EAGLE RIVER INVENTORY AND ASSESSMENT

APPENDICES

Report prepared for the: Eagle River Watershed Council

August 2005

Colorado State University
Engineering Research Center
Fort Collins, CO 80523

Colorado State University

ERIA
2003 - 2005

EAGLE RIVER INVENTORY AND ASSESSMENT

APPENDICES

Report prepared for the
Eagle River Watershed Council

By

Brian Bledsoe, Ph.D.
John Meyer
Elaina Holburn
Christopher Cuhaciyan
Stephen Earsom
Keith Olson
Ben Snyder

August 2005

Colorado State University
Engineering Research Center
Fort Collins, CO 80523

NOTICE AND DISCLAIMER OF WARRANTY

TABLE OF CONTENTS

APPENDIX A

Descriptions of Selected Projects

Sections A.1 through A.4 are reports prepared by different individuals or agencies. Sections A.1 through A.3 are formatted with their own Table of Contents, Lists of Tables and Figures, and Addendums. These are all presented as stand-alone reports.

CAMP HALE

Environmental Restoration and Historical Preservation

APPENDIX A.1

"Let the river meander to build again its floodplain, adding slowly but surely more topsoil, another leaf-littered layer of life to cover the bare terrain that was Camp Hale"

Martin Murie,
A citizen soldier looks beyond war,
High Country News, March 31st, 2003

APPENDIX A.1

TABLE OF CONTENTS

APPENDIX A.1

APPENDIX A.1

LIST OF FIGURES

APPENDIX A.1

APPENDIX A.1

LIST OF TABLES

APPENDIX A.1

EXECUTIVE SUMMARY

A very popular project among stakeholders in the Eagle River Watershed is the restoration of Camp Hale, the former military base of the 10th Mountain Division. In 1942, the U.S. Army began constructing Camp Hale in the glacial valley known as Eagle Park. To construct the base, the Eagle River was channelized and centered in the valley. Wetlands in the valley bottom were drained and covered with 270,000 cubic yards of fill material leaving the river incised and disconnected from the valley floor. Native riparian vegetation has not re-colonized and the valley is covered in upland and invasive plant species. The instream habitat is generally poor and homogeneous. Historical and aerial photos taken prior to construction are being used with site surveys, geomorphic analysis, and a variety of other information to examine the feasibility of restoring the river channel to some semblance of its pre-channelized state. Restoration alternatives under consideration include re-creating a sinuous planform, instream habitat enhancements, streambank bioengineering and riparian plantings, as well as educational and historical improvements. Although it is not as urgent as other projects in the basin, restoration of the Eagle River and riparian wetlands at Camp Hale could bring a wealth of ecological benefits to this large, unique system. Because Camp Hale is on the National Register of Historic Places, any changes must be sensitive to the historical value of the site. At the time of this writing, the most plausible project involves restoring a meandering form and riparian connectivity to approximately five miles of channel by removing part of the fill material along a floodplain swath, leaving the straight channel as a historical floodplain remnant, relocating willow/alder bank vegetation from channelized reaches and using bioengineering to establish additional riparian vegetation. Several preliminary alternative site concepts that simultaneously enhance historical and ecological aspects of the site have been developed. The restored site could simultaneously increase awareness of the 10th Mountain Division legacy and the ecological significance of the valley, wetlands, and meandering river. There was significant momentum for this project several years ago, prior to the designation of all of Camp Hale as a National Historic site; and it was easily the most popular project suggested by stakeholders involved in creating a preliminary project list.

INTRODUCTION

In 1942, the Eagle River through Eagle Park (Figure 1) was channelized to prepare for the construction of Camp Hale. After being used for 6 years, the base was abandoned. In 1966 the property was turned over to the United States Forest Service (USFS). Camp Hale was placed on the National Register of Historic Places in 1992. Today the valley is used mostly for recreational purposes and by visitors interested in its historical aspects.

The impetus for this study is two-fold. First, the ecological integrity of the Camp Hale valley has diminished significantly over the years due to the totality of the infrastructure placed with Camp Hale. Second, and perhaps more importantly, this study will suggest how to mesh a valley restoration with historical enhancements and homage to the men who served the United States in the 10^{th} Mountain Division.

This document was developed to provide guidance for river and wetland restoration within the valley. The design was completed while keeping in mind the historical significance of the site and is intended to work in conjunction with facilities to commemorate the soldiers of Camp Hale.

BACKGROUND

The uniqueness of the valley at Camp Hale was the attraction to the US Army, who needed a large, flat area for a military base, where buildings and other infrastructure could easily be constructed. They also needed a high altitude location to train soldiers to fight and survive in winter conditions while in a mountain setting. The valley's physiographic setting was perfect.

There was, however, a mountain stream meandering through the valley (Figure 1). This created two easily fixable problems: first, streams naturally flood and second, a meandering stream uses a lot of space. The simple answer to these problems was channelization, or channel re-alignment.

A new, deeper channel was cut into the valley in a straight line from top to bottom (Figure 2). The realigned channel carries more water, faster and over a shorter distance, making it more efficient than the natural channel was at conveying water. By carrying the water away quickly the possibility of flooding was reduced. The immediate results are quite effective at satisfying design requirements. However, the negative effects, which historically were not considered, are not as obvious.

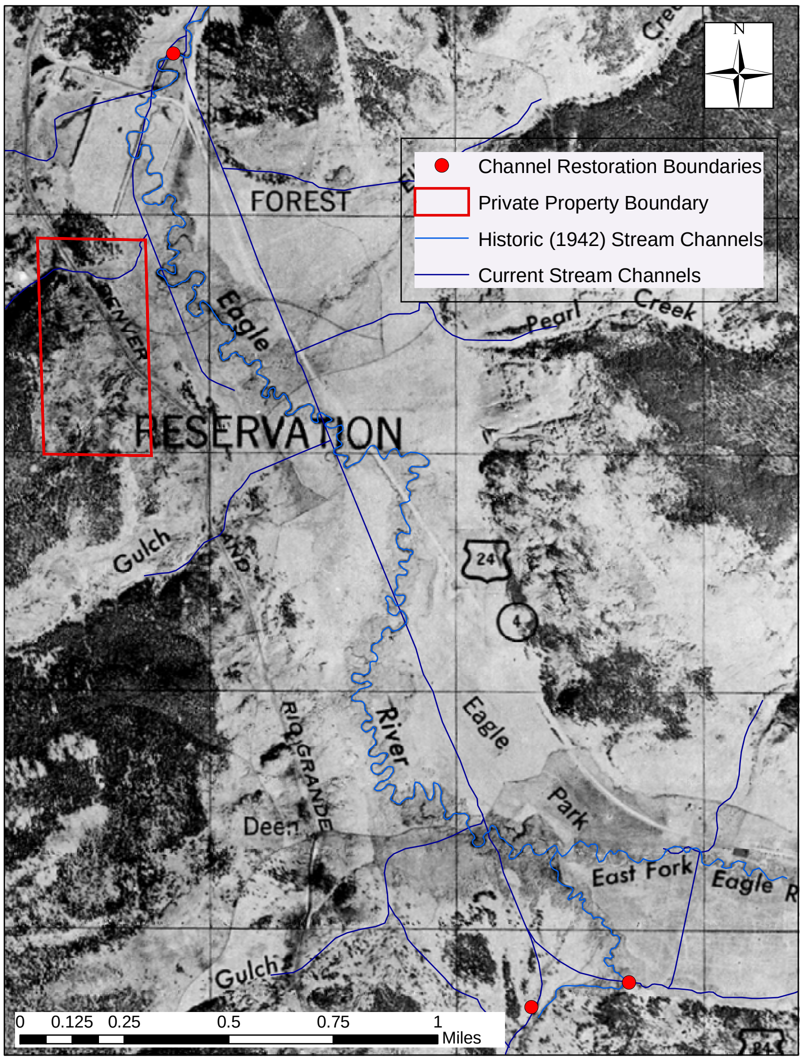


Figure 1: Eagle Park before construction of Camp Hale (1942) showing historic Eagle River.

Figure 2: Channelizing the Eagle River (Photo by Pando Contractors, 1942, courtesy of the Denver Public Library).

A Unique Opportunity for Restoration

The Camp Hale valley is distinct in several ways that makes it an excellent choice for restoration. There is minimum human infrastructure present in the valley and space is available, allowing a full return of its historic processes and equilibrium form. A full meander reconstruction and wetland restoration would have the highest benefit for habitat and process restoration. The return of habitat could greatly increase the quantity and quality of habitat for many species including Colorado River Cutthroat Trout (*Oncorhynchus clarki pleuriticus*) and Boreal Toad (*Bufo boreas boreas*).

Physical Setting

The Camp Hale reach of the Eagle River was formed by glaciers that carved the valley, eventually depositing the material they carved onto the valley floor. The weight of the massive glaciers pulverized the rock leaving a mix of materials from fine silts and clays to boulders. The resulting U-shaped valley is relatively wide and flat, especially when compared to typical mountain valleys.

At over 9200 feet in elevation, this hanging valley is distinct in function from other mountain valleys in several ways including hydrology, hydraulics, ecology, sediment processes, and chemical processes. The type of valley and stream channel found in Camp Hale is more similar to those found in low lying areas where the terrain is flatter, such as on the plains, above some lakes, or near oceans. Having such a long and broad floodplain in a mountain setting is uncommon.

This simple distinction of how the valley was formed has significant implications for the expected form of the river and the processes associated with it. Naturally, the river should be taking a lazy, meandering path through the valley. The sides of the stream would be lush and full of riparian vegetation and the soil would be rich and fertile. Wildlife would be common due to the abundant food sources and refugia. These attributes are a function of the processes at work given the natural configuration of the valley.

Restoration Benefits

Good restoration design restores processes that were once part of the natural system. An important step in planning a restoration is understanding the current and historical conditions, as well as the events that led to the change. Then the processes that have changed can be studied and a plan designed to restore them. The most observable modification at Camp Hale was the channelization of the Eagle River. The physical change is obvious. Other changes, especially the changes in hydrologic, hydraulic, chemical, and ecological processes are not as clear.

When a channel is straightened, its length is shortened, yet the elevation change remains the same. The result is a much steeper channel that increases the shear stress applied to the bed of the channel. The extra shear stress carries bed material away, deepening the channel. Over time the channel bottom is lowered until the channel banks become over-steepened and destabilized. Since the channel is deepened, and therefore larger, flows are no longer able to spill onto the floodplain—a vital ecological process is interrupted. The river is described as being "disconnected" from the floodplain.

Disconnecting a river from its floodplain has several negative effects. Flooding creates floodplains. Sediments, especially the finer grains, are deposited on the floodplain with each passing flood. This sediment builds up and maintains the floodplain in which the channel resides. The regular addition of fertile sediments and nutrient laden water to the floodplain allows a strong riparian community to establish. In turn, the action of flooding reduces the energy that would otherwise degrade the channel.

When the cycle of overbank flows is discontinued by channelization, the groundwater level in the adjacent floodplain is lowered. The riparian vegetation can no longer reach the water it needs to survive and dryland species begin to take over. The lack of densely rooted riparian vegetation leads to increased erosion that may negatively affect downstream reaches.

Streams tend toward a certain morphology characterized by plan form, cross-section from, longitudinal form, and roughness. Channel form is a balance that streams find between the energy they have and the work they do. A stream taken away from its quasi-equilibrium form is out of balance and will tend to return to that form over time. This can be seen occurring throughout Camp Hale today. Sections of streambank are eroding on one side while building point bars on the other. This is the channel adjusting itself laterally. To keep the channel straight would require regular maintenance with heavy equipment. This is opposed to the historic stream, which was created and balanced without human intervention.

These are some of the more basic changes in the physical and hydrologic processes that take place as a result of channel realignment. A complete meander reconstruction of the Eagle River through Camp Hale could return the functions, processes, and aesthetics to the valley. Returning the river channel to its pre-channel realignment form would have the greatest ecological benefits.

Restoration could return the flooding process back to the valley, as well as other processes such as nutrient and chemical cycling. The spatial availability and quality of habitat would thereby be substantially increased. Pre-Camp Hale aerial photographs show the highly sinuous planform and width of the historic channel. Table 1 is a comparison of historic and current channel dimensions taken from aerial photographs.

APPENDIX A.1

Table 1: Current versus historic channel condition.

	Sinuosity [ ]	Length Miles	Slope [ ]
Historic	2.1	5	0.004
Current	1	2.5	0.008

By raising the channel bed and causing bank overtopping on a regular basis, the groundwater level in the valley will rise. This will have several direct benefits including:

1. groundwater storage of water that would otherwise add to downstream flooding
2. a higher water table allowing native riparian vegetation to return to the valley
3. "drowning" of invasive, dry land weeds currently found in the valley
4. improvements in riparian stream cover to provide protective instream habitat and protective shade from solar energy
5. native vegetation establishment to improve habitat, cover, and forage for native animal species including the Boreal Toad and Colorado River Cutthroat; and
6. return of native vegetation to improve stream water quality

The overtopping of the channel will deposit fine sediment and nutrients on top of the floodplain to help rebuild and sustain the native ecological integrity. In doing so, these nutrients are removed from the stream thereby improving downstream water quality. This can be especially important in the case of fine sediments that can cover and destroy habitat for aquatic insects and fish.

Aquatic Habitat

Aquatic insect and fish habitat will also be greatly influenced through the benefits of channel restoration. Aquatic insects are sensitive to water quality parameters such as fine sediment deposition, chemical concentrations, and water temperature, among others. And because aquatic insects are an important food source for fish they serve an important role in ecological integrity. Before healthy fish populations can return, food sources as well as refugia and spawning habitat must be available.

Refugia refers to places where fish can go when in-channel conditions are less than desirable. This can be during high flows when velocities are high and bed material, like gravel and cobble, is moving downstream. In such events, which are both natural and common, fish and other in stream biota need a place to hide and protect themselves. During low flows, this means protection from warm water and predation.

Spawning requirements vary by species, but often include minimum pool sizing and certain substrate characteristics. Straightened channels tend to be relatively homogenous with respect to substrate size and refugia. The lack of complex habitat reduces the biotic carrying capacity of the channel thereby reducing biological richness.

Meander reconstruction addresses this problem by creating complex channel topography. Variations in topography create a variety of hydraulic flow conditions, which may include slow-shallow, slow-deep, fast-shallow, and fast-deep habitats. Because the reconstructed channel would be twice as long, there is potential for twice as much habitat.

The return of habitat could greatly increase the quantity and quality of habitat for many species, thereby improving populations for recreational hunters and fisherman. Listed species that could benefit include Colorado River Cutthroat Trout (*Oncorhynchus clarki pleuriticus*) (Trotter, 1987; Colorado National Heritage Program (CNHP), 2000) and Boreal Toad (*Bufo boreas boreas*) (Hammerson, 1999; CNHP, 2000).

The return of this species is not likely to be a simple matter. Prone to competition and hybridization (Trotter, 1987), a fish barrier would have to be placed down stream of Camp Hale. After ensuring competing species could no longer migrate upstream into the cutthroat's territory, upstream populations of competing species would have to be completely eradicated.

The Boreal Toad requires slow moving water in which to breed. Much of its life is spent near water, although it is occasional found in terrestrial areas (Hammerson, 1999). Currently, the Boreal Toad can be found in nearby Holy Cross City (CNHP, 2000). Restoring wetlands in Camp Hale could provide more habitat and help prevent their populations from declining.

PLANFORM STUDY

Historic Planform

Aerial photographs from 1942 were studied to understand the historic planform of the river through Camp Hale. The photo, provided by the White River National Forest, is shown in Figure 1. The channel is highly sinuous and meanders through a glacially formed valley roughly two miles long and a half-mile wide. Alluvial fans are common along the fringes of the valley causing some forcing of the channel's location.

Radius of curvature (R_c) was analyzed from the historical confluence of the East and South Fork Eagle Rivers to near the downstream end of the project using a 1942 air photo. The goal was to understand the downstream pattern of variation in the radius of the meander bends.

Figure 3 shows the magnitude of radii measured in the downstream direction. Sen's (1968) nonparametric slope estimator was used to determine the significance and magnitude of any downstream trend. The mean, standard deviation, downstream trend in R_c, and 95% confidence interval (n = 129) on trend are presented in Table 2.

These results indicate that there is significant variation in the size of meander bends. The downstream trend in R_c is significant although it does not appear that the trend is linear. In fact, in the central reach of the valley, R_c has a decreasing trend before starting an increasing trend near the confluence of Resolution Creek. It is expected that R_c will increase with distance downstream since R_c is usually proportional to discharge, which does change (increase) with distance downstream. The smaller R_c found mid-valley could be a result of factors such as resistant bed and bank material, thick-resistant vegetation, or a narrowing of the valley though this section by alluvial fans.

The meander wavelength and channel belt width were also measured from the 1942 air photo. The average meander wavelength was 326 ft with a standard deviation of 135 ft. The average belt width is 327 ft. Both had similar patterns to R_c as they decreased with downstream distance before increasing again near the Resolution Creek confluence.

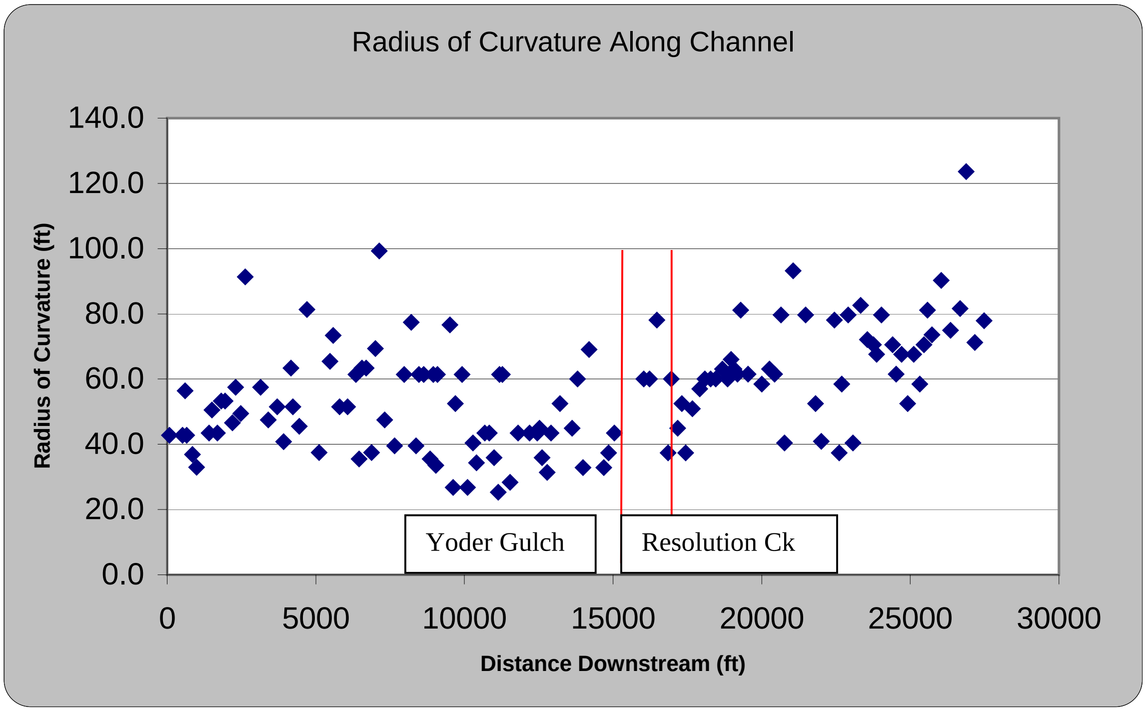


Figure 3: Radius of curvature in the downstream direction. Distance downstream is along the channel.

Table 2: Eagle River at Camp Hale radius of curvature summary statistics.

Average R_c (ft)	Minimum R_c (ft)	Maximum R_c (ft)	Std. Deviation (ft)	Lower 95% C.I. (ft/ft)	Downstream Increase in R_c (ft/ft)	Upper 95% C.I. (ft/ft)
64	25	124	36	0.0006	0.0009	0.0012

As extreme droughts and wet periods have been occurring over the last century (see Design Discharge) and large diversions placed in the watershed, it is difficult to know what discharge the 1942 channel had conformed to. In an attempt to reveal the channel forming discharge, common relationships between bankfull discharge, bankfull width, radius of curvature, and wavelength were used to back-calculate an expected discharge.

Radius of curvature often ranges from 2-3 times bankfull width with an average of 2.7 times width (Leopold and Wolman, 1960; Williams, 1986). Dividing the average radius of curvature (64 ft) by 2.7, the estimated width is 23.7 ft. Using this value in the equation

$$width = 1.8Q^{0.5} \qquad \text{Eq (1)}$$

yields an estimated bankfull discharge of 173 cfs. Applying the range of R_c to width values we get a discharge range of 140 to 316 cfs.

Similar calculations were performed with relationships for meander wavelength (λ) and bankfull width. λ is commonly between 10 and 14 times bankfull width. A common theoretical relationship is

$$\lambda = 4\pi w \quad \text{Eq (2)}$$

where π is 3.14. This results in a discharge of 207 cfs with a range from 176 to 328 cfs. Both ranges are comparable and suggest that bankfull discharge in the valley was about 200 cfs in 1942.

Potential Planform

Current land ownership and infrastructure were used to determine areas that would necessitate deviation from the historic planform. The only private property located within Camp Hale is located near the downstream end of project (Figure 4). While there is no direct overlap between the historical channel location and the private land, they are relatively close.

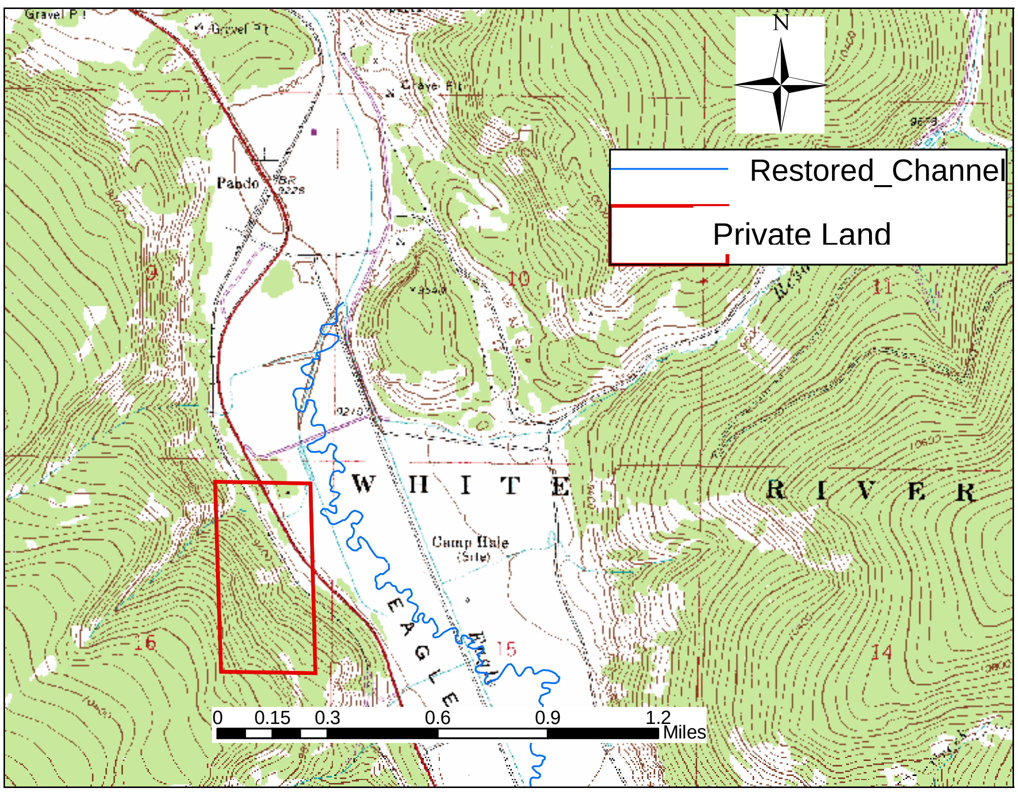


Figure 4: Private property boundaries in Camp Hale valley.

The location of the private land with respect to the channel together with the idea of returning the river to a flooding regime will require careful engineering. Homes located on the property sit fairly low in the valley and the potential for flooding them is real. One possibility is to excavate a path along the reconstructed channel near the private property boundaries that would contain flood flows. Designing such a feature will require hydraulic analysis, beyond the scope of this paper, to ensure that the maximum probable flood is contained.

APPENDIX A.1

To estimate the extent, cost, and size of a newly cut floodplain, an estimated Q_{100} (the discharge expected to occur, on average, every 100 years) based on the Red Cliff gage was used as a design flow (1,200 cfs). A "complex" cross-section was developed and roughness values were estimated from Chow (1959, table 5-6) for the channel and floodplain. The channel geometry was then adjusted until a flow 1200 cfs passed through the channel when water was about to crest the terrace. Figure 5 shows an example of a floodway/channel that is able to pass this flow. This cross-section is not intended as a final design, but as a test of the feasibility of such a design in the space available. A final design will require extensive hydrologic and hydraulic analyses.

Within the restoration boundaries (see Field Study) this is the only location where a deviation from the historical planform may be necessary.

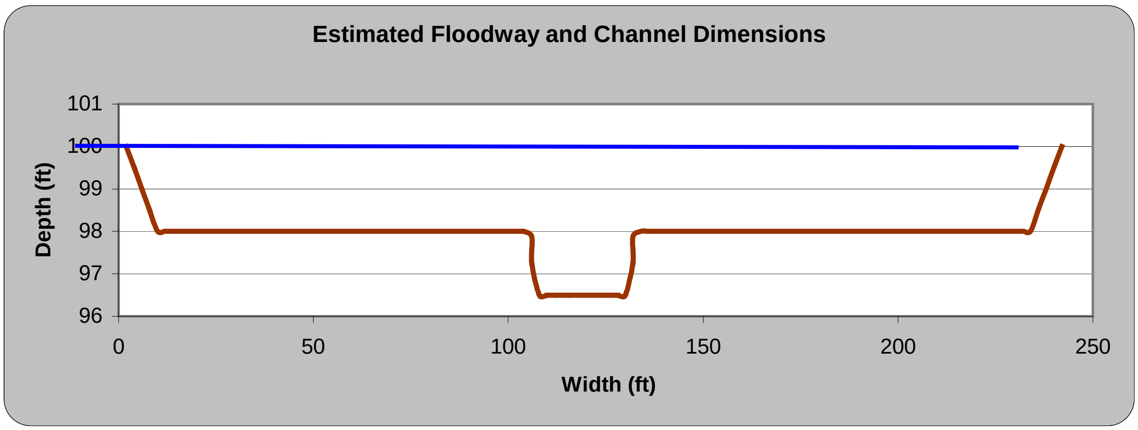


Figure 5: Example floodway to prevent flooding of private land. A Manning's n of 0.15 and 0.036 were used as conservative estimates of floodplain and channel roughness, respectively.

Because the currently channelized portions of the river hold sentimental value to many, a plan will be developed that integrates the straightened reaches as backwater habitat areas. This will allow a new, stable channel to be designed while keeping the historically significant channel intact. Such a design may be the only possible alternative that allows the river to be restored to a more natural condition.

DESIGN DISCHARGE

Determining a design discharge for the Eagle River at Camp Hale is complex. Even though gage records are rather extensive at nearby gages, we must still extrapolate those flows to Camp Hale. And, due to the length of the Camp Hale project and the number of tributaries along this reach, it is necessary to change the design discharge along the channel. Another complicating factor is the large fluctuations in discharge brought about by changes in climate, diversions, and reservoir operations.

A USGS report (Webb *et al.*, 2004) indicates that the years 1906 to 1930 enclose the wettest period on record in the Colorado River Basin. Based on dendrochronology, it may have been the wettest period in the last 500 years. It also states that the current drought may be the driest in the last 500 years. Figure 6 illustrates how average peak discharge has changed over the period of record for the Eagle River gage in Red Cliff, Colorado.

Since the gage record (USGS, 2004) contains both the wettest and driest periods over the last 500 years, it is possible to determine a maximum range of bankfull discharges. The USGS determined the wettest and driest years based on a 5-year average using dendrochronology. Since a 5-year record is inadequate for performing a recurrence interval analysis, a 10-year average was used based on the peak discharges on record (Figure 6). A Weibull distribution recurrence interval was then used to determine $Q_{1.5}$ for the wettest and driest continuous 10 years on record. $Q_{1.5}$ results are 698 cfs and 197 cfs, respectively.

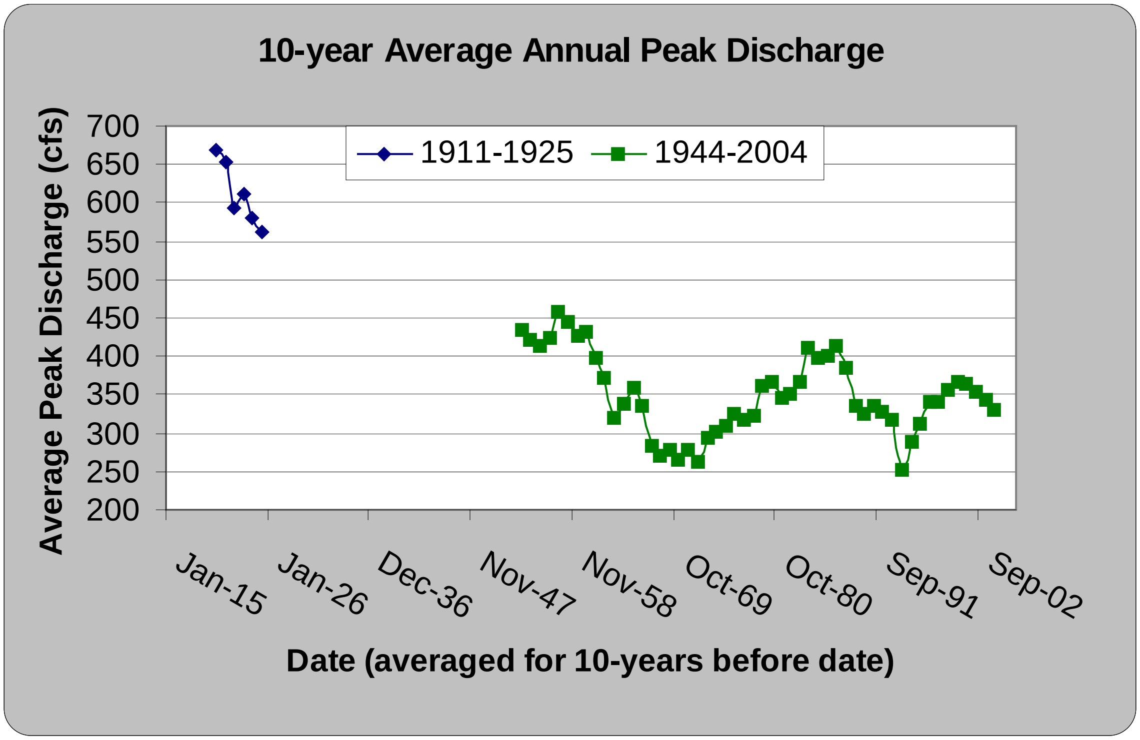


Figure 6: 10-year average annual peak discharge for the Eagle River at Red Cliff.

Further complicating our ability to determine a design discharge are trans-basin diversions and reservoirs in the headwaters of the Eagle River. The resulting decrease in discharge and the frequency of large discharge events will cause a proportional decrease in the size of a stable channel that can be maintained at Camp Hale. The significance discharge has on channel size and stability makes it imperative to have an understanding of the current hydrologic regime and bankfull discharge before designing a stable channel. The design discharge will also have to ensure a flooding regime capable of maintaining any restored wetlands.

A design discharge was estimated using three independent techniques to increase our confidence in the results. First, a recurrence interval discharge was calculated (Addendum I). Bankfull discharge, a commonly used channel maintaining discharge, was estimated to be the discharge that occurs, on average, every 1.5 years. An equivalent way to understand this discharge is that it is the discharge that has a 67% chance of occurring in any one year. This value is calculated by applying a Weibull distribution to instantaneous peak discharges. When using all of the data available after 1944 (post wet-period) $Q_{1.5}$ is calculated to be 251 cfs at the Red Cliff gage.

While we know that $Q_{1.5}$ is not necessarily equivalent to bankfull discharge determined in the field (Williams, 1978), it can be used to give confidence in other results and aid in determining an appropriate design discharge.

The Red Cliff gage (the nearest and most representative gage for this study) is downstream of the Camp Hale reach, requiring that estimates taken from the gage be extrapolated back to the study reach. Two techniques were used here. First, USGS flood recurrence equations were re-fitted to $Q_{1.5}$ and second, discharge per unit area was calculated and areas adjusted back to Camp Hale. The results of adjusting the Eagle River at Red Cliff $Q_{1.5}$ to the reaches of Camp Hale (using refitted USGS equations) are shown in Table 3. Addendum II contains discharges adjusted using both techniques.

Table 3: Design discharge adjusted to reaches of Camp Hale.

Watershed	Bankfull Q (cfs)
Eagle at Red Cliff	251
Eagle near Pando	224
Eagle abv Yoder	171
South Fork Eagle	77
East Fork Eagle	120
Resolution Ck	84
Yoder Gulch	27

The second technique used to estimate a design discharge was to compute the effective discharge (Q_{eff}). Q_{eff} is calculated using daily discharge records for the period of interest. Flows are categorized and average sediment discharges calculated for each category of flow. The median value for the highest category of sediment discharge is taken to be the Q_{eff}. Q_{eff} was calculated using daily Eagle River at Red Cliff gage data since 1944. GeoTool v.3 (Raff and Bledsoe, 2003) was used to expedite calculations. Q_{eff} was extrapolated back to the Camp Hale reach in the same way as $Q_{1.5}$.

Before Q_{eff} could be calculated, a channel cross-section had to be surveyed (following the techniques of Harrelson *et al.* (1994)) to provide inputs for GeoTool. A channel cross-section and slope were surveyed and a Wolman Pebble Count (Wolman, 1954) was conducted. The resulting cross-section is shown in Figure 7. The cross-section was used to provide a width and to calculate a power function to estimate hydraulic radius based on discharge.

The results of the survey are shown in Table 4. The resulting power function for estimating hydraulic radius (R) was determined to be

$$R = 0.24Q^{0.38} \quad \text{Eq (3)}$$

where the hydraulic radius is in feet and discharge (Q) is in cfs.

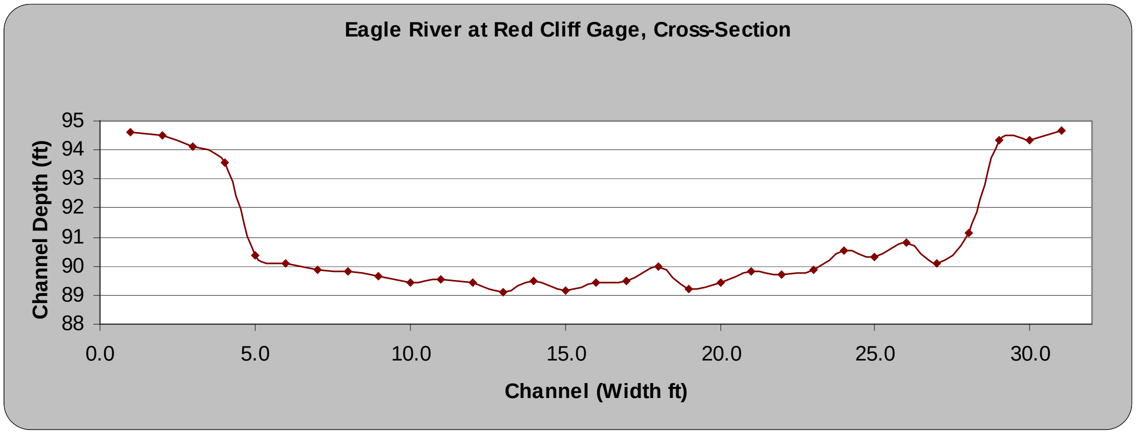


Figure 7: Surveyed cross-section of the Eagle River at the Red Cliff gage.

Table 4: Results of Eagle River at Red Cliff gage survey.

Parameter	Value	Units
Width	25	(ft)
D50	69	(mm)
Slope	0.009	(ft/ft)

Other parameters required to estimate Q_{eff} include the sub-pavement median particle size, percent sand size material present, and channel slope. Calculations were run with 0% sand even though the pebble count shows a significant amount of sand and finer materials were present on the bed. This was done since the sand size material was found near the channel margins and not as part of the bed material matrix. This is important to note as the sediment transport equation used is known to be highly sensitive to the fraction of sand used. Figure 8 shows a set of results for the sediment transport rate at Red Cliff during the wet period (pre-1925) and more recent data (post-1944). Table 5 contains Q_{eff} adjusted to upstream reaches. Q_{eff} was calculated to be 239 cfs at Red Cliff.

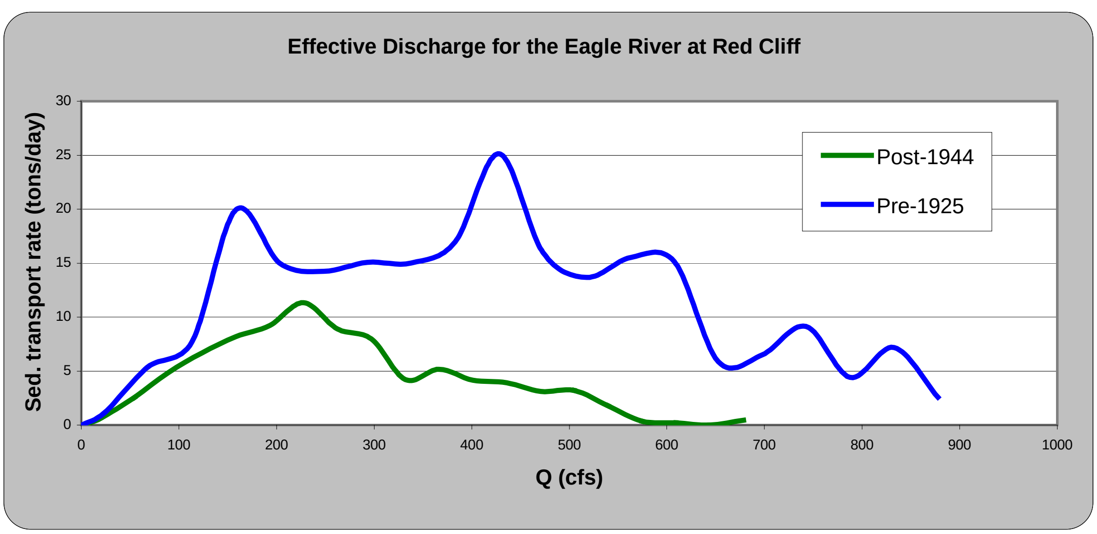


Figure 8: Results of effective discharge calculations.

APPENDIX A.1

Table 5: Effective discharge adjusted to reaches of Camp Hale.

Watershed	Effective Q (cfs)
Eagle at Red Cliff	239
Eagle near Pando	213
Eagle abv Yoder	163
South Fork Eagle	73
East Fork Eagle	114
Resolution Ck	80
Yoder Gulch	26

The third technique for estimating bankfull discharge was the field determination of Q_{BF} at several locations along the Camp Hale reach. Field indicators are used to determine the stage of Q_{BF}. Then the cross-section is surveyed and bankfull stage noted. Manning's n is then estimated and an estimate of the discharge that occurs at incipient flooding is obtained (Q_{BF}). Q_{BF} values calculated for the Camp Hale reach using these techniques are presented in Table 6.

The bankfull discharge estimates using Manning's n values around 0.035 are the most probable. The resulting values of Q_{BF} are high relative to the recurrence interval and effective discharges. This suggests that the channel is still adjusting to changes in discharge and sediment supply since being channelized. Given the channel type (F3 and F4 based on Rosgen's (1996) classification) and channel evolution processes it makes sense that the river is still in a period of adjustment.

Table 6: Field estimated bankfull discharge above and below Resolution Creek.

	Below Resolution Ck		Above Resolution Ck	
Manning's n	Slope	Discharge (cfs)	Slope	Discharge (cfs)
0.025	0.008	615	0.007	535
0.03	0.008	512	0.007	446
0.035	0.008	439	0.007	383
0.04	0.008	384	0.007	335
0.045	0.008	341	0.007	297
0.05	0.008	307	0.007	268

Figure 9 illustrates a conceptual understanding of the channel evolution process. Evidence suggests that the channel is currently in step IV of this process. The channel has degraded vertically (step II), gone through a period of widening (step III), and is now building a bench within the channel that is the initial form of the new floodplain. The fine bed material found at the Eagle River above Resolution Creek cross-section suggests that it is now continuing to the next step. Bed material is depositing on the channel bottom effectively working to reduce the channel cross-sectional area. This disequilibrium state renders the field determined Q_{BF} useless with respect to determining a restoration design discharge, yet it confirms the fact that the channel is not at an equilibrium state.

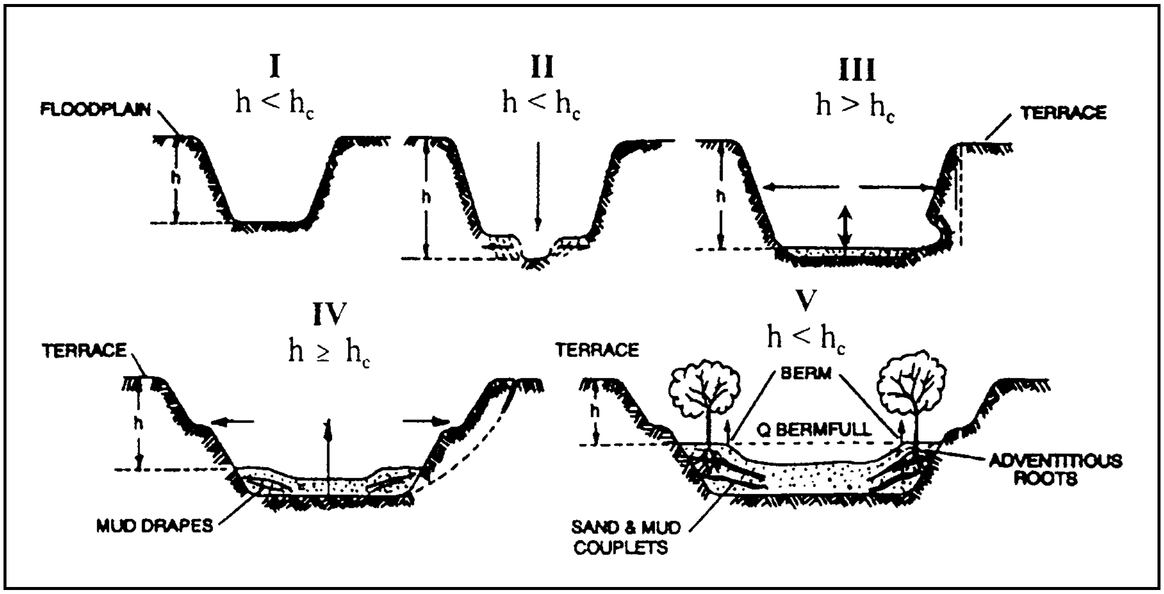


Figure 9: Phases in channel evolution (from Bledsoe *et al.* (2002); after Schumm *et al.* (1984))

Finally, a fourth technique was used to estimate a bankfull discharge. A field estimate of bankfull discharge was determined for a site along Homestake Creek (245 cfs). This value was then compared to recurrence intervals for the Homestake Creek at Gold Park stream gage. Although there is a reservoir and diversions above this point, it is likely that the channel has adjusted to the more recent hydrologic regime (post-1967 reservoir completion) given the currently stable form of the channel. The recurrence interval for Q_{BF} was found to be 1.37. This recurrence interval was then taken from the Eagle River at Red Cliff data using post 1944 data and determined to be 199 cfs. This result is similar to those found for the recurrence interval and effective discharge studies after adjusting them to reaches of Camp Hale.

FIELD STUDY

Several field reconnaissance and survey trips were made to Camp Hale to collect information including valley form, current channel condition, channel potential, bankfull discharge, pebble counts, wetland potential, and channel restoration boundaries. Cross-section surveys are presented in Addendum III and pebble counts are presented in Addendum IV.

Channel restoration boundaries were chosen based on the historic channel, the current channel location, infrastructure, valley form, and channel condition. The goal was to connect the restored channel to the bounds of currently stable reaches, while keeping the channel in the valley bottom to the extent possible. Three boundaries were chosen: the downstream end near Pando, one on the South Fork of the Eagle, and one on the East Fork of the Eagle (Figure 10).

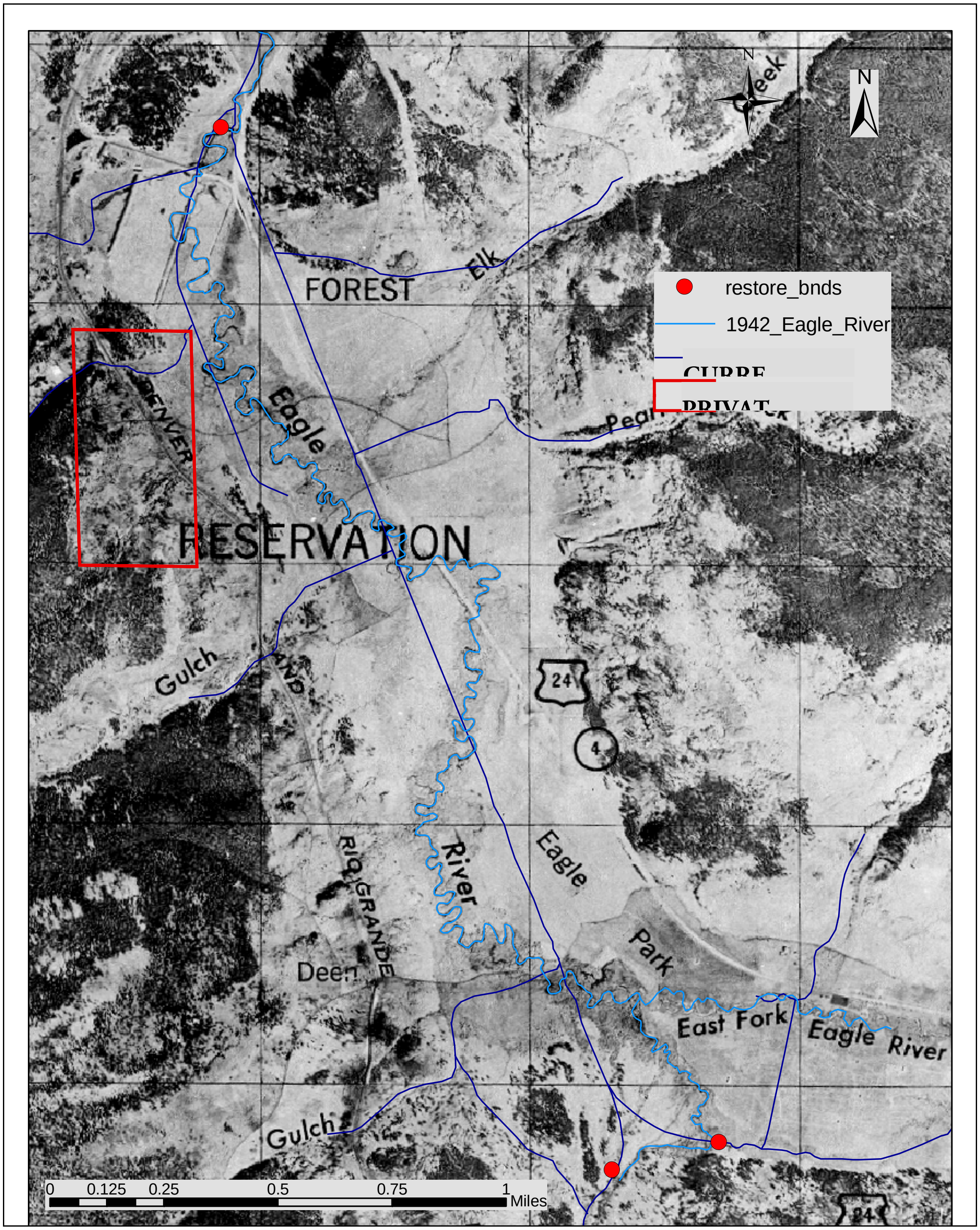


Figure 10: Camp Hale channel restoration boundaries.

South Fork Eagle River

The South Fork Eagle River comes from the south into Camp Hale through a relatively steep and confined valley. Its channel has been pushed up against the right valley wall for a short distance above the confluence with the East Fork. Above this point the river appears stable and appropriate given the valley morphology.

Where the valley begins to open up, before entering Camp Hale, the river has formed an alluvial fan. The left side of the valley (valley left) is the current site of the Camp Hale Campground. Adjacent to the campground, the channel becomes deeply incised into the alluvial fan material as it heads, in a straight line, down the valley. In some places the channel is entrenched as much as 12 feet.

Historically, the channel through this section made frequent lateral adjustments based on woody debris, sediment load, and abundant beaver (*Castor canadensis*) activity. Several abandoned channels are still present on the fan (Figure 11) and historical photos suggest still different channels (Figure 12).

The restoration boundary (Figure 13) for the South Fork Eagle is based on the channel's change from a stable form with vegetated benches and banks to an incised channel with little energy dissipation ability and bare cobble banks. Below this point there is significant potential to bring the channel back to a stable form with increased sinuosity, larger bed material, and stable vegetated banks.

Figure 11: Remnant channels on the South Fork alluvial fan.

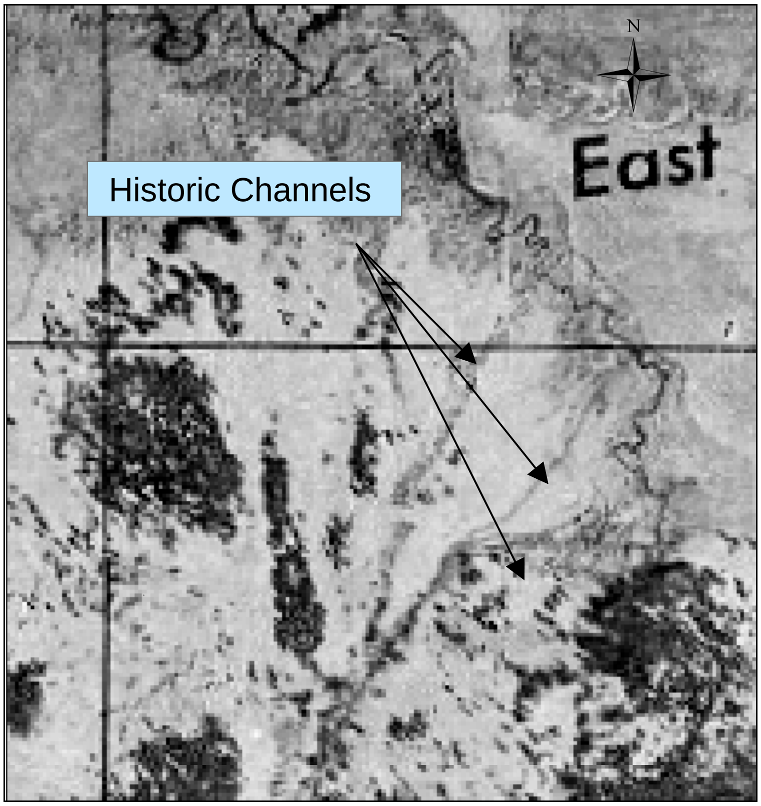


Figure 12: Historical channels of South Fork Eagle River alluvial fan.

Figure 13: South Fork Eagle River project boundary looking upstream.

East Fork Eagle River

The East Fork boundary is not far upstream from the confluence with the South Fork. Here, the valley is wide and the historical floodplain is still available (Figure 14).

The East Fork has been pushed to the left side of the valley to create space for infrastructure built as part of Camp Hale. The channel is still against the left side of the valley and the infrastructure, rows of munitions bunkers, is still present. The channel, which was once highly sinuous and centered in the valley, is still fairly stable and connected to the floodplain for most of the reach. This is likely due to beaver activity that has prevented the channel from downcutting.

Figure 15 shows one of several beaver dams present near the East Fork restoration boundary. Below the dam the channel becomes increasingly incised to a maximum of about 4 meters. Above the dam (Figure 16) the channel remains attached to the floodplain and contains a relatively healthy riparian area.

Because beaver dams and activity are not consistent in time, the upstream channel should undergo a thorough stability analysis and perhaps some instream structures placed to ensure future stability.

Figure 14: East Fork Eagle River project boundary looking north across valley.

Figure 15: Beaver dam on East Fork Eagle River, just below project boundary.

Figure 16: Stable reach above project boundary on East Fork Eagle River.

APPENDIX A.1

Eagle River Near Pando

As the Eagle River heads north towards Pando the valley narrows and the channel passes through the terminal moraine before continuing towards Red Cliff. This is the downstream extent of the severe channelization performed for the construction of Camp Hale and the recommended downstream end of the restoration.

STABLE CHANNEL DESIGN

Stable Planform

It is critical when designing a stable channel to understand what a "stable channel" is given the rivers geomorphic context. We cannot assume that the stable form of the river is a single thread, meandering channel (Kondolf *et al.*, 2001). Obviously, from the 1942 aerial photograph the river was single thread and meandering. Changes in discharge and bed material could affect this tendency, however, so it is imperative we understand if the river is near the meandering-braiding threshold.

The approach used to determine the planform tendency was that of van den Berg (1995). He used valley stream power and median bed material size to develop a discriminant function to discern planform type (Figure 17). To determine unit stream power the equation

$$\omega = 3300 S_v Q^{0.5} \qquad \text{Eq (4)}$$

was used where ω is unit stream power (W/m^2), S_v is the valley slope, and Q is stream discharge in cms. The calculated values for above and below Resolution Creek are 53 and 65 W/m^2, respectively. Given that the current median bed material size is 50 mm and that it will decrease when the slope is decreased to allow for meandering, 50 mm can be used as a maximum. At 50 mm unit stream power would have to exceed 256 W/m^2 to become braided using this scheme. Using the van den Berg equation to back-calculate a median bed material size, we find that the river would have to be a sand bed channel to cause braiding at the given unit valley power.

We can add further evidence that the Eagle River will be a single thread meandering channel by understanding what causes a channel to tend toward a braided form. Braided channels are typically steep, with high unit stream power and are often capacity limited (Bledsoe and Watson, 2001; Bridge, 1993). The alluvial fans at the mouths of Resolution Creek, Yoder Gulch, and the South Fork of Eagle River, are examples of this. In these areas, however, the large sediment supply gets deposited (forming the alluvial fans) as the low unit stream power in the flatter valley can no longer carry the sediment supply. Beaver dams also work to reduce sediment supply since little sediment is able to pass through them. The expected low sediment discharge suggests that the river is not likely to be braided (Bridge, 1993).

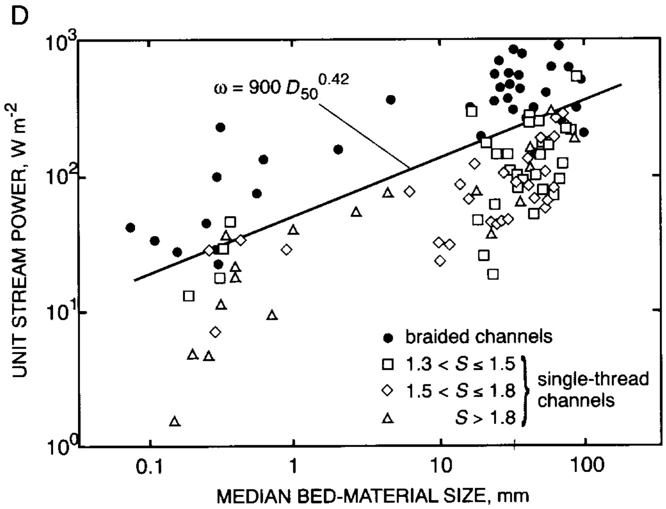


Figure 17: Meandering-braiding threshold (from Knighton (1998); after van den Berg (1995)).

Stable Channel Cross-section

Stable channel design starts by determining a design discharge—the discharge the channel must pass within its banks (see Design Discharge). The new channel must be designed with the capacity to pass this amount of flow. Several techniques were employed in order to decide how to partition the discharge into its components (velocity, width, and depth), while ensuring the stability of the channel. This includes analyses from Andrews (1984), Hey and Thorne (1986), Soar and Thorne (2001), and Yalin (2001). Design parameters calculated were combined with the planform analysis and field study to better target a stable dimension, pattern, and profile, for a sinuous channel reconstruction through Camp Hale.

The analysis began by plotting stable slope versus width combinations based on the design discharges. Discharge, channel roughness (Manning's n), and median bed material size (d_{50}) were held constant while dimensionless critical shear stress (τ_*) was varied in increments of 0.005 from 0.035 to 0.05. Channel top widths (bankfull widths) were adjusted in 1-foot increments from 19 to 45 feet. A bed slope and depth were then calculated for each width.

Sediment transport (Q_s) has a significant affect on channel form. Therefore, the Wilcock and Kenworthy (2002) sediment transport equation (presented in Addendum V) was used to back calculate channel dimensions while holding sediment transport rates constant. Once a design width and slope were calculated, lines of constant sediment discharge were plotted along with the lines of constant dimensionless critical shear stress. Results for the reaches above and below Resolution Creek are presented in Figure 18 and Figure 19, respectively.

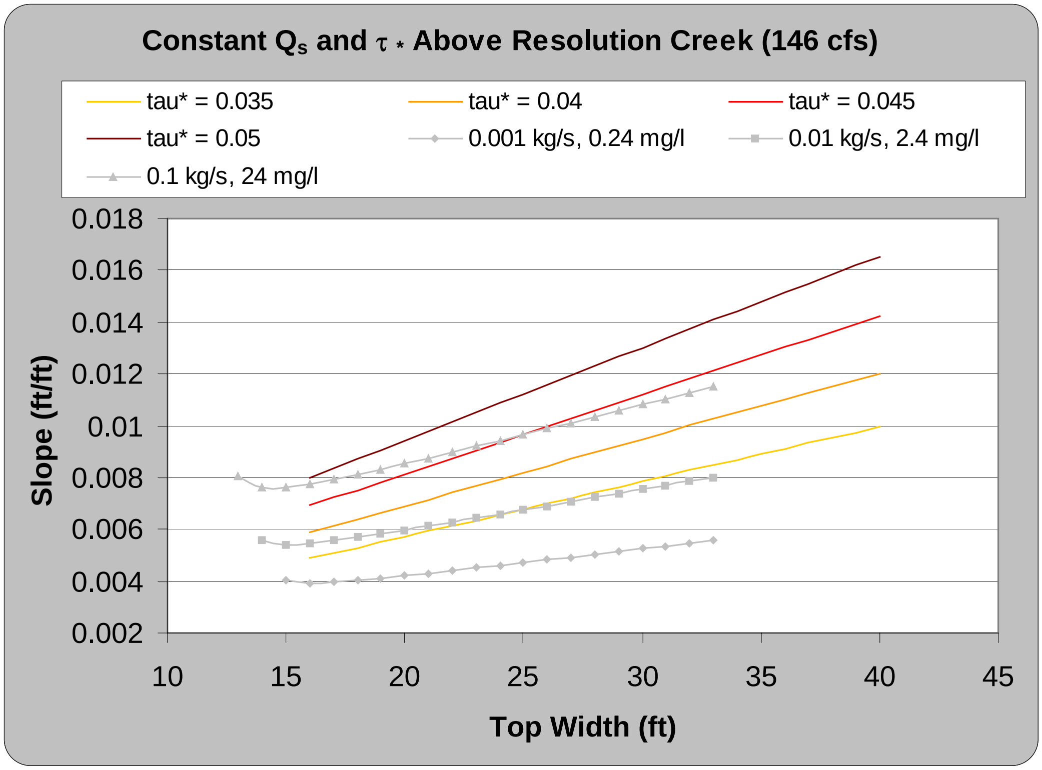


Figure 18: Above Resolution Creek slope and width geometry based on constant values of τ_* and Q_s.

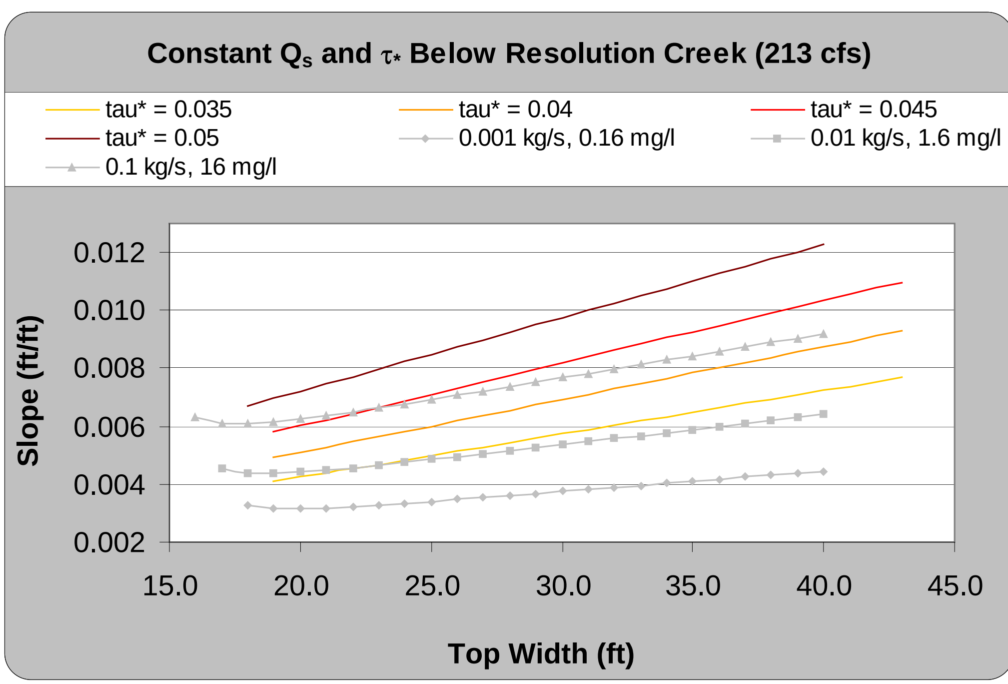


Figure 19: Below Resolution Creek slope and width geometry based on constant values of τ_* and Q_s.

APPENDIX A.1

Starting with these figures, we can narrow down the range of possibilities for stable channel design. We can use our knowledge of gravel bed rivers in Colorado and measured values from the current channel to reduce the results down to expected ranges. Typically we would expect τ_* to range from 0.035 to 0.04, Q_s to range from 0.01 to 0.05 kg/s, and Manning's n to range from 0.03 to 0.04. While these aren't absolute ranges, they give us a place to focus our efforts.

Downstream hydraulic geometry equations are empirical relationships whereby channel width, depth, and slope can be calculated based on discharge. Often developed during regional scale studies, they don't necessary apply to the Eagle River directly. However, we can compare their results to what we would expect for a stable channel.

Andrews

E.D. Andrews (1984) conducted a hydraulic geometry analysis on 24 streams in the Colorado Rockies. Regional appropriateness and data quality would suggest that the results from this study are the most likely to be applicable to the Camp Hale site. The first equation used was

$$Q^* = \frac{Q}{d_{50}^2 \sqrt{\left(\frac{\gamma_s}{\gamma_w} - 1\right) g d_{50}}} \qquad \text{Eq (5)}$$

where Q is discharge in cms, Q* is a dimensionless discharge, d_{50} is the median bed material size, g is the acceleration due to gravity (9.81 m/s^2), γ_s is the specific weight of sediment (26,000 N/m^3), and γ_w is the specific weight of water (9,810 N/m^3). Then two different sets of equations are used to calculate dimensionless width (W*), depth (D*), and slope (S). The first set is for streams with thin bank vegetation.

$$W^* = 4.94 Q^{*0.478} \qquad \text{Eq (6)}$$

$$D^* = 0.485 Q^{*0.377} \qquad \text{Eq (7)}$$

$$S = 0.162 Q^{*-0.406} \qquad \text{Eq (8)}$$

The second set of equations is for streams with thick bank vegetation.

$$W^* = 3.911 Q^{*0.482} \qquad \text{Eq (9)}$$

$$D^* = 0.491 Q^{*0.37} \qquad \text{Eq (10)}$$

$$S = 0.318 Q^{*-0.439} \qquad \text{Eq (11)}$$

Finally, the dimensionless width and depth values are converted to metric units (m) using the following two equations.

$$W = W^* d_{50} \qquad \text{Eq (12)}$$

$$D = D^* d_{50} \qquad \text{Eq (13)}$$

Addendum VI contains the inputs and resulting values for Andrews and other hydraulic geometry equations used.

Hey and Thorne

Hey and Thorne (1986) collected data on gravel bed rivers in the United Kingdom and used them to create a set of hydraulic geometry equations. Although their data set may not be as geographically appropriate as the Andrews' set, Soar and Thorne (2001) found similarity between Hey and Thorne's equations for thin vegetated streambanks and Andrews' equations for thick vegetated streambanks.

Hey and Thorne have four different equations for width depending streambank vegetation thickness. Type I banks are grassy, type II are 1-5% trees or shrubs, type III are 5-50% trees or shrubs, and type IV are greater than 50% tree or shrub cover. Depth and slope have one equation each for all conditions.

$$W_{typeI} = 4.33Q^{0.5} \quad \text{Eq (14)}$$

$$W_{typeII} = 3.33Q^{0.5} \quad \text{Eq (15)}$$

$$W_{typeIII} = 2.73Q^{0.5} \quad \text{Eq (16)}$$

$$W_{typeIV} = 2.34Q^{0.5} \quad \text{Eq (17)}$$

$$D = 0.22Q^{0.37}D_{50}^{-0.11} \quad \text{Eq (18)}$$

$$S = 0.087Q^{-0.43}D_{50}^{-0.09}D_{84}^{0.84}Q_S^{0.1} \quad \text{Eq (19)}$$

where D_{84} (m) is the 84th percentile of the grain size distribution and Q_s (kg/s) is the sediment discharge rate.

Soar and Thorne

Soar and Thorne (2001) collected gravel bed channel geometry data from around the world where the bank vegetation had been classified. Their final data set included data from the above studies and others. After combining the data they developed new equations for channel width with thick and thin bank vegetation types for each individual data set. Only the re-evaluated Andrews' equations were analyzed, although, others may well be appropriate. Four equations were developed, two for thinly vegetated banks and two for thickly vegetated banks. During their analysis they held the exponents constant for one set, and for the second, they allowed the exponent to adjust freely.

$$W_{thin,constant} = 4.18Q^{0.5} \quad \text{Eq (20)}$$

$$W_{thin,adj} = 4.13Q^{0.5} \quad \text{Eq (21)}$$

$$W_{thick,constant} = 3.66Q^{0.5} \quad \text{Eq (22)}$$

$$W_{thick,adj} = 3.88Q^{0.45} \quad \text{Eq (23)}$$

Yalin

Yalin's (2001) equations are based on a small sample of North American rivers. Typically, the resulting hydraulic geometry equations are not well suited for gravel bed, mountain rivers. When calculating Manning's roughness values from the hydraulic geometry we usually find that they are too low. The following equations were used to predict hydraulic geometry.

$$u_c^* = 0.045\left(\frac{\gamma_S}{\gamma_W} - 1\right)gd_{50} \quad \text{Eq (24)}$$

$$W = 1.42\sqrt{Q/u_c^*} \quad \text{Eq (25)}$$

$$D = \frac{d_{50}^{1/7}}{7}\left(\frac{Q}{u_c^*}\right)^{3/7} \quad \text{Eq (26)}$$

$$S = \frac{u_c^{*2}}{g}\frac{7}{D^{1/7}}\left(\frac{u_c^*}{Q}\right)^{3/7} \quad \text{Eq (27)}$$

where u_c^* (m/s) is the critical shear velocity.

Initial Hydraulic Geometry Results

Figure 20 and Figure 21 show the results of overlaying a tractive force, analytical (using Wilcock and Kenworthy (2002)), and hydraulic geometry approach to the reaches above and below Resolution Creek below Resolution Creek, respectively. The black "window" shows where we expect stable channel geometry results. Manning's n and sinuosity were calculated for all the hydraulic geometry results. Those results that were within the window were further assessed to determine which continue to provide acceptable results.

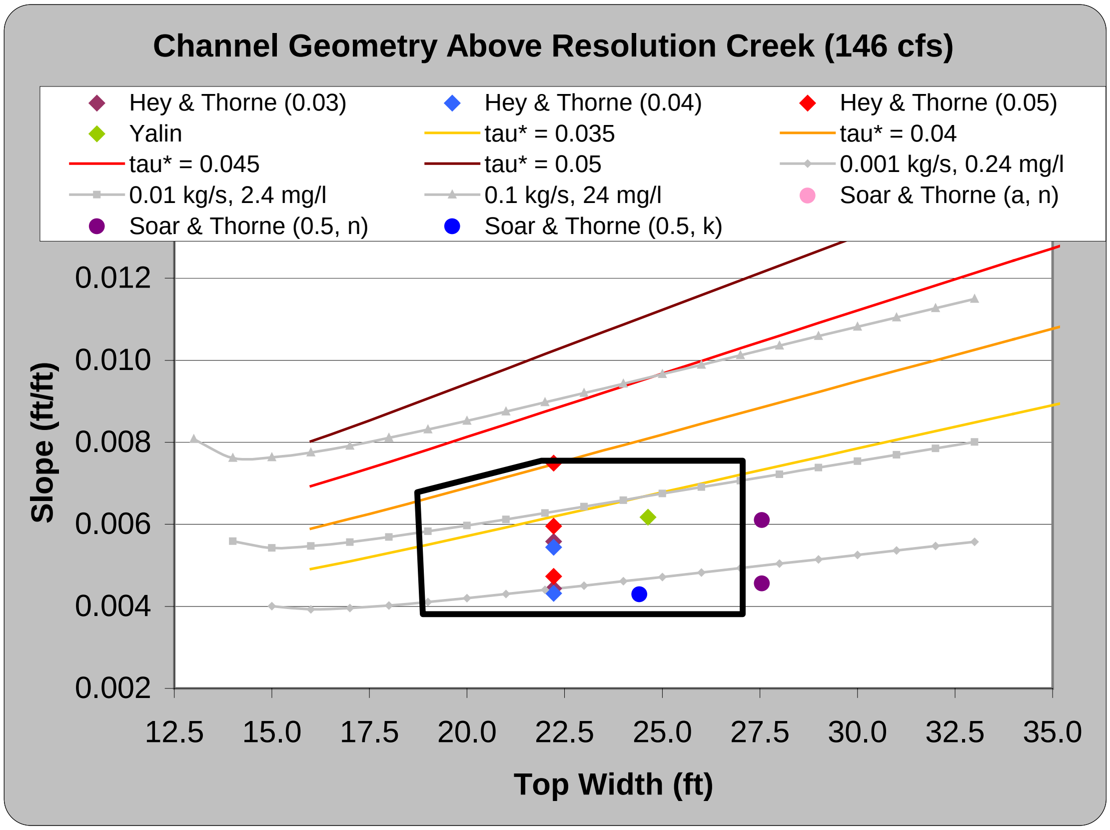


Figure 20: Hydraulic geometry results for reach above Resolution Creek. Thick and thin vegetation are denoted as 'k' and 'n', respectively. Hey and Thorne values in parenthesis are median bed material sizes in meters. Soar and Thorne parentheses represent adjustable (a) and fixed exponent (0.5) equations exponents. The black outline represents the region we expect to find reasonable results.

A historical channel sinuosity of 2 was measured from a 1942 air photo, meaning that the channel was twice as long as the valley. Similarly, we can say that the channel had half the slope of the valley. Given the likely smaller current channel forming discharge, we know that the slope of the channel has to increase in order to maintain stream power and remain stable. The increase in slope means a corresponding decrease in sinuosity. With this knowledge we can put a rough range on expected channel sinuosity. At most the sinuosity should remain 2 and it cannot physically be less than 1. The most likely scenario is that sinuosity should be close to 2.

The increase in slope (from channelization) also means an increase in bed material grain size as stream power is increased. Having conducted several pebble counts, we can place a maximum likely size on historic grain size distributions (~50 mm).

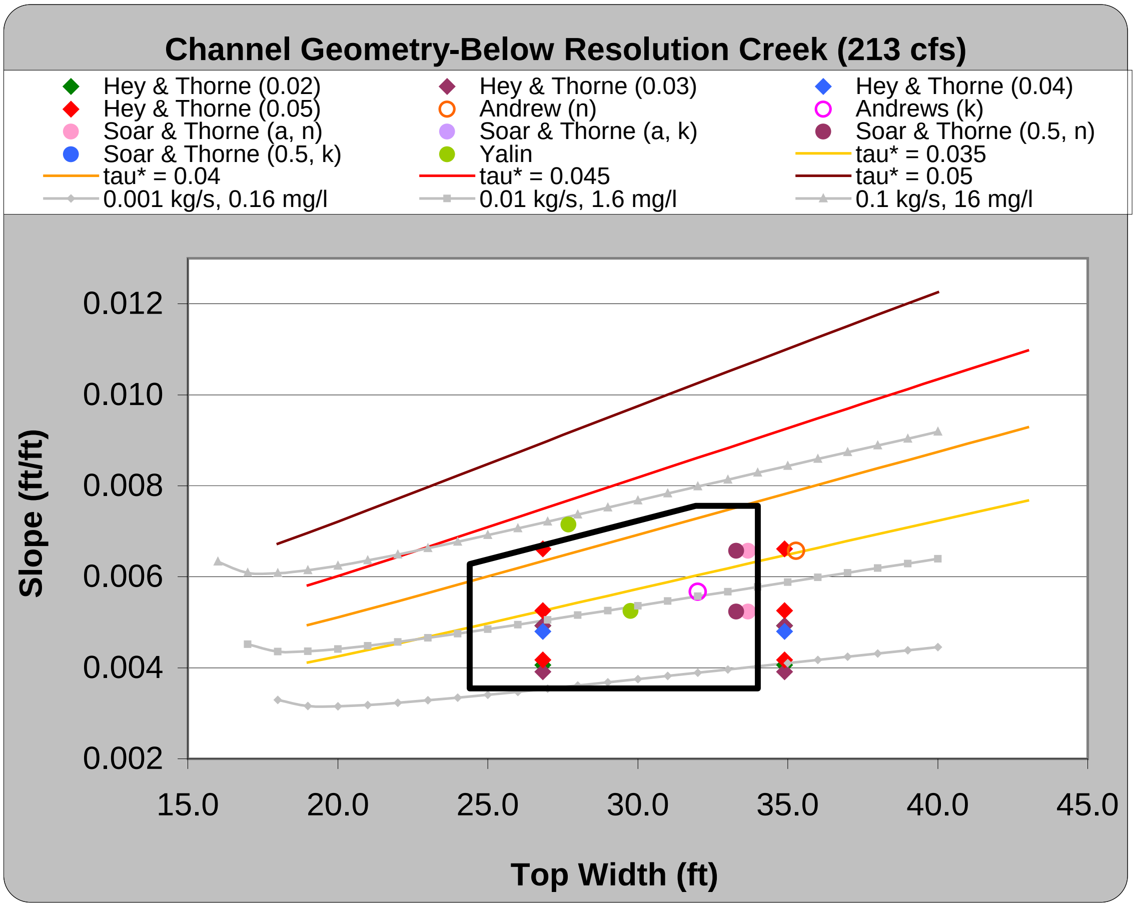


Figure 21: Hydraulic geometry results for reach below Resolution Creek. Thick and thin vegetation are denoted as 'k' and 'n', respectively. Hey and Thorne values in parenthesis are median bed material sizes in meters. Soar and Thorne parentheses represent adjustable (a) and fixed exponent (0.5) equations exponents. The black outline represents the region we expect to find reasonable results.

Using this type of logic we can reduce possible hydraulic geometries by throwing out all those with unreasonable results. Those remaining are further scrutinized until satisfactory results are obtained for channel roughness, τ_*, and sinuosity. The hydraulic geometry that results in all calculated values being of a reasonable magnitude are taken to be the "best" channel form.

Table 7 presents preliminary stable hydraulic geometry results. These are not intended to be the final design parameters. These only serve as close approximations to channel geometry that is likely to be stable. The analysis provided suggests a template upon which continued refinement of the hydraulic geometry should continue. Additionally, the proposed channel design should be tested in a hydraulic model such as the HEC-RAS model (U.S. Army Corps of Engineers (USACE), 2004).

Table 7: Preliminary hydraulic geometry for above and below Resolution Creek.

Q	Qs	D50	D84	Width	Depth	Slope	n	tau*	Sinuosity
cfs	kg/s	m	m	ft	ft	ft/ft	[ ]	[ ]	[ ]
146	0.010	0.035	0.07	22.2	1.8	0.004	0.035	0.035	1.8
213	0.015	0.04	0.08	26.8	2.0	0.004	0.035	0.034	1.9

APPENDIX A.1

Channel Design Considerations

A meander reconstruction through Camp Hale has several challenges that need to be considered during the design process. First and foremost is the short growing season at 9,200 feet. Coupled with low nutrient soils, vegetative succession will occur slowly. As vegetation is a significant component of channel stability, other measures are required to ensure bank stability until the vegetation becomes established.

Several design options are available to help stabilize the streambanks. In short, this requires that the stream bank be sufficiently strong to withstand the shear force applied by the moving water. Bank stability can be achieved by either reducing the erosive forces applied to them or increasing their ability to resist those forces.

A simple way to reduce the erosive forces acting on the streambanks is to construct the channel with a width that is on the wider end of the stable design spectrum. A stable design with a narrow channel will have greater bank shear stress and may cause bank failures long before vegetation is established. A wider channel design should decrease the shear stress on the banks to the point that some deposition occurs. This not only lengthens the available time for vegetation to establish, but it also allows the channel geometry to adjust while staying within the confines of the constructed channel.

Other options to reduce bank shear stress include the installation of cross-vanes and j-hook structures (Rosgen, 2001). Figure 22 and Figure 23 show these structures and include some basic design parameters. Both of these structures work by concentrating flow in the center of the channel, thereby reducing shear stress along the banks. Vertical channel stability is also enhanced with these structures since the streambed cannot degrade below the level of the structure. The scour pool, located on the downstream side of the structure, has the benefit of being good fish habitat (Rosgen, 2001).

Bank stability can also be achieved by placing rock and/or woody debris along the channel or using geotextiles and bioengineering. A wide range of options is available and the technique used will be a function of finances and stability requirements. With potential to need to protect both sides of a 5-mile long project, cost effectiveness will be a prevailing design factor. A relatively inexpensive option is to relocate existing riparian vegetation along the outside edge of the meander bends. While this alone will not provide enough bank resistance, it has several benefits including the immediate establishment of mature vegetation and an immediate seed source for downstream banks.

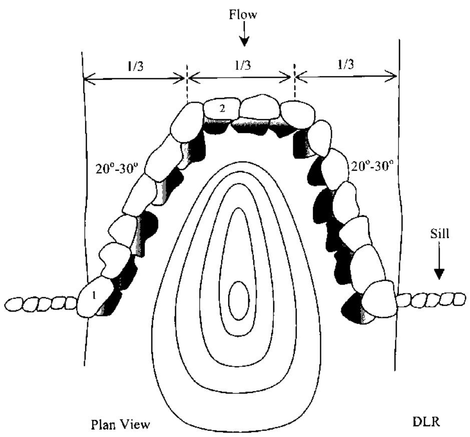


Figure 22: Cross-vane structure, typically used in straight reaches (from Rosgen (2001)).

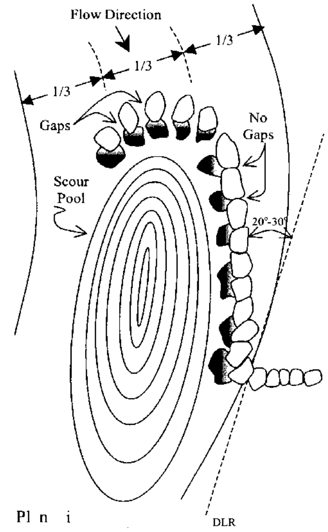


Figure 23: J-hook structure, typically used in meander bends (from Rosgen (2001)).

WETLANDS

A 1989 USFS White River National Forest (WRNF) report on Camp Hale indicates that, historically, wetlands were quite extensive throughout the valley (Figure 24). Early western settlers to the valley made their living by ranching, growing lettuce, and cutting blocks of ice for shipment to Denver. A large amount of wetlands were drained for the purpose of creating land suitable for these activities. By 1939, State Highway 24 and a railroad line crossed the valley. The 1939 extents of wetlands, according to USFS reports, are shown in Figure 25.

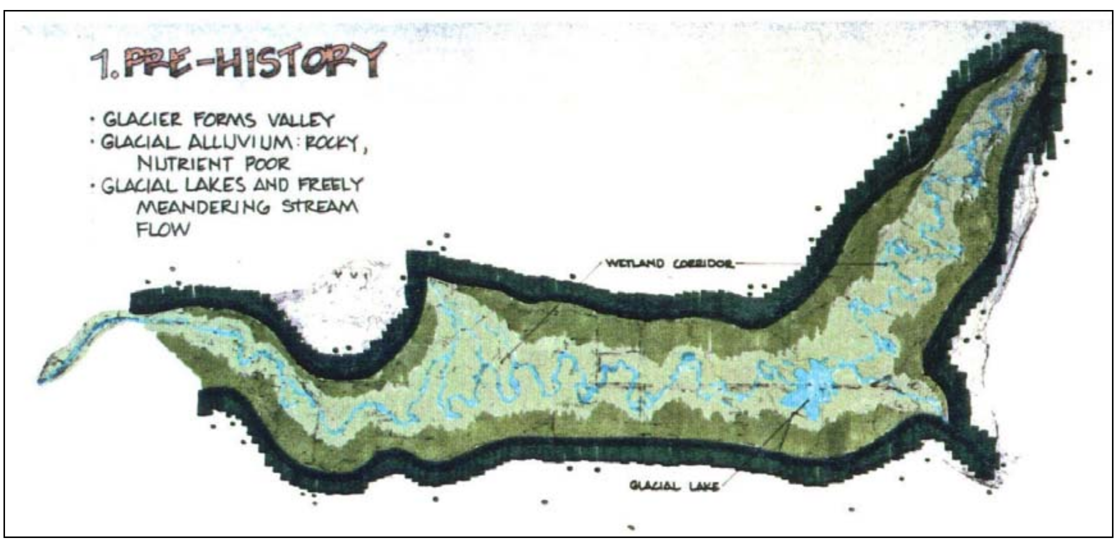


Figure 24: Historic Extents of Wetlands (from USFS, WRNF (1989)). The light green areas represent wetlands.

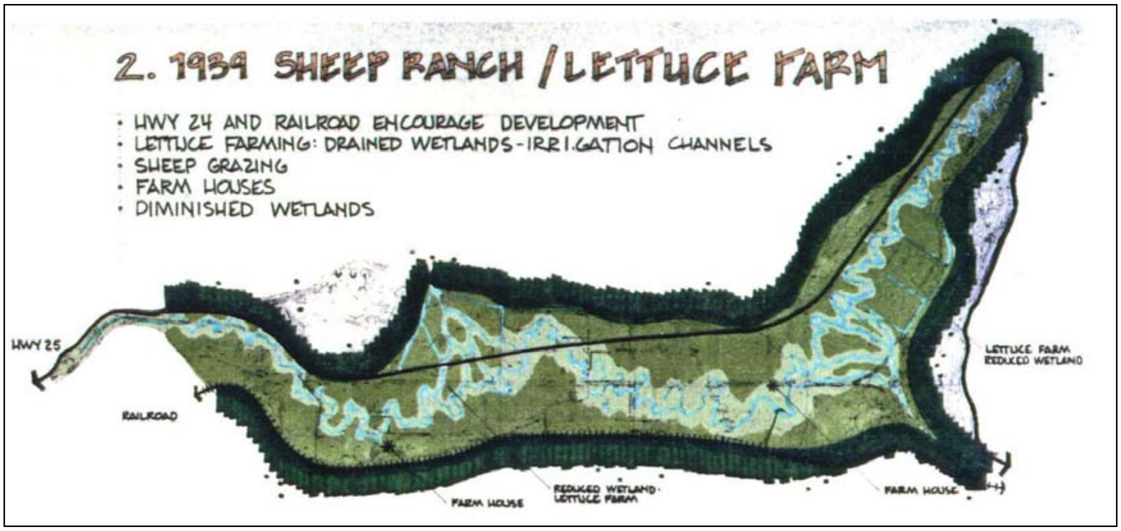


Figure 25: Extents of Wetlands in 1939 (from USFS, WRNF (1989)).

The construction of Camp Hale in 1942 required that remaining wetlands be removed to make the land suitable for buildings and equipment. To make construction of Camp Hale feasible, the river was channelized, the land drained, and fill brought in. It is estimated that 270,000 cubic yards of fill were use in the construction of Camp Hale[1] (Wettstein, 2004). The end result is a lowering of the water table with respect to the land surface.

When the water table was lowered, riparian and wetland plant species were no longer able to reach the moist soil needed to survive. Plants that are able to thrive in drier conditions (like sages) began to establish and take over as the dominant vegetation type. Today, the valley is comprised of mostly upland species and many invasive species.

The creation of wetlands would reverse this process. First, the depth to the water table must be decreased to a point that wetland and riparian species can thrive. This will require re-attaching the river to its floodplain, removing drainage ditches, and excavating wetland areas.

To reverse the effects of the 270,000 cubic yards of fill, it would be useful to know where it was placed. Black and Veatch, the company contracted to do the site plan for Camp Hale was contacted. James Nolanberger and Dave Blasair of the Denver and Kansas City offices of Black and Veatch, respectively, were unable to find the plans. According to Blasair (2004), the site plans have been destroyed.

To understand, in part, where the fill material is located, the drilling logs from the Enertech, Inc. (1993) study are useful (Addendum VII). An examination of the monitoring well drilling logs shows that, in general, more fill was placed in areas closest to the historic stream channel and known wetland areas. Concurrent with many of the fill depths are organic layers that are most likely associated with wetland and riparian areas. For wetlands created in their native locations, it may be beneficial to excavate down to the organic soil horizon. The hydric and nutrient reach soils would help ensure a speedy and healthy return of wetland vegetation and lower the cost of restoration by decreasing the need for imported organic soils.

Finally, an understanding of the historic community structure will be needed to boost the wetland community and encourage its return to a natural state. To increase our knowledge of the ecological community of the valley, Homestake Creek (Figure 26), a neighboring valley and a possible reference site, was

[1]Other sources suggest 200,000 cubic yards (Best, 2003a,b) and 2,000,000 cubic yards (Denver Post, 1942).

visited. The patterns of wetlands and stream channel in the Homestake valley are quite complex. Often it is difficult to separate the stream from the wetlands. This strong hydrologic connection is likely the historic condition of Eagle Park, and should be studied as a potential blue print for the restoration design of Camp Hale.

Figure 26: Homestake Creek.

Plant samples were taken from the Homestake valley for identification and to suggest what plant community should be present in a restored Camp Hale. Common species found in the wetland and riparian areas were

- Geyer'sWillow (*Salix geyeriana*)
- Mountain Willow (*Salix monticola*)
- Diamond Leaf Willow (*Salix planifolia*)
- Currant; Gooseberry spp. (*Ribies* spp.)
- Colorado False Hellobore (*Veratrium tenuipetalum*); and
- Twinberry Honeysuckle (*Lonicera involucrate*).

A USFS, WRNF report (1989) states that at least 600 acres should be returned to wetlands and suggested a total of 840 acres be restored. Ultimately, the area of wetlands to restore will be a function of the desired effect for wetland restoration, funding, and the ability to obtain water rights. Water rights will need to be considered, as wetlands are consumptive users of water. A study by Enertech, Inc. (1993) for the cites of Colorado Springs and Aurora suggests that 600 acres of restored wetlands at Eagle Park could require as much as 975 acre-feet of water in drought years. Average precipitation years could require 460 acre-feet. According to the report, these values were estimated high to be conservative. The high requirements may also be reduced, especially in drier years, since these calculations were based on the assumption that wetland requirements are consistent on a yearly basis. Established wetlands would likely tolerate and naturally occur in fluctuating hydrologic conditions.

MEANDER RECONSTRUCTION COST ESTIMATE

Restoration costs were estimated for a complete wetland and channel meander reconstruction. The magnitude cost estimate is based on several assumptions regarding the amount of work that will be required, sources of raw materials, the length of channel that will be reconstructed, and amount of wetlands that will be restored. The estimate was based on the average characteristics calculated for the stable channel. Addendum VIII is the cost estimate worksheet that contains the details used in the estimate. The total cost estimate for restoring the wetlands and channel is $4.3 million. This does not reflect the cost of post construction monitoring, historical preservation, recreational improvements, roads, or other non-ecological restoration improvements. Historical improvements are estimated at $1 million, bringing the total cost for a complete restoration, including monitoring and historical enhancements to $5.6 million. Considering the possibility for further historical needs, rising fuel costs, inflation, and other expenses not foreseen, the total costs could be as much as $8 million.

RESTORATION OPTIONS AND MASTER PLANS

A multitude of options are available for ecological restoration and preservation that cover the entire spectrum, from a “no action” plan, to a complete return of the original meandering channel and associated wetlands. A goal of this study is to offer an array of preliminary alternatives and show how they could be integrated with a celebration of Camp Hale.

A “no action” plan would be the least expensive alternative. The valley would simply be left as is with any naturally occurring changes allowed. The downsides to this option are the lasting ecological losses and less than desirable historical preservation.

On the other end of spectrum would be a total and complete meander bend and wetland reconstruction. The current straight channel condition of the Eagle River would be completely removed. Historic photographs and accounts of the valley could be used to mimic the natural, historic condition. At the same time, barracks or other structures could be rebuilt and a museum constructed. This plan is likely the most expensive option; however, it has the greatest ecological and commemorative benefits.

Intermediate options include retaining segments of the straight channel while returning meanders to others. Or, the straight channel could be retained, even as flooding returned to the valley, through the placement instream structures that defend against incision. An interesting option would be a complete return of the meandering channel while retaining a section of the straight channel as backwater habitat. The straightened section would be modified to function as a pond (water retention structure) as opposed to a stream (water conveyance structure). This option could have the utmost ecological and historical benefit.

Similarly, wetlands could be completely rebuilt or the land could be left as is. The deciding factors are largely based on finances, desired ecological benefits, and water rights.

APPENDIX A.1

The extent of historical preservation and praise for the 10th Mountain Division will require a separate and thorough study to elucidate the most rational and satisfactory options. The number of buildings to reconstruct or the size of a museum or visitor's center to build, if any, will depend on finances for construction, maintenance, and the degree of public interest

In the late 1980's there was a large push for a re-working of the Camp Hale area by the WRNF (USFS, WRNF, 1989). The goals at the time were similar to those proposed here: increase recreational opportunities, restore the Eagle River and associated wetlands, and preserve the history of the 10th Mountain Division. Several ideas were proposed in the historic preservation of Camp Hale including adding interpretive areas, museums, a visitor's center, and placing it on the list of National Historic Places. A conceptual plan, developed in part by the WRNF (USFS, WRNF, 1989), illustrates their proposed site plan for the valley (Figure 27). Today, interpretive signs are located around the valley, and the site is on the National Register of Historic Places. Other plans for site development have not come to fruition.

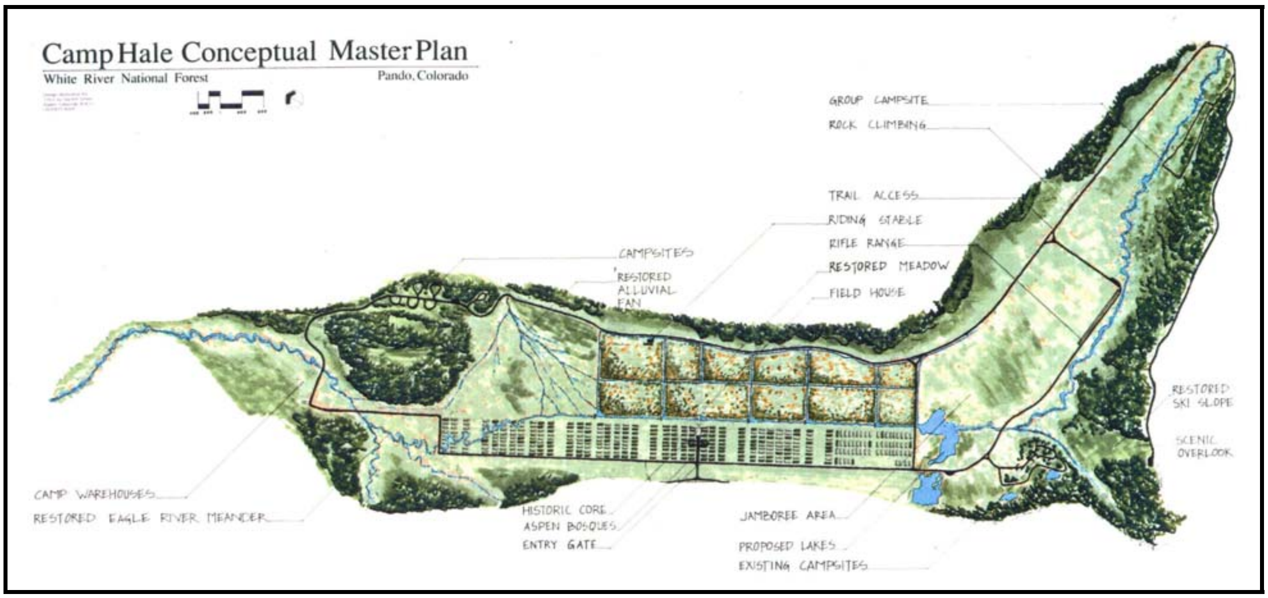


Figure 27: 1989 Proposed Camp Hale Site Plan (White River National Forest).

The Department of Civil Engineering at Colorado State University has collaborated with the Department of Landscape Architecture to develop a number of preliminary restoration alternatives for the site. The common theme for the alternatives is a celebration the achievements and sacrifices of the men of the 10th Mountain Division, while returning the ecological integrity of the valley. To date, fifteen site plans have been developed additional to the USFS plan. A broad assortment of restoration and memorial options are presented, including partial and full meander and wetland reconstructions. Addendum IX contains several of the site alternatives, and includes a brief narrative on the highlights of each.

Possibilities suggested for a new visitor's center include rebuilding historical facilities, such as barracks, the Pando Train Station, and the field house (Figure 28), or building completely new facilities. Tributes to the men of Camp Hale were numerous, including planting a tree for every soldier that served at Camp Hale, building a rock wall and engraving the names of the 10th Mountain Division's soldiers, and creating bronze statues.

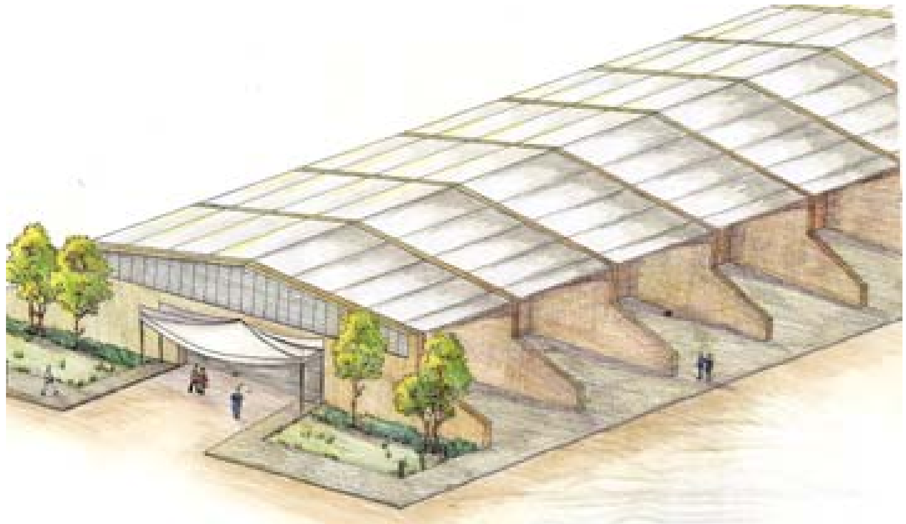


Figure 28: The field house remodeled to serve as a visitor's center.

Often, the straightened channel of Camp Hale is mentioned as a significant attribute of Camp Hale. Therefore, several conceptual designs were developed to symbolize the straightened form including:

- integrating a reach of the straight channel into the restoration design
- designing a reach of the straight channel to function as a backwater area to a full meander reconstruction
- creating a reflection pond along a reach of the straight channel (Figure 29)
- planting an alley way of trees atop the filled channel; and
- building a trapezoidal mound above the straight channel which would be a three dimensional reflection of the historic channel.

Figure 29: A concrete-lined reflection pond serves as a symbol of the channelized river.

The trapezoidal mound offers an interesting idea. It would need to be discontinuous at locations where the restored channel crosses its path, however, it would be relatively low maintenance compared to many other alternatives. At the same time, it is a bold statement about the historic form of the Camp Hale channel and it is a low-cost alternative to hauling away fill from the excavation of the new channel and wetlands.

MUNITIONS CLEANUP

Munitions have been found in Camp Hale long since the military base was closed. Although thought to have been thoroughly removed, their continued discovery prompted the USACE to conduct an intense search for live munitions. Figure 30, provided by the USACE, shows the boundaries of the cleanup.

The cleanup, known as a Time Critical Response Action (TCRA) was completed in August, 2003. There was a total of 24 items found, removed and destroyed over the course of the eleven-week project. Some of the items used at Camp Hale (but not necessarily discovered during the TCRA) include anti-tank rockets, recoilless rifles, rifle grenades, hand grenades, high explosive and illumination mortars, artillery, practice antitank land mines, and small arms.

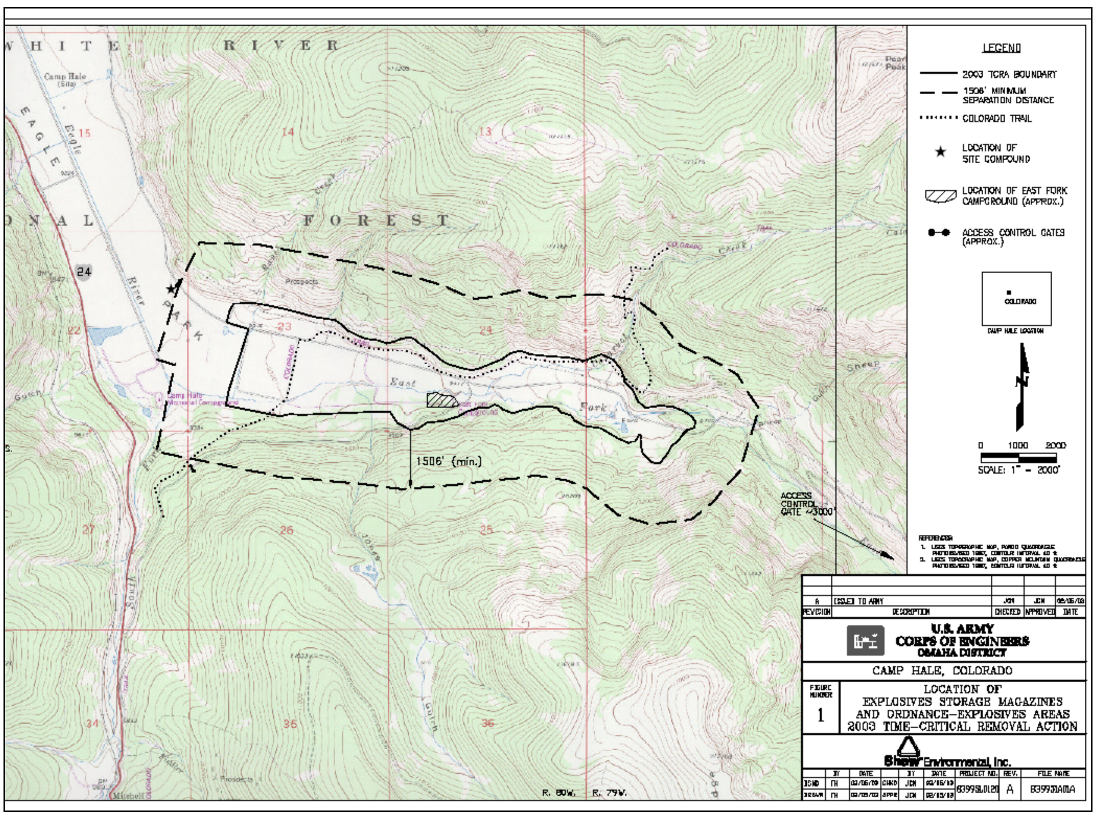


Figure 30: Camp Hale munitions cleanup boundary (from the USACE).

CONCLUSIONS

Camp Hale is an incredible opportunity to restore natural ecologic, hydrologic, hydraulic, energy, and chemical processes, just as it was a unique opportunity to build a mountain and winter warfare training center. Similarly, it is a great chance to commemorate the men of Camp Hale, and show them our appreciation. This report demonstrates the many options available to combine these efforts, and offers an opportunity to discuss the future of Camp Hale.

The next step in the progression of Camp Hale should be open discussions based on these findings. As a final design becomes clear for the stream channel and wetlands, work will need to continue to refine and develop the geomorphic form of the channel.

REFERENCES

Andrews, E.D. (1984). Bed-material entrainment and hydraulic geometry of gravel-bed rivers in Colorado. *Geological Society of America Bulletin* 95:371-378.

Best, A. (2003a). Preservation vs. restoration at Camp Hale. *Historic Preservation, Colorado Central Magazine*, (113):23.

Best, A. (2003b). Straight and true: History meets hydrology. *Forest Magazine*, Winter:19-24.

Blasair, D. (2004). Black and Veatch Kansas City, Kansas Office. Personal communication.

Bledsoe, B.P., and C.C. Watson (2001). Logistic regression of channel pattern thresholds: Meandering, braiding, and incision. *Geomorphology* 38:281-300.

Bledsoe, B.P., C.C. Watson, and D.S. Biedenharn (2002). Quantification of incised channel evolution and equilibrium. *J. American Water Resources Association* 38:861-870.

Bridge, J.S. (1993). The interaction between channel geometry, water flow, sediment transport and deposition in braided rivers. *In* Braided Rivers, Special Publication of the Geological Society of London, J.L. Best and C.S. Bristow (Eds),75:13-71.

Chow, V.T. (1959). Open Channel Flow. McGraw-Hill, Inc.

Colorado National Heritage Program (2000). Biological Survey of Eagle County, Colorado 2000 Final Report. Colorado State University, College of Natural Resources.

Denver Post (1942). Camp Hale builders win race against time—The job is done.

Enertech, Inc. (1993). Eagle Park Project, Preliminary Assessment of Project Operation. Enertech, Inc., Consulting Engineers and Hydrologists, Glenwood Springs, CO.

Hammerson, G.A. (1999). Amphibians and Reptiles in Colorado. Second Edition, University Press of Colorado, Niwot, CO, 484 pp.

Harrelson, C.C, C.L. Rawlins, and J.P. Potyondy (1994). Stream Channel Reference Sites: An Illustrated Guide to Field Technique. USFS, General Technical Report RM-245.

Hey, R.D., and C.R. Thorne (1986). Stable channels with mobile gravel beds. J. Hydraulic Engineering, 112:671-689.

Knighton, D. (1998). Fluvial Forms and Processes: A New Perspective. Oxford University Press, Inc., New York, NY, 383 pp.

Kondolf, G.M., M.W. Smeltzer, and S.F. Railsback (2001). Design and performance of a channel reconstruction project in a coastal California gravel-bed stream. *Environmental Management* 28(6):761-776.

Leopold, L.B., and M.G. Wolman (1960). River meanders. *Geological Society of America Bulletin* 71:769-794.

Nolanberger, J. (2004). Black and Veatch Denver, Colorado Office. Personal communication.

Raff, D., and B.P. Bledsoe (2003). GeoTool Users Manual. Engineering Research Center, Colorado State University, Report to the U.S. Army Corps of Engineers.

Rosgen, D.L. (1996). Applied River Morphology. Wildland Hydrology Books, Catena, 385 pp.

Rosgen, D.L. (2001). The Cross-vane, W-weir, and J-hook Vane Structures…Their Description, Design and Application for Stream Stabilization and River Restoration. ASCE Conference, Reno, NV, August.

Schumm, S.A., M.D. Harvey, and C.C. Watson (1984). Incised Channels: Morphology, Dynamics and Control. Water Resources Publications, Littleton, CO.

Sen, P.K. (1968). Estimates of the regression coefficient based on Kendall's tau. *J. American Statistical Association* 63:1379-1389.

Soar, P.J., and C.R. Thorne (2001). Channel Restoration Design for Meandering Rivers. Prepared for the U.S. Army Corps of Engineers.

Trotter, P.C. (1987). Cutthroat: Native Trout of the West. Colorado Associated University Press. Boulder, CO, 219 pp.

USACE (2004). U.S. States Army Corps of Engineers, Hydrologic Engineering Center, River Assessment System. Accessed July, 2004 at http://www.hec.usace.army.mil/software/hec-ras/documents/userman/index.html.

USGS (2004). The USGS Real-time Water Data. Accessed March, 2004 at http://waterdata.usgs.gov/co/nwis/rt.

USFS, White River National Forest (1989). Camp Hale Historic Preservation-Recreation Development-Stream and Wetland Restoration.

van den Berg, J.H. (1995). Prediction of alluvial channel pattern of perennial rivers. *Geomorphology* 12:259-279.

Webb, R.H., G.J. McCabe, R. Hereford, and C. Wilkowske (2004). Climatic Fluctuations, Drought, and Flow in the Colorado River. USGS Fact Sheet 3062-04.

Wettstein, C. (2004). USFS White River National Forest, Colorado. Personal communication.

Wilcock, P.R., and S.T. Kenworthy (2002). A two-fraction model for the transport of sand / gravel mixtures. *Water Resources Research* 38(10):1194.

Williams, G.P. (1978). Bank-full discharge of rivers. *Water Resources Research* 14(6)1141-1154.

Williams, G.P. (1986). River meanders and channel size. *J. Hydrology*, 88(1986):147-164.

APPENDIX A.1

Wolman, M.G. (1954) A method for sampling coarse river-bed material. *Transactions of the American Geophysical Union* 35(6):951-956.

Yalin, M.S. (2001). Fluvial Processes. International Association of Hydraulic Engineering and Research. Delft, Netherlands.

APPENDIX A.1

ADDENDUM I – RECURRENCE INTERVAL ANALYSIS

APPENDIX A.1

Eagle River at Red Cliff Recurrence Intervals (All Data).

Order	Date of Peak	Peak Q (cfs)	Prob. of Occurrence	Return Interval
1	6/5/1912	1010	0.013	77.00
2	5/19/1911	900	0.026	38.50
3	5/24/1984	846	0.039	25.67
4	6/3/1914	800	0.052	19.25
5	6/10/1921	750	0.065	15.40
6	6/7/1957	712	0.078	12.83
7	6/16/1917	705	0.091	11.00
8	6/11/1918	685	0.104	9.63
9	6/1/1920	685	0.117	8.56
10	6/17/1979	676	0.130	7.70
11	5/20/1948	655	0.143	7.00
12	6/17/1995	653	0.156	6.42
13	6/7/1952	630	0.169	5.92
14	5/28/1953	628	0.182	5.50
15	6/16/1923	608	0.195	5.13
16	6/20/1983	585	0.208	4.81
17	5/10/1916	582	0.221	4.53
18	5/19/1996	551	0.234	4.28
19	6/4/1997	533	0.247	4.05
20	5/26/1958	530	0.260	3.85
21	6/12/1915	510	0.273	3.67
22	5/31/1951	510	0.286	3.50
23	5/25/1993	482	0.299	3.35
24	6/7/1924	480	0.312	3.21
25	6/15/1978	475	0.325	3.08
26	6/9/1960	440	0.338	2.96
27	6/12/1949	433	0.351	2.85
28	6/3/1913	430	0.364	2.75
29	6/10/1973	415	0.377	2.66
30	5/29/1974	415	0.390	2.57
31	6/5/1975	415	0.403	2.48
32	5/28/1922	412	0.416	2.41
33	6/5/1968	408	0.429	2.33
34	5/20/1919	380	0.442	2.26
35	5/10/1947	377	0.455	2.20
36	6/25/2003	375	0.468	2.14
37	6/6/1950	374	0.481	2.08
38	5/24/1956	371	0.494	2.03
39	5/12/1962	362	0.506	1.97
40	6/11/1980	358	0.519	1.93
41	5/29/2000	355	0.532	1.88
42	6/16/1965	350	0.545	1.83
43	6/9/1999	335	0.558	1.79
44	5/24/1964	330	0.571	1.75
45	5/22/1925	325	0.584	1.71

APPENDIX A.1

Eagle River at Red Cliff Recurrence Intervals (All Data).

Order	Date of Peak	Peak Q (cfs)	Prob. of Occurrence	Return Interval
46	5/17/1970	305	0.597	1.67
47	5/27/1969	301	0.610	1.64
48	6/6/1986	301	0.623	1.60
49	6/8/1985	298	0.636	1.57
50	5/29/1971	297	0.649	1.54
51	6/4/1976	279	0.662	1.51
52	5/25/1944	275	0.675	1.48
53	6/6/1946	262	0.688	1.45
54	6/9/1982	255	0.701	1.43
55	5/17/1987	251	0.714	1.40
56	6/5/1990	251	0.727	1.38
57	6/8/1959	234	0.740	1.35
58	5/27/1991	212	0.753	1.33
59	6/6/1972	210	0.766	1.31
60	5/28/1945	201	0.779	1.28
61	6/1/1994	198	0.792	1.26
62	5/30/2001	198	0.805	1.24
63	5/24/1967	196	0.818	1.22
64	5/29/1989	194	0.831	1.20
65	6/2/1998	180	0.844	1.18
66	5/30/1961	170	0.857	1.17
67	6/5/1988	170	0.870	1.15
68	5/27/1992	164	0.883	1.13
69	5/22/1954	135	0.896	1.12
70	5/15/1955	132	0.909	1.10
71	5/7/1966	125	0.922	1.08
72	5/31/1977	117	0.935	1.07
73	5/11/1963	100	0.948	1.05
74	6/6/1981	99	0.961	1.04
75	6/26/2004	89	0.974	1.03
76	6/24/2002	46	0.987	1.01

APPENDIX A.1

Eagle River at Red Cliff Recurrence Intervals (Post-1944).

Order	Date of Peak	Peak Q (cfs)	Prob. of Occurrence	Return Interval
1	6/24/2002	846	0.016	62.00
2	6/26/2004	712	0.032	31.00
3	6/6/1981	676	0.048	20.67
4	5/11/1963	655	0.065	15.50
5	5/31/1977	653	0.081	12.40
6	5/7/1966	630	0.097	10.33
7	5/15/1955	628	0.113	8.86
8	5/22/1954	585	0.129	7.75
9	5/27/1992	551	0.145	6.89
10	5/30/1961	533	0.161	6.20
11	6/5/1988	530	0.177	5.64
12	6/2/1998	510	0.194	5.17
13	5/29/1989	482	0.210	4.77
14	5/24/1967	475	0.226	4.43
15	6/1/1994	440	0.242	4.13
16	5/30/2001	433	0.258	3.88
17	5/28/1945	415	0.274	3.65
18	6/6/1972	415	0.290	3.44
19	5/27/1991	415	0.306	3.26
20	6/8/1959	408	0.323	3.10
21	5/17/1987	377	0.339	2.95
22	6/5/1990	375	0.355	2.82
23	6/9/1982	374	0.371	2.70
24	6/6/1946	371	0.387	2.58
25	5/25/1944	362	0.403	2.48
26	6/4/1976	358	0.419	2.38
27	5/29/1971	355	0.435	2.30
28	6/8/1985	350	0.452	2.21
29	5/27/1969	335	0.468	2.14
30	6/6/1986	330	0.484	2.07
31	5/17/1970	305	0.500	2.00
32	5/24/1964	301	0.516	1.94
33	6/9/1999	301	0.532	1.88
34	6/16/1965	298	0.548	1.82
35	5/29/2000	297	0.565	1.77
36	6/11/1980	279	0.581	1.72
37	5/12/1962	275	0.597	1.68
38	5/24/1956	262	0.613	1.63
39	6/6/1950	255	0.629	1.59
40	6/25/2003	251	0.645	1.55
41	5/10/1947	251	0.661	1.51
42	6/5/1968	234	0.677	1.48
43	6/10/1973	212	0.694	1.44
44	5/29/1974	210	0.710	1.41

APPENDIX A.1

Eagle River at Red Cliff Recurrence Intervals (Post-1944).

Order	Date of Peak	Peak Q (cfs)	Prob. of Occurrence	Return Interval
45	6/5/1975	201	0.726	1.38
46	6/12/1949	198	0.742	1.35
47	6/9/1960	198	0.758	1.32
48	6/15/1978	196	0.774	1.29
49	5/25/1993	194	0.790	1.27
50	5/31/1951	180	0.806	1.24
51	5/26/1958	170	0.823	1.22
52	6/4/1997	170	0.839	1.19
53	5/19/1996	164	0.855	1.17
54	6/20/1983	135	0.871	1.15
55	5/28/1953	132	0.887	1.13
56	6/7/1952	125	0.903	1.11
57	6/17/1995	117	0.919	1.09
58	5/20/1948	100	0.935	1.07
59	6/17/1979	99	0.952	1.05
60	6/7/1957	89	0.968	1.03
61	5/24/1984	46	0.984	1.02

Eagle River at Red Cliff Recurrence Intervals (Pre-1944).

Order	Date of Peak	Peak Q (cfs)	Prob. of Occurrence	Return Interval
1	6/5/1912	1010	0.063	16.00
2	5/19/1911	900	0.125	8.00
3	6/3/1914	800	0.188	5.33
4	6/10/1921	750	0.250	4.00
5	6/16/1917	705	0.313	3.20
6	6/11/1918	685	0.375	2.67
7	6/1/1920	685	0.438	2.29
8	6/16/1923	608	0.500	2.00
9	5/10/1916	582	0.563	1.78
10	6/12/1915	510	0.625	1.60
11	6/7/1924	480	0.688	1.45
12	6/3/1913	430	0.750	1.33
13	5/28/1922	412	0.813	1.23
14	5/20/1919	380	0.875	1.14
15	5/22/1925	325	0.938	1.07

Homestake Creek at Gold Park Recurrence Intervals (Post-1967).

Order	Date of Peak	Peak Q (cfs)	Prob. of Occurrence	Return Interval
1	6/30/1984	930	0.036	28.00
2	6/1/1997	802	0.071	14.00
3	6/19/2000	671	0.107	9.33
4	6/15/1978	639	0.143	7.00
5	7/30/1983	611	0.179	5.60
6	7/4/1975	562	0.214	4.67
7	6/4/1986	530	0.250	4.00
8	6/13/1979	513	0.286	3.50
9	6/30/1998	513	0.321	3.11
10	6/8/1985	470	0.357	2.80
11	6/18/1995	465	0.393	2.55
12	6/9/1981	429	0.429	2.33
13	6/21/1996	410	0.464	2.15
14	6/10/1980	362	0.500	2.00
15	6/14/1993	358	0.536	1.87
16	6/23/1999	337	0.571	1.75
17	6/8/1987	325	0.607	1.65
18	6/7/1990	285	0.643	1.56
19	6/5/1976	270	0.679	1.47
20	6/4/1988	257	0.714	1.40
21	7/24/1977	230	0.750	1.33
22	6/28/1982	217	0.786	1.27
23	6/11/1991	201	0.821	1.22
24	6/25/2001	196	0.857	1.17
25	5/17/1994	183	0.893	1.12
26	7/12/1989	137	0.929	1.08
27	4/29/1992	103	0.964	1.04

APPENDIX A.1

ADDENDUM II – EAGLE RIVER AT RED CLIFF DISCHARGES ADJUSTED TO UPSTREAM WATERSHEDS

Watershed	Discharges Estimated From Refitted USGS Equations (cfs)								Watershed Slope (unitless)	Watershed Area (km^2)
	Maximum					$Q_{1.5}$	Q_{eff}	Minimum		
Red Cliff	698	600	500	400	300	251	239	197	0.30	75.8
Pando	622	535	446	357	267	224	213	176	0.29	66.4
Abv Yoder	476	409	341	273	205	171	163	134	0.28	47.7
SF Eagle	215	185	154	123	92	77	73	61	0.24	18.8
EF Eagle	332	286	238	190	143	120	114	94	0.31	24.6
Resolution	233	200	167	133	100	84	80	66	0.37	11.8
Yoder	75	64	53	43	32	27	26	21	0.25	3.8

* Pando is also called "Below resolution" and Abv Yoder is also called "Abv Resolution".

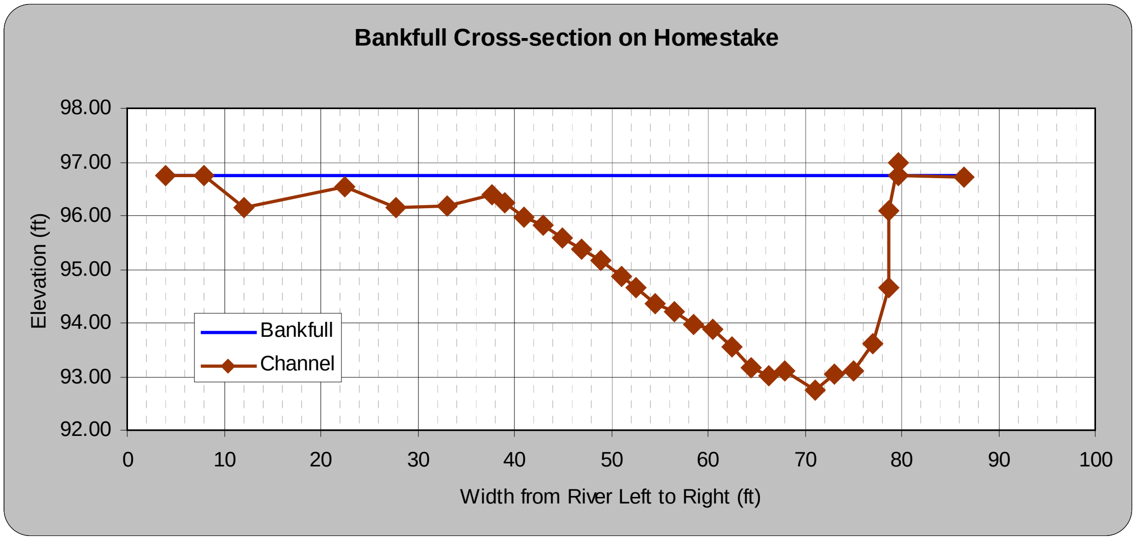
Watershed	Discharges Estimated by Unit Watershed Area (cfs)								Watershed Area (km^2)
	Maximum					$Q_{1.5}$	Q_{eff}	Minimum	
Red Cliff	698	600	500	400	300	251	239	197	75.8
Pando	612	526	438	350	263	220	209	176	66.4
Abv Yoder	439	378	315	252	189	158	150	134	47.7
SF Eagle	174	149	124	99	75	62	59	61	18.8
EF Eagle	227	195	162	130	97	82	78	94	24.6
Resolution	109	94	78	62	47	39	37	66	11.8
Yoder	35	30	25	20	15	13	12	21	3.8

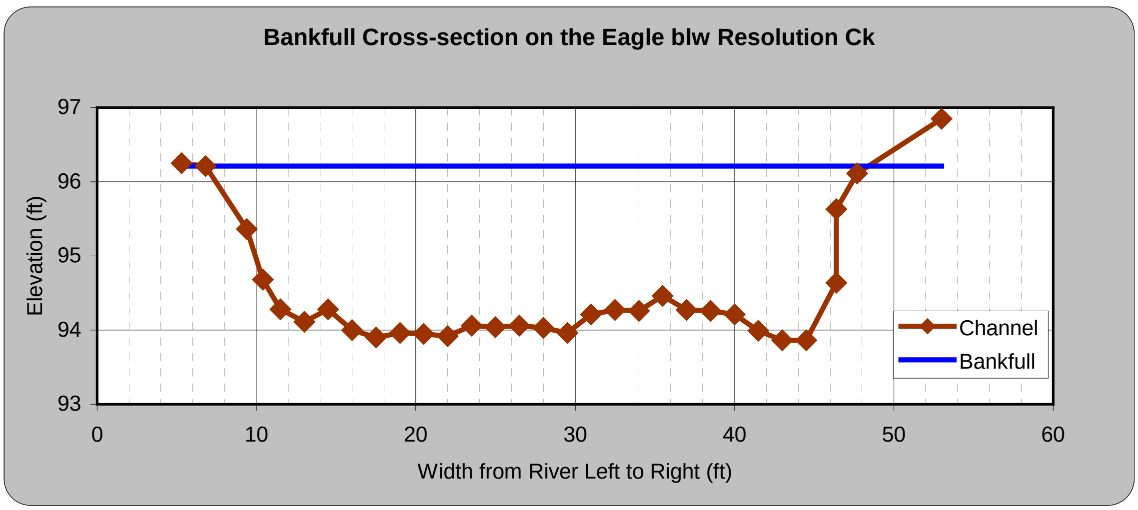
* Pando is also called "Below resolution" and Abv Yoder is also called "Abv Resolution".

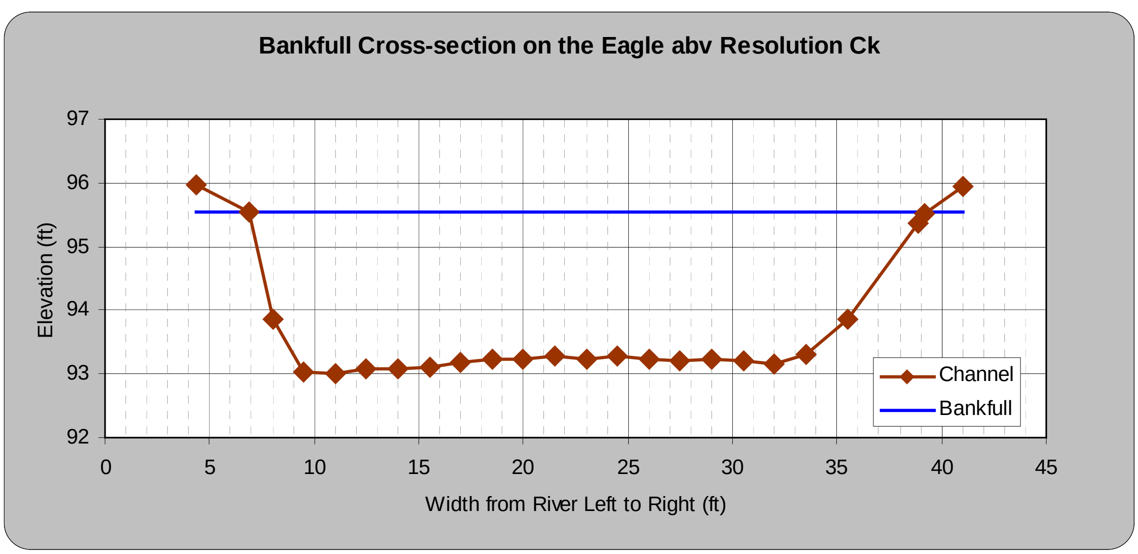
APPENDIX A.1

ADDENDUM III – CHANNEL CROSS SECTIONS

APPENDIX A.1





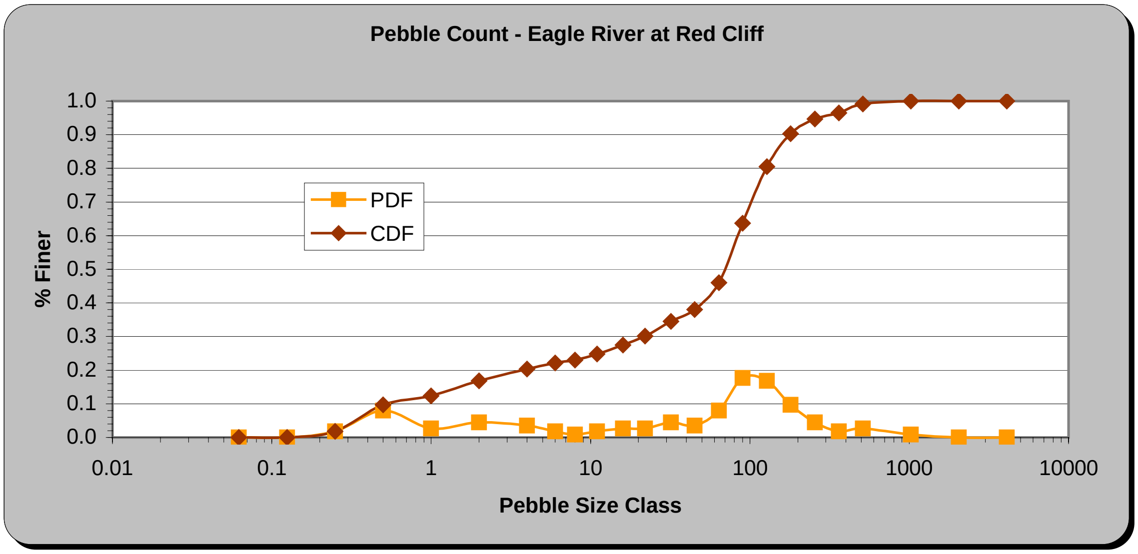


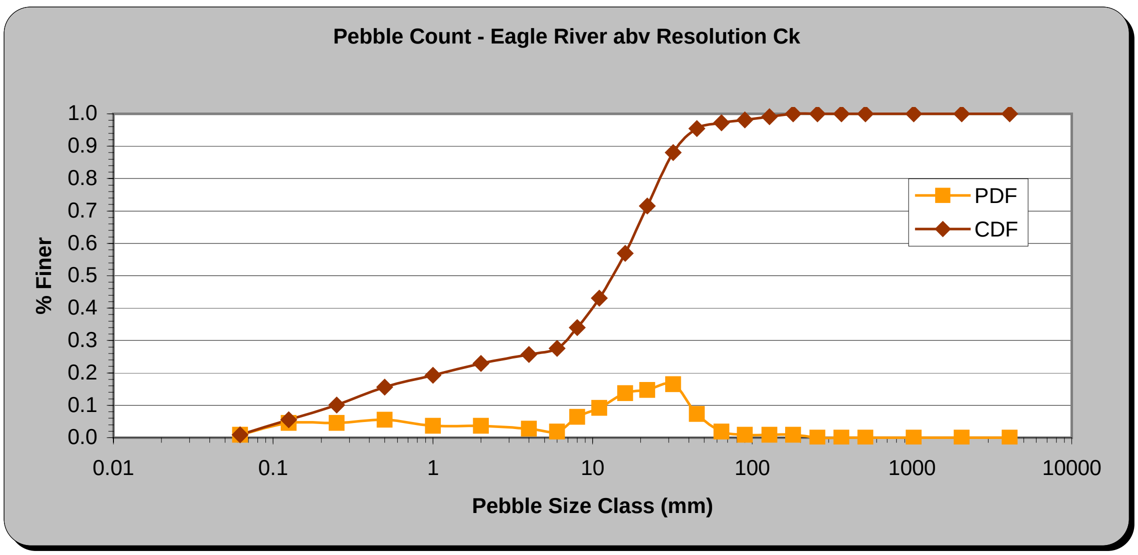
Note: Looking upstream

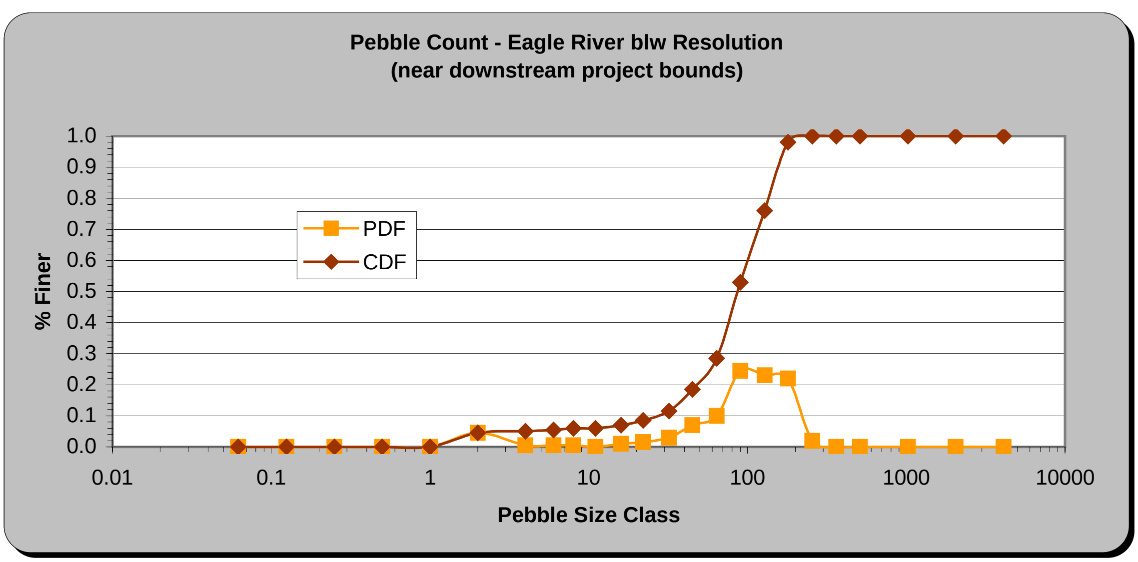
APPENDIX A.1

ADDENDUM IV – WOLMAN PEBBLE COUNTS

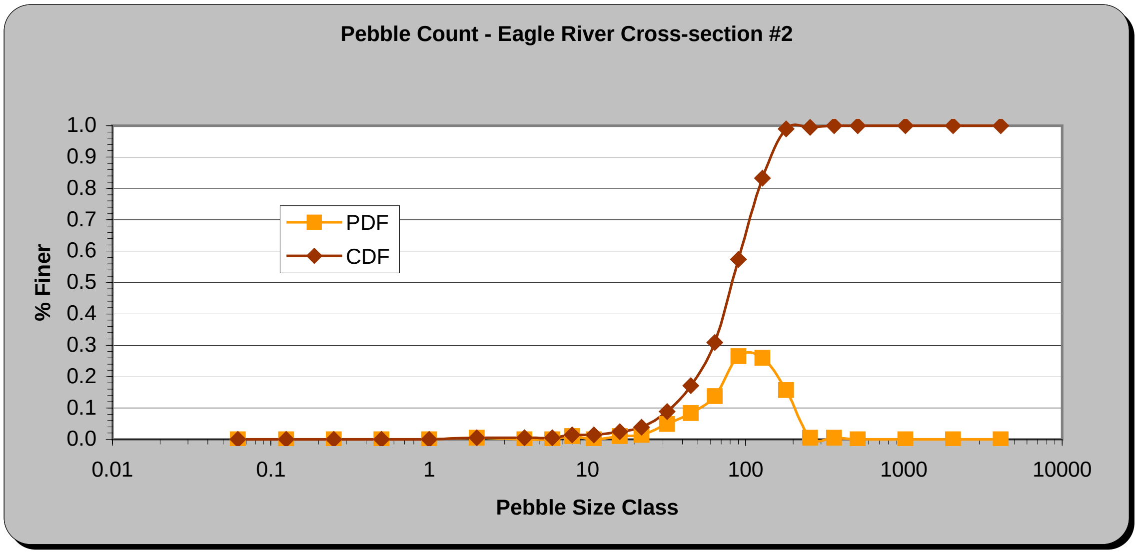
APPENDIX A.1


Pebble Count - Eagle River at Red Cliff
% Finer
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
PDF
CDF
0.01
0.1
1
10
100
1000
10000
Pebble Size Class

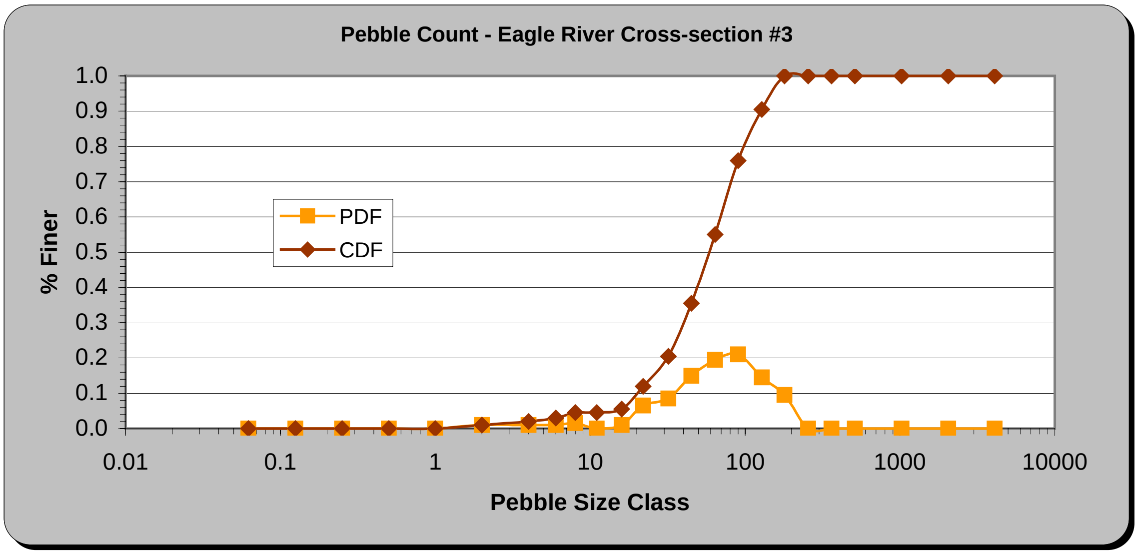

Pebble Count - Eagle River abv Resolution Ck
% Finer
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
PDF
CDF
0.01
0.1
1
10
100
1000
10000
Pebble Size Class (mm)


Pebble Count - Eagle River blw Resolution
(near downstream project bounds)
% Finer
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
PDF
CDF
0.01
0.1
1
10
100
1000
10000
Pebble Size Class

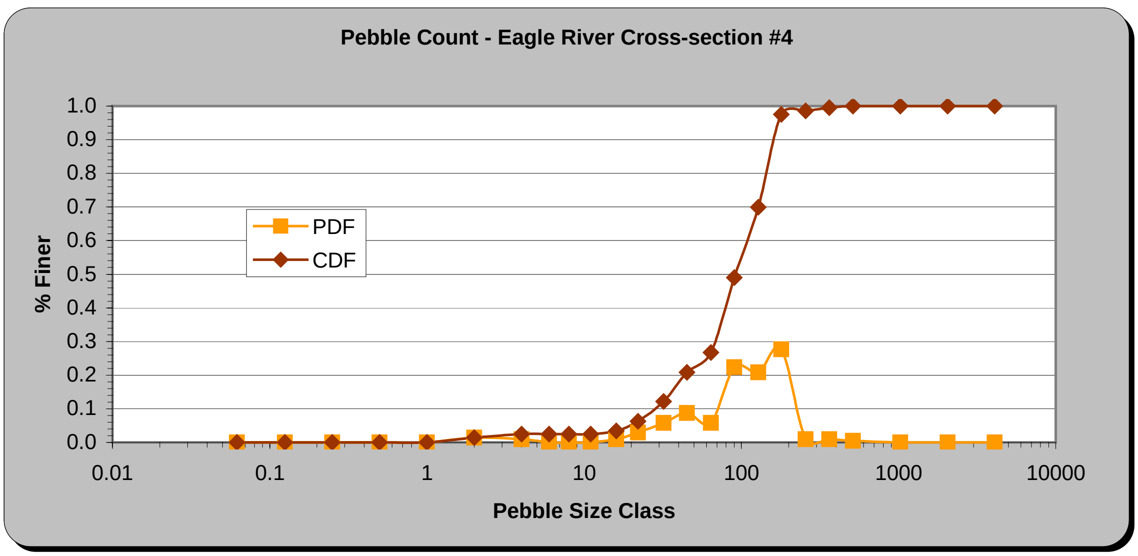
APPENDIX A.1



Pebble Count - Eagle River Cross-section #2
% Finer
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
PDF
CDF
0.01
0.1
1
10
100
1000
10000
Pebble Size Class



Pebble Count - Eagle River Cross-section #3
% Finer
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
PDF
CDF
0.01
0.1
1
10
100
1000
10000
Pebble Size Class



Pebble Count - Eagle River Cross-section #4
% Finer
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
PDF
CDF
0.01
0.1
1
10
100
1000
10000
Pebble Size Class

APPENDIX A.1

Bed Material Summary (in mm)					
Site	D16	D35	D50	D84	D95
Eagle River blw Resolution Ck	39.8	70.1	86.3	144.9	171.8
Cross section 2	42.9	67.5	81.9	129.9	164.9
Cross section 3	26.2	44.5	58.5	109.3	150.4
Cross section 4	37.2	72.6	91.5	152.3	174.4
Eagle River at Red Cliff Gage	1.8	33.5	69.1	144.5	272.0
Eagle River abv Resolution Ck	0.5	8.3	13.3	29.2	44.1

APPENDIX A.1

ADDENDUM V – WILCOCK AND KENWORTHY (2002) BEDLOAD EQUATION

APPENDIX A.1

The Wilcock and Kenworthy (2002) bedload transport method uses a two fraction, sand and gravel, transport model which accounts for the nonlinear effects of sand mixing with gravel on total sediment transport rates. The surface transport model from Wilcock and Kenworthy (2002) is presented below. The user must provide values of D_s and D_g, characteristic surface grain sizes for the sand and gravel fractions, respectively. The value of F_s, somewhere between 0 and 1 is the proportion of the surface sediment in the sand fraction, must also be provided along with values of channel width, *w*, and slope, *S*. The sediment transport is calculated for sand and gravel size fractions separately. In equations (1) through (5) the subscript *i* represents either the sand or gravel size fraction. To calculate the sediment transport per unit channel width the following procedure is complete. First the dimensionless incipient motion criteria is solved for as

$$\tau_{ri}^* = \left(\tau_{ri}^*\right)_1 + \left[\left(\tau_{ri}^*\right)_0 - \left(\tau_{ri}^*\right)_1\right]e^{-14F_s} \qquad \text{Eq (28)}$$

where the incipient motion parameters are given for the surface transport model in Wilcock and Kenworthy (2002) Table 3 as $\left(\tau_{rg}^*\right)_0 = 0.035$, $\left(\tau_{rg}^*\right)_1 = 0.011$ and $\left(\tau_{rs}^*\right)_1 = 0.065$ and

$$\left(\tau_{rs}^*\right)_0 = \left(\tau_{rg}^*\right)_0 \left(D_g \big/ D_s \right). \qquad \text{Eq (29)}$$

The reference shear stress for each size fraction is then calculated as

$$\tau_{ri} = \tau_{ri}^*(G-1)\rho g D_i \,. \qquad \text{Eq (30)}$$

A parameter designed as the ratio of shear stress to reference shear stress

$$\phi = \frac{\tau}{\tau_{ri}} \qquad \text{Eq (31)}$$

is necessary to calculate the reference transport function of the form (dimensionless)

$$W_i^* = \begin{cases} 0.002\phi^{7.5} & \text{for } \phi < \phi' \\ A\left(1 - \dfrac{\chi}{\phi^{0.25}}\right)^{4.5} & \text{for} \phi \geq \phi' \end{cases}. \qquad \text{Eq (32)}$$

Within the transport function above A is a fitted parameter, and ϑ' and χ are chosen to match the value and slope of the two parts of the function. The Wilcock and Kenworthy (2002) calibration using field data gave A = 115, ϕ' = 1.27 and χ = 0.923. The sediment transport per unit channel width is then calculated for each size fraction as

$$q_{bi} = \frac{F_i u_*^3 W_i^*}{g(G-1)}. \qquad \text{Eq (33)}$$

The total sediment transport, per unit channel width, is calculated as the sum of q_s and q_g.

APPENDIX A.1

ADDENDUM VI – HYDRAULIC GEOMETRY

Andrews Equations

Veg. Type	Q (cfs)	Q (cms)	Q*	D50 (m)	Top W (m)	Top W (ft)	D (m)	D (ft)	Slope	n	tau*	Sinuosity
thin	213	6.0	26503	0.02	12.9	42.2	0.45	1.5	0.003	0.03	0.03	3.1
thin	213	6.0	9617	0.03	11.9	39.0	0.46	1.5	0.004	0.03	0.03	2.0
thin	213	6.0	4685	0.04	11.2	36.8	0.47	1.5	0.005	0.04	0.03	1.5
thin	213	6.0	2682	0.05	10.8	35.3	0.48	1.6	0.007	0.04	0.03	1.2
thick	213	6.0	26503	0.02	10.6	34.8	0.43	1.4	0.004	0.02	0.04	2.2
thick	213	6.0	9617	0.03	9.8	32.0	0.44	1.4	0.006	0.03	0.05	1.4
thick	213	6.0	4685	0.04	9.2	30.2	0.45	1.5	0.008	0.03	0.05	1.0
thick	213	6.0	2682	0.05	8.8	28.8	0.46	1.5	0.010	0.04	0.05	0.8

Soar and Thorne's version of Andrews

Veg. Type	Exponent	Q (cfs)	Q (cms)	D50 (m)	Top W (m)	Top W (ft)	D (m)	D (ft)	Slope	n	tau*	Sinuosity
thin	adjustable	213	6.0	0.02	10.27	33.7	0.45	1.5	0.003	0.02	0.03	3.1
thin	adjustable	213	6.0	0.03	10.27	33.7	0.46	1.5	0.004	0.03	0.03	2.0
thin	adjustable	213	6.0	0.04	10.27	33.7	0.47	1.5	0.005	0.03	0.03	1.5
thin	adjustable	213	6.0	0.05	10.27	33.7	0.48	1.6	0.007	0.04	0.03	1.2
thick	adjustable	213	6.0	0.02	8.87	29.1	0.43	1.4	0.004	0.02	0.04	2.2
thick	adjustable	213	6.0	0.03	8.87	29.1	0.44	1.4	0.006	0.03	0.05	1.4
thick	adjustable	213	6.0	0.04	8.87	29.1	0.45	1.5	0.008	0.03	0.05	1.0
thick	adjustable	213	6.0	0.05	8.87	29.1	0.46	1.5	0.010	0.04	0.05	0.8
thin	0.5	213	6.0	0.02	10.14	33.3	0.45	1.5	0.003	0.02	0.02	3.1
thin	0.5	213	6.0	0.03	10.14	33.3	0.46	1.5	0.004	0.03	0.02	2.0
thin	0.5	213	6.0	0.04	10.14	33.3	0.47	1.5	0.005	0.03	0.02	1.5
thin	0.5	213	6.0	0.05	10.14	33.3	0.48	1.6	0.007	0.04	0.02	1.2
thick	0.5	213	6.0	0.02	8.99	29.5	0.43	1.4	0.004	0.02	0.02	2.2
thick	0.5	213	6.0	0.03	8.99	29.5	0.44	1.4	0.006	0.03	0.02	1.4
thick	0.5	213	6.0	0.04	8.99	29.5	0.45	1.5	0.008	0.03	0.03	1.0
thick	0.5	213	6.0	0.05	8.99	29.5	0.46	1.5	0.010	0.04	0.03	0.8

Yalin's Equations - Gravel

Q (cfs)	Q (cms)	D50 (m)	u*c (m/s)	Top W (m)	Top W (ft)	D (m)	D (ft)	Slope	n	tau*	Sinuosity
213	6.0	0.02	0.12	10.0	32.9	0.4	1.4	0.003	0.02	0.04	2.4
213	6.0	0.03	0.15	9.1	29.8	0.4	1.4	0.005	0.02	0.04	1.5
213	6.0	0.04	0.17	8.4	27.7	0.4	1.4	0.007	0.03	0.04	1.1
213	6.0	0.05	0.19	8.0	26.2	0.4	1.3	0.009	0.03	0.04	0.9

Hey and Thorne's Equations - Gravel

Veg. Type	Q (cfs)	Q (cms)	C (mg/l)	Qs (kg/s)	D50 (m)	D84 (m)	Top W (m)	Top W (ft)	D (m)	D (ft)	Dmax (m)	Dmax (ft)	Slope	n	tau*	Sinu-osity
I	213	6.0	0.01	0.0001	0.02	0.06	10.6	34.9	0.66	2.2	1.3	4.2	0.002	0.04	0.04	3.9
II	213	6.0	0.01	0.0001	0.02	0.06	8.2	26.8	0.66	2.2	1.3	4.2	0.002	0.03	0.03	3.9
III	213	6.0	0.01	0.0001	0.02	0.06	6.7	22.0	0.66	2.2	1.3	4.2	0.002	0.02	0.03	3.9
IV	213	6.0	0.01	0.0001	0.02	0.06	5.7	18.9	0.66	2.2	1.3	4.2	0.002	0.02	0.03	3.9
I	213	6.0	1	0.006	0.02	0.06	10.6	34.9	0.66	2.2	1.3	4.2	0.003	0.05	0.06	2.5
II	213	6.0	1	0.006	0.02	0.06	8.2	26.8	0.66	2.2	1.3	4.2	0.003	0.03	0.06	2.5
III	213	6.0	1	0.006	0.02	0.06	6.7	22.0	0.66	2.2	1.3	4.2	0.003	0.03	0.05	2.5
IV	213	6.0	1	0.006	0.02	0.06	5.7	18.9	0.66	2.2	1.3	4.2	0.003	0.02	0.05	2.5
I	213	6.0	10	0.060	0.02	0.06	10.6	34.9	0.66	2.2	1.3	4.2	0.004	0.05	0.07	2.0
II	213	6.0	10	0.060	0.02	0.06	8.2	26.8	0.66	2.2	1.3	4.2	0.004	0.04	0.07	2.0
III	213	6.0	10	0.060	0.02	0.06	6.7	22.0	0.66	2.2	1.3	4.2	0.004	0.03	0.07	2.0
IV	213	6.0	10	0.060	0.02	0.06	5.7	18.9	0.66	2.2	1.3	4.2	0.004	0.03	0.07	2.0
I	213	6.0	100	0.603	0.03	0.06	10.6	34.9	0.63	2.1	1.0	3.3	0.005	0.05	0.06	1.6
II	213	6.0	100	0.603	0.03	0.06	8.2	26.8	0.63	2.1	1.0	3.3	0.005	0.04	0.05	1.6
III	213	6.0	100	0.603	0.03	0.06	6.7	22.0	0.63	2.1	1.0	3.3	0.005	0.03	0.05	1.6
IV	213	6.0	100	0.603	0.03	0.06	5.7	18.9	0.63	2.1	1.0	3.3	0.005	0.03	0.05	1.6
I	213	6.0	0.01	0.0001	0.03	0.06	10.6	34.9	0.63	2.1	1.0	3.3	0.002	0.03	0.02	4.1
II	213	6.0	0.01	0.0001	0.03	0.06	8.2	26.8	0.63	2.1	1.0	3.3	0.002	0.03	0.02	4.1
III	213	6.0	0.01	0.0001	0.03	0.06	6.7	22.0	0.63	2.1	1.0	3.3	0.002	0.02	0.02	4.1

Hey and Thorne's Equations - Gravel

Veg. Type	Q (cfs)	Q (cms)	C (mg/l)	Qs (kg/s)	D50 (m)	D84 (m)	Top W (m)	Top W (ft)	D (m)	D (ft)	Dmax (m)	Dmax (ft)	Slope	n	tau*	Sinu-osity
IV	213	6.0	0.01	0.0001	0.03	0.06	5.7	18.9	0.63	2.1	1.0	3.3	0.002	0.02	0.02	4.1
I	213	6.0	1	0.006	0.03	0.06	10.6	34.9	0.63	2.1	1.0	3.3	0.003	0.04	0.04	2.6
II	213	6.0	1	0.006	0.03	0.06	8.2	26.8	0.63	2.1	1.0	3.3	0.003	0.03	0.03	2.6
III	213	6.0	1	0.006	0.03	0.06	6.7	22.0	0.63	2.1	1.0	3.3	0.003	0.03	0.03	2.6
IV	213	6.0	1	0.006	0.03	0.06	5.7	18.9	0.63	2.1	1.0	3.3	0.003	0.02	0.03	2.6
I	213	6.0	10	0.060	0.03	0.06	10.6	34.9	0.63	2.1	1.0	3.3	0.004	0.05	0.04	2.0
II	213	6.0	10	0.060	0.03	0.06	8.2	26.8	0.63	2.1	1.0	3.3	0.004	0.04	0.04	2.0
III	213	6.0	10	0.060	0.03	0.06	6.7	22.0	0.63	2.1	1.0	3.3	0.004	0.03	0.04	2.0
IV	213	6.0	10	0.060	0.03	0.06	5.7	18.9	0.63	2.1	1.0	3.3	0.004	0.02	0.04	2.0
I	213	6.0	100	0.603	0.03	0.06	10.6	34.9	0.63	2.1	1.0	3.3	0.005	0.05	0.06	1.6
II	213	6.0	100	0.603	0.03	0.06	8.2	26.8	0.63	2.1	1.0	3.3	0.005	0.04	0.05	1.6
III	213	6.0	100	0.603	0.03	0.06	6.7	22.0	0.63	2.1	1.0	3.3	0.005	0.03	0.05	1.6
IV	213	6.0	100	0.603	0.03	0.06	5.7	18.9	0.63	2.1	1.0	3.3	0.005	0.03	0.05	1.6
I	213	6.0	0.01	0.0001	0.04	0.06	10.6	34.9	0.61	2.0	0.9	2.8	0.002	0.03	0.02	4.2
II	213	6.0	0.01	0.0001	0.04	0.06	8.2	26.8	0.61	2.0	0.9	2.8	0.002	0.02	0.02	4.2
III	213	6.0	0.01	0.0001	0.04	0.06	6.7	22.0	0.61	2.0	0.9	2.8	0.002	0.02	0.01	4.2
IV	213	6.0	0.01	0.0001	0.04	0.06	5.7	18.9	0.61	2.0	0.9	2.8	0.002	0.02	0.01	4.2
I	213	6.0	1	0.006	0.04	0.06	10.6	34.9	0.61	2.0	0.9	2.8	0.003	0.04	0.03	2.6
II	213	6.0	1	0.006	0.04	0.06	8.2	26.8	0.61	2.0	0.9	2.8	0.003	0.03	0.02	2.6
III	213	6.0	1	0.006	0.04	0.06	6.7	22.0	0.61	2.0	0.9	2.8	0.003	0.02	0.02	2.6
IV	213	6.0	1	0.006	0.04	0.06	5.7	18.9	0.61	2.0	0.9	2.8	0.003	0.02	0.02	2.6
I	213	6.0	10	0.060	0.04	0.06	10.6	34.9	0.61	2.0	0.9	2.8	0.004	0.04	0.03	2.1
II	213	6.0	10	0.060	0.04	0.06	8.2	26.8	0.61	2.0	0.9	2.8	0.004	0.03	0.03	2.1
III	213	6.0	10	0.060	0.04	0.06	6.7	22.0	0.61	2.0	0.9	2.8	0.004	0.03	0.03	2.1
IV	213	6.0	10	0.060	0.04	0.06	5.7	18.9	0.61	2.0	0.9	2.8	0.004	0.02	0.03	2.1
I	213	6.0	100	0.603	0.04	0.06	10.6	34.9	0.61	2.0	0.9	2.8	0.005	0.05	0.04	1.7
II	213	6.0	100	0.603	0.04	0.06	8.2	26.8	0.61	2.0	0.9	2.8	0.005	0.04	0.04	1.7
III	213	6.0	100	0.603	0.04	0.06	6.7	22.0	0.61	2.0	0.9	2.8	0.005	0.03	0.04	1.7
IV	213	6.0	100	0.603	0.04	0.06	5.7	18.9	0.61	2.0	0.9	2.8	0.005	0.03	0.04	1.7
I	213	6.0	0.01	0.0001	0.05	0.09	10.6	34.9	0.59	2.0	0.9	2.9	0.003	0.04	0.02	3.0

Hey and Thorne's Equations - Gravel

Veg. Type	Q (cfs)	Q (cms)	C (mg/l)	Qs (kg/s)	D50 (m)	D84 (m)	Top W (m)	Top W (ft)	D (m)	D (ft)	Dmax (m)	Dmax (ft)	Slope	n	tau*	Sinu-osity
II	213	6.0	0.01	0.0001	0.05	0.09	8.2	26.8	0.59	2.0	0.9	2.9	0.003	0.03	0.02	3.0
III	213	6.0	0.01	0.0001	0.05	0.09	6.7	22.0	0.59	2.0	0.9	2.9	0.003	0.02	0.02	3.0
IV	213	6.0	0.01	0.0001	0.05	0.09	5.7	18.9	0.59	2.0	0.9	2.9	0.003	0.02	0.02	3.0
I	213	6.0	1	0.006	0.05	0.09	10.6	34.9	0.59	2.0	0.9	2.9	0.004	0.04	0.03	1.9
II	213	6.0	1	0.006	0.05	0.09	8.2	26.8	0.59	2.0	0.9	2.9	0.004	0.03	0.03	1.9
III	213	6.0	1	0.006	0.05	0.09	6.7	22.0	0.59	2.0	0.9	2.9	0.004	0.03	0.03	1.9
IV	213	6.0	1	0.006	0.05	0.09	5.7	18.9	0.59	2.0	0.9	2.9	0.004	0.02	0.02	1.9
I	213	6.0	10	0.060	0.05	0.09	10.6	34.9	0.59	2.0	0.9	2.9	0.005	0.05	0.03	1.5
II	213	6.0	10	0.060	0.05	0.09	8.2	26.8	0.59	2.0	0.9	2.9	0.005	0.04	0.03	1.5
III	213	6.0	10	0.060	0.05	0.09	6.7	22.0	0.59	2.0	0.9	2.9	0.005	0.03	0.03	1.5
IV	213	6.0	10	0.060	0.05	0.09	5.7	18.9	0.59	2.0	0.9	2.9	0.005	0.03	0.03	1.5
I	213	6.0	100	0.603	0.05	0.09	10.6	34.9	0.59	2.0	0.9	2.9	0.007	0.06	0.04	1.2
II	213	6.0	100	0.603	0.05	0.09	8.2	26.8	0.59	2.0	0.9	2.9	0.007	0.04	0.04	1.2
III	213	6.0	100	0.603	0.05	0.09	6.7	22.0	0.59	2.0	0.9	2.9	0.007	0.03	0.04	1.2
IV	213	6.0	100	0.603	0.05	0.09	5.7	18.9	0.59	2.0	0.9	2.9	0.007	0.03	0.04	1.2

Andrews Equations

Veg. Type	Q (cfs)	Q (cms)	Q*	D50 (m)	Top W (m)	Top W (ft)	D (m)	D (ft)	Slope	n	tau*	Sinuosity
thin	213	6.0	18166	0.02	10.7	35.2	0.39	1.3	0.003	0.03	0.03	2.65
thin	213	6.0	6592	0.03	9.9	32.5	0.40	1.3	0.005	0.03	0.03	1.75
thin	213	6.0	3211	0.04	9.4	30.8	0.41	1.3	0.006	0.04	0.03	1.31
thin	213	6.0	1838	0.05	9.0	29.4	0.41	1.4	0.008	0.04	0.04	1.04
thick	213	6.0	18166	0.02	8.8	29.0	0.37	1.2	0.004	0.02	0.04	1.86
thick	213	6.0	6592	0.03	8.1	26.7	0.38	1.3	0.007	0.03	0.05	1.19
thick	213	6.0	3211	0.04	7.7	25.2	0.39	1.3	0.009	0.03	0.05	0.87
thick	213	6.0	1838	0.05	7.3	24.0	0.40	1.3	0.012	0.04	0.05	0.68

Soar and Thorne's version of Andrews

Veg. Type	Exponent	Q (cfs)	Q (cms)	D50 (m)	Top W (m)	Top W (ft)	D (m)	D (ft)	Slope	n	tau*	Sinuosity
thin	adjustable	146	4.1	0.02	8.5	27.9	0.39	1.3	0.003	0.02	0.03	2.6
thin	adjustable	146	4.1	0.03	8.5	27.9	0.40	1.3	0.005	0.03	0.03	1.8
thin	adjustable	146	4.1	0.04	8.5	27.9	0.41	1.3	0.006	0.03	0.03	1.3
thin	adjustable	146	4.1	0.05	8.5	27.9	0.41	1.4	0.008	0.04	0.03	1.0
thick	adjustable	146	4.1	0.02	7.5	24.5	0.37	1.2	0.004	0.02	0.04	1.9
thick	adjustable	146	4.1	0.03	7.5	24.5	0.38	1.3	0.007	0.03	0.05	1.2
thick	adjustable	146	4.1	0.04	7.5	24.5	0.39	1.3	0.009	0.03	0.05	0.9
thick	adjustable	146	4.1	0.05	7.5	24.5	0.40	1.3	0.012	0.04	0.05	0.7
thin	0.5	146	4.1	0.02	8.4	27.6	0.39	1.3	0.003	0.02	0.02	2.6
thin	0.5	146	4.1	0.03	8.4	27.6	0.40	1.3	0.005	0.03	0.02	1.8
thin	0.5	146	4.1	0.04	8.4	27.6	0.41	1.3	0.006	0.03	0.02	1.3
thin	0.5	146	4.1	0.05	8.4	27.6	0.41	1.4	0.008	0.04	0.02	1.0
thick	0.5	146	4.1	0.02	7.4	24.4	0.37	1.2	0.004	0.02	0.02	1.9
thick	0.5	146	4.1	0.03	7.4	24.4	0.38	1.3	0.007	0.03	0.03	1.2
thick	0.5	146	4.1	0.04	7.4	24.4	0.39	1.3	0.009	0.03	0.03	0.9
thick	0.5	146	4.1	0.05	7.4	24.4	0.40	1.3	0.012	0.04	0.03	0.7

Yalin's Equations - Gravel

Q (cfs)	Q (cms)	D50 (m)	u*c (m/s)	Top W (m)	Top W (ft)	D (m)	D (ft)	Slope	n	tau*	Sinuosity
146	4.1	0.02	0.12	8.3	27.3	0.4	1.2	0.004	0.02	0.04	2.0
146	4.1	0.03	0.15	7.5	24.6	0.4	1.2	0.006	0.02	0.04	1.3
146	4.1	0.04	0.17	7.0	22.9	0.4	1.2	0.008	0.03	0.04	1.0
146	4.1	0.05	0.19	6.6	21.7	0.3	1.1	0.011	0.03	0.04	0.7

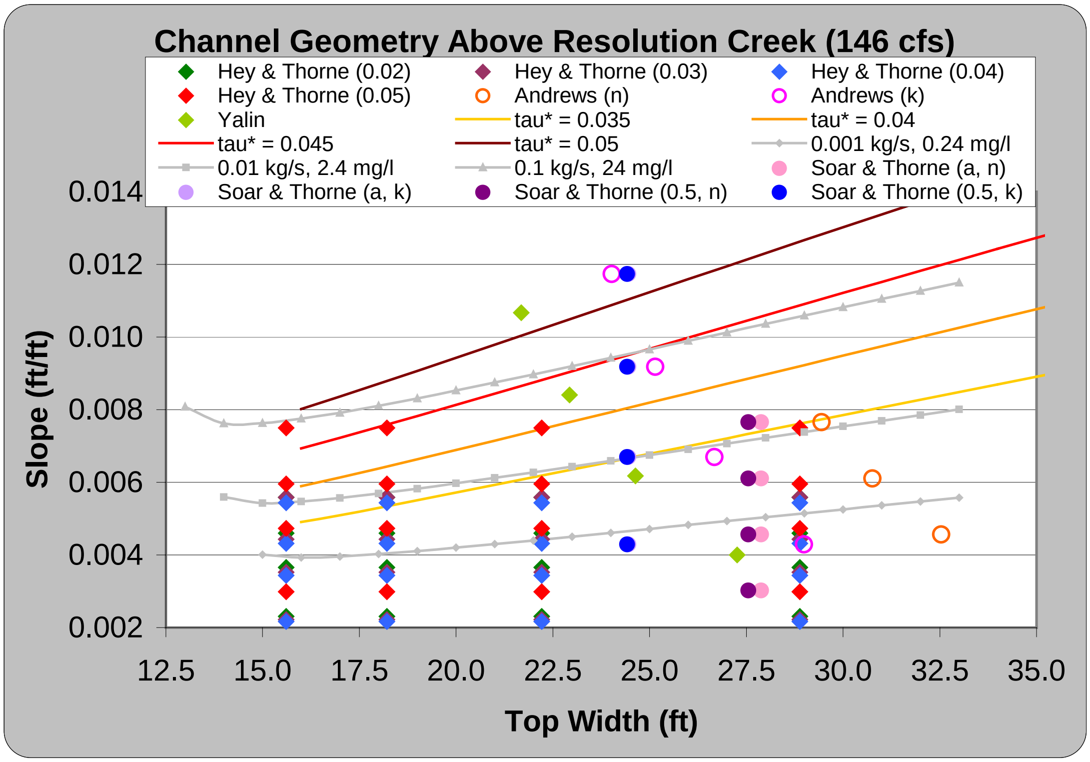
Hey and Thorne's Equations - Gravel

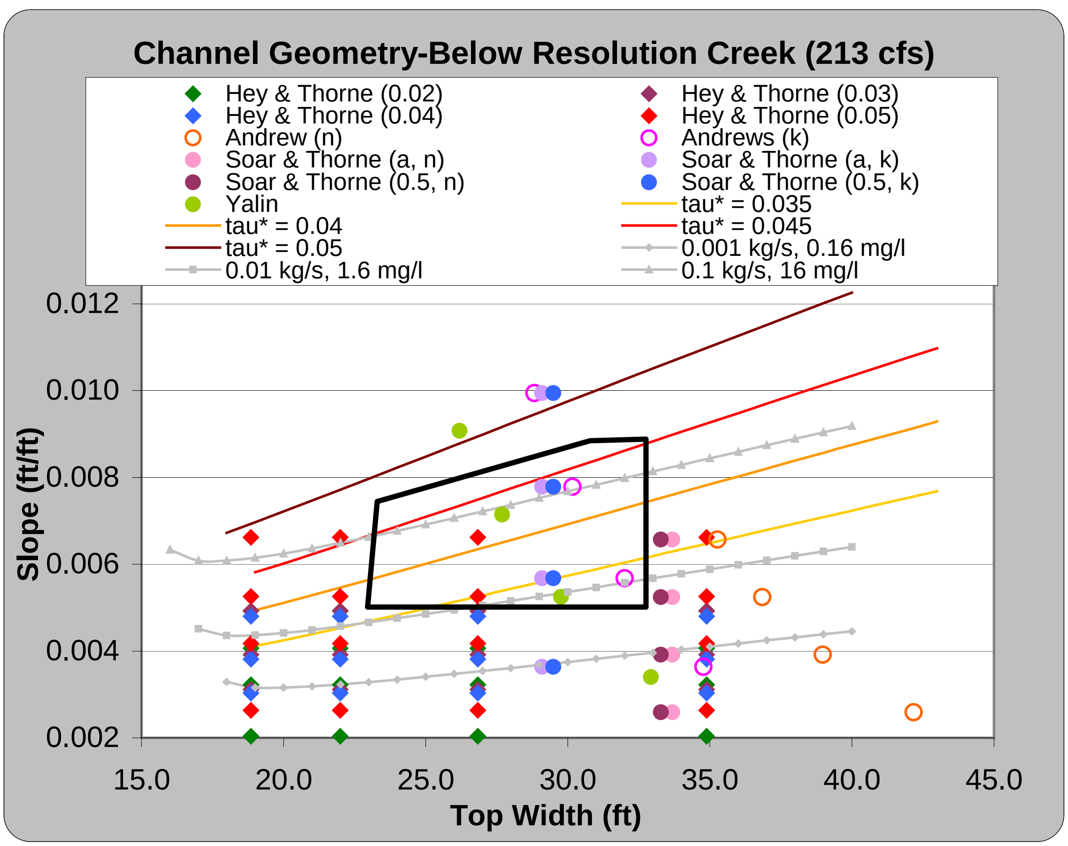
Veg. Type	Q (cfs)	Q (cms)	C (mg/l)	Qs (kg/s)	D50 (m)	D84 (m)	Top W (m)	Top W (ft)	D (m)	D (ft)	Dmax (m)	Dmax (ft)	Slope	n	tau*	Sinu-osity
I	146	4.1	0.01	0.0000	0.02	0.06	8.8	28.9	0.57	1.9	1.1	3.7	0.002	0.04	0.04	3.5
II	146	4.1	0.01	0.0000	0.02	0.06	6.8	22.2	0.57	1.9	1.1	3.7	0.002	0.03	0.03	3.5
III	146	4.1	0.01	0.0000	0.02	0.06	5.6	18.2	0.57	1.9	1.1	3.7	0.002	0.02	0.03	3.5
IV	146	4.1	0.01	0.0000	0.02	0.06	4.8	15.6	0.57	1.9	1.1	3.7	0.002	0.02	0.03	3.5
I	146	4.1	1	0.004	0.02	0.06	8.8	28.9	0.57	1.9	1.1	3.7	0.004	0.05	0.06	2.2
II	146	4.1	1	0.004	0.02	0.06	6.8	22.2	0.57	1.9	1.1	3.7	0.004	0.04	0.05	2.2
III	146	4.1	1	0.004	0.02	0.06	5.6	18.2	0.57	1.9	1.1	3.7	0.004	0.03	0.05	2.2
IV	146	4.1	1	0.004	0.02	0.06	4.8	15.6	0.57	1.9	1.1	3.7	0.004	0.02	0.05	2.2
I	146	4.1	10	0.041	0.02	0.06	8.8	28.9	0.57	1.9	1.1	3.7	0.005	0.05	0.07	1.7
II	146	4.1	10	0.041	0.02	0.06	6.8	22.2	0.57	1.9	1.1	3.7	0.005	0.04	0.07	1.7
III	146	4.1	10	0.041	0.02	0.06	5.6	18.2	0.57	1.9	1.1	3.7	0.005	0.03	0.07	1.7
IV	146	4.1	10	0.041	0.02	0.06	4.8	15.6	0.57	1.9	1.1	3.7	0.005	0.03	0.06	1.7
I	146	4.1	100	0.413	0.02	0.06	8.8	28.9	0.57	1.9	1.1	3.7	0.006	0.06	0.09	1.4
II	146	4.1	100	0.413	0.02	0.06	6.8	22.3	0.57	1.9	1.1	3.7	0.006	0.04	0.09	1.4
III	146	4.1	100	0.413	0.02	0.06	5.6	18.2	0.57	1.9	1.1	3.7	0.006	0.03	0.08	1.4
IV	146	4.1	100	0.413	0.02	0.06	4.8	15.6	0.57	1.9	1.1	3.7	0.006	0.03	0.08	1.4
I	146	4.1	0.01	0.0000	0.03	0.06	8.8	28.9	0.55	1.8	0.9	2.9	0.002	0.03	0.02	3.6
II	146	4.1	0.01	0.0000	0.03	0.06	6.8	22.2	0.55	1.8	0.9	2.9	0.002	0.03	0.02	3.6
III	146	4.1	0.01	0.0000	0.03	0.06	5.6	18.2	0.55	1.8	0.9	2.9	0.002	0.02	0.02	3.6
IV	146	4.1	0.01	0.0000	0.03	0.06	4.8	15.6	0.55	1.8	0.9	2.9	0.002	0.02	0.02	3.6
I	146	4.1	1	0.004	0.03	0.06	8.8	28.9	0.55	1.8	0.9	2.9	0.004	0.04	0.03	2.3
II	146	4.1	1	0.004	0.03	0.06	6.8	22.2	0.55	1.8	0.9	2.9	0.004	0.03	0.03	2.3
III	146	4.1	1	0.004	0.03	0.06	5.6	18.2	0.55	1.8	0.9	2.9	0.004	0.03	0.03	2.3
IV	146	4.1	1	0.004	0.03	0.06	4.8	15.6	0.55	1.8	0.9	2.9	0.004	0.02	0.03	2.3
I	146	4.1	10	0.041	0.03	0.06	8.8	28.9	0.55	1.8	0.9	2.9	0.004	0.05	0.04	1.8
II	146	4.1	10	0.041	0.03	0.06	6.8	22.2	0.55	1.8	0.9	2.9	0.004	0.04	0.04	1.8
III	146	4.1	10	0.041	0.03	0.06	5.6	18.2	0.55	1.8	0.9	2.9	0.004	0.03	0.04	1.8
IV	146	4.1	10	0.041	0.03	0.06	4.8	15.6	0.55	1.8	0.9	2.9	0.004	0.02	0.04	1.8
I	146	4.1	100	0.413	0.03	0.06	8.8	28.9	0.55	1.8	0.9	2.9	0.006	0.05	0.05	1.4

Hey and Thorne's Equations - Gravel

Veg. Type	Q (cfs)	Q (cms)	C (mg/l)	Qs (kg/s)	D50 (m)	D84 (m)	Top W (m)	Top W (ft)	D (m)	D (ft)	Dmax (m)	Dmax (ft)	Slope	n	tau*	Sinu-osity
II	146	4.1	100	0.413	0.03	0.06	6.8	22.2	0.55	1.8	0.9	2.9	0.006	0.04	0.05	1.4
III	146	4.1	100	0.413	0.03	0.06	5.6	18.2	0.55	1.8	0.9	2.9	0.006	0.03	0.05	1.4
IV	146	4.1	100	0.413	0.03	0.06	4.8	15.6	0.55	1.8	0.9	2.9	0.006	0.03	0.05	1.4
I	146	4.1	0.01	0.0000	0.04	0.06	8.8	28.9	0.53	1.7	0.8	2.5	0.002	0.03	0.02	3.7
II	146	4.1	0.01	0.0000	0.04	0.06	6.8	22.2	0.53	1.7	0.8	2.5	0.002	0.02	0.02	3.7
III	146	4.1	0.01	0.0000	0.04	0.06	5.6	18.2	0.53	1.7	0.8	2.5	0.002	0.02	0.01	3.7
IV	146	4.1	0.01	0.0000	0.04	0.06	4.8	15.6	0.53	1.7	0.8	2.5	0.002	0.02	0.01	3.7
I	146	4.1	1	0.004	0.04	0.06	8.8	28.9	0.53	1.7	0.8	2.5	0.003	0.04	0.02	2.3
II	146	4.1	1	0.004	0.04	0.06	6.8	22.2	0.53	1.7	0.8	2.5	0.003	0.03	0.02	2.3
III	146	4.1	1	0.004	0.04	0.06	5.6	18.2	0.53	1.7	0.8	2.5	0.003	0.02	0.02	2.3
IV	146	4.1	1	0.004	0.04	0.06	4.8	15.6	0.53	1.7	0.8	2.5	0.003	0.02	0.02	2.3
I	146	4.1	10	0.041	0.04	0.06	8.8	28.9	0.53	1.7	0.8	2.5	0.004	0.05	0.03	1.9
II	146	4.1	10	0.041	0.04	0.06	6.8	22.2	0.53	1.7	0.8	2.5	0.004	0.03	0.03	1.9
III	146	4.1	10	0.041	0.04	0.06	5.6	18.2	0.53	1.7	0.8	2.5	0.004	0.03	0.03	1.9
IV	146	4.1	10	0.041	0.04	0.06	4.8	15.6	0.53	1.7	0.8	2.5	0.004	0.02	0.03	1.9
I	146	4.1	100	0.413	0.04	0.06	8.8	28.9	0.53	1.7	0.8	2.5	0.005	0.05	0.04	1.5
II	146	4.1	100	0.413	0.04	0.06	6.8	22.2	0.53	1.7	0.8	2.5	0.005	0.04	0.04	1.5
III	146	4.1	100	0.413	0.04	0.06	5.6	18.2	0.53	1.7	0.8	2.5	0.005	0.03	0.04	1.5
IV	146	4.1	100	0.413	0.04	0.06	4.8	15.6	0.53	1.7	0.8	2.5	0.005	0.03	0.04	1.5
I	146	4.1	0.01	0.0000	0.05	0.09	8.8	28.9	0.52	1.7	0.8	2.5	0.003	0.04	0.02	2.7
II	146	4.1	0.01	0.0000	0.05	0.09	6.8	22.2	0.52	1.7	0.8	2.5	0.003	0.03	0.02	2.7
III	146	4.1	0.01	0.0000	0.05	0.09	5.6	18.2	0.52	1.7	0.8	2.5	0.003	0.02	0.02	2.7
IV	146	4.1	0.01	0.0000	0.05	0.09	4.8	15.6	0.52	1.7	0.8	2.5	0.003	0.02	0.02	2.7
I	146	4.1	1	0.004	0.05	0.09	8.8	28.9	0.52	1.7	0.8	2.5	0.005	0.05	0.03	1.7
II	146	4.1	1	0.004	0.05	0.09	6.8	22.2	0.52	1.7	0.8	2.5	0.005	0.03	0.03	1.7
III	146	4.1	1	0.004	0.05	0.09	5.6	18.2	0.52	1.7	0.8	2.5	0.005	0.03	0.02	1.7
IV	146	4.1	1	0.004	0.05	0.09	4.8	15.6	0.52	1.7	0.8	2.5	0.005	0.02	0.02	1.7
I	146	4.1	10	0.041	0.05	0.09	8.8	28.9	0.52	1.7	0.8	2.5	0.006	0.05	0.03	1.3
II	146	4.1	10	0.041	0.05	0.09	6.8	22.2	0.52	1.7	0.8	2.5	0.006	0.04	0.03	1.3
III	146	4.1	10	0.041	0.05	0.09	5.6	18.2	0.52	1.7	0.8	2.5	0.006	0.03	0.03	1.3
IV	146	4.1	10	0.041	0.05	0.09	4.8	15.6	0.52	1.7	0.8	2.5	0.006	0.03	0.03	1.3
I	146	4.1	100	0.413	0.05	0.09	8.8	28.9	0.52	1.7	0.8	2.5	0.007	0.06	0.04	1.1
II	146	4.1	100	0.413	0.05	0.09	6.8	22.2	0.52	1.7	0.8	2.5	0.007	0.04	0.04	1.1
III	146	4.1	100	0.413	0.05	0.09	5.6	18.2	0.52	1.7	0.8	2.5	0.007	0.03	0.04	1.1
IV	146	4.1	100	0.413	0.05	0.09	4.8	15.6	0.52	1.7	0.8	2.5	0.007	0.03	0.04	1.1

APPENDIX A.1


Channel Geometry Above Resolution Creek (146 cfs)
Hey & Thorne (0.02)
Hey & Thorne (0.03)
Hey & Thorne (0.04)
Hey & Thorne (0.05)
Andrews (n)
Andrews (k)
Yalin
tau* = 0.035
tau* = 0.04
tau* = 0.045
tau* = 0.05
0.001 kg/s, 0.24 mg/l
0.01 kg/s, 2.4 mg/l
0.1 kg/s, 24 mg/l
Soar & Thorne (a, n)
Soar & Thorne (a, k)
Soar & Thorne (0.5, n)
Soar & Thorne (0.5, k)
Slope (ft/ft)
0.014
0.012
0.010
0.008
0.006
0.004
0.002
12.5
15.0
17.5
20.0
22.5
25.0
27.5
30.0
32.5
35.0
Top Width (ft)


Channel Geometry-Below Resolution Creek (213 cfs)
Hey & Thorne (0.02)
Hey & Thorne (0.03)
Hey & Thorne (0.04)
Hey & Thorne (0.05)
Andrew (n)
Andrews (k)
Soar & Thorne (a, n)
Soar & Thorne (a, k)
Soar & Thorne (0.5, n)
Soar & Thorne (0.5, k)
Yalin
tau* = 0.035
tau* = 0.04
tau* = 0.045
tau* = 0.05
0.001 kg/s, 0.16 mg/l
0.01 kg/s, 1.6 mg/l
0.1 kg/s, 16 mg/l
Slope (ft/ft)
0.012
0.010
0.008
0.006
0.004
0.002
15.0
20.0
25.0
30.0
35.0
40.0
45.0
Top Width (ft)

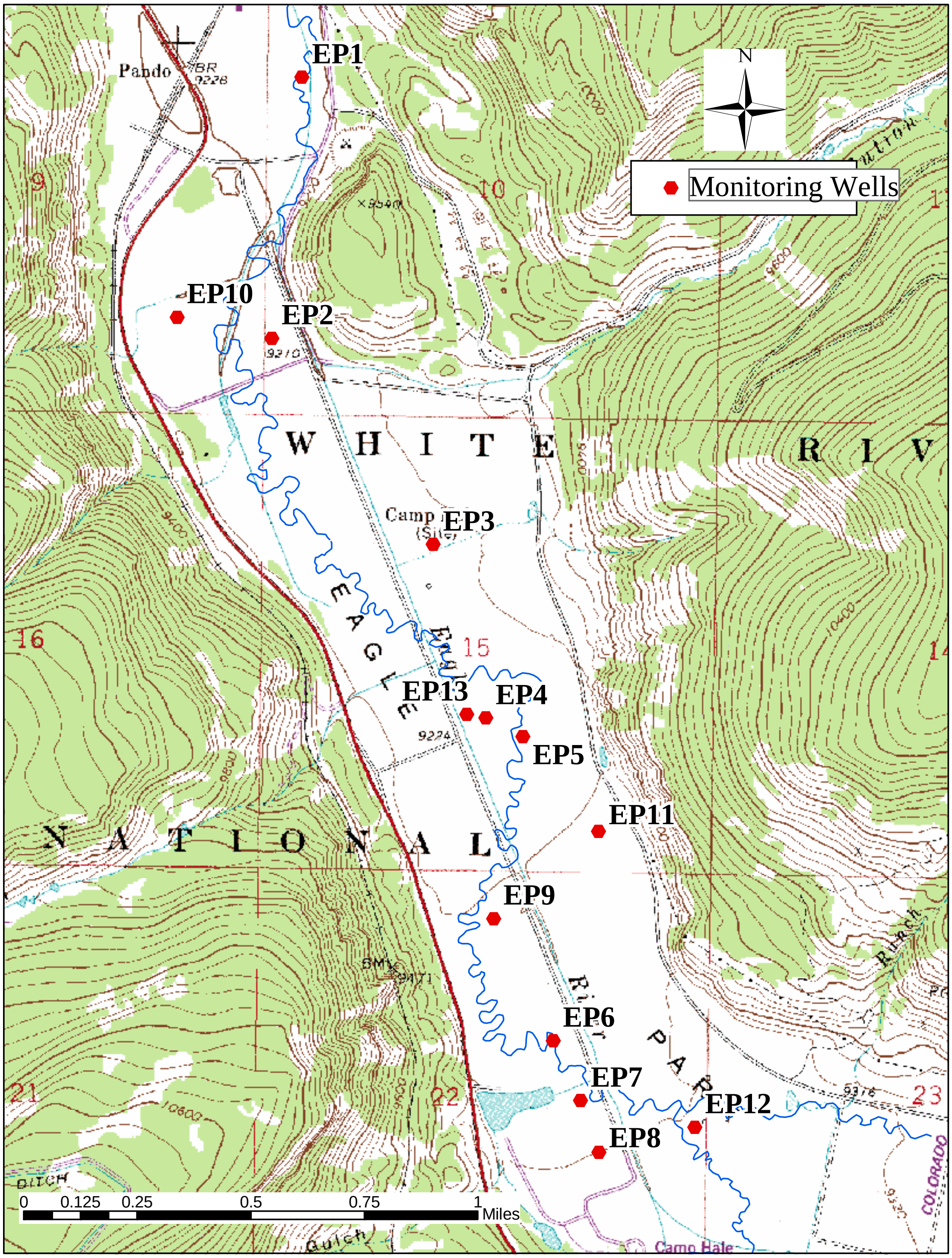
APPENDIX A.1

Hydraulic geometry results for reaches above and below Resolution Creek. Thick and thin vegetation are denoted as 'k' and 'n', respectively. Hey and Thorne values in parenthesis are median bed material sizes in meters. Soar and Thorne parentheses represent adjustable (a) and fixed exponent (0.5) equations. The black outline represents the region we expect to find reasonable results.

APPENDIX A.1

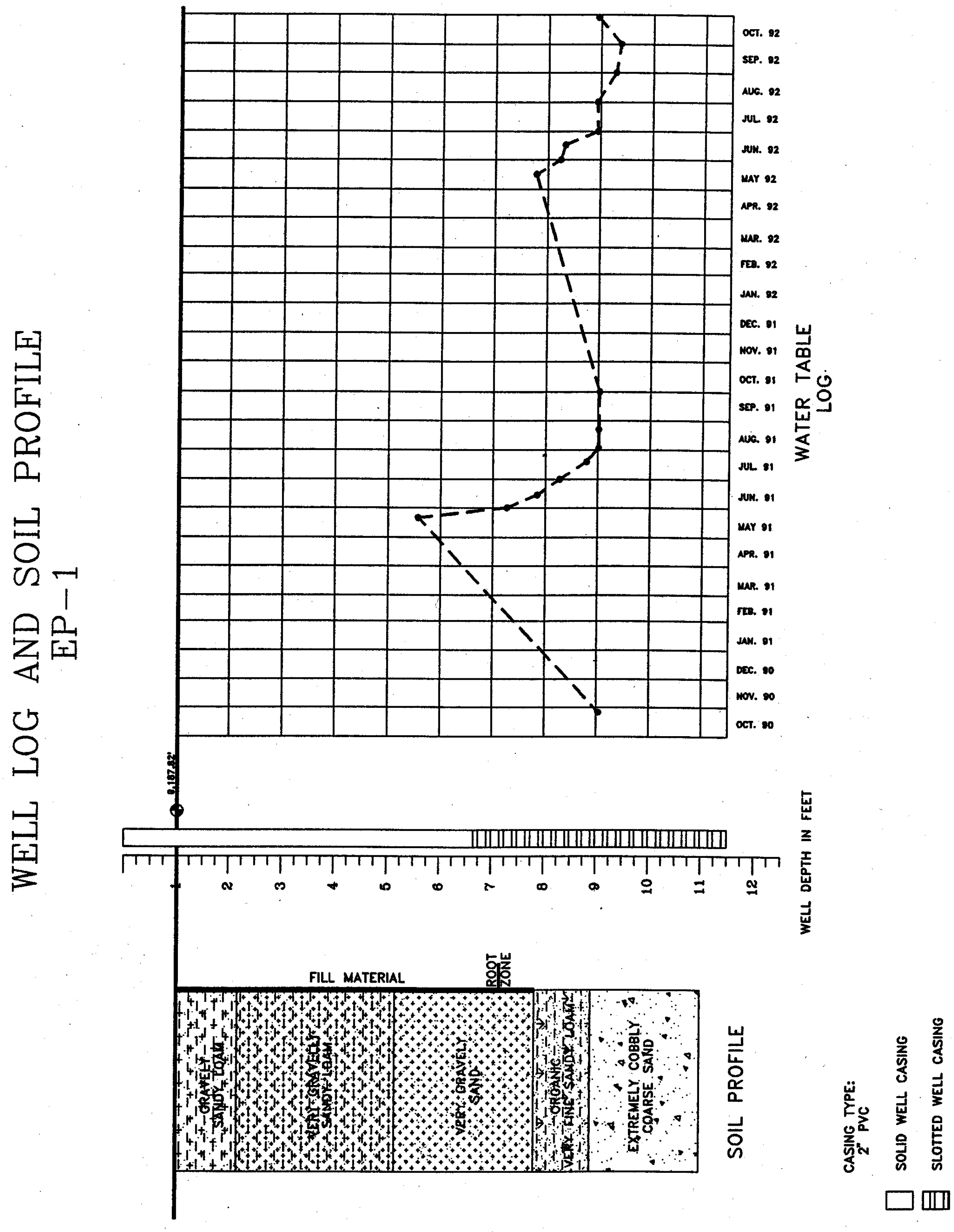
ADDENDUM VII – WELL LOGS

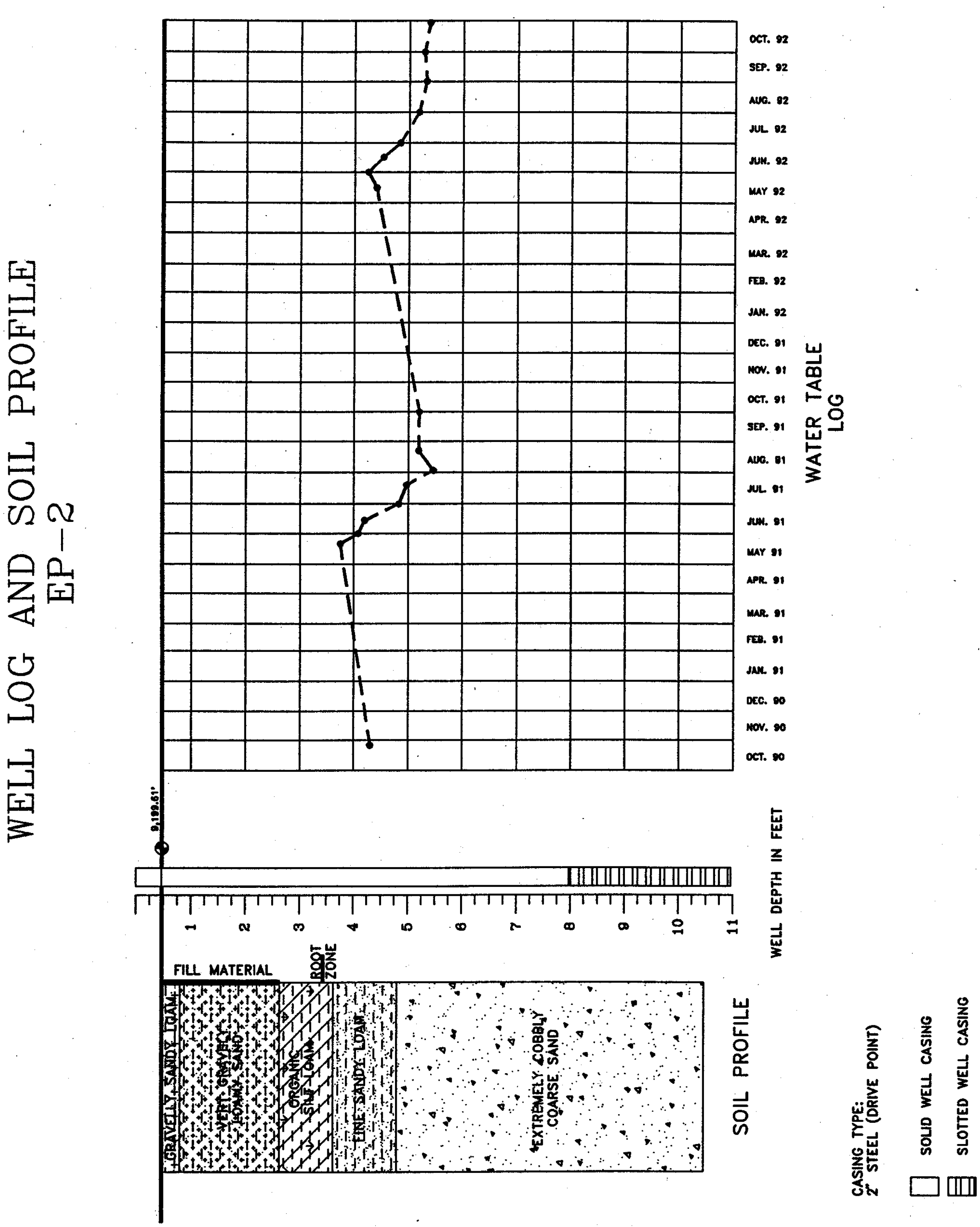
APPENDIX A.1



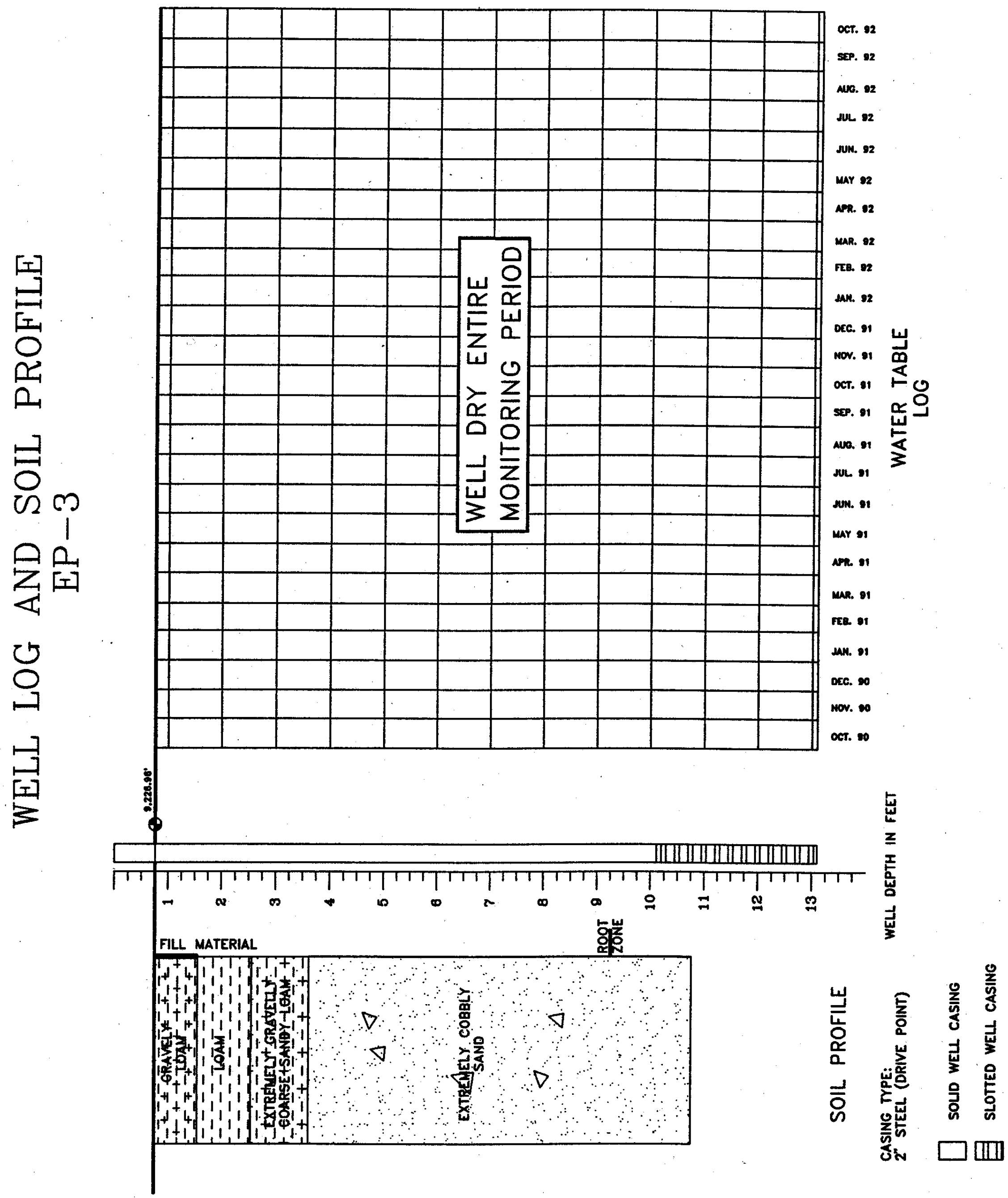
*Monitoring well locations are approximate.

APPENDIX A.1

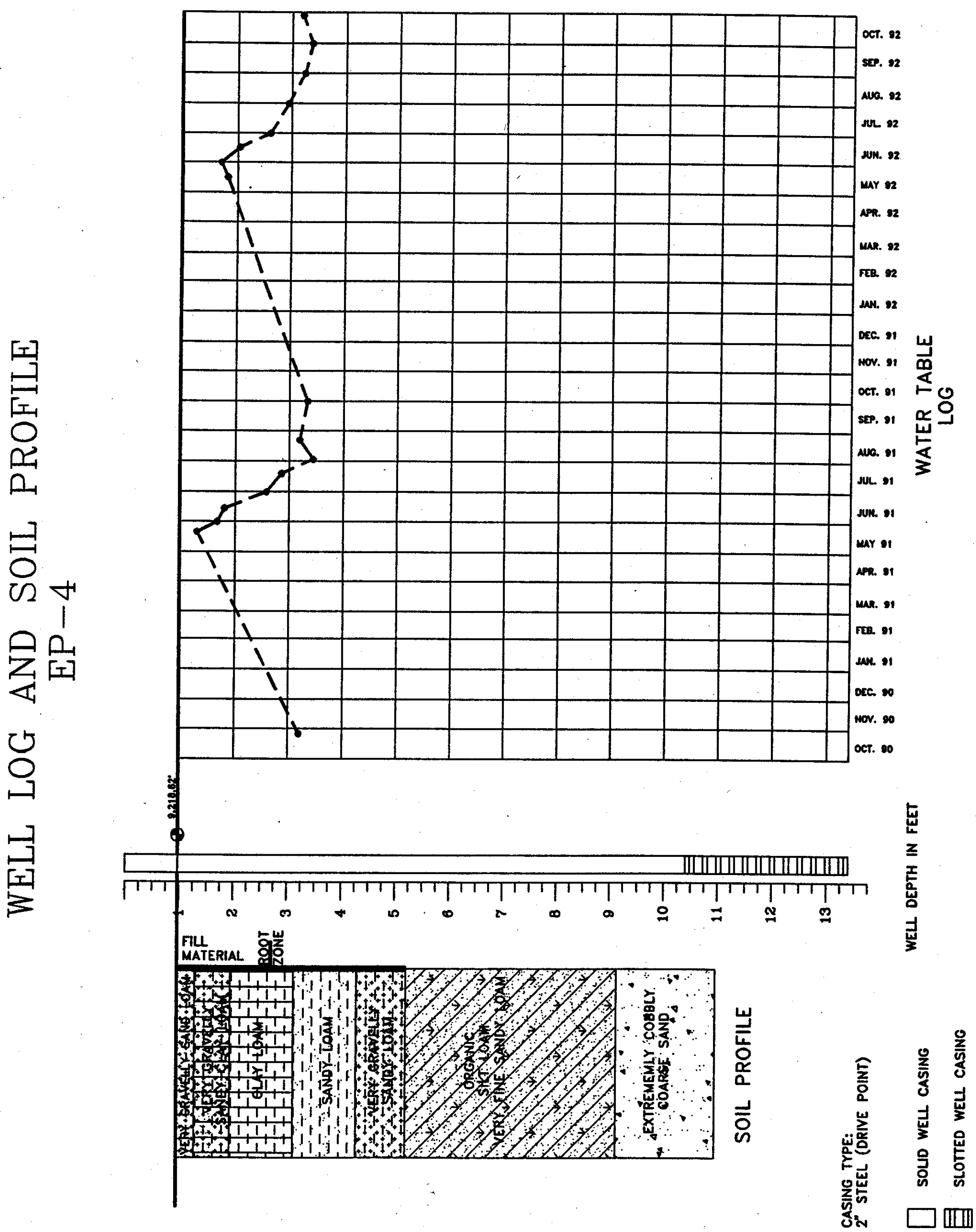

WELL LOG AND SOIL PROFILE
EP—1
OCT. 92
SEP. 92
AUG. 92
JUL. 92
JUN. 92
MAY 92
APR. 92
MAR. 92
FEB. 92
JAN. 92
DEC. 91
NOV. 91
OCT. 91
SEP. 91
AUG. 91
JUL. 91
JUN. 91
MAY 91
APR. 91
MAR. 91
FEB. 91
JAN. 91
DEC. 90
NOV. 90
OCT. 90
WATER TABLE
LOG
1
2
3
4
5
6
7
8
9
10
11
12
WELL DEPTH IN FEET
FILL MATERIAL
ROOT ZONE
GRAVELY SANDY LOAM
VERY GRAVELLY SANDY LOAM
VERY GRAVELY SAND
ORGANIC
VERY FINE SANDY LOAM
EXTREMELY COBBLY COARSE SAND
SOIL PROFILE
CASING TYPE:
2" PVC
SOLID WELL CASING
SLOTTED WELL CASING

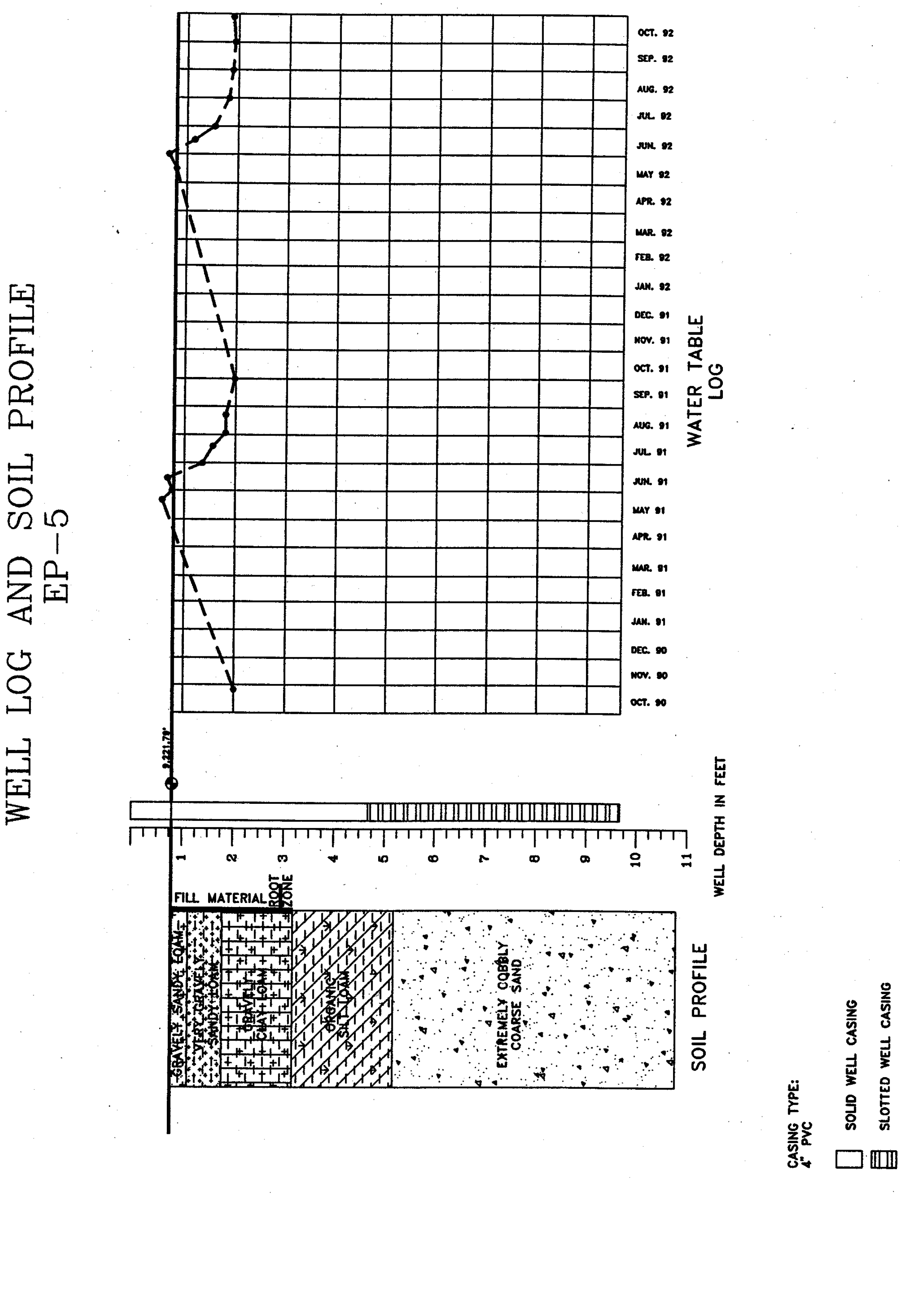

WELL LOG AND SOIL PROFILE
EP—2
OCT. 92
SEP. 92
AUG. 92
JUL. 92
JUN. 92
MAY 92
APR. 92
MAR. 92
FEB. 92
JAN. 92
DEC. 91
NOV. 91
OCT. 91
SEP. 91
AUG. 91
JUL. 91
JUN. 91
MAY 91
APR. 91
MAR. 91
FEB. 91
JAN. 91
DEC. 90
NOV. 90
OCT. 90
WATER TABLE LOG
9,199.61'
WELL DEPTH IN FEET
1 2 3 4 5 6 7 8 9 10 11
WELL DEPTH IN FEET
FILL MATERIAL
ROOT ZONE
GRAVELLY SANDY LOAM
VERY GRAVELLY LOAMY SAND
ORGANIC SILT LOAM
FINE SANDY LOAM
EXTREMELY COBBLY COARSE SAND
SOIL PROFILE
CASING TYPE:
2" STEEL (DRIVE POINT)
SOLID WELL CASING
SLOTTED WELL CASING

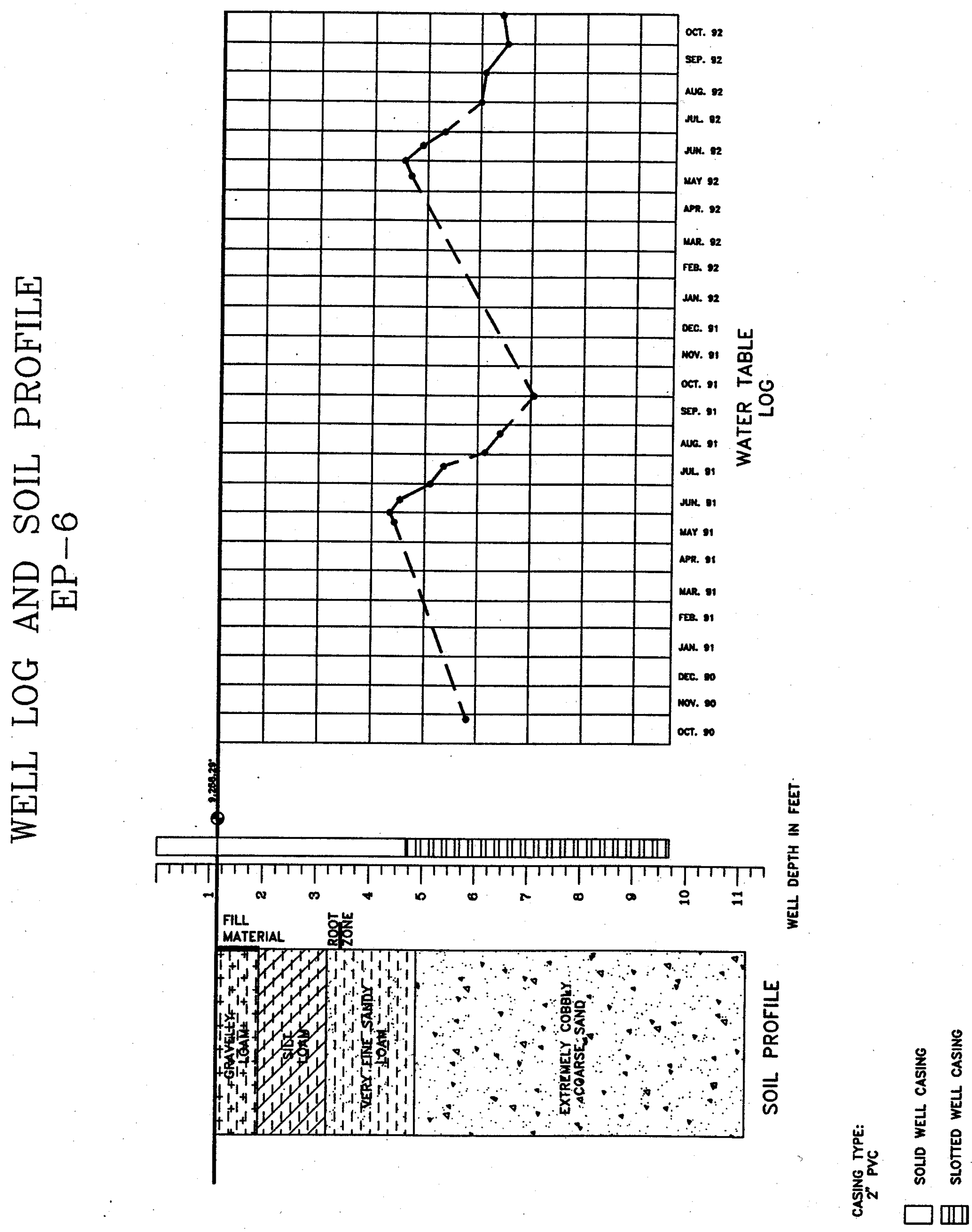
APPENDIX A.1

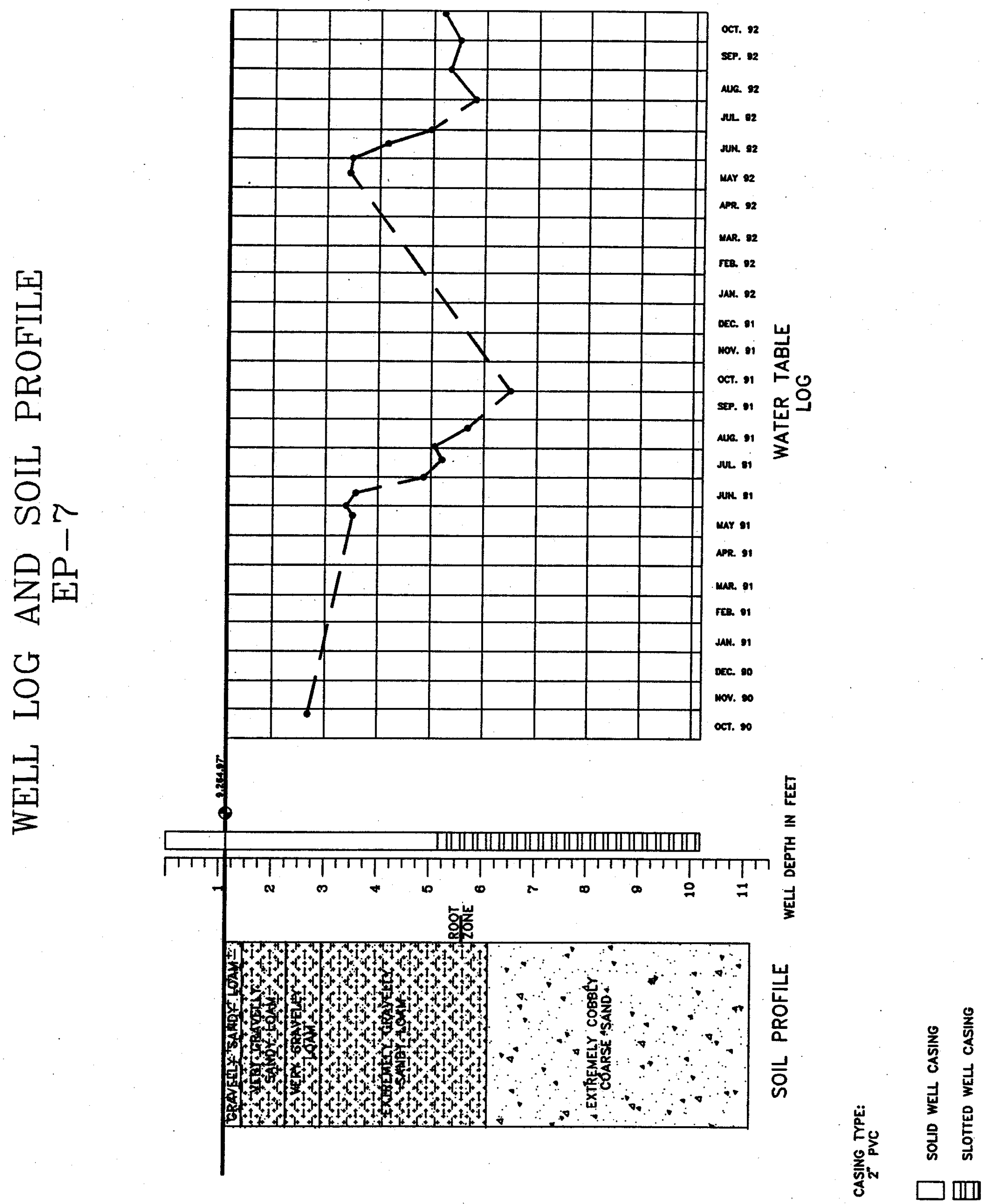


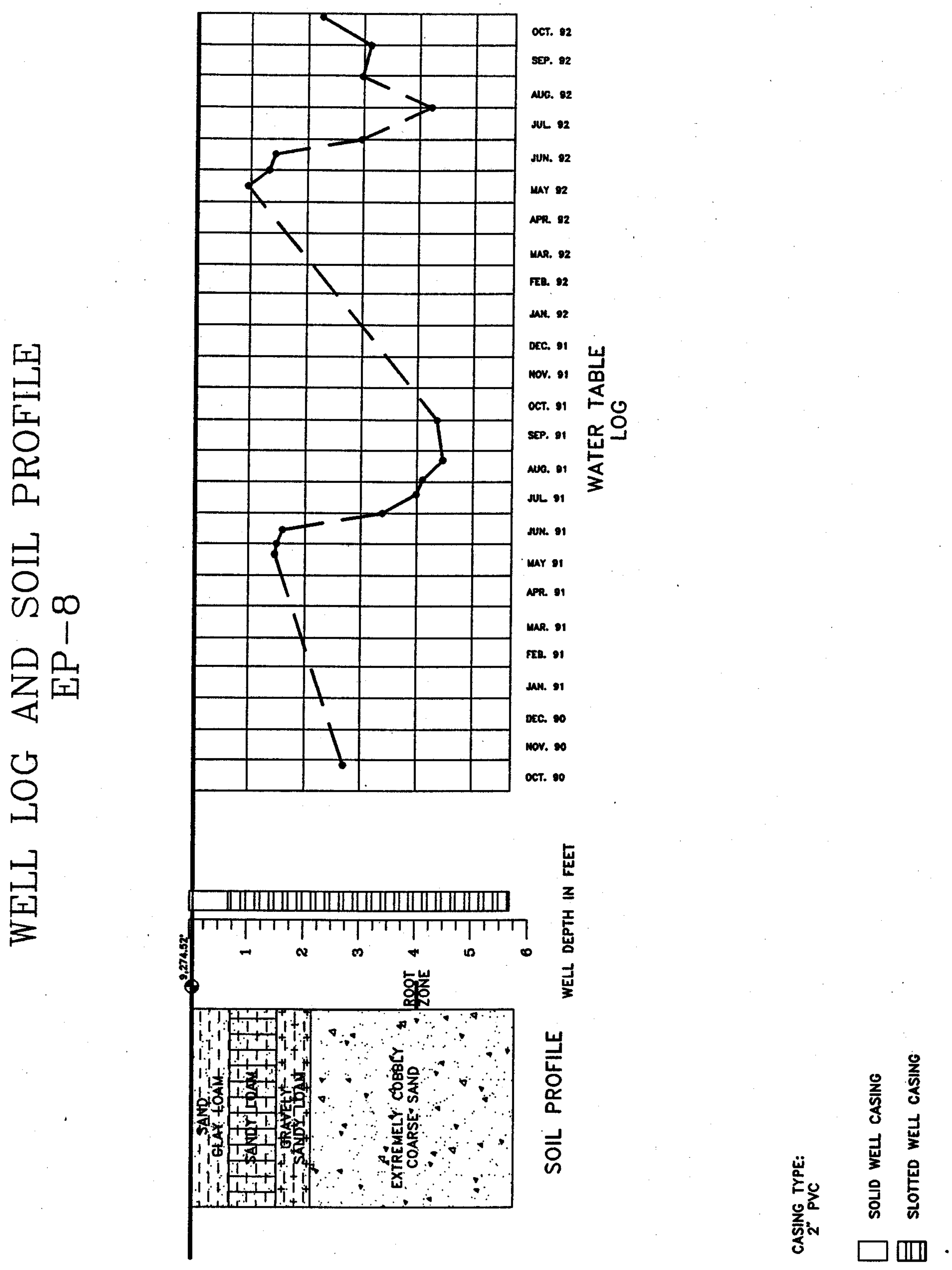
WELL LOG AND SOIL PROFILE
EP-3
WELL DRY ENTIRE
MONITORING PERIOD
OCT. 92
SEP. 92
AUG. 92
JUL. 92
JUN. 92
MAY 92
APR. 92
MAR. 92
FEB. 92
JAN. 92
DEC. 91
NOV. 91
OCT. 91
SEP. 91
AUG. 91
JUL. 91
JUN. 91
MAY 91
APR. 91
MAR. 91
FEB. 91
JAN. 91
DEC. 90
NOV. 90
OCT. 90
WATER TABLE
LOG
1 2 3 4 5 6 7 8 9 10 11 12 13
WELL DEPTH IN FEET
FILL MATERIAL
ROOT ZONE
GRAVELLY LOAM
LOAM
EXTREMELY GRAVELLY COARSE SANDY LOAM
EXTREMELY COBBLY SAND
SOIL PROFILE
CASING TYPE:
2" STEEL (DRIVE POINT)
SOLID WELL CASING
SLOTTED WELL CASING

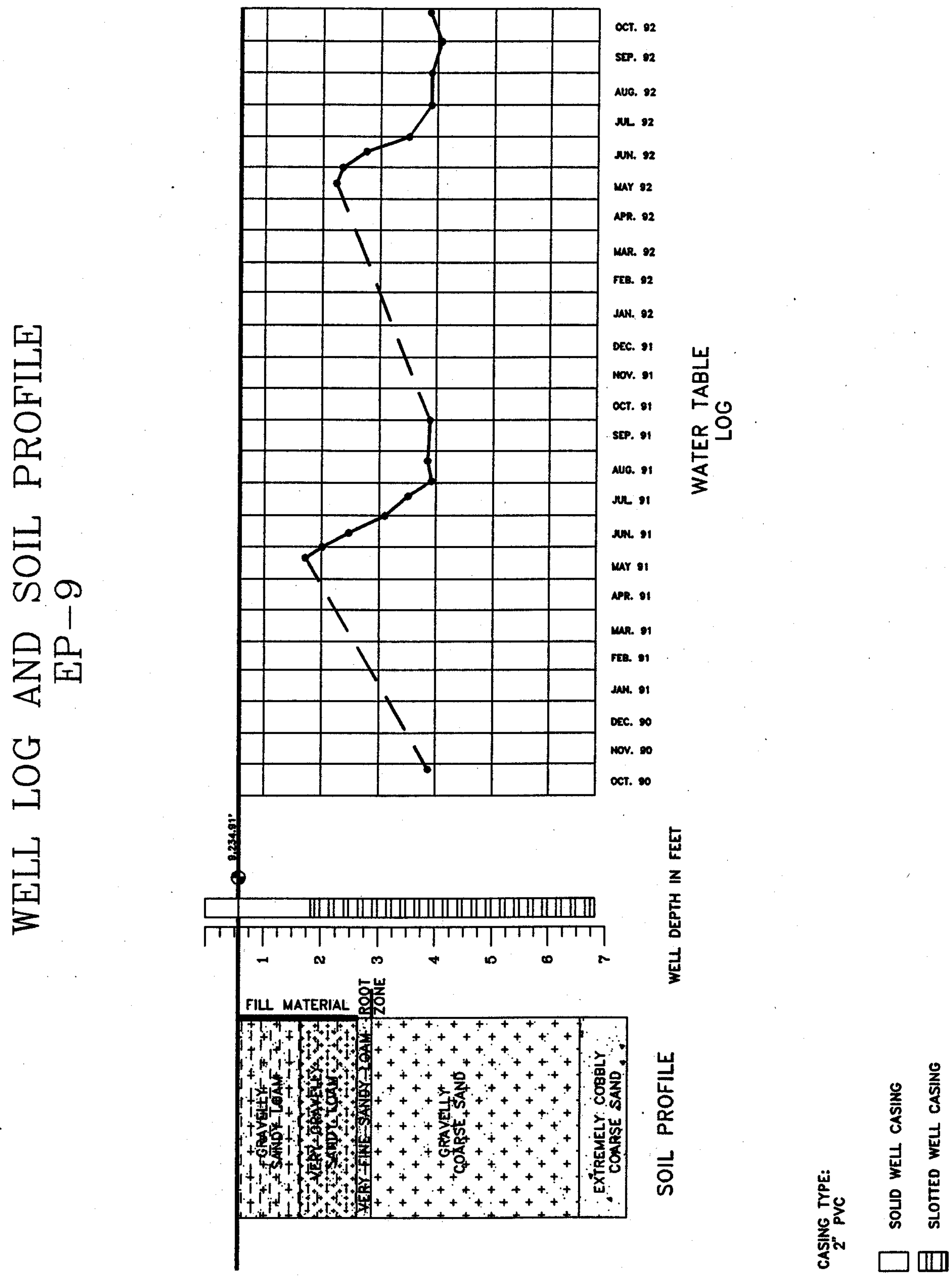

WELL LOG AND SOIL PROFILE
EP-4
WATER TABLE LOG
OCT. 92
SEP. 92
AUG. 92
JUL. 92
JUN. 92
MAY 92
APR. 92
MAR. 92
FEB. 92
JAN. 92
DEC. 91
NOV. 91
OCT. 91
SEP. 91
AUG. 91
JUL. 91
JUN. 91
MAY 91
APR. 91
MAR. 91
FEB. 91
JAN. 91
DEC. 90
NOV. 90
OCT. 90
WELL DEPTH IN FEET
FILL MATERIAL
ROOT ZONE
SOIL PROFILE
CASING TYPE: 2" STEEL (DRIVE POINT)
SOLID WELL CASING
SLOTTED WELL CASING

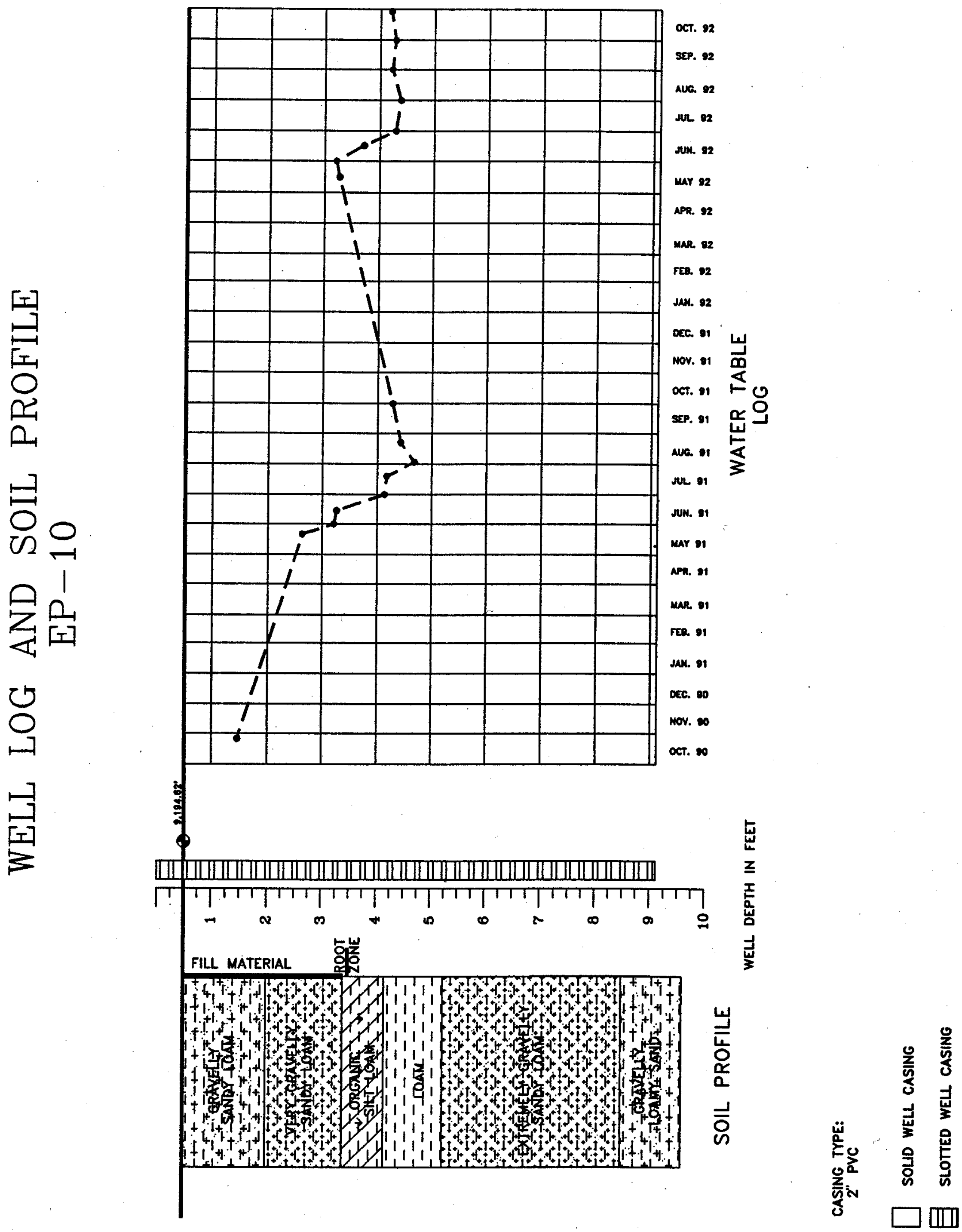

WELL LOG AND SOIL PROFILE
EP—5
WATER TABLE
LOG
OCT. 92
SEP. 92
AUG. 92
JUL. 92
JUN. 92
MAY 92
APR. 92
MAR. 92
FEB. 92
JAN. 92
DEC. 91
NOV. 91
OCT. 91
SEP. 91
AUG. 91
JUL. 91
JUN. 91
MAY 91
APR. 91
MAR. 91
FEB. 91
JAN. 91
DEC. 90
NOV. 90
OCT. 90
WELL DEPTH IN FEET
FILL MATERIAL
ROOT ZONE
GRAVELY SANDY LOAM
VERY GRAVELY SANDY LOAM
GRAVELLY CLAY LOAM
ORGANIC SILT LOAM
EXTREMELY COBBLY COARSE SAND
SOIL PROFILE
CASING TYPE:
4" PVC
SOLID WELL CASING
SLOTTED WELL CASING

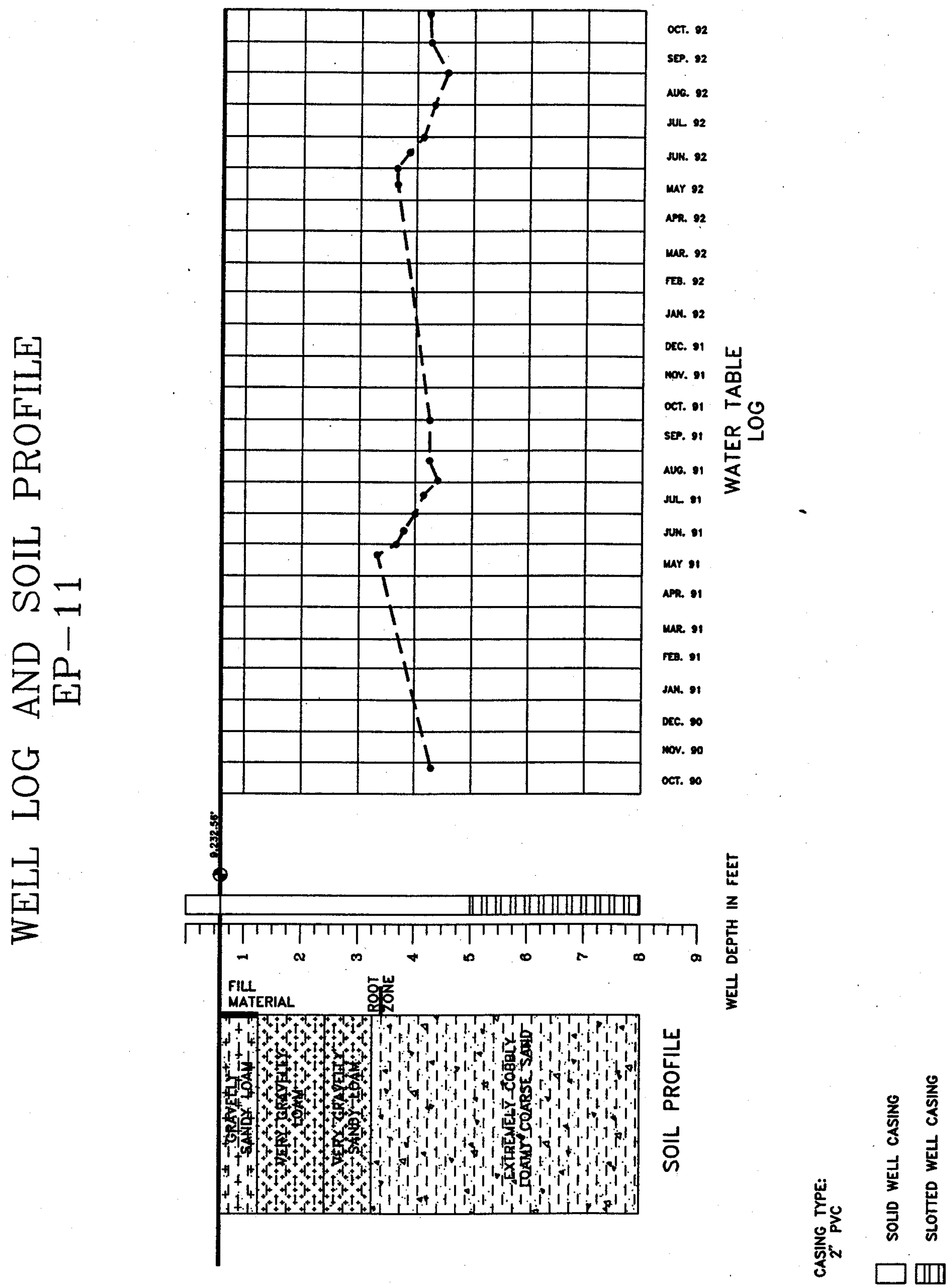

WELL LOG AND SOIL PROFILE
EP-6
OCT. 92
SEP. 92
AUG. 92
JUL. 92
JUN. 92
MAY 92
APR. 92
MAR. 92
FEB. 92
JAN. 92
DEC. 91
NOV. 91
OCT. 91
SEP. 91
AUG. 91
JUL. 91
JUN. 91
MAY 91
APR. 91
MAR. 91
FEB. 91
JAN. 91
DEC. 90
NOV. 90
OCT. 90
WATER TABLE LOG
1
2
3
4
5
6
7
8
9
10
11
WELL DEPTH IN FEET
FILL MATERIAL
ROOT ZONE
GRAVELLY LOAM
SILT LOAM
VERY FINE SANDY LOAM
EXTREMELY COBBLY COARSE SAND
SOIL PROFILE
CASING TYPE:
2" PVC
SOLID WELL CASING
SLOTTED WELL CASING

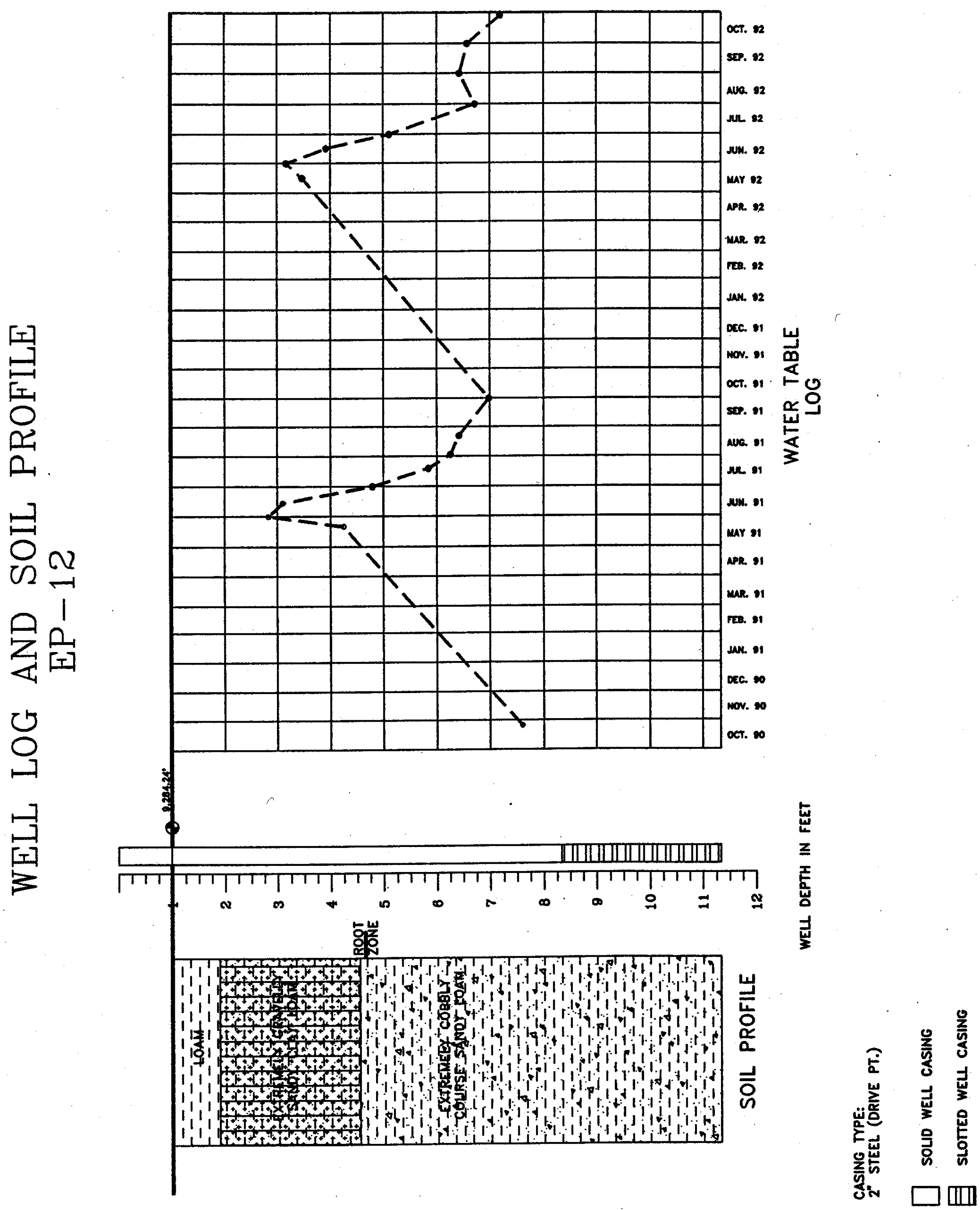

WELL LOG AND SOIL PROFILE
EP-7
OCT. 92
SEP. 92
AUG. 92
JUL. 92
JUN. 92
MAY 92
APR. 92
MAR. 92
FEB. 92
JAN. 92
DEC. 91
NOV. 91
OCT. 91
SEP. 91
AUG. 91
JUL. 91
JUN. 91
MAY 91
APR. 91
MAR. 91
FEB. 91
JAN. 91
DEC. 90
NOV. 90
OCT. 90
WATER TABLE LOG
1 2 3 4 5 6 7 8 9 10 11
WELL DEPTH IN FEET
ROOT ZONE
GRAVELLY SANDY LOAM
VERY GRAVELLY SANDY LOAM
VERY GRAVELLY LOAM
EXTREMELY GRAVELLY SANDY LOAM
EXTREMELY COBBLY COARSE SAND
SOIL PROFILE
CASING TYPE: 2" PVC
SOLID WELL CASING
SLOTTED WELL CASING

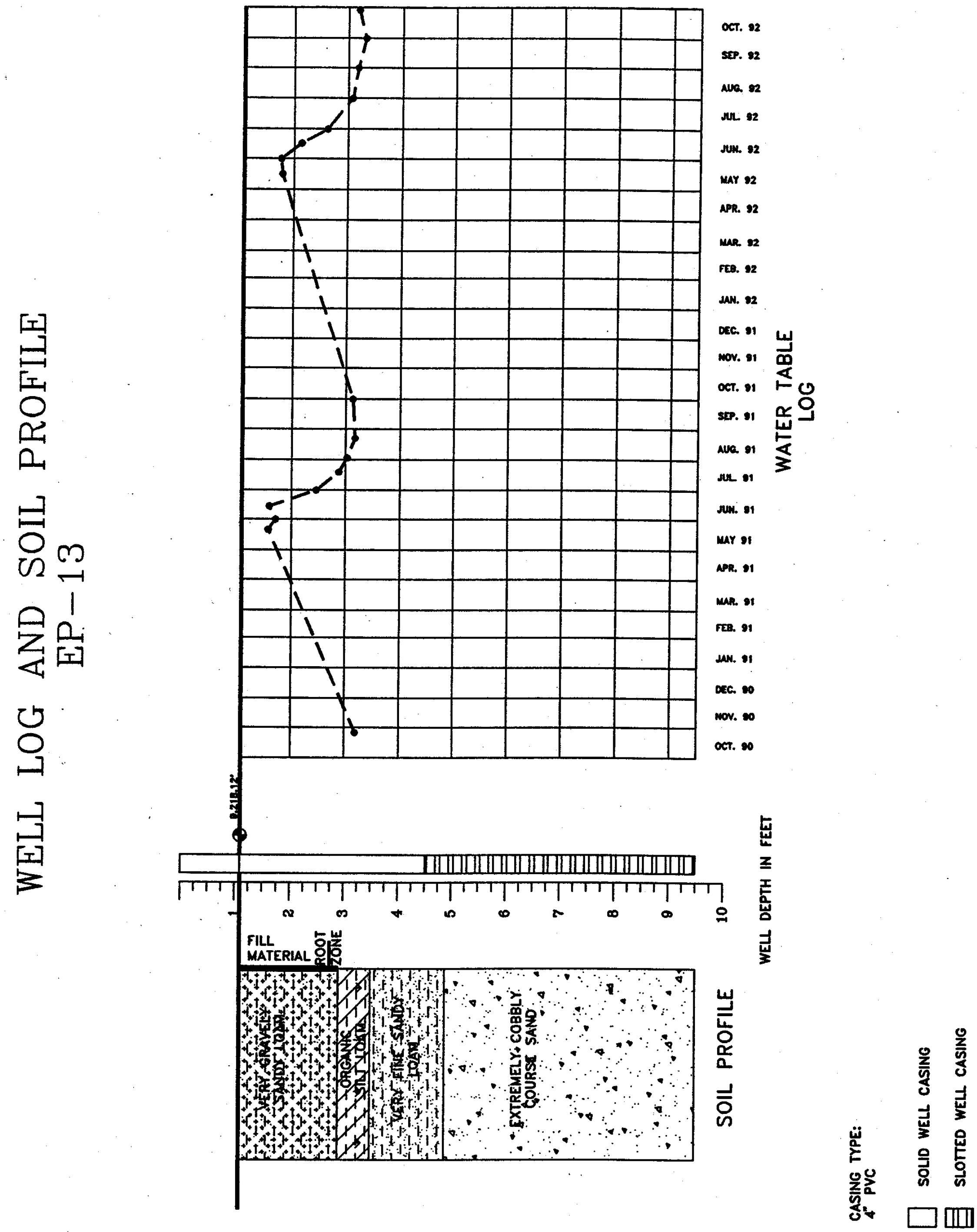

WELL LOG AND SOIL PROFILE
EP-8
OCT. 92
SEP. 92
AUG. 92
JUL. 92
JUN. 92
MAY 92
APR. 92
MAR. 92
FEB. 92
JAN. 92
DEC. 91
NOV. 91
OCT. 91
SEP. 91
AUG. 91
JUL. 91
JUN. 91
MAY 91
APR. 91
MAR. 91
FEB. 91
JAN. 91
DEC. 90
NOV. 90
OCT. 90
WATER TABLE
LOG
9,274.52'
1
2
3
4
5
6
WELL DEPTH IN FEET
ROOT
ZONE
SAND
CLAY LOAM
SANDY LOAM
GRAVELY
SANDY LOAM
EXTREMELY COBBLY
COARSE SAND
SOIL PROFILE
CASING TYPE:
2" PVC
SOLID WELL CASING
SLOTTED WELL CASING


WELL LOG AND SOIL PROFILE
EP–9
OCT. 92
SEP. 92
AUG. 92
JUL. 92
JUN. 92
MAY 92
APR. 92
MAR. 92
FEB. 92
JAN. 92
DEC. 91
NOV. 91
OCT. 91
SEP. 91
AUG. 91
JUL. 91
JUN. 91
MAY 91
APR. 91
MAR. 91
FEB. 91
JAN. 91
DEC. 90
NOV. 90
OCT. 90
WATER TABLE
LOG
9,234.91'
1
2
3
4
5
6
7
WELL DEPTH IN FEET
FILL MATERIAL
ROOT ZONE
GRAVELLY SANDY LOAM
VERY GRAVELLY SANDY LOAM
VERY FINE SANDY LOAM
GRAVELLY COARSE SAND
EXTREMELY COBBLY COARSE SAND
SOIL PROFILE
CASING TYPE:
2" PVC
SOLID WELL CASING
SLOTTED WELL CASING


WELL LOG AND SOIL PROFILE
EP-10
OCT. 92
SEP. 92
AUG. 92
JUL. 92
JUN. 92
MAY 92
APR. 92
MAR. 92
FEB. 92
JAN. 92
DEC. 91
NOV. 91
OCT. 91
SEP. 91
AUG. 91
JUL. 91
JUN. 91
MAY 91
APR. 91
MAR. 91
FEB. 91
JAN. 91
DEC. 90
NOV. 90
OCT. 90
WATER TABLE LOG
1
2
3
4
5
6
7
8
9
10
WELL DEPTH IN FEET
FILL MATERIAL
ROOT ZONE
GRAVELLY SANDY LOAM
VERY GRAVELLY SANDY LOAM
ORGANIC SILT LOAM
LOAM
EXTREMELY GRAVELLY SANDY LOAM
GRAVELLY LOAMY SAND
SOIL PROFILE
CASING TYPE:
2" PVC
SOLID WELL CASING
SLOTTED WELL CASING


WELL LOG AND SOIL PROFILE
EP-11
OCT. 92
SEP. 92
AUG. 92
JUL. 92
JUN. 92
MAY 92
APR. 92
MAR. 92
FEB. 92
JAN. 92
DEC. 91
NOV. 91
OCT. 91
SEP. 91
AUG. 91
JUL. 91
JUN. 91
MAY 91
APR. 91
MAR. 91
FEB. 91
JAN. 91
DEC. 90
NOV. 90
OCT. 90
WATER TABLE LOG
9,232.58'
1
2
3
4
5
6
7
8
9
WELL DEPTH IN FEET
FILL MATERIAL
ROOT ZONE
GRAVELLY SANDY LOAM
VERY GRAVELLY LOAM
VERY GRAVELLY SANDY LOAM
EXTREMELY COBBLY LOAMY COARSE SAND
SOIL PROFILE
CASING TYPE: 2" PVC
SOLID WELL CASING
SLOTTED WELL CASING


WELL LOG AND SOIL PROFILE
EP-12
WATER TABLE LOG
OCT. 90
NOV. 90
DEC. 90
JAN. 91
FEB. 91
MAR. 91
APR. 91
MAY 91
JUN. 91
JUL. 91
AUG. 91
SEP. 91
OCT. 91
NOV. 91
DEC. 91
JAN. 92
FEB. 92
MAR. 92
APR. 92
MAY 92
JUN. 92
JUL. 92
AUG. 92
SEP. 92
OCT. 92
1
2
3
4
5
6
7
8
9
10
11
12
WELL DEPTH IN FEET
ROOT ZONE
LOAM
EXTREMELY GRAVELLY SANDY CLAY LOAM
EXTREMELY COBBLY COURSE SANDY LOAM
SOIL PROFILE
CASING TYPE:
2" STEEL (DRIVE PT.)
SOLID WELL CASING
SLOTTED WELL CASING


WELL LOG AND SOIL PROFILE
EP-13
WATER TABLE LOG
OCT. 90
NOV. 90
DEC. 90
JAN. 91
FEB. 91
MAR. 91
APR. 91
MAY 91
JUN. 91
JUL. 91
AUG. 91
SEP. 91
OCT. 91
NOV. 91
DEC. 91
JAN. 92
FEB. 92
MAR. 92
APR. 92
MAY 92
JUN. 92
JUL. 92
AUG. 92
SEP. 92
OCT. 92
WELL DEPTH IN FEET
1
2
3
4
5
6
7
8
9
10
FILL MATERIAL
ROOT ZONE
VERY GRAVELLY SANDY LOAM
ORGANIC SILT LOAM
VERY FINE SANDY LOAM
EXTREMELY COBBLY COURSE SAND
SOIL PROFILE
CASING TYPE:
4" PVC
SOLID WELL CASING
SLOTTED WELL CASING

APPENDIX A.1

ADDENDUM VIII – CAMP HALE RIVER AND WETLAND RESTORATION COST ESTIMATE

CAMP HALE MAGNITUDE OF COSTS

Item #	Description	Quantity	Unit	Unit Cost	Total Cost	Notes:
1	Restore Historic Channel					
1a	Excavate Channel					
	Clear and Grub	25	AC	$5,000	$125,000	Including construction access
	Excavation	120,000	CY	$4	$480,000	5 miles 30X4 feet average/ use scrapers
	Excavation Hauloff (Alluvium)	120,000	CY	$4	$480,000	Disposal within 1 mile RT (25 acres)
	Care of Water	1	LS		$96,000	20 % of excavation for pumping/ coffer dams etc
1b	Excavate New Floodplain	29,156	CY	$4	$116,622	
	Excavation Hauloff	29,156	CY	$4	$116,622	
1c	Grade Controls					
	Rock Grade Control	100	EA	$4,500	$450,000	key in banks and toe down, over excavate and backfill
1d	Bank Restoration					
	Restore and Stabilize	20,000	FT	$15	$300,000	Fabrics and Soils
1e	Riparian Plantings					
	Riparian Plantings	25	AC	$20,000	$500,000	High Altitude root stock
	Total Channel Costs	26,400	LF	$101	$2,664,244	
2	Restore Historic Wetlands					
	Wetland/Riparian Seeding	800	ac	$400	$320,000	Seeding
	Total Wetland Costs				$320,000	
3	General Construction					
3a	Best Management practices					
	Silt Fence	5,000	LF	$4	$20,000	Reusable fencing
	Plant Native Grasses	40	AC	$500	$20,000	25 acre disposal area; irrigation
	Protect in Place	1	LS	$20,000	$20,000	Utilities? Cultural resources? Bridges?
3b	Mobilization/demobilization	1	LS	$133,212	$133,212	5% total const for staging and access
	Total Site Setup	1	LS	$193,212	$193,212	
4	RESTORATION SUBTOTAL				$3,177,457	

CAMP HALE MAGNITUDE OF COSTS

Item #	Description	Quantity	Unit	Unit Cost	Total Cost	Notes:
5	Historical Enhancements					
	Buildings/parking/memorials				$1,000,000	
6	Additional Work					
	Grant Writing				$20,000	
	Survey Control Network	1	LS	$10,000	$10,000	GPS Control Network
	Base Mapping	1	SQ Mile	$30,000	$30,000	Aerial survey for 2' contour with ground control
	Hydrographic Survey				$40,860	CSU estimate
	Ordnance/HTRW Survey				$25,000	Hazardous, Toxic or Radioactive Waste Survey
	Environmental Assessment				$125,000	Federal Funds/Lands?
	Lands and Easements				$0	Forest Service will be partner
	River Crossings	2	EA	$120,000	$240,000	Vehicle crossings for 30 feet wide channel
	Engineering Design				$298,424	10% construction
	Permitting				$40,000	404 and erosion control etc. Most work done during design
	Plans and Specifications for bid				$158,873	5% construction after design
	Construction Stakeout				$95,324	3% construction
	Construction Monitoring				$40,000	
	Post Restoration Monitoring		5 YR	$40,000	$200,000	CSU estimate
	Plant Comm./Floodplain Study		2 YR	$50,000	$100,000	CSU estimate
	Total Additional Work				$1,423,481	
	TOTAL PROJECT MAGNITUDE COST ESTIMATE				$5,600,938	

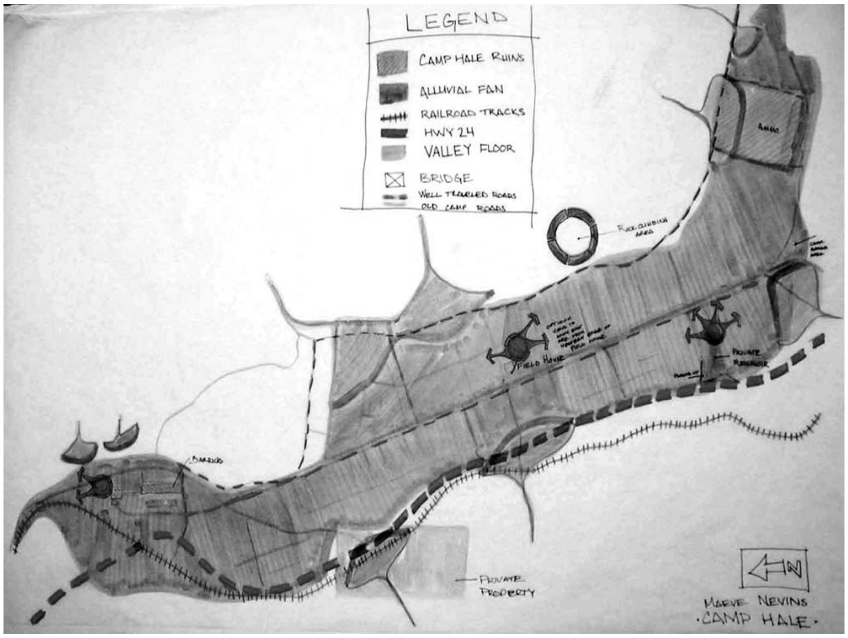
APPENDIX A.1

ADDENDUM IX – LANDSCAPE ARCHITECTURE SITE ALTERNATIVES ANALYSIS

The stream channel, riparian area, and wetlands are reconstructed to near historic conditions. The field house is rebuilt while other Camp Hale remnants are left as is.

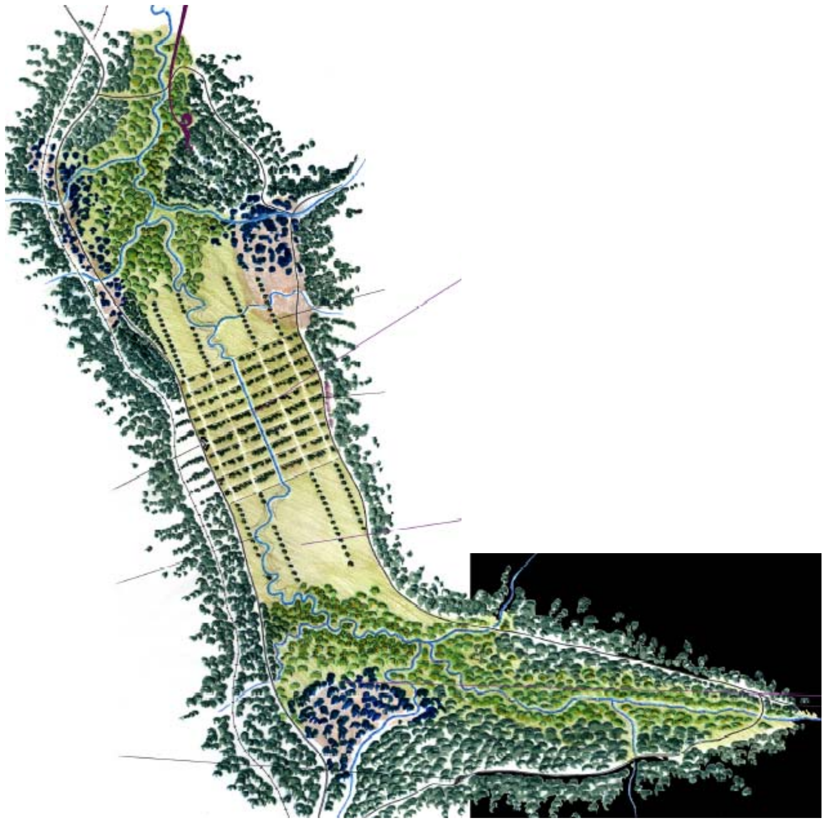
The river is returned to its historic pattern and location. A section of the straight channel is left and connected to the new channel.

APPENDIX A.1



This design emphasizes the historical preservation of Camp Hale. Neither the stream nor the wetlands are restored. The field house is rebuilt and used as a visitor's center.

This intermediate plan retains a portion of the straight channel in the center of the valley above and below which the channel is returned to a meandering form. A new visitor's center is built at the field house. The munitions bunkers are demolished and symbolic botanical gardens planted. The East Fork of the Eagle is restored to its 1942 location.

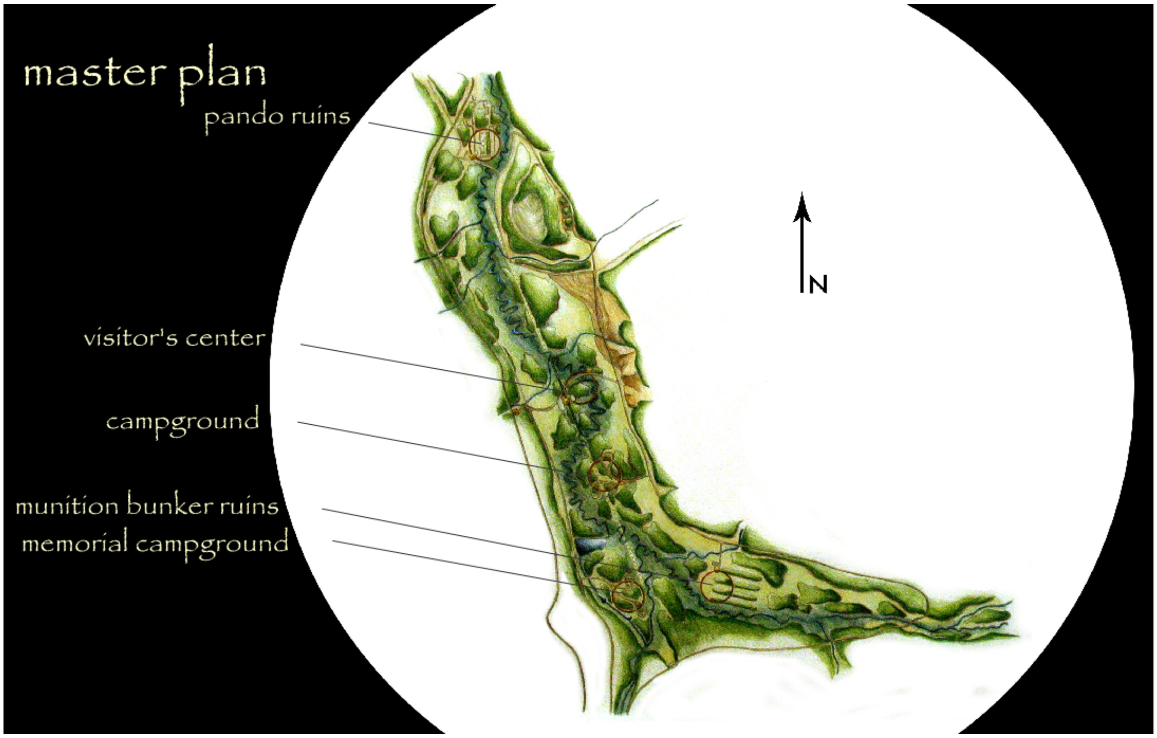


This plan is intended to strongly emphasize the natural and cultural aspects of Camp Hale in distinct areas of the valley. The center of the valley is the focus of the historical preservation of Camp Hale. Barrack mounds are planted with trees and the straight channel left in its form. The upper and lower regions of the valley are returned to native conditions.

A complete stream meander reconstruction completed with much of the historic wetlands returned. A Memorial Bosque is planted with an aspen tree for each soldier that served at Camp Hale. The field house is rebuilt and a separate visitor's center built.

APPENDIX A.1

The stream channel, riparian area, and wetlands are reconstructed to near historic conditions. A row of trees symbolizing the channelized reach is used as a memorial.



In this plan, the East Fork of the Eagle River remains in its current location until past the munitions bunkers where it begins to return to its historic location. The other channels in the valley are returned to their historical form along with the wetlands. The foundations at the lower end of the valley are left as artifacts. New campgrounds are built and the field house remodeled and used for a visitor's center.

APPENDIX A.2

Eagle River at Lake Creek Confluence / Frenchman's Lakes

Prepared by the Colorado State University Engineering Research Center

TABLE OF CONTENTS

LIST OF FIGURES

APPENDIX A.2

BACKGROUND

From a geomorphic standpoint, the Eagle River is largely stable and resilient in most segments due to lateral confinement, very coarse material on the bed and at the toe of banks, and ample sediment transport capacity. There are, however, isolated segments of the Eagle main stem that are unstable and contain poor quality habitat. As might be expected, these areas predominantly occur in relatively low gradient segments of the river and are the result of several decades of various stressors including removal of riparian vegetation, grazing, and subsequent bank erosion. A few relatively long segments of the river corridor with severely degraded habitat provide significant opportunities to reconnect existing high quality habitats and/or reestablish wetland and riparian functions on a disproportionately large scale.

SITE LOCATION AND HISTORY

The candidate restoration site is approximately 8600 feet long and begins 3000 feet downstream of the Edwards bridge and ends at the Hillcrest Drive bridge. The upstream boundary is located at lat. 39° 38' 52.1"N, long. 106° 35' 38.8"W and the downstream boundary is located at lat. 39° 39' 16.2"N, long. 106° 37' 43.3"W. With the exception of a knickzone and entrenched reach near the downstream project boundary, the Eagle River is unconfined in this location as it traverses a broad alluvial valley that includes the Lake Creek confluence. A historical photo of part of this site was taken from the railroad by William Henry Jackson (ca. 1890) of Joseph Brett's Ranch at the mouth of Lake Creek (Figure 1). According to Knight and Hammock (1965), in the 1880's this area "became known as the Frenchman's Lakes and gained a well-merited reputation for its fishing. This is the site of Williams' Fishery where Fremont stopped with Kit Carson in 1845."

Figure 1: Historical photo of Eagle River / Lake Creek confluence area ca. 1890 (Courtesy of Denver Public Library).

Key Issues

Extremely high width to depth ratio, insufficient transport capacity for flushing fine sediments, embedded substrate, high temperatures during low flow season, disconnects relatively high quality habitat upstream and downstream, ecological conditions broadly associated with whirling disease, and high recreational / educational potential. In Summer 2003, CSU measured one cross-section downstream of Lake Creek that was 277.5 feet wide with an average depth of 1.4 feet. This section had a 72-foot wide mid-channel bar.

Potential Constraints

Geomorphically complex valley transitions, tie in channel at Lake Creek confluence and existing knickzone north of mobile home park, maintenance of flood conveyance and mitigation functions, uncertain future land use particularly in upstream portion of site.

Ownership

Multiple private landowners.

Potential Actions

Reduce width and increase depth to improve sediment continuity and flushing of fine material, restore mild sinuosity, bank bioengineering and reshaping, restore native riparian plant communities matched to hydrologic and soil characteristics, wetland / oxbow lake restoration/creation on floodplain, improved recreational access, educational / interpretive enhancements. Several conceptual design alternatives are presented in Figures 2 through 7. The conceptual illustrations presented in these figures do not represent the entire range of alternatives for the site. Instead, the drawings are simply presented as a first order approximation of stable channel configurations that have the potential to significantly improve aquatic habitat in this segment and reconnect river segments with existing high quality habitat. Additional geomorphic, hydraulic, and sedimentation analyses will provide a more robust estimate of longitudinal, cross-sectional, and planform (degree of meandering) characteristics. Nonetheless, this preliminary analysis most likely brackets the geometric and planform attributes of stable channel design alternatives that will result from the more detailed analyses.

APPENDIX A.2

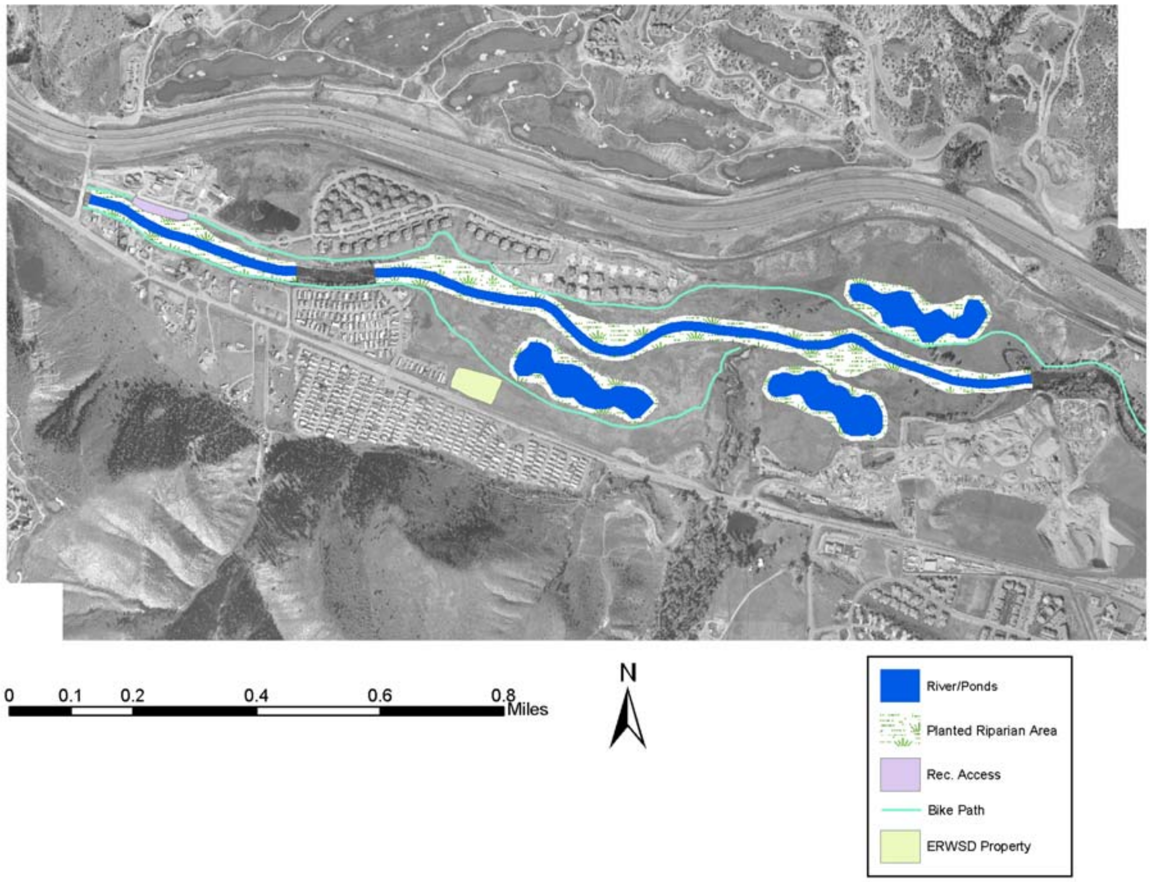


Figure 2: Plan 1

APPENDIX A.2

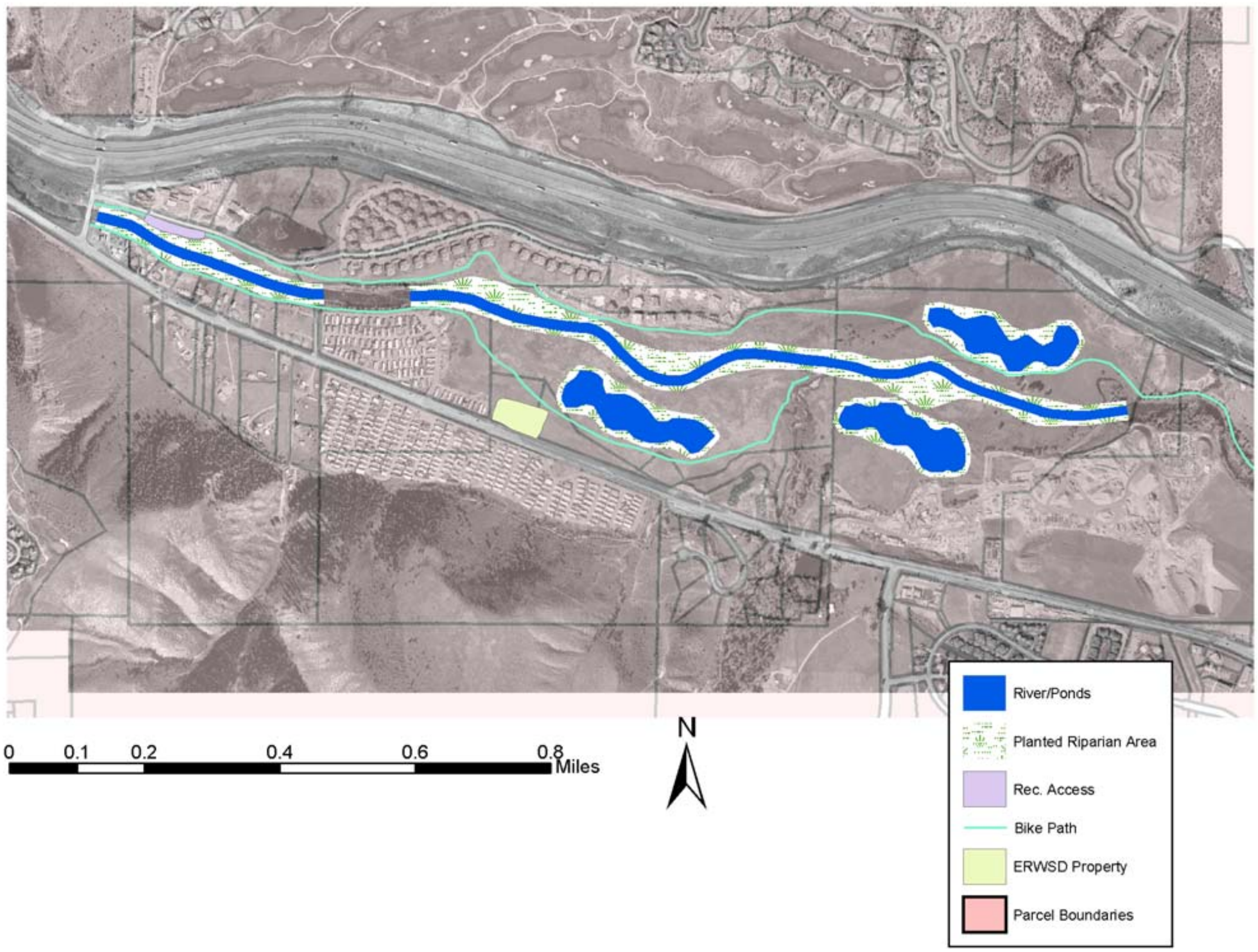


Figure 3: Plan 1 with parcel boundaries

APPENDIX A.2

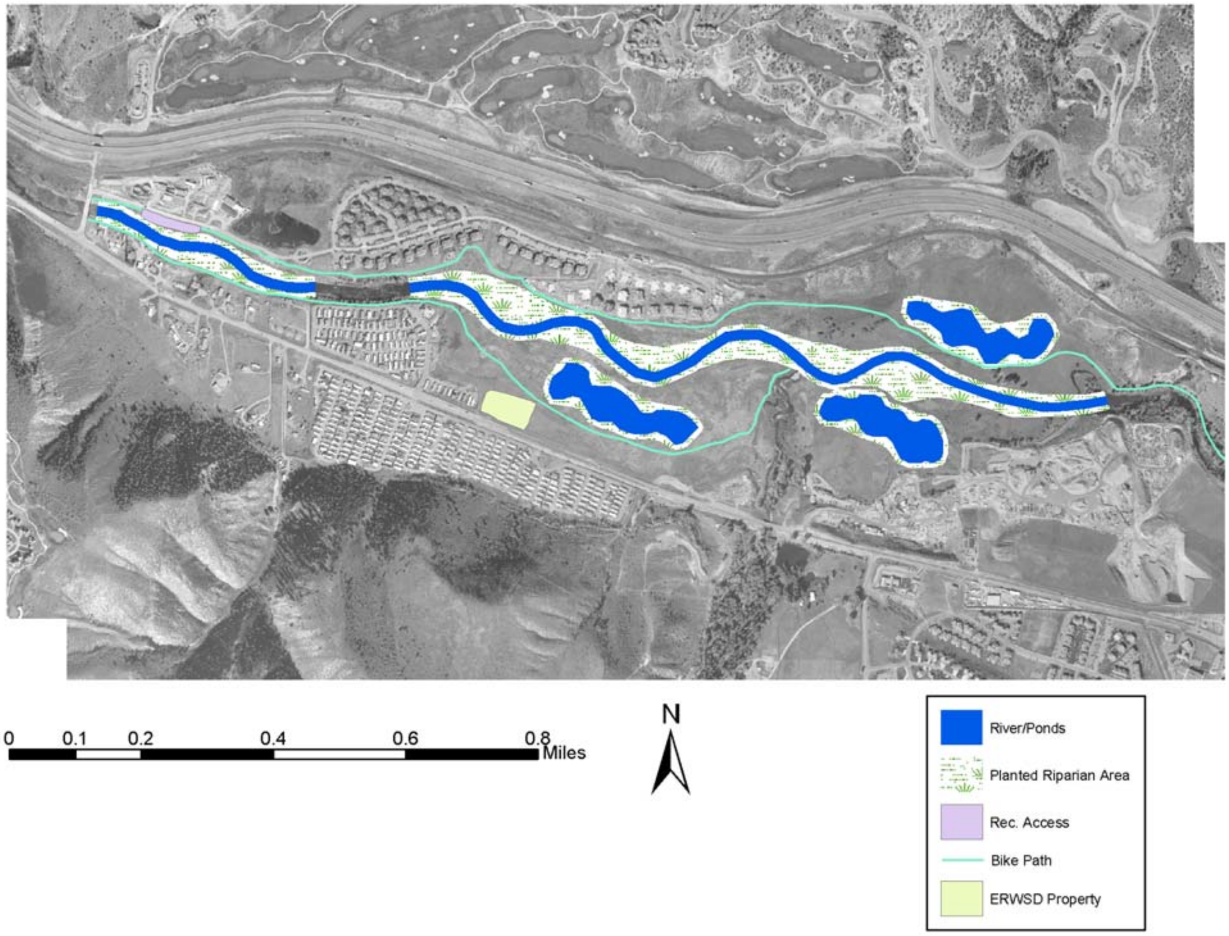


Figure 4: Plan 2

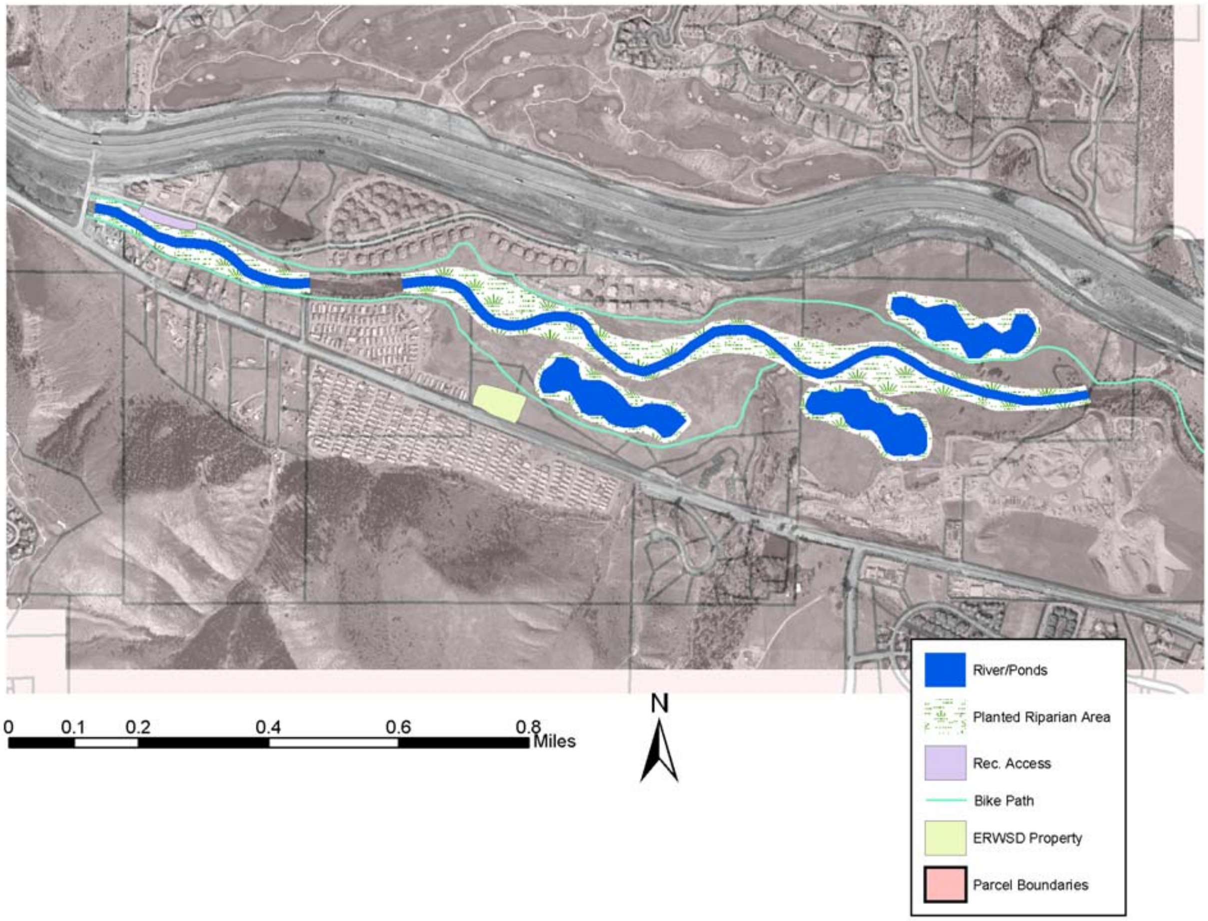


Figure 5: Plan 2 with parcel boundaries

APPENDIX A.2

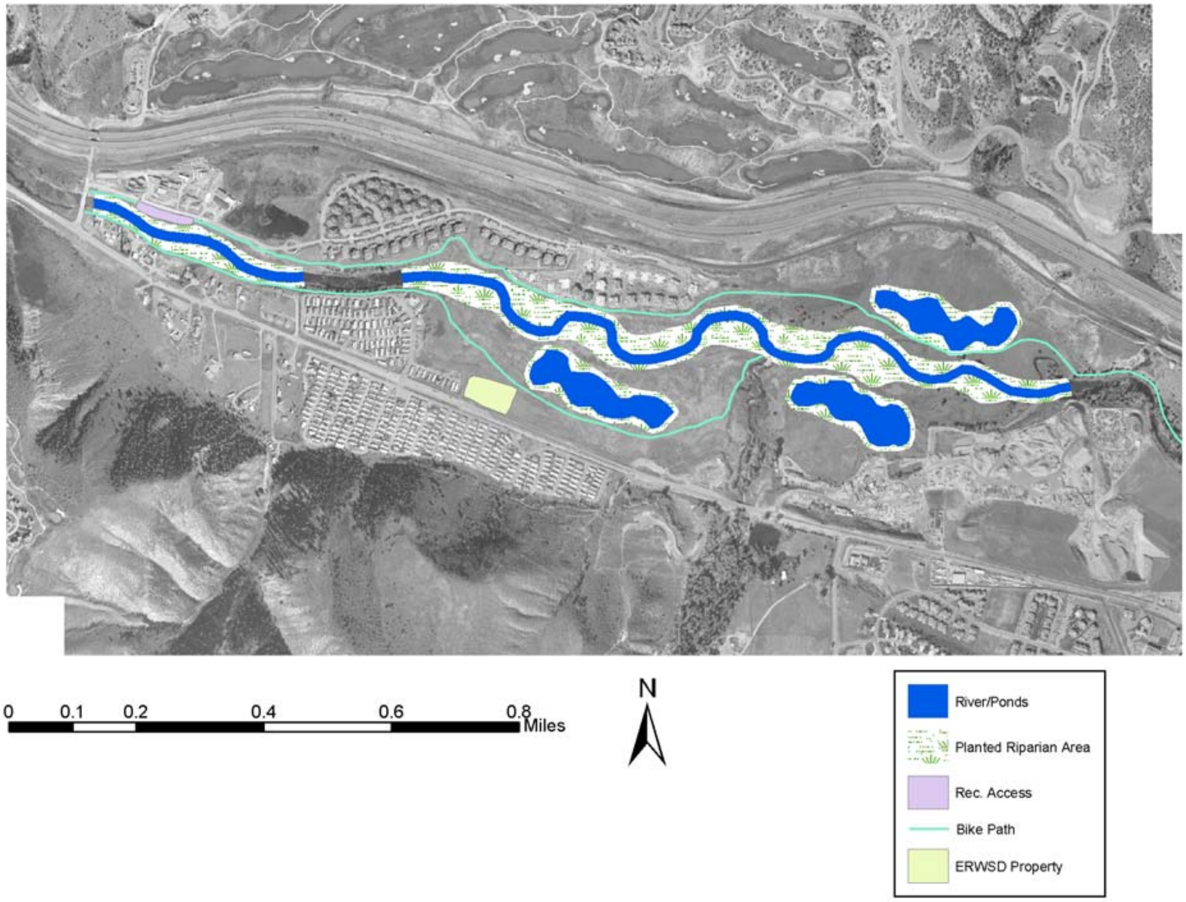


Figure 6: Plan 3

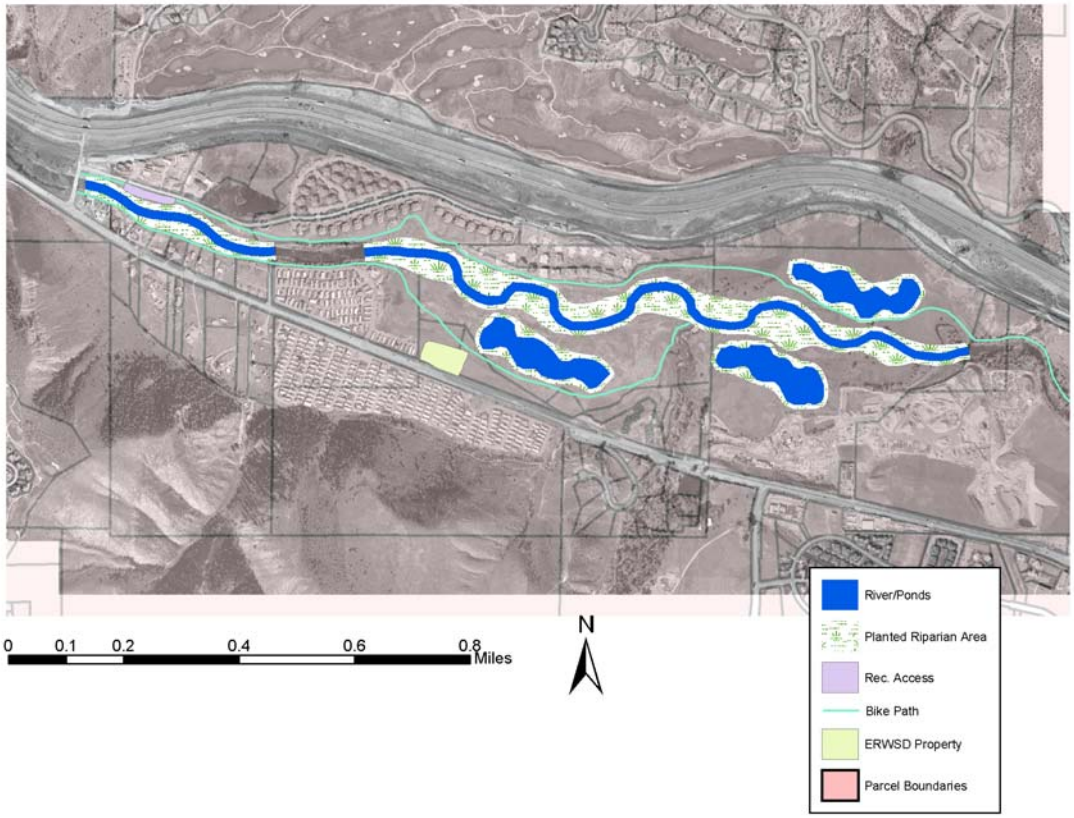


Figure 7: Plan 3 with parcel boundaries

BACKGROUND ON PRELIMINARY DESIGN ALTERNATIVES

- Multi-purpose wetland / pond complexes can be constructed to provide borrow material for channel width reduction and re-alignment, potentially act as stormwater best management practices for future development, add floodwater storage to the floodplain, and enhance habitat and recreational value of the site.

- Reducing the width to depth ratio of the channel will increase sediment transport capacity and flushing of fine sediments. Accordingly, "hard points" of coarse material should be considered in crossing / riffle sections to check potential incision. These features are at grade with the channel bed and will not adversely affect boating and recreation.

- A major design challenge for this site lies in dealing with the distinct change in valley gradient and entrenchment at the upstream end of the site. Over a short distance, the valley changes from relatively steep and confined to a much more connected floodplain and mild gradient. Accordingly, the river rapidly transitions from a supply-limited stream with a high transport capacity to a much lower energy level and sediment transport capacity. Furthermore, the material available for transport rapidly shifts through sorting of the bed material load. Thus, any restoration design for this site must incorporate a transition zone to allow for this shift in sediment transport regimes. One option, as depicted in our preliminary designs, is to partially use what the Eagle River has already established as a transition/sorting zone.

- For preliminary design flows, instantaneous annual peak flow data from the USGS at the Avon gage were used. In 1999, the gage location for this site changed. Because no major flow inputs are located between the old and new sites, it was assumed that the measured streamflows at the two sites are approximately the same and the gage records were combined to increase the data set. The 1.3-year flow estimated from a Weibull distribution at the Avon gage was used as a preliminary estimate of a design discharge. The $Q_{1.3}$ estimate at the Avon gage was adjusted for this larger drainage area using a regional regression equation based on drainage area and basin slope at USGS gauged sites. This yields a preliminary design discharge estimate of 2006 cfs for the upstream end of the site. The confluence of the Eagle River and Lake Creek is located between the upstream and downstream ends of the site. Using a similar Weibull approach, a $Q_{1.3}$ of 409 cfs was estimated for Lake Creek. This value was added to the upstream discharge to estimate a design discharge of 2415 cfs for the section of the site downstream of Lake Creek. Effective discharge computations will be conducted to further refine the current estimates of channel-forming discharge above and below Lake Creek.

- Preliminary hydraulic geometry for the site was estimated with three downstream hydraulic geometry relations for width versus discharge. The three relations are $w = aQ^{0.5}$, where a = 1.4, 1.7, and 2.0. The following table depicts the resulting widths. These widths were used to estimate a meander wavelength (λ) based on the general relation $\lambda = 4\pi w$. This relationship gives an average wavelength of about 1000 ft. Two alternatives were considered for this preliminary design. The first option maintains the current channel location and simply reduces the width of the channel. The second option is based on a more sinuous channel. A quantitative analysis of the meander geometry of other sinuous, low gradient segments of the Eagle main stem is currently in progress.

Q in cfs and channel width in ft.			
	a		
$Q_{1.3}$	1.4	1.7	2.0
2006	62.7	76.1	89.6
2415	68.8	83.5	98.3

- The preliminary range of designs calls for maintaining existing high-quality riparian areas and re-establishing riparian vegetation in areas where past land use practices have resulted in the denudation of stream banks. Riparian vegetation is critical in maintaining the desired channel geometry, stabilizing banks, and improving instream habitat. Highest priority should be given to the left (southern) bank for establishment of woody vegetation with shading potential. Riparian planting could also be extended up Lake Creek in the confluence vicinity.

- Currently, the only ‘developed’ access to the site is via a dirt parking lot at the downstream end of the site near the Edwards Wastewater Treatment Plant and a short section of bike path along the north side of the river. The preliminary design alternatives presented herein include formalizing this downstream access point and converting it into a paved parking area with a boat launch area and restroom facilities. Furthermore, the bike path could be extended upstream to provide access throughout the site, provide access to educational signage and connect to an existing bike path in Edwards.

REFERENCE

Knight, M. and L. Hammock (1965). “Early Days on the Eagle.” Eagle, CO, Knight & Hammock.

APPENDIX A.3

Design Overview, Gypsum Ponds Reach
Eagle River, Near Gypsum, Colorado

Prepared For:

The Colorado Division of Wildlife
West Slope Habitat Section
711 Independent Avenue
Grand Junction, CO 81505

Prepared by:

AquaTerra Services, LLC
P.O. Box 55126
Grand Junction, CO 81505

Claffey Ecological Consulting, Inc.
1371 17 Road
Fruita, CO 81521

Five Rivers, Inc.
8950 Chapman Road
Bozeman, MT 59718

APPENDIX A.3

TABLE OF CONTENTS

APPENDIX A.3

LIST OF FIGURES

APPENDIX A.3

APPENDIX A.3

INTRODUCTION

The Eagle River, near Gypsum, Colorado (see Figure 1), exhibits stability and instability along its course, sometimes with marked changes in comportment over very short distances. In the vicinity of the project area, the channel exhibits the opposing trends of entrenchment vs. widening, gravel starvation vs. excess supply, bed armoring vs. dilation, as well as bar formation and excavation. Such signs are indicative of channels in flux; in the worst case, the trend is toward further instability; in the best case, the trend is toward a more stable state. Given the pronounced land loss occurring over the last few years, evidence of meander extension and the sedimentology of the project area, it would appear that the reach is trending toward instability.

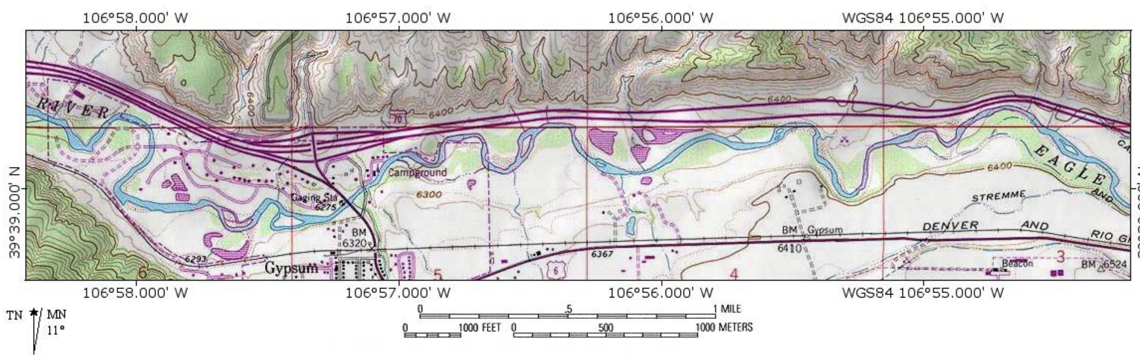


Figure 1: Map of project area taken from USGS Quad.

This condition is not unusual in western Colorado, but part of a series of erosional and depositional periods since the start of the Holocene. Much of what is observed today is the result of the history in the last 3,000 years. In general, deposition and aggradation dominated until about 800 years ago. That period abruptly ended, and was followed by 200 years of strong incision, which was followed just as abruptly, by 400 years of aggradation. The next switch in regime occurred during the settlement period, where both climate change and land use practices combined to create an extensive and intensive cycle of incision lasting until about 1925. Following a short period of adjustment, valleys once again experienced deposition and floodplain building from 1940 to about 1980. The bank erosion and meander extension currently extant probably results from a combination of I-70 construction, flood events in the 1980's and 1990's, and the consequence of geographic position relative to local geology. The river also shows some hints of being underfit, the possibility of which might help explain the tortuous nature of the meander belt. To counter this trend, a restoration plan has been devised and is described below. This plan is the result of cursory evaluation and may change as more information is collected and the restoration budget becomes known.

APPENDIX A.3

SITE CONDITION AND DESIGN GOAL

Reviews of the reach were conducted near base flow in March of 2004. The project reach is characterized by relatively steep un-vegetated stream banks prone to both cantilever and toe failure. Native profiles are comprised of a silty loam overlying a gravel base. The soil is characterized as highly erodible, easily wetted and dried, susceptible to frost and piping losses and difficult to re-vegetate under the current climate regime. When under direct attack from hydraulic forces, these factors contribute to marked and persistent lateral instability (see Figure 2). Excess gravel produced in the reach from bank erosion and that contributed from upstream sources is stored in mid-channel bars and on pronounced point bar slopes. The upper end of the reach is suggestive of headcutting while aggradation in the middle and lower sections has produced development and extension of chutes and competitive side channels. These trends have also deleteriously affected fish habitat by increasing with width-depth ratio, by contributing sediment to an already laden channel, and distributing low flows.

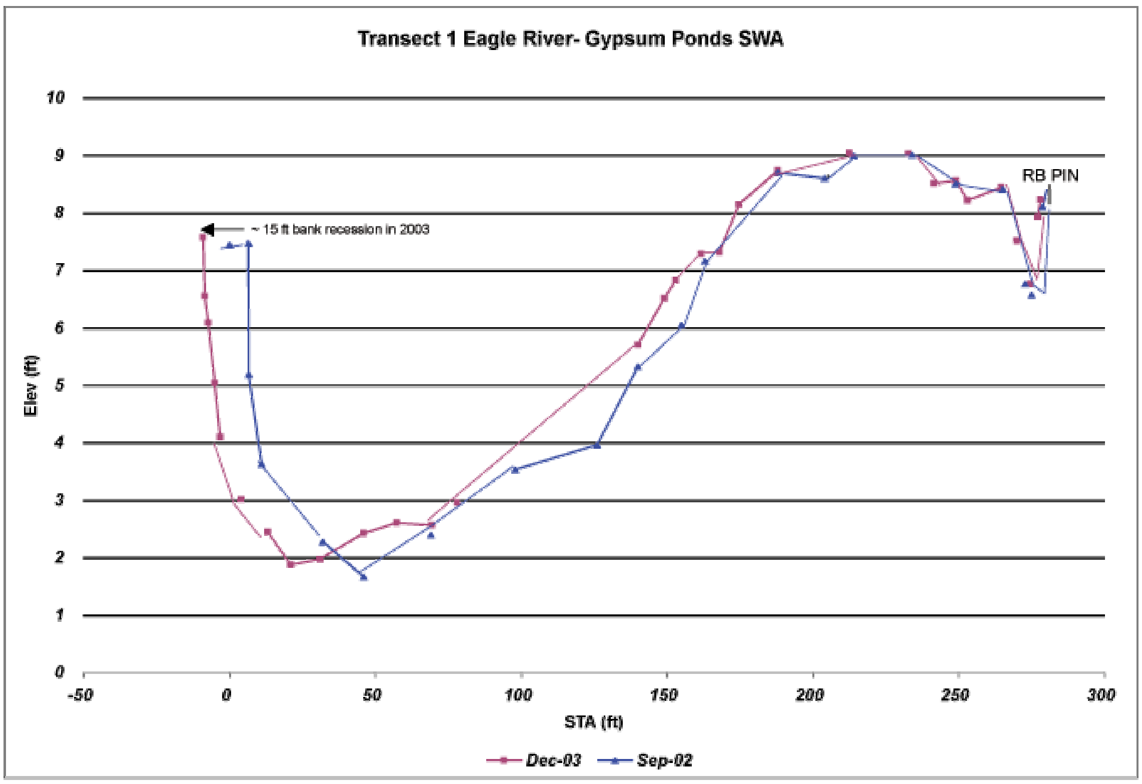


Figure 2: Change in cross-section from 2002-2003 within the project reach. Runoff in 2003 produced about 15 feet of bank recession.

APPENDIX A.3

Some bank protection work has been completed by others inside the project area, mostly to protect against further encroachment toward I-70 or the Colorado Department of Wildlife (CDOW) wildlife ponds. The goal of this work was to prevent further recession as cost-effectively as possible, and as such, was completed at the point of attack. There was no attempt to re-establish a prior bank profile and location, or to establish a different meander geometry or flow pattern. Due to the prior investment in these areas, and the high cost of establishing full meander patterns, the suggested approach for this reach is to follow a natural design technique that focuses on changing cross-sectional geometry to alter flow patterns and improve trout habitat, and reinforces stream banks with a blend of re-shaping, riprap, bio-degradable soil lifts and re-establishment of native riparian plants.

DESIGN APPROACH

There are five major elements involved in this work: 1) an assessment of general hydrology; the range of flows involved, and by proxy, the range of erosive forces likely to be present, 2) an assessment of the existing cross-sectional geometry and modeled hydraulic conditions, 3) modeling of modified stations, 4) calculation of how the modified sections relate to anticipated tractive force along the wetted perimeter and 5) development of bank stabilization techniques that complement both the geotechnical character of the stream banks and the available budget. Due to a combination of available data and limited funds, each step is normally simple and brief. Consequently, many natural channel designs, defined as those that seek to facilitate the operation of as many degrees-of-freedom of river behavior as possible, are often no more than educated guesses. Collecting more information or following more formal engineered solutions might result in more certainty over some aspects of the project, but they still don't provide any improvement in predicting river response, and have their own complications and aesthetic problems.

In this respect, it has been our experience that a process-based design leads to better chances of success in general, and particularly in volatile gravel-bed rivers. A tenet of this approach is to replicate and enhance natural channel features, which reflect operative processes, rather than introduce structural controls. Another tenet is to alter the channel toward pre-existing desirable behavioral trends. This approach also tends to create more usable, diverse and spatially variable trout habitat than structure-oriented improvements. For example, rather than fixing the break between riffle and pool over a short area and fixing that break space and time with a labyrinth weir, this break takes the form of a riffle that adjusts from event to event. This approach is not only more compatible with bedload transport and flow dynamics, it relies on these processes for its efficacy. In this way, the channel retains more degrees of freedom and responds to flows and sediment supply. In practical terms, natural channel designs end up favoring some degrees of freedom more than others, but not to the exclusion of one over another.

HYDROLOGY

Reach hydrology plays a large role in restoration or stabilization considerations. Important parameters include the extent, timing and variability of discharge, hydrograph shape and recurrence intervals for various flows.

Hydrographs

The USGS has maintained gaging station number 09070000 just downstream from the project area from 1946 to present. The Eagle River at this point drains an area of 944 square miles, and inspection of average daily flows shows a fairly stable regime, lacking large variation (see Figure 3). Flood peaks tend to occur predictably, with a slow rise and fall and little bi-modality. Bi-modal peaks can be particularly erosive in areas where bank strength is compromised by natural stratigraphy and an erosion cycle.

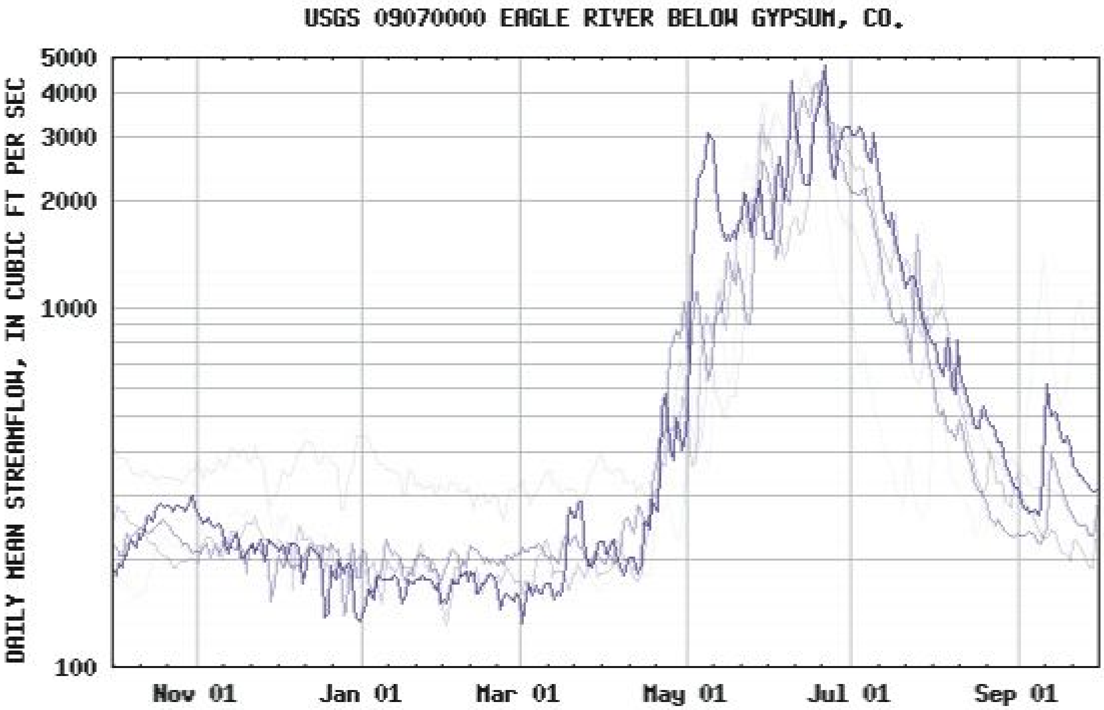


Figure 3: Composite hydrographs for several years taken at random.

Magnitude and Frequency

Annual series peak flood recurrence intervals have geomorphic and hydrologic implications, with estimated bankfull discharge being of particular interest. As shown in Figure 4, the average annual peak discharge for the Eagle at the gage appears to be about 4,000 cfs, which compares favorably with bankfull discharges calculated from cross-sectional geometry referenced to high water marks. The recurrence interval for flows of lesser probability is less clear, however, despite the relatively high correlation. In this case, estimates of probability higher than 1 in 10 should not be trusted. It should be noted, however, that while flows in excess of 7,000 cfs have been recorded, designing around such an event would be cost prohibitive. Thus, the design discharge will focus on the more probable event of about 4,000 cfs.

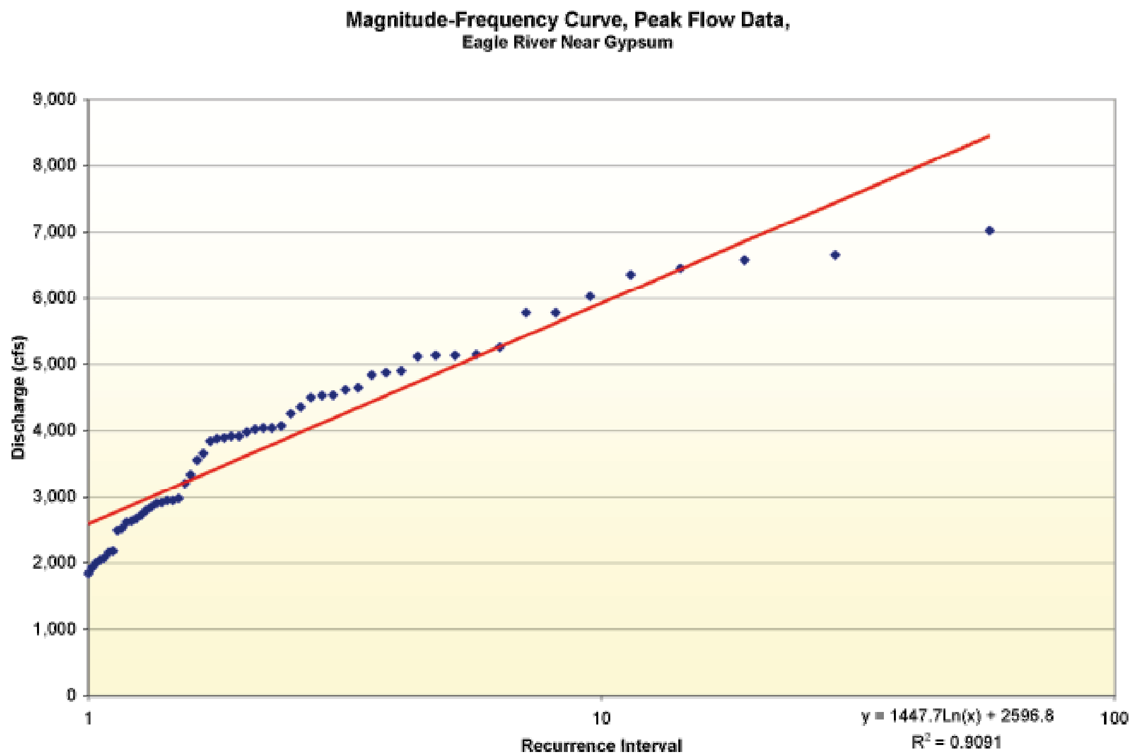


Figure 4: Magnitude-Frequency curve for water years 1946 to 2001; normally 100 years of record are desirable to determine recurrence intervals for larger events, but bankfull discharges can be reliably estimated with this period of record and the data spread.

Flow Duration

Flow duration, compiled from about 20,000 average daily observations, presents complementary information to the calculation of recurrence interval. It also demonstrates the character of the basin's current flow regime and where the locus of mean discharges occurs and can be useful in other ways. For example, as shown in Figure 5, lower flows are more predominant, which reinforces the field observation that transport and deposition of smaller particles is the norm. The presence of relatively large and imbricated particles on steeper riffles indicates the reach may be incompetent to move some of the material comprising its bed at the design discharge. General winnowing of smaller material creates a pavement comprised of coarse cobble sometimes referred to as an armor layer. These layers can be difficult to excavate through, but if extant, can be manipulated to improve vertical channel stability.

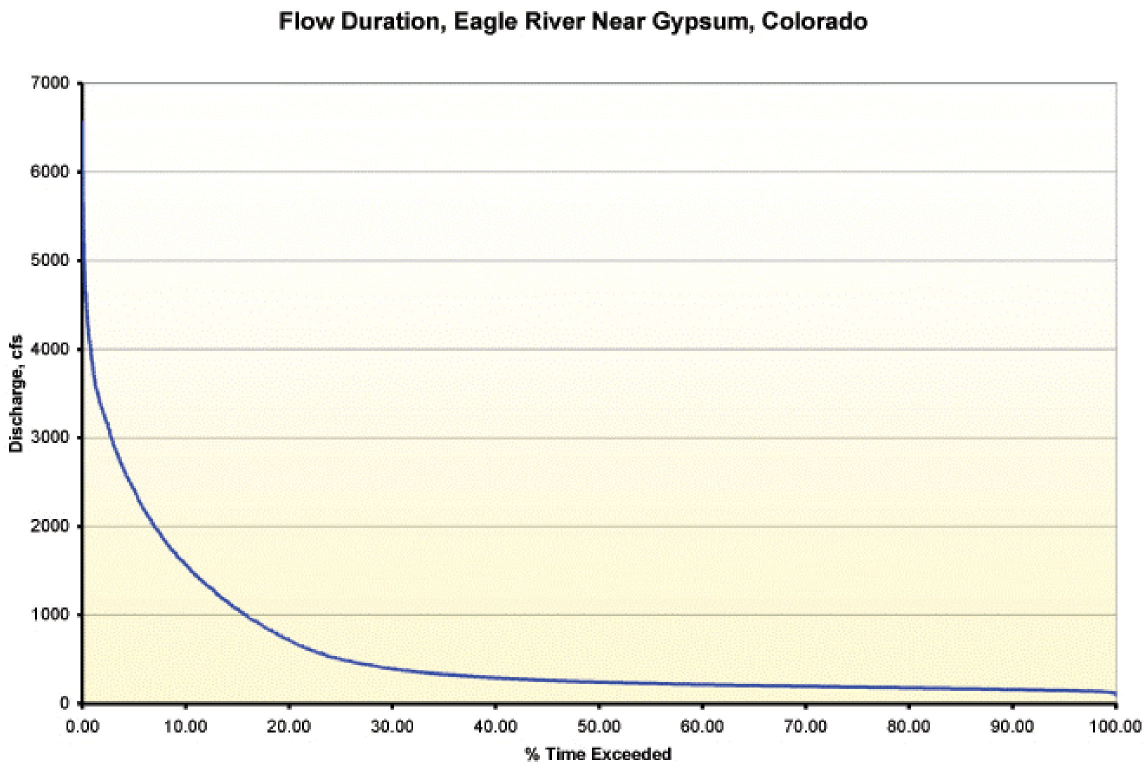


Figure 5: Flow duration curve for water years 1946 to 2001; note the predominance of flows below 500 cfs, the paucity of very low flows, the symmetric spread of discharges between 500 and 2,500 cfs, and the short-term timing of snowmelt peaks.

EXISTING AT-A-STATION HYDRAULICS

Change in flow geometry (width, depth, velocity and other parameters) with discharge at a given location is known as at-a-station hydraulic geometry. Modeling this geometry helps develop channel designs, and requires field surveying of profiles and sections. Partial surveys have been completed by David Graf of the Colorado Division of Wildlife, and this information has been compiled into an initial model, the results of which follow. In all, seven sections have been surveyed, and while they don't cover the entire length of the project reach, and slope data was incomplete at the time of this writing, they provide enough information to illustrate the suggested design direction. A map of the location of each section, and an indication of the amount of bank erosion in recent years is provided as Figure 6 and a recent aerial is provided as Figure 7.

A quick review of the cross-sections, beginning on page 8, shows pronounced thalweg and point bar development in corners and pool approaches, divided flow in areas that are beginning to anastomize and compete for main channel position and the relatively high width-depth ratio in disturbed sections.

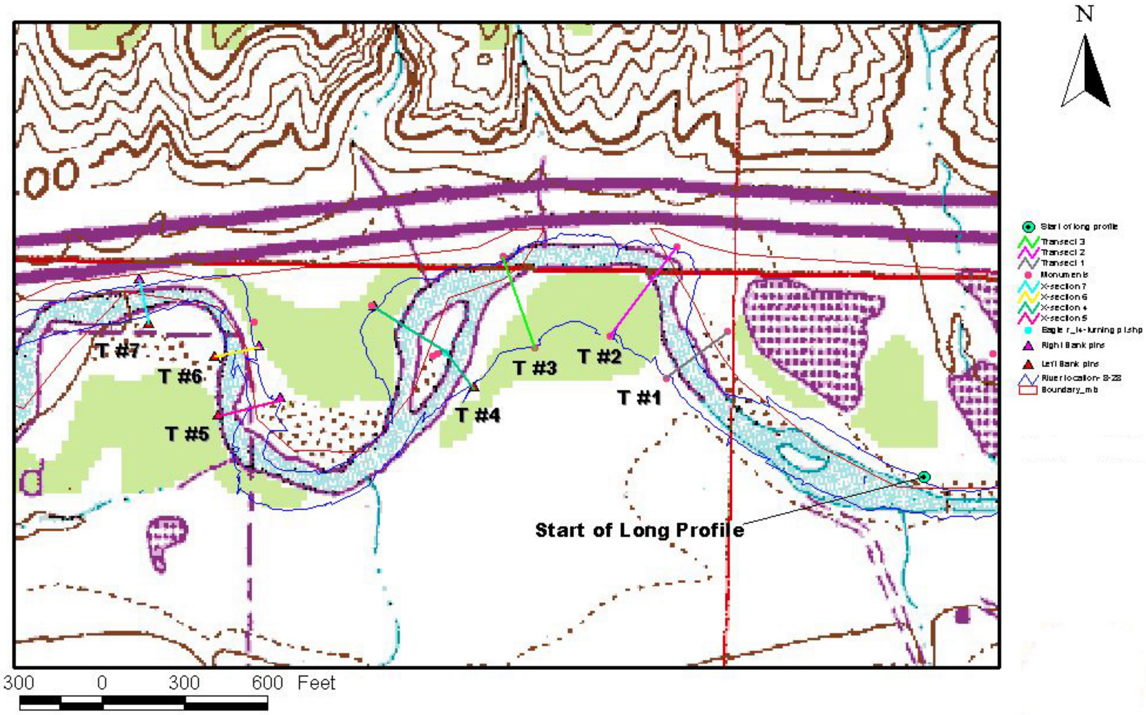


Figure 6: Reach map showing locations of sections 1-7 and start of longitudinal profile Note riprap work has been completed in areas between sections 2 and 3, and between sections 6 and 7. Also note thin blue lines showing meander extension since the time of USGS mapping.

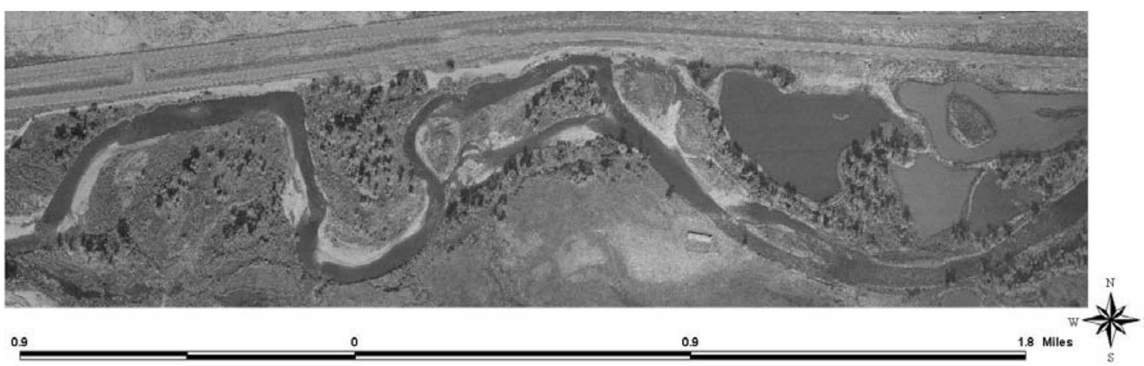


Figure 7: 1999 aerial photo of reach; flow is right to left. Note divided flow, potential capture of the main channel at the first meander, gravel slug in center of channel in the approach to the first meander, extension and tortuous comportment of meanders, nascent oxbow shape to third meander, and 90 degree approaches to riprapped banks.

APPENDIX A.3

Section 1, Existing Condition

Results		
Mannings Coeffic	0.085	
Elevation Range	.41 to 7.58	
Discharge	180.43	cfs
Flow Area	114.2	ft≤
Wetted Perimeter	98.52	ft
Top Width	98.38	ft
Actual Depth	1.93	ft
Critical Elevation	1.50	ft
Critical Slope	0.126952	ft/ft
Velocity	1.58	ft/s
Velocity Head	0.04	ft
Specific Energy	2.38	ft
Froude Number	0.26	
Flow Type	Subcritical	

Results		
Mannings Coeffic	0.045	
Elevation Range	.41 to 7.58	
Discharge	4,084.76	cfs
Flow Area	656.8	ft≤
Wetted Perimeter	188.18	ft
Top Width	186.12	ft
Actual Depth	5.73	ft
Critical Elevation	4.79	ft
Critical Slope	0.021073	ft/ft
Velocity	6.22	ft/s
Velocity Head	0.60	ft
Specific Energy	6.74	ft
Froude Number	0.58	
Flow Type	Subcritical	

Calculation Messages:
Flow is divided.
Water elevation exceeds lowest end station by 0.03 ft.

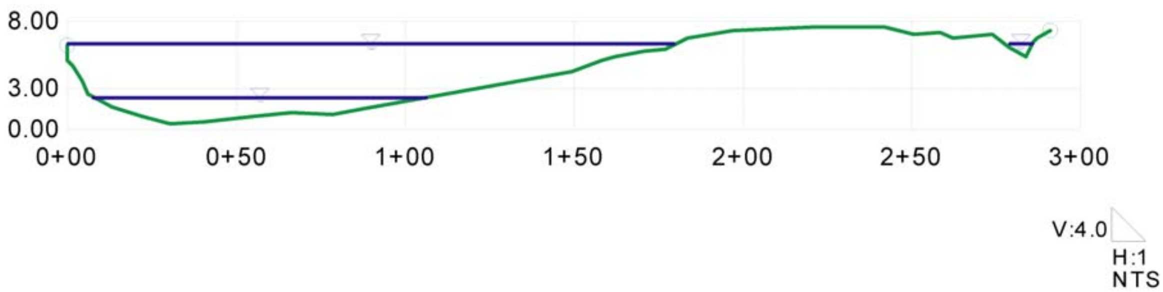


Figure 8: Section 1 at low and high flow, left descending bank on left. Low flow calibrated to survey date, high flow taken from high water marks. Note pronounced asymmetric profile relative to geographic position, indicating possible start of extension.

Section 2, Existing Condition

Results

Mannings Coeffic	0.075	
Elevation Range	.00 to 8.37	
Discharge	180.06	cfs
Flow Area	128.1	ft≤
Wetted Perimeter	158.65	ft
Top Width	157.91	ft
Actual Depth	2.11	ft
Critical Elevation	1.48	ft
Critical Slope	0.105831	ft/ft
Velocity	1.41	ft/s
Velocity Head	0.03	ft
Specific Energy	2.14	ft
Froude Number	0.28	
Flow Type	Subcritical	

Calculation Messages:
Flow is divided.

Results

Mannings Coeffic	0.045	
Elevation Range	.00 to 8.37	
Discharge	4,084.15	cfs
Flow Area	839.7	ft≤
Wetted Perimeter	347.86	ft
Top Width	342.95	ft
Actual Depth	5.35	ft
Critical Elevation	4.00	ft
Critical Slope	0.023186	ft/ft
Velocity	4.86	ft/s
Velocity Head	0.37	ft
Specific Energy	5.72	ft
Froude Number	0.55	
Flow Type	Subcritical	

Calculation Messages:
Flow is divided.

Figure 9: Section 2 at low and high flow, left descending bank on left. Low flow calibrated to survey date, high flow taken from high water marks. Note pronounced asymmetric profile of main channel, near vertical bank profile against riprapped right bank, broad side channel nearly at grade with the main channel and degree of high flow potentially carried by left channel.

Section 3, Existing Condition

Results

Mannings Coeffic	0.085	
Elevation Range	.00 to 8.36	
Discharge	180.18	cfs
Flow Area	117.6	ft≤
Wetted Perimetei	106.22	ft
Top Width	104.75	ft
Actual Depth	1.98	ft
Critical Elevation	1.00	ft
Critical Slope	0.123161	ft/ft
Velocity	1.53	ft/s
Velocity Head	0.04	ft
Specific Energy	2.02	ft
Froude Number	0.25	
Flow Type	Subcritical	

Calculation Messages:
Flow is divided.

Results

Mannings Coeffic	0.045	
Elevation Range	.00 to 8.36	
Discharge	4,088.13	cfs
Flow Area	837.1	ft≤
Wetted Perimetei	344.67	ft
Top Width	338.32	ft
Actual Depth	6.00	ft
Critical Elevation	4.40	ft
Critical Slope	0.022451	ft/ft
Velocity	4.88	ft/s
Velocity Head	0.37	ft
Specific Energy	6.37	ft
Froude Number	0.55	
Flow Type	Subcritical	

Calculation Messages:
Flow is divided.

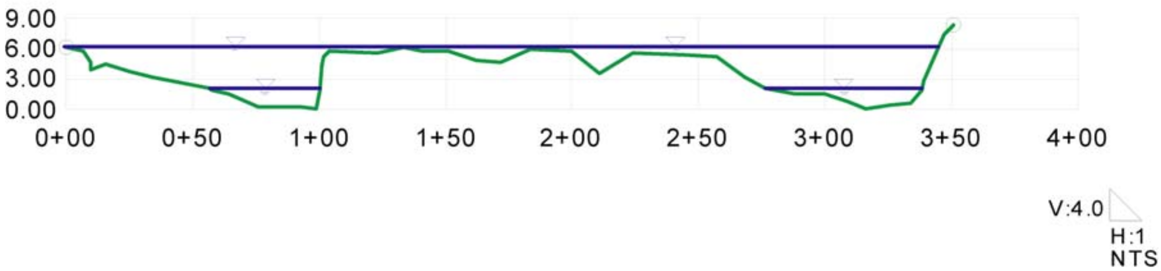


Figure 10: Section 3 at low and high flow, left descending bank on left. Low flow calibrated to survey date, high flow taken from high water marks. Note evenly divided reach asymmetric profile of main channel, near vertical bank profile against riprapped right bank, and side channel at grade with the main channel.

Section 4, Existing Condition

Results		
Mannings Coeffic	0.052	
Elevation Range	.58 to 7.76	
Discharge	181.32	cfs
Flow Area	97.8	ft≤
Wetted Perimetei	102.87	ft
Top Width	102.12	ft
Actual Depth	2.43	ft
Critical Elevation	2.13	ft
Critical Slope	0.043546	ft/ft
Velocity	1.85	ft/s
Velocity Head	0.05	ft
Specific Energy	3.06	ft
Froude Number	0.33	
Flow Type	Subcritical	

Calculation Messages:
Flow is divided.

Results		
Mannings Coeffic	0.048	
Elevation Range	.58 to 7.76	
Discharge	4,097.46	cfs
Flow Area	908.6	ft≤
Wetted Perimetei	382.64	ft
Top Width	374.98	ft
Actual Depth	5.92	ft
Critical Elevation	5.35	ft
Critical Slope	0.027934	ft/ft
Velocity	4.51	ft/s
Velocity Head	0.32	ft
Specific Energy	6.82	ft
Froude Number	0.51	
Flow Type	Subcritical	

Calculation Messages:
Water elevation exceeds lowest end station by 0.77 ft.
Flow is divided.

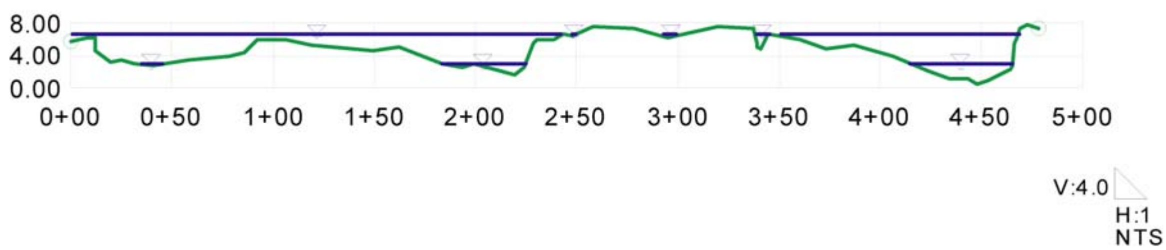


Figure 11: Section 4 at low and high flow, left descending bank on left. Low flow calibrated to survey date, high flow taken from high water marks. Note old point bar by station 3+50, now being dissected, divided reach, near vertical bank profile against right bank, and twin side channels.

Section 5, Existing Condition

Results		
Mannings Coeffic	0.049	
Elevation Range	.00 to 9.58	
Discharge	181.02	cfs
Flow Area	65.3	ft≤
Wetted Perimete	55.35	ft
Top Width	54.82	ft
Actual Depth	2.91	ft
Critical Elevation	2.17	ft
Critical Slope	0.034929	ft/ft
Velocity	2.77	ft/s
Velocity Head	0.12	ft
Specific Energy	3.03	ft
Froude Number	0.45	
Flow Type	Subcritical	

Results		
Mannings Coeffic	0.073	
Elevation Range	.00 to 9.58	
Discharge	4,070.05	cfs
Flow Area	906.9	ft≤
Wetted Perimete	205.13	ft
Top Width	200.78	ft
Actual Depth	8.90	ft
Critical Elevation	6.43	ft
Critical Slope	0.056606	ft/ft
Velocity	4.49	ft/s
Velocity Head	0.31	ft
Specific Energy	9.21	ft
Froude Number	0.37	
Flow Type	Subcritical	

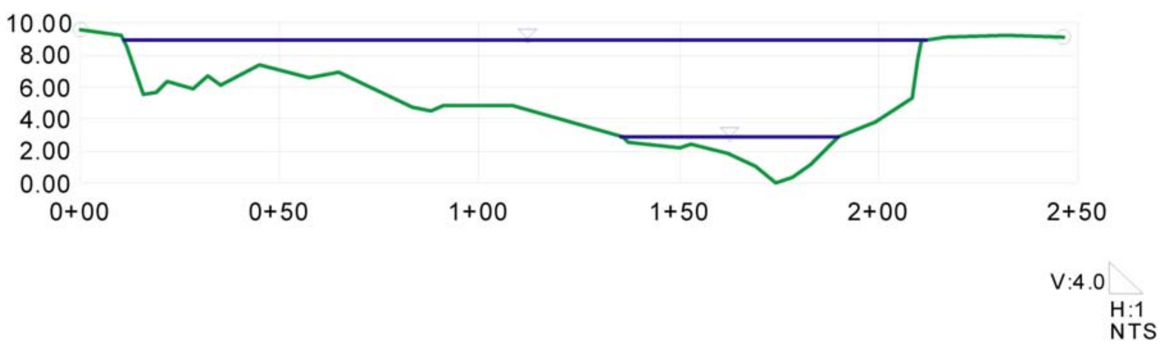


Figure 12: Section 5 at low and high flow, left descending bank on left. Low flow calibrated to survey date, high flow taken from high water marks. Section appears relatively stable except when compared with the condition of the channel at the time of USGS mapping. The thalweg has switched from the left to right bank, and the channel is actively eroding the right bank as part of a nascent oxbow comportment.

Section 6, Existing Condition

Results		
Mannings Coeffic	0.095	
Elevation Range	.00 to 9.40	
Discharge	181.25	cfs
Flow Area	113.2	ft≤
Wetted Perimetei	60.10	ft
Top Width	59.51	ft
Actual Depth	2.79	ft
Critical Elevation	1.26	ft
Critical Slope	0.141380	ft/ft
Velocity	1.60	ft/s
Velocity Head	0.04	ft
Specific Energy	2.83	ft
Froude Number	0.20	
Flow Type	Subcritical	

Results		
Mannings Coeffic	0.073	
Elevation Range	.00 to 9.58	
Discharge	4,070.05	cfs
Flow Area	906.9	ft≤
Wetted Perimetei	205.13	ft
Top Width	200.78	ft
Actual Depth	8.90	ft
Critical Elevation	6.43	ft
Critical Slope	0.056606	ft/ft
Velocity	4.49	ft/s
Velocity Head	0.31	ft
Specific Energy	9.21	ft
Froude Number	0.37	
Flow Type	Subcritical	

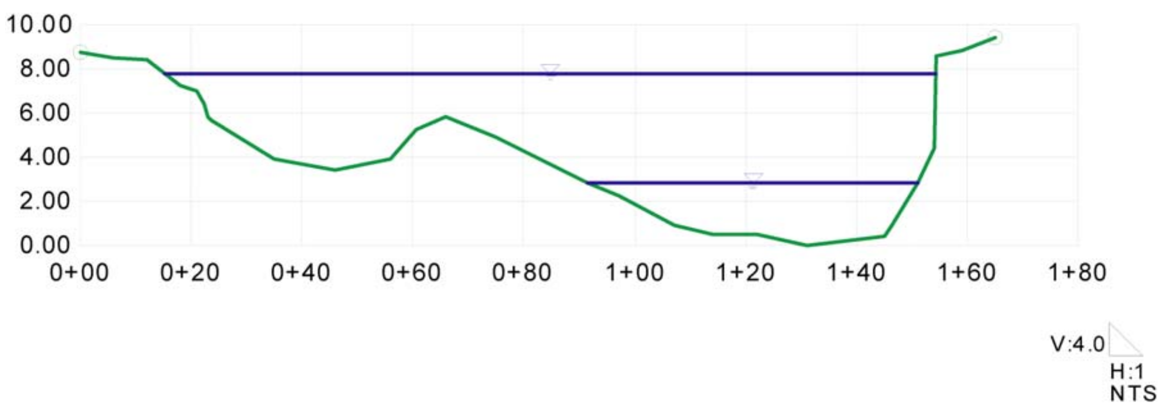


Figure 13: Section 6 at low and high flow, left descending bank on left. Low flow calibrated to survey date, high flow taken from high water marks. Section appears relatively stable except for the steep point bar platform and steep angle on right bank profile.

Section 7, Existing Condition

Results		
Mannings Coeffic	0.070	
Elevation Range	00 to 13.46	
Discharge	180.59	cfs
Flow Area	107.3	ft≤
Wetted Perimete	112.44	ft
Top Width	111.95	ft
Actual Depth	1.66	ft
Critical Elevation	1.10	ft
Critical Slope	0.091999	ft/ft
Velocity	1.68	ft/s
Velocity Head	0.04	ft
Specific Energy	1.70	ft
Froude Number	0.30	
Flow Type	Subcritical	

Results		
Mannings Coeffic	0.045	
Elevation Range	00 to 13.46	
Discharge	4,092.63	cfs
Flow Area	559.1	ft≤
Wetted Perimete	125.42	ft
Top Width	121.79	ft
Actual Depth	5.52	ft
Critical Elevation	4.16	ft
Critical Slope	0.020243	ft/ft
Velocity	7.32	ft/s
Velocity Head	0.83	ft
Specific Energy	6.35	ft
Froude Number	0.60	
Flow Type	Subcritical	

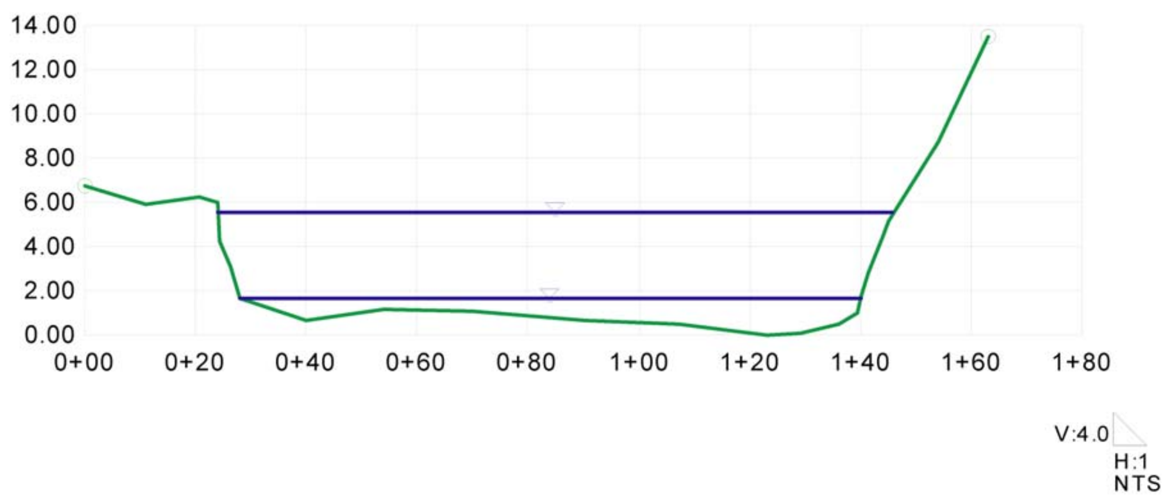


Figure 14: Section 7 at low and high flow, left descending bank on left. Low flow calibrated to survey date, high flow taken from high water marks. Section appears relatively stable.

APPENDIX A.3

MODIFIED AT-A-STATION HYDRAULICS

Given the flow regime and the existing section data, an iterative process can be used to modify channel geometry to provide different dimensions. In this case, the focus was to provide sufficient space for bank reinforcement, re-shape the channel for more efficient transfer of water and sediment, and for divided reaches, to re-establish a single threaded low-flow channel. Improved habitat for all life stages of trout was also considered, and focused on creating more pool volume and depth, longer runs and tail-outs, more asymmetric pool shapes, more riffle area and diversity and more high flow escape opportunity. It is also hoped that when the banks fully re-vegetate, that overhead cover will also be significantly increased. Minor re-alignment of the main channel is also under consideration, as shown in Figure 15.

Typically, several attempts are required, balancing wetted perimeter, velocity, flow area, and habitat potential at low flow, with carrying capacity at the design discharge. In many cases, the new sections are more efficient and can carry the design discharge with greater freeboard than existing sections. Once these goals have been met, a calculation of tractive forces associated with the selected geometry is undertaken, which is discussed in the next section. Cross-sections are adjusted to balance competence across the perimeter, e.g., to help pool areas scour and bar platforms to either transport or drop sediment. If available, the final design can also be compared to near-by geomorphic analogs.

The following proposed modifications to Sections 1 through 7 represent the first iteration and are associated with the suggested re-alignment shown below. While they may change somewhat as the process develops, they are indicative of the design direction.

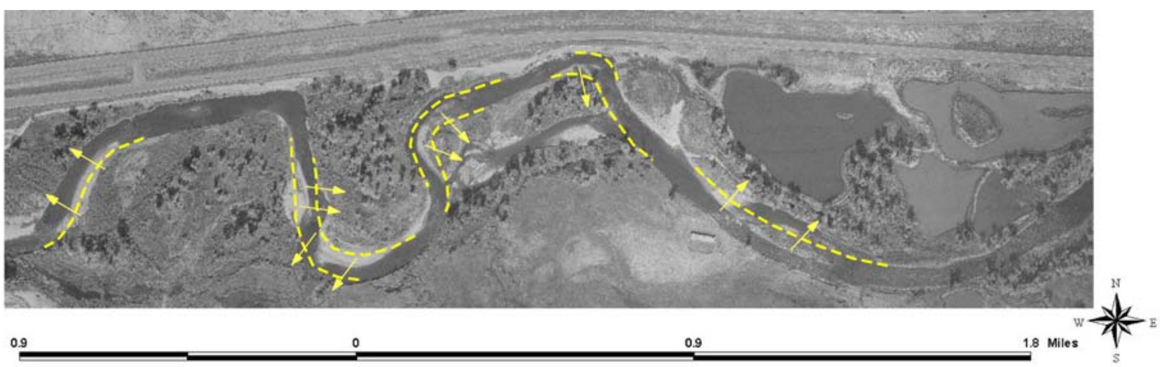


Figure 15: Aerial view of project reach with suggested pattern changes highlighted in dashed line and material management direction shown by arrows.

Section 1, Proposed

Results

Mannings Coeffic	0.045	
Elevation Range	.25 to 7.40	
Discharge	178.92	cfs
Flow Area	81.2	ft≤
Wetted Perimetei	110.35	ft
Top Width	110.31	ft
Actual Depth	1.23	ft
Critical Elevation	2.13	ft
Critical Slope	0.037700	ft/ft
Velocity	2.20	ft/s
Velocity Head	0.08	ft
Specific Energy	2.56	ft
Froude Number	0.45	
Flow Type	Subcritical	

Results

Mannings Coeffic	0.073	
Elevation Range	.00 to 9.58	
Discharge	4,070.05	cfs
Flow Area	906.9	ft≤
Wetted Perimetei	205.13	ft
Top Width	200.78	ft
Actual Depth	8.90	ft
Critical Elevation	6.43	ft
Critical Slope	0.056606	ft/ft
Velocity	4.49	ft/s
Velocity Head	0.31	ft
Specific Energy	9.21	ft
Froude Number	0.37	
Flow Type	Subcritical	

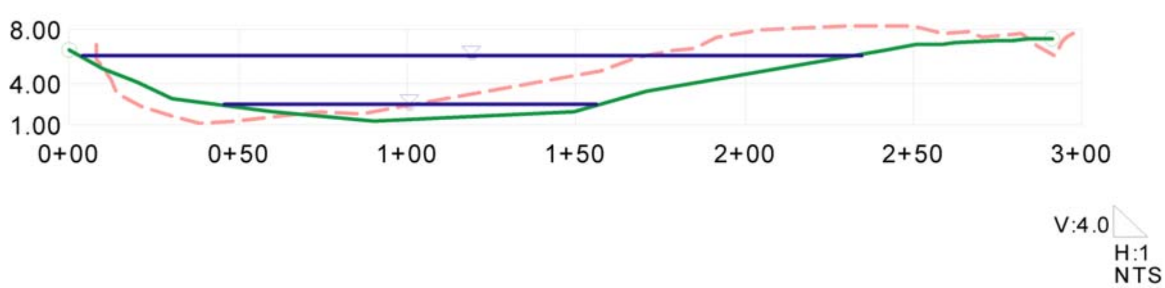


Figure 16: Section 1 at low and high flow, left descending bank on left. Suggested bank work on left bank, change in thalweg location and shape to relieve pressure on downstream meander approach. Existing section superimposed as dashed red line.

Section 2, Proposed

Results		
Mannings Coeffic	0.075	
Elevation Range	.00 to 8.37	
Discharge	179.57	cfs
Flow Area	111.8	ft≤
Wetted Perimetei	113.40	ft
Top Width	113.15	ft
Actual Depth	1.70	ft
Critical Elevation	1.01	ft
Critical Slope	0.101989	ft/ft
Velocity	1.61	ft/s
Velocity Head	0.04	ft
Specific Energy	1.74	ft
Froude Number	0.28	
Flow Type	Subcritical	

Results		
Mannings Coeffic	0.055	
Elevation Range	.00 to 8.37	
Discharge	4,078.12	cfs
Flow Area	1,001.3	ft≤
Wetted Perimetei	400.64	ft
Top Width	398.68	ft
Actual Depth	5.56	ft
Critical Elevation	4.14	ft
Critical Slope	0.035625	ft/ft
Velocity	4.07	ft/s
Velocity Head	0.26	ft
Specific Energy	5.82	ft
Froude Number	0.45	
Flow Type	Subcritical	

Calculation Messages:
Water elevation exceeds lowest end station by 1.01 ft.

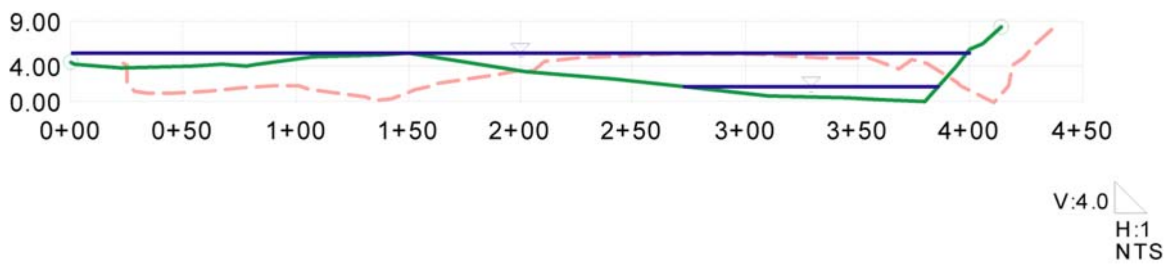


Figure 17: Section 2 at low and high flow, left descending bank on left. Suggested bank work on right bank, excavated pool/point bar, change in thalweg location, and re-shape to relieve pressure on right bank. Existing section superimposed as dashed red line.

Section 3, Proposed

Results		
Mannings Coeffic	0.065	
Elevation Range	.09 to 8.36	
Discharge	177.83	cfs
Flow Area	97.2	ft≤
Wetted Perimetei	100.49	ft
Top Width	100.30	ft
Actual Depth	1.91	ft
Critical Elevation	1.30	ft
Critical Slope	0.072236	ft/ft
Velocity	1.83	ft/s
Velocity Head	0.05	ft
Specific Energy	2.05	ft
Froude Number	0.33	
Flow Type	Subcritical	

Results		
Mannings Coeffic	0.055	
Elevation Range	.09 to 8.36	
Discharge	4,075.68	cfs
Flow Area	929.4	ft≤
Wetted Perimetei	332.79	ft
Top Width	331.39	ft
Actual Depth	5.65	ft
Critical Elevation	4.57	ft
Critical Slope	0.036834	ft/ft
Velocity	4.39	ft/s
Velocity Head	0.30	ft
Specific Energy	6.04	ft
Froude Number	0.46	
Flow Type	Subcritical	

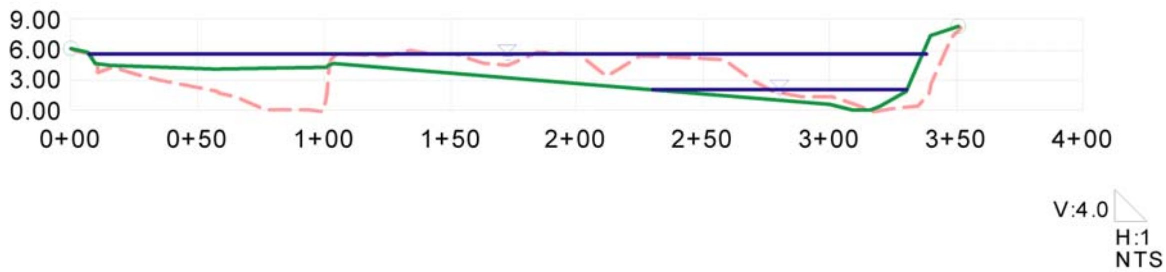


Figure 18: Section 3 at low and high flow, left descending bank on left. Suggested bank work on right bank, excavated pool/point bar, reshape bar slope and fill of left side channel to relieve pressure on right bank. Existing section superimposed as dashed red line.

Section 4, Proposed

Results		
Mannings Coeffic	0.055	
Elevation Range	.00 to 7.76	
Discharge	178.57	cfs
Flow Area	80.0	ft≤
Wetted Perimeteı	58.47	ft
Top Width	58.20	ft
Actual Depth	2.41	ft
Critical Elevation	1.49	ft
Critical Slope	0.046886	ft/ft
Velocity	2.23	ft/s
Velocity Head	0.08	ft
Specific Energy	2.49	ft
Froude Number	0.34	
Flow Type	Subcritical	

Results		
Mannings Coeffic	0.048	
Elevation Range	.00 to 7.76	
Discharge	4,080.55	cfs
Flow Area	972.1	ft≤
Wetted Perimeteı	455.86	ft
Top Width	454.39	ft
Actual Depth	6.37	ft
Critical Elevation	5.21	ft
Critical Slope	0.028244	ft/ft
Velocity	4.20	ft/s
Velocity Head	0.27	ft
Specific Energy	6.64	ft
Froude Number	0.51	
Flow Type	Subcritical	

Calculation Messages:
Water elevation exceeds lowest end station by 0.64 ft.

Figure 19: Section 4 at low and high flow, left descending bank on left. Suggested bank work on right bank, excavated pool/point bar, and fill of left side channel to relieve pressure on right bank. Existing section superimposed as dashed red line.

Section 5, Proposed

Results

Mannings Coeffic	0.049	
Elevation Range	.75 to 9.58	
Discharge	178.63	cfs
Flow Area	64.2	ft≤
Wetted Perimetei	54.16	ft
Top Width	53.83	ft
Actual Depth	2.39	ft
Critical Elevation	2.48	ft
Critical Slope	0.036873	ft/ft
Velocity	2.78	ft/s
Velocity Head	0.12	ft
Specific Energy	3.26	ft
Froude Number	0.45	
Flow Type	Subcritical	

Results

Mannings Coeffic	0.049	
Elevation Range	.75 to 9.58	
Discharge	4,088.58	cfs
Flow Area	703.8	ft≤
Wetted Perimetei	196.59	ft
Top Width	194.26	ft
Actual Depth	7.19	ft
Critical Elevation	6.67	ft
Critical Slope	0.026240	ft/ft
Velocity	5.81	ft/s
Velocity Head	0.52	ft
Specific Energy	8.46	ft
Froude Number	0.54	
Flow Type	Subcritical	

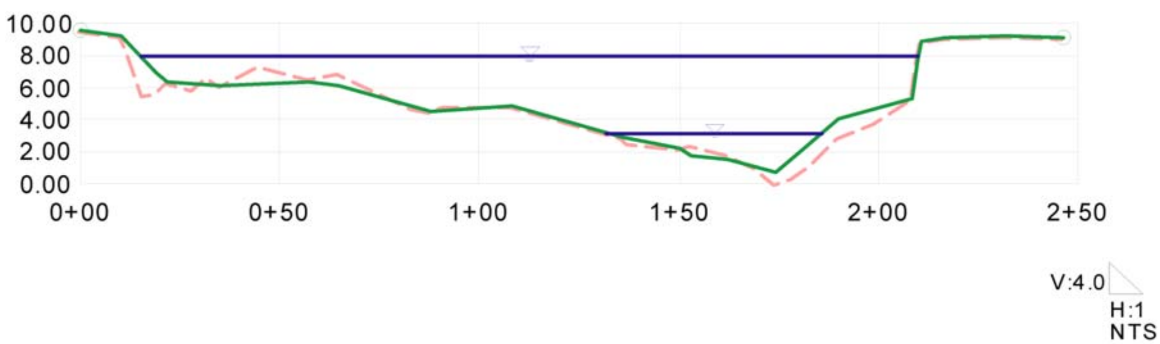


Figure 20: Section 5 at low and high flow, left descending bank on left. Suggested bank work on right bank, and re-shaped point bar to relieve pressure on right bank. Existing section superimposed as dashed red line.

Section 6, Proposed

Results		
Mannings Coeffic	0.068	
Elevation Range	.00 to 9.40	
Discharge	177.71	cfs
Flow Area	108.5	ft≤
Wetted Perimete	59.13	ft
Top Width	58.56	ft
Actual Depth	2.71	ft
Critical Elevation	1.25	ft
Critical Slope	0.072706	ft/ft
Velocity	1.64	ft/s
Velocity Head	0.04	ft
Specific Energy	2.75	ft
Froude Number	0.21	
Flow Type	Subcritical	

Results		
Mannings Coeffic	0.049	
Elevation Range	.00 to 9.40	
Discharge	4,068.75	cfs
Flow Area	612.3	ft≤
Wetted Perimete	139.77	ft
Top Width	135.87	ft
Actual Depth	7.15	ft
Critical Elevation	5.56	ft
Critical Slope	0.024390	ft/ft
Velocity	6.65	ft/s
Velocity Head	0.69	ft
Specific Energy	7.84	ft
Froude Number	0.55	
Flow Type	Subcritical	

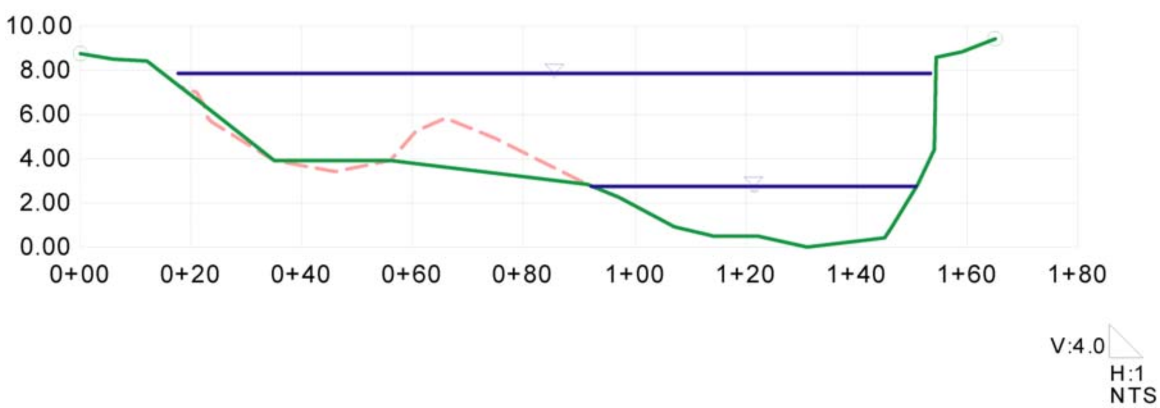


Figure 21: Section 6 at low and high flow, left descending bank on left. Re-shaped point bar to relieve pressure on right bank. Existing section superimposed as dashed red line.

Section 7, Proposed

Results		
Mannings Coeffic	0.070	
Elevation Range	!.00 to 13.46	
Discharge	178.78	cfs
Flow Area	121.3	ft≤
Wetted Perimete	74.11	ft
Top Width	73.43	ft
Actual Depth	3.48	ft
Critical Elevation	-0.25	ft
Critical Slope	0.072162	ft/ft
Velocity	1.47	ft/s
Velocity Head	0.03	ft
Specific Energy	1.51	ft
Froude Number	0.20	
Flow Type	Subcritical	

Results		
Mannings Coeffic	0.045	
Elevation Range	!.00 to 13.46	
Discharge	4,072.35	cfs
Flow Area	558.3	ft≤
Wetted Perimete	125.92	ft
Top Width	123.54	ft
Actual Depth	7.90	ft
Critical Elevation	4.42	ft
Critical Slope	0.019861	ft/ft
Velocity	7.29	ft/s
Velocity Head	0.83	ft
Specific Energy	6.73	ft
Froude Number	0.60	
Flow Type	Subcritical	

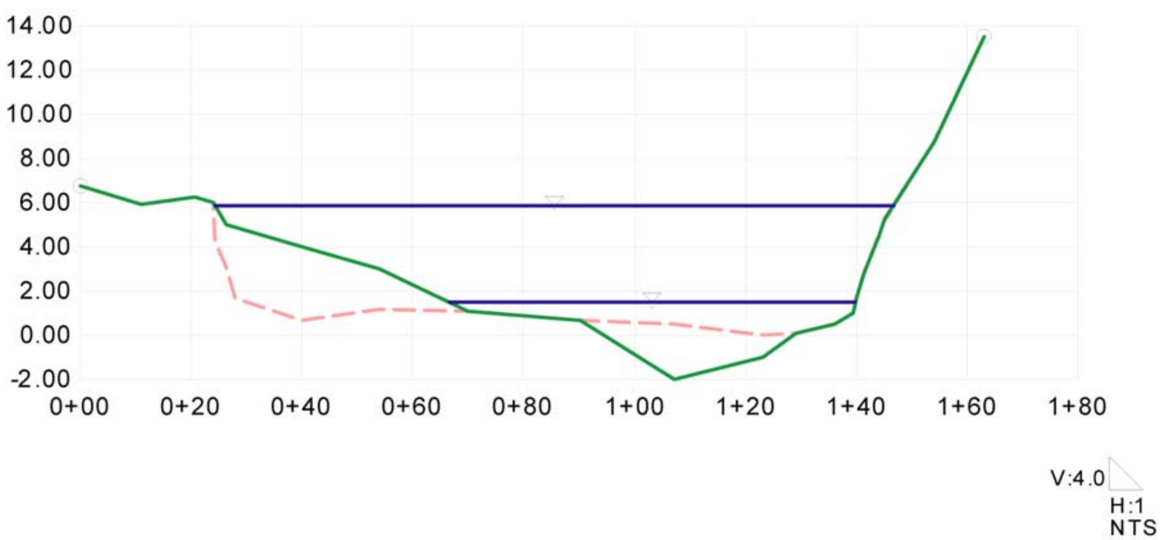


Figure 22: Section 7 at low and high flow, left descending bank on left. Excavated thalweg and filled point bar. Existing section superimposed as dashed red line.

APPENDIX A.3

TRACTIVE FORCE ASSESSMENT

Once new sections have been designed, the next step is to assess their general stability in terms of transportation competence and erosion resistance. Several techniques are available for this work, most of which stem from regime theory, where sections are designed to balance scour and fill. The idea is to adjust the shape of the section to vary the shear stress experienced at channel forming flows, and relies on determining the particle size distributions of bed sediment. Unfortunately, there was not enough time to collect even limited information from the reach, so this step will remain uncompleted until after runoff. However, the procedure can be summarized as follows.

The first step is to construct a shear stress duration curve utilizing increments of flow duration and a simple relation for shear stress. This information is then combined with particle size analyses of both surface and sub-surface material to estimate the initiation of motion, and to plot the duration of transport for target sizes of bed material. The second step is to calculate a dimensionless shear stress for locations along the section. This calculation follows a modified Shields function, and the section is adjusted iteratively to provide the best balance between the opposing tendencies of scour and fill. For a pool section, the idea would be to provide enough shear stress to move material out of the thalweg, but gradually reduce shear over the point bar surface to encourage transport balance or slight deposition toward the bank edge. An example of the results of such an analysis for a similarly sized river is provided as Figure 23.

BANK STABILIZATION AND RE-VEGETATION

The proposed work also includes bank reinforcement efforts because most of the land loss, sediment contribution and poor habitat value in this section of the Eagle is associated with excessive bank erosion. In this respect, it is desirable to make the toe of slope erosion resistant, and to return a semblance of native riparian vegetation on the upper slope components. Two primary schemes are envisioned for revetment: 1) riprap, with a native cobble overlay and complemented by vanes where required, and 2) soil encapsulated lifts constructed of bio-degradable fabrics, with native gravel toe wraps or riprapped toes, and brush layering between lifts.

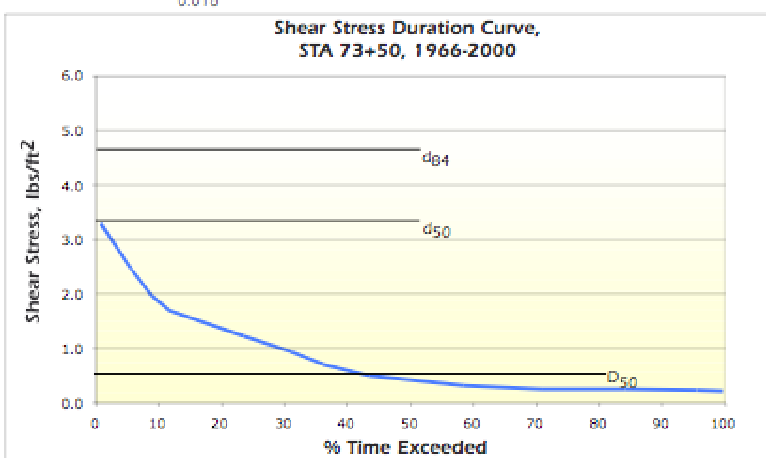
If sufficient angular rock between 2 and 4 ft in median diameter is available, and can be transported to the site economically, the more critical stream banks will be treated in the following manner. For sections where the radius is to be modified, a new toe slope will be established forward of the existing bank. Native cobble excavated from the channel or channel margin will be placed behind this rock line in sequential lifts, with the riprap grading finer upward. If available, willow cuttings will be placed between rocks and lifts, particularly at the anticipated mean low water elevation. Finally, native cobble will be placed over the riprap to provide a substrate for vegetation colonization and improved appearance.

Low-Flow Existing	
Wtd. Mannings Coefficient	0.140
Slope	0.0088 ft/ft
Water Surface Elevation	97.92 ft
A_c	94.4 ft2
W_p	99.9 ft
Top Width	99.6 ft
Mean V	0.96 fps
Froude Number	.17
d_{50}	17 cm
d_{84}	24 cm
D_{50}	3 cm

Low-Flow Proposed	
Wtd. Mannings Coefficient	0.055
Slope	0.0013 ft/ft
Water Surface Elevation	99.2 ft
A_c	40.1 ft2
W_p	47.9 ft
Top Width	47.7 ft
Mean V	0.9 fps
Froude Number	0.17
d_{50}	17 cm
d_{84}	24 cm
D_{50}	3 cm

High-Flow (4,270 cfs) Existing	
Wtd. Mannings Coefficient	0.033
Slope	0.0088 ft/ft
Water Surface Elevation	100.90 ft
A_c	494.0 ft2
W_p	166.8 ft
Top Width	165.0 ft
Mean V	8.7 fps
Froude Number	0.88
Critical t_{d84}	4.7 lbs/ft2
t^*_{d50} Mid-Bar	0.034
t^*_{d50} Thalweg	0.046
t^*_{d84} Mid-Bar	0.024
t^*_{d84} Thalweg	0.030
t^*_c	0.018

High-Flow (4,270 cfs) Proposed	
Wtd. Mannings Coefficient	0.038
Slope	0.0088 ft/ft
Water Surface Elevation	101.50 ft
A_c	535.2 ft2
W_p	167.3 ft
Top Width	165.0 ft
Mean V	7.9 fps
Froude Number	0.77
Critical t_{d84}	4.7 lbs/ft2
t^* Mid-Bar	0.034
t^* Thalweg	0.046
t^*_{d84} Mid-Bar	0.024
t^*_{d84} Thalweg	0.030
t^*_c	0.018



$$t = \frac{RS}{(g_s / g_w) d_n} \qquad t^*_c = 0.0834 \left(\frac{d_{50}}{\hat{D}_{50}}\right)^{-0.872}$$

R = hydraulic radius (taken as depth) in m
d_n = percentile fraction of bed surface material in m
D = percentile fraction of subsurface material in m

AquaTerra Services, LLC

STA 73+50 - Typical Run Channel Design

Date: 2/15/02 Sheet 12 of 17

Figure 23: Results from a shear stress assessment on a similarly sized river. In this case, a strong armor layer is present, sealing off the easily moved sub-surface material.

Vanes will also be constructed at appropriate intervals where the flow net is concentrated at radius bends. These vanes will be low-profile structures comprised of angular rock and will be placed orthogonal to the flow. The purpose of the structures is to keep high velocities and turbulence away from the toe of the slope, and the thalweg oriented more toward the center of the channel. They also provide cover and holding water for trout and can be vegetated if sufficient material exists at the time of construction. A typical design sheet for riprap and vanes is presented as Figure 24.

The second approach for revetment involves the construction of encapsulated lifts utilizing a high tensile, bio-degradable coir fabric. The process for installing the lifts begins with preparation of the stream bank. First, the bank profile is excavated to create a platform a few feet below mean low water. The toe of the slope below the platform is protected with small riprap or native bed material, preferably screened for the largest sizes. This layer helps prevent under cutting prior to vegetation establishment. If riprap is not available, the first few lifts will be constructed with native river cobble, each with a 2:1 front slope and approximately 2 feet thick. Each of these lifts is keyed back into the stream bank. After the platform is established, the first layer of fabric is installed. Native cobble, gravel and soil will be mixed and placed in the lift, consisting of roughly 50% cobble, 40% gravel and 10% soil, with the soil promoting vegetative growth. Once the lift fill material is placed, the fabric is pulled over the top and secured in a key trench along the backside of the lift. Subsequent lifts will be placed above the base with lower percentages of native cobble and gravel, incorporating more of the soils excavated off the original bank slope. The height of the constructed lifts is determined by the anticipated water elevation at the design discharge and secondarily, to cost constraints.

Containerized willows will be placed between each lift and lift faces seeded with native riparian grasses. The upper most lift is typically covered with soil and the entire constructed bank irrigated throughout the growing season with either a gravity feed drip system or gas pump powered lines and heads. After a few years, the coir fabric will decompose, the vegetation will become established and the stream bank will appear and function as a natural bank with some degree of lateral migration expected. A photographic overview of the process is provided as Figure 25.

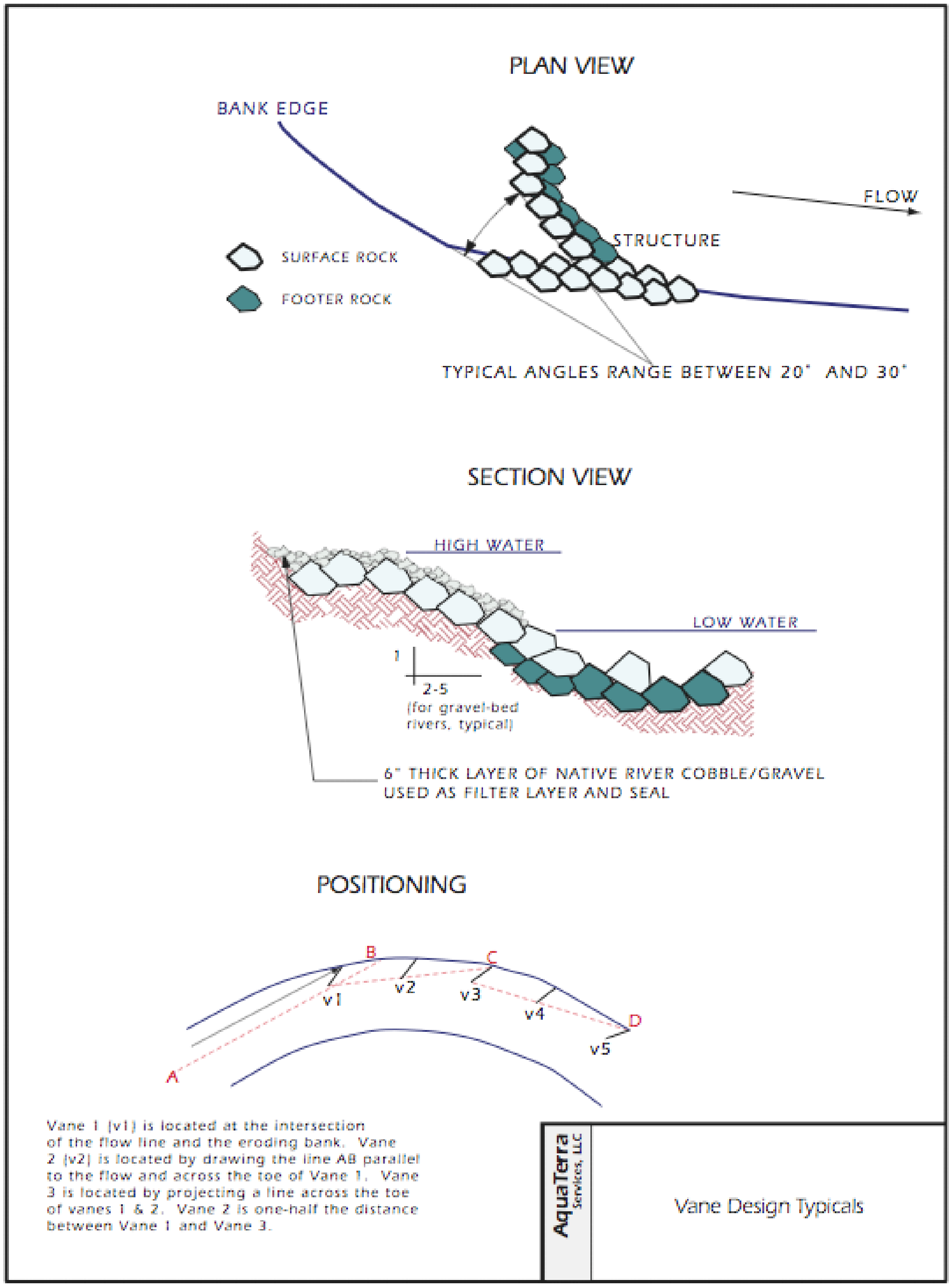


Figure 24: Vane and riprap plan and section along with positioning guideline.

APPENDIX A.3

Figure 25: Typical fabric lift installation. Top left shows original bank; top right shows first lift being placed over the gravel platform. Bottom picture shows soil placement over the last lift, prior to seeding.

APPENDIX A.3

COST ESTIMATE

Costs associated with implementation of this design overview are difficult to determine with certainty due to the nature of the materials involved and the variable nature of the work in general. For example, prices for bio-degradable fabrics, along with plant materials, change with weather in their home regions and with demand in their primary markets. In addition, boulders suitable for this type of work are scarce and have become a real commodity in the valleys of western Colorado. Even sub-standard boulders have found markets in residential and commercial construction and have seen a dramatic increase in price over the last few years. Finally, heavy construction in fluvial environments is notoriously unpredictable, e.g., unexpected pockets of sand, cemented armor layers, clay lenses, old organic accretions, and spatially variable particle size distributions, often force real-time design shifts and changes in construction techniques. That said, this type of construction does tend to fall within a known range for rivers of given size and composition. In this respect, two estimates are provided below; the first for completion of the full scope of work, and the second for a reduced scope of work.

Option 1

The first option includes costs for final design, permitting, acquisition of materials, river manipulation, completion of riprap, bank vanes and full bank reconstruction where required, placement of willows and other plants, seeding, installation of irrigation lines, labor and miscellaneous expenses. This option comprises about 10,500 lineal feet of channel manipulation, 7,650 lineal feet of bank reconstruction utilizing encapsulated lifts, and will involve the use of large tracked excavators, large wheeled loaders, a medium sized dozer, and limited use of several 6-wheel rock trucks. The project is anticipated to require as much as 53 working days, and to have a total estimated cost of $1,070,850. In this Option, the bank work comprises nearly 60% of the total cost, river work 30% and full-time construction supervision 10%.

Option 2

The second option is similar in nature but reduces the treated reach lengths to include only the most critical sections. This option comprises about 8,500 lineal feet of channel manipulation, 5,400 lineal feet of bank reconstruction, and will utilize the same complement of equipment. The project is anticipated to require as much as 42 working days, and to have a total estimated cost of $676,500. In this Option, the bank work comprises 55% of the total cost, river work 37% and full-time construction supervision 8%.

Option 3

The third option maintains the reach lengths in Option 2, but. changes the bank stabilization technique, and involves less intensive channel work. In place of encapsulated lifts, bank profiles will be reshaped and reconstituted utilizing native cobble, gravel and soils, and in some locations, protected from scour by construction of vanes or placement of riprap with cobble overlays. Estimated working time is reduced to about 30 days, and the cost reduced to $475,000. In this Option, the bank work comprises 52% of the total cost, river work 40% and full-time supervision 8%.

APPENDIX A.3

SUMMARY

This document has presented a rudimentary design for the Gypsum Ponds portion of the Eagle River. The design is based on cursory observation of the reach and on quantitative survey data provided by the CDOW. Following runoff in 2004, it is anticipated that more information will be collected by the CDOW and that particle size data can be collected as well, both of which will be utilized to improve on the design. Given the low snowpack and barring any rain on snow events, a discharge of about 2,200 cfs is expected in this reach, as compared to a flow of about 5,140 cfs in 2003. As such, no drastic change in comportment is expected and the design framework established herein should remain valid.

The design will build on the 5 step approach outlined above, and will include reviews of general hydrology; existing and anticipated cross-sectional hydraulic geometry; relations between channel shape, tractive force and desired habitat elements; and finally, derivation of bank stabilization techniques that complement the character of the stream banks and the available budget. In closing, it should be noted that the ultimate design will not be intended as a construction specification, as field conditions commonly require wide latitude in adjustments. This approach results our experience in this work, where it has been demonstrated that it is better to work with the variability of sedimentary conditions characteristic of fluvial environments, rather than against unexpected conditions. Consequently, project goals may shift, and as-built sections and construction techniques may vary from the design. This variation should be taken as normal and expected.

APPENDIX A.3

ADDENDUM I

Figure 26: View looking south at Sections 6 and 5 on May 11, 2004. Discharge is approximately 1,600 cfs. Note riprap completed in April of 2004 in foreground.

Figure 27: View looking west at Section 7 on May 11, 2004. Discharge is approximately 1,600 cfs. Note riprap completed in April of 2004 in foreground.

Figure 28: View looking southwest from Section 3 toward Section 4 on May 11, 2004. Discharge is approximately 1,600 cfs. Note old cabled log vanes in foreground.

Figure 29: View looking west at Section 2 on May 11, 2004. Discharge is approximately 1,600 cfs. Old log vanes just out of site in foreground and barely visible in background.

Figure 30: View looking south at Section 1 on May 11, 2004. Discharge is approximately 1,600 cfs. Note side channel on left bank toward background.

APPENDIX A.4

Non-native Invasive Plant (noxious weeds) Mitigation Projects within the Eagle River Watershed

Dense stand of tamarisk near the confluence of the Colorado and Eagle Rivers

Prepared: November 2003
Author: Stephen Elzinga, Weed & Pest Coordinator
Eagle County Weed & Pest Department

APPENDIX A.4

Invasive non-native plants, "noxious weeds," are recognized as a danger to Colorado's agriculture and natural heritage. These plants interfere with human land management activities and the natural processes that have fashioned our environment. Forty-seven species of plants designated "noxious' by the Colorado Department of Agriculture have been confirmed to reside within the Eagle River Watershed. Eagle County Government's Weed & Pest Department's main working objective is to mitigate the undesirable impacts of these plants.

Integrated Weed Management

Integrated weed management is a systematic approach of planning and implementing a coordinated program utilizing a variety of methods for managing noxious weeds, the purpose of which is to achieve specified management objectives and promote desirable plant communities. Such methods may include but are not limited to education, preventive measures, good stewardship and using the following control techniques when appropriate: Cultural, Mechanical, Chemical and Biological (35-5.5-103. Definitions Colorado Noxious Weed Act).

Education Program

Education and the subsequent heightened awareness is the foundation of an effective noxious weed mitigation effort. Landowners and property managers cannot tackle a problem with which they are unacquainted. Attitudes toward invasive plants range from apathetic to uncompromising depending upon the level of weed awareness the individual posseses.

> **Project opportunity:** Develop educational materials for the Eagle River Watershed and a targeted education program for the private landowner, public land manager, local governments and general land user. The program should be composed of weed identification, prevention and integrated weed management principles.
>
> **Resources needed:** Funding, volunteer and professional time and talents, an environmental organization to act in leadership role.

Inventory/mapping

Inventory information collected should include infestation location and acreage, growth requirements and spread patterns and rates. This data can then be used for developing weed management goals and objectives, establishing a historical database and will later determine the efficacy of the weed management program.

> **Project opportunity:** All lands within the Eagle River Watershed should be inventoried. Presently, due primarily to limited manpower and private land access issues, it is estimated that 80-90% of the land has not been inventoried. The development of a GIS layer has been a weed & pest department effort
>
> **Resources needed:** Volunteers skilled in plant identification and GPS operation, GPS units (Eagle County Weed & Pest would assist with all phases of the inventory data collection, download, correction and the inclusion into the GIS layer).

Weed Control

Control is any activity that reduces weed infestation size and density. Within the Eagle River Watershed there exist multiple infestations of various noxious weed species. Projects should be considered on a priority basis. Priorities generally are highest for natural landscapes with high habitat values or intact native plant communities. Areas that have been significantly altered through drainage, agriculture and other human-generated processes generally rate a lower priority. Weed species can be prioritized several ways. Plants that are very common or nearly naturalized hold a lower priority to new invaders. Plants that are most difficult to control should be attacked aggressively when infestations are small. When these same plants naturalize within a landscape, funds are generally better spent elsewhere in fights that can be won.

The following information was taken from The Colorado Natural Areas Program publication "Creating an Integrated Weed Management Plan – A Handbook for Owners and Managers of Lands with Natural Values."

Attack your Weeds like Wildfire

If you want to concentrate your efforts where they will be the most effective, consider the central principle of weed management:

> ***Small infestations can be eradicated, large infestations can only be controlled.*** *Our usual approach is to attack large areas of weeds first. Most of our resources go to this cause while we ignore small isolated patches. The small patches are not causing any harm now, so we feel they can be ignored temporarily. Before we know it, the small patches have spread, and we are left with more, large weed problems. To be effective, we must reverse our priorities and eradicate all small occurrences as quickly as possible.*

Steven Dewey of the Utah State Extension Service (and others) often compares weed management to fighting wildfires. Notice the similarities as you attack your weed problems by following the four steps below.

Fire:	Weeds:
1. Build a fireline	
One of the first actions taken when fighting a wildfire is to build a fire line to contain the outbreak within certain boundaries.	Rather than a line on the ground, draw a line on a map delineating the extent of large weed infestations. Commit to containing the infestation within this boundary.
2. Eliminate spotfires	
Any fire that jumps the fireline has top priority and is eliminated as quickly as possible before it has a chance to spread. If allowed to spread, the results can be disastrous: fire fighters may be caught between two outbreaks, two large fires will have to be fought rather than one, and many more resources will be needed.	When weeds escape from the boundary you have drawn, they should become top priority. Think of small backcountry infestations as spot fires. If they are located early and attacked aggressively they can be eradicated before they spread; if ignored they will likely become so large they may never be eliminated entirely.
3. Protect critical areas	
Critical areas include places where people and structures are located.	Critical areas include pristine natural sites, critical wildlife habitat, productive rangelands, and rare plant and animal habitat.
4. Control main outbreak	
Often an expensive investment in resources is required. Even with massive control efforts, large fires often are not stopped until weather changes and rain and snow stops the fire.	Large infestations require long-term control efforts. Even with years of effort, these occurrences may never be completely eliminated. Unfortunately their seed banks may be huge, and their natural controls are rarely available. They may require some level of control forever.

Project opportunities: There are many opportunities to implement weed control within the Eagle River Watershed. Following are some possible projects:

APPENDIX A.4

1) **BLM tamarisk patches** (north of I-70). There are two infestations north of the Interstate 70 right-of-way that are about an acre each in size. Some native vegetation is present so these projects would consist of cut stump or basal bark applications of herbicide. Slash could be left on-site (depending on BLM staff recommendations). Some funding would be needed (>$500), volunteer assistance would be appreciated and would provide an awareness/education component to this project.

2) **Lonnie Ward's Tamarisk Infestation** (west of Gypsum). The largest single infestation of tamarisk within the Eagle River watershed is located on this parcel. The landowner has expressed interest in removing the tamarisk but is looking for funding assistance. The project size is less than three acres. Cut stump herbicide treatment would be the recommended course of action. Slash should be chipped (and hopefully stored on site). Equipment needed would be chainsaws, brushcutters, a chipper. Herbicide applications could be performed by or under supervision of a Colorado licensed pesticide applicator. Volunteer labor (depending on liability) or contracted labor would be needed.

3) **Gypsums Ponds CDOW.** The Gypsum Ponds State Wildlife Area has several weed species of concern. The site was inventoried for noxious weeds during the summer of 2003 and funds could assist CDOW staff in implementing a more aggressive weed control program. Contact: Ron St Pierre 970/947-2926

The following noxious weed species have had a detrimental effect on riparian habitat in other areas of the west: Tamarisk, Russian olive and Purple loosestrife. Within Eagle County these three species of plants are present in levels that could merit an eradication strategy. A convincing education program will be needed to change attitudes as all three are thought of as ornamental plants. These plants are commonly found in yards and flower beds from Vail to Dotsero. To my knowledge none have been designated "noxious" and therefore there is no tool to legally require removal.

Legal Jurisdiction The Colorado Weed Management Act tasks the "local governing authority" to design and implement a weed management plan. Within the Eagle River Watershed Eagle County Government has a weed management plan in place for all unincorporated lands. The following municipalities are responsible for overseeing an integrated weed management plan for all lands within their boundaries: Avon, Eagle, Gypsum, Minturn, Red Cliff and Vail.

APPENDIX B

Land Use Analysis Results

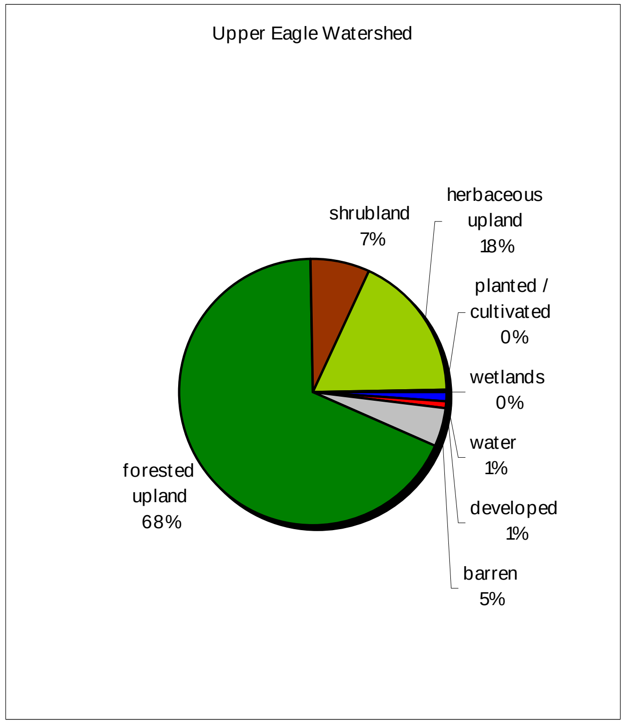


Figure B.1: Upper Eagle River watershed land use based on 1992 National Land Cover Data (Vogelmann *et al.*, 2001).

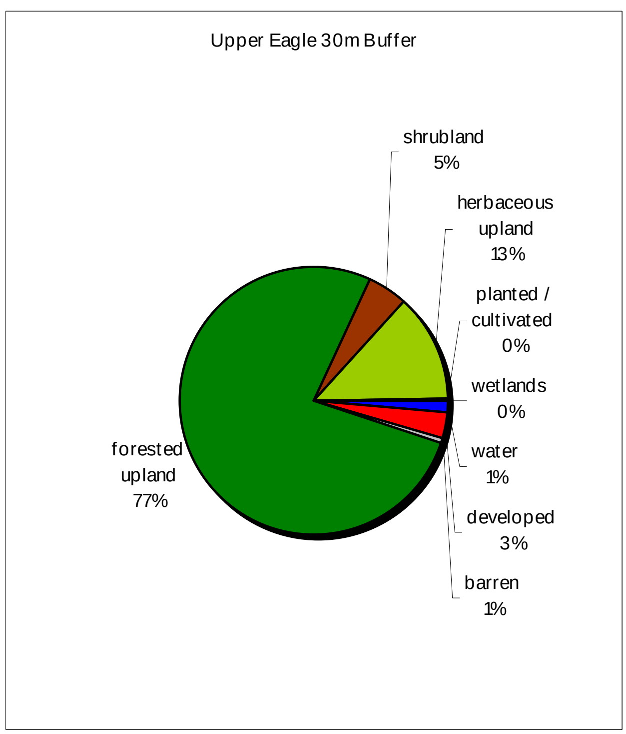


Figure B.2: Upper Eagle River 30-m buffer land use based on 1992 National Land Cover Data (Vogelmann *et al.*, 2001).

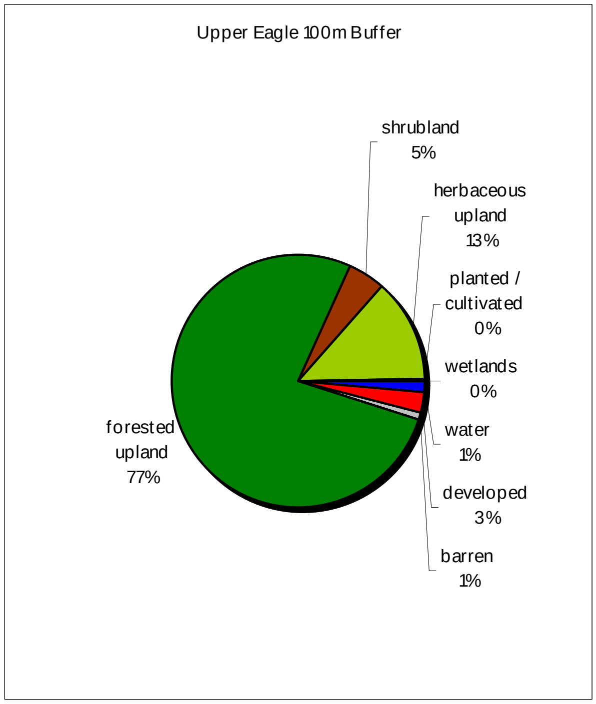


Figure B.3: Upper Eagle River 100-m buffer land use based on 1992 National Land Cover Data (Vogelmann *et al.*, 2001).

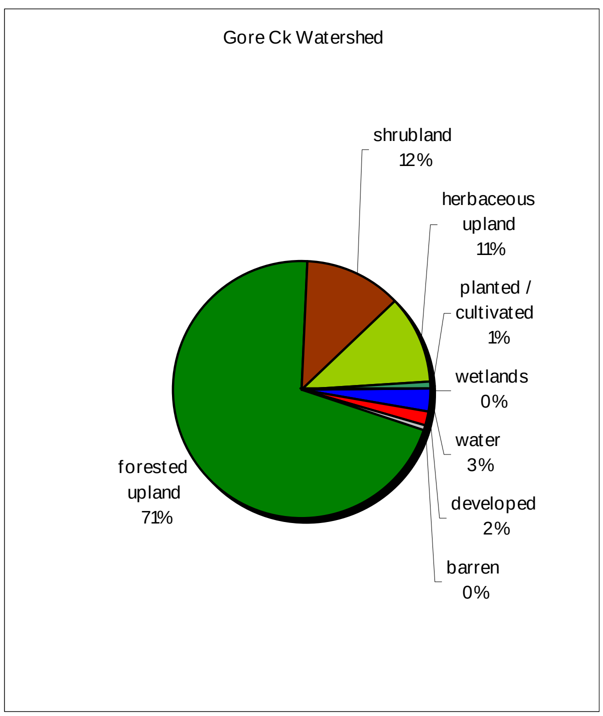


Figure B.4: Gore Creek Watershed land use based on 1992 National Land Cover Data (Vogelmann *et al.*, 2001).

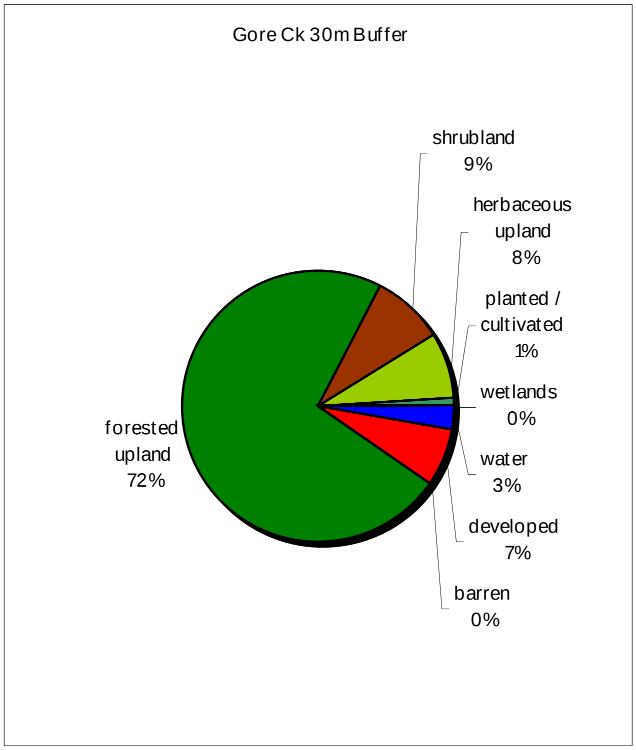


Figure B.5: Gore Creek 30-m buffer land use based on 1992 National Land Cover Data (Vogelmann *et al.*, 2001).

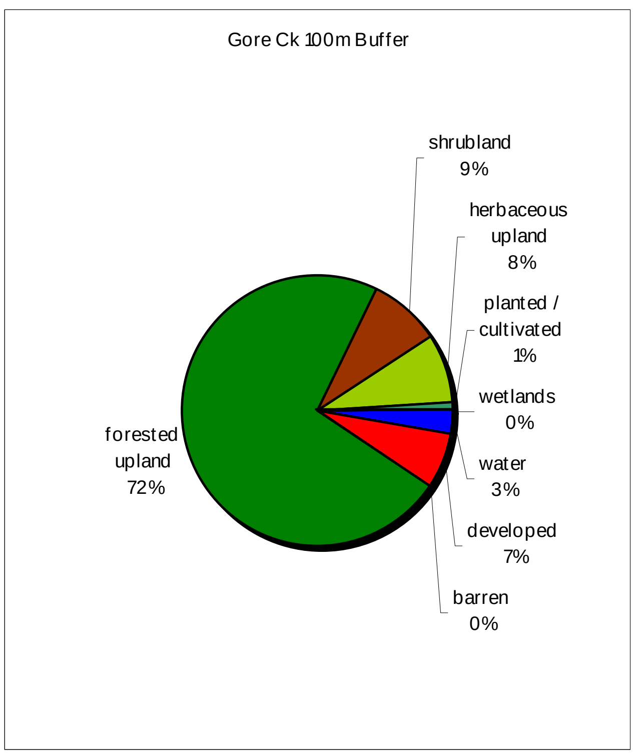


Figure B.6: Gore Creek 100-m buffer land use based on 1992 National Land Cover Data (Vogelmann *et al.*, 2001).

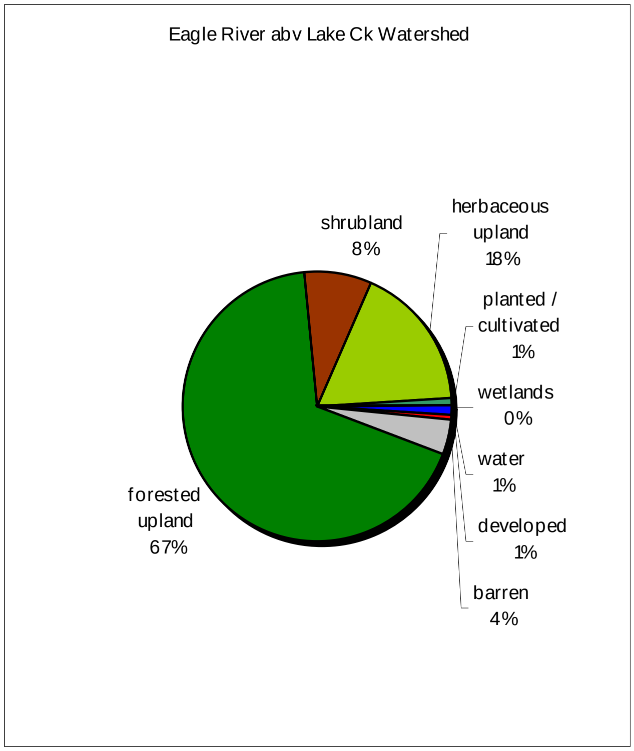


Figure B.7: Eagle River above Lake Creek Watershed land use based on 1992 National Land Cover Data (Vogelmann *et al.*, 2001).

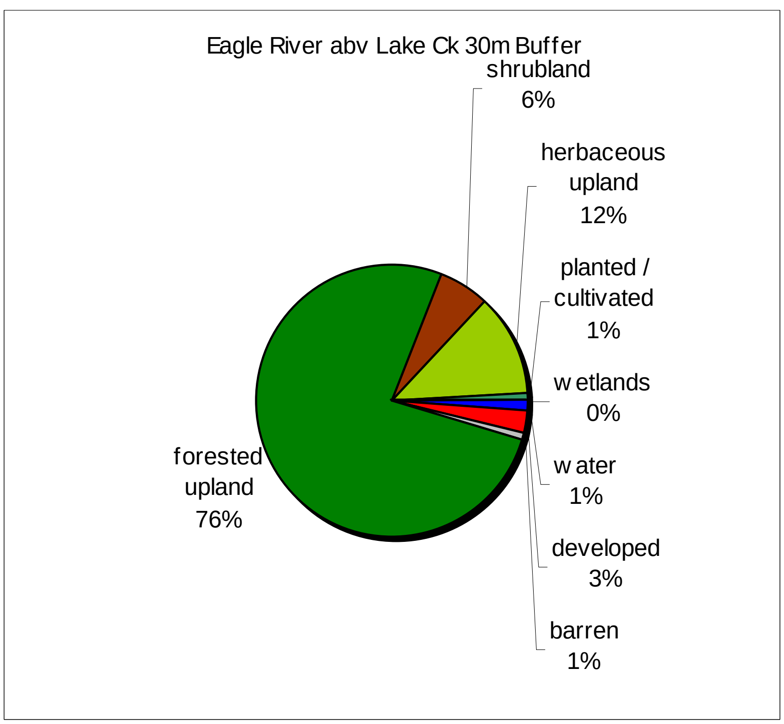


Figure B.8: Eagle River above Lake Creek 30-m buffer land use based on 1992 National Land Cover Data (Vogelmann *et al.*, 2001).

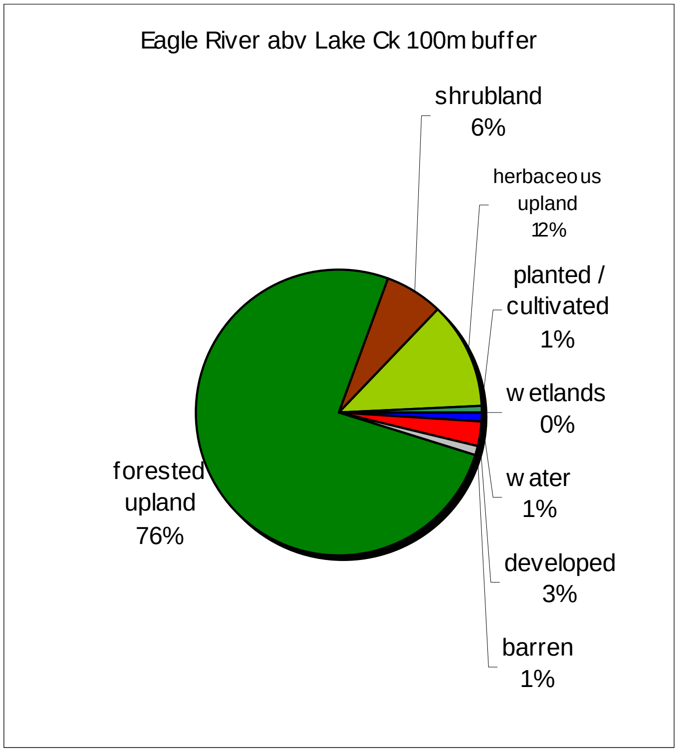


Figure B.9: Eagle River above Lake Creek 100-m buffer land use based on 1992 National Land Cover Data (Vogelmann *et al.*, 2001).

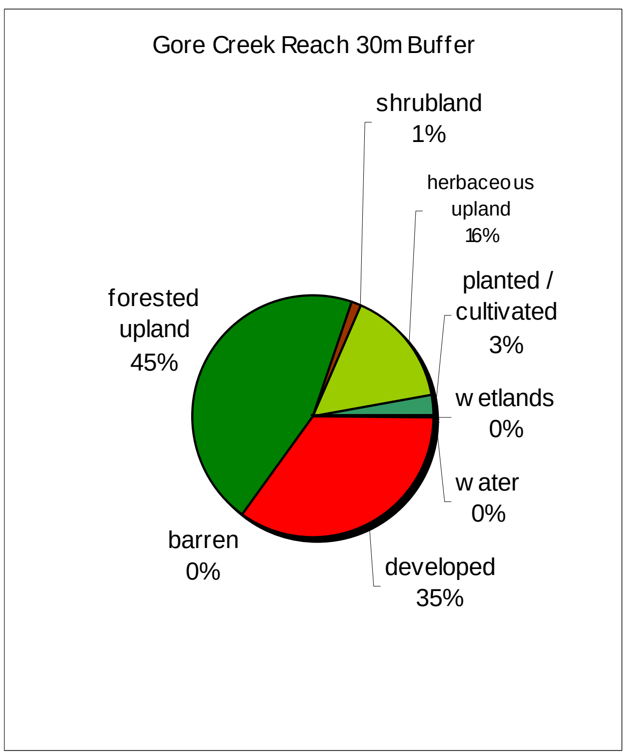


Figure B.10: Gore Creek Reach 30-m buffer land use based on 1992 National Land Cover Data (Vogelmann *et al.*, 2001).

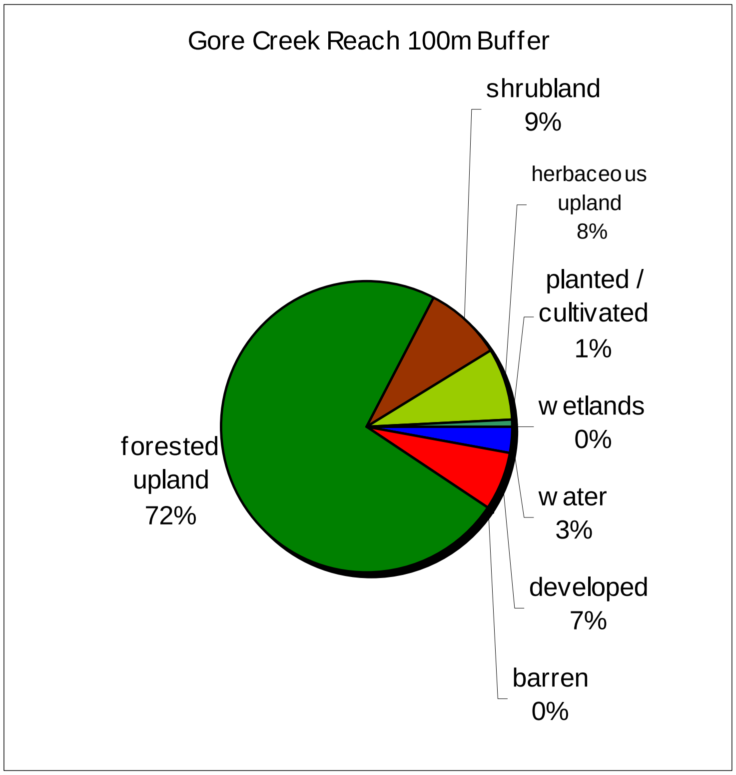


Figure B.11: Gore Creek Reach 100-m buffer land use based on 1992 National Land Cover Data (Vogelmann *et al.*, 2001).

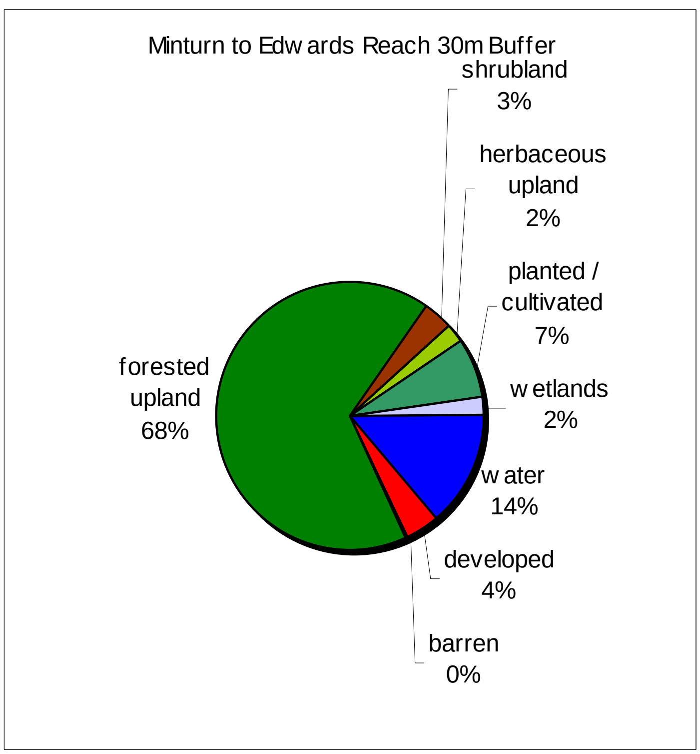


Figure B.12: Minturn to Edwards Reach 30-m buffer land use based on 1992 National Land Cover Data (Vogelmann *et al.*, 2001).

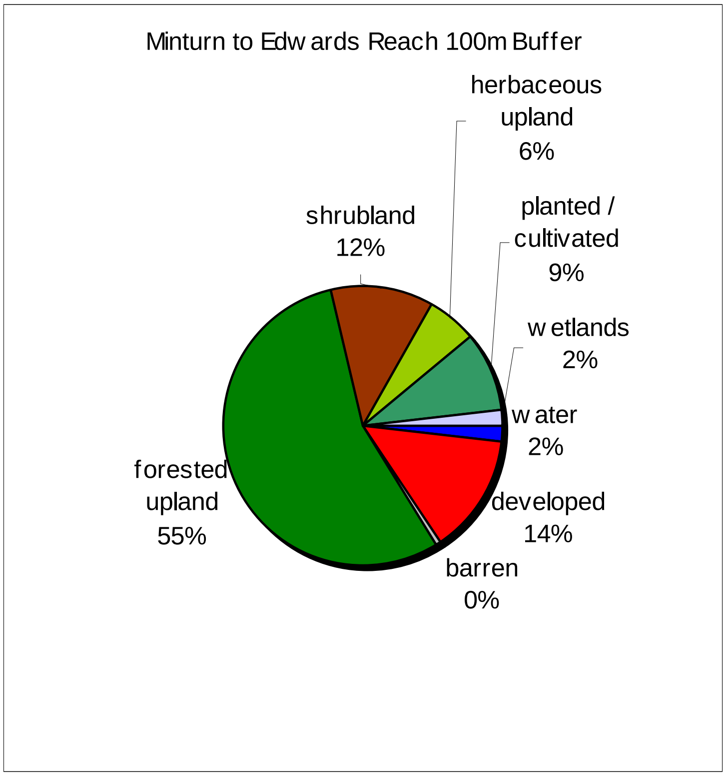


Figure B.13: Minturn to Edwards Reach 100-m buffer land use based on 1992 National Land Cover Data (Vogelmann *et al.*, 2001).

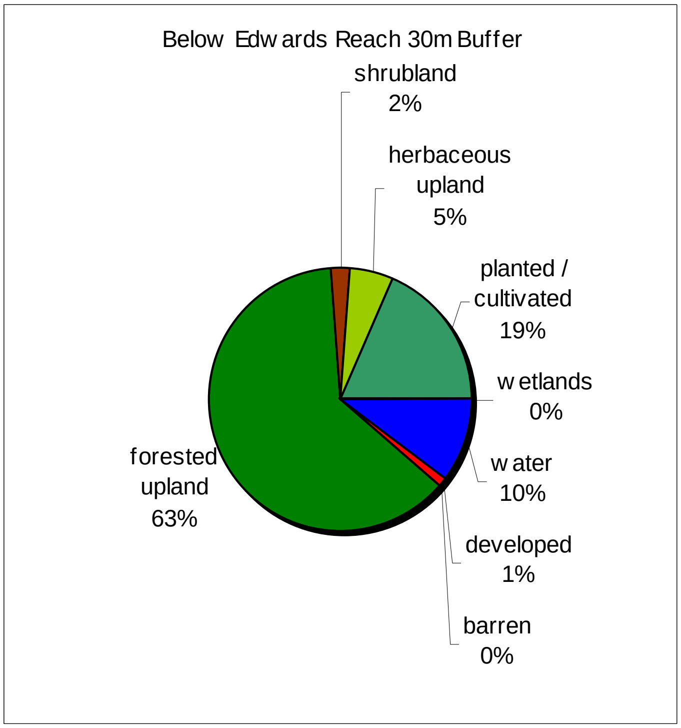


Figure B.14: Below Edwards Reach 30-m buffer land use based on 1992 National Land Cover Data (Vogelmann *et al.*, 2001).

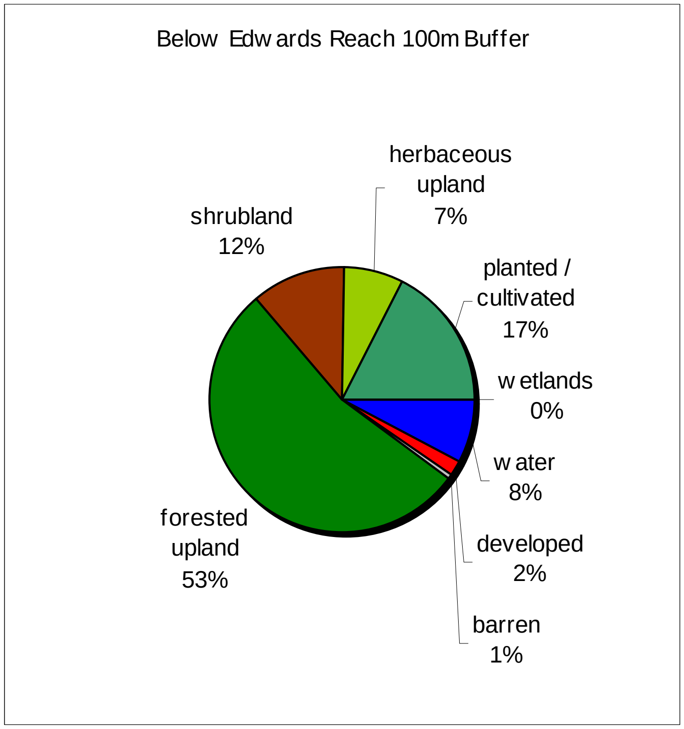


Figure B.15: Below Edwards Reach 100-m buffer land use based on 1992 National Land Cover Data (Vogelmann *et al.*, 2001).

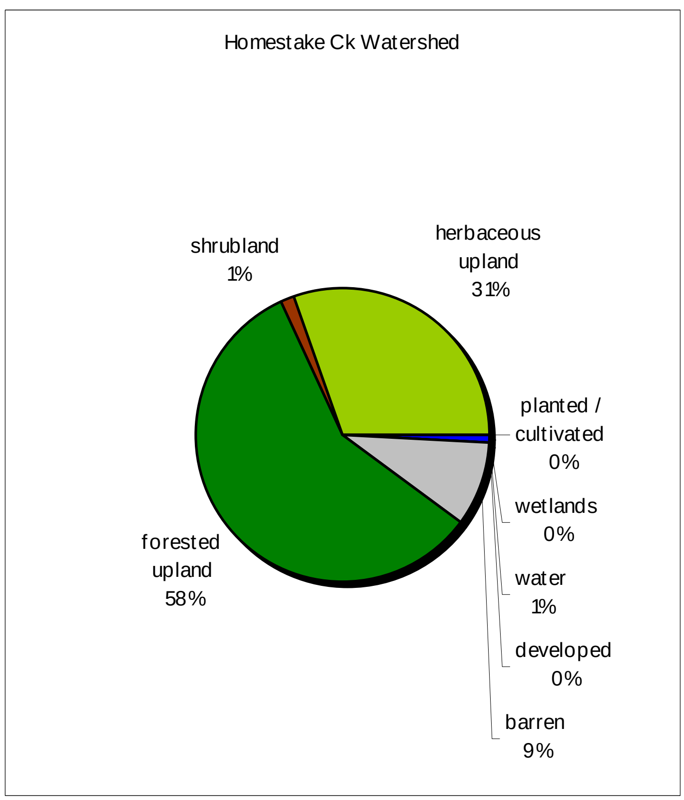


Figure B.16: Homestake Creek Watershed land use based on 1992 National Land Cover Data (Vogelmann *et al.*, 2001).

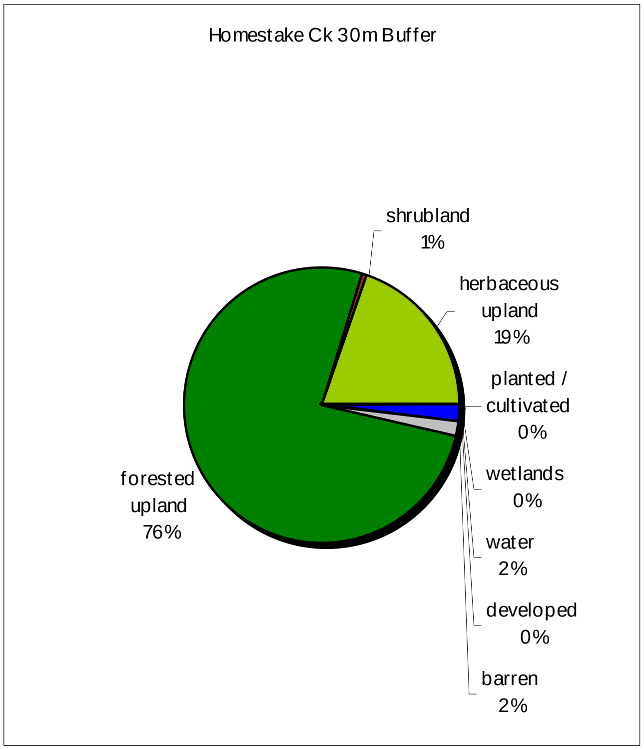


Figure B.17: Homestake Creek 30-m buffer land use based on 1992 National Land Cover Data (Vogelmann *et al.*, 2001).

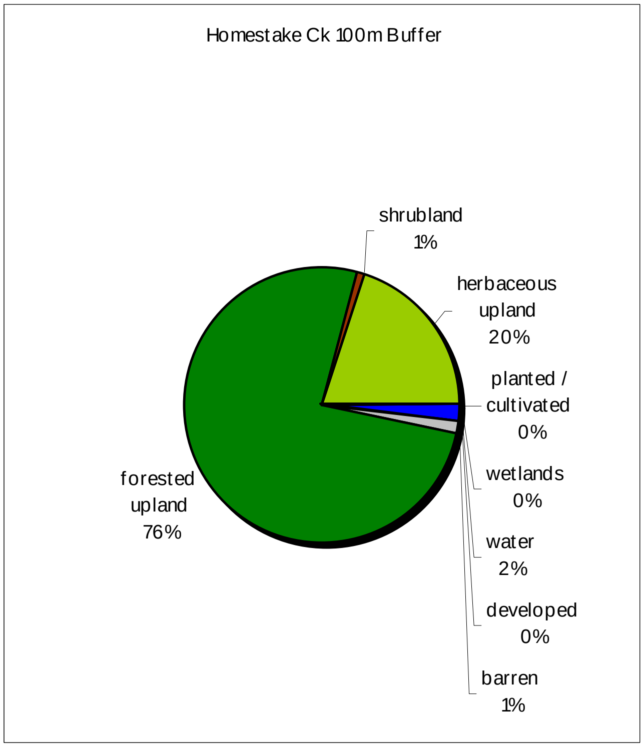


Figure B.18: Homestake Creek 100-m buffer land use based on 1992 National Land Cover Data (Vogelmann *et al.*, 2001).

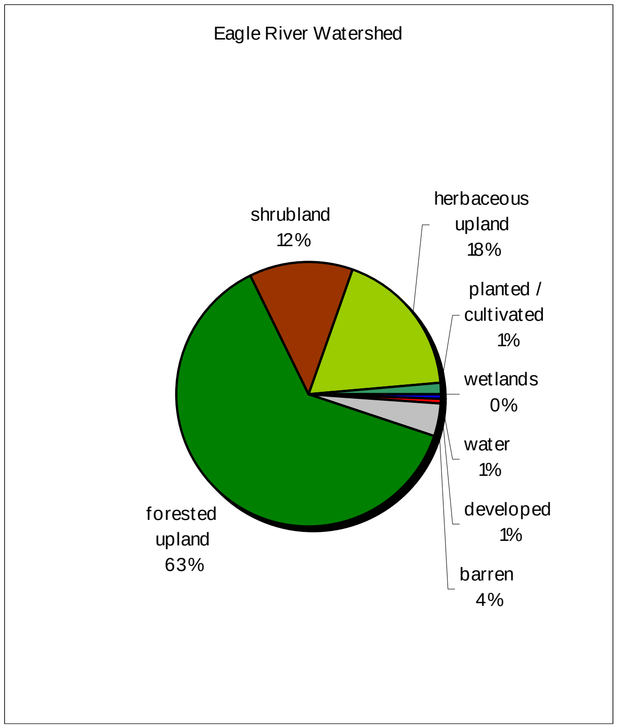


Figure B.19: Eagle River watershed land use based on 1992 National Land Cover Data (Vogelmann *et al.*, 2001).

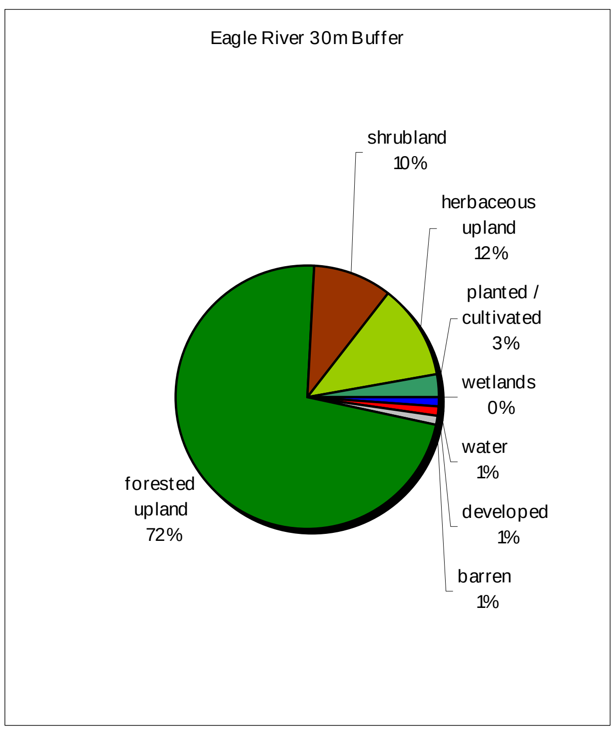


Figure B.20: Eagle River 30-m buffer land use based on 1992 National Land Cover Data (Vogelmann *et al.*, 2001).

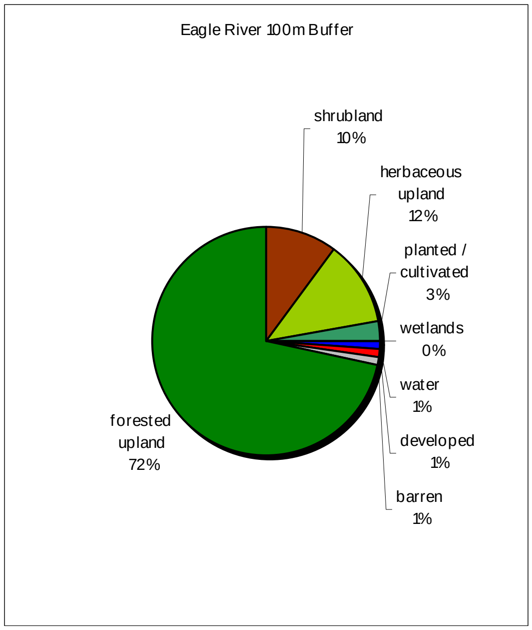


Figure B.21: Eagle River 100-m buffer land use based on 1992 National Land Cover Data (Vogelmann *et al.*, 2001).

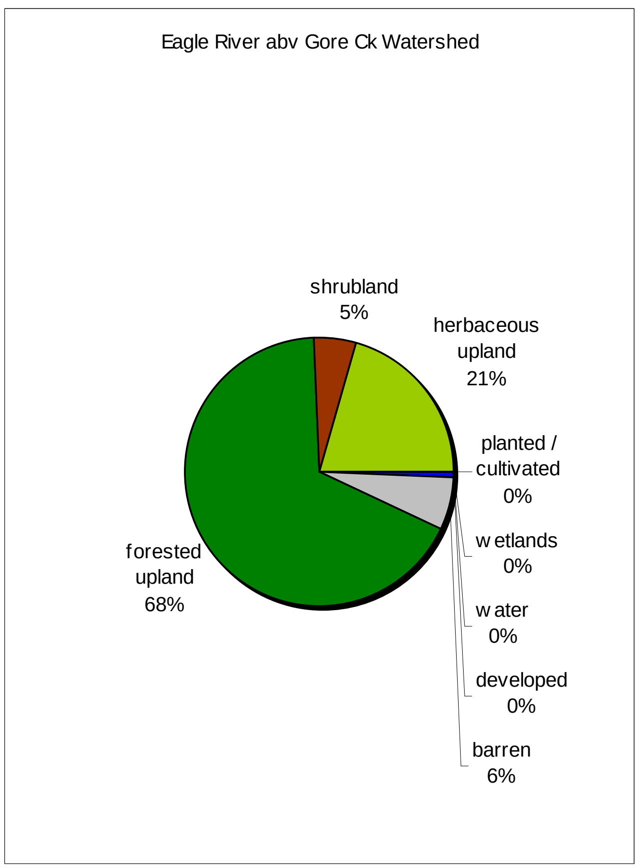


Figure B.22: Eagle River above Gore Creek Watershed land use based on 1992 National Land Cover Data (Vogelmann *et al.*, 2001).

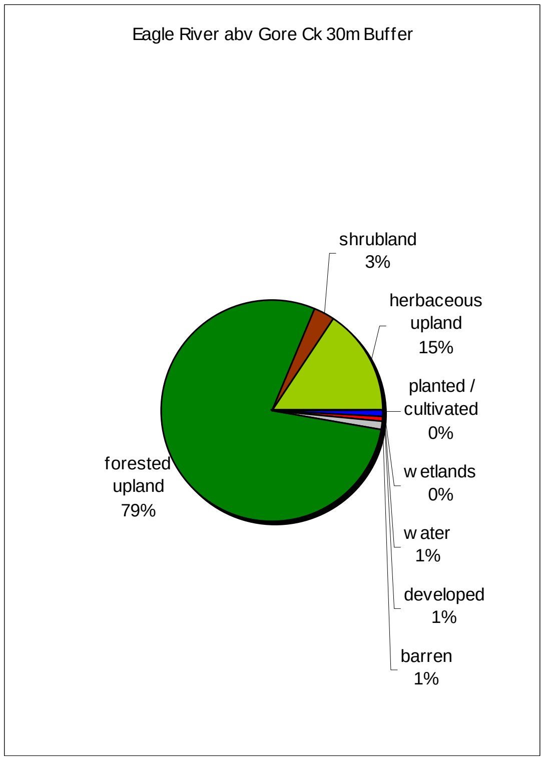


Figure B.23: Eagle River above Gore Creek 30-m buffer land use based on 1992 National Land Cover Data (Vogelmann *et al.*, 2001).

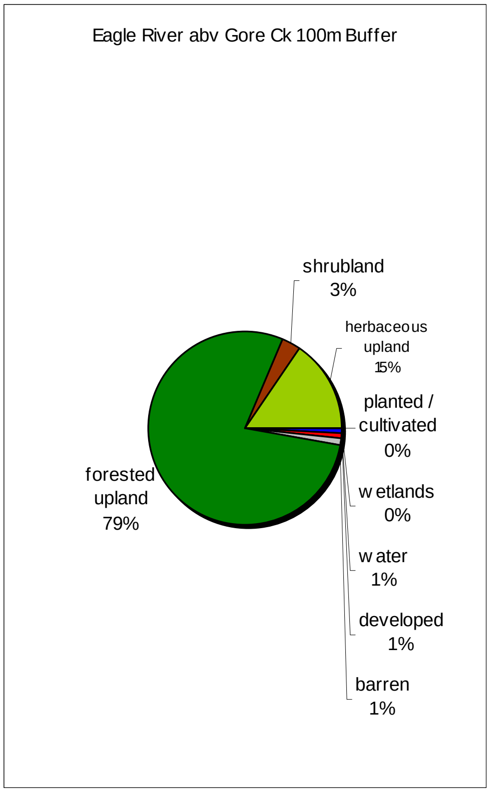


Figure B.24: Eagle River above Gore Creek 100-m buffer land use based on 1992 National Land Cover Data (Vogelmann *et al.*, 2001).

REFERENCE

Vogelmann, J.E., S.M. Howard, L. Yang, C. R. Larson, B. K. Wylie, and J. N. Van Driel, 2001. Completion of the 1990s National Land Cover Data Set for the conterminous United States, *Photogrammetric Engineering and Remote Sensing* 67:650-662.

APPENDIX C

Water Use

Table C.1: USGS water use database for the Eagle River watershed (USGS, 2004).

Category		Units	1985 Value	1990 Value	1995 Value
Totals	Ground-water withdrawals, fresh	MGD	2.88	3.76	3.79
	Ground-water withdrawals, saline	MGD	0	0	0
	Withdrawals, ground water	MGD	2.88	3.76	3.79
	Surface-water withdrawals, fresh	MGD	161.99	98.05	71.43
	Surface-water withdrawals, saline	MGD	0	0	0
	Surface-water withdrawals	MGD	161.99	98.05	71.43
	Fresh-water withdrawals	MGD	164.87	101.81	75.22
	Saline withdrawals	MGD	0	0	0
	Withdrawals	MGD	164.87	101.81	75.22
	Reclaimed wastwater	MGD	0	0	0
	Fresh consumptive use	MGD	28.73	25.48	15.12
	Saline consumptive use	MGD	0	0	0
	Consumptive use, total	MGD	28.73	25.48	15.12
	Conveyance losses	MGD	38.8	28.56	19.86
Population	Total population of the area	thousands	15.54	16.82	22.13
Public Supply	Population served by ground water	thousands	6.3	8.05	10.57
	Population served by surface water	thousands	9.13	8.59	11.29
	Total Population served	thousands	15.43	16.64	21.86
	Groundwater withdrawals	MGD	2.22	2.87	3.01
	Surface water withdrawals	MGD	3.52	2.73	5.07
	Total withdrawals, fresh	MGD	5.74	5.6	8.08
	Ground-water withdrawals, saline	MGD	0	0	0
	Surface-water withdrawals, saline	MGD	0	0	0
	Total withdrawals, saline	MGD	0	0	0
	Total withdrawals, total	MGD	5.74	5.6	8.08
	Water deliveries, public use and losses	MGD	1.78	0.11	1.31
	Water deliveries, total deliveries	MGD	5.74	5.6	6.77
	Per-capita use	gal/d	372	336.54	369.62
	Number of facilities	--	0	15	15
Commercial	Ground-water withdrawals, fresh	MGD	0.18	0.31	0.31
	Surface-water withdrawals, fresh	MGD	0	0	0
	Total withdrawals	MGD	0.18	0.31	0.31
	Deliveries from public suppliers	MGD	1.49	1.2	2.69
	Total withdrawals + deliveries	MGD	1.67	1.51	3
	Consumptive use, total	MGD	0.25	0.23	0.45
Domestic	Self-supplied population	MGD	0.11	0.18	0.27
	Self-supplied ground-water withdrawals, fresh	MGD	0.01	0.02	0.02
	Self-supplied surface-water withdrawals, fresh	MGD	0	0	0
	Total self-supplied withdrawals	MGD	0.01	0.02	0.02
	Per-capita use, self-supplied	MGD	90.91	111.11	74.07
	Public-supplied population	MGD	15.43	16.64	21.86
	Deliveries from public suppliers	MGD	2.47	4.23	4.02
	Per-capita use, public-supplied	gal/d	160.08	254.21	183.9
	Total withdrawals plus deliveries	MGD	2.48	4.25	4.04

Category		Units	1985 Value	1990 Value	1995 Value
Domestic (cont.)	Consumptive use, total	MGD	0.75	1.28	1.21
Industrial	Self-supplied ground-water withdrawals, fresh	MGD	0	0.15	0.15
	Self-supplied ground-water withdrawals, saline	MGD	0	0	0
	Total self-supplied withdrawals, ground water	MGD	0	0.15	0.15
	Self-supplied surface-water withdrawals, fresh	MGD	0	0.06	0.06
	Self-supplied surface-water withdrawals, saline	MGD	0	0	0
	Total self-supplied withdrawals, surface water	MGD	0	0.06	0.06
	Total self-supplied withdrawals, fresh	MGD	0	0.21	0.21
	Total self-supplied withdrawals, saline	MGD	0	0	0
	Total self-supplied withdrawals	MGD	0	0.21	0.21
	Reclaimed wastewater	MGD	0	0	0
	Deliveries from public suppliers	MGD	0	0.06	0.06
	Total withdrawals plus deliveries	MGD	0	0.27	0.27
	Consumptive use, fresh	MGD	0	0.1	0.1
	Consumptive use, saline	MGD	0	0	0
	Consumptive use, total	MGD	0	0.1	0.1
	Number of facilities	--	0	1	1
Total thermoelectric power use	Ground-water withdrawals, fresh	MGD	0	0	0
	Surface-water withdrawals, fresh	MGD	0	0	0
	Surface-water withdrawals, saline	MGD	0	0	0
	Total withdrawals, surface water	MGD	0	0	0
	Total withdrawals, fresh	MGD	0	0	0
	Total withdrawals	MGD	0	0	0
	Deliveries from public suppliers	MGD	0	0	0
	Total withdrawals plus deliveries	MGD	0	0	0
	Consumptive use, fresh	MGD	0	0	0
	Consumptive use, saline	MGD	0	0	0
	Consumptive use, total	MGD	0	0	0
	Power generation	gigawatt hours/year	0	0	0
	Number of facilities	--	0	0	0
Fossil-fuel thermoelectric power use	Ground-water withdrawals, fresh	MGD	0	0	0
	Surface-water withdrawals, fresh	MGD	0	0	0
	Surface-water withdrawals, saline	MGD	0	0	0
	Total withdrawals, surface water	MGD	0	0	0
	Total withdrawals, fresh	MGD	0	0	0
	Total withdrawals	MGD	0	0	0
	Deliveries from public suppliers	MGD	0	0	0
	Total withdrawals plus deliveries	MGD	0	0	0
	Consumptive use, fresh	MGD	0	0	0
	Consumptive use, saline	MGD	0	0	0
	Consumptive use, total	MGD	0	0	0
	Power generation	gigawatt hours/year	0	0	0
	Number of facilities	--	0	0	0

Category		Units	1985 Value	1990 Value	1995 Value
Geothermal thermoelectric power use	Ground-water withdrawals, fresh	MGD	0	0	0
	Ground-water withdrawals, saline	MGD	0	0	0
	Total withdrawals	MGD	0	0	0
	Consumptive use, fresh	MGD	0	0	0
	Consumptive use, saline	MGD	0	0	0
	Power generation	gigawatt hours/year	0	0	0
	Number of facilities	--	0	0	0
Nuclear thermoelectric power use	Ground-water withdrawals, fresh	MGD	0	0	0
	Surface-water withdrawals, fresh	MGD	0	0	0
	Surface-water withdrawals, saline	MGD	0	0	0
	Total withdrawals, surface water	MGD	0	0	0
	Total withdrawals, fresh	MGD	0	0	0
	Total withdrawals	MGD	0	0	0
	Deliveries from public suppliers	MGD	0	0	0
	Total withdrawals plus deliveries	MGD	0	0	0
	Consumptive use, fresh	MGD	0	0	0
	Consumptive use, saline	MGD	0	0	0
	Consumptive use, total	MGD	0	0	0
	Power generation	gigawatt hours/year	0	0	0
	Number of facilities	--	0	0	0
Mining use	Ground-water withdrawals, fresh	MGD	0.03	0.03	0.07
	Ground-water withdrawals, saline	MGD	0	0	0
	Total withdrawals, ground water	MGD	0.03	0.03	0.07
	Surface-water withdrawals, fresh	MGD	0	0	0
	Surface-water withdrawals, saline	MGD	0	0	0
	Total withdrawals, surface water	MGD	0	0	0
	Total withdrawals, fresh	MGD	0.03	0.03	0.07
	Total withdrawals, saline	MGD	0	0	0
	Total withdrawals	MGD	0.03	0.03	0.07
	Consumptive use, fresh	MGD	0.03	0.03	0.07
	Consumptive use, saline	MGD	0	0	0
	Consumptive use, total	MGD	0.03	0.03	0.07
Livestock (stock) use	Total withdrawals, ground water	MGD	0.03	0.04	0.04
	Total withdrawals, surface water	MGD	0.11	0.13	0.12
	Total withdrawals	MGD	0.14	0.17	0.16
	Consumptive use, total	MGD	0.13	0.17	0.16
Livestock (animal specialties) use	Total withdrawals, ground water	MGD	0	0	0
	Total withdrawals, surface water	MGD	0	0	0
	Total withdrawals	MGD	0	0	0
	Consumptive use, total	MGD	0	0	0
Total livestock use	Ground water	MGD	0.03	0.04	0.04
	Surface water	MGD	0.11	0.13	0.12
	Total withdrawals	MGD	0.14	0.17	0.16
	Consumptive use, total	MGD	0.13	0.17	0.16

Category		Units	1985 Value	1990 Value	1995 Value
Irrigation use	Ground-water withdrawals, fresh	MGD	0.41	0.34	0.19
	Surface-water withdrawals, fresh	MGD	158.36	95.13	66.18
	Reclaimed wastewater	MGD	0	0	0
	Total withdrawals, fresh	MGD	158.77	95.47	66.37
	Irrigated land, sprayed	thousand acres	1.04	0.76	0.44
	Irrigated land, flooded	thousand acres	22.23	16.13	9.43
	Irrigated land, total	thousand acres	23.27	16.89	9.87
	Conveyance loss	MGD	38.8	28.56	19.86
	Consumptive use	MGD	27.57	23.67	13.13
	Return Flows	MGD	92.4	43.24	33.38
Hydroelectric power use	Instream water use	MGD	0	0	0
	Power generation, total	gigawatt hours/year	0	0	0
	Number of facilities	--	0	0	0
Wastewater treatment	Number of public wastewater facilities	--	6	6	7
	Number of other facilities	--	6	1	1
	Number of wastewater facilities, total	--	12	7	8
	Returns by public wastewater facilities	MGD	4.29	4.44	5.03
	Reclaimed wastewater released by public wastewater facilities	MGD	0	0	0
Reservoir evaporation	Reservoir evaporation	thousand acres	0	0.93	0.93
	Reservoir surface area	thousand acres	0	0.32	0.32

REFERENCE

USGS (2004). USGS National Water Information System (NWIS) water resources database. Available from http://waterdata.usgs.gov/nwis.

APPENDIX D
Water Rights

APPENDIX D
WATER RIGHTS

The limited water resources of the Western United States required a different set of protocols for assigning water rights than in the East, where water is generally owned by the owner of the land through which it flows. With the Mining Act of 1866 and the Desert Act of 1877, Congress granted states the right to draft their own laws regarding water appropriation. The State of Colorado chose to adopt a doctrine of prior appropriation, wherein water rights were assigned seniority by the date in which the water was first put to beneficial use.

Soon after statehood, Colorado developed a system to identify the seniority, amount, location, and timing of use of surface waters for irrigation throughout the state via the Adjudication Acts of 1879 and 1881. Those Acts stated that only the act of an appropriator placing water to beneficial use can bring into existence a full Colorado water right (Hobbs, 1997).

When settlers of towns and cities placed their claims for water rights at that time, they estimated the total volume of present and future water needs. This resulted in appropriation of more water than could actually be put to beneficial use, and allotted more flow than was actually present in the streams. This led to the development of a system of conditional water rights, wherein priority is assigned by date of application, but does not become a full right until it can be shown that the water is being put to beneficial use (Hobbs, 1997).

A relatively small proportion of water was necessary to support residents of burgeoning towns and villages compared to what was required for irrigation when the original Colorado water laws were drafted, therefore, there were no rights required for water to be used for domestic purposes until 1903.. The Colorado Constitution appears to have provided that domestic use could supersede all other uses, regardless of appropriation date: "[W]hen the waters of any natural stream are not sufficient for the service of all of those desiring the use of the same, those using the water for domestic purposes shall have the preference over those claiming for any other purpose."(Colo. Const. art. XVI, § 7., Hobbs, 1997)

Two important legal developments resulted from the original laws that provided the domestic water rights of cities to have seniority over other rights : (1) water rights can be sold and changed from one use and location to another, and (2) senior vested water rights cannot be taken or superseded without payment of just compensation. In the late nineteenth century, the Colorado Supreme Court determined agricultural water rights could be sold to cities for domestic and municipal purposes, so long as other water rights holders are not adversely affected by the transaction. Hearings on the transfer of ownership of rights from one party to another are open to the public so that concerns of potentially affected parties may be heard. Today, Colorado cities are actively acquiring senior rights from farmers for present and future domestic use (Hobbs, 1997).

"Colorado water law states that a share in a water right is a property right that arises solely by the act of placing water, previously unappropriated, to the appropriator's beneficial purpose. The locations of diversion and water use may occur in different watersheds. Successful application to a beneficial use is required, regardless of the method of capture or conveyance. Ownership of a water right grants the owner the use of the decreed amount of water, so long as the seniority of that right has priority over all others. Beneficial use is not a defined term in the Colorado Constitution, but the statutory definition of 'beneficial use' is the 'use of that amount of water that is reasonable and appropriate under reasonably efficient practices to accomplish without waste the purpose for which the appropriation is lawfully made'." (Colo. Rev. Stat. § 37-92-103(4) (1997); Hobbs, 1997).

Additionally, it is the responsibility of the water right holder to provide efficient transport of the flow from the point of collection to the point of beneficial use. If improving water infrastructure may increase the quantity of useable water, a junior water right holder may gain ownership to the net increase in flow volume if they pay for the improvements (Hobbs, 1997).

Subsequent to application to the land, excess return flows must be available to junior rights holders. The owner of a water right may only take that which may be used for the purposes of the appropriation of the right. Developed flows, such as transmountain diversions, may be used to extinction so long as it suits the beneficial purposes. Pollution of flows by senior rights holders that affects the ability of the flow to meet the needs of junior rights holders is not considered a beneficial use. Colorado water laws also contain a use-it-or-lose-it clause, wherein extended non-use may result in an abandonment of either the whole water right, or a part thereof (Hobbs, 1997).

"Colorado case law and statutes have emerged which recognize a wide variety of purposes. These include: agriculture, stock watering, domestic, municipal, commercial, and industrial uses, power generation, flood control uses, dust suppression, mined land reclamation, boat chutes, fish ladders, nature centers, fish and wildlife culture, recreation, residential environment, release from storage for boating and fishing flows, as well as new and ever-evolving uses such as minimum stream flow appropriations."

"Only the State Water Conservation Board may obtain an appropriation without a means for capturing, possessing and controlling water. This exception was made for the purpose of preserving the natural environment to a reasonable degree. The Board may appropriate water for minimum flow and lake levels in priority, and it may also buy or accept the donation of other rights for change of use to instream flow. The Water Conservation Board holds instream flow rights on approximately 8,000 miles of Colorado streams" (Hobbs, 1997).

Table D.1: Water rights (CDSS, 2004).

Stream/River Name	Total Absolute Rate (cfs)	Total Absolute Storage (acre-ft)	Rate (cfs)	Total Conditional Storage (acre-ft)
Alkali Creek	21.07	343.60	41.11	350,000.29
Beard Creek	4.59	0.20	2.07	2.50
Beaver Creek	99.43	226.00	8.00	0.00
Berry Creek	12.29	0.00	0.00	0.00
Bishop Creek	0.00	0.00	0.00	0.00
Brush Creek	418.18	937.06	174.17	9,305.22
Buck Creek	2.00	0.00	0.00	0.00
Castle Creek	14.29	7.11	10.34	7.00
Cataract Creek	1.00	0.00	90.00	0.00
Cross Creek	84.50	2,185.00	994.00	0.00
Eagle River	1,070.04	3,910.39	3,777.15	495.48
Eby Creek	39.54	1,132.54	1.35	47.14
Elk Creek	0.00	0.00	0.00	0.00
Fall Creek	22.00	1,824.00	280.00	0.00
Game Creek	3.05	0.00	0.00	0.00
Gore Creek	195.84	430.56	1,271.93	920.85
Grouse Creek	41.44	8.00	10.50	0.00
Gypsum Creek	279.77	1,188.64	50.96	600.00
Holland Creek	4.72	0.00	2.29	67.00
Homestake Creek	744.48	44,777.70	2,459.83	219,425.00
Jones Gulch	0.00	0.00	144.00	0.00
June Creek	9.26	38.00	2.67	0.00
Lake Creek	169.90	1,834.02	53.29	30.82
Long Creek	0.00	0.00	0.00	0.00
McCoy Creek	13.43	0.00	5.00	500.00
Milk Creek	62.29	300.00	3.12	0.00
Nontributary	0.19	0.00	0.03	0.00
Nottingham Creek	7.83	0.00	0.00	0.00
Peterson Creek	0.00	0.00	90.00	0.00
Piney Creek	103.50	0.00	725.00	0.00
Red Canyon Creek	0.00	0.00	1.00	5.00
Reese Creek	0.00	0.00	0.00	0.00
Rock Creek	1.00	0.00	0.00	0.00
Rule Creek	0.50	0.00	0.00	0.00
Sheep Gulch	0.00	0.00	20.00	0.00
Short Creek	0.00	0.00	0.00	0.00
Smith Ditch	0.80	0.00	0.00	0.00
Spring Creek	10.97	10.00	6.90	48.00
Squaw Creek	21.42	1.33	4.31	7.27
Stone Creek	42.81	5.19	2.33	0.00
Talmage Creek	6.30	5.57	6.00	36.30
Traer Creek	1.20	0.00	0.00	0.00
Travis Creek	3.57	0.00	4.24	24.00
Turkey Creek	20.51	0.00	0.07	3.00
Two Elk Creek	4.00	0.00	0.00	0.00
Unknown Tributary	0.02	0.00	0.00	0.00
Ute Creek	0.20	0.00	0.00	65,975.00
Warren Gulch	0.13	0.00	0.00	0.00
Whiskey Creek	2.53	0.00	0.00	55.20
Willow Creek	6.00	36.90	0.22	0.00
Yoder Creek	1.00	60.00	0.00	0.00
Total	**3,547.59**	**59,261.81**	**10,241.89**	**647,555.08**

Table D.2: HydroBase dictionary.

Div	water division
WD	water district
ID	
PM	Primary Meridian
TS	township
Rng	range
Sec	Section
SecA	Half section
Q160	160 acre quarter section
Q40	40 acre quarter section
Q10	10 acre quarter section
County	
AdjDate	Adjudication date
PAdjDate	Prior adjudication date
AproDate	Appropriation Date
AdminNum	Administration Number
OrderNo	
PriCaseNo	
AdjType	Adjudication types
Use	Type of water use
NetRateAbs	Absolute rate of water right
NetVolAbs	Absolute volume of water right
NetRateCond	Conditional rate of water right
NetVolCond	Conditional volume of water right
NetRateApex and NetVolApex	Net alternate point of diversion or exchange in either cfs or acre feet; not computed by conversion if rights have mixed units.
Unit	
TabTrib	Identifier of tributary for tabulation
XWRStreamNo	Water right stream number
WDStreamName	Water district stream name
XStrtype	From transact, summarizes xtrtype codes as printed in "tab" report.
ActionComment	This comment describes any issues worth noting for the particular water right action.

Table D.3: Use codes.

ACR	Cumulative accretion to river
ALL	All beneficial uses
AUG	Augmentation
COM	Commercial
DEP	Cumulative depletion from river
DOM	Domestic
EVP	Evaporative
EXB	Export from basin
EXS	Export from State
FED	Federal reserved
FIR	Fire
FIS	Fishery
GEO	Geothermal
HUO	Household use only
IND	Industrial
IRR	Irrigation
MIN	Minimum streamflow
MUN	Municipal
NET	Net effect on river
OTH	Other
PWR	Power generation
RCH	Recharge
REC	Recreation
SNO	Snow making
STK	Stock
STO	Storage
TMX	Transmountain export
WLD	Wildlife

REFERENCES

CDSS (Colorado Decision Support System) (2004). Online Water Management Database. Available online at http://cdss.state.co.us/, June 1st, 2004.

Hobbs, Jr., G.J. (1997). Colorado Water Law: A Historical Overview, 1 U.Denv.Water L. Rev. 1. Water Law Review, Vol. 1, No. 1, Fall, 138 pp.

APPENDIX E

Instream Flows

Table E.1: Number of cross sections for instream flow segment.

Case Number	Stream Name	Segment Length	No. of Transects
5-80CW118	Abrams Creek	4.3 miles	1
5-97CW272	Antones Cabin Creek	1.4 miles	N/A
5-97CW272A	Antones Cabin Creek	2.6 miles	N/A
5-75W2719	Beaver Creek	7 miles	3
5-78W3803	Bennett Gulch	3.5 miles	1
5-80CW125	Berry Creek	4.7 miles	1
5-77W3634	Bighorn Creek	5 miles	1
5-77W3635	Black Gore Creek	10 miles	3
5-86CW230	Black Gore Creek	10 miles	N/A
5-77W3632	Booth Creek	4 miles	1
5-77W3625	Brush Creek	12 miles	1
5-78W3804	Cataract Creek	3.5 miles	1
5-78W3791	Cross Creek	5 miles	1
5-78W3793	Cross Creek	3.5 miles	1
5-78W3795	Cross Creek	8 miles	1
5-78W3788	Eagle River	6 miles	1
5-78W3796	Eagle River	4 miles	1
5-78W3805	Eagle River	2 miles	N/A
5-78W3811	Eagle River	6 miles	1
5-80CW124	Eagle River	12.8 miles	1
5-80CW126	Eagle River	20 miles	1
5-80CW134	Eagle River	10.1 miles	N/A
5-77W3627	East Brush Creek	10 miles	1
5-78W3794	East Cross Creek	2.5 miles	1
5-85CW262	East Fork Eagle River	6.4 miles	1
5-85CW263	East Fork Eagle River	1.7 miles	1
5-80CW123	East Lake Creek	9.3 miles	1
5-78W3789	Fall Creek	8 miles	0
5-78W3785	Game Creek	3.5 miles	1
5-77W3628	Gore Creek	7 miles	1
5-77W3636	Gore Creek	4 miles	1
5-77W3637	Gore Creek	7 miles	4
5-86CW216	Gore Creek	4 miles	1
5-86CW221	Gore Creek	7 miles	1
5-86CW222	Gore Creek	7 miles	4
5-78W3798	Grouse Creek	5 miles	N/A
5-78W3800	Grouse Creek	0.8 miles	1
5-80CW116	Gypsum Creek	16.6 miles	1
5-80CW117	Gypsum Creek	4.3 miles	1
5-87CW271	Hat Creek	4.5 miles	1
5-80CW132	June Creek	3.4 miles	1
5-97CW274	Leeman Gulch	2.1 miles	N/A
5-78W3816	Lime Creek	4 miles	1
5-78W3812	McAllister Gulch	2 miles	1

Case Number	Stream Name	Segment Length	No. of Transects
5-80CW131	Middle Creek	4.8 miles	1
5-78W3802	Mitchell Creek	2.8 miles	1
5-85CW656	Nolan Creek	2.9 miles	1
5-87CW270	Nolan Creek	1.5 miles	1
5-78W3790	Notch Mountain Creek	2.5 miles	1
5-78W3809	Pearl Creek	2 miles	1
5-77W3633	Pitkin Creek	5 miles	1
5-77W3631	Red Sandstone Creek	4.5 miles	1
5-77W3631A	Red Sandstone Creek	2.5 miles	N/A
5-78W3808	Resolution Creek	4 miles	1
5-78W3810	Resolution Creek	2 miles	1
5-78W3806	Rule Creek	1.5 miles	0
5-78W3786	Sopris Creek	3 miles	0
5-78W3801	South Fork Eagle River	6 miles	1
5-80CW135	Squaw Creek	5.3 miles	1
5-80CW133	Stone Creek	2.9 miles	1
5-78W3813	Turkey Creek	6.5 miles	1
5-78W3815	Turkey Creek	3 miles	1
5-78W3797	Two Elk Creek	4 miles	1
5-78W3814	Wearyman Creek	4.5 miles	1
5-77W3626	West Brush Creek	5 miles	1
5-97CW275	West Brush Creek	3.5 miles	N/A
5-78W3792	West Cross Creek	5 miles	1
5-78W3799	West Grouse Creek	5.5 miles	0
5-80CW122	West Lake Creek	6.8 miles	1
5-78W3787	Whitney Creek	2.5 miles	2
5-78W3771	Willow Creek	3 miles	1
5-78W3807	Yoder Creek	3 miles	1

APPENDIX F

Flow Metrics

APPENDIX F
FLOW METRICS

F.1 EXPLANATION OF THE FLOW METRICS

Ninety-five flow metrics were computed for 32 gaging records. Table F.1 and the following discussion provide a brief description of the metrics, their ecological significance (Table F.2), and a comprehensive output table (Tables F.3 and F.4). The first group of flow parameters computed for each gage represents monthly average flows and coefficients of variation. The coefficient of variation is a dimensionless parameter that is equivalent to the standard deviation of the data divided by the mean. A high coefficient of variation indicates high variability. Annual 1 to 90-day minimum and maximum flows and the coefficients of variation are quantified in the second set of metrics. The 1-day minimum and 1-day maximum are the 1-day extrema over the *period of record*. The 3-day minimum and 3-day maximum represent the 3-day extrema *averages*. Similarly, the 7, 30, and 90-day minima and maximum signify the 7, 30, and 90-day extrema averages. Zero days are the number of days during the year with zero or no flow conditions. Base flow values describe the 7-day annual minimum divided by the annual mean flow. The coefficient of variation of the base flow values is also presented.

Julian dates calculated by IHA actually represent the average day of the year that the 1-day minimum or maximum flow occurs. Using the mean of Julian days can be problematic in that the average of December 31 (Julian day 365) and January 1 (Julian day 1) falls in July (Julian day 183). This problem was present in the analysis of the minimum flow Julian dates for the Eagle River watershed. At specific gages, including Homestake at Goldpark, Homestake near Redcliff, and Eagle River at Redcliff, continuous series transformations were performed to determine the true dates of the average minimum streamflows across the period of analysis.

Pulses characterize the periods that the flows are greater or less than the pulse thresholds. The program calculates both the frequency and average duration per year of the high and low pulse. The high-pulse threshold (level) is defined as the mean flow plus one standard deviation, and the low-pulse level is defined as the mean minus one standard deviation.

$$P_h = \bar{Q} + \sigma \qquad \text{(F.1)}$$

$$P_l = \bar{Q} - \sigma \qquad \text{(F.2)}$$

where,

P_h = high-pulse level;
P_l = low-pulse level;
σ = one standard deviation; and
$\bar{Q}$ = mean flow rate.

Table F.1: Streamflow regime metrics.

Flow Metric	Description	Units	Source
Avg_Oct	Average October flow	cfs	IHA
Avg_Nov	Average November flow	cfs	IHA
Avg_Dec	Average December flow	cfs	IHA
Avg_Jan	Average January flow	cfs	IHA
Avg_Feb	Average February flow	cfs	IHA
Avg_Mar	Average March flow	cfs	IHA
Avg_Apr	Average April flow	cfs	IHA
Avg_May	Average May flow	cfs	IHA
Avg_Jun	Average June flow	cfs	IHA
Avg_Jul	Average July flow	cfs	IHA
Avg_Aug	Average August flow	cfs	IHA
Avg_Sep	Average September flow	cfs	IHA
CV_Oct	Coefficient of variation October flow	--	IHA
CV_Nov	Coefficient of variation November flow	--	IHA
CV_Dec	Coefficient of variation December flow	--	IHA
CV_Jan	Coefficient of variation January flow	--	IHA
CV_Feb	Coefficient of variation February flow	--	IHA
CV_Mar	Coefficient of variation March flow	--	IHA
CV_Apr	Coefficient of variation April flow	--	IHA
CV_May	Coefficient of variation May flow	--	IHA
CV_Jun	Coefficient of variation June flow	--	IHA
CV_Jul	Coefficient of variation July flow	--	IHA
CV_Aug	Coefficient of variation August flow	--	IHA
CV_Sep	Coefficient of variation September flow	--	IHA
Mn1d	Average annual 1-day minimum flow	cfs	IHA
CV Mn1d	Coefficient of variation annual 1-day minimum flow	--	IHA
Mn3d	Average annual 3-day minimum flow	cfs	IHA
CV Mn3d	Coefficient of variation annual 3-day minimum flow	--	IHA
Mn7d	Average annual 7-day minimum flow	cfs	IHA
CV Mn7d	Coefficient of variation annual 7-day minimum flow	--	IHA
Mn30d	Average annual 30-day minimum flow	cfs	IHA
CV Mn30d	Coefficient of variation annual 30-day minimum flow	--	IHA
Mn90d	Average annual 90-day minimum flow	cfs	IHA
CV Mn90d	Coefficient of variation annual 90-day minimum flow	--	IHA
Mx1d	Average annual 1-day maximum flow	cfs	IHA
CV Mx1d	Coefficient of variation annual 1-day maximum flow	--	IHA
Mx3d	Average annual 3-day maximum flow	cfs	IHA
CV Mx3d	Coefficient of variation annual 3-day maximum flow	--	IHA
Mx7d	Average annual 7-day maximum flow	cfs	IHA
CV Mx7d	Coefficient of variation annual 7-day maximum flow	--	IHA
Mx30d	Average annual 30-day maximum flow	cfs	IHA
CV Mx30d	Coefficient of variation annual 30-day maximum flow	--	IHA
Mx90d	Average annual 90-day maximum flow	cfs	IHA
CV Mx90d	Coefficient of variation annual 90-day maximum flow	--	IHA
ZeroD	Number of days per year with zero flow	days	IHA
CV ZeroD	Coefficient of variation of days per year with zero flow	--	IHA

Flow Metric	Description	Units	Source
BaseQ	7-day minimum flow divided by mean flow for that year	--	IHA
CV BaseQ	Coefficient of variation 7-day minimum flow divided by mean flow for that year	--	IHA
DatMn	Julian date of the minimum flow	Day of year	IHA
CV DatMn	Standard deviation Julian date of the minimum flow	--	IHA
DatMx	Julian date of the maximum flow	Day of year	IHA
CV DatMx	Standard deviation Julian date of the maximum flow	--	IHA
NLoPl	Average number of low pulses, low pulse defined as 1 standard deviation above the mean	--	IHA
CV NLoPl	Coefficient of variation of low pulses, low pulse defined as 1 standard deviation above the mean	--	IHA
DLoPl	Average duration of low pulses	days	IHA
CV DLoPl	Coefficient of variation duration of low pulses	--	IHA
NHiPl	Average number of low pulses, low pulse defined as 1 standard deviation below the mean	--	IHA
CV NHiPl	Coefficient of variation of low pulses, low pulse defined as 1 standard deviation below the mean	--	IHA
DHiPl	Average duration of high pulses	days	IHA
CV DHiPl	Coefficient of variation duration of high pulses	--	IHA
RiseR	Rise rate – mean of all positive differences	cfs/day	IHA
CV RiseR	Rise rate – coefficient of variation of all positive differences	--	IHA
FallR	Fall rate – mean of all negative differences	cfs/day	IHA
CV FallR	Fall rate – coefficient of variation of all negative differences	--	IHA
Revs	Number of flow reversals	--	IHA
CV Revs	Coefficient of variation of flow reversals	--	IHA
Ma3	Coefficient of variation of daily flows	--	Olden & Poff
Ma40	(Mean monthly flow - median monthly flow) / median monthly flow	--	Olden & Poff
Ma41	Mean annual runoff divided by catchment area	feet	Olden & Poff
Ma44	Average variability in daily flows divided by median daily flows for each year, where variability is calculated as 90th - 10th percentile	--	Sanborn & Bledsoe
Ml13	CV in minimum monthly flows	--	Olden & Poff
Ml14	Mean of lowest annual daily flow divided by median annual daily flow averaged across all years	--	Olden & Poff
Ml22	Mean annual minimum flows divided by catchment area	cfs/mi^2	Olden & Poff
Mh1	Max monthly flow for Oct	cfs	Olden & Poff
Mh8	Max monthly flow for May	cfs	Olden & Poff
Mh17	Mean of 25th percentile from the flow duration curve divided by median daily flow across all years	--	Olden & Poff
Fl3	Total number of low flow spells (threshold equal to 5% of mean daily flow) divided by record length in years	--	Olden & Poff
Fh11	Mean number of discrete flood events per year	--	Olden & Poff
Dl13	Mean annual 30-day minimum divided by median discharge	--	Olden & Poff

Flow Metric	Description	Units	Source
Dh12	Mean annual 7-day maximum divided by median discharge	--	Olden & Poff
Dh13	Mean annual 30-day maximum divided by median discharge	--	Olden & Poff
Th3	Max proportion of the year (num days / 365) during which no floods have ever occurred over the period of record	--	Olden & Poff
SS1	(Sum(Abs(Qt+1-Qt)) / #days) / Qavg	--	Sanborn & Bledsoe
PMAR_Oct	Proportion of mean annual runoff in October	--	Sanborn & Bledsoe
PMAR_Nov	Proportion of mean annual runoff in November	--	Sanborn & Bledsoe
PMAR_Dec	Proportion of mean annual runoff in December	--	Sanborn & Bledsoe
PMAR_Jan	Proportion of mean annual runoff in January	--	Sanborn & Bledsoe
PMAR_Feb	Proportion of mean annual runoff in February	--	Sanborn & Bledsoe
PMAR_Mar	Proportion of mean annual runoff in March	--	Sanborn & Bledsoe
PMAR_Apr	Proportion of mean annual runoff in April	--	Sanborn & Bledsoe
PMAR_May	Proportion of mean annual runoff in May	--	Sanborn & Bledsoe
PMAR_Jun	Proportion of mean annual runoff in June	--	Sanborn & Bledsoe
PMAR_Jul	Proportion of mean annual runoff in July	--	Sanborn & Bledsoe
PMAR_Aug	Proportion of mean annual runoff in August	--	Sanborn & Bledsoe
PMAR_Sep	Proportion of mean annual runoff in September	--	Sanborn & Bledsoe

Table F.2: The following ecological example influences were extracted from a literature review of Richter *et al*. (1996), Poff *et al*. (1997), and Whiting (2002). Further citations can be found within each document.

IHA & Flow SStats Statistics Group	Hydrologic Parameters	Example Influences
Magnitude of monthly water conditions	• Mean value for each calendar month	o Habitat availability for aquatic organisms o Soil moisture availability for plants o Availability of food, cover, and water for terrestrial animals o Access by predators to nesting sites o Influences water temperature, oxygen levels, photosynthesis in water column
Magnitude and duration of annual extreme water conditions	• Annual 1-day minima • Annual minima, 3-day means • Annual minima, 7-day means • Annual minima, 30-day means • Number of zero-flow days (zero flow) • 7-day minimum flow/mean for year (base flow) • Annual minima, 90-day means	o Balance of competitive, ruderal, and stress-tolerant organisms o Creation of sites for plant colonization o Structuring of aquatic ecosystems by abiotic vs. biotic factors o Structuring of physical habitat conditions o Soil moisture stress in plants o Dehydration in animals
	• Annual 1-day maxima • Annual maxima, 3-day means • Annual maxima, 7-day means • Annual maxima, 30-day means • Annual maxima, 90-day means	o Anaerobic stress in plants o Volume of nutrient exchanges between rivers and floodplains o Duration of stressful conditions such as low oxygen and concentrated chemicals in aquatic environments o Distribution of plant communities in lakes, ponds, floodplains o Duration of high flows for waste disposal, aeration of spawning beds in channel sediments

IHA & Flow SStats Statistics Group	Hydrologic Parameters	Example Influences
Magnitude of flow events, average-flow conditions	• Variability in daily flows • Skewness in monthly flows • Mean annual runoff • Variability across mean annual flows	o Potential for algal scour and wash out of organic matter o May create stranding of species o Sustainability of sensitive species o Quality of aquatic habitat o Increased variation can cause life cycle disruption. o Establishment of exotic species with increased flow stabilization o Availability of water and nutrients to floodplain for vegetation recruitment
Magnitude of flow events, low-flow conditions	• Variability across minimum monthly flows • Mean of annual minimum flows • Specific mean annual minimum flows	o Maintenance of hydrologic connectivity (Ward and Standford, 1989) o Sustainable water temperature and depth for fish o Availability of oxygen for aquatic species o Pollutant dilution levels o Dehydration in animals o Drought stress on plants
Magnitude of flow events, high-flow conditions	• Mean maximum monthly flows-October • Mean maximum monthly flows-May • High flow discharge • Specific mean annual maximum flows	o Population dynamics of native and non-native stream fishes (Olden and Poff, 2003) o Relative abundance of trout species (Strange *et al.*, 1992) o Structure of fish communities (Strange *et al.*, 1992) o Scour of floodplains soils for riparian vegetation recruitment sites
Timing of annual extreme water conditions	• Julian date of each annual 1-day maximum • Julian date of each annual 1-day minimum	o Compatibility with life cycles of organisms o Predictability/avoidability of stress for organisms o Access to special habitats during reproduction or to avoid predation o Spawning cues for migratory fish o Evolution of life history strategies, behavioral mechanisms

IHA & Flow SStats Statistics Group	Hydrologic Parameters	Example Influences
Timing of flow events, high-flow conditions	• Seasonal predictability of non-flooding	o Loss of peaks can disrupt spawning, egg hatching, and migration cues for fish o Ecosystem processes (e.g. microbial activity, litter composition, nitrogen flux) o Reduced peaks lead to invasion of less sensitive exotic species o Reduction or elimination of riparian plant recruitment
Frequency and duration of high and low pulses	• Number of low pulses within each year • Mean duration of low pulses within each year • Number of high pulses within each year • Mean duration of high pulses within each year	o Frequency and magnitude of soil moisture stress for plants o Frequency and duration of anaerobic stress for plants o Availability of floodplain habitats for aquatic organisms o Nutrient and organic matter exchanges between river and floodplain o Soil mineral availability o Access for waterbirds to feeding, resting, reproduction sites o Influences bedload transport, channel sediment textures, and duration of substrate disturbance (high pulses)
Frequency of flow events, low-flow conditions	• Frequency of low-flow spells	o Affects competition between species o Alters migrational patterns of species o Affects the biogenetic demands of aquatic organisms during the quiescent period (Stanford, 1994)
Frequency of flow events, high-flow conditions	• Flood frequency	o Nutrient and organic matter exchanges between river and floodplain o Soil mineral availability o Access for waterbirds to feeding, resting, reproduction sites
Duration of flow events, low-flow conditions	• Mean of 30-day minima of daily discharge	o Duration and magnitude of soil moisture stress for plants o Duration of anaerobic stress for plants o Concentration of aquatic organisms o Density of plant cover o Diversity of plant species

IHA & Flow SStats Statistics Group	Hydrologic Parameters	Example Influences
Duration of flow events, high-flow conditions	• Mean of 7-day maxima of daily discharge • Mean of 30-day maxima of daily discharge	o Volume of nutrient exchanges between rivers and floodplains o Ability of riparian forest patch types to persist within their natural range of abundance (Richter and Richter, 2000) o Maintenance of riparian diversity through sediment dynamics (Olden and Poff, 2003) o Vegetation functional types o Availability of riffle habitat for aquatic species
Rate and frequency of water condition changes	• Means of all positive differences between consecutive daily values • Means of all positive differences between consecutive daily values • Number of hydrological reversals • Flashiness	o Drought stress on plants (falling levels) o Entrapment of organisms on islands, floodplains (rising levels) o Desiccation stress on low-mobility streamedge (varial zone) organisms o Failure of seedling establishment

Table F.3a: Comprehensive output table.

GageID	Avg_Oct (cfs)	Avg_Nov (cfs)	Avg_Dec (cfs)	Avg_Jan (cfs)	Avg_Feb (cfs)	Avg_Mar (cfs)	Avg_Apr (cfs)	Avg_May (cfs)	Avg_Jun (cfs)
beaver_ck_at_avon	4.53	3.63	2.98	2.52	2.39	3.00	6.54	28.88	59.98
homestake_ck_at_gold_park	13.20	9.31	6.90	5.69	5.30	6.11	16.69	84.85	145.60
homestake_ck_nr_red_cliff	18.81	12.78	9.61	8.12	7.89	10.15	46.25	186.45	269.46
turkey_ck_at_red_cliff	5.97	4.27	3.37	2.59	2.61	3.62	14.05	77.95	163.98
black_gore_ck_nr_minturn	3.88	3.38	2.85	2.54	2.46	2.97	7.45	53.50	90.33
black_gore_ck_nr_vail	5.73	4.69	4.01	3.59	3.23	3.44	11.97	77.95	161.13
cross_ck_nr_minturn	13.61	7.21	4.35	3.18	3.04	4.18	21.68	123.05	247.19
eagle_red_cliff	16.10	13.46	11.24	10.39	10.24	11.80	32.39	155.43	193.98
gore_ck_at_upper_station	7.50	4.99	3.69	3.14	3.03	3.64	11.46	67.23	151.71
gypsum_ck_nr_gypsum	25.23	23.13	20.81	19.45	18.11	17.94	19.63	33.61	104.17
alkali_ck_nr_wolcott	0.41	0.26	0.12	0.08	0.24	2.03	6.43	9.07	3.68
bighorn_ck_nr_minturn	2.75	1.69	1.06	0.85	0.83	1.02	4.00	24.53	48.23
booth_ck_nr_minturn	2.84	1.97	1.25	1.00	0.95	1.36	5.63	32.35	62.86
brush_ck_nr_eagle	27.96	23.67	20.25	18.72	17.41	17.66	25.59	77.08	156.27
eagle_at_avon	109.78	81.96	63.08	58.40	55.29	72.96	217.36	1155.72	1683.75
eagle_at_eagle	218.63	168.98	121.89	100.43	103.52	145.42	346.00	1778.43	3107.61
eagle_bl_gypsum	259.57	240.71	198.36	182.22	174.38	189.56	350.74	1337.59	2260.48
eagle_bl_ww_treatment_at_avon	104.12	75.93	70.02	68.05	61.75	67.42	260.32	1144.44	969.81
eagle_nr_minturn	45.12	38.16	30.90	28.12	27.66	32.82	92.99	392.84	502.72
east_brush_ck_nr_eagle	7.02	4.15	3.13	2.64	2.50	2.73	5.43	32.91	70.68
gore_ck_abv_red_sndstn_ck	25.99	19.65	18.71	16.27	15.59	18.30	64.89	381.43	360.77
gore_ck_at_mouth	37.59	27.22	22.40	19.54	18.49	27.00	74.64	428.06	613.78
gore_ck_at_vail	16.79	10.96	6.98	6.61	6.23	8.09	35.90	226.80	510.58
gore_ck_lower_station_at_vail	26.18	19.69	14.65	12.55	11.40	16.37	47.65	306.80	635.47
gore_ck_nr_minturn	29.98	24.62	20.17	17.48	17.49	19.63	68.11	367.38	639.74
lake_ck_nr_edwards	28.61	21.32	14.12	12.20	11.32	12.64	23.80	123.91	234.52
middle_ck_nr_minturn	1.19	0.81	0.49	0.40	0.36	0.40	1.36	12.17	34.08
missouri_ck_nr_gold_park	3.22	1.83	1.11	0.80	0.69	0.84	2.84	15.22	30.91
pitkin_ck_nr_minturn	4.05	2.55	1.80	1.44	1.34	1.49	4.20	24.76	52.73
red_sandstone_ck_nr_minturn	2.00	1.54	1.24	1.07	1.01	1.13	3.53	29.87	48.54
turkey_ck_nr_red_cliff	6.18	4.62	3.68	3.22	3.03	3.53	7.74	47.76	116.74
wearyman_ck_nr_red_cliff	2.78	1.96	1.58	1.37	1.28	1.39	2.19	12.72	44.45

Table F.3b: Comprehensive output table.

GageID	Avg_Jul (cfs)	Avg_Aug (cfs)	Avg_Sep (cfs)	CV_Oct	CV_Nov	CV_Dec	CV_Jan	CV_Feb	CV_Mar
beaver_ck_at_avon	28.23	9.80	5.73	0.37	0.31	0.29	0.27	0.27	0.27
homestake_ck_at_gold_park	73.96	31.10	15.83	0.49	0.39	0.41	0.40	0.38	0.39
homestake_ck_nr_red_cliff	115.46	42.30	22.22	0.64	0.47	0.45	0.46	0.46	0.43
turkey_ck_at_red_cliff	42.33	14.60	8.32	0.36	0.40	0.47	0.53	0.60	0.62
black_gore_ck_nr_minturn	22.26	7.24	4.32	0.47	0.49	0.52	0.45	0.52	0.74
black_gore_ck_nr_vail	48.62	12.12	7.43	0.23	0.18	0.23	0.19	0.21	0.33
cross_ck_nr_minturn	129.21	43.70	22.34	0.67	0.48	0.46	0.51	0.53	0.57
eagle_red_cliff	55.04	25.31	18.03	0.30	0.25	0.22	0.22	0.25	0.28
gore_ck_at_upper_station	70.15	20.58	9.54	0.47	0.44	0.38	0.47	0.54	0.58
gypsum_ck_nr_gypsum	48.53	31.89	26.37	0.16	0.15	0.18	0.15	0.13	0.12
alkali_ck_nr_wolcott	1.56	0.92	0.62	0.95	0.87	1.59	1.25	1.15	1.14
bighorn_ck_nr_minturn	21.80	7.28	3.60	0.55	0.48	0.40	0.42	0.55	0.53
booth_ck_nr_minturn	24.07	5.66	2.96	0.60	0.70	0.50	0.48	0.56	0.76
brush_ck_nr_eagle	73.46	39.66	31.29	0.22	0.16	0.13	0.11	0.11	0.12
eagle_at_avon	721.43	253.14	144.24	0.28	0.22	0.19	0.26	0.23	0.31
eagle_at_eagle	1299.73	446.33	266.42	0.25	0.21	0.13	0.09	0.12	0.19
eagle_bl_gypsum	993.44	382.22	267.02	0.33	0.18	0.14	0.12	0.14	0.18
eagle_bl_ww_treatment_at_avon	255.28	137.29	110.37	0.24	0.06	0.18	0.10	0.15	0.18
eagle_nr_minturn	191.17	83.93	54.25	0.29	0.18	0.20	0.22	0.23	0.28
east_brush_ck_nr_eagle	27.15	11.82	8.39	0.43	0.20	0.30	0.30	0.27	0.27
gore_ck_abv_red_sndstn_ck	77.43	36.48	29.18	0.07	0.12	0.07	0.15	0.20	0.23
gore_ck_at_mouth	179.38	64.47	38.83	0.24	0.21	0.15	0.18	0.14	0.30
gore_ck_at_vail	240.51	52.67	22.00	0.29	0.09	0.19	0.12	0.13	0.32
gore_ck_lower_station_at_vail	232.31	62.71	32.99	0.30	0.24	0.26	0.32	0.26	0.33
gore_ck_nr_minturn	232.79	73.70	33.87	0.27	0.25	0.16	0.11	0.15	0.21
lake_ck_nr_edwards	120.13	57.68	33.65	0.29	0.26	0.22	0.21	0.16	0.16
middle_ck_nr_minturn	12.56	3.12	1.62	0.68	0.75	0.68	1.00	1.16	0.98
missouri_ck_nr_gold_park	19.82	9.11	4.82	0.59	0.52	0.45	0.43	0.46	0.42
pitkin_ck_nr_minturn	28.86	9.44	5.08	0.44	0.26	0.27	0.38	0.43	0.39
red_sandstone_ck_nr_minturn	11.76	3.54	2.18	0.47	0.38	0.32	0.33	0.32	0.27
turkey_ck_nr_red_cliff	46.06	13.85	7.95	0.24	0.23	0.20	0.21	0.23	0.28
wearyman_ck_nr_red_cliff	20.66	6.65	3.80	0.24	0.19	0.19	0.20	0.24	0.24

Table F.3c: Comprehensive output table.

GageID	CV_Apr	CV_May	CV_Jun	CV_Jul	CV_Aug	CV_Sep	Mn1d (cfs)	CV Mn1d	Mn3d (cfs)
beaver_ck_at_avon	0.35	0.46	0.42	0.70	0.58	0.38	0.12	0.31	0.13
homestake_ck_at_gold_park	0.45	0.65	0.85	0.92	0.66	0.41	0.12	0.37	0.12
homestake_ck_nr_red_cliff	0.52	0.50	0.66	0.85	0.63	0.60	0.10	0.49	0.10
turkey_ck_at_red_cliff	0.55	0.35	0.37	0.41	0.37	0.40	0.07	0.69	0.07
black_gore_ck_nr_minturn	0.49	0.41	0.43	0.66	0.53	0.42	0.14	0.40	0.15
black_gore_ck_nr_vail	0.46	0.53	0.42	0.56	0.31	0.40	0.13	0.15	0.13
cross_ck_nr_minturn	0.51	0.37	0.27	0.62	0.60	0.54	0.06	0.61	0.06
eagle_red_cliff	0.52	0.53	0.53	0.53	0.40	0.36	0.10	0.30	0.11
gore_ck_at_upper_station	0.44	0.34	0.30	0.62	0.69	0.44	0.16	0.44	0.17
gypsum_ck_nr_gypsum	0.11	0.37	0.46	0.31	0.20	0.19	0.22	0.18	0.24
alkali_ck_nr_wolcott	1.45	0.92	1.07	0.90	0.61	1.06	0.00	2.65	0.00
bighorn_ck_nr_minturn	0.52	0.41	0.35	0.64	0.63	0.44	0.13	0.55	0.14
booth_ck_nr_minturn	0.56	0.37	0.37	0.74	0.63	0.54	0.11	0.60	0.12
brush_ck_nr_eagle	0.30	0.34	0.38	0.60	0.33	0.28	0.20	0.13	0.21
eagle_at_avon	0.38	0.37	0.36	0.65	0.49	0.25	0.11	0.19	0.11
eagle_at_eagle	0.26	0.22	0.30	0.38	0.35	0.30	0.15	0.10	0.15
eagle_bl_gypsum	0.37	0.39	0.39	0.66	0.53	0.38	0.14	0.15	0.15
eagle_bl_ww_treatment_at_avon	0.14	0.49	0.45	0.48	0.47	0.27	0.09	0.19	0.11
eagle_nr_minturn	0.38	0.43	0.53	0.80	0.49	0.22	0.11	0.25	0.11
east_brush_ck_nr_eagle	0.33	0.50	0.26	0.28	0.39	0.39	0.22	0.37	0.23
gore_ck_abv_red_sndstn_ck	0.14	0.43	0.42	0.46	0.43	0.26	0.14	0.17	0.15
gore_ck_at_mouth	0.26	0.40	0.53	0.52	0.46	0.25	0.15	0.17	0.15
gore_ck_at_vail	0.39	0.53	0.36	0.61	0.37	0.28	0.08	0.21	0.09
gore_ck_lower_station_at_vail	0.40	0.39	0.39	0.74	0.48	0.25	0.12	0.22	0.12
gore_ck_nr_minturn	0.60	0.33	0.31	0.54	0.36	0.23	0.14	0.16	0.15
lake_ck_nr_edwards	0.27	0.38	0.42	0.68	0.65	0.34	0.18	0.21	0.19
middle_ck_nr_minturn	0.81	0.51	0.37	0.78	0.86	0.84	0.03	0.95	0.03
missouri_ck_nr_gold_park	0.58	0.56	0.54	0.86	0.64	0.47	0.08	0.42	0.09
pitkin_ck_nr_minturn	0.41	0.40	0.36	0.72	0.68	0.33	0.18	0.33	0.19
red_sandstone_ck_nr_minturn	0.43	0.43	0.45	0.70	0.72	0.41	0.10	0.32	0.11
turkey_ck_nr_red_cliff	0.52	0.47	0.46	0.67	0.44	0.33	0.10	0.26	0.11
wearyman_ck_nr_red_cliff	0.36	0.56	0.39	0.61	0.49	0.37	0.10	0.24	0.11

Table F.3d: Comprehensive output table.

GageID	CV Mn3d	Mn7d (cfs)	CV Mn7d	Mn30d (cfs)	CV Mn30d	Mn90d (cfs)	CV Mn90d	Mx1d (cfs)	CV Mx1d
beaver_ck_at_avon	0.29	0.13	0.28	0.15	0.27	0.17	0.26	6.70	0.47
homestake_ck_at_gold_park	0.38	0.13	0.38	0.14	0.38	0.15	0.37	8.46	0.70
homestake_ck_nr_red_cliff	0.47	0.11	0.45	0.12	0.42	0.13	0.41	8.31	0.55
turkey_ck_at_red_cliff	0.64	0.07	0.63	0.08	0.60	0.09	0.55	9.29	0.37
black_gore_ck_nr_minturn	0.38	0.15	0.37	0.17	0.38	0.19	0.40	12.83	0.34
black_gore_ck_nr_vail	0.15	0.14	0.15	0.15	0.16	0.17	0.18	12.27	0.38
cross_ck_nr_minturn	0.61	0.07	0.61	0.08	0.57	0.09	0.51	12.55	0.24
eagle_red_cliff	0.26	0.12	0.22	0.13	0.21	0.14	0.19	5.01	0.54
gore_ck_at_upper_station	0.44	0.18	0.45	0.19	0.49	0.21	0.45	17.88	0.32
gypsum_ck_nr_gypsum	0.14	0.25	0.13	0.27	0.13	0.29	0.12	2.57	0.49
alkali_ck_nr_wolcott	2.65	0.00	2.65	0.00	1.26	0.00	1.17	0.73	0.64
bighorn_ck_nr_minturn	0.50	0.15	0.48	0.16	0.46	0.18	0.45	18.49	0.40
booth_ck_nr_minturn	0.56	0.13	0.54	0.14	0.54	0.16	0.52	18.28	0.35
brush_ck_nr_eagle	0.13	0.22	0.11	0.23	0.10	0.25	0.10	3.43	0.43
eagle_at_avon	0.19	0.12	0.19	0.13	0.22	0.14	0.22	6.26	0.31
eagle_at_eagle	0.10	0.15	0.10	0.15	0.10	0.17	0.07	7.51	0.25
eagle_bl_gypsum	0.15	0.16	0.16	0.17	0.15	0.19	0.13	3.74	0.36
eagle_bl_ww_treatment_at_avon	0.29	0.12	0.32	0.14	0.14	0.16	0.09	4.98	0.53
eagle_nr_minturn	0.24	0.12	0.21	0.14	0.23	0.15	0.20	4.37	0.50
east_brush_ck_nr_eagle	0.35	0.23	0.34	0.24	0.32	0.27	0.29	12.14	0.26
gore_ck_abv_red_sndstn_ck	0.17	0.16	0.19	0.19	0.16	0.21	0.17	10.43	0.51
gore_ck_at_mouth	0.17	0.16	0.17	0.17	0.13	0.19	0.15	9.66	0.41
gore_ck_at_vail	0.19	0.09	0.19	0.10	0.17	0.11	0.15	14.12	0.26
gore_ck_lower_station_at_vail	0.23	0.13	0.23	0.14	0.27	0.16	0.27	12.46	0.31
gore_ck_nr_minturn	0.15	0.15	0.13	0.16	0.13	0.17	0.13	9.91	0.29
lake_ck_nr_edwards	0.23	0.20	0.22	0.22	0.16	0.24	0.17	9.17	0.45
middle_ck_nr_minturn	0.90	0.04	0.86	0.05	0.96	0.06	0.84	9.53	0.35
missouri_ck_nr_gold_park	0.44	0.09	0.47	0.10	0.46	0.11	0.40	11.62	0.47
pitkin_ck_nr_minturn	0.31	0.19	0.30	0.22	0.28	0.26	0.35	16.14	0.42
red_sandstone_ck_nr_minturn	0.31	0.11	0.29	0.13	0.30	0.14	0.29	12.26	0.40
turkey_ck_nr_red_cliff	0.25	0.11	0.25	0.12	0.23	0.13	0.21	8.13	0.54
wearyman_ck_nr_red_cliff	0.23	0.12	0.22	0.13	0.22	0.14	0.20	7.52	0.44

Table F.3e: Comprehensive output table.

GageID	Mx3d (cfs)	CV Mx3d	Mx7d (cfs)	CV Mx7d	Mx30d (cfs)	CV Mx30d	Mx90d (cfs)	CV Mx90d	ZeroD (days)
beaver_ck_at_avon	6.32	0.45	5.84	0.45	4.45	0.42	2.71	0.40	0.00
homestake_ck_at_gold_park	7.60	0.72	6.72	0.75	4.72	0.81	2.91	0.72	0.00
homestake_ck_nr_red_cliff	7.64	0.56	6.94	0.57	5.28	0.59	3.38	0.57	0.00
turkey_ck_at_red_cliff	8.78	0.36	8.23	0.36	6.03	0.34	3.29	0.30	0.00
black_gore_ck_nr_minturn	12.33	0.34	11.43	0.34	8.51	0.32	4.49	0.32	0.00
black_gore_ck_nr_vail	11.95	0.38	11.09	0.38	8.70	0.39	4.99	0.36	0.00
cross_ck_nr_minturn	11.66	0.24	10.55	0.25	8.01	0.28	5.03	0.27	0.00
eagle_red_cliff	4.78	0.53	4.45	0.52	3.44	0.52	1.99	0.46	0.00
gore_ck_at_upper_station	16.60	0.30	15.16	0.28	11.55	0.29	6.89	0.29	0.00
gypsum_ck_nr_gypsum	2.47	0.48	2.32	0.47	1.73	0.44	1.04	0.34	0.00
alkali_ck_nr_wolcott	0.61	0.73	0.55	0.80	0.39	1.03	0.25	1.08	69.29
bighorn_ck_nr_minturn	17.14	0.38	15.46	0.36	11.59	0.33	7.17	0.33	0.00
booth_ck_nr_minturn	16.88	0.34	15.42	0.34	11.65	0.33	6.80	0.29	0.00
brush_ck_nr_eagle	3.26	0.43	3.04	0.42	2.36	0.37	1.47	0.33	0.00
eagle_at_avon	6.07	0.31	5.82	0.30	4.76	0.31	3.08	0.32	0.00
eagle_at_eagle	7.31	0.26	6.90	0.26	5.42	0.27	3.34	0.22	0.00
eagle_bl_gypsum	3.58	0.36	3.34	0.36	2.63	0.36	1.66	0.37	0.00
eagle_bl_ww_treatment_at_avon	4.78	0.52	4.30	0.50	3.38	0.45	2.07	0.44	0.00
eagle_nr_minturn	4.19	0.50	3.96	0.49	3.15	0.45	2.01	0.43	0.00
east_brush_ck_nr_eagle	11.39	0.25	10.45	0.24	7.67	0.20	4.60	0.19	0.00
gore_ck_abv_red_sndstn_ck	10.08	0.50	9.00	0.49	6.58	0.43	3.69	0.41	0.00
gore_ck_at_mouth	9.40	0.41	8.80	0.42	6.75	0.43	4.09	0.42	0.00
gore_ck_at_vail	13.48	0.26	12.50	0.25	9.68	0.34	5.83	0.32	0.00
gore_ck_lower_station_at_vail	11.94	0.32	11.27	0.32	8.87	0.34	5.20	0.34	0.00
gore_ck_nr_minturn	9.49	0.29	8.97	0.29	7.01	0.28	4.19	0.25	0.00
lake_ck_nr_edwards	8.37	0.45	7.16	0.39	5.28	0.35	3.42	0.36	0.00
middle_ck_nr_minturn	9.14	0.34	8.48	0.34	6.23	0.35	3.39	0.37	6.05
missouri_ck_nr_gold_park	10.11	0.47	8.55	0.49	5.72	0.57	3.62	0.54	0.00
pitkin_ck_nr_minturn	15.36	0.42	14.13	0.41	11.01	0.38	6.93	0.36	0.00
red_sandstone_ck_nr_minturn	11.71	0.40	10.84	0.39	7.98	0.34	4.21	0.33	0.00
turkey_ck_nr_red_cliff	7.66	0.52	6.99	0.50	5.28	0.44	3.02	0.43	0.00
wearyman_ck_nr_red_cliff	7.19	0.42	6.75	0.41	5.05	0.41	2.82	0.40	0.00

Table F.3f: Comprehensive output table.

GageID	CV ZeroD	BaseQ	CV BaseQ	DatMn (day of yr)	CV DatMn	DatMx (day of yr)	CV DatMx	NLoPl	CV NLoPl
beaver_ck_at_avon	0.00	0.16	0.36	135.48	1.00	163.11	0.06	6.11	0.66
homestake_ck_at_gold_park	0.00	0.16	0.46	122.19	0.97	164.08	0.10	2.84	0.77
homestake_ck_nr_red_cliff	0.00	0.12	0.54	135.21	0.96	156.64	0.10	4.03	0.86
turkey_ck_at_red_cliff	0.00	0.08	0.50	115.80	1.10	161.00	0.05	3.40	0.86
black_gore_ck_nr_minturn	0.00	0.12	0.42	90.38	1.16	155.67	0.07	3.65	0.76
black_gore_ck_nr_vail	0.00	0.11	0.41	105.33	1.08	159.17	0.04	3.50	1.21
cross_ck_nr_minturn	0.00	0.05	0.55	77.21	1.38	165.71	0.07	3.05	0.80
eagle_red_cliff	0.00	0.20	0.38	163.56	0.89	152.44	0.07	6.95	0.64
gore_ck_at_upper_station	0.00	0.09	0.42	55.54	1.15	162.92	0.07	2.85	0.82
gypsum_ck_nr_gypsum	0.00	0.50	0.18	74.25	1.22	164.00	0.06	0.00	0.00
alkali_ck_nr_wolcott	0.79	0.01	2.65	290.43	0.16	147.14	0.33	3.00	0.58
bighorn_ck_nr_minturn	0.00	0.07	0.47	73.08	1.34	159.74	0.08	2.05	0.73
booth_ck_nr_minturn	0.00	0.06	0.46	101.29	1.07	161.79	0.08	3.03	0.76
brush_ck_nr_eagle	0.00	0.37	0.24	69.82	1.40	162.32	0.08	6.41	0.43
eagle_at_avon	0.00	0.13	0.23	207.55	0.80	155.45	0.07	5.36	0.56
eagle_at_eagle	0.00	0.15	0.22	38.46	2.16	160.62	0.06	3.31	0.87
eagle_bl_gypsum	0.00	0.28	0.27	163.36	0.89	160.13	0.07	9.82	0.42
eagle_bl_ww_treatment_at_avon	0.00	0.18	0.18	299.33	0.14	152.33	0.01	14.67	0.24
eagle_nr_minturn	0.00	0.20	0.34	222.15	0.70	153.85	0.07	6.92	0.59
east_brush_ck_nr_eagle	0.00	0.16	0.41	42.43	0.90	164.43	0.07	3.14	1.14
gore_ck_abv_red_sndstn_ck	0.00	0.15	0.24	205.33	0.63	152.33	0.01	7.00	0.38
gore_ck_at_mouth	0.00	0.13	0.28	76.71	0.99	154.71	0.07	4.29	0.58
gore_ck_at_vail	0.00	0.06	0.27	99.67	1.33	164.67	0.07	3.00	0.47
gore_ck_lower_station_at_vail	0.00	0.09	0.34	67.73	1.44	161.55	0.07	3.36	0.76
gore_ck_nr_minturn	0.00	0.13	0.28	104.33	1.40	158.50	0.08	7.00	0.57
lake_ck_nr_edwards	0.00	0.18	0.25	117.89	1.13	158.56	0.08	5.33	0.48
middle_ck_nr_minturn	4.21	0.04	0.74	115.45	0.94	165.95	0.07	3.26	0.90
missouri_ck_nr_gold_park	0.00	0.08	0.54	87.93	1.25	168.97	0.11	2.90	0.67
pitkin_ck_nr_minturn	0.00	0.10	0.37	82.19	1.16	163.92	0.08	2.31	0.57
red_sandstone_ck_nr_minturn	0.00	0.10	0.37	128.51	1.05	154.08	0.06	5.38	0.64
turkey_ck_nr_red_cliff	0.00	0.13	0.37	84.10	1.42	163.77	0.06	3.49	0.63
wearyman_ck_nr_red_cliff	0.00	0.15	0.43	96.61	1.33	165.71	0.05	5.21	0.78

Table F.3g: Comprehensive output table.

GageID	DLoPl (days)	CV DLoPl	NHiPl	CV NHiPl	DHiPl (days)	CV DHiPl	RiseR (cfs/day)	CV RiseR	FallR (cfs/day)
beaver_ck_at_avon	15.26	0.95	1.89	0.54	27.29	0.66	1.65	0.39	-1.33
homestake_ck_at_gold_park	34.70	0.99	3.08	0.63	8.40	1.16	8.97	0.72	-6.32
homestake_ck_nr_red_cliff	25.47	1.15	2.89	0.64	12.29	0.92	14.27	0.65	-10.47
turkey_ck_at_red_cliff	32.15	1.25	1.50	0.55	25.40	0.56	5.32	0.45	-3.88
black_gore_ck_nr_minturn	25.59	1.07	1.46	0.47	29.32	0.52	3.14	0.38	-2.07
black_gore_ck_nr_vail	47.44	0.75	2.17	0.54	27.25	0.83	5.43	0.45	-3.56
cross_ck_nr_minturn	45.86	1.00	3.88	0.43	14.86	0.64	10.84	0.21	-7.97
eagle_red_cliff	14.82	1.21	1.60	0.62	24.98	0.71	7.33	0.71	-5.89
gore_ck_at_upper_station	40.17	0.86	2.50	0.47	22.27	0.65	6.30	0.36	-4.21
gypsum_ck_nr_gypsum	0.00	0.00	1.42	0.56	23.58	0.62	3.19	0.26	-2.43
alkali_ck_nr_wolcott	20.47	0.85	2.00	0.91	17.96	1.91	0.90	0.48	-0.54
bighorn_ck_nr_minturn	53.41	0.69	2.41	0.47	22.06	0.74	2.28	0.43	-1.56
booth_ck_nr_minturn	35.58	0.85	2.61	0.55	23.31	0.74	2.95	0.47	-1.99
brush_ck_nr_eagle	12.50	0.68	2.68	0.52	16.08	0.66	6.30	0.28	-4.68
eagle_at_avon	27.36	1.47	1.91	0.64	35.09	0.61	41.95	0.24	-29.70
eagle_at_eagle	56.11	0.71	2.77	0.53	23.66	0.80	121.60	0.33	-87.90
eagle_bl_gypsum	9.12	0.88	2.48	0.56	22.63	0.78	59.32	0.32	-44.63
eagle_bl_ww_treatment_at_avon	5.79	0.27	2.33	0.25	17.06	0.72	36.38	0.54	-25.12
eagle_nr_minturn	16.31	0.79	1.77	0.62	27.71	0.76	14.65	0.36	-10.83
east_brush_ck_nr_eagle	48.87	0.96	3.57	0.42	15.27	0.65	3.29	0.31	-2.35
gore_ck_abv_red_sndstn_ck	13.30	0.70	2.00	0.00	20.17	0.48	14.68	0.40	-10.07
gore_ck_at_mouth	24.16	0.63	1.71	0.73	32.04	0.76	17.61	0.36	-12.30
gore_ck_at_vail	41.27	0.78	2.33	0.52	24.20	0.73	17.38	0.34	-12.35
gore_ck_lower_station_at_vail	41.22	1.06	1.82	0.54	31.12	0.60	18.40	0.38	-12.69
gore_ck_nr_minturn	22.07	0.88	2.17	0.68	28.91	0.68	20.25	0.29	-13.44
lake_ck_nr_edwards	11.27	0.61	3.89	0.45	14.82	0.78	10.88	0.30	-7.66
middle_ck_nr_minturn	39.10	1.08	1.74	0.59	29.51	0.62	1.06	0.43	-0.70
missouri_ck_nr_gold_park	41.91	1.14	4.07	0.34	8.61	0.78	2.13	0.37	-1.53
pitkin_ck_nr_minturn	46.90	0.80	2.72	0.45	23.34	0.81	2.41	0.46	-1.66
red_sandstone_ck_nr_minturn	25.94	1.51	1.69	0.53	26.86	0.58	1.61	0.38	-1.12
turkey_ck_nr_red_cliff	31.96	1.11	1.59	0.51	29.37	0.65	3.29	0.55	-2.42
wearyman_ck_nr_red_cliff	31.50	1.22	1.29	0.47	31.72	0.57	1.23	0.57	-0.89

Table F.3h: Comprehensive output table.

GageID	CV FallR	Revs	CV Revs	Ma3	Ma40	Ma41 (feet)	Ma44	Ml13	Ml14
beaver_ck_at_avon	-0.40	114.67	0.15	1.63	1.57	1.01	9.17	1.18	0.41
homestake_ck_at_gold_park	-0.62	93.46	0.27	2.02	1.38	1.09	9.83	1.17	0.38
homestake_ck_nr_red_cliff	-0.62	88.39	0.28	1.83	2.05	1.22	13.79	1.41	0.35
turkey_ck_at_red_cliff	-0.48	86.80	0.18	1.93	3.01	1.10	14.96	1.46	0.32
black_gore_ck_nr_minturn	-0.36	72.60	0.26	1.96	3.13	1.52	14.43	1.39	0.46
black_gore_ck_nr_vail	-0.42	69.50	0.35	1.92	3.36	1.65	19.92	1.42	0.44
cross_ck_nr_minturn	-0.22	107.71	0.16	1.71	1.94	1.72	18.17	1.69	0.18
eagle_red_cliff	-0.89	93.77	0.18	1.73	1.70	0.75	7.92	0.83	0.42
gore_ck_at_upper_station	-0.39	79.25	0.21	1.77	2.49	2.34	16.19	1.68	0.35
gypsum_ck_nr_gypsum	-0.27	88.08	0.12	0.93	0.34	0.58	1.70	0.27	0.61
alkali_ck_nr_wolcott	-0.38	65.14	0.19	2.35	1.74	0.09	14.69	1.81	0.03
bighorn_ck_nr_minturn	-0.44	72.90	0.25	1.78	2.09	2.45	15.40	1.61	0.25
booth_ck_nr_minturn	-0.45	79.39	0.22	1.92	3.11	2.24	20.07	1.72	0.29
brush_ck_nr_eagle	-0.28	90.32	0.11	1.13	0.65	0.70	3.64	0.56	0.59
eagle_at_avon	-0.22	121.36	0.16	1.57	2.03	1.11	11.62	1.42	0.37
eagle_at_eagle	-0.36	65.00	0.30	1.53	1.78	1.22	9.51	1.26	0.44
eagle_bl_gypsum	-0.30	125.66	0.09	1.37	1.16	0.68	5.91	0.76	0.53
eagle_bl_ww_treatment_at_avon	-0.40	126.33	0.06	1.57	1.58	0.78	7.40	1.11	0.37
eagle_nr_minturn	-0.35	113.92	0.13	1.54	1.55	0.77	8.14	0.92	0.42
east_brush_ck_nr_eagle	-0.27	88.86	0.20	1.55	1.39	1.73	8.17	1.34	0.40
gore_ck_abv_red_sndstn_ck	-0.40	100.00	0.06	1.81	2.22	1.31	9.58	1.31	0.43
gore_ck_at_mouth	-0.33	108.29	0.04	1.77	2.38	1.44	10.86	1.33	0.40
gore_ck_at_vail	-0.31	82.50	0.14	1.88	3.92	1.89	21.92	1.70	0.29
gore_ck_lower_station_at_vail	-0.33	101.91	0.11	1.86	3.00	1.74	16.58	1.80	0.36
gore_ck_nr_minturn	-0.30	94.33	0.14	1.70	3.03	1.44	14.22	1.35	0.49
lake_ck_nr_edwards	-0.31	105.22	0.09	1.46	1.21	1.34	6.55	1.03	0.38
middle_ck_nr_minturn	-0.44	70.08	0.30	2.08	3.47	1.09	22.68	2.11	0.19
missouri_ck_nr_gold_park	-0.44	93.60	0.21	1.84	1.51	1.35	10.09	1.25	0.23
pitkin_ck_nr_minturn	-0.51	71.83	0.27	1.69	1.78	2.45	12.05	1.49	0.28
red_sandstone_ck_nr_minturn	-0.37	85.72	0.21	2.05	3.28	1.38	17.73	1.47	0.42
turkey_ck_nr_red_cliff	-0.57	85.51	0.23	1.89	2.16	1.05	11.78	1.23	0.41
wearyman_ck_nr_red_cliff	-0.54	75.76	0.25	1.83	2.38	1.00	10.21	1.25	0.41

Table F.3i: Comprehensive output table.

GageID	Ml22 (cfs/mi^2)	Mh1 (cfs)	Mh8 (cfs)	Mh17	Fl3	Fh11	Dl13	Dh12
beaver_ck_at_avon	0.12	0.57	4.07	0.64	0.04	0.48	15.12	137.42
homestake_ck_at_gold_park	0.12	0.87	7.23	0.56	0.00	0.49	13.42	153.86
homestake_ck_nr_red_cliff	0.10	1.15	7.40	0.53	0.26	0.48	12.10	166.37
turkey_ck_at_red_cliff	0.07	0.35	4.78	0.48	0.80	0.40	10.57	252.68
black_gore_ck_nr_minturn	0.14	0.85	10.35	0.73	0.00	0.48	16.37	265.26
black_gore_ck_nr_vail	0.13	0.38	7.94	0.62	0.00	0.50	14.82	257.88
cross_ck_nr_minturn	0.06	1.45	6.46	0.36	0.98	0.40	7.27	229.65
eagle_red_cliff	0.10	0.45	5.52	0.75	0.04	0.45	18.26	145.31
gore_ck_at_upper_station	0.16	1.38	8.04	0.51	0.04	0.44	11.78	218.29
gypsum_ck_nr_gypsum	0.22	0.51	0.94	0.84	0.00	0.42	22.40	44.21
alkali_ck_nr_wolcott	0.00	0.04	0.97	0.31	2.14	0.43	1.71	208.34
bighorn_ck_nr_minturn	0.13	1.77	11.57	0.42	0.54	0.51	9.09	204.74
booth_ck_nr_minturn	0.11	1.38	9.63	0.52	0.66	0.47	10.55	282.59
brush_ck_nr_eagle	0.20	0.59	2.18	0.77	0.00	0.41	19.85	60.72
eagle_at_avon	0.11	0.43	4.70	0.58	0.00	0.55	14.16	145.00
eagle_at_eagle	0.15	0.53	4.38	0.60	0.00	0.54	13.83	144.62
eagle_bl_gypsum	0.14	0.56	2.88	0.78	0.00	0.45	20.01	91.32
eagle_bl_ww_treatment_at_avon	0.09	0.32	4.14	0.74	0.00	1.00	17.82	130.22
eagle_nr_minturn	0.11	0.37	3.90	0.67	0.00	0.46	16.63	112.17
east_brush_ck_nr_eagle	0.22	1.27	6.19	0.57	0.00	0.43	13.67	136.98
gore_ck_abv_red_sndstn_ck	0.14	0.36	6.89	0.71	0.00	0.67	17.65	194.20
gore_ck_at_mouth	0.15	0.48	6.65	0.64	0.00	0.71	14.94	179.57
gore_ck_at_vail	0.08	0.44	8.07	0.48	0.67	0.50	11.47	334.21
gore_ck_lower_station_at_vail	0.12	0.50	6.61	0.57	0.09	0.64	12.32	233.99
gore_ck_nr_minturn	0.14	0.47	5.78	0.66	0.00	0.42	16.55	211.33
lake_ck_nr_edwards	0.18	0.92	4.02	0.58	0.00	0.56	13.97	106.71
middle_ck_nr_minturn	0.03	0.66	4.30	0.49	1.34	0.50	8.53	383.38
missouri_ck_nr_gold_park	0.08	1.14	6.53	0.42	0.33	0.53	8.60	173.82
pitkin_ck_nr_minturn	0.18	1.77	9.24	0.49	0.14	0.50	10.67	159.45
red_sandstone_ck_nr_minturn	0.10	0.70	9.55	0.64	0.18	0.41	15.22	308.49
turkey_ck_nr_red_cliff	0.10	0.51	4.31	0.61	0.03	0.49	14.75	200.74
wearyman_ck_nr_red_cliff	0.10	0.53	3.60	0.61	0.03	0.50	14.95	187.60

Table F.3j: Comprehensive output table.

GageID	Dh13	Th3	SS1	PMAR_Oct	PMAR_Nov	PMAR_Dec	PMAR_Jan	PMAR_Feb	PMAR_Mar
beaver_ck_at_avon	449.37	0.13	0.48	0.03	0.02	0.02	0.02	0.01	0.02
homestake_ck_at_gold_park	463.47	0.17	0.29	0.03	0.02	0.02	0.01	0.01	0.01
homestake_ck_nr_red_cliff	542.48	0.18	0.21	0.03	0.02	0.01	0.01	0.01	0.01
turkey_ck_at_red_cliff	794.16	0.05	0.26	0.02	0.01	0.01	0.01	0.01	0.01
black_gore_ck_nr_minturn	846.79	0.11	0.40	0.02	0.02	0.01	0.01	0.01	0.01
black_gore_ck_nr_vail	867.32	0.02	0.25	0.02	0.01	0.01	0.01	0.01	0.01
cross_ck_nr_minturn	746.73	0.09	0.24	0.02	0.01	0.01	0.01	0.00	0.01
eagle_red_cliff	481.85	0.14	0.20	0.03	0.02	0.02	0.02	0.02	0.02
gore_ck_at_upper_station	712.64	0.11	0.28	0.02	0.01	0.01	0.01	0.01	0.01
gypsum_ck_nr_gypsum	141.75	0.06	0.20	0.07	0.06	0.05	0.05	0.04	0.05
alkali_ck_nr_wolcott	644.37	0.09	2.30	0.02	0.01	0.00	0.00	0.01	0.08
bighorn_ck_nr_minturn	657.55	0.14	0.65	0.02	0.01	0.01	0.01	0.01	0.01
booth_ck_nr_minturn	914.73	0.12	0.57	0.02	0.01	0.01	0.01	0.01	0.01
brush_ck_nr_eagle	201.98	0.09	0.19	0.05	0.04	0.04	0.04	0.03	0.03
eagle_at_avon	508.35	0.13	0.09	0.02	0.02	0.01	0.01	0.01	0.02
eagle_at_eagle	486.58	0.09	0.09	0.03	0.02	0.02	0.01	0.01	0.02
eagle_bl_gypsum	307.67	0.16	0.09	0.04	0.03	0.03	0.03	0.02	0.03
eagle_bl_ww_treatment_at_avon	437.94	0.05	0.11	0.03	0.02	0.02	0.02	0.02	0.02
eagle_nr_minturn	382.44	0.18	0.12	0.03	0.02	0.02	0.02	0.02	0.02
east_brush_ck_nr_eagle	431.26	0.03	0.43	0.04	0.02	0.02	0.02	0.01	0.02
gore_ck_abv_red_sndstn_ck	608.83	0.04	0.14	0.02	0.02	0.02	0.02	0.01	0.02
gore_ck_at_mouth	590.31	0.03	0.12	0.02	0.02	0.01	0.01	0.01	0.02
gore_ck_at_vail	1109.20	0.04	0.15	0.01	0.01	0.01	0.01	0.01	0.01
gore_ck_lower_station_at_vail	788.70	0.06	0.13	0.02	0.01	0.01	0.01	0.01	0.01
gore_ck_nr_minturn	707.74	0.05	0.12	0.02	0.02	0.01	0.01	0.01	0.01
lake_ck_nr_edwards	337.70	0.03	0.20	0.04	0.03	0.02	0.02	0.02	0.02
middle_ck_nr_minturn	1207.23	0.12	1.01	0.02	0.01	0.01	0.01	0.00	0.01
missouri_ck_nr_gold_park	498.76	0.14	0.86	0.04	0.02	0.01	0.01	0.01	0.01
pitkin_ck_nr_minturn	532.36	0.15	0.55	0.03	0.02	0.01	0.01	0.01	0.01
red_sandstone_ck_nr_minturn	973.03	0.11	0.69	0.02	0.01	0.01	0.01	0.01	0.01
turkey_ck_nr_red_cliff	650.49	0.14	0.32	0.02	0.02	0.01	0.01	0.01	0.01
wearyman_ck_nr_red_cliff	601.19	0.11	0.70	0.03	0.02	0.02	0.01	0.01	0.01

Table F.3k: Comprehensive output table.

GageID	PMAR_Apr	PMAR_May	PMAR_Jun	PMAR_Jul	PMAR_Aug	PMAR_Sep
beaver_ck_at_avon	0.04	0.19	0.37	0.18	0.06	0.04
homestake_ck_at_gold_park	0.04	0.21	0.35	0.18	0.08	0.04
homestake_ck_nr_red_cliff	0.06	0.25	0.35	0.16	0.06	0.03
turkey_ck_at_red_cliff	0.04	0.23	0.47	0.13	0.04	0.02
black_gore_ck_nr_minturn	0.04	0.27	0.44	0.11	0.04	0.02
black_gore_ck_nr_vail	0.03	0.23	0.46	0.14	0.04	0.02
cross_ck_nr_minturn	0.03	0.20	0.39	0.21	0.07	0.04
eagle_red_cliff	0.06	0.29	0.34	0.10	0.05	0.03
gore_ck_at_upper_station	0.03	0.19	0.42	0.20	0.06	0.03
gypsum_ck_nr_gypsum	0.05	0.09	0.26	0.13	0.08	0.07
alkali_ck_nr_wolcott	0.25	0.36	0.14	0.06	0.04	0.02
bighorn_ck_nr_minturn	0.03	0.21	0.40	0.19	0.06	0.03
booth_ck_nr_minturn	0.04	0.23	0.43	0.17	0.04	0.02
brush_ck_nr_eagle	0.05	0.15	0.29	0.14	0.08	0.06
eagle_at_avon	0.05	0.25	0.36	0.16	0.06	0.03
eagle_at_eagle	0.04	0.22	0.38	0.16	0.06	0.03
eagle_bl_gypsum	0.05	0.20	0.33	0.15	0.06	0.04
eagle_bl_ww_treatment_at_avon	0.08	0.35	0.29	0.08	0.04	0.03
eagle_nr_minturn	0.06	0.26	0.33	0.13	0.06	0.04
east_brush_ck_nr_eagle	0.03	0.19	0.39	0.15	0.07	0.05
gore_ck_abv_red_sndstn_ck	0.06	0.36	0.33	0.07	0.03	0.03
gore_ck_at_mouth	0.05	0.28	0.39	0.12	0.04	0.02
gore_ck_at_vail	0.03	0.20	0.44	0.21	0.05	0.02
gore_ck_lower_station_at_vail	0.03	0.22	0.44	0.17	0.04	0.02
gore_ck_nr_minturn	0.04	0.24	0.41	0.15	0.05	0.02
lake_ck_nr_edwards	0.03	0.18	0.33	0.18	0.08	0.05
middle_ck_nr_minturn	0.02	0.18	0.49	0.19	0.05	0.02
missouri_ck_nr_gold_park	0.03	0.17	0.33	0.22	0.10	0.05
pitkin_ck_nr_minturn	0.03	0.18	0.38	0.21	0.07	0.04
red_sandstone_ck_nr_minturn	0.03	0.28	0.45	0.11	0.03	0.02
turkey_ck_nr_red_cliff	0.03	0.18	0.44	0.18	0.05	0.03
wearyman_ck_nr_red_cliff	0.02	0.13	0.43	0.21	0.07	0.04

Table F.4a: Comprehensive output table.

GageID	Avg_Oct (cfs)	Avg_Nov (cfs)	Avg_Dec (cfs)	Avg_Jan (cfs)	Avg_Feb (cfs)	Avg_Mar (cfs)	Avg_Apr (cfs)	Avg_May (cfs)	Avg_Jun (cfs)
black_Gore_Creek (1947-1985)	3.91	3.42	2.79	2.37	2.28	2.82	7.39	54.23	91.37
black_Gore_Creek (1993-2001)	3.76	3.21	3.07	3.24	3.27	3.69	7.94	52.67	83.84
Gore_Crk_Upper_Station (1947-1985)	7.29	4.99	3.73	3.19	3.05	3.57	11.45	65.84	153.73
Gore_Crk_Upper_Station (1993-2001)	8.35	4.96	3.49	2.94	2.93	3.99	12.09	76.71	141.18
eagle_River_Bl_Gypsum (1946-1992)	258.06	241.03	199.30	181.28	173.03	185.95	349.44	1317.15	2289.87
eagle_River_Bl_Gypsum (1993-2001)	267.42	239.07	193.47	187.11	181.43	208.39	357.50	1444.35	2107.03
eagle_River_Bl_Gypsum (1946-1964)	239.71	240.41	199.15	180.48	174.87	182.54	367.06	1382.08	2368.29
eagle_River_Bl_Gypsum (1965-1992)	270.52	241.45	199.40	181.83	171.78	188.27	337.48	1273.08	2236.66
eagle_River_Bl_Gypsum (1993-2001)	267.42	239.07	193.47	187.11	181.43	208.39	357.50	1444.35	2107.03
eagle_River_Bl_Gypsum (1946-1964)	239.71	240.41	199.15	180.48	174.87	182.54	367.06	1382.08	2368.29
eagle_River_Bl_Gypsum (1965-2001)	269.77	240.87	197.96	183.11	174.13	193.16	342.35	1314.74	2205.12
homestake_ck_at_gold_park (1947-1953)	11.47	8.32	5.87	4.71	4.30	4.44	20.69	164.64	353.70
homestake_ck_at_gold_park (1972-2001)	13.66	9.58	7.16	5.93	5.54	6.46	15.40	65.49	96.70
homestake_ck_nr_red_cliff (1910-1938)	18.11	12.09	8.85	7.57	7.33	9.35	57.10	258.71	429.72
homestake_ck_nr_red_cliff (1965-2001)	19.45	13.38	10.25	8.55	8.30	10.63	36.88	128.65	144.00
eagle_red_cliff (1910-1924)	19.11	15.29	12.66	12.30	12.40	14.89	50.51	256.88	286.78
eagle_red_cliff (1944-2001)	15.32	13.01	10.89	9.90	9.68	10.98	27.46	128.10	170.42

Table F.4b: Comprehensive output table.

GageID	Avg_Jul (cfs)	Avg_Aug (cfs)	Avg_Sep (cfs)	CV_Oct	CV_Nov	CV_Dec	CV_Jan	CV_Feb	CV_Mar
black_Gore_Creek (1947-1985)	22.47	7.41	4.35	0.51	0.53	0.58	0.48	0.59	0.85
black_Gore_Creek (1993-2001)	20.81	6.45	4.14	0.18	0.20	0.20	0.24	0.10	0.17
Gore_Crk_Upper_Station (1947-1985)	71.43	20.56	9.62	0.50	0.48	0.42	0.50	0.59	0.63
Gore_Crk_Upper_Station (1993-2001)	62.69	20.28	9.19	0.32	0.20	0.17	0.23	0.28	0.36
eagle_River_Bl_Gypsum (1946-1992)	1010.12	380.75	268.67	0.35	0.18	0.14	0.12	0.15	0.18
eagle_River_Bl_Gypsum (1993-2001)	906.36	389.87	258.42	0.25	0.18	0.13	0.13	0.13	0.20
eagle_River_Bl_Gypsum (1946-1964)	998.66	382.39	260.25	0.40	0.15	0.11	0.10	0.13	0.16
eagle_River_Bl_Gypsum (1965-1992)	1017.89	379.64	274.39	0.32	0.20	0.16	0.14	0.16	0.19
eagle_River_Bl_Gypsum (1993-2001)	906.36	389.87	258.42	0.25	0.18	0.13	0.13	0.13	0.20
eagle_River_Bl_Gypsum (1946-1964)	998.66	382.39	260.25	0.40	0.15	0.11	0.10	0.13	0.16
eagle_River_Bl_Gypsum (1965-2001)	990.76	382.13	270.50	0.30	0.19	0.15	0.14	0.15	0.19
homestake_ck_at_gold_park (1947-1953)	138.09	31.58	11.97	0.73	0.65	0.52	0.51	0.42	0.34
homestake_ck_at_gold_park (1972-2001)	59.66	31.55	16.80	0.45	0.33	0.39	0.37	0.37	0.37
homestake_ck_nr_red_cliff (1910-1938)	172.63	49.63	22.76	0.78	0.53	0.50	0.55	0.56	0.45
homestake_ck_nr_red_cliff (1965-2001)	71.85	37.06	21.90	0.52	0.42	0.40	0.40	0.40	0.40
eagle_red_cliff (1910-1924)	77.00	33.07	24.17	0.22	0.20	0.22	0.22	0.24	0.24
eagle_red_cliff (1944-2001)	50.11	23.40	16.49	0.31	0.25	0.21	0.18	0.22	0.25

Table F.4c: Comprehensive output table.

GageID	CV_Apr	CV_May	CV_Jun	CV_Jul	CV_Aug	CV_Sep	Mn1d (cfs)	CV Mn1d	Mn3d (cfs)
black_Gore_Creek (1947-1985)	0.52	0.40	0.41	0.61	0.55	0.44	1.74	0.44	1.79
black_Gore_Creek (1993-2001)	0.42	0.50	0.59	0.94	0.43	0.26	2.16	0.20	2.29
Gore_Crk_Upper_Station (1947-1985)	0.46	0.33	0.29	0.60	0.69	0.47	2.38	0.46	2.48
Gore_Crk_Upper_Station (1993-2001)	0.35	0.38	0.35	0.80	0.72	0.25	2.29	0.33	2.41
eagle_River_Bl_Gypsum (1946-1992)	0.40	0.39	0.37	0.63	0.52	0.40	133.62	0.12	141.25
eagle_River_Bl_Gypsum (1993-2001)	0.22	0.41	0.51	0.89	0.56	0.27	114.11	0.24	124.96
eagle_River_Bl_Gypsum (1946-1964)	0.45	0.36	0.37	0.70	0.48	0.45	130.21	0.10	136.23
eagle_River_Bl_Gypsum (1965-1992)	0.36	0.42	0.38	0.59	0.56	0.38	135.93	0.13	144.65
eagle_River_Bl_Gypsum (1993-2001)	0.22	0.41	0.51	0.89	0.56	0.27	114.11	0.24	124.96
eagle_River_Bl_Gypsum (1946-1964)	0.45	0.36	0.37	0.70	0.48	0.45	130.21	0.10	136.23
eagle_River_Bl_Gypsum (1965-2001)	0.32	0.41	0.40	0.65	0.55	0.35	130.62	0.17	139.86
homestake_ck_at_gold_park (1947-1953)	0.42	0.30	0.31	0.56	0.60	0.54	3.26	0.18	3.31
homestake_ck_at_gold_park (1972-2001)	0.44	0.57	0.64	0.96	0.71	0.38	4.38	0.37	4.61
homestake_ck_nr_red_cliff (1910-1938)	0.52	0.30	0.31	0.62	0.58	0.78	5.19	0.58	5.42
homestake_ck_nr_red_cliff (1965-2001)	0.38	0.47	0.56	0.88	0.66	0.41	5.94	0.42	6.23
eagle_red_cliff (1910-1924)	0.35	0.33	0.35	0.28	0.19	0.24	5.60	0.46	6.35
eagle_red_cliff (1944-2001)	0.47	0.47	0.53	0.59	0.44	0.34	7.13	0.25	7.62

Table F.4d: Comprehensive output table.

GageID	CV Mn3d	Mn7d (cfs)	CV Mn7d	Mn30d (cfs)	CV Mn30d	Mn90d (cfs)	CV Mn90d	Mx1d (cfs)	CV Mx1d
black_Gore_Creek (1947-1985)	0.42	1.84	0.40	1.98	0.41	2.25	0.44	162.26	0.31
black_Gore_Creek (1993-2001)	0.15	2.43	0.16	2.63	0.13	2.85	0.13	159.00	0.48
Gore_Crk_Upper_Station (1947-1985)	0.47	2.55	0.48	2.77	0.53	3.04	0.49	263.82	0.32
Gore_Crk_Upper_Station (1993-2001)	0.32	2.49	0.30	2.67	0.27	2.95	0.23	229.89	0.30
eagle_River_Bl_Gypsum (1946-1992)	0.13	149.24	0.14	159.78	0.14	174.20	0.13	3561.70	0.35
eagle_River_Bl_Gypsum (1993-2001)	0.25	143.18	0.27	167.20	0.21	181.56	0.13	3357.78	0.45
eagle_River_Bl_Gypsum (1946-1964)	0.11	145.09	0.13	154.82	0.13	171.74	0.10	3773.16	0.35
eagle_River_Bl_Gypsum (1965-1992)	0.13	152.06	0.14	163.15	0.14	175.87	0.15	3418.21	0.35
eagle_River_Bl_Gypsum (1993-2001)	0.25	143.18	0.27	167.20	0.21	181.56	0.13	3357.78	0.45
eagle_River_Bl_Gypsum (1946-1964)	0.11	145.09	0.13	154.82	0.13	171.74	0.10	3773.16	0.35
eagle_River_Bl_Gypsum (1965-2001)	0.17	149.90	0.17	164.13	0.15	177.26	0.14	3403.51	0.37
homestake_ck_at_gold_park (1947-1953)	0.18	3.40	0.19	3.83	0.29	4.06	0.24	637.14	0.28
homestake_ck_at_gold_park (1972-2001)	0.37	4.78	0.37	5.15	0.37	5.60	0.36	227.10	0.56
homestake_ck_nr_red_cliff (1910-1938)	0.54	5.61	0.49	5.87	0.43	6.40	0.42	716.86	0.28
homestake_ck_nr_red_cliff (1965-2001)	0.42	6.64	0.41	7.50	0.38	8.29	0.37	301.27	0.47
eagle_red_cliff (1910-1924)	0.37	7.96	0.24	10.21	0.19	11.44	0.15	565.33	0.33
eagle_red_cliff (1944-2001)	0.22	8.13	0.22	8.89	0.20	9.59	0.18	295.29	0.50

Table F.4e: Comprehensive output table.

GageID	Mx3d (cfs)	CV Mx3d	Mx7d (cfs)	CV Mx7d	Mx30d (cfs)	CV Mx30d	Mx90d (cfs)	CV Mx90d	ZeroD
black_Gore_Creek (1947-1985)	156.21	0.32	144.63	0.32	108.00	0.30	57.22	0.31	0.00
black_Gore_Creek (1993-2001)	151.67	0.47	141.27	0.46	104.07	0.42	53.96	0.40	0.00
Gore_Crk_Upper_Station (1947-1985)	243.97	0.30	222.57	0.28	168.65	0.29	99.77	0.28	0.00
Gore_Crk_Upper_Station (1993-2001)	217.52	0.29	199.76	0.28	156.04	0.29	97.16	0.32	0.00
eagle_River_Bl_Gypsum (1946-1992)	3405.18	0.35	3184.10	0.35	2498.81	0.35	1576.67	0.36	0.00
eagle_River_Bl_Gypsum (1993-2001)	3221.85	0.44	3014.92	0.44	2393.17	0.44	1533.12	0.42	0.00
eagle_River_Bl_Gypsum (1946-1964)	3613.16	0.36	3378.04	0.37	2650.99	0.34	1622.16	0.34	0.00
eagle_River_Bl_Gypsum (1965-1992)	3264.05	0.35	3052.50	0.34	2395.55	0.36	1545.80	0.38	0.00
eagle_River_Bl_Gypsum (1993-2001)	3221.85	0.44	3014.92	0.44	2393.17	0.44	1533.12	0.42	0.00
eagle_River_Bl_Gypsum (1946-1964)	3613.16	0.36	3378.04	0.37	2650.99	0.34	1622.16	0.34	0.00
eagle_River_Bl_Gypsum (1965-2001)	3253.78	0.36	3043.36	0.36	2394.97	0.37	1542.71	0.38	0.00
homestake_ck_at_gold_park (1947-1953)	590.43	0.26	539.67	0.25	401.08	0.24	223.18	0.24	0.00
homestake_ck_at_gold_park (1972-2001)	199.72	0.58	172.27	0.61	116.01	0.64	77.33	0.64	0.00
homestake_ck_nr_red_cliff (1910-1938)	664.69	0.28	612.19	0.26	476.58	0.26	294.70	0.27	0.00
homestake_ck_nr_red_cliff (1965-2001)	272.63	0.48	240.90	0.47	174.81	0.48	119.98	0.52	0.00
eagle_red_cliff (1910-1924)	529.24	0.33	481.37	0.34	377.86	0.36	213.87	0.26	0.00
eagle_red_cliff (1944-2001)	284.13	0.49	267.42	0.48	205.51	0.46	120.00	0.42	0.00

Table F.4f: Comprehensive output table.

GageID	CV ZeroD	BaseQ	CV BaseQ	DatMn (day of yr)	CV DatMn	DatMx (day of yr)	CV DatMx	NLoPl	CV NLoPl
black_Gore_Creek (1947-1985)	0.00	0.11	0.43	81.92	1.20	156.26	0.07	3.21	0.86
black_Gore_Creek (1993-2001)	0.00	0.16	0.28	126.33	1.01	152.33	0.07	6.78	0.60
Gore_Crk_Upper_Station (1947-1985)	0.00	0.09	0.45	59.31	1.16	162.38	0.07	2.72	0.82
Gore_Crk_Upper_Station (1993-2001)	0.00	0.09	0.27	38.33	0.75	164.44	0.09	3.89	0.83
eagle_River_Bl_Gypsum (1946-1992)	0.00	0.28	0.27	144.91	0.97	160.79	0.07	9.45	0.40
eagle_River_Bl_Gypsum (1993-2001)	0.00	0.27	0.26	259.67	0.55	156.67	0.07	11.11	0.30
eagle_River_Bl_Gypsum (1946-1964)	0.00	0.27	0.26	133.32	0.98	161.68	0.06	9.68	0.40
eagle_River_Bl_Gypsum (1965-1992)	0.00	0.29	0.27	152.79	0.98	160.18	0.08	9.04	0.41
eagle_River_Bl_Gypsum (1993-2001)	0.00	0.27	0.26	259.67	0.55	156.67	0.07	11.11	0.30
eagle_River_Bl_Gypsum (1946-1964)	0.00	0.27	0.26	133.32	0.98	161.68	0.06	9.68	0.40
eagle_River_Bl_Gypsum (1965-2001)	0.00	0.28	0.27	178.78	0.85	159.32	0.07	9.54	0.40
homestake_ck_at_gold_park (1947-1953)	0.00	0.06	0.33	183.86	0.65	160.57	0.06	2.71	0.51
homestake_ck_at_gold_park (1972-2001)	0.00	0.19	0.32	108.33	1.06	165.40	0.11	3.50	0.94
homestake_ck_nr_red_cliff (1910-1938)	0.00	0.06	0.43	162.07	0.87	160.97	0.07	3.38	0.80
homestake_ck_nr_red_cliff (1965-2001)	0.00	0.16	0.33	109.00	1.06	153.76	0.12	4.81	0.88
eagle_red_cliff (1910-1924)	0.00	0.12	0.31	251.53	0.45	151.40	0.07	8.73	0.40
eagle_red_cliff (1944-2001)	0.00	0.22	0.32	141.02	1.03	152.95	0.07	6.93	0.59

Table F.4g: Comprehensive output table.

GageID	DLoPl (days)	CV DLoPl	NHiPl	CV NHiPl	DHiPl (days)	CV DHiPl	RiseR (cfs/day)	CV RiseR	FallR (cfs/day)
black_Gore_Creek (1947-1985)	36.51	1.00	1.54	0.44	29.46	0.51	3.27	0.37	-2.15
black_Gore_Creek (1993-2001)	15.32	0.75	1.22	0.36	29.11	0.57	2.56	0.38	-1.75
Gore_Crk_Upper_Station (1947-1985)	40.02	0.79	2.36	0.45	22.93	0.66	6.58	0.36	-4.39
Gore_Crk_Upper_Station (1993-2001)	47.74	1.05	2.78	0.53	26.11	0.83	5.09	0.29	-3.44
eagle_River_Bl_Gypsum (1946-1992)	9.69	0.88	2.60	0.51	21.41	0.77	60.54	0.32	-45.46
eagle_River_Bl_Gypsum (1993-2001)	7.28	0.70	2.00	0.79	27.36	0.85	52.97	0.31	-40.29
eagle_River_Bl_Gypsum (1946-1964)	9.39	0.76	2.37	0.55	21.15	0.82	67.17	0.31	-49.24
eagle_River_Bl_Gypsum (1965-1992)	10.56	0.95	2.79	0.46	20.46	0.77	56.04	0.30	-42.89
eagle_River_Bl_Gypsum (1993-2001)	7.28	0.70	2.00	0.79	27.36	0.85	52.97	0.31	-40.29
eagle_River_Bl_Gypsum (1946-1964)	9.39	0.76	2.37	0.55	21.15	0.82	67.17	0.31	-49.24
eagle_River_Bl_Gypsum (1965-2001)	9.68	0.96	2.59	0.53	22.19	0.80	55.29	0.30	-42.26
homestake_ck_at_gold_park (1947-1953)	29.81	0.76	2.43	0.52	23.27	0.62	19.40	0.35	-12.30
homestake_ck_at_gold_park (1972-2001)	41.66	1.07	3.83	0.49	8.31	1.11	6.54	0.50	-4.92
homestake_ck_nr_red_cliff (1910-1938)	21.05	1.01	3.34	0.54	18.33	0.72	21.54	0.42	-15.43
homestake_ck_nr_red_cliff (1965-2001)	23.25	0.97	3.24	0.44	16.34	1.00	8.59	0.44	-6.58
eagle_red_cliff (1910-1924)	14.06	0.99	3.00	0.70	18.70	0.70	14.40	0.50	-12.81
eagle_red_cliff (1944-2001)	16.92	1.15	1.59	0.63	26.34	0.69	5.50	0.40	-4.10

Table F.4h: Comprehensive output table.

GageID	CV FallR	Revs	CV Revs	Ma3	Ma40	Ma41 (feet)	Ma44	Ml13	Ml14
black_Gore_Creek (1947-1985)	-0.35	70.56	0.25	1.95	3.13	1.50	14.98	3.46	0.45
black_Gore_Creek (1993-2001)	-0.39	81.33	0.28	2.03	3.14	1.47	12.09	1.13	0.52
Gore_Crk_Upper_Station (1947-1985)	-0.39	76.56	0.19	1.78	2.53	2.29	16.74	3.46	0.36
Gore_Crk_Upper_Station (1993-2001)	-0.26	90.89	0.22	1.72	2.31	2.29	13.74	1.42	0.31
eagle_River_Bl_Gypsum (1946-1992)	-0.30	124.74	0.10	1.37	1.17	0.69	5.95	0.82	0.55
eagle_River_Bl_Gypsum (1993-2001)	-0.32	130.44	0.06	1.37	1.14	0.67	5.72	0.73	0.45
eagle_River_Bl_Gypsum (1946-1964)	-0.29	116.16	0.08	1.40	1.32	0.70	6.12	0.91	0.55
eagle_River_Bl_Gypsum (1965-1992)	-0.29	130.57	0.08	1.35	1.07	0.68	5.83	0.84	0.55
eagle_River_Bl_Gypsum (1993-2001)	-0.32	130.44	0.06	1.37	1.14	0.67	5.72	0.73	0.45
eagle_River_Bl_Gypsum (1946-1964)	-0.29	116.16	0.08	1.40	1.32	0.70	6.12	0.91	0.55
eagle_River_Bl_Gypsum (1965-2001)	-0.29	130.54	0.07	1.35	1.09	0.68	5.80	0.74	0.52
homestake_ck_at_gold_park (1947-1953)	-0.27	65.57	0.30	1.94	4.40	1.99	26.71	1.67	0.34
homestake_ck_at_gold_park (1972-2001)	-0.50	100.17	0.22	1.70	0.92	0.88	5.89	1.10	0.39
homestake_ck_nr_red_cliff (1910-1938)	-0.42	76.83	0.33	1.74	3.30	1.71	22.36	1.71	0.34
homestake_ck_nr_red_cliff (1965-2001)	-0.41	97.59	0.21	1.53	1.06	0.83	7.04	1.19	0.35
eagle_red_cliff (1910-1924)	-0.64	99.40	0.23	1.71	2.14	1.10	8.87	1.38	0.26
eagle_red_cliff (1944-2001)	-0.39	92.29	0.17	1.64	1.55	0.66	7.65	0.84	0.48

Table F.4i: Comprehensive output table.

GageID	Ml22 (cfs/mi²)	Mh1 (cfs)	Mh8 (cfs)	Mh17	Fl3	Fh11	Dl13	Dh12
black_Gore_Creek (1947-1985)	0.14	0.85	10.35	0.72	0.00	0.46	15.70	273.62
black_Gore_Creek (1993-2001)	0.17	0.37	7.22	0.76	0.00	0.44	19.52	241.19
Gore_Crk_Upper_Station (1947-1985)	0.17	1.38	8.04	0.52	0.05	0.41	12.03	225.79
Gore_Crk_Upper_Station (1993-2001)	0.16	0.85	8.17	0.49	0.00	0.56	11.13	194.21
eagle_River_Bl_Gypsum (1946-1992)	0.14	0.56	2.88	0.77	0.00	0.45	19.96	92.48
eagle_River_Bl_Gypsum (1993-2001)	0.12	0.39	2.63	0.79	0.00	0.56	20.08	84.42
eagle_River_Bl_Gypsum (1946-1964)	0.14	0.56	2.52	0.78	0.00	0.47	20.25	101.49
eagle_River_Bl_Gypsum (1965-1992)	0.14	0.53	2.88	0.77	0.00	0.46	19.80	86.86
eagle_River_Bl_Gypsum (1993-2001)	0.12	0.39	2.63	0.79	0.00	0.56	20.08	84.42
eagle_River_Bl_Gypsum (1946-1964)	0.14	0.56	2.52	0.78	0.00	0.47	20.25	101.49
eagle_River_Bl_Gypsum (1965-2001)	0.14	0.53	2.88	0.77	0.00	0.51	19.87	86.25
homestake_ck_at_gold_park (1947-1953)	0.09	0.72	7.23	0.50	0.43	0.43	12.30	397.65
homestake_ck_at_gold_park (1972-2001)	0.12	0.87	5.87	0.54	0.00	0.60	12.90	100.49
homestake_ck_nr_red_cliff (1910-1938)	0.09	1.15	7.40	0.52	0.69	0.52	11.32	267.83
homestake_ck_nr_red_cliff (1965-2001)	0.10	0.78	6.15	0.57	0.05	0.54	13.24	99.19
eagle_red_cliff (1910-1924)	0.08	0.39	5.52	0.63	0.33	0.47	14.67	160.46
eagle_red_cliff (1944-2001)	0.10	0.45	4.45	0.76	0.00	0.50	18.94	133.71

Table F.4j: Comprehensive output table.

GageID	Dh13	Th3	SS1	PMAR_Oct	PMAR_Nov	PMAR_Dec	PMAR_Jan	PMAR_Feb	PMAR_Mar
black_Gore_Creek (1947-1985)	875.65	0.11	0.40	0.02	0.02	0.01	0.01	0.01	0.01
black_Gore_Creek (1993-2001)	761.46	0.05	0.39	0.02	0.02	0.02	0.02	0.02	0.02
Gore_Crk_Upper_Station (1947-1985)	733.24	0.08	0.28	0.02	0.01	0.01	0.01	0.01	0.01
Gore_Crk_Upper_Station (1993-2001)	650.17	0.04	0.27	0.02	0.01	0.01	0.01	0.01	0.01
eagle_River_Bl_Gypsum (1946-1992)	311.06	0.14	0.09	0.04	0.03	0.03	0.03	0.02	0.03
eagle_River_Bl_Gypsum (1993-2001)	287.18	0.07	0.09	0.04	0.03	0.03	0.03	0.02	0.03
eagle_River_Bl_Gypsum (1946-1964)	341.33	0.08	0.09	0.03	0.03	0.03	0.03	0.02	0.03
eagle_River_Bl_Gypsum (1965-1992)	292.14	0.14	0.09	0.04	0.04	0.03	0.03	0.02	0.03
eagle_River_Bl_Gypsum (1993-2001)	287.18	0.07	0.09	0.04	0.03	0.03	0.03	0.02	0.03
eagle_River_Bl_Gypsum (1946-1964)	341.33	0.08	0.09	0.03	0.03	0.03	0.03	0.02	0.03
eagle_River_Bl_Gypsum (1965-2001)	290.89	0.16	0.09	0.04	0.04	0.03	0.03	0.02	0.03
homestake_ck_at_gold_park (1947-1953)	1266.57	0.01	0.20	0.02	0.01	0.01	0.01	0.01	0.01
homestake_ck_at_gold_park (1972-2001)	290.01	0.20	0.33	0.04	0.03	0.02	0.02	0.02	0.02
homestake_ck_nr_red_cliff (1910-1938)	893.59	0.10	0.18	0.02	0.01	0.01	0.01	0.01	0.01
homestake_ck_nr_red_cliff (1965-2001)	308.48	0.19	0.25	0.04	0.03	0.02	0.02	0.02	0.02
eagle_red_cliff (1910-1924)	539.81	0.06	0.18	0.02	0.02	0.02	0.02	0.01	0.02
eagle_red_cliff (1944-2001)	440.38	0.15	0.21	0.03	0.03	0.02	0.02	0.02	0.02

Table F.4k: Comprehensive output table.

GageID	PMAR_Apr	PMAR_May	PMAR_Jun	PMAR_Jul	PMAR_Aug	PMAR_Sep
black_Gore_Creek (1947-1985)	0.04	0.27	0.44	0.11	0.04	0.02
black_Gore_Creek (1993-2001)	0.04	0.27	0.42	0.11	0.03	0.02
Gore_Crk_Upper_Station (1947-1985)	0.03	0.19	0.42	0.20	0.06	0.03
Gore_Crk_Upper_Station (1993-2001)	0.03	0.22	0.40	0.18	0.06	0.03
eagle_River_Bl_Gypsum (1946-1992)	0.05	0.20	0.33	0.15	0.06	0.04
eagle_River_Bl_Gypsum (1993-2001)	0.05	0.22	0.31	0.14	0.06	0.04
eagle_River_Bl_Gypsum (1946-1964)	0.05	0.20	0.33	0.15	0.06	0.04
eagle_River_Bl_Gypsum (1965-1992)	0.05	0.19	0.33	0.15	0.06	0.04
eagle_River_Bl_Gypsum (1993-2001)	0.05	0.22	0.31	0.14	0.06	0.04
eagle_River_Bl_Gypsum (1946-1964)	0.05	0.20	0.33	0.15	0.06	0.04
eagle_River_Bl_Gypsum (1965-2001)	0.05	0.20	0.32	0.15	0.06	0.04
homestake_ck_at_gold_park (1947-1953)	0.03	0.22	0.46	0.18	0.04	0.02
homestake_ck_at_gold_park (1972-2001)	0.05	0.20	0.28	0.18	0.10	0.05
homestake_ck_nr_red_cliff (1910-1938)	0.05	0.25	0.40	0.17	0.05	0.02
homestake_ck_nr_red_cliff (1965-2001)	0.07	0.26	0.28	0.14	0.07	0.04
eagle_red_cliff (1910-1924)	0.06	0.32	0.35	0.10	0.04	0.03
eagle_red_cliff (1944-2001)	0.06	0.27	0.35	0.10	0.05	0.03

However, if a high- or low-pulse level falls outside the range of data, the 75th and 25th percentile flows are used to represent the high- and low-pulse levels, respectively.

IHA hydrologic analysis also includes an examination of the rises, falls, and reversals in the water conditions. These parameters are calculated as the average rate that the water levels or flow rises and falls and the number of times that the stream hydrograph shifts from a rising to a falling condition or from a falling to a rising condition. The determination of the rate of change, either positive or negative, is calculated as the mean of all the positive or negative differences between consecutive daily means.

The Flow SStats program developed at CSU (Sanborn, 2004) expands the capabilities of IHA by computing numerous parameters that more closely investigate relationships within the data set at each gage. The statistics are grouped by Magnitude (M), Frequency (F), Timing (T), Duration (D), and Rate of change (R). They are further categorized as average (a), low (l), and high (h). Therefore, a metric with an abbreviation Mh is some indicator of the magnitude of the maximum flow. A number is associated with each metric, as multiple metrics provide indicators for each element of the flow regime. Any indicators with an abbreviation of SS denote that the metric was not calculated as interpreted by Olden and Poff (2003), but rather by the CSU software Flow SStats (Sanborn, 2004). All metrics expressing a flow magnitude are presented in units of cfs.

The first supplemental metric, analysis of the variability in the daily flows (Ma3), is computed as the coefficient of variation of the daily flows. A measure of skewness (Ma40) in monthly flows is calculated as:

$$Ma40 = \frac{\left(\bar{Q}\text{-}M\right)}{M} \tag{F.3}$$

where,

Ma40	=	skewness indicator (dimensionless);
$\bar{Q}$	=	mean of the monthly averaged flow values for all years (cfs); and
M	=	median of the monthly averaged flow values for all years (cfs).

The mean annual runoff (Ma41) is a measure of the total annual streamflow for a specified basin and is mathematically expressed as:

$$Ma41 = \frac{\dfrac{\sum_{1}^{12} Q_{d_i} n_i}{N}\Phi}{DA} \tag{F.4}$$

where,

Ma41	=	mean annual runoff (ft);
Q_{di}	=	average daily flow for all years for month i (cfs);
n	=	number of days in month i;
N	=	total number of days in the year;
DA	=	drainage area (ft^2); and
Φ	=	conversion to ft^3 per year.

An index of variability across annual flows (Ma44,SS) is computed as the variability in annual flows divided by the median annual flows, where variability represents the 90th percentile minus the 10th percentile average annual flows.

$$\text{Ma44,SS} = \frac{\sum_{i}^{n} \frac{Q_{90_i} - Q_{10_i}}{M_i}}{n} \tag{F.5}$$

where,

Ma44	=	index of variability across annual flows (dimensionless);
Q_{90i}	=	90th percentile of daily flows for year i (cfs);
Q_{10i}	=	10th percentile of daily flow for year i (cfs);
M_i	=	median of the daily flows for year i (cfs); and
n	=	total number of years in the period of analysis.

More detailed analysis of the minimum flows is determined through a series of metrics. The coefficient of variation in minimum monthly flows measures the variability across all minimum monthly flows (Ml13). A dimensionless measure of the mean of minimum monthly flows (Ml14) can be expressed as:

$$\text{Ml14} = \frac{\sum_{i}^{n} \frac{Q_{dl_i}}{M_{d_i}}}{n} \tag{F.6}$$

where,

Ml14	=	measure of the mean of the annual minimum flows (dimensionless);
Q_{dli}	=	lowest daily flow for year i (cfs);
M_{di}	=	median of the daily flow for year i (cfs); and
n	=	total number of years in the period of analysis.

To determine the specific mean annual minimum flows (Ml22), the mean daily minimum flows averaged across all years are divided by the catchment area.

$$\text{Ml22} = \frac{\left(\frac{\sum_{i}^{n} Q_{dl_i}}{n} \right)}{DA} \tag{F.7}$$

where,

l22	=	specific mean annual minimum flows (cfs/mi^2);
$_{dli}$	=	lowest daily flow for year i (cfs);
n	=	total number of years in the period of analysis; and
DA	=	drainage area for the specified gage (mi^2).

An assessment of the frequency of low-flow spells (Fl3) is accomplished through determination of the annual average number of occurrences of low- flow spells. The low-flow spell threshold is equal to 5% of the mean daily flow. For separate spells to occur within the same year, a 10-day separation must be present. The low flow threshold is computed as:

$$T_{lf_i} = 0.05Q_{md_i} \tag{F.8}$$

where,

$_{lfi}$ = low-flow threshold for year i (cfs); and
$_{mdi}$ = mean daily flow for year i (cfs).

Once the low flow threshold has been determined, the frequency of low-flow spells can be computed.

$$Fl3 = \frac{\sum_{i}^{n} N_{lf_i}}{n} \tag{F.9}$$

where,

$Fl3$ = measure of the frequency of low-flow spells;
N_{lfi} = number of spells that the flow rate falls below T_{lf} for year i; and
n = number of years in the period of analysis.

Maximum flows are also thoroughly evaluated through additional hydrologic parameters. The maximum monthly flows for all years (Mh1) and (Mh8) are measured as the mean maximum October and May flows of all years in the period of analysis, respectively.

A high flow discharge indicator (Mh17) is a function of the mean of the 25th percentile from the flow duration curve and the median daily flows, and can be expressed as:

$$Mh17 = \frac{\left(\sum_{i}^{n} Q_{25_i} \Big/ n \right)}{M} \tag{F.11}$$

where,

$Mh17$ = indicator of high-flow discharge (dimensionless);
Q_{25i} = 25th percentile of the daily flow for year i (cfs);
n = number of years in the period of analysis; and
M = median of daily flows of all years (cfs).

To investigate relationships in flood frequency, the Flow SStats program enumerates a flood frequency parameter. The flood frequency index (Fh11) is computed as the mean number of discrete flood events per year. A discrete event is determined from an annual maximum series as an event that typically occurs once every 1.67 years and has an annual probability of occurrence of 59%. Fh11 is computed with formula F.12.

$$Fh11 = \left. \sum_i^n N_{df_i} \right/ n \qquad (F.12)$$

where:,

- Fh11 = flood frequency index;
- N_{dfi} = number of discrete flood events per year; and
- n = total number of years in the period of analysis.

Duration is also used as a basis from which to measure several supplemental hydrologic parameters. A measure of the mean of the 30-day minima of daily discharge (Dl13) represents the mean annual 30-day minimum flow divided by the median discharge for all years.

$$Dl13 = \frac{\left(\left. \sum_i^n Q_{30l_i} \right/ n \right)}{M} \qquad (F.13)$$

where,

- Dl13 = measure of the 30-day minima of daily discharge (dimensionless);
- Q_{30li} = lowest 30 day average for year i (cfs);
- n = total number of years in the period of analysis;
- M = median of the daily discharges of all years (cfs).

Similarly, the mean of the 7 and 30-day maxima of daily discharge, (Dh13) and (Dh14) are indicators of the mean annual 7 and 30-day maxima divided by the median discharge.

$$Dh12 = \frac{\left(\left. \sum_i^n Q_{7h_i} \right/ n \right)}{M} \qquad (F.14)$$

where,

- Dh12 = indicator of the 7-day maxima of daily discharge (dimensionless);
- Q_{7hi} = highest 7-day average for year i (cfs);
- n = total number of years in the period of analysis; and
- M = median of the daily discharges of all years (cfs).

$$Dh13 = \frac{\left(\left. \sum_i^n Q_{30h_i} \right/ n \right)}{M} \qquad (F.15)$$

where,

- Dh13 = indicator of the 30-day maxima of daily discharge;
- Q_{7hi} = highest 30-day average for year i (cfs);
- n = total number of years in the period of analysis; and
- M = median of the daily discharges of all years (cfs).

The rate at which a stream's hydrograph fluctuates is represented through an indicator of flashiness (SS1), calculated as:

$$SS1 = \frac{\sum_{t}^{n} \left(\frac{|Q_{t+1} - Q_t|}{n} \right)}{Q_{avg}} \tag{F.16}$$

where,

- SS1 = measure of flashiness (dimensionless);
- Q_{t+1} = average daily flow at day t+1 (cfs);
- Q_t = average daily flow at day t (cfs);
- n = total number of days in the period of analysis; and
- Q_{avg} = average daily flow across all days in the period of analysis (cfs).

The last set of hydrologic metrics measures the average monthly percentage of mean annual runoff (MAR) for all months. The MAR is defined as the average annual volume of water that passes through the gage, also referred to as yield. These parameters provide the temporal distribution of streamflow passing a particular point in space.

REFERENCES

Olden, J.D., and N.L. Poff (2003). Redundancy and the choice of hydrologic indices for characterizing streamflow regimes. *River Research and Applications* 19:101-121.

Poff, N.L., J.D. Allan, M.B. Bain, J.R. Karr, K.L. Prestegaard, B.D. Richter, R.E. Sparks, and J.C. Stromberg (1997). The natural flow regime: A paradigm for river conservation and restoration. *BioScience* 47:769-784.

Richter, B.D., and H.E. Richter (2000). Prescribing flood regimes to sustain riparian ecosystems along meandering rivers. *Conservation Biology* 14:1467-1478.

Richter, B.D., J.V. Baumgartner, J. Powell, and D.P. Braun (1996). A method for assessing hydrologic alteration within ecosystems. *Conservation Biology* 10:1163-1174.

Sanborn, S.C. (2004) Predicting Streamflow Regime Metrics for Ungauged Streams in Colorado, Washington, and Oregon. M.S. Thesis, Department of Civil Engineering, Colorado State University, Fort Collins, CO.

Stanford, J.A. (1994). Instream Flows to Assist the Recovery of Endangered Fishes of the Upper Colorado River System. Biological Report 24, July, U.S. Fish and Wildlife Service, Denver, CO.

Strange, E.M., P.B. Moyle, and T.C. Foin (1992). Interactions between stochastic and deterministic processes in stream fish community assembly. *Environmental Biology of Fishes* 36:1-15.

Ward, J.V. and J.A. Stanford (1989) Riverine ecosystyems: the influence of man on catchment dynamics and fish ecology. *Canadian Special Publication of Fisheries Aquatic Science* 106:55-64.

Whiting, P.J. (2002). Streamflow necessary for environmental maintenance. *Annual Review of Earth and Planetary Sciences* 30:181-206.

APPENDIX G

Nutrient Analysis Results

Table G.1: Distribution of nutrient values above selected WWTPs in the Eagle River watershed and all of Southern Rockies Ecoregion 21.

Southern Rockies Ecoregion (CO) Values

TP (µg/L)

SEASON	MEAN	P5	P25	MEDIAN	P75	P95
FALL	46	0.00	2.5	20	40	145
SPRING	68	0.00	10	30	85	220
SUMMER	55	0.00	8	20	70	185
WINTER	34	0.00	4.69	20	42.5	130

NO_3 (mg/L)

SEASON	MEAN	P5	P25	MEDIAN	P75	P95
FALL	0.07	0.00	0.00	0.00	0.04	0.28
SPRING	0.09	0.00	0.00	0.01	0.07	0.25
SUMMER	0.06	0.00	0.00	0.01	0.05	0.28
WINTER	0.13	0.00	0.00	0.00	0.01	0.07

Just Upstream of Vail WWTP

TP (µg/L)

SEASON	MEAN	P5	P25	MEDIAN	P75	P95
FALL	68	<10	17.5	55	82.5	>190
SPRING	96	<40	40	70	160	>200
SUMMER	128	<20	40	80	145	>580
WINTER	125	<20	42.5	60	190	>480

NO_3 (mg/L)

SEASON	MEAN	P5	P25	MEDIAN	P75	P95
FALL	0.58	<0.2	0.30	0.40	0.98	>1.3
SPRING	0.36	<0.1	0.20	0.30	0.50	>1.0
SUMMER	0.45	<0.1	0.30	0.35	0.68	>1.0
WINTER	0.65	<0.1	0.25	0.50	0.80	>1.8

Just Upstream of Avon WWTP						
TP (µg/L)						
SEASON	MEAN	P5	P25	MEDIAN	P75	P95
FALL	101	<20	70	110	120	>180
SPRING	116	<40	70	115	145	>270
SUMMER	164	<30	45	110	135	>860
WINTER	168	<30	50	100	237.5	>700
NO_3 (mg/L)						
SEASON	MEAN	P5	P25	MEDIAN	P75	P95
FALL	0.65	<0.3	0.40	0.60	0.93	>1.3
SPRING	0.47	<0.2	0.30	0.40	0.60	>1.0
SUMMER	0.53	<0.1	0.40	0.55	0.70	>0.9
WINTER	0.73	<0.3	0.45	0.70	0.78	>1.4

Just Upstream of Edwards WWTP						
TP (µg/L)						
SEASON	MEAN	P5	P25	MEDIAN	P75	P95
FALL	183	<30	102.5	190	260	>330
SPRING	218	<70	95	230	297.5	>500
SUMMER	355	<50	70	230	285	>2200
WINTER	235	<40	80	155	365	>740
NO_3 (mg/L)						
SEASON	MEAN	P5	P25	MEDIAN	P75	P95
FALL	1.05	<0.3	0.50	0.70	1.93	>2.3
SPRING	0.73	<0.2	0.40	0.50	0.90	>2.0
SUMMER	1.00	<0.2	0.50	0.80	1.70	>1.9
WINTER	1.38	<0.3	0.55	1.35	1.70	>3.0

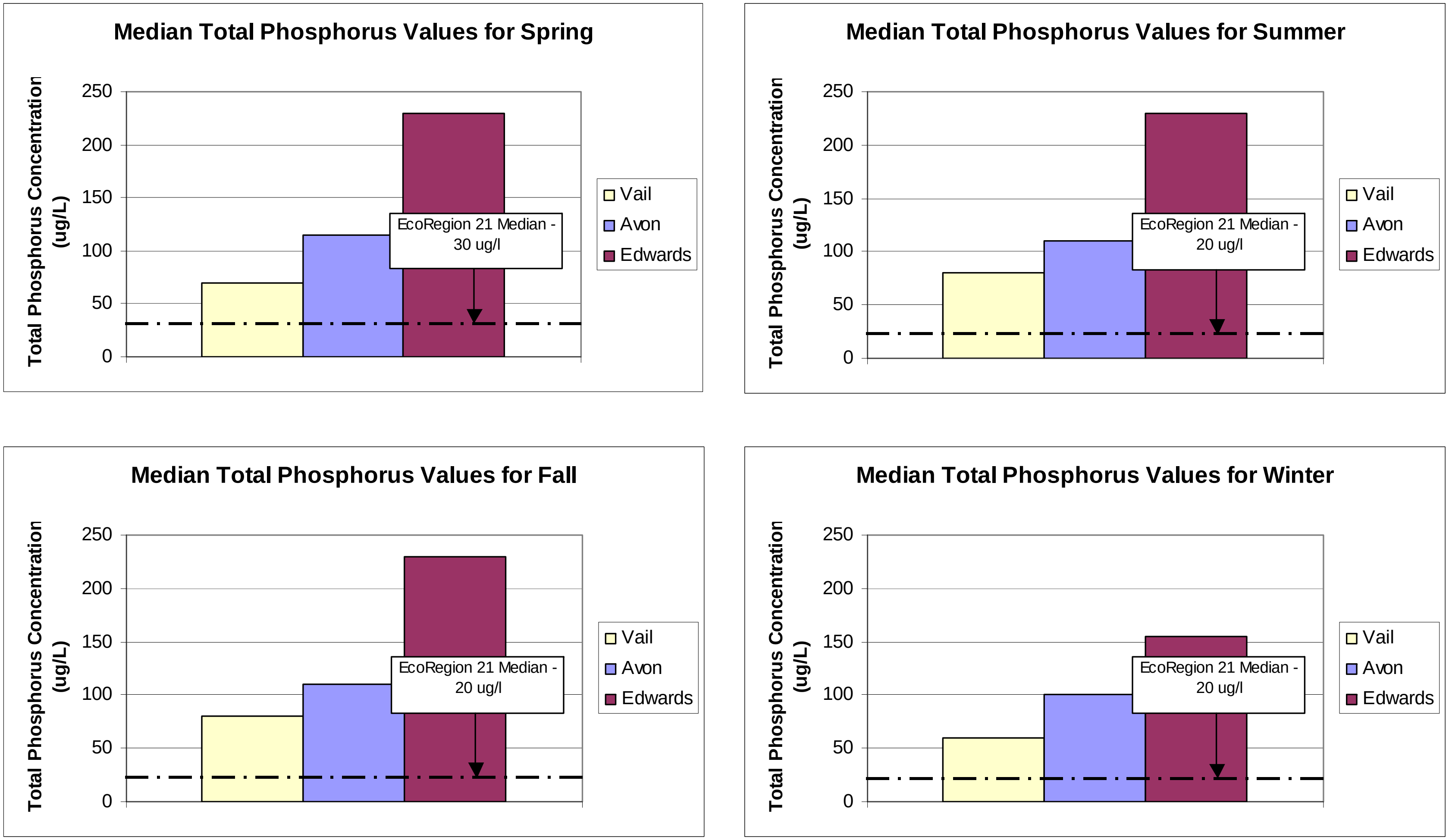


Figure G.1: TP samples taken just upstream of WWTPs at Vail, Avon, and Edwards (data source: Eagle River Water and Sanitation District, 1999 to 2004).

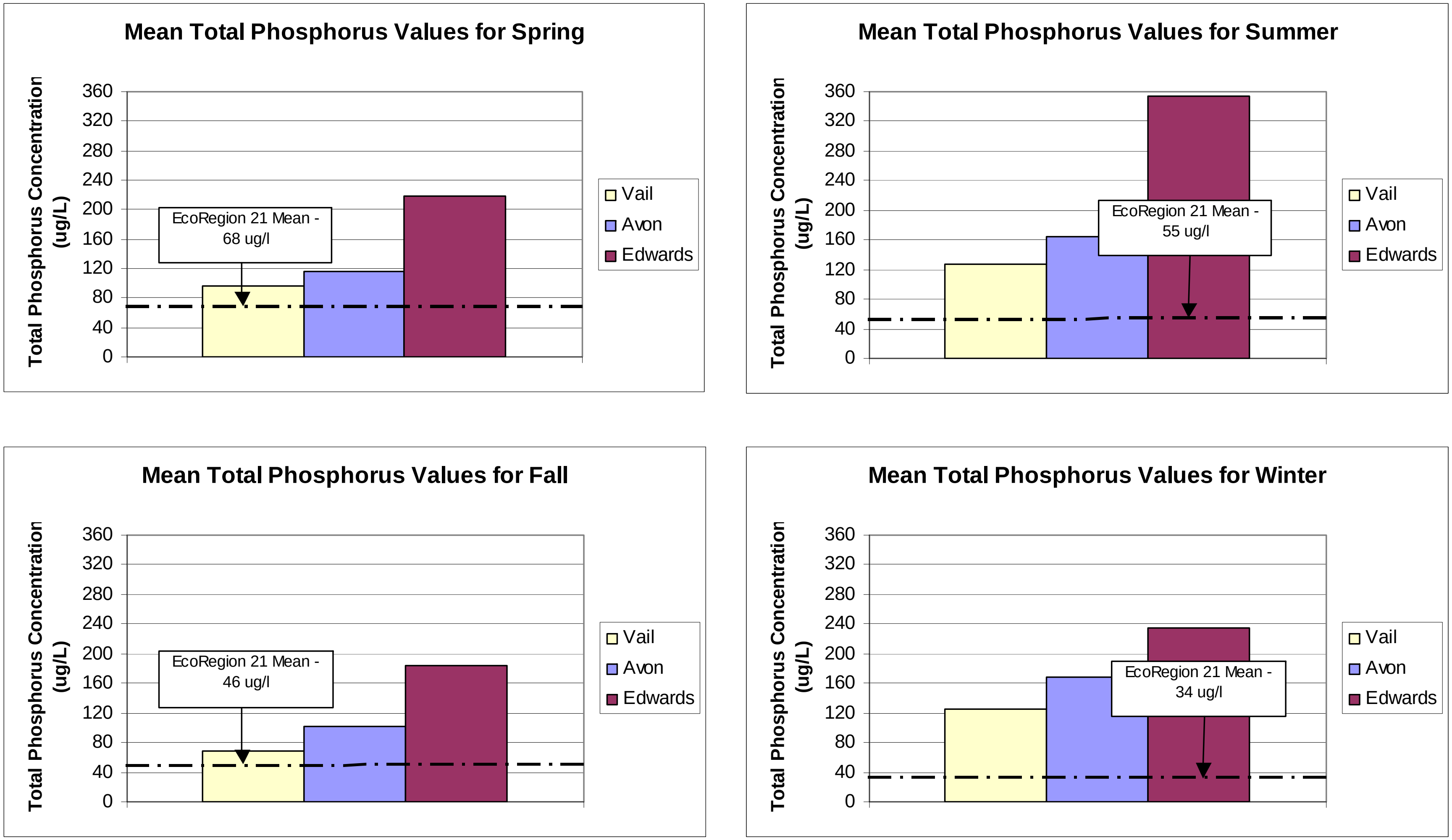


Table G.2: TP samples taken just upstream of WWTPs at Vail, Avon, and Edwards (data source: Eagle River Water and Sanitation District, 1999 to 2004).

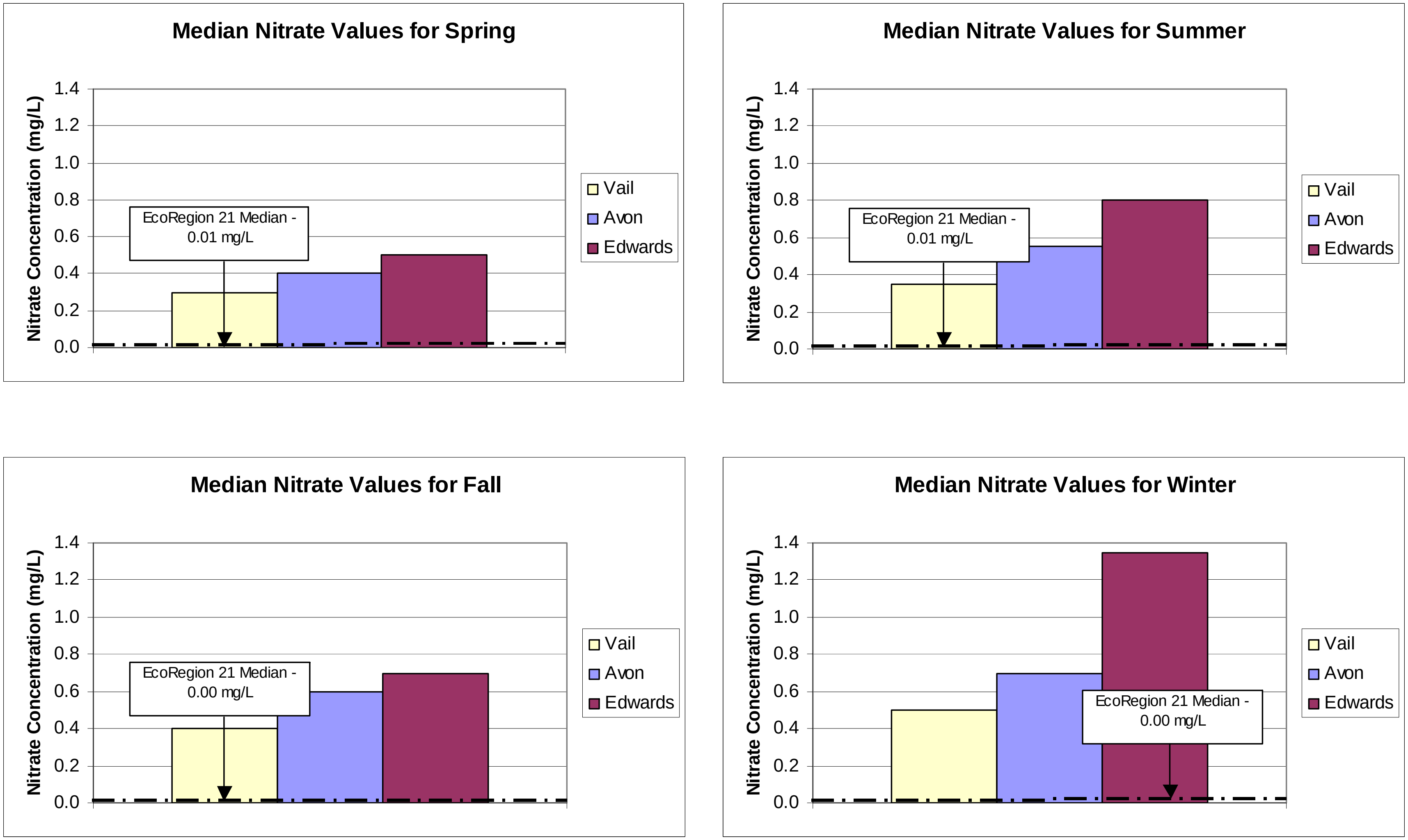


Figure G.3: NO_3 samples taken just upstream of WWTPs at Vail, Avon, and Edwards (data source: Eagle River Water and Sanitation District, 1999 to 2004).

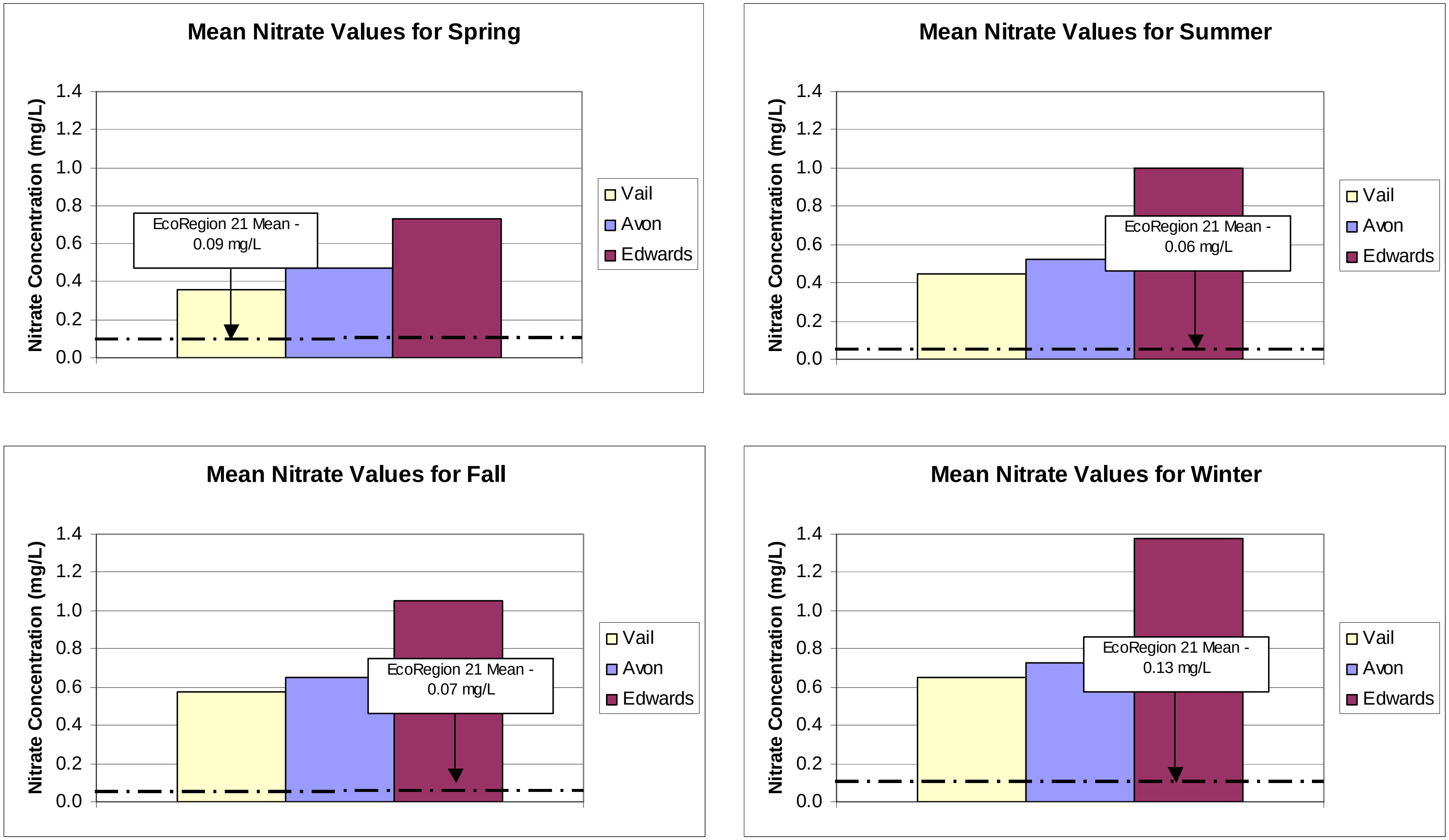


Figure G.4: NO_3 samples taken just upstream of WWTPs at Vail, Avon, and Edwards (data source: Eagle River Water and Sanitation District, 1999 to 2004).

Table G.2: Distribution of nutrient values at selected sites in the Eagle River watershed and all of Southern Rockies Ecoregion 21.

Southern Rockies Ecoregion 21 (CO) Values

TN (mg/L)

SEASON	MEAN	P5	P25	MEDIAN	P75	P95
FALL	0.21	0.04	0.07	0.15	0.28	0.55
SPRING	0.36	0.06	0.12	0.24	0.51	0.84
SUMMER	0.37	0.05	0.12	0.26	0.48	1.20
WINTER	0.28	0.05	0.05	0.23	0.48	0.72

TP (µg/L)

SEASON	MEAN	P5	P25	MEDIAN	P75	P95
FALL	46	0	3	20	40	145
SPRING	68	0	10	30	85	220
SUMMER	55	0	8	20	70	185
WINTER	34	0	5	20	43	130

NO_3 (mg/L)

SEASON	MEAN	P5	P25	MEDIAN	P75	P95
FALL	0.07	0.00	0.00	0.00	0.04	0.28
SPRING	0.09	0.00	0.00	0.01	0.07	0.25
SUMMER	0.06	0.00	0.00	0.01	0.05	0.28
WINTER	0.13	0.00	0.00	0.00	0.01	0.07

Red Cliff

TN (mg/L)

SEASON	MEAN	P5	P25	MEDIAN	P75	P95
FALL	0.19	0.03	0.11	0.25	0.25	0.25
SPRING	0.25	0.04	0.17	0.25	0.25	0.68
SUMMER	0.22	0.03	0.11	0.25	0.25	0.66
WINTER	0.20	0.02	0.13	0.25	0.25	0.25

TP (µg/L)

SEASON	MEAN	P5	P25	MEDIAN	P75	P95
FALL	19	2	5	25	25	54
SPRING	22	5	13	25	25	50
SUMMER	22	2	6	6	25	77
WINTER	20	3	5	25	25	54

NO_3 (mg/L)

SEASON	MEAN	P5	P25	MEDIAN	P75	P95
FALL	0.18	0.01	0.05	0.25	0.25	0.25
SPRING	0.20	0.01	0.12	0.25	0.25	0.27
SUMMER	0.18	0.01	0.03	0.25	0.25	0.34
WINTER	0.18	0.17	0.06	0.25	0.25	0.25

Gore Creek at Vail						
TN (mg/L)						
SEASON	MEAN	P5	P25	MEDIAN	P75	P95
FALL	0.35	0.03	0.14	0.34	0.54	0.71
SPRING	0.53	0.03	0.07	0.25	0.67	2.29
SUMMER	0.20	0.03	0.03	0.19	0.36	0.56
WINTER	0.27	0.03	0.03	0.10	0.43	0.93
TP (µg/L)						
SEASON	MEAN	P5	P25	MEDIAN	P75	P95
FALL	60	5	5	5	170	170
SPRING	15	9	9	10	25	25
SUMMER	8	5	5	7	13	13
WINTER	8	5	5	10	10	10
NO3 (mg/l)						
SEASON	MEAN	P5	P25	MEDIAN	P75	P95
FALL	0.34	<0.01	0.22	0.25	0.48	>.7
SPRING	0.52	<0.04	0.17	0.25	1.16	>1.7
SUMMER	0.62	<0.09	0.17	0.25	0.50	>4
WINTER	1.13	<0.01	0.25	0.34	1.14	>9.39

Gore Creek at Mouth						
TN (mg/L)						
SEASON	MEAN	P5	P25	MEDIAN	P75	P95
FALL	0.56	0.05	0.25	0.25	0.72	2.15
SPRING	0.33	0.03	0.19	0.25	0.45	0.98
SUMMER	0.35	0.05	0.25	0.25	0.40	1.17
WINTER	1.10	0.05	0.25	1.20	1.90	2.40
TP (µg/L)						
SEASON	MEAN	P5	P25	MEDIAN	P75	P95
FALL	156	25	95	130	190	475
SPRING	70	5	24	41	80	280
SUMMER	87	28	32	74	110	200
WINTER	329	135	220	283	425	630
NO_3 (mg/L)						
SEASON	MEAN	P5	P25	MEDIAN	P75	P95
FALL	0.35	0.11	0.22	0.30	0.46	0.77
SPRING	0.19	0.03	0.06	0.12	0.25	1.10
SUMMER	0.50	0.07	0.12	0.18	0.30	3.48
WINTER	0.81	0.38	0.53	0.65	1.00	2.00

Avon						
TN (mg/L)						
SEASON	MEAN	P5	P25	MEDIAN	P75	P95
FALL	0.34	0.02	0.05	0.31	0.44	1.10
SPRING	0.28	0.05	0.17	0.25	0.36	0.56
SUMMER	0.25	0.05	0.18	0.26	0.31	0.49
WINTER	0.64	0.03	0.51	0.62	0.70	1.10
TP (µg/L)						
SEASON	MEAN	P5	P25	MEDIAN	P75	P95
FALL	27	3	8	20	44	91
SPRING	27	5	13	18	39	84
SUMMER	20	5	11	19	23	55
WINTER	68	37	57	67	78	110
NO_3 (mg/L)						
SEASON	MEAN	P5	P25	MEDIAN	P75	P95
FALL	0.35	0.11	0.22	0.30	0.46	0.77
SPRING	0.19	0.03	0.06	0.12	0.25	1.10
SUMMER	0.50	0.07	0.12	0.18	0.30	3.48
WINTER	0.81	0.38	0.53	0.65	1.00	2.00

Edwards						
TN (mg/L)						
SEASON	MEAN	P5	P25	MEDIAN	P75	P95
FALL	0.29	0.25	0.25	0.25	0.25	0.96
SPRING	0.49	0.10	0.25	0.25	0.25	4.79
SUMMER	0.32	0.07	0.25	0.25	0.25	1.25
WINTER	0.62	0.25	0.25	0.25	0.25	3.75
TP (µg/L)						
SEASON	MEAN	P5	P25	MEDIAN	P75	P95
FALL	138	25	60	100	165	380
SPRING	101	19	33	60	125	312
SUMMER	79	23	25	70	90	168
WINTER	242	90	150	210	320	496
NO_3 (mg/L)						
SEASON	MEAN	P5	P25	MEDIAN	P75	P95
FALL	0.14	0.03	0.06	0.10	0.17	0.38
SPRING	0.10	0.02	0.03	0.06	0.13	0.31
SUMMER	0.08	0.02	0.03	0.07	0.09	0.17
WINTER	0.24	0.09	0.15	0.21	0.32	0.50

Wolcott						
TN (mg/L)						
SEASON	MEAN	P5	P25	MEDIAN	P75	P95
FALL	1.30	0.68	0.79	1.10	1.80	2.80
SPRING	0.53	0.24	0.28	0.40	0.68	1.30
SUMMER	0.84	0.27	0.56	0.85	1.07	1.50
WINTER	2.00	0.50	1.60	2.10	2.60	2.90

TP (µg/L)						
SEASON	MEAN	P5	P25	MEDIAN	P75	P95
FALL	111	68	74	98	150	186
SPRING	78	9	25	49	109	330
SUMMER	91	36	65	78	130	164
WINTER	221	178	198	226	240	260

NO_3 (mg/L)						
SEASON	MEAN	P5	P25	MEDIAN	P75	P95
Fall	0.18	0.01	0.05	0.25	0.25	0.25
Spring	0.20	0.01	0.12	0.25	0.25	0.27
Summer	0.18	0.01	0.03	0.25	0.25	0.34
Winter	0.18	0.17	0.06	0.25	0.25	0.25

Gypsum						
TN (mg/L)						
SEASON	MEAN	P5	P25	MEDIAN	P75	P95
FALL	0.53	0.05	0.25	0.25	0.80	1.34
SPRING	0.65	0.23	0.25	0.40	0.81	1.71
SUMMER	0.52	0.05	0.25	0.37	0.60	1.75
WINTER	0.91	0.05	0.25	0.93	1.30	2.00

TP (µg/L)						
SEASON	MEAN	P5	P25	MEDIAN	P75	P95
FALL	61	10	25	50	80	136
SPRING	130	14	40	90	160	422
SUMMER	68	13	25	44	92	181
WINTER	165	50	90	126	160	480

NO_3 (mg/L)						
SEASON	MEAN	P5	P25	MEDIAN	P75	P95
FALL	0.38	0.07	0.25	0.34	0.50	0.89
SPRING	0.29	0.07	0.14	0.25	0.34	0.59
SUMMER	0.24	0.03	0.12	0.22	0.30	0.50
WINTER	0.57	0.14	0.30	0.50	0.65	1.23

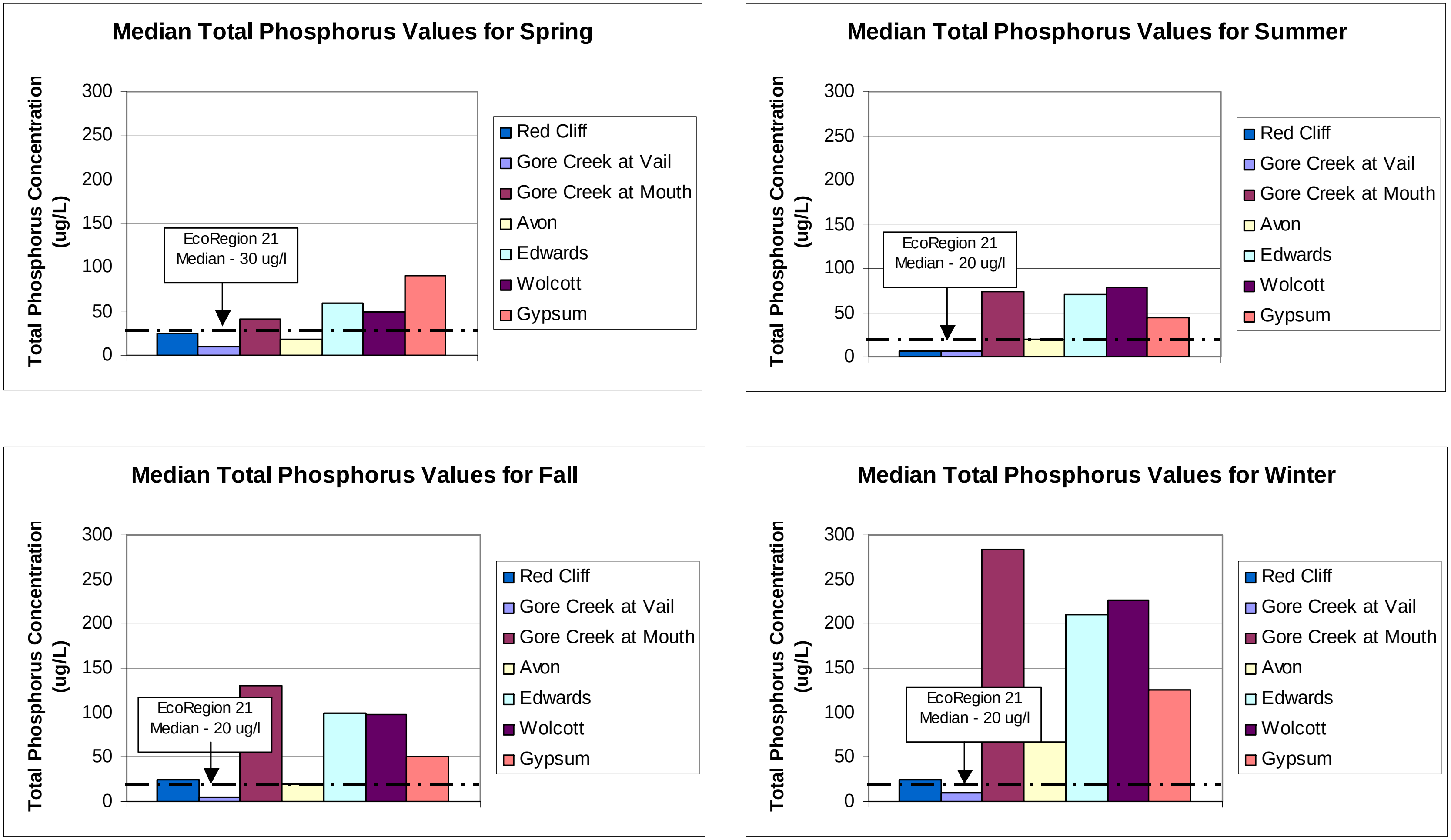


Figure G.5: TP samples (data source: USGS, Eagle River water quality database: http://co.water.usgs.gov/cf/eaglecf/default.cfm).

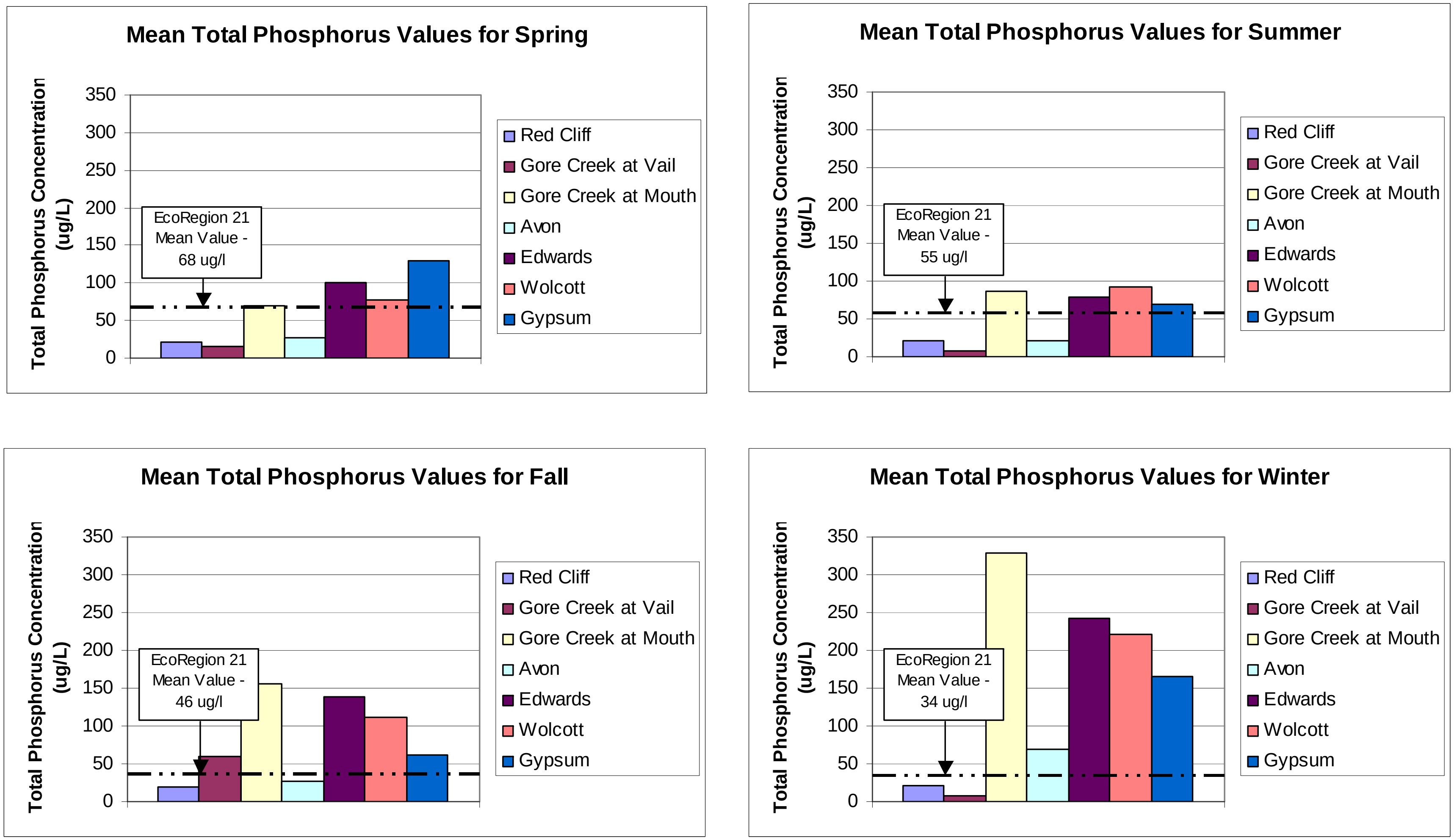


Figure G.6: TP samples (data source: USGS, Eagle River water quality database: http://co.water.usgs.gov/cf/eaglecf/default.cfm).

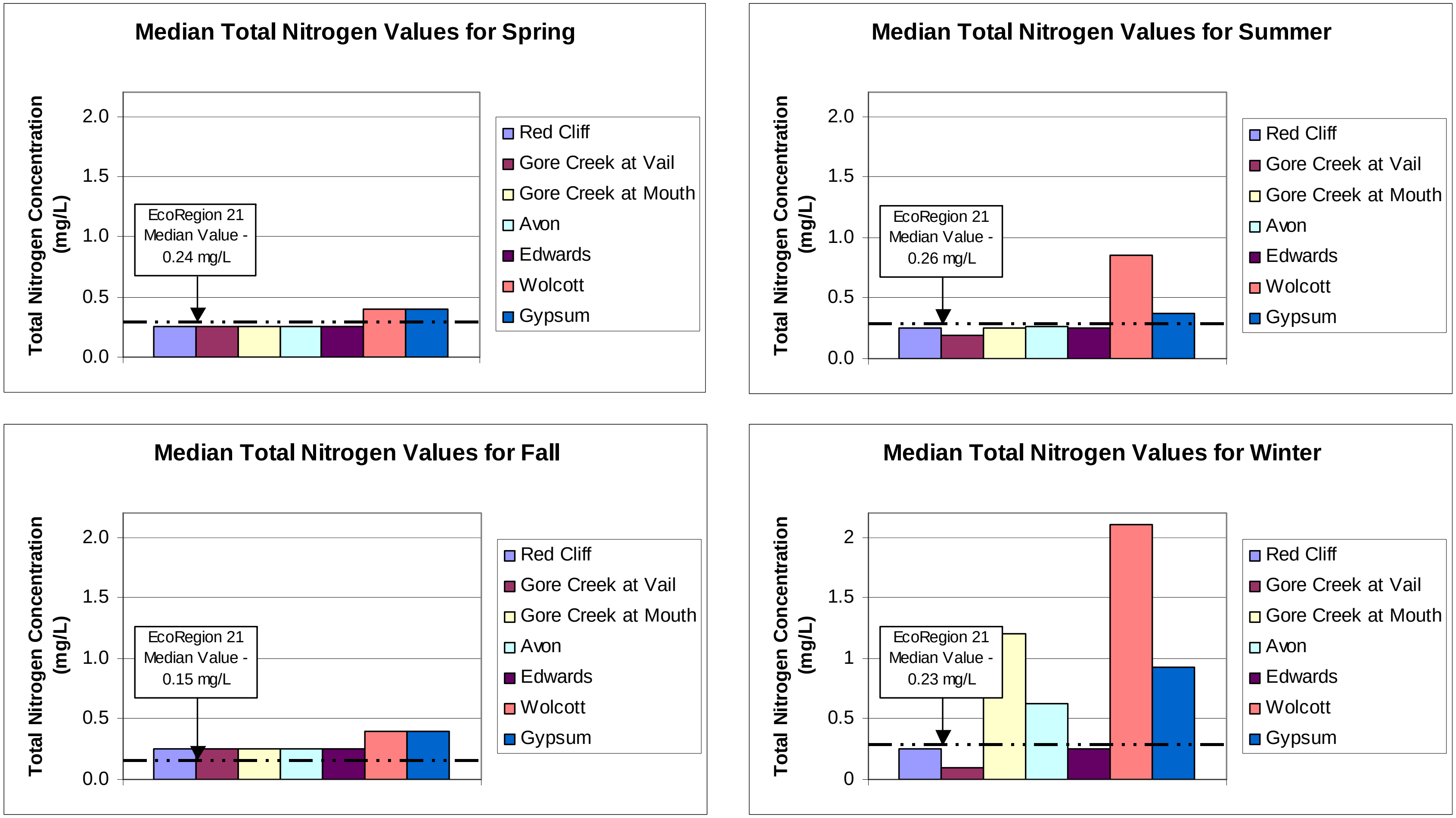


Figure G.7: TN samples (data source: USGS, Eagle River water quality database: http://co.water.usgs.gov/cf/eaglecf/default.cfm).

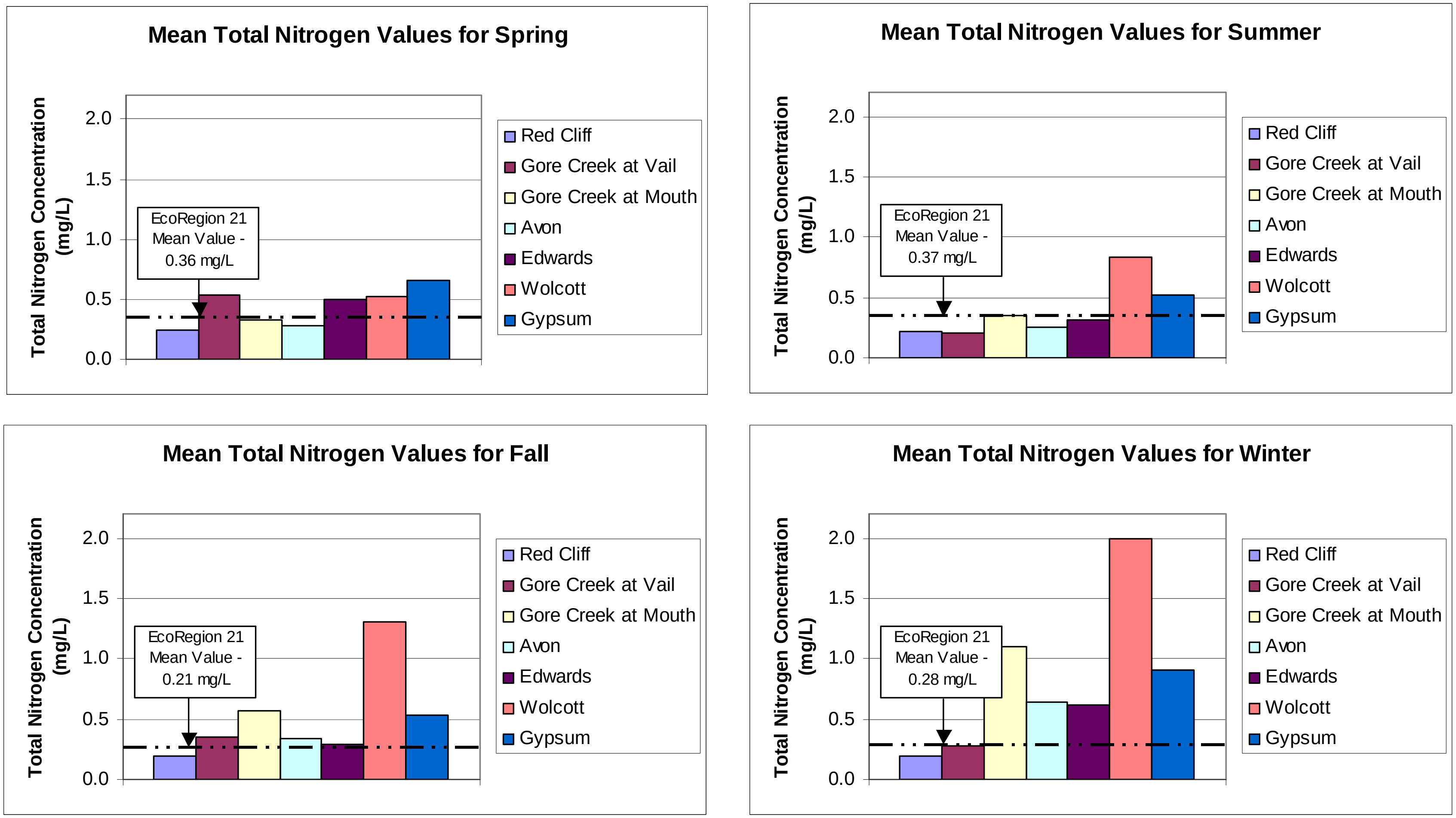


Figure G.8: TN samples (data source: USGS, Eagle River water quality database: http://co.water.usgs.gov/cf/eaglecf/default.cfm).

APPENDIX H

Fish / Metals Analysis Results

APPENDIX H
FISH / METALS ANALYSIS RESULTS

Many toxicological studies have focused on the acute effects individual constituents in the water column, but others suggest that chronic exposure to a mixture of various metals may be detrimental to aquatic biota. Therefore, Clements *et al.* (2000) defined the cumulative criterion unit to quantify the additive effects of chronic metals contamination.

Cumulative criterion units (CCUs) represent the sum of the ratios of the observed total recoverable metal concentrations (zinc, manganese, copper and cadmium, in this case) to the standards for those metals as set by the Colorado Department of Public Health and Environment (CDPHE) as a function of observed hardness within the water column. A CCU value of 1 represents a conservative estimate of the total metals exposure that will negatively impact aquatic life (Clements *et al.*, 2000).

The plots shown present the total fish populations for a given year and the mean CCU value of the previous three years of samples, all taken between March 30 and April 19 of each year. Average CCU values were used preferentially over values for the same year that fish were sampled because of the effect that metals contamination has on fish eggs and spawning capabilities.

Note the shift in peak CCU values after 2000 from Site 3 to Site 2.9. This is due to increased hardness values at Site 3. The bioavailabilty of metals is inversely related to hardness, and the Table Value Standards (TVS) set by the State reflect this. Thus, although total recoverable metal concentrations increase from 2.9 to 3 in most cases, the sum of the ratios of metal concentrations to State standards decreases. Note also the persistence of reduced fish populations at Site 2.9.

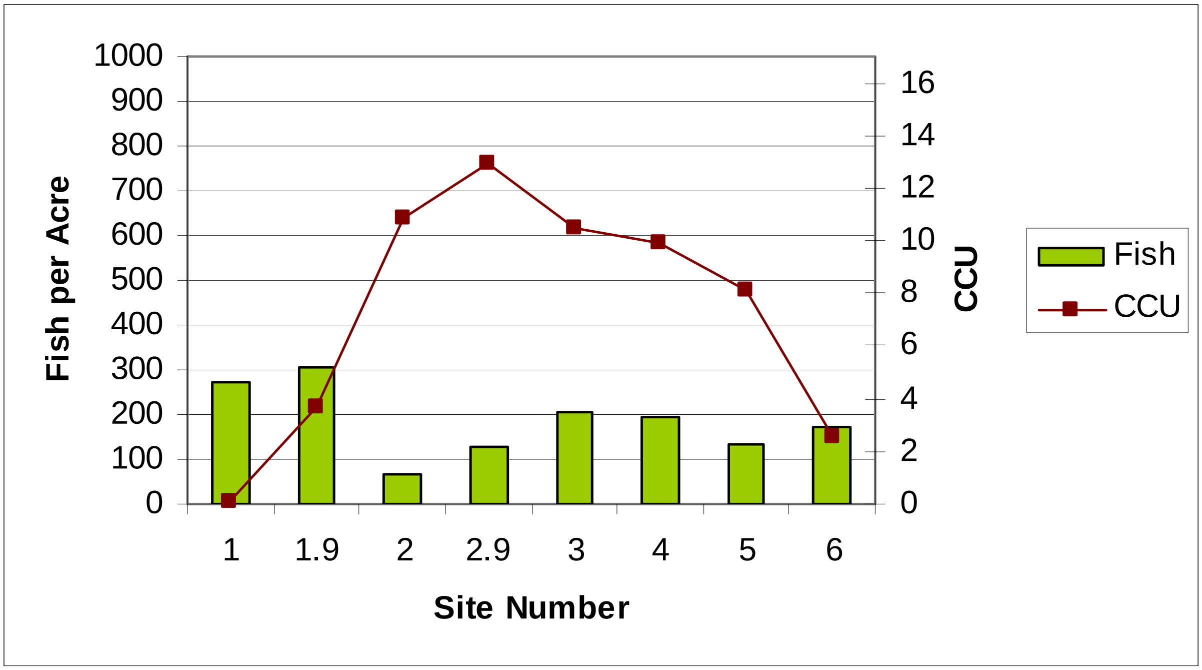


Figure H.1: Fish Population (1997) vs. Mean CCU (1995 to 1997) at Eagle Mine monitoring sites.

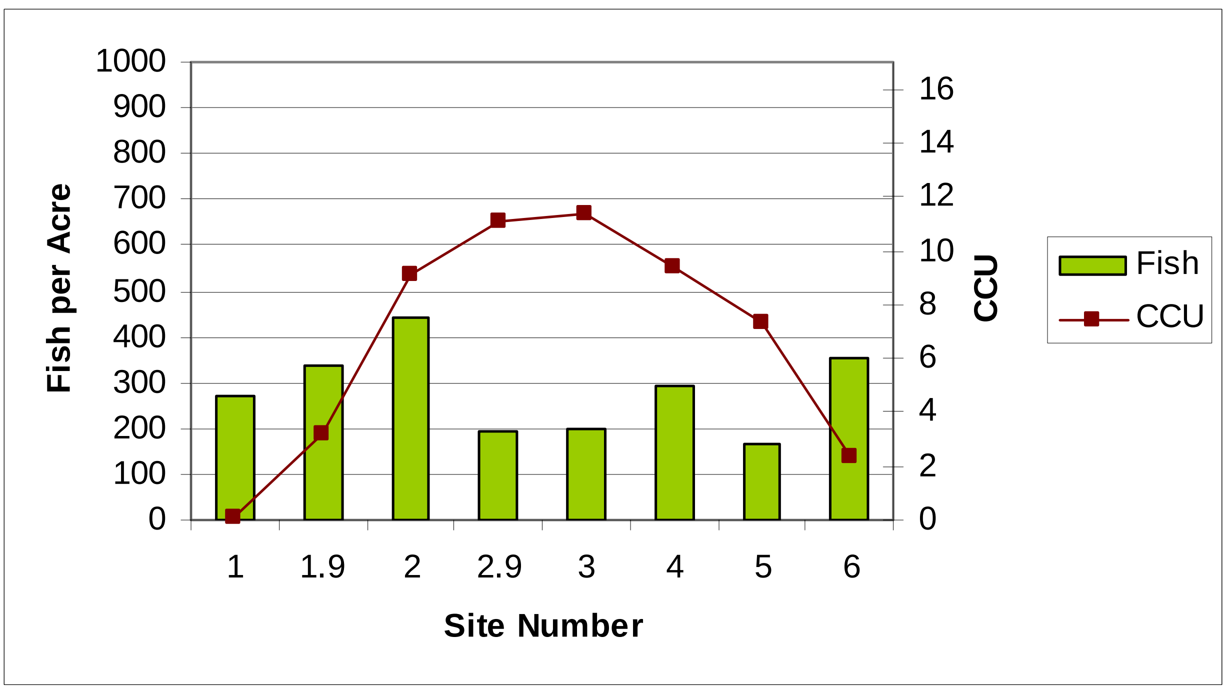


Figure H.2: Fish Population (1998) vs. Mean CCU (1996 to 1998) at Eagle Mine monitoring sites.

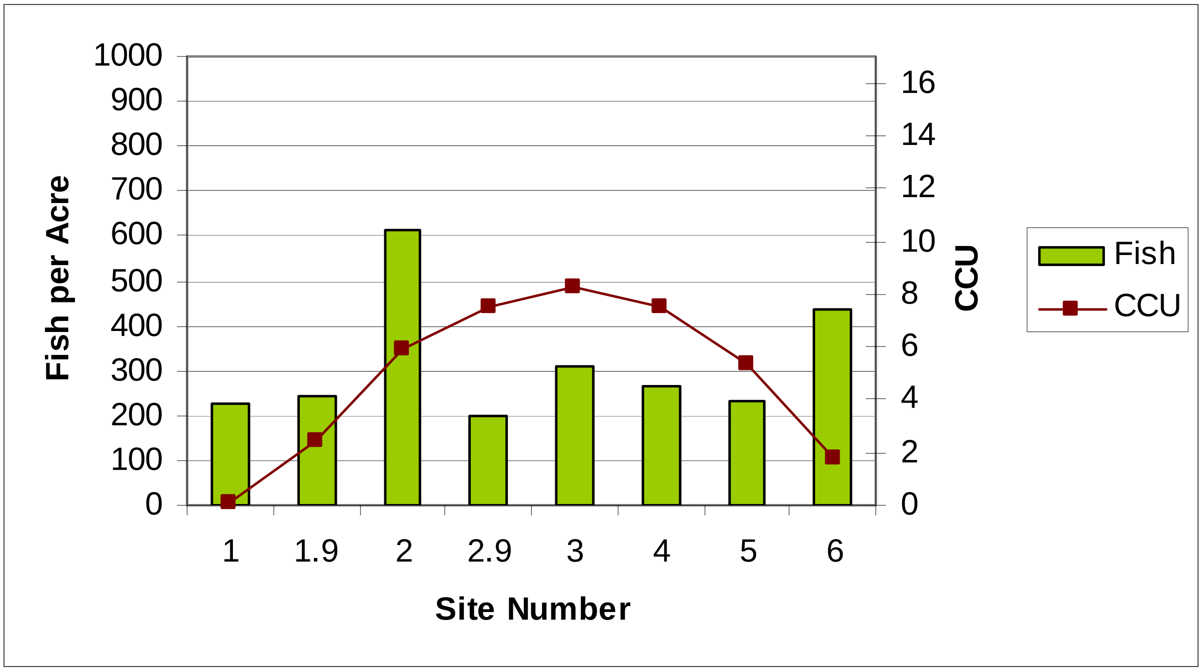


Figure H.3: Fish Population (1999) vs. Mean CCU (1997 to 1999) at Eagle Mine monitoring sites.

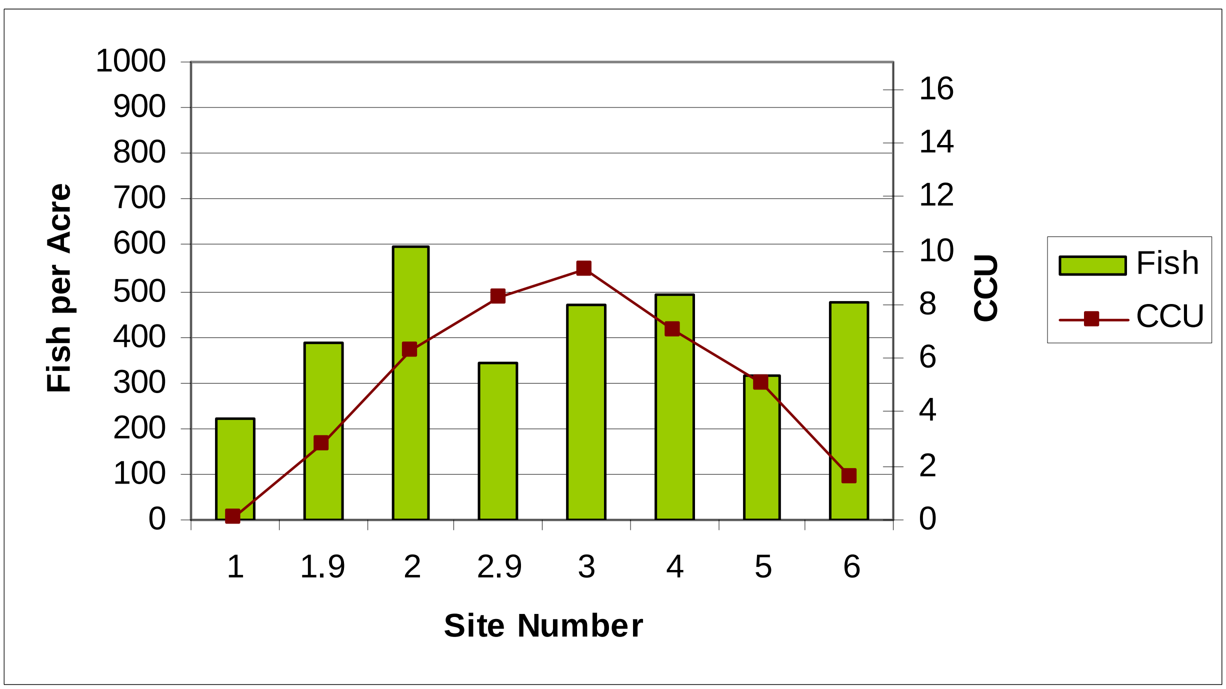


Figure H.4: Fish Population (2000) vs. Mean CCU (1998 to 2000) at Eagle Mine monitoring sites.

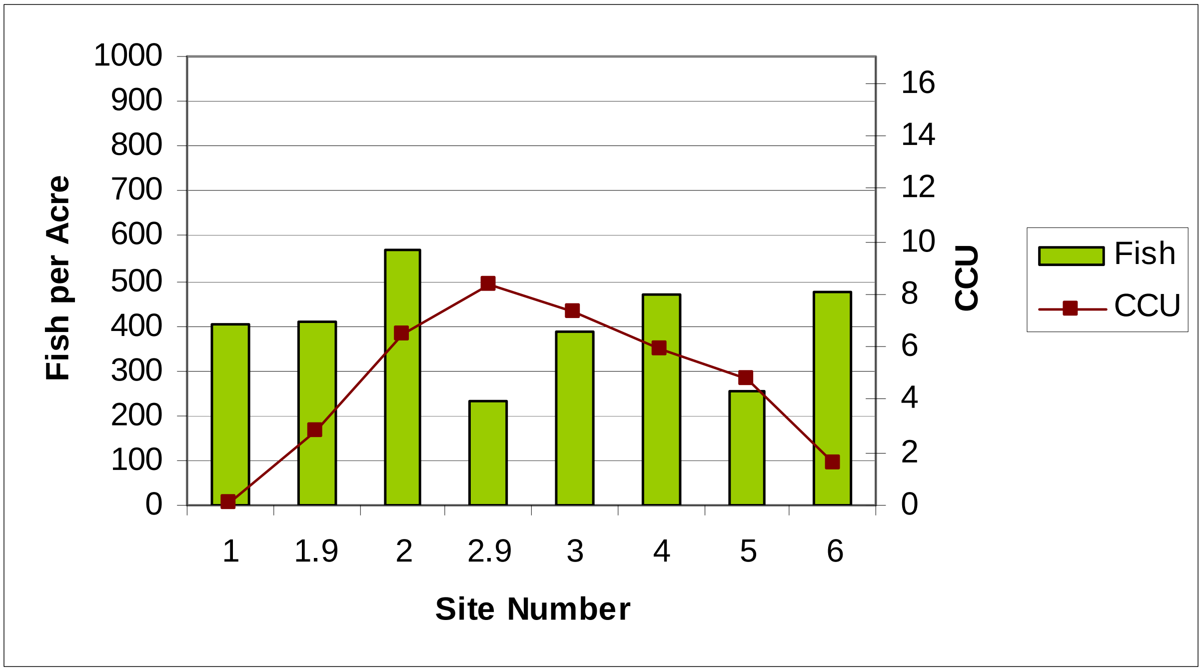


Figure H.5: Fish Population (2001) vs. Mean CCU (1999 to 2001) at Eagle Mine monitoring sites.

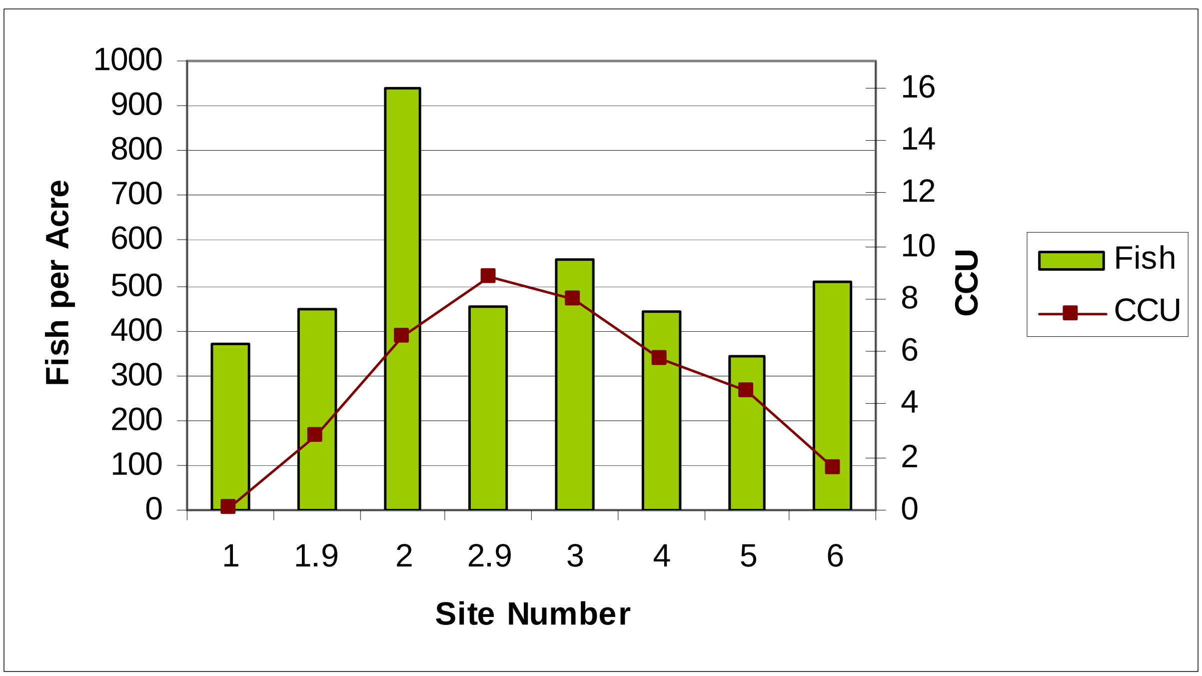


Figure H.6: Fish Population (2002) vs. Mean CCU (2000 to 2002) at Eagle Mine monitoring sites.

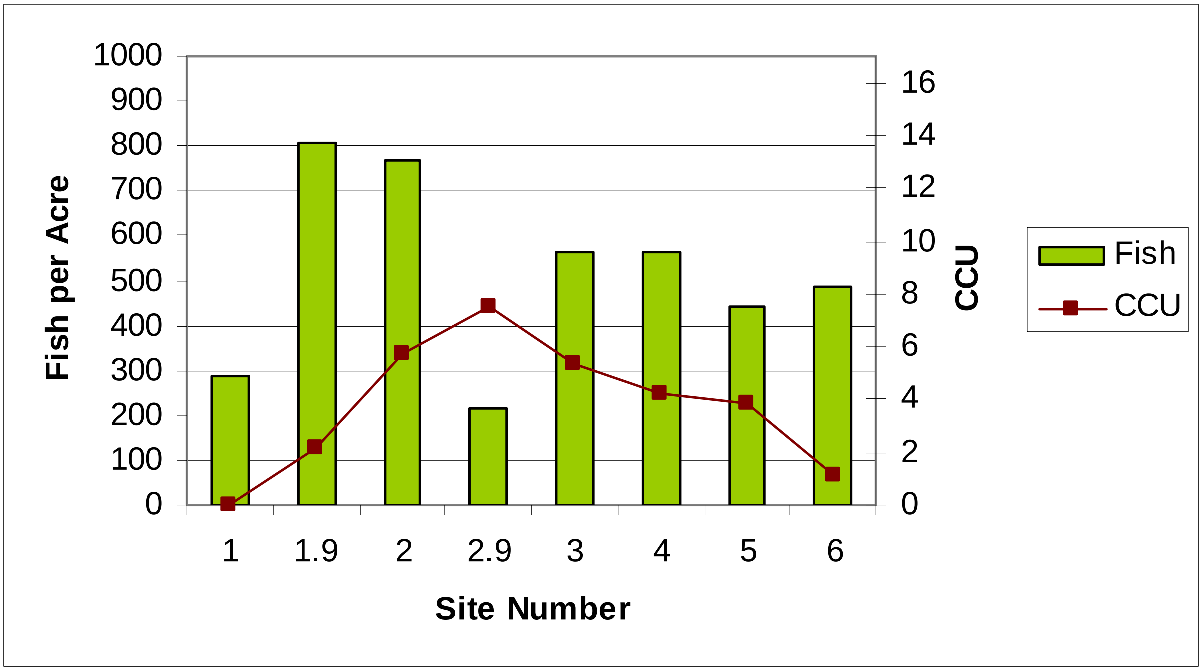


Figure H.7: Fish Population (2003) vs. Mean CCU (2001 to 2003) at Eagle Mine monitoring sites.

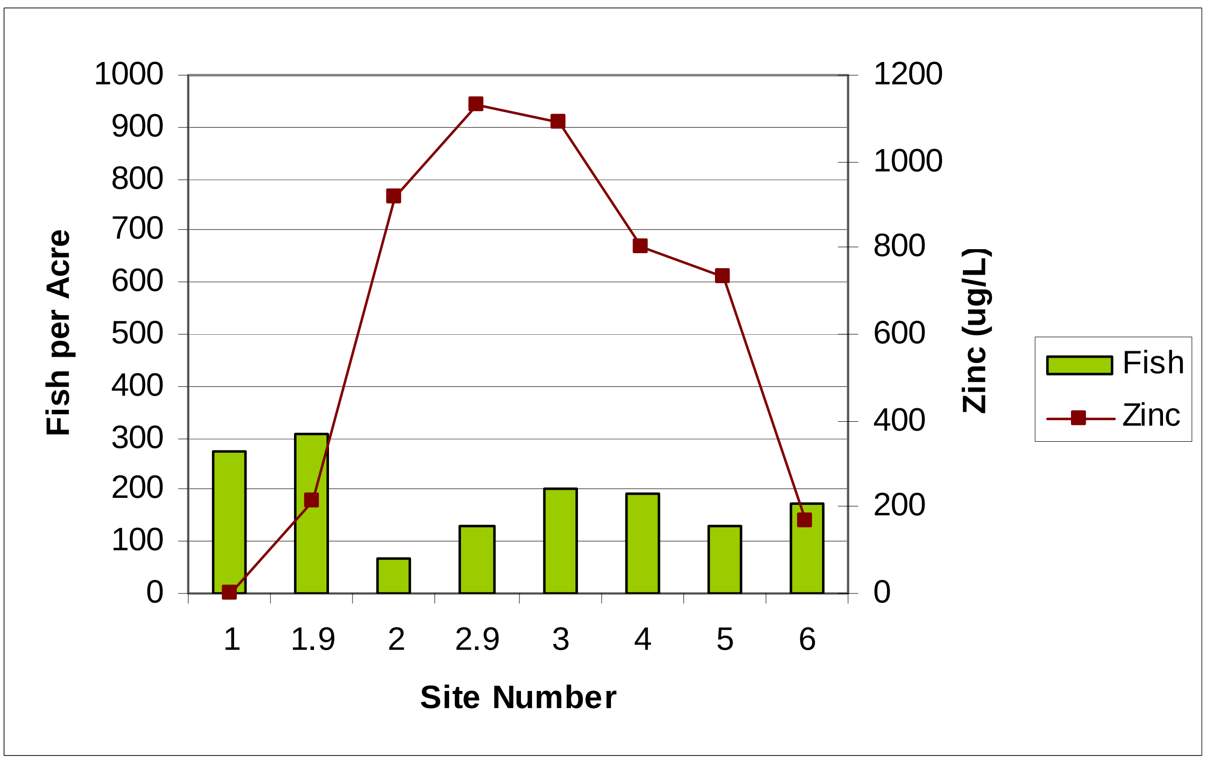


Figure H.8: Fish Population (1997) vs. April Dissolved Zinc Conc. (1996) at Eagle Mine monitoring sites.

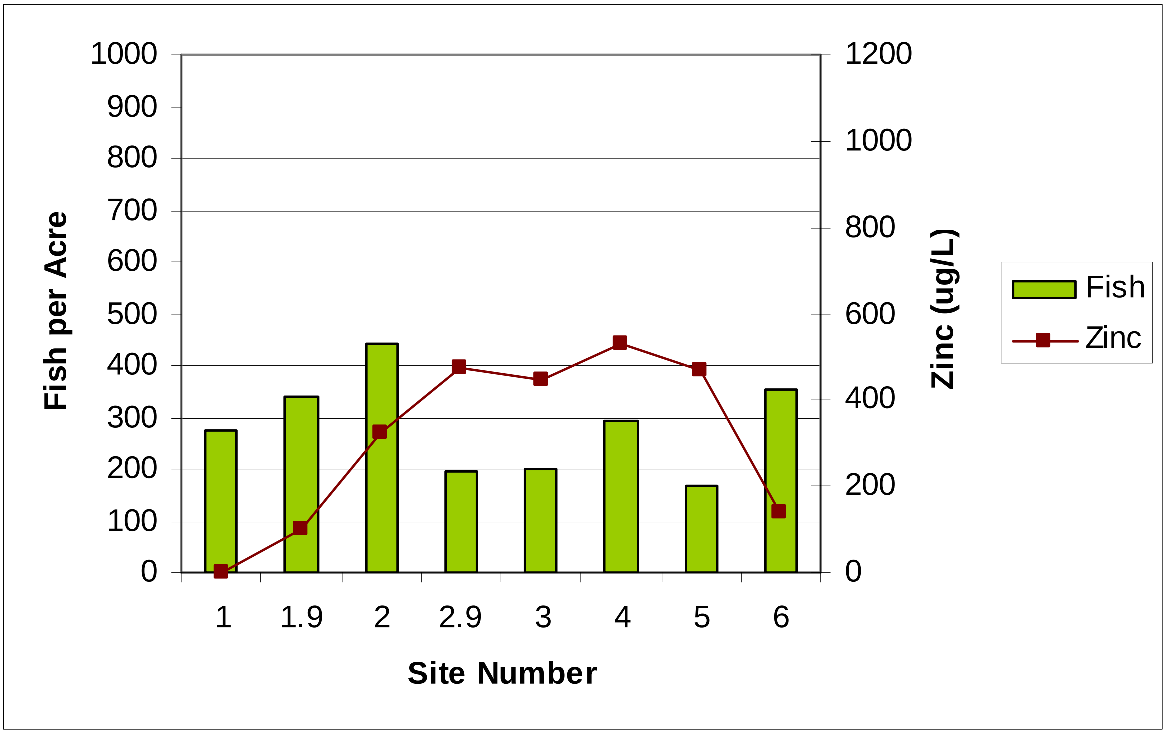


Figure H.9: Fish Population (1998) vs. April Dissolved Zinc Conc. (1997) at Eagle Mine monitoring sites.

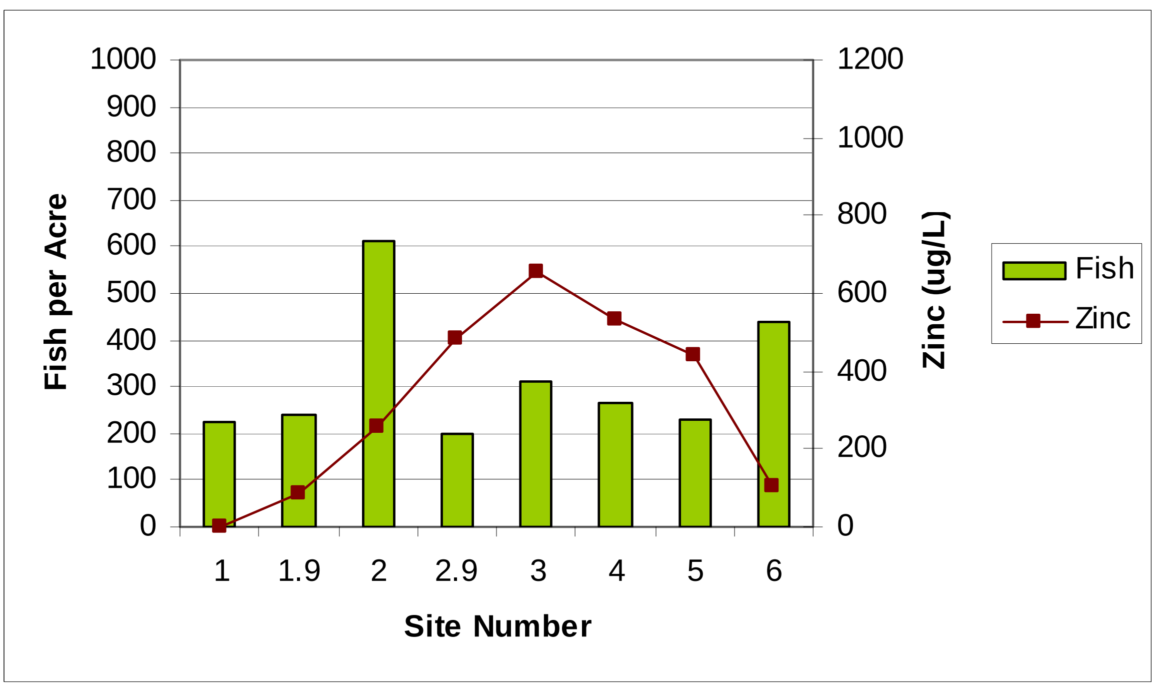


Figure H.10: Fish Population (1999) vs. April Dissolved Zinc Conc. (1998) at Eagle Mine monitoring sites.

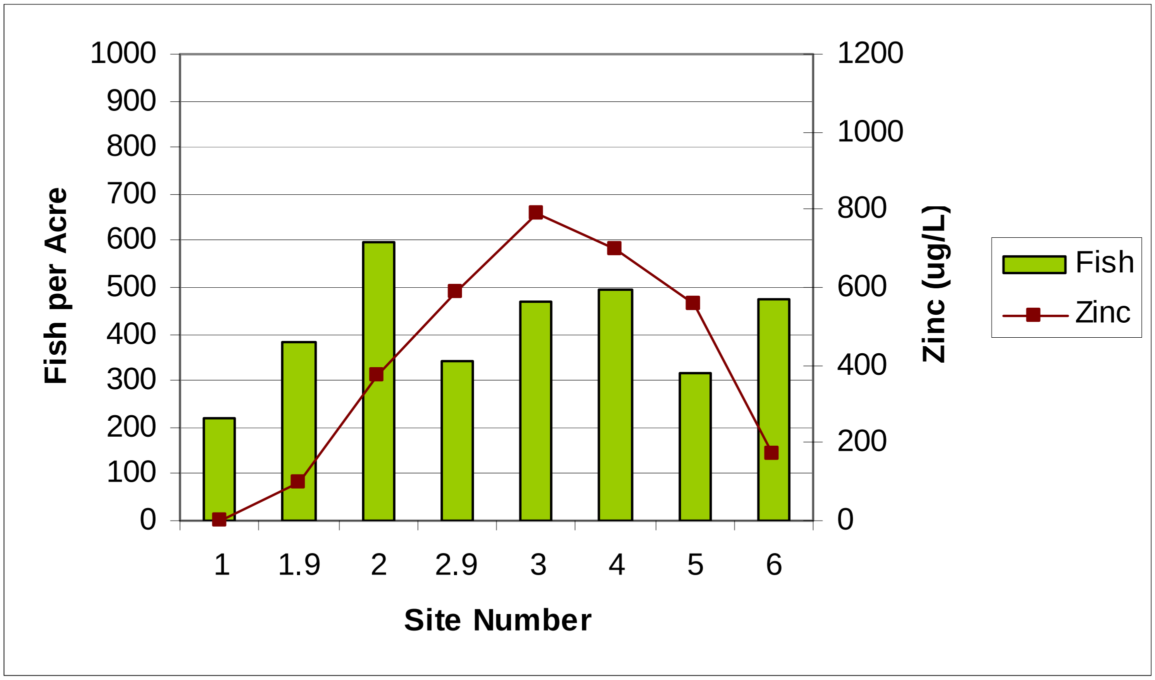


Figure H.11: Fish Population (2000) vs. April Dissolved Zinc Conc. (1999) at Eagle Mine monitoring sites.

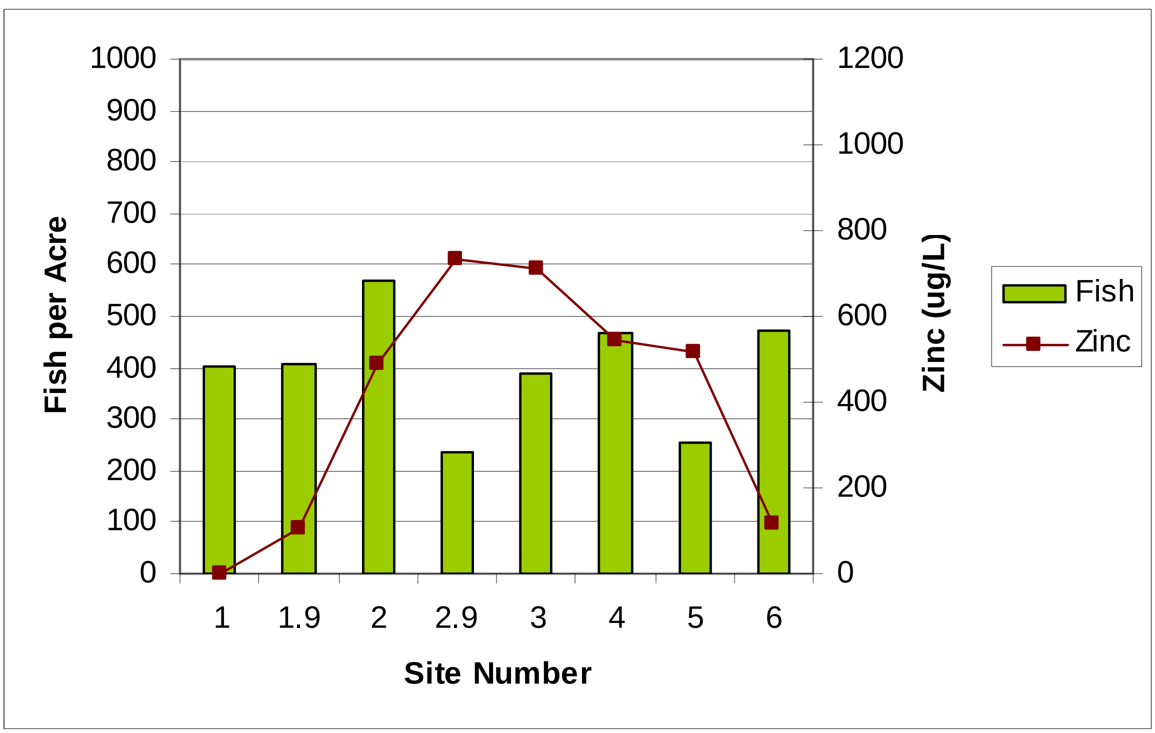


Figure H.12: Fish Population (2001) vs. April Dissolved Zinc Conc. (2000) at Eagle Mine monitoring sites.

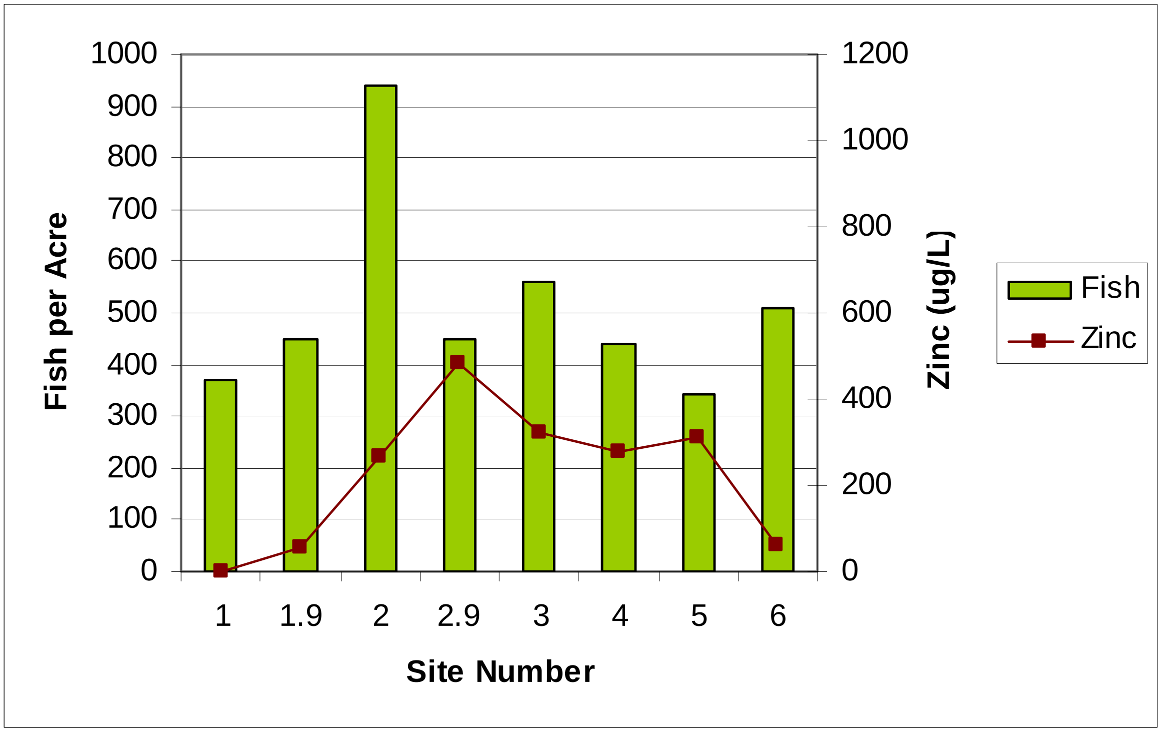


Figure H.13: Fish Population (2002) vs. April Dissolved Zinc Conc. (2001) at Eagle Mine monitoring sites.

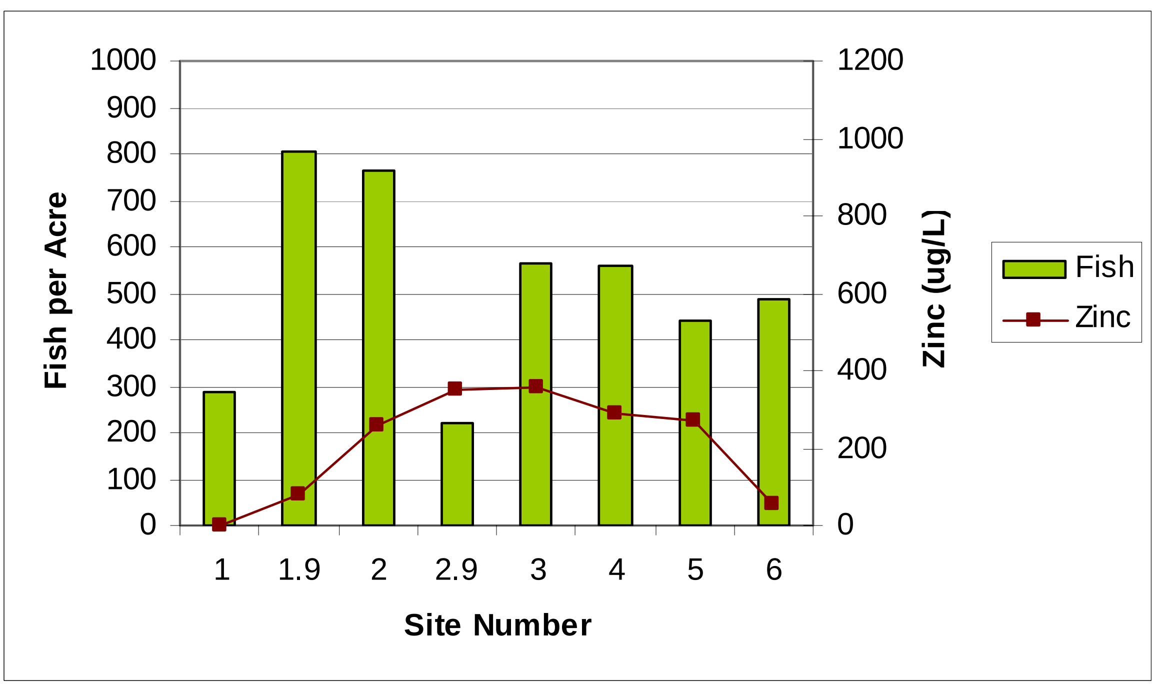


Figure H.14: Fish Population (2003) vs. April Dissolved Zinc Conc. (2002) at Eagle Mine monitoring sites.

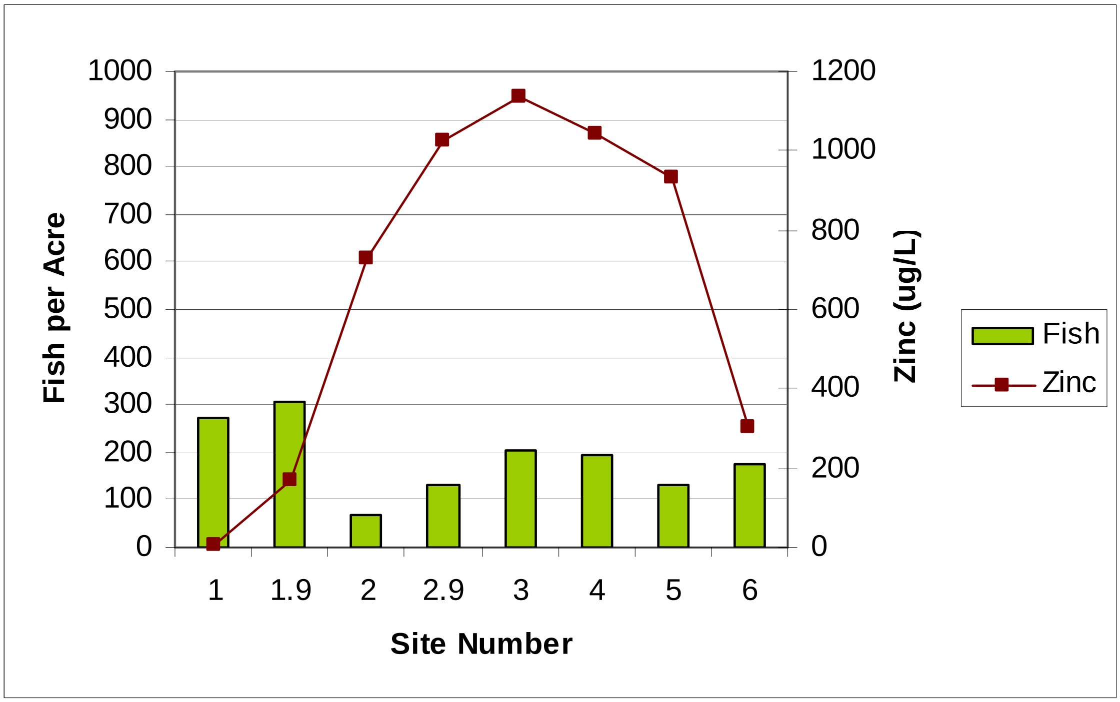


Figure H.15: Fish Population (1997) vs. Mean Total Recoverable Zinc Conc. (1995 to 1997) at Eagle Mine monitoring sites.

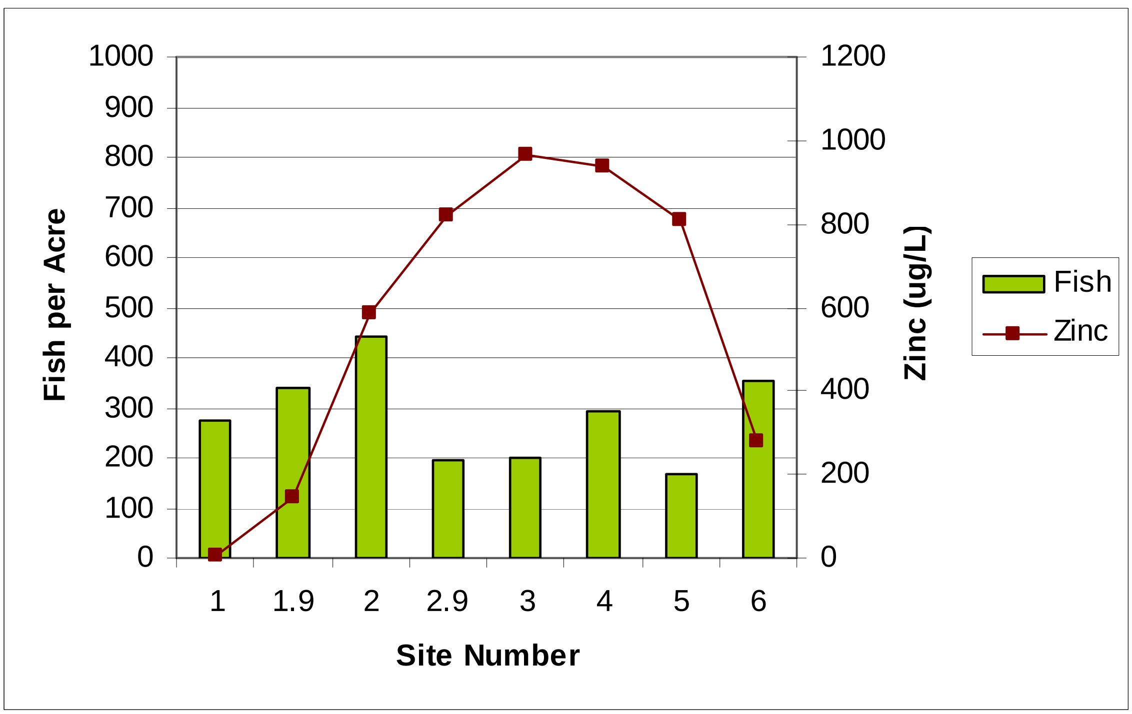


Figure H.16: Fish Population (1998) vs. Mean Total Recoverable Zinc Conc. (1996 to 1998) at Eagle Mine monitoring sites.

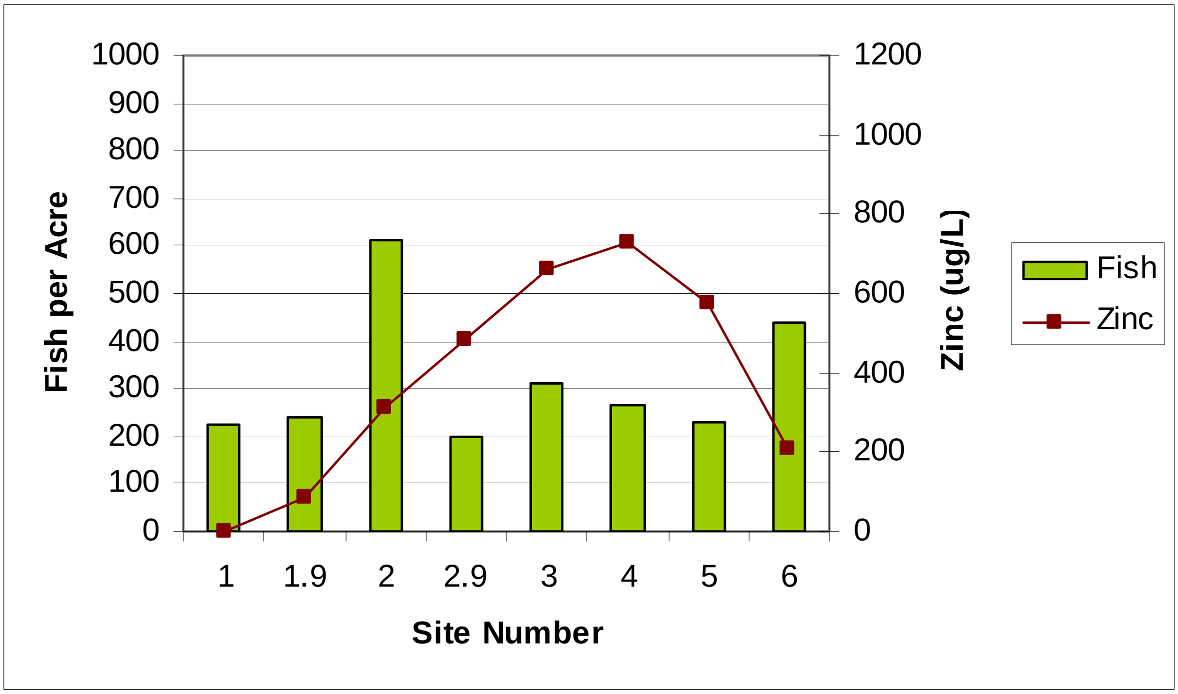


Figure H.17: Fish Population (1999) vs. Mean Total Recoverable Zinc Conc. (1997 to 1999) at Eagle Mine monitoring sites.

Figure H.18: Fish Population (2000) vs. Mean Total Recoverable Zinc Conc. (1998 to 2000) at Eagle Mine monitoring sites.

Figure H.19: Fish Population (2001) vs. Mean Total Recoverable Zinc Conc. (1999 to 2001) at Eagle Mine monitoring sites.

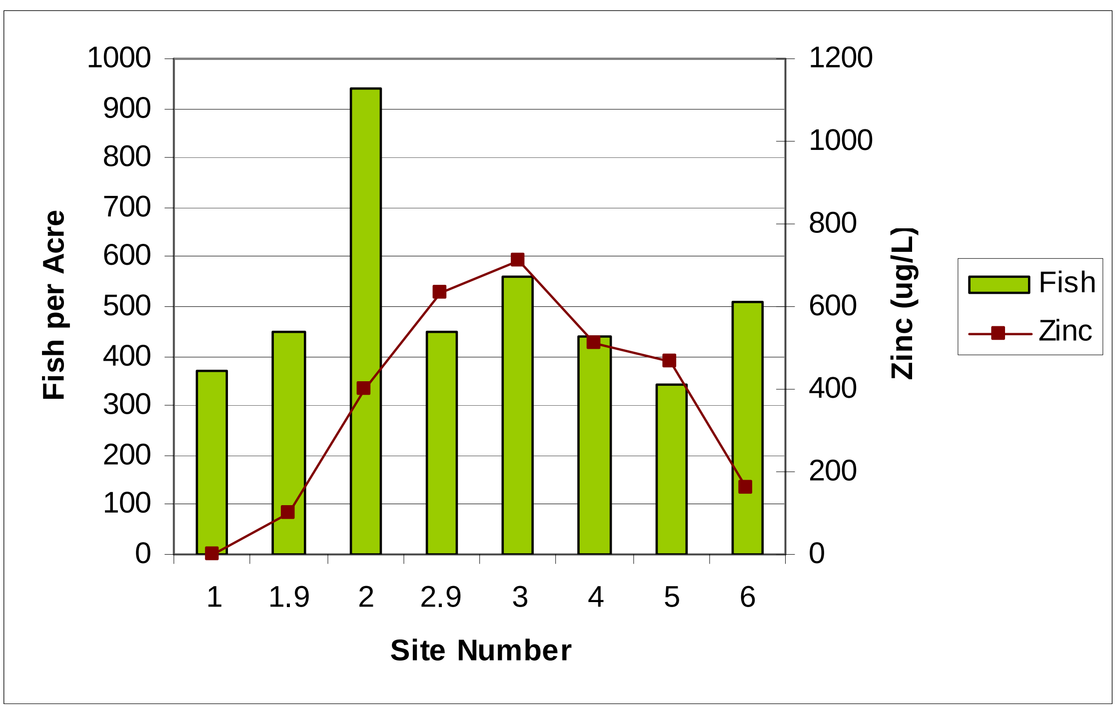


Figure H.20: Fish Population (2002) vs. Mean Total Recoverable Zinc Conc. (2000 to 2002) at Eagle Mine monitoring sites.

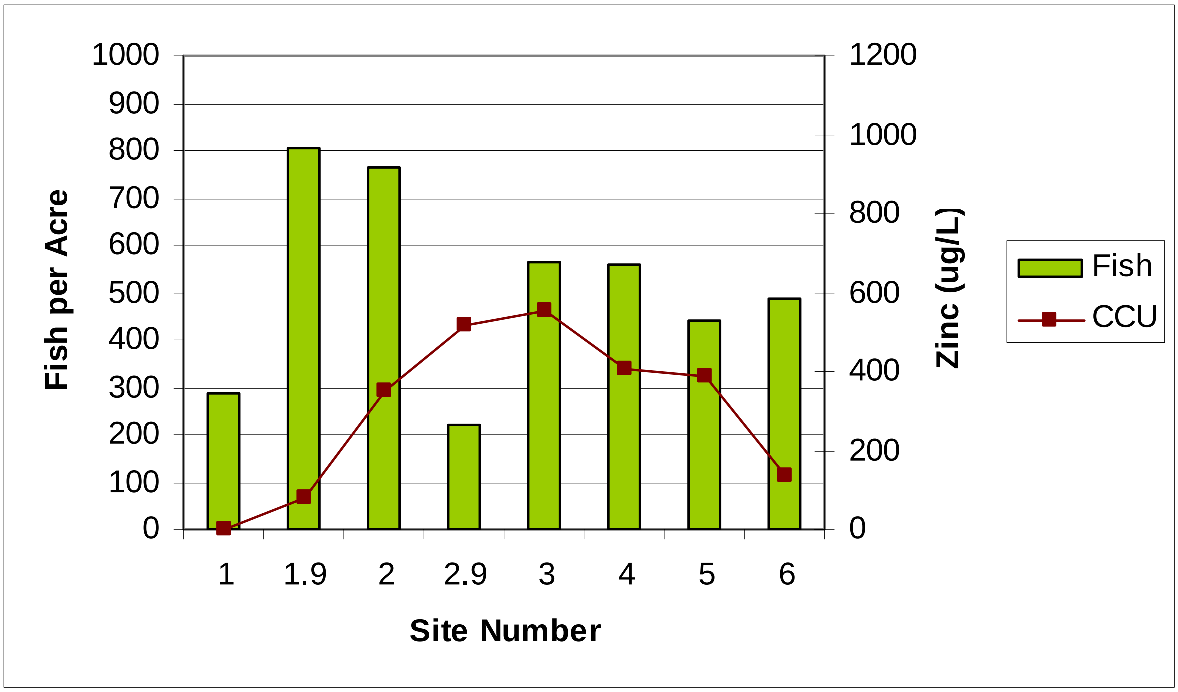


Figure H.21: Fish Population (2003) vs. Mean Total Recoverable Zinc Conc. (2001 to 2003) at Eagle Mine monitoring sites.

REFERENCE

Clements, W.H., D.M. Carlisle, J.M. Lazorchak, and P.C. Johnson (2000). Heavy metals structure benthic communities in Colorado Mountain Streams. *Ecological Applications*, 10(2):626-638.

APPENDIX I

Stormwater Ordinance Review

APPENDIX I
STORMWATER ORDINANCE REVIEW

I.1 REVIEW OF STORMWATER MANAGEMENT

Both the Center for Watershed Protection (CWP) and the U.S. Environmental Protection Agency (USEPA) suggest that local governments have a Stormwater Management Ordinance that embraces three essential components:

- Post Construction Stormwater Runoff Control
- Stormwater Operation and Maintenance
- Illicit Detection

The following discussion identifies the critical components of stormwater management ordinances and provides a summary of the USEPA and CWP recommendations for general stormwater management ordinances that may be modified to meet the needs of individual communities.

I.1.1 Post-Construction Stormwater Runoff Control

The post construction stormwater runoff management section of the ordinances serve to: (1) minimize increases in stormwater runoff from any development; (2) minimize increases in non-point source pollution from runoff; and (3) minimize the total volume of surface water runoff such that the pre-development hydrology is not exceeded either during or following development. The section also aims to reduce current stormwater runoff, non-point source pollution, and erosion rates through the implementation of safe and effective stormwater management practices.

I.1.1.1 Application

The post-construction stormwater runoff control regulations apply to all site plan and subdivision development except when granted a waiver. In addition, the stormwater management runoff control should apply to all small land development meeting a minimum criterion. The size of the site development to which this applies varies among communities. However, a size limit of 5,000 square feet or more is commonly used. A supplemental requirement, based upon the quantity of land converted to impervious surface, can further define the application of the controls. The CWP suggests that for sites less than 5,000 square feet, the authorizing agency may choose to waive the ordinance requirements, provided that the amount of impervious cover created does not exceed 1,000 square feet. The model post-construction stormwater runoff control ordinances provided by the CWP and USEPA provide several activities which are exempt from the requirements, including approved logging or agricultural activities, modifications or additions to single family structures, development less than the minimum size criteria, and repairs to existing stormwater management practices.

The local community should include a clear definition of qualification as redevelopment in completely addressing the applicability of the stormwater management plan. The State of Maryland defines redevelopment as "any construction, alteration, or improvement exceeding 5,000 square feet of land disturbance performed on sites where existing land use is commercial, industrial, institutional, or multifamily residential." (Section 26.11.02.02 of the Maryland Stormwater Management Code). Following the establishment of a clear definition, the local officials must determine the extent to which redevelopment projects should be held responsible for maintaining stormwater runoff controls. Providing cost effective treatment of runoff for redevelopment projects can prove to be extremely complex and sometimes impossible. CWP indicates that these types of development may be provided with less stringent conditions due to site limitations. Maryland's state stormwater management plan requires redevelopment projects to reduce the existing impervious surface area by 20%, manage a minimum of 20% of water quality volume, or use a combination of both.

I.1.1.2 Development of a Stormwater Design Manual

There are various high-quality stormwater design manuals suggested by the CWP that may be used as examples in creating or refining a local manual. These include the Maryland Department of the Environment 2000 Maryland Stormwater Design Manual Volumes I & II and the Stormwater Management Manual for Western Washington, Volumes 1-5. The establishment of a well-developed manual will furnish a register of permissible stormwater treatment practices, as well as specific design standards and operation and maintenance provisions for each stormwater practice. All stormwater treatment practices must be designed to adequately meet water quality standards. Local authorizing agencies will need to determine the minimum water quality standards. For example, the Maryland Stormwater Management regulations require that the water quality volume be treated with BMP's that will meet pollutant removal goals of 80% total suspended solids (TSS) and 40% Phosphorus (P). Both the USEPA and CWP recommend that stormwater management ordinances use an 80% removal goal for TSS.

I.1.1.3 Permit Procedures and Requirements

The USEPA and CWP model post-construction stormwater runoff control ordinances and those across numerous states require a permit in order to assure the review and approval of the stormwater management plan by the local authorization. The ordinance must contain clear application requirements, along with the requisite fees and application procedures, to obtain a permit. The application for a permit should require a conceptual plan for stormwater management, a maintenance agreement, and a fee for the review of the permit. The ordinance should communicate that the fee for the application will be determined based upon the amount of land being disturbed by development and that each local entity will be responsible for the fee structure. The USEPA advises local governments to use the review fees for staff and resources to promote the stormwater management plan. The procedures outlined in the ordinance should contain a statement identifying the length of time for the review of the permit application.

I.1.1.4 Waivers to Stormwater Management Requirements

The option to file a written request for a waiver should be included in the ordinance as described by the USEPA and CWP. Any request to waive the stormwater management plan requirements must be reviewed for approval by the authorizing entity. Partial or complete waivers may be granted for proposed developments which meet outlined criteria. These may include the demonstration that: (1) the development will not hinder the achievement of the objectives of the ordinance; (2) stormwater management by an off-site facility adequately meets requirements; (3) alternative minimum requirements of a local ordinance has been approved by a local government; (4)minimum requirements for onsite management are infeasible due to the physical conditions of the site; (5) non-structural practices will be used which reduce the runoff and pollutant generation and the size and cost of stormwater storage. Eligibility for a variance also requires that the applicant show that such a variance will not cause damage to existing structures, modify erosion and sedimentation processes, deteriorate ecological habitat, or augment the potential for flood damage. In addition, when the authorizing government grants a waiver, the applicant must provide for mitigation through selection or appointment of clearly defined measures. In lieu of complying with stormwater management practices, the USEPA model ordinance includes a provision to obtain a waiver by means of a monetary contribution or dedication of land to be used for the construction of an off-site stormwater management facility.

I.1.1.5 General Performance Criteria for Stormwater Management

The ordinance should provide a list of performance criteria for stormwater management at all proposed development sites. The following information establishes key elements of stormwater management that will need to be addressed according to the individual requirements of the authorizing agency.

1. The stormwater practices for each development must control the peak flow rates of stormwater discharge associated with specified design storms and reduce the generation of stormwater. The use of pervious areas for treatment and infiltration of stormwater runoff should be maximized. The specific design storm size will depend on the depth of water required for treatment.

2. No stormwater runoff generated by new development may be discharged without treatment directly into jurisdictional wetlands or bodies of water. If such a discharge is proposed, the impact on the functional value of the wetland or body of water must be assessed by the applicant using an approved method.

3. A relatively new criterion pertains to annual groundwater recharge. At a minimum, the USEPA suggests that the annual groundwater recharge rates from post development sites be the same as the pre-development annual groundwater recharge rates. Groundwater recharge may be accomplished through the use of both structural and non-structural infiltration measures. This stormwater management element must be considered very early in the development design phase because it relies heavily upon pervious areas.

4. New development should incorporate structural stormwater treatment practices that are capable of removing a specified percentage of annual post-development TSS. Generally, stormwater treatment plants comply with such standards if they are sized to hold the necessary water volume, designed to meet local stormwater specifications, and constructed and maintained properly. As development and populations increase, the NPDES Phase II permit is becoming an issue of high priority in Colorado. For post development stormwater runoff treatment, each local government is confronted with a number of options to meet the water quality standards. The USEPA and CWP review these options at varying levels of management effort and success in treating runoff. These options include:

   - Requiring stormwater treatment practices for stormwater quality
   - Instituting more rigorous design standards for stormwater practices
   - Requiring onsite load calculations
   - Requiring load calculation with stormwater offset fee to provide retrofits on existing development

5. A provision for stream channel protection should be included in order to protect downstream channel from erosion. The USEPA offers three basic options from which to choose: 24-hour detention of the one-year storm event, geomorphically-based runoff control, and bankfull

capacity/duration criteria. The 24-hour detention option allows for storage and release of stormwater in a gradual manner to avoid erosive velocities downstream. The criteria behind the geomorphically-based method are aimed to minimize channel erosion by distributing the erosion potential such that predevelopment values are maintained, and time-integrated sediment transport capacity remains unchanged. Finally, the bankfull capacity/duration criteria maintain that the post-development bankfull flow frequency, duration, and depth should not exceed the predevelopment values for designated control points in the channel. These criteria are most relevant to smaller streams of relatively high potential for vertical and/or horizontal adjustments.

6. Other important elements of the general performance criteria include a provision requiring the potential for additional performance criteria for stormwater discharges to critical areas with sensitive resources, the requirement for stormwater pollution prevention plans for certain industrial developments or areas with high potential pollutant loadings, and a provision requiring applicants to consult with the jurisdictional government for the determination of subjectivity to additional stormwater management practices.

I.1.1.6 Basic Stormwater Management Design Criteria

Many communities use a separate stormwater design manual to define the design criteria and update material regularly. In these cases, this section of the ordinance should refer to the stormwater design manual. This is a preferred method because it allows for specific design requirements and document language to be updated regularly without having to experience the lengthy process of modifying an ordinance. A stormwater design manual should consist of several factors that determine the specified performance criteria for each stormwater management practice. The USEPA advocates the use of the factors defined in the Maryland Stormwater Design Manual.

- Site Design Feasibility
- Conveyance Issues
- Pretreatment Requirements
- Treatment/Geometry Conditions
- Environmental/Landscaping Standards
- Maintenance Needs

In addition to provisions addressing the six factors mentioned above, the design manual must encompass minimum control requirements and encourage non-structural practices. Each community must establish appropriate sizing and design criteria for permitted stormwater practices. A storm event frequency, which meets the water quality and water quantity standards, must be selected. The utilization of non-structural practices should be promoted through the use of credits for the reduction in the amount of stormwater requiring management.

I.1.1.7 Requirements for Stormwater Management Plan Approval

This section of the ordinance provides guidance and requisite information to all applicants proposing development. The ordinance must identify preliminary conceptual plan and final plan requirements. The USEPA encourages local governments to incorporate a security or performance bond provision, which guarantees that all stormwater practices are installed or constructed as shown in the stormwater management plan. Some agencies also require a maintenance bond to ensure the responsible entity complies with a maintenance agreement.

I.1.2 Stormwater Operation and Maintenance

The purpose of the stormwater operation and maintenance section of the ordinance is to define guidelines for the design, maintenance, and inspection of stormwater practices. Stormwater operation and management should not be a single ordinance, but rather a section within the stormwater management plan. The stormwater operation and maintenance is comprised of a description of the design, maintenance, and inspection provisions.

I.1.2.1 Design

The stormwater BMPs should be designed to minimize maintenance and reduce the potential for failure. The guidelines for the design of acceptable BMPs may be located in a stormwater management design manual or within the stormwater management plan. The former is a more efficient method for referencing and updating material. The design should include stormwater easements, provided by the landowner, for purposes of maintenance and inspection by the local agency.

I.1.2.2 Maintenance

Routine and non-routine maintenance needs to define the organization responsible for carrying out and financing activities. Non-routine maintenance will be performed when necessary, and if not completed properly or with appropriate timing, may be completed by the stormwater agency at the expense of the responsible organization.

I.1.2.3 Inspection

Prior to, during, and following construction, inspection should be performed regularly. An additional provision defines the authorization to enter the premises at reasonable times to conduct inspection and maintenance.

I.1.3 Enforcement and Penalties

The ordinance should include a series of steps that will be taken once a violation has been identified. Typically, an initial notice of violation is submitted to the developer with a "stop work order" notice that immediately stops the progress of all construction activates until the specified problem is resolved. If the problem is not corrected in a timely manner, criminal, civil, and monetary penalties may be invoked. Penalties for violations should be evident in the ordinance. The ordinance should include a restoration of the land provision, which designates the violator to return the land to undisturbed condition or face penalties. Additionally, the USEPA recommends the inclusion that the violator will receive holds on all occupation permits until stormwater practices are accepted as satisfactory by the agency of jurisdiction.

I.1.4 Illicit Discharge Detection Program

Illicit detection programs are designed to thwart contamination of ground and surface water supplies by monitoring, inspection and removal of illegal non-stormwater discharges. The illicit discharge detection plan may be an individual ordinance or included as a separate section of the stormwater management ordinance. The program must define illegal discharges and connections and a list of exempted discharges. In addition, an illicit detection ordinance permits the jurisdictional authority to inspect any property under suspicion of discharging contaminated substances into the stormwater drainage system. If a person is found to be in noncompliance with the ordinance, drainage system or MS4 access may be suspended or other penalties invoked subject to authority. Enforcement actions for noncompliance or refusal to grant access must be established within such a plan.

I.2 EROSION AND SEDIMENTATION CONTROL PLAN

In addition to or within a Stormwater Management Ordinance, an Erosion and Sedimentation Control (ESC) Ordinance is necessary to protect properties and natural resources from damage. Soil is most vulnerable to the erosive forces of wind and precipitation during construction. Eroded soils entering streams, rivers, and lakes, can cause serious water quality problems, alter fish and macroinvertebrate habitats, and reduce aesthetic and recreation values (Reice and Carmin, 2000). To minimize the detrimental affects of erosion and sedimentation, ordinances which connect the processes of erosion and sedimentation with stream integrity are necessary. The purpose of this type of ordinance is to protect public welfare, property, and the environment through guidance and regulation of ESC measures associated with construction, clearing and grading activities.

I.2.1 Permits

Every ESC ordinance defines a minimum size construction site that is required to establish an ESC Plan. While the NPDES Phase II program entails regulation for land disturbance activities greater than one acre, local communities have extensively varied application requirements. USEPA recommends that an ESC Plan is a component of a site development permit for sites uncovering 10,000 square feet or more. However, some communities require a Plan for sites disturbing more than 2,000 square feet of land. The requirement varies among regions based upon the location's need for protection. For development within a close proximity to any body of water or wetland, a community should utilize stricter standards for defining the conditions of an ESC Plan.

The ordinance should incorporate a list of activities exempt from the regulations, such as emergency activities to protect the life of the citizens, property, or natural resources. In addition, the USEPA suggests the use of performance bonds to cover the costs of noncompliance and the obligation for development to have a Certified Contractor on site for all days when construction and grading activities will be performed. Review and approval processes and requirements must be outlined for the benefit of both the authorizing agency and the developer.

I.2.2 Erosion and Sedimentation Control Plan

The ordinance should explicitly define the requirements for an ESC Plan. The CWP and USEPA recommend that such a plan have a map scale of no greater than 1" = 100' to sufficiently analyze all aspects of the plan and the surrounding environment. Sequencing of construction activities and temporary and permanent ESC measures should be identified. Where vegetative control measures are used, the developer must identify details of the seeding mixtures, types of sod, fertilizer characteristics, and anticipated mulching activities. The maintenance of all ESC activities must be defined by the developer in addition to expected maintenance costs. If modifications to the Plan are necessary, approval by the local agency is mandatory.

I.2.3 Design Requirements

An ESC Manual typically represents the design criteria satisfactory to each local community. The use of a design manual allows governments to conveniently modify standards when new information becomes available without having to modify the Code or Ordinance language. Additionally, the ordinance outlines the design requirements for the following construction activities.

I.2.3.1 Clearing and Grading

One important aspect to be included in an ESC Ordinance is a requirement for the phasing of construction for sites greater than a specific size. When clearing is moderated, the quantity of sediment exported from a site can significantly decrease. Phasing of clearing activities may reduce sediment loss by 40% when compared to sites utilizing a typical mass-grading system (Claytor, 1997). The phasing approach introduces a technique of erosion prevention rather than sediment control, and is most beneficial on sites of greater size. The USEPA model ordinance recommends that phasing be a requirement for site with a minimum size of 30 acres.

I.2.3.2 Erosion Control

Requirements should be included that regulate the length of time to stabilize soil after clearing and to demonstrate vegetation establishment. The USEPA allows five days to stabilize soil after clearing. The time to establish vegetation within a site will vary upon climate. Dust control measures are extremely important in semiarid regions where the blowing of dust and loose soil provides significant sediment input to streams and lakes. Thus, the ordinance must require stockpile covering at the end of each construction day, stabilization of sites following the termination of construction, and methods to minimize the blowing of dust from sites during construction.

I.2.3.3 Sediment Controls

The USEPA advocates the use of settling basins, sediment traps and perimeter controls for sediment control. Properties adjacent to the site of development should be protected through the combination of vegetated buffer strips and perimeter controls.

I.2.3.4 Waterways and Watercourses

For construction that requires the crossing of wetlands or streams, the developer should provide a temporary stream crossing. Development that includes in-channel work must sustain bank stabilization throughout all stages of construction. Additionally, stabilization should be maintained at all outfalls to protect against erosion.

I.2.3.5 Construction Site Access

Temporary access roads should be constructed at each site. In order to prevent sediment from leaving the site through vehicle tracking or storm drains, local governments should incorporate additional sediment controls.

I.2.4 Inspection and Enforcement

Inspection of construction activities and enforcement of the regulations are essential to the success of the ESC ordinance. In a study performed by the University of North Carolina at Chapel Hill, Dr. Seth Reice and Dr. JoAnn Carmin determined the effectiveness of varying environmental regulations and incentives in protecting the ecological system against sedimentation (Reice and Carmin, 2000). The research monitored large construction sites (>100 acres of disturbance) within three jurisdictions of North Carolina. Stream health was determined through the richness of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). This method, known as an EPT index, is widely acknowledged as an acceptable measure of identifying stream health. Monitoring was conducted upstream of the disturbance, at the site, and downstream of the disturbance.

The study found a direct link between the attitudes and enforcement measures of the regulators of ESC ordinances and the detrimental effects of construction activities to the stream environment. The stream data suggested that the laws of each jurisdiction had a limited influence on the degradation of the stream health. However, the analysis illustrated that the type and frequency of enforcement and inspection activities was significant in reducing sedimentation and stream detriment. The research provides the following recommendations for ESC programs.

- Sufficient inspectors should be available to visit each construction site on a weekly basis.
- Inspectors must be given the authority and possess adequate expertise to implement innovative solutions to erosion problems on a site-specific basis.
- In circumstances of sedimentation violations, inspectors must have authority to issue rigorous penalties, such as stop-work orders.
- The maximum level of fines should be high enough to create concern for developer. The suggested amount is $10,000 per day.
- An ESC program needs to provide for the education of the development community as to the harmful effects of sedimentation on stream ecosystems.

I.3 REFERENCES

Reice, S. and Carmin, J. (2000). Regulating sedimentation and erosion into streams: What really works and why. Proceedings from the National Conference on Tools for Urban Water Resource Management and Protection, Chicago, IL, EPA/625/R-00/001.

Claytor, R. (1997). Practical tips for construction site phasing. *Watershed Protection Techniques* 2(3):413-417.

I.4 STORMWATER MANAGEMENT AND EROSION AND SEDIMENTATION CONTROL TOOLBOX

- The Stormwater Managers Resource Center (SMRC), created and maintained by CWP, is a valuable resource to stormwater management program managers in Phase II locations. The site provides assistance in complying with the NPDES Phase II regulations through its manual-builder resources and website: http://www.stormwatercenter.net
- The USEPA recommends the "Operation, Maintenance, and Management of Stormwater Management Systems" by the *Watershed Management Institute* as a resource for stormwater maintenance BMPs. Available from the USEPA at http://www.epa.gov/owow/nps/wmi/

The following recommended locations are adapted from: http://www.cdphe.state.co.us/wq/Permits Unit/SWFactsheet.pdf

- Urban Drainage and Flood Control District (UDFCD) Drainage Criteria Manual (Vol. 3) UDFCD manual for stormwater management. Updated Sept. 1, 1999. This is a stormwater BMP manual developed for the Denver metro area. Includes regional, residential, industrial, commercial, and construction BMPs. Highly recommended.
  - Manual and accompanying CD – $65, CD only – $30
  - Urban Drainage and Flood Control District, 2480 W. 26th Ave., Ste. 156-B, Denver, CO 80211
  - Phone: (303) 455-6277
  - http://www.udfcd.org/
- USEPA's Menu of BMPs – http://www.epa.gov/npdes/menuofbmps/menu.htm
- National Stormwater Best Management Practices (BMP) Database (USEPA/ASCE, 4/01) Database of monitoring results showing effectiveness of structural and non-structural BMPs. Datacontributions are being solicited on an on-going basis. Available as CD-ROM, or on the web at http://www.bmpdatabase.org
- Stormwater Management for Industrial Activities, Developing Pollution Prevention Plans and Best Management Practices (EPA-832-R-92-006, 9/92)
- Stormwater Management for Construction Activities, Developing Pollution Prevention Plans and Best Management Practices (EPA-832-R-92-005, 9/92)
- Class: "Stormwater Management During Construction" -- One-day course, with an optional additional half-day in the field, on principles and practices of erosion and sediment control. Recommended for municipal erosion control inspectors and those practicing erosion control in the field. Rocky Mountain Education Center, Red Rocks Community College, Lakewood.
  - $175/person
  - Course Information: (800) 933-8394
  - www.osha-redrocks.org

APPENDIX J

Riparian Buffer Ordinance Review

APPENDIX J
RIPARIAN BUFFER ORDINANCE REVIEW

A review of current and recommended stream buffer ordinances throughout the nation was conducted to evaluate the conformity of the Eagle River. Overall, the existing stream buffer ordinances of the Eagle River do not comply with the recommendations provided by model guides, including those of the Environmental Protection Agency (EPA), the Center for Watershed Protection (CWP), and the Natural Resources Conservation Service (NRCS). In addition, the Eagle River stream buffer ordinances are less stringent than many watersheds in the country. Table J.1 demonstrates some existing stream buffer ordinance minimum base width requirements.

Table J.1: Existing minimum stream buffer widths.

Location	Requirement
Baltimore County, MD	75-150 ft
Douglas and Fulton Counties, GA	100-300 ft
Lenexa, KS*	(100-yr flood + 1 foot) + 25 ft
Metropolitan District Commission, MA*	200 ft
Montgomery County, MD	75 ft
Newport News, VA*	200 ft
Orange County, NC*	50-250 ft
Summit County, OH	30-300 ft
Tar-Pamlico River Basin, NC	50 ft
Topeka, KS	30-150 ft
Weathersfield, VT	50-110 ft
Willamette River, OR	50-75 ft
NRCS Recommended	35-100 ft
EPA Recommended	**100 ft**
CWP Recommended	**100 ft**

*Information from Black and Veatch (2001)

The EPA and the CWP strongly acknowledge the importance of the stream buffer in protecting the water quality and ecological integrity of streams of all sizes. The stream buffer is generally measured from the center of first and second order streams and from the top of bank of wider, higher order stream segments.

J.1 ZONING SYSTEMS

J.1.1 Three-Zone Approach

Creating lateral zones within a stream buffer ordinance has become a popular management technique to clearly define the functions of individual buffer segments and the activities permitted within the segments. One widespread practice of implementing buffers is through a system of three zones, as recommended by CWP (Schueler, 1995), and the USEPA (2000).

J.1.1.1 Streamside Zone

The first zone is defined as the streamside zone and consists of a minimum width of 25 ft from each stream bank. The purpose of the streamside zone is to protect the stream ecosystem by preserving the riparian forest. Significant processes, including stream shading, nutrient cycling, accumulation of large woody debris, and geomorphic progression, occur within the streamside zones, and are fundamental components of a healthy stream ecosystem. Within the streamside zones, no development shall be allowed, and land use consists only of footpaths, stormwater channels, and few utility and roadway crossings (Schueler, 1995).

J.1.1.2 Middle Zone

The middle zone extends beyond the streamside zone with a variable width, minimum of 50 ft. Factors controlling the width of the zone may include the stream order, floodplain width, adjacent slope angles, and any wetland regions. The objective of the middle zone is to provide a continued buffer between development and the stream through protection of a mature forest. The land use of this zone is less restricted than the streamside zone and may include some clearing for stormwater management and recreation.

J.1.1.3 Outer Zone

The third zone of this system is known as the outer zone, and is often referred to as a setback from the buffer zones. The outer zone typically extends a minimum of 25 ft from the edge of the middle zone, inclusive of a residential backyard. No permanent structures or septic systems are permitted within the outer zone. The property owner should be educated regarding the importance of this zone, and encouraged to plant trees and shrubs within a residential lawn.

The NRCS recommends a three-zone approach to accomplish the necessary functions of the riparian buffer forest. Zone 1 must have a minimum of 15 ft horizontal width measured perpendicular to the normal water line or top of bank. Occasional removal of some tree and shrub from Zone 1 is permitted as long as the loss of vegetation or harvesting disturbance do not interrupt the purpose and buffer function. Livestock must be controlled within or excluded from Zone 1 as necessary to protect the buffer function.

For the reduction of excess amounts of sediment, organic material, nutrients and pesticides in surface runoff and for the reduction of excess nutrients and other chemicals in shallow groundwater, the NRCS recommends that Zone 2, up-gradient from Zone 1, consist of a minimum of 20 ft. The NRCS suggests that the combined land coverage of Zones 1 and 2 is a minimum of 100 ft in width or 30% of the floodplain, whichever is less, but never less than 35 ft. Within Zone 2, the removal of products such as timber, fiber, nuts, fruit and forbs is permitted and encouraged on a regular basis provided that the riparian buffer function is not compromised. Zone 2 is further extended in locations where the application of animal waste is prevalent and where nutrient concentrations in sediment are high. An additional Zone 3 of the NRCS standard is recommended when the riparian zone is adjacent to cropland or highly erosive soils. The purpose of Zone 3 is to aid in additional filter of sediment, reduce the potential for increased flow erosion, and promote sheet flow.

When addressing concerns related to aquatic habitat and terrestrial wildlife ecosystems, the NRCS proposes that Zones 1 and 2 are expanded to meet the ecological requirements of the species under consideration and are planted with vegetation that satisfy wildlife requirements and promote existing resources. If a purpose of the riparian zone includes increasing the carbon storage in biomass and soils, the NRCS recommends that the width and length of the riparian buffer zone is maximized and that the vegetation include plants that have high rates of carbon sequestration and are suitable for the intended area.

J.1.2 Two-Zone Approach

The number of zones is not as important as the actual width of the overall stream buffer in protecting a stream. The major difference between the two- zone and three-zone systems is the transition between the highly protected zones and the modestly protected zones. This transition is more gradual for a three-zone approach than for a two-zone approach.

Nevertheless, two-zone systems are employed in some of the most progressive stream buffer ordinances, such as that of Baltimore County, Maryland. The Buffer Protection and Management Ordinance of Baltimore County utilizes a forest buffer of a minimum 75 to 100 ft in width and a setback from the forest buffer of a minimum of 25 to 35 ft in width. The guidance document incorporates a multi-faceted approach to improving water quality and enhancing ecological integrity such that almost no activities are allowed within the forested buffer. The Tar-Pamlico River Basin in North Carolina also institutes a two-zone approach in its protection and maintenance of existing riparian buffers. While the combined width of Zones 1 and 2 require only a minimum of 50 ft, the comprehensiveness of the allowable activities within the zones provides exemplary guidance.

The City of Topeka, Kansas Stream Buffer Ordinance defines a fixed buffer width using two zones of different restrictions, but allows for extension of the width based on steep slopes and sensitive areas. The streamside area is adjacent to the waterway, and its uses are limited to flood control, utility corridors, footpaths, and road crossings. The outer area lies adjacent to the stream side area, and has few restrictions allowing activities such as stormwater BMP's, detention/retention structures, biking/hiking paths, managed lawn and residential yards, and landscaped areas. The buffer width for each zone is based on the stream type. Type I streams are defined as perennial streams shown as a solid blue lines on USGS 7.5 minute series topographical maps. Type II streams are intermittent streams shown as dashed blue lines on the maps, and type III streams are waterways or dry channels having a drainage area of 50 acres or greater. The total buffer width for type I streams is 100 ft from the base flow edge of channel. For type II and type III streams, the buffer width is 50 ft and 30 ft from the centerline of the channel, respectively. Type 1 stream buffers are increased by 25 ft if adjacent slopes are between 15 and 25 % and by 50 ft if adjacent slopes exceed 25%.

J.2 OPTIONS FOR DEFINING THE BUFFER WIDTH

There are various options in use by regulating entities to define the riparian zone buffer width when using a multiple zoning method or a single zone approach. For the recommended three zone approach, the various options apply predominantly to the middle zone of the system.

J.2.1 Fixed

A fixed buffer width is often the easiest method to apply, abide by, and enforce in a community. Local governments choose this option for a variety of reasons. First, a uniform width does not require significant scientific knowledge of personnel. Regulations are generally uncomplicated to define in authorized provisions of land use or zoning codes. In addition, surveying land adjacent to waterways and maintaining detailed records is not required. Local governments are also able to easily recognize violations. However, this method lacks scientific justification as larger buffer widths are necessary for certain areas (i.e., steep slopes, erodible soils, wetlands, critical habitats) while smaller widths are sufficient for other segments along a channel. The use of a uniform width is inadequate in providing vital protection to streams and their riparian zones.

J.2.2 Variable

Other watersheds use a variable buffer width option based on site-specific conditions such as slope, stream order, landscape features, and land use intensity. Every stream and riparian corridor is different, and an approach tailored to individual streams provides a more scientific method. However, this option is more difficult to administer and to recognize noncompliance. In addition, using one variable, such as stream order, fails to take significant watershed features into consideration. For example, stream orders of lower values may have more harmful water quality if situated in high intensity development areas, adjacent to steep slopes, or comprised of highly erodible soils. A singular variable buffer definition provides more scientific validation than a uniform width, but still proves to be technically problematic.

J.2.3 Combination

A combination of fixed and variable widths presents an acceptable solution. This approach is accomplished by defining a standard base width, and using specific criteria, such as slopes, habitat value, and wetland presence, to extend or reduce the buffer width. The combination option is utilized in many current stream buffer ordinances and provides the most scientifically based buffer definition.

Across the United States, uniform buffer widths are defined by ordinances with provisions to expand the width based on the slopes of lands adjacent to the waterways. The Willamette Greenway is the area that immediately surrounds the Willamette River from Eugene to Portland, Oregon. Willamette Greenway Code requires minimum vegetation buffer zones based on the adjacent upland slope. For slopes less than 25%, the minimum vegetation buffer width is 50 ft from the ordinary high water or the edge of the floodway, whichever is greater. Slopes greater than 25% adjacent to the Willamette River require a minimum vegetation buffer width of 75 ft from the ordinary high water or the edge of the floodway, whichever is greater. Weathersfield, Vermont requires a 50 foot minimum buffer width for land adjacent to waterways with slopes between 0 and 10%. For every additional 10% increase in slope, 20 ft is added to the 50 foot minimum buffer width. The previously discussed Topeka, Kansas buffer is also dependent upon a standard width varying with slope.

Other buffer ordinances use multiple criteria to expand the base buffer width. Summit County, Ohio recently initiated a riparian buffer ordinance that defines the width of the buffer based on the drainage area of the stream and the adjacent slopes (May, 2002). Drainage areas less than 0.05 square miles (32 acres) are required to have a minimum buffer width of 30 ft on all sides of the stream; between 0.05 and 0.5 square miles require a width of 50 ft; between 0.5 and 20 square miles require a width of 75 ft; between 20 and 300 square miles require a width of 100 ft; and for all drainage areas greater than 300 square miles a minimum buffer width of 300 ft on all sides of the stream is required. If the 100-year floodplain width exceeds these designated measurements, the floodplain width will be used as the minimum buffer requirement. Steep slopes of the land adjacent to the streams also increase the width of the buffer.

An exceptional example of multiple-criteria stream buffer delineation is that of Baltimore, Maryland. The EPA and CWP use this ordinance as a model for guidance. The ordinance employs adjacent land slope, soil erodibility, sensitive area designation, and water use to define the buffer width. The ordinance defines stream types based on designated uses of recreation, public water supply, aquatic habitat, and natural fish and shellfish supply. Uniform widths are derived from the stream types. For streams not designated as recreational trout waters, the minimum base width of the buffer must be the greater of the following:

1. Seventy-five (75) ft,
2. Twenty-five (25) ft from the outer wetland boundary, or
3. Twenty-five (25) ft from the one-hundred-year floodplain reservation or easement boundary.

For those streams designated as natural and recreational trout waters, unless conditions stated in 2 or 3 above are greater, the minimum base width is 100 ft. In addition to this, adjacent lands (within 500 ft of surface water), which demonstrate the potential to be sensitive areas, will be evaluated and scored for steep slopes and erodible soils based on Table J.2 (extracted from the Baltimore County, Maryland Section 14-341 of Article IX, November 26, 2002).

Table J.2: Evaluation criteria for steep slopes and erodible soils.

Factors	Scores		
	High (10)	Medium (5)	Low (0)
Slope (S)	$S \geq 20\%$	$10\% < S < 20\%$	$S \leq 10\%$
Slope Length (SL)	$SL \geq 200'$	$50' < SL < 200'$	$SL \leq 50'$
Soil Erodibility (K)	$K \geq 0.32$	$0.24 < K < 0.32$	$K < 0.24$
Vegetative Cover	Bare soil, fallow land, crops, active pasture in poor condition, orchard-tree farm in poor condition	Active pasture in fair condition, brush-weeds in poor condition, orchard-tree farm in fair condition, woods in poor condition	Active pasture in good condition, undisturbed meadow, brush-weeds in fair condition, orchard-tree farm in good condition, woods in fair condition
Sediment Delivery (distance from down slope limit of disturbance to outer edge of wetlands or top of stream bank)	Adjacent to watercourses or wetlands (<100-ft buffer)	Adjacent to watercourses or wetlands (100-ft to 300-ft buffer)	Not adjacent to watercourses or wetlands (>300-ft buffer)

For areas with high scores (35 or greater), the land will be considered a part of the forested buffer and no development will be allowed. Those areas scoring in the medium range (25 to 30) must be protected through additional measure, but will not be considered part of the forested buffer. Low scoring areas (20 or less) may be developed with standard protection and will not be included in the forest buffer width.

This ordinance further restricts development with the provision of a setback distance or additional passive zone from the forested buffer zone for all residential dwellings and commercial and industrial structures, ranging from 25 to 35 ft.

One Colorado community that encompasses a fairly progressive riparian buffer zone regulation is the City of Fort Collins. Section 3.4.1 of the Fort Collins Land Use Code provides for protection of natural resources and features of wildlife significance. Within this code, buffer zones are required for isolated areas, stream corridors, and special habitat features. The code defines fixed buffer zone standards for each feature. The isolated areas buffer zones include wetlands, lakes and reservoirs, irrigation ditches and ponds, and native patches of grassland or riparian forest. The standard buffer widths for isolated areas range from 50 ft to 300 ft. Stream corridor buffer zone widths are defined for each waterway within the city, with a minimum distance of 100 ft to the boundary of the development lot. Likewise, the natural habitat buffer zone distances are determined by the type of habitat and/or resource, ranging from 300 ft to 2,640 ft. The decision maker may modify the buffer zone standard width for each development on an individual basis. The buffer zone standards do not apply to regions zoned as River Downtown Redevelopment.

Within the buffer zones, very few structures or activities are permitted. The construction activities allowed within the buffer zone include pedestrian walkways or trails granting public access, passive recreation features or park elements, and utility locations that cannot feasibly be placed outside of the zone. Permitted activities include mitigation of development, restoration or enhancement projects, and emergency safety activities.

J.3 CURRENT RECOMMENDED STREAM BUFFERS SPECIFIC TO THE EAGLE RIVER WATERSHED

In addition to the Eagle County Land Use Regulations, the Eagle River Watershed Plan, an ancillary document to the Eagle County Master Plan, recommends that all structures, grading, paving and land disturbance be located outside of the 100 year floodplain or the riparian zone of all live waters, whichever is greater. The riparian zone as defined in the document is as a 75 foot distance, measured horizontally, from the high water mark. To further protect the riparian zones, the Eagle River Watershed Plan recommends requiring greater setbacks than those stated. In regards to vegetation, the Plan proposes that only those vegetative disturbances that include environmentally sound weed control and improvements to the riparian corridor be permitted in the zone. Other development, including approved trails, recreation access sites, bridges, fences, irrigation and diversion structures, and flood control and erosion devices, may be permitted provided that there is little or no disturbance to the riparian areas, or that the disturbances can be mitigated. The Eagle River Watershed Plan suggests that approved underground utilities only be located in the protected areas in the case that no alternate locations will suffice, that there is minimum or no disturbance to protected areas, and that all other required permit and approvals are obtained.

J.4 OTHER IMPORTANT ASPECTS OF STREAM BUFFER ORDINANCES

J.4.1 Plan Management

The definition of the required buffer width will not be effective unless clear and decisive management plans are enacted. Local government entities must define unambiguous restrictions and prohibitions within each zone of the buffer width. In addition, clear statements as to permissible activities should be included in the ordinance. The ordinance must cover aspects of recreation, timber harvest, agriculture and livestock, stream crossings, vegetation removal and treatment, mining, and residential, commercial and industrial use (Univ. of Virginia, 2002). The management plan should also provide for monitoring and maintenance of the buffer zones, imperative measures of successful riparian zone protection.

J.4.2 Public Education and Encouragement

Many landowners and city dwellers are opposed to changes in or implementation of stream buffer ordinances due to a lack of understanding of the significance of the riparian zone to water quality and ecological integrity. While the resources available to public education are often inadequate, low cost techniques can be employed if the methods effectively reach the necessary members of the public. The educational methods should be aimed to increase the community acknowledgement of the buffer zones and their restricted activities.

As incentives to landowners, CWP (Schueler, 1995) suggests providing density grants and conservation easements. Density credits can be used to compensate developers and landowners for land use by buffers, providing greater flexibility in setbacks, frontage distances, or minimum lot sizes. The City of Lacey, WA is currently providing density credits in this manner. The option of granting conservation easements would allow a landowner to donate the use of the buffer as a land trust for charitable contribution as an income tax saving or to a local government for property tax adjustment on the land within the buffer zone. Another incentive to apply wider buffer widths is used in Clayton County, GA. Clayton County allows developers to offset new development with wider buffers as an alternative to other stormwater controls.

The Maryland Department of Natural Resources Forest Service provides two incentive programs to eligible landowners as part of the Chesapeake Bay Protection Act (University of Virginia, 2002). The Buffer Incentive Program provides $300 per acre to encourage landowners to plant buffers on land within 300 ft of waterway. The objective of the program is to give an incentive to landowners to establish forested buffers and assist in minimizing the costs for initiating and maintaining them. Other land use qualifications apply in order to be eligible for the program. A second program to promote the use of private land for stream buffers is through the Income Tax Modification Program. Qualifying landowners will receive an income tax deduction of double the cost of reforestation and timber stand improvement practices. Several regulations define the eligibility of private landowners, and maintenance of the forested buffers is required.

J.4.3 Flexibility of Buffer Widths

In order to avoid excessive consumption of private property without fair compensation, the local government should maintain a flexible administration of the buffer zone. One method of providing flexibility is to allow buffer averaging. This option allows a buffer's size to contract in some sections as long as the average width of the buffer meets the minimum requirements. The purpose of buffer averaging is to permit existing structures, but does not authorize new development within the 100-year floodplain or disturbance to the riparian zone. Another method used to provide flexibility is through the use of variances. Almost all current stream buffer ordinances include the provision for variances or waivers. A variance may be issued to developers for proposed development approved prior to the implementation of the ordinance, to landowners indicating compliance to cause significant financial adversity, to organizations providing public projects and activities where no practical alternative exists, and to agencies for repair and maintenance services intended for public improvement. Within the variance section of the ordinance, a clear process should be outlined, which explains the application for a variance.

J.4.4 Development Plan Requirements

All stream buffer ordinance guides, including those provided by the EPA and CWP, suggest that a set of plan requirements is incorporated into all buffer ordinances. The plan should ultimately contain a map scale requirement of either 1" = 50 ft or 1" = 1,000 ft to sufficiently provide detail. Maps should identify field delineated and surveyed waterways and forest buffers, Federal Emergency Management Agency (FEMA) defined 100-year floodplain limits, hydric soils, steep slopes, and wetlands. Prior to, during, and following construction, the boundaries of all buffers should be evident. Local authorizing agencies should verify the accuracy of all buffer zone delineations. Contractors need to be educated regarding the limits of the buffers and all potential penalties if violations occur. In addition, the buffer limits should be bordered by silt or snow fences during construction to discourage the placement of heavy equipment and machinery within the riparian zone.

J.4.5 Enforcement and Penalty

Because not all residents will respond to public education attempts and clear identification of allowable activities within buffer zones, an enforcement program may be necessary. The local ordinance needs to designate the person(s) responsible for maintaining the buffer and enforcing its limits. The NRCS standard requires periodic inspection of the riparian buffer zone to ensure compliance and protect against excessive pedestrian, livestock and vehicular traffic, wildfire damage, pest infestations, and the use of fertilizers and pesticides. Enforcement programs typically include a series of notices with remedial measures necessary to correct a violation of the ordinance. If the remedial measures are not completed after a specific time period, further consequences should be invoked, including civil and criminal penalties. Some ordinances, like that of Baltimore County, Maryland, require that the violator be responsible for up to twice the cost of buffer restoration in addition to civil fines incurred.

J.4.6 References

Schueler, T. (1995). The architecture of urban stream buffers. *Watershed Protection Techniques* 1(4):155-163.

University of Virginia (2002). A Stream Corridor Protection Strategy for Local Governments. Published by Institute for Environmental Negotiation, Department of Urban and Environmental Planning of the School of Architecture at the University of Virginia, Charlottesville, VA, pp. 23-51.

USEPA (2000). Model Ordinance to Protect Local Resources. Available online http://www.epa.gov/nps/ordinance/mol1.htm.

APPENDIX K

Basin-wide NPDES Permitting

APPENDIX K
BASIN-WIDE NPDES PERMITTING

K.1 WHAT IS WATERSHED-BASED PERMITTING?

The USEPA defines watershed-based NPDES permitting as "an approach to developing NPDES permits for multiple point sources located within a defined geographic area (watershed boundaries) to meet water quality standards" (USEPA, 2003a). By integrating the goals of the watershed with a comprehensive assessment of NPDES discharges, the basin-wide approach provides a permitting strategy that is more environmentally effective and cost efficient. Some activities within watershed-based permitting programs have included synchronizing permit renewals, coordinating monitoring efforts, implementing a statewide basin management program, and developing water quality effluent limits. Throughout the United States, the number of point sources required to obtain an NPDES permit has increased by ten times within the last ten years (USEPA, 2003b). The watershed-based permitting approach to pollutant management offers an innovative technique to simultaneously address the needs for environmental protection and efficiency in NPDES permitting.

K.2 WHAT ARE THE BENEFITS?

Watershed-based permitting presents significant potential benefits for both water quality and the administration and management of permits. Most noteworthy among these benefits are environmental enhancement, integration of correlated programs, and optimization of resources. Environmental benefits can be achieved through large-scale monitoring, permit development that simultaneously accounts for all stream segments, and consideration of factors affecting water quality throughout a river basin. Such benefits have been clearly demonstrated for several large river basins degraded by nutrient enrichment.

Another advantage of the watershed-based permitting technique is the integration of current water related programs working toward the protection of water resources. The use of a watershed approach to permitting can efficiently allocate the resources required to accomplish the most favorable environmental outcome. The watershed approach assists stakeholders in assessing watershed problems and optimizing efforts to provide solutions. NPDES authorities can develop more targeted permitting limits, monitoring, and inspection on a watershed scale, thereby providing a streamlined permitting process, administrative efficiencies, and optimal allocation of resources (USEPA, 2003b). Other benefits of the watershed approach to permitting include the collaboration of point source dischargers in reaching compliance, the basis for a basin-wide monitoring effort that reduces duplication and ensures data quality, facilitation in water quality trading, and the involvement of the community with point source dischargers.

K.3 WHAT ARE THE CHALLENGES?

The most significant challenges in watershed-based NPDES permitting reported by the USEPA include increased involvement of the stakeholders, incorporation of nonpoint sources, the varying jurisdictional requirements, regulatory structure and program infrastructure, and initial investment in time and resources. For every challenge encountered in the establishment of a basin-wide permit, adequate solutions have been achieved.

With the entire watershed involved in the permitting process, the number of stakeholders increases. The coordination of the each stakeholder's interest may be challenging for the permitting authority. In the development of the permit, the authority must take multiple goals and interests into consideration, increasing the technical complexity of the permit and the time required for completion. The USEPA views this challenge in a positive light as it educates stakeholders of the goals and concerns of each party in determining an optimal permit structure.

An additional challenge involves the integration of nonpoint sources, which can become appreciable factors in meeting permit requirements. Nonpoint source involvement, at least by some sectors, is voluntary. As a result, some nonpoint sources avoid participation based on concern that involvement may initiate regulation. Providing incentives and options to nonpoint sources may encourage participation.

Of course, most watersheds are typically comprised of a number of different jurisdictions, often with varying regulations. Permitting requirements, ordinances, and planning cycles may overlap or be in conflict. In such cases, it is necessary for the permitting authorities to perform an analysis of the varying programs to address the differences and identify opportunities for coordination between jurisdictions.

The program infrastructure required for a watershed-wide permit is different from the traditional NPDES program. Due to the increased stakeholder involvement and the number of issues to be addressed in single watershed, the process for permit development requires more flexibility, creativity, and time to complete. The regulatory structure of watershed-based permits presents an additional challenge for stakeholders. The legality and enforceability of the regulations set forth in the permit, such as source trading, require research and analysis. Solutions must then be identified that either function under the existing regulations or require modification.

The final challenge recognized is the development of an initial commitment to the proposal for a basinwide permit. A preliminary investment of time and resources is daunting to permitting agencies with high workloads and tight budgets. Outside stakeholders who initiate the watershed-based permitting must demonstrate through case studies and reports how the change will be beneficial environmentally and administratively to all parties involved. The EPA currently maintains a web site with success stories and implementation guidelines that can be utilized to demonstrate the effectiveness of the watershed-based permit and to reduce the time and capital for realization.

For further information on Basinwide NPDES Permitting see:

- USEPA (2003a). Watershed-Based Permitting Policy Statement. Washington DC. Available online at http://www.epa.gov/npdes/pubs/watershed-permitting-policy.pdf
- USEPA (2003b) Watershed-Based NPDES Implementation Guidance. EPA-833-B-03-004 December 2003. Available online at http://cfpub.epa.gov/npdes/wqbasedpermitting/wspermitting.cfm.
- USEPA (2003c). Water Quality Trading Assessment Handbook: EPA Region 10's Guide to Analyzing Your Watershed. EPA 910-B-03-003, July. Available online at http://yosemite.epa.gov/R10/OI.NSF/34090d07b77d50bd88256b79006529e8/642397cf31d9997388256d66007d53a7?OpenDocument.

K.4 CASE STUDY: NORTH CAROLINA BASINWIDE PLANNING AND NPDES PERMITTING

The State of North Carolina has been successfully implementing watershed-based NPDES permitting as part of a basinwide planning program for several years. This non-regulatory approach to addressing water quality problems has several economic and ecological advantages. The goals of the basinwide planning initiative include:

- Collaboration among entities for improved water quality management strategies
- Equitable distribution of waste assimilative capacity
- Improved evaluation of cumulative effects of pollutants
- Enhanced public awareness
- Identification of water quality problems and restoration of full use to impaired waters
- Protection of high value resource waters
- Protection of healthy waters in tandem with moderate economic growth (NC DWQ, 2000)

The NC Division of Water Quality (DWQ) is responsible for the preparation of individual basin-wide water quality plans for the seventeen major river basins in the state. Local agencies, governments, and stakeholder groups share the task of coordination and implementation of the water quality plans. Basin-wide water quality plans, updated in five-year intervals, serve to inform citizens and governmental entities about (1) the conditions of water quality in each basin, (2) major water quality concerns, (3) forecasted patterns in development and its effects on water quality, (4) long term water quality goals, and (5) recommendations for better management of nonpoint and point sources of pollution (NC DWQ, 2000). Preparation of each basin-wide water quality plan entails a five-year process (Table K.1). As part of the basin-wide process, all NPDES permits in a river basin are evaluated and issued simultaneously based on the results of a coordinated monitoring program that provides up-to-date information. This approach facilitates: 1) comprehensive analysis of the cumulative effects of NPDES discharges from an ecological standpoint, 2) integrated management of point and nonpoint source pollution, and 3) collaboration among dischargers in achieving water quality goals in a market based, cost-effective manner.

Table K.1: Five-year Process for Development of an Individual Basin-wide Plan. Based on NCDWQ (2004).

Years 1 – 2 Water Quality Data Collection and Identification of Goals and Issues	• Identify sampling needs • Conduct biological monitoring activities • Conduct special studies and other water quality sampling activities • Coordinate with local stakeholders and other agencies to continue to implement goals within current basin-wide plan
Years 2 – 3 Data Analysis and Public Workshops	• Gather and analyze data from sampling activities • Develop use support ratings • Conduct special studies and other water quality sampling activities • Conduct public workshops to establish goals and objectives and identify and prioritize issues for the next basin cycle • Develop preliminary pollution control strategies • Coordinate with local stakeholders and other agencies
Years 3 – 5 Preparation of Draft Basin-wide Plan, Public Review, Approval of Plan, Issue NPDES Permits and Begin Implementation of Plan	• Develop draft basin-wide plan based on water quality data, use support ratings, and recommended pollution control strategies • Circulate draft basin-wide plan for review and present draft plan at public meetings • Revise plan after public review period • Submit plan to Environmental Management Commission for approval • Issue NPDES permits • Coordinate with other agencies and local interest groups to prioritize implementation actions • Conduct special studies and other water quality sampling activities

The basin-wide approach to water quality planning provides considerable benefits for the state of North Carolina. The program focuses resources and efforts one major watershed at a time, resulting in improved efficiency. Further improvement in efficiency is achieved through use of the basin-wide NPDES permit schedule as structure for the water quality program. Basin-wide planning increases regulatory effectiveness through application of basic ecological principles. Consistency in decision-making and water quality management is improved through basin-wide planning strategies that focus on long term goals. North Carolina uses the basin-wide water quality plans as educational tools for increased public awareness, involvement, and concern for water quality. A final benefit of basin-wide planning is the integration of both point and nonpoint source pollution management. As part of each basin-wide plan, waste loads from point and nonpoint sources are determined, and thus, management approaches can be developed to secure compliance with water quality regulations.

Through implementation of basin-wide planning, North Carolina has made continuous progress in the identification and management of water quality issues. Basin-wide planning allows for strategic advancement in spatial (by river basin) and temporal (in five year intervals) water quality management. Assessment of water quality issues by river basin involves rigorous investigation of defined geographic regions. Plan updates at five-year intervals provide sufficient time to identify changes in water quality and measure the effectiveness of the management strategies. The application of basin-wide planning in North Carolina demonstrates anticipatory management of water quality issues and is touted by USEPA as an exemplary program.

In summary, basin-wide planning and management benefits water quality by:

- Using sound ecological planning and fostering comprehensive NPDES permitting by working on a watershed scale.
- Ensuring better consistency and equitability by clearly defining the program's long-term goals and approaches regarding permits and water quality improvement strategies.
- Fostering public participation to increase involvement and awareness about water quality.
- Integrating and coordinating programs and agencies to improve implementation of point and nonpoint source pollution reduction strategies.

More information on North Carolina Basin-wide Planning is available from:

- North Carolina Division of Water Quality (DWQ). (Last Updated July 22nd, 2004; Cited July 27th, 2004). Basinwide Planning Program: What is Basinwide Planning? Available online at http://h2o.enr.state.nc.us/basinwide/basinwide_wq_planning.htm.

- North Carolina Division of Water Quality (DWQ). (2000). A Citizen's Guide to Water Quality Management in North Carolina. Available online at http://h2o.enr.state.nc.us/basinwide/basinwide_wq_planning.htm.

APPENDIX L
MCDA

Table L.1: Ecology ranking procedure.

ECOLOGY CRITERIA	
Does the project involve restoring high quality habitat or protecting existing high quality habitat?	If restoration, score the project based on the current state as the before condition and the post-project state as the after condition.
	If protection, score the project based on the potential future degraded state as the before condition and the current state as the after condition.
Most of the categories are rated on a scale from -1 to 1, with -1 being the lowest score possible for negative impacts and 1 being the highest possible score for positive impacts. In the "Inputs" sheet, enter any value between -1 and 1 for each criterion and each project being analyzed.	

HYDROLOGY			
Changes to the flow regime, towards or away from a "pre-diversion" state	Magnitude	Towards	1
		No change	0
		Away	-1
	Timing	Towards	1
		No change	0
		Away	-1
	Duration	Towards	1
		No change	0
		Away	-1
	Frequency	Towards	1
		No change	0
		Away	-1
	Rate of change	Towards	1
		No change	0
		Away	-1
	Change in the amount of water (wetlands, ponds, side channels, backwater channels, saturated soil, etc.) stored in or on the floodplain	Increase	1
		No change	0
		Decrease	-1
	Change in impervious area	Increase	-1
		No change	0
		Decrease	1
	Connections between groundwater and surface water (floodplain connectivity)	Restore lost connections	1
		Enhance existing connections	0.5
		No change to connections	0
		Degrading connections	-0.5
		Eliminate connections	-1

Table L.1 (cont.): Ecology ranking procedure.

HABITAT/GEOMORPHOLOGY		
Change in the width/depth ratio towards or away from the range of variability of reference conditions	Towards	1
	No change	0
	Away from	-1
Changes to the complexity of the flow patterns/hydraulics (e.g. depth-velocity combinations)	Increase complexity	1
	No change	0
	Decrease complexity	-1
Change the complexity/diversity/quality of substrate (i.e. well graded substrates with a low embeddedness)	Increase diversity	1
	No change	0
	Decrease diversity	-1
Changes in channel stability on-site or upstream/downstream of the site (bank stability, aggradation, degradation, etc.)	Towards stable channel	1
	No change	0
	Away from stable channel	-1

RIPARIAN		
Changes in riparian zone width	Restore lost native vegetation	1
	Enhance existing native vegetation	0.5
	No change	0
	Decrease existing native vegetation	-0.5
	Eliminate existing native vegetation	-1
Input of energy sources from riparian vegetation or woody debris	Restore lost inputs	1
	Enhance existing inputs	0.5
	No change	0
	Degrade existing inputs	-0.5
	Eliminate inputs	-1
Changes to the species diversity of riparian vegetation	Increase diversity	1
	No change	0
	Decrease diversity	-1

Table L.1 (cont.): Ecology ranking procedure.

BIOLOGY		
Support biological integrity	Improve	1
	No change	0
	Degrade	-1
Support native flora/fauna	Improve	1
	No change	0
	Degrade	-1
Support trophic structures/food web	Improve	1
	No change	0
	Degrade	-1
Benefits biota identified by the Colorado Natural Heritage Program as "rare or imperiled"	Improve	1
	No change	0
	Degrade	-1
Benefits conservation areas identified by the Colorado Natural Heritage Program	Improve	1
	No change	0
	Degrade	-1

Table L.1 (cont.): Ecology ranking procedure.

PHYSIOCHEMICAL WATER QUALITY		
Each of the following water quality parameters has an optimal range of variability. "Improve" indicates that the project changes the parameter toward this range. "Degrade" indicates the opposite.		
Fine sediment - either loading to downstream reaches or deposition/siltation at the project reach	Definite improvement	1
	Likely improvement	0.5
	No change expected	0
	Likely degradation	-0.5
	Definite degradation	-1
Dissolved oxygen	Definite improvement	1
	Likely improvement	0.5
	No change expected	0
	Likely degradation	-0.5
	Definite degradation	-1
Metals loading	Definite improvement	1
	Likely improvement	0.5
	No change expected	0
	Likely degradation	-0.5
	Definite degradation	-1
Other toxins	Definite improvement	1
	Likely improvement	0.5
	No change expected	0
	Likely degradation	-0.5
	Definite degradation	-1
Water temperature	Definite improvement	1
	Likely improvement	0.5
	No change expected	0
	Likely degradation	-0.5
	Definite degradation	-1
Phosphorus loading	Definite improvement	1
	Likely improvement	0.5
	No change expected	0
	Likely degradation	-0.5
	Definite degradation	-1
Nitrogen loading	Definite improvement	1
	Likely improvement	0.5
	No change expected	0
	Likely degradation	-0.5
	Definite degradation	-1
Nitrogen to phosphorus ratio	Definite improvement	1
	Likely improvement	0.5
	No change expected	0
	Likely degradation	-0.5
	Definite degradation	-1

Table L.1 (cont.): Ecology ranking procedure.

SYSTEM-LEVEL BENEFITS		
Are the benefits of the project limited by other factors in the watershed or by the outcome of other projects?	Entirely limited	-1
	Partially limited	-0.5
	Not limited	0
Length of the restored stream reach (rank all of the projects under consideration from longest to shortest)	Enter an absolute length (use the same units for each project)	
Length of the restored stream reach plus any upstream and downstream high-quality sites that the project reach connects	Enter an absolute length (use the same units for each project)	
Size of the restored floodplain/riparian/wetland area (rank all of the projects under consideration from largest to smallest)	Enter an absolute area (use the same units for each project)	
IF A RESTORATION PROJECT: What is the urgency of the project (how much damage could it cause if not done)? IF A PRESERVATION PROJECT: What is the likelihood that the property will be sold and/or degraded?	Severe degradation possible	1
	Moderate potential	0.5
	Little or no potential	0

Table L.2: Watershed strategy ranking procedure.

Leverages other activities	High	1	High potential to complement other projects and utilize existing funding sources
	Low	0	Completely independent project - low potential for funding
What is the potential for community/volunteer involvement in the project?	High potential	1	Volunteer organizations (TU, FFF, ERWC, local schools, etc.) could/would provide labor support
	Moderate potential	0.5	
	Low potential	0	Too technical for the un-trained volunteer
What is the potential for community fundraising for the project?	High potential	1	Strong community support/high enthusiasm
	Moderate potential	0.5	Moderate support
	Little, if any, potential	0	Little community support/low enthusiasm
Project visibility	High	1	Introduces goals of the ERWC to a much broader audience
	Moderate	0.5	
	Low	0	Isolated project, little PR potential

Table L.3: Practicality (risk, technical uncertainty, economics, politics) ranking procedure.

COMPLEXITY		
What is the complexity of the project with respect to laws involved, permitting, NEPA requirements, etc.?	1	No permits are required
	0.5	404 NWP
	0	
	-0.5	404 individual
	-1	Possible EIS and 404 individual
What is the complexity of the project with respect to landowners involved?	1	Single cooperative land/waterowner, land/waterowner will readily grant access
	0	
	-1	Multiple land/waterowners, many of whom may not grant access
What is the technical complexity of the project?	1	The design and implementation is relatively simple
	0	Average complexity
	-1	The design and implementation is very complex

RISK TO PUBLIC HEALTH AND SAFETY			
How does the project affect public health and safety?	Strong positive	1	The project will greatly reduce safety concern on site or throughout the watershed
	Not applicable	0	Safety is not an issue with this project

Table L.4: Socioeconomics (social, educational, recreational, historical, and cultural issues) ranking procedure.

ECONOMIC BASE			
What are the impacts of the projects on the local economic base?	Strong positive impact	1	Enhancement or long term support of the economic value of the site (e.g. recreational dollars)
	No impact	0	
	Strong negative impact	-1	Greatly long term reduces the economic value of the site

EDUCATION			
What is the potential to use the project for environmental education purposes (interpretive signs, field trip potential, etc.)?	High potential	1	High existing visitor-days and potential for environmental education and signage
	Little potential	0	Small existing number of visitor-days and very little potential for increase

RECREATION			
Does the project increase public access to the river?	Yes	1	New water is opened up for river users
	No	0	The water is still private
How many additional vehicles can be parked at the site?	Give the absolute number		
Does the project enhance the "entertainment value" for whitewater rafters and kayakers?	Increases fun water	1	The new whitewater features created by the project are outstanding
	No change	0	The project has nothing to do with creating good boating
	Decreases fun water	-1	Takes whitewater features out of the river
Does the project increase the quality of habitat for game fish?	Strong positive change	1	More and bigger fish are probable
	No change	0	
	Strong negative change	-1	Habitat is reduced

HISTORY			
Does the project enhance and/or respect the historical value of a site?	Enhances	1	The project preserves and enhances the significant historical features of the site (Camp Hale)
	Not applicable/no change	0	History has nothing to do with this project
	Reduces	-1	The historical value of the site has been reduced by the project

Table L.5: MCDA inputs for ranking by Ecology.

Project	*Hydrology*								*Habitat/Geomorphology*			
	Flow Regime					FP Storage	Impervious	Connectivity	W:D	Flow Complexity	Substrate	Stability
	Magnitude	Timing	Duration	Frequency	Rate of Change							
Camp Hale Restoration	0	0	0	0	0	1	0	1	1	1	0.5	1
Milk/Alkali/Ute Creeks	0	0	0	0	0	0	0	0	0	0	1	1
Flow Management/Decision-Making Tools	1	1	1	1	1	1	0	0	0.1	1	0.25	0.1
Belden Cribbings	0	0	0	0	0	0	0	0	0	0	0	0
Eagle Mine/Belden	0	0	0	0	0	0	0	0	0	0	0	0
Edwards/Lake Creek Segment	0.2	0	0	0	0	0.5	0	0.2	1	1	1	1
Enhance River Habitat in Gypsum Wildlife Area	0.2	0	0	0	0	0.5	0	0.2	0.5	0.5	0.5	0.5
Minturn Confluence Segment	0.1	0	0	0	0	0	0	0	0.5	0.5	0.5	0.2
Bolt's Lake Restoration	0.1	0.1	0.1	0.1	0.1	0	0	0	0	0	0	0
Riparian Tamarisk Removal - Lower River and Tribs	0.05	0	0	0	0	0.05	0	0	0.1	0	0	0.1
Remove Piling in Avon	0	0	0	0	0	0	0	0	0.1	0	0	0.1
Eagle Canyon Litter Cleanup	0	0	0	0	0	0	0	0	0	0	0	0
Basinwide Nutrient Strategy	0	0	0	0	0	0	0	0	0	0	0.8	0
Non-native Species Removal – Camp Hale	0	0	0	0	0	0	0	0	0	0	0	0
Long-term Access Plan for Low Impact Recreation	0	0	0	0	0	0	0	0	0	0	0	0.1
Riparian Work/Bank Stabilization Upstream of Wolcott	0	0	0	0	0	0	0	0	0	0.1	0	0.5
Avon Restoration - Overly wide, Localized Areas	0	0	0	0	0	0	0	0.1	1	0.4	0.4	0.5
Riparian Planting Opportunities - Lower Eagle & Eagle Valley Tribs	0	0	0	0	0	0	0	0	0.1	0	0	0.7

Table L.5 (cont.): MCDA inputs for ranking by Ecology.

Project	*Riparian*			*Biology*				
	Width/Native	Energy Input	Species Diversity	Communities	Natives	Food Web	CNHP Biota	CNHP Areas
Camp Hale Restoration	1	1	1	1	1	1	1	1
Milk/Alkali/Ute Creeks	0	0	0	1	0	0.5	0.5	1
Flow Management/Decision-Making Tools	0	0	0	1	0.2	0.7	1	1
Belden Cribbings	0	0	0	1	0	1	0	0
Eagle Mine/Belden	0	0	0.2	1	0	0.5	0	0
Edwards/Lake Creek Segment	0.9	0.9	0.5	0.8	0.2	0.7	0	0
Enhance River Habitat in Gypsum Wildlife Area	0.8	0.8	0.5	0.6	0.2	0.4	0	0
Minturn Confluence Segment	0.5	0.5	0.1	0.5	0.2	0.3	0	0
Bolt's Lake Restoration	0	0	0	0.1	0	0	0	0
Riparian Tamarisk Removal - Lower River and Tribs	0.5	0.2	0.8	0.5	1	0.3	0	0
Remove Piling in Avon	0	0	0	0	0	0	0	0
Eagle Canyon Litter Cleanup	0	0	0	0	0	0	0	0
Basinwide Nutrient Strategy	0	0	0	1	1	1	0	0
Non-native Species Removal – Camp Hale	1	0	0.5	1	1	0.5	0	0
Long-term Access Plan for Low Impact Recreation	0.1	0	0	0.2	0	0	0	0
Riparian Work/Bank Stabilization Upstream of Wolcott	0.1	0.2	0.1	0.2	0	0	0	0
Avon Restoration - Overly wide, Localized Areas	0.3	0.2	0.1	0.2	0	0.1	0	0
Riparian Planting Opportunities - Lower Eagle & Eagle Valley Tribs	0.7	0.7	0.7	0.6	0.2	0.3	0	0

Table L.5 (cont.): MCDA inputs for ranking by Ecology.

	Water Quality								*System Level*				
Project	Fine Sed.	DO	Metals	Toxins	Temp.	P	N	N:P	Limits	Improv-ed Length	Connect-ed Length	Improv-ed FP	Urgency
Camp Hale Restoration	0	0.2	0	0	0.2	0	0	0	0	12000	20000	2000000	0
Milk/Alkali/Ute Creeks	1	0.2	0.1	0	0.2	0.6	0	0.2	0	40000	50000	10000	0.2
Flow Management/Decision-Making Tools	0.5	0.8	0	0	1	0.2	0.2	0	0	540000	540000	10000000	1
Belden Cribbings	0	0	1	1	0	0	0	0	1	1000	24000	0	1
Eagle Mine/Belden	0	0	1	1	0	0	0	0	1	400	24000	0	1
Edwards/Lake Creek Segment	0.7	0.8	0	0	0.7	0.3	0.4	0	0	3500	15000	610000	0.2
Enhance River Habitat in Gypsum Wildlife Area	0	0.5	0	0	0.4	0.3	0	0	0	3000	3000	520000	0.1
Minturn Confluence Segment	0	0.5	0	0	0.2	0	0	0	-1	700	700	2000	0
Bolt's Lake Restoration	0	0.1	-0.1	0	0.1	0	0	0	-1	0	0	0	0
Riparian Tamarisk Removal - Lower River and Tribs	0	0	0	0	0	0	0	0	0	0	0	5000	0.1
Remove Piling in Avon	0	0	0	0	0	0	0	0	0	0	0	0	0
Eagle Canyon Litter Cleanup	0	0	0.2	0.2	0	0	0	0	0	800	800	0	0
Basinwide Nutrient Strategy	0	1	0	0	0	1	1	1	0.5	540000	540000	0	0.7
Non-native Species Removal – Camp Hale	0	0	0	0	0	0	0	0	0	0	0	5000	0
Long-term Access Plan for Low Impact Recreation	0	0	0	0	0	0.1	0	0	0	540000	540000	10000	0.1
Riparian Work/Bank Stabilization Upstream of Wolcott	0.1	0	0	0	0	0.2	0	0	0	200	200	1000	0
Avon Restoration - Overly wide, Localized Areas	0	0.2	0	0	0.1	0	0	0	0	250	250	1250	0
Riparian Planting Opportunities - Lower Eagle & Eagle Valley Tribs	0.2	0	0	0	0.2	0.2	0	0	0	500	500	2500	0

Table L.6: MCDA inputs for ranking by Watershed Strategy.

Project	*Strategy*			
	Leverage	Volunteer	Fundraising	Visibility
Camp Hale Restoration	0.8	0.7	0.5	1
Milk/Alkali/Ute Creeks	0.1	0.2	0	0.5
Flow Management/Decision-Making Tools	0.8	0	0	1
Belden Cribbings	1	0	0	0.4
Eagle Mine/Belden	1	0	0	0.4
Edwards/Lake Creek Segment	0.2	0.7	0.1	0.6
Enhance River Habitat in Gypsum Wildlife Area	0.2	0.7	0.1	0.6
Minturn Confluence Segment	0	0.7	0.1	0.2
Bolt's Lake Restoration	0	0	0	0.1
Riparian Tamarisk Removal - Lower River and Tribs	0	0.2	0	0.2
Remove Piling in Avon	0	0	0	0
Eagle Canyon Litter Cleanup	0	1	0.1	0.1
Basinwide Nutrient Strategy	1	0	0	0.7
Non-native Species Removal – Camp Hale	0	0.5	0.1	0.6
Long-term Access Plan for Low Impact Recreation	0.2	0.5	0.3	0.7
Riparian Work/Bank Stabilization Upstream of Wolcott	0	1	0	0.2
Avon Restoration - Overly wide, Localized Areas	0	1	0	0.2
Riparian Planting Opportunities - Lower Eagle & Eagle Valley Tribs	0.1	1	0.2	0.2

Table L.7: MCDA inputs for ranking by Practicality.

Project	*Complexity*			*Safety*
	Legal	Landowner	Technical	
Camp Hale Restoration	-1	0.8	-0.5	0
Milk/Alkali/Ute Creeks	-0.5	0.5	-1	0
Flow Management/Decision-Making Tools	-1	-1	-0.5	0
Belden Cribbings	-1	-0.5	-0.4	1
Eagle Mine/Belden	-1	-0.5	-0.8	1
Edwards/Lake Creek Segment	0.1	-0.2	-0.6	0.2
Enhance River Habitat in Gypsum Wildlife Area	0.1	0.1	-0.3	0
Minturn Confluence Segment	0.1	0	0	0
Bolt's Lake Restoration	-0.4	-0.1	-1	0
Riparian Tamarisk Removal - Lower River and Tribs	0.1	-0.5	0.5	0
Remove Piling in Avon	0.8	1	0.5	0.2
Eagle Canyon Litter Cleanup	0	0.5	0.8	0
Basinwide Nutrient Strategy	-1	-1	-0.5	0
Non-native Species Removal – Camp Hale	0	0.8	-1	0
Long-term Access Plan for Low Impact Recreation	0.5	0.2	0.5	0
Riparian Work/Bank Stabilization Upstream of Wolcott	0.5	0	0.3	0
Avon Restoration - Overly wide, Localized Areas	0	-0.2	0.3	0
Riparian Planting Opportunities - Lower Eagle & Eagle Valley Tribs	0	-0.5	0.3	0

Table L.8: MCDA inputs for ranking by Socioeconomics.

Project	*Economic Base*	*Education*	*Recreation*				*History*
			Access	Vehicles	Boating	Game Fish	
Camp Hale Restoration	0.8	1	0	50	0	0.7	1
Milk/Alkali/Ute Creeks	0.5	0.5	0	0	0	0	0
Flow Management/Decision-Making Tools	1	0.2	0	0	0	1	0
Belden Cribbings	1	0.1	0	0	0	0	0
Eagle Mine/Belden	1	0.2	0	0	0	0.4	0
Edwards/Lake Creek Segment	0.6	0.5	1	30	0.3	0.8	0
Enhance River Habitat in Gypsum Wildlife Area	0.8	0.5	0.8	50	0.3	0.8	0
Minturn Confluence Segment	0.4	0.1	0.2	20	0.5	0.7	0
Bolt's Lake Restoration	0.1	0	0.1	30	0.2	0.2	0
Riparian Tamarisk Removal - Lower River and Tribs	0	0.1	0	0	0	0	0
Remove Piling in Avon	0	0	0	0	-0.1	0	0
Eagle Canyon Litter Cleanup	0.1	0.3	0	0	0	0	0
Basinwide Nutrient Strategy	1	0	0	0	0.5	0.8	0
Non-native Species Removal – Camp Hale	0	0.4	0	0	0	0	0
Long-term Access Plan for Low Impact Recreation	1	0.5	1	100	0	0	0
Riparian Work/Bank Stabilization Upstream of Wolcott	0	0.1	0	0	0	0.1	0
Avon Restoration - Overly wide, Localized Areas	0	0.1	0	0	0.1	0.3	0
Riparian Planting Opportunities - Lower Eagle & Eagle Valley Tribs	0	0.3	0	0	0	0.4	0

ELECTRONIC APPENDIX M

Electronic Database of Inbasin Diversions

(Electronic Appendix M is the Excel file located in the 'AppendixM_Electronic_Only' folder.)