DETECTION OF SUBSURFACE METHANE THROUGH GEOPHYSICAL METHODS

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INVERSE METHOD OF SOLUTION

Effect → Cause

Sounding vs. Profiling

PASSIVE (Field Measurement)

ACTIVE (Induced Method)

PASSIVE
FIELD MEASUREMENT

1. Acoustic
2. Electrical Potential
3. Electromagnetic
4. Gravimetric
5. Magnetic
6. Nuclear (Radioactivity)
7. Thermal

ACTIVE
INDUCED METHOD

1. Acoustic
2. Electrical Imaging
3. Electromagnetic
4. Nuclear (Decay Response)
5. Seismic Reflection/Refraction

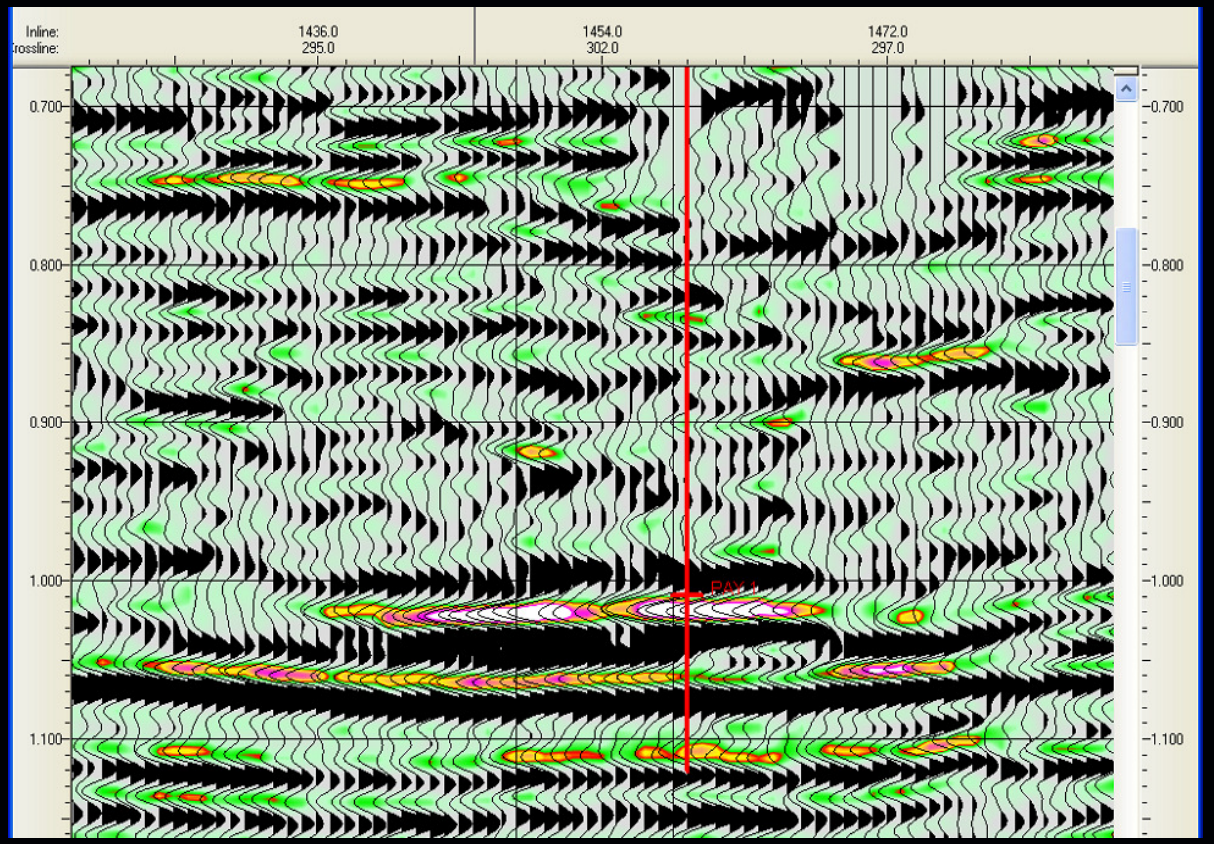
GEOPHYSICAL METHODS WILL NOT ‘SEE’ METHANE IN THE NEAR-SURFACE*

*Except

Bright spot on a seismic line where accumulations of gas impact the velocity of p-wave

Seismic Reflection

Direct Hydrocarbon Indicator



Offshore Gulf of Mexico

GEOPHYSICS CAN PREDICT:

- Habitat
  - Biogenic
    - Landfills
  - Thermogenic
    - Abandoned Gas Wells
    - Leaking Pipe Lines
- Pathway
  - Fracture migration
    - VLF
    - EI
    - Seismic

HABITAT

Landfills and Marshes

Organic compound → CO_2, CH_4 and H_20

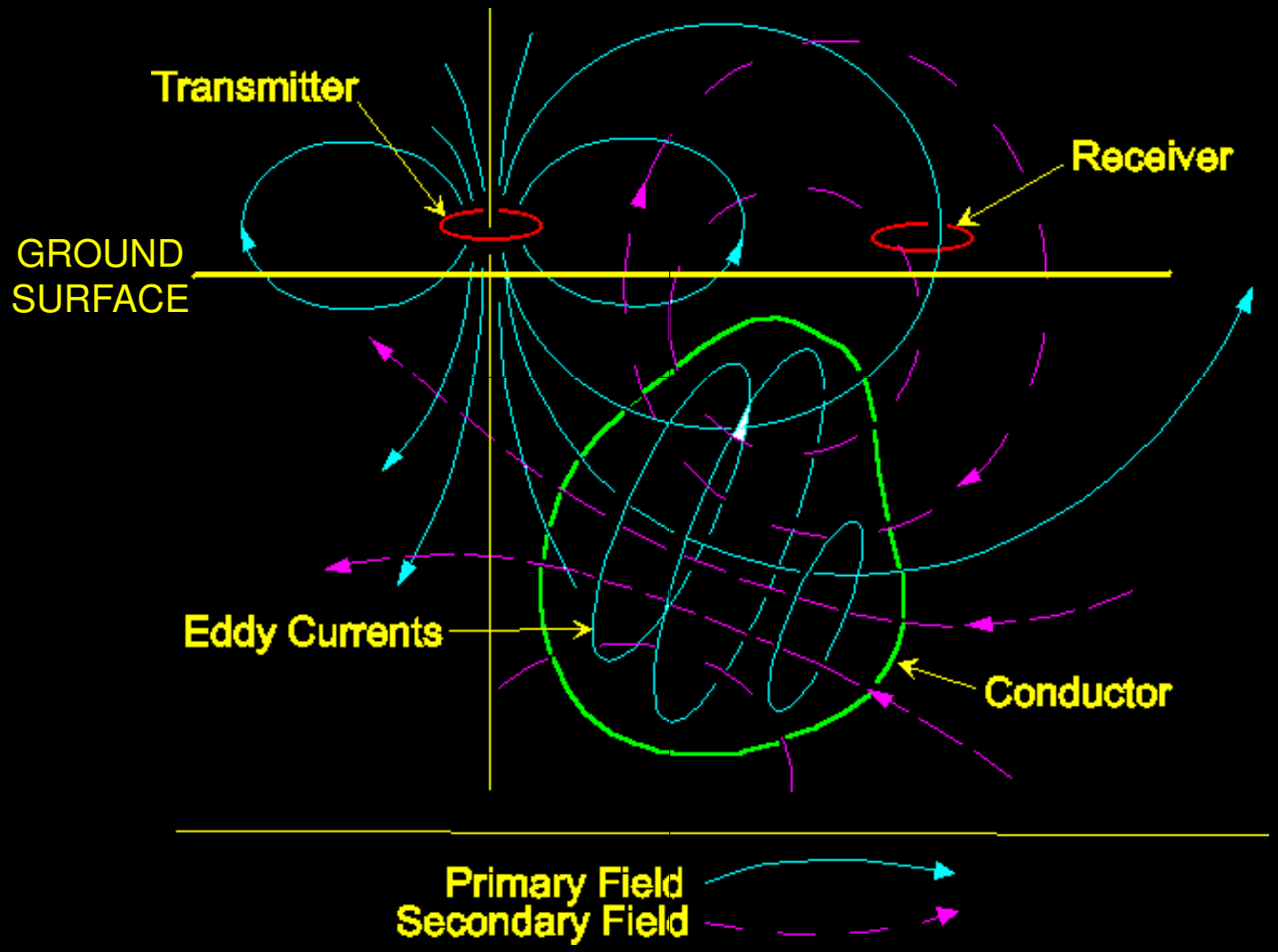
Leachate = H_20 with salts and metal ions

↑ Conductivity

ELECTROMAGNETIC TERRAIN CONDUCTIVITY MAPPING

- Profiling Tool
- Realtime GPS
- Depth Ranges (1 in to 200 ft)
- Uses
  - Landfills (Margin, Thickness, Volume, Gas)
  - Metal Detection
  - Plumes

SCHEMATIC DIAGRAM

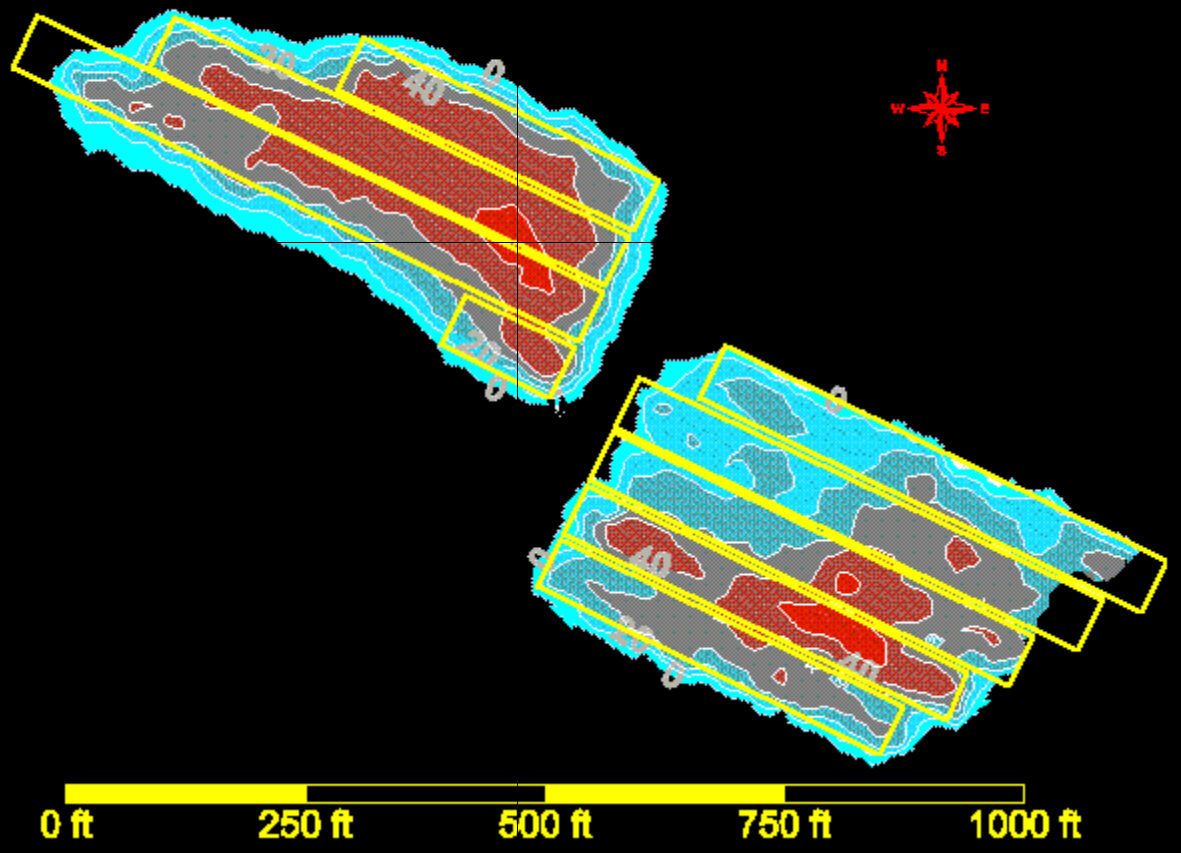


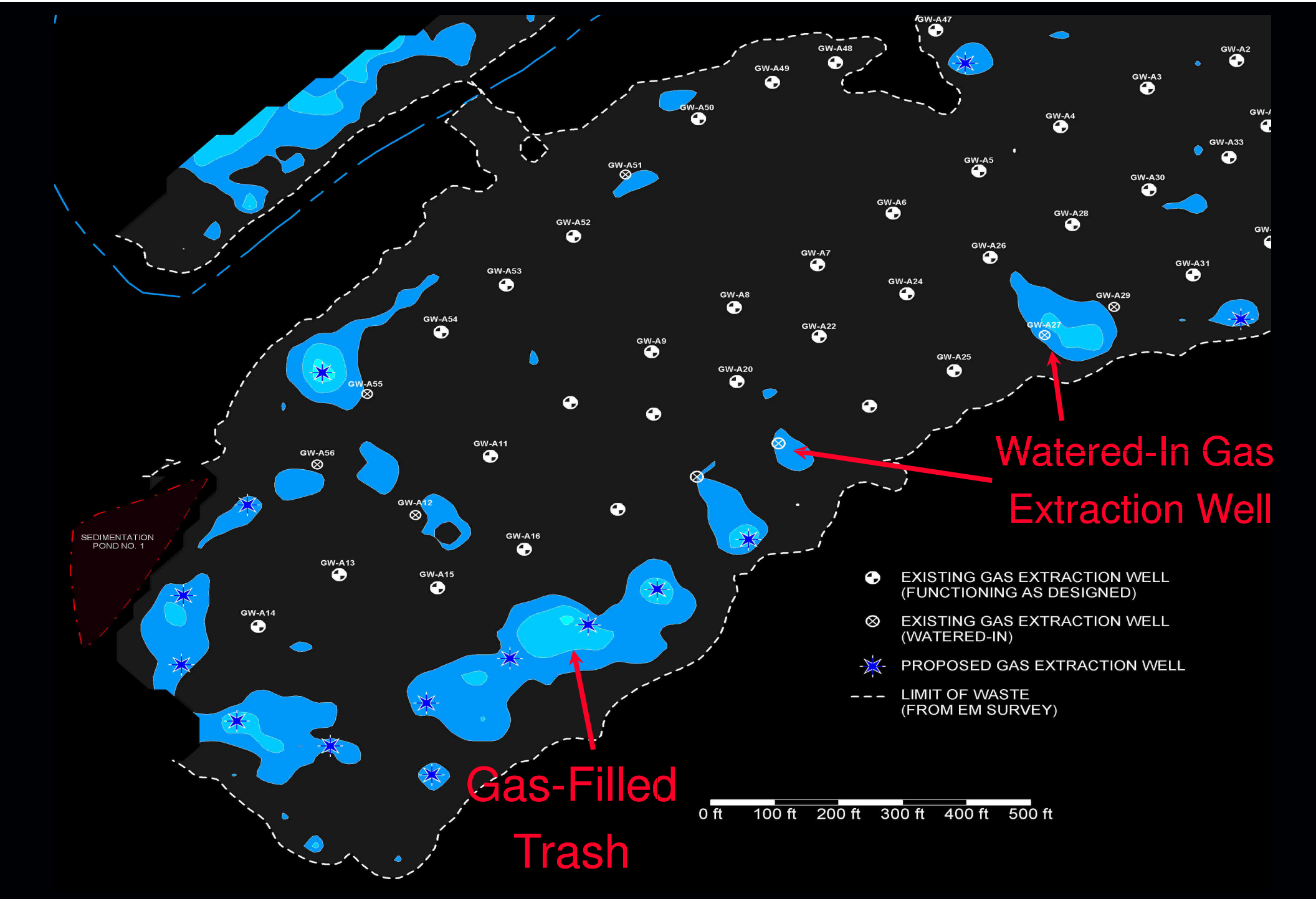
EM-31 CONDUCTIVITY METER WITH ATV

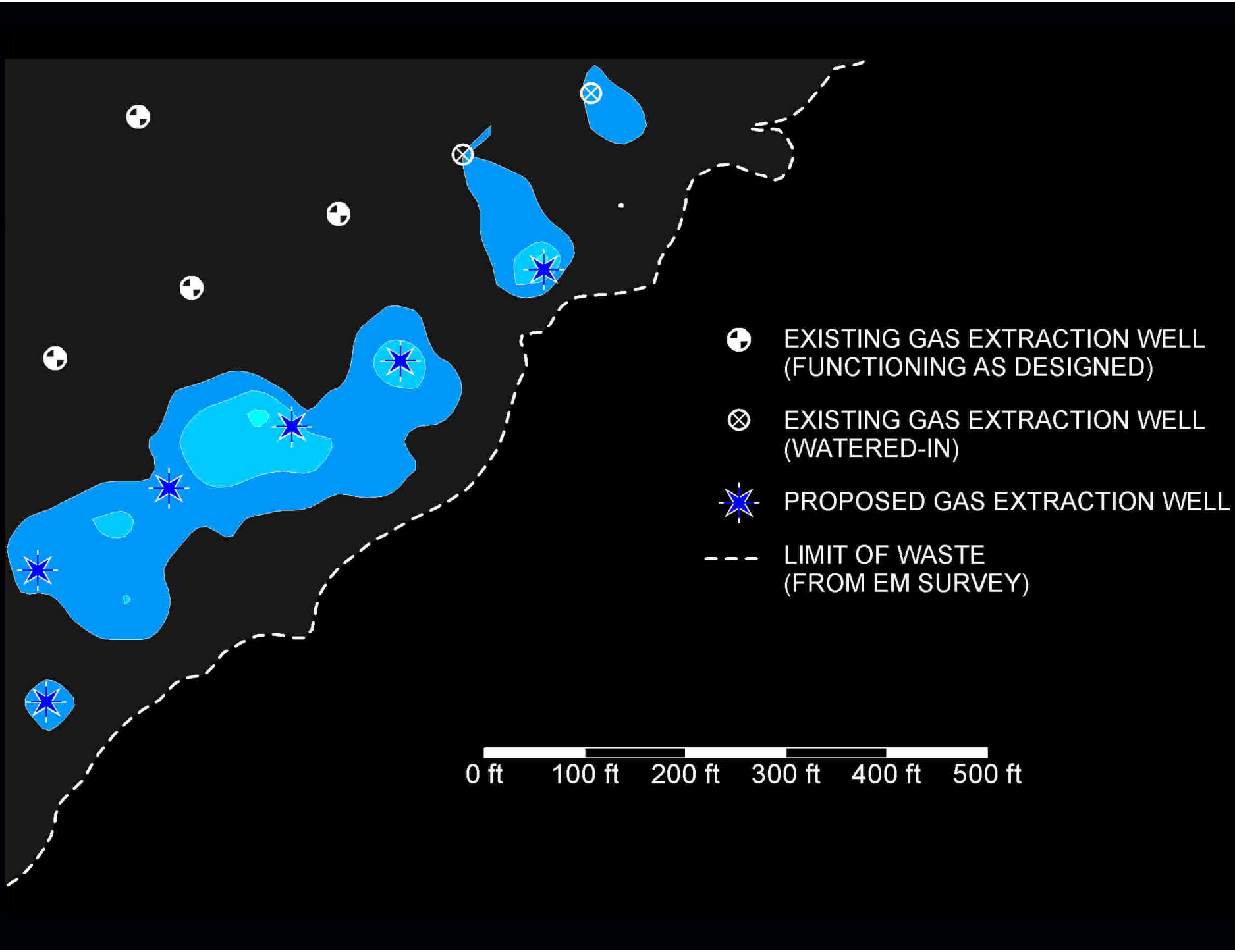
EM-38 CONDUCTIVITY METER

SHALLOW-FOCUSED

APPARENT TERRAIN CONDUCTIVITY MAP




GW-A47
GW-A48
GW-A49
GW-A50
GW-A51
GW-A52
GW-A53
GW-A54
GW-A55
GW-A56
GW-A11
GW-A12
GW-A16
GW-A13
GW-A15
GW-A14
GW-A9
GW-A20
GW-A8
GW-A22
GW-A24
GW-A7
GW-A6
GW-A5
GW-A4
GW-A3
GW-A2
GW-A33
GW-A30
GW-A28
GW-A26
GW-A31
GW-A29
GW-A27
GW-A25
SEDIMENTATION POND NO. 1
Watered-In Gas Extraction Well
Gas-Filled Trash
EXISTING GAS EXTRACTION WELL (FUNCTIONING AS DESIGNED)
EXISTING GAS EXTRACTION WELL (WATERED-IN)
PROPOSED GAS EXTRACTION WELL
LIMIT OF WASTE (FROM EM SURVEY)
0 ft
100 ft
200 ft
300 ft
400 ft
500 ft


EXISTING GAS EXTRACTION WELL
(FUNCTIONING AS DESIGNED)
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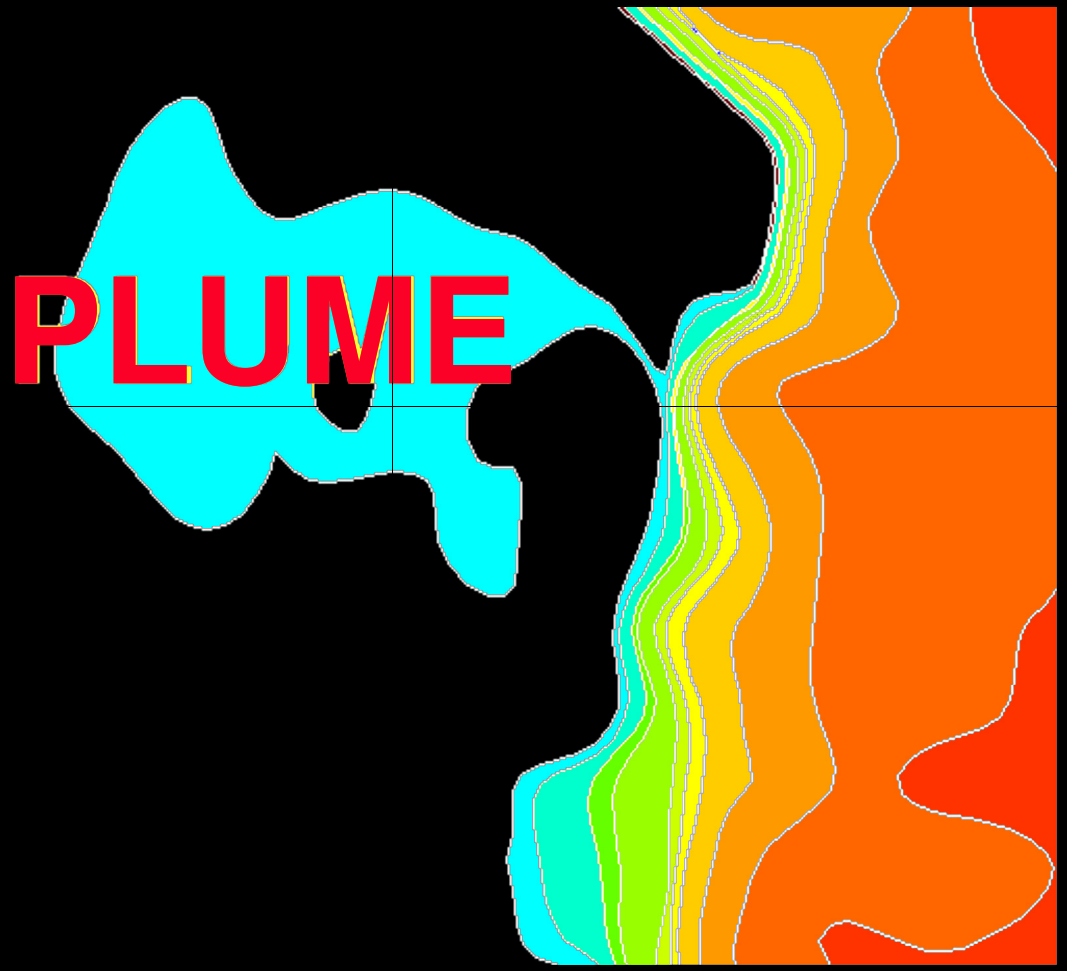
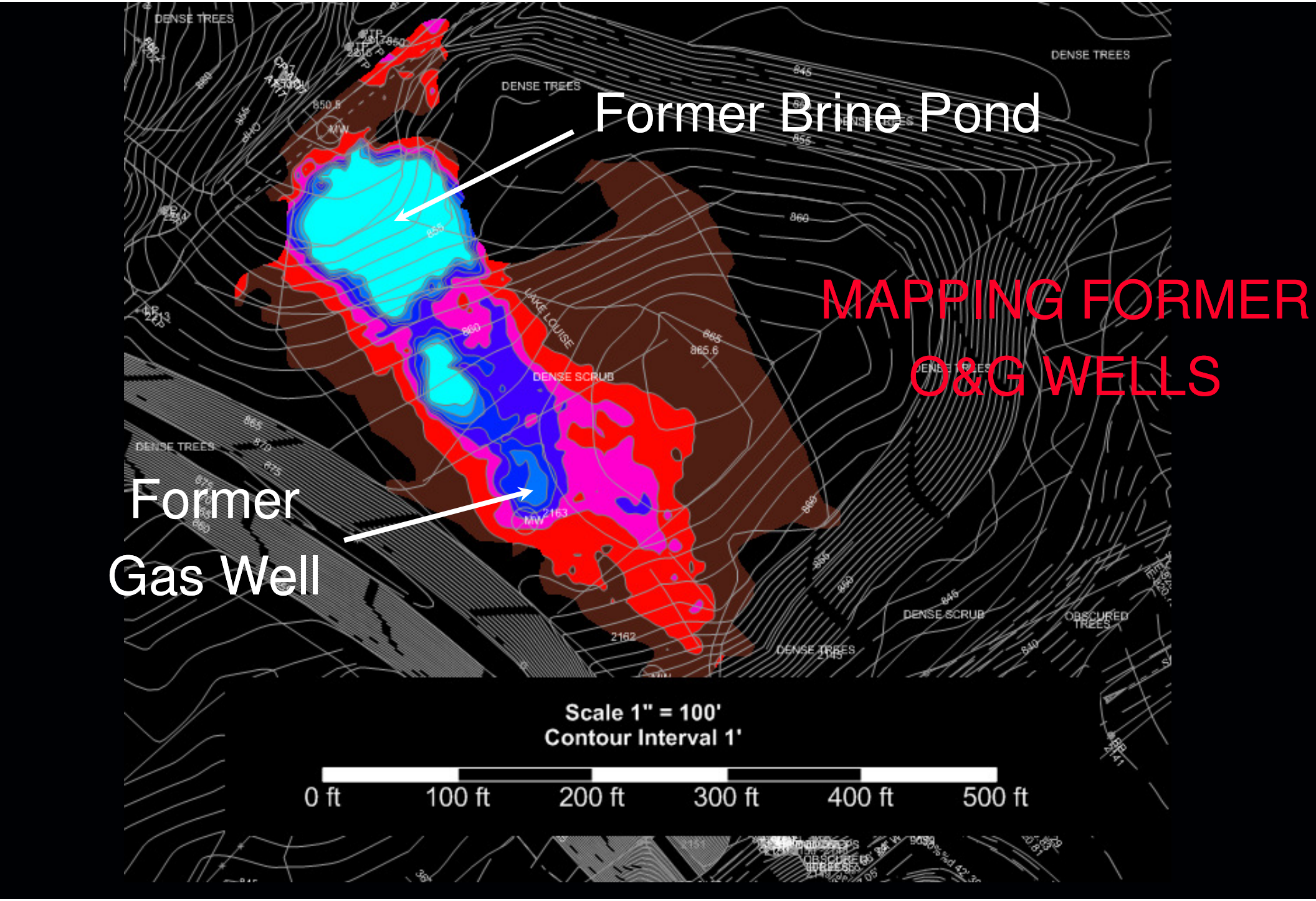
(WATERED-IN)
PROPOSED GAS EXTRACTION WELL
LIMIT OF WASTE
(FROM EM SURVEY)
0 ft
100 ft
200 ft
300 ft
400 ft
500 ft

LANDFILL LEACHATE PLUME



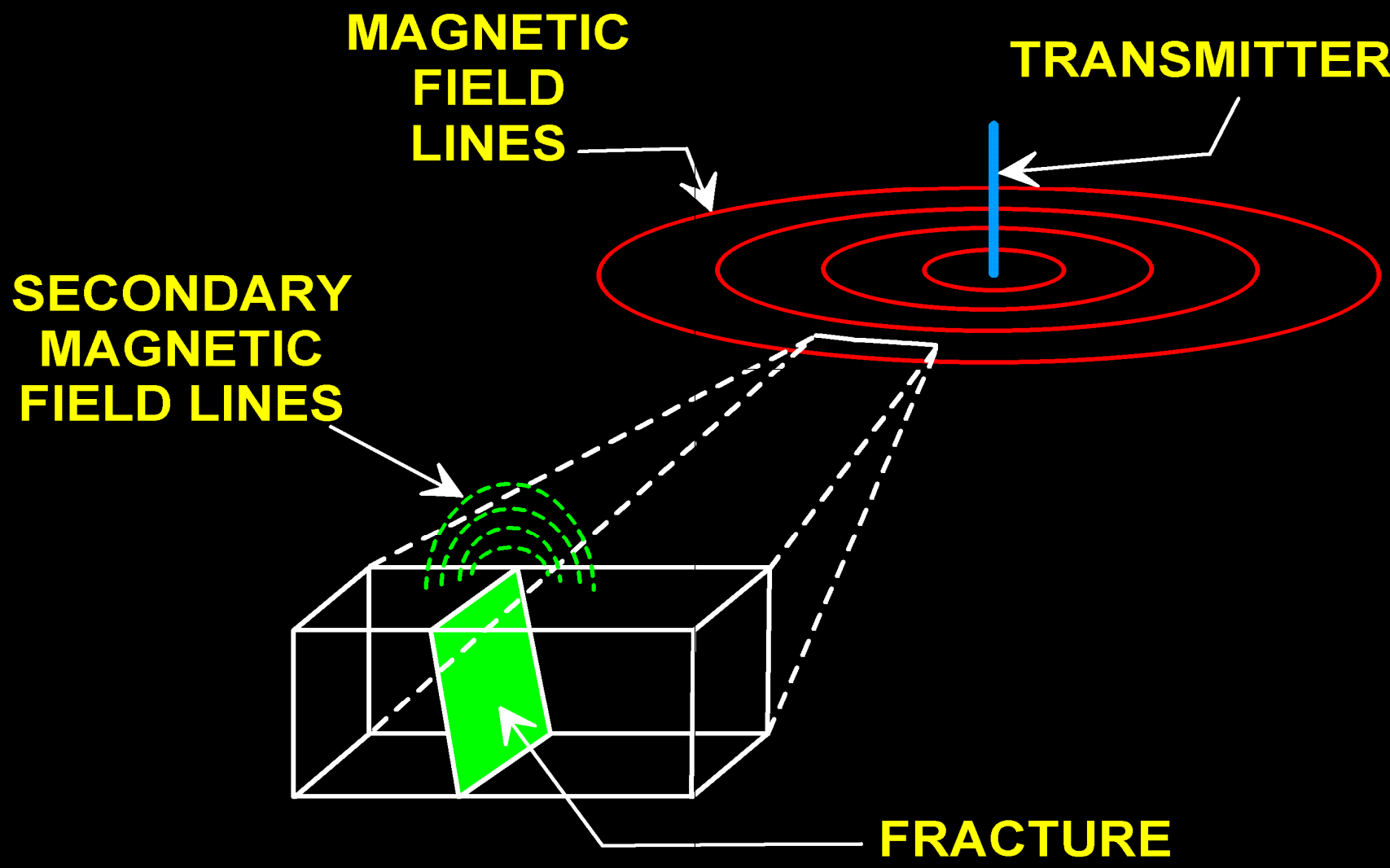

Former Brine Pond
MAPPING FORMER
O&G WELLS
Former
Gas Well
DENSE TREES
DENSE SCRUB
OBSCURED TREES
LAKE LOUISE
Scale 1" = 100'
Contour Interval 1'
0 ft
100 ft
200 ft
300 ft
400 ft
500 ft

PATHWAY

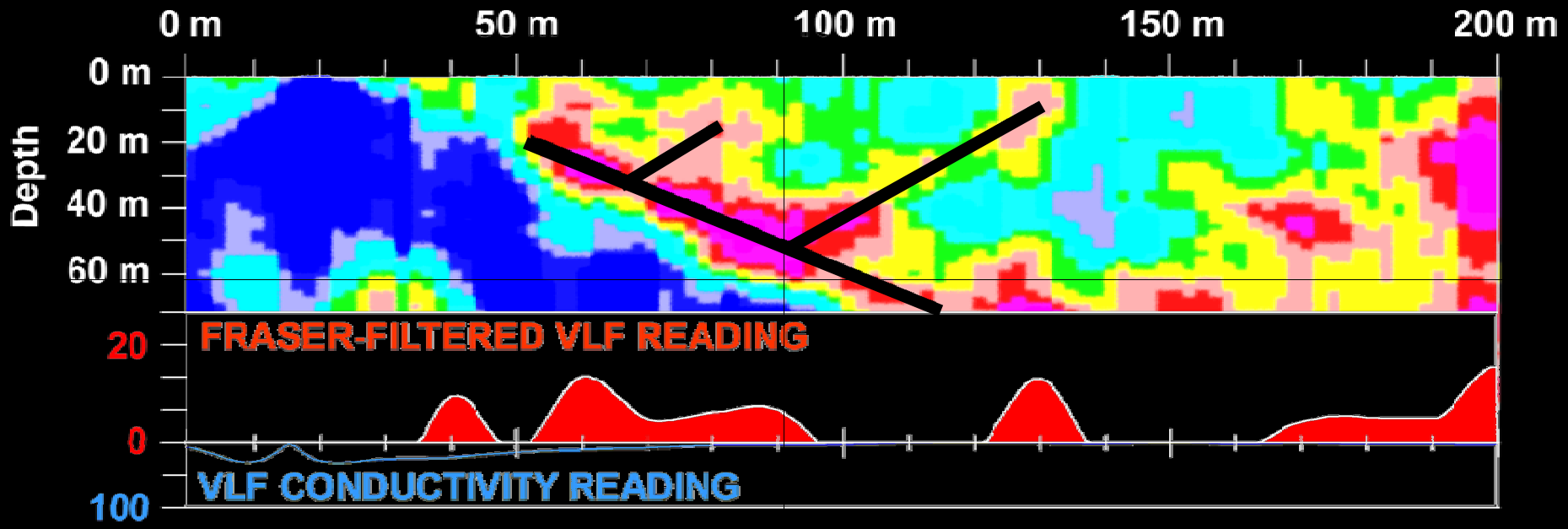
VERY LOW FREQUENCY METER

- Sounding Tool
- Fracture Location
- Uses Military Antenna
- Rapid Deployment - Inexpensive
- Uses
  - Groundwater Resources
  - Deep-mine Induced Fracturing
  - Contamination Pathway

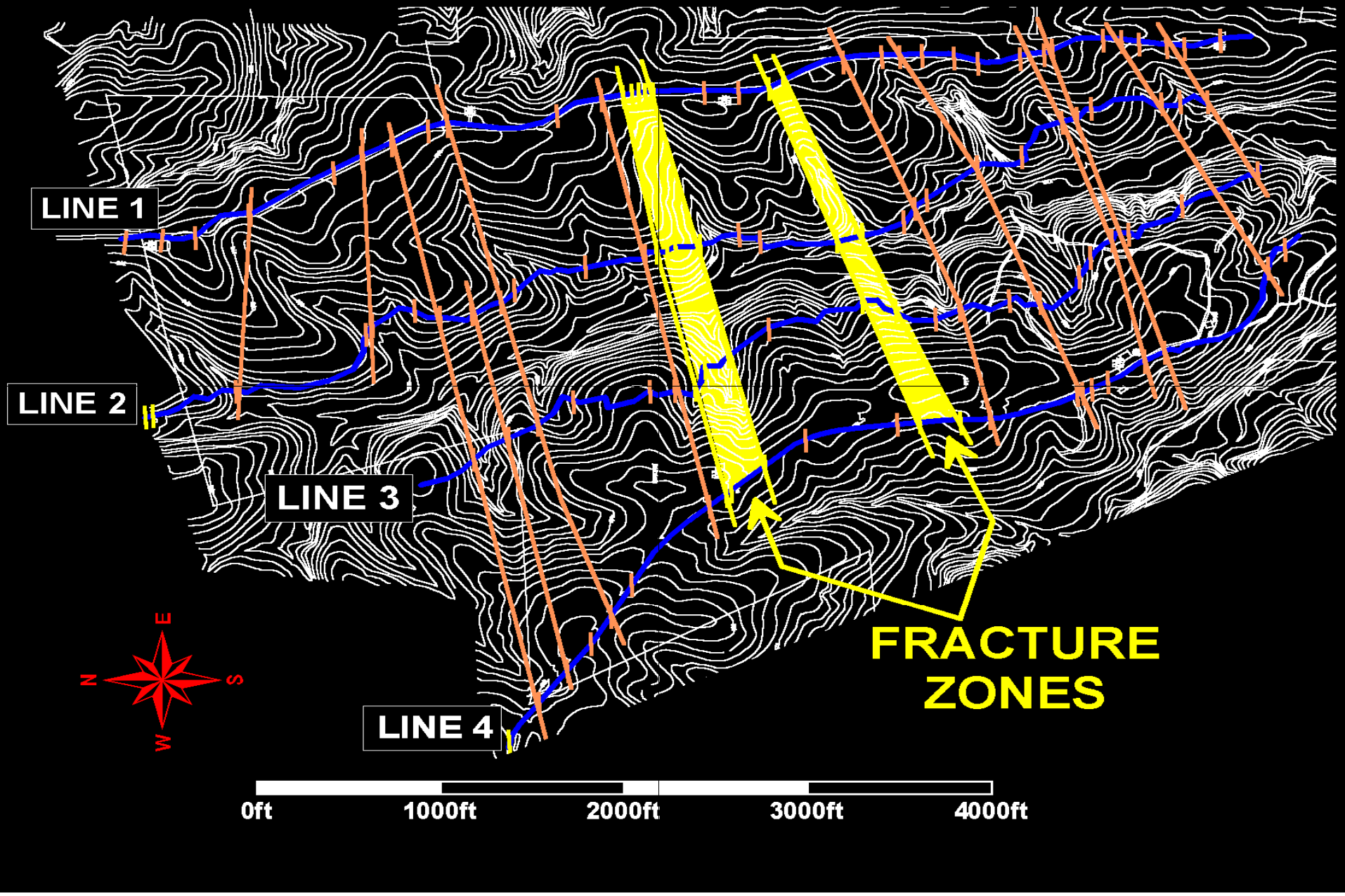
VLF


MAGNETIC FIELD LINES
TRANSMITTER
SECONDARY MAGNETIC FIELD LINES
FRACTURE

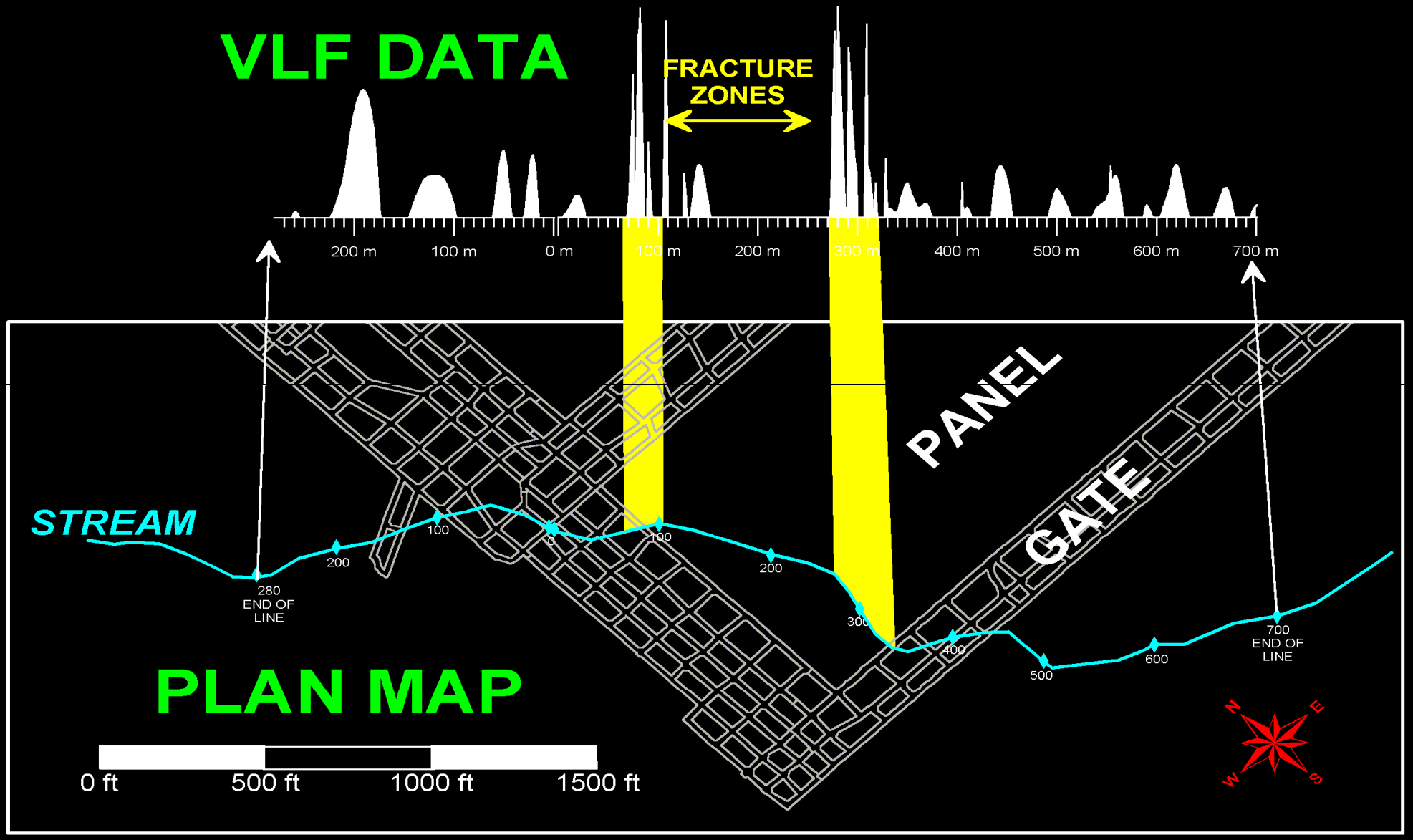
VLF DATA


0 m
50 m
100 m
150 m
200 m
Depth
0 m
20 m
40 m
60 m
20
FRASER-FILTERED VLF READING
0
VLF CONDUCTIVITY READING
100

VLF RESULTS


LINE 1
LINE 2
LINE 3
LINE 4
FRACTURE ZONES
N
E
S
W
0ft
1000ft
2000ft
3000ft
4000ft

DEEP COAL MINE FRACTURING

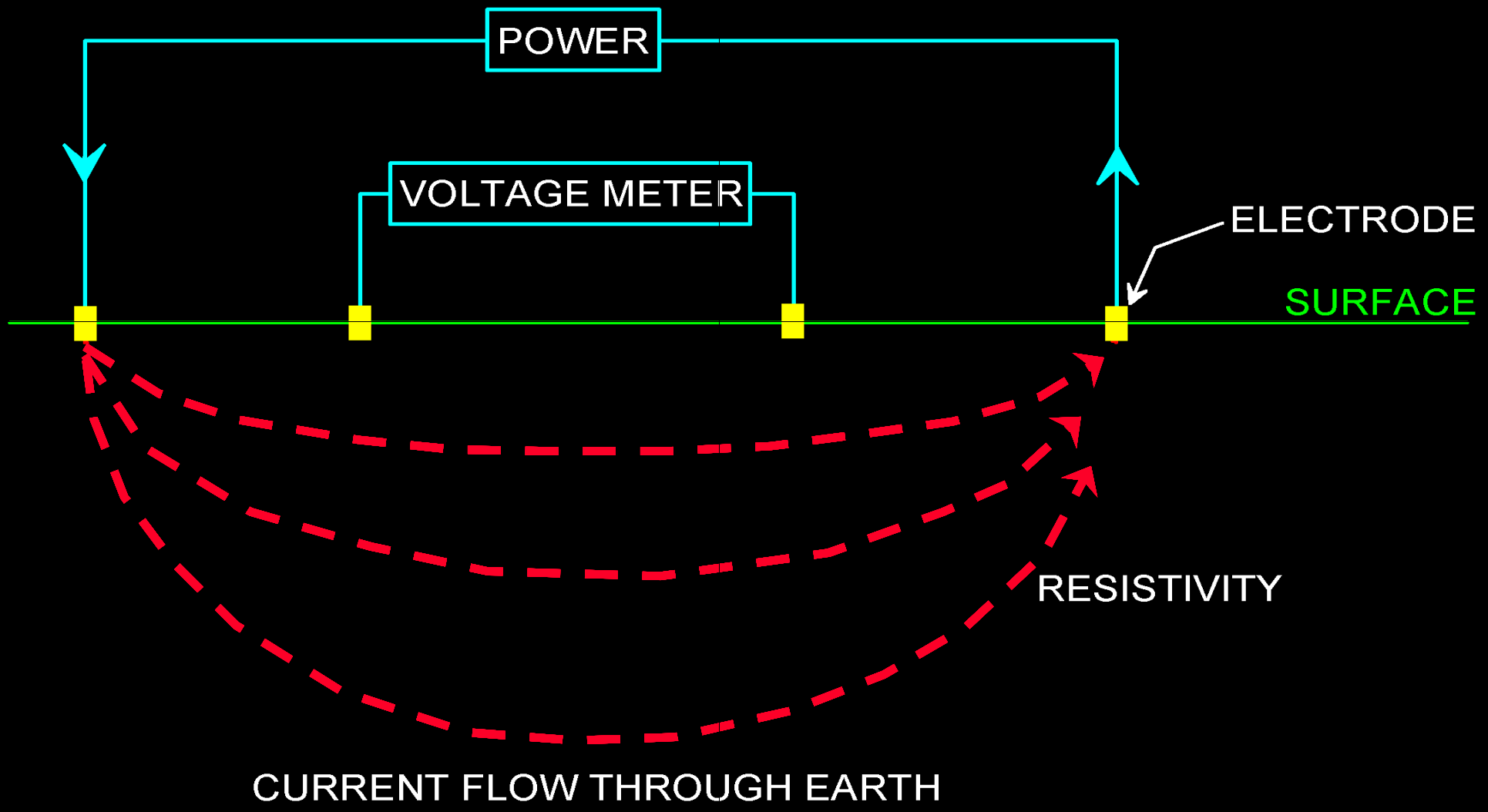


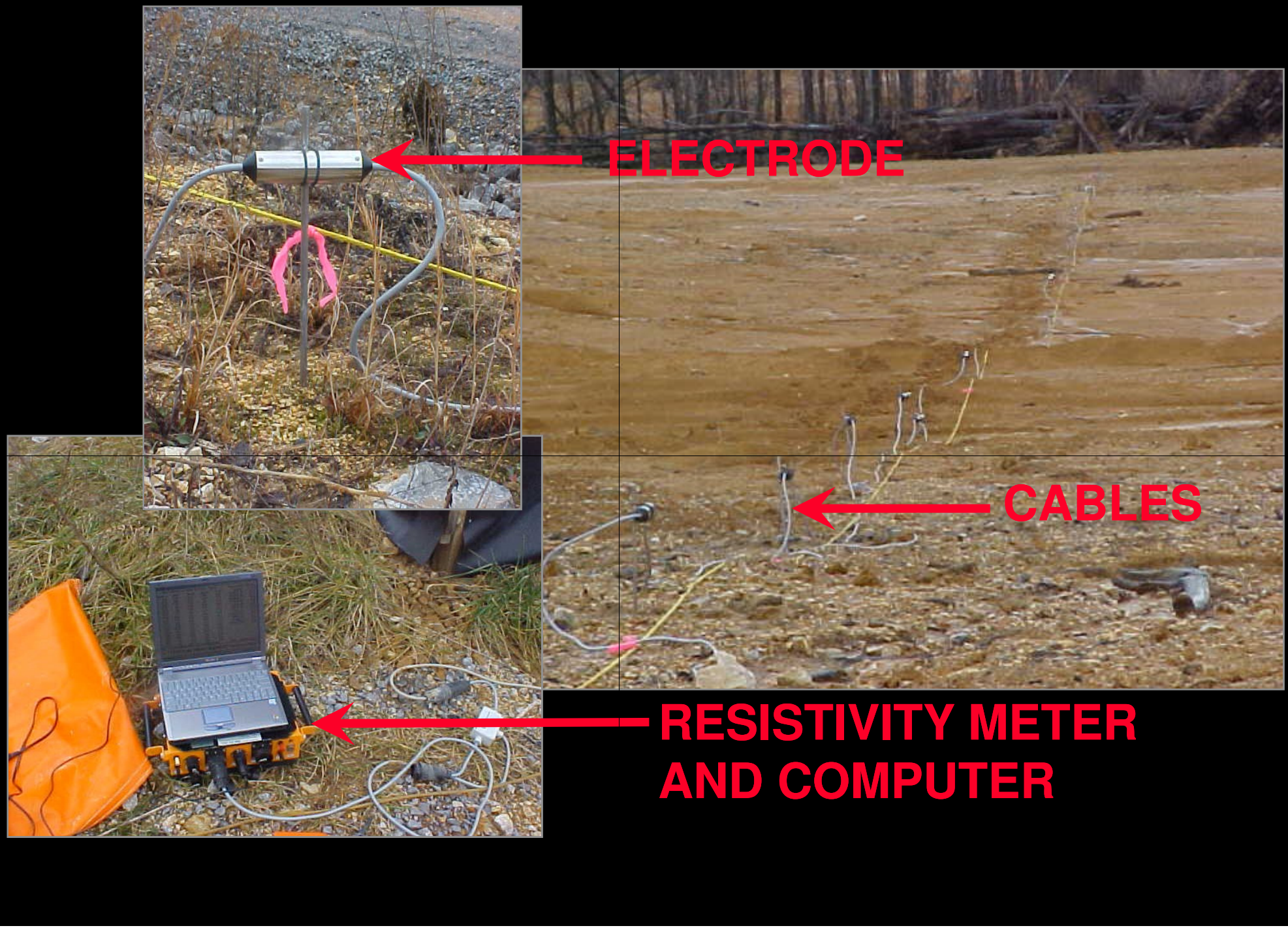
PATHWAY

ELECTRICAL IMAGING

- Profiling using Electrical Current
- Profile Length not Limited
- 3-D Survey
- Used to Image
  - Voids (Karst and Mining)
  - Depth to Bedrock
  - Groundwater Reservoir
  - Grounding Properties

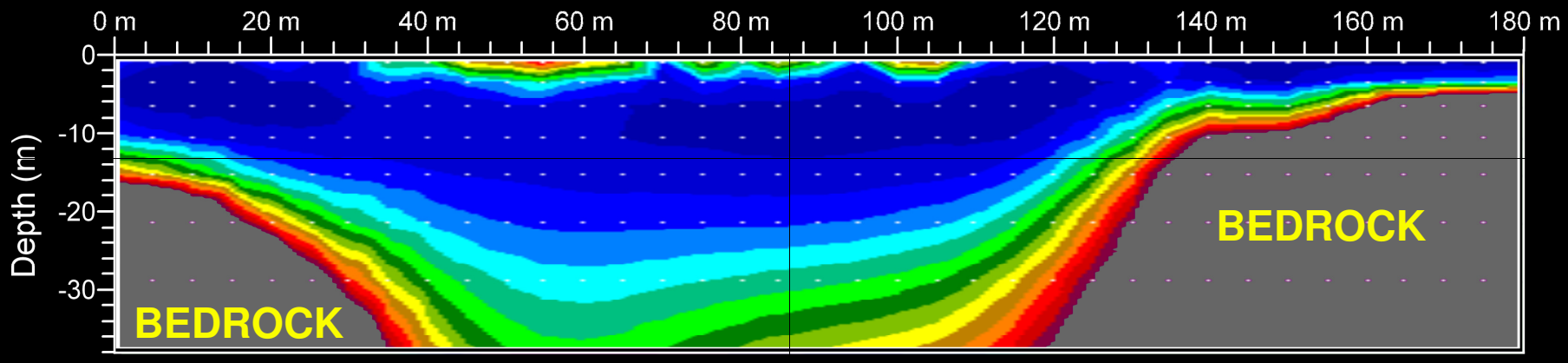
ELECTRICAL IMAGING



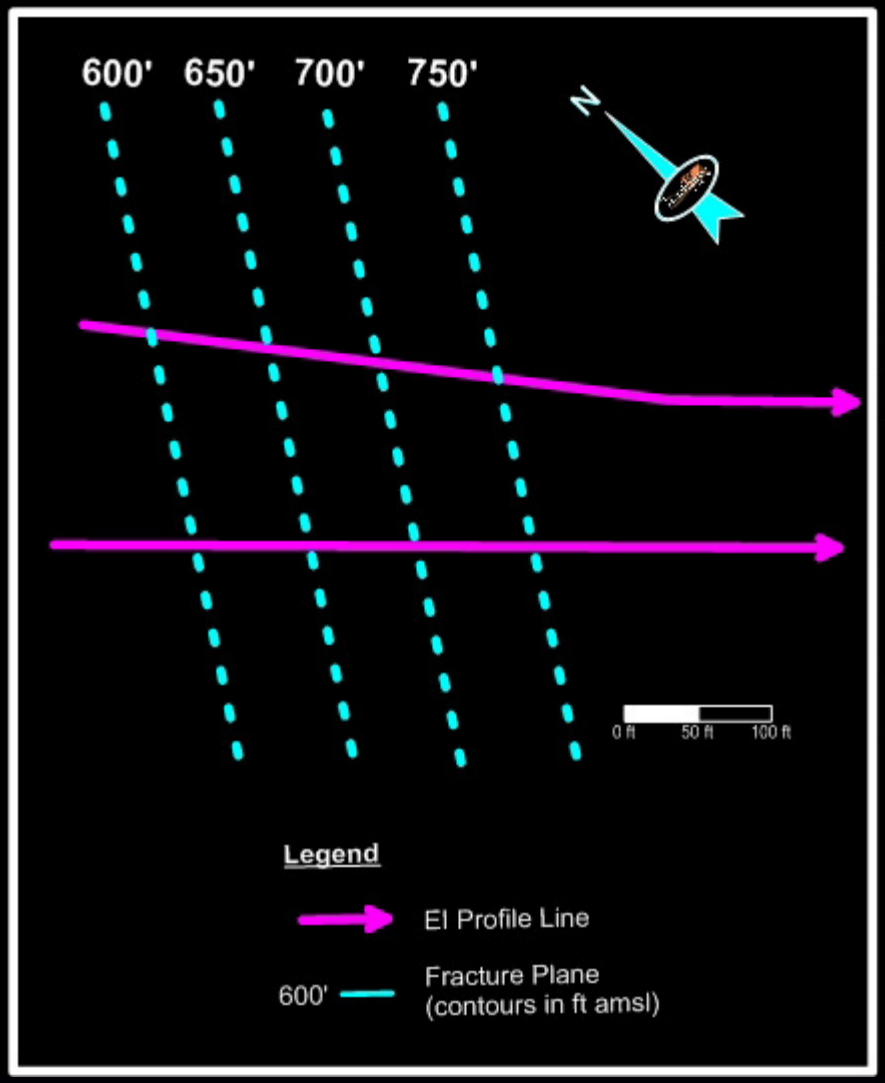

ELECTRODE
CABLES
RESISTIVITY METER
AND COMPUTER

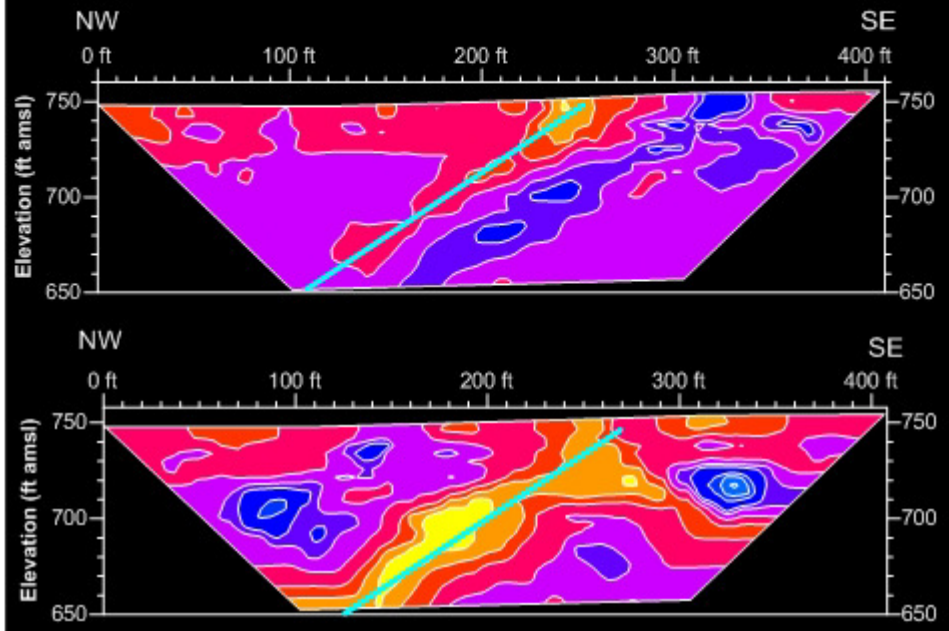
MAPPING STRATIGRAPHY

PALEO-CHANNEL



FRACTURE PLANE MAP





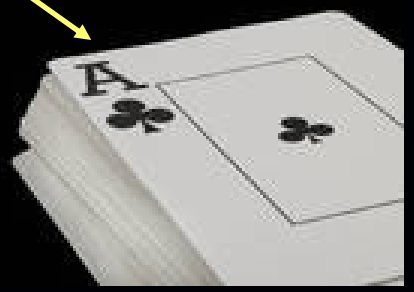
PATHWAY

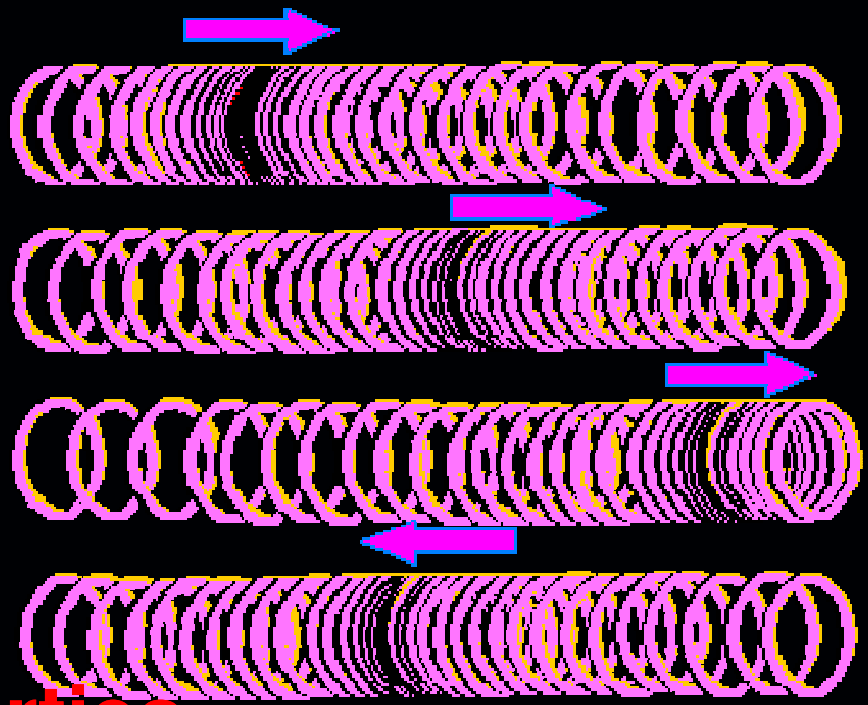
SEISMIC REFLECTION/REFRACTION

- Sounding
- Time-Domain
- Depth to Multiple Horizons
- Interpretive

SHEAR WAVES (s)
COMPRESSIONAL WAVES (p)

- **Compressional**
- **Shear**





Both provide rock/soil properties

REFLECTION SEISMIC

- Reflected from an acoustic contrast
- Can image faults
- Examples
  - Conventional
  - Near-source
  - MASW

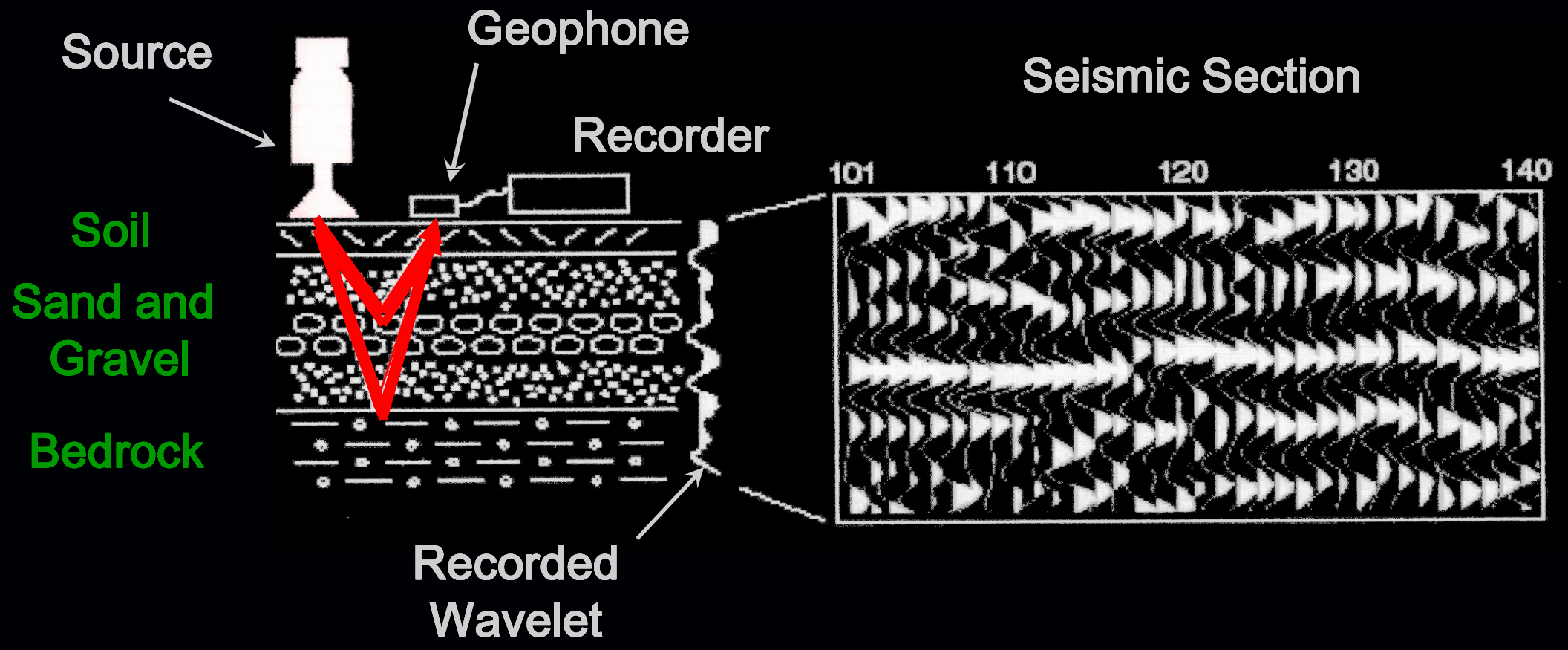
REFRACTION

- **Snell's Law**
  - Change in direction of ray based upon velocity change
- **Velocity Inversions**
- **Works poorly with voids**
- **MASW**
- **Tomography**

FIELD SETUP

- 24 channel, 5-ft receiver spacing
- 5 shots per record (10-lb sledge)
- 3 records per survey
- 1 sec recording time
- 1 ms sampling interval
- Low cut filter out
- 4.5 Hz spike geophones

DATA COLLECTION

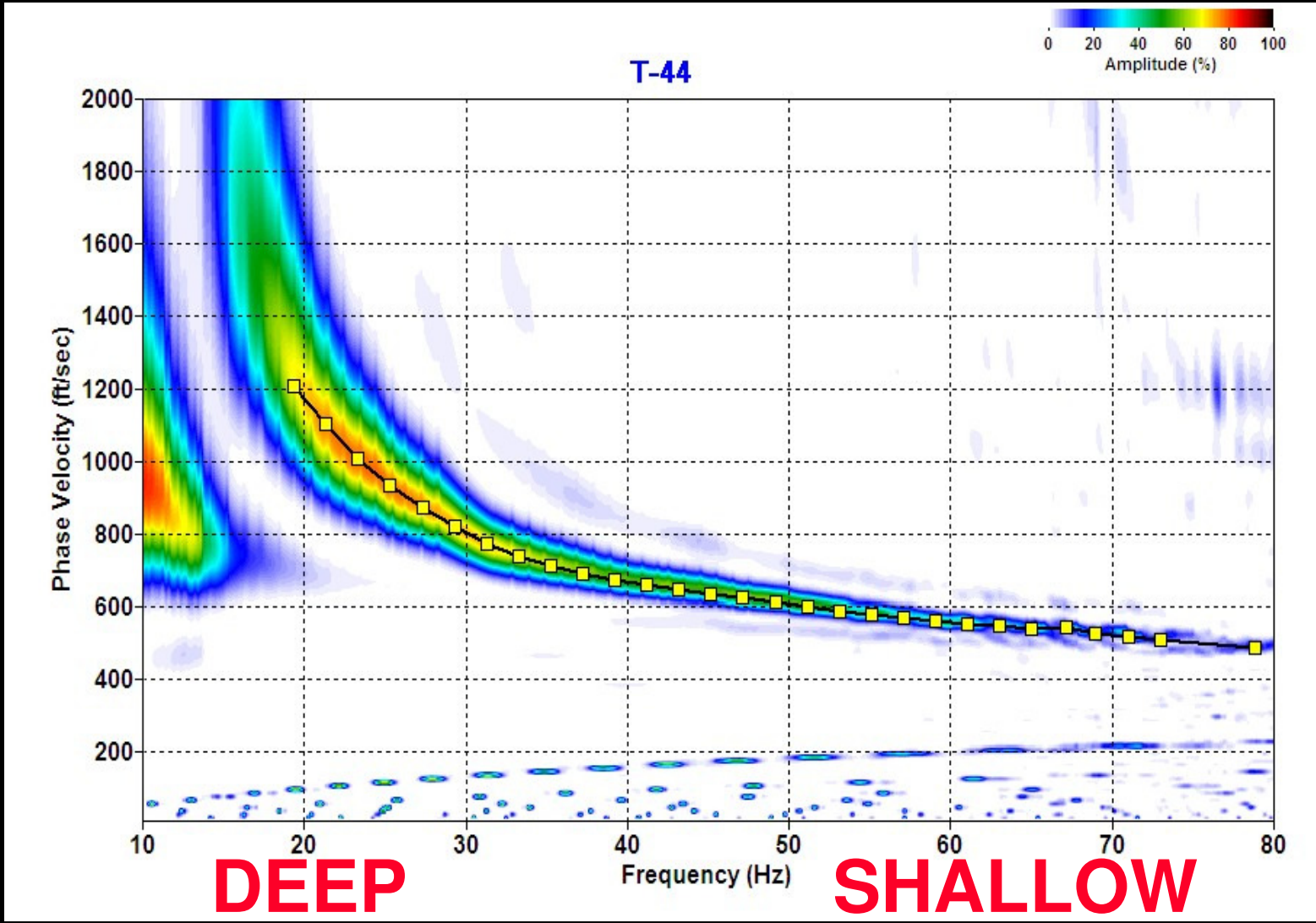


MASW

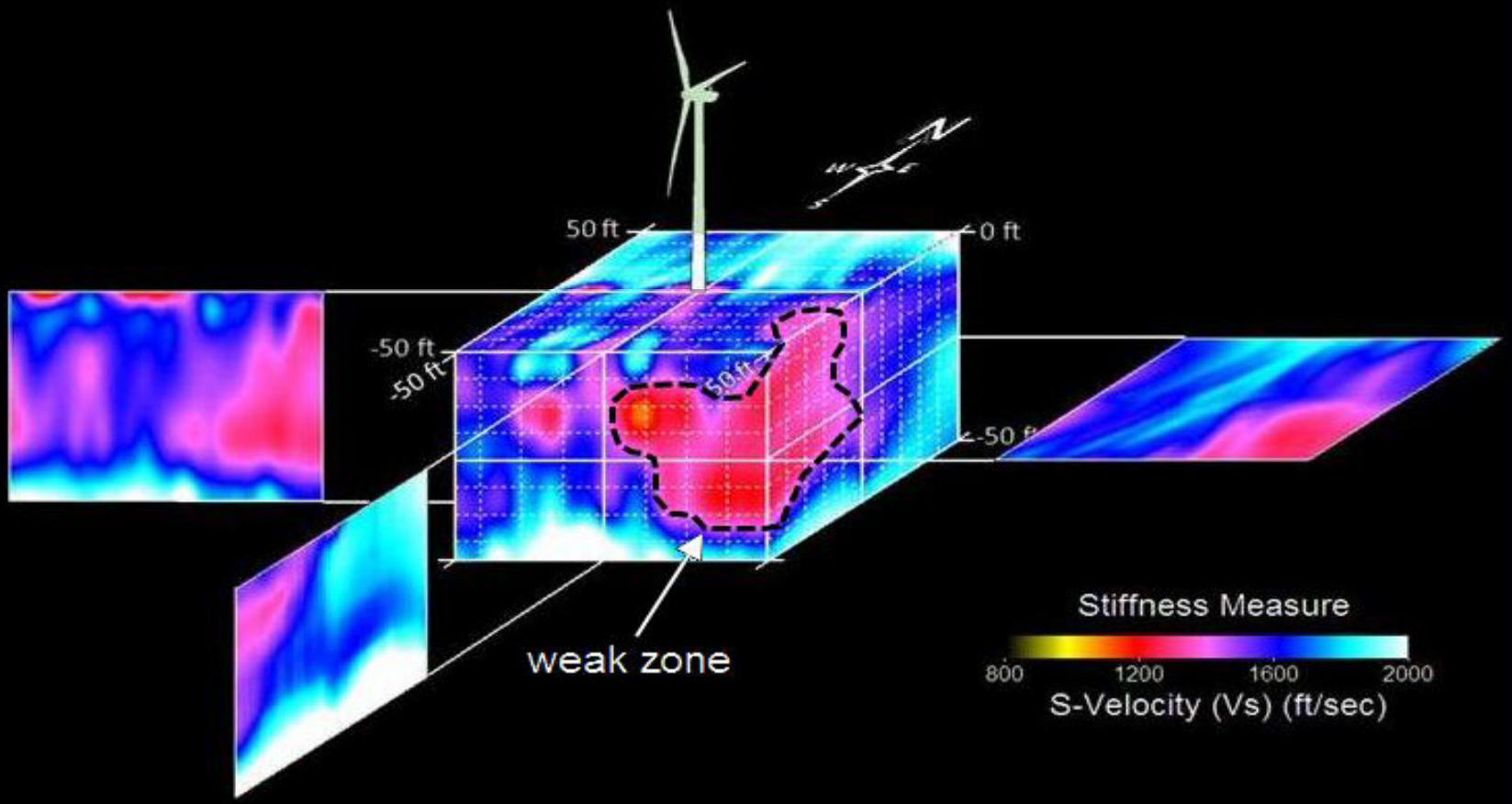
- New, surface waves
- Ease of deployment
- Data Impacted by:
  - Poor interpretation
  - Low energy source
  - “Hard Rock”

Dispersion Curve

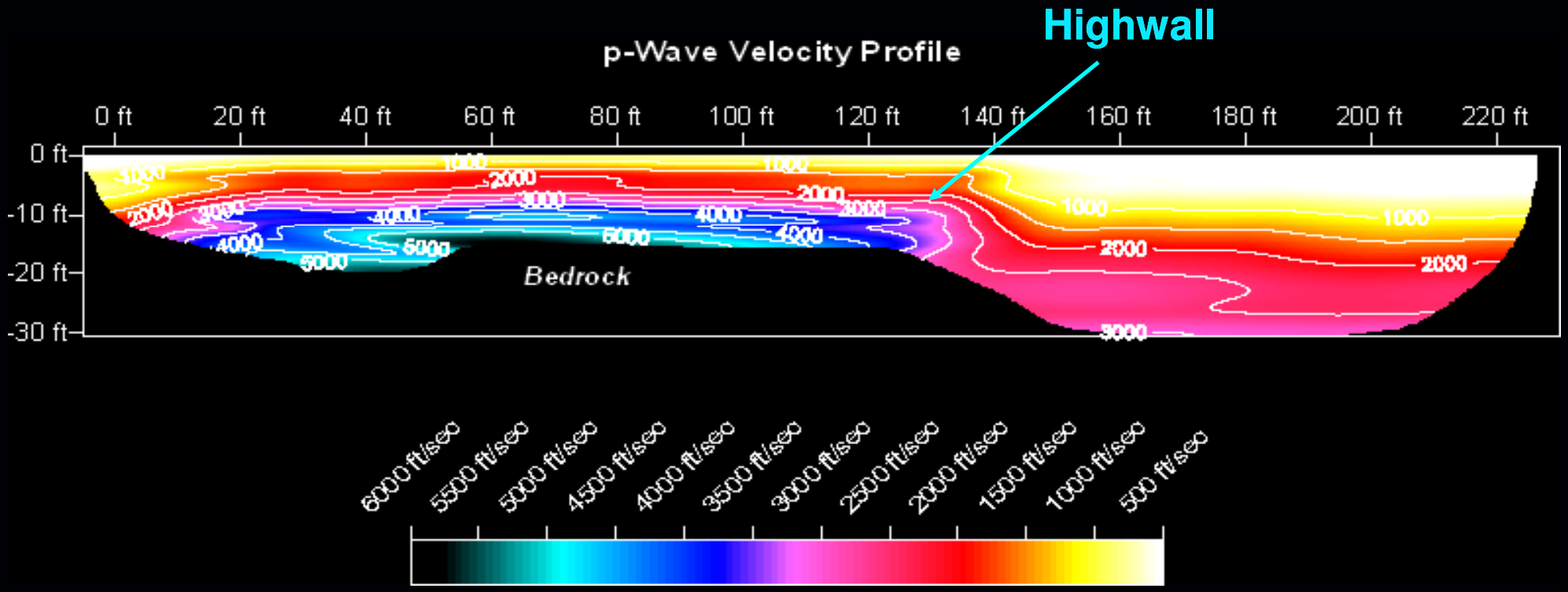
Soil

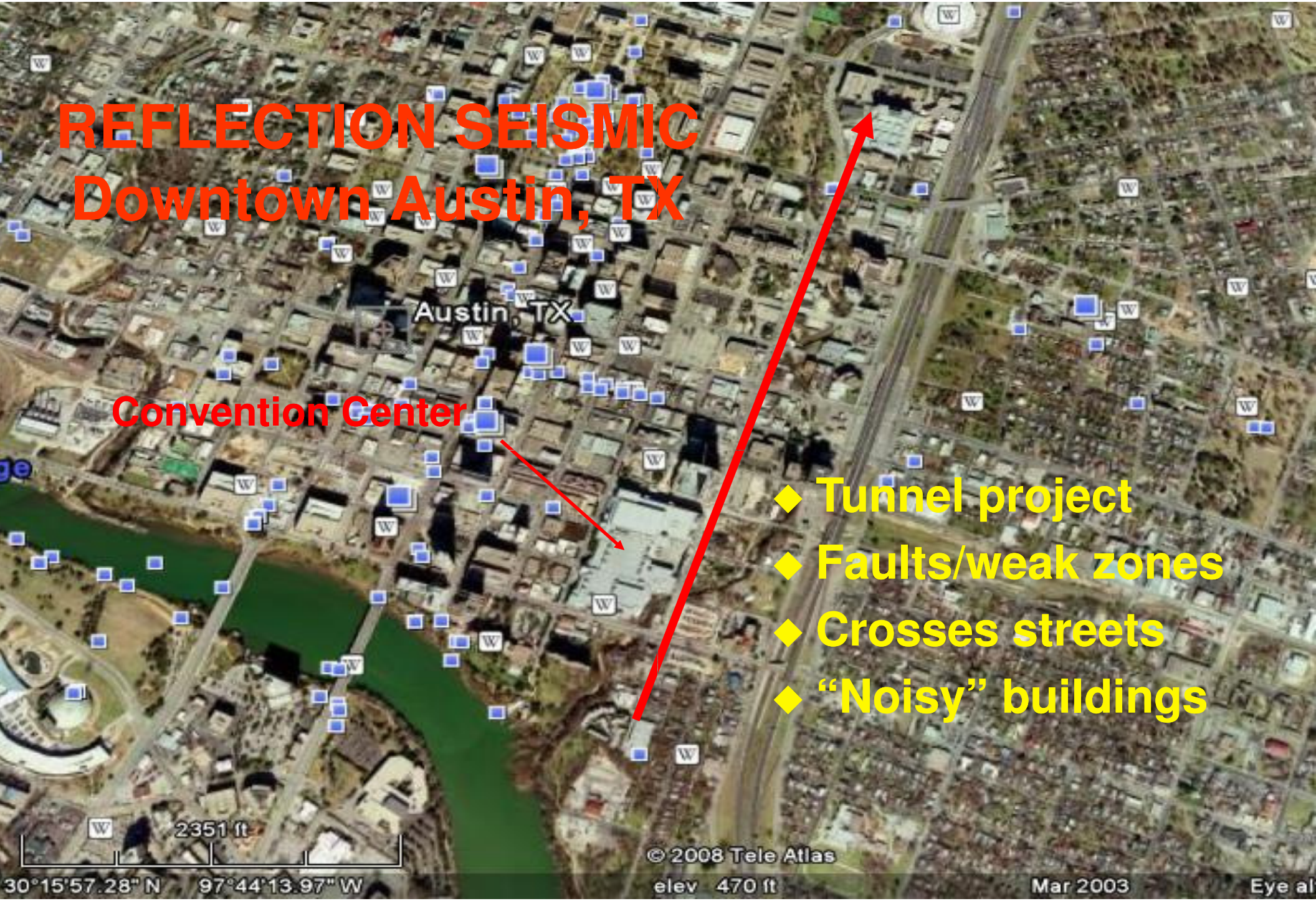


MASW 3-D Example
s-Wave Reflection

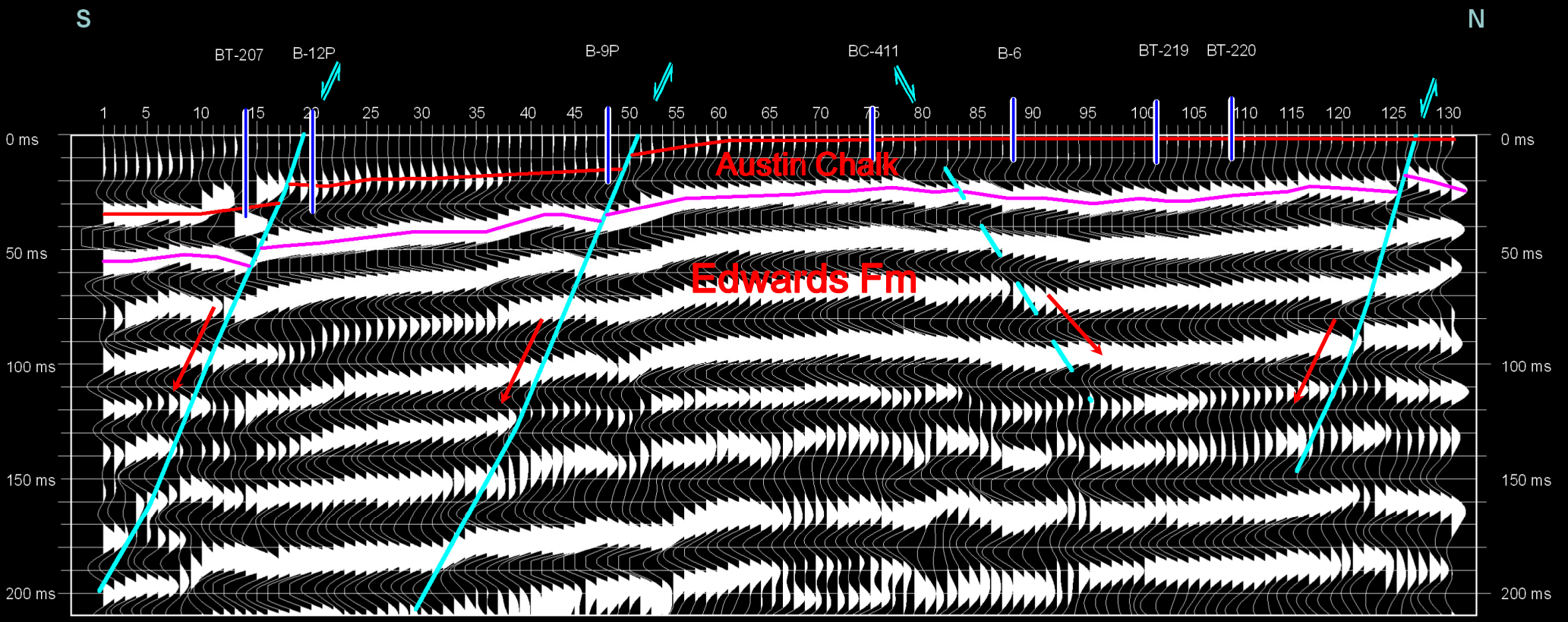


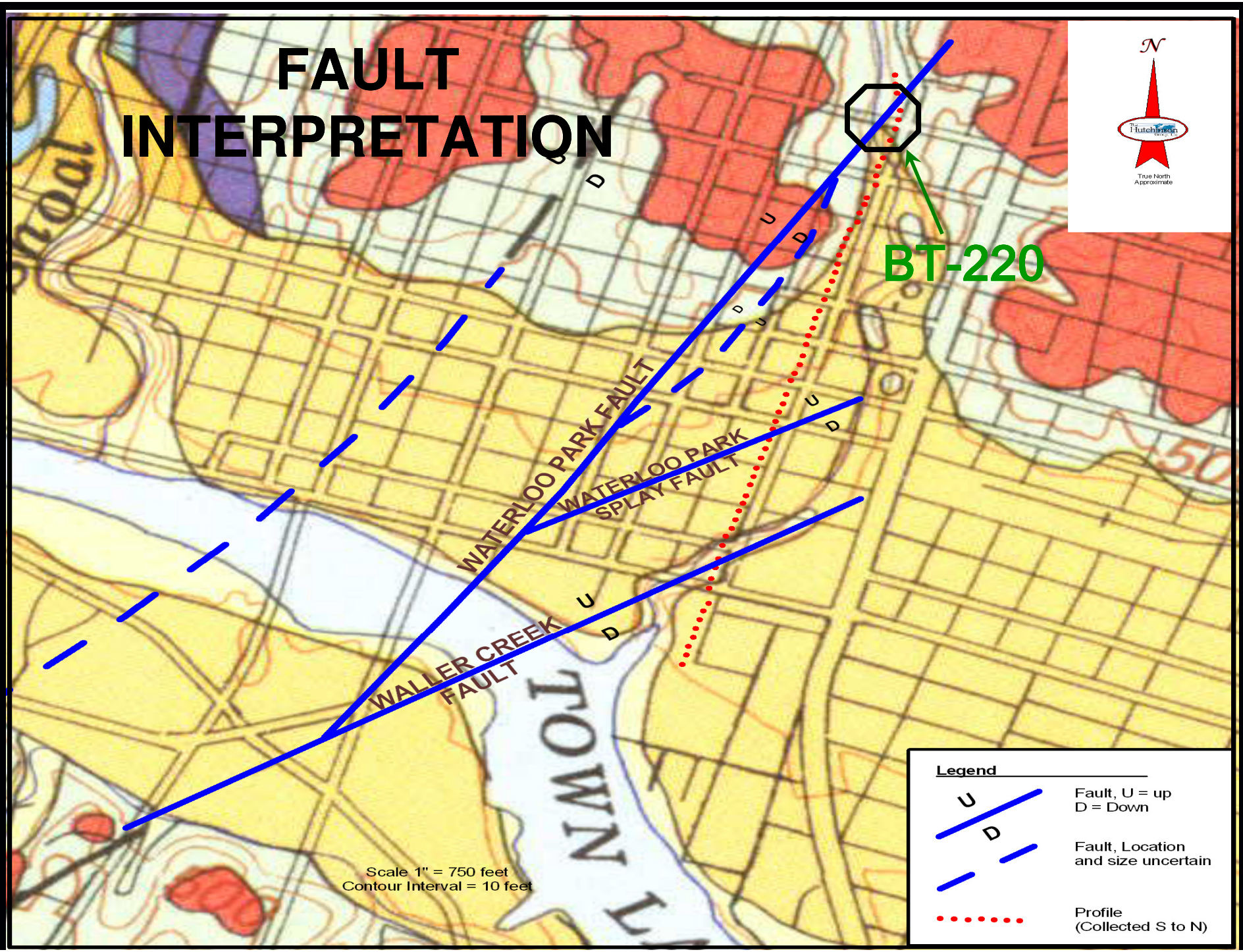
Refraction Tomography
p-Wave



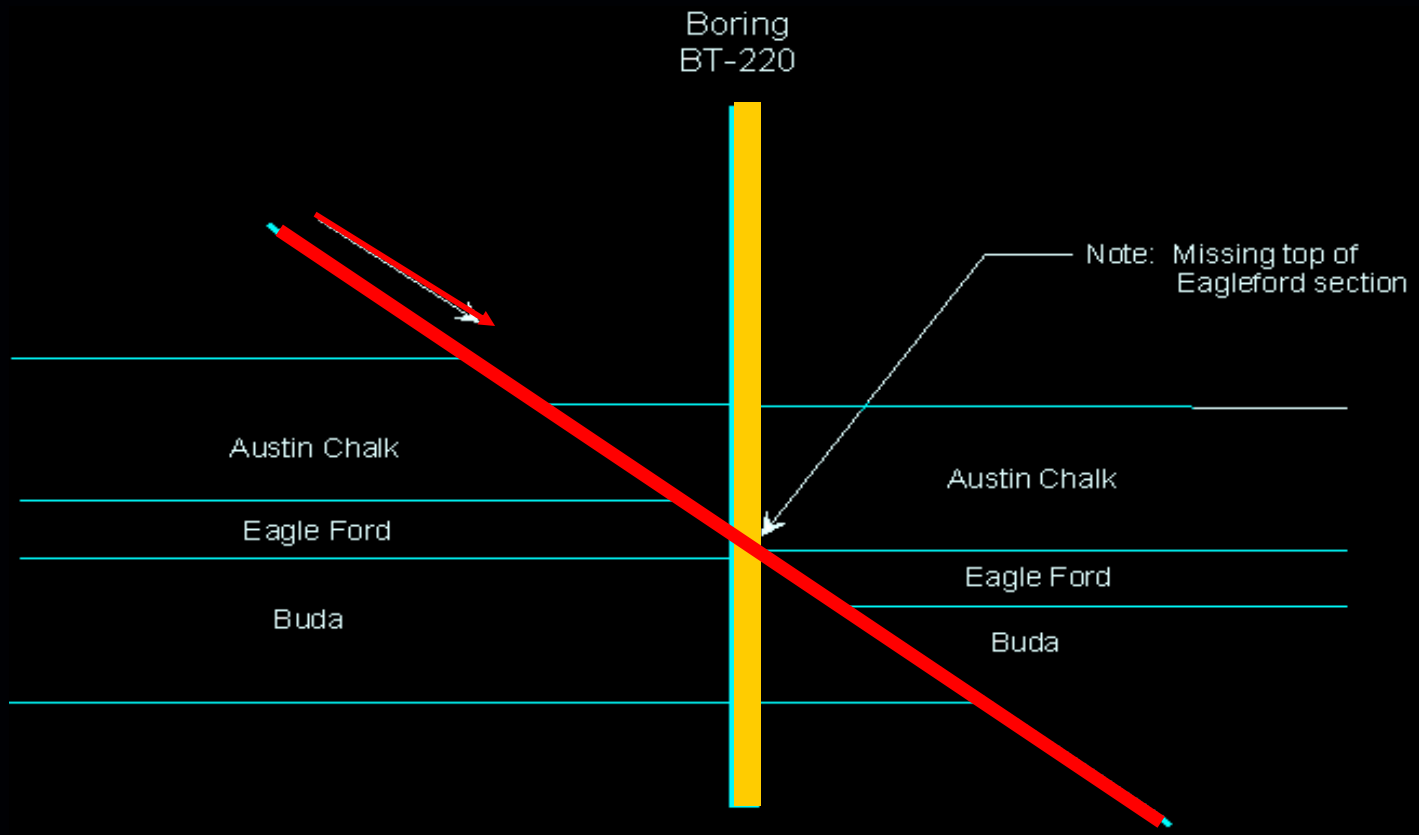

REFLECTION SEISMIC
Downtown Austin, TX
Austin, TX
Convention Center
◆ Tunnel project
◆ Faults/weak zones
◆ Crosses streets
◆ "Noisy" buildings
2351 ft
© 2008 Tele Atlas
30°15'57.28" N 97°44'13.97" W
elev 470 ft
Mar 2003
Eye al

Red River Street Seismic Profile




FAULT INTERPRETATION
BT-220
WATERLOO PARK FAULT
WATERLOO PARK SPLAY FAULT
WALLER CREEK FAULT
TOWN L
U
D
N
True North Approximate
Scale 1" = 750 feet
Contour Interval = 10 feet
Legend
Fault, U = up D = Down
Fault, Location and size uncertain
Profile (Collected S to N)

Successful Fault Prediction



GEOPHYSICAL APPLICATION

- Geophysics cannot image gas
- Can image Habitat
  - Landfills
  - Abandoned gas wells
- Can image Pathways
  - Fracture/Fault - migration

www.geo-image.com