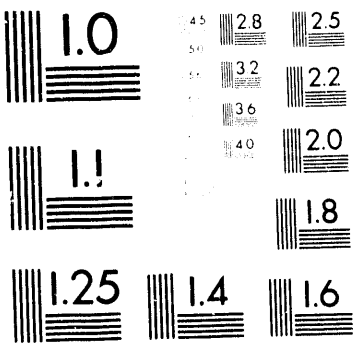
1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
5.0

1 of 1

THREAT OF A SINKHOLE: A REEVALUATION OF CAVERN 4, BAYOU CHOCTAW SALT DOME, LOUISIANA

by

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ABSTRACT

Cavern Lake at Bayou Choctaw salt dome resulted from the failure of Cavern 7 in 1954. Uncontrolled solutioning of this cavern through the thin caprock had set the stage for overburden to collapse into the cavern below. A similar situation developed with nearby Cavern 4, but with less dissolutioning of the caprock. Because pressure loss was already a problem and because another 800 ft diameter lake would have endangered surface operations, solutioning of Cavern 4 was stopped and the cavern abandoned in 1957 in order to protect the already-small site. In 1978 the Strategic Petroleum Reserve (SPR) acquired a number of caverns at Bayou Choctaw, including Cavern 4, and the possible repeat of the Cavern 7 failure and formation of another lake thus became an issue. The cavern dimensions were re-sonared in 1980 for comparison with 1963 and 1977 surveys. Annual surface leveling between 1982-92 showed less subsidence occurring than the site average, and a cavern monitoring system, installed in 1984, has revealed no anomalous motion. Repeat sonar surveys in 1992 showed very little, if any, change occurred since 1980 although a small amount of uncertainty exists as a result of changing sonar techniques. We conclude that significant additional solutioning or erosion of the caprock has not occurred and that there is no increased threat to SPR operations.

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DISCLAIMER

THREAT OF A SINKHOLE: A REEVALUATION OF CAVERN 4, BAYOU CHOCTAW SALT DOME, LOUISIANA

Introduction:

In the history of solution mining, relatively few caverns in domal salt have failed completely, and perhaps only one as dramatically as Cavern 7 at Bayou Choctaw in January, 1954. In those early days before sonar and highly controlled brining, Cavern 7 had no salt roof and was leached completely through the caprock, allowing the overburden to collapse directly into the cavern. [Figure 1] It didn't take more than about a day and an 800 ft diameter sinkhole formed, now filled with water and known as Cavern Lake. [Figure 2; aerial view of Bayou Choctaw dome and Cavern Lake].

Storage operations at Bayou Choctaw have continued to the present; the Strategic Petroleum Reserve (SPR) became a tenant in 1978, co-located with its neighbor Allied, now Union Texas Petroleum, which stores LPG, natural gas, and extracts brine. But the memory of the Cavern 7 event has not been forgotten and it reminds us nearly 40 years later that things can and do happen!

This paper is about Cavern 4, now abandoned but not far from Cavern 7, and with some similar conditions. We review its status and comment on future actions that may assure continued safe operation of adjacent caverns and facilities.

Cavern 4 Geometry and Similarity with Cavern 7

Cavern 4 has no salt roof, having been brined without blanket as in the case of Cavern 7. As with Cavern 7, erosion into the caprock also had occurred and it was abandoned in 1957, after the 1954 collapse of Cavern 7 [Figure 3]. Because of similarities in the geology and cavern size, the 1980 geological characterization report [Acres, 1980] concluded that a similar collapse could occur over Cavern 4, resulting in an 800 ft diameter lake and affecting some of the non-critical SPR facilities, such as the brine pond [Figures 4 and 5]. Because of this potential, several site and system changes were introduced, and a collapse warning system was engineered and installed [Todd and Smith, 1988].

Cavern 4 Status and History

Some 12 years of safe SPR operations have taken place, and although there have been no hints of instability or abnormal subsidence over or near Cavern 4, substantial uncertainty remains regarding the geometry of the cavern roof area, especially the amount of additional caprock removal by leaching or rockfall. PB-KBB, in its 1978 analysis of the situation, suggested it was reasonable to assume that communication was occurring in the lost circulation zone at the caprock/salt interface and that it would continue to promote removal of caprock over the cavern roof. This prediction was based in part on the measured enlargement of the caprock/roof area between 1963 and 1978, as determined from sonar measurements [Figure 6]. Between the 1977 and 1980 surveys, there appeared to have been no further change of significance [Todd and Smith, 1988]. The 1977 volume estimate from sonar was about 5.85 MMB, but 1980 sonar volume measurements indicated 5.94 MMB, an increase of about 1.5 % -- which could represent further dissolutioning, or more likely be within the error range of the survey. Estimates from production records suggested the volume should have been approximately 14.8 MMB, a major inconsistency [PB-KBB, 1978]. PB-KBB suggested that salt solutioning not observable on sonar might be responsible for the disparity. Mills [1993] notes the plan view cross sections in the 1992 sonar report are extremely irregular and support the notion of hidden volume. The shape also makes radius and volume interpretations more difficult and variable.

Contributing Factors: Anomalous Zones

Even though there is little new information at Bayou Choctaw, there is increased understanding of anomalous zones in salt domes in general [Kupfer, 1980, 1990; Thoms and Neal, 1992]. The 1980 report identified a major fault zone (F2), possibly active, that intersects the dome in the vicinity of Cavern 4. Our newly revised caprock and salt maps [Magorian, 1993] clearly show the subsurface expression of this fault as it traverses the top of the dome. It is likely that this external fault is manifested as a shear zone in the salt stock, and is probably a boundary between two discrete spines of salt. Such conditions could account for the pronounced west-extending wing that appears in the sonar profiles [Figs. 6 and 7]. Cavern 1, 800 ft west of Cavern 4, also has a westerly-extending wing paralleling the trend of the fault zone, possibly further substantiating the notion that an anomalous zone exists in that vicinity.

The revised caprock and salt maps map in the recently updated geologic site characterization report [Figs. 7 and 8; ref. Neal and Magorian, 1993] shows this fault transecting the entire dome and which passes directly through Cavern 4, and which is directly in line with the elongation axis of the cavern. This correlation is apparently more than coincidental, and suggests that the enlargement potential of Cavern 4 could [illegible] by the nature of materials along this fault.

August 1992 Re-sonar

To resolve some of these questions, a re-sonar of Cavern 4 was conducted in August 1992 to determine what changes might have occurred in the caprock since 1980. The survey showed that no major change has occured in the comparative appearance of sonar profile graphics [Fig. 6] although there is some evidence of a roof fall about 150 ft west of the wellbore. The overall 6% enlargement in volumetric calculations from 1980 may indicate some additional solutioning in the cavern, although much of the 6% can be attributed to the expected survey inaccuracies and allowable error. Another factor to consider is that cavern creep closure should have reduced cavern volume by about 1% over the 12 yr period between surveys. About one-third (150,000 bbl) of the reported 6% increase from 1980 is at or above the -600 ft level. Slezak [personal communication, 1992] cautions that the two surveys are not comparable in that different tools were used; the 1980 survey employed only horizontal look angles, and the volume at the top of the cavern above the casing at -648 ft is not included in the reported cavern volume, even though the horizontal accuracy was more precise. Todd [1993] considered the evidence and concluded there is no basis to believe that significant change occurred between 1980 and 1992 [Fig. 9].

Conclusions

Thus a degree of uncertainty remains, and shows that a small amount of caprock dissolutioning *may* have occurred during the preceeding 12 years. If change could be proved to have occurred, possible stabilization measures might be considered and mitigation instituted. But little additional action seems justifiable at this time in view of the facts as are known. The injection of grout into the remaining overlying caprock and overburden roof is one course of action

that might be considered at a future date, but this may be impractical. The authors of this report believe a re-sonar of the cavern would be prudent in about five years and provide a rational basis for planning.

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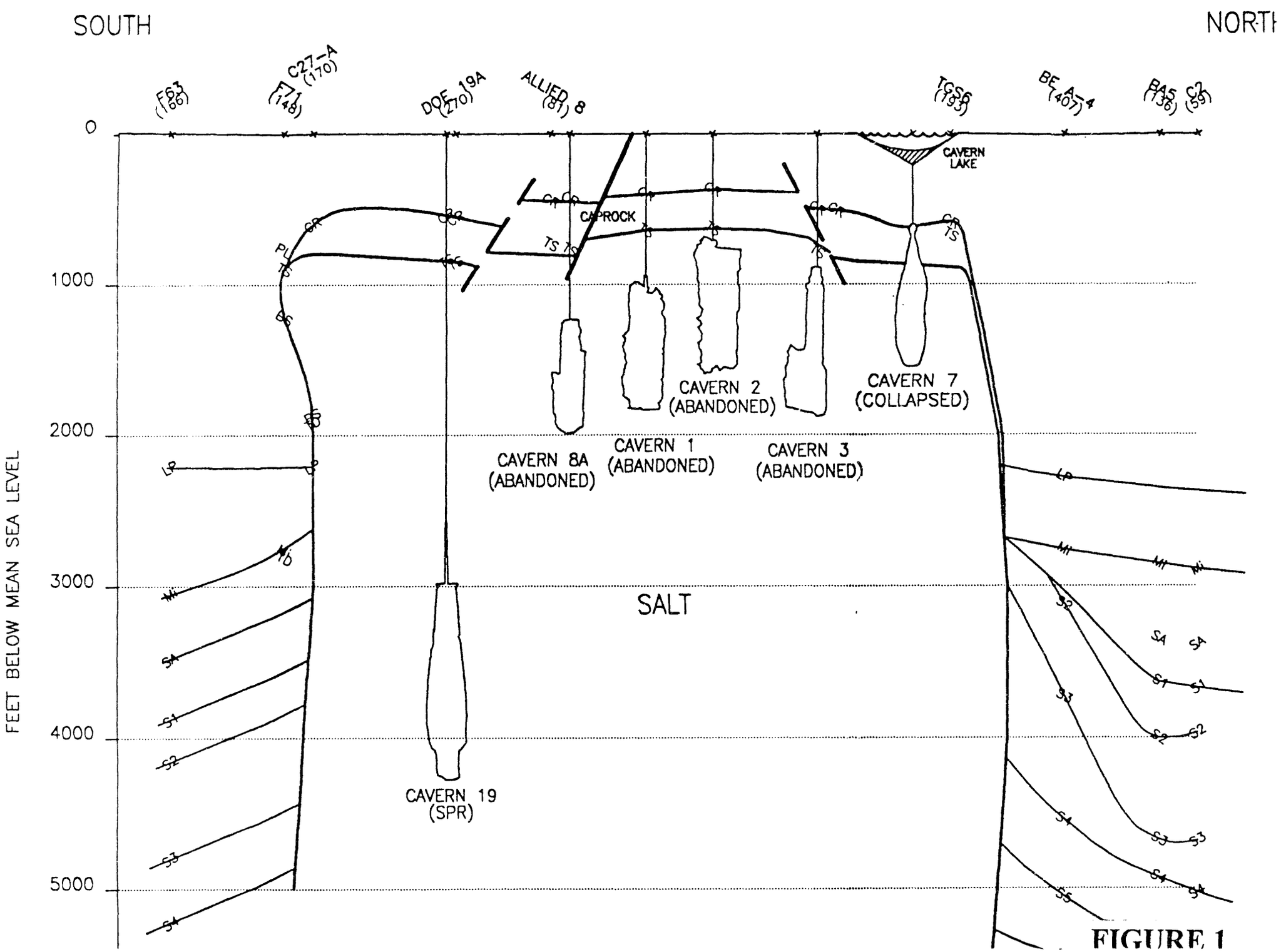
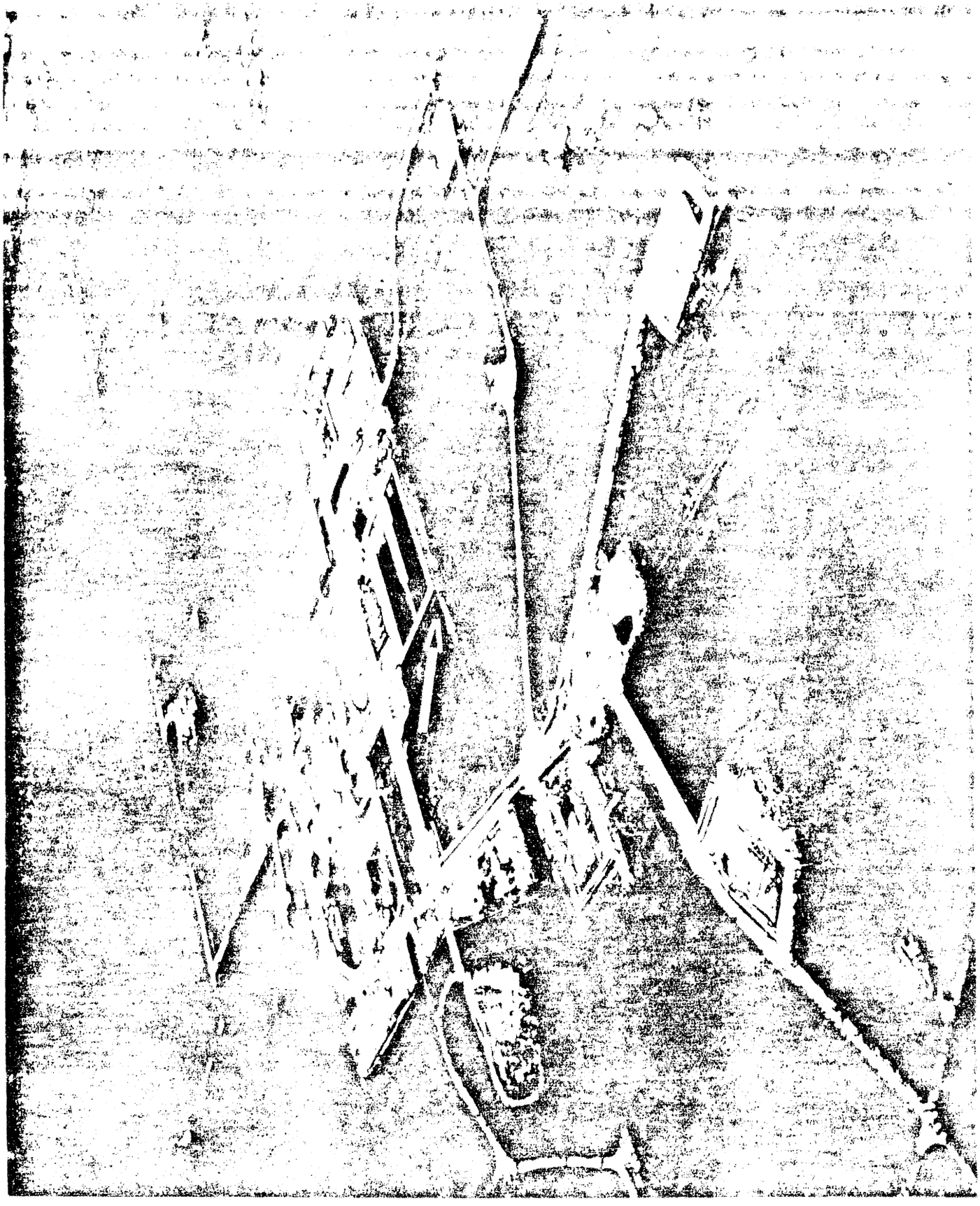

SOUTH
NORTH
FEET BELOW MEAN SEA LEVEL
0
1000
2000
3000
4000
5000
F63 (166)
C27-A (170)
(148)
DOE 19A (270)
ALLIED (81) 8
TGSS (135)
BE A-4 (407)
BAS (138) C2 (59)
CAVERN LAKE
CAPROCK
CAVERN 2 (ABANDONED)
CAVERN 7 (COLLAPSED)
CAVERN 8A (ABANDONED)
CAVERN 1 (ABANDONED)
CAVERN 3 (ABANDONED)
SALT
CAVERN 19 (SPR)

FIGURE 1



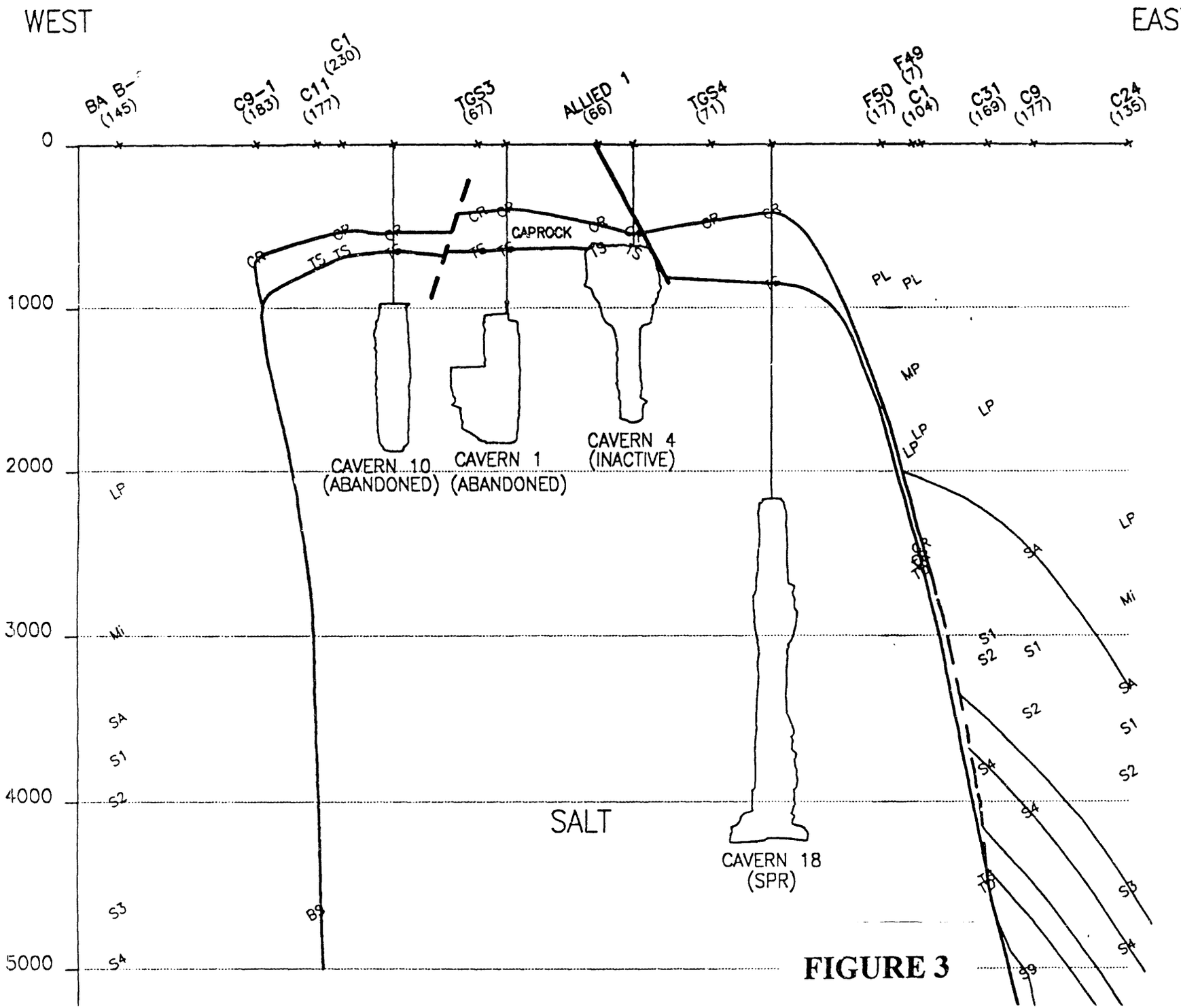
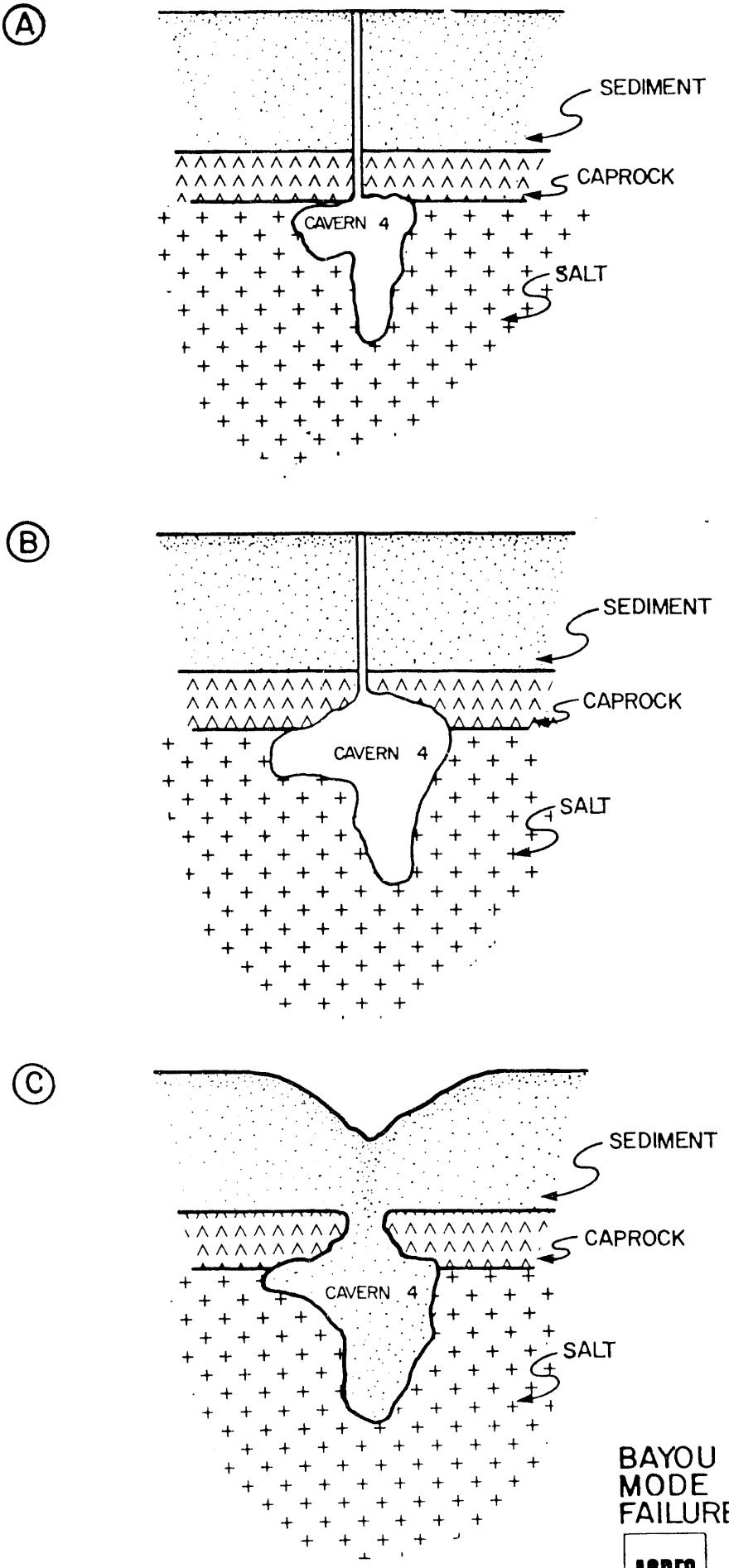

WEST
EAST
BA B-
(145)
C9-1
(183)
C11
C1
(230)
(177)
TGS3
(67)
ALLIED 1
(66)
TGS4
(71)
F50
(17)
F49
(7)
C1
(104)
C31
(169)
C9
(177)
C24
(135)
0
1000
2000
3000
4000
5000
CAPROCK
CAVERN 10
(ABANDONED)
CAVERN 1
(ABANDONED)
CAVERN 4
(INACTIVE)
CAVERN 18
(SPR)
SALT
PL
MP
LP
Mi
SA
S1
S2
S3
S4
B9
T5
T9
99

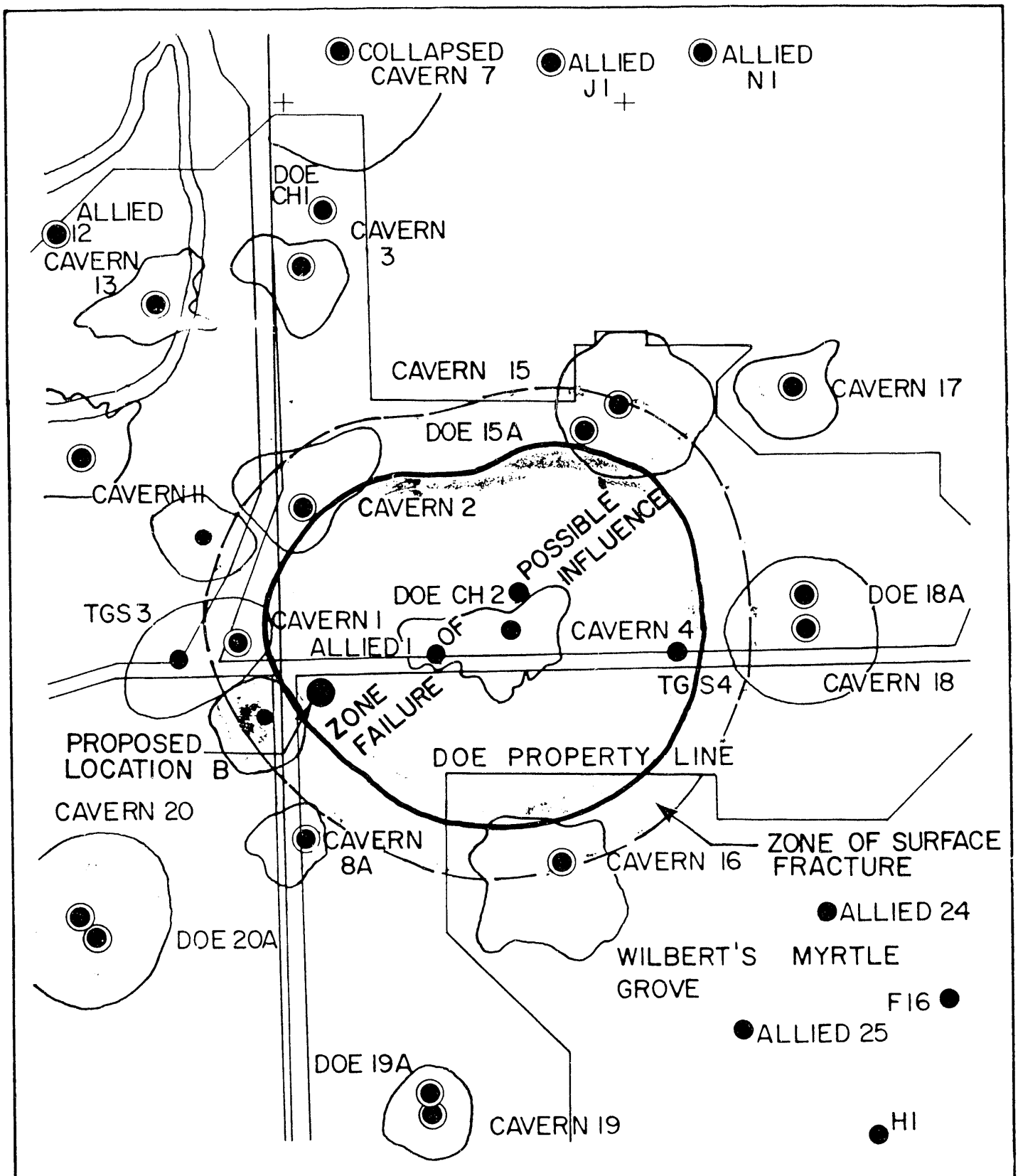
FIGURE 3



BAYOU CHOCTAW SPR SITE
MODE OF POSSIBLE CAVERN 4 FAILURE

ACRES AMERICAN INCORPORATED
T.R. MAGORIAN
SEPTEMBER 1980

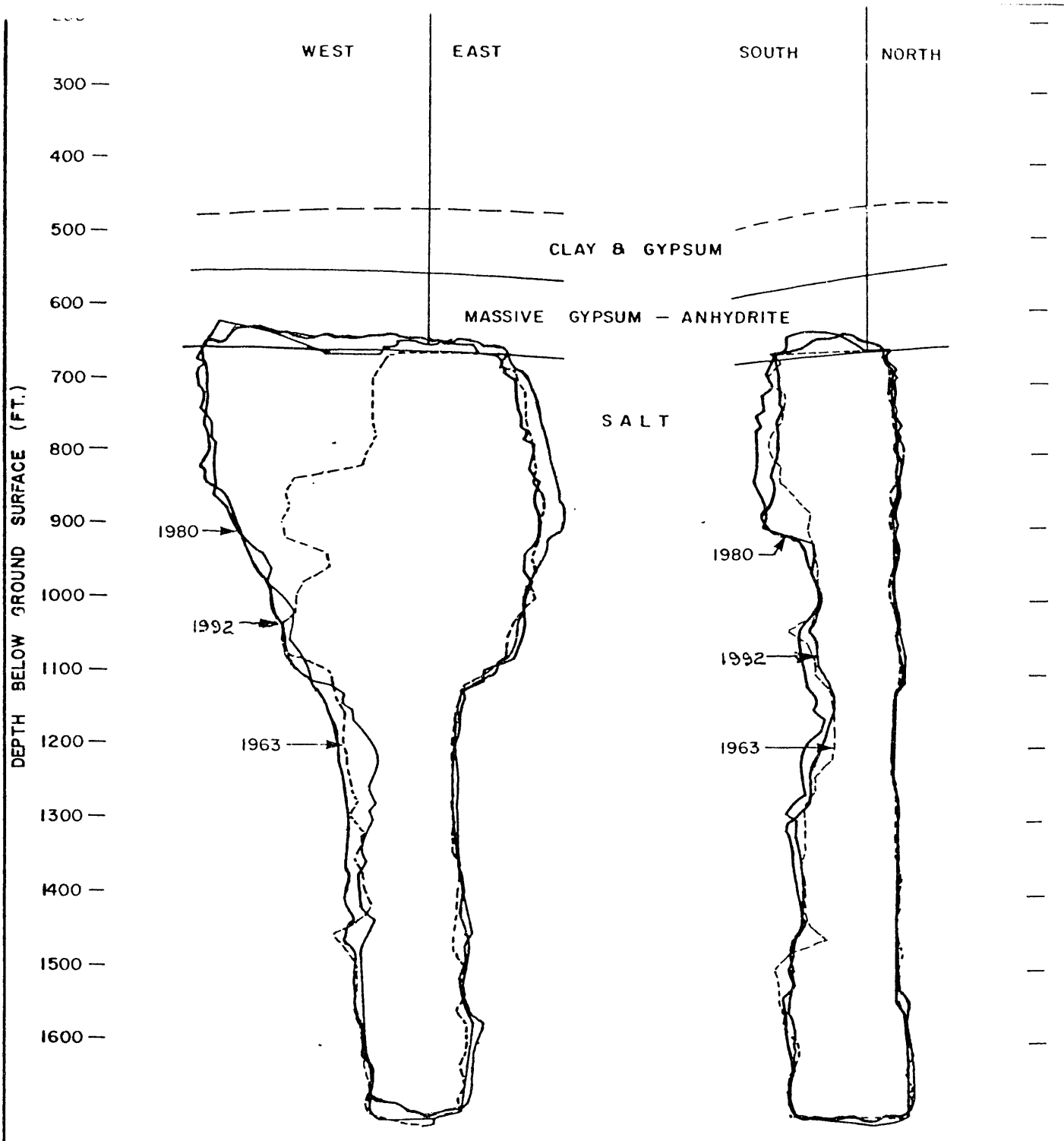
FIGURE 4



BAYOU CHOCTAW SPR SITE
POSSIBLE ZONE OF INFLUENCE
OF CAVERN 4 FAILURE

ACRES AMERICAN INCORPORATED
T.R. MAGORIAN
SEPTEMBER 1980

FIGURE 5



NOTE : DATES REFER TO SONAR SURVEYS
DATE DRILLED : 1935
ELEVATION (MEAN GULF LEVEL) : + 7.4 FEET
TOP OF CAPROCK : 551 FEET
TOP OF SALT : 662 FEET
ORIGINAL TOTAL DEPTH : 1990 FEET
PRESENT CAVERN TOP (1980) : 620 FEET
PRESENT CAVERN BASE (1980) : 1710 FEET
PRESENT CAVERN VOLUME (1980) : 5.94 MM BARRELS

REFERENCE : PB-KBB, 1978b, 1978i, & DOWELL, 1980b

100 0 100 200 400
SCALE IN FEET

BAYOU CHOCTAW SPR SITE
PROFILES OF CAVERN 4

ACRES AMERICAN INCORPORATED
T.R. MAGORIAN

FIGURE 6

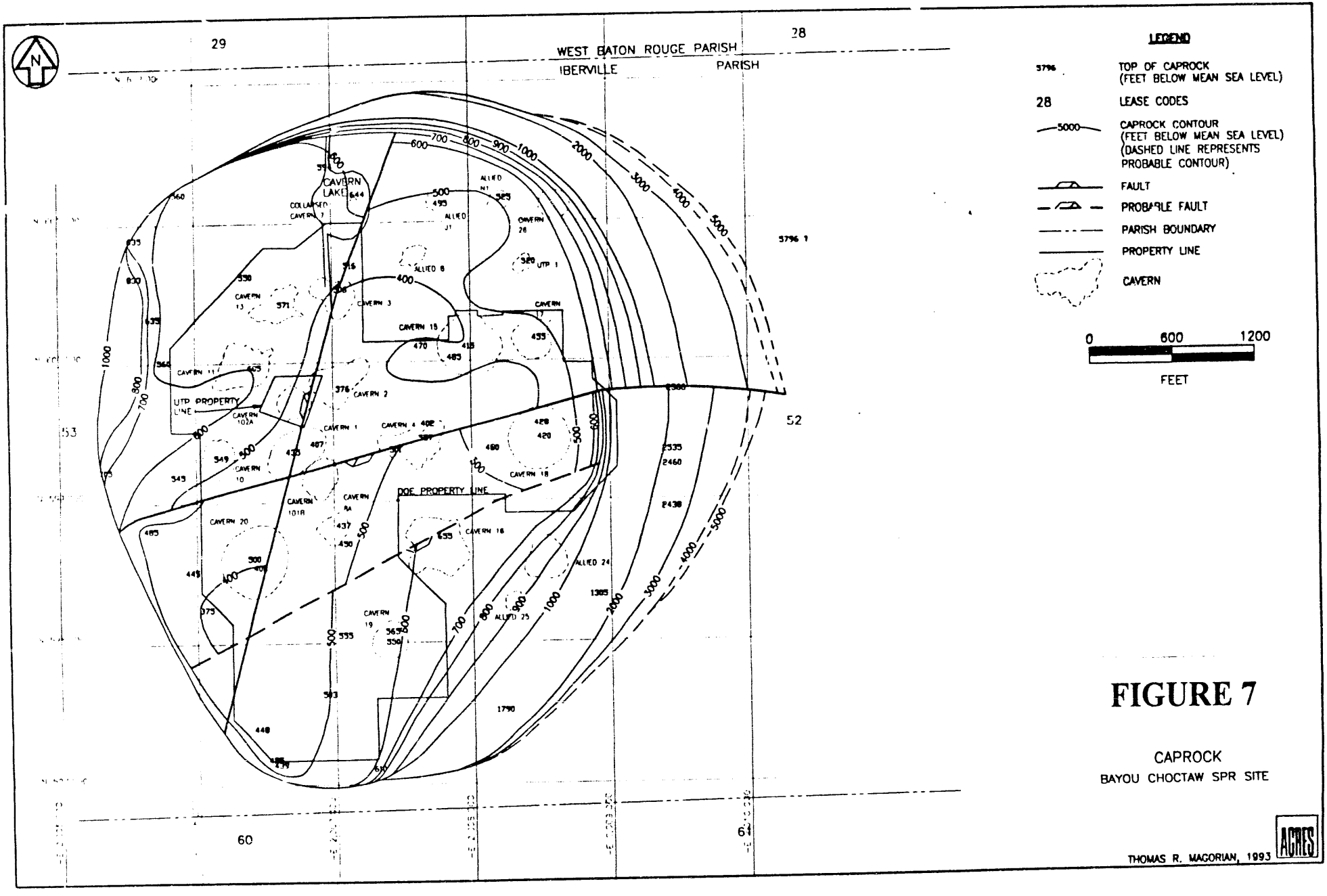


FIGURE 7

CAPROCK

BAYOU CHOCTAW SPR SITE

THOMAS R. MAGORIAN, 1993

ACRES

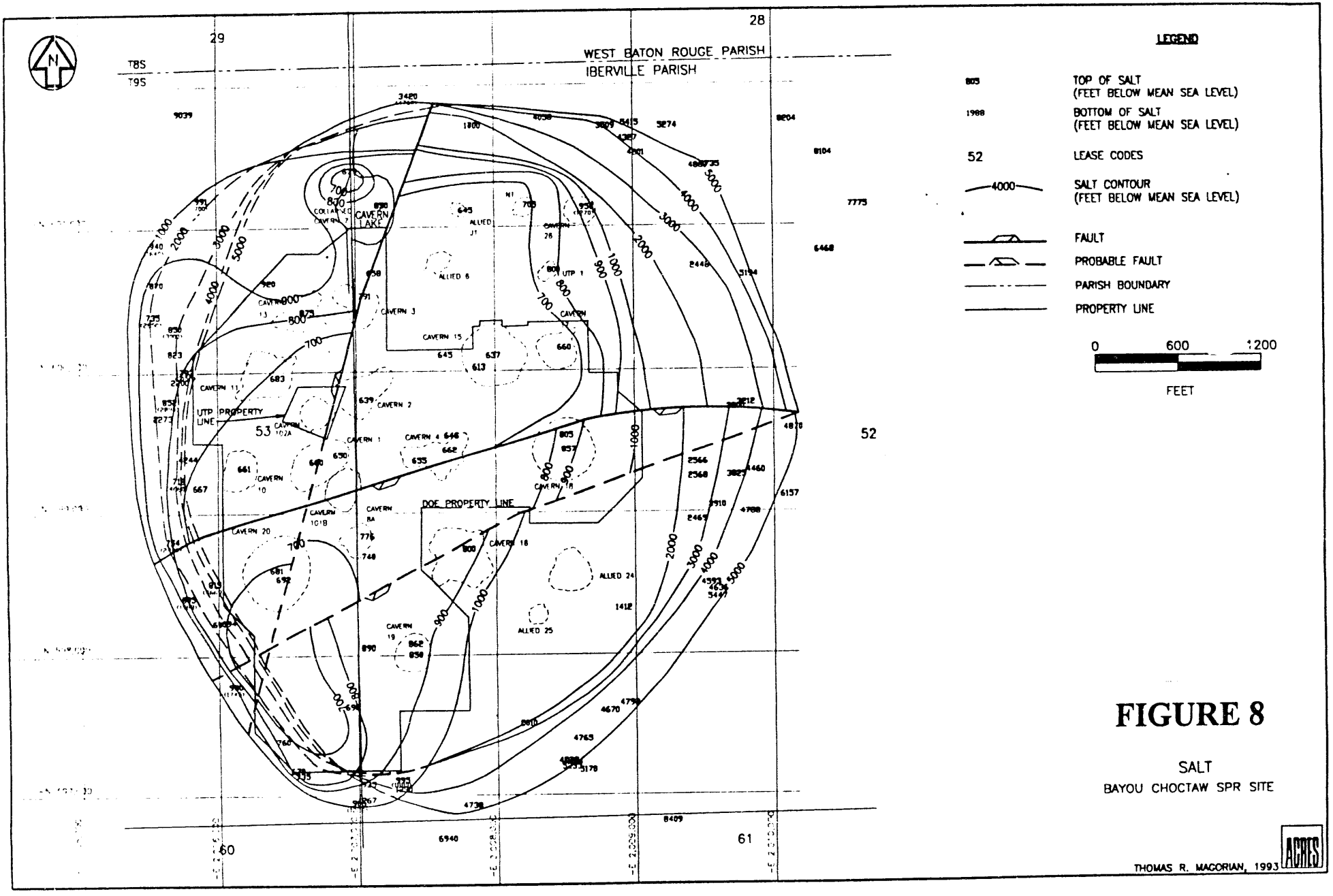


FIGURE 8

SALT

BAYOU CHOCTAW SPR SITE

THOMAS R. MACORIAN, 1993

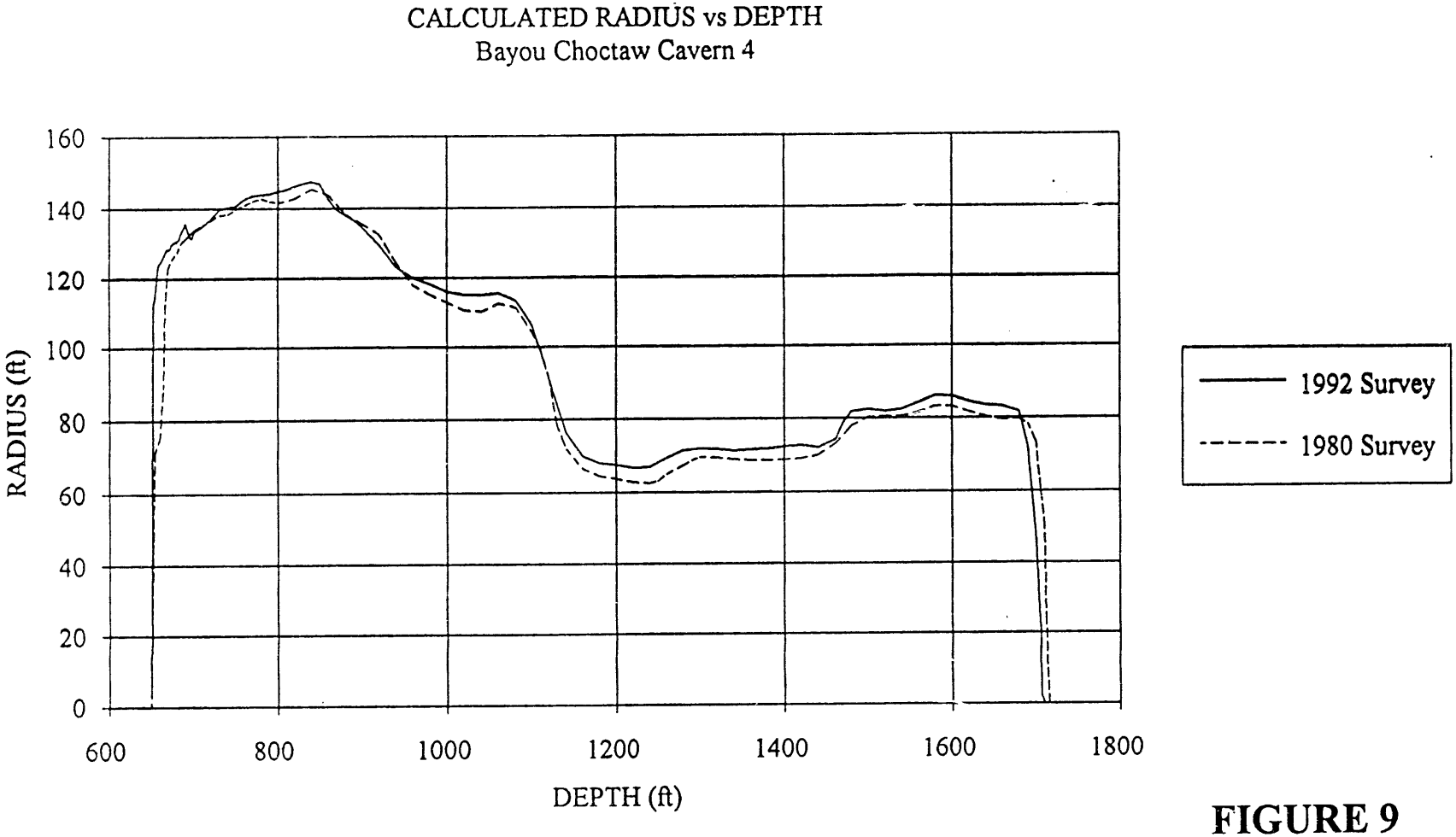
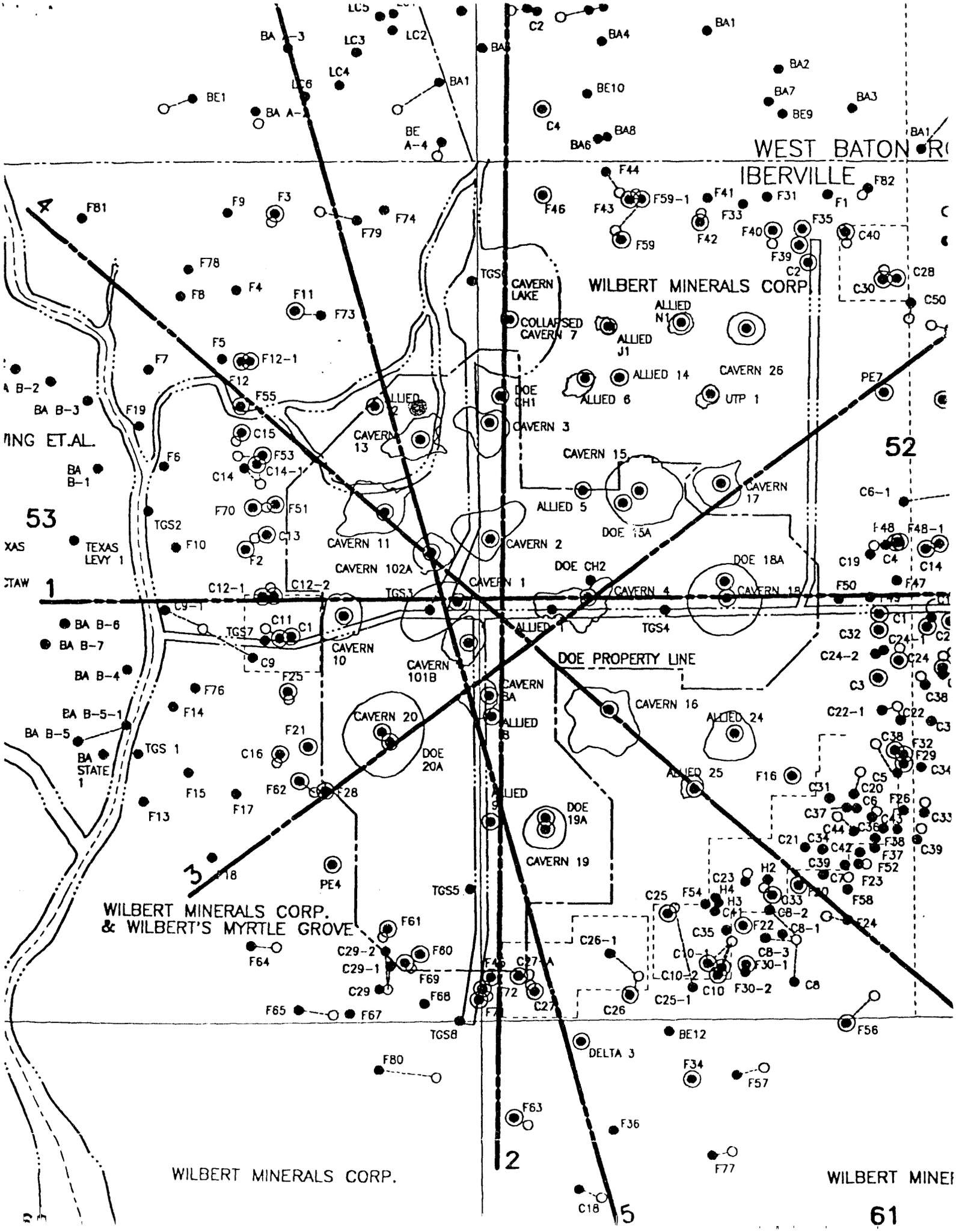

CALCULATED RADIUS vs DEPTH
Bayou Choctaw Cavern 4
RADIUS (ft)
160
140
120
100
80
60
40
20
0
600
800
1000
1200
1400
1600
1800
DEPTH (ft)
1992 Survey
1980 Survey

FIGURE 9


WEST BATON R
IBERVILLE
WILBERT MINERALS CORP.
CAVERN LAKE
COLLAPSED CAVERN 7
ALLIED N1
ALLIED J1
ALLIED 14
CAVERN 26
ALLIED 6
UTP 1
DOE CH1
CAVERN 3
CAVERN 15
CAVERN 17
ALLIED 5
DOE 15A
CAVERN 13
CAVERN 11
CAVERN 2
CAVERN 102A
DOE CH2
DOE 18A
CAVERN 1
CAVERN 4
CAVERN 18
TGS4
ALLIED 1
DOE PROPERTY LINE
CAVERN 10
CAVERN 101B
CAVERN 8A
CAVERN 16
ALLIED 24
CAVERN 20
DOE 20A
ALLIED 8
ALLIED 25
ALLIED 9
DOE 19A
CAVERN 19
WILBERT MINERALS CORP.
& WILBERT'S MYRTLE GROVE
DELTA 3
WILBERT MINERALS CORP.
WILBERT MINE
TEXAS LEVY 1
BA STATE 1
TGS 1
TGS2
TGS3
TGS5
TGS7
TGS8
PE4
PE7
BE12
52
53
61
1
2
3
5

DATE
FILMED
12/7/93
END