REED CANARYGRASS DISTRIBUTION AT THE NATURE CONSERVANCY'S SILVER CREEK PRESERVE

Prepared by:

Eric August, Paul Hook, and Katie Salsbury

INTERMOUNTAIN AQUATICS INC.
ENVIRONMENTAL CONSULTING & HABITAT RESTORATION

P.O. Box 1115 85 South Main Street Driggs, ID 83422
tel: 208.354.3690 fax: 208.247-0941

www.intermountainaquatics.com

June 2006

TABLE OF CONTENTS

SUMMARY

Reed canarygrass' (*Phalaris arundinacea*) aggressive growth is affecting both streamside and instream habitats on The Nature Conservancy's Silver Creek Preserve and adjacent areas. Extensive reed canarygrass stands in the stream channel of Wilson Creek are of particular concern because they have greatly altered channel hydraulics, sediment transport, and aquatic habitat. Reed canarygrass is normally limited to stream banks and channel margins where it degrades riparian habitat but has limited direct effects on instream conditions.

This study evaluated the distribution of reed canarygrass on three area streams in order to understand its undesirable growth in Wilson Creek's channel and guide stream restoration at this location and similar sites. In addition to Wilson Creek, two streams where Reed canarygrass is present but not invading the channel were sampled: Mud Creek and Stalker Creek.

Silt or muck deposits in shallow water zones (0-2') appear to contribute to invasion of the Wilson Creek channel by reed canarygrass. The abundance of fine sediment deposits in shallow water, and the extensive growth of reed canarygrass on these deposits, is the outstanding difference between Wilson Creek and the other two streams sampled. These deposits were often mucky and consisted largely of organic detritus that apparently accumulated in dense stands of submerged aquatic vegetation (SAV). Reed canarygrass in Wilson Creek appears to have grown out onto the surface of SAV stands. Stalker Creek has abundant SAV, fine sediment deposits, and dense reed canarygrass stands on its banks but its channel has not been invaded by reed canarygrass; this may be due to the extremely low slope of Stalker Creek which is expected to result in deeper growing season water levels than Wilson Creek, thus increasing the depth of water over silt or muck deposits. Other factors that were not evaluated, such as nutrient enrichment and occurrence of higher energy flushing flows, may also affect channel invasion.

Study results suggest that restoration of streams with reed canarygrass present should attempt to deter invasion into the channel by minimizing areas of exposed or shallow sediment, especially silt or muck. The central channel should be deep with relatively high velocities that will limit accumulation of fine sediment and maintain adequate depth to thwart colonization by reed canarygrass. Shallow, low-velocity areas are vulnerable to sediment accumulation in SAV stands and subsequent reed canarygrass invasion, and they should be minimized. Soil mixtures with high silt content should be avoided in point bar construction. Aggressive revegetation and reed canarygrass control with herbicide will probably be necessary to limit reinvasion of restored channels and banks.

1.0 – INTRODUCTION

This report summarizes field data collected to investigate reed canarygrass (*Phalaris arundinacea*) distribution in three streams within and adjacent to The Nature Conservancy's Silver Creek Preserve. One of these three creeks, Wilson Creek, has extensive reed canarygrass growth in the stream channel that has greatly altered its hydraulic characteristics, reducing channel conveyance and sediment transport. In some places, dense growth of reed canarygrass covers so much of Wilson Creek that it resembles a flood irrigated field more than a stream channel. These problems developed less than 15 years after large-scale channel dredging and enhancements were implemented to create an open channel and limit reed canarygrass incursion. Reed canarygrass tolerates a wide range of hydrologic conditions, but it is normally limited to stream banks and channel margins. At the two other streams studied, Mud Creek and Stalker Creek (also known as Stocker Creek), Reed canarygrass is present but is not invading the channel significantly. Representative photographs showing these differences are shown in Figure 1. This study evaluated reed canarygrass' distribution in and adjacent to the three streams and its relationships to water levels, bank soils, channel substrates and submerged aquatic vegetation. The goal was to understand reed canarygrass' undesirable growth within Wilson Creek's channel, inform strategies for restoring the channel, and extrapolate the findings to guide stream restoration techniques at similar sites.

1.1 – Reed Canarygrass Ecology

Reed canarygrass is a long-lived perennial, cool-season grass. It is a vigorous, tall-growing plant (3-6'). It is highly competitive even by the standards of aggressive, rhizomatous weeds (Harrison et al. 1996). Reproduction can occur via seed, rhizome growth, or by dispersal of detached rhizome pieces or root-wads.

Reed canarygrass thrives under a wide range of hydrologic environments (Antieau 1998, Kercher and Zedler 2004, Magee and Kentula 2005, Mahaney et al. 2005, Miller and Zedler 2003). It can tolerate prolonged soil saturation and inundation (particularly during the dormant season), as well as periods of dry soil. It is generally not found in areas with standing water present for the entire growing season (Weinmann 1984). It is considered a facultative wetland plant in USFWS Region 9.

Reed canarygrass grows best in full sunlight and is intolerant of extensive shade (Hitchcock 1950). Parent clones can subsidize growth of tillers into shaded microsites (Maurer and Zedler 2002), allowing invasion of short herbaceous vegetation that it can over-top. Growth is suppressed by closed canopies of trees and tall shrubs, but reed canarygrass can persist under shrubs separated by openings. Growth responds strongly to increased nutrient levels (Perry et al. 2004).

Figure 1 A. Mud Creek. Reach view (top) and channel detail (bottom). Reed canary grass is uncommon on banks and absent from the channel.

Figure 1 B. Stalker Creek. Reach view (top) and channel detail (bottom). Reed canary grass is abundant on banks but absent from the channel.

Figure 1 C. Wilson Creek. Reach view (top) and channel detail (bottom). Reed canary grass is abundant on banks and fills large areas of the channel. Photo on report cover shows same reach view in May, 2005.

1.2 – Reed Canarygrass History and Management

Reed canarygrass populations in western North America are probably a mixture of native and introduced genotypes (Harrison et al. 1996). Reed canarygrass was present in the inland Pacific Northwest before settlement by European peoples (Merigliano & Lesica 1998), with large stands at low elevations and smaller stands in the mountains. Improved varieties or selections of reed canarygrass were planted widely in the US during much of the 1900s and remain available from many commercial sources. The United States Department of Agriculture (USDA) Soil Conservation Service (SCS) and other agencies recommended reed canarygrass for pasture improvement and ditch and streambank stabilization for many years. Some recent publications continue to recommend use of reed canarygrass for pasture, stormwater filtration areas, and other applications.

Though native to the US, reed canarygrass is now viewed as an invasive plant in many areas. Possible explanations for the shift to invasive behavior include aggressive growth of non-native genotypes, human disturbance, hydrologic alteration, and nutrient enrichment of wetlands and riparian ecosystems. The role of non-native genotypes in reed canarygrass invasion remains speculative. Nutrient-rich environments have been demonstrated to favor reed canarygrass invasion (Green and Galatowitsch 2001, Maurer et al. 2003), while nutrient-poor environments may favor native wetland plants (Perry and Galatowitsch 2002, Perry et al. 2004). Nutrient enrichment and sediment deposition from agricultural and urban runoff may be an important factor in reed canarygrass invasions.

Reed canarygrass is thought to have been planted in previous decades at the Silver Creek Preserve and in surrounding areas for streambank stabilization (Jeff Yeo, personal communication). If so, it is likely that invasive reed canarygrass populations at the Silver Creek Preserve are improved agronomic varieties. It is not clear if reed canarygrass was present at the Silver Creek Preserve or in the Silver Creek watershed before deliberate plantings. Planting of reed canarygrass by The Nature Conservancy (TNC) or other area land owners would have been consistent with soil and water conservation practices of the mid-1900s.

Reed canarygrass is not listed as a noxious weed in Idaho or other western states except Washington (Center for Invasive Plant Management 2005). It is managed as a nuisance species that degrades wetland and aquatic ecosystems through its effects on native plants, fish, and wildlife. Unlike most native wetland vegetation, dense stands of reed canarygrass have little value for wildlife; few native wildlife species eat the grass, and its dense growth can limit its use as cover for small mammals and waterfowl (Maia 1994). Reed canarygrass control strategies are reviewed later in this report.

1.3 – Reed Canarygrass in the Stream Environment

Most information about the behavior and impacts of reed canarygrass in stream channels is anecdotal, lacks detail, and does not indicate how common growth within channels is. According to the SERNW Reed Canarygrass Working Group, it “is capable of fully clogging stream channels [and] filling shallow ponds and lakes” (Antieau 2002). A dense reed canarygrass stand clearly can reduce channel conveyance and sediment transport as documented for aquatic macrophytes generally (Green 2005). In extreme cases like Wilson Creek, reed canarygrass can form persistent monocultures that choke out native plants, reduce stream velocities, promote excessive sediment deposition, and alter stream channel form, filling pools and eliminating important fish habitat. A poorly defined channel choked with reed canarygrass apparently contributed to stranding of salmon in a Washington stream (Carasco 2000).

Because these reports do not describe how reed canarygrass invaded streams and ponds, they provide little insight about conditions likely to promote invasion or restoration designs likely to resist invasion. Infestations are most likely to develop in streams or ponds when the bottom is shallow and extended periods of low water leave the sediment exposed. Though reed canarygrass tolerates periods of flooding once established (Antieau 1998, Kercher and Zedler 2004, Miller and Zedler 2003), initial seedling establishment is favored by exposed rather than flooded soil (Coops and Van Der Velde 1994). However, in Wilson Creek reed canarygrass appears to have spread into relatively deep, submerged channel areas without exposure of the bed.

2.0 – METHODS

2.1 – Field Sampling

Vegetation, soil composition, hydrology, and survey information was gathered for cross sections at each of the three creeks in late July 2005. Nineteen cross sections were sampled on Wilson Creek, 10 on Mud Creek, and 10 on Stalker Creek (Figure 2 – Study Reach and Cross Section Locations). Cross sections were placed at approximately 100' intervals along the streams. A Nikon DTM-550 Total Station was used for surveying.

Each cross section was surveyed from right to left, facing in the downstream direction. At least two points were surveyed above the water level on each bank. A point was also surveyed at the right and left wetted channel extents (i.e. the waterline at the time of sampling). Spacing between points and the number of points on each cross section varied based on cross section length and the amount of landscape or vegetation change; for example, presence of a mid-channel island or alternating areas of open channel and submerged aquatic vegetation resulted in more points. The average number of points on each cross section was 11 for all creeks. Average cross section length was 83' and average spacing of points along a cross section was 7.5'.

During field data collection at least two researchers worked together. One was positioned on the Total Station instrument and was responsible for obtaining the spatial coordinates and elevations of each point selected on the cross section. The other characterized the vegetation, soil composition, and hydrology at each point on the cross section. Field data sheets were used to record plant, soil and hydrology information and digital photographs were taken at each point (Figure 3). Elevation and location data were stored by the Total Station.

Major plant categories were estimated using a 0.5 meter x 0.5 meter sampling frame made from PVC tubing and quantified with Daubenmire cover classes. Categories were reed canarygrass, submerged aquatic vegetation (SAV), sedge, grass, weed, shrub, and other. Daubenmire values were recorded as the average cover for each cover class (e.g. the 5-25% class was entered as 15%).

Surface soil or sediment was sampled at each point and composition was characterized using visual and physical observations (such as wetting and rolling in hand to check for clay). Soil types included gravel, sand, silt, clay, and loam. Fine, loose sediment overlaid the channel bottom at many points, often held in place by submerged aquatic vegetation or reed canary grass. Elevations of both the channel bed and the top of the overlying, loose sediment deposit were surveyed at these points. The bed elevation was measured at the depth at which the surveying rod was supported firmly by the bed. Soil, channel bed sediment, and sediment deposits above the bed are all referred to as "soil" in this report. For in-channel points, the material called "silt" included loose, organic-rich muck of semi-liquid consistency as well as actual silt-sized mineral sediment.

2.2 – Data Analysis

Field data sheets (Table 1) were transcribed from paper form to electronic form in Excel worksheets. Survey data was downloaded from the Total Station survey instrument into TransIt software and then into Excel worksheets. These data sets were combined and various calculations (i.e., elevations relative to water levels) were then used to analyze the data presented in the following sections. Distributions of vegetation types were examined using scatter plots of plant cover versus hydrology and soil types.

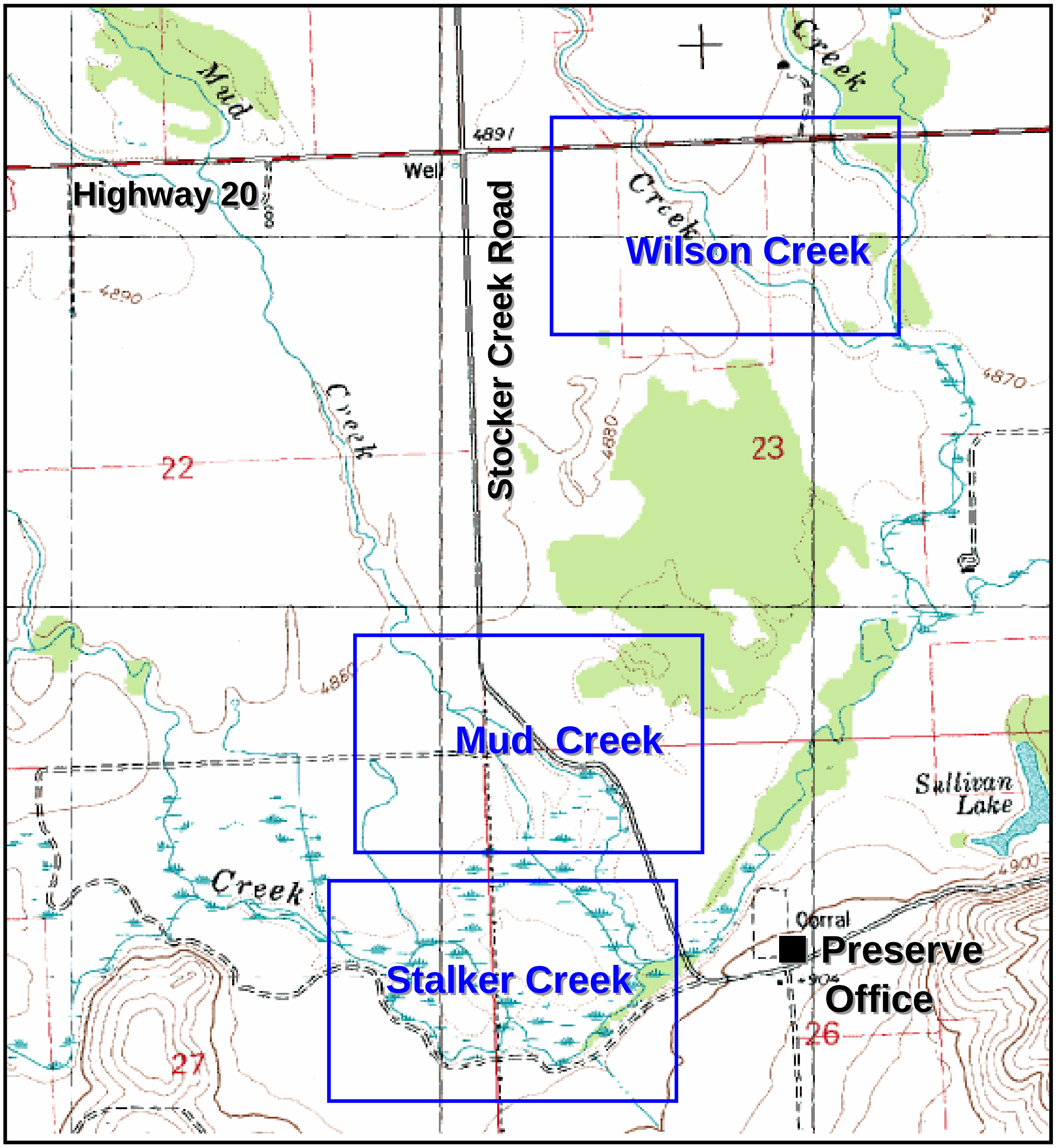


Figure 2 A. Locations of stream reaches sampled. Blue rectangles indicate approximate areas of aerial photographs shown in Figures 2 B-D. Scale: 3.5 inch ≈ 1 mile.

Figure 2 B. Mud Creek cross-section locations. Area shown is approximately 0.8 miles south of Highway 20 and 0.2 miles north of the confluence of Mud and Stalker Creeks.

Figure 2 C. Stalker Creek cross-section locations. Area shown is immediately upstream (west) of Stocker Creek Road bridge.

Figure 2 D. Wilson Creek cross-section locations. Area shown is approximately 1 mile north of the Silver Creek Preserve office. Highway 20 is at top (north) of image.

Figure 3. Examples of digital photographs taken at each observation point. White PVC frame is 0.5 m (20 inches) wide.
Top: Reed canarygrass dominated streambank.
Bottom: Submerged aquatic vegetation in Wilson Creek channel, with reed canarygrass fragments on surface.

TNC-Stream Survey Data Sheet

INTERMOUNTAIN AQUATICS INC.
ENVIRONMENTAL CONSULTING & HABITAT RESTORATION

Date: ______________

Obervers: ______________

Stream: ______________

Cross Section: ______________

Point #:								
Location (x)								
Terrace								
Streambank								
REW								
Stream								
LEW								
Elevation-Ground/Streambed								
Elevation-Deposit								
Vegetation								
Sediment								
Substrate (%)								
Gravel								
Sand								
Silt								
Clay								
Loam								
Hydrologic Condition								
Dry								
Saturated								
Depth of Water (inches)								
Plant Community								
RCG								
SAV								
Sedge								
Grass								
Other Weed								
Shrub								
Other (Describe)								
PHOTO # (Don't Forget Placcard)								

Comments:

Daubenmire Value	
1-5%	2.5
5-25%	15
26-50%	37.5
51-75%	62.5
76-95%	85
96-100%	97.5

Sketch:

Table 1. Field data sheet. REW = right edge of water; LEW = left edge of water; SAV = submerged aquatic vegetation.

3.0 – SITE DESCRIPTIONS

3.1 – Mud Creek

The extents of the Mud Creek survey are shown in Figure 2 B – Aerial Photo and Cross Sections. Along the 1578' channel centerline distance surveyed, Mud Creek drops 2.10' for an average slope of 0.13% (Figure 4 – Mud Creek Longitudinal Profile). At the date of survey, wetted channel width averaged 28' and maximum water depth averaged 2.9' for the 10 cross sections (Figure 5 – Mud Creek Cross Section Plots).

3.2 – Stalker Creek

The extents of the Stalker Creek survey are shown in Figure 2 C – Aerial Photo and Cross Sections. Along the 2029' channel centerline distance surveyed, Stalker Creek drops 0.45' for an average slope of 0.02% (Figure 6 – Stalker Creek Longitudinal Profile). The apparent increases in the water surface elevation along parts of Stalker Creek (Figure 6) are most likely the result of small survey errors. These errors are only significant for the Stalker Creek data because of difficult survey conditions (steep, densely vegetated banks) and the extremely low channel gradient. At the date of survey, wetted channel width averaged 56' and maximum water depth averaged 2.8' for the 10 cross sections (Figure 7 – Stalker Creek Cross Section Plots).

3.3 – Wilson Creek

The upstream extent of the Wilson Creek survey was State Highway 20 and the downstream extent was a pond located about 1/2-mile from the highway (Figure 2 D – Aerial Photo and Cross Sections). Along the 2062' channel centerline distance surveyed, Wilson Creek drops 4.33' for an average slope of 0.21% (Figure 8 – Wilson Creek Longitudinal Profile). At the date of survey, wetted channel width averaged 65' and maximum water depth averaged 2.2' for the 19 cross sections (Figure 9 – Wilson Creek Cross Section Plots).

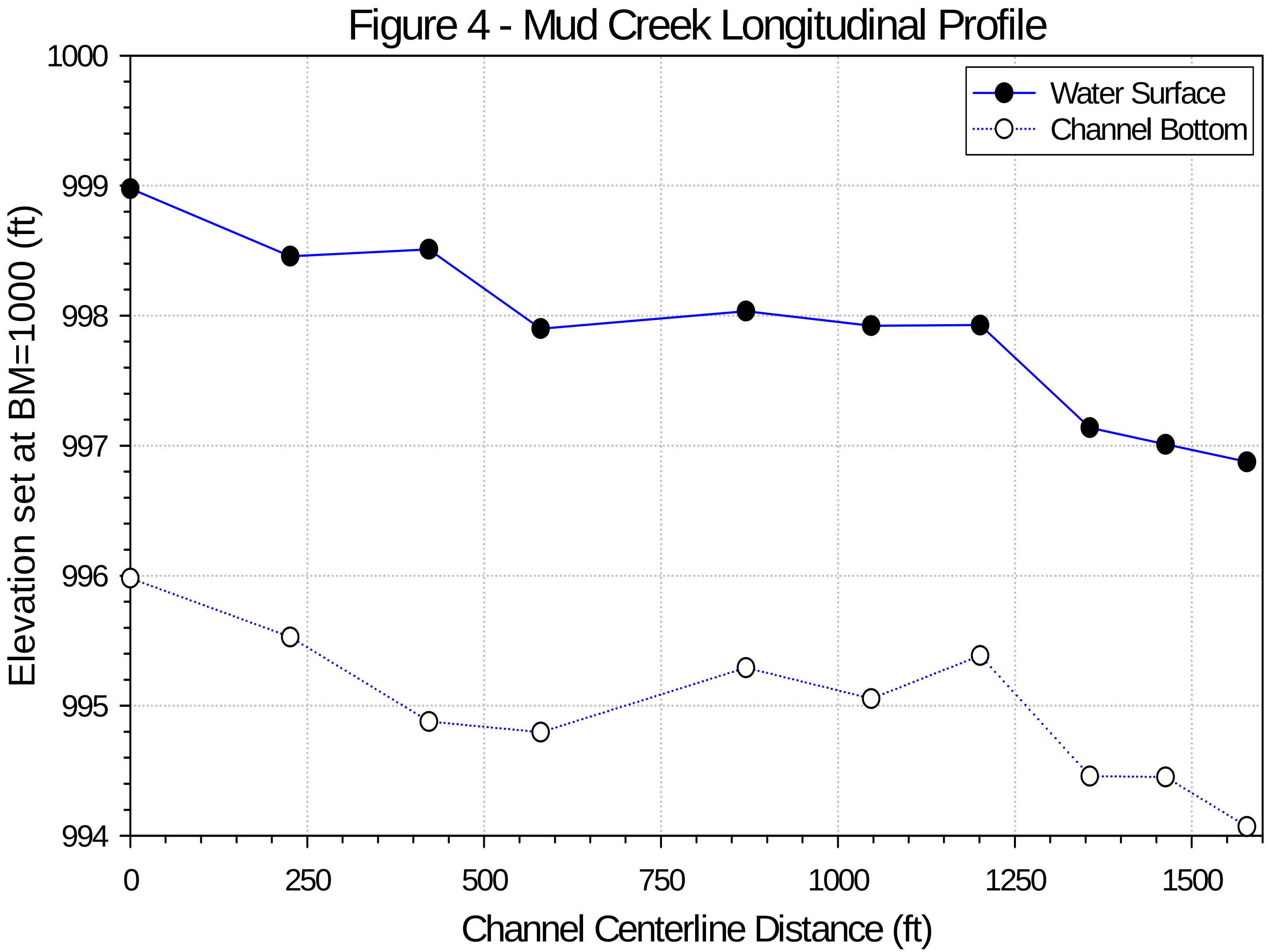


Figure 4 - Mud Creek Longitudinal Profile
Water Surface
Channel Bottom
Elevation set at BM=1000 (ft)
1000
999
998
997
996
995
994
0
250
500
750
1000
1250
1500
Channel Centerline Distance (ft)

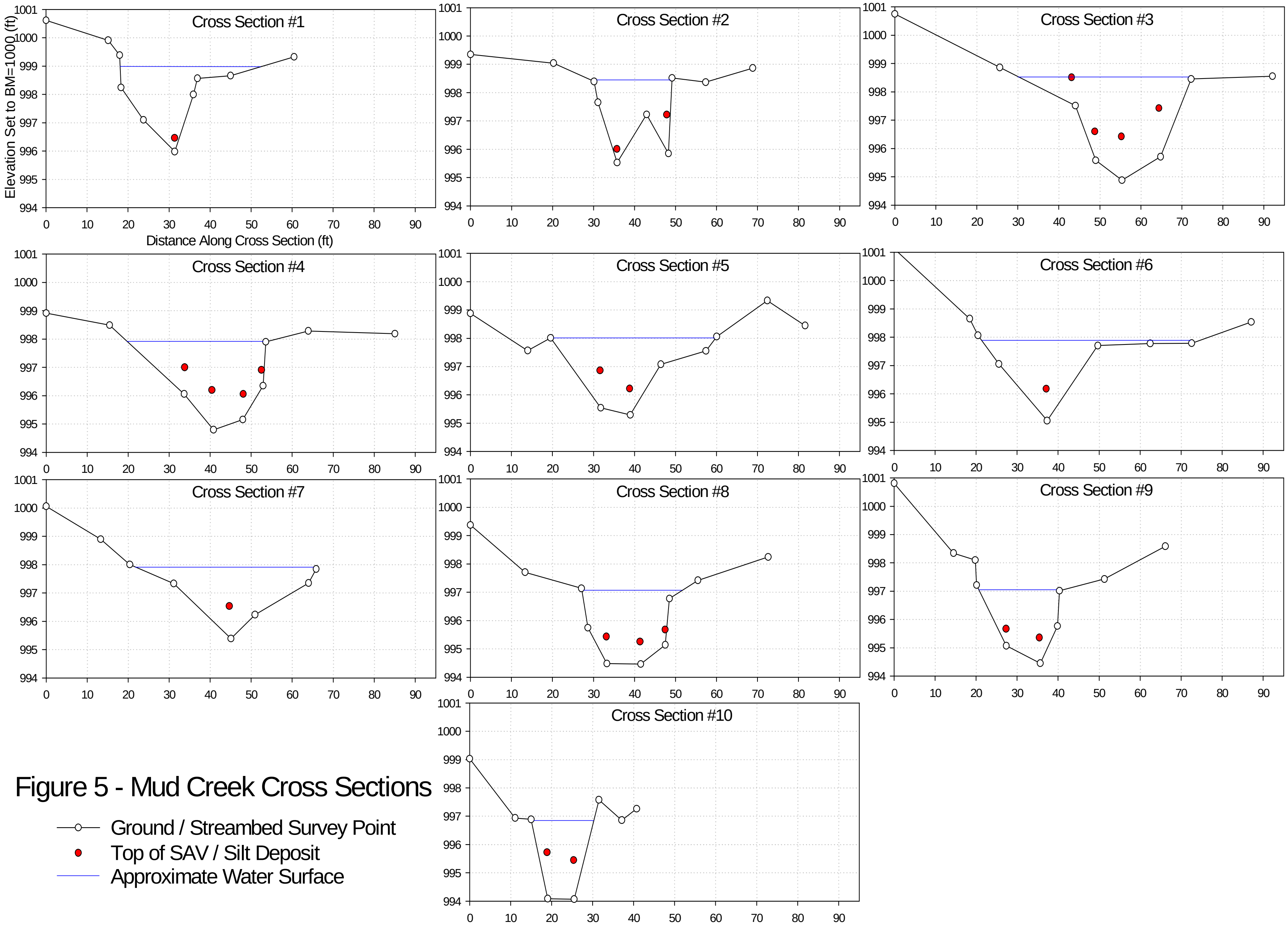


Figure 5 - Mud Creek Cross Sections

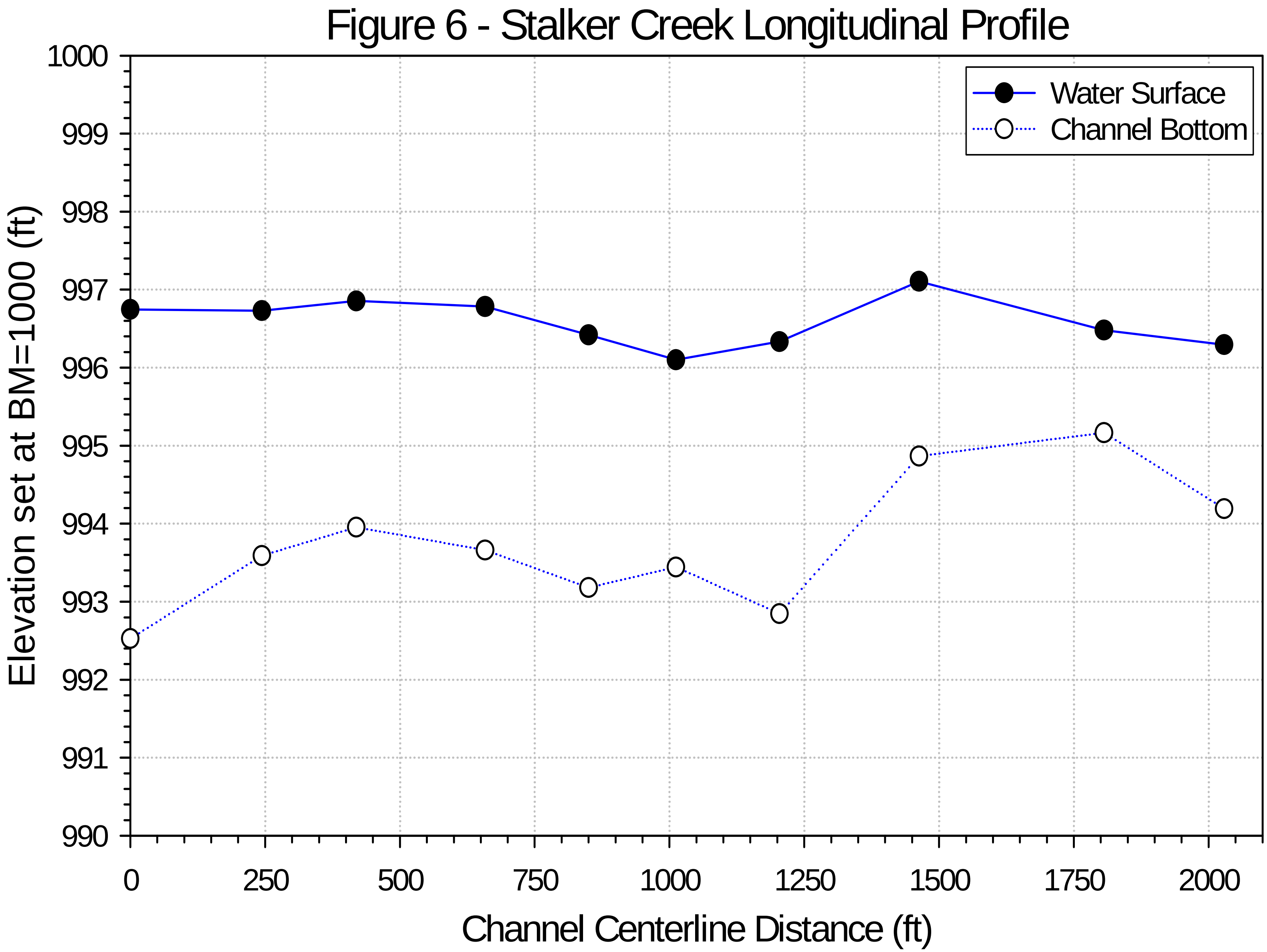


Figure 6 - Stalker Creek Longitudinal Profile
Water Surface
Channel Bottom
Elevation set at BM=1000 (ft)
1000
999
998
997
996
995
994
993
992
991
990
0
250
500
750
1000
1250
1500
1750
2000
Channel Centerline Distance (ft)

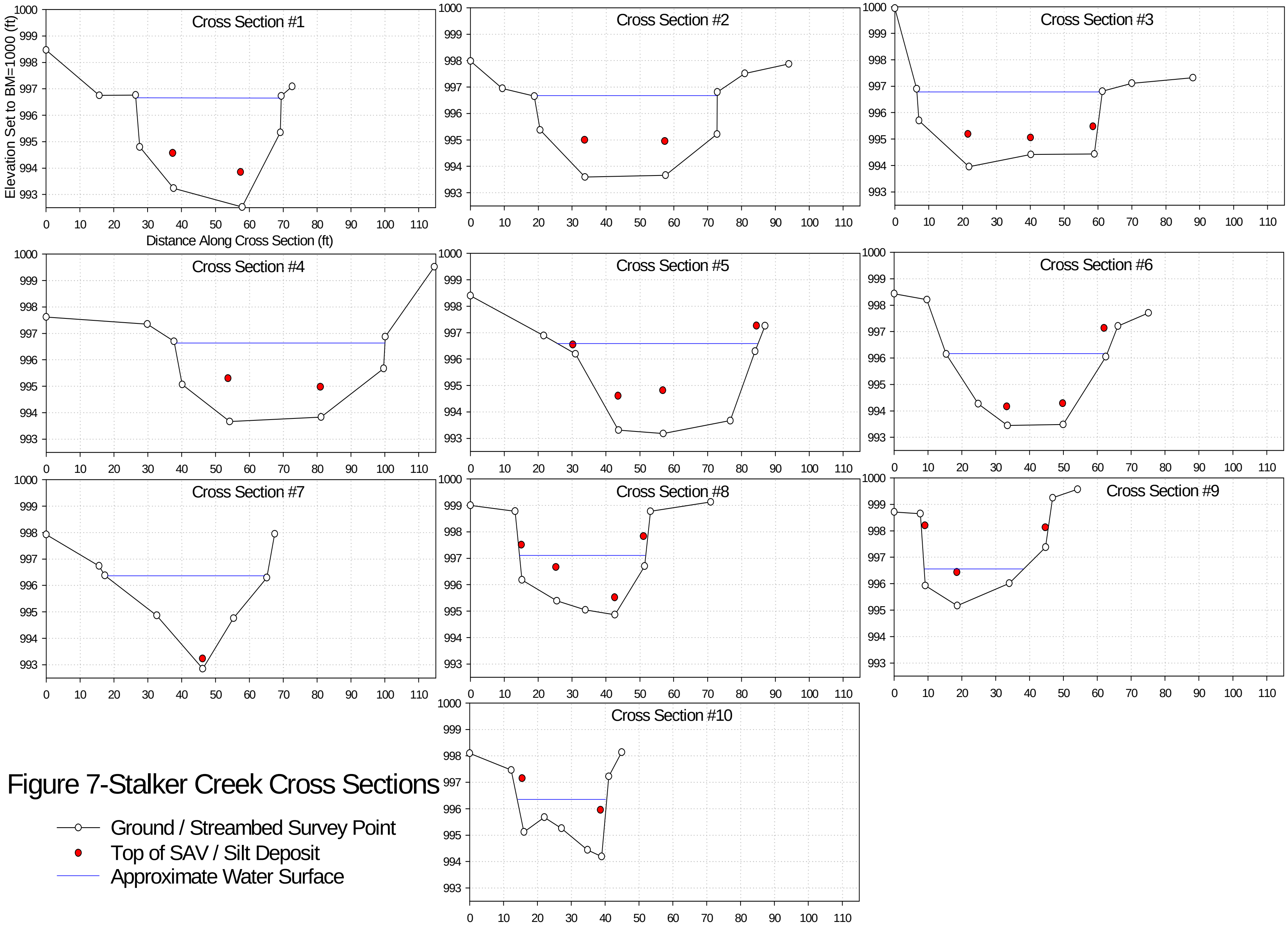


Figure 7-Stalker Creek Cross Sections

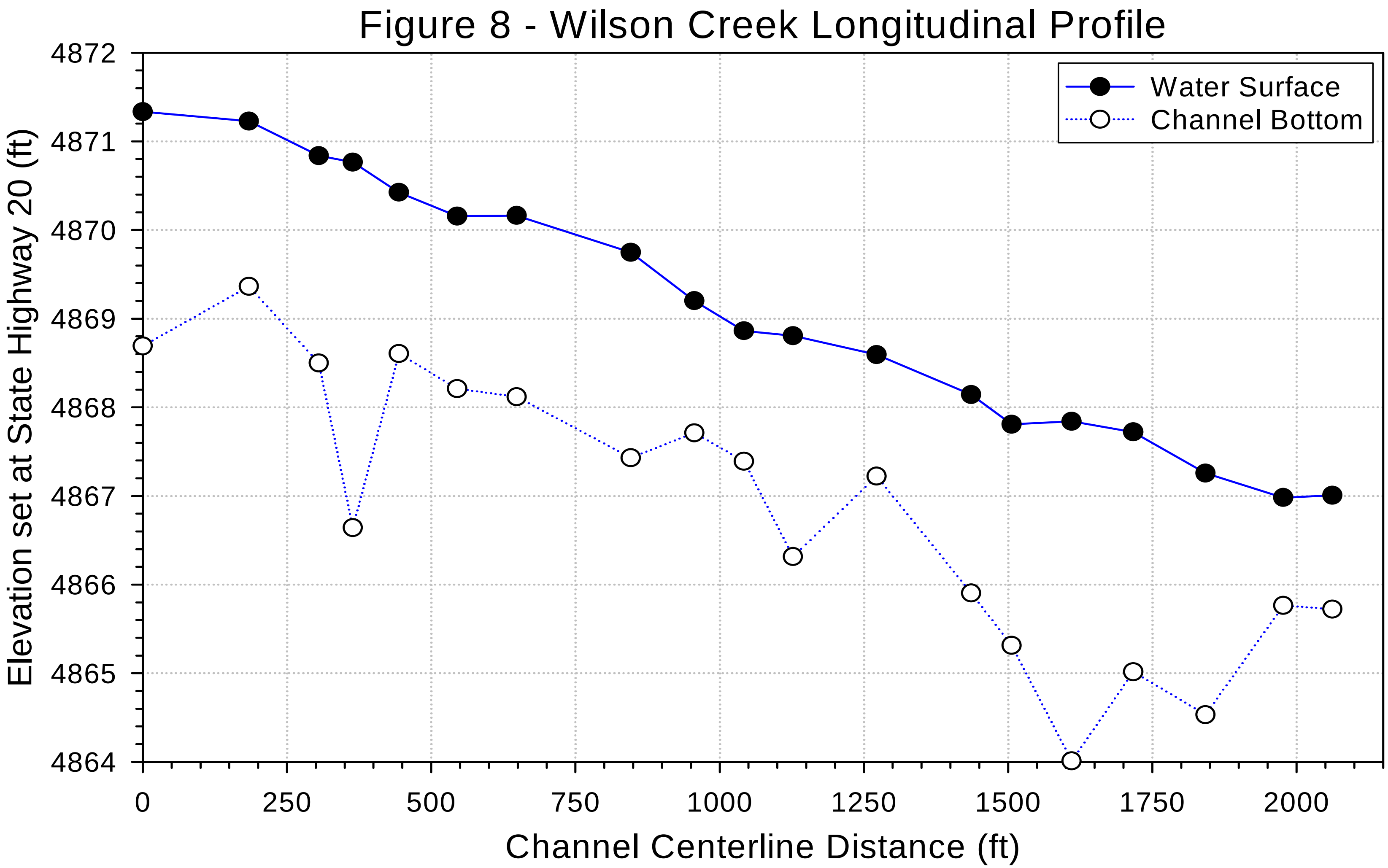


Figure 8 - Wilson Creek Longitudinal Profile
Water Surface
Channel Bottom
Elevation set at State Highway 20 (ft)
4872
4871
4870
4869
4868
4867
4866
4865
4864
0
250
500
750
1000
1250
1500
1750
2000
Channel Centerline Distance (ft)

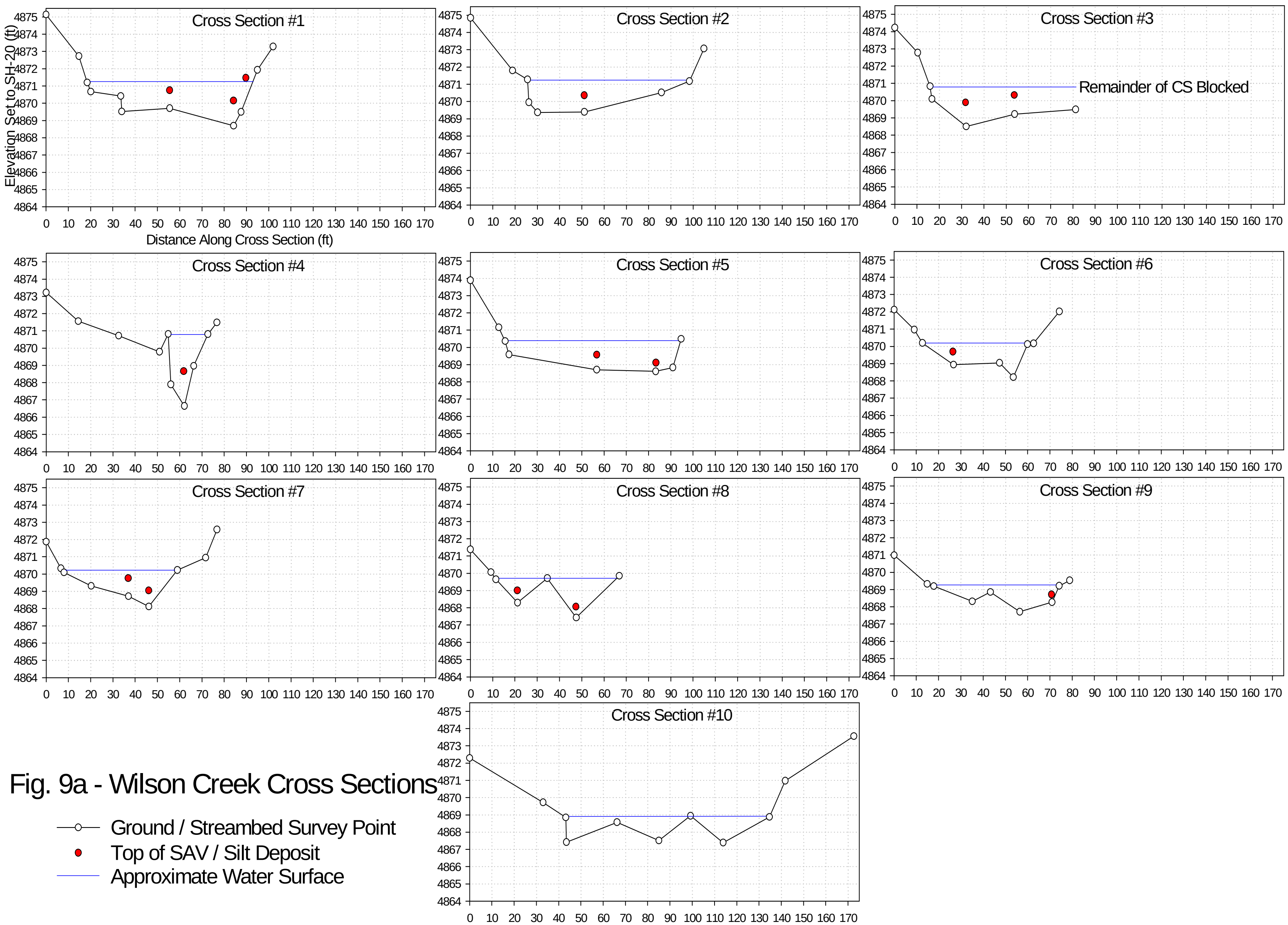


Fig. 9a - Wilson Creek Cross Sections

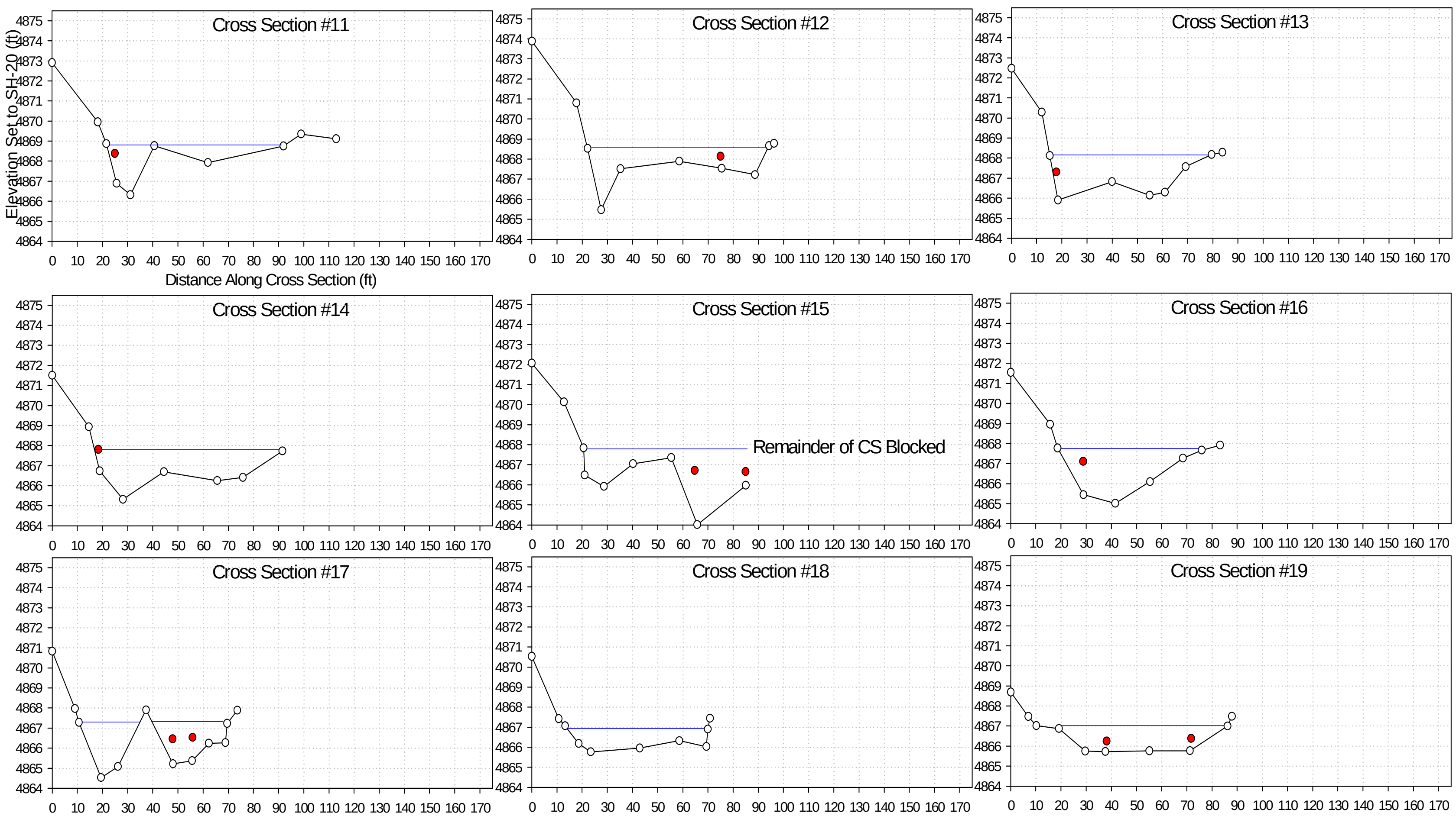


Fig. 9b - Wilson Creek Cross Sections

- Ground / Streambed Survey Point
- Top of SAV / Silt Deposit
- Approximate Water Surface

4.0 – RESULTS

4.1 – Distribution of Plant Communities

The distribution of vegetation types at each of the three creeks is represented below by scatter plots of percent plant cover versus hydrology. Hydrology is represented on the x-axis by elevation above (+) or below (-) the water level at the time of the survey. The vegetation types included in these plots are reed canarygrass (RCG), submerged aquatic vegetation (SAV), sedge and grass. Weed, shrub and other vegetation types were originally included, but were removed from the plots to make them easier to read; these types showed few patterns and did not add useful information to the analysis.

Figure 10 - Mud Creek Vegetation and Water Depth

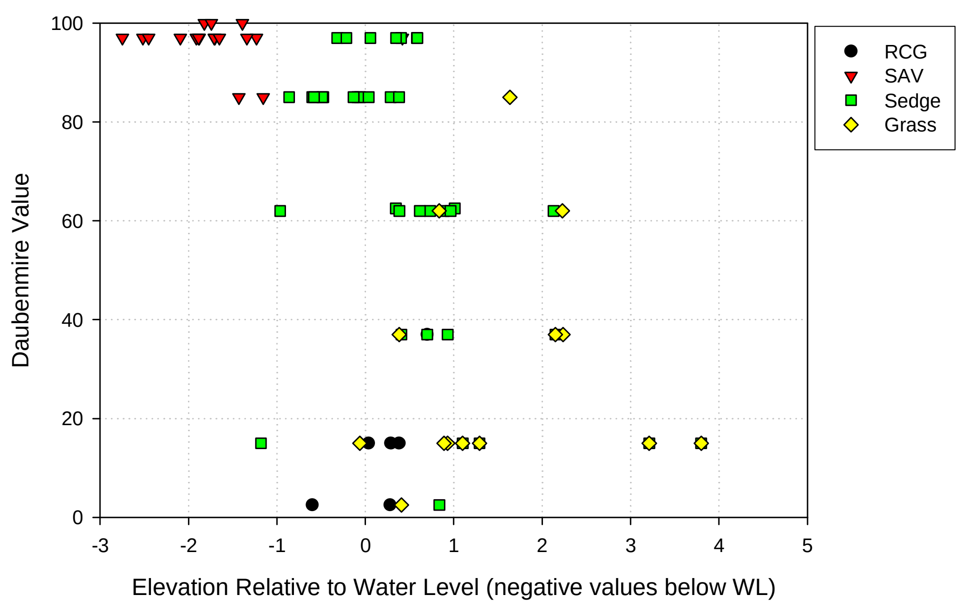
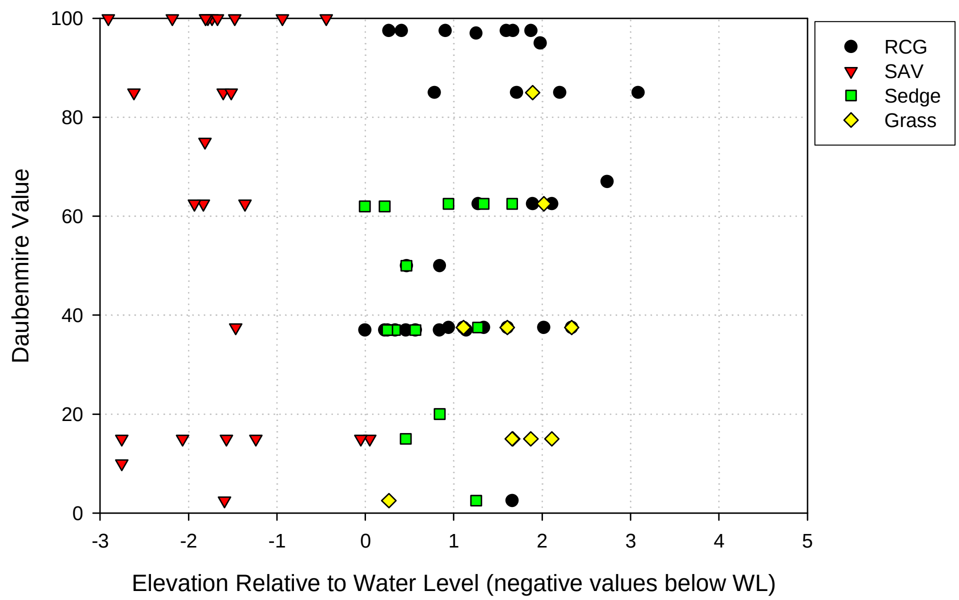


Figure 11 - Stalker Creek Vegetation and Water Depth



Mud and Stalker Creeks (Figures 10 and 11) show vegetation distributions that are typical in Idaho stream environments. SAV is found within the stream channel, sedges are found near water level, and reed canarygrass and other grasses are found above the water level. Reed canarygrass' distribution overlaps strongly with the sedges and the lower range of the grasses, but not with SAV; it occurs on stream banks, not in the channel. Table 2 displays weighted mean elevations of each plant community at Mud and Stalker Creeks.

Table 2 - Weighted Mean Elevations of Plant Communities (ft)

	RCG	SAV	Sedge	Grass
Mud Creek	0.41	-1.68	0.24	1.58
Stalker Creek	1.35	-1.71	0.73	1.82

Although both creeks have vegetation distributed in the expected sequence above or below the water level, reed canarygrass, sedge and grass are located higher above the water level in Stalker Creek than Mud Creek. This may result from seasonal changes in water levels. Mud Creek has an average channel slope of 0.13% within the survey area while Stalker Creek's is only 0.02%. Given these channel slopes and cross sectional forms, a doubling of flow in Mud Creek is expected to result in a water level rise of only 6-inches while a doubling of flow in Stalker Creek would result in a water level rise of about 2-feet. These water level rise estimates were obtained by Manning's Equation calculations. Another factor effecting stage-discharge in Stalker Creek is the aquatic vegetation growth in summer. The differences in stage-discharge relationships of the two creeks may allow wetland vegetation to extend further up the bank on Stalker Creek or closer to the surveyed water level on Mud Creek. Another consideration is that land is generally flatter along Mud Creek than Stalker Creek, with fewer points more than 1.5 ft above the water level.

Figure 12 - Wilson Creek Vegetation and Water Depth

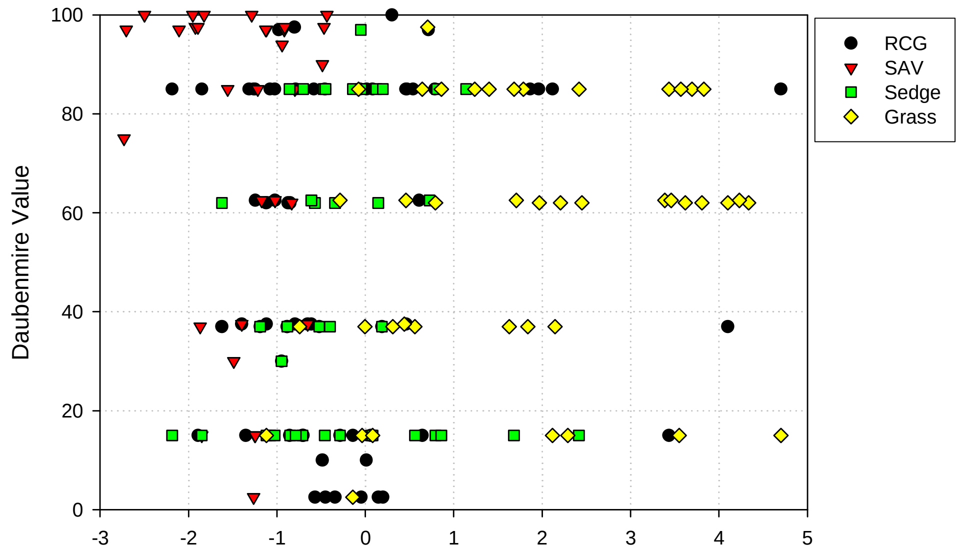


Figure 12 shows the distribution of vegetation types on Wilson Creek. There are obvious differences in the distribution of reed canarygrass and sedges as compared to Mud and Stalker Creeks. On Wilson Creek, reed canarygrass and sedges overlap with SAV, extending into deeper channel locations than on the other streams. In fact, reed canarygrass is found even in relatively deep mid-channel locations, which is unusual. Table 3 shows the data presented as Table 2 with Wilson Creek data added.

Table 3 - Weighted Mean Elevations of Plant Communities (ft)

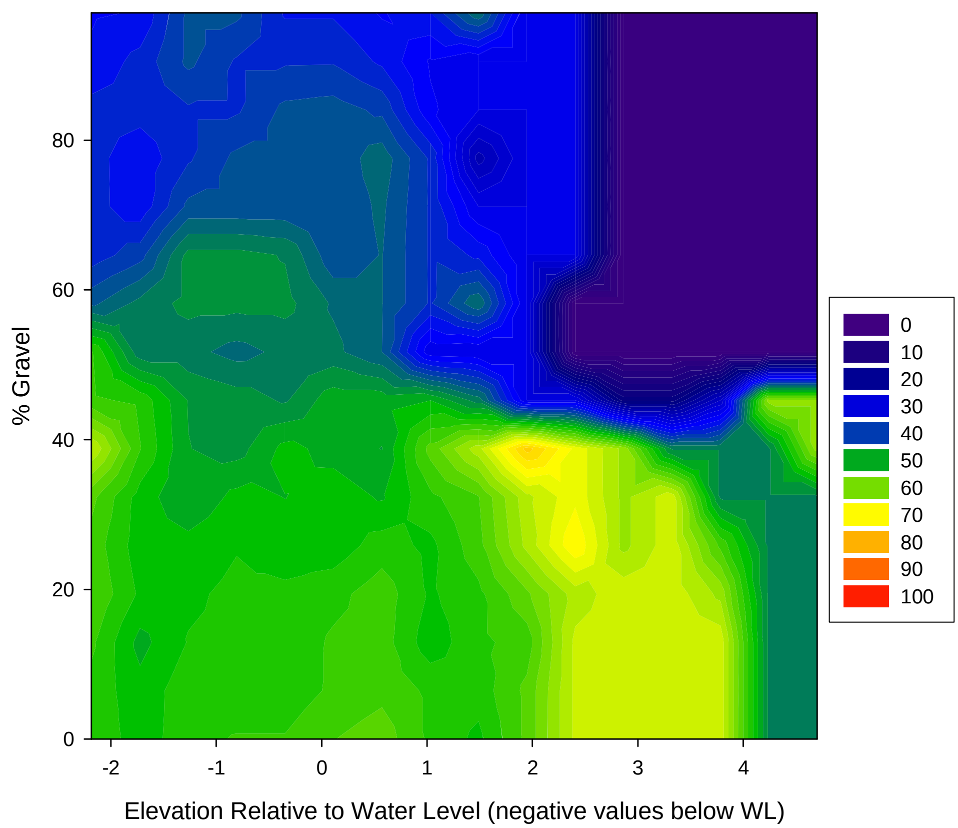
	RCG	SAV	Sedge	Grass
Mud Creek	0.41	-1.68	0.24	1.58
Stalker Creek	1.35	-1.71	0.73	1.82
Wilson Creek	-0.15	-1.40	-0.21	2.12

Reed canarygrass and sedge occurred at lower average elevations along Wilson Creek than Mud or Stalker Creeks. The reed canarygrass found in mid-channel locations was generally not found to be growing from the channel bed. Instead it was usually growing on top of muck deposits that appeared to have accumulated previously in SAV stands. The SAV apparently had been shaded out where the reed canarygrass was dense, but the sediment was a loose, organic-rich muck like that found in SAV stands.

4.2 – Comparisons of Wilson Creek Reed Canarygrass Distribution with Hydrology and Substrate

The results in Section 4.1 imply that hydrology alone is not the controlling factor of abnormally high amounts of reed canarygrass in Wilson Creek. In this section, substrate type is added to the analysis and contour plots are used for data visualization. In each of these figures, the percent cover (Daubenmire Value) of reed canarygrass is represented by colored contours while the X and Y axes represent water level and substrate texture.

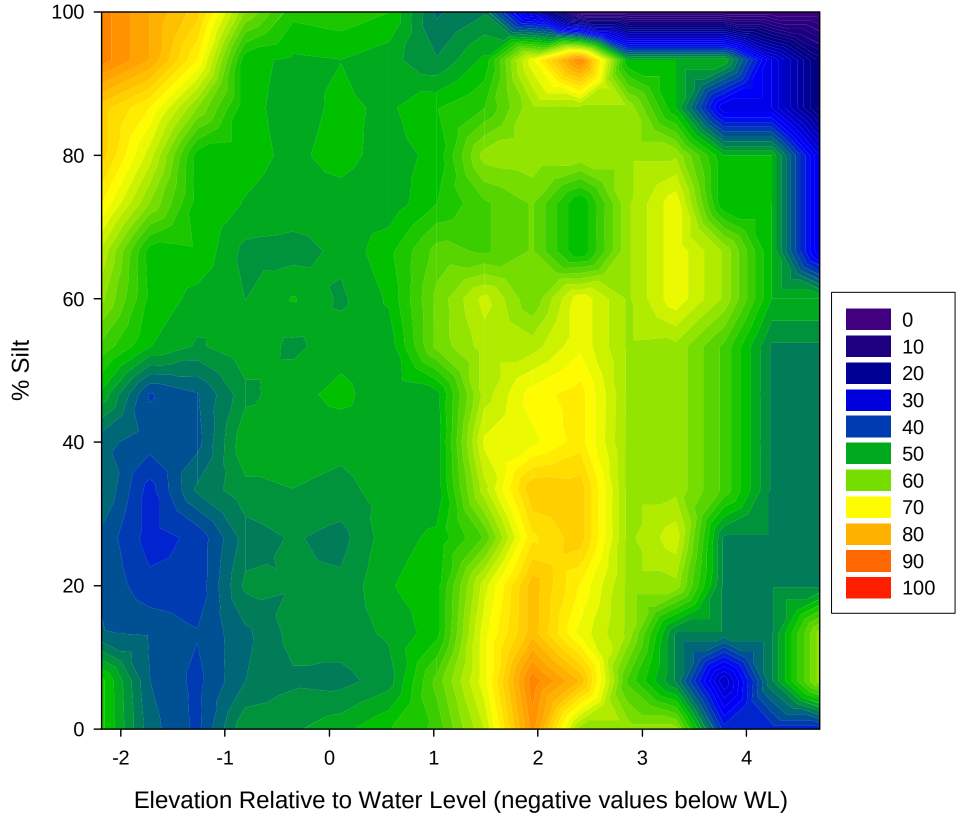
Figure 13 - Wilson Creek RCG Distribution in Gravel



There were 22 instances of reed canarygrass growing in substrate containing some gravel. Figure 13 shows that the amount of reed canarygrass found was more strongly related to the amount of gravel (inverse relationship) than water level. The inverse relationship suggests either that reed canarygrass grows better in substrates other than gravel or that it promotes deposition of fine sediments where it has established.

There was only one instance of reed canarygrass growing in substrate with sand and the values were insignificant (15% reed canarygrass; 10% sand).

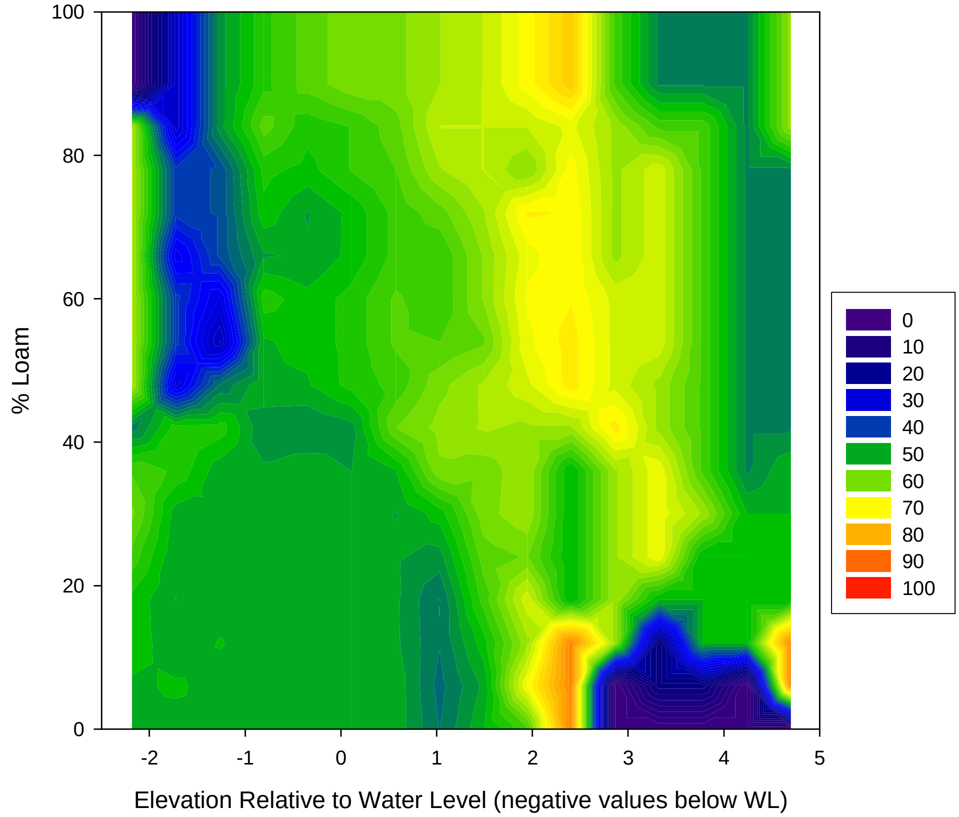
Figure 14 - Wilson Creek RCG Distribution in Silt



There were 57 instances of reed canarygrass growing in substrate containing some silt, including organic-rich muck grouped with silt in this study. From Figure 14, it is evident that reed canarygrass is most abundant in two distinct hydrologic conditions – 1.5' to 2.5' above water level and 0.5' to 2' below water level – and that its relationship with silt differs between these conditions. In the zone above the water line, the prevalence of reed canarygrass was relatively independent of the amount of silt. In the zone below the water line, however, reed canarygrass was only prevalent where silt was the dominant substrate type. In this zone, reed canarygrass was not found in high quantities anywhere that the amount of silt was low. It is important to recall that the reed canarygrass shown as growing in deeper water was actually growing on top of fine sediment deposits; therefore, the plants were actually rooted at a shallower depth than shown.

There were only two instances of reed canarygrass growing in a substrate with clay, and, in both cases clay was not dominant (10 and 20% clay).

Figure 15 - Wilson Creek RCG Distribution in Loam



There were 22 instances of reed canarygrass growing in substrate with loam (Figure 15). Above the water line, reed canarygrass abundance appeared to be independent of loam content. Below the water line, reed canarygrass was more abundant where there was less loam.

4.3 – Substrate Compositions Related to Water Depths

The data presented in Section 4.2 indicates that reed canarygrass can grow well within the stream channel in areas with silt or muck deposits. However, the data presented in Section 4.2 was only for Wilson Creek. This section aims to test whether this hydrology-substrate combination and its association with reed canarygrass is unique to Wilson Creek.

Figure 16 - Silt vs. Depth in Mud Creek

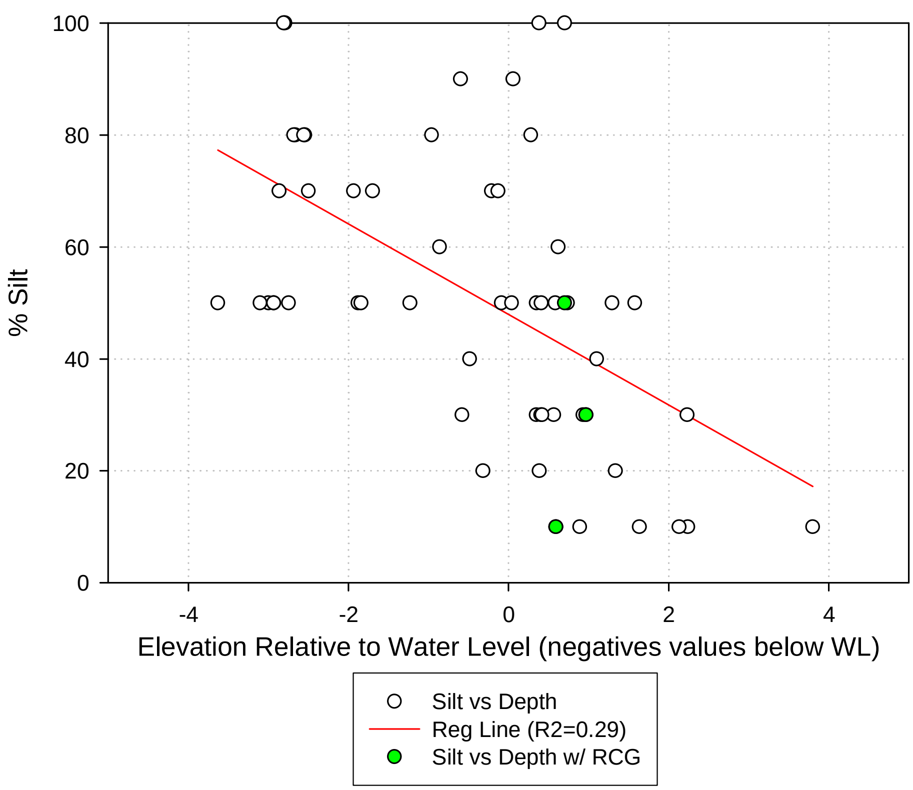


Figure 16 shows that areas with high silt content were uncommon below the water line in Mud Creek. Although areas with 50%-70% silt were common below the water line, there were few areas with 80-100% silt. Fine sediments in the channel did not support reed canarygrass. There were only three instances where reed canarygrass was found with silt along Mud Creek, and all of these locations were above the water line.

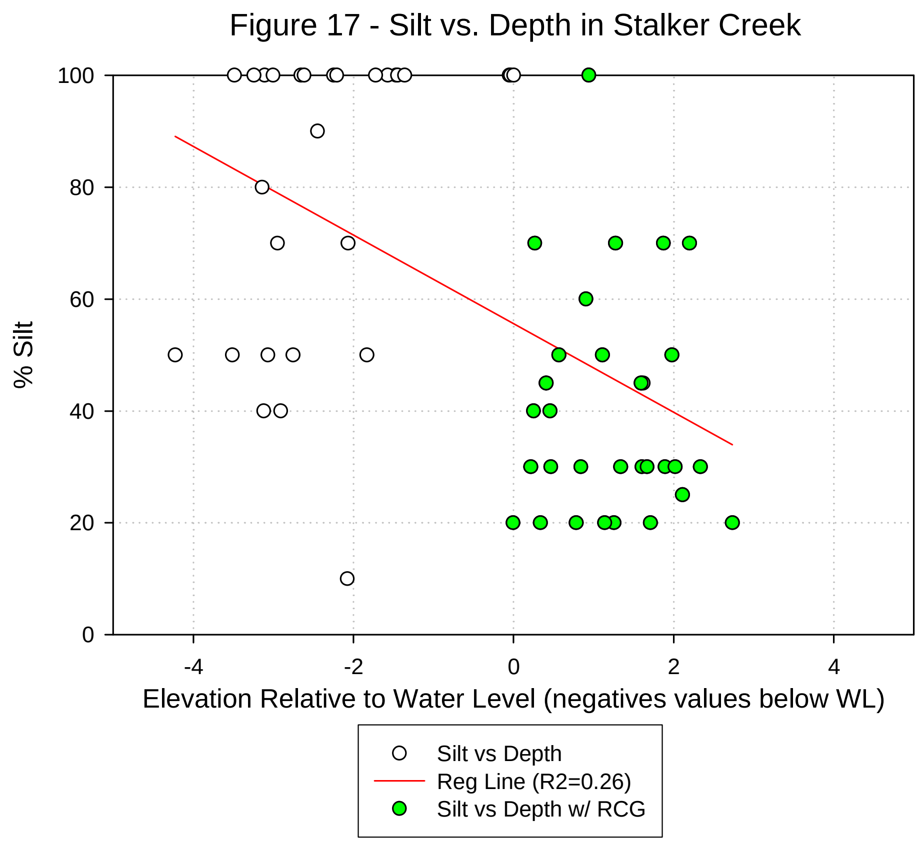
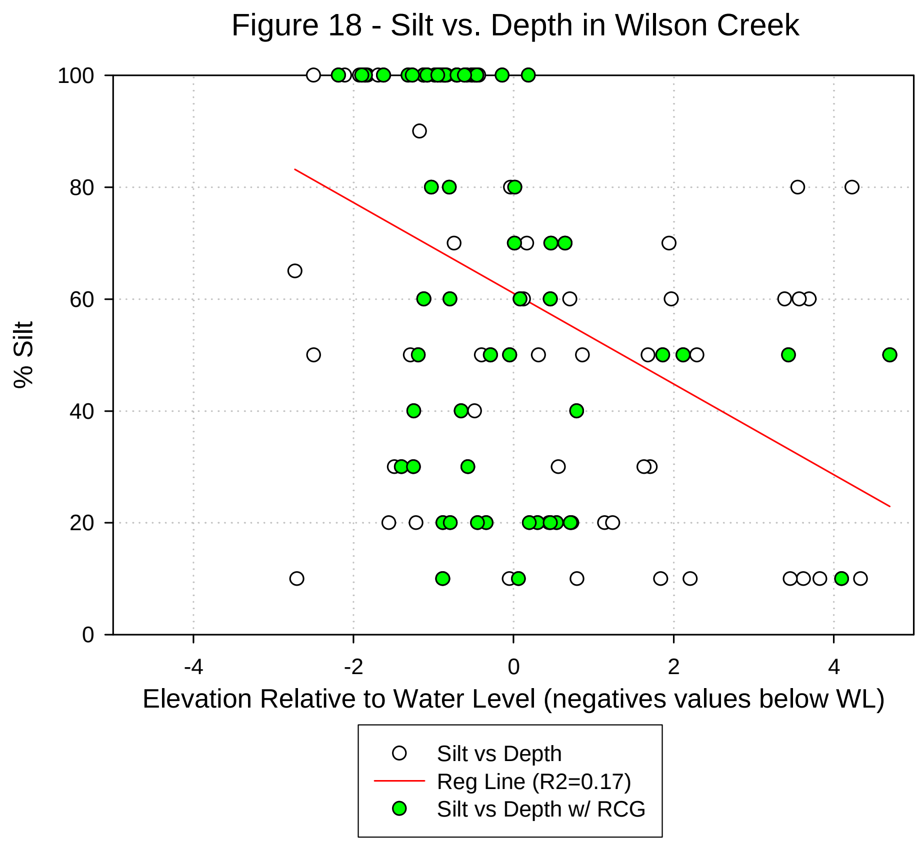


Figure 17 shows that, unlike Mud Creek, significant areas with high silt content were found below the water line along Stalker Creek. All of the locations where reed canarygrass was found with silt, however, were above the water line. The majority of silt found in Stalker Creek was found greater than 2' below the water line.



As shown in Figure 18, areas with high silt content were common below the water line in Wilson Creek, and these areas usually had reed canarygrass. Reed canarygrass occurred across a wide range of silt content near and below the water line and was not exclusively associated with very silty deposits. Comparing these data to Figures 14 and 17 suggests that reed canarygrass can grow particularly well in very silty deposits in the 0-2' deep range and that these conditions are more common in Wilson Creek than Mud or Stalker Creek. The reed canarygrass in Wilson Creek was most prevalent in the 0-2' deep zone; at depths greater than 2', reed canarygrass only occurred at one of the six points that had silt. Presence of silt in the 0-2 ft depth does not fully explain occurrence of reed canarygrass, however. Mud Creek and Stalker Creek both had some areas with silt in the 0-2' deep range that did not have reed canarygrass. In Mud Creek these areas typically had intermediate rather than high silt content. In Stalker Creek there were few points with silt in the 0-2' deep zone; most of the silt deposits were in the 2-4' deep zone.

4.4 – Comparison of Water Depths Among Creeks

Table 4 summarizes depths of each of the three streams with emphasis on the amount of shallow channel areas, especially the areas with fine sediment that seem most vulnerable to reed canarygrass establishment. The first set of values represents water depth above the firm channel bed, ignoring overlying deposits of soft, loose silt or muck that might be more temporary or subject to scouring. The second set of values represents water depth above the sediment regardless of whether the sediment was firm or soft. The third set represents just the points where elevations were measured at the top and bottom of soft deposits. Practically, soft sediment deposits were those that would not support the surveying rod on their own.

The Wilson Creek channel was generally shallower than Mud or Stalker Creek when observed, whether measured at the firm channel bed or the top of soft, loose deposits. The features that distinguished Wilson Creek the most were a high proportion of the channel bed less than 2 ft deep and the presence of overlying silt or muck deposits in these shallow channel areas that made the channel even shallower. Soft deposits were common in all three streams, and their average thickness was similar for all streams – about 1 ft thick. However, the top of these soft deposits was much shallower in Wilson Creek –averaging less than 1 ft deep – because the channel bed was shallower. This summary underscores the possibility that areas of fine sediment deposition under shallow water may contribute to reed canarygrass invasion into Wilson Creek's channel.

Table 4 – Summary of channel depths.

	Wilson Cr	Mud Cr	Stalker Cr
Total number of points in channel	86	38	41
Channel bed measured at top of firm substrate			
Average depth of firm bed, ft	-1.39	-1.77	-1.99
Percent of points at 0-2 ft depth	78%	53%	41%
Percent of points with silt at 0-2 ft depth	60%	14%	9%
Percent of points at 0-1 ft depth	30%	29%	5%
Channel bed measured at top of sediment (firm substrate or soft deposit)			
Average depth	-1.09	-1.24	-1.50
Percent of points at 0-2 ft depth	87%	87%	73%
Percent of points at 0-1 ft depth	49%	32%	10%
Characteristics of soft deposits			
Number of points measured	27	20	18
Average deposit thickness, ft	1.05	1.04	1.11
Average depth to top of sediment, ft	-0.86	-1.63	-1.78

5.0 – CONCLUSIONS

5.1 – Reed Canarygrass Distribution

Based on the data collected during this study, when reed canarygrass is found thriving in channel areas instead of its typical streambank habitat, silt or muck deposits in shallow water zones (0-2') appear to be an important contributing factor. The presence of silt and reed canarygrass in the 0-2' deep zone is the outstanding difference between Wilson Creek and the other two creeks sampled. Exposed sediment or shallow water often favor invasion of facultative wetland grasses into streams and ponds, and the combination of shallow water and sediment deposits in Wilson Creek are the most likely explanation for the reed canarygrass infestation in the channel. Other factors such as nutrient enrichment, seasonal water levels, and occurrence of higher energy flushing flows could also play a role but were not evaluated.

Based on field observations, it is likely that the fine sediment deposits in Wilson Creek preceded reed canarygrass invasion. The instream deposits recorded as having very high silt content were typically loose, semi-liquid muck that appeared to consist largely of organic detritus. This type of sediment often accumulates in dense SAV stands. Where reed canarygrass was growing in mid-channel, its shoot bases and rhizomes were near the sediment surface, not in the firmer stream bed. It often appeared to have "piggybacked" onto SAV stands and stabilized their loose sediments. Because these observations represent a single point in time, these inferences about invasion process are speculative.

The extremely low slope of Stalker Creek may be one reason that its channel has not been invaded by reed canarygrass in spite of abundant submerged aquatic vegetation, fine sediment deposits, and dense reed canarygrass stands on its banks. Due to its lower slope, Stalker Creek is expected to rise much higher than Wilson Creek with increasing flows or increasing SAV, thus increasing the depth of water over silt or muck deposits in Stalker Creek. The hydrology of Mud Creek is probably intermediate between Wilson and Stalker Creeks.

5.2 – Reed Canarygrass Control Strategies

There are inherent challenges in restoration of sites with dense populations of reed canarygrass due to the presence of residual populations adjacent and upstream. Reed canarygrass control and aggressive revegetation practices will probably be necessary components of any channel rehabilitation project. Research literature and management experience in the Pacific Northwest and upper Midwest states indicates that herbicide (usually glyphosate) is the most common and successful control practice, and that control is a long-term challenge requiring several years of follow up treatments and periodic treatments to thwart reinvasion. Information on successful revegetation following control is limited, but recolonization by reed canarygrass is considered a major problem. Establishment of shrubs or trees in infested areas is more successful if larger, better developed material is planted and the surrounding area is kept free of reed canarygrass for several years by tarping the ground or using herbicide. Establishment of sedges and other herbaceous plants probably also requires use of larger, better developed material. Even extremely high rates of seeding with native species (15,000 seeds/m^2) does not suppress recruitment of reed canarygrass when its seed is present (Reinhardt and Galatowitsch 2004).

5.3 – Stream Channel Rehabilitation to Limit Reed Canarygrass Invasion

The data presented in this report suggest that restoration techniques at creeks with reed canarygrass present should focus on creating channel conditions that deter invasion and minimizing areas of exposed or shallow sediment that favor invasion. The channel should feature a deep thalweg with relatively high velocities; the objective should be to limit accumulation of fine sediment and, where sediment does accumulate, to maintain adequate depth to deter colonization by reed canarygrass. Soil mixtures with high silt content should be avoided in point bar construction, and aggressive revegetation should be used to minimize bare sites. Off-channel areas of open water appear to be prone to accumulation of organic detritus produced by SAV and to subsequent invasion by reed canarygrass. Such areas should be included only if maintenance is planned to keep them open.

6.0 – REFERENCES

Antieau, C. 2002. www.sernw.org/rcgrass/rc_home.htm. Society of Ecological Restoration, Northwest Chapter, Reed Canarygrass Working Group.

Center for Invasive Plant Management. 2005. Western State and Provincial Weed Lists, Updated by State and Provincial Weed Coordinators June 2004 with additional updates in 2005. http://www.weedcenter.org/inv_plant_info/2004_weedlist.html

Green, E.K. and S.M. Galatowitsch. 2001. Difference in wetland plant community establishment with additions of nitrate-N and invasive species (*Phalaris arundinacea* and *Typha* x *glauca*). Canadian Journal of Botany 79:170-178.

Harrison, R.D., N.J. Chatterton, R.J. Page, M. Curto, K.H. Asay, K.B. Jensen, and W.H. Horton. 1996. Competition, Biodiversity, Invasion, and Wildlife use of Selected Introduced Grasses in the Columbia and Great Basin. Research Report 155, Utah Agricultural Experiment Station, Logan, Utah.

Hitchcock, A.S. 1950. Manual of the grasses of the United States. Dover Publications, Inc., New York.

Kercher, S.M. and J.B. Zedler. 2004. Flood tolerance in wetland angiosperms: a comparison of invasive and noninvasive species. Aquatic Botany 80:89-102.

Magee, T.K., and M.E. Kentula. 2005. Response of wetland plant species to hydrologic conditions. Wetlands Ecology and Management 13:163-181.

Mahaney, W., D. Wardrop, and R. Brooks. 2005. Impacts of sedimentation and nitrogen enrichment on wetland plant community development. Vegetatio 175:227-243.

Maia, E. 1994. Noxious weeds: A guide to invasive non-native plants. King County Department of Public Works, Surface Water Management Division, Seattle.

Maurer, D.A., R. Lindig-Cisneros, K.J. Werner, S. Kercher, R. Miller and J.B. Zedler. 2003. The replacement of wetland vegetation by reed canarygrass (*Phalaris arundinacea*). Ecological Restoration 21:116-119.

Maurer, D.A. and J.B. Zedler. 2002. Differential invasion of a wetland grass explained by tests of nutrients and light availability on establishment and clonal growth. Oecologia 131:279-288.

Miller, R.C., and , J.B. Zedler. 2003. Responses of native and invasive wetland plants to hydroperiod and water depth. Plant Ecology 167:57–69.

Perry, L.G. and S.M. Galatowitsch. 2002. Lowering nitrogen availability may control reed canarygrass in restored prairie pothole wetlands (Minnesota). Ecological Restoration 20:60-61.

Perry, L.G., S.M. Galatowitsch, and C.J. Rosen. 2004. Competitive control of invasive vegetation: a native wetland sedge suppresses *Phalaris arundinacea* in carbon-enriched soil. Journal of Applied Ecology 41:151-162.

Reinhardt, C. and S.M. Galatowitsch. 2004. Best Management Practices for the Invasive *Phalaris arundinacea* L. (Reed Canary Grass) in Wetland Restorations. University of Minnesota Report, published by Minnesota Department of Transportation, Research Services Section.

Weinmann, F., M. Boule, K. Brunner, and V. Yoshino. 1984. Wetland Plants of the Pacific Northwest. U.S. Army Corps of Engineers, Seattle.