

Achieving Zero-Discharge NORM Waste Disposal Using Slurry Fracture Injection (SFI) Technology

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SFI – Advanced Deep Well Disposal

- TTI's **Slurry Fracture Injection (SFI)** is an **Environmentally Sustainable HF technology**. SFI is used as an advanced deep well disposal process:
 - Large volume of waste disposal (10,000+ m³/month ~ 63,000+ bbl/month)
 - Disposal of multiple wastes: contaminated soil, oily sludge, NORM, E&P waste
 - Fast implementation allowing for rapid deployment and start-up
 - Environmentally sustainable disposal process- Zero Discharge waste management
 - Life-cycle cost effectiveness
- Significant **environmental advantages** for SFI as a waste management strategy:
 - Process Control systems to mitigate risks (OOZI, loss of wellbore integrity, groundwater impact, maintain optimal formation response, max. storage capacity)
 - Permanent disposal: no risk future environmental liabilities
 - Zero Discharge: no interaction of disposed waste with the surface biosphere
 - No ground water contamination, protects soil and air quality
 - Disposal operations do not impair surface lands & water resources
 - Cost effective and time effective waste disposal.
 - Safeguard public health by reducing & removing pollution



Surface Disposal of Waste

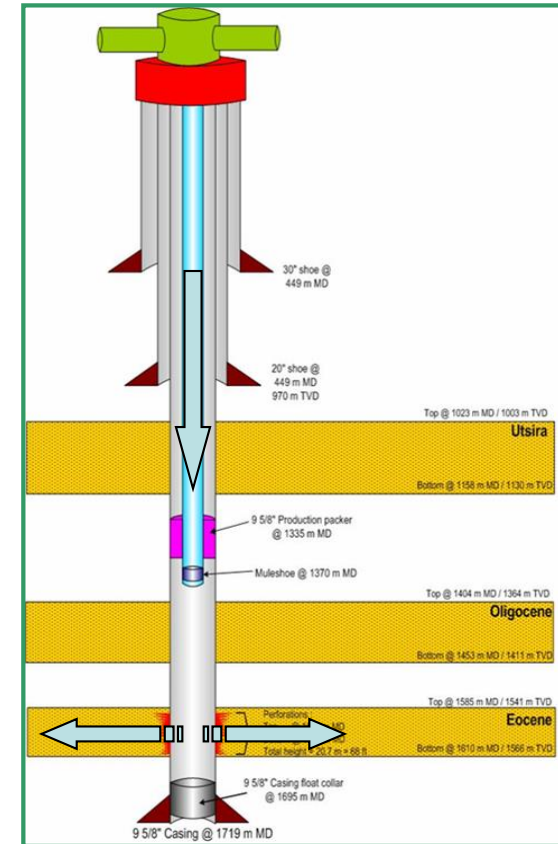


SFI solves this problem



SFI Characteristics

- **Advanced deep well disposal: granular / fines or viscous fluid waste streams**
 - Produced solids, granular fines, and oily sludge
 - These waste streams are slurried into a pumpable slurry
 - Waste water (produced water) used as carrying fluid
 - Multiple waste streams (including **NORM/TENORM**)
- **Heavy slurry – Different ‘slurry design’ for different waste types**
 - 15-25% by volume waste concentration
 - 1.15-1.3 SG & FV < 60 sec
- Long-term, continuous, hydraulic fracturing in ‘soft rock’
 - **Different injection strategies for different waste types**
 - Injection rates and pressures; cycle design
- Injection of large waste volumes (3,000-17,000 m³/month)
- Deep geological sequestration (350-2000 m / 1150-6500 ft)
 - **Thick friable sand formations: optimum fluid-flow and geomechanics**
- Process control for operational & environmental assurance
- **Excellent long-term security & Environmental Advantages**



TTI's proprietary SFI technology provides Zero Discharge solutions with 'Process Control':

1. Formation Containment

- Ensures the integrity of containment of the disposed slurry.

2. Optimization Formation Response

- Ensures optimum sustainable pressures and rates of injection.
- Dissipation of stress/pressure gradients.

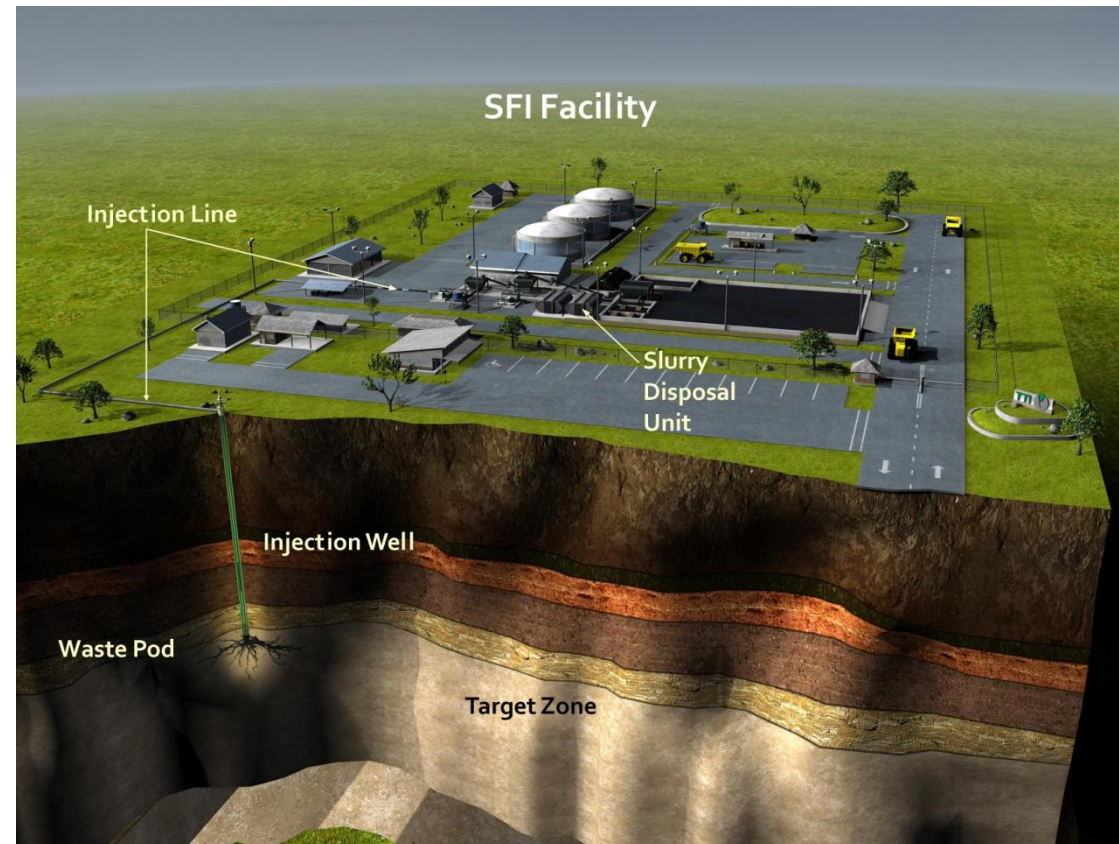
3. Maximization of Storage Capacity

- With strong backgrounds in geomechanics & reservoir engineering, TTI maximizes formation storage capacity.

4. Maintenance of Wellbore Integrity

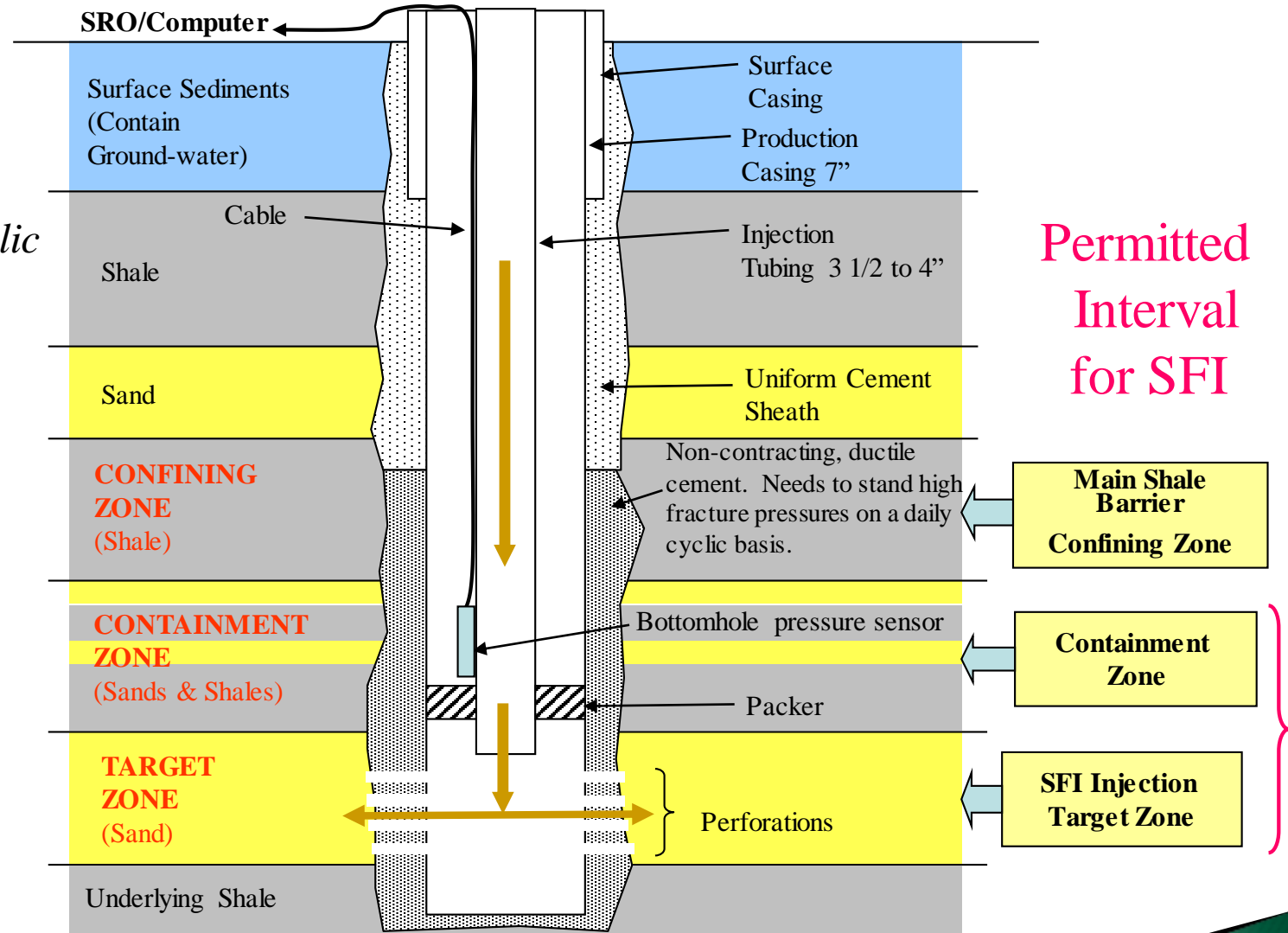
- Ensures mechanical and hydraulic integrity of the wellbore

TTI applies the science of geomechanics in providing customized, long-term & permanent waste disposal solutions to E&P companies ("Bottoms Up vs. Pump & Pray").

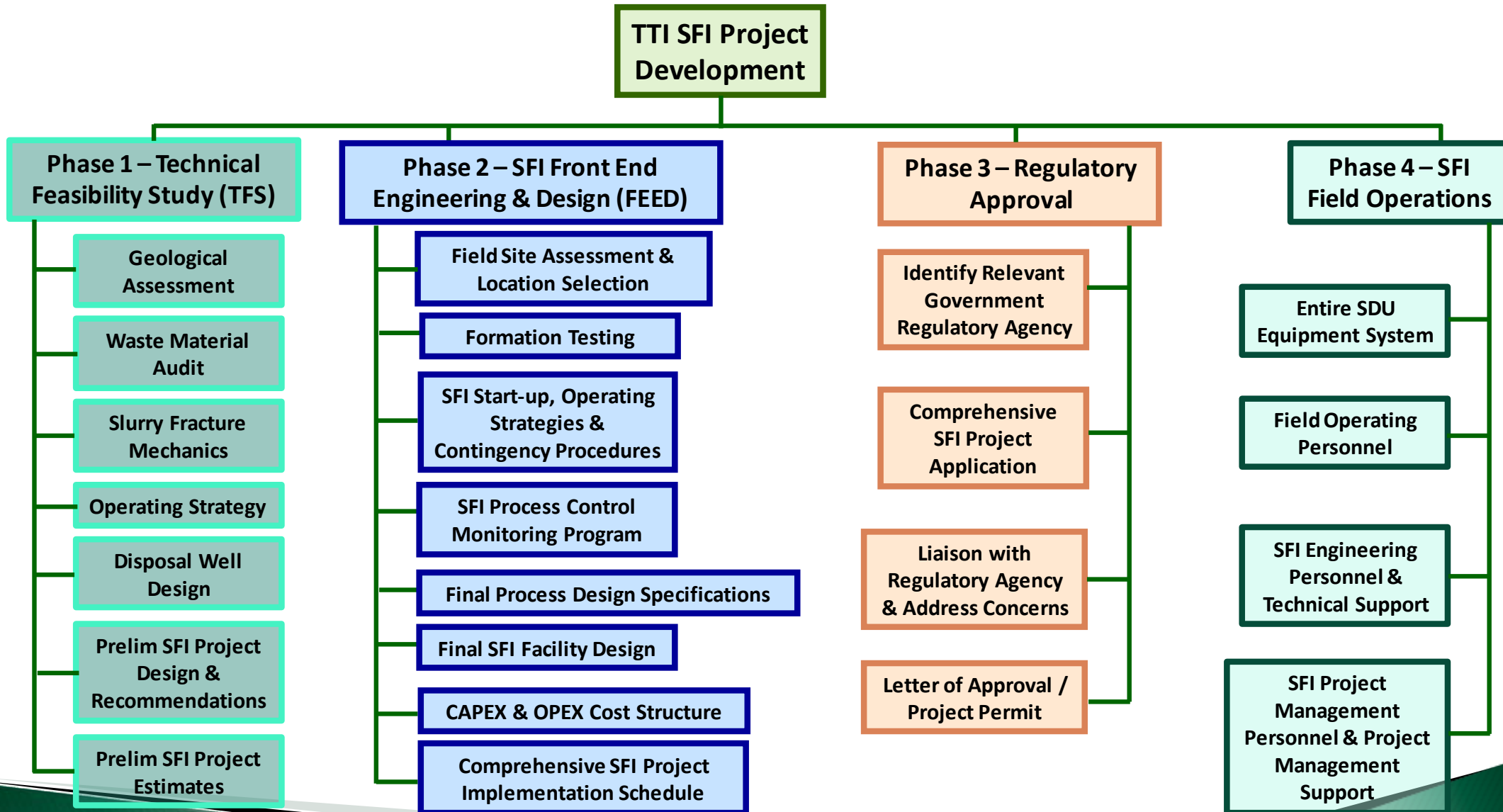


SFI Well, Geology, Hydrogeology

- **Ensures wellbore integrity**
 - Mechanical & hydraulic
- **No surface and groundwater contamination**
 - Multiple barriers to USDW
 - Wellbore & geologic barriers
- **Allows for wellbore monitoring & control**



Project Development Workflow – Best Practices



SFI Field Case #1-KSA: NORM



NORM Storage



NORM Waste

Total 5,000 m³ of NORM disposed
NORM was not pre-treated prior to injection
30+ pCi/gm Radium 226/228 (1.5 Bq/gm)

SFI Field Case #1: NORM Project Site



SFI Field Case #1: NORM Project Site



Louisiana, Chevron Port Fourchon Project

(Summary from SPE 71434, 53821)

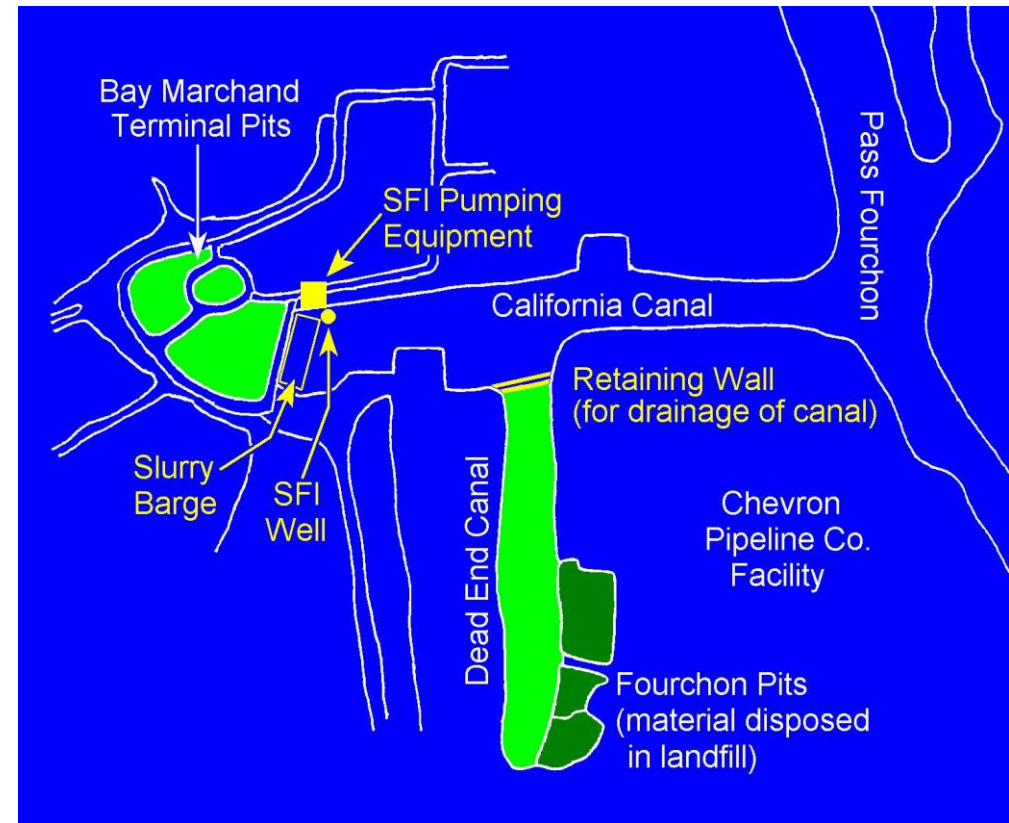
- Port Fourchon, Bay Marchand terminal facility
- Processed oil from nearby offshore platforms since 1949
- Facility cleaned up 1997-2000:
 - NORM: Naturally occurring radioactive material
 - NOW: Non-hazardous oilfield waste
 - Processing pits: Contained drill cuttings, drilling mud, produced sand, pipe scale (barium/calcium precipitate), oily wastes
 - Canal: Sediments were contaminated by overflows from processing pits

SFI Field Case #2: NORM



Location of Port Fourchon

Fourchon Site Map



NORM:

Contamination level

- Maximum ~ 110 pCi/gm Radium 226 (4.1 Bq/gm)
- Average ~ 40 pCi/gm Radium 226 (1.5 Bq/gm)
- U238 and Th 234/Ra 228

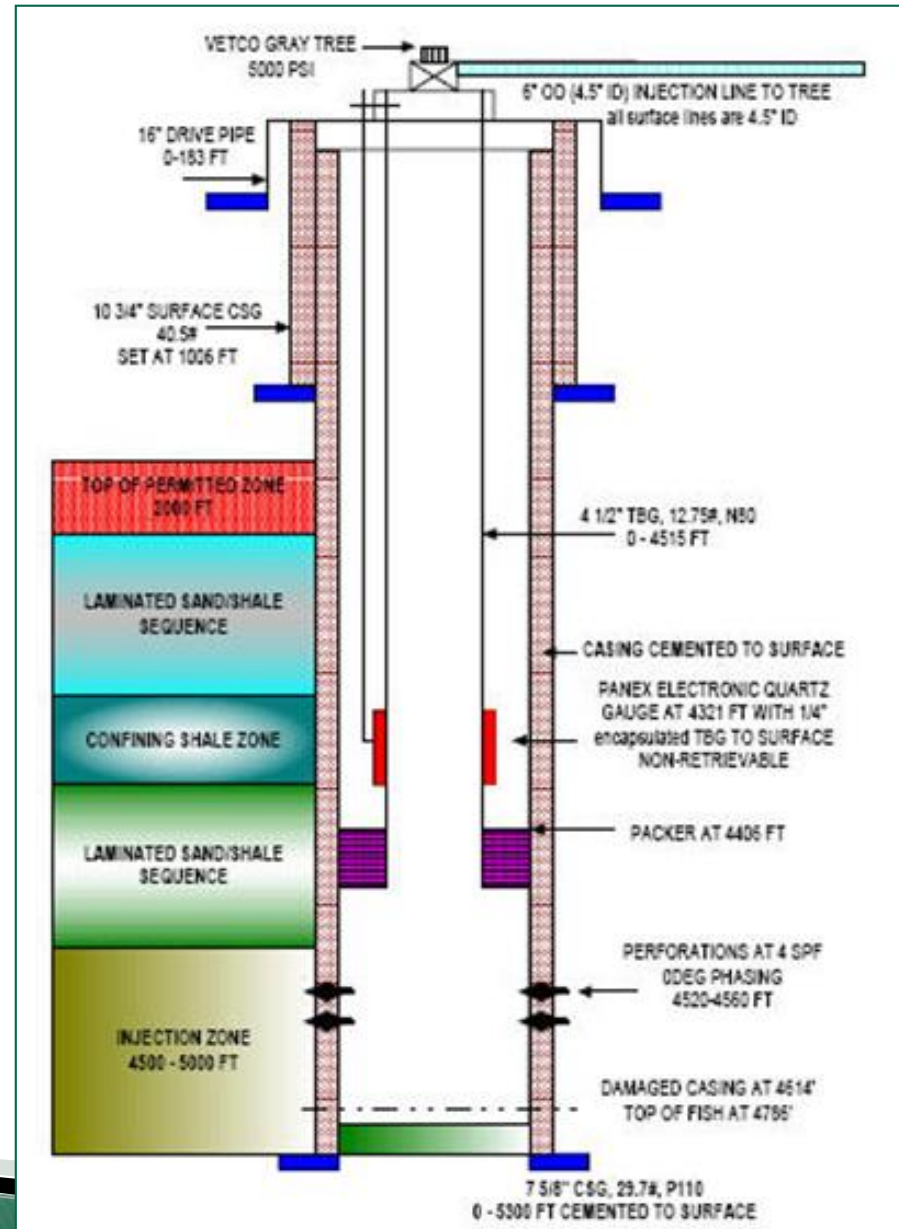
Area

- Bay Marchand Terminal: Pits #1, #2, #3 and some land area
- storage pits for drill cuttings, spent drilling fluids, oily waste, pipe scale, etc

Depth of contamination

- Maximum ~ 12 ft (3.6 meters)
- Average ~ 8 ft (2.4 meters)

SFI Field Case #2: NORM



SFI Field Case #2: NORM

SFI Project – Site Remediation



After....

Final closure criteria:

- upper 15cm soil < 7 pCi/g Ra^{226/228}
- below 15cm soil ~17pCi/g Ra^{226/228}
- unrestricted land use permitted



SFI Field Case #2: NORM

Location	Waste Volume (bbls)
Bay Marchand Pits (Oct 1997 – Sept 1998)	371,600 (59,080 m ³)
Dead End Canal (Feb 1999 – Mar 2000)	623,100 (99,065 m ³)
Other NOW Solids	6,120 (973 m ³)
Total	1,000,800 (~160,000 m ³)

The most common risks/problems effecting overall performance of SFI projects are:

- **Loss of wellbore integrity during injection operations.**
 - Typically related to poor cementing of the disposal-injection well above the disposal zone.
 - loss of hydraulic integrity
 - Injection well collapse/shear above injection formation
 - loss of mechanical integrity
- **Inter-well communication**
 - Hydraulic communication between injection well and offset well(s)
 - containment breach due to intersecting nearby poorly cemented wells
 - Potential for OOZI
- Poor well design wrt the waste type, waste volumes to be injected and disposal zone geology.
 - This factor can result in wellbore plugging and poor formation injectivity.
 - Potential for wellbore integrity problems & OOZI
 - DON'T 'Save' money on the well.....!!!
- Poor geological characterization of the injection zone and target zones.
- Poor (or no) integration of geological assessment, well design, slurry design & injection strategy

Poor integration = poor performance...guaranteed !!!

1. Use 'Best Practices' Workflow.
2. Key Process Monitoring Tools:
 - BHP monitoring at injection well
 - Pump Pressure and WHP are NOT enough
 - Assess formation response to injection operations
 - Formation Testing Program
 - Evaluate formation flow behavior and in-situ stress:
 - SRT to assess stress state & FEP/FER
 - Pressure Fall-off Analyses
 - Tracer & Temperature Logs
 - Evaluate near-well fluid flow & wellbore integrity
 - Fracture geometry
 - Tiltmeters (surface movements)
 - Evaluate fracture geometry at shallow depths (<1000 m)
3. Process Control Analyses:
 - Analyses & Integration of process monitoring data
 - Assessment of injected material in situ & formation response – 'Smart Injection'
 - Wellbore integrity

Environmental Benefits of SFI

- **SFI achieves ‘Zero Discharge’ of wastes**
 - No negative biosphere interaction
 - Protection of USDW, soil quality, air quality
 - Prevents surface water and ground water contamination
- **Does not impair future land use**
 - Protects environmentally sensitive areas
 - Allows for land re-use/development
- **Acceptable to society & community**
 - Reduces pollution to safeguard human health
- **Safe and secure disposal approach**
 - Wastes are safely sequestered
 - Multiple waste stream disposal
- **Efficient & economical waste management strategy**
- **Permanent & secure disposal is best!**
 - Long-term liability and cost to operator/generator is greatly reduced

*To help Clients achieve
Zero Discharge
Operations...*



*...Greater environmental
security with SFI*

Thank-you for your attention...

Questions?

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