

TECHNICAL SERVICE CENTER

Denver, Colorado

Technical Memorandum No. 8220-10-02

# **Analysis of Sediments from the Las Vegas Bay Delta, Lake Mead**

U.S. Department of the Interior  
Bureau of Reclamation



July 2002

**U.S. Department of the Interior  
Mission Statement**

**The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to tribes.**

---

**Bureau of Reclamation  
Mission Statement**

**The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.**

## Table of Contents

Table of Contents .....	i
List of Figures and Tables .....	iii
Introduction .....	1
Sample Collection .....	1
Sample Preparation .....	3
Analytical Methods .....	5
Results .....	6
Sediment Characteristics .....	6
Water and Pore Water Composition .....	6
Sediment Leaching Tests .....	9
Total Sediment Concentrations .....	13
Conclusions .....	16
Acknowledgments .....	17
References .....	18
Appendix A - Complete Analytical Results	

## List of Figures and Tables

Figure 1 - Locations of Las Vegas Wash delta sampling locations . . . . .	2
Table 1 - Locations of Sampling Locations . . . . .	3
Table 2 - Physical Characteristics of Sediment Samples . . . . .	7
Table 3 - Composition of Extract Water and Pore Water . . . . .	8
Table 4 - Concentrations of Test Variables in Sediment Extracts . . . . .	10
Table 5 - Release/Uptake of Test Variables During Sediment Equilibrations . . . . .	11
Table 6 - Comparison of Results to EPA Drinking Water Standards . . . . .	14
Table 7 - Total Concentrations of Test Variables in Delta Sediments . . . . .	15

## **Introduction**

An extensive delta was exposed and extended in Las Vegas Bay in 2001 as a result of falling water levels in Lake Mead. The delta is composed primarily of sediments from Las Vegas Wash that have been continually transported toward Lake Mead and that were exposed as the lake dropped more than 30' during 2001. There has been considerable debate as to the composition and effect of sediments in the delta on water quality in Lake Mead. To answer that question, sediment samples from the delta were collected and analyzed. Analyses included nutrients, metals, and perchlorate in sediments, leachate from equilibrations with water from Lake Mead and Las Vegas Wash, and pore water.

## **Sample Collection**

Thirty-six sediment core samples were collected by Montgomery Watson Harza from nine sites on the exposed delta of the Las Vegas Wash on August 28, 2001. Four cores were taken at each site (Stations LVWD-71-79) in 2" inside diameter plastic tubes, and each core was divided into two sections, one from the surface to 6" and the second from 6-12" below the surface. Three of the core samples from each site (54 total sections) were used for this study, with the intent that one core would be used for analysis of total metals and nutrients, one would be used for pore water analyses, and one would be extracted with water from Lake Mead. The fourth core was sent to the Southern Nevada Water Authority's microbiological laboratory for bacterial analyses. Results of the bacterial analyses are not included in this report.

Cores were shipped by overnight delivery to the Bureau of Reclamation's Denver Environmental Chemistry Laboratory (DECL) for analysis. Unfortunately, the core tubes were not tightly sealed and any pore water that originally may have been present had leaked from the cores prior to their arrival in Denver. As a result, additional sediment was collected by Reclamation personnel as a grab sample on September 25, 2001 from the very edge of the delta where Las Vegas Wash enters Lake Mead (Station LWLVB). That sample was placed on ice and returned to Denver on September 27, 2001.

Water for equilibration tests was collected on August 28, 2001, by personnel from the Southern Nevada Water Authority (SNWA) at their drinking water intake. Those samples were also shipped to DECL by overnight delivery.

Initial analyses indicated that concentrations of some variables in leachate increased when equilibrated with Lake Mead water. An additional sediment grab sample was collected on January 15, 2002, again at the lakeward edge of the delta (Station LWLVB-B), and delivered to DECL on January 17, 2002. This sample was equilibrated with water from Las Vegas Wash and was tested for the same variables and sediment components as the core sediments. The water used for equilibration was collected by the Southern Nevada Water Authority from Las Vegas Wash at Station

LW3.75 upstream of Lake Las Vegas on January 8, 2002. Those water samples were hand delivered to DECL on January 10, 2002.

All sediment sampling locations are shown in Figure 1. Coordinates for each site (NAD-83) were determined by a global positioning system and are listed in Table 1.



Figure 1 - Locations of Las Vegas Wash delta sampling locations (Photo taken 12 December 2001, Lake Mead elevation 1177 ft.

Table 1 - Locations of Sampling Locations (Coordinates in NAD83)

Sample ID	Location	GPS Coordinate (Lat./Long.)	
LVWD-NW-(1,2,3,4)-71	West transect, north of channel	N36.13020	W114.86827
LVWD-N-(1,2,3,4)-72	Center transect, north of channel	N36.12936	W114.86762
LVWD-NE-(1,2,3,4)-73	East transect, north of channel	N36.12916	W114.86673
LVWD-E-(1,2,3,4)-74	East transect, center of delta	N36.12887	W114.86693
LVWD-C-(1,2,3,4)-75	Center transect, center of delta	N36.12913	W114.86803
LVWD-W-(1,2,3,4)-76	West transect, center of delta	N36.12962	W114.86892
LVWD-S-(1,2,3,4)-77	Center transect, south of channel	N36.12885	W114.86831
LVWD-SW-(1,2,3,4)-78	West transect, south of channel	N36.12905	W114.86831
LVWD-SE-(1,2,3,4)-79	East transect, south of channel	N36.12837	W114.86738
LWLVB	Channel center, south edge of delta	N36.12767	W114.86692
LWLVB-B	Channel center, south edge of delta	N36.12728	W114.86667
LW3.75	Las Vegas Wash downstream of demonstration weir	N36.09665	W114.94632

### Sample Preparation

Core samples were homogenized by placing the entire core in a plastic bag and mixing the sediment by hand. Sub-samples were then removed for various analyses or additional processing. Water content and density were determined gravimetrically for each sample to enable results to be reported on a dry weight basis. Ash content was also determined on each sample to provide an indication of organic content.

Samples for analyses of total metals, including calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), aluminum (Al), antimony (Sb), arsenic (As), barium (Ba), beryllium (Be), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), manganese (Mn), mercury (Hg), nickel (Ni), selenium (Se), silver (Ag), thallium (Tl), and zinc (Zn); total Kjeldahl nitrogen (TKN); and total phosphorus (total P) were air dried and then ground prior to analysis. The sediment samples were variable in composition, but consisted primarily of sand and gravel, with some pebbles greater than 1/4" in

diameter. Samples with pebbles greater than 1/4" in diameter were initially ground using a jaw crusher grinder to break the gravel into <1/4" pieces. All samples were then ground using a Braun Pulverizer to a mesh size of approximately 60 to 100 mesh. The pulverized samples were finally ground to less than 100 mesh using a mortar and pestle following sub-sampling using the random shoveling technique.

Samples for total As and total Se were digested using a mixed acid digestion (Method I-5475-85, metals, minor, total-in-sediment, atomic absorption spectrometric, hydride) described by the USGS (Fishman and Friedman, 1989). A 0.5 g sediment sample was heated in a Teflon beaker on a hot plate with concentrated nitric acid (HNO<sub>3</sub>), hydrofluoric acid (HF) and perchloric acid (HClO<sub>4</sub>). Digested samples were then dissolved in concentrated hydrochloric acid (HCl) and deionized water to reduce the selenium to the +4 valence state prior to analysis.

Sediment samples were digested for analysis of total Hg using Method 245.3 (U.S. EPA, 1983). A 0.2 g sample was digested with aqua regia (three volumes concentrated HCl to one volume concentrated HNO<sub>3</sub>) in a BOD bottle, followed by oxidation with potassium permanganate.

Other trace metals were analyzed by USGS Method I-5474-85, metals, major and minor, total-in-sediment, atomic absorption spectrometric, direct. This method was modified by using HNO<sub>3</sub> instead of HCl to dissolve the digested samples. This modification prevents precipitation of silver chloride and also eliminates potential chloride interferences for those elements analyzed by graphite furnace atomic absorption spectrometry (Sb, As, Pb, Se, and Tl).

Total phosphorus in the sediment samples was analyzed in the same mixed acid digest used for analyses of trace metals. Total Kjeldahl nitrogen in the sediments was digested using Method 83-7 (Bremner, 1965).

Analyses for exchangeable nitrate+nitrite-nitrogen (NO<sub>3</sub><sup>-</sup>+NO<sub>2</sub><sup>-</sup>-N) and ammonia-N (NH<sub>3</sub>-N) were performed on air dried sediments using procedures outlined in Method 84-2 by Bremner (1965). Extractable NO<sub>3</sub><sup>-</sup>+NO<sub>2</sub><sup>-</sup>-N and NH<sub>3</sub>-N were determined by shaking 10 g of sediment with 100 mL of 2 M KCl for two hours. The extract was then filtered through a 0.45 μm membrane filter prior to analysis.

Attempts to modify the Bremner (1965) method to determine exchangeable perchlorate (ClO<sub>4</sub><sup>-</sup>) were not successful. Both potassium chloride (KCl, 2 M and 1,000 mg/L) and potassium nitrate (KNO<sub>3</sub>, 1,000 mg/L) solutions produced interferences that could not be overcome. As a result, concentrations of exchangeable ClO<sub>4</sub><sup>-</sup> were estimated from the water extracts.

Sediment extractions were performed by placing 20 g of sediment and 200 mL of filtered Lake Mead water in a 500 mL Erlenmeyer flask and mixing for 72 hours. At the completion of the leaching period, samples were filtered and analyzed for nutrients, trace metals, and perchlorate. Sediments used for the extractions were taken directly from the core samples and were not ground prior to use.

Pore water was separated from the bulk sediment samples collected by Reclamation by direct filtration through a 0.45 µm membrane filter. This method was found to efficiently separate water and solids from the sandy sediment. Pore water was analyzed for nutrients, perchlorate, and most trace metals. The fractions of the pore water samples for orthophosphate and perchlorate analyses were not preserved; other fractions were preserved with sulfuric acid for nutrient analyses and nitric acid for metal analyses.

The volume of pore water obtained was not sufficient for analysis of mercury or TKN for the sample collected on September 25, 2001. In addition, phosphorus, nitrate, and perchlorate analyses for the sediment collected on that date were questionable and therefore were not included in the data analysis.

## Analytical Methods

Sediment samples were visually examined to determine physical composition. Water content, ash content, and sediment density were all determined gravimetrically. The ash content was used to provide an estimate of sediment organic matter.

Nutrients were analyzed using methods presented by the U.S. EPA (1983) with a Perstorp autoanalyzer. Soluble orthophosphate (ortho P) in pore water, lake water, Las Vegas Wash water and leachate samples was analyzed using Method 365.1 (colorimetric, automated, ascorbic acid). Total phosphorus in water samples and sediment digests was analyzed using Method 365.1 and 365.2 (colorimetric, ascorbic acid, single reagent). Nitrate+nitrite-N and ammonia-N concentrations in water and leachate samples were determined colorimetrically using EPA Methods 353.2 (colorimetric, automated, cadmium reduction) and 350.1 (colorimetric, automated, phenate). Total Kjeldahl nitrogen in water and leachate samples was determined using Method 351.2 (colorimetric, semi-automated block digester, AAll). This same method was used for the digested sediment samples. Standards were matched to the same acid matrix as the samples, and all solutions were neutralized in-line for analysis.

Perchlorate was analyzed in water and leachate samples by EPA Method 314 (ion chromatography). A Dionex DX-500 ion chromatograph was used for  $\text{ClO}_4^-$  analyses.

Metals were analyzed by atomic absorption and/or atomic emission spectroscopy. Most metals were analyzed by the inductively coupled plasma emission spectrometric method (EPA Method 200.7) using a Thermal/Jarrel Ash Model ICAP 61E. Analyses for Sb, As, Pb, and Tl in water, leachate and digested sediments, and Se in digested sediments, were conducted by graphite furnace atomic absorption (GFAA) spectrometry. The EPA methods are: Sb - Method 204.2, As - Method 206.2, Pb - Method 239.2, Se - Method 270.2, and Tl - Method 279.2. A 0.1% palladium nitrate/0.25% citric acid solution was used as a matrix modifier for all samples analyzed

by GFAA. A Varian SpectrAA Zeeman 220 atomic absorption spectrophotometer was used for GFAA analyses.

Selenium in leachate and water samples was analyzed by the hydride method (Method 270.3) to provide lower detection limits than GFAA. The Varian SpectrAA Zeeman 220 atomic absorption spectrophotometer with a VGA-77 hydride/cold vapor accessory was used for these analyses.

Mercury was analyzed by the cold vapor technique (Method 245.1 for water and leachate samples and Method 245.3 for sediment samples). Samples were analyzed using flow-injection analysis and the Varian SpectrAA Zeeman 220 atomic absorption spectrophotometer with a VGA-77 hydride/cold vapor accessory.

## **Results**

### **Sediment Characteristics**

Data on solids, density, and organic content are summarized in Table 2, along with a general description of sample characteristics. The core samples were composed of sand, gravel, and pebbles greater than 1/4" in diameter. In general, the upper 6 inches of the cores contained finer material than the bottom 6 inches, but there were several exceptions. Results are presented for duplicate cores and, as the results in Table 2 indicate, the duplicate cores often had quite different characteristics. The sediment grab samples were composed primarily of sand.

Water content averaged 12.8 percent in the cores (range 4.1-18.4%) compared to 19.6 percent in the grab samples (range 16.9-22.4%). Sediment density averaged 2.22 g/mL (range = 1.35-2.57 g/mL) in the core samples and 2.09 g/mL (range = 1.97-2.21 g/mL) in the grab samples. Cores from the center of the stream channel (Station 74, 75, and 76) had a slightly higher water content than the other cores, but density and organic content were similar for all cores.

Organic content was low, averaging 0.58 percent in the core samples and 0.76 percent in the grab samples. Only 2 of the 38 sediment samples tested had more than one percent organic matter.

### **Water and Pore Water Composition**

The composition of the water samples used in leach tests and the pore water concentrations for sediment grab samples are summarized in Table 3. Pore water concentrations should represent values in equilibrium with the delta sediments.

Table 2 - Physical Characteristics of Sediment Samples

Sample ID	Composition	Water Content (%)	Density (g/mL)	Organic Matter (%)
<b>Core Samples</b>				
71 (0-6")	Sand	11.0	1.35	0.59
	Sand, some gravel and pebbles	7.9	2.47	0.52
71 (6-12")	Pebbles and sand	11.7	2.22	0.59
	Sand, gravel, some pebbles	9.6	2.42	0.44
72 (0-6")	Sand	4.1	2.55	0.43
	Sand, some gravel and pebbles	4.8	2.57	0.69
72 (6-12")	Sand, gravel, pebbles	6.9	2.43	0.43
	Sand, some gravel and pebbles	7.6	2.48	0.63
73 (0-6")	Sand and pebbles	18.4	2.15	0.69
	Sand, some pebbles	16.3	2.16	0.71
73 (6-12")	Gravel, pebbles, some sand	12.8	2.31	0.60
	Sand, gravel, pebbles	16.2	2.15	0.62
74 (0-6")	Gravel, pebbles, some sand	9.9	2.40	0.39
	Pebbles, sand	12.5	2.33	0.48
74 (6-12")	Gravel, sand, pebbles	14.4	2.25	0.56
	Sand, gravel, some pebbles	15.4	2.12	<0.1
75 (0-6")	Sand, some gravel and stones	15.1	2.15	2.16
	Sand, gravel, some pebbles	15.9	2.15	0.57
75 (6-12")	Stones, some sand	7.0	2.16	0.84
	Pebbles, some gravel and sand	14.1	2.15	1.01
76 (0-6")	Sand, pebbles, gravel	16.1	2.21	0.56
	Sand, gravel, some pebbles	15.1	2.19	0.47
76 (6-12")	Sand, gravel, pebbles	14.5	2.22	0.54
	Sand, some gravel and pebbles	15.3	2.12	0.45
77 (0-6")	Sand, gravel, pebbles	10.2	2.23	0.41
	Pebbles, some gravel and sand	15.0	2.22	0.57
77 (6-12")	Sand, gravel, pebbles	15.0	2.15	0.46
	Gravel, sand, some pebbles	16.3	2.15	0.73
78 (0-6")	Pebbles, sand, gravel	12.1	2.29	0.40
	Sand, gravel, some pebbles	14.2	2.21	0.61
78 (6-12")	Pebbles, gravel, sand	10.3	2.32	0.33
	Pebbles, some gravel and sand	12.6	2.18	0.55
79 (0-6")	Pebbles, gravel, sand	15.0	2.23	0.46
	Sand	16.9	2.07	0.44
79 (6-12")	Sand, some pebbles	18.4	2.12	0.51
	Sand, gravel, some pebbles	12.3	2.17	0.53
<b>Grab Samples</b>				
LWLVB	Sand	22.4	1.97	0.66
LWLVB-B	Sand	16.9	2.21	0.86

Table 3 - Composition of Extract Water and Pore Water

Variable (concentration units)*	Water Source/Concentration			
	SNWA Intake 8/28/01	LW3.75 1/8/02	Pore Water 9/25/01	Pore Water 1/15/02
<b>Nutrients and Perchlorate</b>				
Ortho P (mg/L)	0.002	0.356	N/A	0.138
Total P (mg/L)	0.002	0.419	N/A	0.169
NH <sub>3</sub> -N (mg/L)	0.015	0.057	0.707	0.631
TKN (mg/L)	0.140	1.12	N/A	2.14
NO <sub>3</sub> <sup>-</sup> +NO <sub>2</sub> <sup>-</sup> N (mg/L)	0.546	12.6	N/A	12.0
ClO <sub>4</sub> <sup>-</sup> (µg/L)	9.39	401	N/A	539
<b>Metals</b>				
Ca (mg/L)	77.2	122	148	151
Mg (mg/L)	26.8	65.7	66.6	74.0
Na (mg/L)	83.8	212	215	240
K (mg/L)	4.2	21.8	21.1	22.0
Al (µg/L)	36.2	341	64.9	<30.0
Sb (µg/L)	<6.0	<6.0	<6.0	<6.0
As (µg/L)	2.3	8.2	12.2	9.4
Ba (µg/L)	107	28.4	87.9	67.0
Be (µg/L)	<0.5	<0.5	<0.5	<0.5
Cd (µg/L)	<4.0	<4.0	<4.0	<4.0
Cr (µg/L)	<4.0	<4.0	<4.0	<4.0
Cu (µg/L)	<4.0	<4.0	9.6	189
Fe (µg/L)	24.5	318	20.9	16.1
Pb (µg/L)	<1.0	<1.0	1.0	<1.0
Mn (µg/L)	4.5	46.6	169	56.2
Hg (µg/L)	<0.13	<0.13	<0.13	<0.13
Ni (µg/L)	<10.0	<10.0	13.4	11.0
Se (µg/L)	2.5	6.4	3.1	7.8
Ag (µg/L)	<4.0	<4.0	<4.0	<4.0
Tl (µg/L)	2.1	<2.0	<2.0	<2.0
Zn (µg/L)	<4.0	43.2	12.1	56.9
*Total metal concentrations reported for SNWA intake and demo weir water. Concentrations reported for pore water are dissolved metals.				

Concentrations of all variables examined were higher in the pore water samples than in the Lake Mead water collected at the SNWA intake. Ammonia-N, TKN, perchlorate were also higher in the pore water than in water from Las Vegas Wash, while concentrations of phosphorus and nitrate-N were lower. The loss of nitrate and increase in ammonia was expected because dissolved oxygen concentrations and redox conditions in sediments are typically lower than those in overlying water, which favors conversion of nitrate to ammonia. In most cases, an increase in phosphorus concentrations is also expected because phosphorus is often bound to iron in sediments and iron is more soluble under low redox conditions.

The lower concentrations of phosphorus in pore water observed in this case may be partially the result of location, because the Las Vegas Wash samples were collected above Lake Las Vegas at some distance from the delta. A water sample collected by Reclamation as part of their Lake Mead monitoring program at the same time and location as the sediment sample had an orthophosphate concentration of 0.22 mg/L, which is lower than the Wash sample collected at the Demo Weir (0.356 mg/L) but still higher than the pore water concentration of 0.138 mg/L. The lower concentration in the pore water may be the result of dilution of pore water at the leading edge of the delta with water from Lake Mead.

Most metal concentrations were higher in the pore water samples than in the water from either Lake Mead or Las Vegas Wash. The only exceptions were aluminum and iron. Both of those metals are associated primarily with soil particles, and are therefore removed during the pore water separation process. Major ion (Ca, Mg, Na, K) concentrations in the pore water were similar for the two sampling dates, but trace metal concentrations were much more variable. In particular, concentrations of Al, Cu, Mn, Se, and Zn differed by more than 100 percent. Movement of the delta and transport of material downstream between the August 2001 and January 2002 sampling dates and the non-homogeneous nature of the test samples are possible causes of the observed differences.

### **Sediment Leaching Tests**

Results of the leaching tests conducted on the 18 core samples collected on August 28, 2001, and leached with Lake Mead water from the SNWA drinking water intake, and the January 15, 2002, grab sample, leached with water from Las Vegas Wash, are summarized in Tables 4 and 5. Equilibrium concentrations of test variables are presented in Table 4, and Table 5 indicates the amount of each variable that was absorbed (negative values) or desorbed (positive values) during the 72-hour leach.

Concentrations of nutrients and perchlorate in the extracts from the core samples were quite variable (Table 4). The maximum and minimum leachate concentrations for phosphorus, ammonia-N and perchlorate differed by more than an order of magnitude, and large differences were also observed for TKN and nitrate. In general, metal concentrations in the leachate were much less variable than the nutrients and perchlorate.

Table 4 - Concentrations of Test Variables in Sediment Extracts

Variable (concentration units)	Lake Mead Extract, 8/28/01 Core Samples			Wash Extract 1/15/02 Grab Sample
	Minimum	Maximum	Average	
<b>Nutrients and Perchlorate</b>				
Ortho P (mg/L)	0.016	0.273	0.104	0.302
Total P (mg/L)	0.026	0.302	0.123	0.320
NH <sub>3</sub> -N (mg/L)	0.005	0.158	0.035	0.071
TKN (mg/L)	0.363	1.038	0.608	1.07
NO <sub>3</sub> <sup>-</sup> +NO <sub>2</sub> <sup>-</sup> N (mg/L)	0.080	0.720	0.304	12.6
ClO <sub>4</sub> <sup>-</sup> (µg/L)	4.2	32.4	15.3	471
<b>Metals</b>				
Ca (mg/L)	66.7	74.0	70.0	136
Mg (mg/L)	25.6	28.5	26.3	71.8
Na (mg/L)	83.8	97.9	87.3	243.0
K (mg/L)	9.7	12.4	10.9	28.6
Al (µg/L)	<30.0	51.4	<30.0	<30.0
Sb (µg/L)	<6.0	<6.0	<6.0	<6.0
As (µg/L)	7.62	15.8	11.3	24.3
Ba (µg/L)	42.5	51.2	46.5	61.0
Be (µg/L)	<0.5	<0.5	<0.5	<0.5
Cd (µg/L)	<4.0	<4.0	<4.0	<4.0
Cr (µg/L)	<4.0	5.7	<4.0	<4.0
Cu (µg/L)	<4.0	11.9	<4.0	63.7
Fe (µg/L)	<4.0	33.2	4.6	5.3
Pb (µg/L)	<1.0	<1.0	<1.0	<1.0
Mn (µg/L)	<4.0	<4.0	<4.0	<4.0
Hg (µg/L)	0.14	0.43	0.26	<0.13
Ni (µg/L)	<10.0	<10.0	<10.0	<10.0
Se (µg/L)	0.48	2.00	1.32	8.35
Ag (µg/L)	<4.0	5.0	<4.0	<4.0
Tl (µg/L)	<2.0	<2.0	<2.0	<2.0
Zn (µg/L)	<4.0	35.1	5.21	13.5

Table 5 - Release/Uptake of Test Variables During Sediment Equilibrations

Variable (concentration units)*	Lake Mead Extract, 8/28/01 Core Samples			Wash Extract 1/15/02 Grab Sample
	Minimum	Maximum	Average	
<b>Nutrients and Perchlorate</b>				
Ortho P (mg/Kg)	0.13	3.44	1.11	-0.54
Total P (mg/Kg)	0.23	3.80	1.32	-0.99
NH <sub>3</sub> -N (mg/Kg)	-0.12	1.81	0.21	0.14
TKN (mg/Kg)	-1.92	4.66	0.64	-0.50
NO <sub>3</sub> <sup>-</sup> +NO <sub>2</sub> <sup>-</sup> N (mg/Kg)	-0.70	5.49	1.76	0.10
ClO <sub>4</sub> <sup>-</sup> (µg/Kg)	-61.7	244	63.4	0.70
<b>Metals</b>				
Ca (mg/Kg)	-108	-29.1	-68.8	140
Mg (mg/Kg)	-11.1	15.4	-4.77	61.0
Na (mg/Kg)	<0.10	128	33.1	310
K (mg/Kg)	51.0	77.7	64.4	68.0
Al (µg/Kg)	-0.37	0.14	-0.14	-3.26
Sb (µg/Kg)	<0.06	<0.06	<0.06	<0.06
As (µg/Kg)	0.05	0.12	0.09	0.16
Ba (µg/Kg)	-0.64	-0.53	-0.58	0.33
Be (µg/Kg)	<0.01	<0.01	<0.01	<0.01
Cd (µg/Kg)	<0.04	<0.04	<0.04	<0.04
Cr (µg/Kg)	<0.04	0.05	<0.04	<0.04
Cu (µg/Kg)	<0.04	0.11	<0.04	0.64
Fe (µg/Kg)	-0.21	0.08	<0.04	-3.13
Pb (µg/Kg)	<0.01	<0.01	<0.01	<0.01
Mn (µg/Kg)	<0.04	<0.04	<0.04	-0.47
Hg (µg/Kg)	1.55	5.00	2.96	<0.0013
Ni (µg/Kg)	<0.10	<0.10	<0.10	<0.10
Se (µg/Kg)	-19.7	-4.50	-11.3	0.02
Ag (µg/Kg)	<0.04	0.04	<0.04	<0.04
Tl (µg/Kg)	<0.02	<0.02	<0.02	<0.02
Zn (µg/Kg)	<0.04	0.32	<0.04	-0.30
*Concentrations reported on a dry weight basis. Positive values indicate release of test variable during equilibration and negative values indicate uptake by sediments.				

Leachate concentrations tended to be higher in the 0-6" section of each core than in the 6-12" section, but there were many exceptions. For example, orthophosphate averaged 0.138 mg/L (range = 0.030 to 0.273 mg/L) in leachate from the upper core sections and 0.069 mg/L (range = 0.016 to 0.171 mg/L) in the lower sections. This would be expected because the finer-grained sediments in the upper portion of the cores (Table 2) would have a greater capacity for absorption and desorption. Metals showed a similar trend, but differences were much less pronounced.

All core samples leached with water from Lake Mead released phosphorus (Table 5). Perchlorate and TKN were each released from all but one core. Ammonia concentrations decreased in 12 of the 18 samples and nitrate concentrations decreased in 7 samples but average concentrations of both ammonia and nitrate increased in the leachate samples.

Potassium and arsenic were also released from all core samples. Sodium was released from most core samples, but the concentration remained unchanged for one core. Magnesium and aluminum were removed from solution by most samples, with losses observed in 16 samples for magnesium and 11 samples for aluminum. Chromium and silver were each detected in one sample (out of eighteen), copper was detected in four samples, and zinc was detected in five samples, but the average change was below the detection limit in each case. In contrast, all core samples absorbed calcium, barium, and selenium from the lake water. Concentrations of antimony, beryllium, cadmium, lead, manganese, and thallium were below detection limits in all leachate samples.

Mercury was also apparently released from all core samples. Although most mercury concentrations were low and all results were below drinking water standards, concentrations were higher than those reported by on-going investigations in Las Vegas Wash. Neither the cores nor the water used for the leaching tests were collected using the ultra-clean techniques required for precise, low-level mercury analyses. As a result, it is possible that the mercury levels observed in the sediment extracts were an artifact of the sampling procedures used.

Because nutrients were released from the core samples to Lake Mead water during the leachate tests, the test was repeated using water from Las Vegas Wash and a sediment grab sample from the edge of the delta. Those results, which are also presented in Tables 5 and 6, were significantly different from the equilibrations using Lake Mead water.

The concentration of orthophosphate, the nutrient of greatest importance to algal growth in Lake Mead, was 0.302 mg/L following equilibration with water from Las Vegas Wash compared to an average of 0.104 mg/L following equilibrations with Lake Mead Water. This still represented absorption of phosphorus from solution, however, because of the much higher orthophosphate concentrations (0.356 mg/L, Table 3) in Las Vegas Wash water. TKN was also removed from solution during equilibration with

Las Vegas Wash Water. Ammonia, nitrate, and perchlorate were still released, but at lower levels than during the equilibrations with Lake Mead water.

In contrast to their removal from solution during equilibration with Lake Mead water, both calcium and magnesium were released during equilibration with Las Vegas Wash water. Potassium, and especially sodium were released at higher levels. These results may reflect greater competition for the limited absorption sites on the sandy sediments with the much saltier water in Las Vegas Wash.

Arsenic and potassium were the only variables which were detected in all samples that were released in each case. None of the variables tested were removed by all test sediments.

Table 6 compares pore water and leachate concentrations to EPA drinking water standards. Primary standards are based on risk to public health, while secondary standards are based on cosmetic (discoloration) or aesthetic (taste, odor, or color) effects.

Nitrate was the only variable tested that exceeded the current primary drinking water standards. Nitrate concentrations drop dramatically in Lake Mead as a result of dilution and algal uptake, and the concentration of 0.546 mg/L at the SNWA intake is well below the standard of 10 mg/L (10,000 µg/L). Arsenic concentrations were below the current standard of 50 µg/L, but both pore water and leachate samples exceed the proposed standard of 10 µg/L.

The concentration of manganese in the pore water samples exceeded the secondary standard of 50 µg/L, which is based on staining of plumbing fixtures and laundry. This metal is soluble under low oxygen conditions, such as those often found in lake sediments, but is readily oxidized to insoluble forms in the presence of oxygen. It was found at only 4.5 µg/L at the SNWA intake.

This highest aluminum concentrations observed were just slightly above the lower range of 50 µg/L for the secondary standard. The range is based on water hardness, and the higher standard of 200 µg/L would apply to Lake Mead.

### **Total Sediment Concentrations**

Total concentrations of the test variables are presented in Table 7. There are no widely-accepted criteria for levels of pollutants in lake sediments (Giesy and Hoke, 1990). Giesy and Hoke described a number of the different criteria that are currently used to evaluate lake sediments and discussed their applications. The criteria that were modified from those presented by Giesy and Hoke and subsequently adopted by the Ontario Ministry of Environment (1996) appear to be among the most comprehensive. Those criteria are presented in Table 7 for comparison with test results. The average concentrations of the test variables in the Earth's crust (Krauskopf, 1979) are also presented in Table 7.

Table 6 - Comparison of Results to EPA Drinking Water Standards

Variable	EPA Standard	Pore Water	Leachate, Extraction with Lake Mead Water	Leachate, Extraction with LV Wash Water
<b>Primary Standards*</b>				
Antimony	6	<6.0	<6.0	<6.0
Arsenic	10**	9.4 - 12.2	7.6 - 15.8	24.3
Barium	2,000	67.0 - 87.9	42.5 - 51.2	61.0
Beryllium	4	<0.5	<0.5	<0.5
Cadmium	50	<4.0	<4.0	<4.0
Chromium	100	<4.0	<4.0 - 5.7	<4.0
Lead	15	<1.0 - 1.0	<1.0	<1.0
Mercury	2	<0.13	0.14 - 0.43	<0.13
Nitrate-N	10,000	12,000	80 - 720	12,600
Selenium	50	3.1 - 7.83	0.48 - 2.00	8.35
Thallium	2	<2.0	<2.0	<2.0
<b>Secondary Standards</b>				
Aluminum	50 - 200	<30.0 - 64.9	<30.0 - 51.4	<30.0
Copper	1,000	9.6 - 189	<4.0 - 11.9	63.7
Iron	300	16.1 - 20.9	<4.0 - 33.2	5.3
Manganese	50	56.2 - 169	<4.0	<4.0
Silver	100	<4.0	<4.0 - 5.0	<4.0
Zinc	5,000	12.1 - 56.9	<4.0 - 35.1	13.5
*All concentrations in µg/L.				
**Proposed standard, current standard is 50 µg/L.				

Table 7 - Total Concentrations of Test Variables in Delta Sediments

Variable	8/28/01 Core Samples			1/15/02 Grab Sample	Lowest Effect Level*	Avg. Conc. in Earth's crust**
	Min	Max	Avg			
<b>Nutrients and Perchlorate</b>						
Total P (mg/kg)	770	1,270	1,036	850	--	1,100
NH <sub>3</sub> -N (mg/kg)	<0.03	3.40	0.60	0.20	--	--
NO <sub>3</sub> +NO <sub>2</sub> -N (mg/kg)	0.27	4.95	1.83	3.13	--	--
TKN (mg/kg)	21.0	85.0	48.2	65.6	--	20
ClO <sub>4</sub> <sup>-</sup> (mg/kg)	--	--	--	0.70	--	--
<b>Metals</b>						
Ca (mg/kg)	57,400	83,600	69,700	48,800	--	41,000
Mg (mg/kg)	12,000	15,200	13,400	10,900	--	23,000
Na (mg/kg)	14,100	18,800	16,700	17,300	--	24,000
K (mg/kg)	21,400	31,500	25,700	26,800	--	21,000
Al (mg/kg)	47,500	59,600	53,900	57,600	--	81,000
Sb (mg/kg)	<0.6	0.72	<0.6	1.19	--	0.2
As (mg/kg)	9.0	14.0	11.0	10.3	6.0	1.8
Ba (mg/kg)	829	1,470	1,050	947	--	500
Be (mg/kg)	0.98	1.24	1.09	1.17	--	3
Cd (mg/kg)	<0.40	<0.40	<0.40	<0.40	0.6	0.15
Cr (mg/kg)	33.7	54.8	41.0	45.0	26	100
Cu (mg/kg)	8.49	16.0	10.4	9.56	16	50
Fe (mg/kg)	14,500	20,000	17,400	17,200	--	54,000
Pb (mg/kg)	9.04	22.6	15.5	15.0	31	12.5
Mn (mg/kg)	283	396	335	355	--	1,000
Hg (mg/kg)	<0.09	0.15	<0.09	<0.09	0.2	0.02
Ni (mg/kg)	10.8	17.0	13.9	14.1	16	75
Se (mg/kg)	0.11	0.27	0.16	0.13	--	0.05
Ag (mg/kg)	<0.40	0.48	<0.40	<0.40	--	0.07
Tl (mg/kg)	<0.20	<0.20	<0.20	<0.20	--	0.8
Zn (mg/kg)	32.3	42.5	37.5	41.2	120	70
*Source: Ontario Ministry of Environment (1996) **Source: Krauskopf (1979)						

Measured total phosphorus concentrations in the delta sediments ranged from 770 to 1,270 mg/kg. These concentrations are typical of concentrations found in inorganic lake sediments and are also very similar to those found in the Earth's crust. Sediment nitrogen concentrations were relatively low, which is expected for sediments with very low levels of organic matter.

Since perchlorate is not typically found in natural waters, there is no basis for comparison of this ion with other sediments. The concentrations extracted from the delta sediments were less than those observed by Reclamation in Las Vegas Wash water from the same location, however, indicating that the delta sediments are not a source of perchlorate.

Concentrations of most metals in the delta sediments were similar to average concentrations in the Earth's crust and were well below the lowest effect levels adopted by the Ontario Ministry of Environment (Table 6). The only exceptions were antimony, arsenic, chromium, and selenium. These four metals were all found at levels over twice as high as average Earth's crust concentrations. In addition, arsenic and chromium exceeded the lowest effect level for all sediments tested. Nickel was found at concentrations that are less than 25 percent of the average concentration in the Earth's crust, but 2 of the 19 sediments tested still exceeded the Ontario lowest effect level for nickel, but only by a very small amount.

## **Conclusions**

Sediments from the delta forming in Las Vegas Bay are composed primarily of sand, gravel, and fine to medium pebbles. The variability observed in test results is largely the result of the non-homogeneous nature of the samples collected. In combination with a very low content of organic matter, the delta sediments have only a limited capacity to absorb or release nutrients and metals.

The leaching tests performed during this study indicated that the delta sediments have the potential to release phosphorus, the nutrient of greatest concern for increasing algal growth in Lake Mead, if they are mixed with lake water, but they remove phosphorus from the water column when mixed with water from Las Vegas Wash. Therefore, the delta sediments are not serving as a significant source of phosphorus to Las Vegas Bay; phosphorus in the bay is supplied by the Las Vegas Wash inflow.

Arsenic was the only test variable which exceeded standards for all water and sediment samples. This element is frequently found at elevated levels in soils in the western United States, and its presence here probably originates from that source.

## **Acknowledgments**

Funding for this study was provided by the Bureau of Reclamation, Lower Colorado Resource Management Office, Boulder City, NV. Figure 1 was provided by Art Ehrenberg, Las Vegas Wash Coordination Committee. Written comments on the report were provided by James Setmire, Bureau of Reclamation, Southern California Area Office, and Kim Zikmund, Las Vegas Wash Coordination Committee.

## References

- Bremner, J.M. 1965. Inorganic forms of nitrogen. pp. 1149-1178, *In* Black, C.A., D.D. Evans, J.L. White, L.E. Ensminger, and F.E. Clark (Eds.). *Methods of Soil Analysis, Chemical and Microbiological Properties*. Agronomy No. 9, Part 2. American Society of Agronomy, Madison, WI
- Bremner, J.M. 1965. Total nitrogen. pp. 1179-1237, *In* Black, C.A., D.D. Evans, J.L. White, L.E. Ensminger, and F.E. Clark (Eds.). *Methods of Soil Analysis, Chemical and Microbiological Properties*. Agronomy No. 9, Part 2. American Society of Agronomy, Madison, WI.
- Fishman, M.J., and L.C. Friedman, Eds. 1989. *Techniques of Water-Resources Investigations of the United States Geological Survey*. Book 5, Chapter A1, *Methods for Determination of Inorganic Substances in Water and Fluvial Sediments*. USGS, Denver, CO.
- Giesy, J.P., and R.A. Hoke. 1990. Freshwater Sediment Quality Criteria: Toxicity Bioassessment. pp. 265-248, *In* R. Baudo, J.P. Giesy, and H. Muntau, eds., *Sediments: Chemistry and Toxicity of In-Place Pollutants*. Lewis Publishers, Inc., Ann Arbor, MI.
- Krauskopf, K.B. 1979. *Introduction to Geochemistry, Second Edition*. McGraw-Hill Book Company, New York.
- Ontario Ministry of Environment. 1996. *Guideline for Use at Contaminated Sites in Ontario*. Appendix 2, Soil, Groundwater, and Sediment Criteria. Queen's Printer for Ontario.
- U.S. EPA. 1983. *Methods for Chemical Analysis of Water and Wastes*, EPA-600/4-79-020, USEPA Office of Research and Development, Cincinnati OH.