QUANTIFYING LONG-TERM GEOMORPHOLOGY OF ANTARCTIC STREAMS

BY

STEVEN WILLIAM CRISP

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Diane M. McKnight

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Michael N. Gooseff

Date____________________

The final copy of this thesis has been examined by the signatories,

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Steven William Crisp (M.S., Civil, Environmental, and Architectural Engineering)

Quantifying long-term geomorphology of Antarctic streams

Thesis directed by Professor Diane M. McKnight

In 1994, 16 stream transects were established in the McMurdo Dry Valleys of Antarctica beginning a long term data set characterizing microbial communities and channel geometry. The transects were established to record microbial mat dynamics and stream geomorphology. To accomplish this, the transects were surveyed for points of interest outside and inside the stream channel. Beginning in 2010 the microbial surveys received ground based LiDAR support. This allowed for greater resolution in mapping and analyzing stream morphology than traditional surveying methods. The purpose of this study was to overlap the traditional methods of surveying individual points of interest with a data cloud representing the entire stream transect to be able to continue the microbial study into the future unabated. Using surveyed microbial mats as an indicator of a location in time, a history of channel elevations was created for 7 transects. In general, the streams have not changed significantly in the 20 year record, with exceptions being the steep channel of Bohner Stream, and Huey Creek, which receives large sediment loads from the sharply incised upstream channel, both of which saw large variations in maximum bed change exceeding 75cm and 150 cm respectively. In addition to creating an elevation history, relative bed change was plotted against the ash free dry mass of the microbial mats sampled to determine the resilience of the mats. It was found that microbial mats are more abundant in areas of near zero change. The four microbial mats studied however, which include green, black, orange, and red mats, differed greatly in adaptability with regards to bed change. Green microbial mats, which are typically hidden under large immobile rocks, were not often found in areas with any significant bed change. Conversely, orange mats were found in the most dynamic parts of the stream bed with outliers seen in areas with change exceeding 50 cm with. Finally black microbial mats had the largest values of ash free dry mass indicating the largest resilience to the scouring effects of high flow.

Acknowledgements

I want to begin with Diane. She has seen may people pass through her wings, and without her persistent and consistent help, I would not be anywhere near where I am today. I believe many would agree. She found me in 2009 lost but entranced by rivers, and brought me along for this journey.

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My parents, while they probably do not fully understand what I do, they are in whole support of my endeavors.

And Heather for being patient while I embarked on my first scientific undertaking.

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1 INTRODUCTION

1.1 Water is life

Located in perennially ice free zones of South Victoria Land in Antarctica lie the McMurdo Dry Valleys (MDV), the largest exposed region of Antarctica encompassing an area of 4500 km^2 or about the size of Rhode Island (Levy 2013). The MDV are known as Dry Valleys because of the arid atmosphere and the less than 10 cm water equivalent annual precipitation (Fountain et al. 2010). The majority of the precipitation falls as snow and rapidly sublimates without making any significant hydrologic contribution (Clow et al. 1988). In contrast, large quantities of water present are trapped in glaciers cascading from saddles in the surrounding mountain ranges and in perennially ice covered lakes. The glaciers supply the lakes with water through ephemeral streams that flow for 6-12 weeks during the austral summer. The streams can be represented as the life force of the valleys and are hot spots supporting dense ribbons of microbial mats in the MDV landscape. The greatest standing biomass in the MDV is associated with the large benthic microbial mats found in the ice covered lakes. The microbial mats in the streams consist of many types of microflora and microfauna including bacteria, cyanobacteria, chlorophytes, diatoms along with lesser numbers of nematodes and tardigrades. The microbial mats in the stream channels are employed in this study to assist in determining geomorphological changes within stream channels.

The soils surrounding wet areas contain nematodes, tardigrades, rotifers, and protozoa (Wharton et al. 1989). Nematodes along with soil microbes are also detected away from water sources where soils still contain low amounts of moisture (Zeglin et al. 2009) where they are responsive to changes in organic matter, pH, and salinity. The microbial mats focused on in this study are comprised predominantly of cyanobacteria and consist mostly of endemic Antarctic species (Stanish et al. 2012) that are only found in significantly wet regions of soil or in streams and lakes. The mats are perennial and are desiccated through the winter. They have been found to begin photosynthesizing within hours of being re-hydrated (Vincent et al. 1986) once streams begin to flow in early December. Mats can cover entire reaches of wetted areas surrounding streams. Shearing forces from flood events can be powerful enough to scour and transport some of the biomass downstream to the endorheic lakes as particulate organic matter (POM) (Cullis et al. 2014). Aeolian processes allow some of the desiccated microbes to be dispersed throughout the valleys, increasing diversity in channels or introducing new species to previously uninhabited regions (Marshall et al. 1997).

The streams are also distinct in that they do not receive nutrients from traditional sources such as leaf litter or feces. Nutrients are primarily obtained through weathering of sediments or atmospheric deposition. The majority of nitrate (NO_3^-) found in the streams is originally produced by auroral activity in the atmosphere (Friedmann et al. 1980) and deposited in the MDV causing surfaces to contain atmospheric nitrate (Green et al. 1988). The hyporheic zone of a stream is the wetted region of soil where surface and subsurface flows mix and plays a large role in weathering and nutrient availability. The hyporheic zone can act as a sink for nutrients essentially delaying nutrient passage downstream at higher flows and eventually dispersing them when the hyporheic zone is drained at lower flows (Koch et al. 2010). The MDV streams are subject to consistent diel flooding patterns that inundate hyporheic zones and braided channels that some years do not see flow. Zones that rarely experience flows can slowly build up nutrients and organic matter and contribute to overall nutrient load of the stream (Koch et al. 2011). Longer streams typically contain higher major ion concentrations than shorter streams primarily due to a longer overall residence time within the hyporheic zone (Gooseff et al. 2002). The microbial mats also affect nutrient availability through uptake that varies throughout the day (Koch et al. 2010).

Microbial mat abundance can be measured based on ash free dry mass (AFDM) and Chlorophyll *a* content of mat material and has been found to be related to a harshness index that gages how hospitable a stream will be to harbor microbial mats. Streams that have lower harshness indices tend to have more microbial mats (Kohler et al. 2015), which can regulate nutrient concentrations in these streams. Streams then, with fewer microbial mats, have been found to contribute higher amounts of dissolved nutrients to the endorheic lakes (McKnight et al. 2004). Huey Creek has few microbial mats along its entire reach and has been found to be limited by available carbon (Koch et al. 2010) while Green Creek conversely has extensive mats covering the benthos and found to be nitrogen limited, unlike the valley floors as mentioned above, and uptake as much as 20% of injected nitrate tracer, which is converted to nitrite (NO_2^-) by dissimilatory reduction (Gooseff et al. 2004). Therefore, dissolved nutrients in the MDV are limited through atmospheric and weathering processes, can be stored in hyporheic zones of stream channels, and taken up via microbial mats, and transferred downstream to closed basin lakes as POM (Cullis et al. 2014).

Relatively little is known however, about Antarctic stream channel morphology in terms of rate and scale of change. Channels have been revealed through satellite imagery; approximately 50% no longer see sustained flow and can be considered relict or abandoned (McKnight et al. 1999). These relict and abandoned channels that no longer experience flow, suggest that change in the hydrologic network has occurred since the last glaciation. The unknowns are when in the past did these form and for what duration.

The first studies examining change in the stream channels focused on establishing transects located on 16 reaches of the MDV streams (Alger 1997) during the austral summer season of 1993/94. These transects were established a few years after the first discharge gages were established in the Taylor Valley of the MDV. The gages measured flow variation that is basic to the understanding of underlying processes and dynamics that control the cold desert ecosystem of the MDV (McKnight et al. 1994). The transects were surveyed topographically while also scanning for features of interest such as boulders, thalweg, and microbial mat locations. Because the time scale with which stream change would be detectable was unknown but change was expected to be slow, so repeat surveys were conducted every 2-3 years. This study later finds that significant change in relative bed elevation can either be caused by individual flood events or more gradually, possibly through freeze thaw processes, over a much larger time scale (McKnight et al. 1999). Features that have been found to significantly change seasonally are thermokarst regions of stream banks (Levy et al. 2013). Repeat LiDAR surveys were taken in Garwood Valley in the MDV and the analysis shows that thermokarsting significantly contributes to overall erosion of stream channels (Fountain et al. 2014).

1.2 Stream response to floods

Flowing water is an extremely powerful force that can scour new channels and deposit large volumes of sediments forming sandbars and beaches where velocities diminish. It is unknown what the main driver for MDV stream channel change is but due to the lack of riparian vegetation, wind and water are the only mechanisms by which change can occur. Gravity pulling dense water down a steep channel at the angle of repose exerts forces that are orders of magnitude more powerful than the strongest winter winds. It has been quantified that a few days of extreme flooding in vegetated regions can cause erosion equivalent to 1000 years of average erosion using published long-term rates (Anderson et al. 2015). Flood events may cause entire bed mobility in the MDV and further increase erosion rates but no study has yet focused on the volume of sediment transfer or flood impacts on MDV stream channels.

Flooding in the MDV occurs on a seasonal scale most often during the presence of strong down valley winds (Doran et al. 2008). The high velocity down valley winds are interesting events that possibly originate from global ENSO and SAM processes (Speirs et al. 2013) and are considered one of the main drivers of high discharges and an influential factor when determining floods effect on channel morphology in MDV streams. First studied in 2004 (Nylen et al. 2004) as katabatic winds and later described as foehn wind events, they have been shown to propagate slowly down valley despite high wind speeds. In addition, foehn winds are extremely warm relative to average temperatures in the MDV. It is presumed that the temperature increase is pressure driven and stems from the polar plateau approximately two miles higher in elevation. The winds are channeled from the continent through the surrounding mountains, and forced down the MDV at sea level (Steinhoff et al. 2014). Turbulence and increased temperature cause surrounding glaciers to melt at higher rates, increasing discharges in the meltwater streams. More often, however, but with lower intensity, are diel pulses and floods that occur when sun aspect is most direct on a source glacier (Conovitz et al. 1998, Jaros 2003).

Long-term record keeping of stream flow in the MDV began in 1969 with the Onyx River in the Wright Valley by the New Zealand Antarctic Program (Chinn 1981), and in Taylor Valley in 1990 by the United States Antarctic Program. Since this time, three flood seasons have been observed in the MDV. The largest of these three happened during the 2001/02 season with streams experiencing discharges upwards of 40 times higher in magnitude than average while Delta Stream had a 6000-fold increase in stream flow (Doran et al. 2008). The other two anomaly flood years in order of magnitude are 2008/09 and 2010/11 (Stanish et al. 2012). Typically the MDV streams experience the highest flows during the last week of December and first week of January and this was the case for the two smaller flood seasons. The three floods also had similar maximum discharges among most of the streams. The defining factor of the largest flood during 2001/02 was the long duration of high flow throughout the season that began in mid-December and tapered off near the end of January whereas the other two floods occurred during typical high flow periods within their respective seasons.

In addition to redefining the geometry of stream channels, floods also affect the local ecosystem. In particular, floods cause bed mobility that increases shearing stresses on microbial mats. The streams of the MDV are prone to swift flood events that overtake channels in a matter of hours and as such the microbial mats residing within the channels are well adapted to high flows (Cullis et al. 2014). Floods therefore have limited impact on microbial mats unless sufficiently large enough to result in shear stresses large enough to mobilize the entire bed and remove organic matter from the substrate (Cullis et al. 2014). Floods are not the only controlling factor however on microbial communities. Intermittency in flow regimes was found to lower diversity of endemic species of diatoms (Stanish et al. 2012). Diversity is affected by low and high intermittency, which in turn cause lower evenness and richness, respectively.

1.3 Hypothesis, Objective, and Approach

1.3.1 Hypothesis

The current ozone hole over the Antarctic is slowly ameliorating while meltwater generation in the MDV is expected to increase beginning a pattern in which floods occur more often and with higher intensity over the next 150 years. Streams may experience larger scouring events causing many channels to become more deeply incised. Microbial mats may be forced to adapt to higher flow conditions, or move to less turbulent sections of streams, such as the wetted regions that black microbial mats currently dominate. Permafrost degradation on the stream banks may increase as rising temperatures may cause permafrost to eventually thaw, and deposit the trapped sediment into the stream. This in turn can release nutrients that have been confined within the permafrost into the streams and lakes, oversaturating an ecosystem with nutrients when the microbial mats have made a niche surviving on very little. An increase in temperatures may then cause a positive feedback loop by increasing the total amount of liquid water present in the MDV that can stabilize local variations in temperature allowing for longer periods of above freezing temperatures and thus generate more meltwater. Regardless, the MDV are expected to increase in temperature over the next few decades. This study will provide an early look into small scale changes in channels that may eventually be considered precursors to larger events.

1.3.2 Objective

The objective of this study was to extend a long-term survey by introducing finer resolution to document any change within a stream channel. Assuming the stream channel experiences greater rates of erosion and deposition than the surrounding bank area, previous microbial transect surveys were overlain to estimate the point-based and transect-wide bed change of the channel. It was expected that flooding would have the greatest effect on channel morphology. To detect change at greater resolution, microbial ash fee dry mass (AFDM) analysis was included in the study. Some microbial mats prefer slow-moving waters or wetted zones while others can withstand and even thrive in heavy discharges located in the thalweg. In the absence of floods, microbial mats can accumulate multiple season's worth of biomass. The effect of floods then can be quantified using AFDM loss after a mat is scoured from a high flow event. Comparing pre-flood to post-flood AFDM provides a glimpse at the stream conditions where mats persist, and how different mat types cope. What this study provides is an analysis of bed changes that occur within varying stream channels as well as the resilience of four types of microbial mats during these changes.

1.3.3 Approach

Beginning in the 1990/91 season, 16 stream microbial mat survey transects were established within the Taylor Valley of the MDV. The transects were marked by two rebar benchmarks (BM1 & BM2) on either side of the stream as reference points for future surveys. These BM extended both up and downstream for approximately 50 meters. Most streams had a single transect along the stretch from glacier to lake, but a few notable longer streams with varying conditions from source to outlet had multiple transects (e.g. Delta, Von Guerard, and Canada).

Transects were established to monitor seasonal microbial mat growth within the stream to determine any variability and drivers. Four microbial mat types (green, orange, red, and black) (Kohler et al. 2015) were found to dominate the wetted regions of stream channels. The four mats have been continually sampled for relative location and elevation, ash free dry mass (AFDM), and chlorophyll *a* (Chl a).

Using microbial survey data from the last twenty years, I generated a basic history of stream channel morphology. Of note is that the exact locations were unknown due to technology available during the first surveys. LiDAR was then introduced in 2010 that allowed precise extraction of the current locations and elevations of every survey point and detect relative temporal change occurring within the stream channel. Integrating LiDAR with older survey technologies allows the long-term record of channel dynamics extended with higher resolution, and greater detection of rates of change within the channel, while maintaining undisturbed microbial mats from unobtrusive electronic scanning.

2 SITE DESCRIPTION

2.1 Site History

The MDV are a collection of ice scoured valleys in the South Victoria Land of Antarctica. At the base of these valleys are endorheic lakes that are fed by ephemeral streams that flow most austral summers. The lakes have been found to have once had a surface elevation 318 meters higher than present (Hall et al. 2000b) possibly within the last 4.6 million years (Doran et al. 1994). The lakes have also dried completely within this time due to a fluctuating past climate. During the LGM, an ice-dammed lake known as Glacial Lake Washburn covered the entire Taylor Valley (Péwé 1960) and deposited organic matter on the soils. These are presently being eroded as streams slowly etch deeper channels into permafrost. Glacial Lake Washburn also left behind a series of perched deltas that were created when the lake level stabilized long enough for streams to deposit sediment in large quantity at the outlets (Kellogg et al. 1980). Since the LGM, the lakes have experienced many changes in elevation and are considered unstable environments that are recharged with liquid water and nutrients by occasional valley-wide flood events (Foreman et al. 2004).

2.2 Research History

The MDV have long held scientific interest beginning with lake level surveys in 1903 by Robert Falcon Scott and his field party in which they mentioned the breadth between two rock faces nearly isolating the West Lobe and East Lobe of Lake Bonney as being 17 feet at its narrowest. A rough estimate of lake level can be interpolated from this measurement while similar measurements are continually conducted in the present allowing estimation of lake levels during periods without record (Bomblies et al. 2001). What Scott's expedition failed to notice, however, was life present within the MDV as they described it as the "Valley of the dead" and noted that "We have seen no living thing, not even a moss or lichen" (Scott 1907). Griffith Taylor later set out to the MDV in 1911 and recorded observations of algae in the lakes and streams (Taylor 1922) along with William and George West who were studying algae throughout Antarctica (West et al. 1911).

Modern research in the MDV began in 1969 on the longest river in Antarctica, known as the Onyx River (Chinn 1971). The Onyx River station was then managed by the New Zealand Antarctic Program. Since then it has been handed over to the United States Antarctic Program that maintains the two gages and controls located at the source at Brownworth Glacier and terminus of the river into Lake Vanda. The Onyx River data record is also the longest continuous record of stream flow in the MDV.

2.3 Streams

In 1990 16 stream gages were established in the MDV and with the creation of the MCMLTER in 1993 began a long term monitoring record. In addition, 16 stream transects were erected on these streams, 7 of which are included in this study (Figure 2-1). The streams begin flowing from cold-based alpine and piedmont glaciers and eventually all but one terminate into endorheic closed basin lakes. Some streams follow long braided channels consisting of fine sediments, whereas other streams have steep gradients where large boulders compose the majority of the streambed. The streams are highly variable in flow and discharge patterns are regulated primarily by the position of the sun on respective source glaciers. On cold cloudy days, streams will wane to a trickle or even cease to flow while during warm and windy days the same streams can expect flows to increase 10-fold. Between the stream surface and the permafrost located a meter below lies the hyporheic zone where surface and subsurface flows mix. Stream tracer studies indicate that mixing is much more rapid than in lower latitude streams. These wetted regions are also a major source of nutrients (McKnight et al. 1993). Located in a barren desert far from most anthropogenic activities, the streams only carbon inputs are localized around field sites that use diesel and propane as fuel. Thus the streams serve as the most significant regulator of organic material and nutrient fluxes to the closed basin lakes.

The seven streams analyzed in this study are ordered from high microbial abundance to low. Canada Stream has the most consistent flow and microbial mat record. Canada Stream also lies within an Antarctic Specially Protected Area (ASPA), which allows for a natural and undisturbed study site. Canada Stream, located near the intersection of Canada Glacier and Lake Fryxell, contains all four types of microbial mats analyzed in this study and experiences smooth transitions from low to high flows allowing the mats to proliferate. Conversely, of the streams in this study, Bohner Stream that is located furthest up valley to the southwest, is a steep and rocky channel with sandy banks that consistently erode into the stream and are deposited a short distance downstream into a large delta where the gradient lessens. Very few microbial mats are found in Bohner Stream. Where they do persist, they are under the protection of large rocks or in slower moving sections of water such as eddies where the current does not scour. Between Canada and Bohner Stream are 5 other streams and creeks that represent a full spectrum of bed types, stream lengths, flow regimes, gradient, and microbial mat coverage.

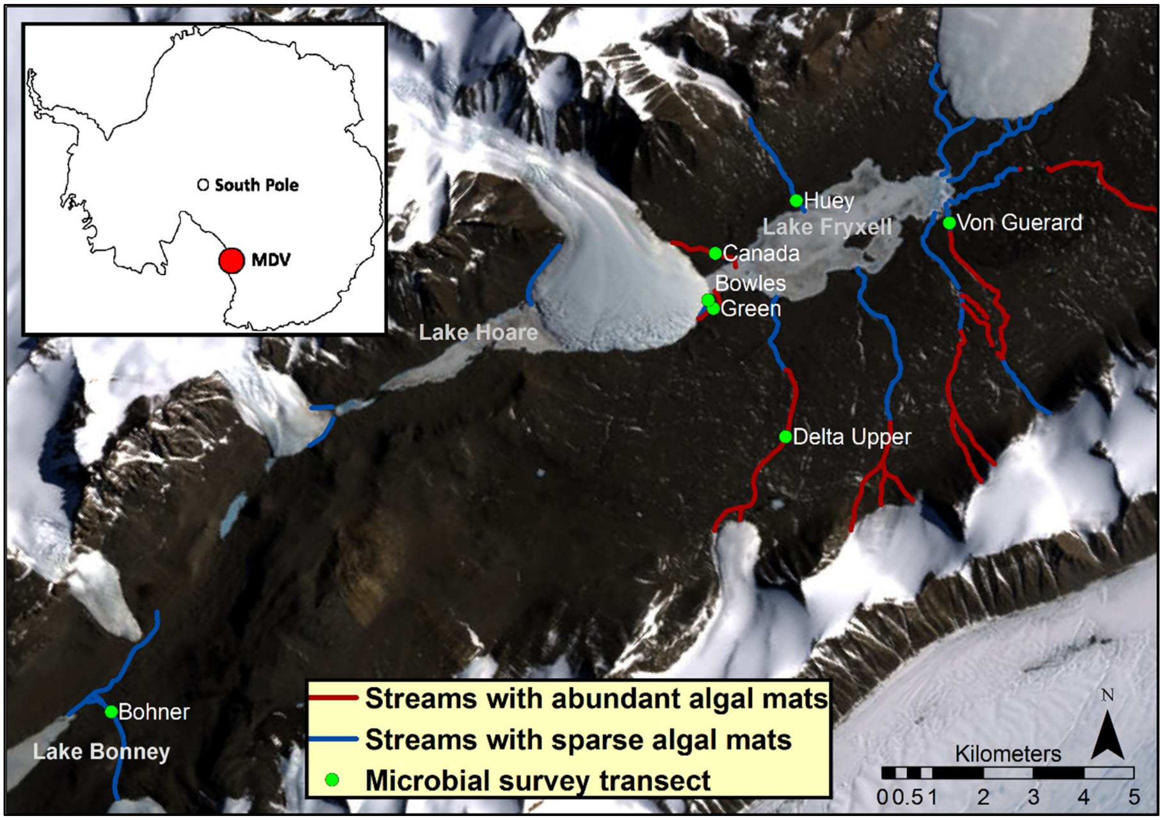

FIGURE 2-1 MAP OF TAYLOR VALLEY TRANSECTS. STREAMS ARE ORDERED FROM HIGH MICROBIAL ABUNDANCE TO LOW AND ARE PLOTTED RED AND BLUE RESPECTIVELY. THE GREEN DOTS INDICATE THE LOCATIONS OF 7 OF THE 16 MICROBIAL TRANSECTS INCLUDED IN THIS STUDY.

2.4 Microbial mats

Where flows persist but not too strongly, lie microbial mats. The mats are located within the thalweg of the streams as well as the fringes where sediments are wetted but rarely experience large surface flow. This study focuses on four different types of microbial mats that dominate the benthos of most streams in the MDV; green, black, orange, and red. Green microbial mats largely consist of the chlorophytes *Prasiola crispa* and *Prasiola calophylla*. Green mats are easily scoured and thus are located on the bottom side of rocks and other large debris where they are protected from high flows (McKnight et al. 2007), yet receive enough energy during low solar aspects. Black microbial mats consist of the cyanobacteria genus *Nostoc* and differ from other mats in that they prefer the outer fringes of stream channels where the soils are wetted from hyporheic exchange. Occasionally these zones experience high flows that scour the loosely held black mats and send them downstream as POM. Orange microbial mats are considered the hardiest of the four microbial mats. Orange mats are found in the thalweg or deepest section of channels where shear stress is greatest. The orange mats are composed of filamentous cyanobacteria *Oscillatoriaceae* and contain β-carotene that gives it the orange hue (Vincent et al. 1993). Finally, red microbial mats, which were only found in one of the streams in this study are very similar to orange mats in that they are composed of filamentous cyanobacteria. They differ by having a dense and rubbery surface layer (Kohler et al. 2015). No conclusions have been made concerning red mats resilience in this study.

3 METHODS

3.1 Introduction

This chapter discusses the integration of traditional surveying methods with high resolution LiDAR and the problems inherent in both. The past record only exists in the traditional method using a Total Station, and extends 20 years in length. Recently LiDAR has been incorporated. This study seeks to combine these two data records to create a cohesive geomorphological history for the stream microbial transects of the MDV.

When the transects were established during the 1990/91 austral summer they were geo-located and referenced using rebar benchmarks as guides. The benchmarks were surveyed manually with a total station. In addition, rocks, stream boundaries, microbial mats, and other prominent features were surveyed. The initial surveys contained upwards of 300 points providing full coverage of the transect. The inherent problems with this method are that in the field it requires a large amount of time to locate, scan, and record each point, while back in the lab, post processing requires extensive knowledge of the area to decipher errors otherwise unknown during the scan. In other words, if mistakes were made during the visit, they would not be detected until back at camp when returning to the field site may not be feasible. In addition, if the surveys only scanned for benchmarks and surrounding mats, there would be too few points to properly discern any changes to the stream channel or microbial mats.

Repeat surveys were conducted every few years and an extensive database was built. Focusing on microbial mats as the location and dominance of these mats can change drastically between seasons, locating the same mat each year was difficult. Therefore repeat scans of exact mats were impossible. A method was needed to survey the entire stream transect and build a grid based system to upload survey data to include on a temporal scale. Until LiDAR was introduced in 2010, such a system did not exist.

LiDAR scanning technology creates a point cloud of millions of points in less than an hour at a resolution of +/- 1 cm at 100 meters. These data are extremely helpful in that the exact elevation of any given point can be extracted to determine any kind of temporal change occurring. What is required for change detection, however, is multiple LiDAR scans. As this study only has single LiDAR scans of all but one stream, the historical TS surveys are useful. Microbial mats that were surveyed over the previous twenty years are referenced to benchmarks that are visible in the LiDAR scans and therefore can be overlain and combined with LiDAR to create a temporal map of the stream transect. Changes are extremely difficult to discern using a total station due to the requirement of surveying hundreds of points at their exact location in X and Y, but LiDAR allows each and every point to have an extracted elevation associated with an X and Y. Therefore, past surveys conducted in the 1990's can be easily integrated using LiDAR and be helpful in continuing a long term database.

With every benefit there is a drawback. LiDAR, as useful and progressive as it may seem, is extremely expensive to operate and process to the extent of deliverable work. Once delivered, each scan is upwards of 7 GB in size and takes hours to run single commands in a LiDAR processing environment such as ArcGIS. LiDAR essentially trades the little time spent in the field with time spent back in a lab [but outputs a map of much higher resolution]. LiDAR scans therefore are recommended to only be done occasionally, but as mentioned later in Section 7 , repeat LiDAR is essential for continuation of this study. The proper combination of traditional methods of surveying and LiDAR scanning is needed to provide an extensive database in which detection of changes can occur in a reasonable timeframe and budget.

3.2 Microbial mat surveying for long term monitoring

Initially, stream transects were surveyed using a Leica© Total Station Theodolite (TS) to establish the location of microbial mats, thalweg, bank geometry, BM, and dominant features such as large rocks or seepage zones. Surveys have continued in the same manner since the initial measurements. The survey requires a two person team with one member (A) stationed at the TS shooting a reflective prism with a laser and recording results. The instrument is erected directly above the first (BM1) of two (BM2) BM along the stream transect. The second member (B) locates features within the stream channel or bank and places a rod with a reflective prism attached on top of the point of interest and aims the prism at member A. Member A records the horizontal angle (HA), the vertical angle (VA), and the longitudinal distance (LD). Figure 3-1 and Figure 3-2 explain how the tripod and the rod are set up along the stream channel and what data is collected from each shot. Also known at this time are the height of the prism rod (HR) and height of the instrument (HI) or tripod. After the data were recorded, secondary processing outside of the field calculated the UTM 58S northing and easting coordinates in meters as discussed in Section 3.2.1 and Figure 9-3 in the appendix.

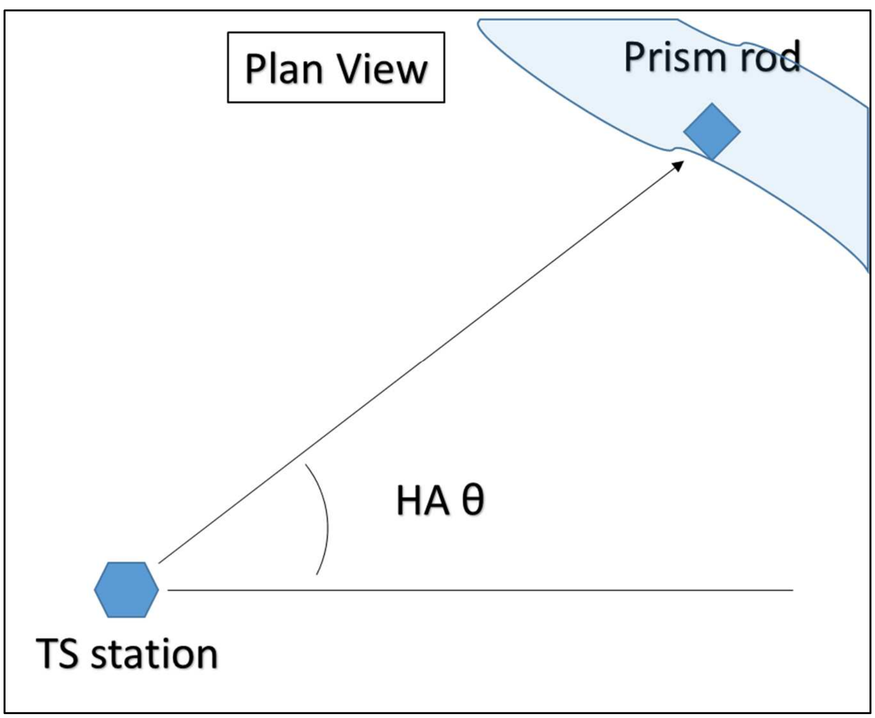

FIGURE 3-1 PLAN VIEW OF TOTAL STATION SETUP. LOCATED IN THE BOTTOM LEFT CORNER IS THE TRIPOD CONTAINING THE TOTAL STATION WHICH IS LEVELED TO THE GROUND. IN THE TOP RIGHT CORNER IS THE STREAM WITH SURVEY MEMBER B HOLDING A ROD WITH A PRISM ATTACHED. THE HORIZONTAL ANGLE TO THE BACKSIGHT IS GATHERED.

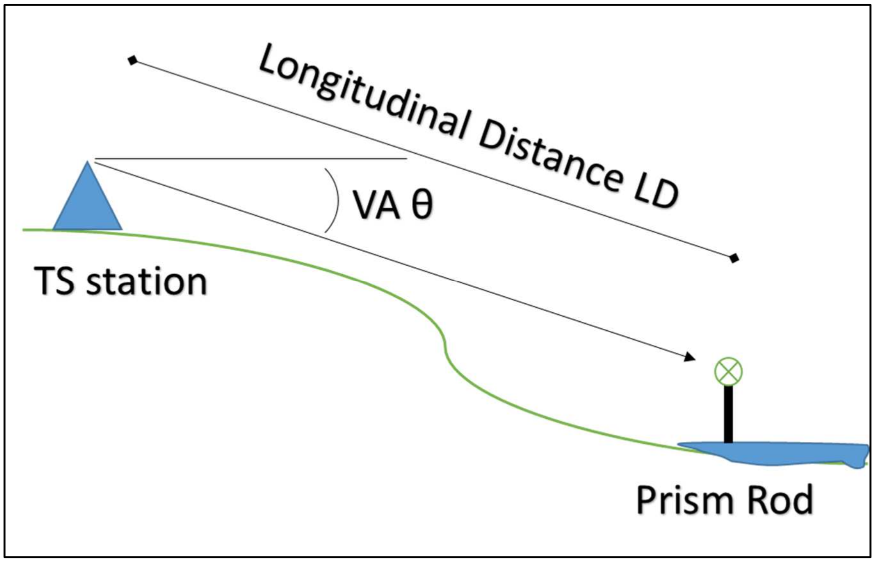

FIGURE 3-2 SIDEWAYS VIEW OF TOTAL STATION SETUP. THE TOTAL STATION IDEALLY IS ABOVE THE STREAM ON A HIGH BANK WITH VIEWS OF THE ENTIRE CHANNEL AND POINTS WORTH RECORDING. THE VERTICAL ANGLE AND LONGITUDINAL DISTANCE ARE GATHERED IN THIS SHOT.

3.2.1 Conversion of Algae data to UTM coordinates

After shooting each point, the TS records and stores the value of HA, VA, and LD. After the survey is finished, these three values are entered into a conversion spreadsheet (Figure 9-3). The spreadsheet contains the X, Y, and Z UTM 58S coordinates for both BM located within the transect. The two BM locations are known and an *azimuth of backsight* (AOB) is calculated using eq. {1} from 0-360 degrees continuing counter-clockwise. The AOB is unknown in the field so the initial setup shot is aligned with BM2, i.e. shooting BM2 from the TS at BM1. The HA is zeroed using BM2 so the first HA is equal to 0. The VA and LD remain unaffected by the configuration. The horizontal distance (HD) is then calculated by converting distance from a longitudinal aspect to horizontal using eq. {2}. Eq. {3} calculates a vertical distance (VD). Lastly before obtaining coordinates, and azimuth of line (AOL) is calculated in eq. {4} using the AOB and HA of each shot.

$$AOB = \tan^{-1}\left(\frac{BM2X - BM1X}{BM2Y - BM1Y}\right)\left(\frac{180}{\pi}\right) \quad \{1\}$$

$$HD = \left|LD * \sin(VA * \frac{\pi}{180})\right| \quad \{2\}$$

$$VD = LD * \cos(VA * \frac{\pi}{180}) \quad \{3\}$$

$$AOL = AOB + HA - HA(BM2) \quad \{4\}$$

Combining the results of equations {1} through {4}, X and Y coordinates in UTM58S can be calculated using equations {5} and {6} respectively. Finally the elevation or Z coordinate of the survey point is calculated by subtracting the height of the prism rod (HR) from the height of the instrument (HI) and adding the value to the VD and BM1Z as in eq. {7}

$$X = BM1X + HD * \sin(\mathrm{AOL} * \frac{\pi}{180}) \quad \{5\}$$

$$Y = BM1Y + HD * \cos(\mathrm{AOL} * \frac{\pi}{180}) \quad \{6\}$$

$$Z = BM1Z + VD + HI - HR \quad \{7\}$$

3.3 LiDAR

During 2009-10 season, with support from UNAVCO, 5 initial transects were scanned using a terrestrial laser scanner (TLS) also known as ground-based LiDAR (Light detection and ranging) using a Riegl VZ-400. As of the 2014-15 season, all 16 stream transects have been scanned using LiDAR. Due to instrument error in the field, corrupted final data, and timing issues, only 7 of the 16 scans were fully processed and analyzed for this study.

A TLS scan begins by geo-referencing the parent station using the BM installed from the 1993/94 austral summer season. The station is erected on a tripod within sight of the two transect BM. The BM have a known location and are used to geo-reference the TLS station. While the TLS is initiating, 4 to 7 tripods with reflective markers are erected within view of the TLS and set up as needed at the discretion of the UNAVCO team. Two of the markers are located directly above the known BM. The tripods are also equipped with Trimble 5700 differential grade GPS rover systems to self-locate within 3D space. The markers are used post-processing by UNAVCO to more accurately reference points in space.

A scan of the area of interest (AOI) is taken at a resolution of 2 cm minimum point spacing at 100m. Once the first scan is taken the TLS is deconstructed and moved in a circular patter around the microbial mat transect to best eliminate shadows and view all surfaces. On average 3 to 5 scans are taken per transect. After 2011 the TLS was equipped with a digital camera (Make Unknown). After each scanning position was complete, the camera photographed a panorama. The photos were used post processing by UNAVCO to assign each point in space with a red, green, and blue value (RGB) for visualization using ArcScene explained in section 3.4.5 .

Processing of the data for LTER use was done at UNAVCO located in Boulder Colorado using RiSCAN Pro software from Riegl. Briefly, the multiple AOI scans were compiled and cropped to our transect specifications. A point cloud was generated using the markers as reference points and a scan was then delivered FTP via UNAVCO website HTTP://TLS.UNAVCO.ORG/REPOSITORY/ as a .csv file that contained latitude and longitude in UTM 58 South and elevation (MSL). Scans that were done with a mounted camera also contained RGB (0-255) following elevation.

3.4 Cartography with ArcGIS

ArcGIS version 10.2 with 3D Analyst, ArcScan, and Spatial Analyst extensions was used in all post processing upon delivery of LiDAR and microbial mat survey data. ArcMap was used to digitize contour plots from the 1993/94 season, plot microbial mat survey data from the past 20 years, and generate digital elevation maps (DEM) from the LiDAR scans to provide reference elevations when assessing geomorphology of stream channels. ArcScene was used in combination with LAStools (Isenburg 2014) to create a navigable 3D color map with which to visualize transects and better identify objects of interest.

3.4.1 Digitalization of Contour Plots

Soon after the transects were established and the first surveys complete, USGS surveyor Gordon Shupe applied a method of interpolation known as kriging to the processed survey data to create topographic maps of the transects. In addition to Total Station (TS) data, photographs were also used to locate features aiding in the creation of the maps. The topographic maps were digitized and overlain on LiDAR scans with the goal of detecting larger stream based changes.

The contour maps were first scanned from the Appendix of Alger (Alger 1997) and saved as a jpg files. Before attaching the jpg to ArcMap the spatial properties were referenced to UTM 58S. Next they were added to the working map by allowing pyramids to be built. Once added, the jpg of the contour plots were georeferenced using the BM locations of the transect and the georeferencing toolbar within ArcMap. Control points were placed on the two BM and within the link table, X and Y coordinates in meters were added. The plot automatically rectifies itself to the correct position. The map is at this step aligned to true north according to the BM.

After georeferencing the plots, the contours were digitized using the Vectorization toolbar of ArcMap. To prepare the contour maps, a new polyline shapefile referenced to 58S was created and an editing session started. Within the Vectorization toolbar of ArcMap, the settings style was changed to contours. Using the trace tool, each contour was traced along the entire path creating a new attribute within the shapefile for each contour line. Elevation for each contour was then added to the associated polyline within the attribute table. The new shapefile was saved for later use in section 4.2 .

3.4.2 Importing LiDAR into ArcMap

Terrestrially based LiDAR data sets contain anywhere from several hundred thousand to thirty million points that requires large amounts of RAM to process and interpret. In addition to a fast computer, software was required that could process the data and display it for use in this study. Many software choices were available that can process LiDAR, but many lacked in other essential tools that this study required. Of the choices available, ArcMap was the most generic and contained the largest online help database for common issues with LiDAR processing.

The LiDAR data was downloaded from the UNAVCO website in multiple packets due to a size limit per package. The packets were then combined using DOS commands

```
copy /b filename1 + filename2 + filename3 outfilename
```

Once the packets were organized into a single file, they were added into ArcMap using add XY data from the file menu. It is worth noting that other methods for importing billions of XY data points caused ArcMap version 10.2 to crash and not recover. Add XY data ran for approximately 45 minutes per transect and once complete, the point cloud that was created was converted into a DEM using point to raster tool. The cell size was set to 0.1 m^2 for all transects as a standard. The process of point to raster requires approximately 3 hours to complete.

The creation of a raster data set from LiDAR has inherent flaws. The cell size created from the point cloud is representative of every point within a 0.01 m^2 area. If there are no points within that area, the return is null. Considering there are millions of points involved, there should be few null returns, but many appear within the transects. These are explained by shadows created by rocks or permafrost polygon indentations. A second cause of null returns is that the infrared wavelength with which LiDAR operates is rapidly absorbed by liquid water and is not reflected back to the scanner. In other words, when the TLS scans a water body it never receives a return and assigns a null value to that location. Data gaps like these cause extraction of elevations at the location of null data to be impossible due to there being no data to extract from as is shown later on in Section 3.5 . Because of null returns, a patch or interpolation is required to fill the gaps. The patch is an interpolation increasing the area of a single cell within the raster from 0.01 m^2 to 0.09 m^2. Raster calculator was used to search for null values and interpolate between valid points to create an accurate representation of stream bed elevations. The code used within raster calculator follows:

```
Con(IsNull("Input_Raster"),FocalStatistics("Input_Raster",NbrRectangle(3, 3),'MEAN'),"Input_Raster")
```

Figure 3-3 and Figure 3-4 are examples of a raster generated from a point cloud without and with patching respectively. After the raster has been created, it is necessary to create a hillshade to visualize slope, aspect, and prominent features. Figure 3-5 shows an example of hillshading being used on a stream transect.

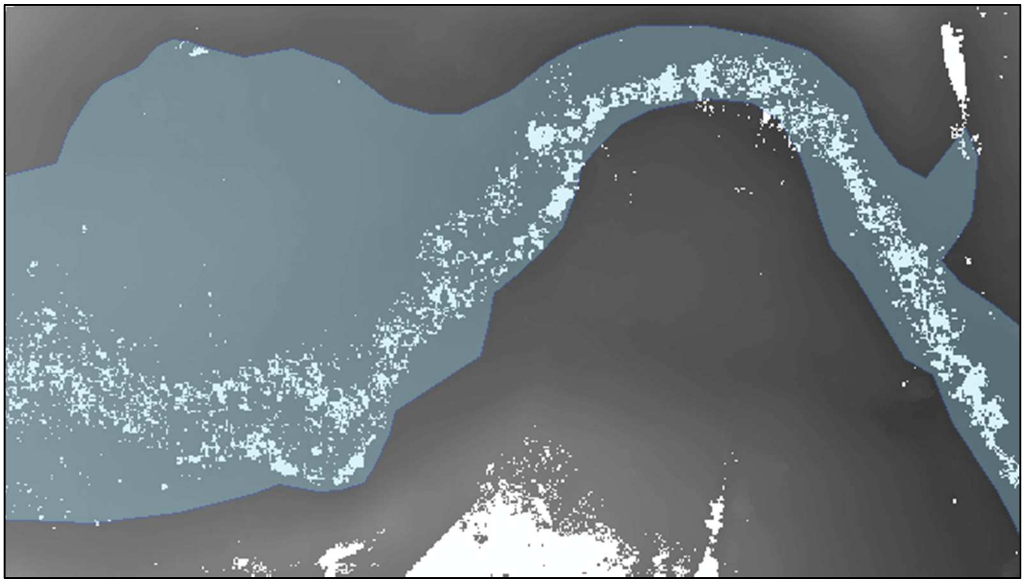

FIGURE 3-3 CANADA STREAM TRANSECT WITHOUT PATCHING. THE GREY ZONE IS THE STREAM BANKS AND SURROUNDING LANDSCAPE WHILE THE BLUE ZONE IS THE WETTED REGION CREATED FROM OBSERVATIONS AND SURVEYS. NOTE THE INCREASE OF GAPS OR NULL DATA FOLLOWING THE STREAM CHANNEL.

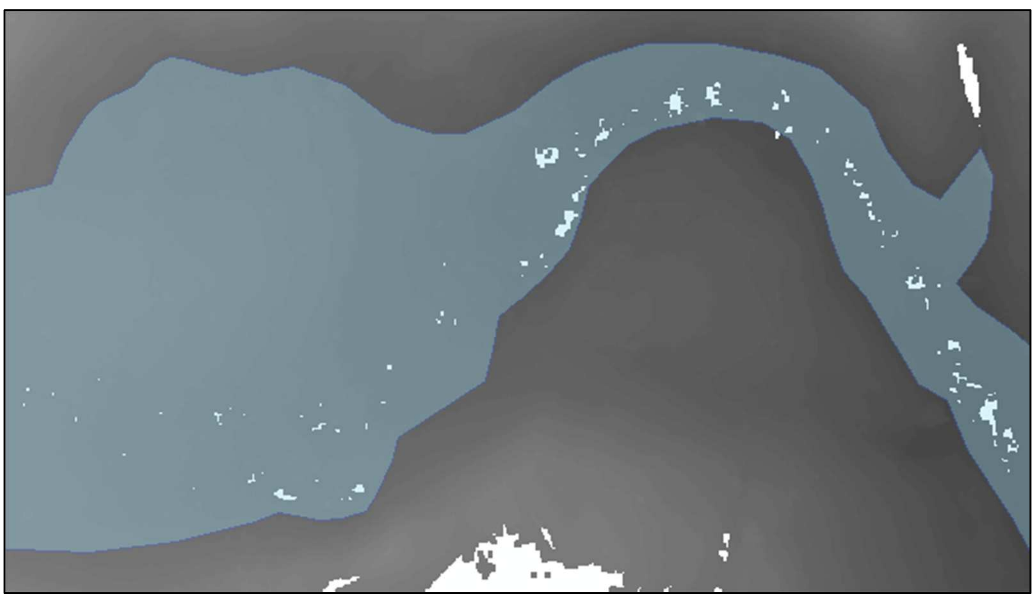

FIGURE 3-4 CANADA STREAM TRANSECT WITH PATCHING. GREY AREA IS STREAM BANKS AND SURROUNDING LANDSCAPE WHILE BLUE IS THE WETTED REGION CREATED FROM OBSERVATIONS AND SURVEYS. NOTE THE FILLED IN GAPS DUE TO PATCHING THAT ARE SEEN IN FIGURE 3-3.

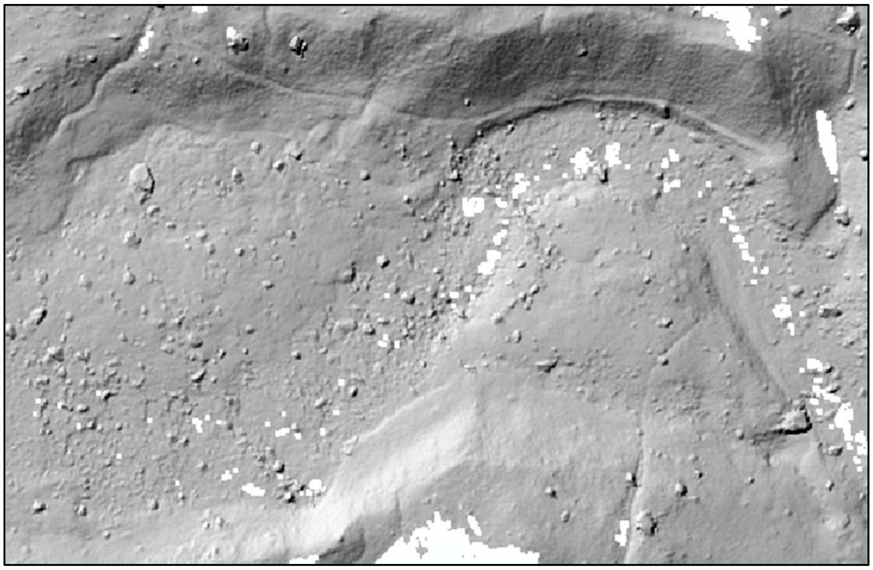

FIGURE 3-5 HILLSHADE EXAMPLE. ONCE A RASTER IS CREATED WITH ELEVATION DATA, A HILLSHADE CAN BE CREATED. THIS TOOL CREATES A SOURCE OF ILLUMINATION TO BETTER VISUALIZE OBJECTS AND TERRAIN.

3.4.3 Importing microbial mat surveys

Once the surveys are completed in the field and post processed back in the lab they are imported into ArcMap. Importing microbial mat data differs from LiDAR regardless of the fact they are both XY data. Instead of adding XY data directly from file, the microbial mat spreadsheets are converted to .csv file containing the X, Y, Z, AFDM, and description. The file created is added to ArcMap and a feature class is created from XY table. Once imported the data can be used for analysis.

3.4.4 Outputting Maps

The final output from ArcGIS is a publishable map. To accomplish this, the Focal Statistics tool again was used (see Section 3.4.2) to expand the raster allowing smooth contour plots to be made. A neighborhood rectangle was chosen with a 16 by 16 cell area. All other defaults were used. The new raster created is a smoothed version of the previous raster getting rid of tiny imperfections that could lead to numerous unwanted contour lines. Next the contour tool from spatial analyst was used to generate the contour lines. The focal statistics raster was input and the contour shapefile was saved as Cont_Foc_Stat. Depending on the stream, 0.5 to 2 m intervals were used. Steeper streams such as Bohner used 2 m contour intervals and shallower gradient streams like Huey used a 0.5 m contour interval to greater detail flatter surfaces. Cleaning up involved deletion of ghost contour values, and connecting lines that contain gaps using the editor tool. Once the map was clean, it was presented in layout view and a north arrow, scale bar, and legend indicating benchmarks, gage box, controls, and stream boundaries were added. The map was then exported into word for the purposes of this study.

3.4.5 Visualizing TLS with ArcScene

When working with maps in ArcGIS it is sometimes difficult to pick out individual objects or areas of interest. There are no point descriptions in a LiDAR scan detailing whether an object is a rock, person, stream, or gage box. There is only hillshade that presents topographic information. As mentioned previously, each LiDAR data set acquired from UNAVCO after 2010 has Red, Green, and Blue (RGB) data assigned to each point in space. The color association with each point was used to create a navigable 3D map using LAStools and ArcScene.

Each row within a .csv LiDAR data set that has RGB attached contains X, Y, Z, R, G, and B values. Using LAStools open source program txt2las.exe it was possible to convert the file from .csv to .las, which is the format ArcScene uses to visualize these RGB data. The .las file was imported into ArcScene like a normal map. To render the map colored, the LAS toolbar was used to change the return value to RGB from elevation.

Within the colored map, relicts can be found throughout the scan. There are two types of relicts found in each LiDAR survey: elevation related relict, and RGB related relict. The elevation relict stems from a person or object not native to the transect being picked up by the scanner inadvertently. This occurs when field members either leave gear within the scanning range or accidentally walk through the scan area while the TLS is still scanning. Two examples are shown in Figure 3-6 and Figure 3-7. The elevation relicts only appear in ArcScene, however, and do not affect elevation extractions mentioned in section 3.5 . The second type of relict related to RGB values occurs after the TLS has scanned an area and begins a panorama photograph of the entire survey area. It is then that the previously mentioned foreign object or field member is caught in the field of vision while the camera snaps a picture. Examples can be seen in Figure 3-8 and Figure 3-9. RGB relicts do not affect the data in any way aside from the distortions of associated colors to points.

FIGURE 3-6 ELEVATION RELICT 1. LOOKING NORTH, A FIELD TEAM SAMPLING MICROBIAL MATS IS CAUGHT IN THE LIDAR SCAN AFFECTING THE LONGITUDINAL DISTANCE OF THE RETURN BEAM. ON LEFT, TEAM MEMBER ON KNEES SAMPLING MATS WHILE ON RIGHT THE OTHER MEMBER IS TAKING NOTES.

FIGURE 3-7 ELEVATION RELICT 2. ANOTHER VIEW LOOKING SOUTH AT THE FIELD TEAM SAMPLING MICROBIAL MATS. ON THE RIGHT, ONE TEAM MEMBER IS ON KNEES COLLECTING SAMPLE WHILE MEMBER ON LEFT IS TAKING NOTES.

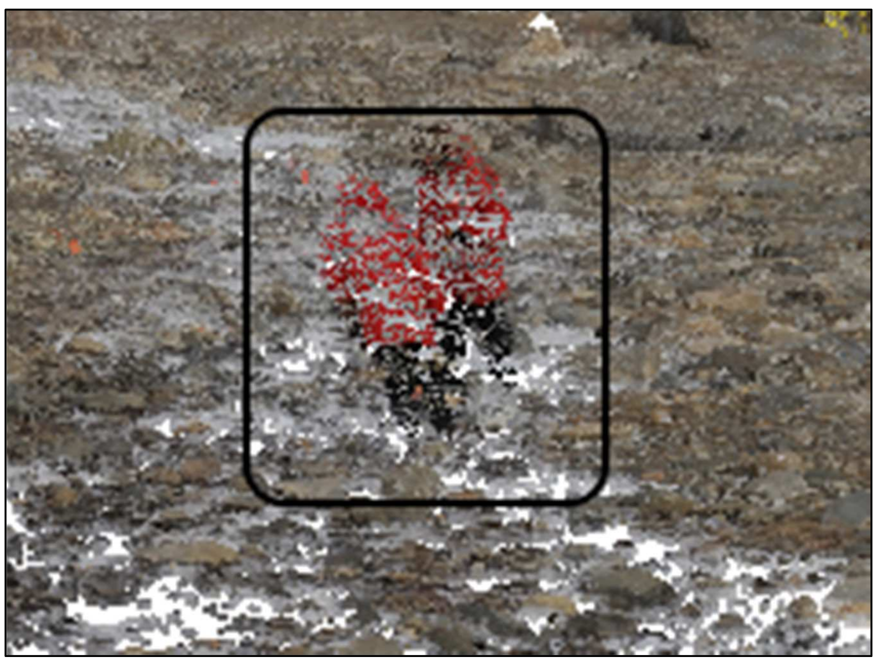

FIGURE 3-8 RGB RELICT 1. FIELD TEAM CAUGHT IN THE VIEW OF THE CAMERA AND NOT LIDAR BEAM. BIG RED JACKETS ARE SEEN WITH BLACK OVERALLS.

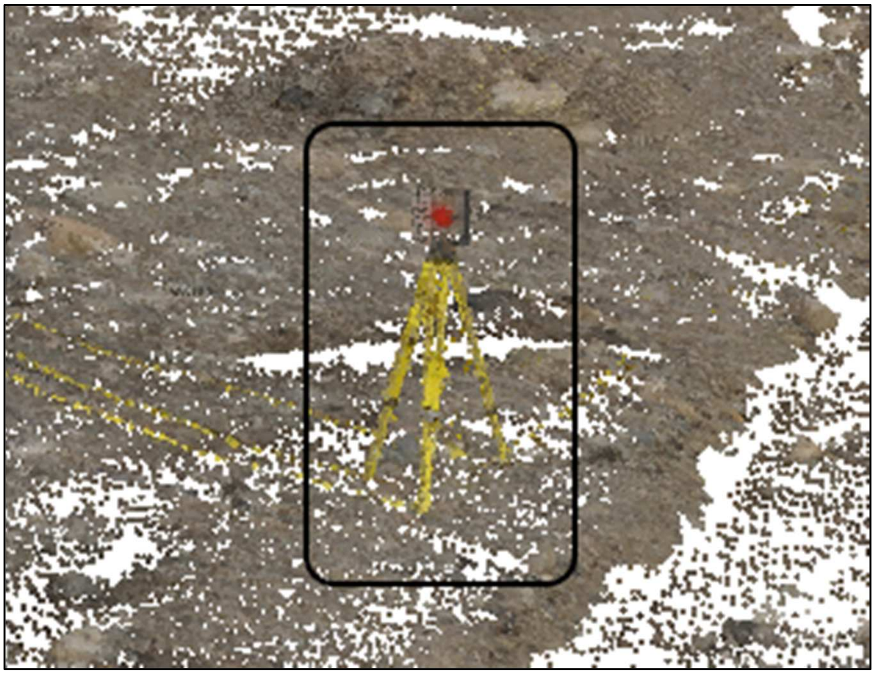

FIGURE 3-9 RGB RELICT 2. REFLECTIVE TRIPOD USED TO REFERENCE SURROUNDING LANDSCAPE LOCATION AND LIDAR SCANNER. RED DISC IS REFLECTOR PROCESSED BY LIDAR SCANNER. PRESUMABLY PLACED ABOVE ONE OF THE TWO BENCHMARKS USED FOR THIS LOCATION.

3.5 Integrating survey data with LiDAR

The surveys conducted by the microbial mat survey teams yielded data on wetted regions of the stream, all four types of algae, stream channel characteristics such as perimeter and thalweg, and prominent features like rocks and BM. These data were compiled into spreadsheets and labeled with X, Y, Z, AFDM, and description. Once the data were imported into ArcMap, elevations were extracted from each X and Y coordinate relative to the DEM and input into a new column within the attribute table. Now the attribute table has the elevation of each point as well as the DEM elevation at the same X and Y coordinates. After this point the survey data can be split in to two different categories: points within the stream channel and points outside. To accomplish this, a stream boundary polygon (Figure 3-10) was created in ArcMap. A clip was performed to create a new file with all the data points within the stream (Figure 3-11), and an erase was performed to create a new file with all the points outside of the stream

(Figure 3-12). After the points were separated, they were exported using export feature attribute to ASCII to a folder linked to Matlab (Guide 1998).

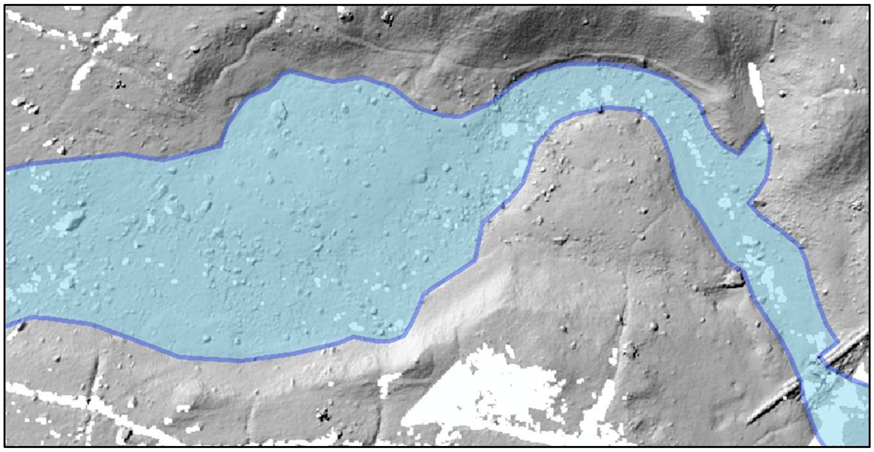

FIGURE 3-10 MICROBIAL TRANSECT WITH STREAM BOUNDARY. THE GREY SURROUNDING AREA IS HILL SHADED TO PROVIDE VISUALIZATION. THE STREAM CHANNEL IN THE MIDDLE WAS CREATED TO SEPARATE POINTS WITHIN THE CHANNEL WHICH ARE PRESUMED TO CHANGE AT GREATER RATES THAN POINTS OUTSIDE THE STREAM CHANNEL IN THE SURROUNDING LANDSCAPE AND BANKS.

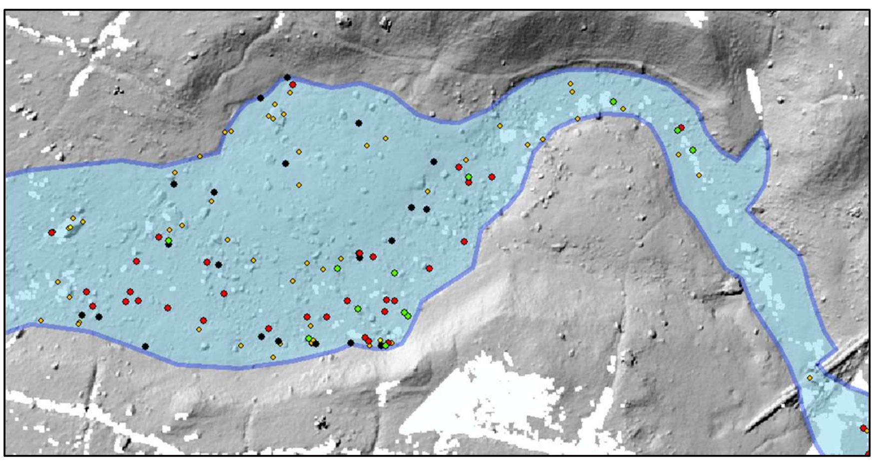

FIGURE 3-11 MICROBIAL TRANSECT WITH POINTS INSIDE CHANNEL. POINTS WERE CLIPPED INSIDE THE CHANNEL TO PROVIDE INSIGHT ON CHANGES HAPPENING INSIDE CHANNEL RELATIVE TO SURROUNDING LANDSCAPE.

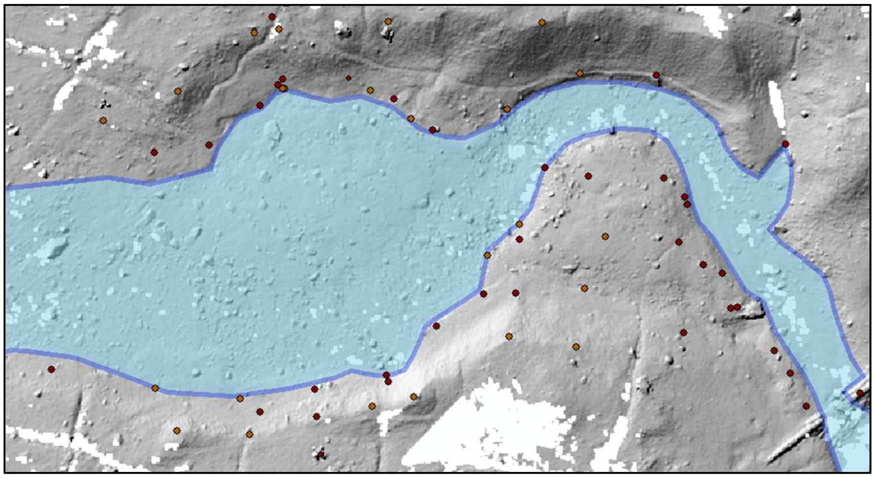

FIGURE 3-12 MICROBIAL TRANSECT WITH POINTS OUTSIDE CHANNEL. POINTS OUTSIDE THE CHANNEL ARE ASSUMED TO BE UNCHANGING WITH RESPECT TO POINTS INSIDE THE CHANNEL WHICH REGULARLY SEE HIGH FLOWS.

With each TS survey of the microbial mat transects there were slight miscalculations stemming from either human error or machine or both. To achieve perfect X, Y, and Z data for each shot, the TS must be erected directly above the first BM, perfectly level to the ground, and have the bubble calibrated to assure the leveling is correct. On the other side of each shot is the rod holder. This team member must make sure that the prism atop the rod is again perfectly level to the ground and is held steady against any winds. All combinations of errors multiply to produce skewed results that can be fixed through some basic corrections. Since the BM elevations were originally measured using GPS technology from 1993, the elevations contained the greatest error. Figure 3-13 shows a typical error in elevation. The entire TS survey is highlighted in blue. There are two parts to the TS survey: the section within the stream channel that is assumed to change with flow, called the clip zone, and the section above the bank that is assumed static throughout time relative to inside the channel, called the erase zone. Since the erase zone is assumed to be unchanging, the average elevation difference between each point in this zone and corresponding location on LiDAR were calculated. The average difference in elevation in the erase zone was then subtracted throughout the entire survey including the clip zone. Figure 3-14 shows a total elevation correction of the entire TS survey and an exaggerated stream channel change highlighted in green. Once the elevations were corrected, actual bed changes for each point in the stream channel were calculated.

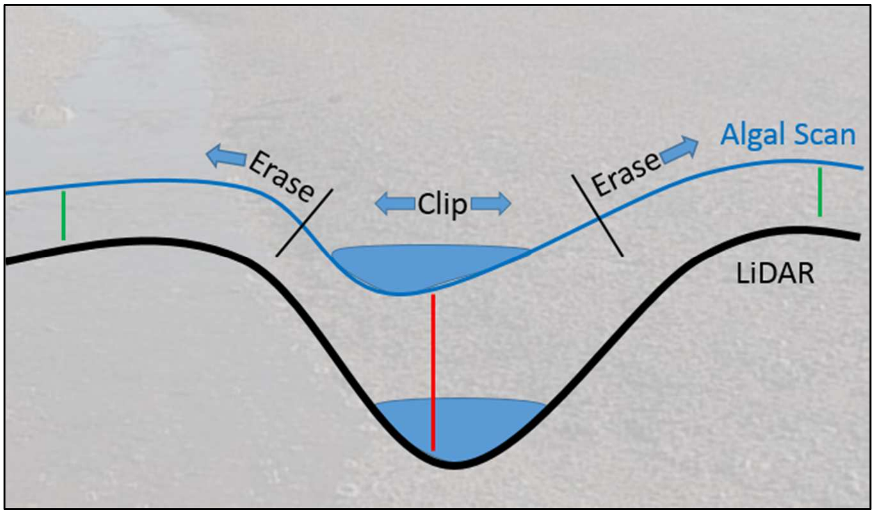

FIGURE 3-13 EXAMPLE OF TOTAL STATION ERROR. THE TOTAL STATION SURVEY (BLUE LINE) IS OFTEN FOUND IN ERROR (RED/GREEN) WITH REGARDS TO ELEVATION. THE ENTIRE SURVEY MUST THEN BE LOWERED OR RAISED TO CORRESPOND WITH THE LIDAR SCAN (BLACK).

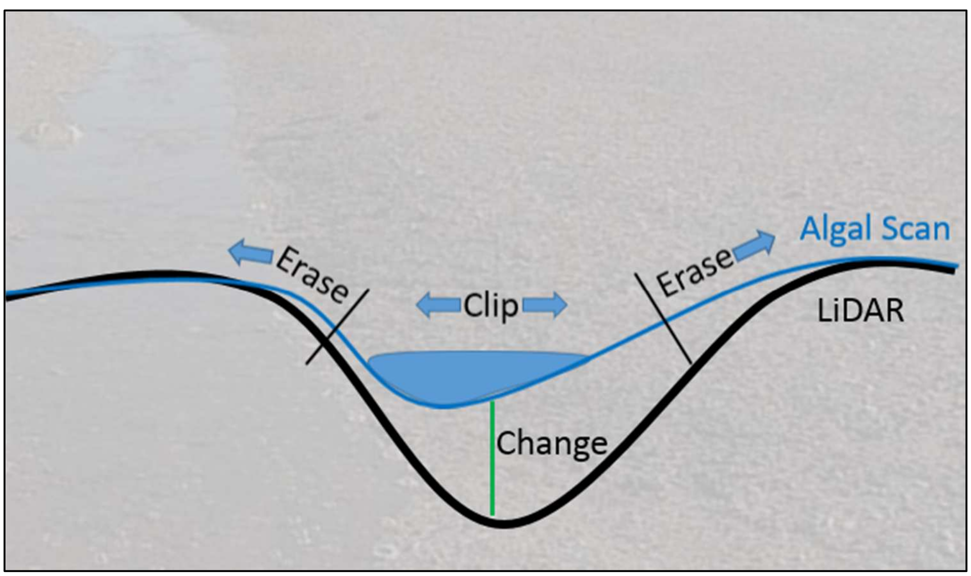

FIGURE 3-14 TOTAL STATION ERROR FIXED. THE ENTIRE TOTAL STATION SURVEY IN THIS FIGURE IS LOWERED TO HAVE THE UNCHANGING LANDSCAPE CORRESPOND TO THE ASSOCIATED LIDAR SCAN. THE DIFFERENCE IN ELEVATION IN THE CHANGING STREAM CHANNEL IS THEN CALCULATED (GREEN).

3.6 Ash Free Dry Mass

Every algae sample that was collected was stored in a whirl pack with stream water and sent back to Crary lab at McMurdo to be analyzed for ash free dry mass (AFDM) and chlorophyll *a* (Chl a). AFDM was determined by drying each sample at 100°C for 24 hours, weighed and then burned at 450°C for 4 hours. The samples were then re-weighed, re-wetted, then dried again to determine mass loss from hydration of sediment (Steinman et al. 1996). Chl a analysis followed the trichromatic method (Strickland 1972) before 2001, and via a fluorometer (Welschmeyer 1994) afterwards. For the purposes of this study, however, only AFDM was used in further analysis.

3.6.1 Relating AFDM to average annual flow

Streamflow for each transect in question was downloaded from the MCMLTER website and plotted against bed change for each type of microbial mat for each stream. For each transect, all flows on record were summed and divided by the total number of seasons with flow to get an average annual volume of water. Every season that had a microbial mat survey then had the streamflow for that stream and season weighted against the average. Seasons with a weighted average greater than 1 were considered higher than average flow years, and seasons with flow less than 1 were considered lower than average flow years. Each microbial mat point with an associated AFDM value was plotted against the weighted average flow for the season of survey.

3.6.2 Relating AFDM to overall bed change

The second AFDM analysis compares AFDM to the amount of local bed change per mat sample. Following methods outlined in Section 3.5 each mat survey point has an associated elevation change in relation to the LiDAR scan. If there is a negative change from the survey season to the LiDAR season then the point in question would have undergone scouring and erosion during the interim. Conversely if there is a positive change, then there would have been sediment or rock deposition. The changes mentioned apply to seasons prior to the season in which the LiDAR scan was taken. Changes after the season of LiDAR would indicate scouring for negative values and deposition for positive values. Each mat survey point containing AFDM data was plotted against a bed change for that point from survey season to LiDAR season.

4 RESULTS & DISCUSSION

4.1 Stream descriptions and streambed changes

Besides the occasional scavenging seabird, the MDV are free of macroscopic life. Disturbance in the MDV is therefore minimal and discharge and large fluctuations in flow patterns are assumed to be the greatest causes of change within the streams (Stanish et al. 2011). This study focuses on channel dynamics of a stream bed. The channels are oversized in that most often stream flow only occupies a portion of the channel, and during flood events new channels can be carved and now occupied by flow. Microbial mats are incorporated in this study to aid in determining these changes by cross referencing their three dimensional locations to known locations derived from LiDAR and differencing the two to detect change. Total annual discharge was also analyzed to determine flood effects on bed change. Seasons with high flow also tend to have higher variability between maximum and minimum flow. Discharge in the MDV is controlled by a number of factors including air temperature, position of the ozone hole, and the presence of high velocity down-valley foehn winds (Doran et al. 2008).

This study assesses 7 different stream transects across the Taylor Valley of the MDV. All but one of the streams outflow into Lake Fryxell on the east side of the valley. Bohner Stream empties into Lake Bonney farther west, higher in elevation, and closer to the polar plateau. The streams are arranged by microbial abundance and can be rated on a harshness index (Esposito et al. 2006, Kohler et al. 2015) to determine which streams are more hospitable to Antarctic life. The scale begins with Canada Stream, which is a short channel with abundant microbial mats dominating most of the reach. The most inhospitable stream in this study is Bohner Stream, which rapidly descends a mixture of boulder pavement and loose sand bank causing large shearing forces that make microbial mats sparse and hidden in a few protected eddies.

4.1.1 Canada Stream F1

DESCRIPTION

Canada Stream drains the glacier of the same name and terminates in Lake Fryxell. It is typically the first stream to flow during the austral summer and possesses one of the most diverse and abundant microbial communities in the MDV. It also has one of the most extensive and complete records of flow dating back to the first visits during the 1990/91 season. Canada Stream is therefore considered the standard when comparing MDV streams. Flow throughout the season follows a smooth transition from early season low flows, to peak summer highs, and back down to end of season lows. Diel variations are very apparent with a predictable peak around 18:00 NZT when the contributing area of Canada Glacier to Canada Stream is most affected by the sun's aspect on the glacier face. Canada Stream is located inside of Antarctic Specially Protected Area (ASPA) 131 requiring human traffic and research be limited to what is necessary, in addition, all helicopter traffic is restricted, including landing and fly overs.

Beginning at the glaciers surface, Canada Stream flows through a series of small ponds with abundant microbial communities. The ponds collect nearby glacial meltwater in addition to flow draining the upper glacier where no microbial mats have been recorded. The stream then follows a shallow gradient of 0.03 m/m through the transect and past the control where it then descends a short cascade with abundant microbial mats and braids out into Canada Delta where it terminates into Lake Fryxell. Worth mentioning is the large wetted zone in the channel on the north side of the transect that contains one of the most extensive black microbial mats in this study.

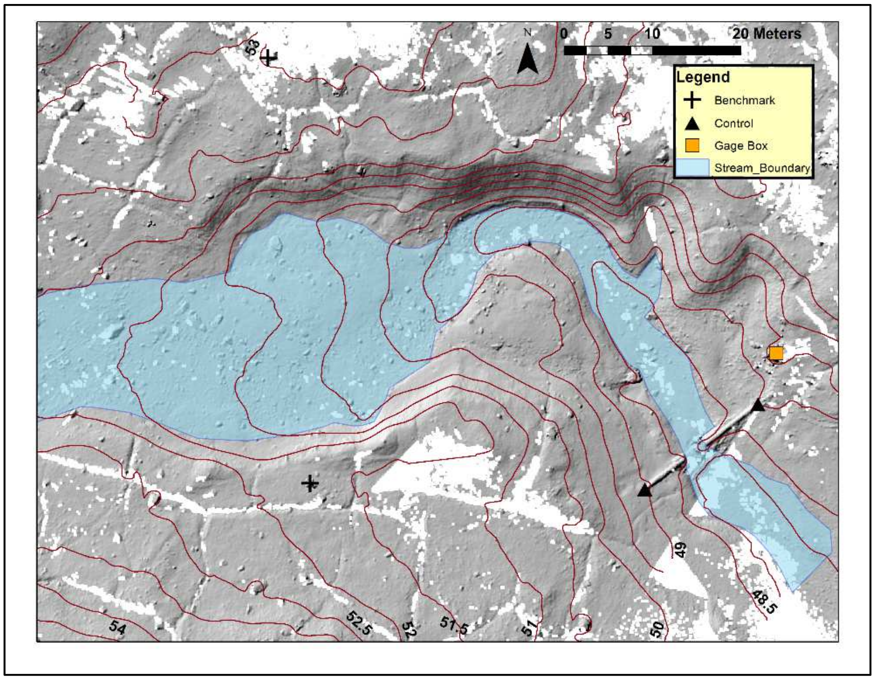

FIGURE 4-1 MAP OF CANADA STREAM F1. TRANSECT IS LOCATED BETWEEN NORTH AND SOUTH BENCHMARKS AND EXTENDS APPROXIMATELY 20 METERS BOTH UPSTREAM AND DOWNSTREAM. FLOW ORIGINATES FROM THE WEST AND CONTINUES DOWNSTREAM TO THE SOUTHEAST. CONTOURS ARE IN 0.5 M INTERVALS.

BED CHANGE ANALYSIS

Figure 4-2 shows little variation in bed change between seasons. This is expected as the flow along Canada Stream is generally slow. Silt content is also low as any sediment originating from the glacier would be deposited within the lakes upstream of the transect. As relative change that is detected falls within standard error for manual surveys, Canada Stream may be considered static. There was a survey conducted on Canada Stream in 2000/01 but points were well outside of predicted locations such as gage box and flume that are assumed to never move. Therefore the survey for the 2000/01 season was not considered in this study. Other problems with the data from Canada Stream are seen in Figure 4-4. Hollow bars indicate seasons where there were not enough points outside the stream channel to detect significant change within the stream channel. When there are fewer than three survey points outside the stream channel where geomorphology is expected to be orders of magnitude slower than inside the stream channel, it is not possible to relate points within the stream channel to other seasons.

All four types of microbial mats are found in Canada Stream and are continually found in similar locations each survey season. The orange and red mats are located in the faster flowing sections of the stream typically in the thalweg and form filamentous stalks that allow them to continually grow despite large flows. The north side of the channel seen in Figure 4-1 is a wetted zone that only sees flow during high discharges and as such holds expansive black mats.

Figure 4-3 shows the overall volume of flow for the 7 analyzed streams in gray and Canada Stream in Blue. There are three distinct flood events that occurred during the 2001/02, 2008/09, and 2010/11 seasons in order of their magnitude. As mentioned above, of the 7 streams represented in this study, Canada Stream has the highest annual volumetric flow. As the flows are presumably smoothed out by the upstream ponds, however, large variations occur over a longer timespan than in other streams that can see sudden spikes in discharge.

Using previously drawn contour maps, a comparison was made between the maps and the survey conducted during the same season of 1993/94. Figure 4-5 shows a comparison of topo data and contour data from the same season and indicates that the digitized contour plot does not conform to a low standard error and therefore was not considered in this study. The 1993/94 topo survey, on the other hand, has a much smaller standard error and shows a relative elevation difference of around 6 cm. Only the survey data and not the contour plot was used for this study.

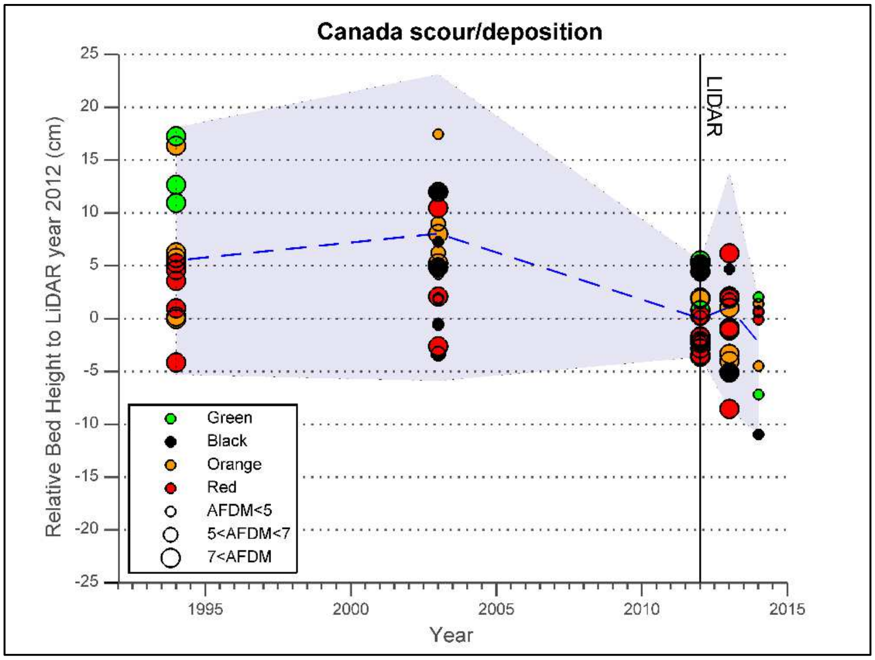

FIGURE 4-2 RELATIVE BED CHANGE PROFILE FOR CANADA STREAM. ALL FOUR TYPES OF ALGAE ARE FOUND IN CANADA STREAM FOR ALL SURVEYS CONDUCTED. AVERAGE CHANGE DETECTED IS WITHIN STANDARD ERRORS AND NEVER EXCEEDS 8 CM CHANGE WITHIN PERIOD OF RECORD. LIDAR SCAN WAS TAKEN IN 2011. ALL OTHER ELEVATIONS ARE BASED OFF OF THIS SCAN.

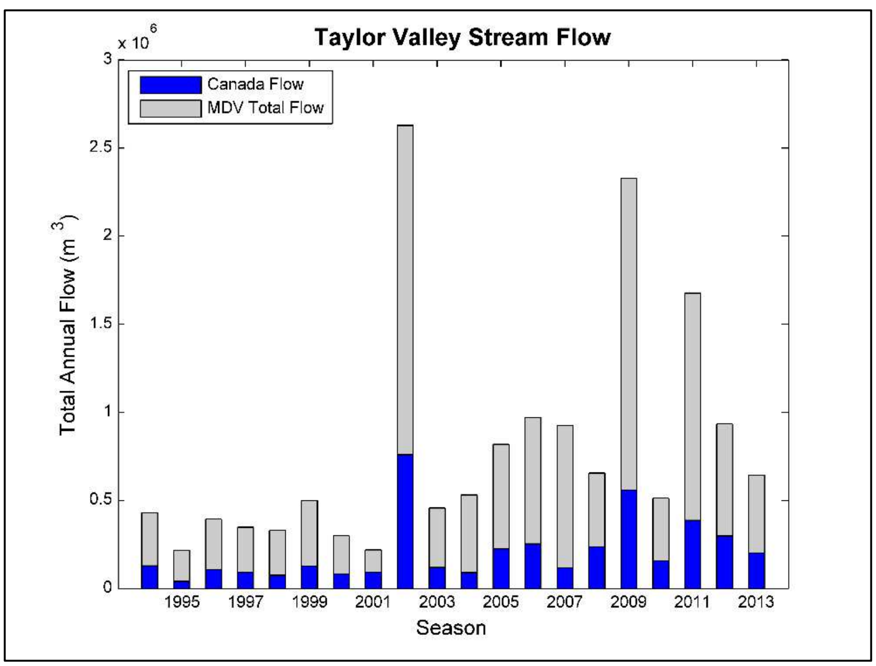

FIGURE 4-3 TOTAL ANNUAL FLOW FOR MDV AND CANADA STREAM. CANADA STREAM IS A MAJOR CONTRIBUTOR OF WATER TO LAKE FRYXELL. OF THE 7 STREAMS ANALYZED, CANADA STREAM HAS THE LARGEST OVERALL VOLUME OF WATER FOR EACH SEASON.

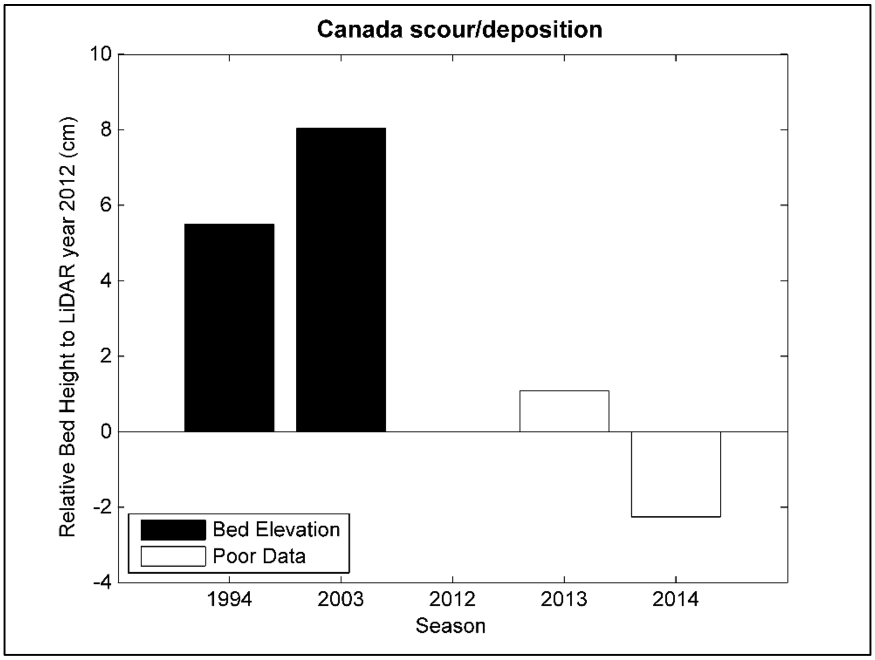

FIGURE 4-4 AVERAGE RELATIVE ELEVATION CHANGE FOR CANADA STREAM. RELATIVE BED CHANGE FOR CANADA STREAM NEVER EXCEEDED 8 CM WHICH IS CONSIDERED WITHIN STANDARD ERROR FOR SURVEY. HOLLOW BARS REPRESENT SEASONS WITH LESS THAN 3 POINTS OUTSIDE STREAM CHANNEL.

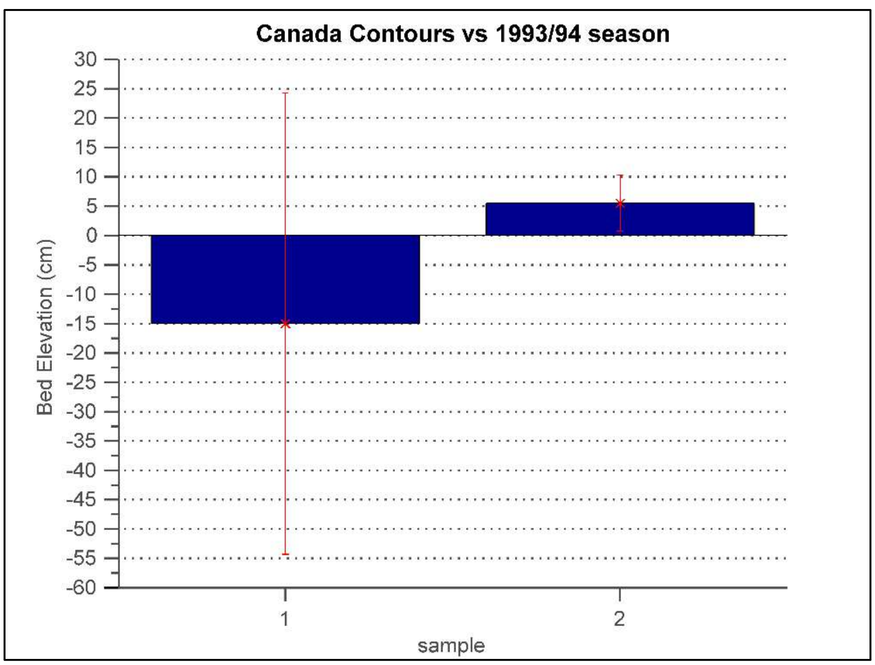

FIGURE 4-5 CANADA TRANSECT CONTOUR PLOT COMPARISON TO 1993/94 SURVEY. ERROR FOR CONTOUR LINES IS VERY LARGE AND THEREFORE NOT CONSIDERED FOR CHANGE DETECTION IN THIS STUDY WHILE SURVEY DATA HAS SMALL ERROR AND SHOWS AN AVERAGE RELATIVE ELEVATION CHANGE OF 6CM.

DISCUSSION

Canada Stream has a very shallow gradient through the transect and as such very little change can be detected. Although there is considerable flow through the channel, it conforms to a regular pattern with low variability allowing the microbial mats to thrive. Seen here are all four types of microbial mats (green, black, orange and red). All are found in their preferred locations, with orange and red being found in the deeper sections of the channel while black mats are located in seepage and wetted zones that rarely see high flows but are continually wet. Very little change was detected on Canada Stream. This is expected as there is little sediment influx into the transect as it is all deposited in the upstream ponds. Despite high flows, the gradient is too shallow to cause significant scouring.

4.1.2 Green Creek F9

DESCRIPTION

Green Creek is a short creek originating on the south end of Canada Glacier and terminating approximately 1.2 km in Lake Fryxell. Microbial abundance is high throughout the creek bed as the gradient does not exceed 0.05 m/m. Three of the four types of microbial mats are found here excluding red mats. Floods sometimes occur on Green Creek when the sun is in the south, but due to this aspect, overall flows are generally lower than in other streams with more northerly source glacier aspects.

Figure 4-6 shows a detailed map of the transect, control, and gage. The area is located approximately 200 meters upstream from the terminus in Lake Fryxell. The north bank is deeply incised and made up of gravel and sand while the south side is much shallower and has continuous wetted zones that are preferred by black mats. Located approximately 100 meters north is Bowles Creek described in section 4.1.3 .

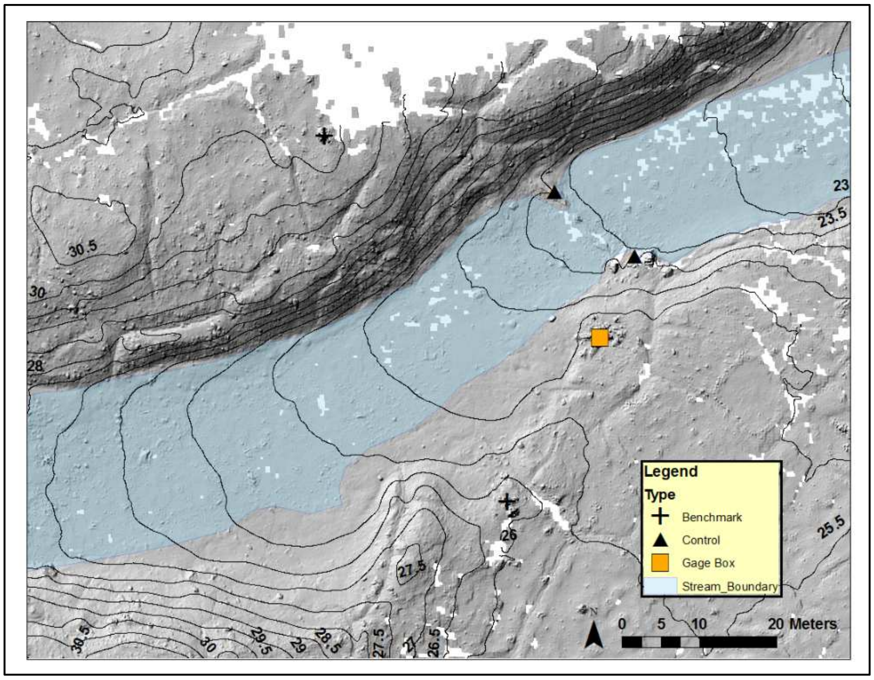

FIGURE 4-6 MAP OF GREEN CREEK F9. FLOW ORIGINATES IN THE WEST AND CONTINUES FLOWING EAST INTO LAKE FRYXELL APPROXIMATELY 200 METERS FARTHER DOWNSTREAM. CONTOURS ARE IN 0.5 M INTERVALS

BED CHANGE ANALYSIS

Green Creek can be considered a static stream in that it rarely experiences flow events large enough to cause change. Figure 4-7 shows a stream channel that never exceeds a few centimeters of change in the vertical, but has large variation in the early seasons of record. The causes for the large variation are unknown. Potentially winter winds blew sand onto the glacier and high flows sent the particles downstream where they settled along the transect where velocities are low. Alternatively the channel took another path from 1993 to the season of LiDAR and was not detected or documented in individual surveys. Figure 4-8 shows flow patterns for Green Creek in comparison to the other six streams analyzed in this study. The three flood years are not as detectable when looking solely at Green Creek. Even when other streams saw low flows, Green Creek had average flows that make it difficult to discern a flood year from a normal year. When comparing flood events to relative bed change in Green Creek, very little is correlated and it appears that floods do not affect Green Creek.

Figure 4-9 shows average bed change along Green Creek for each season a survey was conducted. Average change does not exceed 6 cm, which is within standard error and can be assumed to be unchanging. The 2012/13 season survey did not contain enough points outside of the stream channel to significantly detect change within the channel. As with all other streams, Figure 4-10 compares the contour plot of Green Creek to the survey conducted during the same season of 1993/94 and concludes that the errors were too large for the contour plot to be included in this study.

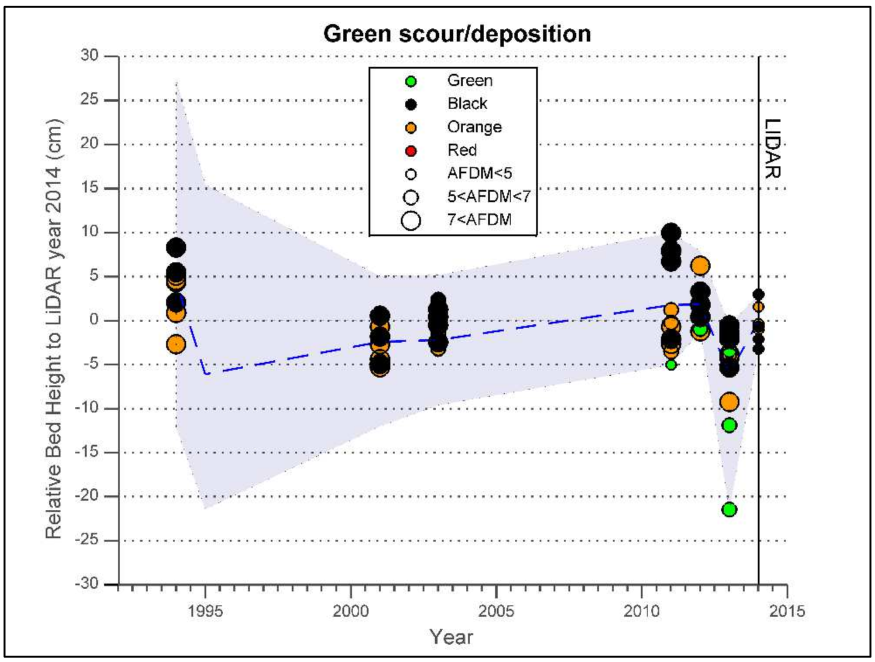

FIGURE 4-7 RELATIVE BED CHANGE PROFILE FOR GREEN CREEK. ALL TYPES OF MICROBIAL MATS ARE FOUND HERE WITH THE EXCEPTION OF RED ALGAE. THE ORIGINAL SURVEY SAW AN AVERAGE BED ELEVATION APPROXIMATELY THE SAME AS DURING THE LIDAR SCAN, BUT VARIATION IN THE SURVEYED POINTS EXCEEDS 25 CM DIFFERENCE. GREEN CREEK IS GENERALLY STATIC AND SEES VERY FEW FLOWS ABLE TO CAUSE LARGE CHANGES IN STREAM BED.

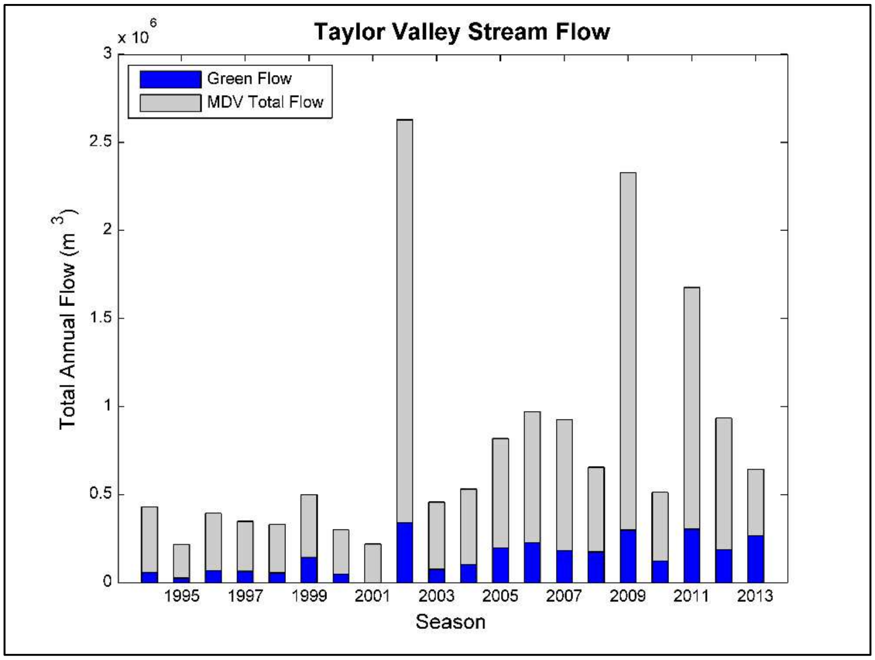

FIGURE 4-8 TOTAL ANNUAL FLOW FOR MDV AND GREEN CREEK. YEARS WITHOUT FLOW FOR GREEN CREEK ARE EITHER MISSING DATA OR NO FLOW WAS RECORDED FOR THAT SEASON.

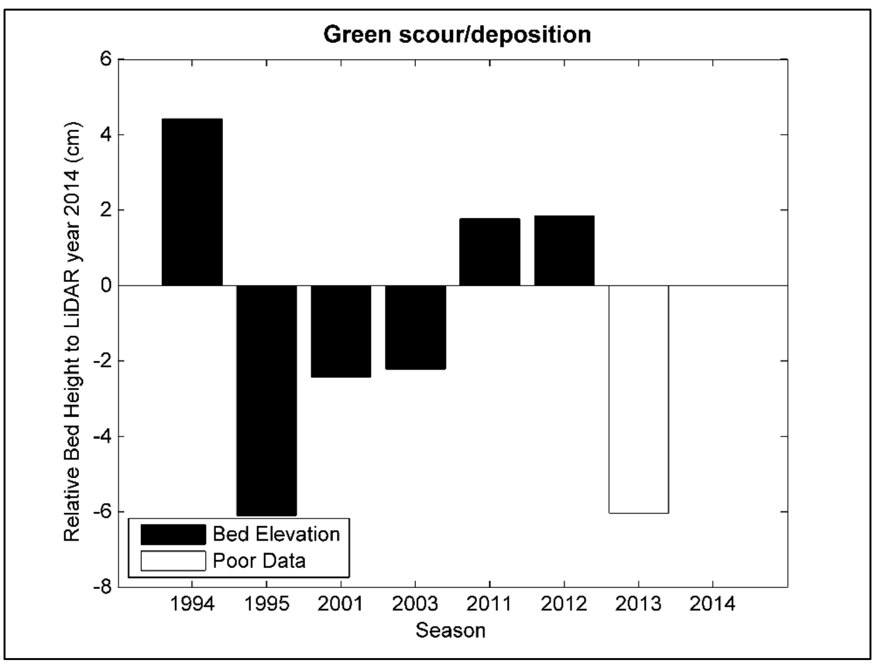

FIGURE 4-9 AVERAGE RELATIVE ELEVATION CHANGE FOR GREEN CREEK. THE 2012/13 SEASON DID NOT HAVE ENOUGH POINTS OUTSIDE OF STREAM CHANNEL TO SIGNIFICANTLY REPRESENT AREA WITHIN STREAM CHANNEL.

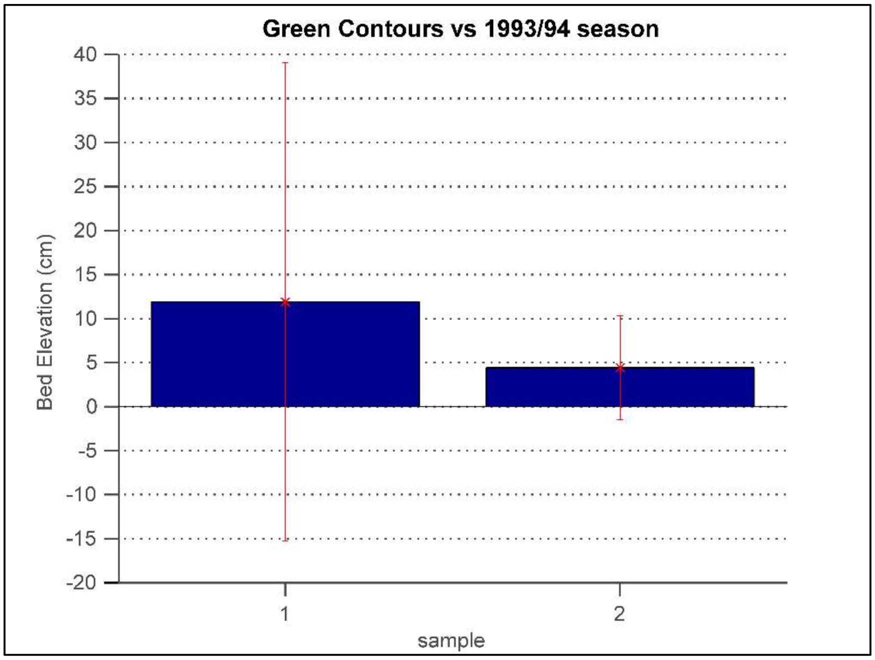

FIGURE 4-10 GREEN TRANSECT CONTOUR PLOT COMPARISON TO 1993/94 SURVEY. AS TYPICAL, THE CONTOUR PLOT HAS A STANDARD ERROR THAT DOES NOT ALLOW AN INCLUSION INTO THIS STUDY FOR ANALYSIS.

DISCUSSION

Overall, Green Creek has a stable bed and does not experience large enoughfluctuations in flow to cause scouring of the channel. There are, however, interesting variations during the first two seasons on record. The average bed elevation remains unchanged compared to LiDAR, but the variation is +/- 20 cm shown in Figure 4-7. Perhaps Green Creek had a different structure twenty years ago and freeze-thaw events eventually caused the creek to follow a different path or there was a particularly dusty winter causing elevated sediment loads to be deposited within the channel after being captured on the glacier. Looking at Bowles Creek section 4.1.3 below might present further insight on changes occurring in Green Creek due to proximity and similar source.

4.1.3 Bowles Creek

DESCRIPTION

Bowles Creek is a short (0.9km) creek 100 meters to the north of Green Creek (Figure 4-11). It is fed via a series of small shallow ponds at the southeast terminus of Canada Glacier. During high flows, water originating from the Canada Glacier can overflow the upstream ponds and contribute to and from adjacent Green Creek. Bowles Creek terminates in Lake Fryxell approximately 15 m from the outlet of Green Creek. There is no gage currently located on Bowles Creek, but site visits are done weekly while there is flow and can be correlated to Green Creek due to the close proximity and similar contributing aspect of the Canada Glacier with a short delay. Bowles Creek is composed of a stone pavement bed and also has the shallowest gradient (0.025 m/m) in this study. Because of low flows and shallow gradient, microbial mats are abundant in Bowles Creek.

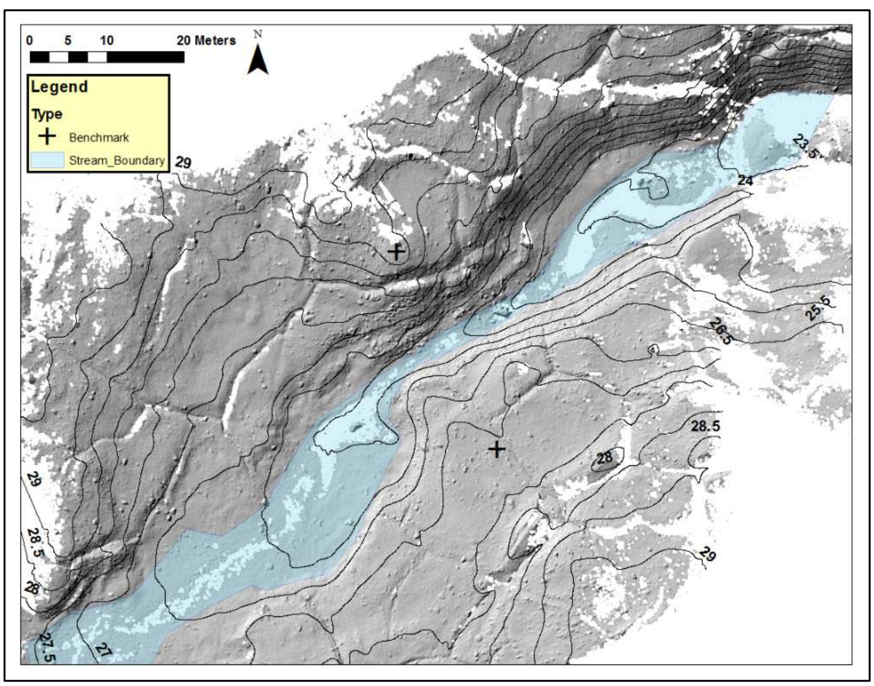

FIGURE 4-11 MAP OF BOWLES CREEK. THE FLOW ORIGINATES IN THE SOUTHWEST AND CONTINUES NORTHEAST UNTIL IT TERMINATES INTO LAKE FRYXELL. NOTE THAT THERE IS NO CONTROL OR GAGE BOX AT THIS LOCATION SO ALL FLOW IS INFERRED FROM GREEN CREEK TO THE SOUTH APPROXIMATELY 100 METERS. CONTOURS ARE IN 0.5 M INTERVALS.

BED CHANGE ANALYSIS

Bowles Creek consists of a narrow channel and a stable stone pavement. Figure 4-12 shows that there is very little bed change throughout time. Low flows and a shallow gradient contribute mostly to this. Black mats tend to stay in stable zones that do not see high flows while an orange mat outlier during the 2002/03 season is surveyed almost 20 cm higher than the same location during the LiDAR scan of 2013/14. During the 2011/12 season there is a drop in streambed elevation, but upon further inspection, levels during this season were shot using a benchmark on the transect of Green Creek located approximately 100 m away and are labeled "poor" as indicated in Figure 4-14. Measuring levels with a tripod from that distance can account for these errors. Similar to Green Creek and draining the same series of ponds, Figure 4-13 was created using the recorded flow at Green Creek gage site. The flow is minimal even during flood years when overall flow maybe doubles whereas for other streams they may see a 10-fold increase in overall flow during a season. It should be noted that seasons with no flow (i.e. no blue bar graph in Figure 4-13) indicates either a season of no flow, or no record of flow due to malfunctioning gage or corrupt data. Again the volumetric flow is for Green Creek as they are analogous. Plotting contour lines for Bowles creek (Figure 4-15) show an almost zero change in streambed elevation when compared to present conditions. Regardless, the error is too great to be of proper use for this study.

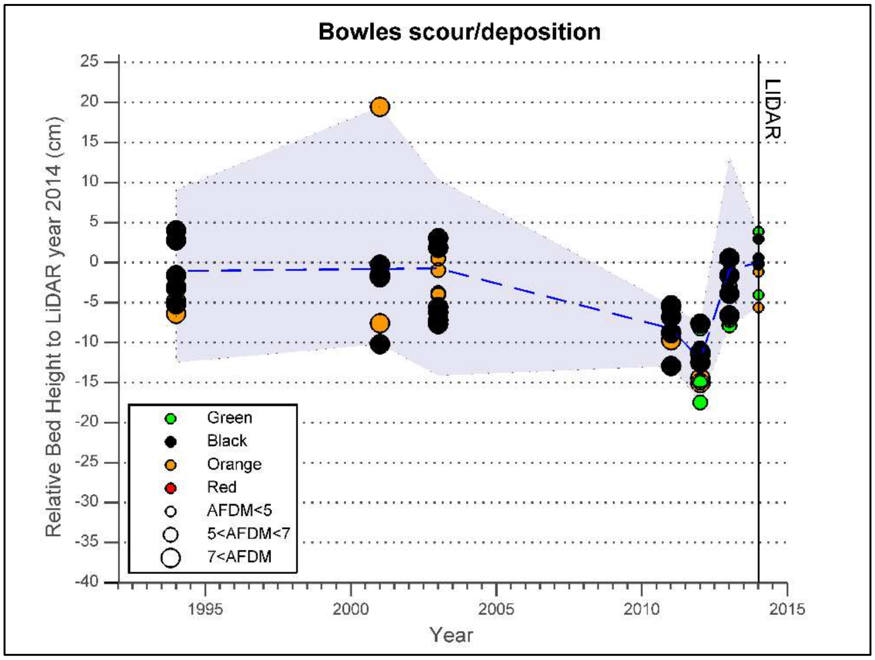

FIGURE 4-12 RELATIVE BED CHANGE PROFILE FOR BOWLES CREEK. AVERAGE CHANGE SEEN AT BOWLES CREEK HOVERS AROUND ZERO AS IT HAS THE LOWEST GRADIENT OF ANY STREAM. THREE OF FOUR MICROBIAL MAT TYPES ARE FOUND IN BOWLES CREEK EXCLUDING RED ALGAE. VARIATIONS IN BED CHANGE MAY BE EXPLAINED BY STANDARD ERROR IN SURVEYS

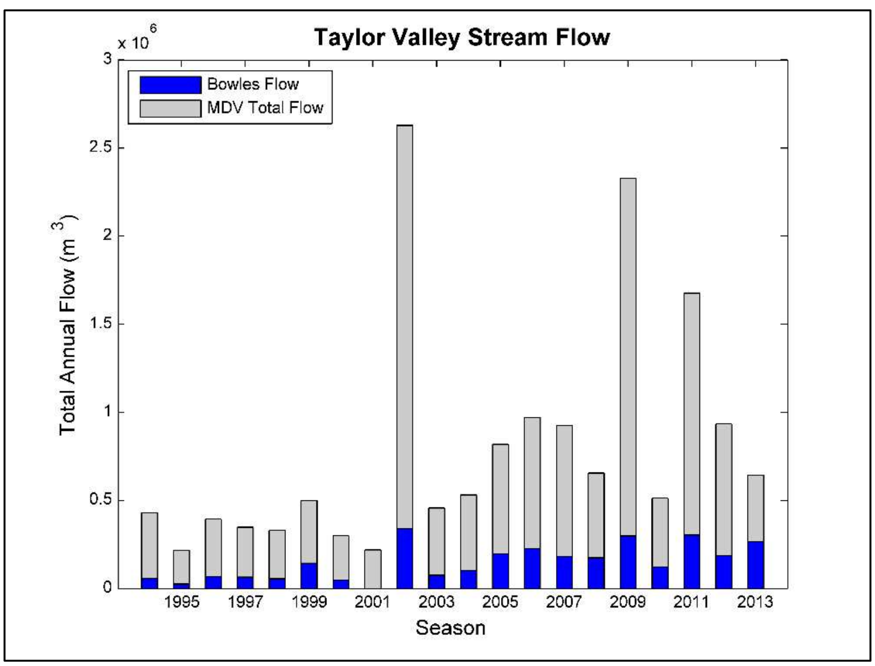

FIGURE 4-13 TOTAL ANNUAL FLOW FOR MDV AND BOWLES CREEK. HERE FLOW IS NOT ACTUALLY BOWLES CREEK DUE TO NO GAGE AT SITE. DATA IN BLUE IS REPRESENTED BY GREEN CREEK AS THEY SHARE SIMILAR FLOW PATTERNS, PEAKS, AND FLUCTUATIONS.

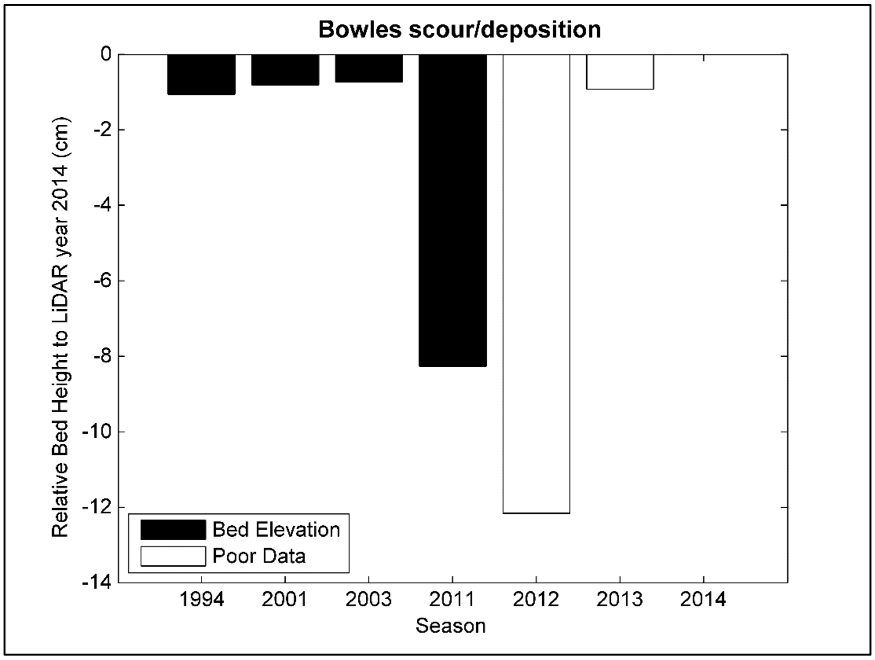

FIGURE 4-14 AVERAGE RELATIVE ELEVATION CHANGE FOR BOWLES CREEK. HIGHLIGHTED IN HOLLOW BOXES ARE SEASONS IN WHICH THERE WERE EITHER FEWER THAN 3 POINTS OUTSIDE THE STREAM CHANNEL BOUNDARY DURING THE SURVEY OR FOR THE 2012 SEASON A GREEN CREEK BENCHMARK 100M AWAY WAS USED INSTEAD OF A NEARBY BOWLES CREEK BENCHMARK. SHOOTING POINTS FROM THIS DISTANCE CAN EXPLAIN THE LARGE CHANGE.

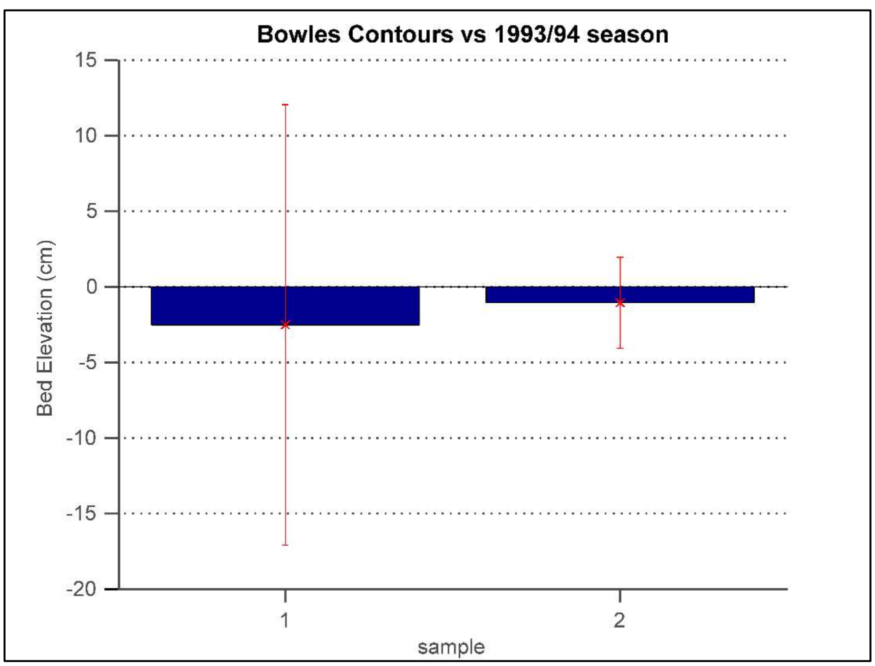

FIGURE 4-15 BOWLES TRANSECT CONTOUR PLOT COMPARISON TO 1993/94 SURVEY. SIMILAR ELEVATIONS ARE SEEN BETWEEN THE TWO METHODS, BUT THE ERROR FOUND IN THE CONTOUR PLOTS CAUSES IT TO BE DISMISSED AS PLAUSIBLE IN THIS STUDY.

DISCUSSION

Bowles Creek is fairly shallow, contains extensive microbial mats, and is assumed to be unchanging. A comparison between Green Creek (Figure 4-7) and Bowles Creek (Figure 4-12) should discern and explain the large variations found in Green Creek during the first seasons on record. Unfortunately no correlation between the two sites was found explaining the variations. Bowles Creek, however, was found to have an interesting erosion event uncovered when comparing this study's only consecutive LiDAR scans of the same transect. Bowles Creek transect was scanned in 2011/12 and again in 2013/14. Using two LiDAR scans it was determined that there was significant loss from permafrost degradation approximately 50 meters upstream of the transect. Briefly, two LiDAR scans were generated into grids containing cell-by-cell elevations. The two grids were then overlain and subtracted from each other using a method known as geomorphic change detection (Wheaton et al. 2010). It was found that Bowles Creek bank lost approximately 0.5 meters of sediment from a 3 meter by 3 meter area near the southern bank. Although little change was detected in the transect, repeat LiDAR scans found a degrading permafrost region that was previously undetected using traditional methods. Further details into the permafrost degradation event and methods can be found in Section 7 (Recommendations).

4.1.4 Upper Delta Stream

DESCRIPTION

Delta Stream is the longest within the Taylor Valley at 11.2 km and cuts through a series of perched lacustrine deltas that are relicts of Holocene Glacial Lake Washburn(Hall et al. 2000a); thus the name Delta. The stream has two established transects within its stretch. The first is at the gage near the outlet into Lake Fryxell and the second is located 3 km upstream to the south and approximately 200 meters higher in elevation. This study focuses on the upstream transect (F10_upper) seen in Figure 4-16.

The upstream transect consists of a wide channel with a stone pavement similar to Green Creek. The upper reach has a moderate gradient of 0.1 m/m and is abundant in microbial mats. The level of microbial mat abundance in the upper transect continues until about 0.5 km from the outlet into Lake Fryxell (Mcknight et al. 1998). Upper Delta transect is abundant in black mats that prefer the wetted regions within the outskirts of the stream to the faster moving thalweg. The high concentration of AFDM within the samples indicates the wetted region is either occasionally dampened with slow moving water, or water is wicked via capillary action, which allows the fragile black mats to proliferate.

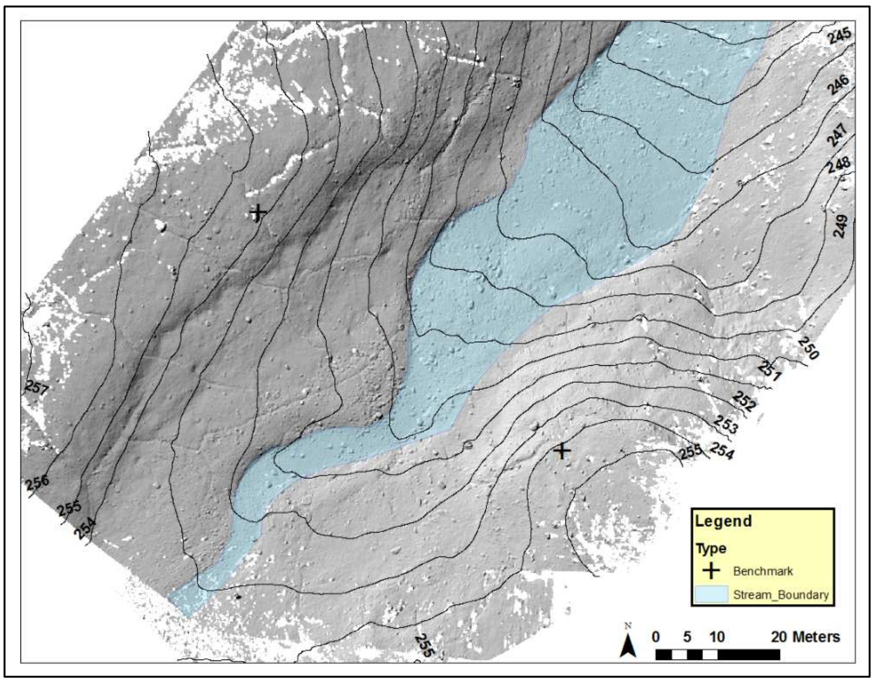

FIGURE 4-16 MAP OF UPPER DELTA TRANSECT F10_UPPER. FLOW BEGINS IN THE KUKRI HILLS FROM HOWARD GLACIER AND FLOWS FROM THE SOUTHWEST TO NORTHEAST ALONG THE LONGEST STREAM IN THIS STUDY AND THE TAYLOR VALLEY AT 11.2 KM. THERE ARE TWO TRANSECTS ALONG DELTA STREAM, AND THIS FIGURE DESCRIBES THE UPPER TRANSECT APPROXIMATELY 3 KM UPSTREAM OF THE OUTLET INTO LAKE FRYXELL WHERE FLOW IS RECORDED AT DELTA STREAM GAGE. CONTOURS ARE IN 1 M INTERVALS.

BED CHANGE ANALYSIS

As seen in Figure 4-17, there is very little seasonal change in average bed elevation. There is, however, variability within the maximum and minimum extent of change. The variability within the data can be explained by survey error, rock mobility, or areas of active thermokarst. Surface deflation of a wetted region may explain the single black mat outlier during the 2002/03 season. The figure also indicates the average bed elevation for Upper Delta to be about 4 cm higher than the elevation at the time of the LiDAR scan (2013/14). No significant measured change occurs after the flood of 2001/02, but the survey indicates a scouring event between 2003 and 2011 seasons possibly caused by either of the two floods that occurred in this period. There were extensive mats found during the 1997/98 season but due to corrupt data, plots were not made of that season.

Figure 4-19 shows that there is very little overall change in the Upper Delta transect. There is some variation between microbial mat points, but as a whole, Upper Delta can be assumed to be static. In addition, the 2011 season did not contain a significant number of points outside of the stream channel to allow for a good representation of change.

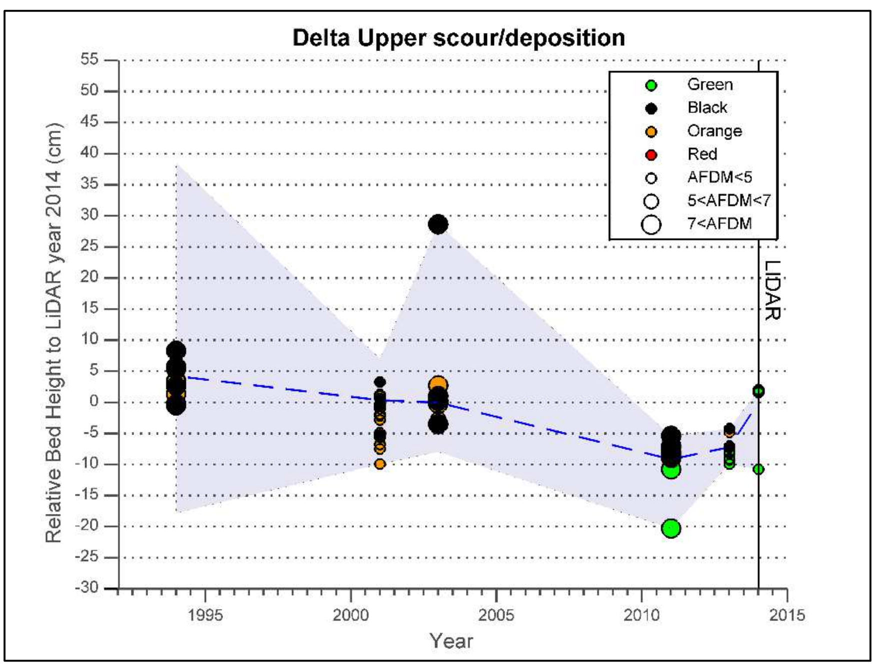

FIGURE 4-17 RELATIVE BED CHANGE PROFILE FOR UPPER DELTA. LARGE VARIATIONS OCCUR IN AVERAGE BED ELEVATION WITH A CONSISTENT DOWNWARD TREND INDICATING A LOSING BED SYSTEM. BLACK ALGAE ARE MOSTLY FOUND HERE AS THERE ARE LARGE SEEPAGE ZONES LOCATED ALONG THE TRANSECT.

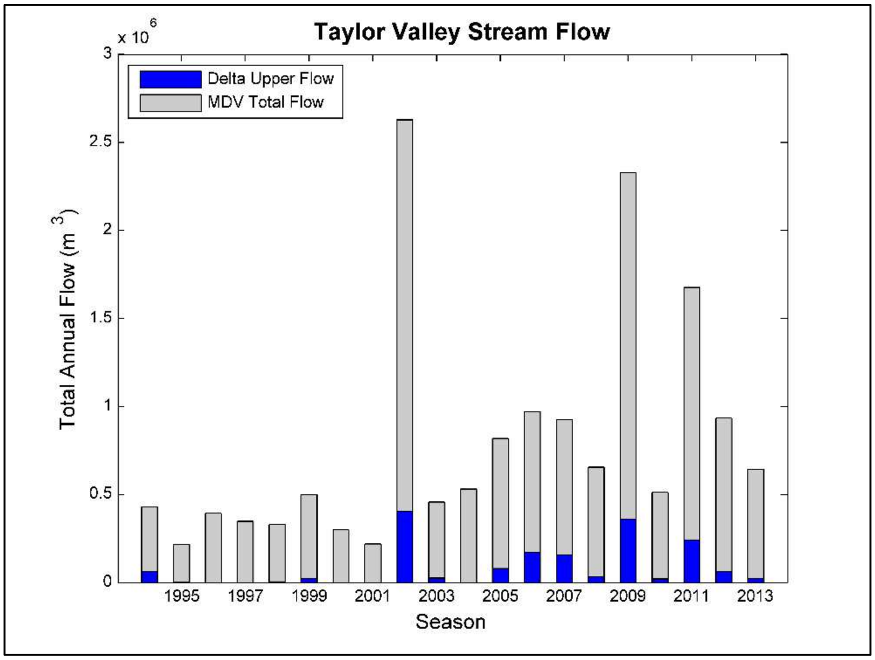

FIGURE 4-18 TOTAL ANNUAL FLOW FOR MDV AND DELTA STREAM. THE PLOTTED FLOW IS FOR DELTA GAGE SITE LOCATED 3 KM DOWNSTREAM. LOSSES AND GAINS MAY HAVE OCCURRED BETWEEN REACH. YEARS PLOTTED WITH NO FLOW INDICATE A SEASON IN WHICH NO FLOW OCCURRED AT SITE FOR SEASON, OR GAGE AND DATA WERE FAULTY AND NO DATA WERE RECOVERED.

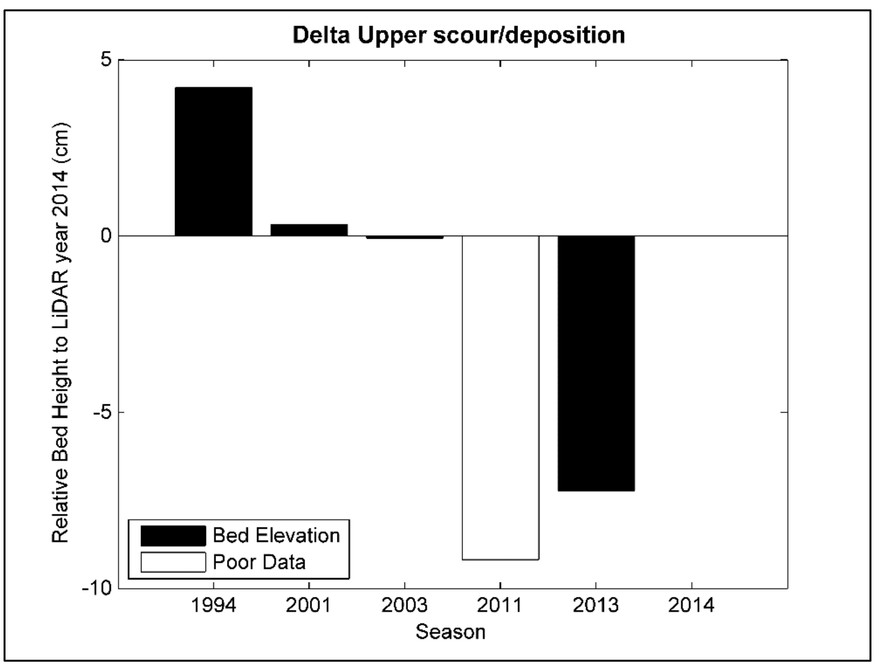

FIGURE 4-19 AVERAGE RELATIVE ELEVATION CHANGE FOR UPPER DELTA STREAM. VERY LITTLE AVERAGE CHANGE IS DETECTED AT THIS SITE. THE 2011 SEASON SURVEY CONTAINED LESS THAN 3 VIABLE POINTS OUTSIDE THE STREAM CHANNEL SO DATA IS ESTIMATED AS POOR.

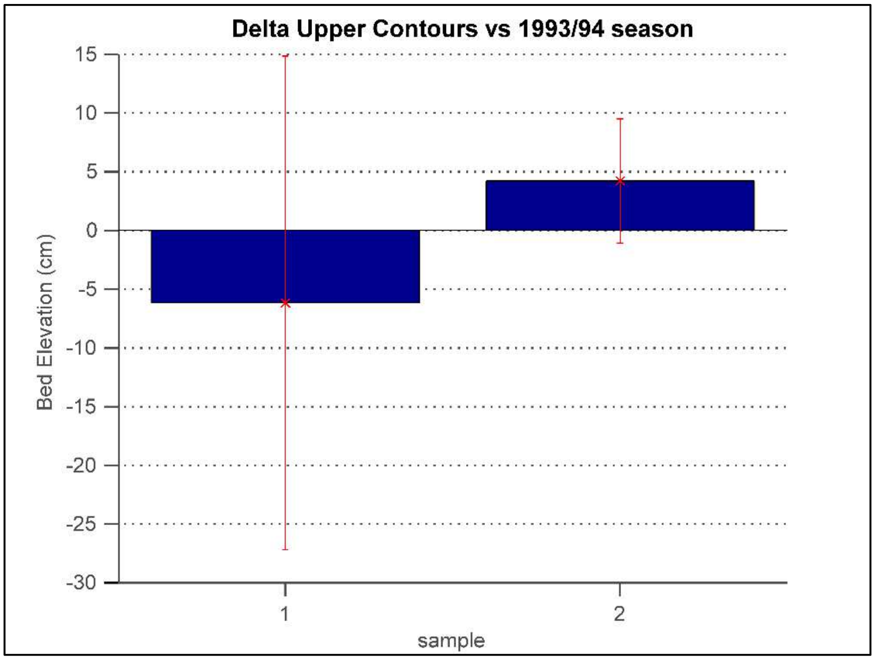

FIGURE 4-20 UPPER DELTA TRANSECT CONTOUR PLOT COMPARISON TO 1993/94 SURVEY. AS TYPICAL WITH CONTOUR PLOTS, AVERAGE BED CHANGE IS WITHIN BOUNDS, BUT STANDARD ERROR IS UNACCEPTABLE FOR USE IN THIS STUDY.

DISCUSSION

Upper Delta Stream (Figure 4-18) flow was determined from the gage at Lower Delta site. Some years do not have plotted flow because either runoff from the Howard Glacier did not reach the gage site 11.2 km away during a low flow season, or the gage was faulty and no workable data was recovered for the season. Regardless, Upper Delta transect may have seen flow during seasons with no plotted flow due to its closer proximity to the source glacier. Delta Stream in general does not have extreme flood events and is not considered a major contributor of flow into Lake Fryxell; it is the 3rd smallest contributor in this study ahead of Von Guerard Stream and Huey Creek. When there is a flood event, however, Delta Stream has an accentuated total flow pattern. During low flow years, Delta Stream contributes approximately 9% of total overall flow in streams considered in this study, while during the three flood years Delta Stream contributed over 15% of overall flow. This is most likely due to the length of the stream allowing significant evaporation and hyporheic filling. When the hyporheic zone is saturated during a flood season, a higher percentage of melt water generated at the source glacier will make it the entire stretch to the gage site near Lake Fryxell.

All seasons of survey except 2000/01 found microbial mats with high AFDM concentrations. A possible reason for this could be the extremely limited amount of water preceding the flood year of 2001/02. Stream flow was found to be decreasing every season until the flood year in which the streams began increasing their average flow. Lower available water meant less time and nutrients available for photosynthetic activity, which led to less overall primary production.

4.1.5 Von Guerard Stream F6

DESCRIPTION

Von Guerard Stream begins in the Kukri Hills and flows northward into Lake Fryxell. Between the source glacier and outlet there are three transects, but for the purposes of this study, only the gage transect nearest to the outlet is considered. The original gage and control when erected were located approximately 100 meters upstream of the outlet into Lake Fryxell. Since that time Lake Fryxell has risen considerably, and has overtaken the original control. The new control was rebuilt after the 2010/11 season (Figure 4-21) and is currently 125 meters away from the encroaching lake.

Von Guerard Stream gage transect consists of a sandy bed similar to a delta outlet of a stream. Flow is slow as the gradient is only 0.05 m/m and follows a braided path. Large rocks in the stream channel appear to be stable. Deltaic sites, relatively, do not have large abundance in microbial mats, (Mcknight et al. 1998) but due to seepage and wetted zones surrounding the stream channel, black microbial mats proliferate. Orange mats are also found in the thalweg of Von Guerard. Green mats, although not as plentiful as orange or black mats are found in protected locations such as eddies or underside of rocks.

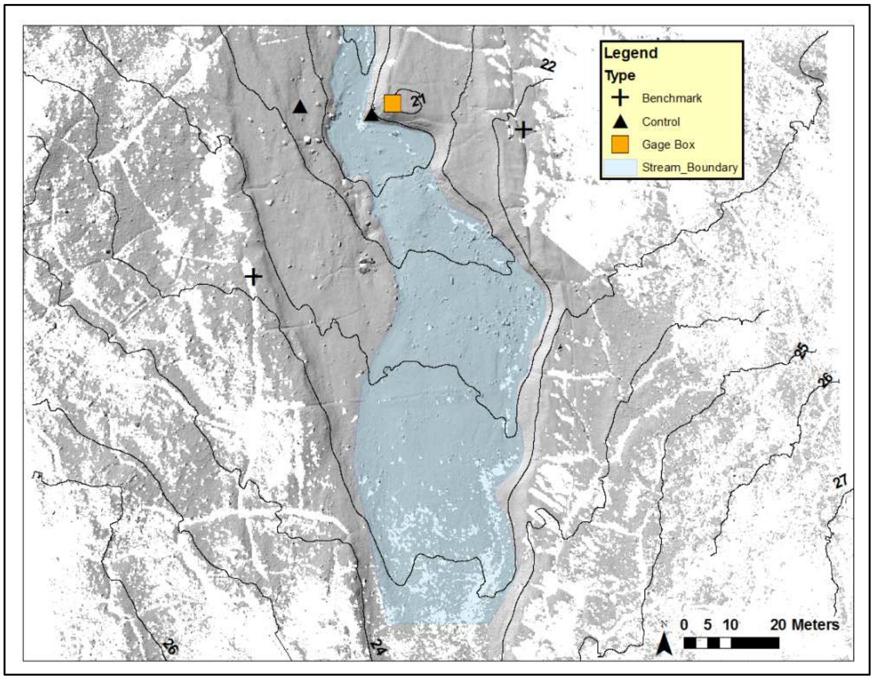

FIGURE 4-21 MAP OF VON GUERARD STREAM F6_GAGE. FLOW BEGINS IN THE KUKRI HILLS TO THE SOUTH AND FLOWS NORTHWARD FOR 4.9 KM UNTIL IT REACHES THE GAGE AND OUTLET INTO LAKE FRYXELL. A NEW GAGE AND CONTROL WERE ERECTED AT THE LOCATION INDICATED AFTER THE LIDAR SCAN WAS TAKEN SO STRUCTURES ARE NOT DISPLAYED IN HILLSHADE. CONTOURS ARE IN 1 M INTERVALS.

BED CHANGE ANALYSIS

Von Guerard Stream is a stable stream channel with erosion limited to its banks. The deltaic substrate becomes mobile during higher flows but rocks in the stream channel may mitigate overall change. Figure 4-22 shows a very stable channel with an exception during the first year of survey where large variations in relative bed elevation are shown. There appears to be significant change after the LiDAR scan of 2010/11, but Figure 4-24 explains that the change is composed of insufficient points. The issue with the last three seasons of record indicated as poor data in Figure 4-24 are caused by a combination of lack of data points outside of the stream channel, and a patchy LiDAR scan. When a manually surveyed point outside of the stream channel is aligned onto a LiDAR grid in which there is no data cell, then elevation cannot be extracted to determine a relative change to LiDAR. A repeat scan of Von Guerard Stream is needed to fix this issue. See Section 7 for further details.

Von Guerard Stream is the second longest stream in this study at 4.9 km, behind Delta Stream. Similar to Delta Stream, Von Guerard shows signs of accentuated flow during flood seasons (Figure 4-23). A significant amount of water is lost during low flow seasons in longer streams to evaporation and hyporheic seepage, but during high flow seasons, the hyporheic zone becomes saturated quickly and greater overland runoff occurs.

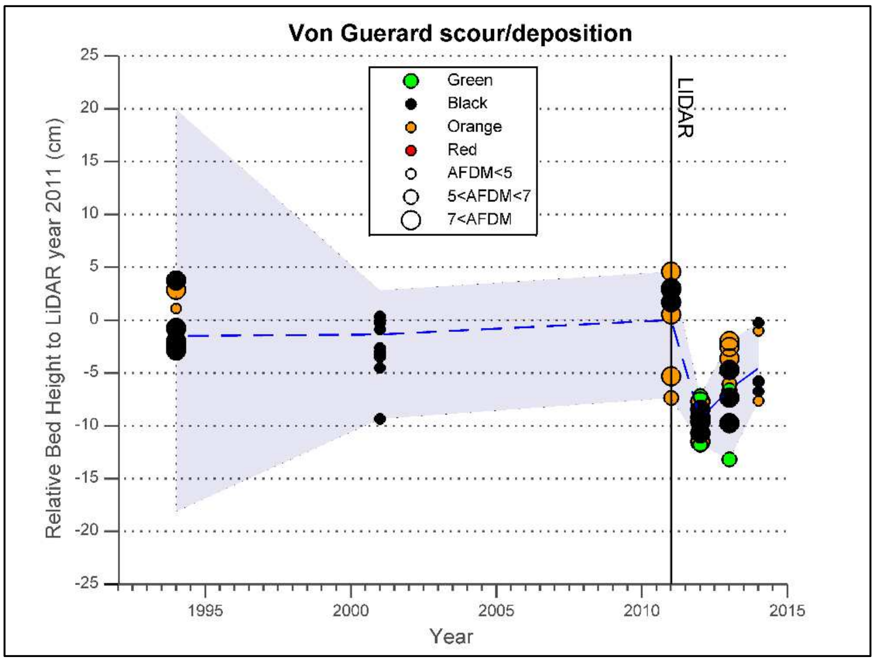

FIGURE 4-22 RELATIVE BED CHANGE PROFILE FOR VON GUERARD STREAM. TYPICAL OF A SHALLOW GRADIENT TRANSECT AND SANDY DELTAIC SUBSTRATE, VON GUERARD STREAM DOES NOT EXPERIENCE MUCH BED CHANGE. THERE IS MOBILITY IN THE SANDY BED, BUT IT IS NOT DEPOSITED AND CONTINUES DOWNSTREAM INTO LAKE FRYXELL.

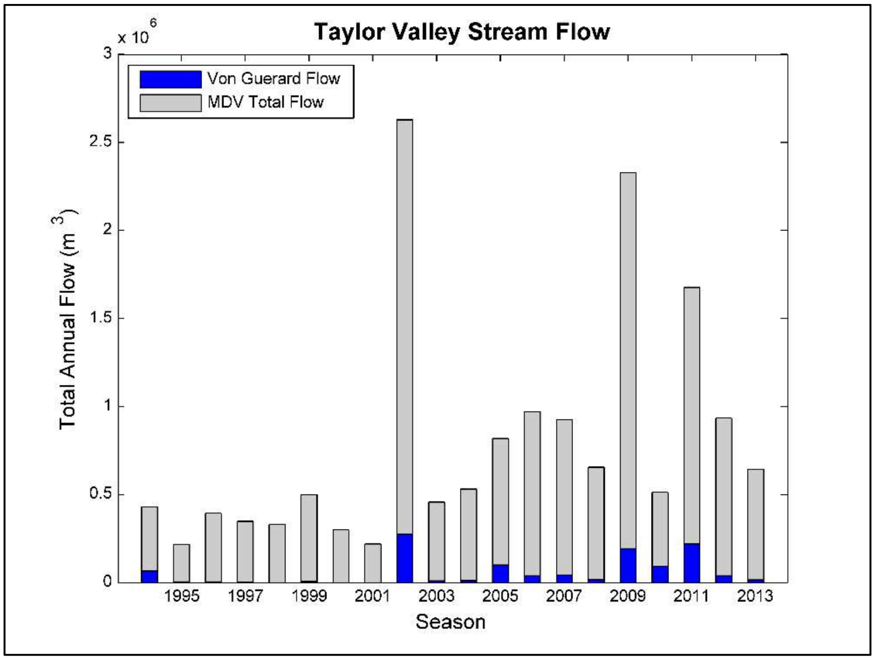

FIGURE 4-23 TOTAL ANNUAL FLOW FOR MDV AND VON GUERARD STREAM. VON GUERARD IS ALSO A LONGER STREAM AT 4.9 KM CAUSING FLOOD YEARS TO BE ACCENTUATED IN COMPARISON TO LOW FLOW SEASONS WHEN SIGNIFICANT AMOUNTS OF WATER ARE LOST TO EVAPORATION AND HYPORHEIC RESIDENCE.

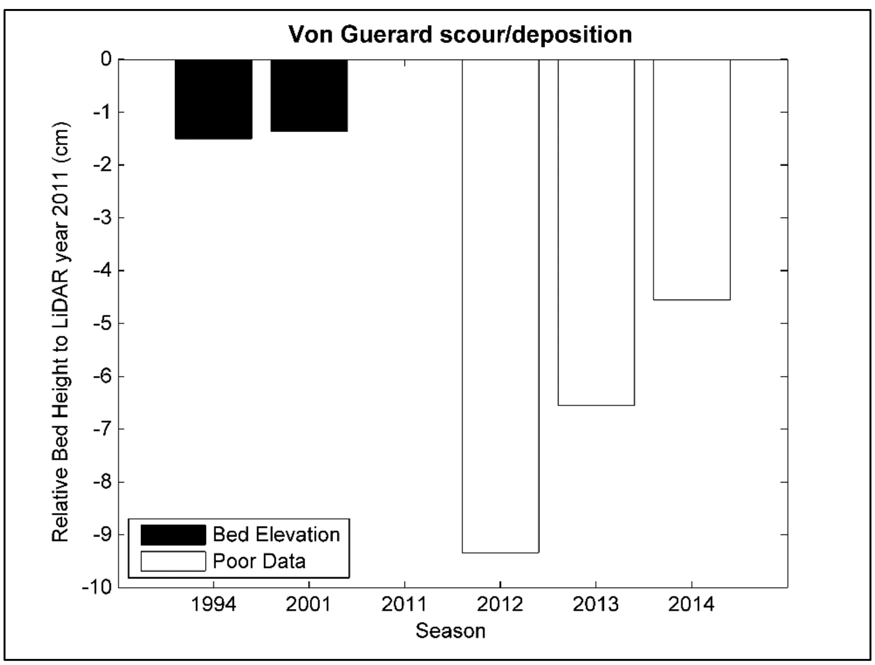

FIGURE 4-24 AVERAGE RELATIVE ELEVATION CHANGE FOR VON GUERARD STREAM. ALTHOUGH VON GUERARD IS ASSUMED TO BE UNCHANGING DUE TO THE SHALLOW GRADIENT, LARGE QUANTITIES OF SEDIMENT HAVE BEEN SEEN ERODING FROM THE BANKS AND BEING DEPOSITED INTO LAKE FRYXELL 125 METERS DOWNSTREAM. YEARS OF POOR DATA HAD FEWER THAN 3 POINTS OUTSIDE OF THE STREAM CHANNEL.

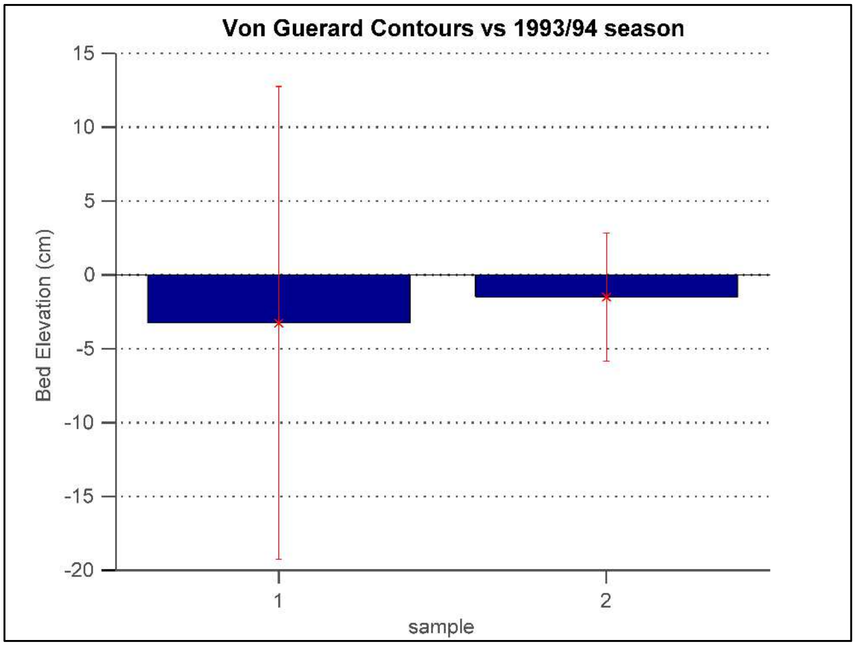

FIGURE 4-25 VON GUERARD TRANSECT CONTOUR PLOT COMPARISON TO 1993/94 SURVEY. SIMILARITIES IN AVERAGE BED ELEVATIONS ARE FOUND IN THE COMPARISON, BUT THE ERROR FOR THE CONTOUR PLOTS IS TOO HIGH TO BE CONSIDERED IN THIS STUDY.

DISCUSSION

Von Guerard is mostly unchanging. Personal observations however have recorded a single erosion event that caused the north bank to erode away during the onset of flow for the 2013/14 season which has not yet been surveyed. Over-winter snow deposits in the stream channel caused a reservoir of melt water to build up during the seasonal onset of flow. Eventually the water overflowed the snow dam and flowed along the stream bank. Approximately 0.5 meters of horizontal stream bank consisting of small sand particulate was sent downstream. The stream bank at this location was 1-2 meters deep. This event caused the stream channel to erode the side of the bank on which the gage box was located 2 meters away. Presently the gage box rests precariously closer to the edge.

It is assumed that for a shallow gradient stream such as Von Guerard, the stream channel will undergo very few changes. It is worth mentioning the event above, however, to indicate the nature of a deltaic site, and that the sediment loads being deposited downstream can play a large role in scouring of microbial mats, or make attachment and establishment of filamentous microbial mats difficult. A repeat LiDAR survey is necessary to quantify the amount of change occurring at this transect.

4.1.6 Huey Creek F2

DESCRIPTION

Huey Creek begins high in the Asgard Range north of Lake Fryxell and travels down a steep slope until the bottom of the Taylor Valley, where it widens and empties into Lake Fryxell. Huey Creek is known to have large flood events that can cause the entire bed to become mobile, and easily transfer rocks 0.25 m in diameter downstream. The source snowfield, located in a hollow at high elevation, only receives sunlight for a short period every day, therefore large diel fluctuations exceeding a 10 fold increase in flow rate are experienced regularly (Alger 1997). The creek experienced multiple large flood events during the 2010/11 season that continually filled the control with large rocks that subsequently froze solid within the control when flow subsided. The gage and control were subsequently relocated upstream nearby the microbial transect where flows are more manageable.

Due to the large fluctuations in flow and bed mobility, microbial mats are sparse in Huey Creek transect. Extreme flows and sediment from upstream cause scouring events that effectively remove the microbial mats. Microbial mats that are present, are found in seepage zones along the fringes of the stream channel. Seepage zones typically receive moisture from hyporheic water, and therefore are generally protected from scouring events that persist in Huey Creek main channel.

Of note is the LiDAR scan used to produce the Huey Creek map (Figure 4-26) and other plots (Figure 4-27) (Figure 4-29). The initial scans were corrupt, and repaired using unorthodox trigonometry to flip the raster grid surface upside down. Therefore, any data gathered from Huey Creek should be assumed to be untrue, and not used in further processing until repeat LiDAR is taken at the site.

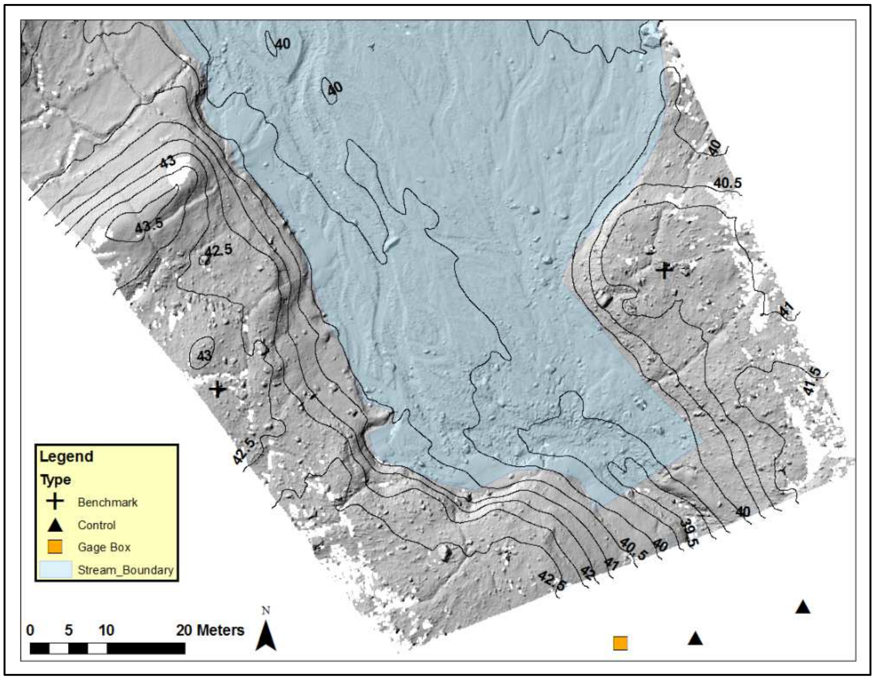

FIGURE 4-26 MAP OF HUEY CREEK F2. HUEY BEGINS HIGH IN THE ASGARD RANGE TO THE NORTH AND CONTINUES SOUTH INTO LAKE FRYXELL. AFTER FLOODS HAD DESTROYED THE PREVIOUS CONTROL IN 2011, THE CONTROL WAS REBUILT IN 2013 CLOSER TO THE TRANSECT NOTED AT THE BOTTOM OF THE MAP. CONTOURS ARE IN 0.5 M INTERVALS.

BED CHANGE ANALYSIS

Huey Creek is one of two streams in this study that experiences large changes after flood events. Figure 4-27 shows Huey Creek gaining and losing across the transect. Above the transect is a delta like site containing many braided streams of which only a few flow during low flows. During high flows, however, the entire channel is inundated with water and the bed can become mobile. The largest variability occurs during the 2000/01 season with bed heights ranging from 140 cm lower and 175 cm higher than during the LiDAR survey season. Note that these values are not caused from the 2000/01 season of flow, but rather detail a geometrical history of the channel. The stream before the flood year of 2001/02 in some locations was 140 cm lower and 175 cm higher than after the flood season. These large variations in bed height create dynamic stream substrate that can be detrimental to mat establishment and abundance.

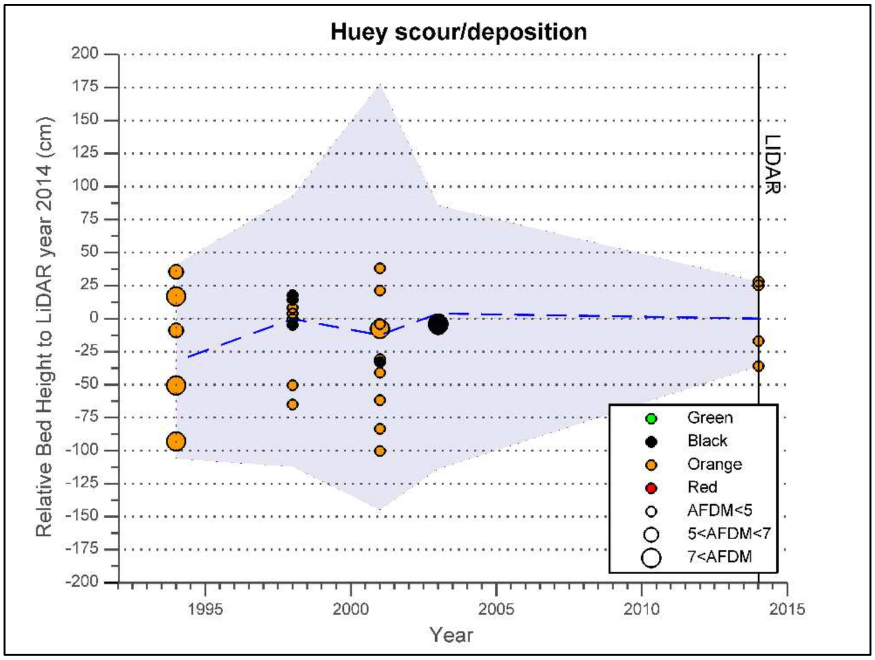

Figure 4-27 Relative bed change profile for Huey Creek. Huey Creek is a tumultuous creek that experiences entire bed mobility during flood events. Only orange and black microbial mats are found in the transect and are located on the outer fringes along seepage zones where flows are less common.

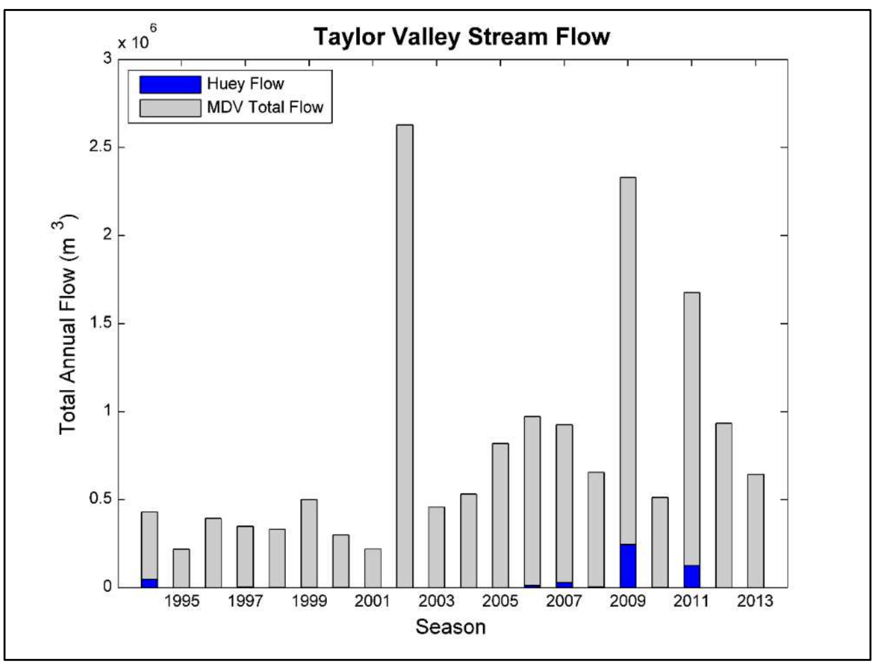

Figure 4-28 Total annual flow for MDV and Huey Creek. Many seasons Huey Creek has not flowed or the data corrupt enough to be unpublishable. Huey Creek is the smallest contributor of water in comparison to streams in this study.

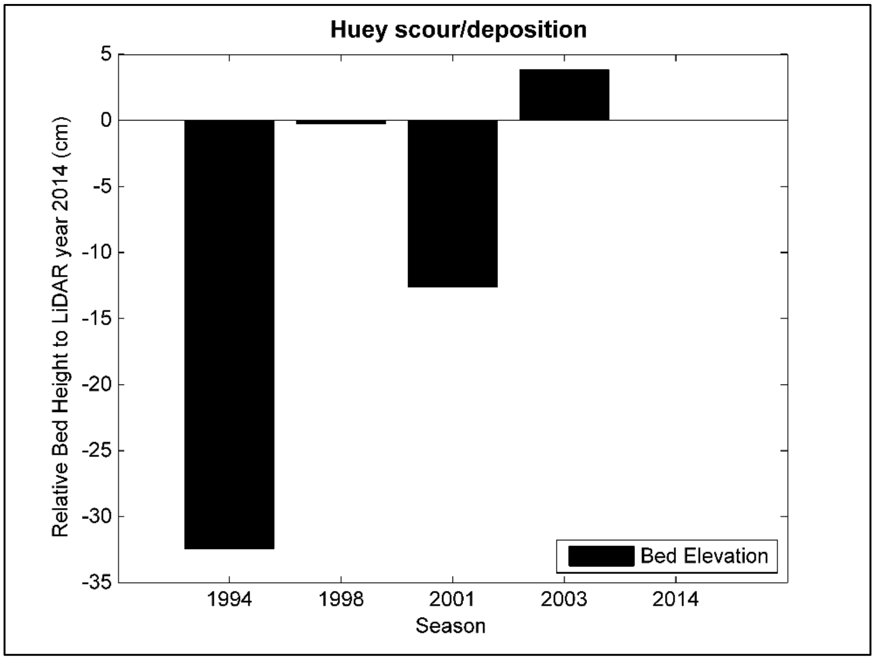

FIGURE 4-29 AVERAGE RELATIVE ELEVATION CHANGE FOR HUEY CREEK. ALL SURVEYS WERE CONDUCTED SUCCESSFULLY AND HUEY CREEK IS SHOWN TO HAVE UPWARDS OF 30 CM OF DEPOSITION OCCUR WITHIN 4 SEASONS. A LIDAR SCAN WAS TAKEN DURING THE 2014 SEASON.

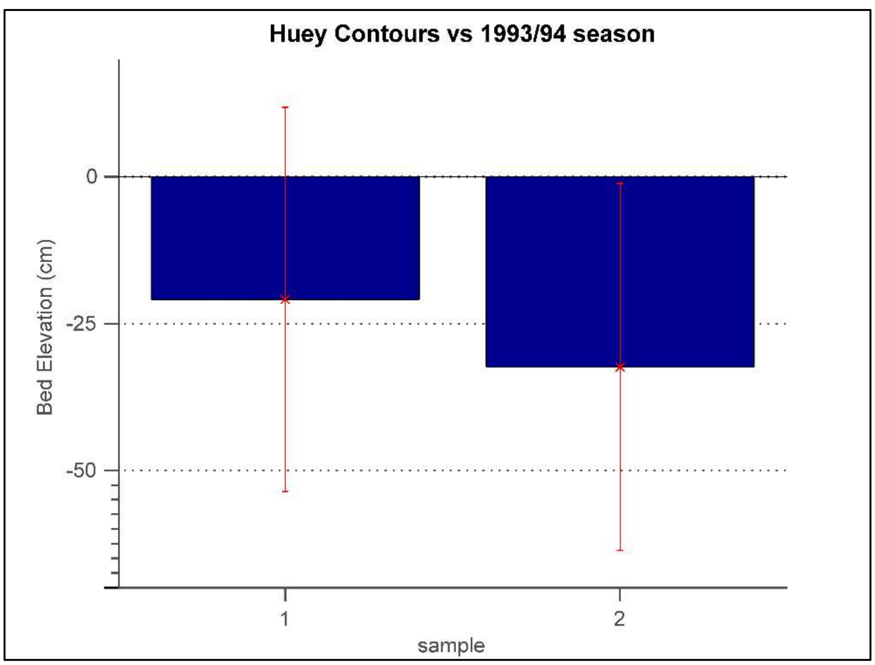

FIGURE 4-30 HUEY TRANSECT CONTOUR PLOT COMPARISON TO 1993/94 SURVEY. NOTE LARGE STANDARD ERROR IN BOTH SETS OF DATA.

DISCUSSION

Huey Creek experiences some of the most unsteady flow patterns in the MDV, and has the lowest volumetric flow rate of the streams involved in this study. Many seasons, there was no flow recorded or the control became inundated with rocks and sediment, that accurate flow record was not possible. Much of the flow for Huey Creek is found stored in the hyporheic zone during floods, and is released later when floods subside. During flood events, much of the overland flow follows braided anabranches that are typical of flood dominated systems (Koch et al. 2010). These systems have not been shown to produce microbial mats, most likely due to the turbulent shear forces of water when present.

Over the last 20 years of record, Huey Creek has risen an average of approximately 32 cm from deposition. Presumably the material forming the layers of deposition originate in the deeply incised channel above. During high flows, sediment and rocks are transferred downstream, and deposited in the Huey Creek transect where the gradient lessens.

4.1.7 Bohner Stream B5

DESCRIPTION

Bohner Stream originates from an alpine glacier in the Kukri hills south of Lake Bonney, and follows a short steep gradient (Figure 4-31) until the confluence with Priscu Stream. Throughout the reach the streambed consists of large rocks and boulders embedded in a sandy substrate. Bohner Creek has a deep channel with loose sand on both banks. Due to the gradient, most of the microbial mats are sheared from the face of the rocks. Only orange and green mats were found at the site and were located in either slower moving eddies, or on the protected underside of large rocks respectively.

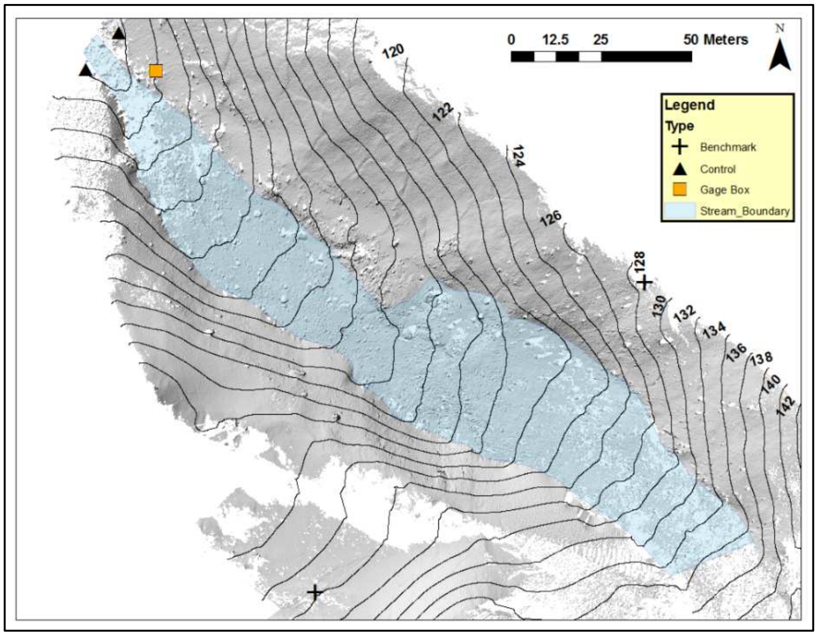

FIGURE 4-31 MAP OF BOHNER STREAM B5. FLOW ORIGINATES IN THE SOUTHEAST AND CONTINUES DOWN A VERY STEEP AND ROCKY CHANNEL UNTIL THE CONFLUENCE WITH PRISCU STREAM FARTHER NORTHWEST. A GAGE AND CONTROL WERE INSTALLED IN 2010 AFTER THE DISMANTLING OF PRISCU STREAM WHEN LAKE BONNEY THREATENED INUNDATION. CONTOURS ARE IN 2 M INTERVALS.

BED CHANGE ANALYSIS

Figure 4-32 shows large seasonal variation with respect to bed elevation. During the 1993/94 season Bohner is estimated to have been 10-20 cm higher than present with large standard variation. There is a slight scouring of the streambed, until the 2002/03 season following the flood year of 2001/02, which caused a large depositional event across the transect. After the flood season, the transect seemingly returned to a steady state approximately 40 cm lower than post-flood conditions. Figure 4-34, however, debates the authenticity of these data as there were not enough points outside of the stream channel to decisively conclude true elevational change.

Before 2010, flows from Priscu Stream gage were used as a proxy for estimating stream flow for Bohner Creek. Bohner Creek is a main tributary for Priscu Stream and thus can be correlated but not used for precise flow analysis. Also of note is that the source glacier of Bohner Stream faces a different aspect than the source glacier of Priscu Stream, therefore peak flow times cannot be correlated. Figure 4-33 describes the relation of stream flow for Bohner and Priscu Streams to other streams in this study. It is worth mentioning that the gage at Priscu Stream was very unreliable due to sediment build up, therefore recorded flows for this period should be used with caution.

Bohner Stream contour plot (Figure 4-35) is similar to the other streams in that there is large standard error associated with the digitized contour plot exceeding +/- 40 cm. The average bed height, however, is very similar to the 1993/93 survey data, but again the contour data cannot be used due to the large standard error.

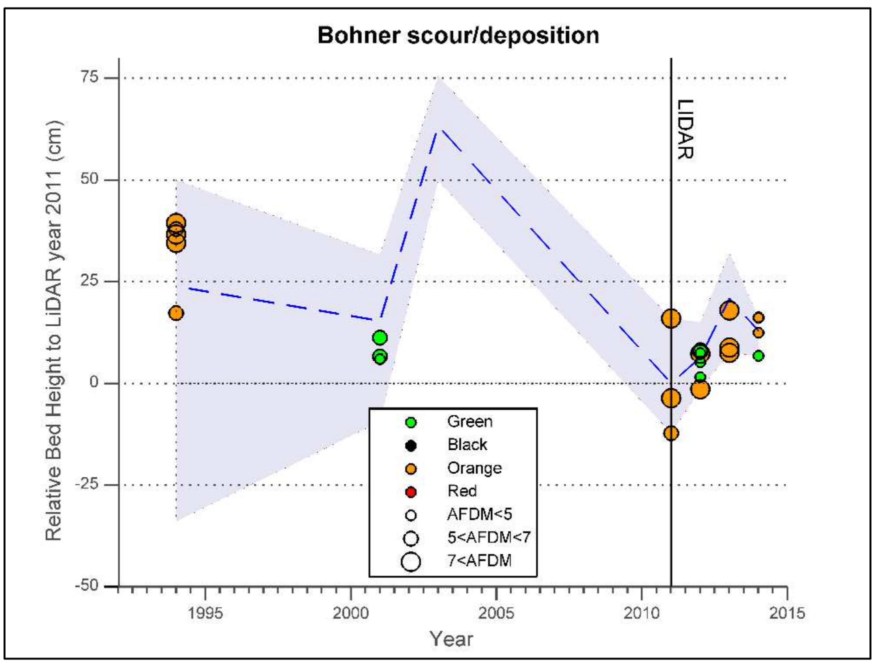

FIGURE 4-32 RELATIVE BED CHANGE PROFILE FOR BOHNER STREAM. THE MOST UNBALANCED STREAM, BOHNER STREAM SEES EXTREME FLOODS AND SEDIMENT LOADS. DUE TO THE SHARPEST GRADIENT OF STREAMS IN THIS STUDY, BOHNER STREAM ALSO HAS THE LARGEST FLUCTUATIONS IN BED ELEVATIONS.

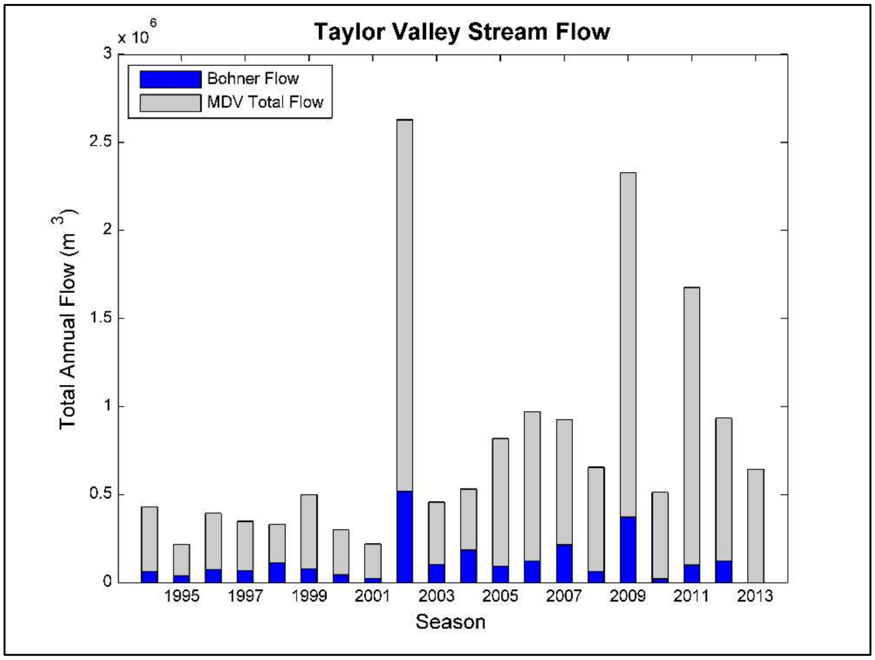

FIGURE 4-33 TOTAL ANNUAL FLOW FOR MDV AND BOHNER STREAM. UNTIL THE 2011 SEASON, THE FLOW FOR BOHNER IS RECORDED AS FLOW FOR PRISCU STREAM FARTHER DOWNSTREAM. PRISCU STREAM HAD A GAGE UNTIL 2010 WHEN IT WAS OVERCOME BY LAKE BONNEY. THE GAGE WAS THEN MOVED TO BOHNER STREAM 600 METERS AWAY AND 60 METERS HIGHER IN ELEVATION.

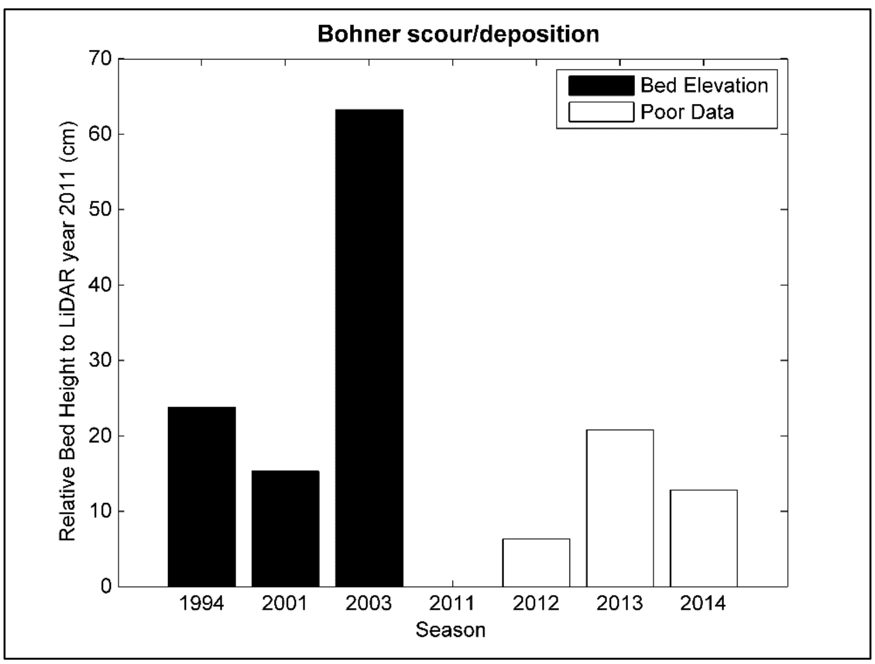

FIGURE 4-34 AVERAGE RELATIVE ELEVATION CHANGE FOR BOHNER STREAM. NOTICE AFTER 2011 NOT ENOUGH POINTS WERE TAKEN OUTSIDE OF THE STREAM CHANNEL TO ACCURATELY DEFINE BED ELEVATION.

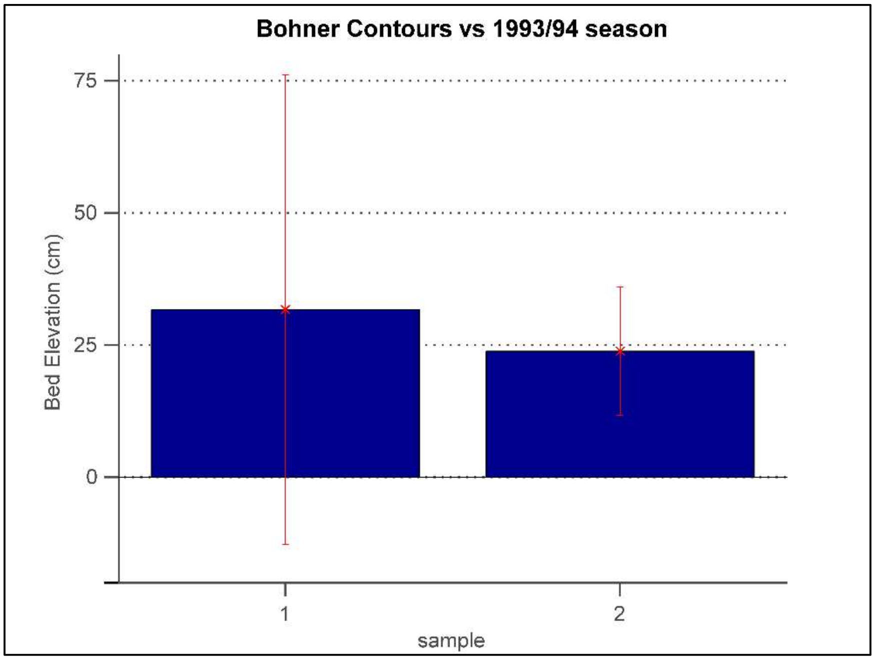

FIGURE 4-35 BOHNER TRANSECT CONTOUR PLOT COMPARISON TO 1993/94 SURVEY. ERRORS ARE TOO HIGH TO USE CONTOUR PLOT IN STUDY.

DISCUSSION

During the 1993/94 season Bohner is estimated to have been 10-20 cm higher than present. The large variation is possibly explained from sampled bed rocks that were once cemented in place by surrounding sediment that have since had the sediment scoured, causing the rocks to shift. Frost-heave events caused by wetting and subsequent freezing of surrounding sediment may also be to blame for the shifts of imbedded rocks. The banks, which are composed of fine sediment, can also cause change within the stream channel. The banks easily erode down the incised channel from wind events, floods, or anthropogenic disturbances, and are deposited in slower moving sections. Upstream of the transect, the remaining stretch is a steep gradient, and as floods occur, transfer rocks and sediment downstream. Therefore detected changes in relative bed elevation may be explained from the bank sediment effectively filling the channel after disturbance events, upstream cobble being transferred downstream to the transect during high flows, or shifts in rocks being caused by frost heave events or sediment erosion.

The microbial mats located in Bohner Stream are not found in typical locations. Orange mats, which most often dominate the thalweg, are found on the outer fringes of the transect. In a stream with such a steep gradient, flows can create shearing stresses too large for the establishment of permanent microbial mats. While orange mats are found in the fringes, green mats are found protected under large rocks. Green mats have also been located under wooden debris from the remnants of a previous Lake Bonney camp that was destroyed during a severe winter storm and deposited into the stream channel. Throughout the entire 20 year record for Bohner Stream, only green and orange microbial mats have been detected and sampled.

4.2 Contour Plot Comparisons

Multiple methods were used to determine overall bed change from the first TS survey to the latest LiDAR scan. One method involved vectorising contour maps drawn in 1997 using survey data and photographs from the 1993/94 season. The plots were drawn by USGS surveyor Gordon Shupe. Methods are described in section 3.4.1 .

A change detection analysis of the contour plots overlain on LiDAR scans led to discouraging results. Contours for all streams were analyzed for change detection, but only Canada (F1) and Bohner (B5) are highlighted as average results. Figure 4-36 shows Canada Stream contour map change detection under the first column, and the topo survey from the 1993/94 season under the second. There is large disconnect between the two data sets in that the contours suggest a stream channel that was approximately 15 cm lower in average elevation relative to the LiDAR scan, while the topo points from the TS survey show a bed about 6 cm higher elevation. Figure 4-37 suggests smaller differences, but similar in size of error. The contour plot and 1993/94 TS survey of Bohner Stream suggest an average elevation of 32 cm and 24 cm respectively. Although the two readings could fall within the range of error using a TS, the standard error of the contour elevation exceeds reasonable doubt that the two can be compared as equals. Canada Stream follows the same trend. Therefore the contour plots were not used for analysis of transect bed change, and all future analysis will require physical topographic points.

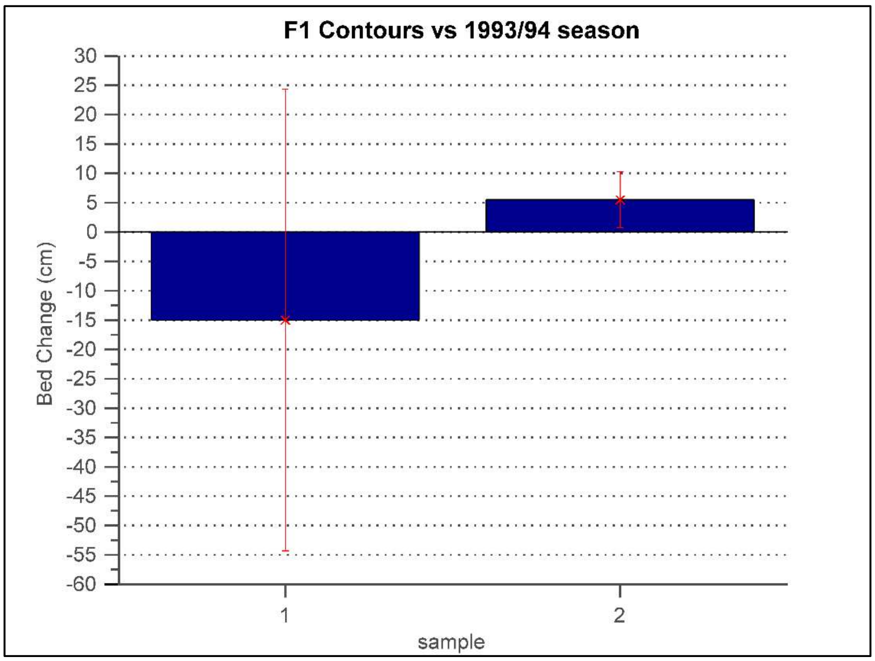

FIGURE 4-36 CONTOUR CHANGE DETECTION FOR CANADA STREAM. ON THE LEFT IS THE DIGITIZED CONTOUR PLOT DESCRIBING AVERAGE RELATIVE BED ELEVATION. THE LARGE STANDARD ERROR IS COMMONLY SEEN ON ALL CONTOUR PLOT DIGITIZED ANALYSES. THE RIGHT BAR DESCRIBES THE RELATIVE BED ELEVATION USING THE 1993/94 SURVEY DATA AND CONTAINS MUCH SMALLER STANDARD ERROR.

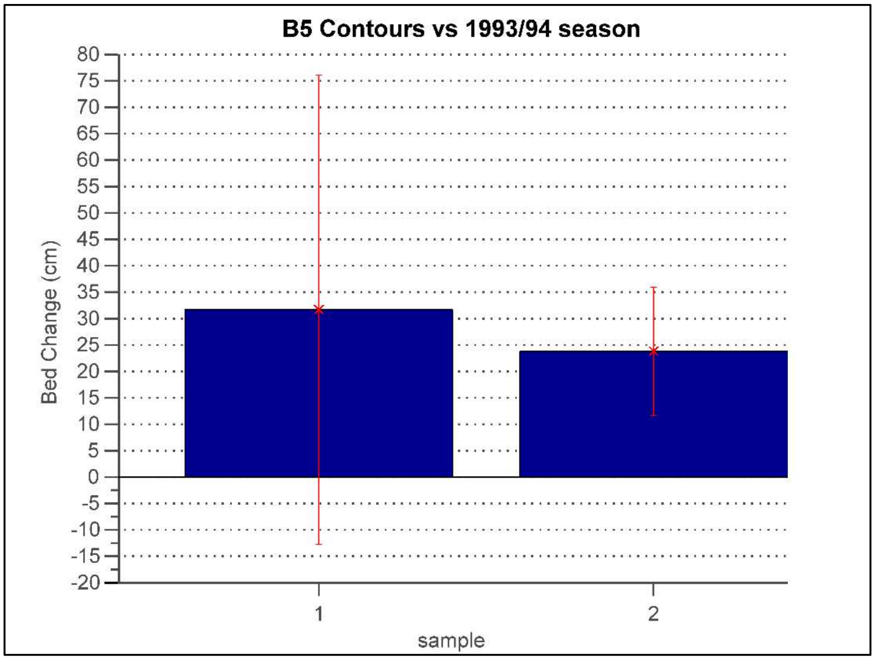

FIGURE 4-37 CONTOUR CHANGE DETECTION FOR BOHNER CREEK. SIMILAR TO FIGURE 4-36, THERE IS LARGE STANDARD ERROR ASSOCIATED WITH THE LEFT BAR WHICH DESCRIBES AVERAGE RELATIVE BED CHANGE DERIVED FROM A DRAWN CONTOUR PLOT. ON THE RIGHT IS THE DATA FROM THE 1993/94 SURVEY AND CONTAINS MUCH LESS STANDARD ERROR.

4.3 Intersite Comparison

All surveys were analyzed for bed change characteristics following flood events. The following seeks to understand the related nature of the valleys, and the response then to flood events as a whole. Below are analyses of temporal bed changes throughout the MCM with respect to floods and AFDM.

4.3.1 Overall

Overall bed changes for each stream were plotted together to visualize and compare streams. Figure 4-38 details streams assumed to be most hospitable in blue with a gradient color scheme towards red for more harsh streams. Harshness was defined as the steeper the gradient, higher chances of floods, larger flow deviations, and zero days of flow in a season, all contribute to a harsher stream (Kohler et al. 2015). Figure 4-38 shows more hospitable streams having very little change with regard to time or flood events. The deviations from zero may be explained by TS survey error or a significant lack of a survey points for that stream and season. The harsher streams such as Bohner and Huey show greater change throughout time, but more data is needed to determine if the changes are flood related or fall within standard error.

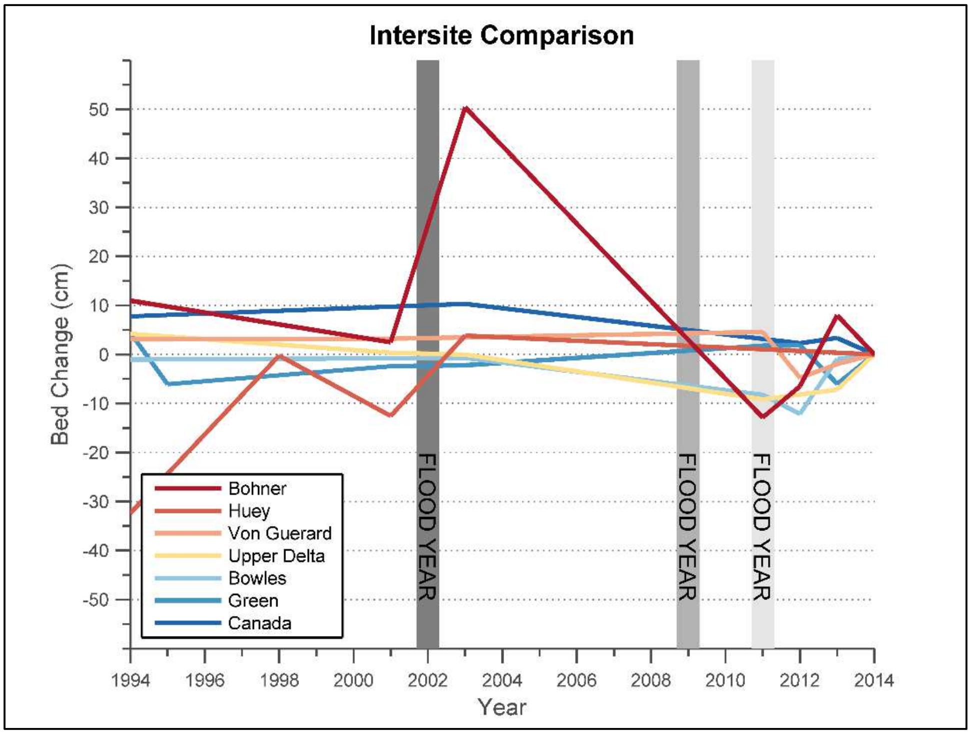

FIGURE 4-38 INTERSITE COMPARISON. THE GRAPH SHOWS TEMPORAL ELEVATION CHANGE OF 7 STREAMS BEGINNING WITH THE MOST HOSPITABLE (BLUE) AND MOVING UPWARDS TO THE MOST DYNAMIC (RED). AS HARSHNESS OF STREAMS INCREASES SO DOES AVERAGE RELATIVE BED HEIGHT. ALSO SHOWN ARE THE THREE LARGEST FLOOD YEARS 2001/02, 2008/09, AND 2010/11.

4.3.2 AFDM vs. Flow

Flow for each stream can vary greatly between seasons and days. While one stream is experiencing peak flow, an adjacent stream may only see a trickle. The suns aspect on a glaciers surface has the largest impact on streamflow (Jaros 2003), and while the sun travels in a circular path around the sky at 77 degrees south latitude, the streams experience diel flow regimes dictated precisely by that path. Seasonal variations in flow patterns are influenced by strong down-valley winds (Doran et al. 2008). For every season a stream had recorded flow, the total annual flow was averaged and a weighting system was created via section 3.6.1 . Figure 4-39 shows no correlation between weighted flow and AFDM per sample. Stanish et al. (2012) and Kohler et al. (2015) defend and expand on this conclusion implying that flow is one of many variables that affect microbial mats. Mats are also shown to not have preference towards seasonal flow variations, but it is worth mentioning that orange and black mats are found throughout all flow variations.

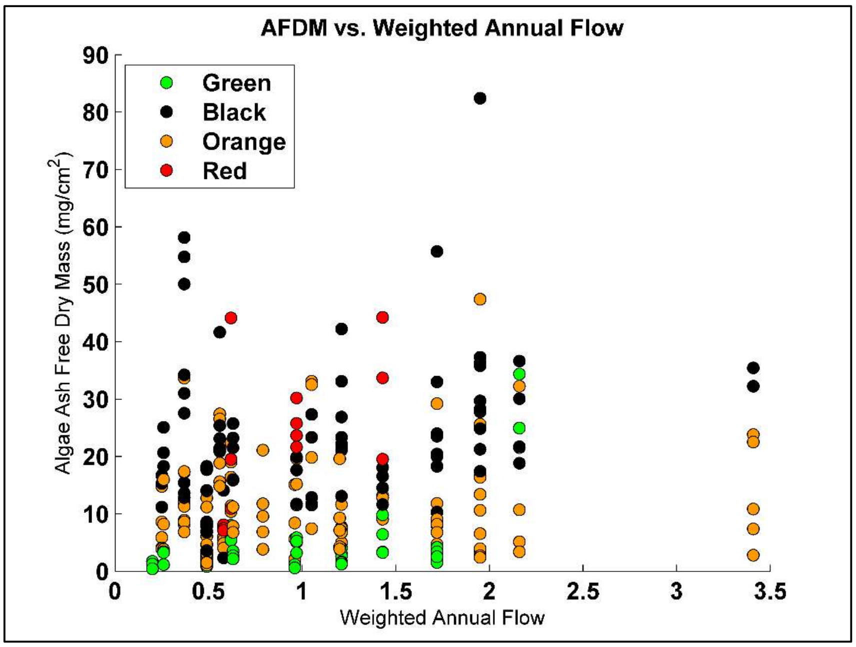

FIGURE 4-39 AFDM VS. WEIGHTED ANNUAL STREAMFLOW. AS SHOWN THERE IS NO CORRELATION BETWEEN STREAM FLOW AND AFDM OF MICROBIAL MATS OF ANY COLOR. FLOW IS JUST ONE FACTOR OF MANY CONTROLLING ABUNDANCE OF MICROBIAL MATS IN THE MDV.

4.3.3 AFDM vs. Bed change

The four types of microbial mats analyzed in this study prefer significantly different habitats from one another. Orange and red mats thrive in fast moving waters while black mats are mostly seen on fringes of wetted zones. Green mats prefer the underside of rocks or other stable benthic structure. Figure 4-40 compares resilience and bed change preference by comparing AFDM of microbial samples to local bed change. Of note there are two distinct outliers in the X and Y axes. In the X direction, orange mats, although centered about zero, are shown to prefer more dynamic stream channels, which experience greater rates of erosion or deposition. In the Y direction, black mats are shown centered about zero change and contain higher densities of AFDM possibly from faster growth rates or lower scouring forces in the wetted regions. A cumulative distribution function curve was generated and plotted against the multivariate data to determine if the data followed a normal distribution with respect to bed change (Figure 4-41). The plot shows microbial mats prefer a stable environment with a mean of 0.29 cm from zero change and a standard deviation of 31.4 cm. The empirical data closely follow theoretical with slight deviations around 10 and 90 percent probabilities.

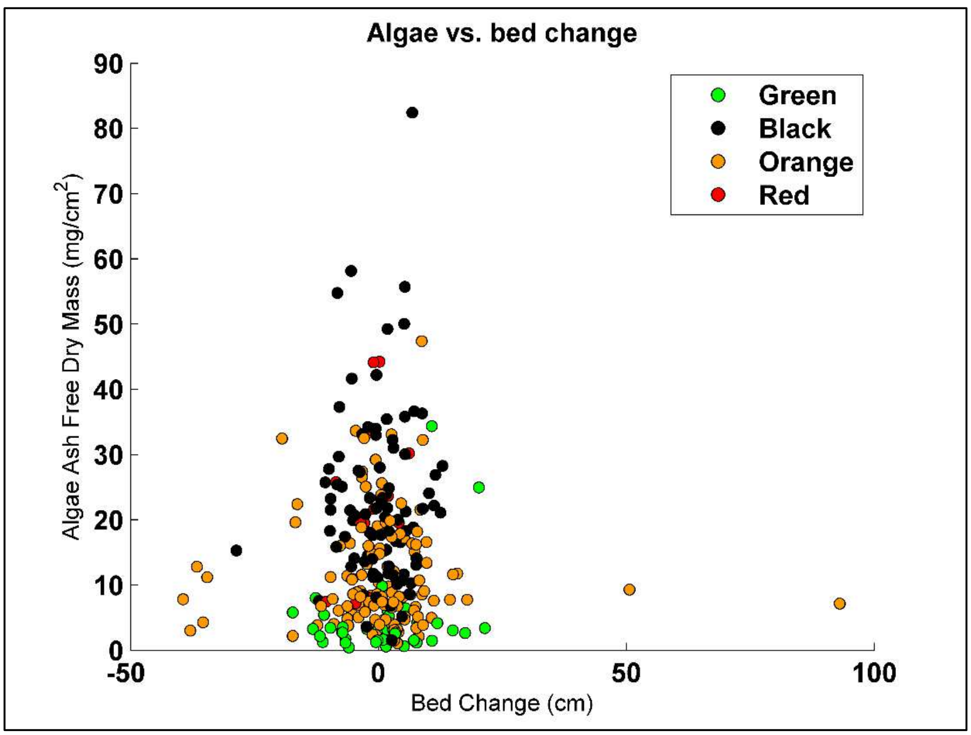

FIGURE 4-40 AFDM VS OVERALL RELATIVE BED CHANGE. EACH MICROBIAL MAT SAMPLED OVER THE PAST 20 YEARS WHICH HAD AFDM DATA ASSOCIATED WITH IT IS PLOTTED ABOVE. ALL MAT TYPES PREFER A STABLE BED ENVIRONMENT IN AREAS OF THE STREAM CHANNEL THAT DO NOT EXCEED 10 CM BED CHANGE IN EITHER DIRECTION WHILE ORANGE MATS ARE SHOWN TO EXIST IN MORE DYNAMIC CONDITIONS. ALSO NOTED ARE LOW AFDM VALUES OF GREEN MATS WHICH EXIST EXCLUSIVELY UNDER LARGE ROCKS AND DEBRIS PROTECTED FROM POWERFUL FLOWS WHILE BLACK MATS THAT CONTAIN HIGHER AFDM VALUES OCCUPY WETTED REGIONS THAT RARELY EXPERIENCE LARGE SURFACE FLOWS.

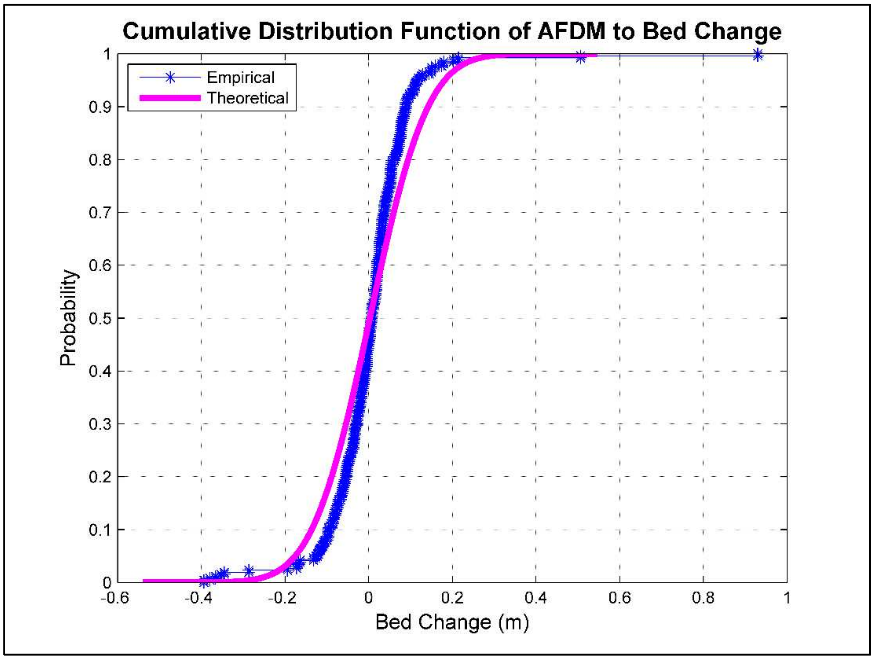

FIGURE 4-41 CDF CURVE RELATING AFDM TO BED CHANGE. SHOWN ABOVE IS A THEORETICAL CUMULATIVE DISTRIBUTION CURVE PLOTTED ALONG AN EMPIRICAL CURVE. THE STRONG CORRELATION SUGGESTS A NORMAL DISTRIBUTION OF MICROBIAL MAT AFDM TO RELATIVE BED CHANGE CENTERED ABOUT A MEAN OF ZERO OVERALL CHANGE.

The following four plots are individual layers from Figure 4-40 and provide a clearer view of individual species preference in regards to bed change. A zero mean for a point indicates that the microbial mat sample location has not significantly changed from the date it was sampled to the date the LiDAR scan was collected. A negative value indicates the point experienced scouring or bed erosion leading up to or after the LiDAR scan. Conversely, a positive value assumes deposition or raising of the bed has occurred. The Y axis is the concentration of AFDM from the survey.

Figure 4-42 shows a plot of green mats versus overall bed change. Green mats prefer the underside of rocks or slow moving waters free from turbulence. The mean and standard deviation support the claim that green mats prefer slower protected waters, as they are centered near zero and have a lower standard deviation (8.9) than the composite plot (31.4)

Black mats (Figure 4-43) prefer wetted areas near hyporheic seepage zones instead of the undersides of rocks where water is less powerful and abrasive (Alger 1997). Black mats follow green mats in that the mean bed change is centered at zero and have a relatively low standard deviation. Where black mats differ, however, is in the large concentration of AFDM per sample. As stated above, black mats prefer seepage zones where there is copious moisture, but the region may not see flow all season due to its raised topography. Black mats are thus protected from the scouring effects of rushing water and allowed to proliferate.

Orange mats shown in Figure 4-44 thrive in faster moving waters and can handle the intermittency and changes in flow for all streams. Like all microbial mats, orange mats prefer a stable environment in regards to bed change, but can survive at the outer fringes as seen with outliers from -40 to +90 cm in elevation change, while having the largest standard deviation of 18cm.

Although red mats do exist in multiple streams within the MDV, of the transects sampled, they were only found within the Canada transect. Due to the lack of data no conclusive evidence can be claimed on behalf of red mats other than they are centered about a mean of zero and have a standard deviation similar to green and black mats.

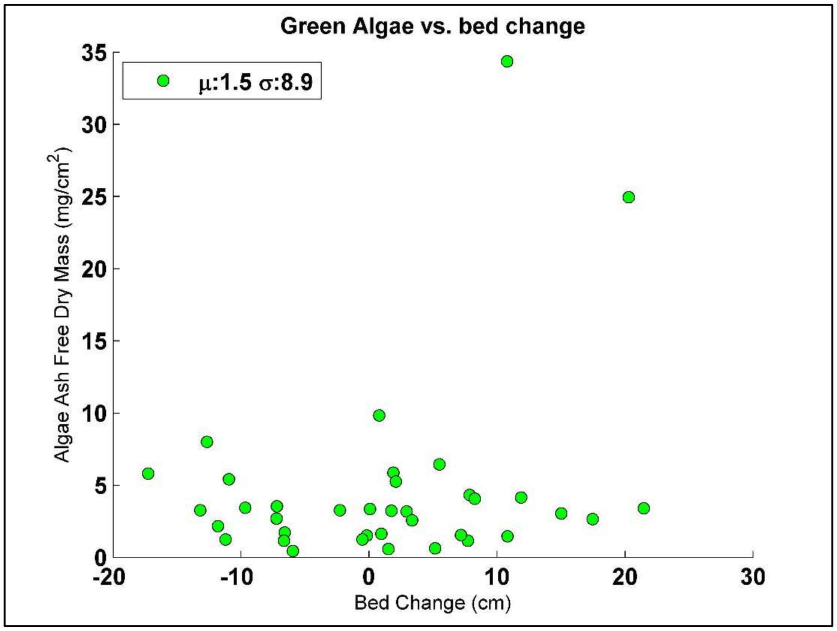

FIGURE 4-42 GREEN MICROBIAL MAT AFDM VS OVERALL BED CHANGE. THE MEAN SLIGHTLY FAVORS DEPOSITIONAL CHANGE WHILE MAINTAINING A VERY LOW AFDM CONCENTRATION RELATIVE TO OTHER MATS PRESUMABLY DUE TO BEING PRIMARILY LOCATED UNDER LARGE ROCKS INUNDATED BY SUBSTANTIAL FLOW.

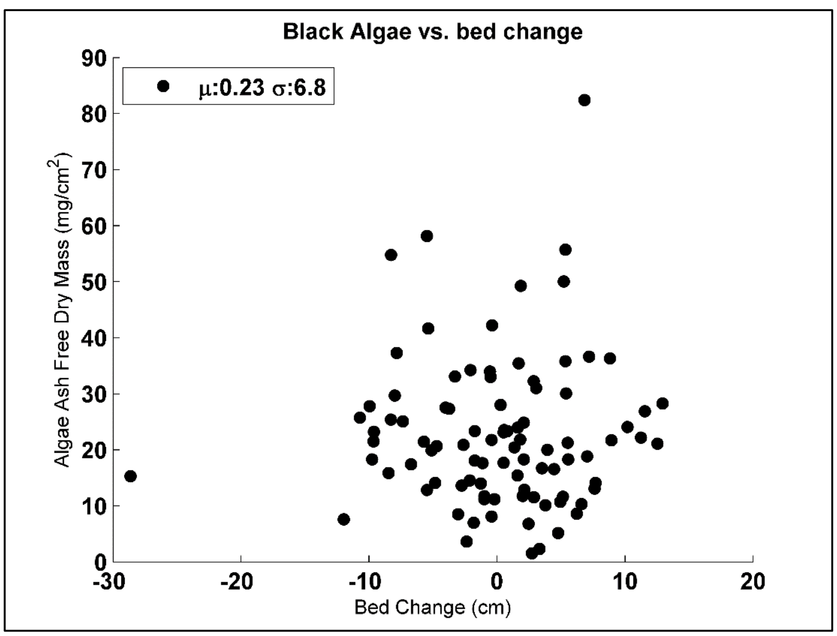

FIGURE 4-43 BLACK MICROBIAL MAT AFDM VS OVERALL BED CHANGE. BLACK MATS THRIVE OUTSIDE THE STREAM CHANNEL IN WETTED ZONES PROPAGATED THROUGH HYPORHEIC ACTIVITY. THEREFORE BLACK MATS RECEIVE MOISTURE AND NUTRIENTS FROM THE STREAM WITHOUT BEING FLOODED AND SCOURED FROM SURFACE FLOW WHICH MAY EXPLAIN THE HIGH AFDM CONTENT.

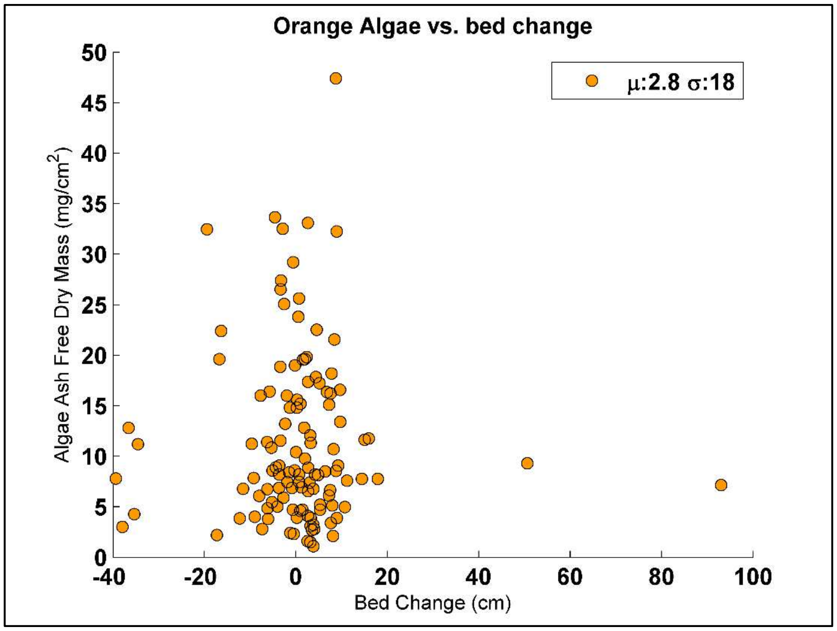

FIGURE 4-44 ORANGE MICROBIAL MAT AFDM VS OVERALL BED CHANGE. ORANGE MATS ARE PRIMARILY LOCATED IN THE THALWEG OR DEEPEST PART OF A STREAM CHANNEL. THESE FILAMENTOUS ALGAE ARE ABLE TO WITHSTAND LARGE FLUCTUATIONS IN FLOW WHILST REMAINING UNSCOURED. THE FIGURE ABOVE SHOWS ORANGE MATS BEING CAPABLE OF WITHSTANDING LARGE BED CHANGES UP TO 90 CM IN DEPOSITION AND 40 CM OF SCOURING.

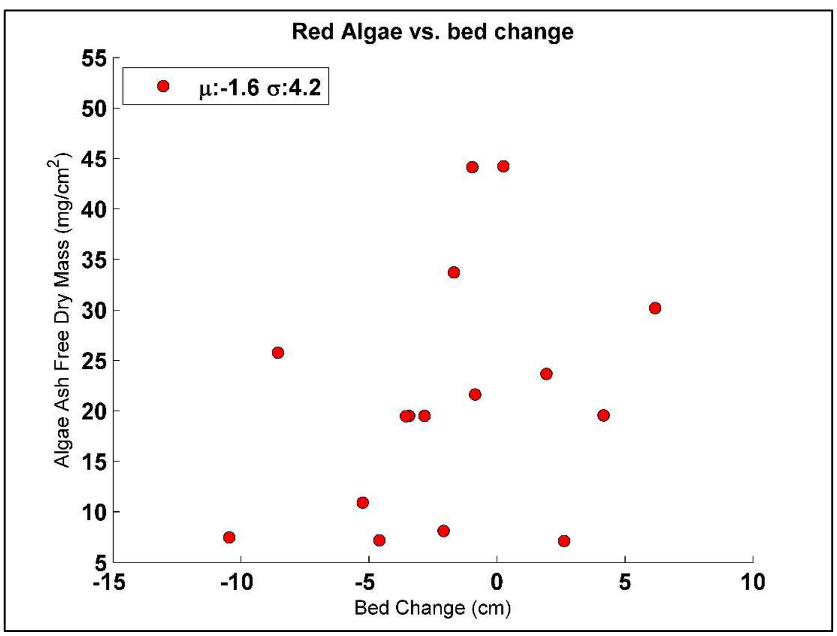

FIGURE 4-45 RED MICROBIAL MAT AFDM VS OVERALL BED CHANGE. RED MATS WERE ONLY FOUND IN CANADA STREAM AND THUS DO NOT PROVIDE SUBSTANTIAL CROSS TRANSECT EVIDENCE REGARDING BED CHANGE PREFERENCE OR REACTIVITY.

5 SYNTHESIS AND LONG TERM ANALYSIS

5.1 Erosion and Deposition

In 1903 when Scott and his field team visited the MDV, and Taylor Valley in particular, he presumed and recorded that the valleys were lifeless. The only animals they found were mummified and bleaching in the sun. What they did not realize, however, was that the valleys were teaming with microscopic life in the soils, lakes, and streams. The adage “Where there is water there is life” is certainly true here. Every austral summer when temperatures rise, flow starts and life begins where it left off the season before, frozen in time.

The MDV at first glance may be assumed to be unchanging over time. The permafrost is a relict of millennia of cold weather, the glaciers are not retreating nor advancing compared to arctic cousins, and only the lake levels have altered significantly in the past few decades. The streams, however, are a driving force of change in the MDV. During high flow events entire stream beds can mobilize and be sent tumbling downstream, taking POM along. Thermokarst occurring on the banks of streams add large quantities of sediment to the stream that is deposited in sections with slower velocities. Thermokarst may eventually erode enough material to divert and change the pathway for a stream altogether. The rate at which permafrost degradation occurs is currently being studied and with repeat LiDAR scans, these events may be quantitatively mapped.

The ability to extend the long-term record back to the beginning allowed for a more comprehensive look into what changes the stream channels and microbial mats may be going through. As was presumed, the data show very little change in the stream channels that have shallow gradients and extensive microbial mats. These streams that experience little change typically either have a rocky pavement bed that is lain over thousands of years to a state of equilibrium through periglacial processes or a sandy bed in which flows do not reach flood status often enough to remove the deposited sediment. The exception to this is Huey Stream, which has a relatively shallow gradient but sees extreme flood events from the very steep gradient and incised channel upstream that sends debris and cobble downstream. The bed becomes mobile during these events and scours all but the most protected microbial mats.

5.2 Microbial mats

The four microbial mat types analyzed in this study were found to succeed in a wide range of habitats within the streams. The filamentous orange and red mats tend to thrive in deeper waters attached to the substrate well enough to endure the shearing forces brought on by floods. Conversely, black mats spread extensively throughout the wetted areas that see little surface flow with exceptions during flood events. Flood events, which are indicative of highly variable flow, cause drastic immediate changes to black microbial mats. The mats are sheared off and what is left attached to the bed must begin anew. Lastly, green microbial mats are distinct in that they are scarce and found under stable rocks or debris in the main channel. The AFDM concentrations associated with green mats are extremely low compared to the other three mat types. Green microbial mats may have low AFDM because they are forced to live in the main channel where they are mostly protected but are not able to form large mats in areas of high shear stress like orange and red mats are. Presumably if green mats were to grow large enough, the shear stresses experienced in these locations would immediately scour them off. Slow growth rate in green microbial mats may account for the low AFDM as well. If orange and red mats grow quicker than green mats, after a scouring event, they may be able to occupy a previously scoured location and recover more quickly than green mats.

5.3 Integration

In 1997, Alger presented results on the abundance and species distribution of microbial mats found at 16 stream sites within the MDV. This was accomplished by manually surveying each microbial transect with a Total Station. This method of manually gathering points is useful for particular points of interest, but takes time and manpower that in the field may both be scarce and expensive. Total stations in this regard are not efficient for a complete transect scan due to the low number of points per unit effort. LiDAR, on the other hand, which was first introduced to this study in 2010, is able to scan an entire transect and generate millions of points in the lesser part of an hour. LiDAR can then combine X, Y, and Z coordinates with RGB data to create a fully navigable 3D color map of a transect. Where LiDAR is lacking however is in the highlighting of key points of interest. The microbial mats, water surface elevation, wetted perimeter, and seepage zones are not detectable using LiDAR scans and require a manual survey using a total station to collect. The most valuable product thus can be achieved by using the two systems together to form one cohesive map containing elevation, color, and points of interest to be able to fully analyze the dynamic nature of the streams within the MDV. In this study I used past survey data, combined it with present LiDAR and total station data to create a coherent 20-year history of the streams and built a platform on which future survey data can be easily input and combined with repeat LiDAR to detect the more minute changes in an otherwise unchanging environment.

6 CONCLUSION

Changes in stream channels were analyzed using state of the art survey technology as well as traditional surveying methods. The two technologies were combined to form a cohesive navigable map that describes temporal and spatial change within a stream microbial transect. In addition to scanning for changes in ground level, four different types of microbial mats were continually surveyed for changes in community abundance and productivity, both of which are affected by streambed change and provide greater detail of the dynamic nature of the ephemeral streams. The resulting 3D maps showed very little change between seasons for shallow gradient streams with low variability in flow, while steep transects composed of cobbles sometimes experienced mobile beds during high flow events that shear microbial mats from the bed. Microbial mats located in the channel require time to repair after being removed from the bed, and AFDM of the mats is shown to decrease after streams experience shifts in elevations. As the MDV are trending towards increases in temperature and meltwater generation, the stream channels are expected to experience faster rates of change while microbial mats may shift dominance altogether. With LiDAR technology, the long-term record of stream morphology can not only be extended but enhanced with greater resolution and detection. Permafrost degradation will play a large role in the sediment budget, and may possibly be predicted in the future before detection.

7 RECOMMENDATIONS

This study was founded on the notion that traditional survey methods could be combined with higher resolution LiDAR technology. A 20-year data set existed when LiDAR scans were first being implemented. The need to combine these two was pertinent if miniscule changes were to be detected in a reasonable timeframe. Very little research has been conducted with regards to combining low density point clouds with high density LiDAR, especially in Antarctica. As such, many unpredictable problems arose and were promptly taken care of and addressed in the methods. As a benefit for those that seek to further delve into this type of study, a few recommendations follow below.

The first and largest problem associated with the data sets is the lack of points inside and outside the stream channel. The first seasons contained upwards of 300 points based on rocks, channel geometry, interesting deviations from the normal, and microbial mats. As time progressed the microbial mat surveys became just that, microbial mat surveys. It is important to not just shoot a reference benchmark and microbial mats but also points assumed to be unchanging on the outer banks such as rocks and polygons and more dynamic features of the stream channel such as the wetted zone and thalweg. This allows for greater precision when calculating reference elevations mentioned in Section 3.5 . This issue was not a problem until this study’s methods required significant numbers of outside points to cross reference total station surveys to LiDAR.

Second, I recommend that repeat LiDAR be taken every 2-4 years for dynamic streams like Bohner and Huey, and every 4-7 years for more stable streams such as Canada and Green. With repeat LiDAR, changes will be detectable by computational methods rather than manually scanning an excel chart. Thermokarst regions that evolve slowly can be detected and studied before they show major signs of collapsing into the channel. Figure 7-1 shows such a thermokarst region detected on Bowles Creek. The blue area of the map is a thermokarst region with an area of 9 m^2, and analyzing the depth, approximately 0.5 meters has eroded away between 2011 and 2014. This is a very basic workup of a thermokarst region using “geomorphic change detection” and repeat LiDAR scans, but provides the framework for continued use of LiDAR scans in accurately detecting changes in and around stream channels.

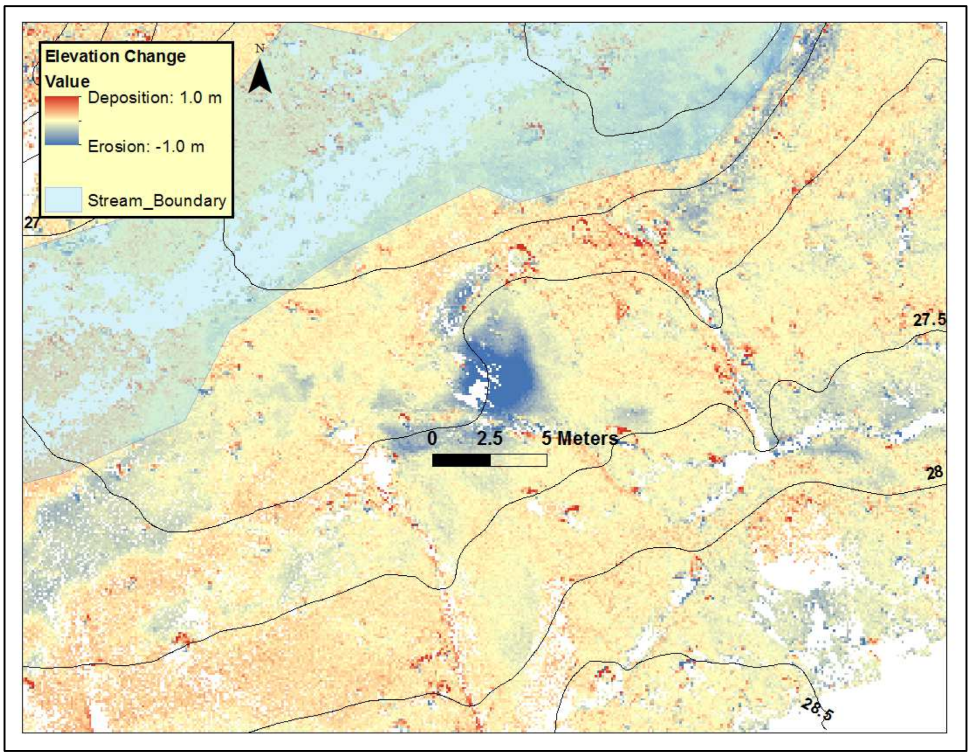

FIGURE 7-1 THERMOKARST REGION OF BOWLES CREEK. THE RED REGIONS ARE POINTS OF DEPOSITION AND ARE SMALL ENOUGH TO EITHER BE CAUSED BY FOOTPRINTS OR RATHER ERRORS IN THE SCAN. THE LARGE BLUE REGION HOWEVER IS A THERMOKARST REGION WITH AN AREA OF 9 M^2 AND AN APPROXIMATE EROSION DEPTH OF 0.5 METERS. NOTE BOWLES CREEK A FEW METERS NORTH OF THE THERMOKARST.

Additionally, more streams should be analyzed for geomorphic change. This study focuses on 7 of the 20 transects that exist as of this writing. Reasons for not including the remaining transects include 1) benchmark locations and elevations that need to be resurveyed for exactness, 2) the transect has not been scanned with LiDAR yet, or 3) historical data are missing or corrupt. The framework and procedures for working up further data are outlined in this study so that a continuation is streamlined.

Microbial mats were analyzed back in the lab for AFDM as well as Chl a. This study only focused on AFDM of microbial mats in relation to relative bed change. Chl a could potentially be included in future studies as an indicator of change that has not been confirmed from surveys as well as reinforce ideas and theories originating from AFDM analysis in this study.

An analysis of the actual stream boundary would be helpful in determining what parts of the stream actually change versus those that can be assumed to be static. The stream boundary generated in Section 3.5 was created manually by searching through past surveys, rasters that describe channel elevations, and navigable 3D color maps of the transect in question. Still, the boundary could potentially be incorrect and not include wetted regions or worse, not include areas that experience the greatest changes, like deep sandy incised banks. Including banks in the stream boundary may be required for proper analysis, but may have to be included as a different subset of change. The banks do not have a source of sediment once they erode unlike the streams that may see a constant supply of upstream sediment. Further analysis on stream boundaries would be required.

Finally, an analysis of shear stress at the interface between the stream and the microbial layer in comparison to bed change would provide insight on discharges required to scour microbial mats and stream channels. An index for each stream could be created that estimated the amount of scouring within the channel as well as determine the resilience of each type of microbial mat at specific flows. Expanding on the “Law of the wall” which provides an averaged velocity at a given height above the streambed we can derive the basal shear stress at the interface between stream and microbial mat using equation {8}. Using the maximum recorded flow for each season from the MCMLTER website and the known geometry from the LiDAR survey, the height H, of the stream above the mats, at peak flow can be extrapolated. The gradient can be found in Figure 7-2 and converted into an angle (θ). A comparison of shear stress and AFDM or bed change can then be made to determine any correlations between intensity of flow, and regulation of microbial mats or scouring effects. A prediction model can be made that can input discharge amounts and output anticipated changes within microbial mat communities as well as scouring effects in the stream channel. Another method may be to use roughness coefficients and pebble counts published in Alger et al. (1997) versus calculated peak power for each stream to better determine scouring effects at the microbial mat and stream interface.

$$\tau_b = \rho_f g H \sin\theta \tag{8}$$

Transect	Gradient (m/m)
Canada	0.03
Green	0.05
Bowles	0.025
Upper Delta	0.1
Von Guerard	0.05
Huey	0.03
Bohner	0.25

FIGURE 7-2 GRADIENT OF STREAM TRANSECTS.

All of the above recommendations would be added to a microbial mat survey team handbook detailing why these transects are surveyed. Included would be detailed maps of transects, so that locations of repeat measurements would be swift and searching for benchmarks would not take as much time as it sometimes does. An outlined procedure section would be necessary to mitigate error in the field, diminishing the need for a costly re-survey. Lastly, the procedure handbook would be included in the stream team manual carried by all team members throughout the field season.

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9 APPENDIX

9.1 Summary Data

		Confirmed Location (UTM 58S)			Estimated Coordinates (UTM 58S)		
Stream Transect	Benchmark	Easting(m)	Northing(m)	Elevation(MSL)	E	N	El
Adams	1				470879	1329697	
	2				470935	1329698	
	3				470893	1329706	301
	4				470917	1329685	299
Anderson	T011				449912.75	1382818.47	78.97
	T012				449939.56	1382811.43	77.88
Bohner	T151 NE	442069.906	1374244.198	128.374	442069.19	1374244.74	129.74
	T152 SW	441978.64	1374158.576	123.878	441977.92	1374159.06	125.32
Bowles	T101 SE	453532.184	1382897.174	27.269	453532.36	1382896.64	29.7
	T102 NW	453519.161	1382922.739	28.776	453519.32	1382922.2	31.24
Canada Delta	T041				453793.53	1383880.95	24.72
	T042				453800.48	1383856.28	23.39
Canada Gage	T031	453377.168	1384018.938	53.302	453377.54	1384018.36	55.46
	T032	453381.807	1383970.681	51.859	453332.96	1383999.26	52.85
Crescent	East 1				456445	1382978	
	West 2				456413	1383035	
Delta Gage	T081				454812.5	1382696.64	31.78
	T082				454756.78	1382652.61	35.28
Delta Upper	T071	454646.627	1379597.444	254.281	454646.79	1379596.84	256.72
	T072	454597.389	1379635.999	254.206	454597.59	1379635.4	256.73
Green	T091	453553.621	1382824.428	30.181	453553.78	1382823.85	32.58
	T092	453577.282	1382777.215	26.269	453577.4	1382776.69	28.72
House	T021				446008.86	1380429.32	85.42
	T022				446015.47	1380420.36	85.89
Huey	T111				455014.53	1385308.68	41.15
	T112				454956.6	1385293.3	
Lawson	T141				435176.78	1371328.03	79.13
	T142				435126.2	1371296.78	85.08
Priscu	T131	441495.939	1374232.849	70.586	441495.23	1374233.2	71.96
	T132	441440.367	1374306.38	75.215	441433.02	1374301.32	76.64
V. G. Gauge	T121	458214.426	1384618.425	22.23	458213.69	1384618.96	23.87
	T122	458160.24	1384588.914	22.865	458159.6	1384589.47	24.53
V. G. Middle	T061				459040.96	1383518.46	89.19
	T062				459017.73	1383477.86	88.92
V. G. Upper	T051				459492.26	1381827.71	169.27
	T052				459540.01	1381868.2	175.41
Wharton	OLC1				446184.32	1380197.98	83.42
	OLC2				446297.38	1380261.65	83.28
Miers Outlet	1				474729	1330385	
	2				474727	1330342	
Garwood	1				474593	1338822	
	2				?	?	?

FIGURE 9-1 BENCHMARK LATITUDE, LONGITUDE, AND MSL. ALL 20 STREAMS WITHIN TAYLOR, GARWOOD, AND MIERS VALLEYS. LEFT COLUMN OF DATA INDICATE EXACT LOCATION. RIGHT COLUMN OF DATA ARE ESTIMATED LOCATIONS.

Location	93/94	94/95	97/98	00/01	02/03	08/09	09/10	10/11	11/12	12/13	13/14	14/15
Adams(S of Upper Miers)									X L (SP)		X	
Anderson	X		X	X	X			L				
Bohner	X			X	X			X L	X	X	X	
Bowles	X			X	X			X L	X	X	X L	
Canada Delta	X*	X			X							
Canada Gage	X			X	X		L	X**L	X	X	X	
Crescent										X L	X	
Crescent Perched Delta											L	
Delta Gage	X		X	X	X			X	X	X	X	L**
Delta Upper	X		X	X	X			X L		X	X	
Garwood										L.csv	X	
Green	X	X		X	X		L	X L**	X	X	X L	
House	X		X		X*							
Huey	X		X	X	X		L***			L.csv	X	
Lawson	X		X	X	X				X(newT) L	X		
Miers Outlet									X L		X	
Priscu	X*	X	X	X	X			L				
Von Guerard Gauge	X			X	X**	L**	L**	X L	X	X	X	
Von Guerard Middle/lower	X*			X	X		L		X L	X	X	
Von Guerard Upper	X*			X	X*	L***					L	
Von Guerard Drift							L					
Wharton		X		X	X							

X Survey Conducted

L Lidar Scan

* = less than 20 survey points

** =Survey completed but data missing

*** = Data corrupt or year unknown

FIGURE 9-2 RECORD OF SCANS AND LIDAR TAKEN. "X" INDICATES A TOTAL STATION SURVEY WAS CONDUCTED. AN "L" INDICATES LIDAR WAS SHOT DURING SEASON.

Date		BM 1			BM 2					
1-Jan-14	Origin X =	450000		Backsight X =	450000					
	Origin Y =	1380000		Backsight Y =	1380000					
	Origin Elevation =	100		Backsight Elevation =	100					
					HI (m) =	0	Height Instrument			
	Azimuth of Backsight =		EQ {1}		HR (m) =	0	Height Survey Rod			
	Hz Angle to Backsight =		C10							
Point Number	Description	Horizontal Angle	Vertical Angle	Long Distance	Horizontal Distance	Vertical Distance	Azimuth of Line	X	Y	Elevation
1	Backsite	0	0	0	EQ {2}	EQ {3}	EQ {4}	EQ {5}	EQ {6}	EQ {7}
2	Orange Mat	0	0	0	EQ {2}	EQ {3}	EQ {4}	EQ {5}	EQ {6}	EQ {7}

FIGURE 9-3 CONVERSION SPREADSHEET. THIS SPREADSHEET PROVIDES THE BASIC OUTLINE OF HOW TO CONVERT SURVEY DATA FROM A TOTAL STATION INTO DELIVERABLE XYZ COORDINATES IN UTM 58S. CELLS HIGHLIGHTED IN YELLOW REQUIRE USER INPUT, WHILE OUTLINED CELLS REQUIRE EQUATIONS DISCUSSED IN SECTION 3.2.1 .

Stream\Season	9394	9495	9596	9697	9798	9899	9900	0001	0102	0203	0304
B5\B1	6.35E+07	4.12E+07	7.53E+07	7.10E+07	1.12E+08	7.81E+07	4.63E+07	2.53E+07	5.18E+08	1.05E+08	1.87E+08
F1	1.30E+08	4.17E+07	1.10E+08	9.30E+07	7.69E+07	1.29E+08	8.54E+07	9.37E+07	7.61E+08	1.21E+08	9.17E+07
F10\up	6.33E+07	2.47E+06	N/A	N/A	6.12E+06	2.57E+07	N/A	N/A	4.07E+08	2.77E+07	N/A
F9\Bowles	5.83E+07	2.72E+07	6.80E+07	6.61E+07	5.71E+07	1.46E+08	4.83E+07	N/A	3.41E+08	7.67E+07	1.05E+08
F2	4.81E+07	N/A	N/A	4.22E+06	3.22E+06	1.09E+06	1.74E+06	N/A	N/A	N/A	N/A
B3	N/A	1.00E+08	1.35E+08	1.10E+08	7.62E+07	1.14E+08	1.19E+08	1.02E+08	3.25E+08	1.16E+08	1.36E+08
F6\mid	6.77E+07	5.86E+06	6.53E+06	4.59E+06	7.20E+05	7.27E+06	N/A	N/A	2.76E+08	1.21E+07	1.25E+07
Totals	4.31E+08	2.19E+08	3.95E+08	3.49E+08	3.32E+08	5.01E+08	3.01E+08	2.21E+08	2.63E+09	4.58E+08	5.32E+08

Stream\Season	0405	0506	0607	0708	0809	0910	1011	1112	1213	Average
B5\B1	9.43E+07	1.25E+08	2.16E+08	6.39E+07	3.73E+08	2.25E+07	1.01E+08	1.23E+08	N/A	1.29E+08
F1	2.26E+08	2.55E+08	1.18E+08	2.38E+08	5.59E+08	1.58E+08	3.88E+08	2.99E+08	2.02E+08	2.09E+08
F10\up	8.08E+07	1.74E+08	1.58E+08	3.39E+07	3.60E+08	2.17E+07	2.44E+08	6.56E+07	2.47E+07	1.13E+08
F9\Bowles	1.98E+08	2.28E+08	1.83E+08	1.75E+08	3.00E+08	1.23E+08	3.04E+08	1.88E+08	2.67E+08	1.56E+08
F2	1.20E+05	1.25E+07	3.05E+07	5.18E+06	2.46E+08	1.66E+06	1.27E+08	N/A	N/A	4.01E+07
B3	1.18E+08	1.37E+08	1.79E+08	1.22E+08	2.95E+08	9.40E+07	2.91E+08	2.18E+08	1.34E+08	1.54E+08
F6\mid	1.01E+08	4.06E+07	4.31E+07	1.81E+07	1.94E+08	9.37E+07	2.21E+08	4.06E+07	1.70E+07	6.46E+07
Totals	8.19E+08	9.71E+08	9.27E+08	6.56E+08	2.33E+09	5.14E+08	1.68E+09	9.35E+08	6.45E+08	7.92E+08

FIGURE 9-4 OVERALL SEASONAL FLOW FOR MDV STREAMS. DATA WERE TAKEN FROM MCMLTER.ORG AND EVERY DAY WITH FLOW WITHIN SEASON WAS ADDED INTO AN OVERALL COMPOSITE FLOW FOR EACH STREAM.

Stream\Season	9394	9495	9596	9697	9798	9899	9900	0001	0102	0203	0304	0405	0506	0607	0708	0809	0910	1011	1112	1213
B5\B1	0.5	0.3	0.6	0.6	0.9	0.6	0.4	0.2	4.0	0.8	1.5	0.7	1.0	1.7	0.5	2.9	0.2	0.8	1.0	N/A
F1	0.6	0.2	0.5	0.5	0.4	0.6	0.4	0.5	3.6	0.6	0.4	1.1	1.2	0.6	1.1	2.7	0.8	1.9	1.4	1.0
F10\up	0.6	0.0	N/A	N/A	0.1	0.2	N/A	N/A	3.6	0.3	N/A	0.7	1.5	1.4	0.3	3.2	0.2	2.2	0.6	0.2
F9\Bowles	0.4	0.2	0.4	0.4	0.4	0.9	0.3	N/A	2.2	0.5	0.7	1.3	1.5	1.2	1.1	1.9	0.8	2.0	1.2	1.7
F2	1.2	N/A	N/A	0.1	0.1	0.0	0.0	N/A	N/A	N/A	N/A	N/A	0.3	0.8	0.1	6.1	0.0	3.2	N/A	N/A
B3	N/A	0.7	0.9	0.7	0.5	0.7	0.8	0.7	2.1	0.8	0.9	0.8	0.9	1.2	0.8	1.9	0.6	1.9	1.4	0.9
F6\mid	1.1	0.1	0.1	0.1	0.0	0.1	N/A	N/A	4.3	0.2	0.2	1.6	0.6	0.7	0.3	3.0	1.5	3.4	0.6	0.3
Totals	4.3	1.5	2.5	2.3	2.3	3.3	1.9	1.3	19.9	3.1	3.6	6.1	7.0	7.4	4.3	21.8	4.0	15.2	6.2	4.0

FIGURE 9-5 WEIGHTED OVERALL FLOW FOR MDV STREAMS. DATA WERE SUMMED AND AVERAGED TO GET A WEIGHTED FLOW FOR SEASON. $X > 1$ INDICATES AN ABOVE AVERAGE FLOW REGIME WHILE $X < 1$ INDICATES A LOWER THAN AVERAGE FLOW SEASON.

9.1.1 Canada Stream F1

SURVEYS

Point #	UTM Easting (m)	UTM Northing (m)	Height (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
1	453381.80	1383970.73	51.70	T BM T032		
2	453378.38	1384006.44	52.18	T topo		
3	453378.85	1384001.42	50.48	T wat edg bow		
4	453379.00	1383999.88	50.40	T wat edg bow		
5	453379.78	1383991.75	50.73	T topo isle top		
6	453380.44	1383984.81	50.51	T water edge		
7	453381.12	1383977.84	50.44	T water edge		
8	453381.50	1383973.81	51.59	T topo		
9	453369.77	1383972.61	52.25	topo		
10	453375.86	1383972.32	51.62	topo		
11	453386.20	1383974.65	51.66	topo		
12	453389.69	1383975.50	51.94	topo		
13	453397.69	1383980.52	51.37	topo		
14	453403.31	1383979.66	50.89	topo		
15	453404.06	1383984.63	49.61	topo		
16	453405.78	1383988.93	49.73	topo		
17	453404.51	1383997.61	48.90	dis a		
18	453401.43	1383995.80	49.04	water edge		
19	453400.70	1383994.78	49.25	water edge		
20	453398.54	1383989.97	49.39	water edge		
21	453395.85	1383987.37	49.64	water edge dis b		
22	453388.02	1383977.77	50.33	water edge		
23	453386.04	1383977.51	50.39	water edge		
24	453380.90	1383977.66	50.56	water edge		
25	453370.90	1383978.95	51.14	water edge		
26	453360.23	1383979.60	51.43	water edge		
27	453356.87	1383979.75	51.60	water edge		
28	453360.13	1383979.42	51.48	water edge whi l		
29	453367.95	1383976.16	51.20	water edge whi l		
30	453375.07	1383975.31	51.01	water edge whi l		
31	453377.46	1383976.48	50.90	water edge whi l		
32	453378.12	1383977.71	50.70	water edge whi l		
33	453404.05	1383999.99	48.91	dis a		
34	453387.58	1384007.04	52.00	topo		
35	453400.46	1384006.93	52.01	topo		
36	453368.29	1383987.77	51.13	moss sam 1		
37	453373.72	1383996.51	50.62	moss sam 2		
38	453373.38	1383986.88	50.93	moss sam 3		
39	453374.64	1383977.52	50.84	moss sam 4		

FIGURE 9-6 CANADA 1993/94 (1/2)

Point #	UTM Easting (m)	UTM Northing (m)	Height (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
40	453380.89	1383977.78	50.53	moss sam 5		
41	453368.15	1383986.53	51.09	algae red 1	19.56	6.91
42	453372.63	1383984.69	50.96	algae red 2	19.47	2.30
43	453388.00	1383986.78	50.07	algae red 3	7.18	5.20
44	453391.12	1383989.62	49.75	algae red 4	44.14	6.10
45	453385.18	1383985.31	50.25	algae red 5	10.93	4.37
46	453373.08	1383982.13	50.86	algae orange 1	19.00	7.92
47	453384.08	1383981.46	50.39	algae orange 2	10.40	10.37
48	453391.36	1383984.32	49.92	algae orange 3	11.40	7.71
49	453396.94	1383992.46	49.27	algae orange 4	16.40	3.24
50	453413.71	1383996.83	48.58	algae orange 5	22.40	2.83
51	453414.81	1383994.83	48.45	algae green 1	5.80	9.87
52	453413.46	1383996.61	48.51	algae green 2	5.40	7.87
53	453407.68	1383999.15	48.75	algae green 3	8.00	8.54
54	453403.88	1384000.67	48.89	sno cover water		
55	453403.62	1384002.72	49.34	sno cover water		
56	453397.57	1383999.70	49.28	sno cover water		
57	453394.58	1383993.96	49.43	water edge		
58	453391.21	1383991.15	49.69	water edge dis b		
59	453383.52	1383985.19	50.36	water edge		
60	453375.71	1383985.08	50.87	water edge		
61	453369.36	1383988.15	51.18	water edge		
62	453357.96	1383987.64	51.44	water edge		
63	453359.68	1383988.81	51.35	water edge rock		
64	453360.55	1383988.50	51.35	rock		
65	453359.16	1383987.17	51.36	rock		
66	453359.32	1383987.95	52.02	rock top		
67	453380.08	1383988.62	51.14	moss edg		
68	453372.01	1383990.34	51.08	moss edg		
69	453379.75	1383994.70	50.56	moss edg		
70	453385.80	1383995.19	50.38	moss edg		
71	453387.47	1383995.87	50.27	moss edg		
72	453389.47	1383998.90	50.11	moss edg		
73	453386.06	1384001.25	50.30	moss edg		
74	453378.68	1384001.44	50.57	moss edg		
75	453373.19	1383996.41	50.78	moss edg		
76	453370.96	1383994.23	51.07	moss edg		
77	453368.69	1383992.88	51.20	moss edg		
78	453378.14	1383997.15	50.49	rock		
79	453377.08	1383997.80	50.54	rock		
80	453377.60	1383998.85	50.50	rock		
81	453378.45	1383998.02	50.49	rock		
82	453377.46	1383997.60	50.89	rock top		
83	453363.54	1383998.69	51.98	topo		
84	453369.82	1384001.18	52.28	topo		
85	453376.25	1384006.10	52.24	topo		

FIGURE 9-7 CANADA 1993/94 (2/2)

Point #	UTM Easting (m)	UTM Northing (m)	Height (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
1	453375.17	1383998.03	51.65	Rock Top		
2	453340.23	1383983.02	51.64	Flume Front		
3	453339.18	1383982.95	51.67	Flume Middle		
4	453338.41	1383982.96	51.66	Flume Back		
5	453376.18	1383970.07	52.40	Near Lost BM		
6	453376.29	1383972.03	52.21	Topo		
7	453376.27	1383974.50	51.45	Salt Crust		
8	453376.35	1383978.55	50.80	Water Edge		
9	453376.08	1383980.41	50.70	Topo		
10	453377.60	1383974.85	51.40	Salt Crust		
11	453380.34	1383976.20	51.26	Salt Crust		
12	453382.55	1383978.35	51.06	Salt Crust		
13	453371.52	1383975.38	51.51	Salt Crust		
14	453367.96	1383976.69	51.54	Salt Crust		
15	453369.34	1383978.64	51.05	Wetted Edge		
16	453372.76	1383978.34	51.06	Wetted Edge		
17	453378.58	1383978.04	50.95	Wetted Edge		
18	453381.98	1383979.46	50.78	Wetted Edge		
19	453381.61	1383981.25	50.65	Water Edge		
20	453379.54	1383979.33	50.73	Water Edge		
21	453375.63	1383978.95	50.82	Water Edge		
22	453371.67	1383978.91	50.97	Water Edge		
23	453368.40	1383979.08	50.96	Water Edge		
24	453375.72	1383981.37	50.73	Thalweg		
25	453378.51	1383982.04	50.61	Thalweg		
26	453380.44	1383982.89	50.55	Thalweg		
27	453370.48	1383981.30	50.86	Thalweg		
28	453371.05	1383983.12	50.88	Water Edge		
29	453374.67	1383984.21	50.82	Water Edge		
30	453377.87	1383983.92	50.71	Water Edge		
31	453379.66	1383985.81	50.60	Water Edge		
32	453371.60	1383978.92	50.89	Snow		
33	453376.37	1383978.55	50.81	Snow		
34	453371.77	1383977.49	51.18	Snow		
35	453372.88	1383975.57	51.43	Snow		
36	453376.14	1383975.15	51.33	Snow		
37	453378.25	1383977.35	51.06	Snow		
38	453352.34	1383981.34	51.15	Water Edge		
39	453357.88	1383980.45	51.13	Water Edge		
40	453364.50	1383979.62	51.03	Water Edge		
41	453384.83	1383983.47	50.47	Water Edge		
42	453385.66	1383986.65	50.29	Water Edge		
43	453388.19	1383990.10	50.15	Water Edge		
44	453393.20	1383993.80	49.97	Water Edge		
45	453395.58	1383997.84	49.75	Water Edge		
46	453397.84	1384001.73	49.64	Water Edge		
47	453398.24	1384006.36	49.46	Water Edge		
48	453400.54	1384009.29	49.40	Water Edge		
49	453397.09	1384011.54	49.38	Water Edge		

FIGURE 9-8 CANADA 2000/01 (1/3). NOT USED IN STUDY.

Point #	UTM Easting (m)	UTM Northing (m)	Height (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
50	453395.35	1384006.46	49.44	Water Edge		
51	453392.46	1384003.25	49.66	Water Edge		
52	453389.78	1384000.18	49.88	Water Edge		
53	453387.14	1383997.83	49.99	Water Edge		
54	453384.99	1383992.50	50.14	Water Edge		
55	453381.22	1383986.51	50.40	Water Edge		
56	453377.61	1383983.76	50.72	Water Edge		
57	453371.04	1383983.12	50.92	Water Edge		
58	453364.40	1383983.85	51.06	Water Edge		
59	453360.01	1383985.78	51.15	Water Edge		
60	453394.48	1383994.13	49.98	B4		
61	453389.27	1383990.56	50.11	B3		
62	453385.97	1383987.42	50.22	B2		
63	453387.29	1383990.32	50.06	O2		
64	453381.36	1383982.85	50.53	O4		
65	453380.75	1383982.57	50.56	G2		
66	453369.64	1383979.09	50.92	B1		
67	453364.34	1383982.40	51.01	G4		
68	453378.39	1383983.04	50.58	O1		
69	453380.79	1383985.29	50.35	G3		
70	453381.89	1383987.14	50.31	O3		
71	453379.97	1383996.25	50.39	M1		
72	453395.14	1383993.00	50.17	M2		
73	453375.94	1383985.28	50.96	M3		
74	453376.53	1383994.80	50.38	Moss		
75	453376.57	1383996.64	50.34	Moss		
76	453377.77	1383997.59	50.30	Moss		
77	453379.41	1383996.44	50.30	Moss		
78	453378.02	1383995.31	50.30	Moss		
79	453377.41	1383994.07	50.38	Moss		
80	453378.09	1383996.29	50.04	Moss		
81	453391.52	1384010.43	51.68	Topo		
82	453391.30	1384005.66	50.83	Topo		
83	453386.95	1384008.96	51.79	Topo		
84	453382.41	1384008.82	51.91	Topo		
85	453381.38	1384003.40	51.19	Topo		
86	453384.02	1383998.28	50.89	Topo		
87	453380.33	1383992.21	50.43	Topo		
88	453377.74	1383987.28	51.00	Topo		
89	453369.58	1383988.30	51.39	Topo		
90	453371.36	1383998.09	51.05	Topo		
91	453374.21	1384009.09	52.36	Topo		
92	453390.46	1383980.23	51.80	Topo		
93	453384.14	1383975.61	51.91	Topo		
94	453377.84	1383971.87	52.19	Topo		
95	453369.23	1383973.67	52.25	Topo		
96	453361.54	1383973.44	52.75	Topo		
97	453360.62	1383982.38	51.06	Thalweg		
98	453370.53	1383981.38	50.83	Thalweg		
99	453376.57	1383981.63	50.65	Thalweg		

FIGURE 9-9 CANADA 2000/01 (2/3). NOT USED IN STUDY.

Point #	UTM Easting (m)	UTM Northing (m)	Height (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
100	453381.19	1383984.76	50.33	Thalweg		
101	453384.68	1383988.65	50.16	Thalweg		
102	453388.30	1383991.17	50.07	Thalweg		
103	453392.64	1383996.27	49.81	Thalweg		
104	453394.80	1384002.99	49.46	Thalweg		
105	453397.26	1384007.45	49.27	Thalweg		
106	453375.81	1383998.16	50.67	Rock Rim		
107	453375.54	1383997.26	50.64	Rock Rim		
108	453375.00	1383997.63	50.75	Rock Rim		
109	453374.36	1383997.94	50.79	Rock Rim		
110	453374.82	1383998.58	50.81	Rock Rim		
111	453375.36	1383998.36	50.79	Rock Rim		
112	453375.15	1383997.93	51.47	Rock Top		
113	453376.20	1383970.45	52.35	New BM		
114	453376.20	1383970.46	52.35	New BM		
115	453376.21	1383970.45	52.35	New BM		

FIGURE 9-10 CANADA 2000/01 (3/3). NOT USED IN STUDY.

Point #	UTM Easting (m)	UTM Northing (m)	Height (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
1	453381.80	1383970.76	52.96	backsight		
2	453381.49	1383973.81	52.66	slope glacier side		
3	453381.36	1383976.06	52.07	wetted perimeter		
4	453381.06	1383977.99	51.68	stream edge		
5	453380.77	1383979.26	51.58	thalweg		
6	453379.19	1383983.21	51.73	stream edge		
7	453378.25	1384001.70	51.82	wetted perimeter		
8	453377.78	1384007.48	53.50	east slope		
9	453348.57	1383978.99	52.92	stream on glacier side		
10	453359.35	1383981.85	52.50	stream on glacier side		
11	453387.35	1383977.28	51.51	stream on glacier side		
12	453400.72	1383994.76	50.40	stream on glacier side		
13	453406.85	1383998.08	52.91	stream on glacier side		
14	453413.50	1383994.40	49.69	stream on glacier side		
15	453433.13	1383963.07	48.77	stream on glacier side		
16	453435.19	1383964.48	48.75	stream on non-glacier side		
17	453427.24	1383975.78	49.87	gage on non-glacier side		
18	453425.16	1383974.67	49.75	gage on glacier side		
19	453410.38	1384000.43	50.47	stream on non-glacier side		
20	453397.60	1383996.98	50.27	stream on non-glacier side		
21	453381.88	1383984.27	51.65	stream on non-glacier side		
22	453345.75	1383982.83	52.92	stream and rock with high point		
23	453348.54	1383981.17	52.94	thalweg		
24	453358.36	1383983.20	52.50	thalweg		
25	453388.23	1383981.45	51.28	Orange mat		
26	453400.09	1383995.33	50.29	thalweg		
27	453408.59	1383998.46	49.94	thalweg		
28	453415.33	1383992.63	49.47	thalweg		
29	453430.88	1383967.19	48.91	thalweg		
30	453429.96	1383970.23	49.00	Orange mat (no sample)		
31	453430.04	1383967.62	48.94			
32	453431.69	1383966.10	48.84			
33	453432.95	1383966.41	48.90			
34	453430.23	1383969.97	48.96			
35	453434.49	1383969.96	49.30	wetted perimeter non-glacier side		
36	453420.94	1383996.75	49.93	wetted perimeter non-glacier side		
37	453410.13	1384002.49	50.55	wetted perimeter non-glacier side		
38	453378.69	1384002.21	51.86	wetted perimeter non-glacier side		
39	453367.85	1383995.99	52.48	wetted perimeter non-glacier side		
40	453348.13	1383995.46	53.27	wetted perimeter non-glacier side		
41	453347.97	1383974.76	53.32	wetted perimeter - glacier side		
42	453359.22	1383977.78	52.86	wetted perimeter - glacier side		
43	453376.79	1383974.23	52.21	wetted perimeter - glacier side		
44	453387.52	1383976.73	51.84	wetted perimeter - glacier side		
45	453398.28	1383984.17	51.17	wetted perimeter - glacier side		
46	453391.74	1383993.79	50.89	Black Mat 1	7.58	0.11
47	453398.60	1383988.70	50.73	wetted perimeter - glacier side		
48	453395.55	1383984.12	51.08	Moss 1		
49	453391.57	1383981.43	51.41	Black Mat 2	15.15	0.19

FIGURE 9-11 CANADA 2002/03 (1/2)

Point #	UTM Easting (m)	UTM Northing (m)	Height (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
50	453404.37	1383994.02	50.51	wetted perimeter - glacier side		
51	453410.74	1383993.87	50.11	wetted perimeter - glacier side		
52	453385.68	1383978.23	51.48	red mat 2	8.11	2.53
53	453384.39	1383977.80	51.48	black mat 3	2.31	0.05
54	453412.37	1383980.85	50.44	wetted perimeter - glacier side		
55	453426.12	1383961.05	49.75	wetted perimeter - glacier side		
56	453422.67	1383974.69	49.48	Black and green moss		
57	453421.35	1383977.41	49.50	Black and green moss		
58	453419.99	1383979.36	49.49	Black and green moss		
59	453416.90	1383982.98	49.77	Moss 2		
60	453415.66	1383985.83	49.69	black algal mat		
61	453414.08	1383986.60	50.00	black algal mat		
62	453411.97	1383988.44	50.19	black algal mat		
63	453412.45	1383992.28	49.87	black algal mat		
64	453430.44	1383967.94	48.85	Orange Mat 1	5.46	3.58
65	453348.78	1383986.48	52.95	Black mat-entire wetted covered		
66	453368.67	1383991.83	52.30	black mat		
67	453372.26	1383991.10	52.07	black mat		
68	453378.57	1383993.63	51.77	black mat		
69	453391.30	1383997.91	50.96	black mat		
70	453388.00	1384000.56	51.20	black mat		
71	453378.70	1384001.23	51.55	black mat		
72	453372.49	1383996.64	51.98	black mat		
73	453416.39	1383982.94	49.88	moss 3		
74	453412.74	1383991.64	49.82	black mat 4	1.61	0.06
75	453342.78	1383982.23	53.09	orange algae 3 and red mat 1	6.07	1.90
76	453357.78	1383987.56	52.62	orange algae 4	4.01	2.60
77	453379.25	1384000.66	51.53	orange algae 2	4.84	1.11
78	453376.72	1383999.95	51.68	moss 4		
79	453376.39	1383999.42	51.61	black mat 5	14.08	0.18
80	453394.82	1383991.95	50.55	red mat 3	7.46	1.56
81	453360.87	1383982.28	52.40	red mat 4	7.11	3.40

FIGURE 9-12 CANADA 2002/03 (2/2)

Point #	UTM Easting (m)	UTM Northing (m)	Height (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
1	453377.17	1384018.97	53.35	North BM - Backsight		
2	453361.41	1383980.98	51.44	Red 4	44.23	7.64
3	453364.36	1383981.45	51.29	Red 2	19.52	4.57
4	453365.50	1383981.53	51.27	Red 1	33.70	9.10
5	453365.34	1383984.96	51.19	Orange 1	9.07	7.89
6	453368.15	1383986.80	51.20	Green 1	3.35	4.07
7	453371.60	1383984.91	51.00	Orange 3	13.22	7.74
8	453371.27	1383979.76	51.08	Red 3	19.52	4.57
9	453376.40	1383978.34	50.83	Black 1	16.56	12.68
10	453377.97	1383977.95	50.69	Black 2	14.54	5.52
11	453381.31	1383977.67	50.58	Black 3	18.06	3.01
12	453387.11	1383977.51	50.45	Black 4	11.63	5.98
13	453387.67	1383977.77	50.40	Orange 4	9.78	5.27
14	453389.43	1383980.18	50.39	Green 4	6.43	5.42
15	453385.03	1383980.77	50.45	Green 3	9.82	9.71
16	453383.15	1383984.37	50.38	Green 2	3.26	3.11
17	453380.48	1383980.10	50.57	Orange 2	12.82	8.25

FIGURE 9-13 CANADA 2011/12

Point #	UTM Easting (m)	UTM Northing (m)	Height (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
1	453377.17	1384018.95	53.35	north benchmark - backsight		
2	453389.75	1383989.76	49.95	Black 4		
3	453388.22	1383983.93	50.20	Green 1	3.22	2.69
4	453387.54	1383981.60	50.26	Orange 4	19.60	6.24
5	453387.36	1383980.51	50.31	Orange 4	15.20	12.84
6	453387.03	1383977.97	50.84	Top of round, pointy rock		
7	453387.49	1383977.54	50.40	Green 2	5.86	1.57
8	453385.09	1383985.68	50.36	Red 3	30.18	7.60
9	453382.23	1383980.07	50.46	Orange 2	11.54	8.65
10	453380.61	1383978.16	50.58	Green 3	5.24	2.58
11	453377.10	1383979.03	50.73	Red 4	21.63	12.74
12	453368.06	1383980.89	51.17	Red 2	23.66	10.23
13	453366.10	1383977.48	51.24	Black 2	19.91	8.24
14	453361.99	1383980.03	51.42	Black 1	17.62	8.31
15	453364.78	1383982.27	51.21	Red 1	25.77	5.60
16	453360.45	1383980.21	51.48	Black 3	11.72	4.96
17	453367.28	1383987.16	51.21	Orange 3	5.02	7.78
18	453359.43	1383987.98	52.07	center point of big upstream rock		

FIGURE 9-14 CANADA 2012/13

Point #	UTM Easting (m)	UTM Northing (m)	Height (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
1	458187.08	1384603.53	22.28	BM?		
2	458190.78	1384589.46	21.11	B3		
3	458191.24	1384589.98	21.02	O1		
4	458181.98	1384611.62	19.48	O2		
5	458187.48	1384610.46	19.64	B2		
6	458191.33	1384611.31	19.71	O3		
7	458200.26	1384598.30	20.58	B1		

FIGURE 9-15 CANADA 2013/14

RELATIVE BED CHANGES

Year	Mean	Max	Min
1994	0.08	0.20	-0.03
2003	0.10	0.25	-0.04
2012	0.02	0.08	-0.01
2013	0.03	0.16	-0.06
2014	0.00	0.04	-0.09

FIGURE 9-16 CANADA RELATIVE BED CHANGES.

AFDM COMPARISON

Change	AFDM	Type
-0.17	5.80	1
-0.13	8.00	1
-0.11	5.40	1
-0.07	0.00	1
-0.02	3.26	1
0.00	3.35	1
0.01	9.82	1
0.02	3.22	1
0.02	5.86	1
0.02	0.00	1
0.02	5.24	1
0.05	6.43	1
-0.12	7.58	2
-0.11	0.00	2
-0.07	0.00	2
-0.05	19.91	2
-0.05	14.08	2
-0.02	14.54	2
-0.02	0.00	2
-0.02	0.00	2
-0.02	18.06	2
-0.01	17.62	2
-0.01	11.72	2
0.00	0.00	2
0.01	0.00	2
0.03	2.31	2
0.04	16.56	2
0.05	0.00	2
0.05	11.63	2
-0.17	0.00	3
-0.16	22.40	3
-0.09	4.01	3
-0.08	6.07	3
-0.06	11.40	3
-0.06	4.84	3

Change	AFDM	Type
-0.06	16.40	3
-0.05	5.46	3
-0.04	0.00	3
-0.04	0.00	3
-0.04	5.02	3
-0.04	9.07	3
-0.03	11.54	3
-0.02	13.22	3
0.00	19.00	3
0.00	10.40	3
0.01	0.00	3
0.01	15.20	3
0.01	0.00	3
0.02	12.82	3
0.02	19.60	3
0.02	9.78	3
-0.10	7.46	4
-0.09	25.77	4
-0.05	10.93	4
-0.05	7.18	4
-0.04	19.47	4
-0.03	19.52	4
-0.03	19.52	4
-0.02	8.11	4
-0.02	33.70	4
-0.01	44.14	4
-0.01	21.63	4
0.00	0.00	4
0.00	44.23	4
0.01	0.00	4
0.02	23.66	4
0.03	7.11	4
0.04	19.56	4
0.06	30.18	4

FIGURE 9-17 CANADA AFDM COMPARISON. FIRST COLUMN IS RELATIVE CHANGE AT POINT IN STREAM. SECOND COLUMN IS AFDM. THIRD COLUMN IS MICROBIAL MAT TYPE (1=GREEN, 2=BLACK, 3=ORANGE, 4=RED)

FLOW COMPARISON

AFDM	Flow	Type
9.82	1.43	1
8.00	0.62	1
6.43	1.43	1
5.86	0.97	1
5.80	0.62	1
5.40	0.62	1
5.24	0.97	1
3.35	1.43	1
3.26	1.43	1
3.22	0.97	1
0.00	NaN	1
0.00	NaN	1
19.91	0.97	2
18.06	1.43	2
17.62	0.97	2
16.56	1.43	2
14.54	1.43	2
14.08	0.58	2
11.72	0.97	2
11.63	1.43	2
7.58	0.58	2
2.31	0.58	2
0.00	0.58	2
0.00	0.58	2
0.00	0.58	2
0.00	0.58	2
0.00	0.58	2
0.00	0.97	2
0.00	NaN	2
22.40	0.62	3
19.60	0.97	3
19.00	0.62	3
16.40	0.62	3
15.20	0.97	3
13.22	1.43	3

AFDM	Flow	Type
12.82	1.43	3
11.54	0.97	3
11.40	0.62	3
10.40	0.62	3
9.78	1.43	3
9.07	1.43	3
6.07	0.58	3
5.46	0.58	3
5.02	0.97	3
4.84	0.58	3
4.01	0.58	3
0.00	0.58	3
0.00	0.58	3
0.00	NaN	3
0.00	NaN	3
0.00	NaN	3
44.23	1.43	4
44.14	0.62	4
33.70	1.43	4
30.18	0.97	4
25.77	0.97	4
23.66	0.97	4
21.63	0.97	4
19.56	0.62	4
19.52	1.43	4
19.52	1.43	4
19.47	0.62	4
10.93	0.62	4
8.11	0.58	4
7.46	0.58	4
7.18	0.62	4
7.11	0.58	4
0.00	NaN	4
0.00	NaN	4

FIGURE 9-18 CANADA FLOW COMPARISON. FIRST COLUMN IS AFDM. SECOND COLUMN IS WEIGHTED FLOW FOR SEASON OF SURVEY. THIRD COLUMN IS MICROBIAL MAT TYPE (1=GREEN, 2=BLACK, 3=ORANGE, 4=RED)

9.1.1 Green Creek F9

SURVEYS

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
1	453558.78	1382814.14	28.84	T topo		
2	453563.31	1382805.11	25.03	T wet zone		
3	453563.89	1382803.94	24.92	T water edge		
4	453565.80	1382800.11	24.80	T thalwag		
5	453569.26	1382793.23	24.89	T water edge		
6	453573.53	1382784.69	25.33	T wet zone		
7	453575.86	1382780.04	25.74	T topo		
8	453570.62	1382805.12	24.62	algae orange 1	8.90	7.99
9	453565.64	1382802.65	24.77	algae orange 2	33.66	3.99
10	453563.80	1382797.56	24.91	algae orange 3	8.59	10.09
11	453561.05	1382792.78	25.01	algae orange 4	17.36	3.57
12	453553.81	1382794.61	25.23	algae orange 5	6.87	8.57
13	453567.75	1382807.75	24.74	algae black 1	114.41	
14	453558.22	1382800.14	25.08	algae black 2	58.15	39.62
15	453575.50	1382797.33	24.71	algae black 3	12.82	60.78
16	453573.71	1382794.23	24.81	algae black 4	54.76	19.39
17	453565.26	1382789.00	25.09	algae black 5	34.23	
18	453568.09	1382809.03	24.78	moss sam 1		
19	453557.42	1382801.56	25.26	moss sam 2		
20	453575.99	1382795.75	24.77	moss sam 3		
21	453575.04	1382792.05	24.84	moss sam 4		
22	453565.90	1382786.80	25.18	moss sam 5		
23	453581.47	1382783.14	25.85	topo		
24	453585.80	1382790.77	25.49	topo		
25	453570.85	1382774.21	26.68	topo		
26	453564.49	1382771.47	27.50	topo		
27	453562.17	1382782.12	25.58	wet zone		
28	453568.58	1382783.02	25.47	wet zone		
29	453578.94	1382788.41	25.13	wet zone		
30	453584.50	1382793.07	25.03	topo		
31	453580.65	1382798.36	24.81	wet zone		
32	453575.67	1382802.49	24.55	water edge		
33	453575.98	1382794.43	24.76	water edge		
34	453566.31	1382790.61	25.03	water edge		
35	453561.20	1382787.27	25.31	water edge		
36	453558.44	1382784.42	25.49	water edge		
37	453554.41	1382794.29	25.19	thalwag		
38	453557.54	1382795.54	25.11	thalwag		
39	453563.25	1382797.96	24.90	thalwag		

FIGURE 9-19 GREEN 1993/94 (1/2)

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
40	453567.27	1382802.74	24.72	thalwag		
41	453569.53	1382806.18	24.65	thalwag		
42	453568.37	1382808.24	24.71	water edge		
43	453561.19	1382802.03	24.93	water edge		
44	453557.82	1382799.94	25.10	water edge		
45	453554.96	1382796.94	25.24	water edge		
46	453553.64	1382800.20	25.47	wet zone		
47	453556.63	1382802.00	25.43	wet zone		
48	453564.63	1382806.52	25.10	wet zone		
49	453566.35	1382808.87	25.10	wet zone		
50	453571.20	1382808.88	24.57	water edge dis		
51	453576.24	1382803.56	24.52	water edge dis		
52	453563.54	1382820.45	28.93	topo		
53	453561.21	1382813.28	28.13	topo		
54	453553.81	1382807.32	28.33	topo		
55	453548.22	1382805.14	28.44	topo		
56	453544.65	1382810.74	29.30	topo		
57	453560.30	1382826.34	29.41	topo		
58	453573.44	1382804.25	24.81	rock b1		
59	453572.87	1382804.18	24.54	rock b1		
60	453573.28	1382803.77	24.61	rock b1		
61	453573.97	1382804.00	24.55	rock b1		
62	453573.75	1382804.80	24.52	rock b1		
63	453558.43	1382788.57	25.65	rock b2		
64	453557.86	1382788.38	25.34	rock b2		
65	453558.43	1382788.67	25.25	rock b2		
66	453559.23	1382788.63	25.26	rock b2		
67	453558.98	1382788.27	25.35	rock b2		

FIGURE 9-20 GREEN 1993/94 (2/2)

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
1	453577.20	1382777.38	26.34	T092		
2	453356.40	1382448.05	53.62	NZ_BM_T10		
3	453273.29	1382583.45	31.93	stream_center		
4	453281.23	1382588.51	31.85	stream_center		
5	453293.77	1382597.42	31.63	stream_center		
6	453305.56	1382596.46	31.54	stream_center		
7	453318.02	1382607.97	31.40	stream_center		
8	453316.36	1382610.38	31.39	pool_edge		
9	453283.98	1382634.02	31.43	pool_edge		
10	453286.27	1382647.86	31.45	pool_edge		
11	453300.80	1382657.71	31.47	pool_edge		
12	453310.47	1382673.16	31.49	pool_edge		
13	453333.62	1382682.11	31.46	pool_edge		
14	453344.71	1382673.81	31.43	pool_edge		
15	453350.13	1382670.11	31.43	pool_edge		
16	453345.27	1382660.39	31.47	pool_edge		
17	453344.27	1382650.61	31.43	pool_edge		
18	453346.86	1382638.50	31.44	pool_edge		
19	453347.07	1382627.50	31.41	pool_edge		
20	453355.49	1382627.59	31.43	pool_edge		
21	453349.35	1382618.46	31.43	pool_edge		
22	453342.14	1382622.80	31.43	pool_edge		
23	453332.18	1382602.28	31.43	pool_edge		
24	453329.05	1382610.41	31.41	pool_edge		
25	453316.34	1382610.40	31.40	pool_edge		
26	453348.64	1382672.44	31.47	stream_center		
27	453359.37	1382680.30	31.27	stream_center		
28	453372.38	1382681.21	31.03	stream_center		
29	453396.13	1382686.46	30.42	stream_center		
30	453402.44	1382700.51	30.11	stream_center		
31	453406.43	1382722.92	29.72	stream_center		
32	453414.62	1382731.62	29.62	stream_center		
33	453433.90	1382741.92	29.48	stream_center		
34	453449.39	1382747.19	29.32	stream_center		
35	453456.93	1382757.52	29.19	stream_center		
36	453474.18	1382759.44	29.10	stream_center		
37	453491.26	1382768.51	28.58	stream_center		
38	453504.88	1382770.44	27.61	stream_center		
39	453522.97	1382773.57	26.75	stream_center		
40	453544.31	1382784.08	25.70	stream_center		
41	453565.46	1382799.97	24.79	stream_center		
42	453583.11	1382812.06	23.81	stream_center		
43	453590.50	1382808.09	23.91	GC_weir		
44	453587.15	1382812.22	23.91	GC_weir		
45	453585.78	1382813.79	23.80	flume_right		
46	453585.68	1382814.14	23.77	flume_center		
47	453585.46	1382814.29	23.76	flume_left		
48	453584.27	1382815.80	24.03	GC_weir		
49	453579.84	1382818.45	24.45	GC_weir		

FIGURE 9-21 GREEN 1994/95 (1/6)

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
50	453587.69	1382815.67	23.43	stream_center		
51	453609.07	1382824.26	22.84	stream_center		
52	453626.96	1382830.57	22.13	stream_center		
53	453642.80	1382839.65	21.15	stream_center		
54	453667.90	1382852.53	20.58	stream_center		
55	453685.00	1382871.90	19.85	stream_center		
56	453701.72	1382899.21	19.27	stream_center		
57	453706.06	1382922.70	18.96	stream_center		
58	453707.84	1382946.60	18.67	stream_center		
59	453696.55	1382968.05	18.36	stream_center		
60	453691.71	1382977.28	18.13	stream_center		
61	453685.19	1382980.08	17.85	stream_center		
62	453677.10	1382979.16	17.31	Cen_lake_edge		
63	453677.33	1382980.84	17.33	GC_stream_right_edge		
64	453687.17	1382981.45	17.93	GC_stream_right_edge		
65	453697.29	1382975.01	18.24	GC_stream_right_edge		
66	453706.66	1382960.51	18.58	GC_stream_right_edge		
67	453716.42	1382939.84	18.76	GC_stream_right_edge		
68	453713.61	1382918.52	19.01	GC_stream_right_edge		
69	453706.25	1382902.46	19.22	GC_stream_right_edge		
70	453700.91	1382883.60	19.54	GC_stream_right_edge		
71	453692.21	1382866.86	19.88	GC_stream_right_edge		
72	453684.83	1382856.47	20.10	GC_stream_right_edge		
73	453598.51	1382807.95	23.74	topo_shot		
74	453598.25	1382800.80	25.29	topo_shot		
75	453613.39	1382767.96	25.34	topo_shot		
76	453623.43	1382744.71	26.10	topo_shot		
77	453617.52	1382813.30	23.12	topo_shot		
78	453619.82	1382808.03	24.24	topo_shot		
79	453631.69	1382779.65	25.27	topo_shot		
80	453647.84	1382761.49	25.71	topo_shot		
81	453640.81	1382819.88	22.38	topo_shot		
82	453642.74	1382812.50	23.60	topo_shot		
83	453653.11	1382789.92	24.69	topo_shot		
84	453662.83	1382772.02	25.89	topo_shot		
85	453662.69	1382829.26	21.69	topo_shot		
86	453665.86	1382821.09	23.34	topo_shot		
87	453676.00	1382796.84	24.67	topo_shot		
88	453684.33	1382781.43	25.72	topo_shot		
89	453686.06	1382843.09	21.16	topo_shot		
90	453693.56	1382829.44	23.04	topo_shot		
91	453707.26	1382806.88	25.25	topo_shot		
92	453718.06	1382790.96	26.82	topo_shot		
93	453703.94	1382857.16	20.54	topo_shot		
94	453710.04	1382847.20	22.61	topo_shot		
95	453727.16	1382822.40	25.31	topo_shot		
96	453739.69	1382807.63	27.61	topo_shot		
97	453714.95	1382876.23	20.13	topo_shot		
98	453722.81	1382866.43	22.45	topo_shot		
99	453740.58	1382848.78	23.92	topo_shot		

FIGURE 9-22 GREEN 1994/95 (2/6)

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
100	453758.39	1382832.11	26.61	topo_shot		
101	453719.05	1382903.68	19.65	topo_shot		
102	453743.63	1382891.38	22.63	topo_shot		
103	453766.83	1382876.74	24.22	topo_shot		
104	453779.66	1382865.16	25.20	topo_shot		
105	453717.23	1382926.07	19.14	topo_shot		
106	453732.66	1382921.22	21.33	topo_shot		
107	453760.89	1382911.50	22.15	topo_shot		
108	453780.47	1382907.45	22.75	topo_shot		
109	453717.42	1382943.72	19.06	topo_shot		
110	453739.56	1382944.19	22.16	topo_shot		
111	453766.41	1382939.40	20.84	topo_shot		
112	453787.90	1382941.54	20.86	topo_shot		
113	453710.96	1382959.53	18.81	topo_shot		
114	453716.13	1382961.73	20.07	topo_shot		
115	453746.43	1382965.21	22.64	topo_shot		
116	453775.59	1382970.98	19.87	topo_shot		
117	453708.35	1382981.64	18.70	topo_shot		
118	453716.75	1382983.32	20.36	topo_shot		
119	453741.23	1382988.42	22.46	topo_shot		
120	453767.73	1382995.82	19.53	topo_shot		
121	453695.19	1382992.89	18.29	topo_shot		
122	453708.14	1383001.39	19.32	topo_shot		
123	453730.20	1383012.79	21.71	topo_shot		
124	453682.26	1383006.44	17.31	topo_shot		
125	453699.27	1383023.60	18.37	topo_shot		
126	453716.65	1383034.61	18.47	topo_shot		
127	453736.76	1383039.04	17.50	topo_shot		
128	453685.14	1383012.52	17.21	fryxell_lake_edge		
129	453694.73	1383039.94	17.24	fryxell_lake_edge		
130	453713.29	1383041.35	17.39	fryxell_lake_edge		
131	453730.37	1383045.90	17.18	fryxell_lake_edge		
132	453679.00	1382977.93	17.38	GC_40		
133	453677.93	1382977.89	17.27	fryxell_lake_edge		
134	453669.98	1382979.29	17.24	fryxell_lake_edge		
135	453663.34	1382989.39	17.28	fryxell_lake_edge		
136	453655.90	1382992.03	17.29	fryxell_lake_edge		
137	453682.52	1382972.02	18.39	topo_shot		
138	453675.69	1382969.94	19.63	topo_shot		
139	453659.53	1382971.91	20.84	topo_shot		
140	453647.77	1382974.85	19.33	topo_shot		
141	453691.65	1382947.54	18.97	topo_shot		
142	453686.20	1382948.12	19.67	topo_shot		
143	453651.35	1382949.70	21.00	topo_shot		
144	453639.13	1382952.01	20.83	topo_shot		
145	453687.56	1382924.21	19.34	topo_shot		
146	453679.53	1382926.21	20.23	topo_shot		
147	453644.86	1382934.06	23.05	topo_shot		
148	453632.20	1382935.50	22.54	topo_shot		
149	453672.97	1382899.82	20.03	topo_shot		

FIGURE 9-23 GREEN 1994/95 (3/6)

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
150	453666.66	1382902.95	21.57	topo_shot		
151	453639.28	1382919.57	24.20	topo_shot		
152	453625.10	1382927.44	23.09	topo_shot		
153	453653.82	1382886.91	20.66	topo_shot		
154	453644.91	1382890.63	22.17	topo_shot		
155	453625.83	1382902.14	26.00	topo_shot		
156	453613.63	1382912.85	24.35	topo_shot		
157	453642.56	1382867.78	21.13	topo_shot		
158	453632.96	1382872.86	22.59	topo_shot		
159	453614.06	1382887.99	26.83	topo_shot		
160	453601.71	1382901.09	25.39	topo_shot		
161	453640.10	1382855.93	21.38	topo_shot		
162	453632.69	1382858.55	22.22	topo_shot		
163	453606.80	1382879.04	26.91	topo_shot		
164	453594.78	1382889.52	26.36	topo_shot		
165	453636.52	1382840.65	21.51	GC_30		
166	453633.32	1382842.85	22.04	topo_shot		
167	453621.82	1382853.49	23.77	topo_shot		
168	453601.11	1382872.61	26.42	topo_shot		
169	453588.50	1382882.47	26.68	topo_shot		
170	453615.50	1382836.65	22.94	topo_shot		
171	453608.44	1382840.30	25.59	topo_shot		
172	453588.63	1382859.03	26.81	topo_shot		
173	453581.01	1382871.11	26.78	topo_shot		
174	453600.52	1382828.12	23.33	topo_shot		
175	453595.10	1382834.12	27.28	topo_shot		
176	453579.44	1382849.30	27.18	topo_shot		
177	453555.80	1382865.19	30.13	topo_shot		
178	453584.16	1382820.28	23.86	topo_shot		
179	453576.05	1382827.13	27.74	topo_shot		
180	453566.63	1382837.81	28.37	topo_shot		
181	453550.62	1382853.32	29.99	topo_shot		
182	453571.78	1382813.14	24.91	topo_shot		
183	453562.97	1382820.58	29.10	topo_shot		
184	453554.09	1382832.74	29.95	topo_shot		
185	453544.28	1382845.86	30.20	topo_shot		
186	453551.57	1382799.79	25.62	topo_shot		
187	453547.09	1382804.87	28.75	topo_shot		
188	453537.83	1382821.04	29.94	topo_shot		
189	453529.19	1382831.15	29.91	topo_shot		
190	453548.04	1382793.89	25.53	GC_20		
191	453531.77	1382794.42	26.61	topo_shot		
192	453529.16	1382798.19	28.24	topo_shot		
193	453523.40	1382812.95	30.82	topo_shot		
194	453517.71	1382823.07	30.06	topo_shot		
195	453514.10	1382792.35	27.69	topo_shot		
196	453510.65	1382797.70	28.24	topo_shot		
197	453503.36	1382810.91	29.49	topo_shot		
198	453496.52	1382824.20	29.71	topo_shot		
199	453488.14	1382782.02	28.77	topo_shot		

FIGURE 9-24 GREEN 1994/95 (4/6)

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
200	453485.48	1382791.76	28.88	topo_shot		
201	453479.50	1382801.52	28.98	topo_shot		
202	453474.13	1382817.38	29.43	topo_shot		
203	453468.66	1382777.06	29.30	topo_shot		
204	453466.40	1382784.57	29.90	topo_shot		
205	453459.52	1382804.22	29.42	topo_shot		
206	453451.33	1382828.58	29.38	topo_shot		
207	453448.41	1382767.44	29.38	topo_shot		
208	453449.26	1382777.78	29.60	topo_shot		
209	453448.73	1382796.00	29.31	topo_shot		
210	453439.94	1382818.69	29.34	topo_shot		
211	453431.51	1382753.65	29.61	topo_shot		
212	453431.73	1382765.06	30.88	topo_shot		
213	453428.56	1382784.55	29.42	topo_shot		
214	453421.29	1382801.92	29.49	topo_shot		
215	453413.72	1382738.81	29.75	topo_shot		
216	453413.43	1382742.41	30.74	topo_shot		
217	453414.52	1382751.21	29.68	topo_shot		
218	453407.87	1382768.36	29.81	topo_shot		
219	453403.58	1382786.75	29.72	topo_shot		
220	453399.65	1382727.64	29.87	topo_shot		
221	453393.95	1382737.03	31.34	topo_shot		
222	453383.91	1382751.89	30.40	topo_shot		
223	453379.16	1382761.52	30.25	topo_shot		
224	453401.34	1382697.21	30.13	GC_10		
225	453387.56	1382705.45	30.49	topo_shot		
226	453373.22	1382722.67	32.18	topo_shot		
227	453361.40	1382736.65	32.51	topo_shot		
228	453355.19	1382676.26	31.42	GC_0		
229	453353.98	1382695.57	31.44	topo_shot		
230	453352.09	1382707.27	31.65	topo_shot		
231	453343.29	1382714.37	31.93	topo_shot		
232	453336.99	1382719.02	32.34	topo_shot		
233	453402.64	1382641.52	31.44	topo_shot		
234	453409.21	1382638.26	31.82	topo_shot		
235	453423.55	1382627.92	31.41	topo_shot		
236	453431.25	1382612.47	31.51	topo_shot		
237	453399.72	1382661.79	31.10	topo_shot		
238	453407.80	1382657.12	32.90	topo_shot		
239	453430.41	1382645.94	31.54	topo_shot		
240	453449.18	1382633.47	31.25	topo_shot		
241	453409.48	1382681.68	30.68	topo_shot		
242	453414.89	1382678.99	32.08	topo_shot		
243	453433.13	1382664.60	34.11	topo_shot		
244	453456.77	1382647.67	31.65	topo_shot		
245	453418.59	1382700.36	30.30	topo_shot		
246	453426.74	1382694.85	32.49	topo_shot		
247	453442.64	1382682.18	32.14	topo_shot		
248	453460.83	1382668.38	31.25	topo_shot		
249	453441.65	1382724.79	29.73	topo_shot		

FIGURE 9-25 GREEN 1994/95 (5/6)

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
250	453452.05	1382718.69	31.58	topo_shot		
251	453465.93	1382708.00	31.92	topo_shot		
252	453481.81	1382696.70	30.69	topo_shot		
253	453455.29	1382734.58	29.51	topo_shot		
254	453465.61	1382730.73	30.39	topo_shot		
255	453477.99	1382719.17	31.18	topo_shot		
256	453491.25	1382709.28	30.68	topo_shot		
257	453478.10	1382743.25	29.35	topo_shot		
258	453479.58	1382739.80	30.35	topo_shot		
259	453488.38	1382728.47	31.31	topo_shot		
260	453503.25	1382718.42	31.04	topo_shot		
261	453494.68	1382758.85	28.95	topo_shot		
262	453495.97	1382754.26	29.90	topo_shot		
263	453504.66	1382740.34	30.97	topo_shot		
264	453518.28	1382730.85	30.13	topo_shot		
265	453502.13	1382766.62	27.83	topo_shot		
266	453507.41	1382762.51	29.85	topo_shot		
267	453519.30	1382747.80	31.35	topo_shot		
268	453530.24	1382735.73	29.84	topo_shot		
269	453521.28	1382768.79	27.26	topo_shot		
270	453524.59	1382763.59	28.86	topo_shot		
271	453528.61	1382751.52	31.37	topo_shot		
272	453541.57	1382735.12	28.56	topo_shot		
273	453542.49	1382769.47	26.60	topo_shot		
274	453542.25	1382757.98	29.98	topo_shot		
275	453546.64	1382747.41	29.35	topo_shot		
276	453558.79	1382738.91	26.58	topo_shot		
277	453558.10	1382773.40	26.11	topo_shot		
278	453561.08	1382762.18	27.56	topo_shot		
279	453576.56	1382738.68	25.98	topo_shot		
280	453592.09	1382724.34	27.16	topo_shot		
281	453579.05	1382787.20	25.18	topo_shot		
282	453582.24	1382781.96	25.94	topo_shot		
283	453602.80	1382748.81	26.13	topo_shot		
284	453615.56	1382734.35	26.43	topo_shot		
285	453588.57	1382797.44	25.31	GC_gage_box		

FIGURE 9-26 GREEN 1994/95 (6/6)

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
1	453577.24	1382777.29	26.32	BS1		
2	453580.50	1382780.44	25.85	Topo		
3	453582.67	1382784.96	25.55	Topo		
4	453583.47	1382791.69	24.98	Topo		
5	453584.47	1382796.21	24.89	Topo		
6	453578.40	1382793.64	24.85	Topo		
7	453573.39	1382790.50	24.89	Topo		
8	453568.03	1382786.90	25.12	Topo		
9	453562.69	1382783.07	25.48	Topo		
10	453557.00	1382779.29	25.59	Topo		
11	453559.62	1382775.12	25.93	Topo		
12	453561.41	1382779.65	25.66	Topo		
13	453563.06	1382776.94	26.65	Topo		
14	453566.50	1382776.12	27.10	Topo		
15	453552.48	1382777.24	25.63	Wetted Edge		
16	453554.90	1382779.80	25.55	Wetted Edge		
17	453558.10	1382784.23	25.42	Wetted Edge		
18	453562.02	1382787.58	25.21	Wetted Edge		
19	453566.50	1382789.39	24.98	Wetted Edge		
20	453571.61	1382792.32	24.80	Wetted Edge		
21	453576.44	1382796.89	24.63	Wetted Edge		
22	453577.90	1382801.36	24.55	Wetted Edge		
23	453579.99	1382804.31	24.27	Wetted Edge		
24	453579.43	1382808.89	24.04	Water Edge		
25	453575.94	1382806.50	24.34	Water Edge		
26	453573.30	1382801.95	24.54	Water Edge		
27	453567.87	1382799.08	24.65	Water Edge		
28	453564.63	1382796.00	24.81	Water Edge		
29	453562.31	1382791.67	24.92	Water Edge		
30	453559.33	1382787.87	25.25	Water Edge		
31	453555.18	1382784.98	25.42	Water Edge		
32	453551.23	1382780.58	25.57	Water Edge		
33	453549.53	1382781.48	25.53	Thalweg		
34	453553.26	1382784.61	25.42	Thalweg		
35	453555.58	1382789.95	25.35	Thalweg		
36	453556.99	1382793.88	25.07	Thalweg		
37	453559.07	1382795.25	24.97	Thalweg		
38	453564.45	1382798.10	24.74	Thalweg		
39	453567.77	1382802.18	24.58	Thalweg		
40	453571.45	1382805.16	24.42	Thalweg		
41	453576.24	1382808.40	24.21	Thalweg		
42	453575.90	1382810.84	24.28	Water Edge		
43	453569.97	1382807.36	24.50	Water Edge		
44	453566.29	1382804.76	24.61	Water Edge		
45	453564.34	1382800.49	24.69	Water Edge		
46	453558.26	1382798.59	24.97	Water Edge		
47	453553.98	1382795.29	25.18	Water Edge		
48	453549.31	1382793.39	25.33	Water Edge		
49	453544.58	1382789.41	25.57	Water Edge		

FIGURE 9-27 GREEN 2000/01 (1/2)

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
50	453540.93	1382793.10	25.85	Wetted Edge		
51	453546.34	1382793.93	25.54	Wetted Edge		
52	453553.77	1382796.30	25.20	Wetted Edge		
53	453560.43	1382800.78	24.88	Wetted Edge		
54	453568.06	1382807.61	24.61	Wetted Edge		
55	453574.88	1382810.87	24.33	Wetted Edge		
56	453579.21	1382812.92	24.06	Wetted Edge		
57	453576.29	1382815.46	24.59	Salt Crust		
58	453570.60	1382811.46	24.75	Salt Crust		
59	453566.13	1382807.76	24.96	Salt Crust		
60	453560.64	1382803.22	25.14	Salt Crust		
61	453552.48	1382799.58	25.48	Salt Crust		
62	453546.35	1382796.82	25.69	Salt Crust		
63	453529.36	1382797.41	28.14	Topo		
64	453538.04	1382798.81	27.75	Topo		
65	453545.87	1382804.16	28.72	Topo		
66	453553.84	1382808.88	28.66	Topo		
67	453561.62	1382817.11	29.01	Topo		
68	453560.40	1382821.38	29.47	Topo		
69	453555.09	1382817.19	29.60	Topo		
70	453549.15	1382813.63	29.20	Topo		
71	453577.32	1382777.15	26.30	BS2		
72	453551.42	1382782.94	25.48	O1	5.20	12.07
73	453553.74	1382791.14	25.35	O2	8.19	14.63
74	453567.10	1382801.31	24.65	O3	17.84	
75	453570.96	1382806.11	24.48	O4	8.85	12.23
76	453573.31	1382790.96	24.84	M3		
77	453568.24	1382787.36	25.06	M4		
78	453557.64	1382781.15	25.52	M1		
79	453555.65	1382783.87	25.45	B1	33.96	18.23
80	453554.39	1382798.62	25.20	M2		
81	453558.31	1382799.54	24.96	B2	21.81	32.10
82	453566.64	1382805.45	24.57	B3	10.70	20.14
83	453532.18	1382897.31	26.44	ST101 (Near)		

FIGURE 9-28 GREEN 2000/01 (2/2)

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
1	453553.63	1382824.40	30.83	backsight		
2	453558.62	1382812.50	29.10	slope		
3	453563.95	1382805.01	25.52	wetted perimeter		
4	453564.84	1382803.38	25.31	non-glacier side stream edge		
5	453566.29	1382800.25	25.36	thalweg		
6	453568.50	1382794.94	25.50	stream edge		
7	453573.27	1382784.20	25.96	wetted perimeter		
8	453518.73	1382769.93	27.72	stream edge		
9	453553.23	1382777.93	26.28	stream edge		
10	453558.99	1382786.35	26.06	stream edge		
11	453573.33	1382802.79	25.21	Orange 2	3.10	8.01
12	453575.14	1382799.28	25.29	stream edge		
13	453583.58	1382807.30	24.68	orange 1	1.60	9.72
14	453588.01	1382811.68	24.45	gage and non-glacier side stream edge		
15	453595.67	1382812.64	23.95	gage and non-glacier side stream edge		
16	453618.96	1382821.50	23.42	gage and non-glacier side stream edge		
17	453616.32	1382825.00	23.29	thalweg		
18	453613.04	1382831.81	23.37	glacier side stream edge		
19	453588.46	1382822.35	23.98	gage and non-glacier side stream edge		
20	453585.62	1382814.96	24.35	stream edge		
21	453567.40	1382795.21	25.49	orange 3	4.70	8.08
22	453557.44	1382787.90	26.00	orange 5	1.50	7.22
23	453557.93	1382799.11	25.67	orange 4	4.70	3.37
24	453567.55	1382805.47	25.28	glacier side stream edge		
25	453553.95	1382794.88	25.86	glacier side stream edge		
26	453541.67	1382789.11	26.42	glacier side stream edge		
27	453519.04	1382785.42	27.64	glacier side stream edge		
28	453519.94	1382772.57	27.55	thalweg		
29	453537.29	1382779.30	26.76	thalweg		
30	453540.18	1382783.54	26.48	thalweg		
31	453551.47	1382790.25	26.02	thalweg		
32	453571.36	1382804.82	25.17	thalweg		
33	453565.89	1382807.41	25.65	wetted perimeter - glacier side		
34	453544.32	1382796.09	26.52	wetted perimeter - glacier side		
35	453518.57	1382792.22	27.99	wetted perimeter - glacier side		
36	453520.38	1382767.99	28.11	wetted perimeter - non-glacier side		
37	453555.45	1382771.85	26.71	wetted perimeter - non-glacier side		
38	453564.37	1382788.19	25.77	black 3	8.10	0.13
39	453573.12	1382787.53	25.68	moss 1		
40	453575.15	1382797.44	25.37	black 2	3.60	0.06
41	453581.88	1382805.16	24.85	black 1	6.80	0.21
42	453616.04	1382814.64	23.63	wetted perimeter - non-glacier side		
43	453585.73	1382803.09	25.07	wetted perimeter - non-glacier side		
44	453582.82	1382790.07	25.71	wetted perimeter - non-glacier side		
45	453557.80	1382781.26	26.31	wetted perimeter - non-glacier side		
46	453549.38	1382794.37	26.03	black 5	14.00	0.09
47	453556.64	1382798.58	25.74	black 4	17.70	0.83
48	453556.65	1382800.25	25.79	moss 3		
49	453566.50	1382806.25	25.31	moss 2		

FIGURE 9-29 GREEN 2002/03

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
1	453553.63	1382824.41	30.13	T091		
2	453556.41	1382797.51	25.05	B2	27.80	57.09
3	453559.90	1382796.44	24.79	O2	2.71	1.09
4	453564.85	1382799.77	24.68	O3	2.41	1.97
5	453566.17	1382801.35	24.55	G1		
6	453568.88	1382803.27	24.48	O4	6.55	6.09
7	453571.11	1382804.02	24.44	O5	25.62	3.01
8	453574.01	1382800.53	24.54	B5	37.29	38.75
9	453568.99	1382803.27	24.48	B4	24.86	28.19
10	453569.11	1382794.16	24.77	B3	17.40	44.42
11	453561.02	1382788.55	25.13	B1	29.68	25.30
12	453554.82	1382786.32	25.31	O1	3.92	4.15
13	453553.64	1382824.41	30.15	T091		

FIGURE 9-30 GREEN 2010/11

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
1	453577.29	1382777.20	26.16	South benchmark-BS		
2	453565.65	1382791.89	24.71	Black 1	23.35	13.39
3	453569.00	1382792.72	24.65	Black 2	33.08	11.93
4	453574.28	1382794.81	24.48	Black 3	42.20	8.40
5	453575.46	1382797.78	24.39	Black 4	21.76	20.45
6	453572.83	1382808.61	24.16	Orange 1	6.92	5.57
7	453566.96	1382805.15	24.41	Orange 2	7.44	4.92
8	453556.31	1382813.84	27.59	Orange 3	8.63	7.14
9	453553.17	1382795.39	25.05	Orange 4	6.74	11.32
10	453585.32	1382817.13	23.27	Green 3	1.63	2.52
11	453585.77	1382815.71	23.31	Green 1	2.03	3.94
12	453588.21	1382813.12	23.30	Green 2	1.50	2.13
13	453591.91	1382813.12	23.10	Green 4	1.23	2.80
14	453586.40	1382813.96	23.79	Top of control rebar		

FIGURE 9-31 GREEN 2011/12

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
1	453577.28	1382777.22	26.30	south benchmark-BS		
2	453586.32	1382814.01	23.95	top-down rebar		
3	453575.67	1382797.12	24.65	Black 2	23.52	13.45
4	453570.61	1382793.50	24.80	Black 4	18.28	8.98
5	453565.72	1382791.98	24.93	Black 1	20.44	13.04
6	453567.86	1382795.55	24.80	Orange 4	3.22	4.66
7	453562.27	1382794.14	24.94	Orange 3	6.78	3.99
8	453556.77	1382790.51	25.24	Orange 2	4.71	1.06
9	453553.12	1382782.59	25.46	Orange 1	9.07	7.65
10	453548.65	1382779.50	25.64	Green 1	2.56	0.84
11	453547.33	1382789.02	25.43	Green 2	4.14	6.16
12	453548.77	1382791.16	25.25	Green 3	3.39	11.59
13	453555.18	1382797.33	25.09	Black 3	55.73	17.29
14	453566.97	1382804.95	24.61	Orange 5	8.19	4.09
15	453591.14	1382807.43	24.45	bolt on rock by control		

FIGURE 9-32 GREEN 2012/13

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
1	453577.28	1382777.23	26.32	Ref?		
2	453561.74	1382786.76	25.21	B4		
3	453561.38	1382791.13	25.07	O4		
4	453574.78	1382797.18	24.63	B1		
5	453572.54	1382799.51	24.63	O2		
6	453568.22	1382807.90	24.56	B2		
7	453565.49	1382803.70	24.69	O3		
8	453558.64	1382799.60	25.00	O1		
9	453556.59	1382798.33	25.08	B3		

FIGURE 9-33 GREEN 2013/14

RELATIVE BED CHANGES

Year	Mean	Max	Min
1994	0.04	0.27	-0.12
1995	-0.06	0.15	-0.21
2001	-0.02	0.05	-0.12
2003	-0.02	0.05	-0.10
2011	0.02	0.10	-0.05
2012	0.02	0.08	-0.01
2013	-0.06	-0.01	-0.21
2014	0.00	0.03	-0.03

FIGURE 9-34 GREEN RELATIVE BED CHANGES

AFDM COMPARISON

Change	AFDM	Type
0.12	4.14	1
0.22	3.39	1
0.03	2.56	1
0.01	1.63	1
0.00	1.50	1
-0.01	1.23	1
0.05	0.00	1
-0.05	58.10	2
0.05	55.70	2
-0.08	54.80	2
0.00	42.20	2
-0.08	37.30	2
-0.02	34.20	2
-0.01	34.00	2
-0.03	33.10	2
-0.08	29.70	2
-0.10	27.80	2
0.02	24.90	2
0.01	23.50	2
-0.02	23.30	2
0.02	21.80	2
0.00	21.80	2
0.01	20.40	2
0.02	18.30	2
0.01	17.70	2
-0.07	17.40	2
-0.01	14.00	2
-0.05	12.80	2
0.05	10.70	2
0.00	8.10	2
0.02	6.80	2
-0.02	3.60	2
-0.02	0.00	2
-0.03	0.00	2

Change	AFDM	Type
-0.01	0.00	2
0.03	0.00	2
-0.05	33.70	3
0.01	25.60	3
0.04	17.80	3
0.03	17.40	3
0.09	9.07	3
-0.04	8.90	3
0.03	8.85	3
-0.05	8.59	3
0.01	8.19	3
0.04	8.19	3
-0.02	7.44	3
0.01	6.92	3
-0.01	6.87	3
0.04	6.78	3
-0.06	6.74	3
0.03	6.55	3
0.05	5.20	3
0.05	4.71	3
0.01	4.70	3
-0.01	4.70	3
0.00	3.92	3
0.04	3.22	3
0.03	3.10	3
0.04	2.71	3
-0.01	2.41	3
0.03	1.60	3
0.03	1.50	3
-0.01	0.00	3
0.00	0.00	3
0.02	0.00	3
0.03	0.00	3

FIGURE 9-35 GREEN AFDM COMPARISON. FIRST COLUMN IS RELATIVE CHANGE AT POINT IN STREAM. SECOND COLUMN IS AFDM. THIRD COLUMN IS MICROBIAL MAT TYPE (1=GREEN, 2=BLACK, 3=ORANGE, 4=RED)

FLOW COMPARISON

AFDM	Flow	Type
4.14	1.72	1
3.39	1.72	1
2.56	1.72	1
1.63	1.21	1
1.50	1.21	1
1.23	1.21	1
0.00	1.95	1
58.10	0.37	2
55.70	1.72	2
54.80	0.37	2
42.20	1.21	2
37.30	1.95	2
34.20	0.37	2
34.00	NaN	2
33.10	1.21	2
29.70	1.95	2
27.80	1.95	2
24.90	1.95	2
23.50	1.72	2
23.30	1.21	2
21.80	NaN	2
21.80	1.21	2
20.40	1.72	2
18.30	1.72	2
17.70	0.49	2
17.40	1.95	2
14.00	0.49	2
12.80	0.37	2
10.70	NaN	2
8.10	0.49	2
6.80	0.49	2
3.60	0.49	2
0.00	NaN	2
0.00	NaN	2

AFDM	Flow	Type
0.00	NaN	2
0.00	NaN	2
33.70	0.37	3
25.60	1.95	3
17.80	NaN	3
17.40	0.37	3
9.07	1.72	3
8.90	0.37	3
8.85	NaN	3
8.59	0.37	3
8.19	NaN	3
8.19	1.72	3
7.44	1.21	3
6.92	1.21	3
6.87	0.37	3
6.78	1.72	3
6.74	1.21	3
6.55	1.95	3
5.20	NaN	3
4.71	1.72	3
4.70	0.49	3
4.70	0.49	3
3.92	1.95	3
3.22	1.72	3
3.10	0.49	3
2.71	1.95	3
2.41	1.95	3
1.60	0.49	3
1.50	0.49	3
0.00	NaN	3
0.00	NaN	3
0.00	NaN	3
0.00	NaN	3

FIGURE 9-36 GREEN FLOW COMPARISON. FIRST COLUMN IS AFDM. SECOND COLUMN IS WEIGHTED FLOW FOR SEASON OF SURVEY. THIRD COLUMN IS MICROBIAL MAT TYPE (1=GREEN, 2=BLACK, 3=ORANGE, 4=RED)

9.1.2 Bowles Creek

SURVEYS

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
1	453521.64	1382917.88	27.73	T topo		
2	453524.46	1382912.33	25.32	T wet zone		
3	453525.08	1382911.13	25.08	T water edge		
4	453525.69	1382909.93	25.05	T water edge		
5	453526.22	1382908.88	25.40	T wet zone		
6	453527.71	1382905.96	26.20	T topo		
7	453530.04	1382901.97	26.66	T topo		
8	453528.89	1382912.65	24.85	algae orange 1	8.15	10.81
9	453526.67	1382911.42	25.00	algae orange 2	17.22	7.16
10	453517.74	1382906.01	25.40	algae orange 3	11.32	6.70
11	453511.51	1382896.78	25.42	algae orange 4	8.50	15.26
12	453507.88	1382888.47	25.74	algae orange 5	12.07	14.73
13	453528.81	1382912.17	24.91	algae black 1	15.42	13.48
14	453527.52	1382911.05	25.08	algae black 2	13.61	120.06
15	453517.38	1382906.50	25.46	algae black 3	27.53	91.22
16	453517.61	1382899.99	25.43	algae black 4	31.01	112.57
17	453509.81	1382890.53	25.60	algae black 5	50.04	93.06
18	453528.69	1382913.73	25.02	moss sam 1		
19	453525.29	1382912.15	25.21	moss sam 2		
20	453518.80	1382905.76	25.43	moss sam 3		
21	453518.42	1382897.20	25.55	moss sam 4		
22	453512.03	1382889.36	25.74	moss sam 5		
23	453510.31	1382888.76	25.71	water edge		
24	453511.81	1382897.21	25.44	water edge		
25	453518.87	1382898.82	25.46	water edge		
26	453516.98	1382903.04	25.45	water edge		
27	453518.69	1382905.98	25.33	water edge		
28	453528.25	1382911.97	25.01	water edge		
29	453528.34	1382912.80	24.92	water edge		
30	453522.36	1382909.52	25.18	water edge		
31	453517.08	1382906.66	25.43	water edge		
32	453509.84	1382900.89	25.48	water edge		
33	453508.27	1382902.68	25.80	wet zone		
34	453515.54	1382907.55	25.75	wet zone		
35	453520.84	1382910.03	25.44	wet zone		
36	453527.54	1382914.58	25.38	wet zone		
37	453528.78	1382910.84	25.19	wet zone		
38	453524.67	1382907.89	25.50	wet zone		
39	453520.28	1382905.70	25.63	wet zone		
40	453518.63	1382901.24	25.63	wet zone		
41	453520.25	1382897.24	25.70	wet zone		
42	453523.98	1382893.89	26.81	topo		
43	453523.25	1382900.70	26.56	topo		
44	453522.22	1382905.63	26.41	topo		
45	453526.40	1382905.40	26.27	topo		
46	453530.18	1382909.67	26.03	topo		
47	453533.67	1382904.90	27.07	topo		
48	453527.13	1382898.91	27.03	topo		
49	453510.14	1382907.81	26.26	topo		
50	453513.95	1382913.76	26.96	topo		
51	453526.25	1382923.76	27.52	topo		

FIGURE 9-37 BOWLES 1993/94

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
1	453516.73	1382918.91	27.81	Topo		
2	453520.88	1382917.71	27.78	Topo		
3	453524.55	1382918.78	26.95	Topo		
4	453528.03	1382916.52	25.55	Topo		
5	453531.10	1382918.82	25.42	Topo		
6	453534.08	1382919.04	24.85	Topo		
7	453535.66	1382918.44	24.52	Wetted Edge		
8	453533.64	1382916.87	24.59	Wetted Edge		
9	453530.94	1382915.48	24.88	Wetted Edge		
10	453526.95	1382913.21	25.10	Wetted Edge		
11	453523.74	1382911.42	25.22	Wetted Edge		
12	453520.84	1382909.21	25.28	Wetted Edge		
13	453517.44	1382907.15	25.43	Wetted Edge		
14	453517.73	1382906.66	25.37	Wetted Edge		
15	453518.42	1382905.59	25.37	Water Edge		
16	453520.65	1382908.34	25.21	Water Edge		
17	453520.71	1382907.84	25.22	Water Edge		
18	453523.63	1382909.88	25.10	Water Edge		
19	453523.64	1382909.17	25.07	Water Edge		
20	453526.25	1382911.79	25.00	Water Edge		
21	453526.42	1382910.69	25.02	Water Edge		
22	453529.62	1382913.60	24.76	Water Edge		
23	453529.20	1382912.64	24.81	Water Edge		
24	453535.74	1382917.78	24.36	Water Edge		
25	453535.91	1382916.58	24.37	Water Edge		
26	453538.07	1382918.66	24.23	Water Edge		
27	453537.45	1382917.38	24.19	Water Edge		
28	453534.99	1382916.71	24.57	O2	32.47	21.64
29	453526.02	1382912.48	25.08	M2		
30	453525.19	1382911.39	25.04	B4	49.25	31.70
31	453523.30	1382909.51	25.05	O3	16.21	20.18
32	453521.93	1382909.11	25.18	O1	19.56	7.26
33	453518.44	1382907.29	25.35	M1		
34	453521.55	1382908.31	25.22	B3	28.02	27.68
35	453519.02	1382906.62	25.29	B2	24.05	41.90
36	453529.96	1382911.87	24.97	M3		
37	453537.51	1382916.25	24.37	Wetted Edge		
38	453536.24	1382915.87	24.50	Wetted Edge		
39	453535.23	1382914.96	24.62	Wetted Edge		
40	453533.76	1382913.67	24.73	Wetted Edge		
41	453532.56	1382913.02	24.73	Wetted Edge		
42	453531.55	1382912.48	24.71	Wetted Edge		
43	453529.95	1382911.83	24.96	Wetted Edge		
44	453522.98	1382908.61	25.28	Wetted Edge		
45	453528.38	1382911.04	25.12	Wetted Edge		
46	453519.96	1382906.65	25.42	Wetted Edge		
47	453526.36	1382909.71	25.26	Wetted Edge		
48	453519.99	1382902.95	25.79	Topo		
49	453520.36	1382905.62	25.63	Topo		

FIGURE 9-38 BOWLES 2000/01 (1/2)

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
50	453522.52	1382905.55	26.40	Topo		
51	453520.91	1382905.25	25.91	Topo		
52	453527.13	1382906.64	26.07	Topo		
53	453522.35	1382904.32	26.36	Topo		
54	453531.17	1382909.30	26.26	Topo		
55	453529.94	1382910.37	25.59	Topo		
56	453534.04	1382907.72	27.12	Topo		
57	453530.60	1382911.34	25.12	Topo		
58	453537.22	1382912.19	25.86	Topo		
59	453532.94	1382911.40	25.49	Topo		
60	453540.98	1382907.46	26.87	Topo		
61	453533.54	1382910.04	26.22	Topo		
62	453538.89	1382902.85	27.11	Topo		
63	453536.97	1382914.13	25.04	Topo		
64	453535.56	1382901.66	27.02	Topo		
65	453537.48	1382912.39	25.74	Topo		
66	453528.23	1382900.40	26.98	Topo		
67	453539.48	1382910.69	26.47	Topo		
68	453519.17	1382922.74	28.80	BS2		
69	453553.54	1382824.40	30.17	To ST091		

FIGURE 9-39 BOWLES 2000/01 (2/2)

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
1	453522.21	1382916.31	27.75	slope		
2	453523.80	1382912.37	26.17	wetted perimeter		
3	453524.65	1382910.67	25.86	glacier side stream edge		
4	453524.92	1382909.78	25.88	non-glacier side stream edge		
5	453525.87	1382907.99	26.39	wetted perimeter		
6	453529.15	1382902.59	27.48	slope		
7	453477.48	1382866.02	27.97	non-glacier side stream edge		
8	453483.30	1382868.89	27.66	non-glacier side stream edge		
9	453486.51	1382873.28	27.36	non-glacier side stream edge		
10	453495.03	1382876.84	27.30	non-glacier side stream edge		
11	453509.21	1382888.47	26.56	non-glacier side stream edge		
12	453511.47	1382897.85	26.26	stream edge - braided becomes one from here		
13	453516.74	1382899.20	26.25	stream edge - braided becomes one from here		
14	453516.93	1382903.82	26.24	stream edge - braided becomes one from here		
15	453533.55	1382914.03	25.23	stream edge - braided becomes one from here		
16	453531.69	1382914.82	25.36	big rock and glacier side stream edge		
17	453533.79	1382915.42	25.24	big rock and glacier side stream edge		
18	453544.27	1382921.23	24.86	non-glacier side stream edge		
19	453545.29	1382925.76	24.83	non-glacier side stream edge		
20	453543.99	1382926.90	24.76	glacier side stream edge		
21	453540.54	1382920.27	24.83	glacier side stream edge		
22	453537.71	1382917.85	24.96	O4	2.80	1.85
23	453536.36	1382917.63	25.14	O5	2.30	6.24
24	453507.83	1382898.12	26.32	glacier side stream edge		
25	453501.45	1382886.80	26.81	glacier side stream edge		
26	453491.63	1382885.71	27.05	glacier side stream edge		
27	453484.58	1382876.17	27.54	glacier side stream edge		
28	453478.50	1382875.95	27.78	glacier side stream edge		
29	453473.22	1382872.39	28.05	glacier side stream edge		
30	453466.71	1382875.05	28.70	glacier side stream edge		
31	453470.97	1382882.43	29.08	glacier side wetted perimeter		
32	453473.07	1382875.68	28.55	glacier side wetted perimeter		
33	453480.02	1382879.10	28.94	glacier side wetted perimeter		
34	453493.51	1382893.45	27.20	glacier side wetted perimeter		
35	453500.27	1382892.84	27.09	glacier side wetted perimeter		
36	453505.68	1382902.64	26.68	glacier side wetted perimeter		
37	453510.09	1382904.25	26.52	glacier side wetted perimeter		
38	453513.78	1382908.21	26.60	glacier side wetted perimeter		
39	453516.07	1382907.35	26.32	glacier side wetted perimeter		
40	453525.48	1382913.94	26.09	glacier side wetted perimeter		
41	453530.66	1382916.15	25.87	glacier side wetted perimeter		
42	453537.57	1382921.00	25.30	glacier side wetted perimeter		
43	453544.80	1382933.02	25.16	glacier side wetted perimeter		
44	453549.34	1382922.42	25.30	non-glacier side wetter perimeter		
45	453520.08	1382905.52	26.43	non-glacier side wetter perimeter		
46	453521.35	1382898.42	26.63	non-glacier side wetter perimeter		
47	453519.15	1382893.49	26.67	non-glacier side wetter perimeter		
48	453515.62	1382891.58	26.68	non-glacier side wetter perimeter		
49	453509.90	1382881.24	26.98	non-glacier side wetter perimeter		

FIGURE 9-40 BOWLES 2002/03 (1/2)

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
50	453499.12	1382876.17	27.28	non-glacier side wetter perimeter		
51	453475.83	1382853.78	28.42	non-glacier side wetter perimeter		
52	453505.33	1382881.05	26.78	moss 1		
53	453515.21	1382897.07	26.34	moss 2		
54	453519.22	1382907.70	26.05	Black algae 1	14.10	0.08
55	453519.51	1382907.25	26.04	Orange algae 1	6.10	1.57
56	453524.72	1382910.38	25.85	Orange algae 2	1.10	10.77
57	453525.44	1382911.62	25.88	Black algae 2	8.50	0.02
58	453527.22	1382912.09	25.79	Orange algae 3	4.60	0.95
59	453530.35	1382914.15	25.49	Black algae 3	7.00	
60	453531.10	1382912.68	25.54	moss 3		
61	453536.67	1382916.53	25.09	Black algae 4	18.30	0.07
62	453549.85	1382925.60	24.80	moss 4		
63	453509.80	1382890.40	26.38	Black algae 5	8.60	0.11

FIGURE 9-41 BOWLES 2002/03 (2/2)

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
1	453532.18	1382897.17	27.27	T101		
2	453519.17	1382922.72	28.78	T102		
3	453508.84	1382897.09	25.41	O1	3.62	30.97
4	453511.24	1382894.63	25.48	B1	21.25	37.30
5	453512.35	1382899.46	25.33	O2	10.62	7.19
6	453515.07	1382899.29	25.34	B2	28.25	32.58
7	453517.40	1382905.25	25.36	O3	47.39	66.86
8	453517.86	1382904.99	25.37	B3	36.31	52.98
9	453519.24	1382906.86	25.29	O4	13.41	20.88
10	453519.12	1382906.55	25.31	B4	82.42	47.53
11	453529.09	1382912.70	24.76	O5	16.57	36.64
12	453530.25	1382914.32	24.63	O6	16.35	34.41
13	453530.96	1382914.84	24.58	B5	35.79	60.48

FIGURE 9-42 BOWLES 2010/11

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
1	453519.17	1382922.71	28.78	North BM - Backsight		
2	453505.85	1382890.67	25.67	Orange 1	11.63	20.55
3	453507.09	1382890.41	25.66	Black 1	21.10	19.09
4	453504.55	1382890.27	25.73	Green 1	1.45	3.59
5	453506.97	1382894.88	25.49	Orange 2	4.98	7.39
6	453509.31	1382893.81	25.47	Black 2	22.16	13.54
7	453505.03	1382890.83	25.66	Green 2	2.64	5.52
8	453517.16	1382905.31	25.36	Orange 3	7.58	9.46
9	453516.66	1382903.22	25.39	Black 3	13.08	7.34
10	453508.17	1382896.53	25.45	Green 3	4.05	8.40
11	453522.60	1382909.13	25.06	Orange 4	7.75	7.69
12	453524.19	1382909.38	25.02	Black 4	26.87	21.31
13	453523.04	1382909.40	25.04	Green 4	3.04	6.78

FIGURE 9-43 BOWLES 2011/12

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
1	453519.16	1382922.73	28.80	north benchmark-BS		
2	453513.96	1382898.64	25.40	Black 4	10.31	14.45
3	453510.37	1382897.41	25.41	Orange 1	8.11	11.92
4	453509.25	1382893.82	25.56	Black 3	23.96	31.18
5	453507.63	1382893.27	25.62	Orange 2	7.93	2.21
6	453505.46	1382891.78	25.69	Green 3	4.32	4.91
7	453504.44	1382890.31	25.76	Green 2	1.54	7.26
8	453503.06	1382886.12	25.87	Orange 3	11.81	12.69
9	453504.66	1382886.08	25.88	Green 1	3.17	5.45
10	453499.57	1382886.33	26.10	Black 2	33.00	17.65
11	453495.21	1382884.18	26.22	Orange 4	29.21	10.74
12	453494.58	1382885.15	26.17	Black 1	20.00	27.60
13	453501.60	1382886.63	26.25	double-pyramid rock far tip		
14	453502.13	1382886.17	26.21	double-pyramid rock close tip		

FIGURE 9-44 BOWLES 2012/13

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
1	453519.16	1382922.74	28.82	T102		
2	453527.90	1382912.17	25.01	G3		
3	453527.49	1382911.29	25.06	B2		
4	453523.44	1382909.68	25.11	G1		
5	453522.65	1382909.24	25.18	O2		
6	453521.51	1382908.07	25.27	B1		
7	453520.05	1382907.63	25.24	G2		
8	453519.69	1382907.48	25.33	O1		
9	453517.70	1382906.23	25.34	O3		
10	453517.38	1382906.09	25.40	B3		

FIGURE 9-45 BOWLES 2013/14

RELATIVE BED CHANGES

Year	Mean	Max	Min
1994	-0.01	0.09	-0.12
2001	-0.01	0.19	-0.10
2003	-0.01	0.10	-0.14
2011	-0.08	-0.05	-0.13
2012	-0.12	-0.08	-0.17
2013	-0.01	0.13	-0.08
2014	0.00	0.04	-0.06

FIGURE 9-46 BOWLES RELATIVE BED CHANGES

AFDM COMPARISON

Change	AFDM	Type
0.08	4.32	1
0.08	4.05	1
0.03	3.17	1
0.15	3.04	1
0.17	2.64	1
0.07	1.54	1
0.11	1.45	1
0.04	0.00	1
0.00	0.00	1
-0.04	0.00	1
0.07	82.42	2
0.05	50.04	2
0.02	49.25	2
0.09	36.31	2
0.05	35.79	2
-0.01	33.00	2
0.03	31.01	2
0.13	28.25	2
0.00	28.02	2
-0.04	27.53	2
0.12	26.87	2
0.10	24.05	2
0.02	23.96	2
0.11	22.16	2
0.06	21.25	2
0.13	21.10	2
0.04	20.00	2
0.06	18.30	2
0.02	15.42	2
0.08	14.10	2
-0.03	13.61	2
0.08	13.08	2
0.07	10.31	2
0.06	8.60	2
-0.03	8.50	2

Change	AFDM	Type
-0.02	7.00	2
0.03	0.00	2
0.01	0.00	2
0.00	0.00	2
0.09	47.39	3
-0.19	32.47	3
-0.01	29.21	3
0.02	19.56	3
0.05	17.22	3
0.10	16.57	3
0.07	16.35	3
0.08	16.21	3
0.10	13.41	3
0.03	12.07	3
NaN	11.81	3
0.15	11.63	3
0.03	11.32	3
NaN	10.62	3
0.06	8.50	3
0.05	8.15	3
NaN	8.11	3
NaN	7.93	3
0.14	7.75	3
0.11	7.58	3
0.07	6.10	3
0.11	4.98	3
0.01	4.60	3
NaN	3.62	3
0.04	2.80	3
0.00	2.30	3
0.04	1.10	3
-0.01	0.00	3
0.04	0.00	3
-0.06	0.00	3

FIGURE 9-47 BOWLES AFDM COMPARISON. FIRST COLUMN IS RELATIVE CHANGE AT POINT IN STREAM. SECOND COLUMN IS AFDM. THIRD COLUMN IS MICROBIAL MAT TYPE (1=GREEN, 2=BLACK, 3=ORANGE, 4=RED)

FLOW COMPARISON

AFDM	Flow	Type
4.32	1.72	1
4.05	1.21	1
3.17	1.72	1
3.04	1.21	1
2.64	1.21	1
1.54	1.72	1
1.45	1.21	1
0.00	NaN	1
0.00	NaN	1
0.00	NaN	1
82.40	1.95	2
50.00	0.37	2
49.30	NaN	2
36.30	1.95	2
35.80	1.95	2
33.00	1.72	2
31.00	0.37	2
28.30	1.95	2
28.00	NaN	2
27.50	0.37	2
26.90	1.21	2
24.10	NaN	2
24.00	1.72	2
22.20	1.21	2
21.20	1.95	2
21.10	1.21	2
20.00	1.72	2
18.30	0.49	2
15.40	0.37	2
14.10	0.49	2
13.60	0.37	2
13.10	1.21	2
10.30	1.72	2
8.60	0.49	2
8.50	0.49	2

AFDM	Flow	Type
7.00	0.49	2
0.00	NaN	2
0.00	NaN	2
0.00	NaN	2
47.40	1.95	3
32.50	NaN	3
29.20	1.72	3
19.60	NaN	3
17.20	0.37	3
16.60	1.95	3
16.30	1.95	3
16.20	NaN	3
13.40	1.95	3
12.10	0.37	3
11.80	1.72	3
11.60	1.21	3
11.30	0.37	3
10.60	1.95	3
8.50	0.37	3
8.15	0.37	3
8.11	1.72	3
7.93	1.72	3
7.75	1.21	3
7.58	1.21	3
6.10	0.49	3
4.98	1.21	3
4.60	0.49	3
3.62	1.95	3
2.80	0.49	3
2.30	0.49	3
1.10	0.49	3
0.00	NaN	3
0.00	NaN	3
0.00	NaN	3

FIGURE 9-48 BOWLES FLOW COMPARISON. FIRST COLUMN IS AFDM. SECOND COLUMN IS WEIGHTED FLOW FOR SEASON OF SURVEY. THIRD COLUMN IS MICROBIAL MAT TYPE (1=GREEN, 2=BLACK, 3=ORANGE, 4=RED)

9.1.3 Upper Delta Stream

SURVEYS

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
1	454631.95	1379614.07	249.01	algae black 1	23.13	54.11
2	454623.31	1379621.56	248.68	algae black 2	25.37	44.42
3	454622.94	1379610.81	249.30	algae black 3	21.45	13.40
4	454624.51	1379602.85	249.70	algae black 4	41.63	47.59
5	454616.79	1379600.76	250.08	algae black 5	20.88	46.57
6	454624.34	1379619.23	248.72	algae phil 1		
7	454623.63	1379617.21	248.87	algae phil 2		
8	454620.48	1379600.47	249.85	algae phil 3		
9	454619.77	1379599.90	249.92	algae phil 4		
10	454622.87	1379603.93	249.64	algae phil 5		
11	454632.56	1379620.00	248.54	rock		
12	454631.80	1379620.03	248.68	rock		
13	454631.83	1379620.86	248.61	rock		
14	454632.47	1379621.07	248.63	rock		
15	454632.13	1379620.31	248.95	rock top ctr		
16	454625.63	1379607.79	249.58	rock top ctr		
17	454625.41	1379607.67	249.41	rock		
18	454625.73	1379607.56	249.46	rock		
19	454625.89	1379607.86	249.45	rock		
20	454625.49	1379608.02	249.40	rock		
21	454622.97	1379608.77	249.47	rock		
22	454622.97	1379609.05	249.40	rock		
23	454622.82	1379608.61	249.41	rock		
24	454623.18	1379608.52	249.39	rock		
25	454623.29	1379608.83	249.40	rock		
26	454644.18	1379599.37	253.50	T topo		
27	454640.45	1379602.28	252.23	T topo		
28	454635.15	1379606.43	250.21	T topo		
29	454631.80	1379609.05	249.63	T wet zone		
30	454627.79	1379612.19	249.23	T water edge		
31	454626.98	1379612.83	249.20	T water edge		
32	454625.49	1379614.00	249.09	T water edge		
33	454623.91	1379615.23	248.97	T thalwag		
34	454622.88	1379616.04	249.03	T water edge		
35	454621.36	1379617.23	249.29	T wet zone		
36	454615.47	1379621.84	249.91	T topo		
37	454607.21	1379628.32	251.37	T topo		
38	454600.48	1379633.57	253.45	T topo		
39	454597.40	1379635.99	254.21	T topo		
40	454601.63	1379641.19	254.14	topo		
41	454605.90	1379647.69	253.86	topo		
42	454590.96	1379629.43	254.38	topo		
43	454583.83	1379621.11	254.79	topo		
44	454587.71	1379617.14	253.54	topo		

FIGURE 9-49 UPPER DELTA 1993/94 (1/2)

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
45	454595.76	1379623.40	252.86	topo		
46	454609.88	1379633.97	251.17	topo		
47	454614.74	1379639.00	250.72	topo		
48	454622.15	1379631.15	249.05	topo		
49	454617.78	1379624.25	249.62	topo		
50	454610.35	1379614.75	250.70	topo		
51	454604.02	1379607.87	251.31	topo		
52	454613.79	1379602.29	250.58	wet zone		
53	454616.62	1379606.88	250.22	wet zone		
54	454621.16	1379613.36	249.57	wet zone		
55	454621.87	1379622.80	248.90	wet zone		
56	454623.74	1379627.86	248.46	wet zone		
57	454624.55	1379627.15	248.10	water edge		
58	454622.81	1379624.18	248.41	water edge		
59	454623.14	1379620.91	248.68	water edge		
60	454622.81	1379611.21	249.21	water edge		
61	454622.55	1379609.01	249.42	water edge		
62	454621.51	1379606.04	249.64	water edge		
63	454618.70	1379602.26	249.94	water edge		
64	454616.05	1379600.72	250.18	water edge		
65	454611.89	1379600.76	250.39	water edge		
66	454610.87	1379596.16	250.45	water edge		
67	454620.81	1379598.62	249.91	water edge		
68	454624.58	1379601.37	249.74	water edge		
69	454625.88	1379607.94	249.45	water edge		
70	454630.52	1379613.08	249.10	water edge		
71	454633.57	1379615.37	248.89	water edge		
72	454635.95	1379619.65	248.54	water edge		
73	454625.66	1379610.52	249.35	water edge frk		
74	454625.97	1379614.82	249.09	water edge		
75	454625.92	1379617.59	248.79	water edge		
76	454628.70	1379623.72	248.31	water edge		
77	454639.61	1379614.87	248.94	wet zone		
78	454633.56	1379613.07	249.28	wet zone		
79	454628.48	1379606.94	249.79	wet zone		
80	454626.57	1379601.38	250.07	wet zone		
81	454621.83	1379596.89	250.37	wet zone		
82	454612.55	1379593.25	251.03	wet zone		
83	454616.38	1379586.47	251.67	topo		
84	454628.55	1379590.37	251.85	topo		
85	454635.18	1379599.62	251.29	topo		
86	454638.38	1379609.28	249.92	topo		
87	454643.59	1379614.59	249.21	topo		
88	454654.32	1379612.36	250.51	topo		
89	454651.15	1379606.60	252.75	topo		
90	454645.61	1379602.46	253.07	topo		
91	454639.76	1379592.44	253.64	topo		
92	454623.77	1379620.24	248.65	algae orange 1	14.80	9.37
93	454623.70	1379616.50	248.90	algae orange 2	27.40	
94	454624.65	1379610.67	249.27	algae orange 3	26.52	14.55
95	454624.57	1379604.61	249.59	algae orange 4	18.85	13.32
96	454618.75	1379599.64	249.96	algae orange 5	15.59	8.94

FIGURE 9-50 UPPER DELTA 1993/94 (2/2)

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
1	454607.02	1379633.47	253.13	left strm edge		
2	454601.98	1379630.13	253.25	left strm edge		
3	454596.67	1379630.65	253.36	left strm edge		
4	454595.40	1379632.70	253.54	left strm edge		
5	454594.92	1379633.74	253.73	left strm edge		
6	454593.03	1379633.36	254.03	left strm edge		
7	454589.56	1379632.30	254.33	left strm edge		
8	454589.68	1379629.87	254.41	left strm edge		
9	454589.45	1379627.46	254.68	left strm edge		
10	454590.06	1379625.04	254.69	left strm edge		
11	454591.13	1379620.35	254.81	right strm edge		
12	454596.16	1379621.32	254.62	right strm edge		
13	454599.74	1379623.67	254.47	right strm edge		
14	454603.25	1379626.70	254.34	right strm edge		
15	454605.36	1379631.21	254.10	right strm edge		
16	454605.41	1379635.97	253.96	right strm edge		
17	454603.23	1379632.64	253.79	right strm edge		
18	454601.67	1379632.08	253.68	right strm edge		
19	454601.07	1379631.75	253.54	right strm edge		
20	454600.23	1379630.58	253.33	right strm edge		
21	454601.73	1379628.72	253.18	right strm edge		
22	454604.37	1379626.67	252.97	right strm edge		
23	454605.47	1379628.70	253.22	wet zone		
24	454605.84	1379634.51	253.39	wet zone		
25	454597.46	1379629.36	253.49	wet zone		
26	454595.88	1379632.07	253.62	wet zone		
27	454596.29	1379634.43	253.78	wet zone		
28	454596.29	1379635.00	253.99	wet zone		
29	454593.35	1379633.75	254.15	wet zone		
30	454591.02	1379633.75	254.35	wet zone		
31	454591.39	1379629.75	254.66	wet zone		
32	454591.35	1379627.46	254.80	wet zone		
33	454592.08	1379624.31	254.97	wet zone		
34	454594.48	1379619.85	255.03	wet zone		
35	454598.84	1379621.75	254.88	wet zone		
36	454602.97	1379625.00	254.64	wet zone		
37	454606.82	1379628.33	254.50	wet zone		
38	454607.36	1379634.21	254.36	wet zone		
39	454607.20	1379635.12	254.29	wet zone		
40	454604.74	1379635.25	253.97	wet zone		
41	454604.77	1379634.59	253.68	wet zone		
42	454605.88	1379633.48	253.52	wet zone		
43	454610.20	1379634.27	253.40	wet zone		
44	454613.35	1379630.13	253.00	wet zone		
45	454614.07	1379626.51	252.83	wet zone		
46	454611.25	1379623.82	253.75	topo shot		
47	454613.92	1379620.47	255.56	topo shot		
48	454616.56	1379617.79	257.37	topo shot		
49	454607.05	1379613.21	257.73	topo shot		

FIGURE 9-51 UPPER DELTA 1997/98 (1/2)

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
50	454603.71	1379616.11	256.41	topo shot		
51	454596.33	1379621.02	254.91	topo shot		
52	454593.95	1379623.92	254.81	topo shot		
53	454587.04	1379620.18	255.87	topo shot		
54	454582.88	1379634.91	255.24	topo shot		
55	454579.69	1379627.02	255.72	topo shot		
56	454583.93	1379623.74	255.53	topo shot		
57	454591.52	1379627.42	255.29	topo shot		
58	454592.57	1379623.16	255.56	topo shot		
59	454588.63	1379616.28	256.34	topo shot		
60	454587.72	1379609.31	257.30	topo shot		
61	454590.50	1379609.02	256.68	topo shot		
62	454599.52	1379616.85	255.33	topo shot		
63	454594.79	1379625.43	254.47	topo shot		
64	454593.31	1379633.61	254.34	topo shot		
65	454587.93	1379629.91	253.98	topo shot		
66	454583.73	1379626.44	254.63	topo shot		
67	454589.46	1379627.04	254.68	black#1		
68	454589.63	1379626.55	254.64	orange#1		
69	454589.34	1379625.05	254.64	fil. green#1		
70	454590.27	1379623.68	254.61	black#2		
71	454600.43	1379625.31	254.42	orange#2		
72	454601.66	1379627.63	254.39	black#3		
73	454602.52	1379628.23	254.32	orange#3		
74	454604.37	1379633.85	253.89	fil. green#2		
75	454602.68	1379632.40	253.79	fil. green#3		
76	454600.67	1379632.31	253.78	orange#4		
77	454602.61	1379630.55	253.74	moss#1		
78	454601.11	1379631.64	253.32	fil. green#4		

FIGURE 9-52 UPPER DELTA 1997/98 (2/2)

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
1	454605.00	1379599.13	250.76	Water Edge		
2	454609.76	1379600.53	250.53	Water Edge		
3	454613.37	1379600.41	250.33	Water Edge		
4	454616.27	1379600.91	250.17	Water Edge		
5	454618.93	1379602.30	249.90	Water Edge		
6	454621.51	1379606.59	249.59	Water Edge		
7	454622.58	1379610.15	249.34	Water Edge		
8	454622.75	1379613.51	249.09	Water Edge		
9	454622.70	1379617.25	248.96	Water Edge		
10	454622.91	1379621.27	248.70	Water Edge		
11	454622.41	1379624.99	248.47	Water Edge		
12	454624.18	1379627.63	248.03	Water Edge		
13	454627.00	1379631.94	247.62	Water Edge		
14	454629.92	1379634.81	247.36	Water Edge		
15	454632.93	1379636.69	247.19	Water Edge		
16	454636.36	1379637.07	247.01	Water Edge		
17	454639.49	1379638.05	246.83	Water Edge		
18	454642.88	1379638.74	246.69	Water Edge		
19	454644.39	1379635.08	246.69	Water Edge		
20	454641.64	1379632.64	246.83	Water Edge		
21	454637.79	1379630.60	247.06	Water Edge		
22	454633.13	1379630.02	247.32	Water Edge		
23	454630.23	1379629.24	247.63	Water Edge		
24	454628.43	1379626.45	247.96	Water Edge		
25	454627.76	1379623.42	248.38	Water Edge		
26	454626.01	1379620.35	248.69	Water Edge		
27	454625.43	1379617.77	248.82	Water Edge		
28	454624.55	1379613.80	249.12	Water Edge		
29	454625.12	1379610.99	249.35	Water Edge		
30	454625.34	1379607.54	249.48	Water Edge		
31	454623.14	1379601.39	249.80	Water Edge		
32	454619.60	1379598.47	250.04	Water Edge		
33	454614.11	1379596.37	250.31	Water Edge		
34	454610.72	1379596.08	250.50	Water Edge		
35	454608.02	1379594.76	250.68	Water Edge		
36	454605.30	1379593.19	250.86	Water Edge		
37	454621.28	1379653.30	251.36	Topo		
38	454618.35	1379651.05	251.93	Topo		
39	454614.80	1379648.06	252.29	Topo		
40	454609.32	1379641.88	252.80	Topo		
41	454603.77	1379636.77	253.25	Topo		
42	454597.99	1379631.26	253.58	Topo		
43	454592.49	1379625.62	253.88	Topo		
44	454586.05	1379620.81	254.33	Topo		
45	454580.67	1379613.89	254.56	Topo		
46	454576.99	1379606.88	254.69	Topo		
47	454582.99	1379602.75	253.23	Topo		
48	454586.66	1379606.11	252.94	Topo		
49	454589.69	1379609.77	252.77	Topo		

FIGURE 9-53 UPPER DELTA 2000/01 (1/4)

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
50	454593.86	1379614.33	252.62	Topo		
51	454597.27	1379617.57	252.39	Topo		
52	454600.85	1379621.43	252.20	Topo		
53	454604.99	1379626.16	251.65	Topo		
54	454608.74	1379629.94	251.21	Topo		
55	454612.67	1379634.20	250.81	Topo		
56	454616.50	1379638.38	250.36	Topo		
57	454621.25	1379642.49	249.93	Topo		
58	454625.69	1379645.74	249.30	Topo		
59	454630.50	1379648.80	248.67	Topo		
60	454634.33	1379652.22	248.10	Topo		
61	454636.73	1379645.40	246.94	Topo		
62	454631.80	1379640.80	247.71	Topo		
63	454629.00	1379637.91	248.07	Topo		
64	454625.17	1379635.12	248.61	Topo		
65	454621.97	1379630.62	249.01	Topo		
66	454619.00	1379625.07	249.46	Topo		
67	454615.83	1379619.71	249.95	Topo		
68	454612.41	1379614.57	250.48	Topo		
69	454609.55	1379609.18	250.98	Topo		
70	454604.17	1379604.96	251.46	Topo		
71	454598.31	1379600.94	251.82	Topo		
72	454601.27	1379599.05	251.24	Topo		
73	454604.53	1379601.75	251.08	Topo		
74	454607.76	1379603.68	251.10	Topo		
75	454610.95	1379605.38	250.99	Topo		
76	454614.10	1379608.29	250.64	Topo		
77	454616.83	1379611.60	250.27	Topo		
78	454618.85	1379614.77	249.92	Topo		
79	454621.16	1379611.20	249.63	Topo		
80	454619.35	1379608.96	249.97	Topo		
81	454617.39	1379606.17	250.19	Topo		
82	454615.28	1379603.14	250.56	Topo		
83	454612.05	1379581.42	252.14	Topo		
84	454615.47	1379584.05	251.98	Topo		
85	454618.66	1379586.73	251.79	Topo		
86	454622.56	1379590.85	251.41	Topo		
87	454626.00	1379594.08	251.25	Topo		
88	454629.46	1379597.52	250.83	Topo		
89	454631.37	1379600.26	250.66	Topo		
90	454633.38	1379605.83	250.13	Topo		
91	454635.52	1379610.32	249.57	Topo		
92	454638.36	1379614.35	249.03	Topo		
93	454641.81	1379618.16	248.47	Topo		
94	454644.51	1379620.95	247.95	Topo		
95	454646.74	1379623.68	247.37	Topo		
96	454649.53	1379627.71	247.07	Topo		
97	454652.25	1379632.34	246.40	Topo		
98	454648.11	1379633.25	246.81	Topo		
99	454643.44	1379628.86	247.38	Topo		

FIGURE 9-54 UPPER DELTA 2000/01 (2/4)

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
100	454640.00	1379625.33	247.81	Topo		
101	454636.85	1379621.24	248.32	Topo		
102	454633.48	1379615.72	248.86	Topo		
103	454630.80	1379610.21	249.52	Topo		
104	454629.65	1379604.37	250.17	Topo		
105	454627.03	1379598.95	250.57	Topo		
106	454623.31	1379595.47	250.90	Topo		
107	454617.94	1379593.67	250.98	Topo		
108	454612.72	1379592.05	251.34	Topo		
109	454607.70	1379590.40	251.55	Topo		
110	454626.75	1379614.39	249.13	Topo		
111	454627.14	1379617.95	248.90	Topo		
112	454628.03	1379621.37	248.66	Topo		
113	454628.91	1379624.77	248.25	Topo		
114	454631.10	1379627.74	247.82	Topo		
115	454635.47	1379629.07	247.31	Topo		
116	454639.23	1379630.75	247.14	Topo		
117	454653.44	1379612.08	250.66	Topo		
118	454649.15	1379611.33	250.81	Topo		
119	454643.96	1379609.59	250.98	Topo		
120	454639.56	1379606.21	251.16	Topo		
121	454636.45	1379601.20	251.33	Topo		
122	454634.09	1379596.59	251.85	Topo		
123	454632.03	1379592.39	252.01	Topo		
124	454631.35	1379587.75	252.51	Topo		
125	454622.56	1379584.44	252.15	Topo		
126	454616.41	1379581.65	252.20	Topo		
127	454637.88	1379592.75	253.32	Topo		
128	454640.07	1379598.52	252.93	Topo		
129	454643.19	1379602.44	252.69	Topo		
130	454646.83	1379605.41	252.63	Topo		
131	454651.15	1379607.65	252.34	Topo		
132	454649.82	1379600.35	254.01	Topo		
133	454604.23	1379597.35	250.70	Thalweg		
134	454608.12	1379599.05	250.55	Thalweg		
135	454612.05	1379598.27	250.30	Thalweg		
136	454614.48	1379598.34	250.18	Thalweg		
137	454617.73	1379600.00	250.02	Thalweg / Orange Algae		
138	454620.24	1379601.20	249.79	Thalweg / Orange Algae		
139	454622.44	1379602.82	249.72	Thalweg / Orange Algae		
140	454621.03	1379604.17	249.74	B1	13.52	23.78
141	454622.45	1379604.34	249.65	BAD POINT		
142	454623.29	1379603.98	249.56	O1	37.05	24.34
143	454623.34	1379605.17	249.53	O3	20.88	10.47
144	454623.66	1379608.24	249.37	Thalweg / Orange Algae		
145	454622.98	1379609.20	249.39	B2	20.79	7.22
146	454623.73	1379609.90	249.27	O2	13.83	12.49
147	454623.83	1379612.20	249.12	Thalweg / Orange Algae		
148	454623.49	1379615.27	248.97	Thalweg / Orange Algae		
149	454623.77	1379618.74	248.72	Thalweg / Orange Algae		

FIGURE 9-55 UPPER DELTA 2000/01 (3/4)

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
150	454624.84	1379621.59	248.57	Thalweg		
151	454624.86	1379623.71	248.36	Thalweg		
152	454626.09	1379626.54	247.93	Thalweg / Orange Algae		
153	454627.09	1379629.13	247.73	Thalweg / Orange Algae		
154	454628.52	1379632.17	247.47	Thalweg / Orange Algae		
155	454624.33	1379603.30	249.68	B3	19.91	34.56
156	454630.98	1379633.75	247.27	Thalweg / Orange Algae		
157	454625.30	1379608.82	249.39	B4	12.73	8.53
158	454633.74	1379634.29	247.13	Thalweg / Orange Algae		
159	454627.28	1379610.58	249.40	Thalweg		
160	454637.24	1379634.99	246.88	Thalweg / Orange Algae		
161	454633.12	1379615.81	248.83	Thalweg		
162	454639.53	1379635.27	246.77	Thalweg / Orange Algae		
163	454643.21	1379636.20	246.67	Thalweg		
164	454645.76	1379637.47	246.54	Thalweg		
165	454648.79	1379638.30	246.38	Thalweg		
166	454610.71	1379594.90	250.73	Wetted Edge		
167	454608.49	1379601.41	250.70	Wetted Edge		
168	454615.11	1379595.98	250.52	Wetted Edge		
169	454613.56	1379602.53	250.62	Wetted Edge		
170	454619.81	1379596.63	250.31	Wetted Edge		
171	454616.55	1379603.68	250.28	Wetted Edge		
172	454623.11	1379599.52	250.11	Wetted Edge		
173	454618.09	1379605.57	250.14	Wetted Edge		
174	454625.51	1379602.10	249.95	Wetted Edge		
175	454620.09	1379607.54	249.77	Wetted Edge		
176	454626.82	1379606.83	249.68	Wetted Edge		
177	454621.54	1379610.26	249.55	Wetted Edge		
178	454627.30	1379610.54	249.41	Wetted Edge		
179	454622.03	1379612.80	249.35	Wetted Edge		
180	454630.76	1379613.62	249.09	Wetted Edge		
181	454622.10	1379615.53	249.18	Wetted Edge		
182	454633.63	1379615.33	248.90	Wetted Edge		
183	454622.07	1379619.03	248.99	Wetted Edge		
184	454639.89	1379618.76	248.44	Wetted Edge		
185	454621.95	1379623.24	248.71	Wetted Edge		
186	454639.27	1379625.34	247.80	Wetted Edge		
187	454622.92	1379627.29	248.43	Wetted Edge		
188	454639.71	1379629.65	247.26	Wetted Edge		
189	454626.07	1379631.38	247.98	Wetted Edge		
190	454643.36	1379632.84	246.95	Wetted Edge		
191	454628.39	1379634.17	247.61	Wetted Edge		
192	454649.02	1379633.49	246.74	Wetted Edge		
193	454632.12	1379636.94	247.34	Wetted Edge		
194	454636.43	1379641.40	247.02	Wetted Edge		
195	454639.18	1379646.22	246.66	Wetted Edge		

FIGURE 9-56 UPPER DELTA 2000/01 (4/4)

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
1	454605.50	1379629.92	252.44	slope		
2	454621.71	1379617.37	250.09	snow edge and wetted perimeter		
3	454622.36	1379616.01	249.74	stream edge		
4	454625.44	1379615.00	249.84	stream edge		
5	454630.97	1379609.17	250.33	wetted perimeter		
6	454635.84	1379605.54	251.24	slope		
7	454623.56	1379610.49	250.02	orange 2	3.90	1.19
8	454610.27	1379602.33	251.56	wetted perimeter		
9	454617.27	1379607.71	250.93	wetted perimeter		
10	454621.58	1379621.90	249.76	snow edge and wetted perimeter		
11	454622.41	1379628.98	249.61	snow edge and wetted perimeter		
12	454632.75	1379638.99	248.22	snow edge and wetted perimeter		
13	454636.63	1379636.96	247.72	end of snow and stream edge		
14	454639.71	1379632.64	247.61	stream edge and snow edge		
15	454640.25	1379631.28	247.79	snow edge		
16	454645.17	1379617.86	249.32	wetted perimeter		
17	454631.17	1379610.01	250.23	wetted perimeter		
18	454626.01	1379600.92	250.81	snow edge and wetted perimeter		
19	454614.00	1379593.10	251.92	wetted perimeter		
20	454612.46	1379594.55	251.48	snow edge		
21	454611.14	1379596.02	251.23	stream edge and snow edge		
22	454620.05	1379598.65	250.75	snow edge		
23	454624.37	1379603.23	250.42	snow and stream edge		
24	454626.18	1379619.29	249.51	O3	14.80	1.67
25	454630.53	1379628.44	248.46	stream edge		
26	454625.86	1379627.82	248.66	O4	8.60	4.21
27	454622.79	1379621.98	249.40	snow and stream edge		
28	454621.96	1379607.10	250.22	stream edge		
29	454620.76	1379605.75	250.48	orange 1	5.90	7.03
30	454618.50	1379601.43	250.74	stream edge		
31	454609.42	1379600.32	251.21	stream edge		
32	454632.32	1379630.46	248.11	orange 5	4.10	2.24
33	454636.77	1379623.27	248.76	black 1	11.20	0.03
34	454632.54	1379620.35	249.35	black 2	11.20	0.02
35	454631.42	1379619.06	249.45	black 3	16.70	0.12
36	454631.99	1379618.82	249.80	black 4	15.30	0.05

FIGURE 9-57 UPPER DELTA 2002/03

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
1	454597.44	1379635.96	254.28	T072		
2	454622.62	1379623.10	248.54	B4	30.06	61.53
3	454623.90	1379619.76	248.69	O5	21.55	2.61
4	454624.23	1379619.47	248.66	G1	34.35	104.20
5	454623.94	1379616.61	248.75	G2	24.94	47.53
6	454623.50	1379612.27	249.11	O4	5.12	2.61
7	454625.61	1379609.91	249.31	B3	21.70	24.69
8	454623.54	1379607.91	249.38	O3	3.39	2.59
9	454623.04	1379605.11	249.51	O2	32.25	1.54
10	454621.26	1379604.45	249.70	B2	36.62	31.47
11	454624.38	1379602.88	249.66	B1	18.83	15.14
12	454619.80	1379601.33	249.83	O1	10.70	4.74
13	454597.43	1379635.96	254.27	T072		

FIGURE 9-58 UPPER DELTA 2010/11

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
1	454646.59	1379597.47	254.22	ST07-BM1		
2	454631.77	1379598.31	251.52	top of rock right side		
3	454616.34	1379597.84	250.11	O1	13.39	14.45
4	454619.73	1379598.63	249.95	B3	53.00	27.34
5	454619.27	1379600.33	249.91	O2	16.48	8.59
6	454622.79	1379607.46	249.39	G1	4.41	1.57
7	454623.43	1379617.41	248.78	G2	7.18	5.42
8	454625.92	1379619.59	248.65	B2	15.46	14.32
9	454636.95	1379628.27	247.20	B1	38.02	13.45
10	454636.15	1379629.50	247.10	O3	9.69	24.86
11	454636.62	1379631.10	246.93	O4	8.33	10.05
12	454629.34	1379630.44	247.50	G3	10.22	2.30
13	454617.06	1379602.97	250.61	Top of rock		
14	454610.71	1379611.65	249.61	Top of rock		
15	454642.24	1379601.82	253.08	Top of rock		
16	454646.58	1379597.48	254.22	ST07-BM2		

FIGURE 9-59 UPPER DELTA 2012/13

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
1	454597.44	1379635.96	254.29	BM		
2	454613.94	1379598.23	250.27	O1		
3	454622.67	1379602.82	249.74	O2		
4	454623.87	1379606.43	249.52	O3		
5	454623.46	1379613.00	249.16	O4		
6	454614.33	1379598.16	250.27	G1		
7	454618.88	1379599.87	250.01	G2		
8	454622.98	1379617.89	248.81	G3		

FIGURE 9-60 UPPER DELTA 2013/14

RELATIVE BED CHANGES

Year	Mean	Max	Min
1994	0.04	0.39	-0.18
2001	0.00	0.07	-0.10
2003	0.00	0.29	-0.08
2011	-0.09	-0.05	-0.20
2013	-0.07	-0.04	-0.10
2014	0.00	0.02	-0.11

FIGURE 9-61 UPPER DELTA RELATIVE BED CHANGES

AFDM COMPARISON

Change	AFDM	Type
0.11	34.35	1
0.20	24.94	1
0.08	0.00	1
0.10	0.00	1
0.09	0.00	1
0.02	0.00	1
0.02	0.00	1
-0.11	0.00	1
-0.05	41.63	2
0.07	36.62	2
0.05	30.06	2
-0.08	25.37	2
0.01	23.13	2
0.09	21.70	2
-0.06	21.45	2
-0.03	20.88	2
0.07	18.83	2
0.04	16.70	2
-0.29	15.30	2
0.00	11.20	2
-0.01	11.20	2
0.00	0.00	2
-0.03	0.00	2
0.05	0.00	2
-0.01	0.00	2
0.04	0.00	2
0.07	0.00	2
0.07	0.00	2
0.09	32.25	3
-0.03	27.40	3
-0.03	26.52	3
0.08	21.55	3
-0.03	18.85	3
0.00	15.59	3

Change	AFDM	Type
-0.01	14.80	3
0.00	14.80	3
0.08	10.70	3
0.00	8.60	3
-0.03	5.90	3
0.08	5.12	3
0.03	4.10	3
0.03	3.90	3
0.08	3.39	3
0.02	0.00	3
0.08	0.00	3
-0.01	0.00	3
0.06	0.00	3
0.01	0.00	3
0.06	0.00	3
0.05	0.00	3
0.03	0.00	3
0.02	0.00	3
0.07	0.00	3
0.10	0.00	3
0.02	0.00	3
-0.01	0.00	3
0.01	0.00	3
-0.01	0.00	3
-0.01	0.00	3
0.01	0.00	3
0.05	0.00	3
0.04	0.00	3
0.09	0.00	3
0.08	0.00	3
0.02	0.00	3
0.02	0.00	3
0.02	0.00	3
0.02	0.00	3

FIGURE 9-62 UPPER DELTA AFDM COMPARISON. FIRST COLUMN IS RELATIVE CHANGE AT POINT IN STREAM. SECOND COLUMN IS AFDM. THIRD COLUMN IS MICROBIAL MAT TYPE (1=GREEN, 2=BLACK, 3=ORANGE, 4=RED)

FLOW COMPARISON

AFDM	Flow	Type
34.40	2.16	1
24.90	2.16	1
0.00	0.22	1
0.00	0.22	1
0.00	0.22	1
0.00	NaN	1
0.00	NaN	1
0.00	NaN	1
41.60	0.56	2
36.60	2.16	2
30.10	2.16	2
25.40	0.56	2
23.10	0.56	2
21.70	2.16	2
21.50	0.56	2
20.90	0.56	2
18.80	2.16	2
16.70	0.25	2
15.30	0.25	2
11.20	0.25	2
11.20	0.25	2
0.00	NaN	2
0.00	NaN	2
0.00	NaN	2
0.00	NaN	2
0.00	0.22	2
0.00	0.22	2
0.00	0.22	2
32.20	2.16	3
27.40	0.56	3
26.50	0.56	3
21.50	2.16	3
18.90	0.56	3
15.60	0.56	3

AFDM	Flow	Type
14.80	0.56	3
14.80	0.25	3
10.70	2.16	3
8.60	0.25	3
5.90	0.25	3
5.12	2.16	3
4.10	0.25	3
3.90	0.25	3
3.39	2.16	3
0.00	NaN	3
0.00	NaN	3
0.00	NaN	3
0.00	NaN	3
0.00	NaN	3
0.00	NaN	3
0.00	NaN	3
0.00	NaN	3
0.00	NaN	3
0.00	NaN	3
0.00	NaN	3
0.00	NaN	3
0.00	NaN	3
0.00	NaN	3
0.00	NaN	3
0.00	NaN	3
0.00	NaN	3
0.00	0.22	3
0.00	0.22	3
0.00	0.22	3
0.00	0.22	3
0.00	NaN	3
0.00	NaN	3
0.00	NaN	3
0.00	NaN	3

FIGURE 9-63 UPPER DELTA FLOW COMPARISON. FIRST COLUMN IS AFDM. SECOND COLUMN IS WEIGHTED FLOW FOR SEASON OF SURVEY. THIRD COLUMN IS MICROBIAL MAT TYPE (1=GREEN, 2=BLACK, 3=ORANGE, 4=RED)

9.1.4 Von Guerard Stream F6

SURVEYS

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
1	458190.87	1384590.76	20.90	algae o 5	33.08	21.72
2	458187.76	1384600.58	20.35	algae o 2	32.51	3.05
3	458196.81	1384607.17	20.32	algae b 5	27.31	10.62
4	458190.68	1384594.81	20.68	algae b 3	23.35	5.91
5	458190.08	1384594.89	20.62	algae o 4	19.82	10.15
6	458186.64	1384605.85	19.95	algae b 1	12.86	3.86
7	458199.99	1384606.80	20.54	moss sam 1	11.85	9.01
8	458190.48	1384592.81	20.78	algae b 4	11.76	15.59
9	458188.19	1384599.35	20.36	algae b 2	11.54	12.19
10	458187.98	1384598.00	20.41	algae o 3	7.44	5.38
11	458160.33	1384588.96	22.89	T BM T122		
12	458212.59	1384617.42	22.17	T topo		
13	458210.37	1384616.21	21.52	T topo		
14	458206.07	1384613.88	21.21	T topo		
15	458200.72	1384610.96	21.23	T topo		
16	458198.98	1384610.01	20.49	T wet zone		
17	458198.05	1384609.51	20.15	T water edge		
18	458197.71	1384609.32	20.07	T thalwag		
19	458196.50	1384608.67	20.11	T water edge		
20	458192.26	1384606.35	20.47	T topo		
21	458189.12	1384604.64	20.38	T topo		
22	458187.17	1384603.58	20.13	T water edge		
23	458186.64	1384603.29	20.13	T water edge		
24	458184.65	1384602.21	20.57	T topo		
25	458183.27	1384601.45	20.69	T wet zone		
26	458181.01	1384600.23	21.24	T topo		
27	458176.64	1384597.84	21.66	T topo		
28	458165.30	1384591.67	21.81	T topo		
29	458162.60	1384590.20	22.60	T topo		
30	458197.96	1384606.02	20.42	algae o 1		
31	458196.66	1384606.21	20.49	moss sam 2		
32	458188.66	1384604.12	20.24	moss sam 3		
33	458188.10	1384596.36	20.61	moss sam 4		
34	458191.58	1384591.92	20.90	moss sam 5		
35	458216.53	1384604.29	22.54	topo		
36	458213.64	1384606.50	22.51	topo		
37	458210.63	1384621.61	21.99	topo		
38	458208.52	1384620.48	21.43	topo		
39	458210.39	1384610.75	21.56	topo		

FIGURE 9-64 VON GUERARD 1993/94 (1/2)

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
40	458211.11	1384604.74	21.70	topo		
41	458210.16	1384603.44	21.59	topo		
42	458204.80	1384607.20	21.34	topo		
43	458202.29	1384615.53	21.12	topo		
44	458199.59	1384619.87	20.63	topo		
45	458198.28	1384619.44	20.25	wet zone		
46	458199.48	1384616.80	20.28	wet zone		
47	458198.48	1384611.22	20.40	wet zone		
48	458201.37	1384608.43	20.81	wet zone		
49	458207.40	1384603.50	21.03	wet zone		
50	458205.95	1384600.83	20.62	water edge		
51	458201.06	1384604.80	20.58	water edge		
52	458197.36	1384611.66	20.02	water edge dis		
53	458198.00	1384615.04	19.83	water edge		
54	458194.89	1384617.44	19.74	water edge		
55	458197.13	1384618.68	19.79	water edge		
56	458198.51	1384615.71	19.89	water edge		
57	458190.33	1384615.60	19.65	water edge		
58	458194.39	1384613.81	19.77	water edge		
59	458195.98	1384611.41	19.92	water edge dis		
60	458200.08	1384601.83	20.57	water edge		
61	458204.99	1384599.04	20.63	water edge		
62	458197.39	1384594.00	20.97	topo		
63	458194.46	1384598.60	20.85	topo		
64	458189.34	1384609.27	20.13	topo		
65	458195.61	1384609.14	20.10	wet zone flow		
66	458192.14	1384610.66	19.82	wet zone flow		
67	458188.69	1384610.64	19.72	wet zone flow		
68	458186.63	1384608.99	19.72	water edge		
69	458186.49	1384606.18	19.94	water edge		
70	458188.51	1384599.66	20.41	water edge		
71	458190.20	1384594.86	20.61	water edge		
72	458189.32	1384594.47	20.63	water edge		
73	458186.94	1384599.74	20.40	water edge		
74	458185.63	1384607.33	19.86	water edge sno		
75	458186.36	1384610.78	19.82	water edge sno		
76	458179.33	1384607.85	20.28	sno bank top		
77	458181.59	1384602.79	20.60	wet zone top sno		
78	458181.94	1384593.53	21.39	wet zone		
79	458180.06	1384591.15	21.68	topo		
80	458181.91	1384596.64	21.39	topo		
81	458178.14	1384604.69	21.21	topo		
82	458169.47	1384580.90	22.03	topo		
83	458165.58	1384579.62	23.03	topo		
84	458160.16	1384602.22	22.25	topo		
85	458162.81	1384602.89	21.56	topo		

FIGURE 9-65 VON GUERARD 1993/94 (2/2)

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
1	458214.37	1384618.39	22.22	BS1		
2	458209.88	1384622.60	21.81	Topo		
3	458211.43	1384618.90	22.04	Topo		
4	458212.91	1384612.16	22.24	Topo		
5	458214.03	1384605.25	22.47	Topo		
6	458212.83	1384601.89	21.78	Topo		
7	458210.22	1384608.15	21.56	Topo		
8	458208.48	1384616.92	21.28	Topo		
9	458206.77	1384628.93	21.03	Topo		
10	458200.54	1384632.32	20.76	Topo		
11	458191.97	1384636.02	20.73	Topo		
12	458188.51	1384631.06	20.87	Topo		
13	458187.63	1384625.19	21.03	Topo		
14	458191.94	1384623.44	21.00	Topo		
15	458199.16	1384620.15	20.58	Topo		
16	458201.49	1384614.76	21.09	Topo		
17	458201.82	1384610.10	21.20	Topo		
18	458206.99	1384605.80	21.36	Topo		
19	458212.17	1384601.11	21.65	Topo		
20	458214.48	1384594.76	20.96	Salt Crust		
21	458210.84	1384597.89	21.02	Salt Crust		
22	458206.37	1384602.85	20.77	Salt Crust		
23	458201.72	1384606.42	20.64	Topo		
24	458198.98	1384609.39	20.47	Topo		
25	458197.31	1384614.32	19.78	Topo		
26	458197.35	1384618.21	19.79	Topo		
27	458190.04	1384620.33	19.53	Topo		
28	458184.29	1384621.76	19.47	Topo		
29	458183.12	1384624.80	19.23	Topo		
30	458184.22	1384629.80	19.02	Topo		
31	458180.13	1384630.37	19.18	Topo		
32	458178.55	1384624.78	19.27	Topo		
33	458175.87	1384618.70	19.51	Snow		
34	458178.43	1384613.88	19.69	Snow		
35	458178.24	1384610.10	20.19	Snow		
36	458180.71	1384606.11	20.16	Snow		
37	458183.21	1384605.13	20.03	Snow		
38	458186.57	1384606.69	19.88	Snow		
39	458188.48	1384611.85	19.63	Snow		
40	458187.16	1384616.71	19.54	Snow		
41	458182.16	1384624.29	19.24	Snow		
42	458185.90	1384602.85	20.14	Black Algae Mat 1		
43	458187.25	1384600.27	20.31	Black Algae Mat 1		
44	458186.06	1384598.86	20.41	Black Algae Mat 1		
45	458184.54	1384599.54	20.41	Black Algae Mat 1		
46	458184.85	1384598.00	20.38	Black Algae Mat 1		
47	458187.66	1384597.89	20.38	Black Algae Mat 1		
48	458189.35	1384594.42	20.64	Black Algae Mat 1		
49	458190.42	1384591.81	20.82	Black Algae Mat 1		

FIGURE 9-66 VON GUERARD 2000/01 (1/2)

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
50	458191.04	1384594.80	20.72	Black Algae Mat 1		
51	458188.85	1384599.20	20.44	Black Algae Mat 1		
52	458185.30	1384598.49	20.35	B3 - Black Algal Mat Sample 3		
53	458186.38	1384602.20	20.21	B1 - Black Algal Mat Sample 1		
54	458198.94	1384598.12	20.66	Black Algae Mat 2		
55	458196.37	1384594.84	20.84	Black Algae Mat 2		
56	458214.39	1384618.40	22.22	Backsight		
57	458203.02	1384597.71	20.65	Black Algae Mat 2		
58	458199.00	1384598.16	20.66	Black Algae Mat 2		
59	458197.88	1384595.36	20.79	B2 - Black Algal Mat Sample 2		
60	458198.40	1384603.85	20.50	Topo		
61	458195.91	1384606.34	20.53	Topo		
62	458189.93	1384608.57	20.24	Topo		
63	458190.11	1384602.31	20.61	Topo		
64	458191.51	1384597.34	20.87	Topo		
65	458192.80	1384590.77	21.13	Topo		
66	458193.70	1384587.18	21.38	Topo		
67	458191.95	1384587.43	21.27	Thalweg		
68	458190.97	1384590.33	20.92	Thalweg		
69	458190.63	1384593.16	20.74	Thalweg		
70	458208.31	1384597.72	20.61	Thalweg		
71	458204.33	1384600.59	20.52	Thalweg		
72	458199.83	1384605.03	20.43	Thalweg		
73	458197.62	1384608.21	19.97	Thalweg		
74	458196.23	1384613.64	19.76	Thalweg		
75	458190.11	1384618.28	19.51	Thalweg		
76	458173.55	1384619.52	20.16	Topo		
77	458175.93	1384613.96	20.30	Topo		
78	458176.83	1384606.37	21.15	Topo		
79	458180.96	1384597.99	21.39	Topo		
80	458182.07	1384591.17	21.37	Topo		
81	458178.63	1384584.18	21.79	Topo		
82	458169.91	1384584.58	21.90	Topo		
83	458167.29	1384593.43	21.68	Topo		
84	458163.70	1384602.75	21.51	Topo		
85	458214.40	1384618.41	22.22	BS2		

FIGURE 9-67 VON GUERARD 2000/01 (2/2)

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
1	458185.23	1384598.63	20.37	B3	79.11	39.88
2	458187.59	1384611.09	19.63	B2	35.41	14.04
3	458188.18	1384598.30	20.41	B4	32.25	45.21
4	458184.70	1384615.07	19.45	O4	23.81	58.43
5	458187.64	1384600.38	20.32	O5	22.53	19.87
6	458198.33	1384603.96	20.40	O1	10.85	29.76
7	458186.49	1384611.65	19.57	O3	7.38	49.32
8	458196.10	1384614.75	19.66	O2	2.79	12.09
9	458214.35	1384618.38	22.20	T122		
10	458293.59	1384094.70	40.85	VGD_BM1		
11	458183.12	1384620.20	19.84	TOP G1		

FIGURE 9-68 VON GUERARD 2010/11

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
1	458198.47	1384598.13	20.63	Black 2	25.73	24.69
2	458187.24	1384610.69	19.60	Black 3	23.22	52.85
3	458204.35	1384592.63	20.79	Black 1	21.50	25.75
4	458186.31	1384612.19	19.52	Orange 3	15.99	31.15
5	458184.41	1384611.38	19.54	Black 4	15.86	20.96
6	458202.40	1384596.33	20.64	Orange 1	11.23	18.94
7	458197.97	1384599.21	20.54	Orange 2	7.84	18.17
8	458191.48	1384611.43	19.67	Orange 4	6.78	20.60
9	458187.42	1384618.39	19.48	Green 3	3.52	3.28
10	458198.37	1384604.25	20.42	Green 1	2.69	4.67
11	458196.30	1384611.71	19.88	Green 2	2.16	1.31
12	458160.31	1384588.95	22.87	BM on west bank		
13	458182.96	1384620.30	19.90	Temporary Rebar from 2010-2011		
14	458184.32	1384620.32	19.77	New Top-down rebar from 2011-2012		

FIGURE 9-69 VON GUERARD 2011/12

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
1	458185.34	1384598.34	20.40	Black 3	49.38	44.73
2	458185.78	1384612.33	19.55	Orange 1	25.07	21.38
3	458202.12	1384597.44	20.63	Black 1	25.07	27.08
4	458187.39	1384610.38	19.67	Black 2	20.66	20.82
5	458200.11	1384598.68	20.60	Black 4	18.28	20.87
6	458186.33	1384605.33	19.99	Orange 2	15.99	25.19
7	458187.41	1384602.08	20.27	Orange 3	8.19	12.46
8	458201.10	1384599.52	20.58	Orange 4	3.79	5.01
9	458206.47	1384598.89	20.53	Green 2	3.44	2.92
10	458207.28	1384597.07	20.54	Green 3	3.26	3.79
11	458209.37	1384597.25	20.68	Green 1	1.15	4.09
12	458160.26	1384588.93	22.88	west benchmark-BS		
13	458182.93	1384620.30	19.91	top-down rebar		
14	458184.25	1384620.33	19.79	small rebar		

FIGURE 9-70 VON GUERARD 2012/13

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
Bad Data	458187.08	1384603.53	22.28	BM?		
2	458190.78	1384589.46	21.11	B3		
3	458191.24	1384589.98	21.02	O1		
4	458181.98	1384611.62	19.48	O2		
5	458187.48	1384610.46	19.64	B2		
6	458191.33	1384611.31	19.71	O3		
7	458200.26	1384598.30	20.58	B1		

FIGURE 9-71 VON GUERARD 2013/14

RELATIVE BED CHANGES

Year	Mean	Max	Min
1994	0.03	0.24	-0.14
2001	0.03	0.07	-0.05
2011	0.05	0.09	-0.03
2012	-0.05	-0.03	-0.07
2013	-0.02	0.03	-0.09
2014	0.00	0.04	-0.03

FIGURE 9-72 VON GUERARD RELATIVE BED CHANGES

AFDM COMPARISON

Change	AFDM	Type
-0.07	3.52	1
-0.10	3.44	1
-0.13	3.26	1
-0.07	2.69	1
-0.12	2.16	1
-0.07	1.15	1
0.02	35.40	2
0.03	32.20	2
-0.04	27.30	2
-0.11	25.70	2
-0.07	25.10	2
0.01	23.30	2
-0.10	23.20	2
-0.10	21.50	2
-0.05	20.70	2
-0.10	18.30	2
-0.08	15.90	2
0.02	12.90	2
0.02	11.80	2
0.03	11.50	2
0.03	0.00	2
0.03	0.00	2
0.05	0.00	2
0.04	0.00	2
0.00	0.00	2
0.00	0.00	2
0.00	0.00	2
0.01	0.00	2

Change	AFDM	Type
0.09	0.00	2
0.00	0.00	2
0.00	0.00	2
0.03	0.00	2
0.00	0.00	2
-0.07	0.00	2
-0.06	0.00	2
0.03	33.10	3
-0.03	32.50	3
-0.03	25.10	3
0.01	23.80	3
0.05	22.50	3
0.02	19.80	3
-0.08	16.00	3
-0.02	16.00	3
-0.10	11.20	3
-0.05	10.80	3
-0.04	8.19	3
-0.09	7.84	3
0.01	7.44	3
0.03	7.38	3
-0.12	6.78	3
-0.06	3.79	3
-0.07	2.79	3
-0.01	0.00	3
-0.01	0.00	3
-0.06	0.00	3
-0.08	0.00	3

FIGURE 9-73 VON GUERARD AFDM COMPARISON. FIRST COLUMN IS RELATIVE CHANGE AT POINT IN STREAM. SECOND COLUMN IS AFDM. THIRD COLUMN IS MICROBIAL MAT TYPE (1=GREEN, 2=BLACK, 3=ORANGE, 4=RED)

FLOW COMPARISON

AFDM	Flow	Type
3.52	0.63	1
3.44	0.26	1
3.26	0.26	1
2.69	0.63	1
2.16	0.63	1
1.15	0.26	1
35.40	3.41	2
32.20	3.41	2
27.30	1.05	2
25.70	0.63	2
25.10	0.26	2
23.30	1.05	2
23.20	0.63	2
21.50	0.63	2
20.70	0.26	2
18.30	0.26	2
15.90	0.63	2
12.90	1.05	2
11.80	1.05	2
11.50	1.05	2
0.00	NaN	2
0.00	NaN	2
0.00	NaN	2
0.00	NaN	2
0.00	NaN	2
0.00	NaN	2
0.00	NaN	2
0.00	NaN	2

AFDM	Flow	Type
0.00	NaN	2
0.00	NaN	2
0.00	NaN	2
0.00	NaN	2
0.00	NaN	2
0.00	NaN	2
0.00	NaN	2
33.10	1.05	3
32.50	1.05	3
25.10	0.26	3
23.80	3.41	3
22.50	3.41	3
19.80	1.05	3
16.00	0.63	3
16.00	0.26	3
11.20	0.63	3
10.80	3.41	3
8.19	0.26	3
7.84	0.63	3
7.44	1.05	3
7.38	3.41	3
6.78	0.63	3
3.79	0.26	3
2.79	3.41	3
0.00	1.05	3
0.00	NaN	3
0.00	NaN	3
0.00	NaN	3

FIGURE 9-74 VON GUERARD FLOW COMPARISON. FIRST COLUMN IS AFDM. SECOND COLUMN IS WEIGHTED FLOW FOR SEASON OF SURVEY. THIRD COLUMN IS MICROBIAL MAT TYPE (1=GREEN, 2=BLACK, 3=ORANGE, 4=RED)

9.1.5 Huey Creek F2

SURVEYS

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
1	454993.53	1385312.66	39.71	O4	19.60	2.35
2	454998.84	1385300.67	39.16	O2	9.30	8.23
3	454999.24	1385294.40	38.69	O1	7.14	6.16
4	454992.38	1385315.24	39.94	O5	4.27	2.42
5	454996.51	1385306.85	39.48	O3	3.88	1.79
6	455014.53	1385308.68	41.15	T111		
7	454956.75	1385293.34	42.31	T112		
8	455002.52	1385305.49	39.65	T wet zone		
9	455007.59	1385306.83	40.91	T topo		
10	454997.83	1385304.25	39.31	T wat edge clear		
11	454997.32	1385304.11	39.38	T wat edge clear		
12	454990.31	1385302.25	39.50	T wat edge flour		
13	454989.67	1385302.08	39.51	T wat edge flour		
14	454982.33	1385300.13	39.79	T water edge		
15	454981.04	1385299.79	39.65	T thalwag		
16	454977.94	1385298.97	39.73	T water edge		
17	454976.55	1385298.60	39.85	T wat edge flour		
18	454976.00	1385298.45	39.80	T wat edge flour		
19	454973.31	1385297.74	39.90	T moss e zone		
20	454970.45	1385296.99	40.30	T wet zone		
21	454963.91	1385295.25	41.85	T topo		
22	455003.88	1385301.12	39.18	M1		
23	455005.45	1385314.41	40.31	M2		
24	454974.36	1385296.84	39.84	M3		
25	454971.25	1385299.99	40.17	M4		
26	454973.09	1385305.55	40.28	M5		
27	455012.49	1385301.53	40.39	topo		
28	455008.53	1385303.66	40.59	topo		
29	455007.16	1385310.53	41.19	topo		
30	455008.12	1385314.10	41.23	topo		
31	455005.82	1385315.04	40.37	wet zone		
32	455003.32	1385310.67	40.07	wet zone		
33	455004.95	1385301.71	39.36	wet zone		
34	455009.29	1385296.72	39.01	wet zone		
35	455002.85	1385295.52	38.69	wet zone w flow		
36	455000.85	1385300.02	39.08	wet zone w flow		
37	454998.36	1385303.35	39.35	wet zone w flow		
38	454995.51	1385308.75	39.55	rivlet clear ctr		
39	454992.52	1385314.91	39.94	rivlet clear ctr		

FIGURE 9-75 HUEY 1993/94 (1/2)

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
40	454999.03	1385299.24	39.05	rivlet clear ctr		
41	454999.71	1385293.82	38.58	rivlet clear ctr		
42	454993.37	1385292.57	38.65	rivlet flour ctr		
43	454991.97	1385297.42	39.27	rivlet flour ctr		
44	454988.44	1385306.56	39.76	rivlet flour ctr		
45	454983.70	1385313.04	40.15	rivlet flour ctr		
46	454979.79	1385312.41	40.78	rock top		
47	454980.57	1385312.88	40.39	rock		
48	454979.77	1385311.80	40.34	rock		
49	454978.39	1385311.25	40.30	rock		
50	454979.18	1385312.43	40.47	rock		
51	454977.29	1385310.84	40.17	water edge		
52	454979.65	1385305.59	39.99	water edge		
53	454981.72	1385298.07	39.63	water edge		
54	454980.79	1385291.73	39.45	water edge		
55	454979.34	1385290.69	39.41	water edge		
56	454979.23	1385291.02	39.41	water edge		
57	454979.70	1385296.98	39.58	water edge		
58	454978.17	1385304.74	39.90	water edge		
59	454973.21	1385305.95	40.22	water edge		
60	454975.97	1385299.59	39.89	flow z		
61	454975.58	1385293.30	39.69	flow z		
62	454976.29	1385291.56	39.90	moss edg		
63	454971.78	1385294.88	40.21	wet zone moss ed		
64	454967.53	1385302.52	40.83	wet zone moss ed		
65	454967.84	1385307.67	41.09	wet zone moss ed		
66	454972.68	1385287.34	40.91	topo		
67	454964.44	1385305.15	42.26	topo		

FIGURE 9-76 HUEY 1993/94 (2/2)

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
1	454956.60	1385293.30	42.31	BM T112		
2	455014.39	1385308.64	41.15	BM T111		
3	454983.50	1385297.98	40.00	intermediate		
4	454973.04	1385305.52	40.31	moss zone		
5	454974.25	1385303.89	40.19	moss zone		
6	454974.85	1385301.72	40.11	moss zone		
7	454973.76	1385301.70	40.13	moss zone		
8	454973.49	1385298.67	40.01	moss zone		
9	454975.34	1385297.99	39.93	moss zone		
10	454974.95	1385294.39	39.83	moss zone		
11	454972.96	1385295.18	40.12	moss zone		
12	454972.04	1385297.24	40.19	moss zone		
13	454971.75	1385299.49	40.17	moss zone		
14	454970.95	1385299.91	40.22	moss zone		
15	454971.92	1385300.52	40.27	moss zone		
16	454972.49	1385303.12	40.39	moss zone		
17	454972.76	1385305.26	40.41	moss zone		
18	454978.23	1385311.11	40.36	rock		
19	454979.65	1385311.72	40.40	rock		
20	454980.37	1385312.87	40.49	rock		
21	454979.09	1385312.41	40.57	rock		
22	454967.87	1385307.95	41.08	wet zone		
23	454967.54	1385305.17	40.85	wet zone		
24	454970.62	1385303.37	40.64	wet zone		
25	454971.03	1385300.48	40.38	wet zone		
26	454971.38	1385298.80	40.25	wet zone		
27	454972.03	1385295.60	40.20	wet zone		
28	454974.10	1385293.11	40.12	wet zone		
29	454976.18	1385291.92	40.01	wet zone		
30	454978.69	1385290.22	39.76	wet zone		
31	454976.50	1385288.64	39.74	wet zone		
32	454975.38	1385287.19	39.72	wet zone		
33	454976.02	1385285.28	39.75	wet zone		
34	454977.37	1385283.74	39.75	wet zone		
35	454979.35	1385283.71	39.60	wet zone		
36	454980.93	1385284.58	39.57	wet zone		
37	454977.99	1385284.51	39.42	snow edge		
38	454976.70	1385285.50	39.39	snow edge		
39	454975.84	1385287.62	39.48	snow edge		
40	454978.33	1385288.46	39.38	snow edge		
41	454978.82	1385286.62	39.35	snow edge		
42	455004.35	1385299.35	39.17	moss zone		
43	455003.77	1385300.17	39.18	moss zone		
44	455002.88	1385301.92	39.33	moss zone		
45	455001.80	1385303.95	39.49	moss zone		
46	455002.24	1385305.57	39.73	moss zone		
47	455003.43	1385303.14	39.56	moss zone		
48	455005.02	1385300.65	39.31	moss zone		
49	455006.98	1385300.51	41.46	wet zone		

FIGURE 9-77 HUEY 1997/98 (1/3)

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
50	455003.68	1385303.51	39.57	wet zone		
51	455002.18	1385308.91	42.01	wet zone		
52	455004.11	1385312.19	42.22	wet zone		
53	455006.90	1385316.85	40.51	wet zone		
54	454992.83	1385313.45	39.92	Center, rivulet 1		
55	454995.09	1385309.09	39.64	Center, rivulet 1		
56	454996.85	1385305.31	39.47	Center, rivulet 1		
57	454996.89	1385304.72	39.42	pool		
58	454997.02	1385303.87	39.46	pool		
59	454997.91	1385303.16	39.39	pool		
60	454997.45	1385304.40	39.38	pool		
61	454998.79	1385300.09	39.18	Center, rivulet 1		
62	454998.83	1385296.52	39.04	Center, rivulet 1		
63	454998.60	1385293.09	38.70	Center, rivulet 1		
64	454985.48	1385310.00	40.04	Center, rivulet 2		
65	454989.02	1385305.53	39.81	Center, rivulet 2		
66	454990.18	1385300.29	39.45	Center, rivulet 2		
67	454991.66	1385297.23	39.36	Center, rivulet 2		
68	454991.86	1385295.82	39.00	Seep pool		
69	454993.23	1385293.22	38.80	Wet rivulet		
70	454992.60	1385291.54	38.62	Jnct. of seep strms		
71	454991.37	1385292.67	38.85	Wet rivulet		
72	454990.48	1385293.58	38.99	Seep pool		
73	454985.05	1385284.19	39.04	Rivulet #3		
74	454982.28	1385287.56	39.20	Rivulet #3		
75	454979.25	1385291.92	39.52	Rivulet #3		
76	454980.10	1385297.02	39.69	Rivulet #3		
77	454980.02	1385302.09	39.82	Rivulet #3		
78	454978.13	1385307.25	40.00	Rivulet #3		
79	454975.35	1385311.94	40.34	Rivulet #3		
80	455009.55	1385316.09	41.35	Topo shot		
81	455006.95	1385311.61	41.22	Topo shot		
82	455006.95	1385307.33	40.99	Topo shot		
83	455009.12	1385303.17	40.62	Topo shot		
84	455000.18	1385298.48	39.19	Topo shot		
85	454994.41	1385296.96	39.39	Topo shot		
86	454993.79	1385304.08	39.76	Topo shot		
87	454999.41	1385315.15	40.19	Topo shot		
88	454994.31	1385317.78	40.37	Topo shot		
89	454987.02	1385312.49	40.28	Topo shot		
90	454991.10	1385307.22	39.99	Topo shot		
91	454993.92	1385303.68	39.79	Topo shot		
92	454986.85	1385299.18	39.75	Topo shot		
93	454986.02	1385304.43	39.97	Topo shot		
94	454980.52	1385308.05	40.22	Topo shot		
95	454973.09	1385309.17	40.43	Topo shot		
96	454963.72	1385307.44	39.40	Topo shot		
97	454961.26	1385301.68	39.28	Topo shot		
98	454963.65	1385295.95	39.00	Topo shot		
99	454966.37	1385290.49	38.43	Topo shot		

FIGURE 9-78 HUEY 1997/98 (2/3)

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
100	454972.50	1385287.12	38.00	Topo shot		
101	454974.81	1385282.38	38.00	Topo shot		
102	454981.42	1385282.58	40.43	Topo shot		
103	454985.10	1385290.08	39.37	Topo shot		
104	454973.07	1385298.76	40.04	Moss #1		
105	454976.07	1385299.12	39.92	Moss #3		
106	454974.09	1385303.76	40.17	Moss #2		
107	454996.66	1385304.98	39.49	Black #2		
108	454996.98	1385304.57	39.43	Orange #3		
109	454997.43	1385304.36	39.39	Black #1		
110	454997.54	1385303.80	39.36	Orange #2		
111	454998.14	1385302.36	39.34	Orange #1		
112	454996.14	1385301.86	39.46	Black $3		
113	455003.41	1385302.65	39.44	Moss #4		
114	455004.38	1385299.58	39.15	Moss #5		
115	454992.26	1385294.70	38.95	Orange #4		
116	454991.31	1385292.66	38.88	Orange #5		

FIGURE 9-79 HUEY 1997/98 (3/3)

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
1	454996.04	1385307.00	39.40	O2	18.19	2.00
2	454956.48	1385293.27	42.23	BS1		
3	454963.26	1385294.37	41.72	Topo		
4	454962.44	1385300.37	41.93	Topo		
5	454963.80	1385308.76	42.32	Topo		
6	454956.81	1385315.06	42.79	Topo		
7	454961.99	1385318.62	41.67	Topo		
8	454966.97	1385313.16	40.93	Snow		
9	454970.17	1385306.70	40.48	M3		
10	454970.80	1385300.41	40.32	Topo		
11	454973.81	1385295.15	39.87	Topo		
12	454977.96	1385290.14	39.74	Topo		
13	454972.45	1385287.20	40.78	Topo		
14	454978.89	1385290.98	39.34	Topo		
15	454974.93	1385293.89	39.62	Topo		
16	454972.56	1385300.07	39.99	B1		
17	454972.33	1385301.05	40.04	M1		
18	454972.78	1385306.06	40.15	Topo		
19	454963.06	1385318.93	40.93	Topo		
20	454970.76	1385321.73	40.80	Topo		
21	454975.38	1385313.71	40.39	Topo		
22	454978.61	1385305.96	39.86	Topo		
23	454981.73	1385296.93	39.60	Topo		
24	454987.91	1385289.85	39.06	Orange Stake		
25	454992.44	1385291.54	38.46	Topo		
26	454998.13	1385294.88	38.73	Topo		
27	454992.58	1385303.59	39.61	Topo		
28	454987.03	1385312.80	40.17	Topo		
29	454991.85	1385315.68	39.89	Orange Algae		
30	454993.42	1385312.36	39.66	Orange Algae		
31	454995.30	1385308.58	39.46	Orange Algae		
32	454997.19	1385304.13	39.23	Orange Algae		
33	454998.19	1385301.43	39.16	Orange Algae		
34	454998.77	1385298.65	38.98	Orange Algae		
35	454998.36	1385295.47	38.81	Orange Algae		
36	454999.43	1385293.43	38.51	Orange Algae		
37	455006.91	1385299.21	39.11	Topo		
38	455002.21	1385303.48	39.36	Topo		
39	455001.17	1385309.12	39.71	Topo		
40	455002.89	1385315.29	40.10	Topo		
41	455006.68	1385324.77	40.50	Topo		
42	455012.80	1385323.53	40.78	Topo		
43	455013.60	1385316.73	41.31	Topo		
44	455008.40	1385315.47	41.19	Topo		
45	455006.62	1385310.77	41.04	Topo		
46	455006.99	1385306.24	40.71	Topo		
47	455009.73	1385301.64	40.28	Topo		
48	455005.78	1385289.27	38.30	Snow		
49	455002.41	1385290.99	38.31	Snow		

FIGURE 9-80 HUEY 2000/01 (1/2)

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
50	454992.24	1385287.75	38.43	Snow		
51	454984.82	1385283.86	38.95	Snow		
52	454981.92	1385288.46	39.15	Snow		
53	454980.07	1385289.98	39.28	Snow		
54	454975.29	1385287.49	39.64	Snow		
55	454976.88	1385283.98	39.53	Snow		
56	454973.84	1385314.22	40.28	Snow		
57	454966.62	1385319.27	40.82	Snow		
58	454962.74	1385330.62	41.47	Snow		
59	454955.37	1385330.39	41.61	Snow		
60	454957.90	1385322.89	42.19	Snow		
61	454963.24	1385318.79	40.93	Snow		
62	454967.26	1385312.68	40.88	Snow		
63	454968.00	1385306.47	40.70	Snow		
64	454956.44	1385293.26	42.24	BS2		

FIGURE 9-81 HUEY 2000/01 (2/2)

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
1	454972.51	1385299.89	40.07	Black Algae 2	10.12	0.22
2	454973.27	1385299.27	40.05	Black Algae 1	5.17	0.90
3	454972.31	1385300.15	40.11	Black Algae 3	1.53	1.78
4	454956.42	1385293.25	42.35	backsight		
5	454963.44	1385294.88	41.86	slope		
6	454969.06	1385296.06	40.50	wetted perimeter		
7	454996.75	1385304.47	39.44	W stream edge		
8	454997.39	1385304.61	39.41	E stream edge		
9	455002.02	1385305.64	39.72	wetted perimeter		
10	455007.22	1385306.84	40.97	topo		
11	455010.26	1385293.08	38.91	toe and wetted perimeter		
12	455002.64	1385304.51	39.66	toe and wetted perimeter		
13	455004.07	1385312.50	40.28	toe and wetted perimeter		
14	455003.39	1385318.15	40.39	wetted perimeter		
15	454994.48	1385315.81	40.08	stream edge		
16	454993.10	1385315.46	40.09	stream edge		
17	454991.87	1385315.65	40.03	seep		
18	454993.24	1385313.32	39.97	seep		
19	454980.05	1385316.39	40.18	seep 2		
20	454982.41	1385312.55	40.28	seep 2		
21	454978.13	1385311.17	40.41	High point, big rock		
22	454978.18	1385312.03	40.38	big rock		
23	454980.11	1385312.81	40.57	big rock		
24	454979.15	1385312.12	40.79	big rock		
25	454974.15	1385310.90	40.40	snow edge and wetted perimeter		
26	454971.79	1385307.00	40.32	snow edge and wetted perimeter		
27	454966.73	1385303.36	40.90	snow edge and wetted perimeter		
28	454974.48	1385290.46	40.15	wetted perimeter		
29	454975.02	1385288.60	40.05	snow edge and wetted perimeter		
30	454979.58	1385290.92	39.49	snow edge and wetted perimeter		
31	454983.25	1385287.81	39.25	snow edge and wetted perimeter		
32	454983.25	1385284.72	39.21	snow edge and wetted perimeter		
33	454994.65	1385289.36	38.48	snow edge		
34	455001.84	1385289.84	38.23	snow edge and wetted perimeter		
35	455003.38	1385289.84	38.28	stream and snow		
36	455013.26	1385286.20	38.06	snow		
37	455016.07	1385287.39	38.45	wetted perimeter		
38	455001.53	1385296.22	38.86	stream edge		
39	454996.66	1385307.98	39.69	seep		
40	454989.65	1385311.77	39.89	seep		
41	454995.26	1385307.96	39.65	seep, w. stream edge		
42	454998.36	1385298.04	39.12	stream edge		
43	455000.69	1385296.23	38.86	stream edge		
44	455004.05	1385301.52	39.31	Moss 1		
45	455002.97	1385302.68	39.40	Moss 2		
46	454973.60	1385300.07	40.18	Moss Patch		
47	454970.91	1385299.39	40.28	Moss Patch		
48	454974.46	1385294.95	39.89	Moss Patch		
49	454974.14	1385298.54	39.99	Moss Patch		
50	454972.60	1385301.24	40.15	Moss 3		
51	454972.78	1385298.88	40.03	Moss 4		

FIGURE 9-82 HUEY 2002/03

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
1	454956.85	1385293.37	43.04	BM		
2	455001.80	1385302.47	39.93	O1		
3	454985.77	1385287.33	39.99	O2		
4	454976.19	1385300.87	40.11	O3		
5	454978.46	1385306.60	40.30	O4		

FIGURE 9-83 HUEY 2013/14

RELATIVE BED CHANGES

Year	Mean	Max	Min
1994	-0.32	0.41	-1.06
1998	0.00	0.93	-1.12
2001	-0.13	1.78	-1.45
2003	0.04	0.86	-1.14
2014	0.00	0.28	-0.36

FIGURE 9-84 HUEY RELATIVE BED CHANGES

AFDM COMPARISON

Change	AFDM	Type
0.04	10.10	2
0.05	5.17	2
0.03	1.53	2
-0.18	0.00	2
-0.14	0.00	2
0.05	0.00	2
0.33	0.00	2
-0.17	19.60	3
0.08	18.20	3
0.51	9.30	3
0.93	7.14	3
-0.35	4.27	3
0.09	3.88	3
-0.08	0.00	3
-0.04	0.00	3
0.00	0.00	3
0.51	0.00	3
0.65	0.00	3
-0.38	0.00	3
-0.21	0.00	3
0.04	0.00	3
0.31	0.00	3
0.41	0.00	3
0.62	0.00	3
0.84	0.00	3
1.00	0.00	3
0.25	0.00	3
-0.36	0.00	3
-0.17	0.00	3
0.28	0.00	3

FIGURE 9-85 HUEY AFDM COMPARISON. FIRST COLUMN IS RELATIVE CHANGE AT POINT IN STREAM. SECOND COLUMN IS AFDM. THIRD COLUMN IS MICROBIAL MAT TYPE (1=GREEN, 2=BLACK, 3=ORANGE, 4=RED)

FLOW COMPARISON

AFDM	Flow	Type
10.10	NaN	2
5.17	NaN	2
1.53	NaN	2
0.00	0.08	2
0.00	0.08	2
0.00	0.08	2
0.00	NaN	2
19.60	1.20	3
18.20	NaN	3
9.30	1.20	3
7.14	1.20	3
4.27	1.20	3
3.88	1.20	3
0.00	0.08	3
0.00	0.08	3
0.00	0.08	3
0.00	0.08	3
0.00	0.08	3
0.00	NaN	3
0.00	NaN	3
0.00	NaN	3
0.00	NaN	3
0.00	NaN	3
0.00	NaN	3
0.00	NaN	3
0.00	NaN	3
0.00	NaN	3
0.00	NaN	3
0.00	NaN	3
0.00	NaN	3

FIGURE 9-86 HUEY FLOW COMPARISON. FIRST COLUMN IS AFDM. SECOND COLUMN IS WEIGHTED FLOW FOR SEASON OF SURVEY. THIRD COLUMN IS MICROBIAL MAT TYPE (1=GREEN, 2=BLACK, 3=ORANGE, 4=RED)

9.1.6 Bohner Stream B5

SURVEYS

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
1	441978.67	1374158.60	123.96	T BM T152		
2	442064.42	1374239.05	127.16	T topo		
3	442058.72	1374233.71	124.91	T topo		
4	442051.48	1374226.91	120.80	T wet zone		
5	442048.95	1374224.54	120.23	T flow riv ctr		
6	442045.52	1374221.33	119.98	T seep riv ctr		
7	442040.89	1374216.99	119.83	T topo		
8	442034.01	1374210.52	119.02	T water edge		
9	442030.19	1374206.95	118.67	T topo mid flo z		
10	442022.57	1374199.79	117.46	T water edge		
11	442008.09	1374186.21	125.10	T topo		
12	441981.44	1374202.71	119.58	topo		
13	441989.06	1374195.14	121.95	topo		
14	442002.17	1374189.99	123.55	topo		
15	442017.09	1374180.98	126.44	topo		
16	442026.79	1374167.88	129.86	topo		
17	442033.43	1374176.74	127.68	topo		
18	442046.55	1374178.99	127.72	topo		
19	442037.53	1374186.83	124.22	topo		
20	442049.37	1374187.62	123.88	water edge		
21	442041.63	1374193.17	121.70	water edge		
22	442029.40	1374197.22	119.20	water edge		
23	442015.01	1374202.81	115.59	water edge		
24	442003.83	1374207.58	113.90	water edge		
25	441996.92	1374214.64	112.54	water edge		
26	442003.99	1374219.69	112.82	mid flow rubble		
27	442013.30	1374213.90	115.12	mid flow rubble		
28	442025.08	1374208.98	117.66	mid flow rubble		
29	442038.80	1374204.65	120.61	mid flow rubble		
30	442047.72	1374198.89	122.29	mid flow rubble		
31	442054.36	1374192.30	124.17	mid flow rubble		
32	442059.06	1374198.87	124.13	water edge		
33	442051.26	1374200.69	122.76	water edge		
34	442044.98	1374204.89	121.33	water edge		
35	442040.37	1374208.92	120.40	water edge		
36	442030.68	1374213.17	118.51	water edge		
37	442022.61	1374220.11	116.66	water edge		
38	442010.83	1374220.51	114.31	water edge		
39	442029.34	1374229.11	118.10	topo		

FIGURE 9-87 BOHNER 1993/94 (1/2)

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
40	442027.34	1374230.74	116.58	topo		
41	442028.16	1374234.54	117.20	topo		
42	442032.44	1374233.28	118.59	topo		
43	442050.72	1374216.94	120.87	seep riv ctr		
44	442041.86	1374222.92	119.57	seep riv ctr		
45	442033.20	1374224.89	118.34	seep riv ctr		
46	442057.00	1374217.25	121.50	flow riv ctr		
47	442053.26	1374221.99	120.73	flow riv ctr		
48	442044.22	1374226.31	119.83	flow riv ctr		
49	442036.79	1374228.57	118.81	flow riv ctr		
50	442026.82	1374235.34	116.98	wet zone		
51	442031.73	1374238.09	118.76	wet zone		
52	442034.54	1374234.94	119.00	wet zone		
53	442042.94	1374232.27	119.91	wet zone		
54	442049.74	1374228.66	120.65	wet zone		
55	442056.51	1374223.29	121.56	wet zone		
56	442062.42	1374217.19	122.94	wet zone		
57	442070.24	1374209.88	125.40	wet zone		
58	442078.04	1374219.12	129.40	topo		
59	442070.40	1374228.79	128.63	topo		
60	442078.25	1374232.85	130.75	topo		
61	442089.85	1374226.90	133.33	topo		
62	442046.40	1374253.71	125.60	topo		
63	442043.47	1374267.64	125.54	topo		
64	442059.18	1374253.30	127.06	topo		
65	442051.61	1374236.74	123.79	topo		
66	442043.36	1374222.54	119.73	algae o 1	12.80	1.21
67	442044.38	1374222.45	119.86	algae o 2	7.80	3.03
68	442045.50	1374221.66	119.98	algae o 3	2.20	2.35
69	442048.97	1374219.51	120.48	algae o 4	3.00	2.91
70	442050.11	1374218.51	120.67	algae o 5	11.20	10.29
71	442077.06	1374164.86	132.10	algae green 1	3.07	7.93
72	442077.07	1374164.61	132.13	algae green 2	4.62	0.87
73	442076.61	1374165.45	131.96	algae green 3	0.82	6.64

FIGURE 9-88 BOHNER 1993/94 (2/2)

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
1	441978.60	1374158.54	123.93	BS1		
2	442049.88	1374198.16	122.56	G1	1.72	3.32
3	442054.57	1374197.57	123.35	G2	0.44	1.12
4	442059.44	1374195.01	124.20	G3	1.23	0.56
5	442055.48	1374183.26	125.73	Wetted Edge		
6	442052.66	1374186.31	124.86	Wetted Edge		
7	442047.51	1374189.09	123.35	Wetted Edge		
8	442040.80	1374192.64	121.77	Wetted Edge		
9	442034.14	1374194.67	120.27	Wetted Edge		
10	442027.04	1374196.24	118.81	Wetted Edge		
11	442022.28	1374198.48	117.52	Wetted Edge		
12	442013.09	1374201.73	115.39	Wetted Edge		
13	442006.59	1374205.35	114.16	Wetted Edge		
14	442001.48	1374208.05	113.45	Wetted Edge		
15	441999.68	1374210.31	112.71	Water Edge		
16	442005.84	1374207.19	114.01	Water Edge		
17	442011.26	1374205.79	114.51	Water Edge		
18	442015.49	1374208.15	115.09	Water Edge		
19	442018.52	1374211.92	116.01	Water Edge		
20	442025.40	1374210.46	117.51	Water Edge		
21	442032.95	1374207.53	119.09	Water Edge		
22	442038.54	1374201.83	120.59	Water Edge		
23	442042.99	1374197.46	121.54	Water Edge		
24	442046.63	1374195.87	122.21	Water Edge		
25	442050.52	1374196.41	122.74	Water Edge		
26	442054.99	1374195.49	123.65	Water Edge		
27	442058.00	1374193.66	124.18	Water Edge		
28	442061.73	1374193.18	124.63	Water Edge		
29	442063.52	1374195.05	124.92	Water Edge		
30	442059.10	1374197.22	124.10	Water Edge		
31	442054.31	1374199.28	123.22	Water Edge		
32	442046.99	1374201.43	121.91	Water Edge		
33	442043.38	1374205.91	120.90	Water Edge		
34	442036.10	1374209.99	119.41	Water Edge		
35	442030.36	1374212.17	118.44	Water Edge		
36	442023.94	1374219.49	116.85	Water Edge		
37	442018.35	1374218.79	115.90	Water Edge		
38	442033.38	1374233.38	118.53	Wetted Edge		
39	442039.85	1374230.61	119.05	Wetted Edge		
40	442043.53	1374228.73	119.48	Wetted Edge		
41	442048.00	1374226.87	120.02	Wetted Edge		
42	442052.74	1374223.64	120.60	Wetted Edge		
43	442058.49	1374217.78	121.73	Wetted Edge		
44	442055.49	1374218.44	121.02	Seep		
45	442054.16	1374219.88	120.75	Seep		
46	442052.04	1374221.42	120.41	Seep		
47	442050.84	1374223.12	120.16	Seep		
48	442053.15	1374224.14	120.77	Topo		
49	442059.85	1374224.29	123.54	Topo		

FIGURE 9-89 BOHNER 2000/01 (1/2)

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
50	442055.34	1374230.92	123.47	Topo		
51	442049.83	1374238.27	123.73	Topo		
52	442056.08	1374238.59	125.13	Topo		
53	442062.31	1374235.03	126.18	Topo		
54	442069.34	1374233.44	128.63	Topo		
55	442069.56	1374238.54	128.49	Topo		
56	442062.07	1374247.37	127.34	Topo		
57	442028.80	1374227.01	117.70	Topo		
58	442033.26	1374221.19	118.34	Topo		
59	442039.03	1374218.14	119.30	Topo		
60	442043.00	1374213.95	120.15	Topo		
61	442049.08	1374210.46	121.27	Topo		
62	442054.89	1374205.68	122.73	Topo		
63	442062.85	1374200.61	124.88	Topo		
64	442067.72	1374199.58	125.81	Topo		
65	441978.64	1374158.57	123.96	BS2		
66	441970.98	1374203.25	118.90	Rock Circle		

FIGURE 9-90 BOHNER 2000/01 (2/2)

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
1	441978.64	1374158.58	123.88	backsight		
2	442000.63	1374178.99	123.93	slope		
3	442008.38	1374185.64	125.06	slope		
4	442022.75	1374198.29	117.48	wetted perimeter		
5	442032.35	1374208.01	119.75	W stream channel		
6	442034.46	1374209.59	119.97	E stream channel		
7	442052.30	1374224.63	121.31	wetted perimeter		
8	442074.85	1374202.08	127.51	wetted perimeter		
9	442073.71	1374200.49	127.36	slope		
10	442039.29	1374232.64	119.90	slope		
11	442031.22	1374233.68	119.04	wetted perimeter		
12	442023.54	1374234.11	116.42	wetted perimeter		
13	442017.95	1374240.36	115.75	wetted perimeter		
14	442008.90	1374228.27	114.12	slope		
15	442012.32	1374230.67	115.47	slope		
16	442004.18	1374219.97	113.41	stream edge		
17	442003.23	1374216.96	113.46	stream edge		
18	441998.41	1374210.69	113.51	wetted perimeter		
19	442017.13	1374200.13	116.99	wetted perimeter		
20	442039.96	1374192.95	122.14	wetted perimeter		
21	442055.83	1374180.08	127.13	slope		
22	442057.46	1374182.16	127.03	wetted perimeter		
23	442065.47	1374176.37	129.60	wetted perimeter		
24	442066.78	1374177.96	129.15	stream edge		
25	442068.73	1374179.37	129.15	E stream channel		
26	442062.83	1374194.38	125.54	E stream channel		
27	442060.58	1374193.20	125.18	W stream channel		
28	442052.31	1374193.28	124.25	W stream channel		
29	442048.37	1374197.40	123.08	W stream channel		
30	442052.95	1374199.12	123.73	E stream channel		
31	442029.69	1374201.61	119.56	W stream channel		
32	442033.03	1374210.32	119.59	E stream channel		
33	442024.22	1374211.24	117.88	W stream channel		
34	442007.92	1374213.62	114.61	W stream channel		
35	442009.28	1374216.22	114.89	E stream channel		
36	442030.80	1374230.96	118.75	slope		
37	442026.11	1374226.36	117.87	slope		
38	442022.78	1374227.44	116.92	slope		
39	442025.33	1374230.46	116.76	slope		
40	442051.73	1374222.54	121.19	top of seep		
41	442049.14	1374222.37	120.83	middle of seep		
42	442046.87	1374224.91	120.61	bottom of seep		

FIGURE 9-91 BOHNER 2002/03

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
1	442043.82	1374221.79	119.59	O1	21.10	21.97
2	442044.36	1374221.24	119.65	O2	6.86	16.92
3	441983.91	1374239.98	108.74	O3	9.57	15.69
4	441977.62	1374251.56	106.58	O4	3.84	13.27
5	441966.15	1374261.61	104.93	O5	11.75	33.08
6	441978.59	1374158.53	123.94	T152		
7	441923.03	1374260.39	106.42	TBM		
8	442069.88	1374244.20	128.36	T151		
9	441934.45	1374302.76	98.62	BM1		
10	441914.97	1374305.63	95.32	BM2		
11	441925.60	1374297.94	97.14	TOS		
12	441925.91	1374298.53	96.10	PZF		

FIGURE 9-92 BOHNER 2010/11

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
1	441978.61	1374158.55	123.96	West BM		
2	442045.24	1374198.06	121.81	Green 3	0.62	0.24
3	442039.21	1374201.62	120.58	Green 2	1.15	0.64
4	442032.15	1374202.36	119.24	Green 4		
5	442041.18	1374206.76	120.45	Green 1	0.57	
6	442049.87	1374215.97	120.58	Orange 2	8.41	3.87
7	442048.52	1374218.20	120.24	Orange 3	15.11	2.68
8	442050.42	1374220.13	120.28	Orange 1	2.11	2.29
9	442047.99	1374225.14	119.76	Orange 4	5.64	5.99
10	442023.25	1374197.64	117.70	West edge of water		
11	442043.26	1374191.18	122.02	West edge of water Upstream		

FIGURE 9-93 BOHNER 2011/12

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
1	441978.55	1374158.49	123.96	west benchmark-BS		
2	442040.65	1374220.81	119.26	Orange 2	7.75	2.56
3	442044.26	1374221.24	119.56	Orange 1	6.65	4.96
4	442044.46	1374219.77	119.69	Orange 5	8.55	7.14
5	442049.18	1374222.72	119.92	Orange 3	6.70	10.00
6	442048.73	1374224.58	119.83	Orange 4	8.72	7.06
7	442053.88	1374211.51	122.02	3-sided pyramid		
8	442032.53	1374214.81	118.98	big rock		
9	442028.41	1374211.64	118.53	high point round rock		

FIGURE 9-94 BOHNER 2012/13

Point #	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Point Description	AFDM (mg/cm2)	CHL-A (ug/cm2)
1	441978.61	1374158.55	123.94	BM		
2	442050.11	1374216.08	120.72	O1		
3	442047.32	1374213.47	120.73	O2		
4	442044.86	1374209.45	120.69	O3		
5	442064.85	1374191.54	125.64	G1		
6	442054.98	1374218.95	120.91	G2		
7	442050.90	1374223.32	120.15	G3		

FIGURE 9-95 BOHNER 2013/14

RELATIVE BED CHANGES

Year	Mean	Max	Min
1994	0.11	0.37	-0.47
2001	0.02	0.19	-0.22
2003	0.50	0.63	0.37
2011	-0.13	0.03	-0.25
2012	-0.07	0.02	-0.14
2013	0.08	0.19	-0.05
2014	0.00	0.03	-0.06

FIGURE 9-96 BOHNER RELATIVE BED CHANGES

AFDM COMPARISON

Change	AFDM	Type
NaN	4.62	1
NaN	3.07	1
-0.07	1.72	1
-0.11	1.23	1
0.08	1.15	1
NaN	0.82	1
0.05	0.62	1
0.02	0.57	1
-0.06	0.44	1
0.07	0.00	1
0.07	0.00	1
NaN	0.00	1
NaN	0.00	1
NaN	21.10	3
0.07	15.10	3
-0.37	12.80	3
0.16	11.80	3
-0.35	11.20	3
NaN	9.57	3
NaN	8.72	3
0.09	8.55	3
-0.01	8.41	3
-0.39	7.80	3
0.18	7.75	3
-0.04	6.86	3
NaN	6.70	3
0.08	6.65	3
NaN	5.64	3
-0.12	3.84	3
-0.38	3.00	3
-0.17	2.20	3
0.08	2.11	3
0.16	0.00	3
0.12	0.00	3
0.16	0.00	3

FIGURE 9-97 BOHNER AFDM COMPARISON. FIRST COLUMN IS RELATIVE CHANGE AT POINT IN STREAM. SECOND COLUMN IS AFDM. THIRD COLUMN IS MICROBIAL MAT TYPE (1=GREEN, 2=BLACK, 3=ORANGE, 4=RED)

FLOW COMPARISON

AFDM	Flow	Type
4.62	0.49	1
3.07	0.49	1
1.72	0.20	1
1.23	0.20	1
1.15	0.96	1
0.82	0.49	1
0.62	0.96	1
0.57	0.96	1
0.44	0.20	1
0.00	0.96	1
0.00	NaN	1
0.00	NaN	1
0.00	NaN	1
21.10	0.79	3
15.10	0.96	3
12.80	0.49	3
11.80	0.79	3
11.20	0.49	3
9.57	0.79	3
8.72	NaN	3
8.55	NaN	3
8.41	0.96	3
7.80	0.49	3
7.75	NaN	3
6.86	0.79	3
6.70	NaN	3
6.65	NaN	3
5.64	0.96	3
3.84	0.79	3
3.00	0.49	3
2.20	0.49	3
2.11	0.96	3
0.00	NaN	3
0.00	NaN	3
0.00	NaN	3

FIGURE 9-98 BOHNER FLOW COMPARISON. FIRST COLUMN IS AFDM. SECOND COLUMN IS WEIGHTED FLOW FOR SEASON OF SURVEY. THIRD COLUMN IS MICROBIAL MAT TYPE (1=GREEN, 2=BLACK, 3=ORANGE, 4=RED)