



Bayou Corne Cavern Collapse

Technical Status Update

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CB&I (*formerly Shaw*)

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Louisiana State Legislative Committee Hearing



- Education
 - B.S., Geology, University of Wyoming, 1974
 - M.S. Geological Engineering, Colorado School of Mines, 1978
 - Ph.D. Geology, University of Kansas, 2004
 - Professional Geologist, Wyoming, PG-1229
- Expertise
 - Subsurface characterization and remediation
 - Use of Geographical Information System (GIS) and 3D modeling technologies to analyze subsurface
- Technical lead on 20+ large, complex projects in 17 states over 35 years, 25 years with CB&I

- 3D seismic—seismic investigative method used to image geologic formations, and gas and oil reservoirs in subsurface
- CB&I—formerly Shaw, Shaw purchased by CB&I on Feb. 13, 2013
- CERI—Center for Earthquake Research and Information @ Univ. Memphis
- DRZ—Disturbed Rock Zone, zone of fractured and broken rock adjacent to and above Oxy 3 cavern, also called collapse zone
- Gas—Natural gas migrating through DRZ into MRAA and spreading out over 2 square miles of MRAA, >95% methane
- GIS—Geographical Information System
- MRAA—Mississippi River Alluvial Aquifer, sand and gravel aquifer used for industrial water supply in vicinity of Napoleonville Salt Dome
- ORW—Observation/relief well, aka Vent well
- TBC—Texas Brine Corporation
- VLP—Very long period seismic event (indicates fluid flow)



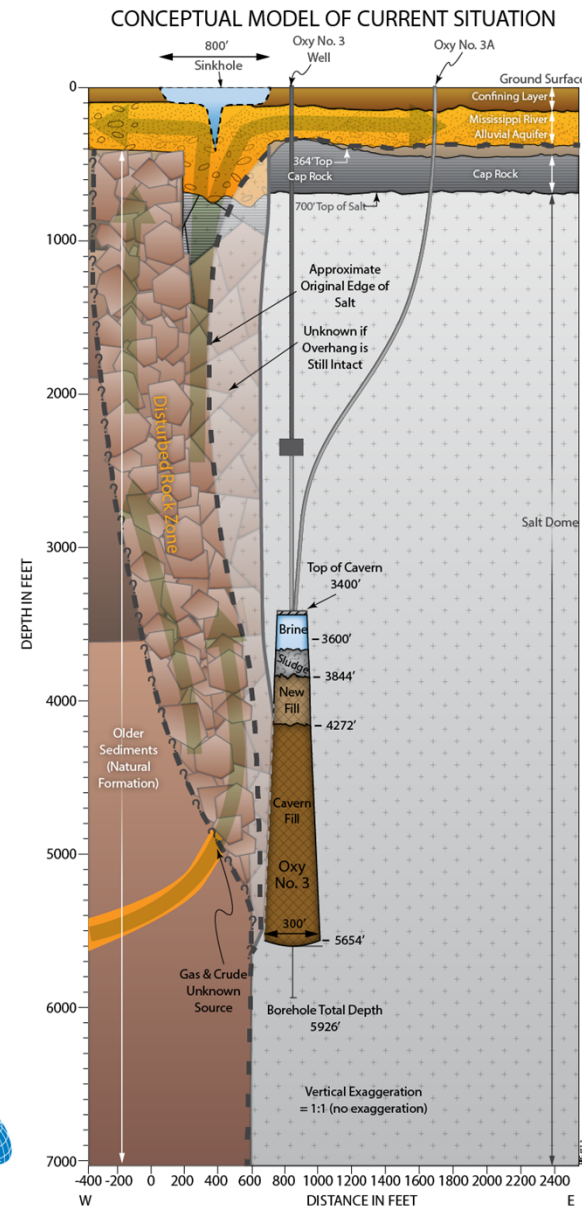
OXY 3 CAVERN COLLAPSE NAPOLEONVILLE SALT DOME

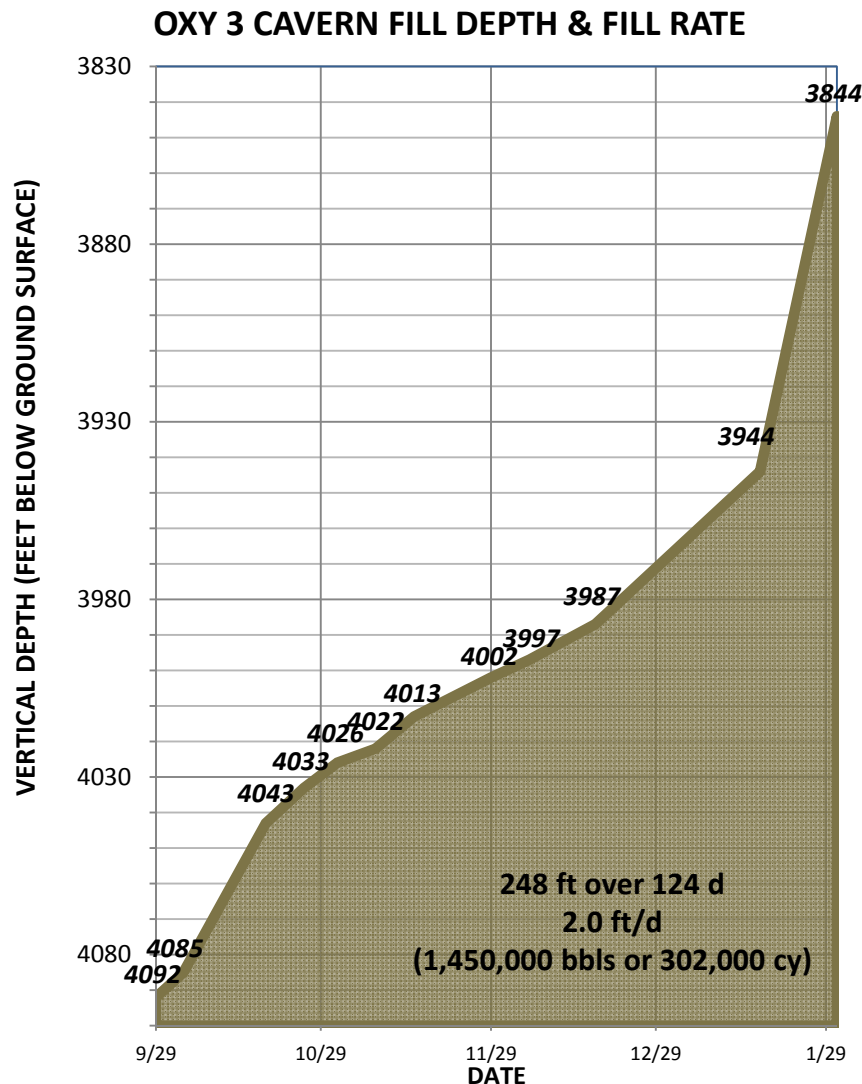


WHY IS BAYOU CORNE UNPRECEDENTED COLLAPSE EVENT?

- Cavern collapse at 5,600 feet that fractured to the surface creating sinkhole
- Sidewall and not roof collapse of brine-mined salt cavern
- Cavern collapse is still ongoing with a number of seismic events detected every day
- Large amounts of gas and some crude oil migrating through Disturbed Rock Zone (DRZ)
 - Flowing into aquifer with gas footprint over 2 square miles
 - Brine and hydrocarbon contamination in sinkhole and potentially in MRAA
 - Estimate of gas in MRAA >50 million cubic feet in place
 - Vent wells have flared ~10 million cubic feet to date
 - Known gas bubble vent rate from MRAA estimated at 20 mcf/d
 - Depth and volume of gas reservoirs is currently unknown

- Cavern currently 80+% full of broken rock
- Evolution of collapse
 - Collapse started prior to appearance of sinkhole
 - Collapse still ongoing
- Disturbed Rock Zone (DRZ) is composed of fractured and broken rock
- Seismic data indicate that there are some voids in the DRZ
- New 3D seismic data will help identify extent and shape of DRZ and gas horizons

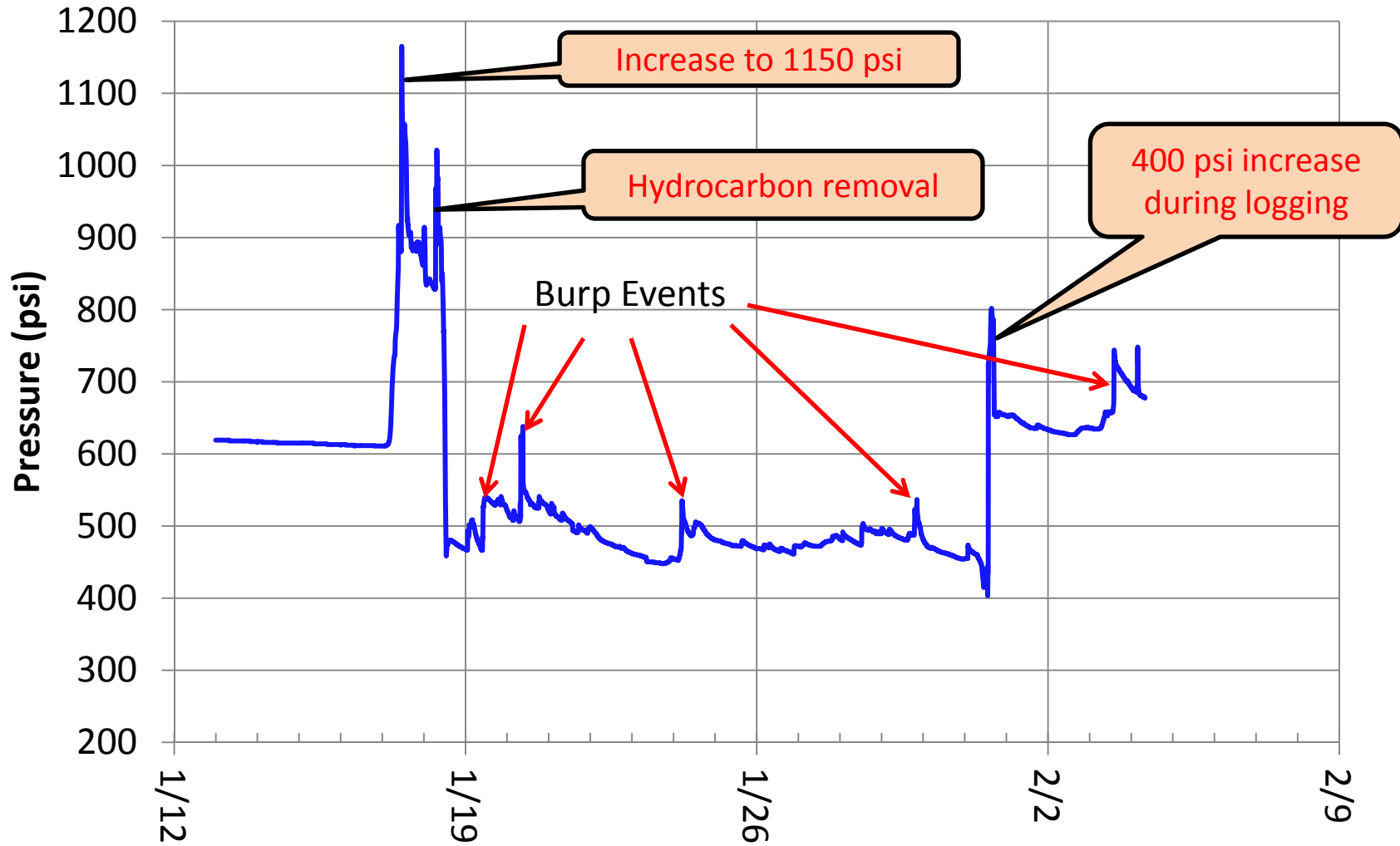




- Cavern filling in over time as rock breaks and fills in
- Filling rate 1-2 feet per day
- Western wall of cavern still collapsing
- Major fill event of 100' from 1/17/2013 to 1/31/2013—related to seismic activity
- Roof of cavern at 3400', ~450' to fill
- Oxy 3A well currently obstructed; TBC working on opening up borehole
- Instability will likely continue at least until cavern is full



OXY 3A CAVERN PRESSURE RELATED TO BURPS IN SINKHOLE



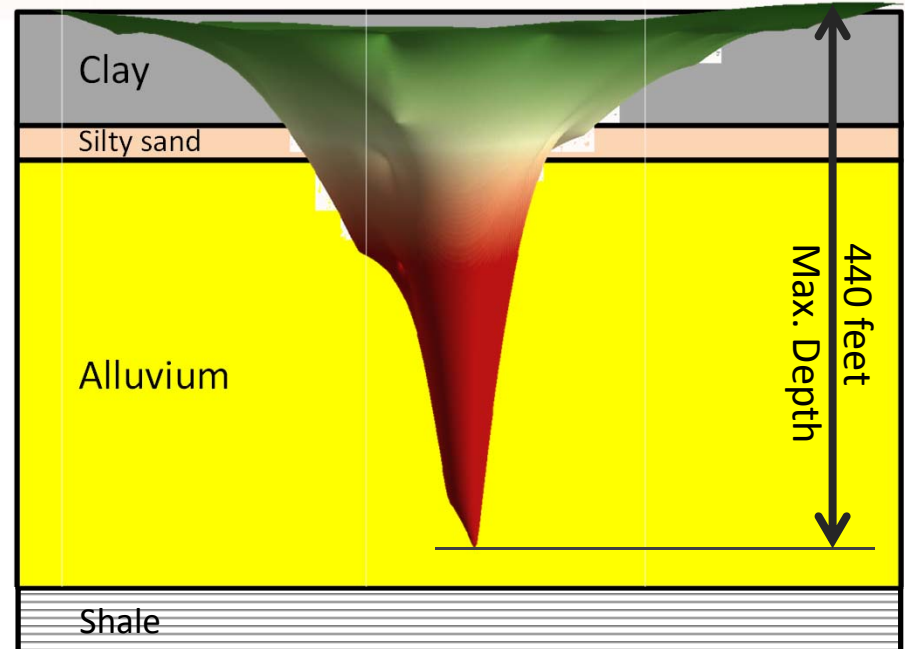
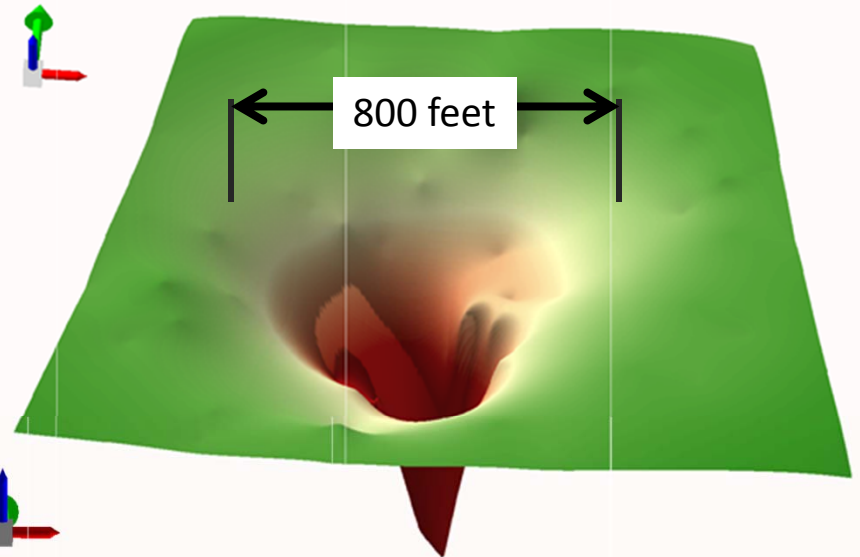


BAYOU CORNE SINKHOLE

Continuously changing



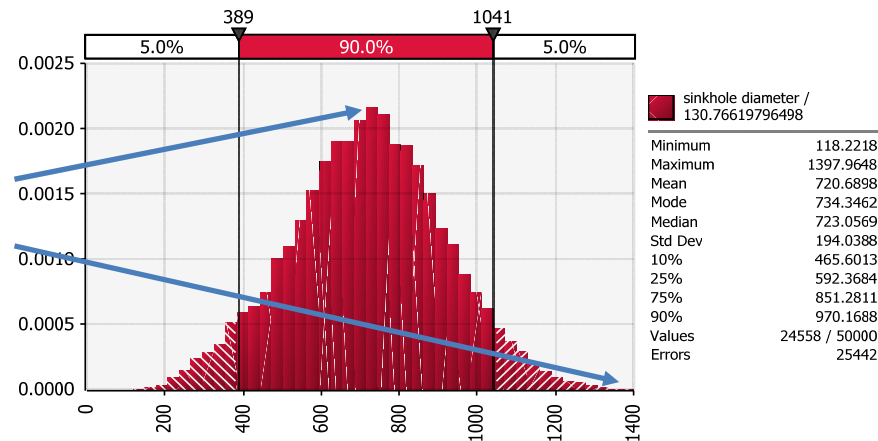
- Area of main sinkhole—9 acres
- Area of subsidence—15+ acres
- Sinkhole regularly changes with gas “burps”
- Main sinkhole over 800 feet across
- Depth changes from 150 feet to over 400 feet with burp events
- Slowly expanding to the west
- Total dissolved solids (TDS) at surface approximately 4,000 mg/L
- TDS at 100 feet 50-70,000 mg/L
- Petroleum hydrocarbons at depth (low conc. at surface)



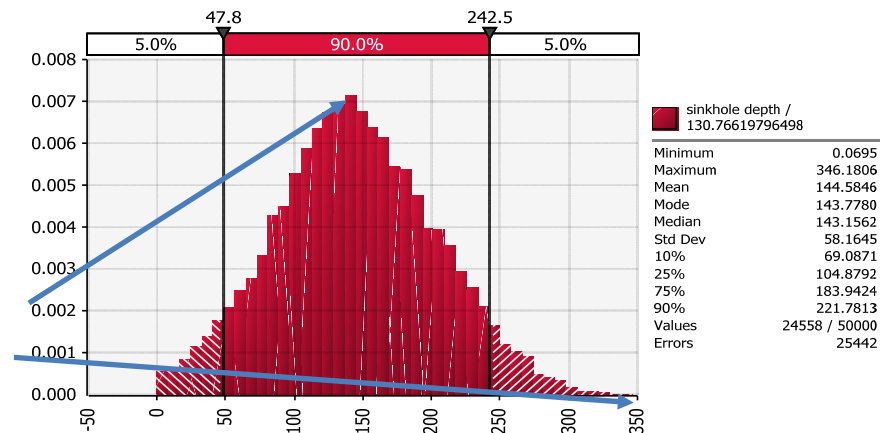


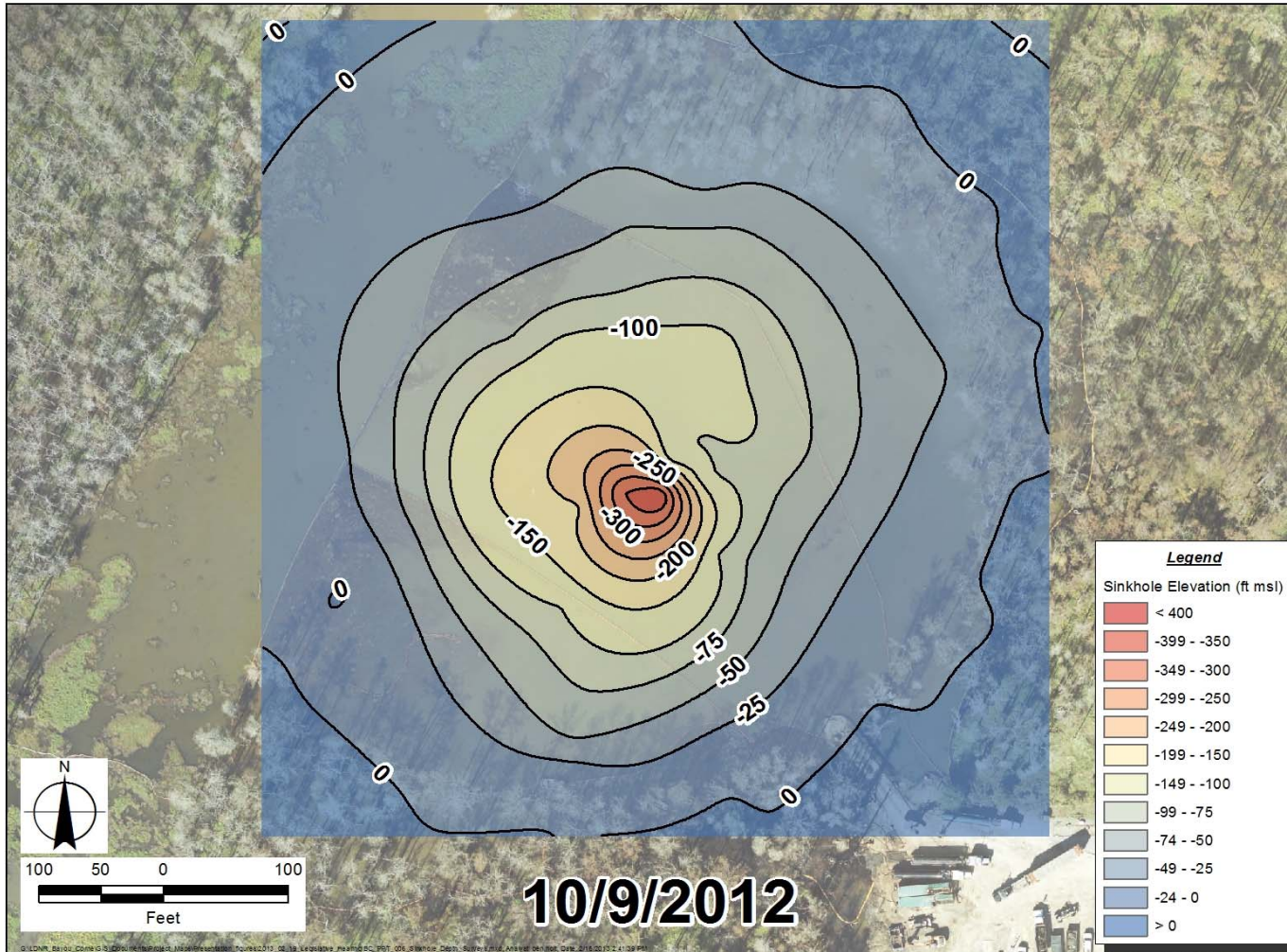
EVENTUAL SINKHOLE SIZE (Size of the lake)

Sinkhole Diameter
Most Likely = 734 ft
Worst Case = 1398 ft

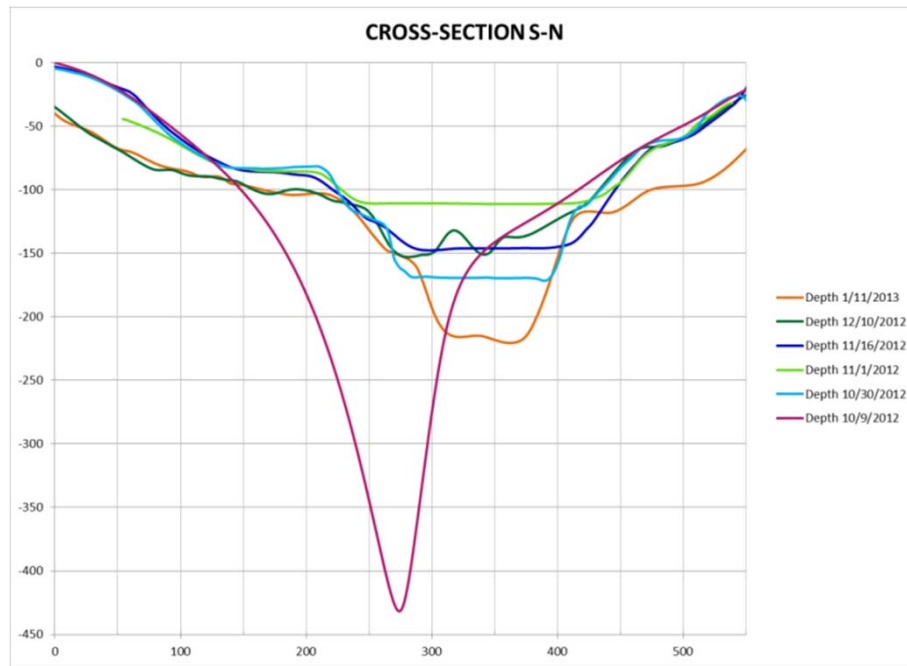


Sinkhole Depth
Most Likely = 144 ft
Worst Case = 346 ft

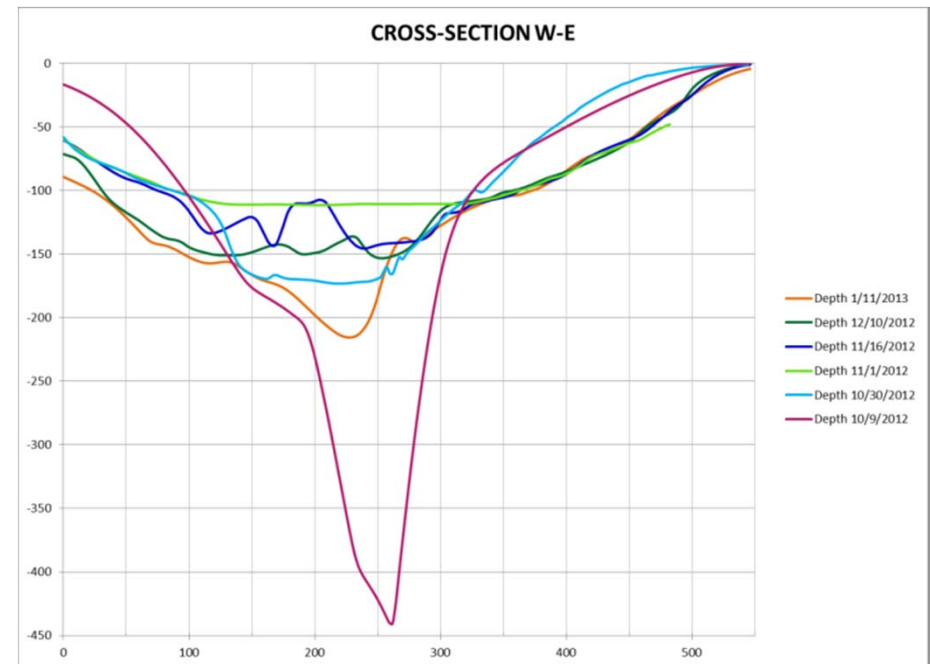




- South to North

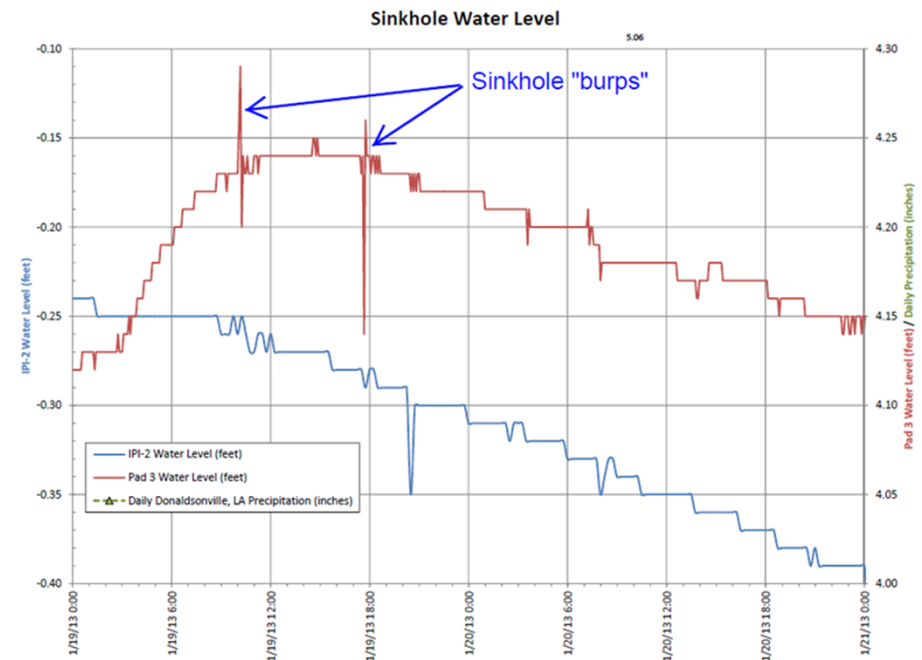


- West to East



BURP EVENTS BRING GAS AND FORMATION LIQUID TO THE SURFACE

- Sinkhole “burps”
 - Strong indication of voids that fill with gas and then release
 - 1/19/13 burp event
 - Indicated that large gas bubble unlikely to reach surface as one bubble,
 - Aquifer diffuses gas into small bubbles
- Seen on seismic instruments as very long period (VLP) events
- Caused by gas build-up in voids in DRZ that reach release pressure and vent to the surface
- Events indicate void sizes between 15,000 & 50,000 cubic feet



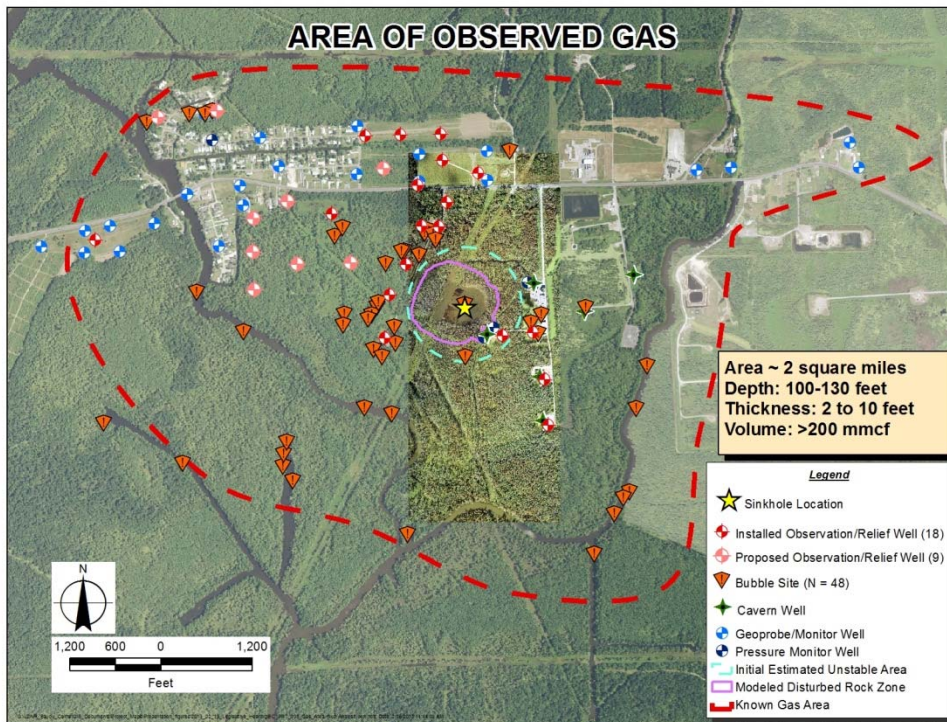


GAS (METHANE)

IN MISSISSIPPI RIVER ALLUVIAL AQUIFER (MRAA)

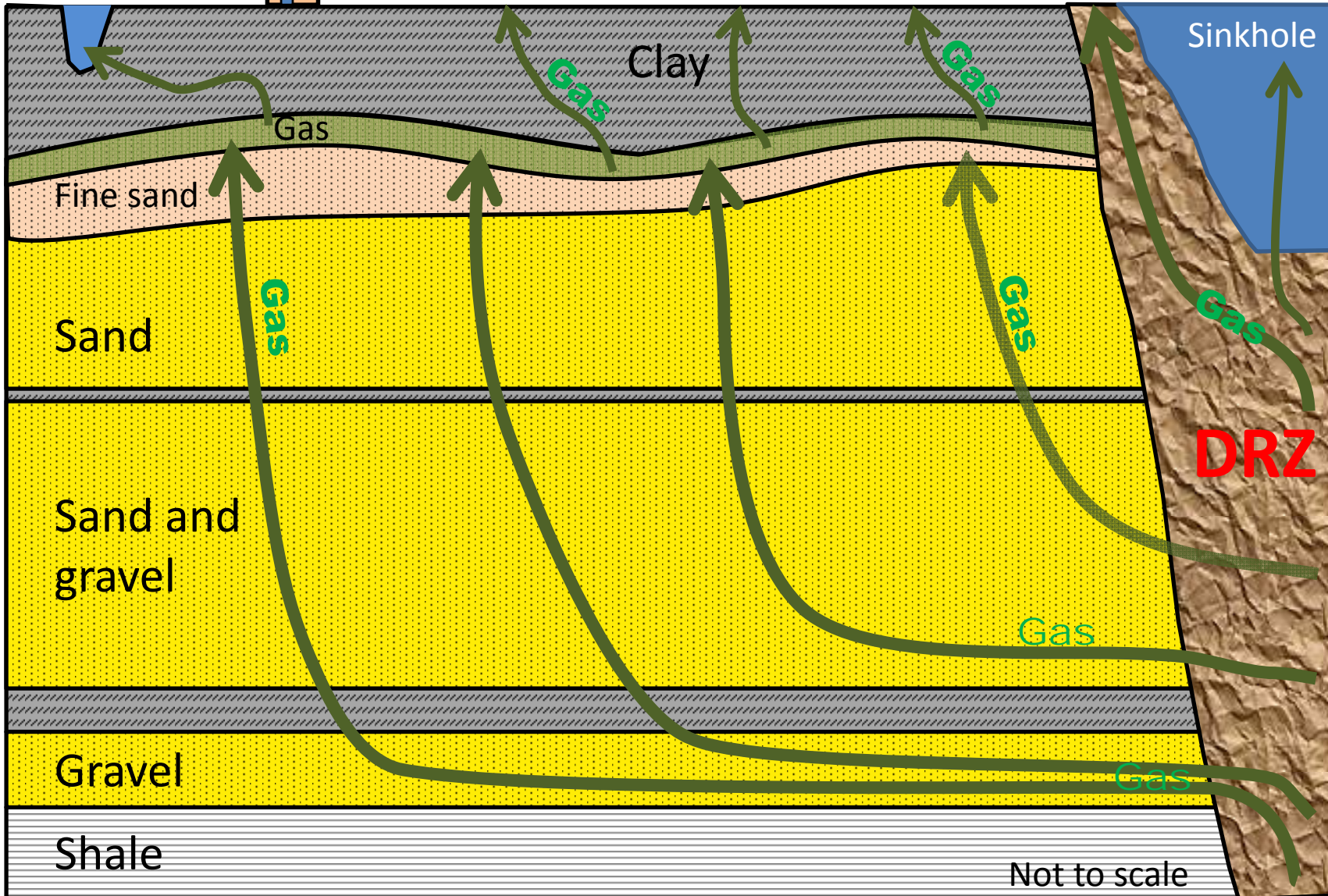
- Current condition and prognosis for near future
- May require long-term management



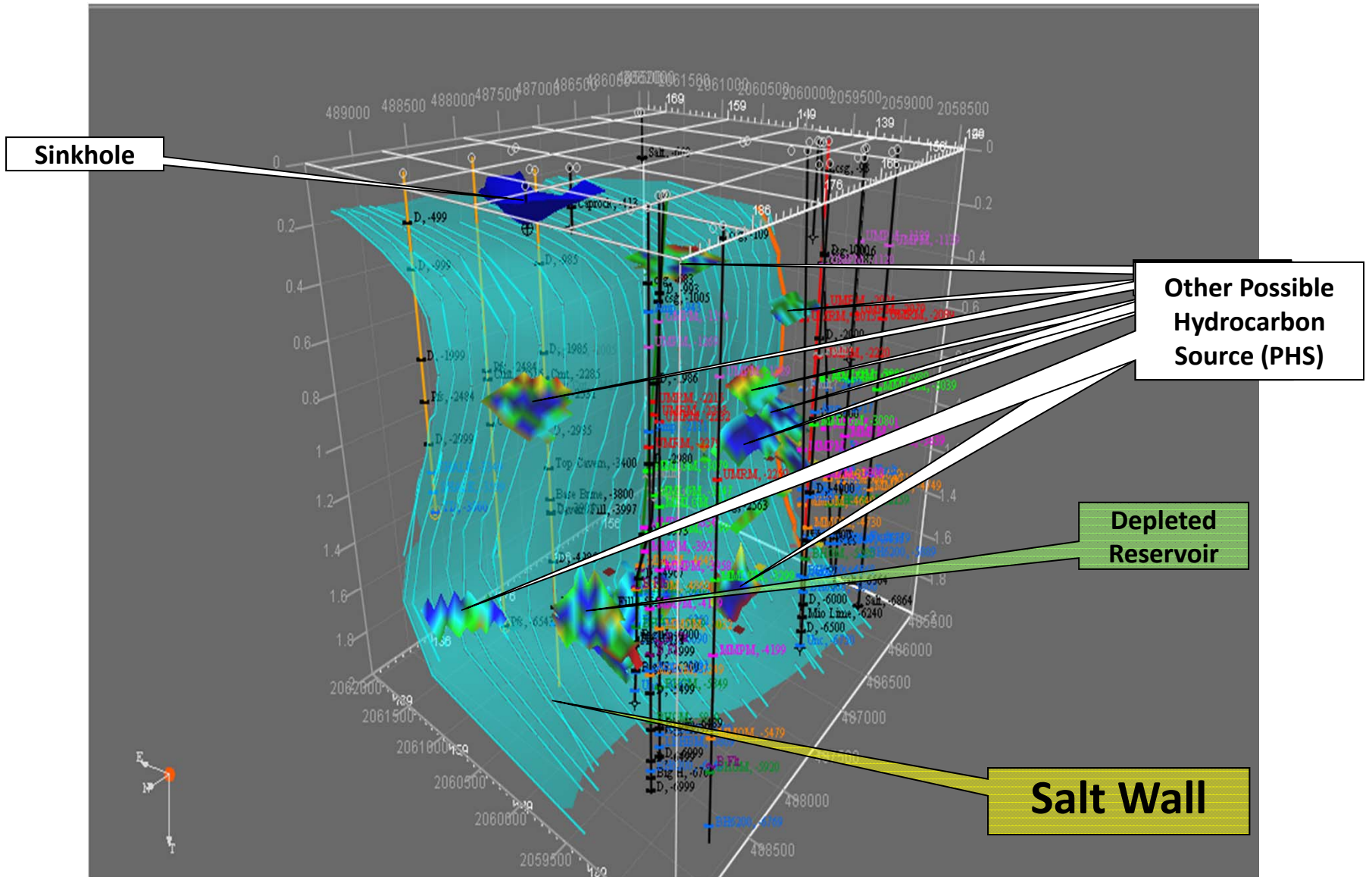


- Over 2 square miles—extent not well defined
- Gas 2 to 10 feet thick across area
- Still seeing pressures in shallow wells even where MRAA gas pressures & saturations have declined
- 20 new bubble sites in past month
 - Mostly on west side of sinkhole
 - Around perimeter of modeled disturbed rock zone
- Estimated volume of gas in MRAA over 50 million cubic feet in place—being refined with new data

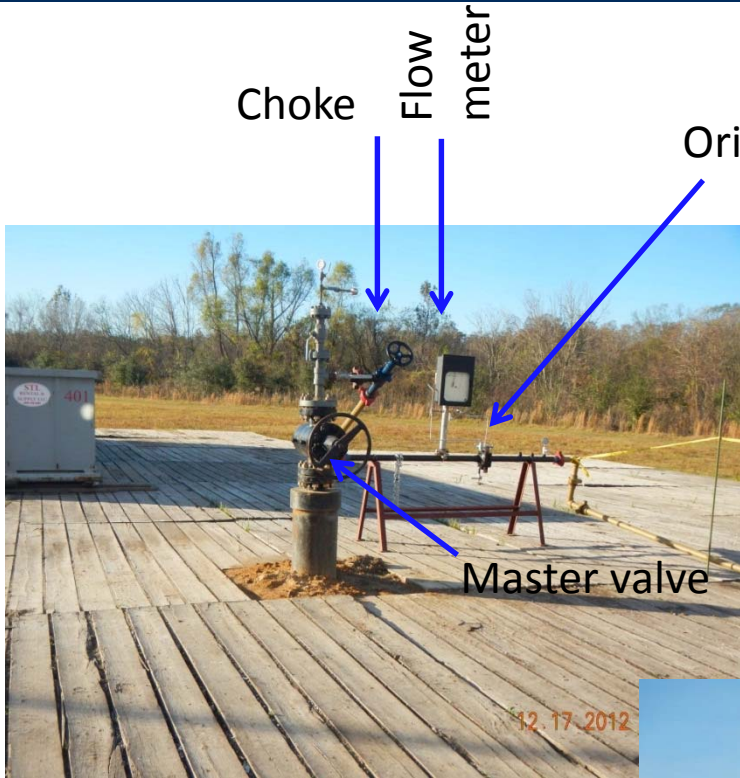
Bayou Corne



WHERE IS GAS COMING FROM? NUMEROUS POTENTIAL ZONES

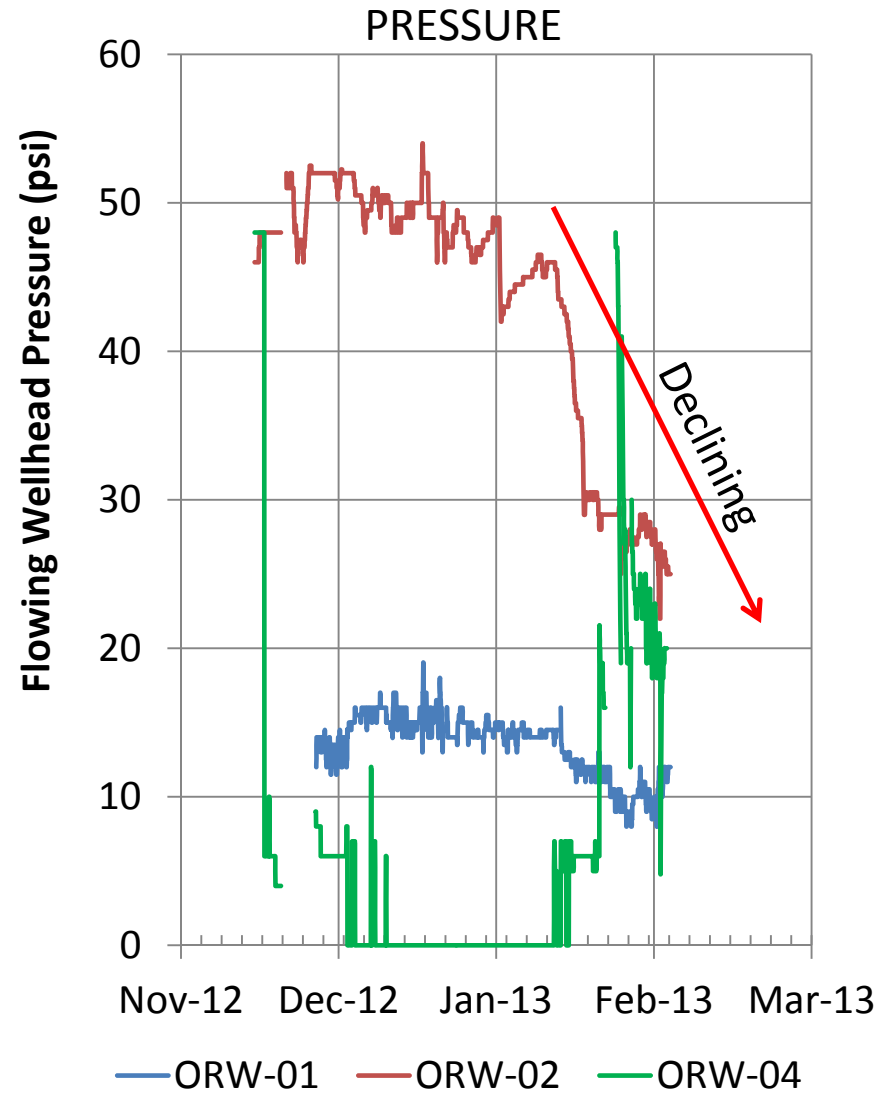
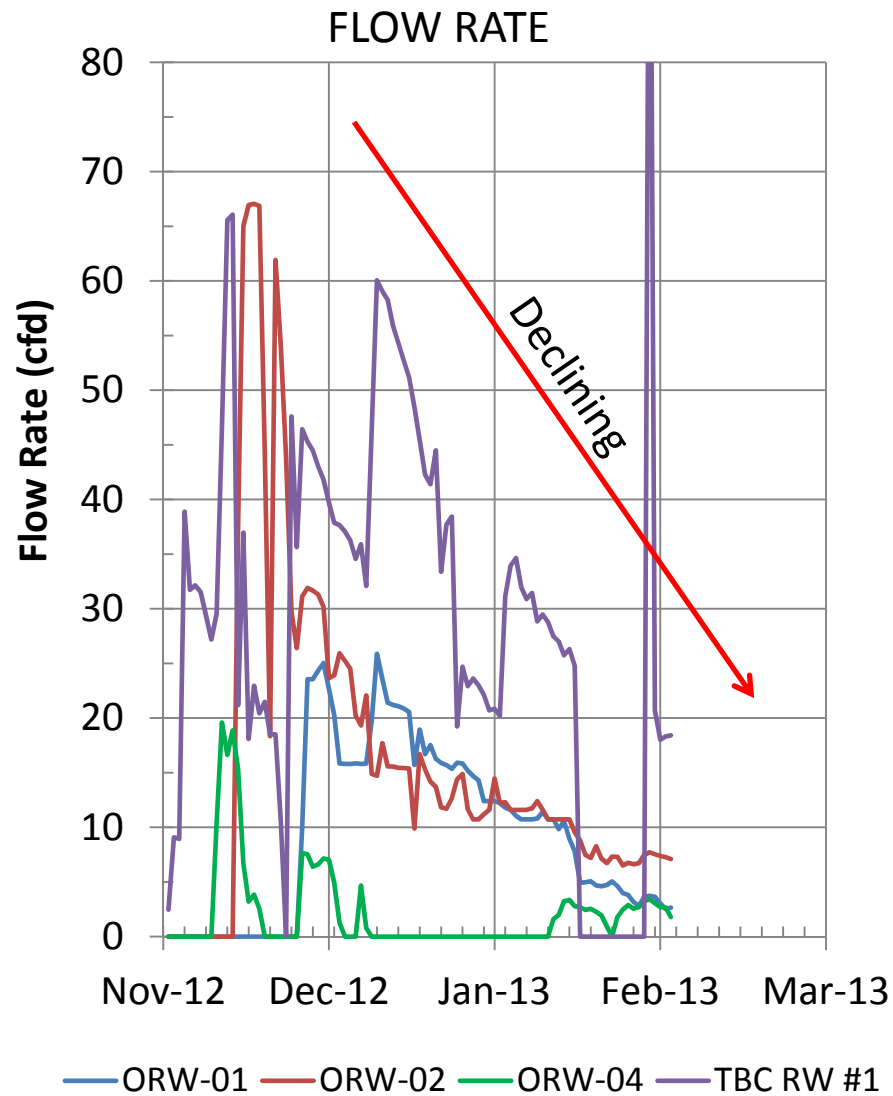


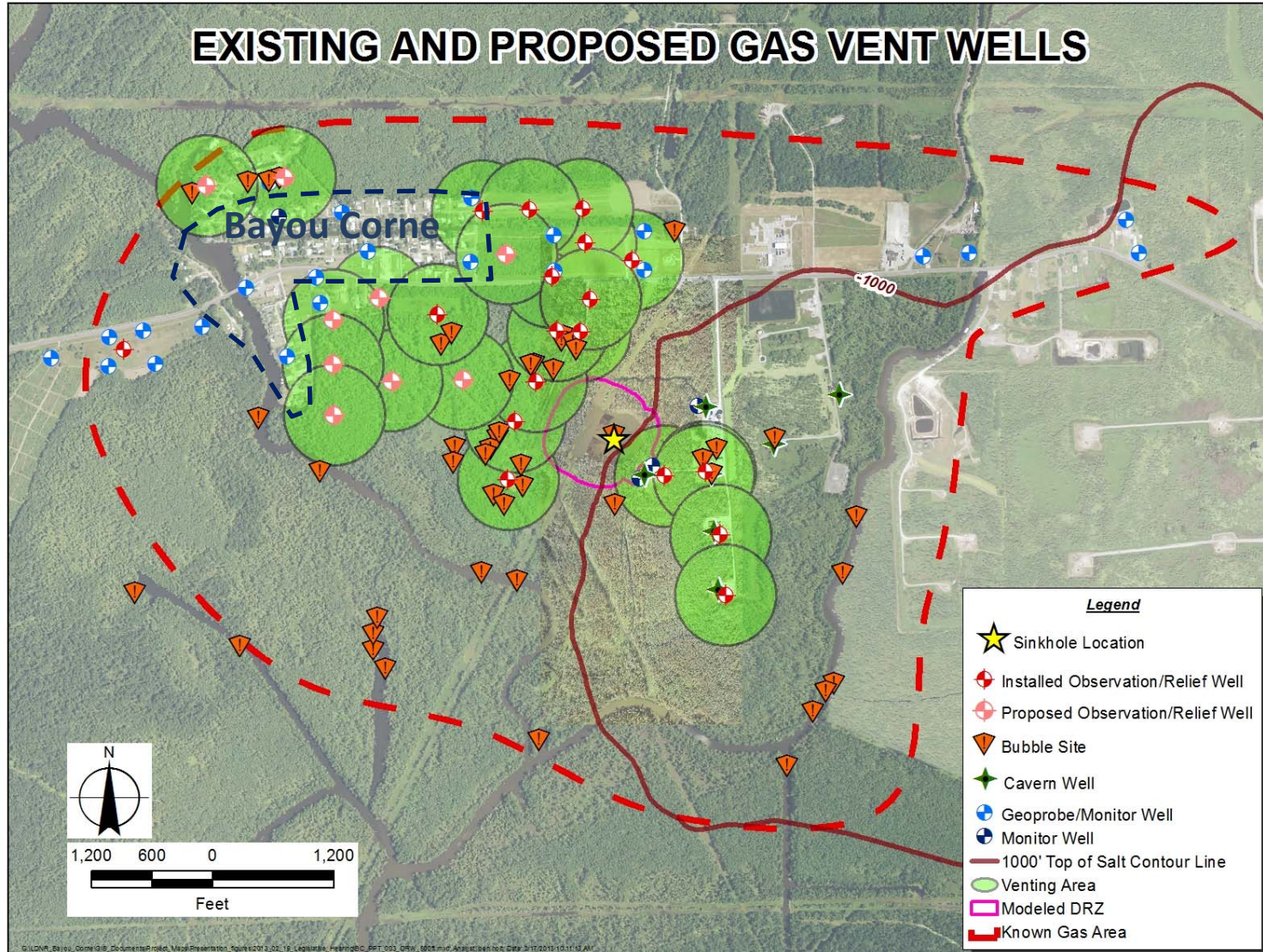
2007 3D seismic by Don Marlin, CPG





VENTING OPERATIONS DEMONSTRATED THAT WELLS REDUCE GAS VOLUME AND PRESSURES





- To get residents back into their homes, gas pressures in the MRAA *must* be reduced to a level that gas will no longer migrate to the surface
- Need to install additional vent wells below community and to east in Grand Bayou
 - Vertical wells: Wells must control gas pressure 100% of time during installation and operation
 - Horizontal wells: No method to control mud break-outs during drilling
 - Unknown volume of gas still coming into MRAA (long-term management)
- Modeling of gas venting operations—Dr. Charles Faust, Tetra-Tech
- 3D seismic investigation
 - High resolution seismic imaging of Disturbed Rock Zone looking for overall size, internal structures, void spaces. Uncertain if this has ever been attempted on a collapse structure.
 - Identify the possible gas source zones and potential for intercepting gas
 - Potentially can identify shallow gas areas but this is uncertain because gas is shallow (~100-120'), thin (2 to 10' thick), high water saturation (>50%)
 - Don Marlin, CPG, will do independent analysis of 3D seismic data

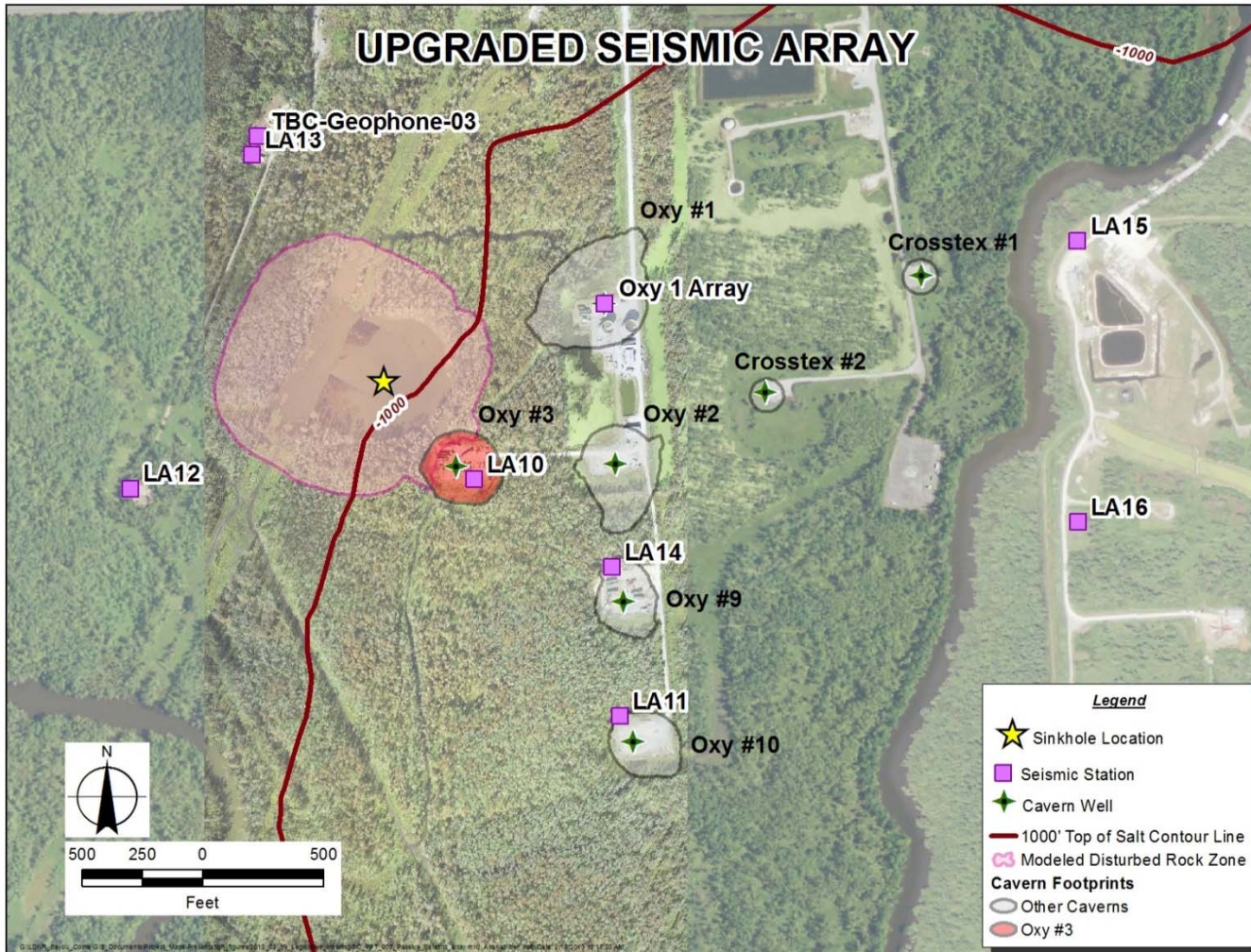


STABILITY OF WESTERN EDGE OF NAPOLEONVILLE SALT DOME

Determine long-term stability of salt and area
operations

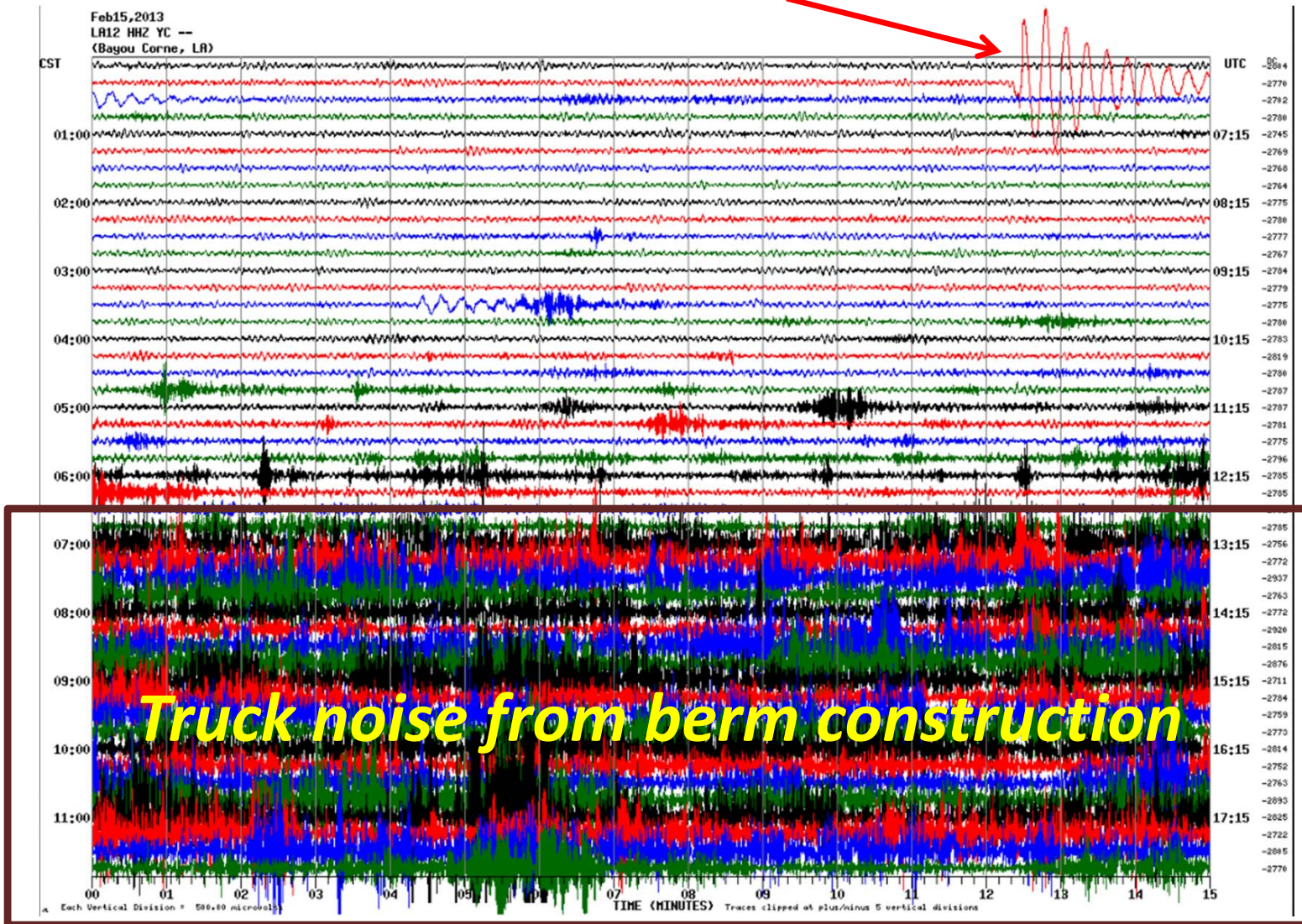


- Approach
 - Seismic monitoring
 - Listen for micro-seismic events that indicate rock may be fracturing
 - Shallow surface array (7 locations), two borehole seismic arrays, and micro-seismic array with 12 geophones in Oxy 1
 - Dr. Horton of CERI retained to assist with seismic evaluations
 - 3D rock mechanics modeling by Itasca
 - TBC drilled 1000-foot corehole and collected samples for rock mechanics testing
 - Extensive suite of geophysical logs on corehole to identify rock structures
 - Using all available data including rock mechanics test results and 3D seismic results
 - Preliminary model running and being updated



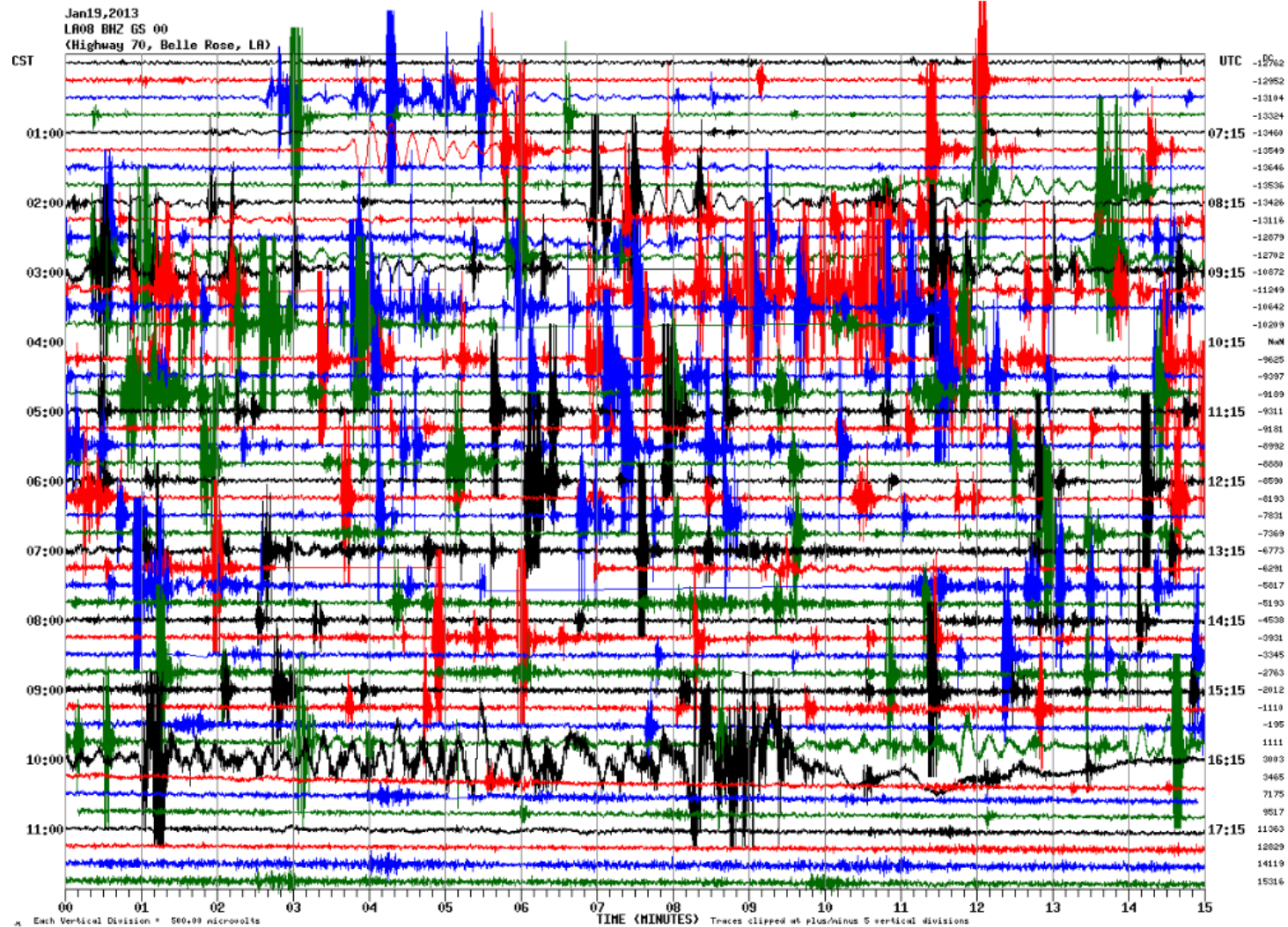
EXAMPLE: VLP BURP EVENT AND CULTURAL NOISE

VLP related to sinkhole slough on Friday 2/15/2013





EXAMPLE: ACTIVE SEISMIC PERIOD, EVENTS OF 1/19/2013



GROWTH OF OXY 3 DISTURBED ROCK ZONE (DRZ)

- *Preliminary results*
- *DRZ reaches ground surface
in approximately 1 year*



BAYOU CORNE CAVERN COLLAPSE AN UNPRECEDENTED EVENT

