

ASSESSMENT OF AQUATIC TOXICITY IN
IRRIGATION DRAINWATER, NEWLANDS
PROJECT AREA
CARSON DESERT, NEVADA, MARCH-
AUGUST 1995



U.S. FISH AND WILDLIFE SERVICE
NEVADA FISH AND WILDLIFE OFFICE
DIVISION OF ENVIRONMENTAL QUALITY
RENO, NEVADA



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by: Damian K. Higgins¹ and John F. Miesner²

¹ U.S. Fish and Wildlife Service, Nevada Fish and Wildlife Office, Reno, Nevada

² U.S. Fish and Wildlife Service, Kansas Ecological Services Field Office, Manhattan, Kansas

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EXECUTIVE SUMMARY

The Nevada Fish and Wildlife Office of the U.S. Fish and Wildlife Service, in cooperation with the U.S. Department of Interior National Irrigation Water Quality Program, investigated the aquatic toxicity of water in irrigation drains in the Newlands Project area near Fallon, Nevada in 1995. Trace elements and other constituents in water that have been identified by previous studies in Lahontan Valley as potentially posing a threat to humans, fish, and wildlife include aluminum, arsenic, boron, dissolved-solids, mercury, molybdenum, and uranium.

The purposes of this report were to: 1) investigate the degree of seasonal variability and its effects on the quality of irrigation drainage in the Newlands Project near Fallon, Nevada; 2) identify source areas of the Newlands Project where irrigation drainage contributes most to aquatic toxicity in Lahontan Valley; and 3) identify specific water quality parameters that contribute to toxicity of aquatic biota. Water samples were collected from a number of drains during March, May, and August 1995 in the Lahontan Valley for trace element residue analysis and toxicity testing. Samples collected in August 1995 were also analyzed for the presence of a variety of pesticides commonly used in the Lahontan Valley. Water samples were used in two types of bioassay tests, 96-hour LC50 *Daphnia magna* and Microtox[®]. Constituent concentrations and bioassay test results were used to fulfill the above purposes.

Water released from Lahontan Reservoir is historically low in dissolved solids ranging from 150 to 500 mg/L (Hoffman et al. 1990; Lico 1992). The rates of water release from Lahontan Reservoir are highly variable and depend on a number of factors such as time of year, irrigation schedule, and water storage in the reservoir. It has been documented that drains throughout the Newlands Project Area have extreme variability in water quality. Flows in drains during the irrigation season can also be highly variable. As a result, dramatic daily changes in various water quality parameters are possible. Upstream parts of the system are particularly variable due to dependence on nearby irrigation whereas larger drains in the lower portion of the system are less variable. Flow measurements conducted by Lico and Pennington (1997) during sampling events for this study averaged 0.689, 9.57, and 13.94 cubic feet per second (cfs) for the March, May, and August periods respectively.

Concentrations of most constituents in drain-water were greater for samples collected during the March period. In general, mortality rates from *D. magna* bioassays were greater for samples collected during August. No toxic effects to bacterium were found in Microtox assays for all sample events. Constituents which commonly exceeded beneficial use criteria and may have contributed to observed aquatic mortality in this study included boron, lithium, molybdenum, nickel, and uranium, with molybdenum being the most common among sites. The Harmon and Stillwater Slough-Kent Lake drain systems were identified as highly contributing to aquatic mortality throughout the study period. Diagonal drain and Upper Paiute drain systems were identified as highly contributing to aquatic mortality during the August sampling period.

INTRODUCTION

In 1990, Congress passed Public Law 101-618 which authorizes and directs the Secretary of the Interior to purchase water rights within the Newlands Project (also known as the Newlands Irrigation Project) with the intent of sustaining an average of approximately 25,000 acres of wetlands near Stillwater National Wildlife Refuge and Carson Lake. Pursuant to Public Law 101-618, the Secretary of the Interior may acquire water rights from areas with the goal of benefitting such a purchase program. However, a lack of data in the Newlands Project with respect to which areas produce substantial amounts of toxic constituents in drain-water have limited the Secretary in identifying which water rights to purchase from specific areas.

In response to growing concerns raised by Congress and environmental groups over potential contamination of irrigation-related water and downstream effects to wetlands, the National Irrigation Water Quality Program (NIWQP) was created in late 1985. Stillwater National Wildlife Refuge was identified (Hoffman et al. 1990) as one of the areas where potentially toxic trace elements and dissolved solids could pose a threat to human health, fish, and wildlife.

Purpose and Scope

The purposes of this report are to: 1) investigate the degree of seasonal variability and its effects on the quality of irrigation drainage in the Newlands Project near Fallon, Nevada; 2) identify source areas of the Newlands Project where irrigation drainage contributes most to aquatic toxicity in Lahontan Valley; and 3) identify specific water quality parameters that contribute to toxicity of aquatic biota. During the summer of 1995, the U.S. Fish and Wildlife Service (USFWS), along with the U.S. Geological Survey (USGS), collected water samples from a variety of agricultural drains throughout Newlands Project in Lahontan Valley, Nevada. This was done as part of on-going water quality monitoring associated with the National Assessment of Water Quality Program studies conducted by the Department of the Interior. These samples were submitted for chemical residue analysis of selected trace elements and pesticides by USGS, and utilized by USFWS in two types of aquatic toxicity tests; 96-hour LC50 tests using *Daphnia magna*, and Microtox[®] procedure using a luminescent bacterium. Analytical results for specific conductance, total dissolved solids, sodium, arsenic, boron, lithium, molybdenum, and uranium in water samples were published by Lico and Pennington (1997). Analytical results not published by Lico and Pennington (1997) but included in our analysis of toxicity testing included alkalinity, aluminum, bicarbonate, chromium, dissolved oxygen, pH, phosphorus, fluoride, nickel, and zinc. These values are provided in combination with the published results from Lico and Pennington (1997) in Tables A1 and A2 in the Appendix of this report.

Description of Study Area

The Bureau of Reclamation completed the construction of the Newlands Project in the early 1900's after which large-scale irrigation began in Lahontan Valley. The Newlands Project

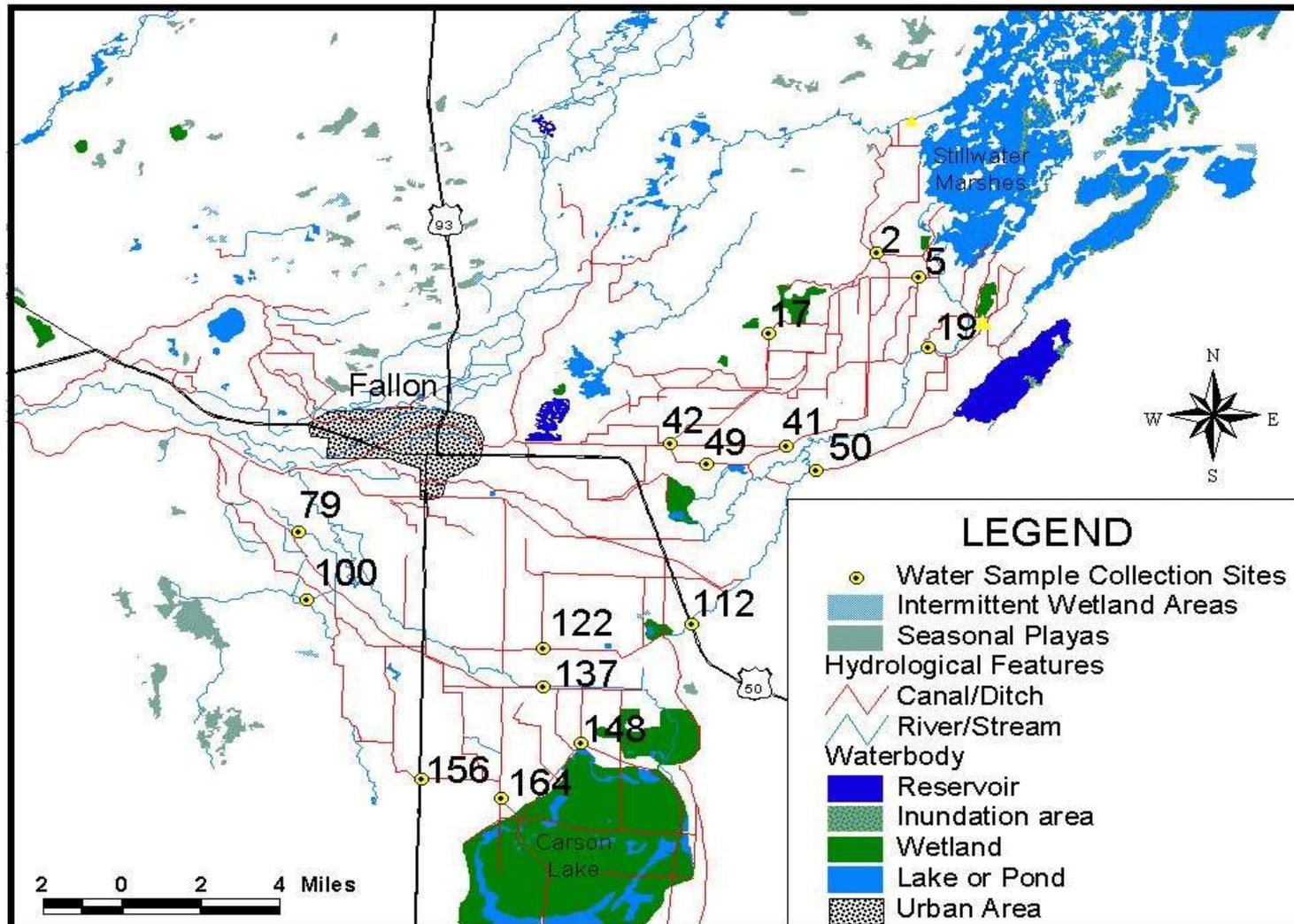
utilizes water stored in Lahontan Reservoir which is provided directly by the Carson River and a diversion from the Truckee River by way of the Truckee Canal. Historically, approximately 143,000 acre feet (AF) per year (1966-91) was diverted from the Truckee River into Lahontan Reservoir via the Truckee Canal whereas 266,000 AF/year (1911-91) was provided directly from the Carson River (Maurer et al. 1996). Water is typically released from the reservoir to the supply canals of the Newlands Project starting in March or April with the irrigation season ending in October or November depending on water availability and weather conditions. The distribution system consists of about 340 miles of canals and laterals (Maurer et al. 1996) and approximately 350 miles of open drains that route irrigation-return flow and groundwater seepage to wetlands at Carson Lake and Stillwater National Wildlife Refuge (Lico and Pennington 1997). Flow in these drains is highly variable and dependent on irrigation schedules, spillage of unused irrigation water, and ground-water levels near drains. Looking at hydrologic conditions during the period of study, the 1995 season was considered greater than a 100% water year with the official irrigation season delayed until March 31 and a precautionary release on April 3rd from Lahontan Reservoir. There were also very few April and May water deliveries throughout the Project with 4.32 inches of precipitation occurring in May. With the increased precipitation during this period, the irrigation season was subsequently extended until December 11. The terminus of the Carson River system received a greater than usual amount of release water during the irrigation season with an estimated 90,123 AF flowing past Sagouspe Dam. Stillwater National Wildlife Refuge received combined spill/drain flows of 7,066 AF from the D-line canal, 3,846 AF from the S-line canal, 16,548 AF from Diagonal drain, and 2,653 AF from the Paiute/TJ drain (Robert Bundy, USFWS, pers. comm., 2001). As a result, the wetlands on the Refuge went from 1,600 surface acres in March to 10,800 surface acres in December. A more detailed description on the operation and components of the Newlands Project can be found in reports by the Bureau of Reclamation (1987, 1994) and Maurer et al. (1994, 1996).

Methods

Water Collection

Water samples were collected in March, May, and August from a number of drains in Lahontan Valley by USGS personnel during the irrigation season of 1995 (Fig.1). These samples were analyzed for trace element residues and water quality parameters using protocols established for the National Water Quality Assessment Program (Shelton 1994). Samples were collected from 14 of the sites in August 1995 and submitted for analysis of common pesticides, including triazine herbicides, chlorophenoxy acid herbicides, carbamate insecticides, organochlorine insecticides, organophosphorous insecticides, amide insecticides, and some of their miscellaneous degradation products. Samples collected by USGS were split for three rounds of toxicity testing that were conducted by USFWS personnel. A description of collection sites was presented in Lico and Pennington (1997). All water samples for toxicity testing were collected using methods described by Shelton (1994) and filtered using a 0.45 µm filter. Filtered water was placed into 10 L Cubitainers® and chilled to 4°C for transport to the U.S. Geological Survey laboratory in Carson City, Nevada.

Figure 1. Data-collection sites and hydrologic features of the Newlands Project near Fallon, Nevada. See Lico and Pennington (1997) for information on numbered sampling sites.



Chemical Analysis

Chemical analysis of water samples collected by USGS was conducted by the National Water Quality Laboratory of the U.S. Geological Survey in Arvada, Colorado. Methods used for determining inorganic substances included inductively coupled plasma analysis, ion chromatography, colorimetric analysis, and hydride-generation atomic absorption analysis (Fishman and Friedman 1985, Fishman 1993). Pesticide residues were extracted from water samples using solid-phase extraction techniques described by Sandstrom et al. (1992) and Zaugg et al. (1995) and then analyzed using gas or high-performance liquid chromatography.

Water samples used for bioassays were placed on metal racks and stored at room temperature (20°C) during use. Temperature was maintained at 20°C by the laboratory's environmental control system, and water temperature was verified using an Ertco NIST-calibrated thermometer. Reference water was collected from Lahontan Reservoir and handled in a similar fashion. A photo-period of 16h light - 8h dark was maintained within the laboratory through the use of electric timer. Basic water quality parameters were measured at the beginning and end of each bioassay test. The parameters measured were temperature, pH, specific conductance, and dissolved oxygen using a Hydrolab® model H20 water quality meter. Temperature was also monitored by the chart recorder in the room. A 400 ml sample of water was required to operate the Hydrolab® water quality meter. A sufficient quantity of each test solution was made at the start of each test to allow measurement with the Hydrolab®. To accommodate measurement of water quality parameters at the end of each test, both 200 ml replicate solutions were combined to produce the 400 ml required for testing. Spent test solution and any remaining unused sample were then discarded.

A 150 ml subsample of each water sample was collected and taken to the Fish and Wildlife Service office in Reno, Nevada and refrigerated until used for Microtox® acute bioassay procedures.

LC50 *Daphnia magna* Bioassay

Culture and rearing of *Daphnia magna* test organisms followed methods described by the U.S. Environmental Protection Agency (EPA 1989). *Daphnia magna* test organisms were obtained from an established population at the University of Nevada-Reno. These organisms had been cultured in moderately hard reconstituted water and fed with algae (*Selenastrum capricornutum*) and a combination of yeast, cereal leaves, and partially digested trout chow (YCT) (EPA 1989). These organisms were placed in 20 L aquariums filled with filtered Lahontan Reservoir water and allowed to establish a brood colony. These organisms were fed daily with 110 ml YCT per 20L aquarium. The aquaria were cleaned by removing 15 L of water along with accumulated metabolic waste product every 7 days. This volume of water was replaced with an equal volume of fresh Lahontan Reservoir water. The population of daphnia was thinned following each round of testing to reduce overcrowding within the aquaria and reduce the possibility of producing male daphnia within the population.

Toxicity testing methods generally followed protocols established by EPA (1989). Some modifications to this method were required because of limited lab space and equipment. These methods and modifications are described below. Twenty-four hours prior to the initiation of testing, ripe female daphnia were selected from the brood colony and placed in 1 L beakers, 10-

20 per beaker, fed with 1.25 ml YCT, and allowed to sit for 24 h. At the end of the 24 h period, all neonates produced in the beaker were removed using an eye dropper and placed in one or two 250 ml beakers, depending on the number of neonates present.

Sample water was diluted with reference (Lahontan Reservoir) water to produce a dilution series of 0% (reference water), 12.5%, 25%, 50%, and 100% sample water. Each dilution of 200 ml was placed in a 250 ml beaker, and two replicate samples were prepared for each dilution, yielding a total of 10 test vessels for each site. After the 24 h-old neonates had been allowed to feed, 10 individuals were selected at random and placed into each test cell. Care was taken while transferring the neonates so as to cause as little stress as possible, and to not introduce too much dilution water into the test container.

Five tests were started each day for three days for a total of 15 concurrent tests in the March and May sampling periods. Physical water quality parameters (temperature, pH, specific conductance, and dissolved oxygen) were measured at the beginning and end of each test series using a Hydrolab® H20 water probe. One site was unavailable for sampling in August, resulting in 14 toxicity tests being conducted in that month. Test vessels were arranged by group in alternating order across the counter-top and underneath a fluorescent lamp which was set on a 16 h light - 8hr dark cycle. Tests were initiated as samples from each site were received. At approximately 0730 of each test day, 0.5 ml of YCT was placed into each test vessel and surviving neonates were allowed to feed for 2h. During this time, surviving daphnia and any neonates produced in the test vessel were counted and the information was recorded on laboratory worksheets. Then, 10% (20ml) of test solution, including any dead daphnia, newly produced neonates or other accumulated solid materials, was siphoned from the bottom of each test vessel, and replaced with fresh solution, which was made daily. Death was defined as a lack movement after gentle prodding. These steps were repeated daily for 10 d, at which time the surviving neonates were counted and reproduction noted, if present.

Microtox® Acute Bioassay

The method of Microtox® acute toxicity testing exposes the luminescent bacterium *Vibrio fischeri* (formerly known as *Photobacterium phosphoreum*) in a reagent to sample water, and measures the increase or decrease of light output by the bacterium. The light output of the bacterium is compared to the light output of a reagent blank that contains no sample. Dilutions of water taken from each sample site were prepared and added to a suspension of bacterium in a cuvette and allowed to reach an equal temperature of 15°C. Three light emission values were recorded for each cuvette at 0, 5, and 15 minute intervals. For a more detailed description of techniques for performing these tests, refer to Henry and Hickey (1991).

Statistical Analysis

LC50 values of *Daphnia magna* and their associated 95% confidence intervals data were estimated for each toxicity test using Probit analysis, provided that data met the assumption of a normal distribution of log tolerances. To test normal distribution, Chi-square and Shapiro Wilk's tests were conducted ($p \leq 0.01$) using Toxstat software.

Measurements from the Microtox[®] acute bioassays at the 5 and 15-minute intervals were compared with initial light level readings at the start of the test (0-minute interval). An effective concentration that reduced light output to fifty percent in test organisms (EC-50) was calculated using the gamma function:

$$\text{gamma} = \text{amount of light lost during test} / \text{light remaining at a particular time}$$

A log-log graph of gamma versus concentration was plotted and an EC-50 value was determined by interpolation.

For each of the three sets of tests conducted by this study, Pearson correlation coefficient values were calculated between trace element concentrations in sample water and both mean values and arc-sine transformed mean values for *D. magna* mortalities at 100% sample concentration. Pearson correlations between mortality and individual or combined constituent concentrations were made using the Systat (v.10) software package. In order to concentrate exclusively on parameters exhibiting a potential relationship to *D. magna* mortality and have statistically calculable results, parameters were eliminated from analysis if they met the following criteria; 1) trace element concentrations were not detected in any sample, 2) trace element concentrations were detected at reportable concentrations, but in less than 50% of the samples, and 3) remaining trace element concentrations for all samples had calculated Pearson correlation coefficient values less than 0.40. After applying these criteria, a total of 14 water quality parameters remained (Table 1). Pearson correlation values were then calculated for remaining constituents in each sampling event conducted in 1995 (Tables 2 through 4). Concentrations of constituents were tested for normality using Lillefors Test along with median values for each constituent by sampling period (Table 5). Concentrations of constituents were then subjected to Kruskal-Wallis one-way ANOVA tests to identify the medians (M) of constituents that were different among sampling events ($p \leq 0.05$) (Table 6). Mann-Whitney tests were then conducted to identify which sampling events were different for each constituent (Table 7). Constituents that were identified as significantly different for each sampling period were then compared to Pearson correlations of *D. magna* mortality to determine whether or not there were parallel differences in water quality parameters. Constituent concentrations and bioassay results from water samples can be found in Tables A1 and A2 in the Appendix at the end of this report.

Table 1. List of inorganic constituents used to evaluate toxicity, by month.

<u>Constituent</u>	<u>Detected in March</u>	<u>Detected in May</u>	<u>Detected in August</u>
Arsenic			X
Bicarbonate	X		X
Boron	X		X
Chromium	X		X
Dissolved Alkalinity			X
Dissolved Phosphorus			X
Fluoride			X
Lithium		X	
Molybdenum	X		
Nickel		X	X
Specific Conductance	X	X	X
Total Dissolved Solids	X	X	X
Uranium	X	X	X
Zinc		X	

Table 2. Pearson correlation coefficients for individual trace elements compared to mortality and the arc-sine transformed mortality for tests conducted in March, 1995.

Constituent	Pearson Value	P	Arc-Sine Pearson Value	Arc-Sine P
Uranium ($\mu\text{g/L}$)	0.718	0.003	0.773	0.001
Boron ($\mu\text{g/L}$)	0.706	0.003	0.741	0.002
Chromium ($\mu\text{g/L}$)	0.643	0.010	0.669	0.006
Specific Conductance ($\mu\text{S/cm}$)	0.633	0.011	0.659	0.008
Total Dissolved Solids ($\text{mg/L @ } 180^\circ\text{C}$)	0.622	0.013	0.650	0.009
Bicarbonate (mg/L as HCO_3)	0.554	0.032	0.598	0.019
Molybdenum ($\mu\text{g/L}$)	0.521	0.046	0.572	0.026

Table 3. Pearson correlation coefficients for individual trace elements compared to mortality and the arc-sine transformed mortality for tests conducted in May, 1995.

Constituent	Pearson Value	P	Arc-Sine Pearson Value	Arc-Sine P
Zinc ($\mu\text{g/L}$)	0.635	0.011	0.724	0.002
Nickel ($\mu\text{g/L}$)	0.600	0.018	0.701	0.004
Specific Conductance ($\mu\text{S/cm}$)	0.576	0.025	0.679	0.005
Total Dissolved Solids ($\text{mg/L @ } 180^\circ\text{C}$)	0.575	0.025	0.679	0.005
Lithium ($\mu\text{g/L}$)	0.526	0.044	0.632	0.011
Uranium ($\mu\text{g/L}$)	0.464	0.081	0.566	0.028

Table 4. Pearson correlation coefficients for individual trace elements compared to mortality and the arc-sine transformed mortality for tests conducted in August, 1995.

Constituent	Pearson Value	P	Arc-Sine Pearson Value	Arc-Sine P
Specific Conductance (µS/cm)	-0.392	0.166	-0.347	0.224
Boron (µg/L)	-0.396	0.180	-0.356	0.233
Fluoride (µg/L)	-0.394	0.183	-0.360	0.226
Total Dissolved Solids (mg/L @ 180°C)	-0.404	0.171	-0.362	0.224
Bicarbonate (mg/L as HCO ₃)	-0.396	0.181	-0.370	0.214
Alkalinity- dissolved (mg/L as CaCO ₃)	-0.412	0.162	-0.390	0.187
Uranium (µg/L)	-0.444	0.128	-0.396	0.180
Arsenic (µg/L)	-0.419	0.154	-0.399	0.177
Phosphorus- dissolved (mg/L)	-0.414	0.160	-0.401	0.174
Chromium (µg/L)	-0.430	0.143	-0.404	0.171
Nickel (µg/L)	-0.522	0.067	-0.493	0.087

Table 5. Tests for normality on constituent concentrations from March to August, 1995.

Month	Constituent	Lillefors Probability (2-tail)	Median	Mean	Skewness	Std. Error Skewness (SES)	Skewness: SES Ratio	Kurtosis	Std. Error Kurtosis SEK	Kurtosis: SEK Ratio
March	Arsenic	0.030	58.5	87.187	2.302	0.564	4.082	6.294	1.091	5.769
	Bicarbonate	0.003	367.5	402.937	1.316	0.564	2.333	0.986	1.091	0.904
	Boron	0.030	3800	6566.875	2.258	0.564	4.004	5.185	1.091	4.753
	Chromium	<0.001	3.5	4.312	2.277	0.564	4.037	5.085	1.091	4.661
	Alkalinity	0.001	314.5	347.687	1.441	0.564	2.555	1.825	1.091	1.673
	Phosphorus	<0.001	0.18	0.632	1.969	0.580	3.395	3.125	1.121	2.788
	Fluoride	0.005	0.65	0.706	1.104	0.564	1.957	0.676	1.091	0.620
	Lithium	<0.001	85	220.625	3.764	0.564	6.674	14.609	1.091	13.390
	Molybdenum	<0.001	46.5	111.625	2.724	0.564	4.830	8.525	1.091	7.814
	Nickel	0.003	4	6.250	2.402	0.564	4.259	6.311	1.091	5.785
	Sp. Cond.	<0.001	3765	5720.000	2.790	0.564	4.947	8.581	1.091	7.865
	TDS	<0.001	2425	3858.000	2.874	0.564	5.096	8.928	1.091	8.183
	Uranium	0.011	42.5	70.250	1.702	0.564	3.018	2.485	1.091	2.278
Zinc	0.009	5	7.467	1.646	0.580	2.838	2.067	1.121	1.844	
May	Arsenic	0.473	34.5	36.375	0.766	0.564	1.358	0.012	1.091	0.011
	Bicarbonate	0.001	249	261.313	1.753	0.564	3.108	2.792	1.091	2.559
	Boron	<0.001	710	2837.500	3.624	0.564	6.426	13.546	1.091	12.416
	Chromium	<0.001	2	3.125	3.047	0.564	5.402	9.821	1.091	9.002
	Alkalinity	<0.001	210	229.063	2.021	0.564	3.583	4.238	1.091	3.885
	Phosphorus	0.007	0.23	0.272	2.061	0.564	3.654	5.344	1.091	4.898
	Fluoride	<0.001	0.45	0.481	2.648	0.564	4.695	5.344	1.091	4.898
	Lithium	<0.001	60	78.125	3.429	0.564	6.080	12.492	1.091	11.450
	Molybdenum	<0.001	19	31.312	2.089	0.564	3.704	3.359	1.091	3.079
	Nickel	<0.001	3	4.600	3.739	0.580	6.447	14.257	1.121	12.718
	Sp. Cond.	<0.001	753	2581.000	3.799	0.564	6.736	14.740	1.091	13.511
	TDS	<0.001	477.5	1912.938	3.881	0.564	6.881	15.269	1.091	13.995
	Uranium	<0.001	20	33.188	2.858	0.564	5.067	8.211	1.091	7.526
Zinc	<0.001	2	3.933	3.471	0.580	5.984	12.611	1.121	11.250	

Table 5 (cont.). Tests for normality on constituent concentrations from March to August, 1995.

Month	Constituent	Lillefors Probability (2-tail)	Median	Mean	Skewness	Std. Error Skewness (SES)	Skewness: SES Ratio	Kurtosis	Std. Error Kurtosis SEK	Kurtosis: SEK Ratio
August	Arsenic	0.396	31.000	30.500	-0.580	0.597	-0.972	0.521	1.154	0.451
	Bicarbonate	1.000	253.000	247.400	-0.029	0.580	-0.050	0.016	1.121	0.014
	Boron	<0.001	660.000	1310.714	3.572	0.597	5.983	13.066	1.154	11.322
	Chromium	0.074	2.000	2.500	1.329	0.597	2.226	2.558	1.154	2.217
	Alkalinity	0.516	214.500	203.714	-0.278	0.597	-0.466	-0.576	1.154	-0.499
	Phosphorus	0.205	0.260	0.286	0.094	0.597	0.157	-0.585	1.154	-0.507
	Fluoride	0.114	0.400	0.421	-0.492	0.597	-0.824	0.220	1.154	-0.507
	Lithium	0.075	50.000	63.571	1.409	0.597	2.360	1.633	1.154	1.415
	Molybdenum	0.022	15.000	20.429	1.755	0.597	2.940	2.431	1.154	2.107
	Nickel	0.089	3.500	3.643	4.760	0.597	7.973	-0.132	1.154	-0.114
	Sp. Cond.	0.025	795.500	840.857	0.658	0.597	1.102	-0.242	1.154	-0.210
	TDS	<0.001	498.500	827.286	3.625	0.597	6.072	13.369	1.154	11.585
	Uranium	0.013	13.000	15.143	2.481	0.597	4.156	7.853	1.154	6.805
	Zinc	0.005	2.000	1.692	0.611	0.616	0.992	-0.776	1.191	-0.652

Table 6. Kruskal-Wallis Test to detect differences in constituent concentrations among sampling events from March to August, 1995.

Constituent	<i>As</i>	<i>Bicarb</i>	<i>B</i>	<i>Cr</i>	<i>Alk</i>	<i>P</i>	<i>F</i>	<i>Li</i>	<i>Mb</i>	<i>Ni</i>	<i>SpCond</i>	<i>TDS</i>	<i>U</i>	<i>Zn</i>
Kruskal-Wallis Statistic	9.358	16.435	14.431	5.353	20.030	0.545	23.700	12.930	11.233	1.437	14.618	12.476	21.630	8.039
Probability> Kruskal-Wallis Statistic	0.009	<0.001	0.001	0.069	<0.001	0.761	<0.001	0.002	0.004	0.488	0.001	0.002	<0.001	0.018

Trace elements are denoted by chemical symbol; Bicarb= bicarbonate; Alk= alkalinity; SpCond= specific conductance.

Table 7. Summary of Mann-Whitney U Tests to determine which sampling event was different for each constituent compared to other sampling events from March to August, 1995.

Variable	March vs. May		May vs. August		March vs. August	
	χ^2	Probability	χ^2	Probability	χ^2	Probability
Arsenic	4.783	0.029	0.293	0.589	8.850	0.003
Bicarbonate	11.387	0.001	0.066	0.797	12.942	<0.001
Boron	8.873	0.003	0.692	0.405	11.765	0.001
Alkalinity	12.820	<0.001	0.052	0.819	16.937	<0.001
Fluoride	15.563	<0.001	0.590	0.443	18.566	<0.001
Lithium	10.213	0.001	1.247	0.264	8.434	0.004
Molybdenum	6.969	0.008	1.173	0.279	8.604	0.003
Specific Conductance	8.642	0.003	0.209	0.647	12.781	<0.001
TDS	8.205	0.004	0.787	0.073	10.116	0.001
Uranium	11.142	0.001	3.356	0.067	17.823	<0.001
Zinc	3.106	0.082	1.515	0.218	7.384	0.007

RESULTS AND DISCUSSION

Trace Element and Water Quality Analysis

Water quality based upon *D. magna* mortality is commonly expressed as an LC50 value calculated from whole effluent toxicity tests such as those conducted in this study using U.S. Environmental Protection Agency protocol. Toxicity tests conducted on water samples from this study, with the exception of two tests on separate sampling events, did not meet the test acceptability criteria of 90% survival in controls as defined by U.S. Environmental Protection Agency (1993). Therefore, for purposes of comparison and discussion, water quality data were compared based upon mortality values from 100% effluent. An explanation for not meeting criteria may be that water used for controls and test dilutions in the bioassays came from Lahontan Reservoir which is known to contain elevated concentrations of mercury, and is part of the EPA Superfund-listed Carson River Mercury Site. However, mercury was not analyzed as a part of this study and determinations about potential effects to bioassay results cannot be made.

Alkalinity (Dissolved)

Dissolved alkalinity values, expressed as mg/L CaCO₃, ranged from 98 to 610 µg/L as measured in the lab (Table A1). There were significant differences in alkalinity concentrations among sampling events ($p < 0.001$). Concentrations in March were higher (M= 314.5 µg/L) and significantly different compared to May (M= 210 µg/L; $p < 0.001$) and August (M= 214.5 µg/L; $p < 0.001$). There was not a significant difference in concentrations between May and August. However, alkalinity concentrations were not significantly correlated with arc-sine transformed *D. magna* mortality for any sampling event. Alkalinity is the capacity of water to react with and neutralize acid and is primarily caused by bicarbonates and carbonates dissolved in water. In the reactions that produce alkalinity in the water column, bicarbonates predominate at pH levels between 6.5 to about 10.0, which is in the range of pH values measured in this study. Alkalinity has been shown to minimize the toxicity of certain metals (Sprague 1985) which could explain the inverse relationship to mortality.

Arsenic

Dissolved arsenic concentrations in test water taken from sampling sites ranged from 10 to 360 µg/L (Table A2). There were significant differences in concentrations among sampling events ($p = 0.009$). Concentrations in March were higher (M= 58.5 µg/L) and significantly different compared to May (M= 34.5 µg/L; $p = 0.029$) and August (M= 31 µg/L; $p = 0.003$). There was not a significant difference in concentrations between May and August. Pearson correlation analysis did not show significant associations between arsenic concentrations and *D. magna* mortality for all the sampling events. The chronic (96-hour) LC50 for *D. magna* to arsenic is 7,440 µg/L and arsenic can be acutely toxic to other invertebrates at concentrations as low as 810 µg/L (EPA 1985). Concentrations in this study did not reach a toxic level that would be of a concern to aquatic biota.

Bicarbonate

Bicarbonate concentrations in field measurements of test water ranged from 118 - 744 mg/L as HCO₃ (Table A1). There was significant differences in concentrations among sampling events ($p < 0.001$). Concentrations in March were higher (M= 367.5 µg/L) and significantly different compared to May (M= 249 µg/L; $p = 0.001$) and August (M= 253 µg/L; $p < 0.001$). There was not a significant difference in concentrations between May and August. Pearson correlation analysis showed a moderate association with arc-sine transformed *D. magna* mortality during the March sampling event that was significant ($r = 0.598$; $p = 0.019$). Little is known about the toxic effects of bicarbonate ion to *D. magna*. A form of bicarbonate, sodium bicarbonate, is one ingredient of “reconstituted” water used for rearing and dilution water for some acute and chronic toxicity tests (EPA 1991). However, it is unlikely that the bicarbonate ion in this system originates from calcium carbonate due to the limited solubility of carbonate at pH levels above 8.3. It is possible that the bicarbonate ion, in unknown complexes with other constituents, may explain the observed mortality correlation in March. However, it is unlikely that the bicarbonate concentrations individually are responsible for the observed mortality.

Boron

Dissolved concentrations of boron in test waters ranged from 290 to 32,000 µg/L (Table A2). There were significant differences in concentrations among sampling events ($p = 0.001$). Concentrations in March were higher (M= 3800 µg/L) and significantly different compared to May (M= 710 µg/L; $p = 0.003$) and August (M= 660 µg/L; $p = 0.001$). There was not a significant difference in concentrations between May and August. The Pearson correlation analysis showed a significant correlation to arc-sine transformed mortality during the March sampling event ($r = 0.741$; $p = 0.002$). The 48-hour LC₅₀ for *D. magna* to boron ranges from 133,000 and 226,000 µg/L (Perry and Suffet 1993). *D. magna* mortality from chronic (21-day LC₅₀) exposure to boron as boric acid has been observed at concentrations ranging from 52,200 to 53,200 µg/L with a maximum allowable toxicant concentration (MATC), determined by analyzing sublethal effects on growth and reproduction, between 6,000 to 13,000 µg/L (Lewis and Valentine 1981; Gersich 1984). Concentrations in water exceeded the MATC at 5 of 14 sites studied. Of the 5 sites exceeding the MATC, all occurred during the March sampling event with the exception of site 49 (March, May, August) and site 156 (March, May). Boron concentrations were also significantly positively correlated to specific conductance measurements ($r^2 = 0.95$; $p \leq 0.05$) which is consistent with other previous studies conducted in Lahontan Valley (Hoffman et al. 1990; Lico 1992; Lico and Pennington 1997; Tuttle et al. 2000). As a note, in 1995 the State of Nevada eliminated the boron criterion (550 µg/L) for the protection of aquatic life.

Chromium

Dissolved chromium concentrations in water ranged from 1 to 15 µg/L (Table A2) and showed a significant correlation to arc-sine transformed mortality ($r = 0.669$; $p = 0.006$) during the March sampling period. However, median concentrations for all sampling events were similar (March= 3.5 µg/L, May= 2 µg/L, August= 2 µg/L). As expected, there were no significant differences in concentrations among sampling events. Chromium in the environment is usually found in the more stable trivalent (Cr⁺³) form followed by the less common hexavalent (Cr⁺⁶)

form. Toxicity of chromium is affected by various water chemistry variables such as pH, temperature, and more importantly water hardness. In general, waters with lower pH and hardness levels increase the toxic effects of Cr. The acute 96-hour LC-50 for *D. magna* to chromium at a water hardness of 215 (mg of CaCO₃) is 58,700 µg/L (EPA 1980). Reduction in fecundity and survival of *D. magna* also has been observed at concentrations of 44.0 µg/L Cr⁺³ and 10.0 µg/L Cr⁺⁶ (U.S. Environmental Protection Agency 1980). The short-term acute toxicity 24-hour LC50 for *D. magna* to chromium was 435 µg/L (Jouany et al. 1982; as cited in Eisler 1986). Given the range of concentrations in this study, possible reduction in survival and reproduction to *D. magna* could occur. However, concentrations of chromium were not at a level of concern for producing toxic effects in the bioassays.

Fluoride

Dissolved fluoride concentrations in test waters ranged from 0.2 to 1.2 mg/L (Table A2). There were significant differences in concentrations among sampling events ($p < 0.001$). Concentrations in March were higher (M= 0.65 µg/L) and significantly different compared to May (M= 0.45 µg/L; $p < 0.001$) and August (M= 0.4 µg/L; $p < 0.001$). There was not a significant difference in concentrations between May and August. Pearson correlation analysis did not show significant associations between fluoride concentrations and *D. magna* mortality for all sampling events. Fieser (1986) determined 48-hour LC50 values ranging between 109 to 354 mg/L for *D. magna* to fluoride. Estimates for 24-hour LC50 values have been determined as high as 680 mg/L (LeBlanc 1980). Toxic effects of fluoride resulting in *D. magna* mortality begin to occur at much higher concentrations than observed in this study.

Lithium

Dissolved lithium concentrations ranged from 20 to 1,700 µg/L (Table A2). There were significant differences in concentrations among sampling events ($p = 0.002$). Concentrations in March were higher (M= 85 µg/L) and significantly different compared to May (M= 60 µg/L; $p = 0.001$) and August (M= 50 µg/L; $p = 0.004$). There was not a significant difference in concentrations between May and August. Pearson correlation analysis showed a moderate correlation with mortality during the March sampling period ($r = 0.526$; $p \leq 0.05$). Lithium is suspected to interact with other elements (arsenic, boron, and molybdenum) to elicit toxic effects in aquatic organisms (Finger et al. 1993). However, very little is known about the effects of lithium to fish and wildlife, and water quality criteria do not exist for this element.

Molybdenum

Dissolved concentrations of molybdenum ranged from 7 to 615 µg/L (Table A2). There was significant differences in concentrations among sampling events ($p = 0.004$). Concentrations in March were higher (M= 46.5 µg/L) and significantly different compared to May (M= 19 µg/L; $p = 0.008$) and August (M= 15 µg/L; $p = 0.003$). There was not a significant difference in concentrations between May and August. Pearson correlation analysis showed a moderate association with Arc-Sine transformed *D. magna* mortality during the March sampling period ($r = 0.572$; $p = 0.026$). The Nevada criterion established for protection of aquatic life is 19 µg/L (Nevada Administrative Code 445A.144). Sixty-three percent (29 of 46) of the samples collected

for the bioassays exceeded the Nevada criterion for protection of aquatic life. Aquatic organisms generally are fairly resistant to molybdenum and show no adverse effects on growth or survival at water concentrations lower than 50,000 µg/L (Eisler 1989). For example, the 96-hour LC50 for the amphipod *Crangonyx pseudogracilis* to molybdenum was 2,650,000 µg/L (Martin and Holdich 1986). Certain species of aquatic algae and invertebrates have a capacity to bioconcentrate high levels of molybdenum without detrimental effects to the organism. However, it is uncertain if molybdenum will bioaccumulate into higher trophic levels.

Nickel

Dissolved nickel concentrations in test waters ranged from 1 to 27 µg/L (Table A2). Nickel concentrations were not significantly different among sampling events. Pearson correlation analysis, however, showed a strong correlation with arc-sine transformed mortality of *D. magna* for the May sampling event ($r= 0.701$, $p=0.004$). The 48-hour LC50 for the daphnid *Ceriodaphnia dubia* is 13.0 µg/L at a pH of 8.0 to 8.5 (Schubauer-Berigan et al. 1993). Kszos et al. (1992) determined the LC50 for *D. magna* to nickel as NiCl₂ to be 2.28 and 3.11 µg/L at a hardness of 42 and 117 mg/L respectively. Nickel occurs in aquatic systems as soluble salts strongly adsorbed to or associated with clay particles, organic matter, and other particles. Nickel salts in combination with metal mixtures (arsenic, cadmium, copper, chromium, lead, zinc) are more toxic to daphnids and fishes than are predicted toxicities based upon the individual components (Enserink et al. 1991). In combination with other metals, nickel may also have an increased toxic effect to aquatic organisms. However, predictions of nickel toxicity in combination with other metals is outside the scope of this study.

Phosphorus

Dissolved phosphorus concentrations ranged from 0.01 to 2.3 mg/L (Table A2). There were no significant differences in concentrations among sampling events. Dissolved phosphorus was not significantly correlated with arc-sine transformed mortality of *D. magna*. Phosphorus is an essential micronutrient to many forms of aquatic biota (Wetzel 1983). Aquatic macrophytes can potentially act as an important sink of phosphorus from the water column during the irrigation season. Release of phosphorus from decaying macrophytes is mineralized quickly, and can be used by bacterial and algal metabolism (Landers 1982). The decay of macrophytes in drains and agricultural fields, and the dissolution of phosphorus from fertilizer use in flood-irrigated agricultural fields possibly contributed to the release of phosphorus into irrigation-return water within drains. The 24-hour EC50 for *D. magna* to orthophosphate (inorganic soluble phosphorus) was >5000 mg/L (Galli et al. 1994) which is well above concentrations determined from this study by several orders of magnitude.

Specific Conductance

Specific conductance values measured in the lab ranged from 397 to 31,200 µS/cm (Table A1). There were significant differences in concentrations among sampling events ($p= 0.001$). Values in March were higher (M= 3765 µS/cm) and significantly different compared to May (M= 753 µS/cm; $p= 0.003$) and August (M= 795.5 µS/cm; $p< 0.001$). There was not a significant difference in concentrations between May and August. Specific conductance was correlated with

the arc-Sine transformed *D. magna* mortality in March ($r= 0.659$; $p \leq 0.05$) and May ($r= 0.679$; $p \leq 0.05$). Specific conductance is a measure of the ability of an aqueous solution to transmit an electric current, and is related to the concentrations of dissolved ions in the solution. Specific conductance is not, in and of itself toxic, as it is an expression of the total amount of potentially toxic constituents present in the water. It should not be surprising, therefore, that specific conductance is strongly correlated with observed mortality in a solution with a large number of dissolved, inorganic constituents. In addition, effects to freshwater aquatic organisms can occur at specific conductance values observed in this study from an inability to maintain an osmotic balance.

Total Dissolved Solids

Total dissolved solids (TDS) values ranged from 248 to 22,300 mg/L (Table A1). There was significant differences in concentrations among sampling events ($p= 0.002$). Concentrations in March were higher (M= 2425 mg/L) and significantly different compared to May (M= 477.5 $\mu\text{g/L}$; $p= 0.004$) and August (M= 498.5 mg/L; $p= 0.001$). There was not a significant difference in concentrations between May and August. TDS concentrations were significantly correlated with arc-sine transformed mortality of *D. magna* for the March and May sampling events (March: $r= 0.650$, $p \leq 0.05$; May: $r= 0.679$, $p \leq 0.05$). TDS is closely related to salinity and for most purposes they are equivalent (EPA 1986). Effects to *D. magna* from salinity were determined previously within Lahontan Valley by Dwyer et al. (1992) and Ingersoll et al. (1992) using reconstituted water similar in nature to water received in drain-water by Stillwater National Wildlife Refuge. Using results from these studies, levels of concern for effects to *D. magna* were determined to be at concentrations from 300 to 6000 parts per million (Dwyer et al. 1992; as cited in U.S. Department of the Interior 1998). The toxicity threshold for *D. magna* was determined to be at concentrations from 6000 to 10,000 parts per million (Ingersoll et al. 1992; as cited in U.S. Department of the Interior 1998). Using these values for comparison, 93 percent of all samples (43 of 46) exceeded the level of concern and 4 percent of samples (2 of 46) exceeded the toxicity threshold.

Uranium

Dissolved concentrations in test waters ranged from 0.3 to 239 $\mu\text{g/L}$ (Table A2). There were significant differences in concentrations among sampling events ($p < 0.001$). Concentrations in March were higher (M= 42.5 $\mu\text{g/L}$) and significantly different compared to May (M= 20 $\mu\text{g/L}$; $p= 0.001$) and August (M= 13 $\mu\text{g/L}$; $p < 0.001$). There was not a significant difference in concentrations between May and August. Uranium concentrations were significantly correlated with arc-sine transformed *D. magna* mortality during the March sampling event ($r= 0.773$; $p= 0.001$). Uranium concentrations during the May sampling event were also correlated with arc-sine transformed *D. magna* mortality ($r= 0.566$; $p= 0.028$). There is a substantial amount of information on the radiological toxicity of uranium. However, there is very limited information on its chemical toxicity. In 1991, the State of Colorado established water quality standards based upon chemical toxicity concerns that are hardness dependent. The chronic aquatic life water quality standard in the State of Colorado at a water hardness of 100 mg/L (as CaCO_3) is 1500 $\mu\text{g/L}$. Environment Canada recommends a level for the protection of

aquatic life at 300 µg/L (Environment Canada 1983). Concentrations in all test waters exceeded those which are considered natural background levels, but were below benchmarks recommended for protection of aquatic life.

Zinc

Dissolved zinc concentrations in test waters ranged from 1 to 28 µg/L (Table A2). There was significant differences in concentrations among sampling events ($p= 0.018$). Concentrations in March were higher ($M= 5 \mu\text{g/L}$) and significantly different compared to August ($M= 2.0 \mu\text{g/L}$; $p= 0.007$). March concentrations were not significantly different compared to May. There was not a significant difference in concentrations between May and August. Zinc concentrations were significantly correlated with arc-sine transformed *D. magna* mortality during the May sampling event ($r= 0.724$; $p=0.002$). Algae are effective accumulators of zinc. Bioconcentration factors for zinc and various species of algae are quite variable and usually range from 76 to 163,750 (Vymazal 1986; U.S. Environmental Protection Agency 1987). Periods of low flow in canals and drains combined with elevated temperatures during the irrigation season (May) could have provided an environment conducive to algae accumulation and reduction of zinc from the water column. Suter and Mabrey (1994) determined a value of $<30 \mu\text{g/L}$ to be the lowest chronic value for all aquatic organisms. Mixtures of zinc and nickel are known to be additive in toxicity to many aquatic organisms (Enserink et al. 1991). Although zinc concentrations were below those associated with aquatic organism mortality, interactions with other metals such as nickel can increase its toxic effects. However, determination of metal mixtures to *D. magna* mortality is outside the scope of this study.

Microtox® Bioassay Analysis

All forty-five samples submitted to the Microtox assay produced a light output $>100\%$ compared with initial light level readings at the start of the test. Therefore, no effective concentration was determined for any sample tested. A possible explanation could be that the species of bacterium used in the Microtox® methodology is a marine species (*Photobacterium phosphoreum*), and most of the contaminants present in agricultural drains are inorganic salts. Microtox® returned an EC50 value of for all samples tested. Microtox® would have been expected to respond to any other anthropogenic compounds present in the drain-water (e.g. herbicides, insecticides): however, the reported concentrations (Lico and Pennington 1997) of these compounds are below the EC50 concentrations reported in Henry and Hickey (1991) by several orders of magnitude.

Pesticide Analysis

Pesticides of the chlorophenoxy acid, organochlorine, and amide families were not detected in samples tested by this study. The following eight pesticides and related compounds were detected at 13 of the sites tested in August 1995, either individually or in combination; atrazine, deethylated atrazine, carbofuran, EPTC, malathion, prometon, propargite, and simazine (Table 8). However, all pesticide detections were at concentrations less than 1 microgram per liter. Low detections of pesticides in Lahontan Valley during the August sampling period could be a result of elevated flows in drains diluting concentrations present in drain-water. Low detections of pesticides could also be the result of sampling during non-peak periods of certain pesticide applications. Regardless of the reason, concentrations of pesticides detected in drain-water were never near levels associated with aquatic toxicity.

Table 8. Pesticide concentrations in filtered water samples in August 1995 from drains near Fallon, Nevada (from Lico and Pennington1997). Concentrations are in µg/l.

Site Number	Deethylated							
	Atrazine	Carbofuran	Atrazine	EPTC	Malathion	Prometon	Propargite	Simazine
2	0.004	--	--	--	--	--	--	e.005
5	0.005	e.026	--	--	--	--	--	e.004
17	--	--	--	--	--	--	--	--
19	0.006	e.004	--	--	--	0.02	--	e.004
41	0.009	--	--	--	--	0.023	--	e.004
42	0.008	--	e.002	--	--	0.022	--	e.005
49	--	--	--	--	--	e.004	--	e.003
79	0.023	--	e.009	--	--	e.005	--	--
100	0.023	--	e.004	0.009	--	--	--	e.003
112	e.004	e.005	e.002	0.014	0.05	--	--	e.005
122	--	--	--	e.002	--	e.009	e.003	e.005
137	0.007	--	e.003	0.042	--	--	--	e.004
148	0.007	--	e.003	0.021	--	e.005	--	e.004
164	0.017	--	e.005	e.003	--	--	--	--

Symbols: e, estimated; --, less than certified reporting limit

Geographic Analysis

As mentioned previously, water flows through a complex system which includes approximately 340 miles of delivery canals and laterals, and approximately 350 miles of return flow and shallow groundwater seep drains (Maurer et al. 1994). Water flowing through the Newlands Project Area drains into two primary drainage groups, Carson Lake and Stillwater Wetlands. Lico and Pennington (1997) divided these drain groups into 10 individual drain systems. Samples for this study were collected from six of the 10 drain systems. Drainage

systems from which samples were collected by this study were arranged by drain group, and then in an upstream to downstream order (Table 9). This is a general description of the ordering of the drains, as some of the drains overlap in terms of which one is the furthest upstream or downstream within the complex Newlands Project Area drainage system. Samples tested by this study were then ordered within their respective drain system in an upstream to downstream order. It should be noted that, simply because one sample site is listed before another sample site within the same drain group does not necessarily mean that the two sites are directly linked in terms of water source or water quality.

In order to get a perspective of toxic effects from drain-water, a short discussion on the quality of the source water for irrigation is pertinent. Water released from Lahontan Reservoir is historically low in dissolved solids ranging from 150 to 500 mg/L (Hoffman et al. 1990; Lico 1992). As mentioned previously under the section “Description of Study Area”, the rates of water release from Lahontan Reservoir are highly variable and depend on a number of

Table 9. Description of USGS sample collection sites used in this study for bioassay tests and listed in general down-gradient order by drain system within drain group.

CARSON LAKE GROUP	Site #
<i>CARSON LAKE DRAIN SYSTEM</i>	
Sheckler drain at St. Clair Road near Fallon, NV	79
Upper West Side drain at Solias Road near Fallon, NV	100
Carson Lake 1 drain on Pasture Road near Carson Lake, NV	156
Carson Lake drain above Carson Lake near Fallon, NV	164
<i>L-DRAIN SYSTEM</i>	
"L" drain at NE corner of Pasture Road and Depp Lane, near Fallon, NV	137
"L" drain above Lee drain near Fallon, NV	148
STILLWATER WETLANDS GROUP	
<i>LOWER DIAGONAL DRAIN SYSTEM</i>	
Lower Diagonal drain at Pasture Road near Fallon, NV	122
Lower Diagonal drain at U.S. Hwy 50 near Fallon, NV	112
Stillwater Point Reservoir Diversion Canal near Stillwater, NV	50
<i>HARMON DRAIN SYSTEM</i>	
S2G drain at Stuart Road near Harmon Reservoir, NV	49
Harmon drain at NV 116 near Fallon, NV	42
Harmon drain at Ditch House Road near Fallon, NV	41
<i>UPPER PAIUTE DRAIN SYSTEM</i>	
S5A drain at Austin Road near Fallon, NV	17
Paiute Diversion drain near Fallon Indian Reservation, NV	2
<i>STILLWATER SLOUGH-KENT LAKE DRAIN SYSTEM</i>	
Stillwater Slough at Stillwater, NV	19
Kent Lake drain at Freeman Road near Stillwater, NV	5

factors such as time of year, irrigation schedule, and water storage in the reservoir. It has been documented that drains throughout the Newlands Project Area have extreme variability in water quality (Hoffman et al.1990; Lico 1992). Flows in drains during the irrigation season can also be

highly variable. As a result, dramatic daily changes in various water quality parameters are possible (Finger et al. 1993). Upstream parts of the system are particularly variable due to dependence on nearby irrigation whereas larger drains in the lower portion are less variable (Lico and Pennington, 1997). Flow measurements conducted by Lico and Pennington (1997) during sampling events for this study averaged 0.689, 9.57, and 13.94 cubic feet per second for the March, May, and August period respectively.

Using mortality values from 100% sample water as a basis for comparison, water quality was compared using three techniques and applying a threshold value of >50% mortality rate (the level of mortality at which a *D. magna* population could not sustain itself). The three techniques used for comparison included; changes at a single site throughout the irrigation season within drain systems, month-by-month changes of individual drainage systems, and general changes and trends between hydrologically connected drain systems.

The comparison for changes at a single site was conducted by plotting the combined mortality rate for the 100% test water solution for each test site to describe the degree of seasonal variability and its effects on the quality of irrigation drainage at each site. Sixteen separate sites were sampled at least once; 13 of these were sampled 3 times, 2 were sampled twice, and one site was sampled once. This comparison was not done for Site 50, as it was only sampled once during 1995.

The comparison for month-by-month changes of individual drainage systems was made by ordering the sites in a “top-to-bottom” fashion to examine differences in water quality during the 1995 irrigation season. Table 9 shows how the sites were ordered. Although many of the sites are hydrologically connected, a direct connection should not be assumed between all of the sites, even within each drain system. Also, it should not be assumed that the drain systems listed are hydrologically connected. For instance, the Lower Diagonal drain system, although listed first in the Stillwater Wetlands Group, drains directly into the Stillwater Point Diversion Canal which empties into Stillwater Point Reservoir. Conversely, the Harmon drain system drains into both the Upper Paiute and Stillwater Slough-Kent Lake drain systems, and other systems not evaluated during this study.

The comparison to look at changes and trends between hydrologically connected drain systems can only be made between the Harmon and Upper Paiute, and the Harmon and Stillwater Slough systems, as these were the only drains sampled that are directly connected hydrologically. The other drain systems sampled in this study do not flow directly one from the other, making upstream-to-downstream evaluations of the change in water quality improper. In this instance, water leaving the Harmon drain systems follows two flow paths, one to the Upper Paiute drain system, and the other to the Stillwater Slough-Kent Lake drain system.

As all sites were not sampled during the study, all the various iterations of the evaluations could not be performed.

Site-Specific Changes of Drain Systems Entering Carson Lake

Carson Lake Drain System

Site 79- Sheckler drain at St. Clair Road near Fallon, NV. Water from site 79 (Fig.1) exhibited evidence of toxicity but never exceeded a 50% threshold. There were no differences in *D. magna* mortality rates among sampling events which ranged from 40 to 45% with peak mortality rate occurring during the May sampling event (Table A1). Water quality and trace element measurements from this site did not exhibit any dramatic fluctuations corresponding with the slightly elevated toxicity level observed from the May sampling event with the exception of molybdenum which had a concentration of 11 µg/L for May versus 7 µg/L and 8 µg/L for March and August respectively. However, the molybdenum concentration observed in May is below the Nevada water quality standard for the protection of aquatic life (19 µg/L) as well as concentrations associated with aquatic invertebrate mortality (Eisler 1989, p.28).

Site 100- Upper West Side drain at Solias Road near Fallon, NV. Water at site 100 (Fig.1) exhibited evidence of acute toxicity producing a mortality rate greater than or equal to the 50% threshold in the March and August sampling events with the highest rate occurring during the August sampling event at 90% (Table A1). Water quality and trace element measurements from this site did not exhibit any dramatic fluctuations corresponding with the elevated toxicity level observed from the August sampling event with the exception of field pH levels (August= 7.9; March and May= 9.2).

Site 156- Carson Lake 1 on Pasture Road near Carson Lake, NV. Water samples at site 156 (Fig.1) were collected during the March and May sampling events only. Water from this site exhibited acute toxicity from the March sampling event producing a 100% mortality rate and moderate toxicity from the May sampling event producing a 35% mortality rate (Table A1). Concentrations of bicarbonate were the highest recorded for this study during the March and May sampling periods (744 and 559 mg/L CaCO₃, respectively). The MATC for boron, as determined by Lewis and Valentine (1981) and Gersich (1984), was exceeded for both the March and May sampling events (12,000 and 7,500 µg/L respectively). Molybdenum concentrations for both sampling events exceeded the State of Nevada criterion for protection of aquatic life by almost an order of magnitude (187 and 112 µg/L, respectively) (Fig. 2). Comparisons of constituents to site-specific mortality illustrate corresponding decreases through the irrigation season (Table 10).

Figure 2. Observed mortality rates in *Daphnia magna* at site 156 along with molybdenum concentrations determined in collected water samples.

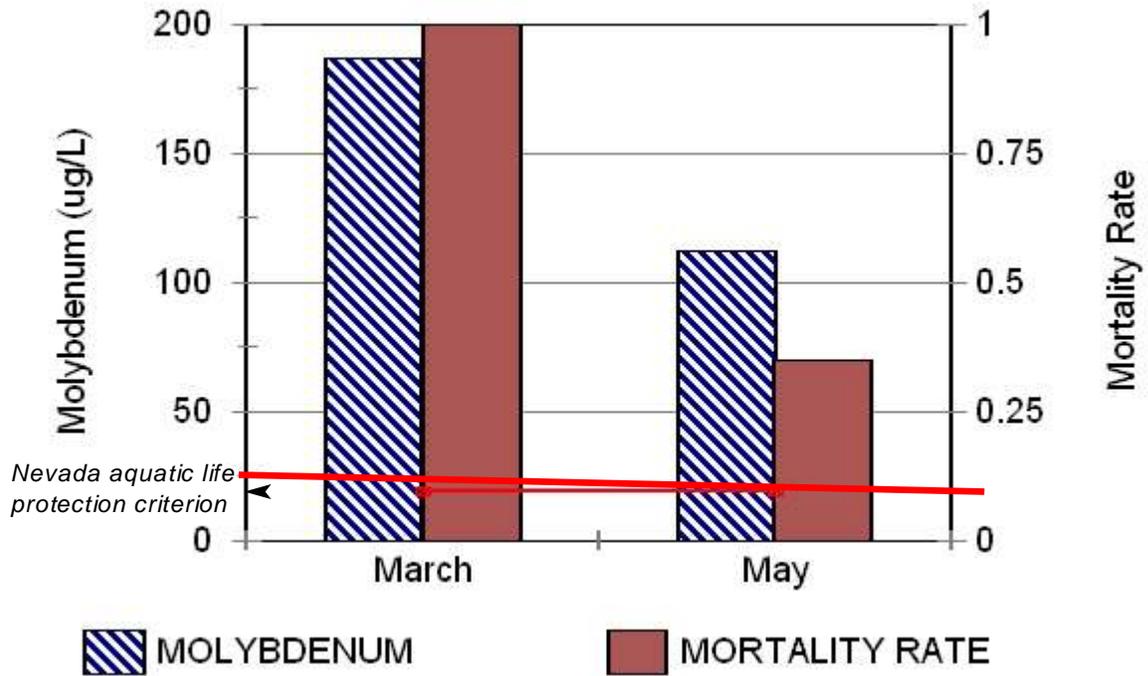


Table 10. Water quality measurements for Site 156 which decreased along with observed *Daphnia magna* mortality from March (100% mortality) to May (35% mortality) 1995.

<u>PARAMETER</u>	<u>CONCENTRATION</u>	<u>SAMPLE PERIOD</u>
bicarbonate (<i>mg/L CaCO₃</i>)	744	March
	559	May
specific conductance (<i>umohs/cm</i>)	8,220	March
	5,030	May
arsenic ($\mu\text{g/L}$)	160	March
	11	May
boron ($\mu\text{g/L}$)	12,000	March
	7,500	May
molybdenum ($\mu\text{g/L}$)	187	March
	112	May
uranium ($\mu\text{g/L}$)	172	March
	104	May

Site 164- Carson Lake drain above Carson Lake near Fallon, NV. Water from site 164 (Fig.1) exhibited evidence of moderate toxicity producing a mortality rate of 33% during the March sampling event and 30% during both the May and August sample events (Table A1). Arsenic concentrations during the March sampling period were elevated compared to other sampling events (110 µg/L versus 40.0 µg/L and 41.0 µg/L for May and August respectively). In addition, the concentration of arsenic during the August sampling event exceeded all other sites for the same sampling period. Molybdenum concentrations for all sampling events exceeded the State of Nevada criterion for protection of aquatic life (19 µg/L) with March, May, and August sampling events having concentrations of 46, 21, and 25 µg/L respectively (Table A2).

L-Drain System

Site 137- “L” drain at NE corner of Pasture Road and Depp Lane near Fallon, NV. Water from site 137 (Fig.1) exhibited evidence of acute toxicity producing 50% mortality from the March sampling event and low to moderate toxicity producing 5% and 45% mortality in the May and August samples respectively (Table A1). Molybdenum concentrations for March and May events exceeded or equaled the State of Nevada criterion for protection of aquatic life at concentrations of 34.0 and 19.0 µg/L respectively. Other water quality and trace element measurements from this site did not document any dramatic fluctuations corresponding with the acute toxicity level observed from the March sampling event with the exception of boron which had a concentration of 1200 µg/L compared to 670 µg/L and 530 µg/L for the May and August sampling events respectively. However, this concentration (i.e., 1200 µg/L) is below the MATC for boron, as determined by Lewis and Valentine (1981) and Gersich (1984).

Site 148- “L” drain above Lee drain near Fallon, NV. Water from site 148 (Fig.1) exhibited acute toxicity during the May sampling event producing a mortality rate of 60% and low to moderate toxicity producing 17% and 35% mortality in the March and August samples respectively (Table A1). Molybdenum concentrations for March and May events exceeded or equaled the State of Nevada criterion for protection of aquatic life with concentrations of 38 and 19 µg/L respectively. Concentrations of trace elements from this site indicate a decreasing trend throughout the irrigation season with the exception of aluminum and barium which had peak concentrations during the May sampling event (Al= 43 µg/L; Ba= 64 µg/L). However, aluminum and barium are not correlated with project-wide mortality and concentrations are not at a level associated with acute or chronic mortality of daphnids.

Site-Specific Changes of Drain Systems Entering Stillwater Wetlands

Lower Diagonal Drain System

Site 122- Lower Diagonal drain at Pasture Road near Fallon, NV. Water from site 122 (Fig.1) exhibited acute toxicity during the August sampling event producing a mortality rate of

100% and moderate to low toxicity producing 25% and 20% mortality in the March and May samples respectively (Table A1). Concentrations of trace elements from this site have a decreasing trend throughout the irrigation season with the exception of aluminum which had peak concentration during the August sampling event (76 µg/L versus 14 and 30 µg/L for March and May respectively). However, aluminum was not correlated with project-wide mortality and concentrations were not at a level associated with acute or chronic mortality of daphnids. Molybdenum concentrations for March and May events exceeded the State of Nevada criterion for protection of aquatic life with the March event exceeding the criterion by more than an order of magnitude (210 µg/L).

Site 112- Lower Diagonal drain at U.S. Hwy. 50 near Fallon, NV. Water quality analyses were conducted for all three sampling periods at site 112 (Fig.1). However, toxicity testing was conducted for only May and August. The concentration of arsenic from the March sampling period was the highest recorded for this study (360 µg/L) and exceeded the State of Nevada chronic criterion for the protection of aquatic life. The MATC for boron, as determined by Lewis and Valentine (1981) and Gersich (1984), was exceeded for the March sampling event (8,200 µg/L). Molybdenum concentrations for all sampling events exceeded the State of Nevada criterion for protection of aquatic life with the March event exceeding the criterion by an order of magnitude (204 µg/L). Water from this site exhibited low toxicity during the May sampling period producing 15% mortality and acute toxicity during the August sampling period producing 100% mortality. Concentrations of trace elements from this site have a decreasing trend throughout the irrigation season, with the exception of aluminum, and there are no dramatic increases in any single water quality parameter during the August sampling event that would explain the 100% mortality observed at this site.

Harmon Drain System

Site 49- S2G drain at Stuart Road near Harmon Reservoir, NV. Bioassay responses from water samples at site 49 (Fig.1) exhibited acute toxicity during the March and May sampling events producing a mortality rate of 100%. For the August sampling event, toxicity was reduced producing a 30% mortality rate. Constituent concentrations were elevated compared to many other sites (bicarbonate, B, Cr, Cu, Li, Mb, Ni, specific conductance, total dissolved solids, U, and Zn). Some constituents were the highest observed for all sites within sampling events (Table 11). The MATC for boron (i.e., 6,000 to 13,000 µg/L) determined by Lewis and Valentine (1981) and Gersich (1984), was exceeded for all sampling events. In addition, the highest boron concentrations observed in this study (32,000 and 27,000 µg/L respectively) were present in both the March and May events. Molybdenum concentrations for all events exceeded the State of Nevada criterion for protection of aquatic life. The nickel concentration for the May sampling event exceeded a 48-hour LC50 value (13 µg/L) associated with acute toxicity for the daphnid *Ceriodaphnia dubia* (Schubauer-Berigan et al. 1993). Uranium concentrations for the March sampling event were the highest observed for the study (239 µg/L) and began to approach the benchmark level recommended for the protection of aquatic life (300 µg/L; Environment Canada

1983).

Table 11. Water quality measurements at Site 49 which equalled or exceeded measurements at all other sites within the specified sampling period.

<u>PARAMETER</u>	<u>CONCENTRATION</u>	<u>SAMPLING PERIOD</u>
Bicarbonate (<i>mg/L CaCo3</i>)	372	August
Boron ($\mu\text{g/L}$)	32,000	March
	27,000	May
	8,800	August
Chromium ($\mu\text{g/L}$)	15	March
	14	May
	6	August
Copper ($\mu\text{g/L}$)	26	March
	23	May
Lead ($\mu\text{g/L}$)	48	May
Lithium ($\mu\text{g/L}$)	280	May
Molybdenum ($\mu\text{g/L}$)	114	May
	60	August
Nickel ($\mu\text{g/L}$)	24	May
	6	August
Specific Conductance- Field measured ($\mu\text{mohs/cm}$)	30,100	March
	33,000	May
	7,900	August
Total Dissolved Solids (mg/L)	22,300	March
	20,200	May
	4,990	August
Uranium ($\mu\text{g/L}$)	239	March
	184	May
	49	August
Zinc ($\mu\text{g/L}$)	26	May
	3	August

Site 42- Harmon drain at NV 116 near Fallon, NV. Water from site 42 (Fig.1) exhibited acute toxicity during the March and August sampling events producing a mortality rate of 50% and 75% respectively and moderate toxicity during the May sampling event producing 35% mortality

(Table A1). Molybdenum concentrations for the March event (i.e., 25 µg/L) exceeded the State of Nevada criterion for protection of aquatic life. Water quality and trace element measurements from this site did not exhibit any dramatic fluctuations corresponding with acute toxicity levels observed from the March and August sampling events.

Site 41- Harmon drain at Ditch House Road near Fallon, NV. Trace element analyses were conducted on water samples collected from site 41 (Fig.1) during all sampling events with the exception of the August event which did not have data for Cr, P, F, and Zn. Water from this site exhibited acute toxicity during all sampling events producing mortality rates of 60%, 65%, and 65% from the March, May, and August sampling events respectively (Table A1). The concentration of arsenic in May (86.0 µg/L) was the highest recorded among all sites for that sampling event. Molybdenum concentrations for March and May events exceeded the State of Nevada criterion for protection of aquatic life (i.e., 19 µg/L) at 53 and 22 µg/L respectively. Other water quality and trace element measurements for all sampling events at this site did not exhibit exceedances of constituent concentrations associated with acute toxicity.

Upper Paiute Drain System

Site 17- S5A drain at Austin Road near Fallon, NV. Water from site 17 (Fig.1) exhibited acute toxicity during all sampling events producing mortality rates of 50%, 65%, and 100% from the March, May, and August sampling events respectively (Table A1). Molybdenum concentrations for March event exceeded the State of Nevada criterion for protection of aquatic life (i.e., 19 µg/L) at 47 µg/L. Other water quality and trace element measurements at this site did not exceed concentrations commonly associated with acute toxicity. Concentrations of water quality parameters were generally highest during the March sampling event and generally the lowest during the August sampling event.

Site 2- Paiute Diversion drain near Fallon Indian Reservation, NV. Water from site 2 (Fig.1) exhibited no toxicity during the March sampling event while water samples from the May sampling event exhibited minimal toxicity producing a 10% mortality rate. Conversely, water samples from the August sampling event exhibited acute toxicity producing a mortality rate of 70% (Table A1). The molybdenum concentration for the March event exceeded the State of Nevada criterion for protection of aquatic life (i.e., 19 µg/L) at 41 µg/L. However, it is unknown why no mortality was observed from this sampling event. The majority of concentrations of trace elements from this site have a decreasing trend throughout the irrigation season with the exception of aluminum which increased throughout the irrigation season (March= 7 µg/L; May= 48 µg/L; August= 95 µg/L). However, aluminum was not a trace element that was correlated with project-wide mortality and concentrations are not at a level associated with acute or chronic mortality of daphnids.

Stillwater Slough-Kent Lake Drain System

Site 19- Stillwater Slough at Stillwater, NV. Water from site 19 (fig.1) exhibited acute toxicity during the March and August sampling events producing a mortality rate of 70% and 100% respectively while water samples from the May sampling event exhibited low toxicity producing a 20% mortality rate (Table A1). The MATC for boron, as determined by Lewis and Valentine (1981) and Gersich (1984), was exceeded for the March sampling event (6,100 µg/L). Molybdenum concentrations for March and August events exceeded the State of Nevada criterion for protection of aquatic life.

Site 5- Kent Lake drain at Freeman Road near Stillwater, NV. Water from site 5 (Fig.1) exhibited acute toxicity during all sampling events producing mortality rates of 100%, 80%, and 65% for March, May, and August respectively (Table A1). Several water quality parameters at this site exceeded concentrations at all other sites within sampling periods (Table 12). The MATC for boron, as determined by Lewis and Valentine (1981) and Gersich (1984), was exceeded for the March sampling event (20,000 µg/L). The lithium concentration from the March sampling event was the highest observed for this study (1,700 µg/L). As discussed previously, lithium is suspected to interact with elements such as molybdenum to elicit toxic effects in aquatic organisms (Finger et al. 1993). However, implications to aquatic effects from lithium in this study are still uncertain. The concentration of molybdenum from the March sampling event exceeded the State of Nevada criterion established for protection of aquatic life (19 µg/L) by an order of magnitude and was the highest observed for this study. The concentration of nickel from the March sampling event (27 µg/L) exceeded the 48-hour LC50 value of 13 µg/L determined for the daphnid *Ceriodaphnia dubia* (Schubauer-Berigan et al. 1993). This site also had the highest concentration of lithium (150 µg/L) and the second highest concentration of molybdenum (51 µg/L) among all sites for August.

Table 12. Water quality measurements at Site 5 which equaled or exceeded measurements at all other sites for the same sampling period.

<u>PARAMETER</u>	<u>CONCENTRATION</u>	<u>SAMPLING PERIOD</u>
Lithium (µg/L)	1,700 150	March August
Molybdenum (µg/L)	615	March
Nickel (µg/L)	27	March
Zinc (µg/L)	28	March

Monthly Changes of Drain Systems Entering Carson Lake

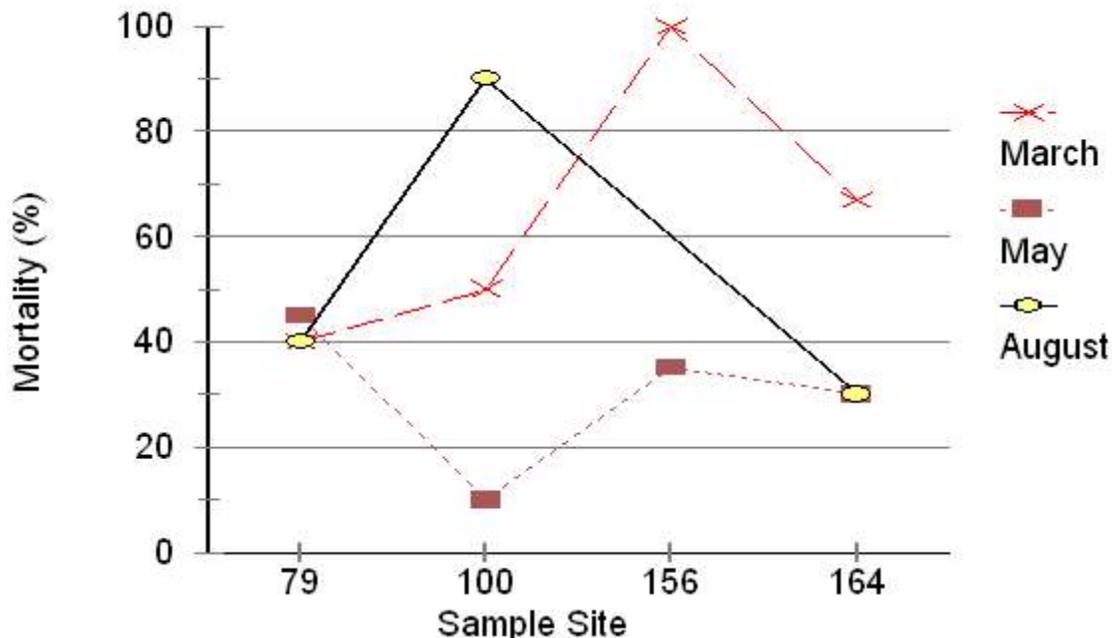
Carson Lake Drain System

The Carson Lake drain system contained four sampling sites (79, 100, 156, 164; Fig.1). For the March sampling event, observed *D. magna* mortality rates increased from 40% at Site 79 to 50% at Site 100 and reached a maximum mortality rate of 100% for the system at Site 156 (Fig. 3). As discussed previously, site 156 during this period had the highest recorded concentration of bicarbonate and exceeded the MATC for boron. The fourth site in the system (Site 164) experienced a reduction in mortality rate to reach 33%, which cannot be explained.

Mortality rates from the May sampling event never exceeded the designated threshold and varied with no consistent trend ranging from a low of 10% at site 100 to a high of 45% at site 79 (Fig. 3).

During the August sampling event, samples were collected at three of the four sites (79, 100, and 164) and observed mortality rates increased from 40% at Site 79 to 90% at Site 100, then declined at Site 164 to 30% (Fig. 3). The high mortality rate for site 100 during this period could not be explained.

Figure 3. Mortality rates of *Daphnia magna* from 100% drain-water proceeding down-gradient through the Carson Lake drain sub-basin, March-August 1995.



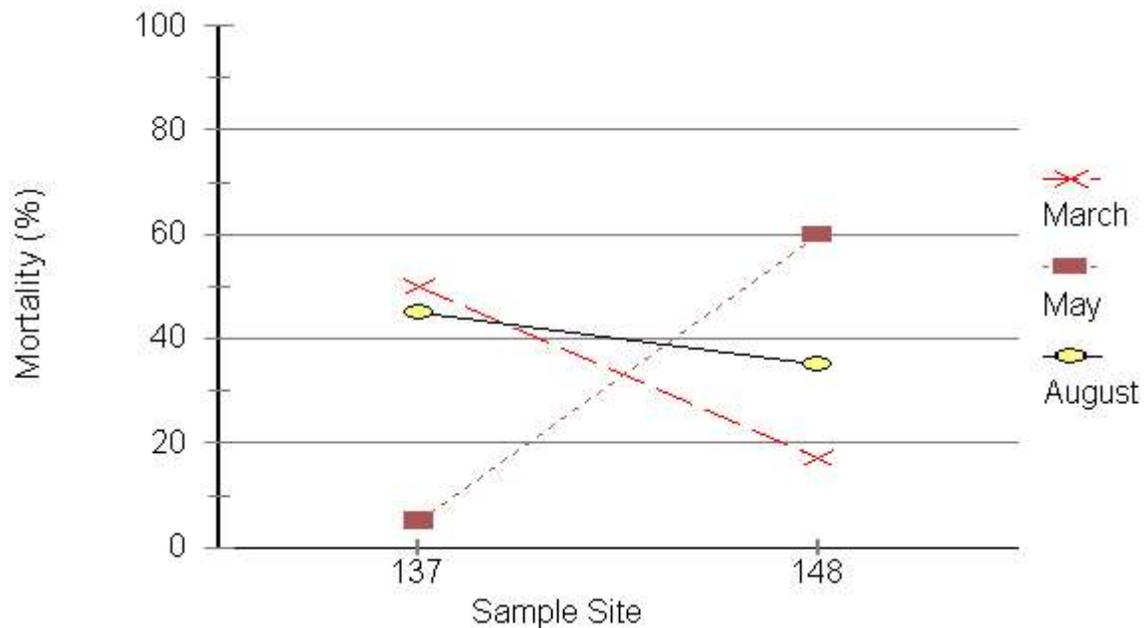
“L”Drain System

The “L”drain system contained two sampling sites (137, 148; Fig.1). For the March sampling event, mortality rate reached the designated threshold of 50% at Site 137 which may be attributed to elevated molybdenum or boron concentrations (see previous section “Site 137”). Down-gradient at site 148, the mortality rate declined to 17% (Fig.4).

For the May sampling event, the mortality rate at Site 137 was minimal at 5% and increased to exceed the designated mortality threshold down-gradient at Site 148 with a rate of 60% (Fig.4).

The August sampling event did not have a site that exceeded the designated mortality threshold and slightly decreased down-gradient from 45% to 35% for Sites 137 and 148 respectively (Fig.4).

Figure 4. Mortality rates of *Daphnia magna* from 100% drain-water proceeding down-gradient through the L-drain sub-basin, March-August, 1995.



Monthly Changes of Drain Systems Entering Stillwater Wetlands

Lower Diagonal Drain System

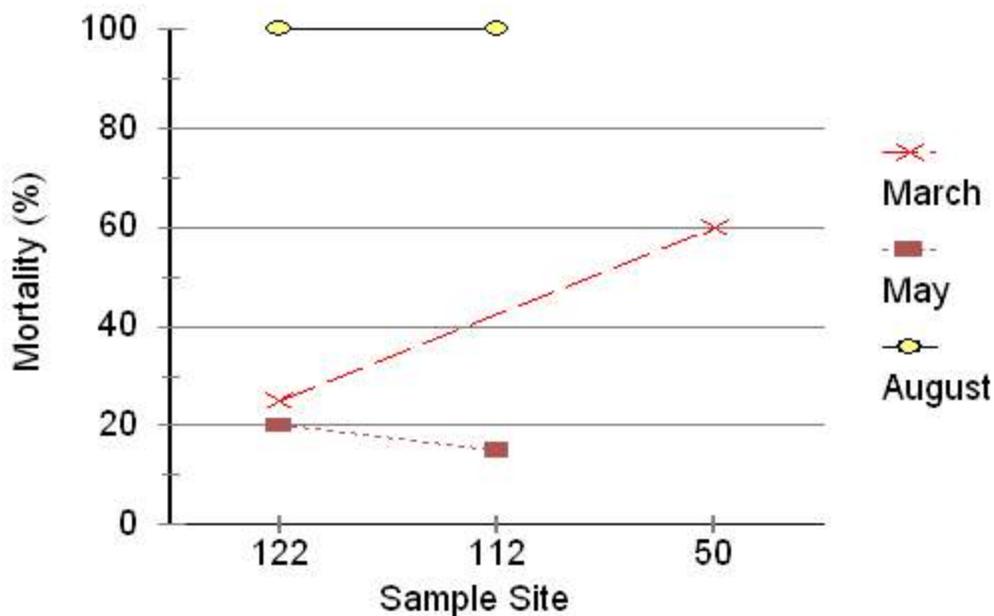
The Lower Diagonal drain system contained three sampling sites (122, 112, 50). However, daphnid mortality was not determined at all sites that were sampled for all three sampling events. Daphnid mortality was determined at site 122 was sampled during all three

events, was determined at site 112 twice (May and August), and only once at site 50 (March). The March sampling event produced a mortality rate of 25% at Site 122 and increased down-gradient to be above the designated threshold at Site 50 with a rate of 60% (Fig.5). The increased mortality rate at Site 50 could be influenced by input from a drain connection to Site 49 in the Harmon drain system which had a 100% mortality and contained some of the highest concentrations of constituents during the same sampling period (see previous section “Site 49”).

The May sampling event produced mortality rates that were minimal at 20% and 15% for Site 122 and Site 112 respectively (Fig.5).

The August sampling event contained drain-water that produced 100% mortality rates to *D. magna* at Site 122 and Site 112 (Fig.5). Individual constituent concentrations during this period were not at elevated levels to be associated with the observed mortalities. Specific conductance measurements in the field, which are an indirect measure of dissolved-solids, were not considered elevated (436 to 712 $\mu\text{S}/\text{cm}$).

Figure 5. Mortality rates of *Daphnia magna* from 100% drain-water proceeding down-gradient through the Lower Diagonal drain sub-basin, March-August, 1995.



Harmon Drain System

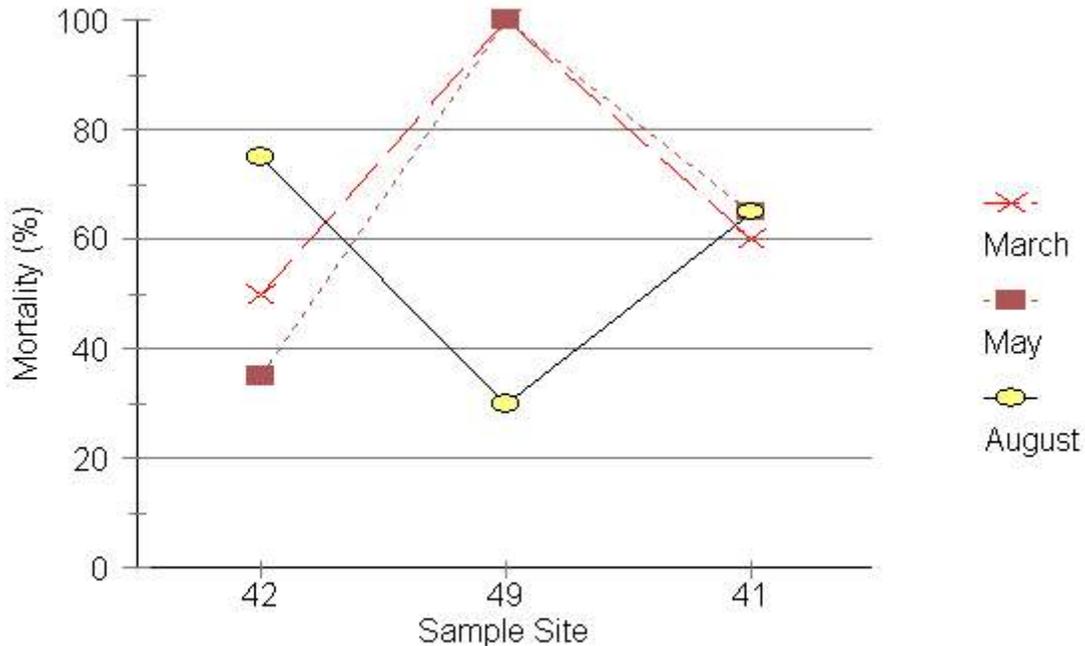
The Harmon drain system contained three sampling sites (42, 49, 41; Fig.1). The March sampling event produced a mortality rate of 50% at Site 42 followed by 100% at Site 49, and 60% at Site 41 (Fig.6). As discussed in previous sections, site 49 contained a number of elevated concentrations of constituents which likely contributed to severe mortality observed at this site.

For the May sampling event, mortality rates were very similar in character to the March sampling event with values of 35%, 100%, and 65% for the respective sites (Fig.6).

The August sampling event produced mortality rates that were generally in reverse trend from the previous two sampling periods with rates of 75%, 30%, and 65% for the respective sites (Fig.6).

Lower mortality rates of *Daphnia magna* in the Harmon drain system, particularly site 42, could be influenced by flows from the S-line canal which enter the system just up-gradient of site 42. Flow measured at Site 49 were the lowest and remained relatively constant with mortality rates at 100% except for August. The lower specific conductance measurements for sites 42 and 41 along with higher flows during March and May compared to site 49 in this sub-basin illustrate this. However, flows for sites 42 and 41 in August were the highest and had high mortality rates. Therefore mortality rates from water collected the Harmon drain system later in the irrigation season appear to be influenced by factors other than flow.

Figure 6. Mortality rates of *Daphnia magna* from 100% drain-water proceeding down-gradient through the Harmon drain sub-basin, March-August, 1995.



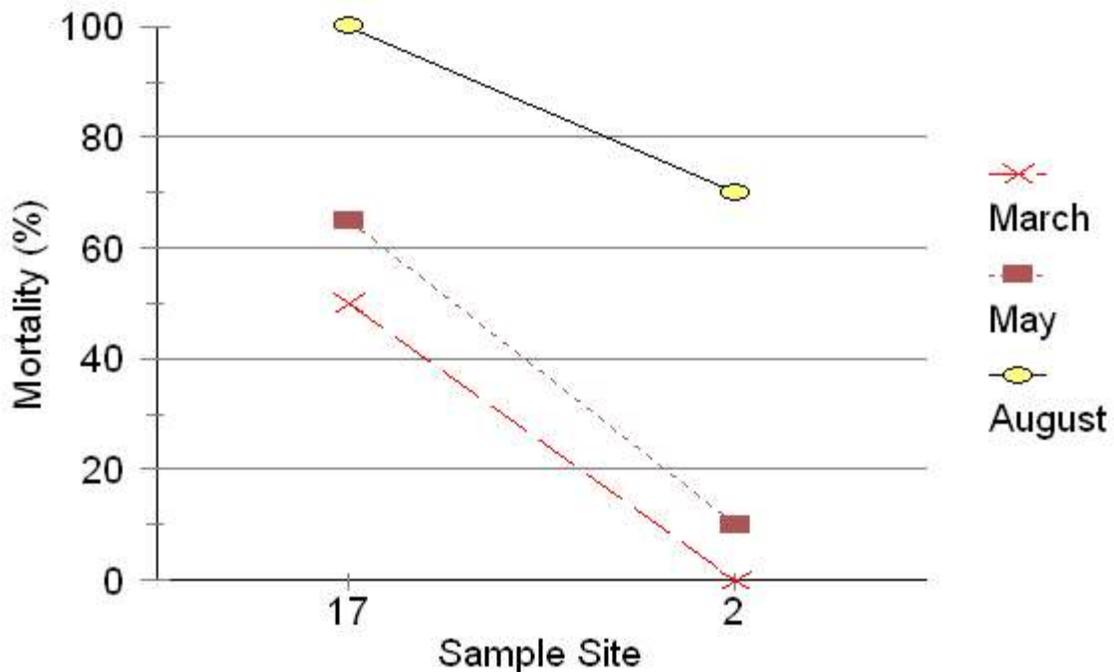
Upper Paiute Drain System

The Upper Paiute drain system contained sampling sites 17 and 2. The mortality rates from the March sampling event decreased in a down-gradient fashion from a rate of 50% at Site 17 to 0% at Site 2 (Fig.7).

The mortality rates from the May sampling event produced similar results to the March event with rates of 65% and 10% for the respective sites (Fig.7). Constituent concentrations determined for site 17 during the May period were similar to those for site 2 with very different mortality results. Therefore, the mortality rate for site 17 cannot be attributed to any of the constituents analyzed by this study and cannot be explained

The August sampling event produced mortality rates that decreased in a down-gradient fashion and exceeded designated thresholds at 100% for Site 17 and 70% for Site 2 (Fig.7). No constituent concentration exceeded levels commonly associated with lethal effects to *D. magna*. Therefore again, the high mortality rate cannot be explained.

Figure 7. Mortality rates of *Daphnia magna* from 100% drain-water proceeding down-gradient through the Upper Paiute drain sub-basin, March-August, 1995.



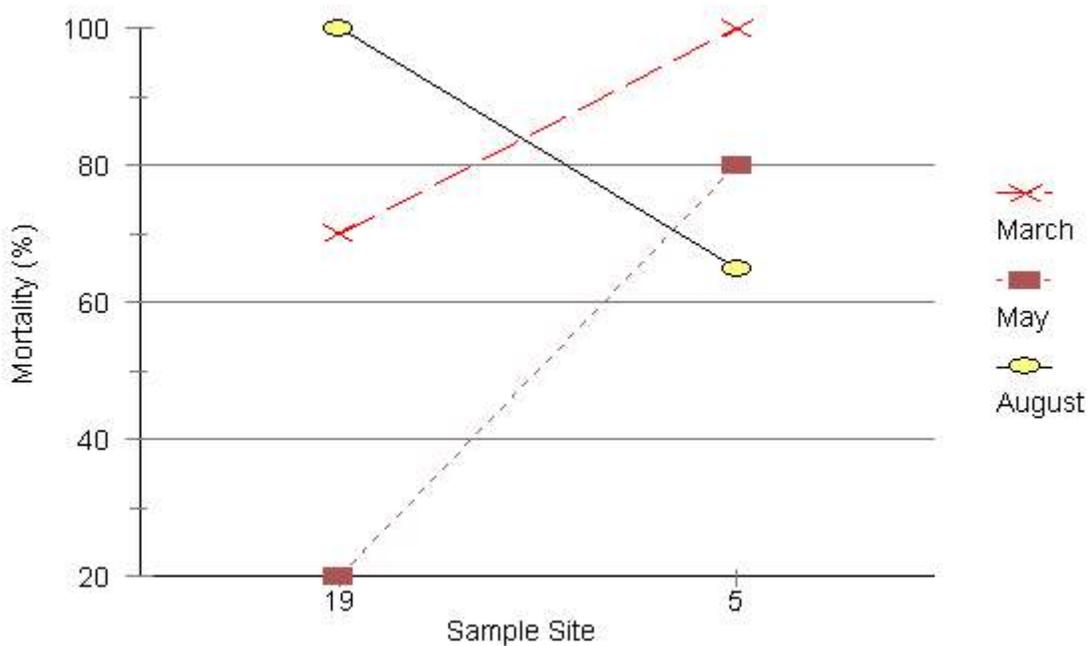
Stillwater Slough-Kent Lake Drain System

The Stillwater Slough-Kent Lake drain system contained two sampling sites (19, 5). Mortality rates from the March sampling event increased in a down-gradient fashion from an acute level of 70% at Site 19 to 100% at Site 5 (Fig.8). Site 5 for the March sampling period had a molybdenum concentration more than 30 times the aquatic life criterion established by the State of Nevada and a nickel concentration that exceeded acute values associated with other similar daphnid species (see previous discussion under Site 5).

The May sampling event exhibited a down-gradient increase in mortality with a low level of 20% at Site 19 followed by an acute level of 80% at Site 5 (Fig.8). The increase in mortality down-gradient occurred along with reductions in constituent concentrations with the exception of Al, Cu, Mo, and Zn. The concentration of aluminum increased down-gradient from 16 to 99 $\mu\text{g/L}$ at site 5, and was the highest observed among all sites for all periods. However, aluminum was not one of the constituents evaluated for toxicity by this study. Copper concentrations increased down-gradient but the increase was not substantial (2 to 6 $\mu\text{g/L}$). Molybdenum concentrations increased down-gradient from 18 $\mu\text{g/L}$ at site 19, which is just below the State of Nevada criterion established for protection of aquatic life at 19 $\mu\text{g/L}$, to 26 $\mu\text{g/L}$ at site 5.

Conversely, the August sampling event had a down-gradient decrease in mortality rate from 100% to 65% at sites 19 and 5 respectively (Fig.8). However, both sites exceeded the designated 50% threshold criteria. Site 5 contained the highest measured concentration of lithium and the second highest concentration of molybdenum measured for all sites within the August sampling event.

Figure 8. Mortality rates of *Daphnia magna* from 100% drain-water proceeding down-gradient through the Stillwater Slough-Kent Lake drain sub-basin, March-August, 1995.

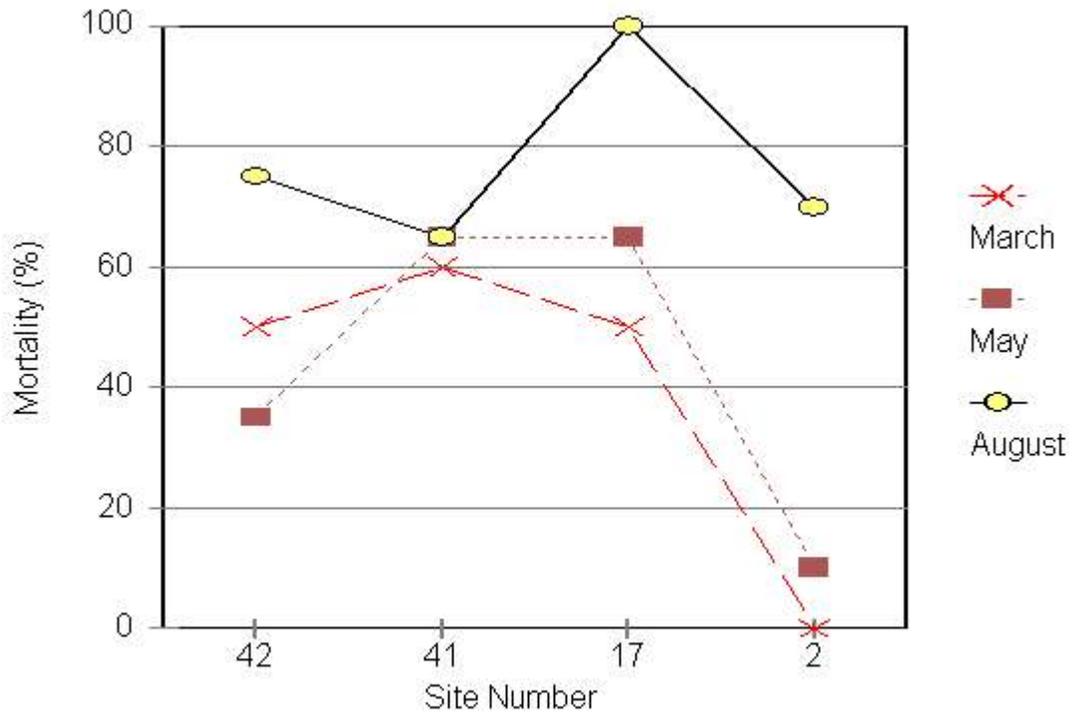


Monthly Trends Between Drain Systems

Harmon and Upper Paiute Systems.

A graphical representation of mortality rates for these systems is provided in Figure 9 below. Data from site 49 was treated as an outlier and excluded. The March and May sampling events suggest mortality rates from drain-water in the Harmon system slightly increase as drain-water proceeds to the Upper Paiute system. Drain-water in the Upper Paiute system for the same period (March and May) showed reductions in mortality rates down-gradient. The August sampling event however showed an inverse trend with mortality rates generally increasing as drain-water proceeded from Harmon to the Upper Paiute system with the highest rate occurring at the beginning of the Paiute system and attenuating but still exceeding designated threshold levels toward the end of the system at site 2.

Figure 9. Mortality rates of *Daphnia magna* from 100% drain-water proceeding down-gradient through the Harmon and Upper Paiute drain systems, March-August, 1995.



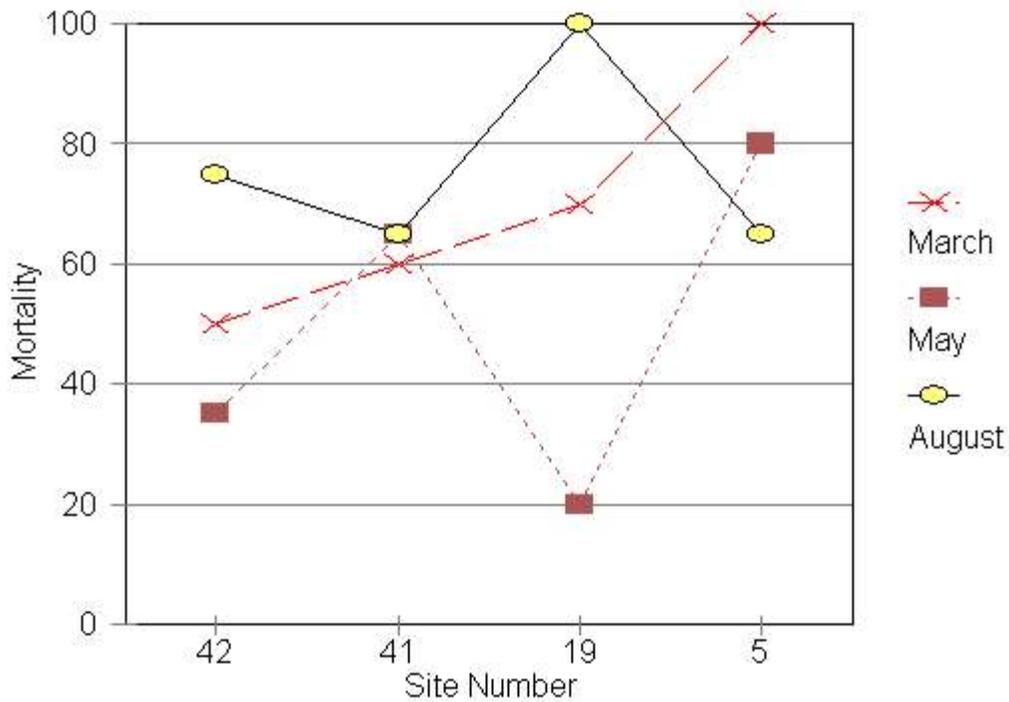
Harmon and Stillwater Slough-Kent Lake Systems.

A graphical representation of mortality rates for this system is provided in Figure 10. As described previously, mortality rates generally increased for the March and May periods in the Harmon system. However, as drain-water proceeded down-gradient to the Stillwater Slough system, mortality rates increased to well above designated threshold levels during the March sampling event, unlike the Harmon-Upper Paiute system.

During the May sampling event, mortality rates were dramatically reduced as drain-water entered the Stillwater system. However, the mortality rate quickly increased to exceed criteria levels as drain-water proceeded through the system toward site 5.

Mortality rates from the August sampling period were similar to the Harmon-Upper Paiute system with a spike in mortality occurring as drain-water enters the Stillwater Slough system. After entering the Stillwater Slough system, drain-water toxicity appears to attenuate through the system as mortality rate decreases. However, designated threshold levels were still exceeded.

Figure 10. Mortality rates of *Daphnia magna* from 100% drain-water proceeding down-gradient through the Harmon and Stillwater Slough-Kent Lake drain systems, March-August, 1995.



SUMMARY & CONCLUSIONS

The U.S. Fish and Wildlife Service (USFWS) was funded by the National Water-Quality Assessment Program and U. S. Department of the Interior National Irrigation Water Quality Program to determine aquatic toxicity in irrigation drains of the Newlands Project Area. Water samples were collected at 16 drain sites in the Newlands Project during March, May, and August 1995 by USFWS and U.S. Geological Survey (USGS) personnel. USGS personnel measured water quality parameters and analyzed samples for trace elements and pesticides analysis. USFWS personnel were provided concurrent water samples to determine toxicity utilizing two bioassay tests; 96-hour LC50 test using *Daphnia magna*, and Microtox® procedure using a luminescent bacterium. Trace element and pesticide concentrations were compared to known concentrations determined in literature to produce toxic effects to biota. Pearson correlation coefficients were calculated for each sampling event conducted in 1995 between trace element concentrations in sample water and bioassay results from both mean values and arc-sine transformed mean values for *D. magna* mortalities at 100% sample concentration. Kruskal-Wallis tests were conducted on individual parameters to: 1) detect differences in medians of water quality parameters by sampling event ($p \leq 0.05$); 2) identify which sampling events were different; and 3) determine whether or not differences in water quality parameters paralleled the correlations with *D. magna* mortality. Using 100% sample concentrations as a basis for comparison, water quality was compared using three techniques and applying a threshold value of >50% mortality rate (the level of mortality at which a *D. magna* population could not sustain itself) which included: changes at a single site throughout the irrigation season within drain systems; month-by-month changes of individual drainage systems; and general changes and trends between hydrologically connected drain systems.

Concentrations of arsenic, bicarbonate, boron, alkalinity, fluoride, lithium, molybdenum, specific conductances, total dissolved solids, and uranium were higher during the March period and significantly different from all other sampling events. Of these constituents, uranium, boron, specific conductance, total dissolved solids, bicarbonate, and molybdenum were associated with observed *Daphnia magna* mortality in bioassays conducted during the March period. The average flow rate of drain-water at all sites during the March sampling event was also the lowest among the three sampling events ($\bar{x} = 0.689$ cfs). Lico and Pennington (1997) described concentrations of constituents in drain-water as generally being greater during the non-irrigation period due to the following; 1) ground-water seepage contributing to a greater proportion of flow in drains, 2) less dilution from surface runoff, and 3) seepage from supply canals not providing water to drains. The delay of the irrigation season due to above average precipitation during 1995 and the subsequent low flow conditions in the project area created concentrations of constituents similar to non-irrigation season effects. There were no significant differences in concentrations of constituents between the May and August sampling periods of this study and only specific conductance and total dissolved solids were associated with mortality during the May period. No constituents were correlated with observed *Daphnia magna* mortality in bioassays conducted during the August period. However, *Daphnia magna* mortality rates were highest in August ($\bar{x} = 0.68$, $s^2 = 0.26$) compared to March ($\bar{x} = 0.54$, $s^2 = 0.29$) and May ($\bar{x} =$

0.40, $s^2 = 0.28$). Pesticide concentrations determined in test waters for the August sampling event were often not detected, or at low levels which were not associated with aquatic toxicity. Therefore, the mortality rates during the August period cannot be attributed to constituents observed by this study. Constituents which exceeded levels of concern published in literature for aquatic toxicity included boron, specific conductance, total dissolved solids, and molybdenum. Uranium concentrations were elevated above background levels but associated effects to aquatic biota are uncertain.

Areas of the Newlands Project irrigation system that contributed most to aquatic mortality throughout the entire study period were Harmon and Stillwater Slough-Kent Lake drain systems. The Harmon drain system contained only two sites that were below the designated fifty percent mortality threshold for the entire study period. The Stillwater Slough-Kent Lake drain system contained only one site that was below the fifty percent designated mortality threshold for the entire study period. Of particular note, Site 49 in the Harmon drain system and site 5 in the Stillwater Slough system contained particularly high concentrations of constituents compared to other sites observed. Two drain systems had notable contributions to aquatic mortality only during the August period, Diagonal drain and Upper Paiute. All sites for these two systems during this period exceeded the designated fifty percent mortality threshold.

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APPENDIX

This appendix contains analytical data from samples collected by USGS and USFWS personnel and contains: Table A1- Water quality measurements and *D. magna* mortality rates for drain-water samples collected in the Newlands Project near Fallon, Nevada (March-August, 1995); and Table A2- Constituent concentrations and *D. magna* mortality rates for drain-water samples collected in the Newlands Project near Fallon, Nevada (March-August, 1995).

Table A1. Water quality measurements and *D. magna* mortality rates for drain-water samples collected in the Newlands Project near Fallon, Nevada (March-August, 1995).

USGS Site #	DATE (YYYYMMDD)	MORTALITY RATE (100% effluent)	SPECIFIC COND (lab) (uS/cm)	TDS RESIDUE (mg/L)	ALKALINITY dissolved (mg/LCaCO ₃)	BICARBONATE (mg/L HCO ₃)	OXYGEN dissolved (mg/L)	LAB pH
79	19950302	0.4	740	454	246	300	8.4	7.9
79	19950504	0.45	735	472	220	268	8.1	7.8
79	19950807	0.4	702	464	232	283	5.4	7.6
100	19950302	0.5	720	445	246	242	13.8	8.5
100	19950502	0.1	695	420	220	195	13.4	8.5
100	19950809	0.9	788	499	276	337	8.4	7.8
156	19950301	1	8220	5200	610	744	4.6	7.6
156	19950502	0.35	5030	3150	533	559	13.1	8.3
164	19950227	0.33	1440	892	306	325	19.2	8.7
164	19950501	0.3	705	430	172	210	8.0	7.8
164	19950808	0.3	1170	730	266	324	9.3	7.9
137	19950301	0.5	1070	692	320	342	18.4	8.4
137	19950501	0.05	730	474	203	242	9.6	7.7
137	19950807	0.45	657	440	209	255	10.2	8.1
148	19950227	0.165	1120	718	330	336	13.8	8.3
148	19950501	0.6	752	481	220	268	10.4	7.9
148	19950808	0.35	573	369	182	221	6.6	7.8
122	19950227	0.25	2700	1920	434	466	15.0	8.5
122	19950502	0.2	896	534	211	257	11.1	7.8
122	19950808	1	454	293	134	164	8.3	7.7
112	19950228	.	5370	3430	530	647	3.0	7.6
112	19950503	0.15	1210	756	238	290	6.9	7.5
112	19950810	1	742	471	194	237	5.2	7.7

Table A1 (cont.). Water quality measurements and *D. magna* mortality rates for drain-water samples collected in the Newlands Project near Fallon, Nevada (March-August, 1995).

USGS Site #	DATE (YYYYMMDD)	MORTALITY RATE (100% effluent)	SPECIFIC COND (lab) (uS/cm)	TDS RESIDUE (mg/L)	ALKALINITY dissolved (mg/LCaCO ₃)	BICARBONATE (mg/L HCO ₃)	OXYGEN dissolved (mg/L)	LAB pH
50	19950301	0.6	4580	2740	324	396	.	7.5
50	19950522	.	418	262	98	120	5.8	7.7
50	19950807	.	807	498	207	253	5.6	7.7
42	19950301	0.5	1340	870	295	360	7.3	7.7
42	19950504	0.35	816	523	211	257	7.2	7.7
42	19950807	0.75	819	546	220	268	5.3	7.5
49	19950301	1	31200	22300	500	610	9.2	7.7
49	19950504	1	24600	20200	448	547	4.9	7.5
49	19950807	0.3	1370	4990	305	372	2.6	8.2
41	19950301	0.6	3710	2480	307	375	12.9	7.9
41	19950505	0.65	1490	896	181	221	6.3	7.5
41	19950807	0.65	.	.	200	244	8.6	
17	19950302	0.5	3820	2370	316	386	10.3	7.9
17	19950502	0.65	648	401	122	149	7.1	7.5
17	19950809	1	803	506	166	203	9.2	7.9
2	19950227	0	4850	3050	228	249	10.3	7.9
2	19950502	0.1	755	471	155	179	11.5	7.5
2	19950808	0.7	397	248	111	118	10.6	8.6
19	19950228	0.7	5840	3580	307	375	9.5	8.0
19	19950503	0.2	1230	758	210	256	7.8	7.8
19	19950809	1	1060	658	212	259	5.4	7.9
5	19950228	1	14800	10600	241	294	13.1	7.7
5	19950503	0.8	598	379	132	163	5.5	6.9
5	19950808	0.65	1430	870	142	173	8.7	7.4

Table A2. Constituent concentrations and *D. magna* mortality rates for drain-water samples collected in the Newlands Project near Fallon, Nevada (March-August, 1995).

USGS Site #	DATE (YYYYMMDD)	AL ($\mu\text{g/L}$)	AS ($\mu\text{g/L}$)	BA ($\mu\text{g/L}$)	B ($\mu\text{g/L}$)	CR ($\mu\text{g/L}$)	CU ($\mu\text{g/L}$)	F (mg/L)
79	19950302	4	42	74	590	1	1	0.5
79	19950504	5	36	73	520	2	2	0.4
79	19950807	5	31	58	480	3	2	0.5
100	19950302	8	66	59	680	2	1	0.6
100	19950502	11	51	47	660	2	2	0.6
100	19950809	4	28	78	600	4	1	0.5
156	19950301	8	160	92	12000	5	9	1.2
156	19950502	13	11	59	7500	7	6	1.0
164	19950227	12	110	46	1800	2	3	0.7
164	19950501	46	40	45	740	2	2	0.4
164	19950808	13	41	55	1200	3	4	0.6
137	19950301	42	78	64	1200	3	2	0.7
137	19950501	31	45	64	670	2	2	0.5
137	19950807	40	31	48	530	3	3	0.4
148	19950227	25	79	52	1300	3	2	0.8
148	19950501	43	52	64	690	2	2	0.5
148	19950808	32	29	44	430	2	2	0.4
122	19950227	14	110	69	4300	2	6	1.0
122	19950502	30	50	54	880	2	2	0.5
122	19950808	76	27	29	390	2	3	0.3
112	19950228	6	360	96	8200	3	7	1.1
112	19950503	47	77	51	1500	3	2	0.5
112	19950810	57	32	50	720	1	2	0.4

Table A2 (cont.). Constituent concentrations and *D. magna* mortality rates for drain-water samples collected in the Newlands Project near Fallon, Nevada (March-August, 1995).

USGS Site #	DATE (YYYYMMDD)	AL (µg/L)	AS (µg/L)	BA (µg/L)	B (µg/L)	CR (µg/L)	CU (µg/L)	F (mg/L)
50	19950301	9	170	118	4600	4	8	0.7
50	19950522	8	15	36	380	1	2	0.3
50	19950807	6	39	54	840	1	1	0.5
42	19950301	4	33	102	1400	4	3	0.6
42	19950504	11	29	74	730	3	2	0.4
42	19950807	9	39	69	790	2	1	0.5
49	19950301	16	51	71	32000	15	26	0.5
49	19950504	22	10	64	27000	14	23	0.4
49	19950807	11	34	77	8800	6	3	0.5
41	19950301	9	38	110	5000	4	8	0.6
41	19950505	5	86	67	1200	3	2	0.4
41	19950807	.	.	.	.	.	.	.
17	19950302	5	16	68	2600	2	4	0.5
17	19950502	38	18	32	510	2	2	0.3
17	19950809	15	19	51	580	2	1	0.4
2	19950227	7	12	124	3300	4	8	0.6
2	19950502	48	19	43	610	2	3	0.4
2	19950808	95	16	39	290	1	1	0.2
19	19950228	5	35	143	6100	4	6	0.7
19	19950503	16	33	64	1200	2	2	0.5
19	19950809	20	30	63	1100	3	2	0.4
5	19950228	18	35	161	20000	11	26	1.2
5	19950503	99	10	56	610	1	6	0.4
5	19950808	29	31	61	1600	2	4	0.3

Table A2 (cont.). Constituent concentrations and *D. magna* mortality rates for drain-water samples collected in the Newlands Project near Fallon, Nevada (March-August, 1995).

USGS Site #	DATE (YYYYMMDD)	LI ($\mu\text{g/L}$)	MO ($\mu\text{g/L}$)	NI ($\mu\text{g/L}$)	P (mg/L)	U ($\mu\text{g/L}$)	ZN ($\mu\text{g/L}$)
79	19950302	70	7	1	0.10	24	1
79	19950504	70	11	4	0.18	20	2
79	19950807	70	8	5	0.39	11	2
100	19950302	70	9	1	.	26	1
100	19950502	70	9	2	0.07	21	1
100	19950809	70	9	3	0.12	17	2
156	19950301	120	187	4	1.30	172	7
156	19950502	120	112	5	0.85	104	5
164	19950227	70	46	2	0.35	51	1
164	19950501	50	21	3	0.21	20	2
164	19950808	50	25	4	0.26	20	2
137	19950301	70	34	3	0.44	35	2
137	19950501	60	19	3	0.30	22	3
137	19950807	40	13	4	0.39	15	1
148	19950227	70	38	3	0.38	36	3
148	19950501	60	19	3	0.28	23	2
148	19950808	40	9	3	0.29	11	1
122	19950227	70	210	3	0.77	78	5
122	19950502	60	31	3	0.34	24	2
122	19950808	20	11	3	0.26	6	2
112	19950228	70	204	3	3.00	116	.
112	19950503	60	52	3	0.55	33	2
112	19950810	40	21	3	0.32	17	1

Table A2 (cont.). Constituent concentrations and *D. magna* mortality rates for drain-water samples collected in the Newlands Project near Fallon, Nevada (March-August, 1995).

USGS Site #	DATE (YYYYMMDD)	LI ($\mu\text{g/L}$)	MO ($\mu\text{g/L}$)	NI ($\mu\text{g/L}$)	P (mg/L)	U ($\mu\text{g/L}$)	ZN ($\mu\text{g/L}$)
50	19950301	70	46	5	2.30	24	9
50	19950522	40	9	2	0.08	8	.
50	19950807	50	23	2	0.23	19	.
42	19950301	100	25	4	0.14	29	2
42	19950504	70	14	4	0.22	14	2
42	19950807	70	17	4	0.38	13	1
49	19950301	270	166	15	0.16	239	21
49	19950504	280	114	24	0.30	184	26
49	19950807	130	60	6	0.42	49	3
41	19950301	120	53	6	0.18	43	7
41	19950505	60	22		0.22	19	1
41	19950807	.	.	.	.	..	.
17	19950302	120	47	11	0.11	65	4
17	19950502	50	10	3	0.13	7	1
17	19950809	50	10	3	0.20	8	1
2	19950227	270	41	7	0.03	19	16
2	19950502	60	14	3	0.24	8	2
2	19950808	30	8	2	0.21	3	1
19	19950228	270	58	5	0.18	42	5
19	19950503	80	18	4	0.15	14	1
19	19950809	80	21	4	0.25	13	2
5	19950228	1700	615	27	0.23	125	28
5	19950503	60	26	3	0.28	10	7
5	19950808	150	51	5	0.42	10	3