Green River Channel Monitoring
Field Data Collection
Yampa and Little Snake Rivers

Report, Cross Section Plots, Photos

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Recovery Implementation Program for Endangered Fish Species
in the Upper Colorado River Basin
Project # 72 BC

Final Report

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February, 1998
Revised, August, 1998

Executive Summary

In 1983 a series of 21 cross sections were surveyed in the Yampa River Canyon in Dinosaur National Monument in conjunction with a sediment transport study and hydrographic data collection program at Mather's Hole (river mile 18.5) funded by the National Park Service Field Support Laboratory in Fort Collins, Colorado. Most of these cross sections were located in the lower 20 miles of the canyon. Although these cross sections were never permanently monumented, they were described in detail in original field notes and documented with photographs. An additional six cross sections were surveyed in the Deerlodge Park reach of the Yampa River in the fall of 1983.

All of these cross sections were resurveyed in August, 1997 as part of the Channel Monitoring Program of the Recovery Implementation Program for Endangered Fish Species in the Upper Colorado River Basin. The purpose of this project was to determine the magnitude of channel morphology changes over the past 14 years and to permanently monument the cross section endpoints before the original data base was lost. The data collection crew chief in 1983 was still available to perform this work and FLO Engineering was contracted to conducted the surveys. Rebar and benchmark caps were used for the endpoints. Estimates of endpoint coordinates and elevations were established with a GPS unit.

All of the Yampa Canyon cross sections were relocated and surveyed. The Deerlodge Park reach of the Yampa River has experienced significant channel morphology changes and the location of the first three upstream cross sections could only be approximated because the endpoints had been lost through bank erosion. The location of all the new endpoints were described in detail in the field notes and documented with a series of four photographs.

A comparison of the 1983 and 1997 Yampa Canyon cross section plots reveal only limited change in the cross section channel geometry. Most of the significant changes were related to the Yampa River flood of record in 1984 and involved bank erosion. In-channel changes of the channel geometry were within the range of seasonal variation observed in 1983. Two of the cross sections have experienced some invasion of tamarisk on one of the banks. The results of the comparison of the two sets of cross sections indicate that the Yampa Canyon is a conveyance reach for the Little Snake sediment load with only limited opportunities for sediment storage.

The six mile Deerlodge Park reach has experienced significant channel morphology changes primarily associated with channel widening and migration. All six cross sections are substantially wider with one or both banks having evidence of extensive erosion. The increased width of the channel at each cross section ranged from 60 ft to 300 ft. One cross section more than doubled in width. The increase in width-to-depth ratio in this reach can be attributed to several factors including the shift of the Yampa and Little Snake River confluence downstream about 0.5 miles, high flows immediately after the confluence shift in 1983 and 1984, and high sediment loads from the Little Snake River.

The Yampa Canyon cross sections should be resurveyed after the next major flood event or in conjunction with future research projects. The Deerlodge Park cross sections should be resurveyed on a five year cycle until the magnitude of the channel morphology changes declines. This channel morphology data base and results can be applied to the Yampa and Little Snake Rivers flow recommendations for the Flaming Gorge biological opinion.

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Project Funding and Support

The Green River Channel Monitoring Program is funded by the Recovery Implementation Program for Endangered Fish Species in the Upper Colorado River Basin. The program was initiated by the U.S. Fish and Wildlife Service Engineering Office in Denver, Colorado. The Recovery Implementation Program is a joint effort of the U.S. Fish and Wildlife Service, U.S. Bureau of Reclamation, Western Area Power Administration, State of Colorado, State of Utah, and State of Wyoming, Upper Basin Water Users, environmental organizations and the Colorado River Energy Distributors Association.

Acknowledgments

This project was administered through the Channel Monitoring Project under the auspices of George Smith as part of the Recovery Implementation Program for Endangered Fish Species in the Upper Colorado River Basin. Ed Wick of the National Park Service in Fort Collins, Colorado provided the original channel cross section survey data collected in 1983 by Jim O'Brien working for the National Park Service.

List of Key Words

Green River channel monitoring, Yampa River, Yampa Canyon, Little Snake River, channel morphology, channel geometry, cross section surveys

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Introduction

The goal of the channel monitoring program is to support the efforts of the Recovery Program in developing flow recommendations, restoring flooded bottomlands and monitoring channel morphology conditions in the rivers of the Upper Colorado River Basin. This program will provide information on changes and trends in river channel morphology and riparian habitat.
Each year, one or two important river reaches are selected for baseline or subsequent surveys depending on annual program guidance and priorities. River channel cross sections are established or resurveyed to collect channel morphology data on baseline and current conditions. Over a period of years, cross sections are monitored to review changes and trends in the channel morphology. Important river reaches are to be resurveyed approximately every five years. To the extent possible, the channel monitoring work is coordinated with other research efforts.

The goal of the 1997 Yampa River channel monitoring effort was to resurvey and monument river channel cross sections initially surveyed in the early 1980's by the National Park Service Field Support Laboratory, then located in Fort Collins, Colorado. The cross section resurvey enables an assessment of the changes in channel morphology of the Yampa River over the past 14 years. The results and analysis of the channel morphology changes will support flow recommendations for the Yampa and Little Snake Rivers. A total of 28 cross sections were resurvey in August, 1997 including 21 Yampa River canyon cross sections and 7 cross sections in Deerlodge Park on the Yampa and Little Snake Rivers. One new cross section was surveyed on the Little Snake upstream of the Yampa River confluence. The other 27 cross sections were originally surveyed in 1983.

This report discusses the goals and objectives of the program, study reaches, methods and procedures, plots of the channel cross sections, analysis of changes in the channel morphology and lists recommendations for future channel monitoring. The 1983 and 1997 original field notes and data are presented in a separate appendix binder. The cross section plots and a photographic record of the cross sections are transmitted as appendices in this report. The original 1983 photographs were developed only as slides. These original 1983 slides and a separate set of 1997 slides are presently being kept on file by FLO Engineering, Inc., Breckenridge, Colorado. Copies of the original data has been transmitted to the US Fish and Wildlife Service, Denver, Colorado. Additional electronic copies of the data are available from FLO Engineering.

Project Goals and Objectives

The project goal was to provide channel morphology data and analyses to support the flow recommendations for the Yampa River from the Little Snake River confluence to the confluence with the Green River. The project goal was to be accomplished through the following objectives:

- Retrieve the original cross section data, photographs and notes from the National Park Service archives in Fort Collins, Colorado.
- Resurvey the 21 Yampa Canyon river cross sections originally surveyed in 1983.
- Resurvey the 6 Deerlodge Park cross sections in the vicinity of the Little Snake River confluence.
- Permanently monument and locate the cross section endpoints with a GPS system.
- Analyze the channel morphology changes and trends based on a comparison of the cross section data.
- Recommend future channel morphology tasks for flow recommendations in the Yampa River.

It was important to resurvey and monument the Yampa Canyon cross sections while the crew chief of the 1983 channel morphology data collection effort was still available to conduct a resurvey effort. In 1983, the National Park Service requested minimal disturbance of the resources in Dinosaur National Monument while undertaking the hydrographic data collection project. As a result, the original cross section endpoints were located with respect to natural objects and features. In order to relocate the cross sections, it was necessary to have the original crew chief (Jim O'Brien, FLO Engineering) available to perform the work. It was an objective of this project to complete the resurvey and permanently monument the cross sections for future long term channel morphology research.

Yampa River Study Area

The study area includes the Yampa River from the Little Snake River confluence to the Green River confluence in northwest Colorado. Almost all of the study area is located in the Yampa Canyon in Dinosaur National Monument. In this reach a total of 26 cross sections were surveyed in 1983 with 21 cross sections located in the Yampa Canyon. The majority of the cross sections (16) are located downstream of Harding Hole (about river mile 20). Only five cross sections are located in the remaining 25 miles of the Yampa Canyon. The study area also includes about one-half mile of the Little Snake River upstream of the Yampa River confluence. Two cross sections are located on the Little Snake River in this reach. The original 21 canyon cross sections are shown in Figure 1.

Figure 1. Yampa River Canyon Cross Section Locations

This distribution of cross sections in the Yampa Canyon was primarily a function of the canyon rock lithology. The upper 25 miles of river canyon consists mainly of the Morgan limestone bed formation (Photos 2.11 thru 3.6, Appendix C). Where the Yampa River flows through Morgan formation, the valley cross section tends to be asymmetrical with a steep river profile. The south side of the valley is generally a steep escarpment while the north side has a more gentle slope and is covered with talus. The asymmetry of the valley cross section is created by the dip of the limestone beds which is approximately 7 to 10 degrees to the southwest. The lower member of the Morgan formation is an incompetent shale which rests on the Round Valley Formation, a limestone. Where the shale is exposed by the river downcutting, it slides on the Round Valley formation causing the overlying rocks to collapse and tumble. Most of the landslides occur on the north side of the valley. In this reach, the river confined by the steep talus slopes and has no floodplain. The channel location in some reaches of the valley is dictated by the ancient landslides (O'Brien, 1984).

In the lower 20 miles of the Yampa Canyon, the Weber formation appears. It is a relatively soft sandstone which is easily eroded by the river and creates a more symmetrical canyon cross section (Photos 3.7 thru 6.3, Appendix C). Smooth, curving walls are often vertical or past vertical depending on the incision of the meander bend. An ancient river meander pattern was superimposed on the Weber formation and the pattern was maintained as the river downcut through the soft sandstone. The river slope is relatively mild compared to the upstream reach through the controlling Morgan formation. The slope decreases as the Yampa river bed elevation approaches the base level of the Green River in Echo Park (O'Brien, 1984).

In 1983, the 21 Yampa canyon cross sections were generally located in pools or in wide reaches of river channel where sediment deposition might occur. The cross sections were established in conjunction with a hydrograph data collection program at Mathers Hole in the middle of the Yampa Canyon. Sediment load and discharge measurements were collected during two high flow seasons including suspended load and bedload to determine the sediment load passing through the canyon. The 21 canyon cross sections were surveyed early in the spring prior to the high flows and again either once or twice more after the peak flows to determine sediment deposition or scour during the high flow season. The Yampa River flood of record of approximately 30,000 cfs occurred in 1984. There were several areas of channel erosion and sediment deposition in the form of large sand bars during both of these years. It was important to record the effects of the 1984 event on the channel morphology prior to another significant rare flood event.

In the fall of 1983, a set of six cross sections were surveyed in Deerlodge Park from the Little Snake River to the Yampa Canyon entrance. It was determined from the 1983 sediment data collection program that approximately 75% of the total sediment load in the Yampa River in the canyon comes from the Little Snake River (O'Brien, 1984, 1987). The six mile reach of the Yampa River from the Little Snake River to the canyon entrance has a relatively mild slope and serves a storage reach for sediment movement into the canyon. For this reason, six cross sections were surveyed to monitor the long term sediment storage and movement in Deerlodge Park.

Survey Methods and Procedures

Conventional river cross section survey methods were employed to accomplish this work. After locating the cross sections, endpoints were established with rebar and aluminum caps on each side of the river above the high water marks. The caps were labeled with the notation CAN-1 thru 21. No tag-line fence posts were used to mark the endpoints. A 1/8 inch kevlar cable was used as the tag-line. A survey level was used to survey the bank topography down the water surface elevation. Below the water surface, elevations were estimated to the nearest 0.1 ft using the survey rod and measuring the flow depth. An arbitrary reference elevation of 100 was assigned to the left endpoint bar and cap. The discharge during the survey trip was approximately 800 cfs. Some of the cross sections could be waded.

A state-of-art mobile GPS unit was used to assign horizontal coordinates and approximate elevations to the bar and caps. Most of the endpoint coordinates were estimated within a range of plus or minus 40 ft. Elevations estimates were not very accurate, usually on the order of plus or minus 100 ft. The list of bar and cap coordinates and elevation is presented in Appendix D. For several cross sections, one endpoint could not be located using the GPS system because of the canyon walls blocked the line-of-sight to the satellite positions. In the future, the bar and caps can be located using a GPS unit, the photographs and, if necessary, a metal detector. All the Yampa Canyon cross sections were relocated, but the Deerlodge Park channel geometry had significantly changed and the location of the first four cross sections could only be estimated through the use of the original field notes and photographs. One of the canyon cross section endpoints was mislocated and as a result the cross section did not match the original channel configuration.

All of the cross sections surveyed in 1997 were documented with field notes and photographs. The field notes describe bank and floodplain conditions, vegetation and channel bed material. The cross sections plots, original field notes, photos, and endpoint coordinate positions were transmitted to the US Fish and Wildlife Service as appendices to this report.

Comparison of the 1983 and 1997 Yampa Canyon Cross Sections

The purpose of this project was to analyze the changes in the Yampa Canyon cross sections after 14 years. During this period the Yampa River experienced one peak over 30,000 cfs (1984), 7 additional peak discharges in excess of 15,000 cfs and 4 peak discharges less than 10,000 cfs. The last three years have been high flow years with the peak discharge exceeding 18,000 cfs. Bankfull discharge in the Yampa River varies between 22,000 cfs and 30,000 cfs in the few locations where floodplains exist in Harding Hole to Mantle Ranch reach . The only major flood event during this period occurred in 1984. Based on field observations in both 1983 and after the peak flow in 1984, almost all of the major channel changes observed in the 1997 re-survey were related to erosion that occurred in 1984.

The resurveyed cross sections were plotted and overlaid with the original cross section surveys in the early 1980's. A summary of the Yampa Canyon cross section channel morphology changes is listed in the following table. The cross section plots are presented in Appendices A and B. The original 1983 cross section data were entered into the data base using a endpoint reference elevation of 100. The original 1983 cross section endpoints did not always correspond to the 1997 endpoints and as a result, the 1983 cross section plots were adjusted in the AutoCAD drawing to match similar positions. This was accomplished by moving the 1983 cross section lines to overlay 1997 positions of bedrock, top of bank or other obvious features in the cross section. The original 1983 cross section data were not revised because all future data will be reference to the 1997 endpoint bar and caps. The cross section drawing with all the cross section plots is available from FLO Engineering, Inc.

Of the 21 Yampa River canyon cross sections, 7 cross sections experienced no significant changes, 6 cross sections had some net deposition, 6 cross sections experienced some net scour or erosion, one cross section had a major change in shape and one cross section (CAN-6) had a misplaced endpoint which did not permit a channel geometry comparative analysis. This cross section (Can-6) was observed to have significant left bank erosion. In the 1983 report, it was discussed that over the course of one high flow season, that 8 cross sections experienced some bed scour and 13 cross sections had some net deposition (O'Brien, 1984). Reviewing the 1983 plots, 7 cross sections experienced only minor changes in the bed, 5 cross sections had some net scour and 10 cross sections experienced some net deposition.

Over the past 14 years, there has been no significant variation in the amount of sand stored in the Yampa Canyon within the active river channel. The variation in the channel cross sections are basically within the expected seasonal changes except for the significant bank erosion caused by the 1984 peak flow of record. Cross sections Can-6 and Can-10 experienced significant left bank erosion when the 1984 high flow cut across the inside of the bends. Sand deposition occurred in two tamarisk stands, at cross sections Can-5 and Can-15, which has narrowed the channel width and reduced the bankfull conveyance capacity in those reaches. The total area of unvegetated sand bars within the active channel in the Yampa Canyon is relatively minor. These few open sand bars are reworked on annual basis which limits encroachment of riparian vegetation, especially exotic vegetation such as tamarisk (e.g. at Can-1 and Can-2). The high variability in flows and confined channel geometry combine to limit sediment storage in the canyon.

Table 1. Summary of Yampa Canyon Cross Section Changes 1983-1997			
Cross Section Name/Location (rm = river mile)	Cross Section No.	Cross Section Changes	Net Scour/Deposition
Anderson Hole (rm 41.8)	Can-1	Right bank sand bar is about 1 ft higher, but unvegetated, reworked annually.	No significant change
Above Tepee Campground (rm 36.8)	Can-2	New unvegetated sand bar on left bank	Slight deposition
Haystack Rock (rm 33.9)	Can-3	1 ft of sand deposition on right bank sand bar with annual vegetation	Minor deposition
Above Little Joe Rapid (rm 29.4)	Can-4	Slight bed scour (1 ft in thalweg)	No significant change
Above Big Joe Rapid (rm 24.0)	Can-5	3 ft deposition (-120 ft) on center cobble bar, sand deposition in vegetation on right sand bar	Net deposition
Below Harding Hole (rm 19.3)	Can-6	Right endpoint was mislocated. No comparison is possible.	-
Replicate Spawning Site (rm 18.5)	Can-7	Scour of cobble bar in center (-0.5 ft) and left bank (2 ft)	Net scour
Above Mathers Hole (rm 17.8)	Can-8	Stable cross section	No significant change
Below Mathers Hole (rm 17.1)	Can-9	Variation of sand and fines deposition against left bedrock wall	No significant change
Upper Cleopatra's Couch Bar (rm 16.7)	Can-10	Left bank eroded in 1984 (80 ft), 5 ft of deposition in right channel, center bar shifted right	Major variation in shape
Below Cleopatra's Couch 1 (rm 16.)	Can-11	Cobble and gravel bar development against right bank on inside of bend	Deposition of cobble bar
Below Cleopatra's Couch 2 (rm 15.8)	Can-12	Left bank erosion (30 ft), probably in 1984	Net erosion
Below Cleopatra's Couch 3 (rm 15.4)	Can-13	Right bank erosion (20 ft), probably in 1984, some deposition on left 1/3 of channel	Net erosion
Below Cleopatra's Couch 4 (rm 15.1)	Can-14	Slight erosion of right bank	No significant change
Near Red Canyon (rm 10.6)	Can-15	Sand deposition on right bank, some sand deposition in mature tamarisks	Net Deposition
End of Ladie Park (rm 9.7)	Can-16	Left bank erosion, removal of end of large sand bar	Net erosion
Above Portal Canyon (rm 9.4)	Can-17	Deposition of cobble and gravel bar in center of channel	Net deposition
At Portal Canyon (rm 9.2)	Can-18	Left bank erosion (20 ft)	Net erosion
Portal Canyon (rm 9.2)	Portal	Deposition on right over bank, scour of bed (2 ft), subject to side canyon flows	-
Tiger Wall (rm 9.0)	Can-19	No significant changes, seasonal variation	No significant change
Below Tiger Wall (rm 8.2)	Can-20	Right bank erosion	Net erosion

Table 1. Summary of Yampa Canyon Cross Section Changes 1983-1997		
Warm Springs Lake (rm 6.5)	Can-21	Endpoint repositioning distorts bank steepness

Comparison of 1983 and 1997 Deerlodge Park Cross Sections

In 1983, six cross sections were surveyed in Deerlodge Park. One cross section was located just upstream of the Little Snake River and Yampa River confluence on each river and the other four cross sections were located between the confluence and Deerlodge Park boat launch and campground. These cross sections were also poorly monumented and no photos could be found for these surveys in 1983. The field notes and map were used to reliably locate the original cross sections. The first four cross section experienced major channel morphology changes as shown in the figures in Appendix B. The last two cross sections had less variation. A brief discussion of the changes in each cross section follows:

DL-1 Yampa River Upstream of the Little Snake River Confluence

This cross section on Yampa River, about 1,000 ft upstream of the Little Snake River confluence, has experienced a substantial cross section change. The left bank retreated about 100 ft and the right bank had approximately 100 feet of deposition within the active channel. The thalweg shifted from the left third to the right third of the channel. The thalweg was about 2 ft deeper in 1983. Overall the cross section is now about 25 percent wider and slightly shallower than it was in 1983.

DL-2 Little Snake River Upstream of the Yampa River Confluence

This cross section is located on the Little Snake River approximately 1,000 ft upstream of the Yampa River confluence. Both banks of this reach of river experienced bank erosion; the left bank was eroded about 15 ft and the right bank lost about 80 ft. Both endpoints had been lost. The channel bed was essentially the same with about a foot increase over two-thirds of the channel. The right overbank has a large stand of mature willows and tamarisks. There was a net increase in the cross section flow area.

DL-2.1 Little Snake River

A new cross section was surveyed about 0.25 miles upstream of DL-2 on the Little Snake River. This cross section was added to determine the future changes in the Little Snake River because the Deerlodge Park reach of the Yampa River appears to be very active. The cross section was surveyed in a very narrow reach of river where erosion of the right bank appeared to be occurring. It is possible that the Little Snake River is still adjusting to the downstream shift in the Yampa River confluence and this cross section can be used to monitor changes further upstream from the confluence. The channel cross section adjustment probably occurred very quickly.

DL-3 Yampa River Downstream of the Little Snake Confluence

This cross section was located by the left endpoint. The right bank retreated over 240 ft. The active channel has almost doubled in width since 1983. The channel bed has about the same elevation.

DL-4 Yampa River near the Photo Turnout

This cross section is also significantly wider (from 460 ft wide in 1983 to 780 ft in 1997). The right bank has eroded about 260 ft and the left bank about 20 ft. The thalweg is on the right one-third of the channel with a large 440 ft open sand bar on the left two-thirds of the channel. The channel is both wider and slightly deeper.

DL-5 Yampa River near the Arroyo

This wide cross section is subject to sediment deposition from the wash entering on the left bank. The debris fan has a mild slope extending from the left bank. This alluvial fan deposition forces the river to the right bank after the wash floods. There was evidence of recent flooding when the cross section was surveyed. A large fresh red-tint sediment deposit was observed on the active river channel from the wash. The right bank has eroded 100 ft since 1983.

DL-6 Yampa River at the Deerlodge Park Boat Launch

Approximately 60 ft of the left bank was eroded since 1983. Conversely, the right bank has experienced a significant deposit extending the bank about 60 ft in the original channel. There is evidence that the channel is migrating to the south with left bank erosion and right bank attachment.

Sometime in the early 1980's (probably 1980 to 1982), the confluence of the Little Snake and Yampa Rivers shifted downstream approximately one-half mile. This shift may have occurred, in part, in response to improve channel stability by local ranchers. In any case, the base level of the Little Snake River was lowered by a few feet resulting in minor headcutting up the Little Snake River and increased sediment loading to the Yampa River. The high flows in 1983 and 1984 accelerated the bank erosion in the Little Snake and Yampa Rivers. The increased sediment loading from the confluence shift, flood bank erosion in 1983 and 1984, and possible higher than average Little Snake sediment loads delivered to the Yampa River resulted in sediment deposition in the Deerlodge Park reach of the Yampa River causing channel widening. The Yampa River in Deerlodge Park appears to be an important sediment storage reach where the sediment transport capacity determines the sand-sized sediment load to the Yampa Canyon and eventually to the Green River in Echo Park. The sediment supply from the Deerlodge Park reach essentially passes through the Yampa Canyon without significant deposition on a seasonal basis. This was confirmed in 1983 when sediment load measurements at the USGS Deerlodge Park gage downstream of the boat launch predicted an annual sediment load almost equal to that computed from sediment load measurements at Mathers Hole (rm 17.5) 28 miles downstream.

Conclusions

All of the original cross sections in the Yampa and Little Snake Rivers surveyed in 1982 to 1984 were resurveyed. The original cross sections were never permanently monumented. The original endpoints consisted of trees, rocks, or I-bolts which were described in some detail in the original field notes. The crew chief of the original survey team, Jim O'Brien, FLO Engineering, Inc. conducted the 1997 resurvey and through the use of the original photos and field notes was able to relocate all the cross section sites. All of the cross sections are now permanently monumented with rebar and survey caps. These bar and caps were assigned coordinate positions with a relatively accurate GPS system. The resolution of the GPS coordinates was limited at some cross sections by the canyon walls which inhibited the tracking of a greater range of satellite positions. A few of the cross sections were repositioned (within a few feet) to permit better siting of the coordinate positions. Most of the endpoints were located with an error of plus or minus twenty feet.

The Yampa River through the canyon in Dinosaur National Monument is essentially a sediment conveyance corridor with a confined channel, very limited floodplain and only a few wide channel reaches where any appreciable amount of sediment can be stored. The upper half of the Yampa River in the Yampa Canyon has a very steep slope, in excess of 13 ft per mile. The steepest reach from Tepee Rapid to Harding Hole exceeds 18 ft per mile. The sediment supply for the Yampa Canyon is Deerlodge Park, a six mile reach to the confluence of the Little Snake River that has a slope of only 3 ft per mile. At the confluence between the Little Snake and Yampa Rivers, the Little Snake River contributes about 75% of the total load in the Yampa River downstream. The Deerlodge Park reach stores a portion of this sediment load depending its sediment transport capacity. The sediment load transported through the Yampa Canyon depends on the sediment supply from the Deerlodge Reach. There is little opportunity for sediment storage within the Canyon and over the long term the sediment load entering the Green River from the Yampa is essentially the sediment load generated transport capacity of the Deerlodge reach.

The Yampa Canyon cross section variability over the course of one season (1983) is shown in the cross section plots in Appendix A. Over the past 14 years, except for two cross section which experienced bank erosion during the 1984 flood of record,, the change in the cross sections is generally less than the seasonal variation observed in 1983. This confirms that the Yampa River in the Yampa Canyon has limited sediment storage capacity. The average sediment load of approximately 2.5 million tons per year is transported through the canyon without substantial deposition or scour (O'Brien, 1987).

Conversely, the Deerlodge Park reach of the Yampa River has undergone significant channel morphology changes during the last 14 years. The primary channel geometry changes are bank erosion and channel widening. Of the original six cross sections in this reach, five cross sections had lost one or both endpoints due to channel migration or bank erosion. Locating the exact position of first three cross sections was impossible but using the original field notes, the original cross sections were located within about 50 ft which allowed an analysis of the magnitude of the cross section change. Two of the six cross sections almost doubled in width. The other cross sections increased in width from 60 ft to 100 ft.

The increased width of the river through bank erosion can be attributed to several factors. One important factor was the shift in the confluence of the Little River and Yampa Rivers in the downstream direction approximately 0.5 miles. This shift occurred just prior to the very high flows in 1983 and 1984. The combination of high peaks flows during these two years, the increased sediment supply from the lower Little Snake River bed degradation and associated channel widening in response to the confluence shift and the corresponding sediment deposition in the Yampa River channel downstream of the new confluence, all contributed to the Yampa River's attack on the alluvial banks in the Deerlodge Park reach.

The dramatic difference in response in these two reaches of the Yampa River to the same flows and sediment load of the past 14 years illustrates the importance of monitoring the entire system and understanding the physical processes occurring in each unique reach of river. It is unlikely that channel morphology and aquatic fish habitat will change significantly in the Yampa Canyon as long as flow variability and high peak flows are sustained to flush the Little Snake sediment load through the system. Conversely, relatively small, short duration perturbations to the system such as the Little Snake confluence shift can significantly effect the alluvial channel Deerlodge Park Reach of the Yampa River.

Recommendations

The results of this channel morphology study can be incorporated in to future flow recommendations for the Yampa and Little Snake Rivers. Flow recommendations regarding fish habitat should be based on maintaining flow variability and peak flows to sustain sediment transport in the Yampa Canyon. The results of this study can also be used to support analyses of flows and sediment transport as it relates to channel morphology changes in the past 14 years.

The Yampa Canyon cross sections will not have to be surveyed again for a period of 10 or mores years. It is recommended that these cross sections be resurveyed after a major flood event to examine channel morphology changes and, if necessary, relocate the endpoints. At that time, missing or damaged endpoints should be replaced or repositioned to maintain the cross section data base. With the increasing accuracy of the GPS technology, it is also recommended that the endpoint coordinates be checked again in about 10 years.

Based on the Yampa River bank erosion and channel migration in the Deerlodge Park reach, the seven cross sections should be resurveyed on a five year cycle to monitor the channel changes.

These cross sections are a good indication of variations in the Little Snake River sediment load and of the response to potential flow reduction. Whereas the observed level of channel migration is healthy for the system, one concern is the potential loss of the old growth cottonwood trees on the floodplain and the lack of regeneration of the cottonwoods. The invasion of exotic riparian vegetation such as tamarisk should be monitored.

References

O'Brien, J.S., 1984. "Hydraulic and Sediment Transport Investigation, Yampa River, Dinosaur National Monument." Report submitted to the National Park Service Water Resources Laboratory, Colorado State University, Fort Collins, CO.

O'Brien, J.S., 1987. "Analysis of Minimum Streamflow and Sediment Transport in the Yampa River, Dinosaur National Monument." Report submitted the Nature Conservancy, Boulder, CO.

Appendix A

Yampa Canyon Cross Section Plots

Appendix B

Deerlodge Park Cross Section Plots

Appendix C

Photo Log and Photographs

Table C.1 Photo Log			
Photo No.	Date	Cross Section No.	Photo Description
1.1	8/16/97	DL-1	Deerlodge Park, Yampa River, Looking from LEP to REP
1.2	8/16/97	DL-1	Deerlodge Park, Yampa River, From TOB, Sta. 0.+32, Looking upstream
1.3	8/16/97	DL-1	Deerlodge Park, Yampa River, From TOB, Sta. 0.+32, Looking downstream
1.4	8/16/97	DL-1	Deerlodge Park, Yampa River, Looking from REP to LEP
1.5	8/16/97	DL-2	Deerlodge Park, Little Snake River, Looking from LEP to REP
1.6	8/16/97	DL-2	Deerlodge Park, Little Snake River, From TOB, Sta. 0.+29, Looking upstream
1.7	8/16/97	DL-2	Deerlodge Park, Little Snake River, From TOB, Sta. 0.+29, Looking downstream
1.8	8/16/97	DL-2	Deerlodge Park, Little Snake River, From Sta. 1+150, Looking upstream
1.9	8/16/97	DL-2	Deerlodge Park, Little Snake River, From Sta. 1+150, Looking downstream
1.10	8/16/97	DL-2	Deerlodge Park, Little Snake River, From TOB, Sta. 0.+32, Looking upstream
1.11	8/16/97	DL-2.1	Deerlodge Park, Little Snake River, Looking from REP to LEP
1.12	8/16/97	DL-2.1	Deerlodge Park, Little Snake River, From left bank looking upstream
1.13	8/16/97	DL-2.1	Deerlodge Park, Little Snake River, From left bank looking downstream
1.14	8/16/97	DL-2.1	Deerlodge Park, Little Snake River, Looking from REP to LEP
1.15	8/17/97	DL-3	Deerlodge Park, Yampa River, Looking from REP to LEP
1.16	8/17/97	DL-3	Deerlodge Park, Yampa River, From TOB, Sta 0+89, looking upstream
1.17	8/17/97	DL-3	Deerlodge Park, Yampa River, From TOB, Sta 0+89, looking downstream
1.18	8/17/97	DL-3	Deerlodge Park, Yampa River, Looking from REP to LEP
1.19	8/17/97	DL-4	Deerlodge Park, Yampa River, Looking from REP to LEP
1.20	8/17/97	DL-4	Deerlodge Park, Yampa River, From TOB, Sta 0+50, looking upstream
1.21	8/17/97	DL-4	Deerlodge Park, Yampa River, From TOB, Sta 0+50, looking downstream
1.22	8/17/97	DL-4	Deerlodge Park, Yampa River, Looking from REP to LEP
2.1	8/17/97	DL-5	Deerlodge Park, Yampa River, Looking from REP to LEP
2.2	8/17/97	DL-5	Deerlodge Park, Yampa River, From TOB, Sta 0+100, looking upstream
2.3	8/17/97	DL-5	Deerlodge Park, Yampa River, From TOB, Sta 0+100, looking downstream
2.4	8/17/97	DL-5	Deerlodge Park, Yampa River, Looking from REP to LEP
2.5	8/17/97	DL-6	Deerlodge Park, Yampa River, Looking from REP to LEP
2.6	8/17/97	DL-6	Deerlodge Park, Yampa River, From TOB, Sta 0+82, looking upstream
2.7	8/17/97	DL-6	Deerlodge Park, Yampa River, From TOB, Sta 0+82, looking downstream

Table C.1 Photo Log			
2.8	8/17/97	DL-6	Deerlodge Park, Yampa River, Looking from REP to LEP
2.9	8/18/97	CAN-1	Yampa Canyon, Looking from REP to LEP
Photo No.	Date	Cross Section No.	Photo Description
2.10	8/18/97	CAN-1	Yampa Canyon, from Sta 0+16, looking upstream
2.11	8/18/97	CAN-1	Yampa Canyon, from Sta 0+16, looking downstream
2.12	8/18/97	CAN-1	Yampa Canyon, Looking from REP to LEP
2.13	8/18/97	CAN-2	Yampa Canyon, Looking from REP to LEP
2.14	8/18/97	CAN-2	Yampa Canyon, from Sta 0+20, looking upstream
2.15	8/18/97	CAN-2	Yampa Canyon, from Sta 0+20, looking downstream
2.16	8/18/97	CAN-2	Yampa Canyon, Looking from REP to LEP
2.17	8/18/97	CAN-3	Yampa Canyon, Looking from REP to LEP
2.18	8/18/97	CAN-3	Yampa Canyon, from Sta 0+30, looking upstream
2.19	8/18/97	CAN-3	Yampa Canyon, from Sta 0+30, looking downstream
2.20	8/18/97	CAN-3	Yampa Canyon, Looking from REP to LEP
2.21	8/18/97	CAN-4	Yampa Canyon, Looking from REP to LEP
3.1	8/18/97	CAN-4	Yampa Canyon, from Sta 0+10, looking upstream
3.2	8/18/97	CAN-4	Yampa Canyon, from Sta 0+10, looking downstream
3.3	8/18/97	CAN-4	Yampa Canyon, Looking from REP to LEP
3.4	8/18/97	CAN-5	Yampa Canyon, Looking from REP to LEP
3.5	8/18/97	CAN-5	Yampa Canyon, from Sta 0+18, looking upstream
3.6	8/18/97	CAN-5	Yampa Canyon, from Sta 0+18, looking downstream
3.7	8/19/97	CAN-6	Yampa Canyon, Looking from REP to LEP
3.8	8/19/97	CAN-6	Yampa Canyon, from Sta 0+71, looking upstream
3.9	8/19/97	CAN-6	Yampa Canyon, from Sta 0+71, looking downstream
3.10	8/19/97	CAN-6	Yampa Canyon, Looking from REP to LEP
3.11	8/19/97	CAN-7	Yampa Canyon, Looking from REP to LEP
3.12	8/19/97	CAN-7	Yampa Canyon, from Sta 1+00, looking upstream
3.13	8/19/97	CAN-7	Yampa Canyon, from Sta 1+00, looking downstream
3.14	8/19/97	CAN-7	Yampa Canyon, Looking from REP to LEP
3.15	8/19/97	CAN-8	Yampa Canyon, Looking from REP to LEP

Table C.1 Photo Log			
3.16	8/19/97	CAN-8	Yampa Canyon, from Sta 1+70, looking upstream
3.17	8/19/97	CAN-8	Yampa Canyon, from Sta 1+70, looking downstream
3.18	8/19/97	CAN-8	Yampa Canyon, Looking from REP to LEP
3.19	8/19/97	CAN-9	Yampa Canyon, from Sta 2+30, looking upstream
Photo No.	Date	Cross Section No.	Photo Description
3.20	8/19/97	CAN-9	Yampa Canyon, from Sta 2+30, looking downstream
3.21	8/19/97	CAN-9	Yampa Canyon, Looking from REP to LEP
4.1	8/19/97	CAN-9	Yampa Canyon, Looking from LEP to REP
4.2	8/19/97	CAN-10	Yampa Canyon, Looking from REP to LEP
4.3	8/19/97	CAN-10	Yampa Canyon, Looking from REP to LEP
4.4	8/19/97	CAN-10	Yampa Canyon, Looking from LEP to REP
4.5	8/19/97	CAN-10	Yampa Canyon, From Sta 1+55 looking upstream
4.6	8/19/97	CAN-10	Yampa Canyon, From Sta 1+55 looking downstream
4.7	8/20/97	CAN-11	Yampa Canyon, Looking from LEP to REP
4.8	8/20/97	CAN-11	Yampa Canyon, From Sta 0+17 looking upstream
4.9	8/20/97	CAN-11	Yampa Canyon, From Sta 0+17 looking downstream
4.10	8/20/97	CAN-11	Yampa Canyon, Looking from REP to LEP
4.11	8/20/97	CAN-12	Yampa Canyon, Looking from LEP to REP
4.12	8/20/97	CAN-12	Yampa Canyon, From Sta 0+15 looking upstream
4.13	8/20/97	CAN-12	Yampa Canyon, From Sta 0+15 looking downstream
4.14	8/20/97	CAN-12	Yampa Canyon, Looking from REP to LEP
4.15	8/20/97	CAN-13	Yampa Canyon, Looking from LEP to REP
4.16	8/20/97	CAN-13	Yampa Canyon, From Sta 0+28 looking upstream
4.17	8/20/97	CAN-13	Yampa Canyon, From Sta 0+28 looking downstream
4.18	8/20/97	CAN-13	Yampa Canyon, Looking from REP to LEP
4.19	8/20/97	CAN-14	Yampa Canyon, Looking from LEP to REP
4.20	8/20/97	CAN-14	Yampa Canyon, From TOB, Sta 0+26 looking upstream
4.21	8/20/97	CAN-14	Yampa Canyon, From TOB, Sta 0+26 looking downstream
5.1	8/20/97	CAN-14	Yampa Canyon, Looking from REP to LEP
5.2	8/20/97	CAN-15	Yampa Canyon, Looking from LEP to REP

Table C.1 Photo Log

5.3	8/20/97	CAN-15	Yampa Canyon, From Sta 0+25 looking upstream
5.4	8/20/97	CAN-15	Yampa Canyon, From Sta 0+25 looking downstream
5.5	8/20/97	CAN-15	Yampa Canyon, Looking from REP to LEP
5.6	8/20/97	CAN-16	Yampa Canyon, Looking from LEP to REP
5.7	8/20/97	CAN-16	Yampa Canyon, From Sta 2+44 looking upstream
5.8	8/20/97	CAN-16	Yampa Canyon, From Sta 2+44 looking downstream
Photo No.	Date	Cross Section No.	Photo Description
5.9	8/20/97	CAN-16	Yampa Canyon, Looking from REP to LEP
5.10	8/20/97	CAN-17	Yampa Canyon, Looking from LEP to REP
5.11	8/20/97	CAN-17	Yampa Canyon, From Sta 3+00 looking upstream
5.12	8/20/97	CAN-17	Yampa Canyon, From Sta 3+00 looking downstream
5.13	8/20/97	CAN-17	Yampa Canyon, Looking from REP to LEP
5.14	8/20/97	CAN-17	Yampa Canyon, Looking from REP to LEP
5.15	8/20/97	CAN-18	Yampa Canyon, Looking from Sta 0+25 to REP
5.16	8/20/97	CAN-18	Yampa Canyon, From Sta 0+78 looking upstream
5.17	8/20/97	CAN-18	Yampa Canyon, From Sta 0+78 looking downstream
5.18	8/20/97	CAN-18	Yampa Canyon, Looking from REP to LEP
5.19	8/20/97	Portal Canyon	Yampa Canyon, Looking into Portal Canyon
5.20	8/20/97	Portal Canyon	Yampa Canyon, Looking into Portal Canyon
6.1	8/21/97	CAN-19	Yampa Canyon, Looking from LEP to REP
6.2	8/21/97	CAN-19	Yampa Canyon, From Sta 2+61 looking upstream
6.3	8/21/97	CAN-19	Yampa Canyon, From Sta 2+61 looking downstream
6.4	8/21/97	CAN-19	Yampa Canyon, Looking from REP to LEP
6.5	8/21/97	CAN-20	Yampa Canyon, Looking from LEP to REP
6.6	8/21/97	CAN-20	Yampa Canyon, From LEP looking upstream
6.7	8/21/97	CAN-20	Yampa Canyon, From LEP looking downstream
6.8	8/21/97	CAN-20	Yampa Canyon, Looking from REP to LEP
6.9	8/21/97	CAN-21	Yampa Canyon, Looking from LEP to REP
6.10	8/21/97	CAN-21	Yampa Canyon, From Sta 0+12 looking upstream
6.11	8/21/97	CAN-21	Yampa Canyon, From Sta 0+12 looking downstream

Table C.1 Photo Log			
6.12	8/21/97	CAN-21	Yampa Canyon, Looking from Sta 2+89 to LEP

Appendix D

List of Cross Section Endpoint Coordinates and Elevations

Table D.1 Yampa River Cross Section Endpoint Bar and Cap Coordinates and Elevations						
Cross Section Name & No.	Left Endpoint B&C			Right Endpoint B&C		
	Coordinates	Accuracy	Elevation	Coordinates	Accuracy	Elevation
DL-1 Yampa River, Deerlodge Park	N 40E 27' 6.34" W 108E 26' 56.18"	±17 ft	5616	N 40E 27' 10.98" W 108E 26' 53.91"	±22 ft	5654
DL-2 Little Snake River, Deerlodge Park	N 40E 27' 22.17 W 108E 27' 7.32	±22 ft	5648	N 40E 27' 25.09" W 108E 27' 9.53"	±15 ft	5635
DL-2.1 Little Snake River, Deerlodge Park	N 40E 27' 31.44" W 108E 26' 50.69"	±16 ft	5638	N 40E 27' 32.86" W 108E 26' 52.48"	±15 ft	5646
DL-3 Yampa River, Deerlodge Park	N 40E 27' 1.83" W 108E 27' 43.42"	±20 ft	5644	N 40E 27' 9.08" W 108E 27' 43.96"	±24 ft	5609
DL-4 Yampa River, Deerlodge Park	N 40E 26' 29.22" W 108E 28' 1.58"	±17 ft	5618	N 40E 26' 30.47" W 108E 28' 13.19"	±24 ft	5629
DL-5 Yampa River, Deerlodge Park	N 40E 26' 19.47" W 108E 29' 57.43"	±20 ft	5606	N 40E 26' 29.85" W 108E 29' 58.43"	±21ft	5550
DL-6 Yampa River, Deerlodge Park	N 40E 26' 48.51" W 108E 30' 42.85"	±17 ft	5658	N 40E 28' 49.69" W 108E 30' 32.82"	±21 ft	5703
CAN-1 Anderson Hole	N 40E 28' 0.83" W 108E 34' 36.48"	±25 ft	5514	N 40E 28' 4.07" W 108E 34' 37.19"	±24 ft	5532
CAN-2 Tepee Rapid	N 40E 27' 51.10" W 108E 38' 1.74"	±40 ft	5532	N 40E 27' 52.04" W 108E 37' 58.35"	±32 ft	5553
CAN-3 Haystack Rock	N 40E 27' 58.98" W 108E 40' 17.54	±23 ft	5420	N 40E 28' 2.66" W 108E 40' 17.44"	±38 ft	5430
CAN-4 Little Joe Rapid	No Reading			N 40E 29' 20.18" W 108E 44' 16.51'	±30 ft	5385
CAN-5 Big Joe Rapid	N 40E 29' 35.03" W 108E 48' 47.88"	±32 ft	5290	N 40E 29' 36.44" W 108E 48' 51.23"	± 41ft	5299

Table D.1 Yampa River Cross Section Endpoint Bar and Cap Coordinates and Elevations

Cross Section Name & No.	Left Endpoint B&C			Right Endpoint B&C		
	Coordinates	Accuracy	Elevation	Coordinates	Accuracy	Elevation
CAN-6 Big Bend	N 40E 28' 7.36" W 108E 51' 16.38"	±32 ft	5237	N 40E 28' 11.38" W 108E 51' 16.57"	±24 ft	5198
CAN-7 Replicate Spawning Bar	N 40E 28' 10.02" W 108E 51' 41.75"	±26 ft	5161	N 40E 28' 5.29" W 108E 51' 40.87"	±27 ft	5174
CAN-8 Above Mathers Hole	No Reading			N 40E 28' 18.51" W 108E 51' 50.47"	±16 ft	5183
CAN-9 Below Mathers Hole	N 40E 28' 33.87" W 108E 51' 49.13"	±29 ft	5213	No Reading		
CAN-10 Above Cleopatra's Couch	N 40E 28' 36.68" W 108E 51' 33.05"	±30 ft	5220	N 40E 28' 31.13" W 108E 51' 30.34"	±44 ft	5198
CAN-11 Below Cleopatra's Couch #1	No Reading			N 40E 28' 57.76" W 108E 51' 43.95"	±38	5138
CAN-12 Below Cleopatra's Couch #2	N 40E 28' 59.89" W 108E 51' 30.09"	±26 ft	5160	N 40E 28' 57.95" W 108E 51' 30.40"	±27 ft	5162
CAN-13 Below Cleopatra's Couch #3	No Reading			N 40E 29' 12.77" W 108E 51' 25.88"	±30 ft	5158
CAN-14 Below Cleopatra's Couch #4	N 40E 29' 11.94" W 108E 51' 44.18"	±36 ft	5158	N 40E 29' 13.97" W 108E 51' 45.81"	±70 ft	5138
CAN-15 Near Red Canyon	N 40E 28' 41.62" W 108E 54' 32.51'	±30 ft	5102	N 40E 28' 42.20" W 108E 54' 27.94"	±28 ft	5120
CAN-16 End of Ladie Park	N 40E 29' 8.59" W 108E 54' 38.66"	±31 ft	5098	N 40E 29' 8.27" W 108E 54' 30.87"	±38 ft	5129

Table D.1 Yampa River Cross Section Endpoint
Bar and Cap Coordinates and Elevations

CAN-17 Above Portal Canyon	N 40E 29' 27.46" W 108E 54' 22.15"	±40 ft	5104	N 40E 29' 24.70" W 108E 54' 19.88"	±200 ft	5203
Cross Section Name & No.	Left Endpoint B&C			Right Endpoint B&C		
	Coordinates	Accuracy	Elevation	Coordinates	Accuracy	Elevation
CAN-18 Portal Canyon	N 40E 29' 35.70" W 108E 54' 21.91"	±48 ft	5133	N 40E 29' 37.28" W 108E 54' 18.49"	±49 ft	5101
CAN-19 Tiger Wall	N 40E 29' 40.31" W 108E 54' 35.66'	±20 ft	5134	N 40E 29' 42.84" W 108E 54' 35.18"	18 ft	5141
CAN-20 Below Tiger Wall	No Reading			N 40E 29' 49.14" W 108E 55' 2.73"	±17 ft	5119
CAN-21 Warm Springs Lake	No Reading			N 40E 31' 0.76" W 108E 55' 28.25"	±37 ft	5155

Appendix E

Report Peer Review and Responses

Request for Peer Review

The Recovery Program for Endangered Species in the Upper Colorado River Basin has a peer review process for technical reports produced by the Program. The report was submitted to Brian Cluer, Hydrologist, National Park Service; Joe Lyons, Bureau of Reclamation; and Ray Tenney, Regional Hydrologist for the Colorado Water Conservancy District. The peer review comments and the response to those comments follows.

Response to Brian Cluer's Comments

Mr. Cluer's insightful comments are appreciated and warrant no specific response. In the future, the accuracy of cross section data collection techniques will continue to improve and advanced data collection systems should be employed where practical. It should be noted that it was necessary to replicate the surveys as cross section lines rather than creating topography of entire reaches to compare the 1997 surveys with the original 1983 cross section surveys.

Response to Joe Lyons' Comments

Mr. Lyons annotated the report with editorial comments. His efforts to improve the readability of the document are greatly appreciated. He provided one comment on page 11 of the Conclusions that indicated that statement, "...enhanced sediment delivery out of the Little Snake River..." should be justified with data or estimates. This requested additional data analysis is beyond the scope of this project, but the enhanced sediment delivery referred to in this statement was the sediment derived from the degradation of the bed and associated channel widening that occurred in the lower Little Snake River in response to the Yampa River confluence shift downstream. The report text was modified to address this.

Response to Ray Tenney's Comments

Mr. Ray Tenney provided extensive comments which require specific responses. Mr. Tenney's original comments in italics were copied electronically from the original file.

Mr. Tenney was criticisms of this study are focused on two primarily issues: 1) That the report promotes unsubstantiated flow recommendations; and 2) That the investigation did not consider the potential changes to fish habitat in the Yampa River in the geomorphic analysis. These two concerns can be addressed by first stating that the purpose of this study was to provide channel morphology data to support future flow recommendations and second by noting that the Yampa Canyon cross sections surveyed in this investigation were established for channel monitoring purposes not fish habitat studies.

General Comments

Comment: "Provision of field data would be useful for review of clarity documentations."

Response 1: Copies of the original field data sheets are available with the Final Report in a separate binder.

Comment: "The report goes further than the reporting of a monumentation and documentation effort in making conclusions about the channel morphology and sediment transport history during the 14 years between surveys without basis such as intervening surveys or sediment sampling data. Additionally, the report attempts to provide a basis for flow recommendations without providing identification and analysis of habitats which would be the object of such recommendations and without providing any hydraulic analyses upon which to base recommendations."

Response 2: The conclusions regarding changes in channel morphology were based on observations and data collected by the same primary researcher on both the 1983 and 1997 field data collection trips. No intervening period data collection efforts were funded to support any other conclusions. It should be noted, however, that the primary researcher made several trips during this intervening period to the Yampa Canyon. The report recommendations refer to future channel monitoring. No flow recommendations were made. The only statement related to flow recommendations indicates that they "...should be based on maintaining flow variability and peak flows to sustain sediment transport in the Yampa Canyon." This statement follows a logical extension of the conclusions and results of the study. It was anticipated that other researchers would use the results of this study to develop flow recommendations for the Yampa and Little Rivers.

Comment: "Further, continuing monitoring recommendations are also made without knowledge of the habitat features requiring monitoring and the flows of concern for those features."

Response 3: The channel monitoring recommendations were proffered on the basis of the observed channel morphology changes in the Deerlodge Reach and the lack of significant channel changes during the 14 year period from 1983 to 1997 in the Yampa Canyon. This study was a channel morphology investigation using the original 1983 Yampa Canyon 21 cross sections distributed over the 45 miles canyon reach. The Yampa River PHABSIM fish habitat site cross sections were not monitored in this study.

Comment: "Scope of Work Paragraph VII. sub paragraph 1 identifies bed samples to be collected where potential for channel change is identified. No bed sample collections were discussed in the above referenced report even though channel change was identified."

Response 4: The scope of work states that "...any changes [in bed material] will be evaluated in relationship to an increase or decrease in the Little Snake sediment load since the early 1980's." It was initially presumed that bed material samples were collected in the Deerlodge Reach of the Yampa River in 1983. When the original data base was reviewed, it was realized that the no bed material samples had been collected in this reach and therefore no comparison of sediment in this river reach since the early 1980's was possible.

Comment: "Scope of Work Paragraph VII. sub paragraph 2 identifies 4 to 5 cross-sections to be established along with measurements of channel bed slope and descriptions of general channel morphology in the Little Snake River to establish a channel monitoring site. In fact the report describes the establishment of only one cross section (pg. 1, para. 2; pg. 2, para. 3 says 2) with no discussion of the other components or the deviation from the approved scope of work."

Response 5: After the first two Little Snake River cross sections were completed, private land considerations restricted access to this reach of river.

Comment: "Scope of Work Paragraph VII. sub paragraph 3 identifies the use of information gained from the monitoring activity for development and refinement of flow recommendations of the Yampa and Little Snake River. ***The analyses described and the data reported in this report do not support the conclusions concerning sediment transport and provides no support for recommendation of flows for the Yampa or Little Snake River as purported.*** *The current Yampa River channel monitoring program as supported by this report does not comply with <u>Findings of the Sediment Monitoring Program Peer Review Panel and Recommended Work Plan</u>, May 1997, yet draws significant conclusions concerning sediment transport in the Yampa River. The level of analysis conducted in this study only detected* ***gross total*** *morphological change over a 14 year period and, without demonstrated basis, attributed nearly all the change to the record breaking flow event of 1984. The work conducted was at too gross geographic and temporal scales to establish a basis for detection and monitoring of the hydraulic and sediment transport processes which would be the object of habitat preserving flow recommendations for the Yampa and Little Snake Rivers. While preservation of peak flow regimes are probably desirable for the needs of the listed fishes, this report contributed little to the support of flow recommendations based on routine maintenance of habitat conditions as it focused (without basis) only on the flow event of record."*

Response 6: This comment **grossly** overstates the purpose of the project and the task description has been selectively taken out of context. It was not the purpose of this project to develop Yampa and Little Snake flow recommendations. The actual task description states, "(t)he information gained from the from the monitoring activity will be used to support the development/refinement of flow recommendations for the Yampa and Little Snake River." It was the intent of the principal investigation/project manager, George Smith of the Fish and Wildlife Service, to resurvey these Yampa Canyon cross sections and determined if any significant changes in the channel morphology in the canyon had occurred. The results would then be made available to other researchers to incorporate into their Yampa and Little Snake River flow recommendations.

Jim O'Brien was able to observe the Yampa River channel condition in response to the 1984 high flows on a trip to the Yampa Canyon in July, 1984. He has been on several trips to the Yampa Canyon since that July, 1984 trip. The observations made in this report concerning the effects of the 1984 high flows on the channel geometry are accurate.

Comment: "Scope of Work Paragraph VII. sub paragraph 3 identifies the formation of an interdisciplinary team to establish and survey the channel monitoring sites while the report includes no interdisciplinary discussions or observations or discussion of the participation of the various disciplines."

Response 7: Our attempts to schedule the field work with George Smith, Ed Wick and others as well as obtaining the advanced GPS equipment that was becoming available at that time delayed the trip until August. Initially we anticipated the field work being completed on the falling limb of the hydrograph in July. The flows dropped quickly and finally the decision was made to forgo organizing a large trip at very low flows in order to facilitate getting the field work done before it was impossible to float river. This project was closely coordinated with the principal investigator and it decided that having a large group on the river at very low flow would have impeded the work effort.

Comment: "Flow recommendations for the creation, preservation and maintenance of habitat conditions required by the native aquatic community, including the listed fishes, necessarily must include maintenance of the meso and mirco (sp)habitat features and conditions upon which these fish depend. The level of detail of the habitat monitoring program established and discussed in this report is inadequate to establish a baseline for and allow relationship of those habitats to specific flow regimes. The project itself demonstrates this by showing little, if any habitat changes in the canyon bound reaches were most of the "important" habitat is know to exist for Colorado squawfish spawning and humpback chubs. Indeed, the report recommends only monitoring these areas on a 10 year basis while other researchers recognize the need to define flow recommendations based on more frequent habitat maintenance needs."

Response 8: In 1983, a series of 21 cross sections were surveyed throughout the Yampa Canyon for the purpose of establishing a long term channel monitoring data base. This is clearly stated in the report. Also in 1983, two PHABSIM sites were also established with their own series of cross sections at RM 17.5 and RM 16.5 in the Yampa Canyon. Mr. Tenney is very familiar with these PHABSIM sites having been on several trips to these sites to resurvey these cross sections. These 21 canyon cross sections were re-surveyed for the first time in 1997 and were established only to determine long term channel geometry changes in a variety of river reaches throughout the canyon. These 21 canyon cross sections were not established for, nor were intended to be associated with, endangered fish habitat. A simple review of the cross section locations should make this very apparent.

Comment: "The "conventional" river cross-section survey methods cited in this report are not current with state of the art surveying and data management techniques employed by the private sector and other government agencies for river surveys and topographic data collection necessary to identify and monitor the physical habitat conditions which are the object the RIP channel monitoring program and an understanding of which is necessary to support flow recommendations. GPS and EDM surveys are readily available from commercial surveyors familiar with river work as close as Craig, Colorado (eg. Epp & Associates) which would provide sub-foot (claimed sub-cm for terrestrial and sub-aqueous in still water) accuracy as were employed in the mapping of the Maybell Diversion in Juniper Canyon (Ayres, 1994) and in developing topographic base maps and monitoring of habitat changes at RM 17.5 and 16.5 in Yampa Canyon (Mussetter Engineering 1993, 1995; USBR 1997) and the mapping of potential fish migration barriers in Cross Mountain Canyon (USGS 1996, included Doppler velocity profiles)."

Response 9: This comment by Mr. Tenney is inappropriate and indicates a lack of comprehension of the scope and purpose of the project. The map on page 3 of the report indicates that the 21 canyon cross section are distributed throughout 45 miles of the Yampa Canyon. The cross sections were surveyed according to accuracy criteria required by the FLO Engineering contract with the Bureau of Reclamation, Albuquerque Project office. In addition, a state-of-the-art GPS system was used to assign coordinates and elevations to the cross section endpoints that had only become available about two weeks prior to the trip. This instrument captured a greater number of tracking satellites for positioning. It should be noted as stated in the report that even with this advanced GPS system as specified in the Task Description, at certain locations in the canyon, a minimum number of satellites could not be tracked by the GPS unit to establish a coordinate position and elevation.

Mr. Tenney's suggestion that more accurate survey techniques and equipment should have been employed in this study is impractical and displays a failure to recognize the objectives of the investigation. To establish more accurate coordinates and elevations for endpoints, it was would have been necessary to use a total station or GPS base station from the canyon rims. These cross sections are so far apart that it would be exceedingly expensive to the Program to establish cross section endpoint elevations and coordinates relative to each other. Again, the fundamental purpose of this channel monitoring project was to monument the 21 Yampa Canyon cross sections before the original research team that established these 1983 cross sections was no longer available to locate them thus losing this valuable data base. It was not necessary to assign endpoint elevations and coordinates to accomplish this objective.

Comment: The report does not demonstrate the major channel changes detected occurred exclusively in 1984 as cited (pg. 5, last line).

Response 10: The primary researcher on this project, Jim O'Brien, surveyed the original cross section in 1983 and returned in July, 1984 after the peak discharge of record. A photo record exists for 1983, 1984 and 1997 which was reviewed when writing the report. The reported observations are accurate.

Comment: Grain size data collection and analysis which may indicate erosion (increase in sediment size) or building (sediment size decrease) of habitat features not readily detectable with the survey techniques employed were not used.

Response 11: In 1984, some bed material samples were collected in the Yampa Canyon. After carefully inspecting the first 11 cross sections in the Morgan limestone reach, it was recognized that channel morphology changes were not associated with any significant sand deposition which might indicate a potential change in flow regime or sediment loading. It was also obvious that the primarily substrate in upper canyon was still boulders and in the lower canyon, cobble, gravel and sand. No aggradation or degradation associated with change in substrate conditions was identified that warranted additional bed material samples in the Yampa Canyon.

Comment: Adjustment of the cross-section end points described in Para. 1, pg. 5 would easily be sufficient to mask channel and habitat changes which might provide useful information to support recommendation of flows on a meaningful recurrence interval.

Response 12: Assuming that the reviewer is referring to Page 6 and not Page 5, the adjustment of the cross section plots to obtain a definitive comparison was accomplished expressly for the purpose of ensuring that the repositioning of the endpoints did not obscure any significant changes in the cross section. FLO Engineering has surveyed and analyzed more than a thousand cross sections in the past eight years (over 700 cross sections on the Rio Grande alone). Most of these cross sections have been surveyed more than once, some cross sections have been surveyed as many as 10 times or more. Our experience in plotting and analyzing river cross section channel geometry, short term cross section variation and long term channel morphology changes was valuable in assessing the Yampa Canyon cross section changes.

Comment: "The report describes the location of the Yampa Canyon cross-sections in 1983 in pools or wide reaches of the river (pg. 4, para. 3) where sediment deposition would occur. The basis for location of monitoring cross-sections in pools is not demonstrated. The ongoing work by CRWCD at RM 17.5 and RM 16.5 along with the low flow studies underway by USFWS and CDOW both above and within the Yampa Canyon demonstrates the importance of riffle features coupled with the understanding of local sediment storage in and transport through pools to habitat creation and maintenance objectives of flow recommendations."

Response 13: As stated in a previous response and as stated in the report, the original 21 Yampa Canyon cross sections were located in reaches where the potential for monitoring long term changes in the channel morphology would be greatest. The two series of PHABSIM cross sections at RM 17.5

and RM 16.5 referred to in the above paragraph which **have been monitored by CRWCD** were established by the project researcher, Jim O'Brien, in 1983 for the sole purpose of analyzing habitat conditions and preparing flow recommendations. Mr. Tenney is confusing the different fish habitat site cross sections with the canyon morphology and is unclear on the goals and objectives of this project.

Comment: "The 1997 cross-sections were located in the same locations except for adjustments to allow GPS positions to be established with 40± foot accuracy (pg. 5, para. 1) and elevation estimates of 100± feet. This field adjustment would easily be sufficient to mask channel changes whose understanding would be important to the development of flow recommendations.

Response 14. See Response 9 above.

Comment: "The conclusion "Over the last 14 years there has been no significant variation in the amount of sand stored in the Yampa Canyon within the active river channel" Pg. 6., para. 3, is inconsistent with the recognition that the description of the last three years being high flow years (pg. 5, para. 4) as sediment transport history through the last 14 years could have been significant to the habitat which is being monitored yet undetected by the temporal scale of this project. The concept of "significant change" requires definition related to the habitat under study."

Response 15. In 1983, the 21 canyon cross sections were located in every significant potential sand deposition reach or obvious sensitive channel morphology reaches. There was no discernible pattern in the cross sections changes observed in 1997. Again, these 21 original cross sections were not established to monitor endangered fish habitat.

Comment: "The "significance" of morphological changes observed relative to the alluvial nature of the Yampa River and confluence of the Little Snake River requires discussion. The Changes which have occurred may not be significant at all. Additionally, the degree of change "documented" could be adversely influenced by the inability to replicate the 1983 cross-sections."

Response 16. A simple review of the plotted cross sections presented in the report of the Deerlodge Park reach of the Yampa River clearly and demonstrably indicates that the cross sections have changed significantly. For example, for cross section DL-3 as stated in the report on page 8; "(t)he active channel has almost doubled in width since 1983."

Comment: *"The significance of the change in location of the Little Snake River confluence is not adequately addressed in the discussion of Deerlodge Park morphology. Potential channel adjustments (ie. headcutting, etc) are alluded to but not documented as might have occurred had the original scope been executed and more cross-sections of the Little Snake River surveyed."*

Response 17: In 1983, only one cross section on the Little Snake had been surveyed. All the cross sections in the Deerlodge Reach were re-surveyed. Adding more cross sections would not have contributed to a comparative analysis of channel morphology changes with respect to the shift in the location of the Little Snake confluence prior to 1983.

Comment: "Assertion that "the sediment supply from the Deerlodge Park reach essentially passes through Yampa Canyon without significant deposition on a seasonal basis." fails to recognize the significance of reach specific sediment dynamics which are important to the listed fishes' habitat (see Mussetter cited above)."

Response 18: The FLO Engineering original comment is an accurate statement. It does not imply that there isn't any sediment deposition occurring in specific reaches in the canyon. The magnitude and nature of sediment deposition on a seasonal basis in specific reaches is relatively negligible in comparison to the mean annual sediment load transported through the canyon (O'Brien, 1984).

Comment: "Pg. 10, para. 1, First sentence. Several of the cross-sections originally surveyed in the reference period located at RM 16.5 do not appear to be included in the data set cited in this report. The end points (steel eye-bolts in the canyon walls and boulders as well as iron pins adjacent to trees), as described in the USNPS field notes were used to survey cross-sections across the Cleopatra's Couch spawning bars in 1993, 1995 and September 1997 by CRWCD."

Response 19: As stated in response 8, the reviewer is confusing the 21 Canyon cross sections with the two PHABSIM cross sections originally established by Jim O'Brien in 1983.

Comment: "The purported accuracy of the GPS system utilized is questionable and of little comparative value when trying to map of field locate the end points. We found most at Cleo's by using our local coordinate system and a total station as well as the USNPS field notes. Better GPS instrumentation is necessary if this kind of information is going to be provided."

Response 20. See comment 9 related to the state-of-the-art GPS system used. It should be noted that Jim O'Brien, the original researcher who established the cross sections at RM 17.5 and RM 16.5 'Cleo's' in 1983, relocated and resurveyed those cross section for the CRWCD prior to the CRWCD establishing a local coordinate system using a total station. Actual state plane coordinate geometry and endpoint elevations were not established by CRWCD at Cleo's because it was too far and too expensive to close the survey loop to a USGS benchmark. The use of the GPS system for this study eliminates the need for a local coordinate system.

Comment: "On a gross scale the statements concerning Yampa Canyon as a sediment conveyance corridor are true (pg. 10, para. 2). On the scale of what is important to the maintenance of aquatic habitat important to native fishes those statements are not supported.

Findings of the Sediment Monitoring Program Peer Review Panel and Recommended Work Plan, May 1997 provides a substantial work plan recommendation to define the sediment transport mechanisms within Yampa Canyon."

Response 21. No response is necessary.

Comment: "Recommendations concerning use of this report to support flow recommendations and the "recommended" flow regime are not supported by the analysis provided in the report. How does flow variability sustain sediment transport in the study area? How is this demonstrated by the data presented in this report? This report cannot support delineation of the effective sediment transport discharges between any of those discharges which have occurred since the original surveys. Other than the conclusion that major bank erosion may have resulted in 1984 the data provided in this report cannot define whether adequate sediment transport capability is maintained by peak flows such as those experienced in 1997 or those experienced in 1994. This report also fails to recognize the potential effect of flows such as those occurring in the Yampa River basin outside the normal peak flow period, for example approximately 7500 cfs in late September 1997 and over 10,000 cfs in April 1998 (data not currently available from USGS as too new for historic record and too old for provisional record)."

Response 22. This comment is beyond the stated goal, objectives and tasks of this project. The purpose of the project was to identify historic trends in channel morphology changes and establish cross sections that can be resurveyed periodically as part of the channel monitoring program. It was hoped that the data and findings would be used by other researches to support their development of flow recommendations for the Yampa and Little Snake Rivers.

Comment: "The report is well organized but makes many statements that seem outside the scope of work relative to sediment transport and omits several of the scoped work items as referenced above."

Response 23. This comment was addressed in several of the previous responses.

Comment: "Although the report is relatively short, much discussion is made outside the original scope of the work particularly concerning sediment transport."

Response 24. See response 22.

Specific Comments

Comment: "Data presentation not at sufficient scale to interpret significant changes."

Response 25. See responses 8 and 9.

Comment: "No sediment data presented as proposed in SOW."

Response 26. See response 4.

Comment: "No references for assertions about significant sediment transport."

Response 27. See response 22.

Comment: "No references on channel morphology in intervening years to support conclusions about channel dynamics."

Response 28.   See responses 6 and 10.

Comment: "No references cited or discussion of "significant" level of channel morphological knowledge necessary to make sediment transport and flow recommendation assertions included in this report."

Response 29. See response 22.