FINAL REPORT

Source Water Assessment for the Las Vegas Valley Surface Waters

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Prepared by:

Thomas Piechota, Ph.D., P.E. and Jacimaria Batista, Ph.D.

University of Nevada, Las Vegas

Department of Civil and Environmental Engineering

4505 Maryland Parkway, Box 454015

Las Vegas, Nevada 89154-4015

P: 702-895-4412; F: 702-895-3936

piechota@unlv.edu and jaci@ce.unlv.edu

Graduate Students: Silvia Albuquerque and Marcelo Reginato

Prepared for:

State of Nevada

Bureau of Health Protection Services

Carson City, Nevada

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ACRONYMS

BHPS	Bureau of Health Protection Services, State of Nevada
BMI	Basic Management Industrial
CCRFCD	Clark County Regional Flood Control District
CCSD	Clark County Sanitation District
CDHS	California Department of Health Services
CLV	City of Las Vegas
COH	City of Henderson
CRWUA	Colorado River Water Users Association
GIS	Geographic Information System
GISMO	GIS Management Office, Clark County
GPS	Global Position System
IOCs	Inorganic compounds
MAFY	Million acre-ft per year
MCL	Maximum contaminant level
MGD	Million gallons per day
NDEP	Nevada Division of Environmental Protection
NPDES	National Pollution Discharge Elimination System
PBE	Physical barrier effectiveness
PCA	Potential contaminating activities
SDWA	Safe Drinking Water Act
SNWA	Southern Nevada Water Authority
SNWS	Southern Nevada Water System
SWAP	Source Water Assessment Program
SOCs	Synthetic organic compounds
TOT	Time of travel
UCMR	Unregulated Contaminant Monitoring Rule
UNLV	University of Nevada Las Vegas
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
UV	Ultraviolet
VOCs	Volatile organic compounds
WRCC	Western Regional Climate Center
WWTP	Wastewater treatment plant

EXECUTIVE SUMMARY

What is the Source Water Assessment Program (SWAP)?

The SWAP is a federally mandated program passed by the U.S. Congress under the Safe Drinking Water Act (SDWA) Amendments of 1996 (Public Law 104-182). SWAP requires the State of Nevada, and all other states in the United States, to delineate areas for source water protection for all sources of public waters, to inventory contamination sources within the area of protection, and to determine the vulnerability of water supply source to contaminating activities. Most importantly, SWAP requires the public be informed of the findings of the assessment to build support for actions that would lead to the protection of public water sources.

SWAP is NOT an assessment of the quality of the tap water that reaches households or industries. Prior to being delivered to the public, the tap water is treated in drinking water treatment facilities. The treated water, by federal law, must meet all federal drinking water standards before it is delivered to homes. SWAP is concerned with the vulnerability of the raw (untreated) water, that is, the source of water that feeds the public water treatment facilities. The information provided by SWAP, combined with other data on the watershed where the water source is located, can provide water resources managers with better understanding of cumulative impacts of various human activities on the quality of the water source. The information can also be used to set priorities and allocate resources to address or prevent degradation of the water source's quality.

Technologically, water sources of varying qualities can be treated to drinking water standards, at a cost. SWAP is a pro-active approach – its goal is to protect the water source, thereby reducing water treatment costs and maintaining the delivery of safe water to the public. In addition, water from protected resources presents a lower risk of exposure to contaminants that are associated with acute or chronic diseases.

SWAP for the State of Nevada

The U.S. Environmental Protection Agency (EPA) issued a final guidance document in 1997 requiring that the states prepare a SWAP document. The EPA guidance document contains the elements required of an EPA-approvable state SWAP and recommendations on what might constitute a source water protection assessment. The State of Nevada, Bureau of Health Protection Services (BHPS), the primary state agency responsible for enforcing the SDWA, prepared a draft SWAP for the State of Nevada in 1998, based on the EPA guidelines and presented it to a combined citizen and technical advisory committee. The committee met three times, and had three public workshops in Las Vegas, Carson City, and Elko. The comments from the committee and the public workshops were incorporated to the state SWAP document. The BHPS submitted a final SWAP document to EPA on February 1999, which was approved by EPA. The Nevada SWAP document contains guidelines for the preparation of an assessment of vulnerability of the **raw water sources** (ground and surface waters) in Nevada. The work presented here is for the surface waters in the Las Vegas Valley of Southern Nevada.

Vulnerability Assessment Determination in Southern Nevada

The major drinking water source for Southern Nevada and the Las Vegas Valley is Lake Mead. It provides 88% of the water resources, and the remaining 12% is supplied by groundwater wells. The drinking water intake (the place where the raw water is drawn to supply the public drinking water treatment facilities) is located at Lake Mead's Saddle Island about 150 feet below the Lake's surface. For Southern Nevada, the assessment of the vulnerability of the water source focuses on the vulnerability of the raw water intake at Lake Mead to contamination and includes: (1) identifying the watershed boundary and source water protection area, (2) preparing an inventory of the potential contaminant sources within the protection area, (3) assigning the vulnerability of the raw water intake at Lake Mead to contamination by each individual source identified within the protection area, and (4) determining the overall vulnerability of the raw water intake at Lake Mead to contamination from all sources combined.

Methodology used in the Assessment for Las Vegas Valley Surface Waters

Identifying the watershed boundary and source water protection area

The SWAP requires the delineation of a protection zone for the water source, that is, a zone must be defined around the Lake Mead raw water intake. Within the source water protection area, the impacts of humans and other activities must be considered on the overall assessment of vulnerability of the intake to contamination. EPA defines a minimum water source protection water area as one that is at least 200 ft wide around the water body and extends at least 10 miles upstream from the intake. In the case of the intake at Lake Mead, most potential contaminating activities are located west of the intake in the urban Las Vegas areas. Ten miles would be the point where the Las Vegas Wash, the major drainage channel for the entire Las Vegas Valley, goes underneath Lake Las Vegas. This distance does not extend to the urban areas of Las Vegas, which are potential sources of contamination. Therefore, in this assessment the source water protection area was extended further upstream (> 10 miles) to the limits of the dry weather flows in storm water channels from the Las Vegas urban area. The rationale is that water present in these channels can transport contaminants downstream to Lake Mead, via the Las Vegas. After establishing the limits of the source water protection area, buffer zones were identified. Zone A extends 500 ft around water bodies, and Zone B extends 3000 ft from the boundaries of Zone A.

Preparing an inventory of the potential contaminating activities (PCA) within the source water protection area

Field investigations were conducted within the established water source protection area to identify potential contaminating activities (PCAs) that could reach the raw water intake. A list of PCAs and the contaminants associated with each one was presented in the Nevada SWAP. PCAs include gas stations, laundromats, septic tanks, animal burial sites, dry cleaners, paint shops, car washes, and laboratories, etc. The contaminants of concern in SWAP are volatiles organic compounds (VOCs), synthetic organic compounds (synthetic organic compounds), inorganic compounds (IOCs), microbiological compounds (i.e., bacteria, viruses), and radionuclides. The specific VOCs, SOCs, IOCs, microbiological contaminants, and radionuclides regulated by EPA can be found at http://www.epa.gov/safewater/mcl.html.

Assigning the vulnerability of the raw water intake at Lake Mead to contamination by each PCA within the protection area

The objective of determining the vulnerability of the water intake at Lake Mead to specific sources of contamination is to call attention to those PCAs and contaminate categories that pose the greatest risk to the water source. SWAP defines the vulnerability of each PCA as:

Vulnerability = PBE + Risk + TOT + Water Quality + other relevant information

Each term in the vulnerability equation is defined below. It is noteworthy that the vulnerability assessment of the water intake to specific contaminants does not take into consideration the potential amount (loading) of contaminant that would reach the water source. As a preliminary assessment, SWAP's goal is to identify contaminating activities and assign a potential risk to these activities. Water resource managers have to combine the information generated by SWAP with other data to allocate and prioritize resources that would lead to the protection of the water source. The specific terms in determining the vulnerability are as follows:

PBE (Physical Barrier Effectiveness) is a measure of how well geological, hydrogeological, and physical characteristics of the watershed act as a barrier to prevent downstream migration of contaminants (or the susceptibility of the watershed). In this study, the following values were assigned to the different PBE levels: Low =5; Moderate = 3; High 1.

Risk is the risk ranking associated with each PCA. The rankings were assigned in the Nevada SWAP based on the potential toxicity associated with the PCA. In assigning the risk associated with each activity the following rankings were used: High =5; Moderate =3; and Low =1.

TOT (Time of Travel) is the estimated time that would take each PCA to reach the water source. Contaminant sources located close to a water intake would pose higher risk than those located further upstream because the time for response would be longer for the latter. In this study, field measurements were performed to estimate the velocity of water in the storm channels and the Las Vegas Wash. The Las Vegas Wash velocity was assumed to be approximately 3 ft/sec. The TOT in this study is the time for the contaminant to reach Lake Mead. The raw water intake at Lake Mead is about seven miles from the end of the Las Vegas Wash. This approached was necessary since there is limited information on the time of travel in Lake Mead from the Las Vegas Wash exit to the raw water intake. Ongoing research by others will provide more information on the TOT in Lake Mead. In computing the final vulnerability of each PCA in Section 3.3.5, the following values are assigned to the different TOTs to Lake Mead: 0-6 hours = 9; 6-12 hours = 7; 12-18 hours = 5; 18-24 hours = 3; > 24 hours = 1.

Water Quality involves evaluating historical raw water quality data at the intake to determine if the source has already been affected by contaminating activities. The EPA SWAP requires evaluating raw water quality data for all contaminants regulated under the SDWA- surface drinking water act (contaminants with a maximum contamination level – MCL), contaminants regulated under the surface water treatment rule (SWTR), the microorganism cryptosporidium, pathogenic viruses and bacteria, and not federally-regulated contaminants that the state determines it threatens human health. The Nevada SWAP has added perchlorate and MTBE to their list of contaminants to be evaluated because of these contaminants have been found in the surface waters in Nevada. If the water quality data shows the presence of a contaminants in a certain category, then that category of contaminants was given a High value = 5. If a contaminant is not present, then that category of contaminant was given a Low value =0.

Results

The source water protection zone delineated for the water intake represents approximately 5% (50,550 acres) of the Las Vegas Valley watershed and is located in the highly developed regions, which drain into the Las Vegas Wash. A total of 320 potential sources of contamination were identified with source water protection Zone A (See Figure A-1). The common contamination source was septic tanks followed by medical institutions and repair shops. In addition 12 National Pollutant Discharge Elimination System (NPDES) discharge permits, for treated municipal and industrial wastewater effluents, were identified which discharge into drainage channels and the Las Vegas Wash within the source water protection zone. Within Zone B, a large portion (45%) of the land use is undeveloped. The next highest land uses within the source water protection zones are residential (22.8%) and highways (13.3%).

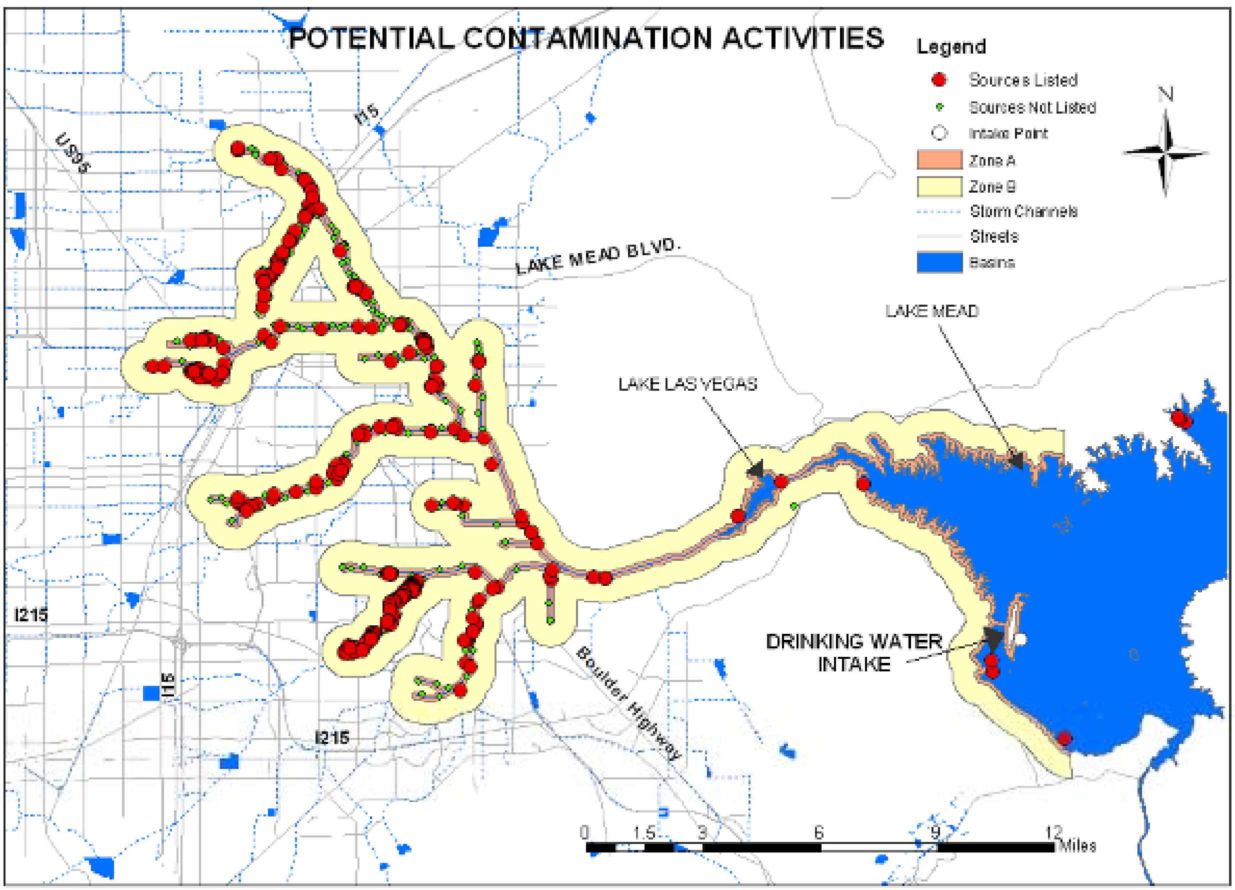

Figure A-1: Protection Zones A and B and the location of PCAs.

The analysis of four years of water quality data for the source water intake revealed that prior to undergoing treatment, the water quality at the intake meets most established MCL's for drinking water. However, the greatest concern is the effect of the Las Vegas Wash on the quality of the water at the intake. The Las Vegas Wash does not completely mix with Lake Mead water and, despite being more than seven miles from the intake and a travel time of 2-4 days, it affects the water quality of the intake. This is most critical during the winter when the Las Vegas Wash sinks to lower depths and higher levels of contaminants are expected at the intake. The presence of the contaminant perchlorate at the intake underlines the concern that a contaminant from the Las Vegas Wash could pose a threat to the water intake.

The vulnerability analysis shows that the PCAs with the highest vulnerability rating include septic systems, golf courses/parks, storm channels, gas stations, auto repair shops, construction, and the wastewater treatment plant discharges. Based on the current water quality data (prior to treatment), the proximity of Las Vegas Wash to the intake, and the results of the vulnerability analysis of potential contaminating activities, it is determined that the drinking water intake is at a Moderate level of risk for VOC, SOC, and microbiological contaminants. The drinking water intake is at a High level of risk for IOC contaminants since perchlorate is present in the raw water source. Vulnerability to radiological contamination is Moderate. Source water protection in the Las Vegas Valley is strongly encouraged because of the documented influence of the Las Vegas Wash on the quality of the water at the intake.

1. INTRODUCTION

The protection of water resources is a concern for the health of the public, securing a safe drinking water supply, and maintaining a strong economy. The Safe Drinking Water Act of 1974 is the national law meant to protect public health by regulating drinking water supplies (USEPA, 1999). The 1996 amendment to the Act created the Source Water Assessment Program (SWAP) with the objective to evaluate potential sources of contamination to drinking water intakes (surface and groundwater). The 1996 amendment to the SDWA required communities to delineate source water protection areas and provide funding for water system improvements, operator training, and public information (USEPA, 1999). The U.S. Environmental Protection Agency (USEPA) defines source water, as all water from rivers, streams, underground aquifers, and lakes that can be used to supply drinking water needs (USEPA, 2001). Guidance on the content of the SWAP document is provided by USEPA (2001) and is detailed for the State of Nevada by the State Health Division, Bureau of Health Protection Services (BHPS, 1999). The steps for developing the SWAP in Nevada as outlined in BHPS (1999) are as follows:

- Identify watershed boundary and source water protection area.
- Prepare an inventory of the potential sources of contamination in the source water protection area.
- Assign a level of risk to each contaminant source as related to the potential of the contaminant reaching the drinking water source.
- Determine the vulnerability of the drinking water sources to contamination from all sources.
- Prepare a final report and make available to the public.

Under the SWAP, each state defined its own approach to assess source water and the assessment plan had to be approved by the USEPA. By the beginning of 2002, all state proposals had been submitted and approved. The SWAP documents for all the states can be found at www.epa.gov/safewater/swapmap.html.

The study presented here assesses the potential sources of contamination from the Las Vegas Valley to the surface drinking water intake (Lake Mead) for southern Nevada. The assessment of potential sources of contamination to groundwater wells in the Las Vegas Valley was performed by a separate contractor and is not included in this study. Lake Mead is the primary drinking water source for the Las Vegas Valley supplying approximately 88% of the domestic water supply. Lake Mead receives water from other rivers (e.g., Muddy River, Virgin River, Colorado River); however, the Las Vegas Wash is the most likely drainage to impact the drinking water intake due to the proximity of its outlet to the drinking water intake. The Las Vegas Wash outlet is approximately 7-8 miles from the drinking water intake. The Virgin River, Muddy River, and Colorado River are more than 40 miles from the intake. It is also noteworthy that this study is based on the presence of contaminating activities and is not a comprehensive analysis of the loads to the drinking water intake.

The outline of this report is as follows. Section 2 provides background material on the Las Vegas Valley watershed, drinking water sources, and water quality in Lake Mead/Boulder Basin and the drinking water intake. Section 3 summarizes procedures used in the SWAP for Las Vegas Valley surface waters. Section 4 provides the results of the SWAP and the vulnerability determination for each potential contaminating activity. Lastly, Section 5 is the final vulnerability assessment for the drinking water source.

2. BACKGROUND

2.1. Description of Watershed

The Las Vegas Valley watershed is located in Clark County, Nevada and has a valley floor elevation of approximately 2,000 feet (WRCC, 2002). To the west, the watershed is bordered by the West Spring Mountains, which ranges from 8,000 to 11,000 feet, and to the north by the Ground Gunnery Range, with peak elevations of approximately 7,000 feet. The watershed area is approximately 1,520 square miles; its washes and storm channels drain first to the Las Vegas Wash and then to Lake Mead (Figure 2-1). Most of the storm drains and channels within the valley are either dry or low flows; however, some washes that used to be ephemeral have become perennial streams (Figure 2-2). One of the primary sources for these perennial flows is overirrigation of ornamental landscaping and turf (Mizell and French, 1995).

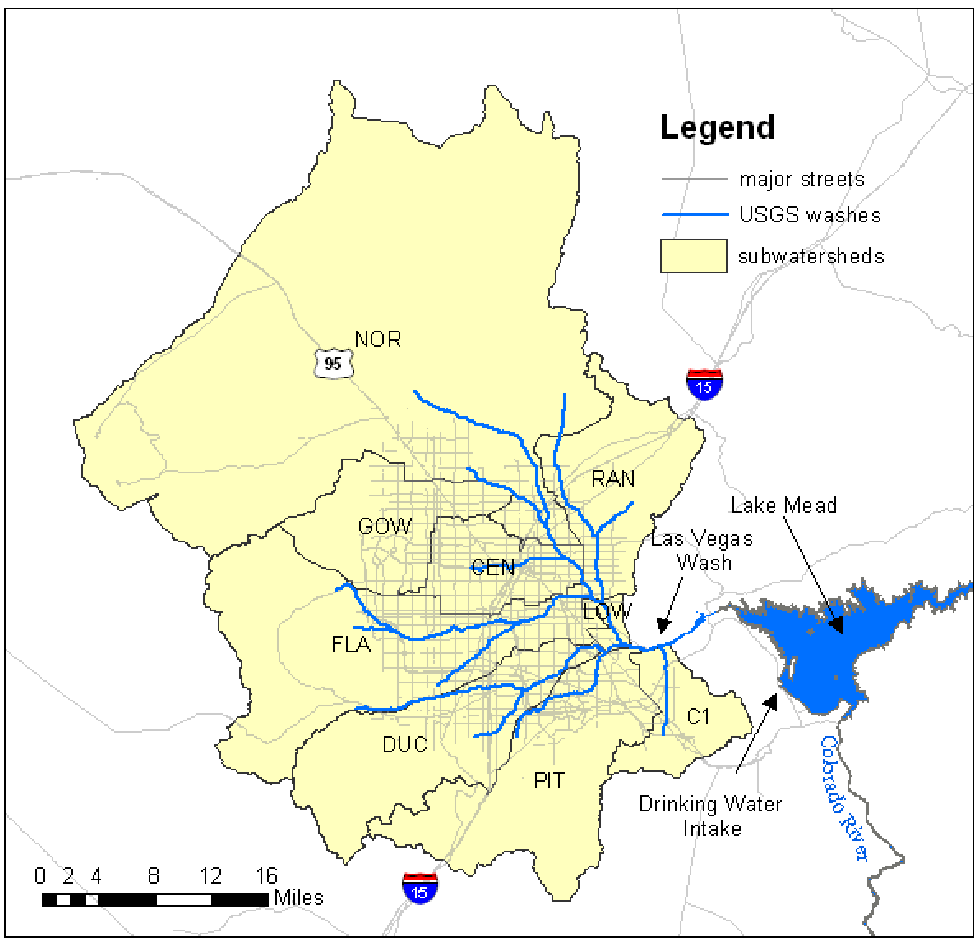

Figure 2-1: Overview of the Las Vegas Valley watershed, subwatershed boundaries, and the proximity to Lake Mead and the drinking water intake point.

Figure 2-2: Typical storm channel during dry weather period. (Range Wash at Charleston).

2.1.1. Demographics

Las Vegas is currently the fastest growing large metropolitan region in the U.S. (Gottdienet et al., 1999). The population growth rate is higher in Clark County than in the City of Las Vegas. This represents urban areas that are outside the Las Vegas city limits but still in Clark County. Population for the Las Vegas Valley is approximately 1.4 million (U.S. Census, 2000). This number represents more than 95% of Clark County's population and more than 65% of the state's population (Table 2-1).

Table 2-1: Population data for Nevada and Southern Nevada, Source: U.S. Census Bureau, Census 2000.

Location	Population in 2000
Las Vegas Valley	1,316,387
Clark County	1,375,765
Nevada	1,998,257

2.1.2. Climate

The Las Vegas Valley is in a desert region that is characterized by high temperatures during the summer (Table 2-2) with relatively low humidity values (11 to 34%) and an average yearly rainfall of 4.13 inches (WRCC, 2002) (See Table 2-2).

Table 2-2: Summary of Las Vegas temperature and precipitation. Data obtained from Western Regional Climate Center (WRCC, 2002).

Season	AverageTemperature Range °F		Precipitation (inches)	
	Minimum	Maximum	Minimum	Maximum
Summer	68°	106°	0	2.6
Fall	43°	95°	0	1.6
Winter	33°	63°	0	3.0
Spring	44°	88°	0	4.8

2.1.3. Soil Types

The soil characteristics in the Las Vegas Valley are summarized in the report "Soil Survey of Las Vegas Valley Area Nevada" (USDA, 1985). This is a comprehensive soil study for the region and designated the different soil types and properties. For the SWAP study, the hydrologic soil groups, determined by the Soil Conservation Service, were used to classify soils. The hydrologic soil groups are based on their infiltration rates, from high (soil A) to low (soil D). (Maidment, 1993).

A large portion of the watershed (58%) is covered by the hydrologic soil group D, which has a very slow infiltration rate and high runoff potential (USDA, 1985). Figure 2-3 displays the spatial distribution of the hydrologic soil groups within the Las Vegas Valley and the watershed boundary. The portions of the watershed that have soil group D are largely in the surrounding mountains. The valley floor of the watershed has B and C soils. The soil characteristics are used in Section 3.3.1 to determine the ability of a contaminant to migrate downstream in the watershed.

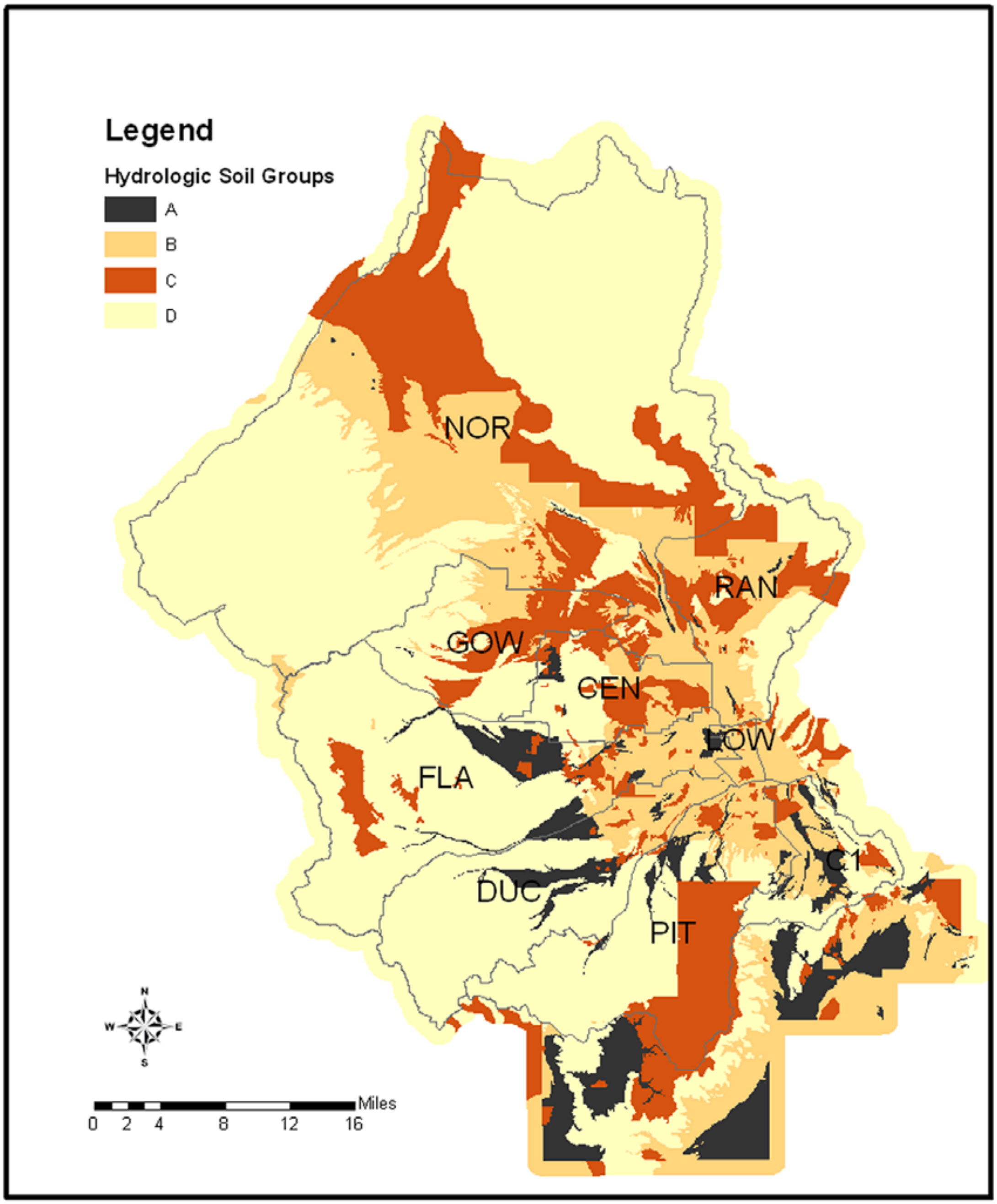

Figure 2-3: Hydrologic soil groups based on data from Clark County GIS Management Office and the U.S. Department of Agriculture (USDA, 1985).

2.1.4. Land Uses

Land use is available from the Clark County Assessor's Office as a database file with parcel information, including land use code and parcel number, which can be displayed in a

Geographic Information System (GIS). There are approximately 70 different land use codes that can be generalized to seven land use categories. Figure 2-4 displays the general land use for the Las Vegas Valley watershed and Table 2-3 summarizes the area of each land use. Approximately 85% of the watershed is undeveloped; however, the critical areas for this source water assessment study are located in the central and southeast portion of the watershed, which is highly developed.

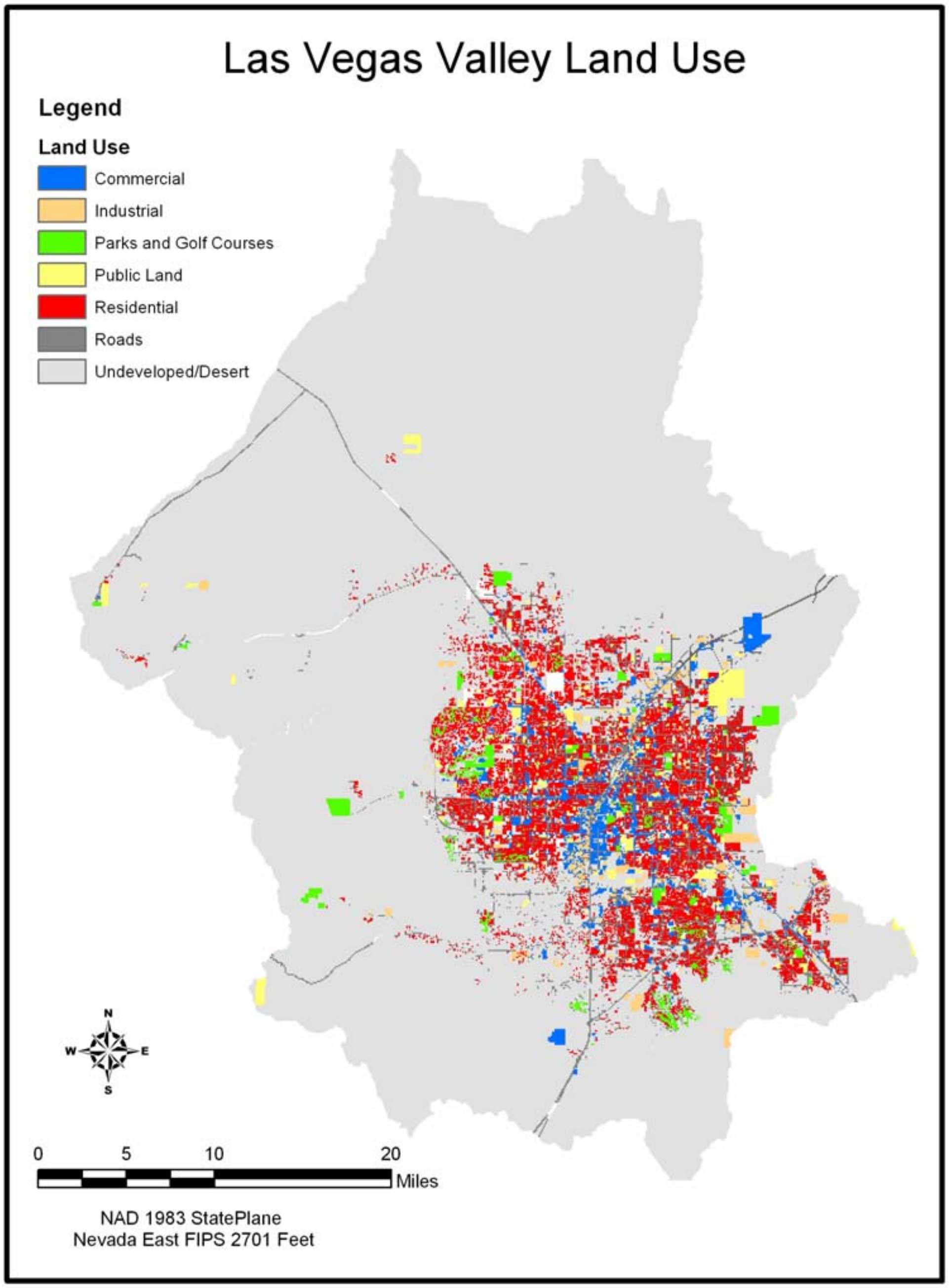

Figure 2-4: Overview of land use compiled from Clark County Assessor's Office data (2001).

Table 2-3: General land use categories for the Las Vegas Valley watershed based on Clark County Assessor's Office parcel data (2001).

Land Use	Area mi^2	Percentage of watershed area (%)
Undeveloped	1267	85.0
Roads and Highways	71	4.0
Commercial	27	1.5
Industrial	16	1.0
Residential	107	5.7
Park/Golf Courses	17	1.1
Public Land	18	1.1

2.1.5. Flood Control Facilities

Since 1960, the Las Vegas Valley has experienced at least nine "million dollar floods," and 26 lives have been lost (CCRFCD, 2002). Being aware of this problem, the Clark County Flood Control District has planned 97 detention basins in the Las Vegas Valley watershed to mitigate flood effects (GISMO, 2002). As of June 2002, 57 of the 97 basins were constructed. Clark County also relies on stormwater channels (lined and unlined) to control floods. Both the storm channels and detention basins in the Clark County Master Plan of Drainage are shown in Figure 2-5.

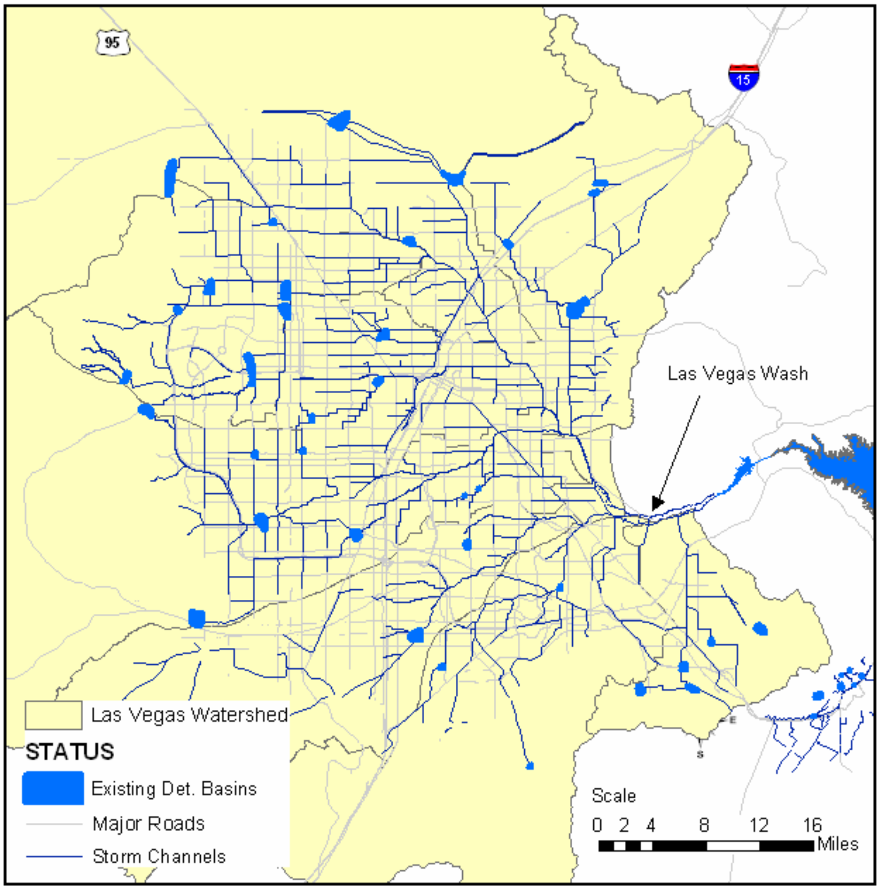

Figure 2-5: Flood control facilities in the Las Vegas Valley.

2.2. Drinking Water Sources

The Colorado River, diverted at Lake Mead is the main source of water for Southern Nevada. The water from Lake Mead supplies Boulder City, Henderson, North Las Vegas, Las Vegas, Clark County and Nellis Air Force Base. Lake Mead stores up to 26 million-acre feet of water (SNWA, 2002a). The Lake's operations started when the construction of Hoover Dam was completed in 1936. Initially, the primary uses of Lake Mead were to generate electricity and to temporarily store water for downstream use, especially for California. Despite the close proximity to Lake Mead, the Las Vegas valley did not utilize the Lake water until 1942. Instead the Valley depended on the groundwater resources. The first reported use of Lake Mead water for the Las Vegas Valley occurred in 1942 for the Basic Management Industrial (BMI) complex operations. In 1954, the water lines were extended to Las Vegas, and approximately 11,100 ac-ft was pumped from the lake during this year (Meier, 1969). This amount gradually increased annually, and was doubled by year 1963 (Meier, 1969).

Nevada's "consumptive use" apportionment of Colorado River water is 0.3 million acre-feet (MAFY). Arizona and California are allowed to divert 2.8 and 4.4 MAFY, respectively (SNWA, 2002a; CRWUA, 2002). Nevada's consumptive use accounts for diversion from Lake Mead minus return flows from all wastewater plant (WWTP) treated effluents discharged to the Las Vegas Wash and Lake Mead. The discharges from the three wastewater treatment facilities are responsible for almost all the flow of the wash (Stave, 2001); therefore, almost all its 153 million gallons that flow per day or 0.17 MAFY, can be added as return flow to the original consumptive use of 0.3 MAFY, increasing the diversion amount.

Besides the Colorado River apportionment, Nevada relies on short and long term water resources. According to the Southern Nevada Water Authority (SNWA) Water Resource Plan (SNWA, 2002a) short-term water resources include surplus Colorado River water, unused Arizona Colorado River apportionment, Colorado River water as part of the Arizona Water Banking Project, and Colorado River water recharged in Southern Nevada's Groundwater Bank.

The drinking water intake for Southern Nevada is located at Lake Mead's Saddle Island (Figure 2-1). Even though the main intake is located more than seven miles downstream from the Las Vegas Wash and 150 feet below the Lake's water surface (SNWA, 2002a), source water contamination by pollutants present in the Las Vegas Wash is a concern. The Saddle Island intake is responsible for approximately 88% of the Las Vegas drinking water (SNWA, 2002a); hence, intake contamination can compromise the water for thousands of inhabitants in Southern Nevada. The other 12% is derived from groundwater wells.

2.3. Characteristics of the Drinking Water Supply (Lake Mead)

2.3.1. Limnology of Lake Mead

The main dimensions and features of Lake Mead are illustrated in Table 2-4.

Table 2-4: Major physical features of Lake Mead (modified from LaBounty and Horn, 1997; Lara and Sanders, 1970).

Parameter	Value (US units)	Value (SI units)
Volume	3×10^7 ac-ft	36.7×10^9 m^3
Surface Area	160,000 ac	660 km^2
Highest Reservoir Level	1230 ft	374 m (mean sea level)
Max Width	9.3 mi	15 km
Max Length	66 mi	106 km
Shoreline Length	550 mi	885 km
Hydraulic Retention Time	3.9 years	3.9 years

The major inflows into Lake Mead are the Colorado River, Virgin River, Muddy River, and Las Vegas Wash (Figure 2-6). Table 2-5 shows the magnitude of the major inflows and outflows in Lake Mead. The Colorado River is the major inflow while Hoover Dam is the major outflow of the Lake. The Las Vegas Wash, while representing only 1.5% of the total inflow to Lake Mead, presents a concern to the overall water quality of Boulder Basin because of its proximity to the drinking water intake at Saddle Island.

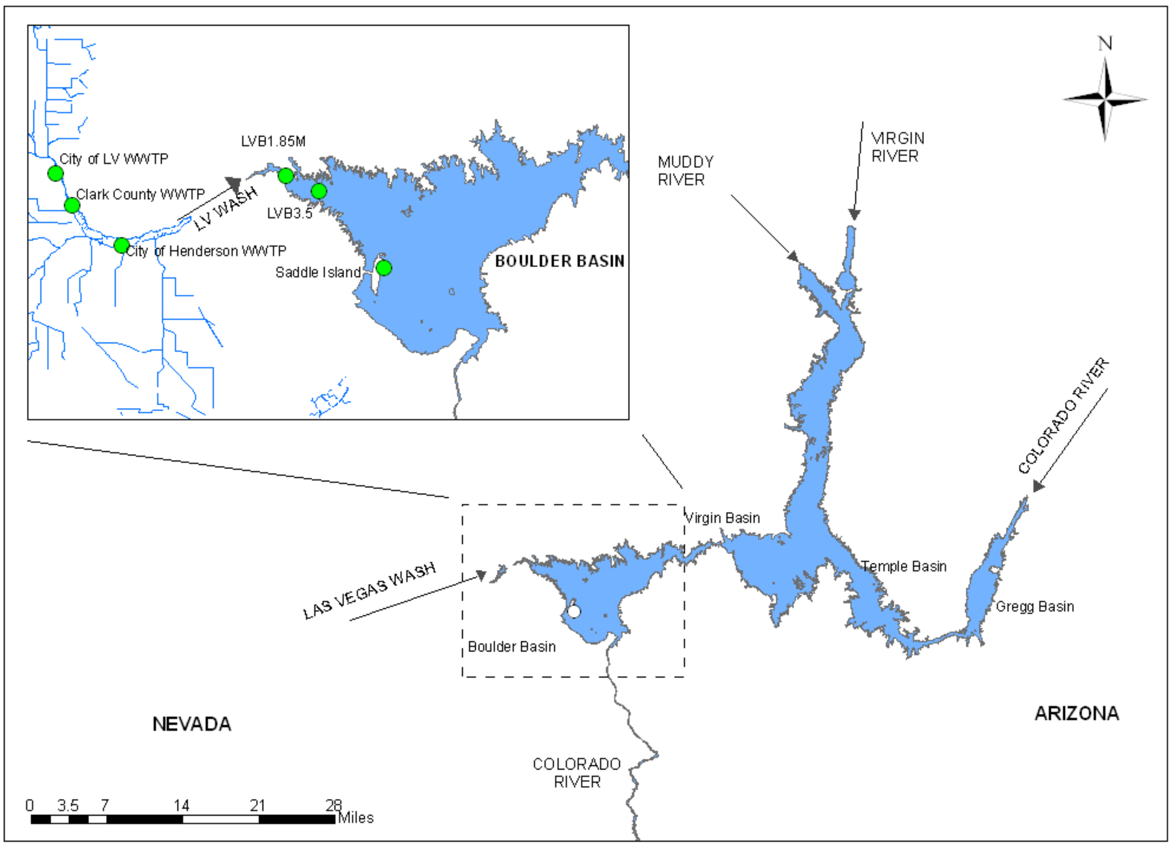

Figure 2-6: Overview of Lake Mead and the various basins. Inset figure displays the key water quality stations used in this study, the drinking water intake at Saddle Island and the wastewater treatment plants (WWTP) along the Las Vegas Wash.

Table 2-5: Lake Mead Water Budget (Modified from LaBounty and Horn, 1997; Roefer et al., 1996; SNWA 2002).

Parameter	Amount	Percentage
Major Inflows		
Colorado River	1.2×10^{10} m^3/yr (1.0×10^7 ac-ft/yr)	97%
Virgin	1.8×10^8 m^3/yr (1.5×10^5 ac-ft/yr)	1.4%
Muddy Rivers	1.2×10^5 m^3/yr (1.0×10^4 ac-ft/yr)	0.1%
Las Vegas Wash	1.9×10^8 m^3/yr (1.5×10^5 ac-ft/yr)	1.5%
Major Outflows		
Hoover Dam Release	1.0×10^{10} m^3/yr (8.9×10^6 ac-ft/yr)	86%
Evaporation (estimated)	1×10^8 m^3/yr (8.9×10^5 ac-ft/yr)	10%
Southern Nevada Water System	5.5×10^8 m^3/yr (4.4×10^5 ac-ft/yr)	4%

Lake Mead has four main sub basins: Boulder, Virgin, Gregg, and Temple, that are separated by four canyons: Boulder, Black, Virgin, and Iceberg (Figure 2-6). Lake Mead is considered to be subtropical, mildly mesotrophic (Vollenweider 1970, Carlson 1977). According to Deacon (1976) the lake surface water temperatures vary from 10.5^0 C in January/ February to 27^0 C in July/August. Thermal stratification develops in May and June. A well-defined thermocline is established between a depth of 10 -15 m in July when the surface water temperature reaches 26^0 C. As the surface water temperature drops in September, the Lake begins to mix. Mixing continues until January/February when the Lake's surface water temperature drops below 10.5^0 C. By this time the Lake is completely destratified.

Individual basins of Lake Mead exhibit unique ecological and water quality characteristics (LaBounty and Horn, 1997). Boulder Basin is the most downstream basin and the most polluted and nutrient rich because of the discharge from the Las Vegas Wash. The Las Vegas Wash is the drainage channel for the entire Las Vegas Valley and it discharges into the Las Vegas Bay of Boulder Basin (Figure 2-6). The Wash contains urban runoff, groundwater discharges, and treated wastewater effluents from all three municipal wastewater treatment facilities. The effluent discharges from the three southern Nevada wastewater treatment facilities are responsible for the vast majority of the flow of the Las Vegas Wash and it amounts to approximately 153 million gallons per day (0.17 MAFY). Drinking water for the Las Vegas Valley is withdrawn from the Lake at Saddle Island, located in Boulder Basin. Thus, Lake Mead has a dual role in the water cycle of the Las Vegas Valley; it is the source of drinking water and the discharge body for treated wastewater effluent as well.

2.3.2. Drinking Water Intakes and Water Treatment

There are three raw water intakes for Southern Nevada at Lake Mead, all located at Saddle Island (Figure 2-1 and 2-6), in Boulder Basin. The tops of the major intakes, SNWS#1 and SNWS#2, are located at 1042 ft and 992 feet (above sea level), respectively, are managed by the Southern Nevada Water System (SNWS) and feed the two major drinking water treatment facilities for the Las Vegas Valley. These intakes are 12 feet in diameter. Water intake SNWS#1 was inaugurated in 1971 and water intake SNWS#2 became operational in 2002 (SNWA, 2002a). A third intake, known as the Basic Management Industrial (BMI) complex is the oldest one and was established in the early 1940s to supply the fabrication of specialized materials for the World War II efforts (SNWA, 2002a). This intake contains six 16" pipes and it draws water from 1050 ft elevation. In 1994, BMI agreed to transfer 14,550 AFY of its Colorado River consumptive use contract to SNWA (SNWA, 2002a). This allocation is used by the City of Henderson, which treats the water in a 15 MGD water treatment facility located in Henderson. The raw water quality for the BMI intake and the SNWS #1 intake are basically the same (Jeff Gebhart, 2002; private communication).

The water taken from SNWS#1 and SNWS#2 is treated in the Alfred Merritt Smith (700 MGD capacity) and River Mountains (600 MGD design capacity), respectively. The Alfred Merritt plant started operation in 1971 and additional improvements were made in the 1980's and 1990's expanding the plant's capacity from 400 to 700 MGD. The River Mountains plant started operation in October 2002 with a current capacity of 150 MGD and a future capacity of 600 MGD. The two plants are state-of-the-art facilities and the treatment trains include pre-chlorination, aeration, coagulation/flocculation with ferric chloride, mixed media filtration, and disinfection with chlorine. In 2003 both facilities will switch to ozonation as their primary disinfectant. The City of Henderson plant has a similar treatment train, except that it uses ultraviolet (UV) for disinfection instead of ozonation. Although the Saddle Island intake is located more than seven miles downstream from the Las Vegas Wash and about 150 ft from the Lake's surface, water quality in the intake is influenced by the Las Vegas Wash discharges, as discussed in the following section.

2.3.3. Influence of the Las Vegas Wash on the Water Quality of Lake Mead at the Water Supply Intake

The hydrodynamics and mixing behavior of the Las Vegas Wash as it reaches the Las Vegas Bay and Boulder Basin are not well understood and few studies have tried to address this question, despite its significance to the quality of the water source at the intakes at Saddle

Island. However, some studies (LaBounty and Horn, 1997; Boralessa and Batista (2000); Fisher and Smith, 1983) have provided insight into the seasonal behavior of the Las Vegas Wash inside Boulder Basin.

The density of the Wash water remains fairly constant throughout the year. However, the wash temperature fluctuates between 20°C in winter to about 28°C in summer (Roline and Sartoris, 1996). In early spring, the Wash flow depth is gradually elevated within the Las Vegas Bay area, and reaches the shallowest depth in late spring when the temperature difference between the Wash water and the Lake water is at its maximum. The thermocline begins to develop in May and the warm lake surface water forces the Wash intrusion to flow deeper. During the summer the Wash sinks as the thermocline is further developed. In fall the thermocline breaks and the Wash water begins to cool down. This forces the Wash to flow deeper in the Lake, within the former hypolimnion. The Wash intrusion continues to flow within the hypolimnion until early spring when the system goes into the next cycle.

Boralessa and Batista (2000) obtained historical perchlorate levels in Lake Mead by analyzing frozen water samples dating from 1991 to 2000. Because perchlorate is a conservative tracer, the results of the study provided insight into the movement of the Wash within Boulder Basin. The results show that the flow of the Las Vegas Wash is primarily within the metalimnion and the hypolimnion layers within the Las Vegas Bay area, and mixes up into the Lake when it reaches the interior sections. In addition, lake stratification was found to significantly affect perchlorate levels at all thermal layers. The epilimnion and metalimnion perchlorate levels during the stratified period were higher than those of the non-stratified period. The hypolimnion perchlorate concentrations were significantly higher during the non-stratified period than the stratified period. These results are consistent with the findings of LaBounty and Horn (1997) and indicate that the Wash sinks to lower depths during the wintertime and therefore higher levels of contaminants, originating from the Las Vegas Wash, are expected in the Saddle Island water intake during this period.

One can infer from the results of the studies mentioned above that, despite comprising only 1.5% of the total inflow to Lake Mead (Table 2-5), the Las Vegas Wash plays a significant role on the quality of the raw water intake at Saddle Island. There is potentially a myriad of organic, inorganic, and microbiological contaminants in the Las Vegas Wash. However, a contaminant entering the Las Vegas Bay and Boulder Basin, via the Wash, may not necessarily reach the water intake; the potential of a contaminant reaching the water intake is dependent upon the type of contaminant, its concentration, its fate, and its interactions with the various environmental components of the Lake. Nonetheless, the current presence of the contaminant perchlorate in the water intake demonstrates that one cannot underestimate the influence of the Las Vegas Wash (i.e., the source of perchlorate to Lake Mead) on the quality of the raw water in the intake at Saddle Island. In 1998, perchlorate concentrations in the Las Vegas Wash (after Lake Las Vegas-Figure 2-6) averaged 800 ppb (Boralessa, 2001) and in the SNWS intake it varied from 14-20 ppb. Although a 40-57 fold dilution in perchlorate concentrations occurred, the contaminant reached the water intake via the Las Vegas Wash.

2.3.4. Discharges to Boulder Basin via the Las Vegas Wash

The Las Vegas Wash flow is composed of treated domestic wastewater effluent, treated industrial wastewater effluent, dry and wet weather runoff, and groundwater seepage. It has been estimated that domestic wastewater effluent discharges account for about 90% of the flow (Stave, 2001; Beavans et al., 1996) and that dry weather runoff flows and groundwater discharges account for about 10% of the total flows. In 1993, treated wastewater effluent constituted about 96% of the annual discharge of the Las Vegas Wash (Beavans et al., 1996). Table 2-6 shows the current National Pollution Discharge Elimination System (NPDES) permits for domestic and industrial wastewater discharge into the Las Vegas Wash. The majority of the flow is due to treated domestic wastewater effluents. In addition, discharge permits exist for industrial effluent discharges from the Kerr McGee Corporation, Titanium Metals Corporation, and for the Kinder Morgan Energy Partners.

There are three municipal wastewater treatment plants (WWTP) located along the Las Vegas Wash, which collect and treat all the municipal wastewater generated in the Las Vegas Valley. They are the City of Las Vegas (CLV), the Clark County Sanitation District (CCSD), and the City of Henderson (COH), which together form the Clean Water Coalition. Due to rapid growth of the Las Vegas Valley, the wastewater flows have currently increased at a rate of 4.7 MGD yearly (Harbour, 2001). Figure 2-7 shows the individual and combined effluent flowrates from the WWTPs in Southern Nevada. All three plants in the Las Vegas Valley treat wastewater to tertiary level with ammonia oxidation and phosphorus removal. However, the increasingly high flows and seasonal nutrient discharge permits into the Las Vegas Wash results in high nutrient (phosphorous and nitrogen) loading in Boulder Basin of Lake Mead (Du, 2002).

Table 2-6: Permitted NPDES discharges to the Las Vegas Wash

Permit #	Name	Flowrate	Discharge	Major Permit Limitations
NV 0021216	Clark County Sanitation District	110 MGD	Domestic Wastewater Effluent	174 lbs P/day (Apr 01 to Sept 30) 502 lbs NH3-N/day (Mar 1-Oct. 31) 30/45 mg/L BOD (30 - 7 day avg.) 30/45 mg/L SS (30 - 7 day avg.) 200 cfu Coliform
NV 0020133	City of Las Vegas	91 MGD	Domestic Wastewater Effluent	130 lbs P/day (Apr 01 to Sept 30) 379 lbs NH3-N/day (Mar 1-Oct. 31)
NV 0022098	City of Henderson	42.5 MGD	Domestic Wastewater Effluent	30 lbs P/day (Apr 01 to Sept 30) 89 lbs NH3-N/day (Mar 1-Oct. 31) BOD SS Coliform
NV 0023060	Kerr McGee Corp.	1.22 MGD	Effluent from ion-exchange plant that treats perchlorate-contaminated groundwater	Perchlorate (3 mg/L), Total Cr =0.1 mg/L, Cr^{+6} = 0.01 mg/L, TSS=135 mg/L, Total Fe = 10 mg/L, Mn = 5 mg/L Total Fe, Mn, Cl, total P, ammonia, TSS, BOD
NV 0000060	Titanium Metals Co.	6.2 MGD	Cooling and scrubbing water, descaling and swap-cooler water	Oil and grease = 10 mg/L Total N = 10 mg/L TDS = 2, 300 mg/L
NV 0023213	Kinder Morgan Energy Partners	0.0144 MGD	Effluent from groundwater treatment contaminated with petroleum	Benzene = 5 μg/L Ethylbenzene = 100 μg/L Toluene = 100 μg/L Total Xylenes = 100 μg/L Total petroleum hydroc. = 1 mg/L MTBE = 20μg/L Total-N = 20 mg/L

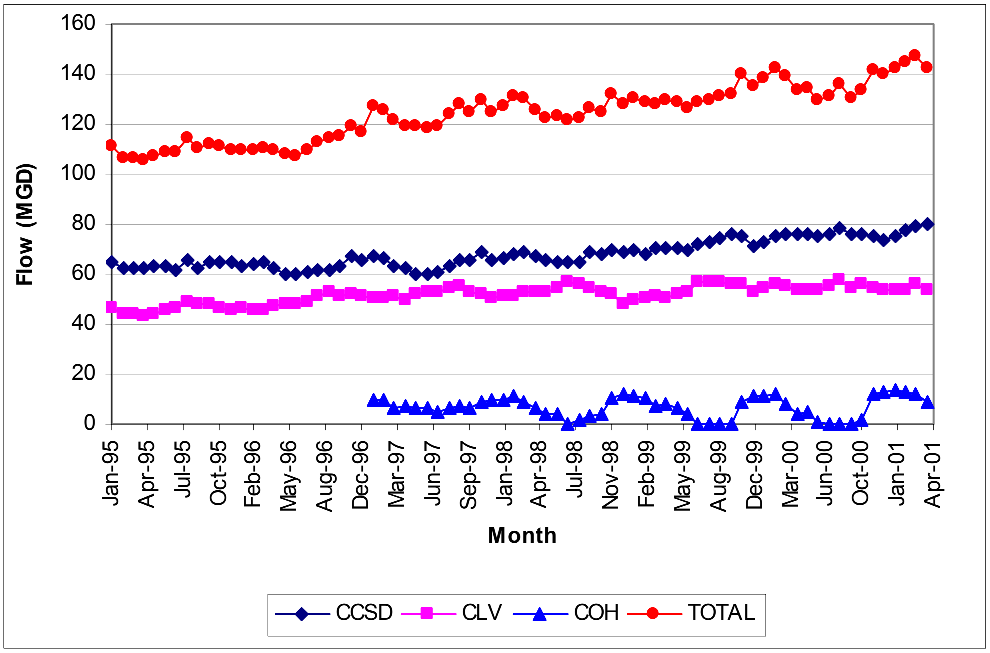

Figure 2-7:The monthly effluent flow rate of the three WWTPs (1995-2001)

There are several reports on water quality problems in Boulder Basin caused by the discharges from the Las Vegas Wash (Sartoris and Hoffman, 1971; Deacon, 1976; Baker et al., 1977; Baker and Paulson, 1980; Dan Szumski and Associates, 1991; Roline and Sartoris, 1996). The high concentration of nutrients in the Las Vegas Bay results in high productivity and the occurrence of abnormal algal blooms (La Bounty and Horn, 1997), such as those reported in 1993 (blue green algae bloom), 1996 (cryptophite algal bloom), and the 2001 green algal bloom (*Pyramichlamys dissecta*) (Du, 2002). Although the algal blooms in Boulder Basin have not been toxic and are not considered an immediate threat to the water supply, there is concern that such blooms transition to toxic forms of algae; cyanobacteria (blue-green algae) blooms may follow a green algal bloom because the cyanobacteria feed on the dead algal material.

Tables 2-7 and 2-8 list annual average levels of nutrients (1992-2000) of the inner (LVB1.8 – Figure 2.6) and outer (LVB3.5-Figure 2.6) Las Vegas Bay, respectively. There have been several changes in land use and wastewater treatment technologies in the Las Vegas Valley, which have affected the composition of the Las Vegas Bay water. Nonetheless, the following conclusions can be drawn regarding nutrient levels of the inner and outer Las Vegas Bay (Du, 2002): (a) the current total phosphorus (TP) concentration in the outer Bay is about 10 ppb while in the inner Bay it is 20 ppb, (b) the Dissolved orthophosphate (DOP) concentrations of the inner Bay are generally higher than those of the outer Bay, but in the last years they have been practically the same, (c) the ammonia and nitrite concentrations of the inner and outer Bay have been similar in the last years, (d) recent nitrate concentrations in the inner Bay have been twice as large as those of the outer Bay, (e) current total nitrogen levels in the inner Bay are about 4.5 ppm while in the outer Bay it is about 1.4 ppm, (f) chlorophyll-a levels in the outer Bay are generally 25% lower than those of the inner Bay.

Table 2-7: Yearly average water quality data of the inner Las Vegas Bay (Data source: SNWA database). Sampling point LVB1.8 was chosen as the center of the inner Las Vegas Bay.

Year	NH_4-N mg/L	NO_3-N mg/L	NO_2-N mg/L	TN mg N/L	TP mg P/L	DOP mg P/L	Alk. mg $CaCO_3$/L	Chl-a mg/m^3	NPOC mg/L
1992	0.521	1.44	0.141	2.41	0.051	0.013	111.7	10.89	23.70
1993	1.289	1.62	0.225	3.20	0.102	0.034	114.6	15.23	14.59
1994	0.440	2.75	0.140	3.30	0.072	0.028	115.7	4.12	30.78
1995	0.888	1.57	0.182	2.67	0.063	0.021	114.4	3.86	18.47
1996	0.638	4.10	0.155	4.85	0.105	0.063	119.9	4.48	45.02
1997	0.743	1.44	0.181	2.49	0.065	0.015	114.0	4.63	25.17
1998	0.787	3.84	0.165	4.62	0.111	0.055	118.7	4.25	-
1999	0.084	1.97	0.074	-	0.033	0.008	115.2	-	-
2000	0.080	2.00	0.068	-	0.020	0.008	121.5	-	-

Table 2-8: Yearly average water quality data of the outer Las Vegas Bay (Data source: SNWA database). Sampling point LVB3.5 was chosen as the center of the outer Las Vegas Bay.

Year	NH_4-N mg/L	NO_3-N mg/L	NO_2-N mg/L	TN mg N/L	TP mg P/L	DOP mg P/L	Alk. mg $CaCO_3$/L	Chl-a mg/m^3	NPOC mg/L
1992	0.437	0.41	0.093	1.00	0.019	2.935	114.1	3.45	5.01
1993	0.183	0.79	0.074	1.08	0.018	0.006	118.7	3.35	4.70
1994	0.445	0.51	0.074	0.94	0.018	0.007	114.7	3.42	4.59
1995	0.257	0.71	0.074	1.14	0.032	0.013	121.9	3.74	5.51
1996	0.399	0.86	0.073	1.35	0.054	0.026	130.3	3.24	-
1997	0.310	0.92	0.146	1.23	0.032	0.017	125.9	3.23	84.52
1998	0.301	0.92	0.080	1.39	0.018	0.011	122.4	3.17	3.66
1999	0.081	0.89	0.069	-	0.011	0.005	-	-	-
2000	0.080	0.80	0.061	-	0.011	0.007	-	-	-

There are only preliminary studies on the contribution of non-point source to the nutrient loading of Lake Mead (Piechota et al., 2002). The Nevada Department of Environmental Protection assumes that the TP contribution from non-point sources to Lake Mead is 100 lbs P/day. However, this value may not represent the actual loading of phosphorus from non-point sources. The explosive growth of the Valley resulted in changes in land use to landscapes that require the use of fertilizers, a source of phosphorus in dry and wet weather runoff flows. In the Las Vegas Valley, nonpoint source runoff is primarily from return groundwater flow, excessive watering of irrigation areas, household uses, and stormwater. Current investigations on the contributions of non-point sources to nutrients in the Las Vegas Bay (Piechota et al., 2002) revealed that in the year 2000, the total nonpoint source total phosphorus (TP) loads were approximately 15% of the TP loads to Lake Mead. This is primarily from wet weather nonpoint source runoff. The TP loading (150 to 300 lbs/day) during wet periods approach the permit level for the WWTPs and exceeds the amount assumed by NDEP for nonpoint sources (100 lbs/day). The total nitrogen (TN) loads are primarily from dry weather flows and amount to approximately 3-4% of the TN load to Lake Mead.

In addition to nutrients, organic, inorganic, and microbiological contaminants have been detected in the Las Vegas Bay water and its sediments. Beavans et al. (1996) found pesticides in sediments and carp tissues samples of the Las Vegas Bay. Covay and Beck (2001) detected 48 synthetic organic compound, including pesticides, PCBs, and dioxins in sediments of the Las Vegas Bay as compared to 28 compounds in the Overton Arm of Lake Mead (Figure 2-6).

The presence of indicator coliform in the Las Vegas Wash and the occurrence of a cryptosporidiosis outbreak in Las Vegas in 1994 are also a water quality concern in Boulder Basin. Fecal coliform indicator bacteria tend to show seasonal density increases to summer high values of 104-105 MPN/100mL in the Las Vegas Wash (Rosenblatt and Amy, 2002). Data generated from monitoring indicate that coliforms being discharged from the WWTPs are low to non-detectable. Studies on the microbiological quality of urban runoff and Las Vegas Wash water indicate that potential sources of indicator organisms include direct deposition from human and wildlife fecal matter in the Wash, surface inflows from yard and street runoff, mostly contributed from tributary channels, shallow groundwater inflows, some from inflows to tributary washes and some from inflows to the Wash (Rosenblatt and Amy, 2002, Piechota et al., 2002). The shallow groundwater itself is likely contaminated by infiltration from surface or near-surface sources, including turf irrigation, nuisance water, and infiltration from the 16,000 septic tanks operating in the Las Vegas Valley. Speciation studies on enterococcal indicators show strong environmental (mostly avian-associated) and human-associated signals in the Las Vegas Wash and its tributaries (Piechota et al., 2002, Rosenblatt and Amy 2002). This result indicates that avian-associated and human-associated species can survive in receiving waters. It does not rule out potential contributions from other sources (bovine, canine, equine and feline hosts).

Goldstein et al. (1996) report on 78 cases of crystosporidiosis in HIV-infected people in Las Vegas in 1994. Although the exact reason for the outbreak was not determined, and despite the state-of-the-art water treatment facilities, the epidemiological data pointed the public water supply as the most likely source for the outbreak (Roefer et al., 1996). A peer-review of the Las Vegas Cryptosporidiosis outbreak, sponsored by the American Water Works Association, recommended, among others, an examination of how the effluents from WWTPs and storm water runoff from the Las Vegas Wash affected the quality of the water supply in Lake Mead (Roeffer et al., 1996). This recommendation points to the potential contamination risk that the Wash poses to the water intake at Saddle Island.

2.4. Water Quality of the Raw Water at the Saddle Island Intake

The water at Saddle Island's intake is drawn 110-150 feet below the Lake's surface, depending on Lake level. The Southern Nevada Water System personnel provided UNLV with four years of data (1999-2002) on the quality of the raw water in the intake. A summary of the historical trends is provided in this section. The frequency of sampling and the amount of data available for each specific contaminant is depicted in Appendix A. Historical water quality data on the intake from the 1970's and 1980's is not available in electronic format or in a format that is easy to compile. Therefore, it was not possible to evaluate whether the water quality in the intake has changed in the last thirty years. Nonetheless the four-year data recorded presented here reflects the current quality of the water supply in the intake at Lake Mead. The intake water is monitored for inorganics, organics, radioactive, and microbiological parameters. The summary of water quality data presented here will be used later in this study to assign levels of vulnerability for contaminant categories.

2.4.1. Inorganic Components

Table 2-9 and Figure 2-8 show yearly averages and standard deviations for inorganic components in the SNWS intake. The raw-water supply from Lake Mead has very low turbidity (< 0.3 NTU) and color (< 5 units), moderate conductivity and alkalinity, and it is hard (hardness > 280 mg/L as $CaCO_3$). The low turbidity of Lake Mead's water is the result of the quiescent conditions present in the reservoir and long retention times that allow particles and/or color to settle to the bottom of the Lake. Low turbidity is indicative of high quality source water because many contaminants in waters, including microorganisms, are present as particles. Therefore, the removal of particles is a vital task in water treatment. Turbidities ranging from 16-26 NTU and 11 NTU have been reported for rivers/ lakes and reservoirs, respectively (Cornwell and Susan, 1979). Thus, Lake Mead's low turbidity makes it a great asset to its use as a water supply.

Table 2-9: Inorganic composition in the raw water supply (prior to treatment) at the SNWS Intake.

Constituent	Unit	1999			2000			2001			2002		
Temperature	^{O}C	15.18	±	1.13	15.52	±	1.15	14.33	±	1.49	13.25	±	1.19
Odor	T.O.N.	1.20	±	0.23	2.05	±	0.87	1.45	±	0.57	1.43	±	0.32
pH	Units	8.20	±	0.06	8.01	±	0.20	8.02	±	0.19	8.18	±	0.06
Color	Units	11.75	±	8.96	4.58	±	2.47	4.33	±	2.64	4.17	±	2.04
Turbidity	mg/L	1.45	±	2.11	0.34	±	0.14	0.37	±	0.18	0.37	±	0.14
Hardness (as $CaCO_3$)	mg/L	285.75	±	4.57	291.25	±	7.63	287.00	±	20.70	283.50	±	8.96
Conductivity	us/cm	905.00	±	18.04	902.77	±	22.88	904.00	±	32.99	929.00	±	9.38
Alkalinity, Bicarbonate	mg/L	132.06	±	3.72	133.37	±	3.25	135.52	±	2.76	145.83	±	19.88
Calcium	mg/L	72.08	±	1.56	73.80	±	2.01	69.61	±	4.60	70.10	±	1.66
Chloride	mg/L	66.70	±	3.14	64.63	±	3.45	70.59	±	9.07	74.62	±	2.11
Bromide	mg/L	0.097	±	0.005	0.061	±	0.012	0.330	±	0.620	0.086	±	0.014
Fluoride	mg/L	0.235	±	0.067	0.316	±	0.174	0.328	±	0.023	0.332	±	0.027
NO_3-N	mg/L	0.428	±	0.013	0.398	±	0.058	0.482	±	0.178	0.420	±	0.019
NO_2-N	mg/L	0.040	±	0.045	0.050	±	0.000	0.177	±	0.304	0.058	±	0.020
Ortho Phosphate	mg/L	0.053	±	0.045	0.050	±	1.1E-09	0.050	±	6.6E-10			
Perchlorate	ppb		±		11.97	±	3.45	8.25	±	1.20			
Sulfate	mg/L	222.89	±	10.47	216.68	±	10.27	222.51	±	18.15	223.07	±	5.81
TDS	mg/L	594.25	±	15.67	599.17	±	25.54	605.92	±	17.58	610.00	±	18.51
TOC	mg/L		±		2.682	±	0.167	2.887	±	0.277	2.769	±	0.129
Methylene Blue Activated	mg/L	0.030	±	0.017	0.025	±	0.018	0.020	±	4.9E-10	0.023	±	0.008

Seasonal variations analysis of the inorganic compounds of the intake at Lake Mead was performed using the entire data set available for the last four years (Appendix A). It is noteworthy that turbidity, conductivity, and TDS, all of which are related parameters, are higher during winter than in the other seasons. This may be explained by the influence of the Las Vegas Wash on the water quality of the Las Vegas Bay and Boulder Basin of Lake Mead. As shown by LaBounty and Horn (1996) and Boralessa and Batista (2000), in Boulder Basin, the Wash does not completely mix with the Lake's water and it travels as an intrusion with varying depth during the year; in the winter the Wash sinks closer to the water intake, influencing water quality the most.

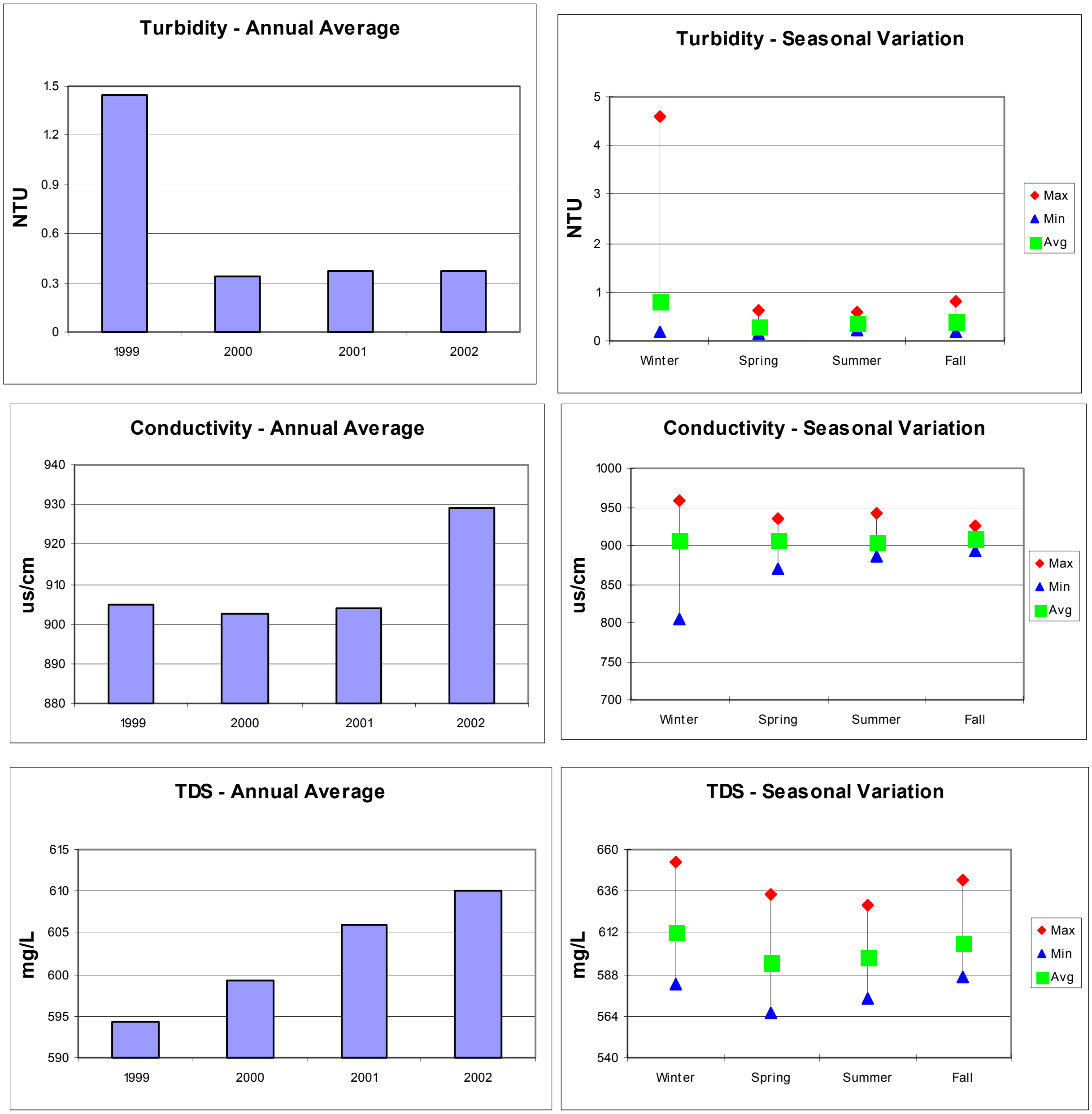

Figure 2-8: Yearly and seasonal variation of TDS, turbidity and conductivity at Lake Mead's water supply intake.

Nitrate and orthophosphate levels in the intake water are approximately 0.4 mg/L NO3-N and 0.05 mg/L, respectively. These levels are lower than those found in the inner and outer Las Vegas Bay (Tables 2-7 and 2-8). However, it cannot be inferred from the analyzed data whether the nitrate and phosphorus concentration in the intake had increased as a consequence of higher effluent discharges from the Las Vegas Wash. Records from the 1970's and 1980's would have to be analyzed to determine such a trend. There are no drinking water standards for phosphate and its presence relates to the protection of the Lake regarding eutrophication. The drinking water standard for nitrate is 10 mg/L NO3-N (Appendix B), which is about 25 times larger than the current level of nitrate in the water intake at Lake Mead. Sulfate and bromide levels in the water intake average 220 and 0.08 mg/L, respectively, and are naturally occurring. The secondary drinking water standard for sulfate is 250 mg/L. The primary drinking water standard for bromate, a byproduct of disinfection of waters containing bromide, is 0.010 mg/L. Therefore, there is a potential for bromate formation when strong oxidants, such as ozone, are used to disinfect the water from Lake Mead.

A contaminant of concern found in the intake is perchlorate. Perchlorate has been produced and handled in Henderson, NV at the Basic Management Industrial (BMI) complex since the early 1940's (Boralessa and Batista, 2000, Zhang 2001). During this period perchlorate was released to the environment by leaks in the industrial plants and storage ponds and by the disposal of perchlorate containing wastes into unlined ponds. Other industries of the BMI complex also disposed of wastes via infiltration in this area (Kaufmann, 1971, Kleinfelder, 1993). These releases caused the contamination of the near surface groundwater aquifer in the area; the contaminated groundwater seeps into the Las Vegas Wash which runs approximately 3 miles from the contaminated site. Perchlorate reaches Lake Mead and the Colorado River via the Wash. Table 2-10 shows the average composition of the contaminated seepage entering the Las Vegas Wash near the City of Henderson WWTP. Notice that in addition to perchlorate, the contaminated water also contains measurable levels of pesticides and toxic metals.

There are currently no drinking water standards for perchlorate. However, given the negative effects of this compound on the thyroid gland, in August 1997, the Nevada Department of Environmental Protection (NDEP) joined other states, implementing a perchlorate action level of 18 ppb. In 1998, perchlorate was placed on the USEPA Contaminant Candidate List for consideration for possible regulation and, in 1999, included in the Unregulated Contaminant Monitoring Rule (UCMR), which required monitoring of all large public water systems and a representative sample of small public water systems for perchlorate (USEPA, 2002). A recent draft risk characterization report by the USEPA (USEPA, 2002) calls for an acceptable level of perchlorate in water of 32 to 1 ppb.

Figure 2-9 shows the perchlorate levels in the raw water supply intake at Lake Mead. The figures show that perchlorate levels in the intake vary from approximately 8-20 ppb. The highest perchlorate levels are observed during the winter due to the dynamics of the Las Vegas Wash intrusion into Boulder Basin, as reported in section 2.3. Currently the contaminated site in the City of Henderson is being cleaned up and the perchlorate loading to Lake Mead is expected to decrease. In 1998 the perchlorate loading to Lake Mead was approximately 920 lbs/day (Boralessa, 2001). Since the installation of an ion-exchange plant to cleanup the contaminated groundwater in Henderson, perchlorate loading has decreased to less than 500 lbs/day (USEPA, 2002). The current perchlorate treatment facility (1100 gpm capacity) is not 100% efficient; the effluent from these plants containing 500-2000 ppb perchlorate is discharged into the Las Vegas Wash. In addition, the ion-exchange plant does not remove other contaminants (i.e. pesticides, metals), contained in the contaminated water; therefore the contaminants are discharged into the Las Vegas Wash and will reach Boulder Basin. Whether the contaminants contained in the seepage that are not removed by the ion-exchange system will reach the water intake at levels that may be a concern is not known. This would depend on the initial concentrations, characteristics and fate of the respective contaminants. In addition to the groundwater, soils along the Las Vegas Wash are also contaminated with perchlorate (USEPA, 2002) and one cannot accurately estimate when the levels of perchlorate in the intake at Saddle Island will subside to below desired levels.

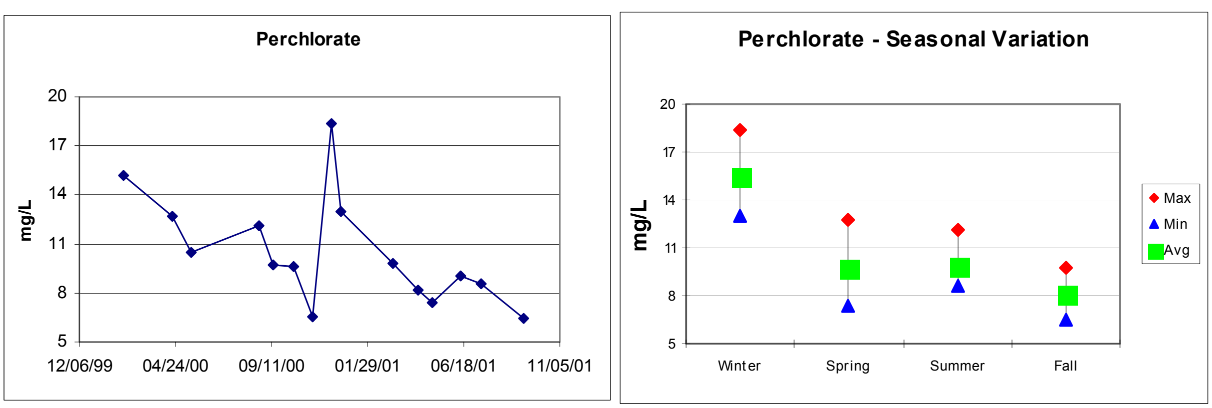

Figure 2-9: Yearly and seasonal variation of perchlorate levels in the intake at Lake Mead.

Table 2-10: Major Water Quality Parameters of the BMI Seepage near the Las Vegas Wash.

Parameter	Concentration (ppb)	Parameter	Concentration (ppb)
Arsenic	140	Beta-BHC	0.37
Barium	0.0183	Delta-BHC	1.71
Boron	4,600	4,4'-DDT & metabolites	0.31
Chromium (total)	620	4,4'-DDE	0.0073
Chromium (VI)	Not Detected	4,4'-DDD	0.0114
Chromium (III)	620	Dalapon	0.79
Copper	8.1	Dicamba	0.099
Iron	100	Dieldrin	0.1
Magnesium	252,000	Dinoseb	0.39
Manganese	1800	Endrin	0.0042
Molybdenum	120	Heptachlor Epoxide	0.0044
Nickel	15.5	Lindane (gamma BHC)	0.110
Potassium	45,800	MCPA	42
Selenium	12	Pentachlorophenol	0.017
Sodium	1,520,000	Silvex (2,4,5-TP)	0.084
Strontium	11,200	2,4,5-T	0.257
Vanadium	51	Chloroform	2
pH	7.65	m-Dichlorobenzene (1,3)	0.5
Color	20 units	o-Dichlorobenzene (1,2)	0.6
Perchlorate	100,000 - 310,000**	p-Dichlorobenzene (1,4)	0.7
Chlorate	100,000	1,1-Dichloroethane	2
TDS	7,300,000	Methyl Tert-butyl ether	5
TSS	14,000	di-2-Ethylhexyl phthalate	4
TOC	5,600	1,2,4-trichlorobenzene	2
Ammonia-N	150	Oil and Grease	3,800
BOD	1,420	Gross Alpha (pCi/l)	96.1
COD	140,000	Gross Beta (pCi/l)	204
Fluoride	1,600	Radium 226+228 (pCi/l)	595
Sulfate	1,950,000	Aldrin	0.0155
Total P	136	Chlordane Alpha	0.0025
Alpha-BHC	65		

*(Source: Modified from the Draft NPDES Permit -NV 0023060 -Submitted to the Nevada Department of Environmental Protection by Kerr McGee Corp.)
** Kerr McGee and UNLV data

2.4.2. Metals

Table 2-11 shows the average concentrations of several metals in the water intake in the last four years. Graphs showing yearly averages and seasonal distributions are shown in Appendix A. The vast majority of the metals in the raw intake water have concentrations several hundred-fold lower than the current maximum contaminant level (MCL) for the metal. Exceptions were found for arsenic and thallium. Thallium concentrations in the intake averaged 0.0015 mg/L; the current MCL for thallium is 0.002 mg/L. Arsenic concentrations in the intake averaged 3.75 ug/L (ppb); the current MCL for arsenic in drinking water is 10 ppb. A recent study by SNWA (2002b) concludes that arsenic is naturally occurring in the inflows to Lake Mead (i.e. Colorado, Virgin and Muddy rivers, and the Las Vegas Wash).

Table 2-11: Averages and standard deviations for metals in the Intake of Lake Mead prior to treatment.

Constituent	Unit	1999	2000	2001	2002
Aluminum	mg/L	0.0103 ± 0.0098	0.0325 ± 0.0260	0.0540 ± 0.0943	0.0050 ± 0.00002
Antimony	mg/L	0.0010 ± 0	0.0010 ± 0	0.0027 ± 0.0020	0.0010 ± 0
Arsenic	mg/L	0.0051 ± 0.0028	0.0032 ± 0.0005	0.0035 ± 0.0019	0.0032 ± 0.0002
Barium	mg/L	0.2950 ± 0.2367	0.0952 ± 0.0063	0.1425 ± 0.1160	0.3659 ± 0.2077
Beryllium	mg/L	0.0010 ± 0.0000	0.0011 ± 0.0003	0.0020 ± 0.0016	0.0020 ± 0.0000
Cadmium	mg/L	0.0005 ± 0	0.0005 ± 0	0.0023 ± 0.0020	0.0007 ± 0.0003
Chromium	mg/L	0.0043 ± 0.0030	0.0052 ± 0.0030	0.0028 ± 0.0019	0.0027 ± 0.0012
Copper	mg/L	0.0510 ± 0.0566	0.0020 ± 0.0001	0.0044 ± 0.0012	0.0058 ± 0.0020
Cyanide	mg/L		0.0200 ± 4.2E-10	0.0383 ± 0.0635	0.0200 ± 0
Iron	mg/L	0.0920 ± 0.1402	0.0729 ± 0.0415	0.2250 ± 0.2148	0.0500 ± 8.3E-10
Lead	mg/L	0.0013 ± 0.0009	0.0005 ± 0	0.0027 ± 0.0019	0.0020 ± 0
Magnesium	mg/L	25.70 ± 0.66	25.99 0.98	27.50 ± 2.47	26.35 ± 1.60
Manganese	mg/L	0.0032 ± 0.0024	0.0033 ± 0.0043	0.0039 ± 0.0015	0.0045 ± 0.0012
Mercury	mg/L	0.0008 ± 0.0004	0.0004 ± 0.0005	0.0008 ± 0.0009	0.0017 ± 0.0005
Nickel	mg/L	0.0050 ± 0	0.0050 ± 1.2E-10	0.0040 ± 0.0016	0.0050 ± 0
Potassium	mg/L	4.25 ± 0.24	4.37 ± 0.54	4.24 ± 0.56	4.49 ± 0.33
Selenium	mg/L	0.0035 ± 0.0018	0.0050 ± 1.2E-10	0.0035 ± 0.0017	0.0027 ± 0.0019
Silica	mg/L	10.13 ± 1.91	9.31 ± 0.24	8.94 ± 2.22	8.97 ± 0.39
Silver	mg/L	0.0253 ± 0.0286	0.0005 ± 0	0.0067 ± 0.0138	0.0400 ± 0.0155
Sodium	mg/L	78.95 ± 1.42	77.29 ± 4.23	76.62 ± 5.75	80.35 ± 1.72
Thallium	mg/L	0.0015 ± 0.0006	0.0010 ± 0	0.0015 ± 0.0005	0.0020 ± 0
Zinc	mg/L	0.0525 ± 0.0548	0.0051 ± 0.0003	0.0410 ± 0.0561	0.1 ± 1.7E-09
Radium	pCi/L		0.3050 ± 0.0976	0.9283 ± 0.1435	
Uranium	ug/L		3.9900 ± 0.1556	3.1225 ± 0.1150	

2.4.3. Microbiological and Radiological Parameters

Average microbiological and radiological parameters for the water intake are shown in Table 2-12. SNWS monitors the water intake for *Cryptosporidium*, coliform bacteria, and several viruses (i.e. HAV, Enterovirus, HIV, *rotavirus*, Norwalk, SRSV G1 and SRSV G3). A cryptosporidiosis outbreak occurred in Las Vegas in 1994 (Goldstein et al., 1996; Roefer et al., 1996) as discussed earlier in this report. Figure 2-10 shows yearly averages and seasonal variations for *Cryptosporidium*, fecal coliform and fecal streptococci. The data reveals higher *Cryptosporidium* counts for 1994 (i.e., approximately 50 counts/ 100ml). In the last eight years *Cryptosporidium* counts have averaged less than 10 counts/100ml. The seasonal variation of the *Cryptosporidium* data shows that higher numbers are observed in the summer and fall. Interestingly, a different trend is observed for the fecal coliform (FC) and fecal streptococci (FE) data. For these, higher numbers are observed during the winter season. It seems that the concentration of both FC and FE observed in the intake are influenced by the Las Vegas Wash, as seem for other parameters (i.e. perchlorate, conductivity and TDS). As a result of the cryptosporidiosis outbreak in 1994, SNWS is switching its disinfection process to ozonation, which is the most effective disinfectant against *Cryptosporidium*.

The intake water was tested negative for all viruses investigated for (Appendix A) except enterovirus, which was present in 14% of the samples tested (Figure 2-11).

For all bacteria tested (Appendix A) for only *Aeromonas sp., Campylobacter jejuni, Vibrio cholerae* (Figure 2-11) have been detected in the intake.

The levels of radium and uranium present in the water intake are at least ten fold smaller than the current drinking water standard (Figure 2-12). Gross alpha and beta particles in the water intake average 3.7 pCi/L and 5.2 pCi/L, respectively (Figure 2-12). Alpha particles concentration is below the drinking water standards of 15 pCi/L.

Table 2-12: Microbiological and radiological parameters at the water supply intake of Lake Mead.

Constituent	Unit	1994	1995	1996	1997	1998	1999	2000	2001	2002
Cryptosporidium	#/100L	48.0 ± 30.6	10.2 ± 4.8	9.2 ± 5.6	8.8 ± 2.2	9.5 ± 1.1	9.8 ± 0.0	6.2 ± 2.8	9.5 ± 0.9	10.0 ± 0.0
Fecal Coliforms	#/100L						0.02 ± 0.14	0.04 ± 0.20	0.24 ± 0.89	0.15 ± 0.38
Fecal Streptococus	#/100L						0.06 ± 0.24	0.12 ± 0.43	1.20 ± 5.12	2.70 ± 6.27
Ecoli	#/100L									0.06 ± 0.25
Gross Alpha	pCi/L							3.60 ± 0.95	3.81 ± 1.63	
Gross Beta	pCi/L							4.68 ± 0.90	5.78 ± 3.69	

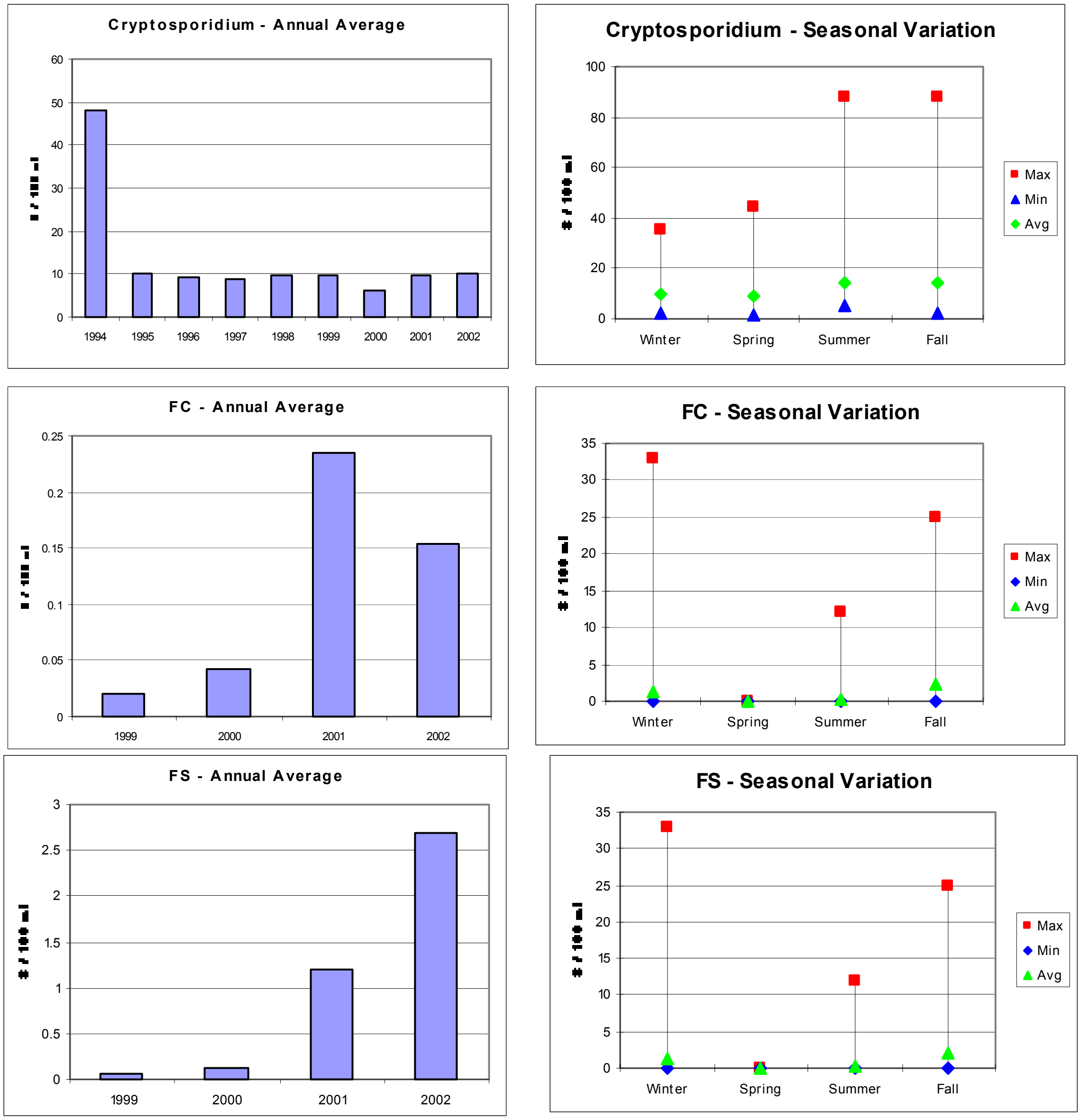

Figure 2-10: Yearly and seasonal variation of cryptosporidium, FS, and FE in the Lake Mead intake.

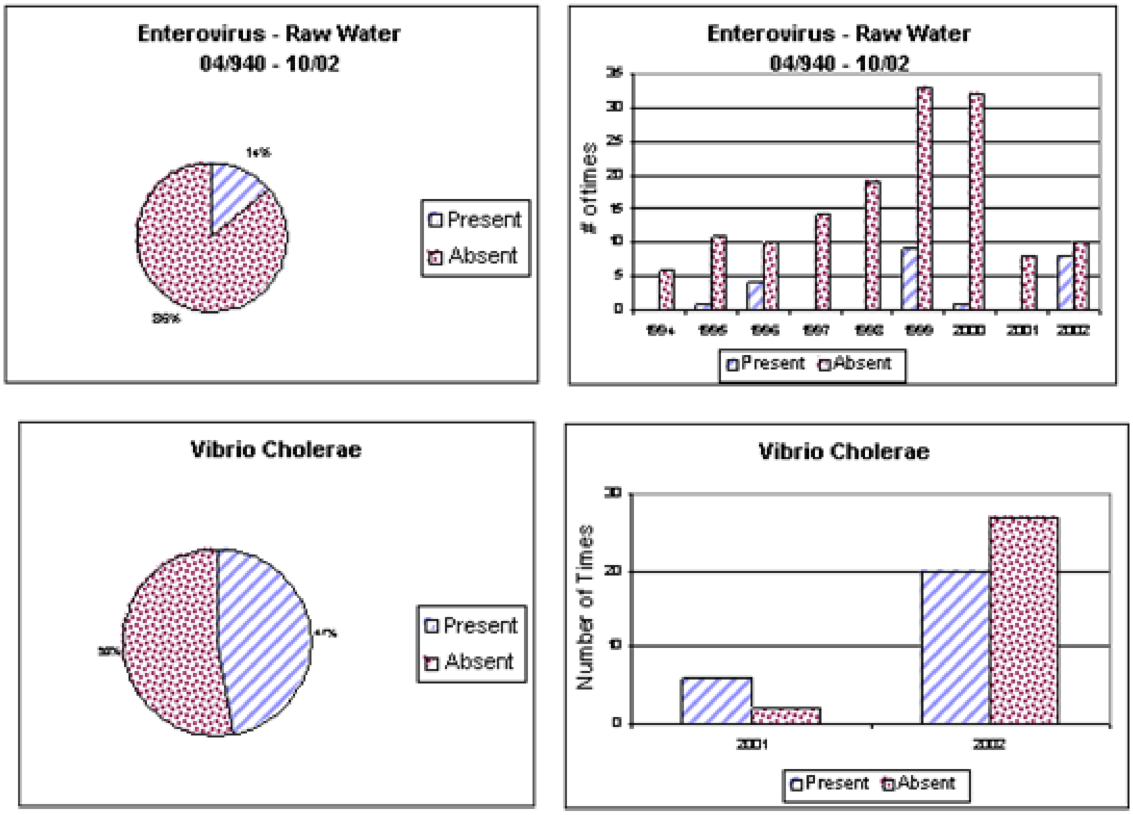

Figure 2-11: Presence and Absence of *Enterovirus and Vibrio Cholerae* in the Water Intake at Lake Mead

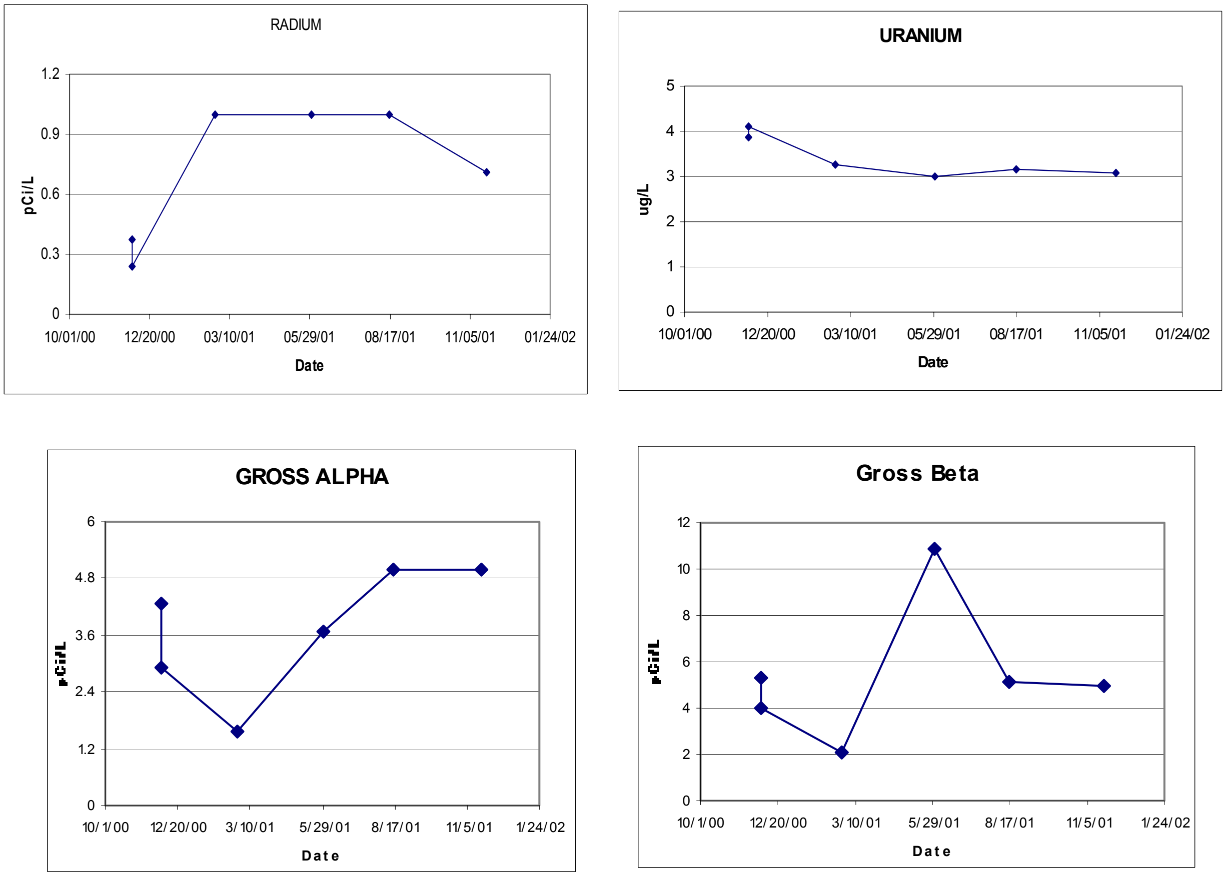

Figure 2-12: Radiological parameters at the Water Intake of Lake Mead

2.4.4. Organic Compounds

There are 33 synthetic organic compounds and 22 volatile organic compounds that are analyzed for, twice a year, at the drinking water intake. A list of the compounds analyzed for is shown in Appendix B. The concentration of all compounds analyzed for in the intake is less than the current drinking water standards show in Appendix B.

3. METHODOLOGY FOR THE SOURCE WATER ASSESSMENT

The methodology for the source water assessment consists of four main steps: (1) identify source water protection area; (2) identify the potential contaminating activities in the source water protection area; (3) perform a vulnerability assessment for each potential contaminating activity and risk that they pose to the drinking water source; and (4) inform the water purveyors and public of the assessment results. Following is a detailed description of each step.

3.1. Delineation of Source Water Protection Areas

The USEPA report “State Methods for Delineating Source Water Protection Areas for Surface Water Supplied Sources of Drinking Water” (USEPA, 1997b) summarizes the methods used to delineate source water protection areas. The main methods are using the topographic boundary, defined setback/buffer zones, or the time of travel (TOT).

In the topographic method, all the areas that contribute to the intake point are considered the source water protection area. The method is conservative and identifies the entire watershed as potentially impacting the water intake point. Setback/Buffer Zones are regions meant to filter overland flow and to reduce adverse impacts of stormwater runoff to water bodies. Setting buffer zones around water bodies is the most common way to prevent major surface water contamination. Time of travel (TOT) of pollutants is another way to define source water protection areas. The method is based on the time it takes the pollutant to travel in the stream and to the intake point (USEPA, 1997a). The method is useful for emergency-response activities, like an oil spill in a water body. The time of travel was not used here to delineate the source water protection zones, but it will be used to identify the response time for hazardous spills. The method used to delineate the source water protection zone for the Las Vegas Valley is based on field investigations as described below.

The approach used to delineate the source water protection zone width is based on USEPA guidance (USEPA, 1997a); however, it can vary for each state. A minimum protection zone delineation outlined by USEPA is to make the protection zones at least 200 feet wide around water bodies, and for it to extend at least 10 miles upstream from intake points.

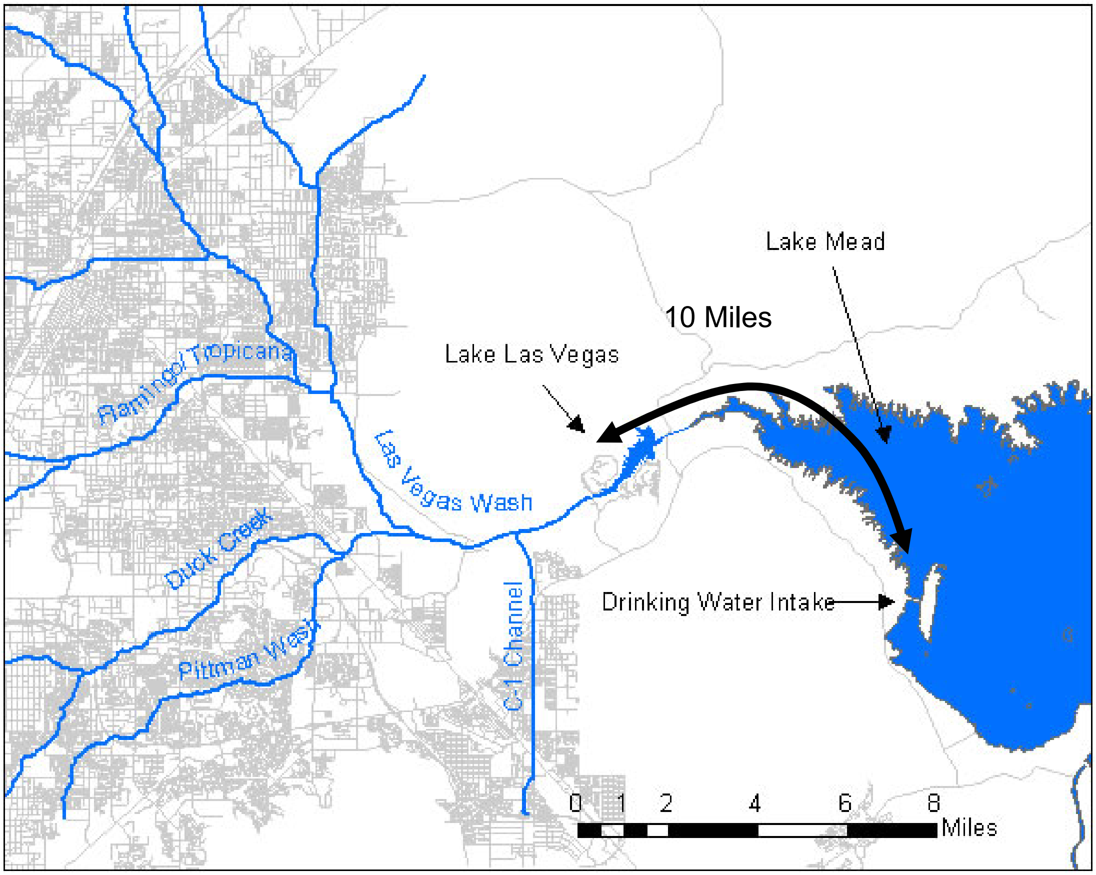

Figure 3-1: Extent of source water protection zones covered by the "minimum 10 miles upstream from intake" criterion.

In the State of Nevada SWAP (BHPS, 1999) two zones of protection are designated –Zone A extends 500 ft around water bodies, and Zone B extends 3000 ft from the boundaries of Zone A. The minimum extent of the source water protection zones is 10 miles from the intake. For the Las Vegas Valley drinking water intake, the 10 miles upstream into the Las Vegas Valley would be at the point where the Las Vegas Wash goes underneath Lake Las Vegas (see Figure 3-1). However, this distance does not extend into urban areas of Las Vegas, which are potential sources of contamination. Therefore, the source water protection zones were extended further upstream to the limits of dry weather flows in the storm channels. This is a reasonable approach since the presence of water in the channels is essential for a pollutant to travel downstream to the Las Vegas Wash into Boulder Basin and to the drinking water intake. The determination of dry weather flow in the Las Vegas Valley is based on field investigations and is presented in Sections 4.1 and 4.2.

3.2. Identification of Potential Contamination Activities (PCAs)

According to Nevada's SWAP, all possible contaminants within source water protection Zone A should be inventoried for future risk analysis and susceptibility of source water contamination (BHPS, 1999).

3.2.1. Potential Contaminating Activities

Fieldwork was conducted within the source water protection zones to identify possible sources of contaminants described in Table 3-1 (BHPS, 1999). A Global Position System (GPS) Trimble Geoexplorer 3 was used to collect information about the channels and to store the data of respective contaminants within the respective source water protection zones. The information collected in the field includes the survey date, facility description, contaminant code, facility address, picture, and geographic coordinates. The GPS data was then downloaded to a computer, the differential correction was executed, photographs were transferred to the computer, and the database tables and shapefiles containing the field points were updated. In addition to the PCAs identified above, National Pollutant Discharge Elimination System (NPDES) permits were obtained from the State of Nevada, Division of Environmental Protection. A GIS coverage obtained from GISMO and the Clark County Health District was used to identify the septic tanks in the source water protection areas. Finally, other activities (e.g., restaurants, residential areas, shopping centers) that are noteworthy, but not included in Table 3-1, were identified.

Table 3-1: Potential contamination sources (BHPS, 1999) (Categories – A=VOC, B=SOC, C=IOC, D=microbiological, E=radionuclides).

Code	Contaminant	Category	Risk Ranking	Code	Contaminant	Category	Risk Ranking
1	Animal burial areas	C, D	High	28	Educational institutions	B, C	Moderate
2	Animal feedlots	B, C, D	High	29	Medical institutions	D	Low
3	Chemical Application	B, C	High	30	Research laboratories	A, B, C, D	High
4	Chemical mixing & storage areas	A, B, C	High	31	Aboveground storage tanks	A	High
5	Irrigated fields	B	Moderate	32	Underground storage tanks	A	High
	Irrigation ditches	C	High	33	Public storage	A	Low
6	Manure spreading & pits	A, C	Moderate	34	Radioactive materials storage	E	High
7	Unsealed irrigation wells	A, C	High	35	Dumps and landfills	A,B,C,D,E	High
8	Chemical manufacturers, warehousing/distribution activities	A, B, C	High	36	Municipal incinerators	B, C, D	Moderate
				37	Recycling & reduction facilities	C	High
9	Electroplaters & fabricators	C	High	38	Scrap & junkyards	A, C	High
10	Electrical products and manufacturing	C	High	39	Septage lagoons, wastewater treatment plants	B, C, D	High
11	Machine & metalworking shops	A	High	40	Sewer transfer stations	B, C, D	High
12	Manufacturing sites	A, B, C	High	41	Airports	A	High
13	Petroleum products production, storage & distribution center	A	High	42	Asphalt plants	A	High
				43	Boat yards/Marinas	A	High
14	Dry cleaning establishments	A	High	44	Cemeteries	D	Moderate
15	Furniture & wood stripper & refinishers	A	High	45	Construction areas	A	Moderate
				46	Dry wells	A, D	High
16	Jewelry & metal plating	C	High	47	Fuel storage systems	A	High
17	Laundromats		Low	48	Golf courses, parks & nurseries	B, C	High
18	Paint shops	A	High	49	Mining	A, C	High
19	Photography establishments & printers			50	Pipelines	A	High
				51	Railroad tracks, yards & maintenance	A, B, C, D	High
20	Auto repair shops	A	High				
21	Car washes	A, C, D	Moderate	52	Surface water impoundments, streams / ditches	D	High
22	Gas Stations	A	High				
23	Road deicing operations: storage & application areas	C	Moderate	53	Stormwater drains & retention basins	A, B, C, D	High
24	Road maintenance depots	A, C	High	54	Unplugged abandoned well	A, B, C, D	High
25	Household hazardous products	A, B, C	Moderate	55	Well: operating		High - Low
26	Private wells	A, B, C, D	Moderate	56	Other		
27	Septic systems, cesspools	B, C, D	High				

3.2.2. Contaminants of Concern

The contaminants of concern in the SWAP are grouped into five categories: volatile organic compounds (VOCs), synthetic organic compounds (SOCs), inorganic compounds (IOCs), microbiological, and radionuclides. VOCs are anthropogenic chemicals that are typical used in industrial and manufacturing processes. SOCs are also anthropogenic chemicals that are typically used for agricultural and industrial uses. IOCs include many chemicals that are naturally occurring in the environment and agriculture and industrial practices. Microbiological contamination happens in the form of bacteria, viruses, and protozoa from human and/or animal fecal matter. Radionuclides are radioactive contaminants that may occur naturally in the environment or generated through anthropogenic sources.

The specific VOCs, SOCs, IOCs, microbiological and radionuclides regulated by USEPA can be found at http://www.epa.gov/safewater/mcl.html. The five contaminant categories are used to identify the type of contamination from the different activities in Table 4-1.

3.3. Vulnerability Analysis for each PCA

The vulnerability of each PCA impacting the drinking water intake was assigned based on the four factors: physical barrier effectiveness; risk potential; time of travel (TOT), and historical water quality. This approach was outlined in the SWAP for the State of Nevada (BHPS, 1999). The vulnerability was assigned for each contaminant (VOCs, SOCs, IOCs, Microbiological, and Radionuclides) associated with each PCA. For instance, a different vulnerability was assigned for VOCs, IOCs, and microbiological contamination from a car wash PCA.

3.3.1. Physical Barrier Effectiveness

The physical barrier effectiveness (PBE) is a measure of how well the geology and hydrogeology characteristics of the watershed act as a physical barrier that prevents downstream migration of contaminates (CDHS, 1999). In other words, it is measures the susceptibility of the watershed to conveying contaminates downstream. The main parameters used to compute the PBE are the type of drinking water source, travel time, general topography, general geology, soil type, vegetation cover, mean precipitation, and amount of groundwater recharge. Appendix D is the form used to determine the PBE – either Low (not an effective barrier) or High (effective barrier). The following values are assigned to the different PBE levels: Low = 5; Moderate = 3; High = 1.

3.3.2. Assignment of Risk Ranking for each PCA

The risk ranking associated with each PCA is assigned according to the levels identified in Table 3-1. These rankings were assigned in the “Potential Contaminant Source Inventory” in the SWAP for Nevada (BHPS, 1999). These rankings are based on the toxicity or degree of hazard associated with the source or activity. In computing the final vulnerability of each PCA in Section 3.3.5, the following values are assigned to the different levels of risk: High = 5; Moderate = 3; Low = 1.

3.3.3. Time of Travel (TOT) for each PCA

The time of travel (TOT) is computed based on field measurements of the storm channels in the Las Vegas Valley and assumptions of flow in the Las Vegas Wash. Velocity measurements were made of the flow in the channels that had dry weather flow. These velocity measurements were then divided into the distance of each PCA from the end of Las Vegas Wash. The velocity in Las Vegas Wash was assumed to be approximately 3 feet/sec. This is a reasonable assumption based on studies by Baker et al., (1977) and field investigations by UNLV. The TOT are computed from the end of Las Vegas Wash to the PCA since it is unclear what the travel time would be once a contaminant enters Boulder Basin/Lake Mead. A study by Sartoris and Hoffman et al., (1971) notes that the velocity of water from Las Vegas Wash at a depth of 100 feet is approximately 0.1 feet/sec. Considering that the end of Las Vegas Wash is approximately six to seven miles from the intake, the time it would take a contaminant to travel from the exit of Las Vegas Wash through Boulder Basin to the intake would be approximately 3-4 days. This is just an estimate and a better estimate could be determined using a hydrodynamic model. Current studies by the Clean Water Coalition will significantly improve the understanding of lake hydrodynamics and travel time from the exit of Las Vegas Wash to the intake.

In computing the final vulnerability of each PCA in Section 3.3.5, the following values are assigned to the different TOTs to Lake Mead: 0-6 hours = 9; 6-12 hours = 7; 12-18 hours = 5; 18-24 hours = 3; > 24 hours = 1.

3.3.4. Historical Water Quality

The last factor in the vulnerability determination is the water quality at the drinking water intake. The SWAP for the State of Nevada (BHPS, 1999) calls for the review of historical water quality data for all contaminants regulated under the Safe Drinking Water Act (SDWA) plus data on perchlorate (ClO4-) and MTBE (methyl-tert-butyl ether). Although MCLs are commonly used to characterize water after treatment, the Nevada SWAP stipulates that water sources cannot be given a low vulnerability ranking if in their raw water quality record: (a) VOC, SOC and IOC have been detected at concentrations greater than the MCL, (b) Total Coliform Rule MCL has been violated and cause has not been permanently corrected, or (c) MCL for radionuclides has been violated.

The historical water quality data discussed in Section 2 will be used as a basis for determining the rating assigned for water quality in the computation of the vulnerability. If the water quality data shows the presence of a contaminants in a certain category, then that category of contaminants was given a High value = 5. If a contaminant is not present, then that category of contaminant was given a Low value =0.

3.3.5. Computation of Vulnerability

Quantitatively, the vulnerability was assigned according to:

$$\text{Vulnerability} = \text{PBE} + \text{Risk} + \text{TOT} + \text{Water Quality} + \text{Other Relevant Information} \quad (3\text{-}1)$$

where PBE is the physical barrier effectiveness, Risk is the level determined from Table 3-1, and TOT is the time of travel from the potential contaminating activity to the outlet of the Las Vegas Wash to Lake Mead. PBE, Risk, and TOT are assigned independently of the load from the individual PCA. Each parameter was assigned a value as noted earlier in Sections 3.3.1 - 3.3.4. The maximum score is 24, which represents the highest possibility of a PCA impacting the drinking water intake. As noted earlier, the vulnerability score is assigned for each contaminant category of each PCA.

3.4. Community Involvement

Community involvement was part of the development of the SWAP program and the preparation of the final SWAP document. The public meetings and presentations are listed below:

- September 28 & 29, 1998: SWAP Advisory Committee meetings (1^{st})
- November 19 & 20, 1998: SWAP Advisory Committee meetings (2^{nd})
- January 21 & 22, 1999: SWAP Advisory Committee meetings (3^{rd})
- December 10, 1999: Public Workshop (Carson City)
- December 15, 1999: Public Workshop (Elko)
- December 17, 1999: Public Workshop (Las Vegas)
- April 24, 2001: Presentation to the Las Vegas Wash Coordination Committee, Las Vegas
- July 19, 2001: Presentation to the Lake Mead Water Quality Forum, Las Vegas
- April 24, 2002: Presentation to USEPA Region IX, State of Nevada, and Southern Nevada Water System, Carson City.
- November 19, 2002: Meeting with Southern Nevada Water System
- TBA: Presentation to the Lake Mead Water Quality Forum, Las Vegas

4. RESULTS OF SOURCE WATER ASSESSMENT

4.1. Summary of Field Investigations of Dry Weather Flows

The extent of dry weather flows in the Las Vegas Valley was determined through field investigations. During the spring, summer and fall of 2001, and the summer of 2002, storm water channels were surveyed to identify which channels had dry weather flows. These data were collected with the Trimble GPS, model Geoexplorer 3. The unit precision is 1 to 5 meters after differential correction, which is reasonable for the objectives of this work. The data were then used to define the extent of the source water protection zones for the Las Vegas Valley.

Figure 4-1 displays the extent of dry weather flows based on the field data. The extent of dry weather flows for all seasons did not vary significantly. A combination of the field data for all four seasons was used to delineate the furthest extent of dry weather flows. Velocity measurements, with a Global Water FP201, were made in the summer of 2001, and these data were used to determine the time of travel for contaminants in storm channels (Figure 4-2). All velocity measurements were less than 1 m/s in the storm channels.

The extent of dry weather flows was plotted against a soils map and it is noteworthy that there is a clear relationship between dry weather flows and the alluvial soil in Figure 4-3. The soil surveys were compiled by the U.S. Department of Agriculture, Geotechnical Considerations of Las Vegas, and the Nevada Bureau of Mines and Geology (GISMO, 2002). The dry weather flows cover a considerable part of the alluvium soils, with the exception of channels located in areas 1, 2 and 3 shown in Figure 4-3. Area 1 is a well-developed commercial area, and areas 2 and 3 are well developed residential areas that may generate flows from overirrigation and/or other urban water uses.

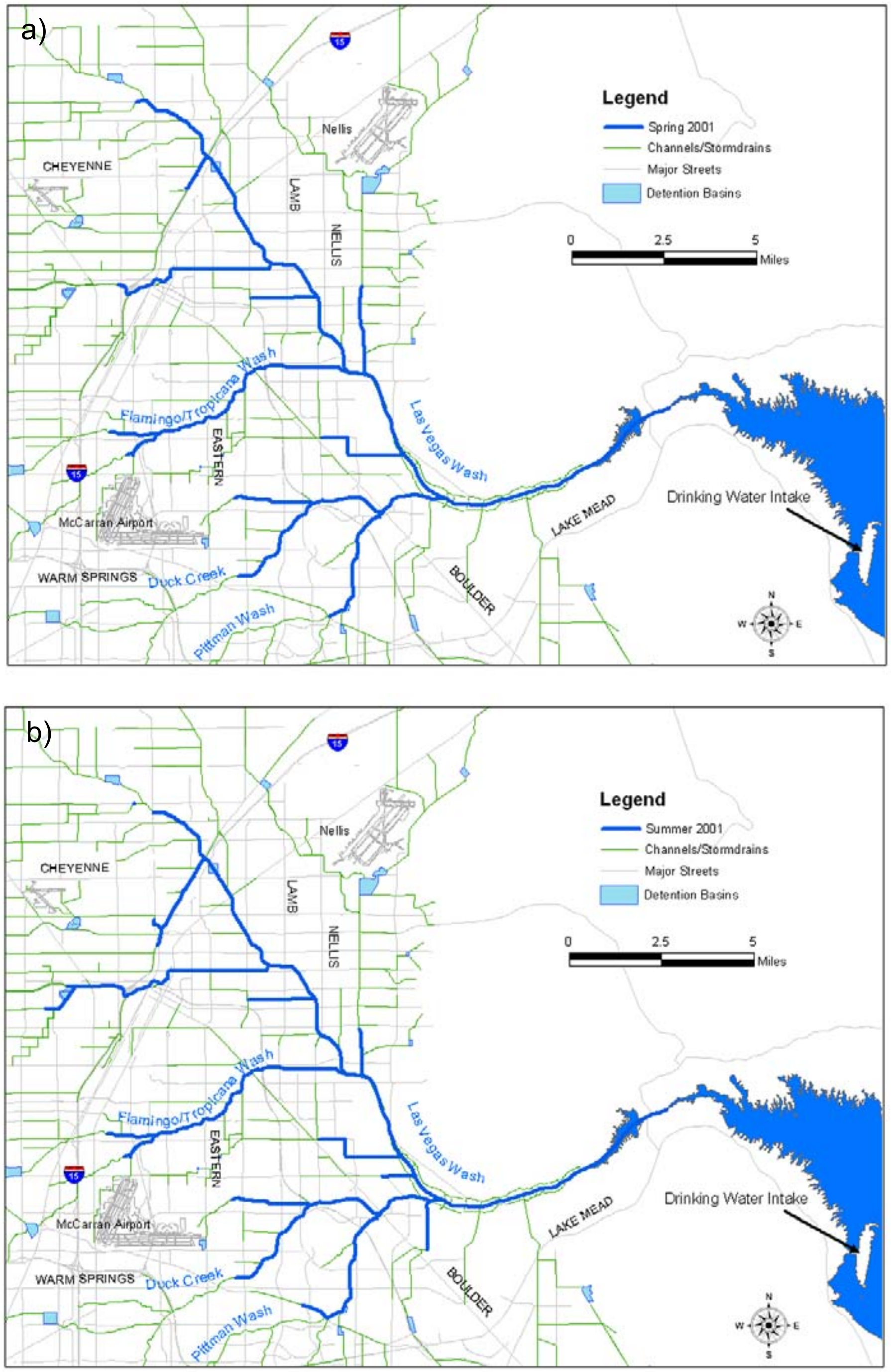

Figure 4-1: Extent of dry weather flows for (a) spring 2001, and (b) summer 2001.

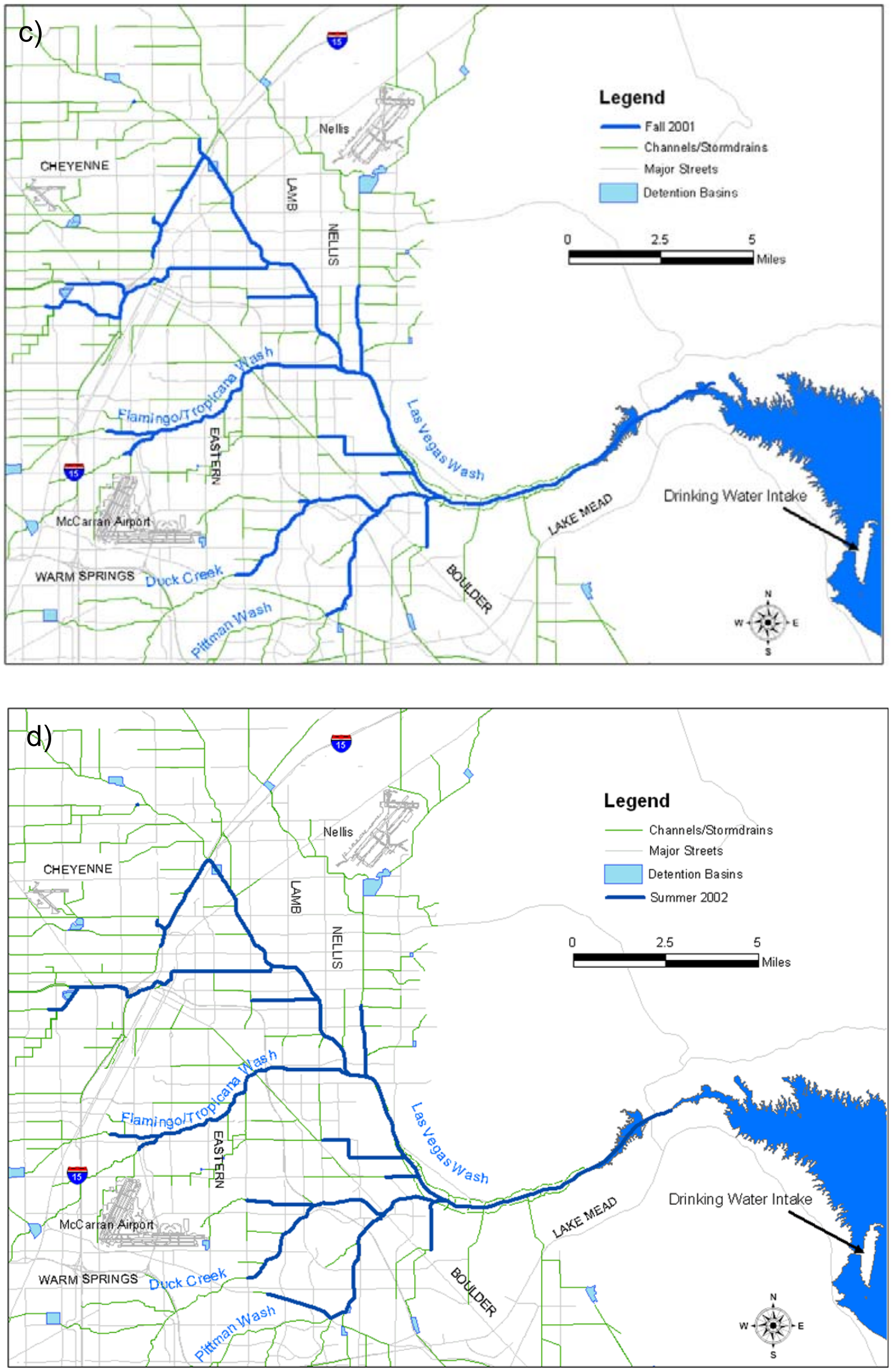

Figure 4-1: Extent of dry weather flows for (c) fall 2001, and (d) summer 2002.

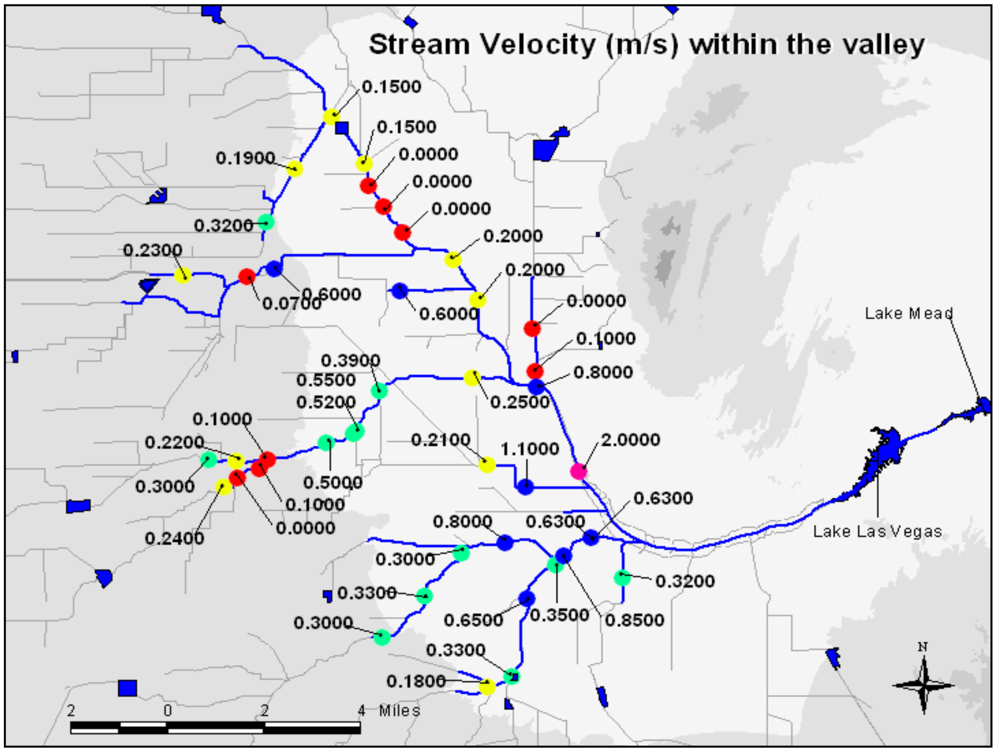

Figure 4-2: Flow velocities measurements for the dry weather flows in the Las Vegas Valley. Values in m/s.

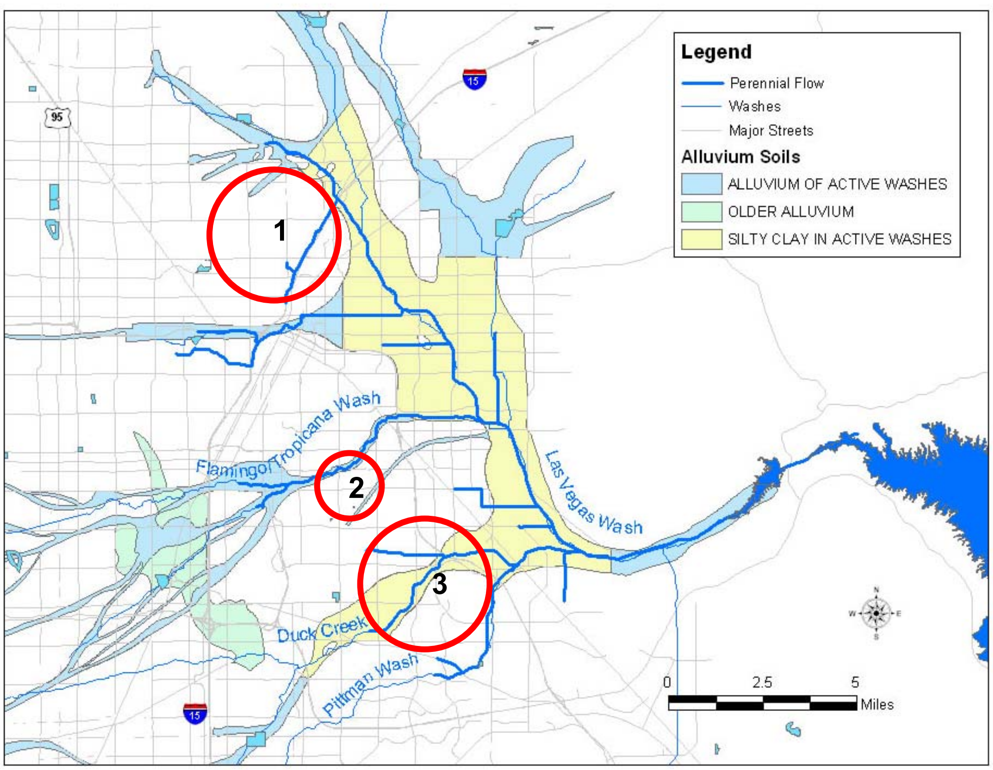

Figure 4-3: Alluvium soils and dry weather flows in the Las Vegas Valley.

4.2. Source Water Protection Areas (Zones)

Following the criteria in Section 3.1, source water protection zones were identified in the Las Vegas Valley. Within these zones, there exists a pathway for the contaminant to reach Lake Mead and the drinking water intake. The extent of dry weather flows was used as a basis for delineating source water protection Zone A (500 foot buffer from the centerline of the dry weather flows), and Zone B (3000 foot buffer from the boundaries of Zone A). The source water protections zones were delineated with ArcView GIS Buffer Wizard tool, and the results are shown in Figure 4-4. The contaminants within the source water protection zones are identified in Section 4.3.

The source water protection zone (A and B) represents approximately 5% (50,550 acres or 79 mi^2) of the total Las Vegas Valley watershed (1520 mi^2) and are located in highly developed areas. Table 4-1 shows the percentage of the total watershed area represented by source water protection zones A and B.

Table 4-1: Areas of the source water protection zones A and B.

	Protection Zone		
	A	B	A+B
Area (acres)	8,250	42,300	50,550
Percent area of the entire watershed	0.8%	3.9%	4.7%

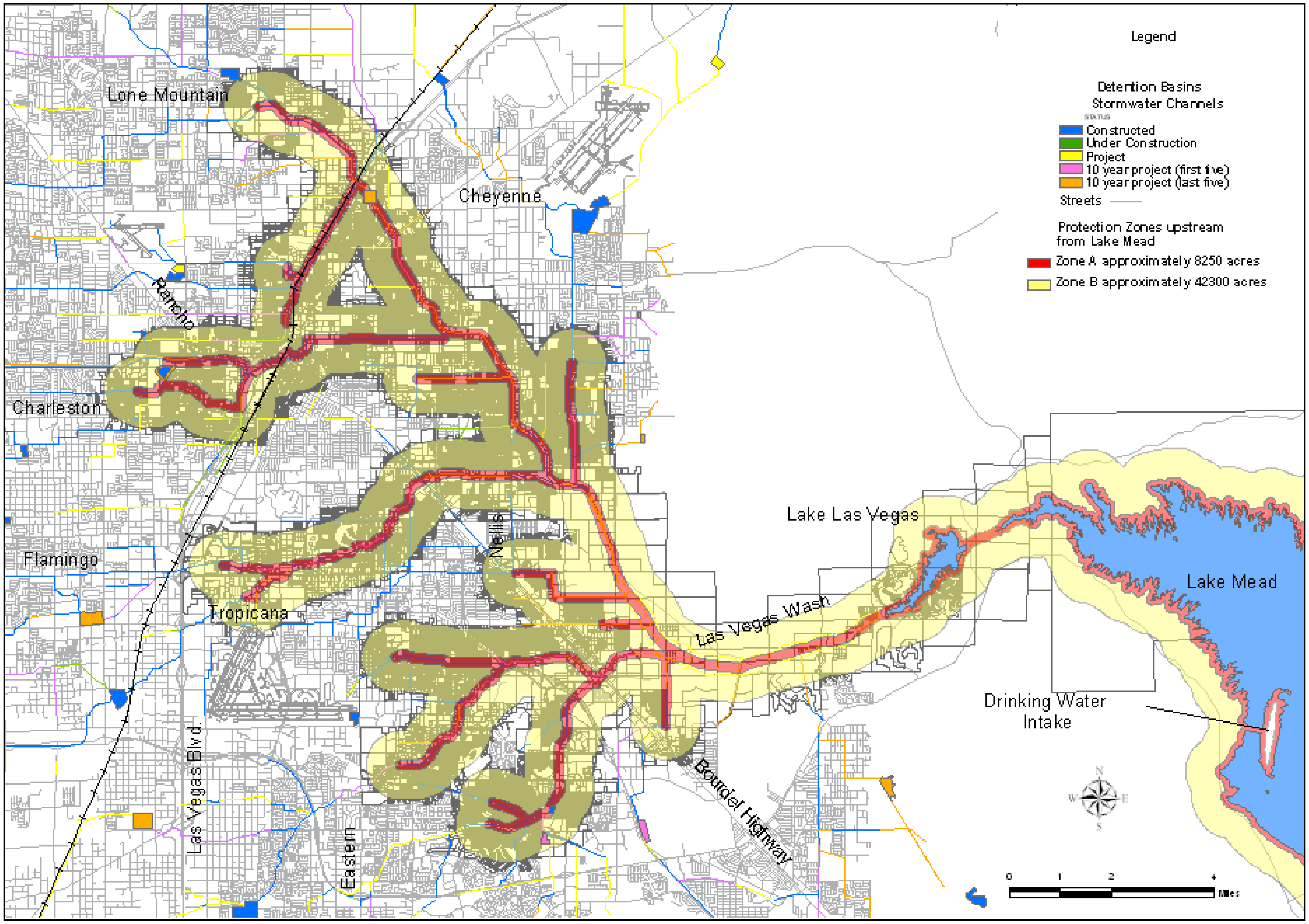

Figure 4-4: Source water protection zones A and B for the Las Vegas Valley watershed.

4.3. Identification of PCAs

Within the source water protection zones, the PCAs were identified in the field and by compiling available NPDES permits and GIS data. A total of 320 PCAs were identified and the locations are presented in Figure 4-5.

The field data were downloaded and stored in a database in GIS. The results for field identification and field location of possible contaminants within source water protection are shown in Table 4-2. An overview of the location of the contaminants within the source water protection zones is presented in Figure 4-5. Table 4-2 shows the number of contaminants identified in the field as well as the respective contaminant code and category. The most common source of contaminant found was septic systems (tanks) followed by medical institutions and auto repair shops.

Table 4-2: Summary of the different contaminant sources within the source water protection Zone A (includes all field investigations, GIS data, and NPDES permits).

Number of sites within buffer zone	Code	Contaminant	Number of sites within buffer zone	Code	Contaminant
123	27	Septic Systems, cesspools	6	45	Construction areas
49	29	Medical Institutions	5	43	Boat yards / Marinas
40	20	Auto Repair Shops	4	17	Laundromats
19	22	Gas Stations	4	19	Photography establishments & printers
10	14	Dry Cleaning Establishments	4	28	Educational Institutions
10	21	Car Washes	3	8	Chemical manufacturers / warehouse / distrbution activities
10	33	Public storage	3	30	Research laboratories
10	48	Golf courses, parks & nurseries	2	11	Machine and metalworking shops
8	39	Septage Laggons, Wastewater Treatment Plants	1	15	Furniture & wood stripper refinishers
8	53	Stormwater drains & retention basins	1	40	Sewer Transfer Stations
			1	56	Other

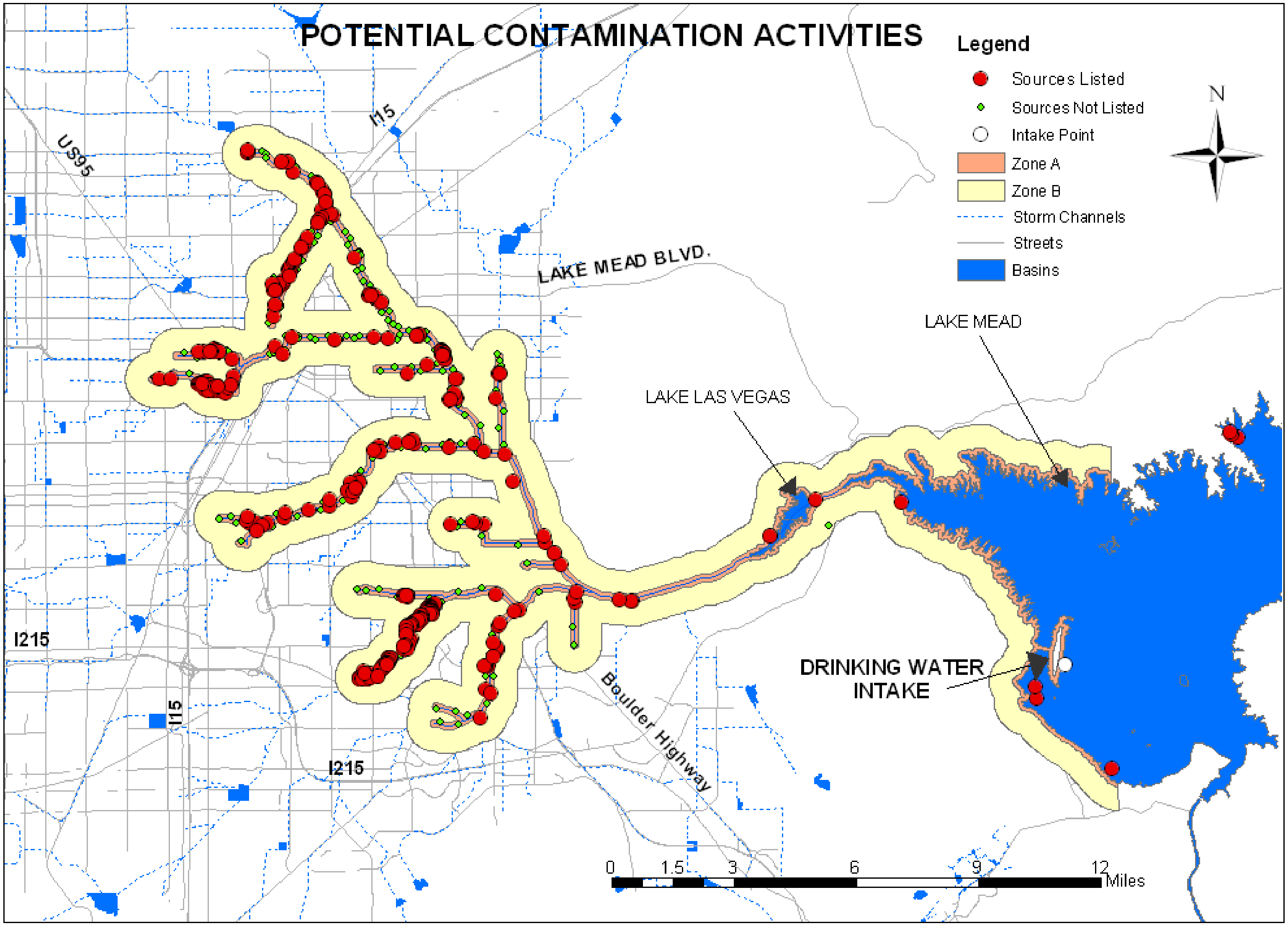

Figure 4-5: Protection Zones A and B and the location of PCAs and other sources not included in the list (Table 3-1).

4.3.1. NPDES Permits

As of February 2003, there were 12 permitted discharges within Zone A of the source water protection area (Table 4-3). The discharges into the Las Vegas Wash were previously discussed in Section 2.3.4. These include the effluent discharge from the three WWTPs (NV0020133, NV0022098, and NV0021261), an effluent discharge from an ion-exchange facility (NV0023060), discharge of cooling and scrubbing water (NV0000060), and effluent discharge a facility treating contaminated groundwater (NV0023213). The other NDPES permitted discharges are to tributaries of Las Vegas Wash and in the source water protection area. These include three facilities discharging treated groundwater (NV 0022870, NV0023078, and NV002837), one facility discharging cooling water and storm runoff (NV0000078), one facility discharging untreated groundwater (NV0022781), and one facility discharging stormwater runoff (NV0020923). All of these permitted discharges are included in the PCA list. Note that three of the NPDES discharges shown on Figure 4-6 are outside the source water protection area; however, field inspection of these facilities noted that the discharges are into the Las Vegas Wash.

Table 4-3: Summary of NPDES permits in the Las Vegas Valley (Categories – A=VOC, B=SOC, C=IOC, D=microbiological, E=radionuclides).

Permit #	Permit Holder	Flow			Contaminant Category
		Daily Max.	7 Days Avg.	30 Days Avg.	
NV0023213	Kinder Morgan Energy Partners	10 gpm	N/A	N/A	A, B, C, MTBE
NV0022870	7-Eleven, Incorporated	10 gpm	N/A	N/A	A, B, MTBE
NV0022781	Arcadium Management Inc.	N/A	N/A	0.2 mgd	C
NV0022837	Circle K Stores Inc.	30 gpm	N/A	30 gpm	A, B, C, MTBE
NV0023060	Kerr-McGee Chemical, LLC	N/A	1.4 mgd	1.22 mgd	C, E, Perchlorate
NV0020923	Pioneer Americas LLC	N/A	N/A	N/A	C
NV0000060	Titanium Metals Corporation	6.2 MGD	N/A	6.2 mgd	C, Perchlorate
NV0000078	Kerr-McGee Chemical, LLC	N/A	N/A	N/A	C, Perchlorate
NV0020133	City of Las Vegas	N/A	N/A	91 mgd	B, C, D
NV0022098	City of Henderson	N/A	N/A	42.5 mgd	B, C, D
NV0021261	Clark County Sanitation District	N/A	N/A	110 mgd	B, C, D
NV0023078	7-Eleven, Inc.	20 gpm	N/A	10 gpm	A, B, C, MTBE

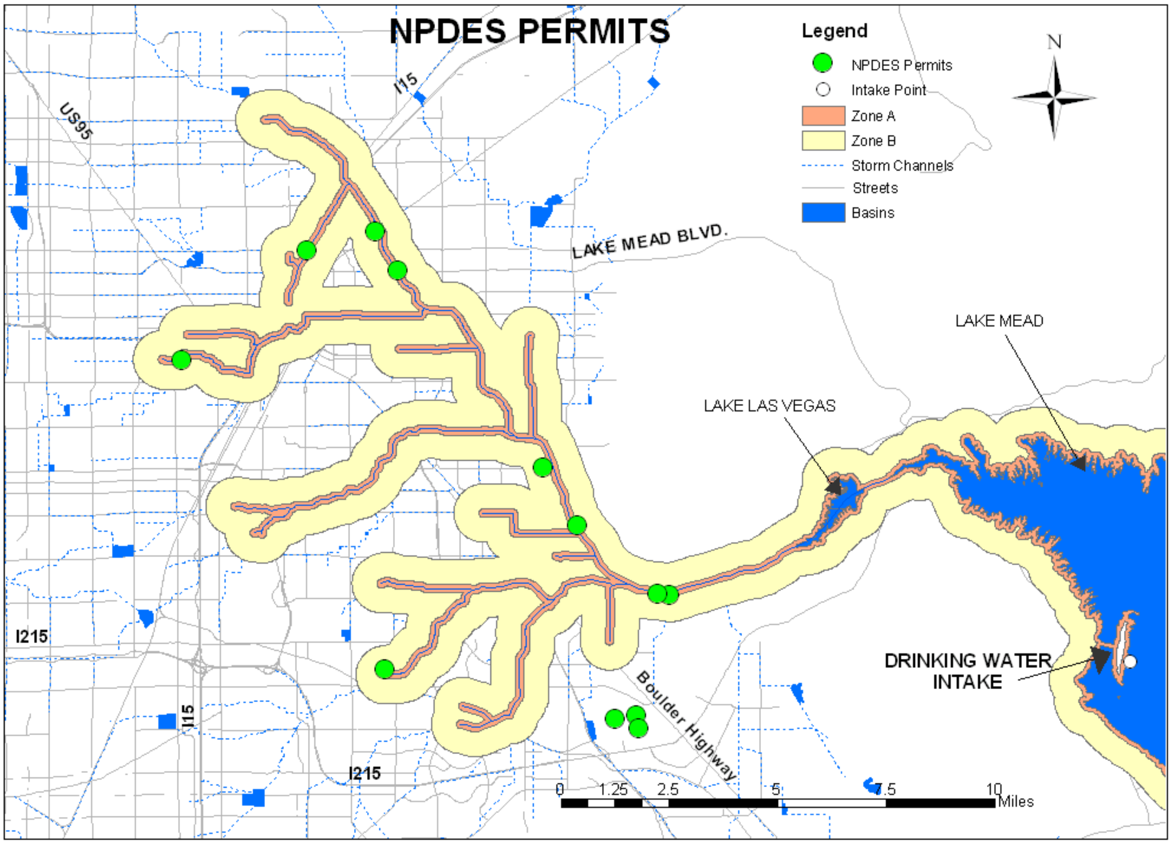

Figure 4-6: Location of NPDES Permits in the Las Vegas Valley.

4.3.2. Septic Tank Locations from GIS

The location of the septic tanks in the Las Vegas Valley obtained from the Clark County Health District and the GISMO database is summarized in Figure 4-7. There are a total of 123 septic systems that are within Zone A (500 feet buffer) of the source water protection area. Note that the point locations shown in Figure 4-7 represent the centroid of the property that was identified as having a septic system. A large portion of the septic systems is located along Duck Creek in the vicinity of Pecos Road and Green Valley Parkway. These are also the closest septic systems to Las Vegas Wash and the drinking water intake. The other tributaries with septic systems include Flamingo Wash and Las Vegas Creek.

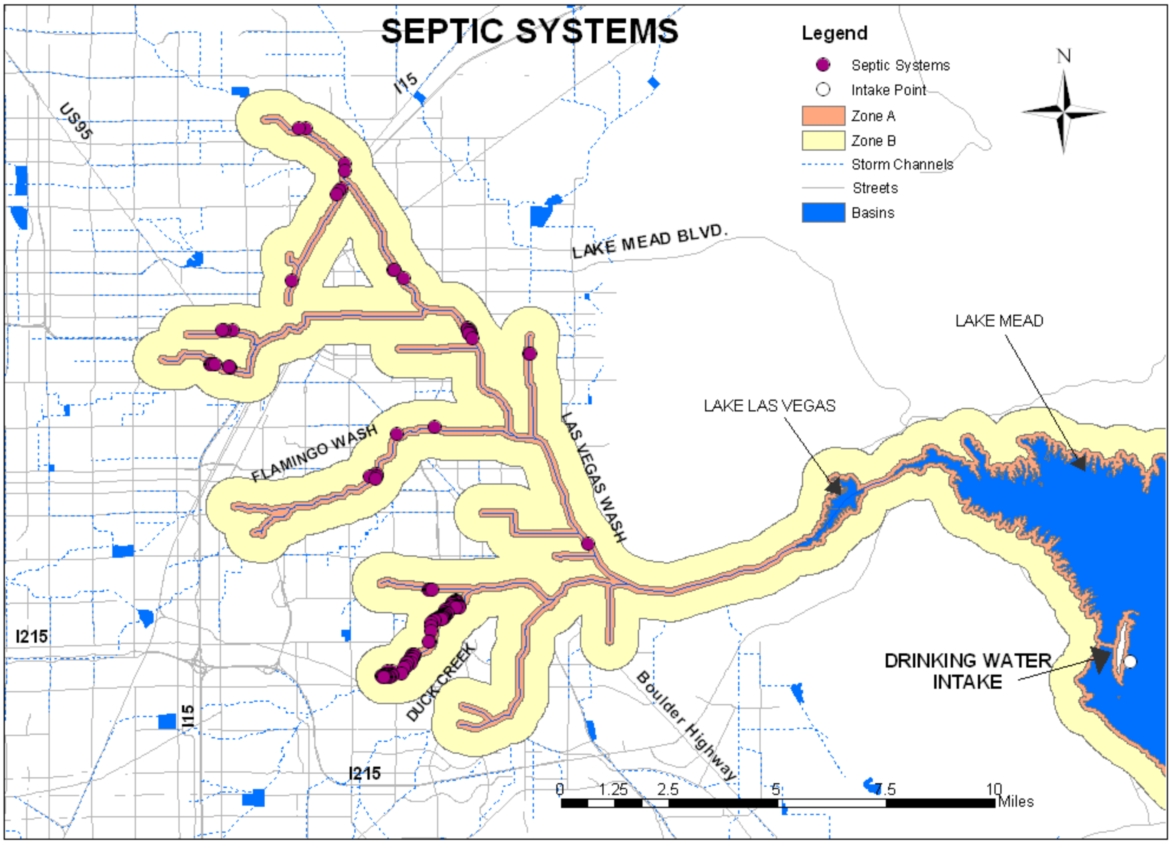

Figure 4-7: Septic tank locations within the source water protection area (Zone A).

4.4. Distance of each PCA to Drinking Water Intake

As noted earlier, the source water protection areas extent beyond the 10 miles required by USEPA. The distance from the drinking water intake to each PCA are shown in Figure 4-8 and summarized in Figures 4-9 and 4-10. Distance to the intake is not explicitly used in making the final vulnerability determination for each PCA; however, it was used with the velocities to determine the time of travel (Section 4.5). Approximately 33% (107 PCAs) of the PCAs are closer than 20 miles to the intake, 7% are within 15 miles, and nine PCAs are within 10 miles (Figure 4-8). Approximately half of the PCAs within 20 miles are septic systems. The other main PCAs within 20 miles are medical, golf courses/parks, and storm drains (Figure 4-9). The medical PCAs include facilities such as hospitals and physician offices. The three WWTPs are all within 15 miles of the intake.

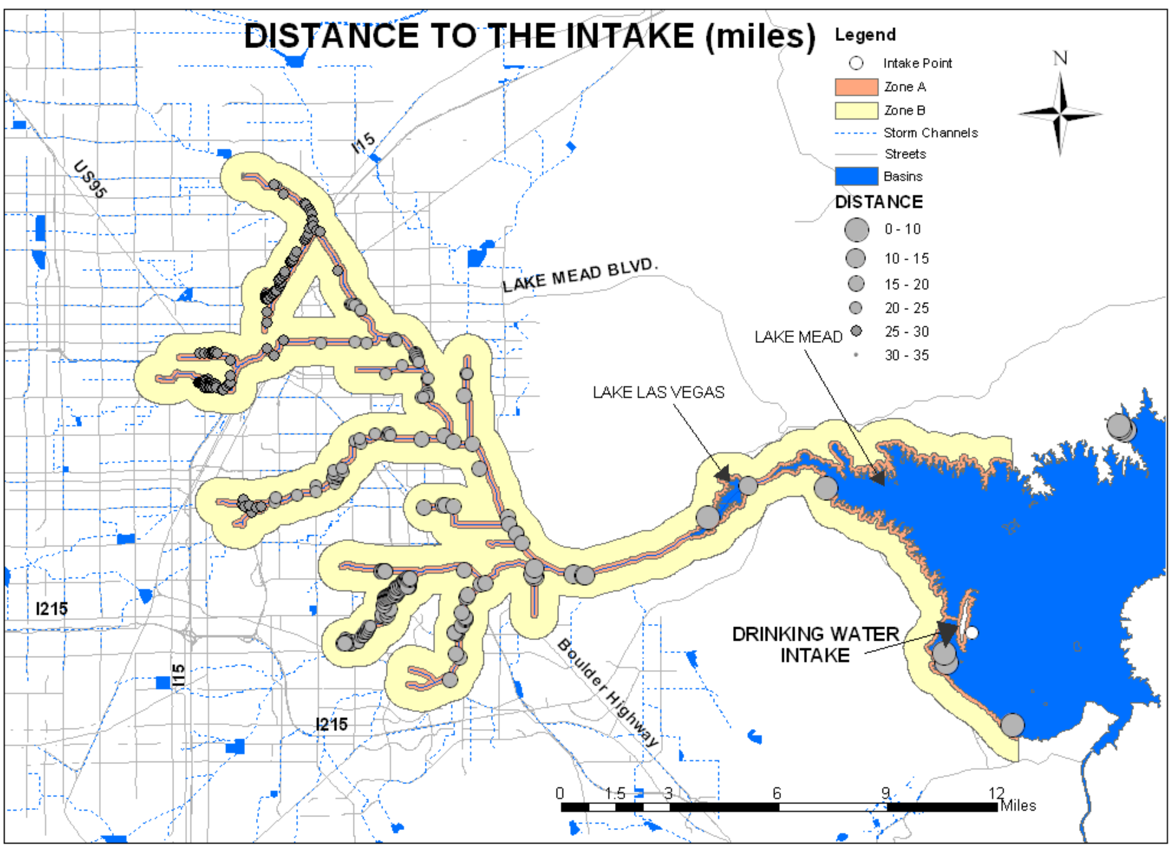

Figure 4-8: Distance of each PCA from the drinking water intake.

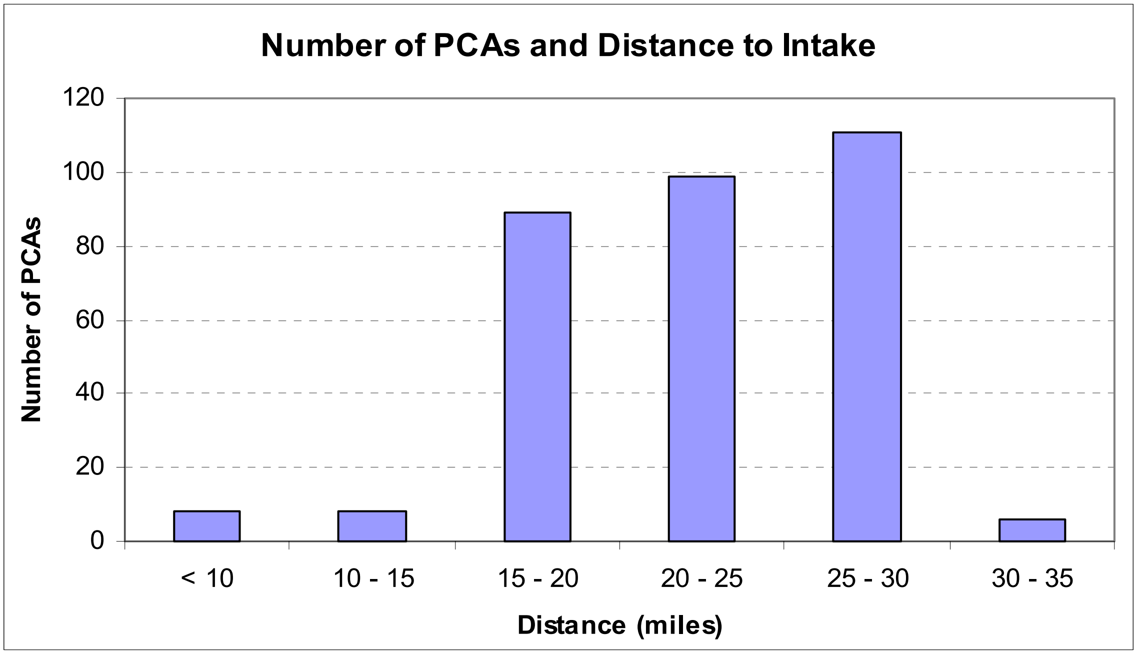

Figure 4-9: Number of PCAs based on distance from intake

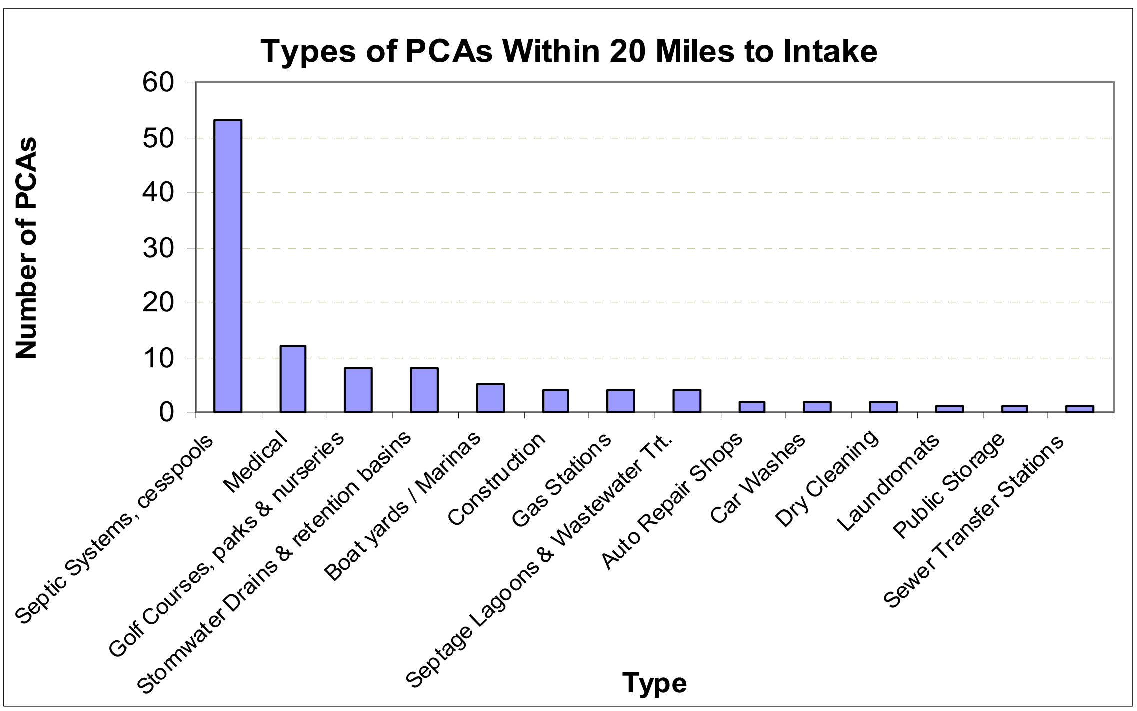

Figure 4-10: Number and type of PCAs within 20 miles of the intake.

4.5. TOT of each PCA to Lake Mead

More important than the distance of each PCA to the drinking water intake is the time that it takes a contaminant to travel from its source to the source water, or the time of travel (TOT). Figures 4-11, 4-12 and 4-13 summarize the TOT for all the PCAs. As noted earlier, the TOT provided in these figures represents the time for a PCA to go from the source to the outlet of Las Vegas Wash to Lake Mead as noted in Section 3.3.3. The TOT in Lake Mead is uncertain and will depend on the particular contaminant of concern.

The velocities in Las Vegas Wash are the highest of all the channels in the watershed during dry weather conditions. This is due to the effluent from the WWTPs. The PCAs that are located closest to Las Vegas Wash will have the lowest TOT. Approximately 22% (70 PCAs) of the PCAs reach Lake Mead in 12 hours or less. The main activities with TOT less than 12 hours to the intake are medical, septic systems, stormwater drains, and golf course/parks. The effluent from the three WWTPs reaches Lake Mead in less than 12 hours.

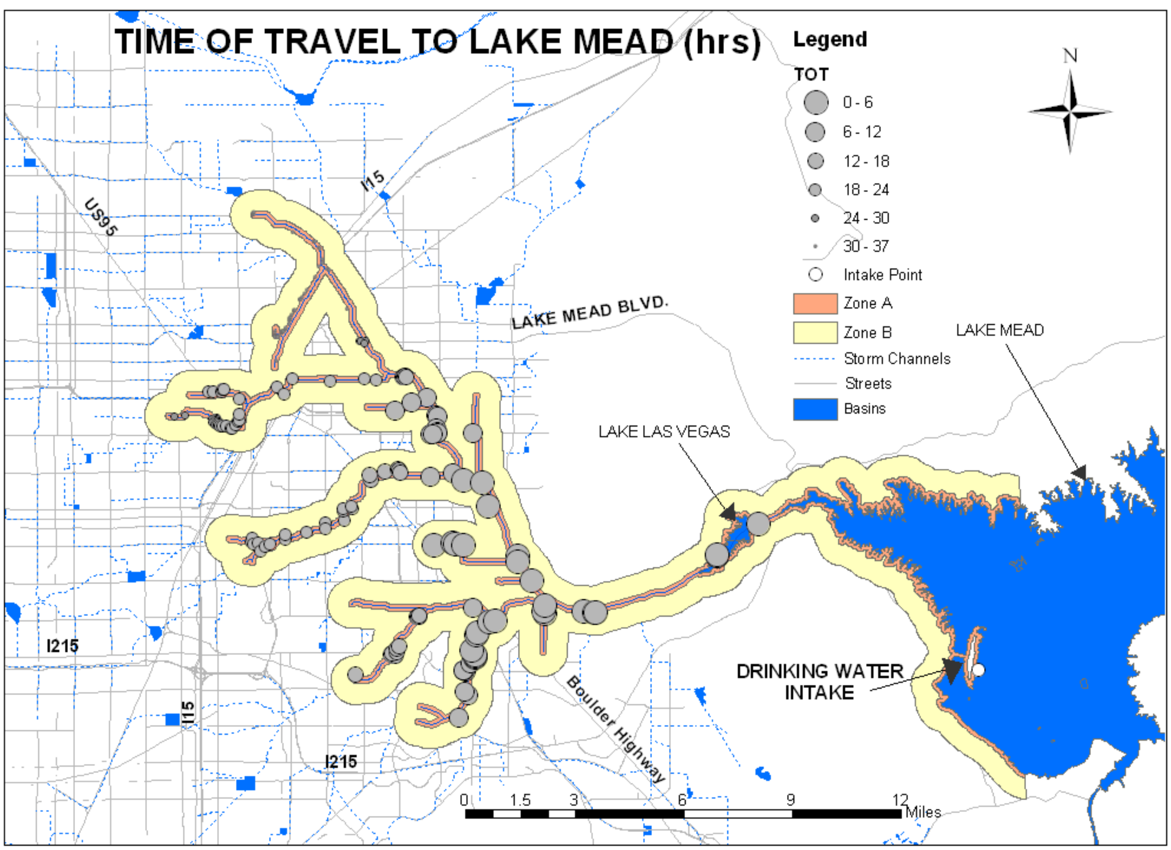

Figure 4-11:Time of travel (TOT) of each PCA to Lake Mead / Las Vegas Bay.

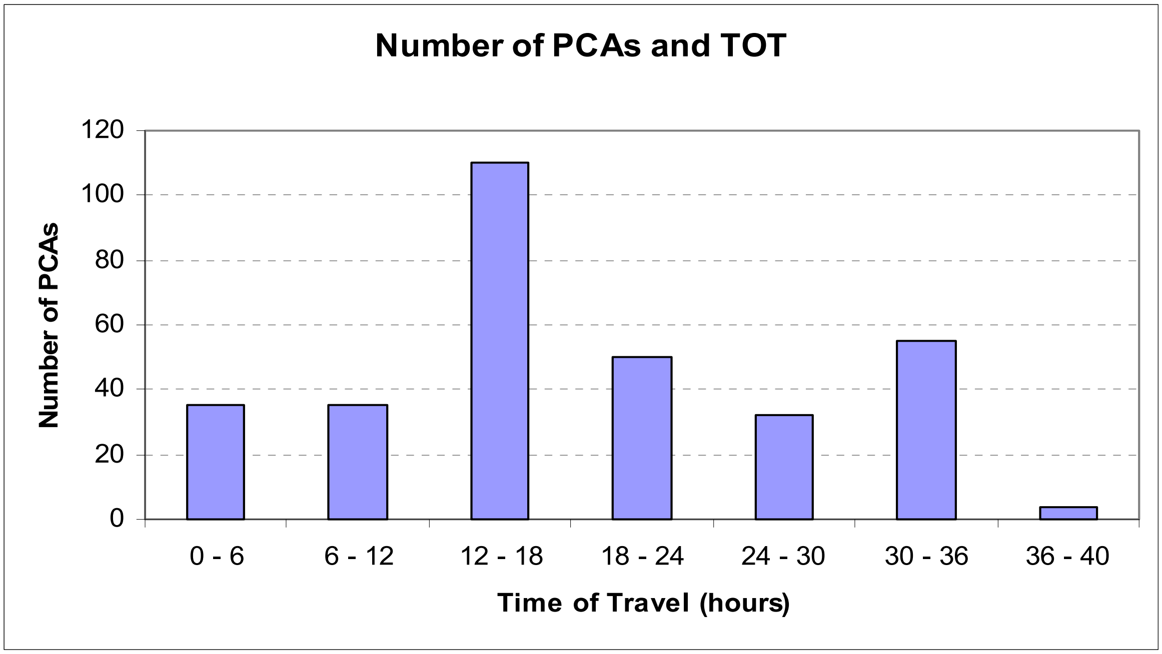

Figure 4-12:Number of PCAs based on time of travel (TOT) to Lake Mead.

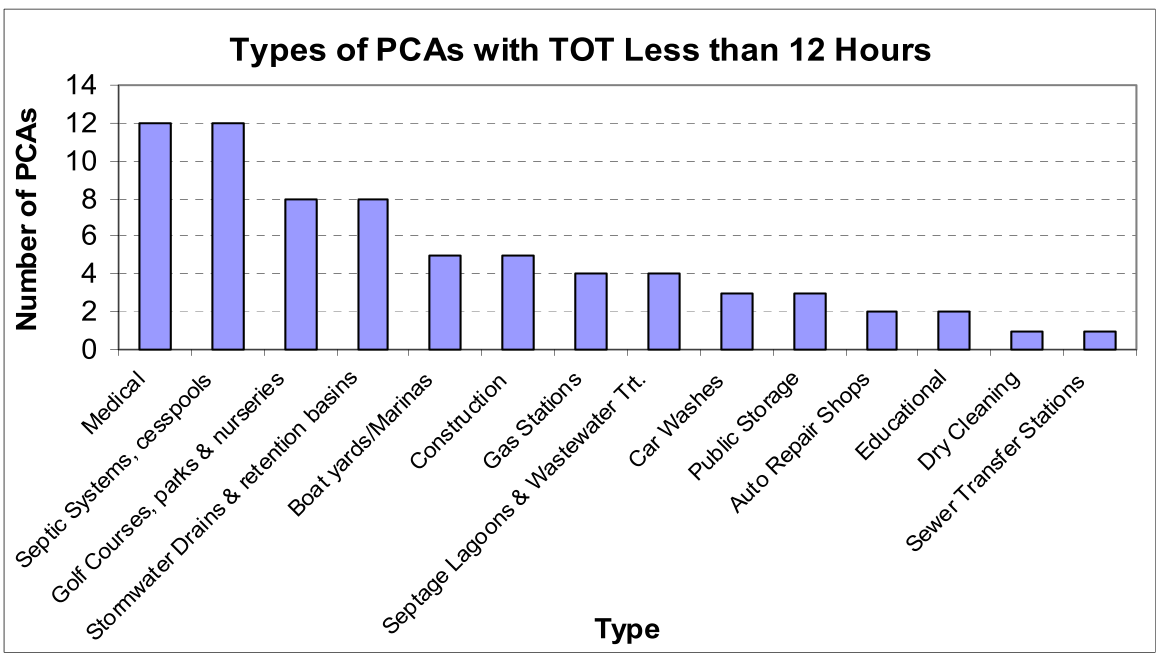

Figure 4-13: Number and type of PCAs that have less than a 12-hour time of travel to Lake Mead.

4.6. PBE for the Watershed

The PBE for the watershed is Low, which means that the watershed and climate conditions of the watershed do not act as an effective barrier for preventing downstream migration of contaminants (See Appendix D). The single criterion that forces the rating to be low is item #9 (influence of groundwater). Many of the Las Vegas Wash and tributaries are influenced by groundwater flow. All of these tributaries are included in the source water protection areas (See Figure 4-4). It is noteworthy that the methodology used here does not account for the magnitude of the flow from groundwater. A Low PBE rating receives a score of 5 to be used in the vulnerability assessment for each PCA.

4.7. Water Quality at the Intake

The water quality compiled in Section 2 was used to determine the ratings for the water quality portion of the vulnerability determination and summarized below. The rating here is assigned based on observed records of water quality at the intake, and is one of four variables used to make the final vulnerability determination for the intake.

VOC = Low. Data records from 2000 to 2002 for 22 VOCs in the raw water intake show that the concentrations of all contaminants analyzed for, during this period, were low and below the MCL.

SOC = Low. Data records from 2000 to 2002 of analyses of 33 SOCs show the concentrations of these contaminants at the water intake at Lake Mead are below detection limits.

IOC = High. The inorganic contaminant of concern in the water intake is perchlorate. There is no Federal mandated MCL for perchlorate. However, due to the effects of this contaminant on the thyroid gland the USEPA has called for an MCL of 1 ppb (USEPA, 2002). The Nevada Department of Environmental Protection (NDEP) has established a provisional level of 18 ppb. The current perchlorate source to Lake Mead (i.e., the Kerr McGee) site is now being cleaned up and the risk of perchlorate contamination to the water intake is expected to decrease with time.

Microbiological = High. There was a *Cryptosporidium* outbreak in Las Vegas in 1994. That outbreak was attributed to the water supply, although no definitive connection was found. Fecal coliform and fecal streptococci are detected in higher numbers in the intake during the winter season, indicating a potential influence of the Las Vegas Wash on the water intake. Enterovirus has been detected in the raw water as well as *Aeromonas, Campylobacter jejuni, Vibrio cholerae.* As a consequence of the cryptosporidum outbreak, the two largest water treatment plants (i.e. Alfred Merrit and River Mountains) are in the process of implementing ozonation as the primary disinfectant. Ozonation significantly reduces the risk of microbial contamination because it is the most effective disinfectant against *Cryptosporidium* and other microbiological components. Therefore, when ozonation has been implemented, the risk of microbiological contamination in the finished water will decrease significantly. In addition, the City of Henderson will have ultraviolet (UV) disinfection by the end of 2003.

Radiological = Low. Levels of radium, uranium, gross alpha, and gross beta particle in the raw water are below the current drinking water standards.

4.8. Land Uses within the Source Water Protection Areas

The Nevada SWAP also requires the identification of land use within boundaries of source water protection Zones A and B. Land use data from 2001 (See Section 2.1.4) were used to identify land use within the source water protection zones. The criterion used to obtain land use within the source water protection zones was that if any part of a parcel was within the buffer, the whole parcel area was taken into account. Therefore, boundary parcels have some of their area outside Zone B. Figure 4-14 and Table 4-4 present the land uses within the source water protection zones.

A large portion (45%) of the land use within the source water protection zones is undeveloped. In relation, approximately 83% of the entire watershed is undeveloped. The next highest land uses within the source water protection zones are residential (22.8%) and highways (13.3%). This suggests that any control of pollutants from these areas will have a high impact on the protection of the drinking water intake.

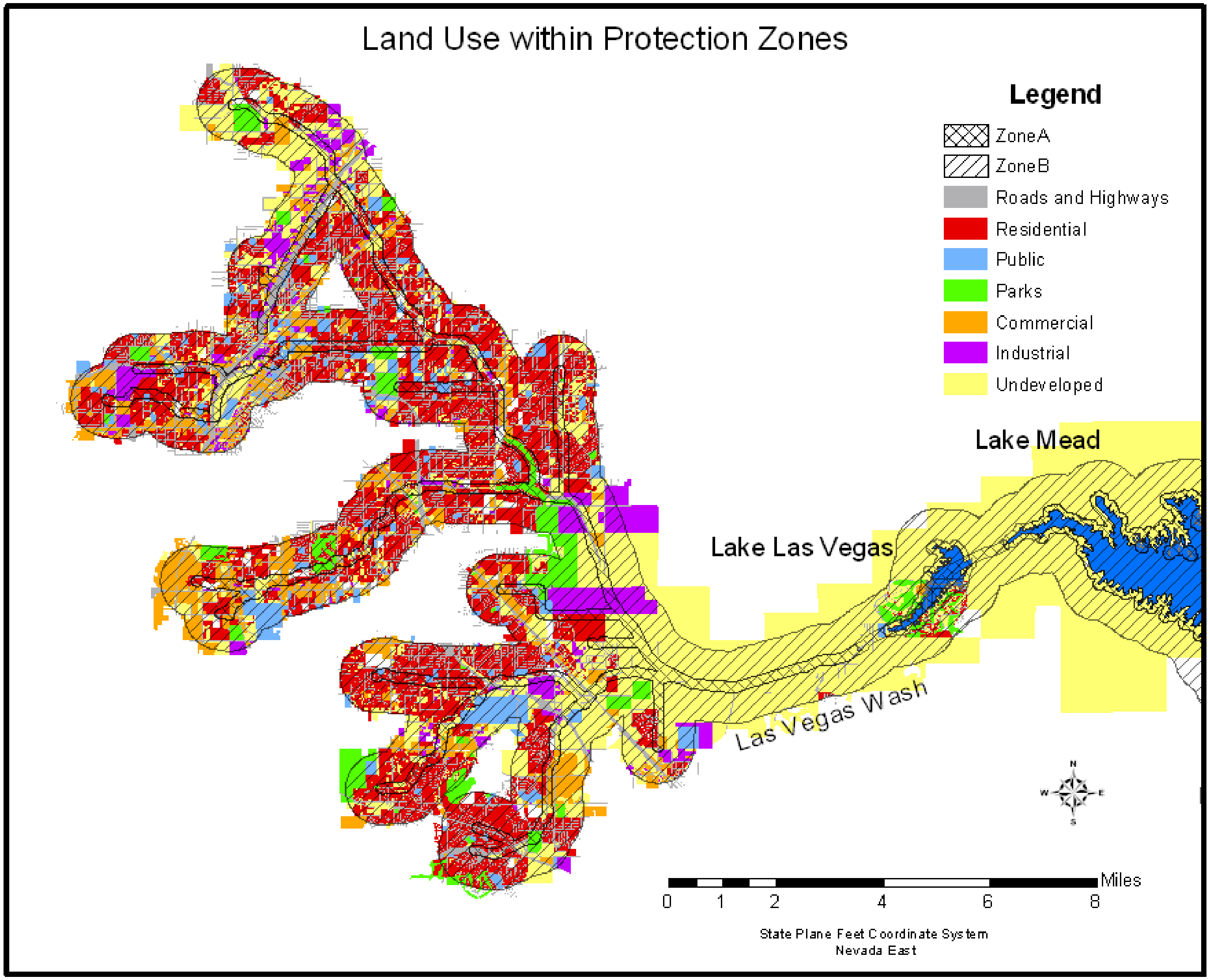

Figure 4-14:Land use within source water protection Zones A and B for the Las Vegas Valley extension of dry weather flows.

Table 4-4: Percentages of land uses within the protection Zones A and B

Land Use	Percentage of land use within protection areas (%)	Watershed percentage (%)
Commercial	7.2	1.8
Highways/Roads	13.3	4.6
Industrial	4.2	1.1
Park/Golf Courses	3.9	1.1
Public Land	3.6	1.2
Residential	22.8	7.1
Undeveloped/Natural Desert	45.0	83.2

4.9. Vulnerability Analysis for each Contaminant Category

The vulnerability of each PCA in relation to the drinking water intake was determined by combining the information in Sections 4.5 – 4.6 with the risk determination outlined in Table 3-1 and the water quality information in Section 4.7 (see Section 3.3.5 for a description of the calculation). The vulnerability analysis was performed for each category of contaminant and summarized in the following sections. A complete listing of the vulnerability rankings is provided in Appendix E.

The maximum vulnerability score of 24 represents a PCA that has a High Risk rating (5), a Low PBE rating (5), a TOT less than six hours (9), and a High Water Quality rating (5). The minimum vulnerability score of 3 represents a PCA that has a Low Risk rating (1), a High PBE rating (1), a TOT greater than 24 hours, and a Low Water Quality rating (0). Within the range of vulnerability scores (3 to 24), ratings were established based on statistics of all the possible combinations of vulnerability scores. The ratings are as follows:

- High = vulnerability score in the upper 10% of the possible scores (> 19).
- Low = vulnerability score in the lower 10% of the possible scores (< 8).
- Moderate = vulnerability scores between 8 and 19.

Figures 4-15 through 4-24 and Table 4-5 summarize the results of the vulnerability analysis for each contaminant category.

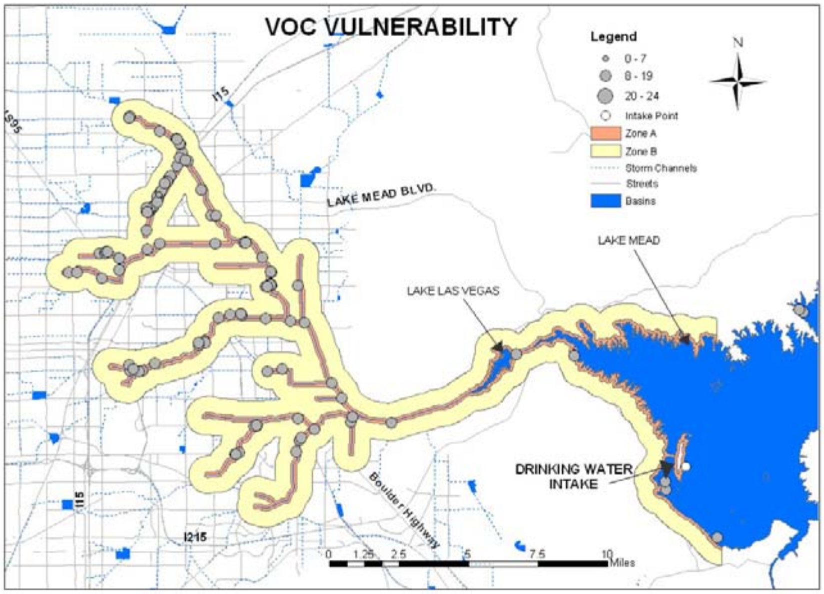

Figure 4-15: Vulnerability of each PCA (VOC) to the drinking water intake.

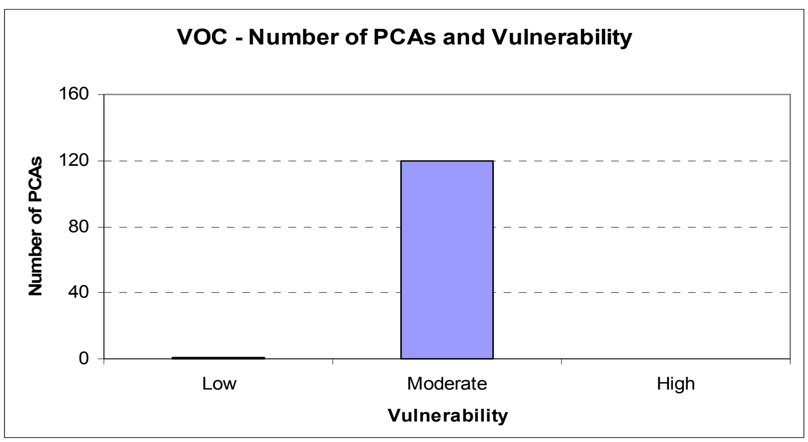

Figure 4-16: Number of PCAs (VOC) based on vulnerability categories. Low = 3-7, Moderate = 8-19, and High = 20-24.

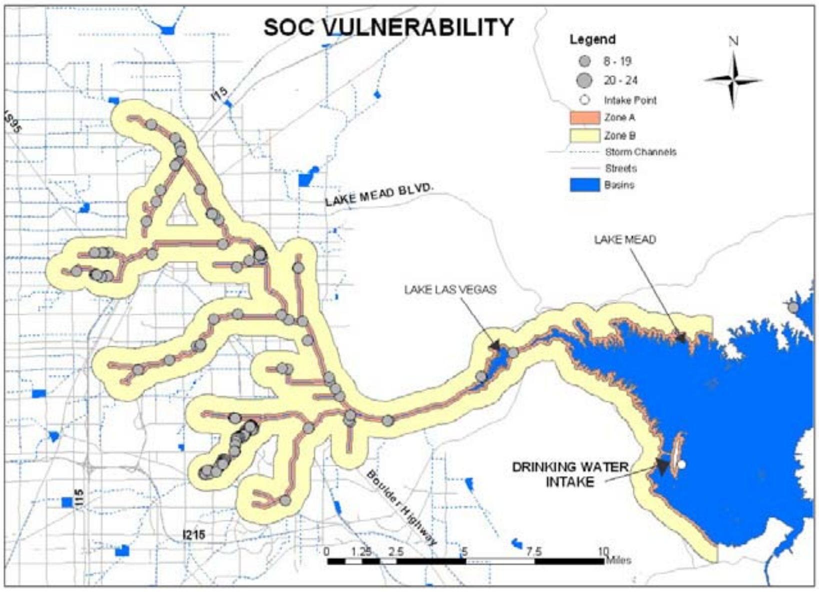

Figure 4-17: Vulnerability of each PCA (SOC) to the drinking water intake.

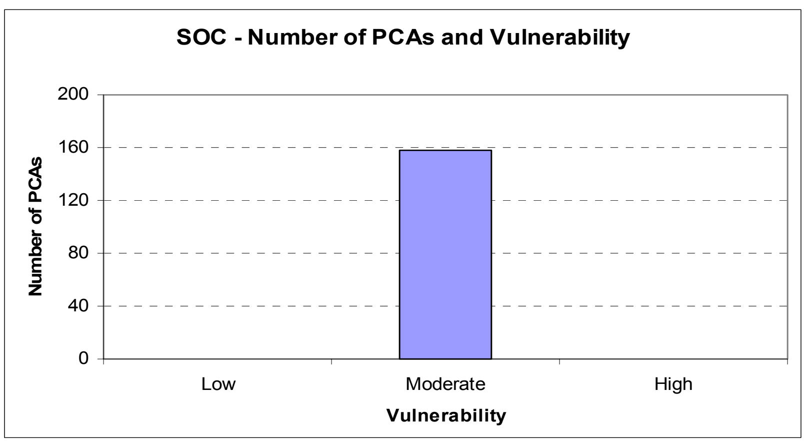

Figure 4-18: Number of PCAs (SOC) based on vulnerability categories. Low = 3-7, Moderate = 8-18, and High = 20-24.

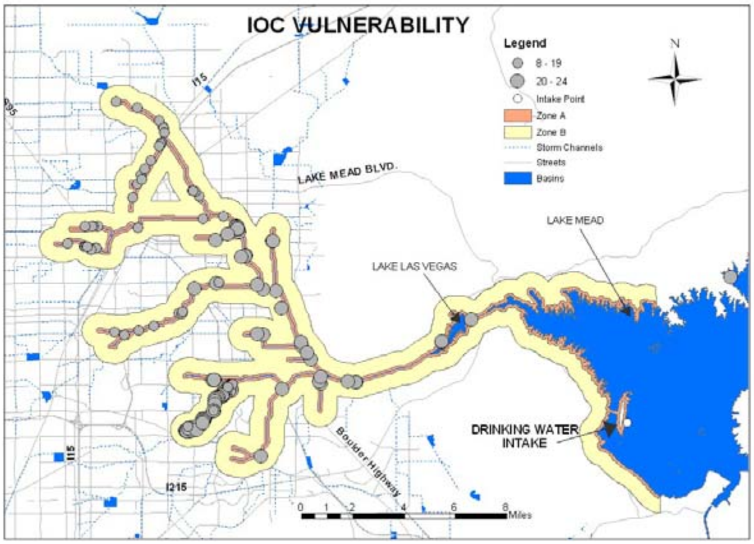

Figure 4-19: Vulnerability of each PCA (IOC) to the drinking water intake.

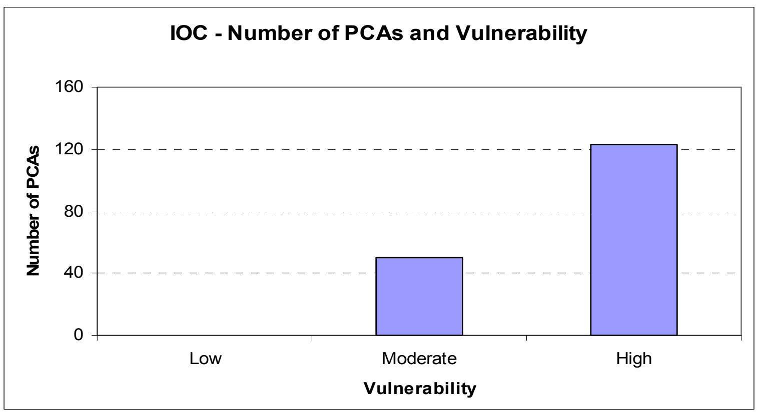

Figure 4-20: Number of PCAs (IOC) based on vulnerability categories. Low = 3-7, Moderate = 8-19, and High = 20-24.

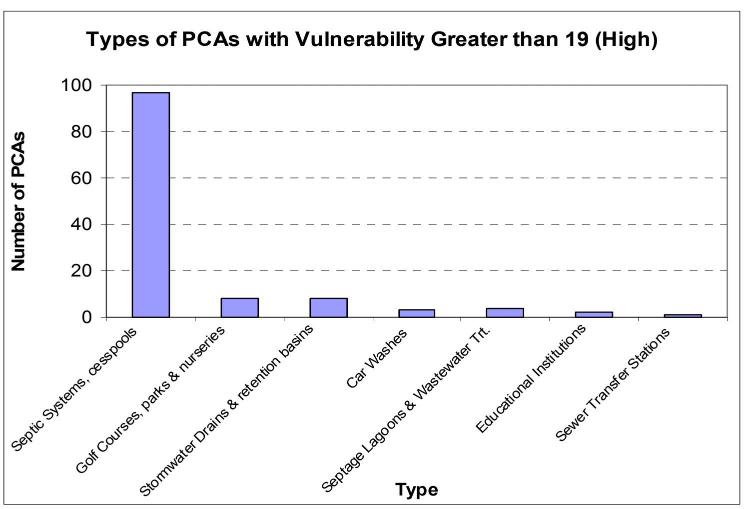

Figure 4-21: Number and type of PCAs (IOC) with vulnerability greater than 19 (High).

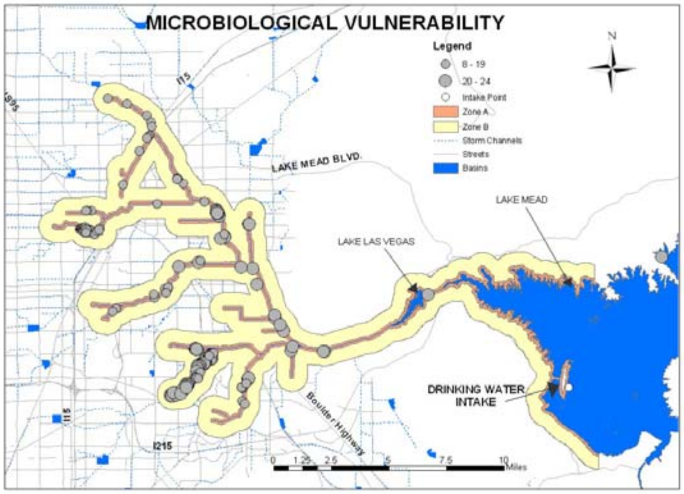

Figure 4-22: Vulnerability of each PCA (Microbiological) to the drinking water intake.

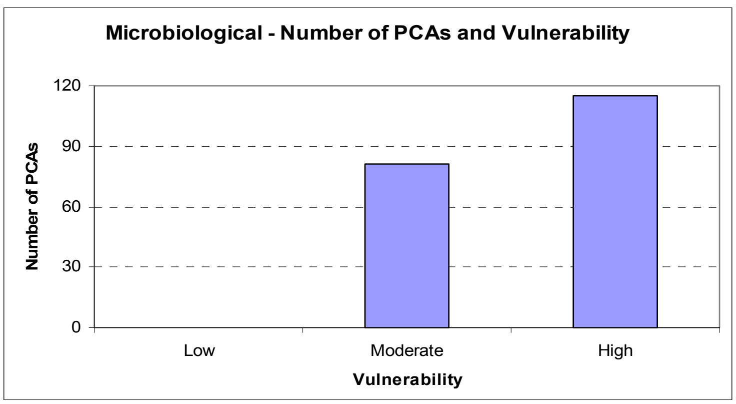

Figure 4-23: Number of PCAs (Microbiological) based on vulnerability categories. Low = 3-7, Moderate = 8-19, and High = 20-24.

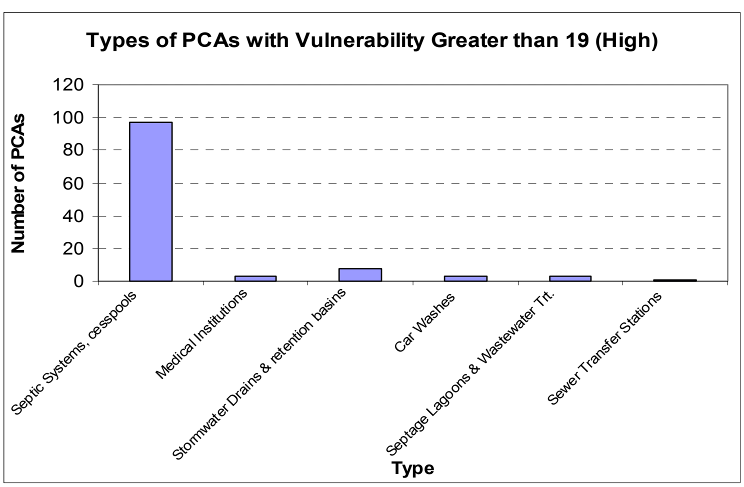

Figure 4-24: Number and type of PCAs (Microbiological) with vulnerability greater than 19 (High).

Table 4-5: Summary of the PCAs for contaminant categories and the final vulnerability ratings based on PBE, TOT, Risk, and Water Quality.

Contaminant Category	Number of PCAs	Maximum	Minimum	Average	Rating
VOC	121	19	7	13	Moderate
SOC	158	19	11	15	Moderate
IOC	173	24	14	20	High
Microbiological	196	24	12	18	Moderate
Radiological	1	19	19	19	Moderate

A summary of the vulnerability of the drinking water intake to different contaminant categories is presented in Table 4-5. The vulnerability scores for each category are calculated based on the average score of each PCA associated with the different contaminant categories. For instance, VOCs were associated with 121 PCAs and the average vulnerability score was 13. Based on the vulnerability calculations, none of the contaminant categories have a Low vulnerability rating (< 8) due to the High rating assigned to the PBE term in the vulnerability equation. The drinking water source is an open reservoir and is influenced by groundwater.

For VOCs and SOCs, the majority of the individual PCAs have a vulnerability score between 11 and 17, which corresponds to a Moderate rating. The average vulnerability score for all PCAs with VOCs and SOCs was 13 and 15, respectively. Therefore, the vulnerability of the drinking water intake prior to treatment to VOCs and SOCs is Moderate. It is noteworthy that a Moderate rating is assigned even though no MCL violations were noted in the record for VOCs of SOCs and the water quality rating in Section 4.7 was Low. This occurs since the other factors (TOT, PBE and Risk) were rated High, and this warrants an overall vulnerability rating of Moderate.

For the IOC category, the majority of the PCAs have a High rating due to the water quality term (see Section 4.7) in the vulnerability equation. Therefore, the vulnerability of the drinking water intake to IOCs is High. Of the PCAs with a High vulnerability score (> 19), septic systems are the major activities.

For the Microbiological category, more than half of the PCAs have a High rating; however, the overall average of the PCAs is a vulnerability score of 18 (See Table 4-5), which corresponds to a Moderate rating. Similar to the IOC category, septic systems are the major activity associated with the PCAs with a High vulnerability score. The Microbiological vulnerability of the drinking water prior to treatment is Moderate.

Lastly, the Radiological category had only one PCA and a Moderate vulnerability rating since the score was 19.

4.10. Major Transportation Routes

As noted earlier, the Las Vegas Valley is one of the fastest growing areas in the nation and much of the source water protection area is located in urbanized areas (See Figure 4-4). A special consideration is the major transportation routes that are located cross or parallel the source water protection zones. At these locations, there is the potential of a vehicle spilling hazardous materials and enter the storm channels. Although this is a rare event, the number of places where this might occur is noted in Figure 4-25. The street centerline data used in this analysis are those designated as "major streets" in the GISMO database.

There are 82 locations where the major streets cross through the source water protection area. More specifically, this represents the intersection of the major streets and the channels that had dry weather flow (wet flow). It is noteworthy that the majority of these intersections is outside the Las Vegas Wash and would have travel times greater than 12 hours. The most critical location would be the crossing downstream of Lake Las Vegas – State Route 147 when it crosses Las Vegas Wash. This is less than 10 miles to the intake and would have a travel time less than one hour to Lake Mead (Baker et al., 1977).

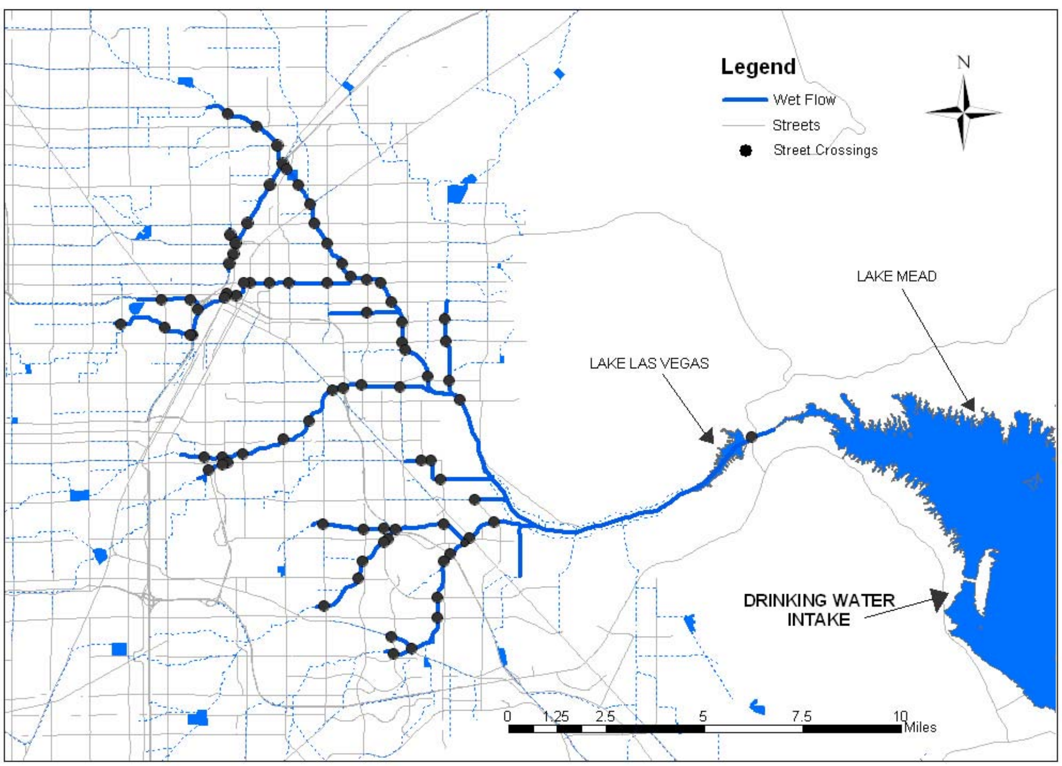

Figure 4-25: Location of major transportation routes in relation to the source water protection areas.

5. FINAL VULNERABILITY ASSESSMENT (TO BE INCLUDED IN SUMMARY SHEET)

Lake Mead supplies 88% of the water to Southern Nevada and the other 12% is from groundwater wells. The vulnerability of the water intakes at Lake Mead to potential sources of contamination from the Las Vegas Valley is assessed in this report. The groundwater wells are being assessed in a separate report. There are three water intakes at Saddle Island of Lake Mead: two feed water treatment plants managed by the Southern Nevada Water System (SNWS) and the third one feeds the water treatment plant managed by the City of Henderson.

The assessment includes an analysis of the current water quality data at the intake, and the vulnerability of the intake to potential contaminating activities (PCAs) located within a defined source water protection area. The vulnerability analysis includes the time of travel from PCAs to the intake, physical barrier effectiveness of the watershed, the risk associated with the PCAs, and evaluation of historical water quality data prior to treatment. It is noteworthy that this study represents an initial survey of the drinking water intake vulnerability and does not account for the loads that would be expected from the source water protection area.

Prior to undergoing treatment, the water quality at the intake meets most established MCL's for drinking water. However, the greatest concern is the effect of the Las Vegas Wash on the quality of the water at the intake. The Las Vegas Wash does not completely mix with Lake Mead water and, despite being more than seven miles from the intake; it affects the water quality of the intake. This is most critical during the winter when the Las Vegas Wash sinks to lower depths and higher levels of contaminants are expected at the intake. The presence of the contaminant perchlorate at the intake underlines the concern that a contaminant from the Las Vegas Wash could pose a threat to the water intake.

The vulnerability analysis shows that the PCAs with the highest vulnerability rating include septic systems, golf courses/parks, storm channels, gas stations, auto repair shops, construction, and the wastewater treatment plant discharges. Based on the current water quality data (prior to treatment), the proximity of Las Vegas Wash to the intake, and the results of the vulnerability analysis of potential contaminating activities, it is determined that the drinking water intake is at a Moderate level of risk for VOC, SOC, and microbiological contaminants. The drinking water intake is at a High level of risk for IOC contaminants. Vulnerability to radiological contamination is Moderate. Source water protection in the Las Vegas Valley is strongly encouraged because of the documented influence of the Las Vegas Wash on the quality of the water at the intake.

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Appendix A: Historical Water Quality Data at the Drinking Water Intake

Frequency of Sampling and Time Period of Data Used to Evaluate Water Quality of the Raw Water at the Intake of Lake Mead

VOC's-Raw Water	
Record Available	**07/2000 - 10/2002**
Frequency	**Monthly**
Item	**Unit**
VINYL CHLORIDE	mg/L
1,1-DICHLOROETHENE	mg/L
METHYLENE CHLORIDE	mg/L
METHYL TERTIARY BUTYL ETHER	mg/L
TRANS-1,2-DICHLOROETHENE	mg/L
CIS-1,2-DICHLOROETHENE	mg/L
1,1,1-TRICHLOROETHANE	mg/L
CARBON TETRACHLORIDE	mg/L
BENZENE	mg/L
1,2-DICHLOROETHANE	mg/L
TRICHLOROETHENE	mg/L
1,2-DICHLOROPROPANE	mg/L
TOLUENE	mg/L
1,1,2-TRICHLOROETHANE	mg/L
TETRACHLOROETHENE	mg/L
CHLOROBENZENE	mg/L
ETHYL BENZENE	mg/L
XYLENES (TOTAL)	mg/L
STYRENE	mg/L
1,4-DICHLOROBENZENE	mg/L
1,2-DICHLOROBENZENE	mg/L
1,2,4-TRICHLOROBENZENE	mg/L

Pathogens	
Record Available	**11/2001-11/2002**
Frequency	**Weekly**
	Unit
Aeromonas hydrophila	present / absent
Vibrio cholerae	present / abs.
Salmonella	present / abs.
Yersinia enterocolitica	present / abs.
Listeria monocytogens	present / abs.
Campylobacter jejuni	present / abs.
Helicobacter pylori	present / abs

VIRUSES - RAW WATER	
Record Available	**07/1994 - 10/2002**
Frequency	**Monthly**
Item	**Unit**
ENTEROVIRUS	1 = present, -1 = absent
HAV	1 = present, -1 = absent
HIV	1 = present, -1 = absent
NORWALK VIRUS	1 = present, -1 = absent
MYCOBACTERIUM	1 = present, -1 = absent
SRSV G1	1 = present, -1 = absent
SRSV G2	1 = present, -1 = absent
ROTAVIRUS	1 = present, -1 = absent

Radionuclides- Raw Water	
Record Available	**12/2000 - 11/2001**
Frequency	**Quarterly**
Item	**Unit**
GROSS ALPHA	pCi/l
GROSS BETA	pCi/l
RADIUM	pCi/l
TRITIUM	pCi/l
STRONTIUM 90	pCi/l
URANIUM	pCi/l

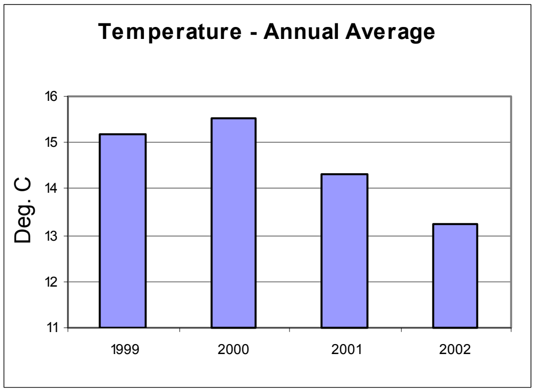
Frequency of Sampling and Time Period of Data Used to Evaluate Water Quality of the Raw Water at the Intake of Lake Mead- CONTINUED

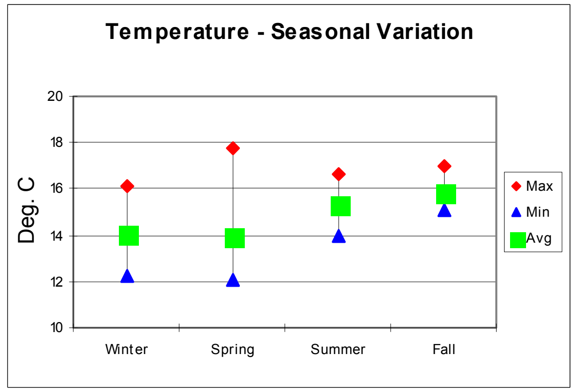
SOC		INORGANICS	
Record Available: **12/2000 - 09/2002**		Record: **01/1999 – 06/2002**	
Frequency: **(irregular, once/1~4 months)**		Frequency: **monthly**	
Item	**Unit**	**Item**	**Unit**
1,2 DIBROMO-3-CHLOROPROPANE (DBCP)	mg/L	COLOR, TRUE	
ETHYLENE DIBROMIDE (EDB)	mg/L	CONDUCTIVITY	us/cm
CHLORDANE	mg/L	ODOR	T.O.N
ENDRIN	mg/L	pH	
HEPTACHLOR	mg/L	TEMPERATURE	^{O}C
HEPTACHLOR EPOXIDE	mg/L	TURBIDITY	NTU
LINDANE	mg/L	HARDNESS (AS CACO3)	mg/l
METHOXYCHLOR	mg/L	CALCIUM	mg/l
POLYCHLORINATED BIPHENYLS (PCB)	mg/L	POTASSIUM	mg/l
TOXAPHENE	mg/L	MAGNESIUM	mg/l
2,4-D	mg/L	SODIUM	mg/l
DALAPON	mg/L	SILVER	mg/l
DINOSEB	mg/L	ALUMINUM	mg/l
PENTACHLOROPHENOL	mg/L	ARSENIC	mg/l
PICHLORAM	mg/L	BARIUM	mg/l
2,4,5-TP (SILVEX)	mg/L	BERYLLIUM	mg/l
ALACHOR	mg/L	CADMIUM	mg/l
ATRAZINE	mg/L	CHROMIUM	mg/l
SIMAZINE	mg/L	COPPER	mg/l
ALDICARB	mg/L	IRON	mg/l
ALDICARB SULFONE	mg/L	MERCURY	mg/l
ALDICARB SULFOXIDE	mg/L	MANGANESE	mg/l
CARBOFURAN	mg/L	NICKEL	mg/l
OXAMYL (VYDATE)	mg/L	LEAD	mg/l
GLYPHOSATE	mg/L	ANTIMONY	mg/l
ENDOTHALL	mg/L	SELENIUM	mg/l
DIQUAT	mg/L	THALLIUM	mg/l
2,3,7,8-TCDD (DIOXIN)	mg/L	ZINC	mg/l
BENZO (A) PYRENE	mg/L	ALKALINITY ,BICARBONATE	mg/l
DI (2-ETHYLHEXYL) ADIPATE	mg/L	BROMIDE	mg/l
DI (2-ETHYLHEXYL) PHTHALATE	mg/L	CHLORIDE	mg/l
HEXACHLOROBENZENE	mg/L	CYANIDE	mg/l
HEXACHLOROCYCLOPENTADIENE	mg/L	AGGRESSIVENESS INDEX	
INORGANICS-continued		LANGELIER INDEX	
PERCHLORATE	ppb	CARBON DIOXIDE	mg/l
FLUORIDE	mg/l	HARDNESS (AS CACO3)	mg/l
PHOSPHATE,ORTHO	mg/l	METHYLENE BLUE	mg/l
SILICA	mg/l	NITROGEN, NITRATE	mg/l
SULFATE	mg/l	NITROGEN, NITRITE	mg/l
		TDS	mg/l
		TOC	mg/l

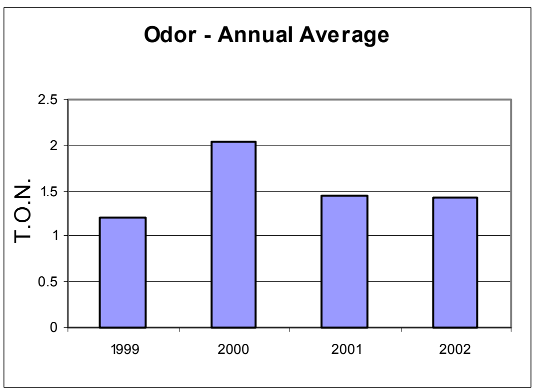
Frequency of Sampling and Time Period of Data Used to Evaluate Water Quality of the Raw Water at the Intake of Lake Mead -CONTINED

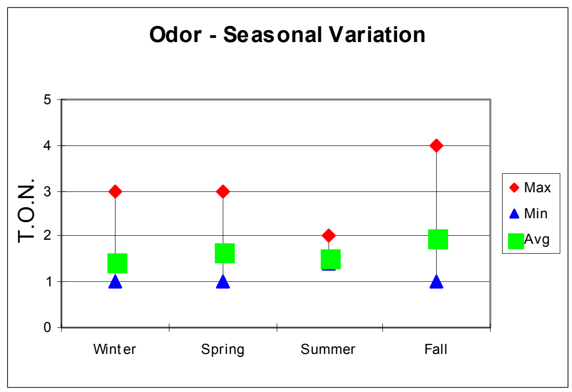
Item	**Units**	**Record Available**	**Frequency**
Fecal Coliform	#/100 ml	01/99 - 03/02	Weekly
Fecal Streptoccoci	**#/100 ml**	**01/99 - 11/02**	weekly
E. Coli	#/100 ml	04/02 –11/02	Weekly
Cryptosporidium	#/100 ml	04/94 - 10/99	

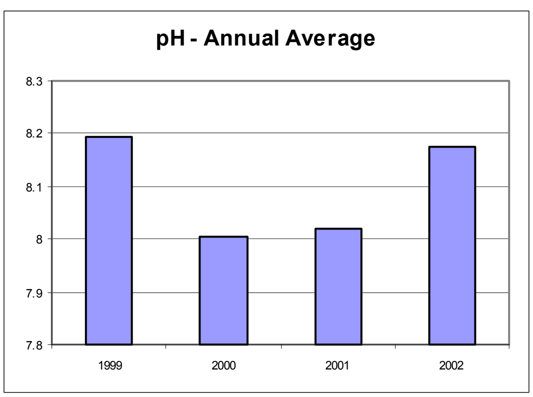
A.1 – Yearly and Seasonal Variation of Inorganic Contaminants at the Lake Mead Intake

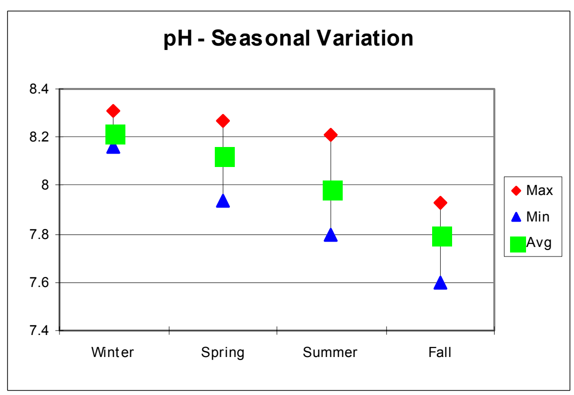


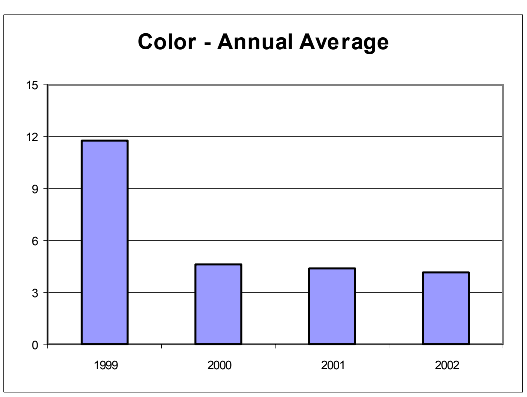


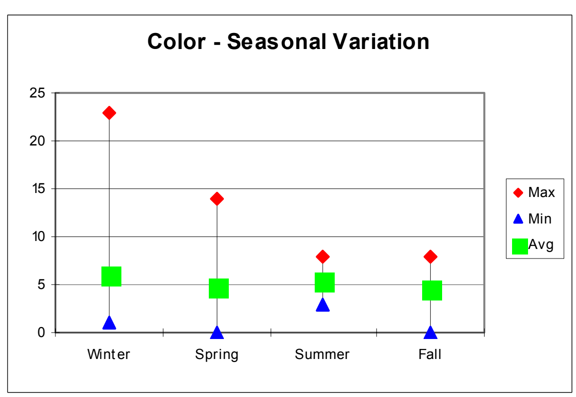


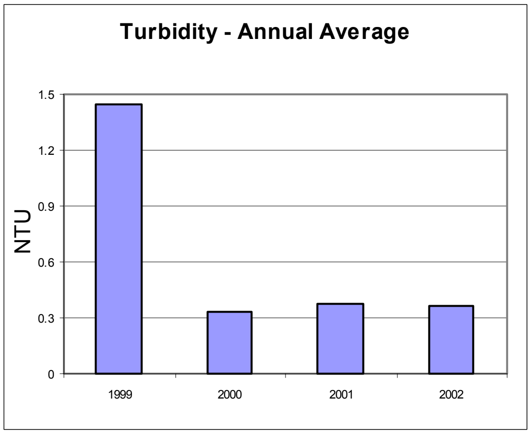


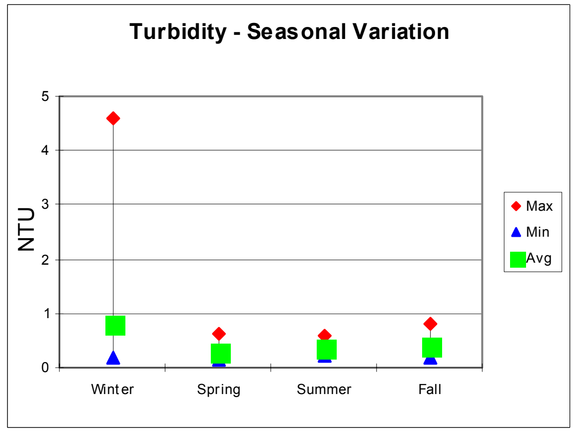


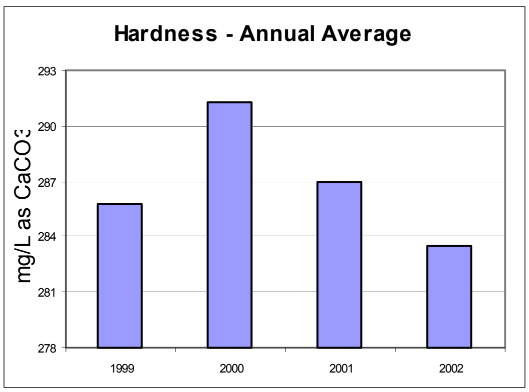


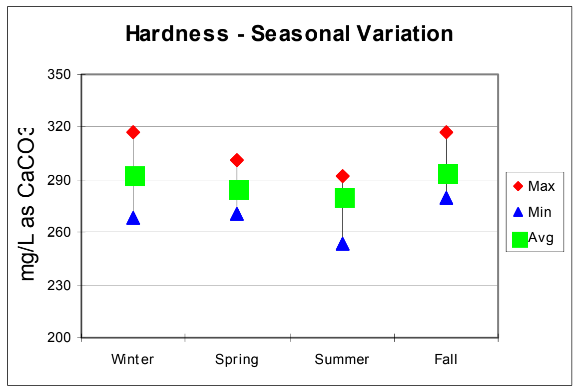


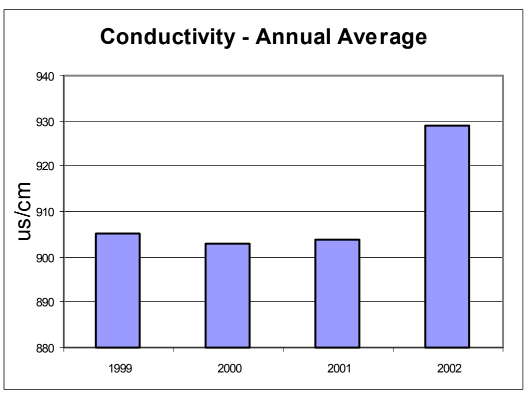


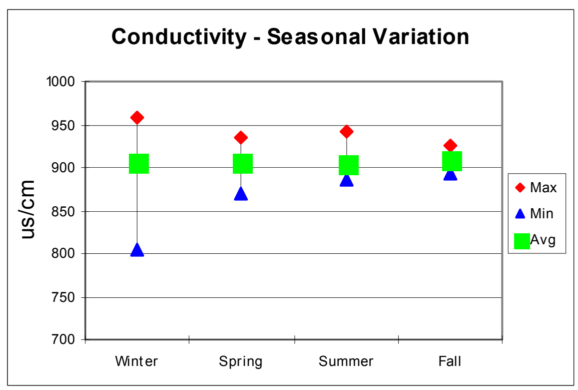

Turbidity - Annual Average
NTU
1.5
1.2
0.9
0.6
0.3
0
1999
2000
2001
2002

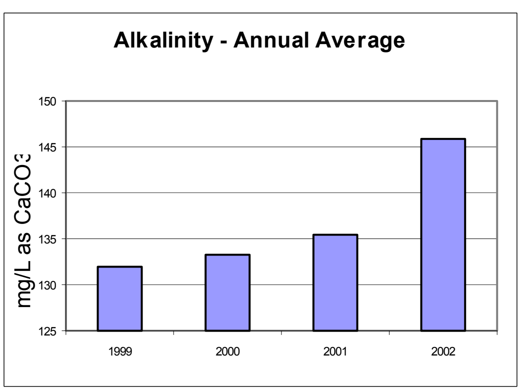

Turbidity - Seasonal Variation
NTU
5
4
3
2
1
0
Winter
Spring
Summer
Fall
Max
Min
Avg

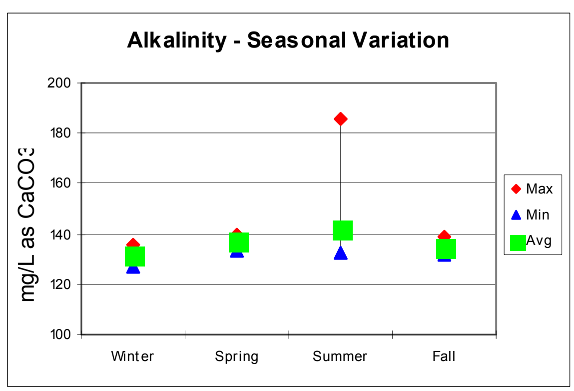

Hardness - Annual Average
mg/L as CaCO3
293
290
287
284
281
278
1999
2000
2001
2002

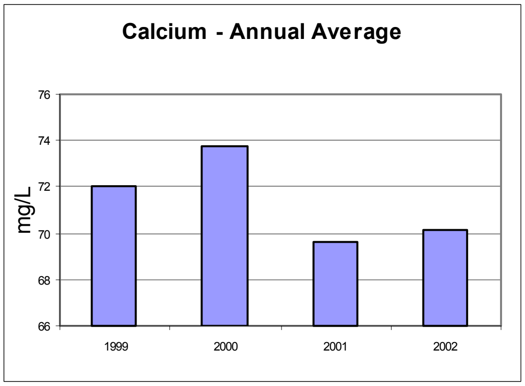

Hardness - Seasonal Variation
mg/L as CaCO3
350
320
290
260
230
200
Winter
Spring
Summer
Fall
Max
Min
Avg

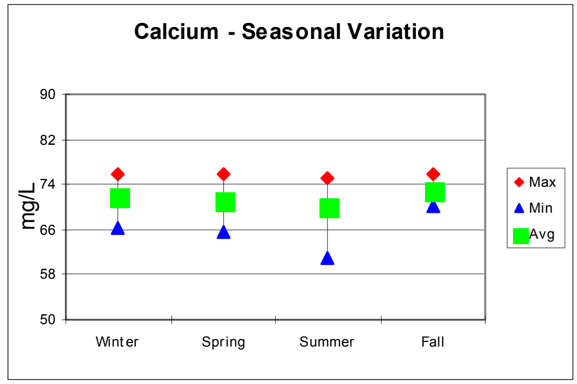

Conductivity - Annual Average
us/cm
940
930
920
910
900
890
880
1999
2000
2001
2002

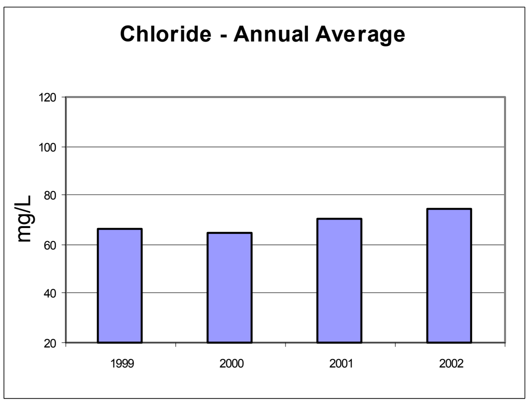

Conductivity - Seasonal Variation
us/cm
1000
950
900
850
800
750
700
Winter
Spring
Summer
Fall
Max
Min
Avg

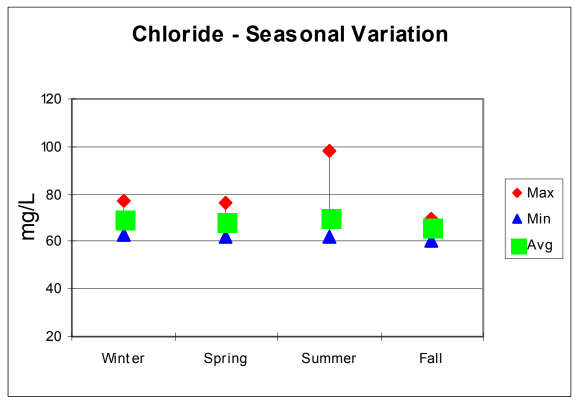

Alkalinity - Annual Average
mg/L as CaCO3
150
145
140
135
130
125
1999
2000
2001
2002

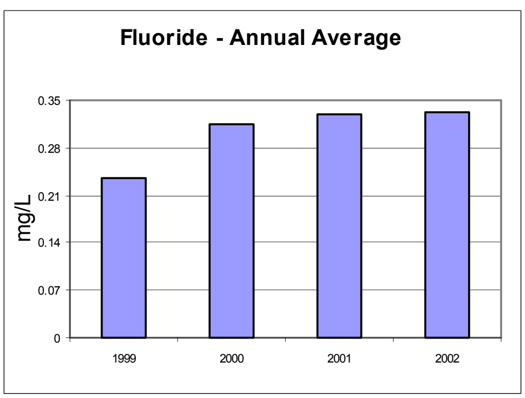

Alkalinity - Seasonal Variation
mg/L as CaCO3
200
180
160
140
120
100
Winter
Spring
Summer
Fall
Max
Min
Avg

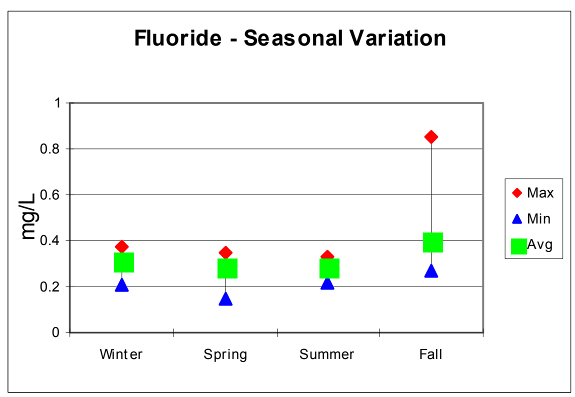

Calcium - Annual Average
mg/L
76
74
72
70
68
66
1999
2000
2001
2002

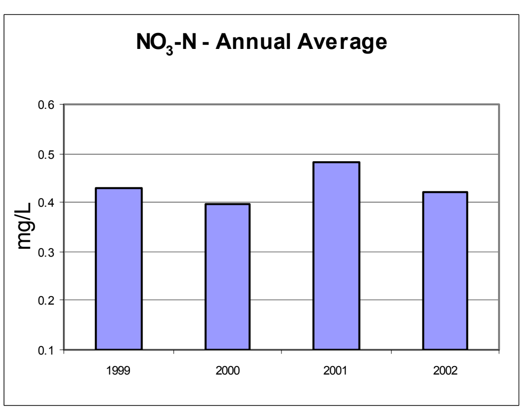

Calcium - Seasonal Variation
mg/L
90
82
74
66
58
50
Winter
Spring
Summer
Fall
Max
Min
Avg

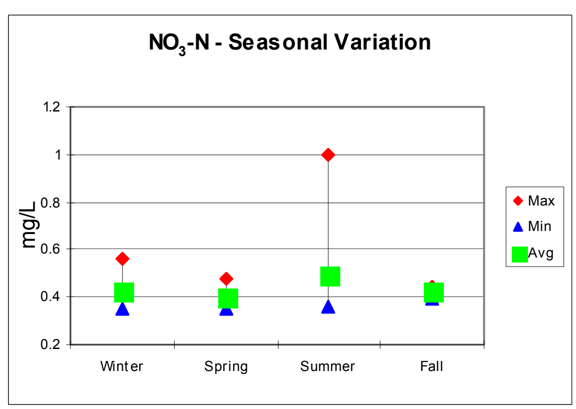

Chloride - Annual Average
mg/L
120
100
80
60
40
20
1999
2000
2001
2002

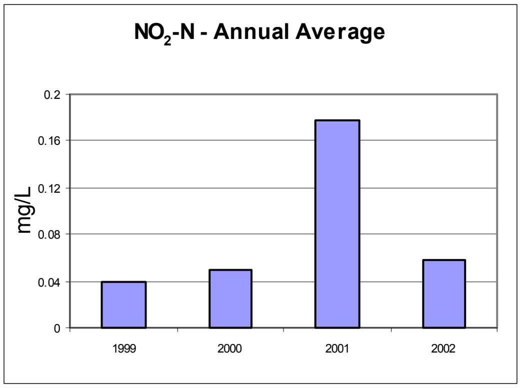

Chloride - Seasonal Variation
mg/L
120
100
80
60
40
20
Winter
Spring
Summer
Fall
Max
Min
Avg

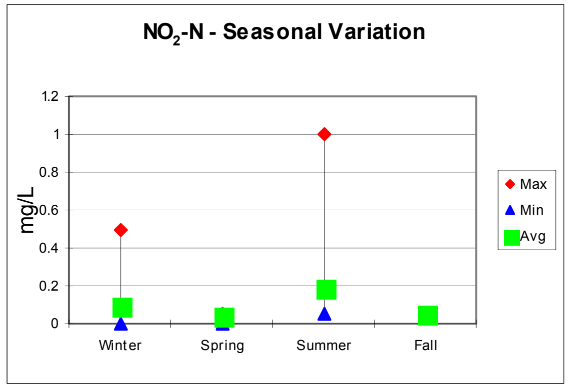

Fluoride - Annual Average
mg/L
0.35
0.28
0.21
0.14
0.07
0
1999
2000
2001
2002

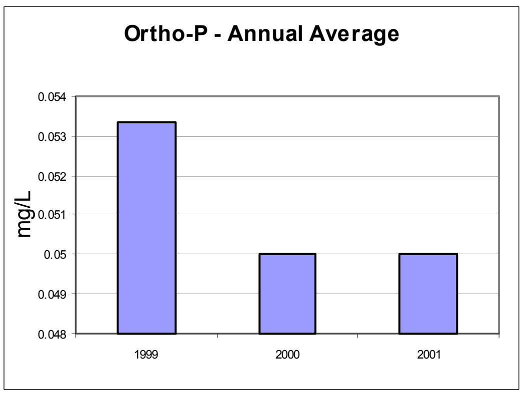

Fluoride - Seasonal Variation
mg/L
1
0.8
0.6
0.4
0.2
0
Winter
Spring
Summer
Fall
Max
Min
Avg

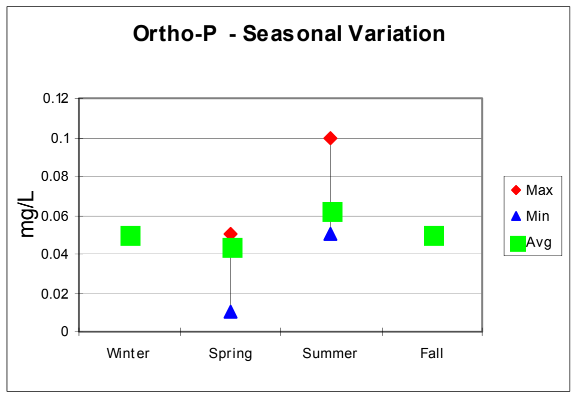

NO_3-N - Annual Average
mg/L
0.6
0.5
0.4
0.3
0.2
0.1
1999
2000
2001
2002

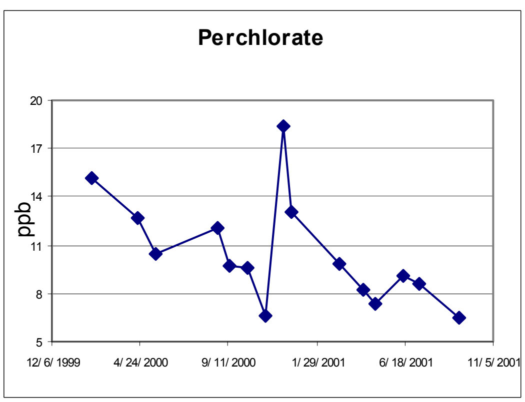

NO_3-N - Seasonal Variation
mg/L
1.2
1
0.8
0.6
0.4
0.2
Winter
Spring
Summer
Fall
Max
Min
Avg

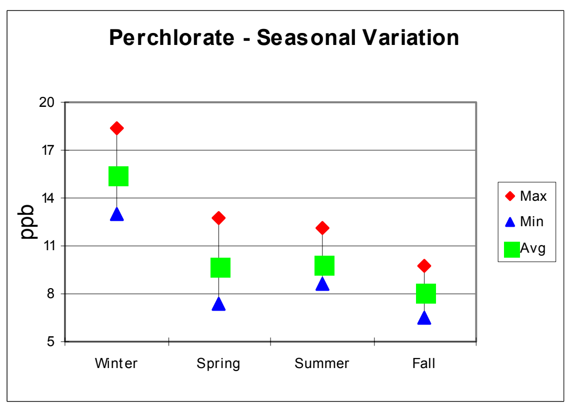

NO2-N - Annual Average
mg/L
0.2
0.16
0.12
0.08
0.04
0
1999
2000
2001
2002

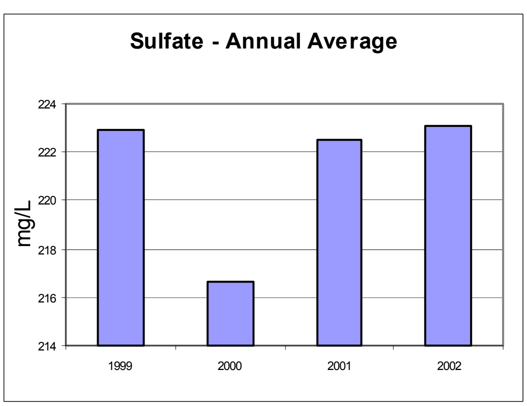

NO2-N - Seasonal Variation
mg/L
1.2
1
0.8
0.6
0.4
0.2
0
Winter
Spring
Summer
Fall
Max
Min
Avg

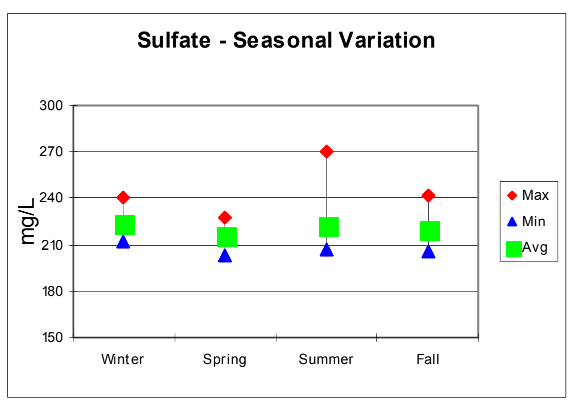

Ortho-P - Annual Average
mg/L
0.054
0.053
0.052
0.051
0.05
0.049
0.048
1999
2000
2001

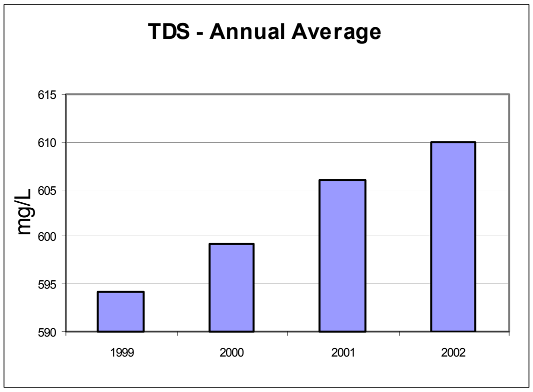

Ortho-P - Seasonal Variation
mg/L
0.12
0.1
0.08
0.06
0.04
0.02
0
Winter
Spring
Summer
Fall
Max
Min
Avg

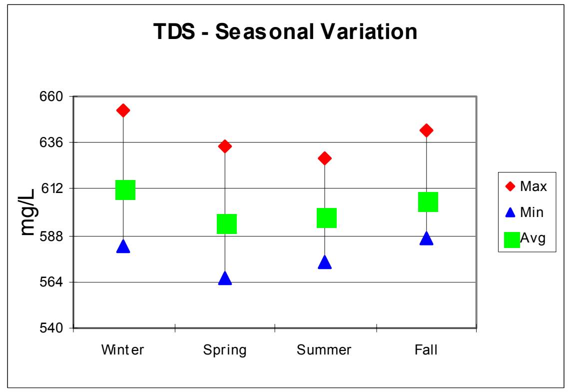

Perchlorate
ppb
20
17
14
11
8
5
12/6/1999
4/24/2000
9/11/2000
1/29/2001
6/18/2001
11/5/2001

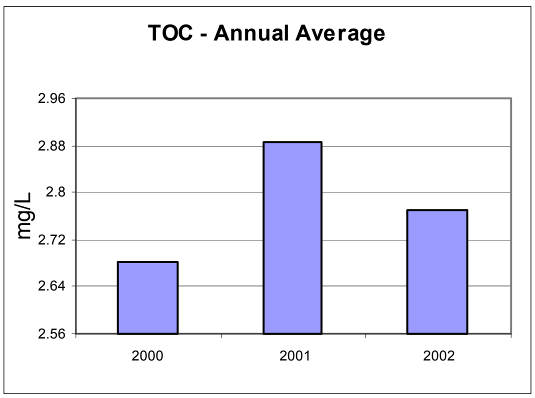

Perchlorate - Seasonal Variation
ppb
20
17
14
11
8
5
Winter
Spring
Summer
Fall
Max
Min
Avg

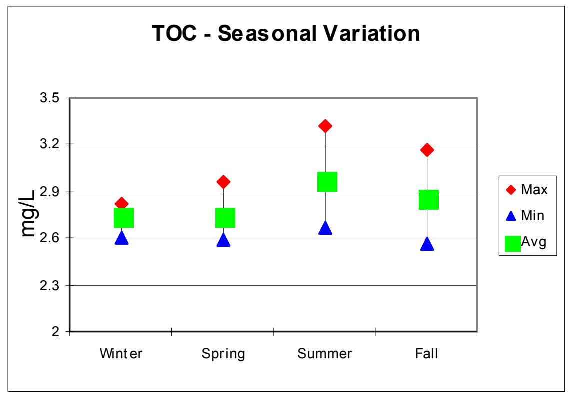

Sulfate - Annual Average
mg/L
224
222
220
218
216
214
1999
2000
2001
2002

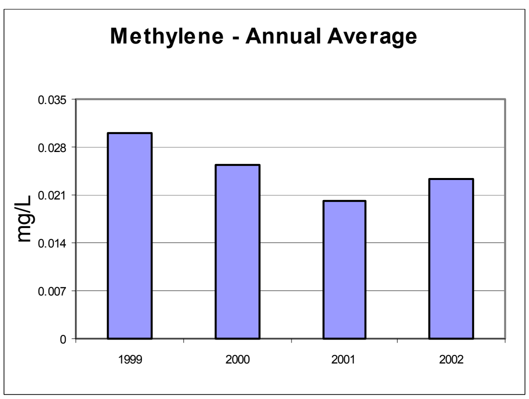

Sulfate - Seasonal Variation
mg/L
300
270
240
210
180
150
Winter
Spring
Summer
Fall
Max
Min
Avg

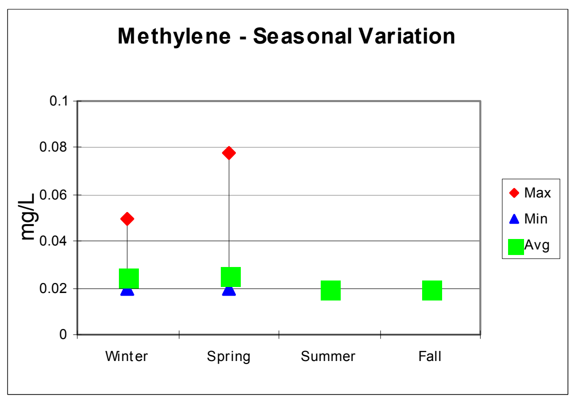

TDS - Annual Average
mg/L
615
610
605
600
595
590
1999
2000
2001
2002


TDS - Seasonal Variation
mg/L
660
636
612
588
564
540
Winter
Spring
Summer
Fall
Max
Min
Avg

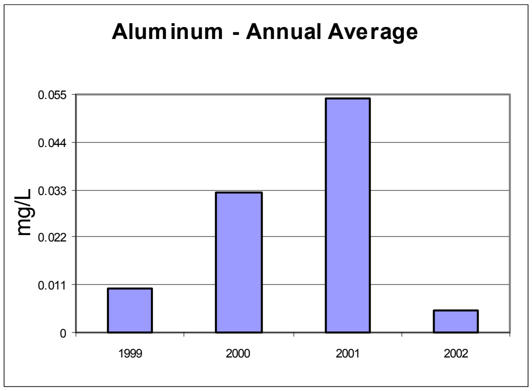

TOC - Annual Average
mg/L
2.96
2.88
2.8
2.72
2.64
2.56
2000
2001
2002

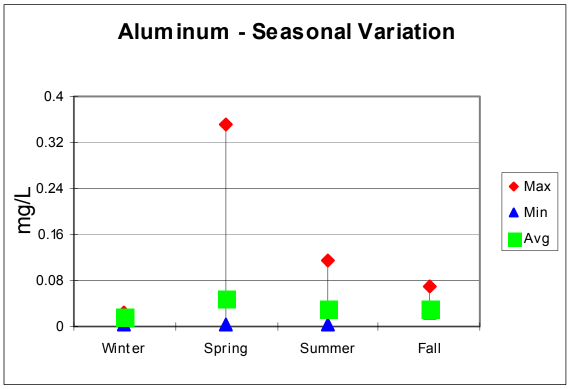

TOC - Seasonal Variation
mg/L
3.5
3.2
2.9
2.6
2.3
2
Winter
Spring
Summer
Fall
Max
Min
Avg

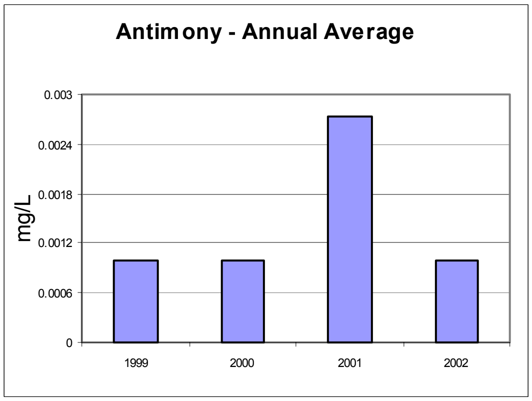

Methylene - Annual Average
mg/L
0.035
0.028
0.021
0.014
0.007
0
1999
2000
2001
2002

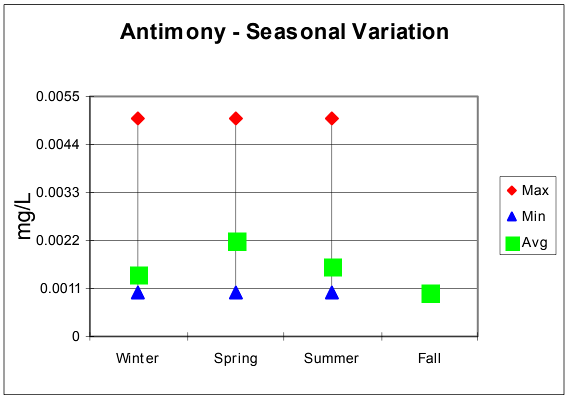

Methylene - Seasonal Variation
mg/L
0.1
0.08
0.06
0.04
0.02
0
Winter
Spring
Summer
Fall
Max
Min
Avg

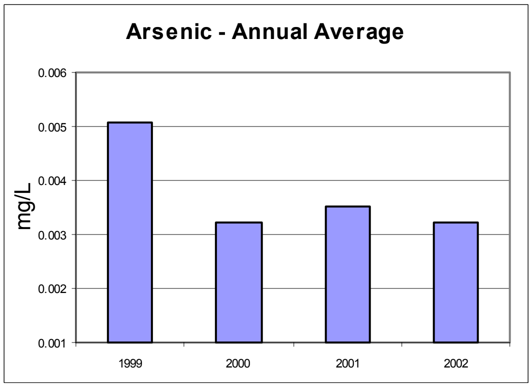
A.2 – Yearly and Seasonal Variation of Metals at the Lake Mead Intake

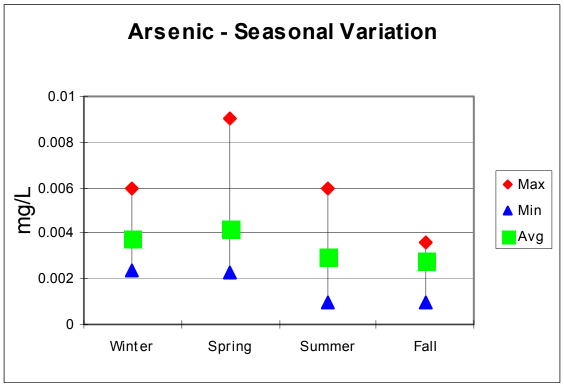


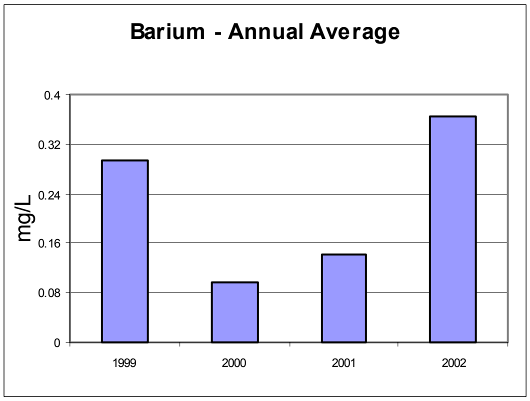


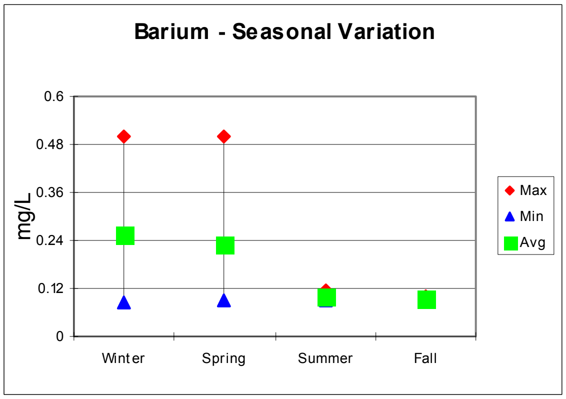


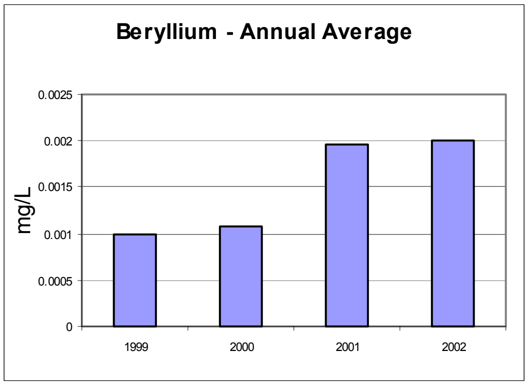




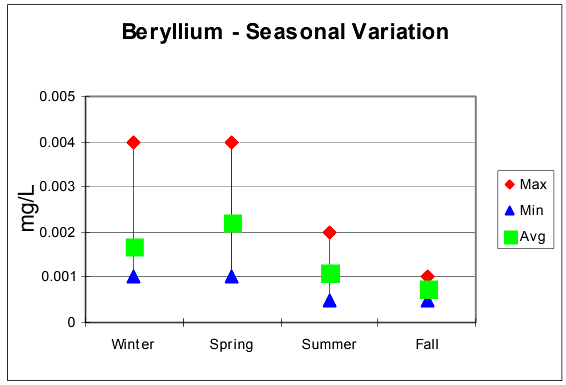




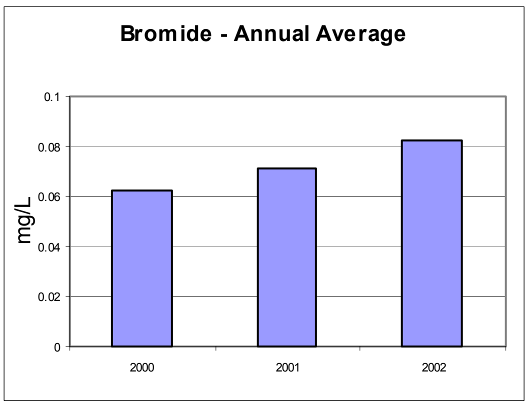




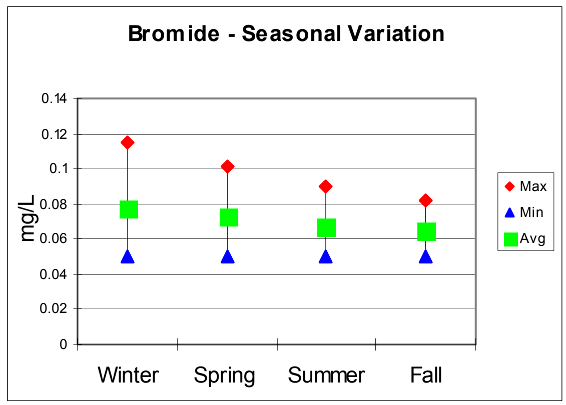
Beryllium - Annual Average
mg/L
0.0025
0.002
0.0015
0.001
0.0005
0
1999
2000
2001
2002



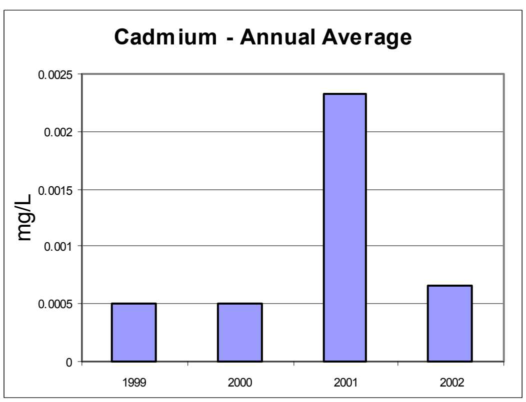
Beryllium - Seasonal Variation
mg/L
0.005
0.004
0.003
0.002
0.001
0
Winter
Spring
Summer
Fall
Max
Min
Avg



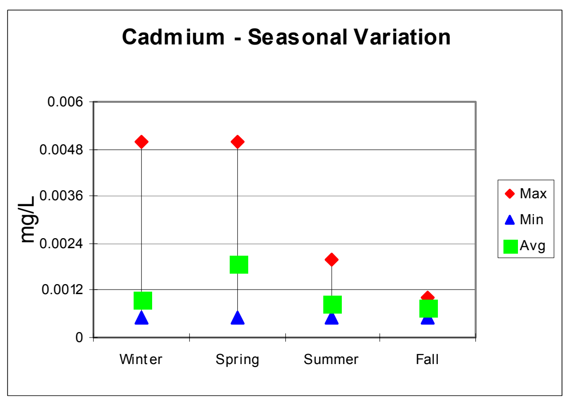
Bromide - Annual Average
mg/L
0.1
0.08
0.06
0.04
0.02
0
2000
2001
2002



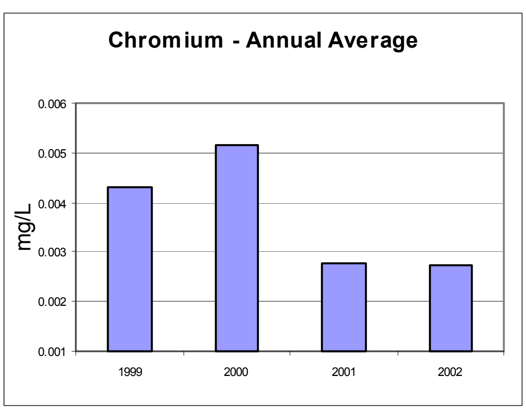
Bromide - Seasonal Variation
mg/L
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Winter
Spring
Summer
Fall
Max
Min
Avg



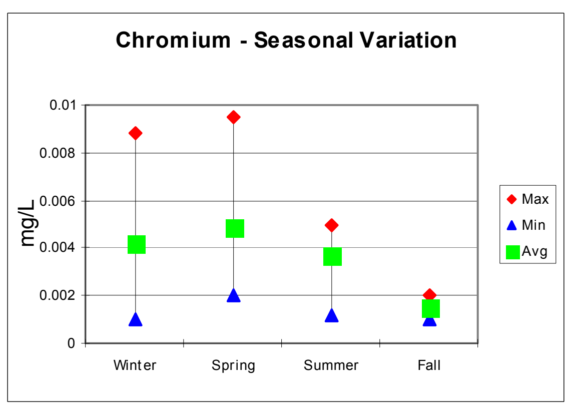
Cadmium - Annual Average
mg/L
0.0025
0.002
0.0015
0.001
0.0005
0
1999
2000
2001
2002



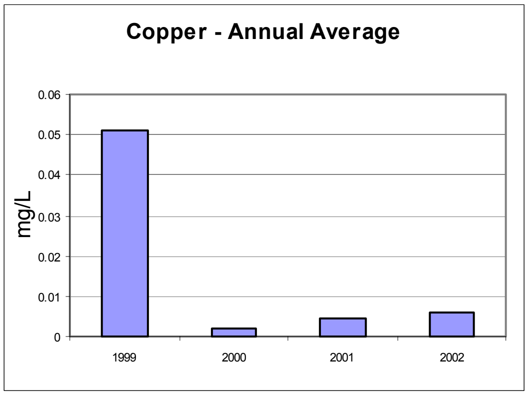
Cadmium - Seasonal Variation
mg/L
0.006
0.0048
0.0036
0.0024
0.0012
0
Winter
Spring
Summer
Fall
Max
Min
Avg

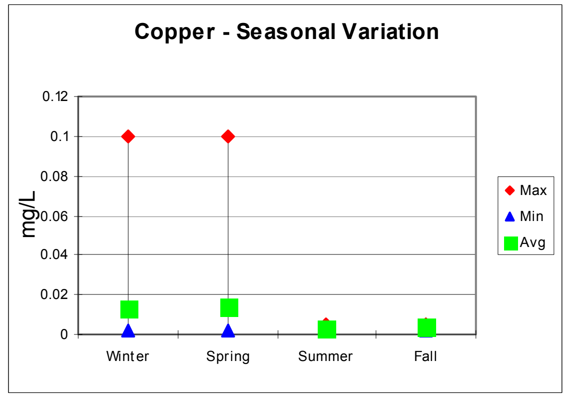


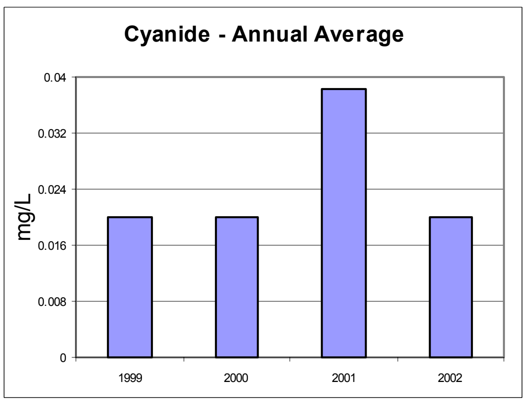
Chromium - Annual Average
mg/L
0.006
0.005
0.004
0.003
0.002
0.001
1999
2000
2001
2002

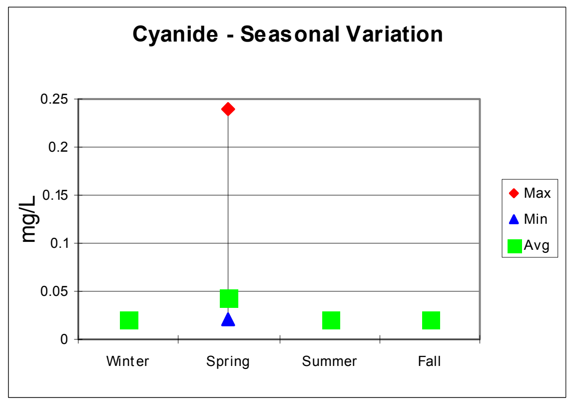


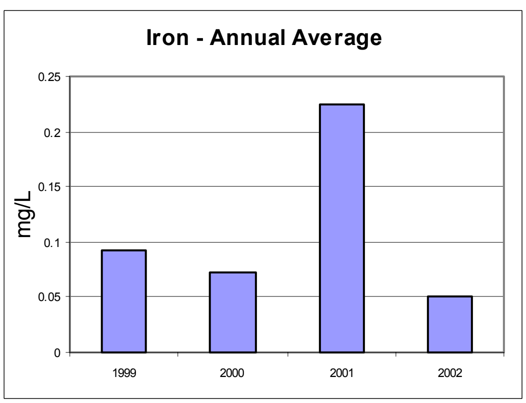
Chromium - Seasonal Variation
mg/L
0.01
0.008
0.006
0.004
0.002
0
Winter
Spring
Summer
Fall
Max
Min
Avg

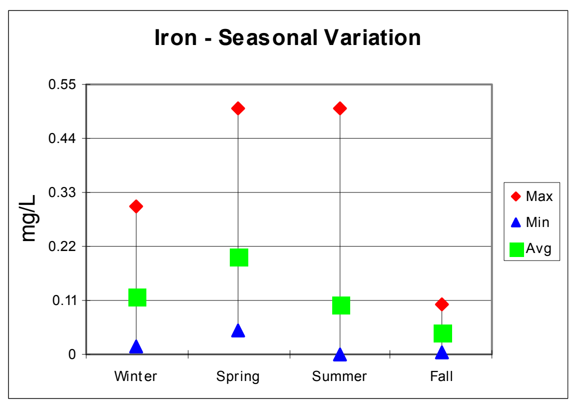

Copper - Annual Average
mg/L
0.06
0.05
0.04
0.03
0.02
0.01
0
1999
2000
2001
2002

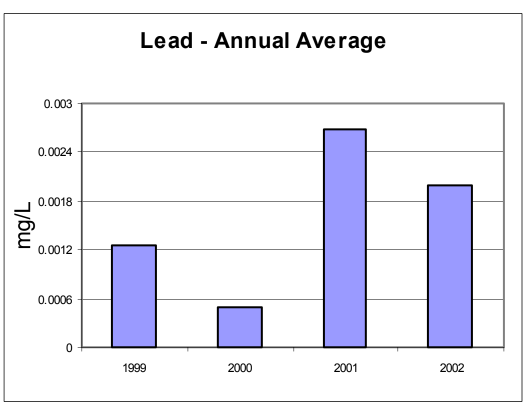

Copper - Seasonal Variation
mg/L
0.12
0.1
0.08
0.06
0.04
0.02
0
Winter
Spring
Summer
Fall
Max
Min
Avg

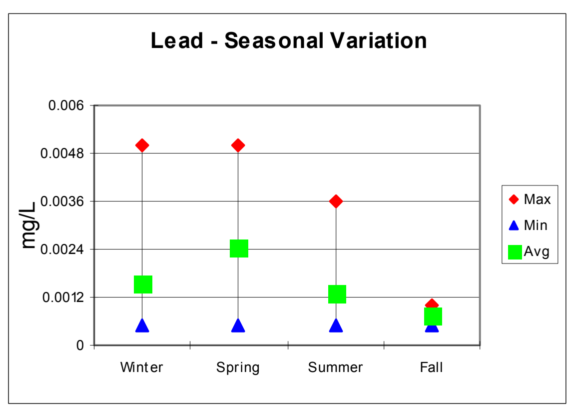

Cyanide - Annual Average
mg/L
0.04
0.032
0.024
0.016
0.008
0
1999
2000
2001
2002

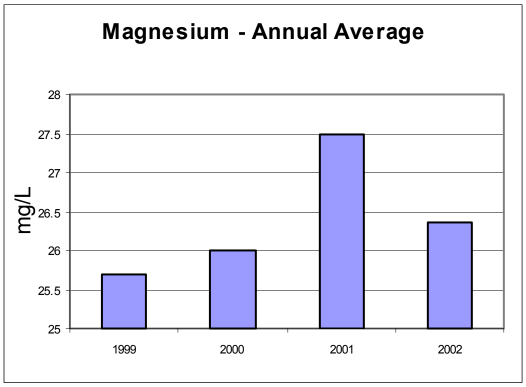

Cyanide - Seasonal Variation
mg/L
0.25
0.2
0.15
0.1
0.05
0
Winter
Spring
Summer
Fall
Max
Min
Avg

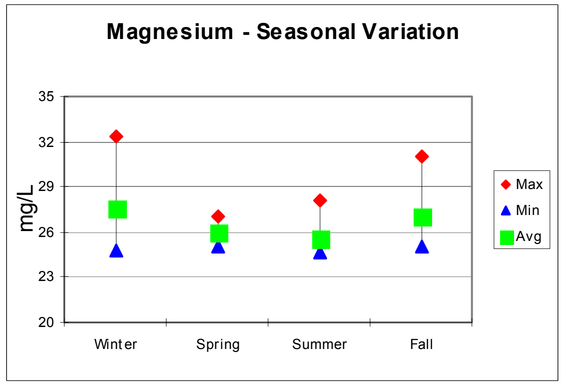

Iron - Annual Average
mg/L
0.25
0.2
0.15
0.1
0.05
0
1999
2000
2001
2002

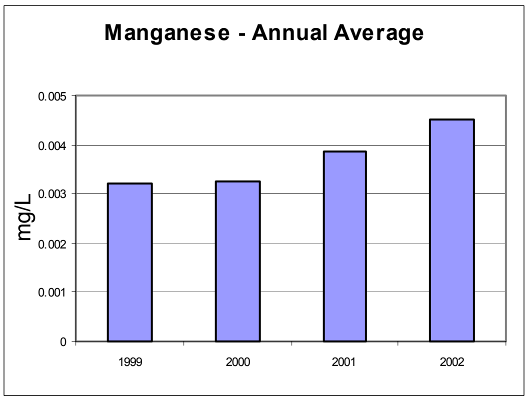

Iron - Seasonal Variation
mg/L
0.55
0.44
0.33
0.22
0.11
0
Winter
Spring
Summer
Fall
Max
Min
Avg

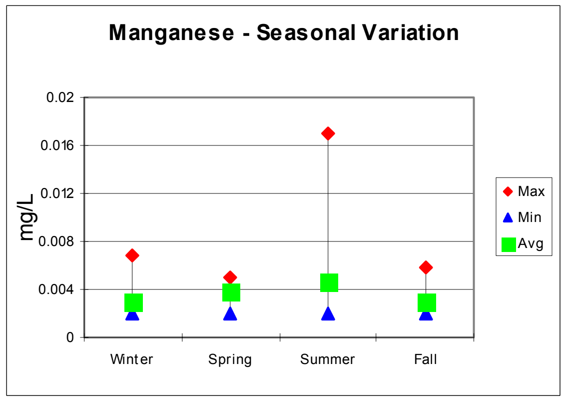

Lead - Annual Average
mg/L
0.003
0.0024
0.0018
0.0012
0.0006
0
1999
2000
2001
2002

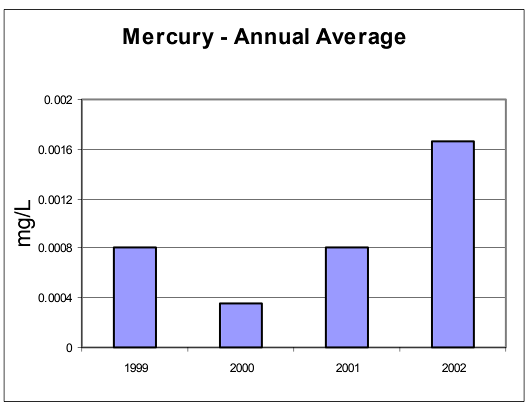

Lead - Seasonal Variation
mg/L
0.006
0.0048
0.0036
0.0024
0.0012
0
Winter
Spring
Summer
Fall
Max
Min
Avg

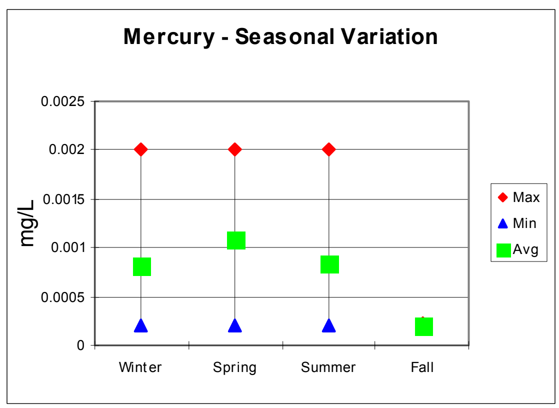

Magnesium - Annual Average
mg/L
28
27.5
27
26.5
26
25.5
25
1999
2000
2001
2002

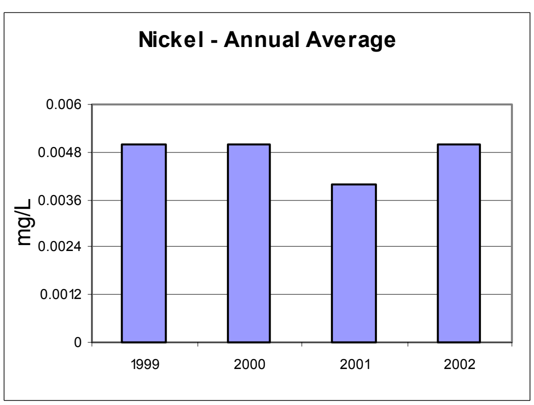

Magnesium - Seasonal Variation
mg/L
35
32
29
26
23
20
Winter
Spring
Summer
Fall
Max
Min
Avg

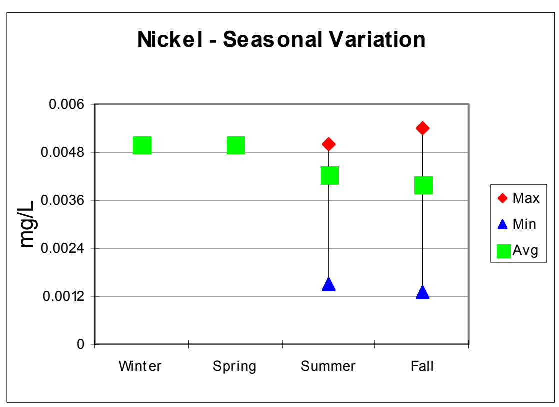

Manganese - Annual Average
mg/L
0.005
0.004
0.003
0.002
0.001
0
1999
2000
2001
2002

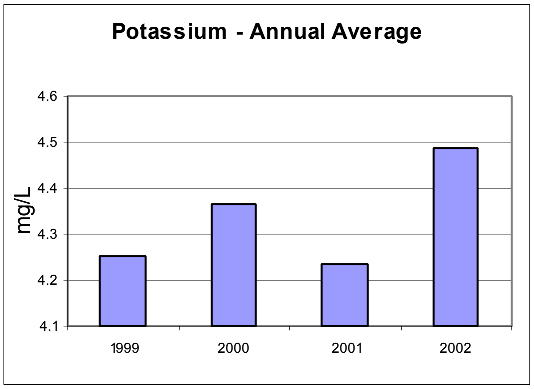

Manganese - Seasonal Variation
mg/L
0.02
0.016
0.012
0.008
0.004
0
Winter
Spring
Summer
Fall
Max
Min
Avg

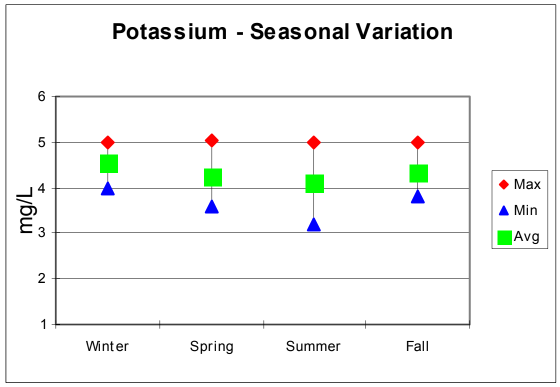

Mercury - Annual Average
mg/L
0.002
0.0016
0.0012
0.0008
0.0004
0
1999
2000
2001
2002

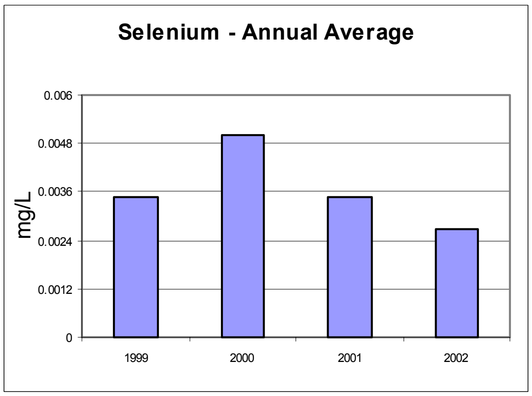

Mercury - Seasonal Variation
mg/L
0.0025
0.002
0.0015
0.001
0.0005
0
Winter
Spring
Summer
Fall
Max
Min
Avg

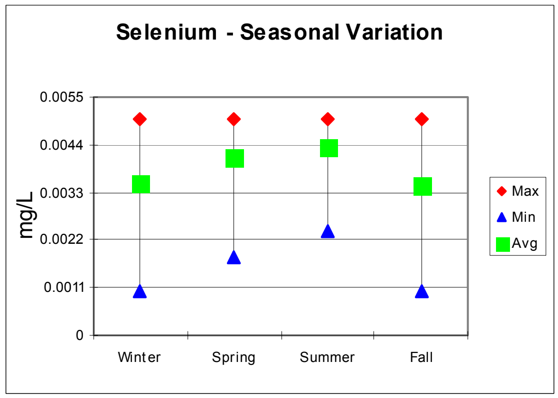

Nickel - Annual Average
mg/L
0.006
0.0048
0.0036
0.0024
0.0012
0
1999
2000
2001
2002

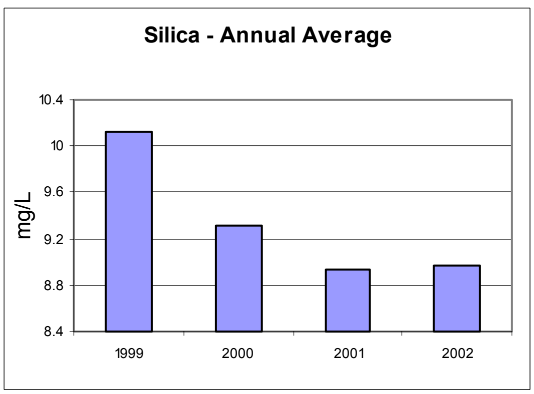

Nickel - Seasonal Variation
mg/L
0.006
0.0048
0.0036
0.0024
0.0012
0
Winter
Spring
Summer
Fall
Max
Min
Avg

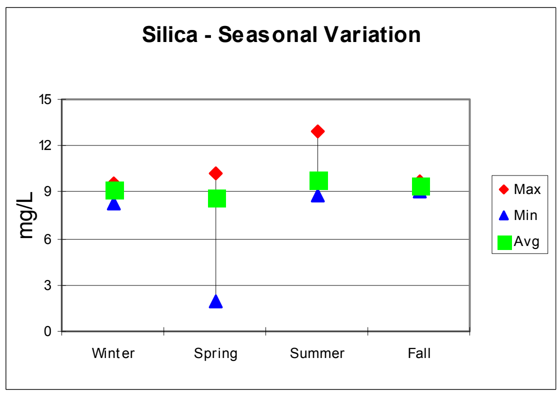

Potassium - Annual Average
mg/L
4.6
4.5
4.4
4.3
4.2
4.1
1999
2000
2001
2002

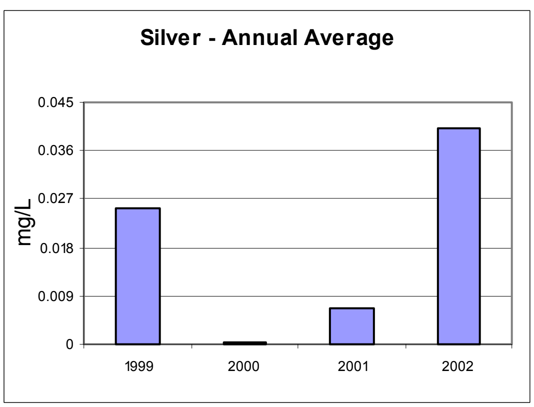

Potassium - Seasonal Variation
mg/L
6
5
4
3
2
1
Winter
Spring
Summer
Fall
Max
Min
Avg

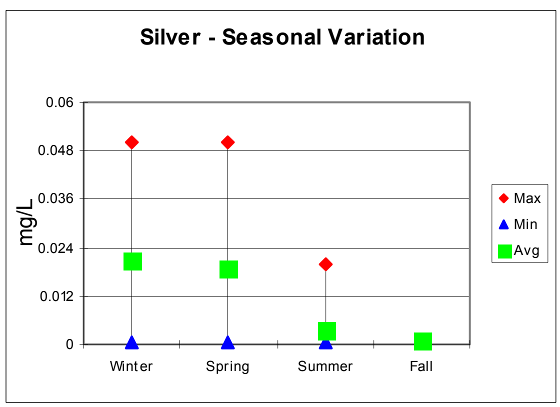

Selenium - Annual Average
mg/L
0.006
0.0048
0.0036
0.0024
0.0012
0
1999
2000
2001
2002

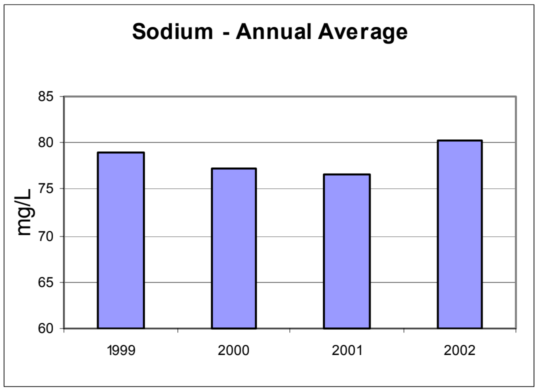

Selenium - Seasonal Variation
mg/L
0.0055
0.0044
0.0033
0.0022
0.0011
0
Winter
Spring
Summer
Fall
Max
Min
Avg

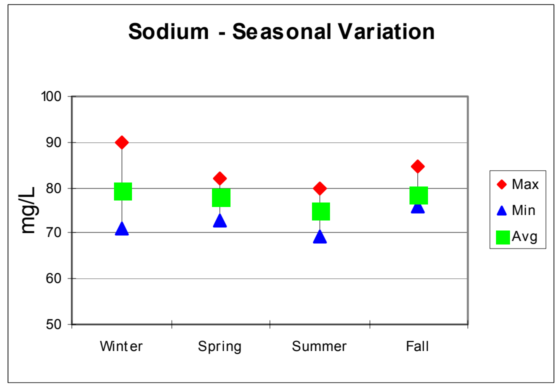

Silica - Annual Average
mg/L
10.4
10
9.6
9.2
8.8
8.4
1999
2000
2001
2002

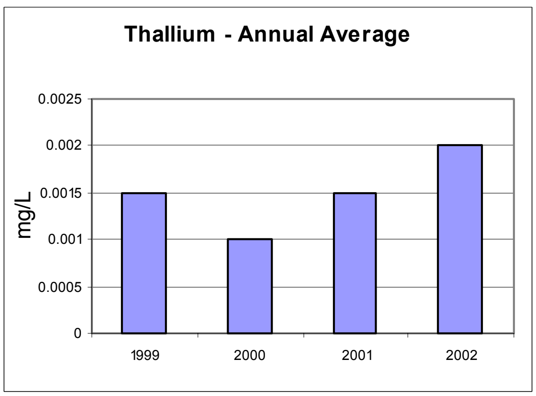

Silica - Seasonal Variation
mg/L
15
12
9
6
3
0
Winter
Spring
Summer
Fall
Max
Min
Avg

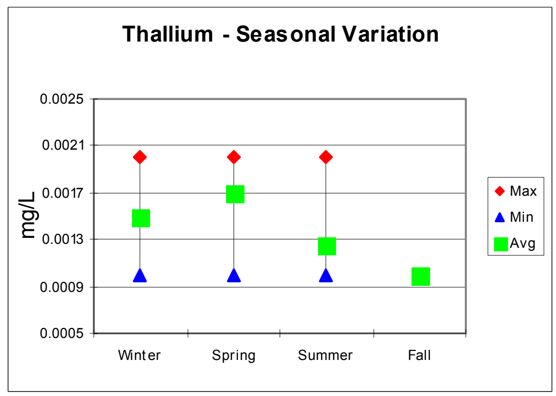

Silver - Annual Average
mg/L
0.045
0.036
0.027
0.018
0.009
0
1999
2000
2001
2002

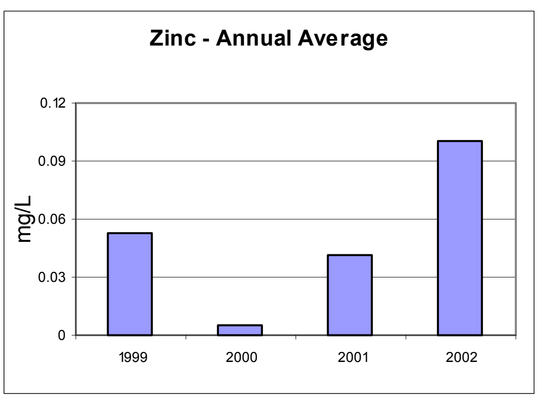

Silver - Seasonal Variation
mg/L
0.06
0.048
0.036
0.024
0.012
0
Winter
Spring
Summer
Fall
Max
Min
Avg

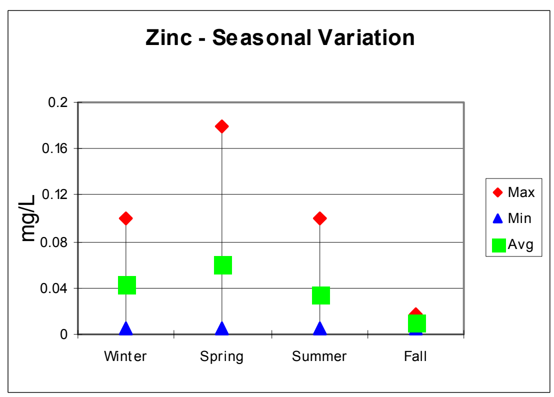

Sodium - Annual Average
mg/L
85
80
75
70
65
60
1999
2000
2001
2002


Sodium - Seasonal Variation
mg/L
100
90
80
70
60
50
Winter
Spring
Summer
Fall
Max
Min
Avg

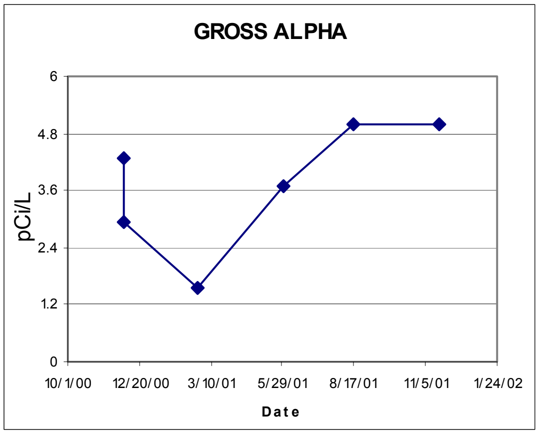

Thallium - Annual Average
mg/L
0.0025
0.002
0.0015
0.001
0.0005
0
1999
2000
2001
2002

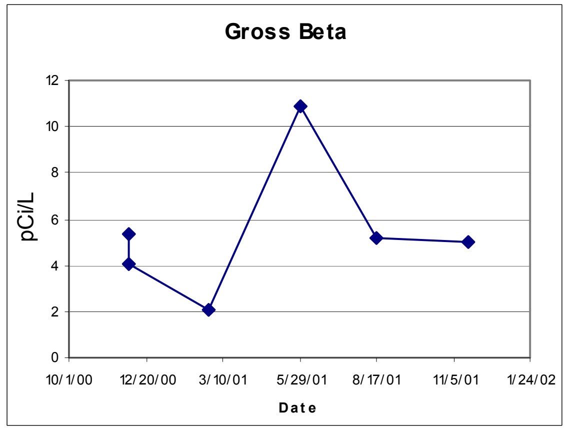

Thallium - Seasonal Variation
mg/L
0.0025
0.0021
0.0017
0.0013
0.0009
0.0005
Winter
Spring
Summer
Fall
Max
Min
Avg

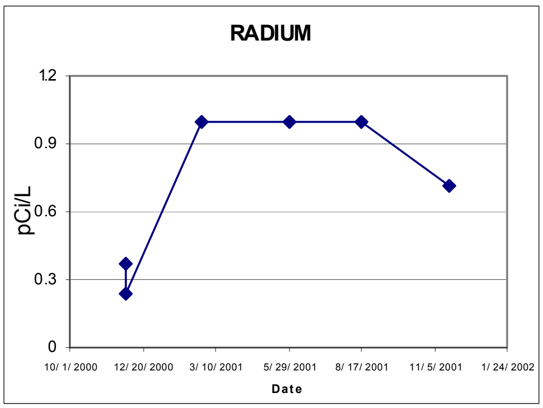

Zinc - Annual Average
mg/L
0.12
0.09
0.06
0.03
0
1999
2000
2001
2002

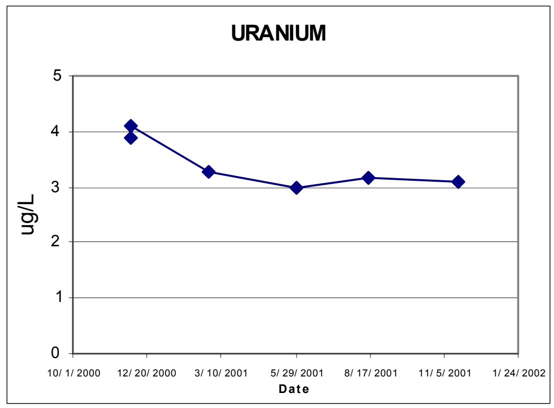

Zinc - Seasonal Variation
mg/L
0.2
0.16
0.12
0.08
0.04
0
Winter
Spring
Summer
Fall
Max
Min
Avg

A.3 – Yearly and Seasonal Variation of Radiological Parameters at the Lake Mead Intake

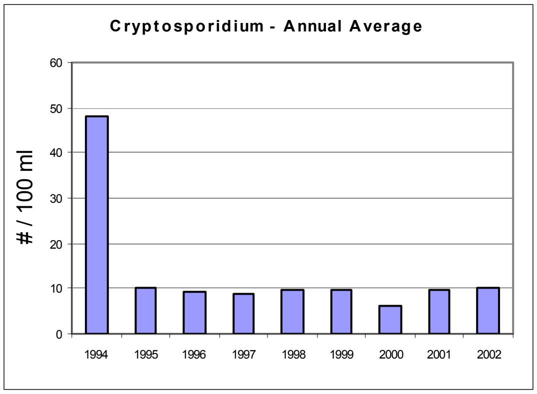


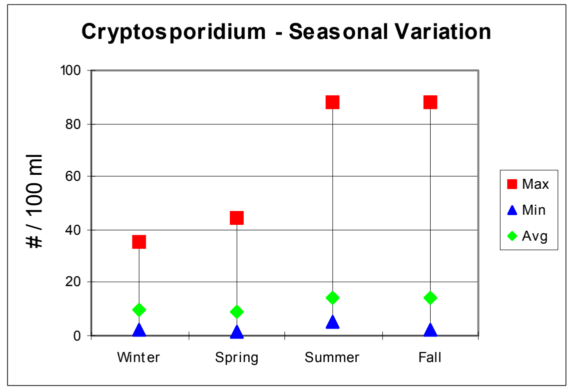


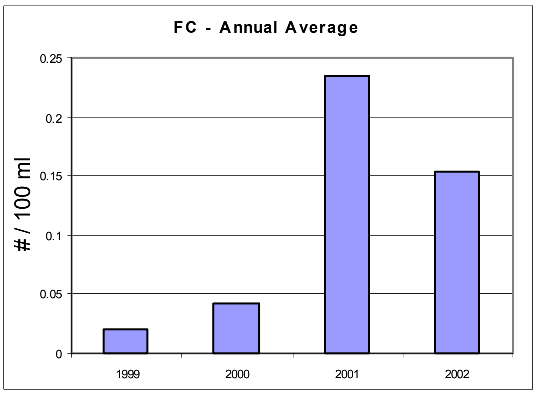


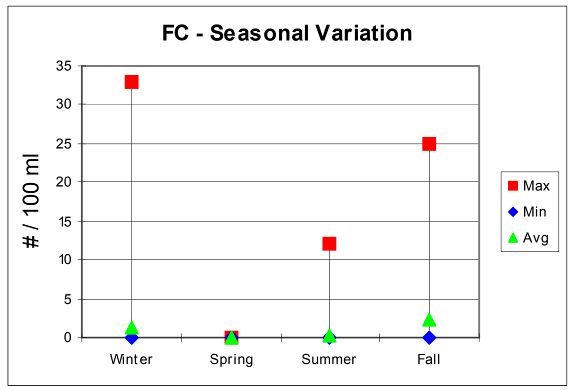


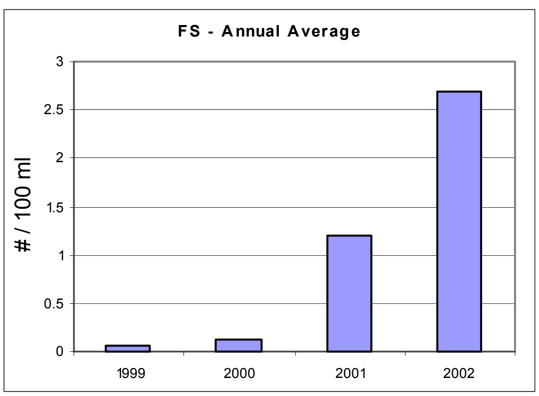
A.4 – Microbiological Parameters for the Water Intake at Lake Mead

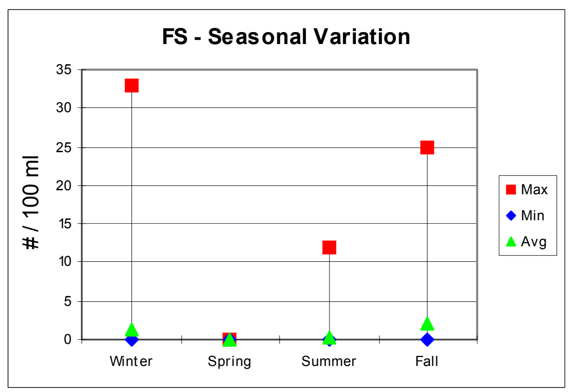


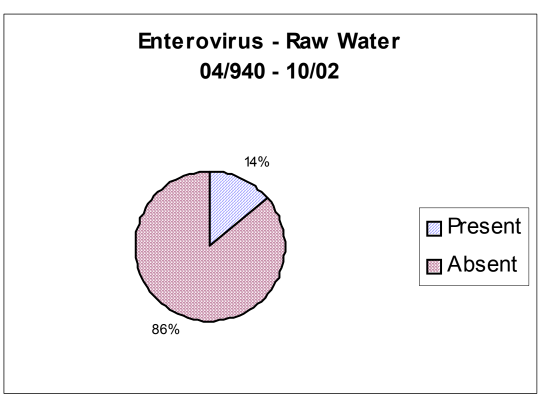


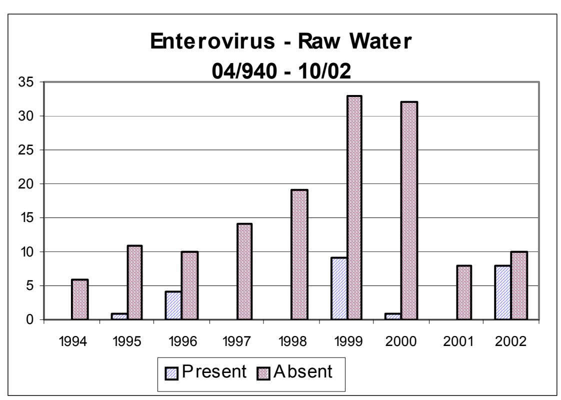


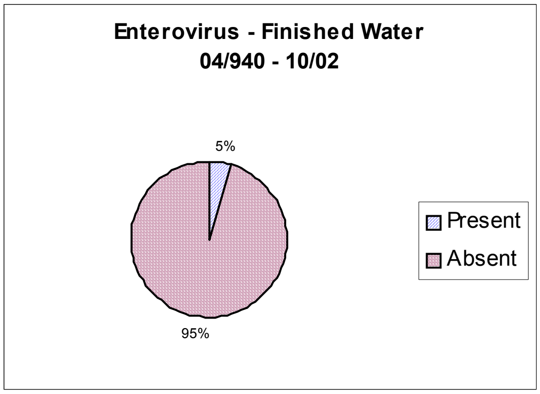


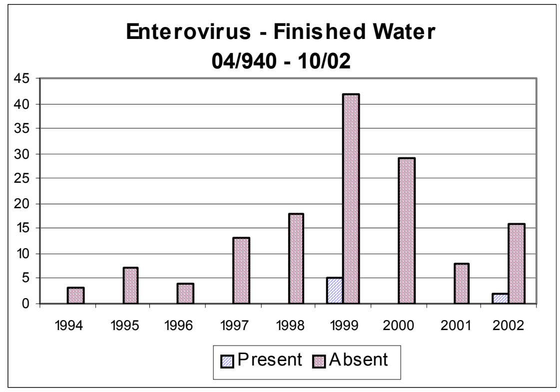


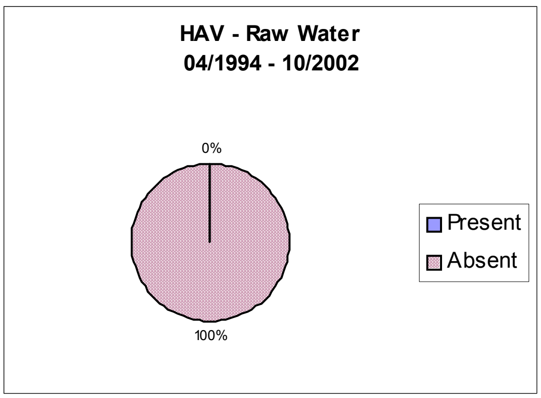


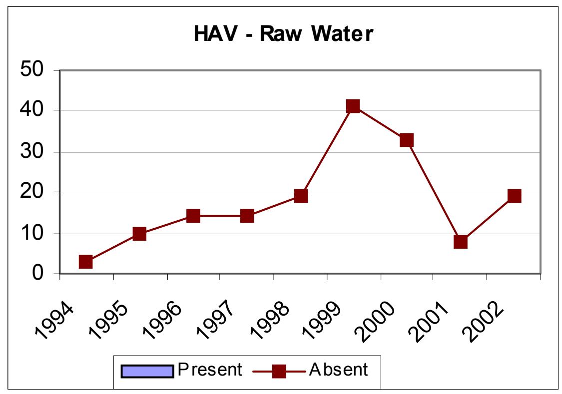


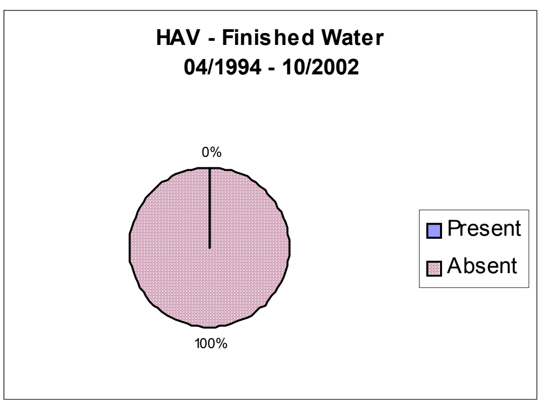


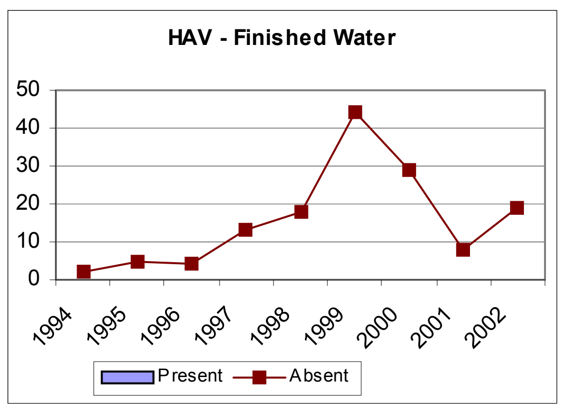

Enterovirus - Finished Water
04/940 - 10/02
5%
95%
Present
Absent

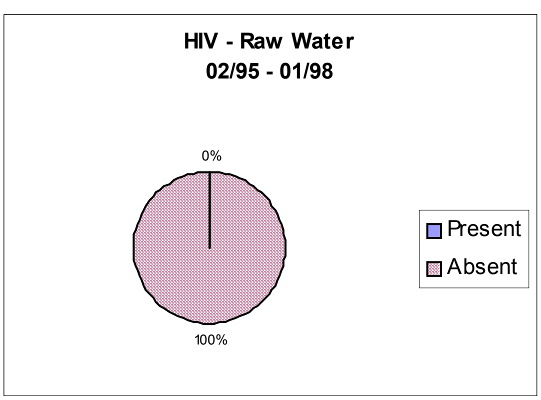

Enterovirus - Finished Water
04/940 - 10/02
45
40
35
30
25
20
15
10
5
0
1994
1995
1996
1997
1998
1999
2000
2001
2002
Present
Absent

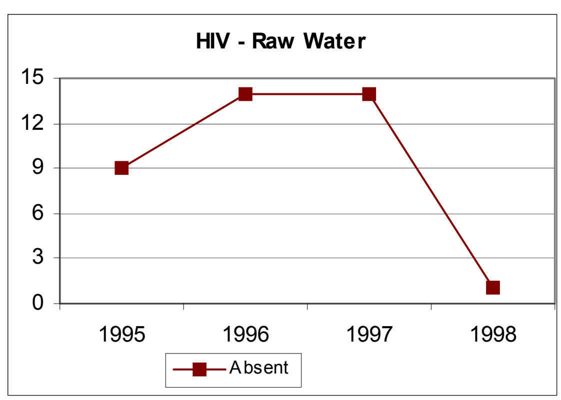

HAV - Raw Water
04/1994 - 10/2002
0%
100%
Present
Absent

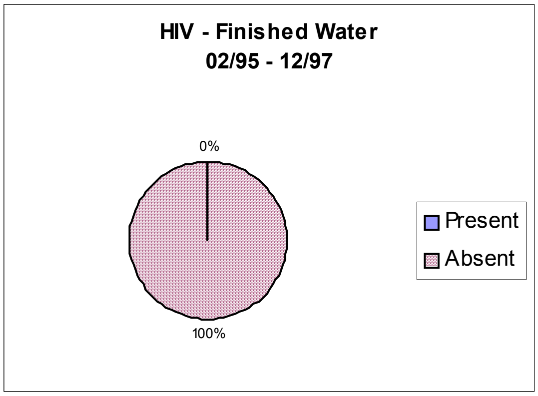

HAV - Raw Water
50
40
30
20
10
0
1994
1995
1996
1997
1998
1999
2000
2001
2002
Present
Absent

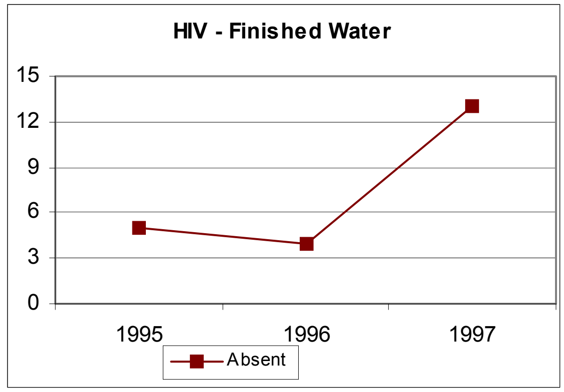

HAV - Finished Water
04/1994 - 10/2002
0%
100%
Present
Absent

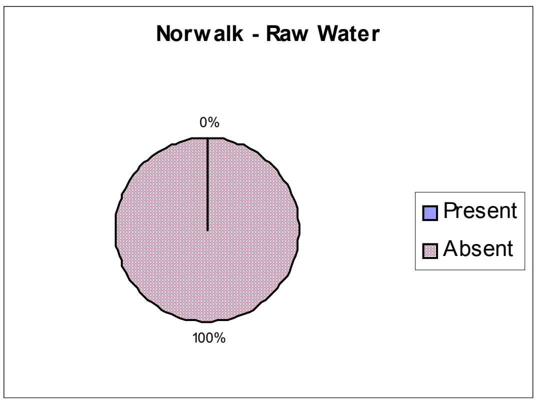

HAV - Finished Water
50
40
30
20
10
0
1994
1995
1996
1997
1998
1999
2000
2001
2002
Present
Absent

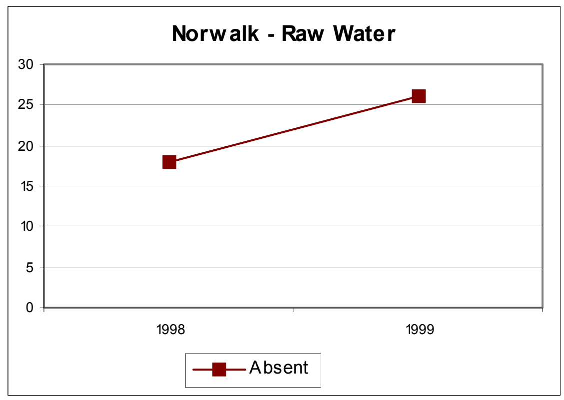

HIV - Raw Water
02/95 - 01/98
0%
100%
Present
Absent

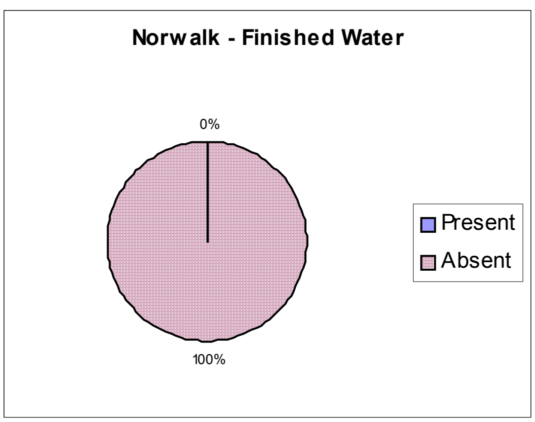

HIV - Raw Water
15
12
9
6
3
0
1995
1996
1997
1998
Absent

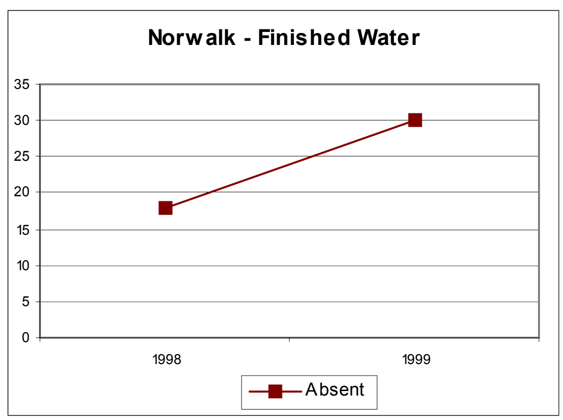

HIV - Finished Water
02/95 - 12/97
0%
100%
Present
Absent

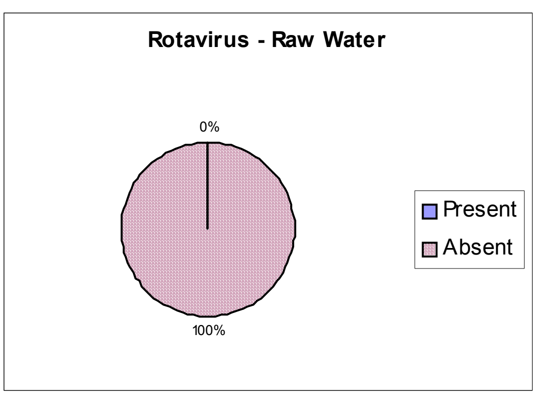

HIV - Finished Water
15
12
9
6
3
0
1995
1996
1997
Absent

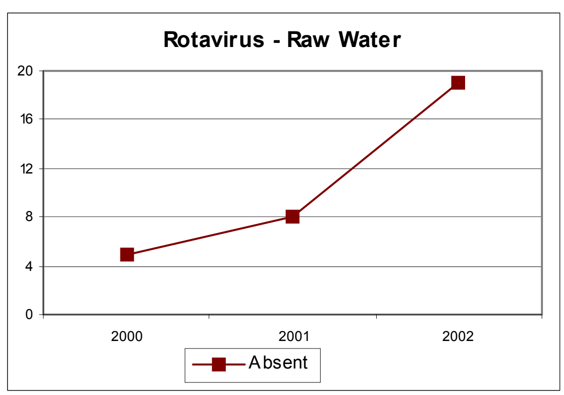

Norwalk - Raw Water
0%
100%
Present
Absent

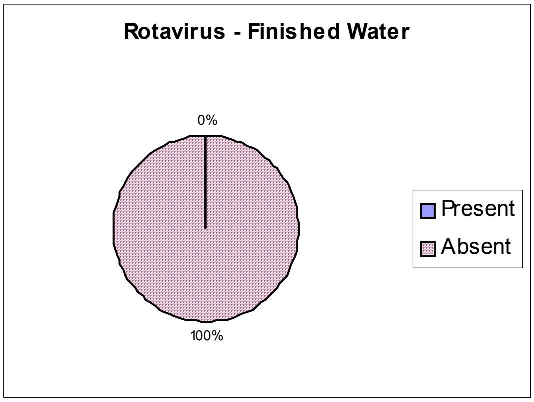

Norwalk - Raw Water
30
25
20
15
10
5
0
1998
1999
Absent

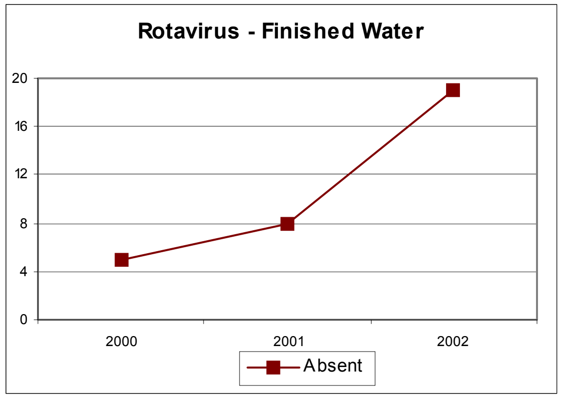

Norwalk - Finished Water
0%
100%
Present
Absent

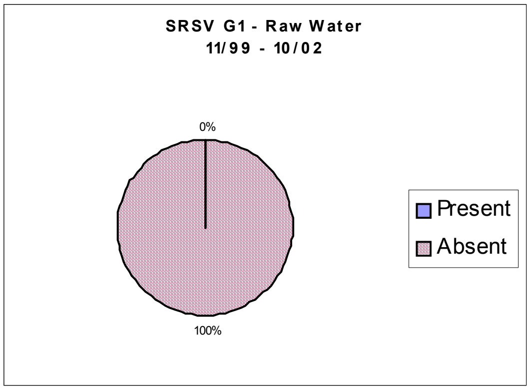

Norwalk - Finished Water
35
30
25
20
15
10
5
0
1998
1999
Absent

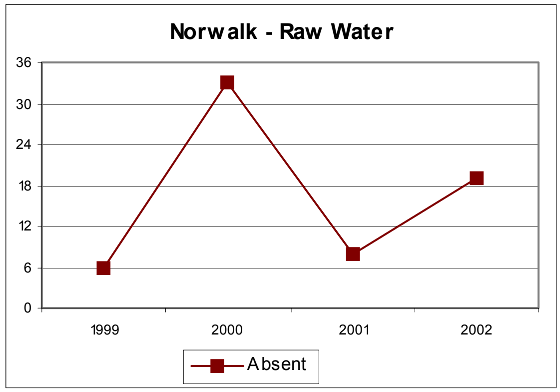

Rotavirus - Raw Water
0%
100%
Present
Absent

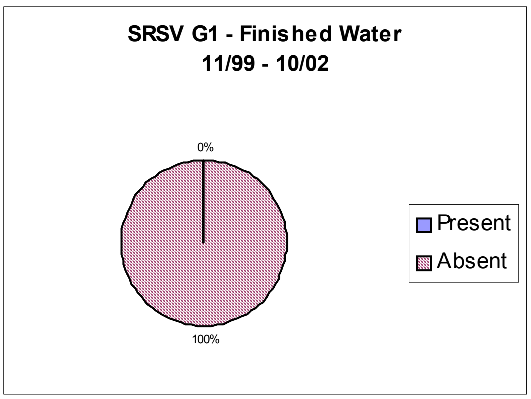

Rotavirus - Raw Water
20
16
12
8
4
0
2000
2001
2002
Absent

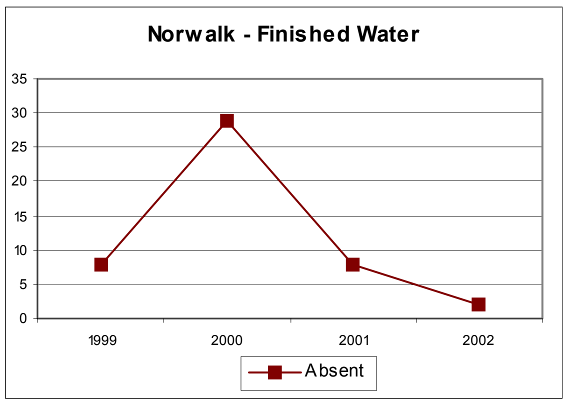

Rotavirus - Finished Water
0%
100%
Present
Absent

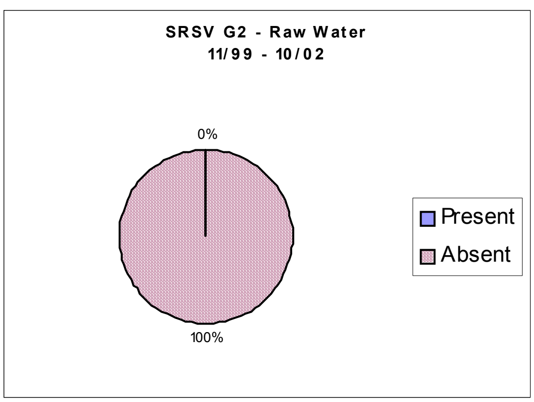

Rotavirus - Finished Water
20
16
12
8
4
0
2000
2001
2002
Absent

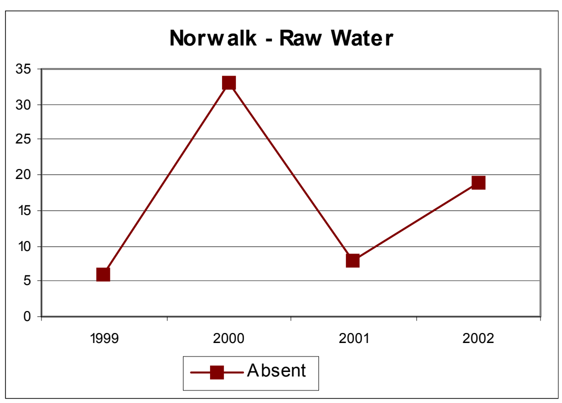

SRSV G1 - Raw Water
11/99 - 10/02
0%
100%
Present
Absent

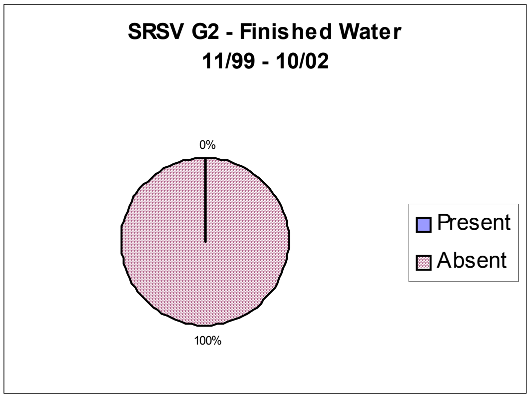

Norwalk - Raw Water
36
30
24
18
12
6
0
1999
2000
2001
2002
Absent

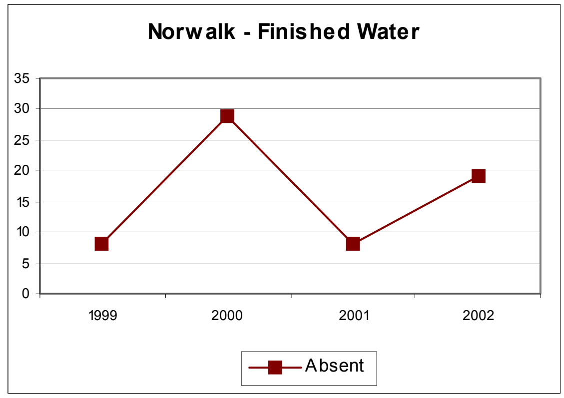

SRSV G1 - Finished Water
11/99 - 10/02
0%
100%
Present
Absent

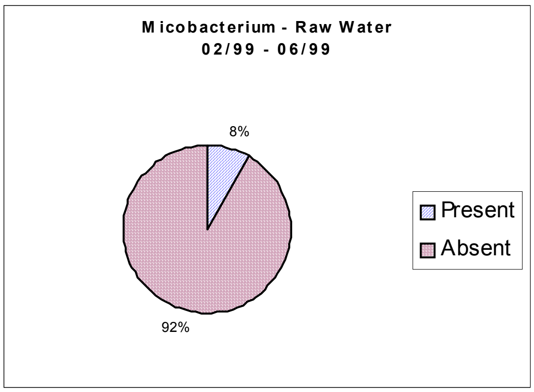

Norwalk - Finished Water
35
30
25
20
15
10
5
0
1999
2000
2001
2002
Absent

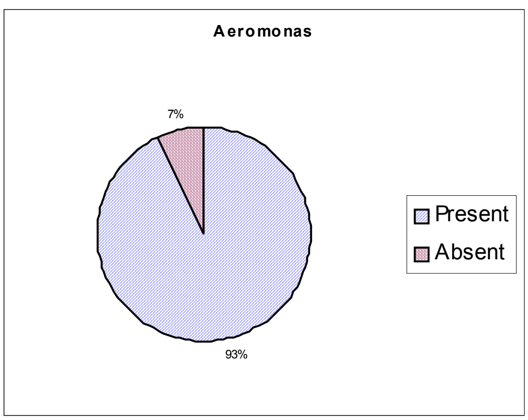

SRSV G2 - Raw Water
11/99 - 10/02
0%
100%
Present
Absent

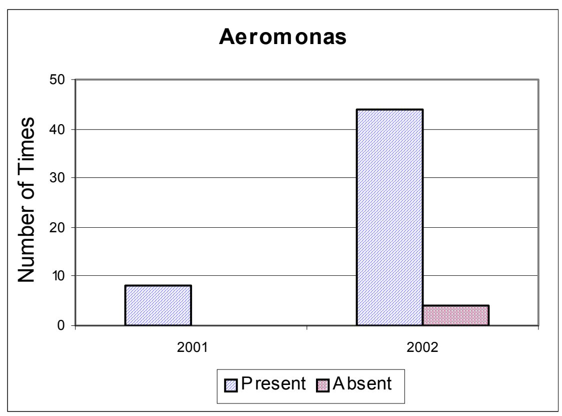

Norwalk - Raw Water
35
30
25
20
15
10
5
0
1999
2000
2001
2002
Absent

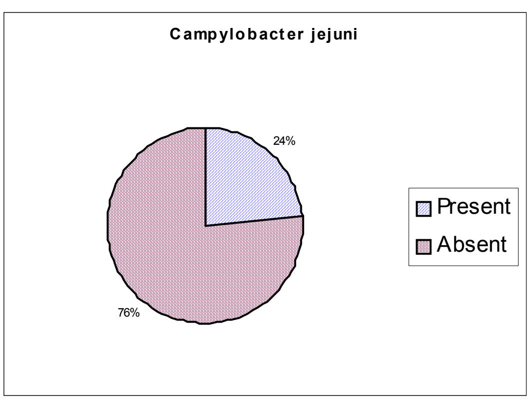

SRSV G2 - Finished Water
11/99 - 10/02
0%
100%
Present
Absent

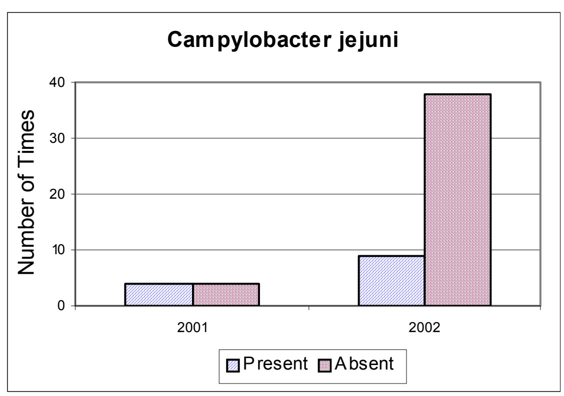

Norwalk - Finished Water
35
30
25
20
15
10
5
0
1999
2000
2001
2002
Absent

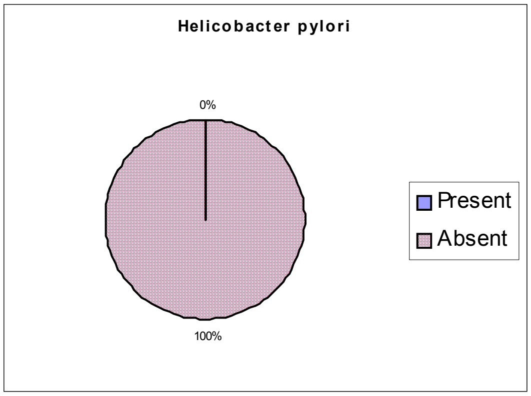

Micobacterium - Raw Water
02/99 - 06/99
8%
92%
Present
Absent

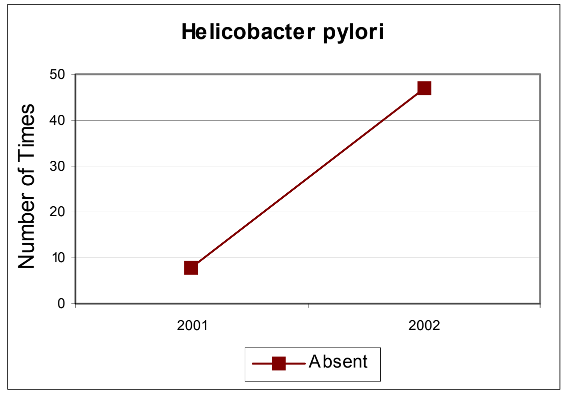

Aeromonas
7%
93%
Present
Absent

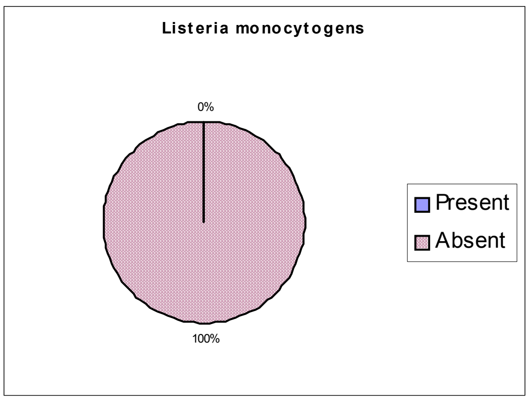

Aeromonas
Number of Times
50
40
30
20
10
0
2001
2002
Present
Absent

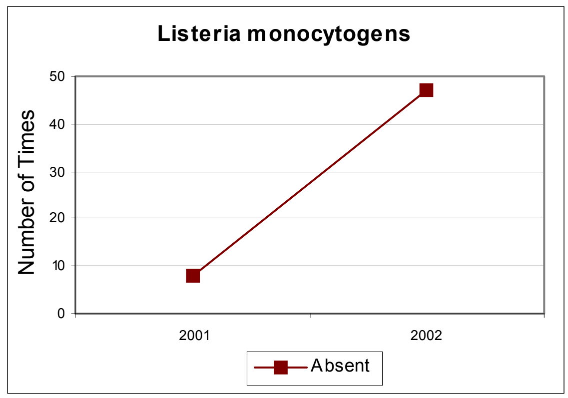

Campylobacter jejuni
24%
76%
Present
Absent

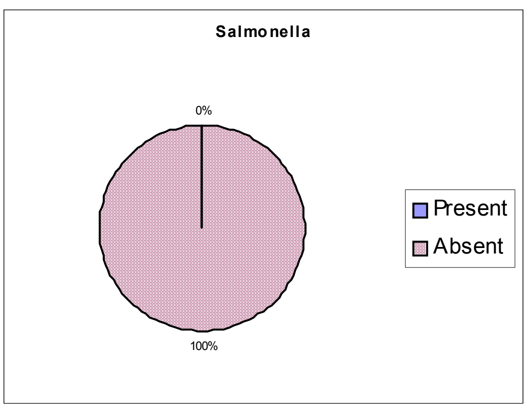

Campylobacter jejuni
Number of Times
40
30
20
10
0
2001
2002
Present
Absent

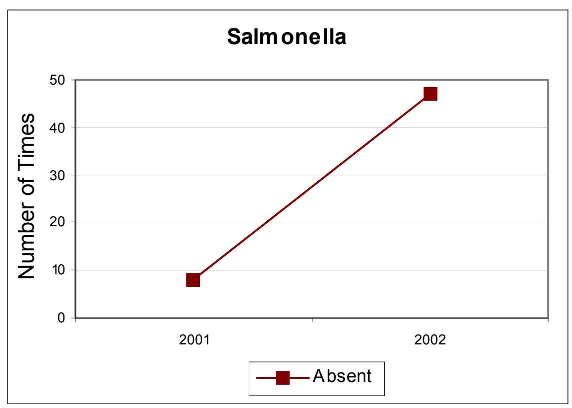

Helicobacter pylori
0%
100%
Present
Absent

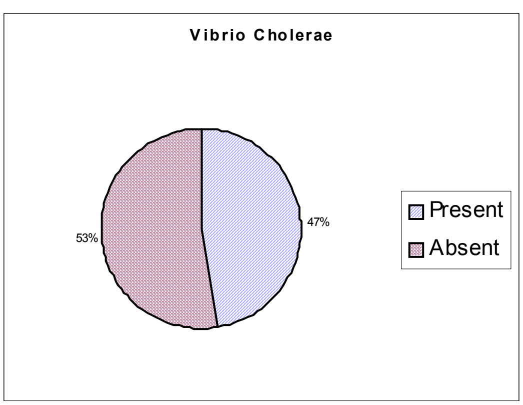

Helicobacter pylori
Number of Times
50
40
30
20
10
0
2001
2002
Absent

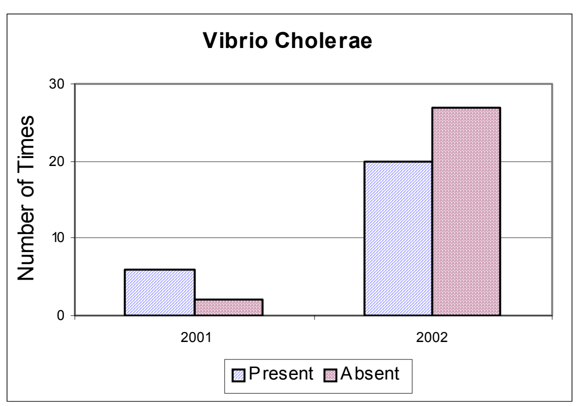

Listeria monocytogens
0%
100%
Present
Absent

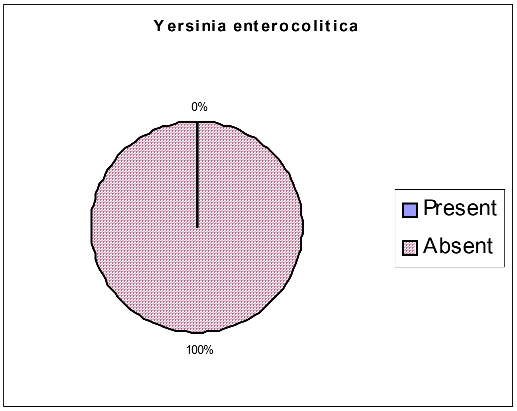

Listeria monocytogens
Number of Times
50
40
30
20
10
0
2001
2002
Absent

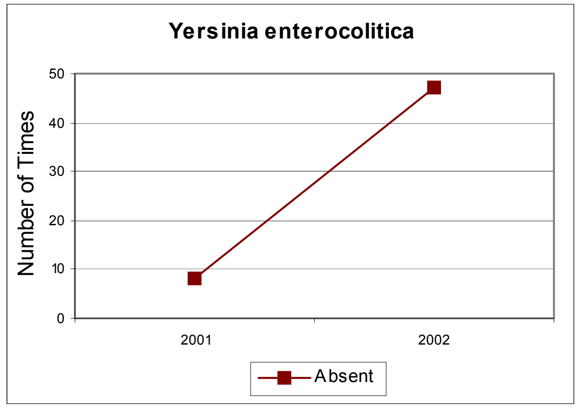

Salmonella
0%
100%
Present
Absent


Salmonella
Number of Times
50
40
30
20
10
0
2001
2002
Absent


Vibrio Cholerae
53%
47%
Present
Absent


Vibrio Cholerae
Number of Times
30
20
10
0
2001
2002
Present
Absent


Yersinia enterocolitica
0%
100%
Present
Absent


Yersinia enterocolitica
Number of Times
50
40
30
20
10
0
2001
2002
Absent

Appendix B: Drinking Water Standards

REGULATED SYNTHETIC ORGANIC CHEMICALS (SOCs) (40 CFR 141.61 (c))			
PHASE II			
		MCL (mg/l) parts per million	**MCL (ppb) parts per billion**
(1)	ALACHLOR	0.002	2
(2)	ALDICARB	0.003	3
(3)	ALDICARB SULFOXIDE	0.004	4
(4)	ALDICARB SULFONE	0.002	2
(5)	ATRAZINE	0.003	3
(6)	CARBOFURAN	0.04	40
(7)	CHLORDANE	0.002	2
(8)	DIBROMOCHLOROPROPANE	0.0002	0.2
(9)	2,4-D	0.07	70
(10)	ETHYLENE DIBROMIDE	0.00005	0.05
(11)	HEPTACHLOR	0.0004	0.4
(12)	HEPTACHLOR EPOXIDE	0.0002	0.2
(13)	LINDANE	0.0002	0.2
(14)	METHOXYCHLOR	0.04	40
(15)	POLYCHLORINATED BIPHENYLS	0.0005	0.5
(16)	PENTACHLOROPHENOL	0.001	1
(17)	TOXAPHENE	0.003	3
(18)	2,4,5-TP	0.05	50
PHASE V			
(1)	BENZO(a)PYRENE	0.0002	0.2
(2)	DALAPON	0.2	200
(3)	DI(2-ETHYLHEXYL)ADIPATE	0.4	400
(4)	DI(2-ETHYLHEXYL)PHTHALATE	0.006	6
(5)	DINOSEB	0.007	7
(6)	DIQUAT	0.02	20
(7)	ENDOTHALL	0.1	100
(8)	ENDRIN	0.002	2
(9)	GLYPHOSATE	0.7	700
(10)	HEXACHLOROBENZENE	0.001	1
(11)	HEXACHLOROCYCLOPENTADIENE	0.05	50
(12)	OXYMAL (VYDATE)	0.2	200
(13)	PICLORAM	0.5	500
(14)	SIMAZINE	0.004	4
(15)	2,3,7,8-TCDD (DIOXIN)	3 x $10^{\wedge -8}$	

<u>UNREGULATED</u> SYNTHETIC ORGANIC CHEMICALS (SOC) (40 CFR 141.40(n))	
(1)	ALDRIN
(2)	BUTACHLOR
(3)	CARBARYL
(4)	DICAMBA
(5)	DIELDRIN
(6)	3-HYDROXYCARBOFURAN
(7)	METHOMYL
(8)	METOLACHLOR
(9)	METRIBUZIN
(10)	PROPACHLOR

REGULATED VOLATILE ORGANIC CHEMICALS (VOCs) (40 CFR 141.61 (a))			
PHASE I AND II			
		MCL (mg/l) parts per million	**MCL (ppb) parts per billion**
(1)	VINYL CHLORIDE	0.002	2
(2)	BENZENE	0.005	5
(3)	CARBON TETRACHLORIDE	0.005	5
(4)	1,2-DICHLOROETHANE	0.005	5
(5)	TRICHLOROETHYLENE (TCE)	0.005	5
(6)	PARA-DICHLOROBENZENE	0.075	75
(7)	1,1-DICHLOROETHYLENE	0.007	7
(8)	1,1,1-TRICHLOROETHANE	0.2	200
(9)	CIS-1,2-DICHLOROETHYLENE	0.07	70
(10)	1,2-DICHLOROPROPANE	0.005	5
(11)	ETHYLBENZENE	0.7	700
(12)	MONOCHLOROBENZENE	0.1	100
(13)	o-DICHLOROBENZENE	0.6	600
(14)	STYRENE	0.1	100
(15)	TETRACHLOROETHYLENE (PCE)	0.005	5
(16)	TOLUENE	1	1,000
(17)	TRANS-1,2-DICHLOROETHYLENE	0.1	100
(18)	XYLENES (TOTAL)	10	10,000
PHASE V			
(1)	DICHLOROMETHANE	0.005	5
(2)	1,2,4-TRICHLOROBENZENE	0.07	70
(3)	1,1,2-TRICHLOROETHANE	0.005	5

<u>UNREGULATED</u> VOLATILE ORGANIC CHEMICALS (VOC) (40 CFR 141.40 (e))	
(1)	CHLOROFORM
(2)	BROMODICHLOROMETHANE
(3)	CLORODIBROMOMETHANE
(4)	BROMOFORM
(5)	DIBROMOMETHANE
(6)	m-DICHLOROBENZENE
(7)	1,1-DICHLOROPROPENE
(8)	1,1-DICHLOROETHANE
(9)	1,1,2,2-TETRACHLOROETHANE
(10)	1,3-DICHLOROPROPANE
(11)	CHLOROMETHANE
(12)	BROMOMETHANE
(13)	1,2,3-TRICHLOROPROPANE
(14)	1,1,1,2-TETRACHLOROETHANE
(15)	CHLOROETHANE
(16)	2,2-DICHLOROPROPANE
(17)	o-CHLOROTOLUENE
(18)	p-CHLOROTOLUENE
(19)	BROMOBENZENE
(20)	1,3-DICHLOROPROPENE

DISCRETIONARY MONITORING STATE REQUIRED VOLATILE ORGANIC CHEMICALS (VOC) (40 CFR 141.40 (j))	
(1)	1,2,4-TRIMETHYLBENZENE
(2)	1,2,3-TRICHLOROBENZENE
(3)	n-PROPYLBENZENE
(4)	n-BUTYLBENZENE
(5)	NAPHTHALENE
(6)	HEXACHLOROBUTADIENE
(7)	1,3,5-TRIMETHYLBENZENE
(8)	p-ISOPROPYLTOLUENE
(9)	ISOPROPYLBENZENE
(10)	TERT-BUTYLBENZENE
(11)	SEC-BUTYLBENZENE
(12)	FLUOROTRICHLOROMETHANE
(13)	DICHLORODIFLUOROMETHANE
(14)	BROMOCHLOROMETHANE

REGULATED INORGANIC CHEMICALS (IOCs) (40 CFR 141.62 (b))			
PHASE II			
		MCL (mg/l) parts per million	**MCL (ppb) parts per billion**
(1)	FLUORIDE	4.0	
(2)	BARIUM	2	
(3)	CADMIUM	0.005	5
(4)	CHROMIUM	0.1	100
(5)	MERCURY	0.002	2
(6)	SELENIUM	0.05	50
(7)	NITRATE	10 as (N)	
(8)	NITRITE	1 as (N)	
(9)	TOTAL NITRATE + NITRITE	10 as (N)	
(10)	ASBESTOS	7 MILLION FIBERS/L LONGER THAN 10um	
PHASE V			
(1)	ANTIMONY	0.006	6
(2)	BERYLLIUM	0.004	4
(3)	CYANIDE	0.2	200
(4)	NICKEL	0.1	100
(5)	THALLIUM	0.002	2
(40 CFR 141.11 (a))			
(6)	ARSENIC	0.05	50

SECONDARY DRINKING WATER STANDARDS NAC 445A.455		
(1)	CHLORIDE	400.0
(2)	COLOR	15.0
(3)	COPPER	1.0
(4)	FOAMING AGENTS (MBAS)	0.5
(5)	IRON	0.6
(6)	MAGNESIUM	150.0
(7)	MANGANESE	0.1
(8)	ODOR	3.0
(9)	pH	6.5 – 8.5
(10)	SULFATE	500.0
(11)	TOTAL DISSOLVED SOLIDS (TDS)	1000.00
(12)	ZINC	5.0
(13)	FLUORIDE	2.0

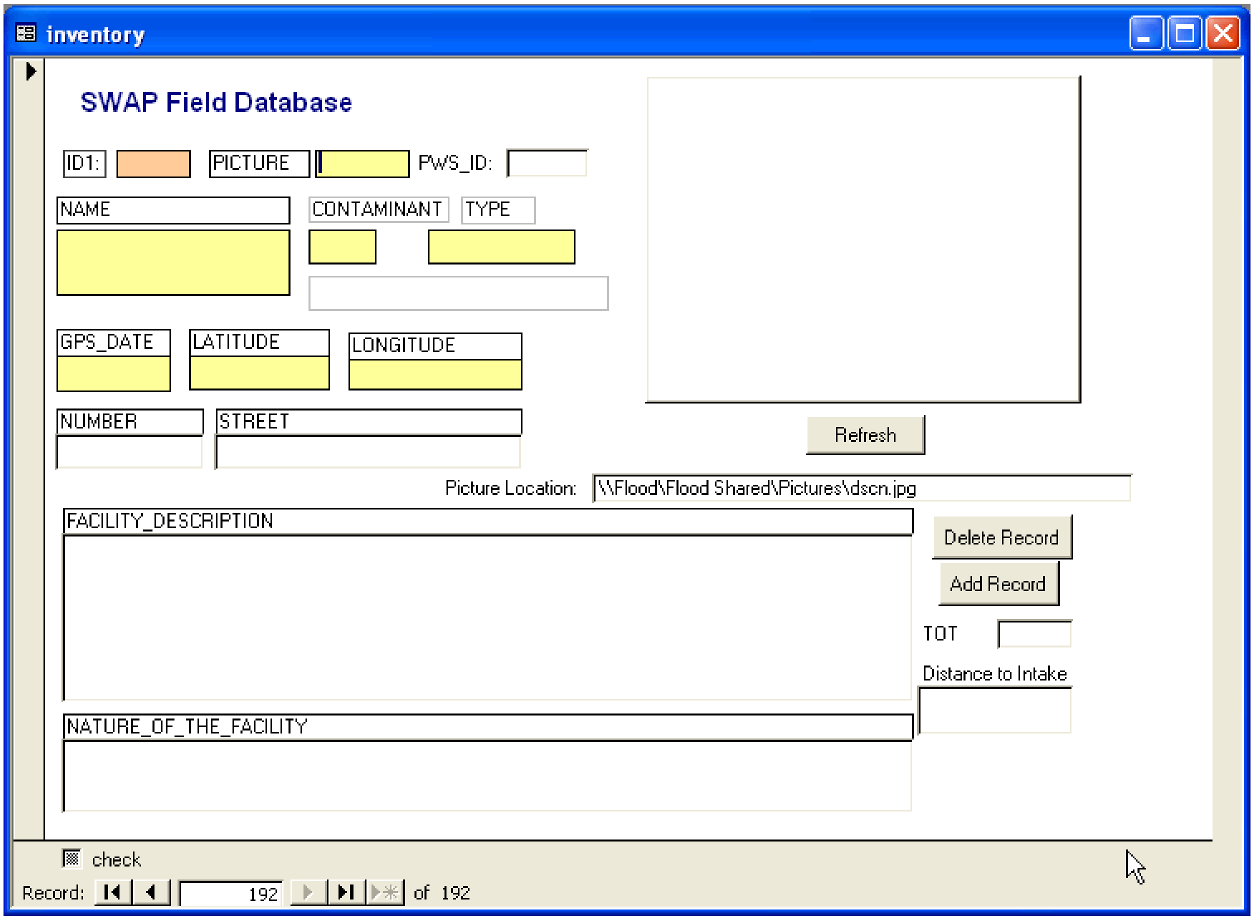
SPECIAL MONITORING FOR SODIUM 40 CFR 141.41	
ANNUALLY FOR SURFACE WATER SOURCES	EVERY 3 YEARS FOR GROUND WATER SOURCES

RADIONUCLIDES 40 CFR 141.15 AND 141.16	
	MCL (pCi/L) picocuries / liter
Combined Radium-226 and 228 Annual average Gross Alpha particle activity	5 15
Annual average Beta and photon particle radioactivity (Applicable only to community surface public water systems serving greater than 100,000 persons)	Annual dose equivalent to the human body or any internal organ may not exceed 4 millirems/year

TURBIDITY 40 CFR 141.13	
	MCL
Community or non-community public water systems using surface water in whole or in part.	One (1) turbidity unit determined by a monthly average unless the State allows five (5) or fewer turbidity units.

TOTAL TRIHALOMETHANES 40 CFR 141.12	
	MCL (ppm) parts per million
Public water systems serving 10,000 or more persons and adding disinfectant	0.10

Appendix C: Typical Field Data Sheet



Appendix D: Physical Barrier Effectiveness (PBE) Form

Physical Barrier Effectiveness (PBE)

(from CDHS, 2002)

1. Is the source an impounded reservoir or a direct stream intake?
   a. Reservoir
   b. Stream intake
   c. Other, describe:

2. Source Characteristics
   a. Area of tributary watershed: 1520 mi^2
   b. Are the primary tributaries seasonal, perennial or both? perennial

3. What is the approximate travel time to the intake for water at farthest reaches of the water body?
   a. Source is direct intake, no impounded water body
   b. Less than 30 days
   c. More than 30 days and less than 1 year
   d. More than 1 year

4. What is the general topography of the watershed?
   a. Flat terrain (<10% slopes)
   b. Hilly (10 to 30% slopes)
   c. Mountainous (> 30% slopes)
   d. Not sure

5. What is the general geology of the watershed?
   a. Materials prone to landslides
   b. Materials not prone to landslides
   c. Not sure

6. What general soil types are on the watershed?
   a. Rock
   b. Loams, sands
   c. Clay
   d. Not sure

7. What type of vegetation covers most of the watershed?
   a. Grasses
   b. Low growing plants and shrubs
   c. Trees
   d. Not sure

8. What is the mean seasonal precipitation on the watershed?
   a. More than 40 inches/year
   b. 10 to 40 inches/year
   c. Less than 10 inches/year

    d. Not sure

9. Is there significant ground water recharge to the water body?
    a. <u>Yes</u>
    b. No
    c. Not sure

Physical Barrier Effectiveness Determination

Parameters indicating <u>Low Physical Barrier Effectiveness (LE)</u>

(A source with any of the parameters listed below would be considered to have less effective physical barrier properties)

3a

4c or 4d

5a or 5c

7c or 7d

8a or 8d

<u>9a</u>

Parameters indicating <u>High Physical Barrier Effectiveness (HE)</u>

(A source would need to have all of the parameters listed below to be considered to have highly effective physical barrier properties)

3d and

4a and

5b and

7a and

8c and

9b

All other sources are considered to have Moderate Physical Barrier Effectiveness

Determination for this source:

Low (LE) due to item 9a (significant ground water recharge to water body)

Appendix E: Vulnerability Rankings for the PCAs in each Contaminant Category

Volatile Organic Compounds (VOCs) Vulneability Assessment

ID	TYPE	DISTANCE TO THE INTAKE (mi)	RISK POTENTIAL H=5 M=3 L=1	PBE L=5 M=3 H=1	TOT (hr) 0-6=9 6-12=7 12-18=5 18-24=3 >24=1	WATER QUALITY H=5 L=0	VULNERABILITY SCORE
1	Dry Cleaning	25.77	5	5	3	0	13
2	Public Storage	25.69	1	5	3	0	9
4	Dry Cleaning	25.85	5	5	3	0	13
5	Gas Stations	25.38	5	5	3	0	13
9	Auto Repair Shops	24.90	5	5	3	0	13
24	Dry Cleaning	22.66	5	5	3	0	13
25	Gas Stations	22.69	5	5	3	0	13
26	Dry Cleaning	22.85	5	5	3	0	13
27	Gas Stations	22.81	5	5	3	0	13
49	Auto Repair Shops	20.66	5	5	5	0	15
50	Gas Stations	20.72	5	5	5	0	15
51	Car Washes	20.70	3	5	5	0	13
54	Public Storage	19.78	1	5	7	0	13
59	Car Washes	20.56	3	5	7	0	15
60	Gas Stations	20.52	5	5	7	0	17
61	Car Washes	20.52	3	5	7	0	15
63	Car Washes	20.49	3	5	7	0	15
65	Public Storage	20.49	1	5	7	0	13
66	Auto Repair Shops	21.52	5	5	5	0	15
68	Public Storage	21.10	1	5	5	0	11
70	Research Laboratories	25.59	5	5	3	0	13
75	Auto Repair Shops	26.56	5	5	3	0	13
86	Auto Repair Shops	29.66	5	5	1	0	11
89	Auto Repair Shops	29.08	5	5	1	0	11
90	Auto Repair Shops	29.08	5	5	1	0	11
92	Machine & Metalworking	28.94	5	5	3	0	13
93	Auto Repair Shops	28.93	5	5	1	0	11
94	Machine & Metalworking	28.92	5	5	1	0	11
95	Auto Repair Shops	28.88	5	5	1	0	11
96	Auto Repair Shops	28.88	5	5	1	0	11
98	Auto Repair Shops	28.80	5	5	1	0	11
99	Auto Repair Shops	28.78	5	5	1	0	11
100	Auto Repair Shops	29.12	5	5	1	0	11
101	Auto Repair Shops	29.21	5	5	1	0	11
102	Auto Repair Shops	29.21	5	5	1	0	11
103	Auto Repair Shops	29.21	5	5	1	0	11
104	Auto Repair Shops	29.21	5	5	1	0	11
107	Auto Repair Shops	29.28	5	5	1	0	11
108	Auto Repair Shops	29.10	5	5	1	0	11
109	Auto Repair Shops	29.11	5	5	1	0	11
111	Auto Repair Shops	28.55	5	5	1	0	11
112	Auto Repair Shops	28.51	5	5	1	0	11
114	Auto Repair Shops	28.46	5	5	1	0	11

Volatile Organic Compounds (VOCs) Vulneability Assessment

ID	TYPE	DISTANCE TO THE INTAKE (mi)	RISK POTENTIAL H=5 M=3 L=1	PBE L=5 M=3 H=1	TOT (hr) 0-6=9 6-12=7 12-18=5 18-24=3 >24=1	WATER QUALITY H=5 L=0	VULNERABILITY SCORE
115	Public Storage	28.38	1	5	1	0	7
116	Auto Repair Shops	28.27	5	5	1	0	11
117	Auto Repair Shops	28.23	5	5	1	0	11
118	Chem. Manuf/warehousing/distribution	28.21	5	5	1	0	11
120	Auto Repair Shops	27.88	5	5	1	0	11
121	Auto Repair Shops	27.85	5	5	1	0	11
122	Car Washes	27.82	3	5	1	0	9
123	Auto Repair Shops	27.70	5	5	1	0	11
124	Chem. Manuf/warehousing/distr.	27.08	5	5	1	0	11
127	Auto Repair Shops	26.88	5	5	1	0	11
130	Gas Stations	27.05	5	5	1	0	11
131	Furniture, wood stripper, refinishers	26.89	5	5	1	0	11
132	Auto Repair Shops	27.54	5	5	1	0	11
133	Construction areas	27.86	3	5	1	0	9
135	Auto Repair Shops	26.61	5	5	1	0	11
136	Auto Repair Shops	26.69	5	5	1	0	11
142	Chem. Manuf/warehousing/distr.	27.34	5	5	1	0	11
143	Auto Repair Shops	27.38	5	5	1	0	11
144	Research Laboratories	27.60	5	5	1	0	11
149	Gas Stations	24.24	5	5	1	0	11
151	Dry Cleaning	24.37	5	5	1	0	11
160	Dry Cleaning	19.72	5	5	7	0	17
163	Gas Stations	18.58	5	5	5	0	15
164	Car Washes	18.74	3	5	5	0	13
165	Gas Stations	18.67	5	5	5	0	15
167	Car Washes	18.55	3	5	5	0	13
170	Dry Cleaning	19.98	5	5	5	0	15
173	Public Storage	20.03	1	5	5	0	11
175	Car Washes	20.03	3	5	5	0	13
180	Gas Stations	18.50	5	5	9	0	19
186	Construction areas	18.06	3	5	9	0	17
190	Gas Stations	31.44	5	5	1	0	11
191	Car Washes	31.44	3	5	1	0	9
192	Dry Cleaning	31.44	5	5	1	0	11
193	Auto Repair Shops	31.44	5	5	1	0	11
194	Gas Stations	28.24	5	5	1	0	11
200	Gas Stations	20.99	5	5	7	0	17
201	Construction areas	21.00	3	5	7	0	15
209	Public Storage	21.61	1	5	7	0	13
210	Car Washes	22.54	3	5	5	0	13
212	Dry Cleaning	22.56	5	5	5	0	15
213	Gas Stations	22.61	5	5	5	0	15
214	Auto Repair Shops	22.60	5	5	5	0	15

Volatile Organic Compounds (VOCs) Vulneability Assessment

ID	TYPE	DISTANCE TO THE INTAKE (mi)	RISK POTENTIAL H=5 M=3 L=1	PBE L=5 M=3 H=1	TOT (hr) 0-6=9 6-12=7 12-18=5 18-24=3 >24=1	WATER QUALITY H=5 L=0	VULNERABILITY SCORE
216	Gas Stations	23.81	5	5	3	0	13
237	Auto Repair Shops	16.93	5	5	9	0	19
238	Auto Repair Shops	16.84	5	5	9	0	19
240	Construction areas	17.39	3	5	9	0	17
243	Construction areas	16.97	3	5	7	0	15
246	Construction areas	16.27	3	5	9	0	17
250	Gas Stations	30.41	5	5	1	0	11
272	Research Laboratories	28.94	5	5	1	0	11
289	Public Storage	27.86	1	5	3	0	9
294	Dry Cleaning	28.69	5	5	3	0	13
297	Public Storage	28.43	1	5	3	0	9
298	Auto Repair Shops	28.45	5	5	3	0	13
299	Auto Repair Shops	28.48	5	5	3	0	13
300	Public Storage	28.39	1	5	3	0	9
305	Gas Stations	27.96	5	5	3	0	13
309	Gas Stations	25.82	5	5	3	0	13
316	Stormwater drains & retention basins	10.60	5	5	9	0	19
405	Auto Repair Shops	27.57	5	5	1	0	11
450	Stormwater drains & retention basins	15.84	5	5	9	0	19
451	Stormwater drains & retention basins	15.19	5	5	9	0	19
452	Stormwater drains & retention basins	14.73	5	5	9	0	19
454	Stormwater drains & retention basins	13.11	5	5	9	0	19
455	Stormwater drains & retention basins	18.30	5	5	9	0	19
456	Stormwater drains & retention basins	18.83	5	5	9	0	19
457	Stormwater drains & retention basins	14.50	5	5	9	0	19
504	Boat yards / marinas	8.39	5	5	9	0	19
505	Gas Stations	8.31	5	5	9	0	19
507	Boat yards / marinas	2.80	5	5	9	0	19
508	Boat yards / marinas	1.11	5	5	9	0	19
509	Boat yards / marinas	0.94	5	5	9	0	19
511	Boat yards / marinas	6.16	5	5	9	0	19
1005	Groundwater Remediati	30.12	5	5	1	0	11
1006	Groundwater Remediati	25.41	5	5	1	0	11
1007	Groundwater Remediati	24.25	5	5	1	0	11
1008	Groundwater Remediati	28.63	5	5	1	0	11
						AVERAGE	**13**
						MAX	**19**
						MIN	**7**

Synthetic Organic Compounds (SOCs) Vulnerability Assessment

ID	TYPE	DISTANCE TO THE INTAKE (mi)	RISK POTENTIAL H=5 M=3 L=1	PBE L=5 M=3 H=1	TOT (hr) 0-6=9 6-12=7 12-18=5 18-24=3 >24=1	WATER QUALIT Y H=5 L=0	VULNERABILITY SCORE
10	Golf Courses, parks & nurseries	24.25	5	5	3	0	13
55	Golf Courses, parks & nurseries	19.18	5	5	7	0	17
70	Research Laboratories	25.59	5	5	3	0	13
81	Golf Courses, parks & nurseries	26.36	5	5	3	0	13
118	Chem. Manuf/warehousing/distribution	28.21	5	5	1	0	11
124	Chem. Manuf/warehousing/distr.	27.08	5	5	1	0	11
142	Chem. Manuf/warehousing/distr.	27.34	5	5	1	0	11
144	Research Laboratories	27.60	5	5	1	0	11
182	Golf Courses, parks & nurseries	17.80	5	5	9	0	19
183	Golf Courses, parks & nurseries	18.00	5	5	9	0	19
196	Golf Courses, parks & nurseries	14.81	5	5	9	0	19
222	Golf Courses, parks & nurseries	19.28	5	5	7	0	17
248	Golf Courses, parks & nurseries	16.39	5	5	9	0	19
272	Research Laboratories	28.94	5	5	1	0	11
296	Educational Institutions	28.83	3	5	3	0	11
316	Stormwater drains & retention basins	10.60	5	5	9	0	19
366	Educational Institutions	22.32	3	5	7	0	15
367	Educational Institutions	21.85	3	5	7	0	15
371	Educational Institutions	23.47	3	5	3	0	11
440	Golf Courses, parks & nurseries	12.06	5	5	9	0	19
449	Golf Courses, parks & nurseries	9.30	5	5	9	0	19
450	Stormwater drains & retention basins	15.84	5	5	9	0	19
451	Stormwater drains & retention basins	15.19	5	5	9	0	19
452	Stormwater drains & retention basins	14.73	5	5	9	0	19
454	Stormwater drains & retention basins	13.11	5	5	9	0	19
455	Stormwater drains & retention basins	18.30	5	5	9	0	19
456	Stormwater drains & retention basins	18.83	5	5	9	0	19
457	Stormwater drains & retention basins	14.50	5	5	9	0	19
506	Sewer transfer stations	8.20	5	5	9	0	19
1001	Municipal Wastewater	17.56	5	5	9	0	19
1002	Municipal Wastewater	16.00	5	5	9	0	19
1003	Municipal Wastewater	13.20	5	5	9	0	19
1005	Groundwater Remediati	30.12	5	5	1	0	11
1006	Groundwater Remediati	25.41	5	5	1	0	11
1007	Groundwater Remediati	24.25	5	5	1	0	11
1008	Groundwater Remediati	28.63	5	5	1	0	11
2000	Septic systems, cesspools	20.68	5	5	5	0	15
2005	Septic systems, cesspools	15.50	5	5	9	0	19
2012	Septic systems, cesspools	27.26	5	5	1	0	11
2013	Septic systems, cesspools	21.53	5	5	7	0	17
2022	Septic systems, cesspools	18.81	5	5	5	0	15
2039	Septic systems, cesspools	27.08	5	5	1	0	11

Synthetic Organic Compounds (SOCs) Vulnerability Assessment

ID	TYPE	DISTANCE TO THE INTAKE (mi)	RISK POTENTIAL H=5 M=3 L=1	PBE L=5 M=3 H=1	TOT (hr) 0-6=9 6-12=7 12-18=5 18-24=3 >24=1	WATER QUALIT Y H=5 L=0	VULNERABILITY SCORE
2040	Septic systems, cesspools	20.77	5	5	5	0	15
2042	Septic systems, cesspools	18.81	5	5	5	0	15
2043	Septic systems, cesspools	18.81	5	5	5	0	15
2046	Septic systems, cesspools	18.88	5	5	5	0	15
2046	Septic systems, cesspools	28.48	5	5	1	0	11
2051	Septic systems, cesspools	28.63	5	5	1	0	11
2055	Septic systems, cesspools	18.81	5	5	5	0	15
2056	Septic systems, cesspools	18.88	5	5	5	0	15
2070	Septic systems, cesspools	18.88	5	5	5	0	15
2071	Septic systems, cesspools	18.88	5	5	5	0	15
2084	Septic systems, cesspools	18.81	5	5	5	0	15
2085	Septic systems, cesspools	18.81	5	5	5	0	15
2086	Septic systems, cesspools	18.81	5	5	5	0	15
2087	Septic systems, cesspools	18.88	5	5	5	0	15
2088	Septic systems, cesspools	18.88	5	5	5	0	15
2091	Septic systems, cesspools	18.88	5	5	5	0	15
2095	Septic systems, cesspools	18.88	5	5	5	0	15
2096	Septic systems, cesspools	18.88	5	5	5	0	15
2112	Septic systems, cesspools	26.92	5	5	1	0	11
2121	Septic systems, cesspools	18.88	5	5	5	0	15
2123	Septic systems, cesspools	18.81	5	5	5	0	15
2125	Septic systems, cesspools	18.88	5	5	5	0	15
2132	Septic systems, cesspools	19.05	5	5	5	0	15
2134	Septic systems, cesspools	21.51	5	5	5	0	15
2139	Septic systems, cesspools	19.10	5	5	5	0	15
2145	Septic systems, cesspools	19.16	5	5	5	0	15
2147	Septic systems, cesspools	27.01	5	5	1	0	11
2149	Septic systems, cesspools	19.16	5	5	5	0	15
2162	Septic systems, cesspools	19.27	5	5	5	0	15
2162	Septic systems, cesspools	21.41	5	5	5	0	15
2164	Septic systems, cesspools	20.61	5	5	5	0	15
2164	Septic systems, cesspools	21.41	5	5	5	0	15
2165	Septic systems, cesspools	20.61	5	5	5	0	15
2166	Septic systems, cesspools	20.56	5	5	5	0	15
2168	Septic systems, cesspools	21.47	5	5	5	0	15
2169	Septic systems, cesspools	19.40	5	5	5	0	15
2170	Septic systems, cesspools	19.34	5	5	5	0	15
2170	Septic systems, cesspools	21.47	5	5	5	0	15
2171	Septic systems, cesspools	19.27	5	5	5	0	15
2171	Septic systems, cesspools	21.47	5	5	5	0	15
2172	Septic systems, cesspools	19.27	5	5	5	0	15
2172	Septic systems, cesspools	21.33	5	5	5	0	15

Synthetic Organic Compounds (SOCs) Vulnerability Assessment

ID	TYPE	DISTANCE TO THE INTAKE (mi)	RISK POTENTIAL H=5 M=3 L=1	PBE L=5 M=3 H=1	TOT (hr) 0-6=9 6-12=7 12-18=5 18-24=3 >24=1	WATER QUALIT Y H=5 L=0	VULNERABILITY SCORE
2173	Septic systems, cesspools	19.27	5	5	5	0	15
2173	Septic systems, cesspools	21.51	5	5	5	0	15
2175	Septic systems, cesspools	19.40	5	5	5	0	15
2175	Septic systems, cesspools	21.51	5	5	5	0	15
2176	Septic systems, cesspools	19.40	5	5	5	0	15
2177	Septic systems, cesspools	19.34	5	5	5	0	15
2178	Septic systems, cesspools	19.27	5	5	5	0	15
2179	Septic systems, cesspools	19.40	5	5	5	0	15
2180	Septic systems, cesspools	19.40	5	5	5	0	15
2181	Septic systems, cesspools	19.34	5	5	5	0	15
2181	Septic systems, cesspools	21.51	5	5	5	0	15
2193	Septic systems, cesspools	21.41	5	5	5	0	15
2194	Septic systems, cesspools	21.41	5	5	5	0	15
2200	Septic systems, cesspools	21.51	5	5	5	0	15
2201	Septic systems, cesspools	21.47	5	5	5	0	15
2204	Septic systems, cesspools	21.47	5	5	5	0	15
2205	Septic systems, cesspools	21.51	5	5	5	0	15
2288	Septic systems, cesspools	22.97	5	5	3	0	13
2288	Septic systems, cesspools	27.12	5	5	1	0	11
2291	Septic systems, cesspools	20.61	5	5	5	0	15
2297	Septic systems, cesspools	19.27	5	5	5	0	15
2298	Septic systems, cesspools	19.16	5	5	5	0	15
2300	Septic systems, cesspools	19.27	5	5	5	0	15
2317	Septic systems, cesspools	20.34	5	5	7	0	17
2318	Septic systems, cesspools	20.34	5	5	7	0	17
2326	Septic systems, cesspools	21.33	5	5	5	0	15
2330	Septic systems, cesspools	21.47	5	5	5	0	15
2369	Septic systems, cesspools	22.91	5	5	3	0	13
2384	Septic systems, cesspools	20.75	5	5	5	0	15
2387	Septic systems, cesspools	20.75	5	5	5	0	15
2390	Septic systems, cesspools	20.68	5	5	5	0	15
2444	Septic systems, cesspools	19.47	5	5	5	0	15
2479	Septic systems, cesspools	19.47	5	5	5	0	15
2488	Septic systems, cesspools	19.53	5	5	5	0	15
2493	Septic systems, cesspools	19.53	5	5	5	0	15
2517	Septic systems, cesspools	20.82	5	5	5	0	15
2521	Septic systems, cesspools	20.82	5	5	5	0	15
2523	Septic systems, cesspools	22.97	5	5	3	0	13
2527	Septic systems, cesspools	19.57	5	5	5	0	15
2552	Septic systems, cesspools	19.65	5	5	5	0	15
2584	Septic systems, cesspools	19.73	5	5	5	0	15
2587	Septic systems, cesspools	29.19	5	5	1	0	11

Synthetic Organic Compounds (SOCs) Vulnerability Assessment

ID	TYPE	DISTANCE TO THE INTAKE (mi)	RISK POTENTIAL H=5 M=3 L=1	PBE L=5 M=3 H=1	TOT (hr) 0-6=9 6-12=7 12-18=5 18-24=3 >24=1	WATER QUALIT Y H=5 L=0	VULNERABILITY SCORE
2588	Septic systems, cesspools	29.19	5	5	1	0	11
2589	Septic systems, cesspools	29.14	5	5	1	0	11
2590	Septic systems, cesspools	29.14	5	5	1	0	11
2596	Septic systems, cesspools	28.73	5	5	3	0	13
2597	Septic systems, cesspools	28.75	5	5	3	0	13
2600	Septic systems, cesspools	23.99	5	5	3	0	13
2621	Septic systems, cesspools	20.92	5	5	5	0	15
2637	Septic systems, cesspools	20.00	5	5	5	0	15
2647	Septic systems, cesspools	20.00	5	5	5	0	15
2736	Septic systems, cesspools	20.97	5	5	5	0	15
2907	Septic systems, cesspools	28.70	5	5	3	0	13
2954	Septic systems, cesspools	21.11	5	5	5	0	15
21061	Septic systems, cesspools	28.34	5	5	3	0	13
21071	Septic systems, cesspools	28.50	5	5	3	0	13
21098	Septic systems, cesspools	29.37	5	5	1	0	11
21178	Septic systems, cesspools	21.84	5	5	7	0	17
21323	Septic systems, cesspools	21.84	5	5	7	0	17
21326	Septic systems, cesspools	21.84	5	5	7	0	17
21420	Septic systems, cesspools	21.70	5	5	7	0	17
21428	Septic systems, cesspools	21.71	5	5	5	0	15
21431	Septic systems, cesspools	24.35	5	5	1	0	11
21447	Septic systems, cesspools	24.31	5	5	1	0	11
21475	Septic systems, cesspools	20.75	5	5	5	0	15
21566	Septic systems, cesspools	21.70	5	5	7	0	17
21572	Septic systems, cesspools	21.70	5	5	7	0	17
21574	Septic systems, cesspools	21.70	5	5	7	0	17
21576	Septic systems, cesspools	21.70	5	5	7	0	17
21732	Septic systems, cesspools	28.56	5	5	3	0	13
22120	Septic systems, cesspools	19.31	5	5	5	0	15
22121	Septic systems, cesspools	19.27	5	5	5	0	15
22124	Septic systems, cesspools	19.22	5	5	5	0	15
212670	Septic systems, cesspools	22.91	5	5	3	0	13
216901	Septic systems, cesspools	19.25	5	5	5	0	15
						AVERAGE	15
						MAX	19
						MIN	11

Inorganic Compounds (IOCs) Vulnerability Assessment

ID	TYPE	DISTANCE TO THE INTAKE (mi)	RISK POTENTIAL H=5 M=3 L=1	PBE L=5 M=3 H=1	TOT (hr) 0-6=9 6-12=7 12-18=5 18-24=3 >24=1	WATER QUALITY H=5 L=0	VULNERABILITY SCORE
3	Photography & Printers	25.89	5	5	3	5	18
8	Photography & Printers	24.91	5	5	3	5	18
10	Golf Courses, parks & nurseries	24.25	5	5	3	5	18
51	Car Washes	20.70	3	5	5	5	18
55	Golf Courses, parks & nurseries	19.18	5	5	7	5	22
59	Car Washes	20.56	3	5	7	5	20
61	Car Washes	20.52	3	5	7	5	20
63	Car Washes	20.49	3	5	7	5	20
70	Research Laboratories	25.59	5	5	3	5	18
81	Golf Courses, parks & nurseries	26.36	5	5	3	5	18
97	Photography & Printers	28.89	5	5	1	5	16
113	Photography & Printers	28.50	5	5	1	5	16
118	Chem. Manuf/warehousing/distribution	28.21	5	5	1	5	16
122	Car Washes	27.82	3	5	1	5	14
124	Chem. Manuf/warehousing/distr.	27.08	5	5	1	5	16
142	Chem. Manuf/warehousing/distr.	27.34	5	5	1	5	16
144	Research Laboratories	27.60	5	5	1	5	16
164	Car Washes	18.74	3	5	5	5	18
167	Car Washes	18.55	3	5	5	5	18
175	Car Washes	20.03	3	5	5	5	18
182	Golf Courses, parks & nurseries	17.80	5	5	9	5	24
183	Golf Courses, parks & nurseries	18.00	5	5	9	5	24
191	Car Washes	31.44	3	5	1	5	14
196	Golf Courses, parks & nurseries	14.81	5	5	9	5	24
210	Car Washes	22.54	3	5	5	5	18
222	Golf Courses, parks & nurseries	19.28	5	5	7	5	22
248	Golf Courses, parks & nurseries	16.39	5	5	9	5	24
272	Research Laboratories	28.94	5	5	1	5	16
296	Educational Institutions	28.83	3	5	3	5	16
316	Stormwater drains & retention basins	10.60	5	5	9	5	24
366	Educational Institutions	22.32	3	5	7	5	20
367	Educational Institutions	21.85	3	5	7	5	20
371	Educational Institutions	23.47	3	5	3	5	16
440	Golf Courses, parks & nurseries	12.06	5	5	9	5	24
449	Golf Courses, parks & nurseries	9.30	5	5	9	5	24
450	Stormwater drains & retention basins	15.84	5	5	9	5	24
451	Stormwater drains & retention basins	15.19	5	5	9	5	24
452	Stormwater drains & retention basins	14.73	5	5	9	5	24
454	Stormwater drains & retention basins	13.11	5	5	9	5	24
455	Stormwater drains & retention basins	18.30	5	5	9	5	24
456	Stormwater drains & retention basins	18.83	5	5	9	5	24
457	Stormwater drains & retention basins	14.50	5	5	9	5	24

Inorganic Compounds (IOCs) Vulnerability Assessment

ID	TYPE	DISTANCE TO THE INTAKE (mi)	RISK POTENTIAL H=5 M=3 L=1	PBE L=5 M=3 H=1	TOT (hr) 0-6=9 6-12=7 12-18=5 18-24=3 >24=1	WATER QUALITY H=5 L=0	VULNERABILITY SCORE
506	Sewer transfer stations	8.20	5	5	9	5	24
1001	Municipal Wastewater	17.56	5	5	9	5	24
1002	Municipal Wastewater	16.00	5	5	9	5	24
1003	Municipal Wastewater	13.20	5	5	9	5	24
1004	Dewatering	21.50	3	5	5	5	18
1005	Groundwater Remediati	30.12	5	5	1	5	16
1007	Groundwater Remediati	24.25	5	5	1	5	16
1008	Groundwater Remediati	28.63	5	5	1	5	16
1009	Miscellaneous	13.47	5	5	9	5	24
2000	Septic systems, cesspools	20.68	5	5	5	5	20
2005	Septic systems, cesspools	15.50	5	5	9	5	24
2012	Septic systems, cesspools	27.26	5	5	1	5	16
2013	Septic systems, cesspools	21.53	5	5	7	5	22
2022	Septic systems, cesspools	18.81	5	5	5	5	20
2039	Septic systems, cesspools	27.08	5	5	1	5	16
2040	Septic systems, cesspools	20.77	5	5	5	5	20
2042	Septic systems, cesspools	18.81	5	5	5	5	20
2043	Septic systems, cesspools	18.81	5	5	5	5	20
2046	Septic systems, cesspools	18.88	5	5	5	5	20
2046	Septic systems, cesspools	28.48	5	5	1	5	16
2051	Septic systems, cesspools	28.63	5	5	1	5	16
2055	Septic systems, cesspools	18.81	5	5	5	5	20
2056	Septic systems, cesspools	18.88	5	5	5	5	20
2070	Septic systems, cesspools	18.88	5	5	5	5	20
2071	Septic systems, cesspools	18.88	5	5	5	5	20
2084	Septic systems, cesspools	18.81	5	5	5	5	20
2085	Septic systems, cesspools	18.81	5	5	5	5	20
2086	Septic systems, cesspools	18.81	5	5	5	5	20
2087	Septic systems, cesspools	18.88	5	5	5	5	20
2088	Septic systems, cesspools	18.88	5	5	5	5	20
2091	Septic systems, cesspools	18.88	5	5	5	5	20
2095	Septic systems, cesspools	18.88	5	5	5	5	20
2096	Septic systems, cesspools	18.88	5	5	5	5	20
2112	Septic systems, cesspools	26.92	5	5	1	5	16
2121	Septic systems, cesspools	18.88	5	5	5	5	20
2123	Septic systems, cesspools	18.81	5	5	5	5	20
2125	Septic systems, cesspools	18.88	5	5	5	5	20
2132	Septic systems, cesspools	19.05	5	5	5	5	20
2134	Septic systems, cesspools	21.51	5	5	5	5	20
2139	Septic systems, cesspools	19.10	5	5	5	5	20
2145	Septic systems, cesspools	19.16	5	5	5	5	20
2147	Septic systems, cesspools	27.01	5	5	1	5	16

Inorganic Compounds (IOCs) Vulnerability Assessment

ID	TYPE	DISTANCE TO THE INTAKE (mi)	RISK POTENTIAL H=5 M=3 L=1	PBE L=5 M=3 H=1	TOT (hr) 0-6=9 6-12=7 12-18=5 18-24=3 >24=1	WATER QUALITY H=5 L=0	VULNERABILITY SCORE
2149	Septic systems, cesspools	19.16	5	5	5	5	20
2162	Septic systems, cesspools	19.27	5	5	5	5	20
2162	Septic systems, cesspools	21.41	5	5	5	5	20
2164	Septic systems, cesspools	20.61	5	5	5	5	20
2164	Septic systems, cesspools	21.41	5	5	5	5	20
2165	Septic systems, cesspools	20.61	5	5	5	5	20
2166	Septic systems, cesspools	20.56	5	5	5	5	20
2168	Septic systems, cesspools	21.47	5	5	5	5	20
2169	Septic systems, cesspools	19.40	5	5	5	5	20
2170	Septic systems, cesspools	19.34	5	5	5	5	20
2170	Septic systems, cesspools	21.47	5	5	5	5	20
2171	Septic systems, cesspools	19.27	5	5	5	5	20
2171	Septic systems, cesspools	21.47	5	5	5	5	20
2172	Septic systems, cesspools	19.27	5	5	5	5	20
2172	Septic systems, cesspools	21.33	5	5	5	5	20
2173	Septic systems, cesspools	19.27	5	5	5	5	20
2173	Septic systems, cesspools	21.51	5	5	5	5	20
2175	Septic systems, cesspools	19.40	5	5	5	5	20
2175	Septic systems, cesspools	21.51	5	5	5	5	20
2176	Septic systems, cesspools	19.40	5	5	5	5	20
2177	Septic systems, cesspools	19.34	5	5	5	5	20
2178	Septic systems, cesspools	19.27	5	5	5	5	20
2179	Septic systems, cesspools	19.40	5	5	5	5	20
2180	Septic systems, cesspools	19.40	5	5	5	5	20
2181	Septic systems, cesspools	19.34	5	5	5	5	20
2181	Septic systems, cesspools	21.51	5	5	5	5	20
2193	Septic systems, cesspools	21.41	5	5	5	5	20
2194	Septic systems, cesspools	21.41	5	5	5	5	20
2200	Septic systems, cesspools	21.51	5	5	5	5	20
2201	Septic systems, cesspools	21.47	5	5	5	5	20
2204	Septic systems, cesspools	21.47	5	5	5	5	20
2205	Septic systems, cesspools	21.51	5	5	5	5	20
2288	Septic systems, cesspools	22.97	5	5	3	5	18
2288	Septic systems, cesspools	27.12	5	5	1	5	16
2291	Septic systems, cesspools	20.61	5	5	5	5	20
2297	Septic systems, cesspools	19.27	5	5	5	5	20
2298	Septic systems, cesspools	19.16	5	5	5	5	20
2300	Septic systems, cesspools	19.27	5	5	5	5	20
2317	Septic systems, cesspools	20.34	5	5	7	5	22
2318	Septic systems, cesspools	20.34	5	5	7	5	22
2326	Septic systems, cesspools	21.33	5	5	5	5	20
2330	Septic systems, cesspools	21.47	5	5	5	5	20

Inorganic Compounds (IOCs) Vulnerability Assessment

ID	TYPE	DISTANCE TO THE INTAKE (mi)	RISK POTENTIAL H=5 M=3 L=1	PBE L=5 M=3 H=1	TOT (hr) 0-6=9 6-12=7 12-18=5 18-24=3 >24=1	WATER QUALITY H=5 L=0	VULNERABILITY SCORE
2369	Septic systems, cesspools	22.91	5	5	3	5	18
2384	Septic systems, cesspools	20.75	5	5	5	5	20
2387	Septic systems, cesspools	20.75	5	5	5	5	20
2390	Septic systems, cesspools	20.68	5	5	5	5	20
2444	Septic systems, cesspools	19.47	5	5	5	5	20
2479	Septic systems, cesspools	19.47	5	5	5	5	20
2488	Septic systems, cesspools	19.53	5	5	5	5	20
2493	Septic systems, cesspools	19.53	5	5	5	5	20
2517	Septic systems, cesspools	20.82	5	5	5	5	20
2521	Septic systems, cesspools	20.82	5	5	5	5	20
2523	Septic systems, cesspools	22.97	5	5	3	5	18
2527	Septic systems, cesspools	19.57	5	5	5	5	20
2552	Septic systems, cesspools	19.65	5	5	5	5	20
2584	Septic systems, cesspools	19.73	5	5	5	5	20
2587	Septic systems, cesspools	29.19	5	5	1	5	16
2588	Septic systems, cesspools	29.19	5	5	1	5	16
2589	Septic systems, cesspools	29.14	5	5	1	5	16
2590	Septic systems, cesspools	29.14	5	5	1	5	16
2596	Septic systems, cesspools	28.73	5	5	3	5	18
2597	Septic systems, cesspools	28.75	5	5	3	5	18
2600	Septic systems, cesspools	23.99	5	5	3	5	18
2621	Septic systems, cesspools	20.92	5	5	5	5	20
2637	Septic systems, cesspools	20.00	5	5	5	5	20
2647	Septic systems, cesspools	20.00	5	5	5	5	20
2736	Septic systems, cesspools	20.97	5	5	5	5	20
2907	Septic systems, cesspools	28.70	5	5	3	5	18
2954	Septic systems, cesspools	21.11	5	5	5	5	20
21061	Septic systems, cesspools	28.34	5	5	3	5	18
21071	Septic systems, cesspools	28.50	5	5	3	5	18
21098	Septic systems, cesspools	29.37	5	5	1	5	16
21178	Septic systems, cesspools	21.84	5	5	7	5	22
21323	Septic systems, cesspools	21.84	5	5	7	5	22
21326	Septic systems, cesspools	21.84	5	5	7	5	22
21420	Septic systems, cesspools	21.70	5	5	7	5	22
21428	Septic systems, cesspools	21.71	5	5	5	5	20
21431	Septic systems, cesspools	24.35	5	5	1	5	16
21447	Septic systems, cesspools	24.31	5	5	1	5	16
21475	Septic systems, cesspools	20.75	5	5	5	5	20
21566	Septic systems, cesspools	21.70	5	5	7	5	22
21572	Septic systems, cesspools	21.70	5	5	7	5	22
21574	Septic systems, cesspools	21.70	5	5	7	5	22
21576	Septic systems, cesspools	21.70	5	5	7	5	22

Inorganic Compounds (IOCs) Vulnerability Assessment

ID	TYPE	DISTANCE TO THE INTAKE (mi)	RISK POTENTIAL H=5 M=3 L=1	PBE L=5 M=3 H=1	TOT (hr) 0-6=9 6-12=7 12-18=5 18-24=3 >24=1	WATER QUALITY H=5 L=0	VULNERABILITY SCORE
21732	Septic systems, cesspools	28.56	5	5	3	5	18
22120	Septic systems, cesspools	19.31	5	5	5	5	20
22121	Septic systems, cesspools	19.27	5	5	5	5	20
22124	Septic systems, cesspools	19.22	5	5	5	5	20
212670	Septic systems, cesspools	22.91	5	5	3	5	18
216901	Septic systems, cesspools	19.25	5	5	5	5	20
						AVERAGE	20
						MAX	24
						MIN	14

Microbiological Compounds Vulnerability Assessment

ID	TYPE	DISTANCE TO THE INTAKE (mi)	RISK POTENTIAL H=5 M=3 L=1	PBE L=5 M=3 H=1	TOT (hr) 0-6=9 6-12=7 12-18=5 18-24=3 >24=1	WATER QUALITY H=5 L=0	VULNERABILITY SCORE
11	Medical Institutions	23.62	1	5	3	5	14
23	Medical Institutions	23.08	1	5	3	5	14
51	Car Washes	20.70	3	5	5	5	18
59	Car Washes	20.56	3	5	7	5	20
61	Car Washes	20.52	3	5	7	5	20
62	Medical Institutions	20.65	1	5	7	5	18
63	Car Washes	20.49	3	5	7	5	20
67	Medical Institutions	23.64	1	5	3	5	14
70	Research Laboratories	25.59	5	5	3	5	18
71	Medical Institutions	25.76	1	5	3	5	14
122	Car Washes	27.82	3	5	1	5	14
144	Research Laboratories	27.60	5	5	1	5	16
150	Medical Institutions	24.34	1	5	1	5	12
164	Car Washes	18.74	3	5	5	5	18
166	Medical Institutions	29.09	1	5	1	5	12
167	Car Washes	18.55	3	5	5	5	18
168	Medical Institutions	19.80	1	5	5	5	16
175	Car Washes	20.03	3	5	5	5	18
177	Medical Institutions	20.09	1	5	5	5	16
178	Medical Institutions	20.09	1	5	5	5	16
191	Car Washes	31.44	3	5	1	5	14
210	Car Washes	22.54	3	5	5	5	18
219	Medical Institutions	20.07	1	5	5	5	16
225	Medical Institutions	18.59	1	5	7	5	18
226	Medical Institutions	18.71	1	5	7	5	18
227	Medical Institutions	18.03	1	5	7	5	18
228	Medical Institutions	18.01	1	5	7	5	18
229	Medical Institutions	18.02	1	5	7	5	18
230	Medical Institutions	18.01	1	5	7	5	18
231	Medical Institutions	18.01	1	5	7	5	18
234	Medical Institutions	17.57	1	5	9	5	20
235	Medical Institutions	17.55	1	5	9	5	20
236	Medical Institutions	17.53	1	5	9	5	20
241	Medical Institutions	17.75	1	5	7	5	18
262	Medical Institutions	29.11	1	5	1	5	12
263	Medical Institutions	29.09	1	5	1	5	12
264	Medical Institutions	29.14	1	5	1	5	12
265	Medical Institutions	29.14	1	5	1	5	12
266	Medical Institutions	29.06	1	5	1	5	12
267	Medical Institutions	29.01	1	5	1	5	12
268	Medical Institutions	28.96	1	5	1	5	12
269	Medical Institutions	28.91	1	5	1	5	12
270	Medical Institutions	28.96	1	5	1	5	12

Microbiological Compounds Vulnerability Assessment

ID	TYPE	DISTANCE TO THE INTAKE (mi)	RISK POTENTIAL H=5 M=3 L=1	PBE L=5 M=3 H=1	TOT (hr) 0-6=9 6-12=7 12-18=5 18-24=3 >24=1	WATER QUALITY H=5 L=0	VULNERABILITY SCORE
271	Medical Institutions	29.01	1	5	1	5	12
272	Research Laboratories	28.94	5	5	1	5	16
273	Medical Institutions	29.03	1	5	1	5	12
274	Medical Institutions	29.06	1	5	1	5	12
275	Medical Institutions	29.07	1	5	1	5	12
276	Medical Institutions	29.08	1	5	1	5	12
277	Medical Institutions	29.03	1	5	1	5	12
278	Medical Institutions	28.98	1	5	1	5	12
279	Medical Institutions	28.86	1	5	3	5	14
280	Medical Institutions	28.85	1	5	3	5	14
282	Medical Institutions	28.78	1	5	3	5	14
283	Medical Institutions	28.69	1	5	3	5	14
284	Medical Institutions	28.04	1	5	3	5	14
287	Medical Institutions	28.53	1	5	3	5	14
288	Medical Institutions	28.48	1	5	3	5	14
308	Medical Institutions	24.77	1	5	3	5	14
316	Stormwater drains & retention basins	10.60	5	5	9	5	24
442	Medical Institutions	28.89	1	5	1	5	12
443	Medical Institutions	28.39	1	5	3	5	14
444	Medical Institutions	28.08	1	5	3	5	14
450	Stormwater drains & retention basins	15.84	5	5	9	5	24
451	Stormwater drains & retention basins	15.19	5	5	9	5	24
452	Stormwater drains & retention basins	14.73	5	5	9	5	24
454	Stormwater drains & retention basins	13.11	5	5	9	5	24
455	Stormwater drains & retention basins	18.30	5	5	9	5	24
456	Stormwater drains & retention basins	18.83	5	5	9	5	24
457	Stormwater drains & retention basins	14.50	5	5	9	5	24
506	Sewer transfer stations	8.20	5	5	9	5	24
1001	Municipal Wastewater	17.56	5	5	9	5	24
1002	Municipal Wastewater	16.00	5	5	9	5	24
1003	Municipal Wastewater	13.20	5	5	9	5	24
2000	Septic systems, cesspools	20.68	5	5	5	5	20
2005	Septic systems, cesspools	15.50	5	5	9	5	24
2012	Septic systems, cesspools	27.26	5	5	1	5	16
2013	Septic systems, cesspools	21.53	5	5	7	5	22
2022	Septic systems, cesspools	18.81	5	5	5	5	20
2039	Septic systems, cesspools	27.08	5	5	1	5	16
2040	Septic systems, cesspools	20.77	5	5	5	5	20
2042	Septic systems, cesspools	18.81	5	5	5	5	20
2043	Septic systems, cesspools	18.81	5	5	5	5	20
2046	Septic systems, cesspools	18.88	5	5	5	5	20
2046	Septic systems, cesspools	28.48	5	5	1	5	16
2051	Septic systems, cesspools	28.63	5	5	1	5	16

Microbiological Compounds Vulnerability Assessment

ID	TYPE	DISTANCE TO THE INTAKE (mi)	RISK POTENTIAL H=5 M=3 L=1	PBE L=5 M=3 H=1	TOT (hr) 0-6=9 6-12=7 12-18=5 18-24=3 >24=1	WATER QUALITY H=5 L=0	VULNERABILITY SCORE
2055	Septic systems, cesspools	18.81	5	5	5	5	20
2056	Septic systems, cesspools	18.88	5	5	5	5	20
2070	Septic systems, cesspools	18.88	5	5	5	5	20
2071	Septic systems, cesspools	18.88	5	5	5	5	20
2084	Septic systems, cesspools	18.81	5	5	5	5	20
2085	Septic systems, cesspools	18.81	5	5	5	5	20
2086	Septic systems, cesspools	18.81	5	5	5	5	20
2087	Septic systems, cesspools	18.88	5	5	5	5	20
2088	Septic systems, cesspools	18.88	5	5	5	5	20
2091	Septic systems, cesspools	18.88	5	5	5	5	20
2095	Septic systems, cesspools	18.88	5	5	5	5	20
2096	Septic systems, cesspools	18.88	5	5	5	5	20
2112	Septic systems, cesspools	26.92	5	5	1	5	16
2121	Septic systems, cesspools	18.88	5	5	5	5	20
2123	Septic systems, cesspools	18.81	5	5	5	5	20
2125	Septic systems, cesspools	18.88	5	5	5	5	20
2132	Septic systems, cesspools	19.05	5	5	5	5	20
2134	Septic systems, cesspools	21.51	5	5	5	5	20
2139	Septic systems, cesspools	19.10	5	5	5	5	20
2145	Septic systems, cesspools	19.16	5	5	5	5	20
2147	Septic systems, cesspools	27.01	5	5	1	5	16
2149	Septic systems, cesspools	19.16	5	5	5	5	20
2162	Septic systems, cesspools	19.27	5	5	5	5	20
2162	Septic systems, cesspools	21.41	5	5	5	5	20
2164	Septic systems, cesspools	20.61	5	5	5	5	20
2164	Septic systems, cesspools	21.41	5	5	5	5	20
2165	Septic systems, cesspools	20.61	5	5	5	5	20
2166	Septic systems, cesspools	20.56	5	5	5	5	20
2168	Septic systems, cesspools	21.47	5	5	5	5	20
2169	Septic systems, cesspools	19.40	5	5	5	5	20
2170	Septic systems, cesspools	19.34	5	5	5	5	20
2170	Septic systems, cesspools	21.47	5	5	5	5	20
2171	Septic systems, cesspools	19.27	5	5	5	5	20
2171	Septic systems, cesspools	21.47	5	5	5	5	20
2172	Septic systems, cesspools	19.27	5	5	5	5	20
2172	Septic systems, cesspools	21.33	5	5	5	5	20
2173	Septic systems, cesspools	19.27	5	5	5	5	20
2173	Septic systems, cesspools	21.51	5	5	5	5	20
2175	Septic systems, cesspools	19.40	5	5	5	5	20
2175	Septic systems, cesspools	21.51	5	5	5	5	20
2176	Septic systems, cesspools	19.40	5	5	5	5	20
2177	Septic systems, cesspools	19.34	5	5	5	5	20
2178	Septic systems, cesspools	19.27	5	5	5	5	20

Microbiological Compounds Vulnerability Assessment

ID	TYPE	DISTANCE TO THE INTAKE (mi)	RISK POTENTIAL H=5 M=3 L=1	PBE L=5 M=3 H=1	TOT (hr) 0-6=9 6-12=7 12-18=5 18-24=3 >24=1	WATER QUALITY H=5 L=0	VULNERABILITY SCORE
2179	Septic systems, cesspools	19.40	5	5	5	5	20
2180	Septic systems, cesspools	19.40	5	5	5	5	20
2181	Septic systems, cesspools	19.34	5	5	5	5	20
2181	Septic systems, cesspools	21.51	5	5	5	5	20
2193	Septic systems, cesspools	21.41	5	5	5	5	20
2194	Septic systems, cesspools	21.41	5	5	5	5	20
2200	Septic systems, cesspools	21.51	5	5	5	5	20
2201	Septic systems, cesspools	21.47	5	5	5	5	20
2204	Septic systems, cesspools	21.47	5	5	5	5	20
2205	Septic systems, cesspools	21.51	5	5	5	5	20
2288	Septic systems, cesspools	22.97	5	5	3	5	18
2288	Septic systems, cesspools	27.12	5	5	1	5	16
2291	Septic systems, cesspools	20.61	5	5	5	5	20
2297	Septic systems, cesspools	19.27	5	5	5	5	20
2298	Septic systems, cesspools	19.16	5	5	5	5	20
2300	Septic systems, cesspools	19.27	5	5	5	5	20
2317	Septic systems, cesspools	20.34	5	5	7	5	22
2318	Septic systems, cesspools	20.34	5	5	7	5	22
2326	Septic systems, cesspools	21.33	5	5	5	5	20
2330	Septic systems, cesspools	21.47	5	5	5	5	20
2369	Septic systems, cesspools	22.91	5	5	3	5	18
2384	Septic systems, cesspools	20.75	5	5	5	5	20
2387	Septic systems, cesspools	20.75	5	5	5	5	20
2390	Septic systems, cesspools	20.68	5	5	5	5	20
2444	Septic systems, cesspools	19.47	5	5	5	5	20
2479	Septic systems, cesspools	19.47	5	5	5	5	20
2488	Septic systems, cesspools	19.53	5	5	5	5	20
2493	Septic systems, cesspools	19.53	5	5	5	5	20
2517	Septic systems, cesspools	20.82	5	5	5	5	20
2521	Septic systems, cesspools	20.82	5	5	5	5	20
2523	Septic systems, cesspools	22.97	5	5	3	5	18
2527	Septic systems, cesspools	19.57	5	5	5	5	20
2552	Septic systems, cesspools	19.65	5	5	5	5	20
2584	Septic systems, cesspools	19.73	5	5	5	5	20
2587	Septic systems, cesspools	29.19	5	5	1	5	16
2588	Septic systems, cesspools	29.19	5	5	1	5	16
2589	Septic systems, cesspools	29.14	5	5	1	5	16
2590	Septic systems, cesspools	29.14	5	5	1	5	16
2596	Septic systems, cesspools	28.73	5	5	3	5	18
2597	Septic systems, cesspools	28.75	5	5	3	5	18
2600	Septic systems, cesspools	23.99	5	5	3	5	18
2621	Septic systems, cesspools	20.92	5	5	5	5	20
2637	Septic systems, cesspools	20.00	5	5	5	5	20

Microbiological Compounds Vulnerability Assessment

ID	TYPE	DISTANCE TO THE INTAKE (mi)	RISK POTENTIAL H=5 M=3 L=1	PBE L=5 M=3 H=1	TOT (hr) 0-6=9 6-12=7 12-18=5 18-24=3 >24=1	WATER QUALITY H=5 L=0	VULNERABILITY SCORE
2647	Septic systems, cesspools	20.00	5	5	5	5	20
2736	Septic systems, cesspools	20.97	5	5	5	5	20
2907	Septic systems, cesspools	28.70	5	5	3	5	18
2954	Septic systems, cesspools	21.11	5	5	5	5	20
21061	Septic systems, cesspools	28.34	5	5	3	5	18
21071	Septic systems, cesspools	28.50	5	5	3	5	18
21098	Septic systems, cesspools	29.37	5	5	1	5	16
21178	Septic systems, cesspools	21.84	5	5	7	5	22
21323	Septic systems, cesspools	21.84	5	5	7	5	22
21326	Septic systems, cesspools	21.84	5	5	7	5	22
21420	Septic systems, cesspools	21.70	5	5	7	5	22
21428	Septic systems, cesspools	21.71	5	5	5	5	20
21431	Septic systems, cesspools	24.35	5	5	1	5	16
21447	Septic systems, cesspools	24.31	5	5	1	5	16
21475	Septic systems, cesspools	20.75	5	5	5	5	20
21566	Septic systems, cesspools	21.70	5	5	7	5	22
21572	Septic systems, cesspools	21.70	5	5	7	5	22
21574	Septic systems, cesspools	21.70	5	5	7	5	22
21576	Septic systems, cesspools	21.70	5	5	7	5	22
21732	Septic systems, cesspools	28.56	5	5	3	5	18
22120	Septic systems, cesspools	19.31	5	5	5	5	20
22121	Septic systems, cesspools	19.27	5	5	5	5	20
22124	Septic systems, cesspools	19.22	5	5	5	5	20
212670	Septic systems, cesspools	22.91	5	5	3	5	18
216901	Septic systems, cesspools	19.25	5	5	5	5	20
						Average	18
						MAX	24
						MIN	12

Radiological Compounds Vulnerability Assessment

ID	TYPE	DISTANCE TO THE INTAKE (mi)	RISK POTENTIAL H=5 M=3 L=1	PBE POINTS L=5 M=3 H=1	TOT (hr) 0-6=9 6-12=7 12-18=5 18-24=3 >24=1	RADIOLOGICA L POINTS H=5 L=0	VULNERABILITY SCORE
1009	Miscellaneous	13.47	5	5	9	0	19