3.5 WATER QUALITY

3.5.1 INTRODUCTION

This section addresses the salinity of the Colorado River and mainstream reservoirs, and the quality of Lake Mead water available for municipal and industrial purposes. The potential changes in the operation of the Colorado River system downstream from Lake Powell under interim surplus criteria alternatives could temporarily affect the salinity of Colorado River water, which affects municipal and industrial uses in the lower basin. In addition, changes in Lake Mead water levels could affect the quality of water arriving at the Southern Nevada Water System pump intakes in the Boulder Basin of Lake Mead, and thereby affect the quality of the water supply for the Las Vegas Valley.

3.5.2 COLORADO RIVER SALINITY

This section discusses potential effects that could result from the implementation of the interim surplus criteria alternatives under consideration. Salinity has long been recognized as one of the major problems of the Colorado River. “Salinity” or “total dissolved solids” (TDS) include all of the soluble constituents dissolved in a river and the two terms are used interchangeably in this document. This section considers potential changes in salinity concentrations from Lake Mead to Imperial Dam. The section also presents a general discussion of the adverse effects of increased salinity concentrations on municipal and industrial systems.

3.5.2.1 METHODOLOGY

Reclamation’s model for salinity is used to create salinity reduction targets for the Colorado River Basin Salinity Control Program (SCP). To do this, the model simulates the effects of scheduled water development projects to predict future salinity levels. This data is then used to compute the amount of new salinity control projects required to reduce the river’s salinity to meet the standards at some point in the future (2015). The model itself does not include future salinity controls because implementation schedules for future salinity control projects are not fixed and vary considerably. The salinity control standards are purposefully designed to be long-term (nondegradation) goals, rather than exceedence standards used for industry or drinking water.

By definition, the SCP is designed to be flexible enough to adjust for any changes caused by the various alternatives being considered. Therefore, it could be concluded that there would be no change in compliance with the standards caused by selecting any one of the alternatives. However, for the purposes of this analysis, each alternative has been evaluated using fixed (existing) levels of salinity controls to identify the differences between alternatives.

General effects of salinity were determined from review of records of historic river flow and salinity data available and economic impacts presented in *Quality of Water Colorado River Basin – Progress Report No. 19*, 1999, U.S. Department of the Interior; *Water Quality Standards for Salinity Colorado River System, 1999 Review*, June 1999, Colorado River Basin Salinity Control Forum and *Salinity Management Study*, Technical Appendices, June 1999, Bookman-Edmonston Engineering, Inc.

The salinity program as set forth in the Forum's 1999 Annual Review enables the numeric criteria to be met through the year 2015. Therefore, it was presumed that the criteria would be maintained through 2015. Although the 1999 Review considers only the period to 2015, it was presumed that future additions to the salinity control program will be sufficient to maintain the criteria through 2050.

3.5.2.2 AFFECTED ENVIRONMENT

3.5.2.2.1 Historical Data

The Colorado River increases in salinity from its headwaters to its mouth, carrying an average salt load of nine million tons annually past Hoover Dam. Approximately half (47 percent) of the salinity concentration is naturally caused and 53 percent of the concentration results from human activities including agricultural runoff, evaporation and municipal and industrial sources (Forum, 1999).

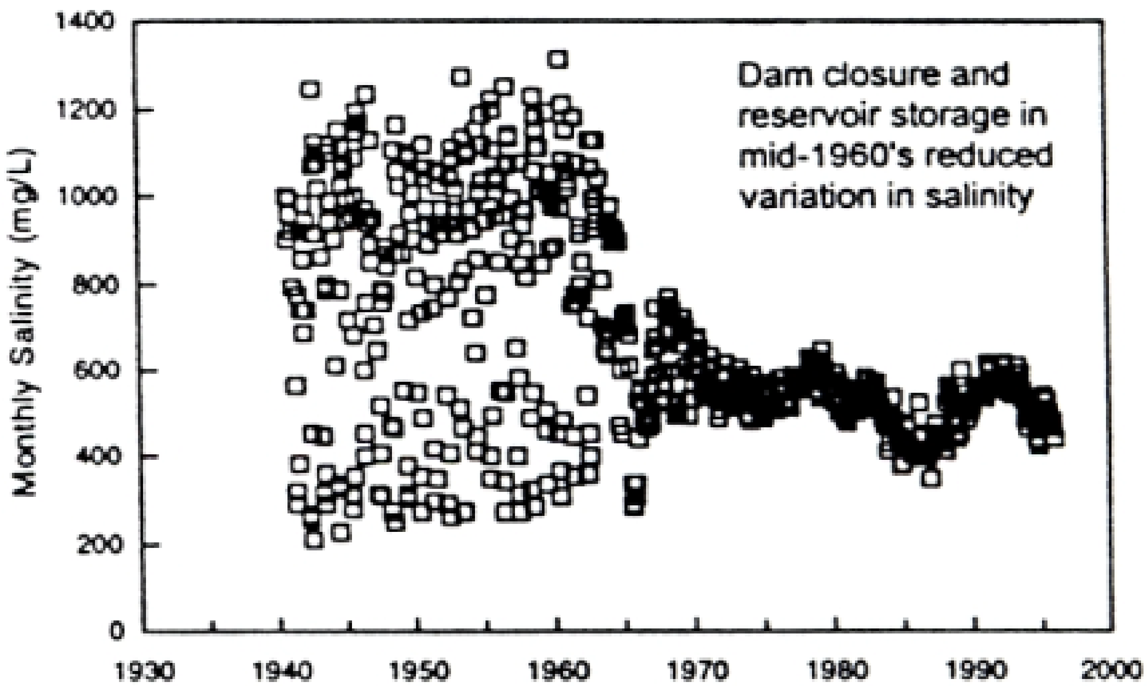
Salinity of the river has fluctuated significantly over the period of record 1941 through 1997. Below Hoover Dam, annual salinity concentrations have ranged from 833 milligrams per liter (mg/l) in 1956 to 517 mg/l in 1986. However, the maximum monthly fluctuation in any one year is approximately 50 mg/l. Salinity of the river is influenced by numerous factors including reservoir storage, water resource development (and associated return flows), salinity control, climatic conditions and natural runoff.

The impact of reservoir storage has all but eliminated seasonal fluctuations in salinity. Annual variations in salinity are primarily driven by natural, climatic variations in precipitation and snowmelt runoff. These hydrologic variations cause differences in both flow and salinity.

As shown in Figure 3.5-1, the salinity of the river varied by as much as 1,000 mg/l prior to the construction of Glen Canyon Dam in 1961. By the 1980s, that variation was reduced to about 200 mg/l due to the mixing and dampening effect of the large volume of storage in Lake Powell. Figures 3.5-2 and 3.5-3 show the comparison between mainstream flows and salinity. Figure 3.5-2 shows the outflow from Glen

Canyon and Imperial dams. Figure 3.5-3 shows the salinity at Imperial, Hoover and Glen Canyon dams.

Figure 3.5-1
Historical Monthly Salinity Concentrations Below Glen Canyon Dam (1940-1995)



3.5.2.2.2 Regulatory Requirements and Salinity Control Programs

In 1972, the EPA promulgated regulations requiring water quality standards for salinity, numeric criteria and a plan of implementation for salinity control. The Seven Colorado River Basin States, acting through the Forum, adopted numeric criteria for flow-weighted average annual salinity, at three points on the river as shown below:

Below Hoover Dam	723 mg/l
Below Parker Dam	747 mg/l
At Imperial Dam	879 mg/l

Figure 3.5-2
Historical Glen Canyon Dam and Imperial Dam Releases

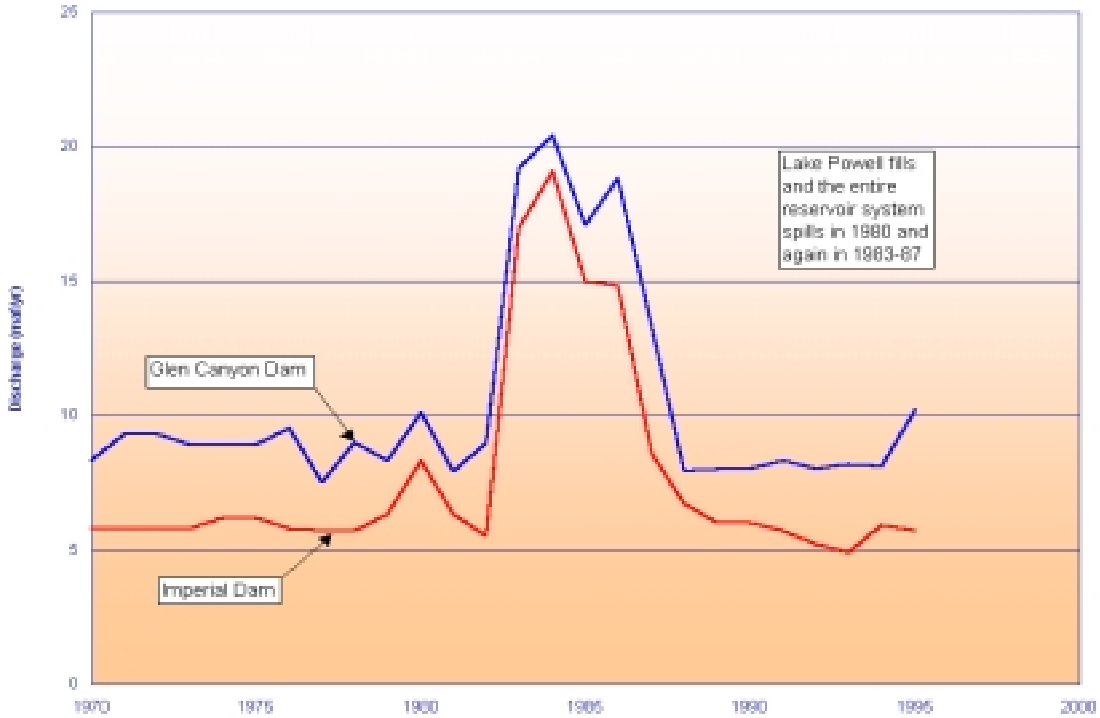
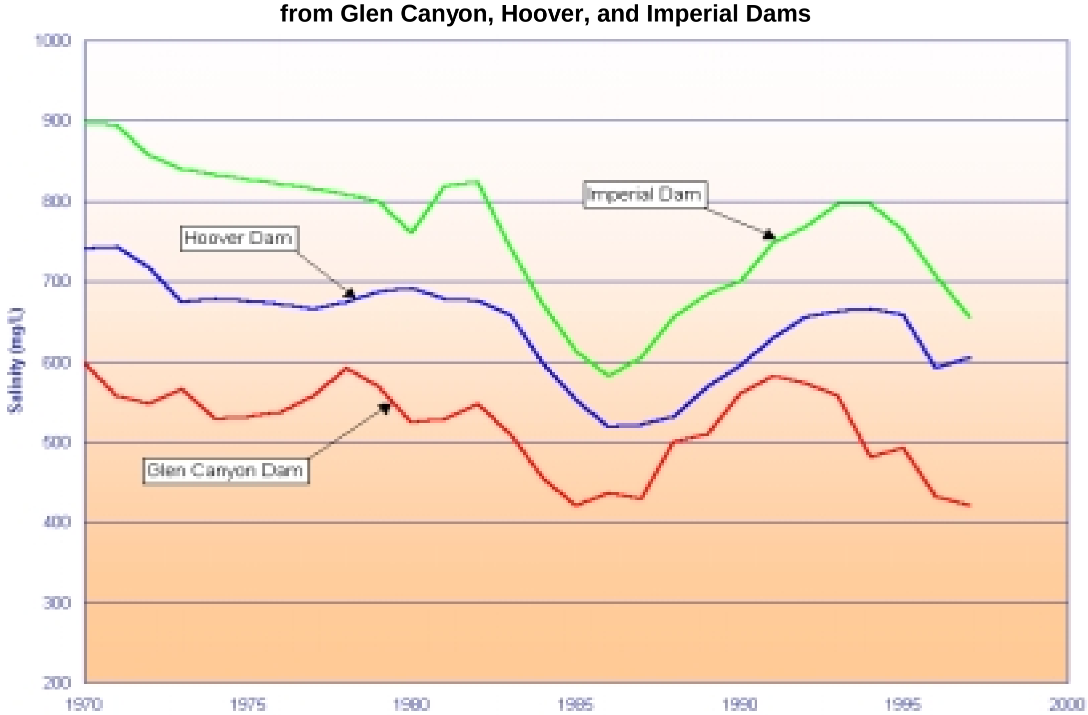


Figure 3.5-3
Historical Salinity Concentrations of Releases from Glen Canyon, Hoover, and Imperial Dams



These criteria applied only to the lower portion of the Colorado River from Hoover Dam to Imperial Dam. Below Imperial Dam, salinity control is a federal responsibility to meet the terms of Minute 242 to the U.S.-Mexico Water Treaty of 1944. Minute 242 requires that salinity concentrations upstream of Mexico's diversion be no more than 115 mg/l ± 30 mg/l TDS higher than the average salinity of water arriving at Imperial Dam.

In 1974, the Colorado River Basin Salinity Control Act (P.L. 93-320) was enacted. The Act contains two Titles: 1) Title I provides the means for the United States to meet its commitment to Mexico; and 2) Title II creates a salinity control program within the Colorado River Basin in order that the numeric criteria will be maintained while the Basin States continue to develop their apportionment of Colorado River water.

The federal/state salinity control program is designed to maintain the flow-weighted average annual salinity at or below the numeric criteria. The program is not intended to counteract short-term salinity variations resulting from short-term water supply. Federal regulations provide for temporary increases above the criteria due to natural variations in flows.

The seven Basin States acting through the Forum reviews the numeric criteria and plan of implementation every three years and makes changes in the plan of implementation to accommodate changes occurring in the Basin States. The latest review was in 1999. The review is currently undergoing adoption by the Basin States and approval by EPA.

At each triennial review, the current and future water uses are analyzed for their impact on the salinity of the Colorado River. If needed, additional salinity control measures are added to the plan to assure compliance with the standards.

The need for one or more additional salinity control projects is determined by monitoring the salinity of the river and making near-term projections of changes in diversions from and return flows to the river system. When an additional project is needed, it is selected from a list of potential projects that have undergone feasibility investigation. A proposal to implement the project is made through coordination with the Basin States. In selecting a project, considerable weight is given to the relative cost-effectiveness of the project. Cost-effectiveness is a measure of the cost per ton of salt removed from the river system or prevented from entering the river system. Other factors are also considered, including environmental feasibility and institutional acceptability.

It is estimated that 1,478,000 tons of salt will need to be removed or prevented from entering the Colorado River system to maintain the salinity concentration at or below the criteria through 2015. To date, over 720,000 tons have been controlled and an additional 756,000 tons will need to be controlled through 2015.

The Forum has found that proposing specific salinity control units beyond a 15-year period is not practicable due to uncertainties associated with future conditions. As such, current model analyses do not include any salinity control measures beyond 2015.

3.5.2.2.3 General Municipal, Industrial, and Agricultural Effects of Increased Salinity Concentrations

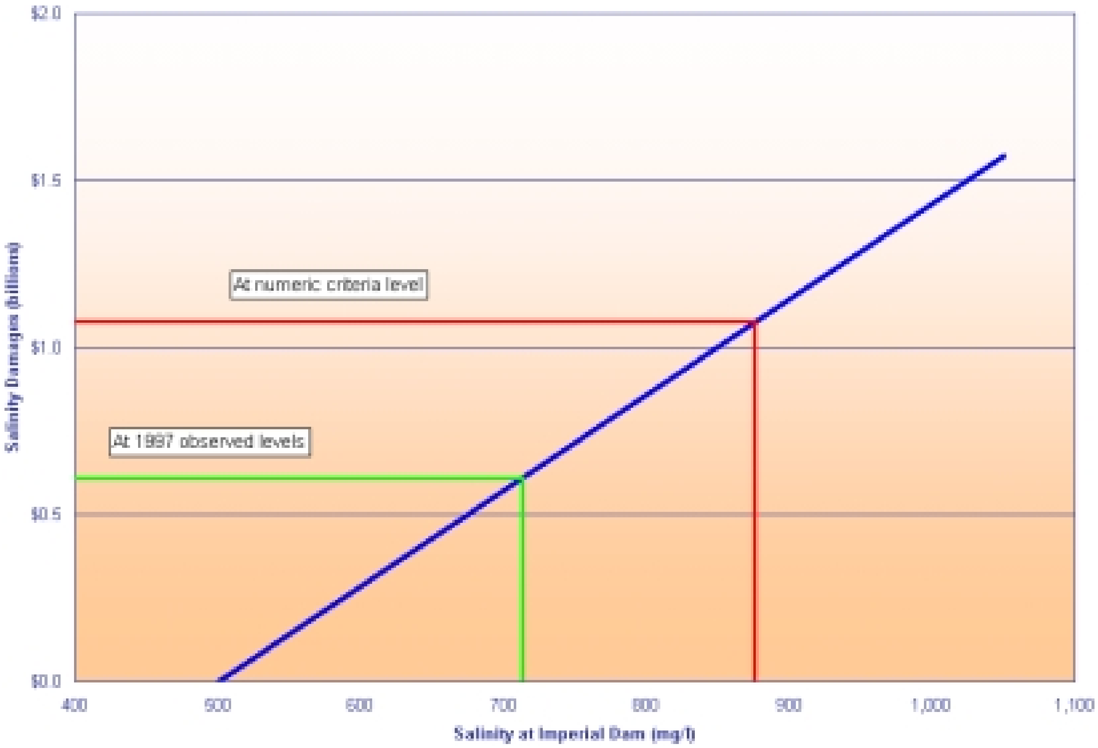
High salinity concentrations can cause corrosion of plumbing, reduce the life of water-using appliances, and require greater use of cleaning products. Industrial users incur extra water treatment costs. Increased salinity in drinking water can create unpleasant taste, often resulting in the purchase of bottled water or water treatment devices. Agriculture experiences economic losses from high salinity through reduced crop productivity and the need to change from less salt-tolerant high value crops, to more salt-tolerant low value crops. Increased salinity can also require more extensive agricultural drainage systems.

High salinity is a significant constraint to water recycling and groundwater replenishment programs. Compliance with regulatory requirements imposed by local water quality management programs to protect groundwater supplies can add significantly to the economic impacts. Restrictions have been placed on reuse or recharge of waters that exceed specific salinity levels. Such restrictions significantly constrain groundwater replenishment programs and wastewater reuse programs. Should salinity of the Colorado River increase, these regulatory actions could create a need for more expensive water treatment processes, such as reverse osmosis, prior to disposal or reuse. If disposal is selected, additional water supplies would need to be developed to meet demands that could have been met by water reuse.

Reclamation has determined that the economic damages from Colorado River salinity in the three Lower Division states served by Colorado River water amount to $2.5 million per mg/l. Figure 3.5-4 shows the relationship between costs of damages and salinity concentrations.

The current model configuration does not include any salinity control units beyond those in place by 2015. As such, modeling of baseline conditions and the alternatives beyond 2015 indicates increases in salinity due to projected increased water consumption in the Upper Basin. However, in practice, these increases would likely be offset as salinity control measures that would continue to be implemented.

Figure 3.5-4
Estimated Cost of Damages Associated with Increased Salinity Concentrations



3.5.2.3 ENVIRONMENTAL CONSEQUENCES

The effects of the alternatives on the salinity of Colorado River water focus on their differences from baseline conditions, as discussed above in Section 3.5.2.1, Methodology. The results are based on the median salinity values calculated by the operational model. Generally, the alternatives cause salinity to be lower at Hoover and slightly higher at Imperial Dam. Progress Report 19 (Interior, 1999) shows the Hoover station needing 67 mg/l of controls while the Imperial station needs only 49 mg/l of controls. Since Hoover is typically the station which is first to exceed the standard, a reduction in salinity at that point is expected to have a slightly positive effect on the salinity control program. The predicted 13 mg/l increase at Imperial station is expected to have no effect on the salinity reduction targets since the Imperial station needs considerably less controls than the Hoover station (i.e., 18 mg/l based on the projections discussed above).

The current operational model configuration does not include any salinity control units beyond those currently scheduled to be in place by 2015. Consequently, the modeling results for baseline conditions and the alternatives beyond 2015 indicate increases in salinity due to projected increased water consumption in the Upper

Basin. However, in practice, these increases would be offset by future salinity control measures.

3.5.2.3.1 Baseline Conditions

As discussed above in Section 3.5.2.1, Methodology, the baseline salinity of Colorado River water at the three monitoring stations is presumed to be the same as the numeric criteria that have been set at each of those respective points, which serve as targets for attainment of the federal/state salinity control program. Tables 3.5-1 and 3.5-2 present the difference between the alternatives and baseline conditions in year 2015 and 2050, respectively. The first column under each monitoring station heading in the tables presents the difference obtained from the model. The second column presents the TDS value calculated by applying the difference to the baseline TDS.

Table 3.5-1
Estimated Colorado River Salinity in 2015
Unit: Total Dissolved Solids (mg/l)

Alternative	Below Hoover Dam		Below Parker Dam		At Imperial Dam	
	Incremental Difference from Baseline	Value	Incremental Difference from Baseline	Value	Incremental Difference from Baseline	Value
Baseline Conditions[1]	--	723	--	747	--	879
Flood Control Alternative	0	723	0	747	0	879
Six States Alternative	-3	720	-2	745	+4	883
California Alternative	-6	717	-5	742	+1	880
Shortage Protection Alternative	-7	716	-7	740	-3	876

1 Baseline conditions assume compliance with the numeric criteria at the locations cited.

Table 3.5-2
Estimated Colorado River Salinity in 2050
Unit: Total Dissolved Solids (mg/l)

Alternative	Below Hoover Dam		Below Parker Dam		At Imperial Dam[1]	
	Incremental Difference from Baseline	Value	Incremental Difference from Baseline	Value	Incremental Difference from Baseline	Value
Baseline Conditions[2]	--	723	--	747	--	879
Flood Control Alternative	0	723	0	747	879	
Six States Alternative	-1	722	0	747	+13	892
California Alternative	-1	722	0	747	+13	892
Shortage Protection Alternative	-1	722	0	747	+13	892

1 Increased salinity at Imperial Dam in year 50 occurs as a result of California water transfers associated with the Six States, California and Shortage Protection alternatives.

2 Baseline conditions assume compliance with the numeric criteria at the locations cited.

3.5.2.3.2 Flood Control Alternative

Modeling indicates that no differences in salinity concentrations would be expected between the Flood Control Alternative and baseline conditions.

3.5.2.3.3 Six States Alternative

Compared to baseline projections, salinity concentrations under the Six States Alternative vary from a decrease of 3 mg/l at Hoover Dam to an increase of 4 mg/l at Imperial Dam during the period through 2015. The numeric difference from baseline conditions in year 2050 varies from a decrease of 1 mg/l at Hoover Dam to an increase of 13 mg/l at Imperial Dam. The increase at Imperial Dam occurs as a result of California water transfers.

3.5.2.3.4 California Alternative

Compared to baseline projections, the effect of the California Alternative on salinity concentrations varies from a decrease of 6 mg/l at Hoover Dam to an increase of 1 mg/l at Imperial Dam during the period through 2015. The difference from baseline conditions in year 2050 varies from a decrease of 1 mg/l at Hoover Dam to an increase of 13 mg/l at Imperial Dam. The increase at Imperial Dam occurs as a result of California water transfers.

3.5.2.3.5 Shortage Protection Alternative

Compared to baseline projections, salinity concentrations under the Shortage Protection Alternative vary from a decrease of 7 mg/l at Hoover Dam to an increase of 3 mg/l at Imperial Dam in 2015. In 2050, the differential from baseline salinity is a decrease of 1 mg/l at Hoover Dam and an increase of 13 mg/l at Imperial Dam. The increase at Imperial Dam occurs as a result of California water transfers.

3.5.2.3.6 General Economic Effects of Increased Salinity

Reclamation estimates that the total economic damages/benefits to all of the Colorado River water users in the states of Arizona, California and Nevada amount to about $2.5 million per mg/l of TDS (1999 Review). The small incremental changes in salinity that could occur as a result of the interim surplus criteria alternatives under consideration would have minimal economic impacts over the short term to 2015.

No definitive studies have determined the economic damages due to salinity incurred by the water users receiving water deliveries from Hoover Dam or by users immediately downstream from Hoover Dam. This includes Las Vegas, the surrounding area and Laughlin area. Salinity in the Laughlin area approximates the salinity below Hoover Dam.

Deliveries from Parker Dam provide full supplemental water to the major portion of MWD's service area extending from portions of Ventura County to the Mexican border in California. In Arizona, the CAP provides Colorado River water to the greater Phoenix and Tucson areas as well as Tribal lands. From Imperial Dam, deliveries serve primarily agricultural water in the Imperial and Coachella valleys in California, and Wellton Mohawk, Yuma Mesa and Yuma Valley lands in Arizona.

3.5.3 LAKE MEAD WATER QUALITY AND LAS VEGAS WATER SUPPLY

This analysis addresses potential impacts of interim surplus criteria alternatives on water quality in Lake Mead, and potential changes to water quality and levels of contaminants at the SNWA intakes. This is a qualitative analysis based on system modeling and existing limnological studies.

3.5.3.1 METHODOLOGY

Evaluation of the environmental consequences of each operational alternative to Lake Mead water quality and Las Vegas water supply are based on a qualitative assessment of existing limnological and hydrodynamic data, and hydrologic modeling as discussed in Section 3.3. Each interim surplus criteria alternative was modeled for comparison to baseline projections. Modeling focused on the probability of decreased Lake Mead surface elevations, which could exacerbate effects of discharge of Las Vegas Wash water into Boulder Basin.

Assessment of potential effects on water quality of Lake Mead, including consideration of Las Vegas Wash inflow on the SNWA intake, relied primarily on system modeling information associated with the probability of future Lake Mead surface elevations. Previous studies of Lake Mead were also an important source of information, particularly those focusing on Boulder Basin, Las Vegas Wash, and hydrodynamics potentially affecting intake water quality.

As discussed in Section 3.3, modeling identified probabilities associated with surface water elevations under baseline conditions as well as projections associated with implementation of the interim surplus criteria alternatives over a 50-year period. As discussed previously, model output utilized for this water quality analysis assumes shortage determinations would occur, if necessary, to protect a surface elevation of 1083 feet msl, which is the Lake Mead minimum power pool elevation. The primary SNWA intake at Saddle Island is at 1050 feet msl, and the secondary intake is at 1000 feet msl. Thus, assuming a strategy to protect 1083 feet msl also provides a level of protection to SNWA's intake water quality.

As discussed below, contaminant dilution and lake water quality are directly proportional to lake volume. As such, a critical element in this assessment is a comparison of projected Lake Mead volumes under the three alternatives relative to baseline conditions. Using hydrologic modeling output, median Lake Mead volumes and surface areas were identified for each of the alternatives associated with projected reservoir elevations under the median modeled probabilities. These data were partitioned into three classes for analysis: years 1 through 15; years 16 through 25; and years 26 through 50. Separate comparisons were then made of the volume and surface area for each alternative as compared to baseline conditions.

3.5.3.2 AFFECTED ENVIRONMENT

The focus of this section is a description of the affected environment related to Lake Mead water quality and the SNWA intake locations, with specific consideration of hydrodynamics of the Colorado River Basin, limnology and water quality (factors that may be influenced by implementation of interim surplus criteria alternatives).

3.5.3.2.1 General Description

Lake Mead is a large mainstream Colorado River reservoir in the Mojave Desert, within the states of Arizona and Nevada as shown on Map 3.2-1. Lake Mead, formed in 1935 following the construction of Hoover Dam, is the largest reservoir in the United States by volume (26 maf active storage). At full pool (reservoir elevation 1221 feet msl, Lake Mead extends 108 miles from Black Canyon (Hoover Dam) to Separation Canyon at the upstream end. Lake Mead has four large sub-basins including Boulder, Virgin, Temple and Gregg. Between these basins are four narrow canyons: Black, Boulder, Virgin and Iceberg. Over 170,000 square miles of the Colorado River Basin watershed are located above Hoover Dam. Boulder Basin, SNWA intake locations and the Las Vegas Wash are shown on Map 3.5-1.

The Muddy and South Virgin mountains border the reservoir on the north, and the Virgin and Black mountains and various desert hills border the reservoir on the south. The shoreline is extremely irregular with a Shoreline Development Value (SLD) of 9.7 (Paulson and Baker, 1981). SLD is the ratio of the length of the shoreline of a lake or reservoir to the length of the circumference of a circle with an area equal to that of the lake (Wetzel, 1975). The shoreline includes several large bays, including Las Vegas and Bonelli, and numerous coves. The principal morphometric characteristics of Lake Mead are summarized below in Table 3.5-3.

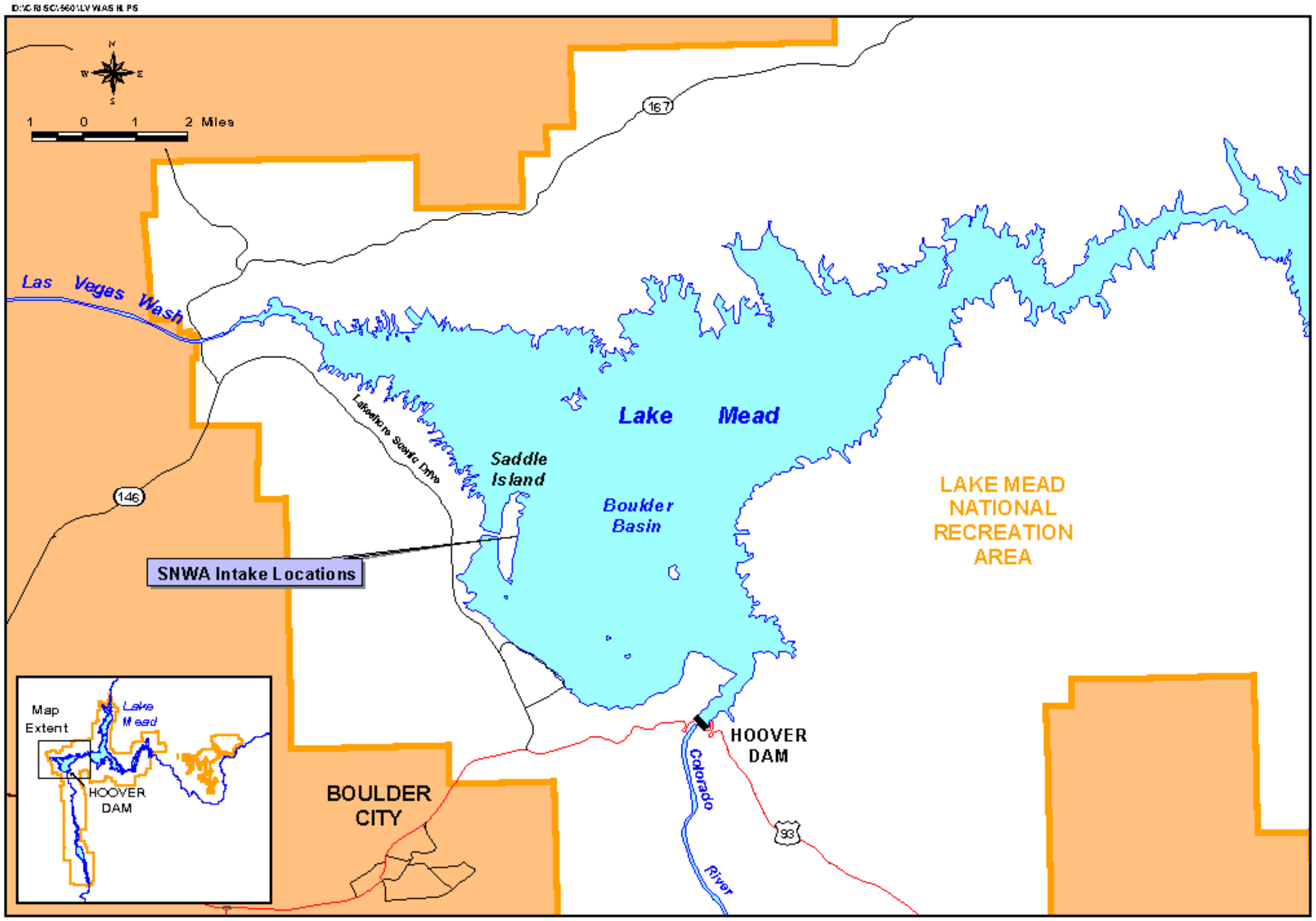
Table 3.5-3
Morphometric Characteristics of Lake Mead

Parameter	Units	Value
Normal operating level (spillway crest)	feet	1,205
Maximum depth	feet	590
Mean depth	feet	180
Surface area	square miles	231
Volume (including dead storage)	maf	30
Maximum length	miles	108
Maximum width	miles	17
Shoreline development	Index Value	9.7
Discharge depth	feet	310
Annual discharge (approximate)	maf	10
Replacement time at maximum operating level	years	3.9

Derived from Interior (1966), Lara and Sanders (1970), Hoffman and Jonez (1973)

LaBounty and Horn (1997) conducted a study of the influence of drainage from the Las Vegas Valley on the limnology of Boulder Basin that is highly relevant to the issue addressed in this section. Unless otherwise noted, the descriptions of reservoir characteristics, hydrodynamics, and general limnology of Lake Mead are drawn from this study.

Map 3.5-1
Las Vegas Wash and SNWA Lake Mead Intake Facilities at Saddle Island



The Colorado River contributes about 98 percent of the annual inflow to Lake Mead; the Virgin and Muddy rivers and Las Vegas Wash provide the remainder. Annual flows from Las Vegas Wash are approximately 155,000 acre-feet, providing the second highest inflow into Lake Mead. Discharge from Hoover Dam is hypolimnetic and occurs 285 feet below the normal operating shown above (1205 feet msl). Average annual discharge is approximately 10 maf.

Boulder Basin, the lowermost basin of Lake Mead, receives all nonpoint surface and groundwater discharges and treated effluent from the Las Vegas Valley and municipal wastewater treatment facilities via drainage from Las Vegas Wash into Las Vegas Bay. Boulder Basin is 9.3 miles wide from Boulder Canyon to Hoover Dam (Black Canyon), and the distance from the confluence of Las Vegas Wash to Hoover Dam is approximately 9.9 miles. The historical Colorado River channel lies along the eastern side of Boulder Basin.

Due to effects of urban runoff and treatment plant effluents on the discharge through Las Vegas Wash (discussed later in this section), Boulder Basin has the highest nutrient concentrations in the Lake Mead system (Paulson and Baker, 1981; Prentki and Paulson, 1983). This is in contrast to the normal upstream-downstream decrease in the pattern of productivity more typical of reservoirs, and results in several limnological features within Boulder Basin that are normally associated with upstream reaches (Kimmel et al., 1990).

Overall, Lake Mead is mildly mesotrophic based on several classification indices (Vollenweider 1970; Carlson 1977), including chlorophyll *a* concentration and secchi transparency measurements. Chlorophyll *a* concentration is a measure of algal biomass and can, therefore, be interpreted as an index of lake productivity. Secchi disk measurements are used to determine the depth to which light penetrates lake water and help to establish the euphotic zone which marks that area of a lake where primary productivity (energy production by photosynthesis) occurs.

Due to abundant nutrient input into Las Vegas Bay, chlorophyll *a* concentrations have been measured greater than 100 milligrams per cubic meter (mg/m^3). Secchi transparency readings of less than 2 feet have been measured in the inner bay (LaBounty and Horn, 1997). However, secchi transparency increases to over 16 feet, and chlorophyll *a* is reduced by 90 percent within the first 2.6 miles from the Las Vegas Wash inflow. These findings suggest that Boulder Basin is a relatively isolated embayment and that it is much more productive than the lake as a whole.

3.5.3.2.2 Lake Mead Water Quality and Limnology

Water quality of Lake Mead and the Colorado River is alkaline with a pH of 8.3 and an average concentration of TDS of approximately 700 milligrams per liter (mg/l).

Chemical characteristics of the river at the inflow to Lake Mead, near the outflow at Hoover Dam, and at Lake Mohave are shown below in Table 3.5-4.

Table 3.5-4
Chemical Characteristics of Colorado River

Parameter	Units	Gage Station Location[1]		
		Grand Canyon	Hoover Dam	Davis Dam
pH		8.0	7.7	8.0
Conductivity	umho/cm[2]	945	1086	1089
Total Dissolved Solids	mg/l	617	705	714
Calcium	mg/l	74	86	84
Magnesium	mg/l	26	28	29
Potassium	mg/l	4.1	4.9	5.0
Bicarbonate	mg/l	170	163	157
Sulfate	mg/l	228	283	293
Chloride	mg/l	79	85	87
Silica	mg/l	7.0	8.3	7.8
Nitrate	mg/l	.50	.41	.28
Phosphate	mg/l	.010	.013	--

[1]USGA data, average for October 1975 – September 1976

The principal constituents of TDS are the anions of sulfate, carbonate and chloride and the cations of sodium, calcium, magnesium and potassium. Nitrate concentrations are moderate (0.28 to 0.50 mg/l), but phosphorus is extremely low (0.01 to 0.03 mg/l). Silica is present in very high concentrations (7.0 to 8.3 mg/l).

Limnological investigations of Lake Mead have found that 80 percent of the inorganic nitrogen within the lake is provided by the Colorado River, and that Las Vegas Wash contributes 70 percent of the inorganic phosphorus (Paulson, Baker, Deacon, 1980). The upper basin of Lake Mead was found to be phosphorus-limited, and the lower basin nitrogen-limited during the summer. Equal proportions of nitrogen and phosphorous were retained in the upper basin of Lake Mead, but nitrogen retention decreased to 7 percent, and phosphorus to 33 percent in the lower basin. Additionally, the high nitrate loss from Hoover Dam greatly reduced nitrogen retention in the lower basin of Lake Mead.

In 1978 the EPA estimated that Lake Mead retained 93 percent of the total phosphorus input versus 52 percent of total nitrogen (EPA, 1978). Phosphorus concentrations are low in the upper basin of the lake due to the low input from the Colorado River, a result of sediment trapping that occurs upstream within Lake Powell.

As recently as 1998, new contaminants to Lake Mead have been discovered as a part of the nonpoint pollutant load of Las Vegas Wash (EPA, 2000). Perchlorate has been detected in the water of the Colorado River and Lake Mead. Ammonium perchlorate is manufactured as an oxygen-adding compound in solid rocket fuel propellant, missiles and fireworks. The EPA identified two facilities that manufactured ammonium perchlorate in Henderson, Nevada, that were found to have released perchlorate to groundwater, resulting in 4 to 16 parts per billion (ppb) concentrations in Lake Mead and the Colorado River (EPA, 2000).

The rate and volume of inflow from the Colorado River are major determinants of the limnology of Lake Mead, with minor contributions to volume coming from the Virgin and Muddy rivers and the Las Vegas Wash (see Table 3.5-5). Due to its lower conductivity within Lake Mead, Colorado River flows can be identified through the reservoir. Flows into Lake Mead average approximately 17,900 to 21,400 cfs. During a seven-day controlled flood in 1996, inflows of 44,600 cfs resulted in a three-foot rise in surface elevation. Flows of this magnitude influence reservoir limnology of Lake Mead well into Boulder Basin (LaBounty and Horn, 1997).

Table 3.5-5
Hydraulic Inputs for Lake Mead

Input	Flow (ac-ft)	% of Total
Colorado River	8,800,000	98
Virgin River	92,000	1
Las Vegas Valley Wash	59,000	0.60
Muddy River	29,000	0.34
TOTAL INPUT	**9,000,000**	**100**

Derived from USGS data from October 1975 – September 1976

The two major outflows from Lake Mead are both in Boulder Basin: Hoover Dam and the SNWA intake. Hoover Dam is operated for flood control, river regulation and power production purposes. The operating elevation for Hoover Dam powerplant ranges from 1083 feet to a maximum elevation of 1221 feet msl. The dam's four intake towers draw water from the reservoir at approximate elevations 1050 and/or 900 feet msl to drive the generators within the dam's powerplant. SNWA pumps water from two adjacent intakes located at Saddle Island that operate down to elevations of 1050 feet and 1000 feet msl. Hoover Dam outflows vary on a daily basis from approximately 2,000 cfs to 50,700 cfs. Capacity of the SNWA intake is 600 cfs. Despite its much smaller volume, the SNWA intake has been shown to influence deep water currents near the entrance to Las Vegas Bay (Sartoris and Hoffman, 1971).

LaBounty and Horn (1997) cite the rarity of complete turnover in Lake Mead due to the great depth (590 feet), and relatively constant temperature gradient. The thermal regime over the period of 1990 through 1996 was characterized by surface temperatures of 14°C in December and January to over 30°C in August. Seasonal thermoclines range from 50 feet in early summer to 100 feet in late summer. Hypolimnetic temperatures remain near 12°C year-round. Though full reservoir turnover seldom occurs, turnover occurs to a depth of approximately 200 to 230 feet in January and February, a sufficient depth for complete mixing in Las Vegas Bay.

As with other reservoirs, dam operation exerts a great influence on the water quality and ecology of the system (Thornton, 1990). The hydrodynamics of this large reservoir are complex and not completely understood. Each basin within Lake Mead is ecologically unique, and therefore responds differently to the inflow-outflow regime. Furthermore, the different sources of water entering Lake Mead often retain their identity for substantial distances into the reservoir and do not necessarily mix completely with the rest of the water column (Ford, 1990). This spatial heterogeneity can lead to significant underestimates of actual water retention time, conveyance and fate of materials transported into the reservoir.

3.5.3.2.3 Hydrodynamics of Lake Mead and Boulder Basin

The Colorado River, Virgin and Muddy rivers and Las Vegas Wash all form density currents in Lake Mead (Anderson and Pritchard, 1951; Deacon and Tew, 1973; Deacon 1975, 1976, 1977; Baker et al., 1977; Baker and Paulson, 1978). Anderson and Pritchard (1951) conducted a detailed investigation of density currents in 1948-1949 using temperature and TDS relationships to trace the river inflows. They found that the Colorado River flowed along the bottom of the old river channel in winter (January-March). The underflow was detectable well into the Virgin Basin and at times extended to Boulder Basin. The underflow created a strong convergence at the point where river water flowed beneath lake water. Up-lake flow of surface water occurred due to frictionally induced, parallel flow of lake water (entrainment) along the boundary of the cold river inflow. This produced a large circulation cell in the upper basin of Lake Mead, as surface water was pulled up-lake to replace that entrained by the underflow.

Hydrodynamics within Las Vegas Bay have also been the subject of research and are particularly important from the standpoint of potential interactions between Las Vegas Wash water and intake water quality. LaBounty and Horn (1997) provide an excellent discussion of flow patterns in this area of Lake Mead. These authors cite unique signatures of both Colorado River water and Las Vegas Wash water that allow mapping of higher conductivity intrusions from Las Vegas Wash into Boulder Basin. Depending on conditions, the intrusion can be measured for over five miles into Lake Mead. Seasonally, the Las Vegas Wash intrusion is deepest in January and February (130 to 200 feet) and shallowest in early spring (33 to 50 feet).

Water quality in Las Vegas Wash, and ultimately in Boulder Basin, is heavily influenced by urban runoff, as well as the treated effluent from three major sewage treatment facilities upstream. Historically, flows in this basin drained wetlands, which allowed for natural cooling and nutrient removal. Flows today are warmer and have doubled in volume over the last 15 years, from 110 cfs to 215 cfs (LaBounty and Horn, 1997). These factors have tended to force the intrusion higher in the water column of Las Vegas Bay.

The existence of contaminants in sediments and fish tissue in Las Vegas Bay, and poor water quality has been well documented (LaBounty and Horn, 1996; Roefer et al., 1996; Bevans et al., 1996). LaBounty and Horn (1997) cite the relatively close proximity of the SNWA intake at Saddle Island to potential intrusions of the Las Vegas Wash, and conclude that changes in hydrodynamics of the basin (e.g., due to drought or management actions) are critical considerations in assessing effects of the Las Vegas Wash on drinking water quality.

3.5.3.3 ENVIRONMENTAL CONSEQUENCES

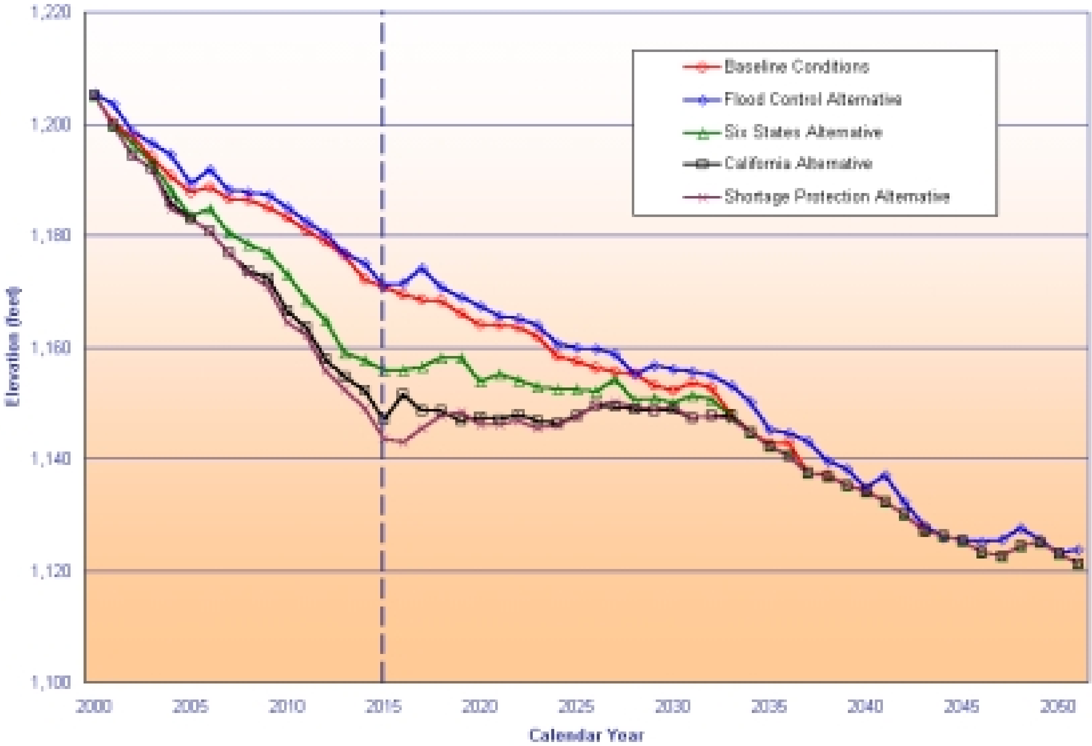
3.5.3.3.1 General Effects of Reduced Lake Levels

This section presents potential water quality changes in Lake Mead associated with reductions in lake levels, and potential effects of these changes on the concentration of Las Vegas Wash water at SNWA water supply intakes. In addition, this section addresses general limnological changes in Lake Mead that may occur under each alternative.

It is important to note that estimates of potential changes in Lake Mead surface elevations are based on system modeling discussed in Section 3.3. Water quality modeling has not been conducted as a part of this investigation; however, literature review and assumptions with regard to Las Vegas Wash mixing in the Boulder Basin under various Lake Mead elevations have been used to estimate potential future water quality conditions.

Results of model runs conducted for this analysis indicate that projections of baseline conditions and each of the interim surplus criteria alternatives indicate increased potential over time for the occurrence of declining Lake Mead surface elevations within and beyond the interim 15-year period, as indicated by the plots of median elevations on Figure 3.5-5.

Figure 3.5-5
Lake Mead End-of-Year Water Elevations
Comparison of Surplus Alternatives to Baseline Conditions
50th Percentile Values



The potential degradation of SNWA intake water is not demonstrated quantitatively in this DEIS, rather the expectation of degradation is based on the assumption that decreasing lake levels, and therefore lake volume and surface area, could result in decreased water quality and, more specifically, increased concentration of Las Vegas Wash inflow at the intake locations. The potential effects associated with Lake Mead elevation declines are described below, and are followed by a tabular comparison of the projected Lake Mead volume and surface area changes under the alternatives and baseline conditions.

3.5.3.3.1.1 Volume Reduction

Reduction in the volume of Lake Mead would likely have deleterious effects on lake water quality and, potentially, on water quality withdrawn by SNWA. These effects occur as a result of changes in mixing patterns in Boulder Basin. Given the hydrodynamics of Boulder Basin associated with the relatively confined nature of the embayment, effects of reduction in volume of Lake Mead would likely be disproportionately greater in Boulder Basin than in the lake as a whole. LaBounty and Horn (1997) cite the importance of salinity and thermal gradients in determining the extent of intrusion of the Las Vegas Wash into Boulder Basin. Lower lake volumes could increase the overall salinity of the Boulder Basin, thereby lowering the differential between lake water and inflows of the Las Vegas Wash. This in turn may act to disperse the intrusion, causing a more diffuse flow from Las Vegas Wash, a greater concentration of nutrients and contaminants throughout Boulder Basin, and greater availability of nonpoint contaminants in the vicinity of the SNWA intakes.

3.5.3.3.1.2 Tributary Water Quality

Lower water surface elevations in Lake Mead could also impact the quality of tributary flows from the Las Vegas Wash, Virgin and Muddy rivers. These effects would be a result of longer channels, and thus, longer travel times for influent streams. Potential effects on Lake Mead could include increased temperature due to warmer tributary flows. Higher evaporative losses and greater concentration of salts and contaminants may also occur in tributaries due to longer channels, leading to higher concentrations of pollutants in the Las Vegas Wash, and potentially greater concentrations of contaminants near the SNWA intakes. However, new riparian habitat development near the mouths of these tributaries would likely develop and would be expected to offset impacts to tributary water quality.

3.5.3.3.2 Comparison of Baseline Conditions and Alternatives

Section 3.5.3.3.1, above, discussed the general water quality effects that may be expected given reduced Lake Mead surface elevations and volumes. The following sections compare predicted surface elevations, volume, and surface area of Lake Mead under baseline and alternative conditions. This analysis is based on system modeling results; specifically the 50 percent (median) probability elevations, as shown on Figure 3.5-5.

Characteristics of Lake Mead (elevation, volume, surface area) under baseline and alternative conditions are shown below for four selected years within the modeled period (years 15, 25, 35 and 50 as shown in Table 3.5-6). A comparison of the alternatives to baseline is shown in Table 3.5-7. It should be noted that in Table 3.5-7, the median probabilities of exceedence of elevation 1083 feet msl converge with the baseline condition, resulting in zero percent differences in years. Brief discussion of differences among the alternatives and baseline conditions are discussed below. This discussion focuses largely on differences in volume, although references to elevation and surface area are also noted.

Table 3.5-6
Modeled Characteristics of Lake Mead Under Baseline and Alternative Conditions

Alternative	Elevation[1] (feet above msl)			Volume (af x 10^6)			Surface Area (x 1000 acres)		
	Years 1-15	Years 16-25	Years 26-50	Years 1-15	Years 16-25	Years 26-50	Years 1-15	Years 16-25	Years 26-50
Baseline Conditions	1186	1164	1127	20.9	18	14	136	121	100
Flood Control Alternative	1188	1167	1128	21.2	18	14.1	138	124	101
Six States Alternative	1179	1154	1127	20	17	14	131	115	100
California Alternative	1175	1147	1127	19	16	14	128	110	100
Shortage Protection Alternative	1175	1146	1127	19	16	14	128	109	100.

[1] Values shown are median elevations (50th percentile) for each year group.

Table 3.5-7
Modeled Comparisons of Alternatives to Baseline Conditions

Alternative	Elevation Change			Volume Change			Surface Area Change		
	Years 1-15	Years 16-25	Years 26-50	Years 1-15	Years 16-25	Years 26-50	Years 1-15	Years 16-25	Years 26-50
Flood Control Alternative	0.13%	0.22%	0.06%	1.3%	2.0%	0.71%	1.0%	1.7%	0.5%
Six States Alternative	-0.6%	-0.8%	-0.02%	-4.7%	-6.2%	0.0%	-3.5%	-5.5%	0.0%
California Alternative	-1.0%	-1.4%	-0.02%	-7.5%	-12.2%	0.0%	-5.7%	-10.5%	0.0%
Shortage Protection Alternative	-1.0%	-1.6%	-0.02%	-7.5%	-12.9%	0.0%	-5.7%	-11.1%	0.0%

3.5.3.3.2.1 Baseline Conditions

Baseline projections indicate decreasing Lake Mead surface elevations, volume and surface area over the 50-year period of analysis, as shown above on Figure 3.5-5 and in Table 3.5-4. This increased potential for lake level reductions would be expected to result in an increased potential for declining water quality of Lake Mead and associated affects on the SNWA intake (discussed in Section 3.5.3.3.1, above) over time under baseline conditions.

3.5.3.3.2.2 Flood Control Alternative

Based on modeled median surface elevations, Lake Mead volume under the Flood Control Alternative is 1.3 percent higher than baseline conditions in years 1 through 15, and 2 percent higher in years 16 through 25. The volume change in years 26 through 50 is .71 percent higher than under baseline conditions.

3.5.3.3.2.3 Six States Alternative

Predicted Lake Mead volume under the Six States Alternative is 4.7 percent lower than baseline conditions in years 1 through 15, and 6.2 percent lower in years 16 through 25. No difference between baseline conditions and the Six States Alternative is predicted for years 26 through 50 as shown in Table 3.3-5.

3.5.3.3.2.4 California Alternative

The California Alternative produces a moderate increased probability (approximately one percent) for decreased Lake Mead surface elevations in years 1-25, in contrast to baseline conditions, to nearly no difference in years 26 through 50, as shown in Figure 3.5-5. Predicted reduction in lake volume is 7.5 percent lower than baseline conditions in years 1 through 15, and 12.2 percent lower in years 16 through 25. Median volume in years 26 through 50 does not differ from baseline conditions.

3.5.3.3.2.5 Shortage Protection Alternative

The Shortage Protection Alternative produces the same volume reduction over baseline conditions (7.5 percent) as the California Alternative in years 1 through 15. However, the predicted reduction in volume during years 16 through 25 is 13 percent greater than baseline conditions. This is almost double the reduction seen with the Six States and California Alternatives over the same period. Predicted surface area reduction is 11 percent lower than baseline in years 16 through 25, approximately twice that of the Six States Alternative and slightly greater than the California Alternative.