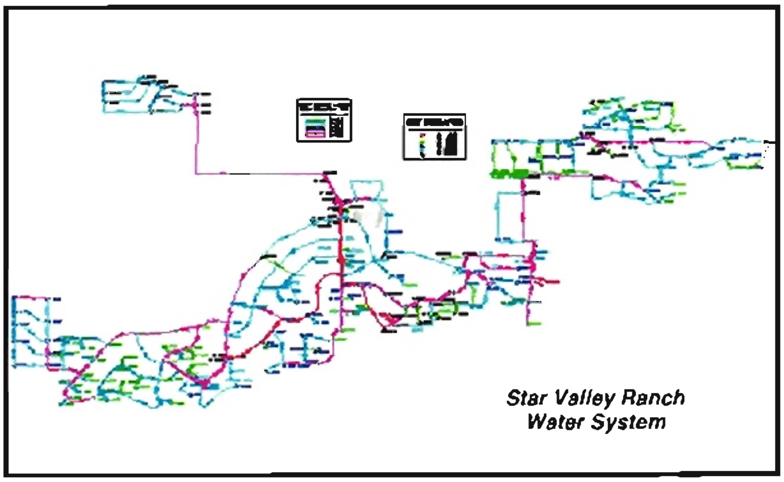
SUMMARY INVESTIGATION OF THE

STAR VALLEY RANCH WATER SYSTEM

March
2004



Submitted to:

STAR VALLEY RANCH ASSOCIATION
PO Box 159, Thayne, Wyoming 83127

PRELIMINARY

Prepared by:

FORSGREN ASSOCIATES / INC.

649 Front Street #201, Evanston, Wyoming 92930 307-789-6735

SUMMARY INVESTIGATION OF THE STAR VALLEY RANCH WATER SYSTEM

TABLE OF CONTENTS

SECTION 1.0
INTRODUCTION

1.1 PROJECT OVERVIEW

The Star Valley Ranch resort was initially developed during the early 1970's. By the mid 1990's, it consisted of 21 plats totaling 2052 lots. Star Valley Ranch also includes 36 holes of golf, two swimming pools, tennis courts, etc.

The initial developer, Leisure Valley, Inc., subsequently sold out their lots within the subdivision. This transition of ownership raised questions relative to the maintenance responsibility and ownership of water system infrastructure and the division of water rights. Those issues were ultimately addressed in a settlement agreement between Leisure Valley, Inc. (LVI) and Star Valley Ranch Association (SVRA) dated August 10, 1998.

Today, SVRA is faced with increasingly serious water system infrastructure problems. These problems include:

- Aging and Deteriorated Piping
- Limited Legal and Physical Water Supply
- Increasingly Regulatory Requirements
- Population Growth
- Limited System Funding for Maintenance and Capital Improvement Needs
- Etc.

1.2 STUDY OBJECTIVES

This study is intended to provide SVRA with a brief summary overview of their existing water system with the goal of identifying and prioritizing future capital project needs. Elements of consideration included:

- Supply Adequacy
- Pipeline Infrastructure
- Storage Adequacy
- System Operation and Reliability

1.3 PROJECT APPROACH

The scope of this study is relatively limited due to budgetary constraints. The primary focus involved he review of previous system reports and records. It is not the intent of this effort to critique those reports, but rather to utilize the information contained therein to provide SVRA with a clearer understanding of the status of the water system and needs.
As part of this investigation, current and former system operators were interviewed. Their help and input was very helpful and very much appreciated.

The existing water system was digitally modeled using WATERCAD software as part of this study. It was felt that modeling the provides a clearer understanding of the current system. In addition, this model will provide SVRA with a very valuable tool for future capital improvement planning and design.

1.4 PREVIOUS STUDIES AND REPORTS

Previous studies and reports referenced herein include:

1. Sunrise Engineering, Inc., Preliminary Engineering Report Evaluating Culinary Water Availability, Needs & Rights, December 1994

2. Jorgensen Engineering and Land Surveying, P.C., Star Valley Ranch Association Water System Master Plan, November 1996.

3. Forsgren Associates, Inc. & Star Valley Ranch Association., Capacity Assessment Worksheet for the Star Valley Ranch Water System to Demonstrate Capacity Development, August 1999.

4. TriHydro Corporation, Hydrogeologic Investigation of Green Canyon Spring, Star Valley Ranch Association, October 1999.

SECTION 2.0
EXISTING WATER SYTEM

The Star Valley Ranch Water System is schematically shown in Figures 2.1-5. System components are briefly described below and discussed more fully in the body of this report.

2.1 EXISTING SERVICE AREA POPULATION AND WATER USE

The water system service area is includes 2032 residential lots as defined in the approved Star Valley Ranch plats (See Figure 2.1). It is our understanding that there are currently 730 homes constructed. Based on a census survey conducted by Jorgensen in August of 1996, it was estimated that each residence average 3.3 persons (including guests) during the summer months. Assuming this continues to hold true, the estimated summertime occupancy of Star Valley Ranch can be calculated as 2409 persons.

2.2 WATER SUPPLY SOURCES

SVRA currently relies upon four water sources briefly described as follows:

2.3.1 Green Canyon Spring (or Stewart Spring)

This spring is the ranch's primary source of supply. This spring was developed in 1985. The Jorgensen study indicates spring yields varying between 150 and 1200 gpm seasonally. Peak flows typically occur in the months of June and July. January and February are typically the lowest flows.

A hydrogeologic investigation of the Green Canyon Spring was conducted by Trihydro Corporation in 1999. That report concluded that the spring is considered a "Gallatin Limestone bed-rock-sourced spring." The water is of good quality. However, particulate tests also taken at that time indicate that there is a potential for the Green Canyon Spring collection system to be considered "under direct surface water influence" by USEPA. These tests also showed evidence of probable rodent access to the collection system. Based on these findings, we believe it would be prudent for SVRA to budget for redevelopment of the spring site in the future in the event that water quality problems become evident.

2.3.2 Prater Canyon Spring

This spring was developed in 1972. The Jorgensen study indicates spring flows of between 100 and 500 gpm seasonally. As with the Green Canyon Spring, high flows typically occur in the early summer months and low flows occur in the early winter months.

2.3.3 Airstrip Well #1

This well, permitted as UW 90328, was constructed in 1993. Well depth is 545 feet. Static water level is 187 feet below ground surface. The casing is 8-inch to 300 feet where it telescopes to 6-inch. The well is gravel packed. Initial pump testing conducted in March or 1993 indicated sustainable yields of 690 gpm with only 14 feet of drawdown. A letter from Nelson Engineering dated July 7, 2000 indicates the well capacity is 290 gpm as currently configured. It is also our understanding that entrapped air likely associated with this well has been an on-going concern. Operation of the well is manual.

2.3.4 Cedar Creek No. 1 Well

This well was initially permitted as UW 37449 in the late 1970s. Correspondence from Nelson Engineering (July 2000) and more recently from Jorgensen Engineering (May 2003) indicate a well capacity of approximately 250 gpm. Operation of the well is manual.

2.3 SYSTEM STORAGE

SVRA currently has two storage tanks totaling 575,000 gallons as follows:

2.4.1 Green Canyon Tank

This 400,000 gallon tank was constructed in 1985. It is an above-ground, reinforced concrete structure. The overflow elevation is approximately 6515.

2.4.2 Prater Canyon Tank

This 175,000 gallon tank was constructed in 1977. It is a buried, reinforced concrete structure. The overflow elevation is approximately 6812.

Wyoming DEQ Chapter XII regulations require water systems serving in excess of 500,000 gallons on the design average daily demand to provide storage capacity of at least 25% of maximum daily demand (plus fire). Based on current estimated maximum demand of 1.7 MGD, this equates to a storage requirement of 420,000 gallons. The current storage capacity is, in our opinion, adequate to meet DEQ requirements.

2.4 CANYON TRANSMISSION PIPING and "INTER-CONNECT" LINE

Green Canyon Water is conveyed to from the springs through 7200 feet of 6-inch diameter PVC pipe constructed in 1985. Water is conveyed from Prater Canyon through a 6-inch diameter HDPE pipe reconstructed in 2001. It is worth noting that there is a 4-inch (and/or 2-inch) "inter-connect" pipe between the two systems installed in 1986. This pipe allows water to be transferred from one system to another. This is accomplished by operating valves and adjusting PRV's. In general, it is used to deliver water during high demand periods from the Green Canyon to the Prater Canyon system.

2.5 DISTRIBUTION PIPING

The initial system design required PVC piping throughout the system. However, steel pipe was often substituted for PVC. It is our understanding that portions of steel pipe have been selectively replaced subject to budgeting limitations. Figures 2.1-5 show line sizing and type based on available records and interviews with the previous system operator in 1999. Steel piping is highlighted in Figure 2.6 and is summarized in Table 2.1 below. This represents approximately 18% of the 167,000 feet of existing distribution piping.

Table 2.1
Existing Steel Piping

PIPE DIAMETER	ESTIMATED LENGTH
4-inch	19,500 feet
6-inch	7,800 feet
8-inch	2,000 feet

2.6 SERVICE METERS

The system is currently unmetered.

2.7 SYSTEM TELEMETRY AND CONTROL

The system is currently manually operated

2.8 FIRE PROTECTION

The existing system is generally not designed to incorporate fire protection. In accordance with Wyoming DEQ Chapter XII regulations, allowable fire flow is calculated based on maintaining a 20 psi residual system pressures during high demand (typically summer day) conditions. Computer modeling data graphically reflecting available fire flows throughout the system is shown in Figure 2.7. Wyoming DEQ requires that fire hydrants be placed on 6-inch or larger mainlines. Dead-end line with hydrants must be at least 8-inch in diameter (over 270 feet). Providing even nominal fire protection throughout the system would require extensive pipeline upgrades and would likely be cost prohibitive.

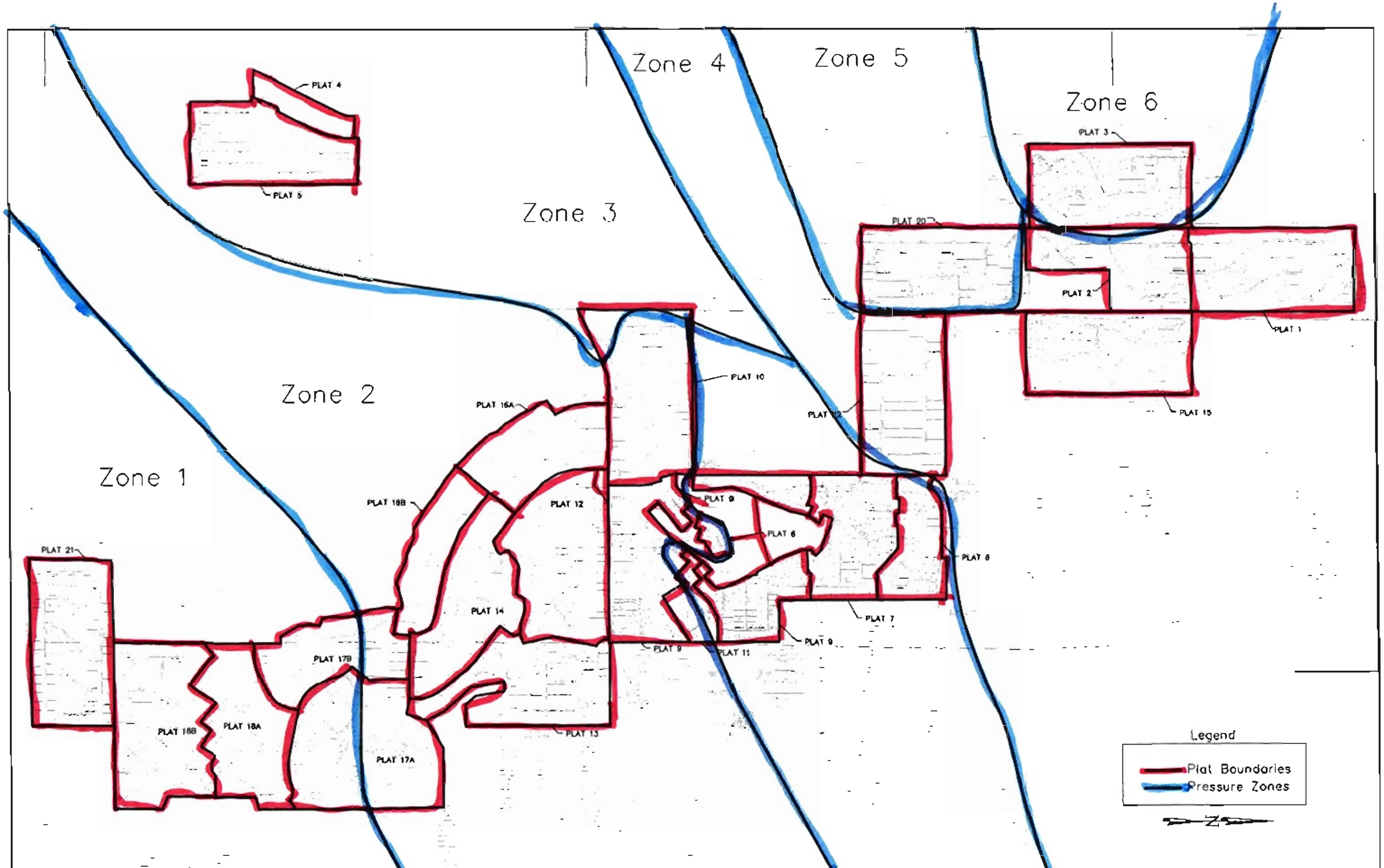
2.9 SYSTEM DISINFECTION

The Prater and Green Canyon Springs currently have no disinfection capability. The Airstrip Well facility is equipped with a simple hypochlorination system.

2.10 WATER QUALITY

In general, it appears that the SVRA water system has a good water quality history. We note that there were a series of bacteriological violations that occurred during the summer and fall of 2003. We believe this is was the result of an aggressive water quality testing program initiated by system operators at that time, in which water samples were taken almost exclusively from dead-end lines. It is our understanding that these lines were subsequently "shock" disinfected and that dead-end lines are now flushed regularly to correct the problem.

We are concerned about the lack of water supply redundancy in the system along with the lack of back-up disinfection capability for the spring sources. In the event of flooding, line breakage, or contamination, the lack of these facilities would represent a severe hardship on residents.

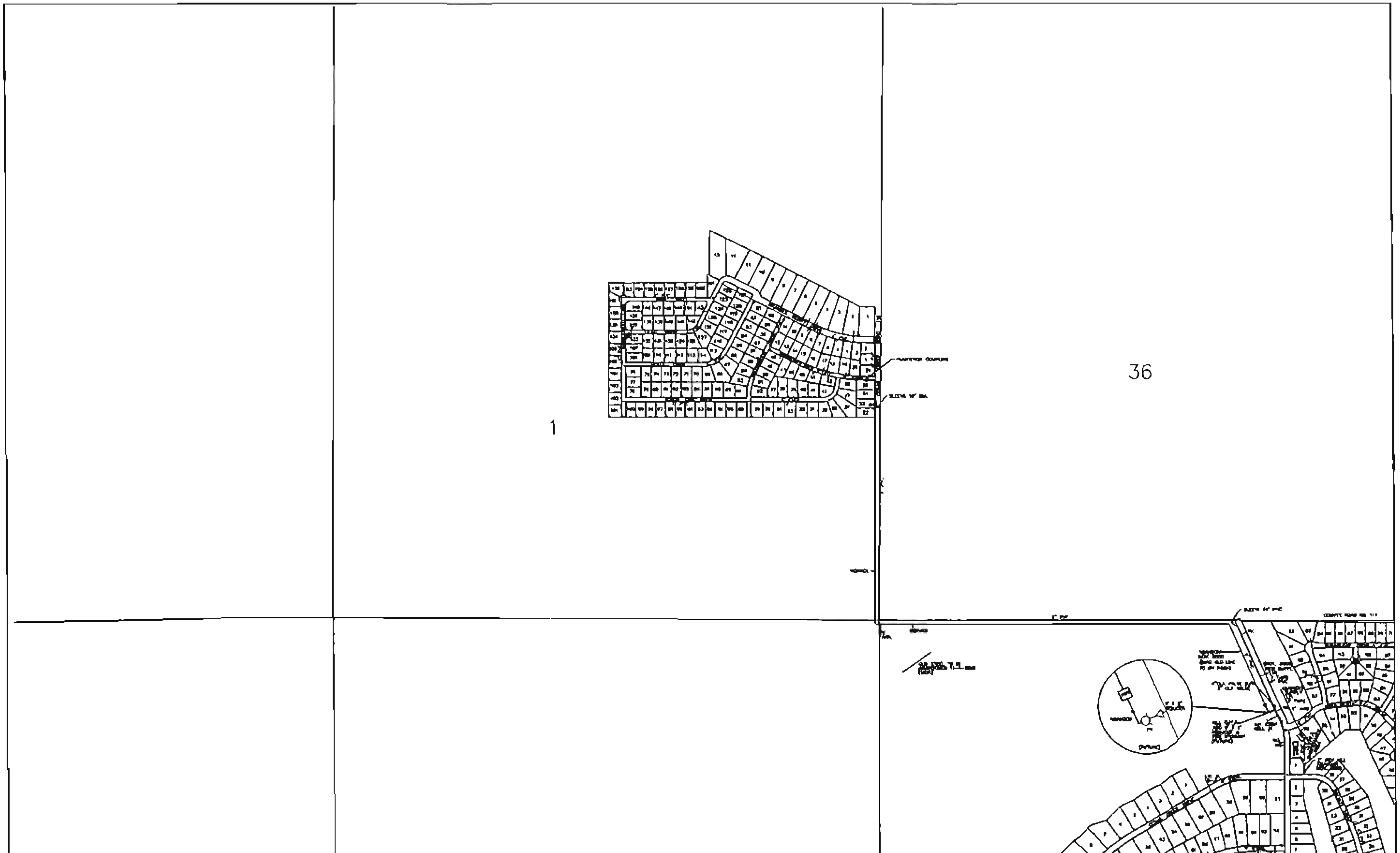


STAR VALLEY RANCH THAYNE, WYOMING	FORSGREN ASSOCIATES, INC. 370 EAST 500 SOUTH, SUITE #200 SALT LAKE CITY, UTAH 84111 (801) 364-4785	STAR VALLEY RANCH WATER SYSTEM PLAT MAP & PRESSURE ZONES	PROJECT NO. 05030213 SHEET NO. 2 1

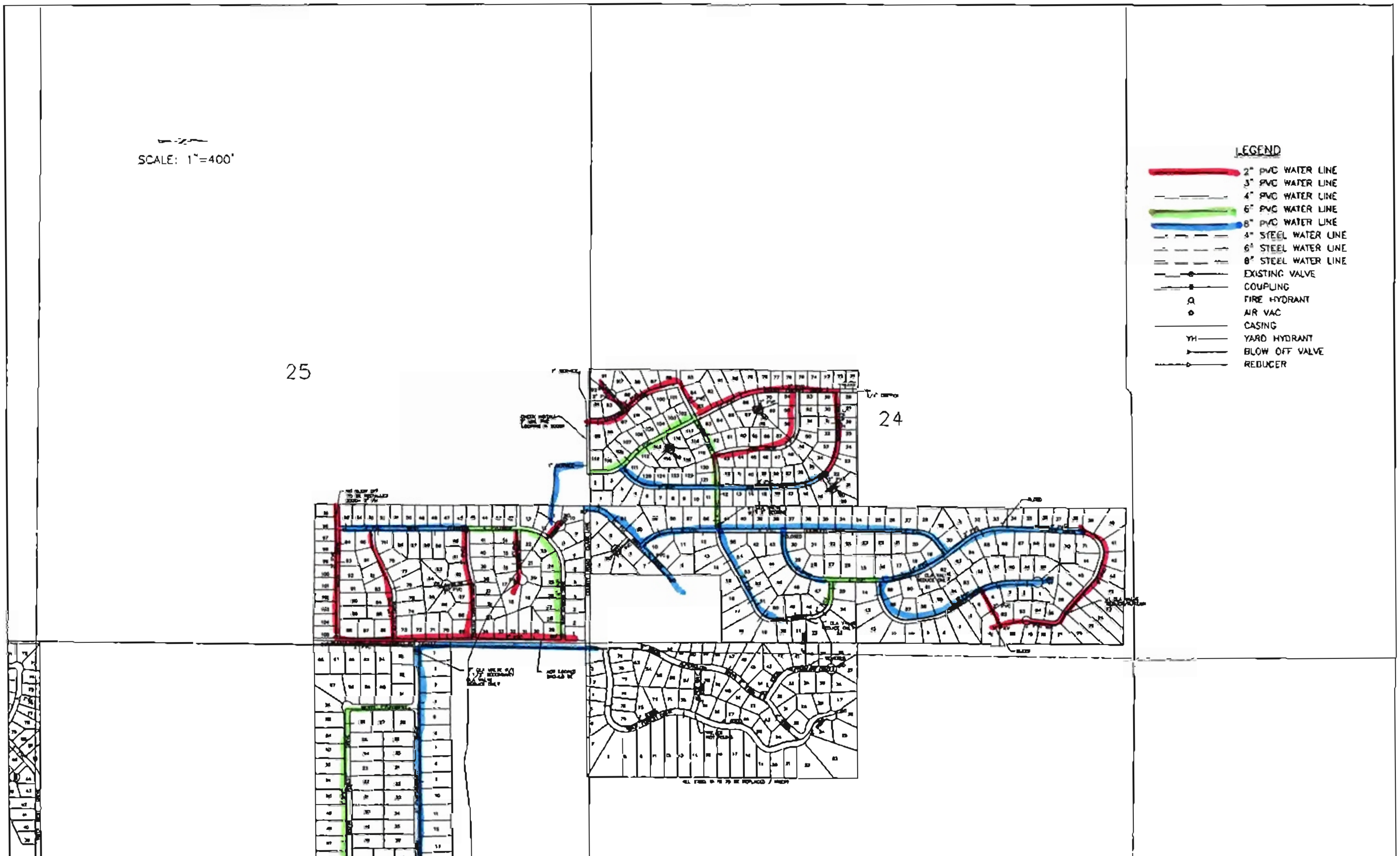
DRAWN ___ DATE ___ CHECKED ___ DATE ___
DESIGNED ___ DATE ___ PROJECT ENGINEER
APPROVED ___ DATE ___ PROJECT MANAGER

NO. | REVISIONS | BY | DATE

This document or any part thereof in detail or design concept is the personal property of Forsgren Associates / Inc. and shall not be copied without the written authorization of Forsgren Associates / Inc.



DRAWN / CHECKED / DESIGNED / APPROVED	STAR VALLEY RANCH	FORSGREN ASSOCIATES / INC.	DOMESTIC WATER SYSTEM	PROJECT NO. 503213
			SOUTHWEST PORTION	SHEET NO. 2.2



NO.	REVISIONS	BY	DATE

This document or any part thereof in detail or design concept is the personal property of Forsgren Associates / Inc. and shall not be copied without the written authorization of Forsgren Associates / Inc.

DRAWN 2/00 MW DATE — CHECKED 2/00 CSK DATE

DESIGNED — DATE — PROJECT ENGINEER

APPROVED 2/00 DATE — CSK PROJECT MANAGER

STAR VALLEY RANCH

FORSGREN ASSOCIATES / INC.

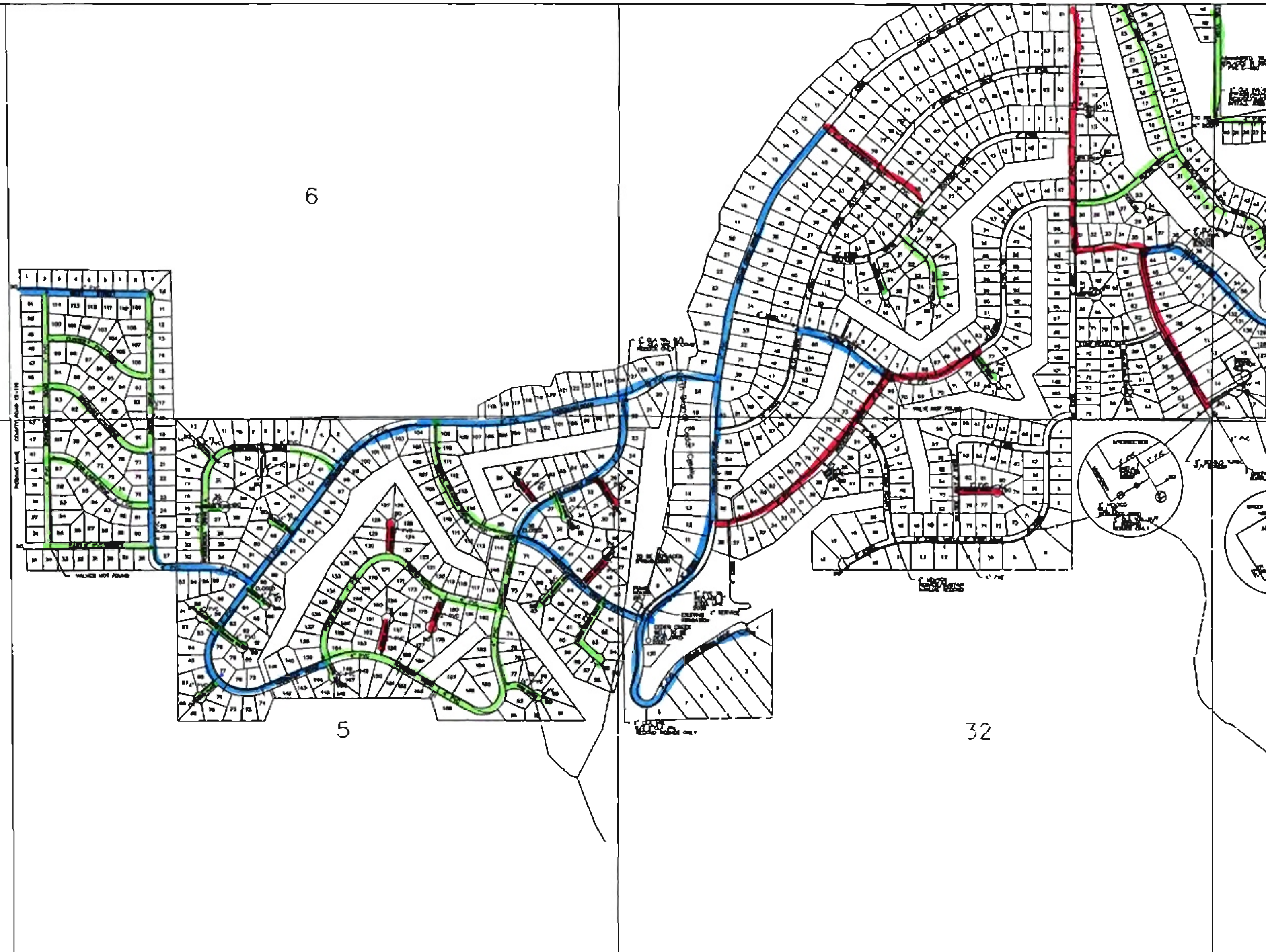
DOMESTIC WATER SYSTEM

NORTHEAST PORTION

PROJECT NO. 503213

SHEET NO. 2.3

SCALE: 1"=400'



LEGEND

- 2" PVC WATER LINE
- 3" PVC WATER LINE
- 4" PVC WATER LINE
- 6" PVC WATER LINE
- 8" PVC WATER LINE
- 4" STEEL WATER LINE
- 6" STEEL WATER LINE
- 8" STEEL WATER LINE
- EXISTING VALVE
- COUPLING
- FIRE HYDRANT
- AIR VAC
- CASING
- YARD HYDRANT
- BLOW OFF VALVE
- REDUCER

NO.	REVISIONS	BY	DATE

DRAWN 3/00 DATE CHECKED 3/00 CSK DATE
CHECKED DATE PROJECT ENGINEER
APPROVED 3/00 DATE CSK PROJECT MANAGER

STAR VALLEY RANCH

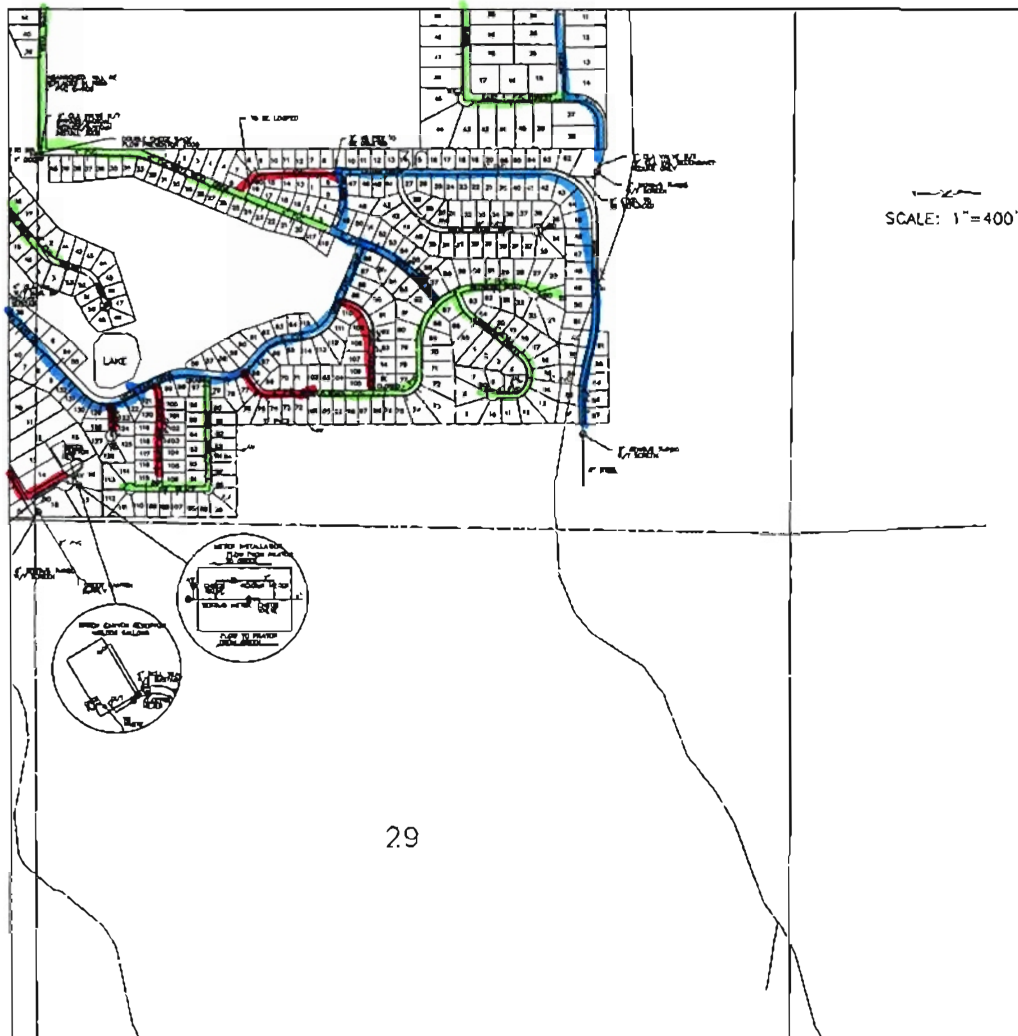
FORSGREN ASSOCIATES / INC.

DOMESTIC WATER SYSTEM

SOUTHWEST PORTION

PROJECT NO. 503213

SHEET NO. 2.4



LEGEND

- 2" PVC WATER LINE
- 3" PVC WATER LINE
- 4" PVC WATER LINE
- 6" PVC WATER LINE
- 8" PVC WATER LINE
- 4" STEEL WATER LINE
- 6" STEEL WATER LINE
- 8" STEEL WATER LINE
- EXISTING VALVE
- COUPLING
- FIRE HYDRANT
- AIR VAC
- CASING
- YH YARD HYDRANT
- BLOW OFF VALVE
- REDUCER

NO.	REVISIONS	BY	DATE

This document or any part thereof in detail or design concept is the personal property of Forsgren Associates / Inc. and shall not be copied without the written authorization of Forsgren Associates / Inc.

DRAWN 3/00 MM DATE — CHECKED 3/00 CSK DATE
DESIGNED — DATE — PROJECT ENGINEER
APPROVED 3/00 CSK DATE — PROJECT MANAGER

STAR VALLEY RANCH

FORSGREN ASSOCIATES / INC.

DOMESTIC WATER SYSTEM
SOUTHEAST PORTION

PROJECT NO. 503213
SHEET NO. 2.5

NO	REVISIONS	BY	DATE

DRAWN ____ DATE ____ CHECKED ____ DATE ____

DESIGNED ____ DATE ____ PROJECT ENGINEER ____

APPROVED ____ DATE ____ PROJECT MANAGER ____

STAR VALLEY RANCH
THAYNE, WYOMING

FORSGREN ASSOCIATES, INC.

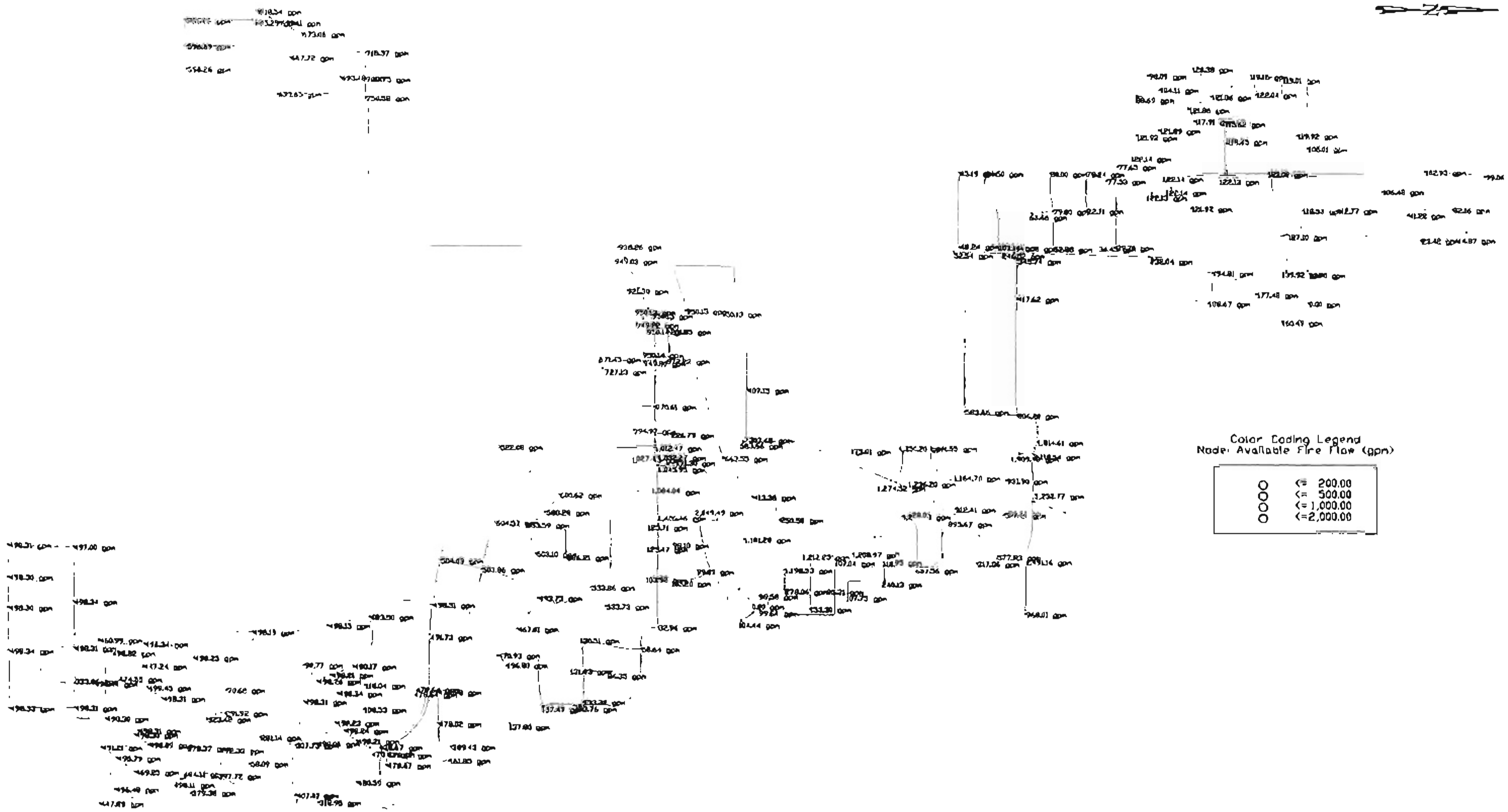
STAR VALLEY RANCH WATER SYSTEM

STEEL PIPE LOCATIONS

PROJECT NO. 05030213

SHEET NO. 2 6

FILE NAME: SCALE:



NO.	REVISIONS	BY	DATE

This document or any part thereof is detail or design concept is the personal property of Forsgren Associates / Inc and shall not be copied without the written authorization of Forsgren Associates / Inc

DRAWN ___ DATE ___ CHECKED ___ DATE ___
DESIGNED ___ DATE ___ PROJECT ENGINEER
APPROVED ___ DATE ___ PROJECT MANAGER

STAR VALLEY RANCH
THAYNE, WYOMING

FORSGREN ASSOCIATES, INC.
370 EAST 500 SOUTH SUITE #200
SALT LAKE CITY, UTAH 84111
(801) 364-4785

STAR VALLEY RANCH WATER SYSTEM

AVAILABLE FIRE FLOW

PROJECT NO. 05030213
SHEET NO. 2.7
FILE NAME | SCALE

SECTION 3.0
WATER SUPPLYCONSIDERATIONS

3.1 IDENTIFICATION OF WATER USE

3.1.1 Existing Domestic Water Use

There are currently 730 homes built in Star Valley Ranch. This represents a 36% build-out of the 2032 platted lots.

Star Valley Ranch In their 1996 study, Jorgenson measured culinary water use from August 12th through 25th , 1996. Based on those measurements, they estimated maximum day use to be 2300 gallons per connection, or 696 gallons/person/day based on 3.3 residents and visitors per home. We note that in the Supplemental Sunrise report specifically took issue with Jorgensen's consumptive use estimates, preferring instead to use 350 gallons/person/day based on Wyoming averages. For the purposes of this study, we have elected to utilize the Jorgensen per capita estimates based on our experience in several other Star Valley and Southeast Idaho communities. While this estimate may appear to be conservatively high, we note that documented per capita water use in the nearby communities of Afton, Thayne, and Cokeville are actually much higher. The summer day water consumption for these communities is approximately 2500, 1200, and 1500 gallons per person respectively.

Based on the above information, the current estimated maximum daily demand is 1,679,000 gallons.

3.1.2 Golf Course Irrigation

The Cedar Creek and Aspen Hills Golf Courses reportedly use up to 315,000 gallons/day and 600,000 gallons/day respectively during the summer. This water is typically drawn from the spring transmission line upstream of the Green Canyon tank. It is also possible to irrigate with water from the Cedar Creek Well. Based on a reported total of 90 acres or irrigated land, this equates to approximately 0.4 inches per day. This relatively high irrigation use may be reflective of a leaky irrigation system(s).

3.1.3 Future Domestic Water Use

Realistically, SVRA is committed to providing water for all of it's residents under a build-out condition. As a matter of practicality, we would assume the true build-out represents approximately 85% of total lots being developed and occupied. This reflects 1727 total homes. Based on current per-capita consumption rates, this equates to a maximum daily domestic demand of 3.97MGD. We note that water use is currently unmetered. Based on comparisons with metered and unmetered communities, we would expect to see at least a 25% reduction ion water consumption if meters were installed. With that conservation tool in place, future projected domestic water consumption would drop to less than 3.0 MGD.

Population growth can be used as a trigger for certain capital improvement needs including storage and source development. Population history and projections based on a future 6% growth rate for Star Valley Ranch are shown in Table 3.1 below:

Table 3.1
Star Valley Ranch Homes

YEAR	NUMBER OF HOMES	ANNUAL GROWTH RATE
1976	40	N/A
1983	136	19%
1990	300	12%
1996	467	8%
2004	730	6.5%
2011	1134	6% assumed
2018 (Approx 85% build-out)	1730	6% assumed

Current and Projected water consumption for Star Valley Ranch is summarized in Table 3.2 below:

Table 3.2
Star Valley Ranch
Estimated Maximum Day Water Consumption

YEAR (CONDITION)	EST. NUMBER OF HOMES	MAXIMUM DAY DOMESTIC WATER USE	GOLF COURSE IRRIGATION	TOTAL WATER CONSUMPTION
2004 (Present)	730	1.679 MGD (1167 gpm)	0.915 MGD (635 gpm)	2.594 MGD (1801 gpm)
2018 (85% build-out without meters)	1730	3.979 MGD (2763 gpm)	0.915 MGD (635 gpm)	4.894 MGD (3398 gpm)
2018 (85% build-out with meters and irrigation improvements)	1730	2.98 MGD (2069 gpm)	0.7 MGD (486 gpm)	3.68 MGD (2555 gpm)

3.2 WATER SOURCE CAPACITY

3.2.1 Green Canyon and Prater Canyon Springs

Historical flow data for both springs is well documented in the Sunrise report, as summarized in Table 3.3. It should be noted that SVRA shares the rights to these springs with Leisure Valley as discussed hereafter.

Table 3.3
Star Valley Ranch
Spring Flow Data (1986-1994)

	JUNE	JULY	AUGUST
PRATER CANYON SPRING			
Average High Yield	481 gpm	545 gpm	312 gpm
Average Low Yield	197 gpm	192 gpm	154 gpm
Average Monthly Yield	320 gpm	347 gpm	229 gpm
GREEN CANYON SPRING			
Average High Yield	1237 gpm	1264 gpm	1220 gpm
Average Low Yield	694 gpm	854 gpm	520 gpm
Average Monthly Yield	1146 gpm	1123 gpm	942 gpm

3.2.2 Well Water Supply

Current well capacity is summarized in Table 3.4 below.

Table 3.4
Well Capacity

WELL NAME	ESTIMATED CAPACITY
Airstrip No. 1	290 gpm
Cedar Creek No.1	250 gpm
Total	**540 gpm**

3.3 WATER SUPPLY NEEDS vs. CONSERVATION OPPORTUNITIES

Obviously, SVRA is obligated to provide adequate domestic water service to each new homeowner as growth continues to occur. Based on current growth of approximately 6% annually, we would expect the Ranch to reach 85% build-out in approximately 15 years. It is prudent for SVRA to secure needed long-term domestic (and irrigation) water supplies in anticipation of that need.

In general, conserving water is less expensive than developing new sources. Using water meters for billings, for example, can reduce per-capita water consumption by 25% to 40%. Approximately 20% of the distribution system consists of older steel pipelines. Replacing these lines should significantly reduce system losses. Repairing and/or replacing the older components of the golf course irrigation system can also result in significant water savings.

3.4 WATER RIGHTS CONSIDERATIONS

The history of water rights pertaining to Star Valley Ranch and Leisure Valley is extensive and complicated to say the least. SVRA and LVI entered into a Settlement Agreement dated August 10, 1998 intended to clarify their respective water rights and shared infrastructure issues. Specifically, this agreement addressed the following items relative to water rights:

- LVI assigned and quit claimed all their rights in the Prater Canyon domestic water rights to SVRA.
- LVI assigned and quit claimed to SVRA all their rights to the Stewart Pipeline Domestic Water Rights.
- LVI assigned and quit claimed to SVRA all their rights to the Cedar Creek Well No.1.
- LVI agreed not oppose the permitting, construction, or filling of an irrigation storage facility in Green Canyon.

Table 3.5
Star Valley Ranch Association
Water Rights

PERMIT NO.	NAME	PRIORITY	AMOUNT	NOTES
UW 13319	Prater Canyon #1	16 Apr 1971	300 gpm	Misc.
UW 82826	1st Enlargement Prater Canyon #1	29 Jul 1985	600 gpm	Misc.
UW82827	2nd Enlargement Prater Canyon #1	16 Jul 1987	900 gpm	Misc.
UW112130	3rd Enlargement Prater Canyon #1	30 Sep 1998	0	Misc.
28143	Stewart (Green Canyon) Springs	9 Sep 1982	997 gpm	Misc.
6973 Enl	1st Enlargement Stewart Springs	16 Jul 1987	0	Misc.
6974 Enl	2nd Enlargement Stewart Springs	8 Sep 1989	0	Tie-line
UW 90328	Airstrip Well #1	30 Nov 1992	600 gpm	Residential
UW 112131	1st Enlargement to Airstrip Well #1	30 Sep 1998	250 gpm	Misc. 200 AF per year
UW 37449	Cedar Creek Well #1			
1579	S.H.	13 Sep 1897	0.86 CFS	Irr
19775	Brog	19 Mar 1943	0.59 CFS	Irr
904E Enl	Enlargement S.H.	13 Aug 1902	0.54 CFS	Irr
5430 Enl	Enlargement Brog	18 Nov 1946	0.51 CFS	Irr
7528	Green Canyon / Cedar Creek	3 Apr 1972	15.4 Ac-ft	Res / Fish Pond

It is our understanding that SVRA and LVI have agreed to regulate their shared interests in the Green Canyon water in accordance with Table 3.6 below.

Table 3.6
Green Canyon Water Regulation
Star Valley Ranch vs. Leisure Valley

PRIORITY DATE	SVRA ALLOCATION	LVI ALLOCATION	TOTAL (GPM)	CUMULATIVE TOTAL
1897	385 gpm (57%)	288 gpm (43%)	673 gpm	673 gpm
1902	248 gpm (24%)	780 gpm (76%)	1028 gpm	1701 gpm
1907	Unused	Unused	-	1701 gpm
1907	Unused	Unused	-	1701 gpm
1909	0	507 gpm	507 gpm	2208 gpm
1943	265 gpm	0	265 gpm	2473 gpm
1946	229 gpm	0	229 gpm	2702 gpm
1966	0	887 gpm	887 gpm	3589 gpm
1972	449 gpm	0	449 gpm	4038 gpm
1982	996 gpm	0	996 gpm	5034 gpm
Totals	**2572 gpm**	**2462 gpm**	**-**	**5034 gpm**

SECTION 4.0
RECOMMENDATIONS AND CONCLUSIONS

4.1 RECOMMENDED SYSTEM IMPROVMENTS

The following improvements are recommended for the Star Valley ranch Water System as briefly discussed below.

4.1.1 Spring Disinfection Facilities

In recent years, spring water supplies have increasing come under the scrutiny of USEPA. The trigger for their attention is generally one or more failed water quality tests. We also note that the Green Canyon Spring development is at some degree of risk from contamination due to flooding, burrowing rodents, and a difficult site location. In the event of water quality problems at the source(s) or in the transmission lines, the ability to provide chlorination will allow SVRA time to properly address the problem without risking public safety and without interruption of supply. The budgets herein reflect a simple hypochlorite system, typical to the Airstrip well facility.

4.1.2 Green Canyon Spring Development

The TriHydro geohydrology study of 1999 indicates that the Green Canyon Spring source is a groundwater supply (as opposed to a surface infiltration gallery). However, they also noted that the spring has a high potential for surface water influence as evidenced through particulate testing. Based on our inspection of the spring site, we concur with those conclusions. We do not believe it would be prudent to reconstruct that spring at this time. However, we do feel it would be in the water users best interest to be in a financial position to react immediately if or when water quality, flooding, or other problems occur.

4.1.3 Steel Pipeline Replacements

As the system continues to age, the steel piping in the system becomes more problematic from the standpoint of leakage and maintenance. This piping represents almost 20% of the distribution system or approximately 30,000 feet as shown in Figure 2.6. It is recommended that SVRA commence an annual program of replacing these lines. We suggest that the prioritization be based on 1) maintenance history and 2) pipe velocity and head losses (see Appendix "A").

4.1.4 New Source Development

We would expect domestic water consumption at the Ranch to more than double of the next 15 years as growth continues. This impact can be blunted through the use of metering and conservation practices. The more efficient use of surface water for golf course irrigation can also help mitigate domestic water concerns. None-the-less, it is felt that SVRA will need to be adding to their domestic source water. Groundwater is clearly preferred over surface water due to the inherent cost of treatment.

4.1.5 Zeroing Box Reconstruction

Air entrainment associated with the existing canyon zeroing boxes has been a concern for many years. We are also concerned about the open nature of the boxes and potential contamination problems.

4.1.6 Cedar Creek Irrigation Storage

The ability to collect and utilize surface water currently being lost downstream will is an obvious benefit to SVRA.. The water rights issues associated with this option are still under investigation.

4.1.7 Water Storage Tank

Wyoming DEQ requires peak system storage to be at least 25% of maximum daily demand for systems delivering over 500,000 gallons per day. Existing system storage currently meets that criteria. Based on 85% build-out conditions, we anticipate the need for an additional 400,000 gallons of storage in the future. The trigger for that need will be approximately 1000 homes. SVRA may wish to accelerate that schedule in order to enhance peaking storage capacity, hence proving better utilization of night-time flows.

We concur with Jorgensen report recommendation that the tank be located to serve the south side of the ranch, preferably near Cedar Canyon (Plat 17). Elevation should be at least 6500 feet. Specific tank sitting can be verified in the computer modeling. We also concur that a partially buried concrete structure would be preferred for aesthetics and maintenance.

4.1.8 PRV Valve Repairs / Upgrades

This is a relatively minor item. None-the-less, there are approximately 20 PRV's in the system that require on-going adjustment and maintenance for proper operation of the system. We suggest a relatively modest annual budget to insure the these valves are rebuilt or replaced on a scheduled basis.

4.1.9 Replace "Inter-connect Line

The spring system inter-connect line is important for the transfer of water between systems, thus better insuring the operators ability to meet system demands in all zones. The recommendation to replace this line was made in the 1996 Jorgensen report, presumably based on pipe condition and installation problems. We concur with that recommendation.

4.1.10 Well and Tank System Telemetry

The installation of a system telemetry will provide more reliable and efficient control of the wells. This type of system could also be beneficial in the future for automating canyon water diversions through the use of actuated valves controlled by metering.

4.1.11 Service line Meters

Meters would be a valuable tool for water management and conservation. In the event that SVRA proceeds with the formation of a water district (or other governmental entity), the community would likely be eligible for state and/or federal funding of system improvements. Metering would likely be a requirement for such funding assistance.

Recommended system improvements are summarized below in Table 4.1. Each is rated by priority and urgency as follows:

- **Importance:** This rating is reflective of potential risks to public health and safety and/or the system's ability to insure domestic water service at current or improved levels.
- **Urgency:** This rating is reflective of recommended project timing. Projects intended to solve problems with a potential risk to public health & safety, interruption of service, and/or significant financial consequences if left unaddressed have a higher urgency rating.

Table 4.1
Star Valley Ranch
Recommended System Improvements

RECOMMENDED IMPROVMENT	EST. COST	IMPORTANCE	URGENCY	NOTES
Spring Disinfection Facilities (2)	$ 85,000	High	High	
Green Canyon Spring Redevelopment	$ 110,000	High	High (see note)	*Current spring development is at high risk from surface water influence and contamination. Recommend "savings account" in the event of water quality problems.*
Steel Pipeline Replacements (29,300 LF)	$ 730,000	High	Medium	*These projects can easily be spread over 5 to 10 years.*
New Source Development (Wells& Appurtenances)	$ 350,000	High	Medium	
Zeroing Box Reconstruction	$ 35,000	High	Medium	
Cedar Creek Irrigation Storage	$ 110,000	Medium	Medium	
Water Storage Tank – approx. 400,000 gallons, concrete	$ 380,000	Medium	(see note)	*Regulatory need for tank will be triggered by growth and associated system demands. Based on 6% growth rate with current per-capita consumption = approximately year 2010. +/-*
PRV Repairs / Upgrades	$ 3000 / yr	Medium	Medium	
Replace "Inter-connect" line between Canyon systems (6500 ' 6-inch)	$ 180,000	Medium	Low	
Well & Tank Telemetry & Control (4 sites)	$ 40,000	Medium	Low	
Meters (750 connections)	$ 400,000	Medium	Low	*Meters would typically be a requirement for government financial aid in the future*

APPENDIX “A”
System Modeling

APPENDIX "A"
SYSTEM MODELING

The best available planning tool today for municipal water system is to develop a computer model which closely simulates the operation of that system. A computer simulation allows the evaluation of system responses to system modifications and/or operations changes prior to their implementation. It is also valuable in identifying system deficiencies before they become a serious problem.

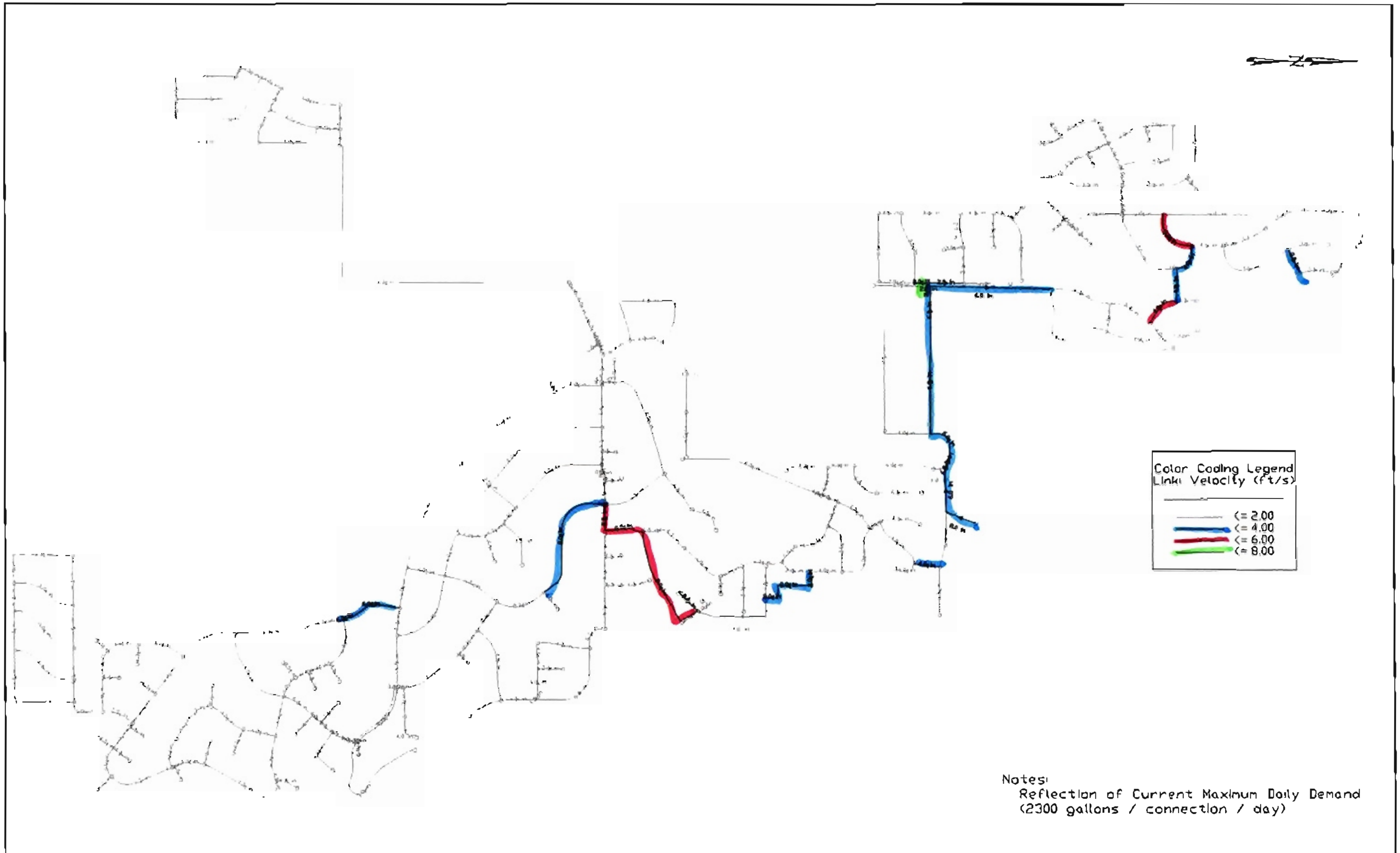
The Star Valley water system was modeled using WATERCAD software from Heasted Methods. Modeling data is based upon available records and interviews with SVRA staff. Although we believe the results to be reasonably reflective of actual conditions, it should be noted that this study did not include the budget for a serious model calibration "ground truth" effort. None-the-less, the model can easily be updated going forward as/if needed.

Specific pipeline sizes and material types used in the model are shown graphically in Figures 2.1 through 2.5 in this report. Figure 2.7 shows theoretically available fire flows. This appendix includes additional modeling output mapping reflecting the following:

- **Pipe Velocities with Maximum Day Demand (Current and Future):** This information is helpful in identifying possible undersized pipes within the system. It is also helpful to overlay this information with known pipeline maintenance problems (steel pipe, for example) to prioritize which lines should be prioritized for replacement.

- **Pipe Frictional Head Losses with Maximum Day Demand (Current and Future):** This information is also helpful in identifying possible undersized pipes within the system. It is also helpful to overlay this information with known pipeline maintenance problems (steel pipe, for example) to prioritize which lines should be prioritized for replacement.

- **System Node Pressures with Maximum Daily Demand (Current and Future):** This information is helpful in identifying piping, PRV, or other operational problems that result in substandard (or excessive) system pressures.



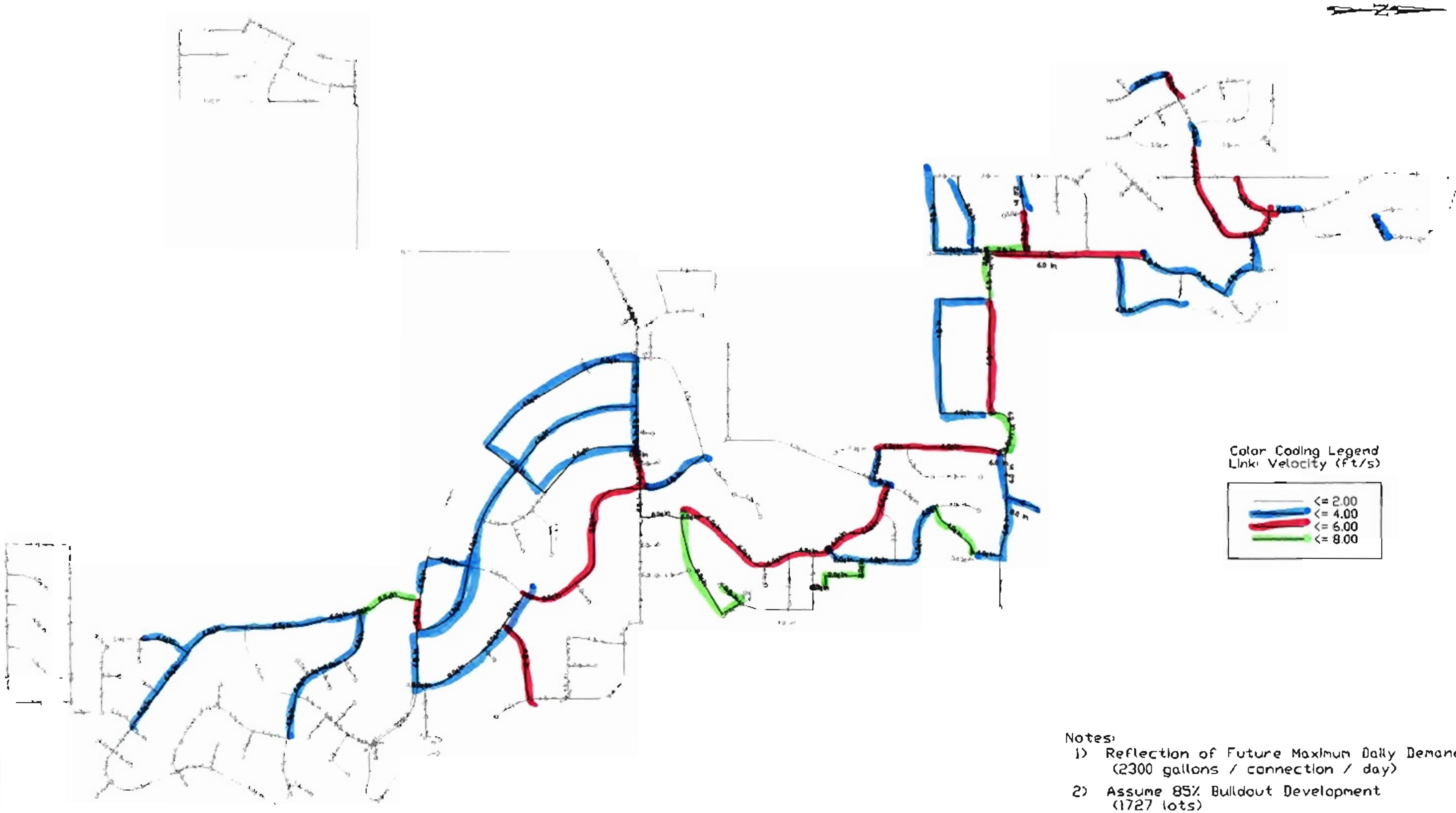
STAR VALLEY RANCH
THAYNE, WYOMING

FORSGREN ASSOCIATES, INC.

STAR VALLEY RANCH WATER SYSTEM

PIPE VELOCITIES – CURRENT

PROJECT NO. 05030213



Notes:
1) Reflection of Future Maximum Daily Demand (2300 gallons / connection / day)
2) Assume 85% Buildout Development (1727 lots)

NO.	REVISIONS	BY	DATE

DRAWN ____ DATE ____ CHECKED ____ DATE ____
DESIGNED ____ DATE ____ PROJECT ENGINEER
APPROVED ____ DATE ____ PROJECT MANAGER

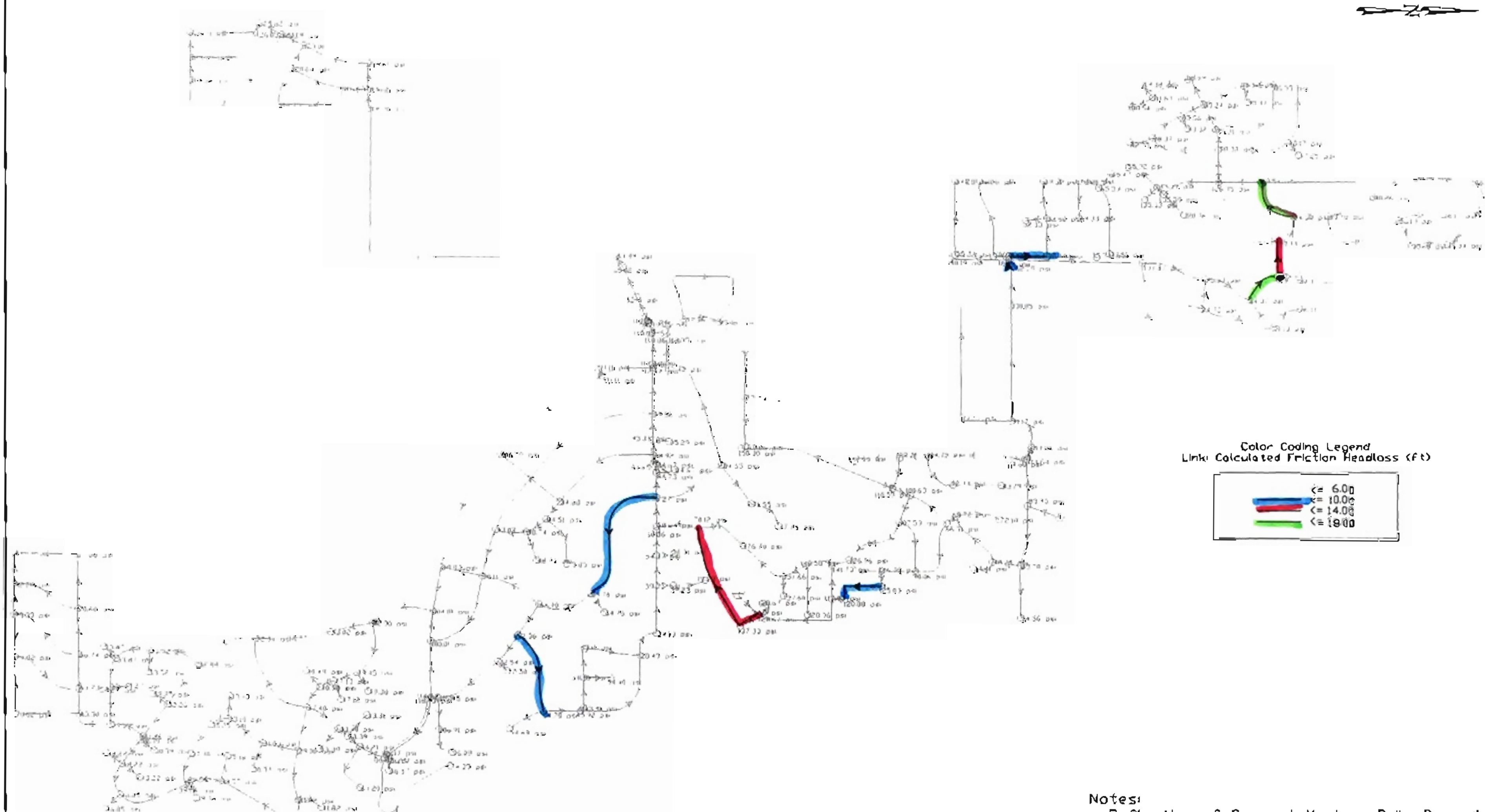
STAR VALLEY RANCH
THAYNE, WYOMING

FORSGREN ASSOCIATES, INC.
370 EAST 500 SOUTH SUITE #200
SALT LAKE CITY, UTAH 84111
(801) 364-4785

STAR VALLEY RANCH WATER SYSTEM

PIPE VELOCITIES - FUTURE

PROJECT NO.: 05030213
SHEET NO.:
FILE NAME:
SCALE:

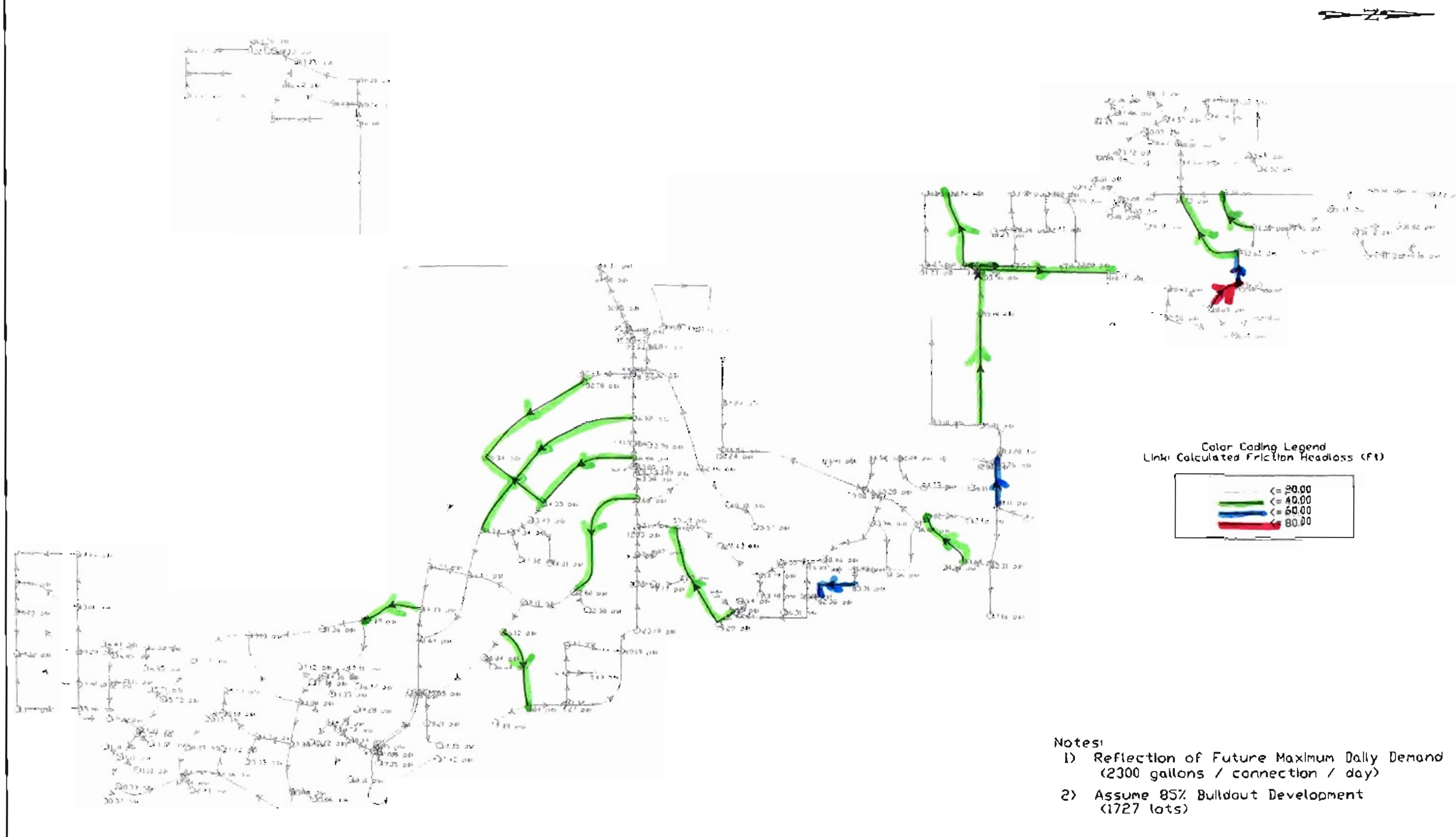


Color Coding Legend
Link: Calculated Friction Headloss (ft)

- <= 6.00
- <= 10.00
- <= 14.00
- <= 18.00

Notes:
Reflection of Current Maximum Daily Demand
(2300 gallons / connection / day)

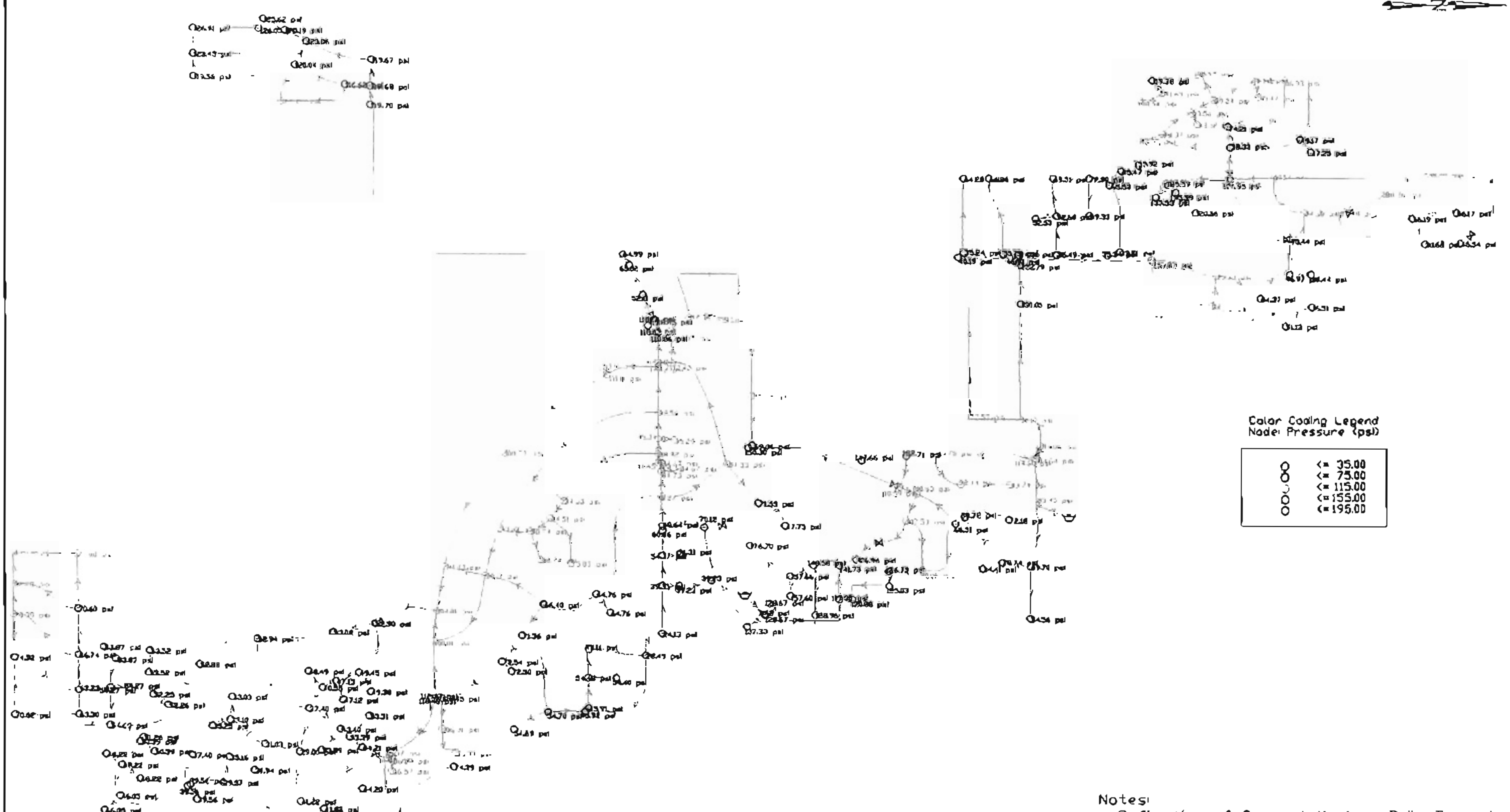
DRAWN / DATE — CHECKED / DATE; DESIGNED / DATE — PROJECT ENGINEER; APPROVED / DATE — PROJECT MANAGER	STAR VALLEY RANCH THAYNE, WYOMING	FORSGREN ASSOCIATES, INC.	STAR VALLEY RANCH WATER SYSTEM PIPE HEADLOSSES - CURRENT	PROJECT NO. 05030213



Notes:

1) Reflection of Future Maximum Daily Demand (2300 gallons / connection / day)
2) Assume 85% Buildout Development (1727 lots)

NO / REVISIONS / BY / DATE	DRAWN ___ DATE ___ CHECKED ___ DATE ___	STAR VALLEY RANCH THAYNE, WYOMING	FORSGREN ASSOCIATES, INC.	STAR VALLEY RANCH WATER SYSTEM	PROJECT NO. 05030213
	DESIGNED ___ DATE ___ PROJECT ENGINEER			PIPE HEADLOSSES - FUTURE	SHEET NO.
	APPROVED ___ DATE ___ PROJECT MANAGER				FILE NAME / SCALE



Notes:
Reflection of Current Maximum Daily Demand
(2300 gallons / connection / day)

NO	REVISIONS	BY	DATE

This document or any part thereof in detail or design concept is the personal property of Forsgren Associates / Inc. and shall not be copied without the written authorization of Forsgren Associates / Inc.

DRAWN ____ DATE ____ CHECKED ____ DATE ____
DESIGNED ____ DATE ____ PROJECT ENGINEER
APPROVED ____ DATE ____ PROJECT MANAGER

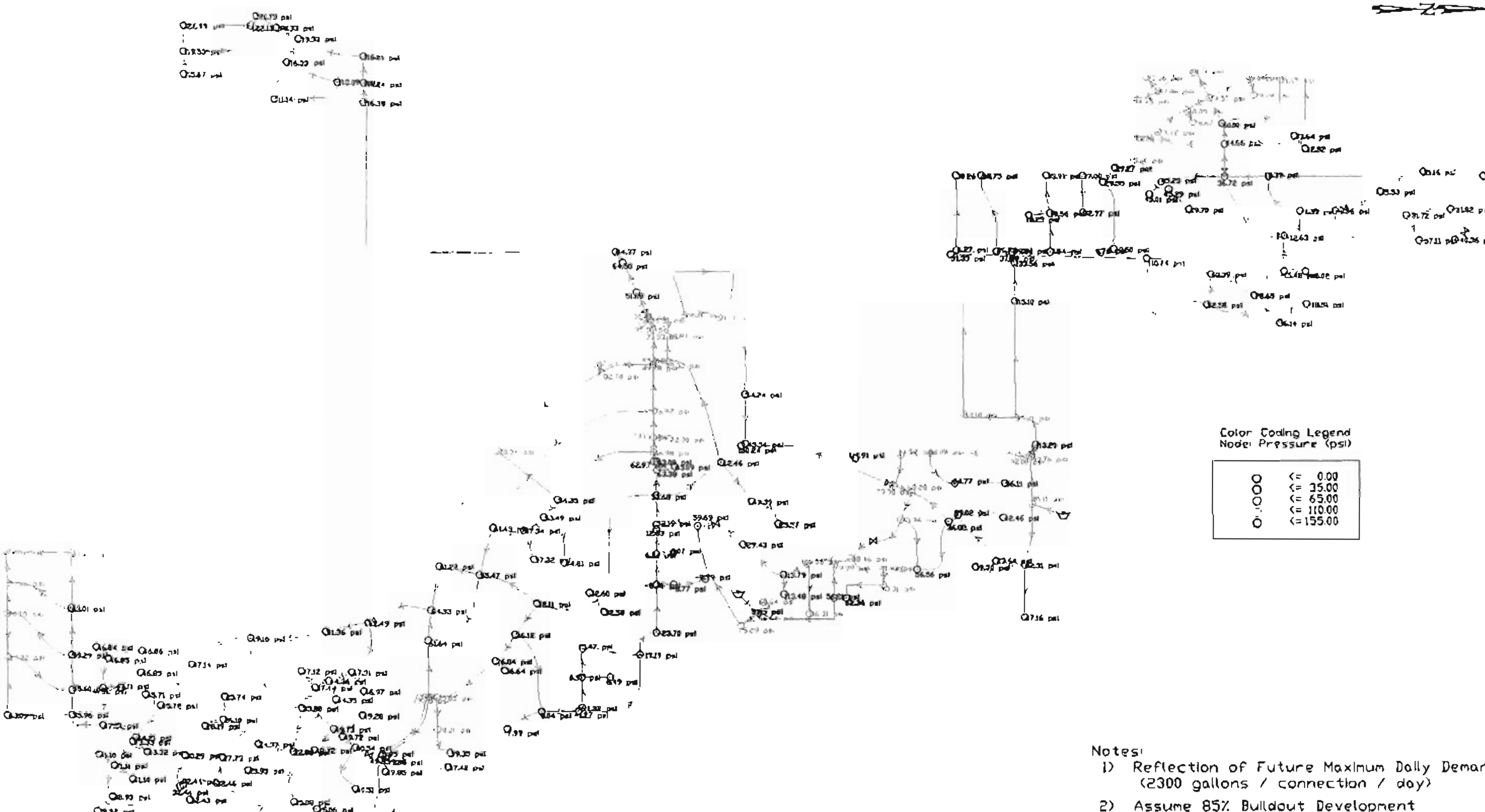
STAR VALLEY RANCH
THAYNE, WYOMING

FORSGREN ASSOCIATES, INC
370 EAST 500 SOUTH, SUITE #200
SALT LAKE CITY, UTAH 84111
(801) 364-4785

STAR VALLEY RANCH WATER SYSTEM

NODE PRESSURES - CURRENT

PROJECT NO. 05030213
SHEET NO.
FILE NAME: SCALE: N.I.



Color Coding Legend
Node: Pressure (psi)

○	<= 0.00
○	<= 35.00
○	<= 65.00
○	<= 110.00
○	<= 155.00

Notes:
1) Reflection of Future Maximum Daily Demand (2300 gallons / connection / day)
2) Assume 85% Buildout Development (1727 lots)

NO.	REVISIONS	BY	DATE

This document or any part thereof in detail or design concept is the personal property of Forsgren Associates / Inc. and shall not be copied without the written authorization of Forsgren Associates / Inc.

DRAWN ____ DATE ____ CHECKED ____ DATE ____
DESIGNED ____ DATE ____ PROJECT ENGINEER ____
APPROVED ____ DATE ____ PROJECT MANAGER ____

STAR VALLEY RANCH
THAYNE, WYOMING

FORSGREN ASSOCIATES, INC.
370 EAST 500 SOUTH SUITE #200
SALT LAKE CITY, UTAH 84111
(801) 364-4785

STAR VALLEY RANCH WATER SYSTEM

NODE PRESSURES - FUTURE

PROJECT NO. 05030213
SHEET NO.
FILE NAME
SCALE

APPENDIX "B"
Green Canyon Spring Hydrogeology Report

TriHydro Corporation

920 Sheridan Street
Laramie, Wyoming 82070
(307) 745-7474
FAX: (307) 745-7729

October 25, 1999

Clarence Kemp
Forsgren Associates, Inc.
849 Front Street, Suite 201
Evanston, WY 82930

RE: Hydrogeologic Investigation of Green Canyon Spring, Star Valley Ranch Association, Thayne, Wyoming

Dear Mr. Kemp:

This letter presents the results of the hydrogeologic investigation of Green Canyon Spring conducted on behalf of the Star Valley Ranch Association (SVRA) of Thayne, Wyoming, during September 1999. The information is intended to provide the SVRA with help during the decision-making process for future actions concerning the Green Canyon Spring water supply system. The SVRA water system is classified as a community groundwater supply and currently uses two developed springs and one back-up well for its public water supply. The U.S. Environmental Protection Agency (USEPA), Public Water System Identification Number for the SVRA system is PWS ID#5600287. Water quality records of the SVRA system are available from USEPA Region VIII in Denver, Colorado.

The SVRA development is located in northern Lincoln County, approximately 10 miles north and 2 miles east of the Town of Thayne, Wyoming. The two developed springs of the SVRA system are Green Canyon Spring and Prater Canyon Spring, and the back-up well is Air Strip #1. Air Strip #1 is located next to the airfield of the SVRA development. The two water supply springs are located in the Salt River Range, which is located to the east of SVRA. Both springs are located on Bridger National Forest land.

Green Canyon Spring issues from the north wall of Green Canyon and is located in the southwest quarter of the northeast quarter of the southwest quarter of Section 28 (unsurveyed), Township 35 North, Range 118 West, Lincoln County, Wyoming (Latitude 42° 58' 59" North and Longitude 110° 56' 51" West). Green Canyon Spring is located at 7,540 feet in elevation and the concrete collection structure is sited at 7,520 feet above mean sea level. Collected spring water is transmitted down Green Canyon via a 6-inch/8-inch PVC transmission pipeline to the Green Canyon water supply tank (400,000 gallon capacity) at 6,500 feet above mean sea level. The water from Green Canyon Spring drops in elevation more than 1,000 feet from the spring to the tank.

The second SVRA water supply spring is located in Prater Canyon with the Prater Canyon Spring collection structure at 7,390 feet above mean sea level. Collected spring water is transmitted down the valley via a 4-inch steel transmission pipeline to the Prater Canyon water supply tank (185,000 gallon capacity) at 6,800 feet above mean sea level. The drop in elevation is greater than 500 feet. Prater Canyon Spring is located in the southeast quarter of the southeast quarter of Section 20 (unsurveyed), Township 35 North, Range 118 West, Lincoln County, Wyoming (Latitude 42° 59' 22" North and Longitude 110° 58' 20" West).

This study investigated the hydrogeology of Green Canyon Spring with regards to its source and the potential for the spring being considered as under direct surface water influence by the USEPA. A site visit to Green Canyon Spring was conducted on September 15, 1999, with Vince Simmer, Jim

Howard, and Bart Barge of SVRA. Bart Barge is the SVRA public water system operator. Green Canyon Spring was visited and the surrounding area in the canyon was investigated both up-gradient and down-gradient of the spring.

The Office of the State Engineer was investigated for records concerning Green Canyon Spring. The geology of the spring area is included on maps at scale of 1:62,500 in Rubey (1958) and Rubey (1973). The regional geology is described in Blackstone and DeBruin (1987), McCalpin, Piety, and Anders (1990), Oriel and Platt (1980), Schultz (1914), and Walker (1965). Discussions of the hydrogeology of the area are included in: Lines and Glass (1975); Ahern, Collentine, and Cooke (1981); and Eddy-Miller, Plafcan, and Clark (1996). Water system evaluations for the SVRA were prepared by Jorgensen Engineering and Land Survey, P.C. in 1995 and 1996.

RESULTS OF INVESTIGATION

Green Canyon Spring issues from the north valley wall of Green Canyon, approximately two hundred feet upstream of the confluence of the north and east forks of Green Canyon. Collected hydrogeologic data indicate Green Canyon Spring is sourced from bedrock near the contact of the Gallatin Limestone and underlying Gros Ventre Formation. The spring is associated with an anticlinal structure orientated approximately north-south and is located on the eastern limb of the anticlinal structure. Based on available data, Green Canyon Spring is issuing from the base of the Late Cambrian-age Gallatin Limestone at the contact with the underlying Middle Cambrian-age Gros Ventre Formation.

Physiographic Setting and Spring Collection System

Green Canyon Spring is located on the Thayne East topographic quadrangle map. Green Canyon is approximately 1.5 miles wide by 3 miles long, beginning in the mountains of the Salt River Range and draining west-southwestward to Star Valley. The depth of Green Canyon ranges from approximately 1,000 to 1,500 feet. The unnamed stream in Green Canyon is an intermittent stream and surface water discharge from the canyon disappears into an alluvial fan deposit at the mouth of Green Canyon. At the elevation of the Green Canyon Spring (7,540 feet), Green Canyon is approximately 1,150 deep on the south side and 1,450 feet on the north side.

Green Canyon Spring, formerly known as Stewart Springs, was reportedly developed in October and November 1986. The developed Green Canyon Spring is not visible at the ground surface. The spring area has been back-filled with older Quaternary-age valley-fill alluvium at the surface. The underground collection pipeline extends upward into the hill side approximately 50 feet into the fractured limestone bedrock of Green Canyon Spring.

Other springs in the vicinity of Green Canyon Spring include Cascade Spring, which is located approximately 40 to 50 feet downstream of Green Canyon Spring, and a small undeveloped spring, which issues from the south side of Green Canyon, approximately due south of Green Canyon Spring. Discharge from Cascade Spring is estimated to be from 600 to 100 gallons per minute, high to low flow rates. The unnamed, undeveloped spring reportedly flows at approximately 20 to 25 gallons per minute throughout the year.

As shown on as-built drawings, Green Canyon Spring is completed as an infiltration gallery and includes a horizontal, 20-foot long, 8-inch diameter, PVC catch pipe (perforated with holes drilled into the pipe) set approximately northwest-southeast into the fractured rock of the spring. The underside of the 8-inch pipe is underlain by three layers of plastic sheeting. Rocks and clay are set on the down-gradient side of the catch pipe to divert flow into the pipe. An 18-foot by 30-foot, 40 ml (0.040-inch) PVC sheet overlies the catch pipe area. At the southeast end of the catch pipe is an 8-inch to 6-inch reducer and a 45-degree 6-inch elbow to the south. The plastic sheeting is gathered together around the down-gradient end of the 8-inch pipe and 8-inch/6-inch reducer and is packed with clay and rocks to divert spring water flow to the inside of the collection pipeline.

As shown on the as-built drawings, approximately 20 feet of 6-inch PVC pipe are then curved to the southwest and another 45-degree 6-inch elbow is fitted. Approximately 30 feet of 6-inch PVC (including one bell-joint) is connected with another 45-degree 6-inch elbow fitted, turning the pipe to the southeast. The 6-inch PVC pipe extends southeast approximately 12 to 14 feet into a steel box, set underground on the north side of the active stream channel. The Green Canyon Spring collection system is buried into the hill side to approximately the steel spring box. The spring area reportedly drops in elevation approximately from 20 feet in elevation to the steel spring box.

Exiting the steel spring box are reportedly two 6-inch PVC pipes with a screen fitted over the open ends of the pipes inside the steel box. The twin 6-inch PVC collection lines run northeast-southwest from the steel box into the concrete collection box, which is at 7,520 feet above mean sea level. The twin, parallel, 6-inch diameter PVC pipelines, are bedded with a 48-foot by 80-foot, 40-ml (0.040-inch) PVC plastic sheet above the lines and carry collected spring water under the presently active stream channel to a concrete collection box.

The concrete collection box is located approximately 100 feet from the steel spring box. The concrete collection box is an 8-foot by 8-foot by 8-foot, 3,000-gallon capacity, reservoir that was cast in place. The horizontal distance from the Green Canyon Spring to the concrete collection box is approximately 100 feet. From the concrete collection box, an 8-inch diameter, PVC transmission pipeline runs down Green Canyon to a SVRA water supply tank. Two pressure relief valves (PRVs) are fitted on the transmission pipeline to relieve high pressure from pipeline. The PRVs reduce pipeline water pressure from 300 to 185 pounds per square inch during 1,000-foot drop in elevation from Green Canyon Spring to southern SVRA water supply tank.

Green Canyon Spring reportedly yields an average of 1,100 to 1,200 gallons per minute during the summer months. The low discharge rate is generally 250 to 300 gallons per minute during the winter season, with the lowest observed flows usually during February and March of each year. During February and March 1999, the lowest recorded Green Canyon Spring flow was observed at 100 gallons per minute and is attributed to conditions of two weeks of very cold (-20°F) weather and unusually low snow cover in the Salt River Range.

On August 23, 1995, a high-rate precipitation event flood occurred in Green Canyon that eroded the area around the Green Canyon Spring and the canyon road. An earlier flood event in mid-Spring 1995 inundated the Green Canyon Spring and caused a break in the transmission pipeline. On August 5, 1997, Green Canyon received two hours of heavy precipitation, which caused the most recent large flood in the Green Canyon. The last previous large flood event occurred on August 23, 1995. These two flood events have extensively eroded the spring collection area and the valley floor of Green Canyon, removing abundant vegetation and unconsolidated sediment ranging from clay to boulder sizes.

Geology and Structural Geology

The geology of the area surrounding the Green Canyon Spring is composed of lithologic units ranging in age primarily from Middle Cambrian to Mississippian. These units include (from youngest to oldest):

QUATERNARY - Valley-Fill Alluvium Deposit - The older valley-fill alluvium deposit ranges from approximately 50 to 100 feet thick and is composed of predominantly clay, silt, and sand with minor gravel (pebble to boulder sizes). The alluvium is poorly sorted and the gravel is generally matrix-supported. This older valley-fill alluvium has been down-cut by the presently active stream channel which is generally a bed of gravel from pea size to boulders up to six feet in diameter. The older valley-fill alluvium is preserved on the lowest levels of the side walls of Green Canyon, in the vicinity of Green Canyon Spring.

MISSISSIPPIAN - Madison Limestone - The Madison Limestone is composed of alternating layers of resistant, massive, crystalline, light gray limestone and of less resistant, thin-bedded, fine-grained, dark gray limestone (Rubey, 1958; 1973). The Madison Limestone is approximately 1,500 feet thick in the Salt River Range and has excellent karst and fracture development throughout the area. The Madison Limestone is a major regional aquifer in the Overthrust Belt with excellent solution and fracture permeability. (Ahern, et al., 1981). Four large Madison Limestone springs flow from less than 350 gallons per minute up to 40,000 gallons per minute (Ahern, et al., 1981).

DEVONIAN - Darby Formation - The Darby Formation consists of alternating beds of black, yellow, and red, calcareous, sandy siltstone, and of dark gray, tan-weathering, massive dolomitic limestone (Rubey, 1958). The variegated siltstone is most conspicuous in the upper part of unit and the massive limestone in the lower part (Rubey, 1958). The Darby Formation ranges from 450 to 550 feet thick in this area and appears to thicken northwestward (Rubey, 1958). The formation is a major aquifer with permeability dependent on degree of fracturing and secondary solution (Ahern, et al., 1981). Four known Darby Formation springs reportedly flow from 5 to 1,100 gallons per minute (Ahern, et al., 1981).

ORDOVICIAN - Bighorn Dolomite - The Bighorn Dolomite is a light gray, dense, massive, dolomite with some 20 to 30 feet of dark gray dolomite at the top of the unit (Rubey, 1958). The Bighorn Dolomite forms prominent ridges and mountain crests and is approximately 600 feet thick (Rubey, 1958). A highly productive aquifer where fracture, secondary solution, and bedding plane permeability are well developed (Ahern, et al., 1981). Three Bighorn Dolomite springs flow from 250 to 450 gallons per minute, and one spring flows 3,200 gallons per minute (Ahern, et al., 1981).

The Star Valley communities of Bedford and Etna have used springs sourced from the Bighorn Dolomite as water supplies (Ahern, et al., 1981).

LATE CAMBRIAN - Gallatin Limestone - The Gallatin Limestone is a gray and tan mottled limestone, massive and dolomitic in the upper part of the formation, more thin-bedded and calcitic in the lower part. The Gallatin Limestone ranges from 300 to 350 feet thick (Rubey, 1958). Well and spring data are not available, however, lithology as well as fracture and secondary solution permeability development are indicative of a potentially productive aquifer (Ahern, et al., 1981).

MIDDLE CAMBRIAN - Gros Ventre Formation - Upper and lower members: Predominantly greenish gray, micaceous shale with beds of oolitic limestone, the lower shale unit is approximately several hundred feet thick and the upper shale unit is about 200 feet thick (Rubey, 1958). Middle member: Resistant gray and tan mottled limestone at top and throughout middle and lower part with a persistent shale bed intervening. The middle limestone member is approximately 350 feet thick and contains a persistent 40-foot thick shale unit about 40 feet below the top of the middle member (Rubey, 1958). The Gros Ventre Formation is generally considered a regional aquitard with low vertical permeability due to upper and lower shale units (Ahern, et al., 1981).

The overall geologic structure of the lower Star Valley area in the vicinity of SVRA development is a normal fault-bounded graben block (valley floor of Star Valley), located between two horst blocks, which are the mountain range uplifts located to the east and west of Star Valley. The structural trend of the valley-bounding normal faults is generally northwest-southeast in this area. Salt River Range is located on the east side of Star Valley and the Gannett Hills, also known as the Caribou Range, are located on the west side.

The Salt River Range is an uplifted block of folded and faulted Paleozoic and Mesozoic formations. The Salt River Range is part of the northern Wyoming Overthrust Belt and forms the eastern topographic boundary of Star Valley. The range was uplifted and thrust northeastward on the hanging wall of the Absaroka thrust during Cretaceous time. This deformation formed a series of approximately northwest-southeast trending anticlines and synclines, including many tightly folded (recumbent) and overturned.

The Star Valley normal fault delineates the western boundary of the Salt River Range. The Star Valley normal fault is known locally as the Bedford fault. A ramp in the underlying Absaroka thrust fault locally controlled the location of the Star Valley normal fault. The floor of Star Valley subsided in relation to the uplifted Salt River Range along this normal fault system. The amount of displacement on the Star Valley normal fault is unknown and likely varies along the length of the valley. The displacement on the Star Valley normal fault is several thousand feet in this area of Star Valley. Post-thrusting, extensional stress produced en echelon normal fault configurations including horst and graben structures.

Most large local springs in the Salt River Range tend issue out of the north side of valleys from exposures of Paleozoic-age carbonate (limestone and dolomite) rocks; for example: Prater, Green, Cedar Creek, and Strawberry canyons all have large springs on the north side of these valleys issuing from Paleozoic-age carbonate rock units.

Above Green Canyon Spring, beds of Gallatin Limestone dip approximately 20 to 30 degrees to the southwest. The Gallatin Limestone unit is a small cliff-former in the walls of Green Canyon.

Hydrogeologic Setting

The available data indicate that Green Canyon Spring is sourced from Paleozoic carbonate rock units located in the mountains north of the spring and above 7,500 feet in elevation. These Paleozoic limestone and dolomite carbonate units include interconnected, enhanced permeability (formed by fracturing and carbonate dissolution) beds of the Gallatin Limestone, Bighorn Dolomite, Darby Formation, and Madison Limestone. The Paleozoic bedrock exposed in the mountains north of the spring, drains groundwater downward to discharge from the spring at an elevation of 7,540 feet above mean sea level.

A review of available hydrogeologic data indicates that groundwater flows through the Gallatin Limestone aquifer, primarily through fracture-permeability and solution-enhanced permeability in carbonate beds within the Early Paleozoic formations. These fracture/solution enhanced zones in Paleozoic carbonate rock units are the most permeable zones in the Salt River Range and can yield up 40,000 gallons per minute from springs (Lines and Glass, 1975).

Groundwater flow through the Paleozoic formations of the Salt River Range is primarily through the more permeable fracture systems in the carbonate beds of the formations. Fracture flow through Paleozoic formations has been documented at other springs in the Salt River Range (Lines and Glass, 1975; and Ahern, et al., 1981). Water flow at the Green Canyon Spring is estimated to range from 1,200 to 100 gallons per minute from fractured bedrock of the Gallatin Limestone. These Gallatin Limestone is not exposed at the spring site. The extent of subsurface fracturing in the Paleozoic formations is unknown in this area.

The recharge area for the Green Canyon Spring is generally located to the north-northeast and from elevations higher than the spring (7,540 feet), including the highlands located between Prater Canyon and Green Canyon, and including Prater Mountain.

Recharge to the Gallatin Limestone is through infiltration of precipitation and surface runoff directly into the outcrops of the Gallatin Limestone and predominantly through overlying Paleozoic formations deposits into subcrops of the Gallatin Limestone.

Based on topography, the inferred groundwater flow direction in the Paleozoic lithologic units near Green Canyon Spring appears to be to the south-southwest in the vicinity of Green Canyon Spring. The up-gradient area is located to the north-northeast of the spring. Recharge to Green Canyon Spring includes the following:

1. Precipitation infiltration directly into the Gros Ventre Formation and Gallatin Limestone and indirectly through overlying Paleozoic formations (Bighorn Dolomite, Darby Formation, and Madison Limestone); and

2. Stream leakage (losing streams) surface water runoff recharge to groundwater, especially along the streams in Prater Canyon and Green Canyon, above 7,540 feet in elevation.

The recharge area for the Green Canyon Spring is the highlands of the Salt River Range, east of Star Valley. Precipitation infiltration from rainfall and snow-melt enters permeable zones in the Paleozoic rock units and migrates downward in elevation through the permeable zones in the carbonate rocks. The high degree of structural deformation associated with the Overthrust Belt has created an interconnected system of fractures and solution enhanced cavities in carbonate rock units.

The valley floor of Green Canyon, up to an elevation of approximately 7,900 feet, is predominantly composed of the upper shale unit of the Middle Cambrian-age Gros Ventre Formation and Late Cambrian-age Gallatin Limestone. From 7,900 to 8,200 feet in elevation, the valley floor dissects the Bighorn Dolomite. Above 8,200 feet in elevation, the valley floor is composed of Quaternary glacial till deposit, which was left as a ground moraine by a local mountain valley glacier which formed in the head of Green Canyon (on the south side of Prater Mountain).

The geological structure exposed in Green Canyon below 8,200 feet in elevation is a series of at least four, sub-parallel, northwest-southeast and north-south trending anticlinal and synclinal couples (Rubey, 1958; and Rubey, 1973). Green Canyon Spring is associated with an anticlinal structure with the fold axis at approximately 7,400 feet above mean sea level as the anticlinal axis crosses the valley floor.

Anticlinal folds are well known for forming zones of fracture-enhanced permeability in the folded beds. These fold-induced fractures have been further enhanced by solution opening of the fractures in carbonate rocks due to the action of carbonic acid-rich groundwater movement through the soluble carbonate rocks.

Exposed in Green Canyon are outcrops of Gros Ventre Formation overlain by Gallatin Limestone. The Gallatin Limestone is overlain by Bighorn Dolomite. The greenish gray micaceous shale of the middle unit of the Gros Ventre Formation is exposed in the stream bed east of Green Canyon Spring. The Gallatin Limestone dips approximately 20 to 30 degrees to the southwest in the area above Green Canyon Spring.

Green Canyon Spring is apparently issuing from the contact between the overlying Gallatin Limestone and the underlying Gros Ventre Formation. The location of the Green Canyon Spring appears to be controlled by:

1. Fracture and solution enhanced permeability formed in Early Paleozoic carbonate units;

2. The low elevation at this point by down-cutting of the valley by the stream; and

3. The low permeability shale of the Gros Ventre Formation underlying and juxtaposed to the base of the Gallatin Limestone.

Groundwater at Green Canyon Spring appears to flow directly from basal Gallatin Limestone bedrock through a thin veneer of old Quaternary valley-fill alluvium to the side wall of the present stream bed of the valley floor.

Water Quality

A summary of available water quality data for Green Canyon Spring is presented in Table 1. The water yielded by the Green Canyon Spring is of the calcium bicarbonate-type with total dissolved solids ranging between 100 and 250 milligrams per liter. This quality of water is typical for shallow Paleozoic-age limestone aquifers in the Overthrust Belt (Lines and Glass, 1975).

In addition to the water quality data listed in Table 1, an analysis for waterborne particulates was conducted by CH Diagnostic and Consulting Service, Inc. of Fort Collins, Colorado, on a water sample collected from Green Canyon Spring on May 22 and 23, 1990, and detected:

1. No sediment;

2. Rare, 1-2 μ diameter, fine amorphous silica debris;

3. Rare plant debris; and

4. The laboratory report concluded by stating, "The small amount of plant debris (rodent fecal detritus) indicates some rodent access to the system (probably a tunneling species)."

The collected May 1990 water sample was at a temperature of 6 degrees Celsius and had a turbidity of approximately 0.2 National Turbidity Units (NTUs).

A microscopic particulate analysis (MPA) was conducted by the Wyoming State Veterinary Lab (Laramie, Wyoming) on a water sample collected from Green Canyon Spring on July 8, 1994. This analysis showed detections of diatoms at 2.96 per 100 gallons, other algae at 12.1 per 100 gallons, too numerous to count large amorphous debris, too numerous to count fine amorphous debris, plant pollen, and nematodes. The July 1994 MPA report comments and/or conclusions included:

1. Filter surface was light brown; visual sediment penetration was about ½ inch.

2. Smear and stain for *Cryptosporidium* was negative.

3. Diatoms included *Nitschia* and/or *Navicula*, *Cymbella* and a few *Fragillaria.*

4. Other algae included *Sphaerocystis* and *Closterium.*

5. Large amorphous debris consisted of filter fiber and plant filament fragments, sediment particles and clumps.

6. Fine amorphous debris was sedimentary grit and flocculent, greenish brown debris that floated on the slide mount.

7. Pollen was probably pine or spruce, judging from the size and three-lobed morphological characteristics.

8. Nematodes were a mixture of larval and young adult or juvenile stages, some of which had oral stylets, characteristic of plant-parasitic species.

9. Other prominent microparticulates were fungal spore casings, some of which were empty, some of which retained spores about 3 or 4 μm diameter; these spores stained blue with the Ziehl-Nielson, allowing differentiation between them and *Cryptosporidium*.

A second MPA was conducted by the Wyoming State Veterinary Lab (Laramie, Wyoming) on a water sample collected from Green Canyon Spring on June 13 and 14, 1996. This analysis showed detections of a few diatoms, too numerous to count large amorphous debris, too numerous to count fine amorphous debris, and nematodes at 8 per 100 gallons. The June 1996 MPA report comments and/or conclusions included:

1. Filter surface and winding profile were white to core. Concentrated sediment was gray, sandy/sedimentary, and settled rapidly on percoll-sucrose column without centrifugation.

2. A few diatom skeletons, *Nitschia* mainly, were seen.

3. Large amorphous debris was largely silica, but a few fragments of old plant stems, roots, etc., were also seen. Largest particles were around 100 μm long/wide.

4. Fine amorphous debris was almost exclusively silicaceous grit.

5. Nematode subadults (larvae/juveniles) outnumbered adults about 3:2.

CONCLUSIONS AND RECOMMENDATIONS

Based on the results of this hydrogeologic investigation, Green Canyon Spring is considered a Gallatin Limestone bedrock-sourced spring. Spring water yielded to the SVRA community water system is of good quality and quantity. However, the September 1999 site visit and May 1990 waterborne particulate analysis indicate that there is potential for the Green Canyon Spring collection system to be considered under direct surface water influence by the USEPA. The May 1990 waterborne particulate analysis provides evidence of probable rodent access to the Green Canyon Spring collection system. The May 1990 analysis indicates that if rodents have access to the spring collection system, then surface water influence may also occur in the future.

Although plastic sheeting is installed over the collection pipeline to help prevent infiltration of surface water into the pipeline, construction features of the collection pipeline, steel spring box, and concrete collection box may allow the spring collection system to be influenced by surface water, particularly during flood events. It is recommended that the engineering and construction of the spring collection system, steel spring box, transmission pipeline to the concrete collection box, and concrete collection box be thoroughly investigated and modified to ensure adequate sealing against direct surface water infiltration.

Recommended engineering actions for the SVRA to consider include:

1. Portions of the existing Green Canyon Spring collection box and associated pipelines should be excavated and investigated for integrity and to help determine if system components need to be rebuilt, repaired, or replaced. The excavation and investigation should be designed to determine the source of the "rodent fecal detritus" which was detected during the May 1990 waterborne particulate analysis. Berm construction may be necessary to help prevent infiltration of surface water into the collection/transmission system by diverting surface water away from the spring collection system from the spring to the concrete collection box.

2. A locking, security fence should be installed around the Green Canyon Spring area and concrete collection box area to limit access of people and large animals to these areas.

3. The active stream channel, which drains the east fork of Green Canyon, should be excavated and re-routed to the south side of the existing concrete collection box. This action would include cutting a channel/ditch along the bank on the south side of the gravel stream bed to capture surface water flow from the east fork of the canyon and divert the surface water flow away from the Green Canyon Spring collection system.

4. The installation and operation of a chlorination system may be investigated to help ensure the safety of the water supply for the SVRA community.

5. The area of Green Canyon Spring, the collection pipeline, and the collection box system may need to be completely excavated and rebuilt/replaced with a new collection system. Re-development of the spring should be carefully engineered and constructed to help reduce the potential for surface water infiltration into the spring collection system. As-built diagrams and construction diagrams/maps with photographs should be prepared to document the engineering and construction of the re-developed Green Canyon Spring collection system.

REFERENCES

Ahern, John, Collentine, Michael, and Cooke, Steve, 1981, *Occurrence and characteristics of ground water in the Green River Basin and Overthrust Belt, Wyoming:* Water Resources Research Institute, University of Wyoming, Laramie, Wyoming, Report to U.S. Environmental Protection Agency, Contract Number G-008269-79, July 1981, 2 volumes, Volumes V-A and V-B, (6 plates), 123 p.

Blackstone, D.L., Jr., and DeBruin, Rodney H., 1987, *Tectonic map of the Overthrust Belt, western Wyoming, northwestern Utah, and southeastern Idaho, showing oil and gas fields and exploratory wells in the Overthrust Belt and adjacent Green River Basin:* The Geological Survey of Wyoming Map Series 23, scale 1:316,800, 1 sheet.

Eddy-Miller, Cheryl A., Plafcan, Maria, and Clark, Melanie L., 1996, *Water Resources of Lincoln County, Wyoming:* U.S. Geological Survey Water-Resources Investigations Report 96-4246, 3 plates, 131 p.

Jorgensen Engineering and Land Survey, P.C., Jackson, Wyoming, 1995, *Star Valley Ranch Association Water Supply Evaluation and Recommendations:* Prepared for Star Valley Ranch Association, Thayne, Wyoming, February 7, 1995, one volume.

________, Jackson, Wyoming, 1996, *Water System Master Plan, Star Valley Ranch Association:* Prepared for Star Valley Ranch Association, Thayne, Wyoming, November 15, 1996, one volume.

Lines, Gregory C., and Glass, William R., 1975, *Water resources of the Thrust Belt of western Wyoming:* U.S. Geological Survey Hydrologic Atlas HA-539, map scale 1:250,000, 3 sheets.

McCalpin, James P., Piety, Lucille A., and Anders, Mark H., 1990, *Latest Quaternary faulting and structural evolution of Star Valley, Wyoming:* in Roberts, Sheila, 1990, *Geologic field tours of western Wyoming and parts of adjacent Idaho, Montana, and Utah:* Geological Survey of Wyoming, Public Information Circular No. 29, 191 p., p 4-12.

Oriel, Steven S., and Platt, Lucian B., 1980, *Geologic Map of the Preston 1° x 2° quadrangle, southeastern Idaho and western Wyoming:* U.S. Geological Survey Miscellaneous Investigations Map I-1127, map scale 1:250,000, 1 sheet.

Rubey, William W., 1958, *Geologic map of the Bedford quadrangle, Wyoming:* U.S. Geological Survey Geologic Quadrangle Map GQ-109, map scale 1:62,500, 1 sheet.

________, 1973, *Geologic map of the Acton quadrangle and part of the Big Pine quadrangle, Lincoln and Sublette counties, Wyoming:* U.S. Geological Survey Miscellaneous Geologic Investigations Map I-686, map scale 1:62,500, 2 sheets.

Schultz, A.R., 1914, *Geology and geography of a portion of Lincoln County, Wyoming:* U.S. Geological Survey Bulletin 543, 141 p.

Thayne East, Wyoming quadrangle, 1980, U.S. Geological Survey 7.5 Minute Topographic Map, map scale 1:24,000, 1 sheet.

Walker, Eugene H., 1965, *Ground water in the upper Star Valley, Wyoming:* U.S. Geological Survey Water-Supply Paper 1809-C, 1 plate, 27 p.

TriHydro Corporation appreciates this opportunity to work with Forsgren Associates, Inc. and the Star Valley Ranch Association. If you have any questions or comments, or desire additional services, please call me at (307) 745-7474, Extension 1312.

Sincerely
TRIHYDRO CORPORATION

Keith E. Clarey

Keith E. Clarey, P.G.
Senior Project Geologist

002-008

Enclosure

Table 1. Summary of Water Quality Data for Green Canyon Spring, Star Valley Ranch Association, Thayne, Wyoming (1990 - 1999).

Parameter (units)	*USEPA MCL*	Sample 3/19/90	Sample 3/23/92	Sample 9/9/93	Sample 3/30/94	Sample 12/20/94	Sample 8/17/95	Sample 10/9/96	Sample 7/21/97	Sample 1/7/99
Analyzed VOCs and SVOCs (µg/L)	*varies*	--	--	All ND	--	All ND	--	--	--	--
Antimony (mg/L)	*0.006*	--	--	--	--	--	ND(0.0026)	ND(0.001)	--	--
Arsenic (mg/L)	*0.05*	--	ND(0.002)	--	--	--	ND(0.0018)	ND(0.005)	--	--
Barium (mg/L)	*2*	--	0.020	--	--	--	0.0087	ND(0.10)	--	--
Beryllium (mg/L)	*0.004*	--	--	--	--	--	ND(0.0010)	ND(0.0005)	--	--
Cadmium (mg/L)	*0.005*	--	ND(0.005)	--	--	--	ND(0.0002)	ND(0.0005)	--	--
Calcium ($mgCaCO_3/L$)	--	--	43.02	--	--	--	92.1	--	--	--
Chloride (mg/L)	*250*	--	1.5	--	--	--	--	--	--	--
Chromium (mg/L)	*0.1*	--	ND(0.006)	--	--	--	ND(0.012)	ND(0.05)	--	--
Color (color units)	*15*	--	5	--	--	--	--	--	--	--
Copper (mg/L)	*1.0*	--	ND(0.01)	--	--	--	ND(0.0030)	ND(0.01)	--	--
Cyanide (mg/L)	*0.2*	--	--	--	--	--	0.02	--	--	ND(0.005)
Fluoride (mg/L)	*2.0*	--	0.11	--	--	--	ND(0.40)	--	--	ND(0.10)
Gross Alpha (pCi/L)	*15*	0.9 +/-1.7	--	--	--	--	--	--	--	--
Gross Beta (mrem)	*4*	3.5 +/-1.6	--	--	--	--	--	--	--	--
Iron (mg/L)	*0.3*	--	ND(0.02)	--	--	--	--	--	--	--
Langelier Index/Corrosivity (unitless)	*non-corr.*	--	+ 0.15	--	--	--	+ 0.18	--	--	--
Lead (mg/L)	*0.005*	--	ND(0.001)	--	--	--	0.0023	ND(0.001)	--	--
Manganese (mg/L)	*0.05*	--	ND(0.02)	--	--	--	--	--	--	--
Mercury (mg/L)	*0.002*	--	ND(0.011)	--	--	--	ND(0.0002)	ND(0.0005)	--	--
Nickel (mg/L)	*0.1*	--	--	--	--	--	ND(0.070)	ND(0.02)	--	--
Nitrate + Nitrite as N (mg/L)	*10*	--	--	--	ND(0.2)	--	--	--	0.24	--
Nitrate as N (mg/L)	*10*	--	0.26	--	--	--	0.17	0.16	--	--
Nitrite as N (mg/L)	*1*	--	--	--	--	--	ND(0.076)	ND(0.10)	--	--
Odor (threshold odor numbers)	*3*	--	1	--	--	--	--	--	--	--
pH (standard units)	*6.5 to 8.5*	--	8.12	--	--	--	7.90	--	--	--
Selenium (mg/L)	*0.05*	--	ND(0.001)	--	--	--	ND(0.0039)	ND(0.005)	--	--
Silver (mg/L)	--	--	ND(0.005)	--	--	--	--	--	--	--
Sodium (mg/L)	--	--	ND(0.09)	--	--	--	0.99	0.32	--	--
Sulfate (mg/L)	*250*	--	2.2	--	--	--	2.3	--	9.0	--
Surfactants/Foaming Agents (mg/L)	*0.5*	--	ND(0.4)	--	--	--	--	--	--	--
Thallium (mg/L)	*0.002*	--	--	--	--	--	ND(0.0012)	ND(0.0004)	--	--
Total Dissolved Solids (mg/L)	*500*	--	158	--	--	--	136	--	--	--
Total Alkalinity ($mgCaCO_3/L$)	--	--	145	--	--	--	131	--	--	--
Zinc (mg/L)	*5*	--	ND(0.01)	--	--	--	--	--	--	--

USEPA MCL = U.S. Environmental Protection Agency Maximum Contaminant Level, Safe Drinking Water Act.

Notes: ND = Not detected at concentration in parentheses.
VOCs and SVOCs = Volatile organic compounds and semi-volatile organic compounds.
µg/L = micrograms per liter.
mg/L = milligrams per liter.
pCi/L = picocuries per liter.
mrem = millirems.