ABSTRACT

As Uinta Basin petroleum production increases – natural gas production increased 189% in the past 10 years, while oil production increased 159% – so has saline water production, increasing the need for economic and environmentally responsible disposal plans. Current water disposal wells are near capacity and permitting for new wells is delayed because of insufficient technical data regarding potential disposal aquifers and questions concerning contamination of fresh water sources. Many Uinta Basin operators claim that petroleum production cannot reach its full potential until a suitable, long-term water disposal solution is determined. The presented research evaluates the potential of the Birds Nest aquifer, formed from the dissolution of saline minerals in the Eocene upper Green River Formation, as a potential large-scale saline water disposal zone.

Evaluation of geophysical logs from over 300 wells, together with 21 core descriptions, 5 measured sections, and creation of 5 regional stratigraphic cross sections were used to map the spatial and vertical extent of the upper and lower Birds Nest aquifer zones that demonstrate potential for large-scale saline water disposal. As ancient Lake Uinta began to recede, its waters became hypersaline, depositing large saline nodules and thin saline mineral beds within a 30 to 110 foot thick interval of dolomitic mudstone, forming the more extensive, ~500 square mile, lower Birds Nest zone. An influx of fresh water, represented by volcaniclastic debris flows recorded in rocks on the east side of the basin (Horsebench Sandstone), decreased the lake's salinity for a period of time, greatly reducing saline mineral deposition. However, as the lake continued to shrink, it once again returned to its hypersaline state, depositing large saline nodules in a less extensive, ~360 square mile and 30-110 foot thick, upper Birds Nest zone, centered farther to the west than the lower zone.

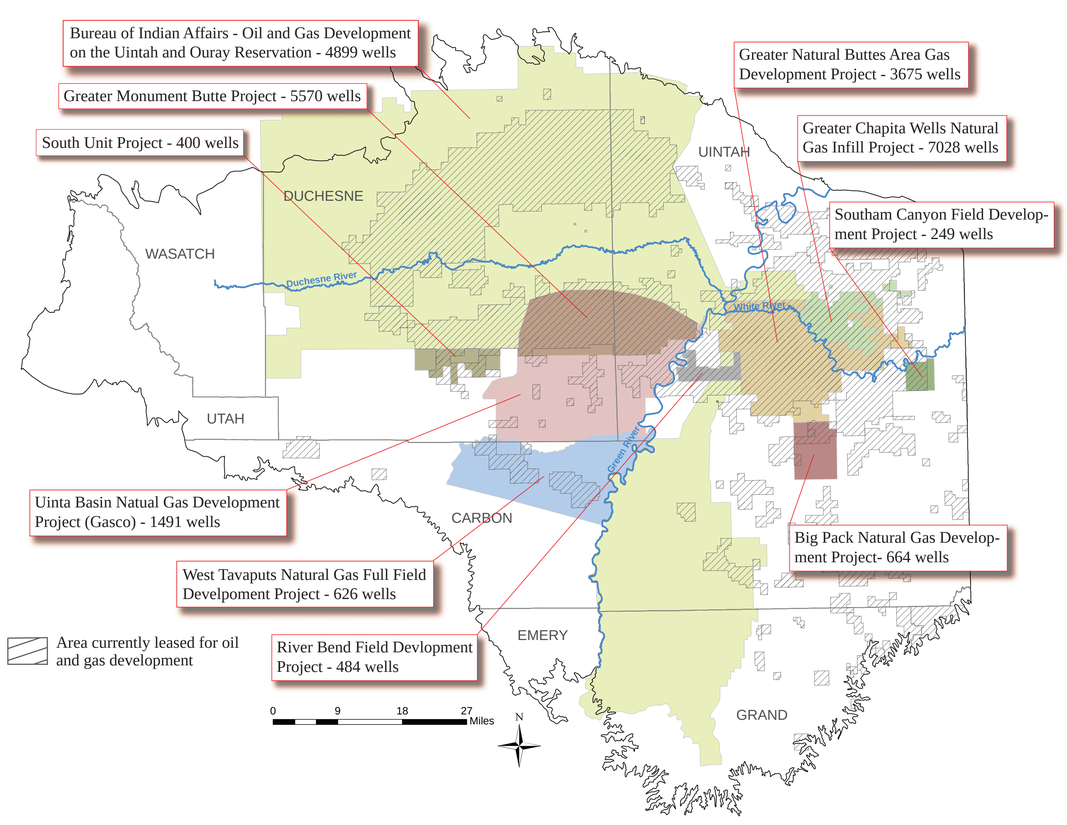
Several other limiting factors will play a role in determining potentially safe saline water disposal volumes into the Birds Nest aquifer, including: 1) chemistry of water currently in the Birds Nest zone –saline water disposal can only occur in an aquifer with water greater than 10,000 mg/L TDS, 2) saline mineral dissolution – only areas with significant saline mineral dissolution can transmit and store saline water, 3) transmission of water via fractures or gilsonite veins, and 4) proximity to potentially developable oil shale resources.

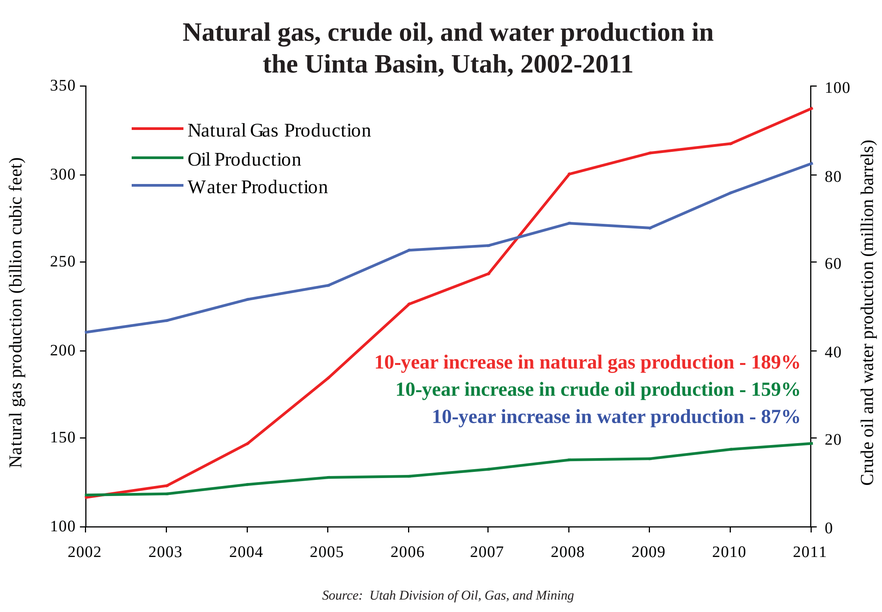
PROBLEM

A lack of saline water disposal options is a significant limiting factor with regard to increases in oil and gas production in the Uinta Basin, Utah.

- Saline water from oil and gas wells can only be injected into aquifers containing water that is >10,000 mg/L TDS salinity.
  - Protection of "freshwater" (0-10,000 mg/L TDS) is a priority
- Current disposal wells are at or near capacity.
- Evaporation ponds cannot handle the increase in saline water and pose several environmental challenges.
  - Brine concentration
  - Potential for contaminating shallow groundwater
  - Wildlife hazard
  - Potential for increased ozone and VOC emissions
- Re-using water is an option, but treatment is expensive.
- Quality groundwater data is lacking, delaying approval of disposal permits.
  - Original reference map is 25 years old
  - >8000 wells have been drilled since 1987

Eastern Uinta Basin natural gas producers have identified the Birds Nest aquifer, located in the Parachute Creek Member of the Green River Formation, as the most promising reservoir suitable for large-volume saline water disposal. However, the Birds Nest aquifer is poorly understood and needs further study to determine potential impacts of using this aquifer as a saline water disposal zone.





Source: Utah Division of Oil, Gas, and Mining

More than 25,000 oil and gas wells are currently proposed for drilling in the Uinta Basin

This future drilling will greatly increase the amount of produced water needing proper disposal

- West Tavaputs Natural Gas Full Field Development Project - 626 new wells - approved
- Uinta Basin Natural Gas Development Project (Gasco) - 1491 new wells - proposed, draft EIS
- Greater Natural Buttes Area Gas Development Project - 3675 new wells - proposed, draft EIS
- South Unit Oil and Gas Development Project - 400 new wells - proposed, draft EIS
- Greater Chapita Wells Natural Gas Infill Project - 7028 new wells - proposed, EIS in process
- Greater Monument Butte Project - 5570 new wells - proposed, EIS in process
- Bureau of Indian Affairs - 4899 new wells - proposed, EIS in process
- River Bend Field Development Project - 484 new wells - proposed, EA in process
- Big Pack Natural Gas Development Project - 664 new wells - proposed, EA in process
- Southam Canyon Field Development Project - 249 new wells - proposed, EA in process

Source: U.S. Bureau of Land Management

RESEARCH / DELIVERABLES

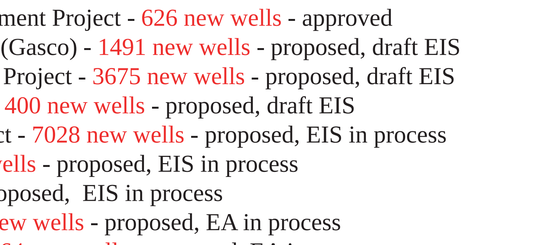
- Comprehensive literature review and historic data collection
  - Very limited data, 38 historical references (many only briefly mention the Birds Nest)
- Water chemistry database
  - 208 analyses from 161 different wells
- Well information database - aquifer tops, formation tops, etc.
  - 322 oil/gas and oil shale wells examined
- 21 detailed core desciptions
  - 22 wells were identified as having all or part of the Birds Nest captured in core (the DP core was not examined because of its close proximity to the examined X-13 core)
- 4 measured outcrop sections
  - Good outcrop exposures can be found on the southeastern side of the basin
  - Qualitative observations were made at several additional field locations
- 5 detailed regional cross sections
- Determination of how disposal into the Birds Nest could affect future oil shale development
- Determination of how gilsonite veins might influence groundwater flow and saline mineral dissolution
- Creation of several GIS-based maps
  - Outcrop
  - Thickness (upper and lower Birds Nest)
  - Overburden
  - Lateral extent
  - Water quality (mapping of the 10,000 mg/L TDS boundary)
  - Interburden between Birds Nest and "economic" oil shale zones

THE BIRDS NEST AQUIFER

Not Your Typical Aquifer

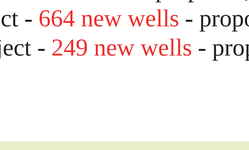
During deposition of the upper Green River Formation in the late Eocene, Utah's Lake Uinta transitioned from a balanced-filled basin dominated by organic-rich, laminated marlstone, to an underfilled restricted basin. During this time, the saline mineral nahcolite ($NaHCO_3$) formed within the deep-lake sediments (depocenter in central Uintah County) as isolated crystals, nodules ranging up to one foot in diameter, and beds ranging from less than an inch to 2 feet thick. Post-deposition, the saline mineral shortite ($Na_2Ca_2(CO_3)_3$) was deposited in fracture zones several feet thick. More recently, the Birds Nest aquifer formed from the dissolution of these saline minerals and subsequent host-rock fracturing.

Macro-Porosity - Dissolution of Large Saline Nodules



Origin of the Birds Nest aquifer name, mud swallow nests in nahcolite cavities.

The Birds Nest aquifer in outcrop along Evacuation Creek, eastern Uinta Basin, Utah. The cavities were created by the dissolution of nahcolite nodules.

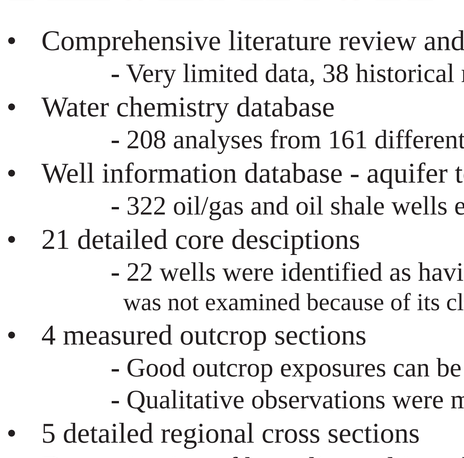


Dissolved nahcolite nodule in the P-4 core (354 ft).

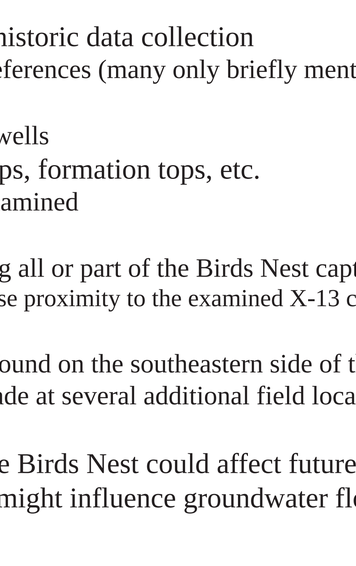
Dissolved nahcolite nodule in the 13X-2 core (1528 ft).

Intact nahcolite nodule in the Utah State 1 core (1825 ft).

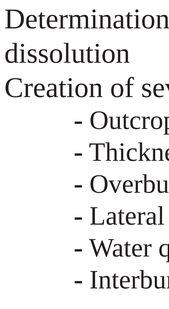
Dissolution of Saline Mineral Fracture Fill



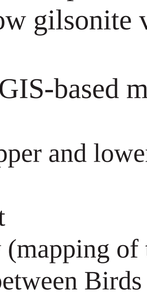
Saline mineral fracture fill near Bitter Creek.



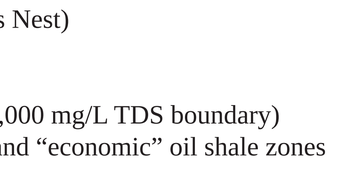
Saline mineral fracture fill near Long Draw.



Dissolved saline mineral fracture fill in the X-13 core (671 ft).

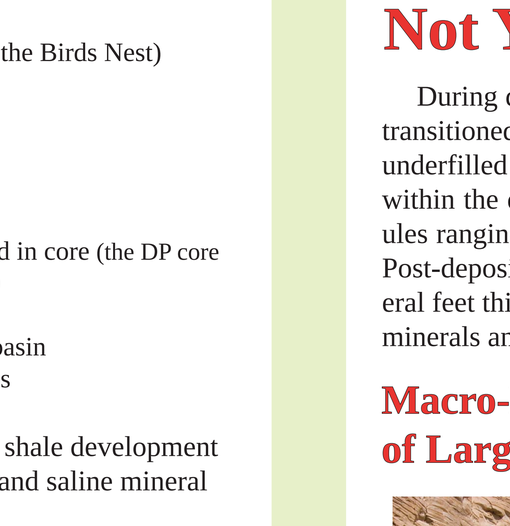


Dissolved saline mineral fracture fill in the P-4 core (365 ft).



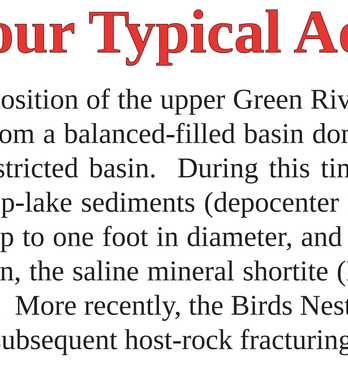
Intact saline mineral fracture fill in the 13X-2 core (1580 ft).

Permeability - Extensive Fracturing

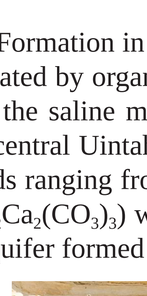


Extensive high-angle fracturing within the Birds Nest aquifer near Evacuation Creek, eastern Uinta Basin, Utah.

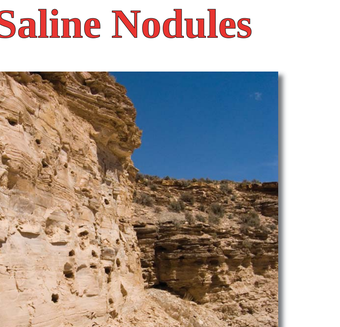
High-angle fracture in the 42-34 core (1815 ft).



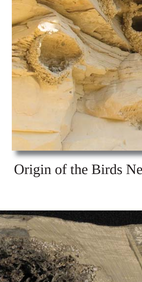
High-angle fractures associated with dissolved saline nodules, near Watson, Utah.



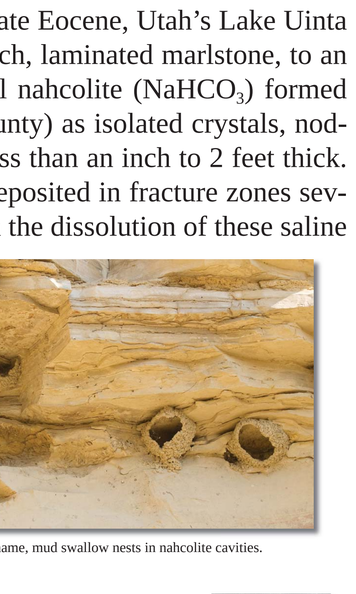
High-angle fracture in the P-1 core (420 ft).



Vertical fractures associated with a dewatering structure near Long Draw.



Near-vertical fracture in the X-13 core (710 ft).



The Birds Nest aquifer in the 42-34 core (1648-1671 ft). The slips of paper (red circles) represent 0.5-1.0 foot gaps in the core created from the dissolution of nahcolite nodules.