Untapped Aquifers
Parowan Valley Drainage Basin

H. Roice Nelson, Jr. & Gary Farnsworth Player - Parowan Valley Water Management Committee

22 August 2019

This presentation, with links, can be downloaded from: http://www.walden3d.com/IronCounty/CedarValleyWater/pdf/190822_Untapped_Aquifers_Parowan.pdf

Discussing Water Rights, A Western Pastime

Introductions and Issues of the Water Management Committee

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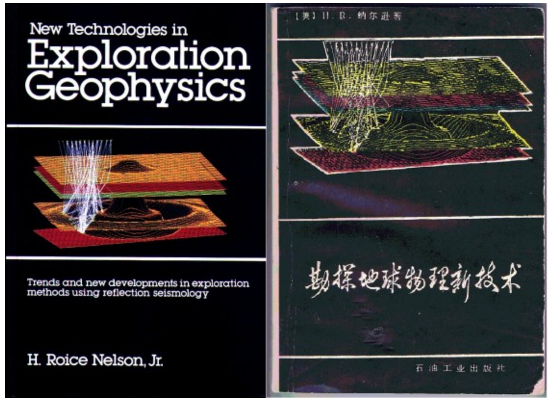
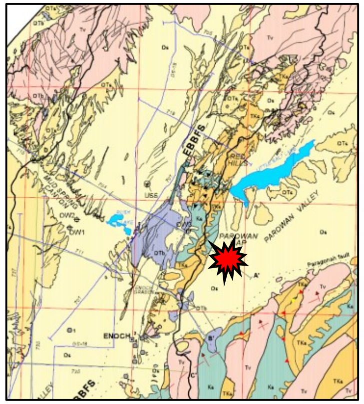
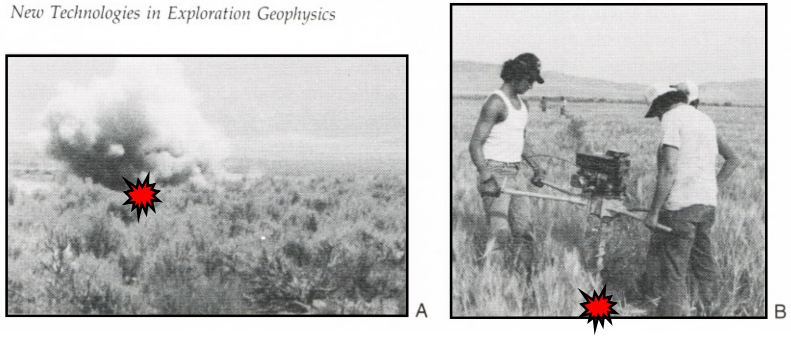




20 *New Technologies in Exploration Geophysics*



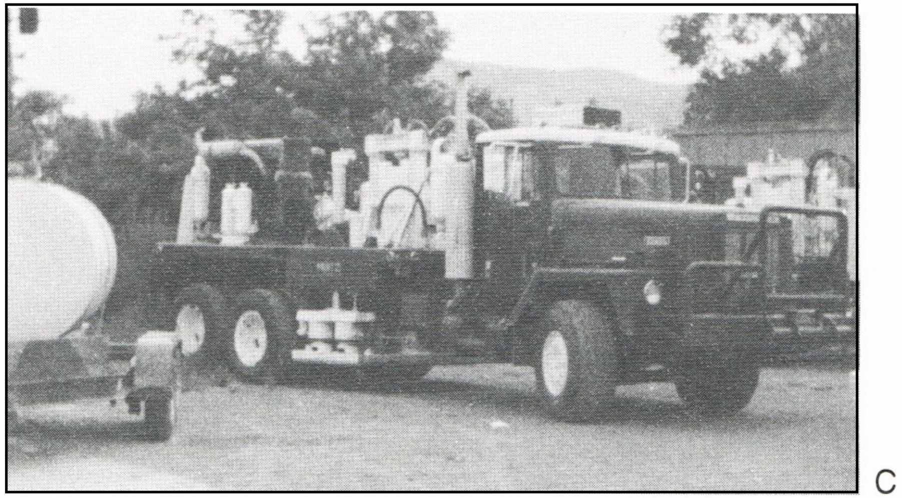


Figure 1-5. Typical land crew operations in southwestern Utah. (A) Surface shooting using ten 5-lb sacks of explosives on a primachord string. The environmental damage is temporary, but overshooting, like overgrazing, can cause long-term problems. (B) Shallow hole shooting of, say, 10 lbs of dynamite per shotpoint is better in agricultural areas. (C) The most common land seismic source is Vibroseis.™ Normally, four of these trucks vibrate in synchronization.

H. Roice Nelson, Jr.

Howard Roice Nelson — Pauline Hafen

Roice Bengt Nelson — Emma Lambson

Gary Farnsworth Player

Lawrence Player — Laura Farnsworth — Philo T. Farnsworth

Lewis Edwin Farnsworth — Serena Bastian

Parowan Valley

Water Problems

(https://www.waterrights.utah.gov/meetinfo/m20181211/20181211-parowan_slides.pptx):

	Well Diversion (acre-feet/year)	Well Depletion (acre-feet/year)
Average Use (Actual)	**32,000**	**30,400**
Allowed (Water Rights)	**53,000**	**32,100**
Sustainable		**18,400 to 22,000**
Reduction		**8,000 to 12,000**
Change in Storage		**8,000 to 11,000**

Groundwater Level Trends
Parowan Valley Aquifer

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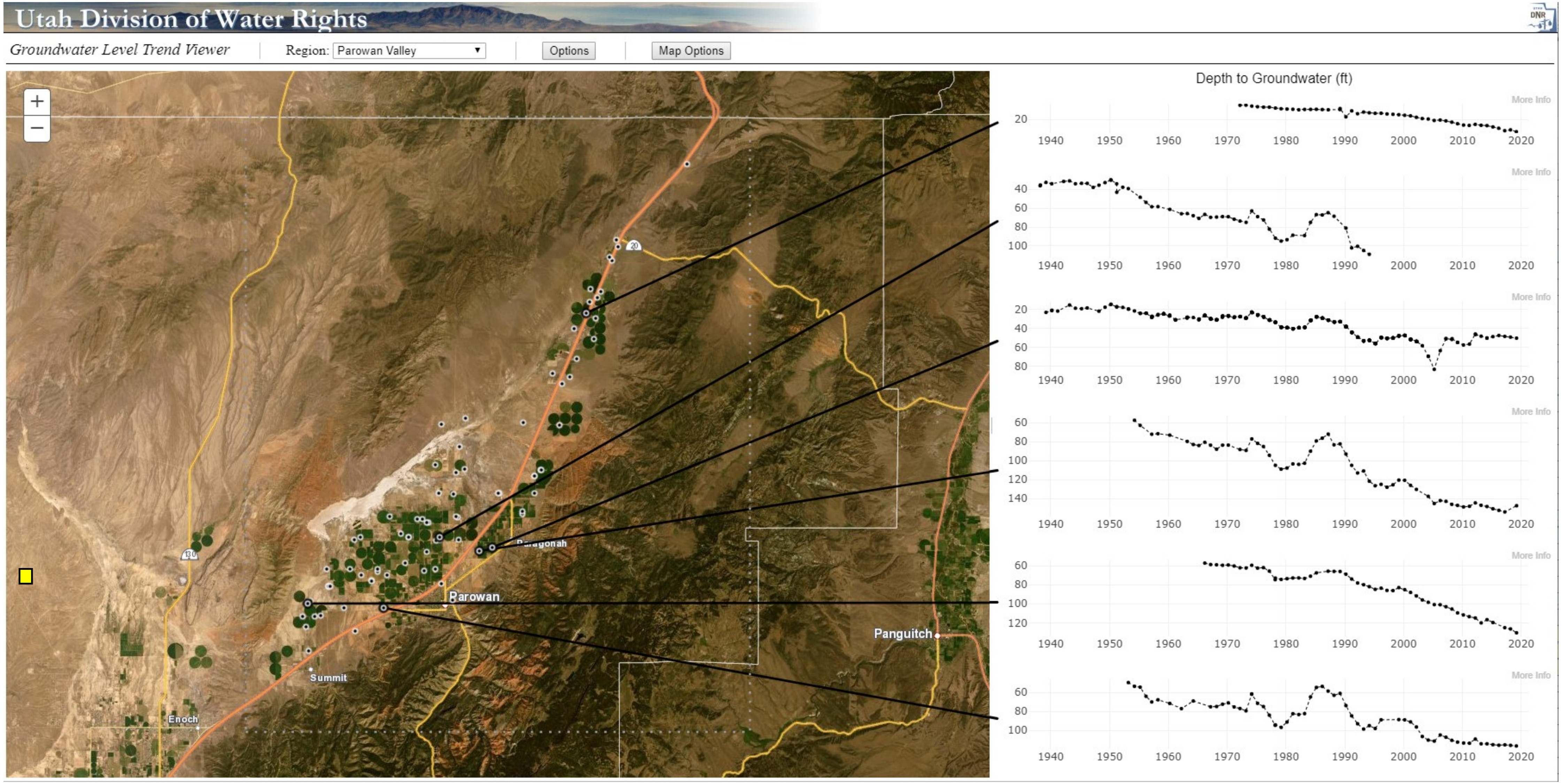

There is a Difference Between The Parowan Valley Aquifer and The Parowan Valley Drainage Basin

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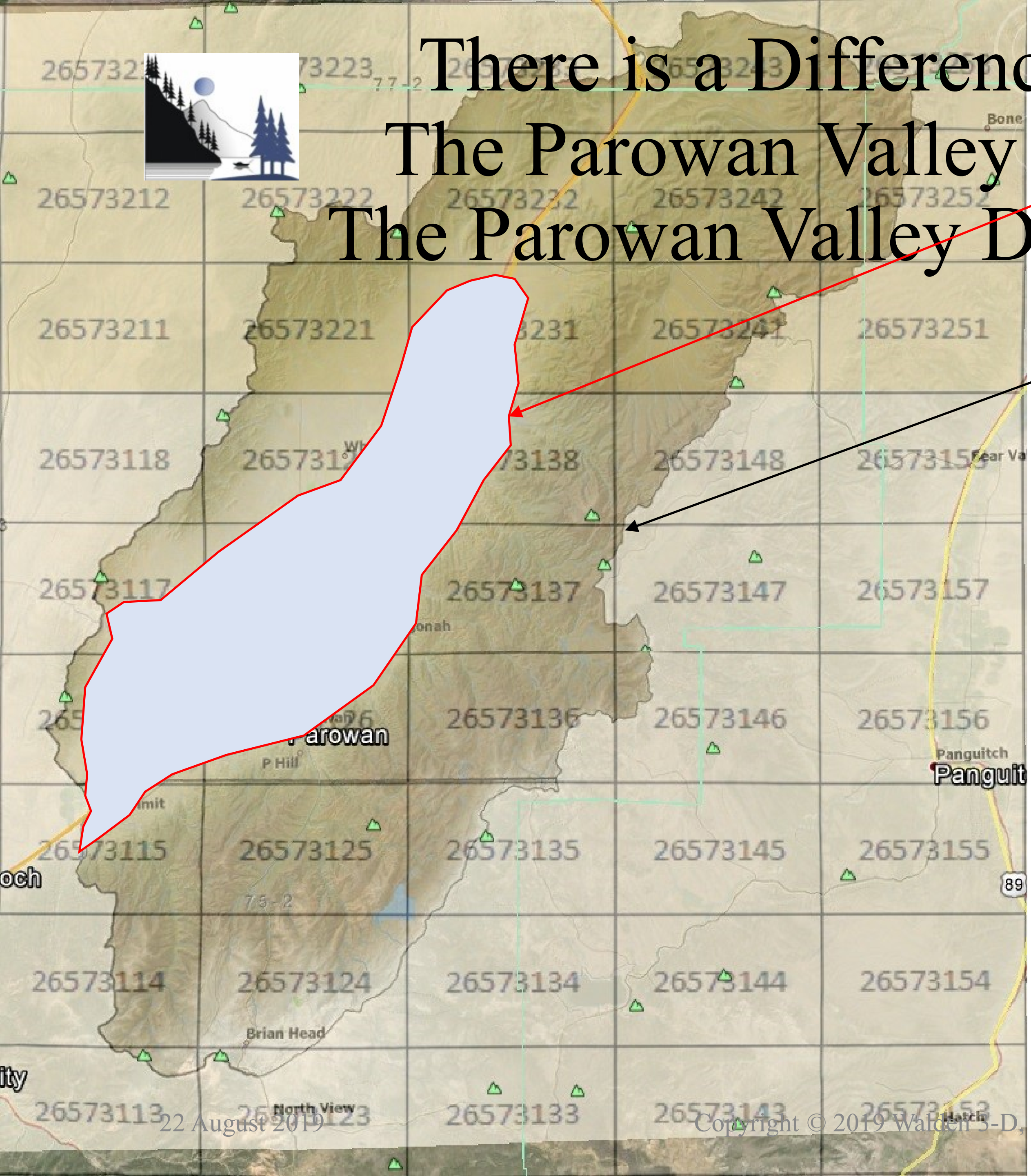

CONSIDER

- Parowan Valley has significant potential of "Bedrock Aquifers" in the surrounding mountains.
- Parowan has transferred water rights from the overallocated Parowan Valley Aquifer to Brian Head, which is within the Parowan Valley Drainage Basin.
- Water from the mountains can be dumped into streams and the existing distribution system used to move water to farms in Parowan Valley.
- This lowers overallocation, and lowers overdraft within the Valley Aquifer.

In Cedar Valley, Politics & Greed Rule

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From Kelly Crane <kcrane@ensignutah.com>
Subject **Summaries from evaluations** 11:00 AM
To Me <melson@walden3d.com>, Gary Player
Cc Paul Monroe

Roice and Gary,

Attached you will find copies of your submissions with comments from the experts about their thoughts on the proposals in red off to the right side. The group that evaluated these are people that have been looking at the Cedar Valley for many years dating back to before the establishment of the District in some cases.

As the District moves forward with projects needed for the good of the aquifer and the sustainability of the Cedar Basin they will be required to utilize the USGS and other State Agencies to verify the science of what they are doing. The science from these experts is telling us that the only reliable long term source of water that we have access to is the Pine and Wah Wah valley water. This is the only source that will provide a new source of water for this valley.

Thank you for submitting the proposals and we look forward to a discussion with you once you have had a chance to digest the comments associated with them.

Kelly Crane

ensignutah.com will be a primary engineering firm, if the community puts up the bond to build a $200 million, no a $300 million, no a $425 million pipeline from Wah Wah and Pine Valleys to Cedar Valley.

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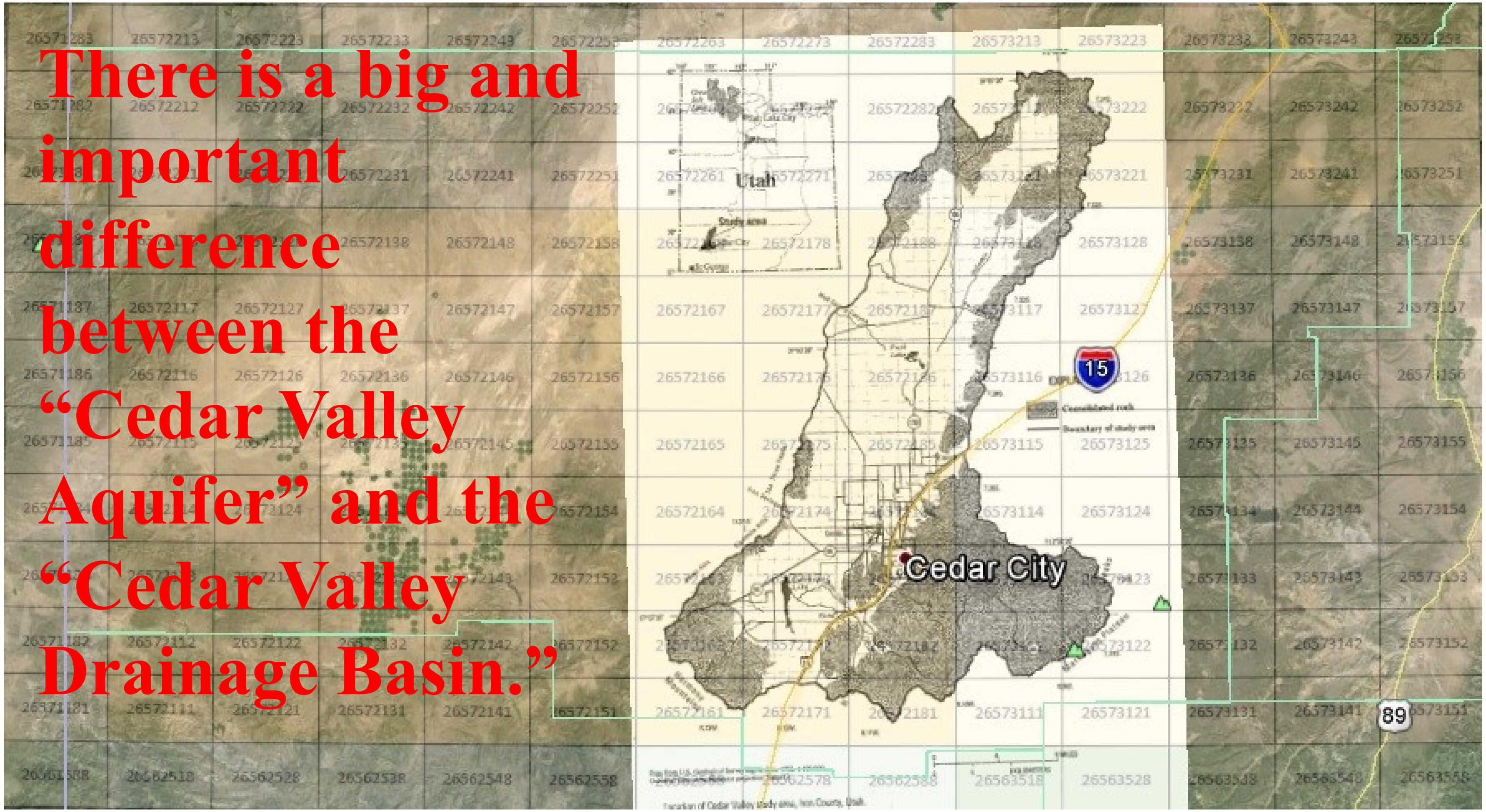
Likewise: Cedar Aquifer (white) is a subset of the Cedar Valley Drainage Basin (black)

There is a big and important difference between the "Cedar Valley Aquifer" and the "Cedar Valley Drainage Basin."



The Cedar Valley Aquifer is a subset of the Cedar Valley Drainage Basin, and is the white area on map to the left.

Black areas are referred to as "Bedrock" areas.

http://www.walden3d.com/IronCounty/ig/IronCounty/IC_CVA.html

Cross-Sections Show Trends

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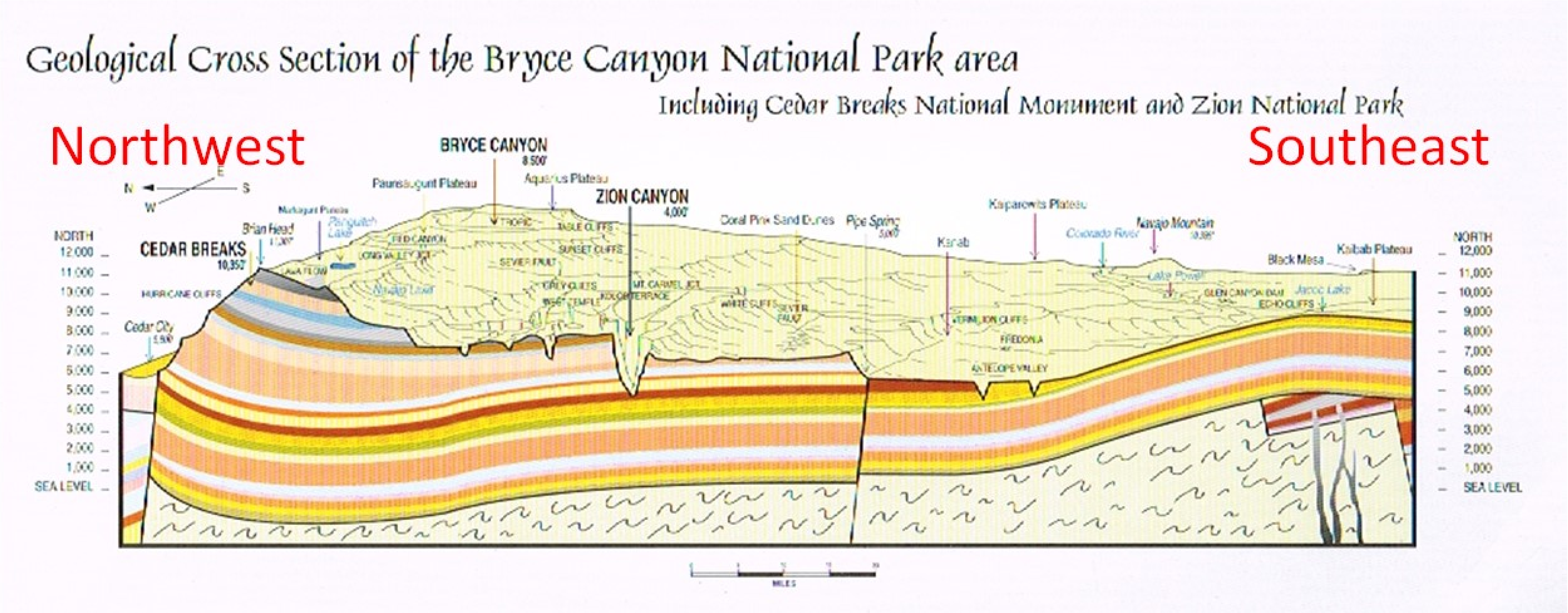

In Cedar we can drive up the Cedar Canyon to study geology faulted down underneath the valley by the Hurricane Fault.

http://www.walden3d.com/IronCounty/ig/IronCounty/IC_Geologic_Map.html

Seismic & Geologic Cross-Sections in Cedar Valley

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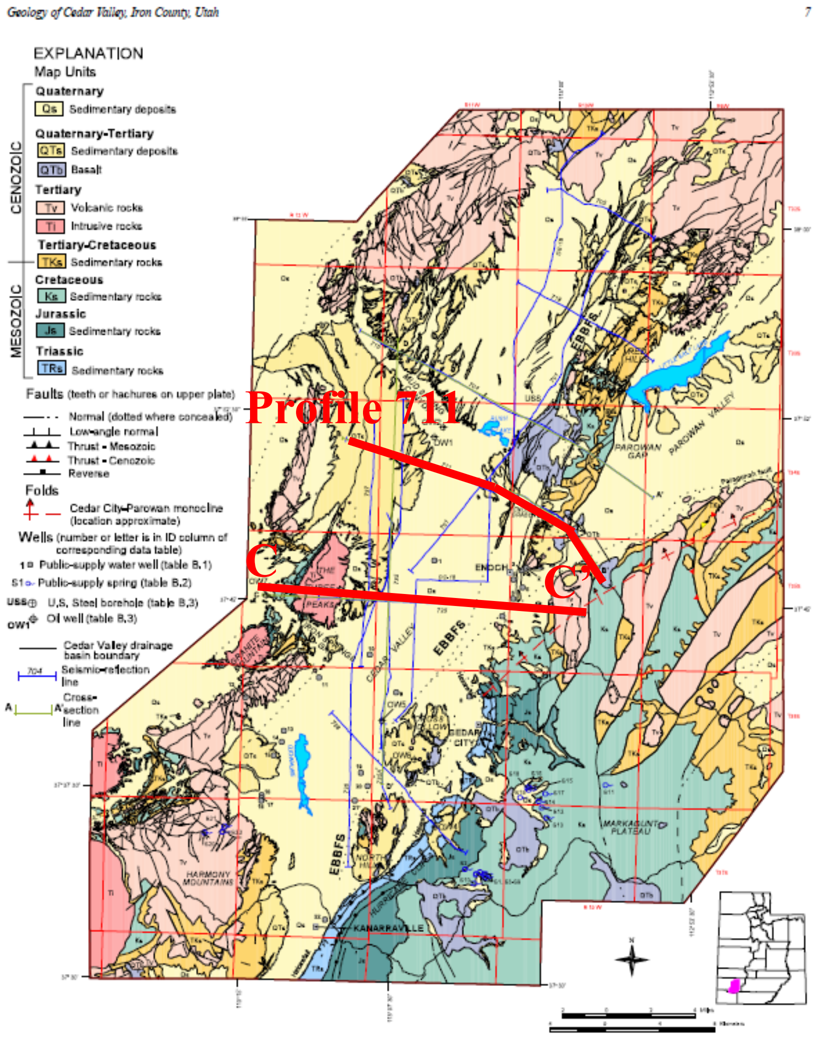
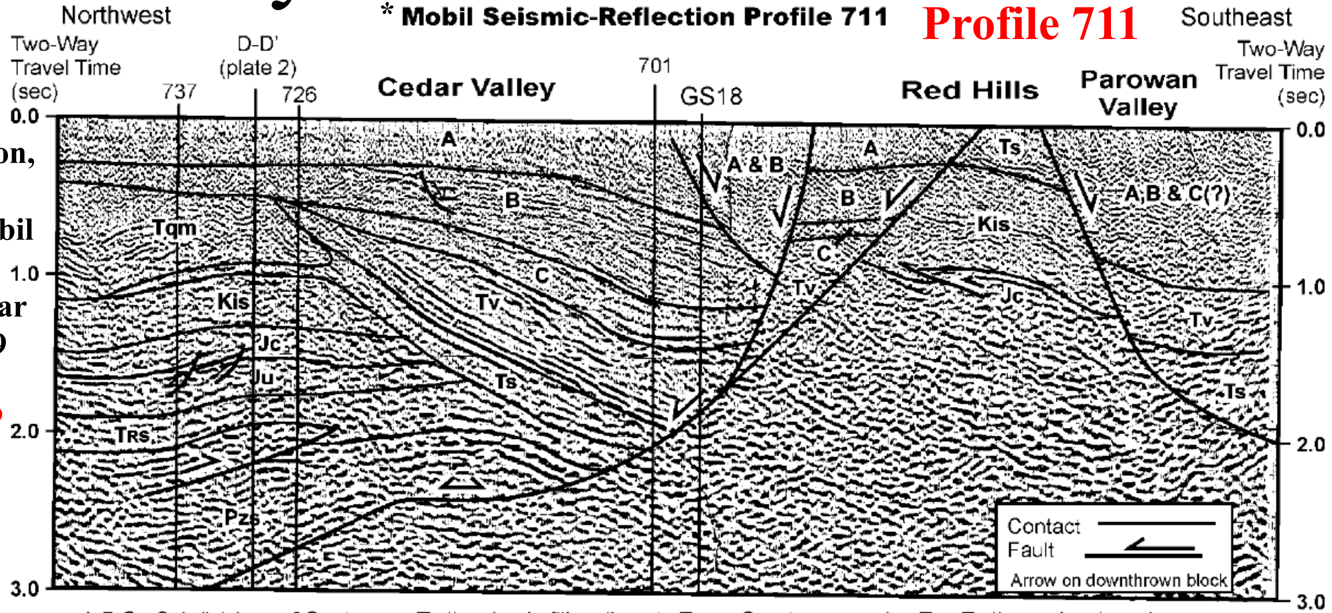


Figure 6. Simplified geologic map of Cedar Valley drainage basin and adjacent areas. EBBFS is eastern basin-bounding fault system. See figure 5 for stratigraphic column, and appendix A for correlation of map units with those on plates 1 and 2.

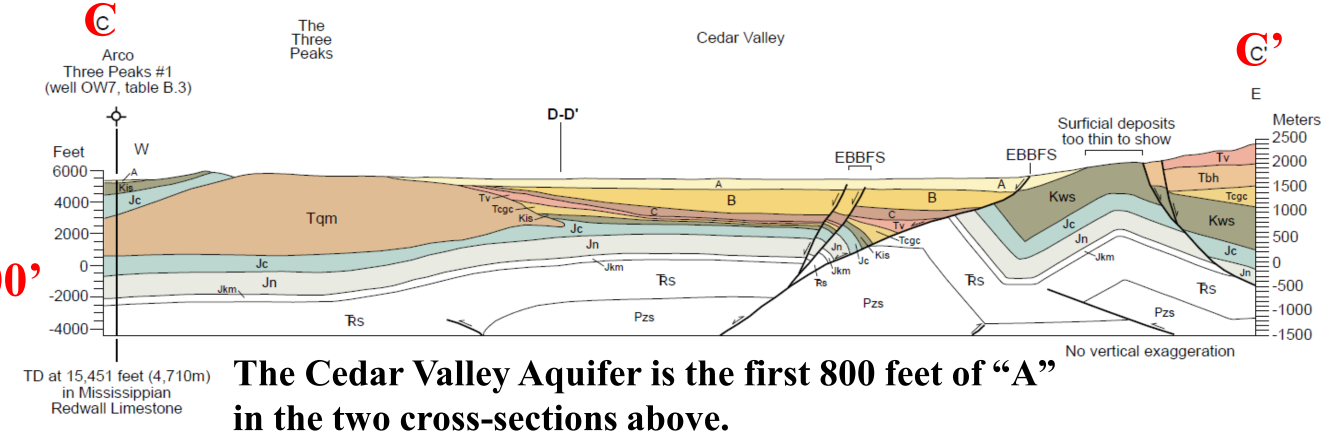
*Roice Nelson, geophysicist running Mobil Oil seismic crew in Cedar in 1978-1979

~7,000'



A,B,C - Subdivisions of Quaternary-Tertiary basin-fill sediment; Tqm - Quartz monzonite; Tv - Tertiary volcanic rocks; Ts - Tertiary sedimentary rocks; Kis - Iron Springs Formation; Jc - Carmel Formation; Ju - Navajo Sandstone, Kayenta, and Moenave Formations, undifferentiated; Ꞧs - Triassic sedimentary rocks; Pzs - Paleozoic sedimentary rocks.

7,000'



The Cedar Valley Aquifer is the first 800 feet of "A" in the two cross-sections above.

The Geology of Cedar Valley, Iron County, Utah, and its relation to ground-water conditions, https://ugspub.nr.utah.gov/publications/special_studies/ss-103.pdf

USGS Groundwater Budget

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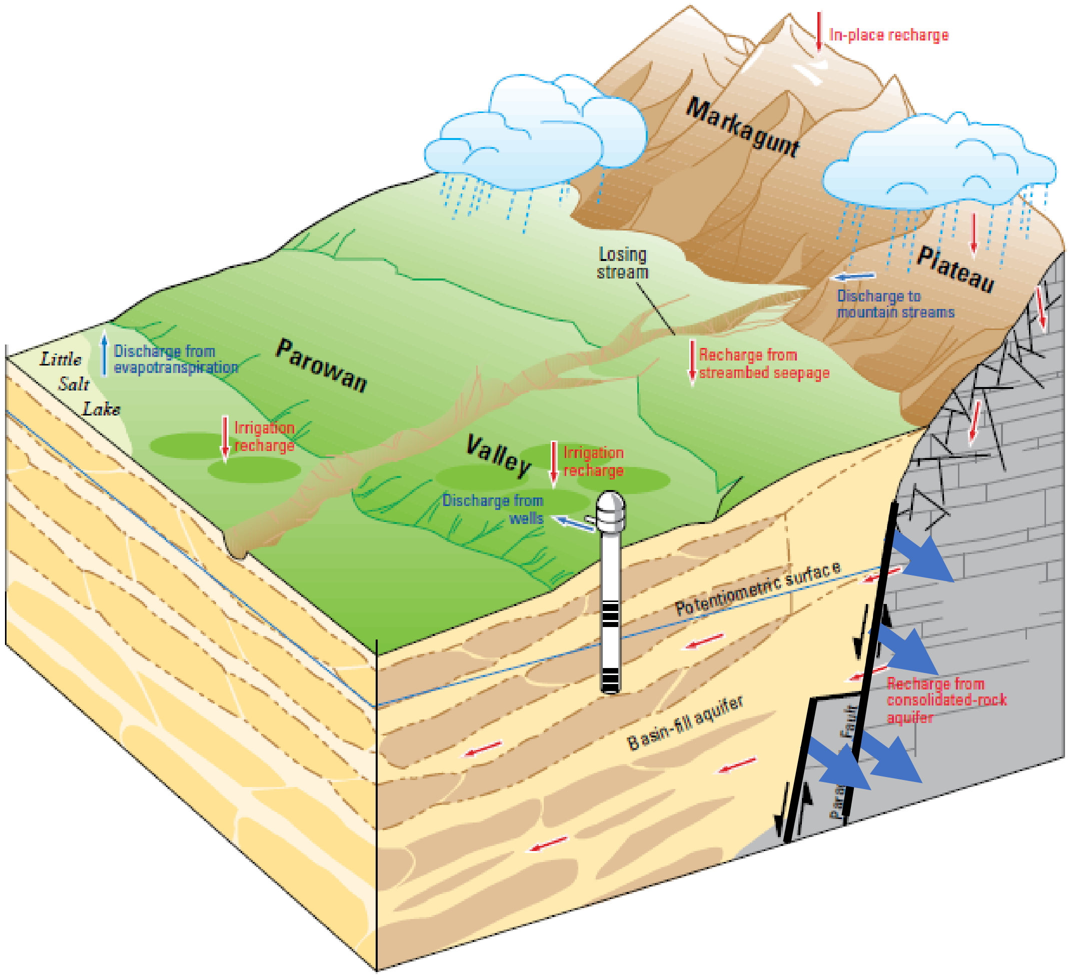

Figure 13. Conceptualized hydrologic setting and groundwater system in the Parowan Valley study area, Iron County, Utah.

USGS Report 2017-5033, Water Resources of Parowan Valley, Iron County, Utah modified with blue south trending, along large faults transport, arrows https://pubs.usgs.gov/sir/2017/5033/sir20175033.pdf.

- USGS Models do not include water that escapes to the East along Cretaceous Transform Faults responsible for canyon erosion from New Harmony to Beaver.
- USGS Models do not include water which escapes to the South along the Hurricane Fault system of faults (blue arrows).
- It appears most of the water entering Parowan and Cedar Valley Aquifers is flowing down streams, and not from underground flow.
- Therefore, it logically follows the best places to capture water to refill the shallow overproduced aquifers, and to replace shallow wells overproducing the aquifers, are the bedrock aquifers surrounding Parowan Valley.

Water & the Potentiometric Surface

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Cedar Mountain water flows east, away from Cedar Valley, as shown by the ice flows just past the landslide area up Cedar Canyon

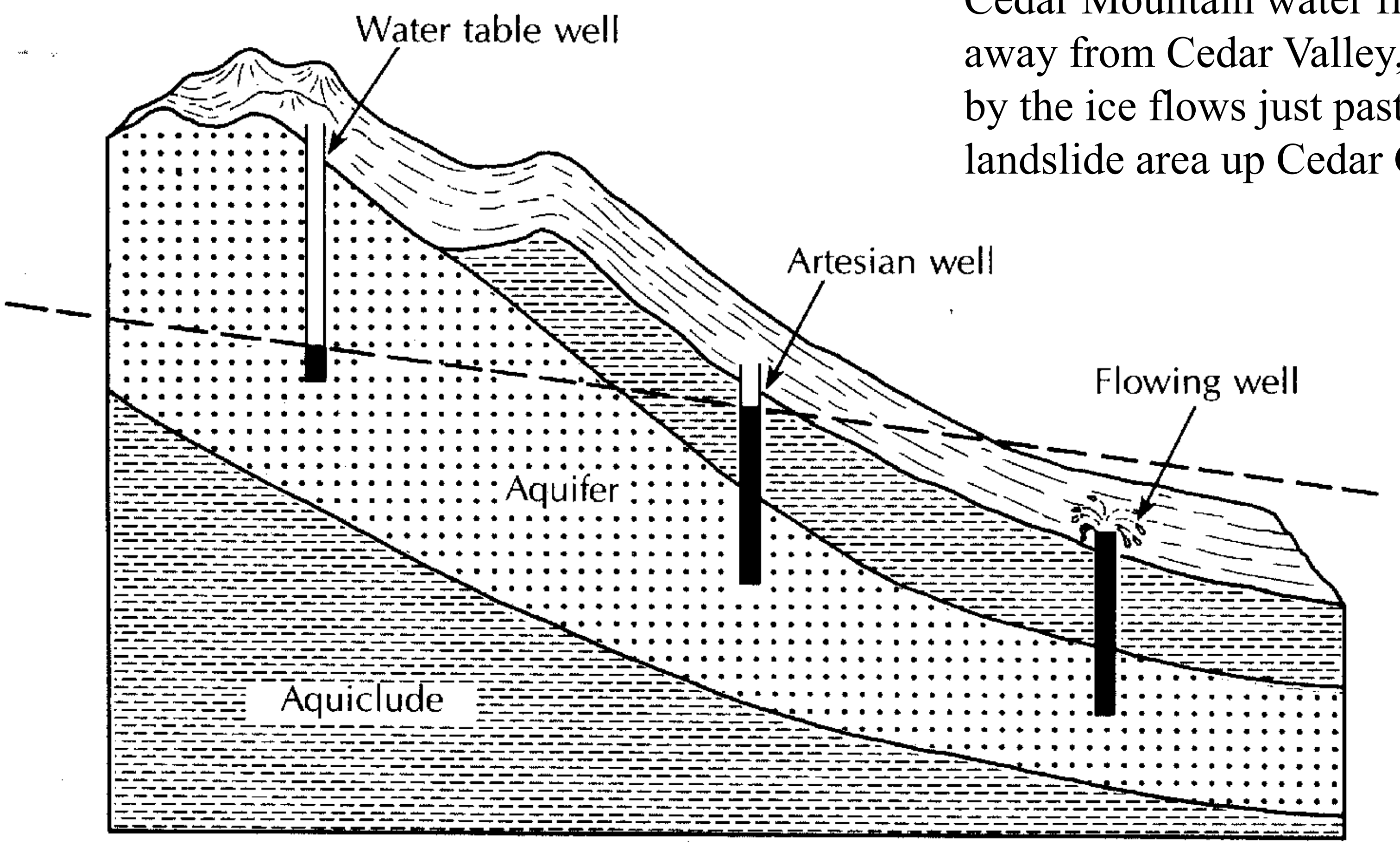

FIGURE 4.21 Artesian and flowing well in confined aquifer.

https://www.slideshare.net/VISHNUBARUPAL/types-of-aquifer-by-bablu-bishnoi-65855846, slide 16 of 24.

Both photos west side of Highway 14
No ice flows on east, due to east dip.

Photos by Gary F. Player

Lower Hydrostatic Pressure

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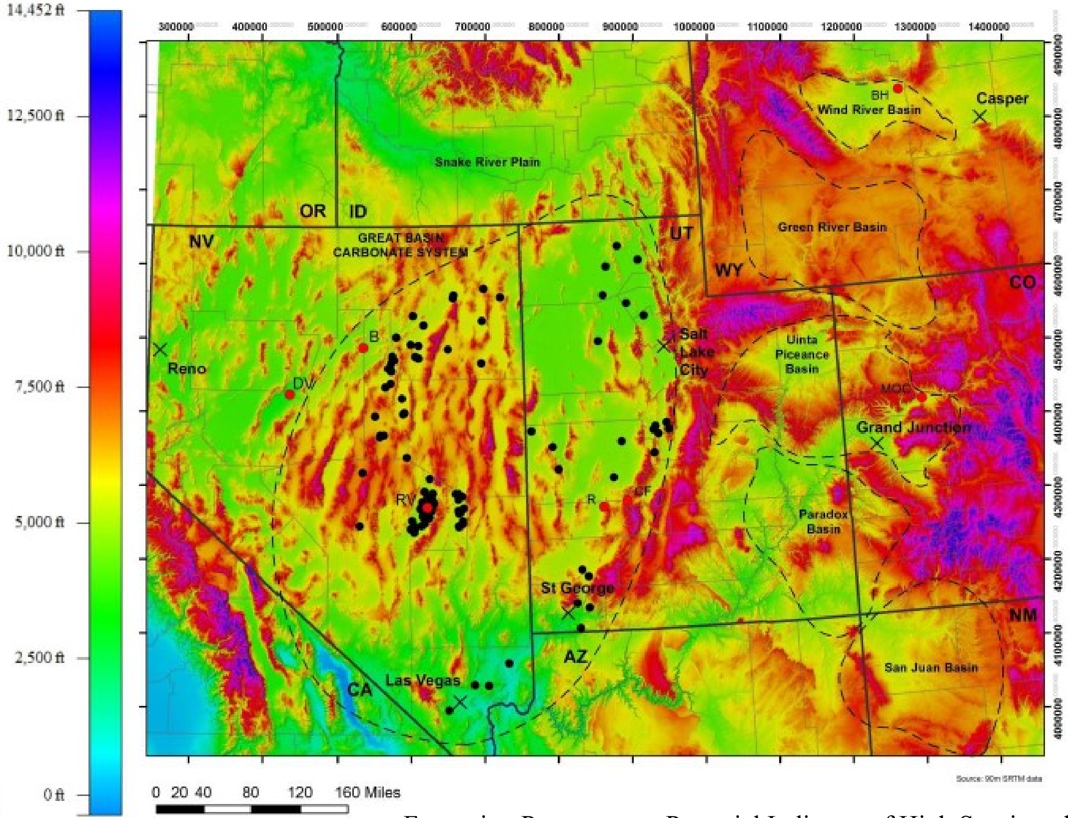
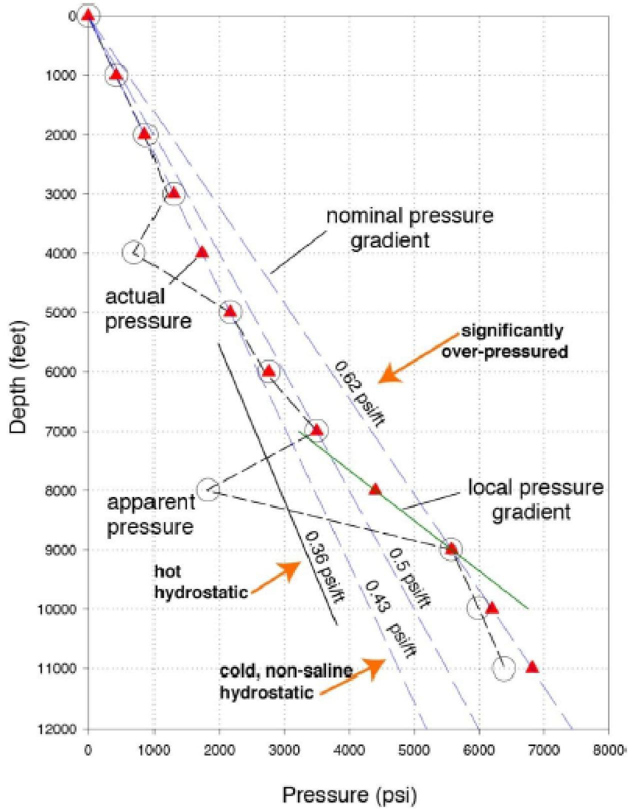
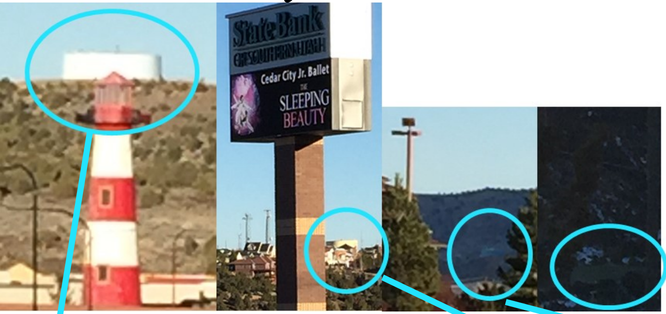
The Southern Great Basin has lower than normal hydrostatic pressure, which the same as when there is low hydrostatic pressure in a city water system, means there is a leak in the system.

The Great Basin leak is Grand Canyon.

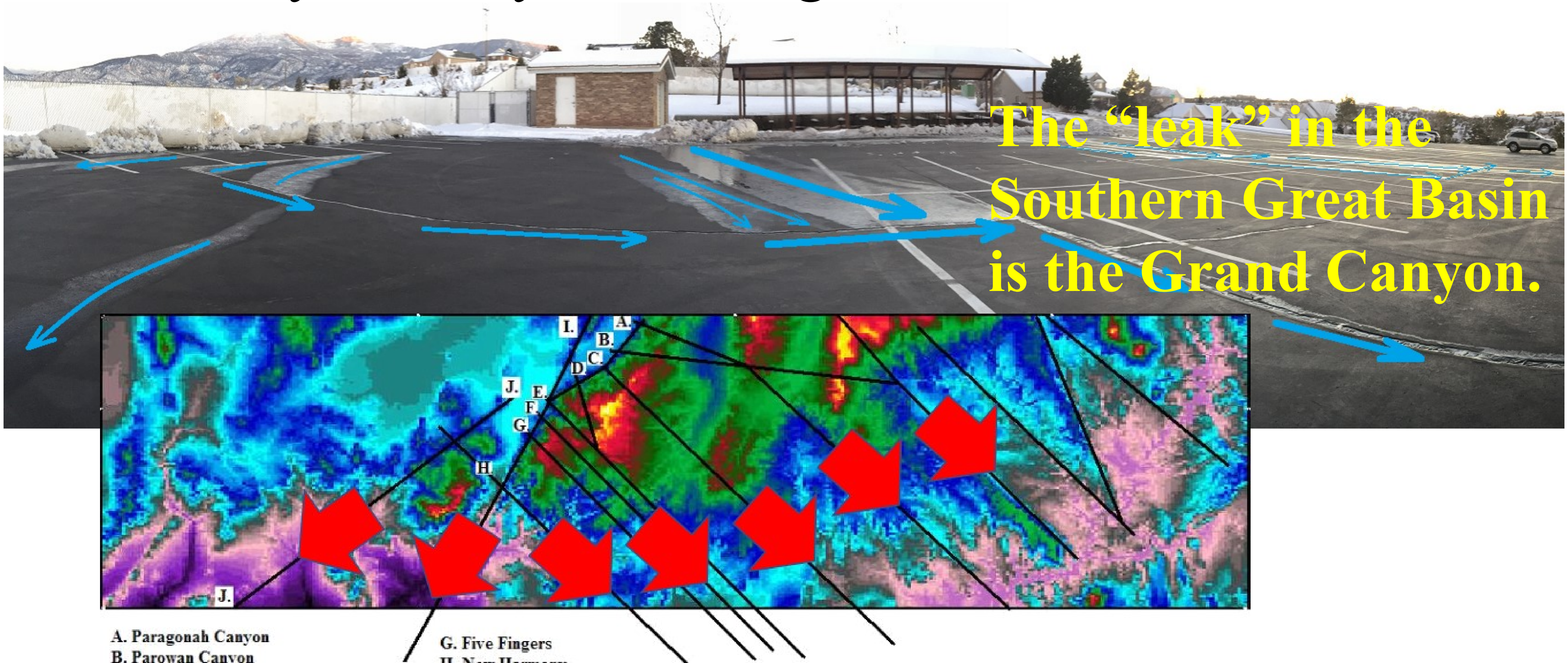


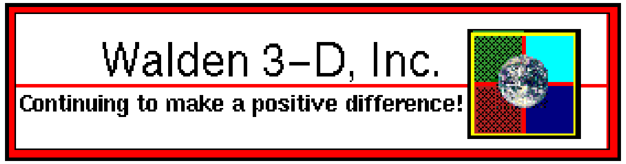


Formation Pressure as a Potential Indicator of High Stratigraphic Permeability, Rick Allis, UGS,
http://www.walden3d.com/IronCounty/CedarValleyWater/140224_Pressure_Permeability_Great_Basin.pdf



Water Flows
by Gravity and along Cracks





A. Paragonah Canyon
B. Parowan Canyon
C. Summit Canyon
D. Fiddlers Canyon
E. Cedar Canyon
F. Kararaville Canyon

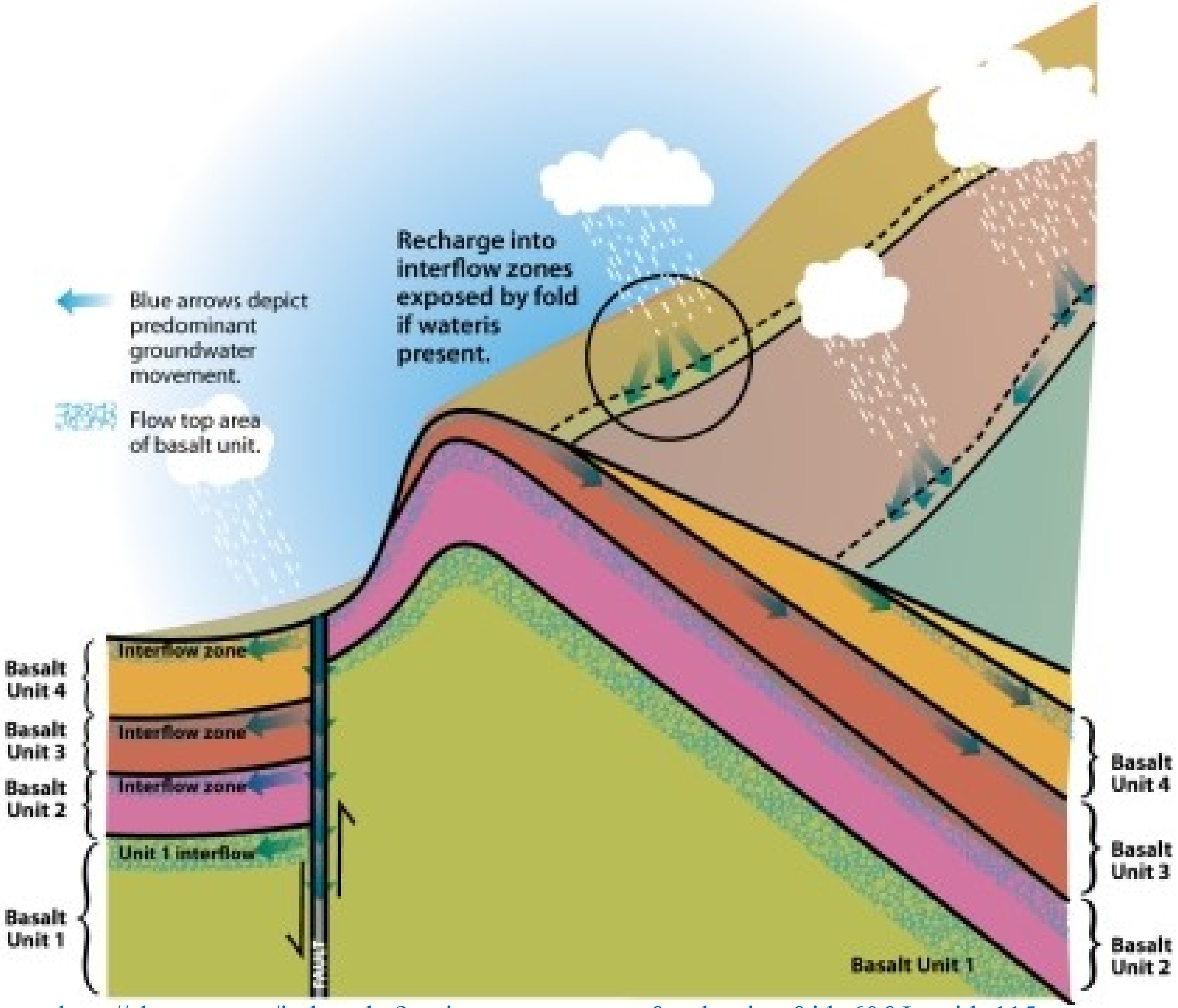
I.

G. Five Fingers
H. New Harmony
I. Hurricane Fault
J. Pinevalley

Possible Fault Geopressure Leak Pathways
from Cedar Valley to the Colorado River

See http://www.walden3d.com/IronCounty/CedarValleyWater/ #8. at bottom of page.

Faults & Dip Force Water Flows from Cedar Mountain East & South



http://cbgwma.org/index.php?option=com_content&task=view&id=60&Itemid=115

- Bedrock dips to the east about 10 degrees;

Photos by Roice Nelson

- Faults bounding the valley disrupt baseflow, especially into the Cedar Valley basin fill aquifer.
- Aquifer overproduction is very shallow (less than 800 feet depth) and except for water flowing down Coal Creek and Fiddler's Canyon these shallow layers are isolated from mountain recharge by layers of clay and the potentiometric surface dip.

10 Groundwater Model of the Great Basin Carbonate and Alluvial Aquifer System Version 3.0

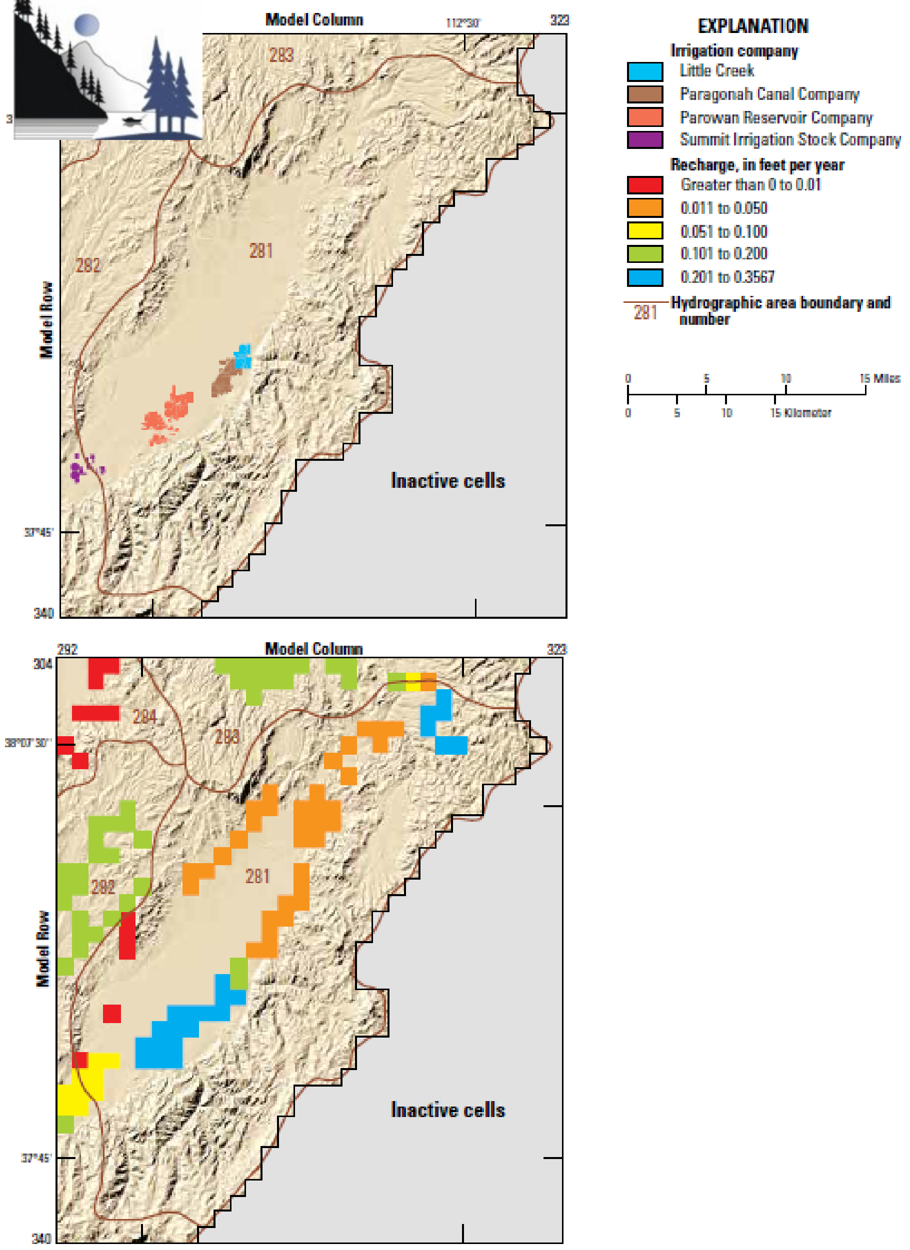


Figure 5. Source of irrigation by surface water and rate of conceptual recharge from runoff and irrigation by surface water in Parowan Valley, Utah.

Models Are Not Reality

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- USGS bases a lot of their recommendations on models.
- The assumptions behind the models often impact results more than data.
- For instance, water movement down and along valley bounding faults is not taken into consideration.
- Recommend models be rerun, assuming most of the water never reaches the shallow valley water production depths.

https://pubs.usgs.gov/sir/2017/5072/sir20175072.pdf, page 10.

The Overproduced Cedar Valley Aquifer

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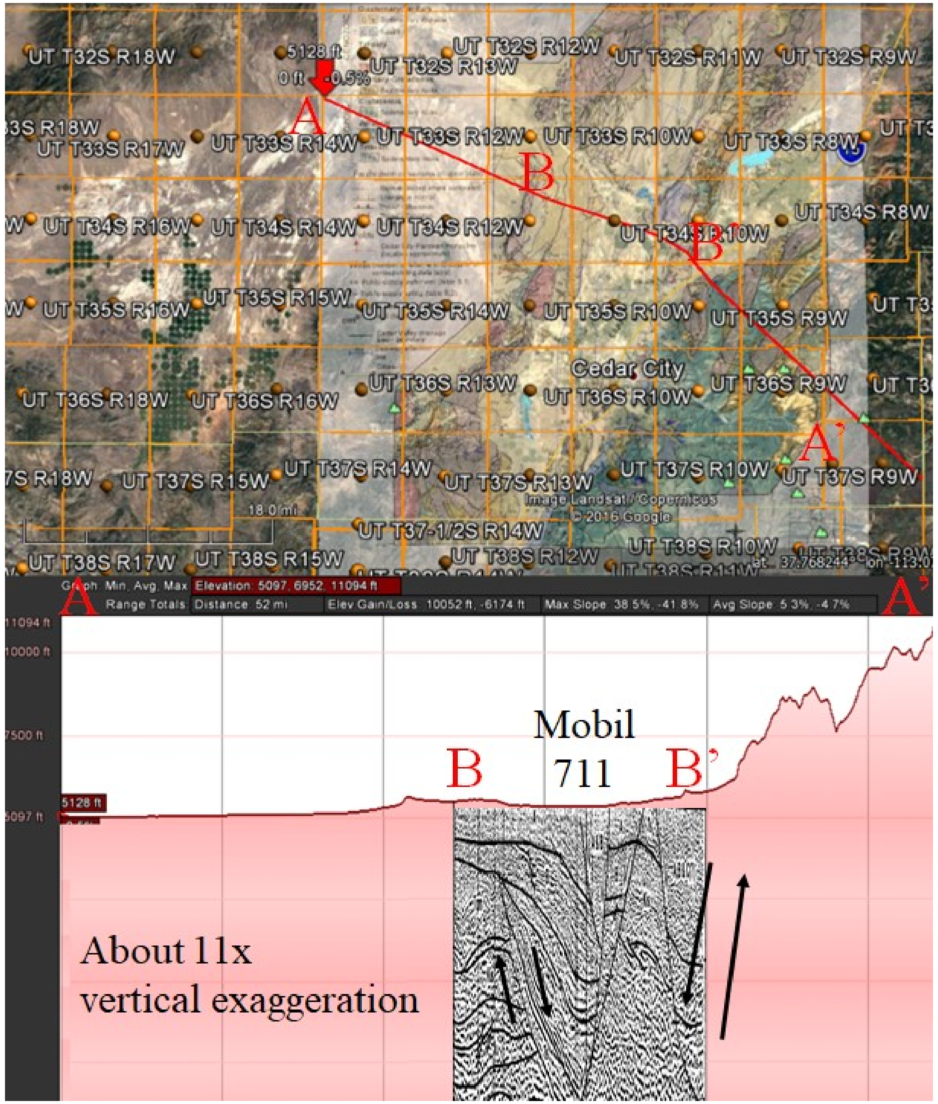

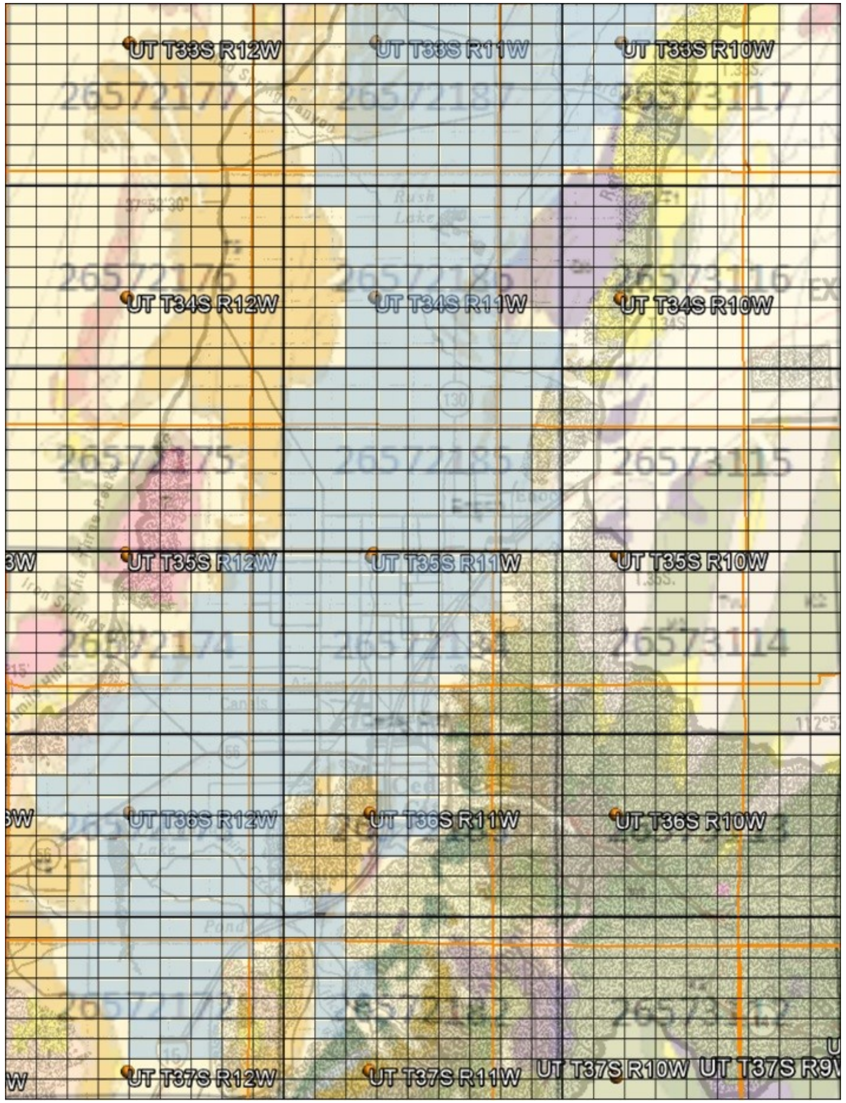

- Map and cross-section to the far left, show configuration under the Cedar Valley aquifer.
- Almost all water wells are less than 800 feet deep.
- With over a mile of sediment, only the first 800 feet have been tested with water wells and produced.
- The Cedar Valley Aquifer is shown by the blue colored squares on map just to left.
- Each colored square is about ~0.36 square miles in size. There are 421 cells covering the Cedar Valley Aquifer, or 152 sq. miles.

http://www.walden3d.com/IronCounty/ig/IronCounty/IC_CVA.html

15,590-foot Arco-3 Dry Oil Well

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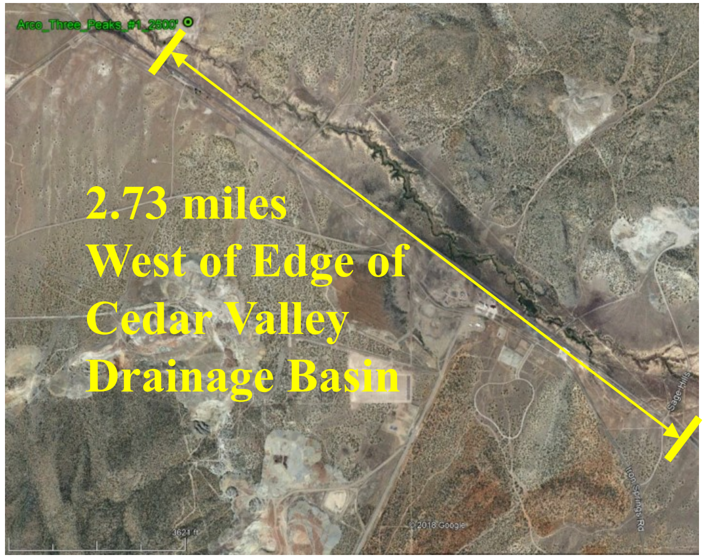
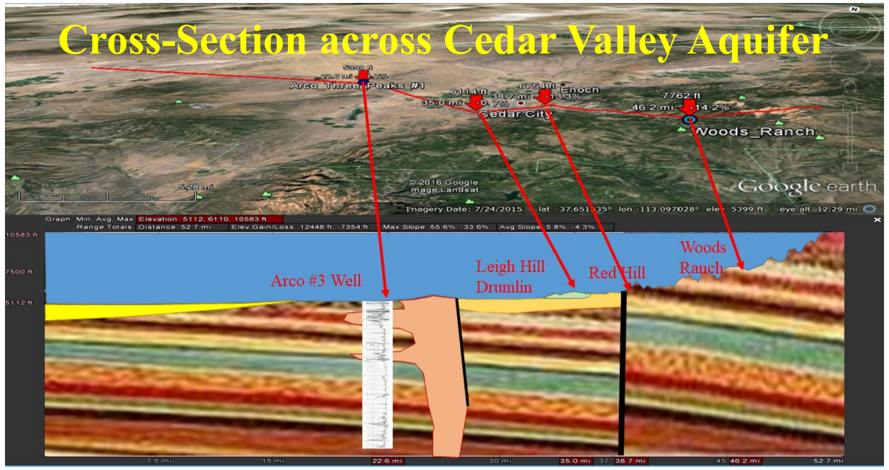




To: Frank Nichols
From: Gary F. Player
Subject: Possible Water Resources Surrounding ARCo Three Peaks No. 1
Date: November 10, 2017

Happy day before Veterans' Day! I just about completed the new casing diagram showing the locations of cement plugs in the subject well, and I couldn't stop myself from doing a little conjecturing about possible water resources.

I have drilled and reviewed dozens of wells completed in fractured granite aquifers in Utah and California, so I feel confident about assigning a very conservative likely porosity of three (3) percent. Given the known thickness of the granitic rocks at Three Peaks (3,964 feet) we can calculate the volume of potential water present in one square mile (640 acres). Here goes:

Area = 640 acres
Thickness = 3,964 feet
Porosity = .03
Water volume = (640)*(3,964)*(.03) = 76,108.8 acre-feet.

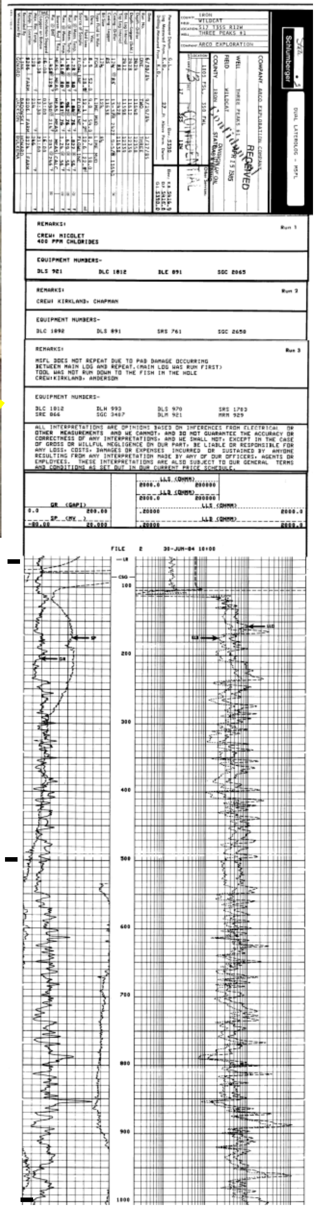
The Iron Mountain granite intrusive extends over an area of about 200 square miles in Iron County, allowing an estimated water resource of (200)*(76,108.8) = **15,221,760 acre-feet**. I believe that possibility is worth an inexpensive test in an existing well: The ARCo Three Peaks No. 1, now owned exclusively by you.

Sincerely,

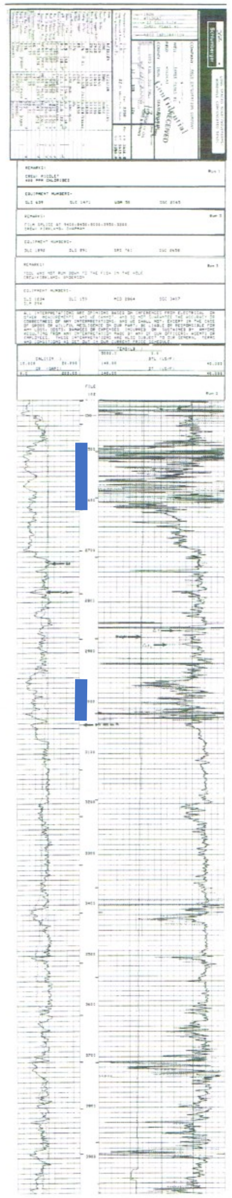
Gary F. Player

Gary F. Player
Utah Professional Geologist No. 5280804-2250

Potential Quartz Monzonite Water:
15,221,760 acre-feet
Probable Annual Recharge:
21,333 acre-feet per year



60 feet -
500 feet -
1,000 feet -



- 2400 feet
- 2600 feet
- 3000 feet
- 3970 feet

33 Traces using Mark Burr's "Passive Seismic" – 01 Mar 2019

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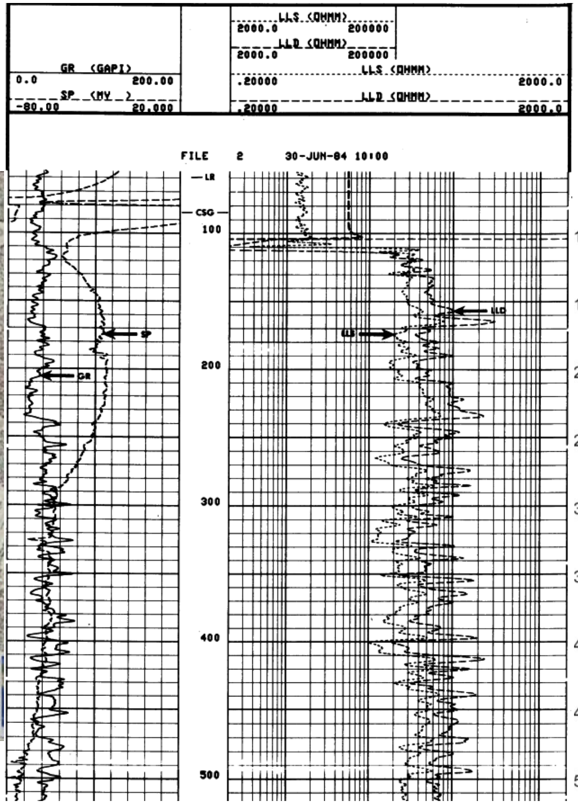
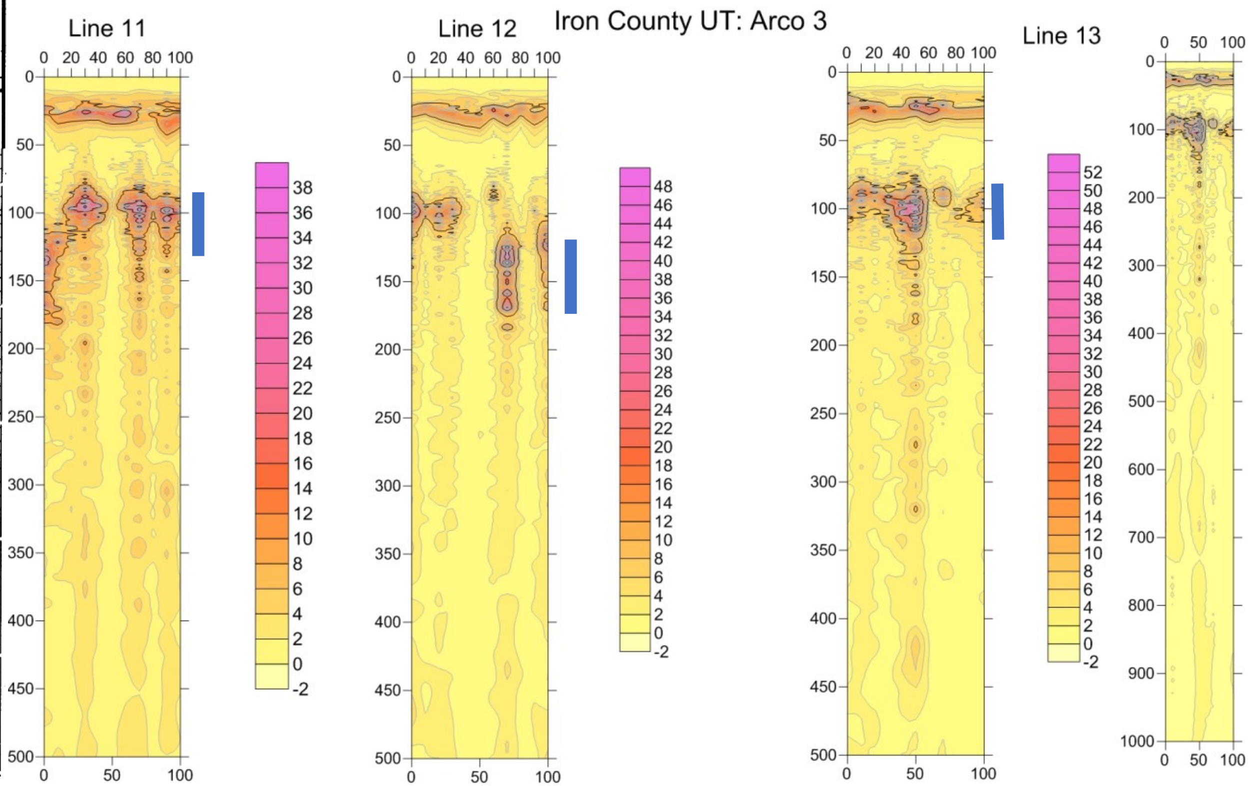
Locations of 33 "Passive Seismic" Measurements by the Arco-1 Well

Schlumberger Resistivity Log



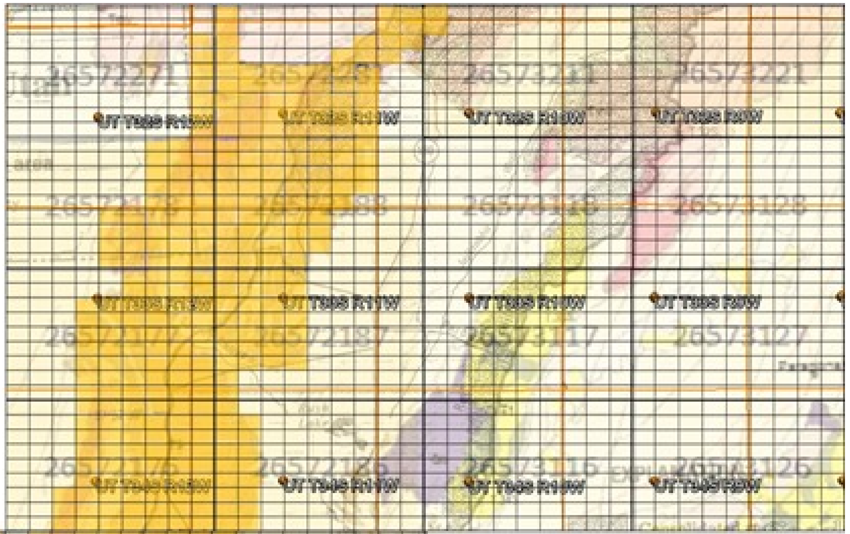
PrimaryWaterTechnologies.com

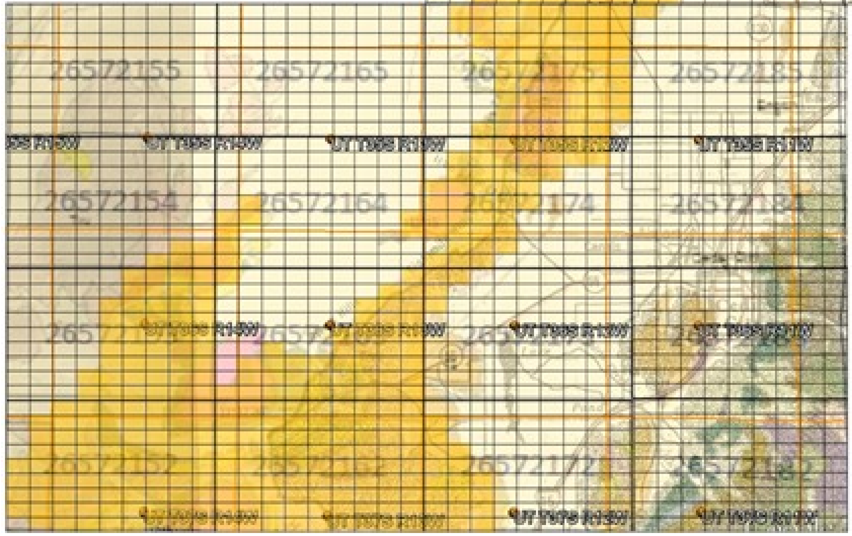


Note these are not primary acoustic signals (seismic), rather they are the calculated spectrum of acoustic signals

The Untapped Quartz Monzonite & Cretaceous Aquifers either side of Cedar Valley

The Fractured Quartz Monzonite Aquifer is shown by the orange colored squares on the map to the right and below.

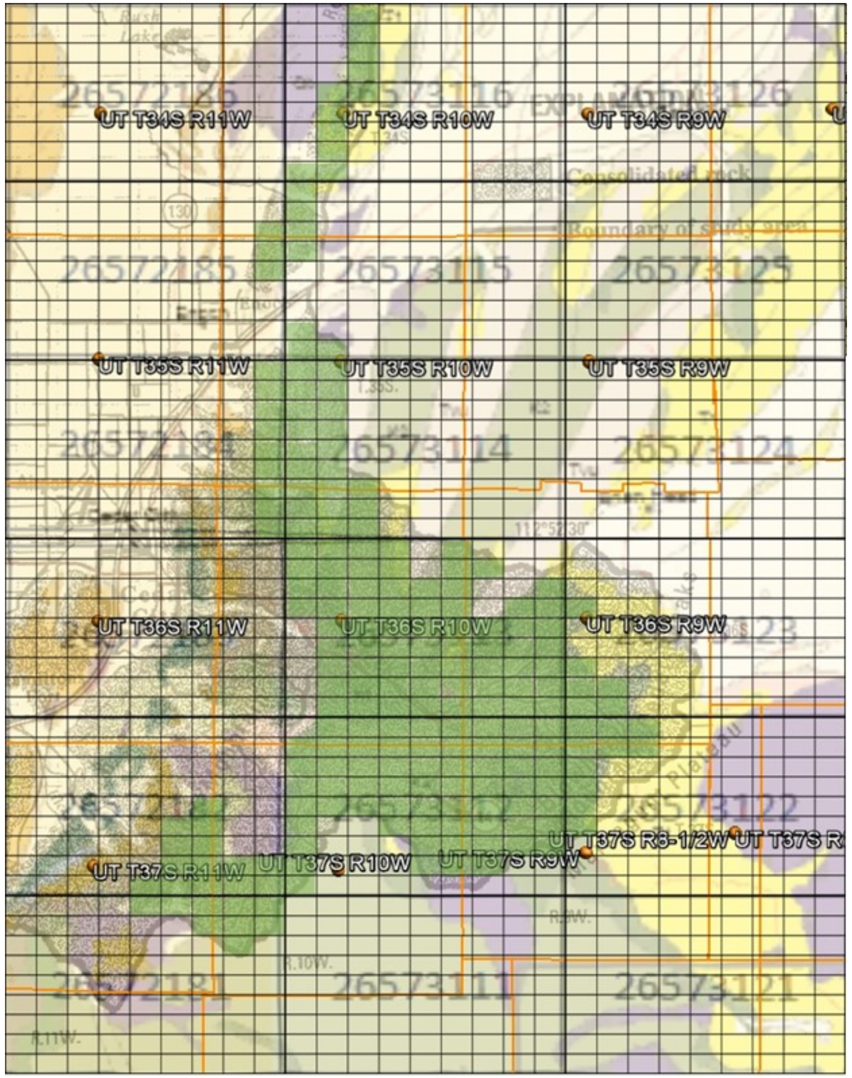




Each gold colored square is about ~0.36 square miles in size. There are 681 cells, or 245 square miles of untapped quartz monzonite aquifer.

To the right, Cretaceous Aquifer is shown by the green colored map squares.

Each colored square is about ~0.36 square miles in size. There are 213 cells covering the Cretaceous Aquifer, or 77 square miles.



http://www.walden3d.com/IronCounty/ig/IronCounty/IC_3_Aquifers.html

The Quartz Monzonite Aquifer

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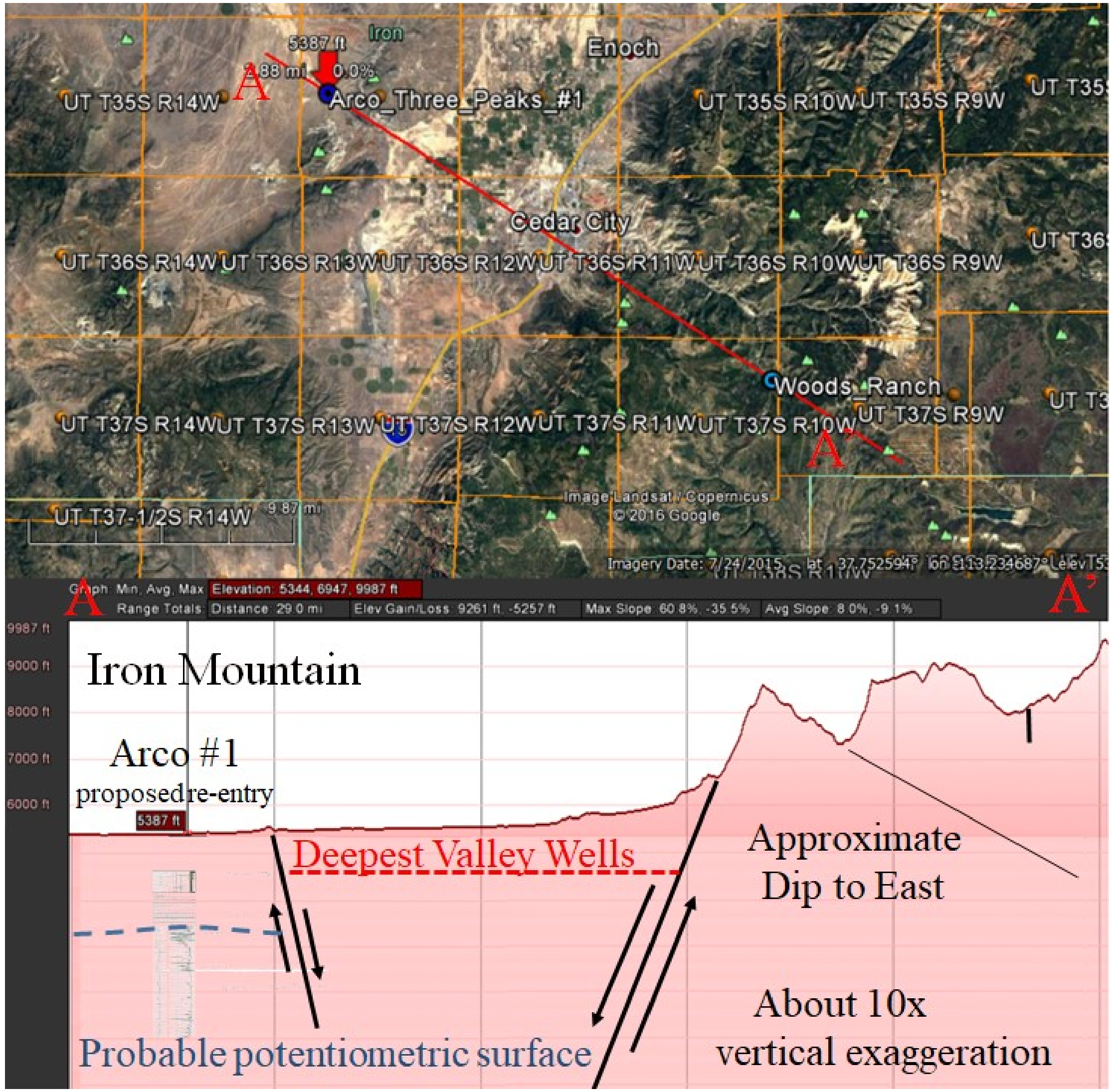

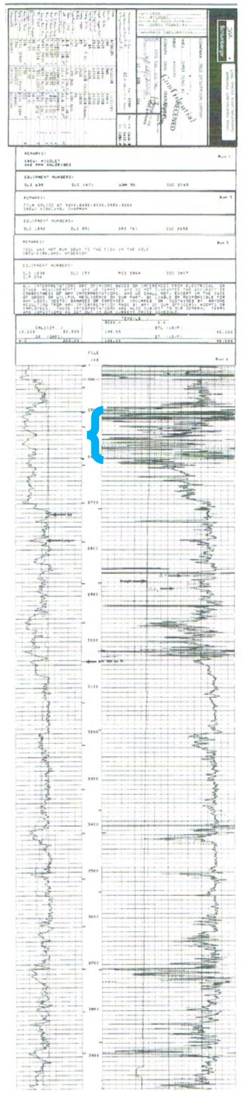

Untapped quartz monzonite aquifer at Blowout Pit, Iron Mountain.

To the left are Schlumberger well log results dated 30 Jun 1984, 20 Sep 1984, and 17 Jan 1985 from a well Arco drilled at Iron Springs. The high porosity, highlighted with { in blue, is from fresh water in the fractured quartz monzonite. This fractured quartz monzonite is the same geology as the successful well drilled in Enoch against the dipping Cretaceous beds.

http://www.walden3d.com/IronCounty/ig/IronCounty/IC_QMA.html

The Cretaceous Aquifer

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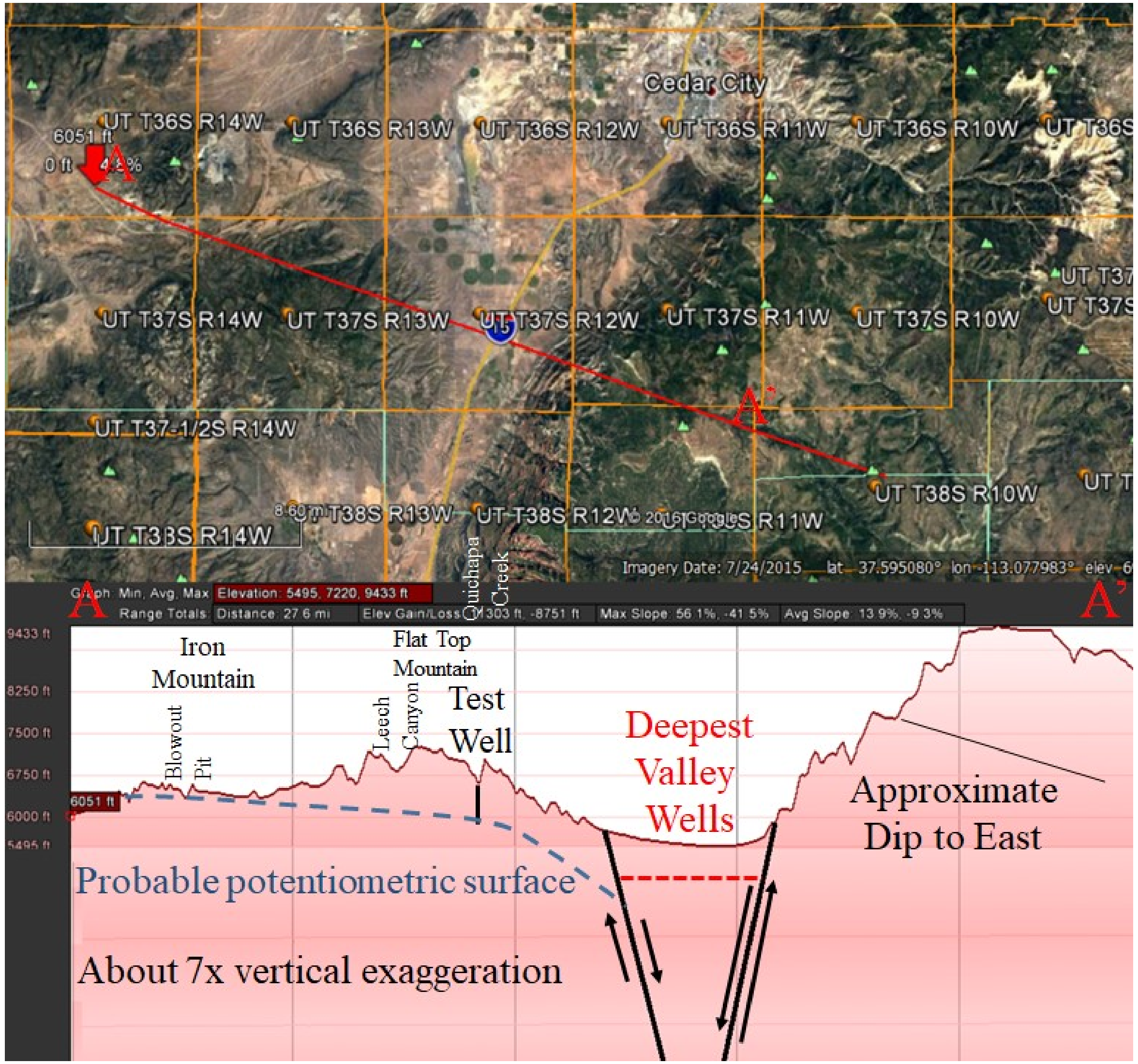
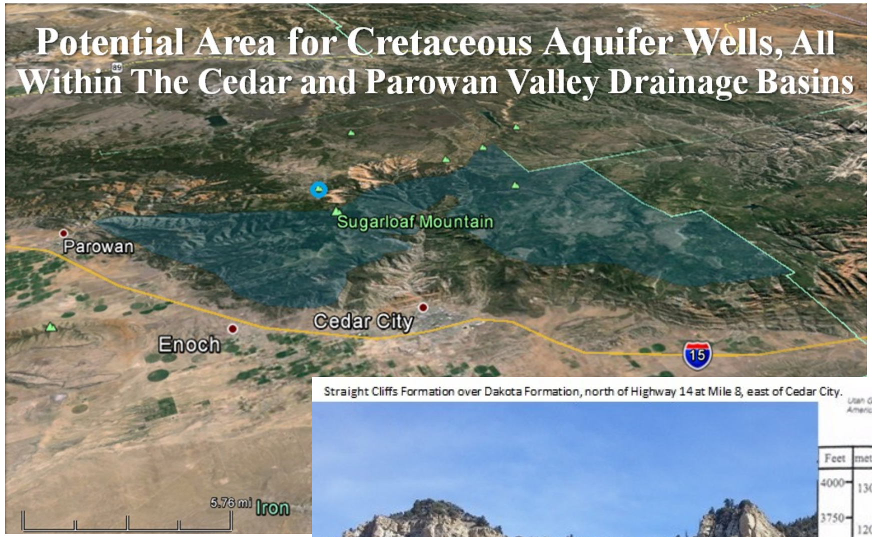
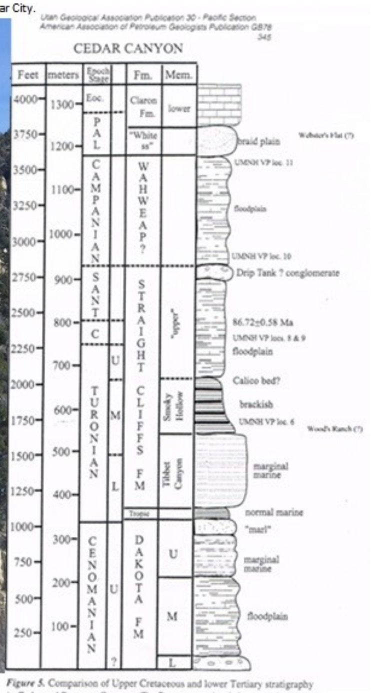




The Cretaceous Aquifer was successfully tapped at Brian Head in the city well.

Straight Cliffs Formation over Dakota Formation, north of Highway 14 at Mile 8, east of Cedar City.

Photo by Gary F. Player, Utah Professional Geologist 5280804-2250, March 14, 2015



The landslides are not a result of the coal mine having been here, they are a result of the coal mine not draining water off of the cliffs.

http://www.walden3d.com/IronCounty/ig/IronCounty/IC_KA.html

Water Districts in Parowan Valley

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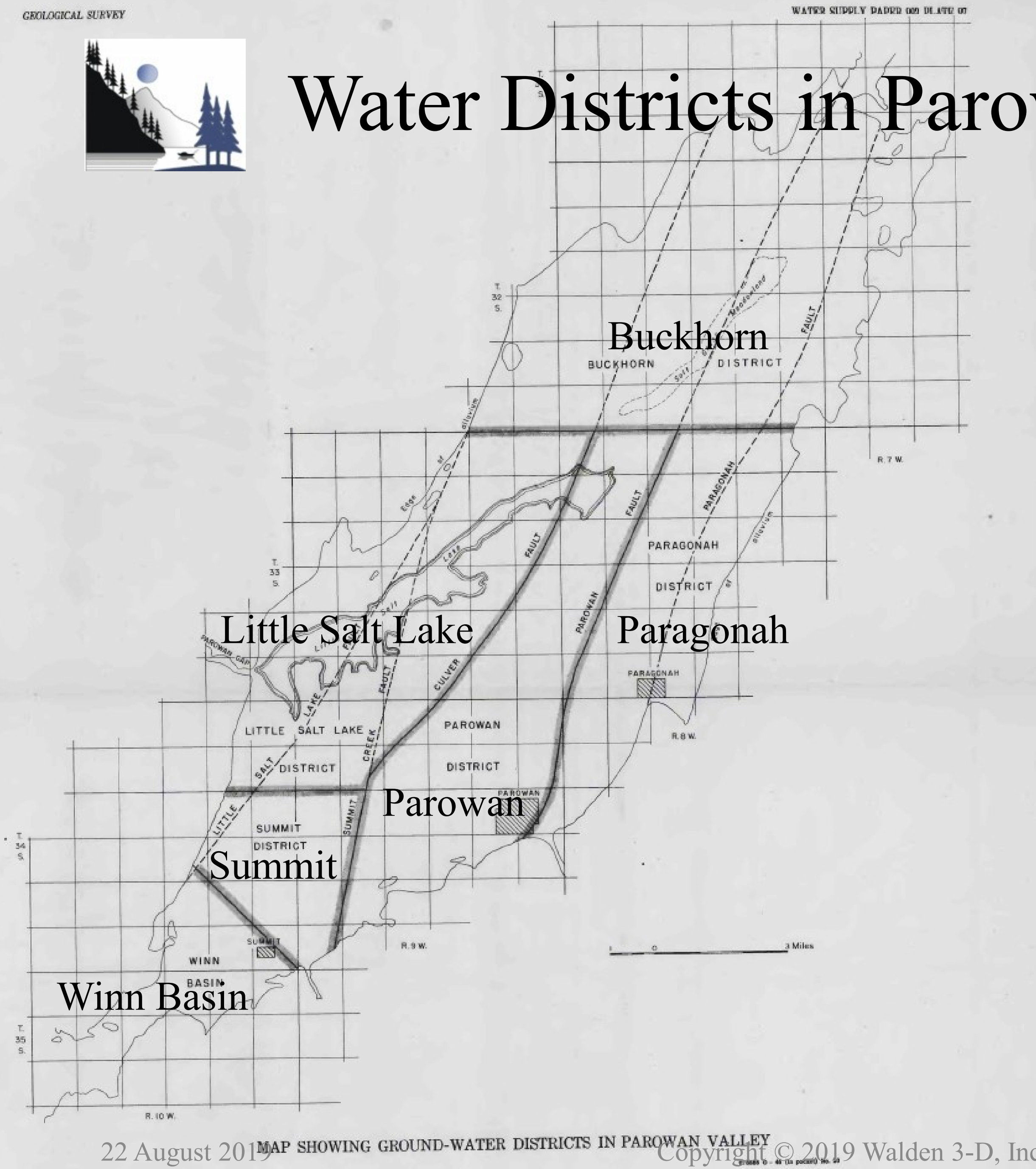

<u>What is an Aquifer?</u>

- A body of permeable rock which can contain or transmit groundwater.
- Aquifers are 3,000-4,000 feet deep under the Parowan Valley Water Districts.
- Wells have only tapped the first few hundred feet of the aquifers. Key considerations:
  - Overproduction collapses aquifers & they are lost.
  - It costs more to pump water from deeper aquifers.
- Overproduction is overcome by:
  - limiting production (State Engineer),
  - recharging the aquifer,
  - Range management of pinon and juniper pine (https://www.waterrights.utah.gov/meetinfo/m20161208/Comments/2017-02-07%20Dave%20Curtis.pdf),
  - Purifying and recycling waste water (https://www.waterrights.utah.gov/meetinfo/m20161208/Comments/2017-01-30%20Peter%20Grimshaw.pdf), and
  - Tap Bedrock Aquifers outside the Parowan Valley Aquifer (https://www.waterrights.utah.gov/meetinfo/m20161208/Comments/2018-04-09%20Gary%20Player.pdf).

Recharging “the Aquifers”

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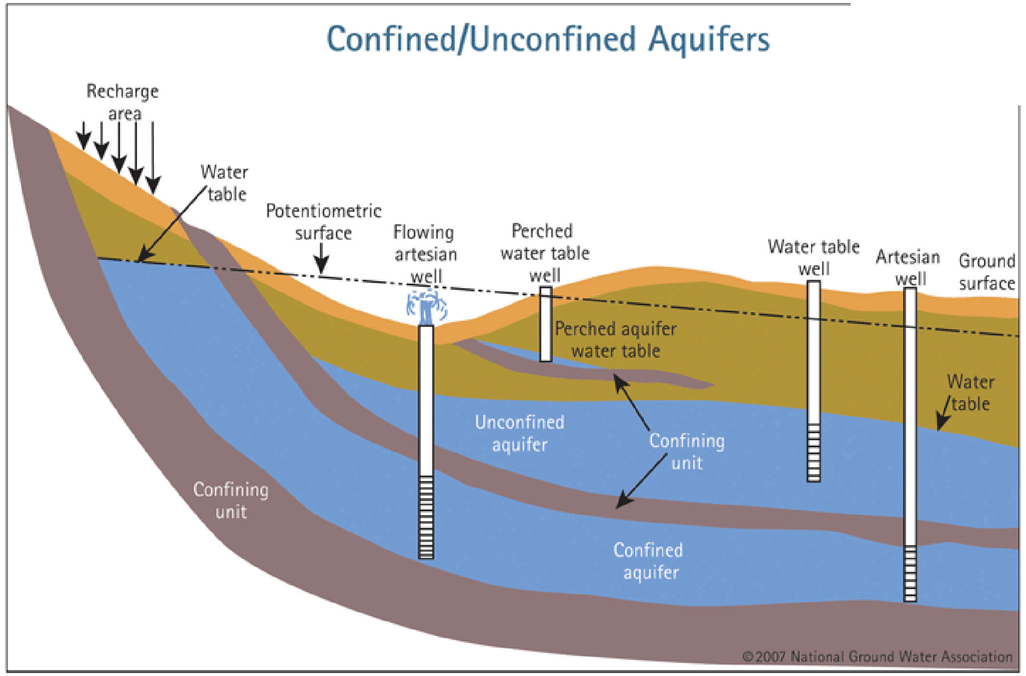
Storage Location	(Acre feet)
Schmidt Pit	520
Airport pits	1,719
Horse Alley pits	719
*Western Rock pit	6,000
Enoch Graben	32
Quichipa	100
Total	**9,990**

*Approximate number



http://jswater.in/featured/jswater-glossaries/gw/

- Our deficit in Cedar Valley is 7,000 acre-feet so we exceeded our deficit by nearly 3,000 acre-feet.
- Cedar City, CICWCD, Iron County and Enoch City should be very proud of the accomplishments to capture this precious resource. It was inter-local agencies and the communities working together that made this possible. We will continue to push for future projects to assist in this effort.
- The results of these efforts will protect private and governmental water rights and even though it will be needed at some point it will delay the need for a very expensive pipeline from Pine Valley. Very grateful for the moisture we have been blessed with.

Paul Cozzens
435-590-7618

Fluvial Systems and Aquifers,

like the Parowan Valley Aquifers, have complex geometries

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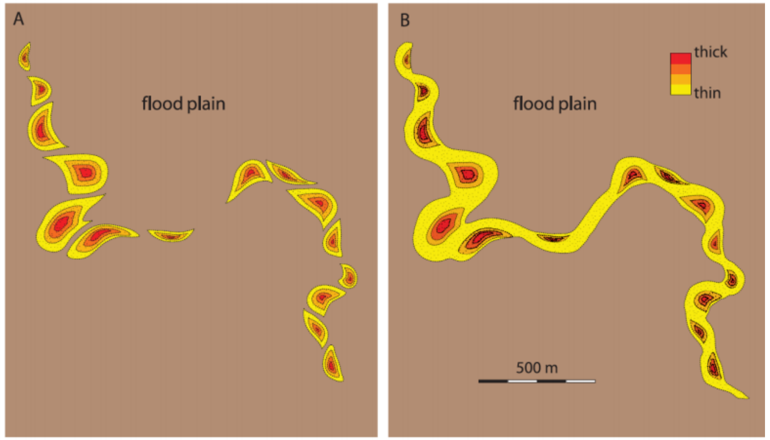
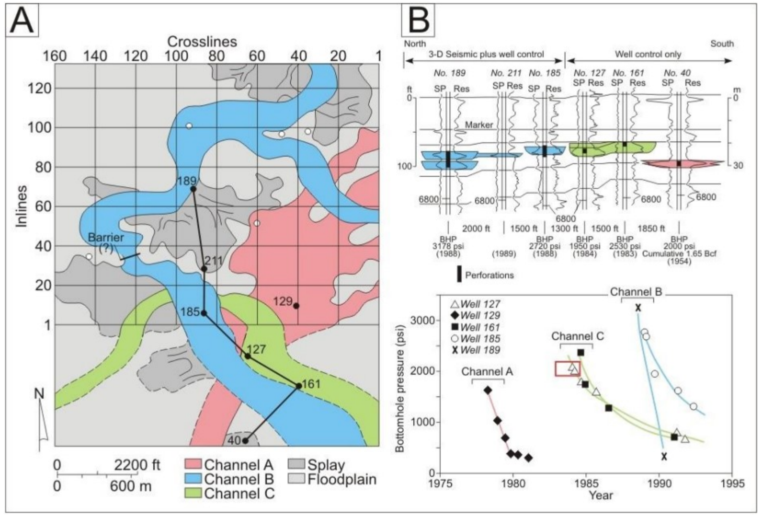
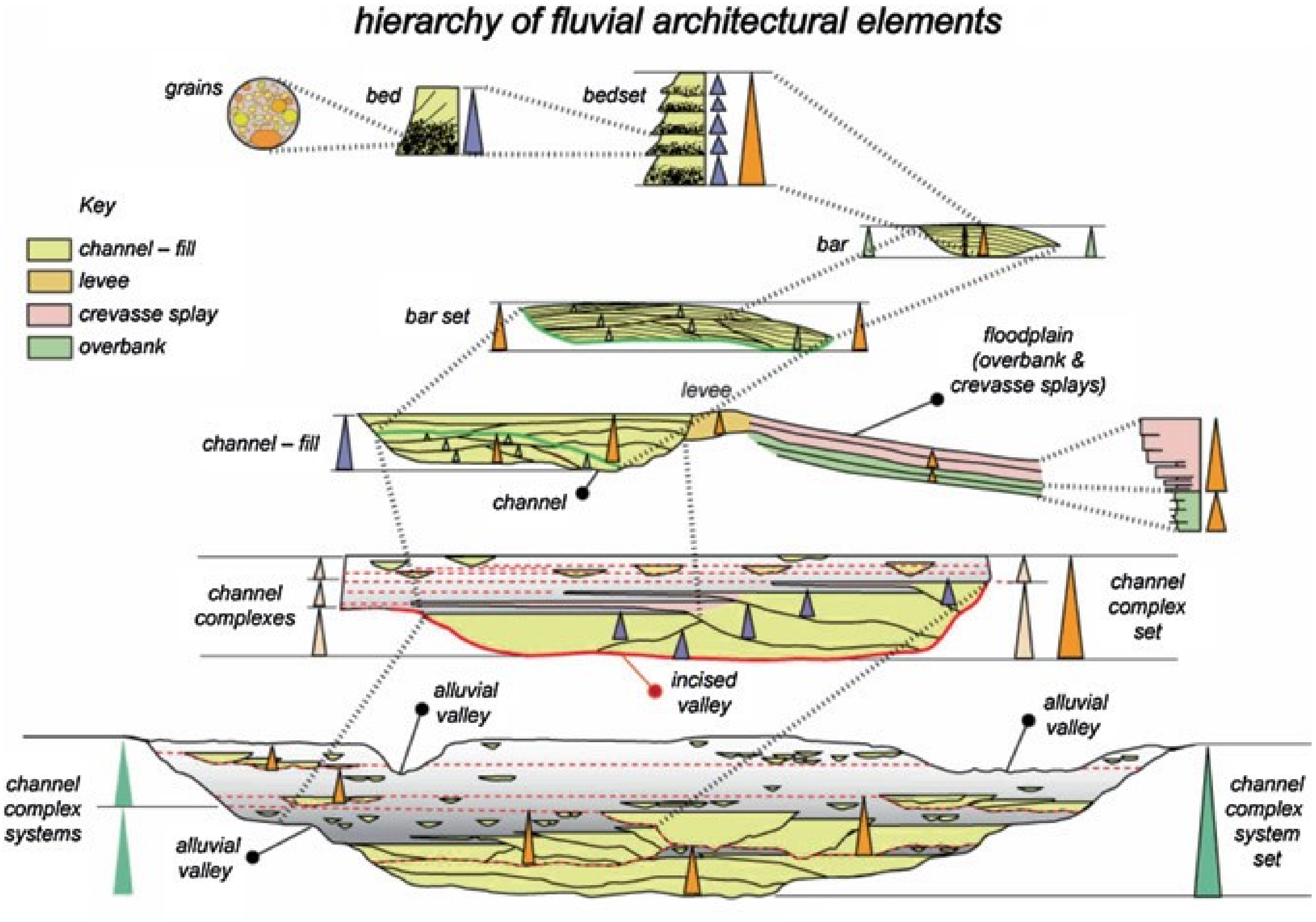


Flow Processes and Sedimentation in a Low-Sinuosity High Net-Sand Content Fluvial Channel Belt: 3D Outcrop Study of the Cedar Mountain Formation, Utah, Bradley Nuse, http://inside.mines.edu/UserFiles/File/CoRE/Thesis_Dissertation/Nuse_Bradley.pdf



A 3-D seismic case history evaluating fluvially deposited thin-bed reservoirs in a gas-producing property, Bob A. Hardage, et. al., Geophysics, Nov. 1994.



Chapter 2, The Facies and Architecture of Fluvial Systems, Figure 2.2, page 11.

Aquifers in Valley Aquifers are Very Com

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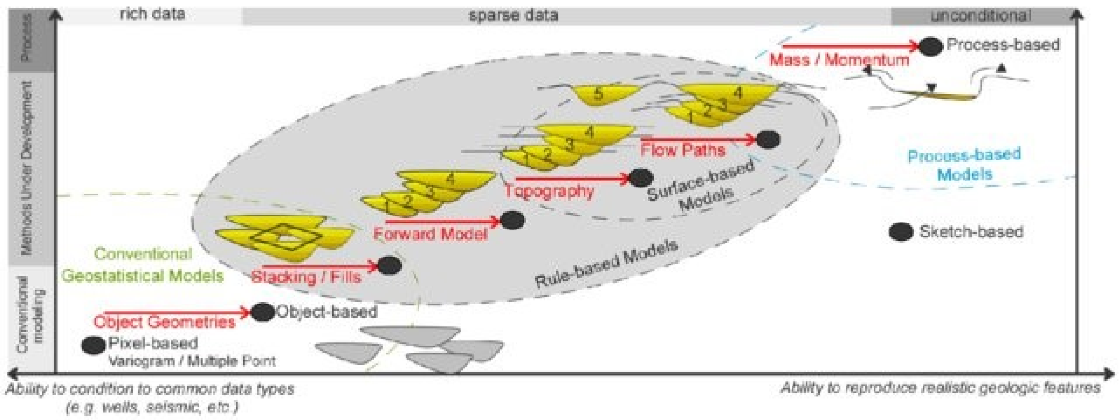
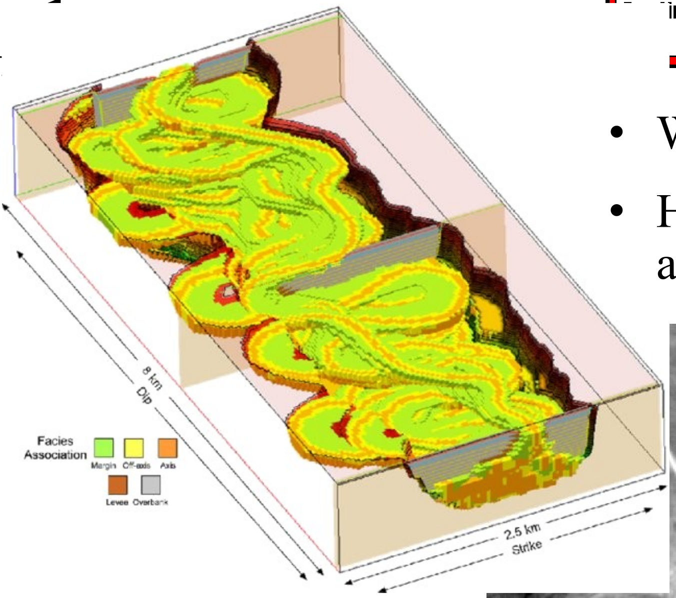
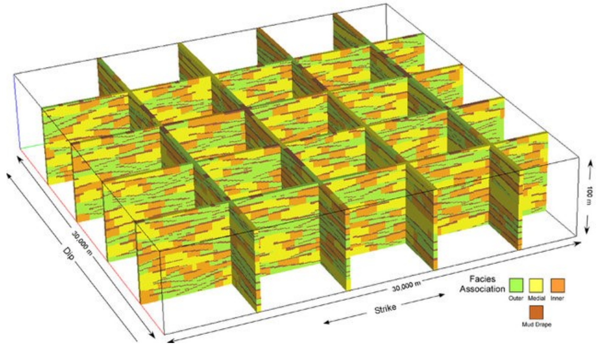
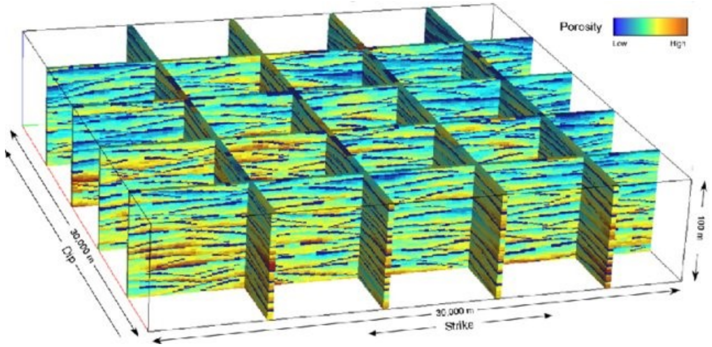


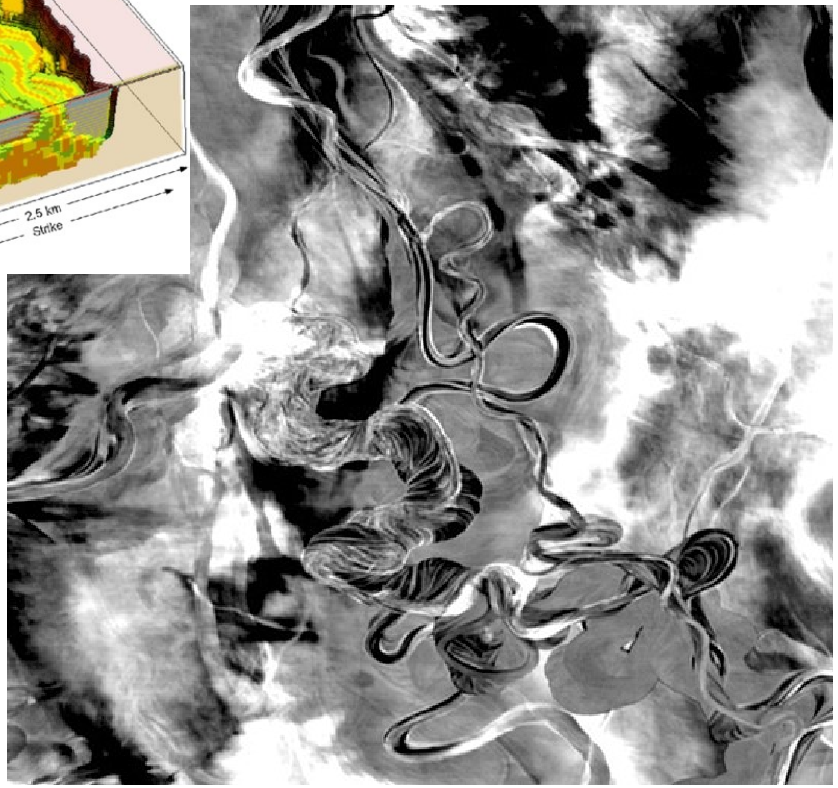


- Water in Aquifers move by Gravity.
- Horizontal and Vertical Leakage are key to understand.



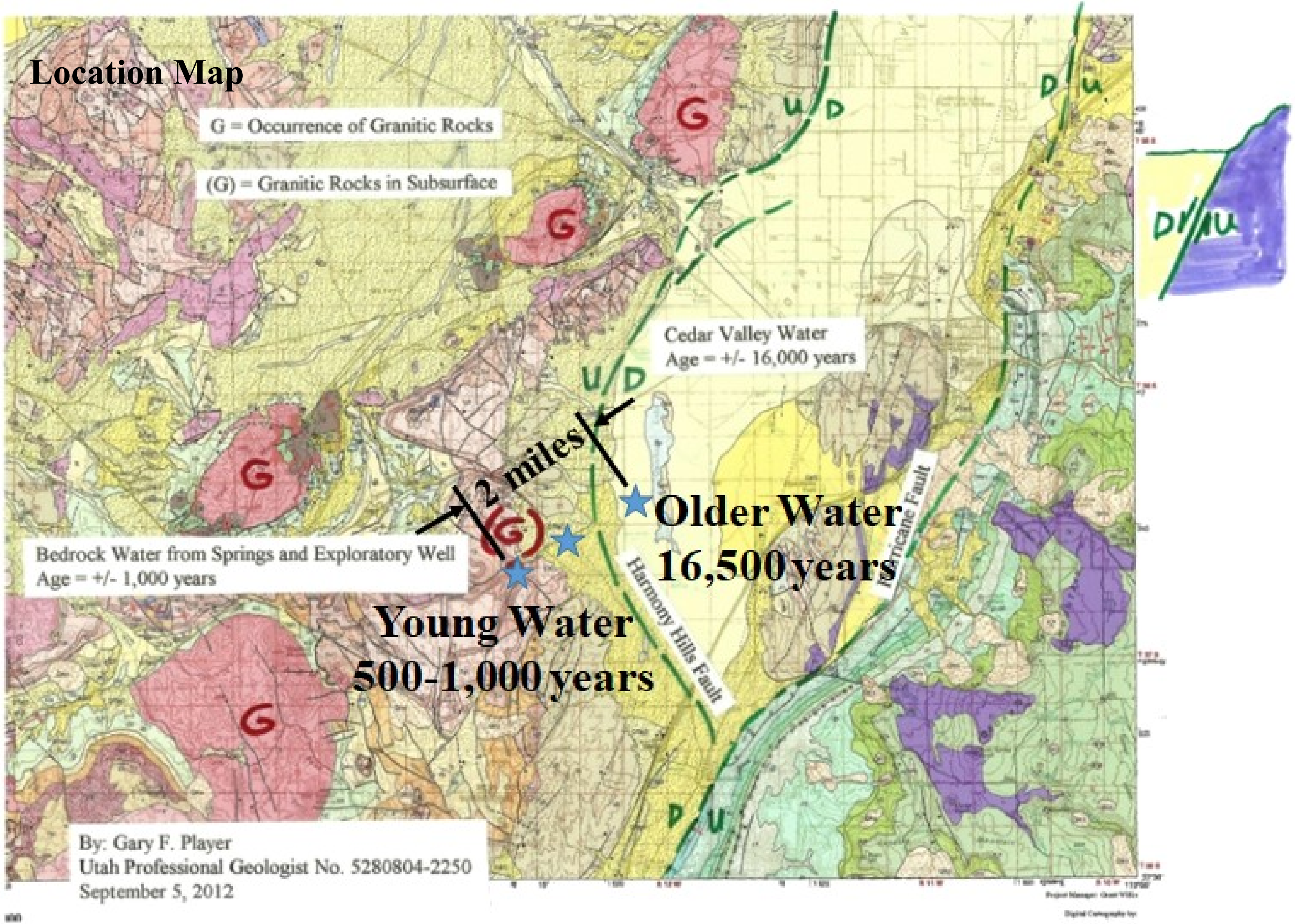


https://www.researchgate.net/publication/303960851_Stratigraphic_rule-based_reservoir_modeling/figures?lo=1



3-D seismic horizontal slice showing fluvial channels
https://www.shearwatergeo.com/ **SEG Leading Edge** Ad

Age of Water and Harmony Hills



Water Age and Isotopes:

- Enables mapping of geologically related aquifers,
- Shows relationships to bedrock aquifers (in Cedar Valley there is no way the bedrock aquifers are recharging the shallow producing aquifers),
- Provides data to convince the State Engineer there are new, untapped, water sources.

Water Isotopes & Water Age Enable Mapping of Aquifer Geometries

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Cost: ($45/sample)

Delivery:

- Spreadsheet Report
- H and O isotope analysis
- Value and Uncertainty
- Reference and quality control samples

Given water isotopes and water age for most of the wells in the valley, Roice will map the relationships and work to determine the aquifer framework.

Requires:

- Clean sample of water at point of origin (well head or as close as possible).
- Store Sample in HDPE bottle with a gas-tight closure.
- No evaporation.
- Keep in a dark environment to limit biological activity

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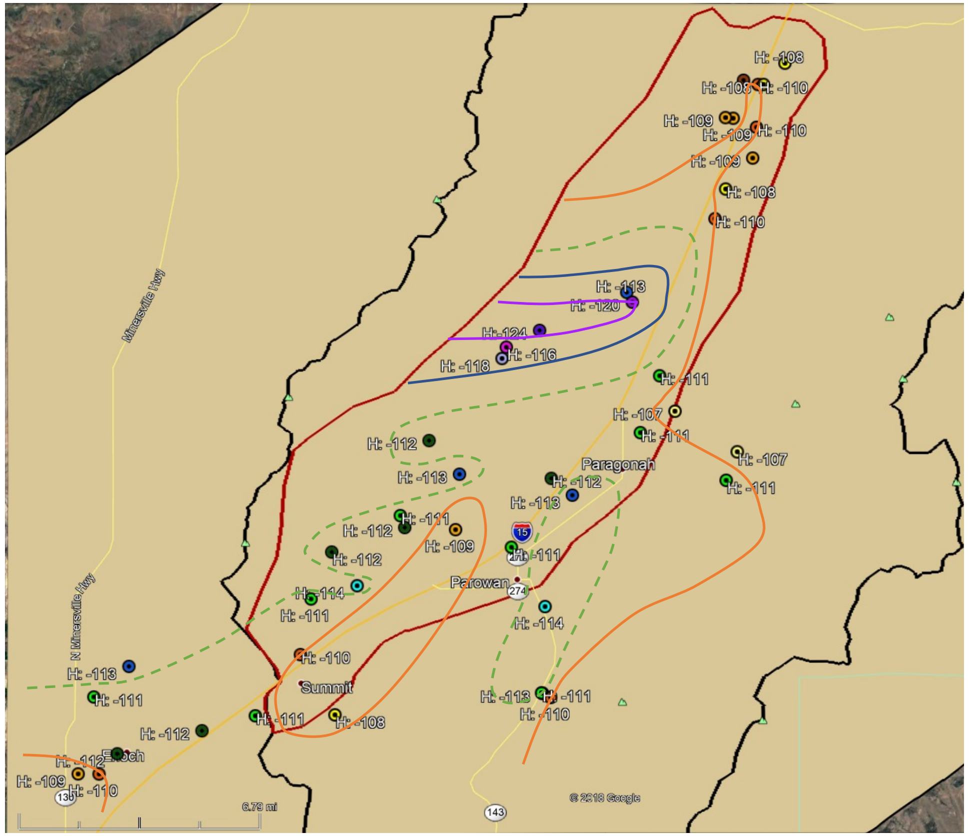
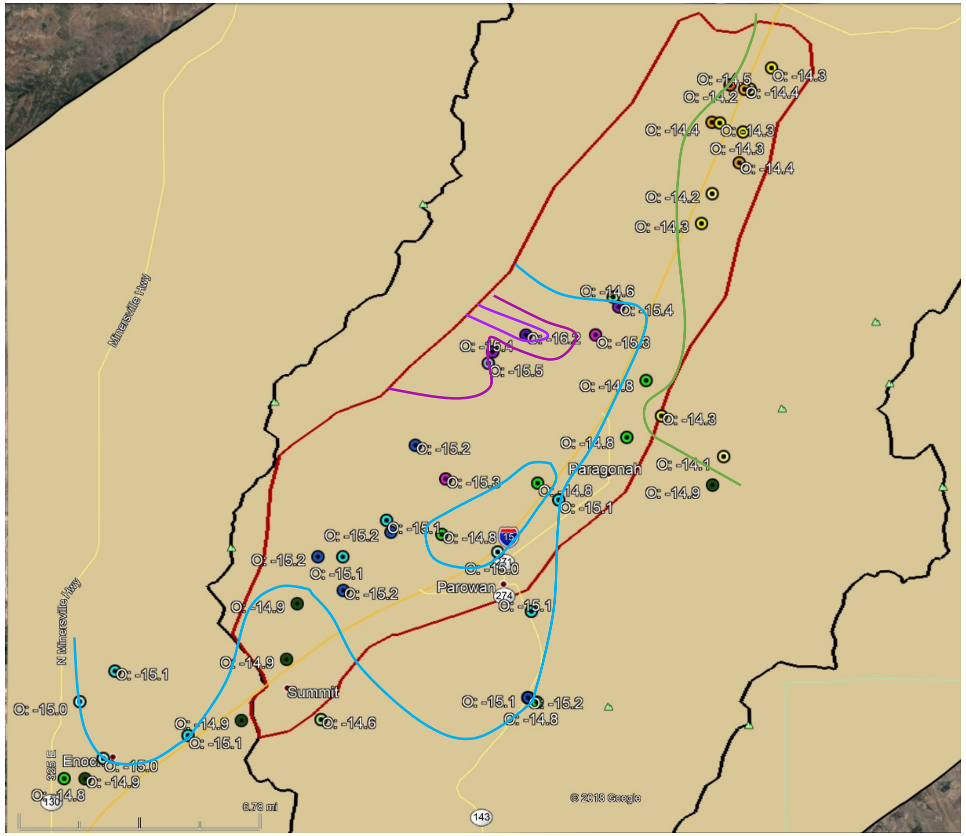
USGS reported some H & O Isotope Results

https://pubs.usgs.gov/sir/2017/5033/sir20175033.pdf, Table 7, page 37.

Roice mapped these two isotopes to demonstrate trends available from additional and more detailed analysis.





The trends are similar for both isotopes, and show the impact of bedrock aquifers on the sides of the Parowan Valley Aquifer on the water geochemistry.

In terms of understanding the Parowan Valley Aquifer in relationship to the surrounding Bedrock Aquifers, mapping the age of the water is likely more important than mapping the H & O Isotopes.

A Goal is to Create a 3D Model

like this 2006 Cedar Valley Study: 145 wells, deepest 820 feet deep

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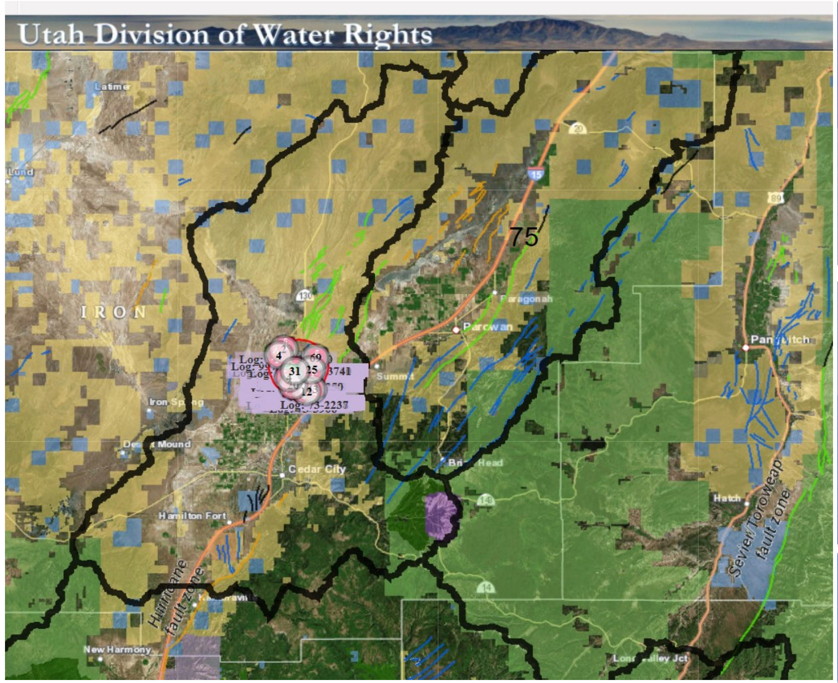

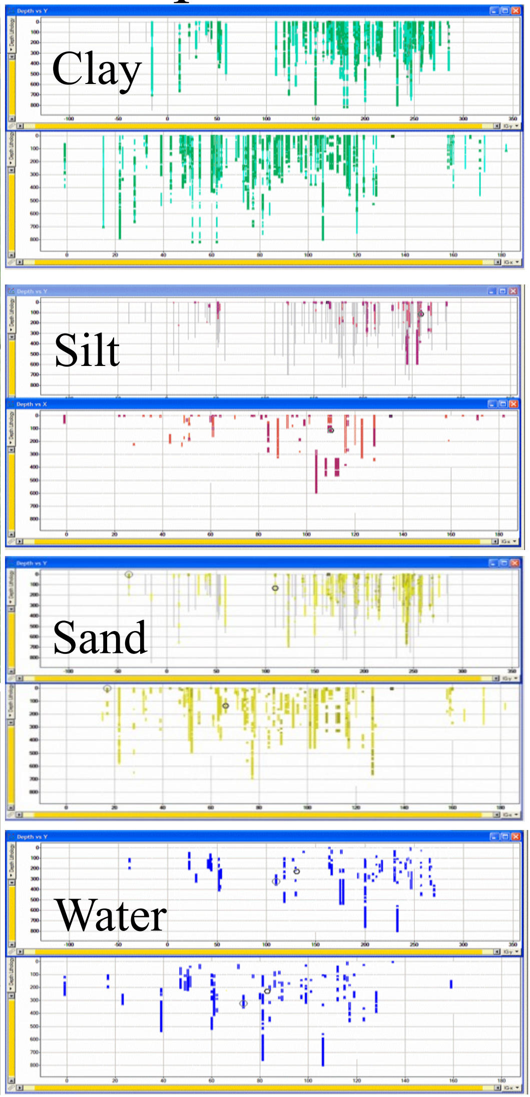

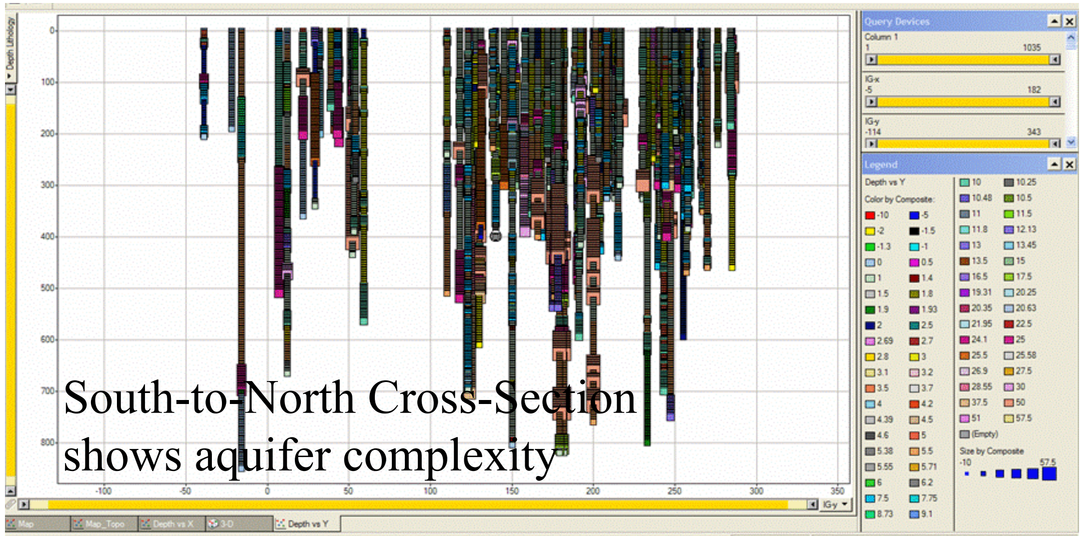

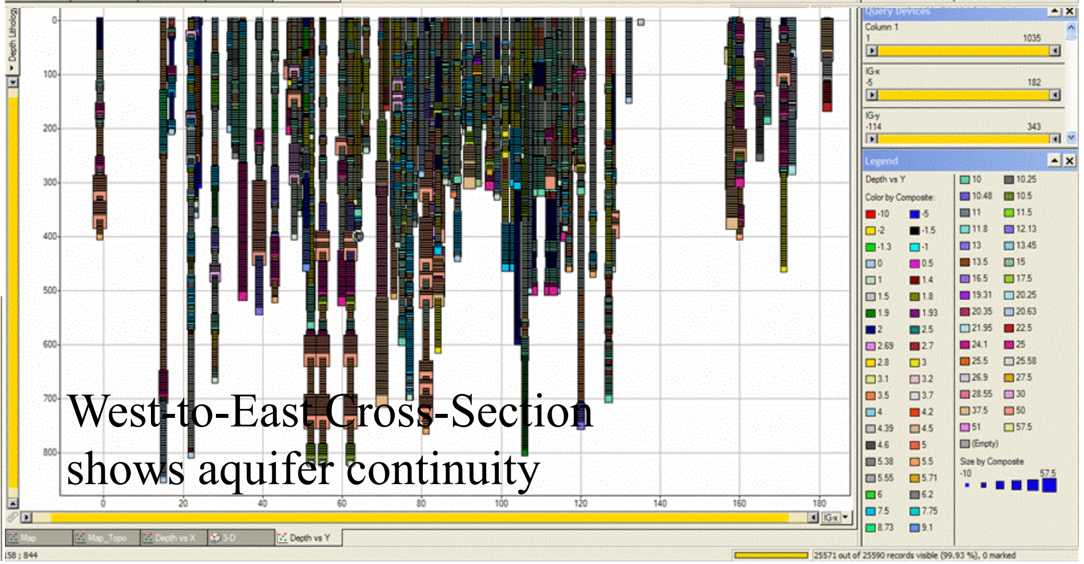

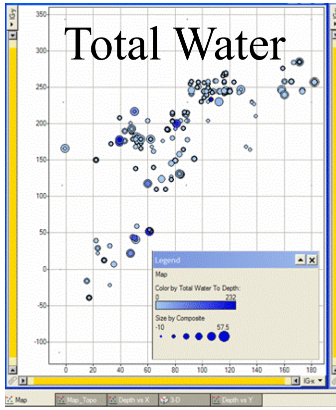

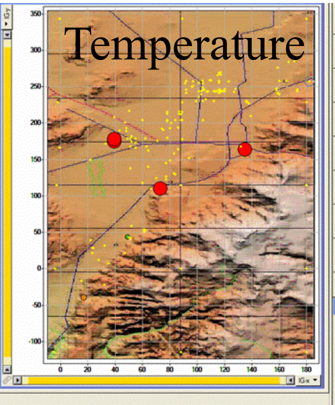

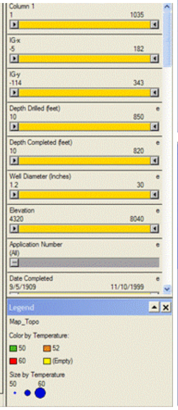

http://www.walden3d.com/IronCounty/CedarValleyWater/060423/index.html

Geologic map of the Panguitch 30' x 60' quadrangle, Garfield, Iron, and Kane Counties, Utah 63

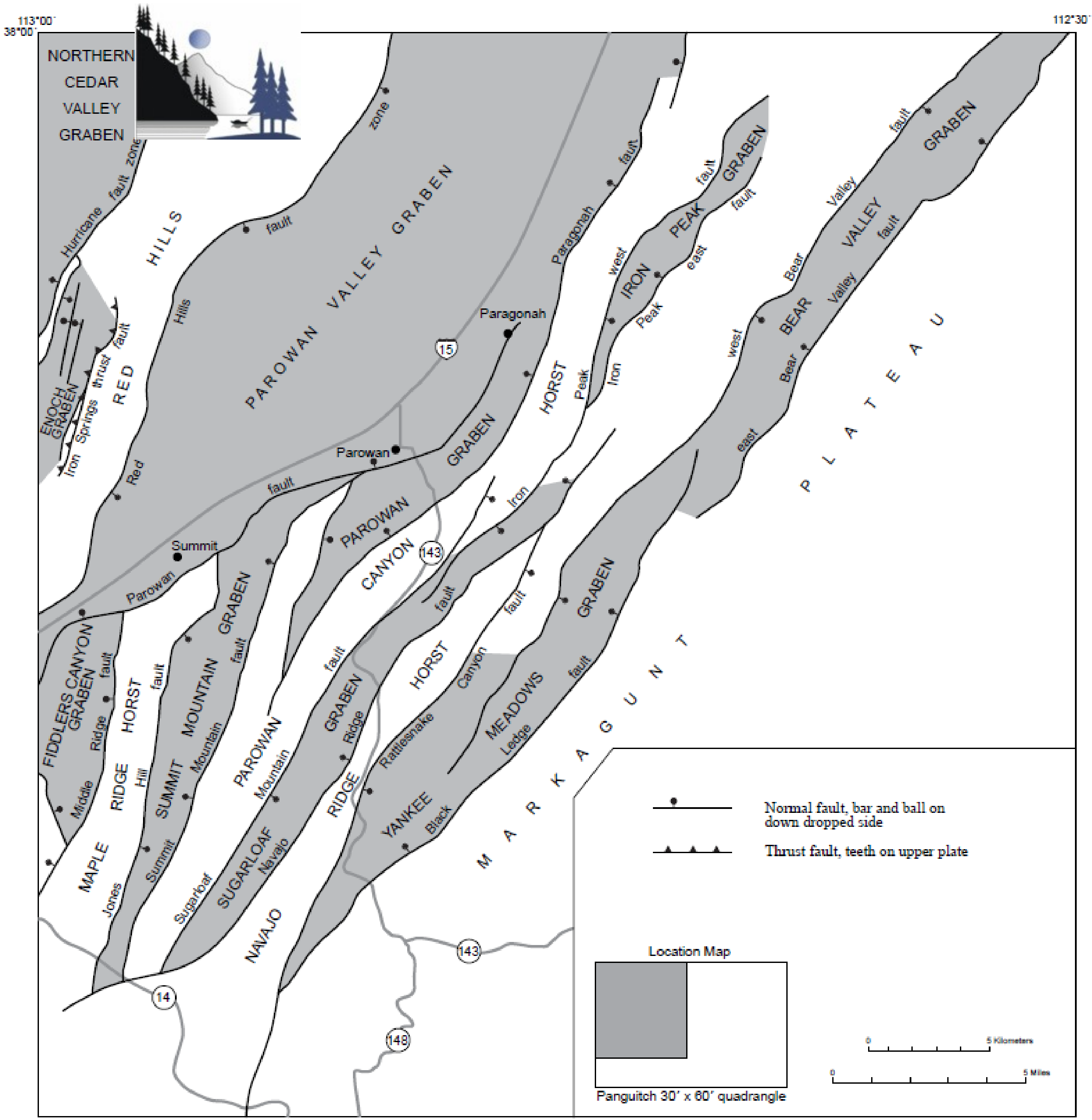

Figure 71. Major faults of the western Markagunt Plateau and Red Hills, and named grabens (shaded) and horsts. Modified after Maldonado and others (1997).

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Geology of the Parowan Valley Drainage Basin is Understood

- Horsts and Grabens associated with the formation of the Great Basin form the major structural framework geologically.
- Details can be added to this framework using geophysical tools like seismic, gravity, magnetics, Lightning Analysis and Passive Seismic.

Geologic Map Around Parowan

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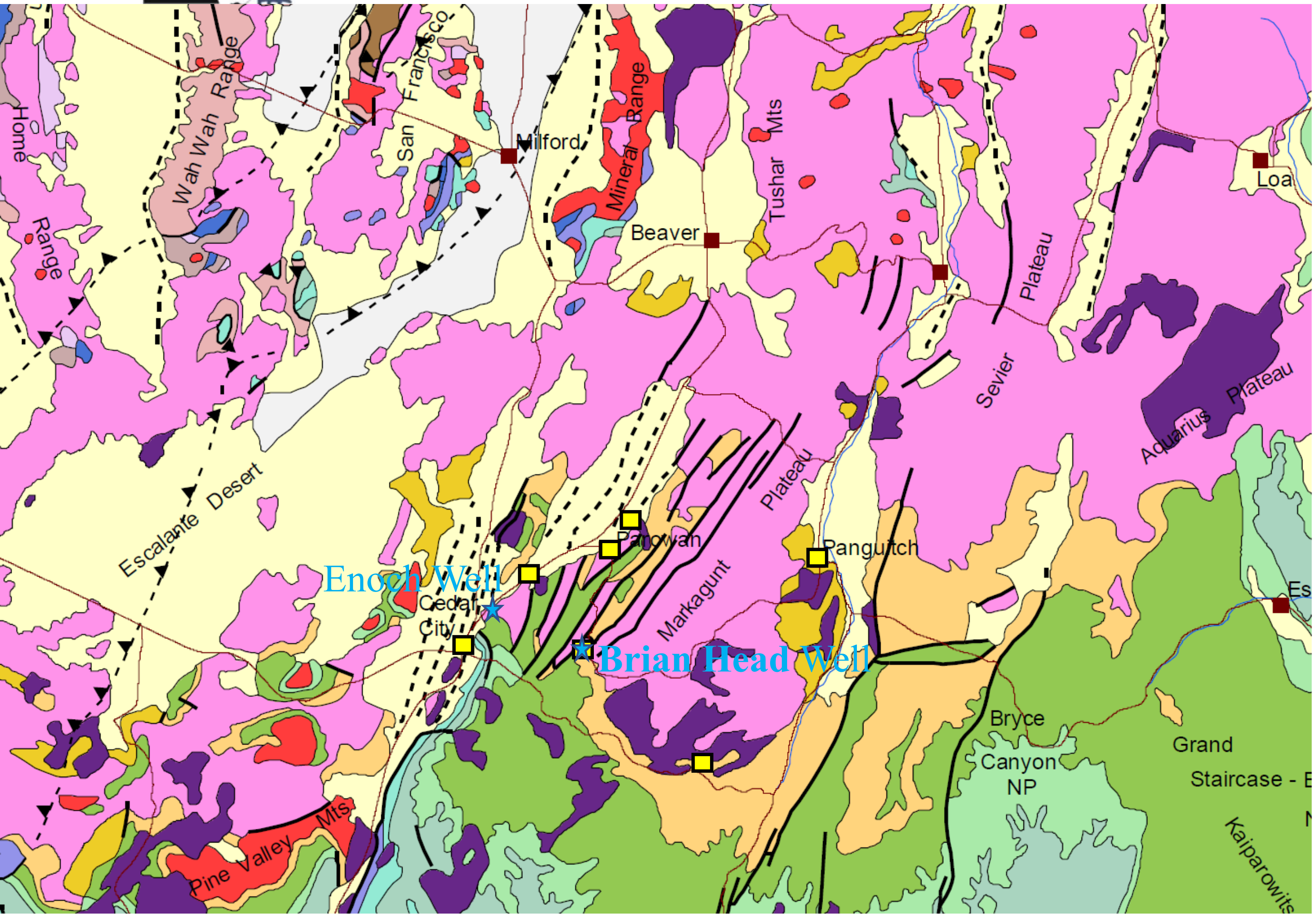
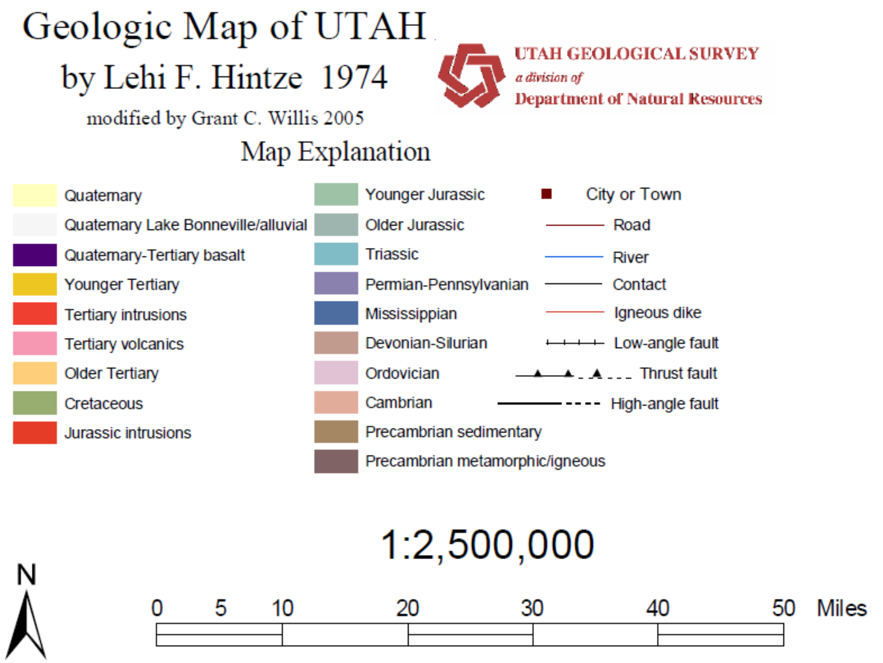
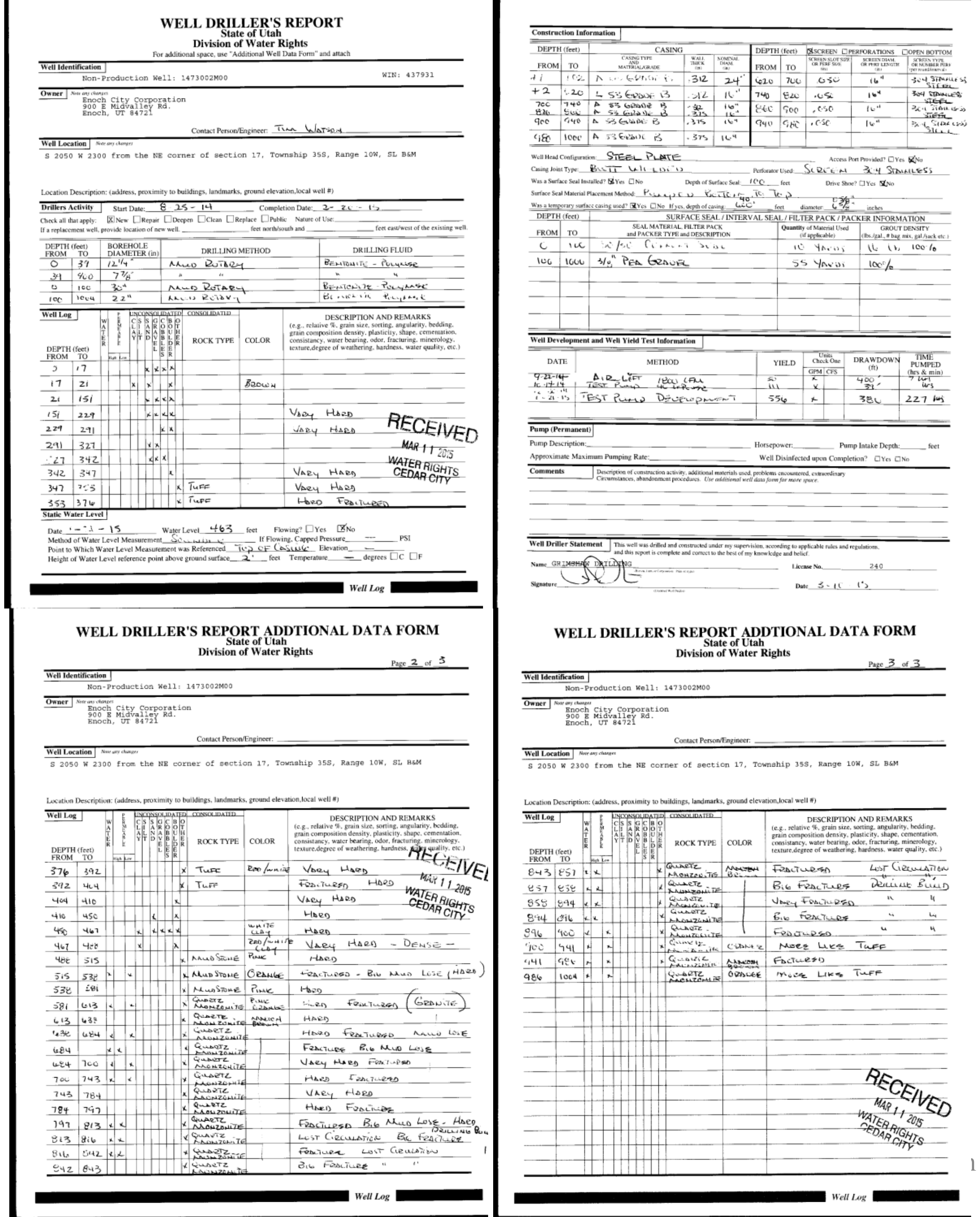




Parowan Valley, even more than Cedar Valley, is surrounded by untapped Bedrock Aquifers.



Enoch Well

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- Near the new Enoch water tank on the hill.
- Drilled between 25 August 2014 and 20 February 2015.
- Aquifer fractured Quartz Monzonite.
- Tertiary Geologic Age.
- Producing 800 gpm or 1,291 acre-feet.
- This well is particularly good news for Parowan because Parowan is surrounded by Quartz Monzonite.
- 6-9 new wells, producing at this rate, solves State Engineer over production issues.

Brian Head Well

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- Near the Town Center.
- Drilled between 12 May 2011 and 12 November 2012.
- Aquifer Claron Formation.
- Eocene Geologic Age.
- Producing 1,000 gpm or 1,614 acre-feet.
- This well is also good news for Parowan as there are a lot of these and Cretaceous Age Rocks north and east of the valley.
- 5-8 new wells, producing at this rate, solves State Engineer over production issues.

WELL DRILLER'S REPORT
State of Utah
Division of Water Rights

Well Identification: Change Appl... WIN: 434816
Owner: Town of Bri... P.O. Box 6... Brian Head
...VANCED ENVIRONMENTAL ENGINEERING ...E LORE 801-200-2638 801-773-3155
Well Location: S 568 E 2182 from t... ip 36S, Range 9W, SL B&M

Location Description: (address, proximity to buildings, landmarks, ground elevation,local well #)

Drillers Activity Start Date: May 12 - 2011 Completion Date: Nov. 01 - 12
Check all that apply: ☒New ☐Repair ☐Deepen ☐Clean ☐Replace ☐Public Nature of Use:
If a replacement well, provide location of new well. feet north/south and feet east/west of the existing well.

DEPTH (feet) FROM	TO	BOREHOLE DIAMETER (in)	DRILLING METHOD	DRILLING FLUID
0	6'	34"	ROTARY	
0	115	28"	MUD ROTARY	BENTONITE / POLYMER
115	750	23"	MUD ROTARY	BENTONITE / POLYMER
750	1502	14 3/4"	MUD ROTARY	BENTONITE / POLYMER

Well Log

DEPTH (feet) FROM	TO	ROCK TYPE	COLOR	DESCRIPTION AND REMARKS
0	5		BLACK	
5	15	LAVA ROCK	BLACK	YELLOW SAND
15	30			
30	65			
65	93	LAVA		VERY HARD FRACTURED
93	96		BLACK & WHITE	
96	112	LAVA	BLACK	HARD
112	129	LAVA	RED BROWN	VERY HARD
129	135		"	CLAY IS TAN ORANGE
135	146		"	" ORANGE

Static Water Level
Date 11-28-11 Water Level 137 feet Flowing? ☐Yes ☒No
Method of Water Level Measurement CABLE If Flowing, Capped Pressure PSI
Point to Which Water Level Measurement was Referenced TOP OF CASING Elevation
Height of Water Level reference point above ground surface 2' feet Temperature 41° degrees ☐C ☒F

Well Log

WELL DRILLER'S REPORT ADDTIONAL DATA FORM
State of Utah
Division of Water Rights
Page 2 of 3

Well Identification: Change Application: a37313 (75-661)
Owner: Town of Brian Head, P.O. Box 65, Brian Head UT 84719
Contact Person/Engineer:
Well Location: S 568 E 2182 from the W4 corner of section 02, Township 36S, Range 9W, SL B&M
Location Description: (address, proximity to buildings, landmarks, ground elevation,local well #)

Well Log

DEPTH (feet) FROM	TO	ROCK TYPE	COLOR	DESCRIPTION AND REMARKS
146	148		ORANGE	
148	174	LAVA RED BROWN	CLAY ORANGE	ISOM FORMATION
174	179	LAVA	RED BROWN & BLK	
179	193	LAVA	BLACK RED BROWN	VERY HARD
193	227	LAVA & QUARTZ	"	" "
227	393	LAVA	"	" "
393	489	LAVA	BLACK	MED HARD
489	509	LAVA	RED BLACK	VERY HARD
509	547	LAVA	BLACK	
547	551	LAVA	BLACK	HARD FRACTURED
551	582	LAVA	BLACK	VERY HARD FRACTURED
582	596	LAVA	RED BROWN	HARD
596	609	LAVA	RED	
609	699	LAVA	RED, BROWN & BLACK	HARD
699	788	LAVA	" "	HARD BRITTLE
788	790	LAVA	RED, BROWN & BLACK SOME WHITE	BIG FRACTURE
790	857	MUDSTONE	WHITE, TAN	CLARON FORMATION
857	879	MUDSTONE	WHITE	HARDER
879	886	MUDSTONE	RED	
886	927	MUDSTONE	WHITE	
927	931	MUDSTONE	WHITE	HARDER FRACTURED

Well Log

Construction Information

DEPTH (feet) FROM	TO	CASING TYPE AND MATERIAL/GRADE	WALL THICK (in)	NOMINAL DIAM. (in)	DEPTH (feet) FROM	TO	SCREEN SLOT SIZE OR PERF SIZE (in)	SCREEN DIAM. OR PERF LENGTH (in)	SCREEN TYPE OR NUMBER PERF
0	6'	A53 GRADE B	.375	30	520	600	.030	14"	304 STAINLESS STEEL
0	115	A53 GRADE B	.312	24"	705	745	.050	16"	304 STAINLESS STEEL
42	520	A53 GRADE B	.312	16"	735 / 745 / 805 / 1200 / 1470	745 / 805 / 1200 / 1430 / 1480	BLANK / .030 / BLANK / .030 / BLANK	8 5/8"	304 STAINLESS STEEL SCREEN / 304 STAINLESS STEEL
600	705	A53 GRADE B	.312	16"					
0	175	A53 GRADE B	.250	4 1/2"					
0	518	A53 GRADE B	.250	2 3/8"					

Well Head Configuration: STEEL PLATE Access Port Provided? ☒Yes ☐No
Casing Joint Type: BUTT WELD Perforator Used: STAINLESS STEEL 304
Was a Surface Seal Installed? ☒Yes ☐No Depth of Surface Seal: 115 feet Drive Shoe? ☐Yes ☒No
Surface Seal Material Placement Method: PUMPED 50/50 TO BOTTOM BACK TO SURFACE
Was a temporary surface casing used? ☒Yes ☐No If yes, depth of casing: 6" feet diameter: 30 inches THIS CASING WAS REMOVED 2012

SURFACE SEAL / INTERVAL SEAL / FILTER PACK / PACKER INFORMATION

DEPTH (feet) FROM	TO	SEAL MATERIAL, FILTER PACK and PACKER TYPE and DESCRIPTION	Quantity of Material Used (if applicable)	GROUT DENSITY (lbs./gal., # bag mix, gal./sack etc.)
0	6	CEMENT & BENTONITE HOLE PLUG	36 CUBIC FEET	
0	115	50/50 SAND CEMENT	11 CUBIC YARDS	18.40 lbs
560	750	3/8 ROUND PEA GRAVEL	45 CUBIC YARDS	
740	1476	12-20 SILICA SAND	16 CUBIC YARDS	
95	113	3/8 BENTONITE HOLE PLUG	13 CUBIC FEET	

PLACED IN HEAVY BENTONITE DRILLING FLUID - OUT SIDE UP INTO 24" CASING

Well Development and Well Yield Test Information

DATE	METHOD	YIELD	GPM	CFS	DRAWDOWN (ft)	TIME PUMPED (hrs & min)
Sept. 00. 11	AIR DEVELOPMENT	600	x		380	46 hrs
10-19 to 10-22-11	TEST PUMP	1163	x		326	184 hrs
10-18 to 20-12	WELL DEVELOPMENT	825	x		304.40	45.25

Pump (Permanent)
Pump Description: Horsepower: Pump Intake Depth: feet
Approximate Maximum Pumping Rate: Well Disinfected upon Completion? ☐Yes ☐No

Comments: Description of construction activity, additional materials used, problems encountered, extraordinary Circumstances, abandonment procedures. Use additional well data form for more space.
PEA GRAVEL WAS EXTRACTED FROM SURFACE TO 560 FEET. THE SCREEN WAS COLLAPSED FROM 524' TO 540' SCREEN SIZE DISTORTED OR UNDERSIZED FROM 540 TO 560' SCREEN WAS SWAGED FROM 522 TO 542' AND 304 STEEL PATCHES WERE PLACED FROM 518.7' TO 527.5 THE SWAGE TOOL WAS UNABLE TO GO BELOW 541'6 3/4". INSTALLED TEST PUMP TO 495' TEST RESULTS WERE SAME AS TEST PUMP 304

Well Driller Statement: This well was drilled and constructed under my supervision, according to applicable rules and regulations, and this report is complete and correct to the best of my knowledge and belief.
Name GRIMSHAW DRILLING License No. 240
Signature Date Nov. 14 - 2012

WELL DRILLER'S REPORT ADDTIONAL DATA FORM
State of Utah
Division of Water Rights
Page 3 of 3

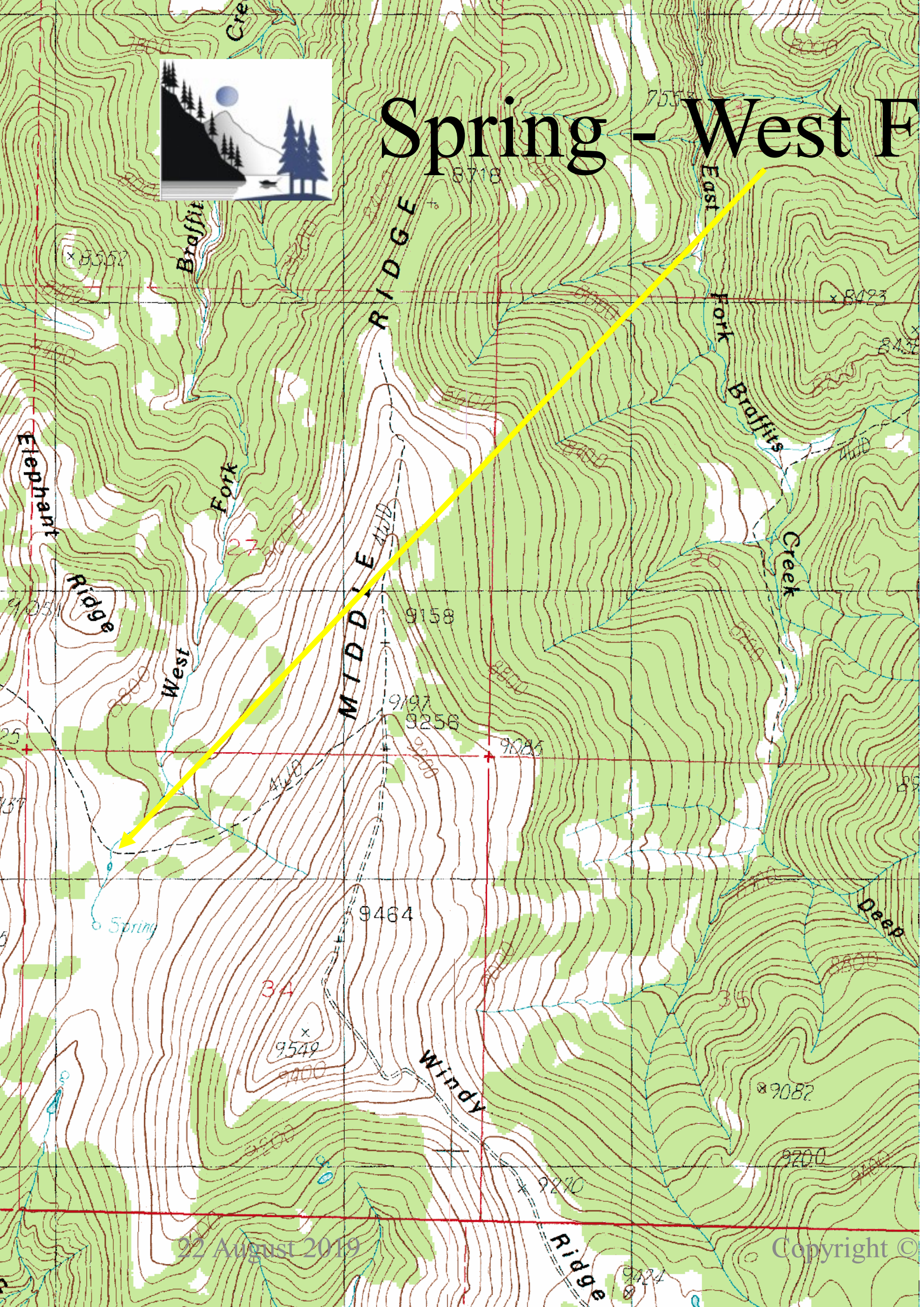
Well Identification: Change Application: a37313 (75-661)
Owner: Town of Brian Head, P.O. Box 65, Brian Head UT 84719
Contact Person/Engineer:
Well Location: S 568 E 2182 from the W4 corner of section 02, Township 36S, Range 9W, SL B&M
Location Description: (address, proximity to buildings, landmarks, ground elevation,local well #)

Well Log

DEPTH (feet) FROM	TO	ROCK TYPE	COLOR	DESCRIPTION AND REMARKS
		MUDSTONE	WHITE	CLARON FORMATION
931	1206	MUDSTONE	ORANGE	FRACTURED BROKEN HARD
1206	1210	MUDSTONE	YELLOW, WHITE & GRAY	FRACTURED
1210	1246	MUDSTONE	ORANGE	FRACTURED HARD
1246	1263	MUDSTONE	ORANGE	VERY HARD FRACTURED
1263	1294	MUDSTONE	ORANGE	HARD
1294	1302	MUDSTONE	ORANGE	HARD FRACTURED BIG FLUID LOSE
1302	1308	MUDSTONE	ORANGE	
1308	1314	MUDSTONE	ORANGE	FRACTURED BIG FLUID LOSE
1314	1322	CONGLOMERATE	WHITE TAN	FRACTURED (GRADED CASTLE FORMATION)
1322	1330	CONGLOMERATE	"	" "
1330	1333	CONGLOMERATE	"	" FRACTURED
1333	1338	CONGLOMERATE	"	"
1338	1354	CONGLOMERATE	"	" FRACTURED
1354	1440	CONGLOMERATE	"	"
1440	1480	CONGLOMERATE	"	"
1480	1502	MUDSTONE	ORANGE RED	CLARON FORMATION

Well Log

Spring - West Fork Braffits Creek

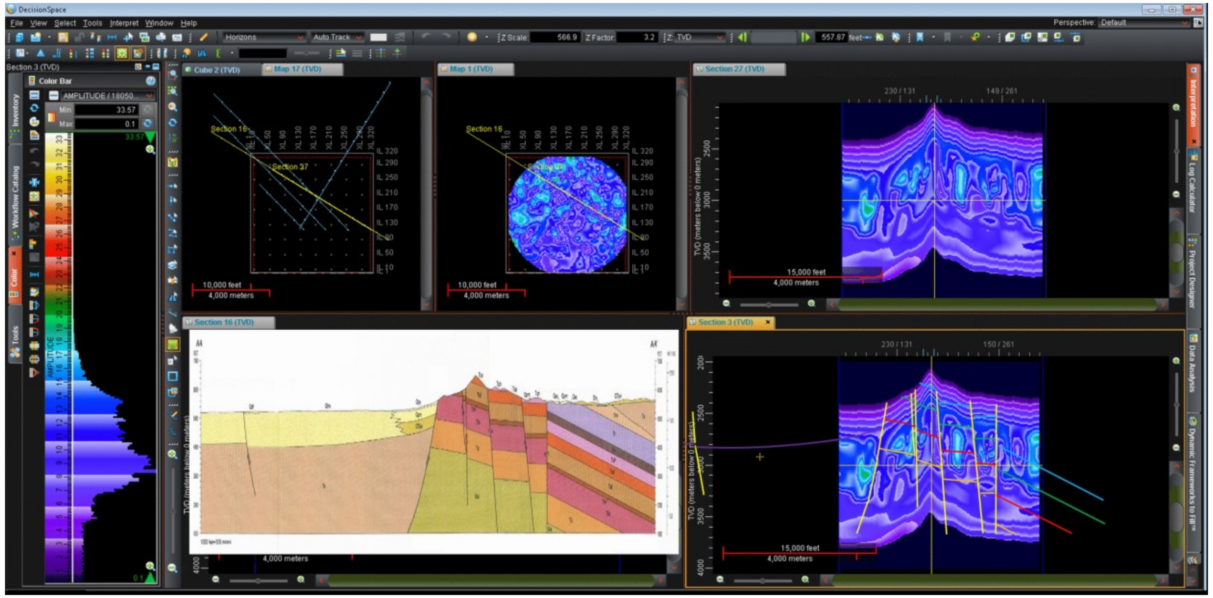


Why are there springs on the top of mountains surrounding Parowan Valley?

Spring just south of Summit Mountain to the south of Parowan Valley, as shown on the previous map.

Seeing Underground

https://www.waterrights.utah.gov/meetinfo/m20181211/20181211-parowan_slides.pptx , Slide 38.



Geophysicists have many tools used to "see underground," including:

Discipline	Technique	Source	Receiver	Power	Remote
Potential Fields	Gravity	Passive	Required	High	Some
Potential Fields	Magnetics	Passive	Required	High	Yes
Electrical Methods	D.C. Resistivity	Required	Required	Low	No
Electrical Methods	Electrical Resistivity Tomography (ERT)	Required	Required	Low	No
Electrical Methods	Induced Polarization (IP)	Required	Required	Low	No
Electrical Methods	Time-Domain IP	Required	Required	Low	No
Electrical Methods	Magnetotellurics (MT)	Passive	Required	Low	No
Electrical Methods	Audio-Frequency MT (AMT)	Passive	Required	Low	No
Electrical Methods	Controlled Source Electromagnetics (CSEM)	Required	Required	Medium	No
Electrical Methods	Transient Electromagnetic Time-Domain EM (TEM)	Required	Required	Low	No
Electrical Methods	Controlled Source Audio Magnetotelluric (CSAMT) techniques	Required	Required	Low	No
Electrical Methods	Frequency-Domain EM Induction	Required	Required	Low	No
Electrical Methods	AquaTrack (leak detection at dams, mines, etc.)	Required	Required	Low	No
Electrical Methods	Borehole Techniques like Self-Potential (SP)	Passive	Required	Low	No
Electrical Methods	Ground Penetrating Radar (GPR)	Required	Required	Low	No
Electrical Methods	Very Low Frequency Methods (VLF)	Required	Required	Medium	No
Electrical Methods	High-Frequency Techniques (radar, etc.)	Required	Required	Low	No
Electrical Methods	Airborne Electromagnetic Systems	Required	Required	Low	No
Electrical Methods	Tipper	Passive	Required	Low	Some
ElectroSeis	ElectroSeis	Passive	Required	Low	No
Seismic	Micro-Seismic	Required	Required	Low	No
Seismic	Earthquake Seismology	Passive	Required	High	Yes
Seismic	Refraction Seismic	Required	Required	Medium	No
Seismic	Reflection Seismic	Required	Required	Medium	No
Satellite	Spatial, Spectral, Temporal, & Geometric Resolution	Passive	Database	Low	Yes
Satellite	Radiometric Resolution: Thermal, Reflectance, Elevation	Passive	Database	Low	Yes
Lightning	National Lightning Detection Network (NLDN)	Passive	Database	High	Yes
Lightning	Global Lightning Database (GLD-360)	Passive	Database	High	Yes

Gary Farnsworth Player Vita

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GENERAL STATEMENT
Gary F. Player is a geologist and manager with fifty years of experience in the application of the earth sciences to problems in exploration, engineering, and the environment. Married to Corrie Lynne Player, he is the father of nine grown children and forty grandchildren. Mr. Player speaks Spanish.

EDUCATION
B.S. Geology, Stanford University, 1964; M.A. Geology, UCLA, 1966

EXPLORATION SUCCESS
He has explored successfully for mineral fuels: Player has helped find more than five billion tons of coal in central Alaska, one trillion cubic feet of natural gas in Cook Inlet Basin, Alaska, and 20 billion barrels of heavy oil on the North Slope of Alaska. He recently discovered oil and gas in a frontier basin in northern California. Player has discovered significant quantities of excellent quality ground water in Utah, California, and Arizona.

GEOLOGICAL EXPLORATION SKILLS
Mr. Player has mastered the following techniques: geophysical well log analysis on mainframe and personal computers, surface and subsurface mapping, sedimentary petrology and petrography, sample and core description, reflection and refraction seismology, sandstone geometry, basin analysis, structural geology, aquifer and reservoir hydrology, drilling supervision, photo geology, computerized data bases, porosity and permeability evaluation from geophysical logs, field, and laboratory measurements, stratigraphy and regional correlation, plate tectonics, petroleum geochemistry, etc..

ENGINEERING GEOLOGY SKILLS
Player has practical experience in project management, resolution of conflicts between agencies and individuals, pipeline route surveys, municipal and industrial waste disposal, subdivision design, groundwater hydrology, active fault studies, field mapping, nuclear power plant safety analysis, drilling, hydraulic fracturing, reflection and refraction seismology, seismicity, environmental impact reports, dam site investigations, foundation engineering, slope stability, soils classification, permafrost description, glaciology, marine geology and open-pit mining.

ENVIRONMENTAL GEOLOGY SKILLS
Gary F. Player supervised multi-company teams of biologists, engineers and geologists monitoring construction of the Trans-Alaska Pipeline System as a consultant to the U.S. Department of the Interior. He later provided environmental inspection services for the 36" diameter Kern River Gas Transportation System in southwestern Utah. As Research Analyst at the University of Alaska's Arctic Environmental Information Data Center he joined interdisciplinary teams of scientists studying northwestern and Arctic Alaska for State and Local government agencies. As a project manager he has written and edited environmental assessments and reports for offshore oil platforms, industrial plant sites, power plants, municipal water systems, arid design landfills, power lines, and proposed pipelines.

GEOGRAPHICAL DIVERSITY OF EXPERIENCE
Gary F. Player has worked throughout the continental United States and Alaska as an explorationist and engineering geologist. He has conducted field investigations in Alaska, Arizona, California, Nevada, Oregon, Utah, Idaho, Wyoming, Texas, Oklahoma, Alabama, Florida, Pennsylvania, Arkansas, Minnesota, Wisconsin, New Jersey, Delaware, Maryland, and Illinois. He also supervised a soils investigation in Puerto Ordaz, Venezuela. Mr. Player has studied the geology of dry lake desert basins, pull-apart basins, rifted continental margins, fore-arc basins, cratonic depressions and glaciated terrains. He identified surface and groundwater resources developed by the Municipality of Anchorage. Player has studied the geology and hydrology of Utah, Idaho, Wyoming and eastern Nevada to aid in the design and permitting of new sanitary landfills. He has discovered large resources of high quality ground water in desert basins and mountains of southern Utah. In California he has studied Los Angeles, San Joaquin, Sacramento, Ventura, Antelope Valley, Owens Valley, Surprise Valley and Honey Lake basins.

Since 1983 Gary F. Player has operated independent consulting firms offering services in engineering geology, water resources, waste management, public education, conflict resolution, seismology, oil and gas exploration, and mining geology. He directs all phases of projects, including client contacts, proposal preparation, cost analysis, technical work and billing.

PUBLICATIONS
Most of Gary F. Player's written and oral presentations have been to proprietary audiences of employers and clients. Significant contributions have been made in the fields of surface and groundwater exploration and development, regional and local fault patterns, alternative landfill designs for arid climates, energy minerals exploration, and methane dissolved in ground water.

Published papers include the following:
Tryck, Nyman and Hayes; Dames and Moore (G. F. Player, Project Geologist); and Leeds, Hill, Jewett, 1973, Anchorage Water Resources, for Anchorage Water Utility and Central Alaska Utilities, 307 p., 258 references. Selkregg, L., Whiteman, K., Wilson, W.J., Aho, M., and Player, G. F., 1976. Northwest Alaska Community Profiles: A Background for Planning. University of Alaska Arctic Environmental Information Data Center, Anchorage, 8 maps with descriptive folios. Wilson, W. J., Buck, Eugene H., Player, G. F., and Dreyer, L. D., 1977, Winter Water Availability and Use Conflicts as Related to Fish and Wildlife in Arctic Alaska: A Synthesis of Information. University of Alaska Arctic Environmental Information Data Center, Anchorage, 252 p. Player, G. F., 1983, Petrology of the Munson Creek Phosphorite Deposit, Ventura Basin, California. Geological Society of America, Cordilleran Section Meeting, (Abstract). Player, G. F., 2007, Economic Production of Sand Bed Methane from Ground Water, American Association of Petroleum Geologists, 2007 Annual Meeting, Long Beach, California Player, G. F., and McDonald, Blair, 2010, Indications of Glaciation in Southwestern Utah and Adjacent States, Pacific Section GSA, Anaheim, California, Poster Session.

PROFESSIONAL REGISTRATIONS
American Association of Petroleum Geologists Number 31523-5
Professional Geologist in Utah, Arizona, Idaho, and California (not active).

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Gary Player <dirtdoctor43@gmail.com>

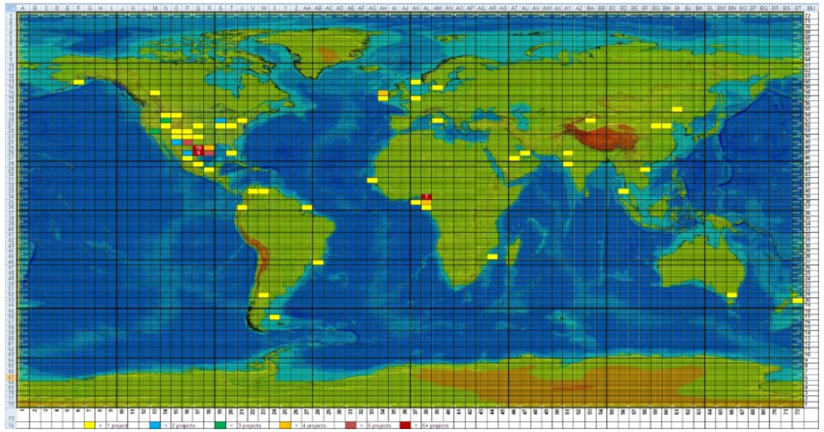
H. Roice Nelson, Jr. Vita

GENERAL STATEMENT

Roice is an experienced interpretation geoscientist who has spent his career working in the international petroleum industry. As a seismic interpreter he has worked over 100 interpretation projects worldwide. Roice has proven success in using, creating, and building new tools and processes for the hydrocarbon exploration industry. In 2008 Roice selected 6 professionals to join with him as co-founders of Dynamic Measurement, LLC (DML), and they have spent the last 10 years laying the groundwork for a new branch in the geophysical service industry: lightning analysis.

As the initial founder of Landmark Graphics, Roice designed the interpretation software, and created a university program which placed advanced interactive interpretation systems in many universities worldwide to support research and teaching. He taught courses on interactive interpretation and new technologies for Landmark and for IHRDC all over the world. He also has a consulting company (W3D) and an exploration company (DRC) to utilize industry and proprietary tools and processes to explore for, develop, and produce natural resources: hydrocarbons, geothermal energy, minerals, etc.

The map below shows locations of many of the exploration projects Roice has worked on since 1970.



W3D Infinite Grid^{SM} Spatial Resume showing Roice's interpretation project locations.

ROICE NELSON CHRONOLOGY

Dynamic Measurement LLC, Co-Founder / Manager, Oct 2008-Present
DML established to exploit using lightning data as an on-shore and shelf NSEM (Natural Sourced Electromagnetic Method) exploration tool and to create a new branch in the geophysical services industry.

Dynamic Resources Corporation, Finder / President, Jan 2001-Present
Generate and drill or mine prospects and commercialize new technologies.

Walden 3-D, Inc., Finder / President, May 1990-Present
W3D established as a new company incubator, doing geotechnical consulting and mini-urban design. Primary companies started include DML, DRC, Walden Visualization Systems, vPatch, Advanced Structures Incorporated, HyperMedia Corporation. Completed major seismic interpretation projects on 5 continents, and developed several unique information technologies including The Infinite Grid^{SM}, The Knowledge Backbone^{SM}, and the Abbott Atlas.

Geophysical Development Corporation (GDC), Vice-President Interpretation Business Development, April 2004- Sep 2007
Opened GDC China market, and helped build an integrated interpretation business. Interpretation for Ji Dong (3700 B/D, largest find in China in 10 years), Tarim (130 BCM, 3rd largest gas field in Xinjiang), Da Qing, Xing Jiang, and Tuha Chinese Oilfields. Created GDC's Tiles^{TM} Studies.

Continuum Resources Intern'l Corp., Co-Founder, Sep 1997-Aug 2000
Demonstrated real-time simultaneous virtual reality collaboration with terabyte databases in London England, Perth Australia, and Houston.

HyperMedia Corporation, Jan 1991-2007, Co-Founder
Designed, built, and produced a UNIX, X-Windows, Motif, Client-Server hypertext engine, sold, and installed site-license to Saudi Aramco.

Landmark Graphics Corporation, Nov 1982-Sep 1992, Co-Founder
Designed user interface of first stand-alone seismic interpretation workstation software, only exploration geophysicist, worked with customers all over the world, established and ran Landmark's University Program.

University of Houston's Allied Geophysical Labs (AGL) & Seismic Acoustics Lab (SAL), Jan 1980-Nov 1982, Founder, General Manager
Managed physical modeling facility at SAL, created 4 new labs.

Mobil Oil Corporation, Jul 1974-Jan 1980, Geophysicist
Seismic interpretation, processing, and acquisition geophysicist.

Amoco Corporation/Pan American Corporation, Summers 1973 & 1970
Summer Intern and Assistant Geophysicist in Denver

EDUCATION

1981, MBA (Master's Business Administration) Southern Methodist Univ.
1974, B.S. Geophysics, University of Utah

OTHER

- Published 220+ technical papers since 1973, including the book New Technologies in Exploration Geophysics in English and Chinese. Details available on request, lightning papers can be reviewed at http://www.dynamicmeasurement.com/TAMU.
- Co-Organized 9 SEG Research Workshops, including Remote Sensing Workshop at the Anaheim, California Convention, Friday, 19 Oct 2018.
- Honorary Membership GSH (Geophysical Society of Houston).
- Enterprise Award SEG (Society of Exploration Geophysicists).
- Key Professional Societies: AAPG, EAGE, GSH, HGS, and SEG.

PROFESSIONAL REGISTRATIONS

American Association of Petroleum Geologists Number 476651
Texas Professional Geoscientist #5120
Louisiana Professional Geoscientist #879 (not active).

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