Establishment of a Green River Gage in Canyonlands National Park, Utah 1995-1996

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of the Upper Colorado River

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Executive Summary

In 1995 and 1996, a level logger and staff gage were erected the vicinity of Bonita Bend of the Green River to provide a researchers and scientists working in Canyonlands National Park with a means of estimating the discharge on site. This equipment was initially installed in conjunction with the Flooded Bottomlands project for the Habitat Restoration Program of the Recovery Program for the Endangered Fishes of the Upper Colorado River. The flooded bottomlands project field work was completed in September, 1995. The discharge data is reported as a hydrograph and has been correlated with upstream level loggers and USGS gaging stations to assist Recovery Program research in Canyonlands.

The level logger and staff gage were surveyed with respect to control benchmarks established for the flooded bottomlands project. In 1995, the level logger was only in operation for 12 days. In 1996, the level logger recorded a stage reading every 30 minutes from April 5 to July 24. During this period the level logger pipe shifted several times when the bolts mounting it to bedrock loosened during high flows. By applying a shift to the stage noted in the level logger data, it was possible to adjust the stage data to more accurately reflect the water surface elevation. Using a rating curve developed with the discharge measurements over two high flow seasons, daily discharges were estimated. A Fortran program was written to apply the rating curve to the level logger data and compute a mean daily discharge from the 30 minute recorder stages. The USGS Green River gage station flows and the Desolation Canyon level logger flows were plotted comparison to Canyonlands level logger discharges.

A companion report was prepared to assess and compare the discharge hydrographs throughout the Green River system. The Canyonlands level logger was one of five level loggers or strip chart recorders installed in 1996. Other level loggers were erect at Desolation Canyon, and downstream of the White River. Strip chart recorders were in operation at Ouray National Wildlife Refuge and Mitten Park. A plot is present displaying all the estimated discharges along with the USGS gage data at Jensen and Green River.

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List of Key Words

river gage, discharge, river hydrology, river hydraulics, geomorphology, peak flows, bankfull discharge, rating curves

Project Funding and Support

This study was funded by the Recovery Implementation Program for Endangered Fish Species in the Upper Colorado River Basin. The Recovery Program is a joint effort of the U.S. Fish and Wildlife Service, U.S. Bureau of Reclamation, Western Area Power Administration, states of Colorado, Utah, and Wyoming, Upper Basin water users, environmental organizations, and the Colorado River Energy Distributors Association.

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The National Park Service (NPS) personnel contributed time, equipment and resources to the data collection effort. Ed Wick (NPS) assisted the data collection effort with his field presence and equipment. Craig Hauke (NPS) participated in the field data collection trips in Canyonlands and also provided permits and equipment. The cooperation of Dave Allen of the US Geological Survey, Utah Division, Salt Lake City in providing flow data for the Jensen and Green River gages was greatly appreciated.

Establishment of a Green River Gage in Canyonlands National Park, Utah 1995-1996

Introduction

Biologists, engineers and scientists working in Canyonlands National Park requested that a river gage be established in this reach of the Green River to support data collection related to the Recovery Program for the Endangered Fishes in the Upper Colorado River Basin. The gage will also support general scientific efforts in the canyon related to river flows. River discharges throughout the Green River were monitored in 1996 and are compared with the discharges estimated in Canyonlands. This data will be valuable to the flow routing predictions in the Green River system.

The initial establishment of the river gage was accomplished in conjunction with the 1995 flooded bottomlands data collection in the Anderson Bottom reach of the Green River in Canyonlands National Park. The flooded bottomlands project encompassed river channel surveys, topographic surveys of the floodplain and side canyon bottomlands, discharge measurements and analysis of the river response to high flows which directly supported the establishment and calibration of the river gage in this reach. This bottomlands investigation was conducted as a component of the Habitat Restoration Program in the Recovery Program for the Endangered Fishes of the Upper Colorado River Basin.

The staff gage was remains in place at Bonita Bend. The level logger was re-installed in 1996 on April 5 and was removed on July 24. It was in operation during the entire high flow season. In 1995, the level operated only 12 days before being dislodged by high flows. A FLO (1995a) report was prepared for the Canyonlands gage installation and operation in 1995 entitled, "Establishment of a Green River Gage in Canyonlands National Park, Utah."

Project Goal

The goal of the project was to establish a discharge relationship between flows in Canyonlands and the discharges reported at the upstream USGS gages and level loggers in the Green River system. To accomplish this goal, a rating curve was established for the Canyonlands reach of the Green River. The project objectives included the erection of staff gages, installation of river stage monitoring equipment, survey and erection of permanent topographic benchmarks, discharge measurements, cross section surveys and maintenance. The initial work to establish the gaging station was conducted by the FLO Engineering field crews working on the flooded bottomlands project.

Site Description

The site of the river gage was originally proposed for the Mineral Bottom reach of the Green River just upstream of the Canyonlands National Park boundary. The proposed site was near the boat ramp at Mineral Bottom where access to the river was convenient. The selected site was Queen Anne Bottom near Bonita Bend, approximately 20 miles downstream, where the flooded bottomlands work was being conducted. The reason for this site selection was that the Recovery Program work being conducted in Canyonlands was focused on this lower reach of river. Also, the FLO field crew needed immediate access to the gage to record staff gage heights after discharge measurements.

The selected site is an historic ferry cross section at Queen Anne Bottom (river mile 32.5). The flooded bottomlands work was conducted from river mile 25.3 to 34.2. The location of the gage is on the left bank on bedrock outcrop where remanent of the ferry crossing can be found (Figure 1). It is approximately 1 mile upstream of the Bonita Bend staff gage. The site can be reached by jeep trail (about 0.5 miles) from the White Rim Trail road. The jeep trail is a rough road down to the river.

Figure 1. Location of the Queen Anne Bottom Gage (from Baars, 1987)

Canyonlands Geology and River Geomorphology

Canyonlands Geology

The narrow canyon corridor in Canyonlands National Park confines the Green River to a narrow floodplain and limits its migration across the canyon bottom. The canyon pattern is a series of entrenched meander bends that were superimposed on the underlying geologic formations (Photo 1). These incised meanders were inherited from an ancestral river that flowed across a mild-sloped floodplain. The general location of the meanders and sinuosity of the reaches has not been substantially altered during the incision process (Harden, 1990).

The geology of the Canyonlands reach of the Green River consists sedimentary rocks exposed by numerous periods of plateau uplift and river down cutting. The stratigraphic record is a series of alternating hard and soft formations forming mesas, buttes, cliffs and steep canyon walls. The most prominent geological formation in Canyonlands is the thick reddish brown sandstone cliffs of the Wingate Sandstone. At river mile 37, the top of the White Rim Sandstone emerges at the river level and becomes the dominant formation in the study reach (Photo 1). Underlying the White Rim Sandstone is the Organ Rock Shale, a soft reddish brown shale, which begins at about river mile 32 near the location of the gage. A more complete discussion of the canyon geology is presented in 1995b FLO Engineering report.

River Geomorphology

Although primary a sand bed, the Green River in Canyonlands can not be considered an alluvial stream with the freedom to adjust its channel geometry. The river's numerous contacts with the bedrock geology in this reach results in slope control, constrictions, ingrown bends into the bedrock, and constraints on channel incision. The average river gradient is 1.22 ft per mile or approximately 0.00023. The historic river channel had several wide reaches with active sand bars which have become encroached with vegetation and attached to the river banks. In addition, the floodplain terrace near the river is now densely vegetated with old tamarisk trees, willows and other riparian vegetation that has cutoff access from the river to the upland vegetation zones. Some of the floodplain bottoms such as Queen Anne, Anderson, and Valentine have a few old cottonwoods or some small cottonwood stands. Most of the older sand bars, islands and terraces have exceedingly dense vegetation. The floodplain terraces are hydrologically disconnected from the river and the development of the floodplain has been static since 1930 (FLO, 1995b).

Response to High Flows

Twenty-two cross sections were surveyed in the study reach as part of the flooded bottomlands

project by FLO Engineering (1995b). There are some cross sections that are wide and shallow, but most of the river channel is relatively narrow and deep. The average channel width is 560 ft. During the seasonal runoff, most of the river cross sections were scoured during the rising limb and peak flow then refilled on the recessional limb. Three surveys of the 22 cross sections in Canyonlands were conducted in 1995: Mid-April, mid-June and mid-September. The cross section plots can be reviewed in FLO Engineering report (1995b). Out of the 22 surveyed cross sections in the Canyonlands study reach, a total of 10 cross sections experienced some fill, 5 cross sections displayed net scour and 7 cross sections were relatively unchanged from spring to fall. The channel geometry in the study reaches adjusted to the variable sediment load with thalweg shifts from one side of the river to the other, sand bar development, thalweg scour to bedrock, and through variation in the cross section geometry.

River Hydrology

General

The Green River hydrology is dependent on the spring snowpack melt of the Rocky Mountains in Wyoming, Colorado and Utah and drains approximately 44,700 mi^2. The principal tributaries include the Yampa and White Rivers in Colorado, and the Duchesne, Price, and San Rafael Rivers in Utah. Flow in the Green River has been regulated by Flaming Gorge Dam near the Utah-Wyoming border since October, 1962. In addition, numerous water storage projects throughout the basin have altered the Green River seasonal hydrograph. These projects include Fontenelle Reservoir on the Green River upstream of Flaming Gorge, Strawberry Reservoir on the Duchesne River, Taylor Dam on the White River, several small reservoirs on tributaries to the Yampa River, transmountain diversion on the Little Snake River, and small water resource projects throughout the basin.

The source areas of water and sediment in the Green River watershed are not distributed equally in the basins. The primary water source areas are located in the headwaters of the various tributaries throughout the Rocky Mountains rimming the basin. These areas have very little sediment yield. On the other hand, sediment is delivered from the semi-arid regions in the middle to lower portions of the watershed (Andrews, 1986).

Peak Flows, Mean Annual Flows and Base Flows

The Green River generally peaks in the late spring with a base flow period extending from about September 1 to March 1. At the Green River gage, the seasonal hydrograph is characterized by a snowmelt runoff peak usually occurring between May 15 and June 15. For entire 95 year period record the mean date of peak flow occurrence was May 30. The highest peak on record at Green River, Utah was 68,100 cfs on June, 27, 1917. The lowest peak on record was 6,460 cfs (May 17, 1934). Both, the highest and lowest peak discharges at the Green River gage occurred before any significant upstream water development (Figure 2). For approximately the first 29 years of record until 1930, the mean annual peak discharge was 39,700 cfs corresponding to the average bankfull discharge in the Canyonlands study reach computed by FLO (1995b). The pre-1963 mean annual peak discharge was 32,730 cfs and post-1963 the mean annual peak was 22,280 cfs.

Base flows for the period of September 1 to March 1 were estimated. Flow regulation in the Green River system has affected the mean base flow in the river. The mean base flow has increased from 2,720 cfs pre-1963 to 3,380 cfs post-1963 at Green River, Utah. This increase in base flow reflects upstream flow regulation and the redistribution of the peak flows throughout the hydrograph. The pre-1963 ratio of mean peak discharge to mean base flow for the period Sept 1 to March 1 was 12.1. Following 1963, this ratio was reduced to 6.6 at Green River gage.

Figure 2.

Discharge Frequency

Table 1 presents the discharge frequency for various return period floods at the Green River gage. The two-year return period flood prior to 1963 was approximately 31,000 cfs and post-1963 was 20,700 cfs. Similarly the 100-year return period flood has been reduced from 69,000 cfs to 53,000 cfs. The decreasing trend in the frequency of high flow events began after 1930 (Figure 2). At Green River the standard deviation of the peak discharges before and after 1963 were 13,550 cfs and 9,720 cfs respectively or about a 28% decrease. For additional discussion and plots of the frequency curves see the FLO report (1995b).

Table 1. Green River Flood Frequency for the Gage at Green River, Utah

Return Period	Probability	Green River Gage (cfs) Pre-1963	Post-1963
1.01	0.99	7,490	5,437
1.11	0.90	16,620	11,070
1.25	0.80	21,010	13,840
2.00	0.50	31,280	20,690
2.33	0.43	33,740	22,420
5.0	0.20	43,750	29,930
10.	0.10	50,920	35,840
25.	0.04	58,880	43,040
50.	0.02	64,100	48,210
100.	0.01	68,810	53,200
250.	0.004	73,080	58,060
500.	0.002	78,200	64,320
Mean Peak		32,730	22,280
Mean Annual Flow		7,960	5,620
Base Flow		2,720	3,380

Flow Duration

Flow duration curves determine the average duration of a given discharge on an annual basis. For the Green River gage the pre-1963 mean peak discharge of 32,700 cfs and post-1963 mean peak discharge of 22,300 were equaled or exceeded an average of 7.3 days per year, but the discharge of 32,700 cfs now only occurs on an average of 1.8 days per year (see FLO, 1995b for the flow duration curve plots). A shift in flow duration signified by a decrease in the high flow duration and a corresponding increase in the base flow duration occurs at 5,300 cfs for the Green River gage. For the Green River gage the pre-1963 mean base flow of 2,720 cfs occurred approximately 56% of the time but now this discharge occurs about 95% of the time.

River Gage Installation and Data Collection

General

Estimating discharge in the Canyonlands reach requires the development of stage-discharge relationship or rating curve. The two components of the rating curve are a discharge measurement and a corresponding survey of river stage. A staff gage was installed at cross section ANB-14 in Bonita Bend on river left. In located in the eddy, between large boulders (house-size) fallen in the river across from Anderson Bottom.

On June 5, 1995, an automatic stage recorder or level logger (WaterLOG Model DH-21 pressure transducer) was installed at Queen Anne Bottom, about 1.5 miles upstream of the staff gage (Figure 1). This level logger was erected when the flow was approaching the peak discharge. It was difficult to stabilize the PVC pipe against the bedrock outcrop at the moderately high discharge and twelve days later the level logger pipe attached from the bedrock. The level logger was successfully recovered, but the stage data collection was limited to the period from June 5 to June 17.

On April 5, 1996, the level logger was reinstalled (Photo 1). The pipe was bolted directly to the bedrock outcrop in several locations both at the bottom and top of the pipe. The soft bedrock was unable to withstand the vibration of the pipe on the mounting bolts and several of the bolts loosened allowing the PVC pipe to shift up and down several times during high flow. The level logger was removed on July 24, 1996.

The level logger and staff gage were initially surveyed with respect to benchmarks established during the FLO Engineering flooded bottomlands field work. The benchmark elevation established on the canyon rim was approximate to the nearest foot. Re-installation of the level logger required a single survey of a reference water surface elevation to the benchmark which was established near the level logger. The staff gage, barring disturbance, can be read in perpetuity to determine discharge.

Discharge Measurements

To calibrate a stage-discharge relationship for the staff gage and level logger, discharge measurements were required near the gage site. Standard discharge measurement equipment and techniques were utilized in performing the discharge measurements which were collected from a boat. In 1995, the discharge measurements were made in conjunction with the flooded bottomlands project. All the 1995 and 1996 discharge measurements were used in the development of a rating curve at the level logger location. The rating curve did not show any noticeable shifts over a wide range of discharges. The channel morphology at the level logger is relatively stable due to the bedrock outcrops in this reach. A summary of the discharge measurements are presented in Table 2.

Photo 1. Installation of the Level Logger Pipe

Table 2. Summary of Discharge Measurements

Cross Section	Date	Time	Q (cfs)	Area (ft^2)	Ave. Vel. (fps)	Temp (EF)
ANB-14	4/14/95	18:30	2,890	1,350	2.14	50
ANB-14	4/16/95	13:30	3,680	1,580	2.33	50
ANB-15	5/17/95	18:30	12,630	3,380	3.74	-
UNB-11	6/4/95	12:15	20,630	3,870	5.34	64
UNB-11	9/21/95	09:00	2,440	2,440	1.17	65

Table 2. Summary of Discharge Measurements						
UNB-11	6/15/96	11:00	18,816	3,512	5.36	68

Results

General

The principal product of the data collection effort is a discharge rating curve for the staff gage and level logger in Canyonlands. With the rating curve, researchers in Canyonlands can estimate the river discharge while working on site. In the FLO, 1995b report, the discharge in Canyonlands was correlated with the Green River and San Rafael gage data. A comparison of the 1995 and 1996 level logger data with the Green River gage indicates that there is significant shift in stage occurring at the Green River gage. The USGS estimates of the discharge at this gage poorly correlated with both upstream and downstream level loggers. A equation correlating the Canyonlands level logger discharge and the Green River gage discharge was not determined for the 1996 data as it was for the 1995 discharge data for this reason.

Derivation of a Rating Curve

It was necessary to derive two ratings curves, one for the staff gage and one for the level logger. The level logger rating curve relates the level logger stage data to a river discharge. Figure 4 depicts the rating curve for the staff gage. An equation has been developed for each rating curve which can be applied to estimate the discharge for a given stage reading. For the staff gage the equation is:

$$Q = 551.92\ (\text{stage})^{1.488}$$

where,

$$\text{stage} = 2.99 + \text{lower staff gage reading} \quad \text{or}$$
$$\text{stage} = 8.38 + \text{upper staff gage reading}$$

The are two staff gages, one higher than the other to enable very high flow or very low flow river stage to be read. The coefficient of determination (r^2) was 0.996 for the staff gage equation. The stage values determined from the above equations represent the water surface elevation above elevation 3940.00. The coefficient and exponent in the above equation varied only slightly from the inclusion of the 1996 data and the coefficient of determination improved slightly. Either the equation or Figure 2 can be used to determine the river discharge after reading the staff gage and converting the reading to obtain the stage.

The rating curve from the level logger is:

$$Q = 210.68\ (\text{stage})^{1.818}$$

where the stage is the water surface elevation above 3940.00. The coefficient of determination for this equation is 0.997. The level logger equation was applied to the level logger data base in the Logger Fortran program to compute a daily discharge. The level logger rating curve is plotted on Figure 3.

Figure 3. Bonita Bend Staff Gage Rating Curve
Figure 4. Canyonlands Level Logger Rating Curve

Discharge Correlation with Upstream Levee Logger Data and USGS Gaging Station Discharges

The level logger data was reduced and converted to a river stage similar to the derivation of the rating curve for the staff gage. A simple Fortran computer program LOGGER was written to extract the data from the level logger file, convert the level logger pressure data to stage, and compute the river discharge from the rating curve derived for the level logger location. The level logger records date, time, day of year, depth in feet below the water surface, and water temperature every 30 minutes (every 15 minutes in 1995). The program averaged the data to determine a daily discharge or temperature. The average daily discharges are computed using the power regression equation for the level logger and are written to file using the 24 hour period starting at time 00:00 (midnight). The data and computer output results are available from the U.S. Fish and Wildlife Service, Water Resources Division, Denver, Colorado.

Utilizing the computed discharge from the upstream level loggers and strip chart recorders, and estimated USGS gaging station discharge, Figures 5 and 6 were developed showing the relationship between the river discharge in Canyonlands and the upstream discharge hydrographs. The Canyonlands level is shown to correlate well with the Below While River and Desolation level loggers. There is some variation in the Canyonlands data around the peak where the shift in the level logger pipe occurred due to the loosened mounting bolts. The Canyonlands discharge does not correlate as well with the USGS Green River gage discharge data.

These figures indicate that there is some variation in the Green River gage data over the course of the high flow season. The USGS Green River gage appears to be subject to rating curve shifts related to sediment movement in the alluvial channel. This phenomena was also noted in the FLO Engineering 1995a report. As the channel bed elevation varies with bed scour or deposition additional discharge measurements to recalibrate the USGS gage. During the 1996 high flow season, three discharge measurements were made on April 25, May 23 and June 25 and the corresponding rating curve shift was 2.4, -0.23 and 1.4 respectively. Reviewing Figure 6 indicates a peak discharge at the Green River gage of 1,000 cfs to 2,500 cfs in excess of the peak flows at Desolation and Canyonlands. On the recessional limb of the hydrograph, the discharge at Green River is consistently less than the discharge at both the Desolation and Canyonlands level loggers. A 1,000 cfs drop in the discharge is observed in the Green River data over a three day period from June 12 to June 14 that is not noted in any of the other gages.

Temperature Data

The level loggers also record temperature data in conjunction with the time interval stage measurement. The Canyonlands temperature data was reduced and plotted as a mean daily temperature in Figure 6 along with the other level logger temperatures and the Green River gage hydrograph. The LOGGER program was applied to compute the mean daily temperature. The

correlation between the level logger temperature data is excellent.

Figure 5

Figure 6

Figure 7

Conclusions

The installation of the Canyonland staff gages and level logger provides a tool for researchers and river engineers to estimate the Green River discharge while working in the canyon. Following two years of discharge data collection, the calibration for the Bonita Bend staff gage is very good and will provide reliable estimates of the discharge by using either the rating curve or equation presented in this report. The level logger operated through the high flow season and was subject to some vertical shifting resulting from loose mounting bolts. A stage shift was made to accommodate the variation where possible. The Canyonland level logger discharge correlated well with the upstream level loggers and USGS gaging station discharge.

The plotted hydrograph results indicated that the USGS Green River gage was apparently subject to frequent stage shifting requiring additional discharge measurements for calibration. The Green River peak discharge exceeded both the Canyonlands level logger discharge downstream and the Desolation level logger discharge upstream. During the recessional limb the Green River gage reported discharge was less than the both the Desolation and Canyonlands discharges.

Maintaining the Canyonlands level logger and staff gage accuracy from year to year requires occasional flow measurements over a wide range of discharge variation. Changes in channel geometry near the gaging site involving sediment deposition or scour can effect the stage-discharge relationship and cause a shift in the rating curve. It is suggested that discharge measurements at the site are periodically collected to recalibrate the rating curve.

The level logger data records the high flow discharge hydrographs which create the critical nursery habitat for larval razorback sucker, not only in the Canyonlands backwater habitat reach, but throughout the entire Green River system. In the future, the level logger data will be used to analyze the effects of Flaming Gorge releases on the timing, duration, and magnitude of flows in the lower Green River system. The information is important to predict timing and duration of flows that open backwater habitat. The level logger data collection program is critical to the habitat restoration and channel monitoring programs of the Recovery Implementation Program for Endangered Colorado River Fishes. This discharge data will enhance our capability to understand and predict water and sediment movement throughout the Green River system.

Recommendations

The discharge monitoring program throughout the Green River system provides important data for biological and river morphology research. River engineers can use the discharge data for hydrologic analyses and predictive flood routing. For the first time in more than 20 years, there are more than two discharge hydrographs to represent the Green River flows. As a result, the Green River gage discharge data has been shown to be less accurate than perceived.

The re-installation of the Canyonlands level logger and the other upstream level loggers requires a relatively minimal effort. The level loggers have to be replaced in the pipes and two or three discharge measurements are recommended to verify the rating curve. This all the work necessary to continue to monitor the seasonal high flow hydrographs throughout the Green River system. The data base will be useful for future analyses of Flaming Gorge releases, flooded bottomlands restoration, FLO-2D flood routing simulation and Recovery Program field research. The discharge monitoring program should be continued with the following specific recommendations:

- The Canyonlands level logger should be replaced in late March or early April in conjunction with the other upstream level loggers.

- A minimum of two or three discharge measurements should be collected each year to calibrate the rating curve.

- More frequent discharge measurements should be collected by the USGS at the Jensen and Green River gages during the high flows in May and June. More discharge data would improve the resolution of the USGS discharge estimates during periods of stage shifts.

- The discharge monitoring program is essential to the calibration of the FLO-2D routing model to predict the effects of Flaming Gorge releases. It is recommended that the discharge monitoring program continue and be closely coordinated with the development of the FLO-2D flood routing system.

References

Andrews, E. D., 1986. "Downstream effects of Flaming Gorge Reservoir on the Green River, Colorado and Utah," Geological Society of America Bulletin, V. 97, pp. 1012-1023.

Baars, D., 1987. "Cataract Canyon, via the Green or Colorado Rivers," Canon Publishers, Ltd., Evergreen, Colorado.

FLO Engineering, Inc., 1995a. "Establishment of a Green River Gage in Canyonlands National Park Utah," Report Prepared for Recovery Program for Endangered Fishes of the Upper Colorado River, U.S. Fish and Wildlife Service, Denver, CO; FLO Engineering, Inc., Breckenridge, CO.

FLO Engineering, Inc., 1995b. "Green River Flooded Bottomlands Investigation Ouray Wildlife Refuge and Canyonlands National Park, Utah," Report Prepared for Recovery Program for the Endangered Fishes of the Upper Colorado River, U.S. Fish and Wildlife Service, Denver, CO; FLO Engineering, Inc., Breckenridge, CO.

Harden, D. R., 1990. "Controlling factors in the distribution and development of incised meanders in the Central Plateau," Geological Society of America Bulletin, V. 102, p. 233-242.