Castle Creek
TMDL Study

Prepared by:
Utah Department of Environmental Quality/Division of Water Quality

EPA Approval Date

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Castle Creek TMDL

Waterbody ID	**Castle Creek and tributaries from confluence with Colorado River upstream to the headwaters.**
Location	**Grand County, Utah HUC# 14030005**
TMDL Pollutants of Concern	**Total Dissolved Solids (TDS)**
Impaired Beneficial Uses	**Class 4: Protected for agricultural uses including irrigation of crops and stock watering.**
Loading Assessment	
Current Load	**8,504 tons/yr**
Loading Capacity	**Not to exceed 1800 mg/l concentration**
Water Quality Targets/Endpoints **TDS**	**Segment Stream above and below Seventh Day Adventist diversion and implement site-specific standard for agricultural use not to exceed 1800 mg/l for lower segment, and maintain 1200 mg/l standard above the diversion.** ***(Footnote 4 of the Utah Water Quality Standards (R317-2) states TDS limits may be adjusted if such adjustment does not impair the designated beneficial use of the receiving water.)***
Implementation Strategy **TDS**	**Implement site-specific standard based on assessment that exceedences are naturally occurring and no current impact on the agricultural defined beneficial use.** **Implement irrigation water management practices where applicable.**
This document is identified as a TMDL for Castle Creek and is officially submitted to the U.S. EPA to act upon and approve as a TMDL.	

Executive Summary

This document addresses water quality impairments within the Castle Creek watershed through the establishment of a Total Maximum Daily Load (TMDL) for Total Dissolved Solids (TDS). The purpose of this TMDL study is to assess conditions and make recommendation or establish endpoints to improve water quality and protect or restore designated beneficial uses. Castle Creek, from the confluence with the Colorado River upstream approximately 15 miles, is listed on the State's 303D list of impaired waters and has been designated as not meeting its agricultural beneficial use (Class 4) due to high concentrations of TDS. The source of impairment originates primarily from seepage from the Paradox formation, a naturally occurring geologic formation that borders the Castle Creek watershed. There are no permitted point source discharges in the watershed.

Castle Creek is the only perennial stream in the valley and flows through the town of Castle Valley. Surrounded by desert terrain, the watershed has an elevation ranging from 6000 to 4200 feet above sea level. Castle Creek runs the length of the valley, and is fed by several springs, ephemeral streams, and snowmelt runoff from the northern end of the La Sal Mountains. The mountain valleys provide contrast to the panoramic view of the deserts and canyons below. This varied topography offers recreational opportunities throughout the year. The Castle Creek Watershed is in a cold desert ecosystem with hot summers, cold winters and moderate spring and fall seasons.

Because of the natural geologic sources of TDS that underlie Castle Valley there will always be TDS non-point source loading into Castle Creek. However, several small projects within the watershed may improve the water quality and riparian habitat of Castle Creek. A locally led watershed planning effort, the Mill, Onion, Castle Creek / Ken's Lake Technical Advisory Committee, is addressing water quality and riparian habitat issues on Castle Creek. There is some potential to implement riparian restoration projects on Castle Creek and to implement irrigation water management control projects on irrigated lands within the watershed.

This study recommends that the current impaired stream reach be segmented and that a site specific standard for total dissolved solids (TDS) be adopted for that portion of the reach where the water during the critical summer period is predominantly groundwater recharge from the paradox formation and is responsible for elevated TDS concentrations. The recommended standard is 1800 mg/l not to exceed an annual load of 12,302 tons/yr. This standard would not impair the beneficial use of the water in the Castle Creek drainage. The new standard would be effective from the diversion southeast of Castle Valley downstream to the confluence with the Colorado River. Upstream from the diversion to the headwaters the standard would remain 1200 mg/l.

1. INTRODUCTION

Castle Creek is a tributary of the Colorado River, located approximately 17 miles northeast of Moab in Grand County, southeastern Utah HUC #14030005. The valley is approximately 3 miles wide and 8 miles long. Exceedences of Utah water quality standards for total dissolved solids were documented at state monitoring site 495803. Monitoring occurred during the intensive monitoring cycle from July 1997- June 1998. This TMDL document addresses those exceedences.

A Watershed Restoration Action Strategy (WRAS) for any implementation projects will be developed for the watershed but it is not included with this document. The Utah Division of Water Quality will work with stakeholders to further develop details of a WRAS. Implementation of recommendations in this document is strictly of a voluntary nature and will be done with full participation of all interested and affected parties. This document is considered to be a component of the WRAS. In the event that new data indicate that the targets used in this analysis are not appropriate or if new standards are adopted, the load capacity will be adjusted accordingly.

Castle Creek is the only perennial stream in the valley and flows through the town of Castle Valley. Surrounded by desert terrain, the watershed has an elevation ranging from 6000 to 4200 feet above sea level. Castle Creek runs the length of the valley, and is fed by several springs, ephemeral streams, and snowmelt runoff from the northern end of the La Sal Mountains. The mountain valleys provide contrast to the panoramic view of the deserts and canyons below. This varied topography offers recreational opportunities throughout the year. The Castle Creek Watershed is in a cold desert ecosystem with hot summers, cold winters and moderate spring and fall seasons.

2. WATER QUALITY STANDARDS

Based on historical water quality data, water quality of Castle Creek does not meet the standards set by the State of Utah for its Class 4 designated beneficial use. Castle Creek was originally listed as impaired on the 1998 303d list. The Utah Division of Water Quality (UDWQ) has adopted numeric water quality standards for total dissolved solids to protect the designated use of agricultural waters.

Tables 2.1 through 2.4 show the TMDL status, pollutant of concern and the beneficial use classification of Castle Creek. Water quality standards have been set at a level to protect and support the beneficial use. The primary standards leading to an assessment of use impairment is the numeric criteria for total dissolved solids of 1200 mg/l. However, it should be noted that exceptions to the 1200 mg/l standard are permissible provided current designated beneficial uses of the receiving water are not impaired. Currently there are no reports of agricultural impairment due to existing water quality conditions.

Table 2.1 – From Utah's 2002 list of stream and river waterbodies needing TMDL analyses.

Water Quality Management Unit	Waterbody Name	HUC	Perennial Stream (Miles)	Beneficial Use Impaired	Cause	Priority For TMDL	Targeted For TMDL
Southeast Colorado	**Castle Creek**	**14030005-009**	**11.88**	**4**	**Total Dissolved Solids**	**High**	**Yes**

Table 2.2 – Beneficial use class and pollutants causing impairment

Waterbody	Beneficial Use Classes (Impaired class shown in **bold**)	Pollutant of Concern
Castle Creek	2B, 3B, **4**	Total Dissolved Solids

Table 2.3 – Explanation of beneficial use classifications for Castle Creek

Class 2 - Protected for recreational use and aesthetics.
Class 2B - Protected for secondary contact recreation such as boating, wading, or similar uses.
Class 3 - Protected for use by aquatic wildlife.
Class 3B - Protected for warm-water species of game fish and other warm-water aquatic life, including the necessary aquatic organisms in their food chain.
Class 4 - Protected for agricultural uses including irrigation of crops and stock watering.

Public Law 92-500, the Federal Water Pollution Control Act (commonly referred to as the Clean Water Act), enacted by Congress in 1972 and amended in 1977 and 1981, provides a national framework for water quality protection. The Clean Water Act recognizes that it is the primary responsibility of the States to prevent, reduce and eliminate water pollution; to determine appropriate uses for their waters and to set water quality criteria to protect those uses. Section 303 of the Clean Water Act requires that each state reviews and, if necessary, revises its Water Quality Standards at least once every three years. This serves to ensure that the requirements of state and federal law are met and that water quality criteria are adequate to protect designated water uses.

Utah's Listing Methodology for Total Dissolved Solids

Utah uses the Total Dissolved Solids criterion of 1,200 milligrams per liter (mg/L) to evaluate attainment of water quality standards for Class 4 waters. The 303(d) listing criteria evaluates beneficial use support based on the number of violations of the water quality criterion for conventional parameters as listed in Table 2.3. A minimum of ten samples collected throughout the year (as in an intensive monitoring cycle) is required for assessment.

Table 2.4 - 303(d) Criteria for Assessing Beneficial Use Support

Degree of Use Support	Conventional Parameter* (TDS)
Full	Criterion exceeded in less than two samples and in less than 10% of the samples if there were two or more exceedences.
Partial	Criterion was exceeded two times, and criterion was exceeded in more than 10% but not more than 25% of the samples.
Non-support	Criterion was exceeded two times, and criterion was exceeded in more than 25% of the samples.

* Based on at least 10 samples during an intensive monitoring cycle

3. WATER QUALITY TARGETS/ENDPOINTS

The desired goal for the TMDL is to meet state water quality standards for the designated beneficial uses of the waterbody. However an exemption to the 1200 mg/l standard is allowed if such adjustment does not impair the designated beneficial use of the receiving water.

TDS in the groundwater is the only identified source of TDS in Castle Creek. Observing that TDS exceedence occurs primarily during the irrigation season when the stream is essentially dewatered from the agricultural diversion.

The source analysis identifies only naturally occurring pollutants. As a result a site-specific criteria is recommended from the diversion downstream to the confluence with the Colorado River. The selected endpoint (1800 mg/l) was derived from the 90th percentile of the historic data plus a small margin of error.

Endpoint Identification

1. TDS < 1800 mg/l from diversion southeast of Castle Valley downstream to confluence with the Colorado River.
2. TDS < 1200 mg/l from diversion southeast of Castle Valley upstream to the headwaters. Current water quality above the diversion is of sufficient quality to maintain the standard and support delisting.

4. TECHNICAL ANALYSIS & SIGNIFICANT SOURCES

Data Inventory and Review

The data used in the development of the TDS TMDL for Castle Creek included physiographic data that described the physical conditions of the watershed and environmental monitoring data that was used to identify potential pollutant sources, their location, and their loading contribution. Table 4.1 presents the various data types and data sources reviewed in the watershed.

Table 4.1 - Inventory of Data Used for the Watershed Assessment

Data Category	Description	Data Source
Watershed Physiographic Data	Land Use	Utah Division of Water Resources
	Stream Reach Coverage	Utah Division of Water Resources
	Stream Characteristics	Utah Division of Water Resources Utah Division of Water Quality
	Soils	Natural Resources Conservation Service
	Geology	Utah Geologic Survey
Environmental Monitoring Data	303(d) Listed Waters	Utah Division of Water Quality
	Water Quality Data	Utah Division of Water Quality
	Streamflow Data	Utah Division of Water Quality

Flow Data

Flow records available for Castle Creek watershed are listed in Table 4.2 with their gage names, station IDs, and periods of record.

Table 4.2 - Flow

Station	Location	Start Date	End Date	Number of Measurements
495803	CASTLE CK AT U128 XING	July 31,1997	June 25,1998	12
495805	CASTLE CK AT WHITE RANCH	January 30,1980	January 27,1981	6
495807	CASTLE CK AT CASTLETON	July 19, 2002	November 21, 2002	5

Water Quality Data

The Utah Division of Water Quality (UDWQ) maintains a water quality database for 3 sites within the Castle Creek watershed; only 1 of these is currently being monitored and is located at the highway crossing at U128. This is the site that was assessed and will be used to determine compliance. A summary of the data available at the stations within the watershed is provided in Table 4.4, and station locations are shown in Figure 4.1.

Table 4.3 - Water Quality Samples

Station	Location	Type	Start Date	End Date	Count
495803	CASTLE CK AT U128 XING	Ambient	July 31,1997	June 25,1998	12
495805	CASTLE CK AT WHITE RANCH	Ambient	January 10,1980	January 27,1981	8
495807	CASTLE CK AT CASTLETON	Ambient	August 22, 2002	August 22, 2002	1

Water Quality Analysis

Total dissolved solids in Castle Creek exceed state standards as can be seen in Figure 4.2. The average value for TDS in Castle Creek at storet site 495803 is 1214 mg/l.

Table 4.4 – Water Quality Analysis

Station	Location	Count	# Exceeding (1200 mg/l)	% Exceeding (1200 mg/l)	Mean (mg/l)
495803	CASTLE CK AT U128 XING	12	3	25	1200
495805	CASTLE CK AT WHITE RANCH	8	6	75	1271
495807	CASTLE CK AT CASTLETON	5	2	40	870

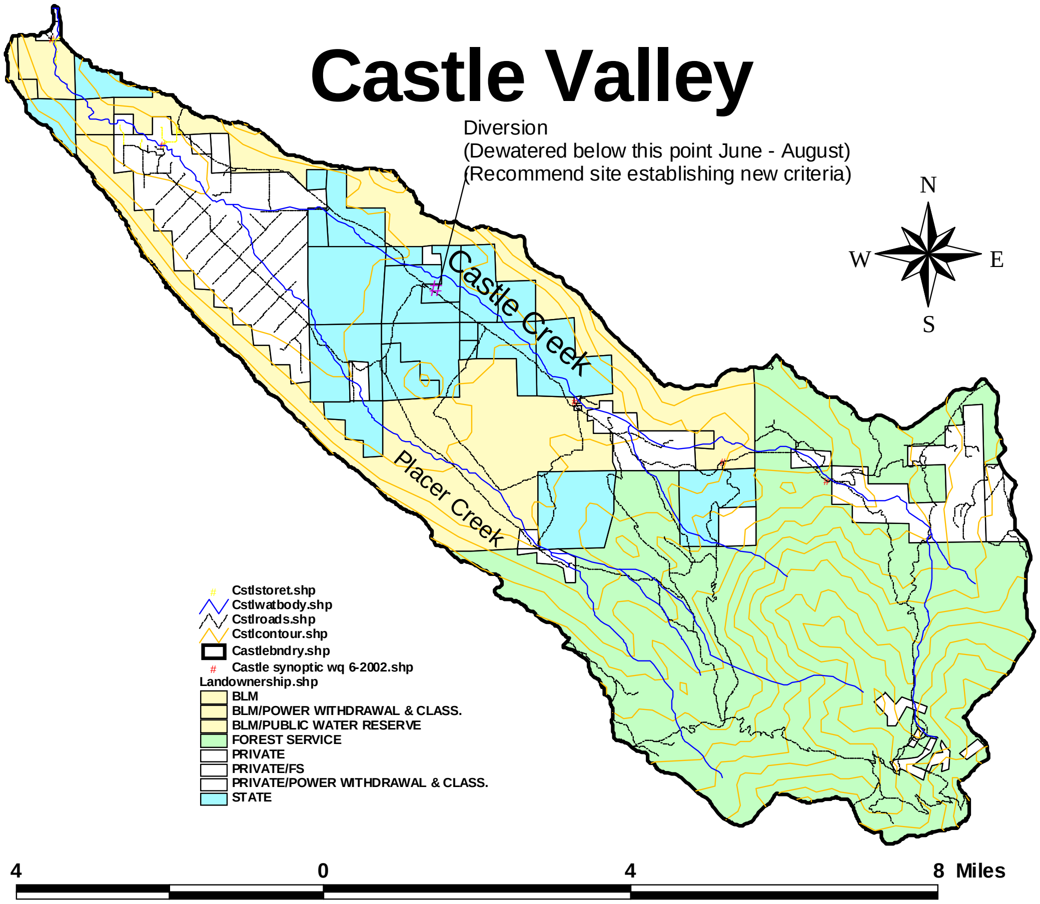
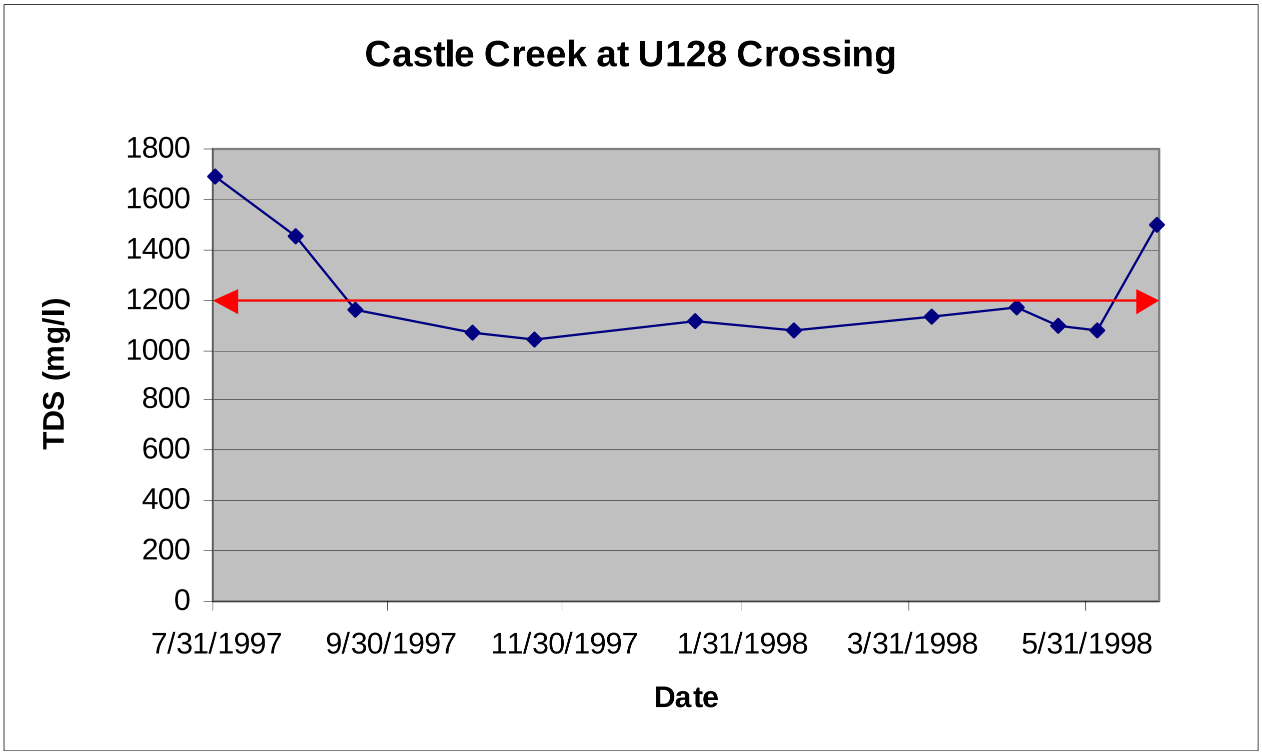


Figure 4.1 - Monitoring Sites in Castle Creek



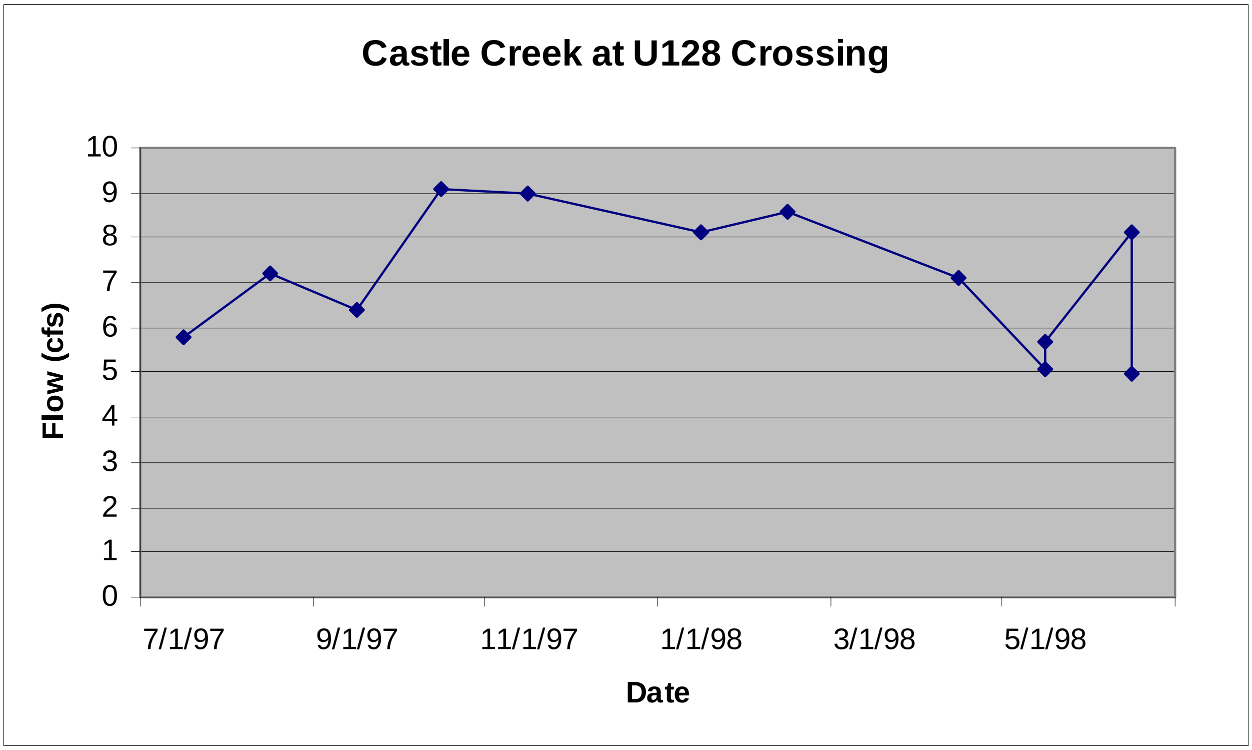


Figure 4.2 - Site 495803 / 1997-1998 Intensive Survey data.
Note: Summertime exceedences occur under low flow conditions.

The entire flow in Castle Creek from the diversion downstream to the narrows is eliminated during the irrigation season from June through August. Flow in this section during this period is attributed to ground water inflow and perhaps some subsurface irrigation return flow (< .5 cfs above the Narrows). A synoptic survey conducted July 5, 2002 showed increasing TDS in a downstream direction (see figure 4.3). Groundwater is the only significant identified potential source of TDS in Castle Creek. Observing that TDS exceedence occurs primarily during the irrigation season (Table 4.5) when the stream is completely de-watered from the diversion downstream to the Narrows supports the conclusion that only natural sources of TDS from groundwater comprise the streamflow.

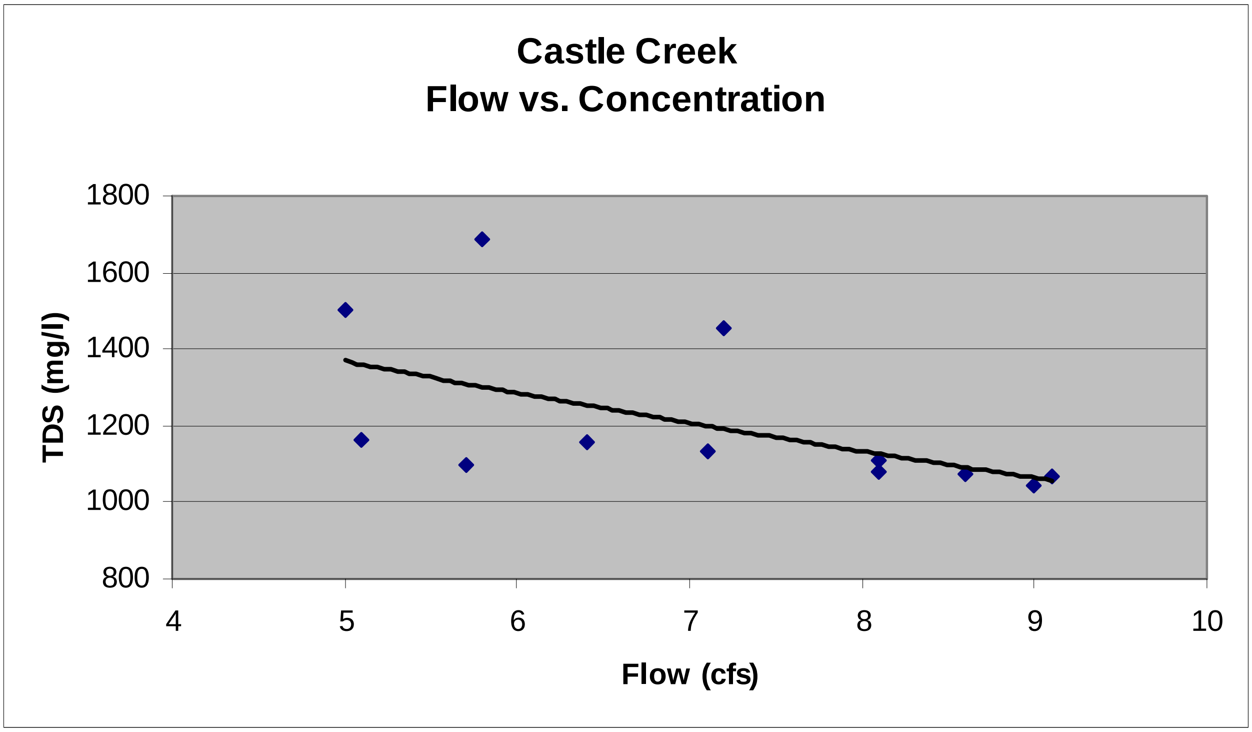


Figure 4.3 - Site 495803 Castle Creek at U128 / 1997-1998 Intensive Survey data.

Table 4.5 – Seasonality of TDS & Flow in Castle Creek 1997-1998 (site 495803)				
Season	**Spring**	**Summer**	**Autumn**	**Winter**
Months	Mar, Apr, May	June, July, Aug	Sept, Oct, Nov	Dec, Jan, Feb
TDS average	1133	**1430**	1088	1094
Flow average	6.0	6.5	8.2	8.4

In 1996 the Utah Geological Survey made investigations into and mapped the groundwater recharge and discharge areas, potentiometric surface elevation, and specific conductance in Castle Valley. The study was done in an effort to produce tools for protecting groundwater quality and managing potential contaminant sources in Castle Valley. The Report of Investigation 229 titled "Recharge Area And Water Quality Of The Valley-Fill Aquifer Castle Valley, Grand County, Utah" by Noah P. Snyder is attached as Appendix A. Synder states that "Water quality in the valley-fill aquifer is generally high in upper Castle Valley, but declines in the lower valley, perhaps due to recharge from saline ground water in bedrock aquifers in contact with Paradox Formation evaporites." He further states, "I believe that the poor-quality ground water in the valley-fill aquifer is the result of recharge from the Cutler and Paradox Formations, not contamination from fertilizers, septic systems, or animal wastes."

Using specific conductivity and total dissolved solids from the 1997-1998 intensive survey. We found a very high correlation (r) of 0.98 between measured TDS and measured conductivity. The regression equation was TDS (mg/l) = 0.632 x conductivity (üS). The synoptic survey of July 5, 2002 used this equation to determine TDS from the measured conductivity. Site 1 was located at the road crossing upstream of Castleton. Site 2 was located near Castleton. Site 3 was above the diversion upstream of Castle Valley. Site 4 was below Castle Valley at the road crossing above the narrows. Site 5 was at the U128 highway crossing. The only observed exceedence of the TDS standard was at site 5 where the entire flow was groundwater return flow.

Water at the mouth of Castle Creek where water quality is monitored is representative of return flow and groundwater. The quality is sufficient for stock watering and for irrigation of higher TDS tolerant vegetation, the current uses.

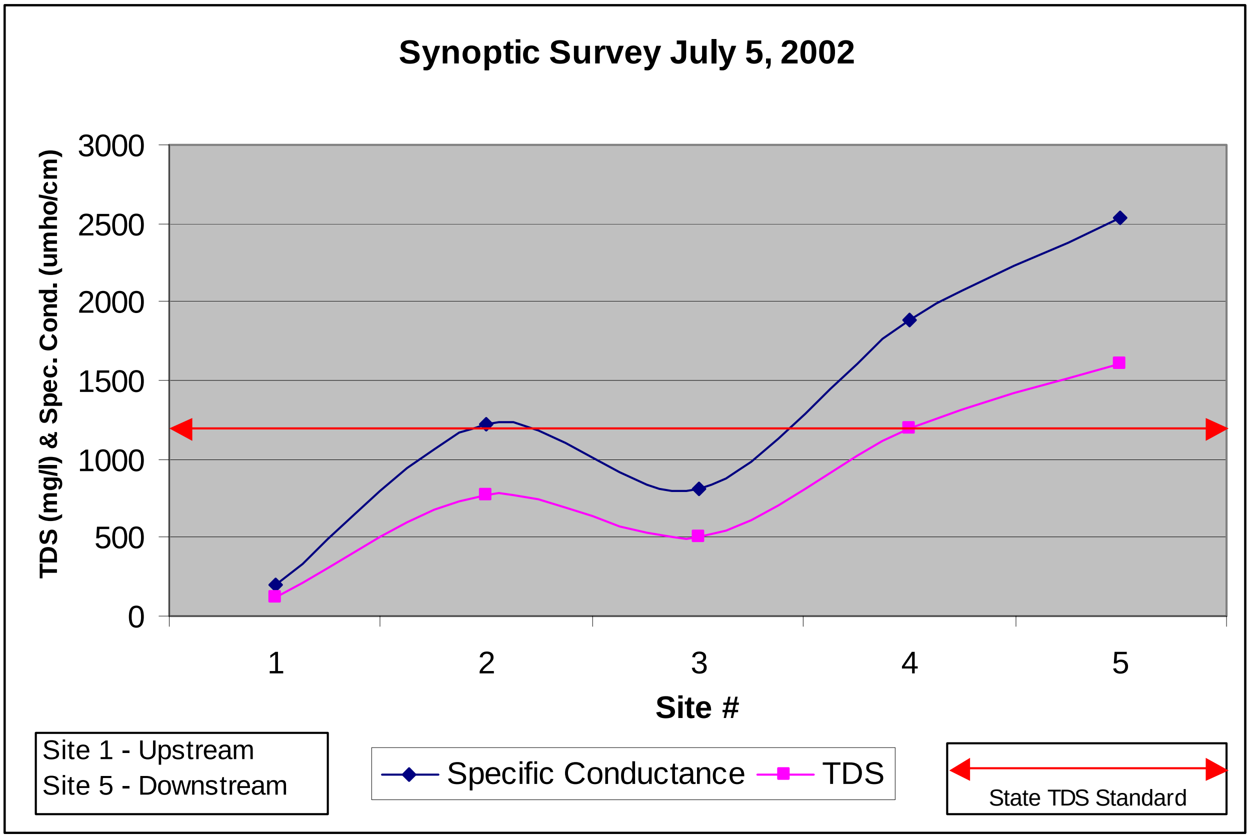


Figure 4.3 – Synoptic Survey June 2002

Table 4.6 - Castle Creek at U128 Crossing (site 495803)

TDS (mg/l)	**Flow (cfs)**	**Date (mm-dd-yy)**	**Number of days**	**Weighted load (tons)**
1686	5.8	7-31-97	32	844
1454	7.2	8-28-97	25	692
1156	6.4	9-18-97	31	618
1066	9.1	10-29-97	32	824
1042	9	11-20-97	39	986
1112	8.1	1-15-98	45	1093
1076	8.6	2-18-98	41	1023
1134	7.1	4-7-98	39	847
1166	5.1	5-7-98	22	353
1100	5.7	5-21-98	14	237
1080	8.1	6-4-98	18	413
1500	5	6-25-98	29	576
Average TDS (mg/l)	**Average Flow (cfs)**		**Total Days**	**Total Annual Load (tons)**
1214	7		365	8504

5. MARGIN OF SAFETY AND SEASONALITY (MOS)

The MOS is a required part of the TMDL development process. There are two basic methods for incorporating the MOS (USEPA, 1991). Implicit methods incorporate the MOS using conservative model assumptions to develop allocations. Explicit methods specify a portion of the total TMDL as the MOS, allocating the remainder to sources.

The recommendation of this study is to develop site-specific criteria for the lower section of Castle Creek. This is based on the conclusion that there are no controllable man induced sources of TDS in this stream reach.

In general no MOS will be identified but a MOS is implied and used in future monitoring and tracking to assure water quality standards are met for the agricultural defined beneficial use based on establishment of site-specific criteria for the lower reach of Castle Creek.

6. ALLOCATION OF LOAD REDUCTIONS

Because the identified source of TDS in Castle Creek is naturally occurring ground water, no allocation will be made.

7. PUBLIC PARTICIPATION

Information concerning the Castle Creek TMDL has been distributed throughout the area. A brochure was developed to help people understand TMDL’s. A public meeting and open house were held to explain the assessment and recommendations to those interested. The main land manager in the basin is the BLM. The local BLM office is represented on the Technical Advisory

Committee for the watershed, as are other major stakeholders. The TMDL report was posted to the Division of Water Quality's web site on the Internet and a comment period of 30 days was offered.

A Technical Advisory Committee was established for the development of the TMDL. Table 7.1 shows the committee membership and the interests' they represent.

Table 7.1 - Technical Advisory Committee members

NAME	REPRESENTING	EMAIL	PHONE #
Mike Allred	Div. Water Quality	mdallred@utah.gov	801-538-6316
Don Andrews	NRCS	don.andrews@utmonticel.fsc.usda.gov	435-587-2481 ext 18
Ann Marie Aubry	BLM	Ann_Marie_Aubry@ut.blm.gov	435-259-2173
Louis Berg	Div. Wildlife Resources	nrdwr.lberg@state.ut.us	435 636-0268
George Carter	Moab SCD, Irr Co.	geoann@citlink.net	435-259-1413
Kathrine Foster	Forest Service	kfoster01@fs.fed.us	435-636-3503
Michael Johnson	Extension	michaelj@ext.usu.edu	435-259-7558
Dale Pierson	Spanish Valley WCD	dpierson@lasal.net	435-259-8121
Todd Stonely	Div. Water Resources	TSTONELY.NRWRES@state.ut.us	801 538-7277
Mark Page	Div. Water Rights	MPAGE.NRWRT@state.ut.us	435-637-1303

APPENDIX A
Groundwater Study

RECHARGE AREA AND WATER QUALITY OF THE VALLEY-FILL AQUIFER CASTLE VALLEY, GRAND COUNTY, UTAH

by
Noah P. Snyder
Utah Geological Survey

Report of Investigation 229
April 1996
UTAH GEOLOGICAL SURVEY
a division of
Utah Department of Natural Resources
in cooperation with
Utah Department of Environmental Quality
Division of Water Quality

ABSTRACT

All culinary water in Castle Valley is from wells. Increased residential development using individual wastewater-disposal systems has raised concerns for the long-term quality of ground water in the valley-fill aquifer. In this study, ground-water recharge and discharge areas, potentiometric surface elevation, and specific conductance were mapped to serve as tools for protecting ground-water quality and managing potential contaminant sources in Castle Valley

Castle Valley is one of several northwest-trending salt anticline valleys on the Colorado Plateau in southeastern Utah. The unconsolidated valley fill is the principal aquifer in the valley and consists of coarse alluvial-fan deposits and stream alluvium, with minor clay. Some recharge to the valley-fill aquifer comes from underflow from bedrock aquifers, but most is from La Sal Mountains runoff via Castle Creek and Placer Creek. Because of the absence of protective, low-permeability confining layers, the valley-fill aquifer is unconfined, and most of the valley is classified as primary recharge area. The only discharge area is along lower Castle Creek.

Water quality in the valley-fill aquifer is generally high in upper Castle Valley, but declines in the lower valley, perhaps due to recharge from saline ground water in bedrock aquifers in contact with Paradox Formation evaporites. Wells tapping the Cutler Formation aquifer beneath the valley fill also yield poor-quality water. The coarse-grained, unconfined valley-fill aquifer is highly susceptible to contamination from surface recharge.

INTRODUCTION

Background

Ground water, chiefly from the unconsolidated valley-fill aquifer, is the only source of drinking water in Castle Valley. Recent increased development in the sparsely populated area has underscored the need to protect the aquifer from contamination. Recharge to the aquifer is mostly by runoff from the north flank of the La Sal Mountains. Recharge areas are typically underlain by fractured rock and/or coarse-grained sediment with relatively little ability to inhibit infiltration or renovate contaminated water. Ground-water flow in recharge areas has a downward component and relatively fast rate of movement. Because contaminants can readily enter an aquifer in recharge areas, management of potential contaminant sources in these areas deserves special attention to protect the quality of ground water. Ground-water recharge-area mapping is thus important to define these vulnerable areas.

Ground-water recharge-area maps typically show: (1) primary recharge areas, (2) secondary recharge areas, and (3) discharge areas (Anderson and others, 1994). Primary recharge areas, usually the uplands and coarse-grained unconsolidated deposits along valley margins, do not contain thick, continuous, fine-grained layers and have downward ground- water gradients. Secondary recharge areas, commonly valley benches, have fine-grained layers thicker than 20 feet (6 m) and downward ground-water gradients. Because Castle Valley does not have extensive clay layers, it has no secondary recharge areas. Ground-water discharge areas are generally in valley lowlands. Ground water in the valley-fill aquifer is unconfined throughout Castle Valley. Discharge areas for unconfined aquifers are where the water table intersects the ground surface, forming springs or seeps. The extent of both recharge and discharge areas may vary seasonally and from dry to wet years.

Purpose and Scope

The purpose of this study is to help state and local government officials and local residents protect the quality of ground water in Castle Valley by defining areas where ground- water aquifers are vulnerable to contamination. The study is a cooperative effort among the Utah Geological Survey (UGS), the Utah Division of Water Quality (DWQ), the Utah Division of Water Rights (DWRT), and the U.S. Environmental Protection Agency (EPA) to map recharge and discharge areas in the Castle Creek drainage basin in Grand County.

The scope of work included a literature review, geologic field reconnaissance, and field measurement of depths to water in wells and specific conductance of water in wells, springs, and Castle Creek. Logs of water wells drilled in the valley prior to October 1995 were collected from the State Engineer's office. Well-log information was entered into a database and well locations were plotted on 1:24,000-scale U.S. Geological Survey topographic maps. Generalized recharge- and discharge-area boundaries were then drawn on the base maps.

Setting

The study area is the drainage basin of Castle Creek in Grand County, Utah (figure 1). Castle Valley is oriented northwest-southeast, and is 12 miles (19 kin) long and 2 miles (3 km) wide.

Physiography and Drainage

Castle Valley is on the Colorado Plateau near Moab, Utah. The La Sal Mountains make up the southeast border of the study area, reaching 12,331 feet (3,758 m) in elevation at Mount Waas. The cliffs of Porcupine Rim, and Parriott and Adobe Mesas, define the southwest and northeast borders, respectively. The study area ends to the northwest at the Colorado River at an elevation of 4,120 feet (1,250 m).

The headwaters of Castle Creek and Placer Creek are in the La Sal Mountains (figure 1). These streams flow into the valley on either side of Cain Hollow and Round Mountain, and join near the town of Castle Valley. In the northwest part of the study area, cliff walls close the valley and Castle Creek flows through a short, narrow canyon and then enters the Colorado River.

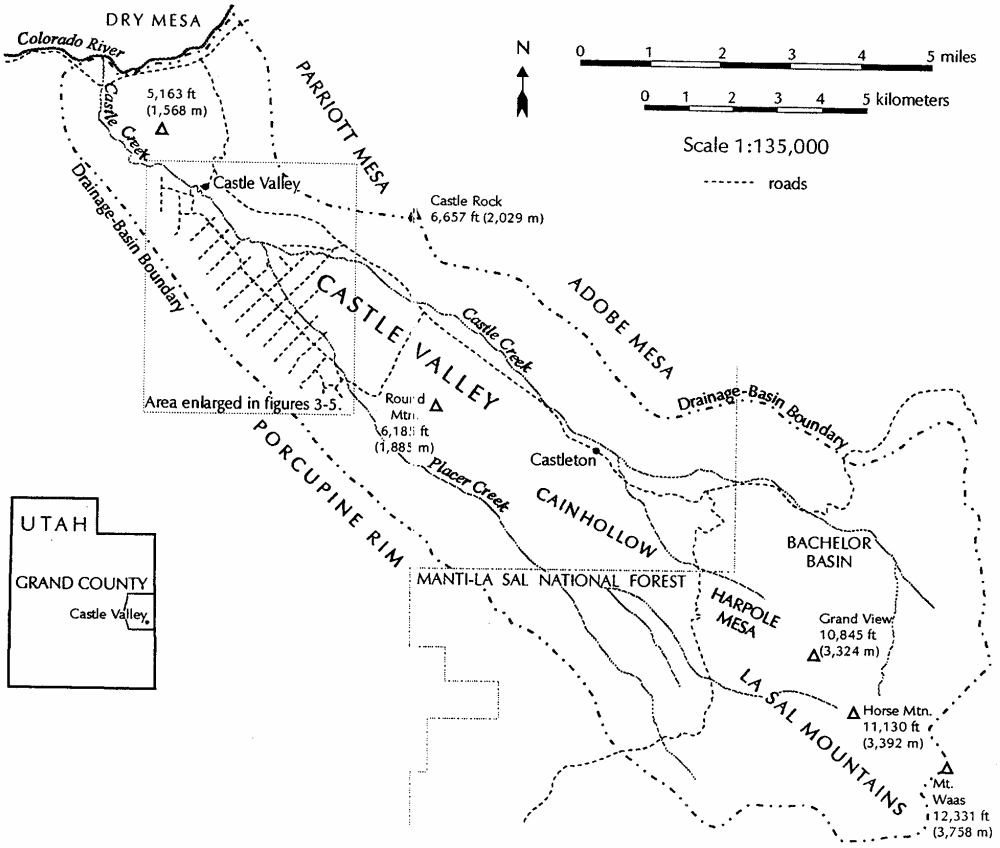


Figure 1. Castle Creek drainage basin study area.

Climate

Average annual precipitation ranges from 9.00 inches (22.9 cm) at elevation 4,021 feet (1,226 m) on the Colorado River in Moab to more than 30 inches (76 cm) in the La Sal Mountains (Blanchard, 1990; Ashcroft and others, 1992). The Castle Valley Institute in the town of Castle Valley, at elevation 4,720 feet (1,439 m), and the town of Castleton, farther up the valley at elevation 5,840 feet (1,780 m), receive 11.50 and 13.63 inches (29.2 arid 34.6 cm) of precipitation per year, respectively (Ashcroft and others, 1992) Average annual evapotranspiration is four times precipitation (Ashcroft and others, 1992). Temperatures in Castleton average 50.2°F (10.1 °C) annually, and may reach above 100°F (38°C) in the summer and below 0°F (-18°C) in the winter (Ashcroft and others, 1992).

Land Use

Castle Valley is becoming increasingly popular as a site for vacation and retirement homes. As a result, the population is growing. Many new homes have been built on 5-acre lots in the town of Castle Valley during the past few years, and this trend is continuing. Approximately 300 people reside in the valley at present (1996). Tourism is an important growth industry in the valley. Cattle graze on the flanks of the La Sal Mountains in the summer, and on the valley floor in the winter. The valley has some irrigated cropland.

Previous Studies

The hydrogeology of Castle Valley has been summarized in several previous studies, including Sumison (1971), Weir and others (1983), and Blanchard (1990). Mulvey (1992) mapped geologic hazards of Castle Valley, including ground-water contamination and flooding. Geologic mapping studies of Castle Valley include Harper (1960), Doelling and Ross (1993), and Ross (in press). Ground- and surface-water quality and supply in Castle Valley are being studied by the DWRT; some data has been published in two progress reports (Ford, 1994; Ford and Grandy, 1995).

METHODS

Recharge and Discharge Areas

The methods used in this study to identify confining layers, classify aquifers, and delineate recharge and discharge areas, are modified from those of Anderson and others (1994). I used driller's logs of water wells to delineate primarily recharge areas and discharge areas, based on the presence of confining layers and water levels. The use of dril1er's logs requires interpretation because of the variable quality of the logs. Correlation of geology from well logs is difficult because lithologic descriptions are generalized and commonly inconsistent among various drillers. Using water-level data from well logs is also problematic because water levels were measured during different seasons and years.

For this project confining layers are defined as any fine-grained (clay and/or silt) layer thicker than 20 feet (6 m). Because no extensive confining layers are present in Castle Valley, the valley-fill aquifer is unconfined and only primary recharge and discharge areas are delineated. Ground-water flow in primary recharge areas has a downward component. Discharge areas in unconfined aquifers are where the water table intersects the land surface (figure 2). Surface water, springs, and phreatophytic plants (wetlands) are indicators of ground-water discharge. Careful analysis of the topography, surficial geology, and ground-water hydrology must be made before using these wetlands to define discharge areas for the valley-fill aquifer.

I did not map small secondary recharge or discharge areas defined by only a few wells surrounded completely by primary recharge areas. Contaminants entering the aquifer system above these clay lenses have a high potential to reach primary recharge areas.

Potentiometric Surface and Specific Conductance

The DWRT and UGS measured depths to water in 70 wells and specific conductance of water for 50 wells, springs, and sites along Castle Creek from March 25 to 28, 1996. Depth to water was measured in about 20 percent of the valley wells. Wellhead elevations were taken from 7.5' USGS topographic maps to produce the Potentiometric surface map. Specific conductance was measured in the field with a YSI 33 S-C-T meter. Specific- conductance samples were obtained from only those wells having pumps. To interpret water quality data collected previously by DWRT (Ford, 1994; Ford and Grandy, 1995), I differentiated wells completed in bedrock from those in valley-fill aquifers for 17 selected wells.

GEOLOGY

Bedrock

Castle Valley is surrounded by Permian to Tertiary sedimentary and igneous rocks. It is part of a large, regional, collapsed salt anticline that includes Paradox Valley to the southeast (Doelling and Ross, 1993). Beneath the valley is the Pennsylvanian Paradox Formation. The Paradox Formation contains thick salt layers deposited in a shallow sea. As these salt layers were buried they became mobile and formed a diapir in what is now Castle Valley. The uplift of the Colorado Plateau in the late Tertiary increased erosion rates and allowed ground water to dissolve the salt layers from the core of the anticline (Doelling and Ross, 1993). Subsequently, the overlying rock collapsed and eroded, leaving the present Castle Valley in the core of the anticline. Mulvey (1992) mapped a suspected Quaternary fault parallel to Porcupine Rim northwest of Round Mountain. Several sinkholes along this fault are attributed to localized dissolution or piping (Mulvey, 1992).

Gypsum, mudstone, and shale of the Paradox Formation caprock crop out along the margins of Castle Valley and around Round Mountain. Sandstone, conglomerate, and shale of the Cutler Formation overlie the Paradox in cliffs at the southwest end of the valley. Triassic shale and sandstone of the Moenkopi, Chinle, Wingate, and Kayenta Formations overlie the Cutler and form the cliffs along the northeast and southwest sides of the valley. Round Mountain and the La Sal Mountains are an upper Tertiary intrusive granodiorite porphyry.

Unconsolidated Sediments

The valley fill of Castle Valley consists of alluvial-fan deposits and stream alluvium. Holocene stream deposits along Castle Creek and Placer Creek are generally poorly sorted sand, silt, and clay, with some gravel lenses, particularly in higher reaches (Doelling, and Ross, 1993). Coarse-grained older alluvium

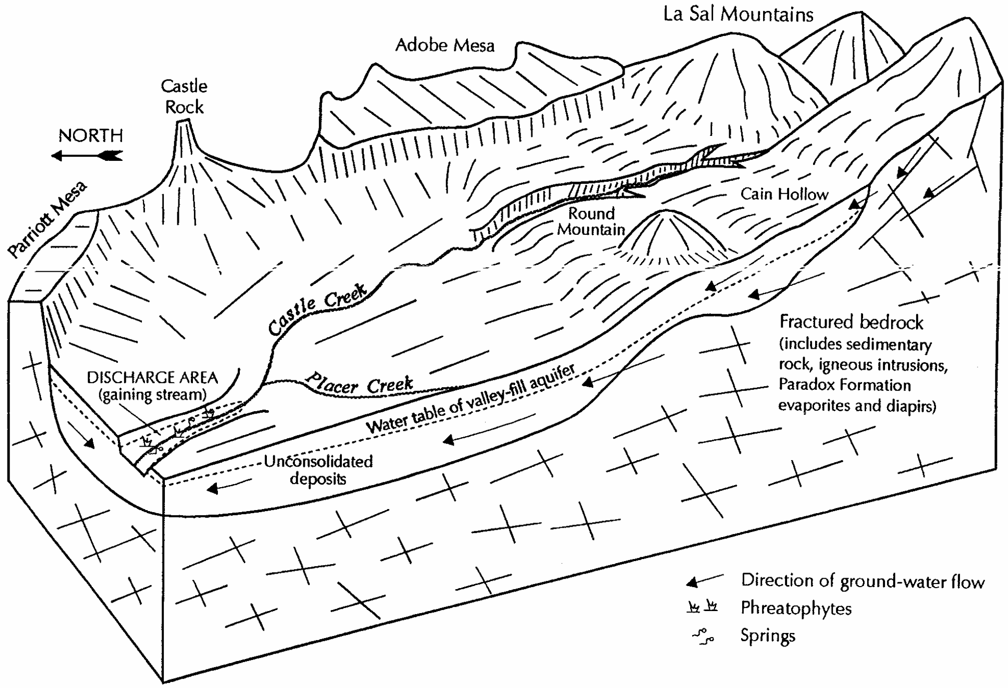


Figure 2. Schematic block diagram showing ground-water flow in Castle Valley.

is exposed in the higher parts of Castle Valley, and underlies the younger stream alluvium in lower Castle Valley (Doelling and Ross, 1993). Alluvial-fan deposits form apron-like gentle slopes at the base of Porcupine Rim. The fans consist of poorly sorted boulders, cobbles, and gravels in a fine-grained matrix (Doelling and Ross, 1993),

GROUND WATER

Ground water is in both fractured-rock and valley-fill aquifers in Castle Valley. Most of the water entering the aquifers falls initially as snow in the La Sal Mountains. All of the homes in Castle Valley use ground water for domestic purposes, although some of the residents in areas with highly mineralized ground water choose not to drink the water.

The quality of ground water in Castle Valley varies widely, depending on its source. Drinking-water and ground-water-protection regulations in Utah classify ground water based largely on total-dissolved-solids concentrations, as shown in table 1. Class IA and II waters are considered suitable for drinking, provided concentrations of individual contaminants do not exceed state and federal ground-water-quality standards. Water with total-dissolved-solids concentrations in the higher part of the class II range is generally suited for drinking water only if treated, but can be used for some agricultural or industrial purposes without treatment. Most water in Castle Valley is class IA, and II.

Table 1. Drinking-water and ground-water-protection regulations in Utah.

CLASS	**TOTAL DISSOLVED SOLIDS** (milligrams per liter)	**APPROXIMATE SPECIFIC CONDUCTANCE** (micromhos per centimeter at 25°C)
IA (pristine)	less than 500	less than 750
II (drinking water quality)	500 to 3,000	750 to 4,700
III (limited use)	3,000 to 10,000	4,700 to 15,000
IV (saline)	more than 10,000	more than 15,000

Fractured-Rock Aquifers

Aquifer Characteristics

Approximately 30 wells receive water from the Cutler Formation aquifer along the base of Porcupine Rim on the west side of the valley (Blanchard, 1990). The Cutler is the only currently used fractured-rock aquifer in Castle Valley. Well depths are generally 150 to 300 feet (45 to 90 m) below the land surface. Recharge to the aquifer is partially from the La Sal Mountains (Doelling and Ross, 1993). The Chinle and Moenkopi Formations are important confining units overlying the Cutler Formation (Blanchard, 1990). Regionally, the Wingate Sandstone is an important fractured-rock aquifer, but exposures of the Wingate in Castle Valley are too localized and do not receive sufficient recharge to be aquifers.

Water Quality

Well water in the Cutler Formation has more total dissolved solids than that in adjacent valley fill (figure 3) Water in the Cutler aquifer is mostly class II, but in some areas may be class III. Specific conductance ranges from 842 to 4,360 micromhos per centimeter at 25°C (Ford and Grandy, 1995) (figure 3); the lowest values come from shallower wells in northern Castle Valley that may be receiving some water from the valley- fill aquifer. The highest values come from areas at the base of Porcupine Rim where large quantities of gypsum along drainages indicate nearby Paradox evaporites. Blanchard (1990) reported that two wells in the Cutler Formation exceeded Utah State primary drinking water standards for selenium and sulfate, although high selenium has not been found in more recent testing (Ford and Grandy, 1995). This poor-quality water is the result of some combination of three possible factors: (I) long residence time and flow path, (2) dissolved fine-grained constituents of the Cutler Formation, and (3) hydraulic connection to the Paradox Formation evaporites beneath the Cutler Formation.

Unconsolidated Valley-Fill Aquifer

The unconsolidated valley-fill aquifer is the most important source of water in Castle Valley because it provides good quality drinking water, however, it is most susceptible to contamination.

Aquifer Characteristics

The valley fill consists of generally coarse-grained gravelly alluvial-fan deposits and stream alluvium. The material is coarsest near source areas at the base of Porcupine Rim and the La Sal Mountains and is finer grained along the lower reaches of Castle Creek. Well logs indicate that a few wells in the valley intersect clay lenses but none is extensive enough to confine or protect the valley-fill aquifer. The valley-fill aquifer is thus unconfined. The water table ranges from 30 feet (9 m) to over 100 feet (30 m) below the land surface. The valley fill is as thick as 350 feet in lower Castle Valley (Doelling and Ross, 1993). Wells are generally drilled less than 150 feet (45 m) into valley fill.

Recharge and Discharge

The potentiometric-surface map, (figure 4) shows that water in the valley-fill aquifer flows generally northwest with Castle Creek and Placer Creek. Some additional flow into the aquifer is from fractured-rock aquifers along the southwest margin (figure 4). Most of the recharge to the valley-fill aquifer is from Castle and Placer Creeks, which originate high in the La Sal Mountains. As Castle Creek crosses the coarse-grained valley fill in the southeastern part of the study area, much of the flow percolates into the aquifer. Castle Creek is a losing stream except near the town of Castle Valley (Ford and Grandy, 1995) (figure 2). The entire valley is primary recharge area except this small discharge area (figure 4). Sources of recharge other than Castle and Placer Creeks include: (1) direct percolation of precipitation, particularly in the higher parts of the valley; (2) percolation and seepage of irrigation water; and (3) inflow from adjacent fractured-rock aquifers.

The area of ground-water discharge from the valley-fill aquifer near the town of Castle Valley is where the channel is incised up to 40 feet (12 m) into the valley fill and has intersected the water table (Ford and Grandy, 1995) (figure 4). Other discharge is from: (1) wells; (2) evapotranspiration, particularly along lower Castle Creek; and (3) underflow into the Colorado River.

Water Quality

Water in the valley-fill aquifer is class IA and II. Several researchers have noted a general down-valley increase in dissolved solids in wells and springs in the valley-fill aquifer (Weir and others, 1983; Ford, 1994). This trend is also apparent in the specific-conductance data from eight wells in the valley-fill aquifer, for which values ranged from 357 to 1,960 micromhos per centimeter at 25°C (Ford and Grandy, 1995) (figure 3) Figure 5 ful1her documents this general down-valley decline in water quality and also shows declines toward the valley margins indicating recharge from the poor-quality Cutler Formation aquifer along the base of Porcupine Rim. The plume of high-quality water along Castle and Placer Creeks confirms that these creeks are a principal source of recharge to the valley-fill aquifer (figure 5). Salty water discharging from a small spring in the northwestern end of the valley comes from Paradox Formation evaporites (Doelling and Ross, 1993). The especially poor-quality water in valley-fill wells and Castle Creek in the far northwestern part *of* the valley is probably related to a local hydraulic connection to water in the Paradox Formation (figures 3 and 5)

I believe that the poor-quality ground water in the valley-fill aquifer is the result of recharge from the Cutler and Paradox Formations, not contamination from fertilizers, septic systems, or animal wastes. Nitrate concentrations are under 1 mg/L in all of the sampled wells, an order of magnitude below state and federal drinking-water standards (Ford and Grandy, 1995). Additionally, Ford and Grandy (1995) found no evidence of high fecal coliform counts in the 15 wells sampled in Castle Valley.

Potential for Water-Quality Degradation

Although water quality is generally high in the valley-fill aquifer, the potential for contamination is significant. The valley fill of Castle Valley has no continuous clay lenses to act as protective confining layers. Pollutants can thus enter the aquifer virtually anywhere. The coarse-grained sediments also have little ability to renovate contaminants once in the system. At present, wells supply culinary water to all of the homes in Castle Valley. These homes also all use septic tanks to treat their wastes, which means that the potential for nitrate contamination of down-gradient wells is very strong. None of the wells sampled by Ford and Grandy (1995) shows such contamination, but it is a possibility, especially as more homes are built. Mulvey (1992) points out that the current practice of platting 5-acre lots helps reduce the potential for water-quality degradation.

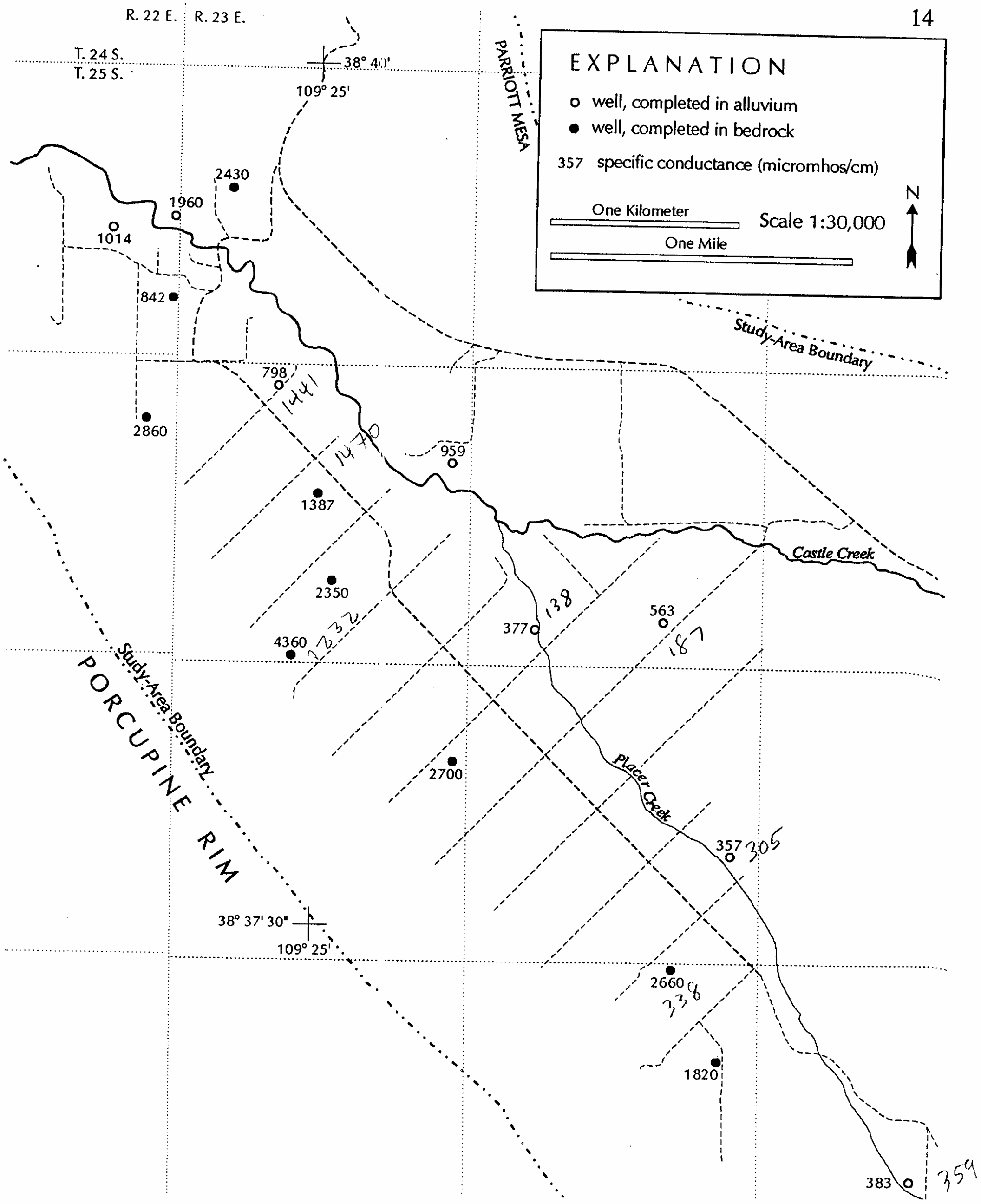


Figure 3. Northern Castle Valley area showing specific conductance of selected wells in bedrock and alluvium (data from Ford and Grandy, 1995).

High specific conductance in wells in the Cutler Formation indicates that the aquifer is an unsuitable source of high-quality water. Highly mineralized water from the Cutler aquifer recharges the valley-fill aquifer along the west and north sides of the valley (figures 3 to 5). At present, the large quantity of good-quality water that flows northwest in the valley-fill aquifer beneath Castle and Placer Creeks dilutes recharge from the Cutler aquifer along the base of Porcupine Rim. Increased recharge to the valley-fill aquifer from the Cutler aquifer and Paradox evaporites is a potential problem associated with increased pumping as more wells are drilled.

Mulvey (1992) lists three possible solutions to some of these potential ground-water problems: (1) culinary water sources could be developed only upgradient of septic systems; (2) a central sewage treatment system could be installed; and (3) a community-wide water system could be developed. The paradox is that these solutions generally are not economically feasible for 5-acre lot development, which has been instrument to maintaining the current quality of ground water.

SUMMARY AND CONCLUSIONS

The valley-fill aquifer of Castle Valley is unconfined and consists of alluvial-fan deposits and strean1 alluvium. Infiltration of stream runoff originating as precipitation in the La Sal Mountains, south of Castle Valley, is the most important source of recharge to the valley-fill aquifer. Ground water flows with Castle Creek and Placer Creek toward the lowest part of Castle Valley, where some of it discharges back to Castle Creek. Except for this small discharge area, the entire drainage basin is primary recharge area. Water in the fractured Cutler Formation aquifer is generally poor quality, with high specific conductance in many wells. The Cutler aquifer recharges the valley-fill aquifer along the western side of the valley. Water quality in the valley-fill aquifer declines from class IA in the higher parts of Castle Valley to class II in the lower parts of the valley, due to hydraulic connections to the Cutler and Paradox Formations. This decline may worsen with increased pumping. The coarse-grained, unconfined valley-fill aquifer has little ability to renovate contaminated water or block its entry, so the potential for ground-water-quality degradation is significant.

ACKNOWLEDGMENTS

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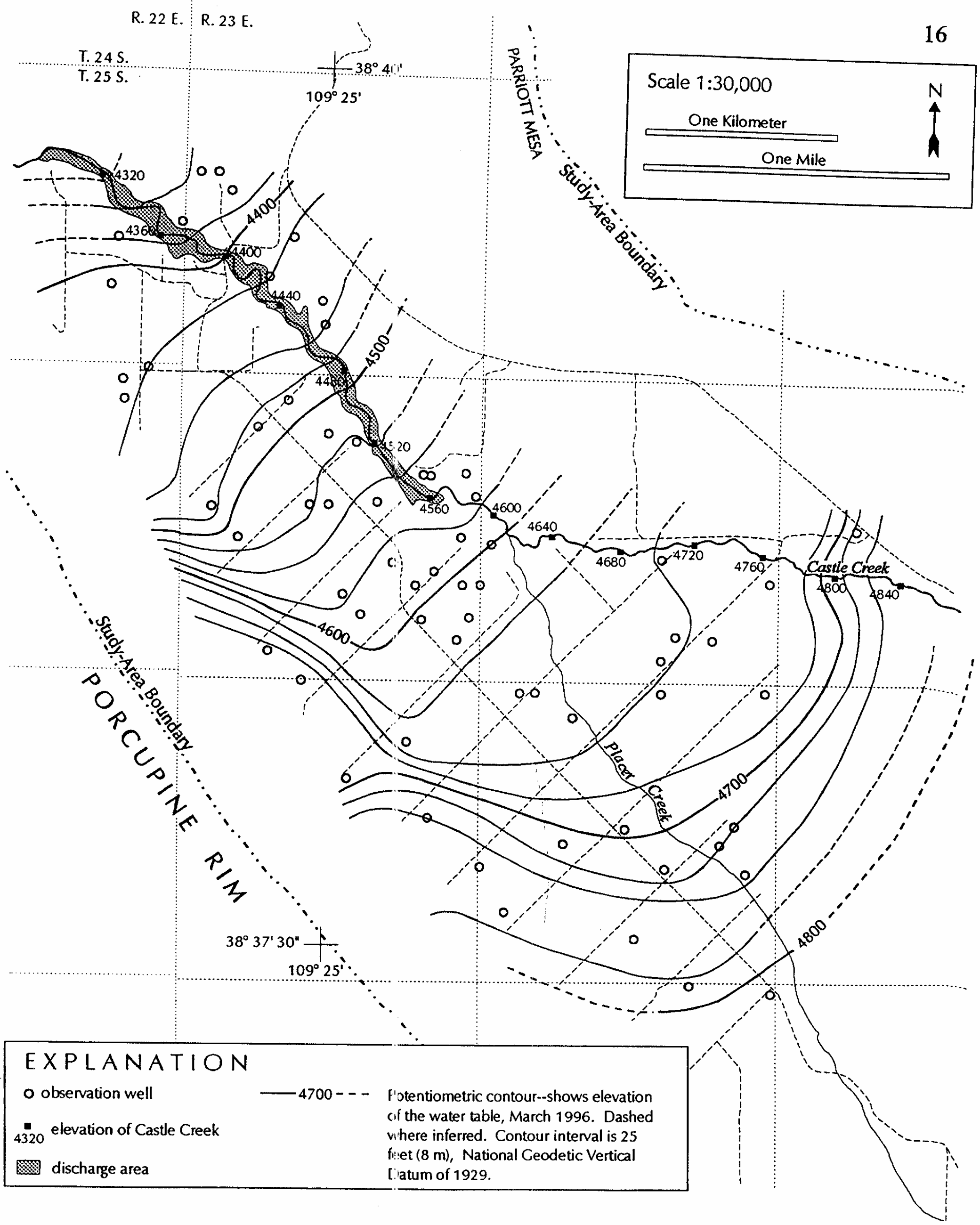

Figure 4. Potentiometric-surface map of northern Castle Valley showing discharge area and elevations of Castle Creek.

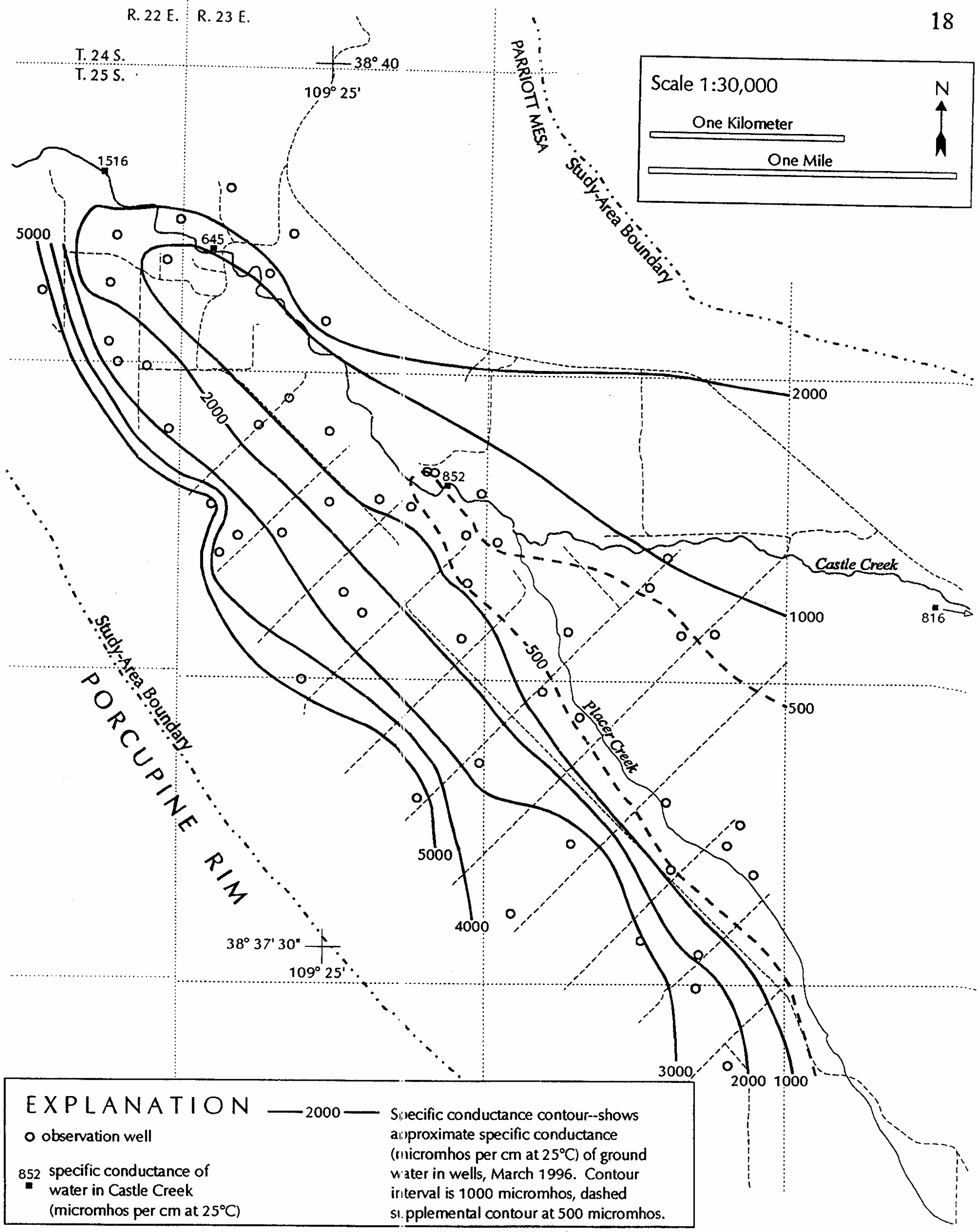

Figure 5. Specific-conductance contour map of northern Castle Valley.

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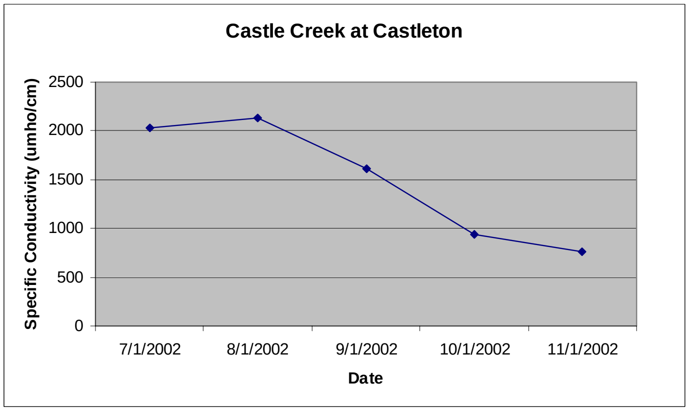
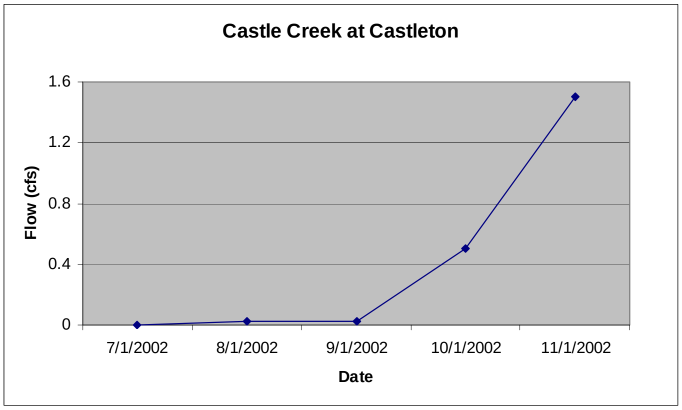
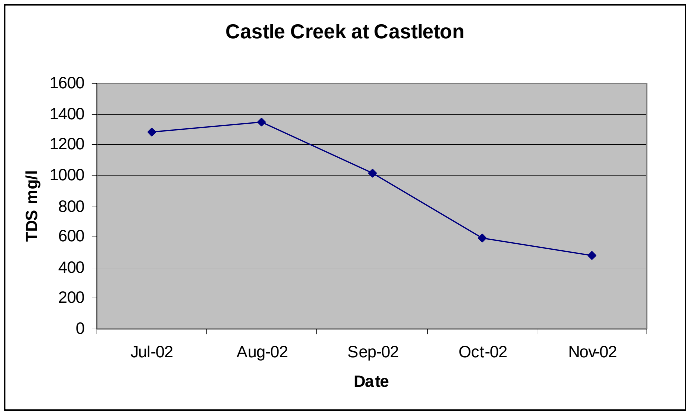
APPENDIX B
Water Quality Data

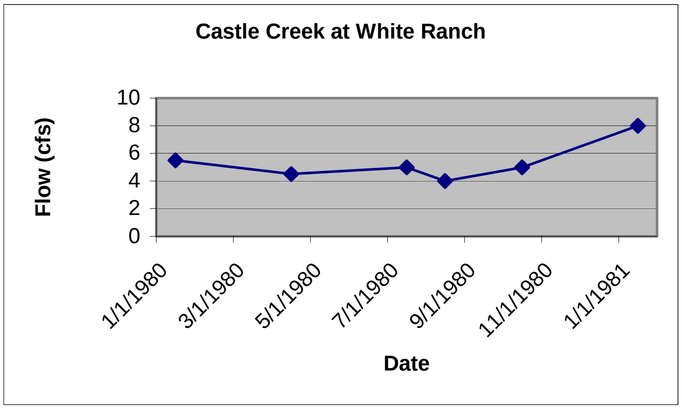
Site	Storet	Date	Total Dissolved Solids (mg/l)	Flow (cfs)
CASTLE CK AT U128 XING	495803	31-Jul-1997	1686	5.8
CASTLE CK AT U128 XING	495803	28-Aug-1997	1454	7.2
CASTLE CK AT U128 XING	495803	18-Sep-1997	1156	6.4
CASTLE CK AT U128 XING	495803	29-Oct-1997	1066	9.1
CASTLE CK AT U128 XING	495803	20-Nov-1997	1042	9
CASTLE CK AT U128 XING	495803	15-Jan-1998	1112	8.1
CASTLE CK AT U128 XING	495803	18-Feb-1998	1076	8.6
CASTLE CK AT U128 XING	495803	7-Apr-1998	1134	7.1
CASTLE CK AT U128 XING	495803	7-May-1998	1166	5.1
CASTLE CK AT U128 XING	495803	21-May-1998	1100	5.7
CASTLE CK AT U128 XING	495803	4-Jun-1998	1080	8.1
CASTLE CK AT U128 XING	495803	25-Jun-1998	1500	5
CASTLE CK AT U128 XING	495803	19-Jul-2002	1764	1.8
CASTLE CK AT U128 XING	495803	22-Aug-2002	1810	2.5
CASTLE CK AT U128 XING	495803	19-Sep-2002	1734	2
CASTLE CK AT U128 XING	495803	17-Oct-2002	1570	3
CASTLE CK AT U128 XING	495803	21-Nov-2002	1436	3.5
CASTLE VALLEY CK AT WHITE RANCH	495805	10-Jan-1980	1278	
CASTLE VALLEY CK AT WHITE RANCH	495805	30-Jan-1980	1276	5.5
CASTLE VALLEY CK AT WHITE RANCH	495805	5-Mar-1980	1292	
CASTLE VALLEY CK AT WHITE RANCH	495805	16-Apr-1980	1452	4.5
CASTLE VALLEY CK AT WHITE RANCH	495805	8-Jul-1980	950	5
CASTLE VALLEY CK AT WHITE RANCH	495805	6-Aug-1980	1838	4
CASTLE VALLEY CK AT WHITE RANCH	495805	22-Oct-1980	1212	5
CASTLE VALLEY CK AT WHITE RANCH	495805	27-Jan-1981	1050	8
CASTLE VALLEY CK AT CASTLETON	495807	19-Jul-2002		0
CASTLE VALLEY CK AT CASTLETON	495807	22-Aug-2002	1730	0.0223
CASTLE VALLEY CK AT CASTLETON	495807	19-Sep-2002		0.0223
CASTLE VALLEY CK AT CASTLETON	495807	17-Oct-2002		0.5
CASTLE VALLEY CK AT CASTLETON	495807	21-Nov-2002		1.5

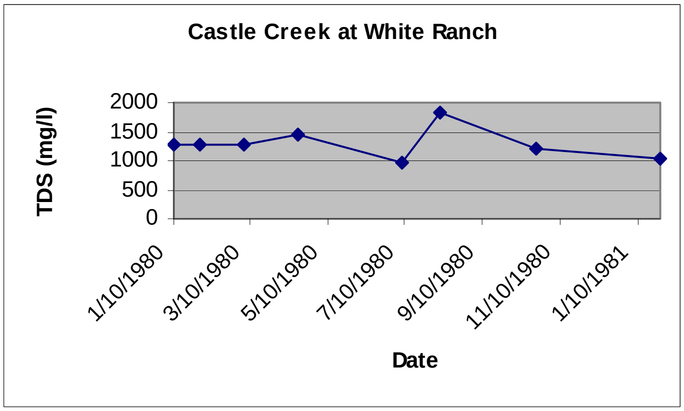
APPENDIX C
Plotted Water Quality Data

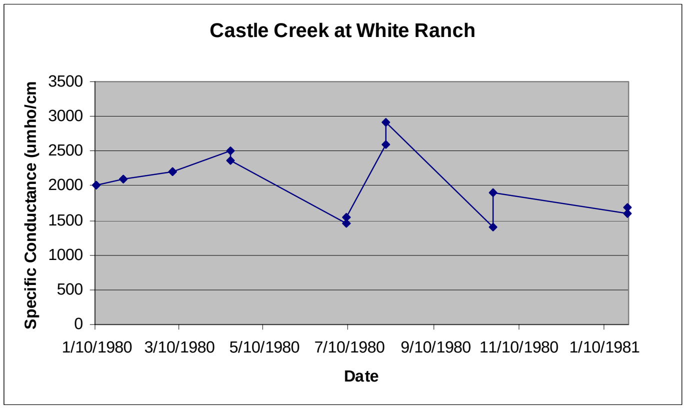

Castle Creek at Castleton
Specific Conductivity (umho/cm)
2500
2000
1500
1000
500
0
7/1/2002
8/1/2002
9/1/2002
10/1/2002
11/1/2002
Date

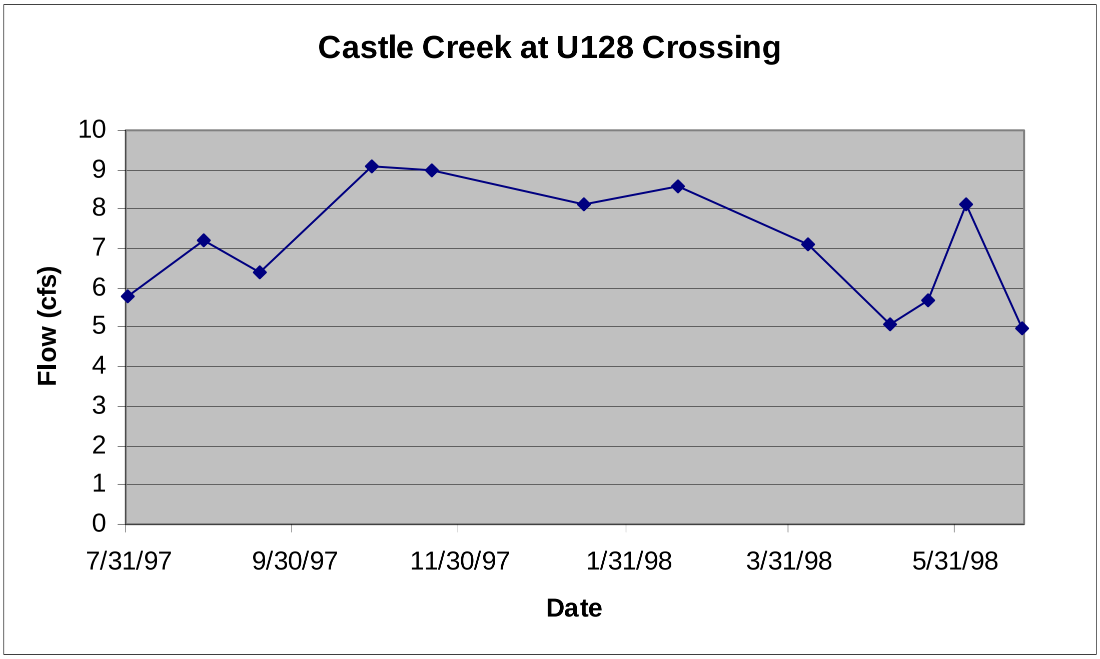

Castle Creek at Castleton
Flow (cfs)
1.6
1.2
0.8
0.4
0
7/1/2002
8/1/2002
9/1/2002
10/1/2002
11/1/2002
Date

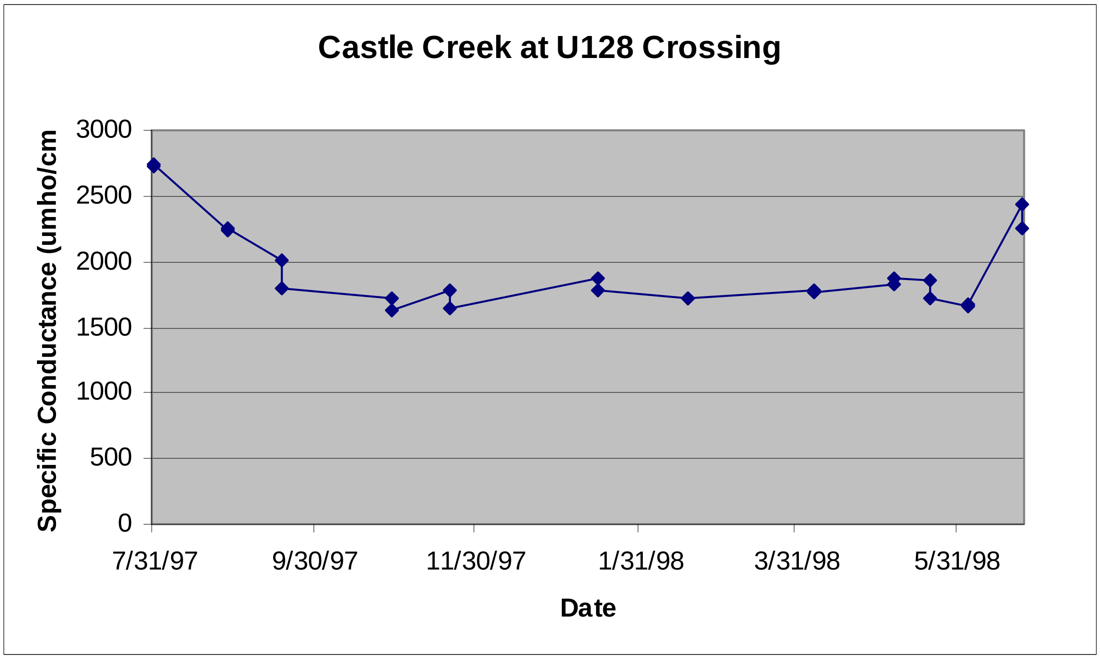

Castle Creek at Castleton
TDS mg/l
1600
1400
1200
1000
800
600
400
200
0
Jul-02
Aug-02
Sep-02
Oct-02
Nov-02
Date

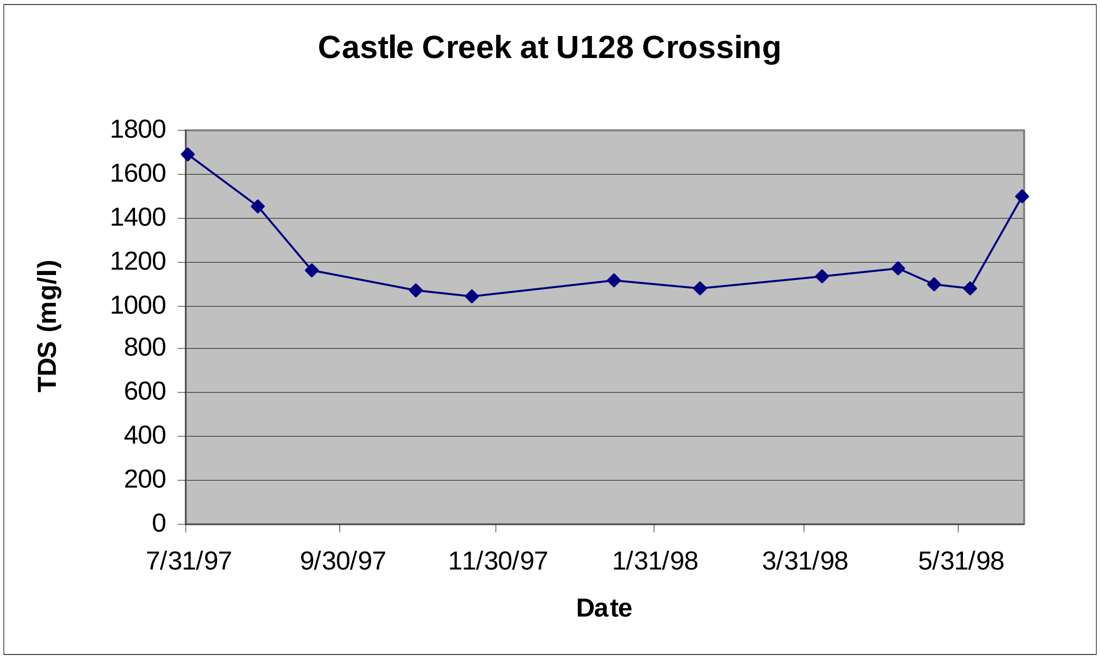

Castle Creek at White Ranch
Flow (cfs)
10
8
6
4
2
0
1/1/1980
3/1/1980
5/1/1980
7/1/1980
9/1/1980
11/1/1980
1/1/1981
Date


Castle Creek at White Ranch
TDS (mg/l)
2000
1500
1000
500
0
1/10/1980
3/10/1980
5/10/1980
7/10/1980
9/10/1980
11/10/1980
1/10/1981
Date

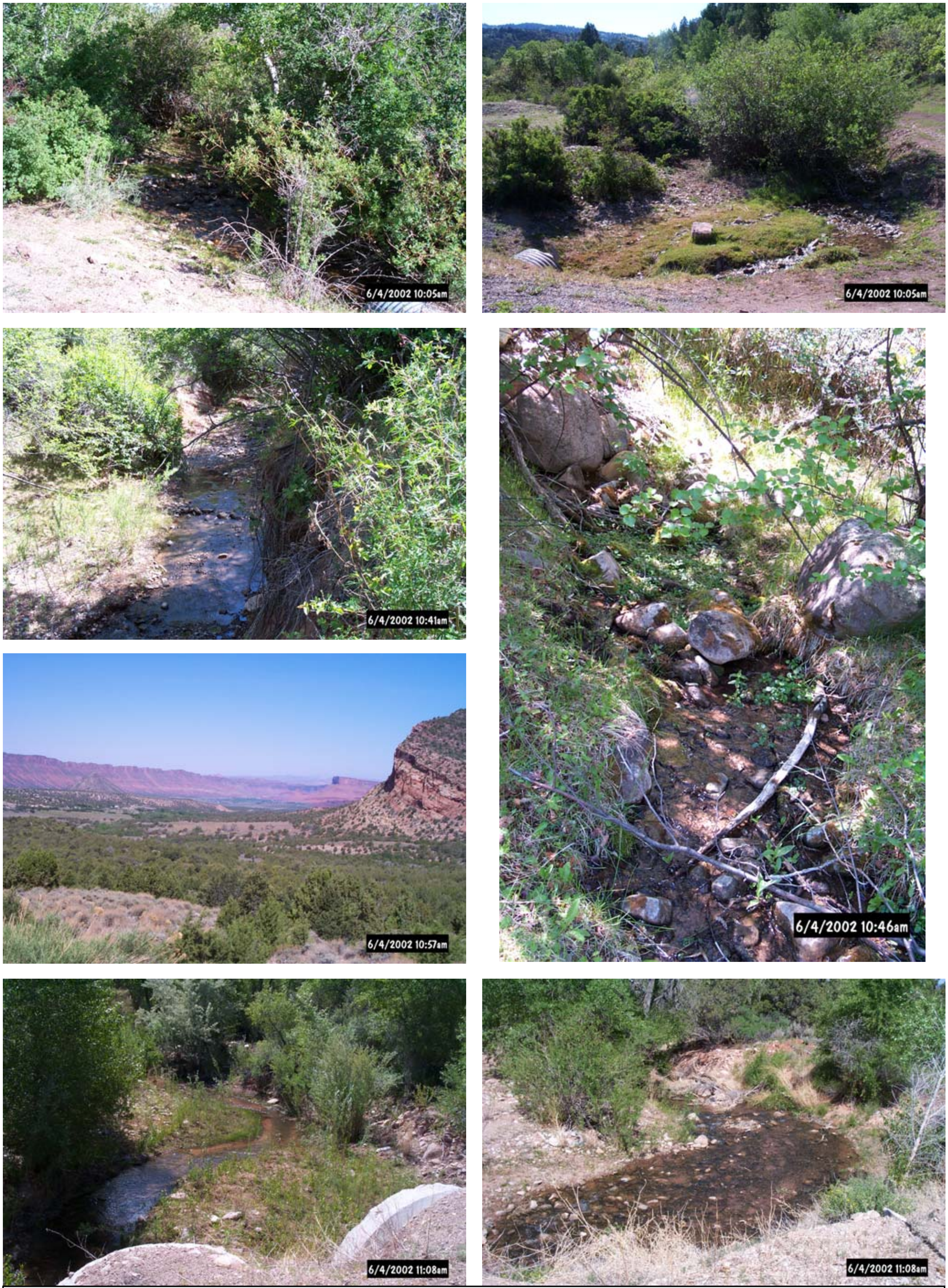

Castle Creek at White Ranch
Specific Conductance (umho/cm
3500
3000
2500
2000
1500
1000
500
0
1/10/1980
3/10/1980
5/10/1980
7/10/1980
9/10/1980
11/10/1980
1/10/1981
Date


Castle Creek at U128 Crossing
Flow (cfs)
10
9
8
7
6
5
4
3
2
1
0
7/31/97
9/30/97
11/30/97
1/31/98
3/31/98
5/31/98
Date


Castle Creek at U128 Crossing
Specific Conductance (umho/cm
3000
2500
2000
1500
1000
500
0
7/31/97
9/30/97
11/30/97
1/31/98
3/31/98
5/31/98
Date


Castle Creek at U128 Crossing
TDS (mg/l)
1800
1600
1400
1200
1000
800
600
400
200
0
7/31/97
9/30/97
11/30/97
1/31/98
3/31/98
5/31/98
Date

APPENDIX D
Synoptic Survey Locations



Pictures of Castle Creek