Impoundments for Cost-Effective Recycling of Produced Water for Hydraulic Fracturing

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Significance of Water to Our Business

- More than ever, water is an integral part of the success of oil and gas operations. So, think about this

- No Water

- No Fracturing

- No Oil and Gas Resource Plays

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Water's Importance

- Water is the most common and most heavily used fluid in the petroleum industry.
- Water is produced along with oil and gas from nearly every well.
- Water is used as a base fluid in drilling, completion, and production operations.
- Water will be mixed, injected, produced, cleaned, and reinjected.
- **Water's use, protection, and disposal are emotionally charged subjects in many communities.**

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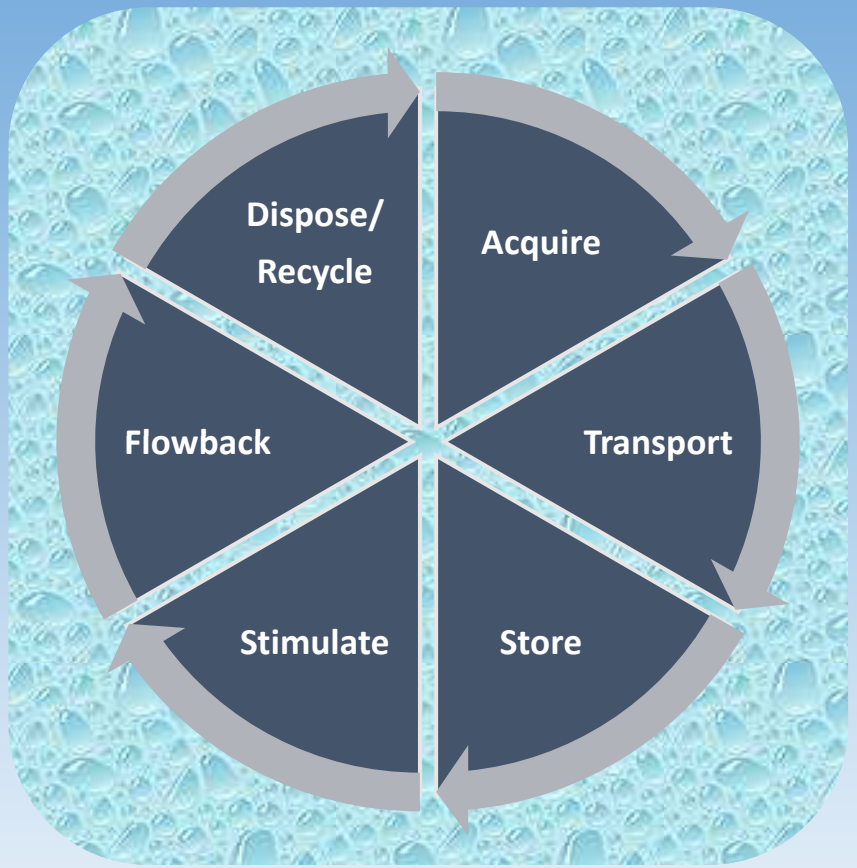
Water Management Cycle

- Water source
  - Subsurface aquifers
  - Rivers, lakes or ponds
  - Rural or urban water supplies
  - Gray Water
  - Acid Mine Drainage
- Water transport
  - Pipeline
  - Trucking
- **Water storage**
  - **Frac Tanks (500 bbls)**
  - **Modular Tanks (up to 60,000 bbls)**
  - **Portadam (size as required)**
  - **Pits or ponds (100,000+ bbls)**
- Water treatment and reuse
  - Biocides
  - Settling
  - Flocculation
  - Electrocoagulation
  - Distillation
  - Crystallization
- Water disposal
  - Evaporation
  - Water disposal wells



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Data Organization

Organizing Data into Layers

Enables users to see both an integrated and customized view with filtering capabilities

Source: Well Sync Consulting

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Water Storage

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Why Is Water Storage Important?

- Water is the base fluid and biggest component of any hydraulic fracturing operation
- Water volumes required for typical completions range from 100,000 to 1,000,000 barrels per well
- Water must be stored near the completion operation in sufficient quantities to finish a job at the desired pump rate
- In the first 90 days after fracturing a well can produce from 30 to 80% of its load back
- To recycle produced water there has to be enough storage for both the produced water and the processed clean water
- Water must be stored in a manner that is economically and environmentally sound

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Storage Considerations

- Storage Capacity Required
- Project Duration
- Mobilization/Demobilization Time
- Construction Time
- Distance Between Drilling Sites
- Move Frequency
- Heating

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Storage Options

- Impoundments
- Portadams
- Large Capacity Above Ground Moveable Tanks
- Frac Tanks

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Water Storage General Comments

Systems have evolved over the years as Shale plays have been developed

- To using large frac ponds (100,000 BBL and larger) both lined and unlined for fresh water
- Lined pits for recycling produced water ranging in size from 300,000 BBL and larger
- Primarily transporting the water through lay flat lines, HDPE, or aluminum (fresh water only), over various distances up to 5 miles for completion operations
- Able to frac at over 100 BPM
- Able to frac using large volumes of water (1+ million BBL/well)

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Project Planning Considerations

Design Basis - To establish the design basis for a produced water reuse system, an initial review of the site specific conditions, requirements and water demand estimates that could impact the design must be completed. Elements to consider in this review include:

- Regulatory Framework
- Water Demand Estimates
- Water Sources
- Drilling/Completion/Production Plan
- Detailed Leasehold Map
- Environmental Site Assessment
- Community/Landowner Relations

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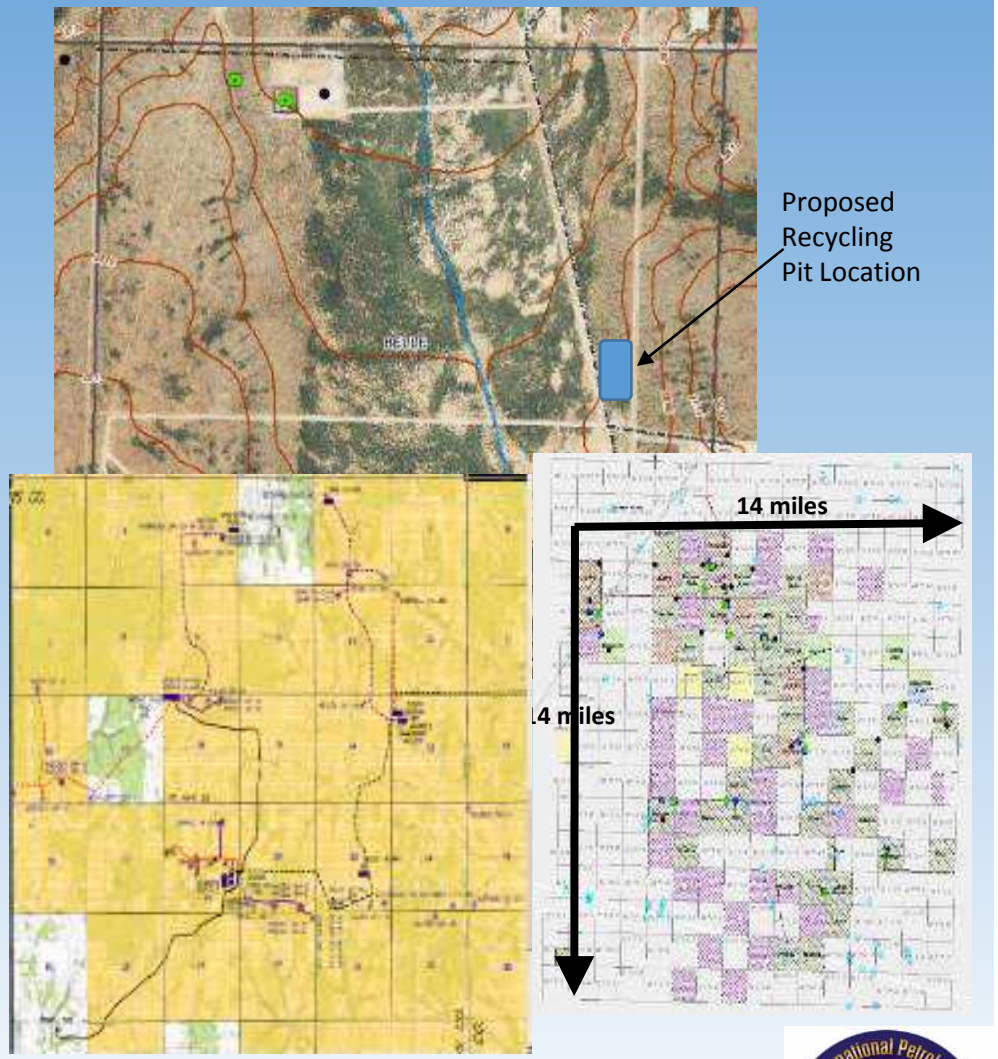
Planning – Detailed Leasehold Map Review

Development Map – The leasehold boundaries and location of existing infrastructure (roads, pipelines, power lines, etc.) within those boundaries need to be mapped.

Assessment of the natural features (surface water, topography, wetlands) and flood plains should be incorporated in the maps constructed to support the planning activities.



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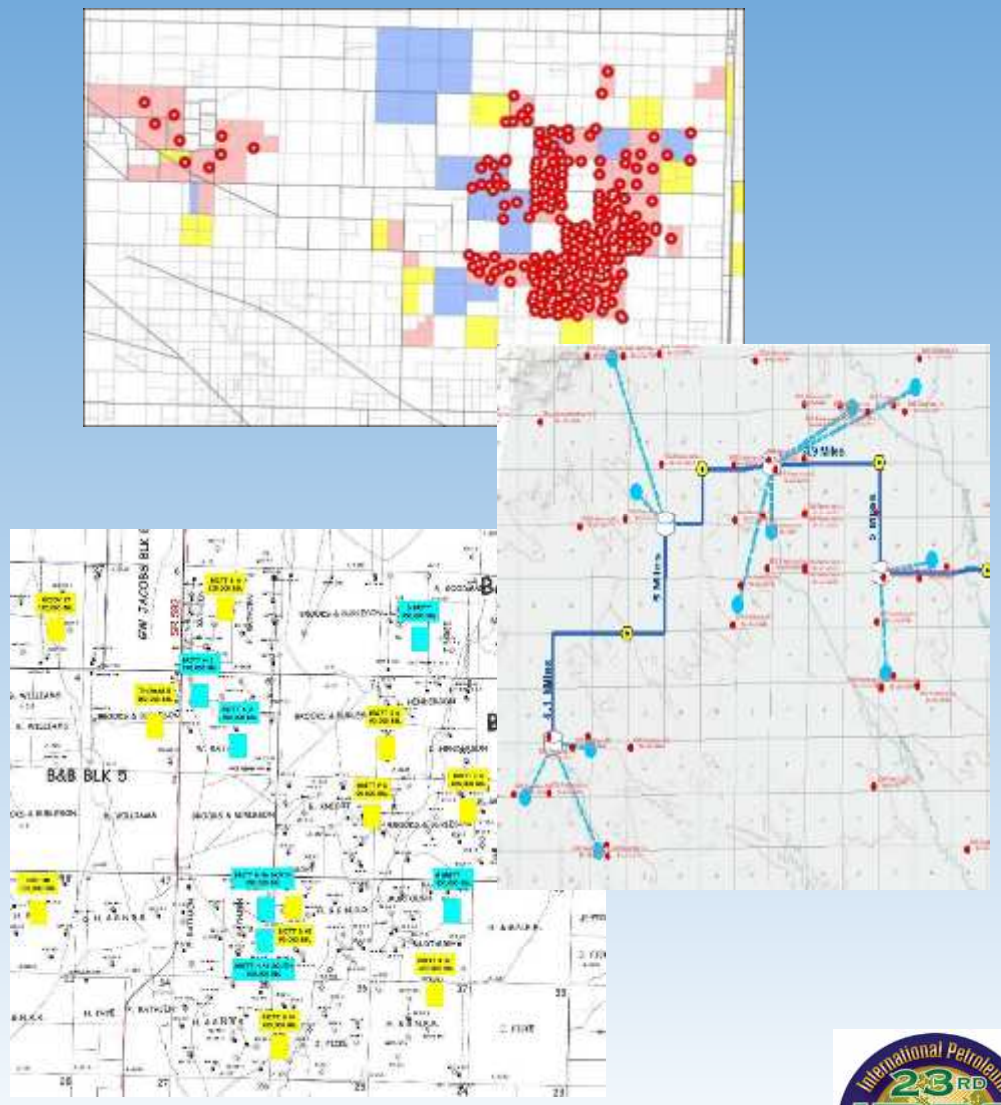
Planning – Review Lease Development Plan

Review of the planned drilling locations within the lease over time, will facilitate preliminary selection of storage and treatment sites and transportation corridors for water delivery.

The sequence of planned development (drilling & completions) will guide the sizing and prioritization of the construction activities.



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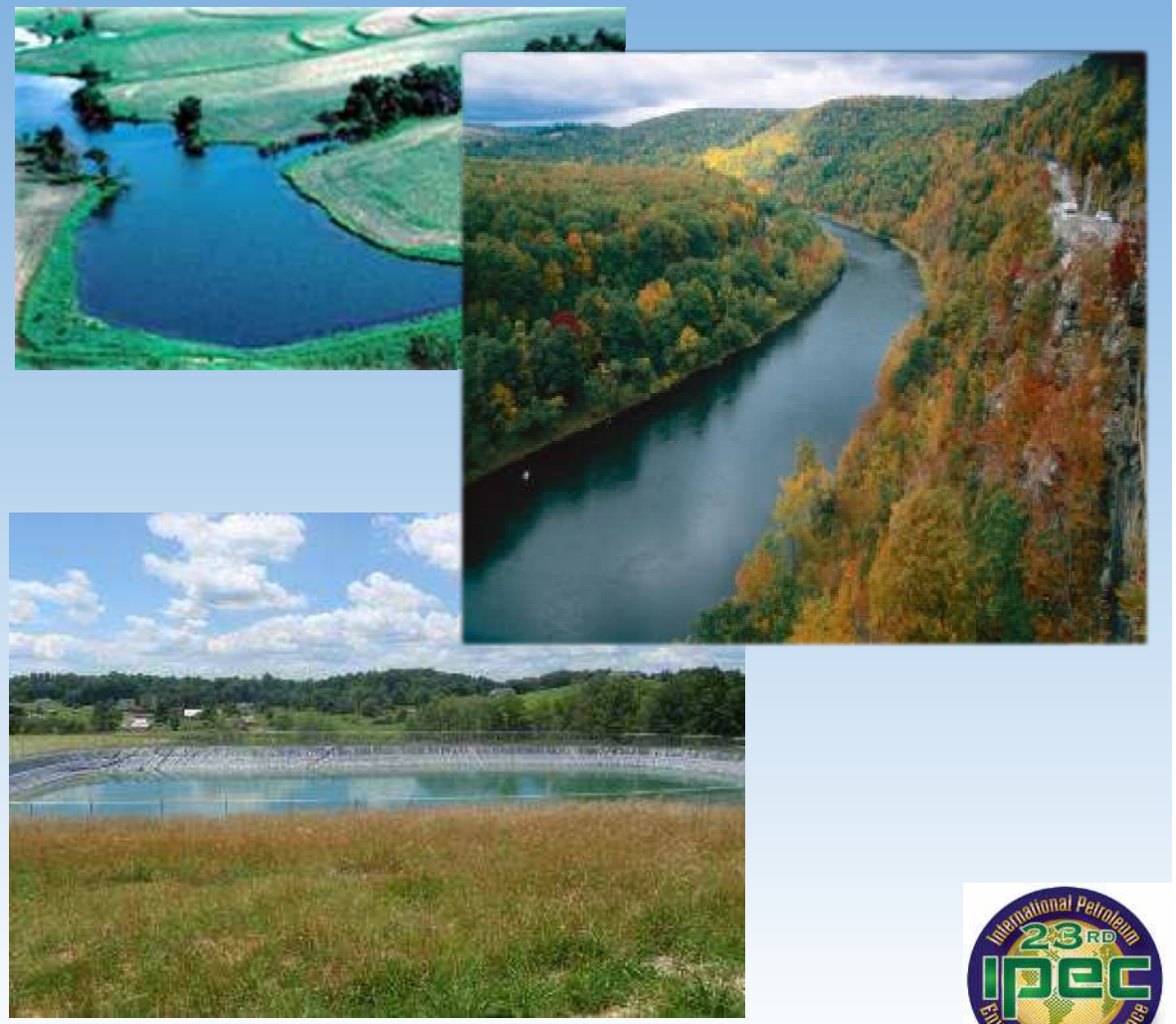
Planning – Environmental Site Assessment

A pre-development assessment of the leasehold should be conducted to document the property condition and identify any potential environmental or legal issues that could/would impact the development plan.



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Pit Siting Considerations

Pre-Construction Site Screening

- To mitigate risk, it is beneficial to have produced water recycling pits on Company Owned Surface Property
- Produced water pits must be sited outside a 100-year flood plain
- Pits should be located near existing infrastructure (existing produced water lines and electrical)
- Pit sites must not interfere with future drilling well pad locations.
- It is beneficial for a pit to be located where the ground slopes onto Company Owned Surface Property (if there was a leak or failure it could be contained on Company Owned Property).

Avoid

- Streams (Blue line streams on USGS topographic maps)
- Intermittent and ephemeral streams
- Flood Plains (FEMA zones A, AE and AO)
- Wetlands (State and Federal)
- Sensitive Habitats
- Historical Areas

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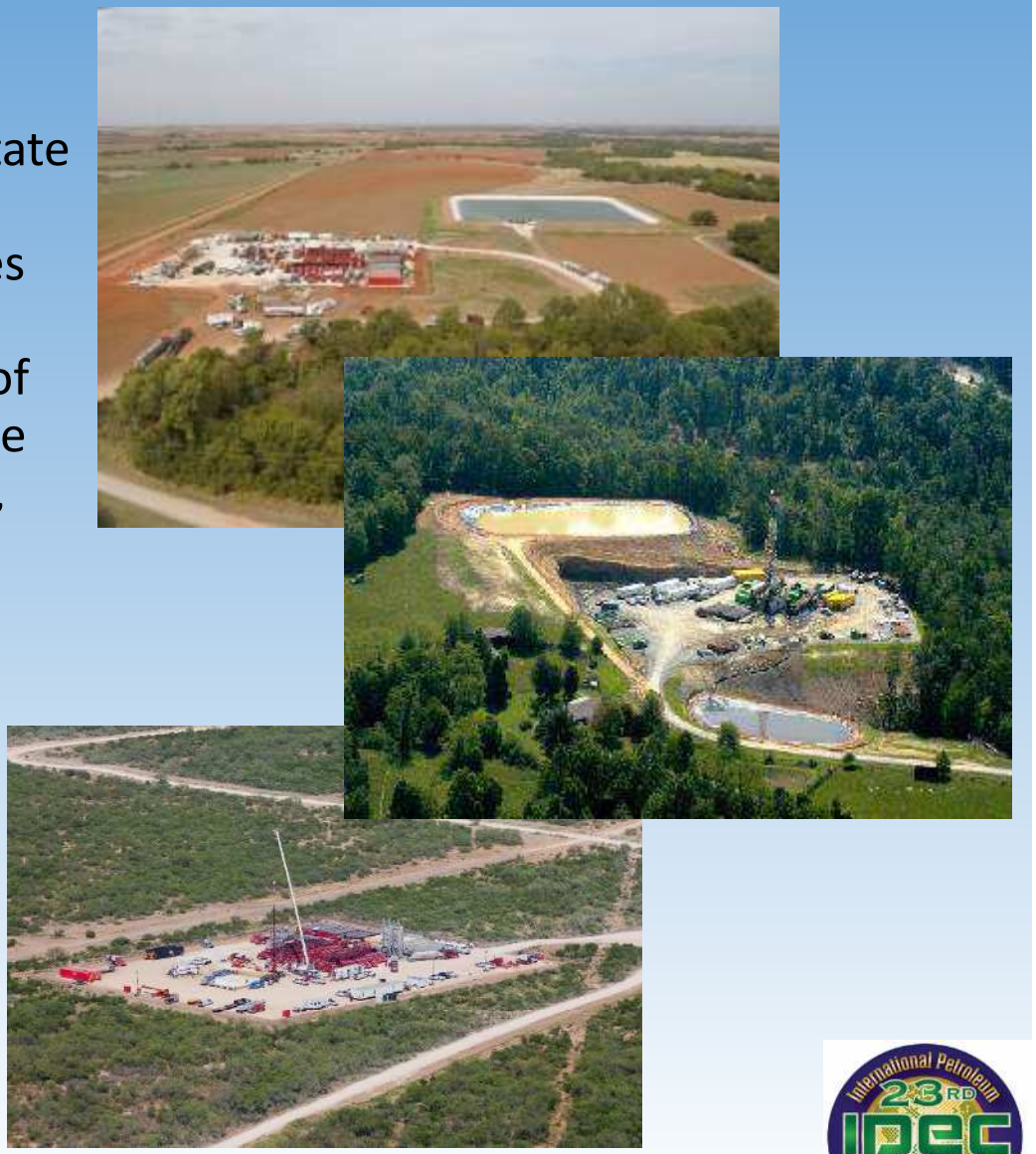
Planning – Assess Regulatory Framework

Regulatory requirements vary by State and therefore it is necessary to understand the applicable local rules and regulations governing storage, transport, treatment, and disposal of produced water, that could influence the design of a water reuse system, including:

- Permits
- Operations Plan
- Monitoring Requirements
- Reporting Requirements
- Impoundment Design
- SPCC Plan



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Planning – Community/Landowner Relations

Consideration should be given any community and/or landowner concerns in the early planning stages and identify steps that could be taken to address those concerns

A clear line of communication needs to be established and maintained with the key stakeholders for the duration of the project

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Planning – Identify Water Sources

In a typical exploration or development project, produced water volumes available initially will likely be insufficient to support operational activities and supplemental water from alternative sources will be required.

Steps to identify an appropriate water source of adequate quality and volume and an efficient delivery method to offset the shortfall should be initiated prior to starting drilling operations.

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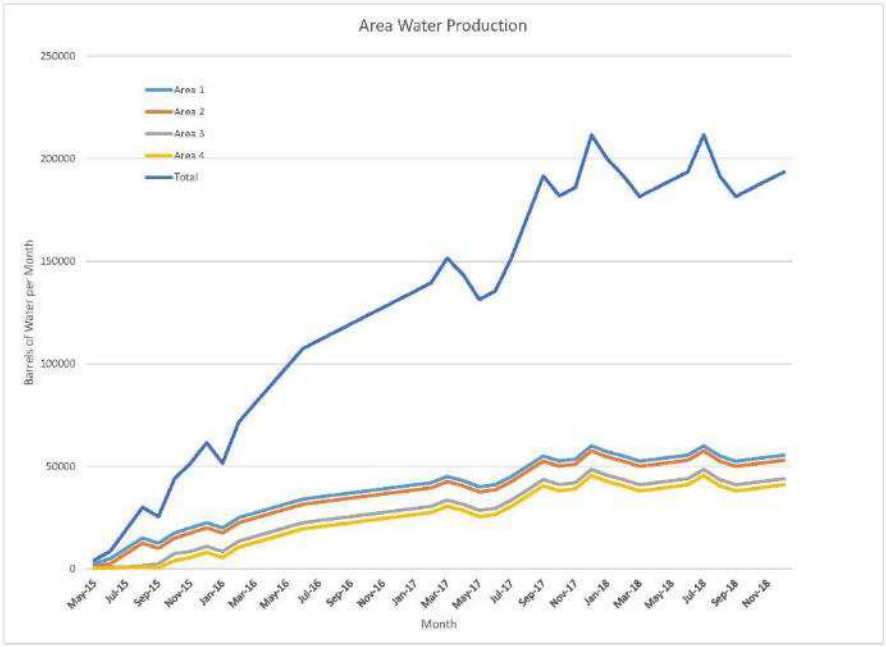
Planning – Estimate Water Demand

The amount of water required at any point in time to support operations will impact the produced water reuse system design, namely:

- Storage Capacity
- Delivery Capacity

The highest water demand will likely occur during the development phase of operations (after HBP drilling is complete). The design point will be the apex of the combined drilling and completion water volume demand from the development plan/schedule.

Produced Water Projections from an Independent E&P Company



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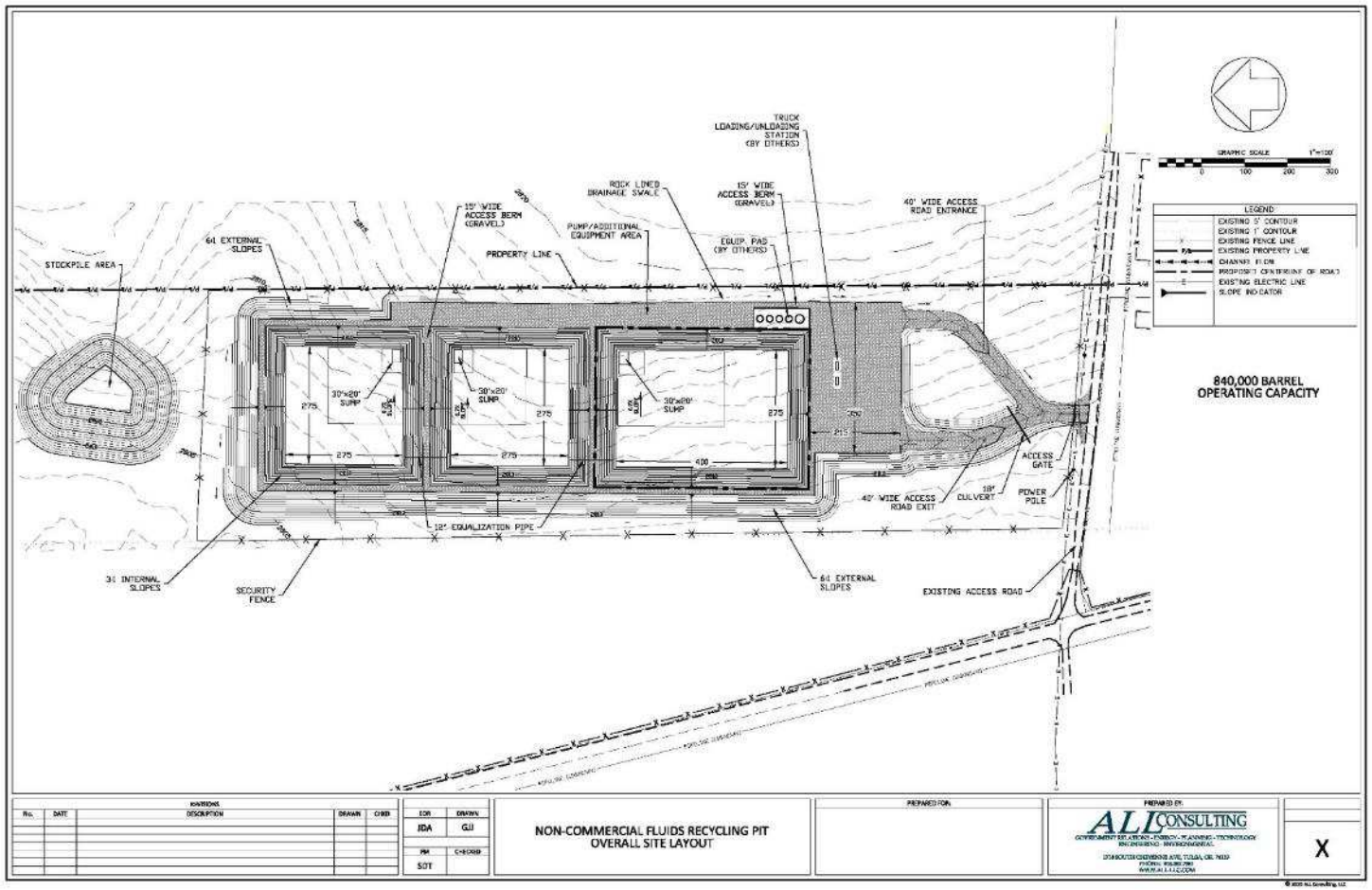
Produced Water Recycle Pit Plan



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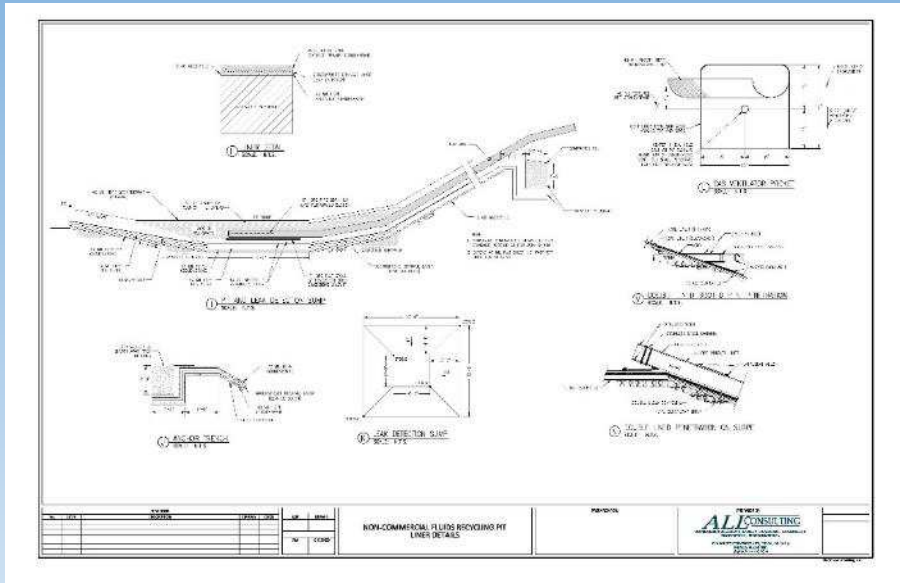
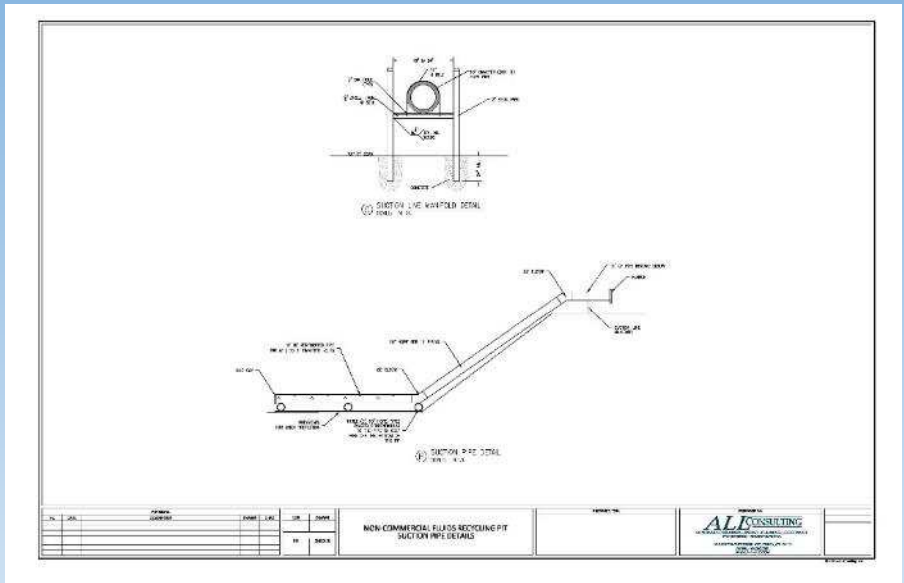
Produced Water Recycle Pit Plan

Leak Detection



Water Transfer Pipe



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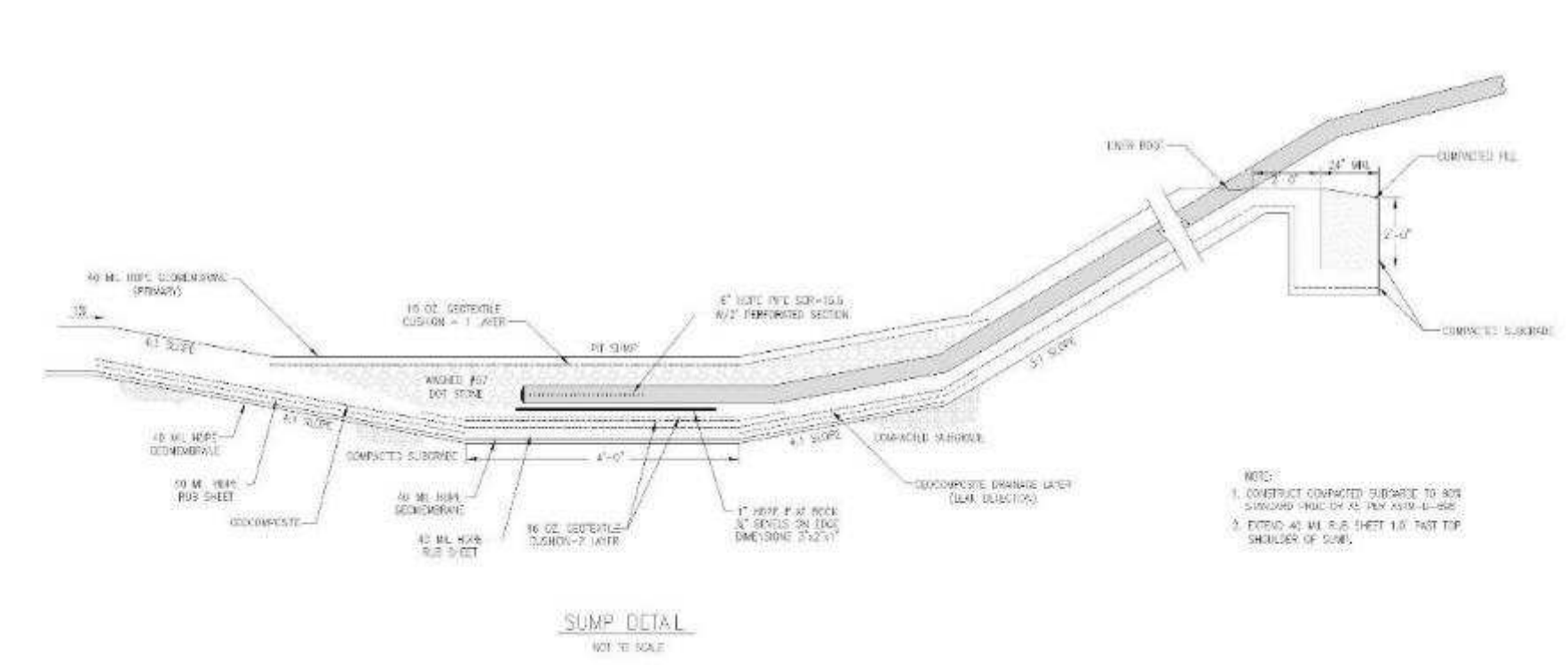
Produced Water Recycle Pit Plan

Typical Leak Detection Detail



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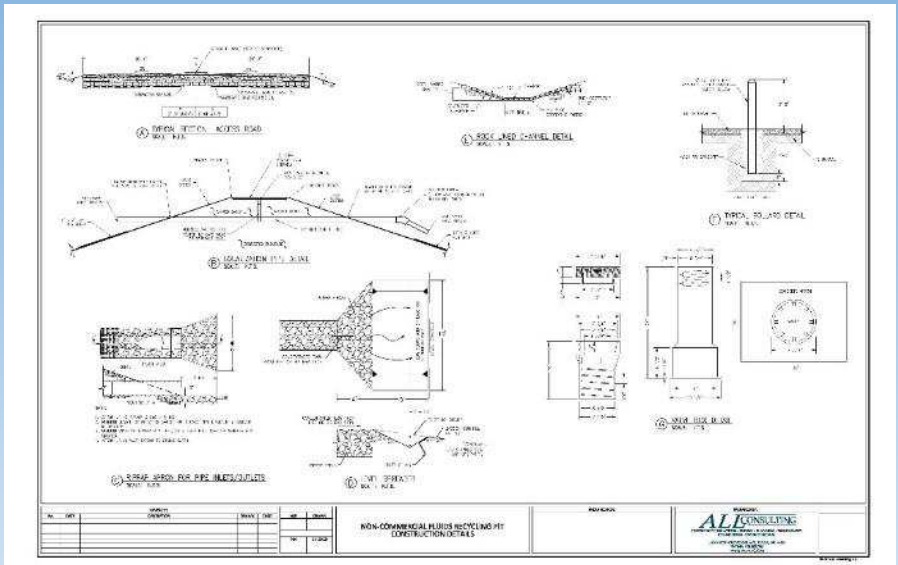
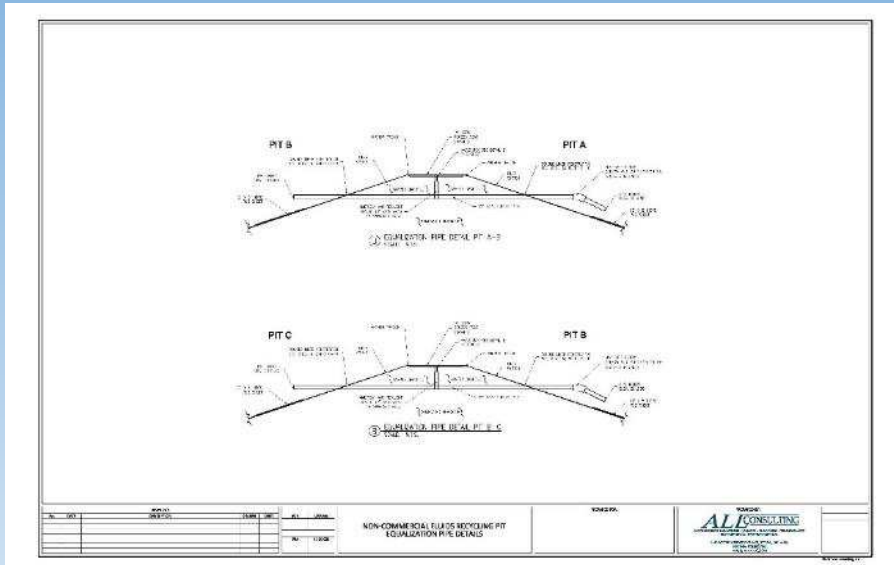
Produced Water Recycle Pit Plan

Equalization Pipe Detail



Equalization Pipe



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Why Reuse Produced Water?

- **Essential Resource**

  Without “water”, unconventional resource development would cease

- **Water Scarcity**

  Availability of suitable quality/quantity of water varies by resource play

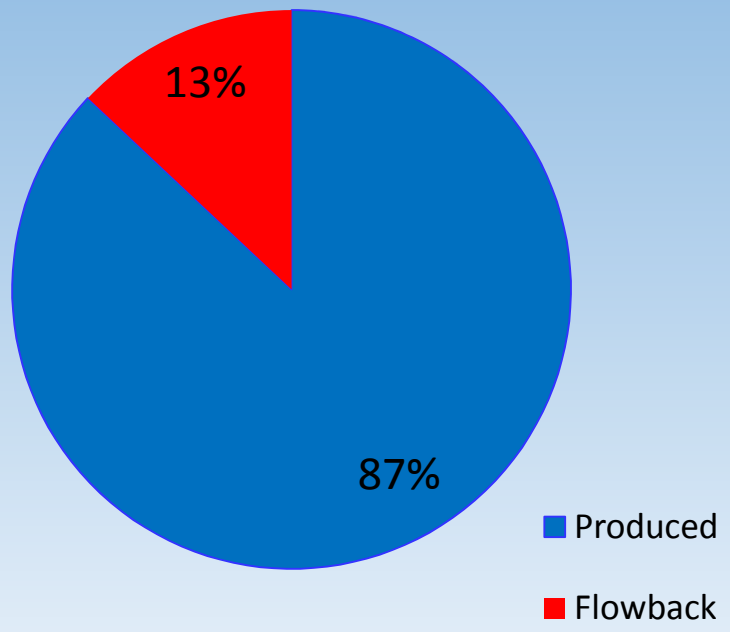
- **Competition**

  Alternative demands for fresh water resources

- **Regulations**

  Variability of regulatory constraints in active basins

Saltwater Disposal Water Type %



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Why Reuse Produced Water? (continued)

- **Environmental Benefit**

  Conservation of fresh water resources

- **Economic Impact**

  Cost of treatment potentially lower than acquisition, transport, storage and disposal

- **Community Relations**

  Minimizing impacts to local community's water supply and infrastructure

- **Sustainable Practice**

  Reduced demand on fresh water resources and the local environment

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Produced Water Treating Objectives

The objective is to economically produce clean brine water from produced water that can be used as a base fluid for hydraulic fracturing.

- Process must be able to remove hydrocarbons, gelling agents, metals, H_2S, iron sulfide, bacteria, boron, and suspended solids.
- Process must be able to handle variable qualities of inlet water.
- Equipment must have a compact footprint.
- Water treatment must be economical compared to the acquisition and disposal of fresh water.

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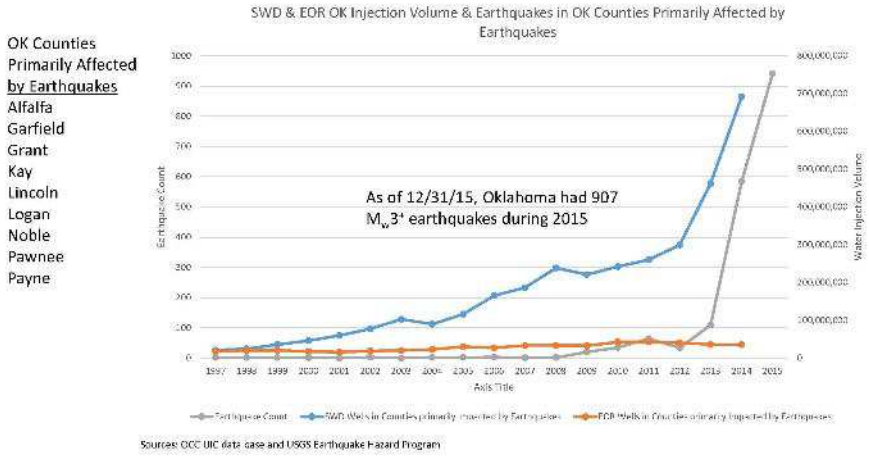
Overview

- Water is scarce and is getting harder to acquire
- Seismicity may reduce or eliminate use of SWDs
- Pointing toward a need for:
  - Increased recycling
  - Treatment for discharge

Comparison of M_w3^+ Earthquakes to Annual Water Injection in Select OK Counties



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Take-Away Points

Development of an effective plan to treat and reuse produced water for HVHF make-up fluid will consider the following:

- Planning is essential
  - Establish the design basis
  - Identify Regulatory requirements
  - Evaluate the potential risks and constraints
- Conduct a thorough review of the alternative storage options suitable for the specific local conditions, gathering/distribution options, measurement and treatment choices
- Select the preferred approach based on the regulatory, economic, technical, environmental and operational requirements
- Obtain the requisite permits and permissions
- Plan, design, construct, install and commission the infrastructure and systems required to support the oprerational needs
  - Storage and treatment site selection
  - Road and pipeline routing
  - Disposal

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Key Messages

- Oil and Gas from shales are going to remain an important source of energy
- Large volumes of water are necessary for stimulation of the reservoirs
- UIC disposal options are limited in some areas
- Reuse of produced water is an increasingly important option
- Treatment technologies are advancing and changing
- Treatment and reuse of produced water can conserve fresh water and reduce waste streams

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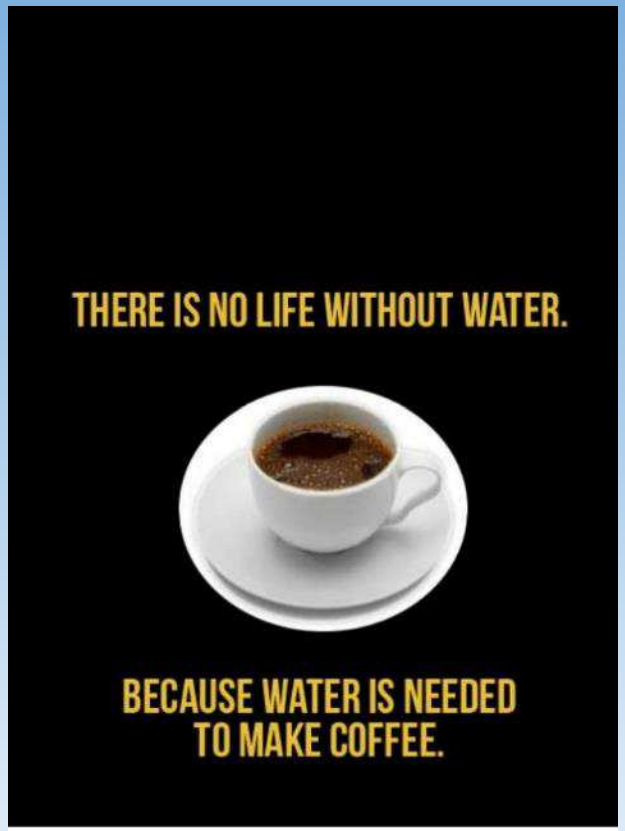
Questions?



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