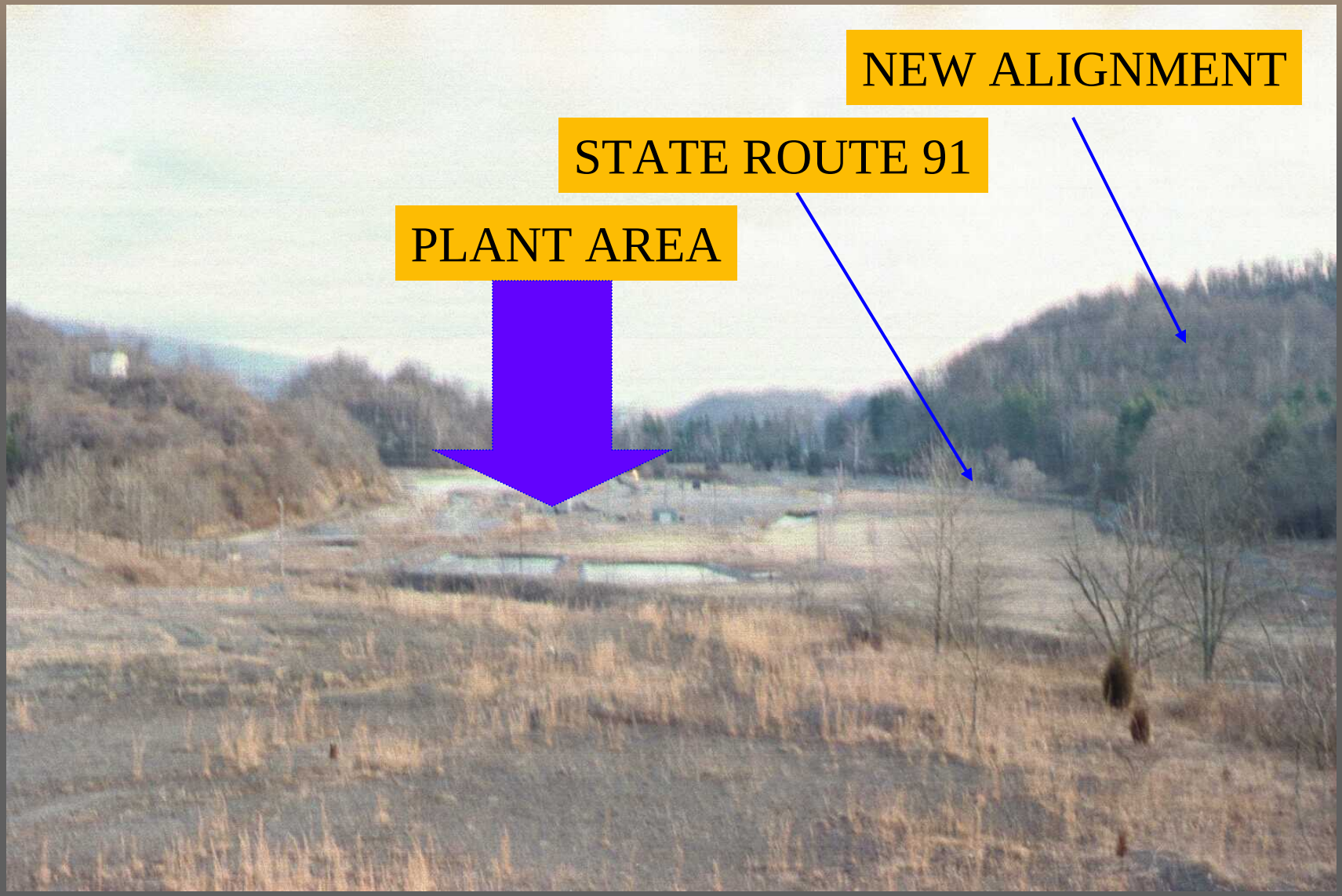
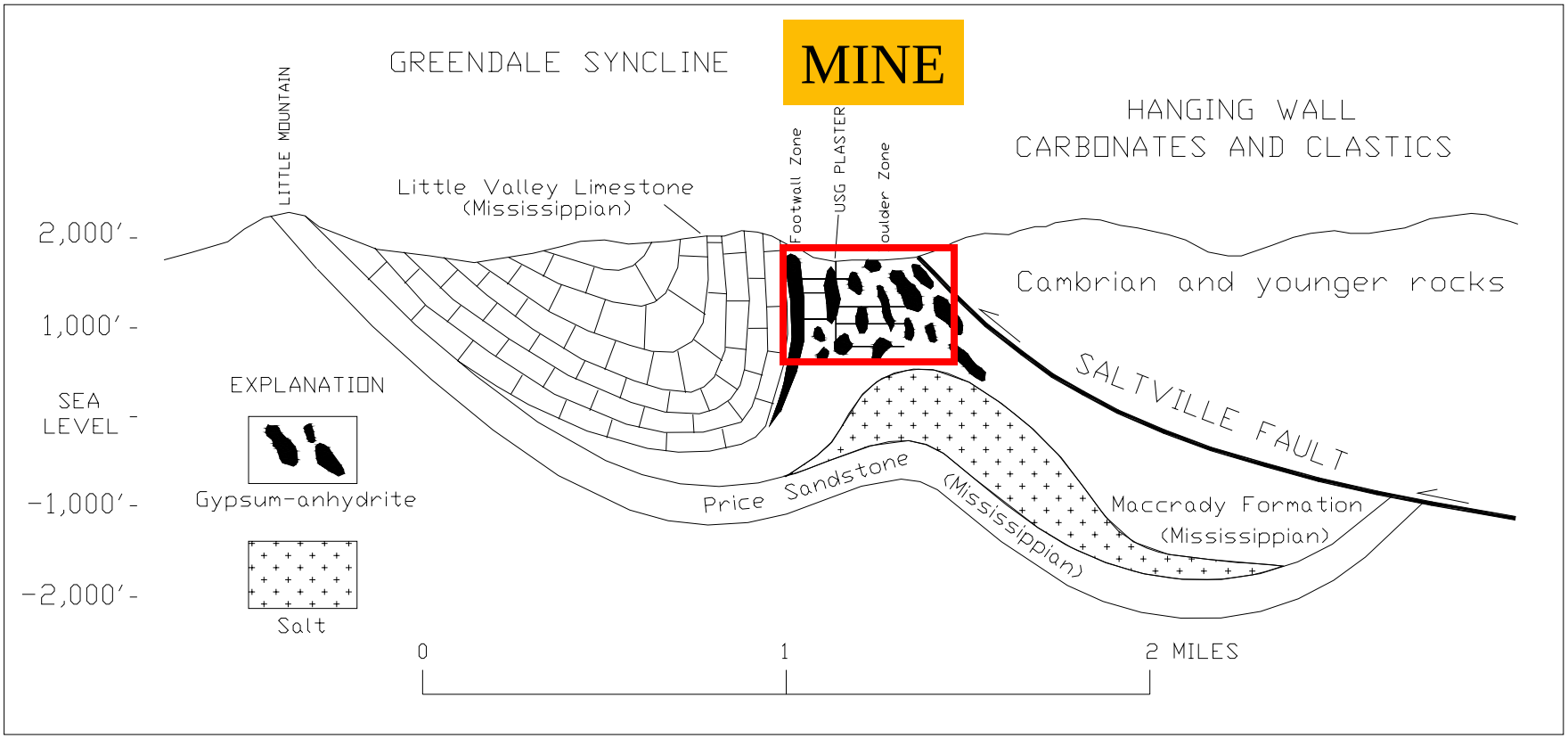
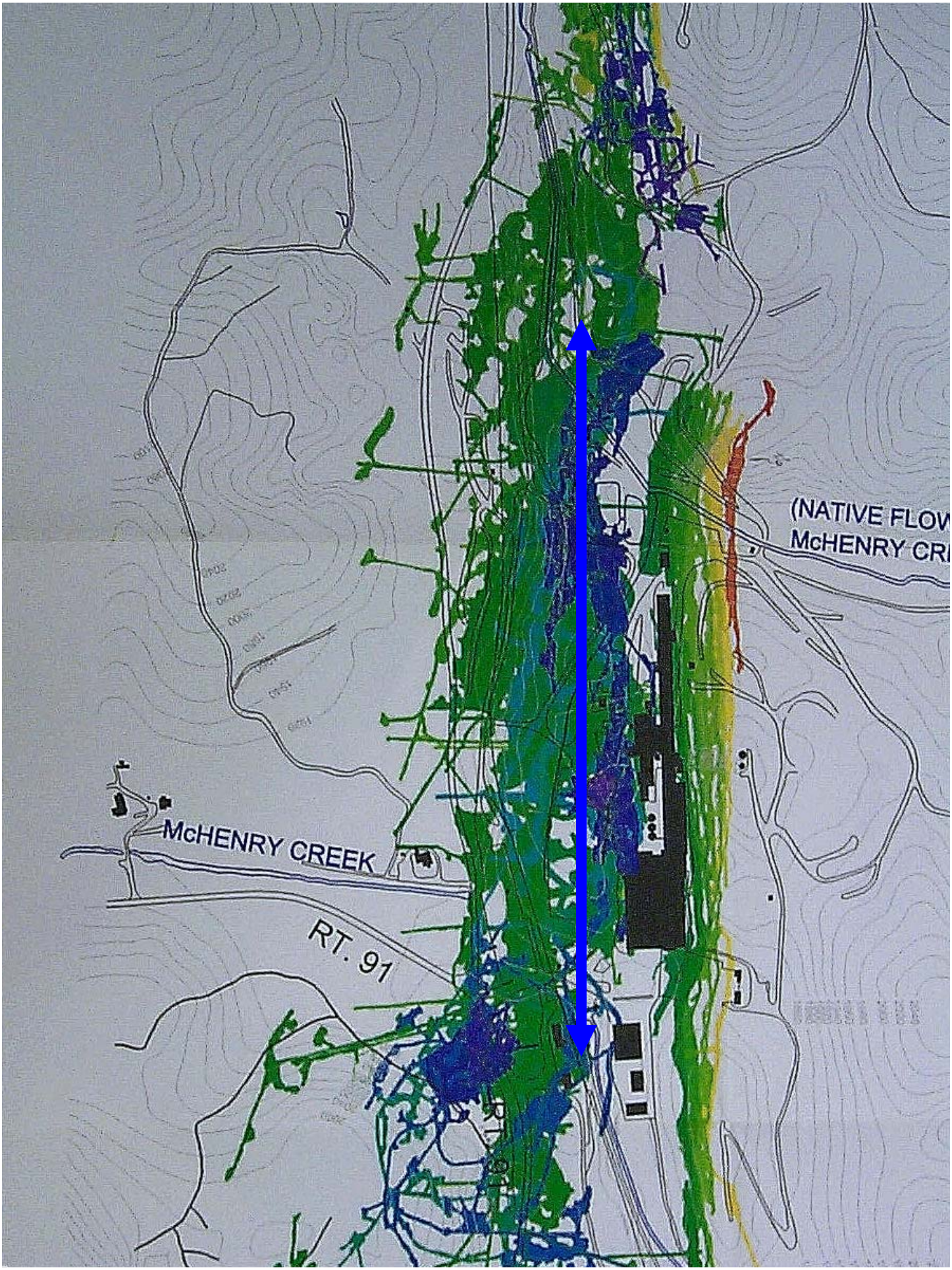
Real Time Monitoring of Subsidence over an Inactive Mine in Virginia using TDR

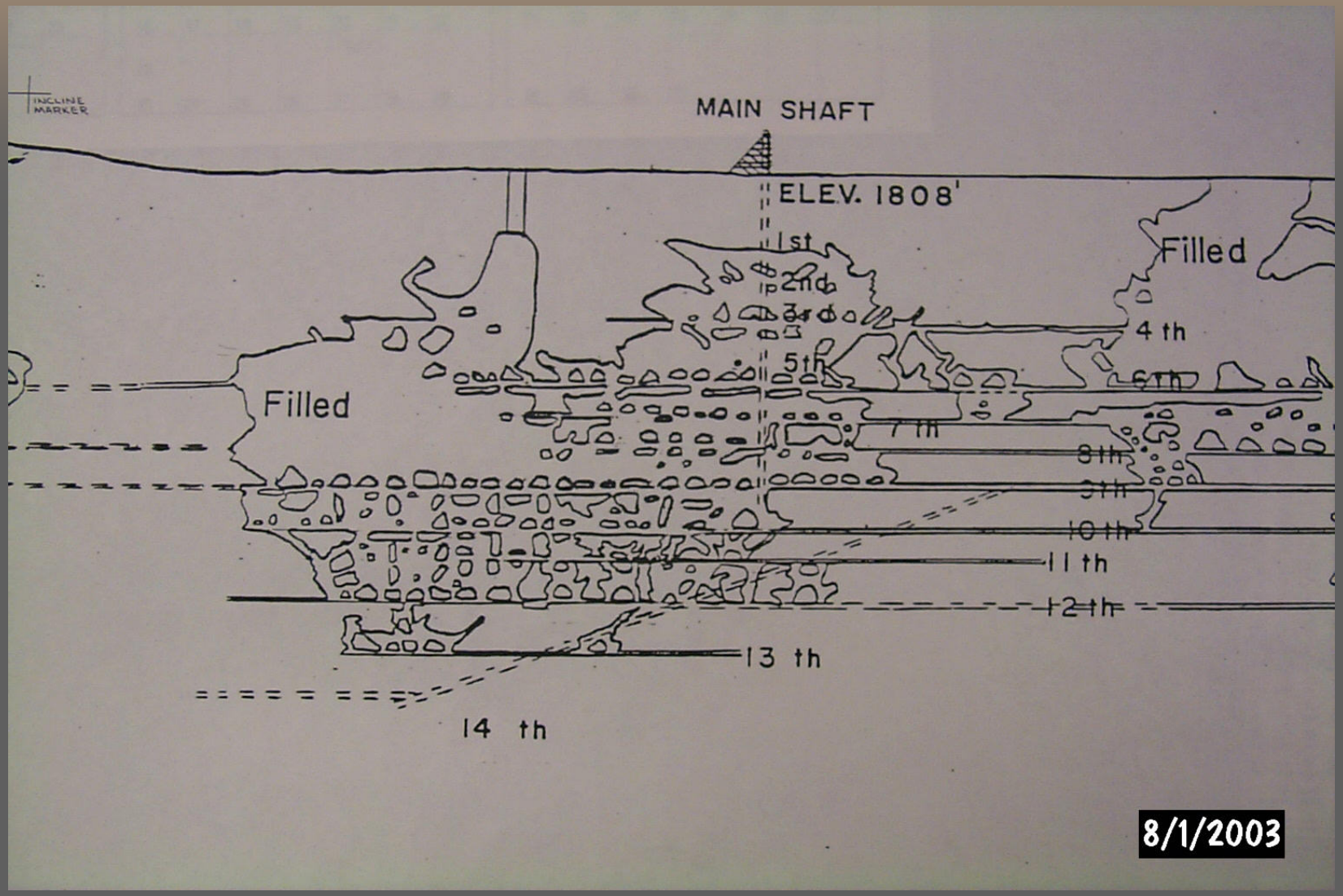
Kevin M. O'Connor	GeoTDR, Inc
Joseph Crawford	United States Gypsum Co.
Kelvin Price	United States Gypsum Co.
Roger Sharpe	United States Gypsum Co.

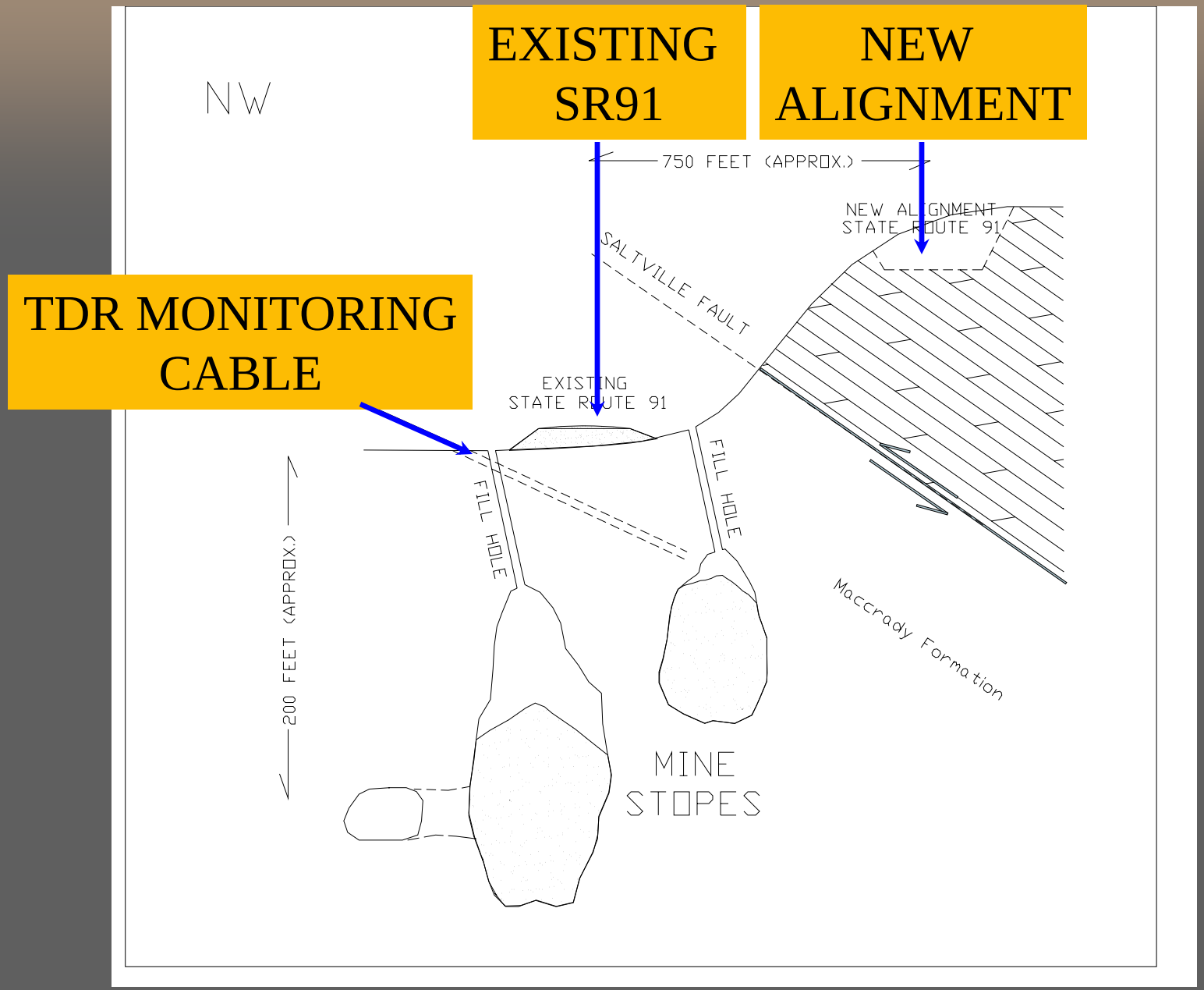

NEW ALIGNMENT
STATE ROUTE 91
PLANT AREA

7/16/2003

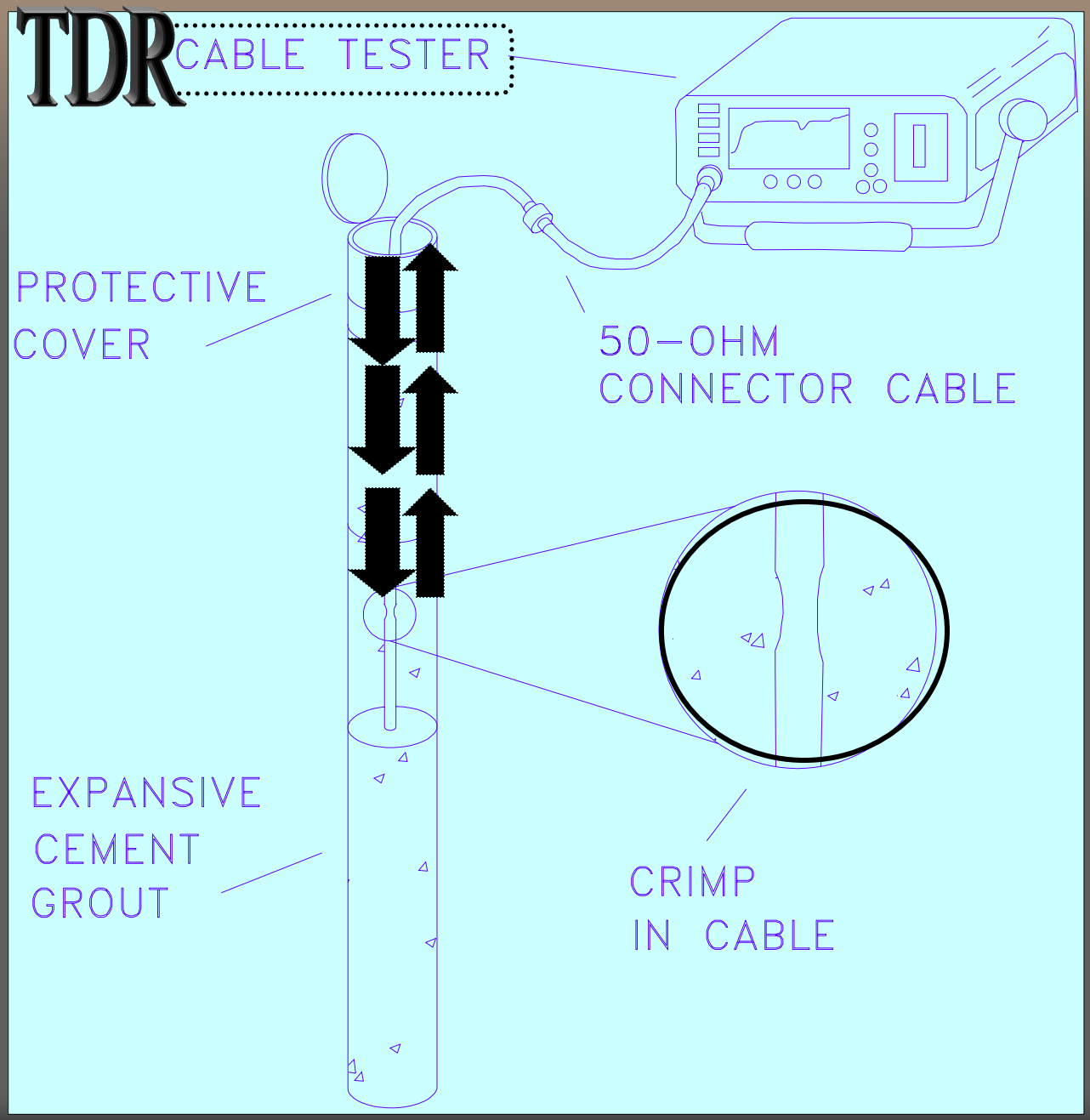

GREENDALE SYNCLINE
MINE
HANGING WALL
CARBONATES AND CLASTICS
LITTLE MOUNTAIN
Little Valley Limestone
(Mississippian)
Footwall Zone
USG PLASTER
Boulder Zone
Cambrian and younger rocks
SALTVILLE FAULT
2,000'
1,000'
SEA LEVEL
-1,000'
-2,000'
EXPLANATION
Gypsum-anhydrite
Salt
Price Sandstone
(Mississippian)
Maccrady Formation
(Mississippian)
0
1
2 MILES


(NATIVE FLOW
McHENRY CR
McHENRY CREEK
RT. 91

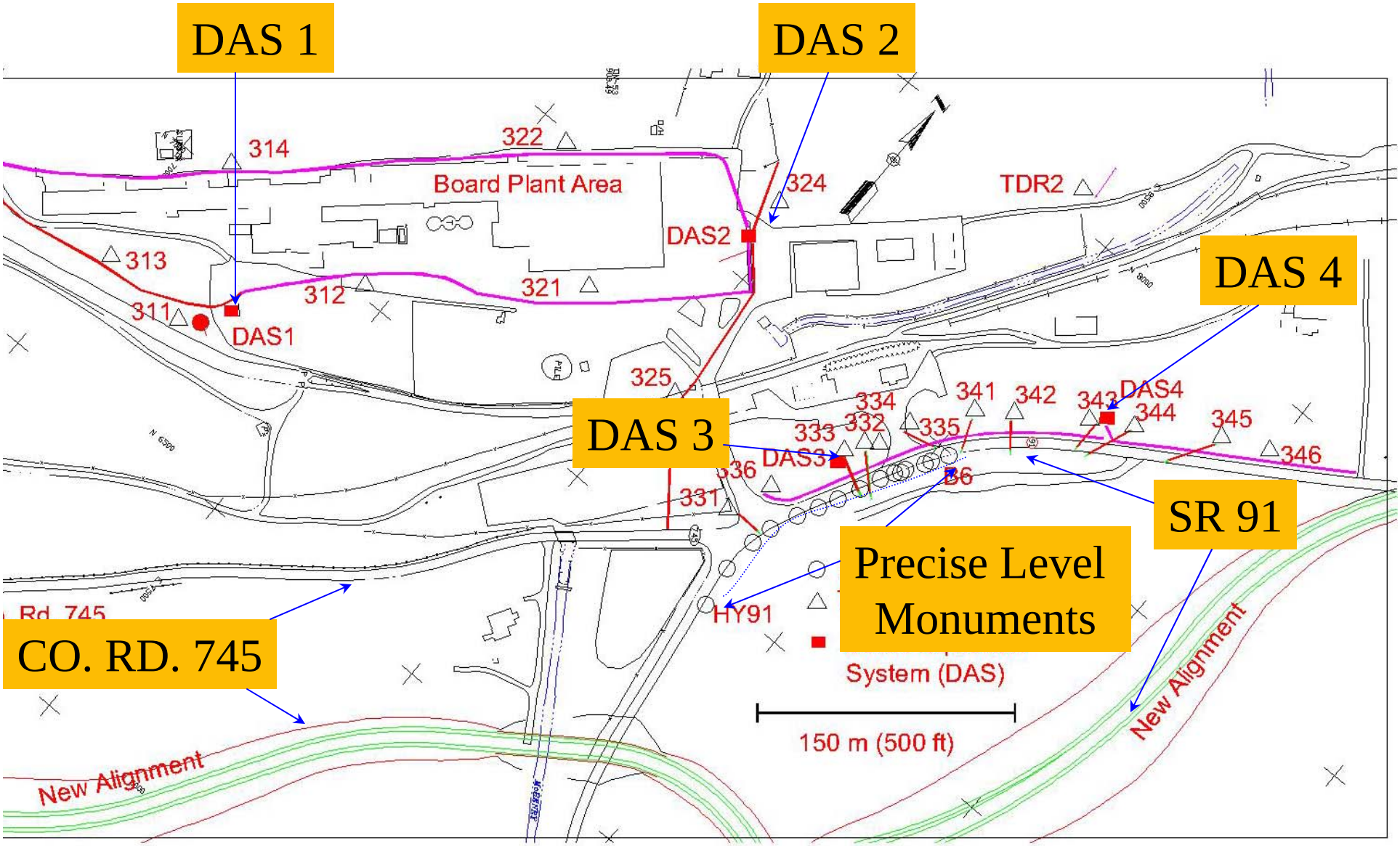

INCLINE MARKER
MAIN SHAFT
ELEV. 1808'
1st
2nd
3rd
5th
Filled
Filled
4 th
6th
7 th
8th
9th
10 th
11 th
12 th
13 th
14 th
8/1/2003


EXISTING SR91
NEW ALIGNMENT
TDR MONITORING CABLE
NW
750 FEET (APPROX.)
NEW ALIGNMENT
STATE ROUTE 91
SALTVILLE FAULT
EXISTING
STATE ROUTE 91
FILL HOLE
FILL HOLE
200 FEET (APPROX.)
Maccrady Formation
MINE
STOPES

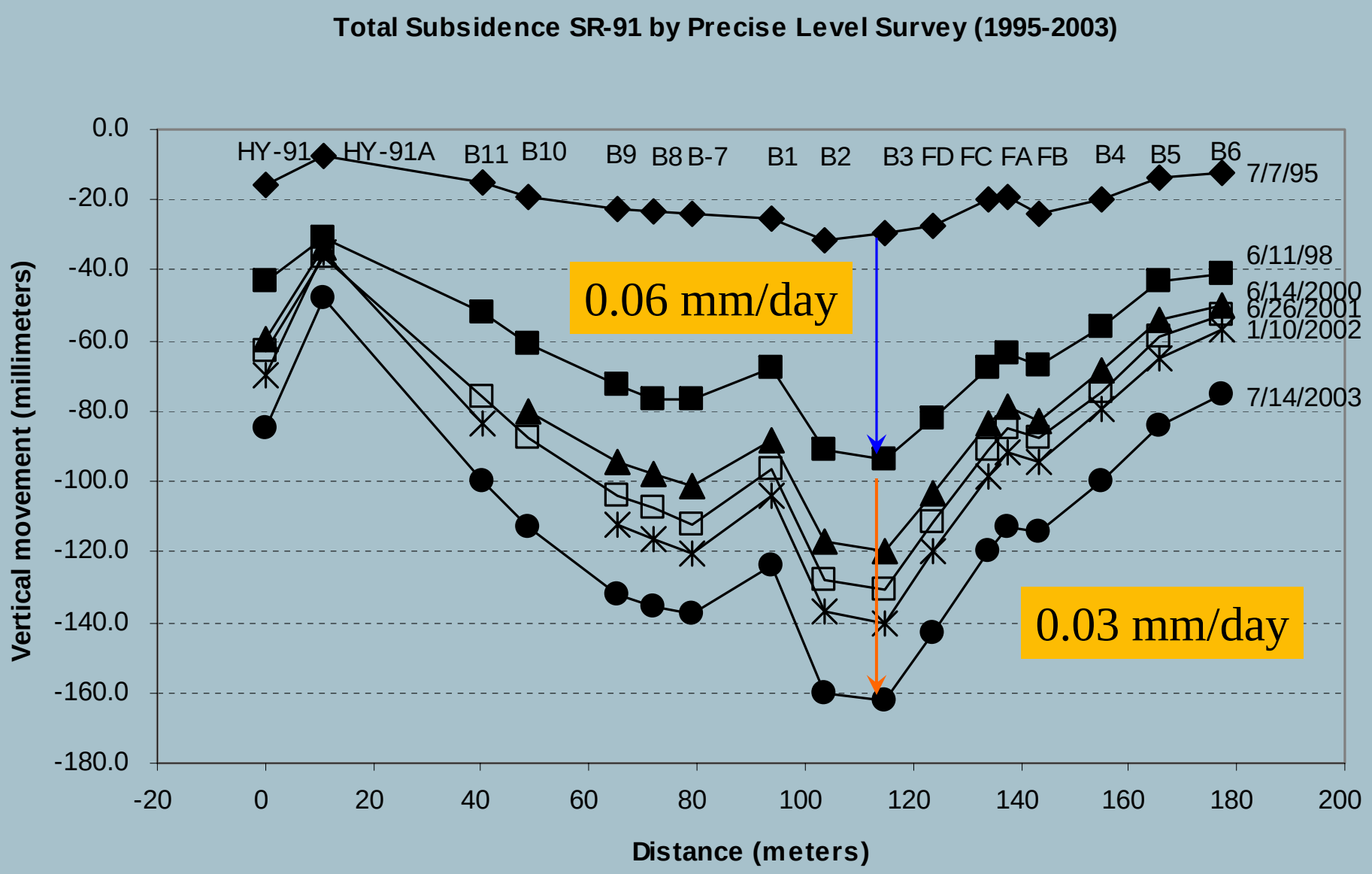
TDR TECHNOLOGY

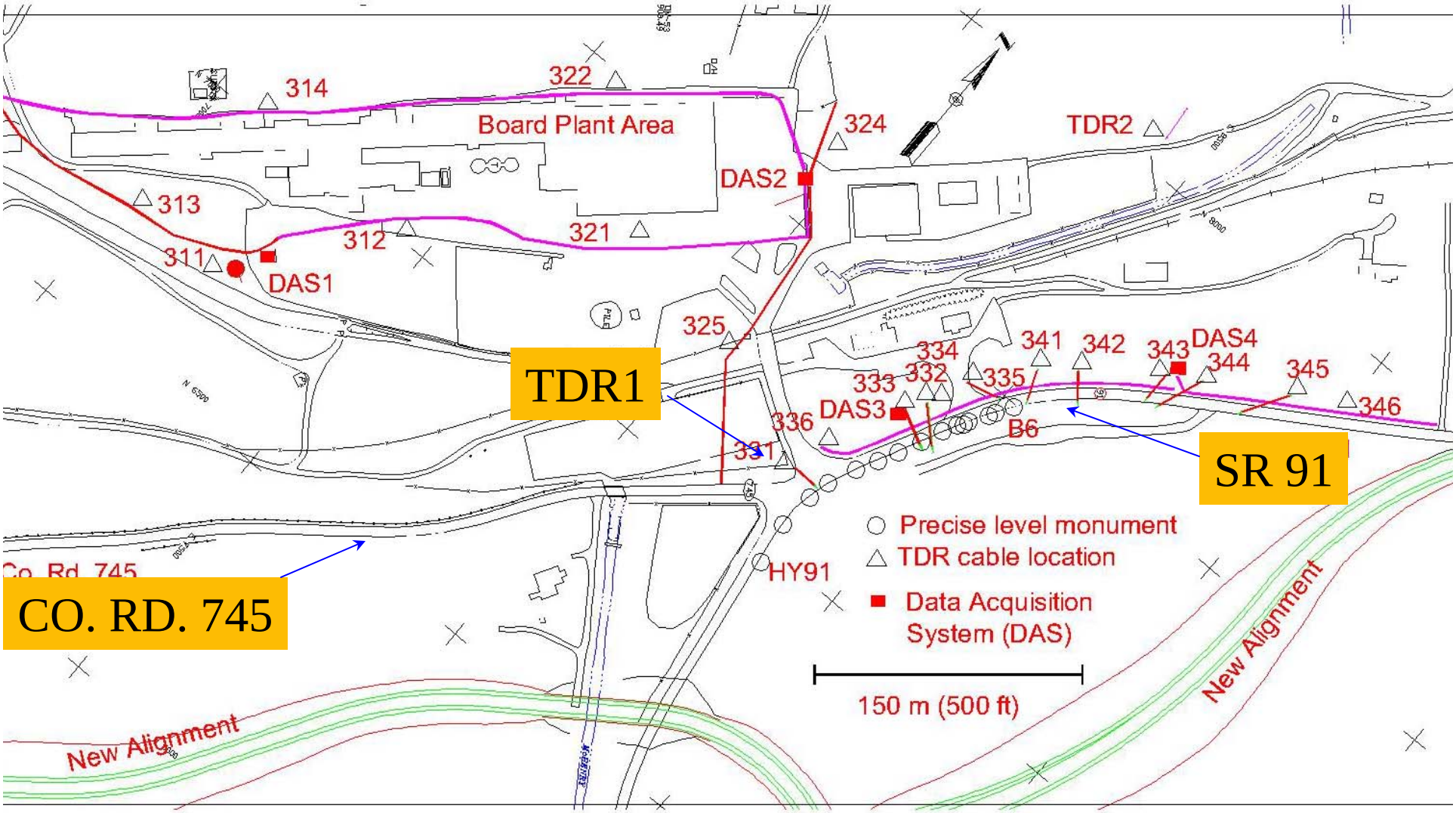

TDR
CABLE TESTER
PROTECTIVE
COVER
50-OHM
CONNECTOR CABLE
EXPANSIVE
CEMENT
GROUT
CRIMP
IN CABLE

PLACE BACKFILL
PLACE CABLE
SR91
DIG TRENCH

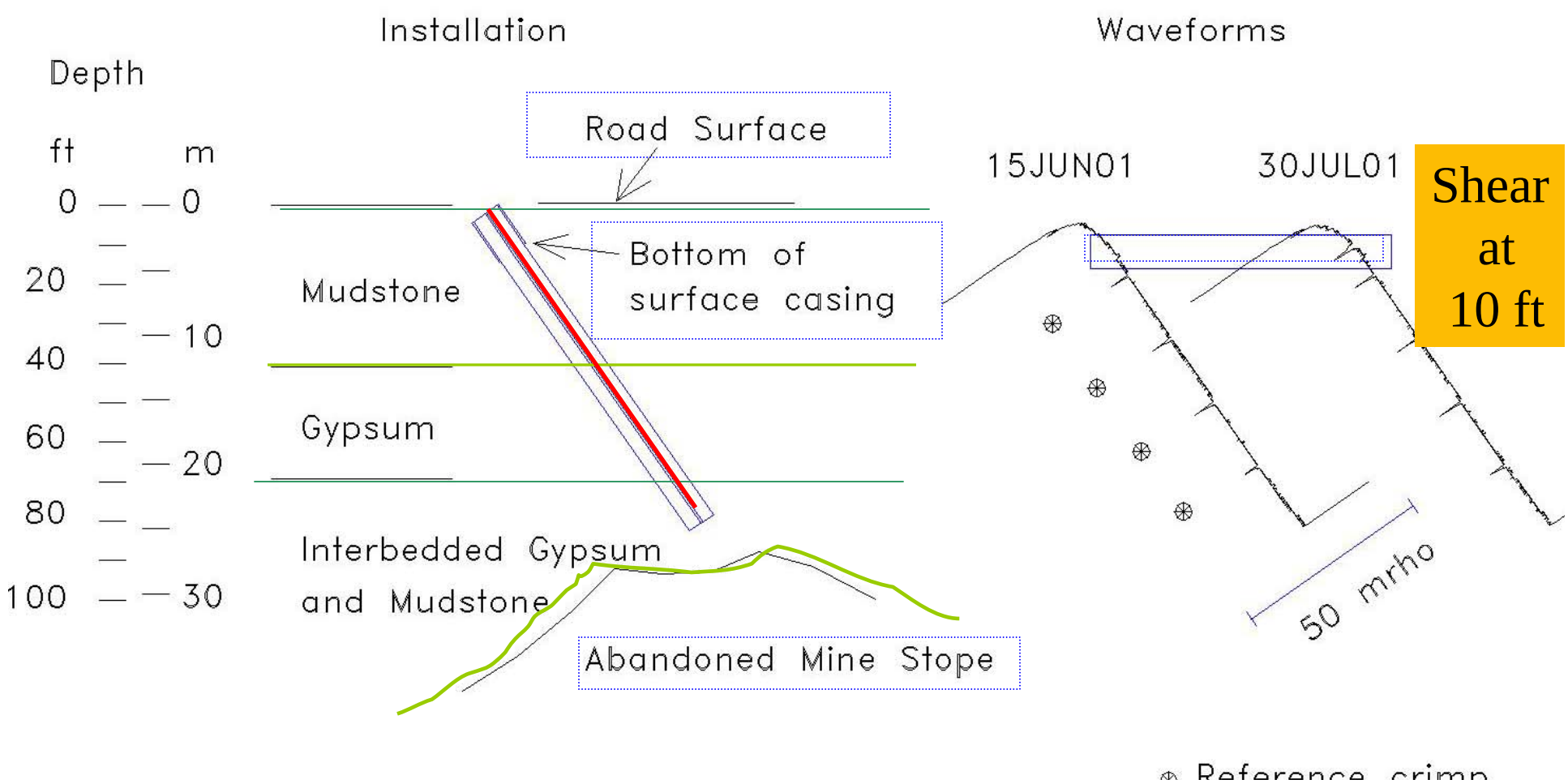

DAS 1
DAS 2
DAS 3
DAS 4
SR 91
Precise Level Monuments
CO. RD. 745
Board Plant Area
314
322
324
TDR2
DAS2
313
312
321
311
DAS1
325
334
332
333
DAS3
336
331
341
342
343
DAS4
344
345
346
335
B6
HY91
System (DAS)
150 m (500 ft)
New Alignment
New Alignment

MEASURED MOVEMENT

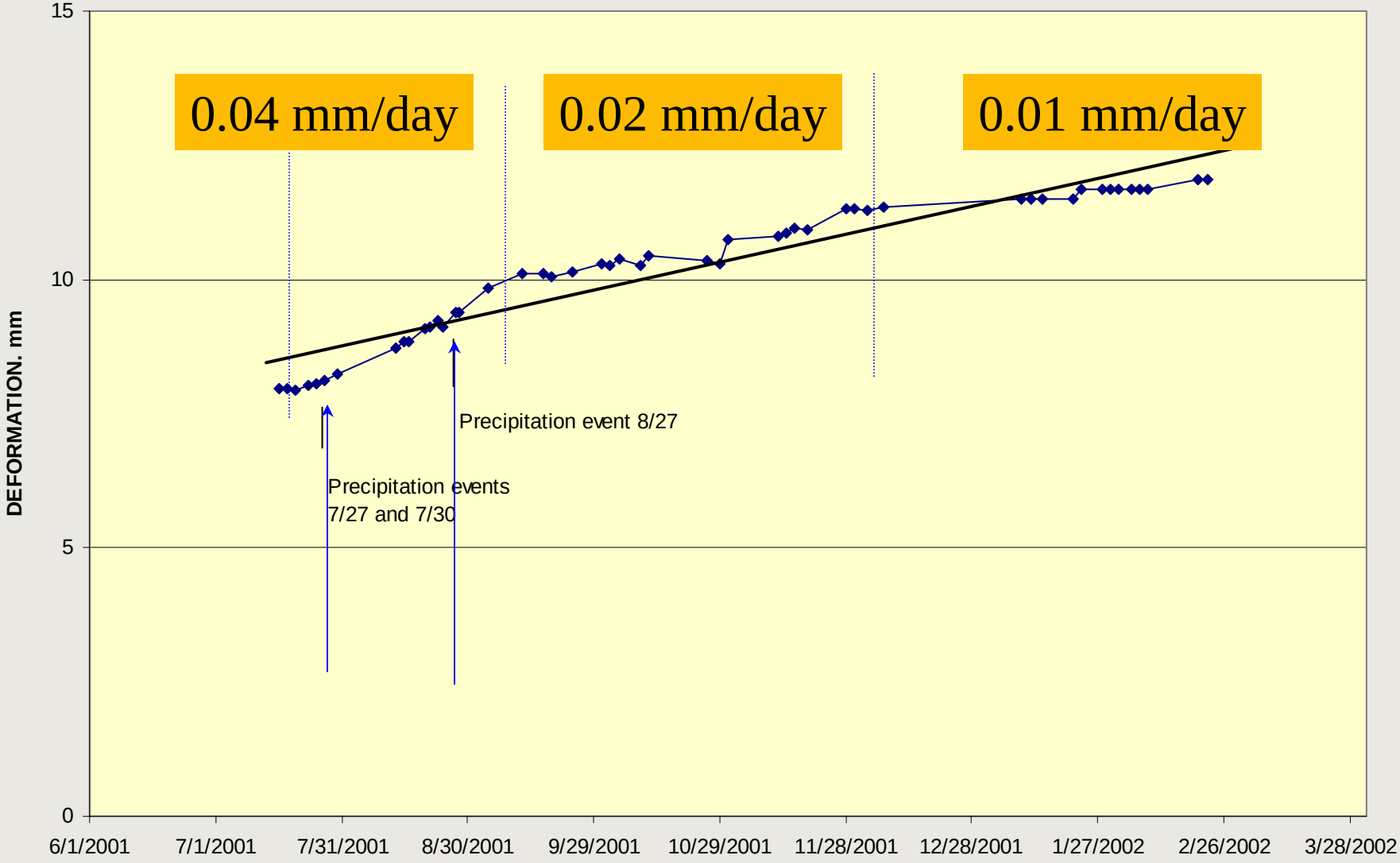

Total Subsidence SR-91 by Precise Level Survey (1995-2003)
Vertical movement (millimeters)
Distance (meters)
0.0
-20.0
-40.0
-60.0
-80.0
-100.0
-120.0
-140.0
-160.0
-180.0
-20
0
20
40
60
80
100
120
140
160
180
200
HY-91
HY-91A
B11
B10
B9
B8
B-7
B1
B2
B3
FD
FC
FA
FB
B4
B5
B6
7/7/95
6/11/98
6/14/2000
6/26/2001
1/10/2002
7/14/2003
0.06 mm/day
0.03 mm/day

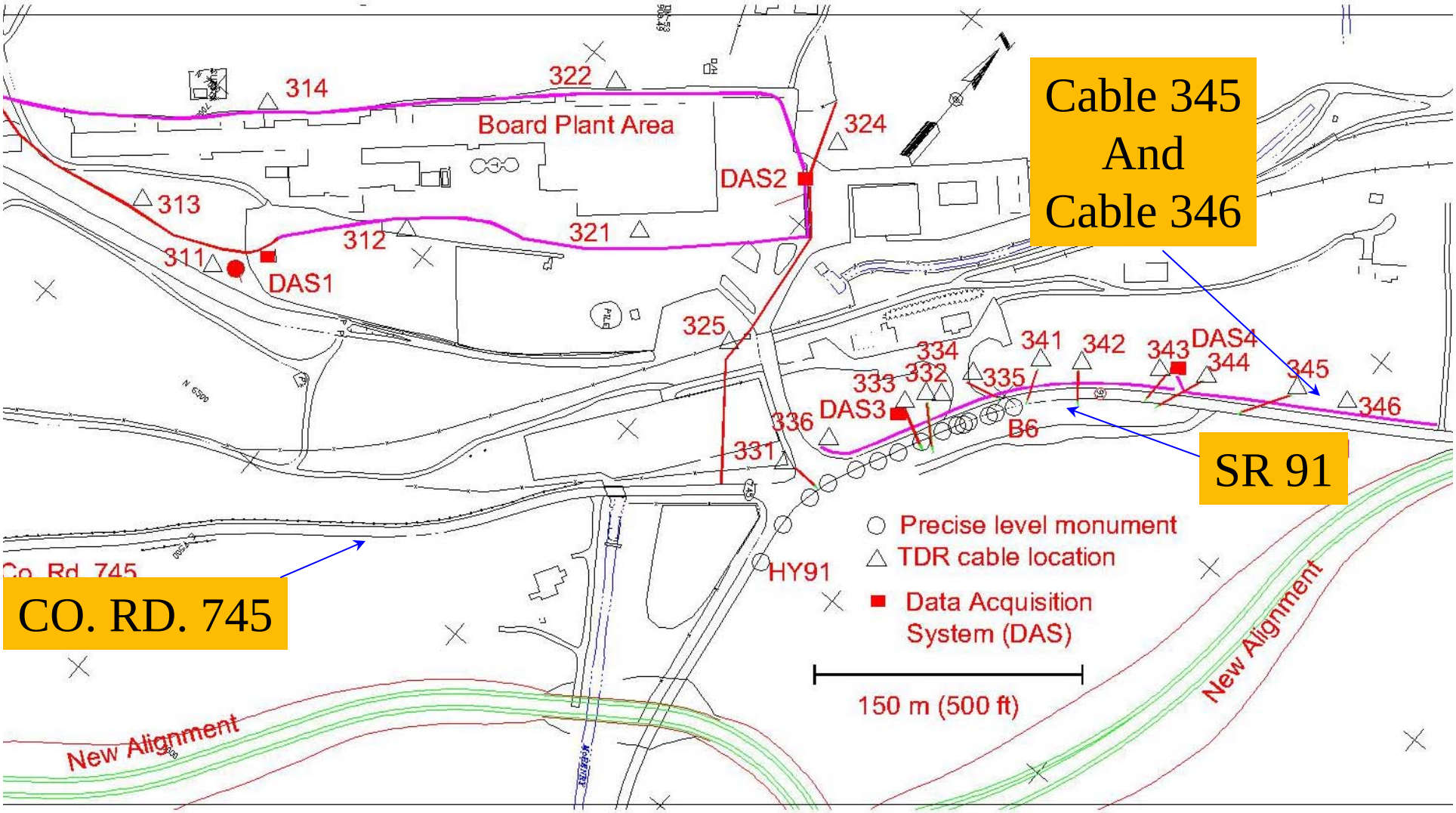

314
322
Board Plant Area
324
TDR2
DAS2
313
312
321
311
DAS1
325
TDR1
334
341
342
343
DAS4
344
345
332
333
335
346
336
DAS3
B6
331
SR 91
Precise level monument
TDR cable location
Data Acquisition System (DAS)
HY91
150 m (500 ft)
New Alignment
New Alignment
CO. RD. 745

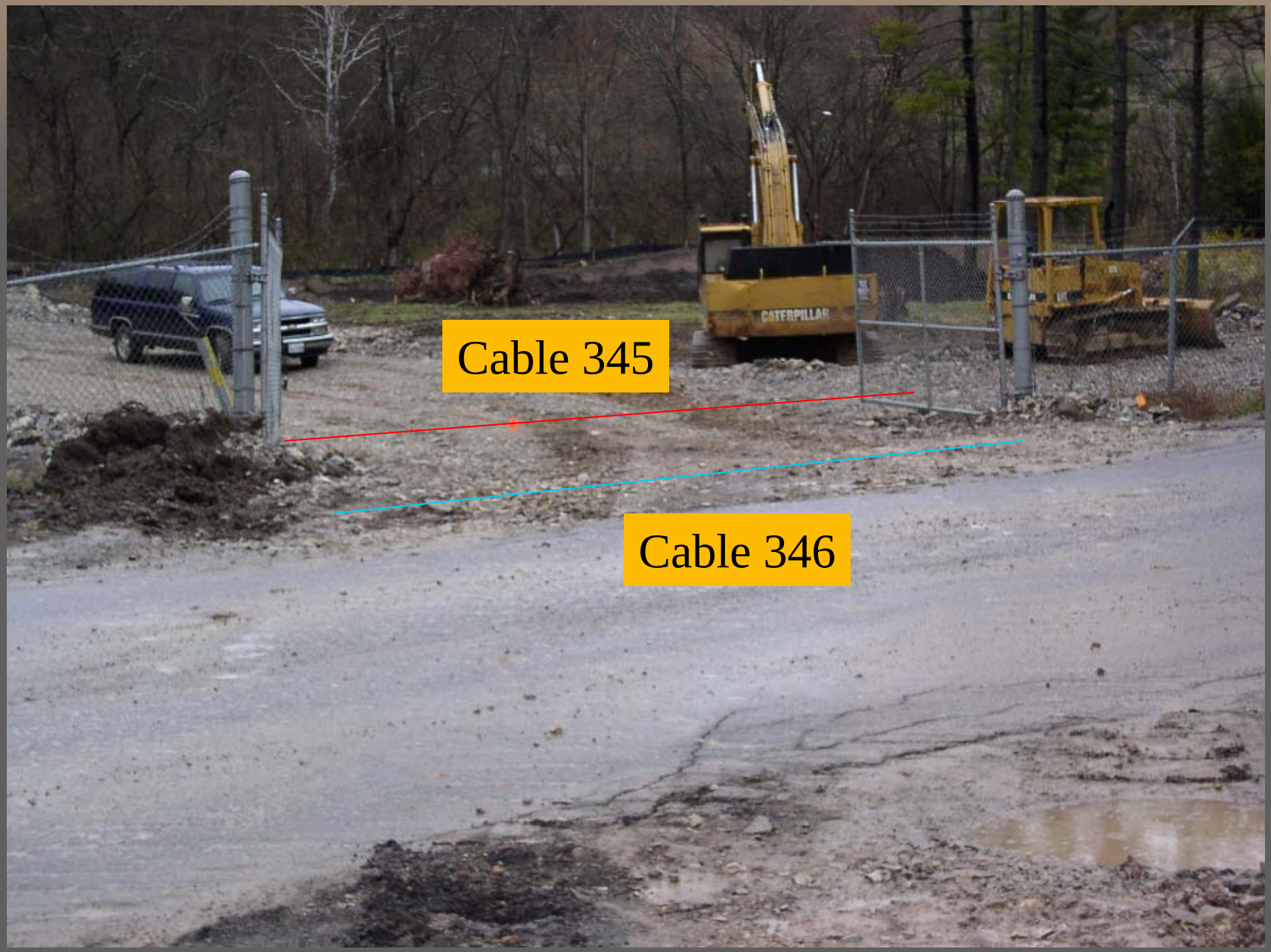
Cable TDR1

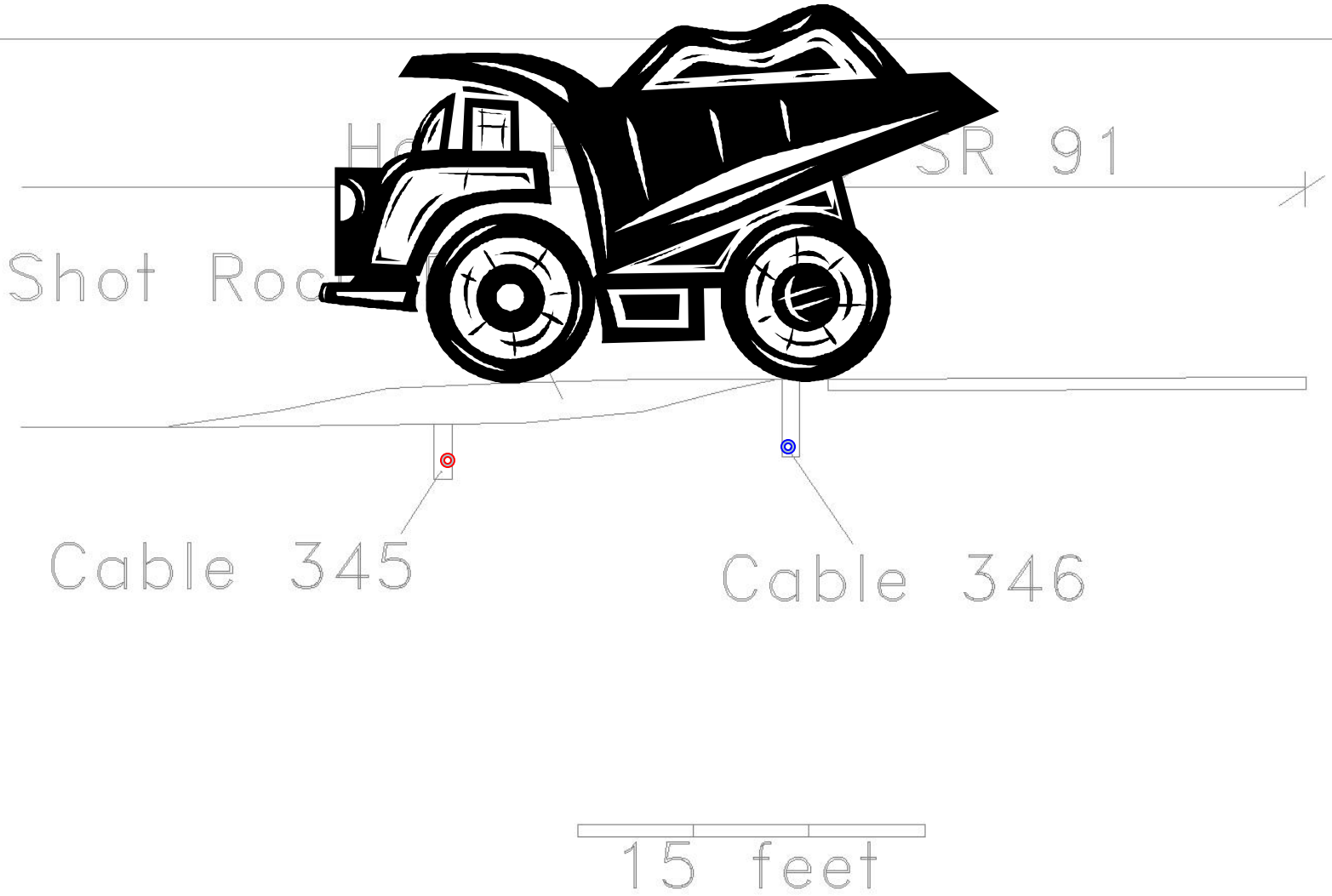

Installation
Waveforms
Depth
ft
m
0
20
40
60
80
100
0
10
20
30
Road Surface
Bottom of surface casing
Mudstone
Gypsum
Interbedded Gypsum and Mudstone
Abandoned Mine Stope
15JUN01
30JUL01
Shear at 10 ft
50 mrho
Reference crimp

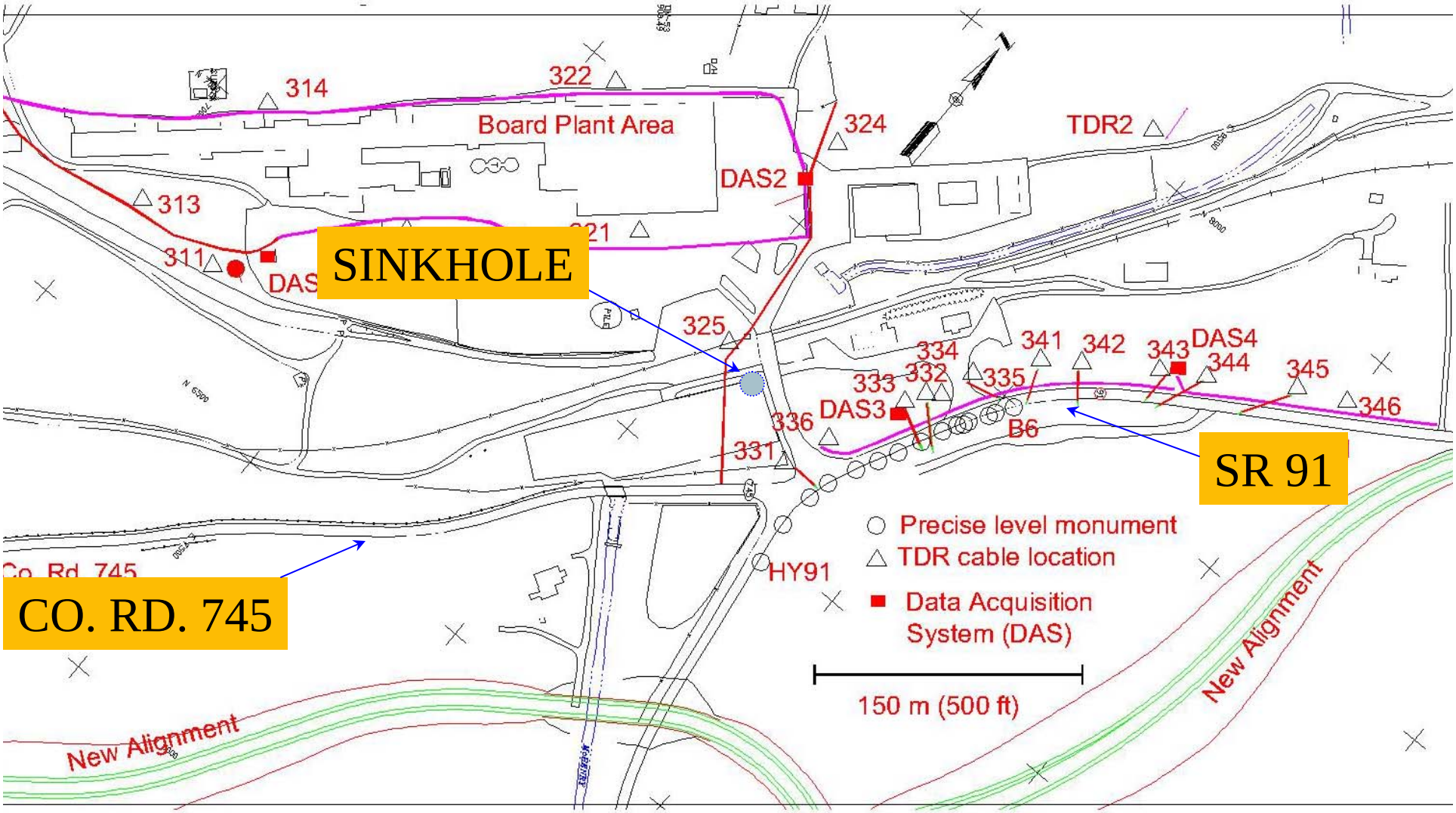
TDR1 Shear at 10 ft




Cable 345
And
Cable 346
SR 91
CO. RD. 745
Board Plant Area
314
322
324
313
312
321
311
DAS1
DAS2
325
334
332
333
DAS3
336
331
341
342
343
DAS4
344
345
346
335
B6
HY91
New Alignment
New Alignment
Precise level monument
TDR cable location
Data Acquisition
System (DAS)
150 m (500 ft)

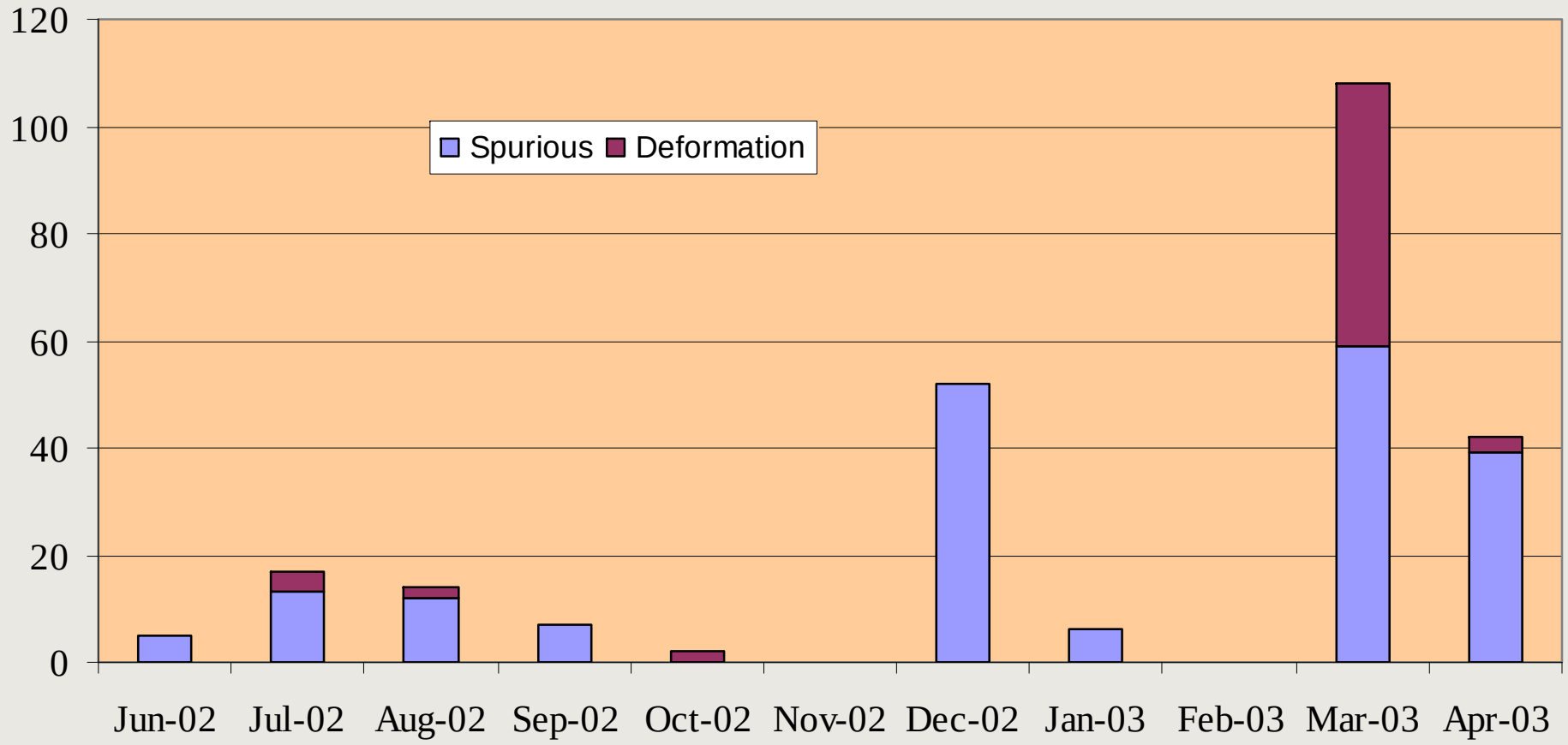

Cable 345
Cable 346
CATERPILLAR


SR 91
Shot Roc
Cable 345
Cable 346
15 feet


314
322
Board Plant Area
324
TDR2
DAS2
313
311
DAS
SINKHOLE
325
334
332
333
DAS3
336
331
341
342
343
DAS4
344
345
346
335
B6
SR 91
Co. Rd. 745
CO. RD. 745
HY91
Precise level monument
TDR cable location
Data Acquisition System (DAS)
150 m (500 ft)
New Alignment
New Alignment

LESSONS LEARNED

ALARM CALLS


120
100
80
60
40
20
0
Spurious
Deformation
Jun-02
Jul-02
Aug-02
Sep-02
Oct-02
Nov-02
Dec-02
Jan-03
Feb-03
Mar-03
Apr-03

Summary and Conclusions
What was learned ?

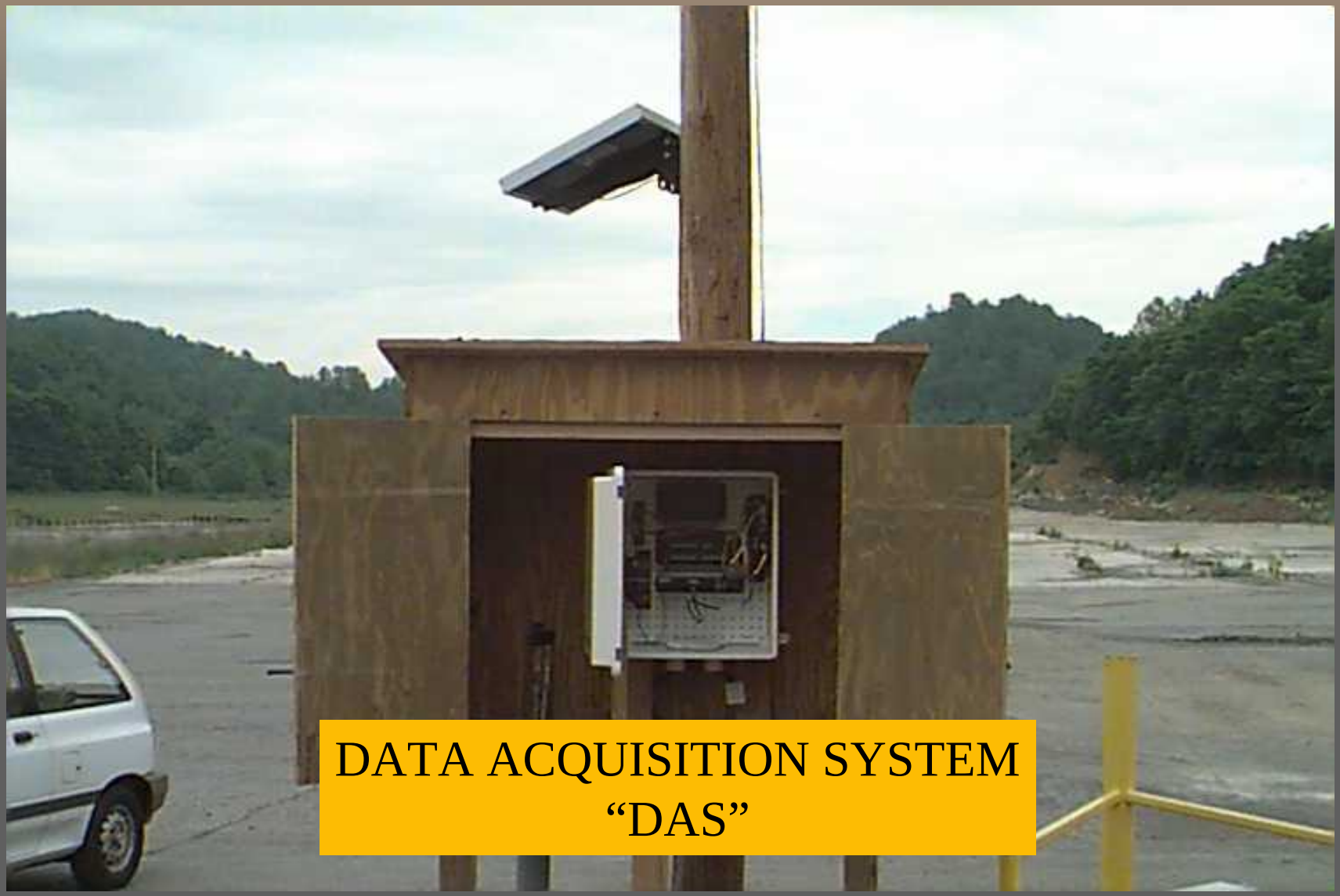
- Answering phone gets “old”, need TEAM of experienced responsible personnel
- Analysis of TDR waveforms is a critical component of action plan…software developed by Jenkins
- Proactively download data and evaluate before alarm condition develops to reduce “burn out”
- Use dummy cable to periodically test system and personnel

Summary and Conclusions
What was learned ?

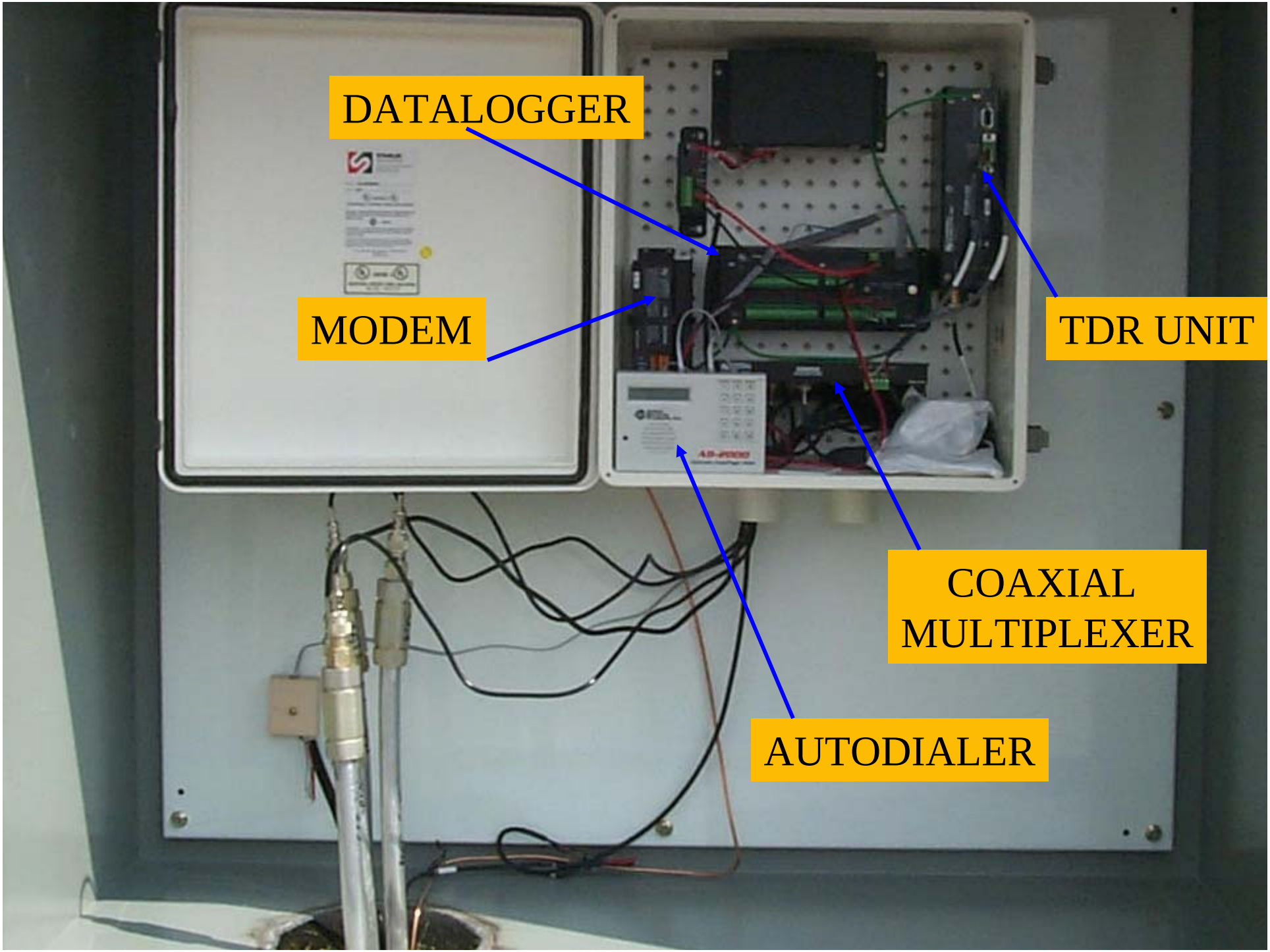
- Installed cost in angled holes $34/ft
- Installed cost in trench $7/ft

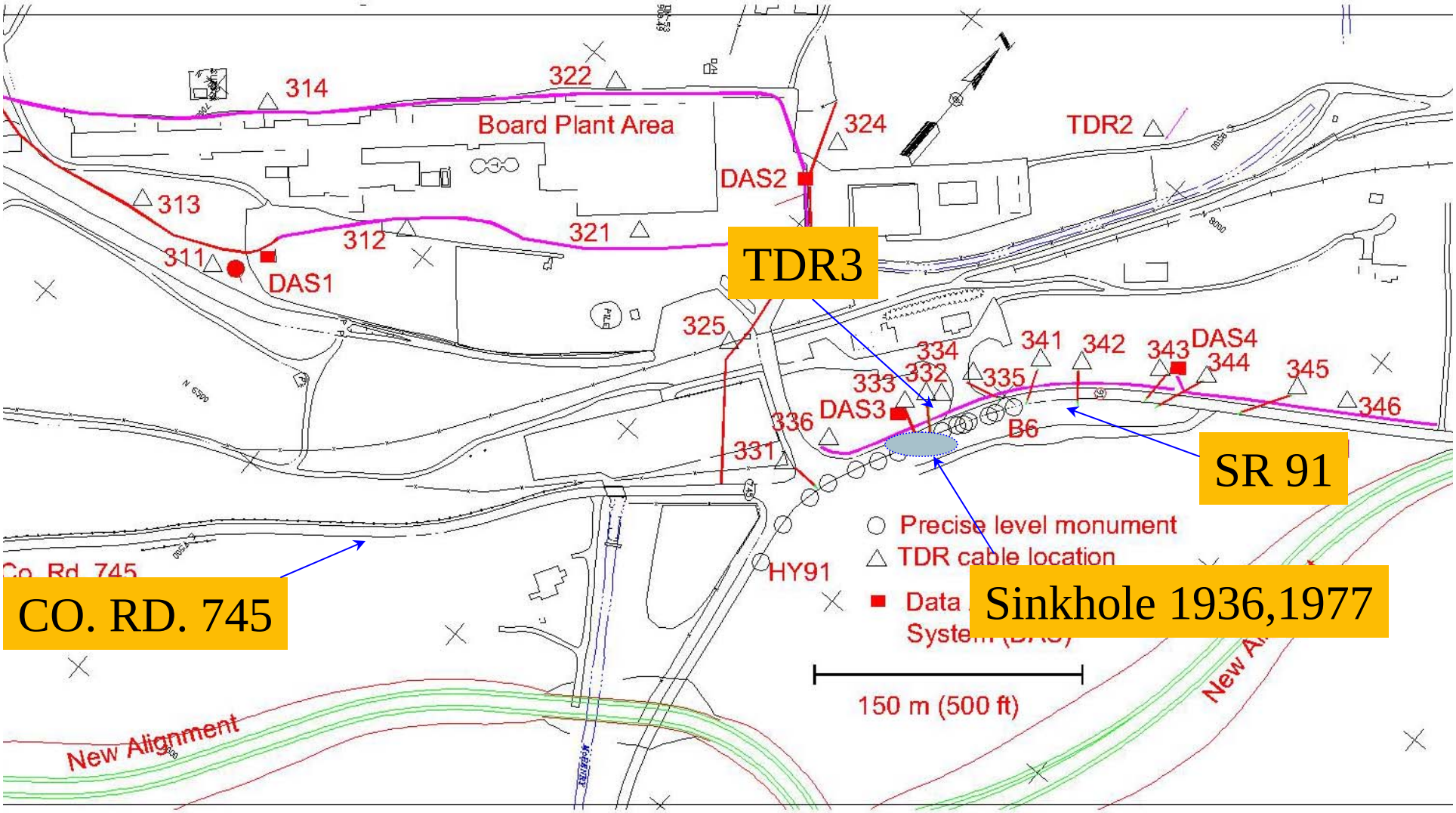
30 FT DIAMETER

PLANT AREA



DATA ACQUISITION SYSTEM
"DAS"


DATALOGGER
MODEM
TDR UNIT
COAXIAL
MULTIPLEXER
AUTODIALER


314
322
Board Plant Area
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TDR2
DAS2
313
312
321
311
DAS1
TDR3
325
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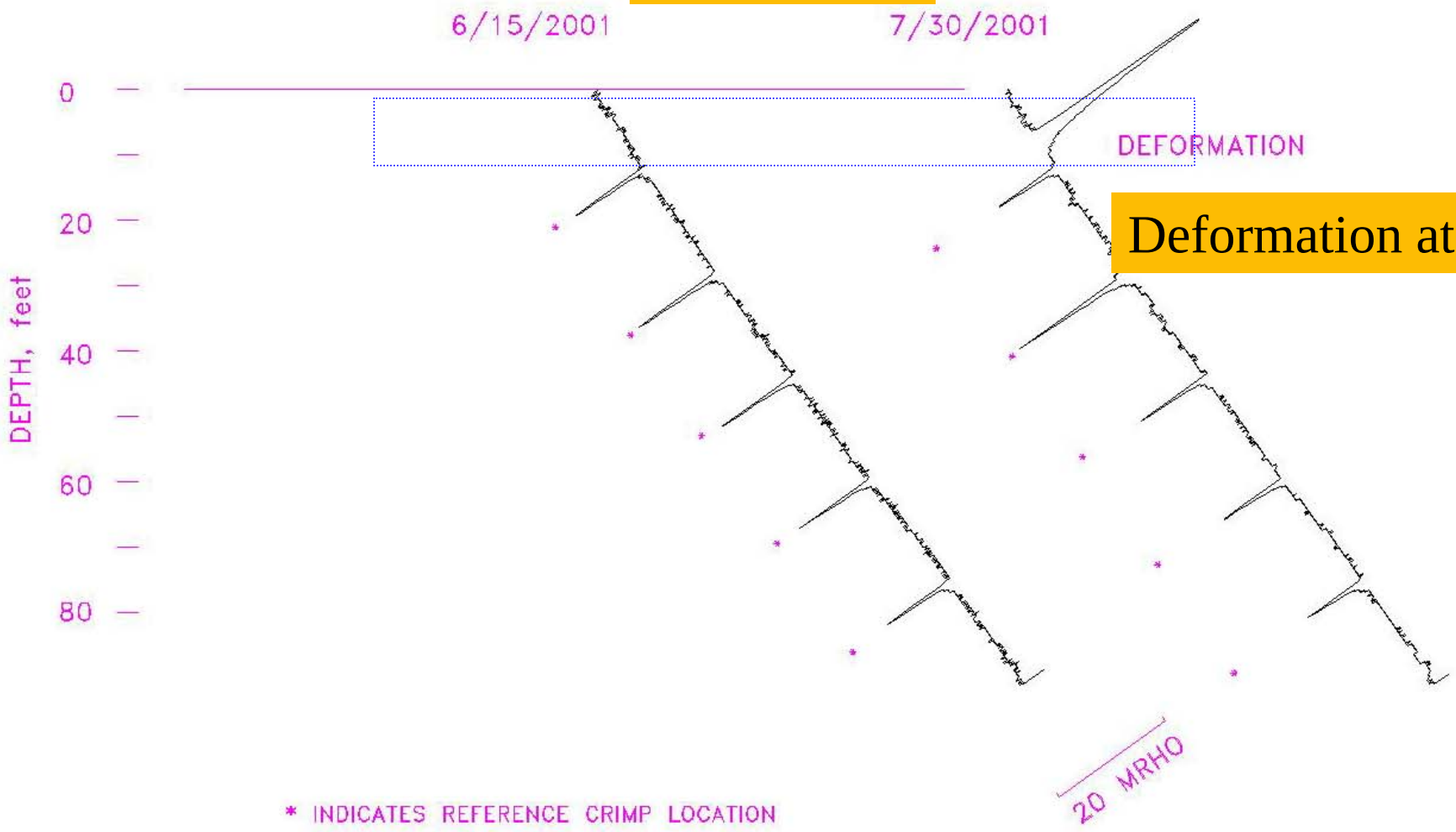
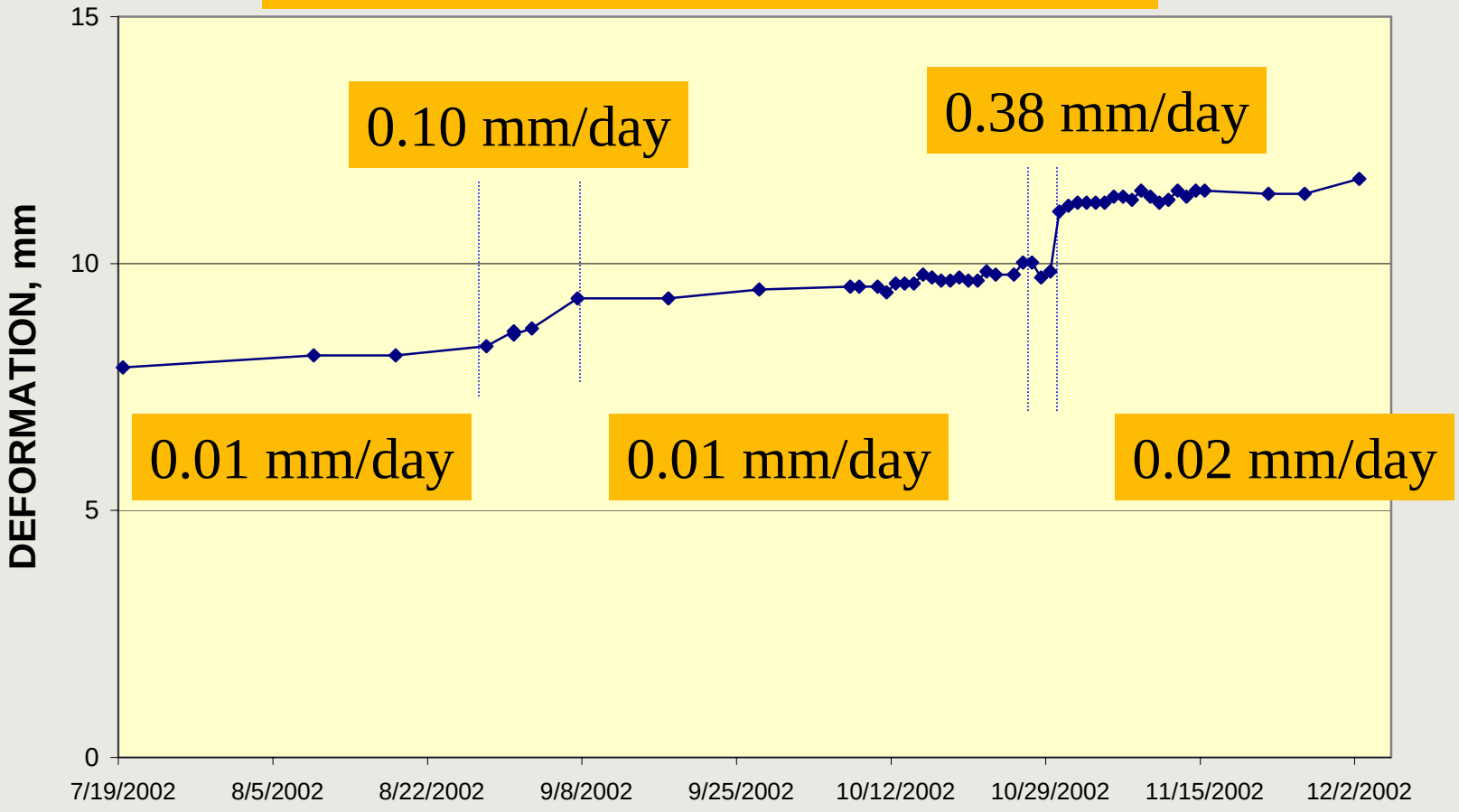
341
342
343
DAS4
344
345
332
335
333
346
336
DAS3
B6
331
SR 91
Precise level monument
TDR cable location
HY91
Data
Sinkhole 1936,1977
150 m (500 ft)
New Alignment
CO. RD. 745

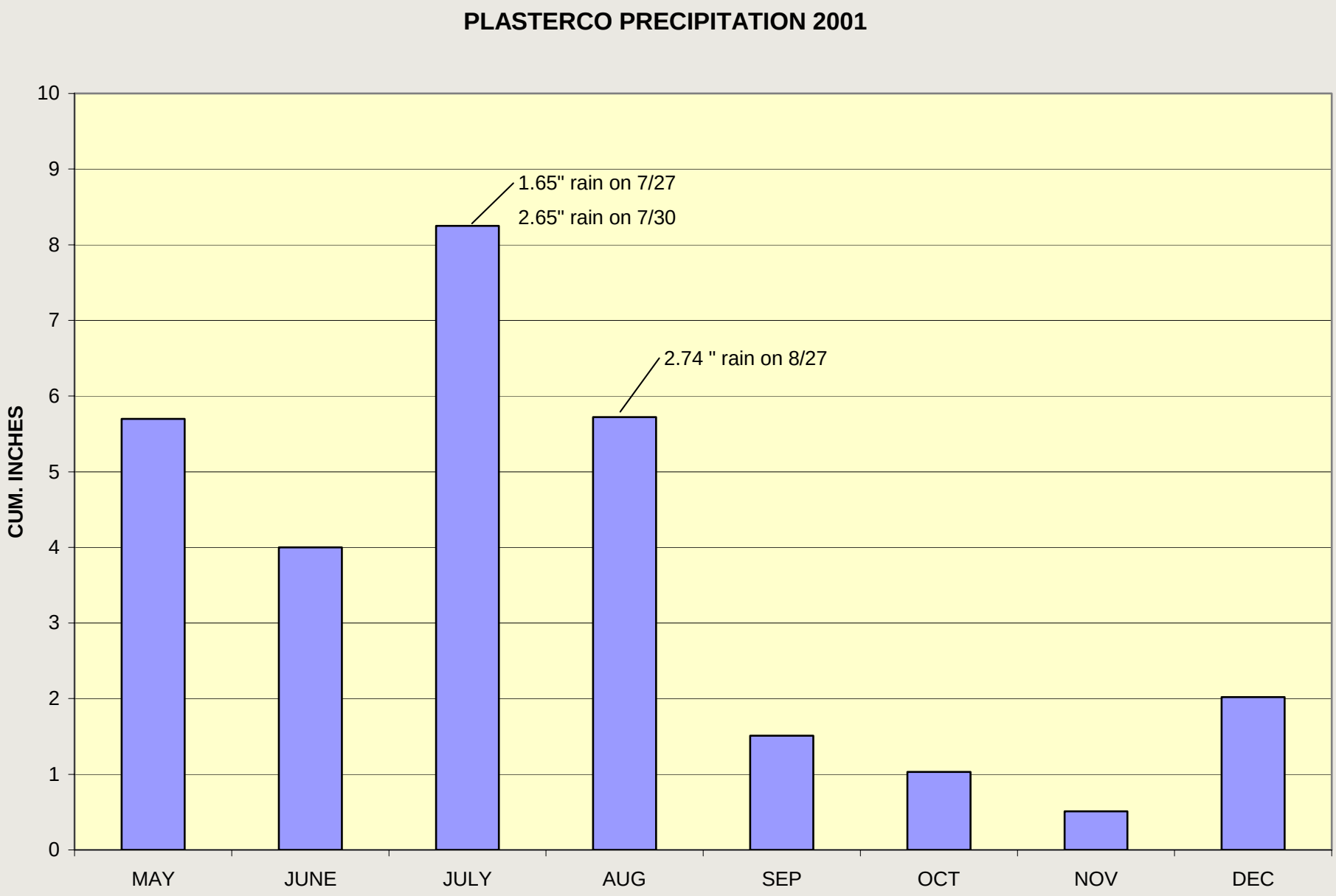
Cable TDR3



Deformation at 8 ft

TDR3 Deformation at 8 ft




PLASTERCO PRECIPITATION 2001
CUM. INCHES
10
9
8
7
6
5
4
3
2
1
0
1.65" rain on 7/27
2.65" rain on 7/30
2.74 " rain on 8/27
MAY
JUNE
JULY
AUG
SEP
OCT
NOV
DEC

Summary and Conclusions Monitoring Philosophy

- Plan of Action:
- TDR reflection magnitude reaches alarm level
- ….site personnel alerted
- ….initiate visual surveillance and review data
- ….determine action level

Transition to Automated Monitoring

- Transition from Phase I manual data acquisition to Phase III automated acquisition
- Phase I Manual trial period (June 2001, 3 cables, 296 linear ft total)
- Phase II Expanded manual monitoring (Feb 2002, 8 cables, 3020 linear ft total)
- Phase III Automated data acquisition (June 2002, 20 cables, 8265 lin. ft + 555 lin. ft)