EERC | UND UNIVERSITY OF NORTH DAKOTA

Critical Challenges. Practical Solutions.

Energy & Environmental Research Center (EERC)

CHARACTERIZATION OF SALT FORMATIONS FOR NGL STORAGE

North Dakota Industrial Commission

January 27, 2021

Jim Sorensen

Director of Subsurface R&D

INTRODUCTION

- *ND salt formations have been investigated for potential construction of caverns to be used for storing NGLs.*
- *NGLs stored in salt caverns supports the petrochemical and energy industries.*

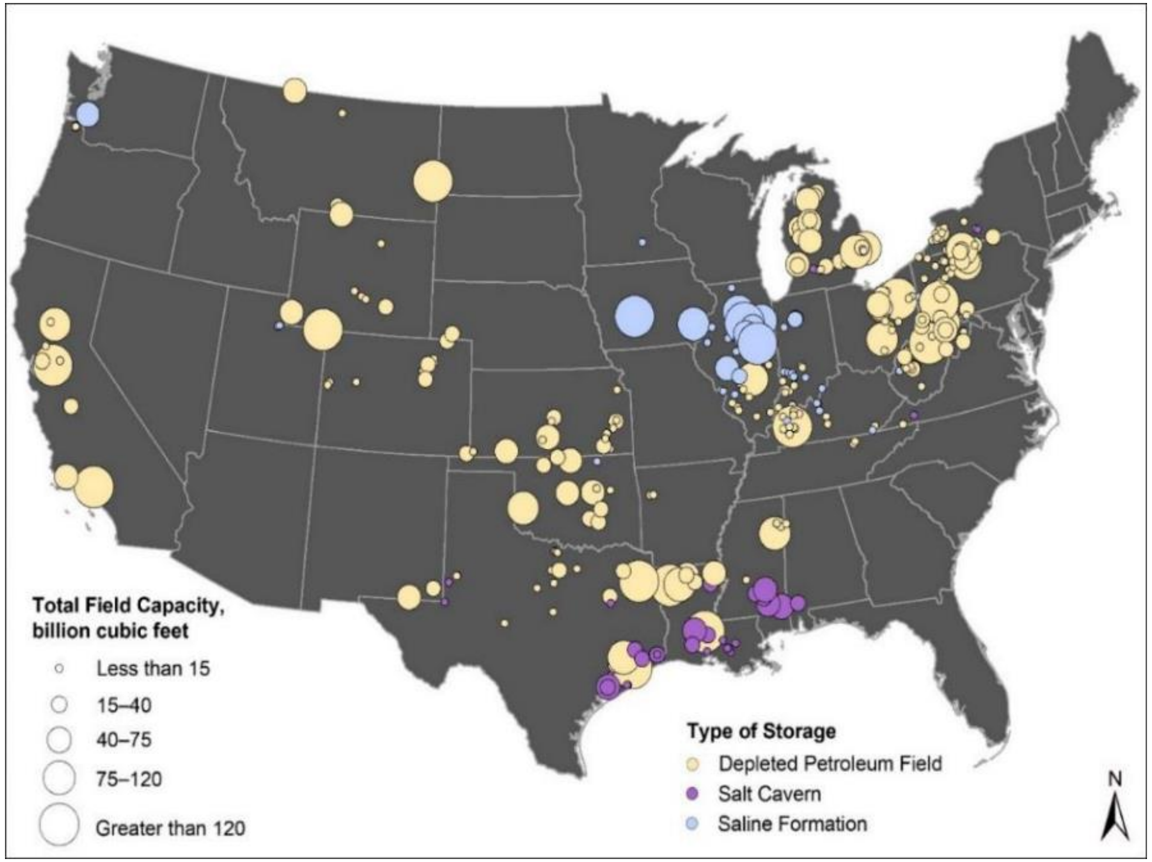
The objectives of this study are to:

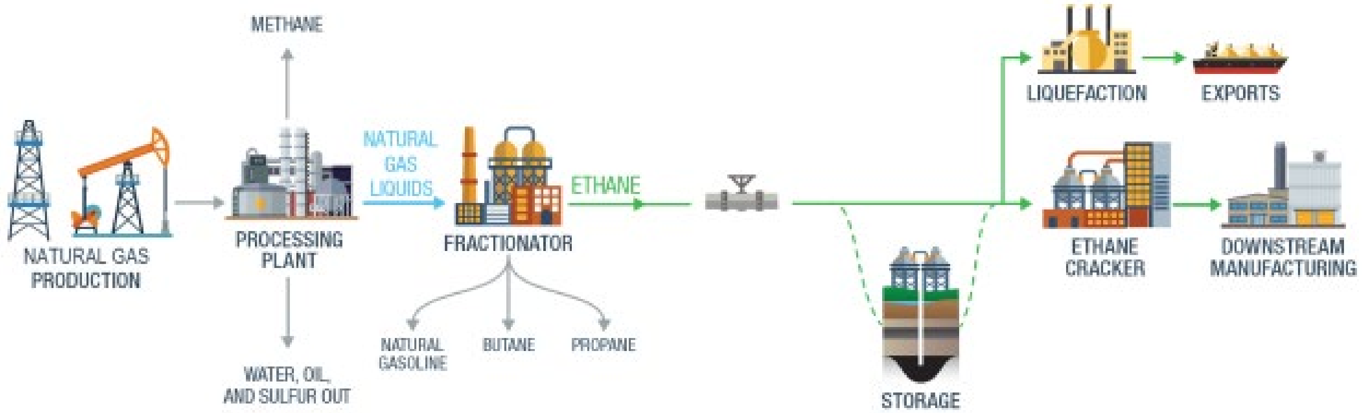
- Identify a regional extent within western North Dakota where infrastructure and required resources are colocated with salt formations that may be suitable candidates for construction of hydrocarbon storage caverns.
- Describe the methods used to construct salt caverns and operate them for hydrocarbon storage.
- Estimate the size of caverns that could be constructed in North Dakota salts, and assess stability, given realistic cavern dimensions, by conducting limited geomechanical simulations.
- Develop estimated costs for selected key surface equipment components of a salt cavern storage facility.
- Identify key regulatory considerations that may affect the development of a salt cavern storage project in North Dakota.

GAS STORAGE

- Gas storage is a proven technology that began in 1915.
- Typically, gas storage is used to supplement energy demands associated with seasonal heating needs.
- Over 300 gas storage locations in the United States are active.
- Salt caverns are an integrated element in the petrochemical process.
- NGL hubs are coincident with oil- and gas-producing regions or areas where export capability exists.

Energy Information Administration, 2020a



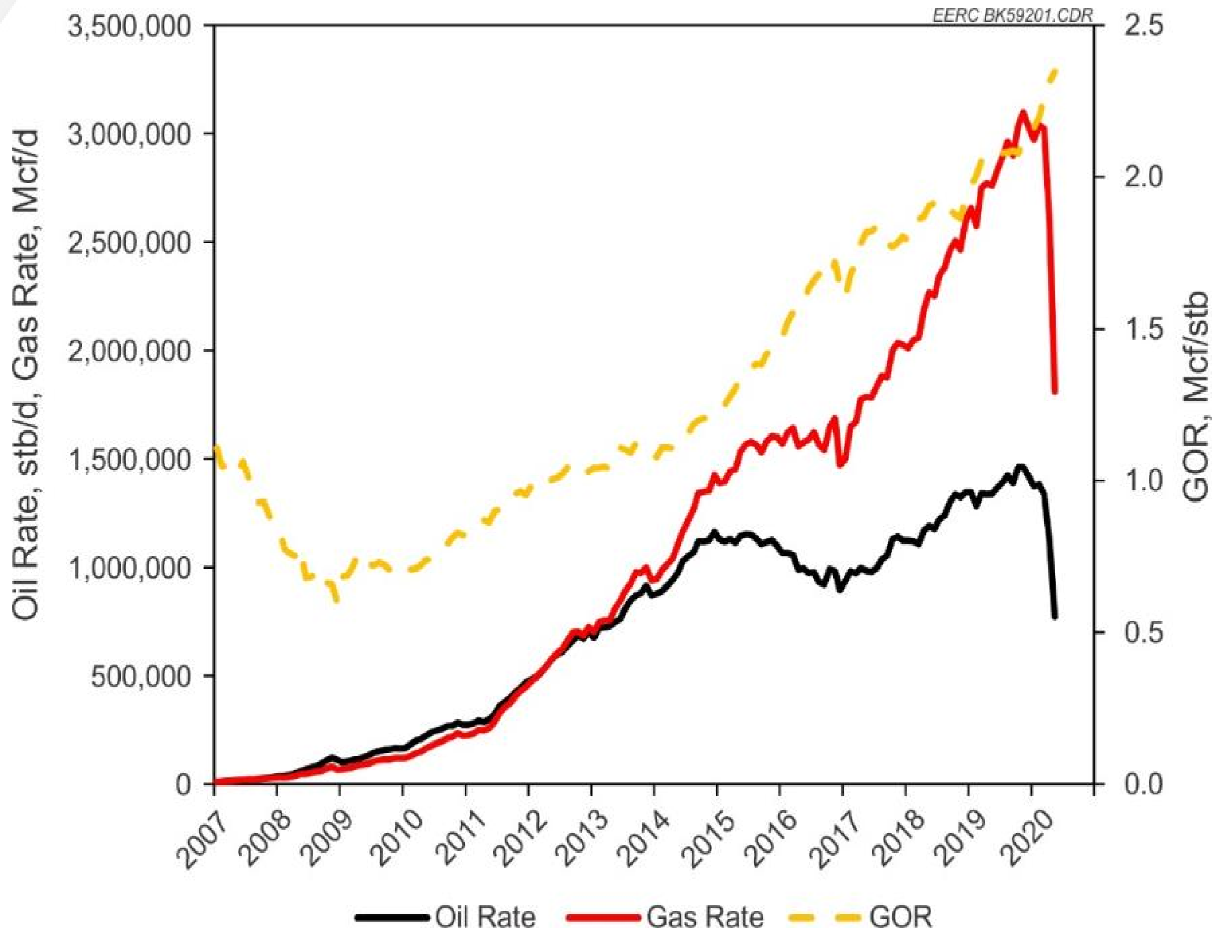


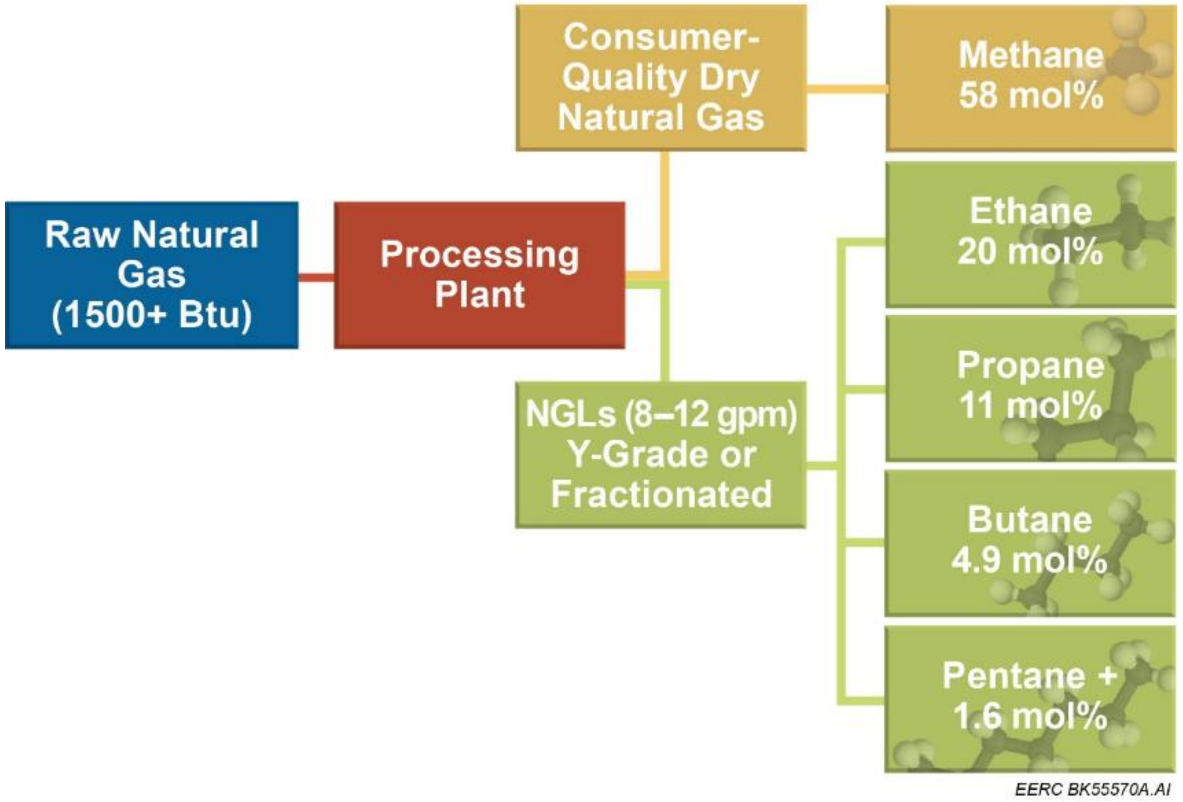
U.S. Department of Energy, 2018

ND GAS PRODUCTION

With continued increases in oil production, the gas-to-oil ratio (GOR) is expected to follow a similar trend.

NGLs are present in as much as 35% of processed gas in ND. Ethane accounts for 20% of these NGLs.



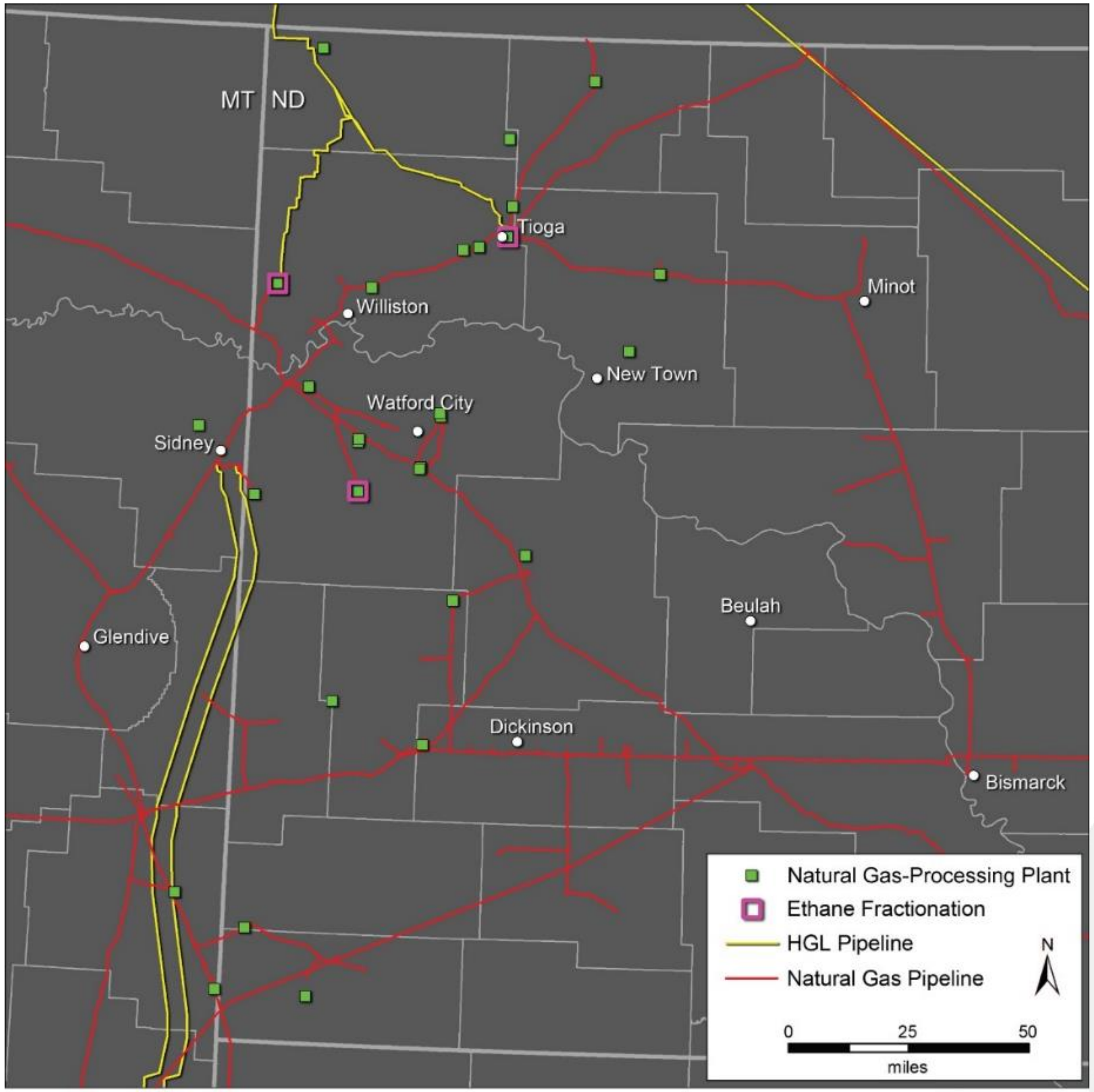


ND GAS PROCESSING AND PIPELINES

- Increasing oil/gas production in ND has resulted in significant investment in gas transportation infrastructure.

- Ethane and HGLs are captured at three processing plants.

- HGL pipelines deliver product to Canadian and U.S. markets.

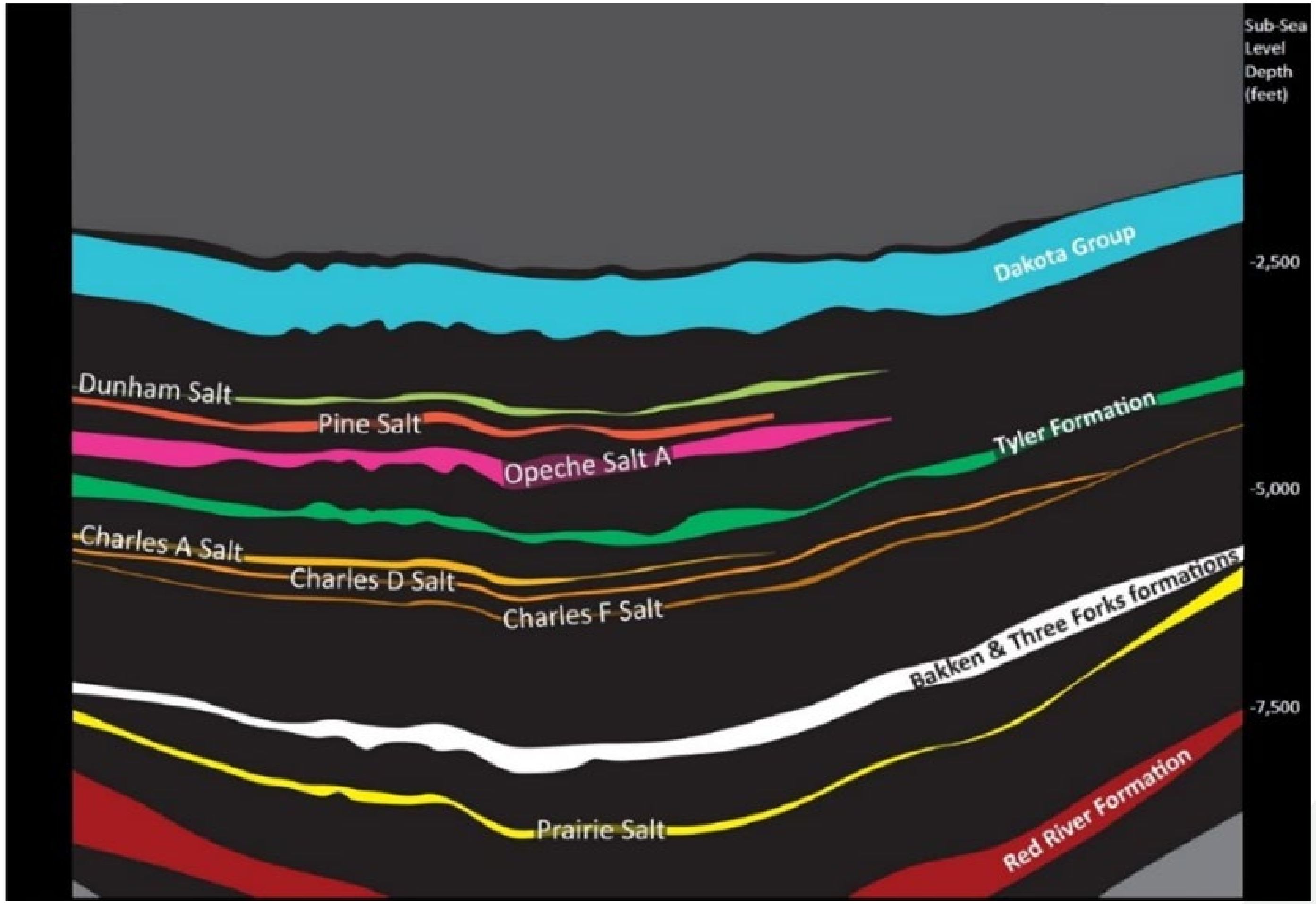


EERC SS59850.AI

GEOLOGICAL REVIEW

- ND geological formations were investigated to identify salt formations with potential for cavern development.
- Critical success criteria include thickness, depth (temperature <180°F), and extent.
- Formations in the study with depths of less than 6500 feet were considered “likely” candidates.
- Screening included proximity to gas supply, water resources, railroads, and water disposal.

ND SALT FORMATIONS



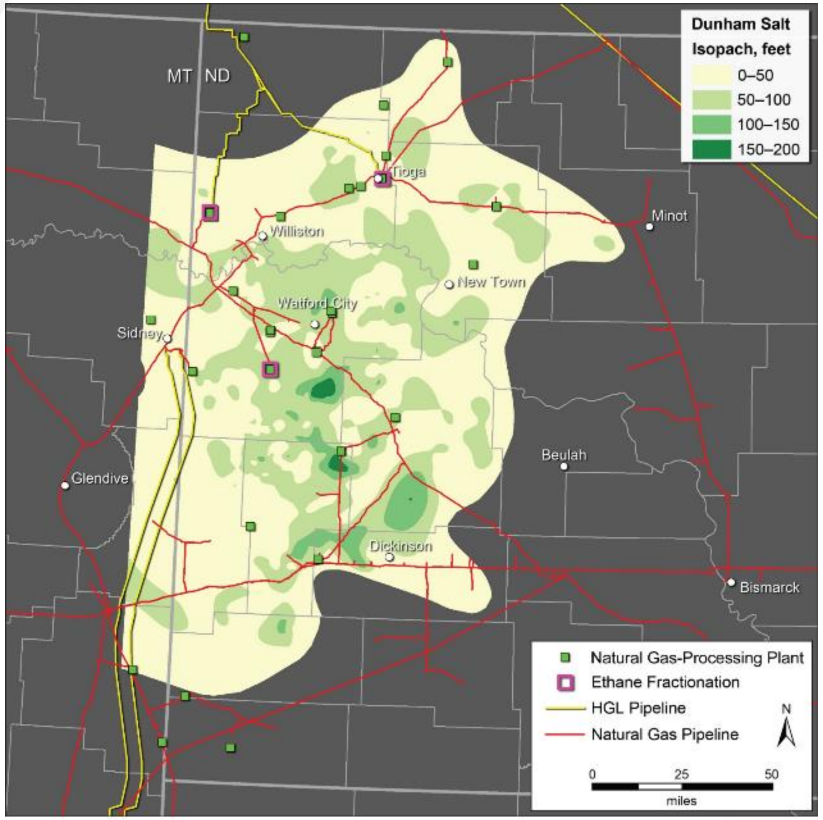
(extracted and modified from Nesheim and LeFever, 2009).

GEOLOGICAL REVIEW

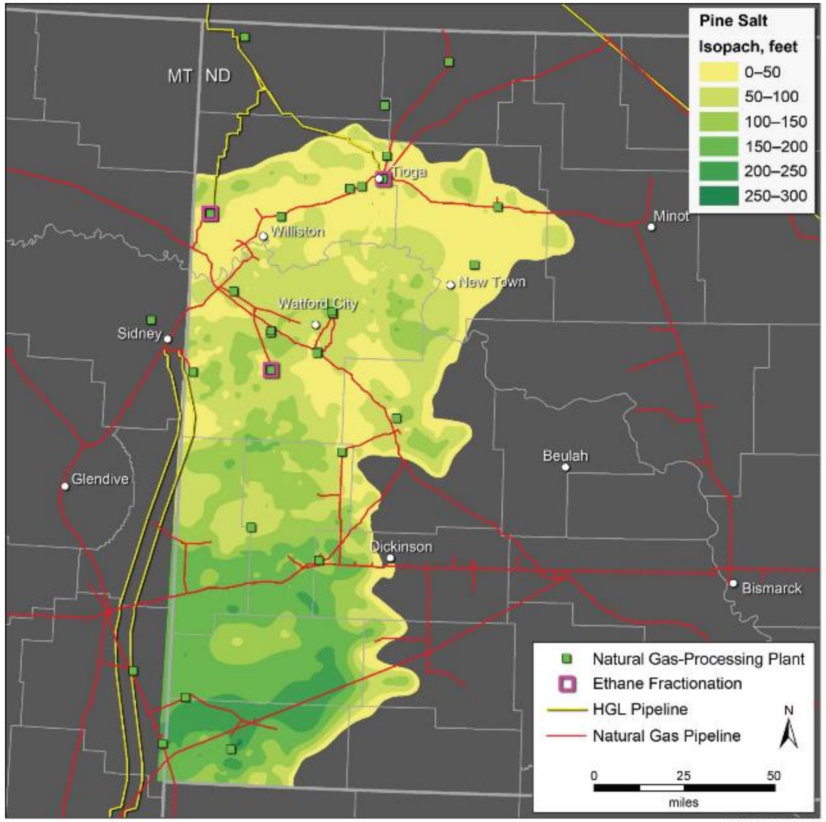
Candidate Salts

- Dunham Salt – thickness <200 ft max., depth <6800 ft
- Pine Salt – thickness <300 ft max., depth <7200 ft
- Opeche A Salt thickness <250 ft max., depth <7400 ft

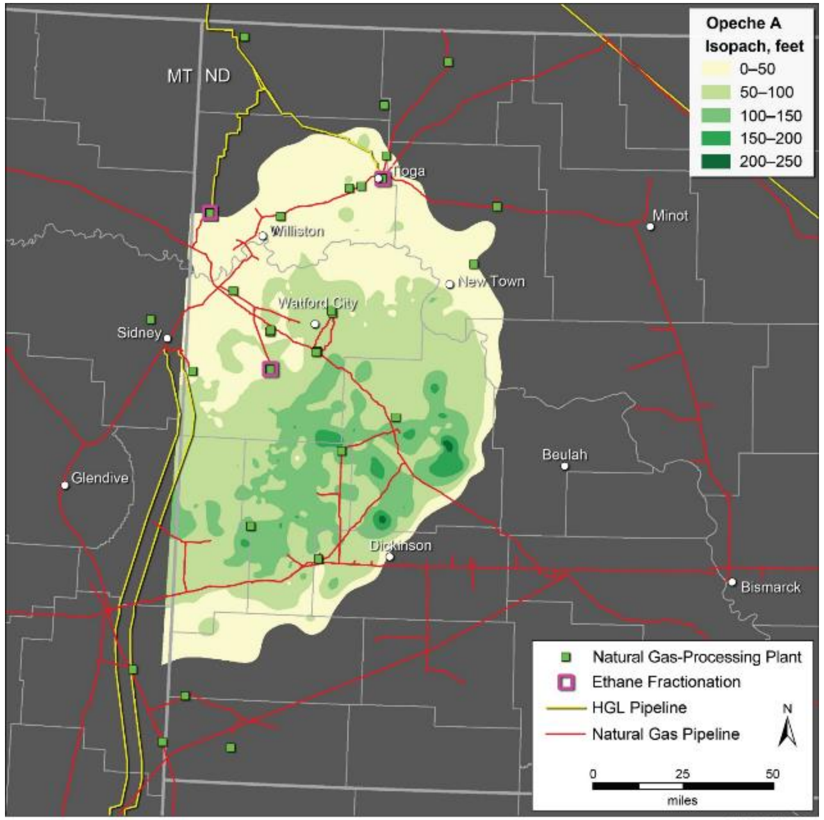
Images show extent, thickness, and proximity to regional infrastructure.



EERC SS59851.AI



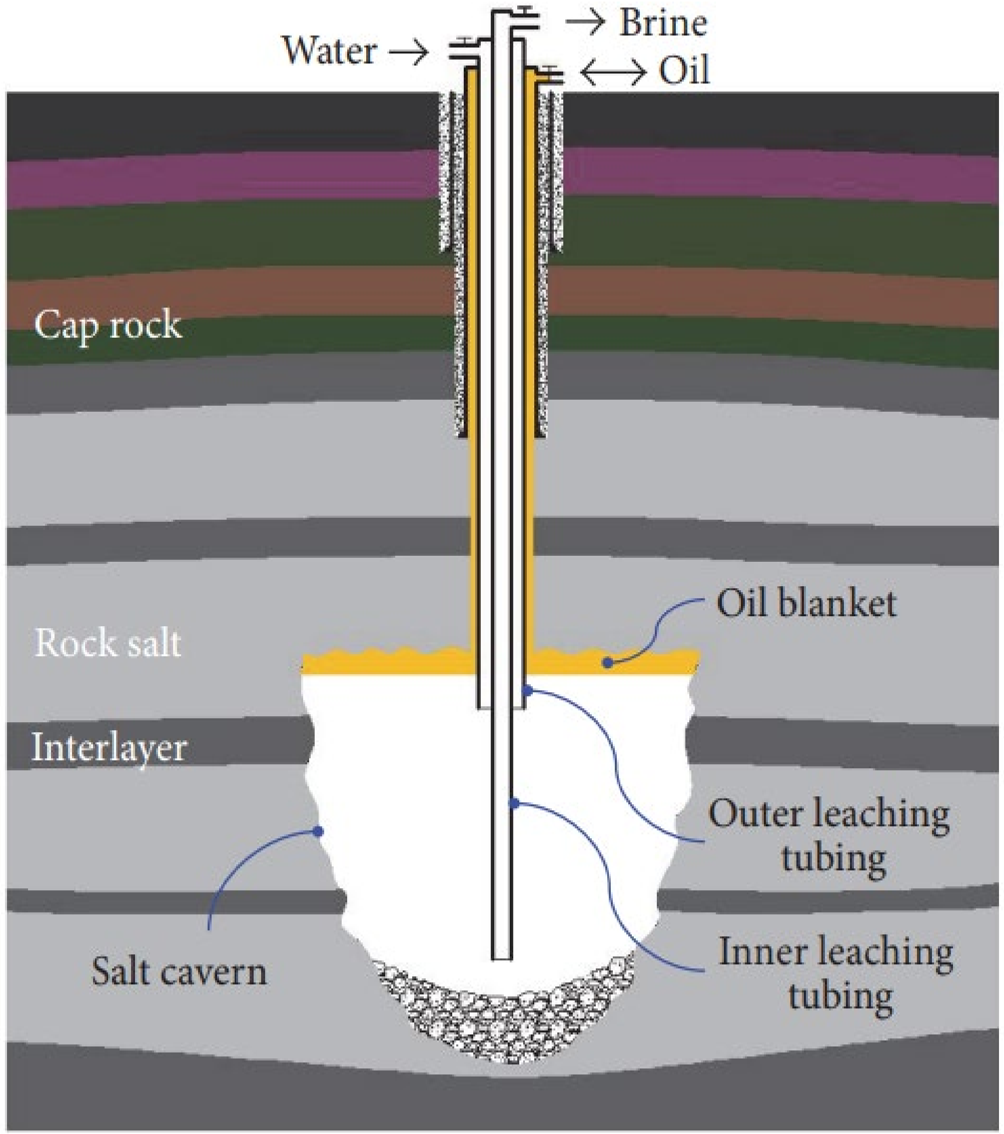
EERC SS59852.AI



EERC SS59853.AI

CAVERN DEVELOPMENT/OPERATION

- Caverns are created by injecting fresh or saline water into salt formations and producing salt to the surface. The process is referred to as ***solution mining.***
  - Diesel or hydrocarbons are commonly injected during cavern creation to prevent dissolution of the upper cavern and control geometry.
- Upon completion of the cavern, brine used in the development is displaced to the surface with NGLs.
- Commonly, this brine is stored on the surface for future on-demand NGL recovery.
- Caverns are commonly operated using constant pressure through the injection of brine for retrieval of NGLs.
  - Geomechanical stability is promoted using this constant pressure technique as pressure cycling is minimized.



GEOMECHANICAL STABILITY OF SALT CAVERNS

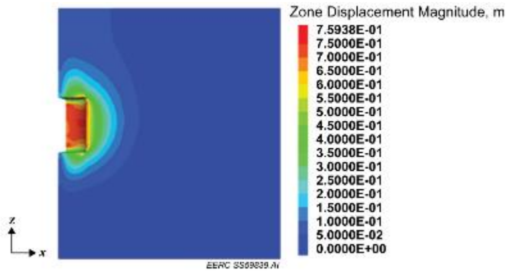
CAVERN STABILITY DEPENDS ON SEVERAL FACTORS

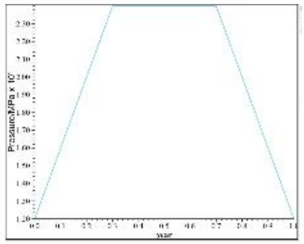
- ***Temperature***
  - At formation temperatures over 180°F, cavern stability may be compromised.
  - At temperatures above 180°F, salts may behave in a plastic manner and begin to flow inward, reducing cavern volume.
- ***Roof Collapse Due to Improper Cavern Geometry***
  - Low height/diameter ratio, low minimum cavern or operating pressure, inadequate roof shape (i.e., too flat as opposed to arched), and thin/incompetent overburden.
- ***Cavern Size***
  - Size depends on volumetric demands.
  - Where necessary, cavern fields are developed using multiple smaller cavern dimensions for greater mechanical integrity.

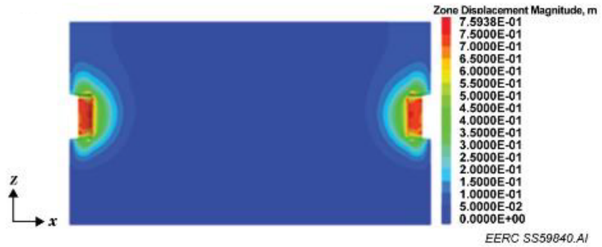
GEOMECHANICAL STABILITY OF SALT CAVERNS

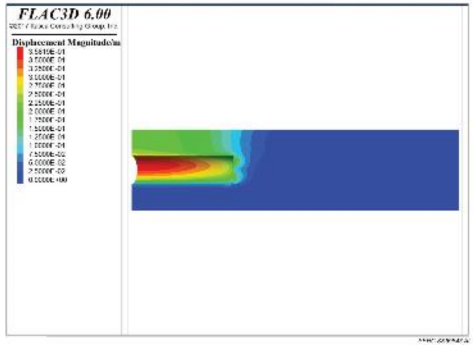
- Simulations of mechanical stability were performed for multiple cavern geometries under cyclic and constant pressure scenarios.
- Single-cavern and multiple-cavern simulations were performed.
- Effects of temperature were evaluated in select simulations.
- Displacement of the cavern roof and cap rock was minimized during constant pressure injection.

Simulation performed under cyclic pressure

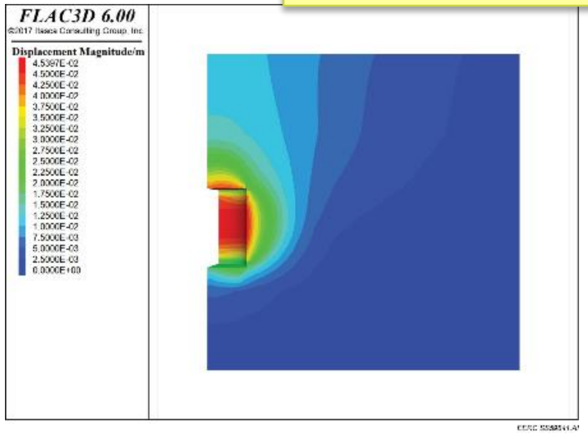


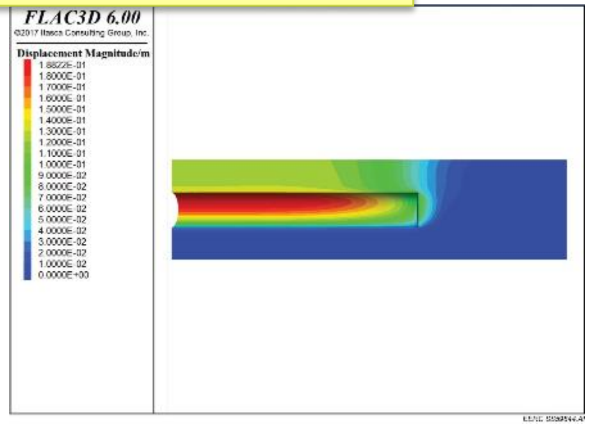






Simulation performed under cyclic pressure





REGULATORY REVIEW

- Regulations pertaining to the development and operation of salt caverns were reviewed in states and provinces where the technology is used.
  - Alberta, Saskatchewan, Kansas, Louisiana, Texas, and Michigan.
  - Information obtained may provide insight for future ND regulation.
- North Dakota regulations pertaining to development and operation of salt caverns were reviewed.
  - NDIC – Geological Survey regulates development and operation of salt cavern dissolution mining and brine disposal.
  - NDIC – Oil and Gas Division regulates NGL production, geologic storage of NGLs, and all injection well construction.
  - ND Public Service Commission – Oversight regarding gas processing and transmission via pipelines.

KEY FINDINGS

- The Dunham, Pine, and Opeche salt beds were identified as candidates for salt cavern development and NGL storage.

- Preliminary simulation results suggest the development of small caverns is achievable in ND salt beds. The use of multiple caverns was found to be a viable design approach and geomechanically stable.

- Regulations pertaining to the development of salt caverns, mineral ownership, brine handling, and injection are under the purview of three state agencies: NDIC's Geological Survey and Department of Mineral Resources – Oil and Gas Division and the North Dakota Public Service Commission.

- Regulations -- Several additional factors need consideration if NGLs are to be injected into the subsurface for storage.
  - Leasing of the salt formation (i.e., mineral extraction).
  - How to define the extent and volume of the solution-mined cavern.
  - Pore space ownership and storage of NGLs is not well defined.
  - Clarity regarding rules governing the use of surface brine storage ponds as part of salt cavern NGL storage facility operations.

- Engineering assessments were performed – evaluated major equipment/components, including compression, brine pumps, surface brine ponds, and electrical needs. Additional operational costs including labor, maintenance of surface equipment, and cooling water needs warrant further investigation.

NEXT STEPS

- Site-specific characterization (e.g., well logs, core evaluation, formation temperatures).
- Investigation regarding the potential for creating and operating long, horizontal galleries.
- Detailed geologic/geochemical modeling using site-specific characterization data of the target formations.
- Additional understanding of the natural gas volume availability for salt cavern development.
- Detailed engineering studies matching ethane source and petrochemical facility needs.
- Further evaluation and discussion with North Dakota regulatory staff will help identify opportunities and challenges to petrochemical and salt cavern storage development that need to be addressed.

Jim Sorensen
Director of Subsurface R&D
jsorensen@undeerc.org
701.777.5287 (phone)

Energy & Environmental Research Center
University of North Dakota
15 North 23rd Street, Stop 9018
Grand Forks, ND 58202-9018

www.undeerc.org
701.777.5000 (phone)
701.777.5181 (fax)

THANK YOU

Critical Challenges. Practical Solutions.

EERC | UND UNIVERSITY OF NORTH DAKOTA

Critical Challenges. Practical Solutions.