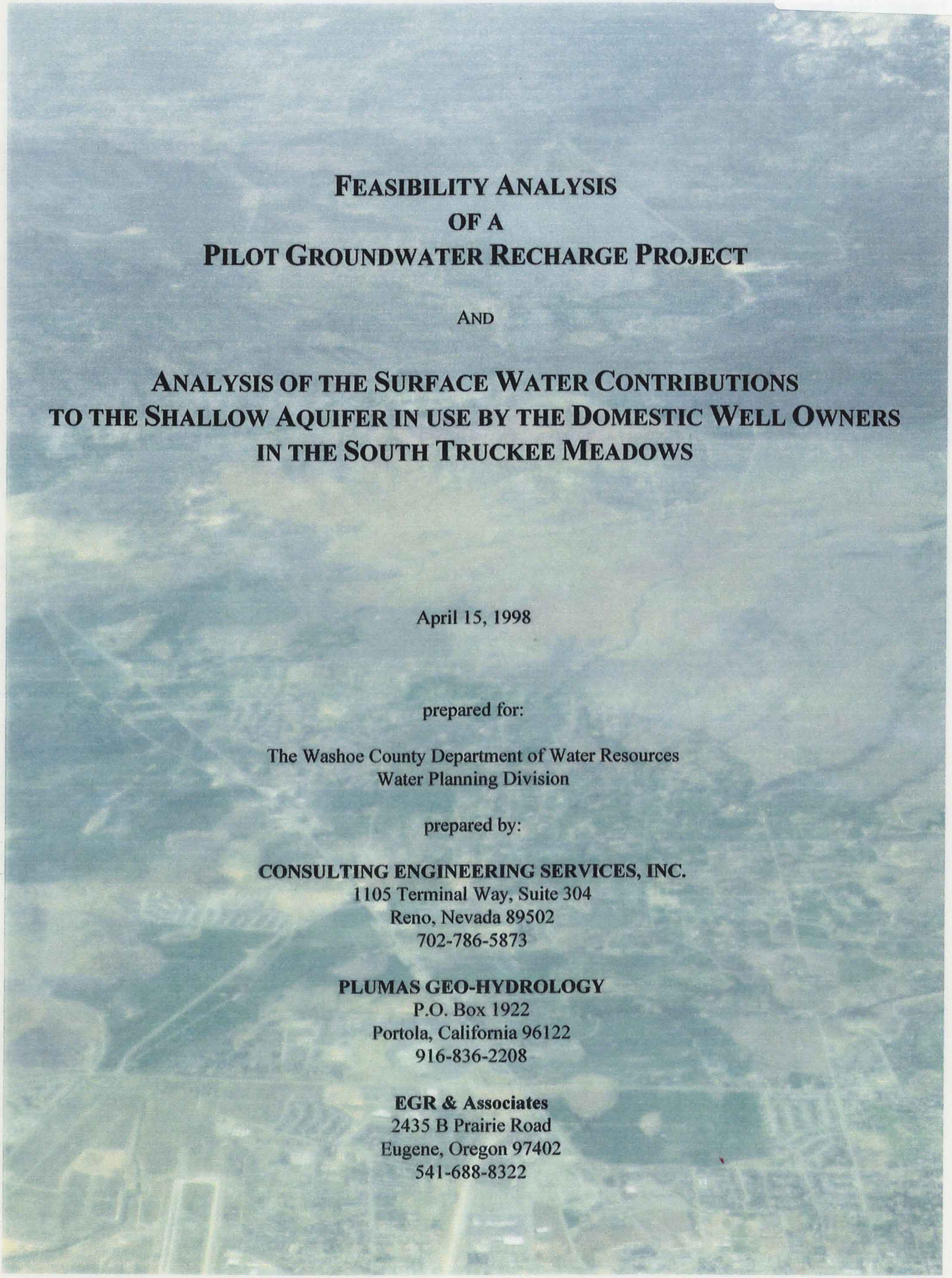
WIDMER

2368-00035



Feasibility Analysis of a Pilot Groundwater Recharge Project

And

Analysis of the Surface Water Contributions to the Shallow Aquifer in use by the Domestic Well Owners in the South Truckee Meadows

April 15, 1998

prepared for:

The Washoe County Department of Water Resources
Water Planning Division

prepared by:

CONSULTING ENGINEERING SERVICES, INC.
1105 Terminal Way, Suite 304
Reno, Nevada 89502
702-786-5873

PLUMAS GEO-HYDROLOGY
P.O. Box 1922
Portola, California 96122
916-836-2208

EGR & Associates
2435 B Prairie Road
Eugene, Oregon 97402
541-688-8322

ACKNOWLEDGMENT

The work described herein was made possible through the help of many organizations and individuals. CES, Plumas Geo-Hydrology and EGR & Associates would like to acknowledge the special contributions to this project made by the following individuals and organizations.

Matt Setty, formerly a staff hydrologist with the office of the Federal Water Master
John Erwin, the Sierra Pacific Power Company
Moni Fox, Washoe County Department of Community Development
Mike Widmer, hydrogeologist for the Washoe County Division of Utility Services
The Washoe Water Protection Association

Fig 2-2, 3-3, 3-4, 3-9
Text 3-5, 3-6, 3-13, 1-1

GLOSSARY OF TERMS AND ABBREVIATIONS

TERMS

acre-foot (AF): the amount of water it takes to cover an area of one acre a depth of 1 foot; approximately equal to 325,900 gallons.

anthropogenic: caused by human activity.

aquifer: a geologic unit which stores and transmits groundwater in sufficient amounts to provide a source of water supply.

artificial recharge: techniques which add recharge to the aquifer. These may include injecting water via wells or some type of land application such as spreading, infiltration basins or galleries which increase recharge to the aquifer over that which occurs naturally.

coefficient of storage or storativity: the property of a geologic unit which describes the volume of water taken into or out of storage for each unit rise or decline in water level over a unit area of material. Storativity is dimensionless.

conjunctive use: the combined use of both surface water and groundwater as sources of water supply. Aquifer storage and recovery projects which use surface water to recharge an aquifer are a type of conjunctive use.

electrical conductivity (EC): a measure of the ability of water to conduct electricity. It is indicative of the total dissolved solids of the water. Units are micro-mhos (**µmhos**) per centimeter or micro-siemens.

equivalents per million (EPM): a measure of the concentration of an ion specie in water. In practice it is obtained by multiplying the concentration in milligrams per liter by the ionic charge and dividing by the molecular weight. EPM is used to describe and analyze water.

evapotranspiration: the sum of **evaporation** (the process by which water passes from the liquid to vapor state) and **transpiration** (the process by which plants give off water vapor through their leaves).

hydraulic gradient: the slope of the water table or potentiometric surface.

hydraulic conductivity: a physical property of a geologic unit which describes the amount of water which flows through a unit area under a unit hydraulic gradient. It is often used interchangeably with permeability, a related property. Common units are gallons per day per square foot or feet per day (**gpd/ft^2** or **ft/day**).

infiltration basin: a pond that is used specifically to increase recharge to an aquifer.

infiltration gallery: a subsurface drain field that is used specifically to recharge an aquifer. It is similar in construction to a septic system leach field.

pH: the inverse logarithm of the hydrogen ion activity of a substance. It is commonly used to describe the acidity of water. The pH of pure water at room temperature is 7. A pH of less than 7 indicates the water is acidic and a pH greater than 7 indicates it is alkaline or basic. It is expressed in standard pH units.

phreatophyte: a plant whose roots extend down to the water table and which draws its water supply from the water table.

potentiometric surface: the level to which water will rise in a well. In an artesian aquifer, the potentiometric surface is above the top of the aquifer. The potentiometric surface of an unconfined aquifer is the water table.

secondary recharge: recharge to the aquifer that is a by product of another water use. The infiltration of a portion of the water applied on the land surface as irrigation or leakage from irrigation ditches are types of secondary recharge.

specific capacity: the pumping rate of a well divided by the drawdown. For recharge wells, it is the injection rate divided by the rise in water level due to injection. It is an expression of the productivity or injectivity of a well. A common unit is gallons per minute per foot (gpm/ft).

total dissolved solids (TDS): a measure of the total concentration of dissolved material in water. It is determined from the weight of the dry residue after evaporating the water. The TDS may be approximated by the electrical conductivity of the water.

transmissivity: a physical property of a geologic unit which describes the amount of water which flows through a unit width of the entire thickness of the unit. It is equivalent to the hydraulic conductivity multiplied by the thickness of the unit. Common units are gallons per day per foot or square feet per day (**gpd/ft or ft^2/day**).

water table: the elevation to which the water level in an unconfined aquifer rises in a well. By definition, the pore pressure in the aquifer is equal to atmospheric pressure at the water table.

Other Abbreviations

GPD: gallons per day.

SPPCo: the Sierra Pacific Power Company.

STMGID: the South Truckee Meadows General Improvement District.

WCUSD: the Utility Services Division of the Washoe County Department of Water Resources

TABLE OF CONTENTS

TABLE OF CONTENTS, CONT.

LIST OF FIGURES

List of Tables

Appendix

1.0 Executive Summary and Recommendations

1.1 Summary

1.1.1 Conditions in the aquifer beneath the southwest Truckee Meadows make it possible to store water underground using recharge wells for later recovery via production wells. A recharge project in this area has the potential to both benefit domestic wells and allow increased withdrawals from municipal wells.

1.1.2 Using the total dissolved solids (TDS) of the groundwater as an indicator, differences between irrigation recharge water and native groundwater can be identified in the wells in the South Truckee Meadows. Based on this analysis, it appears that infiltration of surface water applied to the land surface as irrigation, leakage from irrigation ditches, and individual septic system leach fields comprises a significant proportion of recharge to the aquifer in the southwest Truckee Meadows. As much as 30,000 acre-feet per year of surface water are diverted to the study area. Of this amount, nearly 5,000 acre-feet per year appears to recharge the aquifer. Using nitrate and TDS as indicators, it can also be shown that disposal of residential wastes via individual sewage disposal systems is significantly degrading the chemical quality in the aquifer.

1.1.3 Changes in land use in the study area will affect the quantity and quality of the groundwater resource in the southwest Truckee Meadows. As land use changes from agricultural to residential, there will be a reduction in irrigated acreage, and secondary recharge to the aquifer from irrigation will decline. As irrigated acreage declines, the quantity of high-quality water diverted through the irrigation ditch network will also decrease. This will lead to a reduction in the secondary recharge that results from ditch leakage. Disposal of domestic wastes using individual sewage disposal systems will increase as the population increases. A decrease in secondary recharge means that there will be less fresh water to dilute these wastes. Degradation of the chemical quality of the aquifer will be an inevitable result.

1.1.4 Aquifer recharge, storage and recovery projects in Nevada are hampered by the current regulations that govern these kinds of projects. The State of Nevada's current regulations should be changed to be more applicable to the hydrogeological conditions that exist in the southwest Truckee Meadows so that maximum benefit can be achieved.

1.1.5 The most cost effective type of groundwater recharge and recovery project appears to be seasonal storage. In this type of system, water is injected into the aquifer during the winter and recovered during the summer. Based on preliminary cost analyses and assumptions of recovery efficiency, it appears that use of the existing STMGID wells for this purpose is cost effective, provided the injection water does not need to be purchased from SPPCo.

1.2 Recommendations

1.2.1 The recommended next phase of a recharge project in the southwest Truckee Meadows is a pilot study. The pilot study will provide the additional aquifer and recovery data needed to design a large-scale recharge project and to obtain the necessary permits from the State of Nevada. The best well for use in a pilot recharge study is STMGID Well No. 1. Computer simulations based on an existing groundwater model of the aquifer indicate that the efficiency of a seasonal recharge, storage and recovery program using this well may be as high as 50 to 75 per cent depending on the method used to calculate recovery efficiency. The overall efficiency can be further increased by carefully locating recovery wells with respect to the recharge wells.

1.2.2 Because infiltration of irrigation water comprises a large proportion of groundwater recharge to the study area, it follows that a variety of surface recharge techniques such as infiltration basins (ponds), infiltration galleries (covered trenches), surface spreading (flood irrigation) can be used to augment recharge to the aquifer. Planned changes in existing land use from agricultural to high density rural use may eliminate favorable sites from future consideration in a recharge program. To offset the loss of recharge from former agricultural lands, future residential development in the southwest Truckee Meadows should set aside land dedicated to recharge of the aquifer. Likewise, irrigation ditches should be maintained and operated as recharge mechanisms in addition to their normal function of water delivery.

2.0 INTRODUCTION

2.1 PROJECT DESCRIPTION AND OBJECTIVES

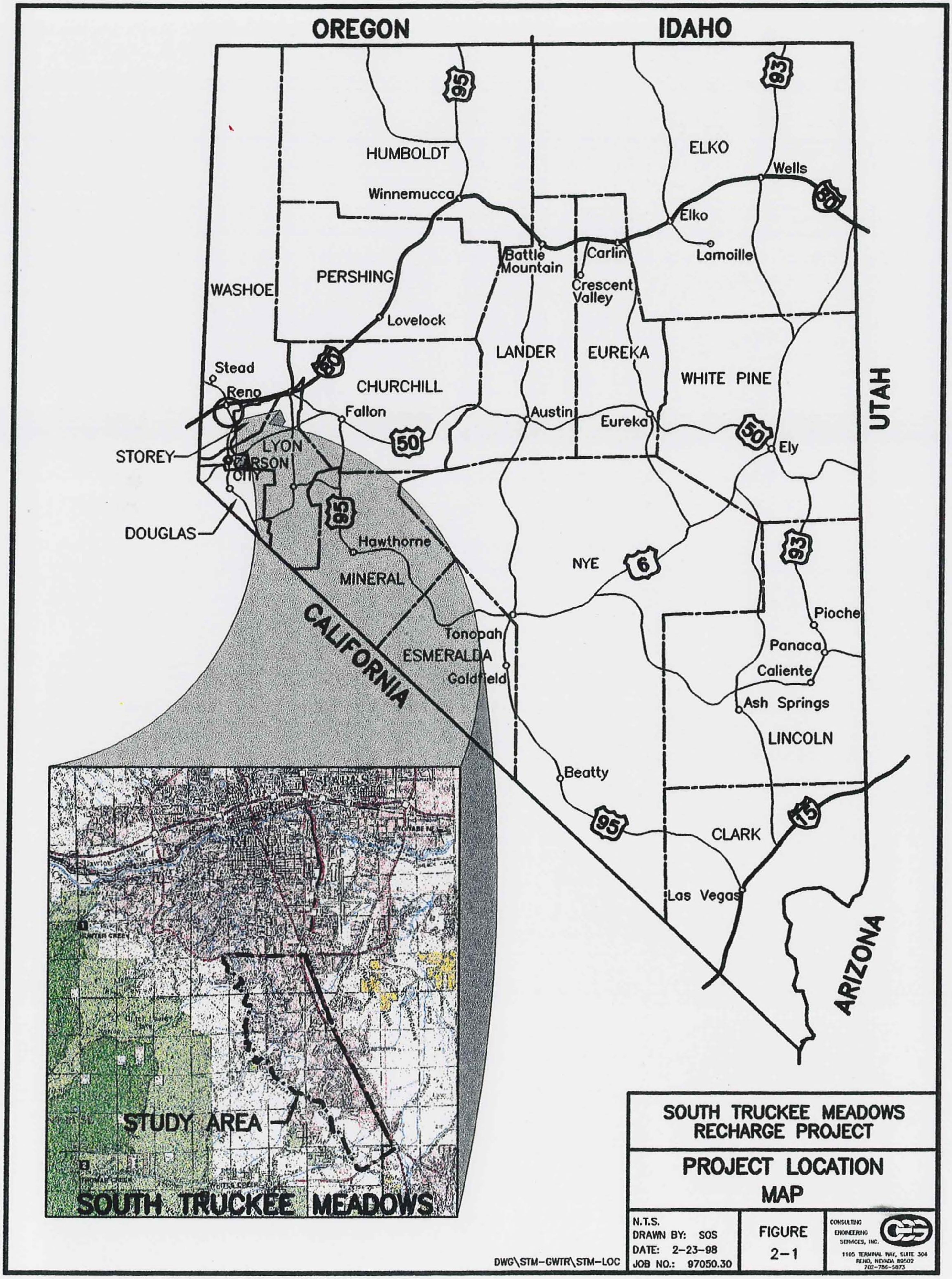
In October, 1997 the Washoe County Water Resources Department engaged a consortium comprising the firms of Consulting Engineering Services, Inc., Plumas Geo-Hydrology, and ERG & Associates to investigate recharge to the alluvial aquifer in the southwest Truckee Meadows of Washoe County (Figure 2-1). The work entailed two different, yet somewhat related topics. Specifically, the team was charged with conducting a "*feasibility analysis of a pilot groundwater recharge project*" and an "*analysis of the surface water contributions to the shallow aquifer in use by the domestic well owners in the south Truckee Meadows*." Specific questions these investigations were expected to answer include:

- Is it feasible to augment the recharge to the aquifer in the study area using existing wells?
- What are the costs to equip existing wells for a pilot groundwater recharge program?
- What percentage of the surface water that is applied as agricultural irrigation recharges the aquifer and does this recharge affect the portion of the aquifer that is exploited by domestic well users?
- Should conjunctive use of the water supply through a program that augments the recharge to the groundwater flow system be pursued on a large scale?

Combining these two topics into a single study makes perfect sense. If it can be demonstrated that infiltration of surface water applied to the land as irrigation represents a significant portion of recharge to the aquifer, then the conversion of lands from irrigated agriculture to residential use or change in the manner of use of surface water rights from irrigation to municipal and industrial use has the potential to affect the availability of water to wells of all types in the study area. Furthermore, methods other than wells may prove to be effective means of recharging the aquifer, mitigating the effects of current groundwater withdrawals as well as moderating potential impacts due to future increases in groundwater withdrawals.

Previous work undertaken in the study area indicated that conditions which favor increasing the recharge to the aquifer do exist in and around the study area. This current study tests the hypothesis that aquifer recharge and recovery of the additional water is feasible for this area.

A computerized data base containing basic information for more than 650 individual domestic wells in the study area was compiled. A second data base containing more than 1,600 water chemistry analyses was also compiled. These are provided on diskettes in the Appendix .



SOUTH TRUCKEE MEADOWS RECHARGE PROJECT

PROJECT LOCATION MAP

N.T.S.
DRAWN BY: SOS
DATE: 2-23-98
JOB NO.: 97050.30

FIGURE 2-1

CONSULTING ENGINEERING SERVICES, INC.
1105 TERMINAL WAY, SUITE 304
RENO, NEVADA 89502
702-786-5873

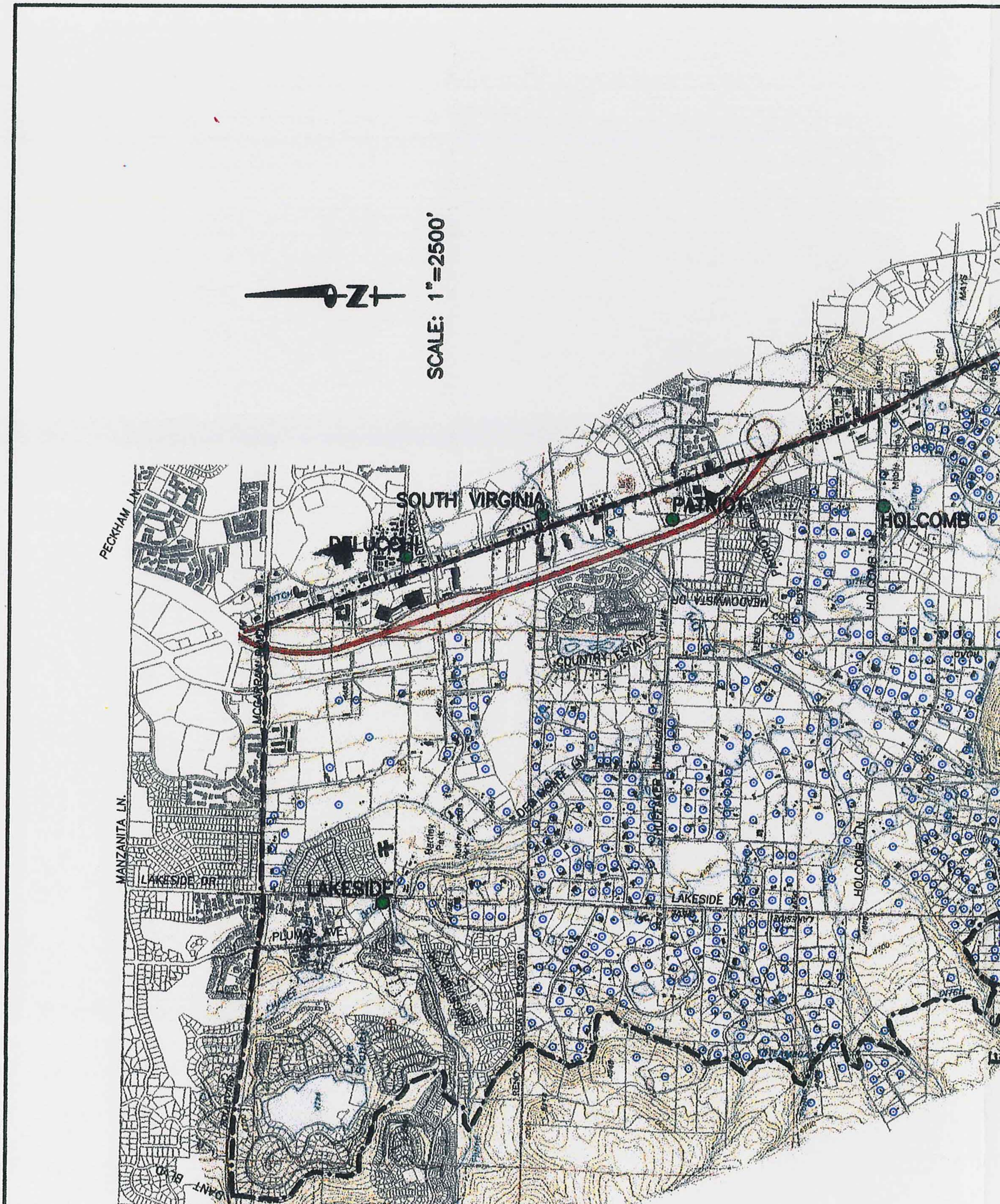
2.2 STUDY AREA

The study area for the projects comprises approximately 10.1 square miles in the southwest Truckee Meadows near Reno, Nevada. It is bounded on the north by McCarran Boulevard, on the west by the Steamboat Ditch, on the south by the Mount Rose Highway (State Route 441), and on the east by South Virginia Street (Figures 2-1 and 2-2). Since roughly the late 1960's and early 1970's, land use in this area has undergone a transition from rural/agricultural to residential.

The study area lies within the Southwest Truckee Meadows planning area defined by the Washoe County Department of Community Development. This planning unit is described as the unincorporated area south of the Truckee River, west of South Virginia Street, north of the Mount Rose Highway, and east of the Toiyabe National Forest boundary. The 1990 census yielded an estimate of 5,600 residents living in the Southwest Truckee Meadows planning area. By the year 2015, the population is expected to grow to 10,900 residents (Washoe County Department of Community Development, 1997).

Within the study area, groundwater is the primary source of water supply to the residents. The sources of water supply include at least 650 individual domestic or residential wells and eight moderate to high-yield municipal wells. The municipal wells include five owned and operated by the Sierra Pacific Power Company (SPPCo) and three owned and operated by the South Truckee Meadows General Improvement District (STMGID). Both entities own and operate additional wells outside, yet close to, the study area. The locations of the municipal water supply wells within the study area and several of the nearby wells outside of the study area are shown in Figure 2-2. Also depicted in Figure 2-2 are land parcels which are known to be served by individual domestic wells. As the population in and around the study area has increased, so have groundwater extractions via wells. In 1985, SPPCo and STMGID combined to extract a total of 1,305 acre-feet per year of groundwater from the southwest Truckee Meadows. By 1996, their combined extractions in the area increased to 3,217 acre-feet. The discharge from individual domestic wells is not metered, but is estimated at approximately 728 acre-feet per year. Consequent to increased pumping, there have been measurable declines in water level in wells over a large area. These declines affected a number of domestic wells, some of which needed to be deepened to keep the pumps from breaking suction.

In the past 20 or so years factors other than increased groundwater pumping may have combined to affect the groundwater resources in the area. For example, there were periods of lower-than-average precipitation in the mid-1970's and late 1980's to early 1990's that may have reduced recharge to the aquifer from precipitation. Likewise, drought periods can affect the groundwater resource by reducing the amount of secondary recharge from irrigation if less surface water is applied as irrigation. In addition, the diversion of Truckee River water via the irrigation ditch network has been reduced to comply the Orr Ditch Decree. This reduction in ditch diversions very likely contributed to a reduction in secondary recharge to the aquifer since the mid 1980's.



MAP BASE: USGS MT. ROSE NE 7.5 MIN. TOPOQUAD
REF: WASHOE COUNTY DEPT. OF WATER RESOURCES

In addition to increased groundwater withdrawals, changes in land use in the study area affect the groundwater resources in other ways. A portion of the water which is applied as irrigation infiltrates the soil and recharges the aquifer that is used as the source of domestic water supply in the study area. As the irrigated acreage decreases, recharge to the aquifer from this source is expected to diminish.

For the reasons addressed above, both the Utility Services Division of the Washoe County Water Resources Department (WCUSD) and Sierra Pacific have expended considerable resources to quantify the groundwater resources of the Truckee Meadows and surrounding valleys. Both entities recognize the potential to store surface water in the aquifer when it is plentiful for use during drought periods or when demand is greater than normal. Utilizing surface water as the source of the water which is stored in an aquifer is a water management tool referred to as conjunctive use. One type of conjunctive use is referred to as aquifer storage and recovery (ASR). ASR can meet a number of water management objectives (Pyne, 1991). Those which may be most applicable to the study area include:

- **Seasonal storage.** Water is stored in the aquifer during parts of the year when it is available and demand is lower than supply. It is recovered later in the year when demand is high.

- **Long-term storage.** Water is stored in the aquifer during years when there is excess water available either through spare capacity or higher than average surface-water supply. It is recovered during drought years when demand exceeds the surface-water supply. This is commonly referred to as "water banking."

- **Emergency storage**. Excess water is stored in the aquifer and used only in the event of a loss of a majors source. In the Truckee Meadows area, this emergency situation might result from a chemical spill in the Truckee River upstream of Reno.

- **Restore groundwater levels.** A consequence of exploitation of an aquifer as a source of water supply is a decline in water levels in the aquifer. Where groundwater extractions are concentrated in a small area, water level declines can be large enough to affect the performance of wells, particularly shallow domestic wells. These declines can be reversed by leaving a small percentage of the stored water in the aquifer each year. Over time, the cumulative effect can cause a significant rise in water level.

- **Enhance well-field production**. Well fields are designed and operated on the basis of the amount of water that the pumping equipment can pump from a specified pumping level. It is normal for the pumping level in a well field to decline over time. As the pumping level approaches a critical depth, the discharge from the well field may need to be reduced to maintain this level. If aquifer storage and recovery can result in a large rise in the pumping level, then the well field capacity can be increased.

ASR in the Truckee Meadows intuitively would entail storing surface water underground using either recharge (injection) wells or other means such as infiltration basins (ponds), galleries (covered trenches), or land application (flood irrigation) for subsequent extraction via wells. For ASR projects utilizing injection wells, the source of water would most likely be treated surface water from Sierra Pacific's Chalk Bluff water treatment plant. In concept, the water would be available during off-peak periods such as the late fall to late spring when the plant's capacity exceeds the water supply demand. Treated or "polished" water is desirable because it limits the potential for the injection wells to plug with fine-sized suspended material that can be associated with surface water. Plugging of the wells reduces their effectiveness and is difficult and expensive to correct. If infiltration basins, galleries or land application are employed, the level of treatment is less than for injection wells. Surface water derived from tributary streams or from the Truckee River via the existing irrigation ditch network would require minimal treatment prior to spreading on the land surface or introduction into ponds.

Conjunctive use of surface and groundwater resources combined with groundwater recharge is a logical next step in water planning and management for the South Truckee Meadows.

2.3 Constraints Placed on The Study

The evaluation of the feasibility of aquifer storage and recovery that is discussed in this report is constrained by several factors. These factors strongly influence the conclusions of the study.

1. The study is limited to existing wells which could be incorporated into an aquifer recharge, storage, and recovery project. There almost certainly are sites within the study area where wells better suited to this purpose than the existing wells could be located and constructed. Likewise, recovery of the stored water can almost certainly be maximized by designing and building a well field specifically for this purpose instead of utilizing existing wells. However, an evaluation of new well sites and the design of a well field that will yield the most efficient recharge program is beyond the scope of this investigation.

2. The overall feasibility of aquifer recharge, storage, and recovery in the Southwest Truckee Meadows is affected by current regulations which govern these types of projects in the State of Nevada. In effect, the current regulations artificially reduce the efficiency of recharge projects in hydrogeologic regimes similar to the study area. Because the overall efficiency is critical to determining whether or not a project is economically viable, the discussion of economic feasibility in this report should be considered to be conservative. If the current regulations can be amended to account for the hydrogeologic conditions found in the study area, then the economic feasibility may more readily incorporate the benefits of a recharge project that cannot be considered under the current regulations.

3. The hydrogeological analyses of water recharge, storage, and recovery are based on a hydrogeologic model of the aquifer which existed at the time of this study. This model, however, does not incorporate recent advancements in the understanding of the groundwater flow regime beneath the study area. These advancements intuitively would improve on the analysis of the recovery water that is stored in the aquifer. Updating the model is beyond the scope of this investigation, but the information summarized in this study will help to improve future modeling efforts. Despite this limitation, the comparisons between various well sites are still valid. The recommended pilot study is expected to improve on the analysis of the recovery efficiency.

The reader of this report is reminded to consider these constraints.

3.0 HYDROGEOLOGY

3.1 PHYSICAL SETTING

The study area lies within the southwest Truckee Meadows. The Truckee Meadows is situated at the juncture to two different physiographic provinces; the Sierra Nevada batholith to the west and the Basin and Range to the east. The Truckee Meadows is a structural depression that is bounded on the east and west by faults. The downward movement of the valley relative to the mountains along these faults has created a structural depression which has filled with detritus that has been eroded from the mountains, transported by streams, and deposited in the valley. Figure 3-1 is a geologic map of the study area. It depicts the various geologic units and the distribution of faults within and surrounding the study area.

The elevation of the floor of the Truckee Meadows is approximately 4,400 feet above sea level. The surrounding mountains include the Carson Range of the Sierra Nevada to the west and the Virginia Range to the east. Elevations range from over 10,000 feet at Mount Rose in the Carson Range and 7,000 feet in the Virginia Range.

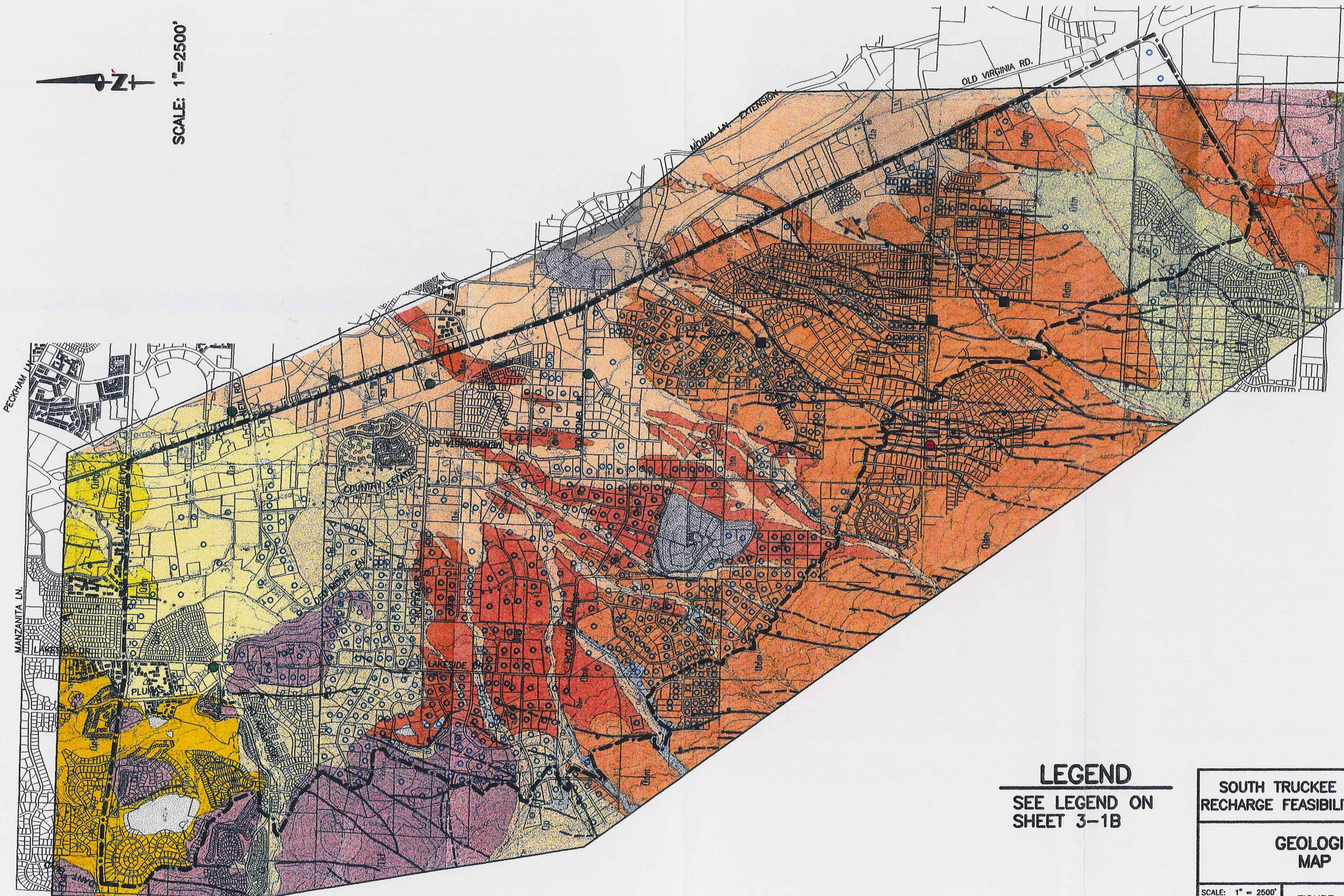
The principal stream in the Truckee Meadows is the Truckee River. It is located approximately three miles north of the study area and traverses the valley from west to east. Tributary streams include Whites, Thomas, Evans, and Steamboat Creeks. Although the Truckee River does not influence the study area directly, irrigation diversions from the river are transported to it via a series of ditches - the Steamboat, Last Chance, and Lake Ditches. Whites and Thomas Creek are the streams which most affect the study area.

3.2 CONCEPTUAL MODEL OF THE GROUNDWATER FLOW SYSTEM

The groundwater-flow regime in the South Truckee Meadows has been described in detail in a number of investigations and reports. The most recent work has been conducted by or for SPPCo and Washoe County. A brief summary of the hydrogeology of the study area is presented below.

Beneath the study area and vicinity, with minor exceptions, groundwater pumped from wells is obtained from unconsolidated to weakly consolidated alluvial deposits. These alluvial deposits comprise a mix of sand, gravel, silt and clay that were eroded from the mountains of the Carson Range to the west of the Truckee Meadows, transported by streams, and deposited in the valley. The moderately sloping land surface that extends from the valley floor to the range front west of the study area is referred to as the Mount Rose alluvial-fan complex. The saturated geologic materials that make up the fan are an important aquifer in the study area.

Groundwater flows from areas of higher elevation to areas of lower elevation. The water table (or potentiometric surface) can be depicted by contour lines of equal water-level elevation. A water-level contour map of the Mount Rose fan area is provided in Figure 3-2. The water-level contours in Figure 3-2 clearly show that groundwater in the fan flows in a more or less easterly direction beneath the study area.



MAP SOURCE: BONHAM & ROGERS, 1983

LEGEND

SEE LEGEND ON SHEET 3-1B

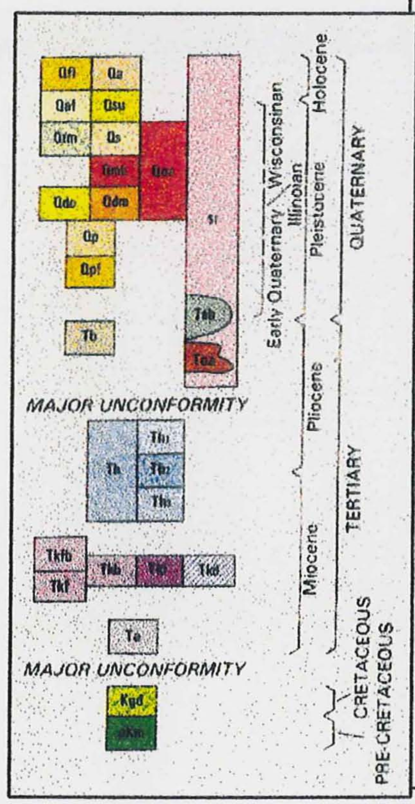
SOUTH TRUCKEE MEADOWS RECHARGE FEASIBILITY PROJECT	
GEOLOGIC MAP	
SCALE: 1" = 2500' DRAWN BY: SOS DATE: 2-23-98 JOB NO.: 97050.30	FIGURE 3-1A

CONSULTING ENGINEERING SERVICES, INC.
1105 TERMINAL WAY, SUITE 304
RENO, NEVADA 89502
702-786-5873

DWG\STM-GWTR\STM-GEO

LEGEND

- ○ DOMESTIC WELLS
- ■ SOUTH TRUCKEE MEADOWS GENERAL IMPROVEMENT DISTRICT/WASHOE COUNTY MUNICIPAL WELL
- ● SOUTH TRUCKEE MEADOWS GENERAL IMPROVEMENT DISTRICT TEST WELL
- ● SIERRA PACIFIC POWER CO. MUNICIPAL WELL



Qfl **Floodplain and lake deposits.** Interbedded gray to pale grayish-yellow silt and fine sand; contains thin lenses of peat; fluvial and lacustrine deposits up to 7 m (23 ft) thick. Little or no soil development (entisols)

Qs **Alluvial bajada deposits.** Thin sheet-like aprons of fine- to medium-grained clayey sand and intercalated muddy, medium pebble gravel; deposits of low gradient streams that reworked older gravelly outwash and alluvial fan deposits; weakly weathered and largely undissected. Little or no soil development (entisols)

Qaf **Alluvial fan of Windy Hill.** Locally derived silty to muddy, medium pebble gravel transported from the large Evans Creek drainage area; engulfs high-standing remnants of Donner Lake Outwash. These fan deposits intertongue with and become part of the alluvial bajada, Qs. Generally undissected, but contains scattered remnants of older alluvium

Qsu **Sand, undifferentiated.** Local deposits of fine to medium sand; eolian, alluvial outwash, and colluvial slope wash deposits

Qtm **Tahoe Outwash—Mount Rose Fan Complex.** Glacial outwash stream deposits of volcanic and granitic composition; light yellowish- to orange-brown; sandy large cobble to boulder gravel containing characteristically fresh granitic leg gravel. Strongly developed 1-m (3 ft) thick soil profile; dark yellowish-brown, prismatic argillic B-horizon; typically no siliceous or calcic duripan development; granitic boulders partly to thoroughly decomposed where buried in soil. Deposits locally only thin veneers; some undifferentiated areas

Qoa **Older alluvium.** Highly dissected remnants of muddy, sandy small pebble gravel in alluvial deposits transported from Thomas Creek; soil profile 1-2 m (3-6 ft) thick with strongly developed argillic B-horizon; local duripan development. Also includes areas of older alluvium in Steamboat Hills

Qs **Sidestream deposits.** Fluvial silt and medium sand associated with Tahoe Outwash deposits along the Truckee River; soil profile similar to Qtm

Qmb **Mud-volcanic breccia.** Heterogeneous mixture of bleached and iron-stained boulders and fragments of volcanic rocks, opaline and chalcedonic sinter, and disintegrated granitic debris

Qdo **Donner Lake Outwash.** Bouldery outwash forming strath terraces on bedrock; extensive mantle thickening eastward; unconsolidated small cobble gravel and interbedded coarse sand. Highly rounded clasts; unit locally contains very large, deeply weathered boulders of basalt and quartz monzonite more than 2 m (6 ft) in diameter. Strongly developed soil profile 2-3 m (6-10 ft) thick; prismatic argillic B-horizon; weakly to strongly developed siliceous and calcic duripan 1-2 m (3-6 ft) thick; granitic clasts thoroughly disintegrated in weathered profile

Qdm **Donner Lake Outwash—Mount Rose Fan Complex.** Pediment and thin fan deposits from major streams draining alpine glaciers on Mount Rose; brown to brownish-gray, sandy, muddy, poorly sorted large pebble gravel; cobbles and small boulders common. Clasts dominantly volcanic (porphyritic andesite and latite); surface granitic clasts rare. Deeply weathered, strongly developed soil profile similar to Qdo; locally overlain by undifferentiated veneer of Qtm; well cemented and/or hydrothermally altered in Steamboat Hills area

Qp **Pediment gravel.** Veneers of moderately to poorly sorted medium pebble to cobble gravel <3 m (10 ft) thick; commonly occurs as gravel sheet <1 m (3 ft) thick over bedrock and older pediment and alluvial fan gravels; clast content dominantly volcanic. Strongly developed soil profile; thick argillic B-horizon locally overlying siliceous and calcic duripan

Qpf **Alluvial fan deposits of Peavine Mountain.** Yellowish-brown gravel and gravelly muddy sand consisting of angular pebbles to small cobble-sized clasts of andesite and white bleached andesite in matrix of muddy sand; unconformably overlies steeply dipping beds of sandstone of Hunter Creek (Th). Strongly developed soil profile; argillic B-horizon ½ m (2 ft) or more thick; typically overlies thick calcic and siliceous duripan

sr **Hot-spring sinter.** Siliceous sinter ranging in age from late Pliocene to present. Older sinter is white to gray chalcedony; locally contains mercury sulfides; younger sinter is light gray to tan porous opal

Tsb **Basaltic andesite of Steamboat Hills.** Dark grey flows with phenocrysts of plagioclase and olivine in intergranular matrix of pyroxene, plagioclase, Fe-Ti oxides. Source of flows is cinder cone in SW/4 S32,T19N,R20E. K-Ar age: 2.53 ±0.1 m.y.

Toa **Old alluvium of Steamboat Hills.** Pediment deposits underlying Tsb. Pebble to cobble gravel consisting of angular to subangular granitic, volcanic, and metamorphic clasts and arkosic sands. Locally well cemented and/or strongly hydrothermally altered

Tb **Basalt and basaltic andesite of Carson Range.** Dark gray basaltic-appearing flows with prominent platy flow jointing; mineralogically similar to Tsb

Th, Th_1, Th_2, Th_3 **Sandstone of Hunter Creek.** Th: Undifferentiated. Th_1: Brown to gray, medium- to thick-bedded, subangular coarse sand; intercalated tuff and subrounded andesite pebble to cobble conglomerate; grades upward into thin-bedded silt and diatomaceous silt. Th_2: White to light gray, massive to thin-bedded diatomaceous siltstone with minor beds of yellowish-tan medium sand; iron oxide staining of fractures in siltstone common. Th_3: Tan, gray to reddish-brown, thin- to thick-bedded, alternating layers of fine to coarse sand; intercalated layers of well rounded pebbles; cross-bedding common in sand fractions; basal contact conformable with Th_2

Tkf, Tkfb, Tkb, Tki, Tkd **Kate Peak Formation.** Tkf: Hornblende-pyroxene andesite and dacite flows with minor breccia and volcanic conglomerate. Tkfb: Hydrothermally bleached Tkf. Tkb: Hornblende-pyroxene dacite and andesite lahars, pyroclastic breccia, volcanic conglomerate, and sandstone with minor flows. Tki: Intrusive hornblende-pyroxene-biotite dacite. Tkd: Flow-dome complexes of hornblende-biotite rhyodacite porphyry

Ta **Alta Formation.** Flows of dark, fine-grained soda trachyte; occurs in Steamboat Hills area

Kgd **Biotite-hornblende granodiorite**

pKm **Metasedimentary and metavolcanic rocks.** Graywacke, argillite, slate, phyllite, hornfels, metatuff and breccia, volcanic conglomerate, and marble

Contact. Dashed where approximately located; dotted where concealed

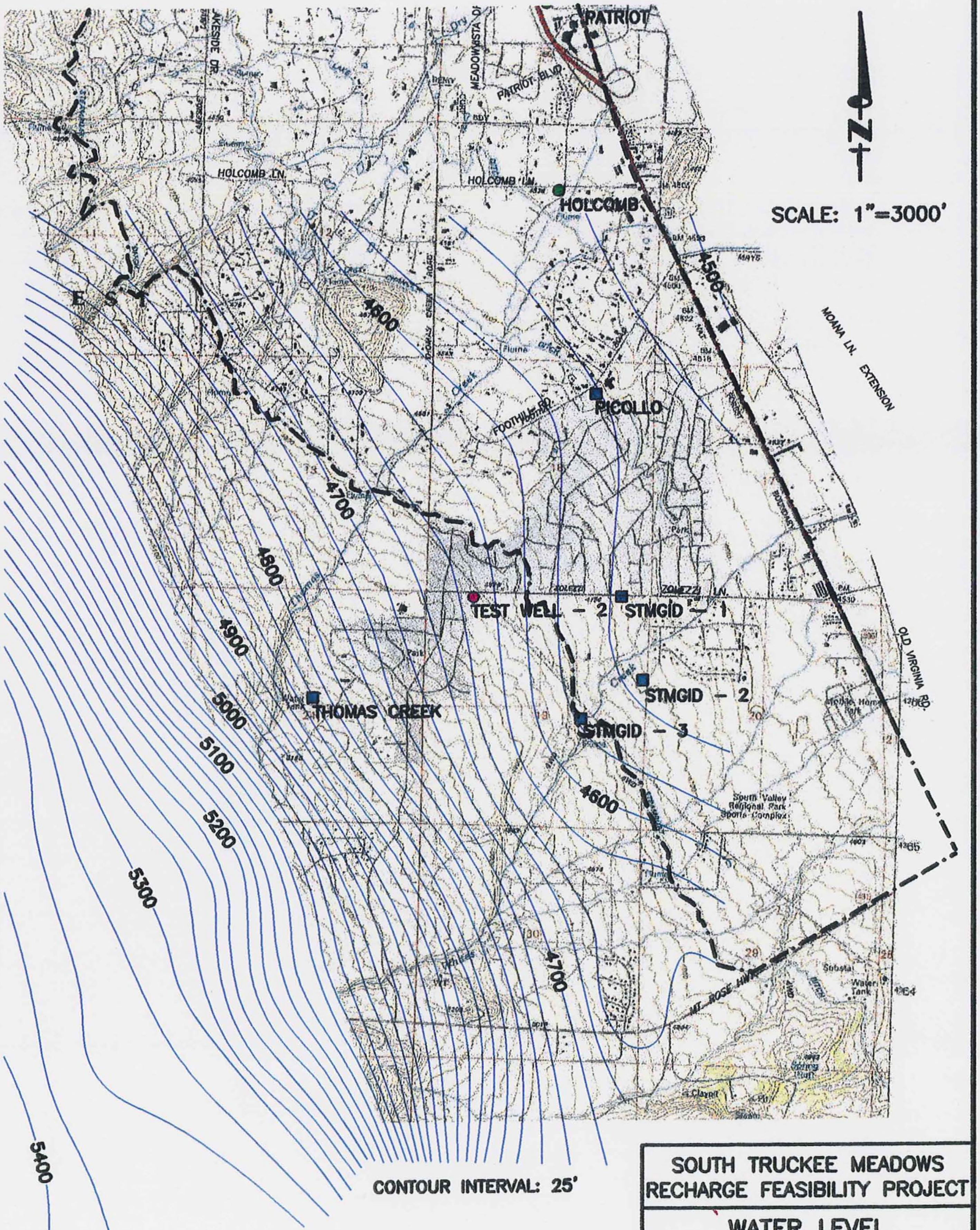
Fault. Dashed where approximately located; dotted where concealed; queried where presence uncertain

- Undifferentiated landslide deposits
- (fill) Artificial fill. Not all fill areas shown
- Strike and dip of beds
- Strike and dip of flow layering
- Phreatic explosion crater. (Steamboat Hills)

DWG\STM-GWTR\STM-GEO

SOUTH TRUCKEE MEADOWS RECHARGE FEASIBILITY PROJECT	
GEOLOGIC MAP	
SCALE: 1" = 2500' DRAWN BY: SOS DATE: 2-23-98 JOB NO.: 97050.30	FIGURE 3-1B

CONSULTING ENGINEERING SERVICES, INC.
1105 TERMINAL WAY, SUITE 304
RENO, NEVADA 89502
702-786-5873



REF: WCUD

DWG\STM-GWTR\STM-WLEV

SOUTH TRUCKEE MEADOWS RECHARGE FEASIBILITY PROJECT

WATER LEVEL CONTOUR MAP

SCALE: 1" = 3000' DRAWN BY: SOS DATE: 2-23-98 JOB NO.: 97050.30	FIGURE 3-2	CONSULTING ENGINEERING SERVICES, INC. 1105 TERMINAL WAY, SUITE 304 RENO, NEVADA 89502 702-786-5873

The slope of the piezometric surface is relatively steep, with a hydraulic gradient of about 0.01 to 0.03 over a large part of the study area. The gradient flattens toward the east.

3.2.1. Sources of Recharge

Recharge to the alluvial deposits of the Mount Rose Fan is derived from a variety of sources. These include:

- Precipitation,
- Infiltration of surface water from streams, primarily Whites and Thomas Creeks;
- Ditch leakage,
- Secondary recharge from irrigation, and
- Secondary recharge from individual septic system leach fields.

Precipitation is the ultimate source of recharge to the aquifer. In and around the Truckee Meadows, precipitation varies from a low of approximately seven to eight inches on the valley floor to as much as 50 to 60 inches in the Carson Range to the west. Most of the precipitation falls as snow between the months of November and March with scattered thunderstorms in the summer months. A portion of the precipitation which is not returned to the atmosphere as evaporation or transpiration directly infiltrates the soil to the recharge the aquifer. The remainder runs off as stream flow. The amount of precipitation varies significantly from year to year as does recharge.

Stream flow originates as runoff, snowmelt, and groundwater discharge in the mountains. Infiltration of the surface water leaking from the streams below the range front is another source of groundwater recharge to the aquifer. Leakage from the streams occurs both in the mountains and on the alluvial fan below the range front. Guyton and Associates (1992a) measured stream flow in Whites and Thomas Creeks below the range front and immediately west of the study area. Their data clearly show that surface water leaks from the streams where they cross the alluvial fans. The infiltration of surface water where streams cross alluvial fans constitutes a significant source of groundwater recharge in most valleys in Nevada.

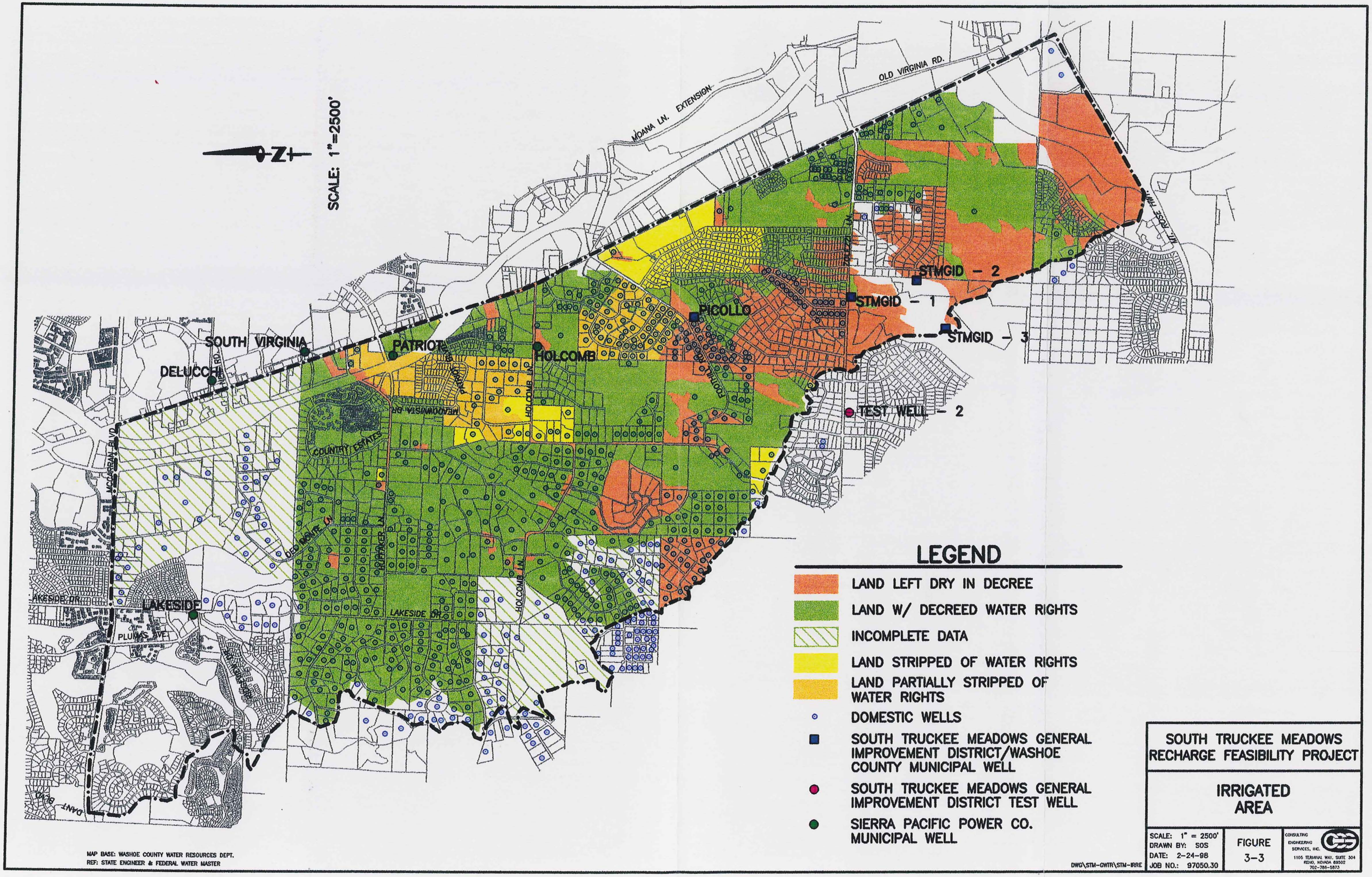
Three irrigation ditches are potentially important sources of groundwater recharge in the study area, particularly the shallower deposits used by domestic well owners. These include the Steamboat Ditch, which forms the western study area border, plus the Last Chance and Lake Ditches which traverse it. Unlined irrigation ditches are prone to leak and leakage may account for a loss of up to 30 percent of the diversion from the river (Matt Setty, personal communication). In fact, the Orr Ditch Decree allows for 30 per cent conveyance losses for the Steamboat Ditch and 20 per cent losses for the Last Chance and Lake Ditches. Soil surveys developed by the Soil Conservation Service [1976] identify specific soil types with high infiltration rates that are traversed by these ditches.

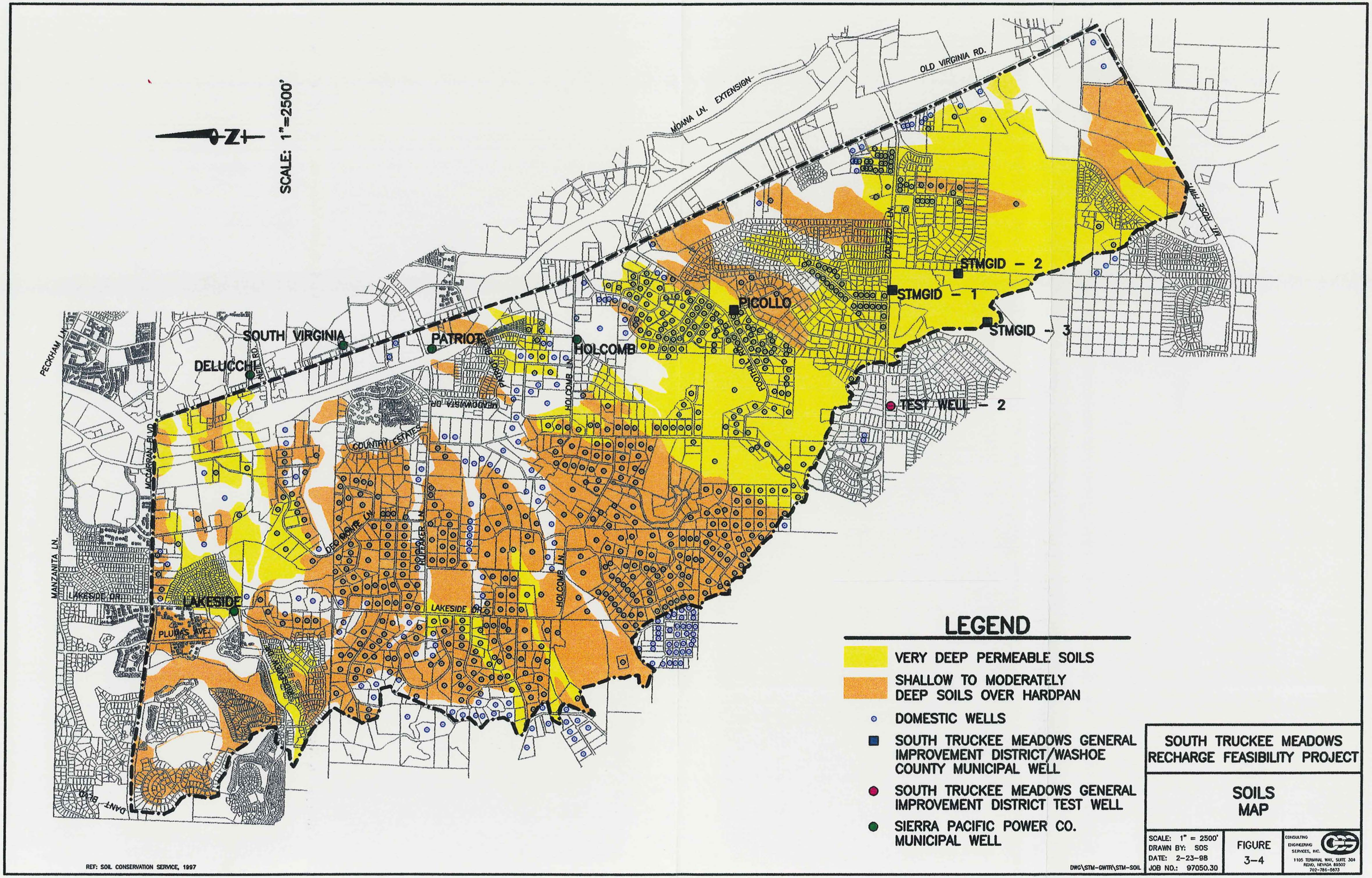
Few comprehensive studies of ditch leakage have been performed in the Truckee Meadows and the total contribution of groundwater recharge from this source is not known with certainty. One published study involved an economic analysis of lining the ditches to reduce conveyance losses (King, 1975). This study, however, made no attempt to refine earlier estimates of leakage. Our first-hand experience with short reaches of ditches in the Truckee Meadows show that leakage can be virtually negligible to extreme depending on the underlying soil, the time of year, and the depth of water in the ditch. At the start of the irrigation season for instance, a ditch may leak severely through dessication cracks in the fine-grained sediments that characteristically coat the bottom. Later in the year, swelling of the cracks and an accumulation of fine-grained sediment and algae plugs the leaks.

Because the ditch flow entering the study area is not measured, leakage from the ditches cannot be determined from existing data with a high degree of accuracy. However, a first approximation can be made using the annual ditch diversions, allowable conveyance losses, and proportioning the leakage according to the length of each ditch through the study area. Using this rationale, an estimated 1,700 acre-feet per year could be leaking from the ditches and recharging the aquifer in the study area.

The general distribution of irrigated lands and large-scale changes in irrigated acreage within the study area are depicted in Figure 3-3. However, Figure 3-3 should not be used to calculate actual irrigated area because irrigated land that has been displaced by roads, houses, driveways, etc. cannot be shown at this scale. Irrigation water rights are appurtenant to approximately 2,500 acres within the study area. However, of this area, approximately 1,620 acres of land are presently irrigated using flood-irrigation practices (Matt Setty, 1998). Most of the irrigated land has sufficient water rights to apply four acre-feet per acre during the irrigation season which typically runs from April to October of each year and a small percentage of the land is entitled to five acre-feet per acre. The actual volume of water applied to the land surface as irrigation is not documented, but is estimated at 6,700 acre-feet per year on the basis of field reconnaissance and the water allocations (*ibid*).

In Nevada, it is commonly assumed that 25 percent of the irrigation water applied by flood irrigation infiltrates the soil and recharges the underlying aquifers. The actual percentage can be greater and has been shown to be as high as 40 per cent for some irrigated lands in Douglas County (*ibid*). Using these criteria, the amount of secondary recharge from irrigation may range between 1,675 and 2,680 acre-feet per year. The actual amount of secondary recharge for a particular site depends on the soil type, slope of the land surface, application rate, antecedent moisture conditions, irrigation frequency, irrigation water management, and other factors. Figure 3-4 shows the general distribution of two broad soil types. One type is associated with hard pan layers which inhibit downward movement of groundwater. The other type represents very deep and highly permeable soils that promote downward percolation of water applied to the surface. From Figure 3-4, it can be inferred that the southern one-half of the study area is underlain by soils which are more suitable to secondary recharge from irrigation.


SCALE: 1"=2500'
N
OLD VIRGINIA RD.
MOANA LN. EXTENSION
SOUTH VIRGINIA
DELUCCHI
PATRIOT
HOLCOMB
PICOLLO
STMGID - 1
STMGID - 2
STMGID - 3
TEST WELL - 2
LAKESIDE
LAKESIDE DR.
PLUMAS AVE.
MCCARRAN BLVD.
MEADOWVISTA DR.
COUNTRY ESTATES
DEL MONTE LN.
HOLCOMB LN.
LAKESIDE DR.
TOLUCA LN.
LEGEND
LAND LEFT DRY IN DECREE
LAND W/ DECREED WATER RIGHTS
INCOMPLETE DATA
LAND STRIPPED OF WATER RIGHTS
LAND PARTIALLY STRIPPED OF WATER RIGHTS
DOMESTIC WELLS
SOUTH TRUCKEE MEADOWS GENERAL IMPROVEMENT DISTRICT/WASHOE COUNTY MUNICIPAL WELL
SOUTH TRUCKEE MEADOWS GENERAL IMPROVEMENT DISTRICT TEST WELL
SIERRA PACIFIC POWER CO. MUNICIPAL WELL
SOUTH TRUCKEE MEADOWS RECHARGE FEASIBILITY PROJECT
IRRIGATED AREA
SCALE: 1" = 2500'
DRAWN BY: SOS
DATE: 2-24-98
JOB NO.: 97050.30
FIGURE 3-3
CONSULTING ENGINEERING SERVICES, INC.
1105 TERMINAL WAY, SUITE 304
RENO, NEVADA 89502
MAP BASE: WASHOE COUNTY WATER RESOURCES DEPT.
REF: STATE ENGINEER & FEDERAL WATER MASTER
DWG\STM-GWTR\STM-IRRE



SCALE: 1"=2500'
N
OLD VIRGINIA RD.
MOANA LN. EXTENSION
MT. ROSE FWY.
PECKHAM LN.
MANZANITA LN.
McCARRAN BLVD
LAKESIDE DR.
PLUMAS AVE.
DANT BLVD.
MEADOWVISTA DR.
COUNTRY ESTATES
HOLCOMB LN.
HUFFAKER LN.
FOOTHILL
ZOLEZZI LN.
DELUCCHI
SOUTH VIRGINIA
PATRIOT
HOLCOMB
PICOLLO
STMGID - 1
STMGID - 2
STMGID - 3
TEST WELL - 2
LAKESIDE
LEGEND
VERY DEEP PERMEABLE SOILS
SHALLOW TO MODERATELY DEEP SOILS OVER HARDPAN
DOMESTIC WELLS
SOUTH TRUCKEE MEADOWS GENERAL IMPROVEMENT DISTRICT/WASHOE COUNTY MUNICIPAL WELL
SOUTH TRUCKEE MEADOWS GENERAL IMPROVEMENT DISTRICT TEST WELL
SIERRA PACIFIC POWER CO. MUNICIPAL WELL
SOUTH TRUCKEE MEADOWS RECHARGE FEASIBILITY PROJECT
SOILS MAP
SCALE: 1" = 2500'
DRAWN BY: SOS
DATE: 2-23-98
JOB NO.: 97050.30
FIGURE 3-4
CONSULTING ENGINEERING SERVICES, INC.
1105 TERMINAL WAY, SUITE 304
RENO, NEVADA 89502
702-786-5873
REF: SOIL CONSERVATION SERVICE, 1997
DWG\STM-GWTR\STM-SOIL

At least 650 residences in the study area rely on septic tanks to treat domestic sewage waste. Effluent from the septic systems is discharged via leach fields. A large portion of the effluent reaches the aquifer as secondary recharge. While the total volume of effluent may be small compared to the other sources of recharge, it may be important from a water quality standpoint. Later sections of this report address this topic.

3.3 GROUNDWATER FLOW MODELS

Groundwater flow is the Truckee Meadows has been analyzed through the use of computerized numerical models since the 1970's. Two recent modeling efforts that are applicable to the study area were undertaken on behalf of SPPCo (McDonald Morrissey Associates, Inc., 1995) and Washoe County (Hydro-Search, Inc., 1991).

The County's groundwater flow model results suggest that groundwater recharge to the Mount Rose Fan may be as much as 10,000 acre-feet annually. The model assumed that irrigation was limited to a small portion of the current study area and that ditch leakage was insignificant. Consequently, it yielded an estimate of secondary recharge from irrigation of approximately 300 acre-feet per year. Despite a different modeling approach, Sierra Pacific's modeling effort yielded a similar estimate of the available groundwater resources. The SPPCo model provided a much greater estimate for secondary recharge from irrigation and incorporated leakage from the irrigation ditches and streams. These aspects of the SPPCo model are more consistent with the our concept of groundwater flow in the study area. However, because SPPCo's model was customized to include program modules that are not readily available to the general public, the County's model formed the basis of many of the analyses of aquifer storage and recovery that are addressed later in the report.

3.4 CHANGES IN THE GROUNDWATER REGIME

3.4.1 ANTHROPOGENIC CHANGES

The exploitation of groundwater as a source of water supply is not without consequences. The water derived from wells is water that is being used elsewhere either as evaporation from soil or free-water surfaces, evapotranspiration by phreatophytes, or stream flow. Pumping water from a well causes the surrounding water level in the aquifer to decline. If withdrawals are small compared to the groundwater flow in the subsurface and spread out over a large area, the decline may be imperceptible. However, if pumping is concentrated in a small area and withdrawals are relatively large compared to the total groundwater flow, a decline in water level may be noticeable and, in the extreme, can affect the performance of wells, particularly shallow ones.

3.4.1.1 INCREASED GROUNDWATER WITHDRAWALS

A recently as 1983, annual groundwater withdrawals from municipal wells in the southwest Truckee Meadows were relatively small. Sierra Pacific pumped a total of 1,109 acre feet from two wells at that time as shown in Figure 3-5. Other groundwater use in the study area was confined to several hundred individual residential wells. SPPCo's usage peaked in 1991 when they pumped 3,115 acre feet from five wells. Since then, SPPCo withdrawals have declined.

STMGID started pumping their well field in 1985 and they pumped a total of 121 acre feet from two wells in the study area that year. By 1996, they pumped a total of 1,663 acre feet from three wells in the study area and three more up-gradient of it. Figure 3-6 illustrates the STMGID pumping data for 1985 through 1996 and part of 1997.

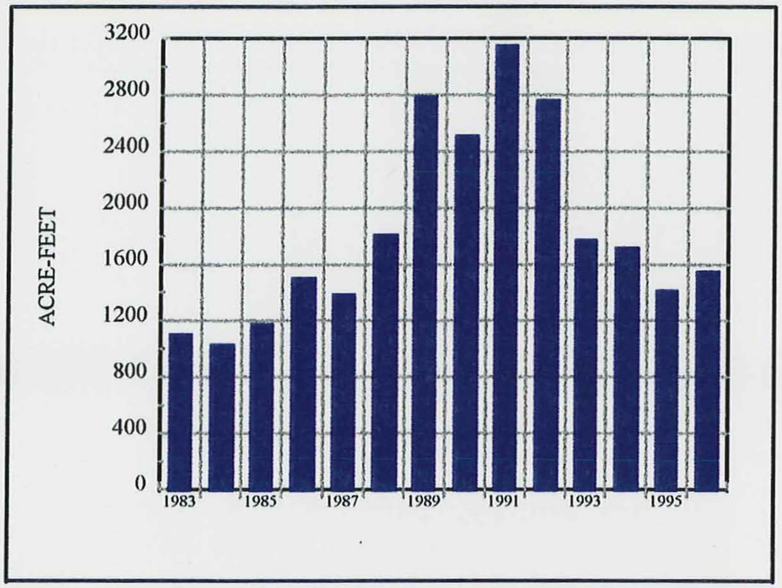


Figure 3-5. Sierra Pacific South Truckee Meadows Well Production

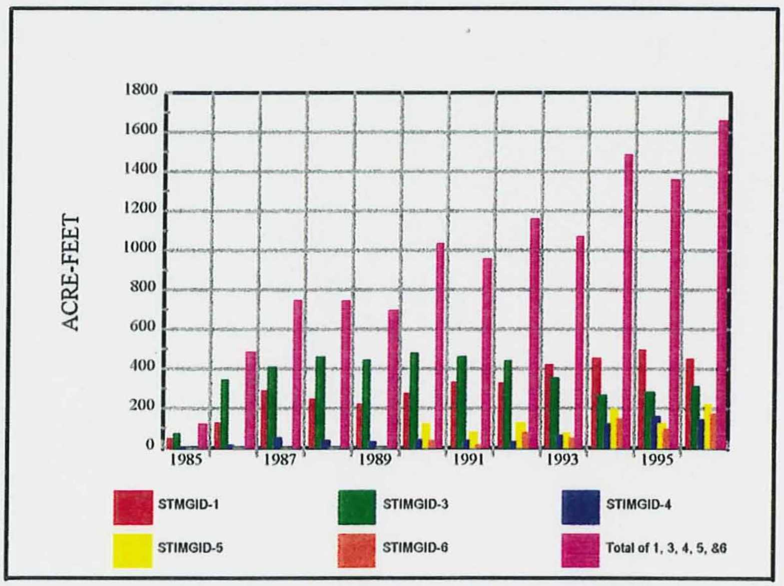
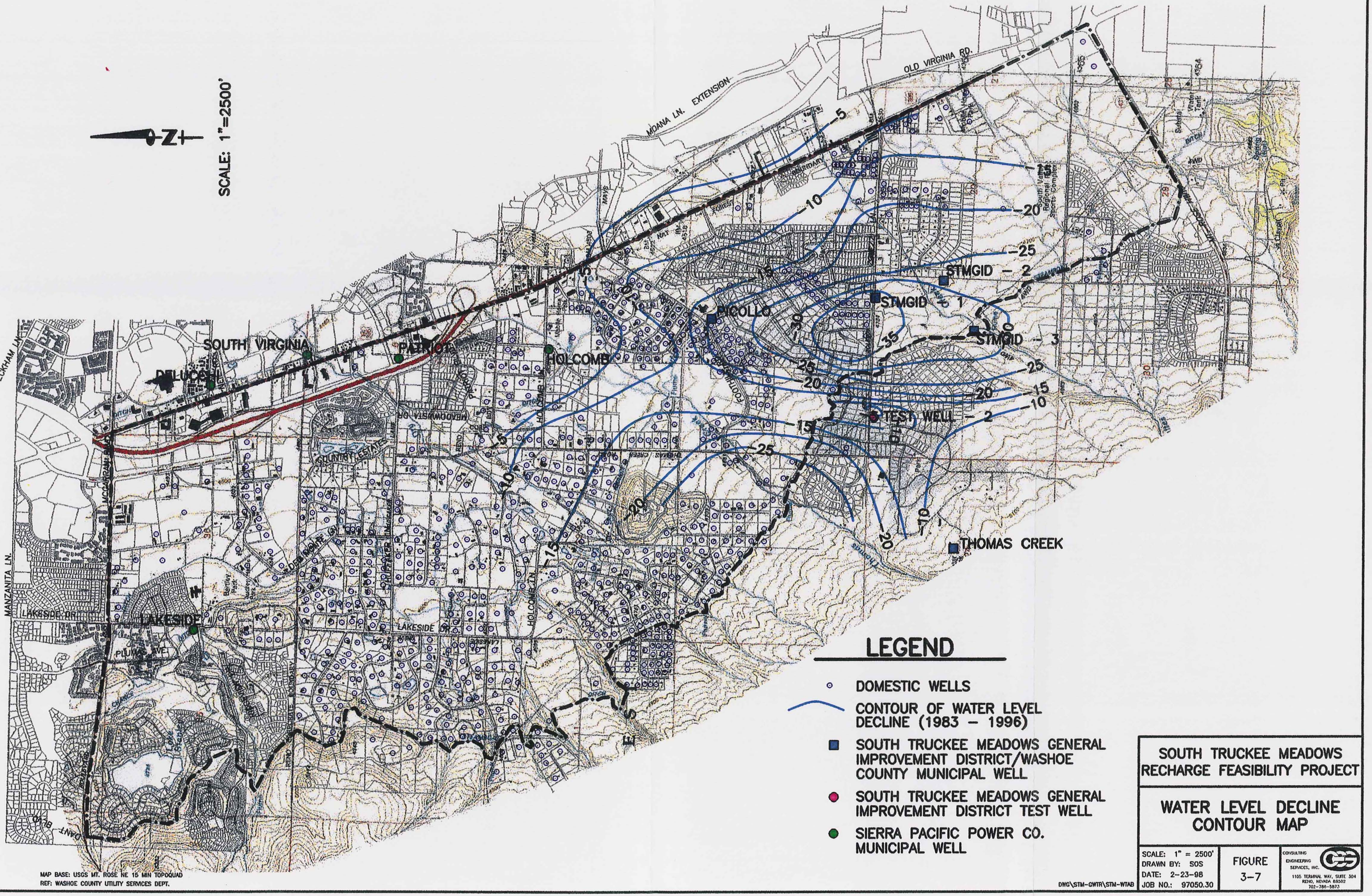


Figure 3-6. STMGID SW Truckee Meadows Well Production.

The combined groundwater withdrawals for the southwest Truckee Meadows for SPPCo and STMGID in 1996 totaled 3,217 acre-feet per year.

A predictable consequence of groundwater withdrawals via wells is a decline in water level in the aquifer which is manifested by a lowering of the water levels in wells. When a well is pumped, groundwater is initially removed from storage in the aquifer surrounding the well. Water levels in the aquifer continue to decline until the withdrawals from storage are balanced by the capture of groundwater moving through the aquifer, at which time a new equilibrium or steady-state condition develops. In fact, groundwater flow through an aquifer cannot be captured unless water-levels are lowered. Figure 3-7 (following page) shows the area where groundwater declines have occurred in the southern two thirds of the study area since 1972. In general, groundwater declines of more than 30 feet have been observed near STMGID Well Nos. 1, 2, & 3 and near SPPCo's Holcomb and Patriot wells. With the decrease in withdrawals from these SPPCo wells, groundwater levels have risen near the Holcomb well.



DWG\STM-GWTR\STM-WTAB

SOUTH TRUCKEE MEADOWS RECHARGE FEASIBILITY PROJECT		
WATER LEVEL DECLINE CONTOUR MAP		
SCALE: 1" = 2500' DRAWN BY: SOS DATE: 2-23-98 JOB NO.: 97050.30	FIGURE 3-7	CONSULTING ENGINEERING SERVICES, INC. 1105 TERMINAL WAY, SUITE 304 RENO, NEVADA 89502 702-786-5873

3.4.1.2 DECREASED IRRIGATED AREA AND IRRIGATION WATER DELIVERIES

The amount of irrigated acreage in the study area remained essentially constant up until the late 1960's, at which time land use in this area started to change. At present there are approximately 1,620 irrigated acres in the study area (Matt Setty, 1998). Although land use has changed from agricultural to residential, irrigation is still practiced on residential "ranchette" property to maintain landscaping and pasture for livestock. Simultaneously, water rights transfers from agricultural to municipal and industrial uses have reduced the irrigated acreage and amount of water applied. Water rights have been totally stripped from approximately 200 acres in the study area and partially stripped from nearly 297 acres (refer back to Figure 3-3). In addition to the water right transfers, residential construction may have removed as many as 800 to 900 acres from irrigation as the land surface is covered by roads, houses, barns, driveways, and other improvements (*ibid*). Analysis of aerial photographs indicates that between 1966 and 1979, irrigated acreage may have declined by as much as 25 per cent (See Figure 3-8). By 1995, irrigated acreage may have declined by an additional 20 per cent (McDonald Morrissey Associates, 1995) for a total decrease of approximately 45 per cent. This reduction in irrigated area may translate to a reduction of as much as 45 percent of the secondary recharge to the aquifer from irrigation within the study area since the late 1960's.

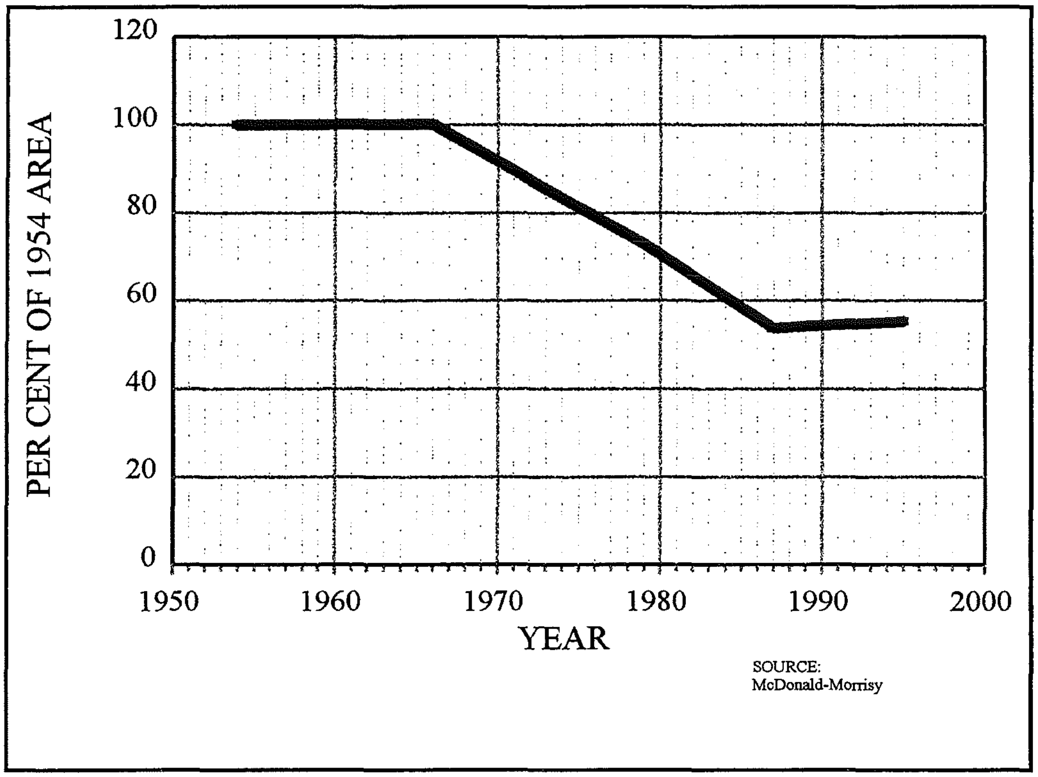


Figure 3-8. Changes in Irrigated Area.

The principal source of the irrigation water applied to land in the study area is Truckee River diversions via the Steamboat, Last Chance and Lake Ditches. The diversions of these ditches for the years 1975 through 1997 are shown in Figure 3-9. In 1985 and 1986 net diversions for the ditches were reduced by more than 50 per cent to be consistent with the Orr Ditch Decree.

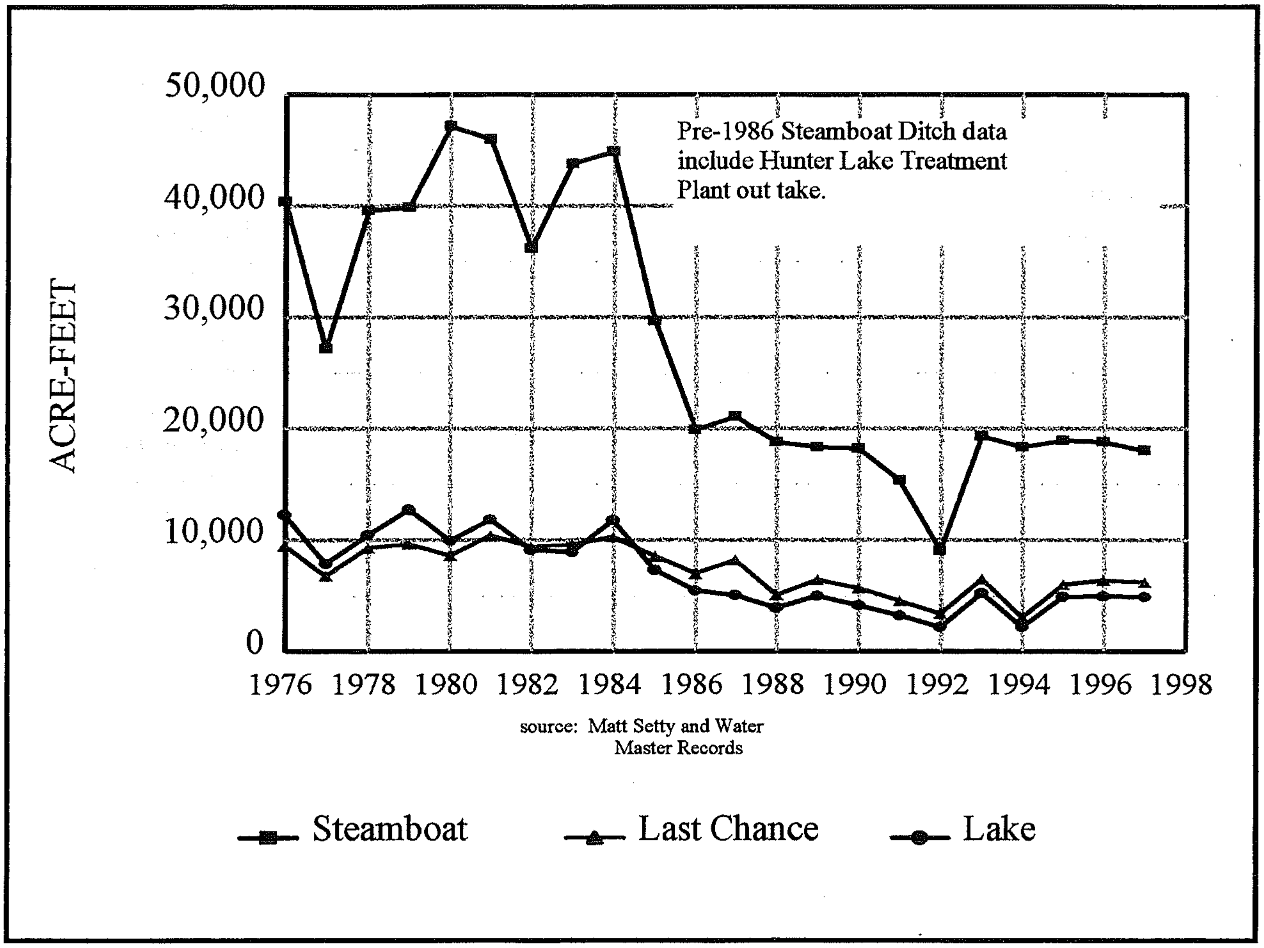


Figure 3-9. Diversion Summary.

The irrigation ditches are known to leak at various locales along their length and presumed to leak within the study area. Consequently, leakage is potentially a source of secondary recharge to the aquifer in the study area as cited earlier. If it is assumed the ditches leak uniformly along their entire length, the amount of secondary recharge from them within the study area may be nearly 1,700 acre-feet per year. Prior to 1985/86, when flow in the ditches was higher than it is at the present, leakage may have been greater than this estimated amount.

3.4.2 OTHER CHANGES

The groundwater recharge to the Truckee Meadows is subject to the vagaries of the climate. Average annual precipitation varies significantly. The area has felt several periods of protracted lower than average precipitation (or drought periods). Most recent droughts were observed in the mid- 1970's and late 1980's/early 1990's.

The effect of recent drought periods on groundwater levels in the Truckee Meadows has not been quantitatively assessed. It may be masked by other the other influences such as decreased irrigation water deliveries, increased pumping, and decreased irrigation.

Reno Precipitation

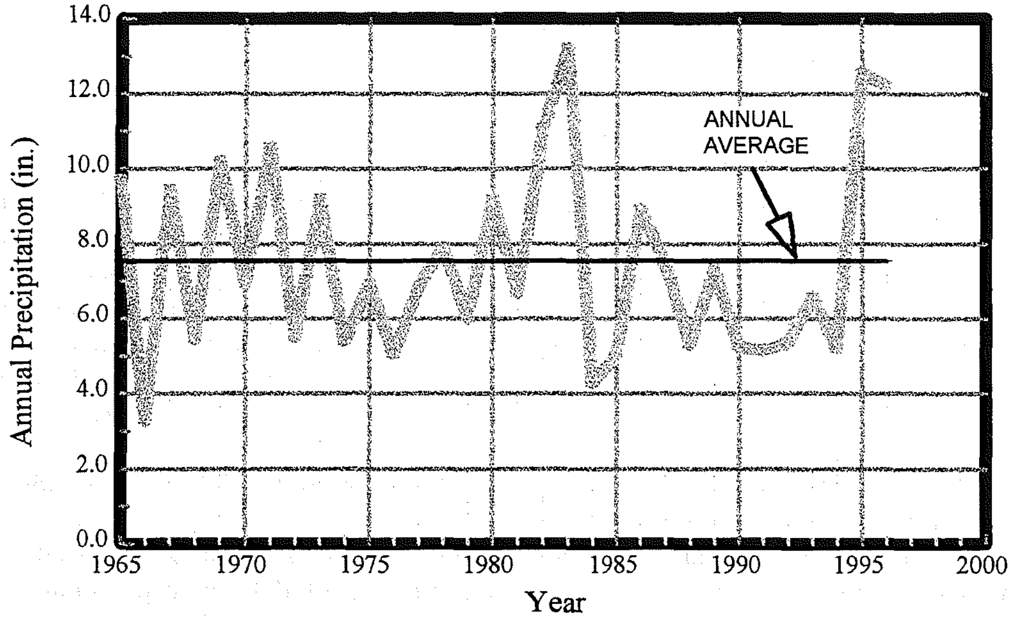


Figure 3-10 - Reno Annual Precipitation

4.0 BENEFITS AND FEASIBILITY ANALYSIS OF A PILOT GROUNDWATER RECHARGE PROJECT

4.1 PREVIOUS INVESTIGATIONS

Both the Washoe County Department of Water Resources Utility Services Division and Sierra Pacific Power Company have previously examined the potential for aquifer storage and recovery in the southwest Truckee Meadows. SPPCo's work examined specific reaches of Thomas and Whites Creek where leakage from the streams was measured. As part of the investigation, general areas where the soils were favorable for recharge via surface applications were also identified (Guyton, 1992a). The SPPCo investigations also concluded that the chemistry of the surface water and groundwater were chemically compatible so that plugging of the aquifer by mineral precipitation resulting from mixing of chemically incompatible surface and groundwater was not a concern (Guyton, 1992a and b). The general conclusion reached by their consultants was that geologic materials of the Mount Rose fan had potential for a groundwater recharge project.

The Guyton studies also addressed aquifer storage and recovery using wells. SPPCo's Lakeside well was identified as a likely candidate for use as an injection well during periods of the year when system demand was low. In 1993, SPPCo conducted a pilot study utilizing its Lakeside Well as a recharge well. The pilot study comprised a 24-hour duration injection test at an injection rate of 490 gallons per minute. In April 1994, a total of 9.2 acre-feet were injected. The following year, a total of 116 acre-feet were injected in April and March at a rate of 500 to 550 gpm (SPPCo, annual reports to the State Engineer). No major problems were encountered during operation of the injection program. However, the cost of operation of the system, including the extensive testing required, for the small quantity of water recovered has limited the system's feasibility.

As part of a broader groundwater resource study, the Washoe County Utility Services Division investigated artificial recharge to the aquifer near the study area. Their primary goal was to find a means of minimizing the depletion of storage in the aquifer and reduce the decline in water levels due to pumping municipal wells located on the Mount Rose alluvial fan. This work entailed simulating groundwater flow in the Mount Rose fan by means of a numerical groundwater model (Hydro-Search, 1991). One of several different scenarios they modeled included injecting a total of 1,674 acre-feet per year via two wells west of the present study area. The study concluded that injection could locally arrest or reduce the decline of groundwater levels in the aquifer even in the face of increased groundwater withdrawals from STMGID wells (Hydro-Search, 1991).

The results of these studies indicated that groundwater recharge projects were a viable part of the strategy to better manage the water resources of the southwest Truckee Meadows. The present study tests this hypothesis and examines whether or not it is feasible to conduct a pilot study using existing facilities.

4.2 CONDITIONS WHICH FAVOR AQUIFER STORAGE AND RECOVERY

This aquifer storage and recovery feasibility study relies primarily on previously existing available data and information to evaluate the potential for groundwater recharge projects in the study area. No significant field investigations were performed. The sources of information examined include published and unpublished reports, water-level data, discharge data for municipal wells, well-construction data, and aquifer-test data.

Conditions which favor aquifer storage and recovery include:

- A large unsaturated zone beneath the land surface (deep water table). This provides space to store the water without the water mound discharging onto the land surface.

- Permeable geologic materials. The aquifer must be capable of accepting and giving up the water at moderate to high rates.

- Semi-confined conditions in the aquifer. Recharge is more effective if the percentage of water that goes into storage per foot of water level rise is relatively large.

The geologic, aquifer-test, water-level and other data examined in the course of this study confirm that these conditions are present beneath the study area.

In order to store large amounts of water in the ground, the water table should be relatively deep. Otherwise, the mound that results from storing the water may breach the land surface. The available groundwater elevation data show the depth to groundwater near the Picollo well is at least 85 feet below the land surface. Near STMGID Well No. 1, which is located near Zolezzi Lane, the cone of depression approaches 180 feet below the land surface. In general, the depth to the water table increases to the west and southwest of the Picollo/STMGID Well No. 1 area and decreases to the east, north and northeast. With the exception of SPPCo's Lakeside well, the water table is close to the land surface near their wells in the study area. This condition does not favor a recharge program using SPPCo wells.

Another condition which favors aquifer storage and recovery is a lowering of the water table due to pumping from existing wells. Under the right circumstances, water injected or otherwise recharged to the aquifer in an existing water table depression can be hydrodynamically contained within it with relative ease. In effect, the recharged water can often be prevented from moving too far from the recovery wells and can be recaptured by them at a later date. While there has been a general decline of several tens of feet in the water table over several square miles within the study area, a large-scale depression which favors hydrodynamic containment of the stored water does **not** exist in the study area. However, as stated above, a large volume of groundwater might still be stored and recovered in the Foothill Road-Zolezzi Lane area because the depth to water is more than 100 feet over a large area.

The hydraulic conductivity and the transmissivity of the aquifer control the rate at which the aquifer can be recharged by wells, as well as the rate at which the water can be recovered. Aquifer-test data for the STMGID wells clearly show the transmissivity of the aquifer is moderately high to very high in the Foothill Road-Zolezzi Lane area. Therefore injection and recovery rates are expected to be moderately high and the effect of injection should be felt over a relatively large portion of the area.

The aquifer's coefficient of storage controls the amount of water which can be stored and recovered per foot of water level rise. Confined aquifers store relatively little water per foot of water level rise. In contrast, unconfined aquifers can store a large amount of water per foot of water-level rise, but they are often associated with high groundwater velocities (Pyne, 1995). In areas where groundwater velocities are high, it is difficult to recover the water that is injected without careful consideration of the relative placement of recharge/injection wells and recovery wells. Semi-confined aquifers strike a balance between the two extremes. Comparison of water level changes in the Zolezzi Lane area with the quantity of water pumped from the nearby STMGID wells suggests a storage coefficient in the range of 0.20, a value typical of the specific yield of an unconfined aquifer.

4.3 RECHARGE PROJECT BENEFITS AND OPERATING SCENARIOS

There are many different benefits to be derived from the creation of a recharge project. Some of these can be quantified, such as the value of water stored and recovered. Other benefits cannot be easily quantified, such as benefits to wildlife and the environment resulting from increased groundwater levels in areas where levels have declined. The following is a brief description of several different goals for operating a recharge project and the significant benefits we perceive as resulting from these operating scenarios. These operating schemes are:

- Short-term or seasonal water storage and recovery
- Long-term water storage and recovery
- Groundwater level management
- Groundwater management in conjunction with increased withdrawals
- Passive recharge

4.3.1 SHORT-TERM OR SEASONAL STORAGE AND RECOVERY

Groundwater recharge and recovery can be operated as a mechanism for short-term storage and recovery of water. In this scenario, water is injected via wells into the groundwater during winter months when demand is low, and recovered during summer months when demand is high. Typically this system would be operated on a seasonal basis, with injection occurring over 6 to 8 months, and recovery occurring over a shorter period during the summer. One important factor is the current policy of the State Engineer. It requires that in order to receive credit for the injected water, the very same water must be recovered. This means that to make the best use of the injected water, as much of the injected water as possible must be recovered, and the injection and recovery wells must be carefully situated for optimum recovery.

We estimate that by locating the injection wells very directly upgradient from the withdrawal wells, and by increasing the withdrawal quantity during the summer, nearly all of the injected water can be recovered. We estimate that recovery percentages could be as high as 80% to 95%, depending upon the tolerable impacts at the recovery well.

The advantages of this system are:

- Treated surface water could be used as recharge during the winter, and withdrawn during the summer during high demand periods.
- Very high water recovery efficiencies can be achieved with proper system design.
- Water production from the specific wells can be increased significantly during the summer month periods of peak demand.

The disadvantages associated with this type of system include:

- Credit for recovered water depends upon capturing the injected water. This requires careful research into site properties and well location to optimize recovery.

- In order to ensure a high recovery efficiency, the recovery well must be pumped at higher quantities than current practice for existing wells. This will produce a net draw-down effect on any residential wells located directly adjacent to the recovery well. As a result, part of the system design may have to include the mitigation of these effects through the deepening of the affected wells or connecting the affected owners to the public water supply.

- Any water that is not recovered within the design recovery period (one season) will escape the recovery well and be lost due to the relatively high velocity of the groundwater in the area. However, this water will produce a beneficial effect on any well owners downstream of the facility, since it is additional recharge to the aquifer.

It is our opinion that this program is both feasible and economical, and the economics will be discussed in detail later in this section of the report. In addition, one of the primary goals of a pilot recharge study is to identify and quantify the actual recovery percentages to be expected for this type of operation.

4.3.2 LONG-TERM STORAGE AND RECOVERY

In this scenario, water would be injected using wells with long-term recovery as the goal. Water injected over a one to five-year period would remain in the groundwater until required due to drought or emergency and then recovered at a relatively high rate.

This type of system is currently used at a number of locations in the west, where groundwater is deep and gradients are flat. However, in the South Truckee Meadows it is probably not feasible due to the steep groundwater gradients, the shallow groundwater levels in the lower regions, and the State Engineer's requirement that to receive water right credit, the very same water that is injected must be recovered. Due to the high groundwater gradients in the area, we estimate that recovery efficiencies will be approximately 20% to 50%, depending upon how quickly the water is withdrawn after injection, and the distance between the recharge wells and the down-gradient recovery wells.

The advantages of this system are:

- Treated surface water could be used for injection during periods of excess capacity, and stored for use during drought or emergency event situations.
- Unrecovered water would produce a benefit to residential well owners in the vicinity due to the increased groundwater elevations as a result of the stored water.

The disadvantages associated with this type of system include:

- The poor recovery efficiency limits the viability of this system. Credit for recovered water depends upon capturing the actual water injected, and thus a very large quantity of water must be injected to produce a limited benefit.
- During a short-duration demand, such as an emergency, the recovery well(s) must be pumped at very high rates. This will produce a large net draw-down effect on any residential wells located near the recovery wells.

It is our opinion that this system will probably not be economical in the South Truckee Meadows due to the low recovery efficiencies. The additional benefits of a large emergency-only water supply are difficult to quantify since other options such as drought restrictions and rationing are alternatives. As a result, we will not examine this option further. If the pilot study results in encouraging recovery efficiencies, then this option may merit additional examination in the future.

4.3.3 GROUNDWATER LEVEL MANAGEMENT

In this scenario, water would be injected or percolated into the groundwater with the express purpose of managing the groundwater elevations throughout the area. As indicated elsewhere in this report, the groundwater levels have declined significantly throughout the area causing many residents to deepen or replace existing wells. The areas of the most significant decline surround the most intensive development where most of the residents have individual wells. Another area of decline is in the vicinity of the municipal wells such as STMGID-1. It would be very difficult to assign dollar values to the benefits of this alternative, since the primary benefits are political and not economical. The following is a brief summary of the advantages and disadvantages of this alternative.

The advantages of this system are:

- The rate of the existing decline in the water levels would be at least arrested and in some areas completely reversed. The primary benefits of this are to the owners of individual wells in the area, who are not protected from additional declines.
- The recharge could be accomplished either by well injection or by spreading. If spreading is selected as one method of recharge, the water quality required is much less than for well injection since plugging of an injection well is not a concern. The most logical source of this water is the Steamboat Ditch, located along the west side of the study area.
- The improvement in groundwater elevations will benefit all the well owners in the area. As such, it may mitigate existing legal issues related to impacts of municipal wells in the area. The benefits of avoided lawsuits are hard to quantify, but very real, nonetheless.

The disadvantages associated with this type of system include:

- Based on the State Engineer's requirement for recovering the exact same water from recharge projects, it will be nearly impossible to claim a water right or credit for the recharged water. Even though some of the recharge water will be removed through wells, it will be almost impossible to identify the actual beneficiaries and assign recovery efficiencies to those wells.
- The use of spreading basins will require significant areas of land to be dedicated to this use. There is a cost associated with the land, however this could be mitigated through the incorporation of the spreading basins into other features such as parks or golf courses.

This type of program is certainly feasible. Whether it is economical depends on how much of the groundwater decline is alleviated, the method of water injection or spreading, and public support. This option merits additional study, however it is beyond the scope of this report, and will not be further analyzed.

4.3.4 GROUNDWATER LEVEL MANAGEMENT WITH ADDITIONAL WITHDRAWALS

In this scenario, as in the other groundwater management option, water would be injected or percolated into the groundwater with the express purpose of managing the groundwater elevations throughout the area. However, in return for providing this benefit to the homeowners in the area, it is assumed that the construction of new municipal wells could be negotiated with the homeowners. Since the State Engineer's regulations are very restrictive in the permitting of recovery wells, we expect that the new wells would have to use groundwater rights transferred from elsewhere in the Truckee Meadows rather than claiming water recovery.

The advantages of this system are:

- The rate of the existing decline in the water levels would be arrested and aggressively managed to prevent negative impacts to the private well owners.
- The recharge could be accomplished either by well injection or by spreading. If spreading is selected as one method of recharge, the water quality required is much less than for well injection since plugging of the well is not a concern. The most logical source of this water is the Steamboat Ditch, located along the west side of the study area.
- The improvement in groundwater elevations will benefit all the well owners in the area. As such, it may mitigate existing legal concerns related to impacts of municipal wells in the area.

The disadvantages associated with this type of system include:

- Based on the State Engineer's requirement for recovering the exact same water from recharge projects, it will be nearly impossible to claim credit for the recharge water. Even though some of the recharge water will be removed through wells, it will be difficult to identify the actual beneficiaries and assign recovery efficiencies to those wells.
- The use of spreading basins will require significant areas of land to be dedicated to this purpose. It is possible however that this could be incorporated into other features throughout the area such as golf courses or parks. Unlined ponds located in parks are one example of such a recharge facility.

This type of program is also technically feasible. Whether it is economical depends on the value to the municipality of a new production well, the value of reduced litigation, and public support. This option also merits additional study, however it too is beyond the scope of this report, and will not be further analyzed herein.

4.3.5 PASSIVE RECHARGE

Although not really part of the scope of this report, we felt it important to discuss the possibility of passive recharge in the area. In this scenario, during the winter when SPPCo has excess capacity, they would supply treated surface water to a portion or all of the STMGID system. This would allow the STMGID wells to recover groundwater elevation, and passively "store" the water they would previously have pumped out of the ground. During the summer months, when demand is high, these wells could then be pumped more and supply water back to SPPCo. The advantages and disadvantages of this system are:

Advantages:

- The only additional infrastructure required would be some additional interties between SPPCo and STMGID. No new wells or well modifications would be required to implement this project.

- The homeowners in the study area would benefit from the increased groundwater elevations during the winter.
- This option could provide additional emergency supply of water to SPPCo since for a relatively short period, in an emergency, the STMGID wells could supply significant quantities of water to the SPPCo system.

Disadvantages:

- It may be necessary to amend the places of use for either the SPPCo or the STMGID water rights to cover the combined SPPCo and STMGID service areas. This process is likely to be protested, and could take a number of months to complete.
- The increased pumping rate during the summer on the STMGID wells could affect neighboring domestic wells, which might require mitigation to nearby wells.
- Politically, it will be difficult to prepare the necessary agreements and get the approvals needed to implement this alternative.

This system appears to be both economically and technically feasible, but could face political challenges. It will not be further discussed in this report.

4.3.6 SUMMARY

It would appear that the most easily implemented economically feasible alternative would be based on a short-term storage and recovery project. This project would require a source of water and a end-user. It is not required that the two be the same, since the local agencies have different capabilities and needs. Most likely, the water supplier would be SPPCo, since only they currently have treated surface water available during the winter months. The most likely recovery beneficiary is also SPPCo, since they will benefit the most from recovery in the wells located at the South Truckee Meadows. However, both STMGID and Washoe County could also benefit from increased well production in the area. It is assumed that if SPPCo injects and recovers their own water, they will not charge for the injection water. However if they supply water that is recovered by another agency, we expect they will charge the full wholesale water rate of $0.85 per 1,000 gallons. As a result, in the economic analyses that follow, we will generate water production costs for both purchased injection water and free injection water.

4.4 SHORT-TERM INJECTION AND RECOVERY POTENTIAL FOR EXISTING WELLS IN THE STUDY AREA

One of the primary objectives of this feasibility study is to identify existing wells which may be used for a pilot aquifer storage and recovery project. There are many sites the study area where aquifer recharge, storage, and recovery could conceivably be accomplished if new injection and recovery wells are constructed. A principal reason for utilizing existing wells is to minimize the cost of the pilot study and future long-term recharge projects.

The evaluation of new well sites was explicitly excluded from the scope of the study. Likewise, the layout of a completely new well field dedicated to a recharge, storage and recovery project was expressly excluded from the study. As discussed in later sections, the percentage of injected water that can be recovered can almost certainly be increased by properly spaced injection and recovery wells. But the design of a new well field will benefit from the pilot test that is the logical next phase of a recharge project beyond this initial feasibility study.

A total of eight municipal wells are located in or very close to the study area. SPPCo operates five such wells and STMGID operates three wells in the study area. Performance data for the wells were used to determine the potential injection rates for each of them. Two additional well sites were also examined - the Picollo Well and Test Well No. 2. The locations of these wells are shown on Figures 2-2 and 3-8.

An initial screening of all of these wells identified several critical criteria with which to rank them in terms of their utility as injection wells. Pertinent data for the wells are summarized in Table 4-1. Projected injection rates were calculated based on the specific capacities for the wells determined through pumping tests and the depth to the water table. The listed injection rates are based, for the most part, on actual operational or test data for the wells. However, because none of the wells have ever been tested for use as injection wells, the estimates should be viewed only as a means of comparing the wells. If a well is to be seriously considered for a recharge program, the rates should be confirmed through pilot testing prior to construction. Because the elevation of the water table has fluctuated over time, more than one depth was used to arrive at a range of probable injection rates. Two values for well efficiency were assumed because injection is often accompanied by a decrease in the efficiency of a well compared to when it is pumping. The potential injection rate for Test Well No. 2 is purely hypothetical since no aquifer stress tests have been conducted. The aquifer properties for Test Well No. 2 were advanced from the nearby STMGID wells and the driller's log of the borehole.

TABLE 4-1. PRELIMINARY ASSESSMENT OF WELL INJECTION POTENTIAL

Well	Transmissivity (gal./day/foot)	Hydraulic Conductivity (feet/day)	Storage Coeff.	Depth to Water (Feet below land surface) Initial	Minimum	Maximum	Recent	Specific Capacity Cs (gpm/ft)	INJECTION CAPACITY @ Cs assume initial water level	@ Cs assume recent water level	@ 0.5 Cs assume initial water level	@ 0.5 Cs assume recent water level
Sierra Pacific												
Lakeside	24,000	14.6			60		74					
South Virginia Street	20,400	16.6	0.0014	8	7	27	20	18	150.7	366.5	75.3	183.2
DeLucchi [a]	12,500	8.6		18	13	42	22	10	175.0	220.0	87.5	110.0
Holcomb [b]	14,100	10		47	32	56	44	18	852.3	796.5	426.2	398.3
Patriot [a]	18,300			23	8	50	26	9	207.0	234.0	104.0	117.0
STMGID & Washoe County												
STMGID-1 [c]	6,800	3.5	0.0002	90	106	130	127	7	630.0	889.7	315.0	444.9
STMGID-2	2,500	1.3		132	130	162	155	3	396.0	464.3	198.0	232.1
STMGID-3	7,000	2.8		160	--	--	--	5.9	944.0		472.0	
STMGID-4	1,500	1.5		492	--	648	648					
STMGID-5 (Thomas Creek-3) [d]	26,000	9	0.0016	298	277	292	292	16.7	4983.3	4874.7	2491.6	2437.4
STMGID-6 (Thomas Creek-2) [e]	46,000	15.8	0.0012	101	101	115	115	23	2323.0	2642.7	1161.5	1321.4
Thomas Creek-1	--	--	--	303	--	--	--	6	1818.0	0.0	909.0	0.0
Picollo [f]	10,000	7	0.0006	38			59	7.9	300.2	462.2	150.1	231.1
Test hole 2 (Zolezzi) [g]	*6,800*				172	184	181	*7*		1267.6		633.8

NOTES: a. Soil in this area has been contaminated by leaking underground storage tanks.
b. The screens in this well are reportedly "brittle" and may not hold up to stress of injection.
c. Current water level data are not available for STMGID-1. The water level was advanced from data from the nearby monitoring well.
d. This well is outside of the study area. Water level data refer to nearby monitoring well
e. This well is outside of the study area. Water level data refer to nearby monitoring well.
f. This well is not equipped with pumping equipment at this time.
g. No production well exists at this site at this time. Aquifer properties are advanced from data for STMGID-1.

After the initial assessment of each well was completed, all of the sites were ranked for use in a pilot recharge study. A scoring matrix is provided in Table 4-2. The SPPCo wells with the highest potential or actual injection rates are the Holcomb and Lakeside Wells, respectively. However, the Holcomb Well has reportedly experienced problems with the structural integrity of the well screen. There is a slim chance that the well might be damaged if used as a recharge well. Consequently, its use in a pilot recharge project is questionable.

TABLE 4-2. RELATIVE RANKING OF RECHARGE WELL SITES

WELL	INJECTION CAPACITY	PROXIMITY TO AREAS OF MAXIMUM WATER LEVEL DECLINE	LOCATION RELATIVE TO ANTICIPATED DEMAND IN S.W. TRUCKEE MEADOWS	EXTENT OF MODIFICATIONS NEEDED FOR PILOT STUDY	SCORE	RANK
	(10 is highest or best, 1 is lowest or worst)				Total, columns 1 through 4	Lowest number is the highest rank
Lakeside	6	1	1	10	18	6
DeLucchi	1	2	7	7	17	7
So. Virginia	2	3	3	7	15	8
Patriot	3	4	4	7	18	6
Holcomb	8	5	5	5	23	5
STMGID-1	7	8.5	10	9	33.5	1
STMGID-2	5	8.5	9	4	26.5	3
STMGID-3	9	8.5	8	3	28.5	2
Picollo	4	6	6	2	18.5	6
Test Well 2	10	7	7	1	25	4

The Lakeside Well is relatively far from areas where the largest declines in water level have been observed. While injection at the Lakeside Well has shown positive results, it would benefit the domestic well owners less than other well sites located farther to the south. The remaining SPPCo wells are hampered by a near-surface water table, even though they are capable of pumping large quantities of groundwater. The shallow water table equates to a relatively small quantity of groundwater which can be stored before the groundwater mound resulting from injection approaches the land surface. They are also close to areas where contamination of soil from leaking underground storage tanks has occurred. The concern with injection in areas of contaminated soils is that the groundwater mound developed as a result of injection will exacerbate or spread the areas of contamination.

STMGID Well No. 1 received the highest ranking with respect to a pilot recharge study. It is located within an area where the maximum water level depression has developed, so that maximum benefit can be derived from the standpoint of arresting or reversing water-level declines. It is close to numerous domestic wells which are expected to derive the most benefit from a recharge program. Declines in water levels that have affected some of these domestic wells can be arrested or reversed, even if well-field production during peak demand is increased above present rates. An existing intertie between the STMGID system and SPPCo's distribution system simplifies the transmission of water from the Chalk Bluff plant to the test site. Furthermore, STMGID No. 1 is equipped with a nearby 6-inch diameter monitoring well. The monitoring well can serve as the injection well for the test. As a result, minimal modifications to STMGID No. 1 are required for the pilot test. Likewise, minimal modifications to the monitoring well are required for it to serve as an injection well. These modifications include installation of injection tubing, control valves, and a connection to the water distribution system. Lastly, STMGID No. 1 is also close to an area of the Sierra Pacific distribution system that could benefit from an additional source of water supply during peak use periods. The other three STMGID well sites have good potential for use in a pilot study, as well as a full-scale aquifer storage and recovery project, for similar reasons.

Even though Test Well No. 2 theoretically has the potential to inject more water than any other site, it is ranked relatively low overall because no production well has previously been completed at the site. It may, however, rank highly for use in a large-scale recharge program. Likewise, the score for the Picollo Well was reduced because it has not been equipped nor can it be readily tied into the STMGID or SPPCo distribution systems. However, its location also makes it a prime candidate for inclusion into a large-scale recharge program.

4.5 Anticipated Outcome of a Pilot Recharge Program

It is important to note that this feasibility study focuses primarily on existing wells and is further limited by the existing infrastructure. If the pilot testing confirms that a recharge project is economically feasible and beneficial, the limiting infrastructure (distribution system, wells, *etc.*) can be modified to increase the amount of water available for this purpose. The analysis of recharge and recovery could not analyze every recharge and recovery well-field layout to determine which one is the most applicable for the conditions which exist at the site. Such an analysis is beyond the scope of this study. However, the analysis does identify limitations of a recharge program and ways to maximize recovery of stored water in the study area.

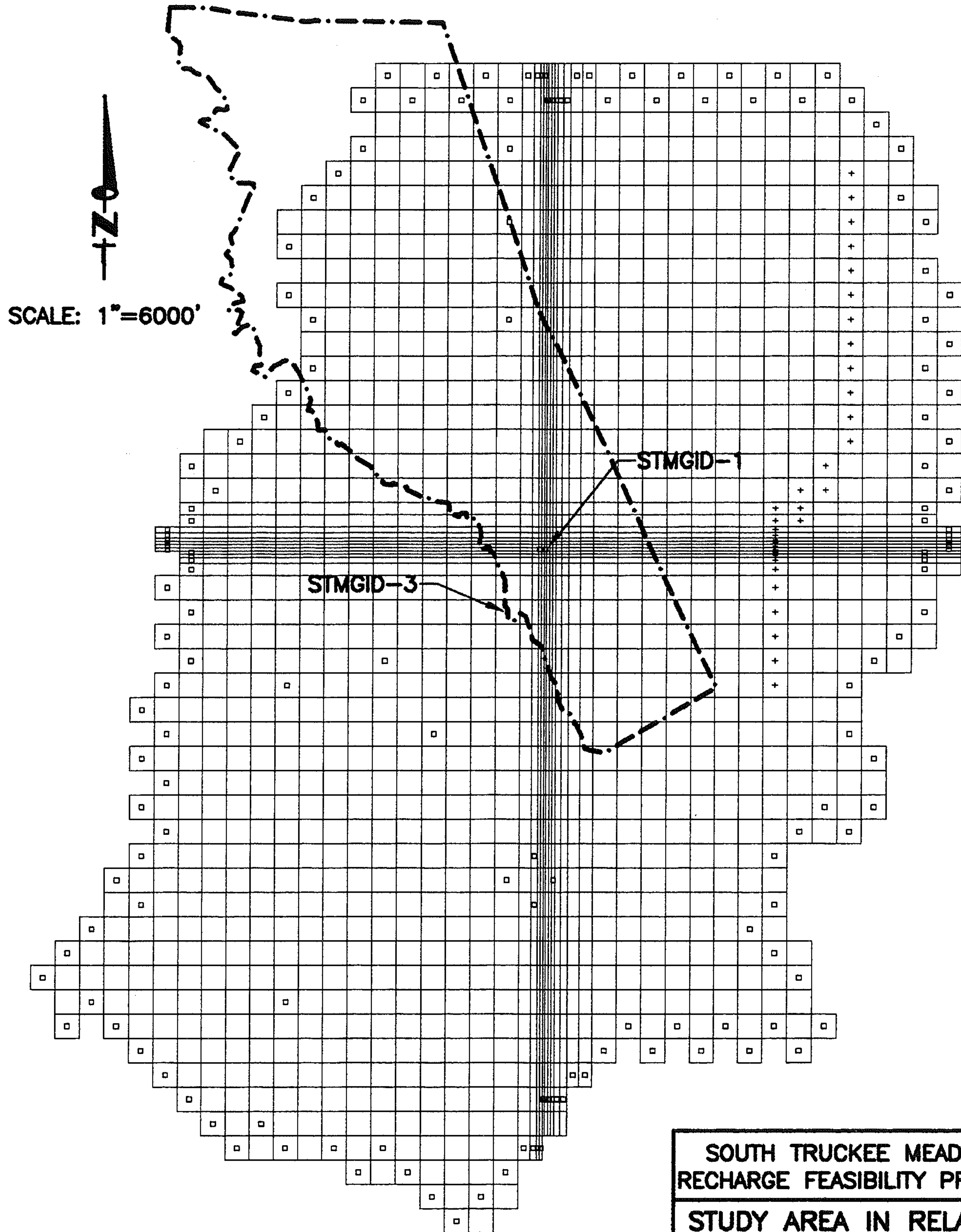
Based on the above review of the available wells, this analysis of recharge, storage, and recovery focuses on using STMGID-1 as the recovery well and using the nearby monitoring well as the recharge well. However, the results of this analysis are directly applicable to the other top candidates - STMGID-2 and 3 - because the conditions in the aquifer which control recovery efficiency are similar for all three sites. The analysis is applicable to both a pilot study and a long-term study, although it was used primarily to anticipate the results of a pilot study.

It is the opinion of SPPCo personnel that they can allocate up to 5,400 acre-feet per year of treated surface water from the Chalk Bluff water treatment plant to a groundwater recharge program (John Erwin, personal communication). The SPPCo distribution system reportedly can reliably provide as much as 1,500 gpm in the off-peak season to the STMGID-1 site. Assuming that this flow rate is continuously available from October through April, approximately 1,200 acre-feet per year could be transported to a recharge project. For a pilot study, the upper limit to the injection rate is estimated to be 600 to 700 gpm, the limiting factor being the injection capacity of STMGID Monitoring Well No. 3. However, because the monitoring well has never been tested as an injection well, the actual recharge rate could vary from the calculated amount.

Aquifer storage and recharge at the STMGID-1 site was examined by modeling the injection of the water via Monitoring Well No. 3 and recovery of the water via STMGID-1. The computerized numerical model of the aquifer developed by Hydro-Search, Inc. (HSI, 1991) for Washoe County was used as the basis for the analysis. In the vicinity of STMGID-1, the model grid spacing was reduced from 1,000 feet to 125 feet. Figure 4-1 shows the modifications made to the County's groundwater model grid. The aquifer properties, boundary conditions, *etc.* were not changed.

The initial model simulations examined water banking, or the long-term storage of water for later use. Under this scheme, 600 acre-feet per year were injected while pumping STMGID-1 at its present average annual rate. At the end of five years, injection was ceased and withdrawals from STMGID-1 were doubled for one year. Some of the results were expected, some were not. Among the anticipated results was the build-up of a water mound in the aquifer that extended north beyond the Picollo Well. After injection ceased and pumping was increased, it took approximately one year for the groundwater mound to decay. In other words, the average annual withdrawals from STMGID-1 could be increased for one year without appreciably increasing drawdown in the aquifer. The end result is an increase in STMGID's withdrawals without adversely affecting nearby domestic wells.

The fate of the injected water was examined using MODPATH, the particle tracking program designed to work with MODFLOW, the model used by the County to model groundwater flow in the study area. The surprising result was that during injection the bulk of the injected water moved northeast so far that it could not be effectively recovered by STMGID-1. Overall efficiency of this long-term scenario was approximately 25 to 30 per cent. In other words, of the 600 acre-feet per year injected via Monitoring Well No. 3, only 150 to 180 acre-feet per year potentially could be captured by STMGID-1. The remainder moved down-gradient beyond the influence of STMGID-1. This does **not** mean that the water is lost to the aquifer and that no benefit is derived from injecting the water. It became clear, however, that to capture a higher percentage of the discharge, recovery wells must be located a considerable distance down-gradient of the recharge wells, and that additional wells located farther down-gradient (northeast) of STMGID-1 are needed to capture the recharge.



SOUTH TRUCKEE MEADOWS RECHARGE FEASIBILITY PROJECT

STUDY AREA IN RELATION TO W.C.U.D. GROUNDWATER MODEL

SCALE: 1" = 6000'
DRAWN BY: SOS
DATE: 2-25-98
JOB NO.: 97050.30

FIGURE 4-1

CONSULTING ENGINEERING SERVICES, INC.
1105 TERMINAL WAY, SUITE 304
RENO, NEVADA 89502
702-786-5873

REF: WCUD

DWG\STM-GWTR\STM-GWMOD

The initial model runs provided other indications that long-term water banking may not be appropriate for the study area. After about five years of constant injection, the height of the water mound achieves a roughly stable elevation as a new equilibrium condition in the aquifer is approached. After this, additional recharge does not raise the water level significantly and it simply sustains the height of the mound.

The recharge and recovery pumping rates and recharge/pumping cycles were varied by trial and error to find ways to improve on the overall efficiency of the storage and recovery using closely-spaced recharge and recovery wells. Figure 4-2 shows the results of a model simulation where 650 gpm were injected via the monitoring well near STMGID-1 for a period of six months, totaling 520 acre feet. The injection resulted in a water level rise of nearly eight feet a short distance from STMGID-1. Roughly 1,000 feet north of STMGID-1, the height of the mound was less, closer to one foot. Near the Picollo School area, the simulated

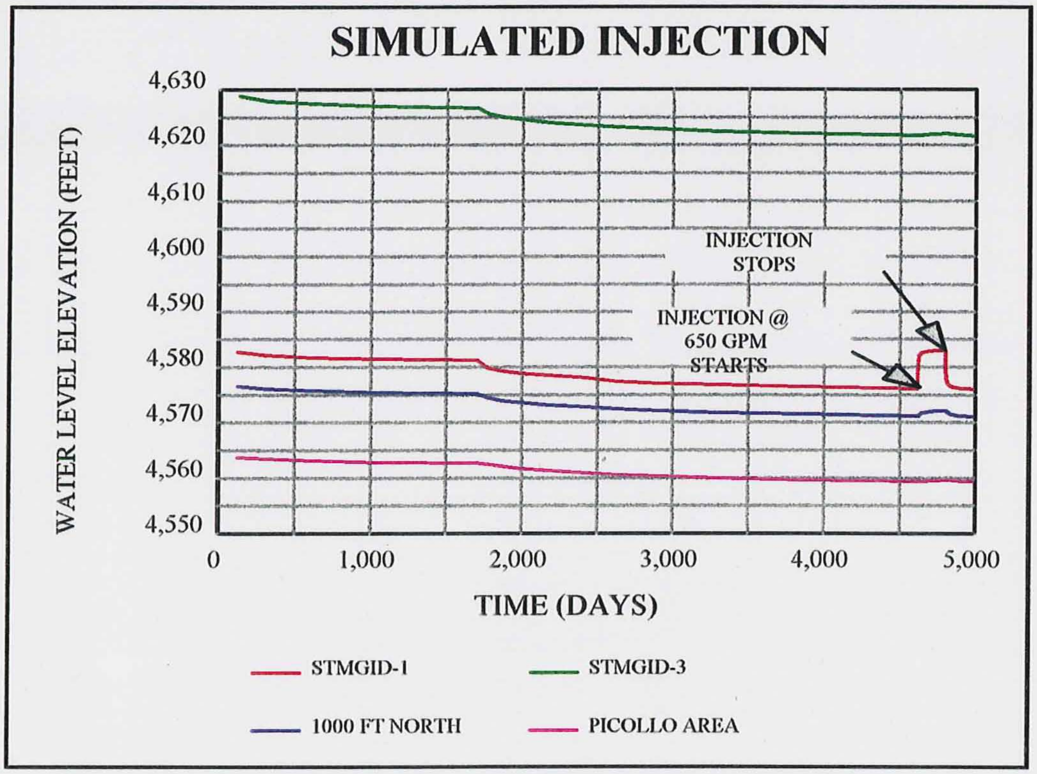


Figure 4-2. Simulated Injection of 650 gpm over a period of six months.

mound was very nearly imperceptible. At the end of the injection period, simulated withdrawals from STMGID-1 were increased by 380 acre-feet over the next six months. At the end of the six month simulated pumping period, the simulated water levels returned to their pre-injection level. In effect, this scenario allowed for pumping an additional 380 acre-feet from the STMGID well field without increasing drawdown in the aquifer over current levels. If less water were withdrawn than was injected, there would have been a net rise in water level after the one-year recharge/recovery cycle. This recharge/recovery scenario achieved an efficiency of 75 per cent, the highest efficiency of any of the simulations.

Most likely the actual recovery efficiency will be higher than the simulations suggest. Relatively recent hydrogeological data for the study area indicate that the many north-trending faults in the area significantly impede the eastward movement of groundwater. Neither of the current groundwater flow models for the study area take this into account. Consequently, the water that is injected at Monitoring Well No. 3 will not move away as rapidly as the simulations suggest, and will be more easily recovered by STMGID-1. However, upgrading the current numerical models of the aquifer to reflect the faults is beyond the scope of this report. Future models of the aquifer will investigate the effect of the faults on groundwater flow velocities.

The results discussed above are consistent with the results of other investigators, who concluded that aquifer storage and recharge is less effective in areas where groundwater velocities are high (Pyne, 1997). However, the recovery efficiency can be improved dramatically by optimally locating recovery wells down-gradient of the recharge wells.

The results discussed above and depicted in Figure 4-2 are directly applicable to a shorter-term pilot study. The principal difference is that the recovery percentage is expected to be greater than 75 percent. This occurs because the injected water will not move too far down-gradient of STMGID-1 in a three month recharge period to be captured by it. As a result, when interpreting the results of the short-term pilot study, care must be taken not to overestimate the recovery efficiency of a full-scale project.

4.6 SHORT-TERM STORAGE AND RECOVERY ALTERNATIVES

4.6.1 BACKGROUND

The following engineering estimates examine the potential of the existing wells in the study area for use as a permanent short-term water recharge and recovery facility. As discussed above, this system would probably be operated as a seasonal storage and recharge operation, since storage over any longer period results in prohibitively low recovery efficiencies.

4.6.2 SITE IDENTIFICATION

Several existing wells and test holes were initially identified as potential recharge sites. During the course of the hydrogeological investigation, several of these sites were rejected due to a shallow water table or other characteristics that made them less desirable locations for recharge. The Sierra Pacific wells have been eliminated due to the several factors outlined below.

TABLE 4-3. WELL EVALUATION

WELL LOCATION	INCLUDED IN ANALYSIS (YES/NO)	COMMENTS
Sierra Pacific		
Lakeside	NO	Previously injected at this well, however is located outside of the area of greatest concern.
South Virginia Street	NO	Shallow water table
DeLucchi	NO	Shallow water table
Holcomb	NO	Experiencing problems with screen
Patriot	NO	Shallow water table
STMGID & Washoe County		
STMGID-1	YES	
STMGID-2	YES	
STMGID-3	YES	
STMGID-4	NO	Outside of study area
STMGID-5 (Thomas Creek 3)	NO	Outside of study area
STMGID-6 (Thomas Creek 4)	NO	Outside of study area
Thomas Creek 1	NO	Outside of study area
Picollo	YES	
Test Hole 2 (Zolezzi)	YES	

4.6.3 INJECTION WELL DESIGN

Figure 4-3 shows a typical injection well. The well equipping is designed to minimize the potential for cascading water to occur inside the well. It is extremely important to prevent cascading in the recharge well since it will entrain air which can cause air binding in the storage zone, and induce geochemical or bacterial activity or structural problems with pipes, valves, and fittings.

4.6.4 AVAILABILITY OF WATER

Sierra Pacific Power Co. was contacted to determine if they can supply the desired flows at the different injection wells during the winter months. They indicated the requested flows in the range of 500 to 700 gallons per minute are available. A copy of their response is included in the Appendix.

4.6.5 INJECTION WELL ALTERNATIVES

The wells that will be evaluated in detail are STMGID Wells 1,2 and 3, the Picollo Well, and the Zolezzi test well number 2. The locations of these wells are shown in Figure 2-2. Two additional options for recharge in this area are developed in Section 5. Two scenarios for each alternative were evaluated. The first scenario assumes the water used for recharge must be purchased from SPPCo at $0.85 per 1,000 gallons, and the second scenario assumes no cost for the water.

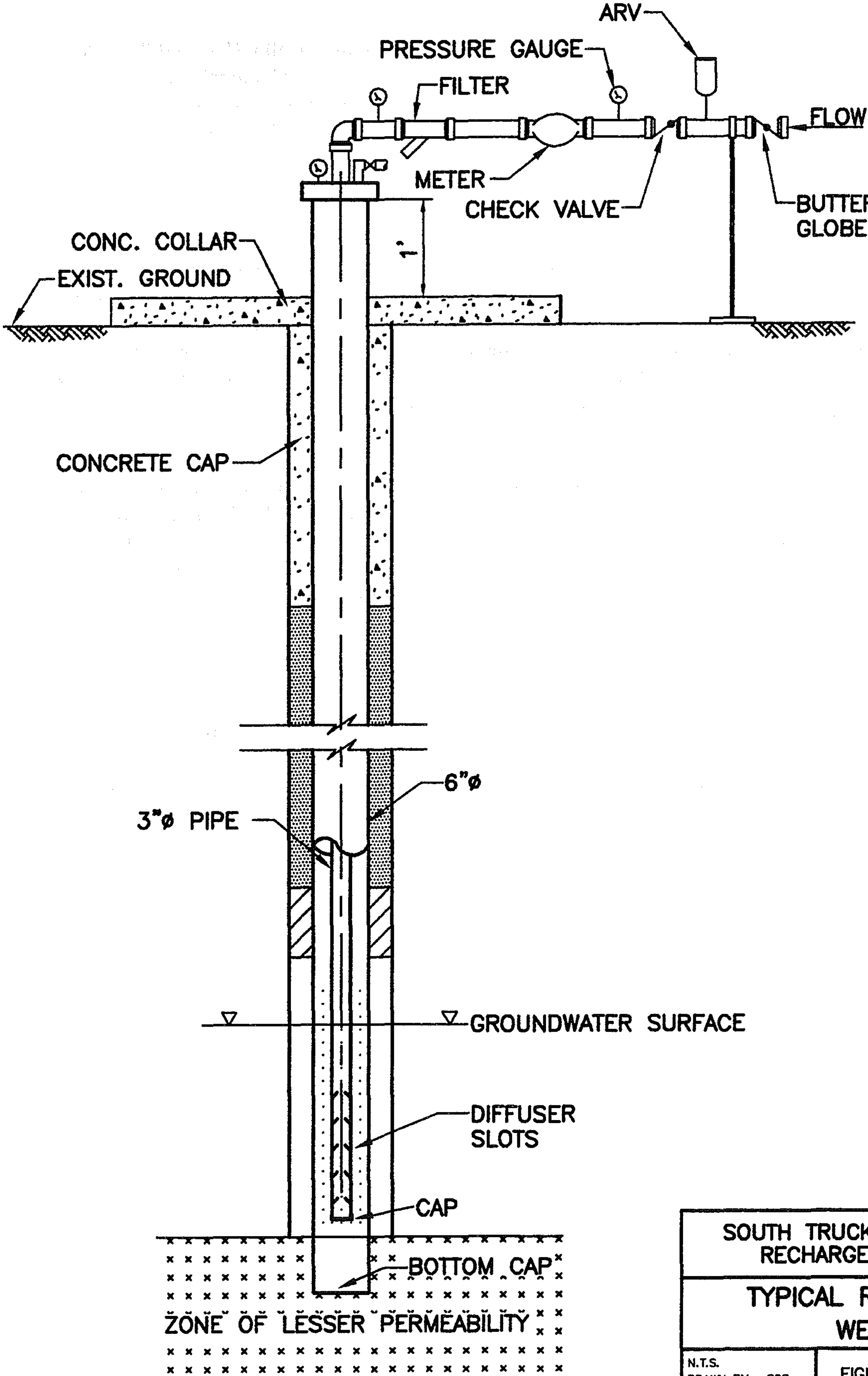
4.6.5.1 ALTERNATIVE 1 - STMGID-1

STMGID-1 is currently in service and is equipped to pump approximately 750 gpm. There is a 6 inch test well located nearby that could serve as an injection well. Although it is possible to use a production well for an injection well, it is much simpler to use a separate injection well. The improvements required to use this facility for recharge/storage and later recovery include modifying the existing test well, a structure for the injection system would be constructed, controls would be installed, an intertie to the Sierra Pacific source would be constructed, and some miscellaneous work would be required at the existing production well site.

The total capital cost for this system is estimated to be $83,000, and the annual O&M, including the purchase of the water from Sierra Pacific Power Co., at $174,000. If water is not required to be purchased, the annual O&M is estimated to be $27,000 per year. When water is purchased, this equates to an annualized cost (20 yrs. at 5%) of $455 per acre-ft of water recovered and $1.40 per 1,000 gallons, assuming a 75% recovery. If water is not required to be purchased, the costs are $85 an acre foot and $0.26 per 1,000 gallons. Table 4-4 outlines the cost estimate for this alternative.

4.6.5.2 ALTERNATIVE 2 - STMGID-2

STMGID-2 is currently equipped to pump 350 gpm. As separate recharge well must be constructed, a structure for the injection system would be constructed, controls would be installed, an intertie to the Sierra Pacific source would be constructed, and some miscellaneous work would be done, as required, at the existing production well site.



D:\DWG\STM-GWTR\STM-WELL2.dwg

SOUTH TRUCKEE MEADOWS
RECHARGE PROJECT

TYPICAL RECHARGE
WELL

N.T.S.
DRAWN BY: SOS
DATE: 1-15-98
JOB NO.: 97050.30

FIGURE
4-3

CONSULTING ENGINEERING SERVICES, INC.
1105 TERMINAL WAY, SUITE 304
RENO, NEVADA 89502
702-784-5873

TABLE 4-4
PRELIMINARY COST ESTIMATE ALTERNATIVE 1 STMGID 1
INJECTION AT 667 GPM FOR 6 MONTHS

CAPITAL COST

ITEM	ITEM NAME	EST. QUANT.	UNITS	EST COST	TOTAL ESTIMATE
MOBILIZATION		1	LS	$8,000	$8,000
INJECTION WELL FACILITIES					
1	Test Well Modification	1	LS	$10,000	$10,000
2	Pipe, Valves, Fittings, Meter and Backflow Prevent	1	LS	$10,000	$10,000
3	Controls	1	LS	$5,000	$5,000
4	Building	1	LS	$15,000	$15,000
5	Site Work and Miscellaneous	1	LS	$2,500	$2,500
WELL INTERTIE TO SOURCE WATER					
1	Pipe, Valves, and Fittings	400	LF	$25	$10,000
RECOVERY FACILITIES					
1	Site Work and Miscellaneous	1	LS	$1,000	$1,000
	SUBTOTAL				$61,500
	CONTINGENCY (@ 15%)				$9,200
	ENGINEERING & LEGAL (@ 20%)				$12,300
			TOTAL CAPITAL COST		**$83,000**

ANNUAL OPERATING COSTS

ITEM	ITEM NAME	EST. QUANT.	UNITS	EST COST	TOTAL ESTIMATE
WATER PURCHASE COSTS					
1	Water Purchase	530	AF	$277	$146,810
INJECTION COSTS					
1	Labor	200	Hrs/Yr	$30	$6,000
2	Electrical	16,000	kw-hrs	$0.062	$992
3	Repairs and Annual Maintenance	1	LS	$788	$788
RECOVERY COSTS					
1	Labor	200	Hrs/Yr	$30	$6,000
2	Electrical	200,000	kw-hrs	$0.062	$12,400
3	Repairs and Annual Maintenance	1	LS	$100	$100
4	Testing	1	LS	$1,000	$1,000
	SUBTOTAL WITH WATER PURCHASE				**$174,090**
	SUBTOTAL WITHOUT WATER PURCHASE				**$27,280**

SUMMARY

ITEM	ITEM NAME			TOTAL ESTIMATE	UNITS
	TOTAL CAPITAL COST			$83,000	TOTAL
	ANNUALIZED CAPITAL COST, 20YRS @ 5%			$6,660	/YR
	ANNUAL O&M INCLUDING WATER PURCHASE				
	ANNUAL O&M			$174,090	/YR
	ANNUAL O&M AND CAPITAL			$180,750	/YR
	WATER RECOVERED @ 75% (AF/YR)			398	AF/YR
	TOTAL ANNUAL COST/AF RECOVERED			$455	$/AF
	TOTAL ANNUAL COST $/1,000 GAL.			**$1.40**	**1,000 GAL.**
	ANNUAL O&M WITHOUT WATER PURCHASE				
	ANNUAL O&M			$27,280	/YR
	ANNUAL O&M AND CAPITAL			$33,940	/YR
	WATER RECOVERED @ 75% (AF/YR)			397.5	AF/YR
	TOTAL ANNUAL COST/AF RECOVERED			$85	$/AF
	TOTAL ANNUAL COST $/1,000 GAL.			**$0.26**	**1,000 GAL.**

Compared to STMGID-1, this well is farther away from the SPPCo. water system and would require more water line to make the connection to their system.

The total capital cost for this system is estimated to be $176,900, and the annual O&M, including the purchase of the water from Sierra Pacific Power Co., at $97,000. This equates to an annualized cost (20 yrs. at 5%)of $538 per acre-ft, and $1.65 per 1,000 gallons, of water recovered assuming 75% recovery. If water does not need to be purchased, the costs are $169 per acre foot and $0.52 per 1,000 gallons. The O&M cost of this well is lower than STMGID-1 simply because less water can be injected at this site, and so the production costs are less. The preliminary cost estimate is shown in Table 4-5.

4.6.5.3 ALTERNATIVE 3 - STMGID-3

STMGID-3 is currently in service at approximately 500 gpm. A recharge well must be drilled, a structure for the system would be constructed, controls would be installed, an inter-tie to the Sierra Pacific source would be constructed, and some miscellaneous work would be done as required at the existing production well site. Compared to STMGID-1, this well is further away from the SPPCo. water system and would require more linear feet of water line to make the connection to their system.

The total capital cost for this system is estimated to be $187,000, and the annual O&M, including the purchase of the water from Sierra Pacific Power Co., at $181,700. This equates to an annualized cost (20 yrs. at 5%)of $466 per acre-ft and $1.43 per 1,000 gallons of water recovered, assuming 75% recovery. If water does not need to be purchased, the costs are $97 per acre foot and $0.30 per 1,000 gallons recovered. Table 4-6 shows the cost estimate for Alternative 3.

4.6.5.4 ALTERNATIVE 4 - ZOLEZZI WELL #2

Zolezzi Well #2 is site of a 2" diameter test well, and is not currently a production well. This well is too small to serve as an injection well, and to provide recharge at this site, both a recharge well and a new recovery well must be constructed. A structure for the system must be constructed, controls would be installed, and an intertie to the Sierra Pacific source located nearby be installed.

The total capital cost for this system is estimated to be $511,000, including the new well construction. If injection water is purchased from SPPCo, the annual O&M is estimated at $247,000. This equates to an annualized cost (20 yrs. at 5%)of $508 per acre-ft and $1.56 per 1,000 gallons of water recovered assuming an 75% recovery. If water does not need to be purchased, the cost of the water recovered is $139 per acre foot and $0.43 per 1,000 gallons. The preliminary cost estimate is shown in Table 4-7.

TABLE 4-5
PRELIMINARY COST ESTIMATE ALTERNATIVE 2 STMGID 2
INJECTION AT 348 GPM FOR 6 MONTHS

CAPITAL COST

ITEM	ITEM NAME	EST. QUANT.	UNITS	EST COST	TOTAL ESTIMATE
MOBILIZATION		1	LS	$20,000	$20,000
INJECTION WELL FACILITIES					
1	Test Well Modification	1	LS	$10,000	$10,000
2	Pipe, Valves, Fittings, Meter and Backflow Preventer	1	LS	$10,000	$10,000
3	Controls	1	LS	$5,000	$5,000
4	Building	1	LS	$15,000	$15,000
5	Site Work and Miscellaneous	1	LS	$2,500	$2,500
WELL INTERTIE TO SOURCE WATER					
1	Pipe, Valves, and Fittings	2,700	LF	$25	$67,500
RECOVERY FACILITIES					
1	Site Work and Miscellaneous	1	LS	$1,000	$1,000
	SUBTOTAL				$131,000
	CONTINGENCY (@ 15%)				$19,700
	ENGINEERING & LEGAL (@ 20%)				$26,200
			TOTAL CAPITAL COST		**$176,900**

OPERATING COST

ITEM	ITEM NAME	EST. QUANT.	UNITS	EST COST	TOTAL ESTIMATE
INJECTION COSTS					
1	Water Purchase	276	AF	$277	$76,452
2	Labor	200	Hrs/Yr	$30	$6,000
3	Electrical	16,000	kw-hrs	$0.062	$992
4	Repairs and Annual Maintenance	1	LS	$1,650	$1,650
RECOVERY COSTS					
1	Labor	200	Hrs/Yr	$30	$6,000
2	Electrical	80,600	kw-hrs	$0.062	$4,997
3	Repairs and Annual Maintenance	1	LS	$100	$100
4	Testing	1	LS	$1,000	$1,000
	SUBTOTAL WITH WATER PURCHASE				**$97,191**
	SUBTOTAL WITHOUT WATER PURCHASE				**$20,739**

SUMMARY

ITEM	ITEM NAME			TOTAL ESTIMATE	UNITS
	TOTAL CAPITAL COST			$176,900	TOTAL
	ANNUALIZED CAPITAL COST, 20YRS @ 5%			$14,195	/YR
	ANNUAL O&M INCLUDING WATER PURCHASE				
	ANNUAL O&M			$97,191	/YR
	ANNUAL O&M AND CAPITAL			$111,386	/YR
	WATER RECOVERED @ 75% (AF/YR)			207	AF/YR
	TOTAL ANNUAL COST/AF RECOVERED			$538	$/AF
	TOTAL ANNUAL COST $/1,000 GAL.			**$1.65**	**1,000 GAL.**
	ANNUAL O&M WITHOUT WATER PURCHASE				
	ANNUAL O&M			$20,739	/YR
	ANNUAL O&M AND CAPITAL			$34,934	/YR
	WATER RECOVERED @ 75% (AF/YR)			207	AF/YR
	TOTAL ANNUAL COST/AF RECOVERED			$169	$/AF
	TOTAL ANNUAL COST $/1,000 GAL.			**$0.52**	**1,000 GAL.**

TABLE 4-6
PRELIMINARY COST ESTIMATE ALTERNATIVE 3 STMGID 3
INJECTION AT 708 GPM FOR 6 MONTHS

CAPITAL COST

ITEM	ITEM NAME	EST. QUANT.	UNITS	EST COST	TOTAL ESTIMATE
MOBILIZATION		1	LS	$20,000	$20,000
INJECTION WELL FACILITIES					
1	Test Well Modification	1	LS	$10,000	$10,000
2	Pipe, Valves, Fittings, Meter and Backflow Preventer	1	LS	$10,000	$10,000
3	Controls	1	LS	$5,000	$5,000
4	Building	1	LS	$15,000	$15,000
5	Site Work and Miscellaneous	1	LS	$2,500	$2,500
WELL INTERTIE TO SOURCE WATER					
1	Pipe, Valves, and Fittings	3,000	LF	$25	$75,000
RECOVERY FACILITIES					
1	Site Work and Miscellaneous	1	LS	$1,000	$1,000
	SUBTOTAL				$138,500
	CONTINGENCY (@ 15%)				$20,800
	ENGINEERING & LEGAL (@ 20%)				$27,700
			TOTAL CAPITAL COST		**$187,000**

OPERATING COST

ITEM	ITEM NAME	EST. QUANT.	UNITS	EST COST	TOTAL ESTIMATE
INJECTION COSTS					
1	Water Purchase	563	AF	$277	$155,951
2	Labor	200	Hrs/Yr	$30	$6,000
3	Electrical	16,000	kw-hrs	$0.062	$992
4	Repairs and Annual Maintenance	1	LS	$1,763	$1,763
RECOVERY COSTS					
1	Labor	200	Hrs/Yr	$30	$6,000
2	Electrical	160,000	kw-hrs	$0.062	$9,920
3	Repairs and Annual Maintenance	1	LS	$100	$100
4	Testing	1	LS	$1,000	$1,000
	SUBTOTAL				**$181,726**

SUMMARY

ITEM	ITEM NAME			TOTAL ESTIMATE	UNITS
	TOTAL CAPITAL COST			$187,000	TOTAL
	ANNUALIZED CAPITAL COST, 20YRS @ 5%			$15,005	/YR
	ANNUAL O&M INCLUDING WATER PURCHASE				
	ANNUAL O&M			$181,726	/YR
	ANNUAL O&M AND CAPITAL			$196,731	/YR
	WATER RECOVERED @ 75% (AF/YR)			422.3	AF/YR
	TOTAL ANNUAL COST/AF RECOVERED			$466	$/AF
	TOTAL ANNUAL COST $/1,000 GAL.			$1.43	1,000 GAL.
	ANNUAL O&M WITHOUT WATER PURCHASE				
	ANNUAL O&M			$25,775	/YR
	ANNUAL O&M AND CAPITAL			$40,780	/YR
	WATER RECOVERED @ 50% (AF/YR)			422.3	AF/YR
	TOTAL ANNUAL COST/AF RECOVERED			$97	$/AF
	TOTAL ANNUAL COST $/1,000 GAL.			$0.30	1,000 GAL.

TABLE 4-7
PRELIMINARY COST ESTIMATE ALTERNATIVE 4 ZOLEZZI WELL-2
INJECTION AT 950 GPM FOR 6 MONTHS

CAPITAL COST

ITEM	ITEM NAME	EST. QUANT.	UNITS	EST COST	TOTAL ESTIMATE
MOBILIZATION		1	LS	$55,000	$55,000
INJECTION WELL FACILITIES					
1	Test Well Modification	1	LS	$10,000	$10,000
2	Pipe, Valves, Fittings, Meter and Backflow Preventer	1	LS	$10,000	$10,000
3	Controls	1	LS	$5,000	$5,000
4	Building	1	LS	$15,000	$15,000
5	Site Work and Miscellaneous	1	LS	$2,500	$2,500
WELL INTERTIE TO SOURCE WATER					
1	Pipe, Valves, and Fittings	1,000	LF	$25	$25,000
RECOVERY FACILITIES					
1	New 12 inch Well Drilling and Testing	1	LS	$120,000	$120,000
2	New Well Equipping	1	LS	$130,000	$130,000
3	Controls	1	LS	$5,000	$5,000
4	Site Work and Miscellaneous	1	LS	$1,000	$1,000
	SUBTOTAL				$378,500
	CONTINGENCY (@ 15%)				$56,800
	ENGINEERING & LEGAL (@ 20%)				$75,700
			TOTAL CAPITAL COST		**$511,000**

OPERATING COST

ITEM	ITEM NAME	EST. QUANT.	UNITS	EST COST	TOTAL ESTIMATE
INJECTION COSTS					
1	Water Purchase	755	AF	$277	$209,135
2	Labor	200	Hrs/Yr	$30	$6,000
3	Electrical	16,000	kw-hrs	$0.062	$992
4	Repairs and Annual Maintenance	1	LS	$1,013	$1,013
RECOVERY COSTS					
1	Labor	200	Hrs/Yr	$30	$6,000
2	Electrical	160,000	kw-hrs	$0.062	$9,920
3	Repairs and Annual Maintenance	1	LS	$12,800	$12,800
4	Testing	1	LS	$1,000	$1,000
	SUBTOTAL WITH WATER PURCHASE				**$246,860**
	SUBTOTAL WITHOUT WATER PURCHASE				**$37,725**

SUMMARY

ITEM	ITEM NAME			TOTAL ESTIMATE	UNITS
	TOTAL CAPITAL COST			$511,000	TOTAL
	ANNUALIZED CAPITAL COST, 20YRS @ 5%			$41,004	/YR
	ANNUAL O&M INCLUDING WATER PURCHASE				
	ANNUAL O&M			$246,860	/YR
	ANNUAL O&M AND CAPITAL			$287,863	/YR
	WATER RECOVERED @ 50% (AF/YR)			566.3	AF/YR
	TOTAL ANNUAL COST/AF RECOVERED			$508	$/AF
	TOTAL ANNUAL COST $/1,000 GAL.			**$1.56**	**1,000 GAL.**
	ANNUAL O&M WITHOUT WATER PURCHASE				
	ANNUAL O&M			$37,725	/YR
	ANNUAL O&M AND CAPITAL			$78,728	/YR
	WATER RECOVERED @ 50% (AF/YR)			566.3	AF/YR
	TOTAL ANNUAL COST/AF RECOVERED			$139	$/AF
	TOTAL ANNUAL COST $/1,000 GAL.			**$0.43**	**1,000 GAL.**

4.6.5.5 ALTERNATIVE 5 - PICOLLO WELL

The Picollo Well was completed and test pumped, but has not been equipped, tied to the distribution system, or placed in service. A recharge well must be constructed, a structure for the system would be constructed, controls would be installed, an intertie to the Sierra Pacific source would be constructed, and the existing production well would be equipped. The total capital cost for this system is estimated to be $267,000 with the additional O&M, including the purchase of the water from Sierra Pacific Power Co., at $108,000. This equates to an annualized cost (20 yrs. at 5%)of $628 per acre-ft or $1.93 per 1,000 gallons of water recovered, assuming an 75% recovery. If water does not need to be purchased, the cost per acre-foot is $258, and the cost per 1,000 gallons is $0.79. Table 4-8 (following page) shows the preliminary cost estimate for this alternative.

Table 4-9 summarizes the cost estimates developed for the various recharge locations.

TABLE 4-9. ALTERNATIVE EVALUATION

Location	Recovery Facilities Required ?	Estimated Injection (AF/yr)	Estimated Recovery Efficiency	Estimated Recovery (AF/yr)	Production Cost With Water Purchase		Production Cost Without Water Purchase	
					Est. Cost per Acre Foot	Est. Cost per 1,000 Gal.	Est. Cost per Acre Foot	Est. Cost per 1,000 Gal.
Alternative 1 - STMGID-1	No	530	75%	398	$455	$1.40	$85	$0.26
Alternative 2 - STMGID-2	No	276	75%	207	$538	$1.65	$169	$0.52
Alternative 3 - STMGID-3	No	563	75%	422	$466	$1.43	$97	$0.30
Alternative 4 - ZOLEZZI 2	Yes	755	75%	566	$508	$1.56	$139	$0.43
Alternative 5 - PICOLLO	Yes	275	75%	206	$628	$1.93	$258	$0.79

TABLE 4-8
PRELIMINARY COST ESTIMATE ALTERNATIVE 6 PICOLLO
INJECTION AT 346 GPM FOR 6 MONTHS

CAPITAL COST

ITEM	ITEM NAME	EST. QUANT.	UNITS	EST COST	TOTAL ESTIMATE
MOBILIZATION		1	LS	$8,000	$8,000
INJECTION WELL FACILITIES					
1	Test Well Modification	1	LS	$10,000	$10,000
2	Pipe, Valves, Fittings, Meter and Backflow Preventer	1	LS	$10,000	$10,000
3	Controls	1	LS	$5,000	$5,000
4	Building	1	LS	$15,000	$15,000
5	Site Work and Miscellaneous	1	LS	$2,500	$2,500
WELL INTERTIE TO SOURCE WATER					
1	Pipe, Valves, and Fittings	50	LF	$25	$1,250
RECOVERY FACILITIES					
1	New Well Equipping	1	LS	$130,000	$130,000
2	Controls	1	LS	$5,000	$5,000
3	Site Work and Miscellaneous	1	LS	$1,000	$1,000
4	Modification to Existing Production Well	1	LS	$10,000	$10,000
	SUBTOTAL				$197,750
	CONTINGENCY (@ 15%)				$29,700
	ENGINEERING & LEGAL (@ 20%)				$39,600
			TOTAL CAPITAL COST		**$267,050**

OPERATING COST

ITEM	ITEM NAME	EST. QUANT.	UNITS	EST COST	TOTAL ESTIMATE
INJECTION COSTS					
1	Water Purchase	275	AF	$277	$76,175
2	Labor	200	Hrs/Yr	$30	$6,000
3	Electrical	16,000	kw-hrs	$0.062	$992
4	Repairs and Annual Maintenance	1	LS	$656	$656
RECOVERY COSTS					
1	Labor	200	Hrs/Yr	$30	$6,000
2	Electrical	160,000	kw-hrs	$0.062	$9,920
3	Repairs and Annual Maintenance	1	LS	$7,300	$7,300
4	Testing	1	LS	$1,000	$1,000
	SUBTOTAL WITH WATER PURCHASE				**$108,043**
	SUBTOTAL WITHOUT WATER PURCHASE				**$31,868**

SUMMARY

ITEM	ITEM NAME			TOTAL ESTIMATE	UNITS
	TOTAL CAPITAL COST			$267,050	TOTAL
	ANNUALIZED CAPITAL COST, 20YRS @ 5%			$21,429	/YR
	ANNUAL O&M INCLUDING WATER PURCHASE				
	ANNUAL O&M			$108,043	/YR
	ANNUAL O&M AND CAPITAL			$129,472	/YR
	WATER RECOVERED @ 50% (AF/YR)			206.3	AF/YR
	TOTAL ANNUAL COST/AF RECOVERED			$628	$/AF
	TOTAL ANNUAL COST $/1,000 GAL.			**$1.93**	**1,000 GAL.**
	ANNUAL O&M WITHOUT WATER PURCHASE				
	ANNUAL O&M			$31,868	/YR
	ANNUAL O&M AND CAPITAL			$53,297	/YR
	WATER RECOVERED @ 50% (AF/YR)			206.3	AF/YR
	TOTAL ANNUAL COST/AF RECOVERED			$258	$/AF
	TOTAL ANNUAL COST $/1,000 GAL.			**$0.79**	**1,000 GAL.**

4.6.6 DISCUSSION AND RECOMMENDED INJECTION ALTERNATIVE

Based on this preliminary analysis, it appears that all of the alternatives are cost effective when compared to SPPCo's wholesale water rate of $0.85/1,000 gallons, if the injection water does not have to be purchased. If the injection water must be purchased, the costs are high at all alternatives since the beginning point is already SPPCo's rate.

From this preliminary analysis it appears that the most cost effective location for installation of a short-term recharge project is at STMGID-1. This site is close to the distribution system, has existing recovery facilities, a high potential injection capacity, and good hydrogeological properties. All of these qualities result in the lowest cost per acre-ft of the five alternatives analyzed. As such, this site is also the recommended site for a pilot study.

4.7 PILOT GROUNDWATER RECHARGE AT STMGID-1

The pilot groundwater recharge project will essentially be similar to the permanent installation outlined above, with the following exceptions: The duration of injection will be 90 days over the late fall/early winter months, and considerable additional water quality testing will be required. The injection facilities will be basically the same, however the enclosing structure may be a temporary facility. Table 4-10 is the preliminary cost estimate for a pilot study at the STMGID-1 well, including the purchase of the injection water. The estimated capital cost for the project is approximately $101,000, including hydrogeologist and engineering time to analyze the results and write a report. Approximately another $80,000 would be required for the operating costs (electricity and water) during the test, however no credit has been included for the benefit of the water produced.

TABLE 4-10
PRELIMINARY COST ESTIMATE PILOT STUDY AT STMGID 1
INJECTION AT 667 GPM FOR 3 MONTHS

CAPITAL COST

ITEM	ITEM NAME	EST. QUANT.	UNITS	EST COST	TOTAL ESTIMATE
MOBILIZATION		1	LS	$8,000	$8,000
INJECTION WELL FACILITIES					
1	Test Well Modification	1	LS	$10,000	$10,000
2	Pipe, Valves, Fittings, Meter and Backflow Preventer	1	LS	$10,000	$10,000
3	Controls	1	LS	$5,000	$5,000
4	Building	1	LS	$9,000	$9,000
5	Site Work and Miscellaneous	1	LS	$2,500	$2,500
WELL INTERTIE TO SOURCE WATER					
1	Pipe, Valves, and Fittings	400	LF	$25	$10,000
RECOVERY FACILITIES					
1	Site Work and Miscellaneous	1	LS	$1,000	$1,000
PERMITS					
1	ASR	1	LS	$2,500	$2,500
2	UIC	1	LS	$1,500	$1,500
OTHER					
1	Water Testing	1	LS	$4,000	$4,000
	SUBTOTAL				$63,500
	CONTINGENCY (@ 15%)				$9,500
	HYDROGEOLOGIST (FIELD AND ANALYSIS)	184	HRS	$85	$15,640
	ENGINEERING & LEGAL (@ 20%)				$12,700
			TOTAL CAPITAL COST		**$101,340**

OPERATING COST

ITEM	ITEM NAME	EST. QUANT.	UNITS	EST COST	TOTAL ESTIMATE
INJECTION COSTS					
1	Water Purchase	265	AF	$277	$73,405
2	Electrical	8,000	kw-hrs	$0.062	$496
RECOVERY COSTS					
1	Electrical	100,000	kw-hrs	$0.062	$6,200
	SUBTOTAL				**$80,101**

SUMMARY

ITEM	ITEM NAME			TOTAL ESTIMATE	UNITS
	TOTAL CAPITAL COST			$101,340	TOTAL
	ANNUALIZED CAPITAL COST, 20YRS @ 5%			$8,132	/YR
	ANNUAL O&M			$80,101	/YR
	TOTAL ANNUAL COST			$189,573	/YR
	WATER RECOVERED @ 75% (AF/YR)			199	AF/YR
	TOTAL ANNUAL COST/AF RECOVERED			**$954**	**$/AF**
	TOTAL ANNUAL COST $/1,000 GAL.			**$2.93**	**1,000 GAL.**

5.0 Hydrogeochemistry of the South Truckee Meadows Area

5.1 INTRODUCTION

In this section of the report it will be shown that:

1. Stream flow and secondary recharge is indeed a significant factor in groundwater recharge.
2. Urbanization has a significant impact on groundwater quality, mostly on the shallow aquifer, but also on the deeper sections.

This analysis relied on a total of about 1600 chemical data sets from 11 municipal wells and more than 600 domestic wells, covering an area of about 40 square miles. Assuming a market price of $200 per chemical analysis, this is a data value of $320,000. More than 98% of the data were collected after 1974. These data provide a valuable record of groundwater chemistry evolution since the early 1970's.

5.2 AMBIENT GROUNDWATER CHEMISTRY

5.2.1 WATER CHEMISTRY TYPES

The different water types prevailing in the STM area are characterized by using the central plot of a Piper diagram in Figure 5-1. The municipal wells all plot as one distinct group in the lower left corner, whereas the surface waters plot further up to the right. The average of 1300 domestic well water samples plot the farthest up to the right. Although both the domestic and the municipal wells are pumping from the same aquifer, average chemical composition is significantly different. This is because since the early 1970's the chemistry in the shallow aquifer (from which the domestic wells pump) has changed significantly, away from a composition that was initially the same as in the municipal wells. These changes are attributed to urbanization effects in the shallow aquifer system.

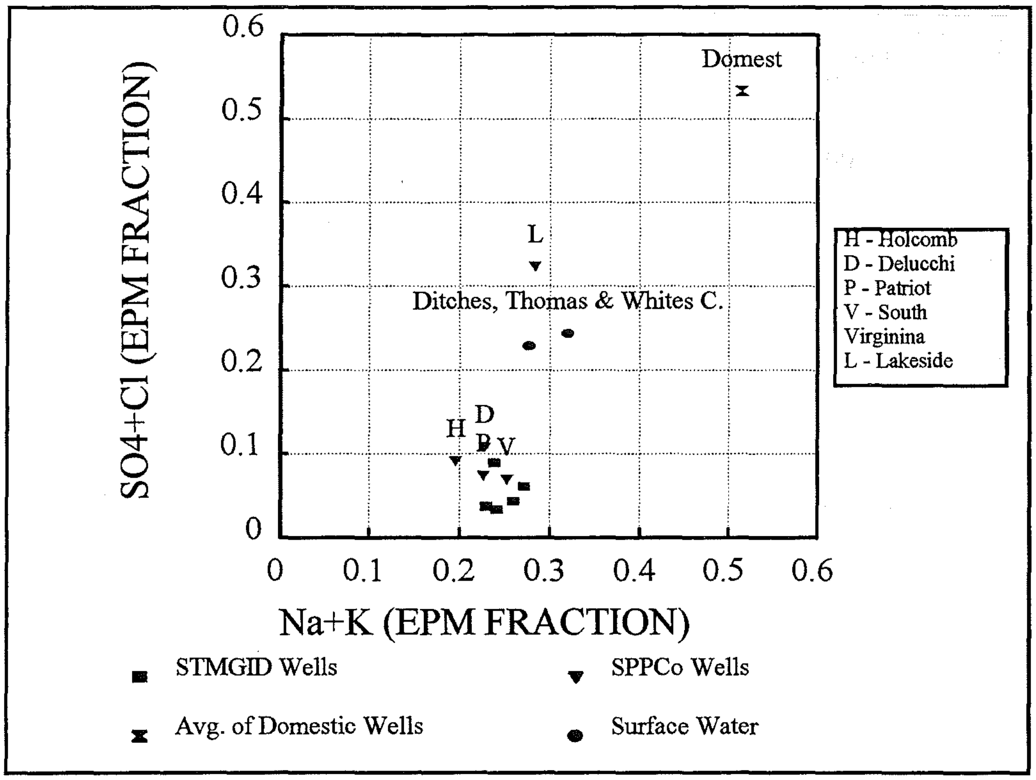


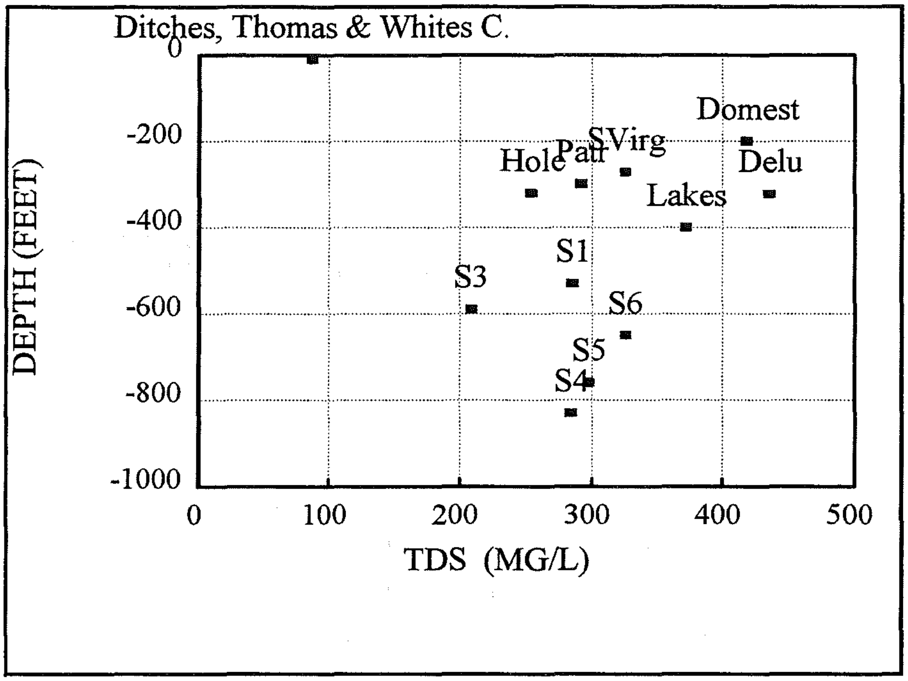
Figure 5-1. Average chemical composition of groundwater and surface waters (Piper Diagram).

5.2.2 IMPACTS OF URBANIZATION ON SHALLOW GROUNDWATER CHEMISTRY CHANGES SINCE 1970

Since 1982 water composition in the shallow aquifer (at least the portion tapped into by domestic wells) has gradually changed. This is evident in chemical changes whereby TDS, chloride and various other chemicals have gradually increased. The most dramatic increases have occurred since 1982. The reason for this is believed to be urbanization, while the deeper municipal wells' water composition has remained largely the same.

What does this mean? It can be argued that domestic wells to a large extent pump water that has been recycled from leach fields. That same water goes through the household again and is recycled again into the shallow aquifer, as the shallow aquifer chemistry gradually changes.

In Figures 5-2 and 5-3 well depth was plotted versus average TDS, chloride and nitrate from municipal and domestic wells. TDS, nitrate and chloride are highest in the shallow wells. Similar patterns are evident when plotting well depth versus sulfate and bicarbonate.



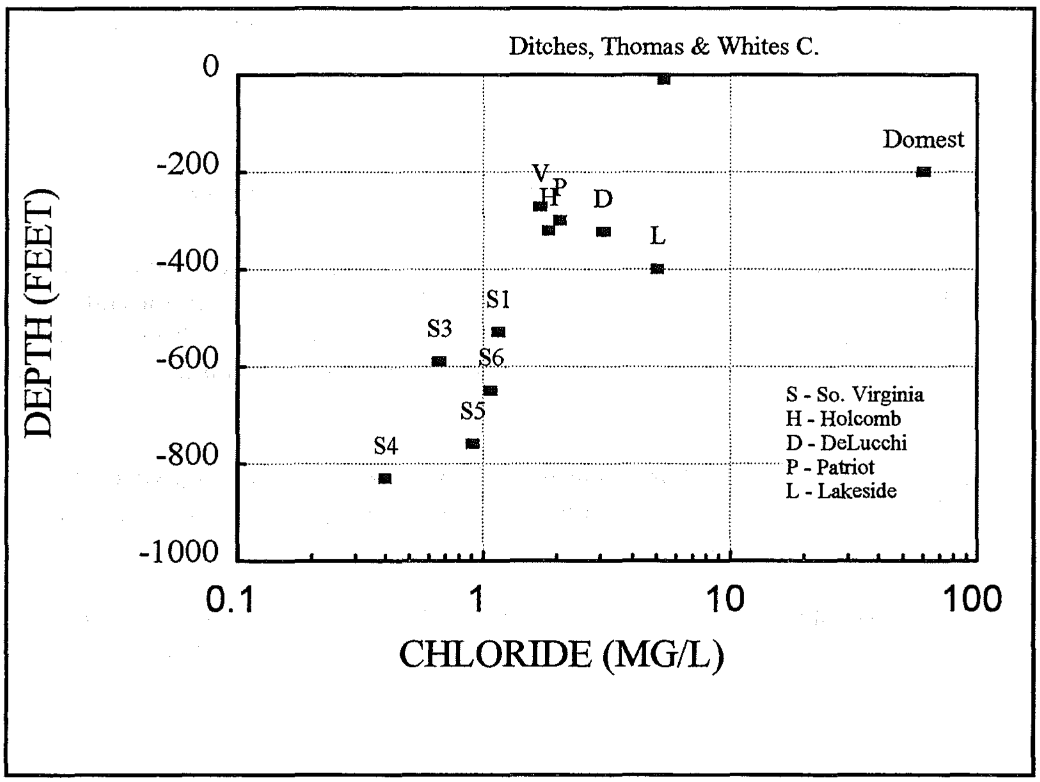


Figure 5-2. Average TDS and chloride levels in municipal and domestic wells, STM area. (Note the changes with depth. See text for explanation).

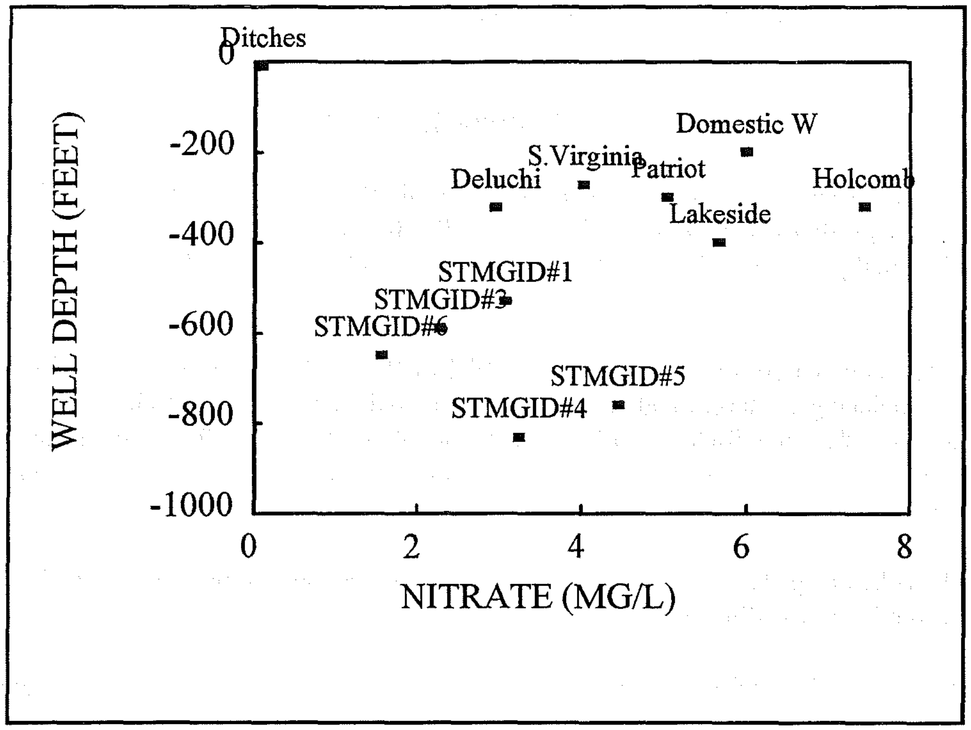


Figure 5-3. Average nitrate levels in municipal and domestic wells. (Note the changes with depth. See text for explanation.)

These patterns suggest that indeed chemicals are introduced from the shallow sub-surface, in the form of increased TDS, chloride, sulfate, bicarbonate and nitrate. Nitrate mimics these trends, suggesting that urbanization is a significant contributor to high TDS levels in the shallow aquifer.

The chemical differences between irrigation and stream waters and shallow groundwater are large enough to suggest that these changes are not due to secondary recharge (irrigation and streams), but rather due to urbanization (septic systems and urban runoff).

5.3 LONG TERM TRENDS IN GROUNDWATER CHEMISTRY AND SECONDARY RECHARGE

5.3.1 TDS AND NITRATE IN MUNICIPAL WELLS

Changes in nitrate and TDS provide a useful means of sorting out two major impacts on the aquifer. Annual nitrate changes are due to urbanization impacts, whereas annual changes in TDS are due to varying degrees of secondary recharge mixing with aquifer water.

TDS and nitrate in the STMGID wells suggest different processes than in the Virginia Street Wells. This is because these two groups of wells typify two distinct aquifer conditions:

1. The STMGID wells are further up on the Mt. Rose fan, with static water levels more than 100 ft below land surface.

2. The Virginia Street Wells are farther down along the alluvial fan, with static water levels between 10 and 70 ft below land surface.

5.3.2 TDS and Nitrate Changes in the Virginia Street Wells

To demonstrate chemistry changes over time, annual TDS and nitrate from the DeLucchi and South Virginia municipal wells were plotted versus time in Figure 5-4. The figure also shows the annual irrigation ditch water supply and annual pumpage. Since 1971, average TDS levels in both wells have increased by about 50 mg/l.

Irrigation ditch flows decreased by about 60% from 1984 to 1987. About at this time TDS in these wells began to increase convincingly. The correlation between irrigation ditch flow and TDS in these wells can also be seen in the early 1990's when ditch flow diminished from about 30,000 ac-ft per year down to less than 15,000 ac-ft per year. Again, at the same time TDS levels in the wells increased markedly, and decreased as soon as flows were increased to normal.

Similar, though less obvious patterns can be recognized in most of the other municipal wells that are located down gradient of the irrigation ditches.

In Figure 5-4, the DeLucchi Well nitrate was also plotted against time, together with irrigation flow and pumping rate. Between 1972 and 1991 nitrate increased from 2 to 8 mg/l, and decreased thereafter back to about 2 mg/l in 1993. Pumping rate doubled from 1983 to 1989, and then diminished in 1994. Clearly nitrate increases with pumping rate. The situation is similar in the South Virginia, Lakeside and Holcomb Wells.

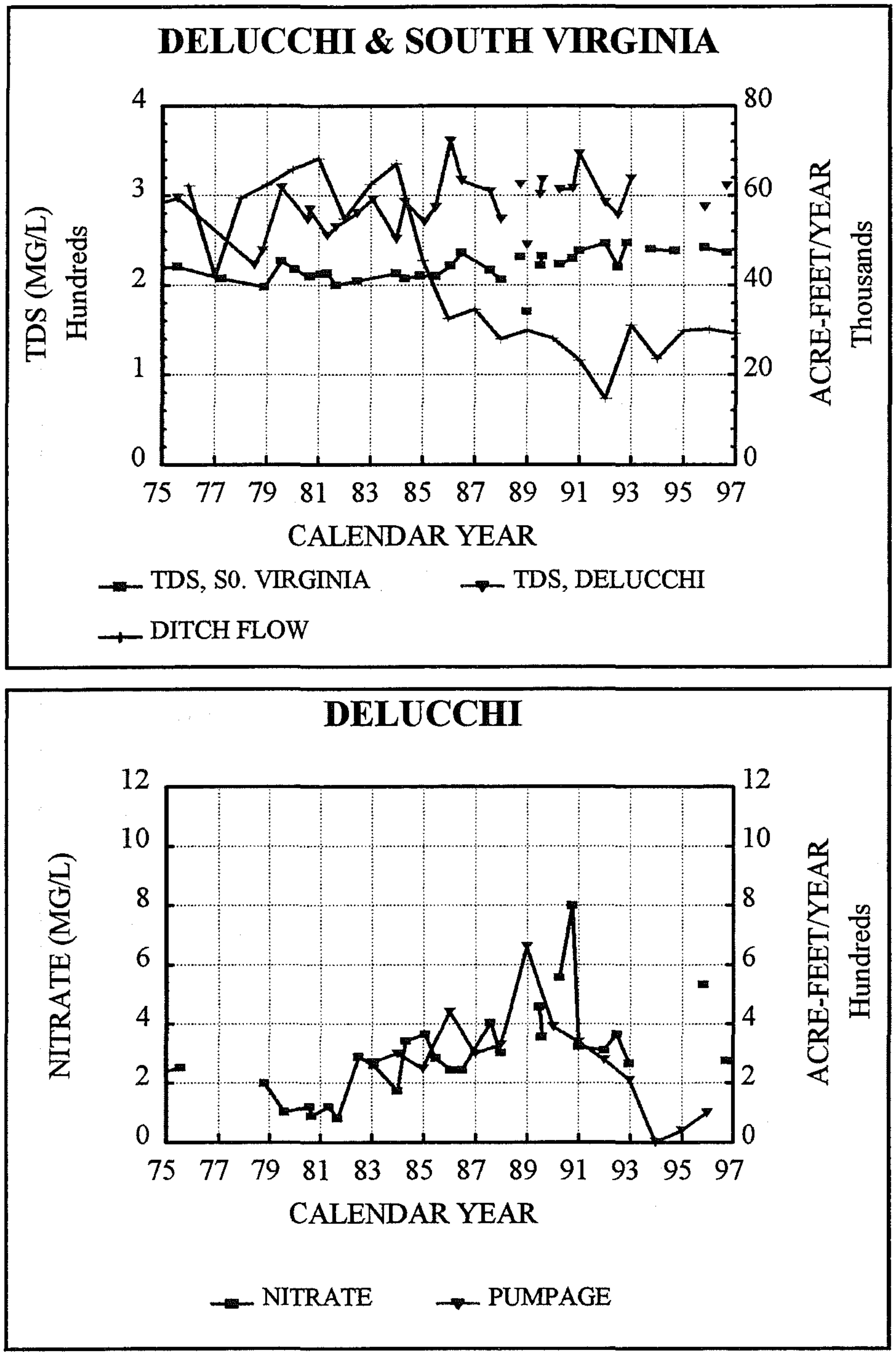
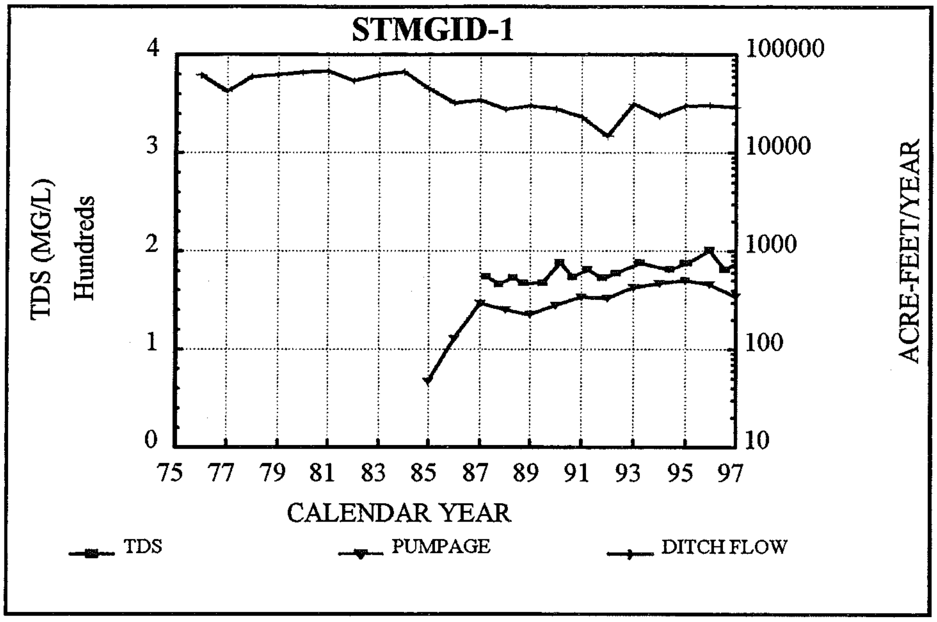


Figure 5-4. South Virginia and DeLucchi Municipal Wells, historical changes in TDS and nitrate with ditch flow and pumpage, STM area.



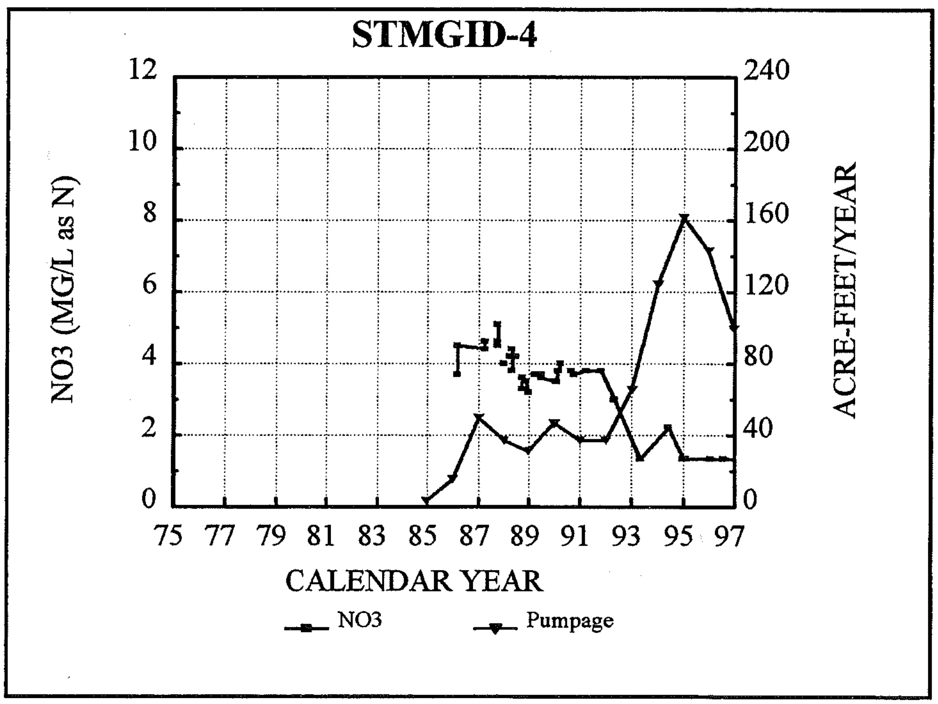


Figure 5-5. STMGID No.1 and 4 Wells, historical changes in TDS and nitrate with ditch flow and pumpage, STM area.

The STMGID wells' responses are different. In Figure 5-5 the historical TDS for STMGID No. 1 was plotted, together with total ditch flow. Here also TDS has increased since 1987. Yet, in 1991/92 the TDS levels did not respond to the dramatic flow reduction in those years, suggesting that secondary recharge is more efficient at the STMGID No.1 well location. In contrast, in the STMGID wells west of Steamboat Ditch, TDS did not increase with decreasing ditch flow, corroborating that secondary recharge is the cause of changing TDS in groundwater. In other words, ditch losses, and/or secondary recharge in groundwater is substantial enough to affect municipal well water chemistry.

Different than in the South Virginia Street wells, nitrate in the STMGID wells decreases with pumping, as for example in STMGID No. 4 (Figure 5-5). Due to pumping, nitrate has diminished from about 4 mg/l to 1.5 mg/l. Similar patterns can be observed in the other STMGID wells.

In summary, all the deep municipal wells east of the irrigation ditches are affected by secondary recharge. Well water chemistry reflects changing irrigation practices and/or changes in total annual ditch loss volume. SPPCo. wells in the study area cause the wells to intercept more groundwater that has been affected by effluent from residential septic systems. The STMGID wells draw more water from greater depth because they are deeper. On the other hand, since the groundwater table is much deeper in the STMGID well area, nitrate may still be migrating through the unsaturated zone.

Using a simple mixing equation, the fraction of secondary recharge in some of the municipal wells was calculated. The amount of irrigation water pumped by some of the municipal wells is substantial:

- Before 1984 the amount of irrigation water in the aquifer may have exceeded 30%.
- Since 1984 the amount of irrigation water in the aquifer has been reduced by about 60%.

5.4 TDS AND NITRATE DOMESTIC WELLS

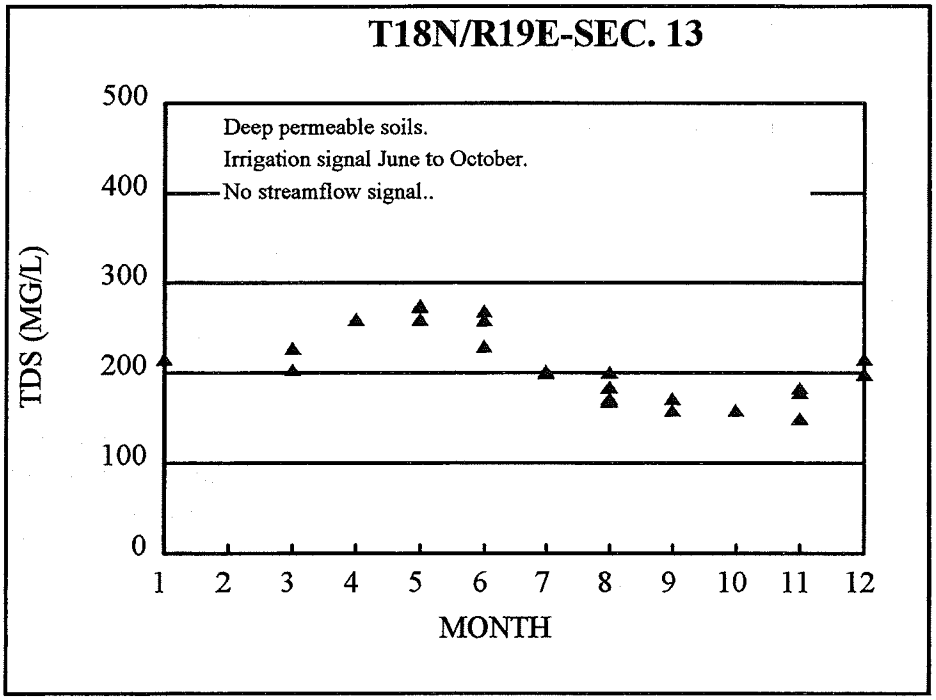
Plotting the monthly moving TDS averages (averaging 5 values at a time), for each section , against sampling month, yields annual cyclical patterns in the sections affected by irrigation or stream flow. As an example, data for two sections are shown in Figure 5-6.

If the aquifer is affected by either stream flow and/or irrigation infiltration, then one would expect two distinct signals in the domestic wells TDS hydrographs:

- A minimum TDS in late winter or spring, from stream flow infiltration.
- A minimum TDS in the summer months, starting in June or later and lasting into early winter from irrigation.

The annual nitrate changes in Figure 5-7 also follow a cyclical pattern, with the highest concentrations in the Spring and in the Fall. The reasons for these fluctuations are as follows:

- Background nitrate is maintained by a balance between year-round septic leach field contributions and ambient groundwater flow.
- Late winter infiltration and flood irrigation (and maybe lawn irrigation) percolate through the soil, carrying elevated nitrate into the aquifer.
- Nitrate decreases are the result of stream channel infiltration diluting nitrate in the aquifer; Stream channel infiltration does not pick up soil nitrate.



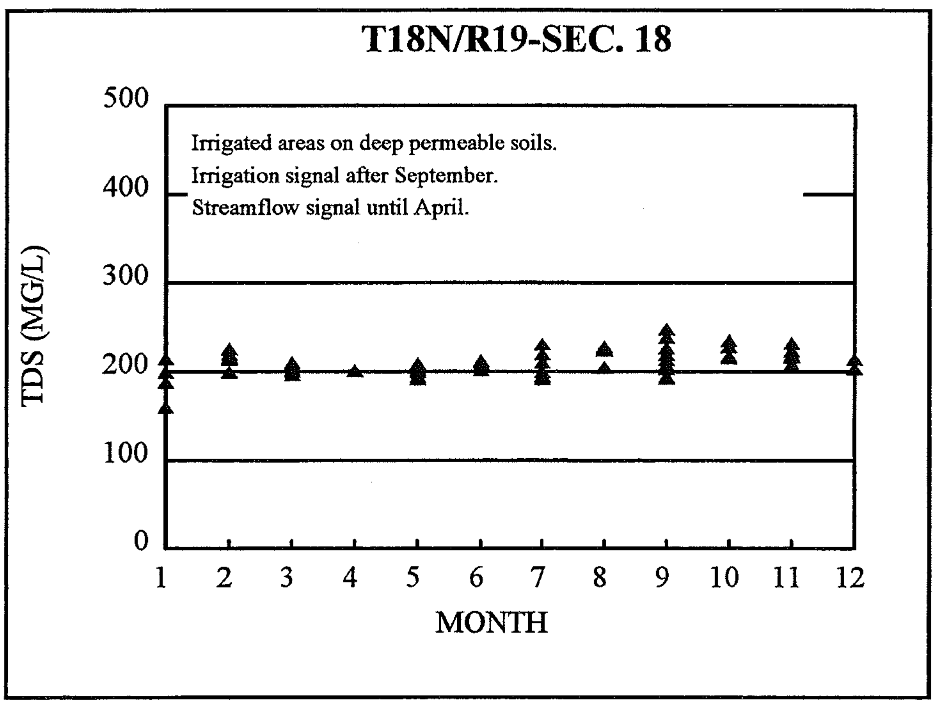
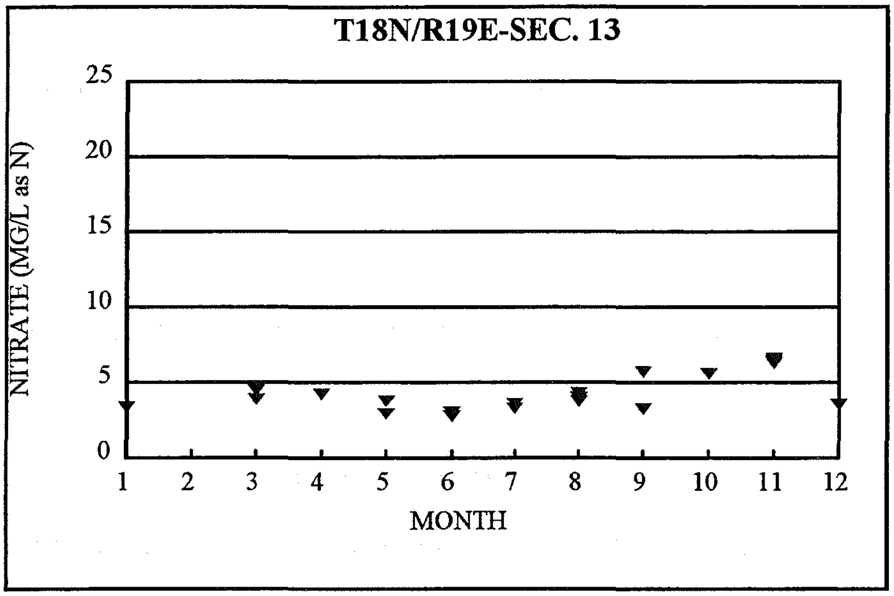


Figure 5-6. Groundwater recharge patterns in Sections 13 and 18, STM area. (Section 18 is located down-gradient from Section 13 and thereby carries more diluted water. Consequently, the impact of low TDS water is less dramatic.)



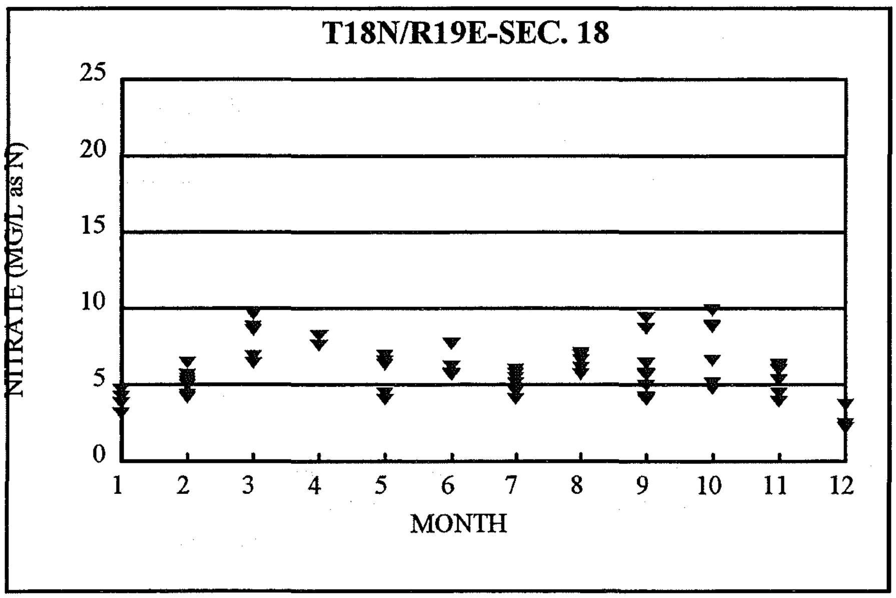


Figure 5-7. Nitrate changes in Sections 13 and 18, STM area. (In Section 13, nitrate peaks in March and October/November. The March peak is due to spring infiltration from precipitation, carrying soil nitrate into groundwater. Once stream channel infiltration affects the aquifer, nitrate levels diminish from 5 mg/l to about 3 mg/l in June. Once stream flow decreases, nitrate levels increase again. At the same time, secondary recharge begins to flush soil nitrate into the shallow aquifer, acting similar as late winter infiltration. By the time stream flow starts to increase again in December, nitrate decreases again as a result of channel infiltration and dilution in the aquifer.)

5.5 AMOUNT OF SECONDARY RECHARGE IN DOMESTIC WELLS

We can assume that the maximum prevailing TDS is the ambient groundwater composition, which is subsequently diluted by secondary recharge. And knowing the TDS in the irrigation water, and using regional groundwater flow estimated from hydrogeologic data, the amount of secondary recharge was calculated, using a simple mixing equation. A similar approach was applied to calculate the stream flow contribution from stream channel infiltration.

Secondary recharge entering the aquifer annually was estimated for Sections 1, 2, 11, 12, 13, 14, 24 and 25 in T.18N.,R.19E., and Sections 6, 7, 17, and 18 in T.18N.,R.20E. The total amount of secondary recharge in these 9 sections is estimated to be:

- 5,000 ac-ft annually from irrigation and ditch losses.
- 1,200 ac-ft annually from stream channel infiltration.

Thereby the average secondary recharge rate from irrigation and ditch losses is about 50% of the water imported to the study area via the ditches. Due to ditch losses the actual volume of irrigation infiltration is probably less than that. By conducting accurate flow measurements in the ditches, it should be possible to more accurately determine these numbers.

These methods are based on assumptions that need to be verified, but which are reasonable. What gives these calculations credibility is their basis in observed trends (the TDS cycles) in the aquifer chemistry. These trends are indicative of some kind of annual dilution process in the aquifer. It is encouraging that the estimated quantities are reasonable, instead of providing astronomical numbers that have little bearing on the problem under consideration.

5.6 CONCLUSIONS FROM GROUNDWATER CHEMISTRY ANALYSIS

The following conclusions are drawn from the groundwater chemistry data analysis:

1. Secondary recharge from irrigation and stream channel infiltration is evident in the underlying aquifer's seasonal chemical changes. Using a simple mixing equation secondary recharge was calculated for the 9 sections where TDS changes indicate significant secondary recharge. Based on these calculations, the total secondary recharge from irrigation (including ditch losses) and from stream channel infiltration was estimated at 5,000 and 1,200 ac-ft per year, respectively.

2. Groundwater recharge in the Southwest Truckee Meadows from surface water sources is very efficient. The seasonal changes in the groundwater system suggest a system open to recharge. This suggests that the option of artificial groundwater recharge by means of surface infiltration ponds is a feasible option.

3. Unfortunately the high efficiency of surface water infiltration also leads to a concern that should be addressed at some time in the near future: the Southwest Truckee Meadows aquifer system is highly vulnerable to groundwater pollution.

4. The continued use of septic leach fields in high density suburban areas may have led to a gradual buildup of residential waste in the aquifer. Domestic wells in some areas apparently pump a significant amount of recycled water. Although the regional groundwater flow replenishes the shallow aquifer every year, gradual build-up of more benign (but not necessarily to be ignored) constituents in the aquifer may occur.

5. The results show the need of a comprehensive wellhead protection program. It should include developing plans on how to gradually eliminate various sources of pollution in the process of urbanization, specifically septic leach fields.

5.7 ARTIFICIAL RECHARGE OF THE AQUIFER USING INFILTRATION BASINS, INFILTRATION GALLERIES, OR OTHER LAND APPLICATION TECHNIQUES

The previous discussion concluded that irrigation and leaky irrigation ditches are very significant sources of groundwater recharge to the aquifer. The analysis of the chemical data is supported by water-level data which showed a large rise in water levels in wells in 1996 after high flows and low-land flooding from Thomas and Whites Creeks (WCUSD, 1996). Highly permeable soils which favor percolation of water are found over a large part of the study area, particularly the southern one-half. In combination, these conclusions suggest that some type of land application of water may be an effective way of artificially increasing recharge to the aquifer that is used by the domestic wells and the municipal wells. It stands to reason that if recharge to the shallow aquifer can be increased, then there is a potential to mitigate problems that might be associated with increasing groundwater withdrawals from the municipal wells and degradation of water quality that is associated with septic leach fields.

Land application of surface water is attractive for parts of the study area because of the study area's location relative to sources of surface water. Relatively undeveloped land in the study area is amendable to this purpose. Water from Thomas and Whites Creeks can be conveyed to recharge sites under gravity-flow conditions. Likewise, water diverted from the Truckee River can be easily conveyed to many areas via the Steamboat Ditch. Land application techniques are also attractive alternatives to recharge wells because a lower level of water treatment is required, so that the cost of water is less compared to recharge wells.

The effectiveness of land application using surface water was also simulated using a variation of the County's groundwater flow model. Specifically, the model was used to simulate the application of 100 acre-feet per year of water on the land surface at a location approximately one-half mile west of the Picollo School. This is the same general area where an 11 feet rise in water level was observed in 1996 that followed significant runoff in Thomas Creek. The result of the simulation, shown in Figure 5-8, was an initial rise in water level near the Picollo School and a later reduction in the rate of water level decline due to pumping wells in the area. Considering that the simulation assumed that recharge was increased by only 100 acre-feet per year, the results are significant in terms of the potential benefits of this kind of a recharge program.

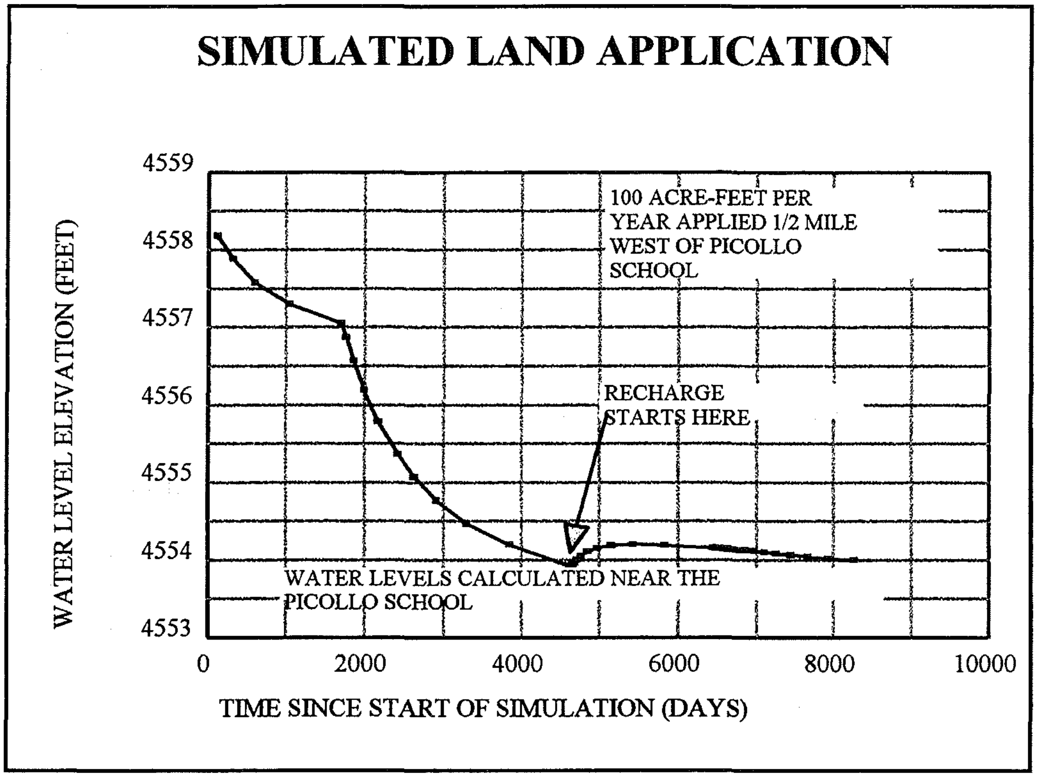


Figure 5-8 Simulated Surface Recharge

If the addition of 100 acre-feet of artificial recharge in this area has the potential to locally stabilize water levels, the converse will be true. That is, reducing secondary recharge from irrigation in this area by 100 acre-feet per year will result in an equivalent lowering of water levels in the domestic wells in the same area.

These results are preliminary, but very encouraging. More work is needed to provide all of the data and information for a rigorous and complete analysis of the potential for recharging the aquifer by these means.

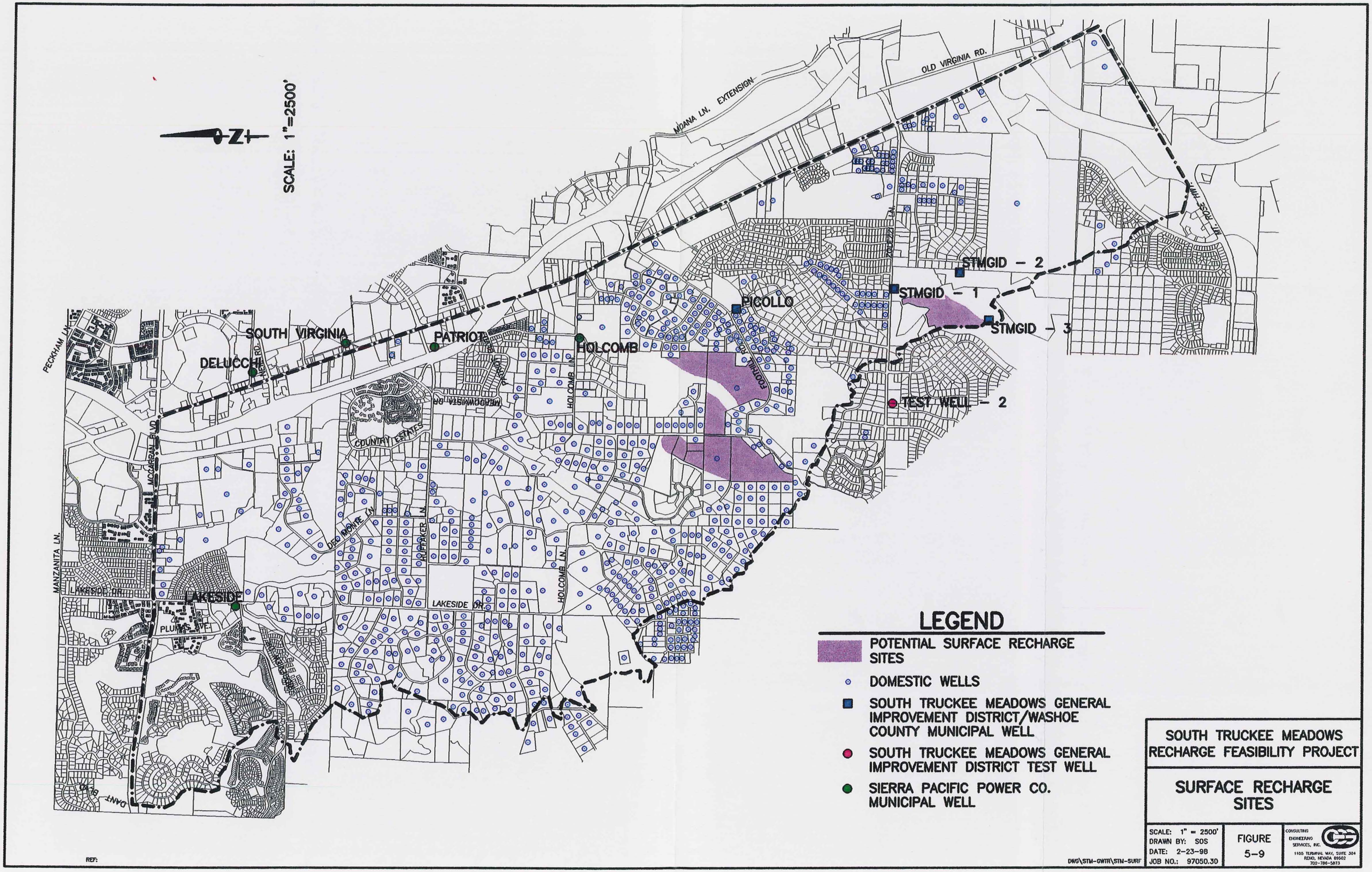
Despite the preliminary nature of this assessment, it seems appropriate to provide preliminary costs for this alternative in the subsequent section so this alternative can be compared with recharge alternatives using wells.

5.8 ENGINEERING CONSIDERATIONS

5.8.1 SURFACE RECHARGE ALTERNATIVES

There are three different ways to achieve surface recharge in the area: ponds, percolation trenches or galleries, and flooding. Which one is used depends primarily on the individual circumstances of each site. Figure 5-9 shows three potential locations for surface recharge identified on the basis of soil type and groundwater levels.

Surface recharge in this area could be achieved utilizing water from the ditch system in the area. This has the advantage of utilizing existing water rights although the manner of use must be changed and eliminates the need to purchase treated water from Sierra Pacific Power Co. If the water rights are not available, they would have to be purchased or leased and this price would add to the capital cost developed in this report. Another advantage is the level of treatment needed prior to using the water. Treatment can be limited to settling basins to remove suspended solids.



SCALE: 1"=2500'
N
OLD VIRGINIA RD.
MOANA LN. EXTENSION
MT. ROSE HWY
STMGID - 2
STMGID - 1
STMGID - 3
PICOLLO
TEST WELL - 2
FOOTHILL RD
SOUTH VIRGINIA
PATRIOT
HOLCOMB
DELUCCHI
PECKHAM LN.
MEADOWVISTA DR
COUNTRY ESTATES
HOLCOMB LN.
DEL MONTE LN.
MANZANITA LN.
LAKESIDE DR.
LAKESIDE
PLUMAS AVE.
DANT BLVD.
LEGEND
POTENTIAL SURFACE RECHARGE SITES
DOMESTIC WELLS
SOUTH TRUCKEE MEADOWS GENERAL IMPROVEMENT DISTRICT/WASHOE COUNTY MUNICIPAL WELL
SOUTH TRUCKEE MEADOWS GENERAL IMPROVEMENT DISTRICT TEST WELL
SIERRA PACIFIC POWER CO. MUNICIPAL WELL
SOUTH TRUCKEE MEADOWS RECHARGE FEASIBILITY PROJECT
SURFACE RECHARGE SITES
SCALE: 1" = 2500'
DRAWN BY: SOS
DATE: 2-23-98
JOB NO.: 97050.30
FIGURE 5-9
CONSULTING ENGINEERING SERVICES, INC.
REF:
DWG\STM-GWTR\STM-SURF

One particular recharge site is planned to become Arrow Creek Golf Course. The recharge for this site could be accomplished by installing a "leaky" pond, or series of ponds, on the golf course. Not only would the pond provide recharge to the Zolezzi Lane area, but it would provide a nice addition to the landscape of the golf course. The golf course personnel would have to be approached regarding this alternative, and because they will irrigate the course with effluent, the Nevada Department of Environmental Protection must be contacted as well. The potential problems surrounding effluent irrigation located near a recharge pond will have to be addressed. Primarily, the effluent will not be allowed to come in contact with the pond.

Two other potential sites are located off of Foothill Drive. This area is currently zoned for high density rural land use and as such, the recharge would need to be accomplished through a series of trenches or ponds possibly integrated into the landscape. Future developments in this area should be required to dedicate land as recharge areas.

5.8.2 ALTERNATIVE 1 - SURFACE RECHARGE AT FOOTHILL

Surface recharge in the Foothill area will require approximately 4,000 linear feet of trench 3 ft in width and 9 ½ ft deep with 6 feet of the sidewall in use for recharge. A comprehensive soils and hydrogeologic investigation must be performed to finalize these numbers. Table 5-1 shows the preliminary cost estimate for this alternative.

5.8.3 ALTERNATIVE 2 - SURFACE RECHARGE AT ARROW CREEK

Surface recharge at the Arrow Creek Golf Course will require approximately 480,000 square feet of infiltration area. This translates into a pond with dimensions of approximately 600 feet by 800 feet or several small ponds integrated into the golf course as water hazards. This will result in a larger capital investment than is outlined in Table 5-2. Increasing the number of ponds also complicates the effluent irrigation issue. For these reasons, this option is not recommended.

TABLE 5-1
PRELIMINARY COST ESTIMATE ALTERNATIVE 1 SURFACE RECHARGE AT FOOTHILL
RECHARGE AT 500 GPM FOR 6 MONTHS

CAPITAL COST

ITEM	ITEM NAME	EST. QUANT.	UNITS	EST COST	TOTAL ESTIMATE
MOBILIZATION		1	LS	$20,000	$20,000
RECHARGE FACILITIES					
1	Excavation	4,200	CY	$3	$12,600
2	Drainrock	2,700	CY	$15	$40,500
3	Fabric	4,100	LF	$1	$4,100
4	Pipe	4,100	LF	$4	$16,400
5	Storage	1	LS	$50,000	$50,000
6	Controls	1	LS	$5,000	$5,000
7	Surface Restoration	1	LS	$10,000	$10,000
RECOVERY FACILITIES					
1	Site Work and Miscellaneous	1	LS	$1,000	$1,000
	SUBTOTAL				$159,600
	CONTINGENCY (@ 15%)				$23,900
	ENGINEERING & LEGAL (@ 20%)				$31,900
			TOTAL CAPITAL COST		**$215,400**

OPERATING COST

ITEM	ITEM NAME	EST. QUANT.	UNITS	EST COST	TOTAL ESTIMATE
RECHARGE COSTS					
1	Repairs and Annual Maintenance	1	LS	$2,079	$2,079
RECOVERY COSTS					
1	Labor	200	Hrs/Yr	$30	$6,000
2	Electrical	160,000	kw-hrs	$0.062	$9,920
3	Repairs and Annual Maintenance	1	LS	$15	$15
	SUBTOTAL				**$18,014**

SUMMARY

ITEM	ITEM NAME			TOTAL ESTIMATE	UNITS
	TOTAL CAPITAL COST			$215,400	TOTAL
	ANNUALIZED CAPITAL COST, 20YRS @ 5%			$17,284	/YR
	ANNUAL O&M			$18,014	/YR
	TOTAL ANNUAL COST			$250,698	/YR
	WATER RECOVERED @ 50% (AF/YR)			199	AF/YR
	TOTAL ANNUAL COST/AF RECOVERED			**$1,260**	**$/AF**
	TOTAL ANNUAL COST $/1,000 GAL.			**$3.87**	**1,000 GAL.**

TABLE 5-2

PRELIMINARY COST ESTIMATE ALTERNATIVE 2 SURFACE RECHARGE AT ARROW CREEK
RECHARGE AT 500 GPM FOR 6 MONTHS

CAPITAL COST

ITEM	ITEM NAME	EST. QUANT.	UNITS	EST COST	TOTAL ESTIMATE
MOBILIZATION		1	LS	$20,000	$20,000
RECHARGE FACILITIES					
1	Excavation	30,000	CY	$5	$150,000
2	Pipe and valves	300	LF	$4	$1,200
3	Controls	1	LS	$5,000	$5,000
4	Site Work and Miscellaneous	1	LS	$10,000	$10,000
RECOVERY FACILITIES					
1	Site Work and Miscellaneous	1	LS	$1,000	$1,000
	SUBTOTAL				$187,200
	CONTINGENCY (@ 15%)				$28,100
	ENGINEERING & LEGAL (@ 20%)				$37,400
			TOTAL CAPITAL COST		**$252,700**

OPERATING COST

ITEM	ITEM NAME	EST. QUANT.	UNITS	EST COST	TOTAL ESTIMATE
RECHARGE COSTS					
1	Repairs and Annual Maintenance	1	LS	$1,662	$1,662
RECOVERY COSTS					
1	Labor	200	Hrs/Yr	$30	$6,000
2	Electrical	160,000	kw-hrs	$0.062	$9,920
3	Repairs and Annual Maintenance	1	LS	$15	$15
	SUBTOTAL				**$17,597**

SUMMARY

ITEM	ITEM NAME			TOTAL ESTIMATE	UNITS
	TOTAL CAPITAL COST			$252,700	TOTAL
	ANNUALIZED CAPITAL COST, 20YRS @ 5%			$20,277	/YR
	ANNUAL O&M			$17,597	/YR
	TOTAL ANNUAL COST			$290,574	/YR
	WATER RECOVERED @ 50% (AF/YR)			199	AF/YR
	TOTAL ANNUAL COST/AF RECOVERED			**$1,460**	**$/AF**
	TOTAL ANNUAL COST $/1,000 GAL.			**$4.48**	**1,000 GAL.**

6.0 PERMITTING

6.1 General

An aquifer storage and recovery program requires permits from the State of Nevada Department of Conservation and Natural Resources. The specific permits required are *water rights*, a *recharge storage and recovery* permit, and an *underground injection control* permit. Within the Department, the Division of Water Resources has jurisdiction over water rights needed for the program and ASR projects. The Division of Environmental Protection administers the permits for underground injection control.

6.2 DIVISION OF WATER RESOURCES

6.2.1 WATER RIGHTS

Recharge and storage is a recognized and approved use of water in the state of Nevada. As with any use aside from individual domestic wells, a water right is required for ASR projects. Water rights in the State of Nevada are administered by the Office of State Engineer of the Division of Water Resources. For the South Truckee Meadows, water that is permitted for use by Sierra Pacific Power Company or Washoe County is the obvious source of water for the project. For the pilot recharge study utilizing wells, the probable source of water would be treated surface water from the Chalk Bluff Water Treatment Plant delivered to the test site through their distribution system.

Sierra Pacific has the capability of delivering a combined total of 85,736 acre-feet per year (AFA) from surface-water and groundwater sources. In 1997, they delivered a total of 71,384 acre-feet. Of the balance of 14,352 AFA, a total of 2,357 acre-feet per year are allocated to specific projects that have not been built, leaving a balance of 11,995 AFA combined surface water and groundwater that are not currently in use or allocated to a specific project. Of this amount, 6,583 AFA is groundwater. If the groundwater component is removed from consideration, at present, a total of 5,412 acre-feet per year of surface water is potentially available for an ASR project (John Erwin, 1998, personal communication; 1997 SPPCo Water Resources Budget Summary).

Washoe County holds small amounts of surface water rights and has the potential to lease surface water rights from willing parties. If ASR is economically feasible, it makes sense for the County to acquire surface water rights to Whites and Thomas Creeks and utilize it for ASR, especially if spreading basins are used as the recharge facility.

6.2.2 RECHARGE, STORAGE, AND RECOVERY PERMIT

The Nevada State Engineer also administers permits for *recharge, storage, and recovery* of water, the term for ASR projects in Nevada. Regulations governing ASR in Nevada are contained in the Nevada Revised Statutes 534.250-534.340 (inclusive). Key elements of the permit are:

- An application. The required information includes "the name and address of the applicant, area of operation of the project, name and address of the land owner, evidence of financial and technical capability, the source, quality, and annual quantity of water, legal basis for acquiring and using water, description of proposed project, a study that demonstrates feasibility, annual report to State Engineer, monitoring of project."

- $2,500.00 application fee and annual fee.

- Processing the application takes a minimum of 90 days from the time a complete application is received by the State Engineer.

- Public notice. Published once each week for two consecutive weeks in the newspaper.

A key element of the permit is the "storage account." This account establishes the recoverable amount of water stored by the project. To date, more than 12 permits have been approved for recharge, storage, and recovery of water. However, no storage accounts have been established as yet.

6.3 DIVISION OF ENVIRONMENTAL PROTECTION

6.3.1 UNDERGROUND INJECTION CONTROL PERMIT

Injection wells used for aquifer storage and recovery are classified as Class V injection wells. As such, they fall under the jurisdiction of the Nevada Division of Environmental Protection Bureau of Water Permits and Compliance. An underground injection control (UIC) permit is required for Class V injection wells. The regulations governing UIC programs are contained in the Nevada Administrative Code 445.422 through 445.4278 (inclusive). The permitting process includes filing an application. Key elements of the permit are:

- An application. The application must include a site plan, plans and specifications for the facility; geology, hydrology, and soil information (if applicable); flood-plain and drainage information, chemical analysis of the groundwater and the recharged fluids, information regarding drinking water sources and wells in the area, verification of financial responsibility, other site and process information.

- Application fee. The amount of the fee varies.

- Processing. Minimum of 90 days of receipt of a complete application. NDEP has 30 days to review the application. If complete, NDEP conducts a technical review of the application. Within 60 to 90 days of receipt of the application, a draft permit is prepared and sent to the applicant for comment. Within 30 to 60 days a public notice is issued. Public comments are reviewed. The draft permit is either finalized, amended, or rejected. A responsiveness summary is prepared and Notice of Determination is mailed to commentors and interested parties. Four to six months are typically required to process the UIC permit.

- Public Notice.

7.0 CRITICAL ISSUES REGARDING AQUIFER RECHARGE IN THE STUDY AREA

7.1 WATER RIGHTS

The probable source of water for use as recharge via wells is treated surface water from Sierra Pacific Power Company's Chalk Bluff water treatment facility. It is SPPCo's opinion that they have sufficient surface water resources to allot as much as 5,400 acre-feet per year to aquifer recharge. However, the staff of the Nevada Division of Water Resources is of the opinion that their available surface water resources may be significantly less than this amount (Hugh Ricci, personal communication). While it may not affect a pilot recharge study, this issue must be resolved prior to initiating a large-scale ASR program.

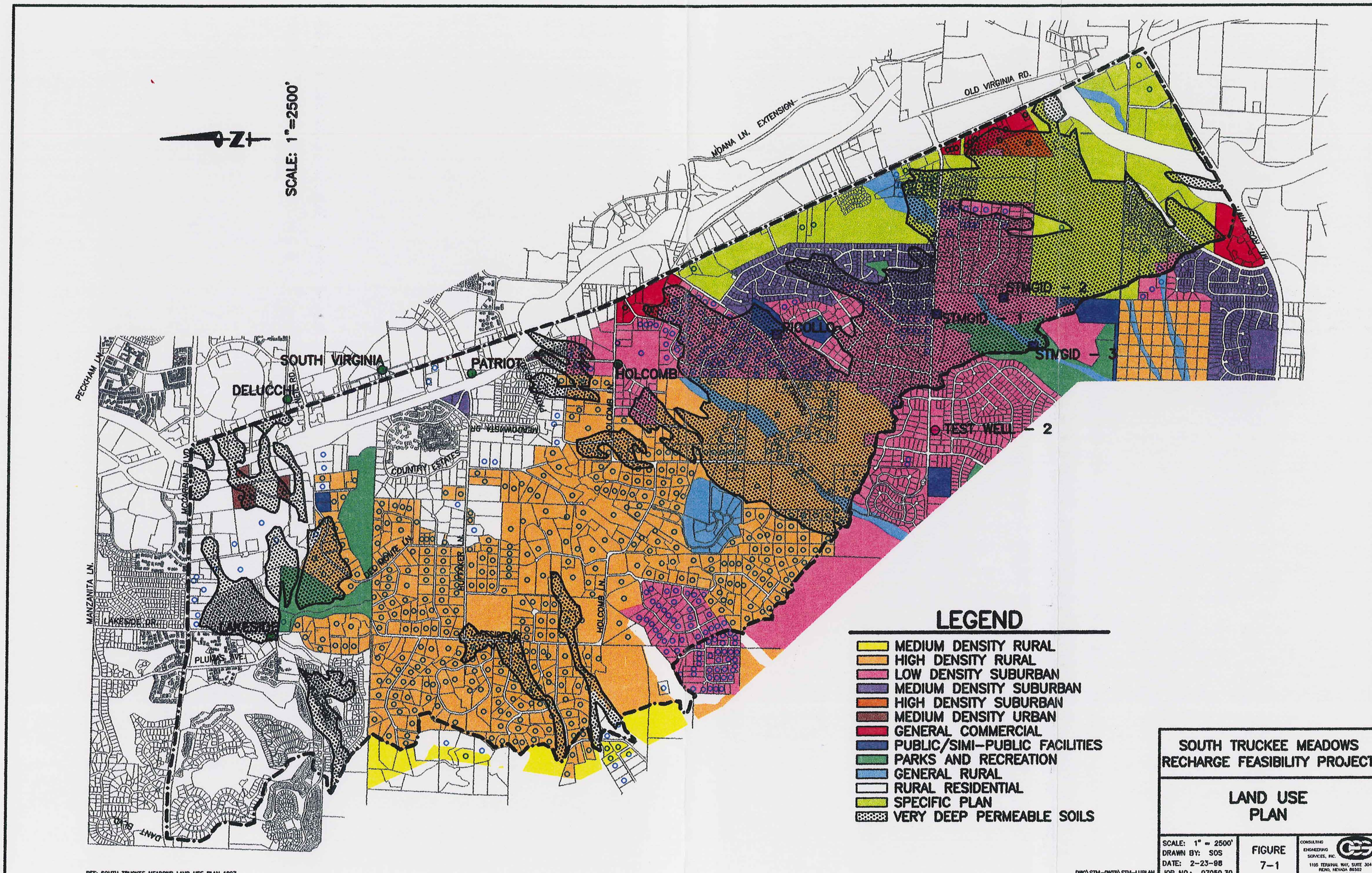
An alternative to an ASR project utilizing recharge wells is one which utilizes ponds, galleries, or other land application of surface water which has undergone minimal treatment. Washoe County holds permits for limited quantities of surface water. For the county to operate a large-scale recharge project of this type, they must acquire water rights through lease or purchase. Probable sources of water for this type of recharge project is the Truckee River (via the Steamboat Ditch), Whites Creek or Thomas Creek. Agricultural water rights acquired for this purpose would require a change in the place and manner of use.

7.2 COMPETING LAND USES

Planned land use may affect the viability of the most favorable sites for a recharge project involving relatively low-cost methods which rely on ponds, infiltration galleries, or spreading. Criteria which favor these methods include highly permeable, well-drained soils; proximity to areas of concentrated water exploitation, and agricultural or other low-density land uses. Areas which meet these criteria are identified in Figure 7-1. An overlay of planned land use shows that a large part of the most favorable sites for this option will compete with high density rural land use and may not be available as recharge sites in the future. While high density rural land use does not rule out a recharge project of this type altogether, it would require a more costly variations in the program. For example, infiltration ponds could be integrated into landscaping or infiltration galleries similar in nature to leach fields could be constructed to minimize surface impacts.

7.3 RECHARGE, STORAGE, AND RECOVERY

For ASR projects in Nevada, you are allowed to take out only the water that you put in. This can be viewed as management of the water on a "molecule-by-molecule" basis. Under this premise, the operator of an ASR project must demonstrate to the State Engineer that the water withdrawn via wells is the *same* water that was injected or otherwise recharged. The ASR project sets up a water account based on the percentage of the actual water injected that is recovered. Exchanging surface water injected into the aquifer for groundwater extracted from the aquifer is strictly prohibited.



SCALE: 1"=2500'
N
OLD VIRGINIA RD.
DANA LN. EXTENSION
PECKHAM LN.
SOUTH VIRGINIA
PATRIOT
DELUCCHI
HOLCOMB
RICOLLO
STMGID - 2
STMGID - 1
STMGID - 3
TEST WELL - 2
MEADOWVISTA DR.
COUNTRY ESTATES
McCARRAN BLVD.
DEL MONTE LN.
HOLCOMB LN.
MANZANITA LN.
LAKESIDE DR.
LAKESIDE
PLUMAS AVE.
DAMONTE RANCH PKWY.
LEGEND
MEDIUM DENSITY RURAL
HIGH DENSITY RURAL
LOW DENSITY SUBURBAN
MEDIUM DENSITY SUBURBAN
HIGH DENSITY SUBURBAN
MEDIUM DENSITY URBAN
GENERAL COMMERCIAL
PUBLIC/SIMI-PUBLIC FACILITIES
PARKS AND RECREATION
GENERAL RURAL
RURAL RESIDENTIAL
SPECIFIC PLAN
VERY DEEP PERMEABLE SOILS
SOUTH TRUCKEE MEADOWS
RECHARGE FEASIBILITY PROJECT
LAND USE
PLAN
SCALE: 1" = 2500'
DRAWN BY: SOS
DATE: 2-23-98
JOB NO.: 97050.30
FIGURE
7-1
CONSULTING
ENGINEERING
SERVICES, INC.
1105 TERMINAL WAY, SUITE 304
RENO, NEVADA 89502
702-786-5873
REF: SOUTH TRUCKEE MEADOWS LAND USE PLAN 1997
DWG\STM-GWTR\STM-LUPLAN

Because of the conditions which exist in the study area, water injected into the aquifer moves down-gradient (to the east) at a relatively high rate. In a short period of time the water can move a considerable distance from its point of injection, so that it could not be captured from a recovery well near the place of recharge. In order to capture the maximum percentage of the injected water, recovery wells must be located some distance directly down-gradient in order to capture enough of the injected water to make a project economically viable on the basis of the water accounting principle. Alternatively, the recovery well can be pumped at a relatively high rate.

For the conditions which exist in the southwest Truckee Meadows, a more appropriate approach is to manage the potentiometric head rather than the actual water. In other words, recharge via wells causes the elevation of the water table to rise even as the water moves down-gradient to the east. This rise can offset the potential interference drawdown related to pumping municipal wells depending on the relative locations of the recharge areas and extraction wells even though the extraction wells recover different water than was injected. An artificial recharge project using this approach would not be permitted unless the State of Nevada's laws are changed.

8.0 RECOMMENDATIONS FOR FUTURE STUDY

8.1 PILOT RECHARGE STUDY

Numerical simulations of aquifer recharge and recovery indicate that this water management tool has the potential to allow increased exploitation of the groundwater resource of the southwest Truckee Meadows while minimizing adverse impacts on existing wells. It even appears to have the potential to reverse declines in water levels in the aquifer that have occurred to date. A primary objective of the pilot recharge study is to verify or refute the conclusion that overall efficiency of an ASR project in this area will be 75 per cent or less.

A 90-day duration is recommended. Injection/recharge will be via STMGID Monitoring Well No. 3. The hypothetical injection rate is 650 gpm based on the aquifer properties for this area and an overall efficiency of the well of 75 per cent. A two-inch diameter injection tube can carry this flow rate while remaining full, so that entrained air in the fluid stream will be minimized. The actual injection rate will depend on the injection capacity of the well which has not yet been documented. STMGID-1 is proposed for use as the recovery well. At the end of the 90-day recovery period, STMGID-1 should be pumped at its maximum capacity for 90 days. Chemical quality of the injectate and the recovered water should be monitored closely to evaluate the amount of recharge water which can be captured. The cost of the pilot study was provided in Table 4-10

8.2 RELATED FOLLOW-UP STUDIES

Management of the water resource depends on good information regarding the components of recharge to the aquifer. Studies which will provide better data regarding the quantity of secondary recharge to the aquifer from irrigation and ditch leakage are addressed below. Estimating the cost of these investigations is beyond the scope of this study.

8.2.1 GEOCHEMICAL STUDIES.

Further geochemical investigation is expected to yield considerable information regarding seasonal variations in the chemical composition of water from wells in the study area. Strategically placed monitoring wells would help refine the trends observed in the domestic well data to date. Each well site should comprise a pair of one shallow and one deep monitoring well to examine the depth in the aquifer to which local recharge from irrigation occurs. Because of the high velocity at which groundwater travels in the study area, the wells should be sampled monthly. In addition to physical chemistry, samples for stable isotopes of oxygen and hydrogen should be collected to help differentiate between various the sources of the water.

The monitoring wells should be equipped with digital water level recorders. Changes in water level coupled with the chemical data will help better quantify the amount of recharge from irrigation and ditch seepage. With a sufficient number of dedicated monitoring wells, annual recharge to the aquifer from these sources can be determined with a high degree of accuracy.

Environmental isotope samples should be collected from pertinent wells and the ditches (preferably in conjunction with major ion analysis), beginning in the spring and continuing all through the summer months until late fall. This should be done in conjunction with reasonably accurate flow measurements (input-output measurement from ditch to ditch). This is anticipated to yield the following results:

- correlation of amount of irrigation water flow with amount of secondary recharge;
- time delay, i.e. time it takes for irrigation water to reach the water table;
- efficiency of flood irrigation.

8.2.2 DITCH LOSS STUDY.

The losses due to infiltration of surface water from the ditches can be analyzed a number of ways. One method is to measure ditch flow over representative reaches through the study area. Reaches can be selected to be between head gates for the distribution ditches. Measurements should be collected at the beginning of the irrigation season, midway through the season, and near the end of the season to establish any variation in leakage. The advantage of this method is that it measures average leakage over relatively long reaches of the ditches so that local variations in ditch bottom hydraulic characteristics are averaged.

An alternative method is to measure selected locations along the ditches with a stream bottom infiltrometer. Sample locations could be selected on the basis of soil type beneath the ditch Up to eight measurements can be made by one person in a single day. As above, measurements should be made several times during the irrigation to establish variability in the leakage. An advantage of this type of measurement is that the hydraulic conductivity of the ditch bottom can be measured directly. A major disadvantage is that it measures only a small area and estimates of overall ditch leakage would be subject to moderate errors.

The most comprehensive program would be a combination of these methods.

8.2.3 FEASIBILITY OF RECHARGE BY LAND APPLICATION METHODS.

The available data indicate that parts of the southwest Truckee Meadows have potential for augmenting recharge to the aquifer using some type of land application techniques such as infiltration ponds, galleries, spreading basins, *etc*. However, the data are insufficient to allow design of these types of facilities or determine the maximum rate water can be applied. Considerable site-specific data are required. The work entails drilling of soil borings to document local conditions, principally the variation of the hydraulic conductivity in the underlying soils and the depth to water. Given these parameters, a pilot study can be performed. The pilot study would be required to establish the water account with the State Engineer. Only then can the feasibility, design, and cost of a large-scale land application recharge project be determined with a degree of confidence.

8.2.4 FURTHER COMPILATION OF ANNUAL DATA

Altogether approximately 1600 chemical data sets were utilized for this study, covering an area of about 50 square miles. Assuming a price of $200 per chemical analysis, this represents a value of $320,000. This accumulated wealth of chemical data has so far not been fully utilized. Since these data enable one to analyze the water quality status of the South Truckee Meadows aquifer system, groundwater chemistry data should continue to be obtained and entered into a systematic computer database

Prior to this project only a small percentage of these data were useable for groundwater management. Assuming that the results of analyzing these data can become truly beneficial for resolving lingering groundwater management questions, it maybe worthwhile to consider establishing a County-wide database in the future, by immediately entering every water chemistry analysis into a centralized database as data become available.

In addition, given the results of this study, any future numerical model of the Southwest Truckee Meadows area should include a solute transport component to accommodate this sort of information content.

Sources of Information

Bibliography

Bateman, R.L. and Scheibach, R.B., 1977, Nevada Bureau of Mines and Geology, Report 25.

Bohnam, H.F., Jr. and D.K. Rogers, 1983. Mt. Rose NE Quadrangle Geologic Map: Nevada Bureau of Mines and Geology Reno Area Map 48g.

Chesley, M., McKay, W.A., and McKenna, S., 1990, The 1988 Truckee River water quality monitoring project report. Desert Research Institute, WRC, July 1990. Public. No. 41128.

Chesley, M., W.A. McKay, and S. McKenna, 1990. The 1998 Truckee River water quality monitoring report: Desert Research Institute, Water Resources Center, July 1990, Pub. No. 41128.

Cohen, P. and Loeltz, O.J., 1964, Evaluation of hydrogeology and hydrogeochemistry of Truckee Meadows area. Washoe County, Nevada. USGS WSP 1779-S.

Guyton and Associates, 1978, Progress report on groundwater conditions in the Reno-Sparks area, Nevada. February 1978. Prepared for Sierra Pacific Power Co.

Guyton, W.F. Associates, 1992a. Summary statement for status report on study of artificial recharge in southwest Truckee Meadows Washoe County, Nevada: consulting report prepared for Westpac Utilities, a division of Sierra Pacific Power Company.

Guyton and Associates, 1992b. Supplemental report on artificial recharge in the central and southwest Truckee Meadows area: consulting report prepared for Westpac Utilities, a division of Sierra Pacific Power Company.

Hydro-Search, Inc., 1991, South Truckee Meadows Groundwater Flow and Transport Model. Prepared for Washoe County Utility Division. October 10, 1991.

Pyne, R. David G., 1991. Groundwater Recharge and Wells: Lewis Publishers, 376pp.

Soil Conservation Service, 1977. Mt. Rose NE Folio Soil Map: Nevada Bureau of Mines and Geology Environmental Series Reno Area.

SPPCo, 1997. Water Resources Budget Summary

Washoe County, 1996, Groundwater level status for portions of Mt. Rose and Galena Fan area, Washoe County, Nevada. Dept. of Public Works, Aug. 1996.

Washoe County, 1991, Notebook on hydrogeology of the South Truckee Meadows. Washoe County Dpt. of Public Works, Utility Division. February 1991.

Van Denburgh, A.S., Lamke, R.D., and Hughes, J.L., 1973, A brief water-resources appraisal of the Truckee River Basin, Western Nevada. Water resources reconnaissance Series, Report 57.

Other sources

Mount Rose, NE U.S.G.S 15-minute topographic quadrangle
Nevada Department of Water Resources - Drillers' reports to the State Engineer
Nevada Division of Health - Water chemistry analysis reports
Nevada State Health Laboratory, 1660 N. Virginia St., Reno, Nevada.
Washoe County Department of Comprehensive Planning
- Parcel Map
- Land Use Map
- Southwest Truckee Meadows Area Plan

Washoe County Utility Services Division
- Well data for STMGID wells
- Annual pumping data for STMGID wells
- Water quality data for STMGID wells

Washoe County, Department of Public Works.
Washoe Water Protection Association, 3773 Baker Lane, Reno, NV 89509. - Water chemistry data .
US Geological Survey, Water Resources Division, Carson City.

Contacts

Dragan, Dan -WCUSD - recharge projects in Washoe County
Erwin, John - SPPCo - Personal communication
- Annual pumping data for Sierra Pacific Power Company wells
- Water level data for Sierra Pacific Power Company wells
- Input files for SPPCo groundwater model

Foree, Mark - SPPCo
Heiskanen, Jerry - SPPCo
Porter, Chip - Data for domestic wells in the southwest Truckee Meadows.
Ricci, Hugh - Nevada Division of Water Resources - aquifer recharge, storage, and recovery regulations
Rossi, Lou - SPPCo - water chemistry data for Sierra Pacific Power Company wells
Setty, Matt - Data from the files of the Federal Water Master
Svetich, Terri - WCUSD - water quality data for STMGID and Washoe County Wells
Warner, Rick - WCUSD - plans for STMGID wells
Widmer, Michael - WCUSD - hydrogeological data and reports
- Input files for County groundwater model

PLUMAS GEO-HYDROLOGY P.O. Box 1922, Portola, CA 96122
LAND AND WATER RESOURCES (530) 836-2208

Secondary Recharge and Impacts of Urbanization on Ground Water Quality of the South Truckee Meadows Area Washoe County, Nevada

prepared for

Dale Bugenig
Hydrogeologist
Consulting Engineering Services, Inc.
1105 Terminal Way
Reno, NV 89502

by
Burkhard Bohm
Hydrogeologist

March 23, 1998

1 Executive Summary

This report focuses on the impacts of secondary recharge from irrigation and streamflow on the shallow aquifer system of the Southwest Truckee Meadows (STM) area. It has been hypothesized that significant amounts secondary recharge from irrigation affect ground water in the STM area. It has also been hypothesized that reduction of irrigation water volumes since the mid 1980's has significantly affected ground water availability for shallow domestic wells in the STM area.

Furthermore large lot urbanization using individual sewage distribution systems results in adding significant amounts of nitrate and TDS to the aquifer, while heavy pumpage from the municipal wells affects ambient ground water flow patterns.

In this report it is demonstrated that

1. Streamflow and secondary recharge is indeed a significant factor in ground water recharge;
2. Urbanization has a significant impact on ground water quality, not only the shallow aquifer, but also the deeper sections.

This study relies on applying hydrogeochemical analysis to the STM area to identify nature and magnitude of secondary recharge and urbanization on shallow ground water. A total of about 1600 chemical data sets were utilized for this study, covering an area of about 40 square miles, together with well depth, pumping, and streamflow data.

The results of this study are:

1. Secondary recharge from irrigation and stream channel infiltration is evident in the underlying aquifer's seasonal chemical changes. The total secondary recharge from irrigation (including ditch losses) and stream channel infiltration was estimated at 5000 and 1200 ac-ft per year, respectively.
2. Ground water recharge in the STM from surface water sources is very efficient. This suggests that the option of artificial ground water recharge by means of surface infiltration ponds is a feasible option.
3. The high efficiency of surface water infiltration makes the STM aquifer system highly vulnerable to ground water pollution.
4. The septic leachfields in the suburban areas has led to domestic wells in some areas pumping a significant amount of recycled water, including increased TDS and various other chemicals. Thereby gradual build-up of more benign (but not necessarily to be ignored) constituents in the aquifer may occur.
5. The results show the need of a comprehensive wellhead protection program. It should include developing plans on how to gradually eliminate various sources of pollution in the process of urbanization, specifically septic leachfields.

2 Introduction

This project is part of a larger project conducted by CES, Inc. to determine the feasibility of artificial ground water recharge in the South Truckee Meadows (STM) area. This report focuses on the impacts of secondary recharge on the shallow aquifer system and ground water recharge. The purpose of applying geochemistry to the STM area is to identify and quantify the nature and magnitude of secondary recharge and urbanization on shallow ground water.

The hypothesis is that significant amounts of irrigation return flows affect ground water in the STM area. It is also hypothesized that reduction of irrigation water volumes since the mid 1980's has significantly affected ground water availability for shallow domestic wells in the STM area, drilled in the last 30 years, if not 50 years..

Furthermore large lot urbanization using individual sewage distribution systems results in adding significant amounts of nitrate and TDS to the aquifer. At the same time heavy pumpage from the municipal wells affects ambient ground water flow patterns.

In this report it will be demonstrated that

1. Streamflow and secondary recharge is indeed a significant factor in ground water recharge;
2. Urbanization has a significant impact on ground water quality, not only the shallow aquifer, but also the deeper sections.

Our analysis was based on using historical ground water chemistry data from 11 municipal wells and more than 600 domestic wells, covering an area of about 40 square miles.

2.1 Ground water chemistry database development

2.1.1 Data sources

An extensive search of ground water chemistry data was conducted for the Truckee Meadows area. The South Truckee Meadows ground and surface water system has been developed since more than 30 years, and an extensive body of data has been accumulated. Most of these data were buried in archives of various agencies or were spread throughout various technical reports and publications.

Specific data used for this study include:

1. Well water chemistry of major ions, and trace metals. We used mostly TDS (calculated by sum from the major ions) and conservative anions, like chloride and nitrate and sulfate:
   a. A total of about 1300 domestic well data sets were gathered from Washoe County Health Department, DRI's former WADS data base, and several literature studies (including Cohen and Loeltz, 1964; Bateman and Scheibach, 1977).
   b. A total of about 300 data sets from 11 municipal wells, obtained from the records of Washoe County and several SPPCo. reports

2. The immediate STM project area includes a total of about 650 domestic well water chemistry data sets.
3. Well depths and/or screened intervals. For the municipal wells these data were obtained from the County and from Sierra Pacific Power Company (SPPCo.). For the domestic wells these records are incomplete, i.e. only about 1/3 of the wells' depth are available.
4. Annual pumping rates from all municipal wells, obtained from the records of SPPCo and Washoe County.
5. Annual irrigation volumes supplied by the three ditches (Steamboat, Last Chance and Lake). Data obtained from the Watermaster.
6. Annual streamflow data, obtained from Washoe County records.
7. Irrigated areas, as deducted from county records and aerial photos

Many of these data were available from preceding engineering and ground water studies. Since most of the water chemistry data had not been compiled previously into one single data base, much time had to be dedicated towards scrutinizing data quality and eliminating poor data sets.

All available data were carefully compiled, by entering them into electronic spreadsheets. To facilitate analysis, the data were then categorized according to area of origin within the STM area, and year and month of sampling. Altogether about 1600 ground water chemistry data sets were utilized for this study, covering an area of about 40 square miles.

2.1.2 Period of time covered by this database

The ground water chemistry data sets from the domestic wells reach back as far as 1945. More than 98% of the data were collected after 1974. Data abundance peaked in the mid 1980's, and then declined into the 1990's. Although the domestic well data are not continuous time-series from discreet locations, they nevertheless provide a record of ground water chemistry conditions since the early 1970's. In other words particular time intervals are represented at many discontinuous locations.

Water chemistry data from the municipal wells range back as far as 1971, but about 90% were collected after 1986. Compared to the domestic well records, the municipal well data provide continuos time-series from several discreet locations.

Data distribution over time and by section number (spatial distribution) are plotted in the Appendix.

2.1.3 Data quality and epm-balance

The epm balance was calculated for each data set, whenever meaningful, i.e. when the major ions are complete. Input errors were checked by visual inspection of epm-balances for unreasonable values.

2.2 Methodology of data analysis

The extent of secondary recharge and impact on underlying aquifer systems can be identified by means of hydraulic data and subsequent modeling. In this study application of ambient hydrochemical tracers has proven beneficial in verifying the results of hydrologic modeling conducted previously.

With this philosophy in mind we applied several approaches:

1. TDS and nitrate turned out to be useful indicators of surface water infiltration and mixing in the aquifer.
2. Ion ratios were used to distinguish between irrigation and septic return flow sources.
3. Conservative ions were plotted versus well depth (or screened depth).
4. Sources and quantity of return flow (recharge) were traced by plotting TDS and nitrate against time (chemical hydrographs), both seasonally and over the years.

Given the large number of water chemistry analysis available, identifying subtle trends over time can become a cumbersome task. The database essentially contains two major types of samples: samples from domestic wells and samples from municipal wells. Each data type has its strengths and weaknesses for identifying hydrologic processes in time and space:

a. Domestic wells typically represent the shallow aquifer portions. Unfortunately most domestic well samples are from different sampling locations at different times. In other words, the data from domestic wells seldom, if ever are true time series samples from one and the same well.

b. The only continuous time series samples from particular single locations are available from municipal wells. These data typically cover shallow and deeper sections, or only deeper sections of the aquifer. Furthermore, they are subject to high pumping rates, and thereby provide more integrated samples from a larger area of the aquifer.

The advantage of domestic well data is that due to their low pumping rate they provide sampling information of discrete, limited aquifer volumes, limited to a small aquifer portion. On the other hand municipal well samples, due to the high and continuos pumping rates, provide integrated samples, representative of a large aquifer volume, both aerial and depth-wise extensive, over several years of time.

Each type of data was analyzed in ways that yields information most efficiently, addressing its unique strengths and weaknesses:

1. Water chemistry parameters were plotted versus depth.
2. Domestic well samples were lumped into 1 square mile areas. In this case we grouped them into sections, by sorting the data base according to Township/Range and Section, and month:
   a. To identify regional trends, averages were calculated for each section, and the most useful chemical parameters were plotted on each section square.
   b. To identify seasonal trends moving averages of certain parameters were plotted by month for each section.
   c. To identify long term trends, moving averages within each section were plotted versus year of sampling.
3. Municipal well samples were lumped into separate sets for each well. These sets were sorted by time (year, month, day):
   a. Seasonality was not very useful, although in some cases seasonal cycles are recognizable.

b. To identify long term trends, certain chemical parameters for each well were plotted versus year of sampling. These trends were compared with annual pumping rate and annual ditch flows.

c. Water chemistry parameters averages for each municipal well were plotted versus depth.

3 Ambient ground water chemistry

3.1 Source waters in the STM hydrologic flow system

The hydrologic system in the STM is dominated by a source area in the west, i.e. the Carson Range, which results in streamflow and ground water flow from west to east. Presumably all ground and surface waters discharge into the Steamboat Creek drainage which then flows into the Truckee River in the North.

We assumed a number of chemical end members in the STM hydrologic system that affect the water chemistry of various portions of the aquifer in specific ways. The source waters for these end members are as follows:

1. Natural ground water recharge in the Carson Range to the west. This is water that is recharged into shallow soils at high elevations, percolates into fractured bedrock (granitics and volcanics) and migrates eastward. At some time it is discharged into the alluvial fan materials and thereby enters the project area. In other areas it occurs in the project area in fractured bedrock.
2. Stream-water from Whites Creek, Thomas Creek, Dry Creek and Evans Creek flow northeast across the Mt. Rose Fan. Some of this water in its course percolates into the streambed to augment ground water flow.
3. Dry Creek discharges into Boynton slough which discharges into the Truckee River. Evans Creek discharges into Last Chance Ditch.
4. There are also a number of smaller streams emerging only a few miles west of the project area, in-between the larger Creeks mentioned above. These are apparently spring fed, and may at time be ephemeral. Typically these streams feed directly into Boynton Slough or via the ditch systems associated therewith.
5. Secondary recharge from irrigation estimated at between 1620 and 3,260 acres of irrigated area in the STM. Chemically these are inputs of Truckee River water fed into the three ditches, Steamboat, Last Chance and lake Ditches. Due to the low TDS levels of less than 100 mg/l these typically result in ambient ground water chemistry dilution.
6. Significant amounts of chemical input is also believed to originate from domestic septic leachfields, and maybe urban runoff. These are characterized by high nitrate and TDS level, and indiscriminant input of various trace chemicals.

3.2 Hydrochemical end-members

There are several chemical end members associated with the above mentioned source waters. Not all of these are represented in the available database. Chemically the end-members are described as follows:

1. Surface water entering the STM area via fractured bedrock. A representative sampling point is the Lakeside Municipal well.
2. Ground water percolating from streams into the subsurface. Representative waters are the creeks like Whites, Thomas and Dry Creeks.
3. Irrigation water imparted from the Truckee River, via the irrigation ditches:

a. A limited amount of EC and pH data were collected by the USGS from Steamboat and Last Chance Ditches , between 1993 and 1995. The EC values for Steamboat and last Chance Ditches range from 69 to 87 and 100 to 148 micromhos, respectively.

b. The most recent data were collected in September 1997 (3 samples per ditch). These data are relatively consistent among all 9 samples. Average TDS is 87 mg/l, and average chloride is 5.44 mg/l.

c. It is noteworthy that TDS in each ditch increases slightly from west to east, suggesting irrigation return flow entering Last Chance and Lake Ditch from the above ditches.

4. Domestic wastewater, percolating from leachfields. The chemical composition is poorly defined, but can be best characterized by high nitrate and TDS values.
5. Urban is typically poorly characterized. No data are available for this end-member.
6. Geothermal water entering via deep-seated faults from the Steamboat Springs geothermal area. This is occurring only on the southeastern periphery of this project area, and does not affect the portions of the aquifer in this study.

The different water types (end-members) are characterized by using the central plot of a piper diagram in Figure 1. Clearly, the municipal wells plot very close together, though showing some variability due to long term trends (and to a lesser extent seasonal fluctuations).

In Figure 1, all municipal wells (except the Lakeside well) plot as one distinct group in the lower left corner, whereas the surface waters plot further up to the right. Average domestic well waters chemistry plots in the upper right hand corner. This average hides a great deal of detail. This is an average of about 1300 domestic well data sets, sampled mostly since the early 1970's, from an area of about 40 square miles. As will be shown later, since the early 1970's average domestic well water quality has changed from a composition similar to that of the municipal wells, to its present average composition.

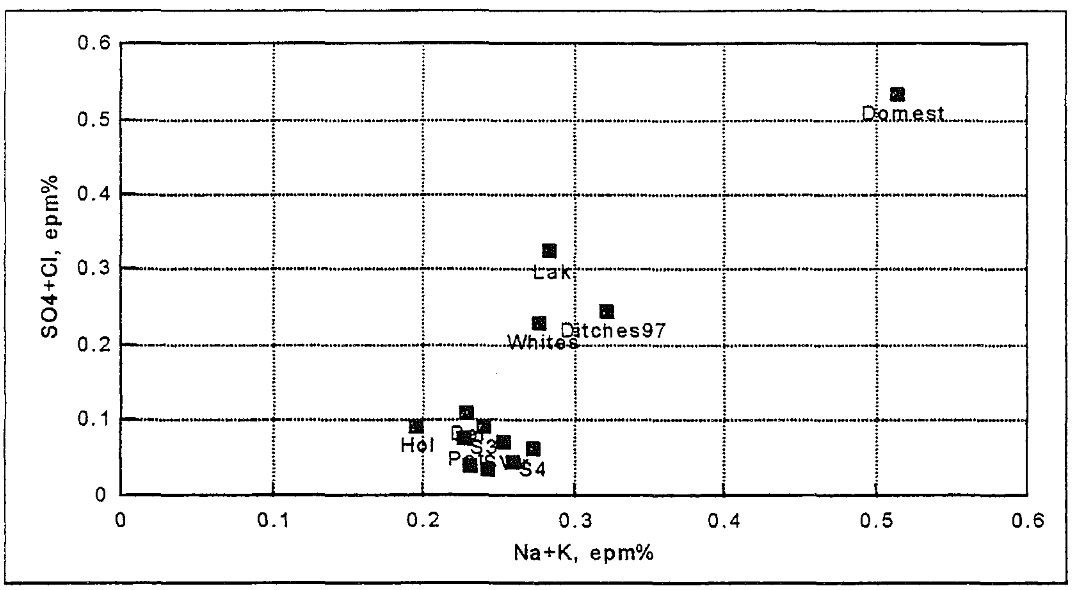


Figure 1. Average chemical composition of STM ground and surface waters (piper diagram).

4 Impacts of urbanization

4.1 Shallow ground water chemistry changes since 1970

In Figure 2, domestic well water samples are plotted on piper diagrams (this is only the central portion of a piper diagram). The data were classified into time groups:

a. before 1982
b. 1983 to 1987
c. 1988 to 1994
d. 1995 to 1996

In Figure 2 the early domestic well waters (1979 to 1982) plot close to the municipal wells. Gradually since 1982 water composition at many (not all) sampling locations has changed, although most samples are still plotting near the initial position (near the municipal wells). This results in many of the plotting positions "migrating" away from the original water composition, thereby covering all ranges on these diagrams.

Evidently since 1982 water composition in the shallow aquifer (at least the portion tapped into by domestic wells) has gradually changed. This maybe due to due to urbanization, while the deeper municipal wells' water composition has remained largely the same.

What does this mean? It can be argued that domestic wells to a large extent pump water that has been recycled from leachfields. That same water goes through the household again and is recycled again into the shallow aquifer. Hence the chemical composition of the shallow aquifer is gradually changed from a well defined chemical composition (of limited range) to a greater variety of water compositions. All this happens while a great portion of this water is mixed with natural ground water flow from the west.

Later in this report it will be shown that the TDS levels of the shallow aquifer also fluctuate seasonally due to irrigation and streamflow infiltration, while the ion ratios are apparently affected by urbanization.

4.2 Distribution of chemical composition with depth

In Figures 3 and 4 well depth was plotted versus average TDS, chloride, bicarbonate and nitrate for municipal wells and domestic wells. TDS and chloride are highest in the shallow wells. A similar pattern is evident for sulfate (not plotted). Bicarbonate trends with depth are less obvious, but here too the highest values are in the shallow wells. In summary all the trends tend to be directed towards the average domestic wells' composition in the upper right hand corner.

(These plots were also tried with average screen depth and other well construction data from the municipal wells. Still well depth shows these trends best.)

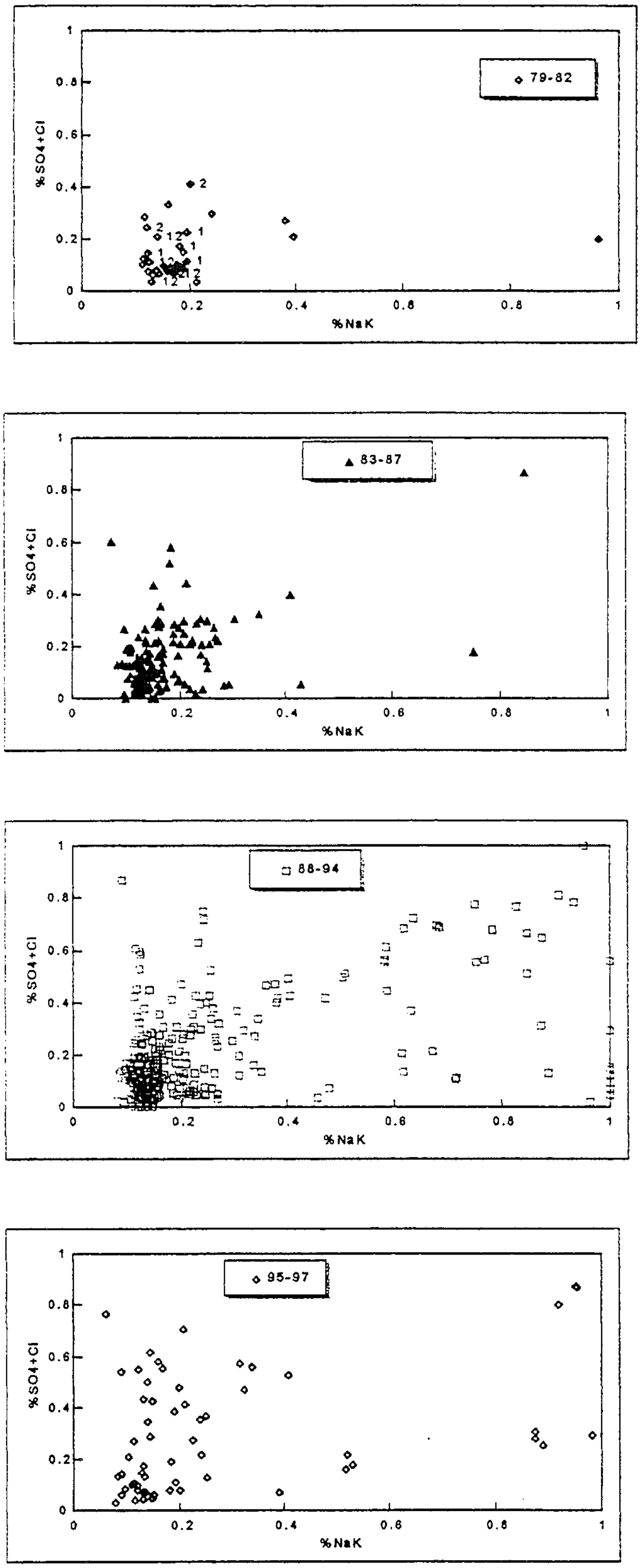


Figure 2. Domestic well waters from the STM area, for the periods 1979-82, 1983-87, 1988-94 and 1995-97, showing the impacts of urbanization on the shallow ground water system

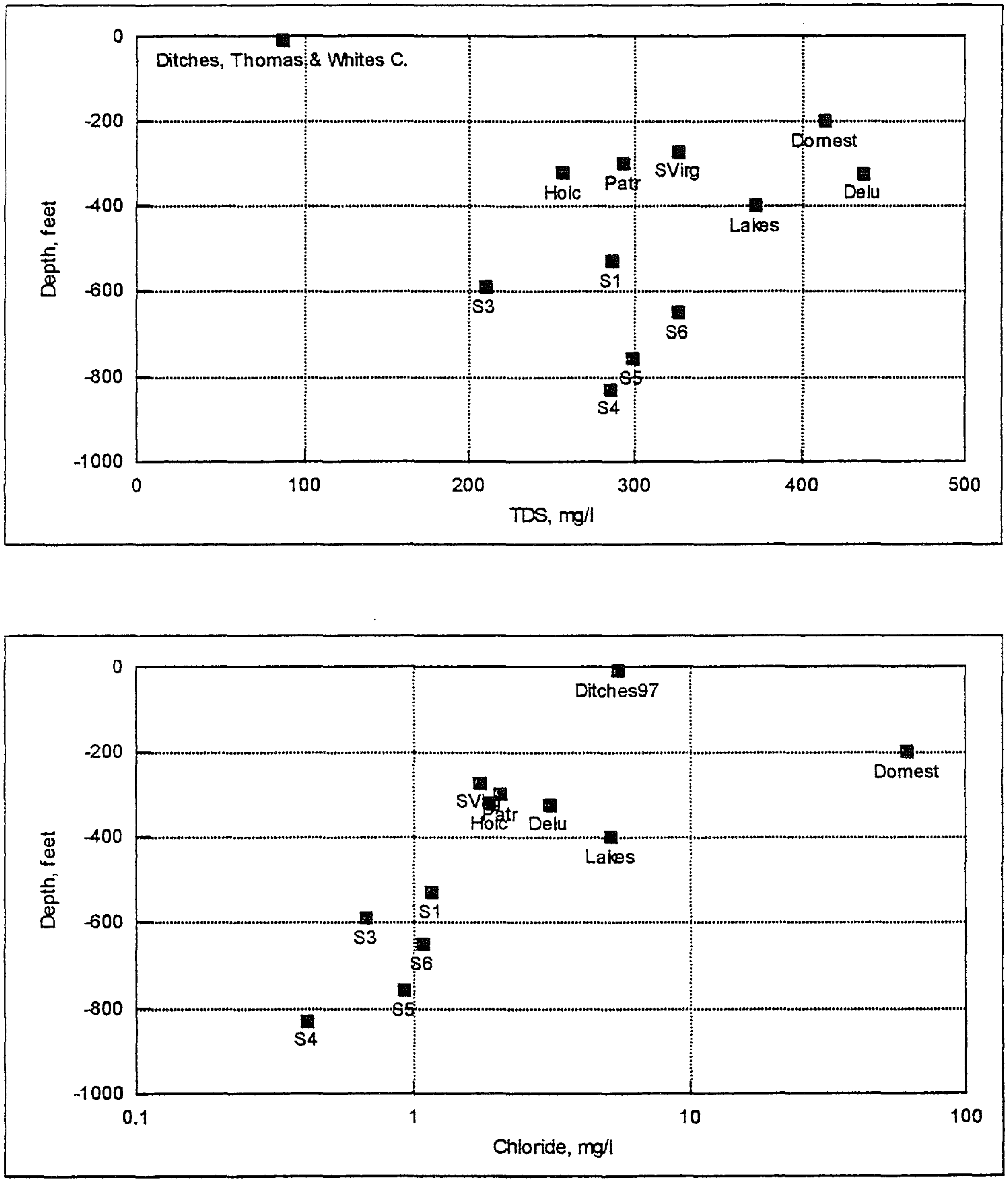
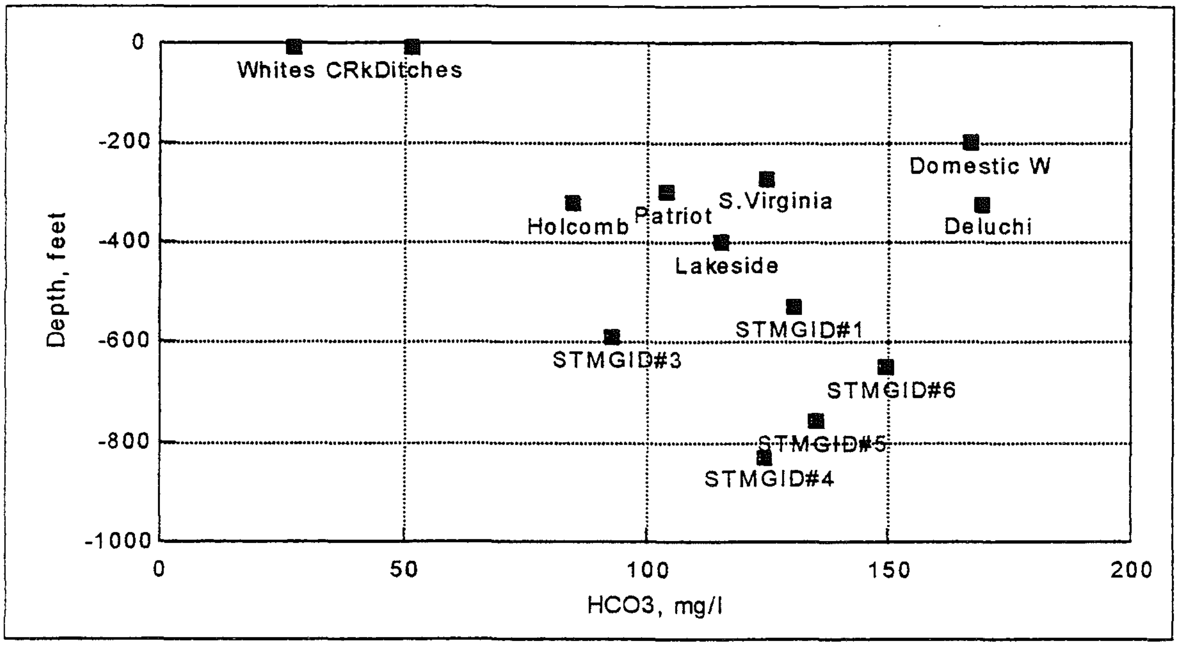


Figure 3. Average TDS and chloride levels in municipal and domestic wells, STM area. Note the changes with depth. See text for explanation.



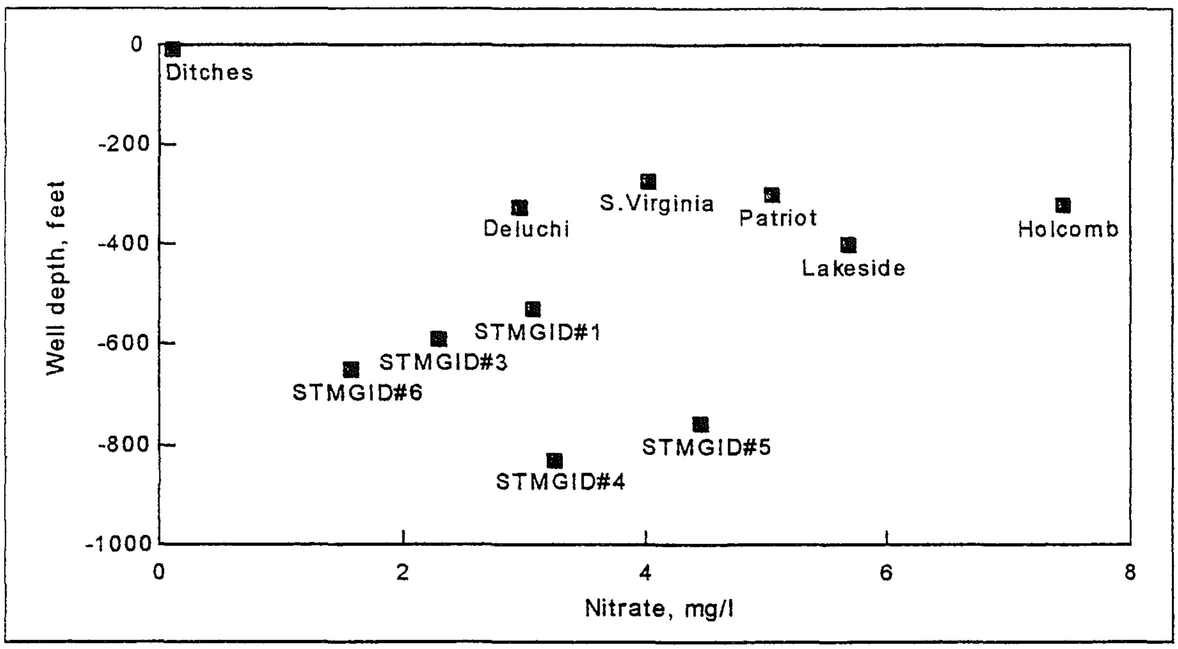


Figure 4. Average bicarbonate and nitrate levels in municipal and domestic wells. Note the changes with depth. See text for explanation.

Obviously aquifer chemistry is not homogeneous with depth. It is peculiar that the domestic well averages always plot at the upper end of these trends, well in line with the larger trend. This may suggest that indeed chemical heterogeneity is induced from the shallow sub-surface, in the form of increased TDS, chloride, sulfate, bicarbonate and nitrate. The fact that nitrate mimics these trends lends support to the hypothesis that urbanization maybe a significant contributor to high TDS levels in the shallow aquifer.

Since the irrigation ditches and streams plot in the upper left hand corner, evidently these changes are not induced from the surface waters. Indeed the contrasts between surface waters and the shallow ground waters are large, which suggests that increases of chemical constituents in the shallow aquifer is not determined by surface waters, but rather by urbanization (septic systems and urban runoff). Fortunately the contrasts also lend themselves well to identify mixing trends as a result of surface water infiltration.

5 Secondary Recharge evidenced in seasonal and long term trends in ground water chemistry

5.1 How much secondary recharge enters the aquifer?

The average annual diversions of water from the three ditches, Steamboat, Last Chance, and Lake Ditch, before 1984 was about 60,000 ac-ft per year. Since 1984 these irrigation flows have been drastically reduced by about 60%, to an average of 25,000 ac-ft per year. Naturally not all of this water is used. With the existing records one is not able to tell how much of this water was applied and how much is applied currently. Presumably a great deal of this water may stay in the ditches or flow across the fields and return via surface runoff into the ditches. Any water left in the ditches is eventually discharged into Steamboat Creek.

Knowing how much water enters the ditches, and knowing how much leaves the ditches, one can estimate how much water enters the ground water system (after evapotranspiration). Unfortunately no numbers are available on how much water enters Steamboat Creek. Therefore alternate methods need to be developed to determine irrigation ditch return flows into ground water.

Fortunately TDS levels in irrigation ditch water are less than 100 mg/l, whereas the underlying aquifer in the area of concern has TDS levels ranging from 200 to 400 mg/l. Given these differences, mixing of low TDS irrigation water with ground water that has at least twice as much TDS should become noticeable in the shallow wells. It will be shown that this has been very useful to identify seasonal secondary recharge into the aquifer. It can also be used to identify stream infiltration.

5.2 Municipal wells: TDS and nitrate

Changes in nitrate and TDS provide a useful means of identifying particular aquifer geochemistry. Nitrate is assumed to be an indicator of urbanization impact, whereas changes in TDS are assumed to be caused by changing impacts from irrigation. The magnitude of both causes has changed, and thereby provides a useful signal in the aquifer chemistry over time.

Evidently TDS and nitrate in the STMGID wells suggest different processes than in the Virginia Street Wells. Notably these two groups of wells typify two different aquifer conditions:

1. The STMGID wells are further up on the Mt. Rose Fan, with static water levels more than 100 ft below land surface.
2. The Virginia Street Wells are farther down along the alluvial fan, with static water levels between 10 and 70 ft below land surface.

5.2.1 TDS and nitrate changes in the Virginia Street Wells

The longest complete record of water chemistry data is available from the Deluchi and South Virginia Wells (both municipal), reaching back to 1971. In Figure 5, historical TDS and nitrate levels in these two wells were plotted versus time of sampling, together with annual irrigation ditch water supply and annual pumpage. (Similar plots were prepared for the other eight municipal wells, and the diagrams are included in the Appendix.)

TDS levels fluctuate from year to year, in part due to seasonal fluctuations. Despite the significant scatter, a gradual upward trend is evident in both wells. Since 1971 average TDS levels in both wells have increased by about 50 mg/l. The trends over a time period of 25 years are difficult to ignore, although the data noise is significant.

Irrigation ditch flows have decreased by about 60% from 1984 to 1987. It is about at this time when TDS in the wells began to increase convincingly. The correlation between irrigation ditch flow and TDS in wells is supported in the early 1990's when ditch flow diminished from about 25,000 ac-ft per year down to less than 15,000 ac-ft per year. At the same time TDS levels in the wells increased markedly, and decreased as soon as flows were increased to normal. Similar patterns occurred earlier in the record, before 1984, although not as convincingly.

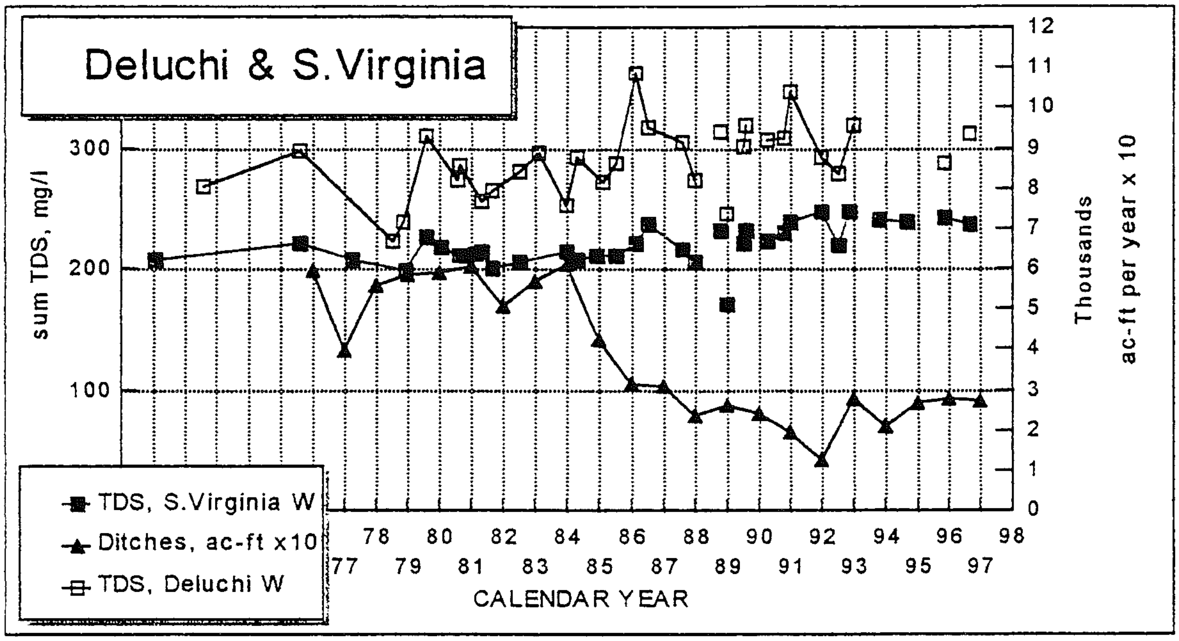
Similar, though less obvious patterns can be recognized in the Lakeside and Holcomb Wells (see Appendix of this report).

Nitrate changes in these wells are different. In Figure 5 nitrate was plotted against time, together with irrigation flow and pumping rate, only for the Deluchi Well. Between 1972 and 1991 nitrate increased from 2 to 8 mg/l, and decreased thereafter back to about 2 mg/l in 1993. Pumping rate doubled from 1983 to 1989, only to diminish to almost nothing in 1994. Although both show significant variability, it is clear that pumping rate and nitrate correlate.

The data from the South Virginia, Lakeside and Holcomb Wells are less obvious, yet, after recognizing the pattern in the Deluchi Well, a similar interpretation is reasonable for these wells too.

5.2.2 TDS and nitrate changes in the STMGID Wells

In Figure 6 the historical TDS for STMGID No. 1 were plotted, together with total ditch flow. This well is located east of Steamboat Ditch and is likely affected by irrigation return flows. Similar as in the Virginia Street wells, here too TDS increased steadily since 1987. Unfortunately no TDS data are available for the time before 1984. Interestingly, the 19991/92 TDS levels did not respond to the dramatic flow reduction in those years. This may suggest that secondary recharge is more efficient at the STMGID No.1 well location.



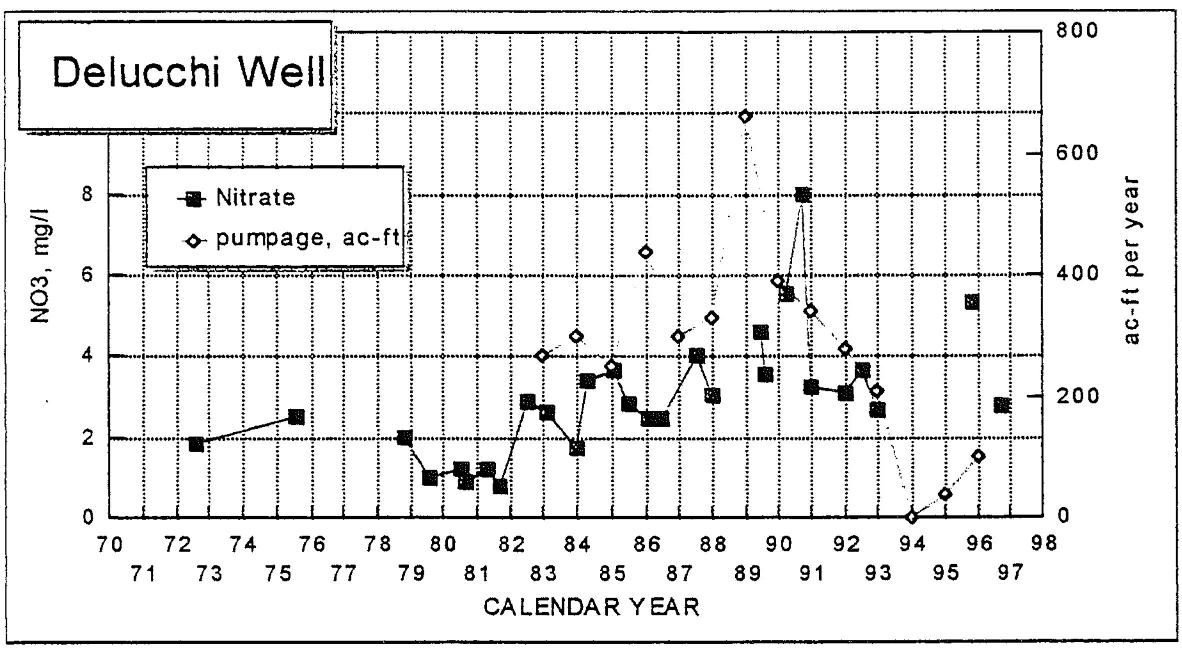
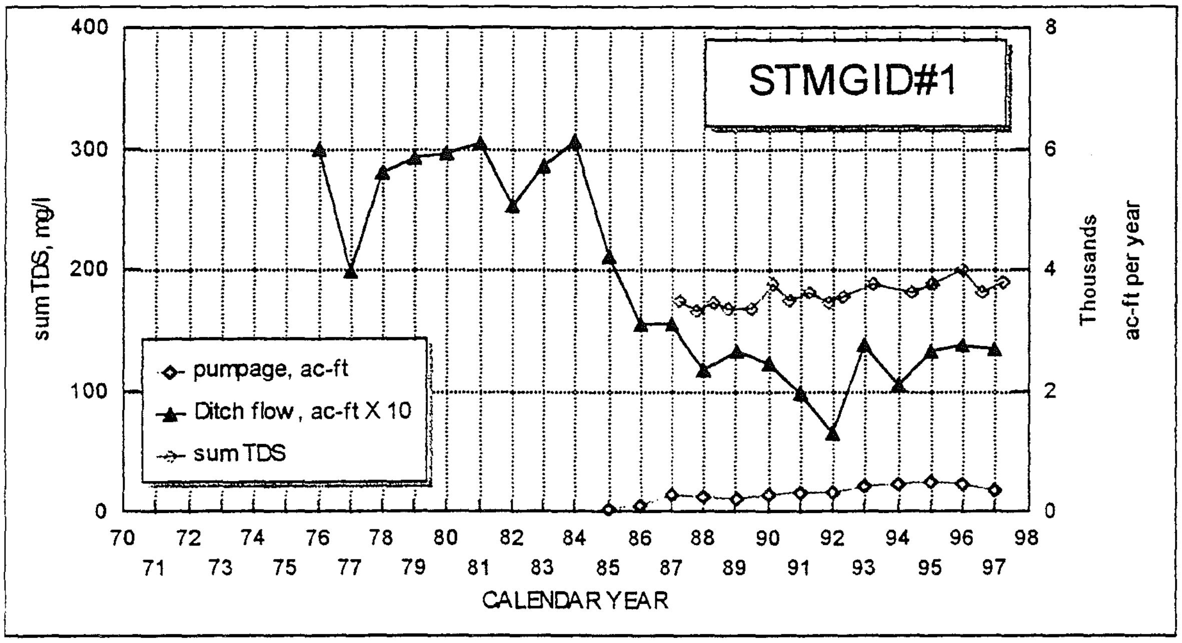


Figure 5. South Virginia and Deluchi Municipal Wells, historical changes in TDS and nitrate with ditch supply flow and pumpage. STM area.



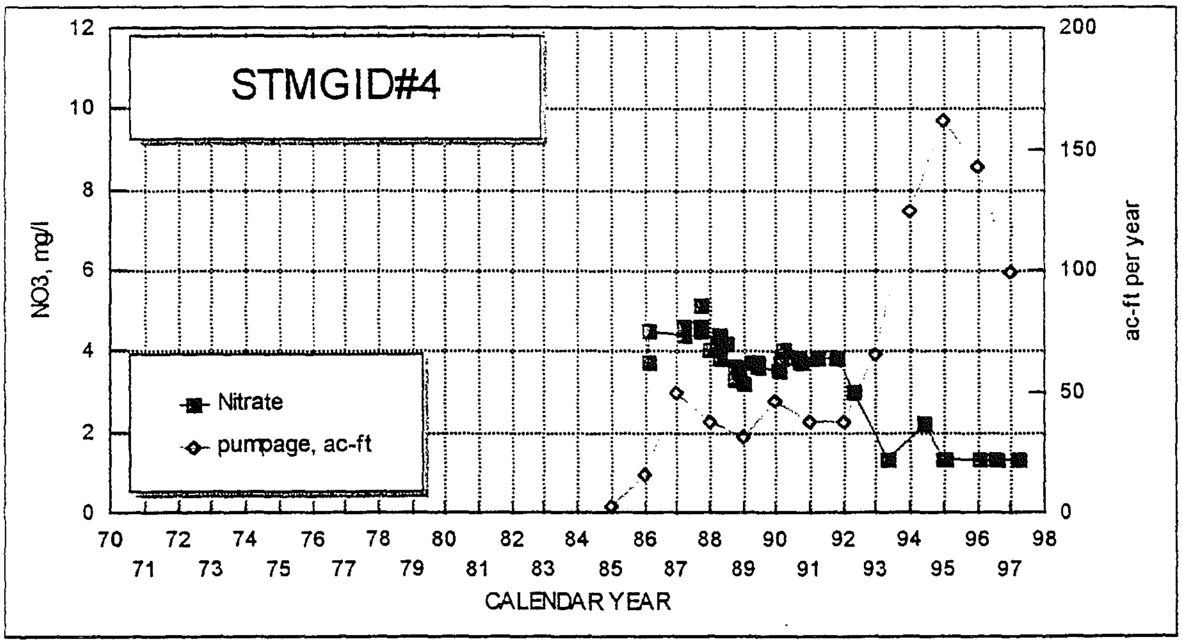


Figure 6. STMGID No. 1 and 4 Wells, historical changes in TDS and nitrate with ditch supply flow and pumpage. STM area.

before 1984. Interestingly, the 19991/92 TDS levels did not respond to the dramatic flow reduction in those years. This may suggest that secondary recharge is more efficient at the STMGID No.1 well location.

In contrast, the STMGID wells located west of Steamboat Ditch do not show TDS increases since the mid 1980's. This substantiates the hypothesis that secondary recharge is indeed the cause of changing TDS in ground water. In other words, ditch losses, and/or secondary recharge in ground water is substantial.

Different than in the South Virginia Street wells, nitrate decreases with pumping rate. The most dramatic example, STMGID No. 4 is also plotted in Figure 6. Here, as a result of pumping, nitrate has diminished from about 4 mg/l to about 1.5 mg/l. Similar patterns, though less dramatic, can be observed in the other STMGID wells (see the Appendix).

5.2.3 What do the TDS and nitrate changes mean?

Clearly, all the deep wells east of the irrigation ditches are affected by secondary recharge and/or ditch losses. Moreover, the wells reflect the changing application volumes of irrigation flow provided by the ditches. No immediate data are available that can tell how much ditch water is actually applied each year. However, the ground water flow system's evident response to a reduction in flow by about two-thirds suggests that the change in supply may have resulted in a change in application rate. It may also be an indication of a change in total ditch loss volume. Or it may indicate both.

It is noteworthy that the nitrate levels respond to pumping different in the STMGID wells than in the Virginia Street wells. Apparently increased pumping in the Virginia Street area draws in increasingly water that has been affected by urbanization, whereas in the STMGID wells it is the other way round.

Where do the STMGID wells draw "cleaner" water from? The pattern of decreasing nitrate with increasing pumping rate occurs independently of where the STMGID wells are located, i.e. whether a well is affected by irrigation or not. There are two possibilities:

1. Due to more water drawn in from greater depth, i.e. water that is less affected by domestic wastewater return flows.
2. Depending on the magnitude of pumping drawdowns in these wells, it could also mean that nitrate may still be "catching up" with decreasing water levels in the cone of depression, migrating through the unsaturated zone.

5.3 Secondary recharge in municipal wells based on mixing calculations

Assuming that the lowest ditch flow in 1991/92 resulted in ground water TDS levels that can be regarded as "ambient ground water TDS", one can back-calculate the fraction of flow produced in each well that was derived from irrigation water supplied by the ditches. The data that are necessary for this type of calculation have to be a relatively continuous record over several years, from one single well, reaching back to before 1984. Among the available municipal well data records there are only three wells suited for this type of calculation, i.e. the STMGID No. 1, Deluchi, South Virginia, and Lakeside Wells.

The mixing formula used here is:

$$C_m = C_g \times (1-V) + C_d \times V,$$

where

C_m is the TDS level in ground water as a result of high irrigation applications. This would be the TDS before 1984.

C_g is the concentration in ground water during the time of least application in 1991/92;

C_d is the TDS level in the ditches, here assumed to be 87 mg/l, as measured in the fall of 1997;

V is the volume fraction (less than 1.0) of ditch water pumped by the respective well.

Fraction of ditch water in the municipal well water pumped is then calculated after rearranging the above equation to:

$$V = (C_m - C_g)/(C_d - C_g)$$

Not all well data are suited for these calculations. But the volume fractions calculated for some of these wells are comparable:

Well	Volume fraction ditch water pumped in 1979	Volume fraction ditch water pumped in 1987/88	Volume fraction ditch water pumped in 1996
STMGID No. 1	no data	18%	no data
Deluchi Well	19% to 34%		19%
Lakeside Well	30%		9%
South Virginia Well	28%		9%

Since the TDS levels in these wells are still rising, these results are conservative estimates, i.e. the pre-1984 fractions of irrigation water pumped are probably higher. Furthermore, as long as irrigation is still affecting ground water TDS, it will not be possible to estimate the actual amount of secondary recharge in the aquifer.

What is important about these observations is that the amount of irrigation water in ground water is substantial. More so:

1. Before 1884 the amount of irrigation water in the aquifer may have been at least (or exceeded) 30%.
2. Since 1984 the amount of irrigation water in the aquifer has been reduced by about 60%.

Further discussion of the seasonal TDS changes determined with the domestic well data will shed further light onto this issue.

5.3 Domestic wells: TDS and nitrate

Using the regular TDS fluctuations in the domestic wells from month to month one can identify the impact of stream flow and irrigation on the underlying aquifer. The data were sorted according to Township, Range, Section number and month of sampling. Then for each section number the monthly moving averages of TDS were calculated for the entire data base, averaging 5 TDS values together at a time (without moving averages the patterns would be very poorly distinguished, i.e. "shotgun patterns").

For each section, the moving averages of TDS were then plotted on the vertical axis, against sampling month on the horizontal axis. The results are impressive, despite the large aerial variability from one section to another. In most sections that are in the proximity of streams, or that are east of at least one of the irrigation ditches, cyclical patterns can be readily discerned. The bands of variance are in some sections well defined, and in others they are wider. Nevertheless the patterns are undeniably there, and after identifying two major signals, one can identify the relative magnitude of mixing from surface water with ground water.

5.3.1 Annual cyclical patterns of TDS in each section

Undoubtedly the TDS hydrographs from the domestic well data show annual cyclical patterns. This has several implications about the aquifer recharge and flow conditions in the western portion of the South Truckee Meadows area:

1. The ground water chemistry has adjusted to a new dynamic equilibrium, the result of the cumulative average of historical mixing between ambient ground water flow, streamflow and secondary recharge.
2. Water chemistry reverts back to its initial conditions, after each year's dilution cycle. If this was not so, the cyclical pattern would be a gradual TDS decrease in each section.
3. This also implies that ambient ground water flow is by far greater than the added streamflow and irrigation components combined.

5.3.1.1 Identification of secondary recharge in TDS hydrographs

Any low TDS flow entering the aquifer is signaled by the first marked reduction of TDS on a hydrograph. To distinguish streamflow from secondary recharge, the following rationale was used:

1. Streamflow records from Thomas and Whites Creek (plots in Appendix) suggest that streamflow begins to increase after September, and decrease after June each year:
   a. The fall and winter flows from September through February are practically constant.
   b. From February through April monthly streamflow increases slightly from 100 to 150 and 120 to 200 cfs, for Thomas and Whites Creek, respectively.
   c. Peak runoff is during the months of May and June July, increasing to 230 and 530 cfs, for Thomas and Whites Creek, respectively.

d. By August runoff is back to baseflow conditions, i.e. 100 and 200 cfs for Thomas and Whites Creeks, respectively.

2. Irrigation flows are reportedly provided from June through September.

Based on the above observations, if the aquifer is affected by either streamflow and/or irrigation return flows, then one would expect two distinct signals in the domestic wells TDS hydrographs:

a. The first signal arriving in late winter or spring, from streamflow infiltration.

b. The second signal arriving in the summer months, not before June and lasting into early winter.

Using the highest TDS level before the advent of the irrigation signal, one can assume a background ground water TDS that is diluted by secondary recharge thereafter. The amount of secondary recharge can then be calculated, by assuming a certain amount of ground water flow in that section (the details and further assumptions for these calculations are outlined below).

A similar approach can be used to calculate the streamflow contribution from channel losses (losing streamflow conditions).

5.3.1.2 Seasonal TDS patterns in ground water

The TDS cycles were plotted on separate diagrams, for each section. To make the patterns more understandable for visual analysis, they were arranged in rows, beginning from the northernmost first row of sections in T18R20 and T18R19. The diagrams were arranged in the sequence of sections from east to west, following the arrangement of sections on the map (see Figure 7). Altogether there are six rows of sections, going from east to west across Virginia Street, and further west across the ditches, and on to the Carson Range. Thereby one can discern the gradual increasing impact of secondary recharge east of the ditches. This approach also very dramatically identifies the change from areas east of the ditches to those west of the ditches.

To demonstrate to the reader how irrigation and streamflow infiltration signals are identified, the diagrams derived from the TDS data in sections 13 and 18 are explained. These diagrams, depicted in Figure 8, were selected due to their particularly well defined patterns. As can be seen in the Appendix, many of the other sections have patterns that are less well defined. Nevertheless regular patterns are evident in almost all of these diagrams.

Section 13 is located in an area with shallow soils and bedrock close to the surface. The beginning irrigation signal is evident in June when TDS levels start to decline from almost 300 mg/l down to about 170 mg/l in October. Evidently, since this area is located atop shallow bedrock, secondary recharge arrives rather rapidly. Secondary Recharge lasts until October, when TDS levels are at their lowest. That is the point when secondary recharge into the aquifer is assumed to cease in this section.

In section 18 the situation is different. Section 18 is located in an area with deep soils, i.e. in alluvium. Here the irrigation signal does not arrive until after September or October. The TDS decline of only about 50 mg/l is, however, much less than in section 13. Also it lasts only until January. The streamflow signal begins after February and lasts until May.

The magnitude of TDS level change is only about 50 mg/l in section 18, compared to about 100 mg/l in section 13. This results in an secondary recharge estimate in section 13 much higher than in section 18.

5.3.2 Seasonal nitrate patterns in ground water

Given the gradual decrease of nitrate and increase of TDS with depth (observed earlier), it seems as if most of the seasonal flow changes occur only in the shallow aquifer. In Figure 9 the nitrate cycles are somewhat different than the TDS cycles. Evidently nitrate changes also follow a cyclical pattern. The highest concentrations occur in the Spring and in the Fall.

The keys to understanding the nitrate cycles are in realizing the two sources of water either increasing or diluting aquifer nitrate:

1. Background nitrate is maintained by a balance between year-round septic leachfield contributions and ambient ground water flow.
2. Late winter infiltration and flood irrigation (and maybe lawn irrigation) percolate through the soil, carrying elevated nitrate into the aquifer.
3. Nitrate decreases are the result of stream channel infiltration diluting nitrate in the aquifer; Stream channel infiltration does not pick up soil nitrate.

This conceptual model can be applied to both sections 13 and 18.

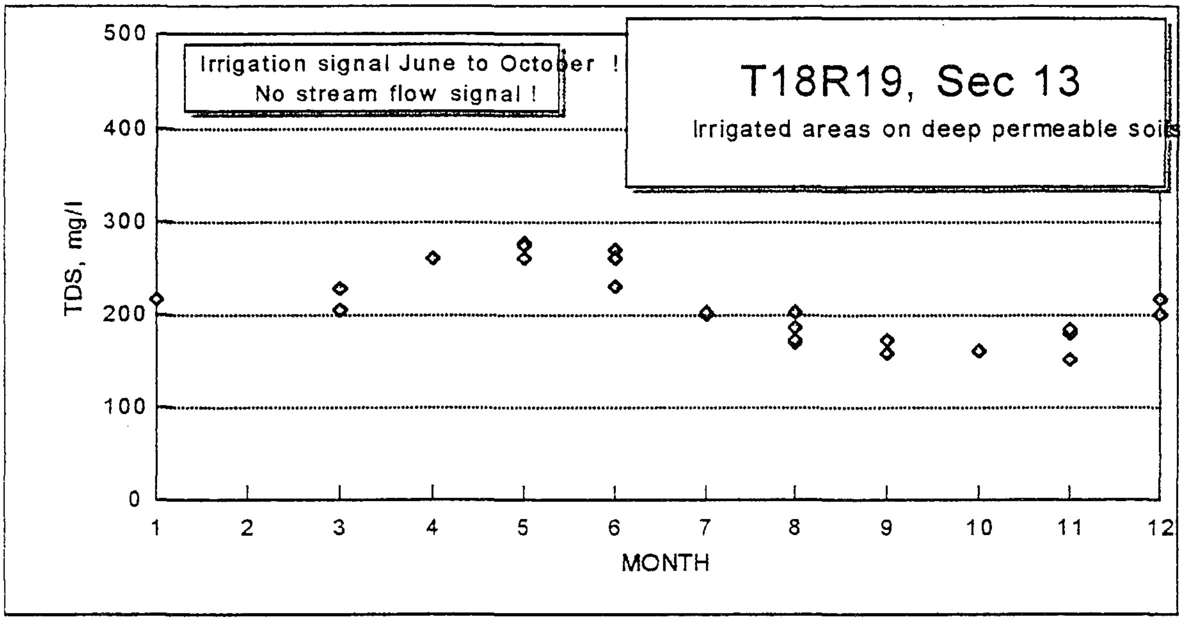
In section 13 nitrate peaks in March and October/November. The March peak is due to spring infiltration from precipitation, carrying soil nitrate into ground water. Once stream channel infiltration affects the aquifer, nitrate levels diminish from 5 mg/l to about 3 mg/l in June. Once streamflow decreases, nitrate levels increase again. At the same secondary recharge begins to flush soil nitrate into the shallow aquifer, acting similar as late winter infiltration. By the time streamflow starts to increase again in December, nitrate decreases again as a result of channel infiltration and dilution in the aquifer.

The March nitrate peaks in section 18 are the result of late winter infiltration of precipitation. However, once stream-channel infiltration sets in nitrate decreases again (after March). Once streamflow diminishes in late summer (after June), nitrate levels again increase, in part due to decreasing dilution and due to increased soil nitrate flushed into the aquifer from secondary recharge.

These explanations should be verified with other data. Yet one fact is certain: the cyclical nitrate patterns are distinct, and are thereby likely due to some seasonal hydrologic event or another. Should it become necessary to further look into this matter, isotope sampling might be a useful method to be applied.

T18R19				T18R20	
4 FIRST ROW	3	2	1	6	5
9 SECOND ROW	10	11	12	7	8
16 THIRD ROW	15	14	13 Figures 8 and 9	18 Figures 8 and 9	17
23 FOURTH ROW	24	25	24	19	20
28 FIFTH ROW	27	26	25	30	29
33 SIXTH ROW	34	35	36	31	32

Figure 7. Sections in the STM area where changes in ground water TDS were depicted in TDS hydrographs (see appendix). Sections in the project area for which secondary recharge was calculated are shown shaded. TDS hydrographs shown in Figures 8 and 9 are indicated by darker shading.



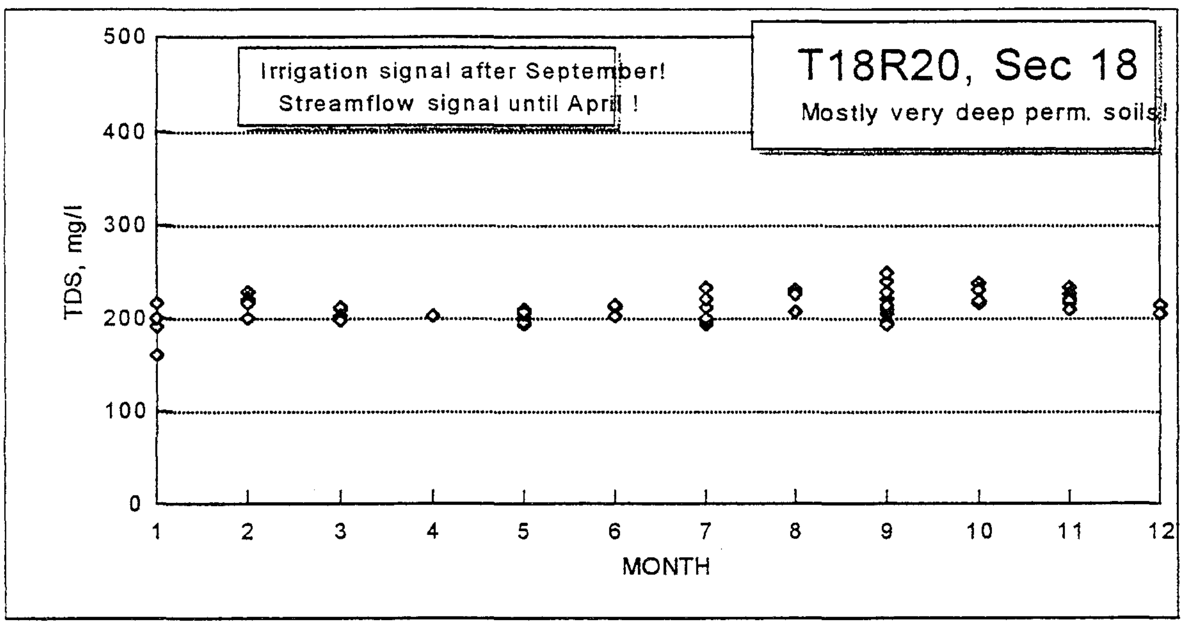
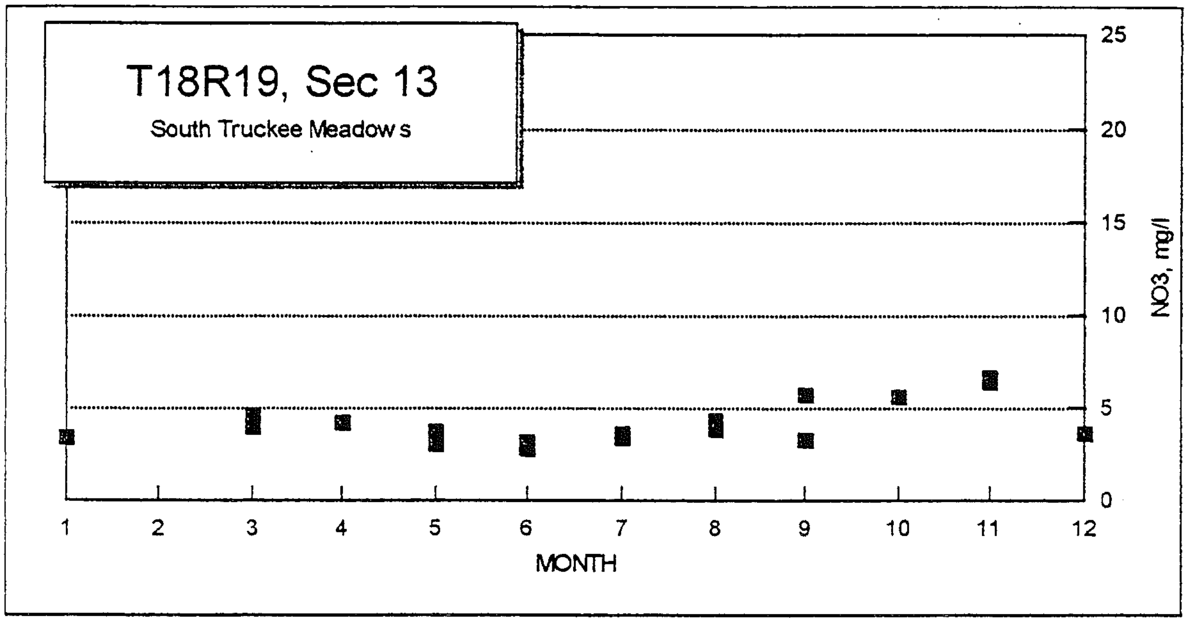


Figure 8. Ground water recharge patterns in Sections 13 and 18, STM area. Section 18 is located down-gradient from Section 13 and thereby carries more diluted water. Consequently the impact of low TDS water is less dramatic.



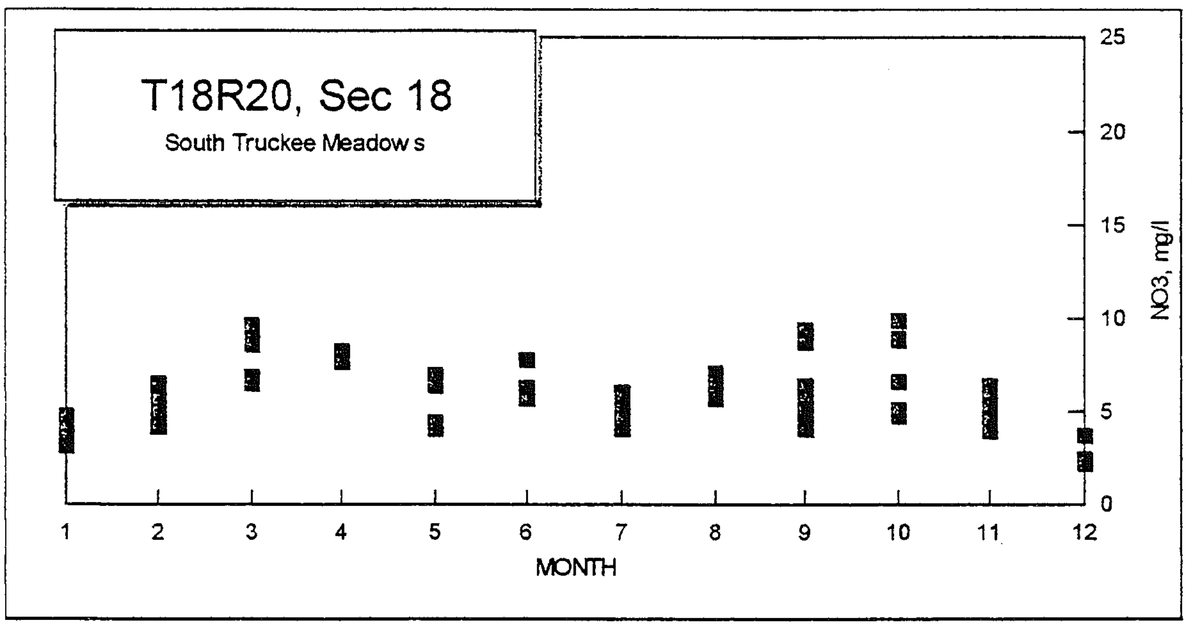


Figure 9. Nitrate changes in sections 13 and 18, STM area. In section 13 nitrate peaks in March and October/November. The March peak is due to spring infiltration from precipitation, carrying soil nitrate into ground water. Once stream channel infiltration affects the aquifer, nitrate levels diminish from 5 mg/l to about 3 mg/l in June. Once streamflow decreases, nitrate levels increase again. At the same secondary recharge begins to flush soil nitrate into the shallow aquifer, acting similar as late winter infiltration. By the time streamflow starts to increase again in December, nitrate decreases again as a result of channel infiltration and dilution in the aquifer.

5.3.3 Secondary ground water recharge based on TDS changes

The following discussion pertains to summarizing observations about TDS and nitrate cycles in each section of the STM area. The TDS cycles help to understand aerial distribution of ground water recharge and secondary recharge patterns. The nitrate cycles help identify the impacts of urbanization on the shallow aquifer.

The discussion is organized by following each row of sections, in a sequence from east to west, beginning with the northernmost row in T18R20 and T18R19. For technical review, the total of all 36 diagrams are included in the Appendix.

When reading this section it is beneficial to study the diagrams one by one, together with a topographic location map of the STM area. Both TDS and nitrate diagrams contain a wealth of information that has to be interpreted in context with what activities we know are occurring in each section.

First Row: Sections 6 through 5:

The secondary recharge signal begins in August, and lasts until October or November. That means the signal lags one to two months behind the advent of the irrigation season. The streamflow signal begins after February.

Sections 3 through 5 are located west of the irrigated areas, and consequently do not show an irrigation signal (the plotting labels are section numbers). No streamflow signal can be discerned.

Second Row: Sections 7 through 10.

The irrigation signal begins in or after July and lasts until October, when TDS starts to increase again. No streamflow signal is evident in section 7, although Thomas Creek would be expected to affect ground water. In section 12 streamflow signal begins late, i.e. in March (Dry Creek and tributaries). In section 11 (upgrading of 12) the streamflow signal arrives even later, in May.

No streamflow signal can be identified in the sections west of section 11.

Third Row: Sections 17 through 14:

Section 17 is located on Virginia Street. In sections 17 and 18 the irrigation signal does not arrive until October, which is much later than in the section 13 to the west. In section 13 the irrigation signal arrives in June, shortly after the advent of the irrigation season. As discussed earlier, this is due to the shallow soils covering fractured bedrock which allows rapid percolation of secondary recharge into the aquifer.

In section 17 two streamflow signals are evident: one beginning in February and one beginning in July. Both signals are separated by distinct high TDS peaks. The early signal is most likely from White's Creek. The second signal can not be linked to any stream, though a lag from the more distant Thomas Creek may be a possibility.

Again no streamflow signals are evident in the sections west of the ditches.

Fourth Row: Sections 21 through 24

Section 21 is located east of Virginia Street with no irrigated areas. This was included for comparison about what happens further east. Section 21 clearly shows no irrigation signal, yet nitrate clearly shows impact of urbanization.

The patterns in section 20 are confusing and scattered. Although a large portion of this section has agricultural areas, in this section irrigation was apparently phased out after 1990. This is indicated when plotting TDS for each year (Figure 10), and should be cross-checked with historical information. The TDS hydrograph suggests a dramatic increase of TDS from about 250 to 420 mg/l between 1989 and 1991.

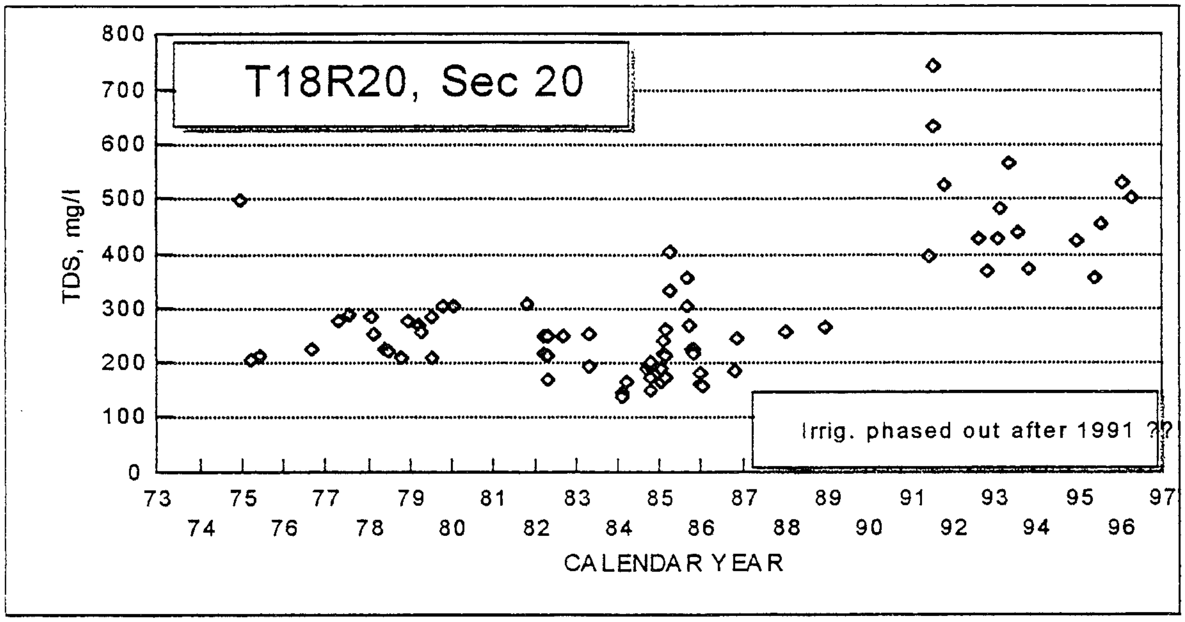


Figure 10. Domestic wells in section 20 of T18R20, STM area, Washoe County

Also, after 1984 TDS in the aquifer increased (from 140 mg/l in January 1984 to 400 mg/l in Spring 1985), apparently in response to irrigation cutbacks dictated by the 1984 State Engineer's decree. Yet, shortly thereafter TDS went back to the previous levels, suggesting continuance of the previous irrigation practices.

Interestingly, Nitrate is the lowest in the spring, apparently when channel losses from streamflow are the highest. Yet nitrate is the highest in the late summer (September) apparently when irrigation flushes soil nitrate into the aquifer.

These diagrams hint at whether nitrate can also be used to estimate irrigation return flow, and whether the spring TDS lows can be used to estimate streamflow contributions to ground water flow.

In Sec 19 of T18R20 no irrigated areas are located. Extremely low TDS (between 130 and 160 mg/l) in ground water is probably affected by year round presence of Thomas and Whites Creek.

Fifth and sixth Rows: T18R19, Sec 24 & 25

None of this area is irrigated but ground water is affected by Thomas Creek in the spring and early summer months. TDS ranges from less than 100 mg/l (in the summer) to more than 200 mg/l later in the year. Apparently a second dilution pulse occurs in the fall, the reason is not understood.

The sections of T18R20, Sec 21 - 24 and T18R20, Sec 25 - 30 are discussed as one unit. When viewed from east to west, i.e. in sequence of increasing section number the impacts of geothermal waters are readily visible in the east. Geothermal waters increase ground water TDS up to more than 2500 mg/l in section 23. The further west one moves from section 26 the more dilute the waters become, decreasing from 2000 mg/l to an average of 1200 mg/l in section 27, 800 mg/l in section 28, 500 in section 29, and 250 mg/l in section 30.

The impact of Steamboat Creek is visible in section 27. As expected, section 30 is impacted by Whites Creek.

5.3.4 Method of calculating secondary recharge section by section

The cyclical patterns observed in the TDS hydrographs are the result of mixing between ambient ground water and secondary recharge. Thereby it has to be understood that the "ambient" ground water TDS has been affected by previous years' mixing. In fact this maybe considered a chemical steady state situation, after about 100 years of irrigation (or at least since 1984, when irrigation flows were reduced by 2/3).

The volume of irrigation water applied in each section can be estimated by using a mixing equation. The results of these calculations are shown in Table 2 below, including the results for all 9 sections where an irrigation signal can be identified. The calculations are explained as follows.

5.3.4.1 Mixing equation

The volume of irrigation water applied in each section can be estimated with the following mixing equation:

$$C_m \times (Q_g+Q_i) = (C_g \times Q_g + C_i \times Q_i)$$

where

- C_m is the mixture concentration, i.e. the lowest TDS observed in an annual cycle;
- C_g is the TDS level in ground water, i.e. the highest TDS observed in an annual cycle;
- Q_g is the ground water flow estimated through that section, based on Darcy's law (see below);
- C_i is the TDS level in the ditch water, assumed here to be 87 mg/l (based on September 1997 data);
- Q_i is the estimated annual secondary recharge (and ditch loss) contributed to ground water.

The above equation is rearranged to solve for Q_d, the secondary recharge component.

5.3.4.2 Estimated aquifer ground water flow

The amount of ground water flow, Q_g, receiving secondary recharge has to be estimated. Estimated ground water flow through the STM area is about 5000 ac-ft per year. However, due to partial penetration, actual ground water flow affecting the shallow wells is much less. This can be estimated by using the average transmissivity derived from shallow domestic well records, which is multiplied by the average gradient and the width for each section. The ground water flow is then calculated for each section, by using a modified form of Darcy's law equation:

$$Q_g = T \times i \times w$$

where: Q_g is the average flow through a particular section;

T is the transmissivity derived from specific capacity data;

w is the width of the section perpendicular to the direction of ground water flow.

The transmissivity can be derived from the well data:

$$T = \text{Specific Capacity} \times C$$

A limited amount of well data are available from domestic well records. Using short term pumping test data, specific capacities can be calculated.

The factor "C" is according to Theis (1936) a value of 2000. However, due to other considerations explained below, this factor had to be modified for the purpose of this study.

5.3.4.3 Mixing calculations: Irrigation and ditch losses

The mixing calculations were conducted by means of a spreadsheet. The spreadsheet results included in the appendix, can be used to review the input variables used for these calculations.

It is believed that due to evapotranspiration, the concentration of secondary recharge water is somewhat higher than irrigation ditch water. Unfortunately the actual TDS of secondary recharge that mixes with ground water is not known. However, it is certain that the secondary recharge TDS can not be higher than the minimum TDS in each TDS hydrograph, i.e. it must be somewhat lower.

Using the ditch water TDS of 87 mg/l as C_i, and dividing it by the minimum irrigation season TDS (C_m) in each section, one can estimate the minimum possible percentage of irrigation return flow in that section. Since it is unreasonable to assume that the mixture TDS will be the same as the secondary recharge TDS (otherwise it would imply an infinite mixing ratio). For the purpose of these calculations the maximum secondary recharge TDS was assumed to be 95% of the mixing TDS. For example in section 13, the lowest average TDS irrigation season TDS is 160 mg/l. The percentage of secondary recharge in the domestic wells can then calculated by:

$$87 \times 100/(160 \times 0.95) = 57\%.$$

Similar values were calculated for all other sections (column 4 in Table 2). Needless to say, if one uses a factor less than 0.95 one may derive higher recharge rates. If, on the other hand one uses a factor greater than that, say 0.99, one will get a lower secondary recharge ratio, i.e. 0.55.

The average secondary recharge rate for all 9 sections where this method was applied, is 49%. Compared to commonly accepted secondary recharge, this is high. For example in the Carson Valley rates of 40% have been demonstrated. The reason for these high values is probably the cumulative effect of irrigation and ditch losses. In other words actual secondary recharge from flood irrigation is probably less, though by how much is not known.

Secondary recharge volumes

The secondary recharge volumes calculated by using the above estimated TDS of 160 x 0.95 = 152 (column 5 in Table 2), are greater than the irrigation water applied in the area (based on data from the Watermaster Office). The reason is that the ambient ground water flow estimate is too high for these calculations. In other words the ground water flow estimates need to be adjusted, to finally get a reasonable secondary recharge volume. Yet, what is a reasonable secondary recharge volume?

It is estimated that irrigation ditches carry about 12000 ac-ft annually upon entering, and 3000 ac-ft when leaving the project area. An estimated 6700 ac-ft per year is applied, and 1700 ac-ft are assumed ditch losses. These are data obtained from the Watermasters Office (D. Bugenig, pers. communic., March 1998).

If one assumes 49% secondary recharge rate, one can calculate a total secondary recharge volume, using the data given above. This is done with the following calculation:

$$6700 \times 0.49 + 1700 = 4983 \text{ ac-ft per year.}$$

Admittedly, this is a conservative estimate, since the actual secondary recharge rate from flood irrigation is somewhat lower. Yet, it may serve well as an initial estimate.

The actual secondary recharge volume for each section is then calculated (column 7 in Table 2). This is done by trial and error, by adjusting the factor in the transmissivity estimate (needed for the ambient ground water flow estimate in column 3), until the total of all nine sections matches the above 4983 ac-ft per year.

Water table fluctuations

To determine whether the results generated are reasonable, the resulting water level changes were determined. The irrigated area for each pertinent section was estimated from the Watermasters map. The estimated volume was then divided by the acreage to determine the hypothesized ground water table fluctuations due to secondary recharge. Assuming a specific yield of 0.20 (D. Bugenig, pers. communic., January 1998), the water table fluctuations are less than 10 ft for most sections. These ranges are comparable with the fluctuations observed by Cohen and Loeltz (1964).

Exceptions occur in sections 11 and 13, where water level rises are more than 40 ft. Given that sections 11 and 13 is located in a bedrock area with thin soils and presumably high infiltration rates, ditch losses maybe one reason why infiltration rates are so high.

5.4.4.4 Mixing calculations: Stream channel infiltration

Stream channel infiltration in most, if not all TDS hydrographs is symptomized by a distinctive low in the aquifer TDS early in the year, before the advent of the irrigation season. The calculations are based on the same rationale, yet some judgment had to be applied about the TDS of the infiltrating stream water. There are three major stream systems that potentially affect the ground water TDS. Dry, Thomas and Whites Creek with TDS levels of 150, 100 and 48 mg/l, respectively (data from US Geological Survey, WRD files).

The estimated secondary recharge from stream channel infiltration is entered into the last column in Table 2. The sum total for all 9 sections is about 1200 ac-ft per year.

5.5 Secondary recharge in domestic wells: results

The total amount of secondary recharge entering ground water annually is estimated by sum of all 9 sections identified by means of TDS hydrographs to receive secondary recharge. As explained above, two sources of secondary recharge have been identified:

1. irrigation and ditch losses
2. stream channel infiltration

Thereby the average secondary recharge rate from irrigation and ditch losses in the STM area turns out to be about 49%, or a total volume of 5000 ac-ft per year. Since this includes ditch losses, the actual value from irrigation is probably somewhat lower. Since we are not able to distinguish the pre-1984 cycles from those after 1984, this estimate is probably an average between the pre-1984 and the post-1984 irrigation return flows. Assuming the 6700 ac-ft applied and 1700 ac-ft assumed ditch losses, this estimate still remains somewhat uncertain. By conducting accurate flow measurements in the ditches, it should be possible to accurately narrow these numbers down. Thereby it can then be determined what the actual, accurate secondary recharge rates are from flood irrigation.

The total of stream channel infiltration is about 1200 ac-ft per year (last column in Table 2).

The average annual volumes of estimated secondary recharge, both irrigation/ditch loss and stream channel infiltration, are depicted on a schematic map in Table 3. This map includes all pertinent sections potentially affected by secondary recharge. Also included are those sections that have been determined to not receive secondary recharge based on the TDS hydrographs included in the Appendix.

credibility is that they are based on observed trends (the TDS cycles) in aquifer chemistry, which are indicative of some kind of annual dilution process in the aquifer. It is encouraging that these estimates are reasonable, instead of providing astronomical numbers that have little bearing on the problem under consideration.

Table 2: Estimated secondary recharge from irrigation and stream channel infiltration.

Section	Estim. Irrig. area, acres	Estim. GW flow at well depth, ac-ft per year	Estimated secondary recharge from irrigation based on TDS differences	Calculated secondary recharge from irrigation, ac-ft per year	Expected fall to summer water table rise due to irrigation, ft	Calculated secondary recharge from stream channel infiltration, ac-ft per year
T18R19, Sec 06	255	20	65%	**306**	6	**469**
T18R19, Sec01	640	155	39%	**1,383**	11	**155**
T18R19, Sec02	320	45	40%	**274**	4	**39**
T18R20, Sec 07	395	29	44%	**244**	3	**23**
T18R19, Sec 12	402	61	55%	**815**	10	**390**
T18R19, Sec 11	10	11	46%	**98**	49)*	**20**
T18R20, Sec 17	390	33	47%	**218**	3	**24**
T18R20, Sec 18	255	18	47%	**56**	1	**5**
T18R19, Sec 13	194	117	57%	**1,604**	41)*	**82**
			49% average	**4,999 ac-ft/year total**	)* - probably ditch losses	**1,207 ac-ft/year total**

STM calculated secondary recharge: stream channel infiltration			
T18R19		T18R20	
2 274	1 1383	6 306	5
11 98	12 815	7 244	8
14	13 1604	18 56	17 218
25	24	19	20
		sum: 4999 ac-ft per year	

STM calculated secondary recharge: stream channel infiltration			
T18R19		T18R20	
2 39	1 155	6 469	5
11 20	12 390	7 23	8
14	13 82	18 5	17 24
25	24	19	20
		sum: 1207 ac-ft per year	

Table 3: South Truckee Meadows area, estimated average secondary recharge from irrigation based on TDS fluctuations (annual cycles) in domestic wells. The large numbers indicate ac-ft annual return flow estimated. The small numbers indicate the section numbers.

6 Conclusions

The following conclusions are drawn from this report's data analysis:

1. Secondary recharge from irrigation and stream channel infiltration is evident in the underlying aquifer's seasonal chemical changes. Using a simple mixing equation secondary recharge was calculated for the 9 sections where TDS changes indicate significant secondary recharge. Thereby the total secondary recharge from irrigation (including ditch losses) and stream channel infiltration was estimated at 5000 and 1200 ac-ft per year, respectively.
2. Ground water recharge in the STM from surface water sources is very efficient. The seasonal changes in ground water system, suggest a system open to recharge. This suggests that the option of artificial ground water recharge by means of surface infiltration ponds is a feasible option.
3. Unfortunately the high efficiency of surface water infiltration also leads to a problem that should be addressed at some time in the near future: the STM aquifer system is highly vulnerable to ground water pollution.
4. The continued use of septic leachfields in high density suburban areas may have led to a gradual buildup of household chemicals. Domestic wells in some areas apparently pump a significant amount of recycled water. Although the regional ground water flow replenishes the shallow aquifer every year, gradual build-up of more benign (but not necessarily to be ignored) constituents in the aquifer may occur.
5. The results show the need of a comprehensive wellhead protection program. It should include developing plans on how to gradually eliminate various sources of pollution in the process of urbanization, specifically septic leachfields.

7 Recommendations

7.1 Further compilation of annual data

Altogether about 1600 chemical data sets were utilized for this study, covering an area of about 40 square miles. Assuming a market price of $200 per chemical analysis, this is a data value of $320,000.

Prior to this project only a small percentage of these data was available fro ground water management. Assuming that the results of analyzing these data can become truly beneficial for resolving lingering ground water management questions, it maybe worthwhile to consider establishing such data basis in the future, by immediately entering every water chemistry analysis into a centralized data base.

This point should be given some serious consideration. Some of the previous ground water models that were developed for the STM area, for this reason were not able to take into account a host of valuable information contained in ground water chemistry data. Essentially, any numerical model should include a solute transport component to accommodate this sort of information content.

7.2 Environmental isotopes

Initially it was intended to also apply environmental isotopes (Deuterium and O-18) to identify secondary recharge in the aquifer underlying the South Truckee Meadows area. Naturally this implied the need for an extensive isotope sampling program. Whatever little data available suggest that the municipal wells and the irrigation ditches have characteristic signatures that are significantly different from each other, suggesting their potential usefulness for this sort of study.

When reviewing the municipal and domestic well chemistry data it was noticed that the TDS levels in many, if not all municipal wells decrease during the summer months, due to secondary recharge. Given this observation, sampling for isotopes after the summer will provide only a synchronic outlook about the differences between surface and ground water. Instead it was decided to conduct a systematic time-series isotope sampling program (preferably in conjunction with major ion analysis), beginning in the spring and continuing all through the summer months until late fall. This should be done in conjunction with reasonably accurate flow measurements (input-output measurement from ditch to ditch). This is anticipated to yield the following results:

1. correlation of amount of irrigation water flow with amount of return flow;
2. time delay, i.e. time it takes for irrigation water to reach the water table;
3. efficiency of flood irrigation.

7.3 Flow measurements in conjunction with chemistry data

The amount of secondary recharge from irrigation varies from year to year. In this study it was demonstrated that this can be significant, yet it is not easy to quantify.

The major problem is that ditch flow into the STM area has never been measured in the past (although outflows into Steamboat Creek have been measured). Once inflow into the project area is known, the actual amount of secondary recharge can be directly estimated, and the ground water mixing method results can be verified, and the method thereby calibrated, maybe to be used elsewhere in other urbanized areas.

This could be done for one irrigation season, maybe once every month, and at various intervals of the entire irrigated area.

One may also want to consider spiking the irrigation water with water that has an entirely different isotope signature, thereby verifying lag time (percolation time) and amount of secondary recharge.

8 Bibliography and data sources

<u>Bibliography</u>

Bateman, R.L. and Scheibach, R.B., 1977, Nevada Bureau of Mines and Geology, Report 25.

Chesley, M., McKay, W.A., and McKenna, S., 1990, The 1988 Truckee River water quality monitoring project report. Desert Research Institute, WRC, July 1990. Public. No. 41128.

Cohen, P. and Loeltz, O.J., 1964, Evaluation of hydrogeology and hydrogeochemistry of Truckee Meadows area. Washoe County, Nevada. USGS WSP 1779-S.

Guyton and Associates, 1978, Progress report on ground water conditions in the Reno-Sparks area, Nevada. February 1978. Prepared for Sierra Pacific Power Co.

Hydro-Search, Inc., 1991, South Truckee Meadows Ground Water Flow and Transport Model. Prepared for Washoe County Utility Division. October 10, 1991.

Van Denburgh, A.S., Lamke, R.D., and Hughes, J.L., 1973, A brief water-resources appraisal of the Truckee River Basin, Western Nevada. Water resources reconnaissance Series, Report 57.

Washoe County, 1991, Notebook on hydrogeology of the South Truckee Meadows. Washoe County Dpt. of Public Works, Utility Division. February 1991.

Washoe County, 1996, Ground water level status for portions of Mt. Rose and Galena Fan area, Washoe County, Nevada. Dept. of Public Works, Aug. 1996.

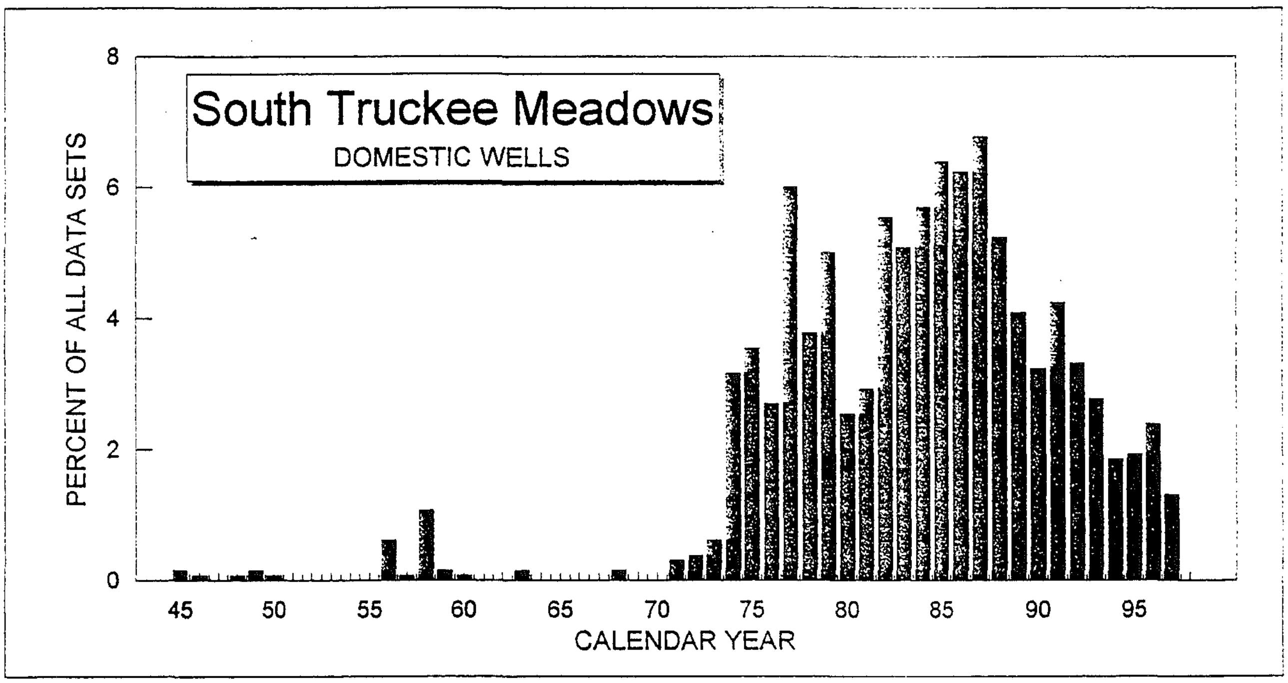
<u>Data sources</u>

The following agencies and/or individuals have provided the data necessary for this study:

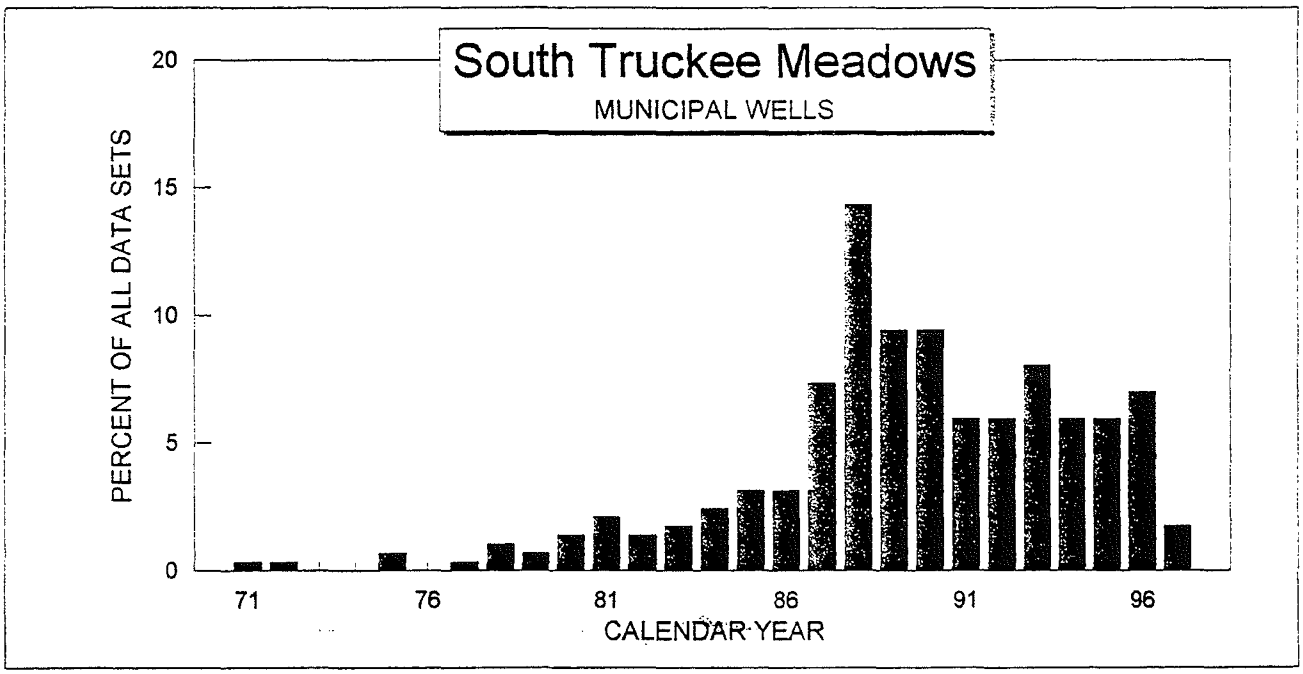
1. Washoe Water Protection Association. 3773 Baker Lane, Reno, NV 89509.
2. US Geological Survey, Water Resources Division, Carson City.
3. Washoe County, Department of Public Works.
4. Nevada State Health Laboratory, 1660 N. Virginia St., Reno, Nevada.

8 Appendix A: Miscellaneous diagrams

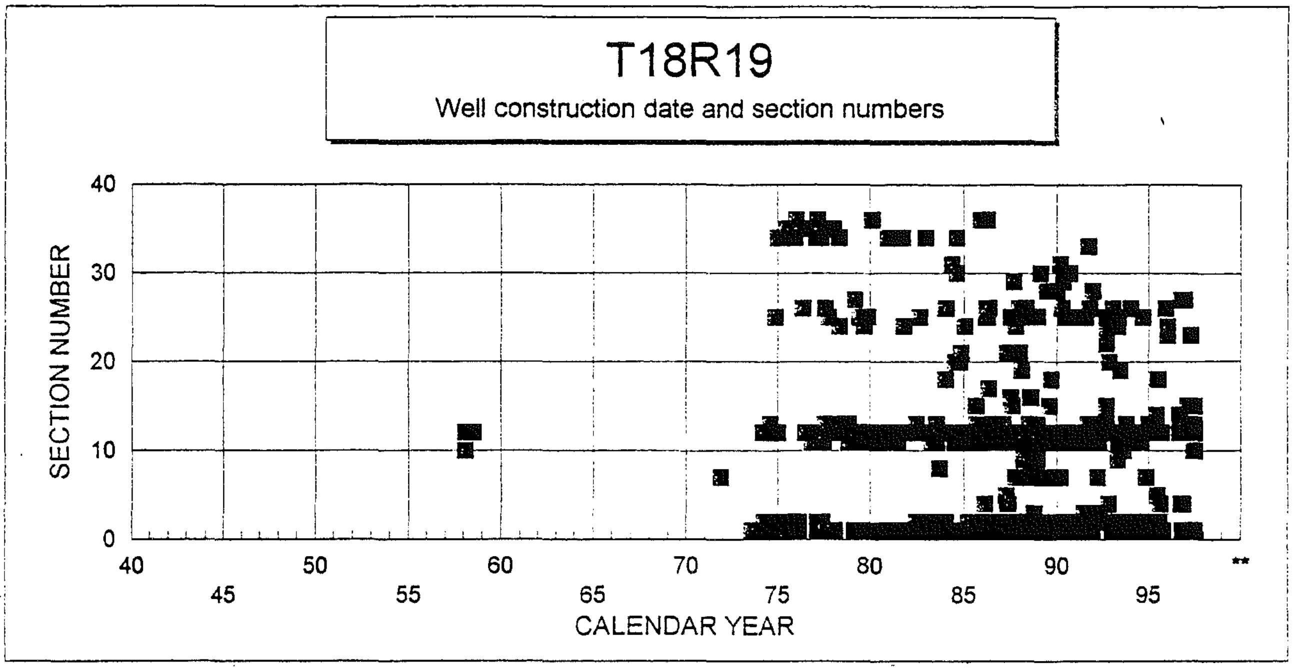
8.1 Data sets per calendar year

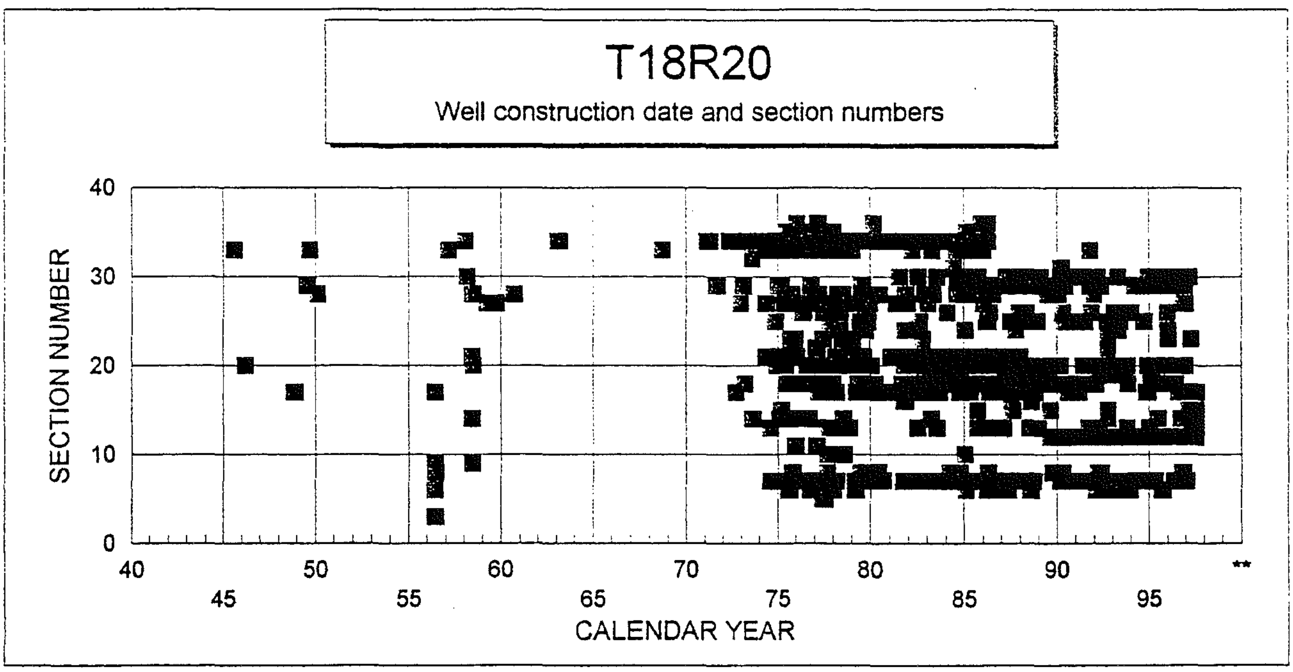

South Truckee Meadows
DOMESTIC WELLS
PERCENT OF ALL DATA SETS
0
2
4
6
8
45
50
55
60
65
70
75
80
85
90
95
CALENDAR YEAR

&A

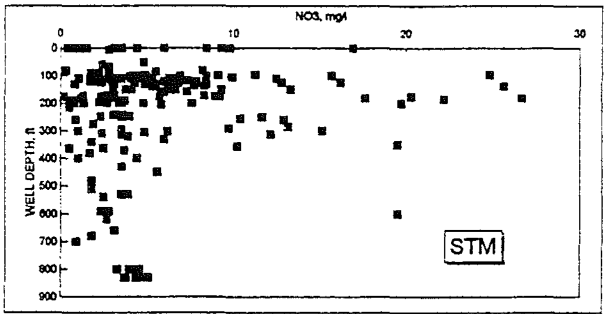

South Truckee Meadows
MUNICIPAL WELLS
PERCENT OF ALL DATA SETS
20
15
10
5
0
71
76
81
86
91
96
CALENDAR YEAR

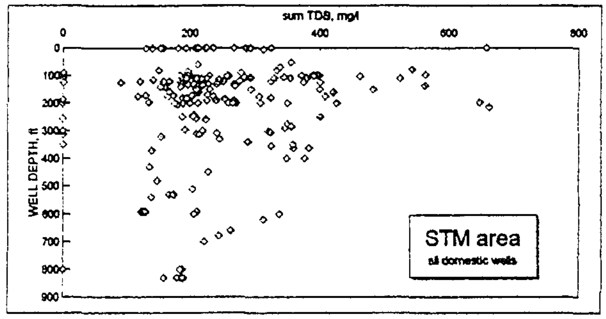
8.2 Number of wells per section number

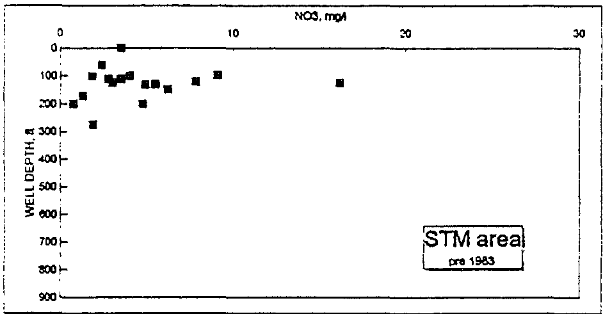

T18R19
Well construction date and section numbers
SECTION NUMBER
0
10
20
30
40
40
45
50
55
60
65
70
75
80
85
90
95
**
CALENDAR YEAR

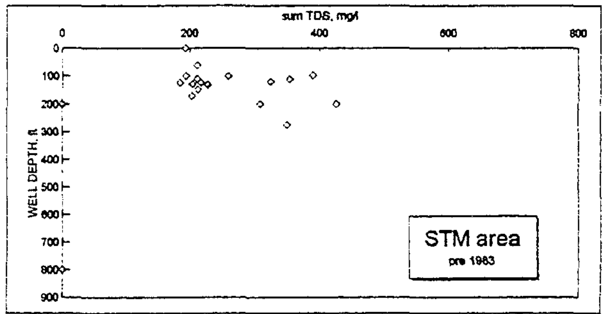

T18R20
Well construction date and section numbers
SECTION NUMBER
0
10
20
30
40
40
45
50
55
60
65
70
75
80
85
90
95
**
CALENDAR YEAR

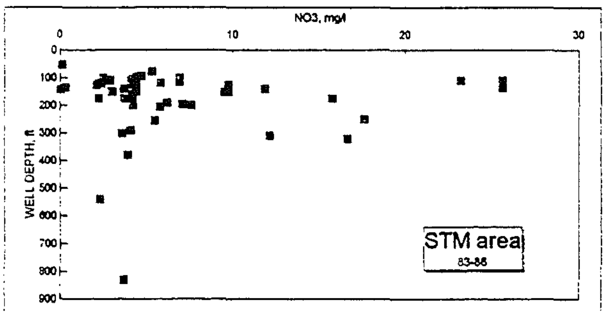
8.3 Nitrate and TDS with well depth

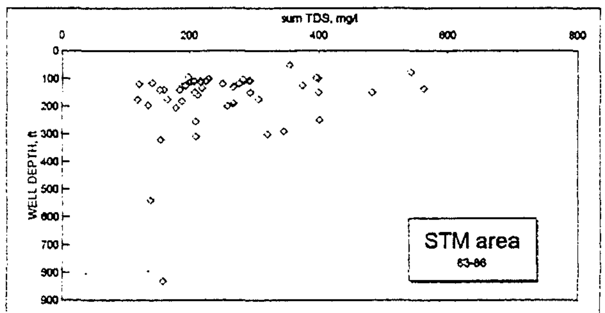

NO3, mg/l
0
10
20
30
WELL DEPTH, ft
0
100
200
300
400
500
600
700
800
900
STM

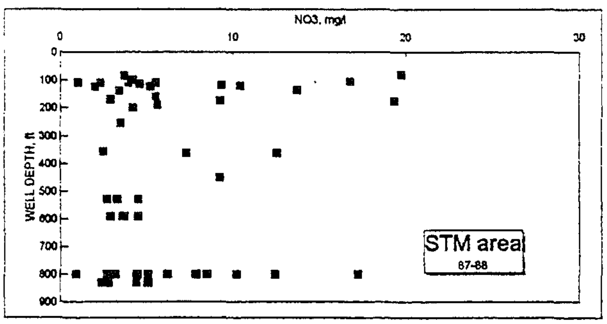

sum TDS, mg/l
0
200
400
600
800
WELL DEPTH, ft
0
100
200
300
400
500
600
700
800
900
STM area
all domestic wells

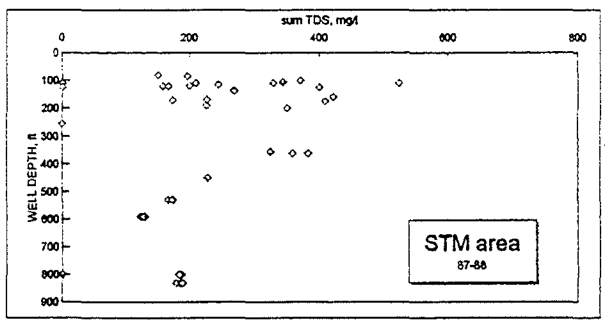

NO3, mg/l
0
10
20
30
WELL DEPTH, ft
0
100
200
300
400
500
600
700
800
900
STM area
pre 1983

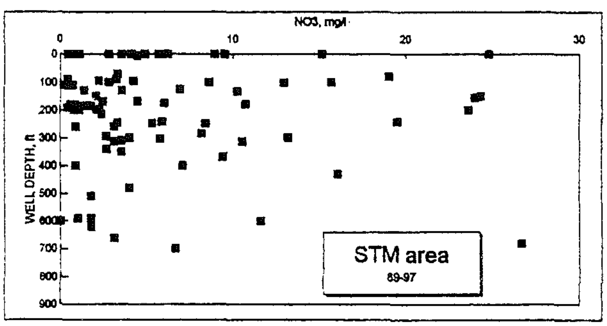

sum TDS, mg/l
0
200
400
600
800
WELL DEPTH, ft
0
100
200
300
400
500
600
700
800
900
STM area
pre 1983

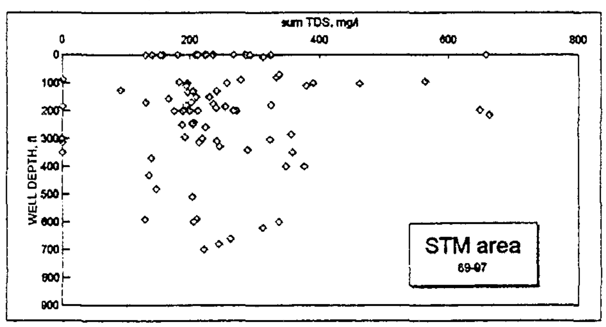

NO3, mg/l
0
10
20
30
WELL DEPTH, ft
0
100
200
300
400
500
600
700
800
900
STM area
83-86


sum TDS, mg/l
0
200
400
600
800
WELL DEPTH, ft
0
100
200
300
400
500
600
700
800
900
STM area
83-86


NO3, mg/l
0
10
20
30
WELL DEPTH, ft
0
100
200
300
400
500
600
700
800
900
STM area
87-88

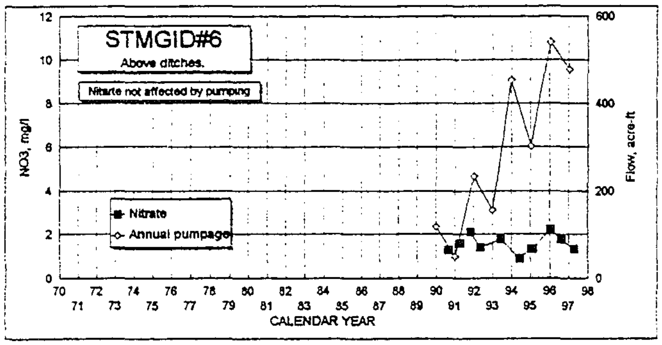

sum TDS, mg/l
0
200
400
600
800
WELL DEPTH, ft
0
100
200
300
400
500
600
700
800
900
STM area
87-88

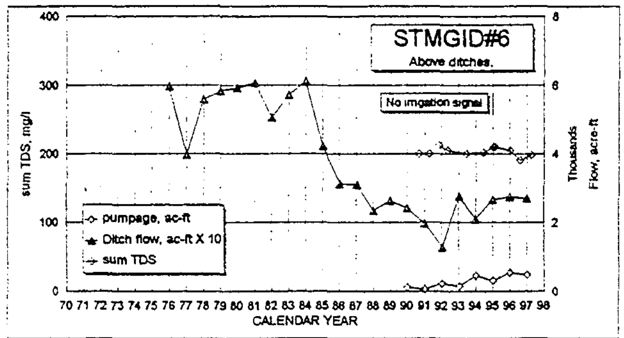

NO3, mg/l
0
10
20
30
WELL DEPTH, ft
0
100
200
300
400
500
600
700
800
900
STM area
89-97

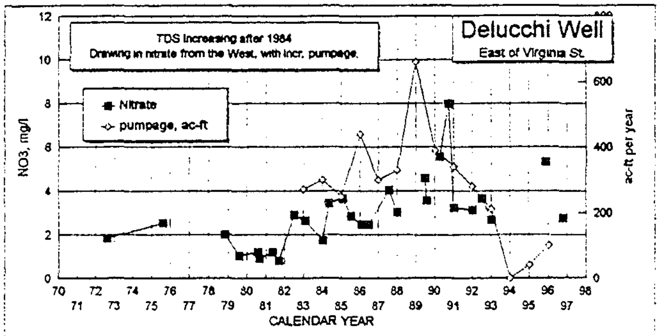

sum TDS, mg/l
0
200
400
600
800
WELL DEPTH, ft
0
100
200
300
400
500
600
700
800
900
STM area
89-97

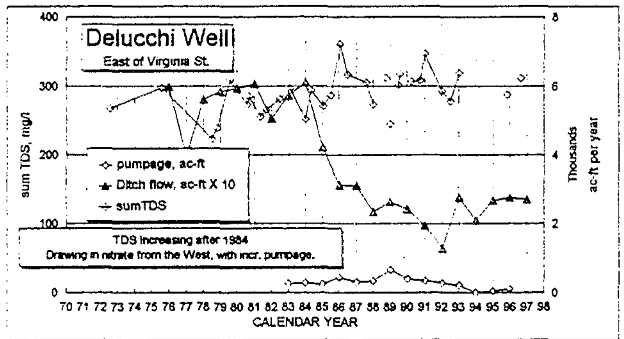
8.4 Nitrate and TDS in municipal wells

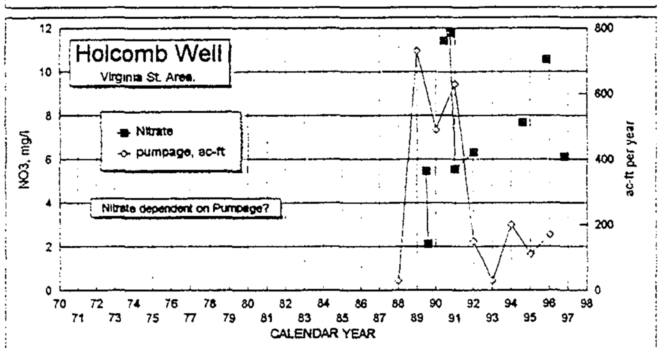
&A

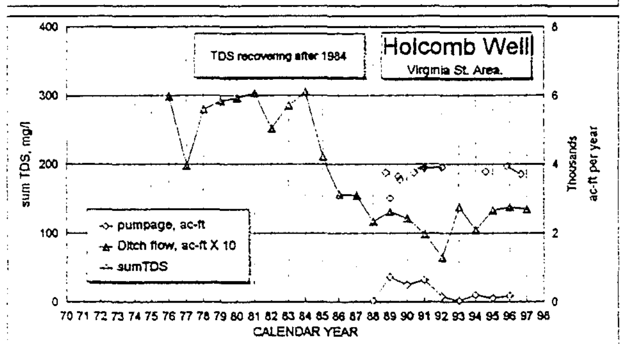

STMGID#6
Above ditches.
Nitarte not affected by pumping
Nitrate
Annual pumpage
NO3, mg/l
Flow, acre-ft
CALENDAR YEAR

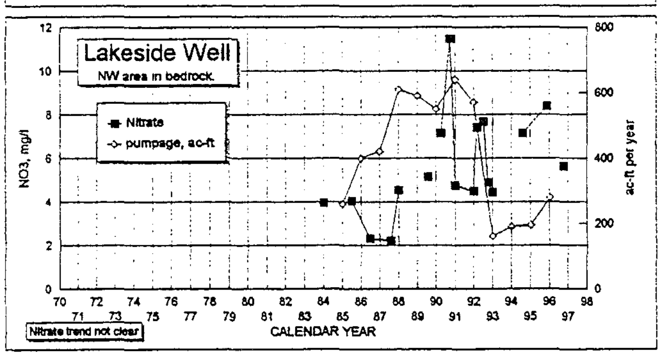

STMGID#6
Above ditches.
No irrigation signal
pumpage, ac-ft
Ditch flow, ac-ft X 10
sum TDS
sum TDS, mg/l
Thousands
Flow, acre-ft
CALENDAR YEAR

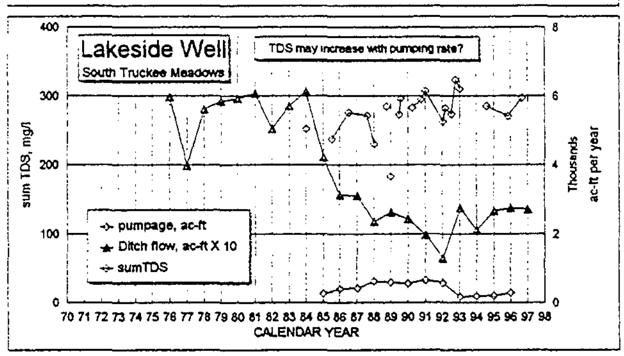

TDS increasing after 1984
Drawing in nitrate from the West, with incr. pumpage.
Delucchi Well
East of Virginia St.
Nitrate
pumpage, ac-ft
NO3, mg/l
ac-ft per year
CALENDAR YEAR

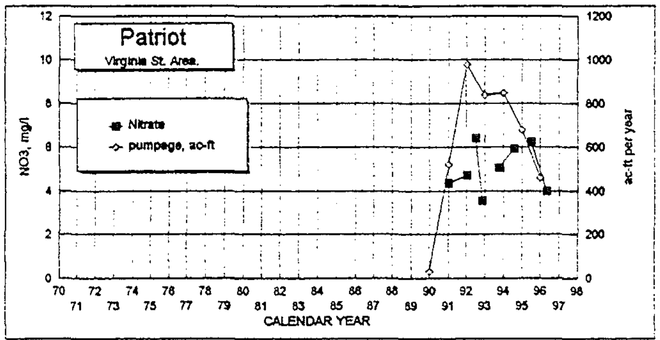

Delucchi Well
East of Virginia St.
pumpage, ac-ft
Ditch flow, ac-ft X 10
sumTDS
TDS increasing after 1984
Drawing in nitrate from the West, with incr. pumpage.
sum TDS, mg/l
Thousands
ac-ft per year
CALENDAR YEAR

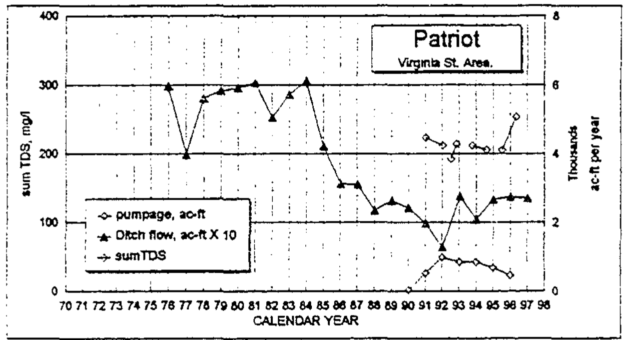

Holcomb Well
Virginia St. Area.
Nitrate
pumpage, ac-ft
Nitrate dependent on Pumpage?
NO3, mg/l
ac-ft per year
CALENDAR YEAR

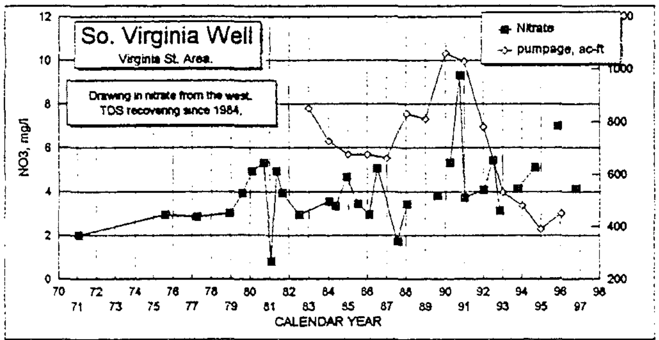

TDS recovering after 1984
Holcomb Well
Virginia St. Area.
pumpage, ac-ft
Ditch flow, ac-ft X 10
sumTDS
sum TDS, mg/l
Thousands
ac-ft per year
CALENDAR YEAR

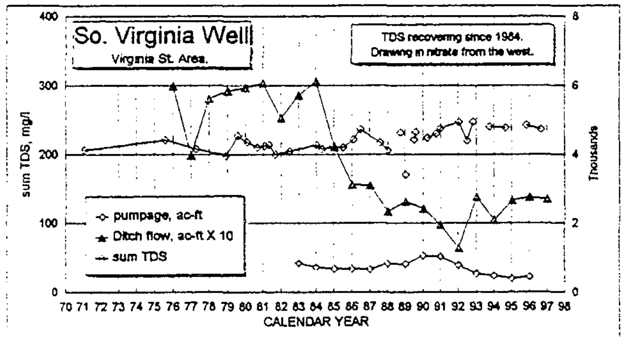

Lakeside Well
NW area in bedrock.
Nitrate
pumpage, ac-ft
NO3, mg/l
ac-ft per year
Nitrate trend not clear
CALENDAR YEAR


Lakeside Well
South Truckee Meadows
TDS may increase with pumping rate?
pumpage, ac-ft
Ditch flow, ac-ft X 10
sumTDS
sum TDS, mg/l
Thousands
ac-ft per year
CALENDAR YEAR

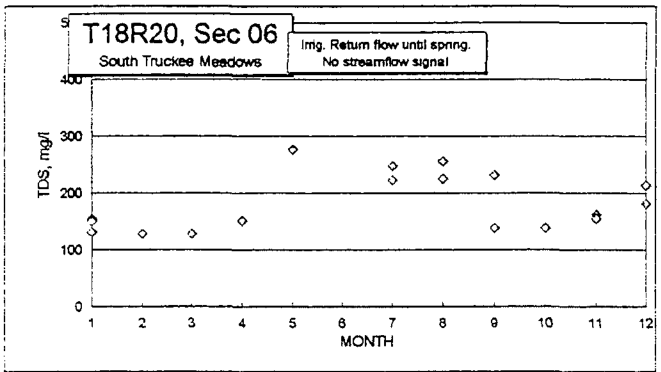

Patriot
Virginia St. Area.
Nitrate
pumpage, ac-ft
NO3, mg/l
ac-ft per year
CALENDAR YEAR

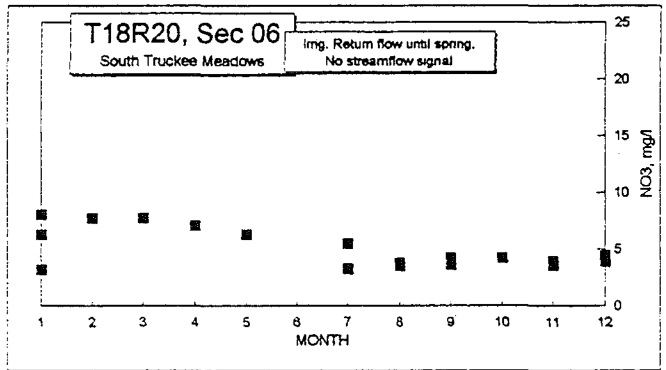

Patriot
Virginia St. Area.
pumpage, ac-ft
Ditch flow, ac-ft X 10
sumTDS
sum TDS, mg/l
Thousands
ac-ft per year
CALENDAR YEAR

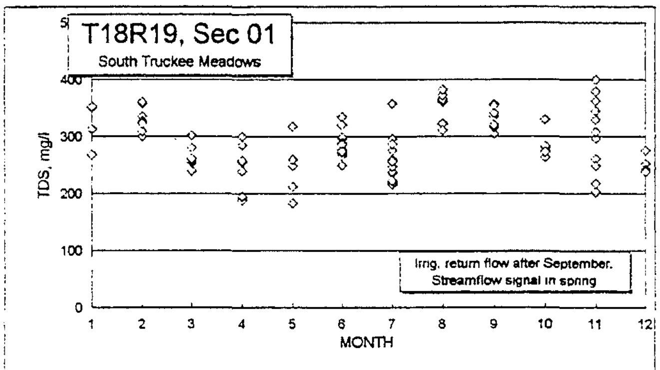

So. Virginia Well
Virginia St. Area.
Nitrate
pumpage, ac-ft
Drawing in nitrate from the west.
TDS recovering since 1984.
NO3, mg/l
CALENDAR YEAR

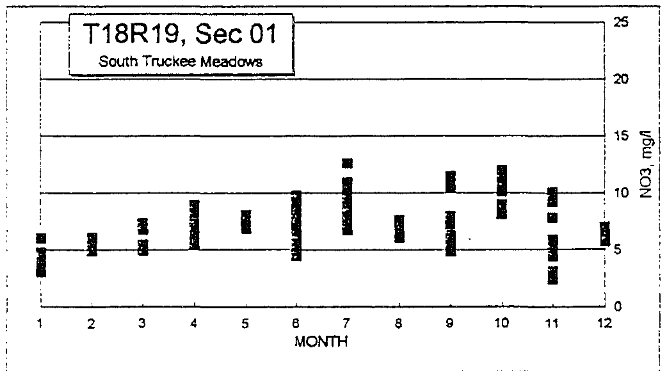

So. Virginia Well
Virginia St. Area.
TDS recovering since 1984.
Drawing in nitrate from the west.
pumpage, ac-ft
Ditch flow, ac-ft X 10
sum TDS
sum TDS, mg/l
Thousands
CALENDAR YEAR

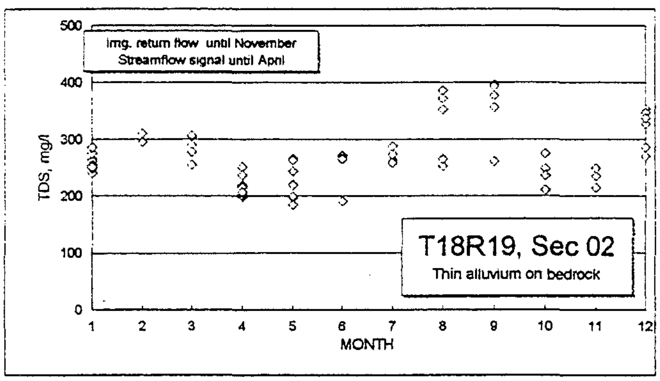
8.5 Nitrate and TDS in domestic wells

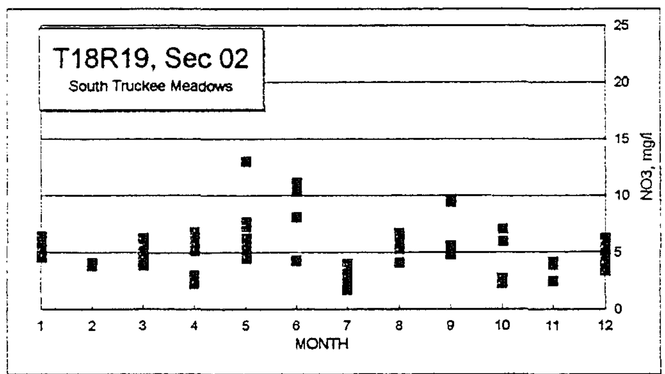

T18R20, Sec 06
South Truckee Meadows
Irrig. Return flow until spring.
No streamflow signal
TDS, mg/l
MONTH

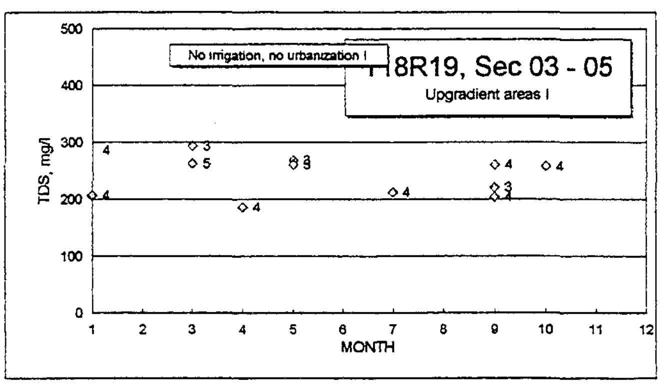

T18R20, Sec 06
South Truckee Meadows
Irrig. Return flow until spring.
No streamflow signal
NO3, mg/l
MONTH

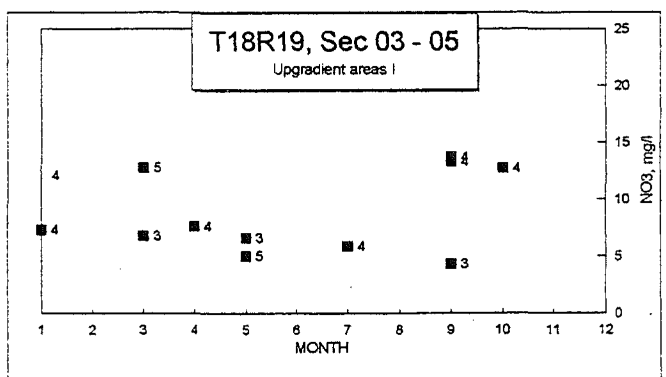

T18R19, Sec 01
South Truckee Meadows
Irrig. return flow after September.
Streamflow signal in spring
TDS, mg/l
MONTH

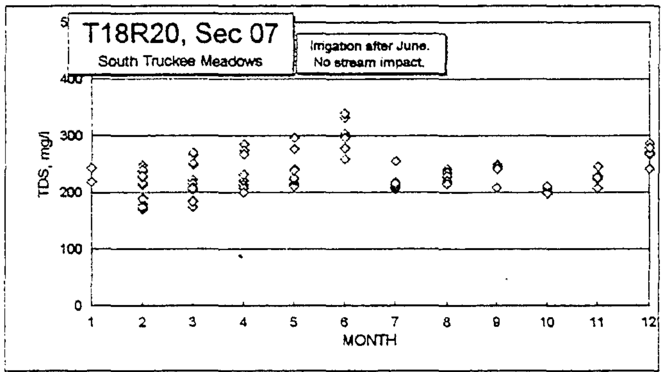

T18R19, Sec 01
South Truckee Meadows
NO3, mg/l
MONTH

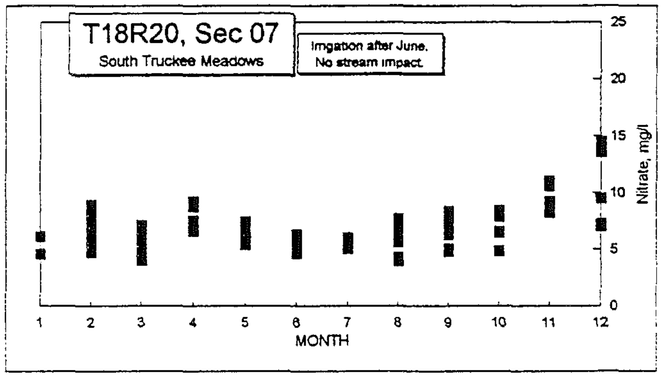

Irrig. return flow until November
Streamflow signal until April
T18R19, Sec 02
Thin alluvium on bedrock
TDS, mg/l
MONTH

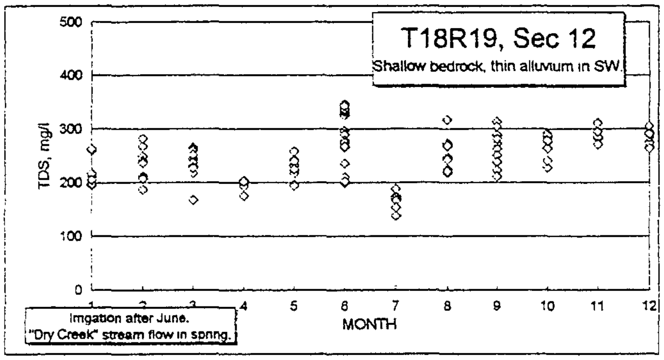

T18R19, Sec 02
South Truckee Meadows
NO3, mg/l
MONTH

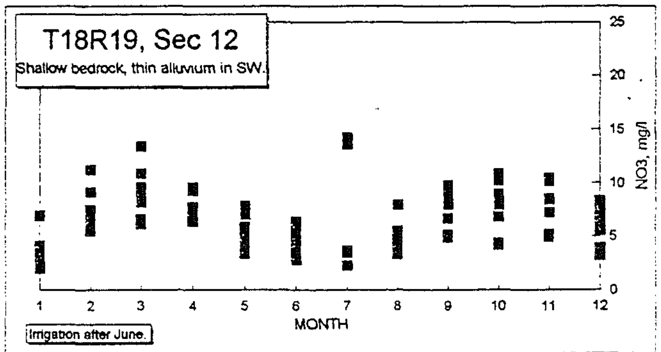

No irrigation, no urbanization !
T18R19, Sec 03 - 05
Upgradient areas !
TDS, mg/l
MONTH

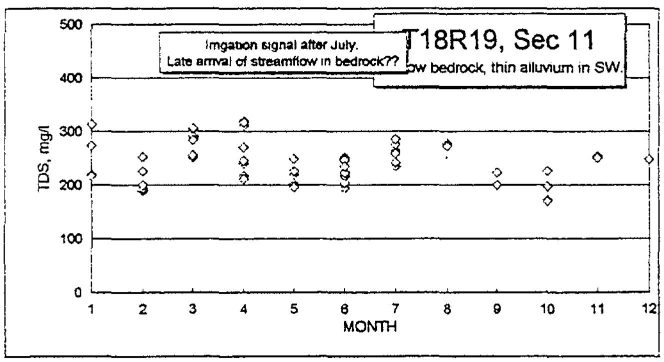

T18R19, Sec 03 - 05
Upgradient areas !
NO3, mg/l
MONTH

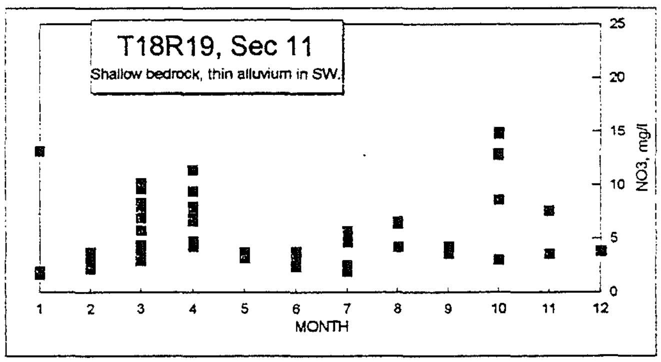

T18R20, Sec 07
South Truckee Meadows
Irrigation after June.
No stream impact.
TDS, mg/l
MONTH

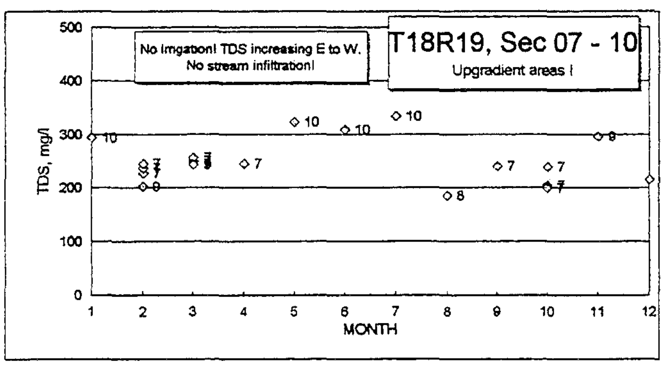

T18R20, Sec 07
South Truckee Meadows
Irrigation after June.
No stream impact.
Nitrate, mg/l
MONTH

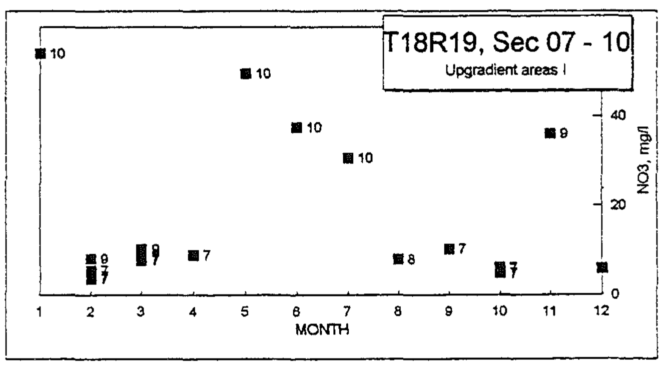

T18R19, Sec 12
Shallow bedrock, thin alluvium in SW.
Irrigation after June.
"Dry Creek" stream flow in spring.
TDS, mg/l
MONTH

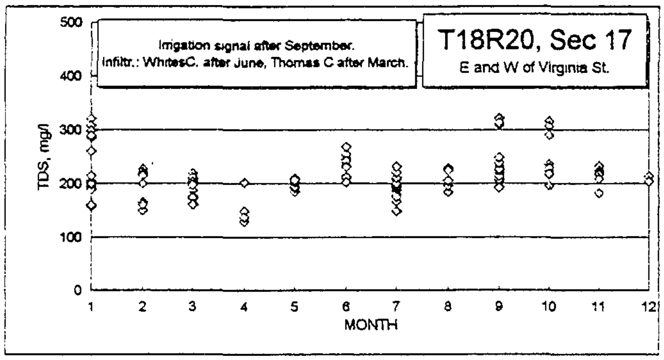

T18R19, Sec 12
Shallow bedrock, thin alluvium in SW.
Irrigation after June.
NO3, mg/l
MONTH

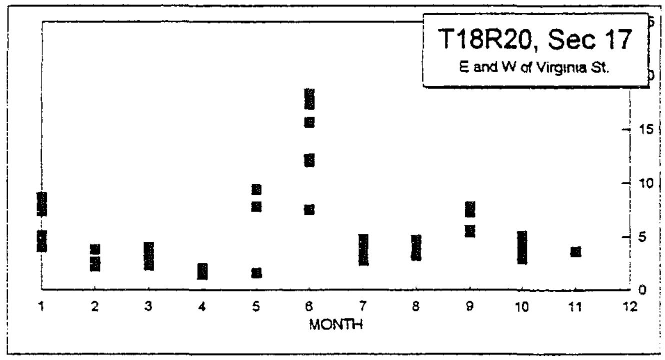

T18R19, Sec 11
Irrigation signal after July.
Late arrival of streamflow in bedrock??
TDS, mg/l
MONTH

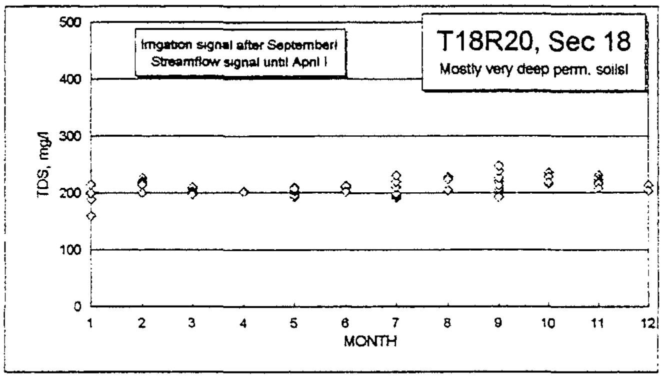

T18R19, Sec 11
Shallow bedrock, thin alluvium in SW.
NO3, mg/l
MONTH

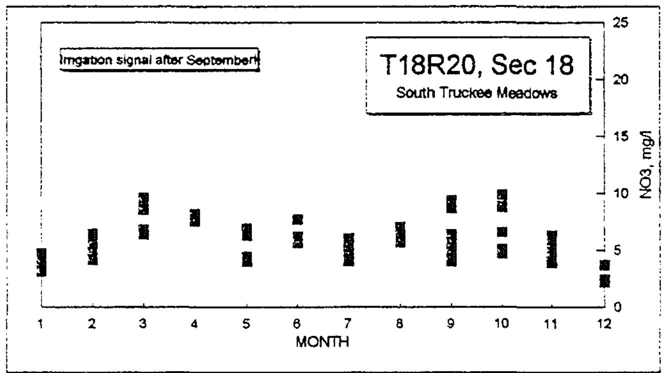

T18R19, Sec 07 - 10
Upgradient areas !
No irrigation! TDS increasing E to W.
No stream infiltration!
TDS, mg/l
MONTH

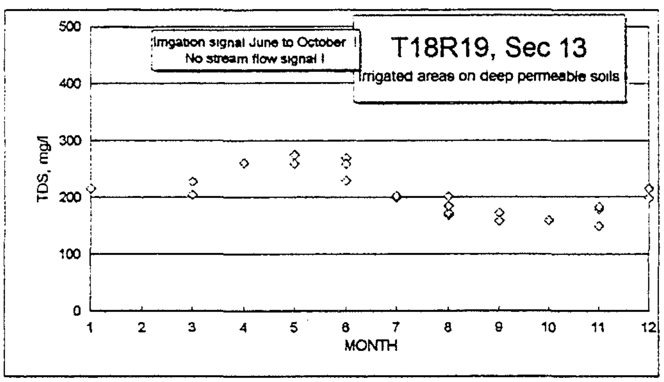

T18R19, Sec 07 - 10
Upgradient areas !
NO3, mg/l
MONTH

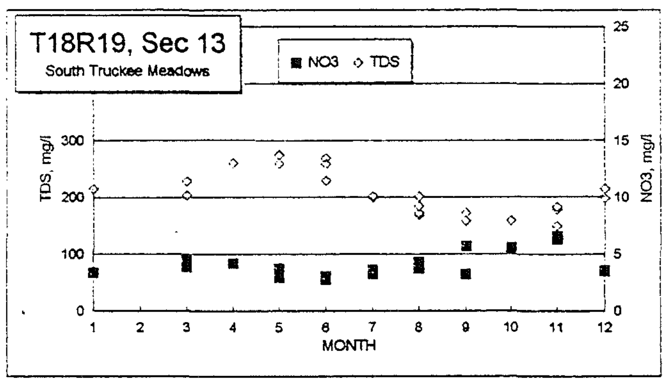

T18R20, Sec 17
E and W of Virginia St.
Irrigation signal after September.
Infiltr.: WhitesC. after June, Thomas C after March.
TDS, mg/l
MONTH

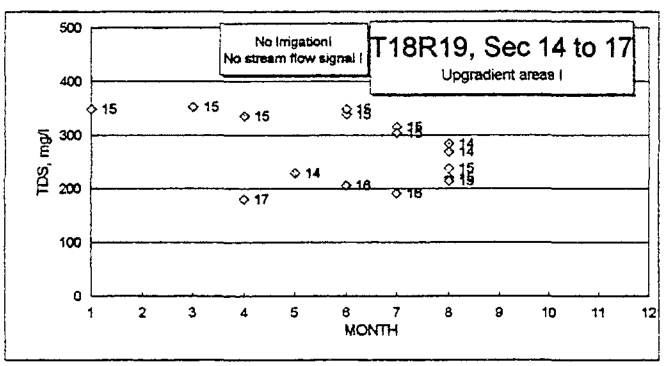

T18R20, Sec 17
E and W of Virginia St.
MONTH

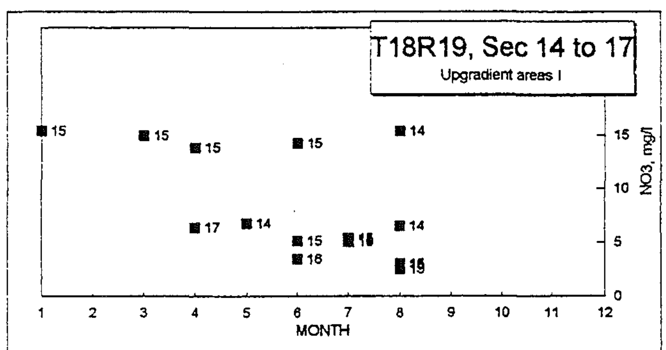

T18R20, Sec 18
Mostly very deep perm. soils!
Irrigation signal after September!
Streamflow signal until April !
TDS, mg/l
MONTH

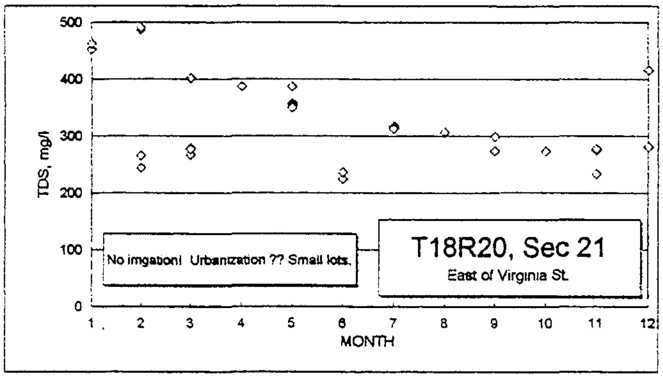

T18R20, Sec 18
South Truckee Meadows
Irrigation signal after September!
NO3, mg/l
MONTH

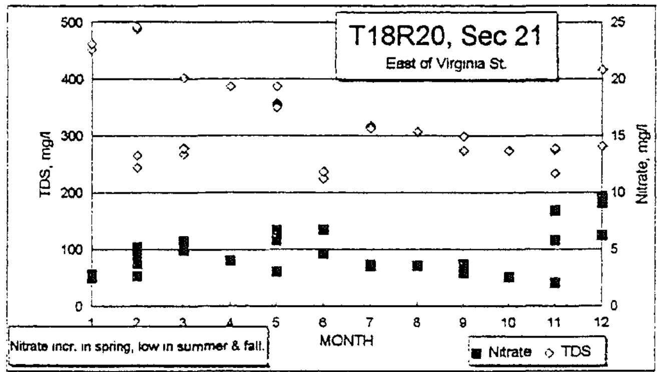

T18R19, Sec 13
Irrigated areas on deep permeable soils
Irrigation signal June to October !
No stream flow signal !
TDS, mg/l
MONTH

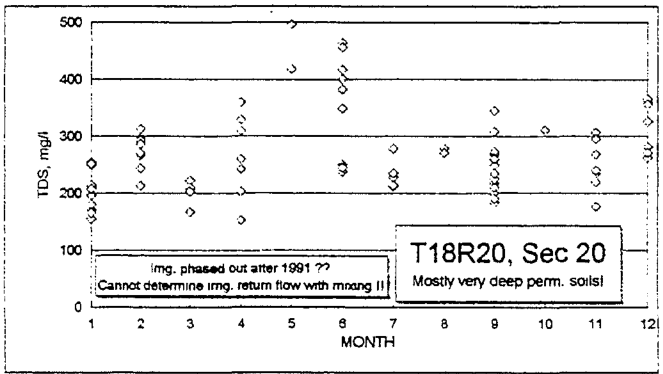

T18R19, Sec 13
South Truckee Meadows
NO3
TDS
TDS, mg/l
NO3, mg/l
MONTH

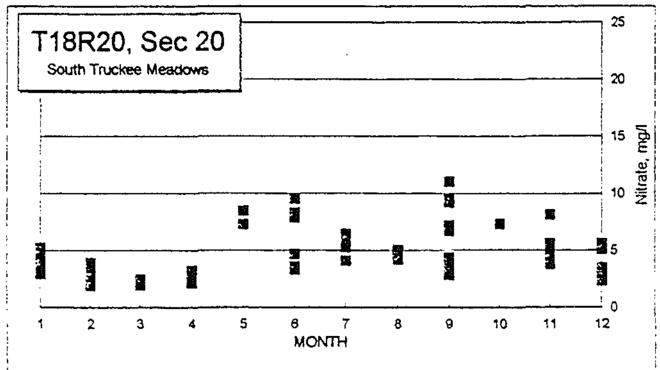

T18R19, Sec 14 to 17
Upgradient areas !
No Irrigation!
No stream flow signal !
TDS, mg/l
MONTH

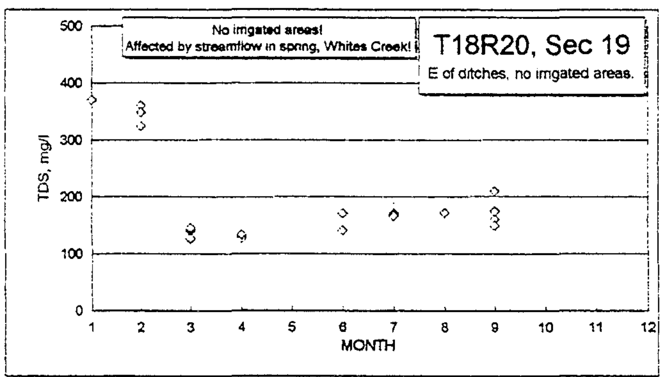

T18R19, Sec 14 to 17
Upgradient areas !
NO3, mg/l
MONTH

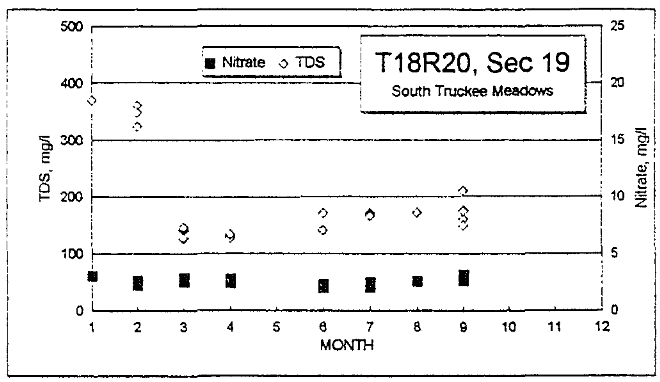

T18R20, Sec 21
East of Virginia St.
No irrigation! Urbanization ?? Small lots.
TDS, mg/l
MONTH

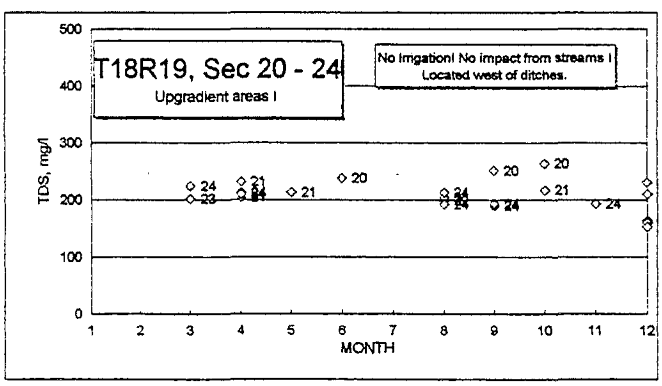

T18R20, Sec 21
East of Virginia St.
Nitrate incr. in spring, low in summer & fall.
Nitrate
TDS
TDS, mg/l
Nitrate, mg/l
MONTH

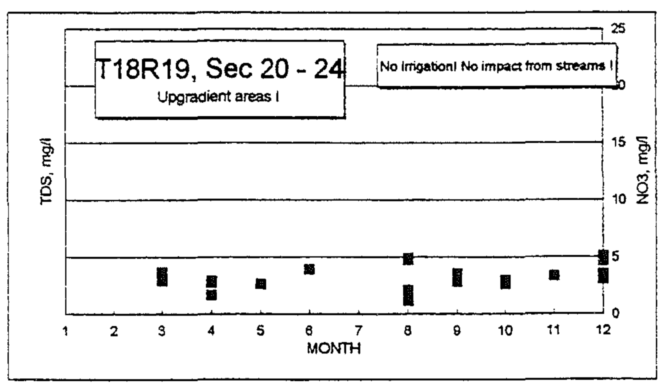

T18R20, Sec 20
Mostly very deep perm. soils!
Irrg. phased out after 1991 ??
Cannot determine irrg. return flow with mixing !!
TDS, mg/l
MONTH

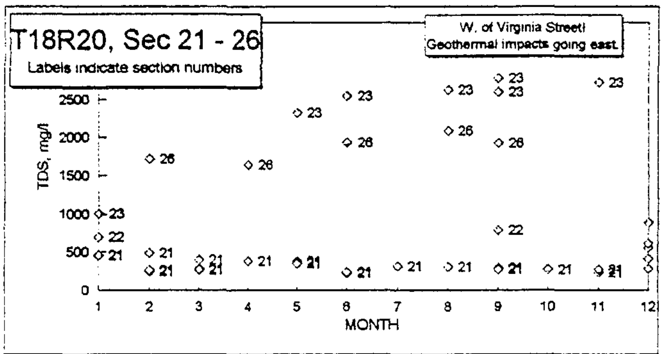

T18R20, Sec 20
South Truckee Meadows
Nitrate, mg/l
MONTH

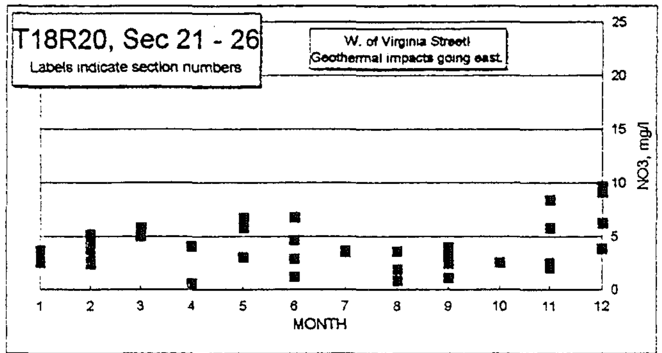

T18R20, Sec 19
E of ditches, no irrigated areas.
No irrigated areas!
Affected by streamflow in spring, Whites Creek!
TDS, mg/l
MONTH

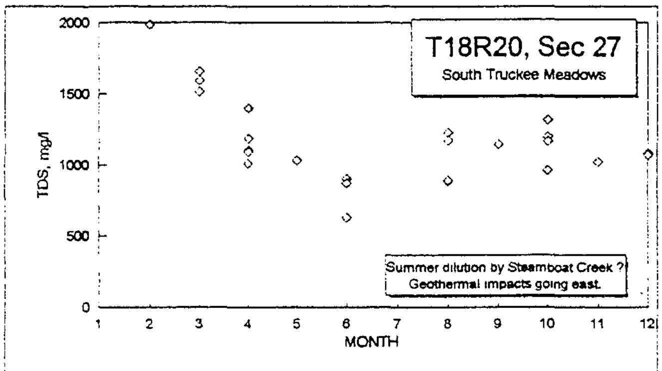

T18R20, Sec 19
South Truckee Meadows
Nitrate
TDS
TDS, mg/l
Nitrate, mg/l
MONTH

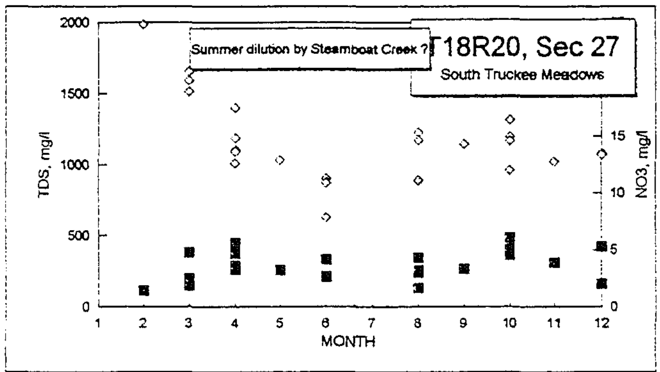

T18R19, Sec 20 - 24
Upgradient areas !
No irrigation! No impact from streams !
Located west of ditches.
TDS, mg/l
MONTH

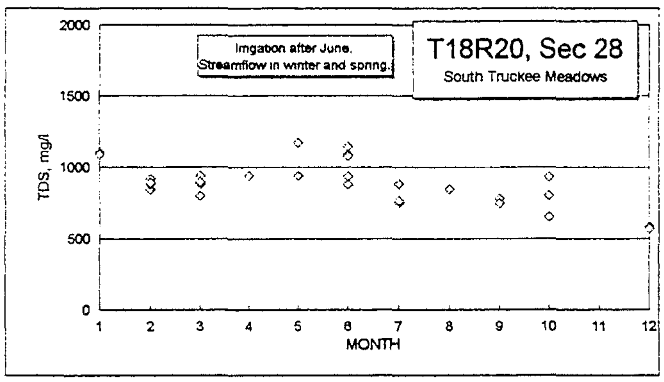

T18R19, Sec 20 - 24
Upgradient areas !
No irrigation! No impact from streams !
TDS, mg/l
NO3, mg/l
MONTH

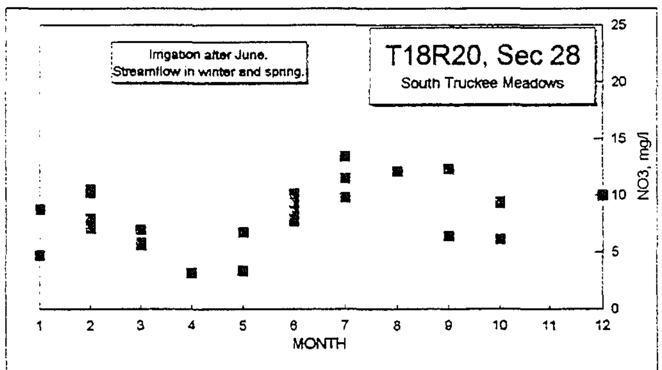

T18R20, Sec 21 - 26
Labels indicate section numbers
W. of Virginia Street!
Geothermal impacts going east.
TDS, mg/l
2500
2000
1500
1000
500
0
1 2 3 4 5 6 7 8 9 10 11 12
MONTH
21
22
23
26

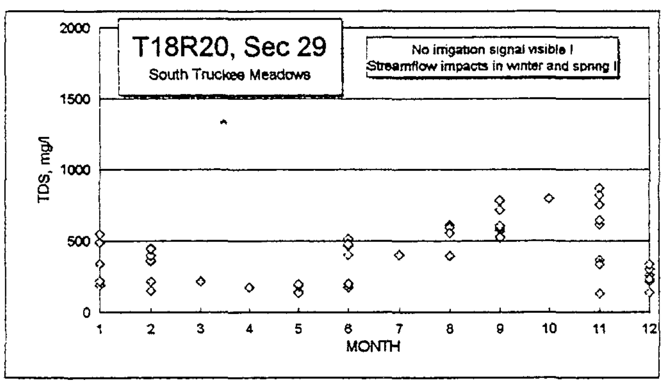

T18R20, Sec 21 - 26
Labels indicate section numbers
W. of Virginia Street!
Geothermal impacts going east.
NO3, mg/l
25
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 12
MONTH

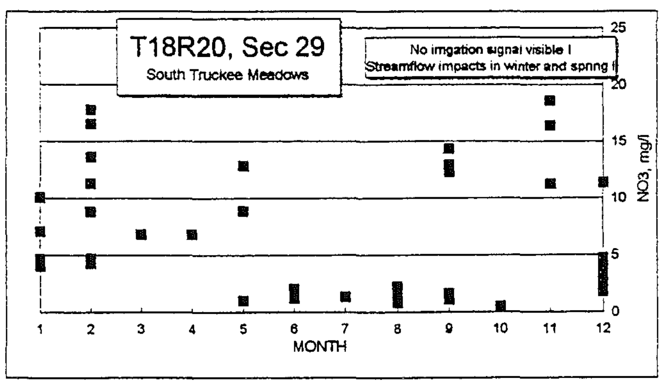

T18R20, Sec 27
South Truckee Meadows
Summer dilution by Steamboat Creek ?
Geothermal impacts going east.
TDS, mg/l
2000
1500
1000
500
0
1 2 3 4 5 6 7 8 9 10 11 12
MONTH

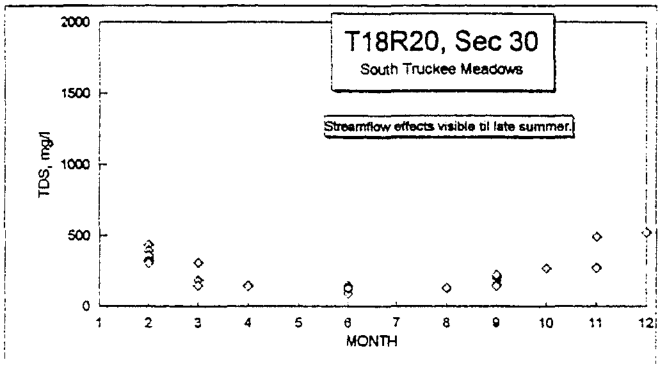

Summer dilution by Steamboat Creek ?
T18R20, Sec 27
South Truckee Meadows
TDS, mg/l
NO3, mg/l
2000
1500
1000
500
0
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 12
MONTH

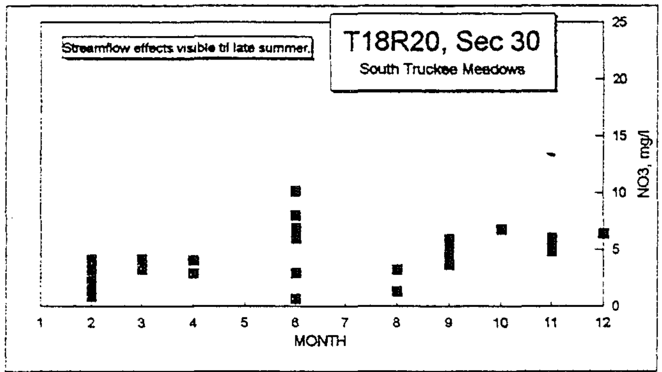

Irrigation after June.
Streamflow in winter and spring.
T18R20, Sec 28
South Truckee Meadows
TDS, mg/l
2000
1500
1000
500
0
1 2 3 4 5 6 7 8 9 10 11 12
MONTH

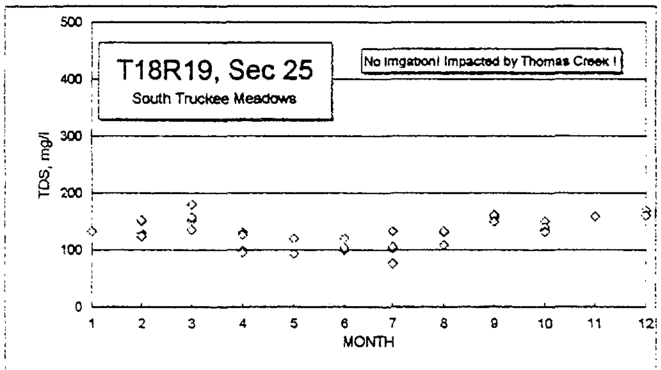

Irrigation after June.
Streamflow in winter and spring.
T18R20, Sec 28
South Truckee Meadows
NO3, mg/l
25
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 12
MONTH

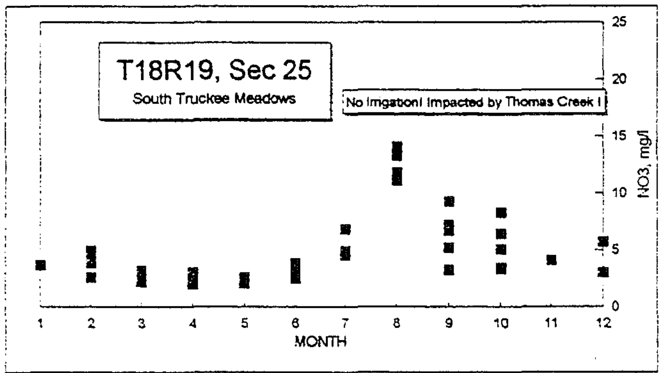

T18R20, Sec 29
South Truckee Meadows
No irrigation signal visible !
Streamflow impacts in winter and spring !
TDS, mg/l
2000
1500
1000
500
0
1 2 3 4 5 6 7 8 9 10 11 12
MONTH

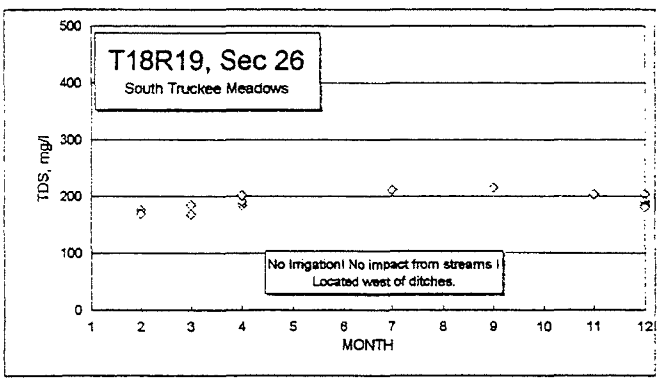

T18R20, Sec 29
South Truckee Meadows
No irrigation signal visible !
Streamflow impacts in winter and spring !
NO3, mg/l
25
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 12
MONTH

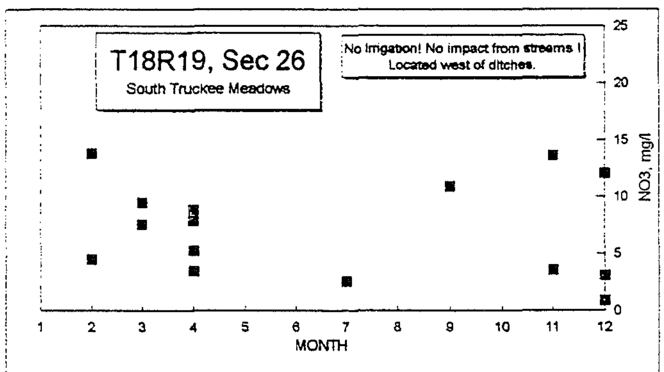

T18R20, Sec 30
South Truckee Meadows
Streamflow effects visible til late summer.
TDS, mg/l
MONTH

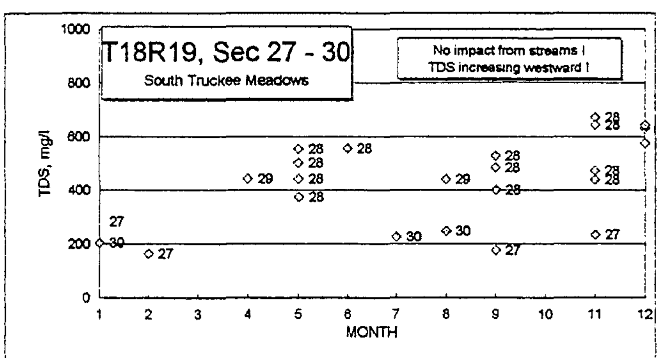

Streamflow effects visible til late summer.
T18R20, Sec 30
South Truckee Meadows
NO3, mg/l
MONTH

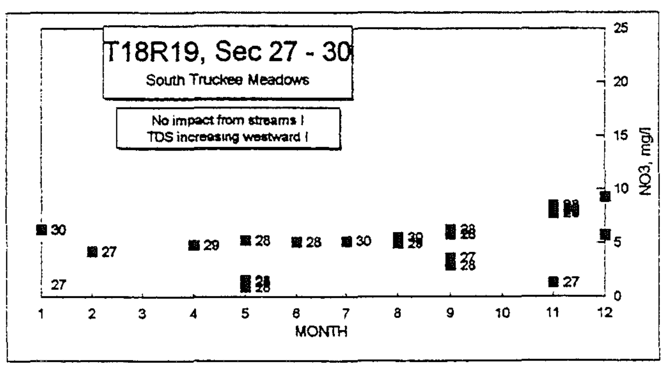

T18R19, Sec 25
South Truckee Meadows
No Irrigation! Impacted by Thomas Creek !
TDS, mg/l
MONTH


T18R19, Sec 25
South Truckee Meadows
No Irrigation! Impacted by Thomas Creek !
NO3, mg/l
MONTH


T18R19, Sec 26
South Truckee Meadows
No Irrigation! No impact from streams !
Located west of ditches.
TDS, mg/l
MONTH


T18R19, Sec 26
South Truckee Meadows
No Irrigation! No impact from streams !
Located west of ditches.
NO3, mg/l
MONTH


T18R19, Sec 27 - 30
South Truckee Meadows
No impact from streams !
TDS increasing westward !
TDS, mg/l
MONTH


T18R19, Sec 27 - 30
South Truckee Meadows
No impact from streams !
TDS increasing westward !
NO3, mg/l
MONTH

8.6 Secondary recharge calculated with seasonal TDS changes in domestic wells (spreadsheet results)

Secondary recharge calculated with seasonal TDS changes in domestic wells:

South Truckee Meadows

Depth of water applied:	4	ft	12000	afa	Inflow:
Assumed irrig. return flow to GW:	25%		6700	afa	water applied
ssumed total GW flow, based on SPC:	488	afa, calcul.	1700	afa	ditch losses:
	4380	afa	3000	afa	ditch return to STB C
			4971	afa	presumed sec. rech.
TDS in ditch:	87	mg/l	or 49%		
Assumed Specific Yield:	20%	from DCB, 2/13/98			sec. rech. TDS below mix TD
Constant for T calc., using spec. cap.:	235				95%
Assumed percent secondary recharge,	67%	due to evapotranspiration.			

	Presumed: Area irrig. acres	irrig. rech. ac-ft	gwflo at well depth ac-ft	max GW TDS mg/l	min GW TDS mg/l	**avg GW TDS mg/l**	max mix TDS mg/l	min mix TDS mg/l	**avg mix TDS mg/l**	estim. second. rechar. %	second. rechar. TDS mg/l	**Avg. sec. rech. ac-ft**	Expected Summ/Fall: WL rise ft
Irrigation:													
T18R19, Sec 06	255	255	20	270	220	**245**	140	140	**140**	65%	133	**306**	6
T18R19, Sec01	640	640	155	380	300	**340**	270	200	**235**	39%	223	**1383**	11
T18R19, Sec02	320	320	45	310	290	**300**	260	200	**230**	40%	219	**274**	4
T18R20, Sec 07	395	395	29	340	260	**300**	220	200	**210**	44%	200	**244**	3
T18R19, Sec 12	402	402	61	360	200	**280**	195	140	**168**	55%	159	**815**	10
T18R19, Sec 11	10	10	11	300	280	**290**	230	170	**200**	46%	190	**98**	49
T18R20, Sec 17	390	390	33	320	200	**260**	220	170	**195**	47%	185	**218**	3
T18R20, Sec 18	255	255	18	260	190	**225**	220	170	**195**	47%	185	**56**	1
T18R19, Sec 13	194	194	117	280	260	**270**	160	160	**160**	57%	152	**1604**	41
Total:	2861	2861	488 ac-ft				Irrigation recharge:			49%		**4999**	ac-ft, total

Percent of applied water, incl. ditch loss: 101%

T18R20, Sec 21 ?? East of Virginia St. No irrigation! Urbanization ??
T18R20, Sec 20 320 Irrig. phased out after 1991 ?? Cannot determine irrig. return flow with mixing !!
T18R20, Sec 19 No irrigated area. Affected by streamflow in spring, Whites Creek!

T18R20, Sec 21-: East of Virginia St.
T18R20, Sec 27 East of Virginia St. Summer dilution by Steamboat Creek ?
T18R20, Sec 28 No irrigation area data available. Ground water flow probably small due to bedrock nearby
T18R20, Sec 29 75 No Irrigation! Impacted by Whites Creek !

Total irrig. return to GW, calculated,
via seasonal TDS changes in domestic wells:

Secondary recharge from irrigation:

	T18R19 —>			<—T18R20
Sections:	2	1	6	5
1	274	1383	306	
2	98	815	244	
3		1604	56	218
4				
			sum:	4627 afa

Assuming total irrigation water provided annually: 20000 afa
Then total secondary recharge via fields and ditch loss is about: 4627
or 23%

Stream channel infiltration:

	Presumed: Area irrig. acres	irrig. rech. ac-ft	gwflo at well depth ac-ft	Background: max GW TDS mg/l	min GW TDS mg/l	**avg GW TDS mg/l**	Streams: max mix TDS mg/l	min mix TDS mg/l	**avg mix TDS mg/l**	Stream rechar. TDS mg/l	Avg. sec. rech. ac-ft	
T18R19, Sec 06	255	255	20	270	220	**245**	130	130	**130**	125	469	Thomas & Dry C.
T18R19, Sec01	640	640	155	380	300	**340**	190	300	**245**	150	155	Dry Crk.
T18R19, Sec02	320	320	45	310	290	**300**	200	260	**230**	150	39	Dry Crk.
			0									
T18R20, Sec 07	395	395	29	340	260	**300**	220	200	**210**	100	23	Thomas Cr.
T18R19, Sec 12	402	402	61	360	200	**280**	195	140	**168**	150	390	Dry Crk.
T18R19, Sec 11	10	10	11	300	280	**290**	230	170	**200**	150	20	Dry Crk.
			0									
T18R20, Sec 17	390	390	33	320	200	**260**	130	210	**170**	48	24	Whites Cr.
T18R20, Sec 18	255	255	18	260	190	**225**	200	200	**200**	100	5	Thomas Cr.
T18R19, Sec 13	194	194	117	280	260	**270**	200	200	**200**	100	82	Thomas Cr.
Total:	2861	2861	488	ac-ft			Stream recharge:				1207	

Secondary recharge from streams:

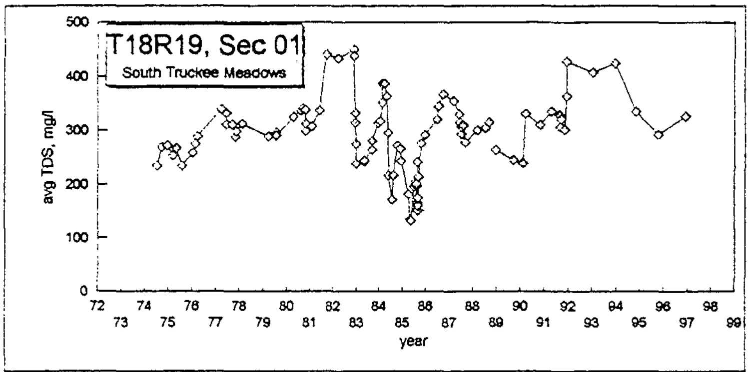
	T18R19 —>		<—T18R20	
Sections:	2	1	6	5
1	39	155	469	
2	20	390	23	
3		82	5	24
4				
			sum:	1207 afa

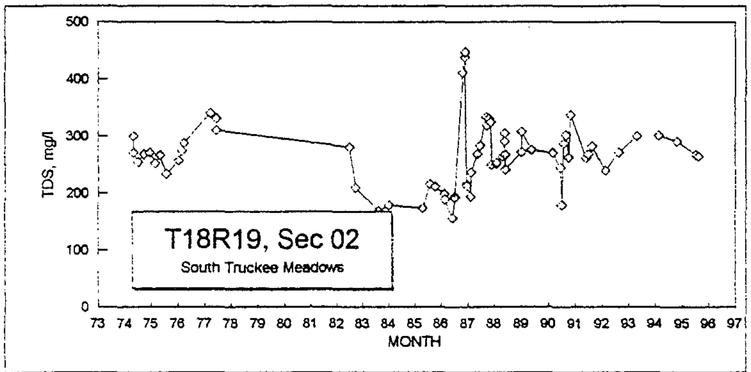
Transmissivities, calculated from specific capacities:

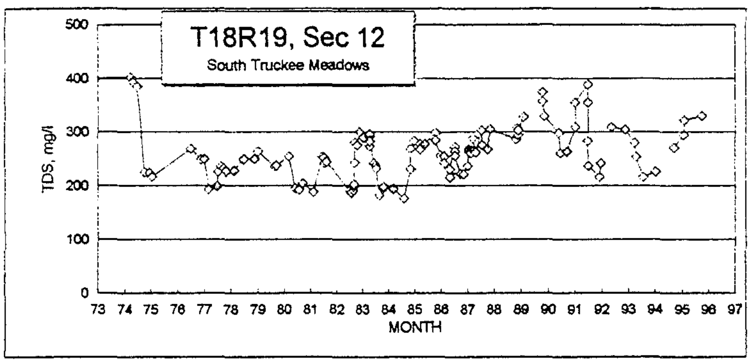
Calculated with Theis' method. Constant used: 235
Data from Dale Bugenig, CES

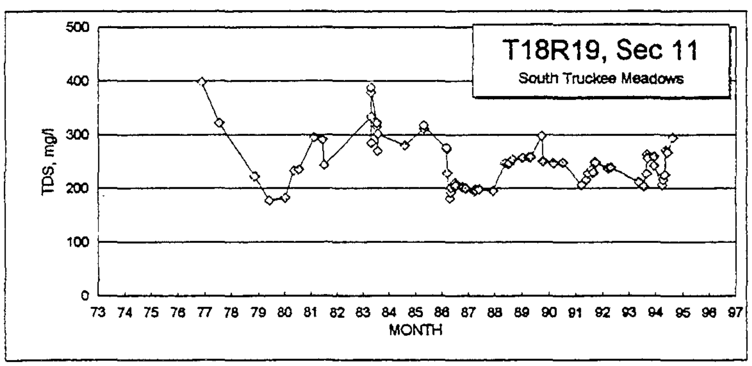
Section	Transmissivities: estimated: gpd/ft	gpd/ft	gpd/ft	No of wells	max gpm	min gpm	avg gpm	Cs min gpm/ft	Cs avg gpm/ft	Cs max gpm/ft
T18R19, Sec 06	82	160	235	2	55	3	29	0.35	0.68	1
T18R19, Sec01	40	1645	13207	21	450	12	62.9	0.17	7	56.2
T18R19, Sec02	31	282	881	18	100	4	38.2	0.13	1.2	3.75
T18R20, Sec 07	9	303	2938	27	325	10	53.7	0.04	1.29	12.5
T18R19, Sec 12	19	430	2820	26	110	10	37.7	0.08	1.83	12
T18R19, Sec 11	24	68	146	12	60	12	29.9	0.1	0.29	0.62
T18R20, Sec 17	19	230	1175	7	55	13	30.4	0.08	0.98	5
T18R20, Sec 18	16	129	783	14	80	10	31.3	0.07	0.55	3.33
T18R19, Sec 13	19	731	4700	14	50	10	27.9	0.08	3.11	20

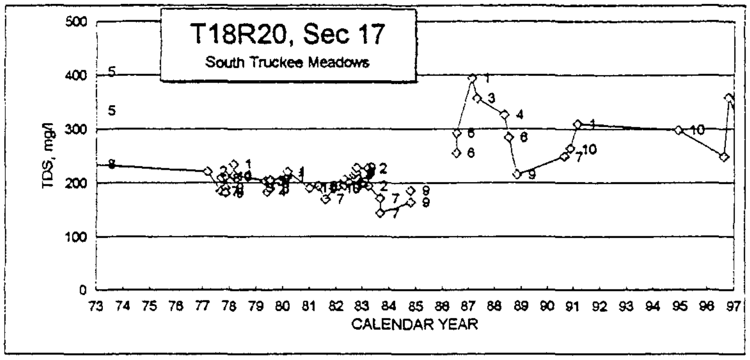
8.7 TDS changes in individual sections ground water

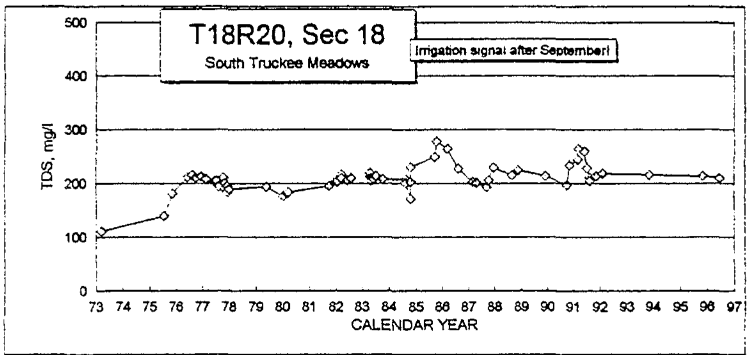

T18R19, Sec 01
South Truckee Meadows
avg TDS, mg/l
year

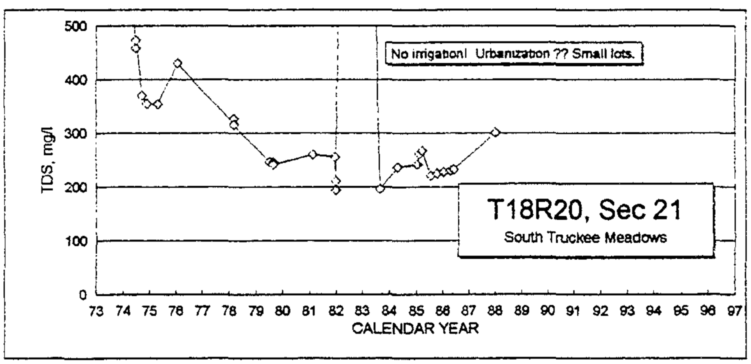

T18R19, Sec 02
South Truckee Meadows
TDS, mg/l
MONTH

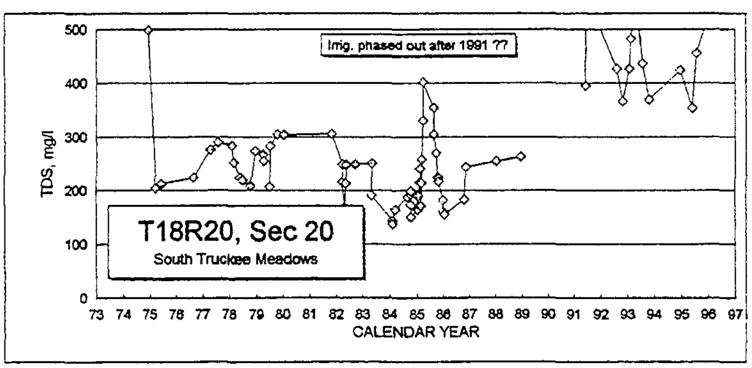

T18R19, Sec 12
South Truckee Meadows
TDS, mg/l
MONTH

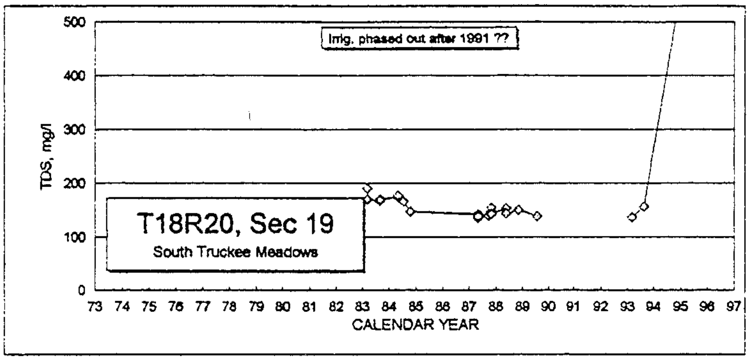

T18R19, Sec 11
South Truckee Meadows
TDS, mg/l
MONTH


T18R20, Sec 17
South Truckee Meadows
TDS, mg/l
CALENDAR YEAR

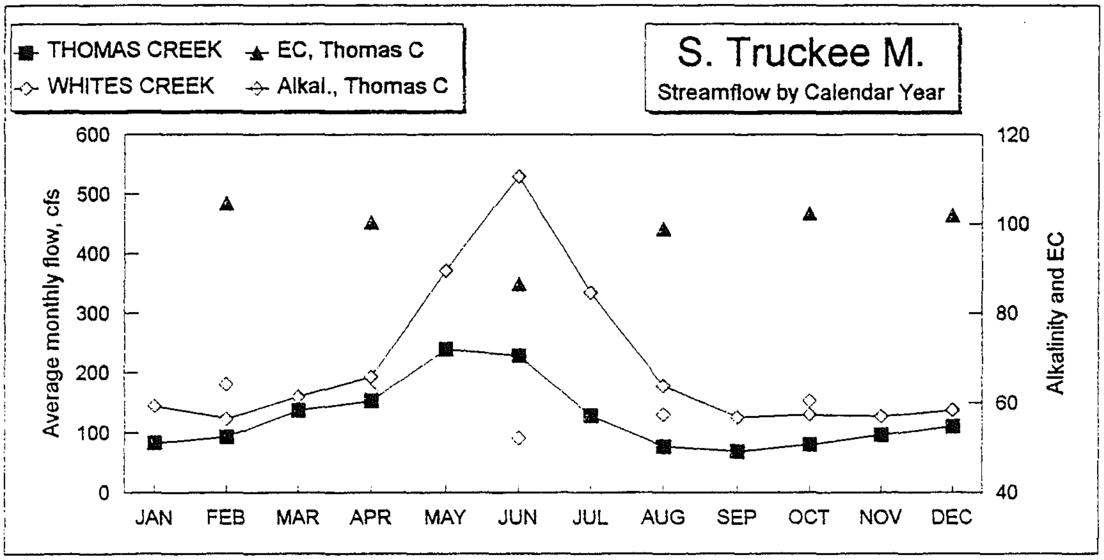

T18R20, Sec 18
South Truckee Meadows
Irrigation signal after September!
TDS, mg/l
CALENDAR YEAR

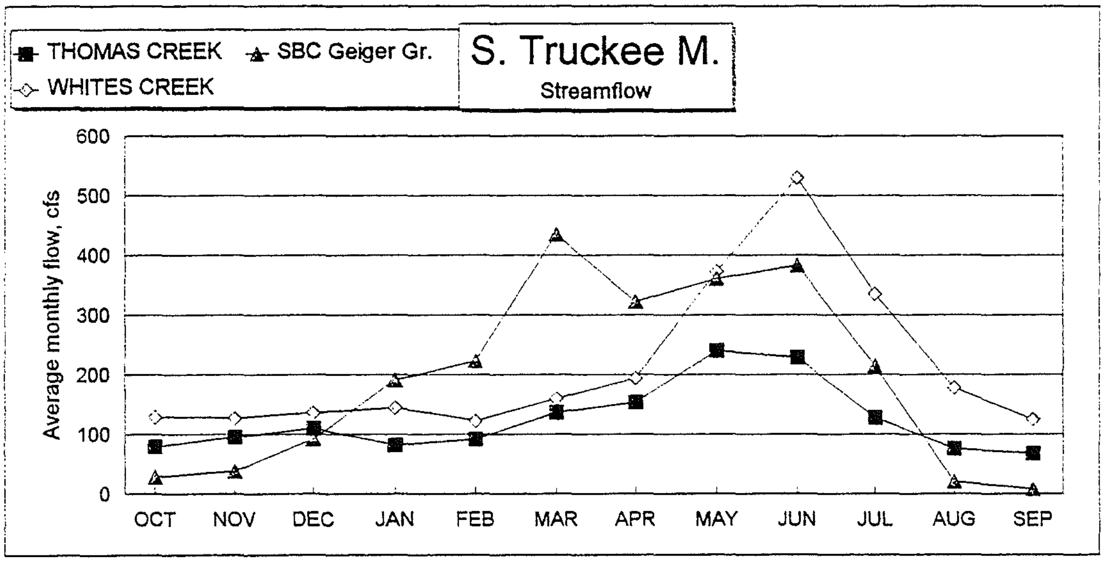

No irrigation! Urbanization ?? Small lots.
T18R20, Sec 21
South Truckee Meadows
TDS, mg/l
CALENDAR YEAR

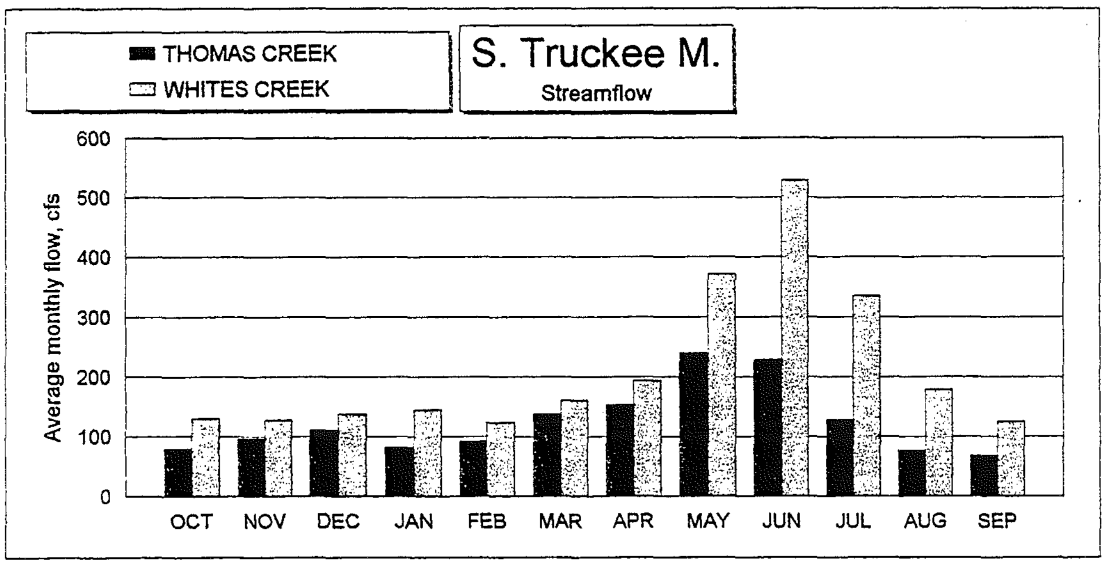

Irrig. phased out after 1991 ??
T18R20, Sec 20
South Truckee Meadows
TDS, mg/l
CALENDAR YEAR

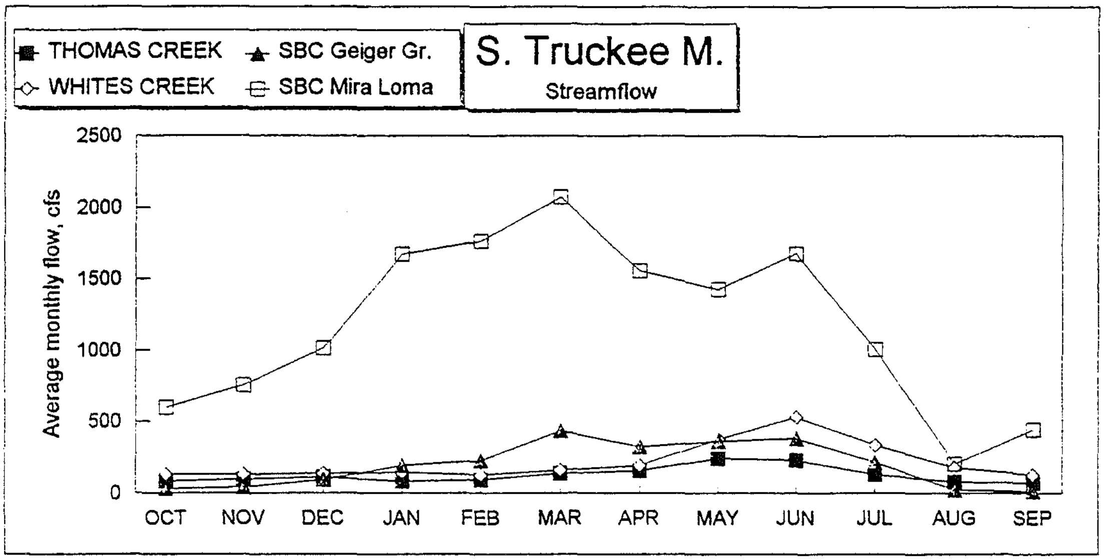

Irrig. phased out after 1991 ??
T18R20, Sec 19
South Truckee Meadows
TDS, mg/l
0
100
200
300
400
500
73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97
CALENDAR YEAR

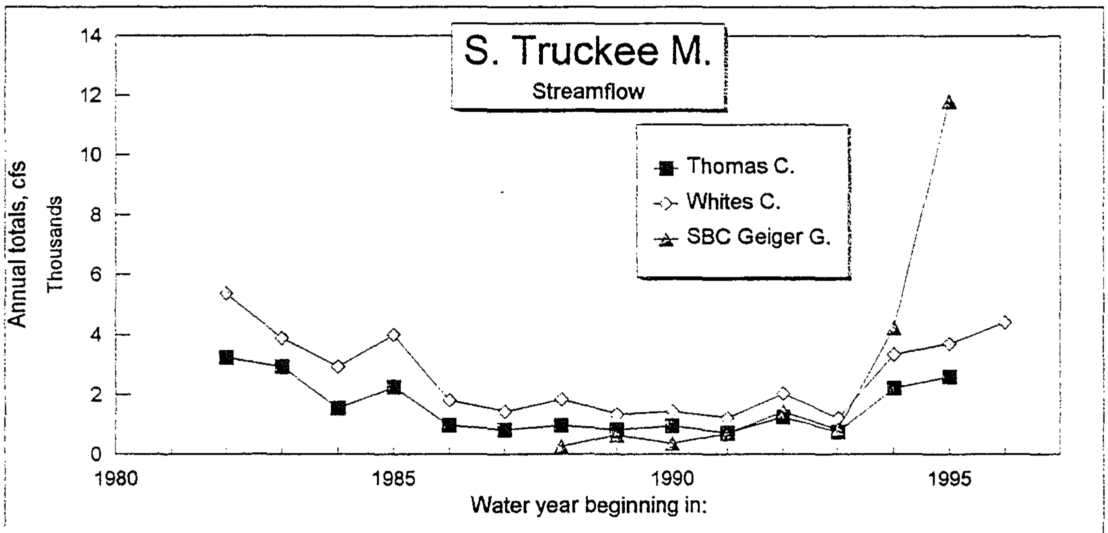
8.8 Streamflow data

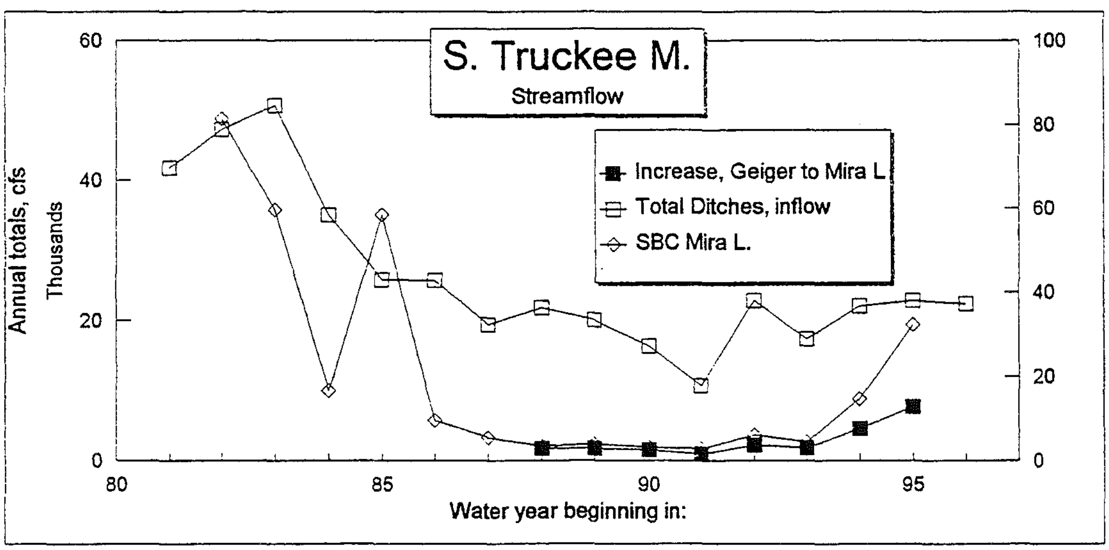

THOMAS CREEK
EC, Thomas C
WHITES CREEK
Alkal., Thomas C
S. Truckee M.
Streamflow by Calendar Year
Average monthly flow, cfs
Alkalinity and EC
600
500
400
300
200
100
0
120
100
80
60
40
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

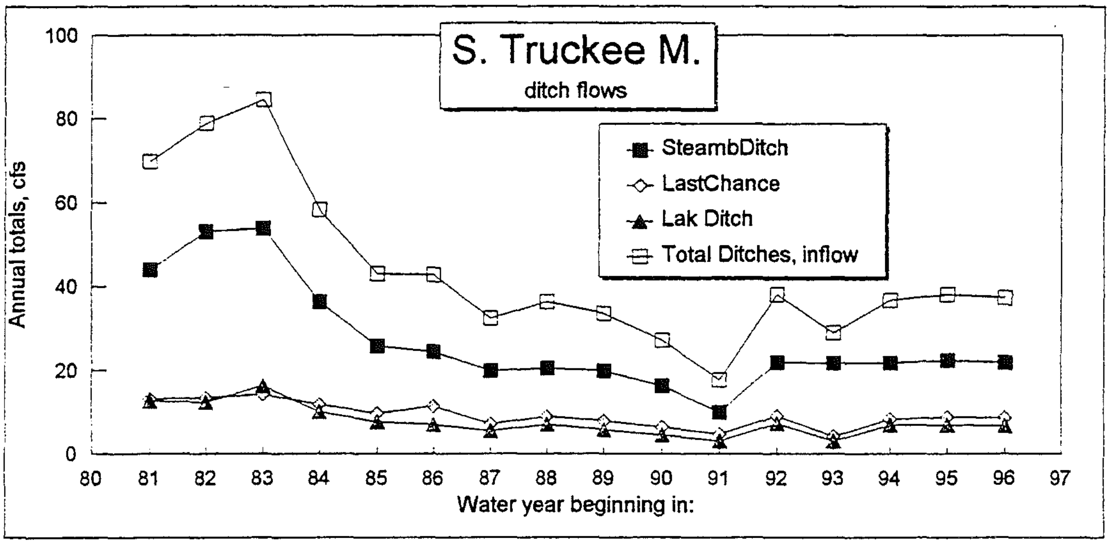

THOMAS CREEK
SBC Geiger Gr.
WHITES CREEK
S. Truckee M.
Streamflow
Average monthly flow, cfs
600
500
400
300
200
100
0
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP


THOMAS CREEK
WHITES CREEK
S. Truckee M.
Streamflow
Average monthly flow, cfs
600
500
400
300
200
100
0
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP


THOMAS CREEK
SBC Geiger Gr.
WHITES CREEK
SBC Mira Loma
S. Truckee M.
Streamflow
Average monthly flow, cfs
2500
2000
1500
1000
500
0
OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP


S. Truckee M.
Streamflow
Thomas C.
Whites C.
SBC Geiger G.
Annual totals, cfs
Thousands
14
12
10
8
6
4
2
0
1980
1985
1990
1995
Water year beginning in:


S. Truckee M.
Streamflow
Increase, Geiger to Mira L
Total Ditches, inflow
SBC Mira L.
Annual totals, cfs
Thousands
60
40
20
0
100
80
60
40
20
0
80
85
90
95
Water year beginning in:


S. Truckee M.
ditch flows
SteambDitch
LastChance
Lak Ditch
Total Ditches, inflow
Annual totals, cfs
100
80
60
40
20
0
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
Water year beginning in:

9 Appendix B: STM Water chemistry Data Files

File names and contents:	
files	**Explanation**
wq-dom1	seq no 1 - 100, domestic wells, seq no 1001 - 1103 STMGID wells
wq-dom2	seq no 101 - 247, domestic wells, from Washoe County Health Lab
wq-dom3	seq no 400 - 743 domestic wells., from Washoe County Health Lab
wq-dom4	seq 750 - 872 domestic wells, from WC Health Lab
wqdata2	seq no 750 - 872 wells; and 101 - 247, domestic wells
wq-sppc	seq no 2001 - 2024 well avaerages, 2030 - 2165 yearly/monthly SPPC wells, 3001 - 3132 effluent.
wq-domes	all domestic wells, finalized
wq-munic	all municipal wells, et al. finalized
dri-wads.wk4	all DRI Wads data from Fordham (1982), domestic wells, seq. No 4000 to In these data, all sets with epm balances off by more than 15% were eliminated.
wq-stmgi.wk4	all STMGID wells, data from Washoe County, seq no 1001 - 1103 STMGID wells
wq-diss.wk4	data from Bohm, 1982, Dissertation; These are data from Bateman and Scheibach (1977), WADS, and Guyton & Assoc. (1978), Merritt, et al. (1978), includes data from entire Truckee Meadows. Only data in the STM project were selected out of this.

Sequential number codes, explanation (WCA - water chemistry analysis)	
WCA No's	**types of data**
1 - 999	domestic wells
1000 - 1999	STMGID wells
2000 - 2999	SPPCo wells, averages and monthly values
3000 - 3999	SPPCo data, effluent only
4000 - 4999	domestic wells from Washoe Water Protection Association. Fordham 1982, DRI-WADS data
5000 -	Bohm, 1982, Dissertation. Bateman and Scheibach (1977), WADS, Guyton & Ass. (1978)

9.1 Data Types

A few comments are in order about how data were entered into the common data base used for this project.

9.1.1 Water chemistry analysis (WCA) numbers

Every data set (record) was given a WCA number (water chemistry analysis), written onto the source data, e.g. the lab result sheets or the data tables in the reports. This made it easier to correct errors or cross-check unusual occurrences.

9.1.2 Alkalinity and HCO3:

In the SPPCo. data provided in their 1997 report (Inorganic WQ Data), it is not clear from these data tables (original report) whether alkalinity is given as HCO3 or CaCO3. This would make a big difference in the epm balance. It is here assumed that alkalinity was given as CaCO3. In this data base it was converted to HCO3.

In the domestic wells, evidently HCO3 is given as HCO3, but alkalinity is given as CaCO3. In this data base everything is taken in as HCO3.

9.1.3 Nitrate:

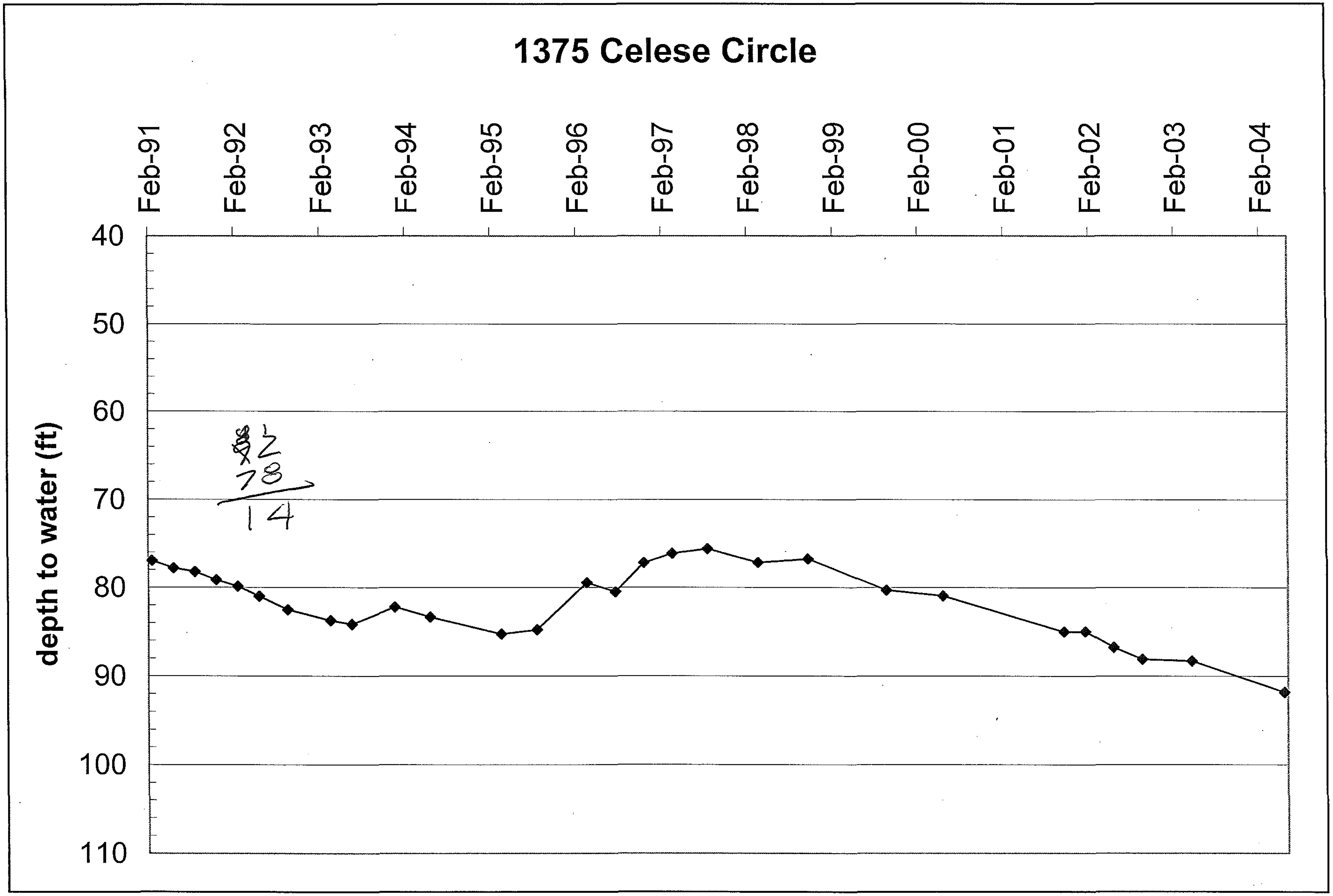
Nitrate in the domestic wells is often given as mg/l nitrogen. In this data base everything was converted to nitrate. For future reference it would be good if the labs remain consistent in how they present their data to avoid unnecessary pitfalls in reporting. We sometimes wonder if the data are entered correctly if the labs continue switching their reporting units, without much rhyme or reason.

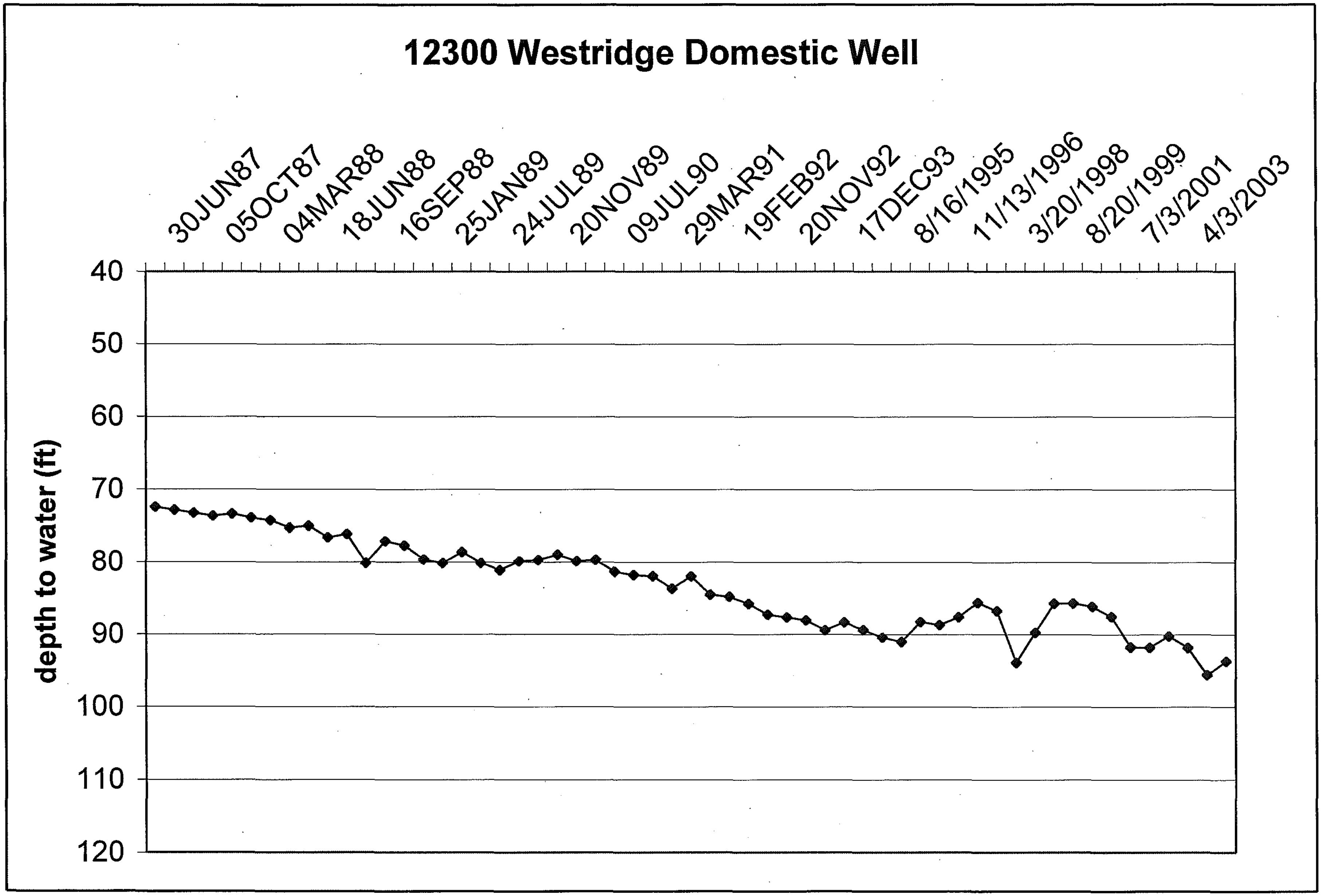
9.1.4 Lab TDS values

Lab TDS values generally underestimate the actual TDS. This can be seen when plotting ratio of sumTDS/labTDS versus alkalinity. The higher the alkalinity the greater the ratio (up to 40% or more), suggesting HCO3 lost due to CO2 escaping during the lab procedure, particularly when much alkalinity is present.

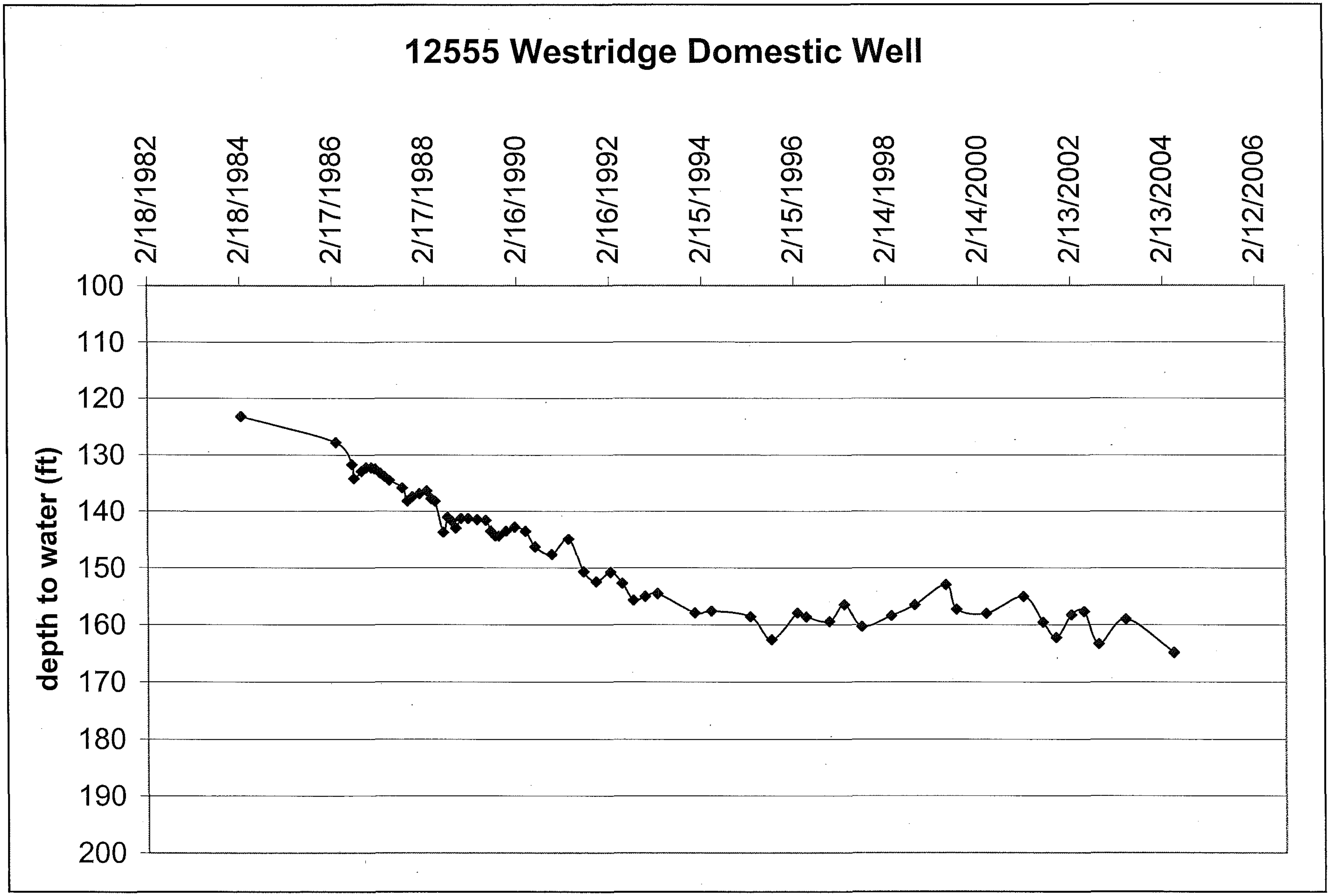
9.2 The epm-balance

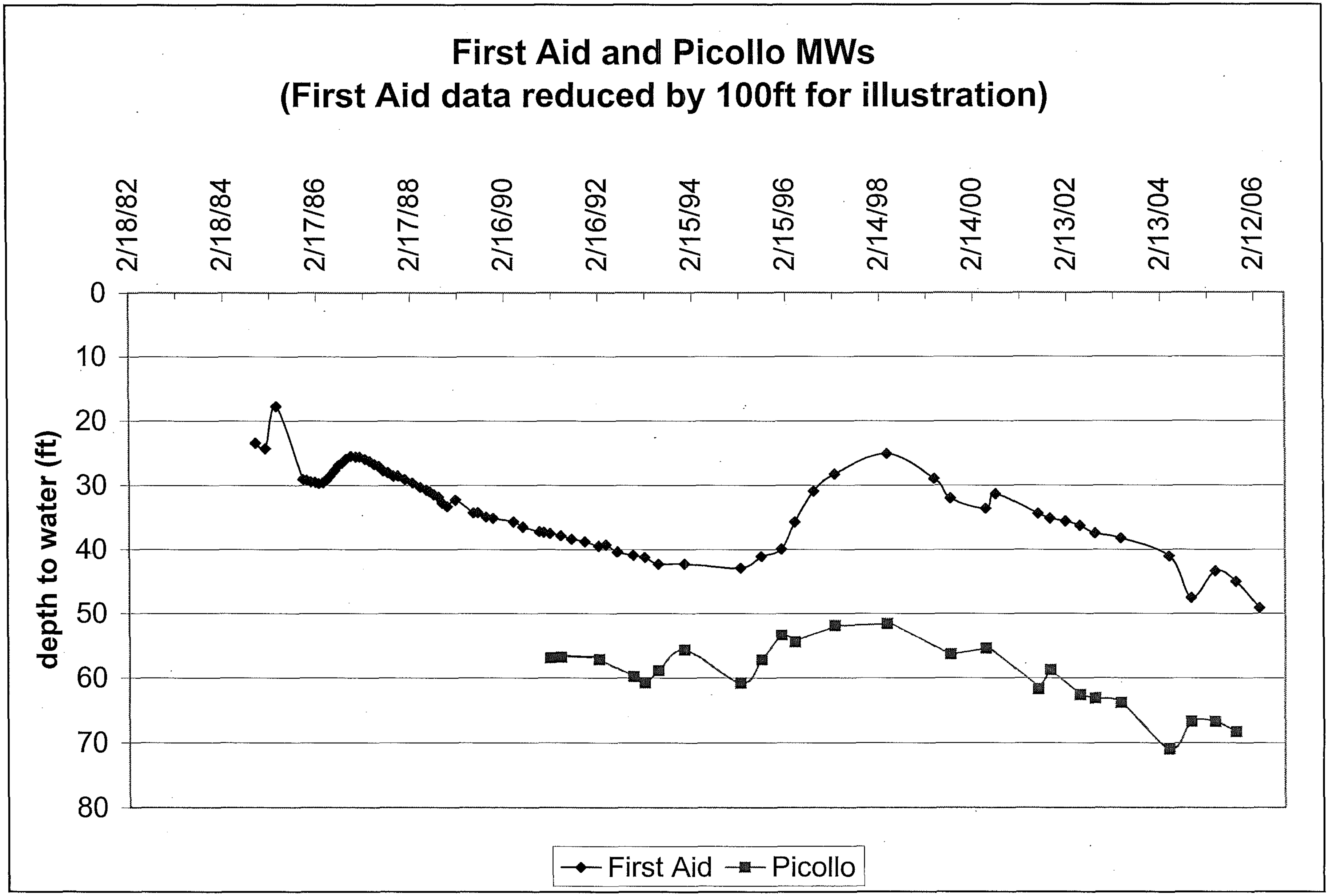
The epm balance was calculated for all data sets, whenever meaningful, i.e. for incomplete data sets it was not calculated. Balances were then visually inspected for unreasonable values, and thereby checked for input errors.


1375 Celese Circle
depth to water (ft)
40
50
60
70
80
90
100
110
Feb-91
Feb-92
Feb-93
Feb-94
Feb-95
Feb-96
Feb-97
Feb-98
Feb-99
Feb-00
Feb-01
Feb-02
Feb-03
Feb-04
92
78
14

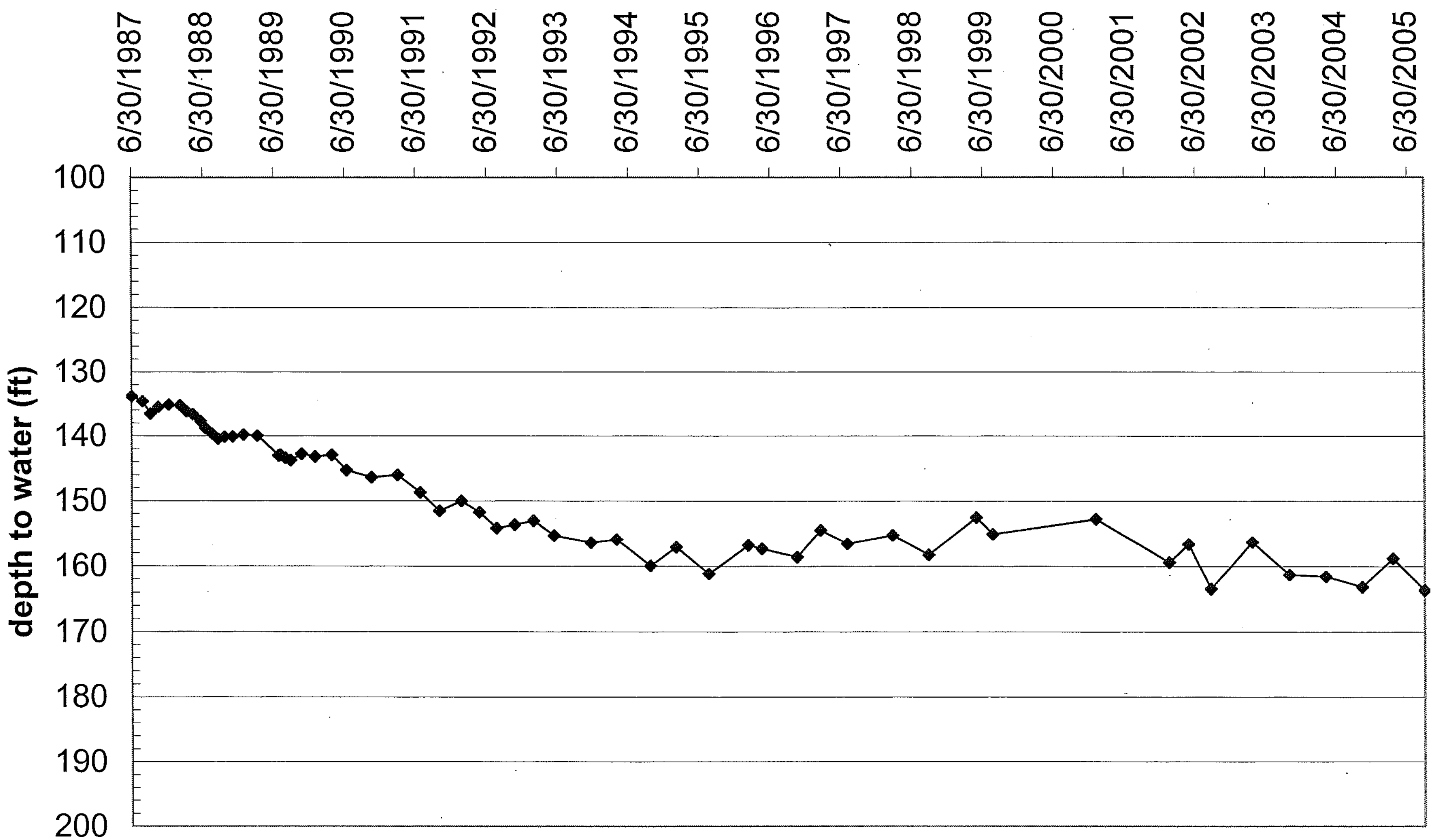


12300 Westridge Domestic Well
depth to water (ft)
40
50
60
70
80
90
100
110
120
30JUN87
05OCT87
04MAR88
18JUN88
16SEP88
25JAN89
24JUL89
20NOV89
09JUL90
29MAR91
19FEB92
20NOV92
17DEC93
8/16/1995
11/13/1996
3/20/1998
8/20/1999
7/3/2001
4/3/2003

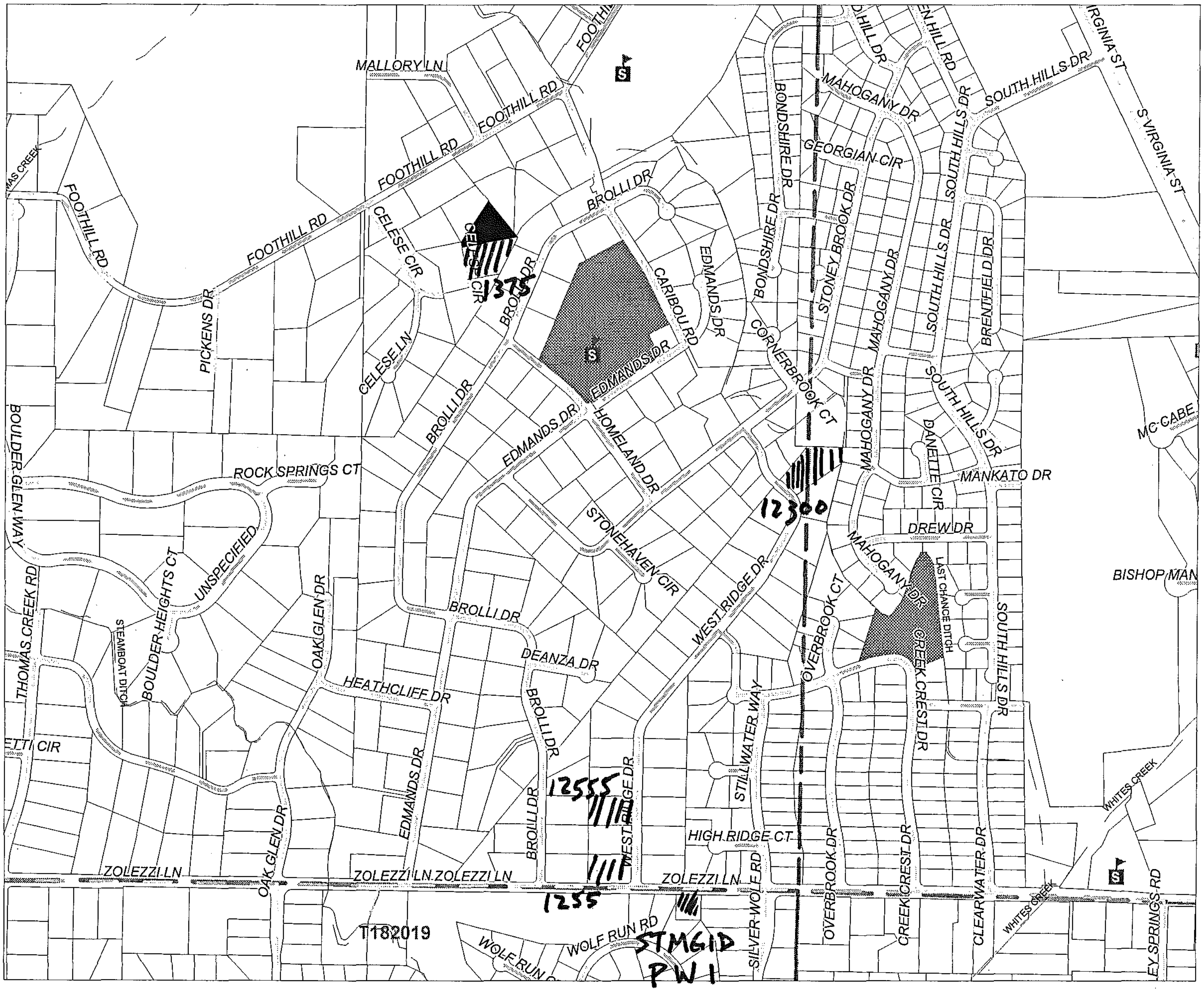

12555 Westridge Domestic Well
depth to water (ft)
100
110
120
130
140
150
160
170
180
190
200
2/18/1982
2/18/1984
2/17/1986
2/17/1988
2/16/1990
2/16/1992
2/15/1994
2/15/1996
2/14/1998
2/14/2000
2/13/2002
2/13/2004
2/12/2006


First Aid and Picollo MWs
(First Aid data reduced by 100ft for illustration)
depth to water (ft)
0
10
20
30
40
50
60
70
80
2/18/82
2/18/84
2/17/86
2/17/88
2/16/90
2/16/92
2/15/94
2/15/96
2/14/98
2/14/00
2/13/02
2/13/04
2/12/06
First Aid
Picollo

1255 Zolezzi Lane



Location map of domestic well hydrographs



SCALE 1 : 10,541

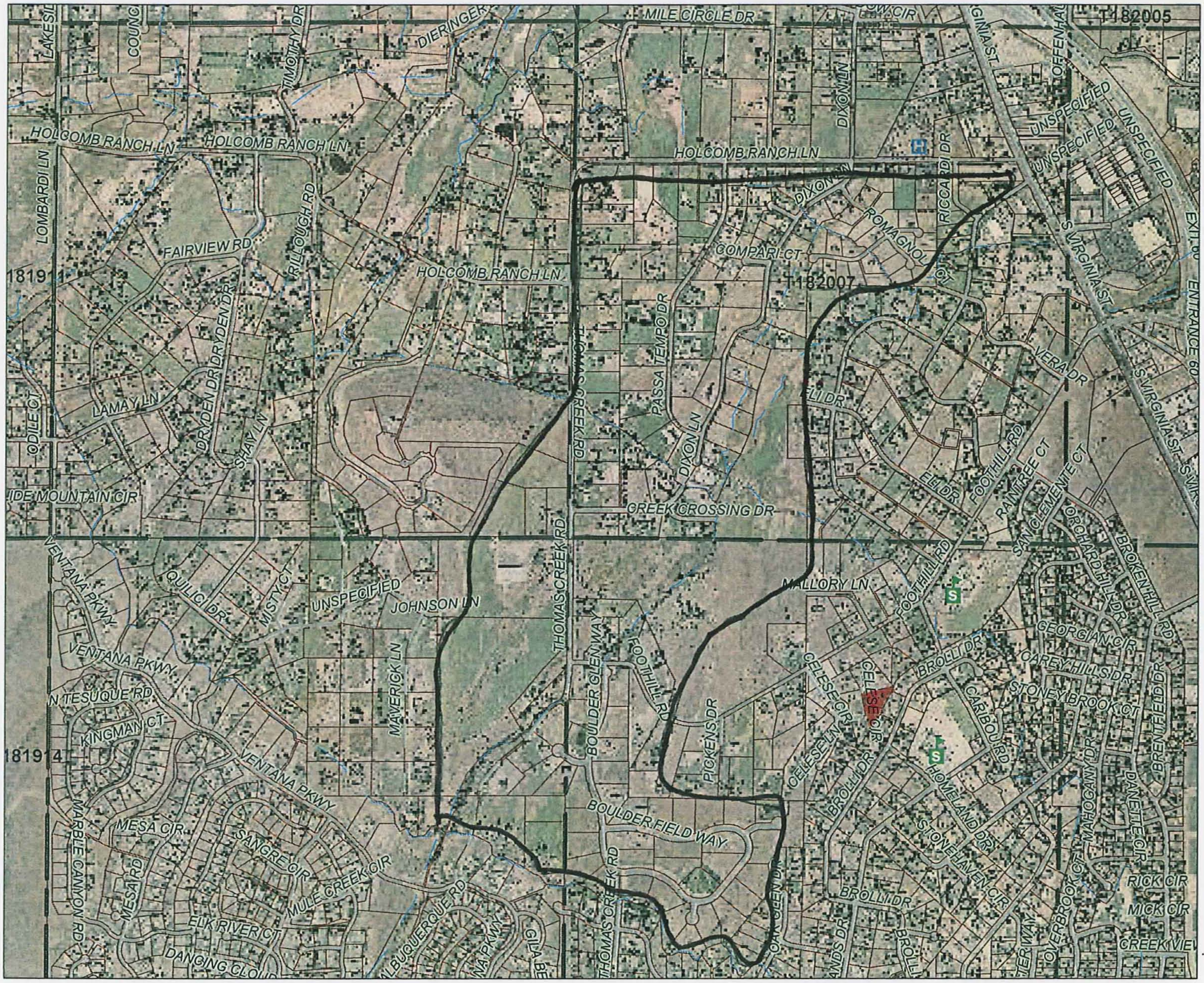
500 0 500 1,000 1,500

FEET

Department of Water Resources

N

Approximate area of active irrigation in 1984

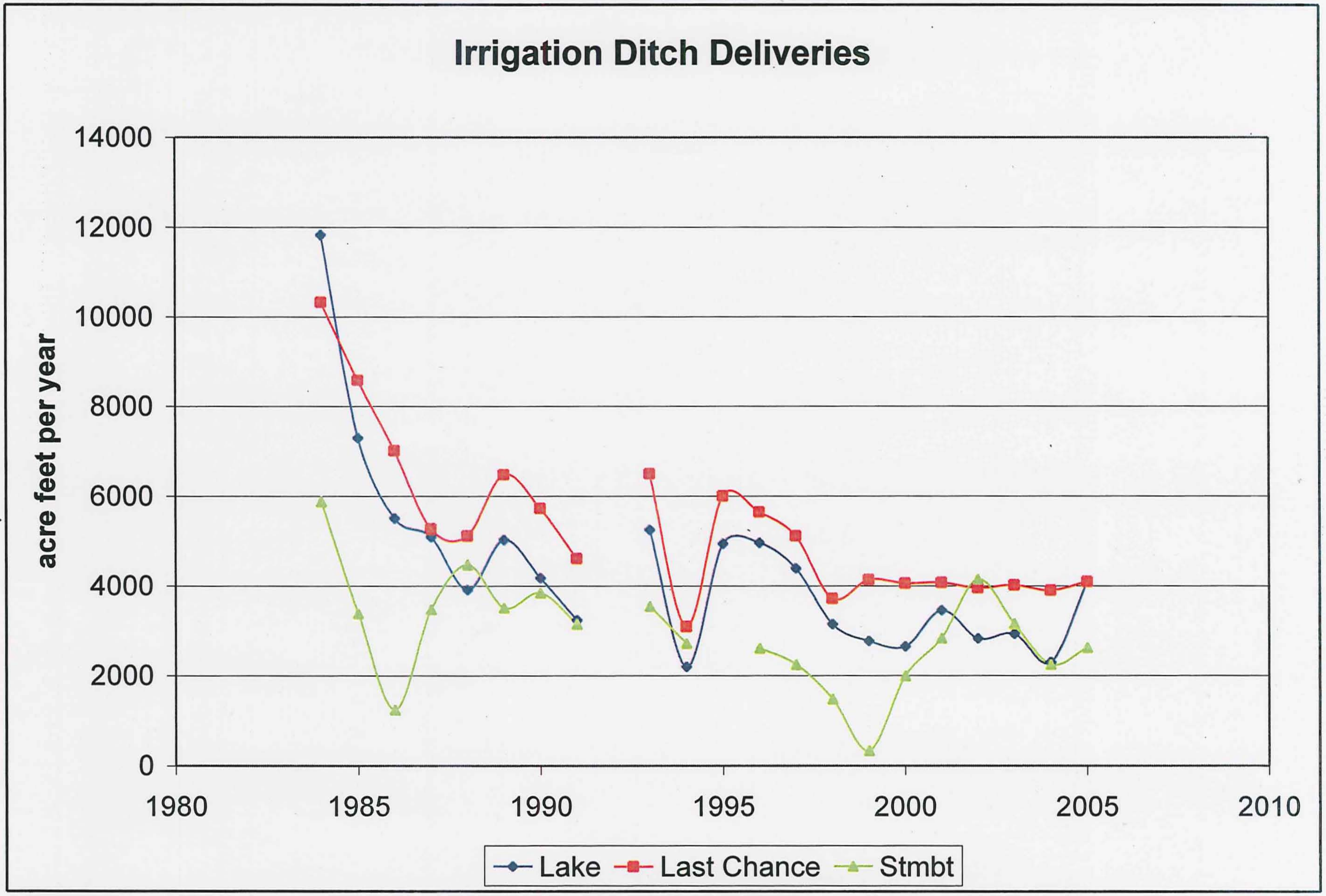


SCALE 1 : 18,378

1,000 0 1,000 2,000 3,000
FEET

Department of Water Resources

N


Irrigation Ditch Deliveries
acre feet per year
14000
12000
10000
8000
6000
4000
2000
0
1980
1985
1990
1995
2000
2005
2010
Lake
Last Chance
Stmbt