebble is embedded or too large to pick-up, the shortest visible axis should be measured. A gravelometer can be used here if available. Original measurements (4.March.2009 and 29.May.2009) were performed with a ruler across the median axis of the pebble. The record sheet is divided into groups that reflect common gravelometer divisions (Harrelson et al. 1994). The surface size data in Part 8 are derived from these data.

Section 4. Left Bank Survey

Supplies:	
• Tape measure • Brunton compass • Camera	• Previous reconnaissance record sheet(s) • Ruler

The survey of the left bank (Section 4) provides a description of the bank material (Part 11); bank vegetation (Part 12); evidence of erosion (Part 13); and evidence of geotechnical failures (Part 14). The presence and/or absence of accumulating material at the toe of the bank is recorded in Part 15.

The left and right banks are traditionally identified by looking downstream so that the water is flowing away from the viewer (Harrelson et al. 1994). Surveys of the left and right banks are performed individually in order to avoid the results of one bank influencing the other. Parts 13 and 14 should be completed independently from one another in order to avoid confusion between erosional features and geotechnical failures (Thorne 1998). The bank surveys provide a crucial component in the understanding of the migration process and bank forming trends for the channel (Simon et al. 2007). The sketch of the bank (below Part 12) should be updated after Part 15 is complete. This should include the vegetation extent, type and trends throughout the reach. The water level relative to the banks and other features should be noted to provide context of the relationship between discharge and channel geometry.

The materials that make-up the bank are first described in Part 11. Non-cohesive layers will be sandy or gravely, while a cohesive bank will be comprised of clay or silt. Layers should be described where there is a change in cohesiveness because a single layer of non-cohesive material in a bank increases the vulnerability to bank failure (Walter and Merritts 2008). Where possible, the material in the bank below the water line should be described as well as those above the present water line. A record of any distinct changes in the colors of soil materials should be noted, particularly oranges or grays. Signs of oxidation may indicate the duration of inundation and water depth trends. Bank height data can be derived from the cross-section; however the bank slope gradients should be measured directly with a Brunton compass.

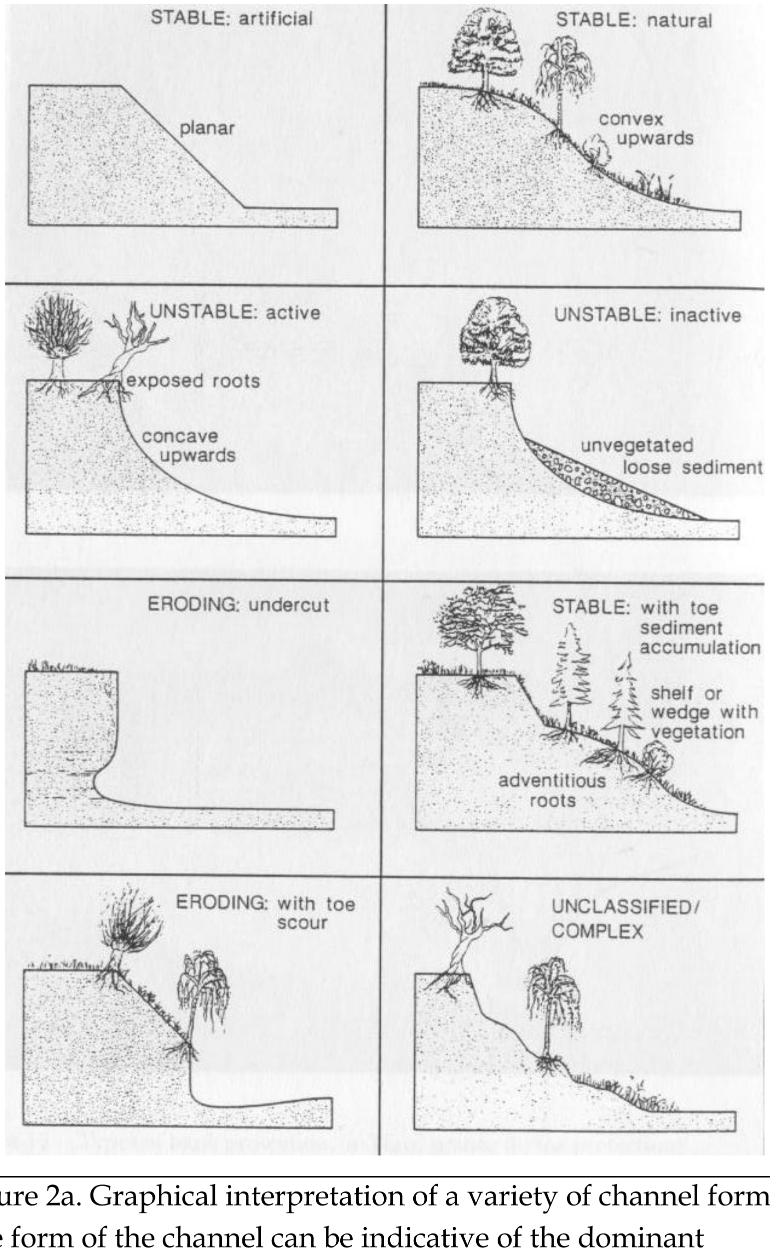


Figure 2a. Graphical interpretation of a variety of channel forms. The form of the channel can be indicative of the dominant processes acting on a stream channel (graphic from Thorne 1998).

The presence, type and health of bank vegetation will change the erosion potential for the banks. If the site visit is done during the off-leaf time of year, vegetation still needs to be described. Any major trees or stands of vegetation should be noted in the Channel Sketch Map (Part 8) and the Bank Profile Sketch. Part 12 begins with a catalog of vegetation types and tree species, if known. The Chambersburg Reservoir was re-planted during the restoration process, thus certain tree species are expected to be found here. The health of trees should be checked, including any protective planting tubes that were used to establish trees in the area. Any leaning of trees should be recorded as it may be a sign of soil creep or an unstable bank.

Erosional features along the left bank are documented in Part 13 of the reconnaissance record sheets. The location of erosional features may provide evidence for the potential migration of the stream. If there are a variety of locations indicating evidence of differing erosional processes, they should be noted with their associated process number in the *Interpretative Observations* section. This will avoid any confusion regarding the location of each different erosional process. The present status of the activity should be noted for each process as well. Actively eroding features may lack a significant accumulation of material at the toe and be devoid of vegetation (Figure 2a). Dormant erosional features may have a collection of material and colonizing vegetation.

It is important to not mistake erosional features (Part 13) from geotechnical failures (Part 14). Failures are frequently associated with locations of erosion, but not inherently (Thorne 1998). Failures of the bank may be indicative of serious instabilities. The location of any failures along the left bank should be noted based on its location along the bank height and relative to any bars or pools. Neither of the reaches studied here include any man-made structures; however both include relict root balls that were buried by sediment when the valley was inundated with water. Failures near these features should be treated like a structure. The presence of scars and/or blocks is evidence for recent failures. Scars are the fresh face of the bank exposed due to the slumped, fallen, or sliding block of material. The block is the intact unit of material that was mobilized. Scallops, concave depressions, along the bank may have been re-vegetated since the failure, but should be noted as dormant. The maturity of the vegetation can provide insight into the time since the failure.

The accumulation of sediment at the toe of a bank is reported in Part 15. This describes the balance of soil accumulation and sediment transport. Sediment stored at a toe is subject to entrainment during high flows and thus a greater accumulation can provide insight into the connectivity of the channel and its banks. Vegetation that colonizes the accumulating sediment can indicate the permanence of the sediment. Trees are excellent indicators of the permanence of the sediment deposit. The age, health, and exposure of the roots should be recorded where applicable.

Section 5. Right Bank Survey

The survey of the right bank should be completed following the same steps used to complete the survey of the left bank.

Manning's n values

Table 1a. Values used for estimation of the Manning's n. Table is reproduced from USGS (1990).

Type of Channel and Description	Minimum	Normal	Maximum
1. Main Channels			
a. clean, straight, full stage, no rifts or deep pools	0.025	0.03	0.033
b. same as above, but more stones and weeds	0.03	0.035	0.04
c. clean, winding, some pools and shoals	0.033	0.04	0.045
d. same as above, but some weeds and stones	0.035	0.045	0.05
e. same as above, lower stages, more ineffective slopes and sections	0.04	0.048	0.055
f. same as "d" with more stones	0.045	0.05	0.06
g. sluggish reaches, weedy, deep pools	0.05	0.07	0.08
h. very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.1	0.15
2. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages			
a. bottom: gravels, cobbles, and few boulders	0.03	0.04	0.05
b. bottom: cobbles with large boulders	0.04	0.05	0.07
3. Floodplains			
a. Pasture, no brush			
1.short grass	0.025	0.03	0.035
2. high grass	0.03	0.035	0.05
b. Cultivated areas			
1. no crop	0.02	0.03	0.04
2. mature row crops	0.025	0.035	0.045
3. mature field crops	0.03	0.04	0.05
c. Brush			
1. scattered brush, heavy weeds	0.035	0.05	0.07
2. light brush and trees, in winter	0.035	0.05	0.06
3. light brush and trees, in summer	0.04	0.06	0.08
4. medium to dense brush, in winter	0.045	0.07	0.11
5. medium to dense brush, in summer	0.07	0.1	0.16
d. Trees			
1. dense willows, summer, straight	0.11	0.15	0.2
2. cleared land with tree stumps, no sprouts	0.03	0.04	0.05
3. same as above, but with heavy growth of sprouts	0.05	0.06	0.08
4. heavy stand of timber, a few down trees, little undergrowth, flood stage below branches	0.08	0.1	0.12
5. same as 4. with flood stage reaching branches	0.1	0.12	0.16
4. Excavated or Dredged Channels			
a. Earth, straight, and uniform			
1. clean, recently completed	0.016	0.018	0.02
2. clean, after weathering	0.018	0.022	0.025
3. gravel, uniform section, clean	0.022	0.025	0.03
4. with short grass, few weeds	0.022	0.027	0.033
b. Earth winding and sluggish			
1. no vegetation	0.023	0.025	0.03
2. grass, some weeds	0.025	0.03	0.033

3. dense weeds or aquatic plants in deep channels	0.03	0.035	0.04
4. earth bottom and rubble sides	0.028	0.03	0.035
5. stony bottom and weedy banks	0.025	0.035	0.04
6. cobble bottom and clean sides	0.03	0.04	0.05
c. Dragline-excavated or dredged			
1. no vegetation	0.025	0.028	0.033
2. light brush on banks	0.035	0.05	0.06
d. Rock cuts			
1. smooth and uniform	0.025	0.035	0.04
2. jagged and irregular	0.035	0.04	0.05
e. Channels not maintained, weeds and brush uncut			
1. dense weeds, high as flow depth	0.05	0.08	0.12
2. clean bottom, brush on sides	0.04	0.05	0.08
3. same as above, highest stage of flow	0.045	0.07	0.11
4. dense brush, high stage	0.08	0.1	0.14

Appendix II.

Locating the Alpha Transect

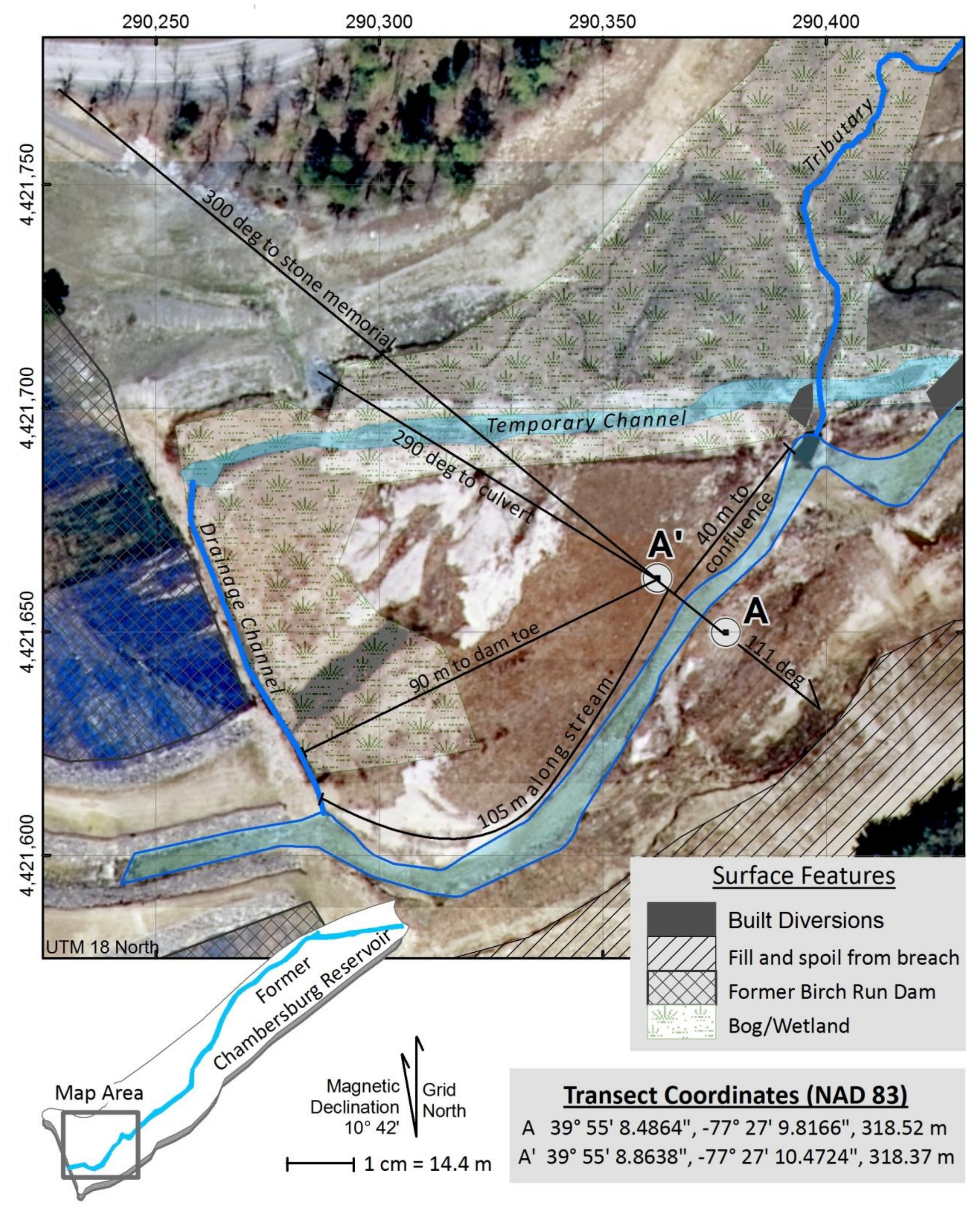


Figure 3a. The location of the *Alpha* study reach as relates to the former Birch Run Dam and other physical features. Map features are projected and the grid is displayed with the Universal Transverse Mercator (UTM) system, 18 North.

Parking

Accessing the *Alpha* transect is easiest by parking in the lower lot (downstream of the former Birch Run Dam) and walking through the breach. Parking is also accessible alongside the top of the former dam; however it is less convenient to walk down from this location and across the wetland.

Walking upstream

The *Alpha* transect is less than 100 m from the upstream toe of the former Birch Run Dam (Figure 3a). A small stream (approximately 50 cm wide) parallel to the dam was dug to drain the wetland. At the time of this report, there is a lightly beaten path near the right bank of the Conococheague Creek. When walking on this path the *Alpha* transect is approximately 105 m after crossing the small drainage stream. The *A′* end-point is on the opposite side of the path than the stream channel (on the left as you walk upstream).

Walking downstream

Upstream of the *Alpha* reach is the confluence of the Conococheague Creek and a minor tributary (Figure 3a). Prior to the confluence, the Conococheague Creek is quite wide (approximately 10 m) and abruptly turns to the right (as viewed looking downstream). If the tributary is dry or has changed routes, the confluence can be identified by the limestone riprap armoring the right side of the tributary banks. The *Alpha* cross-section is 40 m downstream of the confluence. At the time of this study, the *Alpha* transect is within the first clearing of grass as you walk from the confluence.

Orientation

The *A′* end-point of the *Alpha* reach is currently in a grassy clearing. This should allow a clear view of the top of the right side of the dam. There is a large stone monument along the road at the parking area adjacent to the former dam. When viewed from the *A′* end-point, the stone monument is approximately 300 degrees. After locating the A′ end-point, the transect across the stream to the *A* end-point is 111 degrees.

Locating the Bravo Study Reach

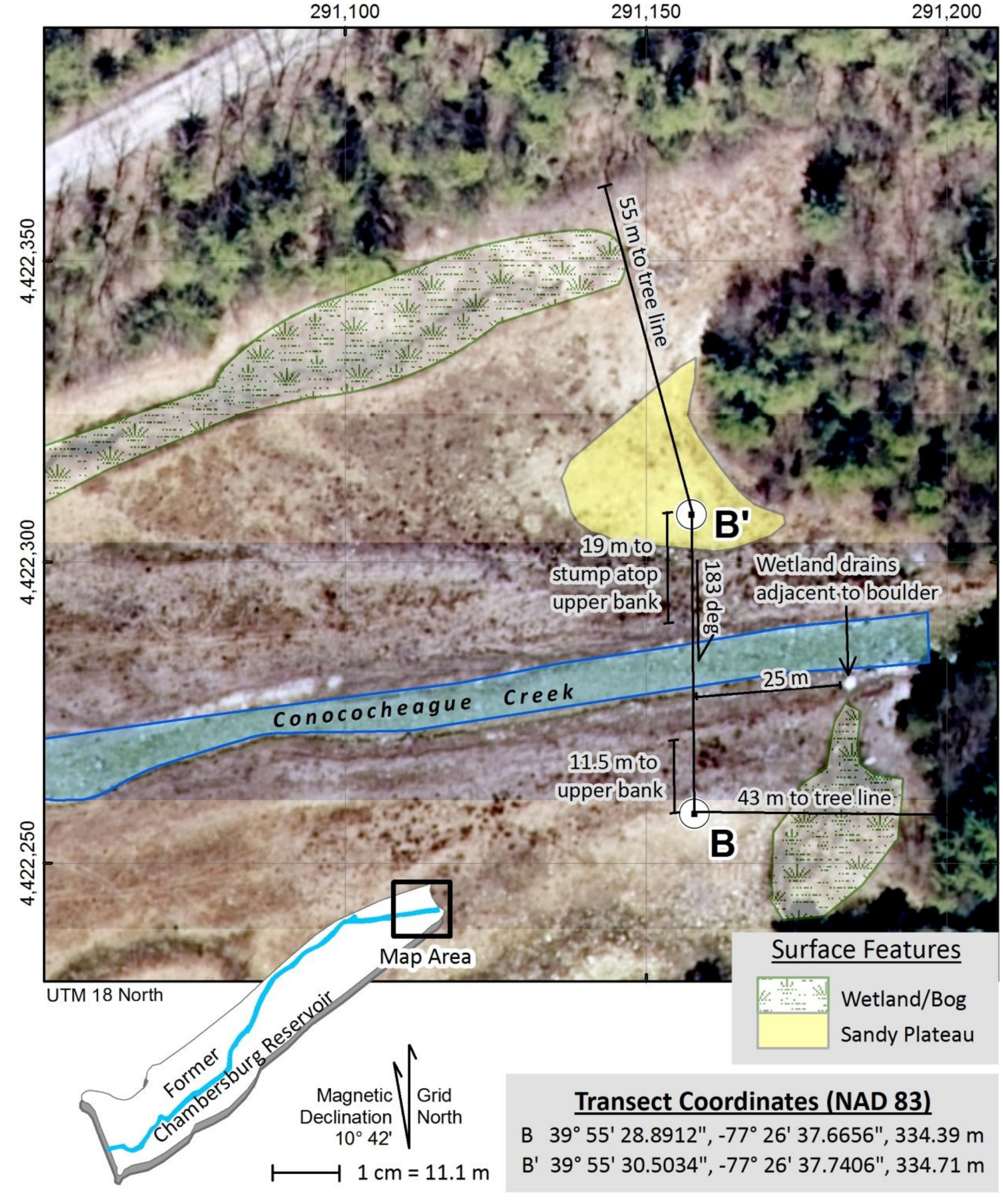


Figure 4a. The location of the *Bravo* transect is identifiable based on its spatial relationship with the relict shorelines of the former Chambersburg Reservoir and the Conococheague Creek. Map features are projected and the grid is displayed with the Universal Transverse Mercator (UTM) system, 18 North.

Parking

Accessing the *Bravo* reach from the road requires finding a safe place to park on the shoulder of the road, State Route 233. There are two places where the shoulder is barely wide enough to park a car. If parking here, do so with extreme caution because there is a sharp turn in the road very nearby. The hill down to the valley is steep. There is a lightly beaten path that can be used to walk down the hill safely.

Walking from the dam

If walking along the stream, the flood plain on the left side of the valley is slightly easier walking due to the barren grasslands that begin approximately halfway to the *Bravo* reach. When walking along the grasslands, beware of minor gullies that are sometimes difficult to see from a distance. The Conococheague Creek flows largely straight from the *Bravo* reach until it reaches the right valley hillside. The wetland area along the toe of the hill drains into the channel near the small island. The *Bravo* reach is approximately 260 meters from this meander, nearly adjacent to the edge of the tree line (Figure 4a).

If walking from the former dam, the fastest route is along the built bench on the south side of the valley. The bench ends more than 200 m before the end of the former impoundment. Continue walking upstream along the treeline to find the *Bravo* reach. At the time of this study, there was standing water along the toe of the bench from the culvert to the bench terminus.

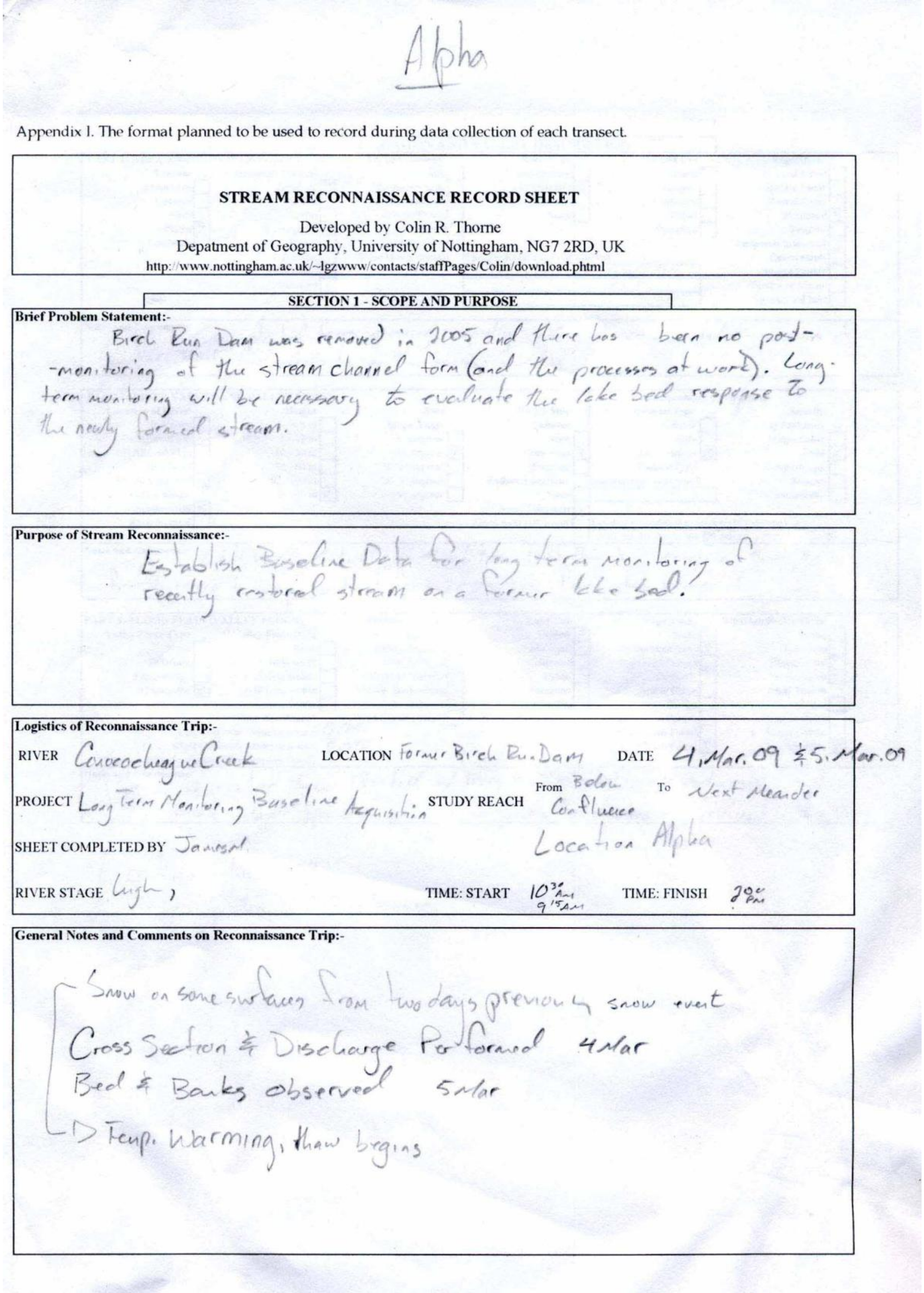
Locating the transect

The *B'* end-point is more than 100 m from the edge of the road. At the edge of the tree line (approximate maximum water elevation for the Chambersburg Reservoir at capacity) there were numerous tree stumps and standing water. From the tree line, the *B'* end-point is approximately 55 m away (Figure 4a).

The end-points of the *Bravo* transect are in large stumps on the grassy floodplain. The end-point on the right floodplain is upon a barren area of sandy soil, less than 15 m from the tree line. The *Bravo* transect, bearing 183 degrees, passes alongside a large stump at the top of the right upper bank, approximately 19 m from the B' end-point. There is a large boulder on the lower terrace, adjacent to where the wetland drains into the Conococheague Creek; the transect is 25 m downstream from the boulder.

Appendix III.

Alpha - Reconnaissance Record Sheets dated, 4-5.March.2009



Alpha

Appendix I. The format planned to be used to record during data collection of each transect.

STREAM RECONNAISSANCE RECORD SHEET

Developed by Colin R. Thorne
Depatment of Geography, University of Nottingham, NG7 2RD, UK
http://www.nottingham.ac.uk/~lgzwww/contacts/staffPages/Colin/download.phtml

SECTION 1 - SCOPE AND PURPOSE

Brief Problem Statement:-

Birch Run Dam was removed in 2005 and there has been no post--monitoring of the stream channel form (and the processes at work). Long-term monitoring will be necessary to evaluate the lake bed response to the newly formed stream.

Purpose of Stream Reconnaissance:-

Establish Baseline Data for long term monitoring of recently restored stream on a former lake bed.

Logistics of Reconnaissance Trip:-

RIVER Conococheague Creek

LOCATION Former Birch Run Dam

DATE 4.Mar.09 & 5.Mar.09

PROJECT Long Term Monitoring Baseline Acquisition

STUDY REACH From Below Confluence To Next Meander

Location Alpha

SHEET COMPLETED BY Jamesm.

RIVER STAGE high,

TIME: START 10^{30} AM 9^{15} AM

TIME: FINISH 2^{00} PM

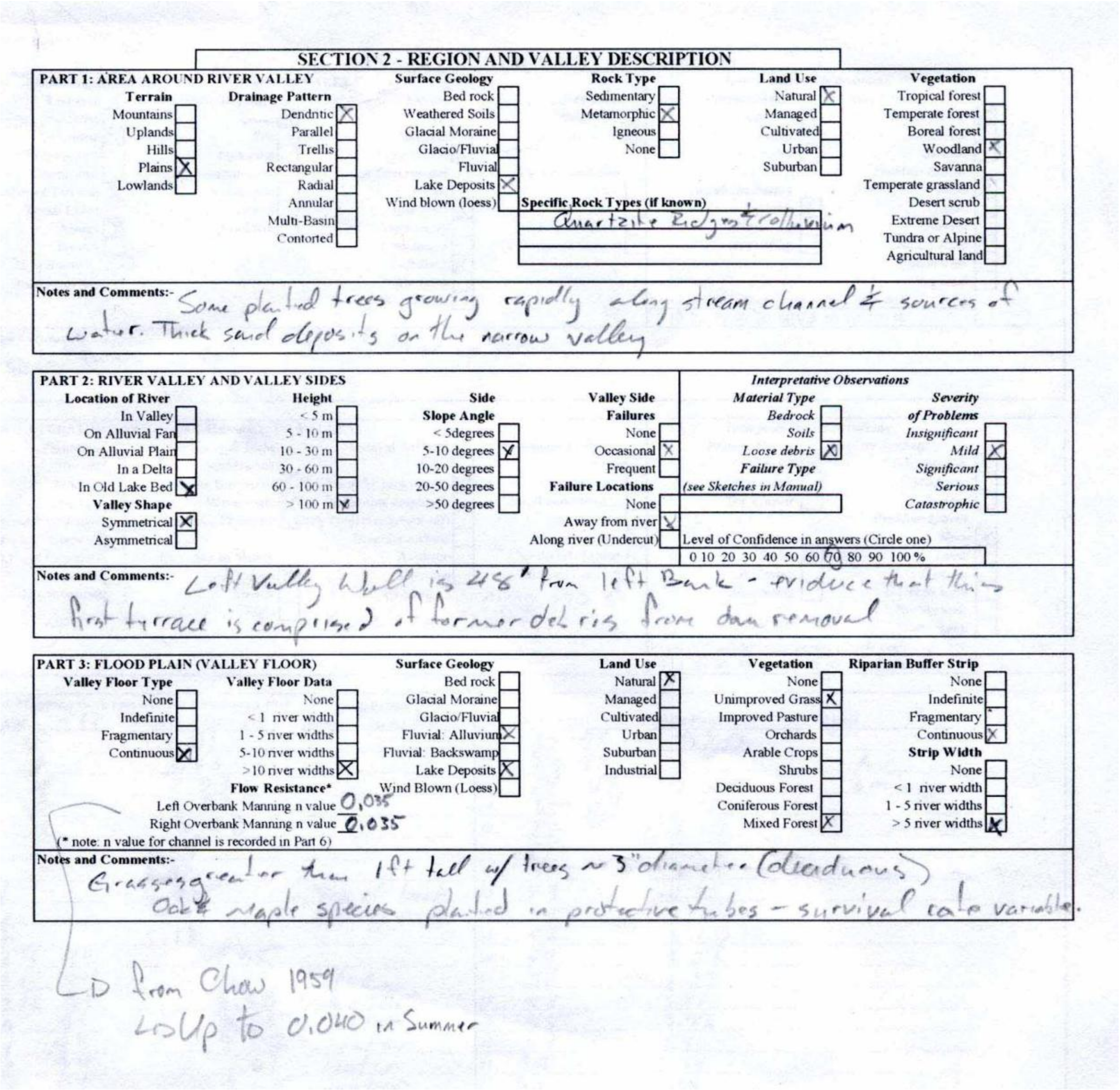
General Notes and Comments on Reconnaissance Trip:-

Snow on some surfaces from two days previous snow event

Cross Section & Discharge Performed 4 Mar

Bed & Banks observed 5 Mar

▷ Temp. warming, thaw begins



SECTION 2 - REGION AND VALLEY DESCRIPTION

PART 1: AREA AROUND RIVER VALLEY

Terrain
- Mountains ☐
- Uplands ☐
- Hills ☐
- Plains ☒
- Lowlands ☐

Drainage Pattern
- Dendritic ☒
- Parallel ☐
- Trellis ☐
- Rectangular ☐
- Radial ☐
- Annular ☐
- Multi-Basin ☐
- Contorted ☐

Surface Geology
- Bed rock ☐
- Weathered Soils ☐
- Glacial Moraine ☐
- Glacio/Fluvial ☐
- Fluvial ☐
- Lake Deposits ☒
- Wind blown (loess) ☐

Rock Type
- Sedimentary ☐
- Metamorphic ☒
- Igneous ☐
- None ☐

Specific Rock Types (if known)
Quartzite Ridges & colluvium

Land Use
- Natural ☒
- Managed ☐
- Cultivated ☐
- Urban ☐
- Suburban ☐

Vegetation
- Tropical forest ☐
- Temperate forest ☐
- Boreal forest ☐
- Woodland ☒
- Savanna ☐
- Temperate grassland ☐
- Desert scrub ☐
- Extreme Desert ☐
- Tundra or Alpine ☐
- Agricultural land ☐

Notes and Comments:- Some planted trees growing rapidly along stream channel & sources of water. Thick sand deposits on the narrow valley

PART 2: RIVER VALLEY AND VALLEY SIDES

Location of River
- In Valley ☐
- On Alluvial Fan ☐
- On Alluvial Plain ☐
- In a Delta ☐
- In Old Lake Bed ☒

Valley Shape
- Symmetrical ☒
- Asymmetrical ☐

Height
- < 5 m ☐
- 5 - 10 m ☐
- 10 - 30 m ☐
- 30 - 60 m ☐
- 60 - 100 m ☐
- > 100 m ☒

Side Slope Angle
- < 5degrees ☐
- 5-10 degrees ☒
- 10-20 degrees ☐
- 20-50 degrees ☐
- >50 degrees ☐

Valley Side Failures
- None ☐
- Occasional ☒
- Frequent ☐

Failure Locations
- None ☐
- Away from river ☒
- Along river (Undercut) ☐

Interpretative Observations

Material Type
- *Bedrock* ☐
- *Soils* ☐
- *Loose debris* ☒

Failure Type
(see Sketches in Manual)

Severity of Problems
- *Insignificant* ☐
- *Mild* ☒
- *Significant* ☐
- *Serious* ☐
- *Catastrophic* ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 [✓ 70] 80 90 100 %

Notes and Comments:- Left Valley Wall is 248' from left Bank - evidence that this first terrace is comprised of former debris from dam removal

PART 3: FLOOD PLAIN (VALLEY FLOOR)

Valley Floor Type
- None ☐
- Indefinite ☐
- Fragmentary ☐
- Continuous ☒

Valley Floor Data
- None ☐
- < 1 river width ☐
- 1 - 5 river widths ☐
- 5-10 river widths ☐
- >10 river widths ☒

Flow Resistance*
Left Overbank Manning n value 0,035
Right Overbank Manning n value 0.035
(* note: n value for channel is recorded in Part 6)

Surface Geology
- Bed rock ☐
- Glacial Moraine ☐
- Glacio/Fluvial ☐
- Fluvial: Alluvium ☒
- Fluvial: Backswamp ☐
- Lake Deposits ☒
- Wind Blown (Loess) ☐

Land Use
- Natural ☒
- Managed ☐
- Cultivated ☐
- Urban ☐
- Suburban ☐
- Industrial ☐

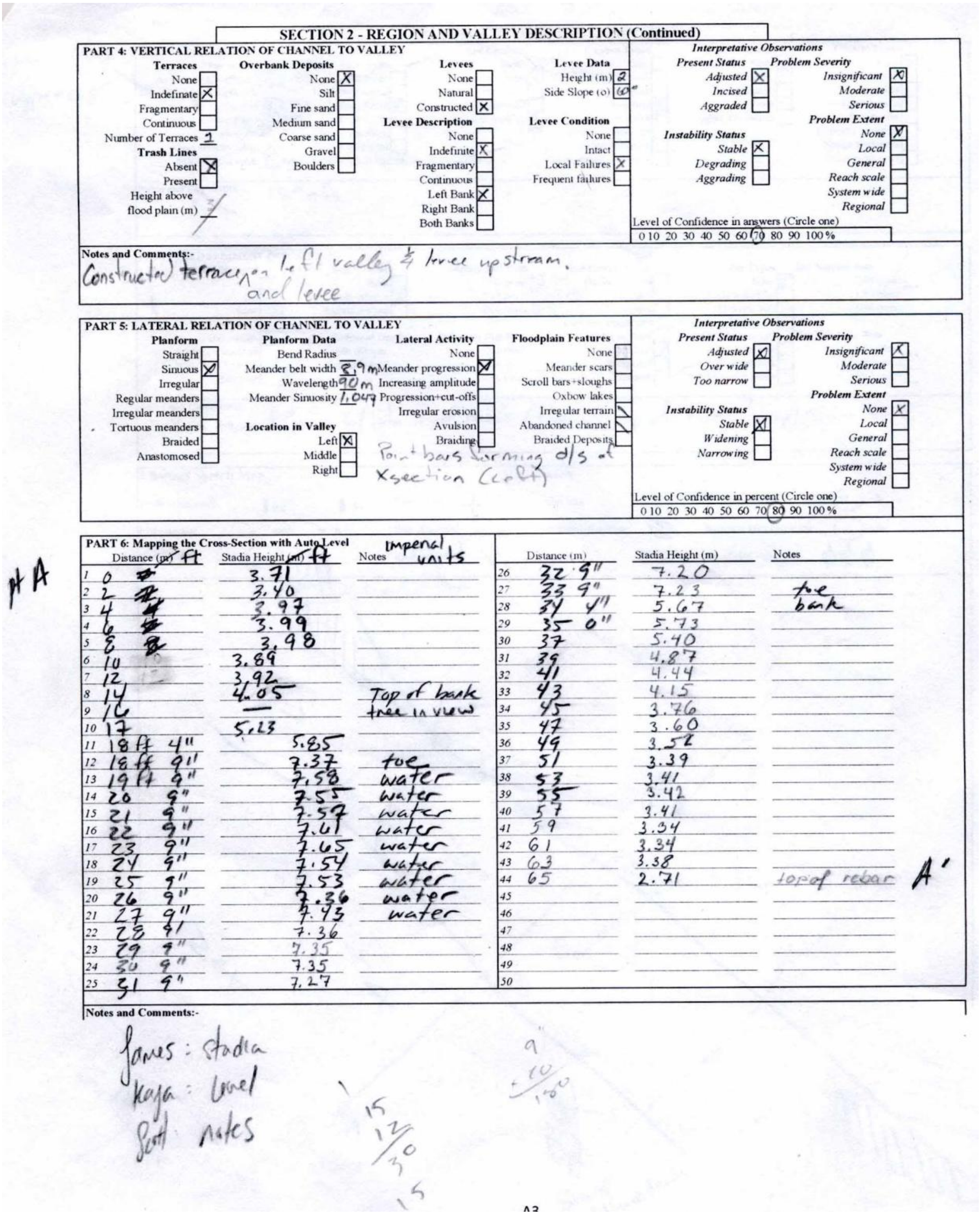
Vegetation
- None ☐
- Unimproved Grass ☒
- Improved Pasture ☐
- Orchards ☐
- Arable Crops ☐
- Shrubs ☐
- Deciduous Forest ☐
- Coniferous Forest ☐
- Mixed Forest ☒

Riparian Buffer Strip
- None ☐
- Indefinite ☐
- Fragmentary ☐
- Continuous ☒

Strip Width
- None ☐
- < 1 river width ☐
- 1 - 5 river widths ☐
- > 5 river widths ☒

Notes and Comments:- Grasses greater than 1ft tall w/ trees ~ 3" diameter (deciduous)
Oak & maple species planted in protective tubes - survival rate variable.

from Chow 1959
Up to 0.040 in Summer



SECTION 2 - REGION AND VALLEY DESCRIPTION (Continued)

PART 4: VERTICAL RELATION OF CHANNEL TO VALLEY

Terraces
- None ☐
- Indefinate ☒
- Fragmentary ☐
- Continuous ☐

Number of Terraces 1

Trash Lines
- Absent ☒
- Present ☐

Height above flood plain (m) –

Overbank Deposits
- None ☒
- Silt ☐
- Fine sand ☐
- Medium sand ☐
- Coarse sand ☐
- Gravel ☐
- Boulders ☐

Levees
- None ☐
- Natural ☐
- Constructed ☒

Levee Description
- None ☐
- Indefinite ☒
- Fragmentary ☐
- Continuous ☐
- Left Bank ☒
- Right Bank ☐
- Both Banks ☐

Levee Data

Height (m) 2

Side Slope (o) 60°

Levee Condition
- None ☐
- Intact ☐
- Local Failures ☒
- Frequent failures ☐

Interpretative Observations

Present Status
- *Adjusted* ☒
- *Incised* ☐
- *Aggraded* ☐

Instability Status
- *Stable* ☒
- *Degrading* ☐
- *Aggrading* ☐

Problem Severity
- *Insignificant* ☒
- *Moderate* ☐
- *Serious* ☐

Problem Extent
- *None* ☒
- *Local* ☐
- *General* ☐
- *Reach scale* ☐
- *System wide* ☐
- *Regional* ☐

Level of Confidence in answers (Circle one)

0 10 20 30 40 50 60 [✓ 70] 80 90 100 %

Notes and Comments:-

Constructed terrace and levee on left valley & levee upstream.

PART 5: LATERAL RELATION OF CHANNEL TO VALLEY

Planform
- Straight ☐
- Sinuous ☒
- Irregular ☐
- Regular meanders ☐
- Irregular meanders ☐
- Tortuous meanders ☐
- Braided ☐
- Anastomosed ☐

Planform Data

Bend Radius

Meander belt width 8,9 m

Wavelength 90 m

Meander Sinuosity 1,047

Location in Valley
- Left ☒
- Middle ☐
- Right ☐

Lateral Activity
- None ☐
- Meander progression ☒
- Increasing amplitude ☐
- Progression+cut-offs ☐
- Irregular erosion ☐
- Avulsion ☐
- Braiding ☐

Floodplain Features
- None ☐
- Meander scars ☐
- Scroll bars+sloughs ☐
- Oxbow lakes ☐
- Irregular terrain ☒
- Abandoned channel ☒
- Braided Deposits ☐

Point bars forming d/s of Xsection (left)

Interpretative Observations

Present Status
- *Adjusted* ☒
- *Over wide* ☐
- *Too narrow* ☐

Instability Status
- *Stable* ☒
- *Widening* ☐
- *Narrowing* ☐

Problem Severity
- *Insignificant* ☒
- *Moderate* ☐
- *Serious* ☐

Problem Extent
- *None* ☒
- *Local* ☐
- *General* ☐
- *Reach scale* ☐
- *System wide* ☐
- *Regional* ☐

Level of Confidence in percent (Circle one)

0 10 20 30 40 50 60 70 [✓ 80] 90 100 %

PART 6: Mapping the Cross-Section with Auto Level imperial units

#A

	Distance ~~(m)~~ ft	Stadia Height ~~(m)~~ ft	Notes
1	0	3.71	
2	2	3.40	
3	4	3.97	
4	6	3.99	
5	8	3.98	
6	10	3.89	
7	12	3.92	
8	14	4.05	Top of bank
9	16	—	tree in view
10	17	5.23	
11	18 ft 4"	5.85	
12	18 ft 9"	7.37	toe
13	19 ft 9"	7.58	water
14	20 9"	7.55	water
15	21 9"	7.57	water
16	22 9"	7.61	water
17	23 9"	7.65	water
18	24 9"	7.54	water
19	25 9"	7.53	water
20	26 9"	7.36	water
21	27 9"	7.43	water
22	28 9'	7.36	
23	29 9"	7.35	
24	30 9"	7.35	
25	31 9"	7.27	

	Distance (m)	Stadia Height (m)	Notes
26	32 9"	7.20	
27	33 9"	7.23	toe
28	34 4"	5.67	bank
29	35 0"	5.73	
30	37	5.40	
31	39	4.87	
32	41	4.44	
33	43	4.15	
34	45	3.76	
35	47	3.60	
36	49	3.52	
37	51	3.39	
38	53	3.41	
39	55	3.42	
40	57	3.41	
41	59	3.34	
42	61	3.34	
43	63	3.38	
44	65	2.71	top of rebar
45			
46			
47			
48			
49			
50			

A'

Notes and Comments:-

James : stadia

Kaja : level

Scott notes

9"
+10
15
12/30
15

SECTION 3 - CHANNEL DESCRIPTION

Lower 0,48
Upper 0.80

PART 6: CHANNEL DESCRIPTION

Dimensions
Av. top bank width (m) 4,876 Lower 8,839 Upper
Av. channel depth (m) ___
Av. water width (m) 4,572
Av. water depth (m) 0,213
Reach slope 0,01
Mean velocity (~~m/s~~) 2,7 ft/s
Manning's n value 0,040

Flow Type
None ☐
Uniform/Tranquil ☐
Uniform/Rapid ☒
Pool+Riffle ☐
Steep + Tumbling ☐
Steep + Step/pool ☐
(Note: Flow type on day of observation)

Bed Controls
~~None~~ ☒
Occasional ☒
Frequent ☐
Confined ☐
Number of controls 2

Control Types
None ☐
Solid Bedrock ☐
Weathered Bedrock ☐
Boulders ☒
Gravel armor ☒
Cohesive Materials ☐
Bridge protection ☐
Grade control structures ☐

Width Controls
None ☒
Occasional ☐
Frequent ☐
Confined ☐
Number of controls ___

Control Types
None ☒
Bedrock ☐
Boulders ☐
Gravel armor ☐
Revetments ☐
Cohesive Materials ☐
Bridge abutments ☐
Dykes or groynes ☐

Notes and Comments:- 13,9cfs

PART 7: BED SEDIMENT DESCRIPTION

Bed Material
Clay ☐
Silt ☐
Sand ☐
Sand and gravel ☐
gravel and cobbles ☒
cobbles + boulders ☐
boulders + bedrock ☐
Bed rock ☐

Bed Armour
None ☐
Static-armour ☒
Mobile-armour ☐

Sediment Depth
Depth of loose Sediment (cm) ___

Surface Size Data
D50 (mm) 32-45
D84 (mm) 90-128
D16 (mm) 8-11

Substrate Size Data
D50 (mm) ___
D84 (mm) ___
D16 (mm) ___

Bed Forms (Sand)
Flat bed (None) ☒
Ripples ☐
Dunes ☐
Bed form height (m) ___

Island or Bars
None ☒
Occasional ☐
Frequent ☐

Bar Types
None ☒
Pools and riffles ☐
Alternate bars ☐
Point bars ☐
Mid-channel bars ☐
Diagonal bars ☐
Junction bars ☐
Sand waves + dunes ☐

Bar Surface data
D50 (mm) ___
D84 (mm) ___
D16 (mm) ___

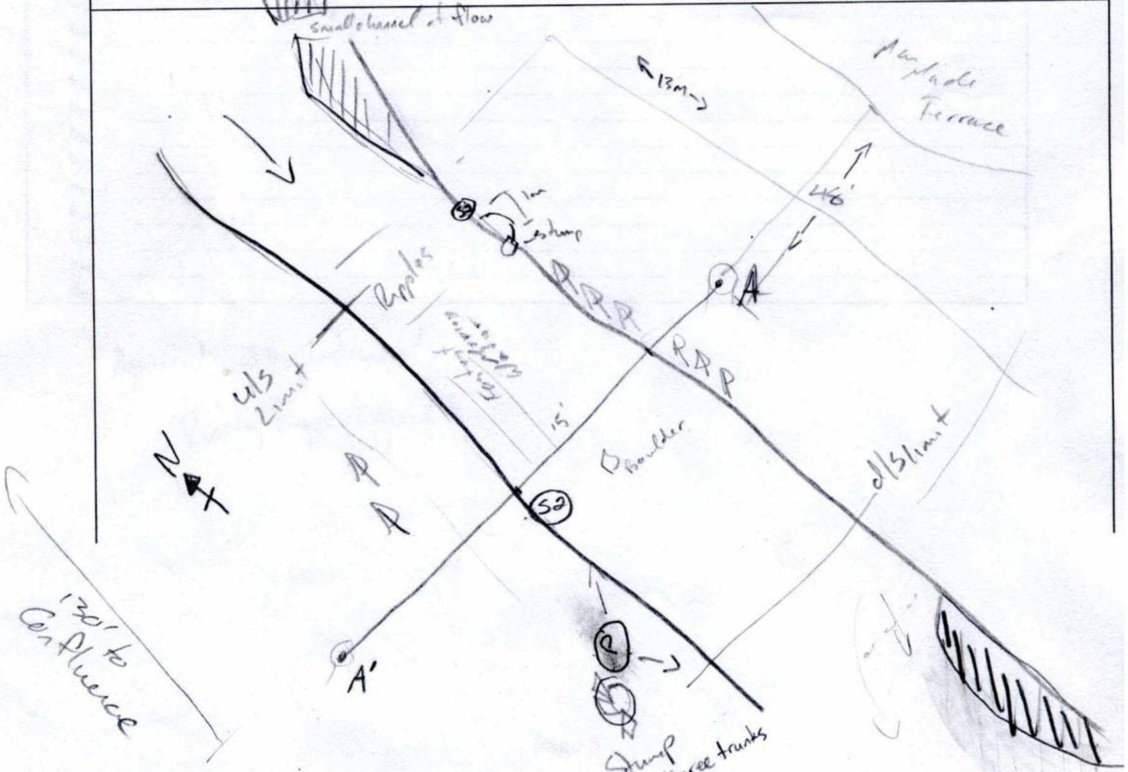
Bar Substrate data
D50 (mm) ___
D84 (mm) ___
D16 (mm) ___

Notes and Comments:-
Both monuments pounded into 1yd rebar (flush w/ top of ~~tree~~ stump)

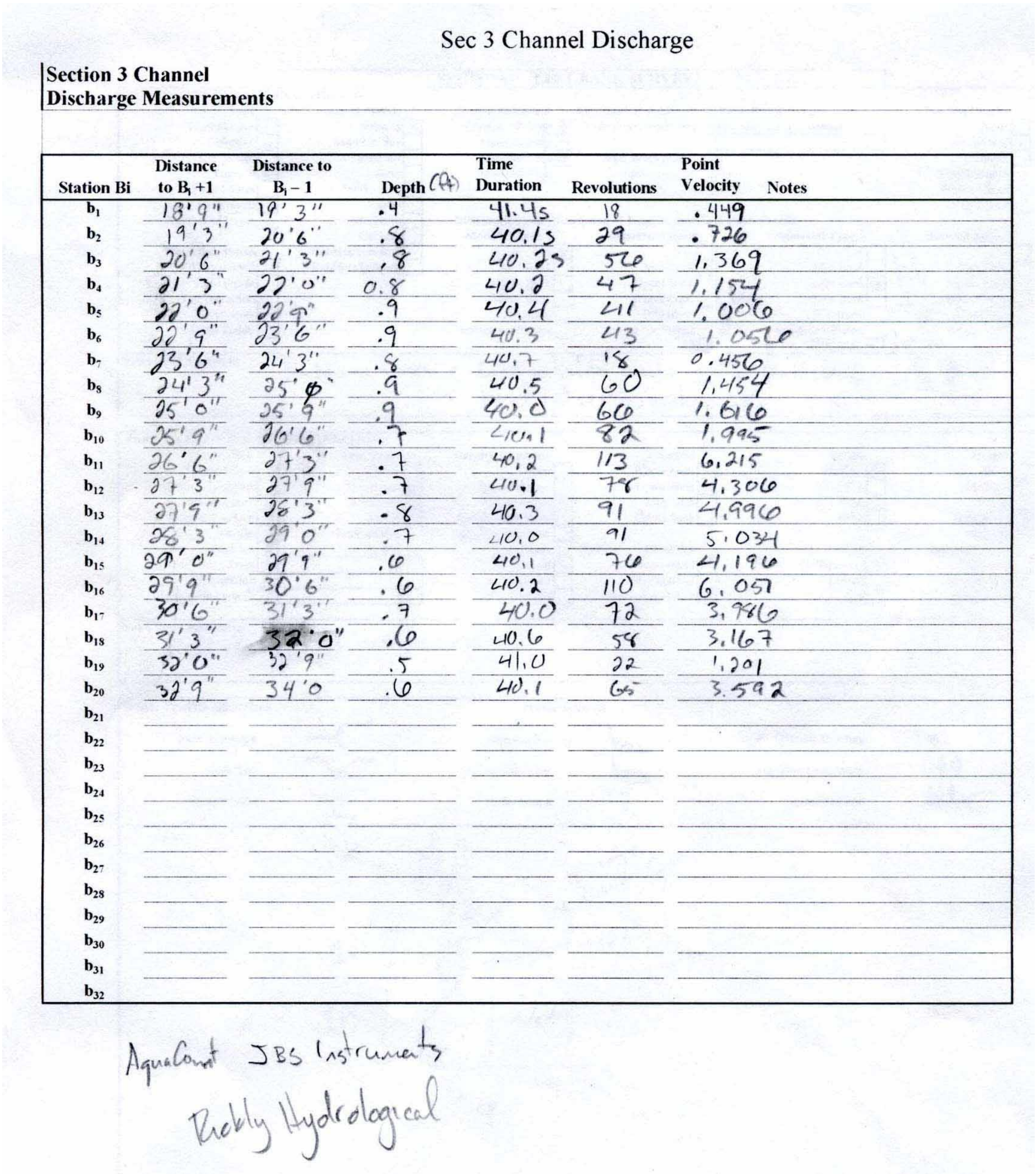
Channel Sketch Map

Map Symbols

Study reach limits ▌u/s ▌d/s
Cross-section A —— A
Bank profile (B3)→
North point (N)
flow direction ↔
impinging flow ↘↘
Cut bank
exposed island/bar
structure ▨
Photo point (P1)→
Sediment sampling point (S1)→
Significant vegetation



A4



Sec 3 Channel Discharge

Section 3 Channel Discharge Measurements

Station Bi	Distance to B_i +1	Distance to B_i – 1	Depth (ft)	Time Duration	Revolutions	Point Velocity	Notes
b_1	18'9"	19'3"	.4	41.4s	18	.449	
b_2	19'3"	20'6"	.8	40.1s	29	.726	
b_3	20'6"	21'3"	.8	40.2s	56	1.369	
b_4	21'3"	22'0"	0.8	40.2	47	1.154	
b_5	22'0"	22'9"	.9	40.4	41	1.006	
b_6	22'9"	23'6"	.9	40.3	43	1.056	
b_7	23'6"	24'3"	.8	40.7	18	0.456	
b_8	24'3"	25'0"	.9	40.5	60	1.454	
b_9	25'0"	25'9"	.9	40.0	66	1.616	
b_{10}	25'9"	26'6"	.7	40.1	82	1.995	
b_{11}	26'6"	27'3"	.7	40.2	113	6.215	
b_{12}	27'3"	27'9"	.7	40.1	78	4.306	
b_{13}	27'9"	28'3"	.8	40.3	91	4.996	
b_{14}	28'3"	29'0"	.7	40.0	91	5.034	
b_{15}	29'0"	29'9"	.6	40.1	76	4.196	
b_{16}	29'9"	30'6"	.6	40.2	110	6.057	
b_{17}	30'6"	31'3"	.7	40.0	72	3.986	
b_{18}	31'3"	32'0"	.6	40.6	58	3.167	
b_{19}	32'0"	32'9"	.5	41.0	22	1.201	
b_{20}	32'9"	34'0	.6	40.1	65	3.592	
b_{21}							
b_{22}							
b_{23}							
b_{24}							
b_{25}							
b_{26}							
b_{27}							
b_{28}							
b_{29}							
b_{30}							
b_{31}							
b_{32}							

AquaCount JBS Instruments

Rickly Hydrological

SECTION 4 - LEFT BANK SURVEY

PART 8: LEFT BANK CHARACTERISTICS

Type
Noncohesive ☐
Cohesive ☒
Composite ☐
Layered ☒
Even Layers ☐
Thick+thin layers ☐
Number of layers ___

Protection Status
Unprotected ☒
Hard points ☐
Toe protection ☐
Revetments ☐
Dyke Fields ☐

Bank Materials
Silt/clay ☒
Sand/silt/clay ☐
Sand/silt ☐
Sand ☐
Sand/gravel ☐
Gravel ☐
Gravel/cobbles ☐
Cobbles ☐
Cobbles/boulders ☐
Boulders/bedrock ☐

Layer Thickness
Material 1 (m) 6"
Material 2 (m) 4"
Material 3 (m) 9"
Material 4 (m) ___

Ave. Bank Height
Average height (m) ___

Ave. Bank Slope
angle (degrees) ___ See Notes

Bank Profile Shape
(see sketches in manual) ___

Tension Cracks
None ☐
Occasional ☐
Frequent ☐

Crack Depth
Proportion of bank height ___

Distribution and Description of Bank Materials in Bank Profile

Material Type 1
Toe ☒
Mid-Bank ☐
Upper Bank ☐
Whole Bank ☐
D50 (mm) ___
sorting coefficient ___

Material Type 2
Toe ☐
Mid-Bank ☒
Upper Bank ☐
Whole Bank ☐
D50 (mm) ___
sorting coefficient ___
2.5Y 4/3
Silty Clay Loam

Material Type 3
Toe ☐
Mid-Bank ☐
Upper Bank ☒
Whole Bank ☐
D50 (mm) ___
sorting coefficient ___
7.5YR 3/3
(orange nodules)
Silty Clay Loam

Material Type 4
Toe ☐
Mid-Bank ☐
Upper Bank ☐
Whole Bank ☐
D50 (mm) ___
sorting coef. ___

Notes and Comments:- Banks are frozen • Unvegetated banks 90° or Undercut
Vegetated upper banks 65°

PART 9: LEFT BANK-FACE VEGETATION

Vegetation
None/fallow ☐
Artificially cleared ☐
Grass and flora ☒
Reeds and sedges ☐
Shrubs ☐
Saplings ☒
Trees ☐

Orientation
Angle of leaning (°) 90°

Tree Types
None ☐
Deciduous ☒
Coniferous ☐
Mixed ☐

Tree species
(if known) ___

Density + Spacing
None ☐
Sparse/clumps ☐
dense/clumps ☒
Sparce/continuous ☐
Dense/continuous ☐

Roots unexposed
Normal ☒
Exposed ☐
Adventitious ☐

Location
Whole bank ☐
Upper bank ☒
Mid-bank ☐
Lower bank ☐

Diversity
Mono-stand ☒
Mixed stand ☐
Climax-vegetation ☐

Health
Healthy ☒
Fair ☐
Poor ☐
Dead ☐

Age
Immature ☒
Mature ☐
Old ☐

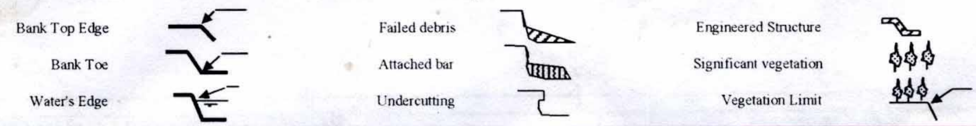
Height
Short ☐
Medium ☒
Tall ☐
Height (m) 3-4

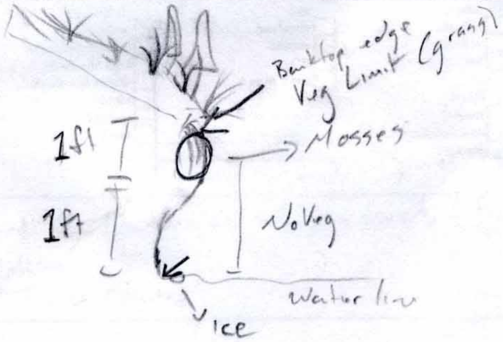
Lateral Extent
Wide belt ☐
Narrow belt ☒
Single row ☐

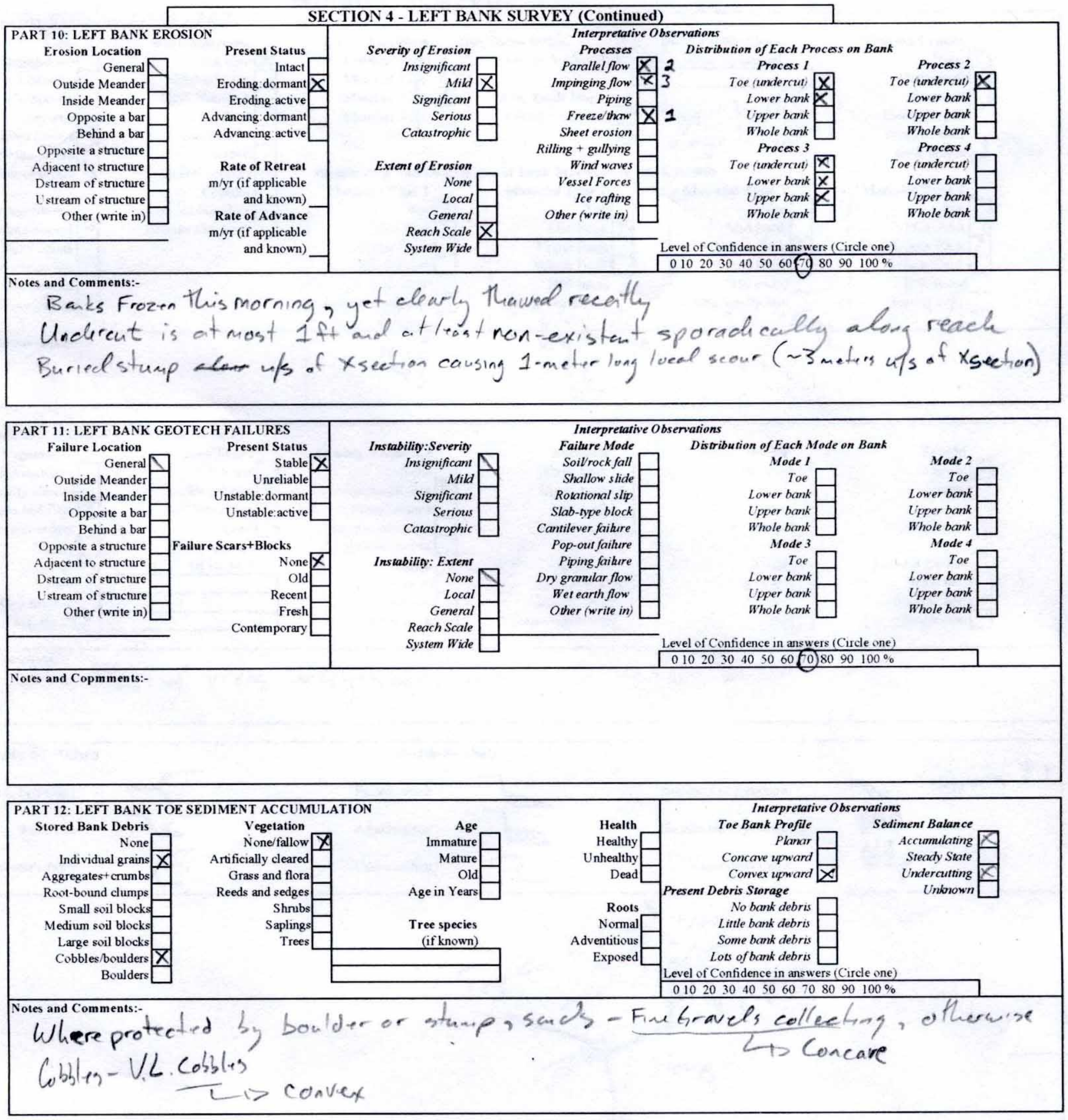
Notes and Comments:- Likely planted trees ~4 years old

Bank Profile Sketches

Profile Symbols







SECTION 4 - LEFT BANK SURVEY (Continued)

PART 10: LEFT BANK EROSION

Erosion Location
- General ☒
- Outside Meander ☐
- Inside Meander ☐
- Opposite a bar ☐
- Behind a bar ☐
- Opposite a structure ☐
- Adjacent to structure ☐
- Dstream of structure ☐
- Ustream of structure ☐
- Other (write in) ☐

Present Status
- Intact ☐
- Eroding:dormant ☒
- Eroding:active ☐
- Advancing:dormant ☐
- Advancing:active ☐

Rate of Retreat m/yr (if applicable and known) ______

Rate of Advance m/yr (if applicable and known) ______

Interpretative Observations

Severity of Erosion
- *Insignificant* ☐
- *Mild* ☒
- *Significant* ☐
- *Serious* ☐
- *Catastrophic* ☐

Extent of Erosion
- *None* ☐
- *Local* ☐
- *General* ☐
- *Reach Scale* ☒
- *System Wide* ☐

Processes
- *Parallel flow* ☒ 2
- *Impinging flow* ☒ 3
- *Piping* ☐
- *Freeze/thaw* ☒ 1
- *Sheet erosion* ☐
- *Rilling + gullying* ☐
- *Wind waves* ☐
- *Vessel Forces* ☐
- *Ice rafting* ☐
- *Other (write in)* ☐

Distribution of Each Process on Bank

Process 1		***Process 2***	
Toe (undercut)	☒	*Toe (undercut)*	☒
Lower bank	☒	*Lower bank*	☐
Upper bank	☐	*Upper bank*	☐
Whole bank	☐	*Whole bank*	☐
Process 3		***Process 4***	
Toe (undercut)	☒	*Toe (undercut)*	☐
Lower bank	☒	*Lower bank*	☐
Upper bank	☒	*Upper bank*	☐
Whole bank	☐	*Whole bank*	☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 [✓ 70] 80 90 100 %

Notes and Comments:-

Banks Frozen this morning, yet clearly thawed recently
Undercut is at most 1ft and at least non-existent sporadically along reach
Buried stump ~~alon~~ u/s of Xsection causing 1-meter long local scour (~3 meters u/s of Xsection)

PART 11: LEFT BANK GEOTECH FAILURES

Failure Location
- General ☒
- Outside Meander ☐
- Inside Meander ☐
- Opposite a bar ☐
- Behind a bar ☐
- Opposite a structure ☐
- Adjacent to structure ☐
- Dstream of structure ☐
- Ustream of structure ☐
- Other (write in) ☐

Present Status
- Stable ☒
- Unreliable ☐
- Unstable:dormant ☐
- Unstable:active ☐

Failure Scars+Blocks
- None ☒
- Old ☐
- Recent ☐
- Fresh ☐
- Contemporary ☐

Interpretative Observations

Instability:Severity
- *Insignificant* ☒
- *Mild* ☐
- *Significant* ☐
- *Serious* ☐
- *Catastrophic* ☐

Instability: Extent
- *None* ☒
- *Local* ☐
- *General* ☐
- *Reach Scale* ☐
- *System Wide* ☐

Failure Mode
- *Soil/rock fall* ☐
- *Shallow slide* ☐
- *Rotational slip* ☐
- *Slab-type block* ☐
- *Cantilever failure* ☐
- *Pop-out failure* ☐
- *Piping failure* ☐
- *Dry granular flow* ☐
- *Wet earth flow* ☐
- *Other (write in)* ☐

Distribution of Each Mode on Bank

Mode 1		***Mode 2***	
Toe	☐	*Toe*	☐
Lower bank	☐	*Lower bank*	☐
Upper bank	☐	*Upper bank*	☐
Whole bank	☐	*Whole bank*	☐
Mode 3		***Mode 4***	
Toe	☐	*Toe*	☐
Lower bank	☐	*Lower bank*	☐
Upper bank	☐	*Upper bank*	☐
Whole bank	☐	*Whole bank*	☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 [✓ 70] 80 90 100 %

Notes and Copmments:-

PART 12: LEFT BANK TOE SEDIMENT ACCUMULATION

Stored Bank Debris
- None ☐
- Individual grains ☒
- Aggregates+crumbs ☐
- Root-bound clumps ☐
- Small soil blocks ☐
- Medium soil blocks ☐
- Large soil blocks ☐
- Cobbles/boulders ☒
- Boulders ☐

Vegetation
- None/fallow ☒
- Artificially cleared ☐
- Grass and flora ☐
- Reeds and sedges ☐
- Shrubs ☐
- Saplings ☐
- Trees ☐

Age
- Immature ☐
- Mature ☐
- Old ☐
- Age in Years ☐

Tree species (if known) ______

Health
- Healthy ☐
- Unhealthy ☐
- Dead ☐

Roots
- Normal ☐
- Adventitious ☐
- Exposed ☐

Interpretative Observations

Toe Bank Profile
- *Planar* ☐
- *Concave upward* ☐
- *Convex upward* ☒

Present Debris Storage
- *No bank debris* ☐
- *Little bank debris* ☐
- *Some bank debris* ☐
- *Lots of bank debris* ☐

Sediment Balance
- *Accumulating* ☒
- *Steady State* ☐
- *Undercutting* ☒
- *Unknown* ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 80 90 100 %

Notes and Comments:-

Where protected by boulder or stump, sands - Fine Gravels collecting, otherwise
↳ Concave
Cobbles - V.L. Cobbles
↳ convex

0

SECTION 5 - RIGHT BANK SURVEY

PART 13: RIGHT BANK CHARACTERISTICS

Type
Noncohesive ☐
Cohesive ☒
Composite ☐
Layered ☒
Even Layers ☐
Thick+thin layers ☒
Number of layers 3

Protection Status
Unprotected ☒
Hard points ☐
Toe protection ☐
Revetments ☐
Dyke Fields ☐

Bank Materials
Silt/clay ☒
Sand/silt/clay ☐
Sand/silt ☐
Sand ☐
Sand/gravel ☐
Gravel ☐
Gravel/cobbles ☐
Cobbles ☐
Cobbles/boulders ☐
Boulders/bedrock ☐

Layer Thickness
Material 1 (~~m~~) 7"
Material 2 (~~m~~) 2¼"
Material 3 (~~m~~) 6"
Material 4 (~~m~~) __

Ave. Bank Height
from bed
Average height (~~m~~) 12ft

Ave. Bank Slope
Average angle (o) 30° (upper Vegetated)
90° unvegetated

Bank Profile Shape
(see sketches in manual)

Tension Cracks
None ☐
Occasional ☒
Frequent ☐

Crack Depth
Proportion of bank height 1:30

Distribution and Description of Bank Materials in Bank Profile

Material Type 1	Material Type 2	Material Type 3	Material Type 4
Toe ☒	Toe ☐	Toe ☐	Toe ☐
Mid-Bank ☒	Mid-Bank ☒	Mid-Bank ☐	Mid-Bank ☐
Upper Bank ☐	Upper Bank ☐	Upper Bank ☒	Upper Bank ☐
Whole Bank ☐	Whole Bank ☐	Whole Bank ☐	Whole Bank ☐
D50 (mm) __	D50 (mm) __	D50 (mm) __	D50 (mm) __
sorting coefficient __	sorting coefficient __	sorting coefficient __	sorting coef. __
Clay	Water line Silty Clay Loam	Silty Clay	
10YR 3/3	2.5Y 6/6	2.5YR 4/3	

Notes and Comments:-

PART 14: RIGHT BANK-FACE VEGETATION

Vegetation
None/fallow ☐
Artificially cleared ☐
Grass and flora ☒
Reeds and sedges ☐
Shrubs ☐
Saplings ☒
Trees ☐

Orientation
Angle of leaning (°) 90°

Tree Types
None ☐
Deciduous ☒
Coniferous ☐
Mixed ☐

Tree species
(if known)

Density + Spacing
None ☐
Sparse/clumps ☒
dense/clumps ☐
Sparce/continuous ☐
Dense/continuous ☐

Roots Unexposed
Normal ☐
Exposed ☐
Adventitious ☐

Location
Whole bank ☐
Upper bank ☒
Mid-bank ☐
Lower bank ☐

Diversity
Mono-stand ☒
Mixed stand ☐
Climax-vegetation ☐

Health
Healthy ☒
Fair ☐
Poor ☐
Dead ☐

Age
Imature ☐
Mature ☐
Old ☐

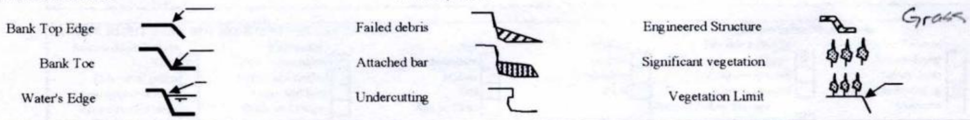
Height
Short ☒
Medium ☐
Tall ☐
Height (m) 3-4

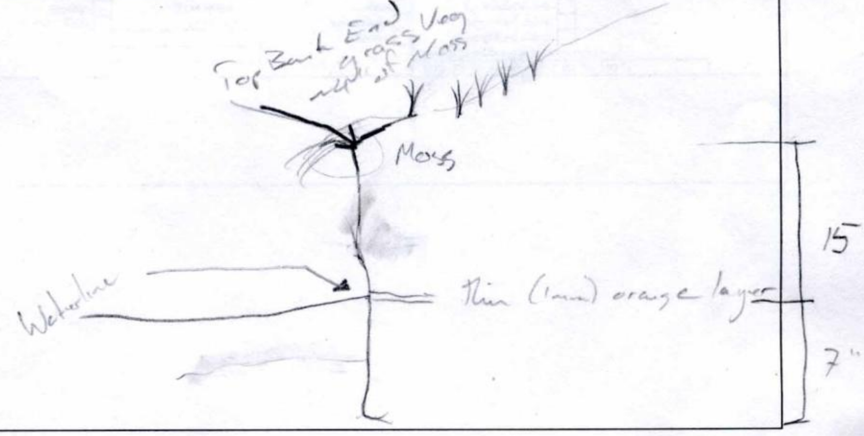
Lateral Extent
Wide belt ☐
Narrow belt ☒
Single row ☐

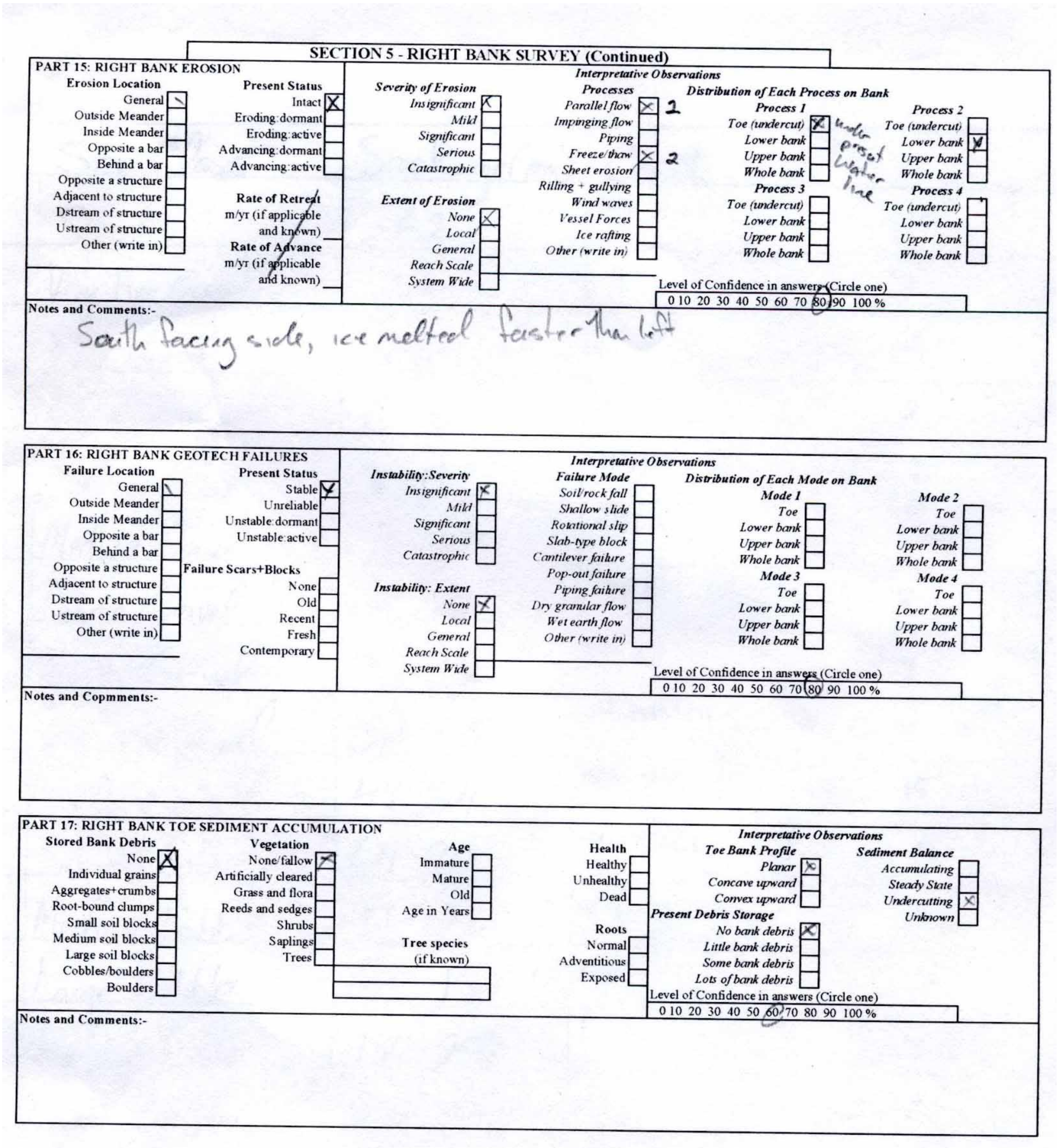
Notes and Comments:- Planted trees ~4yrs ago, unable to ID b/c of winter

Bank Profile Sketches

Profile Symbols







SECTION 5 - RIGHT BANK SURVEY (Continued)

PART 15: RIGHT BANK EROSION

Erosion Location
- General ☒
- Outside Meander ☐
- Inside Meander ☐
- Opposite a bar ☐
- Behind a bar ☐
- Opposite a structure ☐
- Adjacent to structure ☐
- Dstream of structure ☐
- Ustream of structure ☐
- Other (write in) ☐

Present Status
- Intact ☒
- Eroding:dormant ☐
- Eroding:active ☐
- Advancing:dormant ☐
- Advancing:active ☐

Rate of Retreat
m/yr (if applicable and known) ____

Rate of Advance
m/yr (if applicable and known) ____

Interpretative Observations

Severity of Erosion
- *Insignificant* ☒
- *Mild* ☐
- *Significant* ☐
- *Serious* ☐
- *Catastrophic* ☐

Extent of Erosion
- *None* ☒
- *Local* ☐
- *General* ☐
- *Reach Scale* ☐
- *System Wide* ☐

Processes
- *Parallel flow* ☒ 1
- *Impinging flow* ☐
- *Piping* ☐
- *Freeze/thaw* ☒ 2
- *Sheet erosion* ☐
- *Rilling + gullying* ☐
- *Wind waves* ☐
- *Vessel Forces* ☐
- *Ice rafting* ☐
- *Other (write in)* ☐

Distribution of Each Process on Bank

Process 1
- *Toe (undercut)* ☒ under present water line
- *Lower bank* ☐
- *Upper bank* ☐
- *Whole bank* ☐

Process 2
- *Toe (undercut)* ☐
- *Lower bank* ☒
- *Upper bank* ☐
- *Whole bank* ☐

Process 3
- *Toe (undercut)* ☐
- *Lower bank* ☐
- *Upper bank* ☐
- *Whole bank* ☐

Process 4
- *Toe (undercut)* ☐
- *Lower bank* ☐
- *Upper bank* ☐
- *Whole bank* ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 [✓ 80] 90 100 %

Notes and Comments:-
South facing side, ice melted faster than left

PART 16: RIGHT BANK GEOTECH FAILURES

Failure Location
- General ☒
- Outside Meander ☐
- Inside Meander ☐
- Opposite a bar ☐
- Behind a bar ☐
- Opposite a structure ☐
- Adjacent to structure ☐
- Dstream of structure ☐
- Ustream of structure ☐
- Other (write in) ☐

Present Status
- Stable ☒
- Unreliable ☐
- Unstable:dormant ☐
- Unstable:active ☐

Failure Scars+Blocks
- None ☐
- Old ☐
- Recent ☐
- Fresh ☐
- Contemporary ☐

Interpretative Observations

Instability:Severity
- *Insignificant* ☒
- *Mild* ☐
- *Significant* ☐
- *Serious* ☐
- *Catastrophic* ☐

Instability: Extent
- *None* ☒
- *Local* ☐
- *General* ☐
- *Reach Scale* ☐
- *System Wide* ☐

Failure Mode
- *Soil/rock fall* ☐
- *Shallow slide* ☐
- *Rotational slip* ☐
- *Slab-type block* ☐
- *Cantilever failure* ☐
- *Pop-out failure* ☐
- *Piping failure* ☐
- *Dry granular flow* ☐
- *Wet earth flow* ☐
- *Other (write in)* ☐

Distribution of Each Mode on Bank

Mode 1
- *Toe* ☐
- *Lower bank* ☐
- *Upper bank* ☐
- *Whole bank* ☐

Mode 2
- *Toe* ☐
- *Lower bank* ☐
- *Upper bank* ☐
- *Whole bank* ☐

Mode 3
- *Toe* ☐
- *Lower bank* ☐
- *Upper bank* ☐
- *Whole bank* ☐

Mode 4
- *Toe* ☐
- *Lower bank* ☐
- *Upper bank* ☐
- *Whole bank* ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 [✓ 80] 90 100 %

Notes and Copmments:-

PART 17: RIGHT BANK TOE SEDIMENT ACCUMULATION

Stored Bank Debris
- None ☒
- Individual grains ☐
- Aggregates+crumbs ☐
- Root-bound clumps ☐
- Small soil blocks ☐
- Medium soil blocks ☐
- Large soil blocks ☐
- Cobbles/boulders ☐
- Boulders ☐

Vegetation
- None/fallow ☒
- Artificially cleared ☐
- Grass and flora ☐
- Reeds and sedges ☐
- Shrubs ☐
- Saplings ☐
- Trees ☐

Age
- Immature ☐
- Mature ☐
- Old ☐
- Age in Years ☐

Tree species
(if known)

Health
- Healthy ☐
- Unhealthy ☐
- Dead ☐

Roots
- Normal ☐
- Adventitious ☐
- Exposed ☐

Interpretative Observations

Toe Bank Profile
- *Planar* ☒
- *Concave upward* ☐
- *Convex upward* ☐

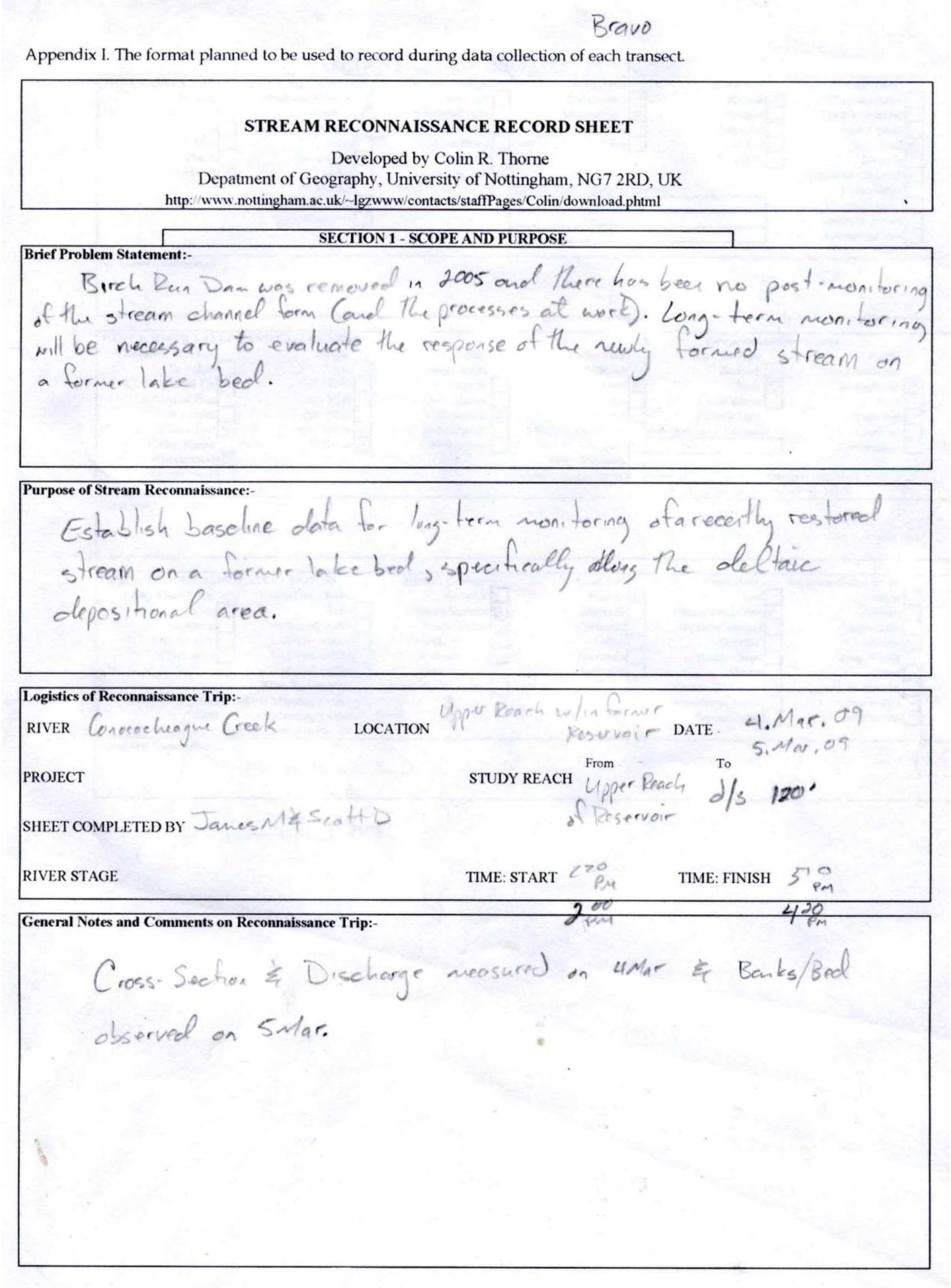
Present Debris Storage
- *No bank debris* ☒
- *Little bank debris* ☐
- *Some bank debris* ☐
- *Lots of bank debris* ☐

Sediment Balance
- *Accumulating* ☐
- *Steady State* ☐
- *Undercutting* ☒
- *Unknown* ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 [✓ 60] 70 80 90 100 %

Notes and Comments:-

Bravo - Reconnaissance Record Sheets dated, 4-5.March.2009



Bravo

Appendix I. The format planned to be used to record during data collection of each transect.

STREAM RECONNAISSANCE RECORD SHEET

Developed by Colin R. Thorne
Depatment of Geography, University of Nottingham, NG7 2RD, UK
http://www.nottingham.ac.uk/~lgzwww/contacts/staffPages/Colin/download.phtml

SECTION 1 - SCOPE AND PURPOSE

Brief Problem Statement:-

Birch Run Dam was removed in 2005 and there has been no post-monitoring of the stream channel form (and the processes at work). Long-term monitoring will be necessary to evaluate the response of the newly formed stream on a former lake bed.

Purpose of Stream Reconnaissance:-

Establish baseline data for long-term monitoring of a recently restored stream on a former lake bed, specifically along the deltaic depositional area.

Logistics of Reconnaissance Trip:-

RIVER Conococheague Creek

LOCATION Upper Reach w/in former Reservoir

DATE 4.Mar.09 5.Mar.09

PROJECT

STUDY REACH From Upper Reach of Reservoir To d/s 120'

SHEET COMPLETED BY James M & Scott D

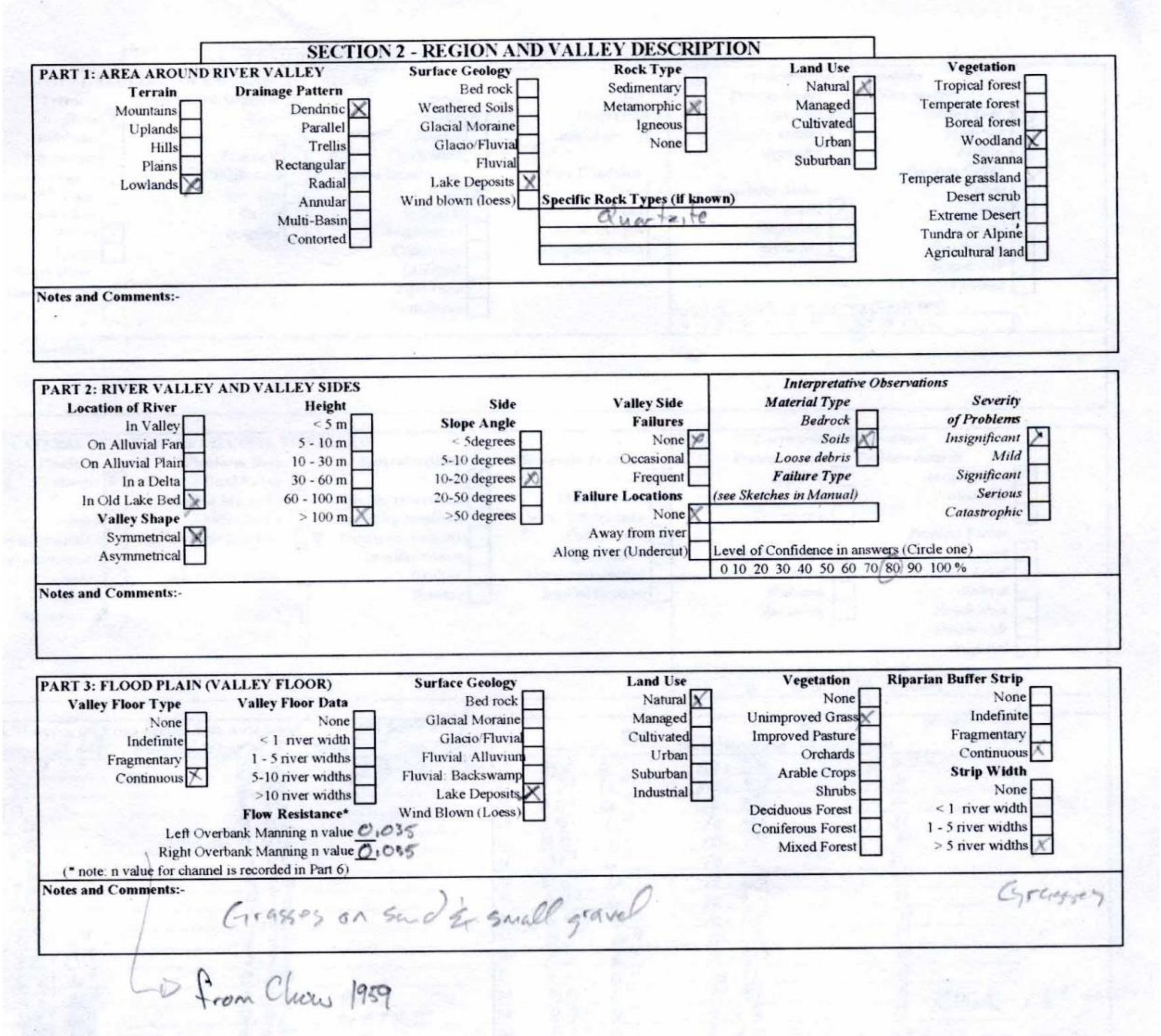
RIVER STAGE

TIME: START 2^{20} PM 2^{00} PM

TIME: FINISH 5^{10} PM 4^{20} PM

General Notes and Comments on Reconnaissance Trip:-

Cross-Section & Discharge measured on 4Mar & Banks/Bed observed on 5Mar.



SECTION 2 - REGION AND VALLEY DESCRIPTION

PART 1: AREA AROUND RIVER VALLEY

Terrain
- Mountains ☐
- Uplands ☐
- Hills ☐
- Plains ☐
- Lowlands ☒

Drainage Pattern
- Dendritic ☒
- Parallel ☐
- Trellis ☐
- Rectangular ☐
- Radial ☐
- Annular ☐
- Multi-Basin ☐
- Contorted ☐

Surface Geology
- Bed rock ☐
- Weathered Soils ☐
- Glacial Moraine ☐
- Glacio/Fluvial ☐
- Fluvial ☐
- Lake Deposits ☒
- Wind blown (loess) ☐

Rock Type
- Sedimentary ☐
- Metamorphic ☒
- Igneous ☐
- None ☐

Specific Rock Types (if known)

Quartzite

Land Use
- Natural ☒
- Managed ☐
- Cultivated ☐
- Urban ☐
- Suburban ☐

Vegetation
- Tropical forest ☐
- Temperate forest ☐
- Boreal forest ☐
- Woodland ☒
- Savanna ☐
- Temperate grassland ☐
- Desert scrub ☐
- Extreme Desert ☐
- Tundra or Alpine ☐
- Agricultural land ☐

Notes and Comments:-

PART 2: RIVER VALLEY AND VALLEY SIDES

Location of River
- In Valley ☐
- On Alluvial Fan ☐
- On Alluvial Plain ☐
- In a Delta ☐
- In Old Lake Bed ☒

Valley Shape
- Symmetrical ☒
- Asymmetrical ☐

Height
- < 5 m ☐
- 5 - 10 m ☐
- 10 - 30 m ☐
- 30 - 60 m ☐
- 60 - 100 m ☐
- > 100 m ☒

Side Slope Angle
- < 5degrees ☐
- 5-10 degrees ☐
- 10-20 degrees ☒
- 20-50 degrees ☐
- >50 degrees ☐

Valley Side Failures
- None ☒
- Occasional ☐
- Frequent ☐

Failure Locations
- None ☒
- Away from river ☐
- Along river (Undercut) ☐

Interpretative Observations

Material Type
- *Bedrock* ☐
- *Soils* ☒
- *Loose debris* ☐

Failure Type
(see Sketches in Manual)

Severity of Problems
- *Insignificant* ☒
- *Mild* ☐
- *Significant* ☐
- *Serious* ☐
- *Catastrophic* ☐

Level of Confidence in answers (Circle one)

0 10 20 30 40 50 60 70 [✓ 80] 90 100 %

Notes and Comments:-

PART 3: FLOOD PLAIN (VALLEY FLOOR)

Valley Floor Type
- None ☐
- Indefinite ☐
- Fragmentary ☐
- Continuous ☒

Valley Floor Data
- None ☐
- < 1 river width ☐
- 1 - 5 river widths ☐
- 5-10 river widths ☐
- >10 river widths ☐

Flow Resistance*

Left Overbank Manning n value 0.035

Right Overbank Manning n value 0.035

(* note: n value for channel is recorded in Part 6)

Surface Geology
- Bed rock ☐
- Glacial Moraine ☐
- Glacio/Fluvial ☐
- Fluvial: Alluvium ☐
- Fluvial: Backswamp ☐
- Lake Deposits ☒
- Wind Blown (Loess) ☐

Land Use
- Natural ☒
- Managed ☐
- Cultivated ☐
- Urban ☐
- Suburban ☐
- Industrial ☐

Vegetation
- None ☐
- Unimproved Grass ☒
- Improved Pasture ☐
- Orchards ☐
- Arable Crops ☐
- Shrubs ☐
- Deciduous Forest ☐
- Coniferous Forest ☐
- Mixed Forest ☐

Riparian Buffer Strip
- None ☐
- Indefinite ☐
- Fragmentary ☐
- Continuous ☒

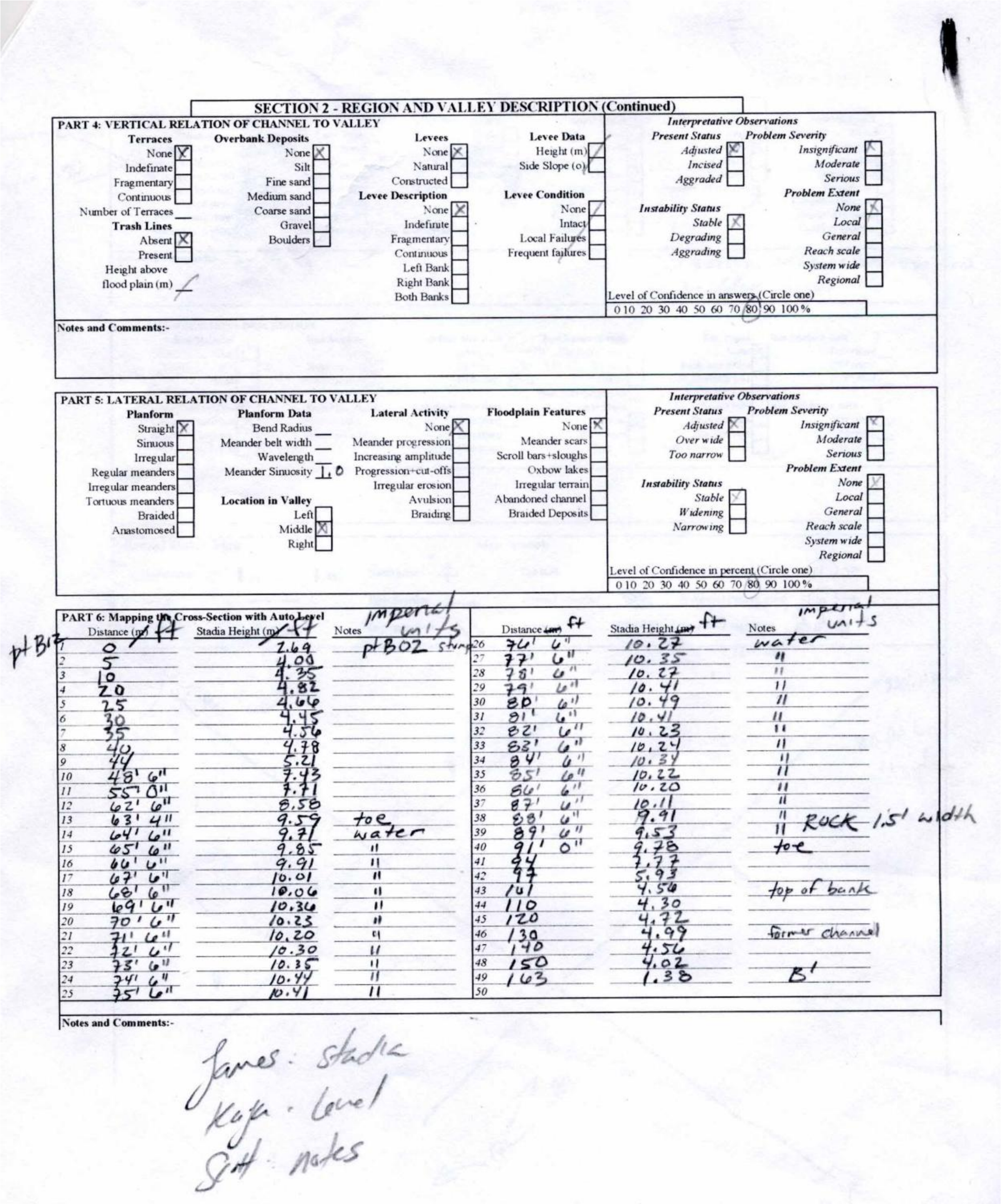
Strip Width
- None ☐
- < 1 river width ☐
- 1 - 5 river widths ☐
- > 5 river widths ☒

Notes and Comments:-

Grasses on sand & small gravel

Grasses

from Chow 1959



SECTION 2 - REGION AND VALLEY DESCRIPTION (Continued)

PART 4: VERTICAL RELATION OF CHANNEL TO VALLEY

Terraces
- None ☒
- Indefinate ☐
- Fragmentary ☐
- Continuous ☐
- Number of Terraces ___

Trash Lines
- Absent ☒
- Present ☐
- Height above flood plain (m) /

Overbank Deposits
- None ☒
- Silt ☐
- Fine sand ☐
- Medium sand ☐
- Coarse sand ☐
- Gravel ☐
- Boulders ☐

Levees
- None ☒
- Natural ☐
- Constructed ☐

Levee Description
- None ☒
- Indefinite ☐
- Fragmentary ☐
- Continuous ☐
- Left Bank ☐
- Right Bank ☐
- Both Banks ☐

Levee Data
- Height (m) ☐
- Side Slope (o) ☐

Levee Condition
- None ☐
- Intact ☐
- Local Failures ☐
- Frequent failures ☐

Interpretative Observations

Present Status
- *Adjusted* ☒
- *Incised* ☐
- *Aggraded* ☐

Instability Status
- *Stable* ☒
- *Degrading* ☐
- *Aggrading* ☐

Problem Severity
- *Insignificant* ☒
- *Moderate* ☐
- *Serious* ☐

Problem Extent
- *None* ☒
- *Local* ☐
- *General* ☐
- *Reach scale* ☐
- *System wide* ☐
- *Regional* ☐

Level of Confidence in answers (Circle one)

0 10 20 30 40 50 60 70 [✓ 80] 90 100 %

Notes and Comments:-

PART 5: LATERAL RELATION OF CHANNEL TO VALLEY

Planform
- Straight ☒
- Sinuous ☐
- Irregular ☐
- Regular meanders ☐
- Irregular meanders ☐
- Tortuous meanders ☐
- Braided ☐
- Anastomosed ☐

Planform Data
- Bend Radius ___
- Meander belt width ___
- Wavelength ___
- Meander Sinuosity 1.0

Location in Valley
- Left ☐
- Middle ☒
- Right ☐

Lateral Activity
- None ☒
- Meander progression ☐
- Increasing amplitude ☐
- Progression+cut-offs ☐
- Irregular erosion ☐
- Avulsion ☐
- Braiding ☐

Floodplain Features
- None ☒
- Meander scars ☐
- Scroll bars+sloughs ☐
- Oxbow lakes ☐
- Irregular terrain ☐
- Abandoned channel ☐
- Braided Deposits ☐

Interpretative Observations

Present Status
- *Adjusted* ☒
- *Over wide* ☐
- *Too narrow* ☐

Instability Status
- *Stable* ☒
- *Widening* ☐
- *Narrowing* ☐

Problem Severity
- *Insignificant* ☒
- *Moderate* ☐
- *Serious* ☐

Problem Extent
- *None* ☒
- *Local* ☐
- *General* ☐
- *Reach scale* ☐
- *System wide* ☐
- *Regional* ☐

Level of Confidence in percent (Circle one)

0 10 20 30 40 50 60 70 [✓ 80] 90 100 %

PART 6: Mapping the Cross-Section with Auto Level

imperial units

	Distance (~~m~~) ft	Stadia Height (~~m~~) ft	Notes		Distance (~~m~~) ft	Stadia Height (~~m~~) ft	Notes
pt B12 1	0	2.69	pt B02 stump	26	76' 6"	10.27	water
2	5	4.00		27	77' 6"	10.35	"
3	10	4.35		28	78' 6"	10.27	"
4	20	4.82		29	79' 6"	10.41	"
5	25	4.66		30	80' 6"	10.49	"
6	30	4.45		31	81' 6"	10.41	"
7	35	4.56		32	82' 6"	10.23	"
8	40	4.78		33	83' 6"	10.24	"
9	44	5.21		34	84' 6"	10.34	"
10	48' 6"	7.43		35	85' 6"	10.22	"
11	55' 0"	7.71		36	86' 6"	10.20	"
12	62' 6"	8.58		37	87' 6"	10.11	"
13	63' 4"	9.59	toe	38	88' 6"	9.91	" ROCK 1.5' width
14	64' 6"	9.71	water	39	89' 6"	9.53	"
15	65' 6"	9.85	"	40	91' 0"	9.78	toe
16	66' 6"	9.91	"	41	94	7.77	
17	67' 6"	10.01	"	42	97	5.93	
18	68' 6"	10.06	"	43	101	4.56	top of bank
19	69' 6"	10.36	"	44	110	4.30	
20	70' 6"	10.23	"	45	120	4.72	
21	71' 6"	10.20	"	46	130	4.99	former channel
22	72' 6"	10.30	"	47	140	4.56	
23	73' 6"	10.35	"	48	150	4.02	
24	74' 6"	10.44	"	49	163	1.38	B'
25	75' 6"	10.41	"	50			

Notes and Comments:-

James: stadia

Kaja: level

SH: notes

SECTION 3 - CHANNEL DESCRIPTION

PART 6: CHANNEL DESCRIPTION

Lower 0.727
Upper 1.50

Dimensions
Av. top bank width (m) 14.0 Lower 20.24 Upper
Av. channel depth (m) ___
Av. water width (m) 8.4
Av. water depth (m) 0.174
Reach slope 0.008
Mean velocity (~~m/s~~) 1.58 ft/sec
Manning's n value 0.050

Flow Type
None ☐
Uniform/Tranquil ☐
Uniform/Rapid ☒
Pool+Riffle ☐
Steep + Tumbling ☐
Steep + Step/pool ☐
(Note: Flow type on day of observation)

Bed Controls
None ☐
Occasional ☐
Frequent ☒
Confined ☐
Number of controls 3

Control Types
None ☐
Solid Bedrock ☐
Weathered Bedrock ☒
Boulders ☒
Gravel armor ☒
Cohesive Materials ☐
Bridge protection ☐
Grade control structures ☐

Width Controls
None ☐
Occasional ☒
Frequent ☐
Confined ☐
Number of controls 2

Control Types
None ☐
Bedrock ☐
Boulders ☒
Gravel armor ☒
Revetments ☐
Cohesive Materials ☐
Bridge abutments ☐
Dykes or groynes ☐

Notes and Comments:- 7.29 cfs

Beach on left slope begins behind boulder

PART 7: BED SEDIMENT DESCRIPTION

Bed Material
Clay ☐
Silt ☐
Sand ☐
Sand and gravel ☐
gravel and cobbles ☒
cobbles + boulders ☒
boulders + bedrock ☐
Bed rock ☐

Bed Armour
None ☐
Static-armour ☒
Mobile-armour ☐

Sediment Depth
Depth of loose
Sediment (cm) 2

Surface Size Data
D50 (mm) 45-64
D84 (mm) 128-180
D16 (mm) 8-11

Substrate Size Data
D50 (mm) ___
D84 (mm) ___
D16 (mm) ___

Bed Forms (Sand)
Flat bed (None) ☐
Ripples ☐
Dunes ☐
Bed form height (m) ___

Island or Bars
None ☒
Occasional ☐
Frequent ☐

Bar Types
None ☒
Pools and riffles ☐
Alternate bars ☐
Point bars ☐
Mid-channel bars ☐
Diagonal bars ☐
Junction bars ☐
Sand waves + dunes ☐

Bar Surface data
D50 (mm) ___
D84 (mm) ___
D16 (mm) ___

Bar Substrate data
D50 (mm) ___
D84 (mm) ___
D16 (mm) ___

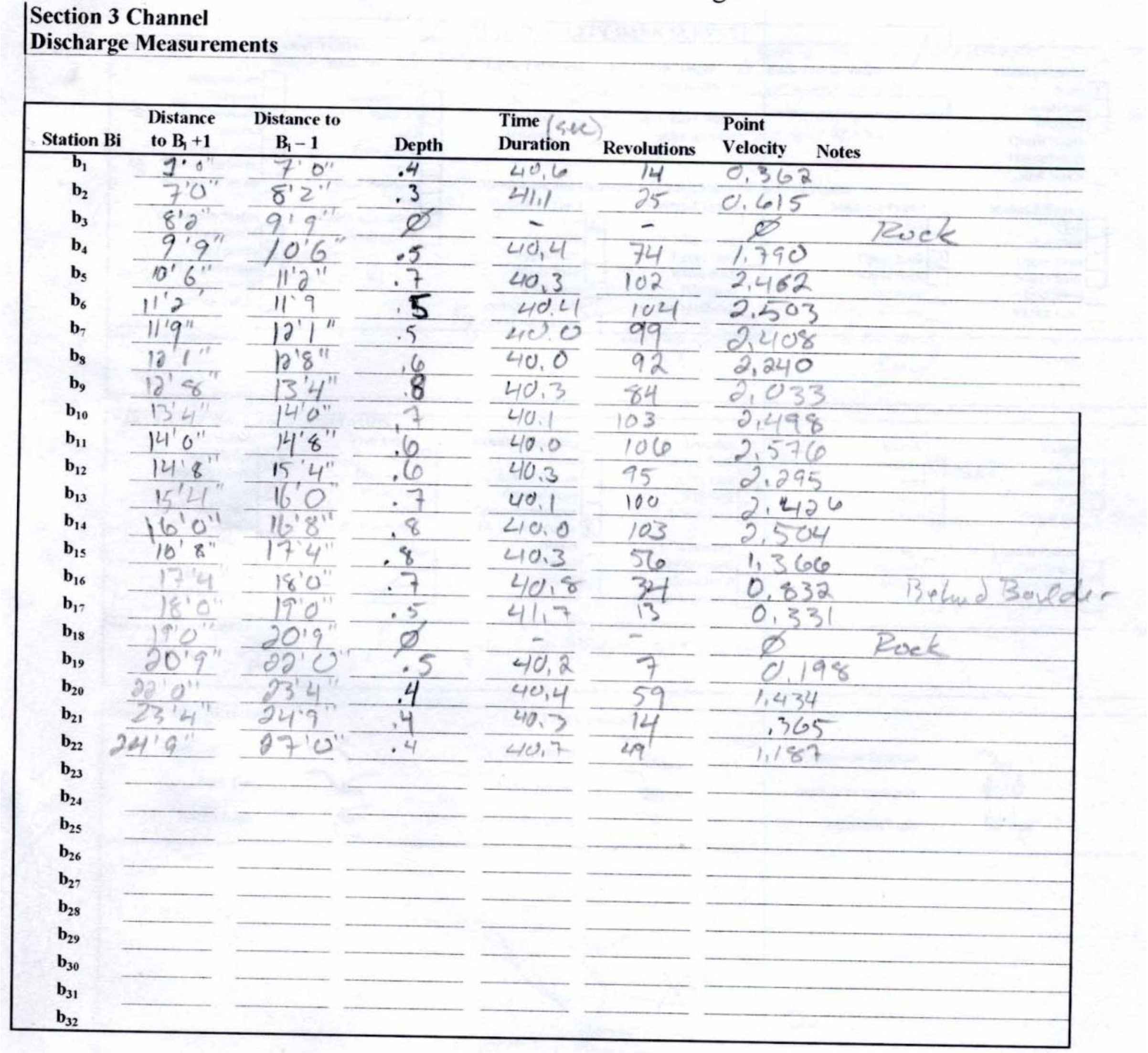
Notes and Comments:-

Channel Sketch Map

Map Symbols

Study reach limits ▌u/s ▌d/s
Cross-section A —— A
Bank profile (B3) →
North point N ✛
flow direction ↔
impinging flow ↘↘
Cut bank
exposed island/bar
structure ▨
Photo point (P1) →
Sediment sampling point (S1) →
Significant vegetation

Sec 3 Channel Discharge



Section 3 Channel Discharge Measurements

Station Bi	Distance to B_i +1	Distance to $B_i - 1$	Depth	Time (sec) Duration	Revolutions	Point Velocity	Notes
b_1	2'0"	7'0"	.4	40.6	14	0.362	
b_2	7'0"	8'2"	.3	41.1	25	0.615	
b_3	8'2"	9'9"	0	-	-	0	Rock
b_4	9'9"	10'6"	.5	40,4	74	1,790	
b_5	10'6"	11'2"	.7	40,3	102	2,462	
b_6	11'2	11'9	.5	40.4	104	2,503	
b_7	11'9"	12'1"	.5	40.0	99	2,408	
b_8	12'1"	12'8"	.6	40.0	92	2,240	
b_9	12'8"	13'4"	.8	40.3	84	2,033	
b_{10}	13'4"	14'0"	.7	40.1	103	2,498	
b_{11}	14'0"	14'8"	.6	40.0	106	2,576	
b_{12}	14'8"	15'4"	.6	40.3	95	2.295	
b_{13}	15'4"	16'0	.7	40.1	100	2.426	
b_{14}	16'0"	16'8"	.8	40.0	103	2.504	
b_{15}	10'8"	17'4"	.8	40.3	56	1,366	
b_{16}	17'4	18'0"	.7	40.8	34	0.832	Behind Boulder
b_{17}	18'0"	19'0"	.5	41,7	13	0.331	
b_{18}	19'0"	20'9"	0	-	-	0	Rock
b_{19}	20'9"	22'0"	.5	40,2	7	0.198	
b_{20}	22'0"	23'4"	.4	40,4	59	1,434	
b_{21}	23'4"	24'9"	.4	40.7	14	,365	
b_{22}	24'9"	27'0"	.4	40.7	49	1,187	
b_{23}							
b_{24}							
b_{25}							
b_{26}							
b_{27}							
b_{28}							
b_{29}							
b_{30}							
b_{31}							
b_{32}							

SECTION 4 - LEFT BANK SURVEY

PART 8: LEFT BANK CHARACTERISTICS

Type
- Noncohesive ☐
- Cohesive ☐
- Composite ☒
- Layered ☐
- Even Layers ☐
- Thick+thin layers ☐
- Number of layers ___

Protection Status
- Unprotected ☐
- Hard points ☒ meter-long boulders
- Toe protection ☐
- Revetments ☐
- Dyke Fields ☐

Bank Materials
- Silt/clay ☐
- Sand/silt/clay ☐
- Sand/silt ☐
- Sand ☐
- Sand/gravel ☐
- Gravel ☐
- Gravel/cobbles ☐
- Cobbles ☐
- Cobbles/boulders ☒
- Boulders/bedrock ☐

Layer Thickness
- Material 1 (m) ___
- Material 2 (m) ___
- Material 3 (m) ___
- Material 4 (m) ___

Ave. Bank Height .3
- Average height (m) ___

Ave. Bank Slope
- angle (degrees) ___ See sketch

Bank Profile Shape from water line / toe armor
- (see sketches in manual)

Tension Cracks
- None ☒
- Occasional ☐
- Frequent ☐

Crack Depth
- Proportion of bank height ___

Distribution and Description of Bank Materials in Bank Profile

Material Type 1	Material Type 2	Material Type 3	Material Type 4
Toe ☒	Toe ☐	Toe ☐	Toe ☐
Mid-Bank ☐	Mid-Bank ☒	Mid-Bank ☐	Mid-Bank ☐
Upper Bank ☐	Upper Bank ☐	Upper Bank ☒	Upper Bank ☐
Whole Bank ☐	Whole Bank ☐	Whole Bank ☐	Whole Bank ☐
D50 (mm) ___	D50 (mm) ___	D50 (mm) ___	D50 (mm) ___
sorting coefficient ___	sorting coefficient ___	sorting coefficient ___	sorting coef. ___
w/gravel armor	Loamy Sand	Loamy Sand	

Notes and Comments:-

PART 9: LEFT BANK-FACE VEGETATION

Vegetation
- None/fallow ☐
- Artificially cleared ☐
- Grass and flora ☒
- Reeds and sedges ☐
- Shrubs ☐
- Saplings ☐
- Trees ☐

Orientation
- Angle of leaning (°) ___

Tree Types
- None ☒
- Deciduous ☐
- Coniferous ☐
- Mixed ☐

Tree species (if known)

Density + Spacing
- None ☐
- Sparse/clumps ☐
- dense/clumps ☐
- Sparce/continuous ☐
- Dense/continuous ☒

Roots
- Normal ☐
- Exposed ☐
- Adventitious ☐

Location
- Whole bank ☒
- Upper bank ☐
- Mid-bank ☐
- Lower bank ☐

Diversity
- Mono-stand ☐
- Mixed stand ☐
- Climax-vegetation ☐

Health
- Healthy ☒ winter
- Fair ☐
- Poor ☐
- Dead ☒

Age
- Immature ☐
- Mature ☐
- Old ☐

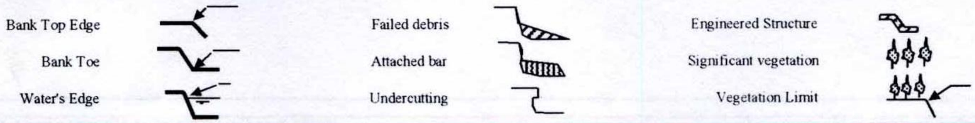
Height
- Short ☐
- Medium ☐
- Tall ☑
- Height (m) 1.0

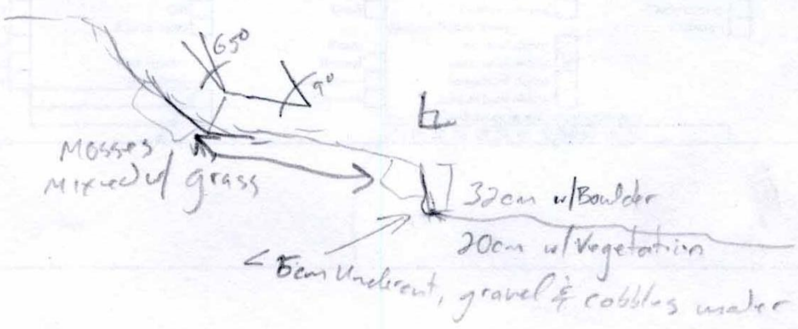
Lateral Extent
- Wide belt ☐
- Narrow belt ☐
- Single row ☐

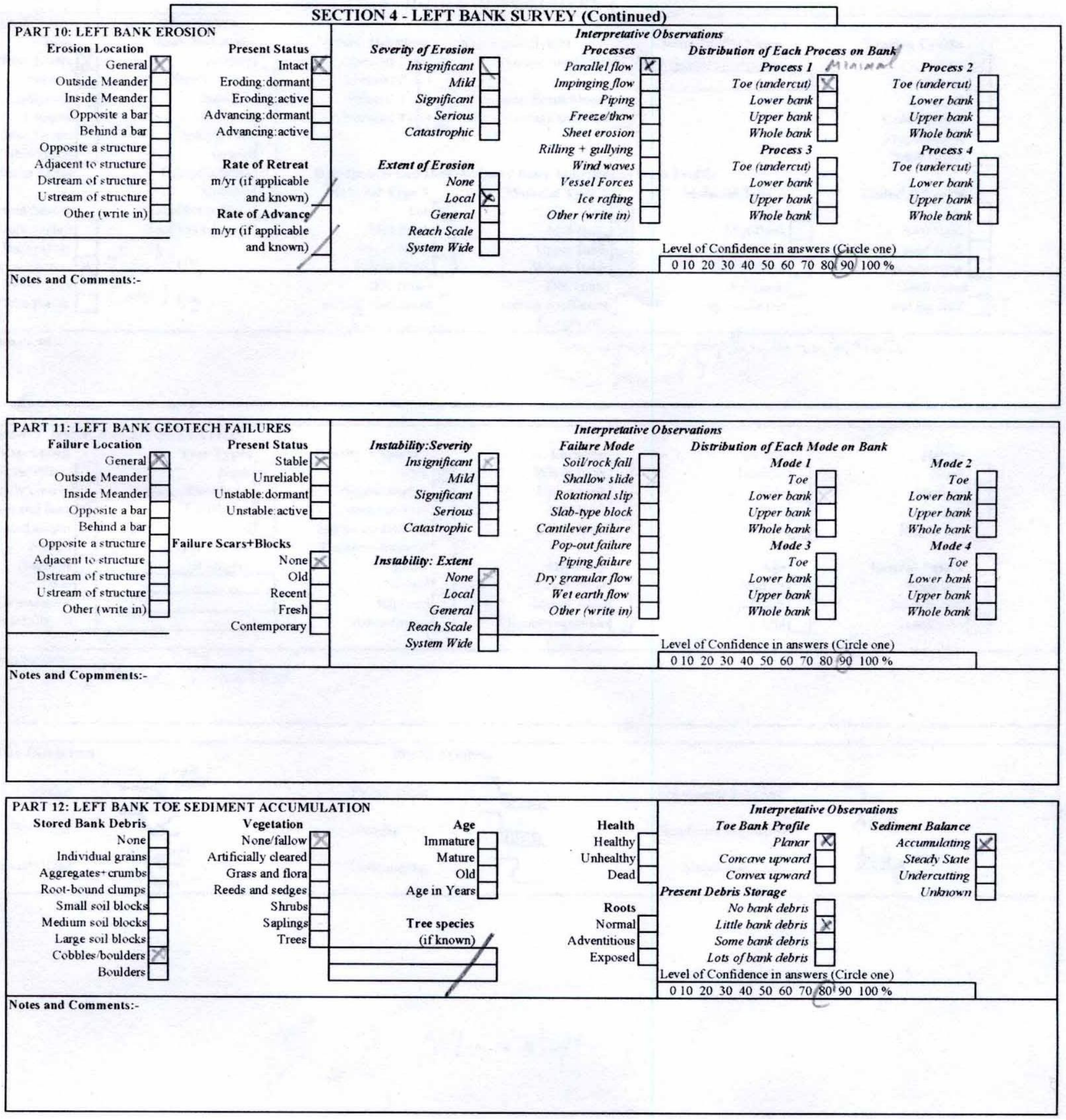
Notes and Comments:- Doesn't appear any of the planted trees survived

Bank Profile Sketches

Profile Symbols







SECTION 4 - LEFT BANK SURVEY (Continued)

PART 10: LEFT BANK EROSION

Erosion Location
- General ☒
- Outside Meander ☐
- Inside Meander ☐
- Opposite a bar ☐
- Behind a bar ☐
- Opposite a structure ☐
- Adjacent to structure ☐
- Dstream of structure ☐
- Ustream of structure ☐
- Other (write in) ☐

Present Status
- Intact ☒
- Eroding:dormant ☐
- Eroding:active ☐
- Advancing:dormant ☐
- Advancing:active ☐

Rate of Retreat
m/yr (if applicable and known)

Rate of Advance
m/yr (if applicable and known)

Interpretative Observations

Severity of Erosion
- *Insignificant* ☒
- *Mild* ☐
- *Significant* ☐
- *Serious* ☐
- *Catastrophic* ☐

Extent of Erosion
- *None* ☐
- *Local* ☒
- *General* ☐
- *Reach Scale* ☐
- *System Wide* ☐

Processes
- *Parallel flow* ☒
- *Impinging flow* ☐
- *Piping* ☐
- *Freeze/thaw* ☐
- *Sheet erosion* ☐
- *Rilling + gullying* ☐
- *Wind waves* ☐
- *Vessel Forces* ☐
- *Ice rafting* ☐
- *Other (write in)* ☐

Distribution of Each Process on Bank

Process 1 Minimal
- *Toe (undercut)* ☒
- *Lower bank* ☐
- *Upper bank* ☐
- *Whole bank* ☐

Process 2
- *Toe (undercut)* ☐
- *Lower bank* ☐
- *Upper bank* ☐
- *Whole bank* ☐

Process 3
- *Toe (undercut)* ☐
- *Lower bank* ☐
- *Upper bank* ☐
- *Whole bank* ☐

Process 4
- *Toe (undercut)* ☐
- *Lower bank* ☐
- *Upper bank* ☐
- *Whole bank* ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 80 [✓ 90] 100 %

Notes and Comments:-

PART 11: LEFT BANK GEOTECH FAILURES

Failure Location
- General ☒
- Outside Meander ☐
- Inside Meander ☐
- Opposite a bar ☐
- Behind a bar ☐
- Opposite a structure ☐
- Adjacent to structure ☐
- Dstream of structure ☐
- Ustream of structure ☐
- Other (write in) ☐

Present Status
- Stable ☒
- Unreliable ☐
- Unstable:dormant ☐
- Unstable:active ☐

Failure Scars+Blocks
- None ☒
- Old ☐
- Recent ☐
- Fresh ☐
- Contemporary ☐

Interpretative Observations

Instability:Severity
- *Insignificant* ☒
- *Mild* ☐
- *Significant* ☐
- *Serious* ☐
- *Catastrophic* ☐

Instability: Extent
- *None* ☒
- *Local* ☐
- *General* ☐
- *Reach Scale* ☐
- *System Wide* ☐

Failure Mode
- *Soil/rock fall* ☐
- *Shallow slide* ☒
- *Rotational slip* ☐
- *Slab-type block* ☐
- *Cantilever failure* ☐
- *Pop-out failure* ☐
- *Piping failure* ☐
- *Dry granular flow* ☐
- *Wet earth flow* ☐
- *Other (write in)* ☐

Distribution of Each Mode on Bank

Mode 1
- *Toe* ☐
- *Lower bank* ☒
- *Upper bank* ☐
- *Whole bank* ☐

Mode 2
- *Toe* ☐
- *Lower bank* ☐
- *Upper bank* ☐
- *Whole bank* ☐

Mode 3
- *Toe* ☐
- *Lower bank* ☐
- *Upper bank* ☐
- *Whole bank* ☐

Mode 4
- *Toe* ☐
- *Lower bank* ☐
- *Upper bank* ☐
- *Whole bank* ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 80 [✓ 90] 100 %

Notes and Copmments:-

PART 12: LEFT BANK TOE SEDIMENT ACCUMULATION

Stored Bank Debris
- None ☐
- Individual grains ☐
- Aggregates+crumbs ☐
- Root-bound clumps ☐
- Small soil blocks ☐
- Medium soil blocks ☐
- Large soil blocks ☐
- Cobbles/boulders ☒
- Boulders ☐

Vegetation
- None/fallow ☒
- Artificially cleared ☐
- Grass and flora ☐
- Reeds and sedges ☐
- Shrubs ☐
- Saplings ☐
- Trees ☐

Age
- Immature ☐
- Mature ☐
- Old ☐
- Age in Years ☐

Tree species
(if known)

Health
- Healthy ☐
- Unhealthy ☐
- Dead ☐

Roots
- Normal ☐
- Adventitious ☐
- Exposed ☐

Interpretative Observations

Toe Bank Profile
- *Planar* ☒
- *Concave upward* ☐
- *Convex upward* ☐

Sediment Balance
- *Accumulating* ☒
- *Steady State* ☐
- *Undercutting* ☐
- *Unknown* ☐

Present Debris Storage
- *No bank debris* ☐
- *Little bank debris* ☒
- *Some bank debris* ☐
- *Lots of bank debris* ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 [✓ 80] 90 100 %

Notes and Comments:-

SECTION 5 - RIGHT BANK SURVEY

PART 13: RIGHT BANK CHARACTERISTICS

Type
- Noncohesive ☒
- Cohesive ☐
- Composite ☐
- Layered ☐
- Even Layers ☐
- Thick+thin layers ☐
- Number of layers ___

Protection Status
- Unprotected ☐
- Hard points ☐
- Toe protection ☒ Boulders Cobbles
- Revetments ☐
- Dyke Fields ☐

Bank Materials
- Silt/clay ☐
- Sand/silt/clay ☐
- Sand/silt ☒
- Sand ☐
- Sand/gravel ☐
- Gravel ☐
- Gravel/cobbles ☐
- Cobbles ☐
- Cobbles/boulders ☐
- Boulders/bedrock ☐

Layer Thickness
- Material 1 (m) 1'
- Material 2 (m) ___
- Material 3 (m) ___
- Material 4 (m) ___

Ave. Bank Height
Average height (m) 1.6

Ave. Bank Slope
Average angle (o) 75°

Bank Profile Shape
(see sketches in manual) ☐

Tension Cracks
- None ☒
- Occasional ☐
- Frequent ☐

Crack Depth
Proportion of bank height ___

Distribution and Description of Bank Materials in Bank Profile

Material Type 1	Material Type 2	Material Type 3	Material Type 4
Toe ☒	Toe ☐	Toe ☐	Toe ☐
Mid-Bank ☐	Mid-Bank ☒	Mid-Bank ☐	Mid-Bank ☐
Upper Bank ☐	Upper Bank ☒	Upper Bank ☐	Upper Bank ☐
Whole Bank ☐	Whole Bank ☐	Whole Bank ☐	Whole Bank ☐
D50 (mm) ___	D50 (mm) ___	D50 (mm) ___	D50 (mm) ___
sorting coefficient ___	sorting coefficient ___	sorting coefficient ___	sorting coef ___
Cobbles	Loamy		

Notes and Comments:- Sand) to 2" depth into substrate then Sand)

PART 14: RIGHT BANK-FACE VEGETATION

Vegetation
- None/fallow ☐
- Artificially cleared ☐
- Grass and flora ☒
- Reeds and sedges ☐
- Shrubs ☐
- Saplings ☐
- Trees ☐

Orientation
Angle of leaning (°) ___

Tree Types
- None ☒
- Deciduous ☐
- Coniferous ☐
- Mixed ☐

Tree species
(if known) ___

Density + Spacing
- None ☒
- Sparse/clumps ☐
- dense/clumps ☐
- Sparce/continuous ☐
- Dense/continuous ☐

Roots
- Normal ☐
- Exposed ☐
- Adventitious ☐

Location
- Whole bank ☐
- Upper bank ☐
- Mid-bank ☐
- Lower bank ☐

Diversity
- Mono-stand ☐
- Mixed stand ☐
- Climax-vegetation ☐

Health
- Healthy ☐
- Fair ☐
- Poor ☐
- Dead ☐

Age
- Imature ☐
- Mature ☐
- Old ☐

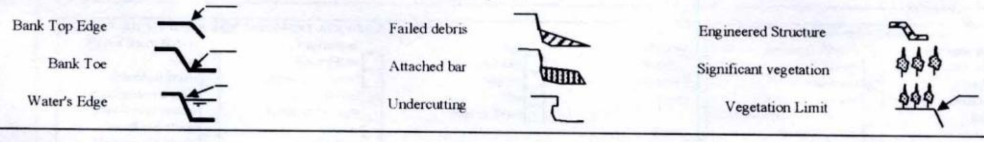
Height
- Short ☐
- Medium ☐
- Tall ☐
- Height (m) ___

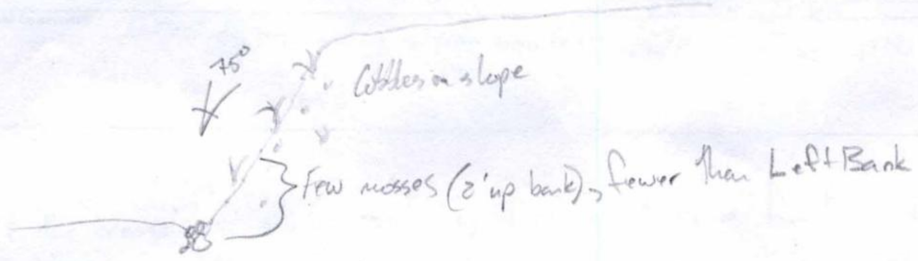
Lateral Extent
- Wide belt ☐
- Narrow belt ☐
- Single row ☐

Notes and Comments:- None Planted

Bank Profile Sketches

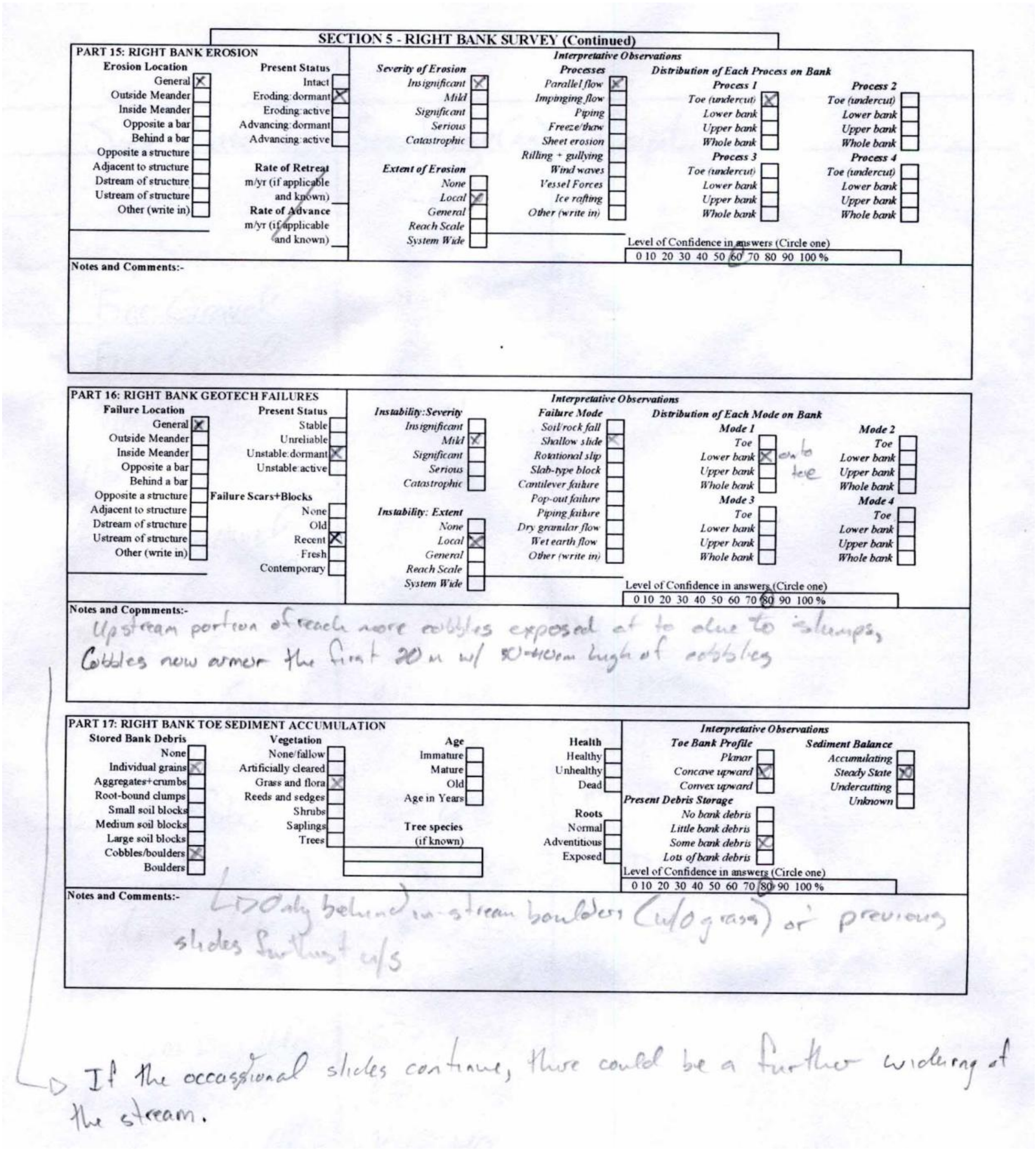
Profile Symbols




75°

Cobbles on slope

Few mosses (2' up bank), fewer than Left Bank



SECTION 5 - RIGHT BANK SURVEY (Continued)

PART 15: RIGHT BANK EROSION

Erosion Location
General ☒
Outside Meander ☐
Inside Meander ☐
Opposite a bar ☐
Behind a bar ☐
Opposite a structure ☐
Adjacent to structure ☐
Dstream of structure ☐
Ustream of structure ☐
Other (write in) ☐

Present Status
Intact ☐
Eroding:dormant ☒
Eroding:active ☐
Advancing:dormant ☐
Advancing:active ☐

Rate of Retreat
m/yr (if applicable and known) /

Rate of Advance
m/yr (if applicable and known) /

Interpretative Observations

Severity of Erosion
Insignificant ☒
Mild ☐
Significant ☐
Serious ☐
Catastrophic ☐

Extent of Erosion
None ☐
Local ☒
General ☐
Reach Scale ☐
System Wide ☐

Processes
Parallel flow ☒
Impinging flow ☐
Piping ☐
Freeze/thaw ☐
Sheet erosion ☐
Rilling + gullying ☐
Wind waves ☐
Vessel Forces ☐
Ice rafting ☐
Other (write in) ☐

Distribution of Each Process on Bank

Process 1
Toe (undercut) ☒
Lower bank ☐
Upper bank ☐
Whole bank ☐

Process 2
Toe (undercut) ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Process 3
Toe (undercut) ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Process 4
Toe (undercut) ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 [✓ 60] 70 80 90 100 %

Notes and Comments:-

PART 16: RIGHT BANK GEOTECH FAILURES

Failure Location
General ☒
Outside Meander ☐
Inside Meander ☐
Opposite a bar ☐
Behind a bar ☐
Opposite a structure ☐
Adjacent to structure ☐
Dstream of structure ☐
Ustream of structure ☐
Other (write in) ☐

Present Status
Stable ☐
Unreliable ☐
Unstable:dormant ☒
Unstable:active ☐

Failure Scars+Blocks
None ☐
Old ☐
Recent ☒
Fresh ☐
Contemporary ☐

Interpretative Observations

Instability:Severity
Insignificant ☐
Mild ☒
Significant ☐
Serious ☐
Catastrophic ☐

Instability: Extent
None ☐
Local ☒
General ☐
Reach Scale ☐
System Wide ☐

Failure Mode
Soil/rock fall ☐
Shallow slide ☒
Rotational slip ☐
Slab-type block ☐
Cantilever failure ☐
Pop-out failure ☐
Piping failure ☐
Dry granular flow ☐
Wet earth flow ☐
Other (write in) ☐

Distribution of Each Mode on Bank

Mode 1
Toe ☐
Lower bank ☒ on to toe
Upper bank ☐
Whole bank ☐

Mode 2
Toe ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Mode 3
Toe ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Mode 4
Toe ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 [✓ 80] 90 100 %

Notes and Copmments:-
Upstream portion of reach more cobbles exposed at to due to slumps,
Cobbles now armor the first 20 m w/ 30-40cm high of cobbles

PART 17: RIGHT BANK TOE SEDIMENT ACCUMULATION

Stored Bank Debris
None ☐
Individual grains ☒
Aggregates+crumbs ☐
Root-bound clumps ☐
Small soil blocks ☐
Medium soil blocks ☐
Large soil blocks ☐
Cobbles/boulders ☒
Boulders ☐

Vegetation
None/fallow ☐
Artificially cleared ☐
Grass and flora ☒
Reeds and sedges ☐
Shrubs ☐
Saplings ☐
Trees ☐

Age
Immature ☐
Mature ☐
Old ☐
Age in Years ☐

Tree species
(if known)

Health
Healthy ☐
Unhealthy ☐
Dead ☐

Roots
Normal ☐
Adventitious ☐
Exposed ☐

Interpretative Observations

Toe Bank Profile
Planar ☐
Concave upward ☒
Convex upward ☐

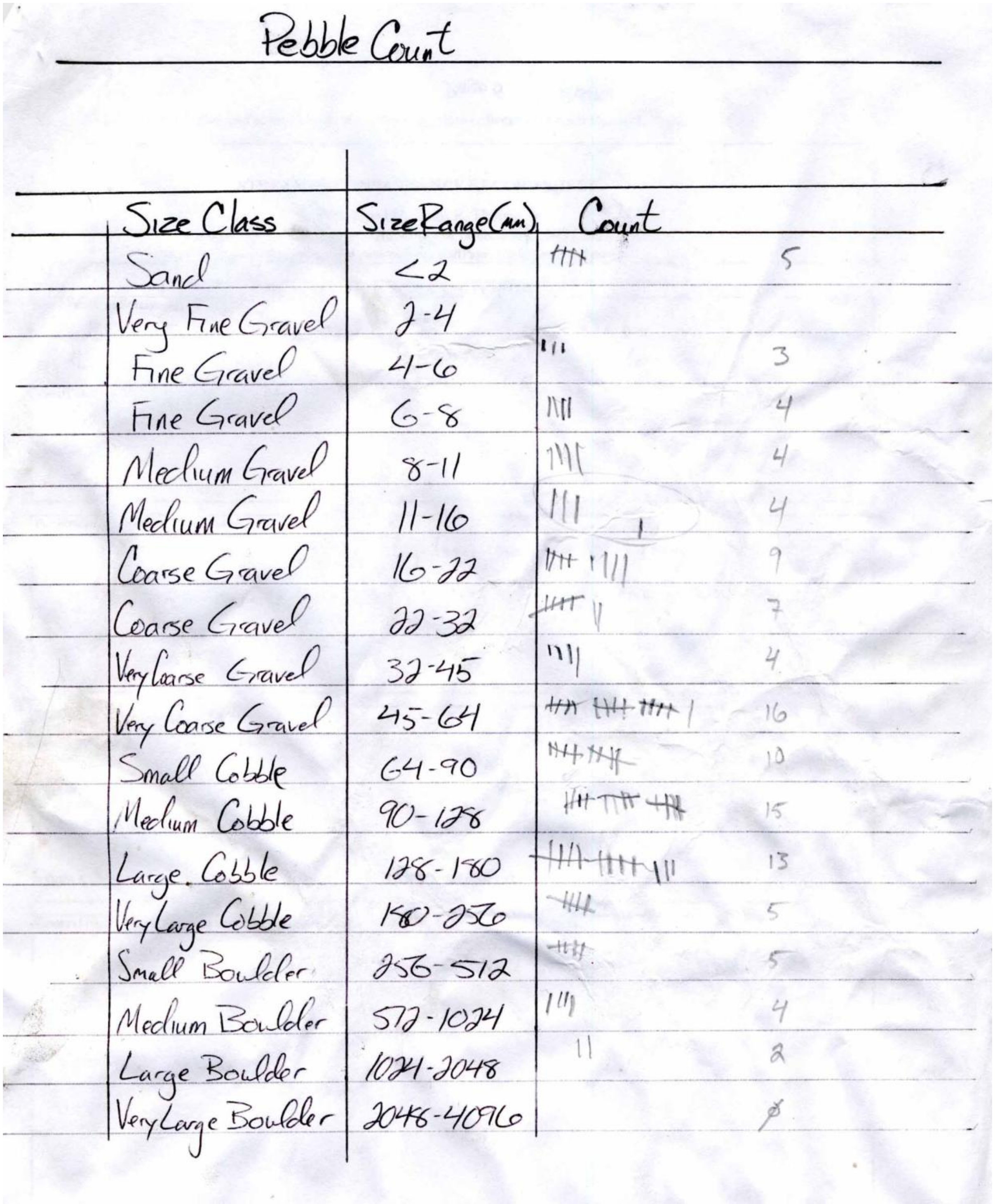
Present Debris Storage
No bank debris ☐
Little bank debris ☐
Some bank debris ☒
Lots of bank debris ☐

Sediment Balance
Accumulating ☐
Steady State ☒
Undercutting ☐
Unknown ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 [✓ 80] 90 100 %

Notes and Comments:-
Only behind in-stream boulders (w/o grass) or previous slides furthest u/s

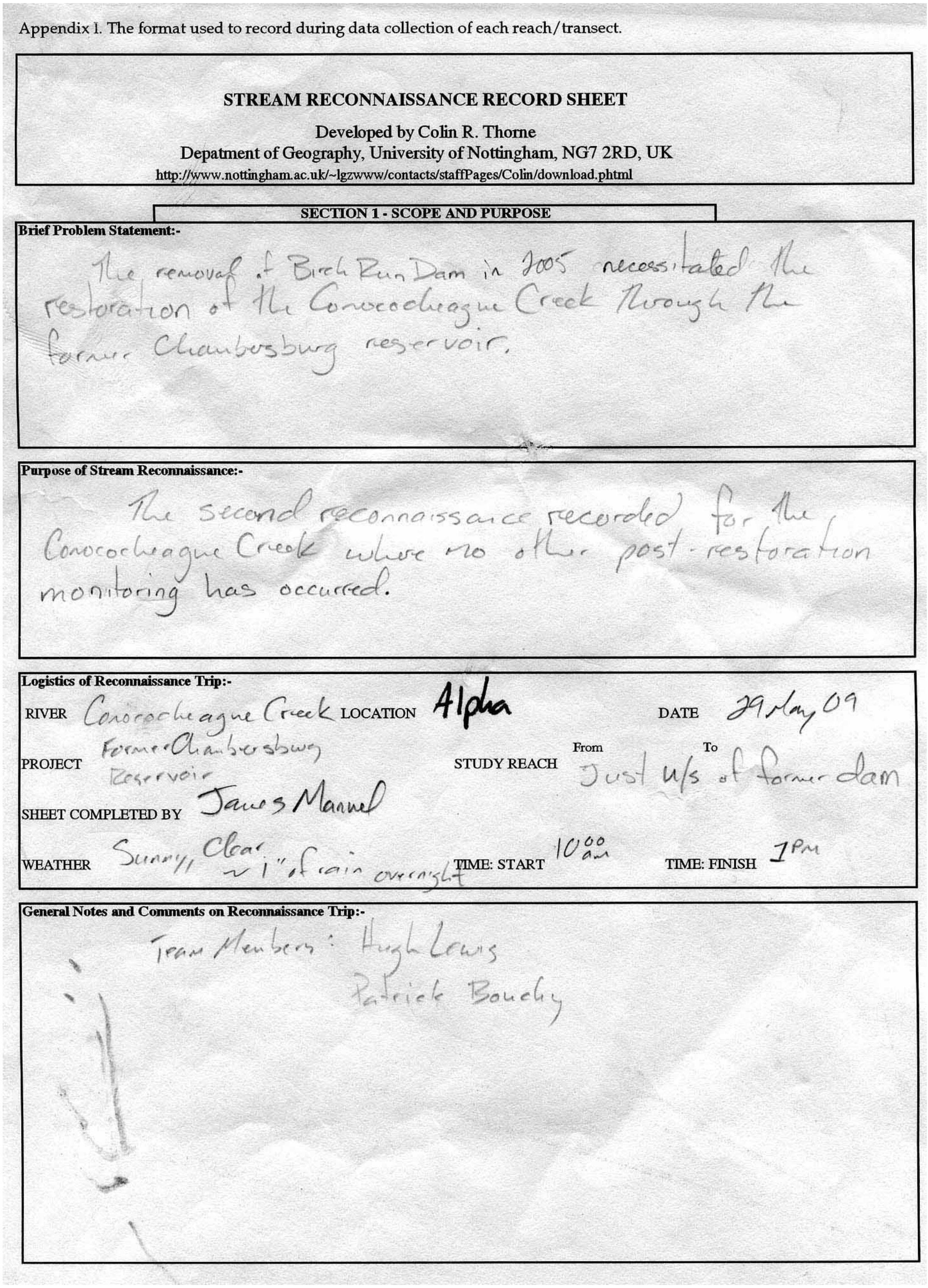
If the occassional slides continue, there could be a further widening of the stream.



Pebble Count

Size Class	Size Range (mm)	Count	
Sand	<2	𝍸	5
Very Fine Gravel	2-4		
Fine Gravel	4-6	|||	3
Fine Gravel	6-8	||||	4
Medium Gravel	8-11	||||	4
Medium Gravel	11-16	||| |	4
Coarse Gravel	16-22	𝍸 ||||	9
Coarse Gravel	22-32	𝍸 ||	7
Very Coarse Gravel	32-45	||||	4
Very Coarse Gravel	45-64	𝍸 𝍸 𝍸 |	16
Small Cobble	64-90	𝍸 𝍸	10
Medium Cobble	90-128	𝍸 𝍸 𝍸	15
Large Cobble	128-180	𝍸 𝍸 |||	13
Very Large Cobble	180-256	𝍸	5
Small Boulder	256-512	𝍸	5
Medium Boulder	512-1024	||||	4
Large Boulder	1024-2048	||	2
Very Large Boulder	2048-4096		0

Alpha - Reconnaissance Record Sheets dated, 29.May.2009



Appendix 1. The format used to record during data collection of each reach/transect.

STREAM RECONNAISSANCE RECORD SHEET

Developed by Colin R. Thorne
Depatment of Geography, University of Nottingham, NG7 2RD, UK
http://www.nottingham.ac.uk/~lgzwww/contacts/staffPages/Colin/download.phtml

SECTION 1 - SCOPE AND PURPOSE

Brief Problem Statement:-

The removal of Birch Run Dam in 2005 necessitated the restoration of the Conococheague Creek through the former Chambersburg reservoir.

Purpose of Stream Reconnaissance:-

The second reconnaissance recorded for the Conococheague Creek where no other post-restoration monitoring has occurred.

Logistics of Reconnaissance Trip:-

RIVER Conococheague Creek LOCATION Alpha DATE 29 May 09

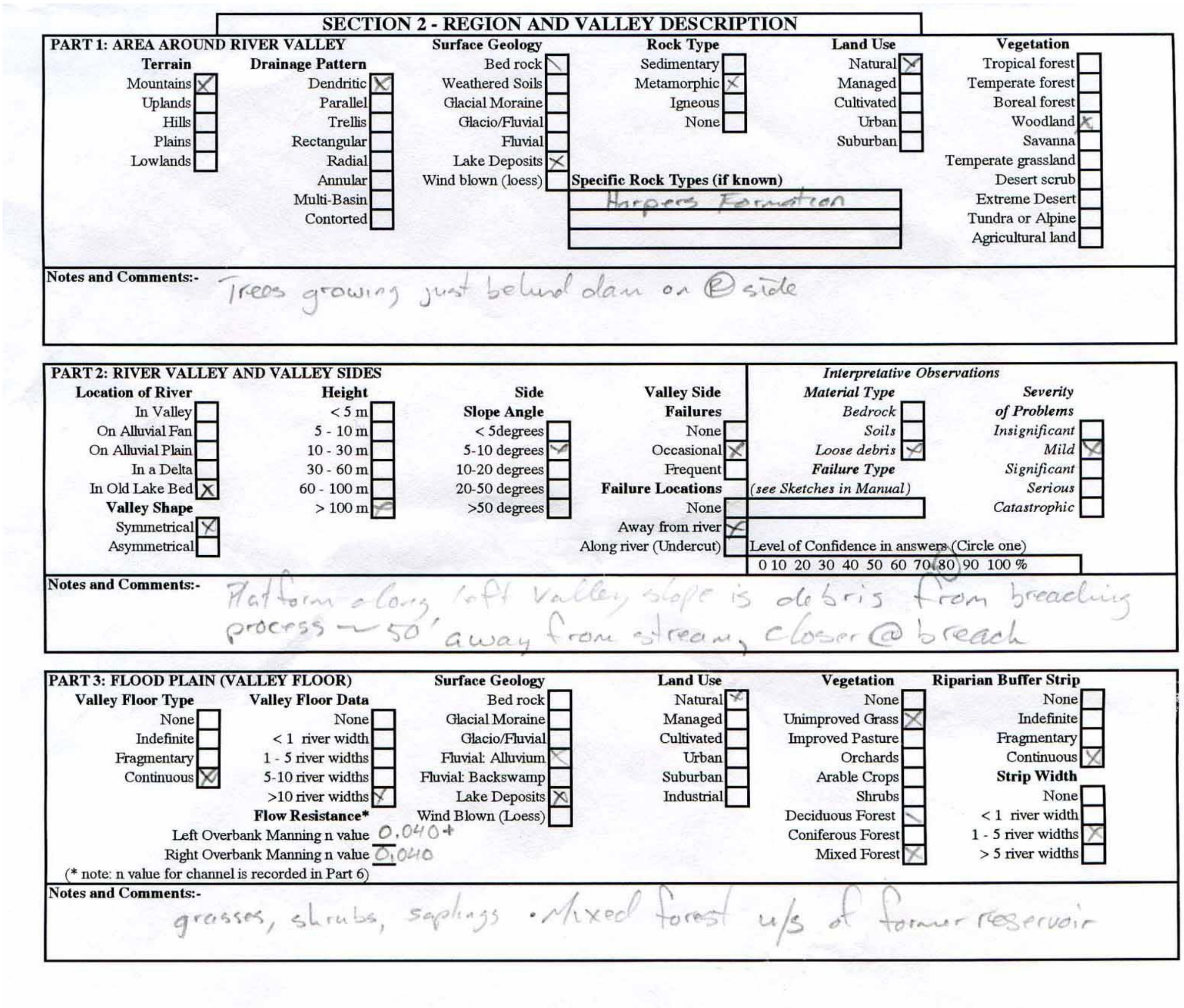
PROJECT Former Chambersburg Reservoir STUDY REACH From To Just u/s of former dam

SHEET COMPLETED BY James Mannel

WEATHER Sunny, Clear ~1" of rain overnight TIME: START 10 00 am TIME: FINISH 1PM

General Notes and Comments on Reconnaissance Trip:-

Team Members: Hugh Lewis
Patrick Bouchy



SECTION 2 - REGION AND VALLEY DESCRIPTION

PART 1: AREA AROUND RIVER VALLEY

Terrain
Mountains ☒
Uplands ☐
Hills ☐
Plains ☐
Lowlands ☐

Drainage Pattern
Dendritic ☒
Parallel ☐
Trellis ☐
Rectangular ☐
Radial ☐
Annular ☐
Multi-Basin ☐
Contorted ☐

Surface Geology
Bed rock ☒
Weathered Soils ☐
Glacial Moraine ☐
Glacio/Fluvial ☐
Fluvial ☐
Lake Deposits ☒
Wind blown (loess) ☐

Rock Type
Sedimentary ☐
Metamorphic ☒
Igneous ☐
None ☐

Specific Rock Types (if known)
Harpers Formation

Land Use
Natural ☒
Managed ☐
Cultivated ☐
Urban ☐
Suburban ☐

Vegetation
Tropical forest ☐
Temperate forest ☐
Boreal forest ☐
Woodland ☒
Savanna ☐
Temperate grassland ☐
Desert scrub ☐
Extreme Desert ☐
Tundra or Alpine ☐
Agricultural land ☐

Notes and Comments:- Trees growing just behind dam on Ⓡ side

PART 2: RIVER VALLEY AND VALLEY SIDES

Location of River
In Valley ☐
On Alluvial Fan ☐
On Alluvial Plain ☐
In a Delta ☐
In Old Lake Bed ☒

Valley Shape
Symmetrical ☒
Asymmetrical ☐

Height
< 5 m ☐
5 - 10 m ☐
10 - 30 m ☐
30 - 60 m ☐
60 - 100 m ☐
> 100 m ☒

Side Slope Angle
< 5degrees ☐
5-10 degrees ☒
10-20 degrees ☐
20-50 degrees ☐
>50 degrees ☐

Valley Side Failures
None ☐
Occasional ☒
Frequent ☐

Failure Locations
None ☐
Away from river ☒
Along river (Undercut) ☐

Interpretative Observations

Material Type
Bedrock ☐
Soils ☐
Loose debris ☒

Failure Type
(see Sketches in Manual) ☐

Severity of Problems
Insignificant ☐
Mild ☒
Significant ☐
Serious ☐
Catastrophic ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 [✓ 80] 90 100 %

Notes and Comments:- Platform along left valley slope is debris from breaching process ~ 50' away from stream, closer @ breach

PART 3: FLOOD PLAIN (VALLEY FLOOR)

Valley Floor Type
None ☐
Indefinite ☐
Fragmentary ☐
Continuous ☒

Valley Floor Data
None ☐
< 1 river width ☐
1 - 5 river widths ☐
5-10 river widths ☐
>10 river widths ☒

Flow Resistance*
Left Overbank Manning n value 0.040+
Right Overbank Manning n value 0.040
(* note: n value for channel is recorded in Part 6)

Surface Geology
Bed rock ☐
Glacial Moraine ☐
Glacio/Fluvial ☐
Fluvial: Alluvium ☒
Fluvial: Backswamp ☐
Lake Deposits ☒
Wind Blown (Loess) ☐

Land Use
Natural ☒
Managed ☐
Cultivated ☐
Urban ☐
Suburban ☐
Industrial ☐

Vegetation
None ☐
Unimproved Grass ☒
Improved Pasture ☐
Orchards ☐
Arable Crops ☐
Shrubs ☐
Deciduous Forest ☒
Coniferous Forest ☐
Mixed Forest ☒

Riparian Buffer Strip
None ☐
Indefinite ☐
Fragmentary ☐
Continuous ☒

Strip Width
None ☐
< 1 river width ☐
1 - 5 river widths ☒
> 5 river widths ☐

Notes and Comments:- grasses, shrubs, saplings • Mixed forest u/s of former reservoir

SECTION 2 - REGION AND VALLEY DESCRIPTION (Continued)

PART 4: VERTICAL RELATION OF CHANNEL TO VALLEY

Terraces
None ☐
Indefinate ☐
Fragmentary ☒
Continuous ☐
Number of Terraces 1 Minor Right

Trash Lines
Absent ☐
Present ☒
Height above flood plain (m) 1' @ Banks
1m Relict

Overbank Deposits
None ☒
Silt ☐
Fine sand ☐
Medium sand ☒
Coarse sand ☐
Gravel ☐
Boulders ☐

Right
Left
Bank

Levees
None ☒
Natural ☐
Constructed ☐

Levee Description
None ☒
Indefinite ☐
Fragmentary ☐
Continuous ☐
Left Bank ☐
Right Bank ☐
Both Banks ☐

Levee Data
Height (m) ☐
Side Slope (o) ☐

Levee Condition
None ☐
Intact ☐
Local Failures ☐
Frequent failures ☐

Interpretative Observations

Present Status
Adjusted ☒
Incised ☐
Aggraded ☐

Instability Status
Stable ☒
Degrading ☐
Aggrading ☐

Problem Severity
Insignificant ☐
Moderate ☒
Serious ☐

Problem Extent
None ☐
Local ☒
General ☐
Reach scale ☐
System wide ☐
Regional ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 [✓ 70] 80 90 100 %

Notes and Comments:-

PART 5: LATERAL RELATION OF CHANNEL TO VALLEY

Planform
Straight ☒
Sinuous ☐
Irregular ☐
Regular meanders ☐
Irregular meanders ☐
Tortuous meanders ☐
Braided ☐
Anastomosed ☐

Planform Data
Bend Radius ___
Meander belt width 89m
Wavelength 90m
Meander Sinuosity 1.047

Location in Valley
Left ☒
Middle ☐
Right ☐

Beginning

Lateral Activity
None ☐
Meander progression ☒
Increasing amplitude ☐
Progression+cut-offs ☐
Irregular erosion ☐
Avulsion ☐
Braiding ☐

Floodplain Features
None ☐
Meander scars ☐
Scroll bars+sloughs ☐
Oxbow lakes ☐
Irregular terrain ☒
Abandoned channel ☒
Braided Deposits ☐

Interpretative Observations

Present Status
Adjusted ☒
Over wide ☐
Too narrow ☒

Instability Status
Stable ☐
Widening ☒
Narrowing ☐

Problem Severity
Insignificant ☐
Moderate ☒
Serious ☐

Problem Extent
None ☐
Local ☐
General ☒
Reach scale ☐
System wide ☐
Regional ☐

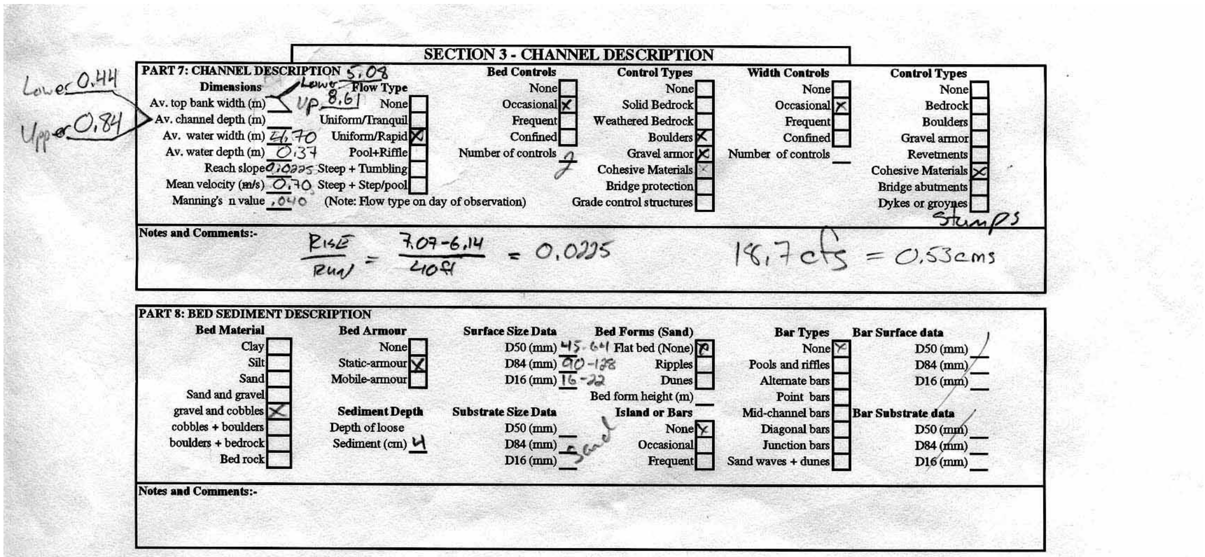
Level of Confidence in percent (Circle one)
0 10 20 30 40 50 60 70 [✓ 80] 90 100 %

PART 6: Mapping the Cross-Section with Auto Level

	Distance ~~(m)~~ ft	Stadia Height ~~(m)~~ ft	Notes		Distance ~~(m)~~ ft in	Stadia Height ~~(m)~~ ft	Notes
1	-20	4.0		26	43'1"	3,47	Top Bank
2	-4.5	3.4		27	46'0"	3,07	
3	4'9"	3,37		28	50'5"	2,91	
4	8'6"	3,44		29	53'11"	2,82	
5	14'10"	3.51	slope	30	61'3"	2,79	
6	15'10"	4.41	slope	31			
7	18'1"	5.38	lower bank,	32			
8	18'11"	6.48	toe, in Water	33			
9	20'0"	7.0	Water	34			
10	21'0"	7.1	Water	35			
11	22 -	6.94	Water	36			
12	23 -	6.99	Water	37			
13	24 -	6.98	Water	38			
14	25 -	6.89	Water	39			
15	26 -	6,93	Water	40			
16	27 -	6,76	Water	41			
17	28 -	6,79	Water	42			
18	29 -	6,72	Water	43			
19	30 -	6,70	Water	44			
20	31 -	6.77	Water	45			
21	32 -	6,59	Water	46			
22	34'3"	6,60	Toe	47			
23	34'9	5,19	Lower Bank	48			
24	37'0"	4, 88		49			
25	40'1"	4,04		50			

Notes and Comments:-

Autolevel - Hugh
Stadia - Patrick
Recorder - James



SECTION 3 - CHANNEL DESCRIPTION

PART 7: CHANNEL DESCRIPTION

Dimensions
- Av. top bank width (m) Lower 5.08 Up 8.61
- Av. channel depth (m) Lower 0.44 Upper 0.84
- Av. water width (m) 4.70
- Av. water depth (m) 0.37
- Reach slope 0.0225
- Mean velocity (m/s) 0.70
- Manning's n value .040

Flow Type
- None ☐
- Uniform/Tranquil ☐
- Uniform/Rapid ☒
- Pool+Riffle ☐
- Steep + Tumbling ☐
- Steep + Step/pool ☐

(Note: Flow type on day of observation)

Bed Controls
- None ☐
- Occasional ☒
- Frequent ☐
- Confined ☐
- Number of controls 7

Control Types
- None ☐
- Solid Bedrock ☐
- Weathered Bedrock ☐
- Boulders ☒
- Gravel armor ☒
- Cohesive Materials ☐
- Bridge protection ☐
- Grade control structures ☐

Width Controls
- None ☐
- Occasional ☒
- Frequent ☐
- Confined ☐
- Number of controls

Control Types
- None ☐
- Bedrock ☐
- Boulders ☐
- Gravel armor ☐
- Revetments ☐
- Cohesive Materials ☒
- Bridge abutments ☐
- Dykes or groynes ☐ Stumps

Notes and Comments:-

$\frac{\text{Rise}}{\text{Run}} = \frac{7.07-6.14}{40 ft} = 0.0225$

18.7 cfs = 0.53 cms

PART 8: BED SEDIMENT DESCRIPTION

Bed Material
- Clay ☐
- Silt ☐
- Sand ☐
- Sand and gravel ☐
- gravel and cobbles ☒
- cobbles + boulders ☐
- boulders + bedrock ☐
- Bed rock ☐

Bed Armour
- None ☐
- Static-armour ☒
- Mobile-armour ☐

Sediment Depth
- Depth of loose Sediment (cm) 4

Surface Size Data
- D50 (mm) 45-64
- D84 (mm) 90-128
- D16 (mm) 16-22

Substrate Size Data Sand
- D50 (mm)
- D84 (mm)
- D16 (mm)

Bed Forms (Sand)
- Flat bed (None) ☒
- Ripples ☐
- Dunes ☐
- Bed form height (m)

Island or Bars
- None ☒
- Occasional ☐
- Frequent ☐

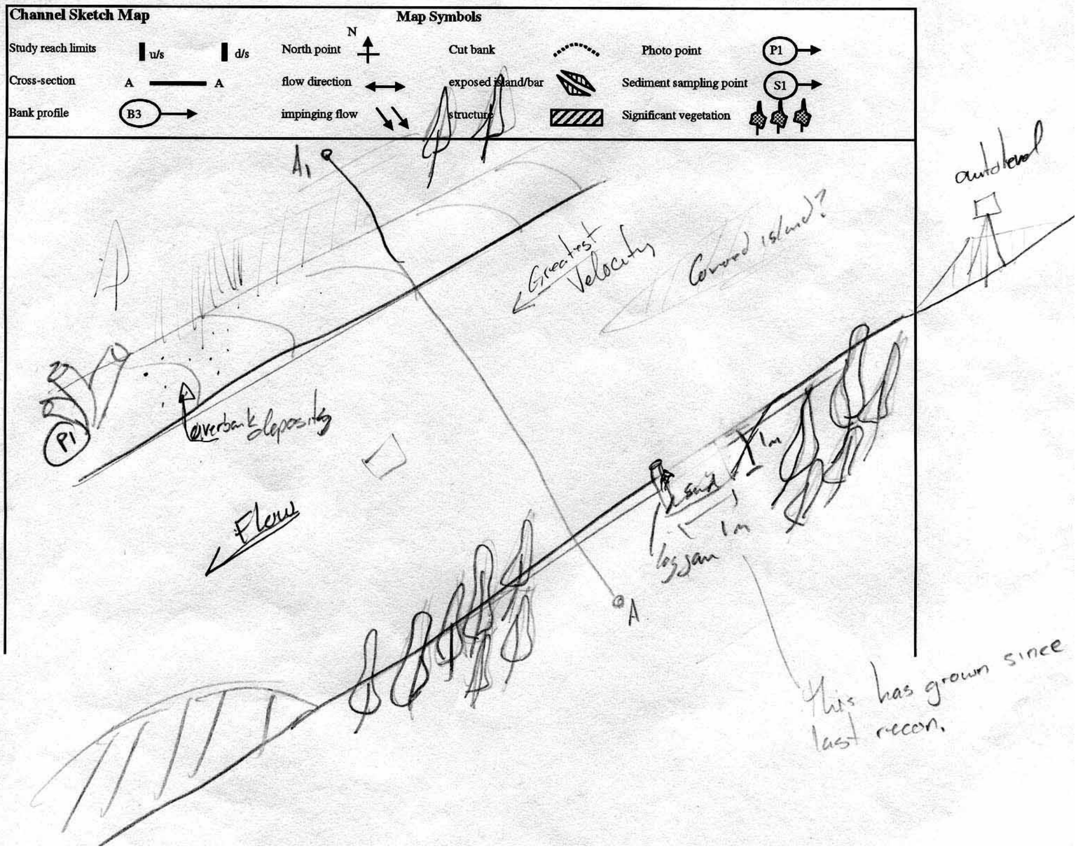
Bar Types
- None ☒
- Pools and riffles ☐
- Alternate bars ☐
- Point bars ☐
- Mid-channel bars ☐
- Diagonal bars ☐
- Junction bars ☐
- Sand waves + dunes ☐

Bar Surface data
- D50 (mm)
- D84 (mm)
- D16 (mm)

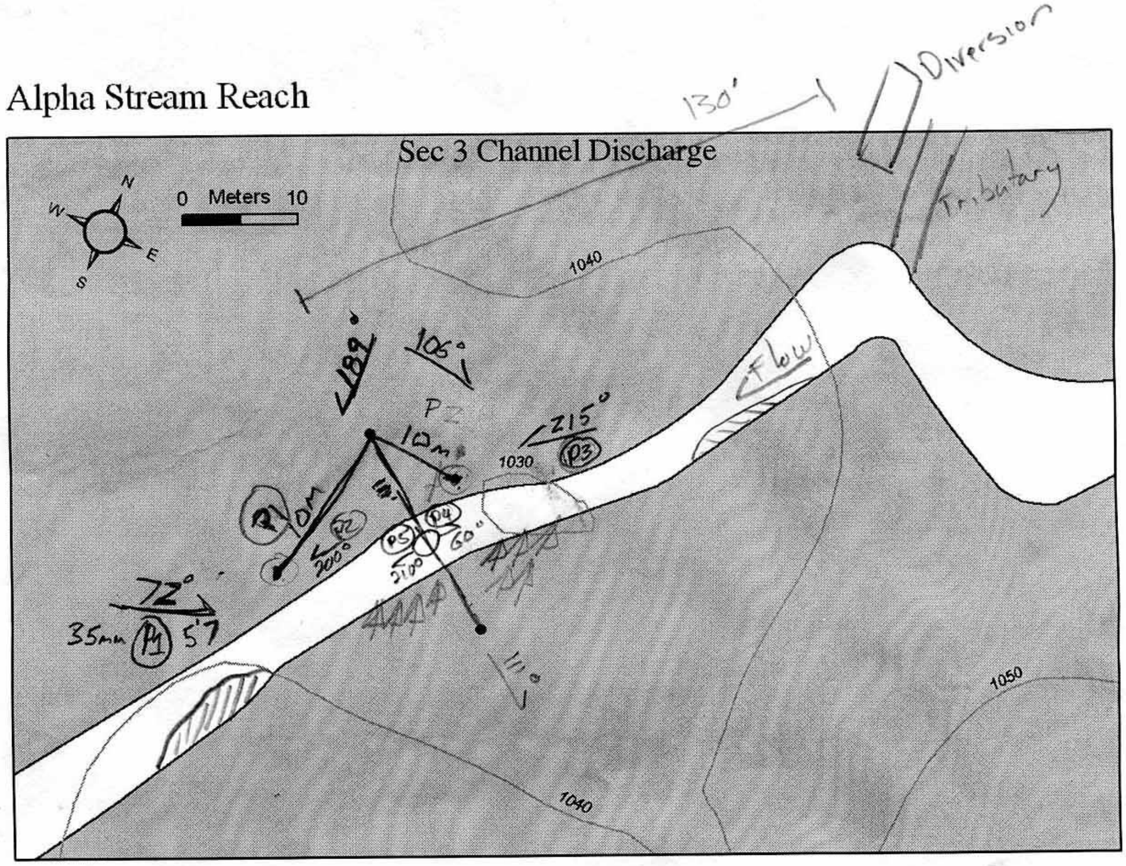
Bar Substrate data
- D50 (mm)
- D84 (mm)
- D16 (mm)

Notes and Comments:-

Channel Sketch Map



Alpha Stream Reach



Sec 3 Channel Discharge

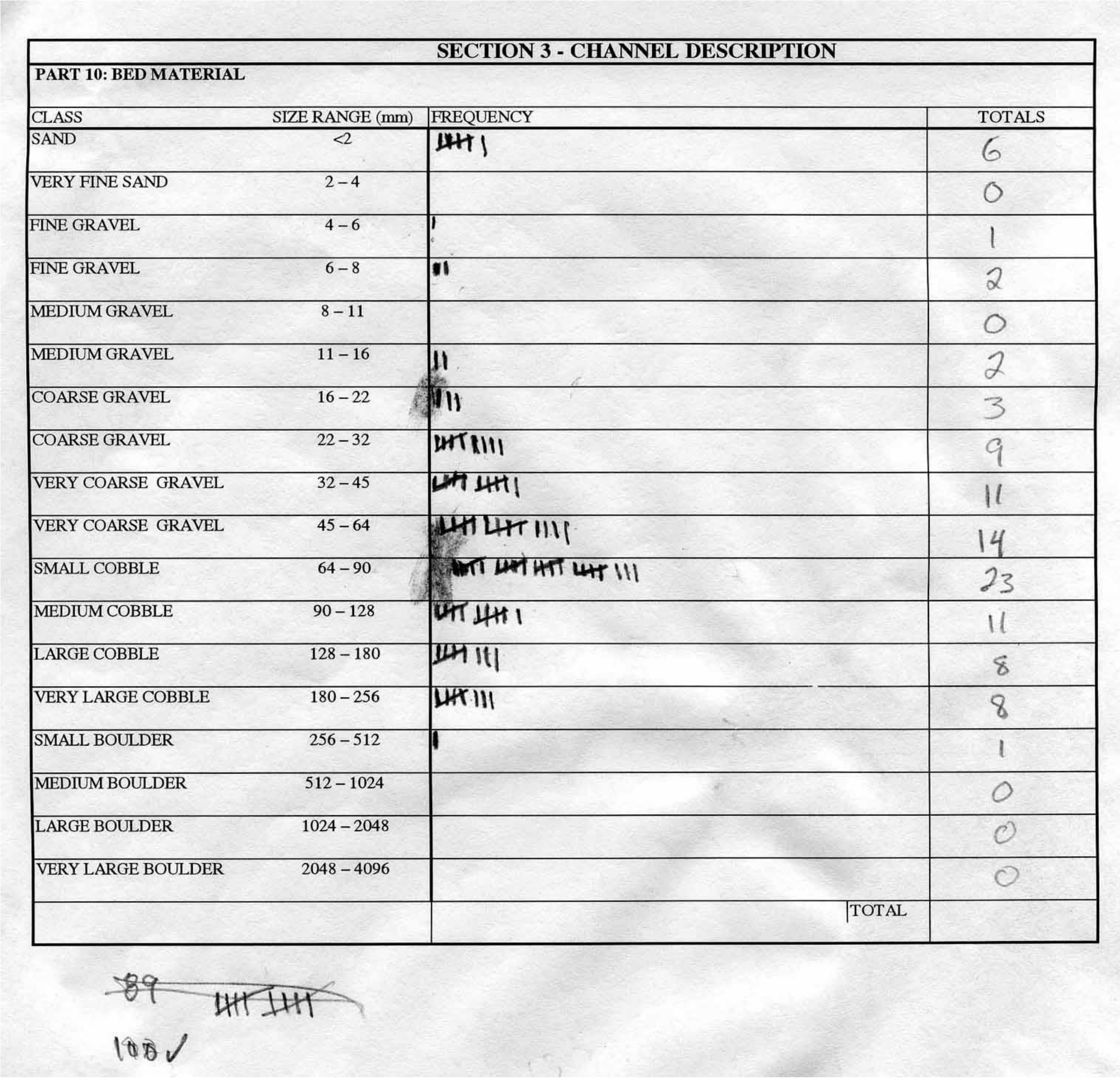
SECTION 3 - CHANNEL DESCRIPTION

PART 9: CHANNEL DISCHARGE

Station Bi	Distance to $B_i + 1$	Distance to $B_i - 1$	Depth '	Time Duration	Revolutions	Point Velocity ft/sec	Notes
b_1	18'9"	19'11"	0.9	40.8	33	.808	
b_2	19'11"	20'10"	0.9	40.1	119	2.881	
b_3	20'10"	21'6"	1.3	40.0	94	2.288	
b_4	21'6"	22'5"	1.4	40.3	73	1.771	
b_5	22'5"	23'2"	1.3	40.4	56	1.362	
b_6	23'2"	23'10"	1.5	40.1	78	1.899	
b_7	23'10"	24'7"	1.4	40.1	59	1.444	
b_8	24'7"	25'4"	1.2	40.4	93	2.242	
b_9	25'4"	26'0"	1.3	40.3	102	2.462	
b_{10}	26'0"	26'8"	1.1	40.2	112	2.707	
b_{11}	26'8"	27'4"	1.2	40.2	121	2.922	
b_{12}	27'4"	28'0"	1.3	40.2	136	3.280	
b_{13}	28'0	28'8"	1.2	40.1	135	3.264	
b_{14}	28'8"	29'4"	1.2	40.3	108	2.605	
b_{15}	29'4"	30'0"	1.1	40.4	109	2.622	
b_{16}	30'0"	30'8"	1.1	40.3	117	2.819	
b_{17}	30'8"	30 8"	1.2	40.1	143	3.456	
b_{18}	31'6"	32'4"	1.0	40.3	77	1.866	
b_{19}	32'4"	33'2"	0.9	40.1	75	1.827	
b_{20}	33'2"	34'2"	0.9	40.1	51	1.253	
b_{21}							
b_{22}							
b_{23}						18.71 cfs	
b_{24}							
b_{25}							
b_{26}							
b_{27}							
b_{28}							
b_{29}							
b_{30}							
b_{31}							
b_{32}							

1.1
2.3
3 3
24
2.73
20
≈ 54.60 cfs

6.14
7.07
40ft



SECTION 3 - CHANNEL DESCRIPTION

PART 10: BED MATERIAL

CLASS	SIZE RANGE (mm)	FREQUENCY	TOTALS
SAND	<2	𝍸 |	6
VERY FINE SAND	2 – 4		0
FINE GRAVEL	4 – 6	|	1
FINE GRAVEL	6 – 8	||	2
MEDIUM GRAVEL	8 – 11		0
MEDIUM GRAVEL	11 – 16	||	2
COARSE GRAVEL	16 – 22	|||	3
COARSE GRAVEL	22 – 32	𝍸 ||||	9
VERY COARSE GRAVEL	32 – 45	𝍸 𝍸 |	11
VERY COARSE GRAVEL	45 – 64	𝍸 𝍸 ||||	14
SMALL COBBLE	64 – 90	𝍸 𝍸 𝍸 𝍸 |||	23
MEDIUM COBBLE	90 – 128	𝍸 𝍸 |	11
LARGE COBBLE	128 – 180	𝍸 |||	8
VERY LARGE COBBLE	180 – 256	𝍸 |||	8
SMALL BOULDER	256 – 512	|	1
MEDIUM BOULDER	512 – 1024		0
LARGE BOULDER	1024 – 2048		0
VERY LARGE BOULDER	2048 – 4096		0
		TOTAL	

~~89 𝍸 𝍸~~

100 ✓

SECTION 4 - LEFT BANK SURVEY

PART 11: LEFT BANK CHARACTERISTICS

Type
Noncohesive ☐
Cohesive ☒
Composite ☐
Layered ☐
Even Layers ☐
Thick+thin layers ☐
Number of layers 1

Protection Status
Unprotected ☒
Hard points ☐
Toe protection ☐
Revetments ☐
Dyke Fields ☐

Bank Materials
Silt/clay ☒
Sand/silt/clay ☐
Sand/silt ☐
Sand ☐
Sand/gravel ☐
Gravel ☐
Gravel/cobbles ☐
Cobbles ☐
Cobbles/boulders ☐
Boulders/bedrock ☐

Layer Thickness
Material 1 (m) 2°
Material 2 (m) __
Material 3 (m) __
Material 4 (m) __

Ave. Bank Height 0.2
Average height (m) __

Ave. Bank Slope
angle (degrees) 67°

Bank Profile Shape
(see sketches in manual)

Tension Cracks
None ☐
Occasional ☐
Frequent ☐

Crack Depth
Proportion of bank height __

Distribution and Description of Bank Materials in Bank Profile

Material Type 1	**Material Type 2**	**Material Type 3**	**Material Type 4**
Toe ☐	Toe ☐	Toe ☐	Toe ☐
Mid-Bank ☐	Mid-Bank ☐	Mid-Bank ☐	Mid-Bank ☐
Upper Bank ☐	Upper Bank ☐	Upper Bank ☐	Upper Bank ☐
Whole Bank ☒	Whole Bank ☐	Whole Bank ☐	Whole Bank ☐
D50 (mm) __	D50 (mm) __	D50 (mm) __	D50 (mm) __
sorting coefficient __	sorting coefficient __	sorting coefficient __	sorting coef. __

Notes and Comments:- Silty Clay Loam

PART 12: LEFT BANK-FACE VEGETATION

Vegetation
None/fallow ☐
Artificially cleared ☐
Grass and flora ☒
Reeds and sedges ☐
Shrubs ☐
Saplings ☐
Trees ☐

Orientation
Angle of leaning (°) 90°

Tree Types
None ☐
Deciduous ☒
Coniferous ☐
Mixed ☐

Tree species
(if known)

Density + Spacing
None ☐
Sparse/clumps ☐
dense/clumps ☒
Sparce/continuous ☐
Dense/continuous ☐

Roots unexposed
Normal ☒
Exposed ☐
Adventitious ☐
⟶ under the undercut ledge

Location
Whole bank ☐
Upper bank ☒
Mid-bank ☐
Lower bank ☐

Diversity
Mono-stand ☒
Mixed stand ☐
Climax-vegetation ☐

Health
Healthy ☒
Fair ☐
Poor ☐
Dead ☐

Age
Immature ☒
Mature ☐
Old ☐

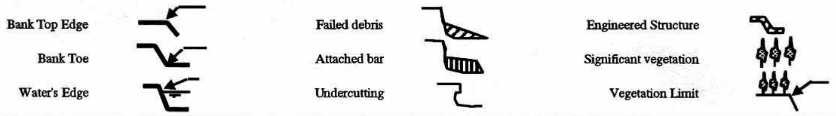
Height
Short ☒
Medium ☐
Tall ☐
Height (m) 3-4

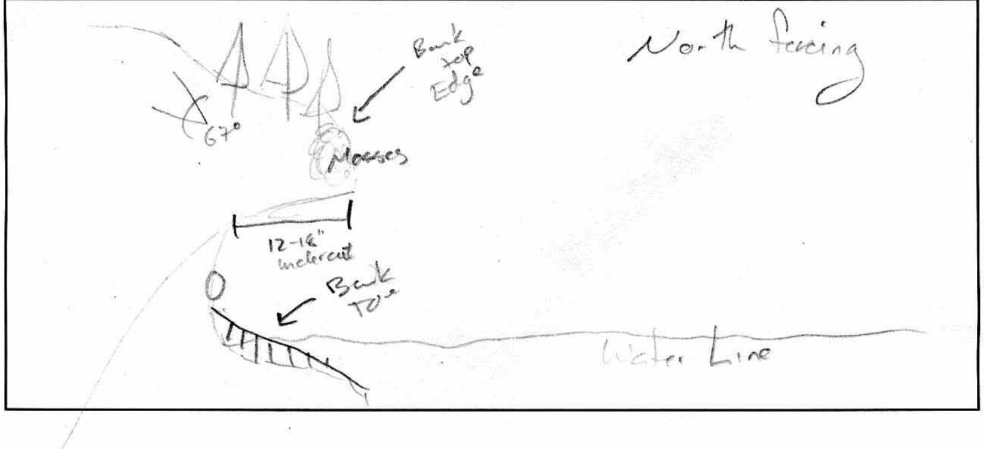
Lateral Extent
Wide belt ☐
Narrow belt ☒
Single row ☐

Notes and Comments:- likely planted after restoration

Bank Profile Sketches

Profile Symbols





This has grown since the last reconnaissance, and more extensive/continuous.

SECTION 4 - LEFT BANK SURVEY (Continued)

PART 13: LEFT BANK EROSION

Erosion Location
General ☒
Outside Meander ☐
Inside Meander ☐
Opposite a bar ☐
Behind a bar ☐
Opposite a structure ☐
Adjacent to structure ☐
Dstream of structure ☐
Ustream of structure ☐
Other (write in) ☐

Present Status
Intact ☐
Eroding:dormant ☐
Eroding:active ☒
Advancing:dormant ☐
Advancing:active ☐

Rate of Retreat
m/yr (if applicable and known)

Rate of Advance
m/yr (if applicable and known)
6" since March

Interpretative Observations

Severity of Erosion
Insignificant ☐
Mild ☐
Significant ☒
Serious ☐
Catastrophic ☐

Extent of Erosion
None ☐
Local ☐
General ☐
Reach Scale ☒
System Wide ☐

Processes
Parallel flow ☒ 1
Impinging flow ☒ 2
Piping ☐
Freeze/thaw ☐
Sheet erosion ☐
Rilling + gullying ☐
Wind waves ☐
Vessel Forces ☐
Ice rafting ☐
Other (write in) ☐

Distribution of Each Process on Bank

Process 1
Toe (undercut) ☒ 1,2
Lower bank ☒ 1
Upper bank ☐
Whole bank ☐

Process 2
Toe (undercut) ☒ 1
Lower bank ☐
Upper bank ☐
Whole bank ☐

Process 3
Toe (undercut) ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Process 4
Toe (undercut) ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 [✓ 70] 80 90 100 %

Notes and Comments:-

- Undercut is continuous d/s from Xsection to end of reach & atleast 1' deep
- Scour u/s of Xsection is deeper, exposing more log/root - sand deposited

PART 14: LEFT BANK GEOTECH FAILURES

Failure Location
General ☒
Outside Meander ☐
Inside Meander ☐
Opposite a bar ☐
Behind a bar ☐
Opposite a structure ☐
Adjacent to structure ☐
Dstream of structure ☐
Ustream of structure ☐
Other (write in) ☐

Present Status
Stable ☒
Unreliable ☐
Unstable:dormant ☐
Unstable:active ☐

Failure Scars+Blocks
None ☒
Old ☐
Recent ☐
Fresh ☐
Contemporary ☐

Interpretative Observations

Instability:Severity
Insignificant ☒
Mild ☐
Significant ☐
Serious ☐
Catastrophic ☐

Instability: Extent
None ☒
Local ☐
General ☐
Reach Scale ☐
System Wide ☐

Failure Mode
Soil/rock fall ☐
Shallow slide ☐
Rotational slip ☐
Slab-type block ☐
Cantilever failure ☐
Pop-out failure ☐
Piping failure ☐
Dry granular flow ☐
Wet earth flow ☐
Other (write in) ☐

Distribution of Each Mode on Bank

Mode 1
Toe ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Mode 2
Toe ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Mode 3
Toe ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Mode 4
Toe ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 [✓ 70] 80 90 100 %

Notes and Copmments:-

PART 15: LEFT BANK TOE SEDIMENT ACCUMULATION

Stored Bank Debris
None ☐
Individual grains ☒
Aggregates+crumbs ☐
Root-bound clumps ☐
Small soil blocks ☐
Medium soil blocks ☐
Large soil blocks ☐
Cobbles/boulders ☐
Boulders ☐

Vegetation
None/fallow ☒
Artificially cleared ☐
Grass and flora ☐
Reeds and sedges ☐
Shrubs ☐
Saplings ☐
Trees ☐

Age
Immature ☐
Mature ☐
Old ☐
Age in Years ☐

Tree species
(if known)

Health
Healthy ☐
Unhealthy ☐
Dead ☐

Roots
Normal ☐
Adventitious ☐
Exposed ☐

Interpretative Observations

Toe Bank Profile
Planar ☐
Concave upward ☐
Convex upward ☒

Present Debris Storage
No bank debris ☐
Little bank debris ☒
Some bank debris ☐
Lots of bank debris ☐

Sediment Balance
Accumulating ☐
Steady State ☐
Undercutting ☐
Unknown ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 [✓ 70] 80 90 100 %

Notes and Comments:-

Recent bankfull event likely washed former accumulation

SECTION 5 - RIGHT BANK SURVEY

PART 16: RIGHT BANK CHARACTERISTICS

Type
- Noncohesive ☐
- Cohesive ☒
- Composite ☐
- Layered ☐
- Even Layers ☐
- Thick+thin layers ☐
- Number of layers 1

Protection Status
- Unprotected ☒
- Hard points ☐
- Toe protection ☐
- Revetments ☐
- Dyke Fields ☐

Bank Materials
- Silt/clay ☒
- Sand/silt/clay ☐
- Sand/silt ☐
- Sand ☐
- Sand/gravel ☐
- Gravel ☐
- Gravel/cobbles ☐
- Cobbles ☐
- Cobbles/boulders ☐
- Boulders/bedrock ☐

Layer Thickness
- Material 1 (m) 18"
- Material 2 (m) ___
- Material 3 (m) ___
- Material 4 (m) ___

Ave. Bank Height
Average height (m) 1'

Ave. Bank Slope
Average angle (o) 31°

Bank Profile Shape
(see sketches in manual) ☐

Tension Cracks
- None ☒
- Occasional ☐
- Frequent ☐

Crack Depth
Proportion of bank height ___

Distribution and Description of Bank Materials in Bank Profile

	Material Type 1	Material Type 2	Material Type 3	Material Type 4
Toe	☐	☐	☐	☐
Mid-Bank	☐	☐	☐	☐
Upper Bank	☐	☐	☐	☐
Whole Bank	☒	☐	☐	☐
D50 (mm)	___	___	___	___
sorting coefficient	___	___	___	___

Silty Clay Loam

Notes and Comments:-

PART 17: RIGHT BANK-FACE VEGETATION

Vegetation
- None/fallow ☐
- Artificially cleared ☐
- Grass and flora ☒
- Reeds and sedges ☐
- Shrubs ☐
- Saplings ☒
- Trees ☐

Orientation
Angle of leaning (°) ___

Tree Types
- None ☐
- Deciduous ☒
- Coniferous ☐
- Mixed ☐

Tree species
(if known)

Density + Spacing
- None ☐
- Sparse/clumps ☒
- dense/clumps ☐
- Sparce/continuous ☐
- Dense/continuous ☐

Roots unexposed
- Normal ☒
- Exposed ☐
- Adventitious ☐

Location
- Whole bank ☐
- Upper bank ☒
- Mid-bank ☐
- Lower bank ☐

Diversity
- Mono-stand ☒
- Mixed stand ☐
- Climax-vegetation ☐

Health
- Healthy ☒
- Fair ☐
- Poor ☐
- Dead ☐

Age
- Imature ☒
- Mature ☐
- Old ☐

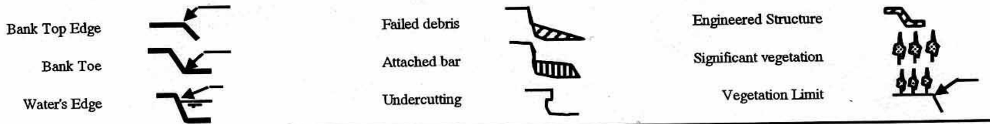
Height
- Short ☒
- Medium ☐
- Tall ☐
- Height (m) 3-4

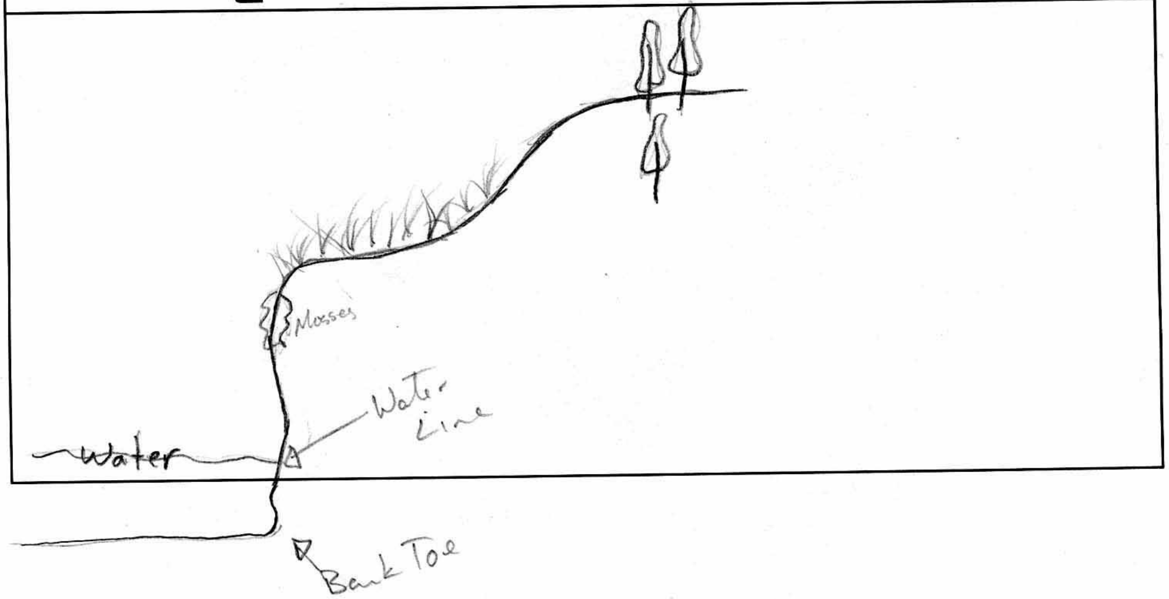
Lateral Extent
- Wide belt ☐
- Narrow belt ☒
- Single row ☐

Notes and Comments:- Trees planted post-restoration

Bank Profile Sketches

Profile Symbols





SECTION 5 - RIGHT BANK SURVEY (Continued)

PART 18: RIGHT BANK EROSION

Erosion Location

General ☒
Outside Meander ☐
Inside Meander ☐
Opposite a bar ☐
Behind a bar ☐
Opposite a structure ☐
Adjacent to structure ☐
Dstream of structure ☐
Ustream of structure ☐
Other (write in) ☐

Present Status

Intact ☒
Eroding:dormant ☐
Eroding:active ☐
Advancing:dormant ☐
Advancing:active ☐

Rate of Retreat
m/yr (if applicable and known)

Rate of Advance
m/yr (if applicable and known)

Interpretative Observations

Severity of Erosion

Insignificant ☐
Mild ☒
Significant ☐
Serious ☐
Catastrophic ☐

Extent of Erosion

None ☐
Local ☐
General ☒
Reach Scale ☐
System Wide ☐

Processes

Parallel flow ☒
Impinging flow ☐
Piping ☐
Freeze/thaw ☐
Sheet erosion ☐
Rilling + gullying ☐
Wind waves ☐
Vessel Forces ☐
Ice rafting ☐
Other (write in) ☐

Distribution of Each Process on Bank

Process 1
Toe (undercut) ☒
Lower bank ☐
Upper bank ☐
Whole bank ☐

Process 2
Toe (undercut) ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Process 3
Toe (undercut) ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Process 4
Toe (undercut) ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 [✓ 80] 90 100 %

Notes and Comments:-

PART 19: RIGHT BANK GEOTECH FAILURES

Failure Location

General ☒
Outside Meander ☐
Inside Meander ☐
Opposite a bar ☐
Behind a bar ☐
Opposite a structure ☐
Adjacent to structure ☐
Dstream of structure ☐
Ustream of structure ☐
Other (write in) ☐

Present Status

Stable ☒
Unreliable ☐
Unstable:dormant ☐
Unstable:active ☐

Failure Scars+Blocks

None ☒
Old ☐
Recent ☐
Fresh ☐
Contemporary ☐

Interpretative Observations

Instability:Severity

Insignificant ☑
Mild ☐
Significant ☐
Serious ☐
Catastrophic ☐

Instability: Extent

None ☒
Local ☐
General ☐
Reach Scale ☐
System Wide ☐

Failure Mode

Soil/rock fall ☐
Shallow slide ☐
Rotational slip ☐
Slab-type block ☐
Cantilever failure ☐
Pop-out failure ☐
Piping failure ☐
Dry granular flow ☐
Wet earth flow ☐
Other (write in) ☐

Distribution of Each Mode on Bank

Mode 1
Toe ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Mode 2
Toe ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Mode 3
Toe ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Mode 4
Toe ☐
Lower bank ☐
Upper bank ☐
Whole bank ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 [✓ 80] 90 100 %

Notes and Copmments:-

PART 20: RIGHT BANK TOE SEDIMENT ACCUMULATION

Stored Bank Debris

None ☒
Individual grains ☐
Aggregates+crumbs ☐
Root-bound clumps ☐
Small soil blocks ☐
Medium soil blocks ☐
Large soil blocks ☐
Cobbles/boulders ☐
Boulders ☐

Vegetation

None/fallow ☒
Artificially cleared ☐
Grass and flora ☐
Reeds and sedges ☐
Shrubs ☐
Saplings ☐
Trees ☐

Age

Immature ☐
Mature ☐
Old ☐
Age in Years ☐

Tree species
(if known)

Health

Healthy ☐
Unhealthy ☐
Dead ☐

Roots

Normal ☐
Adventitious ☐
Exposed ☐

Interpretative Observations

Toe Bank Profile

Planar ☒
Concave upward ☐
Convex upward ☐

Present Debris Storage

No bank debris ☒
Little bank debris ☐
Some bank debris ☐
Lots of bank debris ☐

Sediment Balance

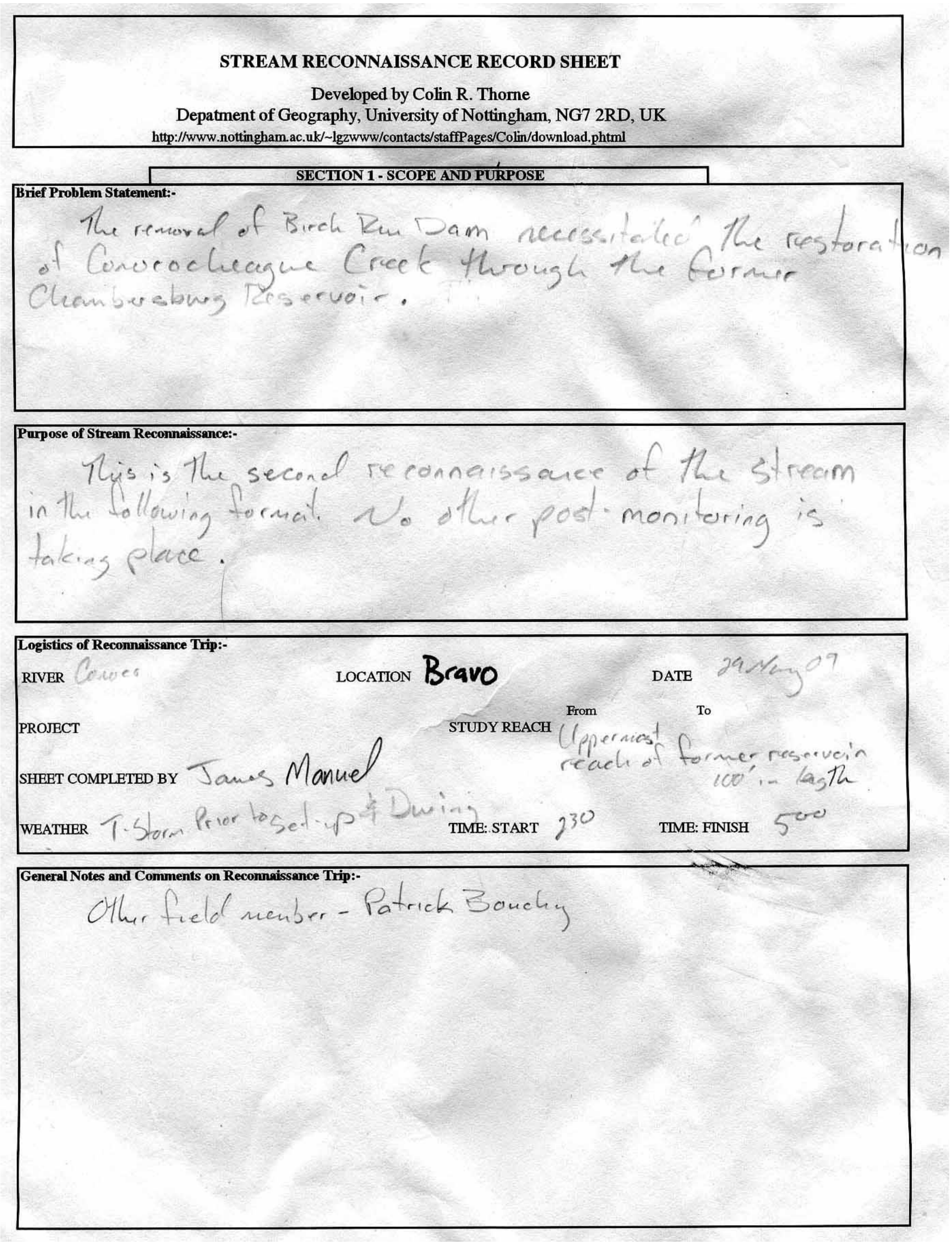
Accumulating ☐
Steady State ☐
Undercutting ☒
Unknown ☐

MINIMAL

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 [✓ 70] 80 90 100 %

Notes and Comments:-

Bravo - Reconnaissance Record Sheets dated, 29.May.2009



STREAM RECONNAISSANCE RECORD SHEET

Developed by Colin R. Thorne
Depatment of Geography, University of Nottingham, NG7 2RD, UK
http://www.nottingham.ac.uk/~lgzwww/contacts/staffPages/Colin/download.phtml

SECTION 1 - SCOPE AND PURPOSE

Brief Problem Statement:-

The removal of Birch Run Dam necessitated the restoration of Conococheague Creek through the former Chambersburg Reservoir.

Purpose of Stream Reconnaissance:-

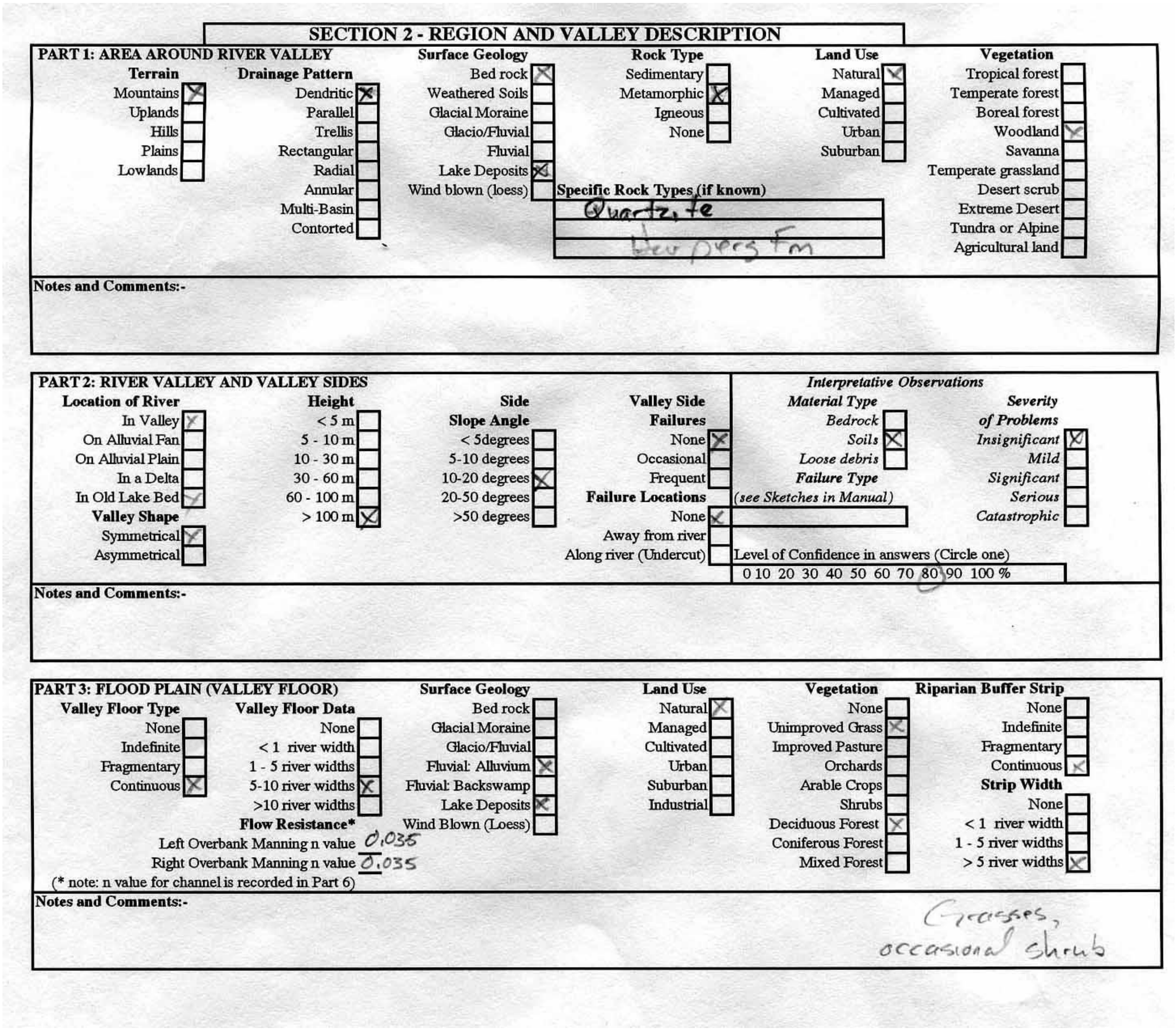
This is the second reconnaissance of the stream in the following format. No other post-monitoring is taking place.

Logistics of Reconnaissance Trip:-

RIVER Conoco
LOCATION Bravo
DATE 29 May 09
PROJECT
STUDY REACH From Uppermost reach of former reservoir To 100' in length
SHEET COMPLETED BY James Manuel
WEATHER T-Storm Prior to set-up & During
TIME: START 230
TIME: FINISH 5^{00}

General Notes and Comments on Reconnaissance Trip:-

Other field member - Patrick Bouchy



SECTION 2 - REGION AND VALLEY DESCRIPTION

PART 1: AREA AROUND RIVER VALLEY

Terrain
- Mountains ☒
- Uplands ☐
- Hills ☐
- Plains ☐
- Lowlands ☐

Drainage Pattern
- Dendritic ☒
- Parallel ☐
- Trellis ☐
- Rectangular ☐
- Radial ☐
- Annular ☐
- Multi-Basin ☐
- Contorted ☐

Surface Geology
- Bed rock ☒
- Weathered Soils ☐
- Glacial Moraine ☐
- Glacio/Fluvial ☐
- Fluvial ☐
- Lake Deposits ☒
- Wind blown (loess) ☐

Rock Type
- Sedimentary ☐
- Metamorphic ☒
- Igneous ☐
- None ☐

Specific Rock Types (if known)

Quartzite

Harpers Fm

Land Use
- Natural ☒
- Managed ☐
- Cultivated ☐
- Urban ☐
- Suburban ☐

Vegetation
- Tropical forest ☐
- Temperate forest ☐
- Boreal forest ☐
- Woodland ☒
- Savanna ☐
- Temperate grassland ☐
- Desert scrub ☐
- Extreme Desert ☐
- Tundra or Alpine ☐
- Agricultural land ☐

Notes and Comments:-

PART 2: RIVER VALLEY AND VALLEY SIDES

Location of River
- In Valley ☒
- On Alluvial Fan ☐
- On Alluvial Plain ☐
- In a Delta ☐
- In Old Lake Bed ☒

Valley Shape
- Symmetrical ☒
- Asymmetrical ☐

Height
- < 5 m ☐
- 5 - 10 m ☐
- 10 - 30 m ☐
- 30 - 60 m ☐
- 60 - 100 m ☐
- > 100 m ☒

Side Slope Angle
- < 5degrees ☐
- 5-10 degrees ☐
- 10-20 degrees ☒
- 20-50 degrees ☐
- >50 degrees ☐

Valley Side Failures
- None ☒
- Occasional ☐
- Frequent ☐

Failure Locations
- None ☒
- Away from river ☐
- Along river (Undercut) ☐

Interpretative Observations

Material Type
- *Bedrock* ☐
- *Soils* ☒
- *Loose debris* ☐

Failure Type

(see Sketches in Manual)

Severity of Problems
- *Insignificant* ☒
- *Mild* ☐
- *Significant* ☐
- *Serious* ☐
- *Catastrophic* ☐

Level of Confidence in answers (Circle one)

0 10 20 30 40 50 60 70 [✓ 80] 90 100 %

Notes and Comments:-

PART 3: FLOOD PLAIN (VALLEY FLOOR)

Valley Floor Type
- None ☐
- Indefinite ☐
- Fragmentary ☐
- Continuous ☒

Valley Floor Data
- None ☐
- < 1 river width ☐
- 1 - 5 river widths ☐
- 5-10 river widths ☒
- >10 river widths ☐

Flow Resistance*

Left Overbank Manning n value 0.035

Right Overbank Manning n value 0.035

(* note: n value for channel is recorded in Part 6)

Surface Geology
- Bed rock ☐
- Glacial Moraine ☐
- Glacio/Fluvial ☐
- Fluvial: Alluvium ☒
- Fluvial: Backswamp ☐
- Lake Deposits ☒
- Wind Blown (Loess) ☐

Land Use
- Natural ☒
- Managed ☐
- Cultivated ☐
- Urban ☐
- Suburban ☐
- Industrial ☐

Vegetation
- None ☐
- Unimproved Grass ☒
- Improved Pasture ☐
- Orchards ☐
- Arable Crops ☐
- Shrubs ☐
- Deciduous Forest ☒
- Coniferous Forest ☐
- Mixed Forest ☐

Riparian Buffer Strip
- None ☐
- Indefinite ☐
- Fragmentary ☐
- Continuous ☒

Strip Width
- None ☐
- < 1 river width ☐
- 1 - 5 river widths ☐
- > 5 river widths ☒

Notes and Comments:-

Grasses,
occasional shrub

SECTION 2 - REGION AND VALLEY DESCRIPTION (Continued)

PART 4: VERTICAL RELATION OF CHANNEL TO VALLEY

Terraces
None ☐
Indefinate ☐
Fragmentary ☐
Continuous ☒
Number of Terraces 1

Trash Lines
Absent ☒
Present ☐
Height above flood plain (m) ___

Overbank Deposits
None ☒
Silt ☐
Fine sand ☐
Medium sand ☐
Coarse sand ☐
Gravel ☐
Boulders ☐

Levees
None ☒
Natural ☐
Constructed ☐

Levee Description
None ☒
Indefinite ☐
Fragmentary ☐
Continuous ☐
Left Bank ☐
Right Bank ☐
Both Banks ☐

Levee Data
Height (m) ☐
Side Slope (o) ☐

Levee Condition
None ☐
Intact ☐
Local Failures ☐
Frequent failures ☐

Interpretative Observations

Present Status
Adjusted ☐
Incised ☒
Aggraded ☐

Instability Status
Stable ☐
Degrading ☒
Aggrading ☐

Problem Severity
Insignificant ☐
Moderate ☒
Serious ☐

Problem Extent
None ☐
Local ☐
General ☒
Reach scale ☒
System wide ☐
Regional ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 [✓ 70] 80 90 100 %

Notes and Comments:-

PART 5: LATERAL RELATION OF CHANNEL TO VALLEY

Planform
Straight ☒
Sinuous ☐
Irregular ☐
Regular meanders ☐
Irregular meanders ☐
Tortuous meanders ☐
Braided ☐
Anastomosed ☐

Planform Data
Bend Radius ___
Meander belt width ___
Wavelength ___
Meander Sinuosity 1.0

Location in Valley
Left ☐
Middle ☒
Right ☐

Lateral Activity
None ☒
Meander progression ☐
Increasing amplitude ☐
Progression+cut-offs ☐
Irregular erosion ☐
Avulsion ☐
Braiding ☐

Floodplain Features
None ☐
Meander scars ☐
Scroll bars+sloughs ☐
Oxbow lakes ☐
Irregular terrain ☐
Abandoned channel ☒
Braided Deposits ☐

Interpretative Observations

Present Status
Adjusted ☒
Over wide ☐
Too narrow ☐

Instability Status
Stable ☒
Widening ☐
Narrowing ☐

Problem Severity
Insignificant ☒
Moderate ☐
Serious ☐

Problem Extent
None ☒
Local ☐
General ☐
Reach scale ☐
System wide ☐
Regional ☐

Level of Confidence in percent (Circle one)
0 10 20 30 40 50 60 70 [✓ 80] 90 100 %

PART 6: Mapping the Cross-Section with Auto Level

	Distance (~~m~~) ft	Stadia Height (~~m~~) ft	Notes
1	157-	3.56	
2	145-	4.03	
3	134-	4.63	
4	121-	4.46	
5	108-	3.97	
6	105-	4.02	
7	103-	4.12	
8	101-	4.43	
9	99-	5.10	Slope
10	97-	6.13	
11	95-	7.29	
12	91'8"	8.88	toe Water
13	91'6"	9.59	"
14	89'6"	9.62	"
15	87'6"	9.87	"
16	85'6"	10.11	"
17	83'6"	9.86	"
18	81'6"	10.30	"
19	79'6"	10.19	"
20	77'6"	10.10	"
21	75'6"	10.22	"
22	73'6"	9.91	"
23	71'6"	9.60	"
24	69'6"	9.87	"
25	67'6"	9.60	"

	Distance (~~m~~)	Stadia Height (~~m~~)	Notes
26	65'6"	9.48	Water
27	64'0"	9.34	Toe
28	63'11"	8.85	Bank
29	62'0"	7.97	
30	60'0"	7.71	
31	58'0"	7.58	
32	56'-	7.58	
33	54'-	7.48	
34	52'-	7.48	
35	50	7.17	
36	48'6"	7.00	
37	47'9"	6.66	
38	46'11"	6.12	
39	45'9"	5.66	
40	44'4"	4.98	
41	42'0"	4.59	
42	38'0"	4.35	
43	26'0"	4.36	
44	16'0"	4.34	
45	3'0"	3.92	
46			
47			
48			
49			
50			

Notes and Comments:-

stadia - Patrick
Autolevel - James
Recorder - James

Valley Slope $\frac{4.12 - 5.38}{60'0''}$

Channel Slope $\frac{10.07 - 10.18}{60}$

SECTION 3 - CHANNEL DESCRIPTION

PART 7: CHANNEL DESCRIPTION

Dimensions

Av. top bank width (m) Lower 11.28 Upper 17.98

Av. channel depth (m) Lower 0.74 Upper 1.26

Av. water width (m) 8.306

Av. water depth (m) 0.3048

Reach slope 0.0018

Mean velocity (m/s) 0.555

Manning's n value 0.050 (Note: Flow type on day of observation)

Flow Type

None ☐
Uniform/Tranquil ☐
Uniform/Rapid ☒
Pool+Riffle ☐
Steep + Tumbling ☐
Steep + Step/pool ☐

Bed Controls

None ☐
Occasional ☐
Frequent ☒
Confined ☐
Number of controls 2

Control Types

None ☐
Solid Bedrock ☐
Weathered Bedrock ☐
Boulders ☒
Gravel armor ☑
Cohesive Materials ☐
Bridge protection ☐
Grade control structures ☐

Width Controls

None ☐
Occasional ☒
Frequent ☐
Confined ☐
Number of controls 2

Control Types

None ☐
Bedrock ☐
Boulders ☒
Gravel armor ☒
Revetments ☐
Cohesive Materials ☐
Bridge abutments ☐
Dykes or groynes ☐

Medium Cobbles Mostly

Notes and Comments:-

23.4cfs = 0.66cms

PART 8: BED SEDIMENT DESCRIPTION

Bed Material

Clay ☐
Silt ☐
Sand ☐
Sand and gravel ☐
gravel and cobbles ☒
cobbles + boulders ☒
boulders + bedrock ☐
Bed rock ☐

Bed Armour

None ☐
Static-armour ☒
Mobile-armour ☐

Sediment Depth

Depth of loose Sediment (cm) 2

Surface Size Data

D50 (mm) 64-90
D84 (mm) 180-250
D16 (mm) 8-11

Substrate Size Data

D50 (mm) ___
D84 (mm) Sand
D16 (mm) ___

Bed Forms (Sand)

Flat bed (None) ☒
Ripples ☐
Dunes ☐
Bed form height (m) ___

Island or Bars

None ☒
Occasional ☐
Frequent ☐

Bar Types

None ☒
Pools and riffles ☐
Alternate bars ☐
Point bars ☐
Mid-channel bars ☐
Diagonal bars ☐
Junction bars ☐
Sand waves + dunes ☐

Bar Surface data

D50 (mm) ___
D84 (mm) ___
D16 (mm) ___

Bar Substrate data

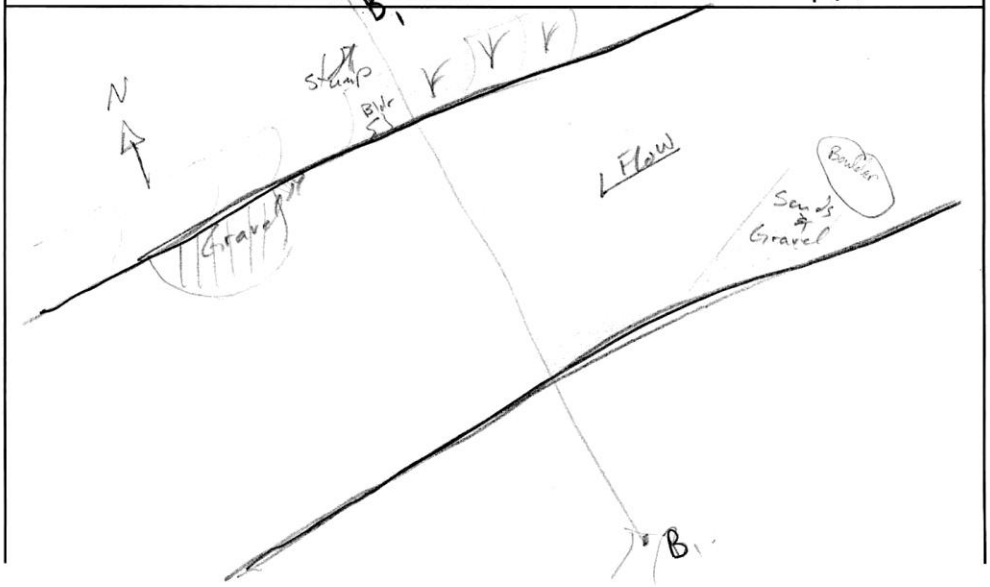
D50 (mm) ___
D84 (mm) ___
D16 (mm) ___

Notes and Comments:-

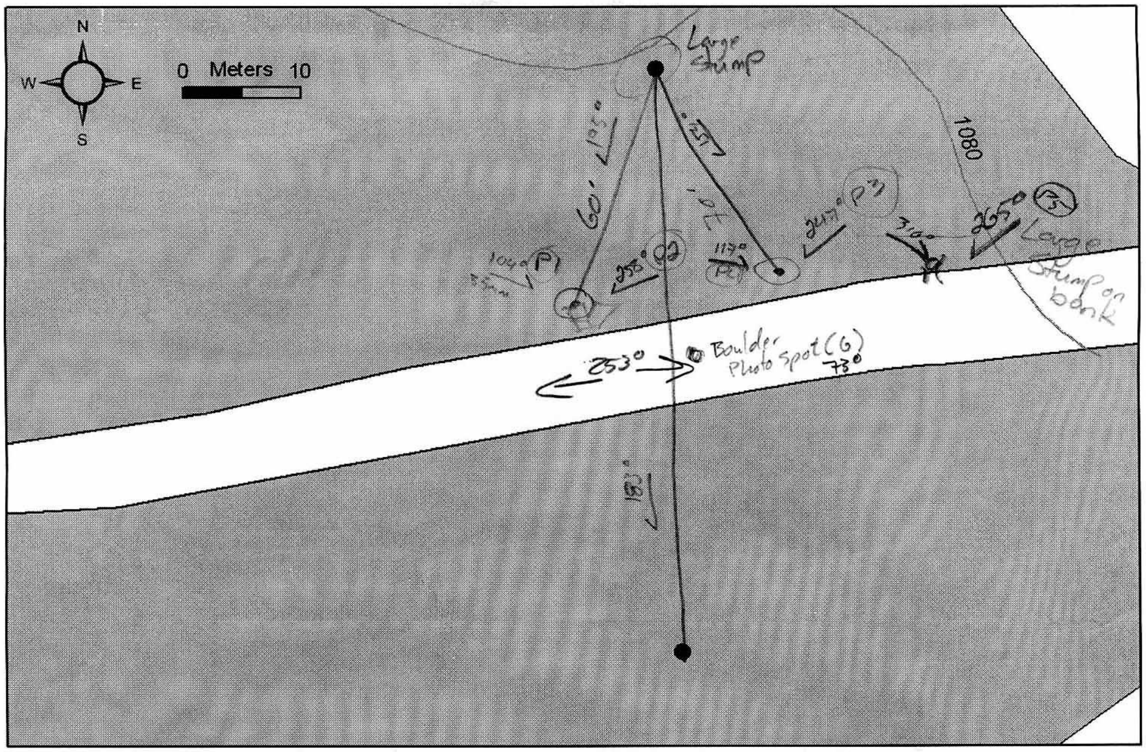
Channel Sketch Map

Map Symbols

Study reach limits ▮ u/s ▮ d/s
Cross-section A ― A
Bank profile (B3) →
North point ↑ N
flow direction ↔
impinging flow ↘↘
Cut bank
exposed island/bar
structure ▨
Photo point (P1) →
Sediment sampling point (S1) →
Significant vegetation



Bravo Stream Reach Photo Locations



Sec 3 Channel Discharge

SECTION 3 - CHANNEL DESCRIPTION

PART 9: CHANNEL DISCHARGE

Station Bi	Distance to B_i +1	Distance to $B_i - 1$	Depth	Time Duration	Revolutions	Point Velocity	Notes
b_1	64'0"	66'0"	0.5	40.6	41	1,001	
b_2	66'0"	68'0"	0.6	40.1	36	0,883	Behind Cobble near surface
b_3	68'0"	69'9"	0.9	40.3	64	1,556	
b_4	69'9"	71'0"	1.0	40.1	82	1,995	
b_5	71'0"	72'0"	1.0	40.9	42	1,017	
b_6	72'0"	73'0"	1.10	40.0	118	2.864	
b_7	73'0"	74'0"	1.0	40,4	77	1.862	
b_8	74'0"	75'0"	1.2	40.1	130	3,145	
b_9	75'0"	76'0"	1.5	40.2	112	2.707	
b_{10}	76'0"	77'0"	1.4	40.2	101	2,444	
b_{11}	77'0"	78'0"	1.2	40.1	94	2.282	
b_{12}	78-	79'5"	1.1	40.2	57	1,393	
b_{13}	79'5"	81'0"	1.3	40.0	89	2,168	
b_{14}	81'0"	82'0"	1.4	40.3	50	1,223	
b_{15}	82'0"	84'6"	0.9	40.3	38	0.937	Near Boulder
b_{16}	84'6"	85'7"	1.0	40.1	90	2,187	
b_{17}	85'7"	86'9"	0.9	40.1	82	1,995	
b_{18}	86'9"	87'8"	0.9	40.1	78	1,899	
b_{19}	87'8"	88'7"	0.5	41.5	29	0.702	
b_{20}	88'7"	91'3"	.5	40.4	91	2,194	
b_{21}							
b_{22}							
b_{23}							
b_{24}							
b_{25}							
b_{26}							
b_{27}							
b_{28}							
b_{29}							
b_{30}							
b_{31}							
b_{32}							

Janos - Recorder
Patrick - Measuring

23.39cfs

SECTION 3 - CHANNEL DESCRIPTION

PART 10: BED MATERIAL

CLASS	SIZE RANGE (mm)	FREQUENCY	TOTALS
SAND	<2	𝍷𝍷	2
VERY FINE SAND	2 – 4		0
FINE GRAVEL	4 – 6	𝍷𝍷	2
FINE GRAVEL	6 – 8	𝍷𝍷𝍷𝍷	4
MEDIUM GRAVEL	8 – 11	𝍸𝍷	6
MEDIUM GRAVEL	11 – 16	𝍸𝍷𝍷	7
COARSE GRAVEL	16 – 22	𝍸𝍷	6
COARSE GRAVEL	22 – 32	𝍷𝍷𝍷	3
VERY COARSE GRAVEL	32 – 45	𝍷𝍷𝍷𝍷	4
VERY COARSE GRAVEL	45 – 64	𝍷𝍷𝍷𝍷	4
SMALL COBBLE	64 – 90	𝍸𝍸𝍷𝍷𝍷	13
MEDIUM COBBLE	90 – 128	𝍸𝍷𝍷𝍷𝍷	9
LARGE COBBLE	128 – 180	𝍸𝍸𝍸	15
VERY LARGE COBBLE	180 – 256	𝍸𝍸𝍸	15
SMALL BOULDER	256 – 512	𝍸𝍷𝍷𝍷	8
MEDIUM BOULDER	512 – 1024	𝍷𝍷𝍷𝍷	4
LARGE BOULDER	1024 – 2048		0
VERY LARGE BOULDER	2048 – 4096		0
		TOTAL	102

SECTION 4 - LEFT BANK SURVEY

PART 11: LEFT BANK CHARACTERISTICS

Type
Noncohesive ☐
Cohesive ☐
Composite ☒
Layered ☐
Even Layers ☐
Thick+thin layers ☐
Number of layers Multiple

Protection Status
Unprotected ☐
Hard points ☒
Toe protection ☐
Revetments ☐
Dyke Fields ☐

Bank Materials
Silt/clay ☐
Sand/silt/clay ☐
Sand/silt ☐
Sand ☐
Sand/gravel ☒
Gravel ☐
Gravel/cobbles ☐
Cobbles ☐
Cobbles/boulders ☒
Boulders/bedrock ☐
occasional Boulder

Layer Thickness
Material 1 (m) .5
Material 2 (m) ___
Material 3 (m) ___
Material 4 (m) ___

Ave. Bank Height 0.3
Average height (m) ___

Ave. Bank Slope
angle (degrees) See Sketch

Bank Profile Shape
(see sketches in manual) ☐

Tension Cracks
None ☑
Occasional ☐
Frequent ☐

Crack Depth
Proportion of bank height ___

Distribution and Description of Bank Materials in Bank Profile

Material Type 1
Toe ☒
Mid-Bank ☐
Upper Bank ☐
Whole Bank ☐
D50 (mm) ___
sorting coefficient ___

Material Type 2
Toe ☐
Mid-Bank ☒
Upper Bank ☒
Whole Bank ☐
D50 (mm) ___
sorting coefficient ___

Material Type 3
Toe ☐
Mid-Bank ☐
Upper Bank ☐
Whole Bank ☐
D50 (mm) ___
sorting coefficient ___

Material Type 4
Toe ☐
Mid-Bank ☐
Upper Bank ☐
Whole Bank ☐
D50 (mm) ___
sorting coef. ___

Notes and Comments:-
Sand Gravel
Fine Sand

PART 12: LEFT BANK-FACE VEGETATION

Vegetation
None/fallow ☐
Artificially cleared ☐
Grass and flora ☒
Reeds and sedges ☐
Shrubs ☒
Saplings ☐
Trees ☐

Orientation
Angle of leaning (°)

Tree Types
None ☐
Deciduous ☒
Coniferous ☐
Mixed ☐

Tree species
(if known)
In Plastic tubes

Density + Spacing
None ☐
Sparse/clumps ☒
dense/clumps ☐
Sparce/continuous ☐
Dense/continuous ☐

Roots
Normal ☒
Exposed ☐
Adventitious ☐

Location
Whole bank ☒
Upper bank ☐
Mid-bank ☐
Lower bank ☐

Diversity
Mono-stand ☒
Mixed stand ☐
Climax-vegetation ☐

Health
Healthy ☐
Fair ☐
Poor ☒
Dead ☐

Age
Immature ☒
Mature ☐
Old ☐

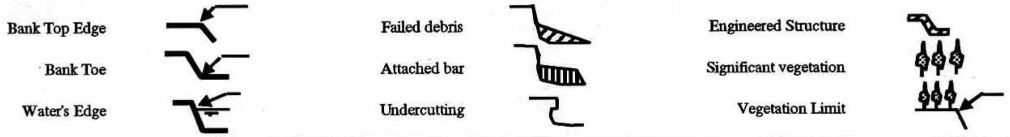
Height
Short ☒
Medium ☐
Tall ☐
Height (m) 1-2

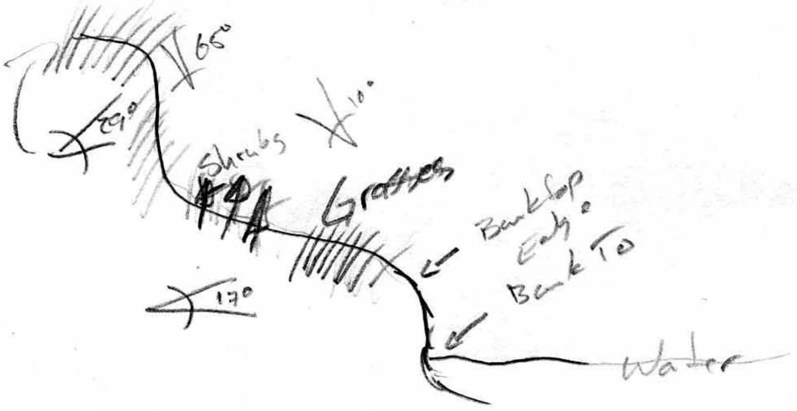
Lateral Extent
Wide belt ☐
Narrow belt ☐
Single row ☒

Notes and Comments:-
A few of the Planted trees are budding on the shelf

Bank Profile Sketches

Profile Symbols





SECTION 4 - LEFT BANK SURVEY (Continued)

PART 13: LEFT BANK EROSION

Erosion Location

- General ☒
- Outside Meander ☐
- Inside Meander ☐
- Opposite a bar ☐
- Behind a bar ☐
- Opposite a structure ☐
- Adjacent to structure ☐
- Dstream of structure ☐
- Ustream of structure ☐
- Other (write in) ☐

Present Status

- Intact ☒
- Eroding:dormant ☐
- Eroding:active ☐
- Advancing:dormant ☐
- Advancing:active ☐

Rate of Retreat

m/yr (if applicable and known)

Rate of Advance

m/yr (if applicable and known)

Interpretative Observations

Severity of Erosion

- *Insignificant* ☒
- *Mild* ☐
- *Significant* ☐
- *Serious* ☐
- *Catastrophic* ☐

Extent of Erosion

- *None* ☐
- *Local* ☒
- *General* ☐
- *Reach Scale* ☐
- *System Wide* ☐

Processes

- *Parallel flow* ☒
- *Impinging flow* ☐
- *Piping* ☐
- *Freeze/thaw* ☐
- *Sheet erosion* ☐
- *Rilling + gullying* ☐
- *Wind waves* ☐
- *Vessel Forces* ☐
- *Ice rafting* ☐
- *Other (write in)* ☐

Distribution of Each Process on Bank

Process 1 near

- *Toe (undercut)* ☒ Boulders
- *Lower bank* ☐
- *Upper bank* ☐
- *Whole bank* ☐

Process 2

- *Toe (undercut)* ☐
- *Lower bank* ☐
- *Upper bank* ☐
- *Whole bank* ☐

Process 3

- *Toe (undercut)* ☐
- *Lower bank* ☐
- *Upper bank* ☐
- *Whole bank* ☐

Process 4

- *Toe (undercut)* ☐
- *Lower bank* ☐
- *Upper bank* ☐
- *Whole bank* ☐

exposing Cobbles

Level of Confidence in answers (Circle one)

0 10 20 30 40 50 60 70 [✓ 80] 90 100 %

Notes and Comments:-

PART 14: LEFT BANK GEOTECH FAILURES

Failure Location

- General ☒
- Outside Meander ☐
- Inside Meander ☐
- Opposite a bar ☐
- Behind a bar ☐
- Opposite a structure ☐
- Adjacent to structure ☐
- Dstream of structure ☐
- Ustream of structure ☐
- Other (write in) ☐

Present Status

- Stable ☒
- Unreliable ☐
- Unstable:dormant ☐
- Unstable:active ☐

Failure Scars+Blocks

- None ☐
- Old ☐
- Recent ☐
- Fresh ☐
- Contemporary ☐

Interpretative Observations

Instability:Severity

- *Insignificant* ☒
- *Mild* ☐
- *Significant* ☐
- *Serious* ☐
- *Catastrophic* ☐

Instability: Extent

- *None* ☐
- *Local* ☒
- *General* ☐
- *Reach Scale* ☐
- *System Wide* ☐

Failure Mode

- *Soil/rock fall* ☐
- *Shallow slide* ☒
- *Rotational slip* ☐
- *Slab-type block* ☐
- *Cantilever failure* ☐
- *Pop-out failure* ☐
- *Piping failure* ☐
- *Dry granular flow* ☐
- *Wet earth flow* ☐
- *Other (write in)* ☐

Distribution of Each Mode on Bank

Mode 1

- *Toe* ☐
- *Lower bank* ☒
- *Upper bank* ☐
- *Whole bank* ☐

Mode 2

- *Toe* ☐
- *Lower bank* ☐
- *Upper bank* ☐
- *Whole bank* ☐

Mode 3

- *Toe* ☐
- *Lower bank* ☐
- *Upper bank* ☐
- *Whole bank* ☐

Mode 4

- *Toe* ☐
- *Lower bank* ☐
- *Upper bank* ☐
- *Whole bank* ☐

Level of Confidence in answers (Circle one)

0 10 20 30 40 50 60 70 80 [✓ 90] 100 %

Notes and Copmments:-

PART 15: LEFT BANK TOE SEDIMENT ACCUMULATION

Stored Bank Debris

- None ☐
- Individual grains ☐
- Aggregates+crumbs ☐
- Root-bound clumps ☐
- Small soil blocks ☐
- Medium soil blocks ☐
- Large soil blocks ☐
- Cobbles/boulders ☒
- Boulders ☐

Vegetation

- None/fallow ☒
- Artificially cleared ☐
- Grass and flora ☐
- Reeds and sedges ☐
- Shrubs ☐
- Saplings ☐
- Trees ☐

Age

- Immature ☐
- Mature ☐
- Old ☐
- Age in Years ☐

Tree species (if known)

Health

- Healthy ☐
- Unhealthy ☐
- Dead ☐

Roots

- Normal ☐
- Adventitious ☐
- Exposed ☐

Interpretative Observations

Toe Bank Profile

- *Planar* ☒
- *Concave upward* ☐
- *Convex upward* ☐

Present Debris Storage

- *No bank debris* ☐
- *Little bank debris* ☒
- *Some bank debris* ☐
- *Lots of bank debris* ☐

Sediment Balance

- *Accumulating* ☒
- *Steady State* ☐
- *Undercutting* ☐
- *Unknown* ☐

Level of Confidence in answers (Circle one)

0 10 20 30 40 50 60 70 [✓ 80] 90 100 %

Notes and Comments:-

SECTION 5 - RIGHT BANK SURVEY

PART 16: RIGHT BANK CHARACTERISTICS

Type
Noncohesive ☒
Cohesive ☐
Composite ☐
Layered ☐
Even Layers ☐
Thick+thin layers ☐
Number of layers ___

Protection Status
Unprotected ☐
Hard points ☐
Toe protection ☒ Cobbles
Revetments ☐
Dyke Fields ☐

Bank Materials
Silt/clay ☐
Sand/silt/clay ☐
Sand/silt ☒
Sand ☐
Sand/gravel ☐
Gravel ☐
Gravel/cobbles ☐
Cobbles ☐
Cobbles/boulders ☐
Boulders/bedrock ☐

Layer Thickness
Material 1 (m) 1'
Material 2 (m) ___
Material 3 (m) ___
Material 4 (m) ___

Ave. Bank Height
Average height (m) ___

Ave. Bank Slope
Average angle (o) ___ See Below

Bank Profile Shape
(see sketches in manual)
☐

Tension Cracks
None ☐
Occasional ☐
Frequent ☐

Crack Depth
Proportion of bank height ___

Distribution and Description of Bank Materials in Bank Profile

Material Type 1
Toe ☒
Mid-Bank ☐
Upper Bank ☐
Whole Bank ☐
D50 (mm) ___
sorting coefficient ___
Cobbles

Material Type 2
Toe ☐
Mid-Bank ☒
Upper Bank ☒
Whole Bank ☐
D50 (mm) ___
sorting coefficient ___
Sand of varying colors & sizes

Material Type 3
Toe ☐
Mid-Bank ☐
Upper Bank ☐
Whole Bank ☐
D50 (mm) ___
sorting coefficient ___

Material Type 4
Toe ☐
Mid-Bank ☐
Upper Bank ☐
Whole Bank ☐
D50 (mm) ___
sorting coef. ___

Notes and Comments:-

PART 17: RIGHT BANK-FACE VEGETATION

Vegetation
None/fallow ☐
Artificially cleared ☐
Grass and flora ☒
Reeds and sedges ☐
Shrubs ☐
Saplings ☐
Trees ☐

Orientation ☐
Angle of leaning (°) ☐

Tree Types
None ☒
Deciduous ☐
Coniferous ☐
Mixed ☐

Tree species
(if known)

Density + Spacing
None ☒
Sparse/clumps ☐
dense/clumps ☐
Sparce/continuous ☐
Dense/continuous ☐

Roots
Normal ☐
Exposed ☐
Adventitious ☐

Location
Whole bank ☐
Upper bank ☐
Mid-bank ☐
Lower bank ☐

Diversity
Mono-stand ☐
Mixed stand ☐
Climax-vegetation ☐

Health
Healthy ☐
Fair ☐
Poor ☐
Dead ☐

Age
Imature ☐
Mature ☐
Old ☐

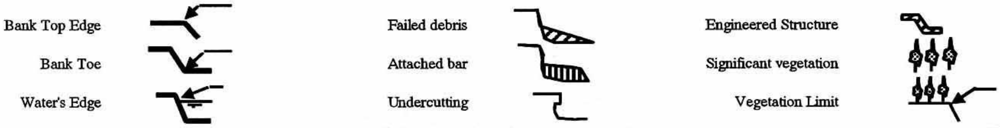
Height
Short ☐
Medium ☐
Tall ☐
Height (m) ___

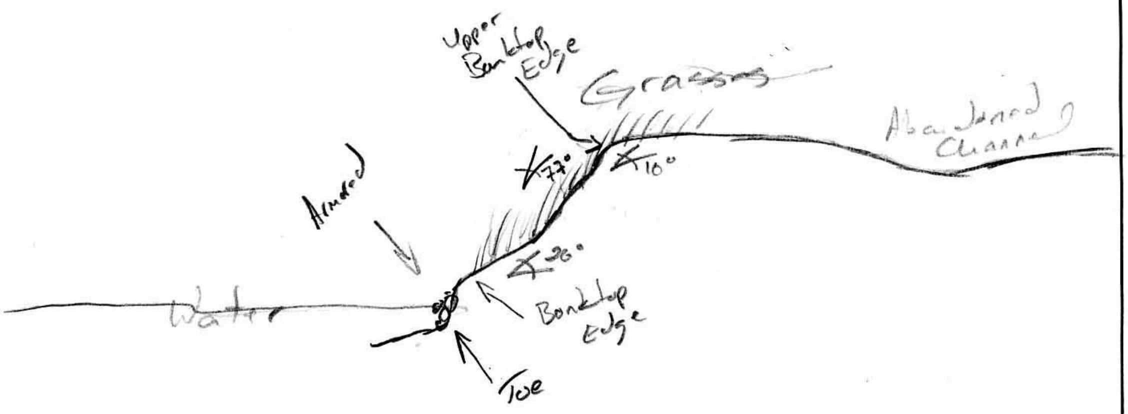
Lateral Extent
Wide belt ☐
Narrow belt ☐
Single row ☐

Notes and Comments:-
No trees planted - None on the flood plain appear alive.

Bank Profile Sketches

Profile Symbols





SECTION 5 - RIGHT BANK SURVEY (Continued)

PART 18: RIGHT BANK EROSION

Erosion Location
- General ☒
- Outside Meander ☐
- Inside Meander ☐
- Opposite a bar ☐
- Behind a bar ☐
- Opposite a structure ☐
- Adjacent to structure ☐
- Dstream of structure ☐
- Ustream of structure ☐
- Other (write in) ☐

Present Status
- Intact ☐
- Eroding:dormant ☑
- Eroding:active ☐
- Advancing:dormant ☐
- Advancing:active ☐

Rate of Retreat
m/yr (if applicable and known)

Rate of Advance
m/yr (if applicable and known)

Interpretative Observations

Severity of Erosion
- *Insignificant* ☒
- *Mild* ☐
- *Significant* ☐
- *Serious* ☐
- *Catastrophic* ☐

Extent of Erosion
- *None* ☐
- *Local* ☒
- *General* ☐
- *Reach Scale* ☐
- *System Wide* ☐

Processes
- *Parallel flow* ☒
- *Impinging flow* ☐
- *Piping* ☐
- *Freeze/thaw* ☐
- *Sheet erosion* ☐
- *Rilling + gullying* ☐
- *Wind waves* ☐
- *Vessel Forces* ☐
- *Ice rafting* ☐
- *Other (write in)* ☐

Distribution of Each Process on Bank

Process 1
- *Toe (undercut)* ☒
- *Lower bank* ☐
- *Upper bank* ☐
- *Whole bank* ☐

Process 2
- *Toe (undercut)* ☐
- *Lower bank* ☐
- *Upper bank* ☐
- *Whole bank* ☐

Process 3
- *Toe (undercut)* ☐
- *Lower bank* ☐
- *Upper bank* ☐
- *Whole bank* ☐

Process 4
- *Toe (undercut)* ☐
- *Lower bank* ☐
- *Upper bank* ☐
- *Whole bank* ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 [✓ 70] 80 90 100 %

Notes and Comments:-

PART 19: RIGHT BANK GEOTECH FAILURES

Failure Location
- General ☒
- Outside Meander ☐
- Inside Meander ☐
- Opposite a bar ☐
- Behind a bar ☐
- Opposite a structure ☐
- Adjacent to structure ☐
- Dstream of structure ☐
- Ustream of structure ☐
- Other (write in) ☐

Present Status
- Stable ☐
- Unreliable ☐
- Unstable:dormant ☒
- Unstable:active ☒

Failure Scars+Blocks
- None ☐
- Old ☐
- Recent ☑
- Fresh ☒
- Contemporary ☐

Interpretative Observations

Instability:Severity
- *Insignificant* ☐
- *Mild* ☒
- *Significant* ☐
- *Serious* ☐
- *Catastrophic* ☐

Instability: Extent
- *None* ☐
- *Local* ☒
- *General* ☐
- *Reach Scale* ☐
- *System Wide* ☐

Failure Mode
- *Soil/rock fall* ☐
- *Shallow slide* ☑
- *Rotational slip* ☐
- *Slab-type block* ☐
- *Cantilever failure* ☐
- *Pop-out failure* ☐
- *Piping failure* ☐
- *Dry granular flow* ☐
- *Wet earth flow* ☐
- *Other (write in)* ☐

Distribution of Each Mode on Bank

Mode 1
- *Toe* ☐
- *Lower bank* ☒
- *Upper bank* ☐
- *Whole bank* ☐

Mode 2
- *Toe* ☐
- *Lower bank* ☐
- *Upper bank* ☐
- *Whole bank* ☐

Mode 3
- *Toe* ☐
- *Lower bank* ☐
- *Upper bank* ☐
- *Whole bank* ☐

Mode 4
- *Toe* ☐
- *Lower bank* ☐
- *Upper bank* ☐
- *Whole bank* ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 [✓ 80] 90 100 %

Notes and Copmments:-

Cobbles armor previous scars

PART 20: RIGHT BANK TOE SEDIMENT ACCUMULATION

Stored Bank Debris
- None ☐
- Individual grains ☒
- Aggregates+crumbs ☐
- Root-bound clumps ☐
- Small soil blocks ☐
- Medium soil blocks ☐
- Large soil blocks ☐
- Cobbles/boulders ☒
- Boulders ☐

Vegetation
- None/fallow ☐
- Artificially cleared ☐
- Grass and flora ☒
- Reeds and sedges ☐
- Shrubs ☐
- Saplings ☐
- Trees ☐

Age
- Immature ☐
- Mature ☐
- Old ☐
- Age in Years ☐

Tree species
(if known)

Health
- Healthy ☐
- Unhealthy ☐
- Dead ☐

Roots
- Normal ☐
- Adventitious ☐
- Exposed ☐

Interpretative Observations

Toe Bank Profile
- *Planar* ☐
- *Concave upward* ☒
- *Convex upward* ☐

Present Debris Storage
- *No bank debris* ☐
- *Little bank debris* ☐
- *Some bank debris* ☒
- *Lots of bank debris* ☐

Sediment Balance
- *Accumulating* ☐
- *Steady State* ☒
- *Undercutting* ☐
- *Unknown* ☐

Level of Confidence in answers (Circle one)
0 10 20 30 40 50 60 70 [✓ 80] 90 100 %

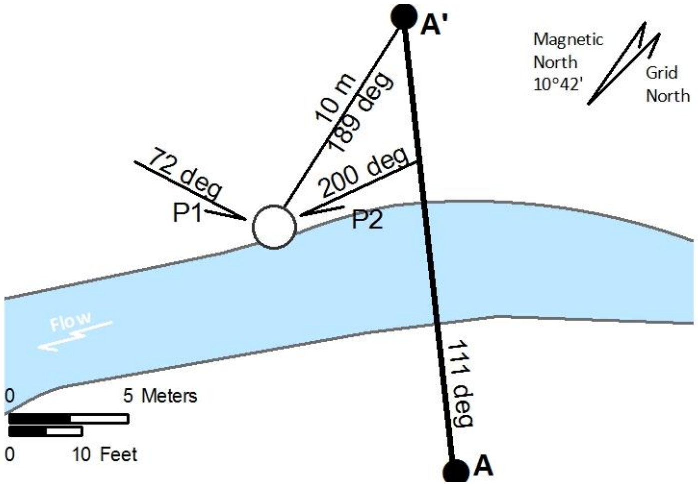
Notes and Comments:-

→ Aggradation only behind or atop boulder / cobbles

Appendix IV

Alpha Photo Station Record

P1 – 4.March.2009

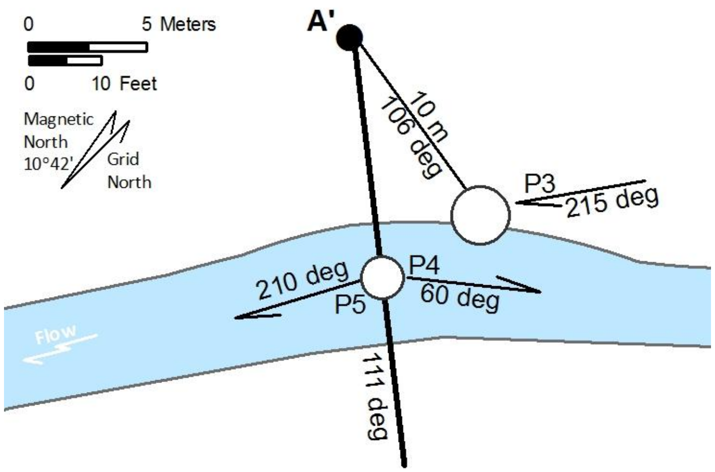


P1 – 29.May.2009

P2 29.May.2009

Figure 5a. The *Alpha* study reach photo station record, photo stations 1-2. The first two photo stations are located at a stump on the lower bench of the right bank. The stump has three trunks and is more than 50 cm off the ground; it is visible in the P3 photo along the right bank.

P3 – 29.May.2009



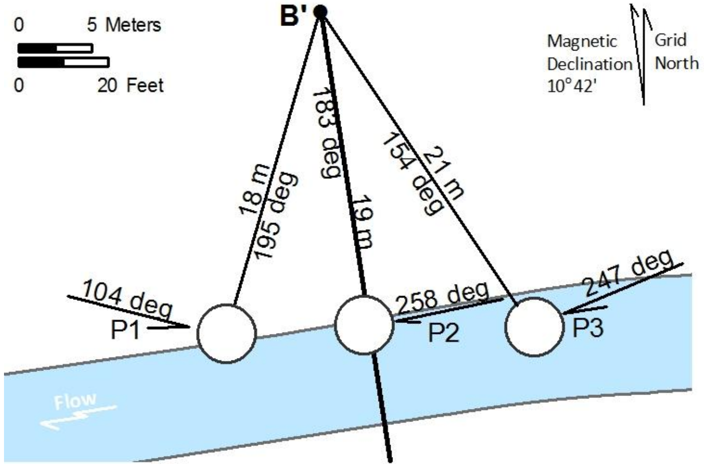
P5 – 4.March.2009

P4 4.March.2009

Figure 6a. The *Alpha* study reach photo station record, photo stations 3-5. The P3 photo station at the *Alpha* study reach forms an equal-angle triangle along the right bank. In the P3 image note the stump with three trunks along the right bank which identifies the location where photos P1 and P2 were taken. Images P4 and P5 were taken in the middle of the cross-section looking up- and downstream, respectively.

Bravo Photo Station Record

P1 – 29.May.2009

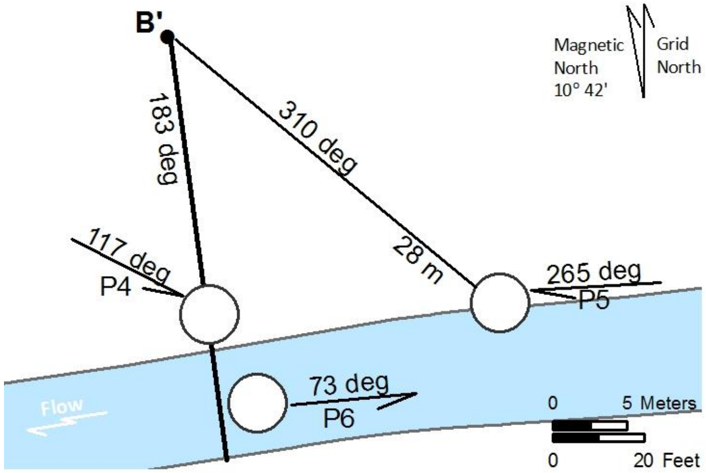


P2 – 29.May.2009

P3 29.May.2009

Figure 7a. The *Bravo* study reach photo station record photo stations 1-3. Photo stations 1-3 are located atop the right bank. Photo P1 is looking upstream; the trees are along the relict shoreline. Photo P2 is along the studied cross-section next to a stump directly downstream of the transect.

P4 – 29.May.2009

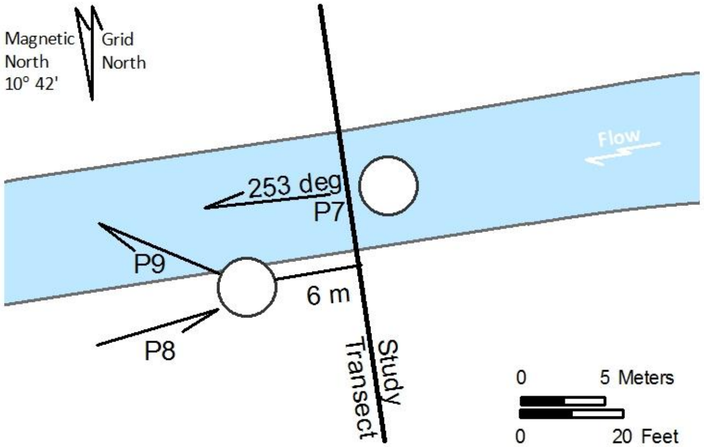


P5 – 29.May.2009

P6 - 29.May.2009

Figure 8a. The *Bravo* study reach photo station record photo stations 4-6. Photo station P4 is viewed upstream; note the plastic sleeve for tree planting is the same as is viewed in P6. Photo station P5 was taken from atop a large stump along the upper edge of the right bank. The stump is partially visible from photo station P6 as adjacent to the tallest shrub on the left side of the image. Photo station P6 was taken from a flat boulder at the middle of the stream width.

P7 – 29.May.2009



P8 – 4.March.2009

P9 4.March.2009

Figure 9a. The *Bravo* study reach photo station record photo stations 7-9. Photo station P7 is taken from the exact same location in the stream channel as image P6, only looking directly downstream. Photo stations P8 and P9 were taken without azimuth data. The view of the right bank is important to record, thus they are included in this report without full reporting.