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Changes in Channel Morphology and Flood-Plain Ecosystems of the Green River between the Flaming Gorge Dam, Utah and the Gates of Lodore, Colorado

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CHANGES IN CHANNEL MORPHOLOGY AND FLOOD-PLAIN ECOSYSTEMS OF THE GREEN RIVER BETWEEN THE FLAMING GORGE DAM, UTAH AND THE GATES OF LODORE, COLORADO

by

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Closure of Flaming Gorge Dam in 1962 reduced the flow rate and variability of discharge on the Green River below this dam. These changes, coupled with the decreased sediment load due to stilling and sporadic peaking in response to demand for hydroelectric power and controlled releases of up to 4500 cfs to cope with snowmelt have impacted the channel morphology and ecosystems of the main stem Green River between the Dam and the Gates of Lodore. Detailed comparative analysis of channel shape and riparian ecosystems or pre-dam and post-dam aerial photographs revealed that significant changes occurred after closure. Channel width has decreased by up to 80 percent and channel banks have shifted by as much as 467 ft. Field studies confirmed that altered hydrology and extensive colonization by Tamarisk have stabilized point bars and channel banks. Controlled releases with peak flows much lower than pre-closure high flows preclude recolonization of cottonwood trees, but because bank erosion occurs at flows of 1000 cfs this riparian system continues to adjust to anthropogenic manipulation.

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CHAPTER I

INTRODUCTION

The Green River between Flaming Gorge Dam, Utah and the Gates of Lodore, Colorado, was altered by the Flaming Gorge Dam (40° 54'30" north latitude, 109° 25'20" west longitude) which was completed in November 1962 (Figure 1). Prior to closure of the dam, the river flowed free of any anthropogenic constraints. Discharge fluctuated with the seasons, event rainfall and snow melt. The general pattern was heavy flow during the peak snow melt months of May and June (Appendix B, Chart 1). Low flow occurred during the winter months when the snows accumulated on the land and the river surface froze.

This area of the United States has always been sparsely populated. Native american tribal groups frequented the low-lying park areas adjacent to the river because there were sources of water and game. In the nineteenth century, fur trappers and traders gave way to infamous outlaws and rustlers that hid in the Hole in the Wall and Brown's Hole. The turn of the twentieth century saw the arrival of a few cattle ranchers who irrigated pasture lands for hay. The U.S. Government started acquiring the present public domain lands to create Browns Park National Wildlife Refuge in July 1965 (USFWS, 1997).

Since the dam closure, November 1, 1962, the river flow has been regulated in direct proportion to the demands for hydroelectricity by the population centers located of Denver and Salt Lake City. This regulation

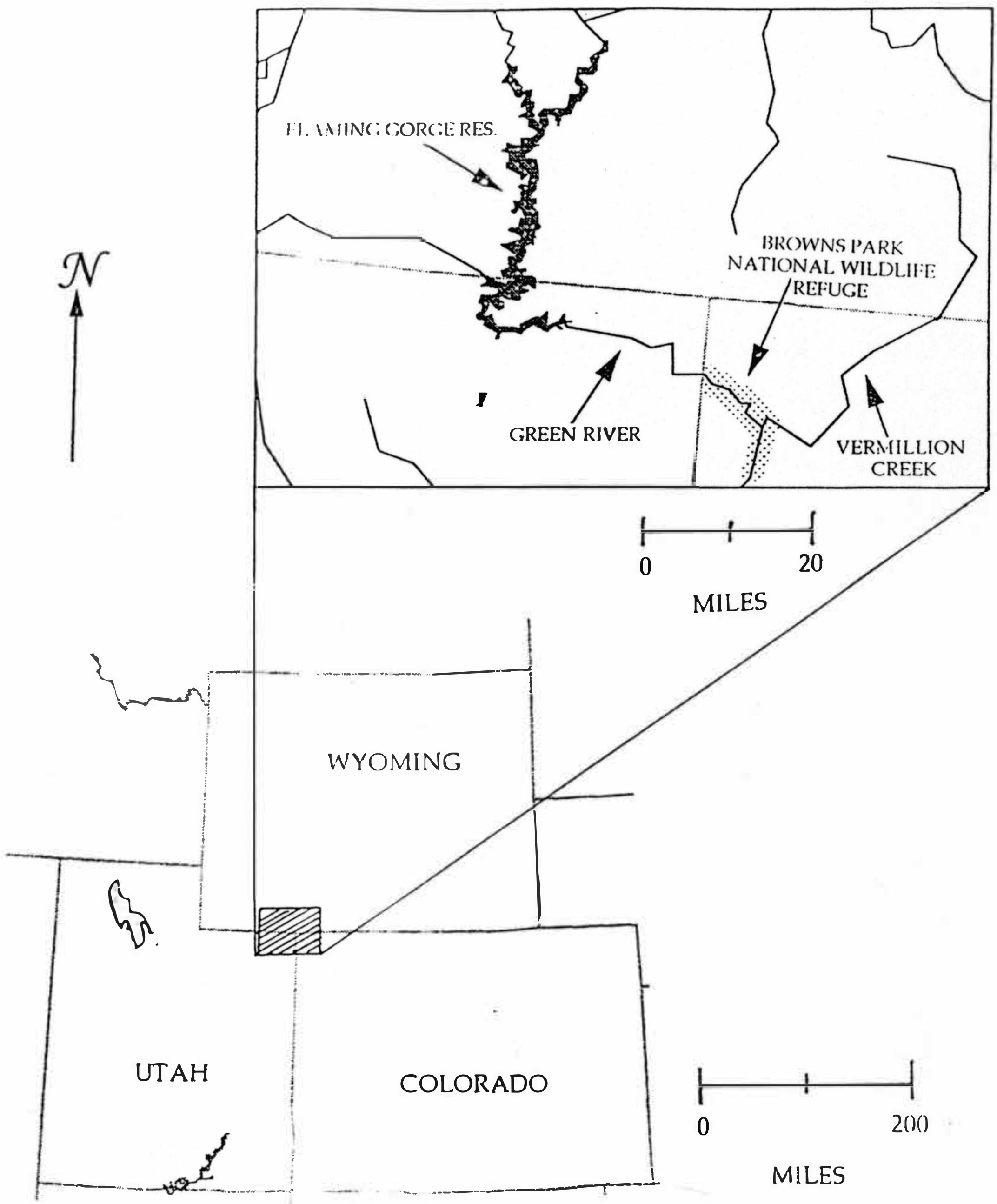


Figure 1. Location Map for the Green River and Browns Park National Wildlife Refuge.

created vastly decreased flows below the dam (Appendix B, Chart 4). Large seasonal fluctuations no longer occurred and the fluctuations generated by weather events occurred only as a product of ephemeral streams that discharged into the main river channel below the dam because ofintense or prolonged rainfall and during snowmelt. Such climatic events do not occur often or on a regular basis due to the semi-arid climate. As a consequence of regulation in response to the demand for power, the long cycle annual fluctuations controlled by precipitation events and snowmelt have been replaced with daily fluctuations in response to the activities of distant cities.

Water released from the dam is drawn from the Flaming Gorge Reservoir. The flow is consistently clear and cold, in contrast to pre-dam conditions when the water was sediment laden and the temperature changed seasonally. Pre-dam water temperatures fluctuated between a low of 33°F in December and January, to monthly highs of 70°F in July. Post-dam temperatures ranged from 38°F in March to 47° in November (Schmidt, Bonebrake, and Larson, 1982). Pre-dam river flows ranged from 1,800 cfs to 19,600 cfs. In contrast, post-dam flows ranged from 2.3 cfs to 4,680 cfs respectively. These changes in temperature, sediment load, and discharge have affected the aquatic and riparian ecosystems downstream from the Flaming Gorge Dam.

Concern about the changes caused by the dam arose within the first ten years after its completion. The National Geographic Society sponsored research expeditions to assess the nature and degree of landscape change that had occurred. Part of this research was to revisit portions of John

Wesley Powell's expedition itinerary and to assess the changes that had occurred over the intervening one hundred years (Graf, 1976). At the present time, a group affiliated with Utah State University, the U.S. Fish and Wildlife Service, Bureau of Reclamation, and National Park Service is studying whether a controlled flood release emanating from the Flaming Gorge Dam, similar to the one implemented in 1996 from the Glen Canyon Dam on the Colorado River, should be executed.

In 1963 the U. S. Fish and Wildlife Service created Brown's Park National Wildlife Refuge along a section of the river downstream from the dam. Althoughportion of this refuge is in Utah, but most of it is in the northwestern corner of Colorado, upstream of the point where the Green River enters the Gates of Lodore and Dinosaur National Monument. This section of the river has been affected by the damming of the river. The upstream, western margin of the refuge is the Colorado-Utah state line which is mile 261.1 on the Green River. The downstream, or southeastern refuge border, is the northern entrance to Dinosaur National Monument, approximately 2 miles north of the Gates of Lodore.

The emphasis of this report will be on the Browns Park Wildlife Refuge section of the Green River. This area is the first park the main channel flows through immediately downstream of the Flaming Gorge Dam. These lowlands have been visibly and perhaps permanently affected by flow constraints on the river. The purposes of this study are (a) to determine if there have been morphological changes to the main channel of the Green River; (b) if changes have occurred, to document them; (c) to determine if restricted flows from the dam have caused these changes; (d) to assess whether these changes have affected the ecosystems; (e) to predict whether a controlled flood release affects; and (f) to make recommendations as to whether the controlled flood release be conducted.

Review of Literature

Studies of channel changes were initiated within the first ten years after dam completion. W. L. Graf (1976) concluded that channel morphology and vegetation had changed due to the growth of tamarisk. E. D. Andrews (1986) continued the research, but concluded that any changes that occurred after 1950 were not due to tamarisk growth. Andrews further suggested that due to renewed degradation the quasi-equilibrium of the river of pre-dam era no longer existed along the channel length. In contrast, Lyons, Pucherelli, and Clark (1992) concurred with Graf and concluded that the Green River below the Flaming Gorge Dam had attained a new quasi-equilibrium condition, with the river transporting just the load supplied to it. Andrews (1986) also stated that there were no reports showing the down stream impact of a resevoir to compare data.

Studies on the riparian and aquatic ecosystems were more in agreement. Schmidt, Bonebrake, and Larson (1982) stated that the hypolimnetic dam discharges had adversely affected the fishery. They proposed a temperature increase that was satisfactory to the dam operation, the maintenance of fish populations and supporting aquatic life. Holden (1991) stated that the Flaming Gorge Dam had created an un-natural situation that had caused some of the fish species to die out. Graf (1976) noted riparian ecosystem changes with the dying out of upper riparian zone plant species. This observation was supported by the Electric Power Marketing Environmental Impact Statement in 1996 (Western Area Power Administration [WAPA] 1996).

Descriptive Geology

The course of the Green River between the Flaming Gorge Dam, Utah and the Gates of Lodore, Colorado lies athwart a large eroded arch-like uplift known as the Uinta Mountains with the long dimension of the arch oriented east-west. Although the Uinta Mountain uplift is generally a simple arch, in the area where the Green River crosses it, the uplift consists of a large main arch with several smaller subsidiary folds south of the main arch. The axes of all the folds trend in general east-west direction, and the supporting ends of the main arch have been broken by faults. The river channel from the dam, mile 290 above the confluence with the Colorado River, to the Gates of Lodore, at mile 245.2, crosses the main arch by a circuitous route through Red Canyon and Browns Park (Hayes and Santos, 1972; Reeside, 1930).

All outcrops along the river channel are composed of sedimentary rocks. They range in age from Pre-Cambrian quartzite and conglomerates of the Uinta Mountain Group in Red Canyon to Tertiary sandstones in Browns Park (Woolley, 1930). The Red Canyon entrance is marked by the Uinta Fault where Pre-Cambrian rocks are in contact with the Pennsylvanian Weber Sandstone (Thomas, 1952). Rocks forming the canyon walls are layers of dark red to brown sandstone, quartzite, conglomerate and shale (Reeside, 1930). The canyon walls stand approximately 2,000 feet above the river surface (Woolley, 1930). The quartzite dips 10° to 20° NW as part of the Uinta anticline north flank. Here the valley is more open than the Canyon of Lodore which is on the southeast end of Browns Park. In contrast to other canyons in the region, talus covers much of the canyon walls permitting trees to take hold and grow (Reeside, 1930). Red Canyon is about 31 miles long (Woolley, 1930). On the lower end of the canyon, another fault forms one side of the Uinta Mountain graben (Thomas, 1952). Browns Park occupies part of this graben. Most of the park is underlain by soft, very light colored sandstone of the Tertiary Browns Park Formation. In addition the Browns Park Formation includes a basal conglomerate, white sandstone and tuffaceous beds.

Immediately downstream from Red Canyon, at mile 276.6, the Green River emerges into a broad low open area approximately 33 miles long, named Browns Park. Here sandstone and terrace gravels form the stream banks. The river gradient flattens from an average of 11.9 feet/mile to 1.6 feet/mile (Woolley, 1930). The current slows in the wide, shallow channel which is bordered by a broad, terraced, vegetated flood plain (Thomas, 1952). The mile-wide alleviated valley is divided by the meanders into "bottoms". According to Hayes and Santos (1972) these terraces were formed during a Pleistocene glacial maximum.

The underlying bedrock, on which the alluvial and lacustrine beds have accumulated, is irregular, and because of this irregularity the river has locally cut through beds these deposits and encountered of quartzite in the Browns Park Formation. Just above mile point 265.9 The river flows through Little Browns Park and then enters Swallow Canyon. Here quartzite forms nearly vertical walls that stand about 200 feet above the Green River. The Green River emerges from Swallow Canyon, at mile 263.7, into the main portion of Browns Park (Hayes and Santos, 1972).

To the north of Browns Park lies Cold Springs Mountain and to the south lies the main Uinta Range. In this area both consist of quartzite of the Uinta Mountain Group. The Browns Park beds dip slightly northeastward along the river channel. They lie unconformably on quartzite which dips at 8° to 15°. The initial uplift of Cold Springs Mountain and the main mass of the Uinta Mountains occurred at the end of the Cretaceous Period (Thomas, 1952).

Land Usage History

When the first American explorers visited the Browns Park area, several Native American tribal groups, including the Comanche, Shoshoni and Utes, were occupying the area as an oasis. Fort Davy Crockett was built in 1837 on present Refuge land to protect settlers and trappers, as well to serve as a trading post. In the 1860's cattlemen utilized the lowlands as winter range. This led to the formation of several grazing ranches that irrigated the bottoms to raise hay and improve pasture lands. The largest of these ranches was the Two Bar Ranch, which controlled as much as 5 million acres at one time (USFWS, 1997). Other ranches in the area included the Jarvie Ranch, located in Little Browns Park, and the Taylor Ranch, located on the upstream end of Swallow Canyon. All of these ranches used the water from the Green River and the more fertile soils of the bottoms, or former meanders. Irrigation was accomplished through channels that diverted high flows of water from the river onto the flood plain. Drainage channels back to the river controlled the amount of water on the land to prevent over-saturation. Thomas (1952) reported that ranching had been discontinued in this area. He also noted that since the drainage channels had not been maintained, the area occupied by swamps and stagnant ponds had increased.

CHAPTER II

METHODS

This study is based on the examination, interpretation, and comparison of a series of aerial photographs taken between 1938 and 1993. Because there was not a set periodicity between fly-overs, a considerable time lapsed between some of the series, especially before 1972. With increased public interest, and technology, aerial reconnaissance occurred more frequently, and an approximate five-year sequence was established.

Because the site, is about 45 miles long, the author believed that the most severe impact of the dam closure would probably be in the location now occupied by the Browns Park National Wildlife Refuge. As a consequence, the study concentrated on the 15-mile stretch of Green River between mile points 258.3 and 245.0 (40° 45' – 40° 51' North Latitude, 108° 52'30" -- 109° 00' West Longitude) (Appendix A). The course of the main channel trends east to southeast as it flows around the north and northeastern ends of Diamond Mountain, Colorado.

Aerial photography, with stereo capability, was analyzed for the years 1938 (U.S. Geological Survey, scale 1:28,400 black and white), 1977-78 (Bureau of Land Management, Colorado 1977, Utah 1978, scale 1:24,000 natural color), 1979-80 (Bureau of Land Management, scale 1:40,000, natural color), 1982-83 (U.S. Geological Survey, scale 1:58,000, color infrared), 1982 (scale 1:40,000 black and white), 1987-89 (U.S. Geological Survey, scale 1:40,000 black and white), and 1993 (U.S. Geological Survey, scale, 1:40,000 black and white). The 1938 photo set was used as the base set from which morphological and ecological changes were established. The quality of many of the photo sets was less than adequate for complete comparison. The author determined that the most contrast existed between the 1938 series and the 1993 imagery.

Dam discharge rates had been recorded by stream gage station 09234500 located on the right bank 0.5 miles downstream from the dam (40° 54' 30" north latitude, 109° 25' 20" west longitude). Period of record is from October 1950 through December 31, 1996 (see Appendix B). Peak discharge rates in the pre-dam years ranged from 833 cfs on October 24, 1962 to 19600 cfs on June 12, 1957. A change in base discharge created another matching peak low on October 24, 1963. Due to the filling of the reservoir in 1963, minimum discharge rates were recorded as 2.3 cfs on March 20, 22, 27, 28, 1963.

The photo sets were compiled into mosaics to show the entire river channel and immediate surrounding area. These mosaics were enlarged to a scale of approximately 1:10,000 for uniformity of comparison. This allowed for analysis and interpretation of possible channel changes and trends in the riparian vegetation. Channel morphology and the presence or absence of channel bars were noted on each set. Comparisons were made between sets to determine what changes had occurred between photographic dates. Measurements were made directly on the aerial photographs and compared to the enlargements. The measurement accuracy for the 1938 photo set is ±23.6 feet and ± 33.3 feet for the 1993 photo set. Accuracy of these measurements and comparisons are limited by the scales of different aerial photographs as well as by the changing scale of a particular year's flight. Specific sites were selected where possible channel change was anticipated. Similar analyses were conducted for the riparian environment. These sites were noted on maps and formed the basis for field analysis.

Validity of the conclusions drawn from analysis of the aerial photography and selected sites was checked by field reconnaissance conducted in the summer of 1996. Photographs were taken to provide current imagery to bring the analyses up to date. These were compared to the historical aerial photographic sequences. Vegetation patterns and species composition were noted. A Map-o-graph Model 55 was used to trace the 1993 photos of the main stem channel onto the 1938 photos (Appendix A). The sites selected for field checking and areas of channel shifting were noted on maps so they would be field checked.

The soil survey of this area is still being compiled by Moffat County and the U.S. Department of Agriculture. The mapping has been completed for the wildlife refuge but the text, description, and soil map with legend have not been created. The soil map, scale approximately 1:24,000, and descriptive report, which served as legend, was compared to the air photo sets at the respective site locations. Special attention was given to the riparian locations.

CHAPTER III

DISCUSSION OF DATA

Stream Discharge

To determine if the discharge of the river may have been an important factor in main channel morphological changes, an analysis of pre-dam *versus* post-dam discharge was conducted. Because the only available stream gage, located down-stream of the dam and up-stream from the first perennial tributary, the Yampa River, was started in October 1950, no earlier discharge data is available. An attempt in the early 1920's to establish a stream gaging station proved futile when the equipment had to be re-established each year due to the large magnitude of the spring run-off. By 1925 upkeep of the gage was discontinued. No stream discharge records exist for this stretch of the Green River for the period from 1925 to the time the gage was re-established in October 1950. The nearest downstream gaging station is located below the confluence of the Green and Yampa rivers. Because the Yampa discharges approximately 7,000 cfs into the river system the data from the lower gage is of no value for this study. Therefore, historic river discharge data are limited and the discharges between the 1938 fly-over and October 1950 are unknown. One can only speculate on amount and seasonal flows utilizing the 1950 to dam closure in 1962 as a base pattern.

The drainage area for the Green River above gaging station number 09234500 is 19,350 square miles. The contributing drainage area is 15,090 square miles. Examining at the daily discharge charts (Appendix B) for this gage, reveals that seasonal hydrologic cycles affecting the site area (Ryan, 1997c). Chart one (Appendix B) shows the historic data from gage initiation, October 1950, through 1961 (Ryan, 1997c). Although discharge highs are cyclic, the amount varies from year to year as a function of precipitation and snow melt. The discharge highs are primarily one event initiated by spring snow melt and recorded as spring run-off. Historically this event begins in late May and lasts about three weeks, ending in mid June. Increase in discharge is very rapid, sometimes almost doubling over night. The ending of the event is just as sudden with a substantial decrease in stream flow. Some of the years experienced two peak major run-off events with just a few days separating the two episodes (Appendix B, Chart 2). These splits may have been due to weather fronts passing through the upper drainage basin, causing a period of cooling before warmer weather resumed and the spring thaw began anew.

The largest discharge, 19,600 cfs, was recorded on June 12, 1957 (Appendix B, Chart 3). This great surge in stream flow was due to a combination of spring run-off and a dam failure upstream. The Fontenelle Dam, similar to the Teton Dam, was an earthen structure that developed a leak. This portion collapsed due to the saturated, weakened wall being over-stressed by the movement of the withdrawing surveillance crews who were monitoring the leakage. The resulting failure contributed to the massive discharge on this date (Harding, 1997). The higher peaks are generally in October when the cold weather fronts pass through the area and precipitation changes from producing rain to snow and evapotanspiration decreases dramatically.

Daily discharge of the Green River at the study site underwent significantly changes during the calendar years from January 1, 1960 through December 31, 1969 (Chart 4, Appendix B). The last uncontrolled discharge year was 1961 (Ryan, 1997c). In 1962 spring run-off was recorded with a discharge maximum of 10,800 cfs on June 25. After that date, river flow became increasingly regulated as the Flaming Gorge Dam neared completion. Complete dam closure occurred on November 1, 1962. Since that date, the Green River has been fully regulated by the dam. Discharge readings from the gage measured the controlled releases as initial filling of the dam took place and later as, the need for hydroelectricity was matched by water releases (Appendix B, Charts 4-6) (Ryan, 1997c). Water was released to meet demands for electric consumption during the summer months, as evidenced by fluctuations between 2500 cfs to 4000 cfs. The demand for electricity for the end of year holidays and cold Januarys also appeared as higher discharges. This pattern continued throughout the 1971-1980 period (Appendix B, Charts 7-8) (Ryan, 1997c). Snider, Hayse, Hlohowsky and LaGory (1994) reported that these fluctuations could be detected in the river more than 100 miles downstream.

Flow of the Green River during the period 1981-1990 was marked by the exceptionally large discharges (Chart 9, Appendix B) that may have caused significant changes in channel and floodplain morphology (Ryan, 1997b). In 1983, a maximum of 13,700 cfs were released. This release was necessary to accommodate the melting of a massive snow-pack which resulted in an abnormally large amount of run-off. Water was released from the dam to accommodate the increase in run-off into the reservoir. Similar events occurred in 1984, when 8,640 cfs were released and in 1986, when flow was 8,020 cfs.

In 1992 (Appendix B, Charts 10-11) a policy change regarding the water releases was implemented. The objectives of this change were to eliminate peaks and to meet the requirements of the U.S. Fish and Wildlife Service Biological Opinion for operation of the dam facility. The requirements directed for high steady flows in May and June, reduced flows and fluctuations in the summer and autumn months, and level flows when the Green River experienced ice (WAPA, 1996). This created a more ecosystem friendly release of near steady flow. Since 1992 flows have been more uniform and large increases and decreases avoided. Pre-snow-melt releases were implemented in anticipation of needed reservoir space for containing the increased run-off. The reduced peak flows are thought to be more favorable for the water and riparian ecosystems immediately downstream. The WAPA (1996) report concluded that the steady flows would be slightly more favorable for riparian vegetation, some of which is listed as endangered.

By comparing the discharge history of the Green River to Vermillion Creek below Douglas Draw near Lodore, Colorado, gaging station number 09235490 (40° 43' 20" north latitude, 108° 45' 26" west longitude), Chart 12-13 (Appendix C), it seems evident that if the dam had not been placed at the current location on the Green River and closed, the stream discharges would still be fluctuating cyclically with the seasons.

1938 Channel Morphology

In 1938, the Green River meandered through the Browns Park region without regulation. The main stem of the channel cut its banks seasonally as discharge increased. Seasonal discharge highs and lows were cyclic. Event highs were of such large magnitude that they re-shaped banks either through deposition or erosion. Channel segments and point bars were repositioned, or eroded, as a function of location within the park area. The riparian ecosystem was one that flourished with this type of fluctuation. The spring run-off caused a rejuvenation of plant and animal life. Groves of Cottonwood (*Populus angustifolio* and *P. fremontii*) trees lined the stream banks and thrived on the periodic influx of sediment and higher water table. In many places the river had cut into the groves causing the trees to fall into the channel (Woolley, 1930). Wetlands were replenished with moisture and sediments. The riparian and water ecosystems were adjusted to these climatic and cyclic fluctuations. Woolley (1930) reported that the bottoms were brush covered and other native vegetation flourished. These conditions were apparent on the 1938 photo set.

The main stem channel as viewed in the 1938 photographic set (Appendix A) was without anthropogenic constraints. The bottoms and cut-off meander, Hog Lake, are depicted as shown in the photographs. Wetlands included Hog Lake. At mile point 276.6 the stream gradient abruptly changed to 1.6 feet per mile. The attendant broadening of the channel slowed the river current and was no longer able to maintain the sediment load in transport. The photographs show that numerous bars had formed and that the larger ones were supporting vegetation. By the first mile below this change in slope the channel had started to meander (Site 2). The first wavelength of the meanders was complete on the downstream end of Warren Bottom. As one follows the channel downstream, the meanders tighten. The presence of abundant scrollwork indicates that the meanders had migrated progressively before 1938. The confluence of Vermillion Creek with the Green River was the site of deposition of a deltaic fan. This was located on the outside bank of the last meander loop within the Browns Park area, just above Site 9 of this study. Downstream from Site 9, the study site ends and the Green River enters the Gates of Lodore.

1993 Channel Morphology

The 1993 fly-over was conducted on two days. The first portion, flown on July 1, 1993, depicts the downstream portion of the study area, from site 6 through site 9 (Appendix B). The remainder of the fly-over was done on August 1, 1993, and depicts sites 1 through site 6. At the time of the flights, stream discharges were 970 cfs and 910 cfs respectively.

As shown on this imagry, the channel was greatly constricted and the meanders and point bars appeared to have changed shape since 1938. The smooth curving point bars have changed into angular bars that formed abrupt corners at the meanders. This was noted as early as 1976 by

Graf. These dramatic changes are thought to have resulted from the invasion of salt cedar or tamarisk (*Tamarix chinensis*) a persistent phreatophyte (Graf, 1976). The tree was imported from Spain in the 1800's to the southwestern portion of the United States. It was originally intended for stream bank stabilization. It has migrated northward up the Colorado River system, colonizing the moist sandbars and stream banks. Dense growths of tamarisk have resulted in the stabilization of the previously mobile sediments and constricted the open channels.

Comparison of the earlier sets of photographs with the 1993 set revealed that the tamarisk had influenced channel changes and continued to do so. Other vegetative changes include the decline in numbers of cottonwood. Many of the groves that existed in 1938 were no longer present. New cottonwoods were not replacing the old or dead trees. Cottonwood seed dispersal occurs during the high flow events in the spring. The floods deposit a moist alluvial substrate which provides a habitat favorable for regeneration of the seeds. By the time the flood water recedes, the seeds have been dispersed. The seeds germinate quickly in the moist soil and lose viability within three weeks (Fenner, Brady, and Patton, 1985). The older trees have deep enough root systems to tap into the phreatic zone but the regeneration of the species requires episode flooding well above the current dam controlled discharge for seedling establishment (Graf, 1976).

Overall the riparian vegetation was not not to as abundant in 1993 as it was in 1933. This can be deected by the lighter tones on the photo representation. By 1993 the riparian environment had colonized the old flood zones. Species that proliferate via subterranean root systems, such as wild licorice, common reed, and scouring rush, had also formed dense thickets along the channel banks (WAPA, 1996). The vegetation was stabilizing the banks and creating a narrower and deeper main stem channel. The cutbanks were steeper with nearly vertical sides.

Wetlands were more numerous and appeared to contain surface water. New wetlands, as opposed to those visible in the 1938 photo set, included Flynn, Nelson, and Hoy Bottoms. These appear as dark images on the 1993 photos. They also show evidence of anthropogenic nesting perches. Warren and Grimes Bottoms appear to have been dry but with newly constructed roads. Hog Lake appeared to be about the same as it did in 1938.

Comparison of 1938 vs. 1993 Channel Morphology

The following discussion is based on the 1938 air photos and uses the 1993 aerial photography for comparison. Please refer to the map in Appendix A. Because only one anthropogenic reference point is present on both photo sets, registering the sets proved difficult. Roads that were depicted in the 1993 set either did not exist in 1938 or followed different routes. Prominent ridge lines on the south side of the refuge were used as the other reference alignment points. The photographs are at different scales and are not multiples of each other. Although the exact scale of the 1938 set is questionable, the set is thought to be fairly accurate. Measurement accuracy is ± 23.6 feet for the 1938 set and ± 33.3 feet for the 1993 set.

Overall from 1938 to 1993, there was a shifting of the main stem of the channel, an increase in the number of bars, and a narrowing of the channel (Table 1). At Site 1, the main change was the attachment of the large vegetated point bar to the southern main channel bank by the sediment filling and drying of the near bank channel. Another change that had occurred was the narrowing of the main channel, which had become constricted with linguoid dunes and non-vegetated bars. Some of the linguoid dunes appear to have been stalled and dissected. Stream width averaged 266 feet in 1993 as opposed to the 1938 width of 467 feet a 43% decrease. No channel shifting was noted at study Site 1.

Table 1

Channel Morphology Changes

Site Location	Change
1	narrowed 43%
2	narrowed 41%
3	narrowed 41%
4	shifted 200 feet northeast
5	shifted 467 feet east
6	widened 13%, shifted 200 feet south
7	narrowed 80%, shifted 330 feet southeast
8	narrowed 49%, shifted 334 feet east
9	narrowed 17%, shifted 467 feet east

Site 2 and Site 3 also showed narrowing of the main channel, many linguoid dunes and non-vegetated bars. At Site 2, there was also a point bar that has become part of the south main channel bank. Much of the southern bank part of the channel experienced vegetated bar growth and had become fixed to the stream bank. The channel width was 267 feet for Sites 2 and 3, for the 1993 photo set. This 41 percent change indicates a significant narrowing from the 460 foot-wide channel that existed in 1938.

At Site 4 the main channel had begun to shift from the original banks of 1938. Here the shift was approximately 200 feet to the northeast of the former bank. Linguoid dunes were seen to be constricting the south bank at the meander crown and were becoming disconnected. Vegetation was stabilizing the dune-bar sediments in the 1993 photographs.

At Site 5 the channel had shifted 467 feet to the east of the 1938 bank. This is the first noted major meander shift within the refuge, but it is consistent with the scrollwork migration on the west bank. A linguoid dune had stabilized and was becoming a point bar, connected to the west bank, at low discharge. On the downstream end of the bar, vegetation had taken root.

At Site 6, the main channel had shifted 200 feet south. This shift was tangential to the previous scrollwork. The main channel had many braided bars in 1993. The near bank channel for the two largest bars appeared to have been filling with sediment or was above water at low stream discharge. Water flow in the main channel was constricted by bars and dunes. This was vastly different from the condition depicted on the 1938 photo set. Then there was only one large in channel braided bar that was heavily vegetated. In 1938 stream flow around the bar was well established on both sides even though the channel width was only 473 feet as compared with 533 feet in 1993. This was the only site where widening of the channel was recorded and it was 13% change.

The main channel at Site 7 had continued to shift, as evidenced in the 1993 photos. The shift was 330 feet to the southeast. This shift is consistent with the normal migration as shown by the historic scrollwork for this meander. In 1993 the two angular vegetated braid bars that existed in 1938 had merged into one. Except at higher stream discharges, the bar had merged with the west bank. Another angular vegetated bar on the east side of the main channel had merged with the east bank. The remainder of the inside of the meander bend had braid bars and islands that were apparently above the water surface at sometimes. Flow was greatly constricted to a width of less than 200 feet. This was an 80% diminution from the channel width of 994 feet in 1938.

In 1993 the entire channel at Site 8 had shifted. The east bank had shifted 334 feet east into the flood plain and the west bank was located at the approximate the location of the 1938 east bank. In 1993 all that remained of the groves of large trees that were on the west bank in 1938, were a few scattered remnants. These changes had resulted in a 49% decrease in channel width. The main channel had constricted from 520 feet in 1938 to 266 in 1993. A large point bar was located on the west bank and was causing most of the constriction. The point bar on the east side of the channel in 1938 had merged with the bank by 1993.

The channel shift continued downstream to the upstream end of Site 9. This upstream point is the cutbank of the last meander in the Browns Park Wildlife Refuge and study site. The north (east side) cutbank had not shifted completely over as it had further upstream. This site is at the confluence of Vermillion Creek with the Green River. This is the first tributary to enter the river within the research area that is a perennial stream (Appendix C). No delta had formed at the mouth of Vermillion Creek but the influx of sediments may have contributed to the resistance of the stream at this point to meander shifting.

At the point where the Green River completes the bend and changes from an easterly to a southern route, a complete bank shift had taken place. As with Site 8, both river banks had shifted the width of the channel. Here the shift was 467 feet to the east, abutting against the upstream end of the quartzite outcrop re-emergence that forms the entrance to the Gates of Lodore and Lodore Canyon. Point bars and linguoid dunes are numerous. At the downstream end of Site 9, the point bar that was sparsely vegetated in 1938 had merged fully into the east bank. The river channel had been 805 feet wide at this site in 1938 but had narrowed 17% to 667 feet in 1993. This merging created a small, well vegetated flood plain. In 1993 there was a point bar fully developed on the cut bank west side of the channel, and it appeared that the river may have shifted its course again. The quartzite outcrop confined the river meanders within the rising cliffs that are the first indication of the massive canyon walls of the Gates of Lodore.

1996 Site Visitation

The Browns Park National Wildlife Refuge is located 75 miles northwest of Craig, Colorado, off Colorado Route 318. This refuge is under the jurisdiction of the U. S. Fish and Wildlife Service (USFWS), Department of the Interior. Access to the various wetlands or bottoms and Hog Lake, is restricted depending on the time of year and wildlife nesting periods. Grimes Bottom was still a restricted area at the time of visitation. Hog Lake was open to the public, during this period, when the north circumference road was dry. Fishing and waterfowl hunting are permitted during season and with permits and limit restrictions.

A weather front had passed the night before the first site visit but the soils appeared dry. The local ephemeral streams showed no discharge. The weather each late afternoon created violent thunderstorms with abundant lightening ground strikes. Brush wildfires were numerous in a 100-mile radius and some were out of control. The fire danger for the site was listed as extreme. Wind velocities were sustained at 40 mph. Air temperature during the day was in the mid 90°'s F. Evening temperatures were in the high 50°'s F. These are typical of August temperature ranges.

River discharge daily recordings held steady at approximately 1490 cfs for the July 30-August 12, 1996 period. Fluctuations in stream height were detected by observing the wetting and then emergence of linguoid dunes and sand channel bars. The fluctuations were gradual throughout the day and could only be detected by revisiting the same site more than once in a day.

At each site, tamarisk was abundant and over-taking the native vegetation. The shrub was successfully competing with the native vegetation in dominance for soil and available water. This situation has caused the USFWS to actively discourage and eliminate this alien vegetation. Intentions are to have Moffat County mow the tamarisk in the fall season and the USFWS spray the new foliage in the spring as a deterrent. At present the USFWS is one year behind schedule and intends to initiate the elimination program in 1997 (Harding, 1997, 1996).

The cottonwood groves were declining even more than depicted in the 1993 photo set. Dead trees outlinedold scrollwork, indicating former stream channel banks. No new seedlings or young trees were noted. Across the Green River, on the south bank, at Site 4, live cottonwoods appeared to be close to the river bank. The cutbank bars on the north bank were covered with scrub-like vegetation and tamarisk. The bar had merged with the bank and appeared stable.

Nelson Bottom supported a luxuriant growth of mature cottonwoods, indicating a readily available sediment supply and abundant water. Spitzie and Flynn Bottoms, as well as Hog Lake, was still supporting standing water and a wetland marsh environment. The other bottoms had been allowed to dry for the season.

Pleistocene terraces exposed in the uplands by road cuts were studied on the north side of the river. The lower bedding was cobbly and unconsolidated. The bedding was alternately layered with fine silts. The cobbly layers fined upward to the present surface. Higher terraces were composed of channel fill material and showed signs of scouring. The lower layers of the exposed cuts were thin horizontal beds of sand which fined to silt in the upper strata. A gravel bed composed the top strata. All beds were poorly consolidated or cemented. This is consistent with stream bedding. Noorganic soil layers were exposed at these sites.

Upstream from Site 2, the south bank was composed of multiple thin layers of fine silts. This bank was higher than the average 5-foot banks of the main river channel. The vegetation was not as abundant exposing expanses of silty alluvium. This was contrary to conditions on the north bank.

The soils that were above water at Hog Lake were light colored fine silts. They were poorly packed with no discernable structure. This could indicate that the fine layers are the result of flood events. Vegetation was riparian and abundant. Much of the Lake was still supporting standing water.

Soils Description

The Moffat County Soil Survey, compiled by the NCRS, USDA, and Moffat County was in preparation at the time of site visitation

The dominant soil on the floodplain is the Baroid-Eghelm complex with 0-3 percent slopes. The unit is 55 percent Baroid and 35 percent Eghelm soils respectively. The Baroid soil is deep and somewhat excessively drained. The surface layer is brown loamy fine sand 3 inches thick. The upper 44 inches of the underlying material is strongly alkaline stratified fine sand, loamy fine sand and fine sandy loam. Permeability is rapid and available water capacity is low. Effective rooting depth is in excess of 60 inches. Seasonal high water table is at a depth of 5 to 7 feet, and runoff is very slow. Hazards of water erosion is slight, soil blowing hazard is high, and flooding is rare.

The Eghelm soil is deep and well drained. The surface layer is pale fine sandy loam 4 inches thick. The upper 17 inches of the underlying material is strongly alkaline stratified sandy clay loam and fine sandy loam. Permeability is rapid. Available water capacity is moderate. Effective rooting depth and seasonal high water table are the same as the Baroid soil. Runoff and hazards are the same as the Baroid soil.

The Baroid-Eghelm complex forms the stream banks on both sides of the main stem channel, and include the land between the river and the wetlands, Hog Lake and the vegetative attached bars. This is true for all the sites except for the north bank at Site 8.

The Youngston Loam with slopes of 0-3 percent is present at the north bank of Site 8, upstream ends of Flynn, Warren, Nelson and Grimes Bottoms, and the downstream end of Grimes Bottom. This soil is deep and moderately well drained. The surface layer is pale brown loam 9 inches thick. The underlying material is stratified loam, clay loam and silt loam to a depth of 60 inches. Permeability is moderate and the available water capacity is high. The effective rooting depth is the same as the Baroid-Eghelm complex as well as the runoff, water erosion and flooding hazards. The seasonal high water table is at a depth of 4 to 6 feet. The hazard of soil blowing is moderate.

The Tipperary Sand with slopes of 5 to 22 percent is persent at two locations, the slightly vegetated attached bar at Site 2, and the north bank area between Sites 3 and 4. This soil is deep and excessively drained. The Surface layer is light yellowish brown sand 3 inches thick. The underlying material is sand to a depth of 60 inches.

Land Use

The land use for the Brown's Park area has changed from pasture and range lands to wildlife refuge and recreational activities. The refuge serves as a nesting and migration habitat for migratory birds such as the Great Canada Goose and various duck species. Approximately 2,500 ducklings and 300 goslings are hatched each year. Other birds in residence are bald and golden eagles and peregrin falcons. Deer, elk and pronghorn antelope are among the animals grazing the uplands and terraces. Riparian animals include river otter and moose.

Nine pumping units have been installed to divert water from the Green River and Vermillion Creek and to thereby maintain the nine marsh units of approximately 1,430 acres. Acquisition of 5,356 acres at a cost of $622,976 was funded through the Migratory Bird Hunting Stamp Act (USFWS, 1997). The rest of the 1,305 acres of the refuge are leased from the state of Colorado. With the exception of one 200-acre privately owned tract, the area is primarily public lands under the jurisdiction of the U.S. Fish and Wildlife Service which also governs the refuge (USFWS, 1997). The private land is primarily agricultural, with grazing being the main land use.

The Diamond Breaks Wilderness Study Area comprises the lands located on the south bank of the Green River adjacent to the wildlife refuge. The tract consists of 3,900 acres. The entire stretch of the Green River from Flaming Gorge Dam through the site area is under consideration for inclusion in the National Wild and Scenic Rivers System(WAPA,1996).

CHAPTER IV

ASSESSMENT OF RESULTS

Morphological Changes

The Green River between Flaming Gorge Dam and the Gates of Lodore, has experienced main channel morphological changes. This is evident in the Browns Park National Wildlife Refuge section of the reach. With the decrease in overall discharge due to dam regulation, the river has been unable to maintain the original channel width. Narrowing of up to 80% of the channel was observed throughout the refuge. The increase in the number of linguoid dunes and point bars is evidence of decreased sediment entertainment. These changes are especially apparent at the upstream sites of the study area.

Andrews (1986) commented that the bed material size decreased downstream through the park until the river bed became entirely sand, with a median diameter of 0.4 mm (medium sand). This is inconsistent with the soil survey and 1996 field reconnaissance. The soil textures fine downstream from predominantly loamy fine sand to loam, a range of .031-.002 mm. The soil depth increases downstream. The exposure of pre-existing sandbars, as the dam released discharge decreased, created backwaters which drained with further reduction in stream flow. Other sand and point bars emerged above the water surface level long enough to permit germination of vegetation. The vegetation stabilized the loamy fine sands. More vegetative species rooted and aided in lowering the level of the available water by transpiration of the increased number of root systems.

The steep sandy side cut banks have been and are being stabilized by the roots of scrub vegetation. The riparian zones have shifted down the elevation gradient to more favorable conditions closer to the present river channel. The woody riparian species, such as the mature cottonwoods and box elder, are remnants of the pre-dam upper riparian zone which was located above the pre-dam annual floods. Their root systems are deep enough to tap the ground-water supply. Rejuvenation of new cottonwood seedlings have not been evident but the other woody species saplings are appearing at a lower elevations (LaGory and Van Lonkhuyzen, 1995). Graf (1976) reported that the cottonwood groves were thinning rapidly due to the lack of rejuvenation and would eventually die out.

The main channel has definitely shifted. This is observable from Site 4 downstream through Site 9. It could be construed that the decrease in discharge caused the shift. The reduction in discharge created a decreased meander size and the historic meanders were no longer stable. The channel readjusted to fit the new lower discharge. Sinuosity increased and the meander wavelength decreased with the reduced flow. Also, the finer, more easily entrained sediments permited meandering as opposed to the sandier materials.

Evidence of the grain size of entrained is the fining of soil textures downstream. Because the river was no longer able to maintain the larger sediment sizes in transport sthe coarser materials were left upstream. As the river flows from a constricted and relatively steep gradient to a wide expanse with low gradient, the Green River slows and channel widens. The erodible sedimentary materials of Browns Park permit bank erosion and dissipates the energy generated in the river flow. The utilization of energy within the stream must change to minimize energy expenditures. Meanders, being a least work phenomena permit the efficient utilization of energy. Therefore with the river flowing downstream within the easily erodible bedrock and soils of Browns Park Refuge, the Green river would begin to meander to use the remaining energy efficiently.

Morphological Changes due to Decrease in Discharge

The question as to whether the damming of the river has caused the morphology of the main channel to change, has two parts. The first part is to whether the channel shifting could have happened if the discharges had remained within the pre-dam magnitudes and fluctuations. At this point, it is only conjecture that the dam closure did affect the meander shifting. It could be postulated that due to the decrease in discharge and resulting lower energy, the river has shifted to adjust to the new energy level. Andrews (1986) stated that the dam caused the changes in width and flow patterns. He reported that due to the sediment-free discharges, the channel was degrading. Channel bed sediments were the materials source for any new bar development.

Lyons et al. (1992) reported that between 1952 and 1964, primarily pre-dam, there was little change in channel width. They concluded that the dam had measurably narrowed the river channel. They continued to state that the narrowing was due to the increases in the number of islands, island size, and the sediment filling with consequent loss of the side channels.

Andrew (1986) noted that the Green River was establishing a new flood plain approximately 4.0 feet lower than the pre-dam plain. He postulated that this was due to a decrease in effective discharge and to a degrading of the stream bed. This adjustment with the channel narrowing was still occurring during the 1996 site visit. This would support the hypotheses that the channel change observed was due to the dam closure.

Morphological Changes due to Vegetation Changes

The other part of the question, whether the dam closure had caused main channel morphological changes, is the manner in which the vegetation may have contributed to the change. The pre-dam discharge would have kept the riparian zones at the former elevations and there would not have been a shift of the zones down-slope towards the new river level. Bar vegetation would have been less, allowing for seasonal aggrading and degrading of the bars and linguoid dunes. Seasonal floods would have made it more difficult for some vegetative species to root and stabilize the channel banks permitting more cut-bank erosion. These floods would have stripped the lower riparian zone and much of the less sturdy upper riparian zone vegetation shoots from the river banks. Lyons et al. (1992) postulated that the reduction in flood events may encourage vegetative growth, stabilizing, trapping and reducing erosion.

Andrews (1986) stated that the tamarisk invasion into the riparian zone may have been a cause of channel change only until 1951. He continued that channel width had narrowed by 27% but that all change had occurred before 1951. He did not state at what locations these changes had occurred. This blanket statement for the entire reach of the Green River, from the dam site to Green River, Utah, or 290 miles of river, is in error. No where does Andrews cite; where the tamarisk was abundant, whether or not there was any observable upstream encroachment, and evidently did not note these aspects even though he was interpreting aerial photographs taken prior to 1962 and after 1980.

The purpose of the planned extermination of tamarisk by the USFWS of the in 1997 disputes Andrews' claim. The USFWS action supports Graf's (1976) observations that in addition to supplying a means of stabilizing bar and banks, the tamarisk had a significant effect on the hydrologic environment through transpiration. Graf continued that the tree may have taproot lengths greater than 10 feet and consume upwards to 4 acre-feet per year per acre of the shrub-like growth. This would have a substantial impact on the local hydrologic cycle and riparian environment. Graf (1976) postulated that the expansion of the bars and islands was not a product of river sediment changes but of the tamarisk. The role of this exotic plant is critical in landscape change. This is due to tamarisk colonization on previously barren bars which stabilized the channel features by trapping and anchoring sediments in their extensive root system. Therefore, the dam through smaller discharges and lower peak flows had changed the riparian ecosystem by permitting the introduction of exotic plant-life.

Changes in the Riparian Ecosystem

The afore mentioned changes have affected both the hydrologic and riparian ecosystems. The riparian system has shifted down in elevation to positions closer to the present river surface. Historically, the vegetation in the lower riparian zone adapted to the seasonal high flows and responded quickly to the changes in the moisture levels. If the changes in flow characteristics had not destabilized the native vegetation exotic flora would not have been able to transgress into the refuge area and stabilize the banks. With the vegetation being allowed to grow on bars, the deflation of the sand deposits by wind erosion has decreased and the bars are more stable.

Changes in the Aquatic Ecosystem

The hydrologic ecosystem was affected by the dam in several ways. As early as 1962, the aquatic life was affected. Poisoning by rotenone application to non-salmonid fish was implemented to protect species favored by the angling public. Some of these local "trash" fish were native but others were introduced species that trout anglers did not want in the reservoir (Collier et al., 1996; Holden, 1991). The detoxification station was located approximately 1.5 miles upstream from Site 1 and Hog Lake. It was anticipated that detoxification would be complete well before the Gates of Lodore, where the Green River entered Dinosaur National Monument.

The poisoning was conducted but the concentration of the rotenone recorded at the detoxification site remained so high that fish were reported to be dead or dying as far downstream as the downstream end of the monument. Heavier losses than initially anticipated of native fish in the refuge area were reported (Collier et al 1996; Holden, 1991).

Even with this change in the species concentration, Holden (1991) theorized that the change in discharge and water temperature had more impact on the aquatic life. The dam has a hypolimnetic release that creates a much colder than pre-dam discharge temperature. Schmidt et al. (1982) reported that the poor growth and survival of stocked rainbow and cutthroat trout fingerlings was due to the extremely cold water temperatures. The diversity of other aquatic life also declined. A shift from 48°F to 55°F saw dramatic increase in the trout fishery and supporting aquatic life. Schmidt et al. (1982) suggested a different depth of withdrawal for dam discharge. The WAPA (1996) reported that the clear cold waters supported new aquatic macro-invertebrates which are the food base for the fishes. The low gradient reaches within Browns Park however support different species of macro-invertebrates. The pre-dam water temperatures and sediment load would not be favorable for any of these species, including the trout fishery. Thus, the dam has affected the aquatic ecosystem as well.

CHAPTER V

EFFECTS OF A CONTROLLED FLOOD RELEASE

General Overview

With the stated morphological and ecological changes, the question that is then raised is whether one or more controlled floods events would reverse some of the changes and perhaps initiate a more favorable ecological setting. Regardless of the type of flood, whether within or out of bank, some basic situations would occur. The following discussion concerns the possible effects of a discharge of flood stage magnitude flowing through the Browns Park National Wildlife Refuge site area.

The gradient from the dam through Red Canyon to Little Browns Park is 11.9 feet/mile. The first widening of the Green River is into a park or flood plain known as Little Browns Park. The river re-enters a constricted area, Swallow Canyon before flowing into the Browns Park area, where the gradient lessens to 1.6 feet/mile.

With the same volume of discharge flowing into a narrower channel, the canyons can be equated to a modified Venturi tube in the constriction of the river flow. The effect downstream, when the flow exits the constriction, where the downstream end of Swallow Canyon meets the beginning of Browns Park, would be similar to a Bernoulli effect. The flow velocity within the constriction would increase in direct proportion to the reduction in channel area. The velocity of the flow would increase, by the continuity law, within the canyons to meet the demands of continued flow. By Bernoulli's principle, the pressure within the flow would decrease while the flow is constricted. This would create a suction,or hydraulic lift, away from the wetted perimeter of the river. As the river flows out of the constriction, Swallow Canyon, into Browns Park, a wider and shallower area in which to flow, the suction would remain for an undetermined distance down the channel. The suction plus the increased velocity would have strong erosion capabilities. Turbulence would be greatest near the wetted perimeter of the channel because of the irregularities in the stream banks.

The energy generated in river discharge may entrain sediments directly from the banks causing erosion or corrasion. The relatively high stream gradient would also have a positive effect on the ability of the river to transport bedload.

It should be anticipated that the turbulence could cause much erosion at the entrance to the refuge at Hog Lake. Both channel banks could be eroded with the north bank being effected the most. Stream velocity would slow quickly due to change in gradient, widening of the channel and shallower channel depth.

Entrained sediment would be deposited quickly due to the inability of the river to maintain the materials in transport. This would probably occur in the channel area of Spitzie Bottom. The release of the entrained materials would fine downstream as the river channel meanders through the refuge. This would account for the progression of soil textures from loamy fine sand to loam downstream. As the river channel become reconstricted, where the Green River enters the canyon entrance to the Gates of Lodore, major deposition could occur due to the river discharge backing-up. The deposition could be expected to occur at and around Grimes Bottom.

When the river discharge lessens, due to the flood event ending, there would be renewed scouring and erosion in the vicinity of Grimes Bottom, as the backed-up flood waters would be siphoned into the narrower and steeped gradient Lodore Canyon channel. This could cause renewed erosion of both river banks at the downstream end of the refuge.

Two scenarios need to be discussed when analyzing a controlled flood release. The first is the effects of a flood event that would be confined to within the main channel river banks. The second would be the effects of a flood event of a greater magnitude which would overflow the main channel banks, flow onto the flood plain, into the riparian ecosystem.

The magnitude of discharge that can be released from the dam is governed by several factors. The maximum power output for the Flaming Gorge Dam is 4600 cfs. Two bypass tubes may be opened, when the reservoir is full, adding an additional 4000 cfs. The tunnel spillway may also be used, when the reservoir is full, to add another 28,800 cfs. If all is utilized, a total maximum of 38,400 cfs output could be initiated (Ryan, 1997a). This magnitude is greater than the flood release, conducted by the Glen Canyon Dam on the Colorado River in March 1996, of approximately 19,000 cfs (Collier et al, 1997).

Effects of a Within Bank Flood

Erosion of the channel banks have historically been a major problem. The erosion could be due to high discharge or wind-wave action. In the spring of 1967, it was noted in the Annual Narrative for Browns Park Refuge (Harding, 1997a) that the river, powered by wind-wave action, cut to within three feet of the entrance road, located upstream from Site 1. The notation continued that the high discharge of approximately 4000 cfs during spring run-off caused a continuing problem.

In the narrative from that year, an entry discussed concern that erosion of the river banks becomes critical with flow as low as 1000 cfs. In response to these concerns, pilings were buried vertically along the river bank, at Site 5, the location of the sub-headquarters living area. Rip-rap was placed between the bank and the barrier fence. This was also done further down stream between Sites 6 and 7, to protect Fort Davy Crockett National Historic Site (Harding, 1997a).

Numerous documentations, through the years and continuing to the present, were made in the Annual Narratives referencing the continuing battle against bank erosion. The main sections impacted by erosion are located on the cut-banks of the meander bends. The entire main stem of the Green River through the refuge has been noted as being severely eroded. The USFWS work projects within the refuge have been repeatedly involved in the stabilization of the river banks. As early as 1968, the agency determined that one of the long-term problems concerning the Green River was bank erosion (Harding, 1997a).

Silt deposition, causing the clogging of pump sites where river water is pumped into the wetlands to maintain a favorable marsh habitat for the riparian ecosystem, has been a continuing problem. At 8200 cfs, the silting shut of pumps becomes even more of a problem, as occurred in 1986 when a discharge of 82oo cfs caused considerable damage. The high flow did permit the use of gravity flow to channel water into Hog Lake.

Another problem with higher stream flows has been the loss of bare sand bar sites for the waterfowl. Prior to being vegetated bars were used by geese and ducks for loafing, roosting, resting and protection from the winds. Flooding of the marshes also created fewer nesting sites, although many of the waterfowl winter in the wetlands. The 1983 Narrative reported that approximately 300 geese wintered and the 3,200 duck population swelled to over 9,000 by March (Harding, 1997a).

The aquatic ecosystem is also sensitive to flooding. flood flows are heavily laden with silt, and endangered fishes, including the Colorado River Squawfish and trout, cannot flourish in water with high sediment loads. These species prefer the clearer flows associated with lower discharges.

Effects of an out of Bank Flood

The best example of the effects of an over bank flood is the 1983 spring run-off. The release of 13,700 cfs caused much damage throughout the refuge. Most of the pump sites were either damaged or inoperable due to silt and sand build-ups. Sand bars formed at the Spitzie pump site causing the preventative shut-down of the pump. Materials behind the bulkhead were washed out. The Grimes pump site was tilted and bulldozer work was necessary to prevent the pump equipment from total washout. The residence quarters No. 1, located at Grimes Bottom, had two inches of water above the foundation floor. The roads in Warren, Spitzie and Hoy Bottoms were flooded (Harding, 1997a). Upstream approximately ten miles from the refuge the Taylor Flat Bridge washed out. This bridge was used by the USFWS and the Utah Division of Wildlife Resources to transport heavy machinery to the southern banks of the Green River.

The riparian and aquatic ecosystems experienced mixed results. There were no river bank nesting sites located after the waters receded. Bank erosion was evident and the vegetation was stripped away. The wetland areas were sub-irrigated and the nesting structures were surrounded by water. The Green River flowed into Spitzie marsh, eliminating the momentary need for pumping. Most of the island vegetation had been removed by the magnitude of the flood event. There was a higher incidence of animal kill including deer. The aquatic ecosystem suffered in the loss of fish as evidenced in fishing success which was reported to have been poor. The moss and silt that had been on the main channel bottom were gone (Harding, 1997a).

CHAPTER VI

CONCLUSION

The Green River from Flaming Gorge, Utah to the Gates of Lodore, Colorado flowed free of anthropogenic constraints until 1962. Prior to 1962, river discharge rates were greatly effected by season and weather events. The annual snow-melt created flood amounts in excess of 8,000 cfs, and river flow amount lowered to less than 1,000 cfs during the summer season. Non-seasonalvariations throughout the year were due to climatic events of short duration. Main stem channel morphology reflected the seasonal discharges. The local riparian and aquatic ecosystems were adapted to river discharge and flourished.

With the closing of the Flaming Gorge Dam in October 1962, river discharge was controlled and altered from historic flow patterns. With less discharge, the main stem channel became narrower and the meandering pattern shifted in adaptation to the lower flow rates. The entrained sediments originated from the Red Creek ephemeral stream watershed. This creek was the only tributary to empty into the Green River of consequence. The historic sediment load of the Green River had originated from watersheds totaling 19,350 square miles. Sediment load after dam closure, at gaging station 0.5 miles below the dam, has been noted as being virtually zero. The main stem channel within the Browns Park Refuge shifted in adjustment. Thus the channel morphology was altered.

The pre-dam riparian and aquatic ecosystems were adapted to the seasonal discharge changes and native species flourished (WAPA, 1996; Woolley, 1930). After dam closure the hypolimnetic water temperatures did not fluctuate with the seasons. This along with the poisoning of the fish population, altered the number of species surviving and permitted exotic new species to enter the habitat. Many of the native fishes are presently on the endangered species list.

The riparian ecosystem had changed. The pre-dam vegetation was native and up-slope from the present ecozones. Cottonwoods rejuvenate by seeds falling on moist silty soils that have been recently deposited by seasonal floods. With the dam controlling the level of discharge, the opportunity for overbank flooding, deposit of fine sediments, and re-supplying moisture to the soils were eliminated. The favorable habitat was eliminated for successful germination of the cottonwood seeds and proliferation of the saplings. Exotic vegetation, in this case tamarisk, was permitted to infiltrate into the riparian zones due to the lack of floods stripping emerging root suckers from the soils. This exotic has been stabilizing the banks and successfully competing with native vegetation.

Major erosion due to river flow occurs with discharge as small as 1,000 cfs. Channel banks have been eroded and entrained sediments have been deposited down stream. Pumps used to keep the marshes wet during nesting season have been damaged or made in-operable due to sediment build-up. Higher discharges have caused flooding of refuge roads and residence quarters even thoughthese structures were all built after the dam was closed.

There is strong advocacy position for conducting a controlled flood release from the Flaming Gorge Dam, on the Green River, much as the recent large discharge released from the Glen Canyon Dam on the Colorado River. The purpose of such a release would be; to scour the river bottom of sediments and re-deposit them along the banks and beaches, as had happened historically (Collier et al., 1997). One advocate, John C. Schmidt (1994), has stated that one needed to emphasize some river-based resources in an attempt to maximize selected environmental values. These selected values would be enhanced at the expense of not augmenting other values. Schmidt (1996, 1994) continued that discharges favorable to some values at a given site may not augment the same values atother river locations.

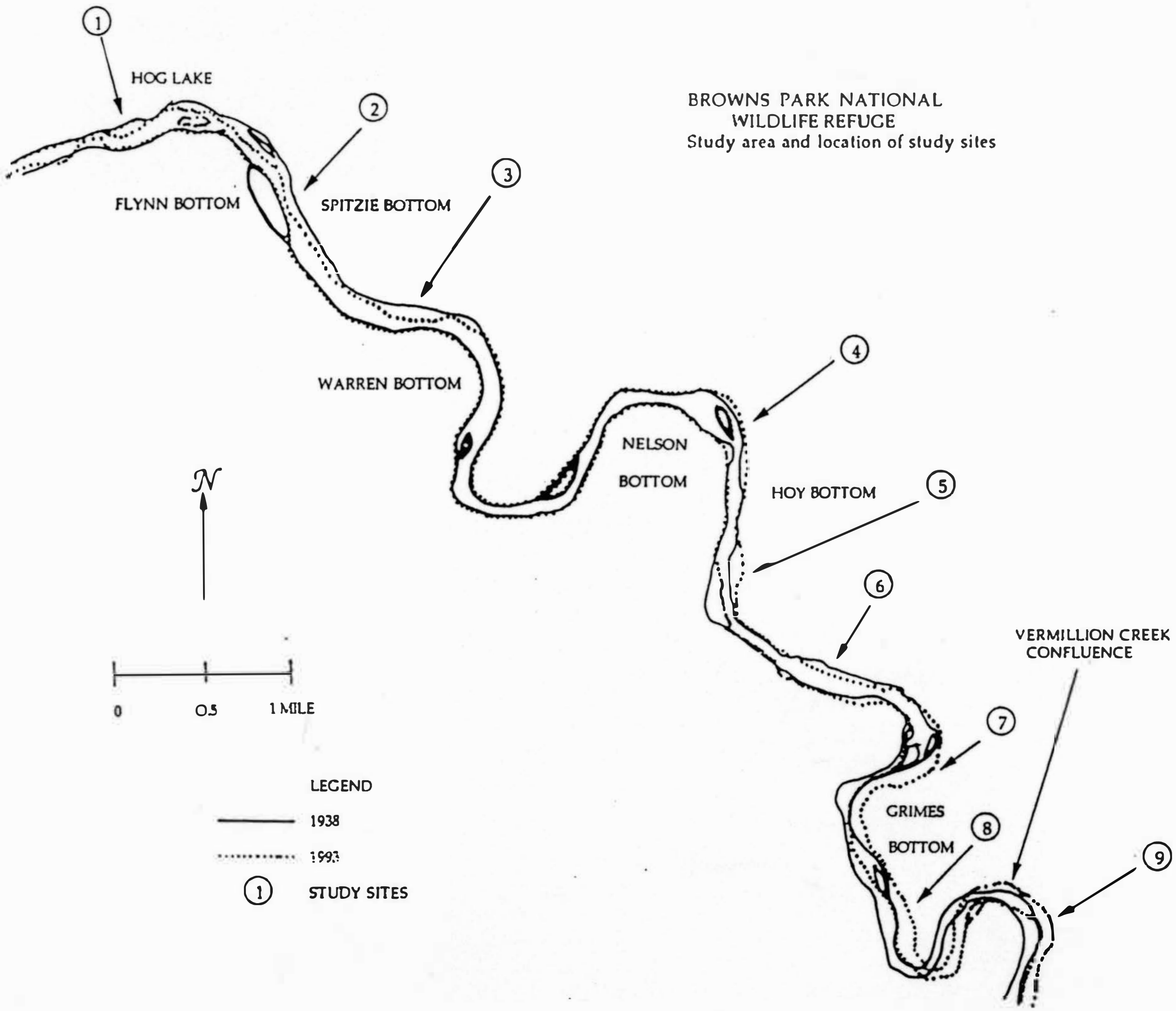
The question is whether a similar controlled flood release should be conducted with information that is now available. Floods are an integral part of the natural equilibrium for the Green River. They are necessary for maintaining channels. The riparian ecosystem needs the replenishing of necessary sediments and nutrients for regeneration and flourishing. It seams likely that floods would deter exotic growth. Some (Collier et al., 1997) believe that the environmental benefits outweigh any damage that might occur.

Given the location of the Browns Park National Wildlife Refuge and the present amount of usable data, it is hard to unequivocally advocate a similar release. There are still many unknown variables. These include but are not exclusive to: (a) the morphology of the main stem channel bed; (b) the textural distribution of materials on channel bed; (c) the origin of the channel bottom sediments; (d) the effects on exotic life; (e) effects on upstream banks and morphology, especially Little Browns Park; (f) effects of various discharge amounts and duration; (g) seasonal timing of discharge; (h) long-term effects; and (i) costs. The implications on the wildlife refuge should be considered carefully. This is a major nesting area and sanctuary for many types of wildlife. Public usage and whether it would enhance or deter visitation should be considered. In addition, this is also prone to massive erosion.

Until more comprehensive research and analysis are conducted, it seams inadvisable to implement, at this time, a controlled flood release. Although it seams likely that a controlled flood will be released from the dam, care should be taken to minimizing the uncertainties that exist surrounding the effects of such an action. It would be unfortunate to sacrifice valuable qualities to augment a few selected high interest aspects of this complex ecosystem. It would be hoped that as we attempt to augment one quality within an environment, the other qualities will not suffer.

Appendix A

Study Area and Location of Study Sites


BROWNS PARK NATIONAL
WILDLIFE REFUGE
Study area and location of study sites
HOG LAKE
FLYNN BOTTOM
SPITZIE BOTTOM
WARREN BOTTOM
NELSON
BOTTOM
HOY BOTTOM
GRIMES
BOTTOM
VERMILLION CREEK
CONFLUENCE
1
2
3
4
5
6
7
8
9
N
0
0.5
1 MILE
LEGEND
1938
1993
1
STUDY SITES

Appendix B

Green River Historic Discharge Data

CHART 11

Green River Discharge Data (station 09234500)

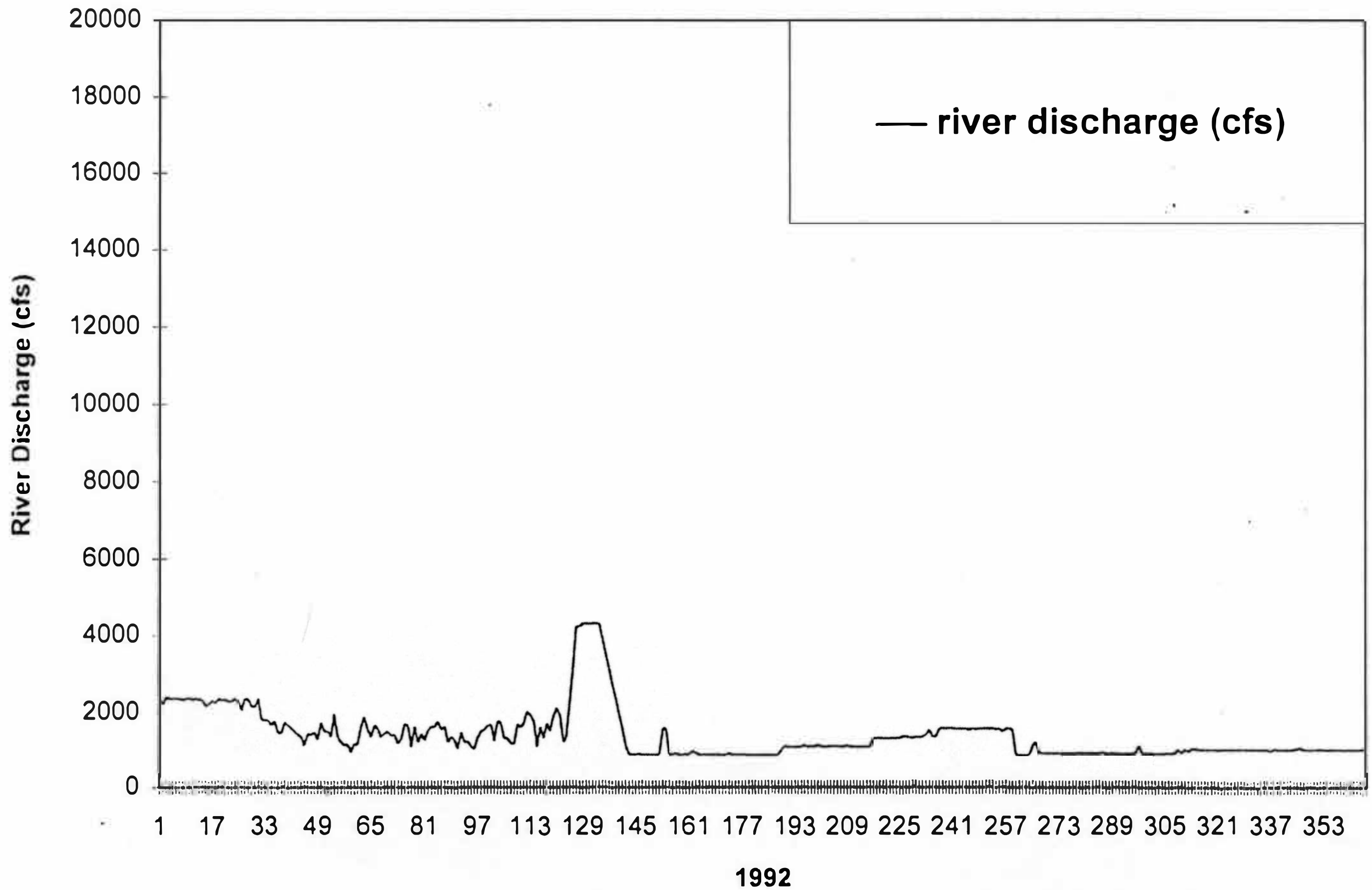


CHART 10

Green River Discharge Data (station 09234500)

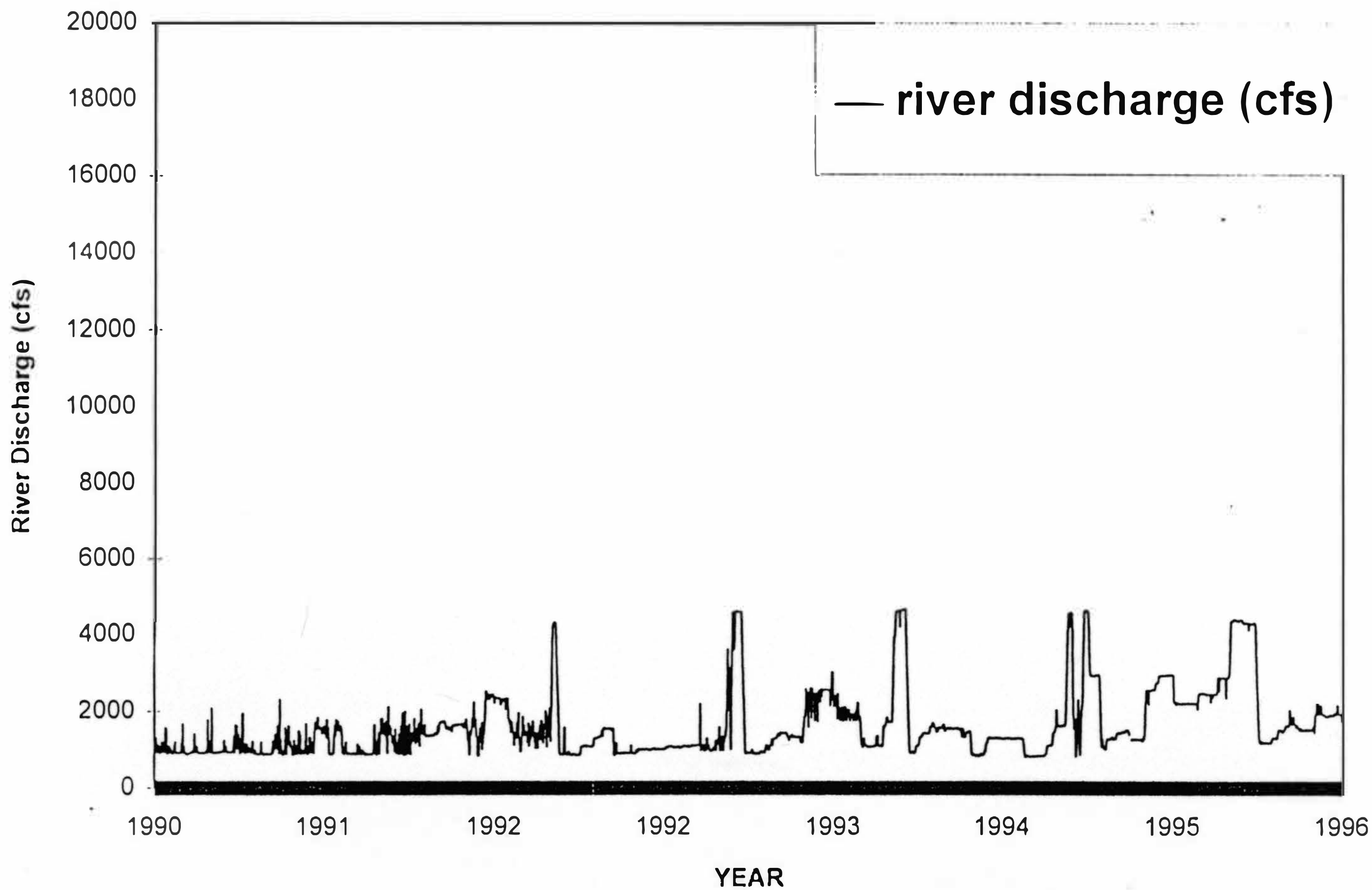


CHART 9

Green River Discharge Data (station 09234500)

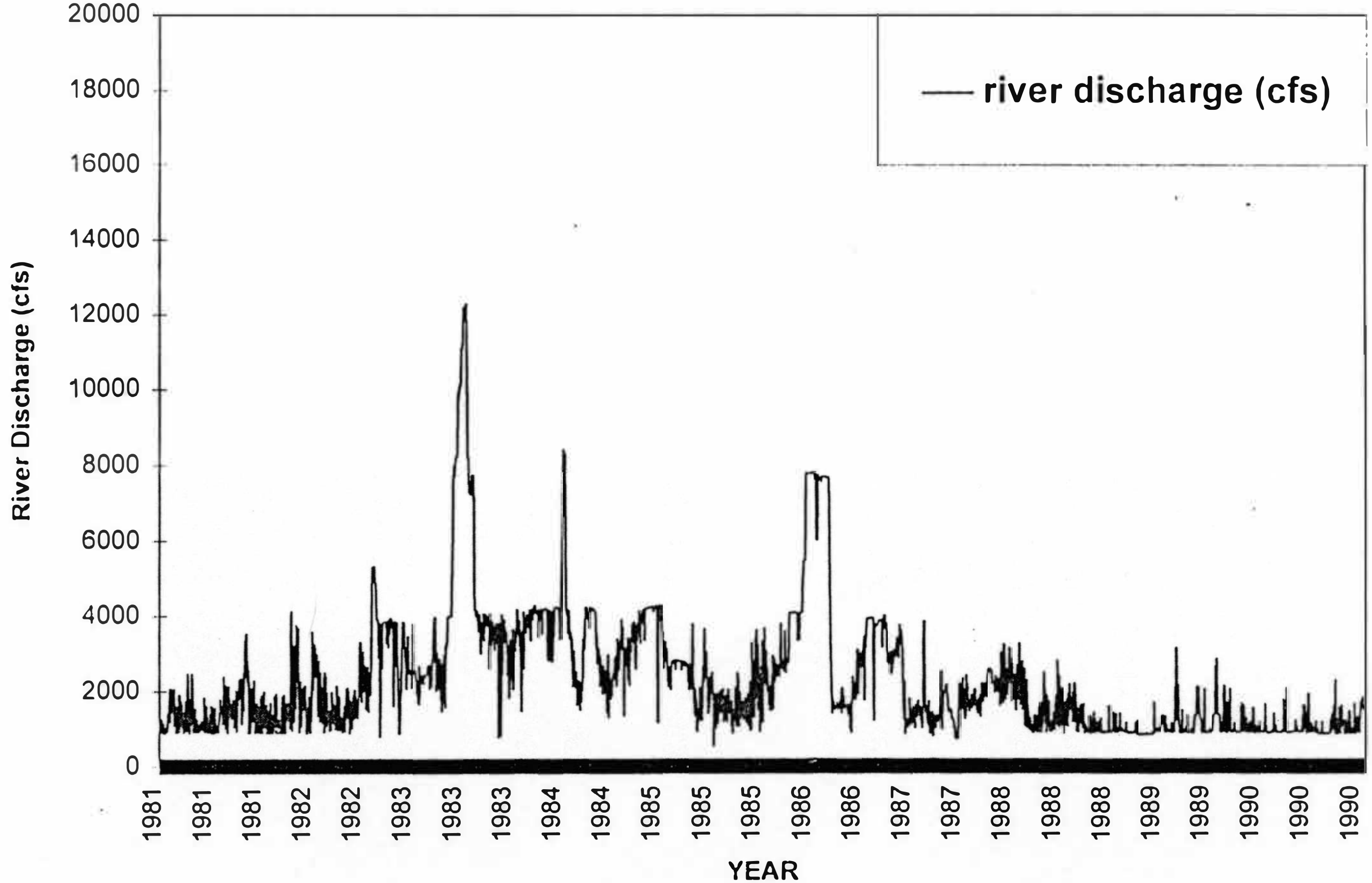


CHART 8

Green River Discharge Data (station 09234500)

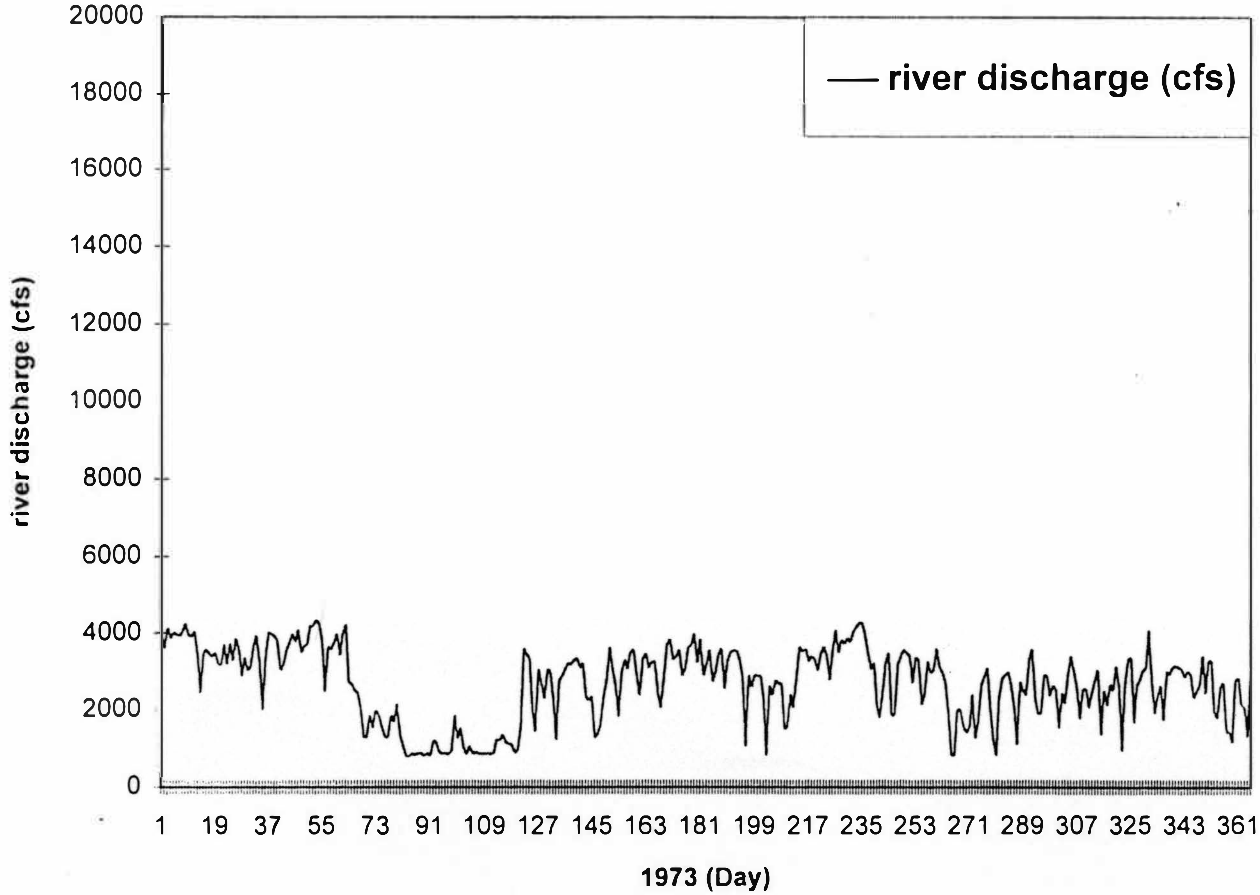


CHART 7

Green River Discharge Data (station 09234500)

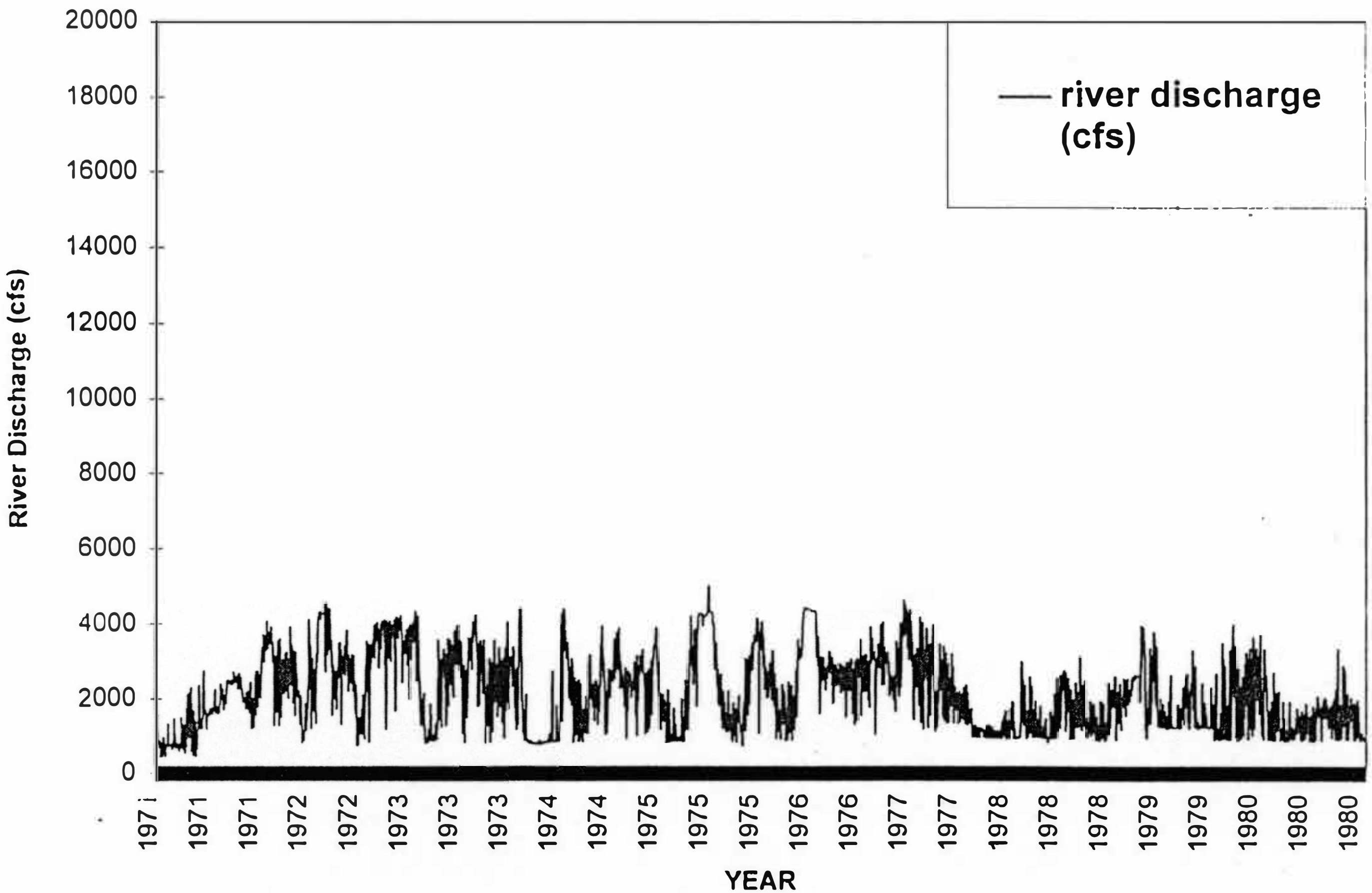


CHART 6

Green River Discharge Data (station 09234500)

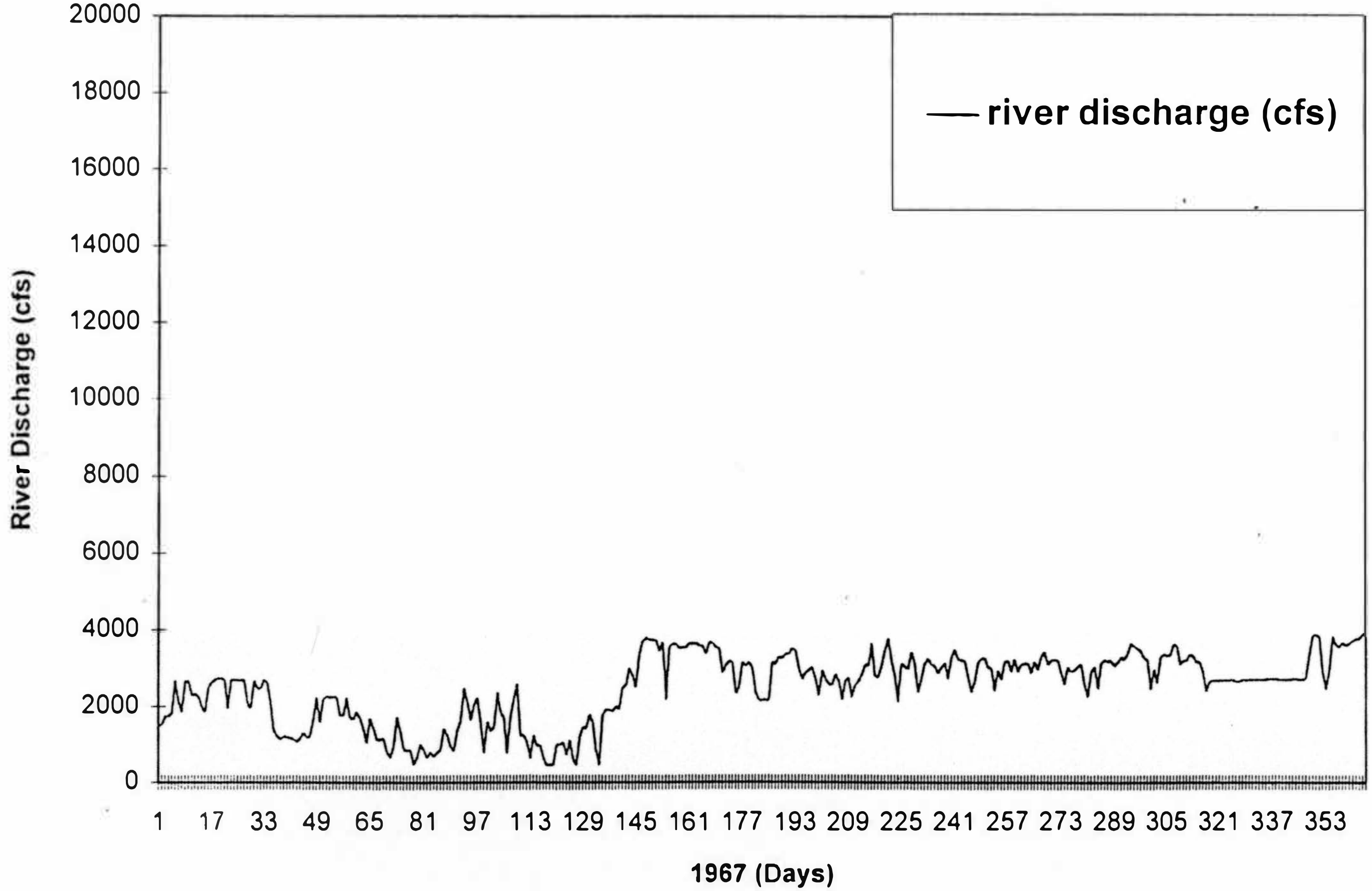


CHART 5

Green River Discharge Data (station 09234500)

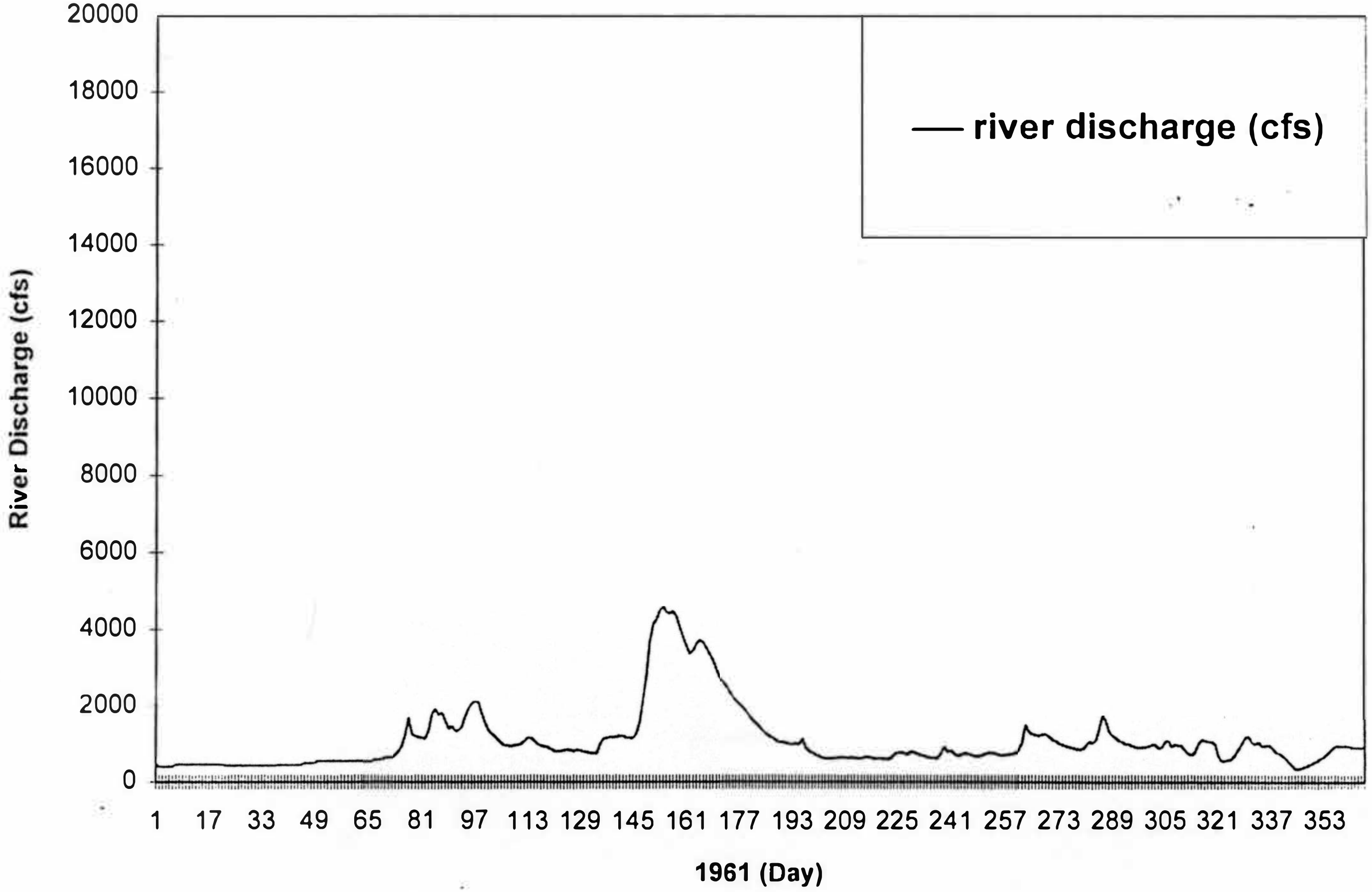


CHART 4

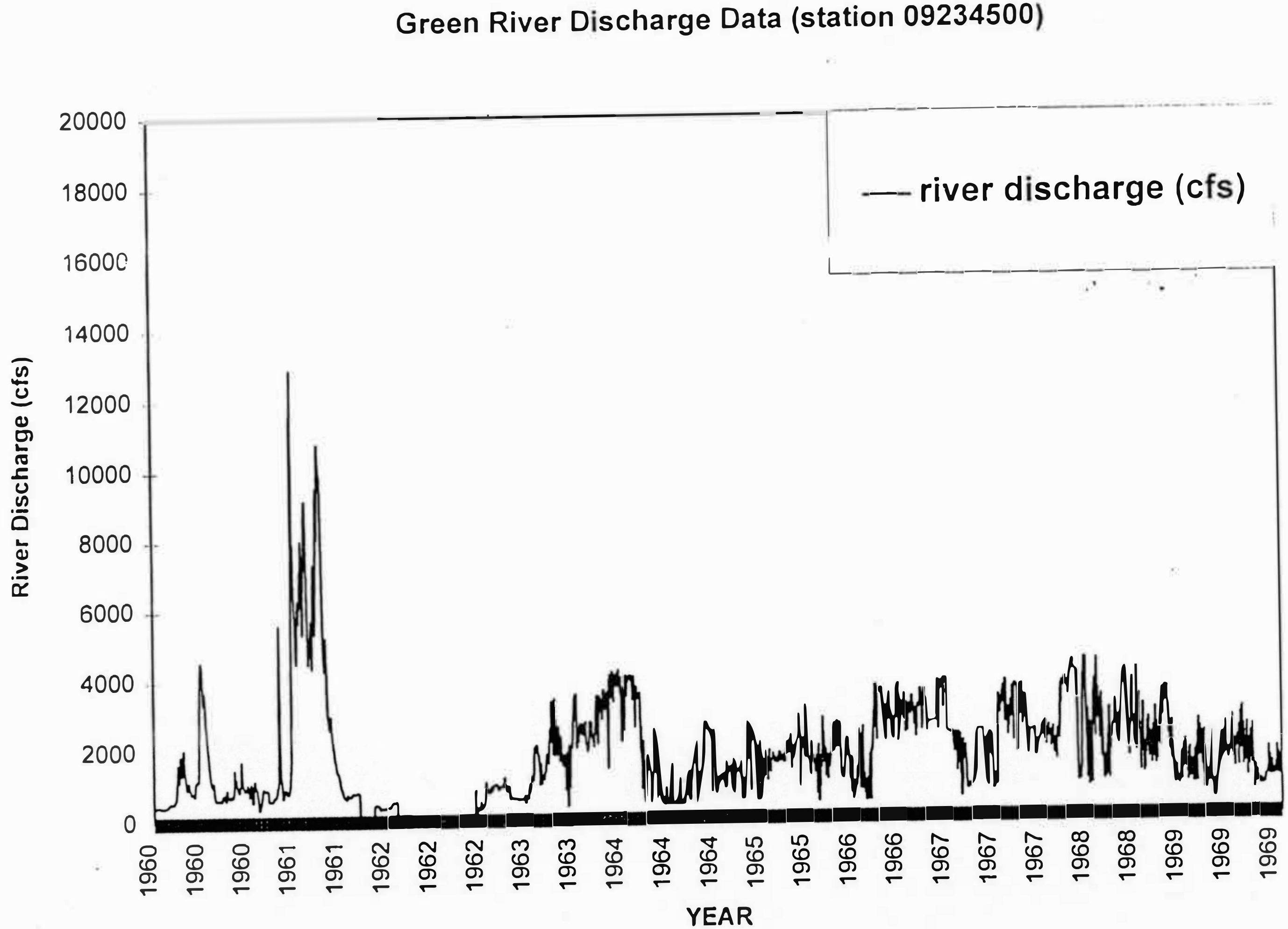

Green River Discharge Data (station 09234500)
river discharge (cfs)
River Discharge (cfs)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
1960
1960
1960
1961
1961
1962
1962
1962
1963
1963
1964
1964
1964
1965
1965
1966
1966
1967
1967
1967
1968
1968
1969
1969
1969
YEAR

CHART 3

Green River Discharge Data (station 09234500)

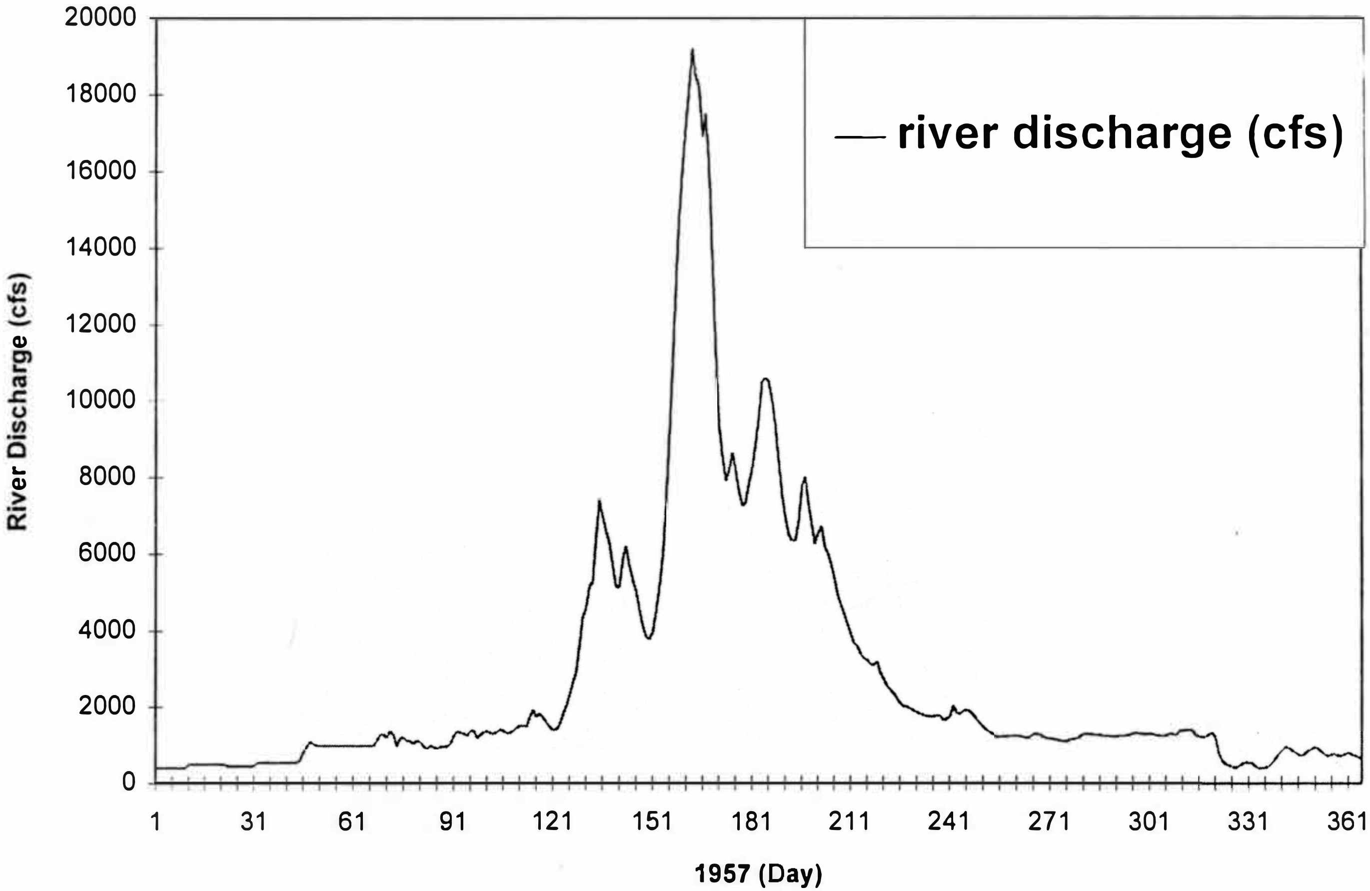


CHART 2

Green River Discharge Data (station 09234500)

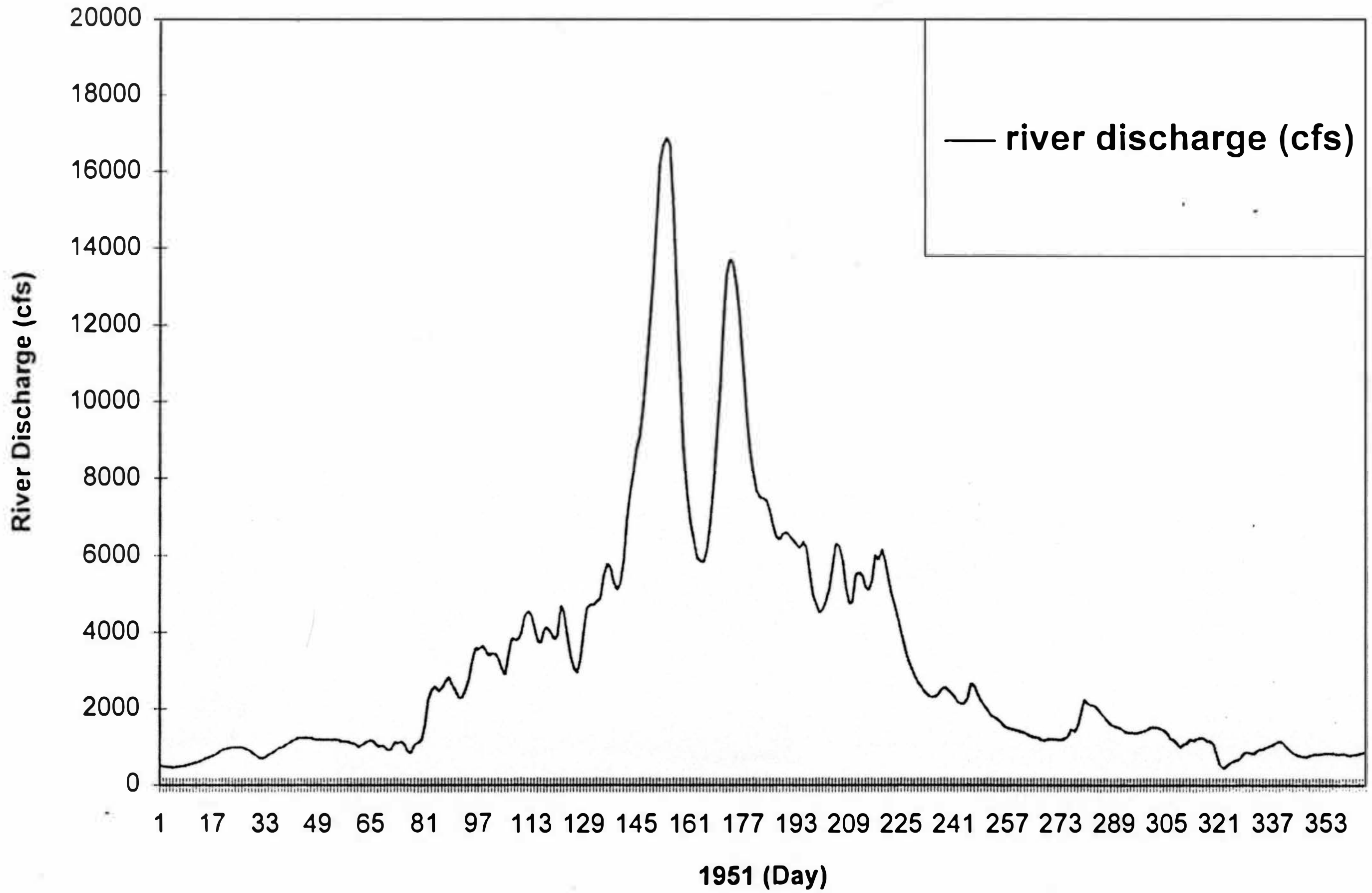
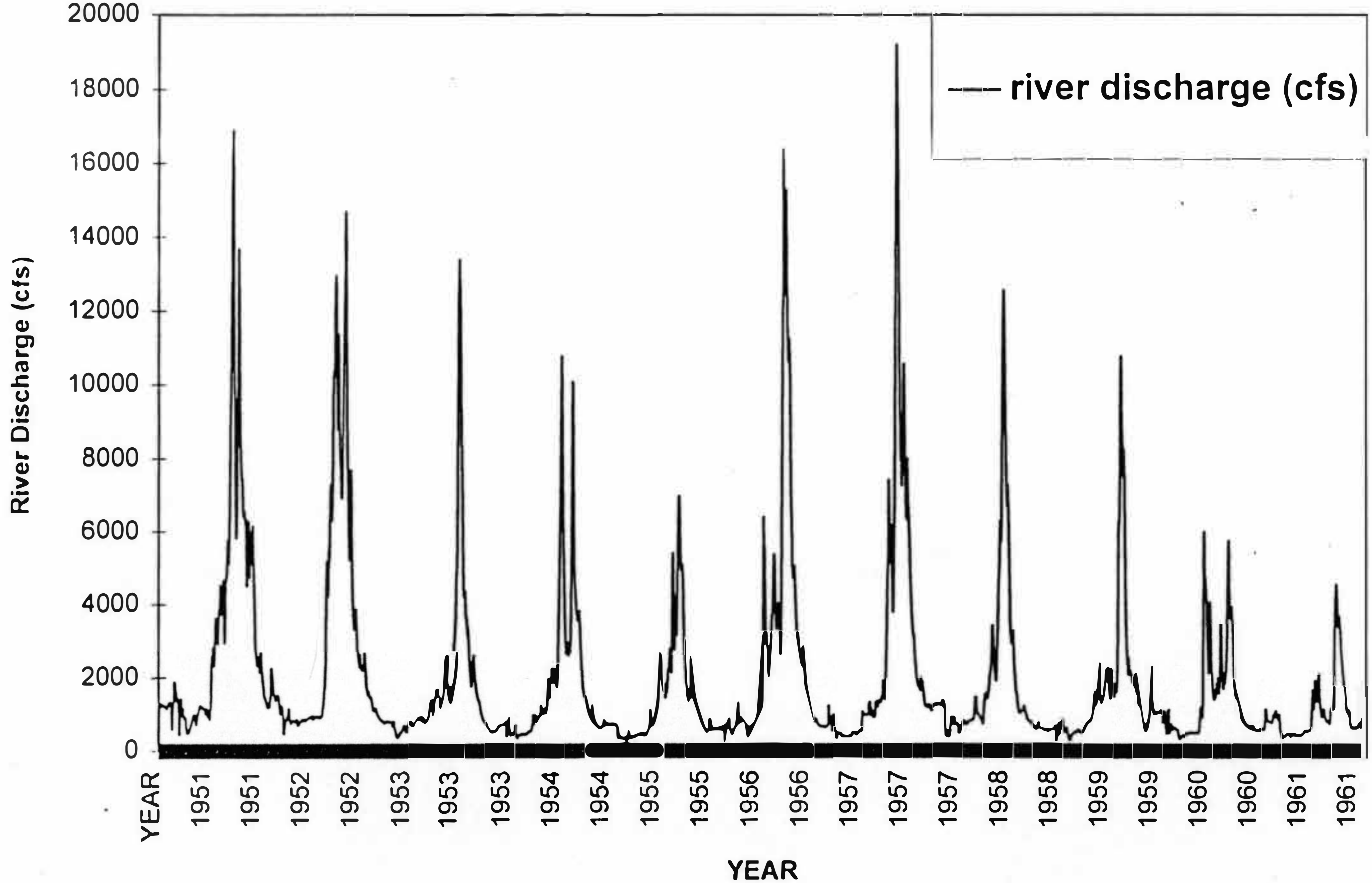


CHART 1

Green River Discharge Data (station 09234500)

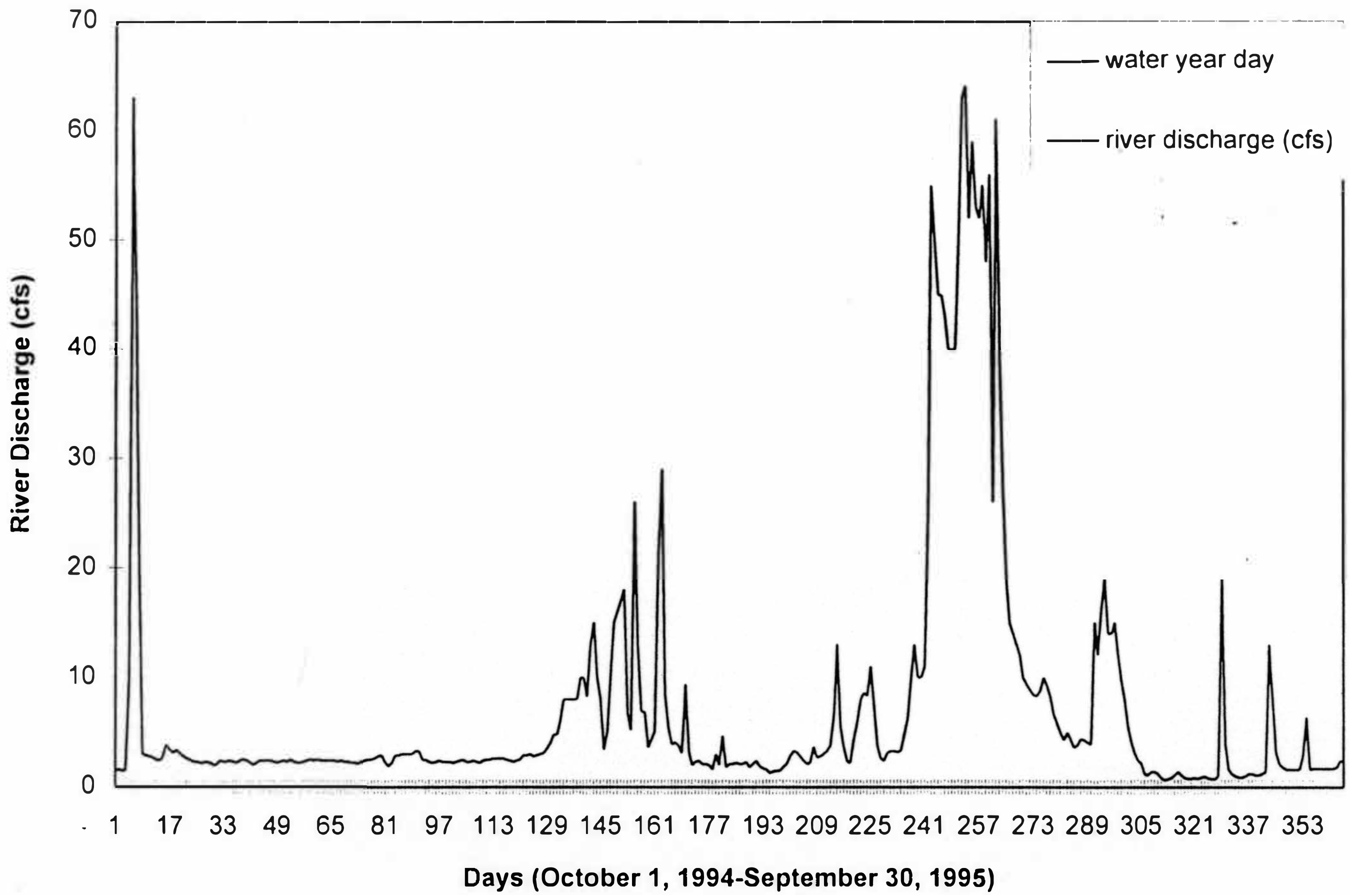


Appendix C

Vermillion Creek Discharge Data

Chart 12

Vermillion Creek Discharge Data (station 09235490)



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