CHARACTERIZATION OF THE AQUATIC ENVIRONMENT IN LAKE MEAD NEAR THE PROPOSED SPRING CANYON PUMPED-STORAGE PROJECT, AND ASSESSMENT OF POTENTIAL AQUATIC IMPACTS

by

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SUMMARY AND CONCLUSIONS

This report draws upon the following information in characterizing the aquatic environment of the Virgin Canyon area of Lake Mead and assessing potential aquatic impacts from the proposed Spring Canyon Pumped-Storage Powerplant (SCPSP): 1) limnological data taken during May 1986 through April 1987 by the University of Nevada, Las Vegas, under the auspices of the Lower Colorado Region Reservoir Monitoring Program including monthly depth profiles of temperature (°C), pH, dissolved oxygen (ppm), conductivity (μmhos cm^{-1}), water transparency, light penetration, phosphorus (total and ortho-phosphorus in μg/l), nitrogen (total, nitrate, nitrite, total kjeldahl, and ammonia in μg/l), chlorophyll a (μg/l), salinity (total salinity, sodium, potassium, calcium, magnesium, chloride, sulfate, bicarbonate and carbonate ion, all expressed as mg/l), and zooplankton (numbers per cubic meter for total Cladocera, Copepoda and Rotifera plus all common species); 2) fisheries data taken in 1986 and 1987 by the Bureau of Reclamation's Denver Environmental Sciences Section, Bureau of Reclamation's Lower Colorado Regional Office, and Biosonics, Inc. of Seattle, Washington (juvenile and adult fishes were sampled and observed with hydroacoustic methods, vertical gill nets, and SCUBA while larval fish were sampled with towed plankton nets); 3) pertinent literature from former and other on-going studies of Lake Mead; and, 4) personal experience and data from other pumped-storage powerplants.

The proposed SCPSP would generate up to 2,000 megawatts of peaking power with maximum flows of some 16,000 ft^3/s (453.1 m^3/s) during pumping and 27,000 ft^3/s (764.6 m^3/s) during generation. Daily cycling of flows are anticipated with alternating pumping and generating activities. Annually, about 5.75 x 10^6 acre-ft of water may be pumped from Lake Mead into the new upper reservoir (forebay), and a similar volume would be released back into Lake Mead.

The SCPSP would require development of a 1,820 acre (736.5 Ha) upper reservoir (forebay). Surface elevation at maximum pond would be 1,950 ft (594.5 m) and the maximum volume would be 218,000 acre-ft (2.69 x $10^8 m^3$). The forebay surface would fluctuate between elevation 1,950 ft (594.5 m) and 1,915 ft (583.8 m) in response to powerplant activity.

Lake Mead surface water elevations were high and relatively stable during this study, ranging between 1,205 - 1,210.5 ft (367.4 - 369.1 m). Future surface levels are projected to drop as full utilization of water users' anticipated share of Colorado River water is realized by the year 2040. Based upon models for the years 2040 - 2086, surface elevations should be above 1,083 ft (330.2 m) about 75 % of the time, above 1,123 (342.4 m) some 58 % of the time, and above 1,142 ft (348.2 m) about half the time. Lake Mead water levels will influence the degree of impacts from powerplant operation. In general, less effect is expected at high water levels compared to low water levels. This is due to proportionally greater lake volume in relation to required powerplant inlet-outlet flows at high surface elevation, but also relationships between lake level and depth of the inlet-outlet. The proposed inlet-outlet will sit at elevation 1,000 ft (304.9 m). At present lake elevations of about 1,210 ft (368.9 m), the inlet-outlet would be submerged some 210 ft (64 m) and inlet-outlet flows would impact upon deep, hypolimnial waters. If Lake Mead dropped to elevation 1,083 ft (330 m), the inlet-outlet would be covered by about 83 ft (25.3 m) and greater interaction between powerplant-induced water flows and shallow, warmer Virgin Canyon water is possible. Further, zooplankton and fishery studies (hydroacoustics) indicate that proportionally greater numbers of organisms would be entrained at lowered Lake Mead levels.

Water Temperature and Water Movements

Water temperature in Virgin Canyon ranged from 10.5 - 28.4 °C. Maximum values occurred in surface waters during August and minimum values occurred near the bottom (344.4 ft, or 105 m) in February. Thermal stratification was most apparent during June through September. During this period, epilimnial waters occurred within 0 - 42.6 ft (0 - 13 m) depths with temperatures of 22.9 - 28.4 °C; metalimnions were observed between 26.2 - 68.9 ft (8 - 21 m) and temperatures ranged from 17.4 - 25.1 °C; and, hypolimnions occurred between 52.3 - 344.4 ft (16-105 m) with temperatures between 12.2-20.5 °C. Some 7 - 13 percent of the volume in Virgin Canyon was epilimnetic, 5-9 percent was metalimnetic, and 78 - 86 percent was hypolimnetic.
During October through May, thermal stratification was weak or nonexistent. Though surface to bottom temperatures differed 5 - 8 °C in October and November, and again during April and May, metalimnions were not well established. Near isothermal conditions existed December through March.

Water withdrawals during pumping are not expected to alter thermal patterns in Virgin Canyon. Water withdrawn during late fall, winter and early spring will originate from most of the water column due to lack of significant density gradients. Withdrawals during summer will be primarily hypolimnetic water. Water temperatures of pumped water will remain cold all year, generally between 11 - 14 °C. The forebay will generally reflect this condition and will be a cold reservoir, though some solar warming of surface waters is expected. With the forebay inlet-outlet structure at elevation 1,870 ft (570.1 m) water cover should range between 46 - 80 ft (14 - 24 m). Some thermal stratification of the forebay is expected during June through September with development of an epilimnetic type of pool that will float on top of a much larger, deeper pool of cooler water. Summer maximum forebay temperatures should never approach those of Lake Mead because of frequent additions of cold water during pumping activities. Because of the relatively shallow forebay inlet-outlet, upper strata waters of the forebay will be withdrawn during generating modes and summer temperatures of return flows to Virgin Canyon may be several degrees higher than ambient canyon waters. Forebay mixing will be extensive both vertically and horizontally during October through May, though turbulence should be minimal.

The inlet-outlet design for Virgin Canyon should contain a velocity cap to direct generating mode flows horizontally, and a minimum of 1,000 ft (305 m) of unobstructed water should be available to prevent surface disturbances and extensive upwelling of water from collision with canyon walls. Flows directed in this manner should minimize disturbances of thermal stratification patterns during June through September. During much of the non-stratified period (generally October through May), greater diffusion of water flows from the forebay throughout the water column in Lake Mead is expected.

Dissolved Oxygen

Dissolved oxygen ranged from 5.1 - 11.5 ppm in Virgin Canyon. Oxygen deficits (<100 % saturation) regularly occurred in deepest waters during summer and fall, though ample oxygen for aquatic life was always present.

No important effects on dissolved oxygen in Virgin Canyon from operation of SCPSP are anticipated. Further, oxygen levels in pumping water should range between 7.0 - 11.0 ppm considering all possible future surface elevations of Lake mead. The Spring Canyon forebay will be well oxygenated and no significant oxygen deficits in deep waters are expected.

pH

pH values in Virgin Canyon ranged from 7.3 - 8.5, well within the general range of 6 - 9 ppm for the majority of open lake systems. pH values are not expected to change significantly in Virgin Canyon, and forebay water should exhibit pH values similar to those in Virgin Canyon.

Conductivity and Salinity

Conductivity ranged from 694 - 856 µmhos cm^{-1} in Lake Mead. Decreases in conductivity during summer beginning within the metalimnion and continuing to about 98 ft (30 m) were attributable to density currents from Colorado River inflows. Conductivity of pumping water should range between 697-820 µmhos cm^{-1}, although values should be 720 - 780 µmhos cm^{-1} some 70 % of the time. Vertical conductivity patterns in Virgin Canyon may be altered through operation of SCPSP but no significant effects on the aquatic system is anticipated.

Estimates for total salinity in Virgin Canyon determined by adding the concentrations of all major ions ranged from 492 - 602 mg/l; most values (75 %) fell within 521 - 560 mg/l. Approximate proportions (percent) of the major ions were: Na, 11.1; K, 0.7; Ca, 12.2; Mg, 4.3; CO_3, 0.3; HCO_3, 29; Cl, 8.8; SO_4, 33.6. No measurable effects on salinity from operation of the SCPSP are anticipated. Additions of salinity from soluble deposits within future inundated areas of the Spring Canyon forebay would be insignificant in Lake Mead.

Water Transparency and Light Penetration

Water transparency (Secchi disc depth) in Virgin Canyon ranged from 8.2 - 19.7 ft (2.5 - 6.0 m) during May through September and 32.8 - 57.4 ft (10.0 - 17.5 m) during October through April. Low summer readings corresponded to periods of increased phytoplankton populations, while high clarity during winter resulted from reduced phytoplankton populations. The euphotic zone (the distance from the surface to a depth where about 1 % of surface light intensity remains) tended to vary directly with Secchi disc depth. The euphotic zone ranged from 34.4 - 45.9 ft (10.5-14.0 m) during May through July, 49.2 - 59.0 ft (15 - 18 m) during October through December, and 52.5 - 62.3 ft (16 - 19 m) during February through April. During the stable thermal stratification periods of June and July, the euphotic zone penetrated well into the metalimnion. Water transparency and the euphotic zone will be decreased locally during construction due to releases of fine clays and silts into Virgin Canyon. Powerplant operation may continue to decrease transparency locally from suspension and release of fine silts and clays now present in the soils of the future forebay reservoir. Though these physical changes will tend to decrease photosynthesis locally, overall Lake Mead photosynthesis should not be affected significantly.

Nutrients and Chlorophyll

Total phosphorus content in Virgin Canyon ranged from 6.4 - 9.4 µg/l, indicating very oligotrophic waters of low productivity. Biologically available phosphorus averaged 2.5 µg/l at the 32.8 ft (10 m) depth and 5.3 µg/l at the 229.6 ft (70 m) depth. Total nitrogen increased significantly with depth with average annual values going from 404 µg/l at 0 - 16.4 ft (5 m) to 628 µg/l at the 229.6 ft (70 m) depth. Total nitrogen to total phosphorus ratios consistently indicated that phosphorus was primarily the limiting factor for photosynthetic activity in Virgin Canyon. Mixing of deep waters with shallow waters would not provide the necessary nutrient concentrations within euphotic zones to significantly increase primary production in Lake Mead under present nutrient regimes.

Present nutrient concentrations in Virgin Canyon will not be altered appreciably through operation of SCPSP. Further, no major alteration of present Virgin Canyon nutrient levels should occur in the proposed Spring Canyon forebay.

Chlorophyll *a* in Virgin Canyon ranged from <1 to about 4 µg/l, which is indicative of oligotrophic waters of low productivity. Chlorophyll *a* levels in local euphotic zones of Lake Mead may be depressed slightly with construction and operation of the SCPSP due to potential increases in suspended silts and clays. Chlorophyll *a* in the proposed Spring Canyon forebay will most probably be lower than in Virgin Canyon due to lower water temperatures.

Zooplankton

Three major groups of zooplankton were well represented in Virgin Canyon: Order Copepoda (65 % of all numbers), Order Cladocera (20 %) and Phylum Rotifera (15 %). Zooplankton were concentrated mainly within shallow depths. Approximately 63 % of all zooplankton numbers were in the 0 - 10 m depth strata, and only 2 -3 % were in the 40 - 50 m depth strata. About 84 % of all numbers were located in the top 20 m. Seasonally, greatest densities of total zooplankton, considering all depths combined, occurred in June (average = 20,153 m^{-3}) and minimum densities were recorded in November and December (average = 2,581-2,855 m^{-3}).

Eleven taxa including a minor, miscellaneous group comprised the Order Copepoda. Major taxa were: immature copepod nauplii (61 % of all Copepoda), Mesocyclops edax (8.1 %), Diaptomus spp. (11.0 %), Cyclops spp. (5.3 %), Cyyclops bicuspidatus (4.3 %), Mesocyclops spp. (4.0 %), Diaptomus siciloides (2.8 %), and Diaptomus ashlandi (2.6 %). Peak average densities of total Copepoda occurred in July (11,671 m^{-3}) and minimum densities were recorded in November (2,204 m^{-3}). Most (80.2 %) of the Copepoda were within the 0 -20 m depth strata.

Four taxa including a minor miscellaneous group comprised the Order Cladocera. Major taxa were: Bosmina longirostis (51.1 % of all Cladocera), Daphnia pulex (32.1 %), and Daphnia galeata (10.6 %). Peak average densities of total Cladocera occurred in June (7,994 m^{-3}) and minimum densities were recorded in December (164 m^{-3}). Most (91.1 %) of the Cladocera were within the 0 - 20 m depth strata.

Seven taxa including a major unidentified group (19.5 % of all numbers) comprised the Phylum Rotifera. Major identified taxa included Polyarthra spp. (47.8 %), Lecane spp. (16.0 %), Ascomorpha spp. (11.4 %) and Synchaeta spp. (4.5 %). Peak average densities of total Rotifera occurred in June (3,453 m^{-3}) and minimum densities were recorded in February (114 m^{-3}). Most (87.3 %) of the Rotifera were within the 0 - 20 m depth strata.

Zooplankton in Lake Mead comprised the major energy transfer linkages between algal productivity and fish productivity. The major concern regarding zooplankton is the potential entrainment and associated injuries and mortalities from passage of large volumes of water through the Spring

Canyon pump-turbines. Though very little is known about zooplankton entrainment effects at pumped-storage plants on local ecosystems, inlet-outlets should be designed to minimize withdrawals and injuries to zooplankton. The deep water position of the proposed Spring Canyon inlet-outlet should minimize zooplankton entrainment especially when Lake Mead surface elevations are high. If Lake Mead surface elevations drop dramatically, zooplankton entrainment will increase. Estimated ranges of densities (No m^{-3}) of total zooplankton in Virgin Canyon waters subject to withdrawal during pumping activities under various hypothetical Lake Mead elevations are as follows: 1,132 - 1,210 ft, 440 - 3,290 m^{-3}; 1,099 - 1,131 ft, 750-3,910 m^{-3}; 1,066 - 1,098 ft, 1,360 - 10,140 m^{-3}; 1,050 - 1,065 ft, 3,300-23,550 m^{-3}. Lake Mead could fluctuate between elevations 1,130 ft (344.5 m) - 1,210 ft (368.9 m) or higher without appreciable change in zooplankton density in pumping water, assuming present vertical zooplankton distribution patterns in Virgin Canyon are maintained after plant operation begins.

Ranges of average, daily percent of zooplankton standing crops in the immediate area of Virgin Canyon (4.05 mi, or 6.75 km; 171,140 acre-ft volume) potentially entrained at Spring Canyon under several hypothetical Lake Mead elevations were estimated as follows: 1,210 ft, 0.7 - 5.5 %; 1,130 ft, 1.3 - 13.4 %; 1,050 ft, 22.3 - 67.3 %. A large increase in this parameter is apparent as elevations approach 1,050 ft (320 m). Local decreases in zooplankton numbers are expected in Virgin Canyon if Lake Mead surface levels drop to approximately 1,130 ft (344.5 m) or lower. Viable zooplankton returned to Virgin Canyon during generating modes are expected to be less in density (numbers m^{-3}) compared to pumping water because of turbine injuries and a harsher (cooler) environment in the forebay in which to grow and reproduce. Local reductions in zooplankton are not expected to alter overall zooplankton standing crops in Lake Mead, based upon the large whole lake volume of Lake Mead and on recent zooplankton model studies of other potential pumped-storage systems.

Benthic Macroinvertebrates

Some 88 species of 68 genera of benthic macroinvertebrates have recently been identified from Lake Mead. Limited data in upper Lake Mead indicate that greatest concentrations of benthic macroinvertebrates occur in deep, profoundal regions and that steep walls such as occur in Spring Canyon support a very limited benthos fauna. The proposed position of the Spring Canyon inlet-outlet structure, about 150 ft (45 m) above the canyon floor, will prevent any significant scouring or diminished benthos productivity. Some macroinvertebrates in the water column, i.e. pupa of aquatic insects, will be entrained in pumping flows and the forebay will rapidly be colonized by this mechanism and others. Lack of substantial amounts of organic matter, cool temperatures, waters of low productivity, and frequent water level fluctuations will result in a limited forebay benthos fauna.

Fish

Though some 23 species of fish occur, or are known to have occurred, in Lake Mead, only eight species were observed in this study. This list included threadfin shad, striped bass, common carp, largemouth bass, bluegill, green sunfish, channel catfish and rainbow trout.

Fish egg and larvae sampling in 1986 and 1987 indicated sparse and non-diverse fish egg and larvae populations for pelagic waters of Virgin Canyon. Considering both years, a total of 138 larvae of the following taxa were collected by filtering 16,536 m^3: sunfish, 69.6 %; threadfin shad, 29.7 %; and, minnows , 0.7 %. Average surface larval densities were 0.036 m^{-3} in 1986 and 0.013 m^{-3} in 1987. Only four larvae were collected from 9,536 m^3 filtered from depths near the proposed inlet-outlet structure. Impacts to the fishery from egg or larval fish entrainment will be minimal. No evidence for larval concentrations near the proposed inlet-outlet structure exists, and spawning behavior of all fish species will assure that eggs and larvae will be found mainly in the upper 15 ft (4.6 m), a large vertical distance from the proposed inlet-outlet structure. Underwater observations along canyon walls provided evidence for successful fish reproduction by largemouth bass and sunfishes. The presently proposed inlet-outlet design should be retained to prevent surface disruptions or collisions between outlet flows and canyon walls. Consequences of these physical alterations would be to damage fish nests directly, or to negatively influence spawning behavior and egg development through direct contact with cool forebay outflows.

Hydroacoustic studies showed that pelagic fish populations of Virgin Canyon were very low in spring and summer, reached highest densities in fall, and decreased to intermediate densities in winter. Daytime data showed fish preferred deeper depth strata in fall and winter compared to spring and summer. Limited nighttime data demonstrated a rapid movement upward in the water column shortly after dusk. It was surmised that most pelagic fish were the young and adults of threadfin shad with a smaller number of striped bass, carp, channel catfish and perhaps some sunfishes. The vast majority of pelagic fish were small, averaging 1.0 - 8.6 in (2.5 - 21.8 cm) in length though individuals longer than 8.6 in (21.8 cm) were common and an occasional fish 24 in (61 cm) or longer was observed.

The combination of a deep water inlet-outlet structure, relatively small fish populations, and distinct upward movement of fish during night in Virgin Canyon will minimize entrainment losses with operation of SCPSP. This is a most important consideration, for fish mortalities in pump-turbines at other pumped-storage facilities have become the major environmental issues. Fall and winter periods will be more critical than spring and summer for SCPSP. Also, lower Lake Mead elevations will result in higher entrainment rates. For Lake Mead elevations of 1,164 - 1,210 ft (355 - 369 m), potential weekly entrainment rates were estimated at about 850 fish in October and November, and 5,422 fish in January. This amounted to about 0.3 % of the local fish population during October and November, and about 5.4 % in January (local fish population was estimated for 5.231 x 10^5 acre-ft of Lake Mead water). For Lake Mead elevations 1,082 - 1,164 ft (330 -355 m), potential weekly entrainment rates were estimated at about 17,142 fish in October and November, and about 8,326 fish in January. This amounted to some 5.9 % of the local fish population in October and November, and about 8.3 % in January. Entrainment and turbine passage will result in considerable fish injury, and some level of mitigation may be required.

The local fish population size of Virgin Canyon was estimated from a volume representing approximately 2 % of the entire Lake Mead volume. Further, the Virgin Canyon area is not noted for fish concentrations in Lake Mead, as are other areas such as the Overton Arm and Las Vegas Bay. Provided that operation of SCPSP does not significantly alter fish distribution in Lake Mead, nor produces a major fish attractant, artificial fish predation by SCPSP should result in no measurable diminishment of total Lake Mead fish populations though local reductions in Virgin Canyon may occur.

Fall and winter behavior of largemouth bass and sunfishes nearshore in Virgin Canyon will subject some individuals to entrainment and subsequent turbine injury and colonization of the forebay.

The Spring Canyon forebay will be colonized rapidly with fishes from Virgin Canyon. Permanent, self-reproducing populations would be uncommon and unlikely due to cool water temperatures during spawning season and large, daily water level fluctuations. Some management and stabilization of water in shallow coves at high forebay surface elevations for fish propagation may be advisable.