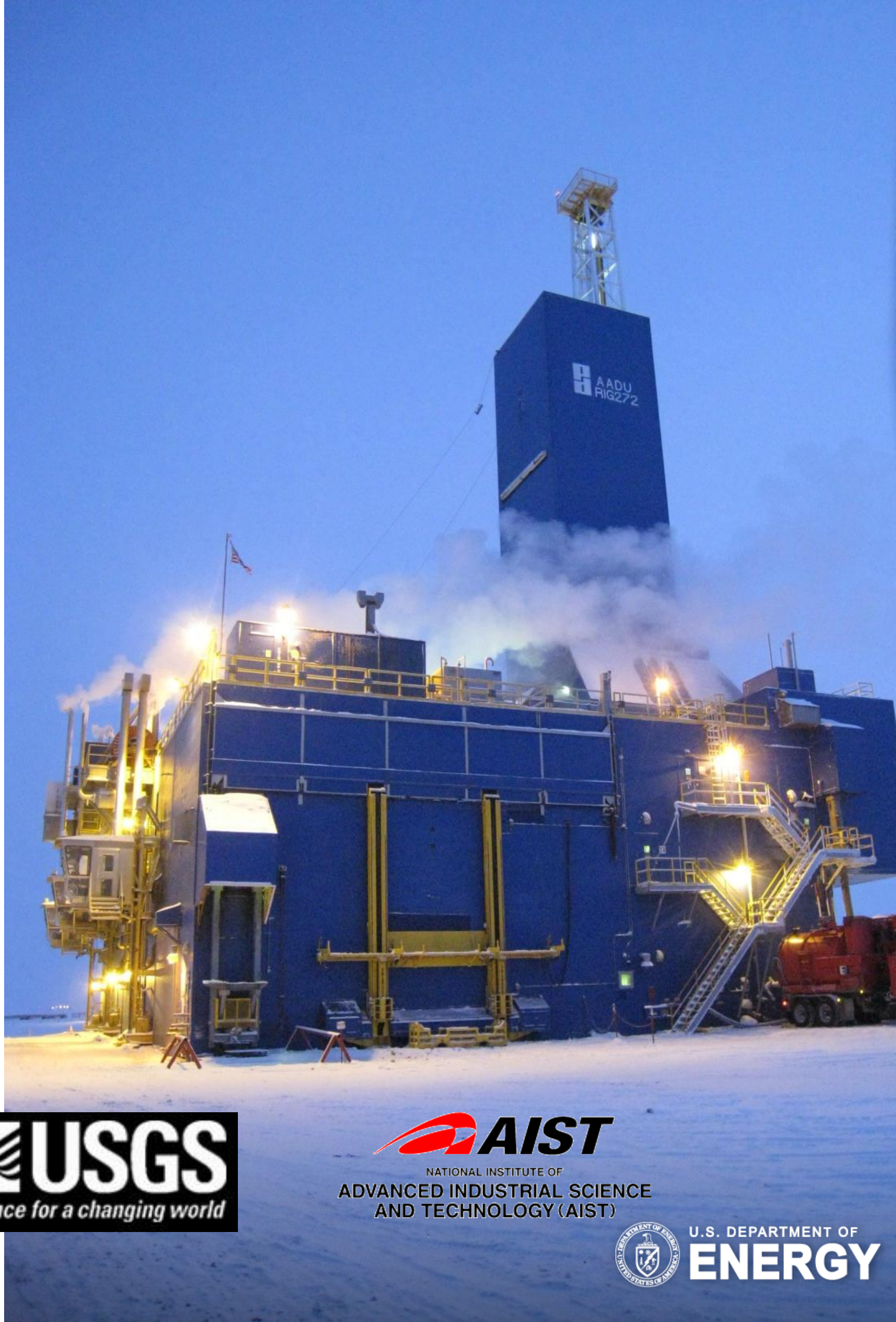
Gas Hydrate Field Experiments on the Alaska North Slope: Project Status

Ray Boswell

Methane Hydrate Federal Advisory Committee Meeting: Galveston, TX

February X, 2020



NATIONAL ENERGY TECHNOLOGY LABORATORY

JOGMEC

USGS science for a changing world

AIST NATIONAL INSTITUTE OF ADVANCED INDUSTRIAL SCIENCE AND TECHNOLOGY (AIST)

U.S. DEPARTMENT OF ENERGY

Status of GH Science (wrt Production Tech.)

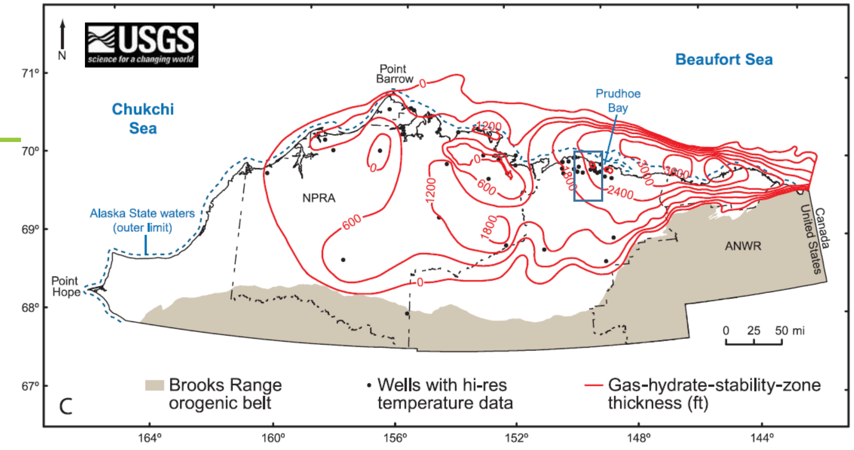
Extended Duration Field Tests are the Global #1 Priority in GH R&D

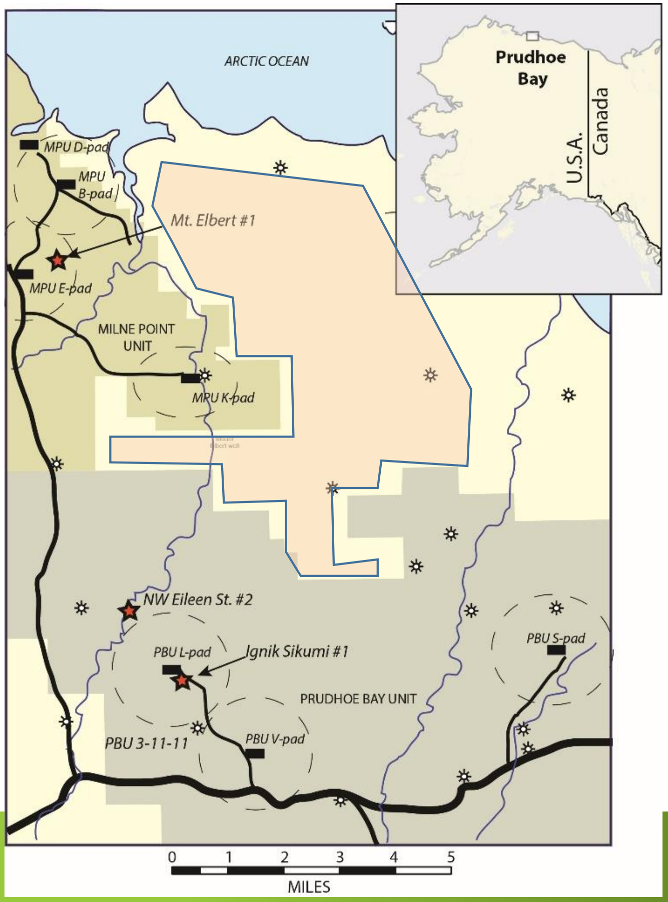
- Active government-led R&D underway in the US and by key US allies for whom future energy security is a priority for US and global energy security. (Japan, India, S. Korea).
- These nations have invested $1billion+ in field programs but have to date been unable to observe hydrate production response for sufficient duration.
  - Onshore (Canada) → lack of infrastructure
  - Offshore (Japan) → high costs and operational complexity
- A two-year effort by US, Japan, and State of Alaska indicated high costs and risks of test outside the PBU infrastructure area.
- ANS greater PBU region provides the only known location to enable viable long-term scientific testing.

Quick History

GH Evaluation in Alaska and N. Canada

- **GH system known in Arctic since the 70s**
  (industry tests NW E-St-2. USGS. Mallik beginning '98)
- **2004: "Hot Ice" Project**
  (failed G&G effort)
- **2007: MPU Mt Elbert Project**
  (off ice: G&G and operational success)
- **2006-07: Japan-Canada Mallik Test**
  (successful depressurization demonstration)
- **2010: PBU L-pad long-term depressurization & injection test**
  (legal/logistical barriers)
- **2011-12: PBU "Iġnik Sikumi" test**
  (on ice test focused on gas injection and well operations)
- **2013: Unit interest waned**
- **2014- 2015: US-Japan AK State Lands Review (w/ DNR)**
  (unacceptable geologic and operational risks)





Project Structure

Statement of Intent (6/2008)

Memorandum of Understanding (4/2013)

Memorandum of Understanding (11/2014)
CRADA (12/2018)

TECHNICAL

CONTRACTUAL

PHASE 1 (Completed): Stratigraphic Test Well

NETL → Contract to PRA → Drilling Services Agreement with BPXA

PHASE 2 (Planned): Production Test Wells

(w/2nd Monitoring well and surface facilities)

Alaska DNR + bp + Hilcorp Alaska: Clarification of the nature of 3rd Party Operations in the Unit and handling of project legacy issues

NETL → Contract to Operator → Drilling Services for 2nd Monitoring Well
Select other services (i.e. water handling/disposal

JOGMEC → Contract to Operator → Services for Surface Facilities construction/operations
Drilling/Testing Services for Production Test Wells

Project Structure

Jointly funded and managed

MOU (general)
CRADA (project specific)

Steering Committee

Brian Anderson (Director of NETL)
Timothy Reinhardt (Director of Supply and Delivery, Office of Fossil Energy, DOE)
Toshikazu Ebato (Executive Vice President)
Koji Yamamoto (Group Leader of Methane Hydrate R&D Group)

Authorize implementation plan at each stage gate.

Administration Coordinator

Contract formulation and execution and budget expenditure.
Nori Okinaka (JOGMEC)
Don Hafer (NETL)

R&D Committee

Science/technology implementation plan.
Nori Okinaka (JOGMEC)
Ray Boswell (NETL)
Tim Collett (USGS)
Many other per Topic

Site Representatives

Real-time decision-making during field programs.
Ray Boswell (NETL), Tim Collett (USGS), Scott Marsteller (NETL)
Nori Okinaka, Motoi Wakatsuki (JOGMEC)

Decision Making Mechanism

Additional Agreements:
DOE-FE - METI (Japan) SoI: DOE/FE – AK DNR MoU

Program Objectives

Robust, Proven, State-of-art Equipment for Well Sampling, Completion, and Monitoring

Science

Full characterization of GH systems → Physical Properties, Geomechanics, Petrophysics

- Sidewall pressure coring (STW)
- Whole core pressure coring (GDW)
- Full suite LWD and wireline logs (all wells)

Observation of controlled perturbation → Dynamic Geomechanics, Petrophysics, Heat Flow

- Fiber-optic Strain, Acoustic, and Temperature Monitoring
- Pressure monitoring (cables and/or gauges)
- Monitoring inside (PTW) and outside (PTW, STW, GDW) casing

Time SeriesVSP via DAS → Reservoir System Response

Technology

Assessment of Mitigations to emergent production challenges (heat flow, permeability, geomechanics)

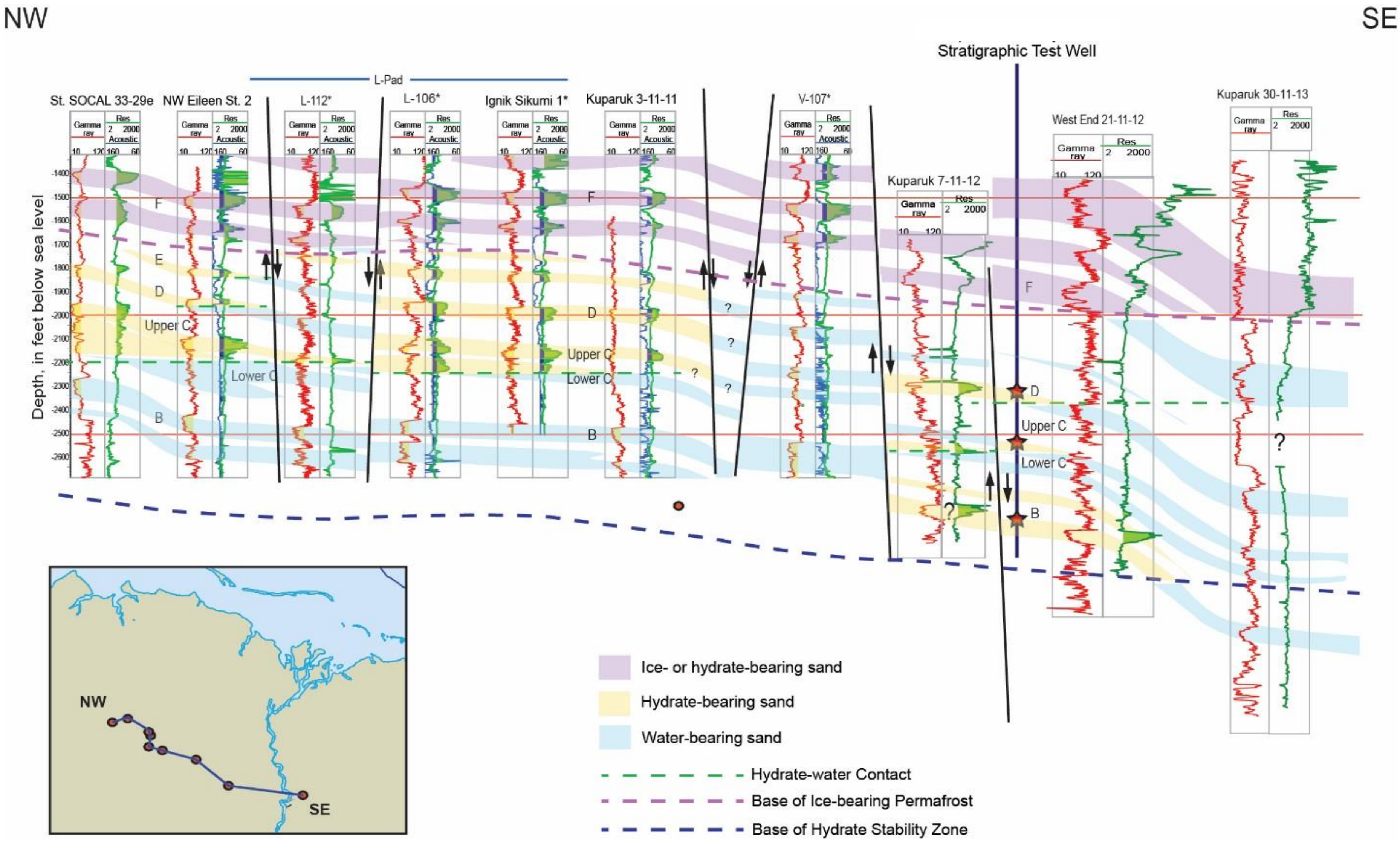
- Sand control/completion/stimulation/shut-in
- Artificial Lift; Hydraulic isolation

Improved evaluation/prediction of productivity and potential

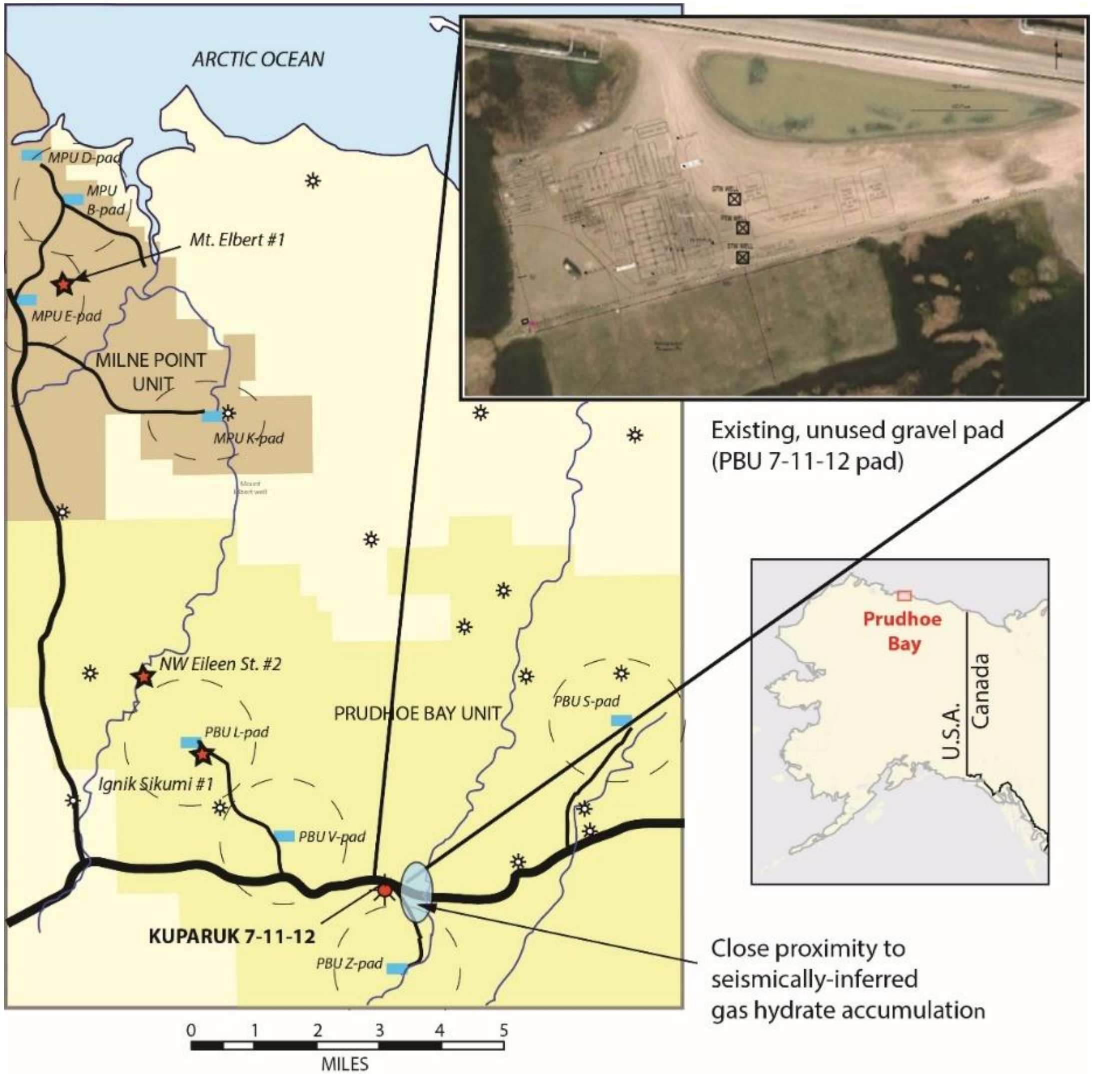
- Numerical simulation (needed validation/calibration datasets)

Examples of tools under consideration

Review of Sites: Westend PBU



2016: Return to the Prudhoe Bay Unit

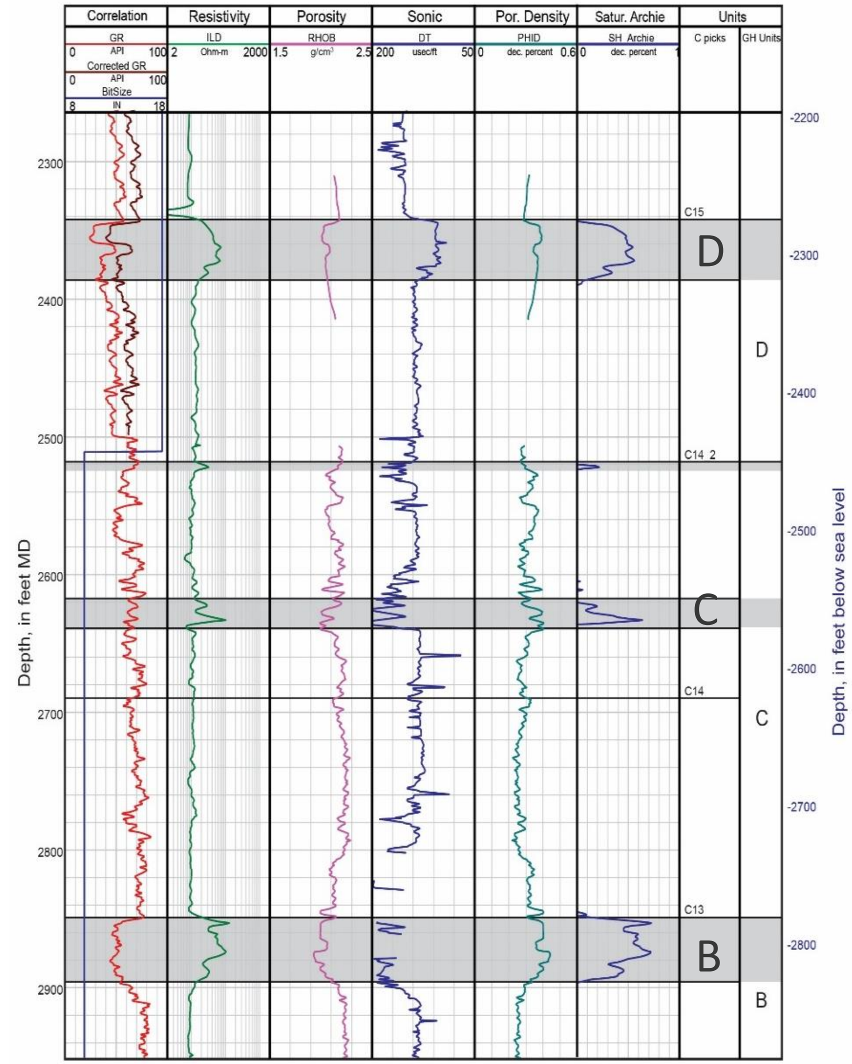


- Working Interest Owners agreed to consider a test that could be conducted with no interference to ongoing operations
- AK DNR/PBU provide regional seismic data
- Promising location identified accessible from an unused gravel pad along a year-round road.
- Existing well and seismic data evaluated to assess geologic risk

Kuparuk 7-11-12 Well Site (PBU)

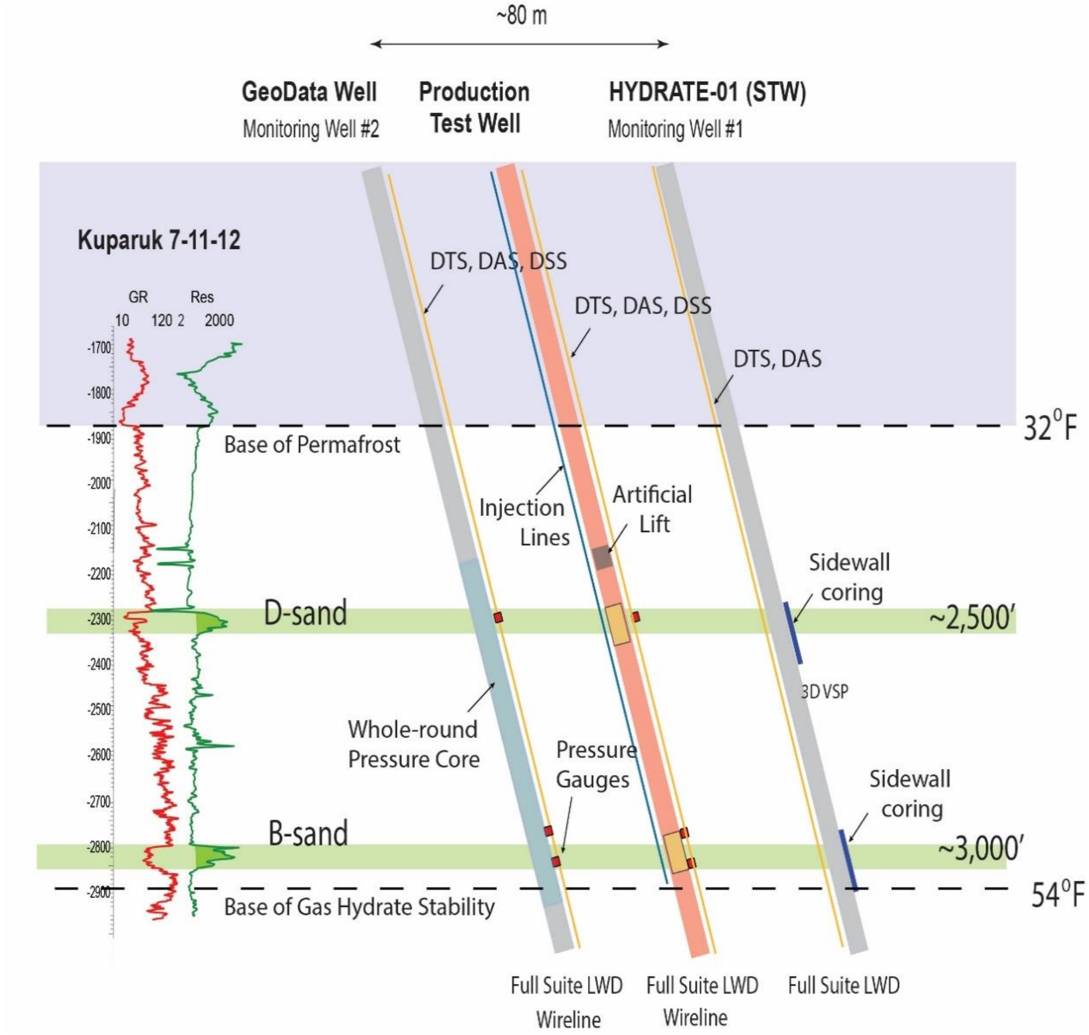
Confirmed GH in D sand. Limited GH in C sand. Uncertain GH in B sand.

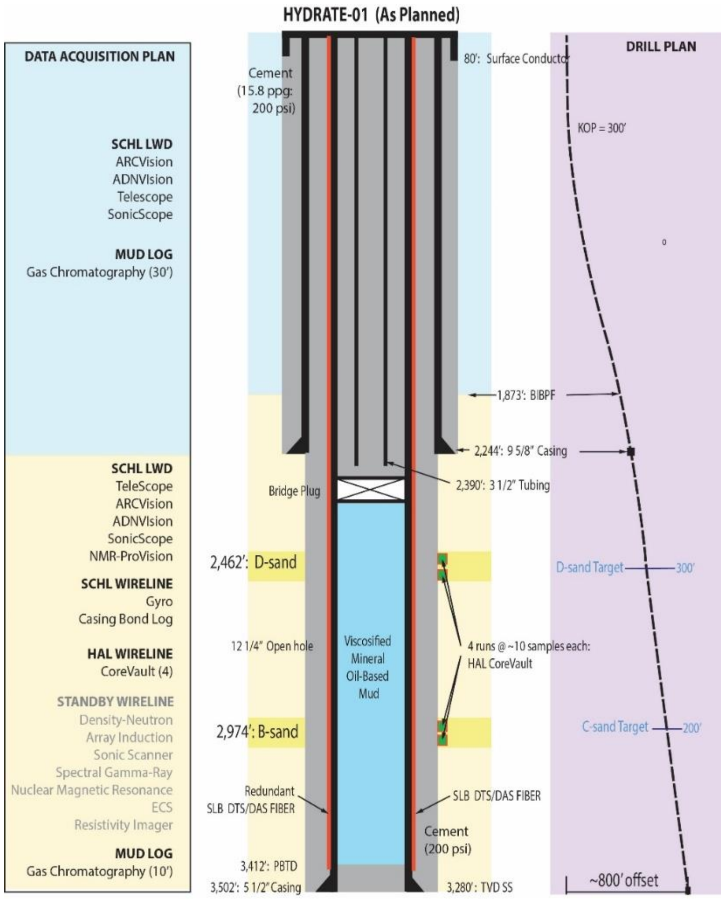
- Two older exploration wells from pad
- D-sand: GH likely (low geologic risk)
- C-sand: limited charge.
- B-sand: HC-charge but poor log quality.
- Drilling-disturbed at time of logging
- B-sand predicted to occur within 100’ of BGHS
- Slight well deviation: BHL away from old boreholes
- Assess potential for nearby free-gas or water
- Map faults



Proposed 7-11-12 Field Program

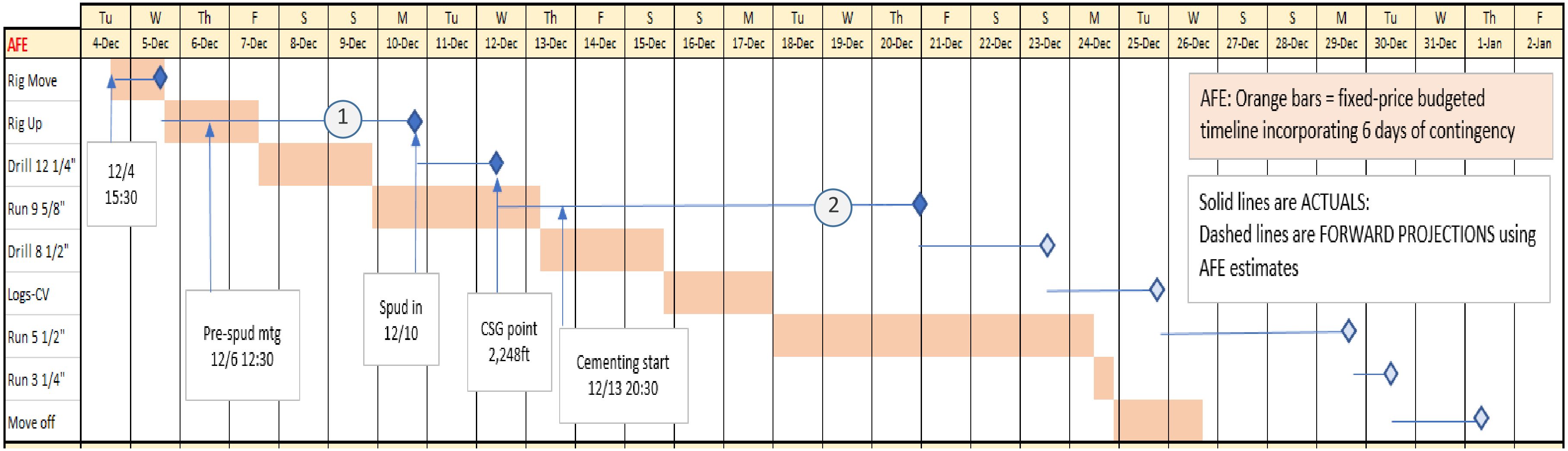
Approved by PBU: BPXA agrees to operate STW (only) as a part of Unit Business.





December 2018 STW Operations

Safe Operations; no injuries or HSE events.



AFE = planned 22-day operational timeline including BAU contingencies = basis for the Fixed-Price estimate.

ACTUAL includes several minor incidences and two primary events of lost time

- (1) An initial 3 day delay prior to well spud that was the result of PBU Operations.
- (2) A second 5-day delay occurred during running surface casing and setting up mud temp controls to drill out.

Ultimately ~25 days of operations (3 days over fixed-price plan).

Data Acquisition – Results Detail

Drilling/wellbore quality (to allow reliable data collection)

- FULLY ACHIEVED: both targets penetrated within provided target*. Mud temperature maintained within set limits (as modified). No incidents of induced GH dissociation; hole in gauge.
- NOTE: Log data indicate 14' fault present in close proximity to wellbore.

Logging-while-drilling (data to confirm/characterize reservoir condition)

- FULLY ACHIEVED: outstanding quality data with all tools!
- NOTE: Sonic data – muted reservoir response in lower portion of B target. Verified proper tool response through two additional MAD passes across the reservoir.

Contingency Wireline data

- DEFERRED PER PLAN: not required due to high quality of LWD data

Sidewall pressure cores (to allow grain size analyses & test well completion design)

- FULLY ACHIEVED: 34 samples recovered spanning full extent of both reservoirs.
- NOTE: Attempts (in US and in Japan) to gather additional petrophysical data from the best samples ongoing.

Fiber Optic cable installation (to enable use of STW as monitoring well)

- FULLY ACHIEVED: two (one as backup) distributed temperature/acoustic sensor cable packages were installed on outside of casing and successfully tested.

Bottom-hole assembly for main hole (from Schlumberger)

*removal of rotary steerable system to assist in mud chilling effort resulted in reduced well directional control. Target was hit 70' east and 20' south of target, within agreed 100' target radius.

Easily Correlated Short Step-out

Unit D

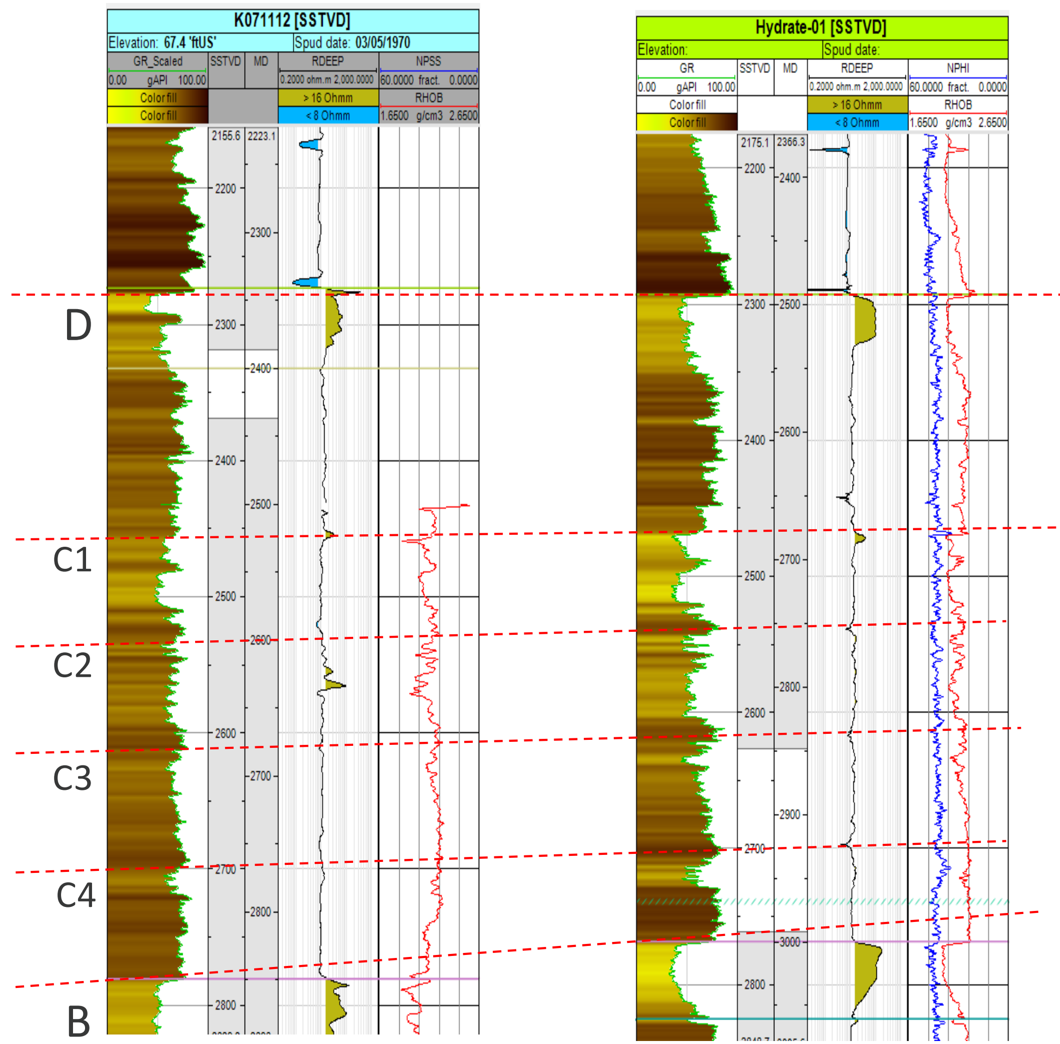
- In better condition (no internal shale break; cleaner top)

Unit C

- Virtually identical.

Unit B

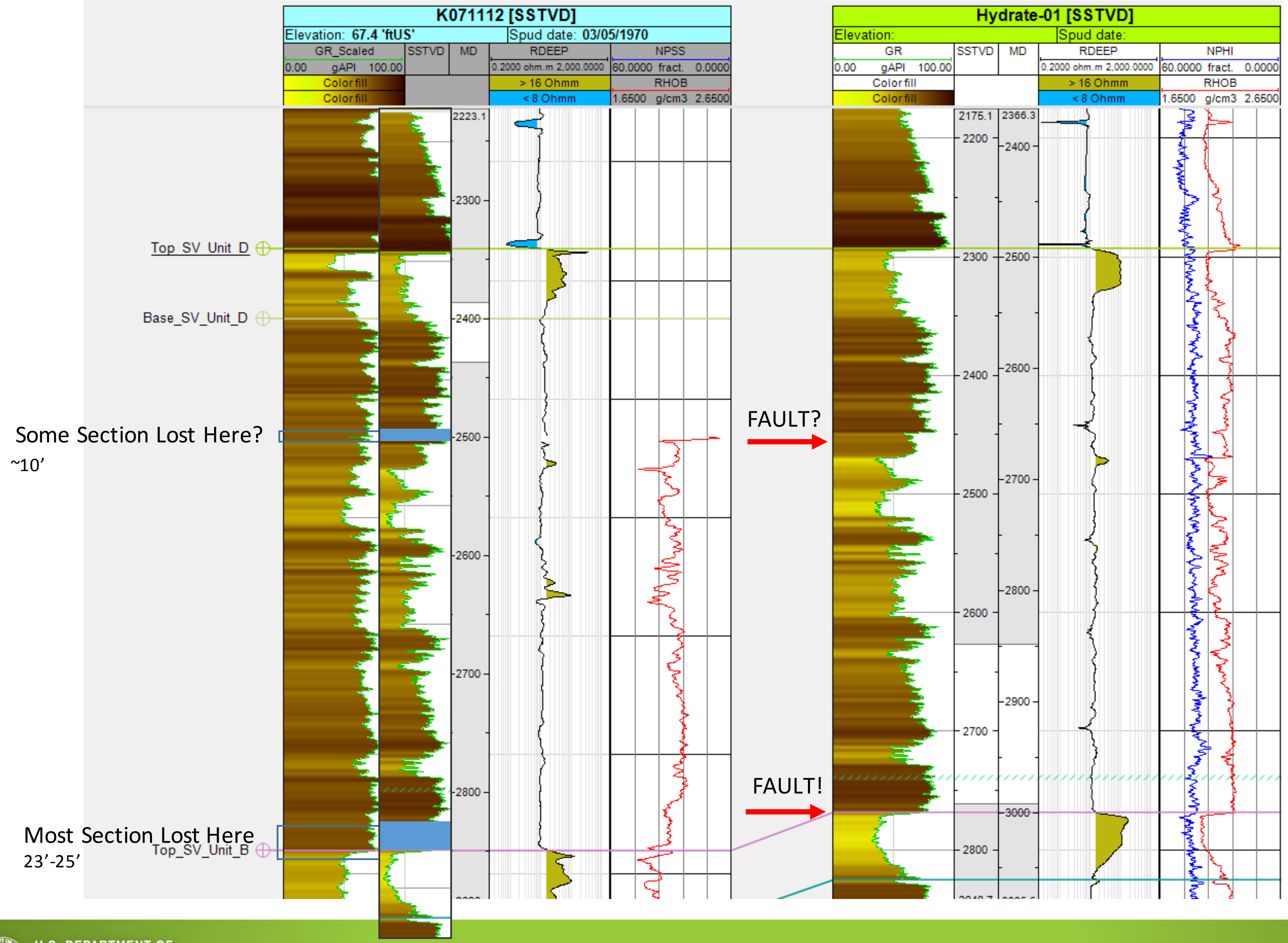
- In better condition (lower GR); more uniform RES and DEN); clear GH indicators (SON)



7-11-12 well

STW

Inferred Faulting in the Hydrate-01 well



Summary STW Log Data

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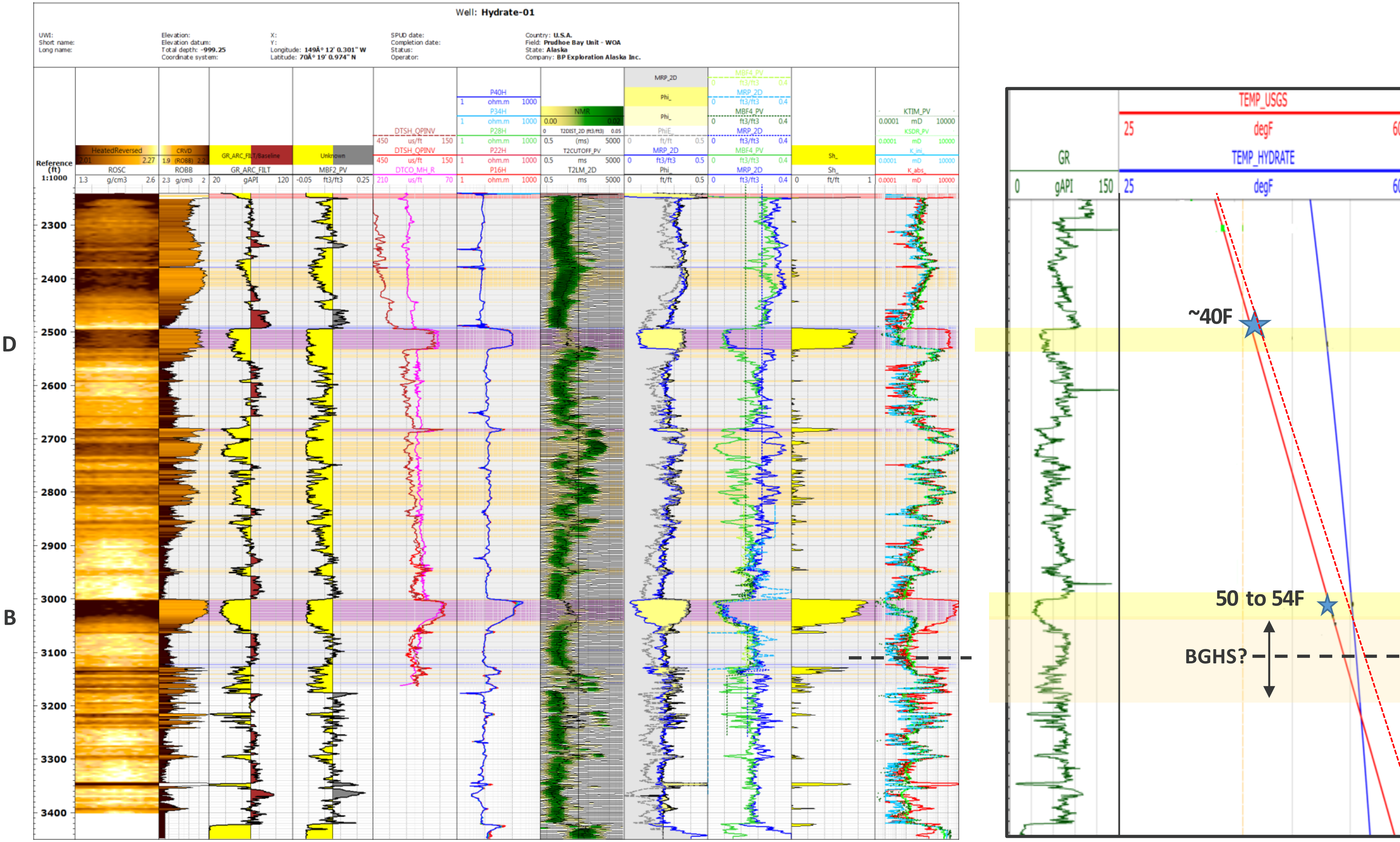
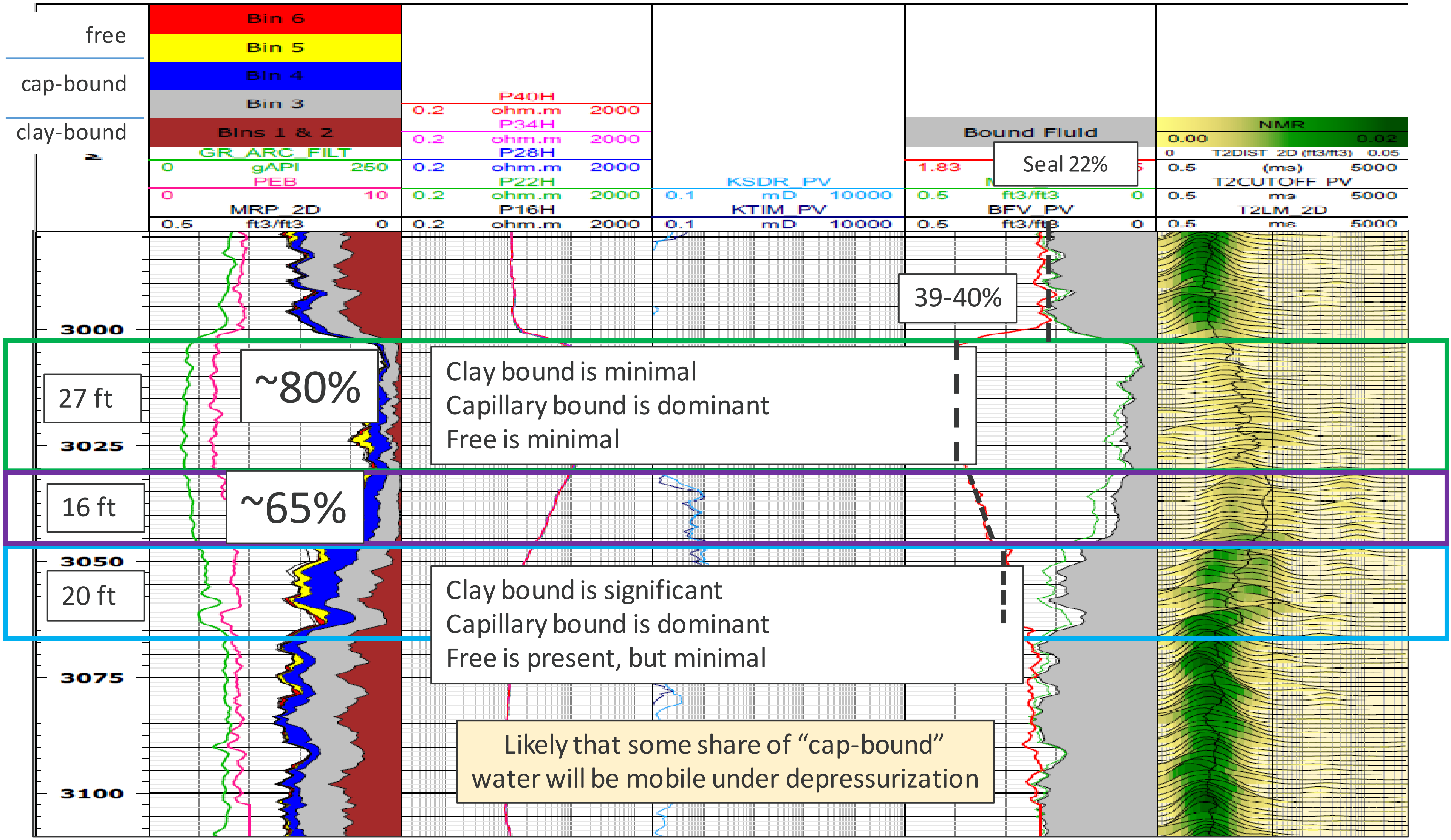
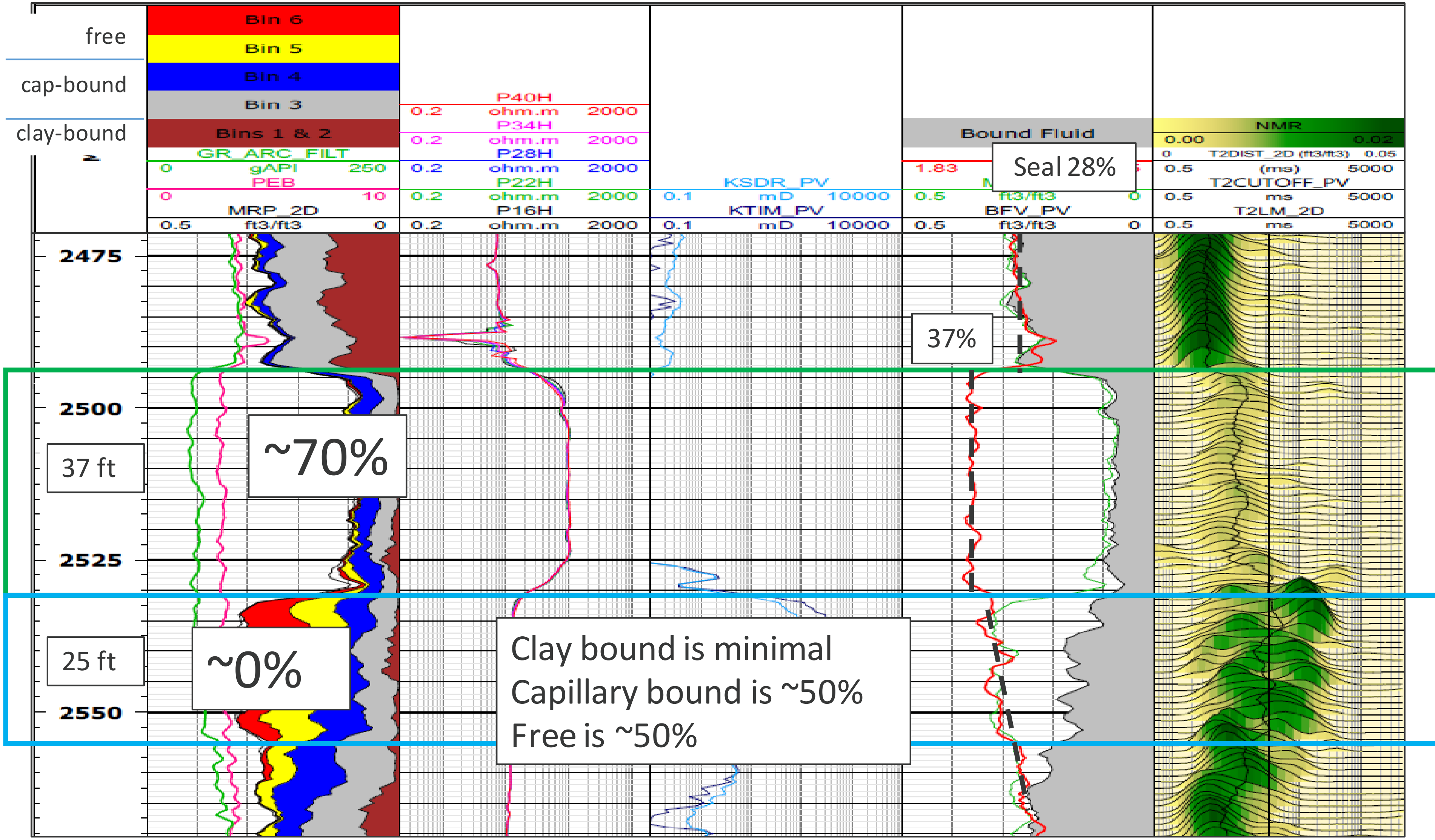


Log Data: Unit B



Log Data: Unit D



Ongoing Site Monitoring

Funded by JOGMEC

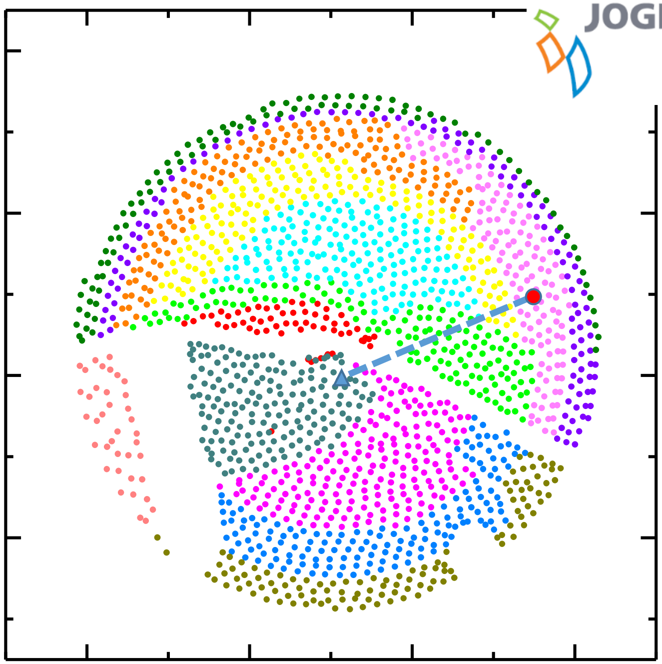
DAS-VSP utilizing FO DAS cables

- Among largest known DAS-VSP acquisitions to date
- Local structural/stratigraphic heterogeneity
- Regional well to seismic tie
- Phase distribution
- Additional 3D-VSPs planned (before, during and after testing).

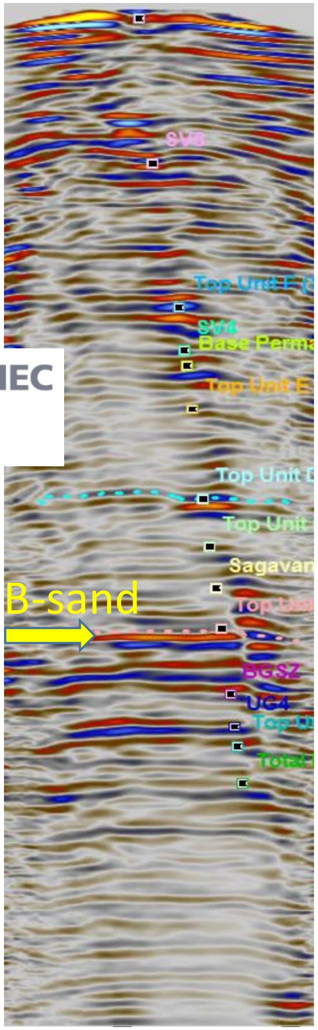
Sub-seismic fault imaged

- Interpreted from log data
- Not visible on surface 3-D seismic

Baseline surveys for elevation (subsidence)

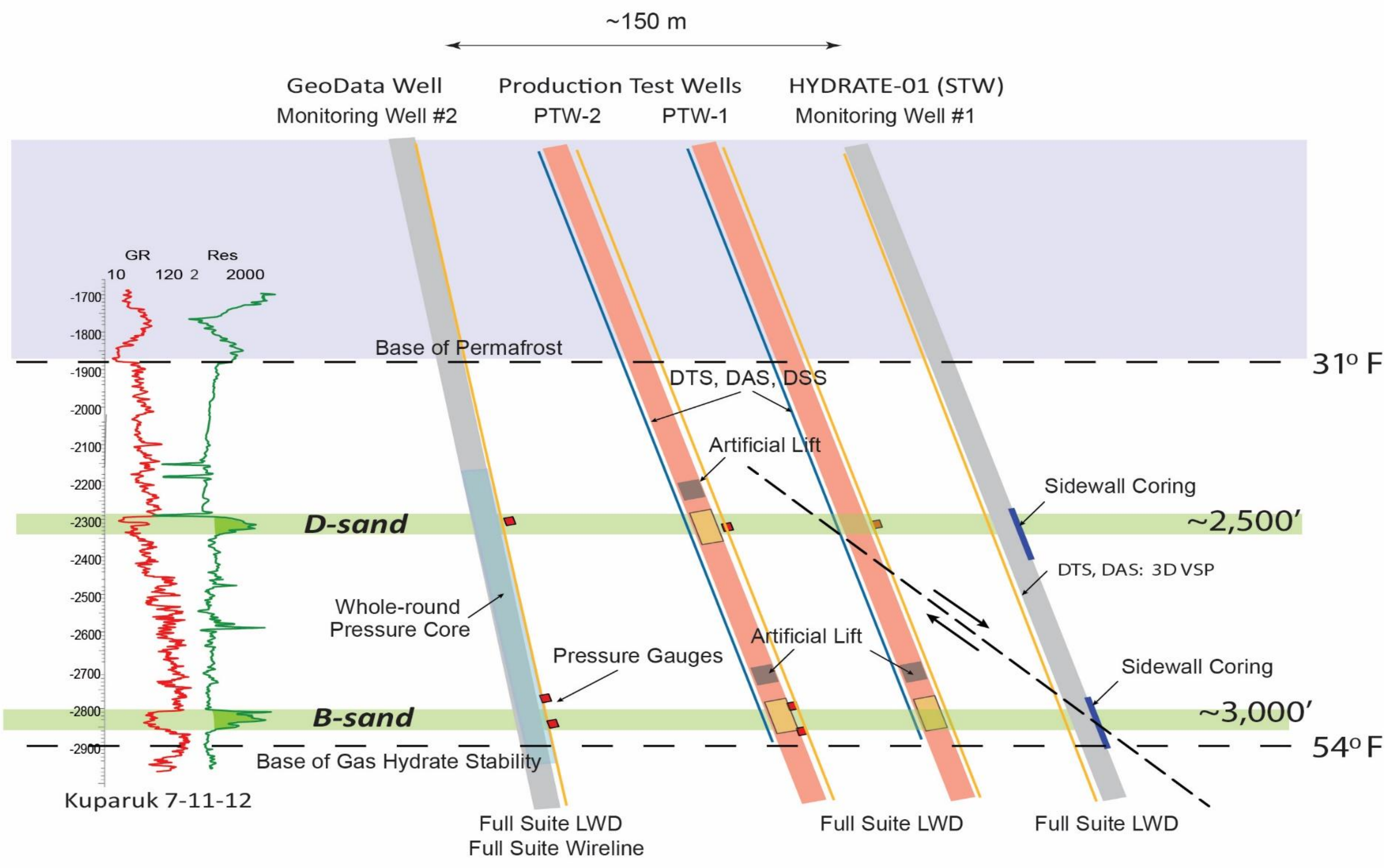


JOGMEC



Current Testing Plan

Addition to the plan of a second PTW to mitigate risk/expand test flexibility



GDW and PTW-1, PTW-2 Data Acquisition

- **GDW LWD:** TeleScope; arcVISION; adnVISION; SonicScope; PowerDrive.
- **GDW WLL:** Not contingent. PEX; RtScanner; SonicScanner; CMR/MRScanner; HNGS; QuantaGeo; ECS
- **GDW:** Left in accessible state for production logging: Gyro; IsolationScanner; RST
- **PTWs Surface LWD:** Simplify (PowerDrive; MWD; GR) to maximize hole quality (assuming data success in GDW)
- **PTWs Main LWD:** As GDW, with WLL (as GDW) contingent on data quality
- **Utilize HPTC in GDW.** Stage PCATS labs on location. No planned conventional coring
- **GDW-PTW Mud-logging** as STW with addition of isotubes.

	STW	GDW	PTW1	PTW2
DTS	✔	✔	✔	✔
DAS	✔	✔	✔	✔
TAS		✔		
P behind CSG		✔	✔	✔
P tubing			✔	✔
DSS		✔	✔	✔

Modeling: Setting Input Model

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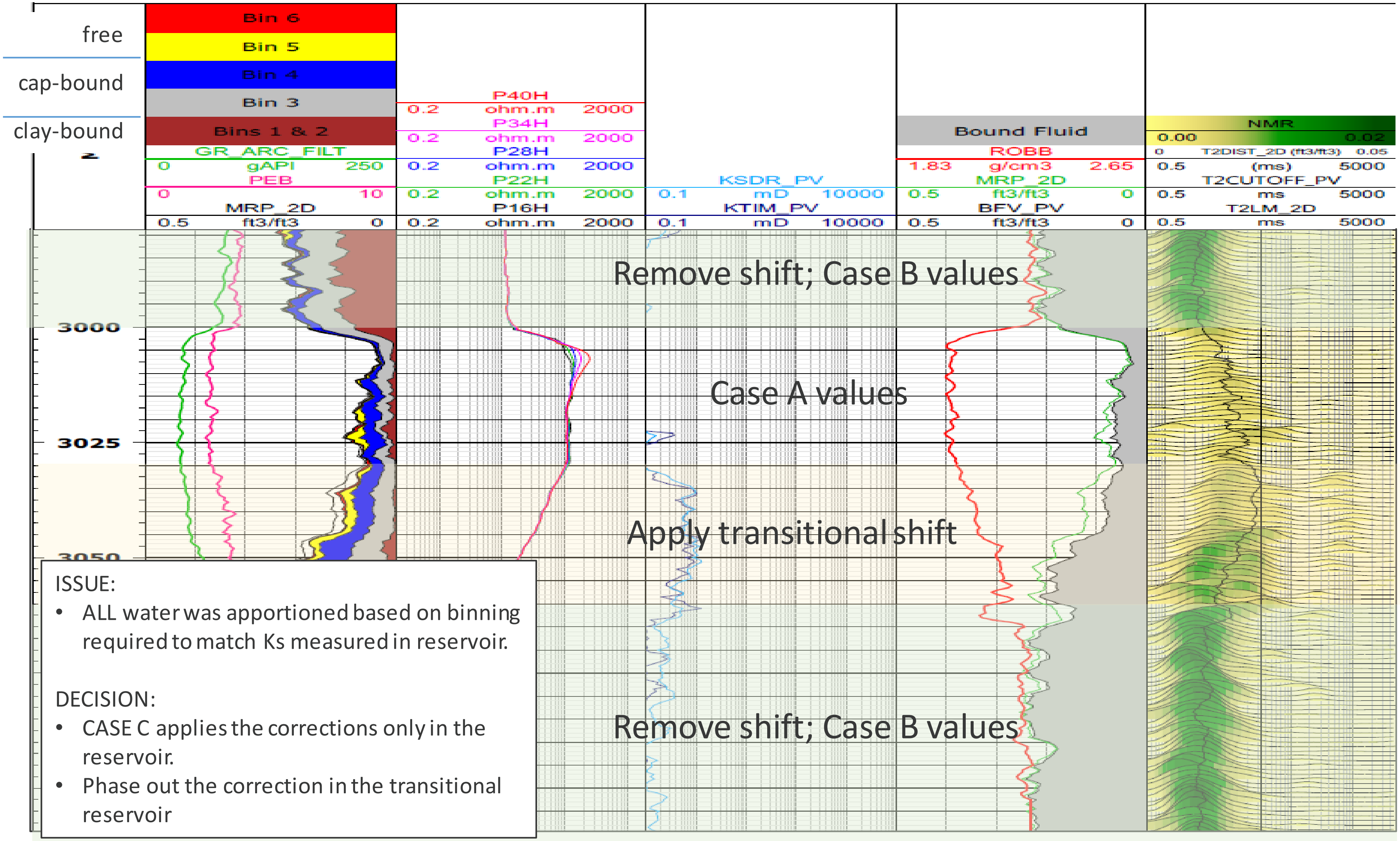
		CASE A & B: WATER DISTRIBUTION					CASE A (core)		CASE B (NMR log)	
Porosity model	Sh	Volume ratio (Total volume=1)					Keff	Kintrinsic	Keff	Kintrinsic
PhiT	Hydrate saturation within PhiT	CBW Volume	BFW volume	FFW Volume	Hydrate volume	Matrix volume	Add cutoff: Ki min (=0.001) set = Kintrinsic where Sh=0 **Final Ki**	Add cutoff: Ka min constrain (=0.001) **Final Ka**		Lower of TC and KC methods
(2.69-Rho_c) /(2.69-1)	DMR method in reservoirs. Set to Zero elsewhere	<3ms	3ms-10ms	>10ms + "False hydrate"	PhiT*Sh	1-(CBW+BFW+FFW+Vmh)				
ft3/ft3	ft3/ft3	ft3/ft3	ft3/ft3	ft3/ft3	ft3/ft3	ft3/ft3	mD	mD	mD	mD
0.248	0.000	0.120	0.075	0.052	0.000	0.752	11.502	11.502	1.353	1.353
0.250	0.000	0.111	0.074	0.065	0.000	0.750	17.111	17.111	2.414	2.414
0.240	0.000	0.105	0.076	0.059	0.000	0.760	18.039	18.039	1.729	1.729
0.237	0.000	0.106	0.074	0.057	0.000	0.763	16.766	16.766	1.557	1.557
0.235	*0.000*	*0.097*	*0.073*	*0.065*	*0.000*	*0.765*	*22.158*	*22.158*	*2.218*	*2.218*
0.244	*0.000*	*0.092*	*0.070*	*0.082*	*0.000*	*0.756*	*29.720*	*29.720*	*4.527*	*4.527*
0.259	*0.000*	*0.080*	*0.072*	*0.108*	*0.000*	*0.741*	*53.061*	*53.061*	*11.462*	*11.462*
0.271	*0.000*	*0.082*	*0.065*	*0.123*	*0.000*	*0.729*	*57.807*	*57.807*	*18.538*	*18.538*
0.305	*0.000*	*0.080*	*0.066*	*0.159*	*0.000*	*0.695*	*97.198*	*97.198*	*51.186*	*51.186*
0.333	0.538	0.066	0.061	0.027	0.179	0.667	26.415	198.542	0.244	159.384
0.367	0.648	0.049	0.059	0.021	0.238	0.633	29.495	451.547	0.102	518.197
0.391	0.740	0.030	0.053	0.019	0.289	0.609	27.706	894.191	0.054	1389.700
0.407	0.805	0.020	0.043	0.017	0.328	0.593	20.741	1315.149	0.029	1743.639
0.422	*0.860*	*0.009*	*0.036*	*0.014*	*0.363*	*0.578*	*14.050*	*1900.280*	*0.012*	*2152.527*
0.430	0.889	0.005	0.031	0.012	0.382	0.570	9.903	2247.402	0.006	2398.479
0.442	0.899	0.005	0.029	0.011	0.397	0.558	8.906	2544.184	0.004	2713.800
0.442	0.905	0.005	0.029	0.008	0.400	0.558	7.742	2528.012	0.001	2715.411
0.435	0.905	0.007	0.026	0.008	0.393	0.565	7.114	2264.573	0.002	2491.406
0.424	0.906	0.007	0.024	0.009	0.384	0.576	6.479	2024.362	0.002	2220.717
0.423	0.909	0.010	0.020	0.008	0.384	0.577	5.523	1870.950	0.002	2158.956
0.431	0.920	0.009	0.017	0.008	0.396	0.569	4.634	2078.145	0.001	2359.881
0.432	0.906	0.011	0.015	0.015	0.392	0.568	6.319	2043.033	0.009	2378.085
0.432	0.919	0.003	0.020	0.012	0.397	0.568	5.373	2368.485	0.004	2461.621
0.435	0.929	0.002	0.021	0.008	0.405	0.565	4.253	2508.381	0.001	2566.160
0.437	0.899	0.004	0.025	0.016	0.393	0.563	8.702	2454.864	0.012	2581.186
0.435	0.891	0.002	0.027	0.018	0.388	0.565	10.347	2496.709	0.020	2559.931
0.430	0.888	0.002	0.033	0.013	0.382	0.570	10.558	2355.308	0.008	2421.566
0.430	0.872	0.005	0.032	0.018	0.375	0.570	13.270	2243.633	0.020	2398.326

CASE C WATER DISTRIBUTION					CASE C (Water)	
Volume ratio (Total volume=1)					Keff	Kintrinsic
CBW Volume	BFW volume	FFW Volume	Hydrate volume	Matrix volume	Add cutoff: Ki min (=0.001) set = Kintrinsic where Sh=0 **Final Ki**	Add cutoff: Ka min constrain (=0.001) **Final Ka**
<3ms + share false hydrate	3ms-10ms + share false hydrate	>10ms + "False hydrate"	PhiT*Sh	1-(CBW+BFW+FFW+Vmh)		
ft3/ft3	ft3/ft3	ft3/ft3	ft3/ft3	ft3/ft3	mD	mD

We have three modeling cases to constrain gas and water rates

- Conservative case (CASE B) based on NMR- Ks
- Aggressive case (CASE A) based on Core-correction of NMR to the entire section.
- Most Likely case (CASE C) based on core-correction only in the main reservoir units AND removal of log resolution "boundary" effects

Most Likely Case



ISSUE:

- ALL water was apportioned based on binning required to match Ks measured in reservoir.

DECISION:

- CASE C applies the corrections only in the reservoir.
- Phase out the correction in the transitional reservoir

Modeling: NETL/JOGMEC

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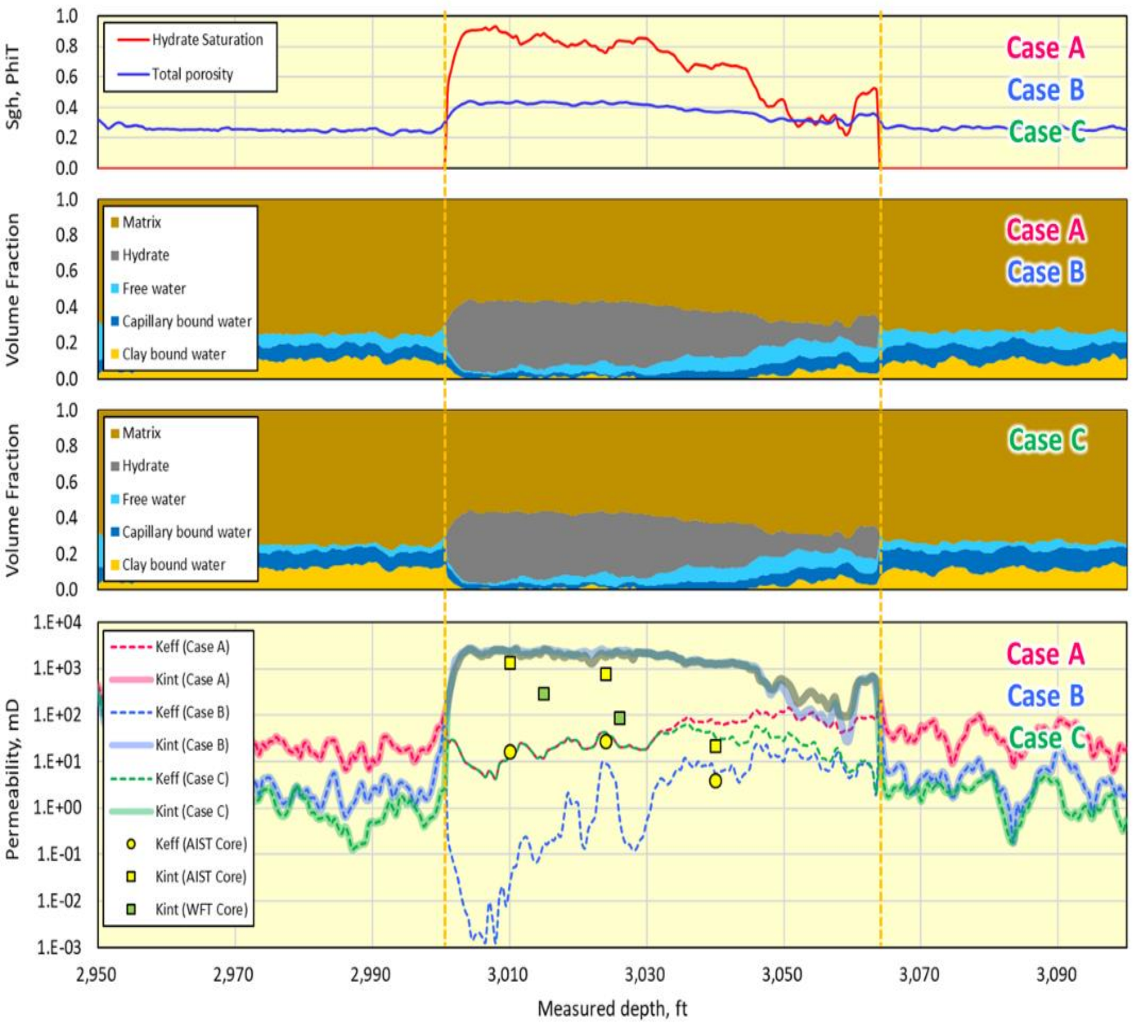
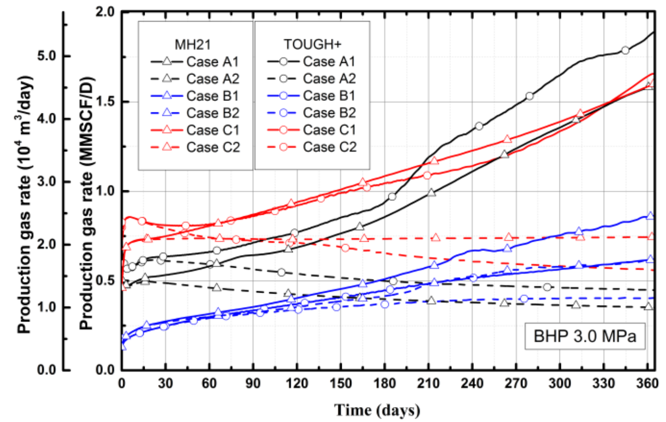
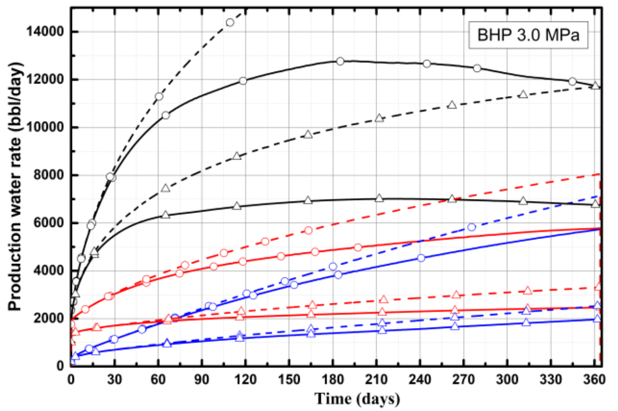
Code Comparision – Constraint on max gas and water rates to guide surface facility design





“confined” (500m)
“unconfined” (3000m)

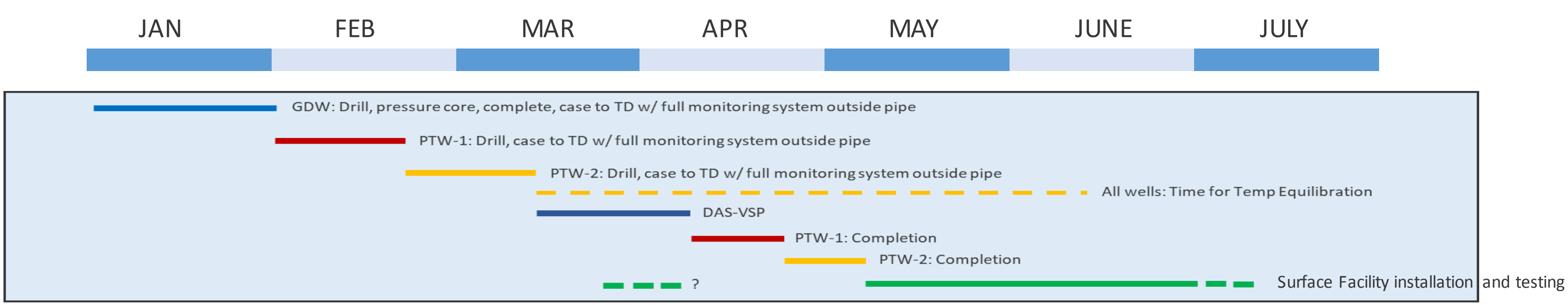


Key Components of Testing Plan

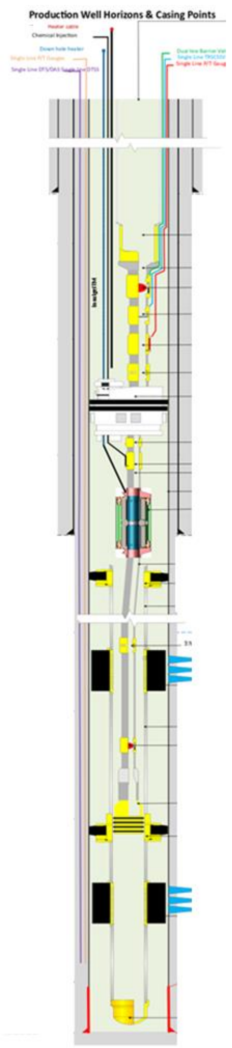
As distinct from PTW completion design

Base Production Method: Depressurization

- Maximize data interpretability by imparting a single driving force
- Employ a step-wise pressure reduction to max. scientific insight and to minimize operational risks associated with large drawdowns
- First step at P > GHS to assess water mobility.
- Add'l steps set at ~2.0 mPa (to be refined via focused engineering studies)
- Follow well intervention/stimulation protocols where reservoir response dictates
- At end of test, impart largest feasible pressure drop



Technical Plans: Testing Phase



- <u>Highest priority</u>: safety; reg. compliance; no disturbance to PBU Ops
- <u>Focus</u>: monitoring reservoir response
  - Periodic VSPs to assess system response (geometry/scale)
  - DTS/DSS and P-gauges in 4 wells to monitor dissociation reaction and impacts in 4D
- <u>Focus</u>: well design & survivability
  - Artificial lift: robust, viable across expected flow range
  - Flow assurance; pre-staged intervention: downhole heater
  - Sand control/Hydraulic isolation – cased/perfed with screens; GeoFORM
  - Staged shut-in and restart procedures (nitrogen)
- Focus: water, gas, and solids handling
  - Water/Sand: local storage w/ sufficient excess. Trucking and disposal in unit facilities
  - Gas: local consumption.
- NOTE: all plans developed to-date by JOGMEC, USGS, DOE will be worked with TPO and PBU WIOs once testing program is authorized to proceed and TPO selected

Intervention Plan

Ongoing

Flow Assurance: Shut-in & remediate

Gas Rate (low, declining, erratic, persistently flat)

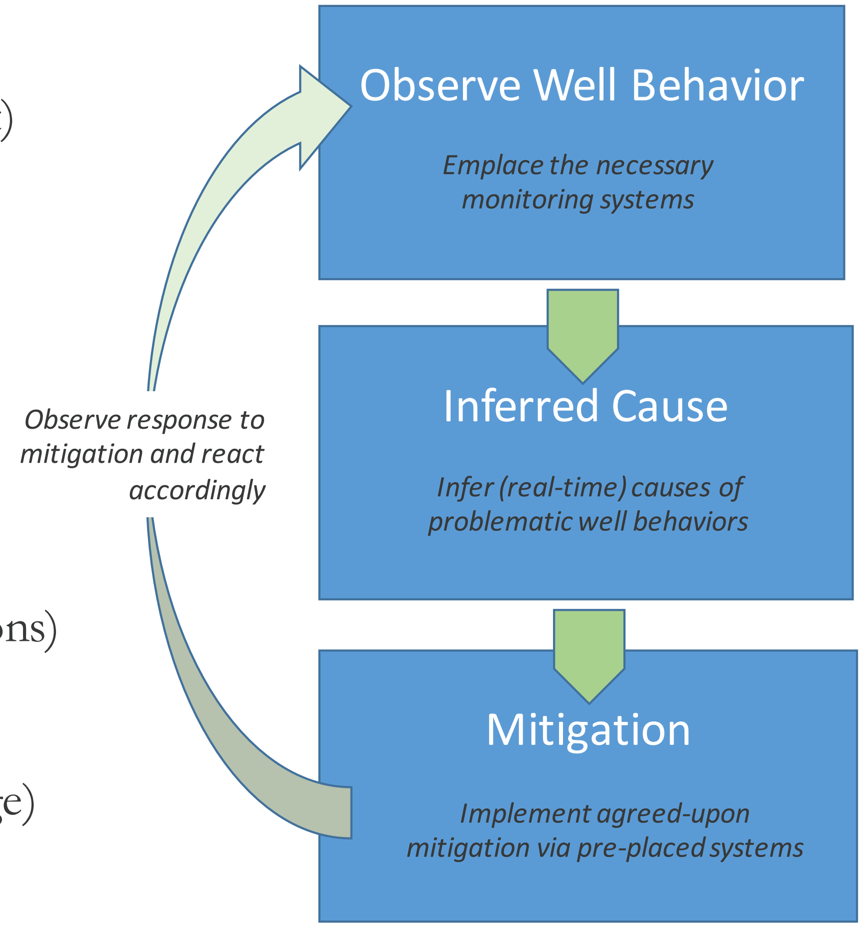
- Hydrate formation → P drop and monitor
- Ice formation→ P drop and monitor: hot methanol
- Sand/fines blockage → P cycling: acid?: re-perf
- Gas-Water block→ P cycling
- Reservoir Limitation → stimulation… TBD
- Equipment failure → shut in and repair

Excessive Sand (robust systems; cleanout options)

- Systems failure → patience, move to D

Excessive Water (ensure adequate onsite storage)

- Reservoir → P drop; P cycling, move to D



Next Project Phase: Status

As of February, 2020

- Initial Stratigraphic Test has confirmed site geologic feasibility
- Steering Committee approved effort to advance to next project phases.
- Limited business case for industry participation; however, PBU has desired to facilitate a "standalone" test.
- An atypical DOE/FE project context: directed to pursue science and technology w/o interested private R&D partners <u>to assume risks and share costs</u>
- Sustaining interest from our partners in Japan and from the State of Alaska.
- Impending exit of BPXA and entrance of Hilcorp, Alaska has challenged efforts to maintain schedule. Currently holding to plan for drilling as early as next winter season

THANK YOU

LWD Sonic

Passive Mud Chiller

CoreVault

Fiber Optic Cables