Title
Post-project appraisal of Martin Canyon Creek restoration

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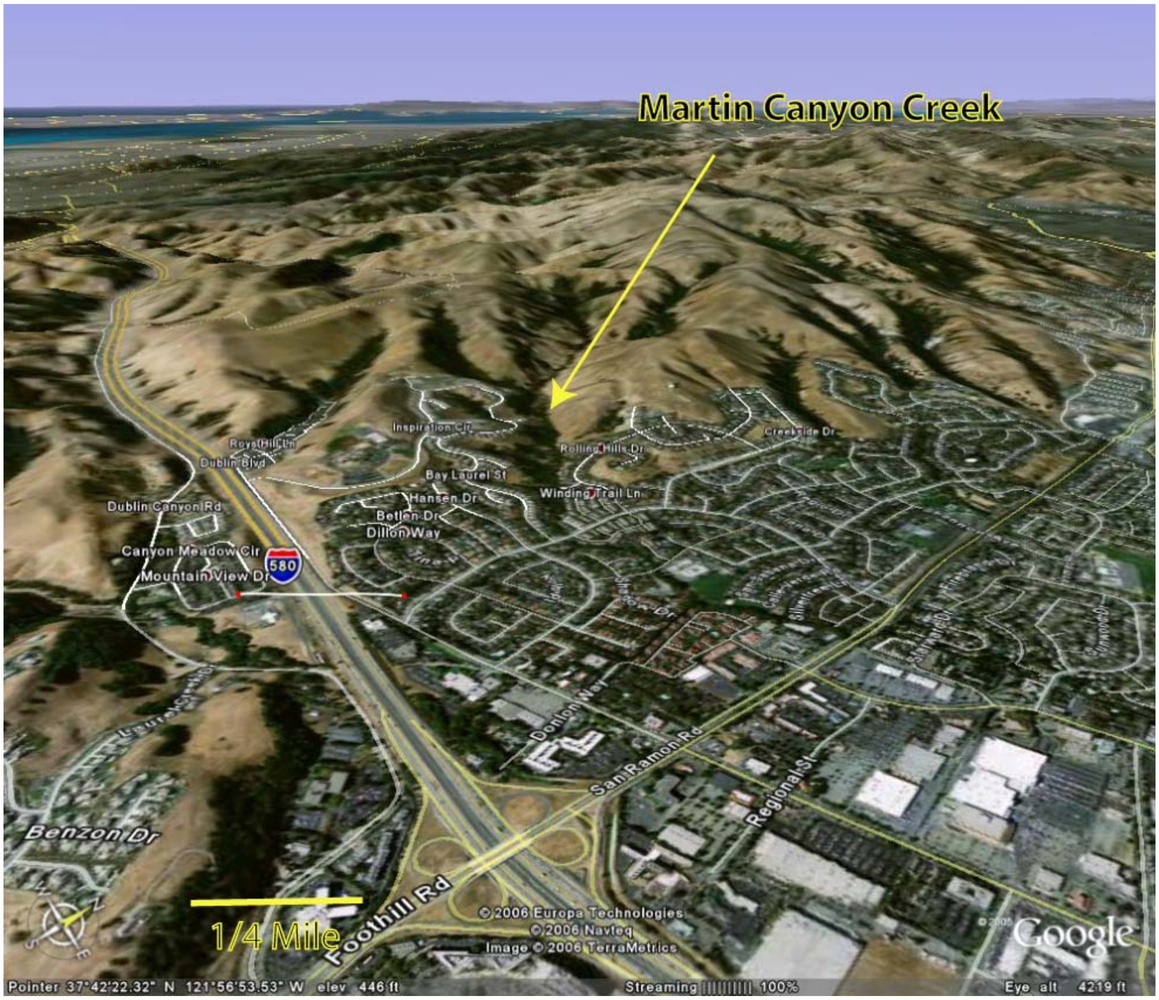
ABSTRACT

Located in Dublin, California, Martin Canyon Creek is a small tributary draining 1.08 square miles in the Alameda Creek watershed. In 1999 a restoration project consisting of gradient control and bank stabilization structures was completed. We conducted a post-project appraisal of the Martin Canyon Creek Restoration Project, comparing current conditions with the project's listed goals and as-built conditions. We surveyed a longitudinal profile and a selected cross section to compare current channel slopes and geometry with pre-project and as-built conditions. In addition, we took photos of grade control and bank stabilization structures at established photo monitoring points and compared them with as-built photos to qualitatively compare and evaluate performance of structural components of the project. Grade control structures appear to be stable and performing as designed, with significant local sedimentation upstream of most grade control structures. Grade Control Structure #4, however, shows significant signs of deterioration and could be prone to failure without maintenance in the near term. We suspect that the deterioration of this structure is related to its location in a bend and a high upstream channel slope, however further research is required to fully understand the performance of this structure. Bank stabilization structures are also performing in terms of protecting neighboring structures, although some show signs of deterioration. Overall the dynamic equilibrium slope that guided the design of the project appears to have been achieved with fewer structures than originally proposed.

INTRODUCTION

This paper presents a post project appraisal (PPA) of a 4400 linear foot project completed in 1999 in Martin Canyon Creek, Alameda Creek Watershed, Dublin, California. While it is alternatively referred to as the Martin Canyon Stream Stabilization project and the Martin Canyon Creek Stream Restoration in project documents, in this paper it is referred to simply as "the project." We performed this PPA approximately eight years after the project's completion to assess its performance relative to its stated goals of minimizing sedimentation in a downstream flood control project, preventing damage to adjacent facilities, maintaining the creek's natural character and ecology, and minimizing the costs of long-term maintenance. PPAs have been identified as an important component of stream restoration projects to assess problems and learn from mistakes.[1] Through this analysis therefore we also reach some general conclusions regarding the broader issue of the appropriateness of this type of hard infrastructure intervention in areas where development abuts a riparian corridor.



Project location

The impetus for the restoration project was the Hanson Hills housing development by developer Warmington Homes. Martin Canyon Creek, which borders Hanson Hills, flows into the J-3 flood channel, which is managed by the Alameda County Flood Control and Water Conservation District. Prior to development of Hansen Hills, the J-3 was experiencing sedimentation problems. Also similar creeks in the area had experienced channel incision and subsequent widening. Therefore the City of Dublin and Alameda County Flood Control and

[1] Tompkins, 2004

Water Conservation District required the developer to, "prevent the oversupply of sediment to downstream reaches, or threats to adjacent structures through channel erosion."[2]

RBF & Associates, an engineering firm, prepared the initial study of the project reach and watershed. They estimated flows in Martin Canyon for a 10-year event at 453 cfs, and a 100-year event at 795 cfs. Peak flow velocities for the 100-year event were estimated at 4-12 fps, with most reaches experiencing 8-10 fps. RBF also prepared the initial project design, which was based on Dublin's recommendation that creek flow velocities be reduced to less than 6 to 7 fps during the 100 year flood.

To reduce flow velocities, RBF's design proposed twenty check dams in the project reach to catch sediment through a stable channel slope. These dams were to be constructed of interlocking vinyl sheet piles.

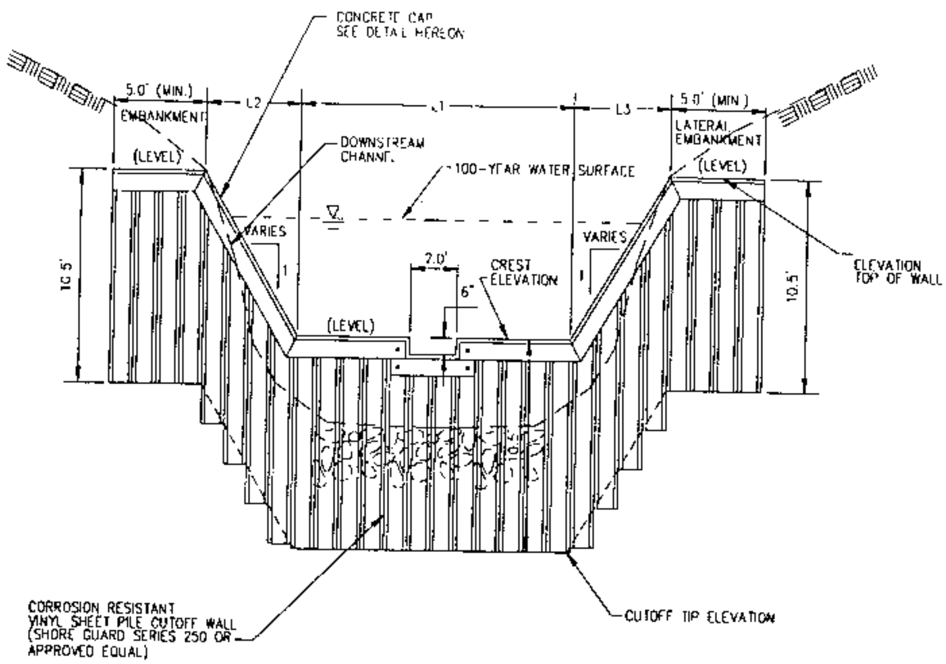


Figure 1: Example check dam design from RBF[3]

RBF also proposed rip-rapping almost 1200 feet of the project reach to protect structures near the creek by preventing stream meander.

The Regional Water Quality Control Board rejected this initial design as "overly structural," as it did not accommodate the natural geomorphic characteristics of the stream or

[2] Haltiner, p.1
[3] Phillips, undated

minimize construction impacts in the creek. It also wasn't "visually compatible with the natural stream aesthetics."[4] Therefore Warmington Homes turned to Philip Williams & Associates to determine a less intrusive plan. The new plan reduced the impact of the project by incorporating a more geomorphic perspective.

PWA Study and Re-design

The geomorphic approach of PWA had several characteristics. The design focused on the dominant discharge, identified as a 2-5 year event, rather than the major design flood. It was based on field observations, including erosion rates and a more specific focus on threatened structures. Finally, it incorporated a hydraulic model, which allowed for a less conservative design than a purely engineering based approach.

PWA first did a sediment budget, which estimated that most sediment entering the flood control channel came from outside the project reach. While sediment budgets are not exact, they do produce an order of magnitude estimate based on survey information. The sediment budget concluded that most of the incision, areas of extreme slope, erodable soil, and large nick points were upstream of the project reach. For example, while they identified a nick point with a 12-foot drop in the southern tributary upstream of the project site, the largest identified nick points in the project reach were only 1.5 feet. The slopes upstream range from ~5-10%, while in the project they ranged from ~1.3 - 2.6%, with an average of 1.7%. The estimate of sediment loads reflects this disparity. Of 50,000 cubic yards of sediment generated in the watershed, 6500 cubic yards or only 13% is from the project reach. When landslide sources are included it pushes the estimate to >90% from outside the project.[5]

[4] Haltiner, p.2
[5] Haltiner, p.9

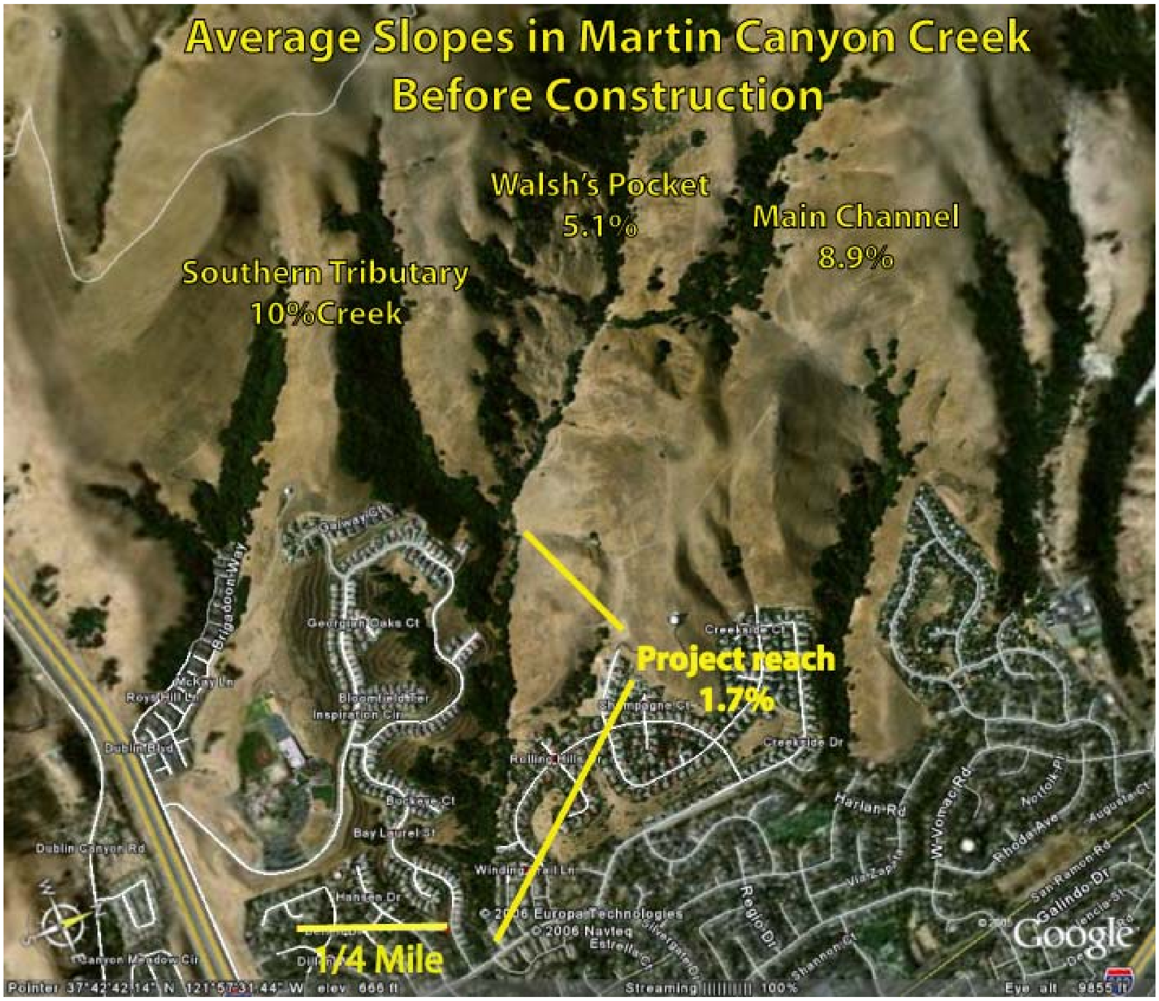


Figure 2: Average Slopes

PWA used this information to estimate the *dynamic equilibrium slope*, defined as the "Condition in which a given fluvial parameter {depth, width, sinuosity, etc} may change in any given year in response to climatic conditions or a change in another variable, but these alterations will vary around some mean or average condition, and not be progressive."[6] The figure for the dynamic equilibrium slope was estimated to be ≥1.15 %, which was the slope of an aggrading reach above the downstream culvert at the bottom of the project reach.[7]

Next they did a field survey that found less incision and meander than initially expected. Finally they incorporated a higher Manning's, raising the estimated roughness and thereby decreasing expected flow rates.

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[6] ibid, p.2
[7] Haltiner, p.12

Project Goals

The final design was based on accomplishing four main goals:[8]

1. *Minimize sedimentation in downstream flood canal*

Grade control structures were used and carefully placed to reduce sedimentation in the downstream flood control system through creation of the dynamic equilibrium slope. These structures were designed to capture sediment upstream and over time decrease average grade. A second role for these structures was to arrest the upward migration of incision. After installation, project designers expected that these structures would capture sediment upstream, thereby lowering the overall project reach slope. Overall eight structures were originally designed, with an additional structure GC3A added subsequently.

2. *Protect structures near stream meanders*

Another goal was to balance natural geomorphic creek properties of meander and erosion with the need to limit property loss and damage from these same processes. Therefore, the second intervention was aimed at arresting stream meander and channel migration, but only in areas near housing development, adjacent fences and access roads. To accomplish this goal, project designers armored the outside banks on meanders that came within 30 feet of development. 19 erosion control structures of 4 general types were installed. They were constructed of erosion control fabric, overlaid by rock armoring, and keyed into the slope and toe of the bank. This reduced the extent and aesthetic impact of the original RBF design for 1200 feet of rip-rap.

3. *Maintain creek's natural character and ecology*

The expected flow rates were decreased from RBF's by using a more localized analysis and less of an "engineering approach."[9] Engineering approaches are generally conservative and safety based. The new design changed the old design of the grade control structures from vinyl to boulder drop structures in an effort to address aesthetic concerns. Where available, local rocks were used for structure construction. The design also added rock lined scour pools to reduce cascading water energy. Locations for grade control structures were identified through threshold criteria, which allowed scaling down the size of the project to 9 boulder check dams.

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[8] "Stabilization Strategy" Haltiner, p.11

[9] PWA P.4

4. Minimize costs of long-term maintenance

Although they proposed "setback protection" outside the current bank in areas where shear stress may at some point bring a meander near a structure or road, they didn't construct any setback protections of this type. They also built several storm drain outlets which would reduce future issues from runoff. The final design was chosen for its ease, low cost, and longer life. Overall these adjustments allowed for a higher average slope and thereby fewer grade control structures.

METHODS

To assess the effectiveness of the project relative to PWA's identified goals, we employed several different methods:

Goal 1: Minimize sedimentation in downstream flood canal

PWA designed grade control structures to capture sediment and arrest the upward migration of incision. To measure performance in this regard, we did a long profile of the creek and compared it to PWA pre-construction and as-built surveys. We also performed a visual analysis of these structures to look for signs of degradation, instability and scour. To document current conditions and standardize our comparison with pre-built conditions, we compared photographs from our field survey to photos taken during the original construction from the same vantage points. In addition, we performed one cross section in the section upstream of GC3A, as the area below GC4 was where we expected the most issues due to the performance of GC4. This was compared to an as-built cross section at the same location.

The benchmark for our long profile was the upstream end of the culvert which goes below Silvergate Drive, at the lower end of the project reach. The elevation at this point was given as 407 feet in the project documentation.[10] The pre-built survey however used this elevation at station 0, which was 675 feet downstream of the culvert (Figure 3). Both the pre-built and as-built surveys place GC1 in the same equivalent location, near station 1970, showing that the stationing appears consistent between the two. For comparative purposes, we therefore adjusted the pre-built survey using 407 feet for the elevation at its station 675, with the remaining upstream values adjusted accordingly. Despite the adjustments, the pre-built survey was still higher than the as-built (Figure 4). While this difference could be due to erosion during

[10] Figure C1, PWA

the high flows in 1998 between the two surveys, it could also be some undetermined difference in surveying techniques.

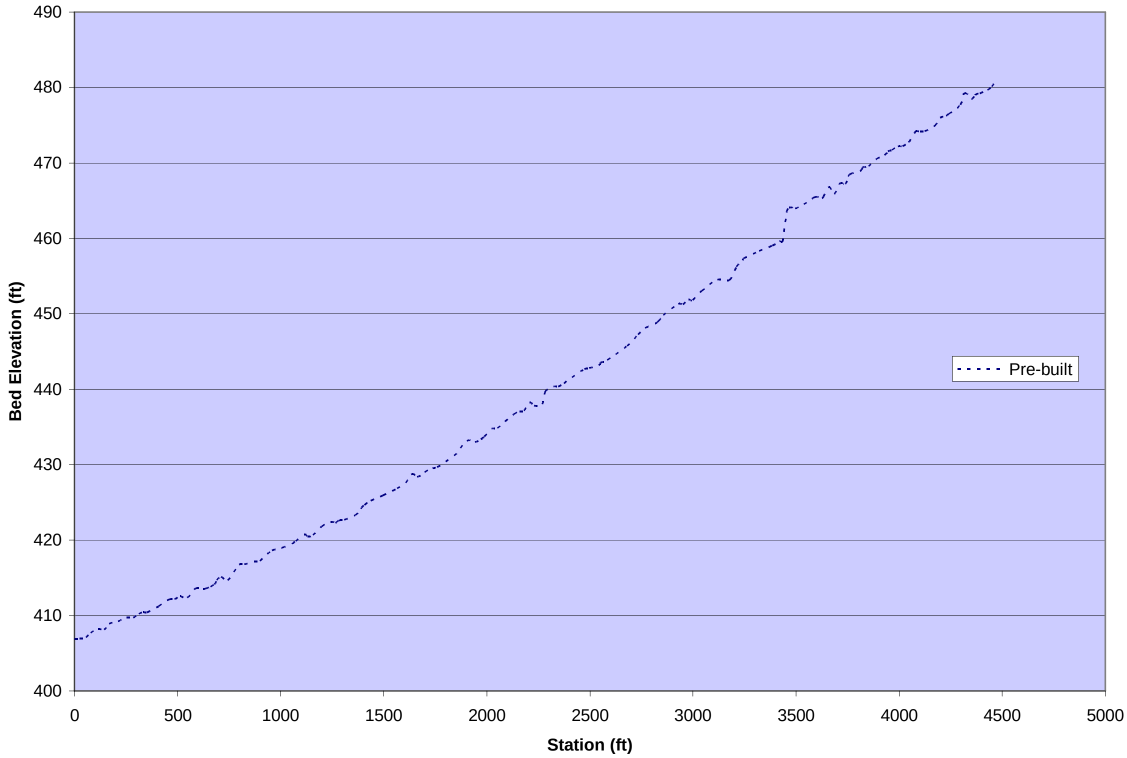

Figure 3: Pre-built long profile (unadjusted)

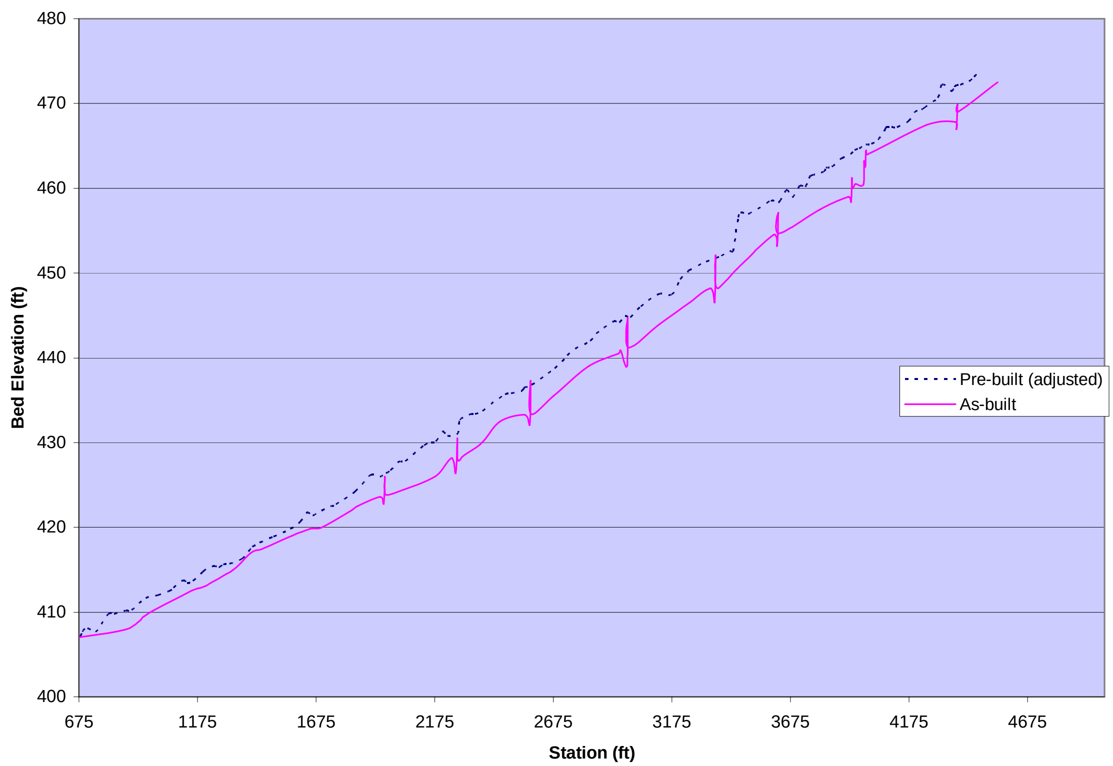

Figure 4: Pre-built (adjusted) vs. As-built long profile

We used a transit level, stadia rod, and hip chain for the survey. We surveyed at major grade changes as well as locations upstream, downstream, and in the low flow notch of the grade control structures. For the station of the stadia rod, we used a hip chain that recorded distance upstream. To assess change as a result of the new grade control structures, we calculated slope by measuring rise from upstream of a structure to downstream of the next grade control structure upstream over the adjusted run for this same length. Our stations were adjusted to fit the as-built stationing by dividing our distances between stations with as-built distances for the same reach. (See Appendix 1 to see the unadjusted profile). As-built values between the grade control structures were estimated from the as-built long profile graph.[11] We calculated the average slopes over the as-built sections of the creek from the notch at the top of one control structure to the spot just below the next structure.

There are some notes on our methods. The project reach was steep, requiring many turning points, and possibly introducing small amounts of error. We were not able close the survey to determine the extent of error, but the results in terms of stationing and elevation appear accurate. There was rain between the two days of the long profile survey. Water depths upstream of GC1 were taken on the second day, adding a slightly increased water height. Also, we used a hip chain to determine stationing. This method doesn't follow the creek thalweg exactly, possibly explaining differences between our survey and the as-built.

Our average slopes between the grade control structures were calculated between the lowest surveyed point upstream of the notch and the furthest upstream point still downstream of the plunge pool. The distances for some values were therefore 50-100 feet away from the grade control structures.

With these notes in methodology, our results reflect what we consider an accurate comparison of the long profiles between the two periods, how the channel slope has changed, and whether the dynamic equilibrium slope for the project reach was accurately estimated by the project designers.

Goal 2: Protect structures near stream meanders

PWA used boulders over erosion fabric to armor the outside banks on meanders that came within 30 feet of developments. To measure the performance of these structures we performed visual and photographic analyses similar to those on the grade control structures.

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[11] Figure C1, PWA

Primary structural issues that were noted included rock stability, visibility of erosion fabric, and evidence of scouring or undercutting.

Goal 3: Maintain creek's natural character and ecology

Using the visual/photographic analysis performed to assess goals 1 and 2, we were able to qualitatively assess the effectiveness of this project at limiting its effect on the stream's natural aesthetic value.

Goal 4: Minimize costs of long-term maintenance

This goal wasn't directly measured, but we make a general assessment of the effectiveness of the project, and how future maintenance may be required.

We also took measurements at each grade control structure of the average height, intermediate axis of the five largest rocks, deepest point of the plunge pool, low flow notch height, and bank width. These figures will be useful to ongoing step stream research at Texas A&M University, but aren't directly analyzed for this paper. [12]

RESULTS

Goal 1: Minimize sedimentation in downstream flood canal

Directly upstream of the grade control structures, the stream bed is aggrading, with fine sediments collecting and visible (Figure 5). The long profile matches that expected by the project designers (Figure 6). Directly below grade control structures however the opposite trend is occurring with localized degradation. This could just be the effect of the plunge pools, but the results are more extensive than just these small areas (Figure 7).

Figure 5: Aggradation upstream of GC1

[12] Chin, 2005

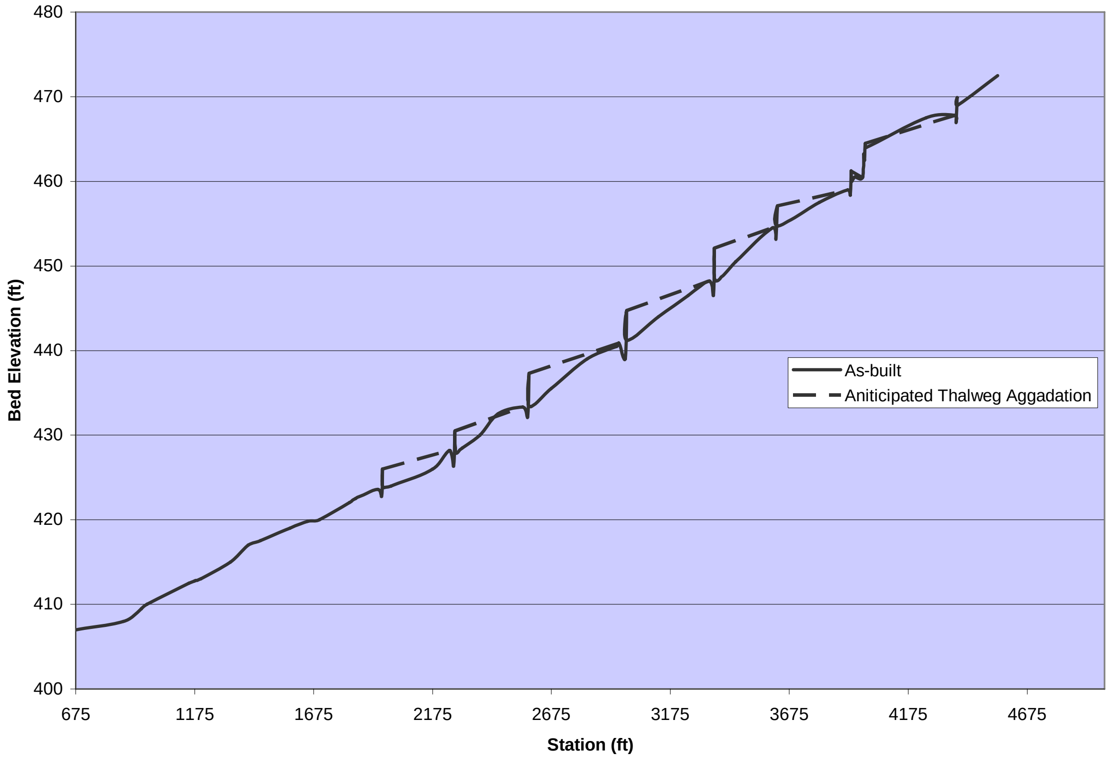

Figure 6: Expected post construction long profile

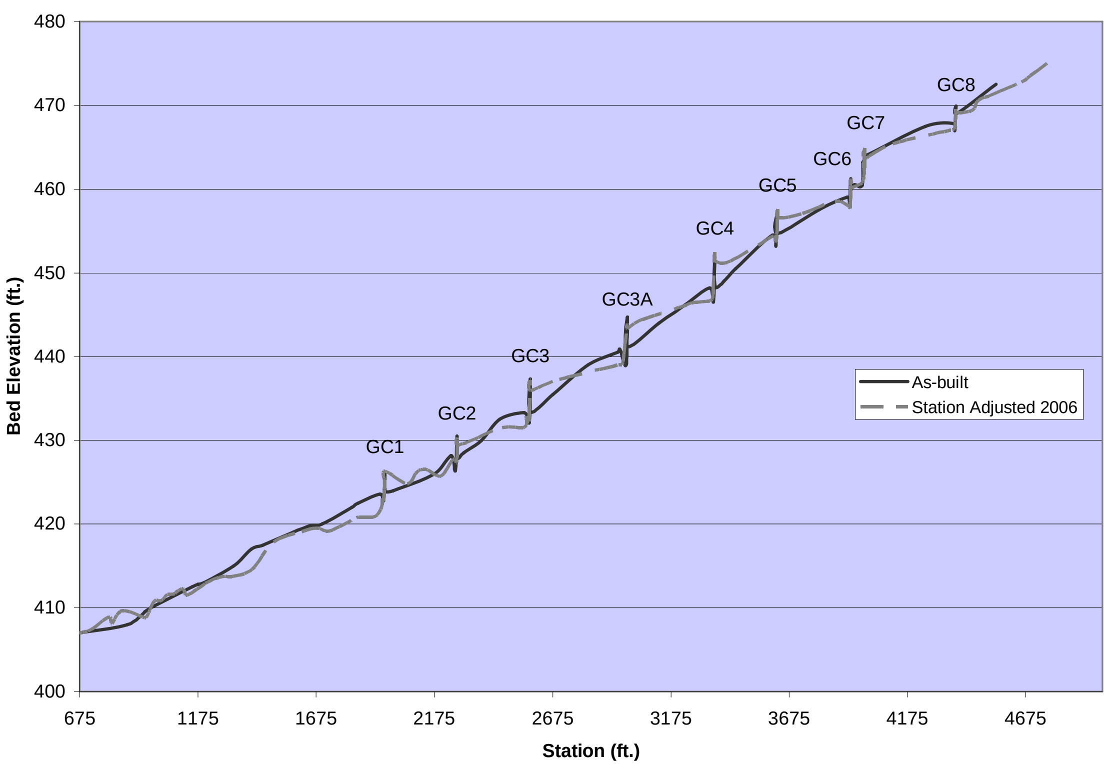

Figure 7: As-built vs. 2006 survey (adjusted)

A small amount of deposition has occurred in the bed in the cross section between grade control structures 3A and 4 (Figure 8). This is probably due to the formation of a point bar and some movement of the thalweg.

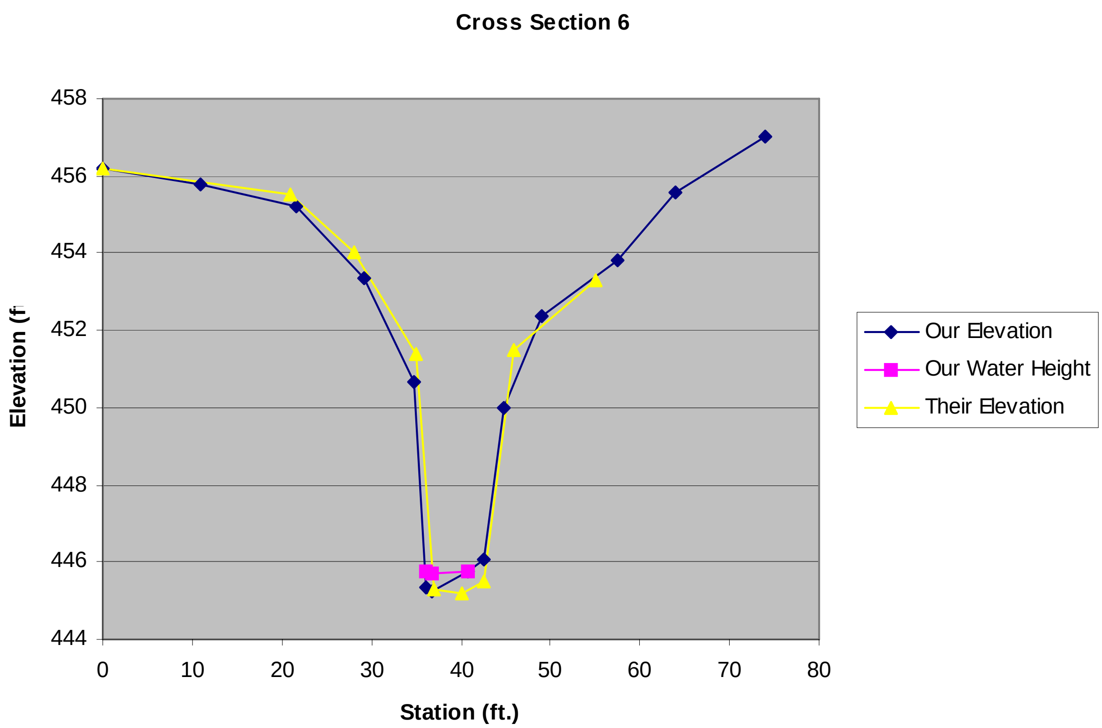

Figure 8: Cross section below GC4

The slope in seven of the eight measured reaches between the structures has decreased. The other slope shows minimal change. Six of nine of our measured slope values are below the projected value for the dynamic equilibrium, 1.15%. One is close, and the final one is above but still within a range given by the designers as approximating the dynamic equilibrium slope.[13] These values are also close to the expected post construction slopes, showing that at least for values this goal was achieved.[14]

[13] .75-1.5% PWA, p.4
[14] PWA, p.4

	Channel Slope US of Structure		
Structure	1999	2006	Change
Culvert at Sivergate Drive	1.31%	1.16%	-0.15%
GC 1	1.55%	1.18%	-0.37%
GC 2	1.91%	0.75%	-1.16%
GC 3	1.99%	0.72%	-1.27%
GC 3A	2.03%	0.94%	-1.09%
GC 4	2.53%	0.70%	-1.83%
GC 5	1.47%	1.41%	-0.06%
GC 6	0.87%	0.71%	-0.16%
GC 7	1.02%	1.08%	0.06%
GC 8*	2.08%	1.58%	-0.50%

* Approximate

Table 1: Channel slopes for as-built compared to station adjusted 2006

The visual and photo analysis largely supports this result, the majority appearing stable with a minimal amount of displaced rocks and scour (See figure 9 as an example and summary in Appendix 2). Grade control structure 4 however has many issues. The right and left banks have scoured downstream below the wing walls. A large number of rocks have washed out and are now downstream of the structure. This was the only grade control placed in a bend and was constructed in half the time of other structures using a different method. Interestingly the designers stated that as the entire width of structure 4 was installed simultaneously, it is likely that it would "possess greater structural integrity."[15] Its stationing was 135 feet upstream of its original placement on plans. It also had the most significant change in upstream slope, from 2.53 to .7%, a change of 1.83%.

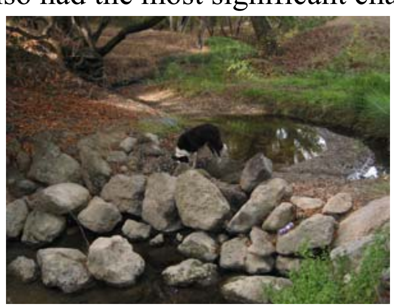

Figure 9:GC2 from downstream appears stable

[15] PWA, p. 10

Figure 10 and 10a: GC4 from downstream with rocks in channel and sides eroded

Goal 2: Protect structures near stream meanders

The bank stabilization structures appear to be largely intact and functioning (See figures 11 and 12, and Appendix 3 for complete notes). The most common problems with these structures were endcutting on the upstream end and loss of rocks. In addition, quite a few had exposed erosion fabric.

Structure 16 was designed to drain the ranch road into the creek and prevent erosion. The erosion fabric and rocks placed to prevent erosion have not performed however, and a large nick point is moving up this drain towards the ranch road (See figure 13).

Figure 11: Upstream of Structure 7 1999 vs. 2006

Figure 12: Upstream of structure 3 1999 vs. 2006

Figure 13: Structure 16 storm drain

Goal 3: Maintain creek's natural character and ecology

The erosion fabric is visible on most of the structures in the creek, and the rocks used to create the structures are larger than would be naturally found in the creek. However, streamside vegetation has grown near and around these structures, limiting their aesthetic impact.

Goal 4: Minimize costs of long-term maintenance

There is some amount of maintenance that is required, particularly on GC4 and Structure 16. Should one of these fail there would be further cost than if they were fixed. Overall the structures do appear to be functioning as designed, resulting in a minimum of maintenance costs. This is further explored in the Conclusions.

CONCLUSIONS

From an engineering standpoint, the project has performed largely as designed. Grade control structures have resulted in a decrease in the average slope, and an accumulation of sediment upstream of structures. There are no notable areas of incision, with the exception of downstream of GC4. This result is qualified though by the change in the profile below each of the grade control structures. Aggradation upstream of the grade controls is being balanced by incision downstream (See figure 7). The targeted figure of the dynamic equilibrium slope has therefore been achieved, but appears to be resulting in degradation below grade control structures. This is most apparent in the instability and scour in GC4. This tendency for "hungry water" to erode the channel until sediment filled in was identified in the project documents, as was the importance of monitoring until equilibrium conditions were achieved.[16]

The goal of minimizing sedimentation in the downstream flood control channel has largely been eliminated from the project goals with the identification of most sedimentation coming from outside the project reach. Therefore the significance of the capture of sediment above the grade control structures isn't so much reducing downstream sedimentation as it is reducing incision and stabilizing the project reach.

This project was also driven by the goal of protecting structures within 30 feet of creek meanders. The structures near the creek have not been harmed since the project went in, but it is not clear whether the creek would have meandered enough to create instability in these structures. Comparisons with non-banked reaches show a significant difference, but still raise the question of whether the structures are necessary or overly cautious.

From an environmental and aesthetic point of view, the project is certainly an improvement over the original, "overly structural" RBF design. The stream has not meandered near bends that are reinforced with erosion control structures. Although the design called for using rock instead of vinyl sheets for the grade control and bank stabilization structures, they still use erosion fabric. This fabric is now shredded or revealed in many locations throughout the project reach, which is aesthetically unpleasing. Overall the project is not, however, aesthetically unattractive nor does it appear unnatural or out of place.

The long-term effects of this project are dependant on the survival of the structures, although it is not clear that they were an absolute necessity. The project has not yet experienced flows above 5-10 year floods, and yet GC4 is already showing significant signs of wear.[17] If any were to fail, the effects could override any positive effects they have so far created. GC4 seems to be the most vulnerable. The scour near GC4 may be the reason GC3A was added to the project, as early documents did not include this structure. GC4 is the only one that is built in a bend in the stream, contradicting PWA's specifications regarding building grade control structures only in straight reaches.[18] While more study is needed, one could assume that this has played some role in its progressive scour. If this structure were to fail, the slope in the channel could change dramatically in a relatively short period of time, establishing a new dynamic

[16] PWA, p.5
[17] Comparison with flows in Alameda Creek, Appendix
[18] PWA, p.8

equilibrium slope. For this reason the reduction of stabilization and grade control structures from the RBF to PWA design was beneficial, unless degradation of GC4 means that the dynamic equilibrium slope was not attained. Therefore, although the project appears to have achieved its goal, it is not clear whether the new dynamic equilibrium slope will be maintained in the future.

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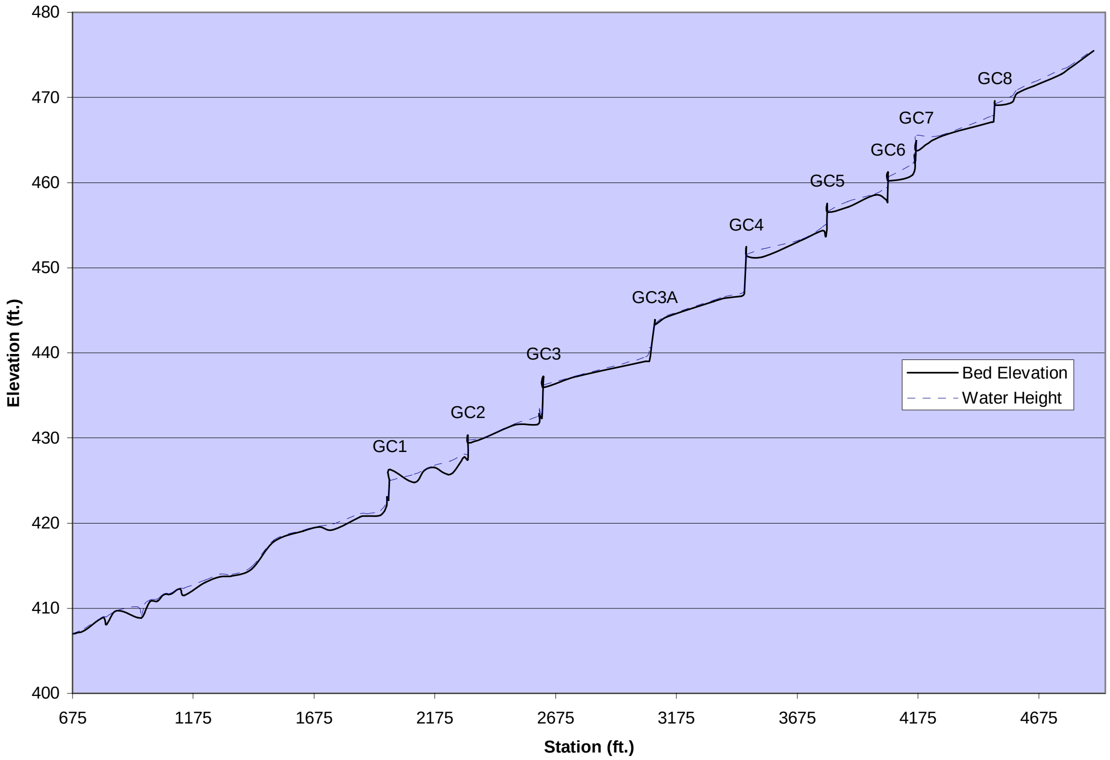
APPENDIX



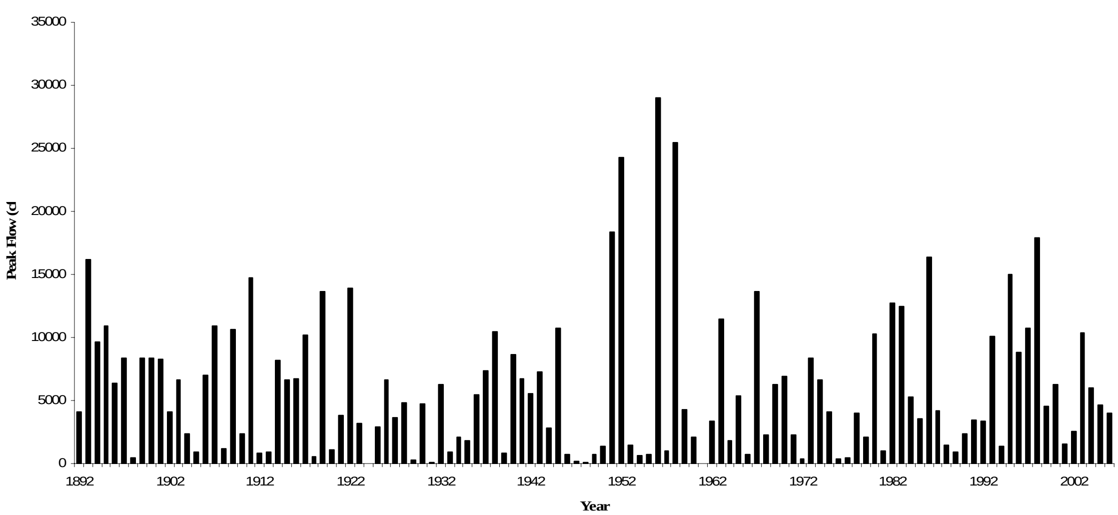
Appendix 1: 2006 unadjusted long profile with water height

Grade Control Structures	
Structure	Notes
GC1	Left bank scour US & DS, boulders in channel, roots visible US
GC2	Three boulders DS in channel, roots holding above, deposition of fines
GC3	Right bank scour US, plunge pool rocked in, sedimentation US, 2nd rock step created, wings unstable
GC3A	Left bank scour DS, erosion fabric visible, right bank blackberries, rocks accumulate US of bridge
GC4	Left bank major scour DS to WW, right bank scour DS to WW, erosion fabric exposed, rocks accumulating DS, metal junk in plunge pool, aggrading fines above
GC5	Left bank scour DS & US, US tree holding on, erosion fabric visible DS, log jam DS, incision US
GC6	Left bank scour DS of WW, erosion fabric visible, right bank scour 30' DS
GC7	Rock movement DS, erosion fabric visible, right bank scour US, right WW scour
GC8	Left bank erosion fabric visible DS, right abnk scour DS, right bank flanking & scour US

Appendix 2: Grade control structure notes

Bank Stabilization Structures	
Structure	Notes
2A	No visible problems.
2B	Endcutting on US end.
3	Erosion in middle.
4	No visible problems.
5	Some rocks fallen out around base.
6	DS collapsing, erosion fabric visible, stream starting 2nd channel
7	Erosion fabric visible, opposite right bank being undermined
8	Logjam gone, some rocks fallen out, large roots visible in bed, vinca patch
9	DS tree now in stream, erosion fabric exposed on top
10	Fill gradually falling away.
11	DS scour, scour below tree roots, erosion fabric visible above, scour at toe
12	DS minor scour, US right bank roots unstable, right bank native grasses?
16	Significant degradation, erosion fabric visible and torn, incision up
17	Covered by blackberries
18	Left bank DS scour (5-6 rocks by orange tag), US erosion fabric visible
19	Less steep slope US of structure
20	Erosion fabric visible US at toe, some rocks in channel
21	Rocks created GC 100' DS, scour right bank, scour at apex, 18" rocks in channel

Appendix 3: Bank Stabilization Structure Notes



Appendix 4: Alameda Creek Peak Flows

Appendix 5: Long Profile raw data

Station	Distance	FS	BS	WD	HI	Bed Elevation	WH	Notes
Setup 1					417			
0	675		10			407	407	From flood apron, by middle metal bar
49	724	9.62		0.25		407.38	407.63	Bottom of Riffle
126	801	8.12		0.1		408.88	408.98	Top of Riffle
140	815	8.9		0.88		408.1	408.98	Pool
182	857	7.32		0.02		409.68	409.7	gravel Bar/Braided
270	945	8.12		1.3		408.88	410.18	Pool
Setup 2					424.32			
270	945		15.44	1.3				Pool
284	959	15.46		0.25		408.86	409.11	Bottom of riffle
298	973	14.9		1.06		409.42	410.48	Pool
322	997	13.5		0.19		410.82	411.01	Top of Riffle
352	1027	13.46		0.2		410.86	411.06	Bottom of riffle
378	1053	12.72		0.09		411.6	411.69	Top of Riffle
405	1080	12.66		0.09		411.66	411.75	Bottom of riffle
445	1120	12.06		0.11		412.26	412.37	Top of Riffle
463	1138	12.82		0.89		411.5	412.39	Pool
550	1225	11.28		0.29		413.04	413.33	Pool
Setup 3					425.94			
550	1225		12.9	0.29				Pool
613	1288	12.22		0.29		413.72	414.01	Top of riffle
660	1335	12.14		0.2		413.8	414	Bottom of Riffle, Creosote X-section
742	1417	11.32		0.29		414.62	414.91	Bottom of Riffle
Setup 4					428.04			
742	1417		13.42	0.29				Bottom of Riffle
835	1510	10.2		0.19		417.84	418.03	Gravel bar 2, Apex of 2nd oxbow, Cairn
956	1631	8.96		0.09		419.08	419.17	Middle of structure "9"
Setup					431.66			

5								
956	1631		12.58	0.09				Middle of structure "9"
1020	1695	12.12		0.1		419.54	419.64	US end of structure 9
1077	1752	12.46		0.68		419.2	419.88	Pool BOR
1191	1866	10.94		0.38		420.72	421.1	Bottom of structure
1219	1894	10.84		0.29		420.82	421.11	Apex of structure, fill area
Setup 6					433.48			
1219	1894		12.66	0.29				Apex of structure, fill area
1274	1949	12.54		0.53		420.94	421.47	Pool at BOR
1300	1975	11.46		0.48		422.02	422.5	Bottom of low step
1301	1976	10.42		0.02		423.06	423.08	Top of low step
1307	1982	10.78		0.4		422.7	423.1	Pool between steps
1309	1984	10.78		0.46		422.7	423.16	Bottom of top step
1313	1988	8.66		0.2		424.82	425.02	Top of top step channel
1312	1987	8.36		0		425.12	425.12	Turning Point
1312	1987	8.5		0		424.98	424.98	Possible intended notch, right side
Setup 7	(Sat.)				435.98			
0			10.86	0.01			0.01	
101	2088	11.19		0.94		424.79	425.73	Pool
146	2133	9.78		0.07		426.2	426.27	TOR
155	2142	8.82				427.16	427.16	TP
Setup 8					435.96			
			8.8					TP
186	2173	9.43		0.25		426.53	426.78	Gravel bar, TOR Tributary RB from bridge
252	2239	10.25		1.6		425.71	427.31	Pool
308	2295	8.21		0.35		427.75	428.1	TOR below GC2
324	2311	8.53		0.64		427.43	428.07	DS GC2
325	2312	6.43		0.14		429.53	429.67	Notch GC2 TP

Setup 9								
			10.1		439.63			TP
326	2313	10.2		0.34		429.43	429.77	US GC2
388	2375	9.68		0.08		429.95	430.03	BOR ~XS St.
519	2506	8.1		0.16		431.53	431.69	TOR TP
Setup 10					447.28			
			15.75					TP
613	2600	15.71		0.98		431.57	432.55	Pool Bottom DS Lower step
620	2607	14.42		0.62		432.86	433.48	Top Lower step
632	2619	14.93		0.4		432.35	432.75	Pool
638	2625	11.3		0.2		435.98	436.18	Notch GC3
639	2626	11.32		0.26		435.96	436.22	US GC3
777	2764	10.02		0.1		437.26	437.36	TOR TP
Setup 11					453.6			
			16.34					TP
1060	3047	14.6		0.52		439	439.52	TP
Setup 12					453.17			
			14.17					TP setup on bridge
1075	3062	14.17		1.62		439	440.62	Pool DS GC3A
1082	3069	13.14		0.61		440.03	440.64	Bottom GC 3A
1099	3086	9.92		0.19		443.25	443.44	Notch GC3A
1100	3087	9.86		0.18		443.31	443.49	US GC3A
1149	3136	8.94		0.15		444.23	444.38	MOR
Setup 13					458.73			
			14.5					TP(releveled from 14.35), positioned
1341	3328	12.7		0.13		446.03	446.16	Pool
1387	3374	12.3		0.18		446.43	446.61	TOR TP
Setup 14					461.72			
			15.29					TP
1457	3444	15.05		0.33		446.67	447	DS Rock Jumble
1468	3455	14.72		0.35		447	447.35	Bottom GC4
1477	3464	10.67		0.13		451.05	451.18	Notch GC4
1479	3466	10.35		0.18		451.37	451.55	US GC4
1545	3532	10.47		0.95		451.25	452.2	Pool TP
Setup 15					457.84			
			6.59					TP
1708	3695	4.56		0.1		453.28	453.38	Gravel bar by outfall LB
Setup 16					469.74			

			16.46					TP
1792	3779	15.36		0.4		454.38	454.78	Bottom Lower Step GC5, Logjam Redo Counter
1805	3792	16.09		1.45		453.65	455.1	Pool Between
1811	3798	14.75		0.12		454.99	455.11	DS GC5
1812	3799	13.5		0.2		456.24	456.44	Notch GC5
1816	3803	13.2		0.1		456.54	456.64	US GC5
1898	3885	12.64		0.68		457.1	457.78	Pool, Newt
Setup 17					476.2			
			19.1					TP
2009	3996	17.65		0.15		458.55	458.7	
Setup 18					477.98			
	3987		19.43					TP
2056	4043	20.02		1.45		457.96	459.41	Pool DS GC6
2062	4049	20.28		1.75		457.7	459.45	DS GC6
2063	4050	17.66		0.18		460.32	460.5	Notch GC6
2066	4053	17.75		0.45		460.23	460.68	
2165	4152	17.05		1.35		460.93	462.28	Pool DS GC7
Setup 19					473.63			
			12.7					TP step pool
2172	4159	10.39		0.17		463.24	463.41	lower notch
2174	4161	11.35		1.2		462.28	463.48	Pool
2177	4164	10.87		0.7		462.76	463.46	DS GC7
2180	4167	9.45		0.37		464.18	464.55	Upper notch GC7
2182	4169	9.9		1.83		463.73	465.56	US GC7
2280	4267	8.21		0.1		465.42	465.52	TP
Setup 20					483.6			
			18.18					TP
		11.2				472.4	472.4	TP
Setup 21					481.23			
			8.83					TP
2493	4480	14.13		0.73		467.1	467.83	Pool DS GC8
2501	4488	14.05		0.74		467.18	467.92	DS GC8
2505	4492	12.51		0.22		468.72	468.94	Notch GC8
2509	4496	12.11		0.14		469.12	469.26	US GC8
2575	4562	11.82		0.76		469.41	470.17	Pool by St.
2600	4587	10.68		0.37		470.55	470.92	TOR
2667	4654	9.9		0.5		471.33	471.83	DS St.
Setup 22					488.95			
			17.62					TP
2782	4769	16.2		0.53		472.75	473.28	Pool in bend
2811	4798	15.61		0.3		473.34	473.64	DS gravel, by big rock
2914	4901	13.45		0.19		475.5	475.69	MOR

Setup 23					495.05			
			19.55					
2945	4932	15.82				479.23	479.23	cairn BM

Appendix 6: Cross section raw data

Cross Section 6							
Station	BS	FS	HI	WD	Elevation	WH	Description
	5.73		461.93				
0					456.2		Ground near rebar
11		6.16			455.77		
21.6		6.71			455.22		
29.1		8.6			453.33		
34.7		11.24			450.69		Top of Left Bank
36.1		16.6		0.42	445.33	445.75	Bottom of Left Bank
36.7		16.67		0.47	445.26	445.73	Thalweg
40.8		16.18		0	445.75	445.75	Edge of Water
42.6		15.85			446.08		Edge of Right Bank
44.9		11.96			449.97		Top of Right Bank
49.1		9.56			452.37		
57.6		8.1			453.83		
64		6.37			455.56		
74		4.9			457.03		Even with Bay Tree

1999	
Station	Elevation
0	456.2
19	455.5
28	454
35	451.4
37	445.3
40	445.2
42	445.5
46	451.5
55	453.2

*All figures estimated from Figure C.6 PWA, 1999