Installation of Westbay Multilevel Systems in Challenging Conditions

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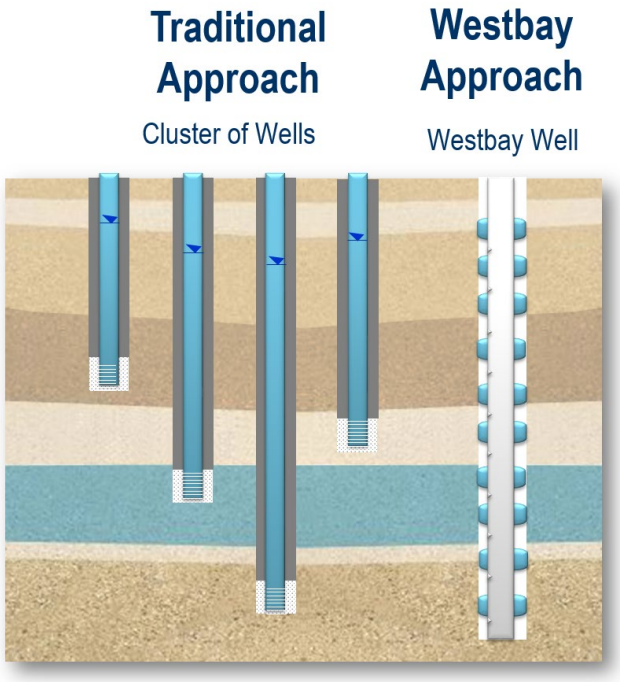
Agenda, Approach and Objectives

Westbay Multilevel Systems Overview
- Westbay systems and components
- Westbay system design
- Westbay system installation (typical)

Site Specific Challenges
- Confidential site overview
- Testing and characterization
- Site conditions vs typical conditions

Hydraulics of Packer Inflation
- Borehole ambient flow conditions
- Packer inflation free body diagrams
- Modified installation techniques

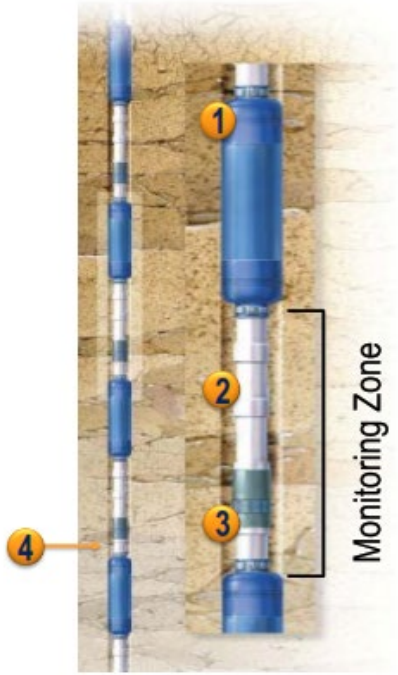
Summary Conclusions



Westbay Multilevel System Overview

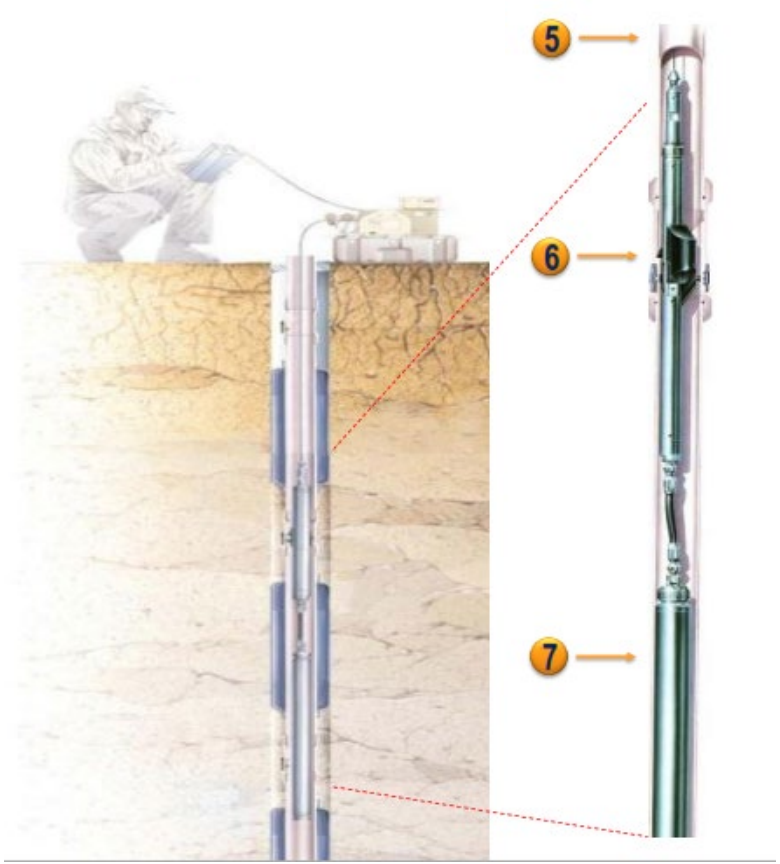
- Multi-level system capable of monitoring discrete zones
- Zones separated by series of inflated packers
- Pressure transducers installed to log pressures at specific zones
- Design based on information gathered during drilling and testing
- System does not require purging when sampling

Westbay Multilevel System Components



1) Packer
2) Measurement Port
   - Pressure Measurement
   - Fluid Sampling
   - Low K Hydraulic Testing
3) Pumping Port
   - Purging
   - Hydraulic Testing
   - QA/QC
4) Central Access Casing
   - PVC or stainless steel

Westbay Multilevel System Components



5) Sealed connections (O-rings)
6) Sampler Probe
   - Measure formation pressures
   - Collect fluid sample
7) Sample Container
   - Gather 250 mL of sample per bottle
   - Sample bottles connected in series

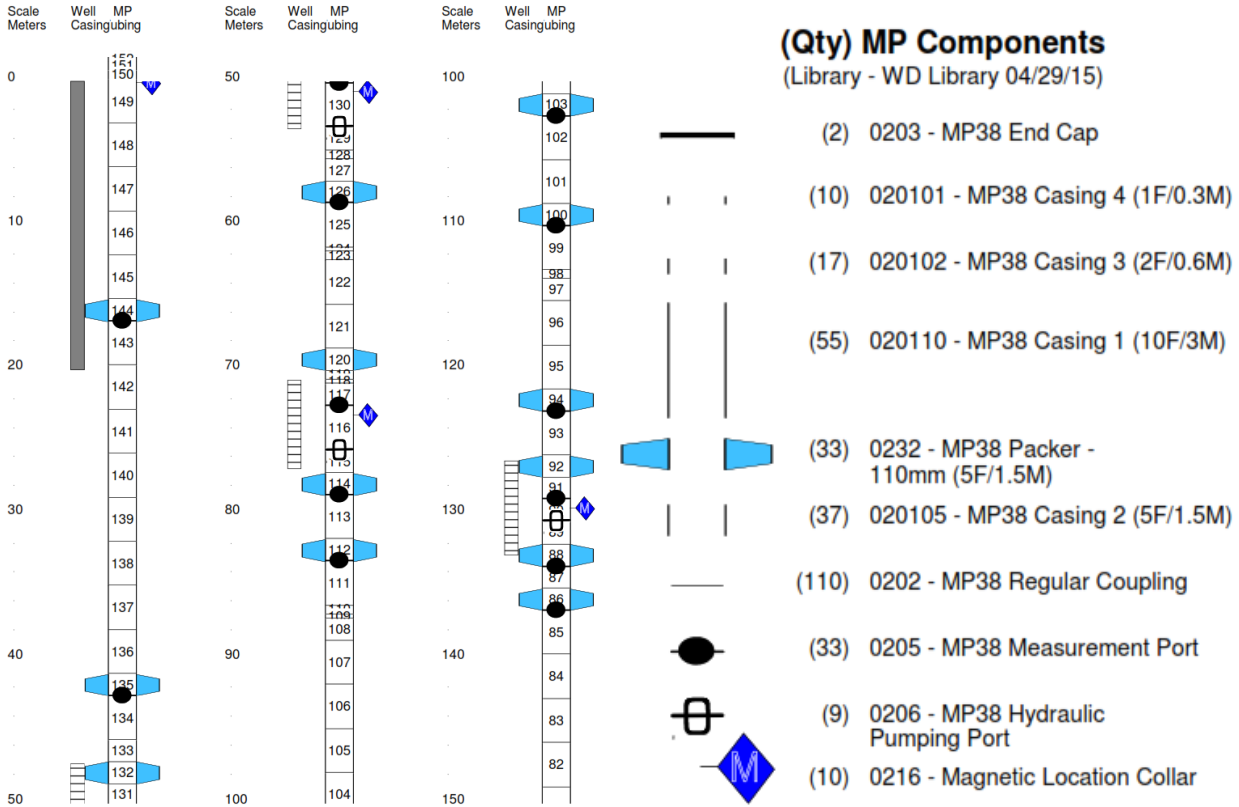
Westbay Multilevel System Components

Westbay MP38 System
MP38 Packer – 110 mm (5F/1.5M)
Part No. 0232

Performance				
Minimum Borehole Diameter[4]	4.8	in	122	mm
Maximum Recommended Diameter	6.3	in	160	mm
Maximum Differential Pressure[5]	150	psi	10.3	bar

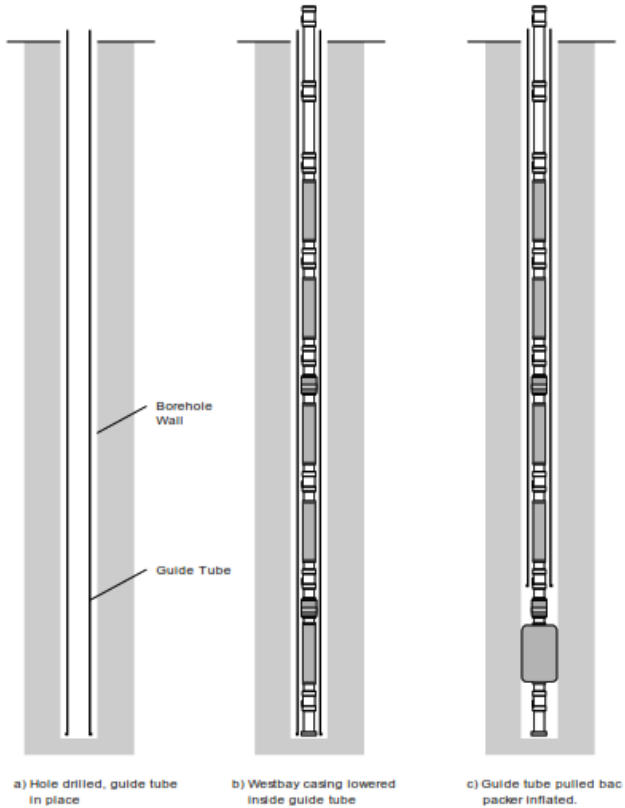
Westbay Multilevel System Design

- Data required for Design:
  - Current Caliper
  - Casing Dimensions
  - Well Construction
  - Water Levels
  - Number of monitoring ports



Westbay Multilevel System Layout

Westbay System Installation (typical)



Typical installation approach:

- Assemble components at surface
- Lower into guide tube or open borehole
- Add water inside Westbay to “float” Westbay into place
- Inflate packers in sequence from the bottom up

Confidential Site Overview

- Four bedrock boreholes – BH 1 to BH 4

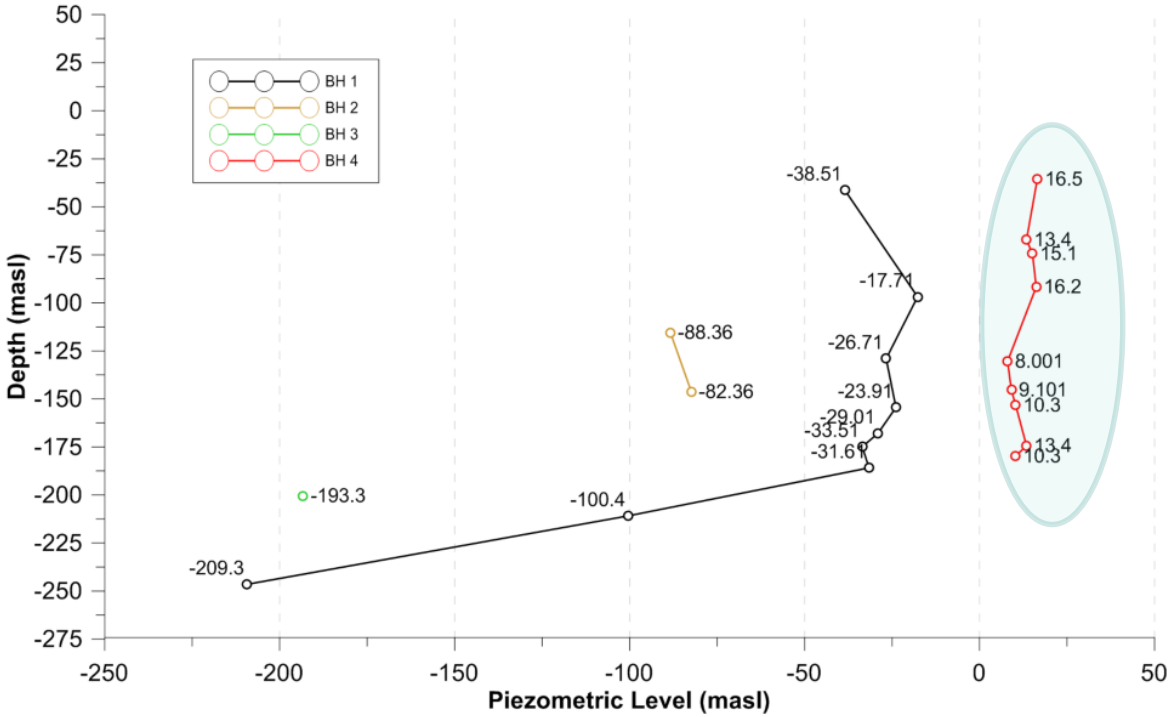
Well ID	6" Casing (mbgs)	Depth to Bedrock (mbgs)	Well Depth (mbgs)	Tagged Water Level (mbTOC)[1]
BH 1	20.0	12.8	294.5	70.3
BH 2	15.2	4.6	201.9	120.6
BH 3	14.3	4.6	241.9	223.7
BH 4	56.1	28.0	208.4	37.0

1. mbTOC = metres below Top of Casing.

Testing and Characterization

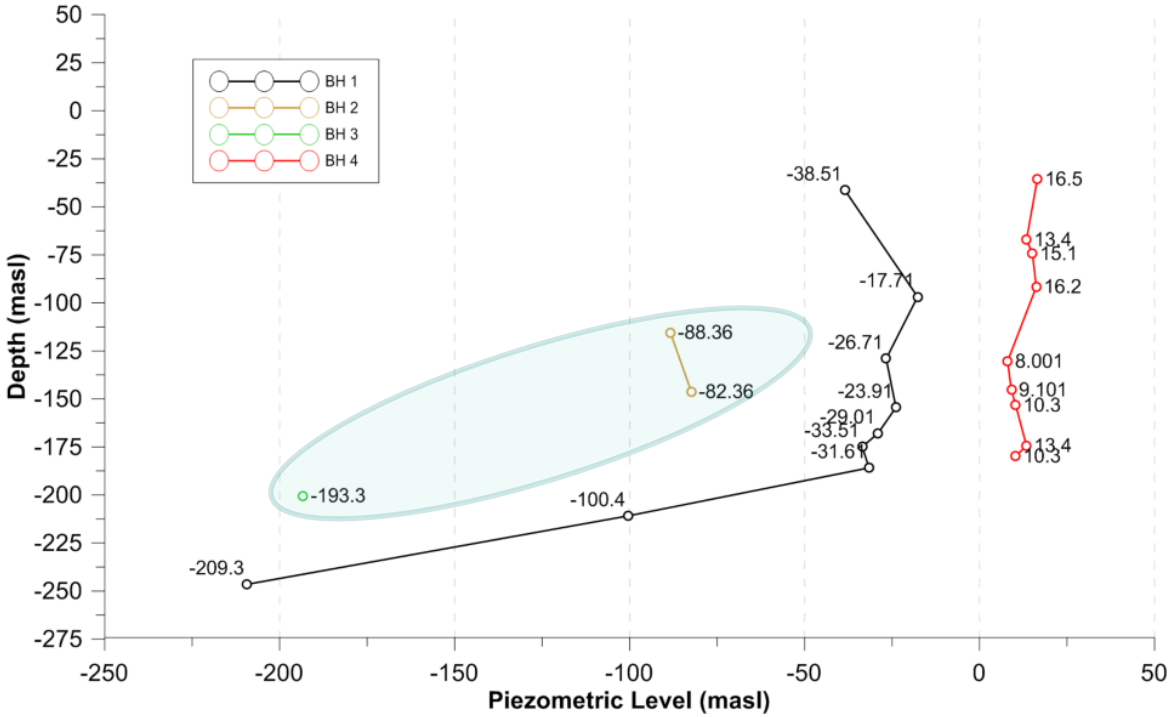
- Lithological logging during drilling
- Geophysical Suite
- Hydrophysical Suite
- Straddle Packer Testing (SPT)
  - Multiple 10/20 ft sections at specified depths
  - Rising head tests
  - Constant discharge tests
  - Water sampling

Testing and Characterization



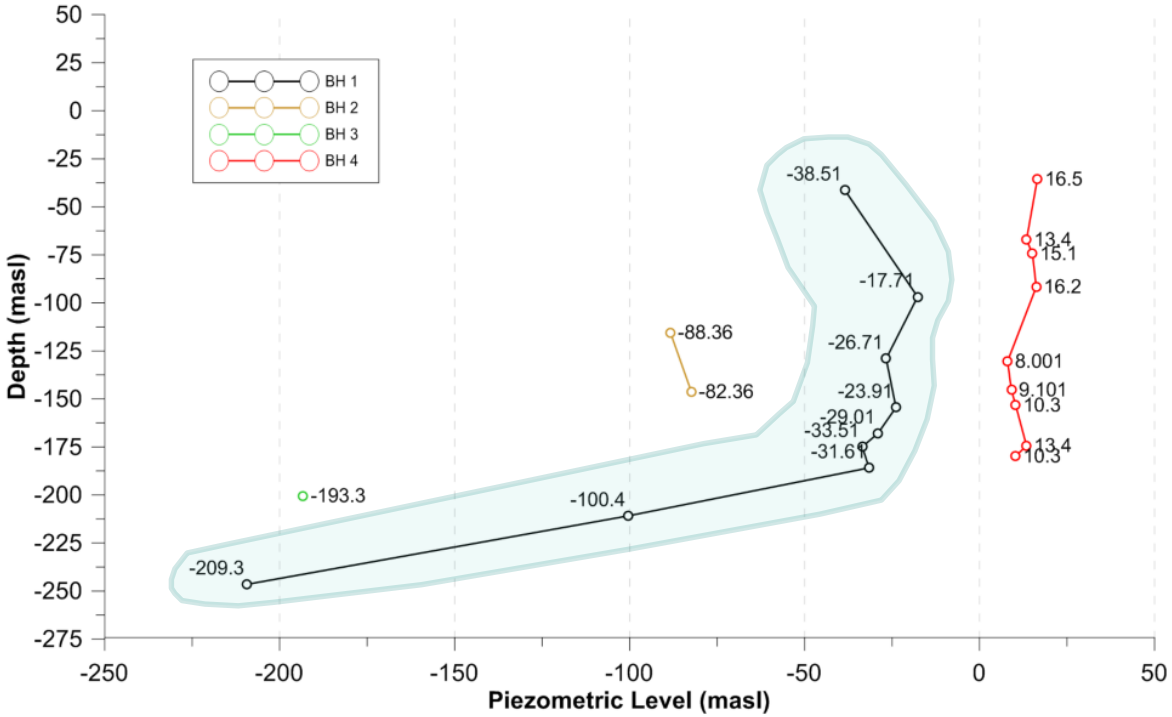
- One Well BH 4 considered typical conditions
  - Piezometric Levels ranged from 8 to 16.5 masl
  - Water level 37 mbTOC

Testing and Characterization



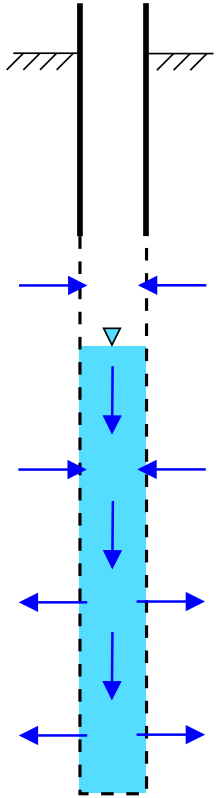
- Two wells BH 2 and BH 3 characterized by deep water tables
  - BH 2 water level 120.6 mbTOC
  - BH 3 water level 223.7 mbTOC

Testing and Characterization



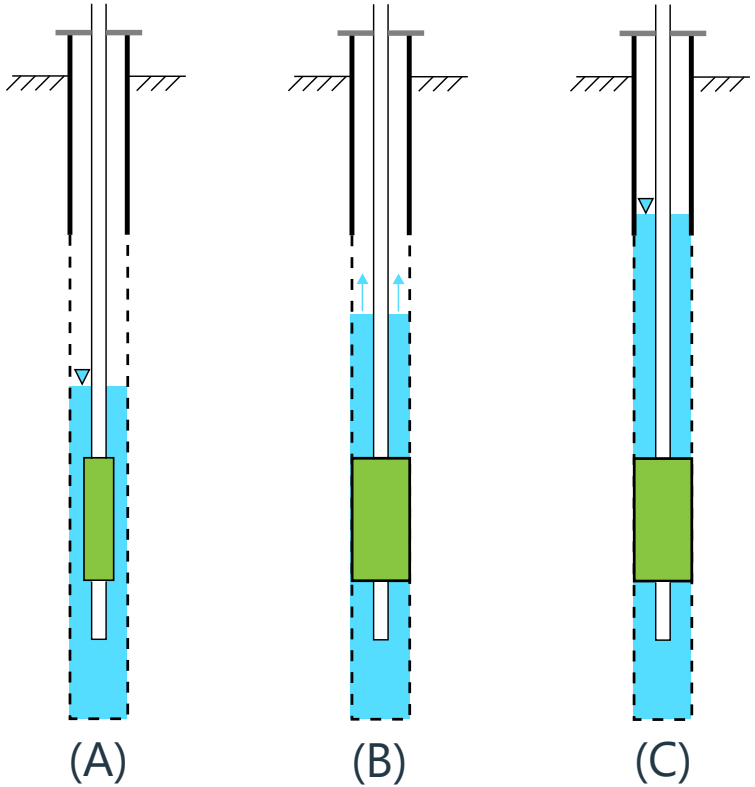
- One well BH 1 exhibited a large head differential of approximately 190 m

Borehole Ambient Flow Conditions



- Groundwater always flowing in/out of borehole
- Inflow/outflow in each discrete zone depends on:
  - Transmissivity
  - Water pressure
- Inflows/outflows will balance-out to a blended water level

Simplified inflation of a single packer

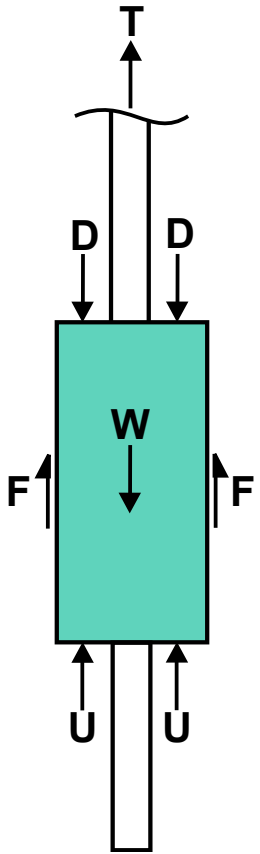


A) Initial ambient conditions prior to inflation

B) Inflation of packer, water pressure changes above and below packer

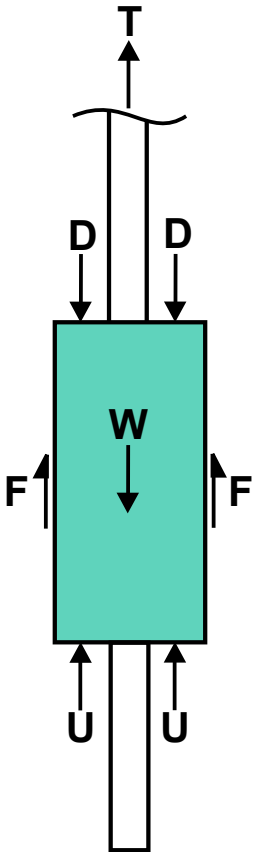
C) Stabilization of pressures, new ambient conditions

Single Inflated Packer Free-body Diagram



- D = Downward force from water above packer
- U = Upward force from water below packer
- F = Frictional force on packer along borehole wall
- W = Weight of Westbay system
- T = Internal tensile load on Westbay system

Single Inflated Packer Free-body Diagram



- Design inflation sequence to satisfy Westbay strength criteria
- Internal load on Westbay system
- Must account for:
  - Long-term static water pressures
  - Short-term changes in interval-specific pressures during inflation

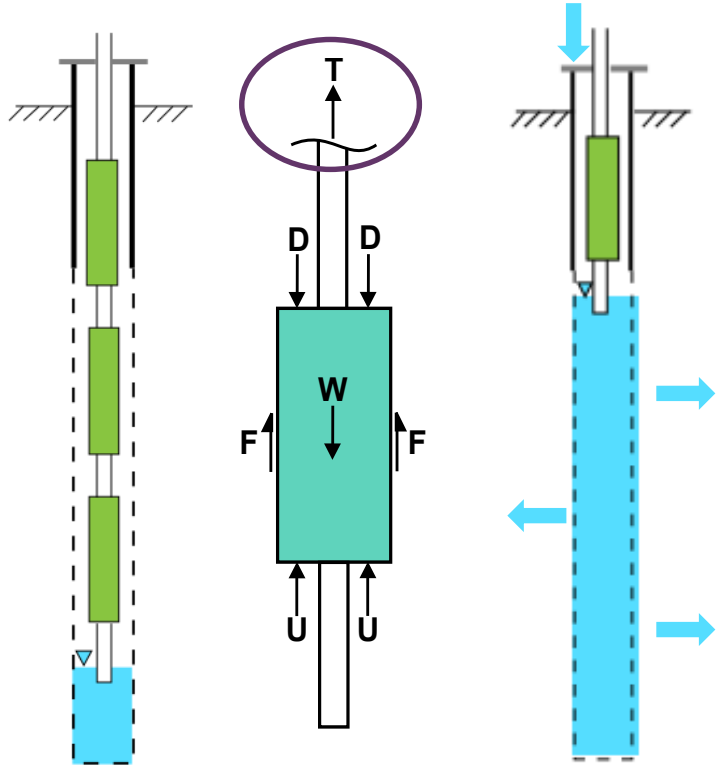
Modified Installation – Deep Water Tables

BH 2 and BH 3:

- Deep water tables
- Tensile strength of coupler connecting WB casing = 1400 lbs

Solution

- Increase water level
- Characterization data used to determine the rate and volume of water to add
- With higher water level Westbay system floated into place for inflation of packers from the bottom up

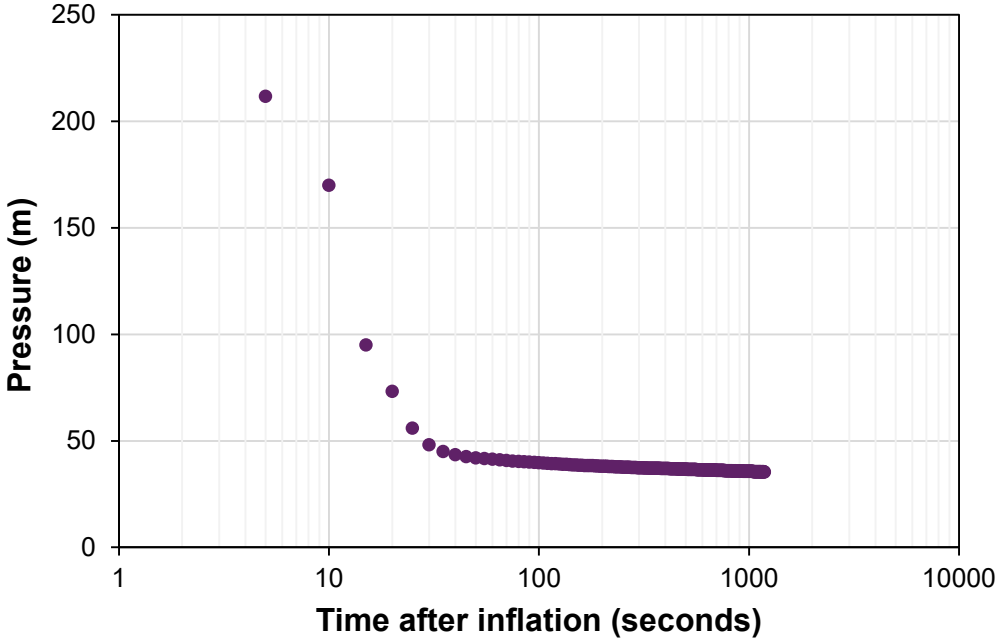


Modified Installation - High Differential Pressure

BH 1 Conditions:

- Downward gradients >10 measured during SPT
- Typical inflation sequence would create:
  - Potential ~190 m pressure differential on 1st inflated packer
  - ~7000 lbs internal load on Westbay in early stages
  - Strength of WB casing coupler = 1400 lbs

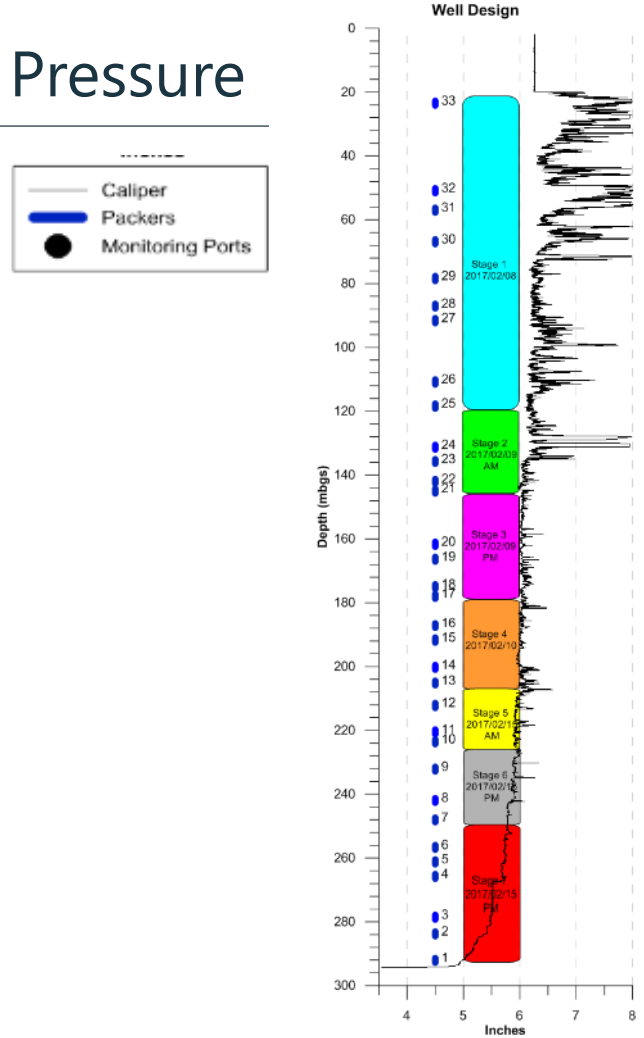
Pressure below packer in BH 1 at 284 mbgs during SPT



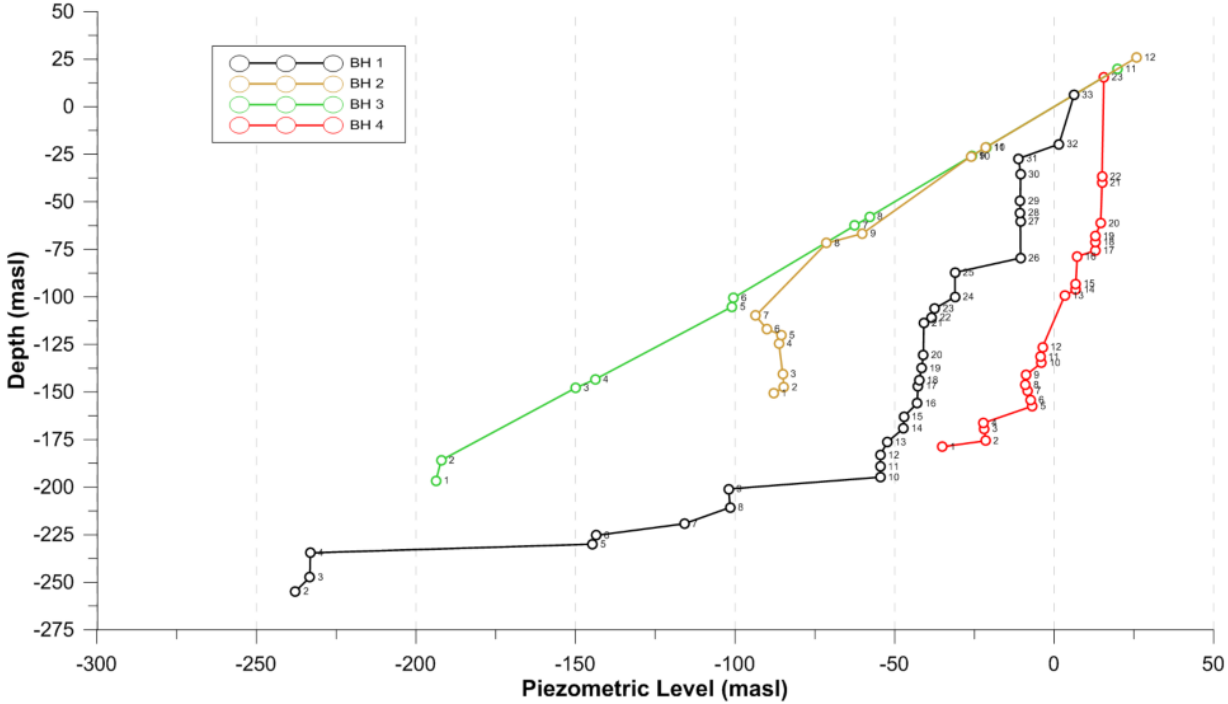
Modified Installation – High Differential Pressure

Solution

- Packer inflation designed to account for low pressures at bottom of borehole
- Inflation of packers in groups
- Pressure profiling for interval heads after inflation
- Sequential inflation limited the stress on Westbay system
- Allowed for the stress to distributed across multiple packers



WestBay Heads (BH1-BH4)



Summary Conclusions

- Westbay multilevel systems are effective for depth-discrete monitoring of:
  - Water levels
  - Water sampling
  - Hydraulic testing
- Successful Westbay installation requires consideration for:
  - Borehole conditions
  - Westbay system component properties and limitations
  - Dynamic relationship which can develop during and after packer inflation


wood.