Appendix B

Colorado River System Facilities and Current River System Operations From Lake Powell to SIB

This appendix describes the dams, reservoirs and river reaches on the mainstream of the Colorado River from Lake Powell to the Southerly International Border with Mexico. This appendix also describes the historical and current operation of those facilities.

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B.1 Natural Runoff and Storage of Water

The Colorado River serves as a source of water for irrigation, domestic, and other uses in the States of Arizona, California, Colorado, Nevada, New Mexico, Utah and Wyoming, and in Mexico. The Colorado River also serves as a source of water for a variety of recreational and environmental uses. The Colorado River Basin is located in the southwestern United States and occupies an area of approximately 250,000 square miles. The Colorado River is approximately 1,400 miles in length and originates along the Continental Divide in Rocky Mountain National Park in Colorado. Elevations in the Colorado River Basin range from sea level to over 14,000 feet above mean sea level (msl) in the mountainous headwaters.

Climate varies significantly throughout the Colorado River Basin. Most of the Colorado River Basin is comprised of arid or semi-arid rangelands, which generally receive less than 10 inches of precipitation per year. In contrast, many of the mountainous areas that rim the northern portion of the Colorado River Basin receive, on average, over 40 inches of precipitation per year. Most of the total annual flow in the Colorado River Basin results from natural runoff from mountain snowmelt. Because of this, natural flow is very high in the late spring and early summer, diminishing rapidly by mid-summer. While flows in late summer through autumn sometimes increase following rain events, natural flow in the late summer through winter is generally low.

Due to variability in climatic conditions, the natural flow in the Colorado River system is highly variable from year to year. In any case, the natural flow of the river represents an estimate of runoff flows that would exist in a natural setting, without storage, alteration or depletion by man. About 86 percent of the Colorado River System annual runoff originates in only 15 percent of the watershed—in the mountains of Colorado, Utah, Wyoming and New Mexico. While the average annual natural flow at the Lees Ferry Compact Point (Lees Ferry) is calculated at approximately 15.1 million acre-feet (maf), annual flows in excess of 23 maf and as little as 5 maf have occurred.

The flow in the Colorado River above Lake Powell reaches its annual maximum during the April through July period. During the summer and fall, thunderstorms occasionally produce additional peaks in the river. However, these flows are usually smaller in volume than the snowmelt peaks and of much shorter duration.

Flows immediately below Glen Canyon Dam consist almost entirely of water released from Lake Powell. Downstream of Glen Canyon Dam, annual river gains from tributaries, groundwater discharge, and occasional flash floods from side canyons average 900,000 acre-feet (af).

Immediately downstream of Hoover Dam, the river flows consist almost entirely of water released from Lake Mead. Downstream of Hoover Dam, the Colorado River gains additional waters from tributaries such as the Bill Williams River and the Gila River, groundwater discharge, and return flows.

Total storage capacity in the Colorado River system is nearly four times the river's average natural flow or about 60 maf. However, the two largest reservoirs in the system, Lake Powell and Lake Mead account for approximately 50 maf of this storage capacity. The various reservoirs that provide storage, their respective capacities and modes of operation, along with the respective river reaches are described in more detail in Section B.2.

Annually, approximately 9 maf are released from Lake Mead to meet the delivery orders of water entitlement holders in the United States and for 1944 Treaty water deliveries to Mexico. Of this amount, some 7.5 maf are entitlements for the Lower Division states (Arizona, California, and Nevada), while the remaining 1.5 maf is delivered to Mexico.

Figure B-1 presents an overview of the historical natural flow calculated at Lees Ferry for 1906 through 2005 (calendar years). The natural flow represents an estimate of the flows that would originate or exist above the Lees Ferry without storage, alteration or depletion by man. This is different than the recorded or historical stream flows that represent actual measured flows. Figure B-2 presents an overview of the historical flows recorded at Lees Ferry for 1922 through 2005.

Figure B-1
Natural Flow of the Colorado River Calculated at Lees Ferry, Arizona
1906 through 2005

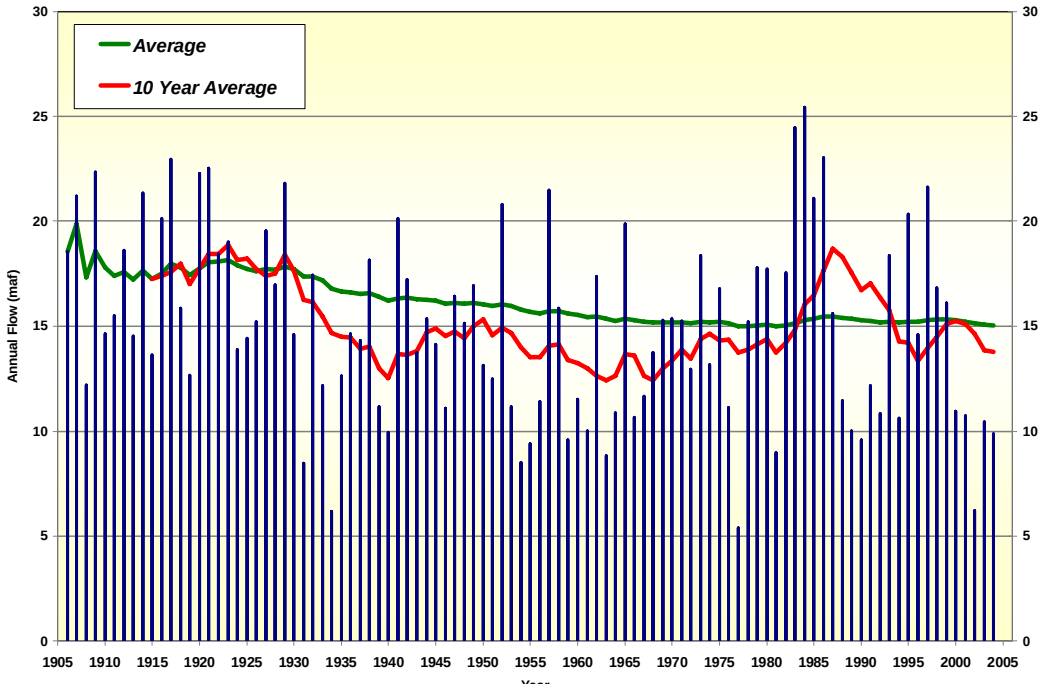
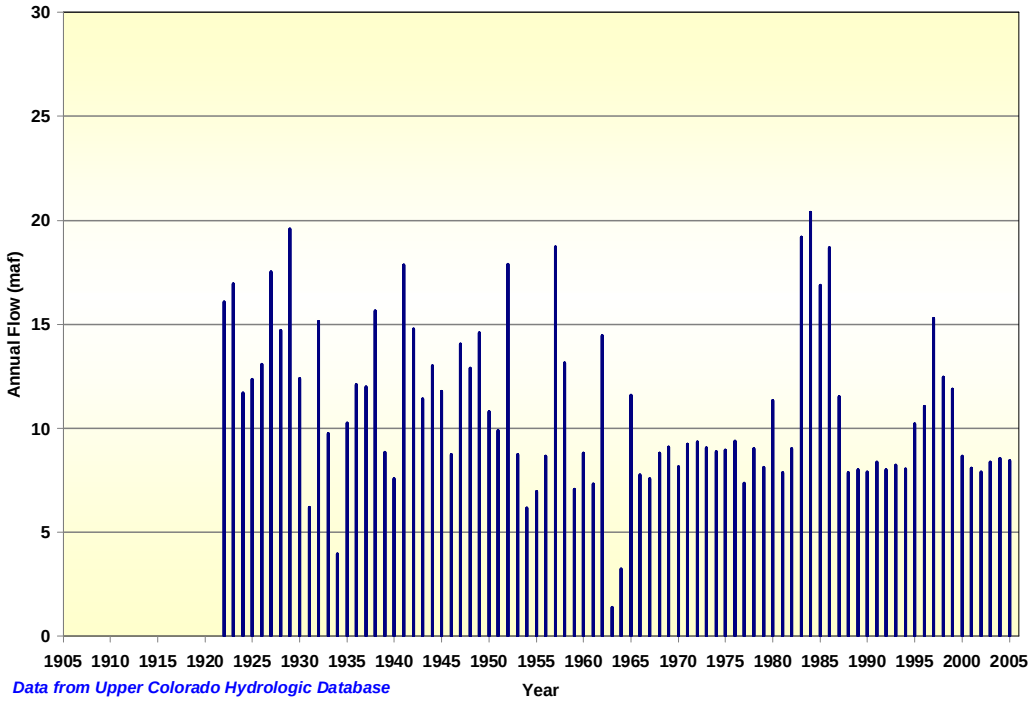


Figure B-2
Historic Annual Flow of the Colorado River Recorded at Lees Ferry, Arizona
1922 through 2005



B.2 Operation of the Colorado River System

The Secretary of the Department of the Interior (Secretary), acting through the Bureau of Reclamation (Reclamation), is vested with the responsibility of managing the mainstream waters of the lower Colorado River pursuant to applicable federal law. This responsibility is carried out consistent with a body of documents referred to as the Law of the River. The Law of the River comprises numerous operating criteria, regulations, and administrative decisions included in federal and state statutes, interstate compacts, court decisions and decrees, an international treaty, and contracts with the Secretary applicable to the allocation, appropriation, development, exportation and management of the waters of the Colorado River Basin. There is no single, universally agreed upon definition of the Law of the River, but it is useful as a shorthand reference to describe this longstanding and complex body of legal agreements governing the management of the Colorado River.

Operation of the Colorado River system and delivery of Colorado River water to the seven Basin States (Arizona, California, Colorado, Nevada, Utah, New Mexico, and Wyoming) and Mexico are conducted in accordance with the Law of the River. Water cannot be released from storage unless there is a reasonable beneficial use for the water. The exceptions to this are releases required for flood control, river regulation, or dam safety. In the Lower Basin, water is released

from the system to satisfy water delivery orders and to satisfy other purposes set forth in the Consolidated Decree entered by the United States Supreme Court in the case of *Arizona v. California*, 547 U.S. 150 (2006) (Consolidated Decree). The principal facilities that were constructed to manage the water in the Colorado River system include Glen Canyon Dam and Hoover Dam.

The Colorado River system is operated by Reclamation pursuant to the Criteria for Coordinated Long-Range Operation of Colorado River Reservoirs Pursuant to the Colorado River Basin Project Act of September 30, 1968 (Long-Range Operating Criteria or LROC) through the issuance of the Annual Operating Plan for Colorado River Reservoirs (AOP). The AOP is required by the Colorado River Basin Project Act of 1968 (CRBPA). The AOP is formulated for the upcoming year under a variety of potential scenarios or conditions. The plan is developed based on projected demands, existing storage conditions, and probable inflows. The AOP is prepared by Reclamation, acting on behalf of the Secretary, in consultation with the Basin States, the Upper Colorado River Commission, Indian tribes, appropriate federal agencies, representatives of the academic and scientific communities, environmental organizations, the recreation industry, water delivery contractors, contractors for the purpose of federal power, others interested in Colorado River operations, and the general public.

Prior to the beginning of the calendar year, Lower Basin diversion schedules are requested from water users entitled to Colorado River water. These schedules are estimated monthly diversions and return flows that allow Reclamation to determine a tentative schedule of monthly releases through the Hoover Powerplant. Actual monthly releases are determined by the demand for water downstream of Hoover Dam, Davis Dam, and Parker Dam. Daily changes in water orders are made to accommodate emergencies, temperature and weather for water orders downstream of Parker Dam.

A minimum of 1.5 maf is delivered annually to Mexico in accordance with the 1944 Treaty. The 1944 Treaty contains provisions for delivery of up to 200,000 af above the 1.5 maf when Lake Mead is in flood control operations and there exists water in excess of that necessary to satisfy the uses in the United States and the guaranteed quantity of 1.5 maf to Mexico. Additionally, excess flows above the 200,000 af may become available to Mexico coincident with Lake Mead flood control releases and Gila River flood flows provided that the reasonable beneficial uses of the Lower Division states have been satisfied.

The Colorado River from Hoover Dam to the Southerly International Boundary with Mexico (SIB) is contained within the shallow Colorado River Valley in which Lake Mohave, Lake Havasu and other smaller diversion reservoirs are located. Within this segment, especially along river reaches below Parker Dam, the Colorado River is fringed with riparian vegetation and marshy backwaters, and contains a number of diversion dams and a system of levees. The northern reach of this segment, including Lake Mohave, lies within the Lake Mead National Recreation Area (LMNRA). The lower reach is bordered by a combination of federal, Tribal and private land. The last 23.7 miles is along the international border with Mexico. Reclamation retains authority and discretion for river operations in the reaches of this segment.

Under the Boulder Canyon Project Act of 1928 (BCPA) and the Decree, releases from Hoover Dam are governed by orders for downstream water deliveries to Arizona, California, Nevada, and Mexico. However, releases may exceed orders when flood releases are required under the United States Army Corps of Engineers' (USACE) flood control criteria, or for other purposes consistent with the BCPA and the Consolidated Decree.

B.2.1 Lake Powell and Glen Canyon Dam

Lake Powell is a large reservoir on the Colorado River formed by Glen Canyon Dam. The reservoir is narrow and over 100 miles long. Lake Powell provides water storage for use in meeting delivery requirements of the Upper Basin to the Lower Basin.

The normal operating range of Lake Powell is between elevations 3,490 feet msl and 3,700 feet msl. Elevation 3,490 feet msl corresponds to the minimum power pool. Releases from Glen Canyon Dam can be made below 3,490 feet msl down to elevation 3,370 feet msl via the river bypass tubes. Elevation 3,700 feet msl corresponds to the top of the spillway radial gates. During floods, the elevation of Lake Powell can go above 3,700 feet msl by raising the radial spillway gates, resulting in spillway releases. In 1983, Lake Powell reached a high elevation of 3,708.34 feet msl. Lake Powell is located within the Glen Canyon National Recreation Area (GCNRA), which is administered by the National Park Service (NPS). Reclamation retains authority and discretion for the operation of Glen Canyon Dam and Lake Powell.

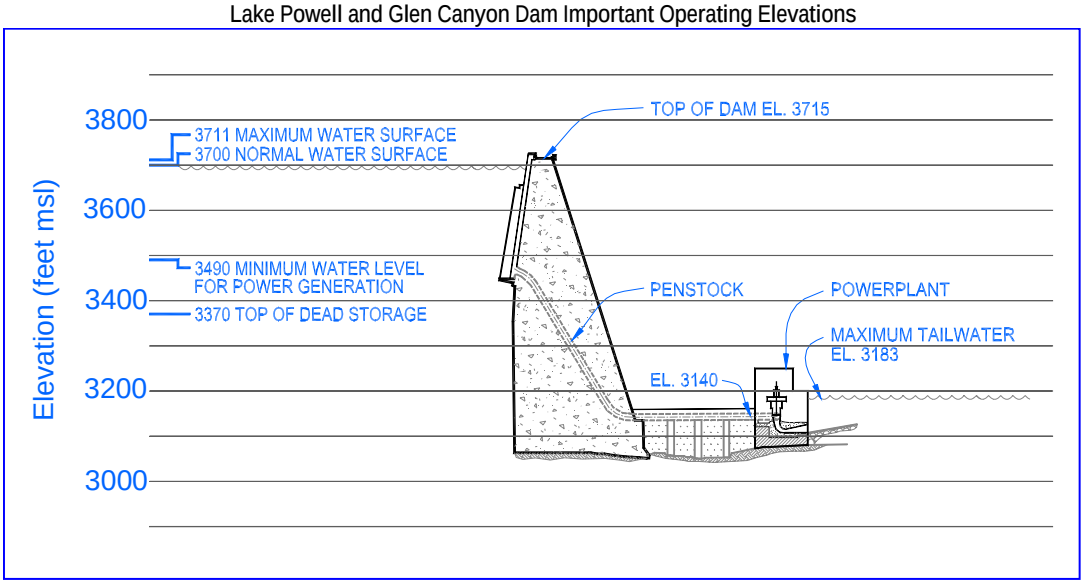
B.2.1.1 Dam and Reservoir Configuration

Glen Canyon Dam is a concrete arch dam rising approximately 700 feet above the level of the Colorado River streambed. A profile of the dam is depicted on Figure B-3. Except during flood conditions, the "full reservoir" water level is 3,700 feet msl, corresponding to the top of the spillway gates. Under normal operating conditions, releases from Glen Canyon Dam are made through Glen Canyon Powerplant by means of gates on the upstream face of the dam. The minimum reservoir elevation at which hydroelectric power can be generated is 3,490 feet msl. Releases in excess of the powerplant capacity may be made when flood conditions are caused by high runoff in the upstream portion of the Colorado River Basin, or when needed to provide Beach/Habitat-Building Flows (BHBF) downstream of the dam.

There are four river outlets at Glen Canyon Dam, comprising 96-inch diameter steel pipes with hollow-jet valves for regulation, each with a capacity of 3,750 cubic feet per second (cfs). The release rate is controlled by the hollow-jet valves from elevation 3,500 feet msl to 3,700 feet msl. At elevation 3,700 feet msl, a hollow-jet valve opening of 79 percent produces the 3,750 cfs. At elevation 3,500 feet msl, the hollow-jet valve must be fully opened to achieve 3,750 cfs.

At elevations below 3,500 feet msl, with the hollow-jet valve fully opened, the flow is reduced below 3,750 cfs as the head is lowered. At elevation 3,490 feet msl, for instance, one river outlet with the hollow-jet valve fully opened will release about 3,660 cfs. At elevation 3,460 feet msl, one river outlet will release about 3,380 cfs. An annual release of 8.23 maf equates to a continuous release of 11,368 cfs. With all four river outlets in service, this release can be achieved down to about elevation 3,440 feet msl. At this elevation, the release capacity from the four river outlets is approximately 11,440 cfs (2,860 cfs per unit).

Figure B-3
Lake Powell and Glen Canyon Dam Important Operating Elevations



B.2.1.2 Operation of Glen Canyon Dam

Flows below Glen Canyon Dam are influenced by storage and release decisions that are scheduled and implemented on an annual, monthly and hourly basis from Glen Canyon Dam.

The annual volume of water released from Glen Canyon Dam is made according to the provisions of the LROC that includes a minimum objective release of 8.23 maf, storage equalization between Lake Powell and Lake Mead under prescribed conditions, and the avoidance of spills. Annual releases from Lake Powell greater than the minimum occur if Upper Basin storage is greater than the storage required by Section 602(a) of the CRBPA, and if the storage in Lake Powell is greater than the storage in Lake Mead. Annual release volumes greater than the minimum objective of 8.23 maf are also made to avoid anticipated spills.

Monthly operational decisions are generally intermediate targets needed to systematically achieve the annual operating requirements. The actual volume of water released from Lake Powell each month depends on the forecast inflow, storage targets and annual release requirements described above. Demand for energy is also considered and accommodated as long as the annual release and storage requirements are not affected.

The National Weather Service's Colorado Basin River Forecast Center (CBRFC) provides the monthly forecasts of expected inflow into Lake Powell and other Upper Basin reservoirs. The CBRFC uses a satellite-telemetered network of hundreds of data collection points within the Upper Basin that gather data on snow water content, precipitation, temperature and streamflow. Telemetry data is input into regression and real-time conceptual computer models to derive an inflow forecast. Reclamation's future release volumes are based on these derived forecasts. Particular attention is paid to April through July forecast which historically has the most impact on the hydrology of the region. Due to the variability in climatic conditions, modeling and data errors, these forecasts are based, in part, on large uncertainties. The greatest period of uncertainty occurs in early winter and decreases as the snow accumulation period progresses into the snowmelt season, often forcing modifications to the monthly schedule of releases.

An objective in the operation of Glen Canyon Dam is to attempt to safely fill Lake Powell each summer. When carryover storage from the previous year in combination with forecast inflow allows, Lake Powell is targeted to reach a storage of about 23.8 maf in July (0.5 maf from full pool). In years when Lake Powell fills or nearly fills in the summer, releases in the late summer and early winter are generally made to lower the reservoir elevation, so that there is at least 2.4 maf of vacant space in Lake Powell on January 1. Storage targets are always reached in a manner consistent with the LROC.

Glen Canyon Dam is operated consistent with the 1996 Glen Canyon Dam Record of Decision (ROD) (62 C.F.R. pt. 9447-9448) developed as directed under the Grand Canyon Protection Act of 1992. The 1996 Glen Canyon Dam ROD describes criteria for dam operations and includes other measures to ensure Glen Canyon Dam is operated in a manner consistent with the Grand Canyon Protection Act of 1992. Among these are an Adaptive Management Program (AMP), BHBFs, and further study of temperature control. Scheduling of BHBF releases from Glen Canyon Dam are discussed in Section B.2.2. The daily and hourly release constraints of Glen Canyon Dam are as provided in Table B-1.

Table B-1
Glen Canyon Dam Release Constraints

Parameter	Flow Rate (cfs)	Conditions
Maximum Flow[1]	25,000	
Minimum Flow	5,000	Nighttime
	8,000	7:00 a.m. to 7:00 p.m.
Ramp Rates		
Ascending	4,000	Per hour
Descending	1,500	Per hour
Daily Fluctuations[2]	5,000 to 8,000	

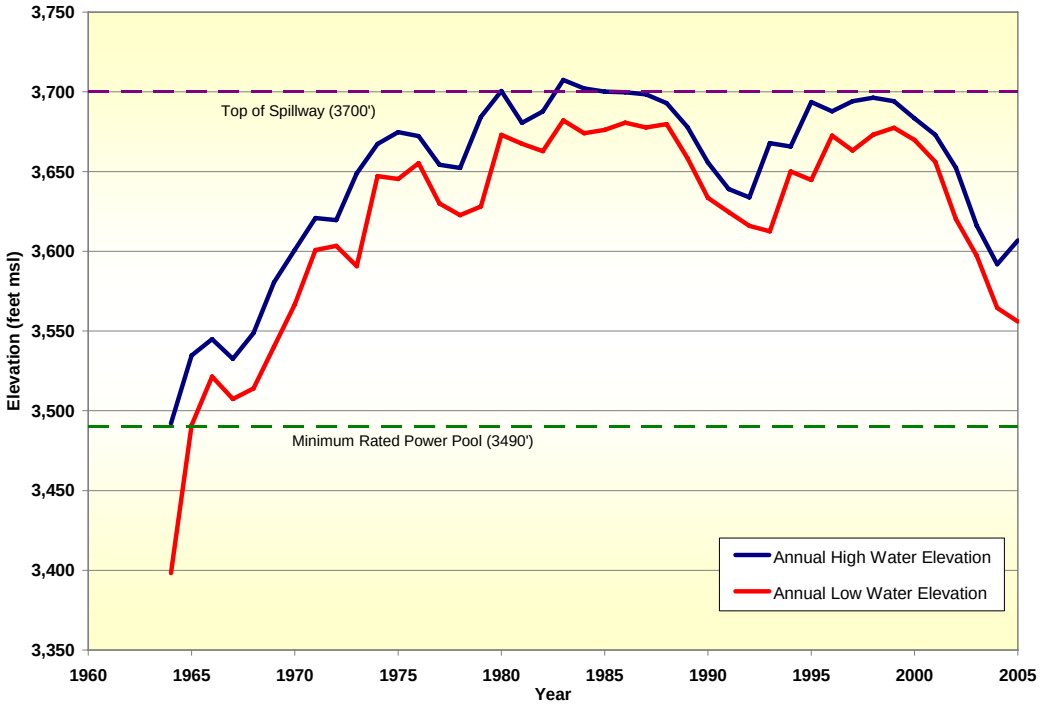
[1] *To be evaluated and potentially increased as necessary and in years when delivery to Lower Basin exceeds 8.23 maf.*

[2] *Daily fluctuation limit is 5,000 cfs for months with release volumes less than 0.6 maf; 6,000 cfs for monthly release volumes of 0.6 maf to 0.8 maf; and 8,000 cfs for monthly volumes over 0.8 maf.*

B.2.1.3 Historic Lake Powell Elevations

Glen Canyon Dam and Lake Powell were designed to operate from a normal maximum elevation of 3,700 feet msl to a minimum elevation of 3,490 feet msl, the minimum for hydroelectric power production. During flood conditions, the elevation of Lake Powell can exceed 3,700 feet msl by raising and adding additional supported panels to the spillway radial gates. Since first reaching equalization storage with Lake Mead in 1974, Lake Powell's elevation has fluctuated from a high of 3,708 feet msl to a low of approximately 3,555 feet msl, as illustrated on Figure B-4.

Figure B-4
Historic Lake Powell Elevations
(Annual Highs and Lows)



B.2.2 Glen Canyon Dam to Lake Mead

The segment of the Colorado River between Glen Canyon Dam and Lake Mead is comprised of a narrow river corridor through the Grand Canyon that is administered primarily by the Grand Canyon National Park.[1] Flows within this reach of the river consist primarily of releases from Glen Canyon Dam as discussed in Section B.2.1.

Issues that may need to be reconsidered within this segment of the river are those associated with a revised program of low steady summer flows and BHBF releases, as well as the ongoing temperature control studies.

B.2.2.1 River Flows between Glen Canyon Dam and Lake Mead

Colorado River flows between Glen Canyon Dam and Lake Mead are a result of controlled releases from Glen Canyon Dam (Lake Powell) and include gains from tributaries in this reach of the river. Releases from Glen Canyon Dam are managed as discussed in Section B.2.1. The most significant gains from tributaries include inflows from the Little Colorado River (approximately 315 miles long) that provides the principal

[1] The 15.9 mile reach between Glen Canyon Dam and Lees Ferry is managed by the Glen Canyon National Recreation Area.

drainageway for the Painted Desert, and the Paria River (approximately 75 miles long) which drains the rugged and arid region northwest of the Colorado River. However, inflows from these perennial streams is concentrated over very short periods of time, and on average, make up approximately two percent of the total annual flow in this reach of the river.

B.2.2.2 Glen Canyon Dam Releases and the Adaptive Management Program

A function of Glen Canyon Dam operations is to maximize power generation. However, power generation was found to be having a negative impact on downstream resources. Realizing the occurrences of such impacts, the Secretary determined in July 1989 that an Environmental Impact Statement (EIS) should be prepared. The *Operation of Glen Canyon Dam EIS* developed and analyzed alternative operation scenarios that met statutory responsibilities for protecting downstream resources and achieving other authorized purposes, while protecting Native American interests. A final EIS was completed in March 1995, and the Secretary signed a ROD on October 8, 1996. Reclamation also consulted with the United States Fish and Wildlife Service (FWS) under the Endangered Species Act of 1973, as amended (ESA) and incorporated FWS's recommendations into the 1996 Glen Canyon Dam ROD. Glen Canyon Dam operates under the 1996 Glen Canyon Dam ROD (Section B.2.1).

The AMP provides a process for assessing the effects of current operations of Glen Canyon Dam on downstream resources, and using the results of these assessments for developing recommendations that in turn can be used to modify operating criteria and other resource management actions. This is accomplished through the Adaptive Management Work Group (AMWG), a federal advisory committee. The AMWG consists of stakeholders that are federal and state resource management agencies, representatives of the seven Basin States, Indian Tribes, hydroelectric power marketers, environmental and conservation organizations and recreational and other interest groups. The duties of the AMWG are in an advisory capacity only. Coupled with this advisory role are long-term monitoring and research activities that provide a continual record of resource conditions and new information to evaluate the effectiveness of the operational modifications.

BHBF and Beach Habitat Maintenance Flow (BHMF) releases are scheduled high releases of short duration that are in excess of power plant capacity required for dam safety purposes and are made according to certain specific criteria. These BHBFs are designed to rebuild high elevation sandbars, deposit nutrients, restore backwater channels, and provide some of the dynamics of a natural system. The first test of a BHBF was conducted in the spring of 1996.

BHFMs releases are releases at or near power plant capacity, which are intended to maintain favorable beach and habitat conditions for recreation and fish and wildlife, and to protect Tribal interests. BHMF releases can be made in years when no BHBF releases are made.

Both BHBFs and BHMFs, along with the testing and evaluation of other types of releases under the AMP, were recommended by FWS to verify a program of flows that would improve habitat conditions for endangered fish. The proposed shortage guidelines and action alternatives could affect the range of storage conditions in Lake Powell and alter the flexibility to schedule and conduct such releases or to test other flow patterns.

In 1994, FWS issued a *Biological Opinion on the Operation of Glen Canyon Dam* (Biological Opinion). One of the elements of the reasonable and prudent alternative in the Biological Opinion, also a common element in the Glen Canyon Dam EIS, was the evaluation of methods to control release temperatures and, if viable, implement controls. Reclamation agreed with this recommendation and included it in the *Operation of Glen Canyon Dam Final Environmental Impact Statement* and subsequent ROD.

Reclamation has also recently initiated planning activities that will consider possible modifications to Glen Canyon Dam for controlling downstream temperatures. The investigations associated with these planning activities are very preliminary and significant information is currently not available to report on this planning process.

In addition, on September 1, 2006, Reclamation and the Center for Biological Diversity, Arizona Wildlife Federation, Living Rivers, Sierra Club – Grand Canyon Chapter, and Glen Canyon Institute entered into a settlement agreement whereby Reclamation agreed to assess the impacts of current and modified operations of Glen Canyon Dam on the Humpback Chub, Bonytail Chub, Razorback Sucker and Colorado Pikeminnow. Reclamation plans to conduct further related environmental studies and anticipates that it will prepare an EIS by October 15, 2008.

B.2.3 Lake Mead and Hoover Dam

Lake Mead is a large reservoir on the Colorado River formed by Hoover Dam. The reservoir provides water storage for use in regulating the water supply and meeting delivery requirements in the Lower Basin. The normal operating range of the reservoir is between elevations 1,219.61 feet msl and 1,050 feet msl. Elevation 1,050 feet msl corresponds to the minimum power-pool of Hoover Dam Powerplant. Releases can be made from Hoover Dam below elevation 1,050 feet msl down to 895 feel msl via the intake towers. During floods, the elevation of Lake Mead can go above 1,219.61 feet msl. The top of the raised spillway gates is at elevation 1,221.0 feet msl. Since its initial filling in the late 1930s, the reservoir elevation has fluctuated from a high of 1,225.85 feet msl (as occurred in July 1983) to a low of 1,083.21 feet msl (as occurred in April 1956).

The reservoir is located within the LMNRA, which is administered by the NPS. However, Reclamation retains authority and discretion for the operation of Hoover Dam and Lake Mead.

The Las Vegas Wash is the primary channel through which the Las Vegas Valley's excess water returns to Lake Mead. The water flowing through the wash comprises less than two

percent of the water in Lake Mead and consists of urban runoff, shallow groundwater, stormwater, and releases from the valley's three water reclamation facilities.

The lower wash stretches 12 miles from the southeast part of the Las Vegas Valley to Lake Mead, entering the lake at Las Vegas Bay. Its once-plentiful wetlands helped polish urban flows on their way to Lake Mead. However, erosion in the wash has reduced wetlands acreage from a peak of approximately 2,000 acres to about 200 acres.

B.2.3.1 Dam and Reservoir Configuration

Hoover Dam and Lake Mead are operated with the following three main priorities:

1) river regulation, improvement of navigation, and flood control;

2) irrigation and domestic uses, including the satisfaction of present perfected water rights; and

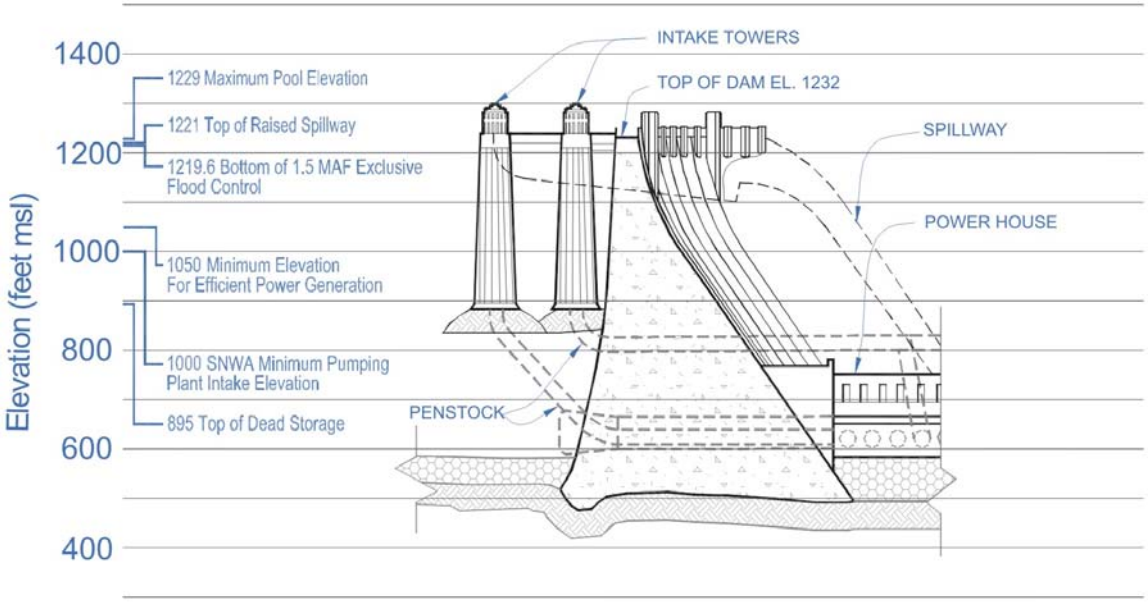
3) power.

The BCPA specified flood control as the project purpose having first priority for operation of Hoover Dam and Lake Mead.

Hoover Dam is the northernmost Reclamation facility on the lower Colorado River and along with Lake Mead it is located at River Mile 342.2. Hoover Dam provides flood control protection and Lake Mead provides the majority of the storage capacity for the Lower Basin as well as significant recreation opportunities. Lake Mead storage capacity is currently estimated to 27.38 maf at a maximum elevation of 1,229.0 feet msl. At this elevation, Lake Mead's water surface area would equal 163,000 acres. The dam's four intake towers draw water from the reservoir at elevations above 895 feet msl to drive 17 generators within the dam's powerplant. The minimum elevation for effective power generation is 1,050 feet msl.

Flood control regulations for Lake Mead were established to manage potential flood events arising from rain and snowmelt. Lake Mead's uppermost 1.5 maf of storage capacity, between elevations 1,219.61 feet msl and 1,229.0 feet msl, is defined as exclusive flood control. Within this capacity allocation, 1.218 maf of flood storage is above elevation 1,221.40 feet msl, the top of the raised spillway gates. Figure B-5 illustrates some of the important Hoover Dam and Lake Mead elevations that are referenced in subsequent sections.

Figure B-5
Lake Mead and Hoover Dam Important Operating Elevations



Lake Mead usually is at its maximum water level in November and December. If required, system storage space-building is achieved between the period of August 1 to January 1. Hoover Dam storage space-building releases are limited to 28,000 cfs, while the mean daily releases to meet the water delivery orders of Colorado River water entitlement holders and power users normally range between 8,000 cfs to 18,000 cfs.

In addition to controlled releases from Lake Mead to meet water supply and power requirements, water is also diverted from Lake Mead at SNWA's Saddle Island intake facilities, Boulder City's Hoover Dam intake, and the Basic Management, Inc.'s (BMI) intake facility for use in the Las Vegas area for domestic purposes by SNWA, BMI and other users.

The diversions by SNWA at its Saddle Island intake facilities entail pumping the water from the intake to SNWA's water transmission facilities for treatment and further conveyance to the greater Las Vegas area and Boulder City. SNWA has low intake facilities. The elevation of the original SNWA intake is approximately 1,000 feet msl. However, the minimum required Lake Mead elevation necessary to operate the pumping units at SNWA's original intake facility is 1,050 feet msl. A second SNWA intake was constructed more recently and it has a second pumping plant with an intake elevation of 950 feet msl. The minimum required Lake Mead elevation necessary to operate the pumping units at SNWA's second intake facility is 1,000 feet msl. The second SNWA intake provides only a portion of the capacity required by SNWA to meet its Lake Mead water supply needs. Therefore, the intake elevation of SNWA's original pumping plant is critical to its ability to divert its full Colorado River water entitlement.

B.2.3.2 Operation of Hoover Dam

Hoover Dam is managed to provide at least 7.5 maf annually for consumptive use by the Lower Division states plus the United States' Colorado River water supply obligation to Mexico pursuant to the 1944 Treaty. Hoover Dam releases are managed on an hourly basis to maximize the value of generated power by providing peaking during high-demand periods. This results in fluctuating flows below Hoover Dam that can range from 1,000 cfs to 49,000 cfs. The upper value is the maximum flow-through capacity through Hoover Dam Powerplant (49,000 cfs). However, because these flows enter Lake Mohave downstream, the affected zone of fluctuation is only a few miles because these flows are regulated in Lake Mohave.

Releases of water from Hoover Dam may also be affected by the Secretary's determinations relating to Normal, Surplus or Shortage Conditions (Section 4.4 of this Final EIS). Another type of release includes flood control releases. For Hoover Dam, flood control releases are defined in this Final EIS as releases in excess of downstream demands.

Flood control was specified as a primary project purpose by the BCPA, the act authorizing Hoover Dam. The USACE is responsible for developing the Flood Control Operation Plan for Hoover Dam and Lake Mead as indicated in 33 C.F.R. pt. 208.11. The Flood Control Operation Plan is the result of a coordinated effort by the USACE and Reclamation. However, the USACE is responsible for providing the flood control regulations and has authority for final approval of the flood control operation plan. Any deviations from the flood control operating instructions provided by the flood control operation plan must be authorized by the USACE. The Secretary is responsible for operating Hoover Dam in accordance with these regulations.

Lake Mead's uppermost 1.5 maf of storage capacity, between elevations 1,219.61 feet msl and 1,229.0 feet msl, is defined as exclusive flood control space. Within this capacity allocation, 1.218 maf of flood storage is above elevation 1,221.0 feet msl, which is the top of the raised spillway gates.

Flood control regulations specify that once Lake Mead flood releases exceed 40,000 cfs, the releases shall be maintained at the highest rate until the reservoir drops to elevation 1,221.0 feet msl. Releases may then be gradually reduced to 40,000 cfs until the prescribed seasonal storage space is available.

The regulations set forth two primary criteria for flood control operations related to snowmelt: 1) preparatory reservoir space requirements; and 2) application of runoff forecasts to determine releases.

In preparation for each annual season of snow accumulation and associated runoff, progressive expansion of total Colorado River system reservoir space is required during the latter half of each year. Minimum available flood control space increases from 1.5 maf on August 1 to 5.35 maf on January 1. Required flood storage space can be accumulated within Lake Mead and upstream in Lake Powell, Navajo, Blue Mesa,

Flaming Gorge and Fontenelle reservoirs. The minimum space required to be reserved exclusively for flood control storage in Lake Mead is 1.5 maf. Table B-2 presents the amount of required flood storage space within the Colorado River system by date:

Table B-2
Minimum Required Colorado River System Storage Space

Date	Storage Volume (maf)
August 1	1.50
September 1	2.27
October 1	3.04
November 1	3.81
December 1	4.58
January 1	5.35

Normal space-building releases from Lake Mead to meet the required August 1 to January 1 flood control space are limited to a maximum of 28,000 cfs. Releases in any month based on water entitlement holders' demand are much less than 28,000 cfs (on the order of 20,000 cfs or less).

Between January 1 and July 31, flood control releases, based on forecast inflow, may be required to prevent filling of Lake Mead beyond its 1.5 maf minimum space requirement. Beginning on January 1 and continuing through July, the CBRFC issues monthly runoff forecasts. These forecasts are used by Reclamation in estimating releases from Hoover Dam. The release schedule contained in the USACE regulations is based on increasing releases in six steps listed in Table B-3.

Table B-3
Minimum Flood Control Releases at Hoover Dam

Step	Flow Rate (cfs)
Step 1	0
Step 2	19,000
Step 3	28,000
Step 4	35,000
Step 5	40,000
Step 6	73,000

The lowest step, zero cfs, corresponds to times when the regulations do not require flood control releases. Hoover Dam releases are then made to meet water and power objectives. The second step, 19,000 cfs, is based on the Parker Powerplant capacity. The third step, 28,000 cfs, corresponds to Davis Powerplant's capacity. In recent years both Parker and Davis Powerplants have undergone an upgrading program to improve the efficiency of the individual powerplants. The current maximum releases are slightly higher for both the Parker Powerplant and Davis Powerplant outputs, as follows: 22,000 cfs and 31,000 cfs, respectively. The fourth step in the USACE release schedule is 35,000 cfs. This flow

corresponds to the powerplant flow-through capacity of Hoover Dam in 1987. However, the present powerplant flow-through capacity at Hoover Dam is 49,000 cfs. At the time Hoover Dam was completed, 40,000 cfs was the approximate maximum flow from the dam considered to be non-damaging to the downstream streambed. The 40,000 cfs flow now forms the fifth step. Releases of 40,000 cfs and greater would result from low-probability hydrologic events. The sixth and final step in the series (73,000 cfs) is the maximum controlled release from Hoover Dam that can occur without spillway flow.

Flood control releases are required when forecast inflow exceeds downstream demands, available storage space at Lake Mead and Lake Powell and allowable space in other Upper Basin reservoirs. This includes accounting for projected bank storage and evaporation losses at both lakes, plus net withdrawal from Lake Mead by the SNWA. The USACE regulations set the procedures for releasing the volume that cannot be impounded, as discussed above.

Average monthly Hoover Dam releases are determined early in each month and apply only to the current month. The releases are progressively revised in response to updated runoff forecasts and changing reservoir storage levels during each subsequent month throughout the January 1 through July 31 runoff period. If the reservoirs are full, drawdown is accomplished to vacate flood control space as required. Unless flood control is necessary, Hoover Dam is operated to meet downstream demands.

During non-flood operations, Lake Mead elevations fluctuate as releases increase and decrease due to downstream water uses, Glen Canyon Dam releases, and 1944 Treaty deliveries to Mexico. Lake Mead's elevations will fluctuate throughout the year for meeting the end-of-month target elevations for Lake Mohave and Lake Havasu, and for releasing to meet downstream requirements. Normally, Lake Mead elevations decline with increasing irrigation deliveries through June or later and then begin to rise again. Lake Mead's storage capacity provides for the majority of Colorado River regulation from Glen Canyon Dam to the border with Mexico.

Each month, Reclamation's water operations personnel send to Western Area Power Administration (Western) a monthly Hoover Powerplant energy target that is based upon Reclamation's most current daily operational data. In order to meet water orders downstream of Hoover Dam, a monthly energy target is set based on water demands below Parker Dam and Davis Dam. The energy target for Hoover Powerplant is broken down into weekly schedules but often it is the monthly target that drives the release at Hoover Dam. Because Hoover Dam is a peaking powerplant, releases will often vary significantly to meet the energy demand. Monitoring of Hoover Dam releases is checked each day for both hourly and daily values.

Hoover Powerplant turbines are fed by four penstocks which in turn are fed by four intake towers. The reservoir elevations that allow water to be fed into the penstocks are 1,045 feet msl and 895 feet msl for the two intake towers, respectively. Eight cylinder gate valves are located at the eight respective intake locations (two for each penstock).

The cylinder gate valves are 75 years old, being part of the original construction of Hoover Dam. Because of their age, each gate valve is operated as either completely open, or completely shut. This is necessary to avoid perturbations associated with partially opening of the valves. Wicket gates located upstream of each turbine control real-time flow and peak power generation.

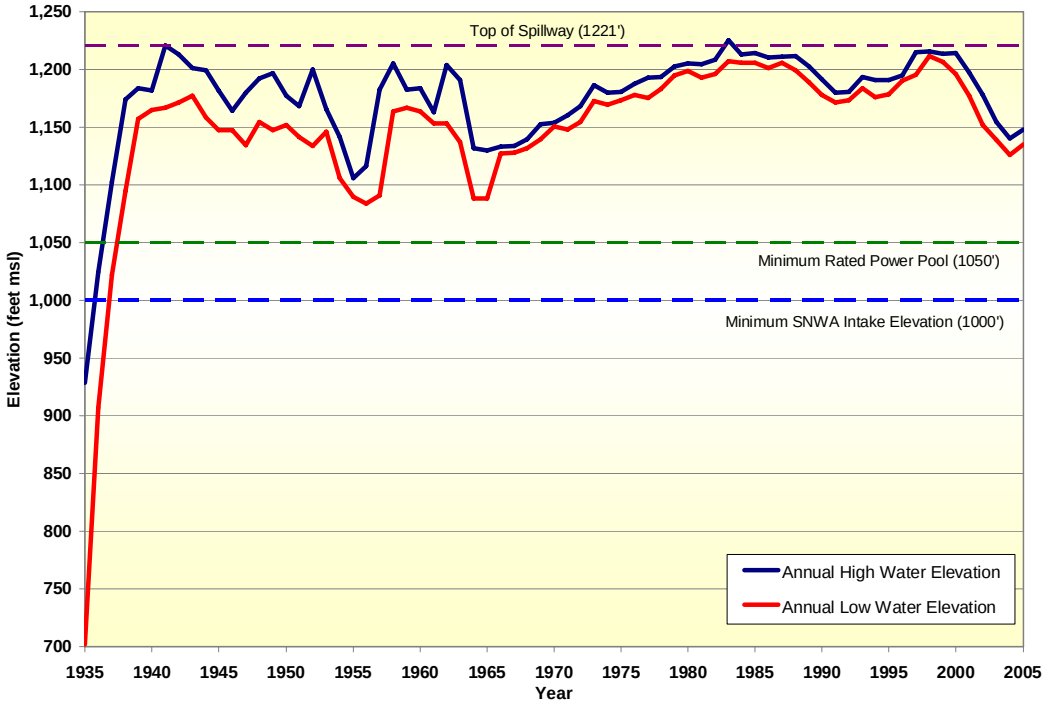
B.2.3.3 Historic Lake Mead Elevations

Figure B-6 illustrates the historic annual elevations (maximum and minimum) of Lake Mead. The annual change in elevations of Lake Mead has ranged from less than ten feet to as much as 75 feet (Figure B-6). The decrease in the elevations within a year observed after the mid-1960s can be attributed to the regulation provided by Lake Powell.

Historic Lake Mead elevations have dropped down to about 1,083 feet msl during two periods (1954 to 1957 and 1965 to 1966). The maximum Lake Mead elevation of approximately 1,225.6 feet msl occurred once, in 1983.

Three Lake Mead elevations of interest are shown in Figure B-6. The first elevation is 1,221 feet msl, the top of the spillway gates. The second elevation is 1,050 feet msl, the minimum elevation for the effective generation of power. The third elevation is 1,000 feet msl, the minimum elevation required for the operation of SNWA's lower intake.

Figure B-6
Historic Lake Mead Elevations
(Annual Highs and Lows)



B.2.4 Hoover Dam to Davis Dam

This reach extends from Hoover Dam to Davis Dam and includes Lake Mohave up to its full pool elevation. Lake Mohave generally comprises the approximately 67-mile length of this reach of the Colorado River. Lake Mohave is formed by Davis Dam and is bound for most of its 67-mile length by the steep walls of Pyramid, El Dorado, and Black Canyons. The lake is relatively narrow, not more than four miles across at its widest point, but provides significant recreation opportunities, and habitat for fish and wildlife. Lake Mohave also captures and delays flash flood discharge from side washes downstream of Hoover Dam. Typical flow time from Hoover Dam to Lake Mohave is four to six hours. Lake Mohave has a storage capacity of approximately 1.818 maf. Davis Dam and Davis Powerplant are located 67 miles downstream from Hoover Dam, and approximately two miles upstream from Laughlin, Nevada, and Bullhead City, Arizona.

B.2.4.1 River Flows between Hoover Dam and Davis Dam

Flows in the Colorado River reach between Hoover Dam and Davis Dam are comprised almost entirely of releases from Hoover Dam. Lake Mohave's primary purpose is to re-regulate Hoover Dam releases and aid in the delivery of water supplies to downstream United States entitlement holders, and to Mexico. Located on the Arizona side of the Colorado River, Davis Dam Powerplant has five generating units, with a generating capacity of 255,000 kW, and with a combined hydraulic capacity of 31,000 cfs. The power is marketed by Western.

Reclamation, as provided in the Interim Surplus Guidelines (ISG) ROD, will continue existing operations in Lake Mohave that benefit native fish through the effective period of the ISG and will explore additional ways to provide benefits to native fish. The normal filling pattern of these two reservoirs coincides well with the fishery spawning period. Since Lake Mohave elevations will be typical of previous years, normal conditions are expected for boating and other recreational uses in future years.

Reclamation is the lead agency in the Native Fish Work Group, a multi-agency group of scientists attempting to augment the ageing stock of the endangered razorback sucker in Lake Mohave. Larval razorback suckers are captured by hand in and around spawning areas in late winter and early spring for rearing at Willow Beach Fish Hatchery which is located below Hoover Dam. The following year, 1-year old razorback suckers are placed into predator-free, lake-side backwaters for rearing through the spring and summer. When Lake Mohave is normally drawn down during August through October, these fish are harvested from these rearing areas and then released to the lake. The razorback suckers grow very quickly, usually exceeding 10 inches in length by September. In 2004, 17,266 razorback suckers were repatriated into Lake Mohave from all sources. In 2005, 12,200 wild larvae were captured from natural spawning congregations on Lake Mohave and delivered to Willow Beach Hatchery.

Under normal conditions, flows in this river reach comprise water deliveries to Colorado River water users that divert water from this reach, and to others located downstream of Parker Dam.

Historic daily river flows since 1963 in this river reach have ranged between 590 cfs to 50,800 cfs. The higher flow rates have been associated with flood flows. Releases since 1963 from Davis Dam have ranged between 1,200 cfs to 44,106 cfs.

B.2.4.2 Historic Lake Mohave Elevations

Hoover Dam flood control releases are passed through Davis Dam. Flood control requirements for Davis Dam were developed through the monthly target elevations developed for Lake Mohave. Flood control releases (from Hoover Dam), as well as side wash inflows, were considered in the development of the target elevations.

Reclamation has discretion to develop and manage Lake Mohave's target elevations and allocated flood control reserved capacity that changes throughout the year by making releases through Davis Dam. This flood control reserved capacity is considered and taken into account in the Davis Dam release calculation. Specifically, the operators use a rule curve with target elevations that coincide with respective vacant storage capacity. The target elevations that are used to assure that sufficient flood control storage capacity is allocated for Lake Mohave are listed in Table B-4 and illustrated on Figure B-7.

Figure B-7
Lake Mohave Monthly Target Elevations

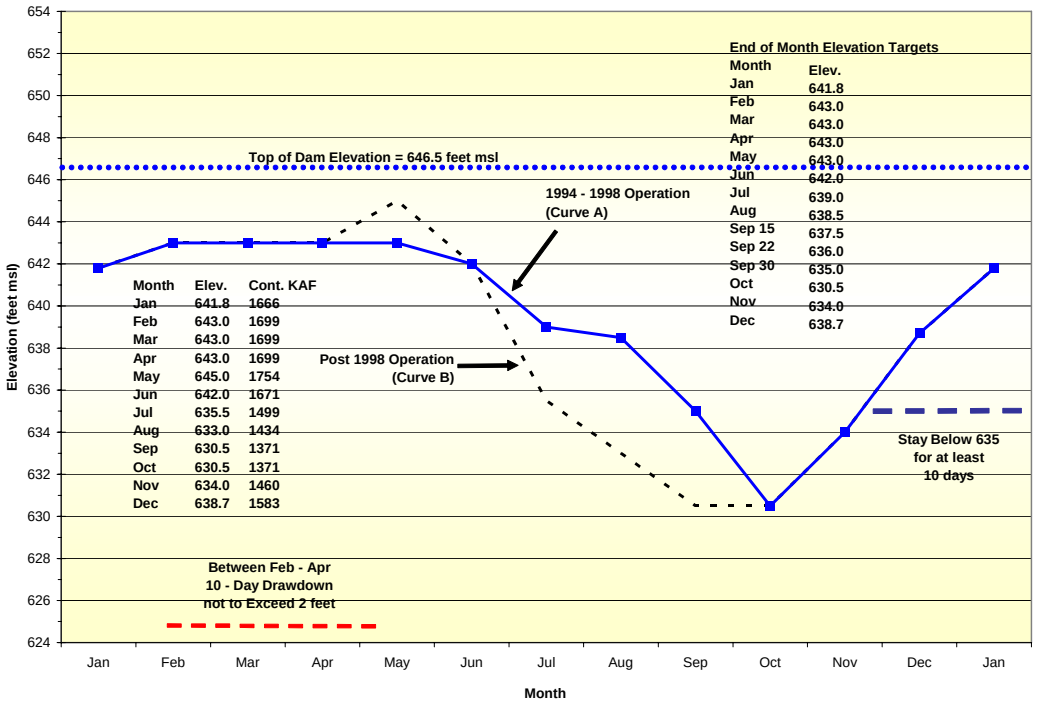


Table B-4
Lake Mohave Monthly Target Elevations

Month	Lake Mohave Target Elevation (feet msl)	Lake Mohave Target Storage (kaf)
January	641.8	1,666
February	643.0	1,699
March	643.0	1,699
April	643.0	1,699
May	645.0	1,754
June	642.0	1,671
July	635.5	1,499
August	633.0	1,434
September	630.5	1,371
October	630.5	1,371
November	634.0	1,460
December	638.7	1,583

The razorback sucker backcove rearing program that began in 1994 can also limit the drawdown to no more than two feet in a ten-day period during the razorback sucker spawning season. Further, the program also requires that the Lake Mohave elevation be maintained above 640 feet msl between March 15 and June 15 to provide sufficient depth for the backcove rearing areas. These limitations require closer coordination of Lake Mohave with that of downstream Lake Havasu as well as adjustment to the Hoover Dam hourly water release and energy production schedules. The operators take all these factors into account in the management of the Lake Mohave daily elevations.

As shown on Figure B-7, Lake Mohave generally reaches its maximum elevation in the spring and its minimum elevation in the fall. Reclamation generally lowers the lake elevation in the fall to provide flood control storage space for runoff that results from large hurricane-type storms coming up-river from Mexico. However, it needs to be noted that these are target elevations only. The actual elevations will sometimes differ from the target elevations with the regulation of Hoover Dam releases and the balancing of arriving flows with downstream water demands.

As with releases from Hoover Dam, factors that must be considered when making the Davis Dam releases include the need to meet downstream water requirements throughout the month and the objective to maintain non-damaging flow levels downstream.

B.2.4.3 Operation of Davis Dam

The primary purpose of Davis Dam is to re-regulate Hoover Dam releases and aid in the delivery of water supplies to downstream United States entitlement holders and the annual delivery of 1.5 maf to Mexico pursuant to the 1944 Treaty. Other benefits

provided by Davis Dam and Lake Mohave include flood control protection, navigation, recreation, and power production.

Reclamation's water schedulers collect and compile water delivery orders from the Central Arizona Project (CAP), the Metropolitan Water District of Southern California (MWD), and other Colorado River entitlement holders that divert water between Davis Dam and Parker Dam. The hourly release schedule for Davis Dam is then integrated with the scheduled water releases of Parker Dam and other objectives to coordinate the maximum release through the power facilities at the time of the peak usage of electricity; to the extent such release is compatible with the timing of the water deliveries and other constraints.

Since 1980, annual release from Davis Dam has varied from a low of 7.3 maf to a high of 21.7 maf. The maximum instantaneous release for Davis Dam is approximately 44,000 cfs and the minimum instantaneous release that can be expected under other than normal operating conditions is about 1,000 cfs. The minimum amount represents approximately one half of the release needed to turn one of the Davis Powerplant's turbines. Such low flows are usually associated with downstream flooding, construction, search and rescue, or other emergency conditions.

Davis Powerplant's generating units are capable of providing moment-to-moment dynamic control. However, there is minimal use of this dynamic capability. If there are changes to hourly flows, the schedule change usually begins ten minutes to the hour and the change is fully implemented ten minutes after the hour. These flow changes are computer controlled and the changes to the unit releases are programmed well in advance.

The minimum elevation of Lake Mohave without resetting the intake stops is at about 630 feet msl. The maximum elevation is 646.5 feet msl, where wave action begins to leak into Davis Dam's inspection gallery. The daily releases are coordinated such that the end of month target elevations are achieved.

B.2.5 Davis Dam to Parker Dam

This reach extends from Davis Dam to Parker Dam and includes Lake Havasu up to its full pool elevation. Parker Dam is located approximately 155 miles downstream of Hoover Dam and approximately 88 miles downstream of Davis Dam. The lower portion of this reach comprises Lake Havasu. Formed by Parker Dam, Lake Havasu is about 45 miles long and can store nearly 648,000 af of water. At its maximum elevation of 450.5 feet msl, Lake Havasu has a surface area of approximately 20,390 acres.

Lake Havasu provides a forebay and desilting basin from which water is pumped into the Colorado River Aqueduct (California) and into the CAP aqueduct system. The pumping plant that pumps water into the Colorado River Aqueduct is located on the west side of the Colorado River and it is operated by the MWD. The pumping plant that pumps water into the

CAP aqueduct system is located on the east side of the Colorado River and it is operated by the Central Arizona Water Conservation District (CAWCD).

B.2.5.1 River Flows between Davis Dam and Parker Dam

The majority of the flows in this river reach are releases from Hoover Dam and flows that pass through Lake Mohave and Davis Dam. There are also some minor gains in this river reach from tributaries such as the Bill Williams River, groundwater discharge, and return flows from agriculture.

Under normal conditions, flows in this river reach comprise water deliveries to Colorado River water users that divert water from this reach, and to others located downstream of Parker Dam.

Historical river flows since 1963 in this river reach have ranged between 1,200 cfs to 44,106 cfs. The higher flow rates have been associated with flood flows.

B.2.5.2 Operation of Parker Dam

Parker Dam's primary purpose is to regulate the storage at and releases from Lake Havasu. Parker Dam also has a powerplant function and may provide a minimal amount of flood control, capturing and delaying flash floods into the Colorado River from tributaries below Davis Dam.

Releases at Parker Dam are scheduled on a daily basis to meet the short-term demands of Colorado River water users located downstream. The hourly release profile may be adjusted to meet electric service customer requirements.

Parker Dam Powerplant is located on the California side of the Colorado River immediately below the dam. It houses four hydroelectric generating units. The installed generating capacity is 120,000 kW, but due to high tailrace elevation, the generation production is approximately 108,000 kW. Four 22-foot diameter penstocks carry up to 5,500 cfs each to feed the generating units. About 50 percent of the plant's power output is reserved in perpetuity by MWD for pumping water along the Colorado River Aqueduct to the southern California coastal area. The remaining power is marketed by Western.

B.2.5.3 Historic Lake Havasu Elevations

Hoover Dam flood control releases also are passed through Parker Dam after deliveries are made to the CAP and MWD diversion facilities at Lake Havasu, and to other users upstream of Parker Dam. Flood control requirements for Parker Dam were developed through the monthly target elevations developed for Lake Havasu. Flood control releases from Hoover Dam, as well as side wash inflows and flood flows on Bill Williams River, were considered in those target elevations. Reclamation has discretion to develop and manage the target elevations of Lake Havasu by making releases through Parker Dam. Lakes Havasu is operated to meet a user-specified target storage at the end of each month. These storage target elevations are provided in Table B-5.

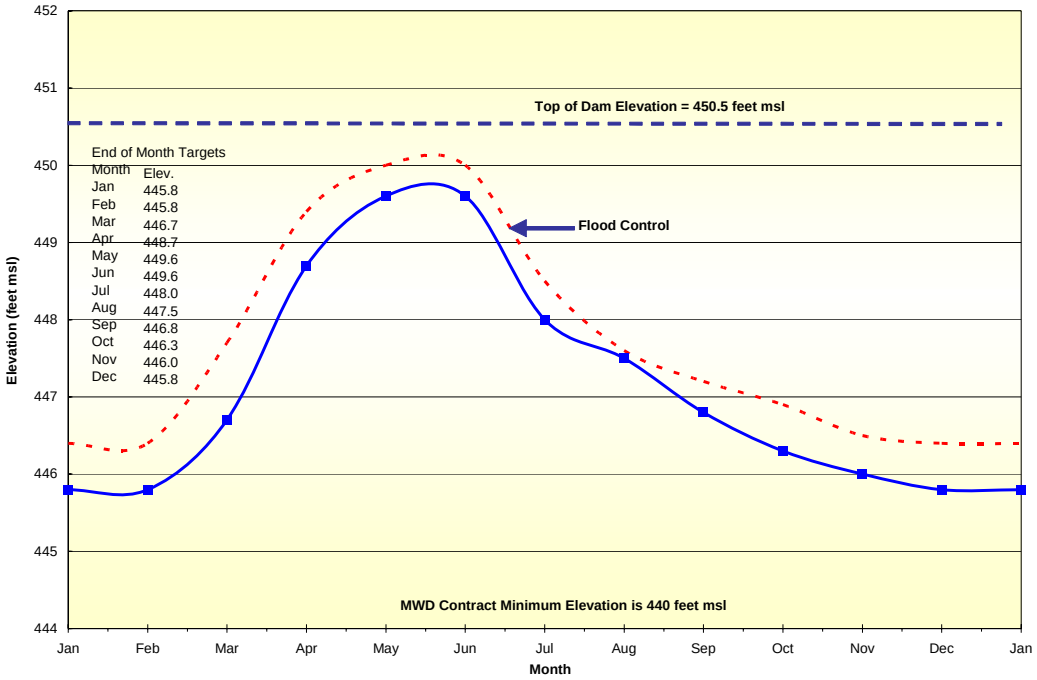
Lake Havasu generally reaches its maximum elevation in the spring and its minimum elevation in the winter. Reclamation generally lowers the lake elevation during the winter months to provide flood control storage space for runoff that results from large storms coming up river from Baja California, Mexico. The actual elevations will sometimes differ from the target elevations (Figure B-8) with the regulation of Hoover Dam and Parker Dam releases and the balancing of arriving flows with downstream water demands.

Figure B-8 illustrates the average, maximum, and minimum monthly elevations of Lake Havasu (elevations measured at midnight on last day of month) for the non-flood control years. The maximum average elevation of approximately 448.7 feet msl occurs in May and the minimum average elevation of about 446.0 feet msl occurs in February. The minimum target elevation for marina operators is 445.8 feet msl. Reclamation attempts to accommodate this minimum target elevation when other higher priority uses are not compromised. The maximum Lake Havasu elevation is 450.5 feet msl.

Table B-5
Lake Havasu Monthly Target Elevations

Month	Lake Havasu Target Elevations (feet msl)	Lake Havasu Target Storage (kaf)
January	445.8	539.1
February	445.8	539.1
March	446.7	557.4
April	448.7	593.6
May	449.6	611.4
June	449.6	611.4
July	448.0	580.0
August	447.5	561.1
September	446.8	557.4
October	446.3	548.2
November	446.0	542.7
December	445.8	539.1

Figure B-8
Lake Havasu Monthly Target Elevations



B.2.6 Parker Dam to Imperial Dam

Parker Dam is the last major dam on the lower Colorado River and provides the last opportunity for Reclamation to provide any significant regulation of river flows. Once released from Parker Dam, water flows relatively unregulated until it reaches Imperial Dam. The transit time between Parker Dam and Imperial Dam is approximately 3 days.

B.2.6.1 River Flows between Parker Dam and Imperial Dam

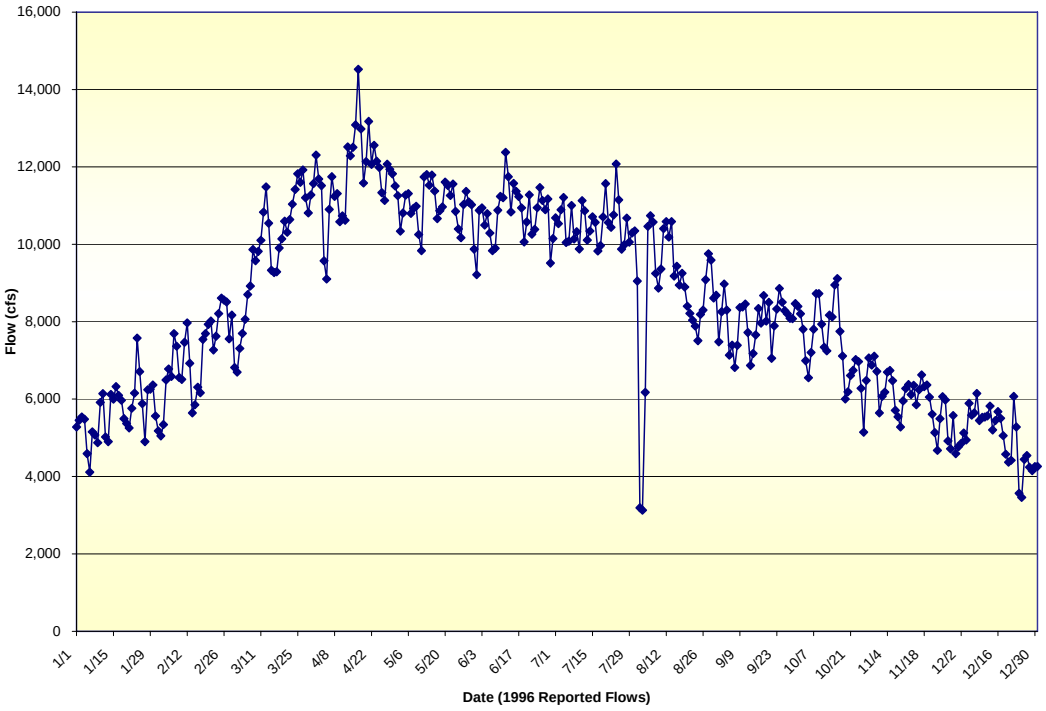
The flow of the Colorado River between Parker Dam and Imperial Dam is normally set at the amount needed to meet the United States consumptive use requirements downstream of Parker Dam plus deliveries to Mexico at the Morelos Diversion Dam. The scheduling and subsequent release of water through Parker Dam creates short-term fluctuations in river flows, depths, and elevations downstream of Parker Dam. These fluctuations of elevations in the Colorado River are most noticeable in the section of the river located immediately downstream of Parker Dam and lessen as the downstream distance increases.

Several features located downstream of Parker Dam are also used to manage the flows in the river and make deliveries to the Colorado River water users that divert water downstream of Parker Dam. These features include the Headgate Rock Dam, Palo Verde Diversion Dam, Senator Wash Dam, Imperial Dam, and Laguna Dam, as discussed in detail below.

Historical river flows since 1963 in this river reach have ranged between 30 cfs to 40,000 cfs. The higher flow rates have been associated with flood flows. An example of the daily fluctuation in flows in this river reach is illustrated on Figure B-9. Historical annual diversions since 1963 from this river reach have ranged between zero af and 152,496 af.

Future flows in this reach of the Colorado River are expected to be affected by the water transfers and exchanges between the California agricultural water agencies and MWD, which will change the point of diversion of some water deliveries. For example, under water transfer between Imperial Irrigation District (IID) and MWD (or San Diego County Water Authority [SDCWA]), the flow that would normally be diverted at Imperial Dam instead would be diverted upstream of Parker Dam. The existing and future California intrastate transfers are included in the simulations of the No Action Alternative and the action alternatives. The California intrastate transfers and any potential environmental effects that would occur as a result of those transfers were previously addressed in the *Implementation Agreement, Inadvertent Overrun and Payback Policy, and Related Federal Actions EIS* (Reclamation 2002).

Figure B-9
Variation of Daily Flows Arriving at Imperial Dam
(reported 1996 daily river flow measurements at Cibola Stream Gage, RM 87.3)



B.2.6.2 Operation of Headgate Rock Dam

Headgate Rock Dam was completed in 1941and forms Lake Moovalya which serves as a diversion dam for the Colorado River Indian Irrigation Project (CRIIP). The dam controls the elevation of a 16-mile stretch of the Colorado River that reaches almost to the tail water of Parker Dam less the diversion by the CRIIP. There is very little daily fluctuation in the elevations upstream of Headgate Rock Dam. Downstream elevations of Headgate Rock Dam reflect the releases from Parker Dam. Irrigation water is diverted from upstream of Parker Dam almost 12 months out of the year. When water is being diverted, the upstream elevation is kept at or around 364.4 feet msl. When water is not being diverted, the elevation of the upstream Lake Moovalya can be lowered by opening the spillway gates, and the elevation is kept at or around 363.4 feet msl and possibly lower, if needed.

When Headgate Rock Powerplant is operational, power is generated through up to three 6.5-megawatt turbine units depending on water release through Parker Dam. The power is used for irrigation projects, Bureau of Indian Affairs' (BIA) needs, power sales, and off-reservation exchanges.

CRIIP's main canal is 18 miles long and includes six major control or diversion structures, as well as minor delivery, drainage, and highway structures. CRIIP operates the diversion on a demand basis. Water users must place their order at least 48 hours in advance, and the irrigation office usually provides that water within 48 hours from the posted end-of-order time each day. Accumulated daily water orders are relayed to Headgate Rock Dam, so that gates on the dam and main canal intake structure are raised or lowered to divert the correct quantity into the irrigation system.

The CRIIP Irrigation Office prepares and submits an annual report that provides the annual projected water use to the River Operations Branch of Reclamation. This report estimates the monthly flow to be diverted for CRIIP use in the next crop year.

B.2.6.3 Operation of Palo Verde Diversion Dam

The Palo Verde Diversion Dam is the intake for the Palo Verde Irrigation District (PVID). Flows between the Palo Verde Diversion Dam and Imperial Dam are set by downstream demands and required deliveries to Mexico.

Palo Verde Diversion Dam is operated by PVID. The diversion dam maintains a constant elevation at the PVID canal intake during periods of normal riverflow. Except during periods of high river discharge, this forebay elevation is maintained at 283.5 feet msl.

B.2.6.4 Operation of Senator Wash Dam

Senator Wash Dam and Regulating Reservoir is located 20 miles northeast of the city of Yuma, Arizona, on the California side of the Colorado River and approximately two miles upstream of Imperial Dam. This strategic off-stream water storage reservoir was constructed by Reclamation to facilitate water scheduling and to help in balancing the river flows and supply with demands. This is achieved by storing part of the Colorado River flow when excess flows are available above Imperial Dam and releasing the water in storage back to the river for downstream use when needed.

Senator Wash Reservoir was designed to have a water surface area of about 470 acres at a maximum operating elevation of 251 feet msl. At this elevation, the design storage capacity is approximately 13,840 af. The reservoir has inactive (dead) storage below elevation 210 feet msl which has an estimated capacity of about 1,577 af. The design active storage is located between elevations 210 feet msl and 251 feet msl and is estimated to be about 12,259 af.

Current operational restrictions limit the use of the full storage capacity available at Senator Wash Reservoir. The operational restriction of Senator Wash Reservoir is associated with Safety of Dams concerns. Previous structural evaluation, studies of the dam, and related facilities have shown evidence of potential piping through and around the foundation of the dam (transportation of dam embankment foundation material caused by seepage that could lead to failure of the dam or dikes). There is a potential for failure of the foundation or embankment which could result from liquefaction during an earthquake. The maximum operating elevation of Senator Wash Reservoir was previously restricted to 235 feet msl with temporary incursions up to 240 feet msl. However, with the recent installation of a geomembrane liner along the bottom of a portion of the reservoir, the maximum unrestricted operating elevation has been raised to 240 feet msl.

B.2.7 Imperial Dam to NIB

This reach extends from Imperial Dam to the NIB between the United States and Mexico. The entire extent of the channel is bound by a system of levees. Several features located between Imperial Dam and the NIB are used to manage river flows and make deliveries to the Colorado River water users that divert water at and downstream of Imperial Dam. This includes Imperial Dam, Laguna Dam, Laguna Desilting Basin, Morelos Diversion Dam, California Wasteway, and Pilot Knob Wasteway. Other features include water conveyance system components (levees, bypass channels, wasteways, etc.), access roads, farmlands, and vegetation. Mittry Lake is also located on the Arizona side of the Colorado River.

The All-American Canal (AAC) system diverts water from the California side of Imperial Dam and serves IID, Coachella Valley Water District (CVWD), the Yuma Project in Arizona and California, and the City of Yuma.

The Gila Gravity Main Canal system diverts water from the Arizona side of Imperial Dam and serves the north and south Gila Valley, Yuma Mesa, and Wellton-Mohawk area. Imperial Dam is also used to regulate deliveries to Mexico.

The AAC Desilting Works, which is located adjacent to the AAC diversion structure, is used to remove most of the sediment carried by the Colorado River prior to the water entering the AAC. The Imperial National Wildlife Refuge (NWR) is located mostly on the Arizona side of the Colorado River. Martinez Lake is a small water cove formed by the impoundment and backwater area located above Imperial Dam.

B.2.7.1 Operation of Imperial Dam

Imperial Dam and the impoundment that it forms upstream of the dam is used to raise the elevation of the upstream river flows by approximately 25 feet to provide controlled gravity flow of water into the AAC and into the Gila Gravity Main Canal. Imperial Dam is situated on the Colorado River some 18 miles northeast of Yuma, Arizona.

The flows arriving at Imperial Dam normally range from a high of about 14,400 cfs (usually occurring in late spring to summer) to a low of about 2,500 cfs. The low flow period usually follows heavy rainfall in the area below Imperial Dam (usually November, December, and January). During these wet weather periods, the rain saturates the farm fields, and the farmers and respective water agencies adjust or cancel their water delivery orders. Mexico's water order is required to be delivered regardless of wet weather or excess rainfall conditions.

The reservoir created by Imperial Dam initially had a capacity of 83,000 af. This storage capacity was not considered a project feature and, as anticipated, the reservoir quickly filled with sediment. The reservoir capacity is now considered to be approximately 1,000 af and intermittent dredging is required to maintain the required diversion capacity at the AAC and the Gila Gravity Main Canal headworks.

The normal operating range of reservoir elevations for Imperial Dam is between 180 feet msl and 180.85 feet msl. However, if the amount of water arriving at Imperial Dam is less than the demands, and pulling water out of the Senator Wash Reservoir cannot keep the reservoir elevation of Imperial Dam from continuing to fall, diversions at elevations below 180.0 feet msl can be made to the AAC or the Gila Gravity Main Canal. Under certain conditions, it is possible to draw down reservoir elevations of Imperial Dam to as low as 178.5 feet msl.

Imperial Dam is operated primarily as a diversion dam, providing water to the AAC and the Gila Gravity Main Canal to meet the beneficial use requirements of entitlement holders in California and Arizona. Releases may also be made to meet a portion of the 1944 Treaty deliveries to Mexico. Occasionally (two to three times per month), water is released through the sluice gates at Imperial Dam to move accumulated sediment to the Laguna Desilting Basin which is located about two miles downstream from Imperial Dam. The Laguna Desilting Basin, located within the Colorado River channel, is used to decant the water that is released from or that passes Imperial Dam.

B.2.7.2 River Flows between Imperial Dam and NIB

The flows in the Colorado River below Imperial Dam are primarily comprised of water delivered to Mexico in accordance with the 1944 Treaty. Mexico's principal diversion is at Morelos Diversion Dam, which is located approximately nine miles southwest of Yuma, Arizona. Mexico owns, operates, and maintains Morelos Diversion Dam.

Much of the water that is delivered to Mexico at the NIB is diverted at Imperial Dam into the AAC where it is conveyed and then returned to the Colorado River through Siphon Drop and Pilot Knob Powerplants. A portion of the NIB deliveries remains in the river, passing through Imperial Dam and Laguna Dam to the Morelos Diversion Dam.

Under normal conditions and when there is no runoff from the Gila River, the delivery of scheduled water to Mexico at the NIB comes from two principal sources: 1) drainage return flows that occur downstream of Imperial Dam; and 2) the diversion of flows to Mexico from Imperial Dam. The drainage return flows are nearly constant throughout the year and from year to year and comprise both gravity and pumped drainage flows.

Water may be delivered to Mexico at the NIB via one or a combination of three routes. Figure B-10 presents a schematic that shows these routes. The following provides an explanation of these three flow routing methods:

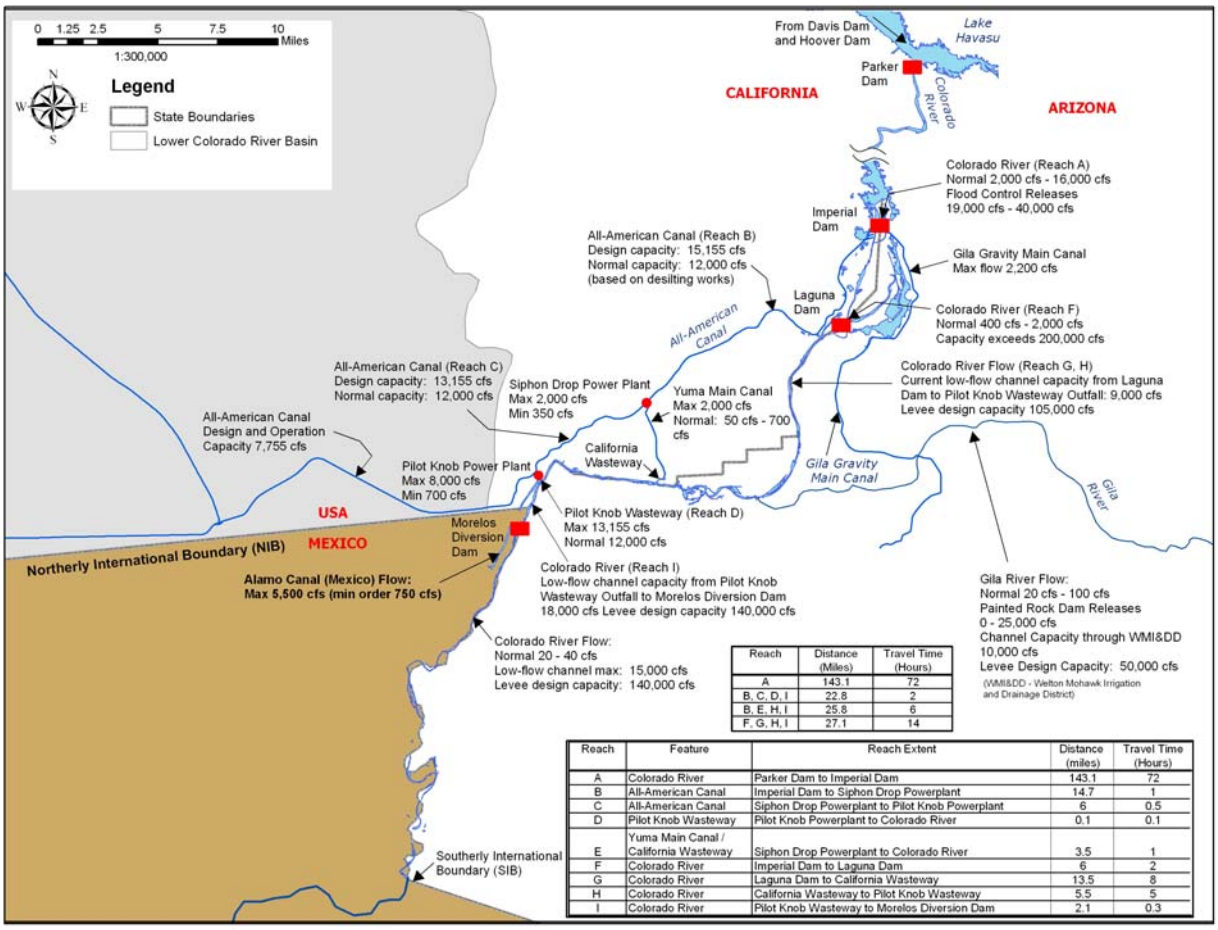
1) water scheduled to be delivered to Mexico is diverted at Imperial Dam, conveyed through the AAC to the Pilot Knob Check, and at a point above the Pilot Knob Check, the flows are diverted from the AAC through the Pilot Knob Power Plant and Wasteway back into the Colorado River. The Pilot Knob Wasteway channel discharges to the Colorado River at a point located approximately 2.1 miles upstream of the NIB;

2) water scheduled to be delivered to Mexico is diverted at Imperial Dam, conveyed through the AAC to the Siphon Drop, and at a point above the Siphon Drop, the flows are diverted from the AAC through the Siphon Drop Wasteway and into the Yuma Main Canal. The water is then conveyed some 3.5 miles within the Yuma Main Canal and then is diverted and discharged back into the Colorado River via the Yuma Main Canal Wasteway. The Yuma Main Canal Wasteway discharges to the Colorado River at a point located approximately 7.6 miles upstream of the NIB; or

3) water scheduled to be delivered to Mexico is delivered directly to the NIB via the Colorado River. Under this method, water is passed through Imperial Dam and Laguna Dam and is allowed to flow via the river channel to the NIB. These flows are in addition to the base flows in the riverbed downstream of Laguna Dam. The base flows are generally consistent throughout the year and result from gate leakage at Imperial Dam, returns to the river below Imperial Dam from the AAC Desilting Basin, and drainage flows from downstream sources. These base flows normally range from 600 cfs to 800 cfs.

Another intermittent water source that is available for delivery to Mexico at the NIB is Gila River. When releases from Painted Rock Dam occur, these flows are used to satisfy a portion of Mexico's delivery, depending on the amount of flow from the Gila River that enters the Colorado River upstream of the NIB.

Figure B-10
Water Routing from Imperial Dam to the NIB
Deliveries to Mexico Pursuant to 1944 Treaty



Reach	Distance (Miles)	Travel Time (Hours)
A	143.1	72
B, C, D, I	22.8	2
B, E, H, I	25.8	6
F, G, H, I	27.1	14

Reach	Feature	Reach Extent	Distance (miles)	Travel Time (Hours)
A	Colorado River	Parker Dam to Imperial Dam	143.1	72
B	All-American Canal	Imperial Dam to Siphon Drop Powerplant	14.7	1
C	All-American Canal	Siphon Drop Powerplant to Pilot Knob Powerplant	6	0.5
D	Pilot Knob Wasteway	Pilot Knob Powerplant to Colorado River	0.1	0.1
E	Yuma Main Canal / California Wasteway	Siphon Drop Powerplant to Colorado River	3.5	1
F	Colorado River	Imperial Dam to Laguna Dam	6	2
G	Colorado River	Laguna Dam to California Wasteway	13.5	8
H	Colorado River	California Wasteway to Pilot Knob Wasteway	5.5	5
I	Colorado River	Pilot Knob Wasteway to Morelos Diversion Dam	2.1	0.3

B.2.7.3 Operation of Laguna Dam

Laguna Dam is located on the Colorado River some 13 miles northeast of Yuma, Arizona, and about five miles downstream from Imperial Dam. The original purpose of this dam was to divert Colorado River water to the Yuma Project area. Laguna Dam now serves as a regulating structure for Colorado River water, for regulating sluicing flows from Imperial Dam, and for downstream toe protection for Imperial Dam. The reservoir created by Laguna Dam is commonly referred to as Laguna Reservoir.

Water can be stored in Laguna Reservoir between elevations 142 feet msl to 151.3 feet msl. The top of the overflow weir at Laguna Dam is at elevation

151.3 feet msl. A small amount of additional storage can be obtained by forcing water into surcharge above the weir. The current estimate of the available storage capacity at Laguna Reservoir, between elevation 142 feet msl and 151.3 feet msl, is about 400 af.

The flows that occur below Imperial Dam and that flow into the Colorado River channel and Laguna Reservoir typically range from about 250 cfs to 350 cfs and comprise principally the return flows from the AAC desilting basins and gate leakage from the California sluiceway gates at Imperial Dam. Occasionally, sluicing flows are released to remove sediment accumulated from the desilting basins in the sluiceway channel. These flows occur two to three times per month, may range from 8,000 cfs to 12,000 cfs, and the duration may be up to 20 minutes. These flows carry the sediment to the Laguna Desilting Basin located about two miles downstream of Imperial Dam.

Flow releases from Laguna Dam typically range between 300 and 500 cfs. Occasionally, flows up to 4,000 cfs or higher may occur coincident with or following heavy rainfall.

Laguna Dam is operated to regulate river flows and to temporarily store water used in sluicing operations at Imperial Dam. Any water that is captured and temporarily stored at Laguna Reservoir is released to meet a portion of the 1944 Treaty deliveries to Mexico.

B.2.7.4 Mittry Lake

Mittry Lake is located on the east side of the Colorado River between Laguna Dam and Imperial Dam. The Mittry Lake Wildlife Area generally surrounds and includes Mittry Lake and includes approximately 600 acres of water surface and 2,400 acres of marsh or upland habitat. Numerous serpentine waterways connect to the main lake body. The Mittry Lake Wildlife Area is jointly managed by the United States Bureau of Land Management, Reclamation, and the Arizona Game and Fish Department.

B.2.8 NIB to SIB

This reach extends from the NIB to the SIB between the United States and Mexico and is approximately 23.7 miles long. This section of the Colorado River serves as the international boundary between the United States and Mexico. This segment of the Colorado River has been highly altered and has levees on both sides.

Located approximately 1.1 miles downstream of the NIB is Morelos Diversion Dam. This dam functions as a diversion control structure for the Alamo Canal, which conveys water to Mexico. Morelos Diversion Dam and the limitrophe section of the Colorado River channel, including the floodplain, are designed to convey a maximum flow of 140,000 cfs. Other major features located within this reach include water conveyance system components (levee, bypass channel, wasteways, etc.), access roads, farmlands, and vegetation.

B.2.8.1 Operation of Morelos Diversion Dam

In accordance with the 1944 Treaty and Minute 242, up to 140,000 afy of Mexico's treaty allocation of 1.5 mafy may be delivered at the SIB. Consequently, Mexico diverts the majority (approximately 1.36 mafy) of its 1944 Treaty allocation at Morelos Diversion Dam.

B.2.8.2 River Flows between Morelos Diversion Dam and the SIB

Flows in this reach of the Colorado River vary. At times the lower part of this reach is dry. Cohen and Henges-Jeck (2001) reported average total flows in this reach of 22,000 af in non-flood years and 2.12 maf in flood years.

The flows that are observed in this river reach typically are the result of seepage from Morelos Diversion Dam, flow releases from Morelos Diversion Dam (flood flows and excess water not diverted by Mexico), irrigation return flows from Mexico and canal wasteways in the United States, and groundwater accumulation from both the United States and Mexico.

The reach of the Colorado River between the NIB and the SIB is commonly referred to by Reclamation as the Limitrophe Reach. Reclamation's authority in this division is limited to maintaining the bankline road, the levee, various drains to the river, and the United States Bypass drain that carries agricultural drainage water to the Cienega de Santa Clara in Mexico. The United States Section of the International Boundary and Water Commission (USIBWC) is obligated to maintain the river channel within this division although Reclamation provides assistance to the USIBWC, when requested, for maintenance needs in this reach of the river.

Under current practice, Mexico is allowed to schedule up to an additional 200 kaf pursuant to the 1944 Treaty during flood control years when water supplies exceed those required for use in the United States. Often, the flood control releases are greater than the surplus uses in both the United States and Mexico and water in excess of Mexico's water schedule (termed excess flows) arrive at the NIB. Excess flows may also arrive at the NIB due to flooding on the Gila River and from operational activities upstream (i.e., cancelled water orders in the United States, maintenance activities, etc.). Mexico has the ability to divert the excess flows that arrive at Morelos Diversion Dam. Excess flows that are of magnitudes greater than what can be used by Mexico are passed through the Morelos Diversion Dam and flow through the Limitrophe Reach to the Colorado River Delta.

B.3 References

Bureau of Reclamation. 2002. *Final Environmental Impact Statement Implementation Agreement, Inadvertent Overrun and Payback Policy, and Related Federal Actions, Lower Colorado River and the States of Arizona, California, and Nevada*. Department of the Interior, Bureau of Reclamation, Lower Colorado Region, October.

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