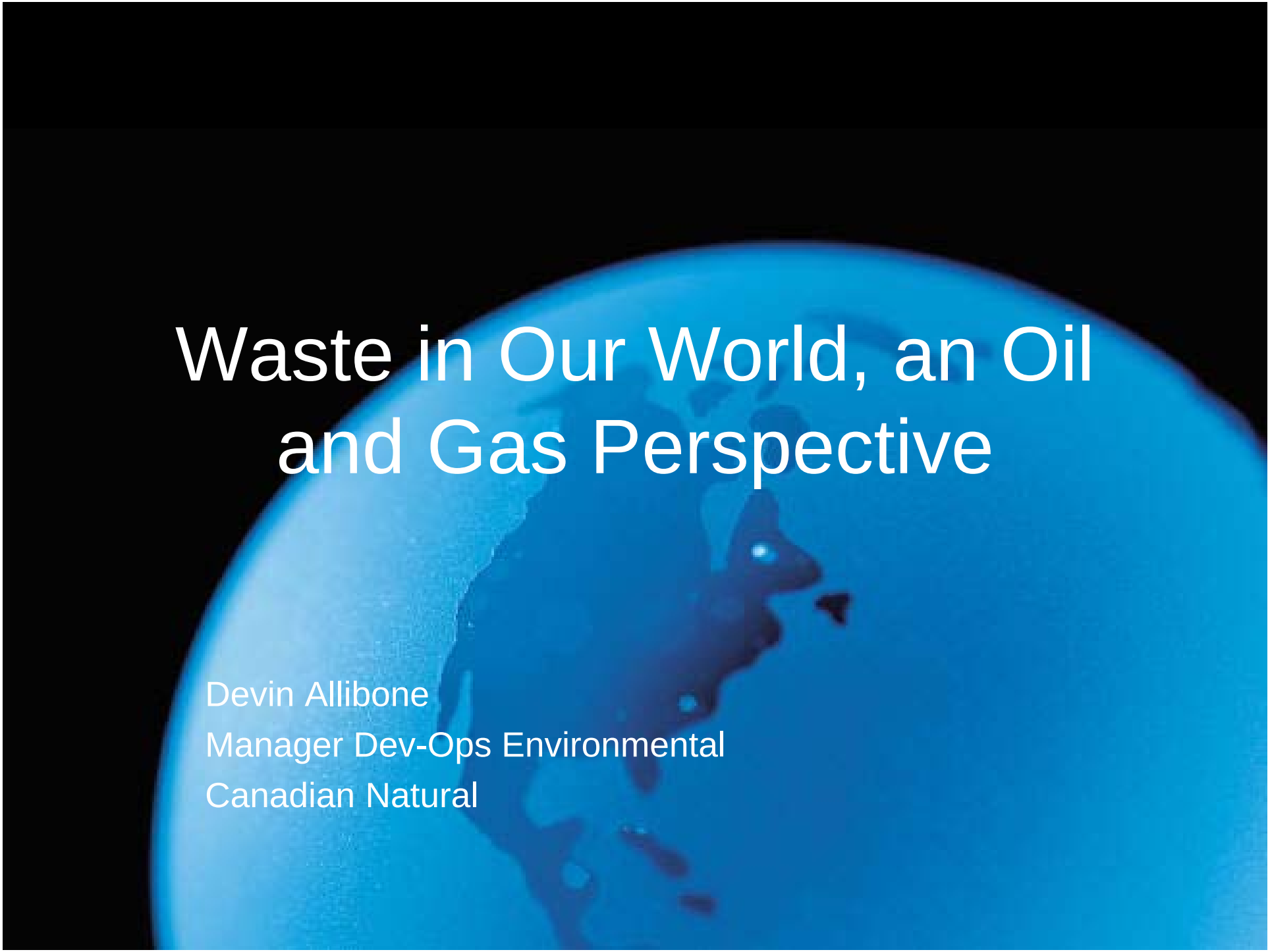

Waste in Our World, an Oil and Gas Perspective

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Outline

- Waste Manifesting and Tracking
- Volumes/Types of Waste
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  - Produced Water
  - Lime sludge
  - Remediation Project waste
  - Camp waste
  - Drilling Waste
- Management Options
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  - Caverns
  - Landfills
  - Disposal Wells
  - Recycling
- Trucking

Waste Manifesting and Tracking

- Oilfield waste shipments must be documented, tracked, and reported in accordance with provincial and federal regulatory requirements.
  - Federal or provincial waste manifest must be used for hazardous waste.
  - All shipping documents must be retained for two years.
- In Alberta, the AER distinguishes **111** different oil & gas industry waste types via use of waste codes.
- Generators are liable for all waste from “cradle to grave”; must track how and where the waste is generated, how it is transported, and how and where it is disposed/treated.
- Waste handling is subject to regulatory audit.
  - Regulator may request info on waste origin and properties, shipping documents, regulatory approvals for disposal facilities, waste classification and characterization documentation.

Waste Tracking – Disposal Facilities

- In 2015 Canadian Natural made use of over **128** third party waste disposal facilities (>60,000 shipment records):
  - **Class II Landfills**
    - contaminated soils, drill cuttings, lime sludge
  - **Oilfield Waste Processing Facilities and Disposal Wells**
    - production fluids, hydrocarbon fluids and sludge's
  - **Recycling Facilities / Transfer Stations**
    - used lubricating oil, filters, batteries, rags & absorbents, empty containers, scrap metal, plastics, miscellaneous debris
- Canadian Natural also owns/operates internal waste disposal facilities:
  - **Waste Caverns**
    - produced sand and water, evaporator blowdown water, lime sludge
  - **Landfills**
    - contaminated soils and camps waste
  - **Disposal Wells**
    - produced water and some waste fluids

Volumes/Types of Waste

- O&G Companies deal with significant volumes that we must manage in a environmentally responsible manner.
- Produced Sand
  - Production of materials can often lead to large volumes of sand as well.
    - Some companies produce, from one field, enough volume to fill a 500,000 tonne landfill cell a year.
  - Produced sand is often benign.
    - Management options are limited though due to shear volume, land application is not an option.

Volumes/Types of Waste

- Lime Sludge
  - Thermal Operations often have water softening requirements.
  - The produced water used is often hard and requires lime treatment to soften.
  - This creates large volumes of lime sludge that must be dried and placed in a Class II landfill.
    - Upwards of 80K m3 of dried lime a year from some operators.
    - Often costly to dry via centrifugation.

Volumes/Types of Waste

- Produced Water
  - Although not technically defined as a waste in Alberta, huge volumes are generated - cost effective management a must.
  - Flowback vs Produced Water.
    - Defining the difference can enable a wider range of disposal options.
  - Deep Well Disposal (Class Ib vs Class II).

Volumes/Types of Waste

- Remediation Project Waste (Dirty Dirt)
  - Inheriting legacy sites adds up.
  - Often, sites are inherited from old companies that are no longer in business.
    - When these sites are evaluated it is often determined the soil needs to be removed to meet Tier I (or equivalent).
    - Volumes of one project can reach over 100K Tonnes, difficult logistics for both sides.
      - Moving large volumes of soil also requires significant back fill and additional equipment.

Volumes/Types of Waste

- Camp Waste
  - As you can imagine, O&G has a need to house people in large camps.
  - To facilitate production and expansion, some operations can have 10,000+ people to accommodate at one time.
  - These camps generate the same amount of waste a comparable sized town would.
  - A camp this size will generate approx. 250 tonnes a week.
    - Due to the remoteness, disposal is not often cheap, or easy.

Volumes/Types of Waste

- Camp Waste cont'd
  - Sewage is also a large consideration for camps.
  - If you feed people, they have a tendency to need a washroom!
  - Permanent camps are a little easier to manage as they install water treatment plants.
  - The bio-solids generated at the septic plants must be landfilled and is a big cost.
- Where feasible, we are looking at composting operations.
  - Difficulty is wildlife concerns.

Volumes/Types of Waste

- Drilling Waste
  - This is actually is the coolest part of what I do.
  - When drilling a well, it is a general rule that we will generate 2 ½ or 3 times the hole volume in waste.
    - A typical heavy oil well will generate 200ish cubes of waste (total waste = solids and liquids).
    - We try to Landspray all of the waste that we can.
    - Landspraying is a very environmentally responsible way to dispose of drill mud and cuttings.

Management options: Land Application

- LWD of Drilling Waste

Drilling Waste

- Pros of conventional DWD
  - Reduced facility disposal.
  - Greatly reduced carbon footprint.
  - Generally, this option is easier to carry out logistically, at a reduced cost.
    - Vacuum trucks are needed on a drilling rig regardless of disposal option.
  - Landowners often prefer this disposal option, particularly in a dry year.
    - Add moisture and micro nutrients to the soil.

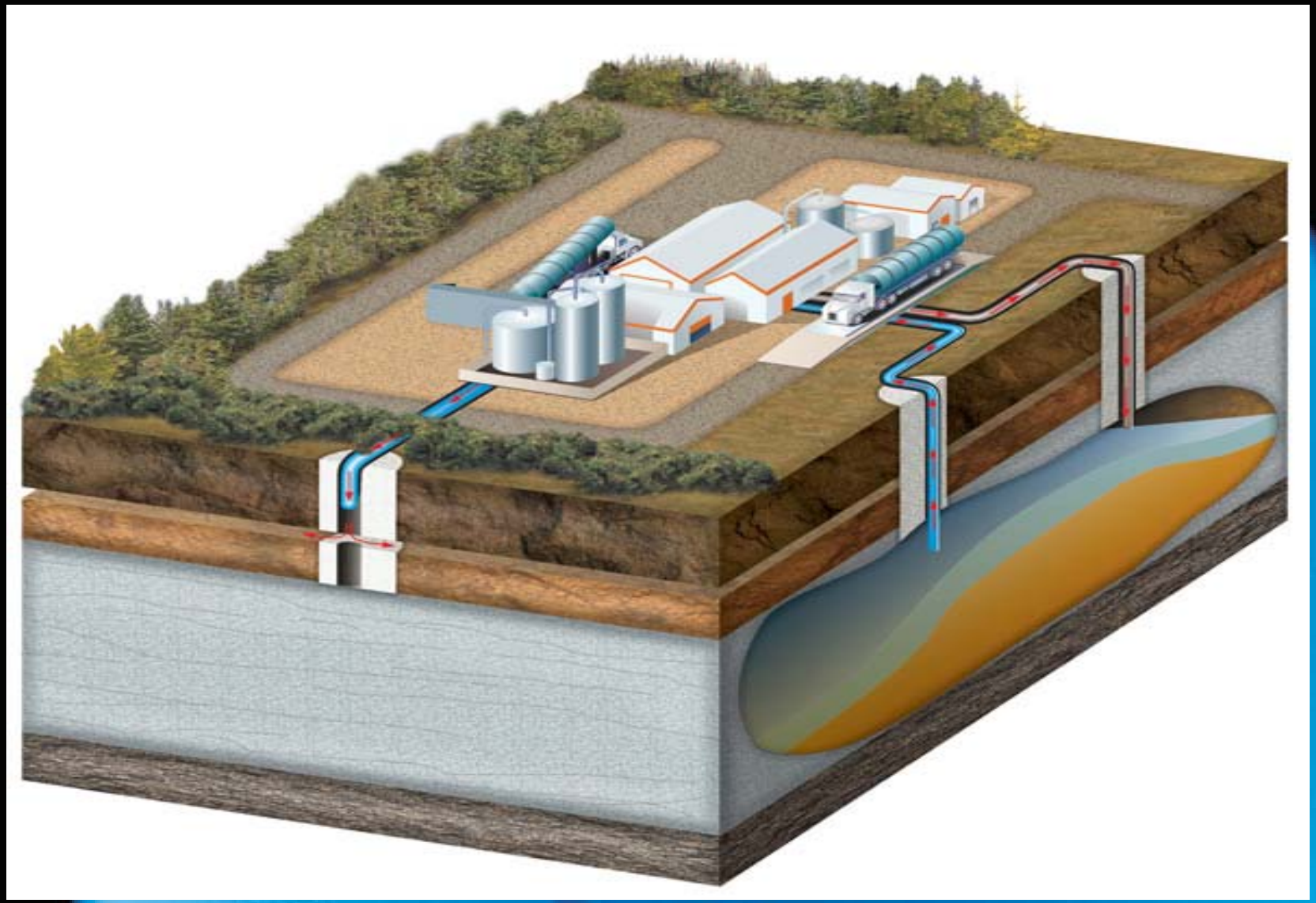
Drilling Waste

- Cons of land application of drilling waste
  - Diligence is very important.
    - We must ensure that the products we are drilling with are benign and environmentally responsible.
    - There are a number of significant testing parameters that we must carry out prior to LWD or mixing on site.
  - Often ROP is sacrificed for the ability to carry out conventional disposal.
    - Invert mud is much faster to drill with, but both the fluid and solids must be managed at an appropriate facility, this makes it a costly option.

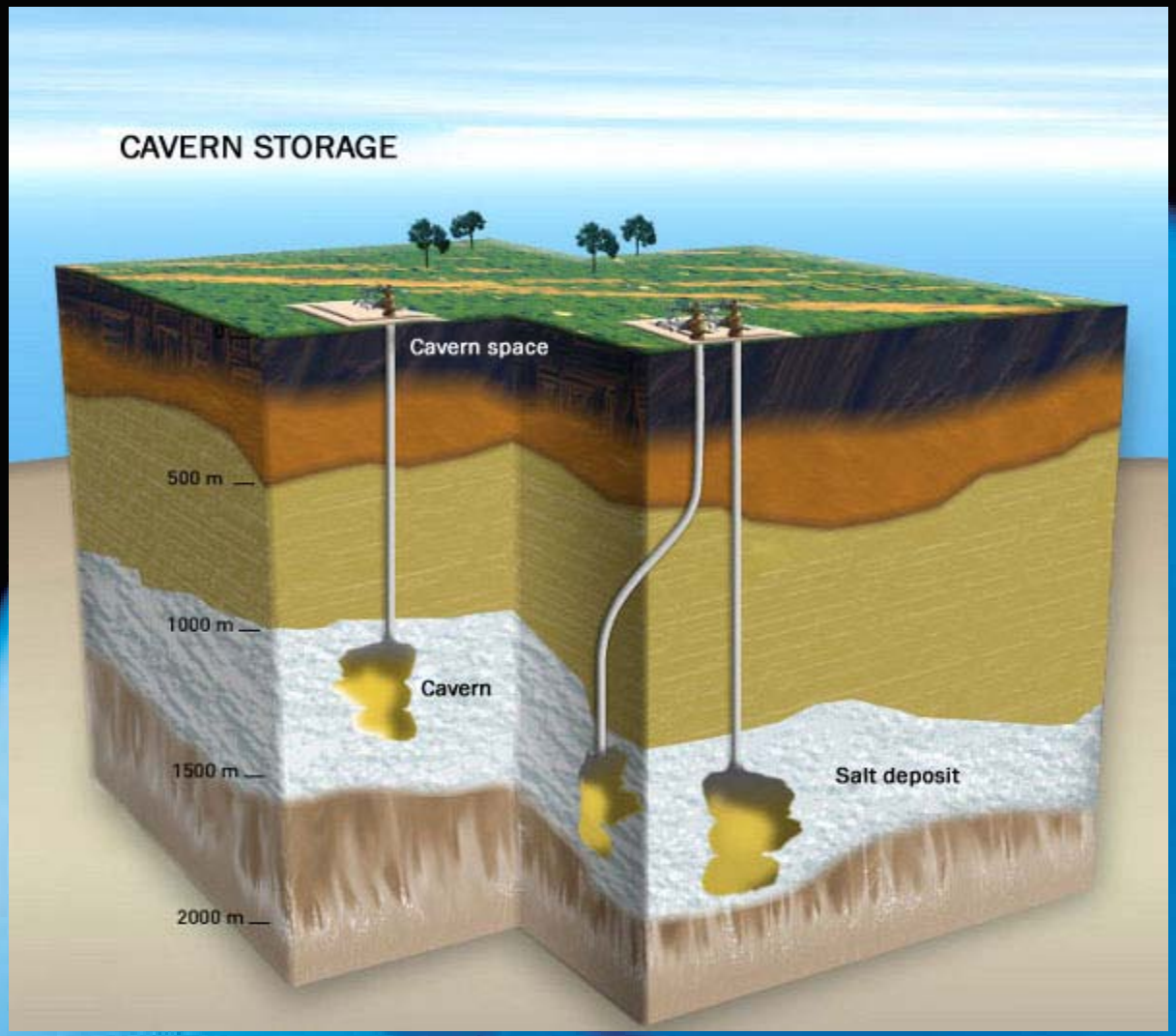
Management options: Caverns

- Caverns
  - A great alternative for the management of large volumes of waste is deposition into salt caverns.
  - In some projects, the volume of sand could fill a 500K tonne cell every year.
  - Salt caverns can be developed to accommodate 500K m3.
    - In the US, there are caverns more than a 1M cubic metres in size.

Caverns



Caverns


CAVERN STORAGE
Cavern space
500 m
1000 m
Cavern
1500 m
Salt deposit
2000 m

Caverns

- Pros of using caverns
  - They are permanent disposal solutions with no migration potential.
  - Caverns act as a separation vessel of sorts.
    - With the heat and pressure from the formation, HC will be separated from the solids and can be returned to surface for treatment to sales quality.
    - This is HC that would remain within the solids when disposed of at a landfill.
  - High volumes can be disposed of per day with little man power.

Caverns

- Cons of using caverns
  - There are limited areas you can put them.
    - You need the geology to be available and have the thickness of salt to make the site economical.
    - Basically, the NE corner of Alberta and NW corner of Sask are the two viable areas that meet the criteria.
  - Significant time to develop a cavern.
    - From drilling to operationally capable to accept waste would be approx. 2-3 years. ROI is strained.
    - Capital required for the supporting surface infrastructure.

Management Options

- Landfills
  - Class I vs Class II.
    - O&G companies do not generate much waste that requires a Class I landfill disposal option.
- TRD
  - Fluid management.
    - Often used to recycle materials as well.
  - Disposal Wells (class Ib, Class II).
    - Defining difference between Brine equivalent and Frac water key.

Recycling

- O&G have tried many technologies to allow for efficient recycling.
  - Drilling Fluid (Mud) recycling has been carried out for years. It reduces the amount of HC that is on drilling cuttings substantially.
  - Reduces need for more invert to be brought into a site.
- Similar tech has been tried on production sand.
  - Results have been promising but still end up with 1000’s m3 of clean sand. What do we do with it?

Trucking

- Trucking is probably the largest single consideration for an O&G company when it comes to managing waste.
  - This could be waste fluids, solids or a combination of both.
- A large oil and gas company can typically spend 70%-80% of its WM budget in trucking material to appropriate disposal.
  - In 2014, CNRL spent $60M in disposal, but almost $220M in trucking the waste to facility.

Trucking

- Proximity to a facility is a big consideration when we are determining the best management plan for our wastes.
  - Remote Operations: Some disposals have had to be shipped for 24 hours in order to reach the nearest facility.
- Often line-ups at facilities.
  - Because of the limited number of facilities, we incur costs for trucks while they are waiting to off load (36 hours in wait times is not unheard off) .
  - As a result, standby costs can result in an exponential increase in our disposal costs above what was budgeted.

Trucking

- Sheer volume of waste often creates a trucking shortage.
  - With large volume areas, there is often a shortage of trucks, driving up costs.
  - A few years ago, CNRL used over 534 different trucking companies just to go to three of the bigger disposal companies.
- Safety is one of our core values and of paramount importance to us, we would love to reduce the distance and number of trucks we use.

Questions