Lower Colorado River Multi-Species Conservation Program

Balancing Resource Use and Conservation

Induced Recharge in McAllister Lake, Arizona to Reduce Salinity for the Possible Introduction of Native Fish Species

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

February 2007

Lower Colorado River Multi-Species Conservation Program
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Induced Recharge in McAllister Lake, Arizona to Reduce Salinity for the Possible Introduction of Native Fish Species

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ABSTRACT

McAllister Lake is a 32-acre isolated floodplain lake along the lower Colorado River (LCR) on Imperial National Wildlife Refuge (Arizona). The lake is typical of "true seepage" wetlands, meaning that there is no surface connection during typical river stages, and that the primary mechanisms for water exchange into and out of the lake are subsurface seepage from the river aquifer and evaporative losses, respectively. True seepage wetlands along the LCR, such as McAllister Lake, tend to concentrate salts, potentially to levels which may result in a diminished ability to support aquatic life forms, including fish.

From 2002 to 2005, a series of five experimental drawdowns were conducted to evaluate the feasibility of reducing specific conductivity at McAllister Lake (or other true seepage wetlands along the LCR) to maintain adequate water quality conditions for native fish (razorback sucker, *Xyrauchen texanus* and/or bonytail, *Gila elegans*). These drawdowns typically removed approximately 59% of the lake volume, which was recharged by groundwater in approximately 1-2 months. Three windmill aerator/mixers were also installed during this study to facilitate mixing, for enhancing dissolved oxygen levels during summer months.

The effect of repeated dilution and flushing was a significant ($\rho < 0.0001$) and linear reduction in specific conductivity during each treatment from the pretreatment mean of 13,657.9 µS/cm to 4,100.5 µS/cm. After an 18-month period without dilution and flushing, specific conductivity levels increased to 10,907.5 µS/cm. Windmill aerator/mixers actually decreased dissolved oxygen levels significantly ($\rho < 0.001$) from 6.4 mg/L to 5.4 mg/L at the point of measurement (although localized increases in dissolved oxygen were only observed near the aerator/mixers).

We suggest that this technique of dilution and flushing may be effective in reducing salinity levels at McAllister Lake, or other true seepage backwaters along the LCR, to levels which may sustain native fish (e.g., razorback sucker and/or bonytail). Windmill aerator/mixers may be inadequate for improving dissolved oxygen above existing levels due to high sediment-oxygen demand. Improving dissolved oxygen levels may require additional techniques such as sediment dredging and/or treatment with aluminum sulfate.

CONTENTS

INTRODUCTION

McAllister Lake (Imperial National Wildlife Refuge, Arizona) was identified by the U.S. Bureau of Reclamation (Reclamation) as a potential native fish protected habitat in support of Region-wide mitigation and conservation programs required to ensure ongoing compliance with the Endangered Species Act (USFWS 1997, USFWS 2001, LCR MSCP 2004). Implementation of these programs requires Reclamation to create and/or restore a combined target goal of 660 acres of backwaters for native fish, including razorback sucker, bonytail, and flannelmouth suckers (*Xyrauchen texanus, Gila elegans,* and *Catastomus latipinnis*, respectively) within the historic floodplain of the Lower Colorado River (LCR). Backwaters restored for razorback sucker and bonytail chub are preferred to be isolated from any non-native predatory fish species. McAllister Lake was targeted as such an isolated habitat.

A secondary goal of initial backwater restoration projects was to explore a range of techniques to enhance institutional knowledge which could be applied to future backwater restoration projects. Techniques previously employed on the LCR included excavation, dredging, and in-situ remediation of existing backwaters. This project at McAllister Lake was the first demonstration of potential *in-situ* remediation of an existing backwater for these programs.

Reclamation chose McAllister Lake as a demonstration project to assess the potential use of dewatering and induced groundwater recharge on water quality conditions in disconnected backwaters of the LCR. The overall goal was to create and/or enhance habitable areas for bonytail chub and razorback sucker.

Historic Habitat Issues

Bio-West Inc. (2005) performed a comprehensive review of the life histories and habitat requirements for razorback suckers and bonytail chub with emphasis on compiling the known literature pertaining to enhancing the success of future conservation activities. Razorback suckers historically were distributed throughout the LCR occupying virtually all components of the riverine environment including low-velocity habitats such as backwaters, sloughs, oxbow lakes, and other slackwater habitats within the main channel. Backwaters are important areas used by native fish species for certain critical life history functions such as nursery areas for juveniles. The loss of backwater habitat possibly means that certain stages of native fish life cycles have been reduced or eliminated altogether resulting in declining numbers and population viability.

Lentic aquatic ecosystems, such as lakes and ponds, have finite lifespans due to their tendencies to accumulate nutrients and/or salts, natural phenomena called eutrophication and salinization, respectively (Cole 1975, Wetzel 1983). Floodplain lakes in general tend to be short-lived and require periodic disturbances to reset them to earlier trophic states to support a primarily fisheries-dominated fauna (LCR MSCP B.A./B.O. 2004). In the absence of natural "resetting" events, periodic anthropogenic interventions would be necessary to maintain disconnected backwaters of the LCR in a state that will support productive fisheries. Simulating this flushing mechanism through dewatering and induced groundwater recharge may produce the necessary disturbance and freshening required to restore a highly saline lake, such as McAllister, to a state which would support native fish.

Site Description

McAllister Lake is a 32 surface acre isolated backwater (floodplain lake) with a mean depth of 4.5 feet. McAllister is located within the Sonoran Desert and is within the Imperial reach of the LCR in Imperial National Wildlife Refuge (INWR). This isolated backwater is roughly 1,200 feet east of the river (approximately at river mile 61) and is seepage-driven with no known surface connections to the river or any other water bodies.

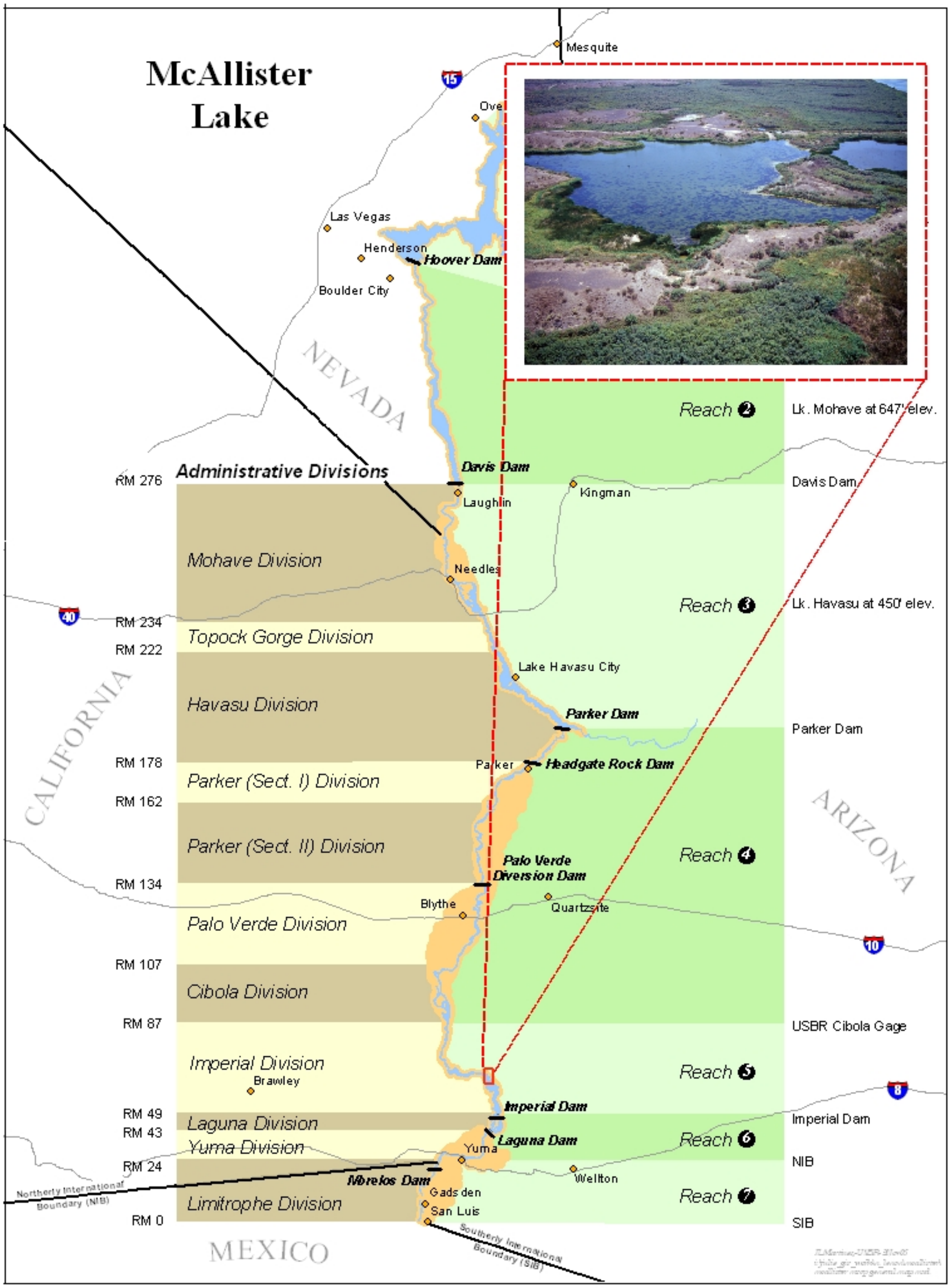
The lake is situated within what is thought of as the "river aquifer" of the LCR. The river aquifer concept infers a significant degree of hydraulic connectivity between the sediments adjacent to the river and the river itself. This connectivity promotes the passage of water between the river and adjacent floodplains.

McAllister Lake, as is typical for many of the LCR's floodplain areas, overlies saturated and partially saturated sediments categorized into younger and older alluvium groupings. The younger alluvium dates back to the Holocene epoch and are the most recently deposited sediments (as old as 10,000 years BP) composed primarily of unconsolidated mixtures of gravel, sand, silt and clay floodplain deposits which can be up to 180 feet thick in some areas. Below the younger alluvium is positioned a more consolidated older alluvium that dates back to the Pleistocene era.

Both of these units are moderately-to-highly transmissive with likely hydraulic conductivities in excess of 500 feet per day. Field observations note that the western flank of McAllister Lake contains some heavier soils, with markedly lower hydraulic conductivities. It has been hypothesized that much of the water that recharges the lake comes from the coarser underlying alluvial sediments.

Climate in the area is arid with an average annual air temperature of 73.5° F (22.9° C) and 3.55 inches (9 cm) of precipitation which primarily occurs during either late summer monsoons or winter precipitation. Summers are extremely hot and winters are mild (33° - 112° F, 1°- 44° C). Open-water evaporation is estimated at nearly 87 inches (2.2 m) per year (Guay 2003).

FIGURE 1. SITE CONTEXT MAP



Groundwater characteristics for McAllister Lake can be inferred from its physical setting. Due to the lake being directly adjacent to the Colorado River, local groundwater conditions are dominated by river discharge with groundwater flowing north to south. Those portions of the river valley not directly connected to the Colorado River typically have a stronger east-west component in groundwater flow paths.

Characteristics of Disconnected Backwaters of the LCR
Anecdotal accounts suggest that true seepage wetlands were historically capable of supporting sport fisheries (pers. comm. Butler 2004, Martinez 1994); however, because water primarily exits these systems through evaporation and evapotranspiration they generally tend to concentrate salts over time eventually leading to a decline in diversity and abundance of aquatic organisms.

McAllister Lake is categorized as a “true seep” (Prieto, 1998) meaning that in the absence of high flows it is physically isolated from surface waters of the Colorado River. Water within the lake is comprised primarily by seepage of the saturated alluvium within the Colorado River’s aquifer. While occasional contributions of water from adjacent uplands occur, their relative contribution is small compared to these seepage inputs. Additional characteristics of true seeps are that they have relatively higher temperatures, specific conductivity, and lower dissolved oxygen levels, as compared to more-connected water bodies with lower residence times.

At high river stages, it is suspected that the Colorado River will be directly connected with McAllister Lake (although pertinent elevations are not known at this time). These high river stages, and subsequent flooding and scouring, are important components of the ecological history of the backwater that is now known as McAllister Lake. Under current conditions, if McAllister Lake were to have a direct connection with the Colorado River, several water quality variables would improve (e.g., salinity, dissolved oxygen). However, a re -connection with the river would likely introduce non-native fish species into the lake which would significantly compromise the proposed function of the lake as a native fishery.

Site Selection
Current land ownership and public use restrictions at McAllister Lake are relatively ideal for establishment of a native fish refuge. Currently there is no viable sportfish population and no angler use. Public vehicle access is restricted to a single observation point with no boating allowed. With these restrictions already in place, no major changes to the public use would be required. Creating habitat for native fish in McAllister Lake would benefit both Reclamation and INWR.

Key determinants in the selection of McAllister Lake as a refuge for native fish relate to it being isolated from surface waters containing non-native fish while still being readily accessible. Existing road and boat access are adequate for staging and deploying a range of large equipment and vehicles which greatly enhances logistical planning of any restoration activities as well as long term monitoring and maintenance. Furthermore, it is expected that INWR's Colorado River water entitlements are sufficient to support the long-term management of this site for the benefit of native fish.

BASELINE CONDITIONS

Water Quality

During the summer immediately preceding this study, prior to initiating an organized monitoring program, observations included typical specific conductivity levels of approximately 19,000 µs/cm^2 or higher. Anoxia was prevalent in the lake throughout the water column suggesting, at the time, an extremely limited capacity to support aquatic life.

Fish Sampling

As of May 2003, Arizona Game and Fish Department had no data on fish populations at McAllister Lake due to minimal public use (pers. comm. Jacobsen 2003). During an initial site visit (July 2002), Reclamation sampled McAllister Lake for the presence of fish using [2] 1-in mesh, 300 ft trammel nets and [6] hoop traps for one night, and [4] ½- in mesh, 75 ft trammel nets, [3] mesh minnow traps (20 1/2 in/52 cm) long cylindrical frames, with a total diameter of 8 1/2 in (22 cm), a throat diameter of 1 1/2 in (3.8 cm), constructed from 1/4 inch (0.64 cm) steel-wire mesh) for two nights. Only mosquitofish were detected (*Gambusia affinis*) (mean TL=44mm, N=9).

It is likely that the very low diversity and biomass of wholly aquatic organisms found at McAllister Lake are the result of water quality conditions outside of the range needed for their survival. Miller (1999) evaluated proposals to enhance water quality in backwaters on Imperial Refuge including McAllister. Consistent with Prieto's (1998) findings, Miller (1999) identified high conductivity and low dissolved oxygen as issues to be addressed if the lake is to be used as native fish habitat.   Preliminary observations were consistent with these previous studies.

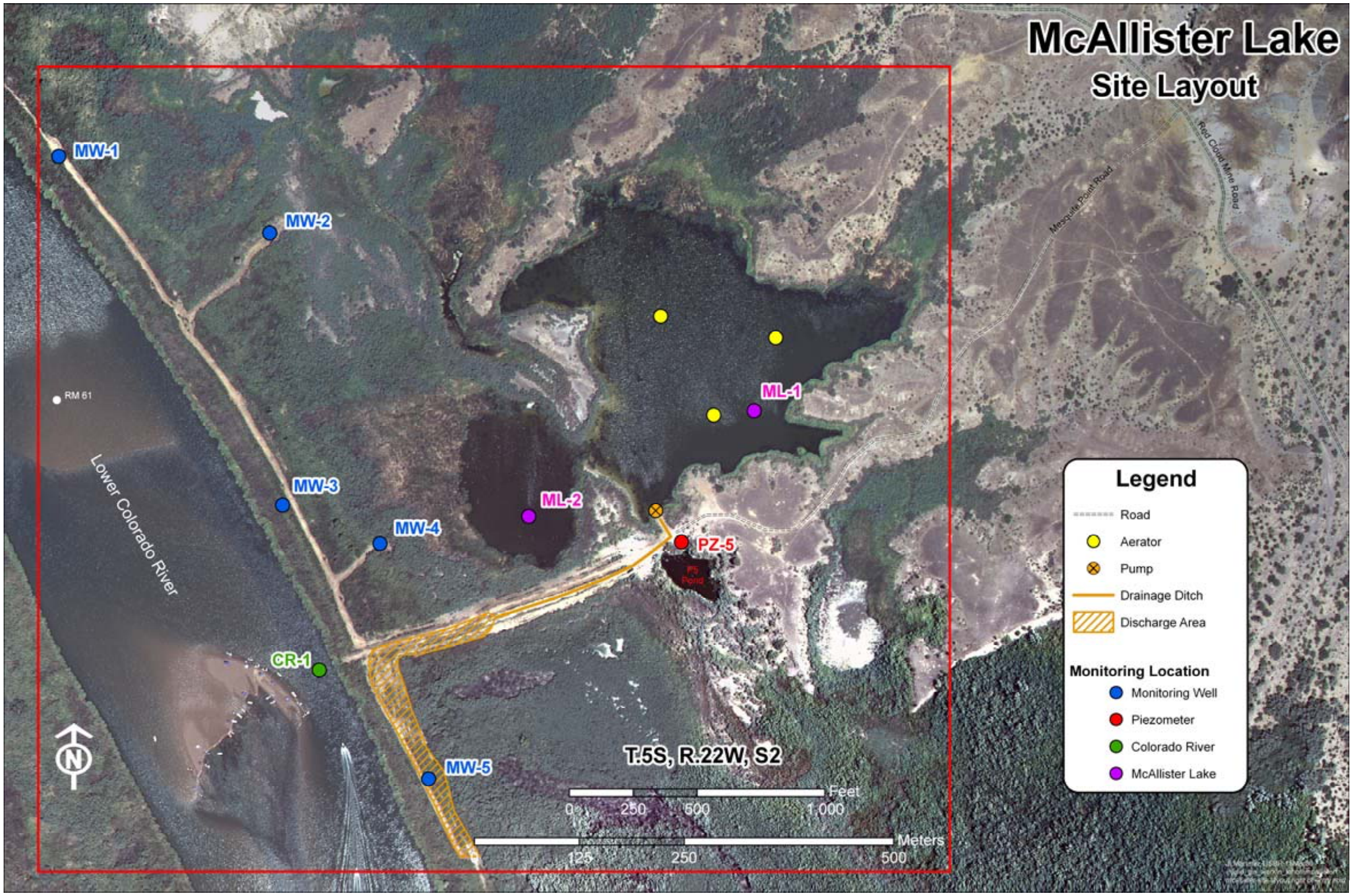
OBJECTIVES

1. Determine the feasibility of inducing groundwater recharge, and subsequent dilution of salts, through dewatering McAllister Lake.
2. Determine whether groundwater recharge at McAllister Lake is likely to provide a reliable source of relatively less saline water at multiple river stages.
3. Determine the approximate longevity of the dilution effect which may result from a drawdown before another treatment is necessary.
4. Approximate the volume of water which would need to be pumped, and at what frequency, to maintain water quality in McAllister Lake within a range

believed to be suitable for native fish (razorback sucker, *Xyrauchen texanus* and bonytail chub, *Gila elegans*).

The primary goal of this document is to provide an assessment of the efficacy of induced drawdown to lower salinity levels in a disconnected backwater of the Lower Colorado River to promote conditions suited for habitability of native fish. This document also archives the majority of materials associated with this investigation; for the sake of posterity and to facilitate future subsequent investigations.

FIGURE 2. SITE LAYOUT



METHODS

This research was conducted in two phases; a Pilot Study Phase (July 2002-September 2003), and a second, more formal Experimental Design Phase (September 2003-December 2005). During the Pilot Study, two draw-downs were conducted (the “first 1 foot drawdown” and the “first 3 foot drawdown”). Under the Experimental Design, three draw-downs were conducted (the “second, third, and fourth 3 foot draw-downs”).

During the Pilot Study, a variety of exploratory data was collected to characterize the lake including bathymetric/fisheries surveys and physicochemical data. An initial 1 foot and 3 foot drawdown was conducted; an Experimental Design was drafted which formalized procedures for the following series of additional 3 foot draw-downs.

Bathymetric Survey
Reclamation conducted a bathymetric survey during two site visits from February to March 2003 using a high resolution Global Positioning System (GPS) (Corvalis Microtechnology® Model MC-GPS, Version 3.7. Corvalis, OR.). Depth below surface was measured at 392 points using a 6 ft (1.83 m) wading rod, marked in 1/10-ft (3 cm) increments, with a 100 $inch^2$ (645 cm^2) steel plate affixed to the bottom to prevent it from sinking into the substrate. Depths beyond the measurement capacity of the rod (6 ft) were measured with a telescoping surveyor's rod, marked in 1/10-ft (3 cm) increments. Depths were logged in the GPS unit at each point.

The lake's water surface elevation was captured daily by recording the water surface elevation (feet above mean sea level) at a staff plate which was tied to a point with a known elevation.

Data was differentially corrected to a horizontal accuracy of approximately 1 m (3.3 ft) and processed with 3-D Analyst in ArcView© Version 3.3 (ESRI, Inc. 2002. Redlands, CA) to produce true elevation contour lines and determine relationships between depth, volume, and surface area. A U.S. Geological Survey Digital Ortho Quarter Quad (1992) for the project area was projected as an image background layer on the map. An additional 405 points were hand plotted in the software to delineate the shoreline, to correspond with the aerial imagery and determine total open water surface area. Shoreline development index (SDI) was calculated based on Cole (1975).

General De-Watering Procedures

Sampling and monitoring activities were conducted prior to starting the pump tests. A description of sampling and monitoring methods is detailed in the following section including water level and water quality measurements, discrete sample collection, and service and calibration of dataloggers[1]. The starting hours and volumes were recorded for all pumps and flowmeters. Following all sampling and equipment checks pumping was initiated. Once started, pumping[2] continued at a constant velocity until McAllister Lake reached the minimum target elevation at which point the pump was disengaged and the lake was allowed to refill naturally via groundwater seepage[3]. Pumping was only stopped for refueling and during a single instance of mechanical failure[4]. The pumping rate was decreased upon approaching the minimum target elevation to avoid cavitation in the pumping system.

During the initial pump test, a 1 foot drawdown was targeted due to unknown recharge rates. All future tests targeted an approximate 3 foot drawdown but achieved draw-downs ranging from 2.1 to 3.0 feet. The three foot value was selected as the target based on location of the intake of the Crisafulli pump that promoted the requisite full pipe conditions for the accurate use of the inline flowmeter. Recharge was calculated by relating hourly lake stage data following each test to volume estimates produced via bathymetric survey. Several spot measurements were made confirming that the volume estimates derived from the bathymetry information were accurate within +/- 15%.

Pumping

A Crisafulli-type, H & H propeller pump driven by the power take-off unit (PTO) unit on a 7810 John Deere tractor was used to rapidly dewater McAllister Lake. The H & H pump maximum displacement is estimated at 28 cfs (12,566 gpm) (Guay 2003). Connected to the H & H propeller pump was approximately 200 ft of 24-in diameter smooth bore PVC irrigation pipe which conveyed the water to a 1,200 ft outflow ditch constructed for this project. An additional 60 feet of 24" corrugated sewer line was used as an extension to minimize channel erosion. All water pumped from McAllister Lake was discharged onto an existing firebreak and allowed to seep into the river alluvium with no surface connection to the river, labeled “discharge location” in Figure 2.

During the November 2003 test, a minimum target elevation was maintained at McAllister Lake using a 6" Gorman Rupp pump, rated from 3.5 to 0.9 cfs (1560 – 420 gallons per minute, gpm). This was done to estimate groundwater recharge and hydraulic conductance rates through the river aquifer during periods of

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[1] For additional details related to the experimental design, see Guay (2003).

[2] Pumping was conducted continuously until the lake elevation reached the minimum target elevation during all tests except March 2003. Due to staff shortages and safety concerns, pumping during the March 2003 test was conducted only from sunrise to sunset.

[3] During the November 2003 pump test additional pumping continued with the 6 inch Rupp pump to maintain the lake at the target elevation.

[4] During the March 2003 pump test, mechanical failure caused an approximately 4 hour pause in pumping.

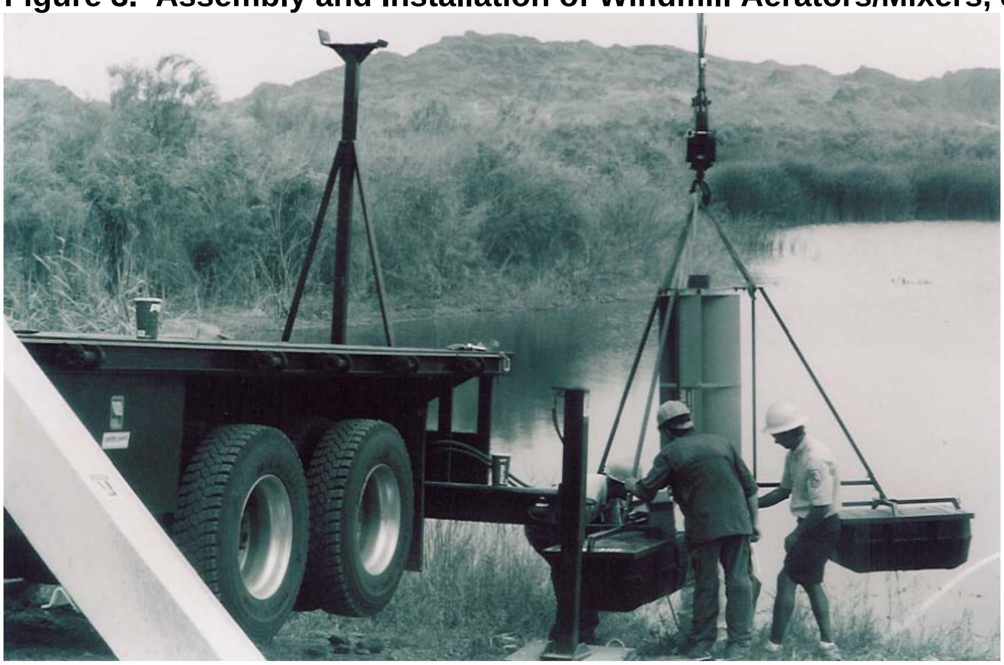
extended pumping. Discharge from the Gorman Rupp pump was conveyed to the drainage ditch using approximately 120 ft of 6" PVC pipe. The Rupp pump discharge was measured with an in-line flow meter.

Windmill-Driven Lake Circulation

To alleviate water quality problems associated with stagnation often found in hyper-eutrophic lakes and ponds and aid in mixing (especially during the critical summer months), three Pond 1® wind-powered aerator/mixers (Lake Aid Systems 1997) were installed at McAllister Lake on July 14, 2004. The Pond 1® units have a reported mixing capability of 400 gallons per minute under average wind-speeds, with a minimum wind-speed requirement of 5 miles per hour, and an effective mixing area of 5 acres in fresh water. Based on windspeed data from Miller (1999), wind at and above this threshold is common at McAllister Lake.

The aerator/mixers were partially assembled at the refuge maintenance yard into 5-piece kits which were trucked to the lake. A 50-foot crane was used to suspend the units during final assembly and placement in the water. The assembled aerators/mixers were then towed into deep water areas (Fig. 2) and anchored with three 70 lb concrete blocks which were attached to 100 foot lengths of ¼ inch galvanized steel cable. The water intakes were set 3 feet below surface, to accommodate fluctuating water levels.

Figure 3. Assembly and Installation of Windmill Aerators/Mixers, July 2004.



Pilot Study (July 2002 - September 2003)
Water quality in the lake was logged continuously in one-hour intervals using a Hydrolab® datasonde at a single deep-water site known as ML-1 (see site layout figure). The HydroLab Datasonde was tethered to a buoy at a fixed monitoring station to maintain sensors at 0.5 meters depth during fluctuating water elevations. Parameters monitored included temperature, specific conductivity, dissolved oxygen, and pH. Data downloads and instrument calibration was conducted at 2-3 week intervals depending on the datasonde model[5].

Additional water sampling was conducted using Hydrolab units (quanta, minitroll, datasonde) at other in-lake locations, an adjacent piezometer, and the Colorado. Discrete grab samples were taken from various depths within the lake using a Van Dorn bottle. These data were excluded from the statistical analyses due to small sample sizes but are summarized in the appendices in the back of this document.

Water elevation was monitored during the first one-foot draw-down by visually noting the water elevation at a staff plate where elevation was determined by laser level and an established benchmark. Prior to the first three-foot drawdown, the water elevation at ML-1 was monitored using a DH-21 pressure transducer/data logger on an hourly interval with downloads and calibration being conducted every 2-3 weeks.

The data collection station referred to as ML-1 consisted of a firmly mounted steel post driven into the lake bed. In order to minimize the measured effect of wave action on water level monitoring, the pressure transducer was affixed inside of a stilling well comprised of a six-foot length of 2-inch galvanized steel pipe open at both ends and firmly mounted to the monitoring station. The elevation of the top of the stilling well was determined using the same method previously described for the staff plate.

Experimental Design Phase (September 2003 – November 2005)

Monitoring Locations
During the Experimental Design Phase, water quality and water level was monitored at a total of eight locations; one lake surface water location (ML-1), six groundwater locations (MW-1 through MW-5, and PZ-5), and one Colorado River surface water location (CR-1). All of these locations are marked on the site layout figure, and detailed in Table 1.

In-situ recording of water quality conditions at McAllister Lake was done through use of the Hydrolab Datasonde, as described above. In addition, water quality profiles were collected at all eight locations during draw-downs and instrument

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[5] Hydrolab Datasonde 4a's were used during the first year, until being upgraded to the Hydrolab Datasonde 4x self-cleaning technology in 2004.

calibration. These additional profiles were used only for reference and were not included in the statistical analyses.

Monitoring Wells

Five monitoring wells were installed on September 2nd and 3rd of 2003 around the McAllister Lake area (see Table 1**.**) These wells were installed to elucidate the relationship between McAllister Lake surface elevations, and the water elevations associated with the proximate groundwater system and the Colorado River.   The study also utilized a sixth monitoring well, referred to as Piezometer No. 5 (PZ-5) which was installed by the FWS in 1996.

Three of the monitoring wells are directly adjacent to the eastern bank of the Colorado River (MW-1, MW-3 & MW-5, see Fig. 2). Two wells are situated approximately midway between McAllister Lake and the Colorado River (MW-2 & MW-4.), while the preexisting monitoring well, PZ-5, is located directly south of McAllister Lake.

Recording devices were deployed in the monitoring wells over the period of September 3, 2003 through March of 2005. Generally, over this nineteen-month period, data was collected at hourly intervals, while site visits were made on a periodical basis (roughly on a monthly schedule.)

The drilling of the monitoring wells also allowed the opportunity to collect soil samples to characterize the underlying alluvium. A sieve analysis was performed to determine particle size. More detailed information can be found in *Appendix A: Monitoring Wells*.

Table 1. Measurement Sites Associated with the McAllister Lake Project

	Site Name / Description	Site ID	Parameters Collected at Site	Site Coordinates Lat./Long. (DDMMSS)	Remarks
Surface Water	McAllister Lake[1]	ML-1	Salinity/TDS, DO, Ph, Redox, turbidity, temperature, Se, WSEL[2]	330105.36 N 1142950.4 W MP=187.4	Hydrolab located @ ML-1: other data collected throughout the Lake
	McAllister Lk. Outflow[3]	---	Volume, flow	variable	See Fig. 2 - *Site Layout*
	Colorado River Circa McAllister Lk.	CR-1	WSEL, WQ	330005.35 1143010.23 MP=180.92	Manual stage meas's only (staff plate)
	Colorado River Circa Cibola Lk.[4]	CR-Stage	WSEL (used to est. CR-1 record)	331316.4 1144020.5	Station run by USBR-Blythe
Ground Water[5]	North of Firebreak	MW-1	WSEL, WQ, Particle Size	330115.51 1143022.19 MP=189.5	MWs 1-to-5 drilled in Sept.-2003
	Old Channel	MW-2	WSEL, WQ, Particle Size	330112.61 1143011.79 MP=188.4	Interior well, NW of McA-Lk.
	Mid-Firebreak	MW-3	WSEL, WQ, Particle Size	330106 1143014.38 MP=188.5	Adj. to Colo. River
	West of McAllister	MW-4	WSEL, WQ, Particle Size	330100.25 1143007.6 MP=186.4	Interior well, W of Mc-A. Lk.
	South Firebreak	MW-5	WSEL, WQ, Particle Size	330048.14 1143004.36 MP=189.4	Adj. to Colo. River
	Piezometer No. 5	PZ-5	WSEL, WQ	330100.02 1142956.9 MP=191.949	Due South of McA-Lk. (drilled in 1996)

[1] Hydrolab DataSonde located at ML-1: other limnological data collected throughout the Lake (e.g. sediment, heavy metals, WQ grab samples, etc)
[2] WSEL=water surface elevation
[3] The water volume pumped out of McAllister Lake was tracked from this site (totalizer & wading meas.)
[4] This gage tracks river elevations, and is located thirty miles north of McAllister Lake / CR-1
[5] Monitoring wells MW-1 –thru- MW-5 all drilled Sept-2003 (USBR-Yuma), while PZ-5 was one of five wells drilled by Heber Mining (USFWS contract) in November of 1996. Surveyed Coordinates provided by USGS-Tucson (Datum is NAD 27 for x/y and NGVD29 for elevation.)

River Elevation

To fully assess the usefulness of pumping as a tool to decrease salinity, a clear understanding of how river operations affect the conditions of backwaters are required. The scope of this report does not permit in-depth analysis of this relationship: Rather, this report serves to more generally describe the particulars of the hydrologic data that was collected for the facilitation of subsequent analyses.

The elevation of the Colorado River is a key variable associated with any study assessing the feasibility of establishing habitat for native fish by reducing salinity in a disconnected saline backwater of the LCR. This particular study examines pumping water out of the backwater, and allowing less saline groundwater recharge to refill the backwater (i.e. "dilution and flushing").

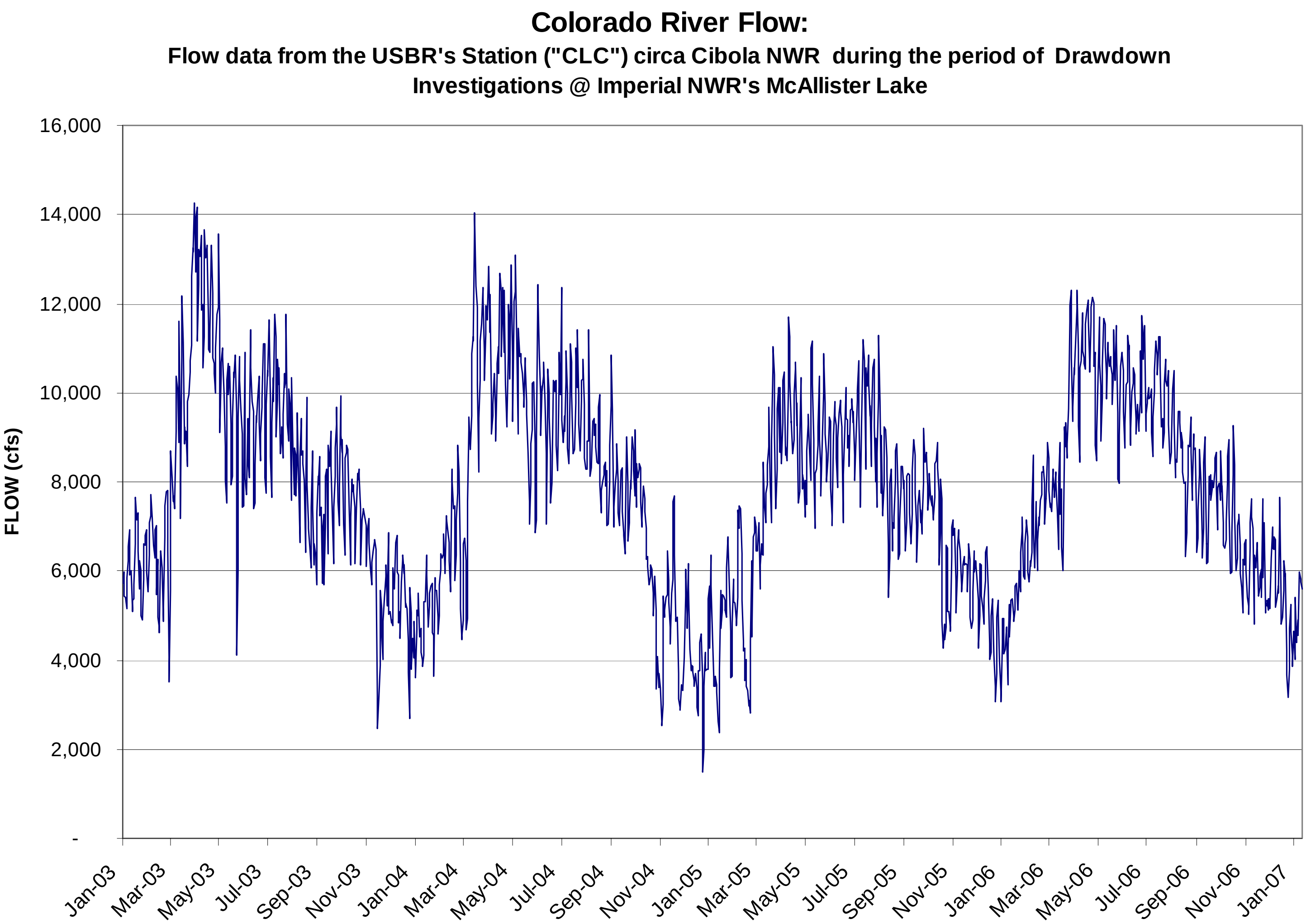
To estimate the elevation of the Colorado River in the area of McAllister Lake, extrapolated data was used from an upstream gaging station referred to as *Colorado River Station circa Cibola, Az* (maintained by the USBR-Blythe Hydrography Office.)

Observations of river stage were made on a staff plate (CR-1) established on the eastern bank of the river, directly adjacent to McAllister Lake (see Fig.2). These observations were then regressed against USBR-Blythe's *Colorado River Station circa Cibola, Az.* to generate hourly estimates of river stage directly proximate to McAllister Lake.

During the Experimental Design Phase, water quality and water level was monitored at a total of eight locations; one lake surface water location (ML-1), six groundwater locations (MW-1 through MW-5, and PZ-5), and one Colorado River surface water location (CR-1). All of these locations are marked on the site layout figure (Fig. 2).

In-situ recording of water quality conditions at McAllister Lake was done with a Hydrolab Datasonde, as described above. Water quality profiles were collected at all eight locations during draw-downs and instrument calibration. These additional profiles were used only for reference and were not included in the statistical analyses.

Figure 4. Flow values (in cfs) of the Lower Colorado River (circa Cibola NWR) during the time of this investigation. This graph represents typical river operations followed by the Water Master (USBR) where highest flows are observed during late spring and summer to meet irrigation demand. Lowest flows are observed during winter when irrigation demand is relatively low.



RESULTS

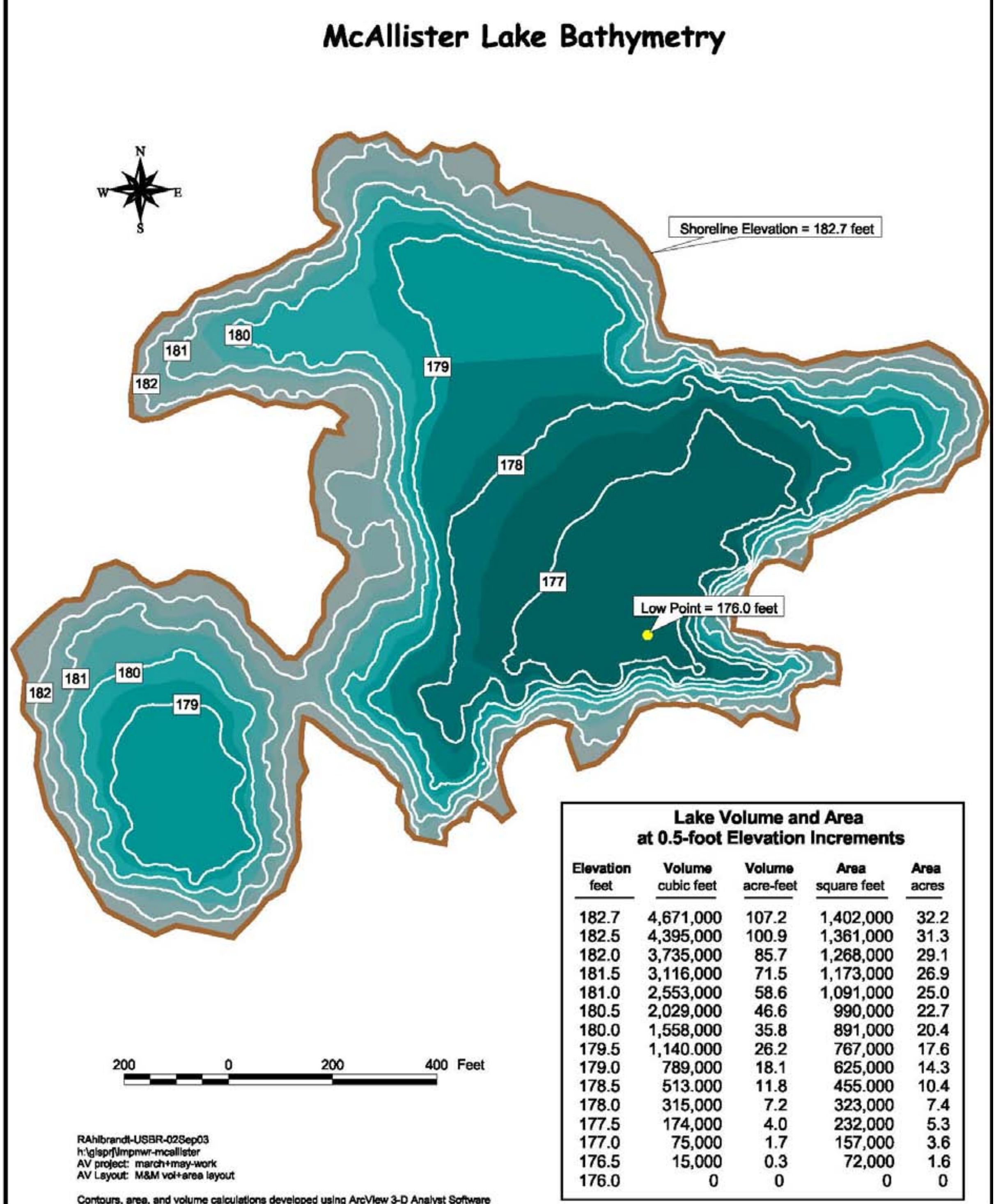
Bathymetry

The total open water surface area, not including emergent vegetation, was 26.5 acres. The total marsh area, which could not be accounted for during the bathymetry survey, was calculated through shoreline delineation of the bathymetry map and totaled 5.8 acres. Combining surface water and marsh together resulted in total backwater acreage of 32.3 acres. The shoreline perimeter was 8,077 feet, with a shoreline development index of 1.924. The mean depth was 4.5 feet. High water is approximately 183 ft above mean sea level (MSL).

Morphologically, McAllister Lake contains two somewhat distinct basins. To the west, lies a circular pond, which is referred to in this document as the "Western Lobe". This western lobe represents approximately ¼ of the total area of the lake, and maintains no surface connection to the main basin of the lake at elevations below 181 ft above MSL.

All bathymetry data uses NAVD88 vertical datum.

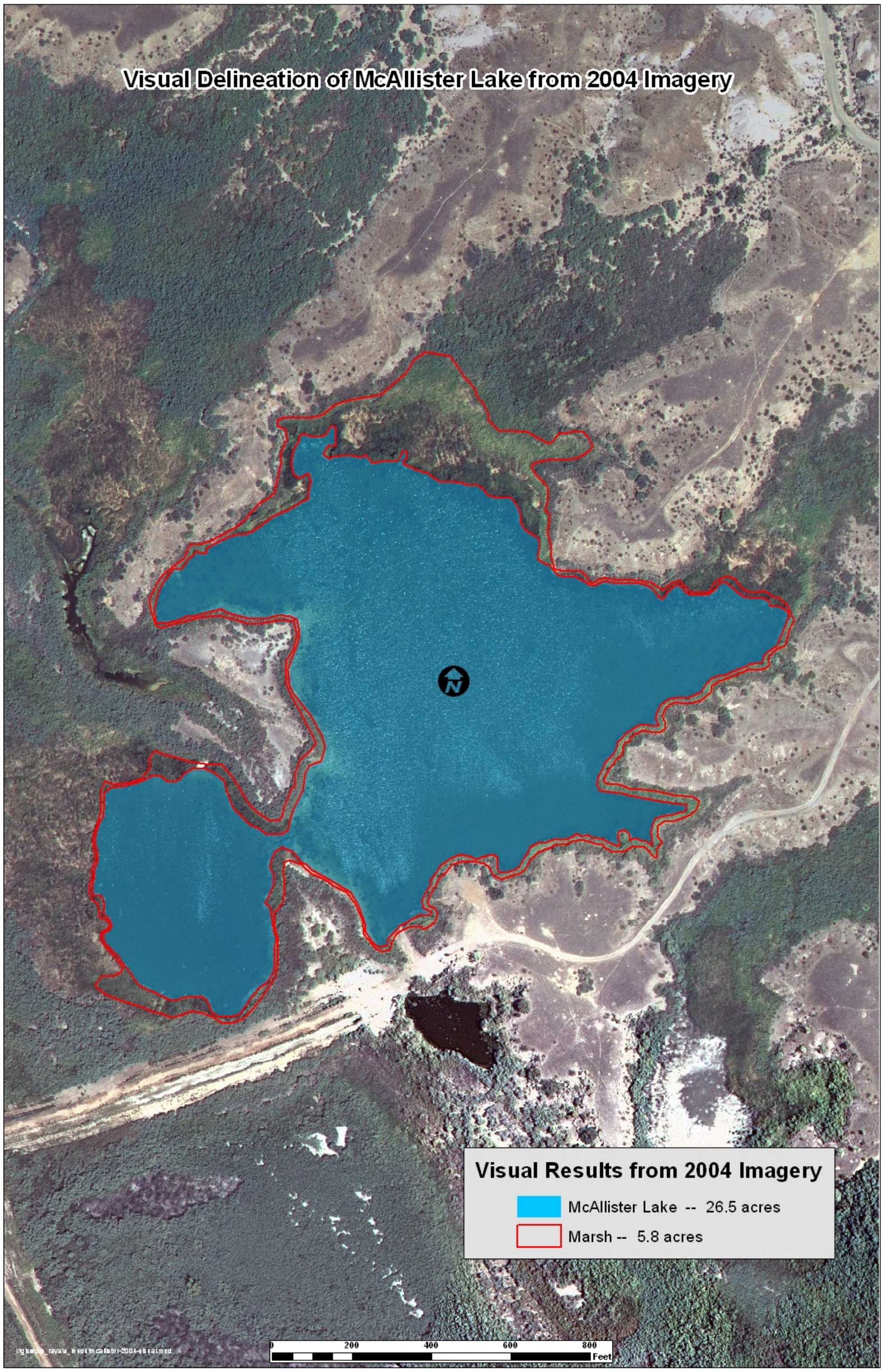
Figure 5. Bathymetry (using NAVD88 vertical datum)



Lake Volume and Area at 0.5-foot Elevation Increments

Elevation feet	Volume cubic feet	Volume acre-feet	Area square feet	Area acres
182.7	4,671,000	107.2	1,402,000	32.2
182.5	4,395,000	100.9	1,361,000	31.3
182.0	3,735,000	85.7	1,268,000	29.1
181.5	3,116,000	71.5	1,173,000	26.9
181.0	2,553,000	58.6	1,091,000	25.0
180.5	2,029,000	46.6	990,000	22.7
180.0	1,558,000	35.8	891,000	20.4
179.5	1,140.000	26.2	767,000	17.6
179.0	789,000	18.1	625,000	14.3
178.5	513.000	11.8	455.000	10.4
178.0	315,000	7.2	323,000	7.4
177.5	174,000	4.0	232,000	5.3
177.0	75,000	1.7	157,000	3.6
176.5	15,000	0.3	72,000	1.6
176.0	0	0	0	0

Figure 6. McAllister Lake Imagery, 2004



Drawdowns
The first 1 foot drawdown was accomplished in 12 hours, and replaced approximately 30.9 acre-feet, or approximately 26% of the lake's total volume from the highest observed water surface elevation of 183 feet. Subsequent 3 foot drawdowns ranged from 37 to 240.5 hours replacing an average of 70.3 acre-feet, or approximately 59% of the lake's total volume. A typical flow rate during these draw-downs was approximately 8,000 gallons per minute (gpm), 1.5 acre-feet/hour, and was mainly limited by the operational capacity of the flow-meters.

Table 2. Summary of Pumping Times and Volumes

Test Number	Start Date	End Date	Total Hours	Total Volume (acre-feet)	Total stage change (feet)
1st One Foot Draw-down	12/18/2002	12/19/2002	12	30.9	1
1st Three Foot Draw-down [6]	3/10/2003	3/14/2003	37.5	80.5	2.9
2nd Three Foot Draw-down					
Phase I (drawdown)	11/03/2003	11/05/2003	48.5	59.5	2.5
Phase II (maintenance)	11/05/2003	11/13/2003	192	30.8	0
3rd Three Foot Draw-down	1/26/2004	1/28/2004	48.5	61.9	3.0
4th Three Foot Draw-down	3/02/2004	3/4/2004	37	48.3	2.1

[6] During the March 2003 test, pumping was conducted during daylight hours only due to staffing limitations.

Figure 7. Recharge Curve

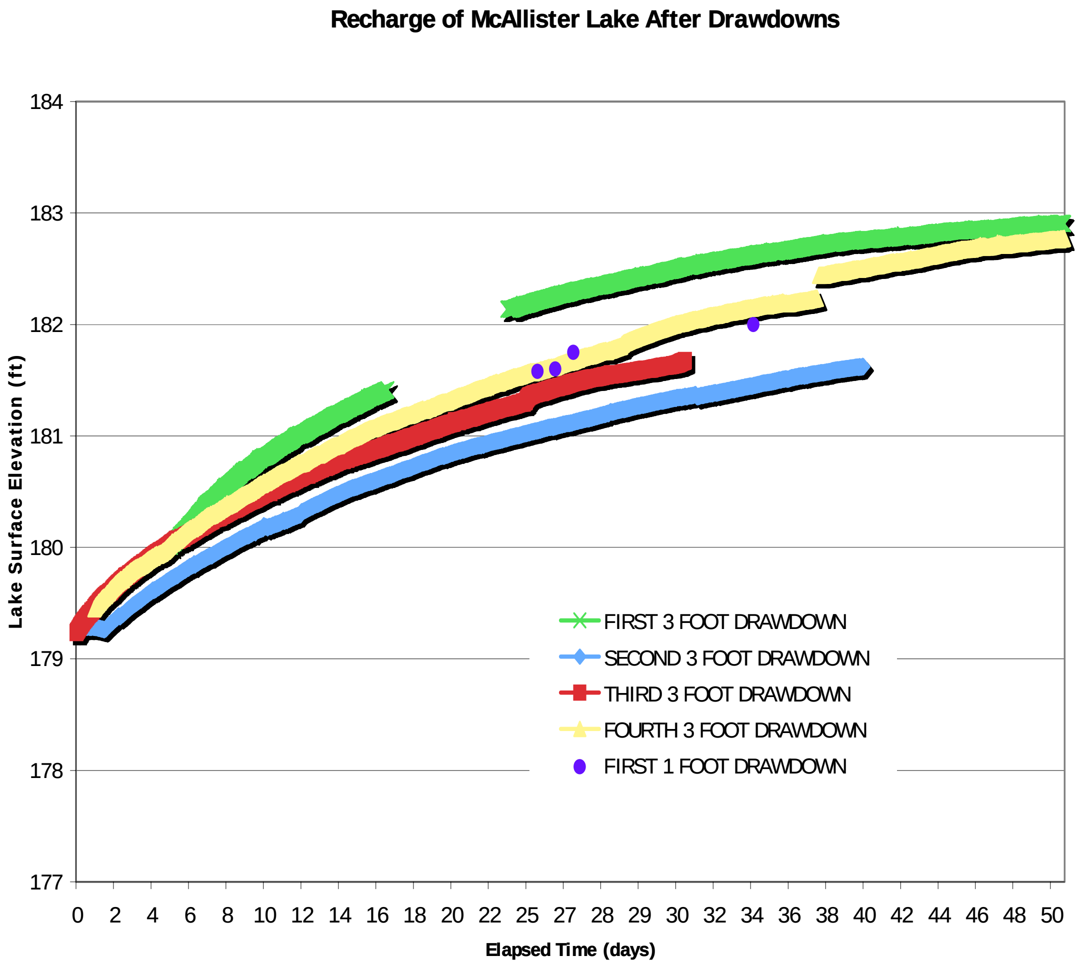


Figure 8. McAllister Lake Prior to First 1 Foot Drawdown, December 2002.

Figure 9. McAllister Lake after First 3 Foot Drawdown, March 2003.

Figure 10. McAllister Lake after Fourth 3 Foot Drawdown, September 2004.

Figure 11. McAllister Lake 18 Months after Pumping, September 2005.

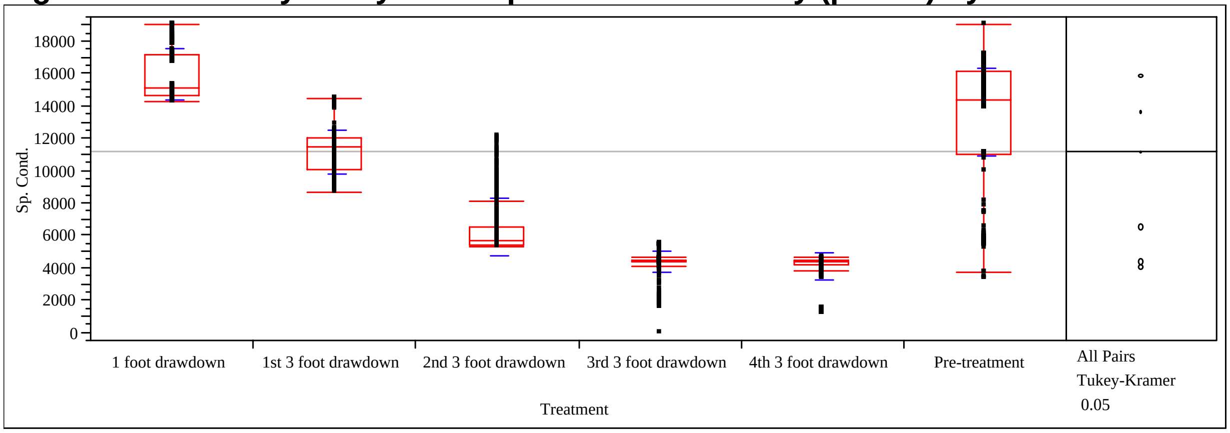
To analyze the effect of each treatment on levels of specific conductivity, equitable boundaries had to be placed around each treatment so that comparisons could be made. Each treatment had differing amounts of time between the ending of one and the beginning of another so the inclusion of all data between treatments made little sense. We used lake elevation as a proxy to determine which data to include for any given treatment. The initial 3 foot draw-down started with the highest elevation so excluding any data over the grand mean of the following 3 foot draw-downs resulted in a very small sample size for the 1 foot draw-down. Therefore, the initial one foot draw-down includes data from the beginning of pumping to the beginning of the first, 3 foot draw-down; a time period of approximately 4 months. The remaining 3 foot draw-downs had a maximum grand mean elevation of 181.66 feet so any specific conductivity data taken when the lake was over this elevation was excluded. This method was the most equitable and representative way to compare inter-treatment effects.

In order to capture as much temporal variation as possible in the pre-treatment data, the most comprehensive historical data that existed was obtained during 2000. This data takes into account seasonal variation in specific conductivity levels and covers Jan - Feb and June - Sept. 2000. Since this data covered a longer time frame and captured more seasonal variability than any of the intra-treatment data, the standard deviation was higher in this group than the others. This had an obvious effect on the grand mean which was actually lower in the pre-treatment compared to the one foot drawdown treatment.

Specific conductivity decreased significantly, and linearly, during each treatment ($p < 0.0001$). The largest decreases were observed between the 1 foot draw-down and the first and second 3 foot draw-downs. The fourth 3 foot draw-down had the lowest levels of specific conductivity (0 = 4,100) but there was little difference between this treatment and the third 3 foot draw-down (0 = 4,387). This may indicate that this project observed the lowest specific conductivity levels that could feasibly be achieved in McAllister given future and anticipated recharge, dilution, and flushing rates.

The dataset for selenium had greatly different samples sizes so analysis of trends is difficult to determine, however, it would appear that selenium levels decreased in accordance with dilution and flushing. Levels at the beginning of the study were 14.15 µg/L decreasing to below detectable limits at the end of the study.

Figure 12. One-way Analysis of Specific Conductivity (µS/cm) by Treatment



Oneway Anova

Summary of Fit

Rsquare	0.817404
Adj Rsquare	0.817339
Root Mean Square Error	1771.823
Mean of Response	11260.36
Observations (or Sum Wgts)	14083

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Treatment	5	1.97832e11	3.9566e10	12603.33	0.0001
Error	14077	4.41927e10	3139356.7		
C. Total	14082	2.42024e11			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1 foot drawdown	2499	15928.5	35.444	15859	15998
1st 3 foot drawdown	5070	11189.0	24.884	11140	11238
2nd 3 foot drawdown	1145	6550.6	52.362	6448	6653
3rd 3 foot drawdown	891	4386.6	59.358	4270	4503
4th 3 foot drawdown	1101	4100.5	53.398	3996	4205
Pre-treatment	3377	13657.9	30.490	13598	13718

Std Error uses a pooled estimate of error variance

Means Comparisons

Positive values show pairs of means that are significantly different.

q*	Alpha
2.85015	0.05

Abs(Dif)-LSD	1 foot drawdown	Pre-treatment	1st 3 foot drawdown	2nd 3 foot drawdown	3rd 3 foot drawdown	4th 3 foot drawdown
1 foot drawdown	-143	2137	4616	9198	11345	11645
Pre-treatment	2137	-123	2357	6935	9081	9382
1st 3 foot drawdown	4616	2357	-100	4473	6619	6921
2nd 3 foot drawdown	9198	6935	4473	-211	1938	2237
3rd 3 foot drawdown	11345	9081	6619	1938	-239	59
4th 3 foot drawdown	11645	9382	6921	2237	59	-215

Levels not connected by same letter are significantly different

Level							Mean
1 foot drawdown	A						15928.482
Pre-treatment		B					13657.875
1st 3 foot drawdown			C				11189.002
2nd 3 foot drawdown				D			6550.586
3rd 3 foot drawdown					E		4386.646
4th 3 foot drawdown						F	4100.465

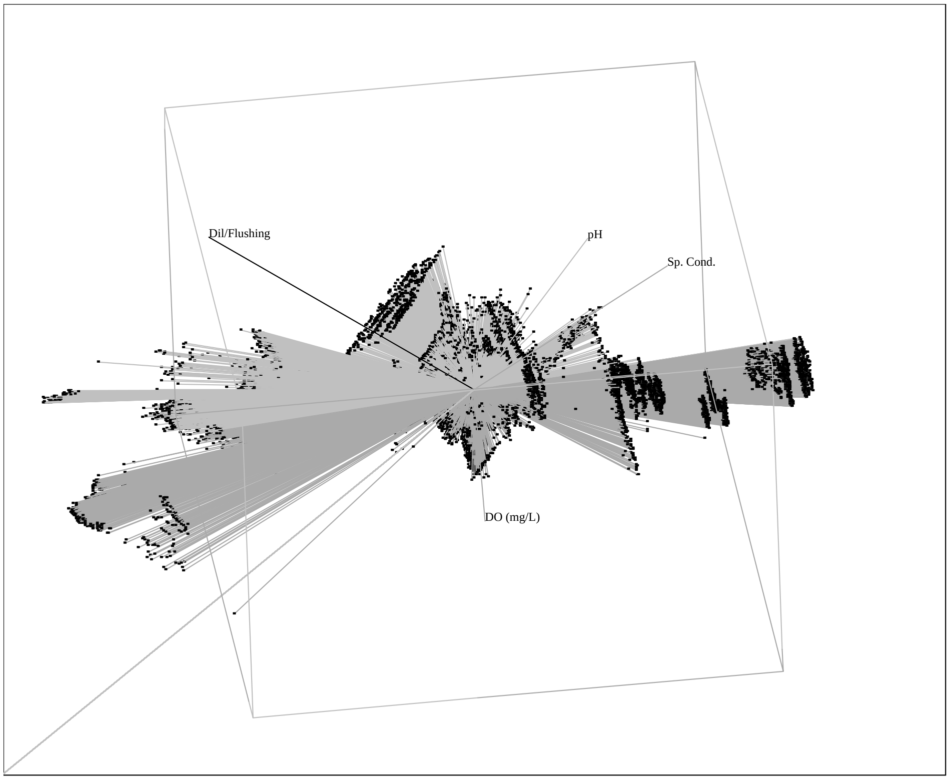
Level	- Level	Difference	Lower CL	Upper CL	Difference
1 foot drawdown	4th 3 foot drawdown	11828.02	11645.35	12010.68	
1 foot drawdown	3rd 3 foot drawdown	11541.84	11344.79	11738.88	
Pre-treatment	4th 3 foot drawdown	9557.41	9382.15	9732.66	
1 foot drawdown	2nd 3 foot drawdown	9377.90	9197.68	9558.11	
Pre-treatment	3rd 3 foot drawdown	9271.23	9081.04	9461.42	
Pre-treatment	2nd 3 foot drawdown	7107.29	6934.59	7279.99	
1st 3 foot drawdown	4th 3 foot drawdown	7088.54	6920.63	7256.44	
1st 3 foot drawdown	3rd 3 foot drawdown	6802.36	6618.91	6985.80	
1 foot drawdown	1st 3 foot drawdown	4739.48	4616.05	4862.91	
1st 3 foot drawdown	2nd 3 foot drawdown	4638.42	4473.18	4803.65	
Pre-treatment	1st 3 foot drawdown	2468.87	2356.70	2581.04	
2nd 3 foot drawdown	4th 3 foot drawdown	2450.12	2236.97	2663.28	
1 foot drawdown	Pre-treatment	2270.61	2137.35	2403.86	
2nd 3 foot drawdown	3rd 3 foot drawdown	2163.94	1938.34	2389.54	
3rd 3 foot drawdown	4th 3 foot drawdown	286.18	58.62	513.74	

In a database as large ("highly-dimensional") as this, data reduction to detect trends is critical. Principle components analysis (PCA) and a corresponding Gabriel bi-plot were chosen as the best way to examine the structure of the data as completely as possible. The Gabriel bi-plot shows the transformed data cloud while the eigenvalues in the PCA report explain the variance of each component to the overall data cluster.

The Gabriel biplot is the best way to show an approximation to a set of both variables and points in one graph. As the higher dimensions are reduced the variables that were originally thought of as orthogonal become closer to each other. *The variables that are the most correlated become closest.*

For this analysis, we examined the inverse of the elevation data and labeled it “dilution/flushing". The Gabriel biplot shows an inverse correlation between the level of dilution/flushing and conductivity; increased dilution/flushing resulted in lower levels of specific conductivity. The reason it's not exactly inverse is because the treatment effect showed diminishing significance over time. As expected, dilution/flushing and specific conductivity explain the most amount of variance in the data followed by pH and DO.

Figure 13. Principle Components Analysis and Gabriel Bi-Plot Correlation for Dilution/Flushing, Specific Conductivity, pH, and Dissolved Oxygen



Principal Components

Eigenvalue	2.1463	1.4994	0.3543	0.0000
Percent	53.6571	37.4851	8.8578	0.0000
Cum Percent	53.6571	91.1422	100.0000	100.0000
Eigenvectors				
Dil/Flushing	-0.66355	0.17192	0.17363	0.70711
Sp. Cond.	0.69887	-0.17192	-0.17363	0.70711
DO (mg/L)	0.02157	0.75043	-0.66060	0.00000
pH	0.34488	0.61461	0.70945	0.00000

Dissolved Oxygen

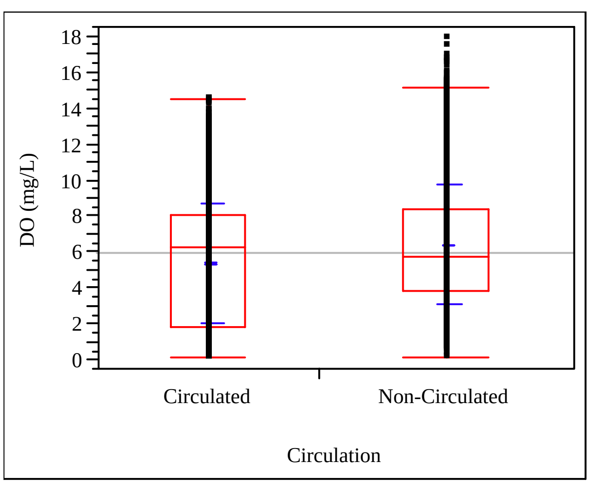
To determine the effect of the installed circulators on water quality, specifically dissolved oxygen, we compared dissolved oxygen data for one year pre- and post installation of the circulators. Dissolved oxygen levels were actually significantly higher during pre- rather than post installation ($p < 0.001$, 0 = 6.4 and 5.4 mg/L respectively). This is likely due to pumping treatments bringing surface water in closer contact with anoxic sediments and this sediment oxygen demand exerting its influence throughout the water column.

While overall mean dissolved oxygen levels were lower post- rather than pre-treatment, there may have been some small, localized effect of increased dissolved oxygen within close proximity to the circulators. During late July 2004, dissolved oxygen levels actually increased with depth at 10 and 20 feet from the windmills whereas sites 30, 50, and 70 feet away showed oxygen depletion with increasing depth. As with most management techniques meant to increase water quality, if no discernible effect is noted this does not necessarily mean the technique failed, rather, it may mean the technique, when combined with another strategy would reach the targeted goal.

It should be noted that “circulation” and “aeration” are not synonymous. Circulation is often used to decrease algal biomass and rate of primary production which may or may not affect dissolved oxygen levels. A large biomass of algae, during the day and on the rising limb of a growth curve, will raise dissolved oxygen levels as a by-product of photosynthesis. Hyper-eutrophic waters are often super-saturated with dissolved oxygen. The problem of low dissolved oxygen levels ensues when, through respiration, carbon dioxide sequestered during photosynthesis is released back into the water, thus decreasing dissolved oxygen levels. This happens on a daily or *Diel* basis but also through cloudy days, suspended sediment, or senescence later in the summer and into fall. Dissolved oxygen loss also occurs through bacterial respiration. In hyper-eutrophic systems, such as McAllister, the largest amount of bacterial respiration almost always occurs within anoxic sediments. It is the extremes in dissolved oxygen levels, caused by having a large algal biomass and rate of bacterial respiration, which is the most stressful to aerobic aquatic life with steady-state conditions always being a more desirable situation from a managerial standpoint. For example, it is more desirable to have DO levels with a range of 5.4 - 7.4 mg/l than it is 18.0 - 0.01 mg/L in every circumstance.

Using super-saturation of dissolved oxygen as a proxy for primary production, the extremely high levels were more noticeable during the pre-treatment period which might indicate that algal biomass was elevated during this time as well. Unfortunately, only very limited data is available on primary production and algal biomass for this study. Studies subsequently undertaken by the University of Arizona will address dissolved oxygen and algal biomass in further detail.

Figure 14. Dissolved Oxygen Levels by Circulation Treatment.



Oneway Anova
Summary of Fit

Rsquare	0.022837
Adj Rsquare	0.022763
Root Mean Square Error	3.340204
Mean of Response	5.950315
Observations (or Sum Wgts)	13118

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Circulation	1	3420.00	3420.00	306.5348	<.0001
Error	13116	146334.73	11.16		
C. Total	13117	149754.73			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Circulated	6098	5.40247	0.04277	5.3186	5.4863
Non-Circulated	7020	6.42620	0.03987	6.3481	6.5043

Std Error uses a pooled estimate of error variance

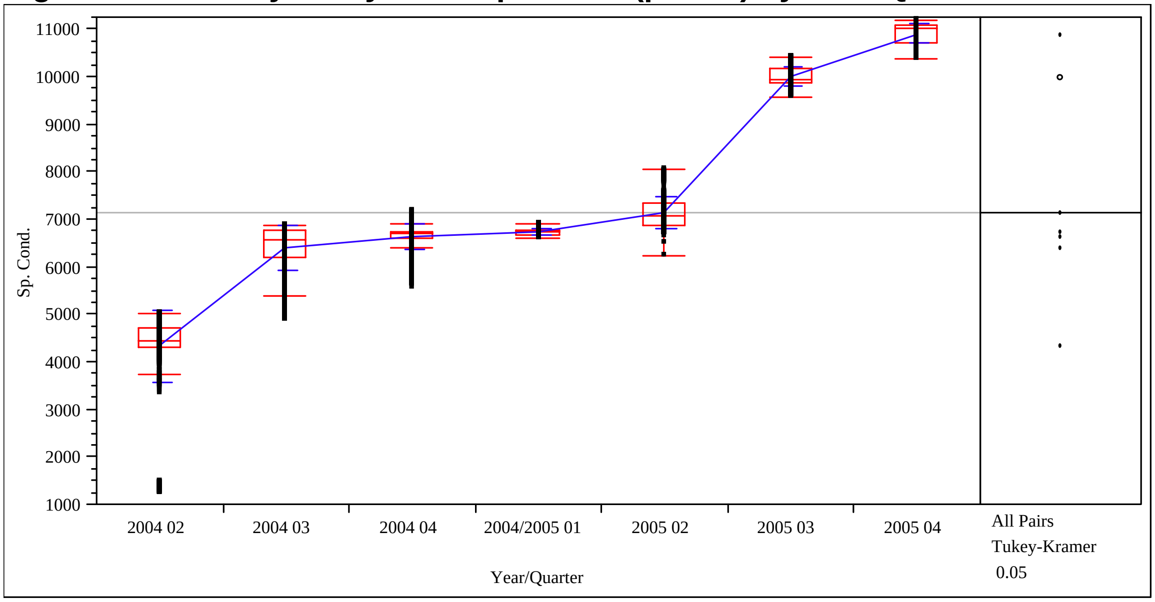
Longevity

Levels of specific conductivity increased following the end of the treatment period. The largest increases occurred between the 2nd ("spring") and 3rd ("late summer/early fall") quarters of both 2004 and 2005 (conductivity data is lacking from June of 2005). This makes sense as this is usually the hottest and driest time of year when evaporation peaks.

As stated earlier, it appears infeasible to expect levels of specific conductivity in McAllister below 4,000 µs/cm. This level was observed during March of 2004 (post-treatment). The average conductivity of the 3rd and 4th quarters of 2004 (the first summer/fall following treatment) was approximately 6,500 µs/cm which seems like a logical point at which to set the upper limit.

Using the 4,000 – 6,500 µS/cm range, and examining the mean monthly data for March-August of 2004, it appears that overall longevity of treatment is approximately 4 - 5 summer months before levels exceed the 6500 µs/cm upper limit. Obviously, longevity depends upon several other variables such as recharge rate, climate, rainfall, evapotranspiration, etc. and could fluctuate greatly from this 4 - 5 month estimate. It is expected, however, that similar decreases in conductivity would occur if drawdown treatments were periodically continued. Additionally, refinement of some sort of automated method to perform future drawdowns might result in maintaining conductivity levels in a range suitable for bonytail chub and razorback sucker for the indefinite future. Due to the hydraulic connection with the Lower Colorado River, it is expected that future drawdowns would be influenced by river stage with higher stages re-filling McAllister Lake at a relatively faster rate than lower stages.

Figure 15. Oneway Analysis of Sp. Cond. (µS/cm) by Year/Quarter



Oneway Anova

Summary of Fit

Rsquare	0.957505
Adj Rsquare	0.957482
Root Mean Square Error	404.4554
Mean of Response	7138.02
Observations (or Sum Wgts)	11331

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Year/Quarter	6	4.1739e+10	6.95649e9	42525.47	0.0000
Error	11324	1852427368	163584.19		
C. Total	11330	4.35914e10			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
2004 02	1734	4347.7	9.713	4329	4367
2004 03	1616	6401.8	10.061	6382	6422
2004 04	1657	6643.3	9.936	6624	6663
2004/2005 01	2097	6748.0	8.832	6731	6765
2005 02	2003	7153.2	9.037	7135	7171
2005 03	828	10004.0	14.056	9976	10032
2005 04	1396	10907.5	10.825	10886	10929

Positive values show pairs of means that are significantly different

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

q*	Alpha
2.94889	0.05

Abs(Dif)-LSD	2005 04	2005 03	2005 02	2004/2005 01	2004 04	2004 03	2004 02
2005 04	-45.1	851.2	3712.7	4118.3	4220.9	4462.1	6517.0
2005 03	851.2	-58.6	2801.5	3207.0	3309.9	3551.2	5606.0
2005 02	3712.7	2801.5	-37.7	367.9	470.3	711.5	2766.4
2004/2005 01	4118.3	3207.0	367.9	-36.8	65.5	306.7	2361.7
2004 04	4220.9	3309.9	470.3	65.5	-41.4	199.8	2254.7

q*	Alpha						
2004 03	4462.1	3551.2	711.5	306.7	199.8	-42.0	2012.9
2004 02	6517.0	5606.0	2766.4	2361.7	2254.7	2012.9	-40.5

Level	- Level	Difference	Lower CL	Upper CL	Difference
2005 04	2004 02	6559.871	6516.983	6602.759	
2005 03	2004 02	5656.354	5605.972	5706.736	
2005 04	2004 03	4505.686	4462.105	4549.267	
2005 04	2004 04	4264.191	4220.861	4307.521	
2005 04	2004/2005 01	4159.494	4118.295	4200.693	
2005 04	2005 02	3754.333	3712.750	3795.917	
2005 03	2004 03	3602.169	3551.195	3653.142	
2005 03	2004 04	3360.674	3309.914	3411.433	
2005 03	2004/2005 01	3255.977	3207.024	3304.929	
2005 03	2005 02	2850.816	2801.539	2900.093	
2005 02	2004 02	2805.538	2766.416	2844.661	
2004/2005 01	2004 02	2400.377	2361.664	2439.091	
2004 04	2004 02	2295.680	2254.707	2336.654	
2004 03	2004 02	2054.185	2012.946	2095.424	
2005 04	2005 03	903.517	851.201	955.834	
2005 02	2004 03	751.353	711.472	791.234	
2005 02	2004 04	509.858	470.251	549.464	
2005 02	2004/2005 01	405.161	367.897	442.424	
2004/2005 01	2004 03	346.192	306.713	385.672	
2004 04	2004 03	241.495	199.797	283.194	
2004/2005 01	2004 04	104.697	65.494	143.900	

Levels not connected by same letter are significantly different

.Level								Mean
2005 04	A							10907.526
2005 03		B						10004.008
2005 02			C					7153.193
2004/2005 01				D				6748.032
2004 04					E			6643.335
2004 03						F		6401.840
2004 02							G	4347.655

Figure 16. Mean Average Conductivity Levels; March - August 2004

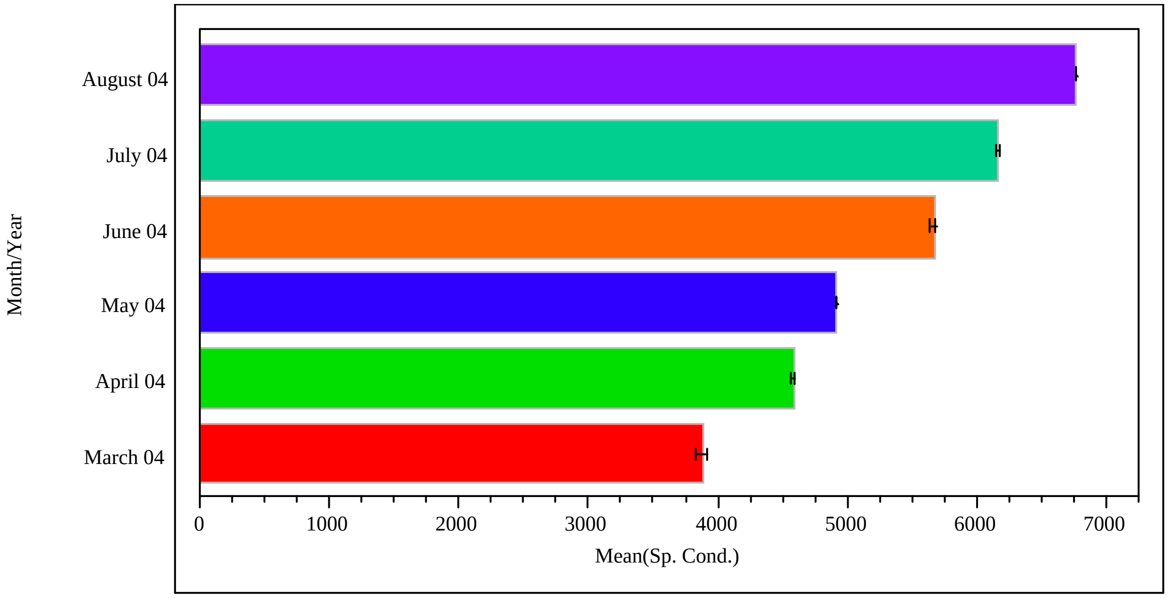
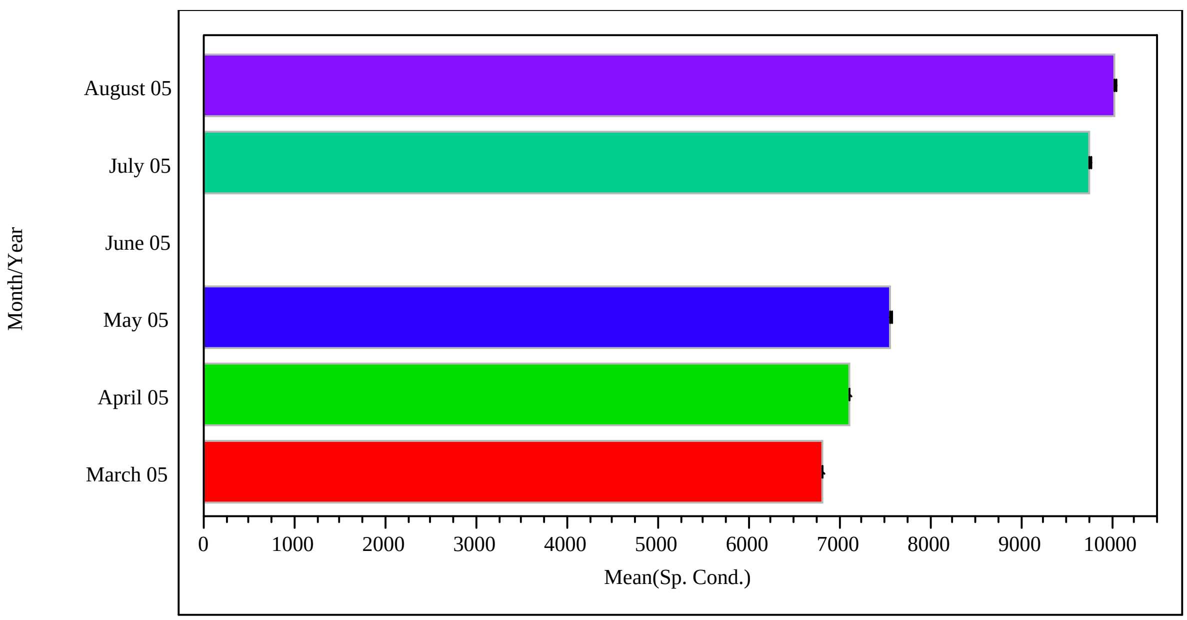


Figure 17. Mean Average Conductivity Levels; March - August 2005



DISCUSSION

It appears that dewatering and subsequent recharging of McAllister Lake shows promise as a method to significantly decrease salinity levels to those which could sustain native fish species. Constraints or stressors, however, are usually layered and as one is lifted another emerges. In the case of McAllister, hyper-salinity is one obvious constraint to survivability of native fish but others still exist which this work does not address including issues associated with hyper-eutrophication and anoxia. These other constraints are being closely examined in related studies and recommendations will be soon be made in an attempt to alleviate these stressors as well.

Constraints to implementation of drawdown/recharge in McAllister do exist. It is unlikely that large-scale drawdown treatments could be implemented during the Sept. 15 - Mar. 15 timeframe so as not to disturb Yuma clapper rails. Additionally, moving heavy equipment into and out of the area at the intervals needed would likely cause too much disturbance, in the long-term, to rely on this exact methodology. A more ideal situation, one in which disturbance is kept to a minimum, would be to have a permanent on-site pumping station to remove small but frequent amounts of water from McAllister so that recharge would maintain conductivity levels between the 4,000-6,500 µS/cm previously described in this report. This would avoid the large spikes in conductivity that would undoubtedly occur between larger, but infrequent, drawdowns.

There were many complicating factors in this project. Several of these are typical in environmental studies while others made clear-cut analysis of effect(s) difficult. Pump times, durations, volumes, and collection of pre-treatment data were all different between and among treatments. Combining these complications with typical observational study complicating factors such as differences in recharge rate, river discharge, temperature, humidity, evapotranspiration, etc. meant that caveats must be placed on any exact statements about effect and longevity. However, even in light of these complicating factors, it appears as if treatments were highly successful in reducing conductivity levels to those which could support either bonytail chub or razorback sucker.

Significant variability exists between the five drawdowns conducted with this study (e.g., different pumping durations and pre-pumping lake elevations, magnitude and seasonality, various river stages, etc.). It is therefore difficult to accurately estimate what pump volumes might support salinity levels within a range needed for McAllister Lake to be deemed habitable by native fish species. The data generated by this investigation does, however, allow general statements to be made regarding the volume of water that might be pumped, and at what rate, to keep salinity levels within a range which does not physiologically stress, or cause outright mortality of, both bonytail chub and razorback sucker.

Data generated by this investigation generally indicate that salinity levels could likely be kept below the 6,500 µS/cm threshold if the pumped volume is 67 acre-feet or more. This volume represents the mean water volume pumped during the first three 3-foot drawdowns all of which exhibited a marked decrease in salinity levels. This volume is somewhat speculative as many other factors could impact salinity levels within McAllister besides volume of water pumped. It is, however, based upon empirical data generated during this investigation.

A viable alternative to sporadic, large-scale pumping would be a strategy using low-level pumping rates on a quasi-constant basis which maintains levels of specific conductivity between 4,000 and 6,500 µS/cm. It is estimated this pumping rate could be designed to match the rate of seepage from the Colorado River into the backwater. As discussed elsewhere in this document, seepage rate will vary depending upon differences in elevation between the river, aquifer, and backwater. Guay (2004) calculated that the seepage rate into the backwater is approximately 4 acre-feet per day; a value which should be refined but is likely adequate for planning purposes.

Information in the literature about exact preferences in environmental conditions, including salinity, for survivability, growth, or reproduction of either razorback sucker or bonytail chub is depauperate. One study done over 20 years ago by Pimental & Bulkley (1983) is the only study to examine preference and avoidance of ranges of salinities in juvenile Colorado River fishes including bonytail chub. This study found that age 0 - 1 year bonytails preferred conductivity levels of between 6150 - 7050 µS/cm and avoided conductivities less than 840 and more than 9,900 µS/cm. This would support our assignment of the 4,000 - 6,500 µS/cm conductivity range, with a built-in margin of safety.

A primary objective for the creation of managed habitat for any species shouldn't be whether it can merely survive, but whether it can thrive in an area to become a managed, self-sustaining, population. Research is needed to determine specific environmental variables preferred by individual native fish species to achieve these goals. Trying to determine habitat suitability without first obtaining this data might be considered pre-mature and result in limited success.

While these drawdown/recharge treatments show great promise in alleviating hyper-saline conditions within McAllister, they were not designed to address other stressors such as extremely low dissolved oxygen levels. Dissolved oxygen dynamics are more dependent upon internal feedback mechanisms, and are somewhat of a more complicated issue, than salinity and will likely require a different technique (or set of techniques) to alleviate. Issues regarding dissolved oxygen dynamics, algal productivity, and linking biological to physico-chemical variables is on-going by the University of Arizona in both McAllister and Butler Lakes and a report will be made available by February 2007.

To summarize, the de-watering and recharge study at McAllister showed excellent results in decreasing specific conductivity levels within the lake. This is a major initial step in engineering McAllister as a large, habitable area for either bonytail chub or razorback sucker. McAllister, however, should not be considered habitable for either species until further constraints have been lifted. The following list describes what would need to be implemented in order to determine feasibility of McAllister as habitable area by bonytail chub or razorback sucker.

1) Determine best methods to alleviate hyper-eutrophication and frequent anoxia (research underway by the University of Arizona).

2) Determine non-destructive and minimally intrusive methods to maintain specific conductivity levels between 4,000 and 6,500 µS/cm throughout the year.

3) Ensure that de-watering/recharge does not interfere or disturb Yuma clapper rails when they are known to be present.

Very general and preliminary results from subsequent studies indicate that the oxygen demand of the sediments might be alleviated through dredging and/or the use of aluminum sulfate. This would likely increase dissolved oxygen levels within the water column and greater enhance the possibility that McAllister could become a successful refuge for native fish species.

It is our view that McAllister Lake has the potential to be a viable, relatively large, long-term habitat for either bonytail chub or razorback sucker and that alleviating problems associated with hyper-salinity, as this study has proven is possible, is an essential first step toward making this a reality.

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PERSONAL COMMUNICATIONS

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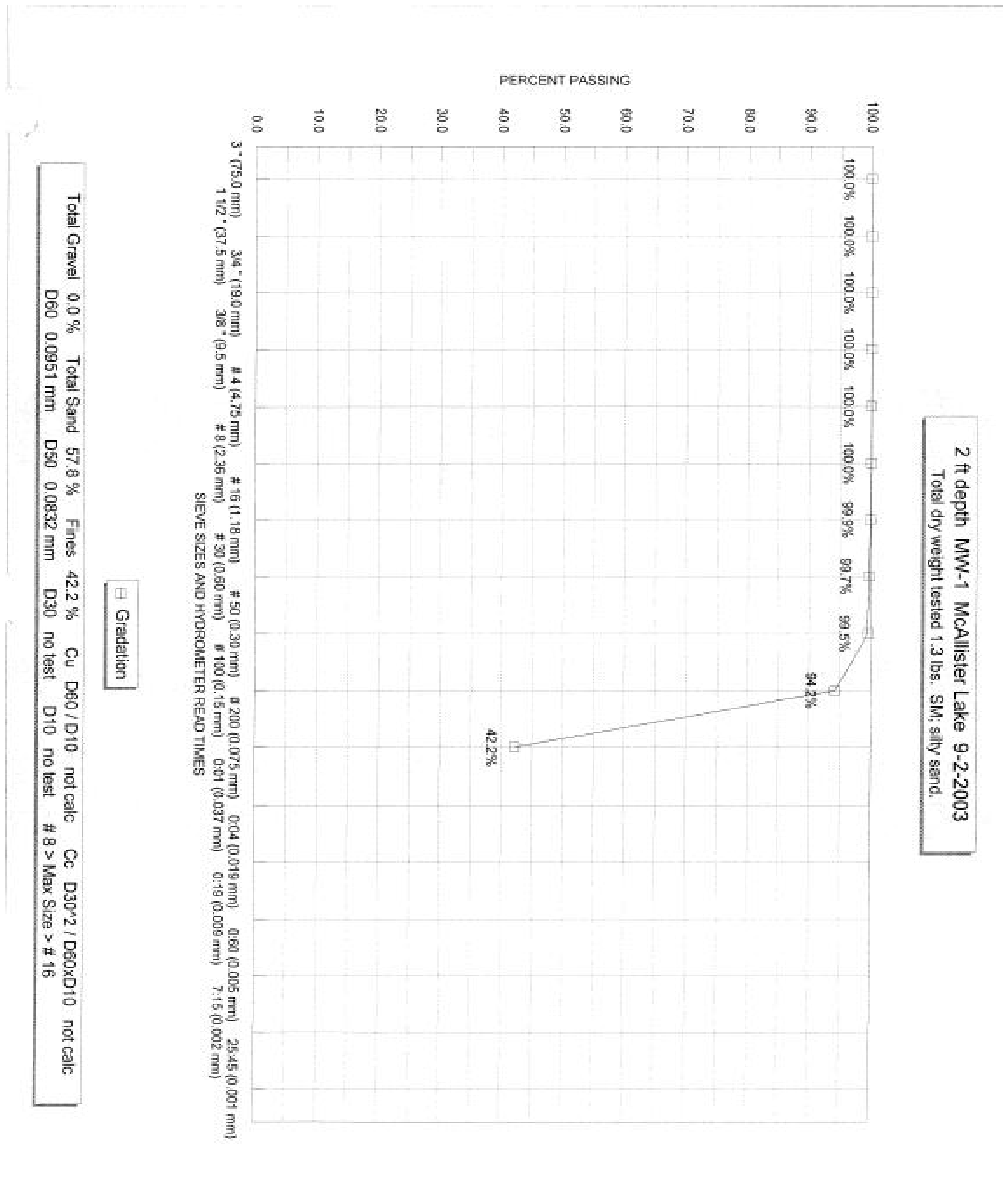
APPENDICES

Appendix A. Monitoring Well Data

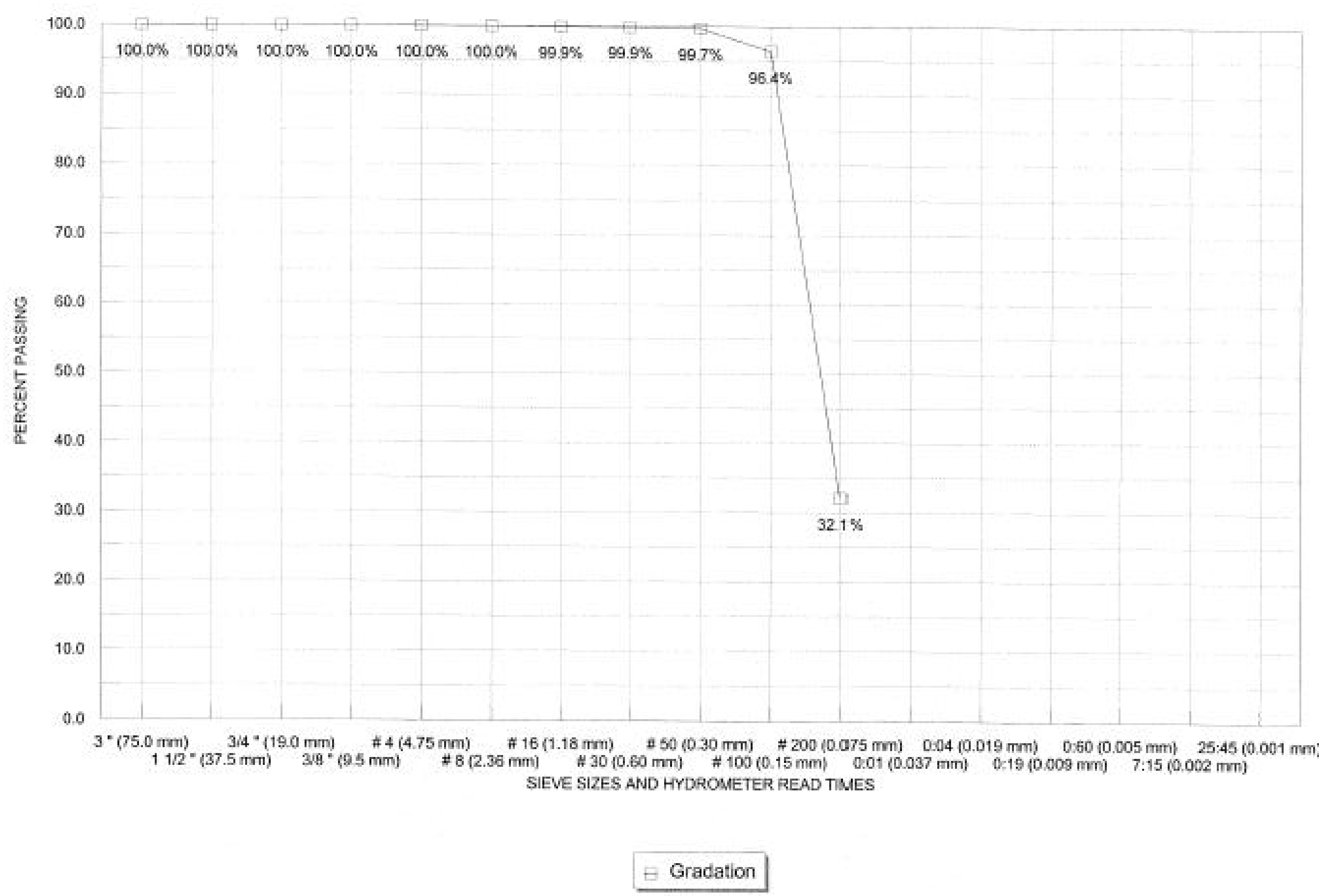
Table A1. Monitoring Well Details and Sieve Analyses

WELL NAME	local / other Identifier PROVISIONAL	ADWR Well Registration Number	Lat (X) PROVISIONAL	Long. (Y) PROVISIONAL	SIEVE ANALSIS
MW-1	N. Firebreak	55-599945	33° 01' 19.0" N	114° 30' 24.3" W	2 ft depth: silty sand 8 ft depth: silty sand 20 ft depth: silt w/ sand
MW-2	Old Channel	55-599946	33° 01' 12.78" N	114° 30' 15.00" W	3 ft depth: silty sand 8 ft depth: sandy silt 15 ft depth: sandy silt 22 ft depth: sandy silt 23 ft depth: silt
MW-3	Mid.Firebreak	55-599947	33° 01' 06.66" N	114° 30' 18.36" W	3 ft depth: sandy silt 8 ft depth: sandy silt 15 ft depth: sandy silt 20 ft depth: silt w/ sand
MW-4	W. of McAll	55-599948	33° 01' 00.30" N	114° 30' 10.08" W	3 ft depth: silty sand 8 ft depth: silty sand 15 ft depth: sandy silt 20 ft depth: silt w/ sand
MW-5	S. Firebreak	55-599949	33° 00' 48.66" N	114° 30' 07.50" W	2 ft depth: silty sand 8 ft depth: sandy silt 15 ft depth: silt w/ sand 20 ft depth: silt w/ sand



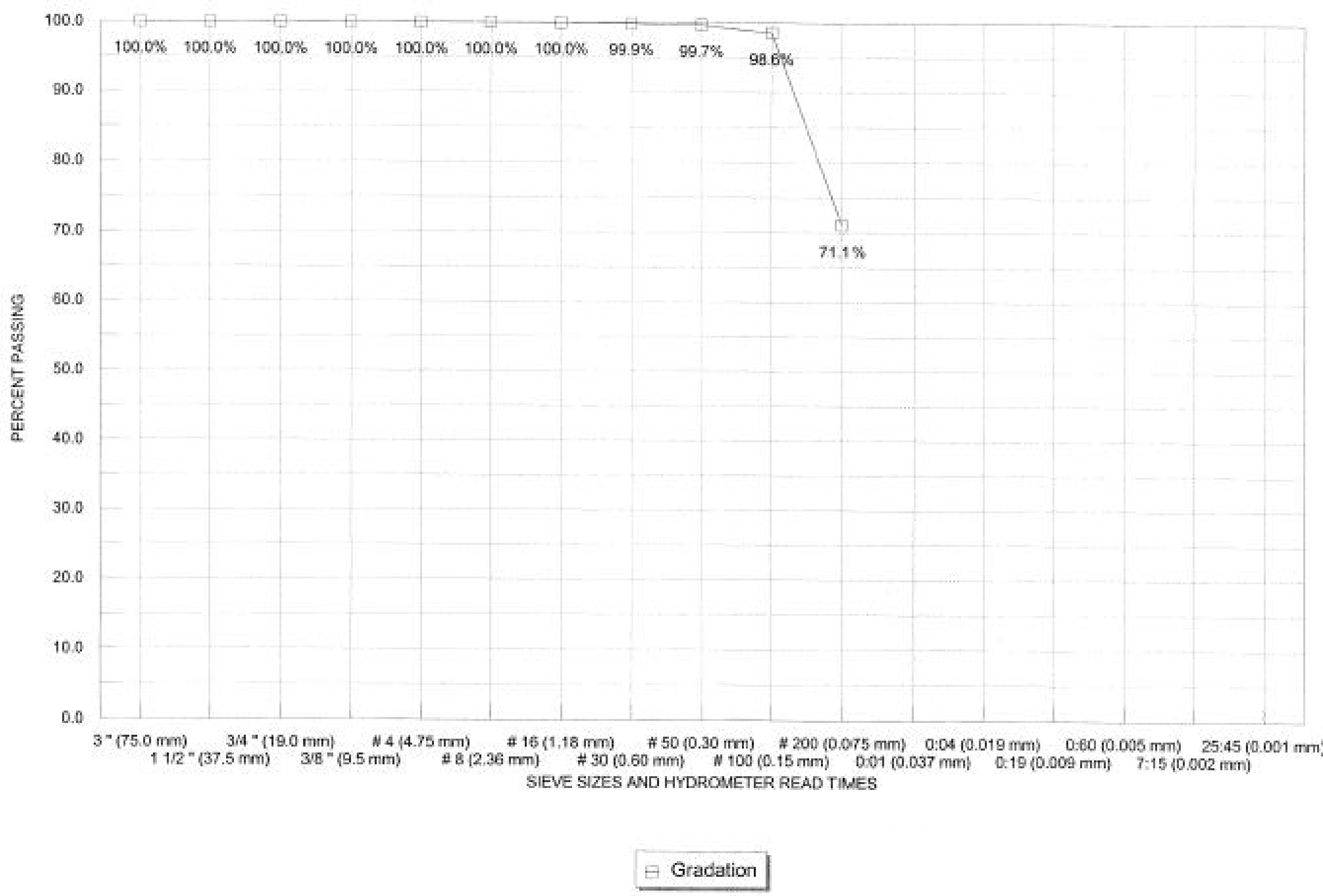
2 ft depth MW-1 McAllister Lake 9-2-2003
Total dry weight tested 1.3 lbs. SM; silty sand.
PERCENT PASSING
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
100.0%
100.0%
100.0%
100.0%
100.0%
100.0%
99.9%
99.7%
99.5%
94.2%
42.2%
3 " (75.0 mm)
1 1/2 " (37.5 mm)
3/4 " (19.0 mm)
3/8 " (9.5 mm)
4 (4.75 mm)
8 (2.36 mm)
16 (1.18 mm)
30 (0.60 mm)
50 (0.30 mm)
100 (0.15 mm)
200 (0.075 mm)
0:01 (0.037 mm)
0:04 (0.019 mm)
0:19 (0.009 mm)
0:60 (0.005 mm)
7:15 (0.002 mm)
25:45 (0.001 mm)
SIEVE SIZES AND HYDROMETER READ TIMES
Gradation
Total Gravel 0.0 % Total Sand 57.8 % Fines 42.2 % Cu D60 / D10 not calc Cc D30^2 / D60xD10 not calc
D60 0.0951 mm D50 0.0832 mm D30 no test D10 no test # 8 > Max Size > # 16

8 ft depth MW-1 McAllister Lake 9-2-2003
Total dry weight tested 0.5 lbs. SM; silty sand.



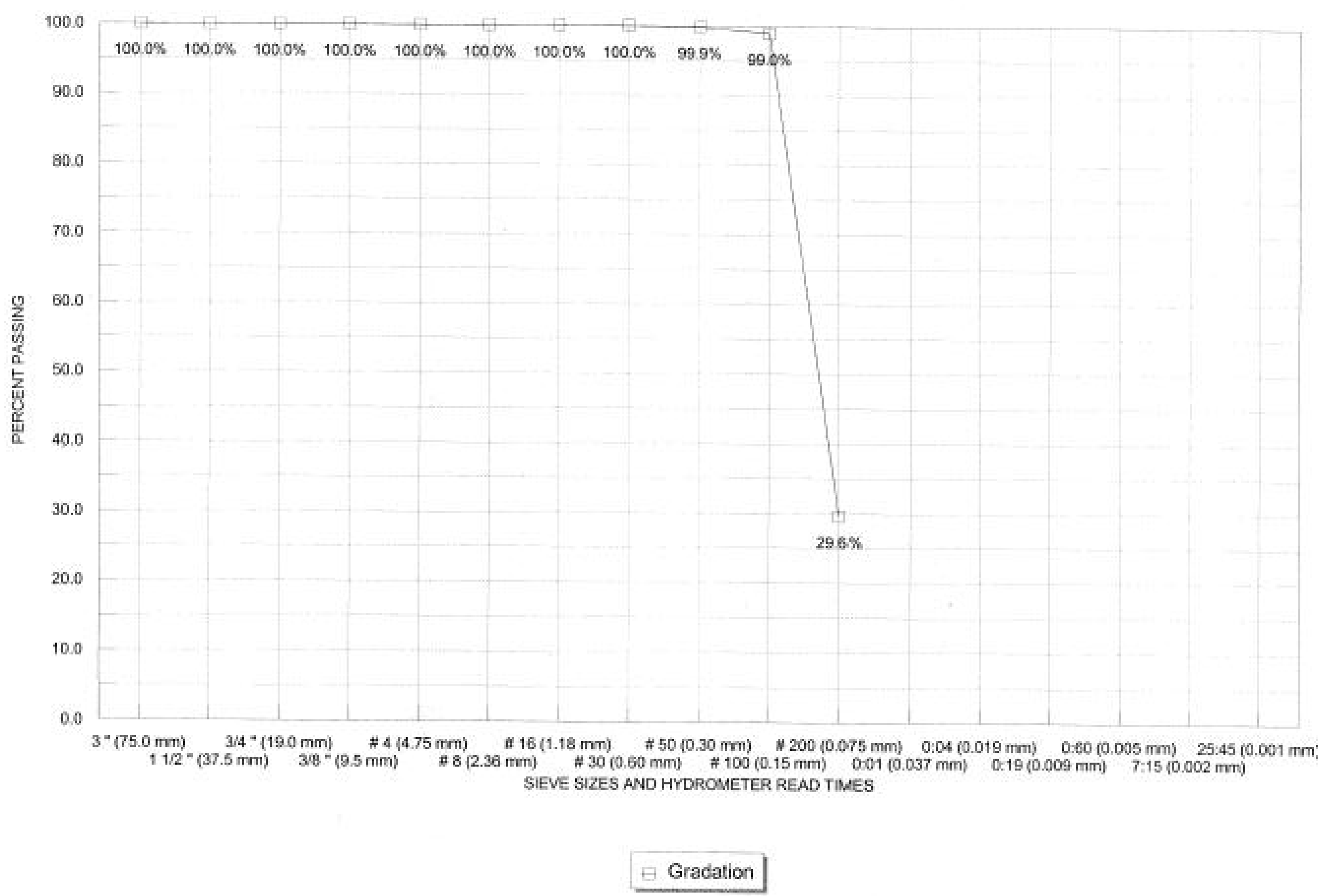
Total Gravel 0.0 % Total Sand 67.9 % Fines 32.1 % Cu D60 / D10 not calc Cc D30^2 / D60xD10 not calc
D60 0.1013 mm D50 0.0909 mm D30 no test D10 no test # 8 > Max Size > # 16

20 ft depth MW-1 McAllister Lake 9-2-2003
Total dry weight tested 0.8 lbs. ML; silt with sand.



Total Gravel 0.0 % Total Sand 28.9 % Fines 71.1 % Cu D60 / D10 not calc Cc D30^2 / D60xD10 not calc
D60 no test D50 no test D30 no test D10 no test # 16 > Max Size > # 30

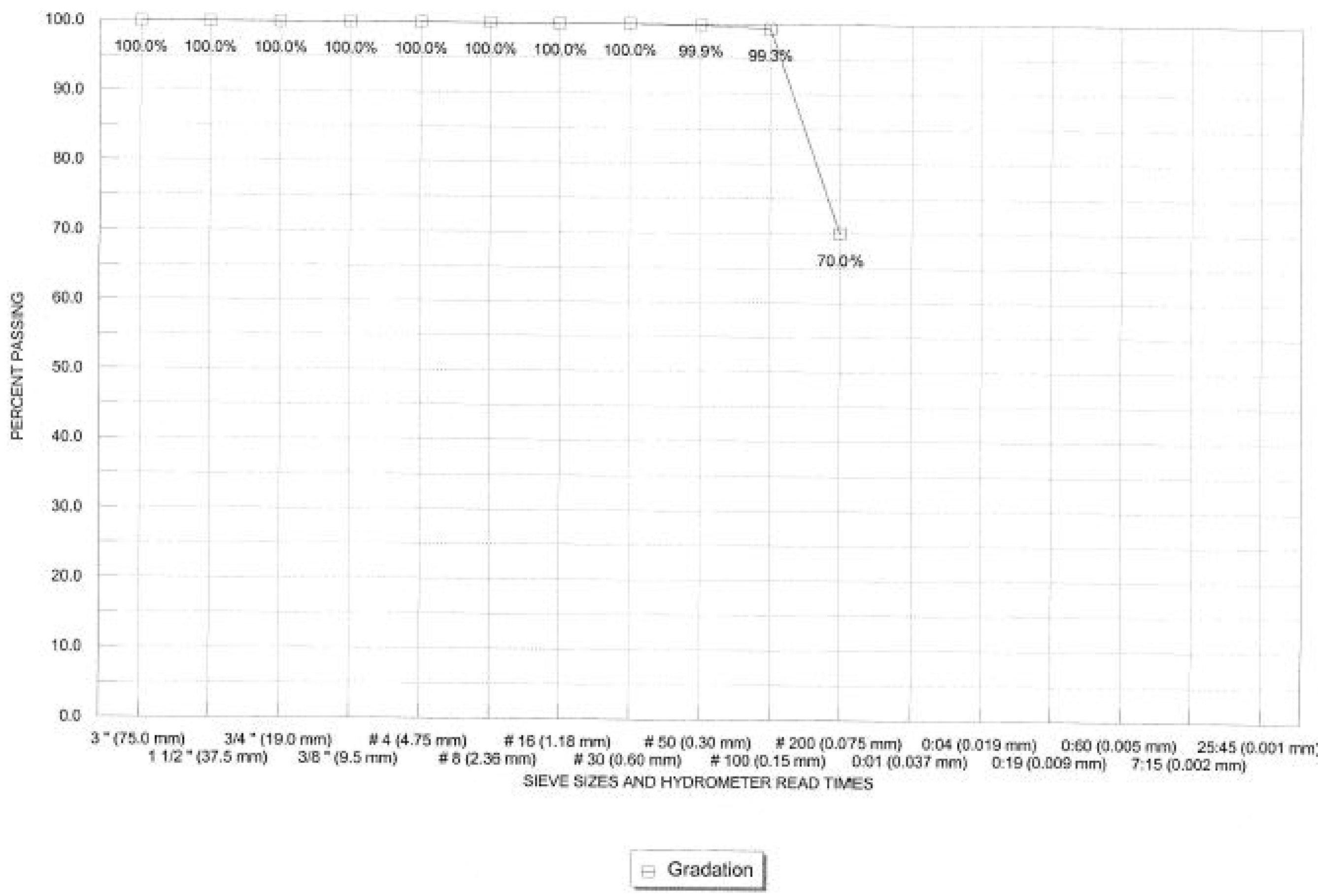
3 ft depth MW-2 McAllister Lake 9-3-2003
Total dry weight tested 0.8 lbs. SM; silty sand.



Total Gravel 0.0 % Total Sand 70.4 % Fines 29.6 % Cu D60 / D10 not calc Cc D30^2 / D60xD10 not calc
D60 0.1016 mm D50 0.0920 mm D30 0.0753 mm D10 no test # 30 > Max Size > # 50

8 ft depth MW-2 McAllister Lake 9-3-2003

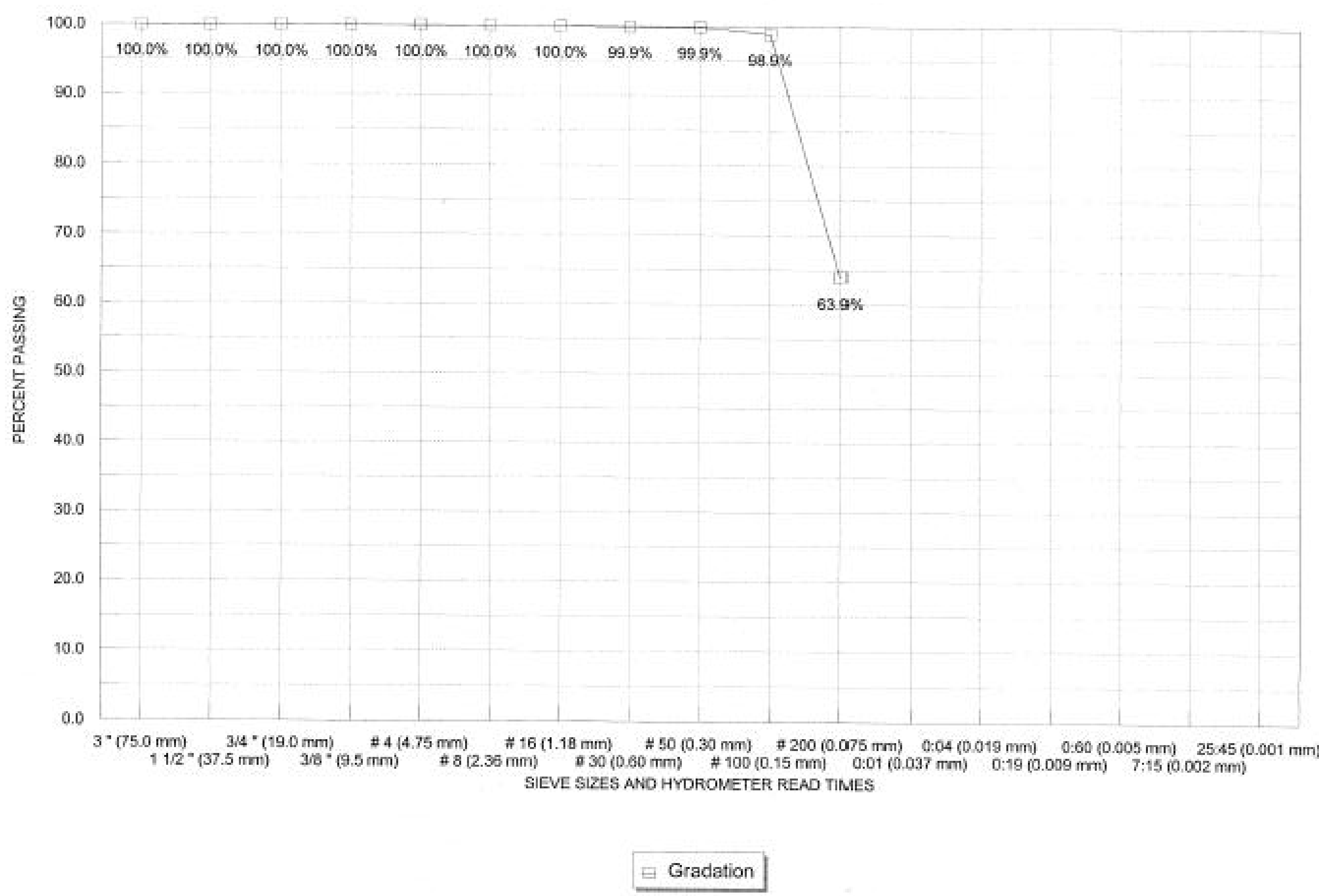
Total dry weight tested 1.5 lbs. ML; sandy silt.



Total Gravel 0.0 % Total Sand 30.0 % Fines 70.0 % Cu D60 / D10 not calc Cc D30^2 / D60xD10 not calc

D60 no test D50 no test D30 no test D10 no test # 30 > Max Size > # 50

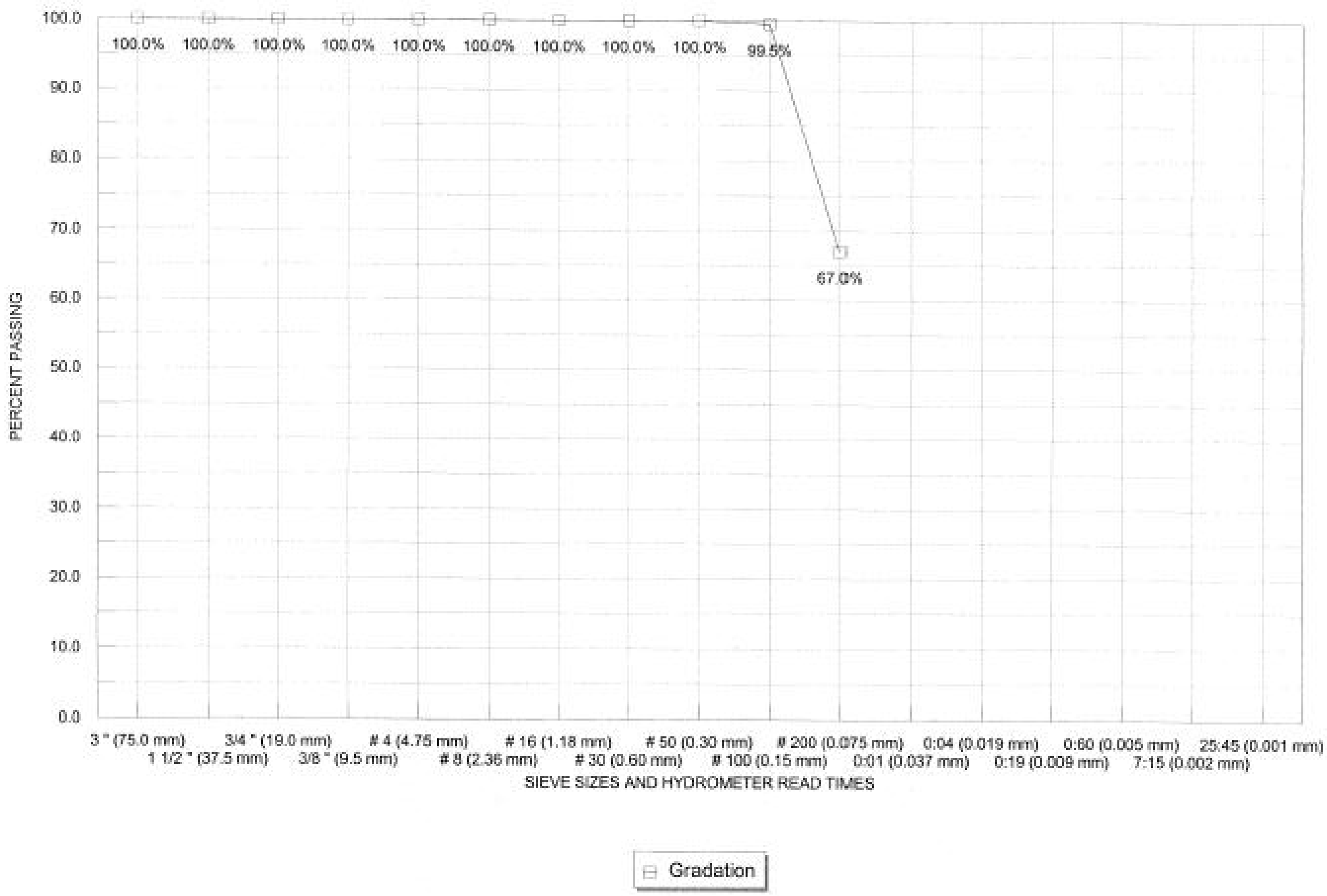
15 ft depth MW-2 McAllister Lake 9-3-2003
Total dry weight tested 0.7 lbs. ML; sandy silt.



Total Gravel 0.0 % Total Sand 36.1 % Fines 63.9 % Cu D60 / D10 not calc Cc D30^2 / D60xD10 not calc
D60 no test D50 no test D30 no test D10 no test # 16 > Max Size > # 30

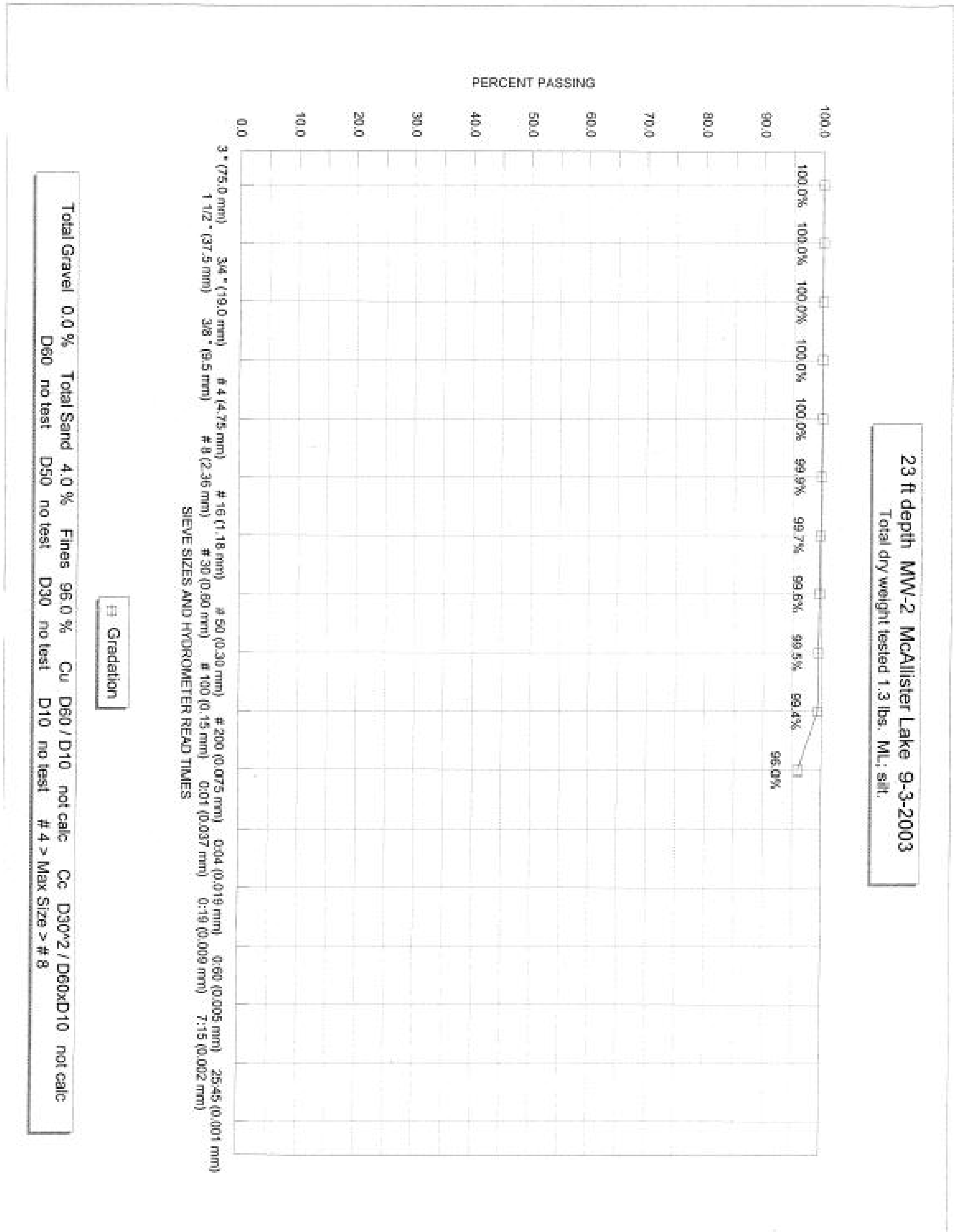
22 ft depth MW-2 McAllister Lake 9-3-2003

Total dry weight tested 0.8 lbs. ML; sandy silt.



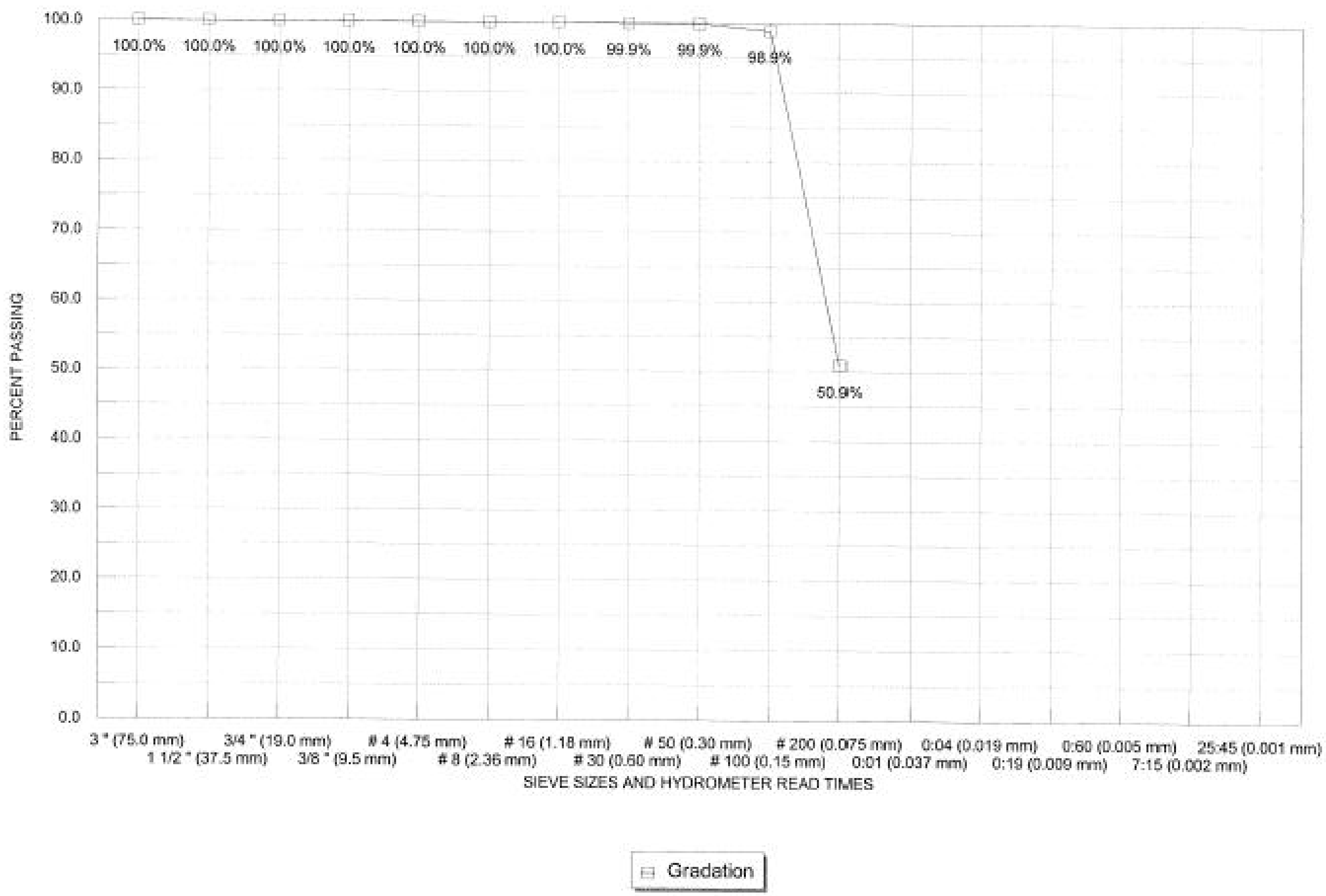
Total Gravel 0.0 % Total Sand 33.0 % Fines 67.0 % Cu D60 / D10 not calc Cc D30^2 / D60xD10 not calc

D60 no test D50 no test D30 no test D10 no test # 50 > Max Size > # 100



23 ft depth MW-2 McAllister Lake 9-3-2003
Total dry weight tested 1.3 lbs. ML; silt.
PERCENT PASSING
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
100.0%
100.0%
100.0%
100.0%
100.0%
99.9%
99.7%
99.6%
99.5%
99.4%
96.0%
3" (75.0 mm)
1 1/2" (37.5 mm)
3/4" (19.0 mm)
3/8" (9.5 mm)
4 (4.75 mm)
8 (2.36 mm)
16 (1.18 mm)
30 (0.60 mm)
50 (0.30 mm)
100 (0.15 mm)
200 (0.075 mm)
0:01 (0.037 mm)
0:04 (0.019 mm)
0:19 (0.009 mm)
0:60 (0.005 mm)
7:15 (0.002 mm)
25:45 (0.001 mm)
SIEVE SIZES AND HYDROMETER READ TIMES
Gradation
Total Gravel 0.0 % Total Sand 4.0 % Fines 96.0 % Cu D60 / D10 not calc Cc D30^2 / D60xD10 not calc
D60 no test D50 no test D30 no test D10 no test # 4 > Max Size > # 8

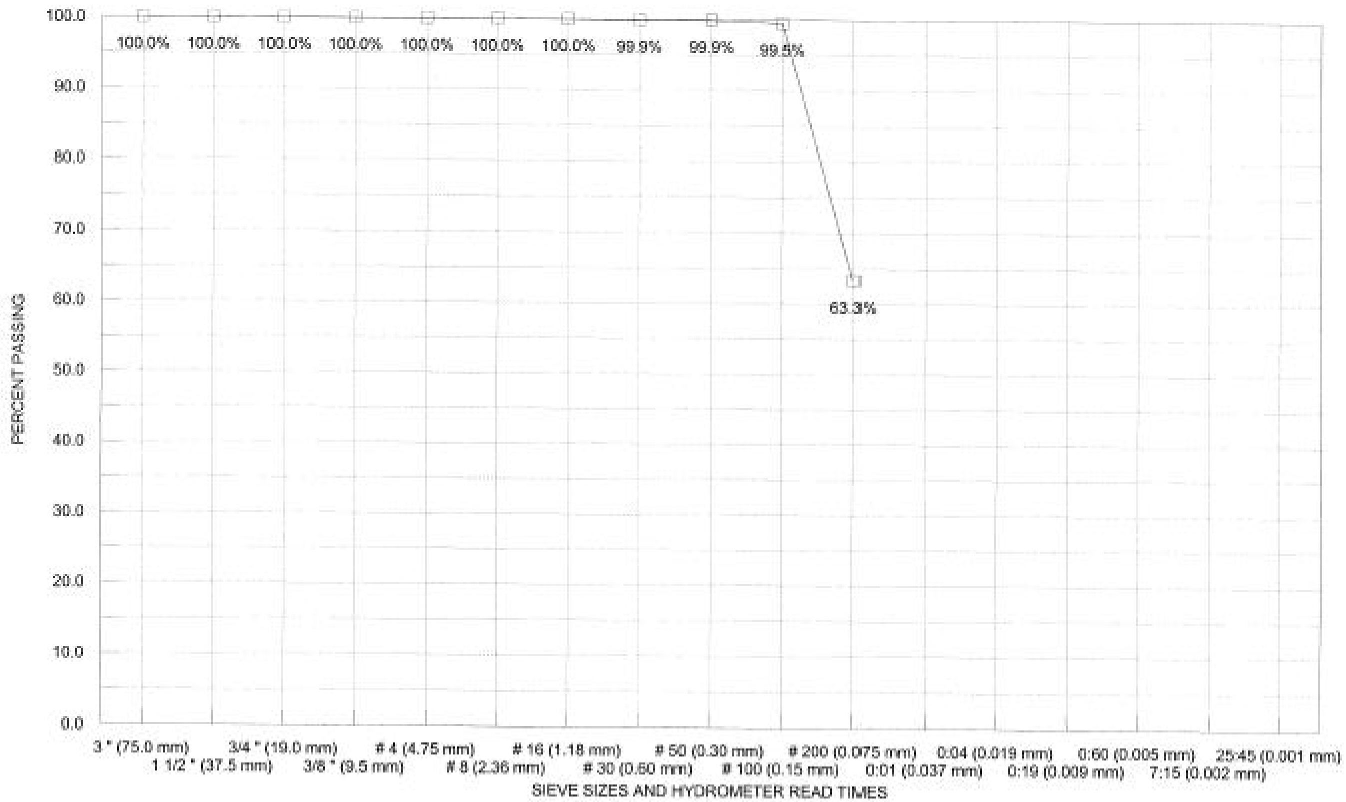
3 ft depth MW-3 McAllister Lake 9-2-2003
Total dry weight tested 0.5 lbs. ML; sandy silt.



Total Gravel 0.0 % Total Sand 49.1 % Fines 50.9 % Cu D60 / D10 not calc Cc D30^2 / D60xD10 not calc
D60 0.0856 mm D50 no test D30 no test D10 no test # 16 > Max Size > # 30

8 ft depth MW-3 McAllister Lake 9-2-2003

Total dry weight tested 0.6 lbs. ML; sandy silt.

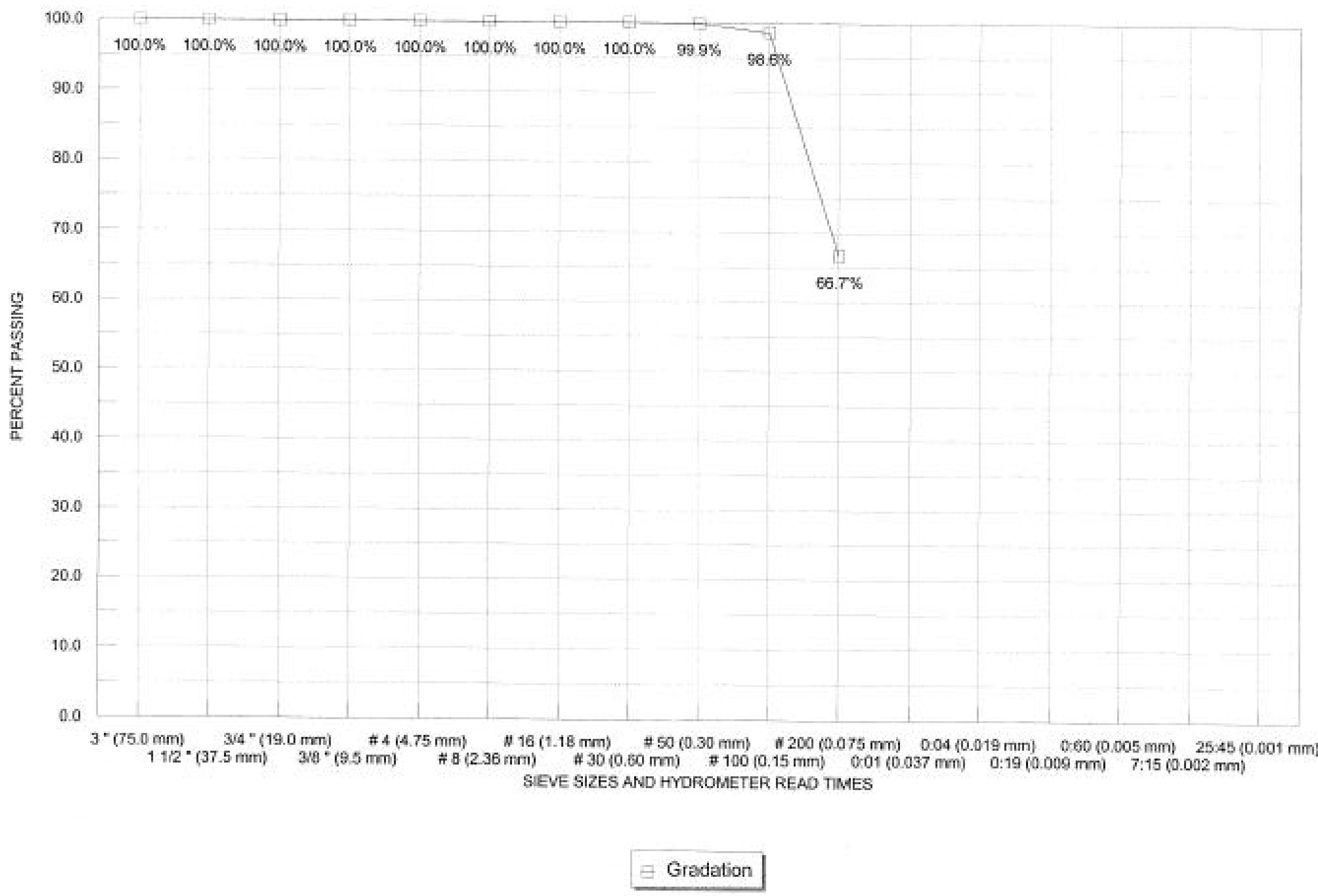


Gradation

Total Gravel 0.0 % Total Sand 36.7 % Fines 63.3 % Cu D60 / D10 not calc Cc D30^2 / D60xD10 not calc

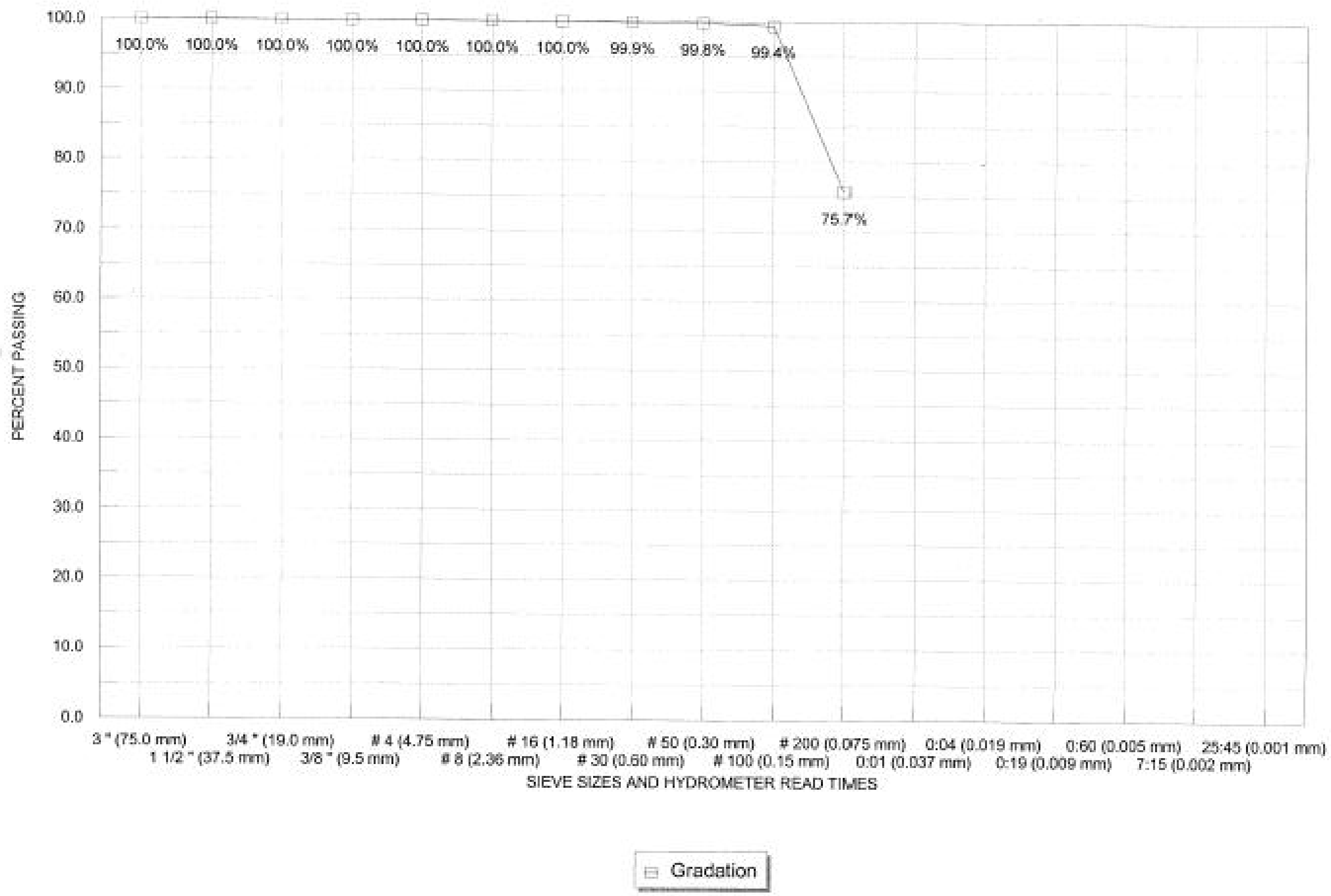
D60 no test D50 no test D30 no test D10 no test # 16 > Max Size > # 30

15 ft depth MW-3 McAllister Lake 9-2-2003
Total dry weight tested 0.8 lbs. ML; sandy silt.



Total Gravel 0.0 % Total Sand 33.3 % Fines 66.7 % Cu D60 / D10 not calc Cc D30^2 / D60xD10 not calc
D60 no test D50 no test D30 no test D10 no test # 30 > Max Size > # 50

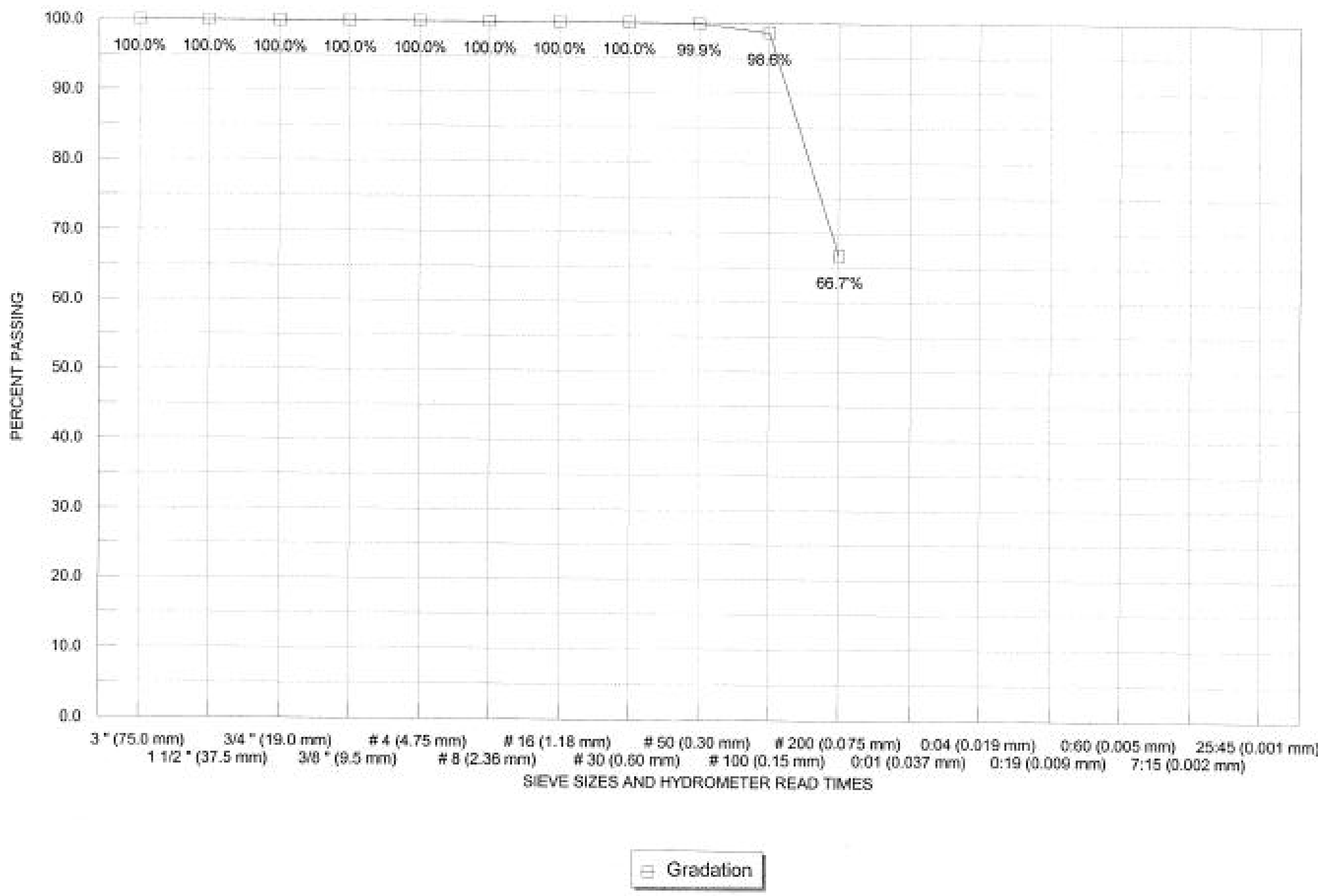
20 ft depth MW-3 McAllister Lake 9-3-2003
Total dry weight tested 0.9 lbs. ML; silt with sand.



Total Gravel 0.0 % Total Sand 24.3 % Fines 75.7 % Cu D60 / D10 not calc Cc D30^2 / D60xD10 not calc
D60 no test D50 no test D30 no test D10 no test # 16 > Max Size > # 30

15 ft depth MW-3 McAllister Lake 9-2-2003

Total dry weight tested 0.8 lbs. ML; sandy silt.

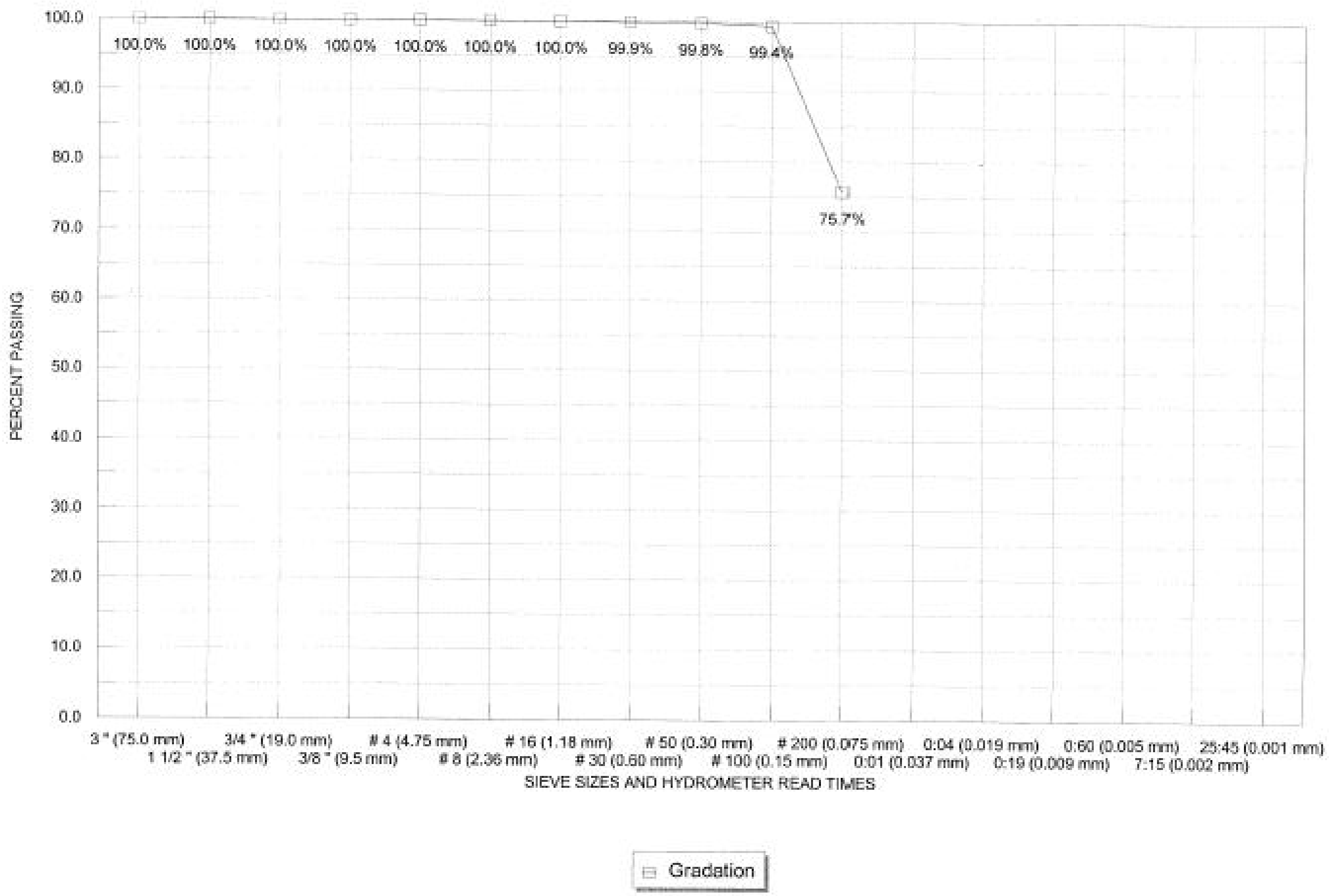


Total Gravel 0.0 % Total Sand 33.3 % Fines 66.7 % Cu D60 / D10 not calc Cc D30^2 / D60xD10 not calc

D60 no test D50 no test D30 no test D10 no test # 30 > Max Size > # 50

20 ft depth MW-3 McAllister Lake 9-3-2003

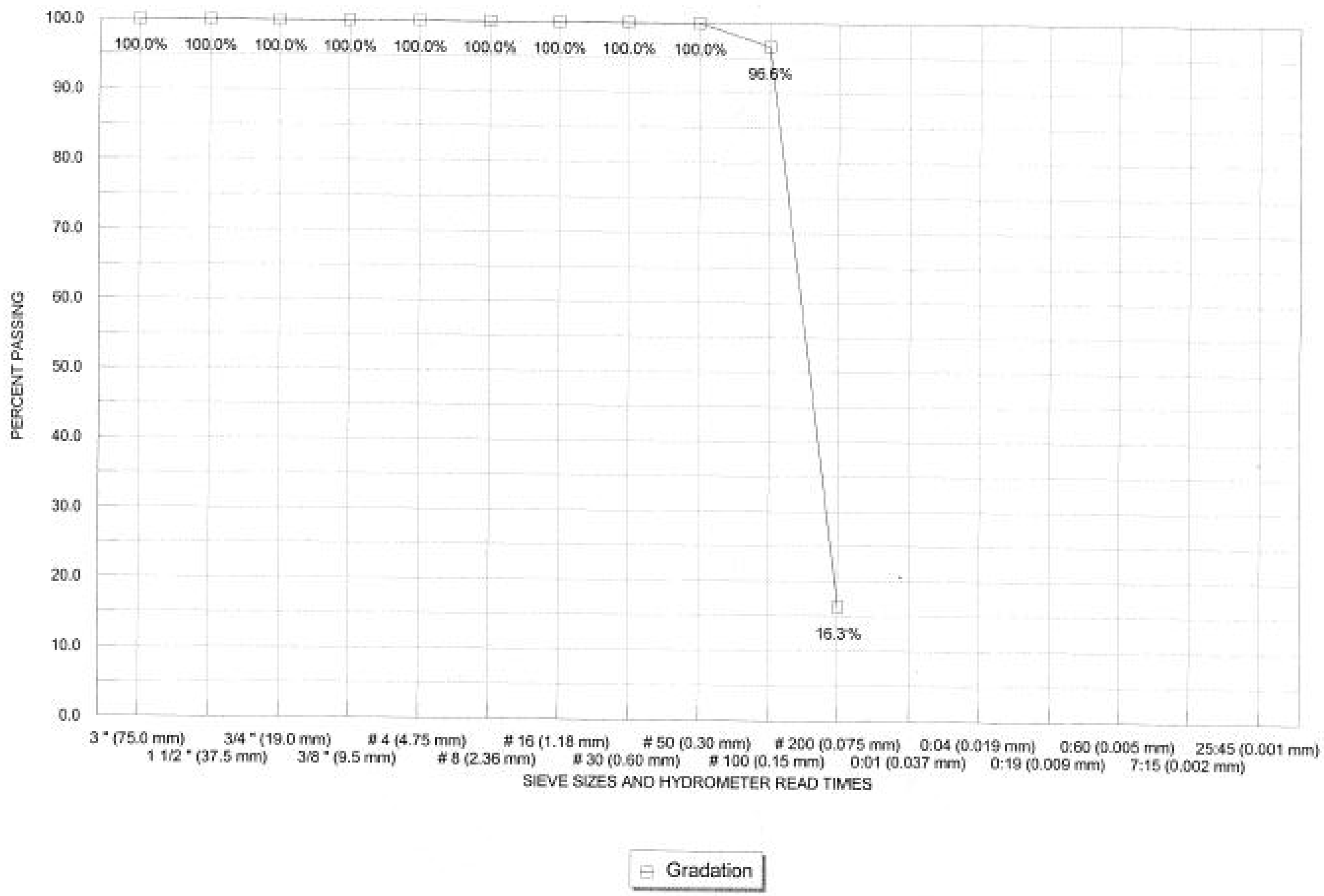
Total dry weight tested 0.9 lbs. ML; silt with sand.



Total Gravel 0.0 % Total Sand 24.3 % Fines 75.7 % Cu D60 / D10 not calc Cc D30^2 / D60xD10 not calc
D60 no test D50 no test D30 no test D10 no test # 16 > Max Size > # 30

3 ft depth MW-4 McAllister Lake 9-3-2003

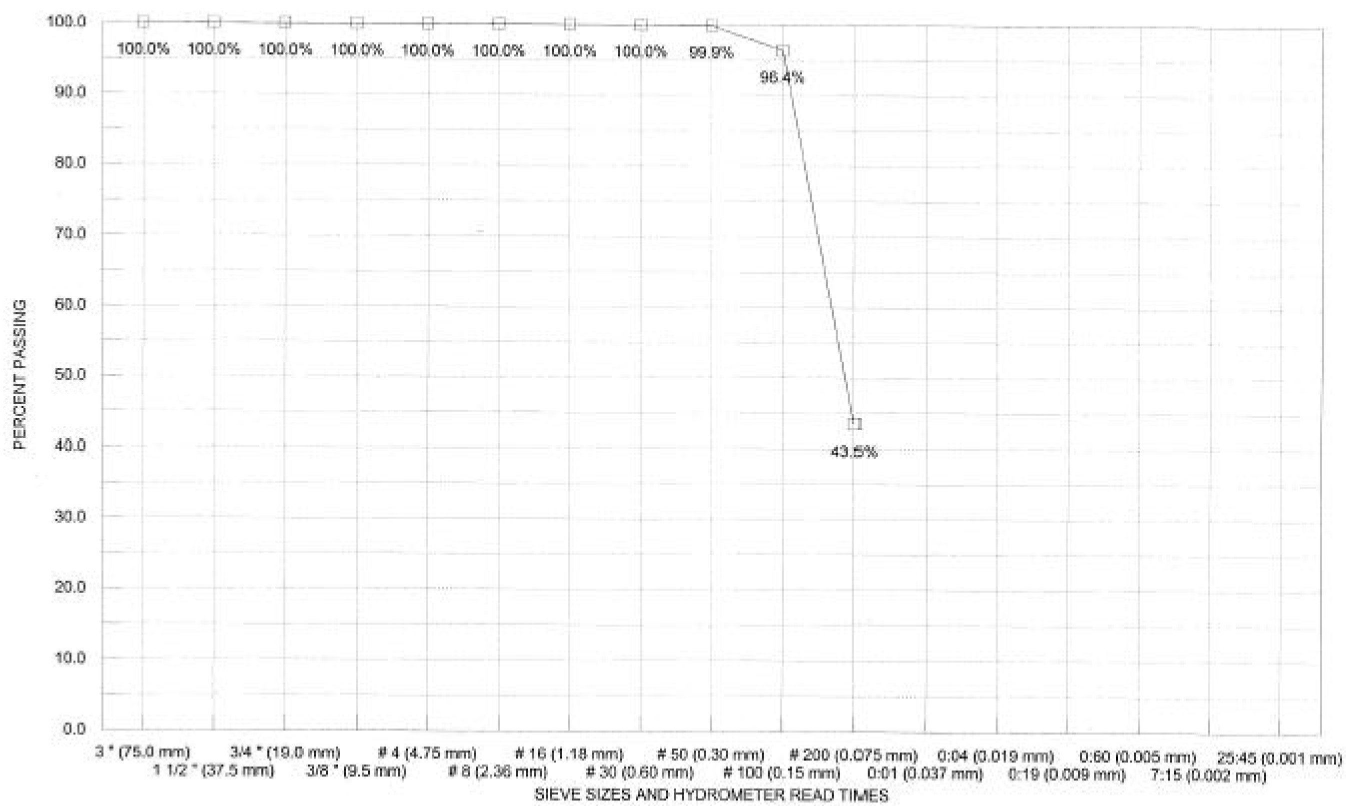
Total dry weight tested 0.6 lbs. SM; silty sand.



Total Gravel 0.0 % Total Sand 83.7 % Fines 16.3 % Cu D60 / D10 not calc Cc D30^2 / D60xD10 not calc

D60 0.1094 mm D50 0.1003 mm D30 0.0844 mm D10 no test # 50 > Max Size > # 100

8 ft depth MW-4 McAllister Lake 9-3-2003
Total dry weight tested 0.5 lbs. SM; silty sand.

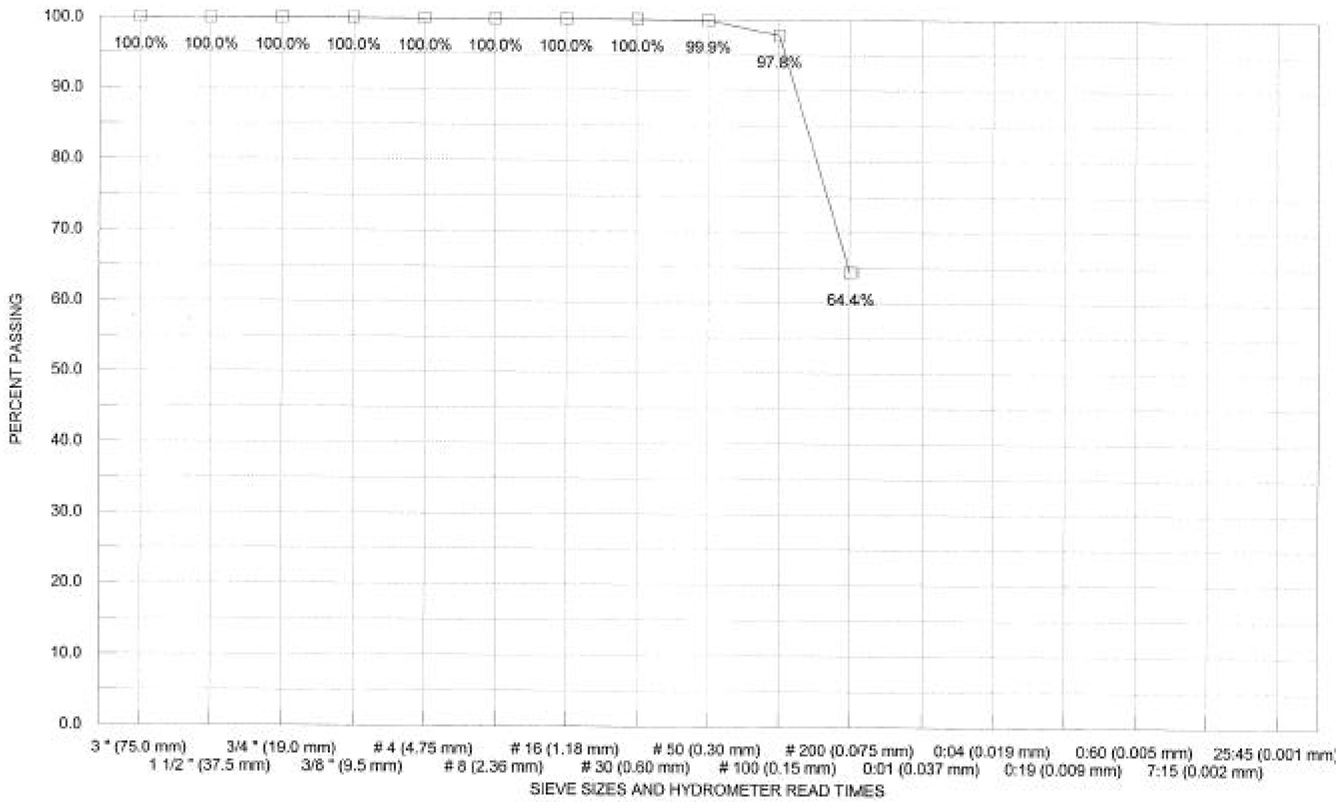


Gradation

Total Gravel 0.0 % Total Sand 56.5 % Fines 43.5 % Cu D60 / D10 not calc Cc D30^2 / D60xD10 not calc
D60 0.0931 mm D50 0.0817 mm D30 no test D10 no test # 30 > Max Size > # 50

15 ft depth MW-4 McAllister Lake 9-3-2003

Total dry weight tested 0.9 lbs. ML; sandy silt.

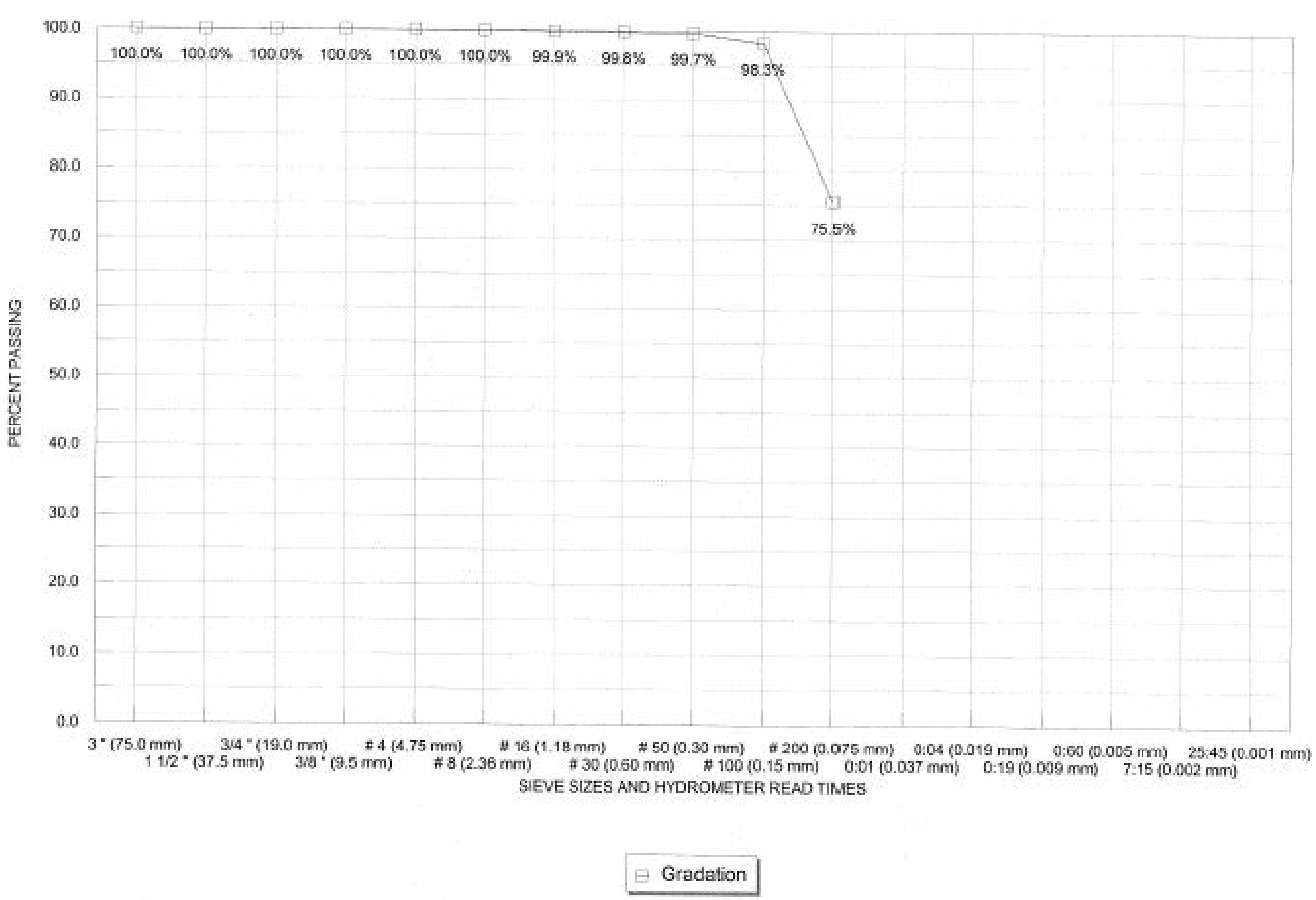


Total Gravel 0.0 % Total Sand 35.6 % Fines 64.4 % Cu D60 / D10 not calc Cc D30^2 / D60xD10 not calc

D60 no test D50 no test D30 no test D10 no test # 30 > Max Size > # 50

20 ft depth MW-4 McAllister Lake 9-3-2003

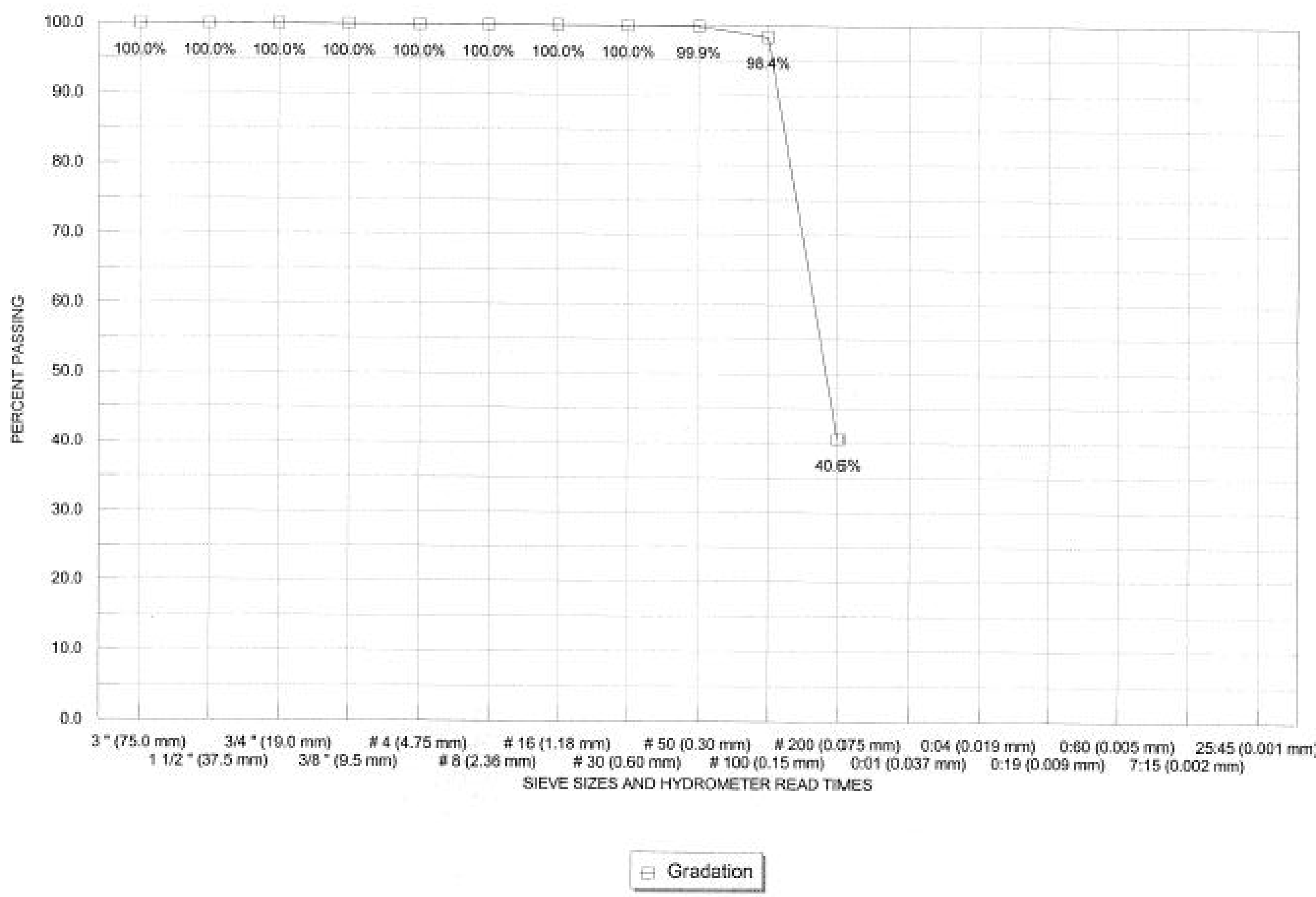
Total dry weight tested 1.6 lbs. ML; silt with sand.



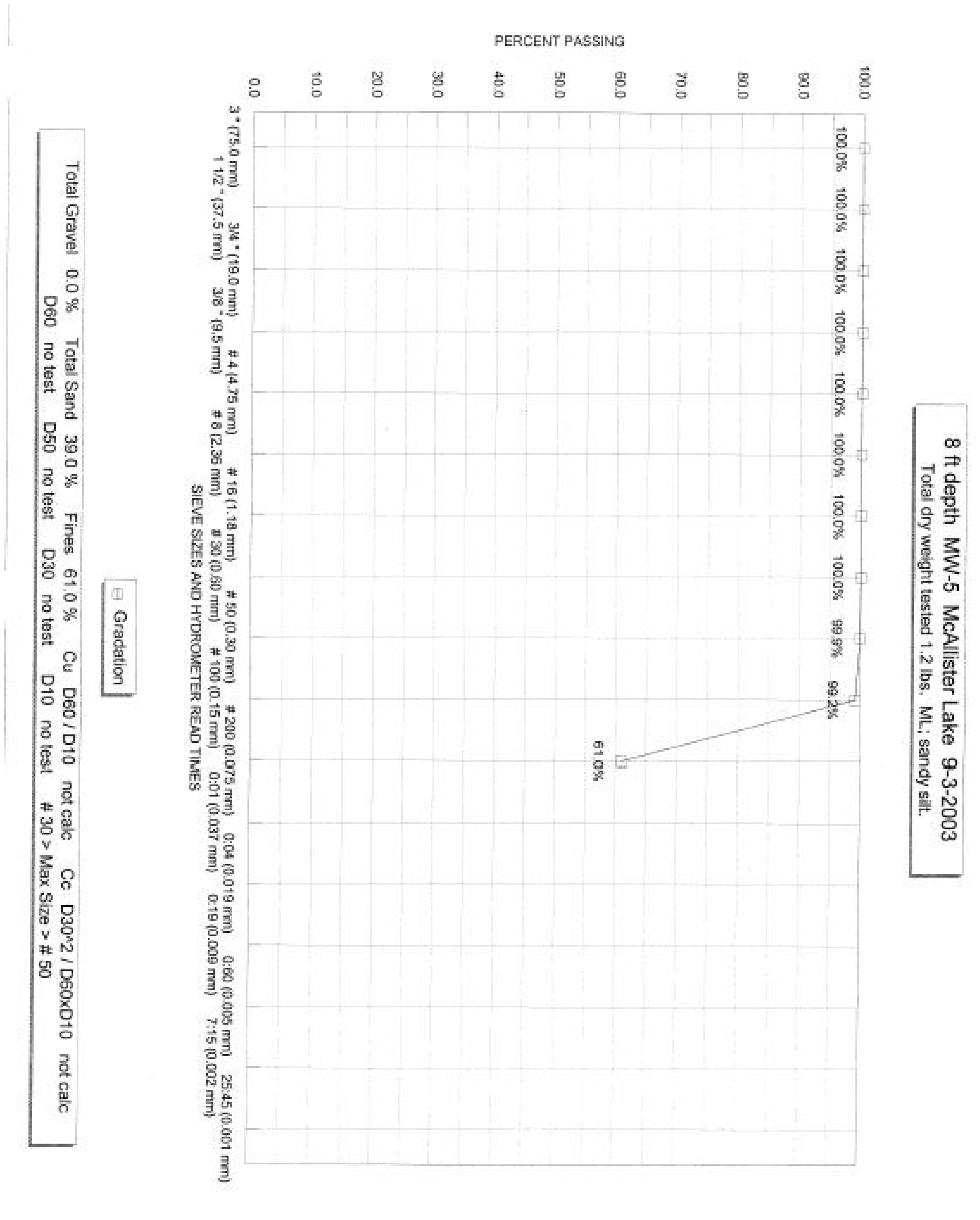
Total Gravel 0.0 % Total Sand 24.5 % Fines 75.5 % Cu D60 / D10 not calc Cc D30^2 / D60xD10 not calc
D60 no test D50 no test D30 no test D10 no test # 8 > Max Size > # 16

2 ft depth MW-5 McAllister Lake 9-3-2003

Total dry weight tested 0.9 lbs. SM; silty sand.



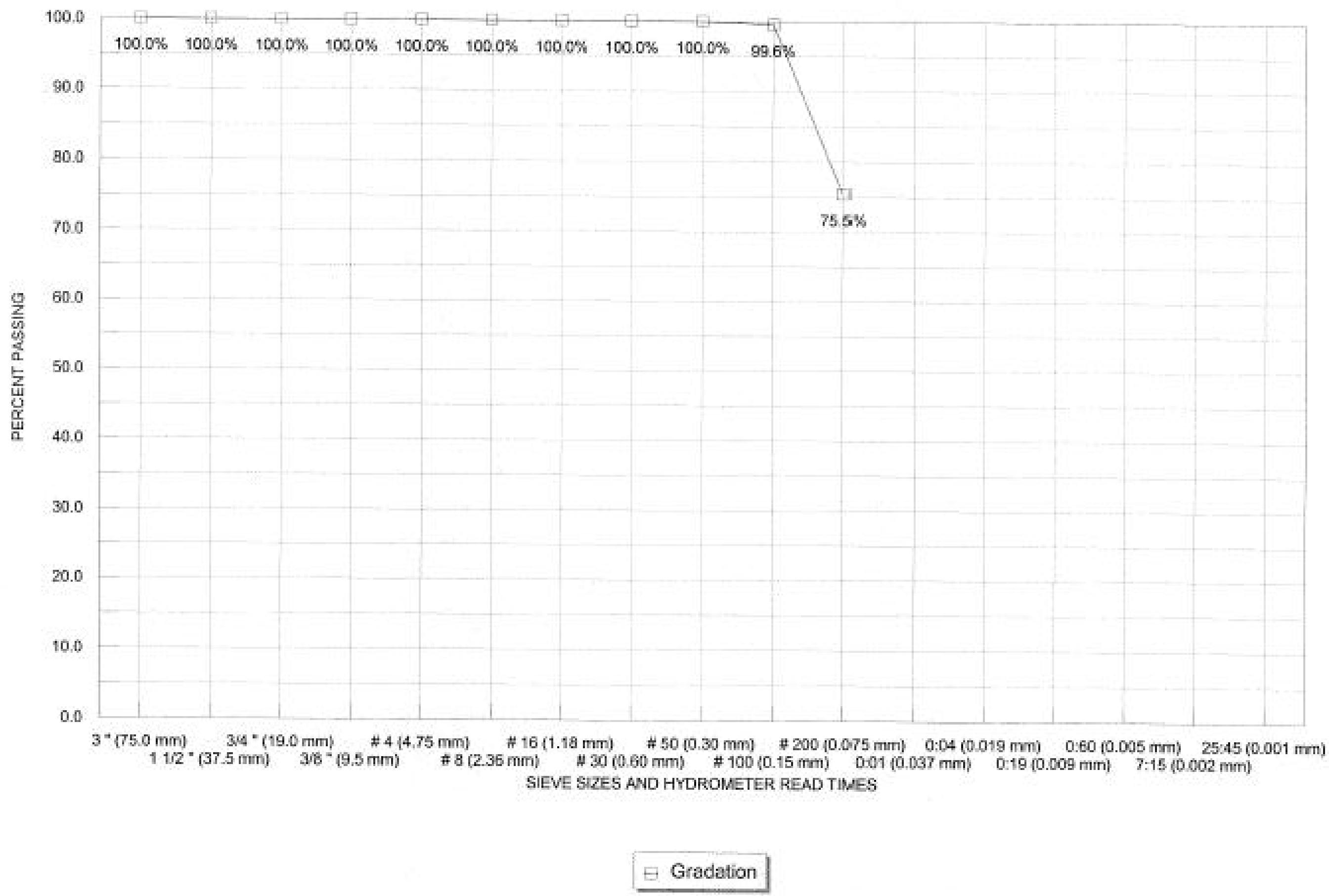
Total Gravel 0.0 % Total Sand 59.4 % Fines 40.6 % Cu D60 / D10 not calc Cc D30^2 / D60xD10 not calc
D60 0.0947 mm D50 0.0840 mm D30 no test D10 no test # 30 > Max Size > # 50



8 ft depth MW-5 McAllister Lake 9-3-2003
Total dry weight tested 1.2 lbs. ML; sandy silt.
PERCENT PASSING
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
100.0%
100.0%
100.0%
100.0%
100.0%
100.0%
100.0%
100.0%
99.9%
99.2%
61.0%
3 " (75.0 mm)
1 1/2 " (37.5 mm)
3/4 " (19.0 mm)
3/8 " (9.5 mm)
4 (4.75 mm)
8 (2.36 mm)
16 (1.18 mm)
30 (0.60 mm)
50 (0.30 mm)
100 (0.15 mm)
200 (0.075 mm)
0:01 (0.037 mm)
0:04 (0.019 mm)
0:19 (0.009 mm)
0:60 (0.005 mm)
7:15 (0.002 mm)
25:45 (0.001 mm)
SIEVE SIZES AND HYDROMETER READ TIMES
Gradation
Total Gravel 0.0 % Total Sand 39.0 % Fines 61.0 % Cu D60 / D10 not calc Cc D30^2 / D60xD10 not calc
D60 no test D50 no test D30 no test D10 no test # 30 > Max Size > # 50

15 ft depth MW-5 McAllister Lake 9-3-2003

Total dry weight tested 1.7 lbs. ML; silt with sand.

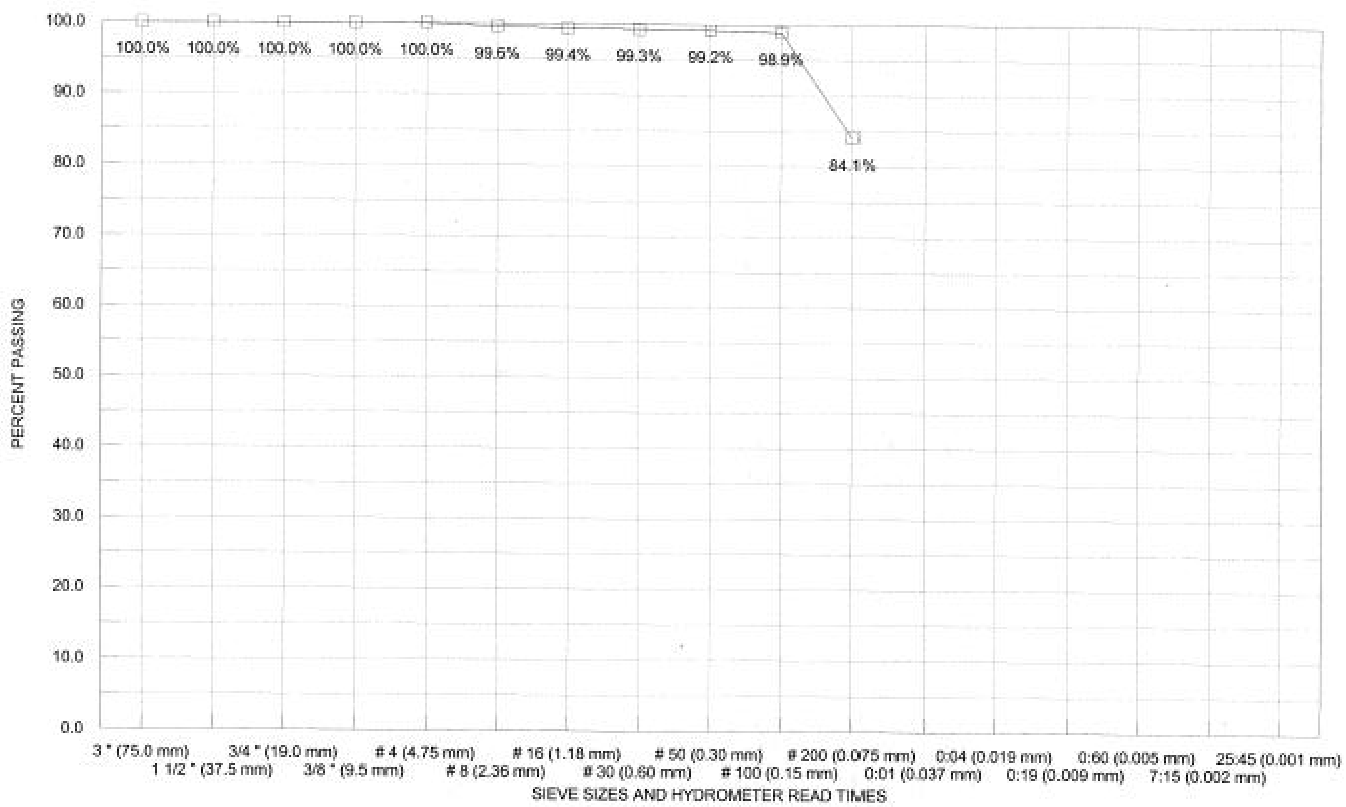


Total Gravel 0.0 % Total Sand 24.5 % Fines 75.5 % Cu D60 / D10 not calc Cc D30^2 / D60xD10 not calc

D60 no test D50 no test D30 no test D10 no test # 50 > Max Size > # 100

21 ft depth MW-5 McAllister Lake 9-3-2003

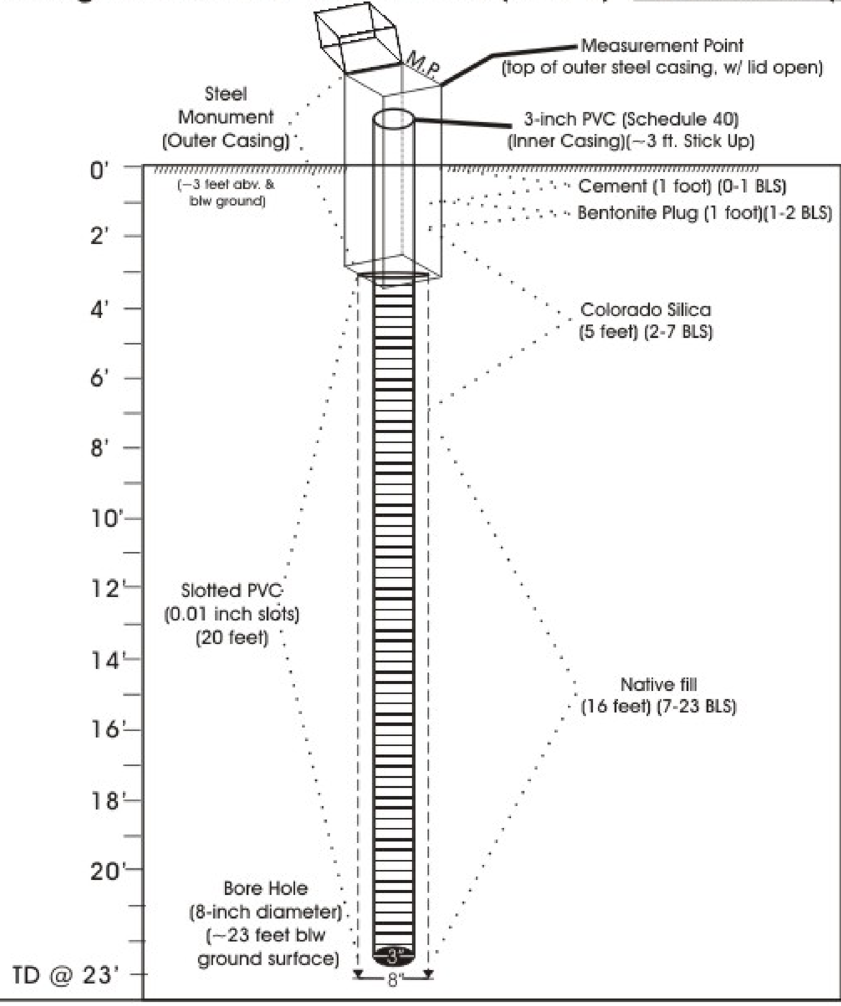
Total dry weight tested 0.9 lbs. ML; silt with sand.



Gradation

Total Gravel 0.0 % Total Sand 15.9 % Fines 84.1 % Cu D60 / D10 not calc Cc D30^2 / D60xD10 not calc
D60 no test D50 no test D30 no test D10 no test # 4 > Max Size > # 8

Well Construction Diagram: USFWS - Imperial NWR (928 783-3371)
Monitoring Well ONE B-5-22-2CCB (MW-1) <u>AS DRILLED (09/02/03)</u>



<u>McAllister Lake Razorback Refugia Project</u> USFWS Personnel: J. Broska, A. Hautzinger
<u>I-NWR Monitoring Well ONE (MW-1)</u>(aka N. Firebreak) Installation Date: 9/2/2003 (13:00 - 14:00)
Drilling Crew: USBOR-YAO (Ronnie Torres - Crew Leader); Nathan Lenon (USBR Project Lead)
All depths in feet below land surface (BLS). Sediment samples taken directly from auger at approximate depths according to drillers at 2, 8, 15 and 23 feet BLS. Groundwater encountered at 1-2 feet BLS.

<u>Description of Sediments Encountered</u>:

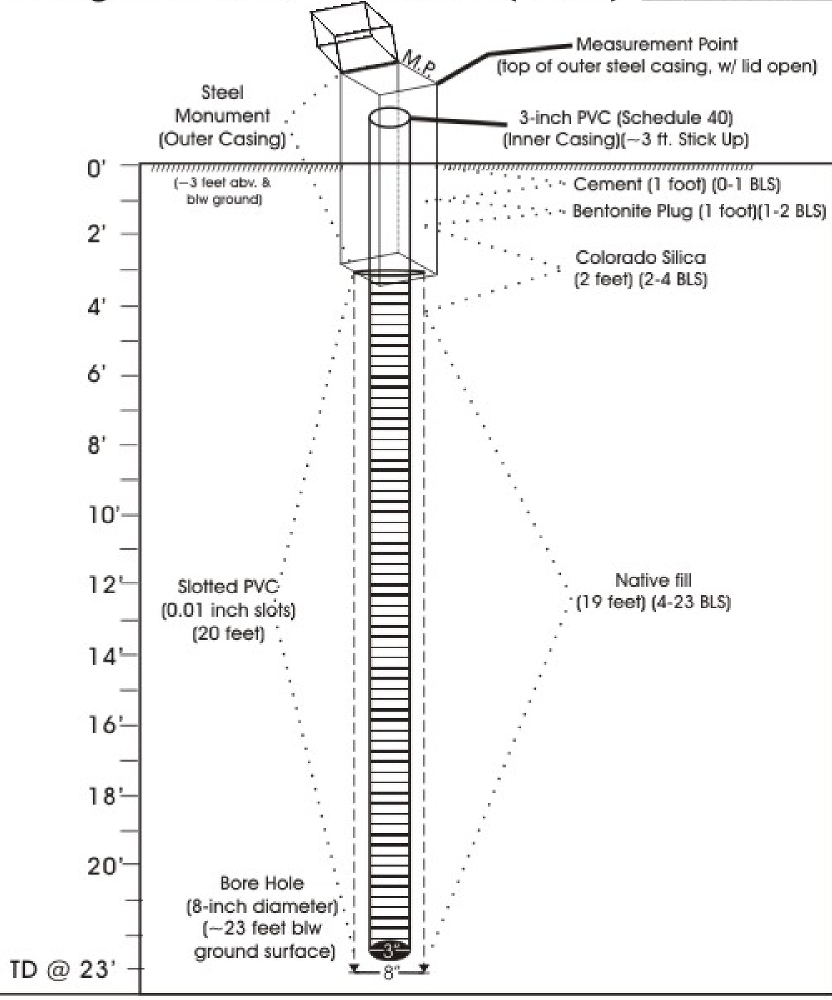
0-2'	Very fine sand; grayish-brown color; wet-forms ball; some organics present; silty
2'-8'	Same as above; some light brown mottling in color; no organics
8'-15'	Same as above; well sorted very fine sands; very silty
15'-23'	Same as above

<u>Final Well Specifications</u>: (3-inch schedule 40 PVC)

Total Depth	23 feet BLS
Screened interval	3 to 23 feet BLS (0.01" slots)
Sand Pack	2 to 7 feet BLS
Bentonite	1 to 2 feet BLS
Cement	0 to 1 feet BLS
Steel Monument	above & below land surface ~3 feet

<u>MW-1 Location Details</u>: (coordinates from FWS' RTK GPS Survey done Nov-2003) **<u>ADWR No. 55-599945</u>**
Township 5 S., Range 22 W., Section 2, SW¼SW¼NW¼ (USGS Naming Designation: B-5-22-2CCB)
Latitude: 33° 01' 15.6" N; Latitude: 114° 30' 25.0" W
Measurement Point Elevation: 189.18 (reference is top of outer steel casing (with lid open))

Well Construction Diagram: USFWS - Imperial NWR (928 783-3371)
Monitoring Well TWO B-5-22-2ABC (MW-2) AS DRILLED (09/03/03)



McAllister Lake Razorback Refugia Project USFWS Personnel: J. Broska, A. Hautzinger
I-NWR Monitoring Well TWO (MW-2)(aka: Old Channel) Installation Date: 9/3/2003 (13:10 - 14:30)
Drilling Crew: USBOR-YAO (Ronnie Torres - Crew Leader); Nathan Lenon (USBR Project Lead)
All depths in feet below land surface (BLS). Sediment samples taken directly from auger at approximate depths according to drillers at 2, 8, 15, 22 and 23 feet BLS. Groundwater encountered at 2-3 feet BLS.

Description of Sediments Encountered:

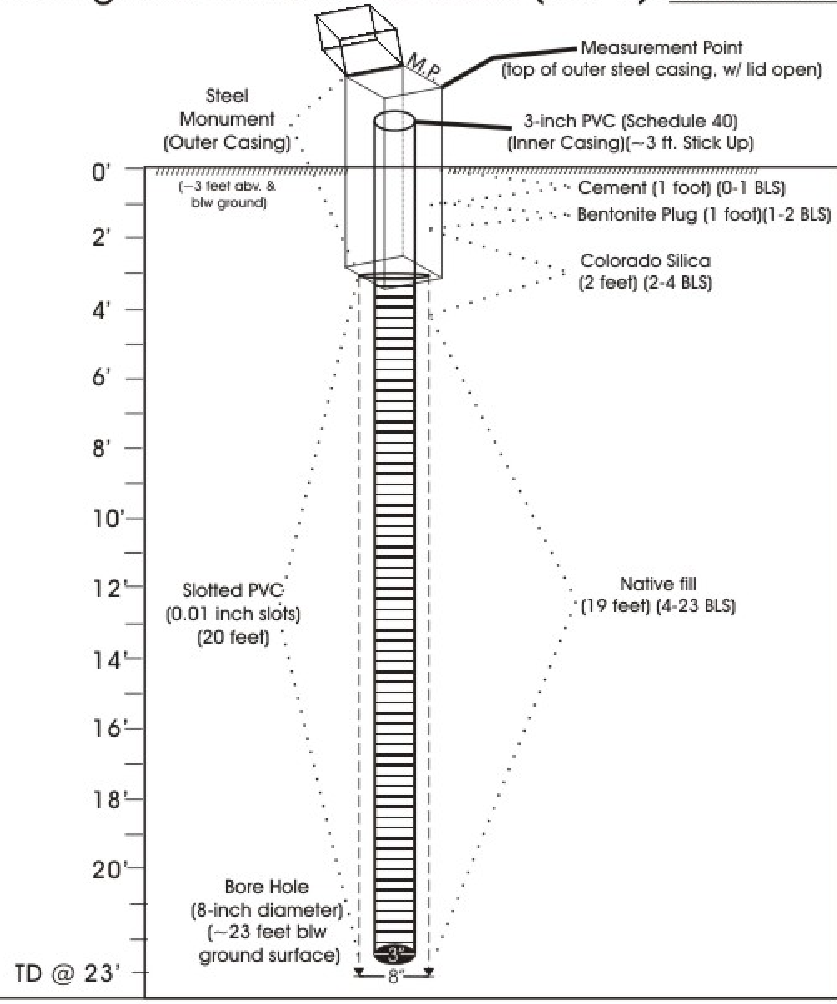
0-3'	Fine sand; brown color; moist-forms ball;
3'-8'	Very fine sand; silty; dark grey; wet-forms ball
8'-15'	Same as above; well sorted very fine sands; very silty
15'-23'	Same as above
23'	Clay; grey; wet; sticky

MW-2 Final Well Specifications: (3-inch schedule 40 PVC)

Total Depth	23 feet BLS
Screened interval	3 to 23 feet BLS (0.01" slots)
Sand Pack	2 to 4 feet BLS
Bentonite	1 to 2 feet BLS
Cement	0 to 1 feet BLS
Steel Monument	above & below land surface ~3 feet

MW-2 Location Details: (coordinates from FWS' RTK GPS Survey done Nov-2003) **ADWR No. 55-599946**
Township 5 S., Range 22 W., Section 2, NE¼NW¼SW¼ (USGS Naming Designation: B-5-22-2ABC)
Latitude: 33° 01' 12.7" N; Latitude: 114° 30' 14.6" W;
Measurement Point Elevation: 188.21 (reference is top of outer steel casing (with lid open))

Well Construction Diagram: USFWS - Imperial NWR (928 783-3371)
Monitoring Well THREE B-5-22-2DBC (MW-3) AS DRILLED (09/03/03)



McAllister Lake Razorback Refugia Project USFWS Personnel: J. Broska, A. Hautzinger
I-NWR Monitoring Well THREE (MW-3)(aka: Mid-Firebreak)
Drill Start: 9/2/2003 (15:00); Date Finish: 9/3/2003 (08:45)
Drilling Crew: USBOR-YAO (Ronnie Torres - Crew Leader); Nathan Lenon (USBR Project Lead)
All depths in feet below land surface (BLS). Sediment samples taken directly from auger at approximate depths according to drillers at 2, 8, 15, 22 and 23 feet BLS. Groundwater encountered at ~2 feet BLS.

Description of Sediments Encountered:

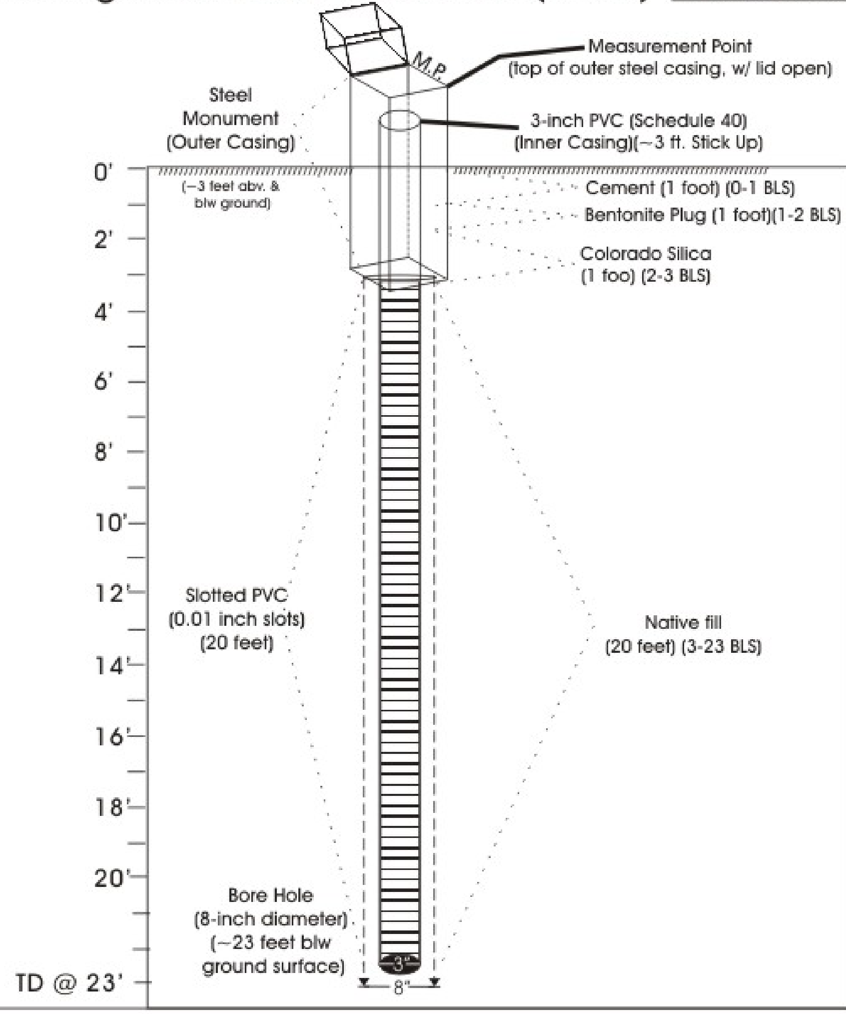
0-2'	Very fine sand; grayish-brown color; mottled; wet-forms ball; silty
2'-8'	Same as above; uniform grayish-brown color
8'-15'	Same as above; finer sand; silty
15'-23'	Same as above

Final Well Specifications: (3-inch schedule 40 PVC)

Total Depth	23 feet BLS
Screened interval	3 to 23 feet BLS
Sand Pack	2 to 4 feet BLS
Bentonite	1 to 2 feet BLS
Cement	0 to 1 feet BLS
Steel Monument	above & below land surface ~3 feet

MW-3 Location Details: (coordinates from FWS' RTK GPS Survey done Nov-2003) **ADWR No. 55-599947**
Township 5 S., Range 22 W., Section 2, SE¼NW¼SW¼ (USGS Naming Designation: B-5-22-2DBC)
Latitude: 33° 01' 06.1" N; Latitude: 114° 30' 17.2" W;
Measurement Point Elevation: 188.19 (reference is top of outer steel casing (with lid open))

Well Construction Diagram: USFWS - Imperial NWR (928 783-3371)
Monitoring Well FOUR B-5-22-2BDC (MW-4) <u>AS DRILLED (09/03/03)</u>



<u>McAllister Lake Razorback Refugia Project</u> USFWS Personnel: J. Broska, A. Hautzinger
<u>I-NWR Monitoring Well FOUR (MW-4)(aka: W. of McAllister)</u>
Installation Date: 9/3/2003 (09:45 - 11:00)
Drilling Crew: USBOR-YAO (Ronnie Torres - Crew Leader); Nathan Lenon (USBR Project Lead)
All depths in feet below land surface (BLS). Sediment samples taken directly from auger at approximate depths according to drillers at 2, 8, 15, 22 and 23 feet BLS. Groundwater encountered at 2-3 feet BLS.

<u>Description of Sediments Encountered (MW-4)</u>:

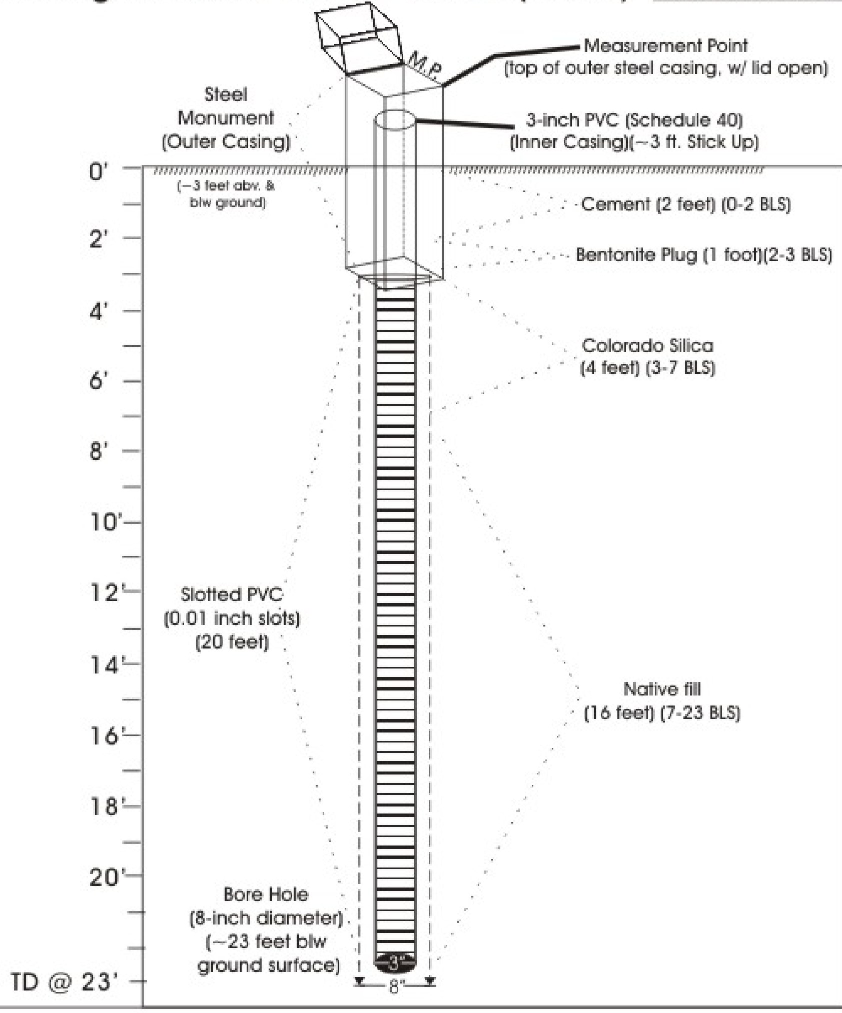
0-3'	Fine sand; brown color; silty
3'-8'	Very fine sand; some light brown mottling in color; very silty
8'-15'	Same as above; lighter grey color
15'-23'	Same as above; brownish grey color

<u>MW-4 Final Well Specifications</u>: (3-inch schedule 40 PVC)

Total Depth	23 feet BLS
Screened interval	3 to 23 feet BLS
Sand Pack	2 to 3 feet BLS
Bentonite	1 to 2 feet BLS
Cement	0 to 1 feet BLS
Steel Monument	above & below land surface ~3 feet

<u>MW-4 Location Details</u>: (coordinates from FWS' RTK GPS Survey done Nov-2003) **<u>ADWR No. 55-599948</u>**
Township 5 S., Range 22 W., Section 2, NW¼SE¼SW¼ (USGS Naming Designation: B-5-22-2BDC)
Latitude: 33° 01' 00.4" N; Latitude: 114° 30' 10.4" W;
Measurement Point Elevation: 186.85 (reference is top of outer steel casing (with lid open))

Well Construction Diagram: USFWS - Imperial NWR (928 783-3371)
Monitoring Well FIVE B-5-22-2CDC (MW-5) <u>AS DRILLED (09/03/03)</u>



McAllister Lake Razorback Refugia Project USFWS Personnel: J. Broska, A. Hautzinger

I-NWR Monitoring Well FIVE (MW-5)(aka: S. Firebreak)

Installation Date: 9/3/2003 (11:05 - 12:00)

Drilling Crew: USBOR-YAO (Ronnie Torres - Crew Leader); Nathan Lenon (USBR Project Lead)

All depths in feet below land surface (BLS). Sediment samples taken directly from auger at approximate depths according to drillers at 2, 8, 15, 22 and 23 feet BLS. Groundwater encountered at 2-3 feet BLS.

Description of Sediments Encountered (MW-5):

0-2'	Fine sand; dark grey color; silty
2'-8'	Same as above; very fine
8'-15'	Same as above; very fine
15'-23'	Same as above; very fine

MW-5 Final Well Specifications: (3-inch schedule 40 PVC)

Total Depth	23 feet BLS
Screened interval	3 to 23 feet BLS
Sand Pack	3 to 7 feet BLS
Bentonite	2 to 3 feet BLS
Cement	0 to 2 feet BLS
Steel Monument	above & below land surface ~3 feet

MW-5 Location Details: (coordinates from FWS' RTK GPS Survey done Nov-2003) **ADWR No. 55-599949**

Township 5 S., Range 22 W., Section 2, SW¼SE¼SW¼ (USGS Naming Designation: B-5-22-2CDC)

Latitude: 33° 00' 48.3" N; Latitude: 114° 30' 07.2" W;

Measurement Point Elevation: 189.04 (reference is top of outer steel casing (with lid open))

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APPENDIX B. Additional Laboratory Analyses

YUMA DESALTING PLANT LABORATORY DATA ANALYSIS

Date Sampled: 7/17/02 Date Completed: 7/18/02 Date Released:

Client: GEO Sampler: FCROXEN

Sample Time: :

Comments/Notes: McCallister Well (P2-5)

Order Number	Site Code	Description of SiteCode
8719	W0990	GEO-MISC

Test Name	Result	UNITS
Bicarbonate as CaCO3	239.00	mg/L
Bicarbonate	291.58	mg/L
Carbonate as CaCO3	0.00	mg/L
Carbonate	0.00	mg/L
Hydroxide as CaCO3	0.00	mg/L
Hydroxide	0.00	mg/L
Chloride	2120	mg/L
Conductivity	12400	uS/cm
Fluoride	<2.0	mg/L
Calcium as CaCO3	1172.50	mg/L
Magnesium as CaCO3	1004.50	mg/L
Total Hardness as CaCO3	2177.00	mg/L
Boron	<10.0	mg/L
Barium	<1.0	mg/L
Calcium	469	mg/L
Iron	<1.0	mg/L
Potassium	15.5	mg/L
Magnesium	245	mg/L
Manganese	0.14	mg/L
Sodium	2200	mg/L
Silicon Dioxide	29.6	mg/L
Strontium	10.5	mg/L
Ammonia as N	0.190	mg/L
Nitrate as N	<2.0	mg/L
P-Alkalinity as CaCO3	0.00	mg/L
pH	7.56	
Total Alkalinity as CaCO3	239	mg/L
PO4 as P	<2.0	mg/L
Sulfate	3910	mg/L
Sum of Anion Milliequivalents	146.00	meq
Sum of Cation Milliequivalents	139.65	meq
Total Sum (Bicarbonate Corrected)	9133.24	mg/L
Percent Difference Cation Anion	-2.22	%
Total Salt to Conductivity Ratio	0.74	
Total Salt	9251.58	mg/L
Total Sum of Major Analytes	9281.18	mg/L
Total Dissolved Solids @ 180 C	10000	mg/L

Surface- Station 3 (East)

YUMA DESALTING PLANT LABORATORY
DATA ANALYSIS

Date Sampled: 7/17/02 Date Completed: 7/22/02 Date Released:

Client: GEO Sampler: FCROXEN
Sample Time: :

Comments/Notes: McCallister #2

Order Number	Site Code	Description of SiteCode
8710	W0990	GEO-MISC

Test Name	Result	UNITS
Bicarbonate as CaCO3	231.40	mg/L
Bicarbonate	282.31	mg/L
Carbonate as CaCO3	59.60	mg/L
Carbonate	35.76	mg/L
Hydroxide as CaCO3	0.00	mg/L
Hydroxide	0.00	mg/L
Chloride	2750	mg/L
Conductivity	16200	uS/cm
Fluoride	5.5	mg/L
Calcium as CaCO3	191.50	mg/L
Magnesium as CaCO3	1373.50	mg/L
Total Hardness as CaCO3	1565.00	mg/L
Boron	<10.0	mg/L
Barium	<1.0	mg/L
Calcium	76.6	mg/L
Iron	<1.0	mg/L
Potassium	64.7	mg/L
Magnesium	335	mg/L
Manganese	<0.10	mg/L
Sodium	3430	mg/L
Silicon Dioxide	48.4	mg/L
Strontium	3.86	mg/L
Ammonia as N	<0.050	mg/L
Nitrate as N	<2.0	mg/L
P-Alkalinity as CaCO3	29.8	mg/L
pH	8.83	
Total Alkalinity as CaCO3	291	mg/L
PO4 as P	<2.0	mg/L
Sulfate	5200	mg/L
Sum of Anion Milliequivalents	191.87	meq
Sum of Cation Milliequivalents	182.24	meq
Total Sum (Bicarbonate Corrected)	12080.03	mg/L
Percent Difference Cation Anion	-2.58	%
Total Salt to Conductivity Ratio	0.75	
Total Salt	12174.87	mg/L
Total Sum of Major Analytes	12223.27	mg/L
Total Dissolved Solids @ 180 C	12700	mg/L

Mid (0.75m) Station 3 (East)

YUMA DESALTING PLANT LABORATORY
DATA ANALYSIS

Date Sampled: 7/17/02 Date Completed: 7/22/02 Date Released:

Client: GEO Sampler: FCROXEN

Sample Time: :

Comments/Notes: McCallister #3

Order Number	Site Code	Description of SiteCode
8711	W0990	GEO-MISC

Test Name	Result	UNITS
Bicarbonate as CaCO3	227.40	mg/L
Bicarbonate	277.43	mg/L
Carbonate as CaCO3	58.60	mg/L
Carbonate	35.16	mg/L
Hydroxide as CaCO3	0.00	mg/L
Hydroxide	0.00	mg/L
Chloride	2750	mg/L
Conductivity	16200	uS/cm
Fluoride	5.7	mg/L
Calcium as CaCO3	228.25	mg/L
Magnesium as CaCO3	1377.60	mg/L
Total Hardness as CaCO3	1605.85	mg/L
Boron	<10.0	mg/L
Barium	<1.0	mg/L
Calcium	91.3	mg/L
Iron	<1.0	mg/L
Potassium	64.5	mg/L
Magnesium	336	mg/L
Manganese	<0.10	mg/L
Sodium	3470	mg/L
Silicon Dioxide	48.6	mg/L
Strontium	3.87	mg/L
Ammonia as N	<0.050	mg/L
Nitrate as N	<2.0	mg/L
P-Alkalinity as CaCO3	29.3	mg/L
pH	8.82	
Total Alkalinity as CaCO3	286	mg/L
PO4 as P	<2.0	mg/L
Sulfate	5190	mg/L
Sum of Anion Milliequivalents	191.34	meq
Sum of Cation Milliequivalents	184.80	meq
Total Sum (Bicarbonate Corrected)	12122.72	mg/L
Percent Difference Cation Anion	-1.74	%
Total Salt to Conductivity Ratio	0.75	
Total Salt	12214.89	mg/L
Total Sum of Major Analytes	12263.49	mg/L
Total Dissolved Solids @ 180 C	12500	mg/L

Bottom (1.5m) station 3 (East)

YUMA DESALTING PLANT LABORATORY
DATA ANALYSIS

Date Sampled: 7/17/02 Date Completed: 7/22/02 Date Released:

Client: GEO Sampler: FCROXEN

Sample Time: :

Comments/Notes: McCallister #4

Order Number	Site Code	Description of SiteCode
8712	W0990	GEO-MISC

Test Name	Result	UNITS
Bicarbonate as CaCO3	241.00	mg/L
Bicarbonate	294.02	mg/L
Carbonate as CaCO3	53.00	mg/L
Carbonate	31.80	mg/L
Hydroxide as CaCO3	0.00	mg/L
Hydroxide	0.00	mg/L
Chloride	2750	mg/L
Conductivity	16200	uS/cm
Fluoride	5.5	mg/L
Calcium as CaCO3	203.25	mg/L
Magnesium as CaCO3	1389.90	mg/L
Total Hardness as CaCO3	1593.15	mg/L
Boron	<10.0	mg/L
Barium	<1.0	mg/L
Calcium	81.3	mg/L
Iron	<1.0	mg/L
Potassium	65.0	mg/L
Magnesium	339	mg/L
Manganese	<0.10	mg/L
Sodium	3480	mg/L
Silicon Dioxide	49.1	mg/L
Strontium	3.94	mg/L
Ammonia as N	<0.050	mg/L
Nitrate as N	<2.0	mg/L
P-Alkalinity as CaCO3	26.5	mg/L
pH	8.76	
Total Alkalinity as CaCO3	294	mg/L
PO4 as P	<2.0	mg/L
Sulfate	5200	mg/L
Sum of Anion Milliequivalents	191.72	meq
Sum of Cation Milliequivalents	184.99	meq
Total Sum (Bicarbonate Corrected)	12141.54	mg/L
Percent Difference Cation Anion	-1.79	%
Total Salt to Conductivity Ratio	0.75	
Total Salt	12241.62	mg/L
Total Sum of Major Analytes	12290.72	mg/L
Total Dissolved Solids @ 180 C	12600	mg/L

Surface station 2 (center) This later became MW

YUMA DESALTING PLANT LABORATORY
DATA ANALYSIS

Date Sampled: 7/17/02 Date Completed: 7/22/02 Date Released:

Client: GEO Sampler: FCROXEN
Sample Time: :

Comments/Notes: McCallister #5

Order Number	Site Code	Description of SiteCode
8713	W0990	GEO-MISC

Test Name	Result	UNITS
Bicarbonate as CaCO3	229.60	mg/L
Bicarbonate	280.11	mg/L
Carbonate as CaCO3	59.40	mg/L
Carbonate	35.64	mg/L
Hydroxide as CaCO3	0.00	mg/L
Hydroxide	0.00	mg/L
Chloride	2760	mg/L
Conductivity	16200	uS/cm
Fluoride	5.6	mg/L
Calcium as CaCO3	155.25	mg/L
Magnesium as CaCO3	1394.00	mg/L
Total Hardness as CaCO3	1549.25	mg/L
Boron	<10.0	mg/L
Barium	<1.0	mg/L
Calcium	62.1	mg/L
Iron	<1.0	mg/L
Potassium	65.8	mg/L
Magnesium	340	mg/L
Manganese	<0.10	mg/L
Sodium	3490	mg/L
Silicon Dioxide	48.8	mg/L
Strontium	4.01	mg/L
Ammonia as N	<0.050	mg/L
Nitrate as N	<2.0	mg/L
P-Alkalinity as CaCO3	29.7	mg/L
pH	8.83	
Total Alkalinity as CaCO3	289	mg/L
PO4 as P	<2.0	mg/L
Sulfate	5220	mg/L
Sum of Anion Milliequivalents	192.31	meq
Sum of Cation Milliequivalents	184.57	meq
Total Sum (Bicarbonate Corrected)	12160.83	mg/L
Percent Difference Cation Anion	-2.05	%
Total Salt to Conductivity Ratio	0.75	
Total Salt	12254.15	mg/L
Total Sum of Major Analytes	12302.95	mg/L
Total Dissolved Solids @ 180 C	12600	mg/L

Middle (1.0m) Station 2 (center) (ML-1)

YUMA DESALTING PLANT LABORATORY
DATA ANALYSIS

Date Sampled: 7/17/02 Date Completed: 7/22/02 Date Released:

Client: GEO Sampler: FCROXEN

Sample Time: :

Comments/Notes: McCallister #6

Order Number	Site Code	Description of SiteCode
8714	W0990	GEO-MISC

Test Name	Result	UNITS
Bicarbonate as CaCO3	229.60	mg/L
Bicarbonate	280.11	mg/L
Carbonate as CaCO3	59.40	mg/L
Carbonate	35.64	mg/L
Hydroxide as CaCO3	0.00	mg/L
Hydroxide	0.00	mg/L
Chloride	2750	mg/L
Conductivity	16300	uS/cm
Fluoride	5.6	mg/L
Calcium as CaCO3	222.75	mg/L
Magnesium as CaCO3	1377.60	mg/L
Total Hardness as CaCO3	1600.35	mg/L
Boron	<10.0	mg/L
Barium	<1.0	mg/L
Calcium	89.1	mg/L
Iron	<1.0	mg/L
Potassium	64.6	mg/L
Magnesium	336	mg/L
Manganese	<0.10	mg/L
Sodium	3440	mg/L
Silicon Dioxide	49.9	mg/L
Strontium	3.88	mg/L
Ammonia as N	0.250	mg/L
Nitrate as N	<2.0	mg/L
P-Alkalinity as CaCO3	29.7	mg/L
pH	8.83	
Total Alkalinity as CaCO3	289	mg/L
PO4 as P	<2.0	mg/L
Sulfate	5160	mg/L
Sum of Anion Milliequivalents	190.77	meq
Sum of Cation Milliequivalents	183.38	meq
Total Sum (Bicarbonate Corrected)	12063.73	mg/L
Percent Difference Cation Anion	-1.98	%
Total Salt to Conductivity Ratio	0.74	
Total Salt	12155.95	mg/L
Total Sum of Major Analytes	12205.85	mg/L
Total Dissolved Solids @ 180 C	12500	mg/L

Bottom (2.0m) Station Z (center) (ML-1)

YUMA DESALTING PLANT LABORATORY
DATA ANALYSIS

Date Sampled: 7/17/02 Date Completed: 7/22/02 Date Released:

Client: GEO Sampler: FCROXEN
Sample Time: :

Comments/Notes: McCallister #7

Order Number	Site Code	Description of SiteCode
8715	W0990	GEO-MISC

Test Name	Result	UNITS
Bicarbonate as CaCO3	258.80	mg/L
Bicarbonate	315.74	mg/L
Carbonate as CaCO3	45.20	mg/L
Carbonate	27.12	mg/L
Hydroxide as CaCO3	0.00	mg/L
Hydroxide	0.00	mg/L
Chloride	2760	mg/L
Conductivity	16200	uS/cm
Fluoride	5.8	mg/L
Calcium as CaCO3	167.00	mg/L
Magnesium as CaCO3	1406.30	mg/L
Total Hardness as CaCO3	1573.30	mg/L
Boron	<1.0	mg/L
Barium	0.12	mg/L
Calcium	66.8	mg/L
Iron	<0.10	mg/L
Potassium	66.4	mg/L
Magnesium	343	mg/L
Manganese	0.024	mg/L
Sodium	3500	mg/L
Silicon Dioxide	49.0	mg/L
Strontium	3.95	mg/L
Ammonia as N	<0.050	mg/L
Nitrate as N	<2.0	mg/L
P-Alkalinity as CaCO3	22.6	mg/L
pH	8.70	
Total Alkalinity as CaCO3	304	mg/L
PO4 as P	<2.0	mg/L
Sulfate	5250	mg/L
Sum of Anion Milliequivalents	193.52	meq
Sum of Cation Milliequivalents	185.50	meq
Total Sum (Bicarbonate Corrected)	12218.35	mg/L
Percent Difference Cation Anion	-2.12	%
Total Salt to Conductivity Ratio	0.75	
Total Salt	12329.56	mg/L
Total Sum of Major Analytes	12378.56	mg/L
Total Dissolved Solids @ 180 C	12600	mg/L

Surface Station 1 (West) This later became (ML-2)

YUMA DESALTING PLANT LABORATORY
DATA ANALYSIS

Date Sampled: 7/17/02 Date Completed: 7/22/02 Date Released:

Client: GEO Sampler: FCROXEN

Sample Time: :

Comments/Notes: McCallister #8

Order Number	Site Code	Description of SiteCode
8716	W0990	GEO-MISC

Test Name	Result	UNITS
Bicarbonate as CaCO3	243.40	mg/L
Bicarbonate	296.95	mg/L
Carbonate as CaCO3	38.60	mg/L
Carbonate	23.16	mg/L
Hydroxide as CaCO3	0.00	mg/L
Hydroxide	0.00	mg/L
Chloride	2700	mg/L
Conductivity	15900	uS/cm
Fluoride	5.5	mg/L
Calcium as CaCO3	222.75	mg/L
Magnesium as CaCO3	1385.80	mg/L
Total Hardness as CaCO3	1608.55	mg/L
Boron	<10.0	mg/L
Barium	<1.0	mg/L
Calcium	89.1	mg/L
Iron	<1.0	mg/L
Potassium	64.1	mg/L
Magnesium	338	mg/L
Manganese	0.12	mg/L
Sodium	3390	mg/L
Silicon Dioxide	51.9	mg/L
Strontium	4.02	mg/L
Ammonia as N	<0.050	mg/L
Nitrate as N	<2.0	mg/L
P-Alkalinity as CaCO3	19.3	mg/L
pH	8.65	
Total Alkalinity as CaCO3	282	mg/L
PO4 as P	<2.0	mg/L
Sulfate	5070	mg/L
Sum of Anion Milliequivalents	187.35	meq
Sum of Cation Milliequivalents	181.37	meq
Total Sum (Bicarbonate Corrected)	11873.04	mg/L
Percent Difference Cation Anion	-1.62	%
Total Salt to Conductivity Ratio	0.75	
Total Salt	11971.81	mg/L
Total Sum of Major Analytes	12023.71	mg/L
Total Dissolved Solids @ 180 C	12300	mg/L

(0.5m) Middle Station / (West) (ML2)

YUMA DESALTING PLANT LABORATORY
DATA ANALYSIS

Date Sampled: 7/17/02 Date Completed: 7/22/02 Date Released:

Client: GEO Sampler: FCROXEN
Sample Time: :

Comments/Notes: McCallister #9

Order Number	Site Code	Description of SiteCode
8717	W0990	GEO-MISC

Test Name	Result	UNITS
Bicarbonate as CaCO3	245.40	mg/L
Bicarbonate	299.39	mg/L
Carbonate as CaCO3	37.60	mg/L
Carbonate	22.56	mg/L
Hydroxide as CaCO3	0.00	mg/L
Hydroxide	0.00	mg/L
Chloride	2700	mg/L
Conductivity	15900	uS/cm
Fluoride	5.4	mg/L
Calcium as CaCO3	312.50	mg/L
Magnesium as CaCO3	1365.30	mg/L
Total Hardness as CaCO3	1677.80	mg/L
Boron	<10.0	mg/L
Barium	<1.0	mg/L
Calcium	125	mg/L
Iron	<1.0	mg/L
Potassium	62.9	mg/L
Magnesium	333	mg/L
Manganese	0.14	mg/L
Sodium	3340	mg/L
Silicon Dioxide	52.3	mg/L
Strontium	4.06	mg/L
Ammonia as N	<0.050	mg/L
Nitrate as N	<2.0	mg/L
P-Alkalinity as CaCO3	18.8	mg/L
pH	8.64	
Total Alkalinity as CaCO3	283	mg/L
PO4 as P	<2.0	mg/L
Sulfate	5070	mg/L
Sum of Anion Milliequivalents	187.39	meq
Sum of Cation Milliequivalents	180.54	meq
Total Sum (Bicarbonate Corrected)	11853.74	mg/L
Percent Difference Cation Anion	-1.86	%
Total Salt to Conductivity Ratio	0.75	
Total Salt	11953.35	mg/L
Total Sum of Major Analytes	12005.65	mg/L
Total Dissolved Solids @ 180 C	12300	mg/L

Bottom (0.8m) station 1 (West) (ML-2)

YUMA DESALTING PLANT LABORATORY
DATA ANALYSIS

Date Sampled: 7/17/02 Date Completed: 7/22/02 Date Released:

Client: GEO Sampler: FCROXEN
Sample Time: :

Comments/Notes: McCallister #10

Order Number	Site Code	Description of SiteCode
8718	W0990	GEO-MISC

Test Name	Result	UNITS
Bicarbonate as CaCO3	249.60	mg/L
Bicarbonate	304.51	mg/L
Carbonate as CaCO3	31.40	mg/L
Carbonate	18.84	mg/L
Hydroxide as CaCO3	0.00	mg/L
Hydroxide	0.00	mg/L
Chloride	2700	mg/L
Conductivity	15900	uS/cm
Fluoride	5.5	mg/L
Calcium as CaCO3	227.75	mg/L
Magnesium as CaCO3	1377.60	mg/L
Total Hardness as CaCO3	1605.35	mg/L
Boron	<10.0	mg/L
Barium	<1.0	mg/L
Calcium	91.1	mg/L
Iron	<1.0	mg/L
Potassium	64.1	mg/L
Magnesium	336	mg/L
Manganese	0.13	mg/L
Sodium	3360	mg/L
Silicon Dioxide	52.4	mg/L
Strontium	4.01	mg/L
Ammonia as N	<0.050	mg/L
Nitrate as N	<2.0	mg/L
P-Alkalinity as CaCO3	15.7	mg/L
pH	8.58	
Total Alkalinity as CaCO3	281	mg/L
PO4 as P	<2.0	mg/L
Sulfate	5080	mg/L
Sum of Anion Milliequivalents	187.59	meq
Sum of Cation Milliequivalents	179.99	meq
Total Sum (Bicarbonate Corrected)	11852.95	mg/L
Percent Difference Cation Anion	-2.07	%
Total Salt to Conductivity Ratio	0.75	
Total Salt	11955.05	mg/L
Total Sum of Major Analytes	12007.45	mg/L
Total Dissolved Solids @ 180 C	12300	mg/L

FILENAME: McAllister Pond Report 122002.xls

United States Bureau or Reclamation
Lower Colorado Regional Laboratory

Report of McAllister Pond Selenium Screening

Date Received: 12/20/02

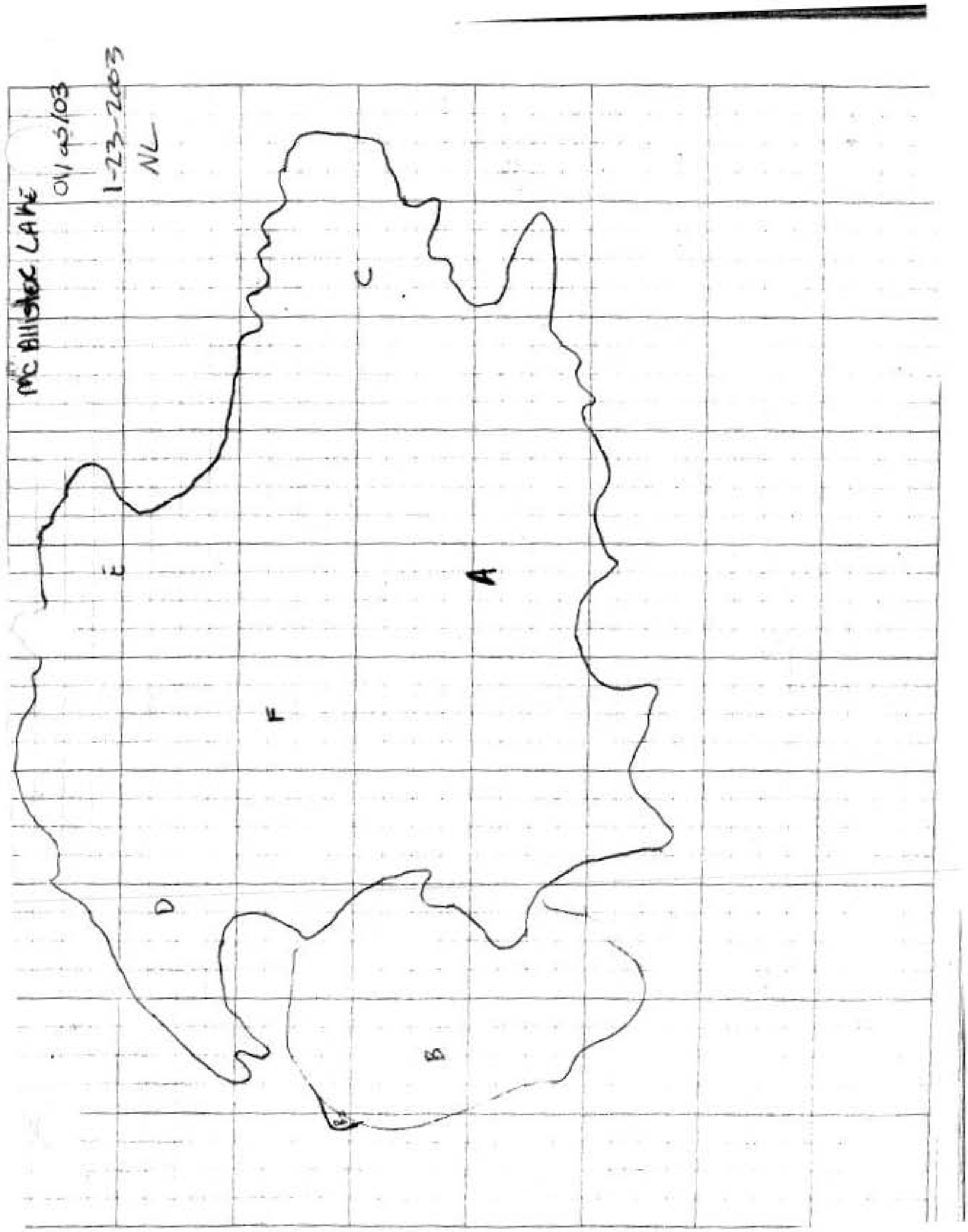
Lab No.	Station Code	Selenium µg/L
023195	1	14.69
023196	2	16.75
023197	3	11.01

"Station 1" is "ML-2"

"Station 2" is "ML-1"

"Station 3" is at East end of the lake

Reviewed By: [illegible] 1-9-2003


1-23-2003
NL
C
E
A
F
D
B

NL 1-23-2003

Sample #	Location	depth
1	A	surf
2	A	1.5 m
3	B	0
4	B	0.5 m
5	D	0
6	D	0.75 m
7	F	0
8	F	1.2 m
9	E	0
10	E	1 m
11.	C	0
12	C	1 m

Water Analysis for McAllister Lake

Laboratory Number	Station Code	Date Sampled	EC uS/cm	pH	TDS ppm	Anions in ppm CO3	HCO3	Cl	SO4	Cations in ppm Na	K	Ca	Mg	Selenium* ppb
030213	1	01/23/03	15670	8.65	11364	58.6	759.3	2462.7	4193.3	3220.0	60.0	95.0	289.5	3.93
030214	2	01/23/03	15740	8.62	11344	77.8	738.8	2422.7	4243.2	3210.0	60.5	96.5	291.5	4.05
030215	3	01/23/03	14250	8.21	10132	47.0	760.3	2212.4	4043.5	2880.0	54.5	117.5	273.0	6.09
030216	4	01/23/03	14280	8.13	10128	8.6	791.5	2172.4	4168.3	2845.0	53.0	117.0	269.5	6.29
030217	5	01/23/03	15840	8.42	11204	73.0	748.6	2392.6	4293.1	3185.0	60.0	96.0	289.5	4.31
030218	6	01/23/03	15710	8.37	11200	42.2	785.7	2372.6	4517.8	3225.0	60.0	98.0	291.0	4.62
030219	7	01/23/03	15730	8.38	11232	51.8	766.2	2372.6	4592.6	3185.0	59.5	94.5	286.5	8.93
030220	8	01/23/03	15780	8.37	11176	63.4	754.4	2392.6	4492.8	3150.0	59.0	94.5	284.5	9.96
030221	9	01/23/03	15610	8.38	11000	45.1	766.2	2392.6	4093.4	3175.0	57.5	93.0	281.5	2.19
030222	10	01/23/03	15800	8.36	11184	78.7	754.4	2392.6	3993.6	3140.0	58.5	94.0	283.5	4.43
030223	11	01/23/03	15380	8.37	10932	58.6	729.1	2312.5	4293.1	3115.0	58.0	95.0	279.0	5.68
030224	12	01/23/03	15680	8.33	11064	48.0	749.6	2392.6	4442.9	3185.0	59.5	93.5	279.0	4.07

* Selenium results are for screening purposes only.

Electrical Conductivity for McAllister Lake

Received: 2-7-03

Laboratory Number	Sample Identification	EC uS/cm
030292	McAllister	14880
030293	DU 2 Pond 1	4750
030294	Colorado River @ DU Ponds	1024

Sample taken on 2-06-03

For QA/QC

020703McAllister.xls

Reviewed By: [illegible] 2-11-2003

Water Analysis for McAllister Lake

Laboratory Number	Station Code	Date Sampled	EC uS/cm	pH	TDS ppm	Anions in ppm CO3	HCO3	Cl	SO4	Cations in ppm Na	K	Ca	Mg
030361	Channel Surface	02/11/03	5460	7.8	3644	< 1.4	791.5	665.7	1410.2	980.0	15.0	113.3	91.3
030362	Channel 0.5 M	02/11/03	5480	7.8	3676	< 1.4	781.8	670.7	1322.9	995.0	15.3	113.0	92.3
030363	Marsh Surface	02/11/03	17940	8.2	12800	< 1.4	299.6	3073.4	5341.4	3465.0	38.0	242.5	298.0
030364	Marsh 0.5 M	02/11/03	17940	8.2	12836	< 1.4	293.8	3063.4	5291.5	3410.0	38.0	247.0	300.0
030365	Hydrolab Station Surface	02/11/03	15460	8.5	10748	70.1	750.5	2382.6	4393.0	3010.0	56.0	94.0	269.0
030366	Hydrolab Station bottom	02/11/03	15550	8.5	10712	61.4	752.5	2422.7	4268.2	3025.0	56.5	94.0	270.5

"Channel" Refers to water body to the Nortwest of McAllister LAKE

"Hydrolab Station" = ML 1

"Marsh" = PZ-5 pond, to the South of McAllister Lake. Pond, not the peizometer

021403McAllister.xls

Reviewed By: [illegible]

United States Bureau of Reclamation
Lower Colorado Regional Laboratory

Actually 3/10

Water Analysis for McAllister Lake

Laboratory Number	Station Code	Date Sampled	EC uS/cm	pH	TDS ppm	Anions in ppm CO3	HCO3	Cl	SO4	Cations in ppm Na	K	Ca	Mg
030545	1	03/14/03	13740	8.3	9632	< 1.4	778.8	2182.4	3744.0	2765.0	53.0	121.5	252.5
030546	2	03/14/03	13640	8.3	9632	< 1.4	778.8	2192.4	3744.0	2815.0	53.5	117.0	254.5
030547	3	03/14/03	14300	8.5	10116	14.4	789.6	2322.6	3993.6	2990.0	55.0	100.5	261.5
030548	4	03/14/03	14370	8.4	10120	< 1.4	793.5	2352.6	3993.6	2965.0	54.5	96.5	258.0
030549	5	03/14/03	14320	8.4	10060	< 1.4	781.8	2282.5	3993.6	2955.0	54.5	86.0	259.5
030550	6	03/14/03	14380	8.4	10116	< 1.4	801.3	2242.5	4018.6	2985.0	55.0	96.0	260.0

Samples TAKEN at 7:00 AM on 3/10/03, before starting pump test #2.

031403McAllister.xls

Reviewed By: [illegible] 4-23-2003

United States Bureau of Reclamation
Lower Colorado Regional Laboratory

Water Analysis for McAllister Lake MLI

Laboratory Number	Depth (Meters)	Date Sampled	EC uS/cm	pH	TDS ppm
030813	0.5	04/23/03	8790	8.6	5912

Reviewed By: [illegible] /5-6-2003

Sampled 9-~~?~~24-03

Department of Geosciences
...ratory of Isotope Geochemistry

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U.S. Bureau of Reclamation
Nathan Lenon, LC-2457
PO Box 61470
Boulder City, NV 89006-1470

October 14, 2003

REPORT OF ANALYSES
8 water samples for d18O and dD

W number	Sample	δ18O ‰	δD ‰
16216	MW 2	-12.3	-100
16217	MW 3	-12.1	-97
16218	MW 4	-12.4	-101
16219	MW 5	-12.4	-102
16220	P2-5	-6.8	-75
16221	Colorado River CR-1	-11.6	-97
16222	MW 1	-12.4	-101
16223	McAllister Lake ML-1	0.4	-40
Analytical Precision		0.08	0.9

C. J. Eastoe
C.J.Eastoe
Staff Scientist

United States Bureau of Reclamation
Lower Colorado Regional Laboratory
Report of Water Analysis for
McAllister

Date Sampled: 9-24-03 ✓

Lab No.	Sample Identification	Trace Metals Selenium in ppb (ug/L)
032063	MW-1	< 2.0
032064	MW-2	< 2.0
032065	MW-3	< 2.0
032066	MW-4	< 2.0
032067	MW-5	< 2.0
032068	P5	< 2.0
032069	McAllister Lake	< 2.0

Reviewed By: [illegible] / [illegible]

092503McAllister.xls

United States Bureau of Reclamation
Lower Colorado Regional Laboratory
Report of Water Analysis for the
McAllister

Date Sampled: ~~14-5-03~~ 11-03-03

Lab No.	Station Code	EC (uS/cm)	pH	TDS ppm	Anions in ppm CO3	HCO3	Cl	SO4	Cations in ppm Na	K	Ca	Mg
032258	CR 1	1183	8.0	759	< 1.4	192	101	287	120	4.71	81.6	30.6
032259	ML 1	12120	8.4	8252	23.0	641	1752	2995	2430	45.5	97.5	180
032260	MW 2	1114	7.6	738	< 1.4	250	79.1	252	113	3.93	89.0	23.0
032261	MW 4	1124	7.5	706	< 1.4	318	85.1	205	119	4.08	76.4	29.1
032262	MW 7	12140	8.5	8276	33.6	632	1702	3145	2400	45.0	97.0	178
032263	PS	8700	7.6	5916	< 1.4	531	1140	2371	1685	11.2	192	93.0

Lab No.	Station Code	Minors in ppm SiO2	F	Nutrients in ppm NO3	NO3 as N	Ortho PO4	PO4 as P	Total PO4	PO4 as P	NH3	NH3 as N	Boron ***
032258	CR 1	12.0	0.42	1.06	0.24	< 0.05	< 0.03	< 0.05	< 0.03	< 0.05	< 0.04	0.21
032259	ML 1	63.2	4.52	3.18	0.72	< 0.05	< 0.03	0.26	0.08	0.29	0.24	2.96
032260	MW 2	31.3	0.37	< 0.08	< 0.06	0.13	0.04	0.34	0.11	0.73	0.60	0.13
032261	MW 4	24.2	0.47	1.76	0.40	0.08	0.03	1.21	0.39	2.54	2.09	0.13
032262	MW 7	62.6	4.42	3.36	0.76	< 0.05	< 0.03	0.28	0.09	0.39	0.32	2.90
032263	~~PS~~ PZ-5	56.8	5.16	< 0.08	< 0.06	0.16	0.05	0.38	0.12	0.21	0.17	2.58

***estimates

Lab No.	Station Code	Trace Element Results in ppb (ug/L) Aluminum	Barium ***	Arsenic	Selenium	Manganese	Iron
032258	CR 1	5.55	359	2.20	< 2.00	2.92	12.4
032259	ML 1	6.49	164	6.15	< 2.00	2.08	35.0
032260	MW 2	8.34	359	3.95	< 2.00	280	36.7
032261	MW 4	4.57	269	2.71	< 2.00	1137	10.5
032262	MW 7	10.8	164	6.89	< 2.00	2.37	80.0
032263	~~PS~~ PZ-5	11.3	165	3.79	< 2.00	894	< 1.00

*** Barium results are estimates.

"MW7" is a duplicate sample of ML1 for QA/QC

Reviewed By: [signature] 11-12-2004

FILENAME: [illegible]

SAMPLES TAKEN BEFORE Pump TEST #4

United States Bureau of Reclamation
Lower Colorado Regional Laboratory
Report of Water Analysis for the
McAllister

Date Sampled: 1-26-04

Lab No.	Station Code	EC (uS/cm)	pH	TDS ppm	Anions in ppm CO3	HCO3	Cl	SO4	Cations in ppm Na	K	Ca	Mg
040292	CR 1	1182	7.9	742	< 1.4	182	100	300	122	4.90	80.9	31.8
040293	PZ 5	17970	7.2	13484	< 1.4	351	2870	5590	3230	17.5	618	368
040294	MW 2	1129	7.8	755	< 1.4	239	85.1	250	118	4.79	89.5	23.4
040295	MW 4	1153	7.7	733	< 1.4	321	99.1	240	126	4.51	74.2	30.3
040296	ML 1	5370	8.5	3451	43.2	431	661	1300	1040	18.3	66.8	70.8
040297	ML 2	5420	8.5	3492	42.2	426	736	1370	1030	18.5	71.8	71.8

Lab No.	Station Code	Minors in ppm SiO2	F	Nutrients in ppm NO3	NO3 as N	Ortho PO4	PO4 as P	Total PO4	PO4 as P	NH3	NH3 as N	Boron ***
040292	CR 1	10.2	0.41	1.79	0.40	0.017	0.006	0.03	0.01	< 0.05	< 0.04	0.1
040293	PZ 5	28.7	2.97	0.98	0.22	0.018	0.006	2.99	0.98	0.15	0.12	5.8
040294	MW 2	21.7	0.36	1.09	0.25	0.066	0.022	1.09	0.36	0.90	0.74	0.3
040295	MW 4	29.8	0.42	1.76	0.40	0.07	0.02	1.29	0.42	2.74	2.25	1.0
040296	ML 1	23.7	2.92	3.78	0.85	0.054	0.018	0.42	0.14	< 0.05	< 0.04	1.3
040297	ML 2	26.2	2.93	3.30	0.74	0.025	0.008	0.42	0.14	< 0.05	< 0.04	1.3

***estimates

Lab No.	Station Code	Trace Element Results in ppb (ug/L) Aluminum ***	Barium	Arsenic	Selenium	Manganese	Iron
040292	CR 1	28600	< 100	3.35	< 1.50	2.09	< 1.0
040293	PZ 5	26.0	584	< 1.50	< 1.50	2140	105
040294	MW 2	3380	518	4.59	< 1.50	305	8.16
040295	MW 4	55.6	562	4.51	< 1.50	1240	1010
040296	ML 1	1440	445	2.96	< 1.50	4.19	27.6
040297	ML 2	11.5	301	3.26	< 1.50	3.13	46.6

*** Results are estimates.

United States Bureau of Reclamation
Lower Colorado Regional Laboratory
Report of Water Analysis for the
McAllister

Date Sampled: 1-26-04 ✓

Lab No.	Station Code	EC (uS/cm)	pH	TDS ppm	Anions in ppm CO3	HCO3	Cl	SO4	Cations in ppm Na	K	Ca	Mg
040292	CR 1	1182	7.9	742	< 1.4	182	100	300	122	4.90	80.9	31.8
040293	PZ 5	17970	7.2	13484	< 1.4	351	2870	5590	3230	17.5	618	368
040294	MW 2	1129	7.8	755	< 1.4	239	85.1	250	118	4.79	89.5	23.4
040295	MW 4	1153	7.7	733	< 1.4	321	99.1	240	126	4.51	74.2	30.3
040296	ML 1	5370	8.5	3451	43.2	431	661	1300	1040	18.3	66.8	70.8
040297	ML 2	5420	8.5	3492	42.2	426	736	1370	1030	18.5	71.8	71.8

Lab No.	Station Code	Minors in ppm SiO2	F	Nutrients in ppm NO3	NO3 as N	Ortho PO4	PO4 as P	Total PO4	PO4 as P	NH3	NH3 as N	Boron ***
040292	CR 1	10.2	0.41	1.79	0.40	0.017	0.006	0.03	0.01	< 0.05	< 0.04	0.1
040293	PZ 5	28.7	2.97	0.98	0.22	0.018	0.006	2.99	0.98	0.15	0.12	5.8
040294	MW 2	21.7	0.36	1.09	0.25	0.066	0.022	1.09	0.36	0.90	0.74	0.3
040295	MW 4	29.8	0.42	1.76	0.40	0.07	0.02	1.29	0.42	2.74	2.25	1.0
040296	ML 1	23.7	2.92	3.78	0.85	0.054	0.018	0.42	0.14	< 0.05	< 0.04	1.3
040297	ML 2	26.2	2.93	3.30	0.74	0.025	0.008	0.42	0.14	< 0.05	< 0.04	1.3

***estimates

Lab No.	Station Code	Trace Element Results in ppb (ug/L) Aluminum ***	Barium	Arsenic	Selenium	Manganese	Iron
040292	CR 1	28600	< 100	3.35	< 1.50	2.09	< 1.0
040293	PZ 5	26.0	584	< 1.50	< 1.50	2140	105
040294	MW 2	3380	518	4.59	< 1.50	305	8.16
040295	MW 4	55.6	562	4.51	< 1.50	1240	1010
040296	ML 1	1440	445	2.96	< 1.50	4.19	27.6
040297	ML 2	11.5	301	3.26	< 1.50	3.13	46.6

*** Results are estimates.

Filename: 030304McAllister.xls

SAMPLES WERE TAKEN BEFORE PUMP TESTS

United States Bureau of Reclamation
Lower Colorado Regional Laboratory
Report of Water Analysis for the
McAllister

Date Sampled: ~~3-3-04~~ 3-02-04

Lab No.	Station Code	EC (uS/cm)	pH	TDS ppm	Anions in ppm CO3	HCO3	Cl	SO4	Cations in ppm Na	K	Ca	Mg
040469	CR 1	1154	8.0	759	< 1.4	189	103	284	117	4.84	83.1	31.4
040470	MW 2	1110	7.9	720	< 1.4	248	88.1	222	114	4.22	83.0	24.2
040471	MW 4	1171	7.7	734	< 1.4	321	102	222	121	3.81	73.3	31.6
040472	ML 1	4360	8.2	2792	< 1.4	428	581	1120	808	14.0	72.5	57.3
040473	ML 7	17390	7.5	12820	< 1.4	346	2770	5240	3300	18.0	486	342
040474	PZ 5	17410	7.4	12968	< 1.4	346	2850	5490	3280	18.0	495	347

Lab No.	Station Code	Minors in ppm SiO2	F	Nutrients in ppm NO3	NO3 as N	Ortho PO4	PO4 as P	Total PO4	PO4 as P	NH3	NH3 as N	Boron ***
040469	CR 1	8.9	0.38	1.83	0.41	0.006	0.002	0.07	0.02	< 0.05	< 0.04	0.20
040470	MW 2	24.6	0.33	3.05	0.69	0.032	0.010	0.46	0.15	0.76	0.63	0.43
040471	MW 4	26.5	0.38	0.96	0.22	0.073	0.024	0.25	0.08	3.09	2.54	0.31
040472	ML 1	27.8	2.58	0.86	0.19	0.013	0.004	0.37	0.12	< 0.05	< 0.04	1.11
040473	ML 7	18.8	2.95	2.08	0.47	0.007	0.002	0.09	0.03	0.08	0.07	6.30
040474	PZ 5	18.2	3.22	2.18	0.49	0.008	0.003	0.07	0.02	0.08	0.07	6.44

***estimates

Lab No.	Station Code	Trace Element Results in ppb (ug/L) Aluminum ***	Barium	Arsenic	Selenium	Manganese	Iron
040469	CR 1	767	499	3.25	3.40	1.83	< 1.00
040470	MW 2	704	455	4.12	< 1.50	387	3.87
040471	MW 4	1880	826	4.50	< 1.50	285	1.70
040472	ML 1	1560	327	4.02	< 1.50	6.22	12.3
040473	ML 7	2730	404	< 1.50	< 1.50	1750	22.9
040474	PZ 5	716	496	< 1.50	< 1.50	1450	3.01

*** Results are estimates.

"ML 7" is a duplicate of PZ-5 for QA/QC

Sampled September 2, 2003

Algae 1
Chlorophyll *a*: 7.737 mg/m³
Pheophytin *a*: 5.439 mg/m³
** chl a:pheo a ratio may be unnaturally high due to non-preservation of sample*

Algae Count & ID

Division	Genus	Units/mL	% of Total
Chlorophyta	Chlorella	5,512	41.5
Pyrrophyta	Glenodinium	3,045	22.9
Chrysophyta	Fragilaria	1166	8.8
Cyanophyta	Lyngbya	1,030	7.8
Cyanophyta	Chroococcus	857	6.4
Chrysophyta	Chaetoceros	584	4.4
Cyanophyta	Merismopedia	328	2.5
Chlorophyta	Haematococcus	311	2.3
Cyanophyta	Arthrospira	297	2.2
Chlorophyta	Thoracomonas	115	0.9
Cyanophyta	Trichodesmium	43	0.3

Total units/mL: 13,288

Algae 2
Chlorophyll *a*: 8.703 mg/m³
Pheophytin *a*: 5.815 mg/m³
** chl a:pheo a ratio may be unnaturally high due to non-preservation of sample*

Algae Count & ID

Division	Genus	Units/mL	% of Total
Chlorophyta	Chlorella	5,628	40.9
Pyrrophyta	Glenodinium	2,657	19.3
Cyanophyta	Lyngbya	1384	10.1
Cyanophyta	Chroococcus	1218	8.8
Chrysophyta	Fragilaria	891	6.5
Cyanophyta	Merismopedia	509	3.7
Chrysophyta	Chaetoceros	390	2.8
Cyanophyta	Arthrospira	372	2.7
Chlorophyta	Haematococcus	343	2.5
Chlorophyta	Thoracomonas	188	1.4
Chrysophyta	Amphiprora	93	0.7
Chrysophyta	Cymbella	80	0.6

Total units/mL: 13,753

Dr. David Walker
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Phone: 520-626-2386
email: dwalker@ag.arizona.edu

FILENAME: McAllister Algae 070804.doc

Algae Counts and Identification from Samples ML1 and ML2
Collected on 07/08/04

ML1

Division	Genus	Units/mL	% of Total
Chlorophyta	Chlorococcum	3073	41.7
Chrysophyta	Nitzchia	1314	17.8
Cyanophyta	Gloeocystis	720	9.8
Chrysophyta	Nitzchia	488	6.6
Cyanophyta	Oscillatoria	362	4.9
Chrysophyta	Fragilaria	351	4.8
Chrysophyta	Gomphoneis	327	4.4
Chrysophyta	Pinnularia	305	4.1
Chlorophyta	Chodatella	264	3.6
Cyanophyta	Anabaenopsis	73	1.0
Cyanophyta	Anabaena	59	0.7
Cyanophyta	Arthrospira	25	0.3

Total units/mL: 7361

Chlorophyll *a*: 4.642 mg/m^3
Pheophytin *a*: 1.218 mg/m^3

ML2

Division	Genus	Units/mL	% of Total
Chlorophyta	Chlorococcum	3673	41.3
Cyanophyta	Anabaenopsis	2393	27.0
Chrysophyta	Nitzchia	835	9.4
Cyanophyta	Oscillatoria	712	8.0
Cyanophyta	Gloeocystis	425	4.8
Cyanophyta	Microcystis	282	3.2
Chrysophyta	Navicula	260	2.9
Cyanophyta	Anabaena	111	1.2
Chlorophyta	Coelastrum	83	0.9
Euglenophyta	Trachelomonas	49	0.5
Euglenophyta	Euglena	31	0.3
Chrysophyta	Gomphoneis	25	0.3

Total units/mL: 8879

Chlorophyll *a*: 5.743
Pheophytin *a*: 1.640

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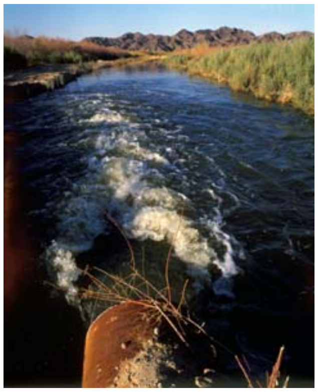
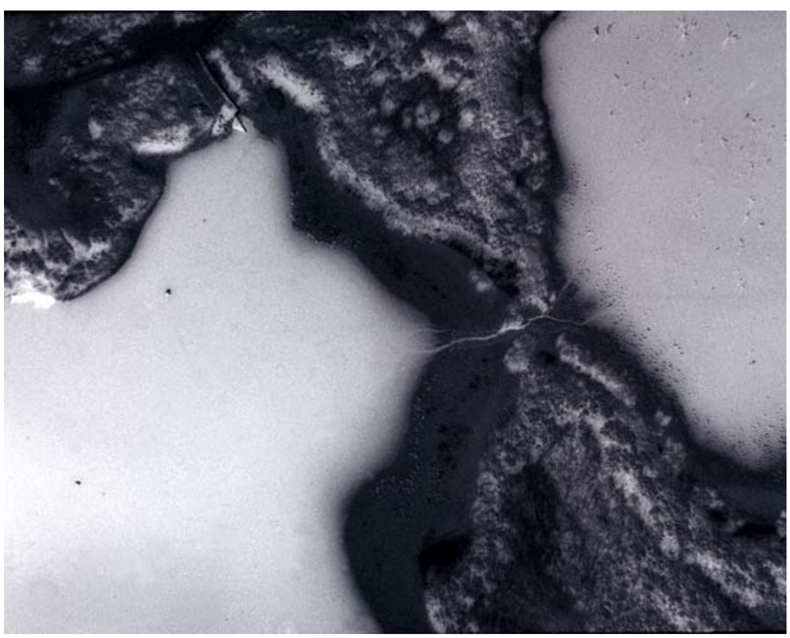
Appendix C: Additional Photographs & Figures

Above: Tractor-driven Crisafulli pump and 24-inch pipeline used for conveying lake water to discharge location. Below: 24-inch pipeline and discharge into drainage ditch.



Above: McAllister Lake following the first 3-foot drawdown, March 2003

The photos below were taken with infrared film following the second 3-foot drawdown, November 2003. At elevations below 181 ft, the two basins of McAllister Lake become isolated. The isolation and reduced circulation between basins is believed to be responsible for the differences observed in water quality, clarity, and color.



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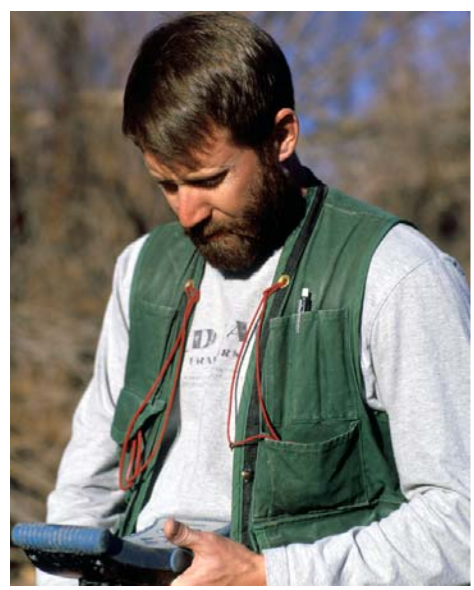
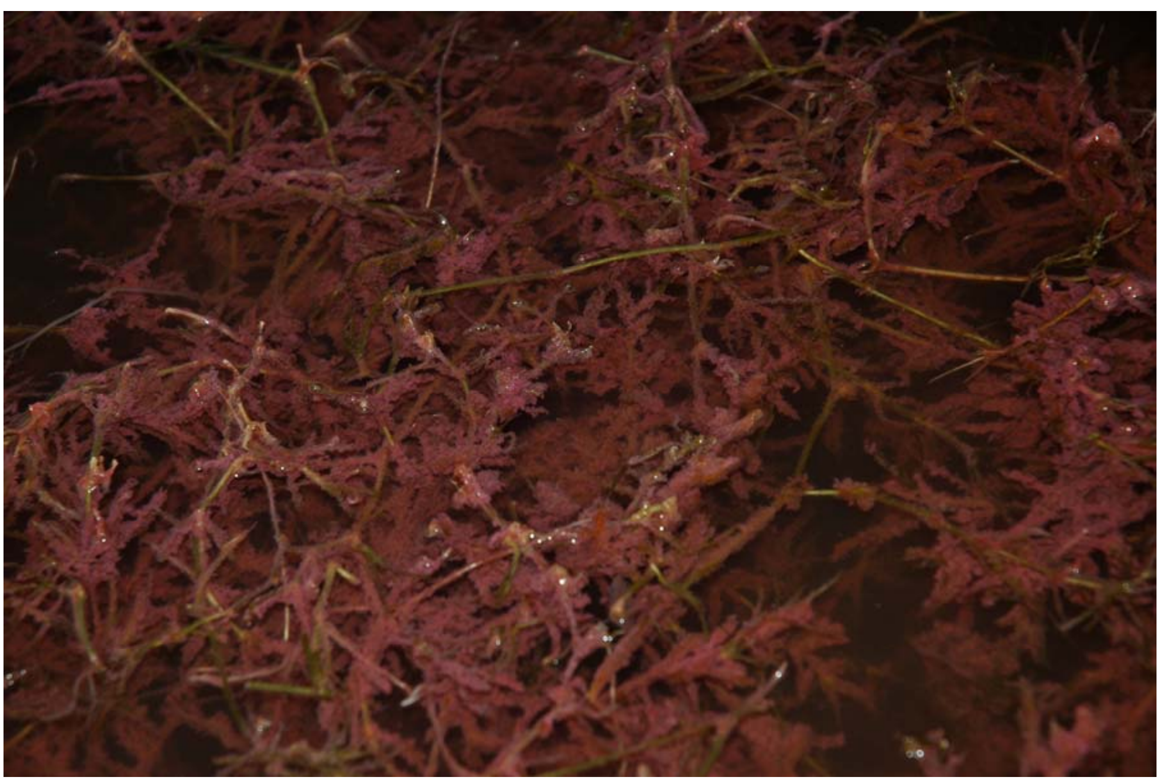
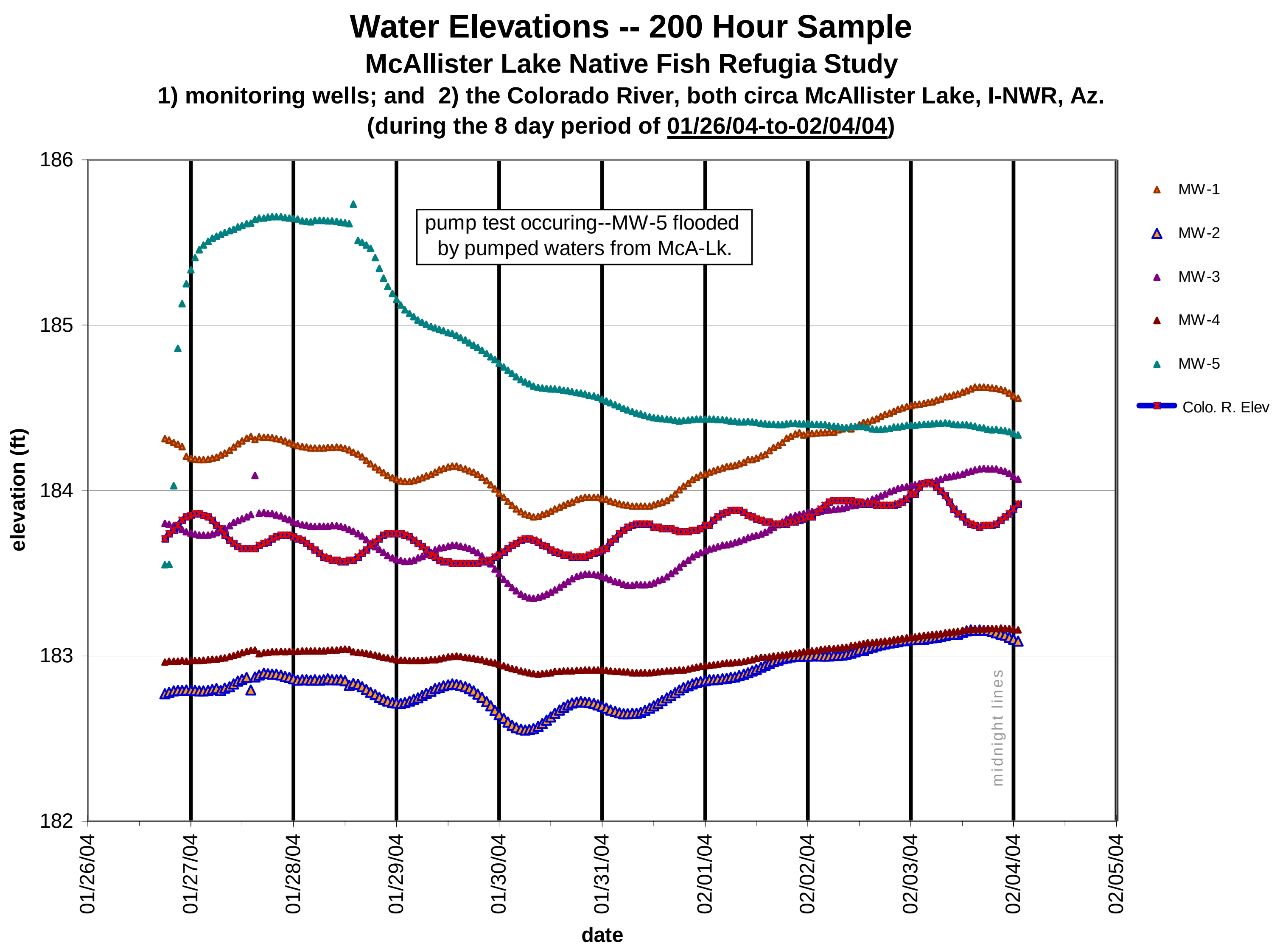
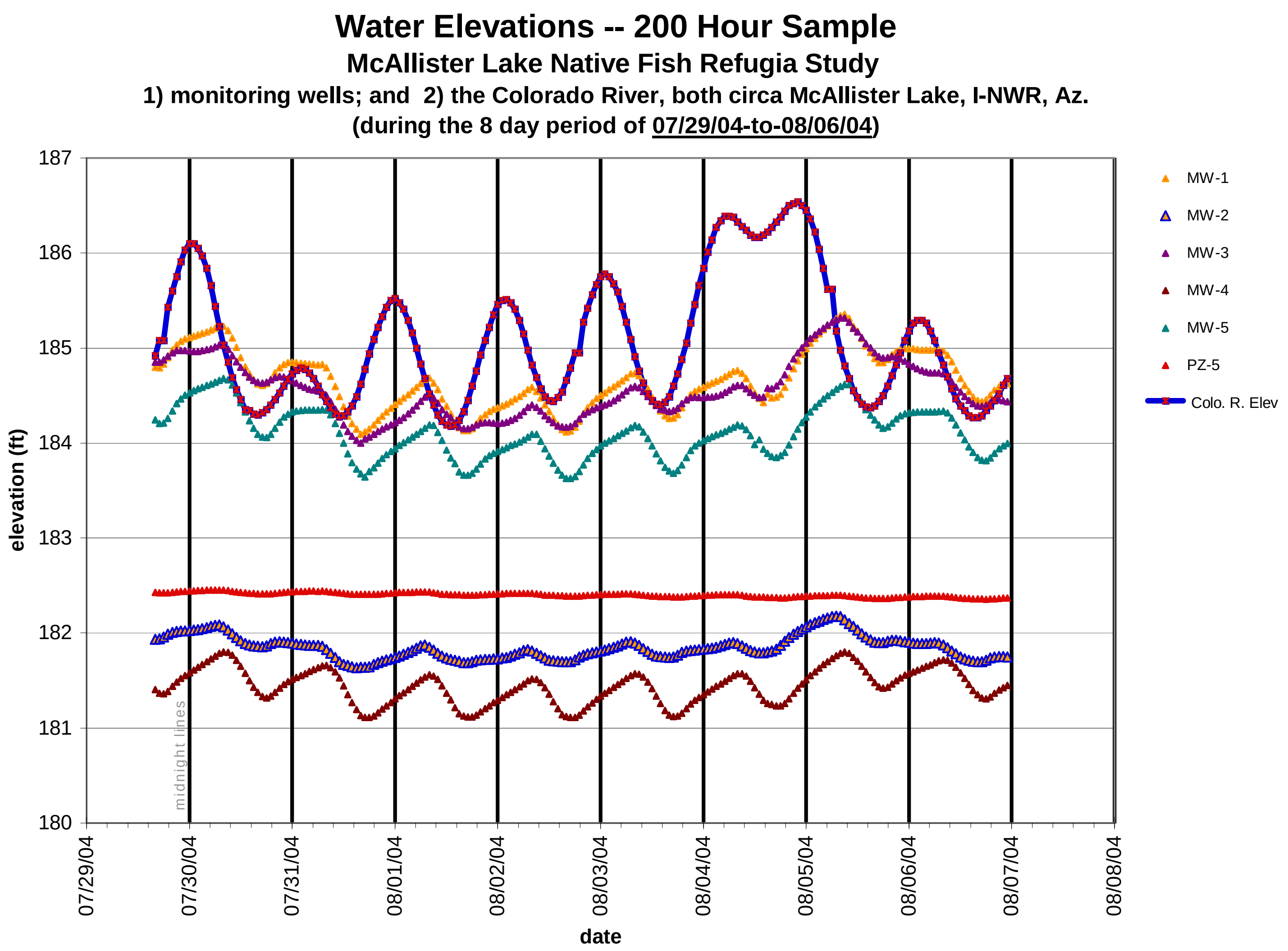
Above: Deploying Hydrolab Datasonde© in McAllister Lake at the monitoring station known as ML-1. Below: Collecting water quality and water level data from monitoring wells using Minitroll© pressure transducers and Hydrolab MiniSonde©.



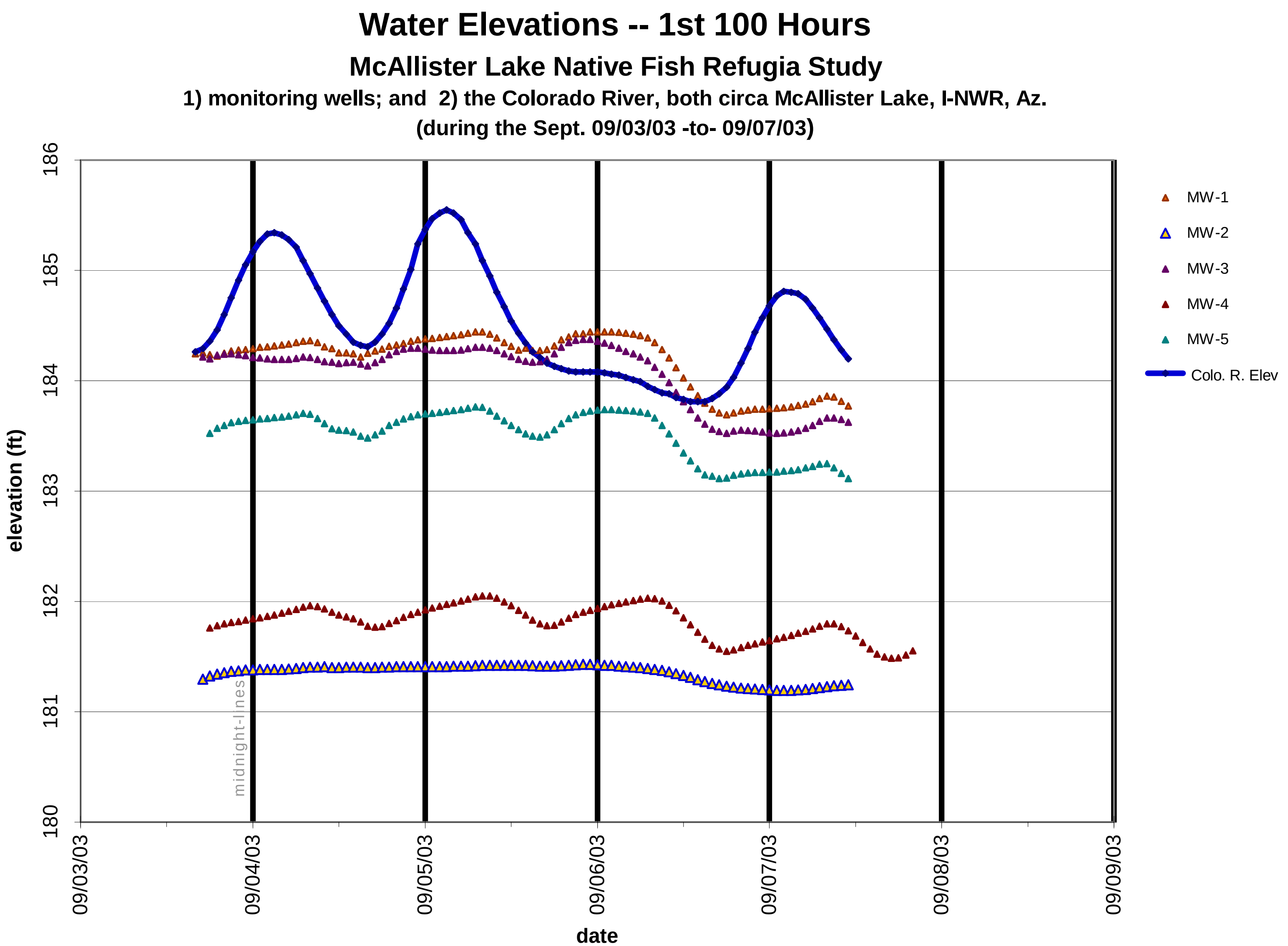
Above: Windmill aerator-circulators, in relation to the ML-2 Monitoring station. Below: abundant mats of submerged aquatic macrophytes, spiny naiad, colored pink with decomposing cyanobacteria, 18 months following the fourth, and final 3-foot draw-down, September 2005.

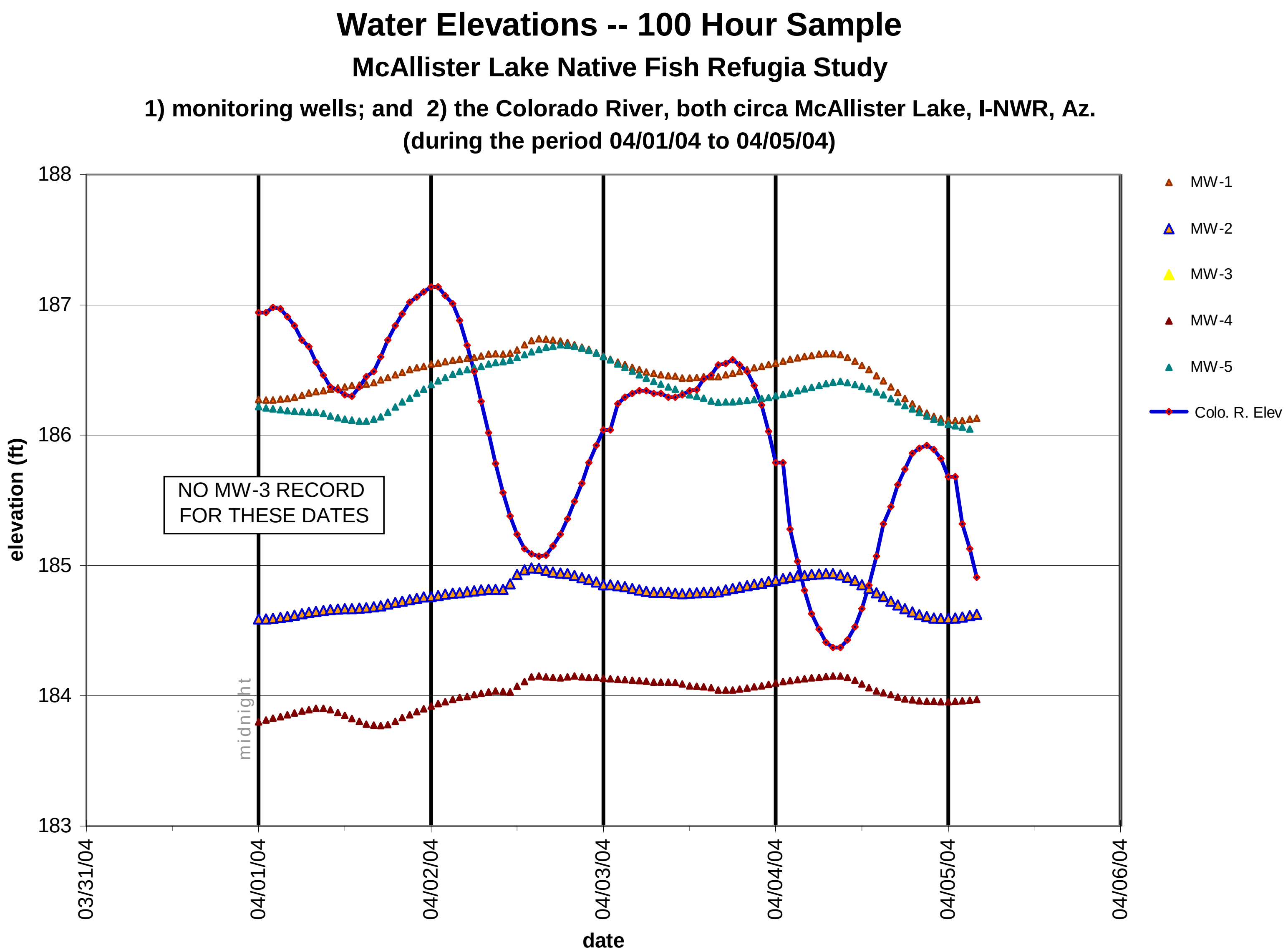


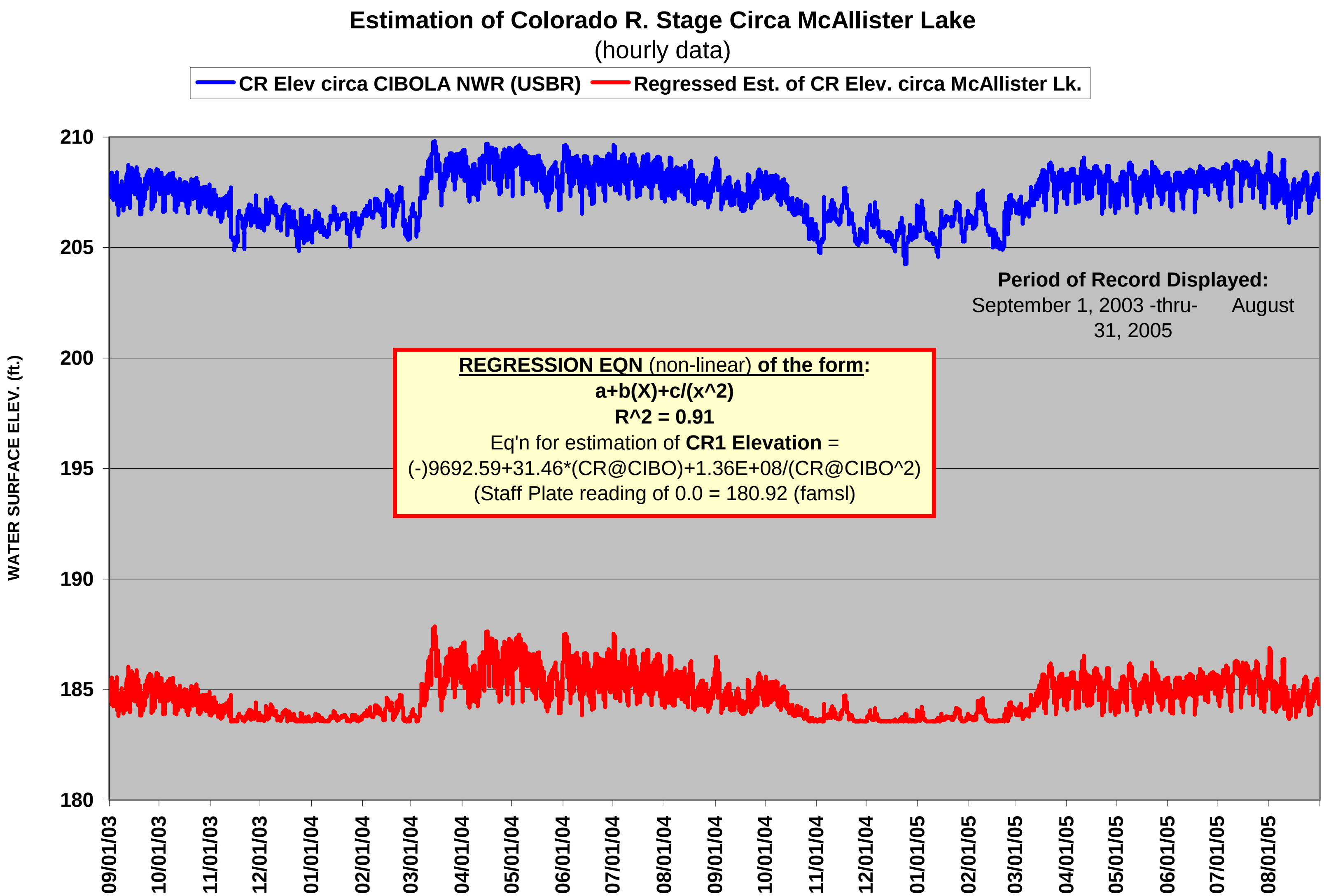

Water Elevations -- 200 Hour Sample
McAllister Lake Native Fish Refugia Study
1) monitoring wells; and 2) the Colorado River, both circa McAllister Lake, I-NWR, Az.
(during the 8 day period of 01/26/04-to-02/04/04)
pump test occuring--MW-5 flooded by pumped waters from McA-Lk.
elevation (ft)
186
185
184
183
182
date
01/26/04
01/27/04
01/28/04
01/29/04
01/30/04
01/31/04
02/01/04
02/02/04
02/03/04
02/04/04
02/05/04
midnight lines
MW-1
MW-2
MW-3
MW-4
MW-5
Colo. R. Elev

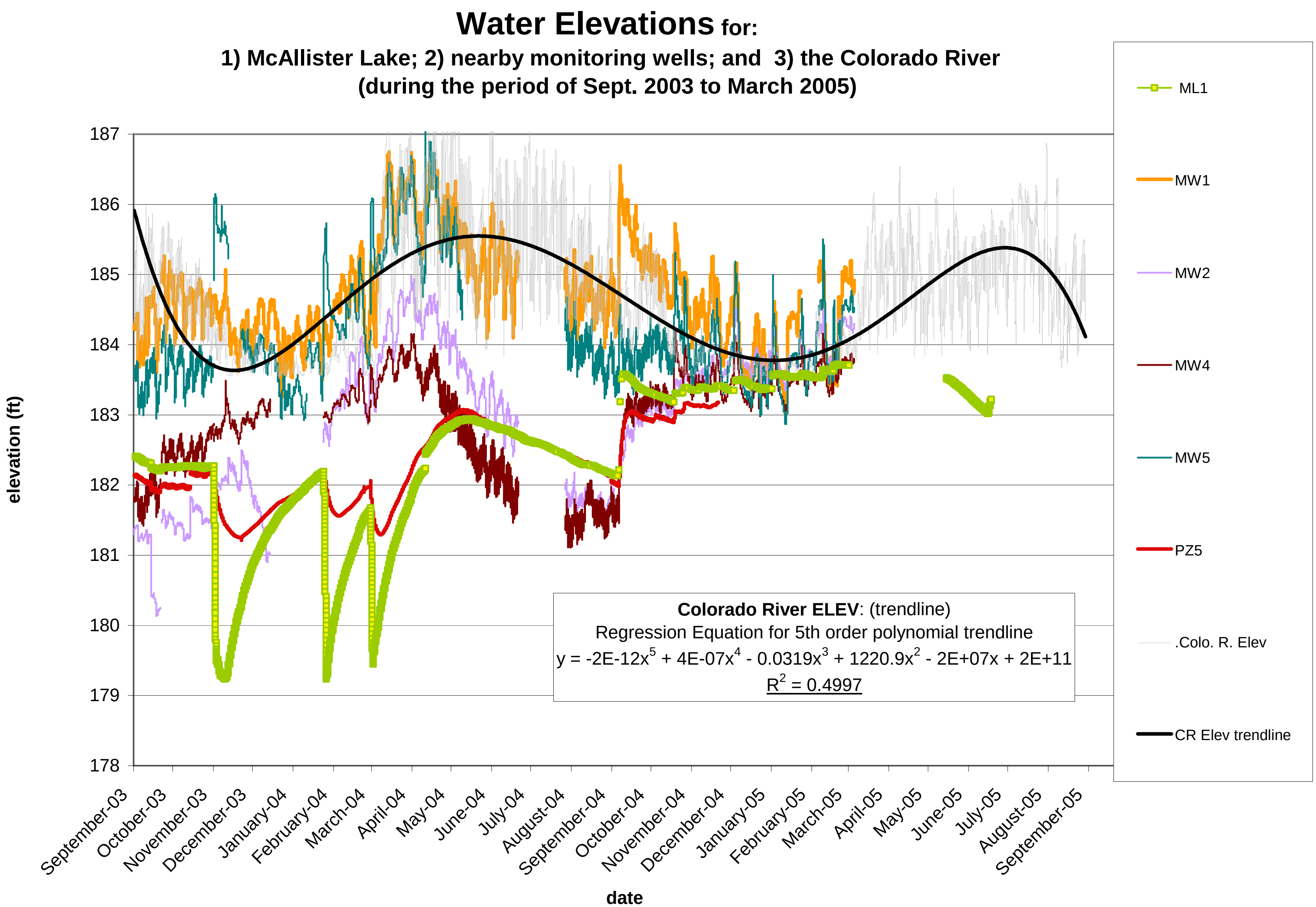


Water Elevations -- 200 Hour Sample
McAllister Lake Native Fish Refugia Study
1) monitoring wells; and 2) the Colorado River, both circa McAllister Lake, I-NWR, Az.
(during the 8 day period of 07/29/04-to-08/06/04)
elevation (ft)
187
186
185
184
183
182
181
180
midnight lines
07/29/04
07/30/04
07/31/04
08/01/04
08/02/04
08/03/04
08/04/04
08/05/04
08/06/04
08/07/04
08/08/04
date
MW-1
MW-2
MW-3
MW-4
MW-5
PZ-5
Colo. R. Elev


Water Elevations -- 1st 100 Hours
McAllister Lake Native Fish Refugia Study
1) monitoring wells; and 2) the Colorado River, both circa McAllister Lake, I-NWR, Az.
(during the Sept. 09/03/03 -to- 09/07/03)
elevation (ft)
186
185
184
183
182
181
180
midnight-lines
09/03/03
09/04/03
09/05/03
09/06/03
09/07/03
09/08/03
09/09/03
date
MW-1
MW-2
MW-3
MW-4
MW-5
Colo. R. Elev


Water Elevations -- 100 Hour Sample
McAllister Lake Native Fish Refugia Study
1) monitoring wells; and 2) the Colorado River, both circa McAllister Lake, I-NWR, Az.
(during the period 04/01/04 to 04/05/04)
188
187
186
185
184
183
elevation (ft)
NO MW-3 RECORD
FOR THESE DATES
midnight
03/31/04
04/01/04
04/02/04
04/03/04
04/04/04
04/05/04
04/06/04
date
MW-1
MW-2
MW-3
MW-4
MW-5
Colo. R. Elev


Estimation of Colorado R. Stage Circa McAllister Lake
(hourly data)
CR Elev circa CIBOLA NWR (USBR)
Regressed Est. of CR Elev. circa McAllister Lk.
WATER SURFACE ELEV. (ft.)
210
205
200
195
190
185
180
Period of Record Displayed:
September 1, 2003 -thru- August 31, 2005
REGRESSION EQN (non-linear) of the form:
a+b(X)+c/(x^2)
R^2 = 0.91
Eq'n for estimation of CR1 Elevation =
(-)9692.59+31.46*(CR@CIBO)+1.36E+08/(CR@CIBO^2)
(Staff Plate reading of 0.0 = 180.92 (famsl)
09/01/03
10/01/03
11/01/03
12/01/03
01/01/04
02/01/04
03/01/04
04/01/04
05/01/04
06/01/04
07/01/04
08/01/04
09/01/04
10/01/04
11/01/04
12/01/04
01/01/05
02/01/05
03/01/05
04/01/05
05/01/05
06/01/05
07/01/05
08/01/05



Water Elevations for:
1) McAllister Lake; 2) nearby monitoring wells; and 3) the Colorado River
(during the period of Sept. 2003 to March 2005)
elevation (ft)
187
186
185
184
183
182
181
180
179
178
September-03
October-03
November-03
December-03
January-04
February-04
March-04
April-04
May-04
June-04
July-04
August-04
September-04
October-04
November-04
December-04
January-05
February-05
March-05
April-05
May-05
June-05
July-05
August-05
September-05
date
Colorado River ELEV: (trendline)
Regression Equation for 5th order polynomial trendline
$y = -2E-12x^5 + 4E-07x^4 - 0.0319x^3 + 1220.9x^2 - 2E+07x + 2E+11$
$R^2 = 0.4997$
ML1
MW1
MW2
MW4
MW5
PZ5
.Colo. R. Elev
CR Elev trendline