Possible Influence of Injected Brine Water at Westwater Farms on Spanish Valley Well Water Quality

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Executive Summary

An application has been received by Grand County Engineer Mark Wright from Westwater Farms, LLC to allow the injection of up to 10,000 barrels per day of oil-field brine water into a well to be drilled at Harley Dome, located just north of Interstate 70 about five miles from the Colorado State line

The injection well application identifies the injection zone to be the Kayenta and Wingate formations located between 877 and 1,667 feet below land surface. Brine waters from 15 wells in the Uinta and Piceance Basins may be typical of that received at the Westwater Farms operation, and have an average concentration of 33,150 mg/L TDS.

Concern was expressed over the possible mixing of injected brine water into high-quality Moab area water that has a TDS concentration of less than 500 mg/L TDS.

A discussion is presented in this report of the Glen Canyon Aquifer supplying the city of Moab (Navajo, Kayenta, and Wingate formations) from its recharge area in the La Sal Mountains. Water quality measurements in the Glen Canyon Aquifer are not similar to measurements outside the aquifer, and there is no evidence of mixing.

Review of geologic maps prepared by the Utah Geologic Society and logs of wells drilled in the Harley Dome vicinity shows that geologic formations in the Harley Dome area slope to the north and west, rather than toward Moab, and would carry injected water toward the Uinta Basin.

Examination of maps of the geologic strata between the Harley Dome formations and the Glen Canyon Group indicates significant areas of discontinuity, making it virtually impossible for injected water beneath Harley Dome to make its way into Moab wells.

The injection of well field brine water at Harley Dome would not contaminate the Glen Canyon Aquifer from which the Moab and Spanish Valley wells draw their water.

Introduction

Drilling and development of oil and gas wells at several hundred feet in depth in Utah geology entails withdrawal of saline water, perhaps with total dissolved solids (TDS, usually salts) of 20,000 to 40,000 milligrams per liter (mg/L) concentration. Recommended drinking water levels are less than 3,000 mg/L TDS.

State regulations do not allow these waters be disposed on the land surface. Utah Administrative Code R649-5 outlines requirements for treatment or disposal of these waters and specifies the requirements of an Underground Injection Control Permit should subsurface injection be chosen as the preferred disposal method. Underground injection of oil and gas brine water is an allowable disposal method as long as the injection waters do not exceed the water quality of the receiving ground water and do not impact public water supplies.

Westwater Farms has applied for an injection well permit to dispose of oil and gas brine waters in volume not to exceed 10,000 barrels per day in a well to be drilled at Harley Dome (NWNE Section 10, T19S, R25E, SLM) in northeastern Grand County, Utah. The Harley Dome location is just north of Interstate 70 about five miles from the Colorado State line. It lies about 60 miles directly northeast of the city of Moab. The application also describes their intent to also treat some accepted water to less than 500 mg/L TDS for nearby crop irrigation.

The purpose of this report is to evaluate the likelihood that injected untreated brine water will affect water currently captured by the Moab City and Spanish Valley wells. The report is divided into four parts:

1. A discussion of the Moab and Spanish Valley well fields and water sources.
2. A discussion of the geology of the Harley Dome and the effect of deep well injection there.
3. An examination of the geology between the two areas.
4. Conclusions

1. Moab and Spanish Valley Aquifers

Most ground water in the Moab-Spanish Valley area comes from one of two aquifer systems,-the Glen Canyon aquifer, which consists of the Wingate, Kayenta, and Navajo Formations, and the unconsolidated valley-fill aquifer. Water supply for these aquifers comes from infiltrated rain and snowmelt in the La Sal Mountains, about 25 miles southeast of Moab, and from direct precipitation. Recharge water from the La Sal Mountains flows underground toward the Moab fault which runs beneath the surficial aquifer of Spanish Valley (Chan, 2001). Secondary infiltration, minor compared to the subsurface La Sal flow, comes from surface water along portions of Mill and Pack Creeks (Lowe, 2007).

Glen Canyon Aquifer. The Glen Canyon Aquifer System encompasses about 76,000 acres in an irregularly shape area approximately 22 miles long by 9 miles wide (Figure

1). Drinking water production is from one developed spring from the Wingate Sandstone and three developed springs and five drilled wells from the Navajo Sandstone. The lower Jurassic Wingate Sandstone, overlain by the Kayenta Sandstone, overlain by the Navajo Sandstone comprises the approximately 800 feet thick Glen Canyon Aquifer System (Figure 2). Water production is primarily due to fracture flow. Combined production of the water system can be greater than 4,775 gallons per minute with 3,000,000 gallons of storage. The boundaries of the aquifer were determined by hydrogeologic mapping, which is the area interpreted to contribute water to the springs and wells. The aquifer is exposed at the surface within its service area and considered to be moderately to very vulnerable (EPA, 2002).

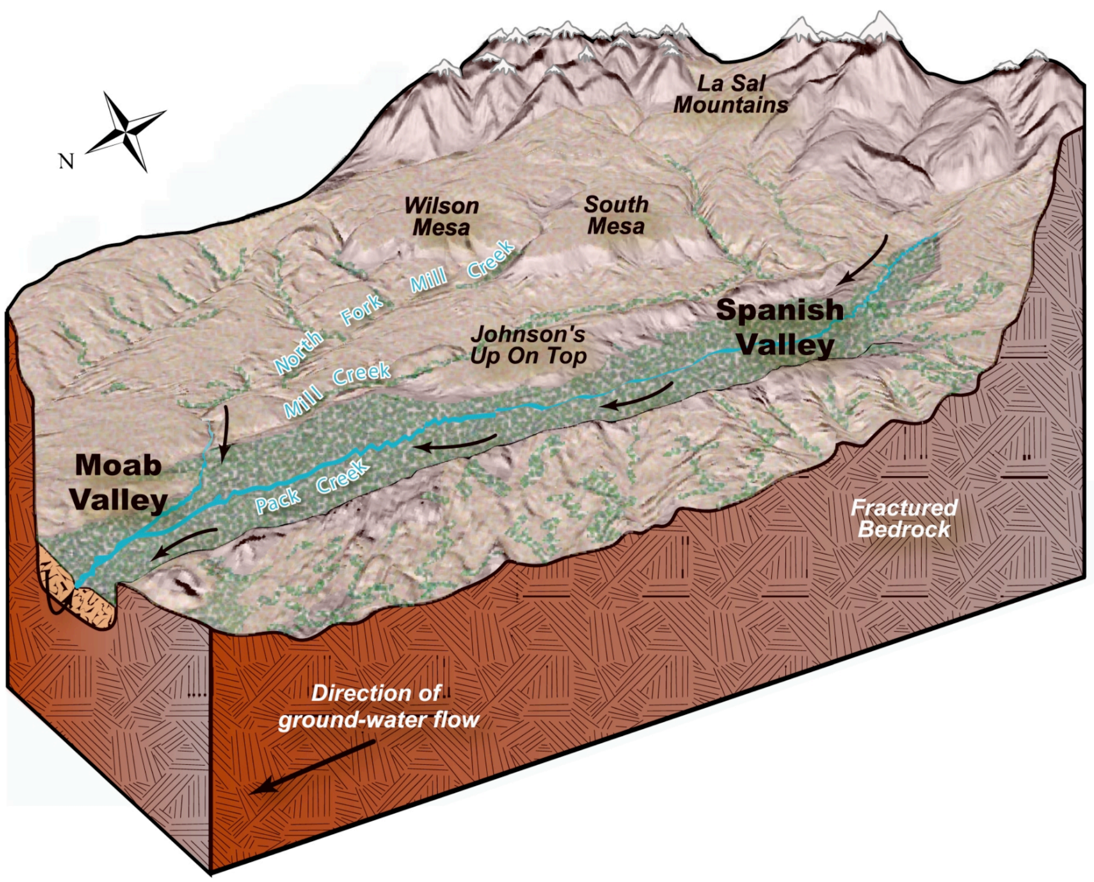

Figure 1. Schematic block diagram showing the source area of water for the Glen Canyon and valley fill aquifers of Moab-Spanish Valley(Lowe, 2007).

The portion of the Glen Canyon aquifer system specifically identified in the Sole Source Aquifer designation for Moab is part of a larger regional aquifer system underlying most of the Colorado Plateau. In the Moab area, it consists of the Navajo, Kayenta, and Wingate Formations. These layers have been upturned by igneous intrusion of the La Sal Mountains and are exposed at the ground surface in some areas (Foster, 2007). The Navajo Sandstone is one of the shallowest and most permeable formations, generally producing water having low total dissolved solids concentrations. It is therefore the target for most bedrock wells and the principal source of drinking water in Moab and Spanish Valley (Eisinger, 1999).

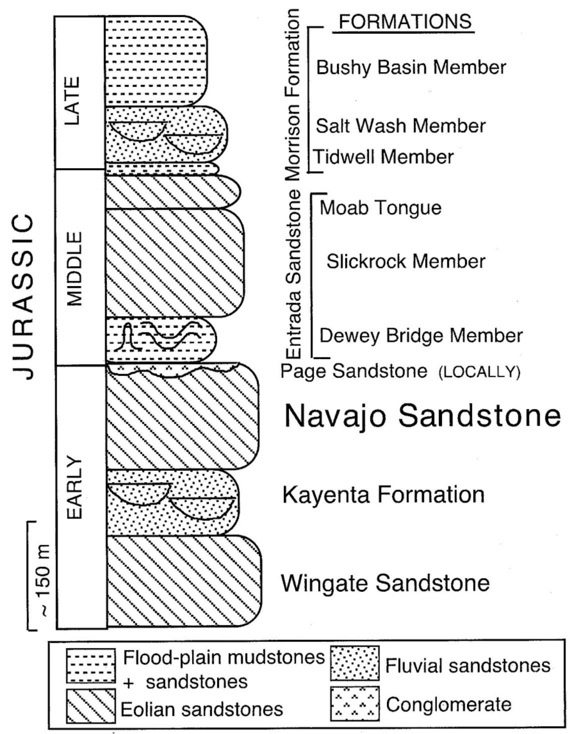

Figure 2. Stratographic bedrock columns containing the Glen Canyon Aquifer (Navajo, Kayenta, and Wingate)

Analysis of outcrops and information from well logs in Spanish Valley indicate the Glen Canyon Group is at least partially fractured. Fracturing provides primary control on aquifer characteristics of the Glen Canyon Group, altering hydraulic conductivity and effective porosity by several orders of magnitude (Hood and Patterson, 1984).

Ground water is stored in the fractures, joints, bedding planes, and cavities of the rock mass and its availability is largely dependent on the nature of the fractures and their interconnection. In sedimentary formations like those of the Glen Canyon aquifer, there may also be storage of water in the matrix or pore space of the rock. High values of hydraulic conductivity encountered in culinary supply wells along the eastern margin of Spanish Valley are attributed to fracturing of the bedrock aquifer (Eisinger and Lowe, 1999).

Most groundwater flow in the Glen Canyon aquifer is through rock fractures (joints and faults). The city of Moab draws water from five groundwater wells located in or near the east side of the Moab golf course. These wells are located on a fault line that runs roughly northwest to southeast between the golf course and the hanging wall bedrock of the southeast side of Spanish Valley. Moab City public supply wells are completed at a depth of approximately 600 feet in the Glen Canyon aquifer. Average groundwater use is approximately 3,335,674 gal/day (Moab, 1999). Wells No. 4, 5, 7, and 10 are pumped at close to the same rate (425 gal/min) while well No. 6 is pumped at about 600 gal/min.

Several springs located near the Moab golf course are also connected to the Moab municipal water system.

Spanish Valley Aquifer. The valley-fill aquifer is primarily used for domestic and agricultural purposes. It consists mainly of stream, alluvial-fan, mass-movement, and wind-blown deposits that are more than 400 feet thick near the Colorado River (Doelling, 2004). Recharge in the La Sal Mountains is ultimately the source of recharge to the unconsolidated Spanish Valley aquifer. Most of the recharge to this valley-fill aquifer is from springs and subsurface flow from the Glen Canyon aquifer system, from direct precipitation, and from infiltration of stream flow from Pack and Brumley Creeks and Kens Lake (Foster, 2007). Kens Lake is supplied by water diverted from Mill Creek. In valley-fill aquifers, groundwater is stored in the pore spaces between grains or particles of the silts, sands, and gravels that make up the aquifer.

Two wells provide most of the withdrawn water from the valley-fill aquifer: George White Well No. 4 (approx. 650 gal/min), and George White Well No. 5 (approx. 1,000 gal/min). These wells are located along the eastern valley wall, southeast of the golf course and west of Johnson's Up-On-Top. There are various smaller agricultural and private wells with no current pumping rate data.

Water Quality. Utah's ground water quality classification is based mostly on total dissolved solids (TDS) concentrations as follows (Table 1):

Table 1. Utah ground water quality classification.

Class	Name	TDS (mg/L)
Class IA	Pristine	Less than 500
Class II	Drinking Water Quality	500 to less than 3,000
Class III	Limited Use	3,000 to less than 10,000
Class IV	Saline	10,000 and greater

The Glen Canyon aquifer generally yields ground water of less than 500 mg/L TDS. Moab City wells consistently yield water of about 260 mg/L TDS. Ground water quality in the Glen Canyon aquifer along the northeastern margin of the Spanish Valley has been designated a Sole Source Aquifer by the U.S. Environmental Protection Agency, and is classified as Class IB, Irreplaceable Ground Water (EPA, 2006).

Ground water quality in the valley-fill aquifer ranges from 140 to 1,818 mg/L TDS and averages 690 mg/L. This water is classified as Class IA (Pristine) and Class II (Drinking Water) based on data from 72 wells and one Pack Creek sample. This data is illustrated for the Moab-Spanish Valley area in Figure 3 (Lowe, 2007).

To put the water quality of the Moab and Spanish Valley aquifers in perspective, brine waters from 15 wells in the Uinta and Piceance Basins may be typical of that received at the Westwater Farms operation, and have an average concentration of 33,150 mg/L TDS.

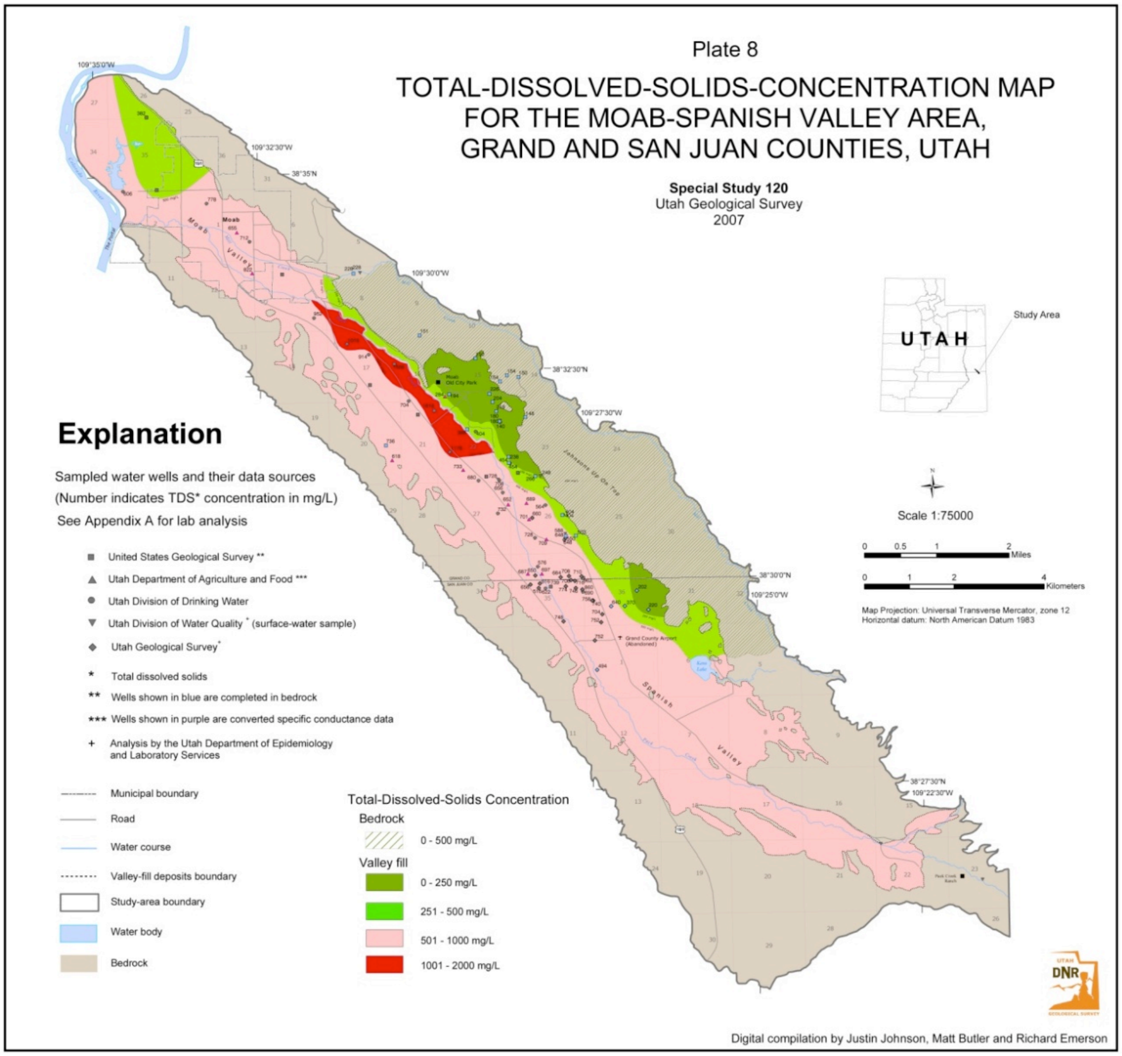

Figure 3. Water quality in the bedrock-valley fill aquifers as TDS.

2. Harley Dome Geology

Harley Dome is located approximately 60 miles northeast of Moab. Dome structures are found where forces beneath the earth's crust have thrust a portion of the earth upward.

Between 1967 and 1975 an operator from California named Arlyne Lansdale drilled a series of wells that defined the vertical profile of the Harley Dome to a depth of approximately 1,500 feet below land surface. Bedrock stratigraphy at Harley Dome was determined from the well logs of nearby wells Lansdale Government 1, 4, 5, 9, and 13 and from geologic mapping efforts by the Utah Geological Survey (UGS).

The surficial sediments at Harley Dome are comprised of Tununk and Mancos shale, beneath which lies Dakota Sandstone at a depth of about 10 feet. Sequentially in depth are the Cedar Mountain formation, Morrison formation, Summerville formation, Entrada sandstone, Kayenta formation, Wingate sandstone, and the Chinle formation. Table 2 describes the depth to top of each formation, its thickness and salinity. Figure 4, from the Harley Dome 7.5' Quadrangle map, illustrates the stratigraphy beneath Harley Dome.

Table 2. Formation description at Harley Dome

Formation	Depth below ground surface	Thickness (ft)	Salinity mg/L TDS
Dakota Sandstone	10	80	25,000
Cedar Mountain	95	65	20,000
Morrison	160	672	17000
Summerville	832	45	20,000
Entrada	877	248	<10,000
Kayenta	1,125	208	
Wingate	1,333	334	20,000
Chinle	1,667	138	

A few comments on these formations:

- The upper confining zones at Harley Dome are composed of the Morrison and Summerville formations, and are expected to prevent migration of injectate into any water lying in the surficial sediments.
- The perforated region of the injection well is designed to confine injection to the Entrada, Kayenta, and Wingate formations, an interval of approximately 456 feet.
- The Entrada sandstone is a regional aquifer that locally discharges some water to the Colorado River from an outcrop located five to six miles southeast of Harley Dome.
- The Kayenta formation has relatively low permeability and generally acts as a barrier to water movement. It is expected to act as an intermediate confining zone between the two proposed injection zones.
- The Chinle formation has very low permeability and is a regional confining unit.

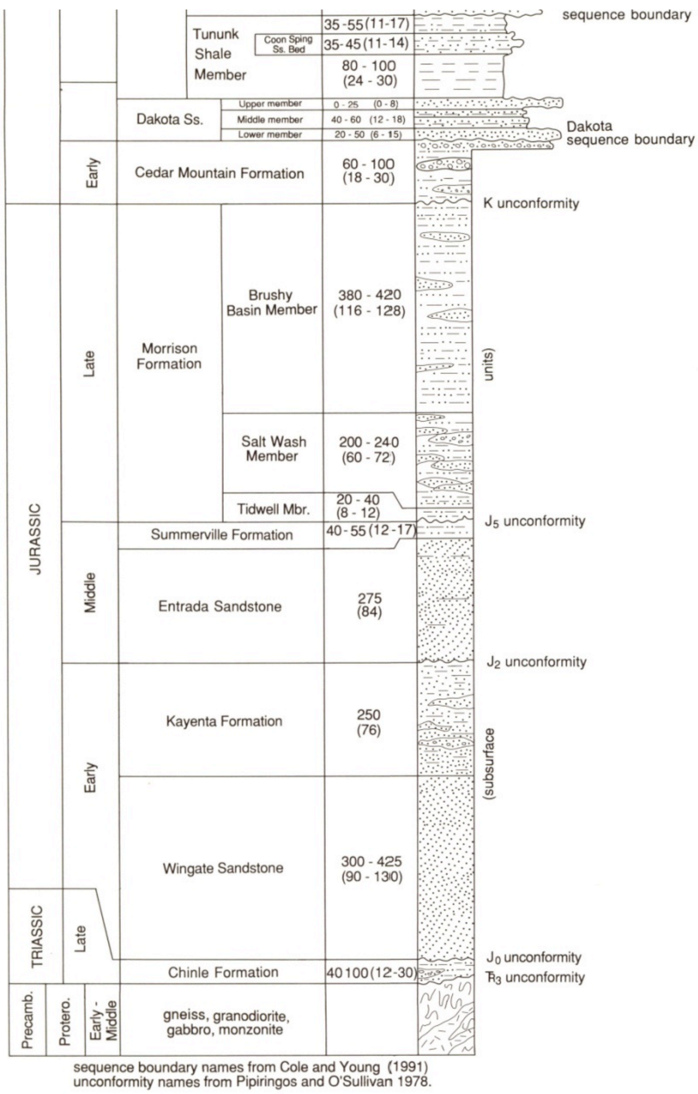

Figure 4. Stratigraphic column beneath the Harley Dome in SE Utah.

The extent and inclination of these formations is documented in the following publications:

1. Geologic Map of the Harley Dome Quadrangle by Grant C. Willis, UGS Map 157 (1994).
2. Petroleum Geology of the Harley Dome Field by Roger L Bon. UGS Oil and Gas Field Study 21 (1999).
3. Geologic Map of the Agate Quadrangle by Grant C. Willis, Hellmut H. Doelling and Michael L. Ross. UGS Map 168 (1996).
4. Geologic Map of the Moab and Eastern Part of the San Rafael Desert 30’x60’ Quadrangles by Hellmut Doelling. UGS Map 180 (2001).

5. A Summary of the Ground Water Resources and Geohydrology of Grand County, Utah by Chris Eisinger and Mike Lowe. UGS Circular 99 (May 1999).

3. Discussion of Connection Geology

Geologic maps indicate that the inclination of formations beneath the Harley Dome, particularly the Entrada and Wingate, dip to the north and west from the Dome, directing subsurface flow to the northwest beneath the Bookcliffs and toward the Uinta Basin. This conclusion from map inspection is illustrated with the graphic of UGS Map 180 with added arrows showing the direction of ground water flow (Figure 5).

Note the Paradox fold and fault belt near the center of the graphic. It is located near the Uncompahgre Uplift boundary fault. These features combine to disrupt the geologic continuity between the Moab hydrogeologic zone and the Harley Dome. The Entrada formation found above the Kayenta and Wingate formations at Harley Dome is not found in that location in the Moab area, being replaced by the Navajo formation. This discontinuity is illustrated by the geologic cross section Southwest to Northeast displayed in Figure 6, from UGS Map 180. The Glen Canyon Group is indicated by geologic nomenclature JTr, and is the sliver of brown on top of the cross section. It is discontinuous across much of the distance between Moab and Harley Dome, making the movement of water from Harley Dome to the Moab Glen Canyon Group virtually impossible.

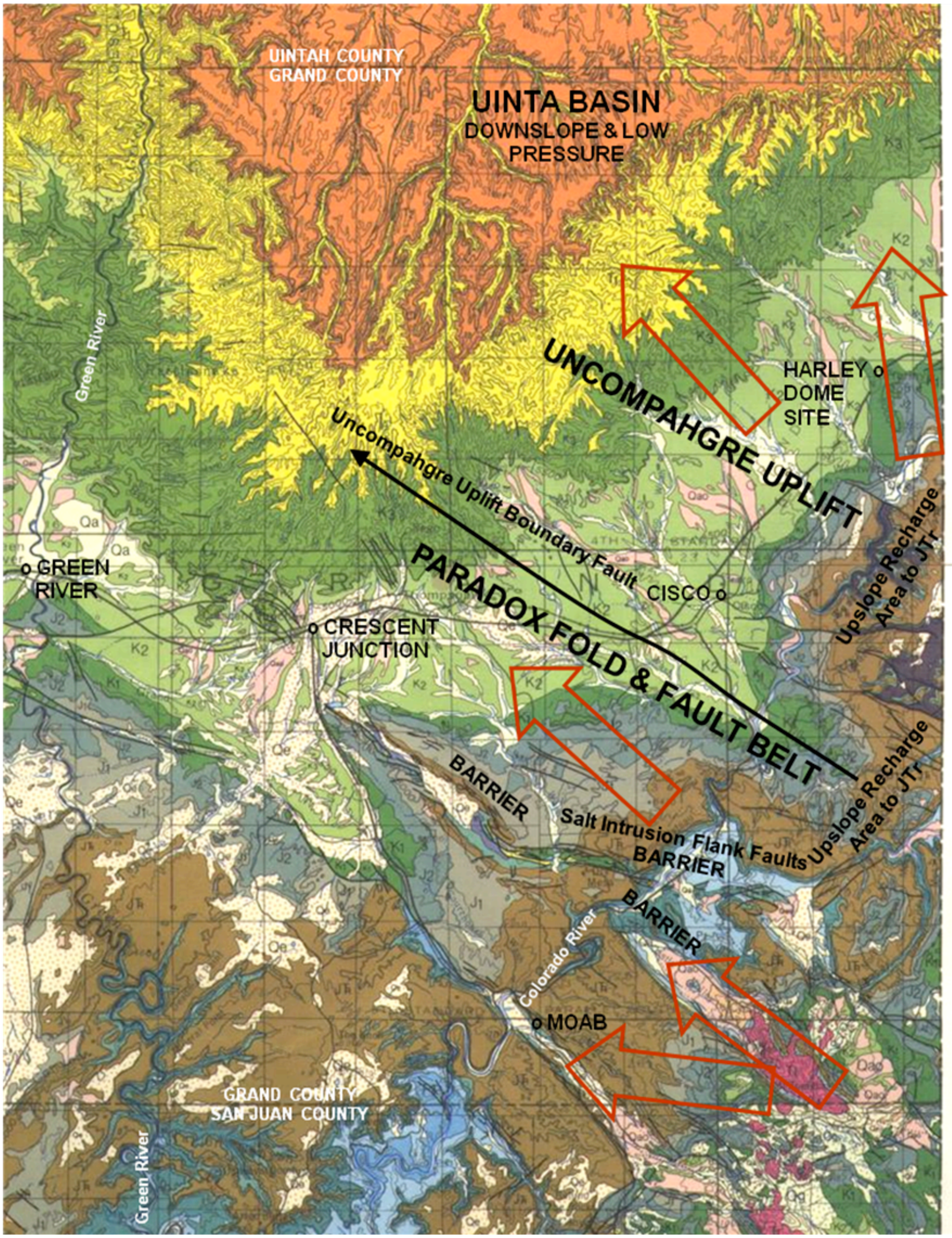
UINTAH COUNTY
GRAND COUNTY
UINTA BASIN
DOWNSLOPE & LOW PRESSURE
Green River
UNCOMPAHGRE UPLIFT
HARLEY DOME SITE
Uncompahgre Uplift Boundary Fault
GREEN RIVER
PARADOX FOLD & FAULT BELT
CISCO
CRESCENT JUNCTION
Upslope Recharge Area to JTr
Upslope Recharge Area to JTr
BARRIER
Salt Intrusion Flank Faults
BARRIER
BARRIER
Colorado River
MOAB
GRAND COUNTY
SAN JUAN COUNTY
Green River

Figure 5. UGS Map 180 showing surface geology of the Moab-Harley Dome area. Text and arrows showing direction of ground water flow have been added.

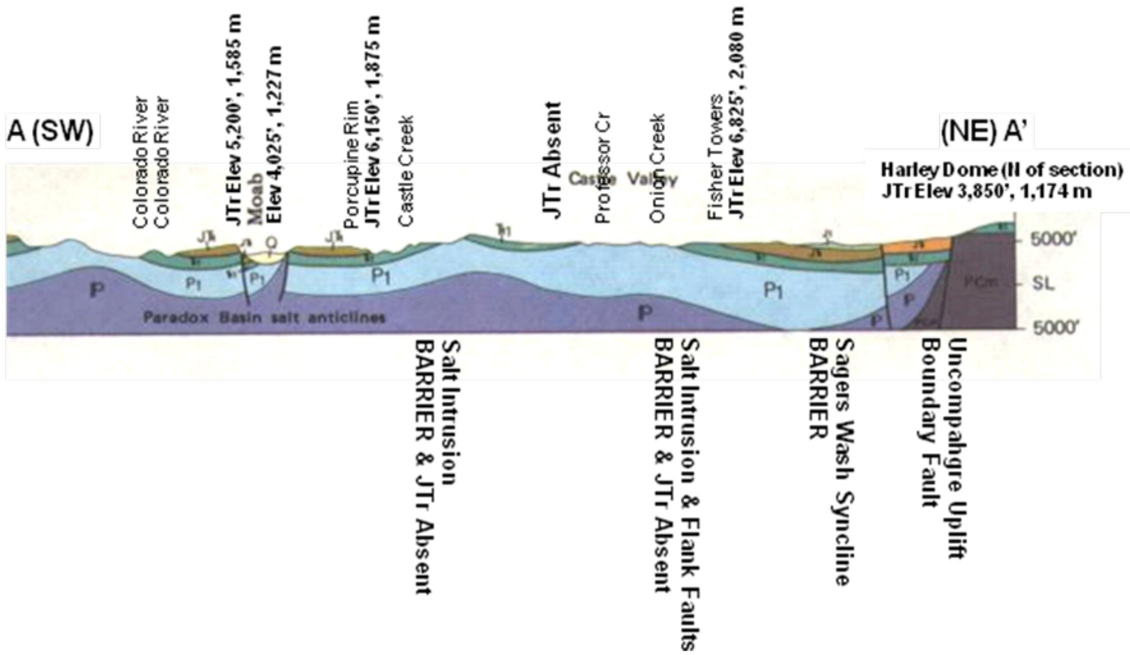

Figure 6. Geologic cross-section southeast to northwest between Moab and Harley Dome. From UGS Map 180.

4. Conclusion

The observed salinity of water from the Moab area wells, where measurements of less than 500 mg/L are common, is markedly different from the Harley Dome area, where measurements of thousands of mg/L are recorded. The Moab, Glen Canyon Aquifer, is designated as a Class IB Irreplaceable Ground Water, and shows no evidence of mixing with Harley Dome groundwater.

Salinity measurements in the formations beneath Harley Dome show the Entrada formation to have considerably better water quality than its neighbors. It would not be surprising to have the State of Utah consider it a Limited Use or Drinking Water Aquifer and prohibit injection of oil field brine water. This would leave Westwood Farms with approx. 334 feet of injection length with which to work.

Formation inclination beneath Harley Dome area of the Uncompahgre Plateau slopes to the north and west into the Uinta Basin. Water recharged through injection should move down-dip away from Moab. Furthermore, pressure measurements made in wells in the

Uinta Basin are lower than those in the upper Uncompahgre Plateau, drawing water toward the Uinta Basin.

A large amount of water injected into the Harley Dome may result in some leakage into the Colorado River from the base of the Entrada formation, which emerges near the river for a short distance, but this would require large injection pressures to push the water upgradient.

Careful examination of the geologic strata between the Glen Canyon Group, supplying water to the Moab area wells, and the Harley Dome formations indicates significant areas of discontinuity, making it virtually impossible for injected water beneath Harley Dome to make its way into Moab wells.

The injection of well field brine water at Harley Dome would in no way contaminate the Glen Canyon Aquifer from which the Moab well field draws its water.

References

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