Final Report

Regional Water Planning Commission Septic Nitrate Baseline Data and Risk Assessment Study for Washoe County

PHASE I: PRIORITIZATION OF STUDY AREAS & ASSESSMENT OF DATA NEEDS

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Executive Summary

This study was conducted for the Regional Water Planning Commission (RWPC). The goals of the study were to investigate the potential for septic nitrate contamination in the metropolitan and suburban areas of the Reno-Sparks metropolitan area (RSMA) and to provide recommendations for prioritizing additional study of areas potentially contaminated by septic nitrate.

This project investigates the current risk posed by septic systems (individual sewage disposal systems or ISDS) by examining the location and density of ISDS, their proximity to sensitive receptors (water supply wells, creeks, rivers, and lakes), and the concentration of nitrate in ground water. Determining where ground water is at risk from nitrate contamination is essential for management and planning activities, especially when deciding where to allocate resources for monitoring, cleanup, or implementation of alternative management practices (Nolan et. al., 2002).

Following a review of the literature, the first stage in the investigation consisted of an examination of existing data. This data was used to locate potential areas of concern (Project Areas) within the RSMA and outlying county developments. Sixteen Project Areas were identified for investigation and are depicted in Figure 1. Data from these specific areas was then organized into a meaningful database and analyzed to determine the potential for areas with high-density ISDS (HDI) to contribute to water quality degradation. The basis for potential water quality degradation was based on density factors and proximity to sensitive receptors. During this process, data gaps became more apparent and were noted for future investigations. Finally, a prioritized list of Project Areas that exhibit a high likelihood (relative to other Project Areas) of degrading water quality was developed, along with recommendations for further study and analysis.

Analyzing the potential impact from more than 18,000 parcels on ISDS in Washoe County was a significant undertaking. Numerous data sets from multiple agencies were reviewed and assembled into a useable database. This data was critical in order to identify potential areas of concern, analyze data for all sixteen areas, and prioritize the project areas for further investigation.

Results of this study and previous studies pointed to the importance of density of ISDS, distance to sensitive receptors, and parcel size. Ranking the Project Areas based on these factors revealed three distinct groupings:

- Previously studied areas with sufficient data and known impacts to sensitive receptors.
- Areas with insufficient data and suspected impacts to sensitive receptors.
- Areas with insufficient data and not suspected to impact sensitive receptors.

Based on the information collected and analyzed in this report, there is sufficient data in five Project Areas to make recommendations for management actions. These areas are of low priority for additional information, but of high priority for management action.

There is insufficient information, however, to take action with respect to nine of the Project Areas. These Project Areas ranked high on the priority list, but required additional information in order to take management action. These nine areas are therefore the High Priority Project Areas (HPA). Only two Project Areas out of the sixteen studied were suspected to be of low risk to receptors and are of low priority. The table below lists the categorized final rankings based on data needs and relative risk.

Project Area	Final Rank
Spanish Springs	1
Cold Springs	2
Washoe	3
Heppner	4
Mt. Rose	5
Golden Valley	6
Ambrose	7
Hidden Valley	8
Huffaker	9
Verdi	10
Geiger	11
Island 18	12
Mogul	13
Silver Knolls	14
Pleasant Valley	15
New Washoe	16

Sufficient data and known impacts

Insufficient data with suspected impacts

Insufficient data with little suspected impact

Based on the information obtained from the data review and conclusions drawn from the body of evidence, the following recommendations are made:

- Collect additional water quality and water level data from domestic well owners in all Project Areas.
- Collect water quality samples from surface water bodies adjacent to and downstream of HDI
- Additional analysis of currently available data for HPAs.
- Perform basic mass balance modeling of HPAs.
- Perform basic vadose-zone modeling of HPAs.
- Perform a GIS-based analysis of land-use, ISDS age, and water quality trends around water supply wells.
- Consider the potential for other sources of nitrate within HPAs

"The very act of living results in changes to the world around us. The acquisition of resources to sustain us and the discharge of our wastes causes alteration to the surface environment and, therefore, result in alteration of the underlying groundwater." (Freeze, 2001)

"Septic systems are both the most frequently reported source of ground-water contamination in the United States, and the single largest source (by volume) of wastewater discharges to the ground water." (Pye et. al., 1983; Bauman and Schafer; 1985)

1.0 Introduction

As the driest and fastest growing state in the nation, water planners in Nevada are forced to make critical decisions regarding ground-water protection, management, and forecasting. This is especially important since all surface water resources are fully appropriated (Nevada Department of Conservation and Natural Resources, 1999) and Nevada turns to its ground-water resources to meet the needs of its growing population (Lopes, 2006). This project is the product of a proactive approach to water planning that is needed in this water-starved state.

Ground water is the drinking water source for half of the population of the United States (Rose et. al., 1998), making up 37% of water withdrawals for cities and towns and 98% of private users (Hutson, et. al., 2004). In the Reno-Sparks metropolitan area (RSMA), the Truckee Meadows Water Authority (TMWA) provides water to almost 90,000 water services and the Washoe County Department of Water Resources (WCDWR) provides water to approximately 22,000 residential customers. The majority of the WCDWR demand and approximately 15% of TMWA demand is met with ground water.

The RSMA is growing faster than it has in recent history. This growth has lead to increasing water demands coupled with increasing threats to water quality. As development intensifies, population centers expand, and water needs multiply, ever-increasing pressure is put on already stressed ground water and surface water resources.

Along with supply pressures, ground water and surface waters are threatened by contaminants impacting water quality. Possibly the largest threat to water systems nation-wide is nitrate, from both natural and anthropogenic sources (Nolan et. al., 2002). "Nitrate" and concentrations of nitrate throughout this report are defined in terms of nitrate as Nitrogen (nitrate-N), with a maximum contaminant level (MCL) of 10 parts per million (ppm). The WCDWR has identified areas of water quality degradation as a result of septic system (hereafter referred to as individual sewage disposal system or ISDS) effluent, occurring predominantly in areas with high-density ISDS (HDI). There are approximately 18,300 individual sewage disposal systems in Washoe County, contributing an estimated 4,700 acre feet of water per year (AFY) to ground-water recharge. This recharge varies by basin and development, with at least sixteen areas that may exhibit densities high enough to pose a problem to potable ground-water supplies. In addition to high densities, contributing factors include shallow depths to ground water, permeable soil conditions, and proximity to sensitive receptors. These conditions are present in Spanish Springs Valley (Rosen et. al., 2006), Golden Valley (Widmer and McKay, 1994), Washoe Valley (McKay, 1991; Zhan and McKay, 1998), Lemmon Valley (Widmer and McKay, 1994; Seiler, 1996) and have been shown to impact water quality.

In Spanish Springs Valley, fifteen years of ground-water quality monitoring have shown increasing levels of nitrate contamination in municipal wells. Almost 2,000 septic systems are located within a four square-mile area, with almost half of these systems within 2,000 feet of one or more municipal water supply wells. Two of six municipal wells in the highly developed portion of Spanish Springs Valley have nitrate concentrations at or approaching the MCL of 10 ppm. A 1999 U.S. Geological Survey (USGS) study suggested that increasing nitrate levels may be linked to local septic systems (Seiler, 1999; Seiler et al, 1999). A recent study by the USGS and WCDWR found that nitrate concentrations of 44 mg/L from septic effluent in the densely populated portion of the valley account for approximately 30 tons of nitrogen entering the ground-water system every year (Rosen et al, 2006). An on-going study by the WCDWR shows nitrate concentrations increasing to over 73 ppm in the shallow aquifer during Third Quarter, 2007 sampling activities.

Using lessons learned in these areas, and especially in Spanish Springs Valley, the WCDWR expanded the scope of the ISDS effluent investigation throughout the densely populated portions of Washoe County.

2.0 Purpose and Scope

This project was initiated under the direction of the Regional Water Planning Commission (RWPC) in order to investigate the potential for nitrate contamination from ISDS in the metropolitan and suburban areas of the RSMA.

This project investigates the current risk posed by ISDS by examining the location and density of ISDS, their proximity to sensitive receptors (water supply wells, creeks, rivers, and lakes), and the concentration of nitrate in ground water. Determining where ground water is at risk from nitrate contamination is essential for management and planning activities, especially when deciding where to allocate resources for monitoring, cleanup, or implementation of alternative management practices (Nolan et. al., 2002)

Work on the susceptibility of Nevada's aquifers to contamination by Lopes, 2006 found that Nevada's aquifers are highly susceptible, with the highest susceptibility being in those areas with few clay layers to restrict the natural downward migration of nitrates to ground water. Most alarming, is that "urbanizing areas with few clay layers and downward flow describe primary recharge on alluvial fans, secondary recharge on irrigated land, and well fields in Reno-Sparks…" (Lopes, 2006).

Following a review of the literature, the first stage in the investigation will consist of an examination of existing data. This data will be used to locate potential areas of concern

(Project Areas) within the RSMA and outlying county developments. Data from these specific areas will be organized into a meaningful database and analyzed to determine the potential for HDI to contribute to water quality degradation. The basis for potential water quality degradation will revolve around density factors and proximity to sensitive receptors. During this process, data gaps will become more apparent and will be noted for future investigations. Finally, a prioritized list of Project Areas, that exhibit a high likelihood (relative to other Project Areas) of degrading water quality, will be recommended for further study and analysis. In-depth analysis of high priority areas will be proposed as subsequent phases of this investigation.

3.0 Background

3.1 Hydrogeologic Setting

The RSMA, like much of western Nevada, is located within the orographic "rain shadow" since it lies on the leeward side of the Sierra Nevada. Gates and Watters (1992) described the region as having a cool semi-arid continental climate with warm summers and cold winters. The greatest precipitation falls from December through February, mainly in the form of snow and freezing rain, with minor amounts of precipitation coming from summer storm events (Berger et al, 1997). Precipitation varies with elevation, with higher elevations receiving the majority of precipitation that recharges the ground water in the valleys.

Hydrographic regions in this study are characterized by broad alluvial desert basins underlain by basin-fill aquifers separated by generally parallel, north- to northeast-trending mountain ranges (Harrill and Prudic, 1998). Aquifer recharge, from precipitation during the winter months, occurs either in the mountains from melting snowpack or along streams flowing over alluvial deposits adjacent to the mountains (Harrill and Prudic, 1998). Most ground-water discharge is from evapotranspiration (Harrill and Prudic, 1998) or ground-water pumping. Precipitation in valleys within the study area is approximately 8 inches per year.

Aquifer hydrogeologic units in the study area are primarily younger basin-fill deposits consisting of unconsolidated to semi-consolidated deposits in (1) alluvial fans and pediments (unsorted to poorly sorted silt, sand, gravel, and boulders), (2) valley lowlands and playas (unsorted to poorly sorted clay, silt, sand, and gravel), and (3) stream flood plains (moderately sorted to well-sorted beds of silt and clay or sand and gravel) (Harrill and Prudic, 1998). At depth within the basins, there may be older basin-fill deposits consisting of semi-consolidated to consolidated fanglomerate, sandstone, siltstone, mudstone, limestone, and interbedded volcanic rocks (Harrill and Prudic, 1998).

3.2 Basin Hydrogeology

Although basin and range geology is fairly similar among the basins in this study, the hydrogeology may be quite different. Brief hydrogeologic descriptions of each basin or the major valley within each basin are summarized below. Figure #1 depicts the RSMA study area and individual Project Areas addressed in this study. Individual hydrobasin maps to accompany the basin descriptions below are included in Appendix A.

3.2.1 Truckee Meadows

The Truckee Meadows Hydrographic area encompasses 195 square miles, and includes five Project Areas: Ambrose (5.8 mi^2), Island 18 (7 mi^2), Hidden Valley (6.9 mi^2), Huffaker (24 (mi^2), and Geiger (6.6 mi^2). A map depicting the location and general features of the Truckee Meadows Basin is included in Appendix A..
The following geologic and hydrogeologic information for the Truckee Meadows is summarized from a report by WorleyParsons Komex, 2007

The Truckee Meadows hydrographic basin is bounded on the east by the Virginia Range and Pah Rah mountains, to the west by the Carson Range, to the south by the Steamboat Hills, and to the North by Peavine Mountain and associated bedrock outcrops.

The Truckee Meadows consists of five geologic units: Quaternary glacial outwash with modern fluvial and alluvial deposits; Cenozoic fluvial and deltaic/lacustrine sedimentary rocks; Cenozoic andesitic volcanic rocks; Mesozoic Sierran plutonic rocks; and Late Paleozoic to Mesozoic metavolcanic and metasedimentary rocks. Metamorphic, plutonic, and volcanic bedrock units form the surrounding mountains, the low hills along the margin of the basin, and the basement rocks beneath younger sedimentary fill. These units are considered impermeable, except for secondary permeability from fracturing. Depth to bedrock is estimated to be less than 3,000 feet in the center of the basin and thinning to less than 2,500 feet towards the South Truckee Meadows.

The basin-fill sedimentary units are divided into two categories: the older and less permeable Truckee Formation (now called the Verdi Basin sediments) and the younger, less consolidated, and more permeable Quaternary alluvium. The Quaternary alluvium is the principal water-supply aquifer, although some wells have been completed in the deeper and less permeable Verdi Basin sediments.

The Truckee River flows from West to East through the Truckee meadows. Its largest tributary, Steamboat Creek, collects tributary water from agricultural return flows, Galena, Whites, and Thomas Creek before joining the Truckee River east of Reno.

Ground water generally flows parallel to the Truckee River from West to East, with localized influence from municipal water-supply wells and the Truckee River. In the western portion of the Truckee Meadows, the Truckee River appears to have little influence on ground-water elevations. In the central portion of the Truckee Meadows, ground-water mounding occurs due to infiltration from Truckee River recharge. To the east, ground water flows towards the Truckee River where it may intercept the water table. Although there may be local hydraulic separation between what is defined as a shallow aquifer and a deeper aquifer, some areas suggest that municipal pumping from deeper aquifers may draw down shallower ground water.

Ground-water recharge to the Truckee Meadows is estimated at 27,000 AFY (Van Denburgh et al, 1973).

3.2.2 Lemmon Valley

The Lemmon Valley Hydrographic area, composed of the East and West Lemmon Hydrographic regions, encompasses 96.8 square miles. It includes three Project Areas: Silver Knolls (6.5 mi^2), Heppner (9.4 mi^2), and Golden Valley (10.7 mi^2). A map depicting the location and general features of the Lemmon Valley Basin is included in Appendix A.

The following geologic and hydrogeologic information for Lemmon Valley is summarized from a report by Widmer and VanHoozer, 2000.

Lemmon Valley hydrographic basin is bounded by Peavine Mountain on the southern boundary and to the west by the Sierra Nevadas. Lemmon Valley is separated from Sun Valley by Peterson Mountains, the Granite Hills, and the Hungry Hills, which form fault scarps on the eastern side.

Lemmon Valley basin consists of five geologic units: Quaternary alluvium; Tertiary sediments; Tertiary volcanics; intermediate volcanic extrusives and detritus recently uplifted by Cretaceous granodiorite; Cretaceous granodiorite; and Mesozoic metasediments and metavolcanics, which typically have a low ground-water yield. Normal faulting created north-south trending mountain ranges comprised of granodiorite and metavolcanic rocks with sediments and alluvial filled basins. The fault structures mostly trend northeast-southwest. The Airport Fault found in central Lemmon Valley originates in southern Hungry Hills and trends south to Peavine Mountain. The Airport Fault is an east-dipping normal fault interpreted as an impermeable barrier to ground-water flow.

Lemmon Valley is a hydrologically closed basin-fill aquifer. The general trend of ground-water flow is southwest to northeast with the steepest gradient for the system located in the mid-fan area. Precipitation, mostly from Peavine Mountain, is the primary source of ground water in the Valleys. Surface runoff is infrequent in the east due to low precipitation; however, other factors determining runoff in the area also include soil thickness, topography of the area, type and abundance of vegetation, soil moisture content, temperature and humidity. Surface waters from Lemmon Valley drains into Silver Lake Playa in the west sub basin and Swan Lake in the east sub basin and evaporates. The primary discharge of this area is evapotranspiration.

The valley floor sediments are well-sorted and fine-grained. The greatest ground-water yield tends to come from valley fill deposits. Valley fill deposits are estimated to be thickest at 1,000 feet. The thickest areas tend to be under the playa, where the clay layer (abundant to a depth of 200’ beneath land surface) thins laterally. There are two hydrostratigraphic units in the east: an upper unconfined unit and lower confining layers,

which contain distinctively separate aquifers. There appears to be little or no connection between the aquifers as evidenced by the fact that deeper pumping wells have no notable effect on shallow monitoring wells.
Ground-water recharge to Lemmon Valley is estimated at 1,500 AFY (Harrill, 1973; VanHoozer, 2007).

3.2.3 Pleasant Valley

The Pleasant Valley Hydrographic area encompasses 39 square miles, and includes two Project Areas: Mt. Rose (12.5 mi^2) and Pleasant Valley (8.8 mi^2). A map depicting the location and general features of the Pleasant Valley Basin is included in Appendix A.

The following geologic and hydrogeologic information for Pleasant Valley is summarized from a report by Felling, 2003.

The Pleasant Valley Hydrographic basin is bound to the North and East by the Steamboat Hills, to the East by the Virginia Range, and to the West by the Carson Range. Pleasant Valley is separated from Washoe Valley to the south by a topographic and hydrologic divide created by low hills of granitic, volcanic, and metavolcanic rocks.

Mt. Rose alluvial fan materials are found to be thin, with bedrock sloping roughly parallel to land surface from the range to the valley floor (Skalbeck, 2001). High-energy fan sediments on the Mt. Rose fan consist of poorly sorted sand, gravel, and clay with cobbles and boulders. Quaternary alluvial sediments reach a maximum thickness of 800 feet just north of the Mt. Rose Highway, but are typically around 300 to 500 feet thick. Sediments on the east side of the valley, derived from the Virginia Range, are poorly sorted sand, gravel, and clay stream deposits with some cobbles and boulders. Valley floor sediments consist of sandy clay, underlain by the Truckee formation. The eastern and central portions of the valley have Quaternary alluvial sediments estimated to be less than 500 feet thick.

Ground water flows generally toward the northeast, and from the Carson and Virginia ranges towards the valley center. Ground-water recharge is estimated at 10,000 AFA (VanDenburgh, 1973), and occurs mostly as mountain-front recharge since recharge to the aquifer from precipitation on the valley floor is estimated to be very small or zero.

3.2.4 Washoe Valley

The Washoe Valley Hydrographic area encompasses 82.8 square miles and includes two Project Areas: Washoe (12.6 mi^2) and New Washoe (3.1 mi^2). A map depicting the location and general features of the Washoe Valley Basin is included in Appendix A.

The following geologic and hydrogeologic information for Washoe Valley is summarized from a report by Widmer, 1997b.

Composed of 29 sub-basins, Washoe Valley is a basin-fill aquifer with a flat valley floor bordered by alluvial fans. Washoe Valley is a north-south oriented structural depression resulting from regional Basin and Range extension and uplift of the Sierra Nevada batholith. The east side of Washoe Valley has an "active tectonic history" and has been "stratagraphically disrupted." There is a volcanic ridge 200 feet under sediments to the southeast of Washoe Lake.

Eastern Washoe Valley (the Virginia Range) is composed of pre-Cretaceous metasediments, Cretaceous granodiorite and Tertiary volcanics, while Western Washoe Valley (the Carson Range) mostly Cretaceous granodiorite of Sierra NV. The western side of Washoe Valley is up to 2,000 feet deep of coarse-grained alluvial fan sediments. There are significant debris flows within the upper to mid Ophir Creek watershed. Washoe Valley lithology is composed of granodiorite-derived sediments on the western margin and volcanic, metasediments and granodiorite-derived clasts on east, north and south margins.

The basement is variable and controlled by basement faults, between 150 – 300 feet deep over the southern portion of New Washoe City. Some of the deeper wells in New Washoe City are thought to penetrate the volcanic basement. The valley has a granodiorite basement with overlying basin sediments of pluvial origin which consist of feldspathic sands and clay sands. The clay lenses suggest a semi-confining layer. Blue clays have abundant organic material, suggesting a "reducing lacustrine environment."

The granitic soil is medium to coarse grained and is moderately to very highly permeable. The hydrogeologic units within Washoe Valley include: fractured, weathered or saprolitic granodiorite; granodiorite-derived sands and clay sands; fine to medium-grained sand and lenses of silt and clay; fluvial deposits of gravel; and fractured volcanic basement rock.

Most of the precipitation in Washoe Valley is consumed by vegetation and evaporation. Estimated annual yield from the Virginia Range is only 900 acre feet per year; however, the estimated annual yield from Carson Range is 25,000 acre feet. A large contributor of the annual yield comes from water run-off from the surrounding mountains, which drain primarily from Jumbo, Winters, Davis, Ophir, Franktown, Hobart, Lewers, Muskgrove, and McEwen Creek watersheds.

There are two different ground-water flow regimes in the area. In the west, there is abundant ground-water recharge from creek runoff; however, in the east, recharge of ground water is poor due to the lack of surface water recharge. Because Washoe Valley is an asymmetric, fault-bounded half graben, tilted to the west, the ground water moves east to west discharging near Washoe Lake. The artesian conditions from wells near the lake are also assumed to be fault related. A small amount of geothermal ground water discharges near Bowers Mansion Park. In southwest Washoe Valley, the ground water has an elevated water temperature, higher fluorine levels, greater total dissolved solids, and a higher pH.

The ground-water table in the valley is high, especially towards the western slopes. The average slope is 15% above the valley floor and between 0-5% on the valley floor. Ground-water recharge is estimated at 15,000 AFY (Rush, 1967).

3.2.5 Truckee Canyon

The Truckee Canyon Hydrographic area encompasses 83.5 square miles, and includes two Project Areas: Mogul (6.4 mi^2) and Verdi (3.7 mi^2). A map depicting the location and general features of the Truckee Canyon Basin is included in Appendix A.

The following geologic and hydrogeologic information for the Truckee Canyon hydrobasin is summarized from a report by Widmer, 2007.

The Truckee Canyon hydrobasin is bound by the Verdi Range to the west, Peavine Mountain to the North, and the Carson Range to the south. The Truckee River flows north towards Verdi, then flows east through Mogul and Reno. Perennial creeks include Dog and Roberts Creeks, as well as several unnamed ephemeral tributaries.

There are five geologic units in the basin: a thin veneer (<100 ft) of Quaternary alluvial Truckee River deposits; Tertiary sediments; Tertiary volcanics; Mesozoic Metavolcanics; and Cretaceous Granodiorite. The tertiary sediments, now known as the Verdi Basin Sediments, have been commonly associated with the Truckee Formation, the Coal Valley Sequence, and the Sandstone of Hunter Creek. This unit consists of diatomite, silt and mudstone, sandstone, and conglomerate.

Precipitation on the valley floor ranges from 15" to 22" annually. Ground-water recharge in the basin is estimated at 4,000 to 5,000 AFY. Three aquifer systems that decrease in permeability with depth are known to exist: a phreatic system tied to the Truckee River, underlain by a semi-confined sedimentary rock aquifer, underlain by a volcanic rock aquifer with connectivity to the upper aquifers. The ground-water cycle is estimated to be short, as recharged water quickly flows to the Truckee River. This is in part due to the minimal thickness of the shallow alluvial phreatic aquifer system. Ground-water gradients are found to be steep in the bedrock of the Verdi range, but flatten on the valley floor.

3.2.6 Cold Springs

The Cold Springs Hydrographic area encompasses 29.5 square miles with the Cold Springs Project Area covering 7.5 square miles. A map depicting the location and general features of the Cold Springs Basin is included in Appendix A.

The following geologic and hydrogeologic information for Cold Springs Valley is summarized from reports by Dowden et. al., 1982 and Van Denburgh, 1981.

The topographically closed Cold Springs hydrobasin is bounded on the west by Petersen Mountain, on the east by the Granite Hills, an unnamed sedimentary fault block on the southwest, and by Peavine Mountain on the Southeast.

Cold Springs Valley consists of seven geologic units comprising either valley-fill sediments or consolidated rocks. Quaternary valley-fill units from youngest to oldest consist of playa and lake-floor deposits; beach and delta deposits; and fan, sheetwash, and flood-plain alluvial deposits. Consolidated units from youngest to oldest consist of

Tertiary sedimentary rocks; Tertiary andesitic volcanic rocks; Cretaceous granitic intrusive rocks; and pre-Cretaceous metavolcanic and metasedimentary rocks.

Maximum depth of basin-fill sediments is unknown, but they are estimated to increase in thickness towards the southeast. They are known to be greater than 350 at one location and are estimated to reach a maximum depth of around 1,500 to 2,000 feet. Basin-fill sediments grade from permeable sands and gravels on the slopes to silts and clays on the playa.

The only perennial streams in the valley originate from Peavine Mountain far to the south. There are other channels in the valley, but they are ephemeral in nature. All streams in the Valley discharge into White Lake, a broad flat lake bed that remains dry except in response to appreciable runoff.

Ground-water recharge was estimated at 900 AFY by Rush and Glancy (1967). That estimate was revised by Van Denburgh (1981) and Dowden (1982) to be around 500 AFY. Ground-water flow in Cold Springs Valley is generally towards the center of the valley, towards White Lake.

3.2.7 Spanish Springs

The Spanish Springs Hydrographic area encompasses 80.1 square miles, with the Project Area covering 11.1 square miles. A map depicting the location and general features of the Spanish Springs basin is included in Appendix A.

The topographically closed valley is typical of Nevada Basin and Range geology with its north-trending alluvial-fill basin, which is down-faulted relative to the adjacent mountains (Harrill, 1973).

Spanish Springs Valley is bounded on the east by the Pah Rah Range and on the west by Hungry Ridge. A narrow (~0.5 mile) topographic divide between Hungry Ridge and the Pah Rah Range separates Warm Springs Valley to the north and Spanish Springs Valley to the south. The bedrock-dominated southern boundary includes a low alluvial divide where the Orr Ditch enters and the North Truckee Drain exits the basin (Berger et al., 1997).

The valley is filled with unconsolidated igneous, volcanic, and metavolcanic sediments derived from the surrounding mountains and playa lake deposits (Cochran et al., 1986). The erosional valley fill material consists of clay, silt, fine to coarse-grained sand, and gravel. The playa lake deposits consist mostly of clay, silt, and fine-grained sand. Coarse fill materials are located near the mountain fronts while finer deposits are located near the center of the valley, coincident with the historical locations of the playa lakes.

Berger et al. (1997) identified five major geologic units in the valley, but segregated them into two general groups based on their hydrogeologic properties: (1) basin fill, generally of high porosity and transmissivity, and (2) consolidated rock, generally of low porosity and permeability, except where fractured.

The basin-fill unit, consisting of younger and older alluvium, comprises the most productive zones of ground water in the Valley (Harrill, 1973). Lithology of the unconfined valley-fill material includes clay, silt, sand, and gravel. The valley fill is estimated to have a maximum thickness of approximately 1,000 feet along the western boundary of the modeled study area and thins toward the bedrock outcrops around the valley perimeter (Berger et al., 1997).

It is estimated that around 8 in/yr precipitation falls on the valley floor and has an insignificant impact on ground-water recharge (Berger et al., 1997). Little natural surface water flows in the valley, as prolonged storm events occur infrequently. Being a closed basin with no natural surface outflow, intermittent surface waters collect in the southern portion of the Valley and eventually evaporate or infiltrate.

The Orr Ditch has been importing Truckee River water to the southern portion of the valley since 1878 for agricultural use; which, in turn supplements ground-water recharge (Berger et al., 1997). Orr Ditch water returns to the Truckee River through the North Truckee Drain. It originates within the south-central portion of the valley and transmits unused irrigation water and possibly ground-water discharge south to the Truckee River (Berger et al., 1997). Irrigation watering demands are greatest in the summer months from April through September, and drops off from October to March when flows are restricted to lower-flow stock-watering demands (Berger et al, 1997). From 1976 through 1984, surface water inflow from the Orr Ditch averaged 16,600 acre-ft annually and decreased from 1985 through 1994 when flows averaged just 9,220 acre-ft per year (Berger et al, 1997). An overdraft situation is likely to occur as Orr Ditch deliveries are reduced by more than 90% at total build-out of approved development in the valley (ECO:LOGIC, 2004).

3.3 Sources of Nitrate

Nitrate (NO_3^-) is an inorganic anion resulting from the natural biological and physical oxidations of elemental nitrogen and is ubiquitous in the environment (Ridder and Oehme, 1974). Nitrate is an essential nutrient for plant growth and plays a major role in the nitrogen cycle of soil and water. Nitrates exist in both organic and inorganic forms. Organic forms of nitrate are found in explosives, pharmaceuticals, natural fertilizers, animal waste, atmospheric deposition, and human sewage. Inorganic forms of nitrate include chemical fertilizers such as potassium nitrate and ammonium nitrate.

Nitrate occurs naturally in soils containing nitrogen-fixing bacteria and decaying plants, and has been found trapped in deep vadose zones in desert environments (Hartsough, 2001; Walvoord, et. al., 2003). Naturally-occurring concentrations of nitrate in the subsurface can be from “dissolution of nitrogen-bearing minerals, evaporative concentration, and infiltration of water through organic material.” (Lopes, 2006)

Animal sources of nitrate are assumed to have minimal leaching impact due to near-surface processes acting on animal waste such as plant fixation, soil adsorption, volatilization, and low infiltration rates – especially in the arid west (Zhan and McKay, 1998; Widmer and McKay, 1994; Seiler, 1996).

3.4 ISDS Effluent Source

Although there are several sources for nitrate contamination, this study focuses on the ISDS effluent source. This is mainly due to previous studies in Spanish Springs Valley (Rosen et. al., 2006), Golden Valley (Widmer and McKay, 1994), Washoe Valley (McKay, 1991; Zhan and McKay, 1998), and Lemmon Valley (Widmer and McKay, 1994; Seiler, 1996) that found ISDS effluent to be the major source of nitrate contamination in the aquifers under investigation. In fact, in Spanish Springs Valley, Seiler (2005) found that "the principal cause of elevated NO_3 concentrations in residential parts of the study area is wastewater and not natural NO_3 or fertilizers".

In the United States, it is estimated that approximately one-third of the nation's sewage is disposed of via ISDS (Finnemore, 1993; Harman et. al., 1996;). Most of these systems occur in urban fringe and rural residential areas as well as rural institutional buildings and recreational developments (Finnemore, 1993).

The purpose of an ISDS is to collect domestic wastewater, convert harmful human wastes to nitrate, and discharge its effluent; not prevent the contamination of ground water. ISDS removes solid waste from wastewater when the heavier solids settle to the bottom of the tank and the lighter weight material floats to the surface of the tank and forms a mat of scum. Bacteria digest the solids, reducing the volume of solids in the tank and leaving wastewater to be discharged. In the tank, bacteria decomposes the human wastes into ammonia and carbon dioxide. Ammonia combines with water and forms ammonium ions (Kaplan, 1991). A drainfield, composed of perforated plastic pipe is buried in a gravel-lined trench. Wastewater from the tank discharges through the holes in the pipe and seeps down through the gravel lined trench. Wastewater laden with ammonium ions is then filtered in the trench and the soil and broken down by microbes along the way. Aerobic bacteria oxidize the ammonium and through almost complete nitrification, ammonium is converted to nitrate (Wilhelm et al., 1994). In the soil, if bacteria have a carbon-rich and anaerobic environment, nitrate is converted to nitrous oxide and molecular nitrogen . Through denitrification, these gases then escape to the atmosphere (Kaplan, 1991). Studies by the USGS and WCDWR in Spanish Springs show that denitrification below the leach line is around 25% (Rosen et al, 2006). Nitrate that is not denitrified is then transported to the groundwater under the influence of the effluent plume emanating from the ISDS.

ISDS effluent discharge rates vary considerably in the literature. The United States Environmental Protection Agency (USEPA) estimates 45 gallons per day per capita (135-180 gallons/day for a three bedroom home). Previous work in Washoe County estimated ISDS effluent discharge at 200 gallons per day per house (g/d/h) (Widmer and McKay, 1994). Recent estimates for ISDS effluent in Spanish Springs Valley independently estimated effluent at 228 g/d/h from usage records and 233 g/d/h from modeling efforts for a rough average of 230 g/d/h. This value was used for mass balance modeling efforts between the USGS and the WCDWR (Rosen et al, 2006).

Harman et al (1996) found that nitrate concentrations in ground water increased as ISDS densities increased. In Spanish Springs Valley, where ISDS densities were up to 500 per square mile (before 10% were converted to sewer), concentrations of nitrate in ground water beneath these subdivisions are greater than 73 mg/L. In modeling work and field evidence collected by Pang et al (2006), they found that clustered ISDS have a cumulative impact on nitrate concentrations in ground water; but have only a localized effect on fecal coliform concentrations in ground water.

Sensitivity analysis on mass balance models conducted by Bauman and Schafer (1985) state that there are four variables that "are most responsible for large changes in predicted groundwater nitrate-nitrogen: 1) hydraulic conductivity and gradient, 2) natural recharge, 3) housing unit density, and 4) concentration of effluent nitrate-nitrogen reaching the water table." In addition, when nitrate loading is a significant component of recharge, as in the case of ISDS effluent, and that effluent represents a significant percentage of total recharge, the potential for ground-water nitrate contamination increases. This has occurred in Lemmon Valley and Golden Valley (Widmer and McKay, 1994) in addition to Spanish Springs Valley (Berger, 1997; Rosen et. al., 2006).

3.5 Nitrate in the Environment

The proliferation and migration of nitrate in the environment is dependent upon several sources important in this study. Geologic, hydrogeologic, and recharge considerations need to be taken into account.

3.5.1 Geology

The terrestrial environment allows nitrate to percolate below the root zone and through the intermediate vadose zone to the underlying aquifer and potentially recharge deeper aquifers. Nitrate may also be discharged to surface water and eventually reach ground water over time. At greater depths, ground water generally moves slowly; however, under the influence of ground-water gradients, contamination tends to remain concentrated in areas, so that even after nitrate sources diminish, contamination can remain for decades or longer, and in most cases, reclamation is difficult or impossible (Follett, 1995). It has also been noted that nitrogen contamination may only be detected in a deeper aquifer system after 15-50 years (Aldeman, et. al., 1985 and Cary, 1985)

Well-drained soils easily transfer nitrate to the water table, while poorly drained soils tend to impede nitrates from leaching into ground water despite elevated levels of nitrates (Nolan, 2001). In addition, well-drained soils over unconsolidated sand and gravel aquifers are highly permeable and are the most vulnerable to contamination; Conversely, confined aquifers provide a level of protection due to the presence of a confining layer (Clawges, et. al., 1999).

3.5.2 Hydrogeology

Some research suggests that "higher conductivities and gradients result in higher ground-water velocities, providing a greater diluting capacity (lower nitrate-N concentration) for the system" (Bauman and Schafer, 1985). Pang et. al., 2006 also found that high hydraulic conductivities resulted in higher ground-water flux and lower nitrate concentrations. Conversely, they found that low hydraulic conductivity aquifer materials do not allow discharged effluent to be flushed away easily, resulting in an increase in nitrate concentration. The same study also identifies lower gradient and conductivity ground-water systems as having little dilution capacity and potentially more susceptible to "appreciable contamination".

Given the arid conditions and generally shallow ground-water gradients at basin centers in Washoe County, the following statement is relevant: "Geographical areas with higher precipitation and infiltration will be better able to dilute septic system nitrogen…arid and semi-arid parts of the country may be at greater risk from such contamination" (Bauman and Schafer, 1985). If areas in this study are found to have high soil permeabilities coupled with known low rainfall recharge, this could lead to a significant impact to water quality over time as septic effluent will recharge ground water faster through highly permeable soils and will not benefit from dilution due to low precipitation rates on valley floors.

3.5.3 Recharge

Climate and the water balance are equally important in predicting nitrate contamination, as lower precipitation and high recharge rates result in higher nitrate concentrations at the water table due to the lack of dilution by infiltration from good quality water (Hantzsche and Finnemore, 1992). Hantzsche and Finnemore (1992) also suggest that "the greatest potential for ground-water nitrate-nitrogen problems arises in areas of low rainfall recharge and high development density." Both of these conditions exist in Spanish Springs Valley and in many of the basins and Project Areas under consideration in this study.

3.6 Nitrate and Drinking Water

Nitrate is a federally regulated drinking water contaminant. The USEPA sets the standards for water quality regulations under the Safe Drinking Water Act (SDWA) and its amendments (SDWA 1974). The SDWA defines the concentrations above which adverse human health effects may occur as the maximum contaminant level (MCL) (USEPA 2002b). This MCL may only be enforced on public drinking water systems and government or privately run water purveyors supplying drinking water to ≥ 25 people or with ≥ 15 service connections (USEPA 2003); household domestic wells are not covered under the USEPA regulations. The MCL for nitrate in drinking water is set at 10 mg/L (ppm) as nitrate-nitrogen (nitrate-N). All values presented in this report are as nitrate-N.

Nitrogen loading is important to monitor for several reasons. High drinking water nitrate levels have been shown to cause methemoglobinemia (a potentially lethal decreased ability of the blood to transport oxygen) in infants (Cambareri, 1989). As a co-occurring contaminant, high nitrate concentrations in ground water have also been correlated with higher concentrations of regulated drinking water contaminants, such as volatile organic compounds (Eckhardt, et al, 1986; Lopes, 2006). However, the link of high nitrate levels to methemoglobinemia is the most well-established and extensive research leading to the calculation of a MCL of 10 ppm nitrate-N (Cambareri, 1989)

Nitrate contamination in surface waters can lead to eutrophication – an environmental effect of excessive nutrient inputs. Nutrient enrichment leads to abundant growth of algae and aquatic plants, that when decomposing, consumes large quantities of oxygen, leading to fish kills and increased water-treatment costs (Puckett, 1994).

Nitrates do not bind with soils, are highly water soluble, and travel with ground water with little or no retardation or degradation. These characteristics allow for the high likelihood of nitrates to impact surface or ground water. Nitrates do not evaporate thus, allowing them to remain in water until consumed by plants or other organisms. In addition, nitrates remain in soil until consumed by plants or other organisms, or, until flushed from the soil by recharging waters.

The characteristics that make nitrate a common contaminant in ground water also allow it to persist for decades and accumulate to high levels in ground water (Nolan et. al., 1998). Since it is a conservative solute, nitrate tends to accumulate in ground water; degraded only by limited denitrification and dilution capacity within an aquifer (Pang et. al., 2006).

Risk analysis models developed by the USGS concluded that “nitrate contamination of ground water is not caused by any single factor, but depends on the combined, simultaneous influence of factors representing Nitrogen loading sources and aquifer susceptibility characteristics” (Nolan, 2001). The possibility of nitrate impacting ground water and ultimately water supply wells depends on several factors including source, geology, recharge, and supply well specifications. Source considerations include source type and age, as well as density and magnitude of source zones. Geologic controls include the type and thickness of soil and bedrock, and their hydrogeologic makeup. Aquifer recharge considerations include precipitation, surface water, recharge basins, septic effluent, irrigation (parks, golf courses, agriculture, and domestic lawn watering). Water supply well concerns include flow gradient and proximity to source, depth and length of screen, and pumping rate.

Nitrate concentrations typically decrease with depth within an aquifer mainly due to the increasing age of the ground water with depth (Nolan et. al., 1998; Lopes, 2006). Nitrates have been shown to remain stratified in the upper portions of the aquifer in Spanish Springs Valley and in other studies (Hill, 1982; Spruill, 1983). Aquifer stratification due to heterogeneity may also contribute to limiting the vertical extent of contamination (Bauman and Schafer, 1985). Age-dating analysis in Spanish Springs Valley (Kropf, 2007) and throughout Nevada (Lopes, 2006) shows a decreasing ground-water age with increasing nitrate contamination, indicative of urban development increasing nitrate concentrations in ground water. Typical mixing depths are on the order of 40 to 80 feet (Bauman and Schafer, 1985) and were shown to be approximately 60 feet in work on-going in Spanish Springs Valley (Kropf, 2007).

However, ground-water pumping affects water quality by vertically mixing shallow contaminated water with deeper water within the aquifer system. Studies in Lemmon Valley and Golden Valley indicate that pumping effects may draw down contamination into cones of depression under the influence of pumping (Widmer and McKay, 1994). In Spanish Springs Valley, cones of depression in residential areas created by large municipal supply wells (Berger et al, 1997) may enhance downward migration of shallow ground water containing ISDS effluent toward the deeper portions of the aquifer (Seiler, 2005; Lopes, 2006).

Once nitrate enters the ground water, dilution and denitrification have the greatest impact on reducing nitrate concentrations, with denitrification permanently removing nitrate and dilution merely lowering the concentration but not the total mass of nitrogen in the system (Poiani, 1996). Although dilution reduces nitrate concentrations in the short term, it is not a long-term solution due to the decreasing dilution capacity of the aquifer over time (McCray et. al., 2005).

Methods of treatment exist to remove nitrate at the wellhead or at a treatment facility, including dilution/blending, biological removal, chemical precipitation, membrane technology (reverse osmosis), and ion exchange (White, 1996). In-situ treatment methods have some potential and include mound systems and low pressure dosing (Crist et. al., 1996) as well as denitrifying septic systems. Nitrate removal approaches employing bioremediation include bacterial denitrification with carbon enhancement (Lamarre, 1998) and constructed wetlands (Crist et. al., 1996).

Nolan et. al. 2002, state that "groundwater with nitrate concentration greater than 10 mg/L is nearly impossible to remediate." Given this dilemma, prevention is our best resource in reducing groundwater contamination. Studies have shown that addressing nitrate contamination through investment in best management practices is more cost-effective in reducing contamination than to seek alternate sources of safe drinking water supplies (Yadav and Wall, 1998).

3.7 Nitrate as an Indicator Contaminant

Elevated levels of nitrate in ground water (above background) can be an indicator of overall water quality degradation. The natural background concentration for nitrate is typically ≤ 2 mg/L (Mueller and Helsel, 1996; Lopes, 2006). Concentrations of nitrate above 3 mg/L (Edwin and Tesoriero, 1997) or above 4 mg/L (Nolan et. al., 2002) are typically seen as being impacted by anthropogenic sources of nitrate.

Anthropogenic influence may suggest the possible presence of other contaminants such as disease-causing organisms, pesticides, or other inorganic and organic compounds that could pose health concerns. ISDS effluent may also contain endocrine disruptors, carcinogens, bacteria, viruses, detergents, cleaners, antibiotics and other prescription medications, personal care products, and plasticizers (Swenson and Evenson, 2003). In fact, microbial contamination of ground water causes more than 50% of the water-borne disease outbreaks in the U.S. (Woessner et. al., 2001)

Concentrations of nitrate in ground water, above background levels, is typically indicative of contamination resulting from human influence, land-use changes, and development (Cambereri et. al., 1989). Human activities that effect contaminant levels include lawn fertilizers, ISDS effluent, sewer pipe leaks, industrial wastes, animal manure, automobile exhausts, and industrial smokestacks (Clawges et. al., 1999).

Work by the University of California, Davis found that “if nitrate-loading rates do not decline appreciably, historical breakthroughs of contaminants at wells merely represent the beginning of a gradual deterioration in ground water quality” (Fogg, 2001). In addition, Fogg et. al. (1999) notes a “significant time lag existing between the solute arrival at the water table and its presence in water supply wells.”

If an aquifer is susceptible to nitrate contamination, it is reasonable to expect that the aquifer is also susceptible to contamination from other forms of water-soluble chemicals. Potential inorganic contaminants include nitrogen, chlorides, phosphorous, and metals.

Nitrate was used as the only indicator contaminant of concern in this study due to its persistence and the fact that it is frequently measured in water quality analyses. Also, according to Lopes, 2006, wells in Nevada “that had nitrate-N concentrations > 2 mg/L had significantly more detections of pesticides and volatile organic compounds than wells that had nitrate-N concentrations < 2 mg/L.”

3.8 Previous ISDS Studies in Washoe County

Although there are several sources for nitrate contamination, this study focuses on the ISDS effluent source. This is mainly due to previous studies in the Verdi Area (Mahin, 1985), Golden Valley and Lemmon Valley (Widmer and McKay, 1994), Washoe Valley (McKay, 1991; Zhan and McKay, 1998) and Spanish Springs Valley (Seiler, 2005; Rosen et al, 2006) that found ISDS effluent to be the major source of nitrate contamination in ground water under investigation. In fact, in Spanish Springs Valley, Seiler, 2005 found that “the principal cause of elevated nitrate concentrations in residential parts of the study area is wastewater and not natural nitrate or fertilizers”.

3.8.1 Verdi Area

A tracer study completed by the WCDWR in 1985 assessed the impact of ISDS to the Truckee River in the Verdi area. Prior to this study, the Nevada State Department of Health recognized ISDS as the source of ground-water contamination as early as 1935. And in 1951, a USGS study found that bacterial contamination of the ground water in the area was due to ISDS, cesspools, and outhouses (Robinson et. al., 1951). The 1985 WCDWR study was conducted to observe if chemical contamination of ground water from ISDS is coincident with bacterial contamination, since the USGS study in 1951 did not collect chemical water quality analyses. This contaminated ground water could be transported via a spring that discharges to the Truckee River at two cubic feet per second.

The WCDWR study found faster-than-expected travel times from the ISDS to monitoring locations, and indicated a ground-water velocity of about 190 to 350 meters per day (623 to 1,148 feet per day). Travel time from the center of Verdi to the Truckee River was estimated at four days and was not seen as adequate time to remove pathogens before entering the river or impacting wells that depend on the alluvial aquifer. The study also estimated approximately 3,000 to 6,600 pounds of nitrogen enter the Truckee River each year from the 220 residences in Verdi on ISDS at that time. Ground-water flow from upgradient of the central Verdi area was assumed to dilute the contaminants, but the extent to which this may happen was not determined.

3.8.2 Lemmon Valley Basin

A study by the WCDWR in 1994 found that concentrations of nitrate in domestic wells in the Lemmon Valley basin were above the MCL of 10 ppm for nitrate-N (Widmer and McKay, 1994). The two areas most affected by ISDS effluent were Golden Valley and the Heppner Subdivision. Both areas have experienced ground-water mining resulting in water level declines of as much as 60 feet from 1974 to 1994, with an estimated continued decline of one to three feet per year. Resultant large cones of depression under each area may contribute to concentrating ISDS effluent in the ground water (Widmer and McKay, 1994).

3.8.2.1 Heppner Subdivision

At the time of the report published in 1994, ground-water pumpage exceeded recharge by 520 AFY. It is believed that this deficit is made up from ISDS effluent recharge. This effluent recharge is also believed to be equal to or more than natural recharge in this valley. According to the report, livestock feces appear to be a significant additional contributor to ground water nitrate concentrations. The report also noted temporal trends depicting a nitrate increase from a maximum of around 4 mg/L in pre-1985 data to around 13 mg/L in post-1985 data (Widmer and McKay, 1994).

3.8.2.2 Golden Valley

Ground-water withdrawals in Golden Valley are even more extreme, with pumpage exceeding natural recharge by as much as 500% at the time of publication in 1994. Maximum concentrations of nitrate in this valley increased from 15 mg/L In 1984 to 19 mg/L in 1993. The study also noted an “increasingly pervasive “spreading” of above-background-level nitrate occurrences in Golden Valley” (Widmer and McKay, 1994). The study observed that the ISDS effluent contamination is largely controlled by soil conditions, especially where fast draining soils exist.

3.8.3 Cold Springs

The WCDWR has sampled monitoring wells throughout HDI parcels for nitrate for a number of years. Data from 1991, 1997, and 2001 indicate that nitrate has risen above the MCL of 10 mg/L in the shallow ground water. A ground-water flow and contaminant transport model was developed for a portion of Cold Springs Valley in 1992. This model was developed to evaluate potential impacts to ground water from a development that was to be constructed with ISDS. The results of the model indicated that nitrate concentrations would increase over time past the MCL of 10 mg/L (Simon Hydro-Search, 1992).

3.8.4 Washoe Valley

Zhan and McKay (1998) modeled nitrate concentrations in ground water on the east side of Washoe Valley. Water quality samples obtained in previous studies (Armstrong and Fordham, 1977; McKay, 1991) found elevated levels of nitrate in ground water above the MCL of 10 mg/L. Although it is assumed that nitrate in ground water resulted from ISDS effluent as well as animal waste, Zhan and McKay (1998) found that ISDS effluent was the most significant nitrate contributor, as there was no spatial correlation between animal corrals and high nitrate levels.

3.8.5 Spanish Springs Valley

Using mass balance models (Bauman and Schafer, 1985; Hantzsche and Finnemore, 1992) the WCDWR and USGS developed forecasts for Spanish Springs Valley (Rosen et. al., 2006). Results of their extensive field work and sample collection concluded that nitrate concentrations ranged from less than 3 mg/L to around 400 mg/L from soil water directly below ISDS leach fields. Rosen et. al, 2006 also found that this ISDS effluent impacted ground water adjacent to these leach fields at concentrations from 6.2 mg/L to 31.2 mg/L, with a median value of 15.3 mg/L. Using the median value of 44 mg/L nitrate emanating from the bottom of the leach fields (after denitrification of approximately 12-25%), the study concluded that nitrate concentrations in the Valley over time could reach 29 mg/L nitrate (Rosen et. al., 2006).

Studies currently underway in the Valley show concentrations of nitrate as high as 73.5 mg/L with an average concentration within HDI parcels of 15.5 ppm during Third Quarter, 2007. Concentrations of nitrate have increased in shallow ground water from 22 mg/L to 73.5 mg/L in the most contaminated well in the five-year period that water quality data has been collected. Since municipal wells were installed in Spanish Springs Valley, concentrations in municipal wells have reached maximum concentrations of 10 mg/L in DS#1, DS#3, and SC#3; 6.1 mg/L in SC#2; and 5.6 in DS#4.

This study, along with Bauman and Schafer (1985) and Hantzsche and Finnemore (1992) show the important relationship between ISDS recharge and natural recharge over a limited aerial extent. In Spanish Springs, the recharge from ISDS effluent versus precipitation is estimated to occur at a factor of 10 to 1 (Kropf, 2002). Natural recharge is an important component in these studies because it is the primary diluting factor in areas of ISDS recharge, since most if not all of the HDI are located near valley centers away from mountain front recharge. Recharge from precipitation at the valley floor is often estimated as negligible due to evapotranspiration.

Nitrate contamination appears to be coupled with increased development as well. As shown in Figure #2, nitrate concentrations have increased steadily since development of homes on ISDS began in earnest in 1979. Given the variability in ground-water age-dating results, the sample with an age-date of 1975 was left out of the analysis on the table because it could as easily be identified as post-development as pre-development. In addition, ground-water age dates confirm that recently discharged waters are the most shallow and highly contaminated ground water (Kropf, 2006). As depicted in Figure #3, average concentrations of nitrate in shallow ground water beneath HDI versus samples collected from areas outside HDI shows an almost 17-fold increase in nitrate under HDI parcels (16.8 mg/L versus 1.1 mg/L).

4.0 Methods

A qualitative approach was used to analyze the data as a quantitative analysis was beyond the scope of this study. A quantitative analysis of aquifer vulnerability in Nevada, by Lopes (2006), showed that weak correlations existed between nitrate, well depth, and clay layering. Although weak, these correlations indicate that nitrate is from sources near land surface. Based on previous studies in Washoe County, the most-likely source for this nitrate is from ISDS effluent. Given the amount of data and analysis required to come to that conclusion, this study focuses on qualitative comparisons between characteristics of basins with a history of confirmed ISDS effluent nitrate contamination as well as areas having similar characteristics in neighboring basins.

Data sets for the RSMA are plentiful, but contain many data gaps. These data gaps will be addressed in a later section. Numerous data sets were compiled to investigate ten main properties: ISDS location and density, parcel size, water quality, proximity to sensitive receptors, water supply well capture zones, depth to water, recharge from precipitation versus ISDS, geology, and soils. The available data was compiled from numerous sources, including: WCDWR, TMWA, the Nevada Division of Environmental Protection (NDEP), USGS, and the U.S. Department of Agriculture (USDA).

The final outcome of this study is a prioritized list of Project Areas that may pose a threat to water quality in the RSMA. To create this list, data from a smaller and less subjective subset of parameters was analyzed quantitatively where possible to remove bias and subjectivity. Final rankings are qualitative in that they are ranked against other Project Areas and not a definitive set of variables. Final recommendations are qualitative also, in that they include special circumstances specific to a Project area and incorporate variables that are not easily comparable between Project Areas.

Collected data is organized into tables within this report, and represented graphically in a geographic information system (GIS) in the form of a map. All maps are included as

Appendices, by Project Area. For example, any maps associated with the Ambrose Park Project Area are included in Appendix B: Ambrose Park.

4.1 Identification of Project Areas

The first step in this process was to identify all ISDS within Washoe County, paying special attention to those occurring in areas of high population density. All parcels on ISDS were identified easily within GIS using the Washoe County parcel base. Project Areas were identified as simply having HDI within a easily-defined geographical area. Areal extent of the Project Areas were just large enough to include the HDI parcels and any nearby sensitive receptors. Once all the parcels on ISDS were identified and located on a map, an ISDS density was calculated based on the number of parcels on ISDS within the Project Area boundary. This information is plotted on Figure #4 for the major metropolitan area of Reno and Sparks. Individual maps of ISDS density by basin and by Project Area are shown in the Appendices.

The information allowed the project team to investigate appropriate areas within the RSMA. Sixteen areas of elevated ISDS density were identified, ranging from a density of 61 ISDS per square mile in Pleasant Valley to 177 ISDS per square mile in Cold Springs. These Project Areas were defined by a boundary within which all data collection and subsequent GIS analysis would occur. They were then ranked from highest to lowest ISDS density and subsequently by the total number of ISDS within the Project Area in the case of similar ISDS densities. This ranking provided the initial prioritization for the study areas. The initial ranking is listed below in Table #1.

Table 1. Initial Ranking Based on ISDS Density within Project Area

Project Area Name	Project Area ISDS Density (per mi^2)	Number of ISDS within Project Area	Rank
Cold Springs	177	1,325	1
Spanish Springs	166	1,848	2
Island 18	130	907	3
Geiger	130	858	4
Hidden Valley	113	780	5
Washoe	103	1,296	6
Heppner	101	954	7
Verdi	92	341	8
Mogul	85	544	9
Mt. Rose	82	1,026	10
Ambrose	82	475	11
Silver Knolls	81	529	12
Golden Valley	79	845	13
Huffaker	74	1,746	14
New Washoe	64	197	15
Pleasant Valley	61	535	16

With all ISDS located and an initial ranking established, all work completed after this step was to refine this initial ranking. The prioritization process continued and was refined using the following parameters: ISDS density analysis, water quality, depth to water, capture zones, geology, recharge from precipitation and ISDS effluent, and soils. The following sections go into more detail for each parameter.

4.2 Parameters

4.2.1 ISDS Density

As noted above, parcels on ISDS were the first parameter analyzed in order to obtain some basic information about the number of ISDS in the RSMA, their location, and their density.

Analysis of ISDS per Project Area versus ISDS per Basin indicates that the majority of the ISDS within a basin were captured within the defined Project Area. In fact, the percent of all ISDS in a basin located within each Project Area ranged from 79% in Spanish Springs Valley to 95% in Cold Springs Valley. This was deliberate, in order to focus on the major impact from ISDS rather than on the basin as a whole. This, in effect, treats these HDI areas as a single large point source rather than as a collection of non-point sources. It points out that approximately 80% to 95% of the ISDS effluent discharged to ground water within a basin, regardless of basin size, is occurring in a well-defined area. ISDS located outside of these project boundaries, 5 to 21% of all ISDS within a basin, occur on large parcels, are not densely located, and/or are located in comparatively large basins. These lots could be treated as non-point sources of ISDS effluent.

Using GIS, a new ISDS density was created which places less weight on the overall project area and more weight on the actual density of ISDS. This density is calculated in GIS based on the number of parcels on ISDS within a one square mile area within a 50 square foot grid in each Project Area. Densities ranged from 50 ISDS per square mile in Pleasant Valley and New Washoe to 350 ISDS per square mile (sq. mi.) in Cold Springs. The modified ranking based on weighted ISDS density is listed below in Table #2.

Table 2 Ranking Based on Weighted ISDS Density within Project Area

Project Area Name	Maximum ISDS Density (per mi^2)	Number of ISDS within Project Area	Previous Rank	New Rank
Cold Springs	350	1,325	1	1
Spanish Springs	300	1,848	2	2
Huffaker	300	1,746	14	3
Washoe	300	1,296	6	4
Geiger	300	858	4	5
Island 18	250	907	3	6
Heppner	200	954	7	7
Hidden Valley	200	780	5	8
Mt. Rose	150	1,026	10	9
Golden Valley	150	845	13	10
Mogul	150	544	9	11
Silver Knolls	150	529	12	12
Ambrose	150	475	11	13
Verdi	100	341	8	14
Pleasant Valley	50	535	16	15
New Washoe	50	197	15	16

The State of Nevada recommends a density of no greater than 200 ISDS per square mile per basin before requiring a ground-water study be performed to assess the impact to water quality (Nelson, 1991). Nelson (1991) identified many basins that require a ground-water study at much lower ISDS density thresholds. Table #3 below lists basins in this study and their corresponding ISDS density limit identified by the State of Nevada along with the maximum density identified in the basin by this project.

Table 3 ISDS limit per basin identified by the State of Nevada

Basin Name	State of Nevada ISDS Density Limits per Basin	Maximum Density Identified w/in the Basin
Spanish Springs	118	300
Cold Springs	92	350
Lemmon Valley	138	200
Truckee Canyon	188	150
Truckee Meadows	120	300
Pleasant Valley	170	150
Washoe Valley	200	300

All basins except for Pleasant Valley and Truckee Canyon exhibit densities greater than those recommended by the State of Nevada. The average for the basins in this study is approximately 150.

Additional analysis of the GIS ISDS density data was completed to investigate parcel size in relation to ISDS density. Based on the average ISDS limit of 150 per square mile for the basins listed above, a contour interval 150 units per square mile was used in the following analysis. Lower contour intervals were used for the Pleasant Valley, New Washoe, and Verdi Project Areas. Table #4 displays the average parcel size on ISDS within the Project Area as well as within the 150 IDSD/square mile contour interval.

Table 4 ISDS parcel size within Project Area and within 150 density contour

Project Area Name	Avg Size ISDS Parcel Project Area (acres)	Rank		Avg Size ISDS Parcel Within 150 Density Contour (acres)	Rank		Joint Rank
Hidden Valley	0.5	1		0.4	1		1
Island 18	0.7	2		0.6	2		2
Cold Springs	0.9	3		0.6	3		3
Mogul	1	4		0.8	4		4
Ambrose	1.1	5		0.9	6		5
Spanish Springs	1.2	6		0.8	5		6
Geiger	1.2	7		0.9	7		7
Verdi	1.2	8		0.9	8		8
Heppner	1.4	9		1.1	10		9
Mt. Rose	1.4	10		3	16		13
Golden Valley	1.6	11		1.2	11		10
New Washoe	1.7	12		1.4	12		12
Huffaker	1.8	13		1	9		11
Washoe	1.8	14		1.4	13		14
Silver Knolls	2	15		2.2	15		15
Pleasant Valley	2.3	16		2	14		16

In general, the ISDS parcel size within the 150 ISDS/sq. mi. density contour decreases in size. This is expected, as a higher density requires a smaller lot size. An increase in lot size can be attributed to few lots occurring within the 150 ISDS/sq. mi. density contour, and those that do are larger lots (see Mt. Rose and Silver Knolls Septic Density maps).

4.2.2 Water Quality

Water quality data (if available) was collected from any and all wells located within each Project Area. As described above, nitrate is an excellent indicator of anthropogenic contamination of ground water and, therefore, was used as the sole water quality indicator. In addition, it is almost always analyzed in samples collected for water quality analysis. Water quality data sets were collected from the following sources:

- Washoe County Department of Water Resources
- Washoe County District Health Department
- Nevada Department of Conservation and Natural Resources
- Truckee Meadows Water Authority
- Central Truckee Meadows Remediation District

Nitrate concentrations were plotted on the Project Area maps using GIS. Average concentrations of nitrate within each Project Area ranged from 0.3 mg/L in Hidden Valley to 11.9 mg/L in Golden Valley. Maximum nitrate concentrations ranged from 0.5 in Hidden Valley to 63.9 mg/L in Spanish Springs. These maps can be found in Appendices by basin. Analysis of these maps is shown below in Table #5.

Table 5 Ranking Based on Water Quality within Project Area

Project Area Name	Avg. Nitrate (ppm) Project Area	Rank		Max Nitrate (ppm) Project Area	Rank		Joint Rank
Golden Valley	11.9	1		36	3		2
Spanish Springs	11.2	2		63.9	1		1
Washoe	5.3	3		49.2	2		3
Cold Springs	4.5	4		24.5	6		4
Island 18	4.0	5		26	5		5
Heppner	3.4	6		20	7		6
Huffaker	2.2	7		12.5	10		8
Mt. Rose	2.1	8		12.7	9		9
Pleasant Valley	2.0	9		17	8		10
New Washoe	1.9	10		5.9	14		12
Silver Knolls	1.7	11		27	4		7
Geiger	1.2	12		7.3	12		11
Ambrose	1.1	13		5	15		15
Mogul	1.0	14		6.9	13		14
Verdi	0.6	15		11	11		13
Hidden Valley	0.3	16		0.5	16		16

This analysis accounted for the Project Area as a whole due to a lack of water quality data points within the 150 ISDS/sq. mi. density contour. For the ten Project Areas with sufficient data, nitrate concentrations remained high within the 150 ISDS/sq. mi. contour. Six of the ten Project Areas showed an increase in concentrations of nitrate within the 150 ISDS/sq. mi. contour compared to the average nitrate within the Project Area as a whole. This data is shown in table #6. .

Table 6 Comprehensive data for all Project Areas

Basin Name	Truckee Meadows (87)					Lemmon Valley (92A & 92B)			Pleasant Valley (88)		Washoe Valley (89)		Truckee Canyon (91)		Cold Springs	Spanish Springs
Project Area	Ambrose	Island 18	Hidden Valley	Huffaker	Geiger	Silver Knolls	Heppner	Golden Valley	Mt Rose	Pleasant Valley	Washoe	New Washoe	Mogul	Verdi	Cold Springs	Spanish Springs
# Parcels on Septic - Project Area	475	907	780	1,764	858	529	954	845	1,026	535	1,296	197	544	341	1,325	1,848
# Parcels on Septic - Basin	5,870					2,670			1,665		1,852		1,020		1,397	2,346
Basin included w/in Project Area	81%					87%			94%		81%		87%		95%	79%
Area (mi²) Project Area	5.8	7.0	6.9	24.0	6.6	6.5	9.4	10.7	12.5	8.8	12.6	3.1	6.4	3.7	7.5	11.1
Area (mi²) Basin	195.0					96.8			39.0		82.8		83.5		29.5	80.1
Max Density by GIS Analysis (per mi²)	150	250	200	300	300	150	200	150	150	50	300	50	150	100	350	300
Septic Density (per mi²) Project Area	82	130	113	74	130	81	101	79	82	61	103	64	85	92	177	166
Septic Density (per mi²) Basin	30					28			43		22		12		47	29
Septic Recharge (AFY) Project Area	122	234	201	454	221	136	246	218	264	138	334	51	140	88	341	476
Septic Recharge (AFY) Basin	1,512					688			429		477		263		360	604
G W Recharge (AFY) Basin	27,000					1,500			10,000		15,000		4,000		500	600
Recharge (per basin)	5%					31%			4%		3%		6%		42%	50%
Septic Loading Rate (in/yr) Project Area	0.40	0.63	0.55	0.36	0.63	0.39	0.49	0.38	0.40	0.29	0.50	0.31	0.41	0.45	0.85	0.80
Precip. Recharge (in/yr) Project Area	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Recharge to GW Septic to Precip Ratio	1.0	1.6	1.4	0.9	1.6	1.0	1.2	1.0	1.0	0.7	1.2	0.8	1.0	1.1	2.1	2.0
Avg Septic Parcel (acres) Project Area	1.1	0.7	0.5	1.8	1.2	2.0	1.4	1.6	1.4	2.3	1.8	1.7	1.0	1.2	0.9	1.2
Avg Septic Parcel (acres) in 150 SD contour	0.9	0.6	0.4	1.0	0.9	2.2	1.1	1.2	3.0	2.0*	1.4	1.4*	0.8	0.89**	0.6	0.8
Avg Depth to Water (ft) in Project Area	147.6	69.0	97.7	176.5	130	94.5	78.4	102.4	136	76.5	83.3	67.8	105.1	83.0	35.3	61.4
Avg Depth to Water (ft) in 150 SD contour	No Wells	No Wells	No Wells	124.5	2 Wells: 300 ft, 75 ft	98.5	89.9	78	153.8	56.6*	82.3	52.5*	116.8	44.3**	21.9	56.4
Avg Nitrate-N (ppm) in Project Area	1.1	4.0	0.3	2.2	1.2	1.7	3.4	11.9	2.1	2.0	5.3	1.9	1.0	0.6	4.5	11.2
Avg Nitrate-N (ppm) in 150 SD contour	No Wells	No Data	0.4	3.3	1.5	2.5	3.3	7.4	No Wells	2.0*	4.8	1.9*	1.2	0.28**	8.5	12.9
Max Nitrate-N (ppm) in Project Area	5	26	0.5	12.5	7.3	27	20	36	12.7	17.0	49.2	5.9	6.9	11	24.5	63.9
Max Nitrate-N (ppm) in 150 SD contour	No Wells	No Data	0.4	12.5	7.3	7.7	15.7	16.0	No Wells	17.0*	44.1	5.9*	6.9	2.6**	18.3	63.9

* Within 50 ISDS/sq. mi. contour

** Within 100 ISDS/sq. mi. contour

Water quality data was not uniform for most of the Project Areas and therefore should not be considered to be representative of water quality in the Project Area. Data was collected from monitoring, municipal, and domestic wells with varying screened intervals, pumping rates, and completion depths. The water quality data does not represent a specific aquifer horizon (shallow, deep, etc.) or even a snapshot in time of water quality. The data is simply a representation of potential impacts to ground water at varying depths, and it can be assumed that the most highly contaminated wells are the shallowest wells. At best it is a picture of the worst-case shallow ground-water nitrate contamination based on available data and available wells.

There are a few exceptions, such as Spanish Springs Valley, Golden Valley, Cold Springs, and Heppner, where sufficient data exists to make a more thorough determination of contaminant depth and extent. In these areas, ground-water nitrate concentrations are found to be higher simply because there are monitoring wells available to detect shallow ground-water contamination. The majority of the wells used in this study are domestic or municipal wells with deeper screened intervals – not monitoring wells that are typically screened across the initial shallow, unconfined aquifer.

Additionally, a Project Area with a low average nitrate concentration doesn't mean a problem doesn't exist. It may mean that there are not enough data points within a Project Area to adequately characterize the aquifer, especially shallow ground water. The opposite is true with more data points not necessarily resulting in adequate characterization of the aquifer, especially since most wells used in the analysis are deeper domestic or municipal wells. As noted in Table #7, the number of data points used in creating the nitrate maps varies considerably; from 177 wells in Washoe Valley to 7 wells in Hidden Valley.

Table 7 Number of data points used in water quality assessment

Project Area Name	Number of Data Points Used per Project Area
Washoe	177
Silver Knolls	128
Pleasant Valley	122
Verdi	86
Mount Rose	83
Cold Springs	58
Huffaker	54
Geiger	38
Spanish Springs	36
Island 18	23
Golden Valley	19
Mogul	18
Heppner	16
New Washoe	11
Ambrose Park	9
Hidden Valley	7

4.2.3 Proximity to Sensitive Receptors

Sensitive receptors are defined in this study as: public water supply wells and surface water bodies (Truckee River, creeks, and lakes). Sensitive receptors are identified on all Project Area maps included in the appendices. Domestic wells are sensitive receptors and may be impacted by ground-water contamination from ISDS; however, the State and local governments do not regulate domestic well water quality, and therefore are not included in this analysis. A qualitative analysis of proximity of parcels on ISDS to sensitive receptors was conducted for each Project Area. Distances were estimated from the closest parcel on ISDS and from the center of the highest density contour to the sensitive receptor. A general ground-water gradient was determined from water table elevation maps (included in the Appendices), previous reports, or individual knowledge of the areas. Relative risk was assigned as "High", "Medium", or "Low", based on the minimum distance to parcels on septic and the distance to the center of HDI parcels. If available, capture zones created for wellhead protection activities were included in the analysis. Capture zone maps for Project Areas that have wellhead protection programs in place are included in the Appendices where available. Results of this analysis are summarized in Table #8.

Table 8 Proximity of Parcels on ISDS to Sensitive Receptors

Project Area	Min. Distance to Receptors (feet)	Highest Density Center Distance to Receptors (feet)	Receptor	Gradient towards receptor?	Relative Risk
Cold Springs	0	0	Water Supply Wells	Potentially	High
Washoe	0	1,800	Jumbo Creek	Yes	High
	700	5,300	Washoe Lake	Yes	High
Spanish Springs	200	0	Water Supply Wells	Yes	High
	3,300	7,250	N. Truckee Drain	Potentially	Medium
Heppner	650	2,750	Water Supply Wells	Potentially	High
Verdi	0	0	Truckee River	Yes	High
Mogul	0	2,250	Truckee River	Yes	High
Mt Rose	0	0	Galena Creek	Potentially	High
	0	0	Jones Creek	Potentially	Medium
	1,000	1,000	Water Supply Wells	Yes	High
Ambrose	0	2,000	Truckee River	Yes	High
Island 18	0	3,900	Truckee River	Yes	Medium
Huffaker	2,500	3,900	Water Supply Wells	Potentially	Medium
	0	2,650	Water Supply Wells	Potentially	High
	0	3,300	Thomas Creek	Potentially	Medium
	0	3,300	White's Creek	Potentially	Medium
Golden Valley	1,300	6,500	Water Supply Wells	Potentially	Medium
New Washoe	100	3,200	Washoe Lake	Yes	Medium
Hidden Valley	0	2,650	Steamboat Creek	Varies	Medium
Pleasant Valley	0	0	Steamboat Creek	Yes	Medium
	0	N/A	Water Supply Wells	No	Low
Geiger	650	4,750	Steamboat Creek	Yes	Low
Silver Knolls	1,800	5,500	Water Supply Wells	Yes	Low

In addition to ranking the Project Areas from closest to farthest distance to sensitive receptors, a simple risk category was assigned. Without further analysis, a more definitive determination of risk cannot be made. A relative risk, categorized as “High”, “Medium”, or “Low”, allows room for additional study and changing climatic, hydrogeologic, environmental, or anthropogenic conditions. For this reason, there are no sensitive receptors areas that are considered to be at “no” risk.

For the purposes of comparison, the Project Areas were ranked based on the distance to a sensitive receptor and relative risk. Sensitive receptors were equally weighted. For example, over an equal distance, a municipal well is considered at equal risk as a surface water body. A municipal well may have deep screens, but over time may draw down ISDS effluent and the supplied water may have more of a direct impact on the end user. Conversely, a surface water body may be more quickly impacted, but the contamination will be more readily diluted before reaching the end-user.

Table 9 Relative risk to sensitive receptors by Project Area

Project Area	Highest Density Centroid Distance to Receptors (feet)	Relative Risk	Rank
Spanish Springs	0	High	1
Cold Springs	0	High	2
Mt Rose	0	High	3
Golden Valley	0	High	4
Verdi	0	High	5
Washoe	1,800	High	6
Ambrose	2,000	High	7
Mogul	2,250	High	8
Huffaker	2,650	High	9
Heppner	2,750	High	10
Pleasant Valley	0	Medium	11
Hidden Valley	2,650	Medium	12
New Washoe	3,200	Medium	13
Island 18	3,900	Medium	14
Geiger	4,750	Low	15
Silver Knolls	5,500	Low	16

Given the sensitivity of surface waters to contamination and their usage as a nitrogen sink by wastewater operations, the total potential nitrogen load should be considered in addition to the actual concentrations of nitrate reaching a surface water body. This is especially important since nitrate concentrations can be diluted en route to the receptor. The total mass of nitrogen over time is likely more meaningful.

4.2.4 Depth to Water

Depth to water data was collected from available data points within each Project Area. Basic analysis of the data is included in Table #6. Using the basic assumption that a shallower depth to water increases the likelihood of ground-water contamination, Project Areas were ranked based on shallowest to deepest depth to ground water. Again, depending on the location of wells within the Project Area, there may be factors that skew the results. For example, there may be more wells in topographically high areas that bias the data towards a deeper depth to water measurement. In addition, the well data is not assumed to come from monitoring wells that are typically screened across the water table and provide a better reading of static water level. Given this quandary, lower priority was given to this ranking, but it is included for comparison. Table #10 displays the average depth to water within each Project Boundary. Depth to water plots are included in the Appendices by Project Area.

Table 10 Average Depth to water with the Project Area boundary

Project Area Name	Average Depth to Water (feet)	Rank
Cold Springs	35.3	1
Spanish Springs	61.4	2
New Washoe	67.8	3
Island 18	69	4
Pleasant Valley	76.5	5
Heppner	78.4	6
Verdi	83	7
Washoe	83.3	8
Silver Knolls	94.5	9
Hidden Valley	97.7	10
Golden Valley	102.4	11
Mogul	105.1	12
Geiger	130	13
Mt. Rose	136	14
Ambrose	147.6	15
Huffaker	176.5	16

4.2.5 Ratio of ISDS Effluent Recharge to Precipitation Recharge

There is estimated to be little precipitation occurring on the Valley floor within the RSMA; approximately eight inches per year. Of the precipitation that does occur on the valley floor, very little recharges the ground water. It is estimated in some valleys that only 5% of all precipitation actually recharges the ground water (Berger et. al., 1997). Overall, recharge from ISDS effluent (230 gal/day/home) is significant, compared to recharge from precipitation. Using these assumptions above, a ratio of ISDS effluent recharge to precipitation recharge occurring over the Project Area was developed. ISDS effluent recharge rate (inches per year per Project Area) was calculated from all ISDS within each Project Area at a rate of 230 gal/day/home for one year over the areal extent of the Project Area. Precipitation recharge was estimated at 0.4 inches per year per Project Area. Any Project Area with a value of 1 or higher means that there is at least as much recharge from ISDS effluent as there is from precipitation over the Project Area. Listed below in Table #11 are the results of that analysis.

Table 11 ISDS effluent recharge to precipitation recharge ratio

Project Area Name	Ratio of ISDS Recharge to Precipitation Recharge	Number of Parcels on ISDS in Project Area	Rank
Cold Springs	2.1	1,325	1
Spanish Springs	2	1,848	2
Island 18	1.6	907	3
Geiger	1.6	858	4
Hidden Valley	1.4	780	5
Washoe	1.2	1,296	6
Heppner	1.2	954	7
Mt. Rose	1	1,026	8
Golden Valley	1	845	9
Silver Knolls	1	529	10
Ambrose	1	475	11
Huffaker	0.9	1,764	12
New Washoe	0.8	197	13
Pleasant Valley	0.7	535	14
Verdi	0.5	341	15
Mogul	0.4	544	16

The importance of recharge from ISDS is shown above and also in Table #6 (main table). The percentage of ISDS effluent per hydrographic basin was determined using ground-water recharge figures from State of Nevada Water Reconnaissance reports compared to the total amount of ISDS effluent recharging per basin annually (based on 230 gal/day/house). Recharge numbers from the State Water Reconnaissance reports were used, to determine estimates of ground-water recharge for each basin. Modeled recharge estimates differ depending on the modeler and the purpose of the project. Table #12 below summarizes the percentage of ISDS effluent making up ground-water recharge per basin.

Table 12 Percentage of ISDS effluent in ground-water recharge per basin

Basin Name	Ratio of ISDS Effluent to Ground-Water Recharge	Rank
Spanish Springs	50%	1
Cold Springs	42%	2
Lemmon Valley	31%	3
Truckee Canyon	6%	4
Truckee Meadows	5%	5
Pleasant Valley	4%	6
Washoe Valley	3%	7

These analyses are important, but incomplete because it may not include all components of recharge for each basin. Additional sources of recharge such as river, ditch, and creek losses, as well as artificial recharge will act to dilute the overall nitrate concentration once it reaches the ground water. This dilution is less likely to occur concurrent with ISDS effluent recharge, since the majority of additional recharge occurs at the mountain-front. At best, this is a worst-case scenario of the proportion of ISDS recharge that makes up ground-water recharge in each Project Area.

It is important to note that this ratio is also dependent upon the dimensional area in question. As the area decreases to more tightly constrain HDI, the ratio of ISDS effluent recharge to precipitation recharge increases. This has the effect of decreasing the aerial extent of precipitation available to dilute the ISDS effluent, which remains relatively unchanged. Tightening the Project Areas around the HDI would allow for a better understanding of their direct impact to ground water.

4.2.6 Geology and Soils

Geologic data was modified from Bonham, 1969 in GIS form. Instead of mapping all geologic units, an effort was made to identify alluvium versus bedrock. Geologic maps depicting alluvium and bedrock in relation to parcels on ISDS are included in the Appendices by Project Area.

Soils data was obtained from the U.S Department of Agriculture, Natural Resources Conservation Service (USDA-NRCS) soils database, known as STATSGO (Soil Survey Staff, USDA). Of the various soil characteristics available, soil drainage was found to be the most suitable for our investigation due to the emphasis on ISDS effluent and its potential to impact sources of drinking water. Soil drainage zones were plotted for each Project Area. The dataset was condensed down to four zones: excessively drained, well drained, poorly drained, and no data. Soil maps are included in the Appendices by Project Area. Table 13 below summarizes the soils data qualitatively, as a quantitative analysis was beyond the scope of this study.

Table 13 Soil drainage characteristics by Project Area

Project Area	General Geologic Composition Under High Density ISDS	General Soil Drainage Under High Density ISDS	Relative Risk
Cold Springs	Alluvium	80% Excessively Drained 20% Well Drained	High
Washoe	95% Alluvium 5% Bedrock	70% Excessively Drained 25% Well Drained 5% Poorly Drained	High
Hidden Valley	Alluvium	50% Excessively Drained 50% Well Drained	High
Geiger	Alluvium	10% Excessively Drained 90% Well Drained	Medium
Spanish Springs	Alluvium	5% Excessively Drained 95% Well Drained	Medium
Heppner	Alluvium	5% Excessively Drained 95% Well Drained	Medium
New Washoe	80% Alluvium 20% Bedrock	5% Excessively Drained 95% Well Drained	Medium
Ambrose	Alluvium	Well Drained	Medium
Golden Valley	Alluvium	Well Drained	Medium
Island 18	Alluvium	Well Drained	Medium
Silver Knolls	Alluvium	Well Drained	Medium
Verdi	Alluvium	Well Drained	Medium
Mogul	80% Alluvium 20% Bedrock	Well Drained	Medium
Mt Rose	80% Alluvium 20% Bedrock	Well Drained	Medium
Huffaker	Alluvium	95% Well Drained 5% Poorly Drained	Medium
Pleasant Valley	80% Alluvium 20% Bedrock	10% Excessively Drained 45% Well Drained 45% Poorly Drained	Low

As expected, the majority of parcels on ISDS are located above alluvial basin-fill geologic material. This is the same geologic material that makes up most of the water-supply aquifers in the Basin and Range province. Unexpectedly, however, the majority of soil types underlying parcels on ISDS are almost exclusively well-drained to excessively-drained. This may be of little consequence, since most ISDS leach trenches are filled with 2 ½" gravel and completed to depths of 12 feet with some reaching depths of up to 16 feet below land surface.

Geologic material and soil type underlying the high density ISDS area for each Project Area was used to determine a qualitative risk factor from High, Medium, to Low. For example, an HDI area underlain by alluvium and mostly excessively-drained soils received a “High” relative risk whereas an HDI are underlain by some bedrock and mostly poorly-drained soils received a “Medium” or “Low” relative risk. Given that the STATSGO database typically only characterizes the upper 5-15 feet of the soil zone, and the inherent heterogeneity in basin-fill alluvial deposits, this information will be only be used to qualitatively weight the final rankings.

5.0 Results and Discussion

5.1 Combined Rankings

Individual Project Area rank per parameter is summarized below in Table #14. A combined ranking was the first attempt at creating a prioritized list of Project Areas. The outcome of this combined ranking was influenced by incomplete and biased data sets described above, and left out important information that is specific to each Project Area.

Table 14 Combined rankings

Project Area Name	Maximum ISDS Density in Project Area Rank	Nitrate in Project Area Combined Rank	Distance to Receptors and Relative Risk Rank	Depth to Water within Project Area Rank	Ratio of ISDS to Precipitation Recharge Rank	Soils Relative Risk	Totals
Spanish Springs	2	1	1	2	2	Medium	8
Cold Springs	1	4	2	1	1	High	9
Washoe	4	3	6	8	6	High	27
Island 18	6	5	14	4	3	Medium	32
Heppner	7	6	10	6	7	Medium	36
Golden Valley	10	2	4	11	9	Medium	36
Mt. Rose	9	9	3	14	8	Medium	43
Geiger	5	11	15	13	4	Medium	48
Huffaker	3	8	9	16	12	Medium	48
Hidden Valley	8	16	12	10	5	High	51
Verdi	14	13	5	7	15	Medium	54
Silver Knolls	12	7	16	9	10	Medium	54
Pleasant Valley	15	10	11	5	14	Low	55
New Washoe	16	12	13	3	13	Medium	57
Mogul	11	14	8	12	16	Medium	61
Ambrose	13	15	7	15	11	Medium	61

5.2 Project Area-Specific Considerations

Project Area-specific considerations take into account information not easily analyzed or integrated into the above tables. This information is qualitative at best, but it explains some of the bias and/or removes the bias noted above. It also incorporates knowledge gained from previous studies, especially where surface waters are concerned. This information will be used as a qualitative weighting of the final prioritized list.

5.2.1 Ambrose

Nitrate maps depict no impact from the 475 parcels on ISDS to the ground water. However, data from domestic wells were used in this Project Area and do not characterize the shallow ground water. In addition, flow paths may periodically head towards the river; for this reason, it is assumed that the 475 ISDS have an impact on the Truckee River. This is important given their close proximity to the river as some are in close proximity to the river's edge, while the center of the parcels on ISDS are approximately 2,000 feet from the river. Based on information gained through studying the Verdi Area, the Ambrose Park Area is assumed to impact the Truckee River in a similar manner.

Although the Ambrose Project Area ranks last, this area should be considered for additional study given its shallow depth to ground water and its close proximity to the Truckee River.

5.2.2 Island 18

Ranked fourth in the combined rankings, the Island 18 area raises concerns due to its high maximum ISDS density of 250 ISDS/mi^2, proximity to the Truckee River, and the shallow depth to ground water. The shallow depth to ground water and the elevated nitrate concentrations occur near the river from approximately 60 parcels on ISDS. There are no wells in the vicinity of the HDI, therefore, no data for water quality or depth to water is readily available. The high-density development is approximately 100 to 400 feet above the river. Wells to the southeast, outside of the Project Area indicate depths to ground water of greater than 100 feet. More information is needed within the HDI area before a realistic risk can be defined for this Project Area.

5.2.3 Hidden Valley

Ranked tenth in the combined rankings, the Hidden Valley Project Area raises concerns due to its excessively drained soils and its proximity to Steamboat Creek, which drains to the Truckee River. Again, there is little information within the HDI. Wells outside of the HDI point to shallow ground water proximal to, and having gradients toward, the Steamboat Creek. With Steamboat Creek assumed to be a gaining creek at this reach, ground-water impacts in this area could be high. More information is needed in this area, especially within, and down gradient of, the HDI.

4.2.4 Huffaker

Ranked ninth in the combined rankings, the Huffaker Project Area raises concerns due to its high maximum ISDS density of 300 ISDS/mi^2 and proximity to water supply wells. The area appears to be adequately characterized with a number of wells distributed throughout the Project Area. Depth to ground water may be skewed towards the deeper side, with more wells occurring higher on the fan. In addition, well depths may underestimate water quality concerns if they are screened at greater depth. The highest area of concern appears to be the HDI between Well TC1 and Well DD1. Gradients here appear to be towards DD1, but there is no information immediately down gradient of this HDI. As shown in the nitrate map, nitrate levels in the water supply wells down gradient of the HDI are higher than those up gradient of the HDI. Larger parcels on ISDS to the north are lower in density (around 100 to 150 ISDS/mi^2), but are numerous. The overall impact to ground water from these parcels may be high, as gradients are towards municipal wells (SVA, PAT, and LL). As shown in the nitrate map, nitrate levels in the water supply wells down gradient of the HDI are higher than those up gradient of the HDI.

Thomas Creek flows from southwest to northeast through the project area. Though the parcels on ISDS are large near the lower reach of Thomas Creek, there may be an impact to this reach of the stream from impacted ground water. Widmer and Jesch (2002) found that total dissolved solids (TDS) concentrations and fecal coliform counts increased downstream; typically from upstream of the parcels on ISDS to the reach below parcels on ISDS. They speculate that this increase may be due to livestock activities in the mid reaches and from ground-water influx at the lower reaches.

5.2.5 Geiger

Ranked eighth in the combined rankings, the Geiger Project Area poses a concern due to its high maximum ISDS density (300 ISDS/mi^2) and assumed ratio of recharge from ISDS versus precipitation. There are no water supply wells in the Project Area. The only sensitive receptor besides domestic wells appears to be Steamboat Creek, which is close to individual ISDS, but nearly a mile from the HDI centers. This area probably poses little risk to Steamboat Creek given the distance to it from HDI; however, Steamboat Creek may be a gaining creek at this reach and may be impacted.

5.2.6 Silver Knolls

Ranked twelfth in the combined rankings, the Silver Knolls Project Area appears to have impacted a small number of domestic wells in the area. Water quality values were only available for the TMWA wells to the east of the Project Area. Nitrate concentrations in these wells are at or below background concentrations. No information was available from the private water company wells (SKM).

5.2.7 Heppner

Ranked fifth in the combined rankings, the Heppner Project Area poses a concern due to the high maximum ISDS density (200 ISDS/mi^2) and relatively shallow depth to ground water. Domestic wells appear to be impacted by high nitrate concentrations in the northern portion of the HDI. According to the capture zone maps, the water supply wells appear to be slightly upgradient within a shallow-gradient aquifer. Over time, with changes in gradient and/or recharge, these wells may draw down contamination from the HDI, but nitrate concentrations in these wells are currently low (below 2 mg/L).

5.2.8 Golden Valley

Ranked sixth in the combined rankings, the Golden Valley Project Area has already been shown to impact ground water according to previous studies and recent sampling events. LV#3 was turned off when a sample for nitrate came back at 43 mg/L in 2005. Animal farming activities on nearby parcels may be contributing to the elevated nitrate concentrations seen in this well. The Golden Valley Park well is situated within the HDI and has shown elevated nitrate concentrations (as high as 8.6 mg/L). The other water supply wells (LV5, 6, and 8) appear to be outside of the highly impacted ground water area. It appears that ground water is impacted in this Project Area.

5.2.9 Mt. Rose

Ranked seventh in the combined rankings, the Mt. Rose Project Area poses a concern given the proximity of HDI to water supply wells and Galena and Jones Creeks.

All water supply well capture zones intercept at least one parcel on ISDS, except for MT5 and MT6. These wells, however, are within the maximum ISDS density contour of 150 ISDS/mi^2. MT2 and MT3 appear to show an impact from anthropogenic nitrate sources with values of 5.7 and 4.4 mg/L, respectively. There are over 1,000 parcels on ISDS in this Project Area. The parcels are large and consequently the density is relatively low. There appears to be two distinct HDI areas (southwest and northeast) that may best be studied separately.

Galena and Jones Creeks may be losing streams in this reach and may not be impacted by ground water. However, both creeks have a HDI area immediately adjacent to their banks. Galena Creek may be more at risk as it appears to be down gradient from the southwestern HDI. In fact, ground water is known to discharge to Galena Creek within the mid-reach (Widmer and Jesch, 2002), located approximately 1 mile downstream of the southwestern HDI. No data was available from the stream reach adjacent to or immediately downstream of the southwestern HDI. Widmer and Jesch (2002) also found that fecal counts increased downstream, most likely under the influence of ISDS located in the mid- and lower-reaches.

5.2.10 Pleasant Valley

Although the relative ranking is low, there may be a moderate to high risk posed to Galena and Steamboat Creek as they flow immediately adjacent to the HDI to the west of the Project Area. The density of this small subdivision is probably closer to 200 ISDS/mi^2. As mentioned above, Galena Creek is known to be receiving ground water within the reach just upstream of this Project Area. Conversely, Galena and Steamboat Creek may be losing streams here, recharging the aquifer and not receiving water from ground water and ISDS discharges; however, to make such a determination would require further analysis. Water supply wells SE1, 2, and 3 each intercept one or more parcels on ISDS within a 2-year travel time of capture.

5.2.11 Washoe

Ranked third in the combined rankings, the Washoe Project Area has already been shown to impact ground water according to previous studies and recent sampling events. There are no water supply wells within the Project Area, but there are numerous domestic wells. These domestic wells have shown to be impacted from anthropogenic nitrate. Washoe Lake and Jumbo Creek (ephemeral stream) may also be impacted since ground-water gradients are toward them, but more information and study would be required to make that determination. According to a report by Widmer and Jesch, 2002, “septic systems represent the largest single source for potential pollution to the watershed”. It would appear, that ground water is impacted in this Project Area.

5.2.12 New Washoe

Ranked fourteenth in the combined rankings, the New Washoe Project Area appears to pose little concern given the distance to sensitive receptors and low septic density (50 ISDS/mi^2). However, ground water in this Project Area is shallow and the potential for ground-water contamination, even from a small development, could be possible.

5.2.13 Verdi and Mogul

Verdi and Mogul, ranked eleventh and fifteenth, respectively, occur in similar settings with similar concerns.

Widmer, 2007 estimates that the Verdi-Mogul Basin receives 15” to 22” of rainfall on the valley floor annually. An increase in precipitation from an estimated 8” annually for the other Project Areas to 18.5” annually for the Verdi-Mogul Basin appears to contribute significantly to the dilution of contamination as it migrates to ground water. The ratio of ISDS effluent recharge to precipitation recharge is cut in half, from 1.0 to 0.5. It seems likely that precipitation has a dramatic effect on the overall quality of water impacting ground water. Although this will act to dilute the effluent’s impact on ground water, it does not change the total nitrogen load to ground water or the River. The impact to ground water and the River may occur over very short time frames given the thin-bedded alluvial aquifer that is directly connected to the Truckee River.

The Mahin (1985) study recommended that no additional ISDS facilities be allowed in the Verdi area on a permanent basis. At that time, there were 220 ISDS in use. Since that time, there have been 200 ISDS installed in the study area, for a current total of 341 ISDS (does not account for 79 ISDS that may not be accounted for due to differences in the study area dimensions). The current Study Area does not extend as far east as the Mahin study area, but it does extend further west. If we assume that 79 ISDS from the Mahin study are still in existence, we can compare 1985 to 2007 ISDS numbers for the Verdi area using current information on ISDS effluent volumes (230 gal/day/house). Total ISDS effluent in 1985 is estimated at almost 57 AFY (220 homes) and current ISDS effluent is estimated at almost 108 AFY (220 ISDS in 1985 plus 200 additional

ISDS since 1985), representing an increase of 90% from 1985. Using the same equations as Mahin, 1985, this results in an additional 2,700 to 5,900 pounds of nitrogen entering the Truckee River since 1985 for a total of approximately 5,700 to 12,500 pounds annually. Expansion of homes on ISDS appears to have occurred, despite the recommendations against it in the Mahin (1985) report.

5.2.14 Cold Springs

Ranked second in the combined rankings, the Cold Springs Project Area has already been shown to impact ground water according to previous studies and recent sampling events. Water supply wells within the HDI (CS1 and 2) have nitrate concentrations around or below 2 mg/L. However, domestic wells have shown to be impacted from anthropogenic nitrate. Ground water is likely impacted by ISDS in this Project Area.

5.2.15 Spanish Springs

Ranked first in the combined rankings, the Spanish Springs Project Area has already been shown to impact ground water according to previous studies and recent sampling events. Deep water supply wells and shallow monitoring wells have both shown an increase in nitrate over time. The shallow aquifer has been the most-highly degraded from anthropogenic nitrate with concentrations over 73 mg/L. Studies to date indicate that ground water is impacted in this Project Area.

It should be noted that the Orr Ditch currently provides a hydraulic barrier to plume migration to the south. If the Orr Ditch is decommissioned, that barrier would be removed and the plume may migrate southward towards the North Truckee Drain, which flows to the Truckee River. In a watershed assessment performed for tributaries of the Truckee River, most of the North Truckee Drain was classified as sensitive (Widmer and Jesch, 2002).

5.3 Final Rankings

Density of ISDS and proximity to sensitive receptors may be the most important output from this study to consider. This is supported by a study completed by the USGS utilizing GIS data in Douglas County, Nevada, that found wells with increasing nitrate and dissolved solids concentrations over time had a high percentage of parcels on ISDS nearby (Shipley and Rosen, 2005). They also found that “density of contaminant sources is of greater importance than age of contaminant sources”.

Data collected in Spanish Springs, Cold Springs, Washoe Lake, Golden Valley, Heppner, and Verdi seemingly verify the impact of HDI on shallow ground-water quality. These studies suggest an increase in nitrate concentrations in shallow ground water, as well as municipal and domestic wells, in close proximity to HDI. In Spanish Springs, it has also been observed that smaller-sized lots have a greater impact on water quality than larger lots (Kropf, 2002).

Additional parameters collected and analyzed per Project Area is susceptible to bias. Water quality and depth to water data are biased due to spatial considerations (well location, well depth, screened interval), temporal considerations (sample collection date), and lack of information (no wells). Ratio of ISDS effluent recharge to precipitation recharge is biased by the aerial extent of the Project Boundary. Soils and Geology are qualitative at best, with estimates of depth for each, dependent upon the availability of well data.

Given these considerations, the Project Areas were ranked again by Maximum ISDS Density, Distance to Sensitive Receptors, and ISDS Parcel Size. Maximum ISDS Density and ISDS Parcel Size are purely quantitative with little bias and a proven impact on nitrate concentrations. Distance to Sensitive Receptors is also quantitative spatially and removes the bias of receptor type (surface vs. ground water). A qualitative aspect of this parameter aids in ranking areas that may have similar distances. Table #15 below summarizes those results.

Table 15 Final ranking based on Density, Distance to Receptors, & Parcel Size

Project Area	Maximum ISDS Density in Project Area Rank	Distance to Receptors and Relative Risk Rank	Average ISDS Parcel Size in Project Area Combined Rank	Total	Rank
Spanish Springs	2	1	3	6	1
Cold Springs	1	2	6	9	2
Washoe	4	6	2	12	3
Heppner	7	10	1	18	4
Mt. Rose	9	3	9	21	5
Golden Valley	10	4	10	24	6
Ambrose	13	7	4	24	7
Hidden Valley	8	12	5	25	8
Huffaker	3	9	14	26	9
Verdi	14	5	7	26	10
Geiger	5	15	8	28	11
Island 18	6	14	11	31	12
Mogul	11	8	13	32	13
Silver Knolls	12	16	12	40	14
Pleasant Valley	15	11	15	41	15
New Washoe	16	13	16	45	16

5.4 Data Gaps

Inexpensive and easily obtained geochemical information such as dissolved oxygen, electrical conductivity, and iron may provide useful in determining an aquifer's sensitivity to nitrate contamination (Trojan, et. al, 2002). Many studies extol the benefits of analyzing chloride as well as nitrate to determine nitrate source (Shaw et al, 1991; Seiler, 1996). Total dissolved solids (TDS) values can indicate altered ground-water circulation in aquifers that are stressed by large withdrawals or are simply receiving high TDS recharge water from ISDS effluent or lawn irrigation (Shipley and Rosen, 2005).

Obvious data gaps exist due to the number, location, and type of wells in each Project Area. As described earlier, Project Areas with a large number of wells, especially monitoring wells, typically have higher nitrate concentrations. With a typical mixing depth for nitrate of around 60 feet below water table surface, the majority of the wells used for this study are assumed to be completed below this depth based on the type of well alone (domestic and water supply). Consequently, these wells are assumed to underestimate nitrate concentrations in the shallow aquifer. Except for Spanish Springs, Cold Springs, and Golden Valley, there are insufficient shallow monitoring wells to adequately characterize the shallow aquifer in each of the Project Areas. This is an obvious data gap for each Project Area.

In addition to the above chemical analyses, spatial data gaps exist in a number of the Project Areas due to lack of monitoring points (surface, ground water, or both). The following table lists the Project Area and data needs. For areas that indicate “none needed” under the Data Needs, it should be noted that additional data it is always beneficial. A possible cost-effective avenue of obtaining additional data is from domestic well owners in the area. Table #16 below identifies data needs by Project Area.

Table 16 Data needs by Project Area

Project Area Name	Data Needs
Ambrose	Truckee River water quality near HDI Ground-water quality and depth within HDI
Cold Springs	None Needed
Geiger	Steamboat Creek water quality down gradient of HDI
Golden Valley	Ground-water quality and depth within northern HDI
Heppner	None Needed
Hidden Valley	Steamboat Creek water quality down gradient of HDI Ground-water quality and depth within and down gradient of HDI
Huffaker	Ground-water quality & depth w/in southern HDI west of well DD1 Thomas and Whites Creek water quality down gradient from HDI
Island 18	Ground-water quality and depth within and down gradient of HDI Truckee River water quality near well SW
Mogul	Ground-water quality and depth within and down gradient of HDI Truckee River water quality near HDI
Mt. Rose	Ground-water quality and depth w/in & down gradient of SW HDI Jones & Galena Creek water quality down gradient from each HDI
New Washoe	None Needed
Pleasant Valley	Galena & Steamboat Creek water quality down gradient from HDI
Silver Knolls	None Needed
Spanish Springs	Orr Ditch and North Truckee Drain water quality
Verdi	Truckee River water quality near HDI
Washoe	Washoe Lake water quality

6.0 Conclusions

Analyzing the potential impact from more than 18,000 parcels on ISDS in Washoe County is a significant undertaking. Numerous data sets from multiple agencies have been reviewed and assembled into a useable database. This data was critical in order to identify potential areas of concern, analyze data for all 16 areas, and prioritize the project areas for further investigation.

Literature review, previous studies, and data from this investigation have come together to answer a difficult question: "How do we prioritize areas with HDI (high density ISDS) for further study?". As shown, numerous data sets were compiled and analyzed, but it is likely that a simpler and direct approach is best.

Previous studies pointed to the importance of density of ISDS, distance to sensitive receptors, and parcel size. Ranking the Project Areas based on these factors revealed three distinct groupings:

- Previously studied areas sufficient data & known impacts to sensitive receptors.
- Areas with insufficient data and suspected impacts to sensitive receptors.
- Areas with insufficient data and not suspected to impact sensitive receptors.

Table #17 below, categorizes the final rankings based on data needs and known or suspected impacts.

Table 17. Categorized final rankings based on data needs and risk

Project Area	Final Rank
Spanish Springs	1
Cold Springs	2
Washoe	3
Heppner	4
Mt. Rose	5
Golden Valley	6
Ambrose	7
Hidden Valley	8
Huffaker	9
Verdi	10
Geiger	11
Island 18	12
Mogul	13
Silver Knolls	14
Pleasant Valley	15
New Washoe	16

Sufficient data and known impacts

Insufficient data with suspected impacts

Insufficient data with little suspected impact

The outcome of this study is a prioritized list of Project Areas that require further investigation, based on knowledge gained on areas that have already shown to be impacted. With that as the basis for prioritization, it appears that the analysis performed during this study revealed final rankings that fall in line with that requested task. It should be no surprise that the most well-documented and highest-contaminated Project Areas were found to have the highest ranking. This final ranking may be looked at as a ranking from most contaminated to least contaminated; however, insufficient information is available to make such a determination.

The color-coded raking above, points to those Project Areas that require additional information to help understand the full impact of HDI on sensitive receptors. Based on the information collected and analyzed in this report, there is sufficient data in the Project Areas coded green to make recommendations for management actions. These areas are of low priority for additional information, but of high priority for management action. There is insufficient information, however, to take action with respect to the Project Areas coded in yellow. Project Areas coded yellow, are therefore the High Priority Project Areas (HPAs). Areas coded in blue are suspected to be of low risk to receptors and are of low priority.

7.0 Recommendations

Based on the information obtained from the data review and conclusions drawn from the body of evidence, it is recommended that further data be collected from the areas indicated in Table #16. The type of data which would prove most valuable are outlined as follows:

- Collect additional water quality and water level data from domestic well owners in all Project Areas.
  - Focus on the HPAs (coded Yellow).
  - Focus on areas within and downgradient of HDI.
  - Focus on areas close to surface water bodies.
  - Focus on wells with shallow screened intervals.
  - Information will help better define ground-water gradients.
  - Water quality analysis at a minimum should include nitrate, chloride, TDS, and conductivity.
- Collect water quality samples from surface water bodies adjacent to and downstream of HDI; especially in HOAs. Locations are noted in the Data Gaps section above.
- Additional analysis of currently available data for HPAs.
  - Sort well data by location, screened interval, and date to focus on the shallow aquifer, if possible.
- Perform basic mass balance modeling of HPAs.
  - To determine the potential impact to ground water over time
  - Much of the ground work has been completed in this study
- Perform basic vadose-zone modeling of HPAs.
  - To determine travel times to ground water.
- Perform a similar GIS-based analysis similar to that completed by the USGS in Douglas County.
  - Focus on municipal supply wells in HPAs.
  - Analyzes land use, ISDS density, ISDS age, and water quality trends within a 500 m buffer around water supply wells to determine the relationship between land use and increasing nitrate concentrations (Shipley and Rosen, 2005).
- Consider the potential for other sources of nitrate within HPAs.
  - Treated wastewater
  - Industrial effluent
  - Fertilizer
  -

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9.0 List of Acronyms

AFY: Acre-feet per year – defined by the volume of one acre of surface area to the depth of one foot. Equal to 43,560 ft^3 or 325,851.4 gallons.

GIS: Geographic Information System – a system for capturing, storing, analyzing and managing data and associated attributes which are spatially referenced to Earth

HDI: High-Density ISDS – a large number of parcels on ISDS in a small area

HPA: High-Priority Porject Area – Project Areas ranked high on the final priority list requiring more information

ISDS: Individual Sewage Disposal Systems – septic tank and leach field

MCL: Maximum Contaminant Level. MCL for nitrate-nitrogen is 10 mg/L

NDEP: Nevada Division of Environmental Protection

NRCS: Natural Resources Conservation Service

PPM: Parts Per Million – unit of measure equivalent to mg/L

RSMA: Reno-Sparks Metropolitan Area

RWPC: Regional Water Planning Commission – created in 1995 to provide a forum and method for the planning and coordination of water use, flood control and wastewater management throughout the region.

SD: Septic Density – abbreviated for use in tables

SDWA: Safe Drinking Water Act – the main federal law that ensures the quality of Americans' drinking water

STATSGO: State Soil Geographic Database, revised and updated and renamed as he U.S. General Soil Map

TDS: Total Dissolved Solids -- the total mass content of dissolved ions and molecules or suspended microgranules in a liquid medium.

TMWA: Truckee Meadows Water Authority – the main water purveyor in the RSMA

USDA: United Sates Department of Agriculture

USEPA: United States Environmental Protection Agency

USGS: United States Geological Survey

WCDWR: Washoe County Department of Water Resources – the main water purveyor to areas outside of the RSMA

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