LONQUIST FIELD SERVICE

Surface Expression Impact Zone Estimate
Sulphur Mines Salt Dome
Cavern No. 006 & No. 007
Updated: November 27, 2023

Analysis was performed to estimate the size and location of a potential subsidence zone at the Sulphur Mines Salt Dome if a cavern-to-flank pillar failure of Cavern No. 007 were to occur. To represent a "worst-case" scenario, it was assumed that Cavern No. 006 would also be impacted and included in this event due to the small web thickness between the two caverns, thereby assuming a coalescing of the caverns. The sinkhole associated with the collapse of Oxy-Geismar Cavern No. 003 ("Oxy 3") at the Napoleonville Dome was analyzed for reference. A major structural failure occurred at Oxy 3 in 2012. This resulted in a transfer of underground material into the cavern and the development of a sinkhole at the surface. Three-dimensional models were developed for the Napoleonville and Sulphur Domes and utilized to estimate the location and extent of an initial and final theoretical subsidence zone associated with Caverns 6 and 7.

The 3-D model for the Napoleonville dome included top of salt contours, original cavern geometry for Oxy 3, and the location and shape of the sinkhole. The cavern geometry was modeled using the 10/6/2007 sonar survey performed by SOCON Sonar Well Services. Because digital sonar data is not available, the cavern shape was estimated using the average radius at each of the 110 depth intervals where sonar data was listed on the publicly available report. The resulting 3-D cavern model is symmetrical about the z-axis and was determined to be a sufficient approximation of the geometry for this exercise. The initial and final sinkhole geometries were modeled in 3-D using surveys from and October 2012 and June 2015. These surveys are included in *Attachment 1* and *Attachment 2*, respectively. The initial and final sinkhole contours were both imported into the 3-D model. Interpolation between the contours was performed to create a 3-D approximation of the sinkhole geometry.

The analysis of Oxy 3 revealed that the epicenter of the sinkhole formed above the outermost extent of the salt dome in the region where the cavern was closest to the edge of salt. The sinkhole formed in this location as material entered through a breach of the cavern wall near its closest point to the dome edge. Review of the 3-D model indicates that disturbed material traveled downward along the edge of salt, following the shape of the dome overhang that exists above Oxy 3. The epicenter was defined as the deepest point within the initial shape of the sinkhole. The sinkhole initially formed in a funnel shape. As material settled over time, it became flatter with a larger radius and shallower center. Average diameters for the initial and final subsidence zones at Napoleonville were observed to be 670 ft and 1,819 ft, respectively. The cavern geometry, edge of salt, and initial and final sinkhole shapes are shown in *Figure 1* and *Figure 2* below.

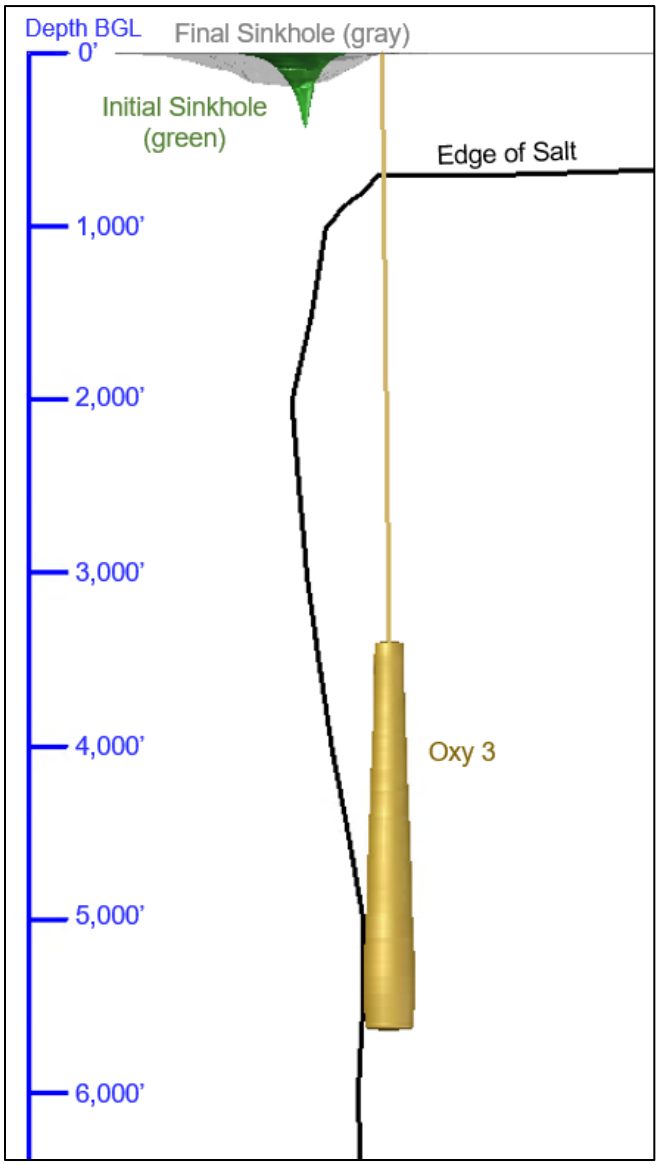


Figure 1 – Side View of Oxy 3 Model

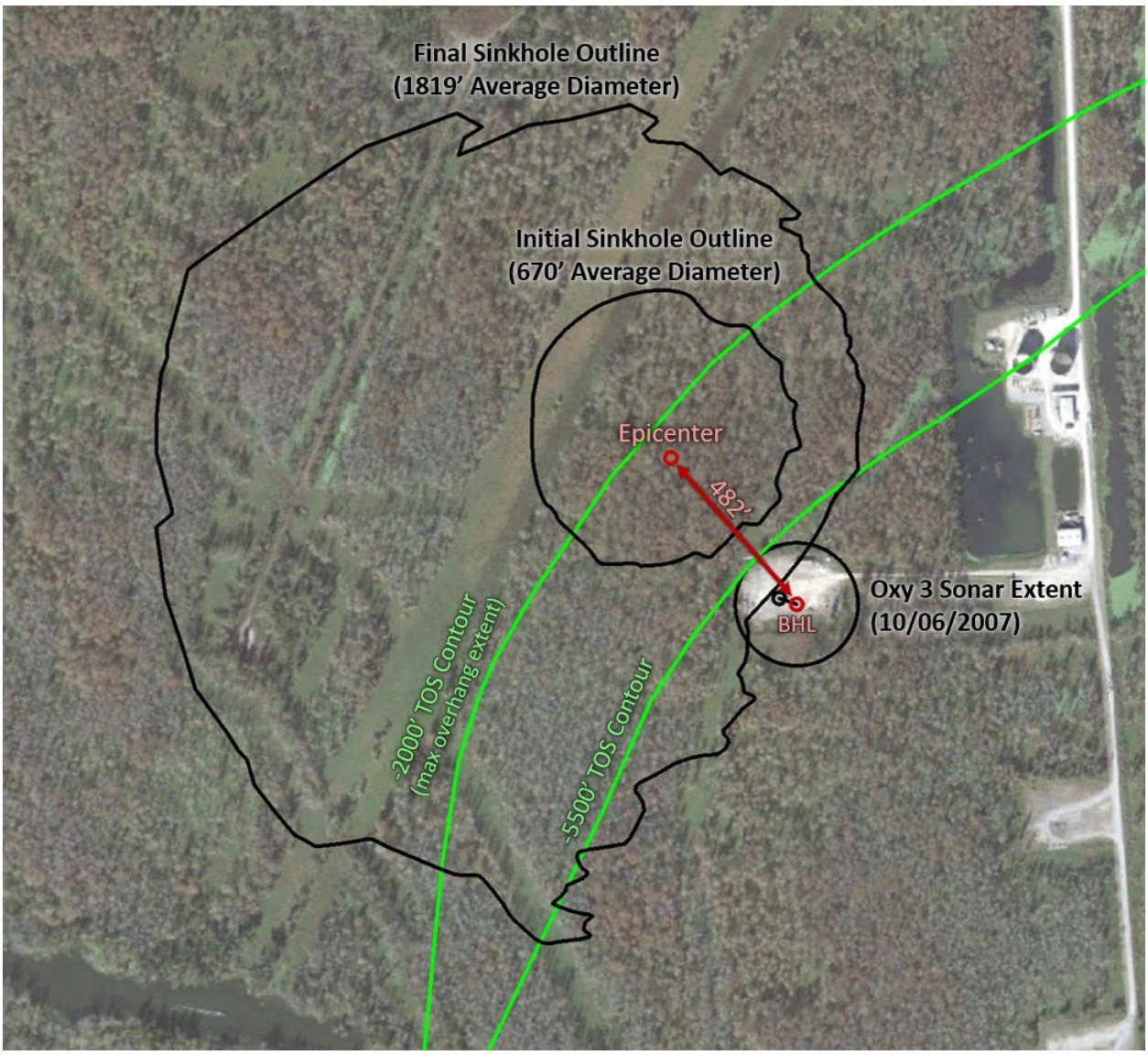


Figure 2 – Top View of Oxy 3

In the same manner as for Napoleonville, a 3-D model for Sulphur Mines including cavern geometry and salt dome contours was developed. Caverns 6 and 7 were modeled from the 3/12/2022 and 7/26/2023 sonar surveys, respectively. Top of salt contours as submitted to the LDNR on 10/13/2023 were utilized. Observations from the Napoleonville event modeling were applied to the Sulphur Mines model to estimate the potential epicenter for subsidence should a similar collapse event occur. Because a dome overhang is not present near Caverns 6 and 7, it was assumed that the path of disturbed material would be vertical, originating at the point on the flank that is nearest to Cavern 7. The theoretical subsidence epicenter was positioned directly above this point. A cross section depicting the epicenter location relative to the caverns and flank is included below as *Figure 3*.

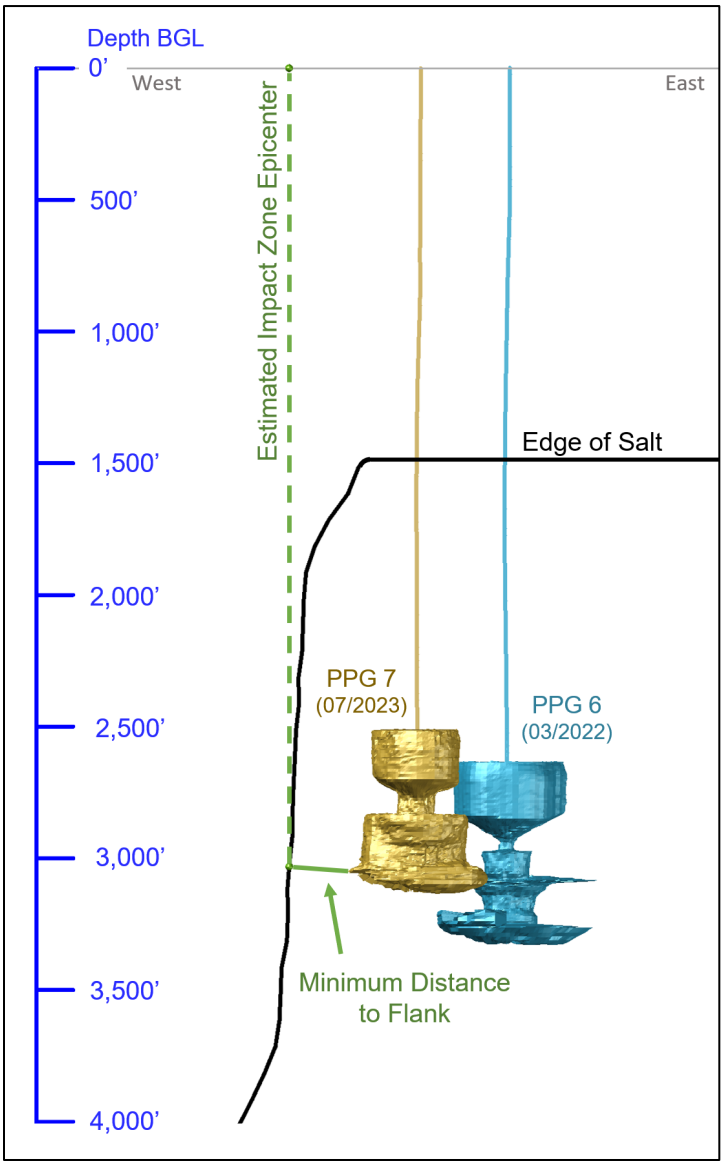


Figure 3 – Side View of Sulphur Mines Model

The diameter of the theoretical subsidence zone at Sulphur Mines was estimated through mathematical comparison to Napoleonville. In a theoretical event that the dome flank collapses into Cavern 7, due to the minimal web thickness between Caverns 6 and 7, it was assumed that the salt pillar between the two caverns would structurally fail and the caverns would coalesce. The diameter of the theoretical impact zone at Sulphur Mines was calculated based on the total volume of Cavern 6 and Cavern 7. Oxy 3 had a total volume of 19,207,568 bbls as measured by the 10/6/2007 sonar survey which was the most recent survey prior to the collapse event. Caverns 6 and 7 at the Sulphur dome have a combined total volume of 19,921,988 bbls as measured by the 3/12/2022 and 7/26/2023 sonar surveys, respectively. During the collapse event at Oxy 3, the majority of the cavern was filled with rubble. It was assumed that Caverns 6 and 7

would be filled the same amount, resulting in a surface subsidence volume that is proportional to the volume of the compromised caverns. This methodology also assumes that compaction and bulking of the displaced material would occur in a similar way to Oxy 3. To calculate the expected impact zone diameter, the sinkhole was approximated as a uniform cone. The radius of a cone is proportional to the cube root of its volume. This calculation is described by Equation 1 below. The sinkhole at Napoleonville had initial and final diameters of 670 ft and 1,819 ft, respectively. The calculated impact zone diameters at Sulphur Mines were 678 ft and 1,841 ft.

Eq. 1:

$$\frac{r_1}{r_2} = \frac{\sqrt[3]{V_1}}{\sqrt[3]{V_2}}$$

Derivation of Eq. 1:

$$V = \pi r^2 \frac{h}{3} \ , where \ \ h = x * r \ \ \rightarrow \ V = \pi r^2 \frac{x*r}{3} \ \rightarrow \ V = \pi r^3 \frac{x}{3} \ \rightarrow \ r = \sqrt[3]{\frac{3V}{x\pi}} \ \rightarrow$$

$$\frac{r_1}{r_2} = \frac{\sqrt[3]{\frac{3V_1}{x\pi}}}{\sqrt[3]{\frac{3V_2}{x\pi}}} \ \rightarrow \ \frac{r_1}{r_2} = \frac{\sqrt[3]{V_1}}{\sqrt[3]{V_2}}$$

Variables Defined:

$V = Volume$
$r = Radius$
$h = Height$
$x = ratio\ of\ radius\ to\ height$ (assumed constant for both cases)

The initial impact zone is positioned central to the epicenter. The center of the final impact zone is positioned 400 ft away from the epicenter in the direction opposite the dome. The impact zone extents were positioned in this way to match what has been observed at Oxy 3. The estimated location and areal extent of the impact zones can be seen below in *Figure 4*.

This analysis is based upon the assumption that formations adjacent to and overlying Cavern 6 and 7 are similar in composition, geophysical, and geomechanical properties to those at the Napoleonville Dome. We believe this is a reasonable assumption based upon the information available regarding the geology adjacent to and overlying Louisiana salt domes in general. Due to these assumptions and the simplistic nature of this evaluation, the conclusions stated herein include a significant degree of uncertainty. Additional analysis, including geomechanical modeling that considers site-specific geology, would likely result in a more reliable estimation of the impact zone. Only the surface subsidence, referred to as the “sinkhole” or “impact zone”, has been evaluated. Other sub-surface disturbed rock volumes have not been considered. RESPEC is currently conducting a geomechanical evaluation which may result in changes to this impact zone analysis at a later date.

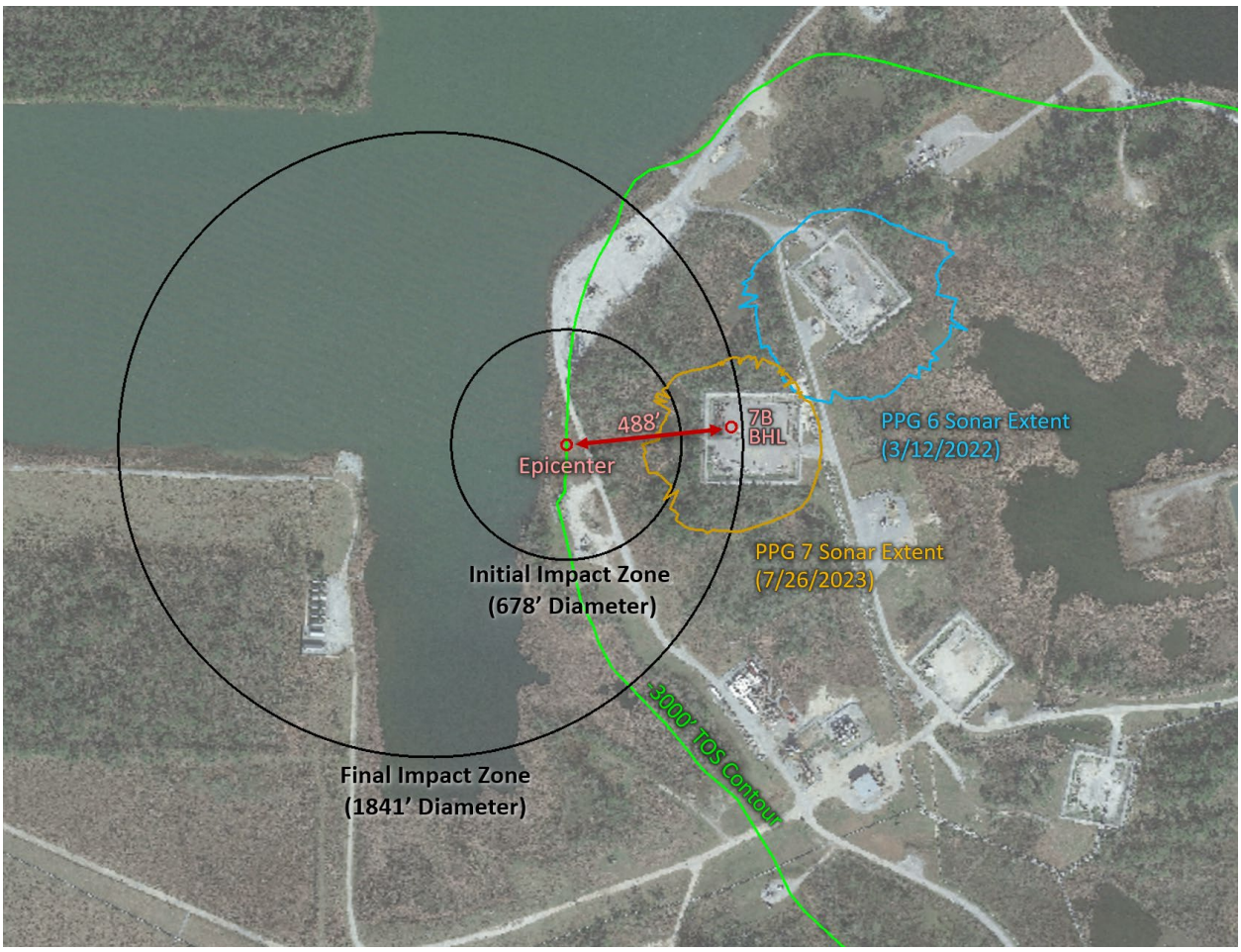


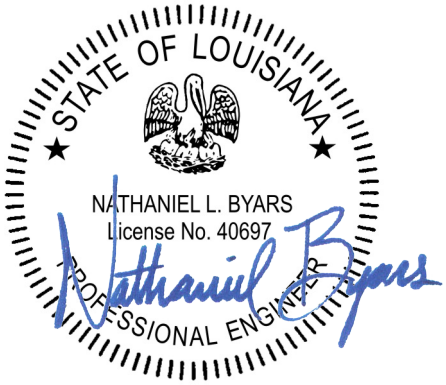
Figure 4 – Top View of Caverns 6 & 7 with Theoretical Sink Hole Projection

Please feel free to contact Nathaniel Byars at the Lonquist & Co. Austin office if you require additional information or clarification. Contact information is below:

Lonquist & Co., LLC
12912 Hill Country Blvd., Suite F-200
Austin, Texas 78738
Phone: 512-600-1779
Cell: 512-636-7795
nathaniel@lonquist.com

Respectfully submitted:

Certified By:
Lonquist & Co., LLC
Louisiana Registration No. EF-5937



Date Signed: November 27, 2023
Austin, Texas

Nathaniel L. Byars, P.E.
Principal Engineer
Louisiana License No. 40697

ATTACHMENTS

1. Bayou Corne Cavern Collapse Technical Status Update, 2/19/2013
2. Bayou Corne/Grand Bayou Sinkhole Plan & Profile, June 2015

ATTACHMENT 1

Bayou Corne Cavern Collapse Technical Status Update, 2/19/2013

1415 Louisiana St., Suite 3800 | Houston, Texas 77002 USA | Tel 713.559.9950 | Fax 713.559.9959

Bayou Corne Cavern Collapse

Technical Status Update

Gary R. Hecox, Ph.D., PG

CB&I *(formerly Shaw)*

February 19, 2013

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

DEFINITIONS AND ACRONYMS

- 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 grave 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

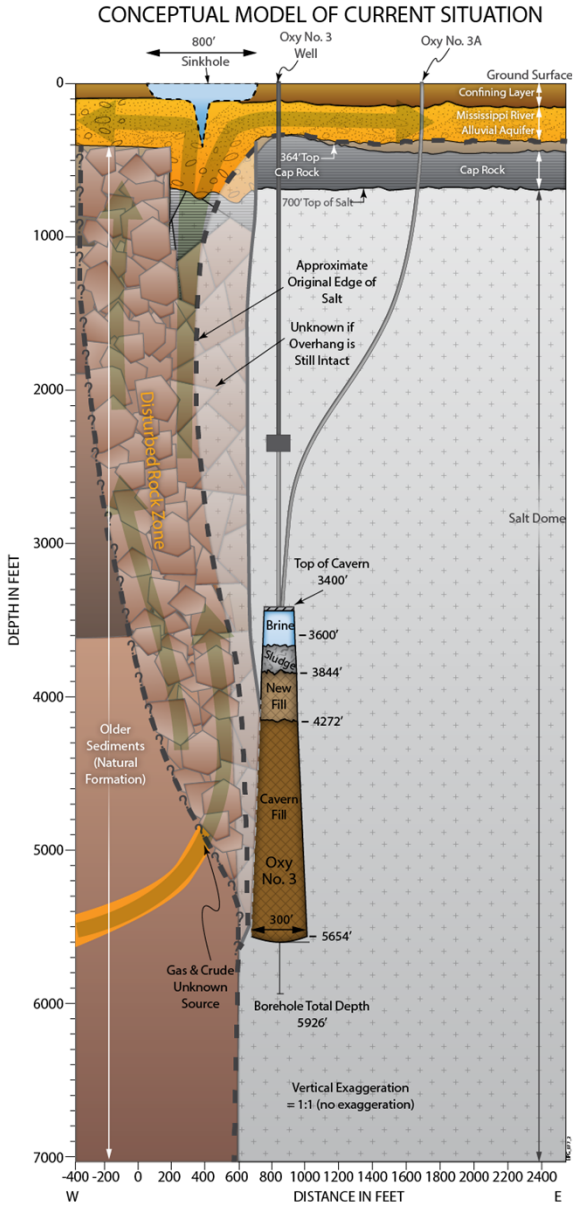
NAPOLEONVILLE SALT DOME

WHY IS BAYOU CORNE UNPRECEDENTED COLLAPSE EVENT?

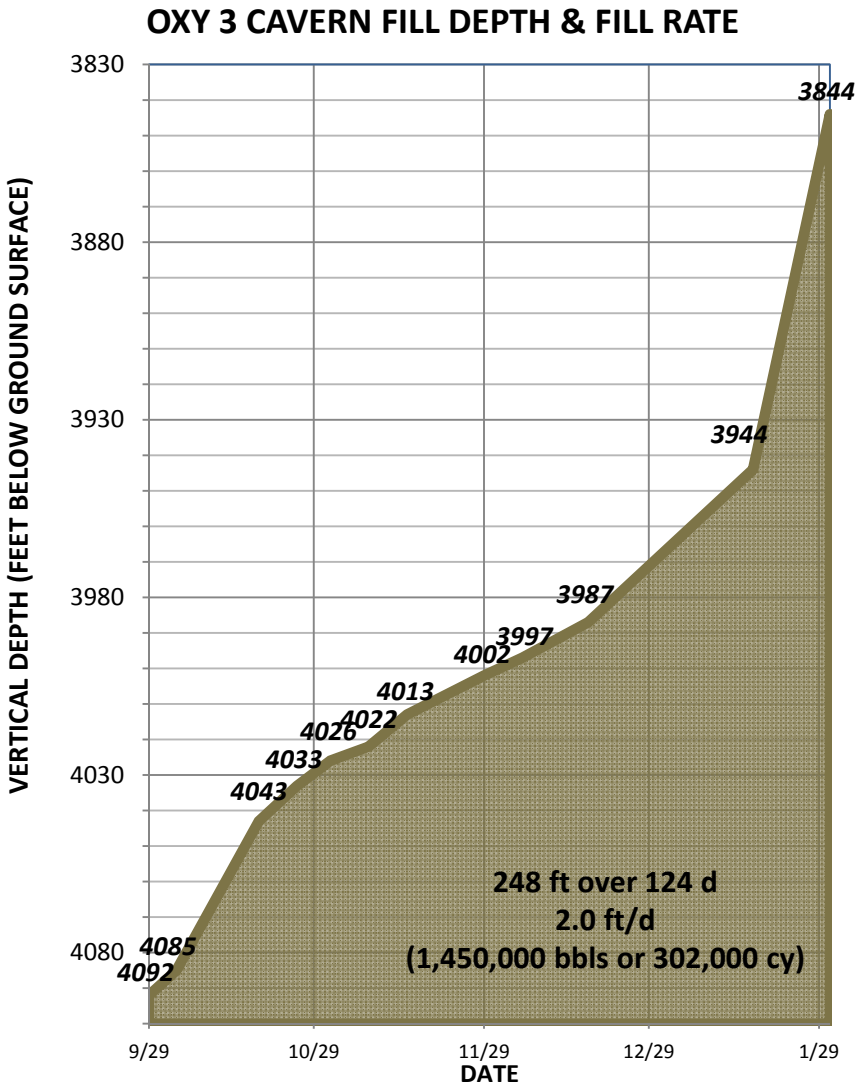
- Cavern collapse at 5,600 feet that fractured to the surface creating sinkhole
- Sidewall and not roof collapse of brine-mined salt cavern
- Cavern collapse is still ongoing with a number of seismic events detected every day
- Large amounts of gas and some crude oil migrating through Disturbed Rock 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 mcfd
  - Depth and volume of gas reservoirs is currently unknown

CONCEPTUAL MODEL OF COLLAPSED CAVERN

- 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

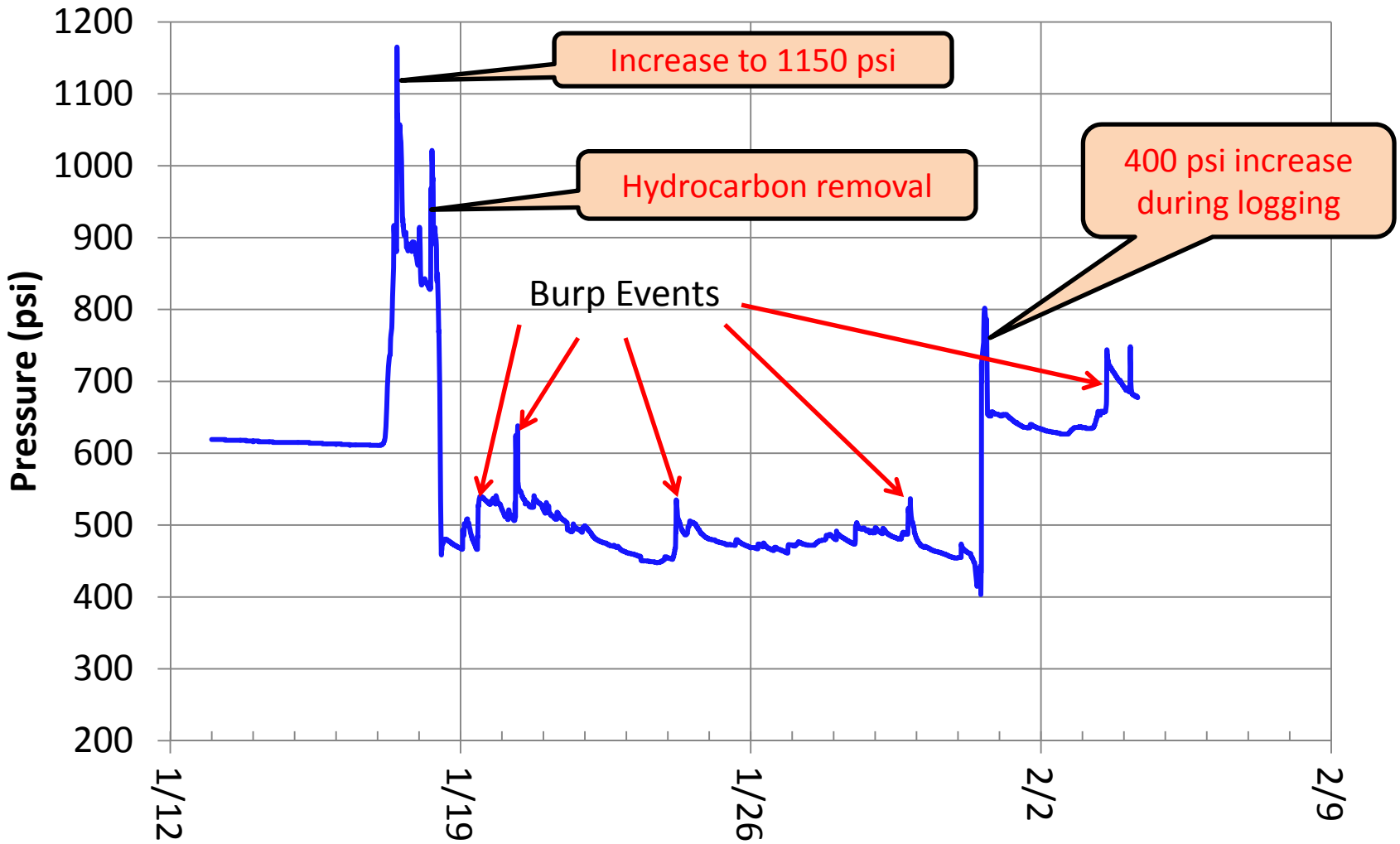


CAVERN IN-FILLING RATE



- 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

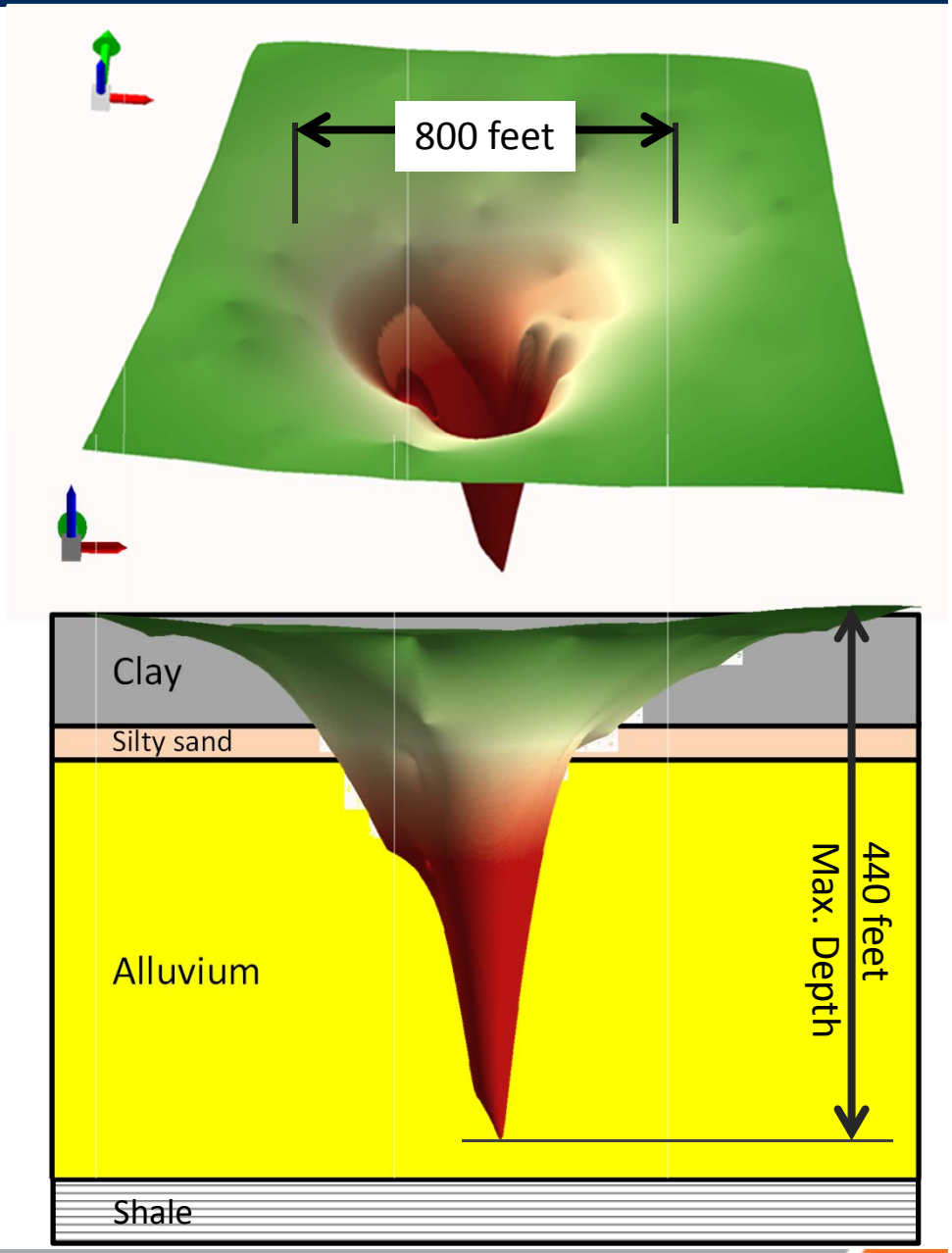


BAYOU CORNE SINKHOLE

Continuously changing

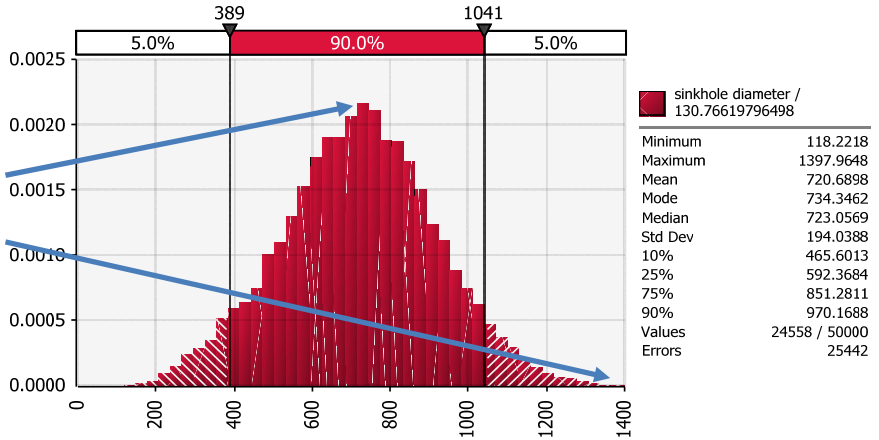
BAYOU CORNE SINKHOLE

- 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)

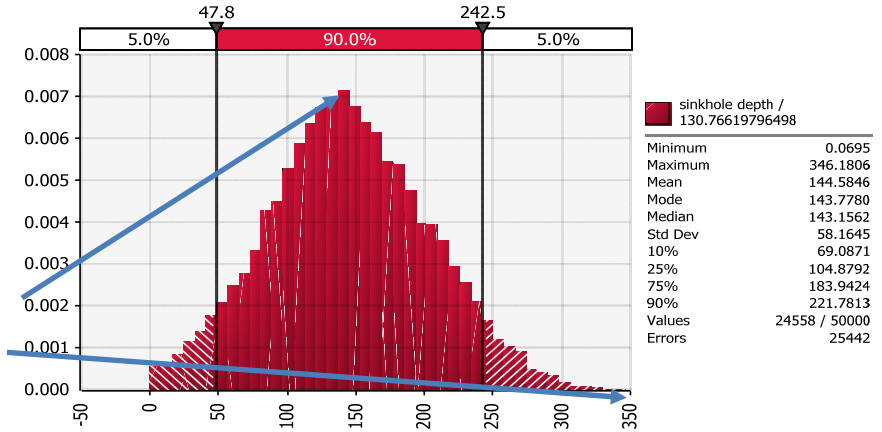


EVENTUAL SINKHOLE SIZE (Size of the lake)

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

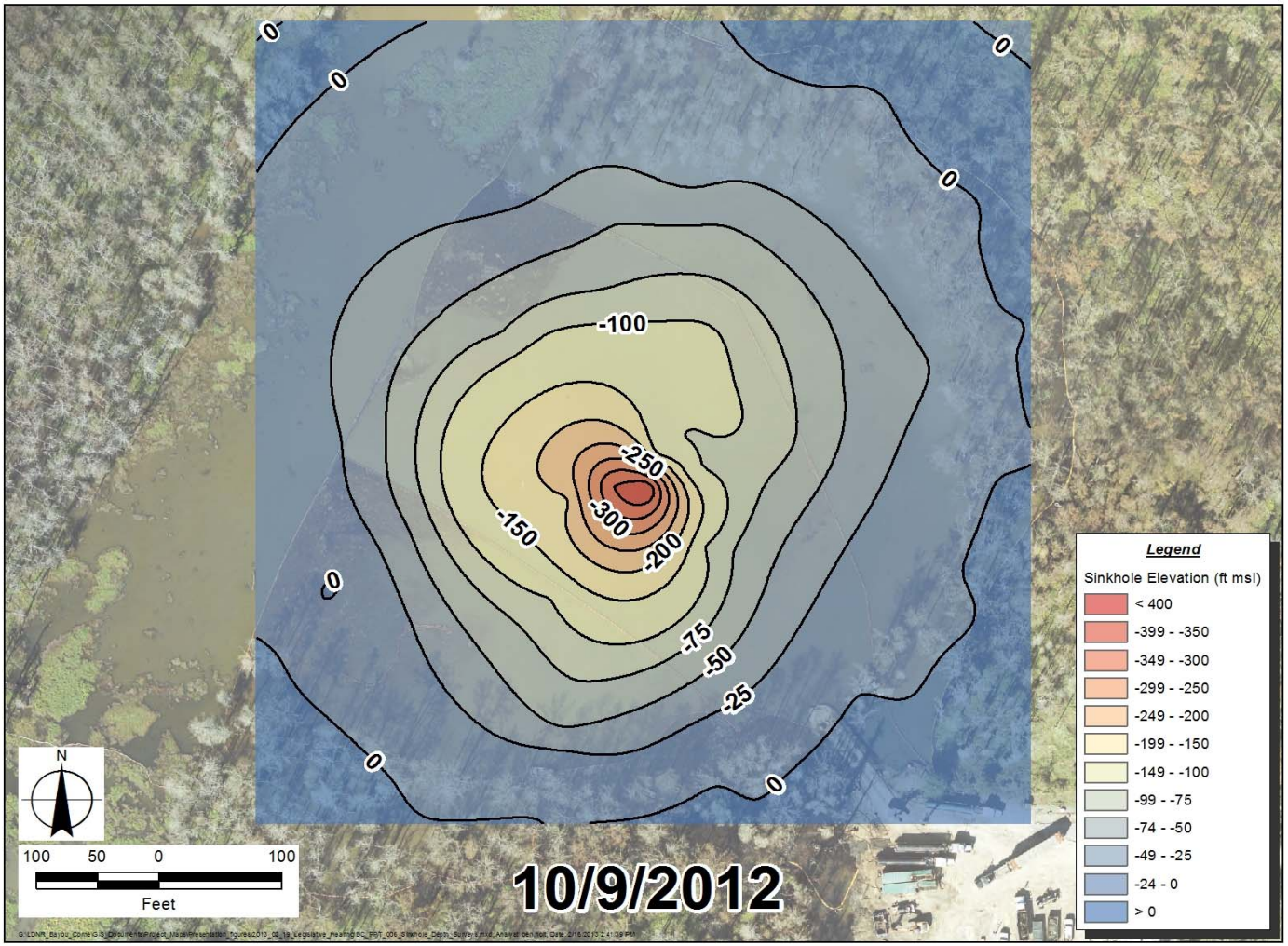


Sinkhole Depth
Most Likely = 144 ft
Worst Case = 346 ft

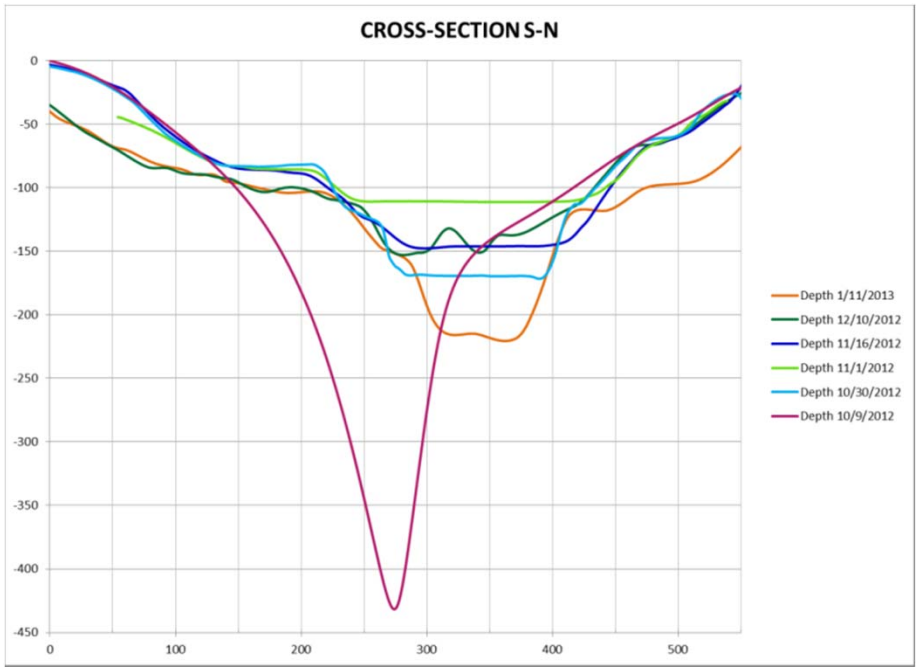


Itasca analysis

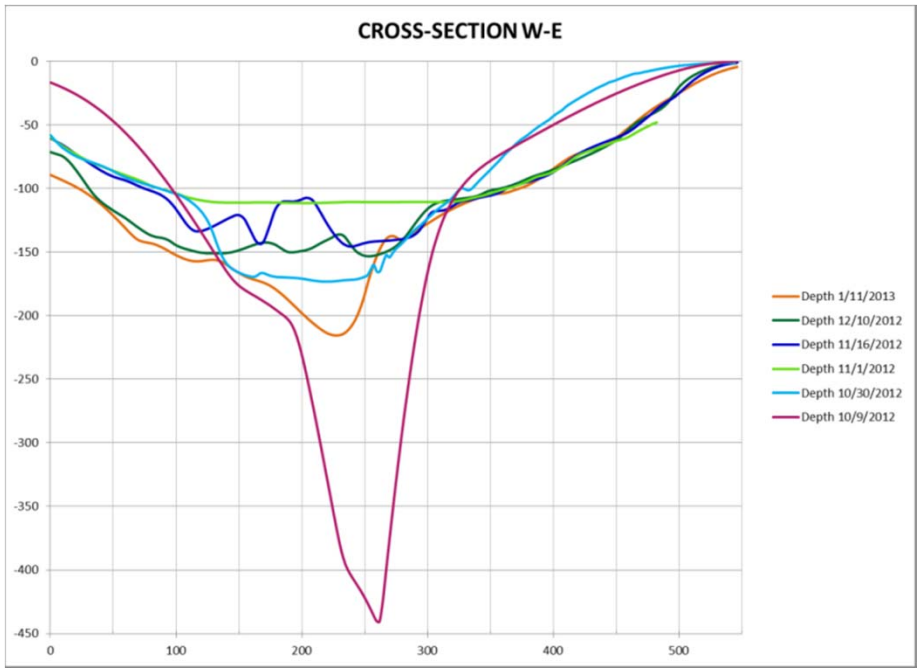
BAYOU CORNE SINKHOLE CHANGES WITH TIME



- South to North



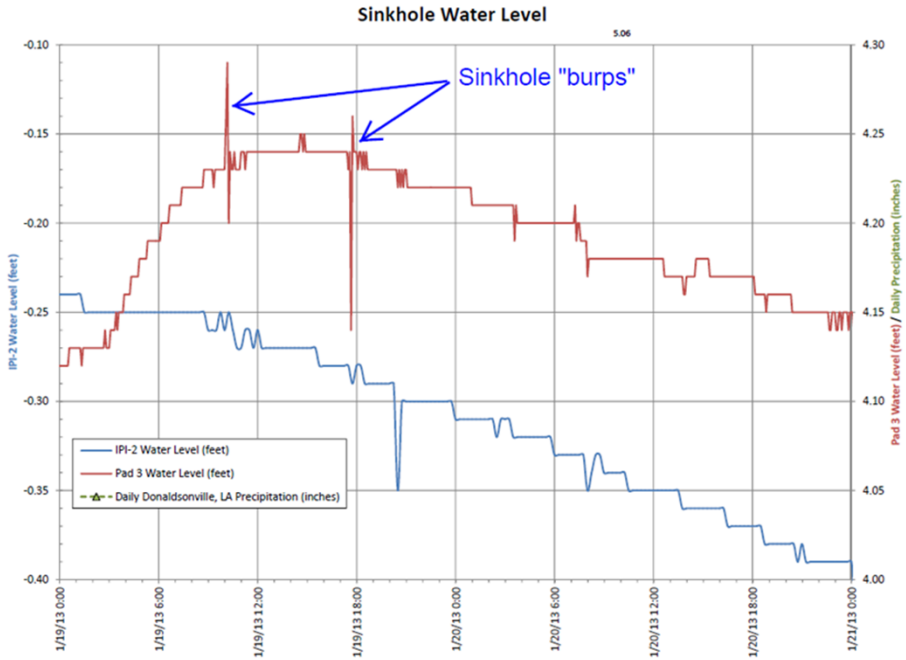
- West to East



SINKHOLE GAS BURP EVENTS

- 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

BURP EVENTS BRING GAS AND FORMATION LIQUID TO THE SURFACE

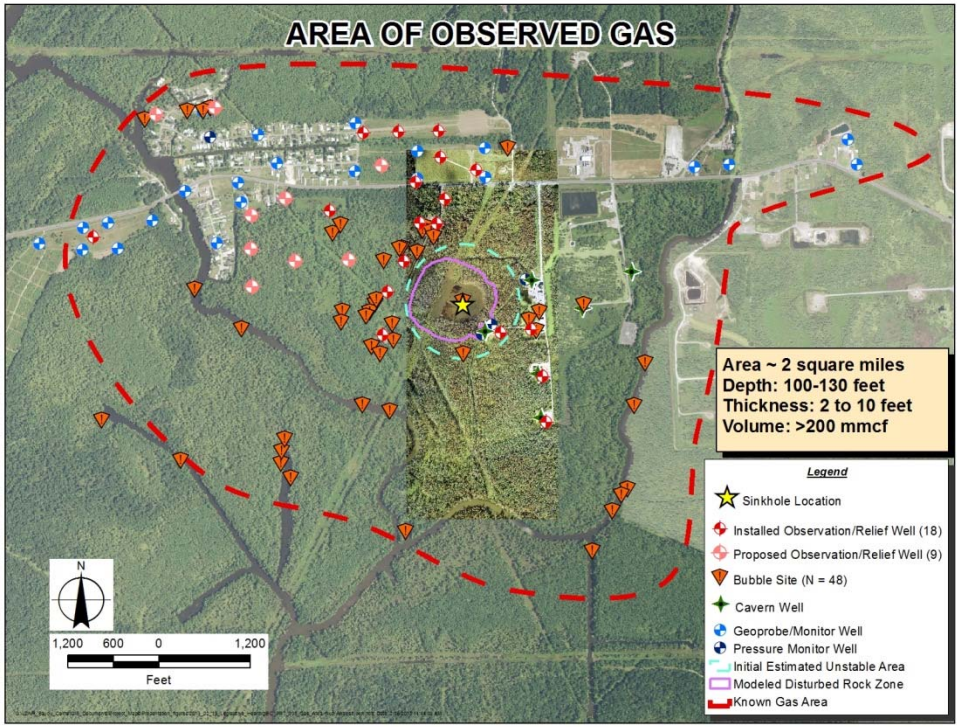


GAS (METHANE)

IN MISSISSIPPI RIVER ALLUVIAL AQUIFER (MRAA)

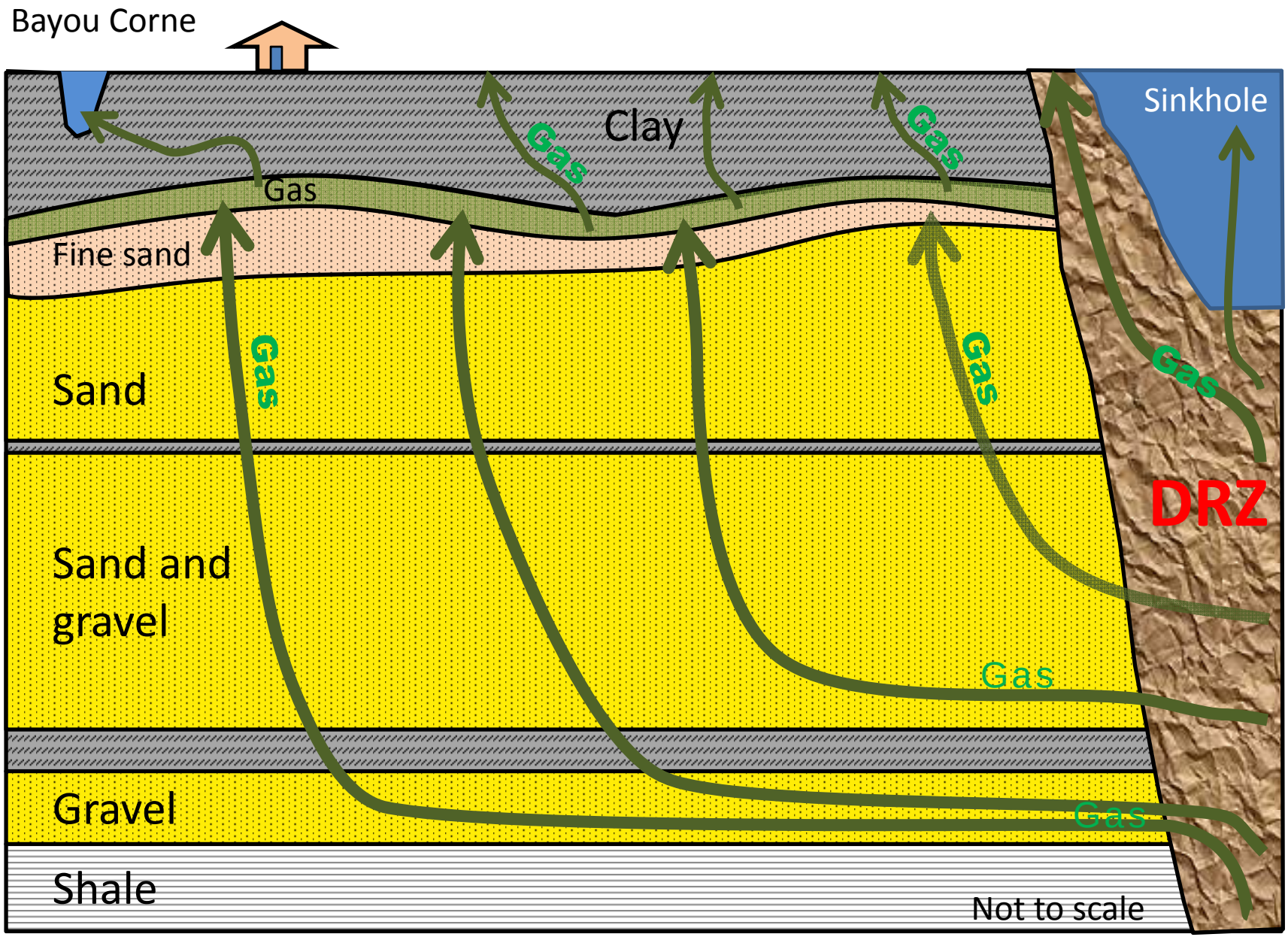
- Current condition and prognosis for near future
- May require long-term management

AREA OF NATURAL GAS (METHANE)



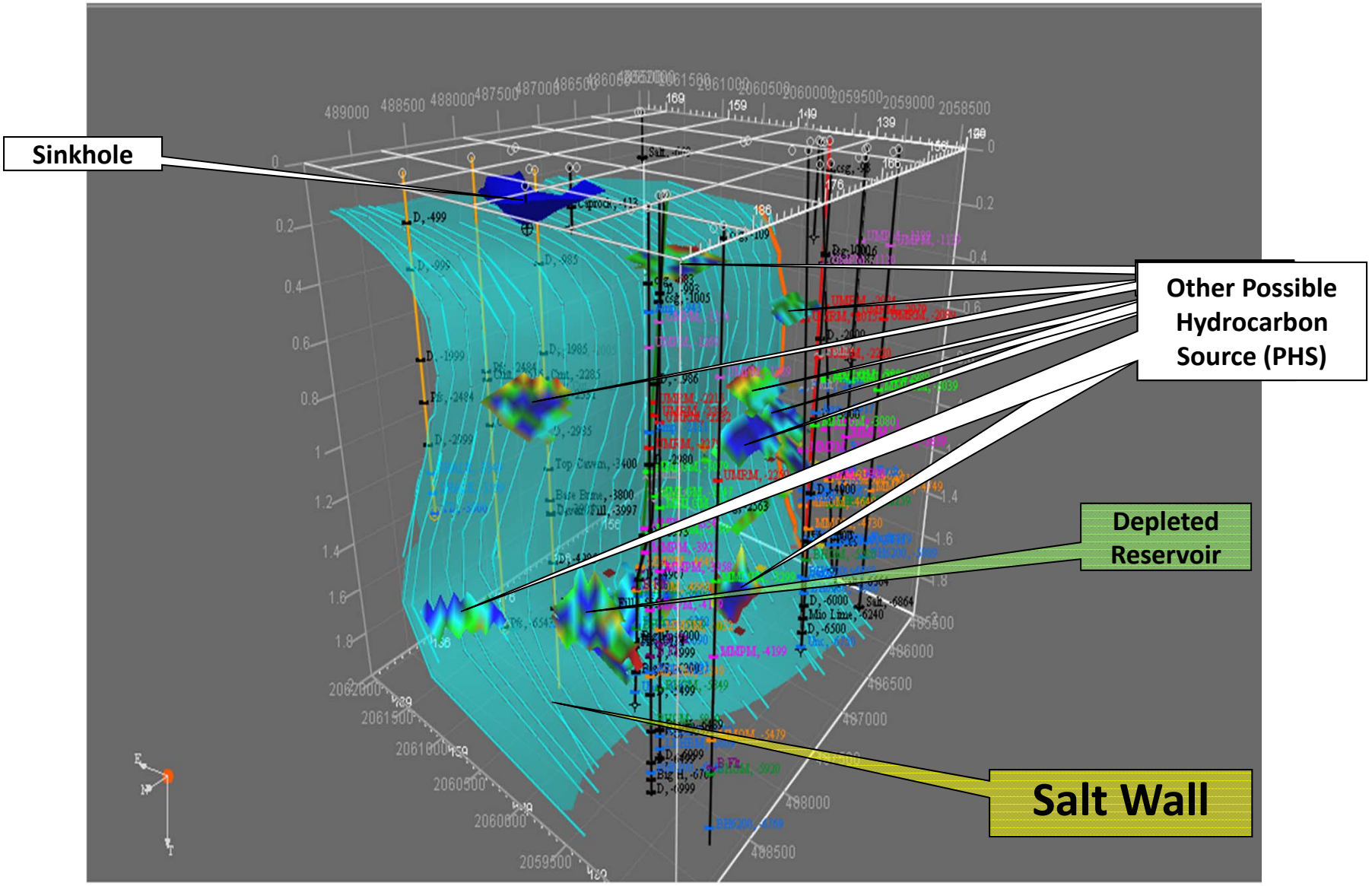
- Over 2 square miles—extent not well defined
- Gas 2 to 10 feet thick across area
- Still seeing pressures in shallow wells even where MRAA gas pressures & saturations have declined
- 20 new bubble sites in past month
  - Mostly on west side of sinkhole
  - Around perimeter of modeled disturbed rock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

GAS MIGRATION CONCEPTUAL MODEL



WHERE IS GAS COMING FROM?

NUMEROUS POTENTIAL ZONES

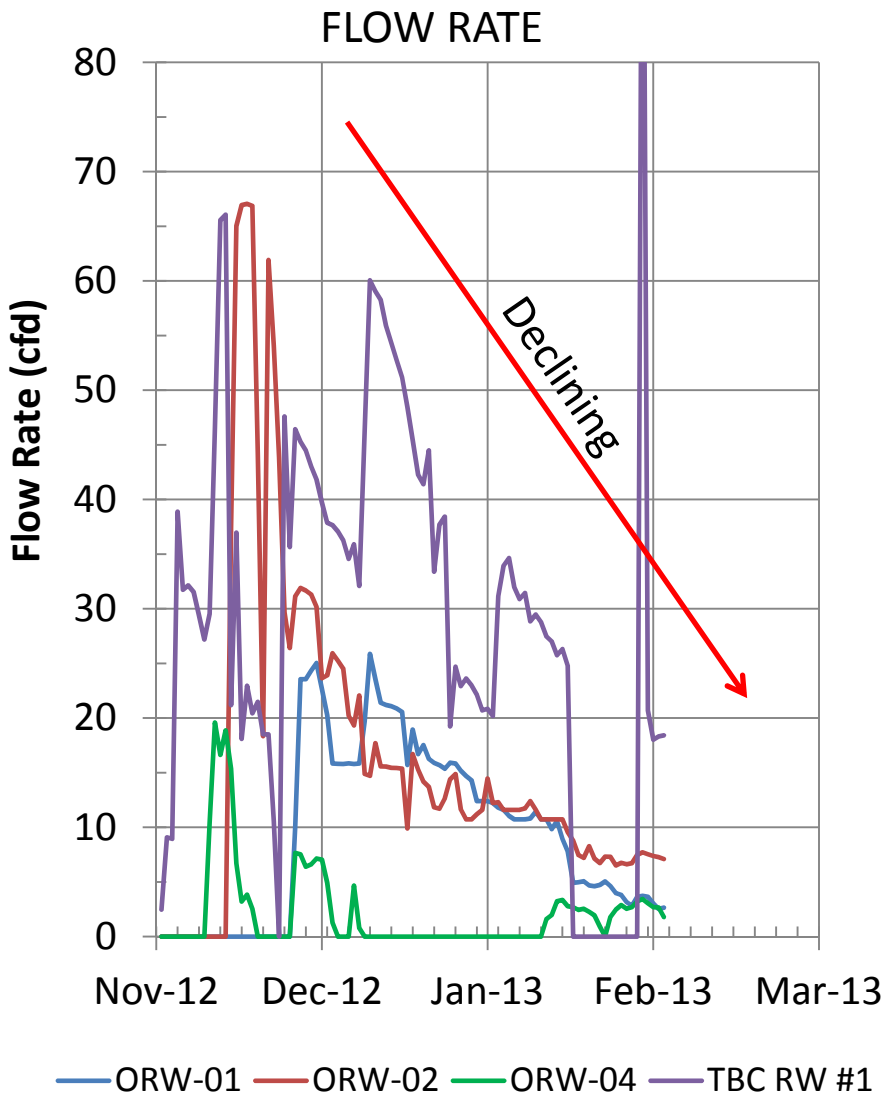


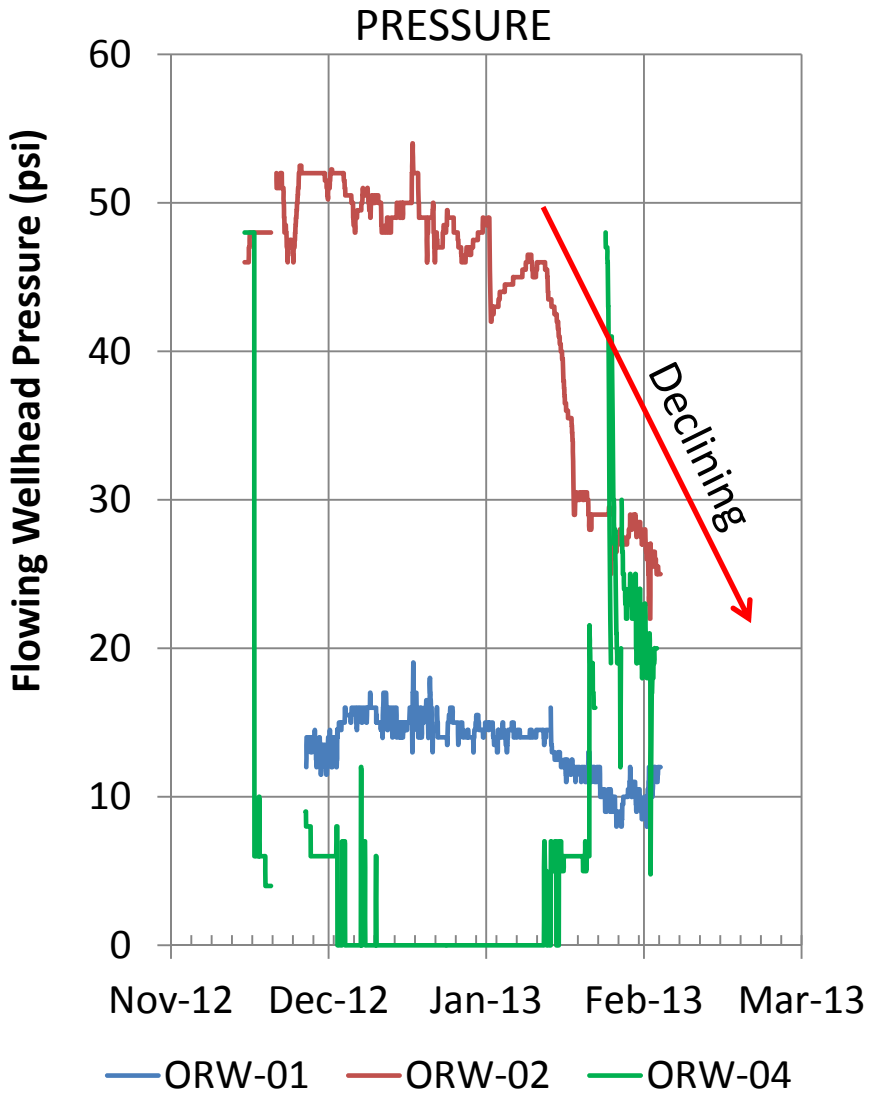
2007 3D seismic by Don Marlin, CPG

MRAA GAS VENTING OPERATIONS

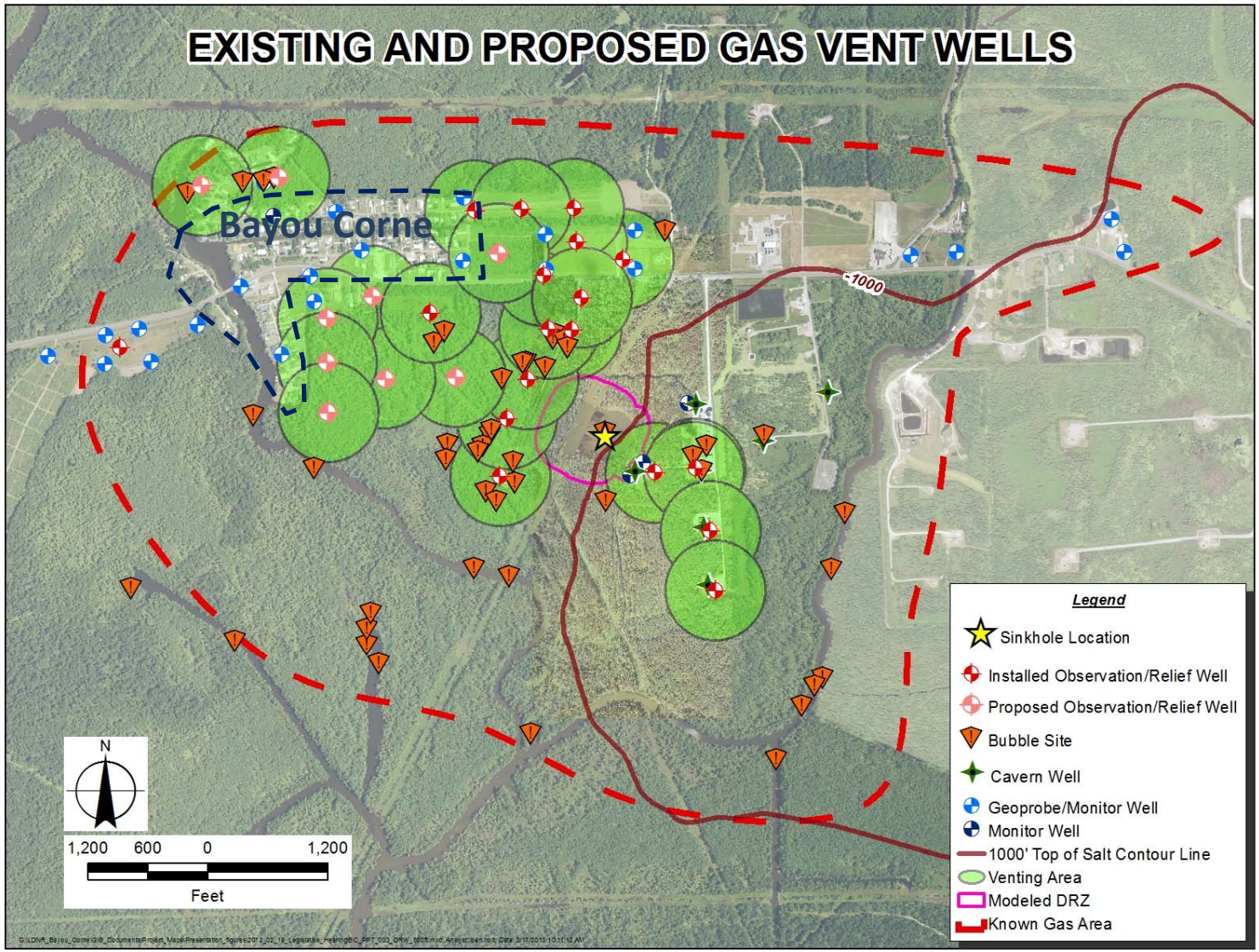
Flare stack

VENTING OPERATIONS DEMONSTRATED THAT WELLS REDUCE GAS VOLUME AND PRESSURES





PROPOSED VENT WELLS & AREAS OF GAS VENTING



MITIGATION OF GAS—PATH FORWARD

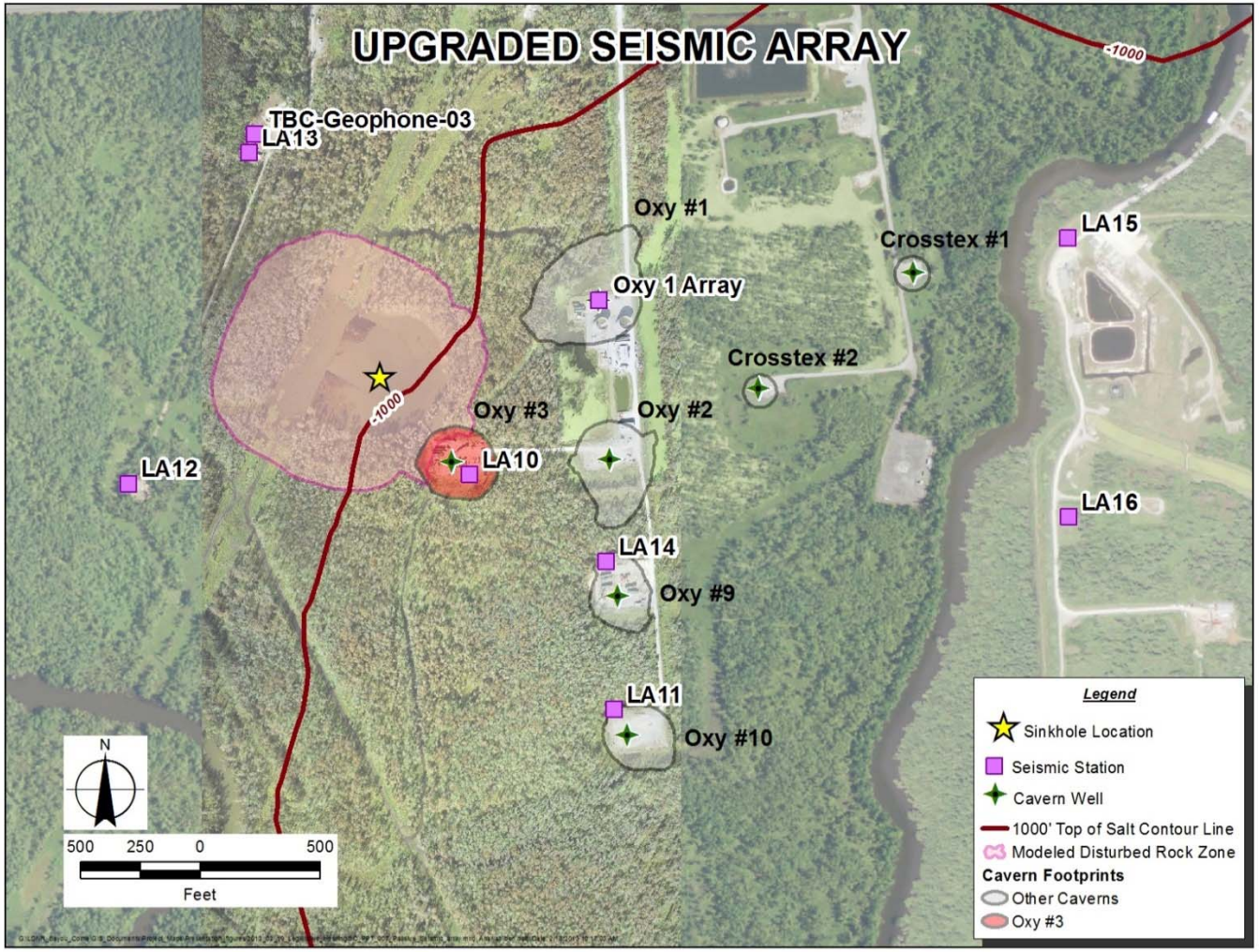
- To get residents back into their homes, gas pressures in the MRAA ***must*** be reduced to a level that gas will no longer migrate to the surface
- Need to install additional vent wells below community and to east in Grand Bayou
  - Vertical wells: Wells must control gas pressure 100% of time during 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

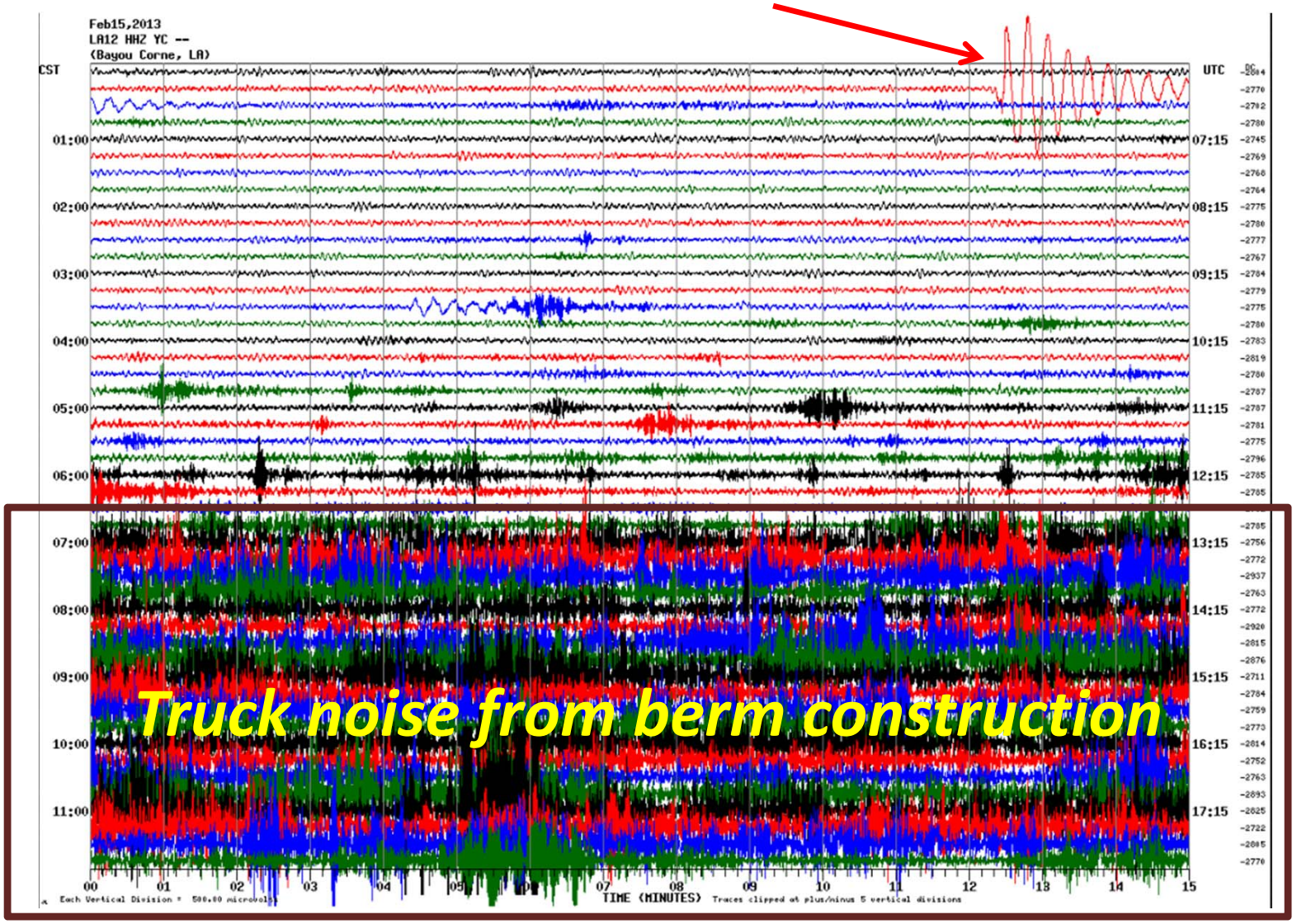
- Approach
  - Seismic monitoring
    - Listen for micro-seismic events that indicate rock may be fracturing
    - Shallow surface array (7 locations), two borehole seismic arrays, and micro-seismic array with 12 geophones in Oxy 1
    - Dr. Horton of CERI retained to assist with seismic evaluations
  - 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

SEISMIC MONITORING ARRAY

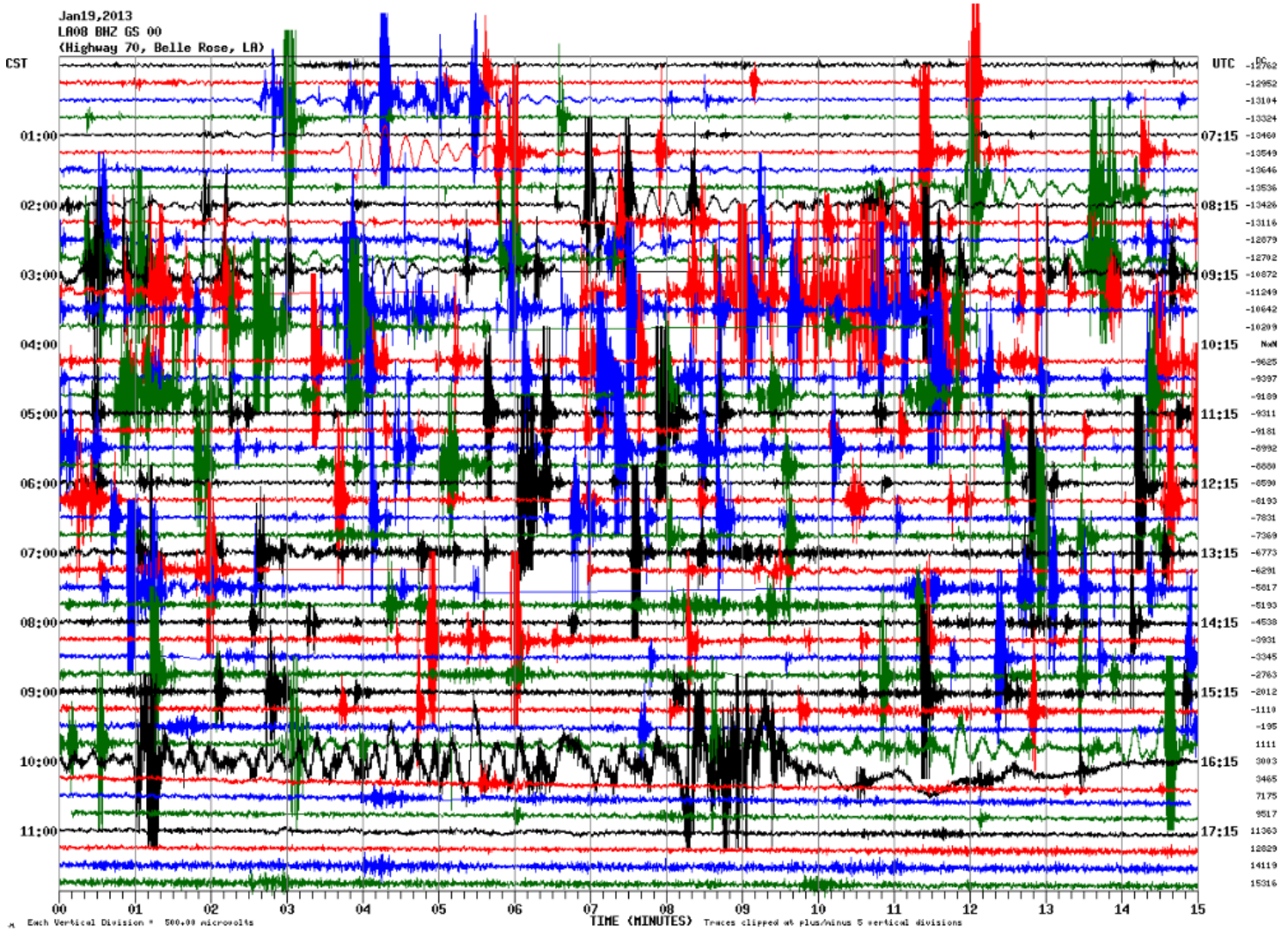


EXAMPLE: VLP BURP EVENT AND CULTURAL NOISE

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

ATTACHMENT 2

Bayou Corne/Grand Bayou Sinkhole Plan & Profile - June 2015

AERIAL IMAGE TAKEN ON 2/06/15.

06-26-15 SURVEY NOTES:

1) Bubble activity observed on northeast side of sinkhole.
2) Water visibility observed to a depth of approximately -8'.
3) Bottom elevation by fathometer was approximately -180'.
4) Bottom elevation by wireline was approximately -194'.

WEIGHTED WIRELINE MEASUREMENTS ... ... ▲
(TAKEN ON 06/26)

ROD SOUNDING LOCATION ... ●
(TAKEN ON 06/26 - 06/29)

AREA & VOLUME CALCULATIONS:
USING THE LIMITS OF THE -10' CONTOUR AS SHOWN AND AN UPPER ELEVATION LIMIT OF -2.0', THE SINKHOLE RAW INTERNAL VOLUME MEASURES APPROXIMATELY 3,454,790 CU. YDS.

USING THE LIMITS OF THE SURVEY AND WITH AN UPPER ELEVATION LIMIT OF -2.0', THE SUBSIDENCE AREA (-2' TO -10') RAW INTERNAL VOLUME MEASURES APPROXIMATELY 142,548 CU. YDS.

APPROXIMATE AREA OF -10.0' CONTOUR = 32.5 ACRES
APPROXIMATE SUBSIDENCE AREA = 27.2+ ACRES
TOTAL AREA = 59.7+ ACRES
NOTE: CONTAINMENT ROAD NOT USED IN CONTOURS AND VOLUME CALCULATIONS.

STATE OF LOUISIANA
MATTHEW JOHN FORE
License No. 4941
PROFESSIONAL LAND SURVEYOR

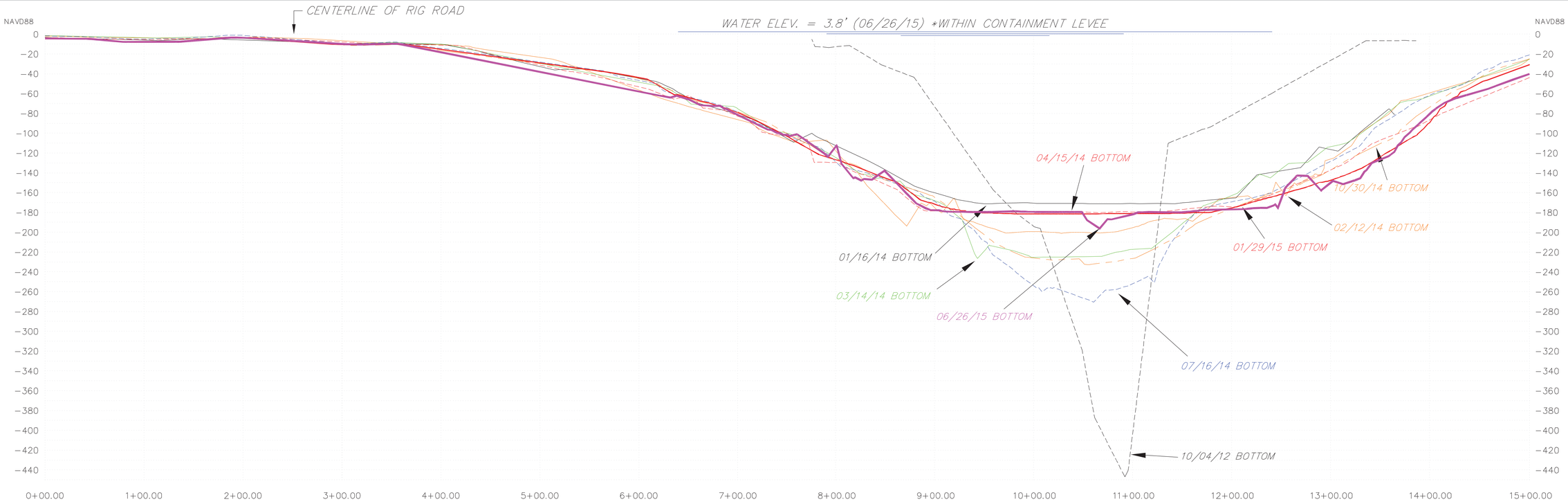
06/29/15

Miller Engineers & Associates, Inc.
Consulting Engineers & Land Surveyors
601 Main Street P.O. Box 223
Franklin, La. 70538

TEXAS BRINE
BAYOU CORNE/GRAND BAYOU SINKHOLE
PLAN AND PROFILE

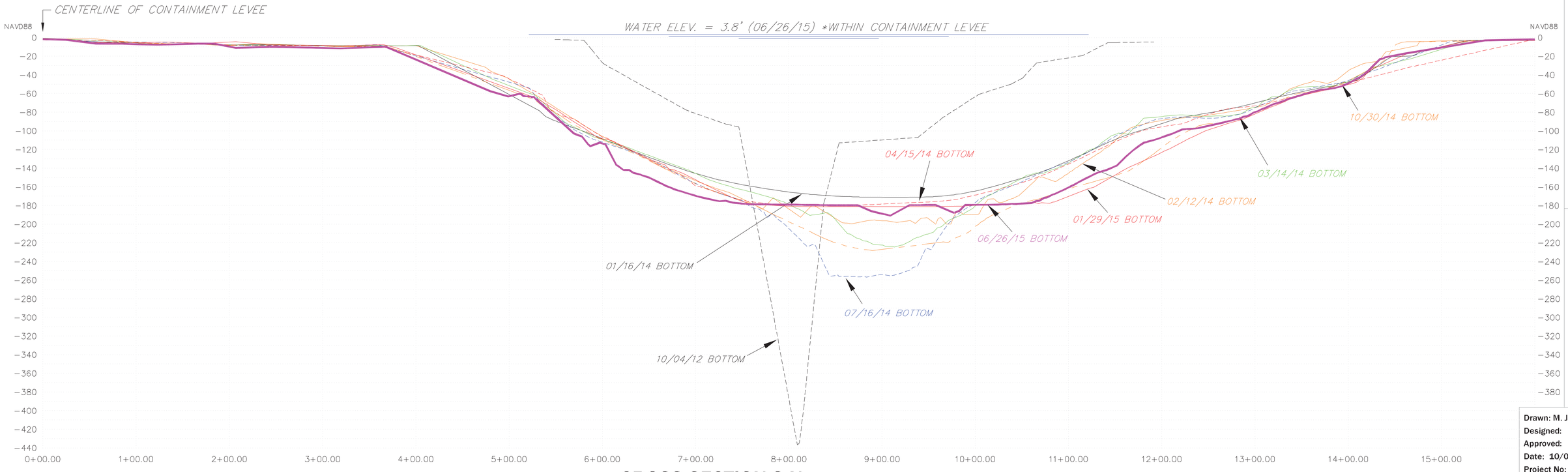
JUNE 2015
PLAN & PROFILE

Drawn: M. J. Fore, PLS
Date: 10/04/2012
Project No: 13512
Scale: As Shown
Revised: 06/29/15
Sheet 1 of 3



CROSS SECTION W-E

PROFILE:
HORIZONTAL: 1"=50'
VERTICAL: 1"=50'



CROSS SECTION S-N

PROFILE:
HORIZONTAL: 1"=50'
VERTICAL: 1"=50'

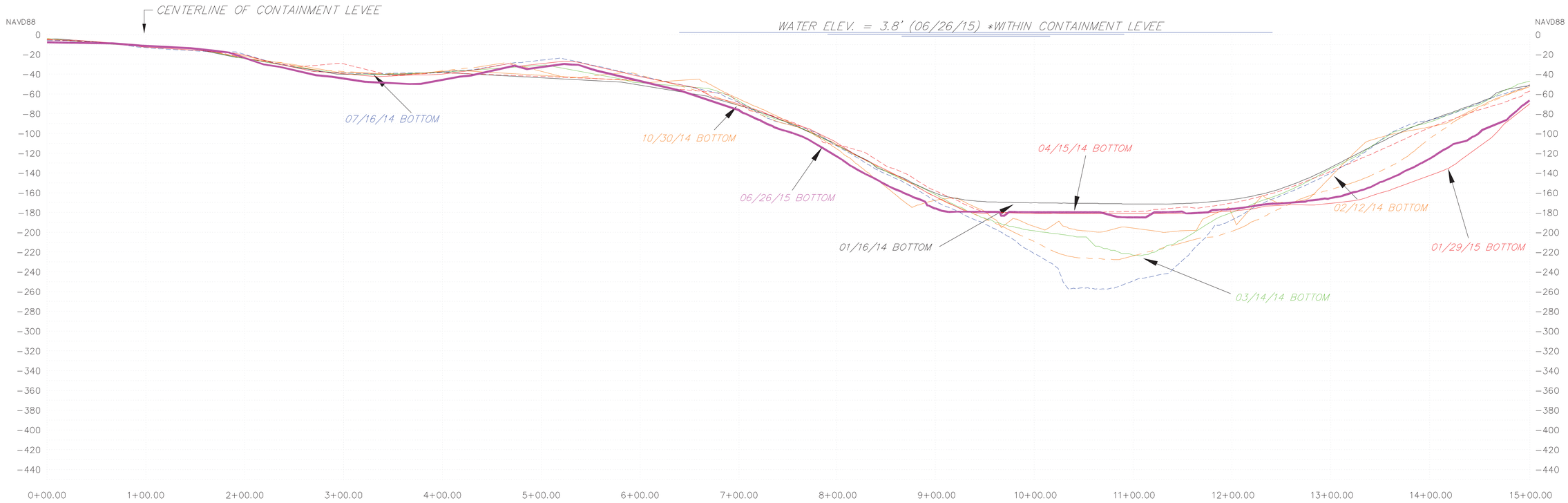
STATE OF LOUISIANA
MATTHEW JOHN FORE
License No. 4941
PROFESSIONAL
LAND SURVEYOR
06/29/15

Miller Engineers & Associates, Inc.
Consulting Engineers & Land Surveyors
601 Main Street P.O. Box 223
Franklin, La. 70538

TEXAS BRINE
BAYOU CORNE/GRAND BAYOU SINKHOLE

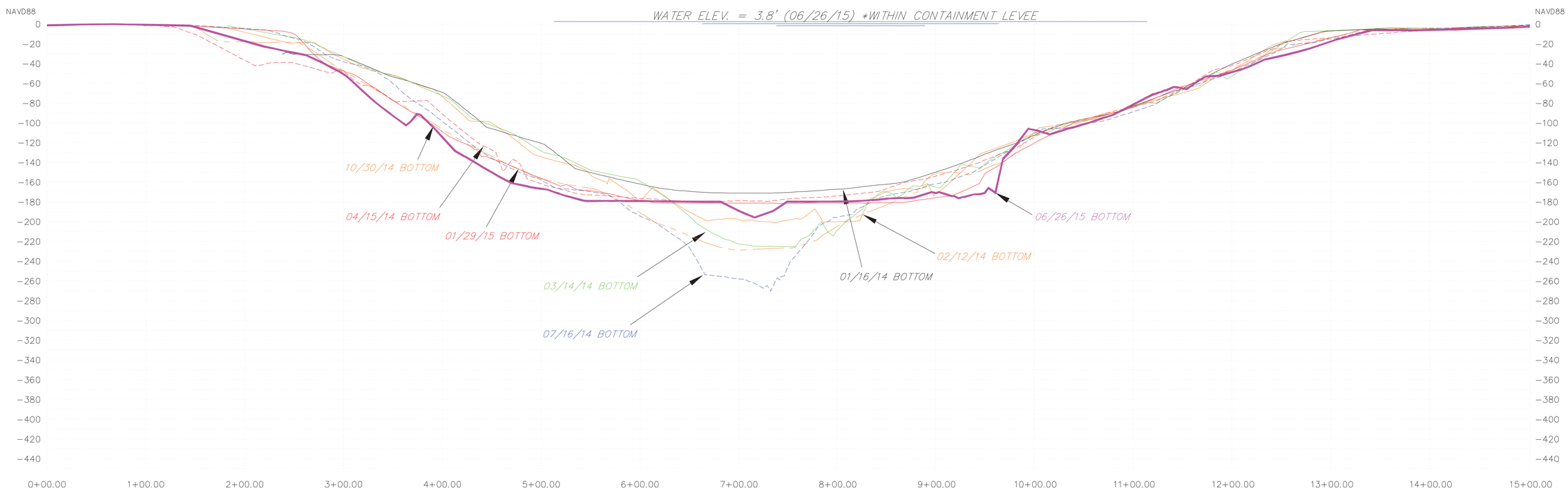
JUNE 2015
PLAN & PROFILE

Drawn: M. J. Fore, PLS
Designed:
Approved:
Date: 10/04/2012
Project No: 13512
Scale: As Shown
Revised: 06/29/15
Sheet 2 of 3



CROSS SECTION SSW-NNE

PROFILE:
HORIZONTAL: 1"=50'
VERTICAL: 1"=50'



CROSS SECTION SSE-NNW

PROFILE:
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VERTICAL: 1"=50'

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