CHAPTER 13

Determining Whether Excavation Will Improve Drainage of Adjacent Agricultural Lands

13.1 Introduction to Characteristic Indicators of Improved Drainage after Excavation (Goal 12)

Preserving the agricultural function of existing farmland while improving habitat conditions for endangered species is of vital importance to King County's residents. An important component to preserving these low-lying farmlands is the maintenance of agricultural waterways for drainage as most of the watercourses flow characteristics directly impact the drainage of adjacent lands. When maintenance practices are neglected, vegetation and fine sediment increase to a level which both raises the water surface elevation and restricts flow. This in turn causes flooding throughout the surrounding areas. Furthermore, without vegetation and sediment removal, the flooded portions do not fully drain, resulting in water ponding which restricts or removes the lands' agricultural viability.

What is needed is a methodology to help predict water levels after excavation of reed canarygrass and sediment. With the assistance of KCDNRP staff, the following research hypotheses were posed in relation to this study component:

> Hypothesis 1: Maintaining select channel segments will not alter drainage of adjacent agricultural lands as indicated by statistically significant decreases in water surface elevation within the channel, compared to baseline conditions.
>
> Hypothesis 2: Maintaining select channel segments will not alter agricultural channel drainage in terms of hydraulic parameters (e.g., wetted-perimeter, bed slope, and channel roughness) compared to baseline conditions.

As a result of these hypotheses, the purpose of Goal 12 is two-fold: The first is to investigate the effects of dredging clogged waterways on adjacent agricultural lands. The second is to measure and report the changes said dredging has on hydraulic parameters within the cleaned waterways.

In order to address the first purpose, researchers monitored maintenance operations and documented their effects on adjacent lands. The watercourse maintenance operation involved removing vegetation and sediment from a watercourse in order to increase flow and decrease water surface elevations and channel roughness (Manning's n). The theory behind the maintenance of agricultural watercourse is that the subsequently improved drainage capability would dry out surrounding ponded regions leaving the land usable for agricultural use. Documenting improvements to adjacent lands included first-hand accounts by landowners and WSU staff who observed changes in land use practices. Measurements of pre- and post- dredged water surface elevations, channel characteristics, and flow velocities also illustrated enhanced drainage since management practices were resumed.

The second purpose was analyzed using a combination of site surveys, data collection, and calculations. Sites under various stages of maintenance were surveyed and their geomorphology and flow characteristics measured. Using the collected data the values were then analyzed with a US Army Corps of Engineer's computer model called Hydrologic Engineering Centers River Analysis System (HEC-RAS) which reported selected hydraulic parameters. In this way pre and post maintenance conditions were reported for use in subsequent drainage, flood, and management calculations and decisions.

13.2 Summary of Relevant Research

Depending on flow and channel characteristics, free-surface open channel flows can be theoretically classified as (Chaudhry 1993):

1. Steady Uniform Flow
2. Steady Nonuniform (Varied) Flow
    a. Gradually Varied
    b. Rapidly Varied
3. Unsteady Uniform Flow
4. Unsteady Nonuniform (Varied) Flow
    a. Gradually Varied
    b. Rapidly Varied

The terminology steady versus unsteady refers to whether or not the flow velocity at a point changes with time. In steady flow situations, the velocity (and therefore the discharge) is assumed to be nearly constant. In unsteady flow cases, the velocity at a point changes with respect to time. Uniform versus nonuniform refers to whether or not the flow rate changes with respect to longitudinal distance. For uniform flow, there is no change in flow with respect to the longitudinal flow direction along the channel. For nonuniform flow, the flow is assumed to change with distance.

Flow is referred to as "gradually varied flow" if the rate of depth variation is small with respect to distance. Conversely, they are referred to as "rapidly varied flow" if the rate of depth variation is large with respect to distance.

Natural open channel flow conditions may represent either by steady uniform flow (Case 1), steady nonuniform flow (Case 2) or unsteady nonuniform flow (Case 4). While theoretically possible, the occurrence of unsteady uniform flow (Case 3) does not occur in nature.

To be truly uniform, the channel must be 1) straight, 2) have constant slope, and 3) have constant cross-sectional area. Because of these three constraints, few natural channels actually qualify as uniform although approximations that allow for this simplified solution are often made. Steady uniform flow (Case 1) can be expressed using the well known Manning's Equation. In English units, this equation can be expressed as:

$$Q = \frac{1.49}{n} A R^{2/3} S_o^{1/2} \qquad (13\text{-}1)$$

where A is cross-sectional area [ft^2], n is the Manning's roughness coefficient, R is the hydraulic radius [ft], and S_o is the bed slope [ft/ft].

Hydraulic roughness parameters for varying types of channels have been well-documented. Typical roughness values were covered in detail by Chow (1959). Chow recommends maximum Manning's n values for un-maintained excavated channels of 0.08 to 0.14 depending on the levels of vegetation present. For maintained excavated channels, he recommends Manning's n not exceed 0.06 to 0.08. However, these values were developed for engineered flow conveyance channels and natural streams, not for the level of vegetation present in some of the agricultural drainage channels within King County.

For relatively short sections of drainage canals typically involved in maintenance activities, the assumption of steady gradually varied nonuniform flow (Case 2 a) may be more appropriate than steady uniform flow because channel bottom slopes are unlikely to be constant. In this case, an iterative approach to solving the following expression is used:

$$\Delta x = \frac{\left[\frac{V_1^2 - V_2^2}{2g}\right] + y_1 - y_2 - h_L}{S_o - S_f} \qquad (13\text{-}2)$$

where V is the average cross-sectional velocity [ft/s], g is gravity [ft/s^2], y is flow depth [ft], h_L is head loss due to expansion, contractions, and bridge piers [ft], S_o is the bed slope [ft/ft], and S_f is the friction slope (slope of the energy grade line) [ft/ft]. The subscripts in Equation 13-2 refer to upstream and downstream cross-sections along the agricultural waterway.

Unlike steady uniform flow where the bed slope is assumed equal to the slope of the energy grade line, in steady nonuniform flow, the two terms in the denominator must be different to avoid dividing by zero. With the bed slope known from field measurements, the friction slope is typically estimated by rearranging Manning's Equation as:

$$S_f = \left(\frac{n\,Q}{1.49\ A\ R^{2/3}}\right)^2 \qquad (13\text{-}3)$$

Using this approximation, Equation 13-2 can be solved. It should be noted that for the mild slope conditions existing in agricultural waterways, this expression is controlled by a known downstream flow level and is solved by progressing upstream.

A thorough discussion of one-dimensional flow calculations is beyond the scope of this document. Readers wishing to learn more about the specific procedures are referred to the Hydraulics Reference and Users Manuals produced by the US Army Corps of Engineers (2002a; 2002b).

The unsteady gradually varied flow scenario (Case 4) requires time dependent flow conditions and complex simulation that were not considered feasible for this task.

13.3 Methods

13.3.1 Site Selection

Three field sites were chosen for conducting the sampling and surveys. Each one was selected based on characteristics that were representative of conditions found throughout all the King County APDs. In addition, the chosen sites also were appropriate due to the advanced nature of their flow restrictions and pending scheduled cleaning operations.

The first site was the portion of Mullen Slough owned/leased by Smith Brothers' Dairy in Kent, Washington (shown in Figure 13-1, E-1 to C-4). A tributary to Mullen Slough is located in unmaintained King County road right of way adjacent to property owned by the Boscolo, Vilog, and Primero families was also used and illustrated as Boscolo B (see Figure 13-1). Both sites are located in the Lower Green River APD. Mullen Slough afforded a unique location from which to observe the effects of agricultural watercourse maintenance on site drainage. During the course of the study maintenance activities were scheduled at Smith Brother's resulting in the site's selection for survey data collection. Prior to maintenance operations Mullen Slough was severely clogged with reed canarygrass which was restricting channel flow and causing local ponding in surrounding agricultural lands. During the sampling at Mullen Slough hand-cleaning operations were underway offering a unique opportunity for direct comparison between un-cleaned and cleaned channel characteristics. Figure 13-2 and Figure 13-3 depict pre-maintained conditions along sections of the Mullen Slough drainage. Field inundation on the dairy property can be clearly seen in Figure 13-3. Alternately, Figure 13-4 shows the same section of waterway after maintenance.

The waterway adjacent to Boscolo, Vilog, and Primero properties was located upstream from the dairy, along a tributary to Mullen Slough. Pre- and post- maintenance photographs are presented in Figure 13-5 and Figure 13-6, respectively. King County performed maintenance activities after survey data was obtained so the reaches included in analysis were still heavily vegetated.

A third site was a segment of Big Spring Creek in Enumclaw, Washington at was Engberg/Dryer property as seen in Figure 13-7. This site was selected because its' un-maintained status gave researchers an excellent opportunity to survey and analyze pre-dredge channel characteristics. The Engburg portion of Big Spring Creek flowed through a portion of agricultural land inhabited by a small cattle herd. Other segments were unused at the time of sampling and vegetated primarily by grass species. Figure 13-8 shows a typical section of Big Spring Creek with its high levels of vegetation. Figure 13-9 shows the project post-maintenance.

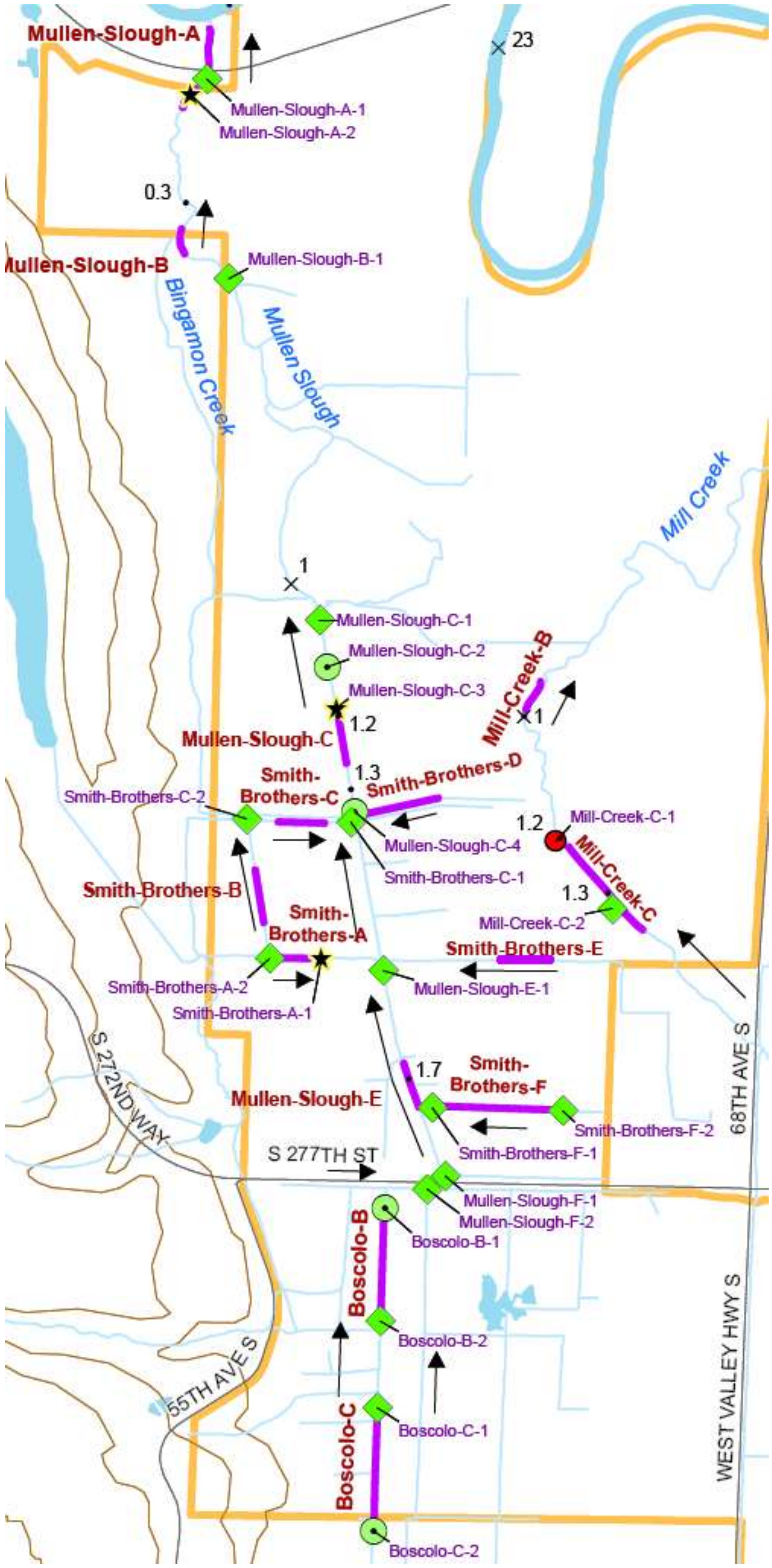

Figure 13-1. Mullen Slough study site location in Lower Green APD

Figure 13-2. Pre-maintained Mullen Slough agricultural waterway

Figure 13-3. Smith Brothers Dairy property April 8, 2004

Figure 13-4. Smith Brothers' Dairy channel on August 15, 2005 prior to mitigation

Figure 13-5. Waterway along Boscolo, Vilog, and Primero properties on April 4, 2003

Figure 13-6. Boscolo, Vilog, and Primero waterway on September 26, 2005

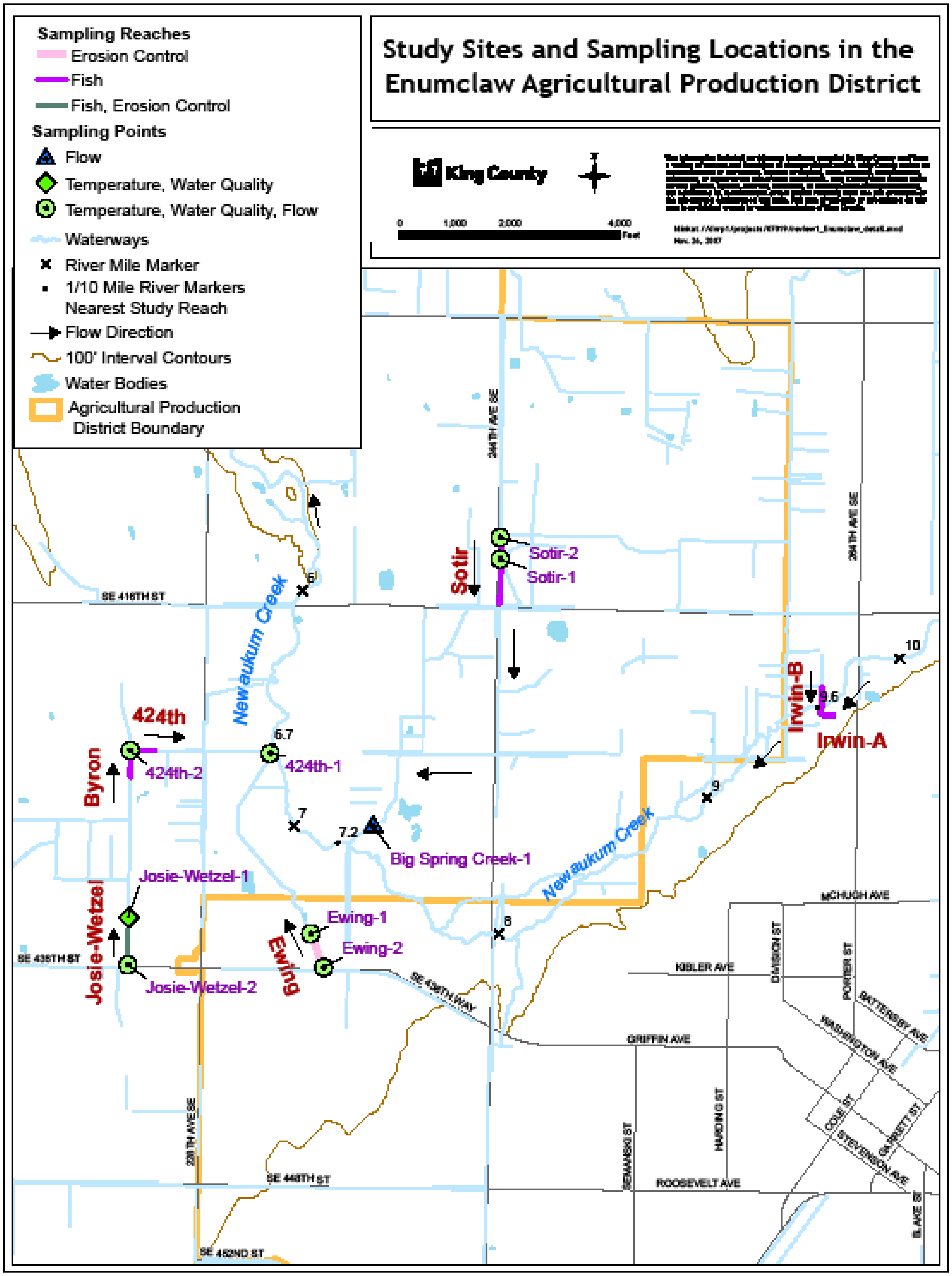

Figure 13-7. Big Spring Creek study site location

Figure 13-8. RCG vegetation growing in Big Spring Creek on June 21, 2005

Figure 13-9. Big Spring Creek on September 26, 2006 post-maintenance

13.3.2 Field Measurements

For collecting the survey data a Total Station EDM (Electronic Distance Measurement) device was used along with an extendable 8.5 ft target rod with a mounted prism placed at various points along the watercourse edge or bed. Typical cross-sections were surveyed in heavily vegetated reaches of Big Spring Creek and Mullen Slough. Additionally, survey data was taken at recently hand-cleaned portions of Mullen Slough to compare to the un-maintained regions. Sufficient data was collected to provide a characteristic representation of a cleaned watercourse.

The longitudinal and elevation data was acquired using a hand-held GPS device at the base of the EDM at both the Big Spring Creek and Mullen Slough locations. The accuracy of the GPS unit was approximately ± 23 ft making the absolute elevations calculated somewhat approximate. Because of this the GPS points were used as a general reference to location but longitudinal data and channel geometry were taken with the more precise EDM and their relative positions were then used in calculations. Flow was calculated using traditional stream-gauging techniques and devices (tape measure, wading rod, and pigmy velocity meter). This data was collected by Elizabeth Milburn, Tom Cichosz, and Dr. Michael Barber on June 21-22, 2005.

13.3.3 Observations

Land use observations were collected throughout the study duration. Most recently, observations were made at two hand-cleaned sites: 1) the Mullen Slough Smith Brother's Dairy property and 2) the Mullen Slough tributary waterway adjacent to the Boscolo property in Kent, Washington in the Lower Green River APD. Additionally pre-dredge observations and measurements were conducted at both Mullen Slough (Smith Brothers Dairy) and Big Spring Creek (Engburg/Dryer family) located in the Enumclaw APD. Changes to surrounding agricultural landscape were observed visually and recorded throughout the study duration. WSU staff and Smith Brothers' Dairy staff both contributed by noting anecdotal drainage trends and land usability at various stages of channel maintenance. Smith Brother's site manager Jack Woods visually monitored changes to Mullen Slough and adjacent fields and his comments are in the results section.

13.3.4 Numerical Analysis

Our initial aspiration was to create a simple spreadsheet capable of solving for gradually varied flow. While such a task is relatively simple for prismatic channels with two cross-sections and relatively simple channel geometry, the complexity of handling multiple segments, variable cross-section geometries, and multiple segments along the reach led us to pursue a slightly more sophisticated numerical approach. Balancing cost and complexity with need, the HEC-RAS simulation model was selected as the most appropriate model. This model is widely used and available (http://www.hec.usace.army.mil/software/hec-ras/hecras-download.html).

Improvements to drainage were quantified using the HEC-RAS model. The model was used in conjunction with the survey data to evaluate changes to wetted perimeter, channel roughness, and bed slope. The collected survey and flow data was entered into the program which calculated flow depths based on the variables collected in this study by iterating between different known parameters. When the modeled water depths matched those observed the roughness input from the calibrated model was recorded. In this way a representative roughness value was chosen for both cleaned and vegetated scenarios. The roughness values can then be used in future flood prediction calculations and evaluations of drainage potential as well as a mechanism for estimating flow velocities in water quality models. A typical HEC RAS geometric data entry window is displayed in Figure 13-10. As illustrated, the window contains cross-section characteristics relating station to elevation, Manning's roughness values for the left and right overbanks (flood plains) and main channel, contraction and expansion head loss coefficients, and a graphical depiction of the cross-section.

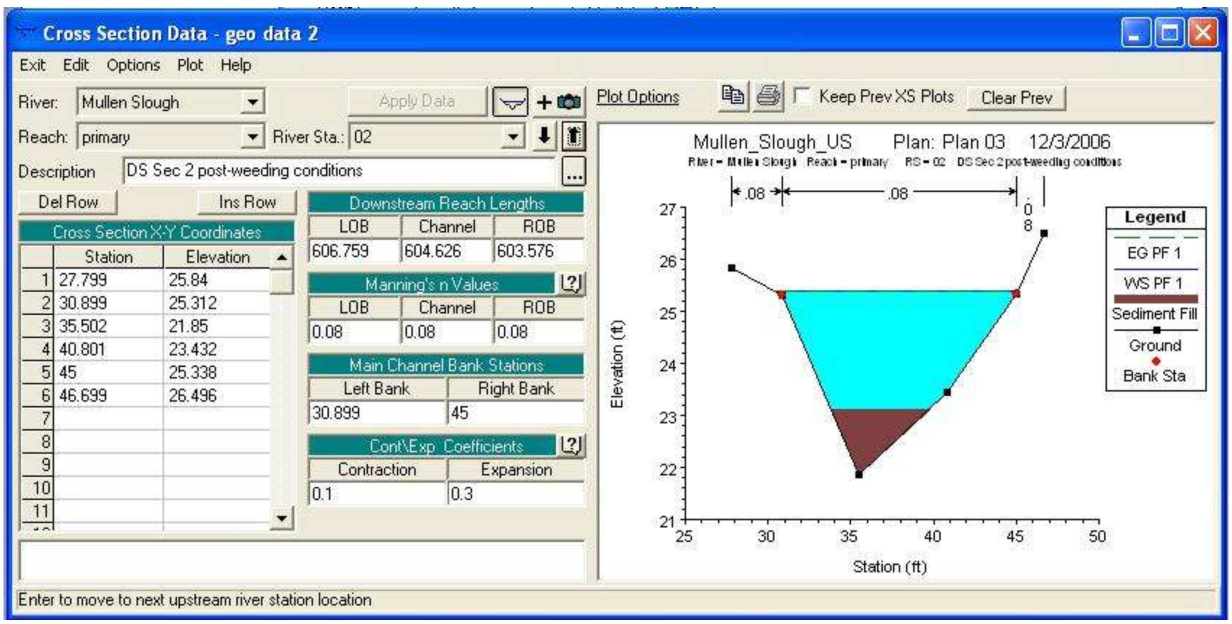

Figure 13-10. Typical HEC-RAS data frame window

In addition to HEC-RAS, Manning's roughness values were also calculated using a spreadsheet in Microsoft Excel. The channel trapezoidal geometry values were entered into Manning's equation along with known water surfaces. Manning's n was then determined by iterating different roughness values until the known discharge was obtained. Due to the amount of variables HEC-RAS accounts for including sediment depth and impacts from adjacent reach segments, the Excel and HEC-RAS values were anticipated to differ somewhat with the HEC-RAS results being more accurate. This discrepancy is to be expected in a natural system with a high number of variables. The Excel values should confirm the HEC-RAS outputs by illustrating a general trend agreement and will be discussed accordingly in the Results section of this report.

13.4 Results

13.4.1 Surveying

Some small discrepancies in water surface elevations across cross-sections were found during survey conduction. This was due to the difficulty in measuring a true perpendicular cross-section. As a result one water edge point demonstrated a slightly different elevation than the estimated corresponding perpendicular point. This difficulty arose from the clogged vegetation which obstructed an adequate visual line from being taken as well as presented a mobility challenge to the samplers. An average between the two measured elevations was used during modeling calculations.

13.4.1.1 Big Spring Creek

The reach surveyed for Big Spring Creek included a 683 ft long section with the survey equipment situated at GPS station N47^{o} 13.053' W122^{o} 1.511' at elevation 599 ft above sea level. Typical conditions were shown previously in Figure 13-8. The water surface elevation change from the far upstream point to the far downstream point was approximately 1.64 ft for a slope of 0.29 % over the entire 683 ft reach. A typical cross section for the upstream direction can be seen in Figure 13-11 as plotted by HEC-RAS 3.1 modeling software. Similarly, Figure 13-12 shows a typical downstream cross section.

The creek depth varied from approximately 3.0 ft to 1.4 ft upstream to downstream with an average flow depth of 2.1 ft over the entire survey length.

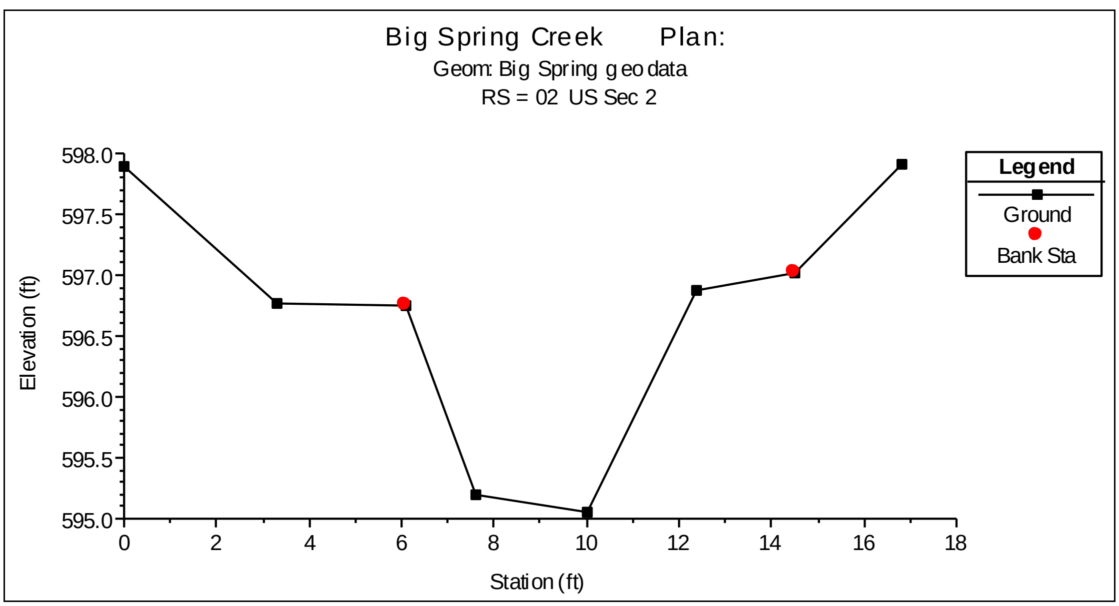

Figure 13-11. Characteristic upstream cross-section of Big Spring Creek

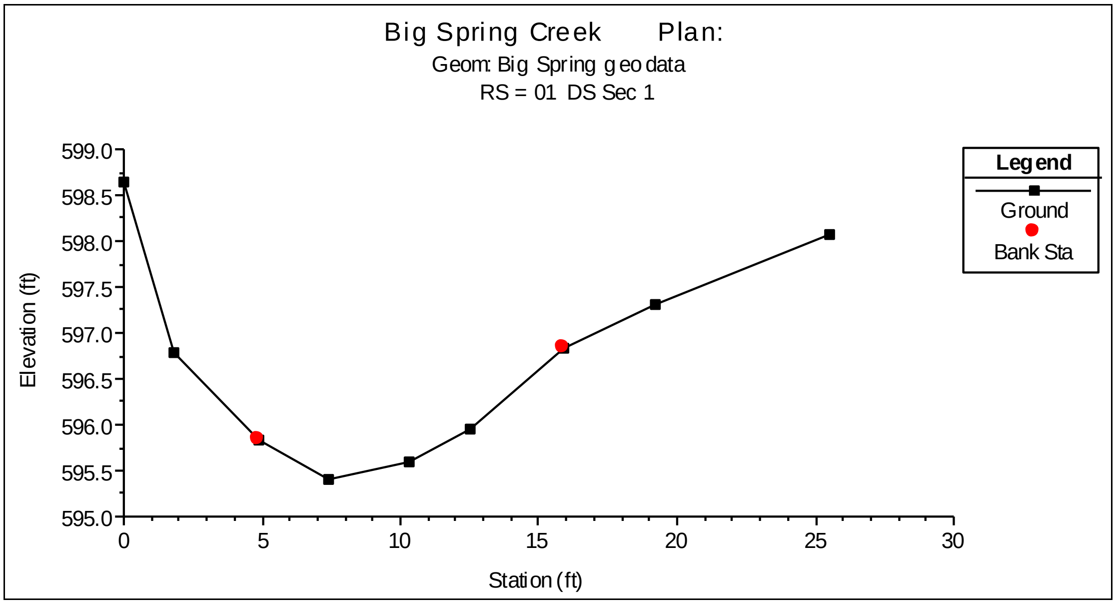

Figure 13-12. Characteristic downstream cross-section of Big Spring Creek
(Big Spring Creek location is seen in Figure 13-7)

13.4.1.2 Mullen Slough

The reach surveyed for Mullen Slough was a relatively straight, flat section 1,594 ft long with the survey equipment situated at GPS station N47.27.648 W122.15.663 (Mullen Slough E-1 to Mullen Slough C-1 in Figure 13-1) at elevation 31.0 ft above sea level. Figure 13-3 illustrated pre-maintained conditions in the lower segment of Mullen Slough (Mullen Slough C) at the Smith Brothers' Dairy. Figure 13-13 shows the same location after being cleaned.

Figure 13-13. Typical post-cleaned conditions at Mullen Slough (Figure 13-1, Mullen Slough C)

Approximately 184.4 m (604.9 ft) between Mullen C-3 and Mullen C-1 (the most downstream segment) was devoid of vegetation due to ongoing hand cleaning. The remaining 301.5 m (989.1 ft) between the Slough's confluence with Smith Brothers Reach C and Mullen Slough E-1 was clogged with reed canarygrass (RCG). The water surface elevation change of the vegetated portion from the far upstream point to the far downstream point was approximately 0.43 m (1.4 ft) for a slope of 0.14 % over the entire reach. The weeded portion had a water surface elevation change of approximately 0.0012 m (0.004 ft) over the 184.4 m (604.9 ft) length giving a slope of 0.00066 %. Typical cross sections for upstream and downstream directions can be seen in Figure 13-14 and Figure 13-15 respectively.

Mullen Slough's creek depth varied from approximately 1.04 m (3.4 ft) upstream to 1.10 m (3.6 ft) downstream with an average flow depth of 1.05 m (3.4 ft) over the entire survey length.

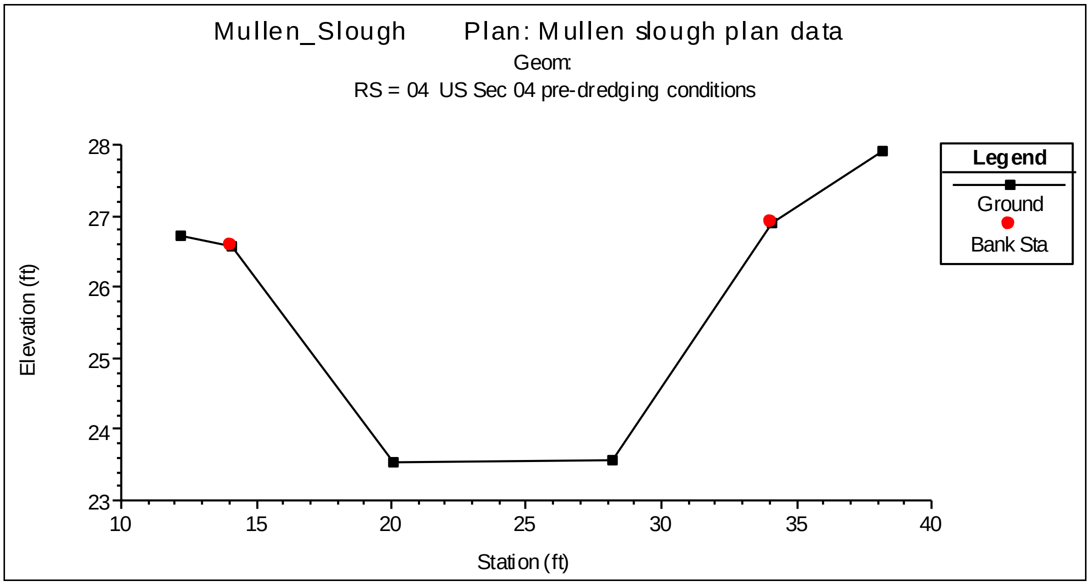

Figure 13-14. Characteristic pre-cleaned upstream cross-section of Mullen Slough

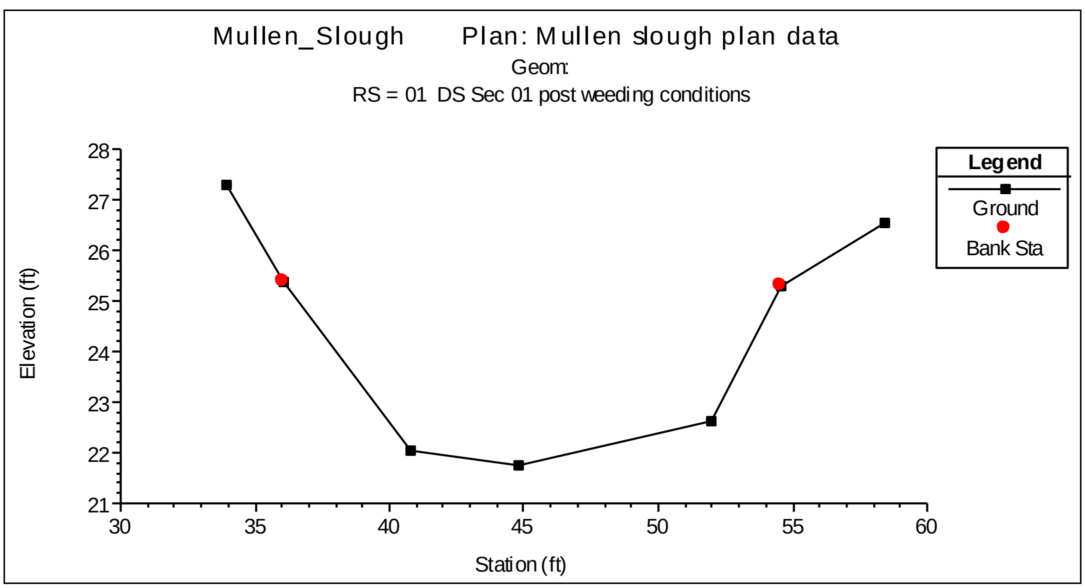

Figure 13-15. Characteristic post-cleaned downstream cross section of Mullen Slough

13.4.2 Flow Data

13.4.2.1 Big Spring Creek

In most areas the creek was clogged with thick vegetation consisting primarily of reed canarygrass. As illustrated in Figure 13-16 in one location, local livestock appeared to have cleared an area downstream from a small bridge. This was the location chosen for flow measurements. Discharge was determined to be 0.058 m^3/s (2.05 ft^3/s) and the maximum velocity was 0.25 m/s (0.81 ft/sec).

Figure 13-16. Stream gauging location on Big Spring Creek

13.4.2.2 Mullen Slough

Due to thick vegetation in Mullen Slough, the flow was not able to be measured using traditional stream gauging techniques. Employees of the Smith Brothers Dairy had weeded the reach downstream from the survey equipment which made flow observation more feasible. However the flow downstream was still not measured due to the thick silt approximately 1.2 m (4 ft) deep which caused the stream gauging equipment to jam. Flow was therefore estimated by taking the cross sectional area and one stream gauge data point. Discharge was determined to be approximately 0.0142 m^3/s (0.5 ft^3/s) at a maximum velocity of 0.034 m/s (0.11 ft/s) at the channel center. Sampling teams in July measured flow in the maintained reaches at 0.043 m^3/s (1.52 ft^3/s) downstream from an inflow source (Smith Brothers C). Researchers also attempted to measure in the un-maintained reaches but were unable to observe enough discernible flow for an accurate reading. This difficulty in measuring reliable values was taken into account, therefore flow inputs were considered approximate when Manning's n was being calculated. A summary of these values for both Mullen Slough and Big Spring Creek can be found in Table 13-1.

13.4.3 HEC-RAS Analysis

Manning's n values were determined from HEC-RAS simulations. Energy grade slopes were also calculated in HEC-RAS. See Table 13-1 for a summary of these results. Results from the waterway at Boscolo, Vilog, and Primero properties were not obtained because an accurate measurement of flow prior to maintenance could not be obtained.

Table 13-1. Results summary for Manning's n and energy grade slopes

Site Name	Maintained Status	Length (ft)	Energy Grade Slope (ft/ft)	Discharge (cfs)	Manning's n
Mullen Slough	Cleaned	604.9	0.000021	1.52	0.08
	Un-cleaned	989.0	0.0029	0.5	1.9
Big Spring Creek	Un-cleaned	683.0	0.011	2.05	0.41

The difference in slopes for both sites can best be illustrated by a longitudinal profile of the reach system. In Figure 13-17 the highly variable slope of the un-maintained Big Spring Creek site is shown. By contrast, in Figure 13-18 the cleaned portion of Mullen Slough has a much lower slope gradient beginning at River Station 03. Note the varied gradient upstream between stations 03 and 07 where cleaning operations had not yet begun.

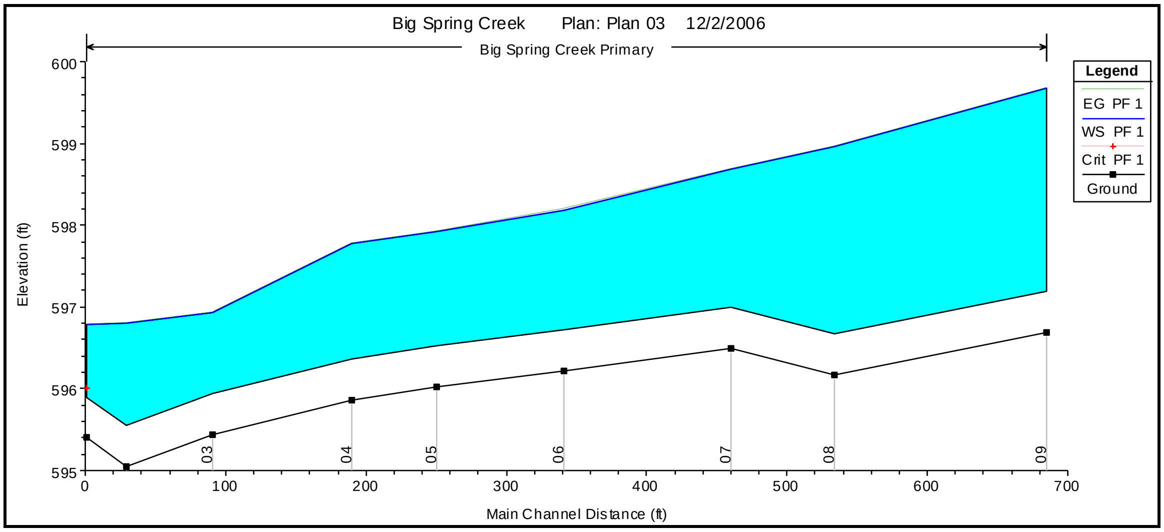

Figure 13-17. Longitudinal profile of Big Spring Creek showing a highly variable flow gradient throughout the un-maintained reach

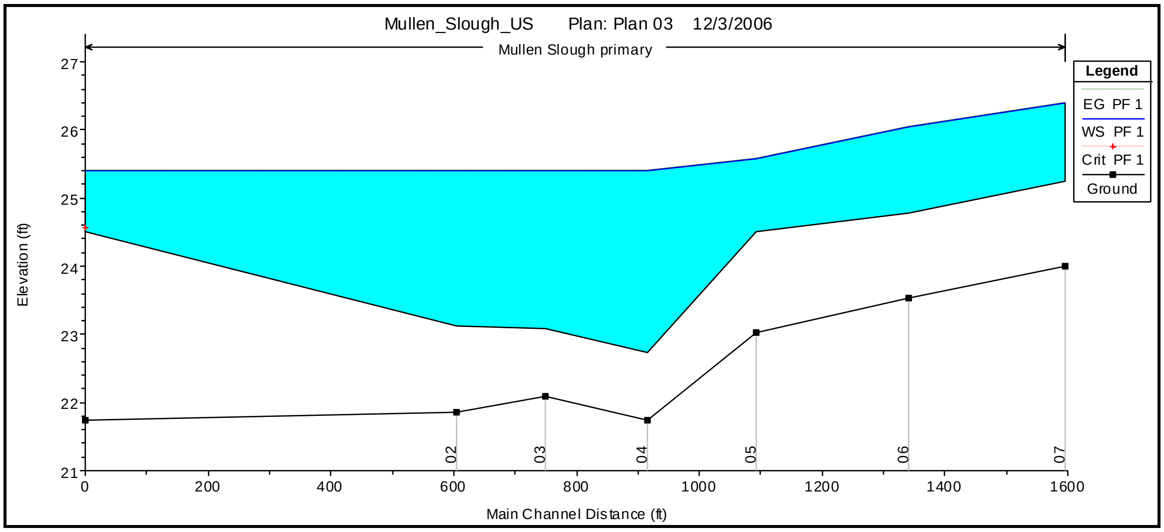

Figure 13-18. Longitudinal profile of Mullen Slough illustrating altered flow gradient as a result of cleaning operations

Note that the simulations are based on known sediment elevations which appear as a white space between the ground level and the water /sediment interface. The nature of the maintained reach sediment was that of a low-density silty medium with a high degree of decaying organic matter. Due to these characteristics the surveying prism protruded through the sediments resulting in a measurement of the firm watercourse bottom below.

13.4.4 Anecdotal Observations

Throughout the course of the study various alterations to channels and adjacent lands have been observed. The Smith Brothers' site provides a particularly applicable scenario of the effects of maintenance operations. Hand-and mechanical cleaning was undertaken on Mullen Slough in early summer of 2005 and took 5.5 months to complete. As a result, according to Jack Woods, Smith Brothers' site manager, the surrounding land became useable for agricultural purposes almost immediately and they were able to harvest crops for the first time in thirteen years. It is a bit unclear as to the impact of below-average precipitation on this outcome. Annual precipitation amounts recorded at both the Seattle-Tacoma International Airport and the Boeing Field Airport indicate that the 2005 water year (Oct 2004-Sep 2005) rainfall amounts were about 20% below normal. The first growing season following vegetation removal, Smith Brothers harvested livestock feed from their property and a neighbor planted pumpkins. Mr. Woods also noted the improvements to accessibility that the cleaning efforts provided, including the ability to reach parts of the property by motorized vehicle that previously had been too saturated to drive across. He also has not seen ponded or standing water on the property since cleaning commenced where prior there had been significant portions of the property rendered unusable by standing water. Mr. Woods was also impressed that after a recent flood event in King County (November, 2006 – conversation with Elizabeth Millburn) Mullen Slough drained out within two days while Mill Creek (an uncleaned reach in the same vicinity) was still at bank-full depth in late December. It should be noted that Mill Creek and Mullen Slough have very different channel and watershed characteristics but nevertheless, public perception is that the project was beneficial. Additionally, since cleaning operations commenced, the Dairy has been able to generate income off the land by leasing parcels to local growers who have continued harvesting pumpkins and hay where prior to watercourse maintenance activities the land was saturated.

WSU staff has noted changes as well, including an increased ability to gain access to certain reaches due to decreased saturation. Regions which were formally ponded have now drained significantly to the point where the areas could potentially be used for agricultural purposes.

13.5 Discussion

The discussion of results must be qualified by explaining the difference between maintenance procedures involving:

1) mechanical excavation resulting in the removal of vegetation only,
2) mechanical removal of both vegetation and sediment,
3) hand removal of vegetation only, and
4) hand removal of vegetation/sediment (rarely done).

In the first case, heavy equipment is used to remove the reed canarygrass and other unwanted vegetation and tree roots from the watercourse. In this case, most of the sediment is left in place leaving a high dissolved oxygen demand and relatively “soft” bottom. While immediate improvement of the hydraulics is expected, the regrowth of vegetation may be facilitated by the remaining sediments. In the second case, mechanical removal of vegetation and sediment, as depicted in Figure 13-19, results in a cleaner ditch and better overall water quality conditions (DO and BOD are improved) and a firmer bottom which may be beneficial to benthic organisms. The sides of the waterways may be bare and subject to erosion prior to establishment of new vegetation. In general, this is a much more invasive approach that can lead to downstream pulses of sediment if not adequately controlled. However, it is anticipated that this would need to be done less frequently than the other maintenance techniques. In the third case, hand removal of vegetation only produces the same basic conditions as case 1. Hypothetically, it might be easier to be more selective using this approach, even leaving some vegetation if short-term cover is deemed essential, but practically a crew removes most all the vegetation using hand-tools such as rakes and shovels. Because it is a slower process, there is less chance for larger disturbances than with mechanical excavation. The fourth case, hand removal of vegetation and sediment is very labor intensive and would result in conditions similar to case 2. We did not encounter any situations where this was implemented during our study.

Figure 13-19. Typical example of mechanically excavated removal of sediment and vegetation

The Manning's n values obtained in this study differ significantly from typically reported industry standards. Chow (1959) recommends a maximum roughness value of 0.120 for un-maintained excavated channels with dense weeds. By contrast, the channels in this study were demonstrating a range of 0.41 to 1.9 for Manning's n. These values, which are much greater than those used under standard conditions, illustrate the inability to apply typical equations to the agricultural waterways. The uniqueness of the hydraulic characteristics of an un-maintained agricultural channel dictates a higher level of measurement and analysis than similar non-agricultural waterways. Before modeling these reaches, a detailed survey should be conducted and used for roughness calculations as well as other relevant hydraulic parameters. Once the channels are maintained they begin demonstrating roughness characteristics in accordance with Chow's recommendations. He lists a maximum n value of 0.08 for excavated channels with clean bottoms and dense brush on the banks (Chow, 1959). The maintained portions of Mullen Slough possessed an average Manning's n of 0.08. This value is toward the high end of Chow's values, but considering the variability of measuring a channel undergoing drastic alterations it shows a remarkable fit.

The difference in water surface elevation, slope, and energy gradient for maintained channels suggests an increased drainage capability. The lowered uniform slope of the maintained reach will specifically provide greater flood drainage capabilities and improved fish passage. Similarly, a reach with a lowered surface elevation should be cooler than its vegetated counterpart leading to improved fish habitat.

Observed agricultural improvements at the Smith Brothers' site indicate increased drainage due to hand cleaning operations. This restoration of the land's agricultural purpose serves both the landowner and the surrounding community which has demonstrated an interest in maintaining agricultural activities in the valley. The subsequent discussion with the Smith Brothers' Dairy land manager identified the increased usability of the property and the generation of additional income as a result of the project.

13.6 Conclusions and Recommendations

Periodic cleaning of agricultural waterways has been quantitatively and qualitatively shown to significantly reduce the negative aspects of farmland flooding and improve the economics of agriculture in King County. Numerical modeling with HEC-RAS and roughness coefficients much greater than typical reported values has been shown to produce results that accurately match measured water surface elevations. The cause of this additional roughness at the study sites was the growth of excess reed canarygrass. This methodology and results developed by this work can be used in the future to predict the post-dredge water surfaces. The exact roughness value to use will depend on the level of RCG and sediment clogging the channel. There was insufficient information to develop a reliable means of estimating this as a function of RCG density or other metric, however, the relationship is clear. Hand excavation of the vegetation, even while leaving sediments in place, was responsible for dramatic reduction of the water surface.

A quick estimate of the drop in elevation may be obtained simply by examining the slope of the water surface. As shown at both sites, RCG and sediment are such impediments to the movement of water that a considerable head builds up in the system. Post-maintenance water surface elevations are much milder in slope. As was illustrated in Figure 13-188, the slope is significantly reduced even after hand cleaning. Thus Hypothesis 1 was disproved and the conclusion that vegetation removal will improve drainage of adjacent agricultural lands can be made. In addition, mechanical cleaning would likely improve the drainage even further. This is based on the fact that the Manning's roughness determined for Mullen Slough after hand excavation was still considerably higher than the n=0.050 value for "dredge channel with very irregular side slopes and bottom, in dark-colored waxy clay, with growth of weeds and grass" reported by Chow (1959).

Hypothesis 2 was effectively disproved by the results of the HEC-RAS modeling which demonstrate significant changes in hydraulic parameters as a result of dredging. The hydraulic and energy grade line slopes were shown to be reduced dramatically by a factor of more than 100 as the result of a significant decrease in headloss. Correspondingly, the roughness value (n) was reduced by a factor of over 20 (1.9 to 0.08 after maintenance). Higher headloss under pre-maintained conditions result in greater flooding potential as the resistance to flow moving through the channel will force the water level to rapidly rise upstream and find its way out of the channel. Increased roughness due to excessive RCG also contributes to flooding problems physically by decreasing the cross-sectional flow area which raises the surface elevation even further and causes additional flooding. As the water surface rises the wetted perimeter also increases which, when paired with a lowered cross-sectional area reduces the hydraulic radius thereby decreasing the available flow path. Maintaining the channel regularly eliminates these negatives and improves channel hydraulics.

The original question was to determine characteristic indicators indicating excavation will improve drainage. We must begin with the understanding that excavation is never detrimental to drainage. Therefore, what is being assessed is the need for excavation versus the level of improvement. The results of this research suggest the following three procedures could be used for determining when excavation will be appropriate:

1) slope of water surface elevation,
2) Manning's roughness coefficient,
3) HEC-RAS flood study.

The energy grade slope in a slow moving open channel is essentially equal to the slope of the water surface elevation since the velocity head ($V^2/(2*gravity)$) is negligible for velocities (V) less than 2 feet/second. A quick survey can identify when the water surface slope significantly exceeds the typical value for excavated conditions.

While insufficient data existed to determine a qualitative expression relating "n" to reed canarygrass density, there is a substantial reduction in roughness caused by the removal of vegetation. Waterways could be surveyed and discharge could be measured. If the resulting Manning's roughness exceeds a threshold value, then excavation is warranted.

If exact water levels are necessary, the research indicated that HEC-RAS could be used to predict resulting water surface levels. This would be the most time consuming of all the approaches and would require the most extensive amount of field data.

Setting threshold values for water slope or channel roughness is subjective and likely to be very sensitive to site location. A comparison of the un-cleaned energy grade lines for Mullen Slough and Big Spring Creek (0.0029 versus 0.011 ft/ft) illustrates this point. Furthermore, the economic benefits are expected to be highly variable depending on topography, hydrology (wet, dry, average), and land use. However, establishing base-line or target values for water surface slopes or Manning's roughness values is something that King County should work towards over time. Each time a waterway is excavated; this information should be collected and entered into a database so that site-specific comparisons can be made the next time.

13.7 References

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