

**CHANNEL MONITORING TO EVALUATE GEOMORPHIC CHANGES
ON THE MAIN STEM OF THE COLORADO RIVER**



Final Report
Recovery Program Project Number 85A

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EXECUTIVE SUMMARY

The 15-mile and 18-mile reaches of the Colorado River in western Colorado provide important habitat for two endangered fishes: the Colorado pikeminnow (*Ptychocheilus lucius*), and the razorback sucker (*Xyrauchen texanus*). Success in recovering these fishes will depend in large part on the maintenance and improvement of existing habitats which have been lost or altered as a result of water-management activities in the upper Colorado River basin. Under certain conditions, reservoir operations can be modified to allow a portion of the spring runoff to bypass reservoirs, boosting peak flows in the 15- and 18-mile reaches. The purpose of this study, therefore, was to assess the geomorphic effects of coordinated reservoir operations, and to develop a better understanding of the timing of sediment supply and sediment transport in the 15- and 18-mile reaches of the Colorado River. The specific objectives of this study were to:

1. Monitor rates of channel change and assess the geomorphic effects of coordinated reservoir releases and normal snowmelt flows.
2. Define the window of time of peak sediment delivery from unregulated tributaries.
3. Verify discharge thresholds for coarse-sediment transport.
4. Examine processes of fine-sediment transport and deposition on the falling limb of the hydrograph.
5. Develop a matrix which can be used by the coordinated reservoir operations group to tailor operations to target multiple objectives of habitat maintenance and creation.
6. Provide data on thresholds and durations of discharges that perform important geomorphic functions so that biologists can integrate this information with biological information and refine flow recommendations as necessary.

Conditions in specific reaches were monitored from 1998-2004 to verify thresholds for sediment transport and to provide additional information on discharges that perform important geomorphic functions. Field measurements focused on geomorphic effects of late spring-early summer flows and seasonal variations in the movement of fine sediment.

Coordinated reservoir operations were implemented for 7 days in 1998, the initial year of this study. Runoff that bypassed reservoirs in 1998 increased daily discharges into the 15-mile reach by a maximum of about 60 m³/s (~2100 ft³/s). Similar procedures were implemented for 10 days in 1999; these flows increased daily discharges in the 15-mile reach by a maximum of about 70 m³/s (~2500 ft³/s). The bypass flows were successful in boosting background discharges by 10-20%, which appeared to be sufficient to mobilize small proportions of the bed in the 15- and 18-mile reaches. Conditions reflecting widespread entrainment and transport of the bed material (complete mobilization) were not evident in 1998 or 1999. The limited availability of water in

subsequent years prevented further tests of the effects of bypass flows. It appears on the basis of these few observations, that the geomorphic effects of 10-20% increases in discharge at these flow levels is difficult to detect at this scale, and techniques other than those used here would be needed to evaluate the impact of bypass flows.

The period from 2000-2004 included two years of severe drought and three other years of below-average precipitation and runoff. Spring runoff during this period was far below average, thus the thresholds for mobilizing cobble- and gravel-sized sediment in the 15- and 18-mile reaches were not exceeded very frequently. Over the 7-year period of the study, the discharge required to produce initial motion (~1/2 the bankfull discharge) was exceeded for a total of 78 days, which is only about 1/3 the frequency recommended in previous reports. The discharge required to completely mobilize the bed (bankfull discharge) was never exceeded.

Geomorphic changes in the 15- and 18-mile reaches were monitored using periodic surveys of main-channel cross sections and backwaters, and comparative analysis of aerial photographs taken in 1993 and 2000. These measurements indicate that, overall, the large-scale morphology of the Colorado River has changed little in the last decade. Vertical and lateral deposition of fine sediment occurred in all of the side channels monitored, however, the changes detected in these features were again relatively minor.

Additional analyses of suspended sediment records from gauging stations in the study area reconfirm the importance of late-spring flows for carrying fine sediment. The analysis indicates that roughly 80% of the sediment carried in suspension consists of silt- and clay-sized particles. Concentrations of suspended sediment at all gauging stations are consistently higher on the rising limb of the hydrograph than they are on the falling limb. Both sediment concentration and water discharge are highest during the late-spring rise in flow, thus the total annual sediment load is dominated by conditions during this period of time (late May-early June). About 20% of the total suspended sediment load consists of sand. This sediment reaches a peak 2-3 weeks after the peak in water discharge, and not far in advance of the typical period of time when Colorado pikeminnow are preparing to spawn. It is not clear that the sand moving at this time of the year represents a problem in an ecological sense. However, it is evident that sand has the potential to move either in suspension or in contact with the bed, with the threshold in transport mode occurring at flows between 125 and 150 m³/s (4400-5300 ft³/s).

Intensive field measurements, coupled with results from a one-dimensional hydraulic model, were used to assess variations in flow properties with discharge in a 0.8-km study reach. Field measurements within the reach indicate that there is a relatively abrupt transition in the water-surface width and wetted area of the channel between discharges of 125 and 175 m³/s (4400-6200 ft³/s). At discharges < 125 m³/s most of the flow is confined to the baseflow channel, and more than half the channel perimeter is dry. At discharges > 125 m³/s flow begins to cover low-

lying bar surfaces; width increasing steadily from there until $\sim 280 \text{ m}^3/\text{s}$ ($10,000 \text{ ft}^3/\text{s}$) when most of the channel bed is inundated. This discharge is consistent with flow-modeling results indicating that the threshold for initial motion of the gravel and cobble bed material in this reach is exceeded at a discharge of $286 \text{ m}^3/\text{s}$ ($10,100 \text{ ft}^3/\text{s}$). That value is within 3% of the value recommended in previous reports. Adjusting the model results to account for spatial variations in grain size increases the threshold slightly, indicating there is very little movement of cobble- and gravel-sized sediment within the reach at flows less than $300 \text{ m}^3/\text{s}$ ($\sim 10,600 \text{ ft}^3/\text{s}$).

The results discussed in this report are consistent with the results presented in previous reports, therefore, all of the previous flow recommendations are retained. It is assumed that periodic entrainment of the bed material of the Colorado River is important for maintaining habitats used by native fishes and other aquatic organisms. Periodic entrainment is also important for limiting the growth of non-native vegetation, especially tamarisk, thereby maintaining an active channel with some morphologic complexity and habitat heterogeneity. Finally, it is assumed that the mass balance of sediment carried by the Colorado River must be maintained over the long run, otherwise there will be continued narrowing and simplification of the channel, with further loss of in-channel habitats.

Coordinated reservoir operations can assist in providing higher flows to achieve these purposes. While it is not easy to quantify the effects of 10-20% increases in discharge, especially with low-cost techniques such as those used here, there is little question that sediment transport efficiency increases as discharge increases. Bypasses should be coordinated, therefore, to take advantage of the nonlinear relation between flow and sediment transport rate, and reservoir operations should be tailored to boost peak flows by as much as possible within the shortest time. In other words the objective from a geomorphic standpoint should be to maximize the peak, rather than extend the duration of a lower moderate flow. The coordinated reservoir operations program should be continued and expanded, and the Recovery Program should pursue the recommendation given in the Coordinated Facilities Operation Study to augment spring flows by another 20,000 acre-ft, above the releases generated by coordinated reservoir operations.

If channel monitoring is to continue in the future, the most cost-effective means for assessing the geomorphic effects of bypass flows is to develop more detailed hydrodynamic models of flow and sediment transport in the reaches of interest. As part of this work the Recovery Program may wish to consider funding additional sediment studies focusing on seasonal trends in the movement of sand-sized sediment. With additional support, the USGS could expand their data collection activities at the Palisade and State Line gauges to include measurements of both the concentration and grain size of the suspended load. Measurements of bed load would likewise be useful, however, it may take several years of intensive sampling before an accurate bed load rating curve can be developed for application in this setting.

Recommendations for flows that perform important geomorphic functions are as follows:

A. Category: Bankfull Discharge

15-Mile Reach: 608 m³/s (21,500 ft³/s)

18-Mile Reach: 979 m³/s (34,600 ft³/s)

Purpose: Flows that reach or exceed the bankfull discharge are capable of mobilizing most of the framework particles forming the river bed. Entrainment of cobble- and gravel-sized sediment is necessary for maintaining clean substrates, especially in frequently used habitats such as riffles and runs; removal of interstitial fine sediment also improves habitat for benthic invertebrates and other native fishes. Periodic mobilization of the substrate is required to change channel morphology and maintain habitat complexity. Flows exceeding bankfull inundate the floodplain in selected areas. Overbank flows entrain organic matter from the floodplain, thus providing nutrients to stimulate primary productivity. Bankfull flows should occur with sufficient frequency (see below) to maintain the mass balance of sediment, so as to limit deposition in secondary channels, prevent further narrowing of the main channel and limit the growth of non-native vegetation on low-lying gravel bars.

Duration: 5 days per year, averaged over a period of no more than three years

Frequency: No less than one out of every three years

B. Category: Discharge for Initial Motion (approximately one-half the bankfull discharge)

15-Mile Reach: 278 m³/s (9,800 ft³/s)

18-Mile Reach: 548 m³/s (19,400 ft³/s)

Purpose: Flows equal to one-half the bankfull discharge produce limited entrainment and transport of cobble- and gravel-sized sediment. Silt- and sand-sized sediment that forms a veneer on the bed surface can be brought into suspension, however, entrainment and flushing of fines from the pore spaces (interstices) within the substrate is limited. At this discharge most low-lying bars are covered with a substantial depth of water (many 10s of centimeters), thus most of the bed is inundated. At these flows small numbers of framework grains start to move, and the potential exists to disturb emerging vegetation such as tamarisk. In addition, at this flow level, many secondary channels are inundated, thus the potential exists to flush fine sediment from backwaters.

Duration: at least 30 days per year, averaged over a period of no more than two years

Frequency: No less than one out of every two years

C. Category: Discharge for Suspending Sand in Riffles

15-Mile Reach: 125-150 m³/s (4,400-5,300 ft³/s)

18-Mile Reach: 275-330 m³/s (9,700-11,700 ft³/s)

Purpose: Discharges in this category are recommended to keep sands finer than about 0.5 mm in suspension over riffles. Riffles provide spawning habitat for Colorado Pikeminnow, thus it is important to keep sands from accumulating on the bed on the falling limb of the hydrograph when spawning normally occurs. This recommendation should be considered provisional, to be evaluated with field data over a period of several years.

Duration: 10 days per year, on the receding limb of the annual hydrograph; in typical years, this would occur in the period from late June to early July.

Frequency: Every year

A matrix summarizing the above flow recommendations is given on the following page (Table ES-1). The matrix lists thresholds and durations of discharges that perform important geomorphic functions, and discusses the purposes of different flow levels in terms of the expected geomorphic responses. The matrix can be used by the coordinated reservoir operations group to tailor operations to target multiple objectives of habitat maintenance and creation in alluvial reaches of the Colorado River near Grand Junction.

Table ES-1. Flow matrix for the 15-mile and 18-mile reaches of the Colorado River.

Category	Discharge		Flow Conditions and Intended Purposes
	15-mile	18-mile	
A	608 m ³ /s (21500 ft ³ /s)	979 m ³ /s (34600 ft ³ /s)	<ul style="list-style-type: none"> o Bankfull discharge: This discharge will mobilize cobble- and gravel-sized sediment on most of the channel bed; widespread mobilization of coarse substrates is required to create and maintain the suite of habitats used by native fishes. o Flows leading up to the bankfull discharge transport a large proportion of the total annual sediment load; maintaining the sediment-transport capacity of the river is the key to limiting further channel narrowing and reduction in habitat complexity. o Flows exceeding the bankfull level inundate limited portions of the floodplain; overbank flows entrain coarse particulate organic matter from the floodplain, providing nutrients to stimulate primary productivity.
<p>Duration: 5 days/year, averaged over no more than three years</p> <p>Frequency: No less than one out of every three years</p>			
B	278 m ³ /s (9800 ft ³ /s)	548 m ³ /s (19400 ft ³ /s)	<ul style="list-style-type: none"> o One-half the bankfull discharge: This discharge will mobilize coarse sediment on limited portions of the channel bed; silt and sand deposited on the bed surface can be put into suspension, however, entrainment of fines from within the bed is limited. o This flow inundates most low-lying gravel bars, thus limiting the growth of woody plants, especially tamarisk, that can stabilize channel bars once they become established o Most of the channel perimeter is inundated by this flow; the increase in wetted area provides additional habitat for aquatic organisms, including native forage fishes, and benthic invertebrates.
<p>Duration: at least 30 days/year, averaged over a period of no more than two years</p> <p>Frequency: No less than one out of every two years</p>			
C	125-150 m ³ /s (4400-5300 ft ³ /s)	275-330 m ³ /s (9700-11700 ft ³ /s)	<ul style="list-style-type: none"> o Approximately one-fourth of the bankfull discharge: Discharges in this range are needed to keep fine-medium sand in suspension over riffles. Concentrations of suspended sand appear to reach a peak after the peak in water discharge, roughly at the time of year when Colorado pikeminnow are preparing to spawn. o Riffles provide spawning habitat for Colorado pikeminnow; it is important to keep sand from accumulating on the bed during the period of spawning to increase spawning success. o Sand can move in either in suspension or in contact with the bed; sand moving in contact with the bed moves more slowly through the system, increasing the tendency for fines to accumulate in the bed, potentially limiting native fishes use of riffle and run habitat.
<p>Duration: 10 days per year, on the receding limb of the hydrograph</p> <p>Frequency: Every year</p>			