HAWTHORN PARK LANDFILL
APPENDIX III-4G
MCBRIDE-RATCLIFF ASSOCIATES, INC. – GEOLOGIC FAULT ASSESSMENT

APPENDIX D

GEOLOGIC FAULT ASSESSMENT
HAWTHORN PARK RECLAMATION PROJECT
AND RECYCLING CENTER
HARRIS COUNTY, TEXAS

Prepared For

SANIFILL OF TEXAS, INC.
HOUSTON, TEXAS

Prepared By

McBRIDE-RATCLIFF AND ASSOCIATES, INC.
HOUSTON, TEXAS

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330.65 (b)(5)(J) GEOLOGIC FAULT ASSESSMENT

Introduction

The requirements of the Texas Water Commission (TWC) Municipal Solid Waste Management Regulations (MSWMR) section 330.65 (b)(5)(J) **Active Geologic Faults** states, "a site located in areas subject to differential subsidence or active geological faulting must include detailed fault studies" in the permit application. The Hawthorn Park Reclamation Project and Recycling Center (HPRPRC) is located in Harris County, Texas. Parts of Harris County are effected by active geologic faults and subsidence. Presented in the following sections is our fault evaluation for the HPRPRC site.

Various investigative techniques have been outlined in the above referenced regulations. These techniques consist of the following:

- (i) Structural damage to constructed facilities (roadways, railways, and buildings).
- (ii) Scarps in natural ground.
- (iii) Presence of surface depressions (sag ponds and ponded water).
- (iv) Lineations noted on aerial maps and topographic sheets.
- (v) Structural control of natural streams.
- (vi) Vegetation changes.
- (vii) Crude oil and natural gas accumulations.
- (viii) Electrical spontaneous potential and resistivity logs (correlation of subsurface strata to check or stratigraphic offsets).
- (ix) Earth electrical resistivity surveys (indications of anomalies which may represent fault planes).
- (x) Open trench excavations (visual examinations to detect changes in subsoil texture and/or weathering indicating stratigraphic offsets).
- (xi) Changes in elevations of established benchmarks.
- (xii) References to published geological literature pertaining to area conditions.

Our fault evaluation is presented in two phases. Phase one presents our report of surface fault evidence, addresses clauses (i), (ii), (iii), (iv), (v), (vi), (vii), (x), (xi), and (xii) of MSWMR 330.65 (b)(5)(J). Phase Two of our report presents our subsurface evaluation for the presence of possible on-site faults, and addresses clauses (viii) and (ix) of MSWMR 330.65(b)(5)(J). Each clause is noted in our report.

The results of our study are that the HPRPRC site is not traversed by an active fault. The zones of influence of active faults in the vicinity have been identified and these zones of influence will not impact the containment design of the landfill. Our study also shows the HPRPRC site is not effected by localized differential subsidence.

Phase One - Surface Fault Evaluation

Presented in this section are the results of our Phase One Surface Fault Evaluation. The purpose of this section is to identify surface evidence which may indicate the presence of a fault being located on-site or near a site.

Scope of Work. Our Phase 1 assessment of the potential for surface faulting at the HPRPRC site included the following tasks:

- Review of geologic literature and our file data pertaining to surface fault documentation within the general vicinity of the site
- Analysis of topographic maps for geomorphic features which may represent surface fault activity
- Remote-sensing analysis utilizing black and white and false-colored infrared aerial photography to check for photo linears which may be related to surface faults
- Site and general area reconnaissance to check for physical evidence of distress resulting from surface fault activity.

These tasks were conducted in general accordance with the March 1985 Houston Geological Society Bulletin ***Recommended Standards of Practice for Investigating Geologic Faults in the Texas Gulf Coast Region.***

Fault Characteristics. The entire gulf coast of Texas is underlain by a thick wedge of sediments. Exploration, principally by the petroleum industry, has identified these sediments to be extensively disrupted by "growth" faults and faults associated with shallow piercement and deep-seated salt domes.

The Texas Gulf Coastal Plain is traversed by numerous growth faults. Growth faults are essentially slip surfaces formed by "landslides" that occurred at the same time of sediment deposition. The subsurface displacement of strata increases with depth. Faults associated with salt domes are similar to growth faults in that the faulting takes place in the sediments, but the mode of deformation is generated by mobile salt migration.

The inclination of the fault planes is a few degrees from vertical. The width of the fault zones has not been researched extensively. Our observations of distress in structures over active faults in other parts of Houston suggest that the vertical displacement may occur on more than one plane, and in a zone several feet wide. Secondary motions consisting of buckling or folding of beds adjacent to the fault are noted paralleling the fault trace.

Fault Activity. Evidence of continuing activity of faults is demonstrated by minor topographic scarps and aligned ponded water on virgin land, and disruption of pavements, structures, land subsidence, etc., in developed areas. The relationship of mapped subsurface faults and ground-surface displacement related to faults has been demonstrated by various researchers.

Most investigators relate current rates of ground surface displacement in the Houston-Galveston area by faulting to the removal of groundwater, and to a lesser extent, oil and gas in the relatively shallow subsurface. Extensive groundwater development began in the late thirties and has increased to the present. These investigators believe the near-surface movement of faults in the area is due to differential consolidation of sediments bounding the faults. Sediments are depressured by heavy pumping, thus inducing consolidation. It is postulated that this differential consolidation is manifested in movement along the pre-existing fault planes, which is then propagated to the surface.

The HPRPRC site fault evaluation was conducted using four lines of evidence: geologic literature and MRA file data, topographic maps, aerial photographs, and site reconnaissance. Each line of evidence was assessed individually then in conjunction with observations from other evidence.

Geologic Literature and File Search. The work presented in this sections covers MSWMR 330.65(b)(5)(J) clauses **(xii) References to published geological literature pertaining to area conditions, (vii) Crude oil and natural gas accumulations,** and **(xi) Changes in elevations of established benchmarks.**

Past area studies performed by our geologic staff have indicated that the site is located in an area traversed by a regional fault system designated as the Addicks Fault System. Based on area experience, the Addicks fault system is composed of five en-echlon segments (parallel sections of off-set fault lines). Each segment is characterized as a down the coast oriented fault. The faults are situated on a trend of about southwest to northeast traversing about 28 miles of west and north Harris County, Texas. Associated with the down the coast faults are two antithetic faults (faults formed due to stresses related to the movement of the down the coast faults). The antithetic faults are up the coast oriented faults. The Addicks Fault System includes the down the coast Addicks, Brittmoore, Breen, Woodgate, and Hardy faults. The up the coast antithetic faults include the White Oak and the West faults. The HPRPRC site is situated southeast of the Brittmoore Fault and southwest of the White Oak Fault.

In a report published by Turner Collie and Braden, Inc. of Houston in 1966, Dewitt C. Van Siclen presented a map which represented his interpretation of the surface location of faults in the general vicinity of the study area. Figure D-1 illustrates the Van Siclen fault map. Van Siclen has interpreted the surface location of 2 faults in the area of the HPRPRC site. Fault 1 represents Van Siclen's interpretation of the surface location of the Brittmoore Fault. Fault 2 is Van Siclen's representation of the surface location of an interpreted "possible" fault (projection of the White Oak Fault). As illustrated on Figure D-1 Fault 2 traverses the middle of the HPRPRC site.

As a partial fulfillment of the Master Degree in geology at the University of Houston, Wolfgang C. Heuer presented his 1979 thesis entitled ***Active Faults In The Northwestern Houston Area***. The HPRPRC site is situated in Heuer's mapping area. Figure D-2 illustrates the interpreted location of faults and "possible" fault related features interpreted by Heuer in the area of the HPRPRC site. As shown on Figure D-2, the fault features designated as 10, 10A, and 10B are located in the HPRPRC site.

A 1980 report by Dewitt Van Siclen to Trammell Crow Company entitled ***Geologic Fault Investigation West by Northwest Business Park Fairbanks Area Harris County, Texas***, presents a surface and subsurface fault evaluation for a site located northwest of the HPRPRC site. This study site is situated on line with the projection of the White Oak Fault and the HPRPRC site. Figure D-3 illustrates the location of the Van Siclen study site with respect to the HPRPRC site and the White Oak Fault. The conclusions of the report in part state:

> No faulting is present on the West by Northwest Business Park property within the 400-ft depth of investigation. The age of the strata at this depth is not known, but a reasonable estimate would be early Pleistocene, more than 1,000,000 years old.

The second phase of the geologic literature search concentrated on addressing MSWMR 330.65(b)(5)(J) clause **(vii) Crude oil and natural gas accumulations.**

Petroleum accumulations in the Gulf Coast of Texas have been identified as being controlled by deep subsurface faults, salt domes and salt-dome-formed anticlinal bedding, and radial faults associated with salt dome structures. Sources of evidence used to evaluate the area for crude oil and natural gas accumulations included the revised 1982 **Geologic Atlas of Texas, Houston Sheet**, the 1983 Bureau of Economic Geology ***Atlas of Major Texas Oil***

Reservoirs, and the 1991 Geomap Company Upper Texas Gulf Coast Map Number - UTGC 4, dated April 26, 1991.

As shown in the literature the HPRPRC disposal area site is located about 1 mile southwest of the southwest flank of the Fairbanks oil and gas field. Petroleum accumulations for the Fairbanks field are reported as associated with faulted and anticlinal structure associated with the formation of a deep seated salt dome and regional faulting.

Based on our knowledge of the location of the Brittmoore Fault, it is our interpretation that this fault traverses much of the Fairbanks oil and gas field.

Well sites located in the HPRPRC site area are reported on the Geomap Company map as being dry holes. Petroleum accumulations thought to exist at the well sites have either been depleted by production or are non-existing in the area explored by the wells.

The third phase of our geologic literature search address MSWMR 330.65(b)(5)(J) clause **(xi) Changes in elevations of established benchmarks.**

A review of benchmark levelling data for a total of 15 benchmarks, located as shown on Figure D-5, was performed for this task. These benchmarks represent the National Geodetic Survey (NGS) benchmarks in a 3 mile radius of the site. The data was provided by the Harris-Galveston Coastal Subsidence District. The table below presents a summary of the data reviewed.

SUMMARY OF BENCHMARK DATA

Benchmark No.	1973 Elev. Ft, MSL	1978 Elev. Ft, MSL	Difference (1978-1973) Ft	1987 Elev. Ft, MSL	Difference (1987-1978) Ft
1		92.176		90.253	-1.923
2	96.013	95.322	-0.691	93.515	-1.807
3	101.226	100.459	-0.767	98.551	-1.908
4				96.524	
5	107.276	106.572	-0.704	104.421	-2.151
6		108.552		106.513	-2.039
7		110.303		108.318	-1.985

SUMMARY OF BENCHMARK DATA					
Benchmark No.	1973 Elev. Ft, MSL	1978 Elev. Ft, MSL	Difference (1978-1973) Ft	1987 Elev. Ft, MSL	Difference (1987-1978) Ft
8	90.685	89.768	-0.917	87.757	-2.011
9				89.926	
10	94.090	93.375	-0.715	91.694	-1.681
11	94.907	94.218	-0.689	92.489	-1.729
12	93.209	92.969	-0.240	90.945	-2.024
13				114.553	
14	111.797	111.200	-0.597	109.245	-1.955
15	115.757	115.290	-0.467	113.063	-2.227

The above data shows, for the time period between 1973 and 1978 that an average subsidence rate of 0.129 ft/yr was exhibited for the area encompassed by the benchmarks. Between the time period 1978 and 1987, the average subsidence rate is 0.217 ft/yr or an increase of 0.088 ft/yr (about 1 inch).

The observed subsidence appears on a regional scale and not exhibiting large variations in measurements between benchmarks. It is our opinion that the area encompassed by the benchmarks is exhibiting subsidence that is regional to the site vicinity.

Topographic Map Analysis. The topographic map analysis allows for the identification of surface features which may have been manifested by a fault. These features include scarps, aligned natural drainage features, and/or aligned ponded waters. This section addresses the following MSWMR 325.74 (b)(5)(J) clauses:

1. **(ii) Scarps in natural ground**
2. **(iii) Presence of surface depressions**
3. **(iv) Lineations noted on aerial maps and topographic sheets**
4. **(v) Structural control of natural streams**

Historic topographic maps of Harris County, Texas were completed in the early 1900's using a 1-ft contour interval. These maps are very useful in identifying topographic features which may be manifested by faults in the relatively flat Harris County area of which the HPRPRC disposal area is located.

The site is located on the 1918 Hillendahl, Texas topographic map (Figure D-4). No evidence of on-site topographic scarps related to active faulting was identified. The surface topography as shown on the 1918 Hillendahl topographic map is marked by an extensive area of "pocky" topography. This type of topography is indicative of distributary channel fill depositional environments and wind blown surface features of the silty top soil covering most of the Lissie Formation identified throughout Harris County, Texas. This topographic feature is not interpreted as being manifested by a fault. No evidence of lineations or topographic scarps were observed during our review of the 1918 Hillendahl topographic map at the site. A drainage system located north of the site is shown on the topographic map as changing trend from southwest - northeast to northwest - southeast. It is our interpretation that this drainage system formed as a result of headward erosion and is controlled by a distributary channel fill depositional environments traversing the area.

Remote-Sensing Analysis. The use of aerial photographs is a useful tool in the recognition of surface evidence which may be manifested by a fault. The performance of our remote-sensing analysis addresses the following MSWMR 325.74(b)(5)(J) clauses:

1. **(iii) Presence of surface depressions**
2. **(iv) Lineations noted on aerial maps and topographic sheets**
3. **(v) Structural control of natural streams**
4. **(vi) Vegetation changes**

The aerial photographs which were used for the remote-sensing analysis included black and white photographs from the years 1953, 1957, 1964, and 1987. A 1981 NASA high altitude false colored infra-red photo imagery was also reviewed during our remote-sensing analysis.

Aligned surface depressions may form along the downthrown side of a fault. Also a lineation or "photo-linear" may be identified on photo imaginary in areas where a fault scarp has experienced the accumulation of water on the downthrown side of a fault. No on-site photo linears or aligned surface depressions were interpreted as being located in the HPRPRC site. A faint to distinct photo-linear was identified off-site in the area coincident to the surface location of the Brittmoore Fault.

As stated above in the topographic map analysis a drainage featured is situated north of the site. This feature changes trend near the surface location of the Brittmoore Fault.

No discrete vegetative changes which we interpret as being the product of on-site faults were identified during our remote-sensing analysis. Subtle color change noticed along the photo-linear of the Brittmoore Fault are interpreted as locating minor vegetative changes due to the change in moisture content from the upthrown side of the fault to the downthrown side.

Site and General Area Reconnaissance. A site and general area reconnaissance is performed for the purpose of identifying specific evidence that may be interpreted as being the product of an active fault. The reconnaissance was performed by driving through the area encompassing the site, walking and viewing subtle surface features, viewing area drainage features, excavations, and open fields for evidence of a fault. This section of our report addresses the following MSWMR 325.74(b)(5)(J) clauses:

1. **(i) Structural damage to constructed facilities**
2. **(ii) Scarps in natural ground**
3. **(vi) Vegetation changes**
4. **(x) Open trench excavations**

Site reconnaissance for the HPRPRC site has been performed on a number of occasions from 1986 with the most recent being January 16, 1992. Except where noted, the following discussion references the reconnaissance of January 16, 1992.

Our on-site reconnaissance did not reveal the presence of structural damage which we interpret as being manifested by an active fault to site specific roads or building structures. No topographic scarps or vegetation changes were identified in the site boundaries. Exposed side walls of excavation for the existing facility did not reveal the presence of a fault or stratigraphic displacement of bedding planes.

Areas of off-site concern which were reviewed during our reconnaissance included the location of the Brittmoore Fault and the White Oak Fault. Figure D-6 illustrates the relationship of the location of the Brittmoore Fault and the White Oak Fault to the HPRPRC site. The surface location of these faults were mapped on January 16, 1992. As shown, the HPRPRC site is not traversed by either fault. Surface evidence of the White Oak faults terminates northwest of the site about 2 miles. Surface evidence of the White Oak Fault was noted on a northeast trend away from the HPRPRC site. A well defined scarp identifies the surface location of the Brittmoore Fault throughout the vicinity. Structural distress in roads and building structures situated above both faults indicate that these faults are active.

During our site reconnaissance, observations were made relative to the horizontal distress visible in areas where the Brittmoore Fault crossed beneath rigid structures. The zone of influence for the fault is defined as an area parallel to the fault line which exhibits distress related to the movement of the fault. Our measurements were obtained on a line perpendicular to the fault line for both the upthrown and downthrown sides of the fault. The measurements were obtained along Empire Central Drive, Dac Road, Brittmoore Road at Holly Hill, McGinty Road, and Cunningham Road. The areas where measurements were obtained are located near the site, are crossed by the fault, and demonstrate structural distress. A summary of the measurements are presented in the following table.

SUMMARY OF ZONE OF INFLUENCE OBSERVATIONS
BRITTMOORE FAULT

Location of Measurement	Observations, FT		Total Zone of Influence
	Upthrown Side	Downthrown Side	
Empire Central Drive	30	100	130
Dac Road	25	100	125
Brittmoore @ Holly Hill	30	120	150
McGinty Road	20	85	105
Cunningham Road	35	100	135

Based on the data presented and our experience with fault movements in the Houston area it is our interpretation that a representative zone of influence for the Brittmoore Fault could be as much as 200 ft on the downthrown side and 75 ft on the upthrown side or a total of 275 ft. The project site is located outside of this zone.

Phase Two Fault Evaluation

Our Phase Two study addresses MSWMR 325.74(b)(5)(J) regulation, "when an active fault is known to exist within one-half mile, the site shall be investigated for unknown faults". This portion of our report addresses the following clauses:

1. **(viii) Electrical spontaneous potential and resistivity logs (correlation of subsurface strata to check for stratigraphic offsets)**, and

2. **(ix) Earth electrical resistivity surveys.**

<u>Subsurface Investigation</u>

The use of earth resistivity surveys is a useful tool for evaluating the subsurface for faults given that the conditions are conducive for use of this method. Surface resistivity curves are dominantly measuring the electrolytic properties of subsoil fluids. This method was not used for this investigation due to the fact that dewatering of the subsurface strata has been employed at the site. Dewatering was required for the past sand mining operations of the site and adjacent areas. Thus, our subsurface investigation used geophysical logging techniques employing spontaneous potential, single point resistance, and natural gamma ray curves for subsurface strata identification in deep test holes.

Thirty-two test holes located as shown on Figure D-7, were drilled, geophysically logged, and grouted for the subsurface evaluation of the HPRPRC site. A testhole depth of 300 ft below the ground surface was selected to penetrate stratigraphic units which could be readily correlated over the site. Geophysical logs were obtained immediately upon completion of the drilling. Three geophysical curves were obtained from each log, natural gamma ray, spontaneous potential, and single-point resistance. The three curves are interpreted to identify distinct stratigraphic units, referred on the cross-sections as Marker Beds. The logs are placed in a cross-sectional form and are analyzed to identify subsurface anomalies which are characteristic of faults.

The subsurface test holes were drilled on different time periods. All test holes were drilled by personnel of Buford Drilling Company, Inc. of Houston, Texas. The geophysical logs for B-1 through B-19 were obtained by Mr. Chuck Daniels, deceased, of CEDCo Logging Company. The geophysical logs for B-20 through B-32 were obtained by personnel of MRA using a CoLog Inc. geophysical logging unit.

<u>Analysis of Subsurface Data</u>

The subsurface stratigraphy is represented by geophysical log cross-sections as shown on Figures D-8 through Figure D-15. The stratigraphic markers represent our interpretation of some of the common markers located throughout the subsurface. The following table summarizes our interpretation of Marker locations.

SUMMARY OF MARKER BED DEPTHS AND ELEVATIONS

Test Hole Number	Surface Elevation	Marker A		Marker B		Marker C	
		Depth (ft)	Elev. (ft) msl	Depth (ft)	Elev (ft) msl	Depth (ft)	Elev (ft) msl
B-1	106	264	-158	160	-54	52	+54
B-2	105	264	-159	164	-59	52	+53
B-3	104	262	-158	164	-60	55	+49
B-4	103	262	-159	164	-61	58	+45
B-5	103	261	-158	166	-63	54	+48
B-6	103	261	-158	168	-65	58	+45
B-7	104	262	-158	162	-58	56	+48
B-8	103	262	-159	160	-57	52	+51
B-9	103	262	-159	160	-57	56	+47
B-10	106	264	-158	160	-54	54	+52
B-11	104	260	-156	166	-62	56	+48
B-12	103	261	-158	164	-61	56	+47
B-13	103	262	-159	162	-59	56	+47
B-14	106	264	-158	164	-58	60	+46
B-15	103	261	-158	162	-59	56	+47
B-16	105	262	-157	166	-61	54	+51
B-17	105	261	-156	166	-61	58	+47
B-18	103	263	-160	160	-57	52	+51
B-19	105	260	-155	162	-57	52	+53
B-20	103	260	-157	162	-59	58	+45
B-21	103	263	-160	162	-59	58	+45
B-22	102	262	-160	164	-62	60	+42
B-23	100	258	-158	164	-64	60	+40
B-24	100	258	-158	166	-66	56	+44
B-25	100	258	-158	166	-66	58	+42
B-26	99	259	-160	164	-65	54	+45
B-27	100	258	-158	158	-58	56	+44
B-28	101	256	-155	162	-61	54	+47
B-29	101	258	-157	161	-60	60	+41
B-30	101	258	-157	164	-63	58	+43
B-31	102	258	-156	164	-62	56	+46
B-32	104	260	-156	166	-62	58	+46

Marker A was identified between elevations -155 ft, MSL to about -160 ft, MSL. This marker is interpreted to represent a boundary between a channel fill sand layer and an overlying clay layer. As illustrated on the geophysical log cross-sections, Figure D-7 through Figure D-14, no offset of Marker A has been identified which we would interpret as the manifestation of a fault.

Marker B was identified at about elevation -54 ft at B-1 to -66 ft at B-24 and B-25. This marker represents the boundary between the base of channel fill sand layers and overlying clay layers. Based on our log cross-section review (Figure D-7 through D-14), it is our interpretation that no stratigraphic offset which we interpret as the manifestation of a fault has been identified.

Marker C as exhibited on the geophysical log cross-sections, Figures D-7 through Figure D-14, represents the boundary between distributary channel fill sand layers and underlying clay layers. This marker was identified at about elevation +41 ft at B-29 to about +54 ft at B-1. Based on our review of the geophysical log cross-sections, it is our interpretation that no stratigraphic offsets indicative of faulting have been identified.

Our interpretation of the geophysical data did not reveal evidence indicative of geologic faulting.

Conclusions

Several lines of evidence have been analyzed to identify features which represent the manifestation of surface faulting with respect of the proposed HPRPRC disposal area site located in Harris County, Texas. Our study was conducted in general accordance with **MSWMR 325.74(b)(5)(J). Active Geologic Faults**. Our conclusions follow:

1. Based on our review of all evidence identified we do not interpret the site as being traversed or along the projected trend of an active surface fault.

2. A review of geologic literature showed that the site is located about 1850 ft southeast of the Brittmoore Fault.

3. Several documented features termed "possible faults" were mapped by Dewitt VanSiclen and Wolfgang Heuer as being located in the site boundaries.

4. An analysis of topographic maps and aerial photographs did not identify features we interpret as the manifestation of surface faulting within the boundaries of the site.

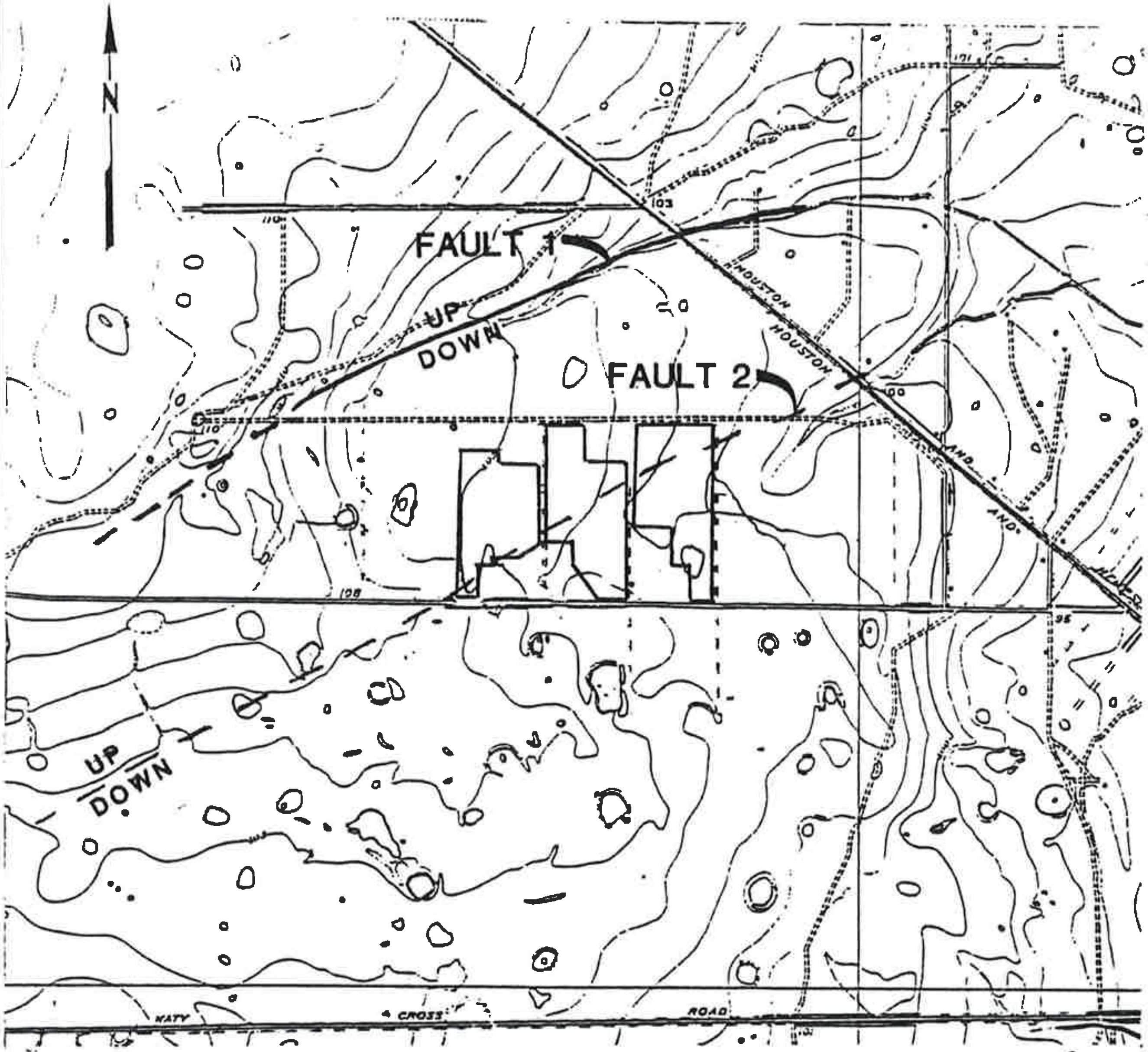
5. The site area is experiencing regional subsidence. Our review of benchmark data through 1987 show the subsidence between 1978 and 1987 to be between (-1.681 ft) and (-2.227 ft).

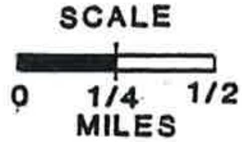
6. A site reconnaissance of the area adjacent to the site did identify structural damage to roadways and building structures situated above the Brittmoore Fault. The trend of the Brittmoore Fault was mapped and does not traverse or project to the HPRPRC site.

7. The White Oak Fault is active along a southwest to northeast tread about 2 miles northeast of the HPRPRC site. Evidence produced by Dewitt Van Siclen (for a site situated between the HPRPRC site and the last known point of surface evidence of the White Oak Fault) indicates that the fault either terminates northeast of the site or dips beneath the surface at a depth greater than 400 ft beneath the groundsurface.

8. The zone of influence for the Brittmoore Fault as measured at two locations traversed by the fault shows a zone of influence of about 100 ft. The greatest observed distress was on the downthrown side of the fault. The HPRPRC site is located outside of the interpreted zone of influence for fault movement associated with the Brittmoore Fault.

9. A subsurface geophysical logging project was performed to evaluate the potential of the HPRPRC site as being traversed by a fault. Our interpretation of the geophysical log cross-sections developed for the site did not reveal the presence of a fault.

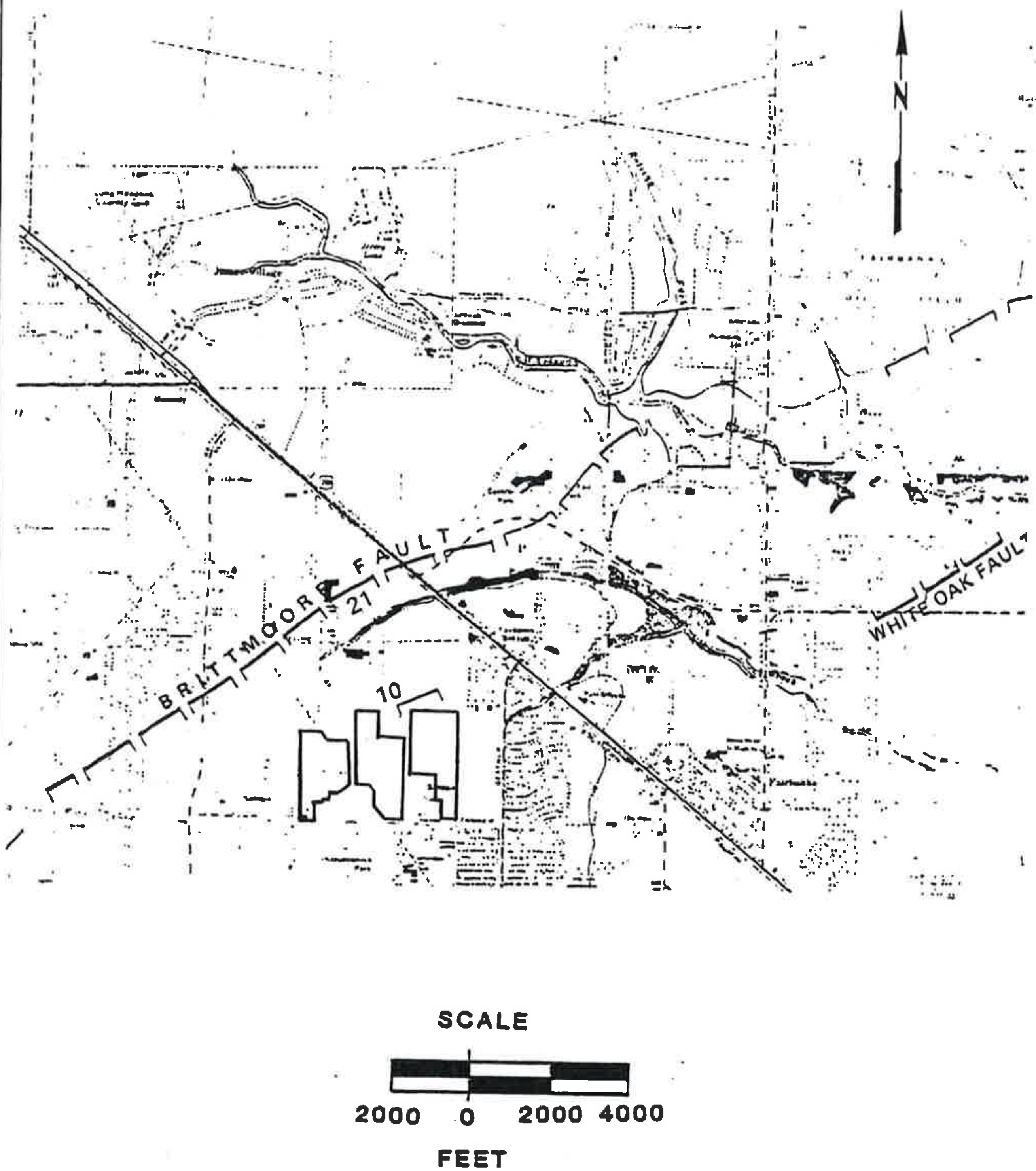




LOCATION OF FAULTS OF VAN SICLAN, 1966
COPIED ON U.S.G.S. TOPOGRAPHIC BASE

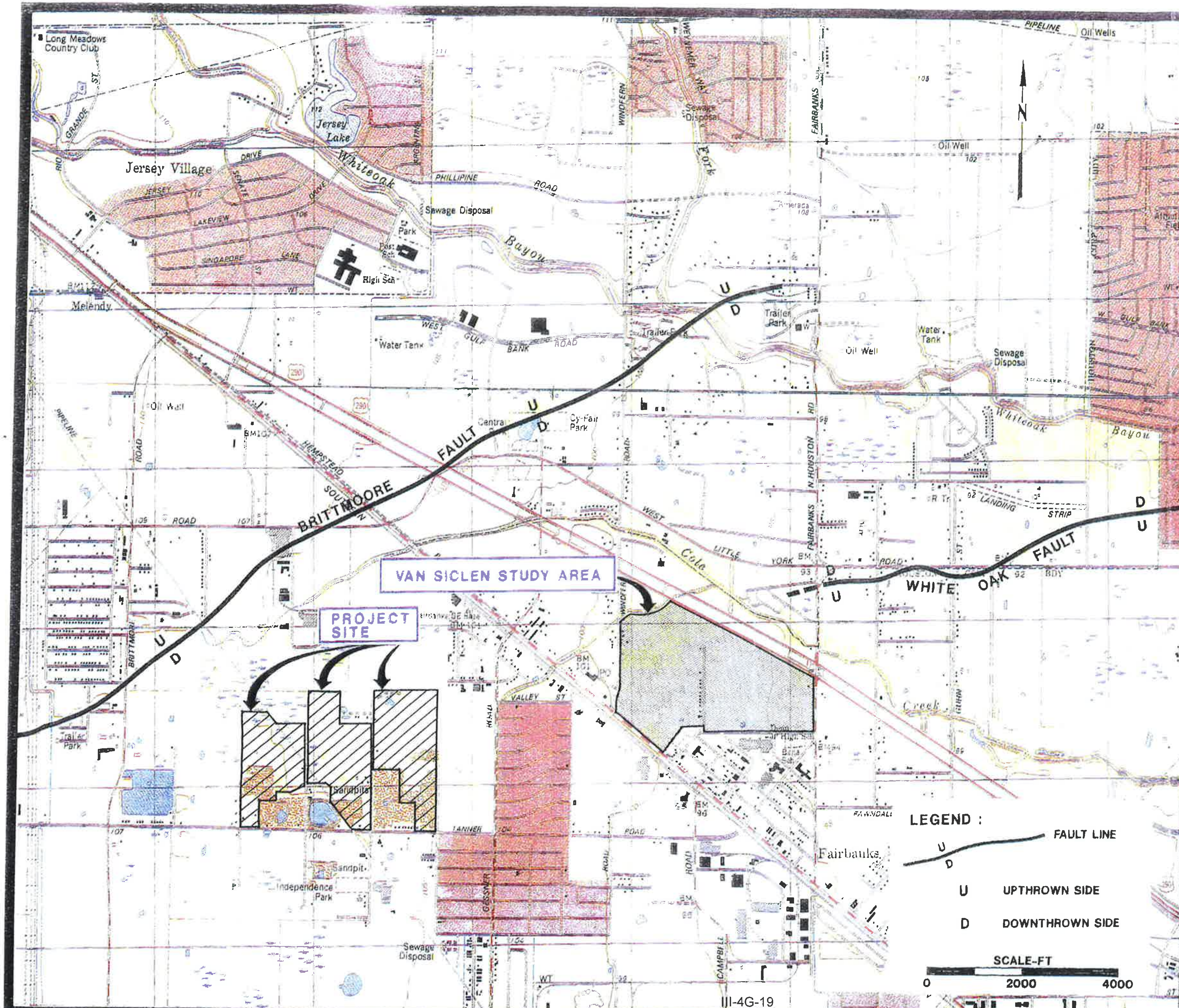
FROM TURNER, COLLIE, AND BRADEN, 1966.

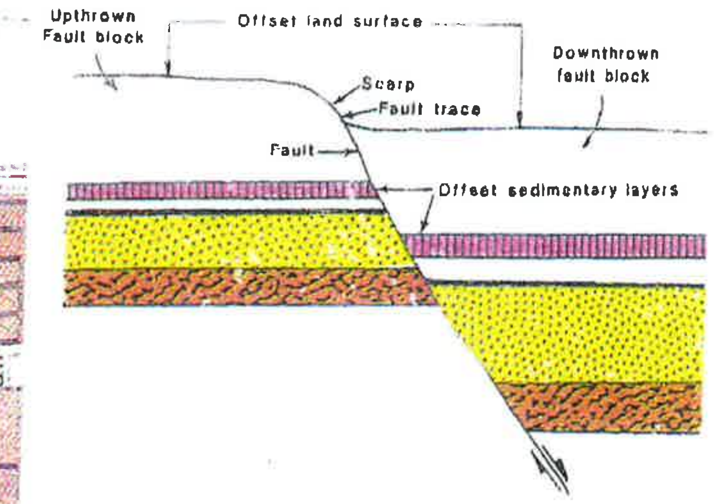
PROJECT NO.90-0638
FIGURE D-1
McBride-Ratcliff and Associates, Inc.



HEUER FAULT LOCATION MAP 1979

PROJECT NO. 90-0638
FIGURE D-2





Vertical section through a hypothetical fault in the Houston area. Land surface was originally level, but has since been displaced by movement along the fault. Note thickening of sedimentary layers on the downthrown side. This indicates that faulting occurred repeatedly over a long period of time, while the sediments were being deposited. Such faults are common in the Texas Gulf Coast.

According to E.R. Verbeek, K.W. Ratzlaff and U.S. Clanton, rigid structures such as highways, runways, and building foundations, where built astride active faults, commonly display the consequences of differential vertical movement and horizontal extension. Breakage occurs as the sinking ground surface on the downthrown side no longer supports the structural load. Maximum damage normally occurs on and immediately adjacent to the fault scarp, within a zone that is typically 2-3 m wide, but which may vary in width from less than 1 m to more than 10 m. To either side of this zone, some limited fault-related failure may be seen in brittle material, but the most visible effect of fault movement here is tilting. The amount of tilt progressively decreases away from the fault scarp and is, for most faults, minor at distances of 20-30 m from the scarp. Surveying data, however, suggest that detectable amounts of tilt may be found as much as 70 m away from some faults.

Based on our observation of structural distress along the Brittmoore Fault northwest of the proposed site, the zone of surface deformation of this fault conforms to the description by Verbeek, Ratzlaff, and Clanton. It is confined to an area less than 200 ft on the downthrown block of the fault.

TEXT FROM "FAULTS IN PARTS OF NORTH-CENTRAL AND WESTERN HOUSTON METROPOLITAN AREA, TEXAS" BY E.R. VERBEEK, K.W. RATZLAFF ADN U.S. CLANTON, 1979.

TOPOGRAPHIC MAP FROM U.S. GEOLOGICAL SURVEY, HEDWIG VILLAGE, TEXAS, 1982.

HAWTHORN PARK RECLAMATION PROJECT AND RECYCLING CENTER
HARRIS COUNTY, TEXAS

SANIFILL OF TEXAS, INC.
HOUSTON, TEXAS

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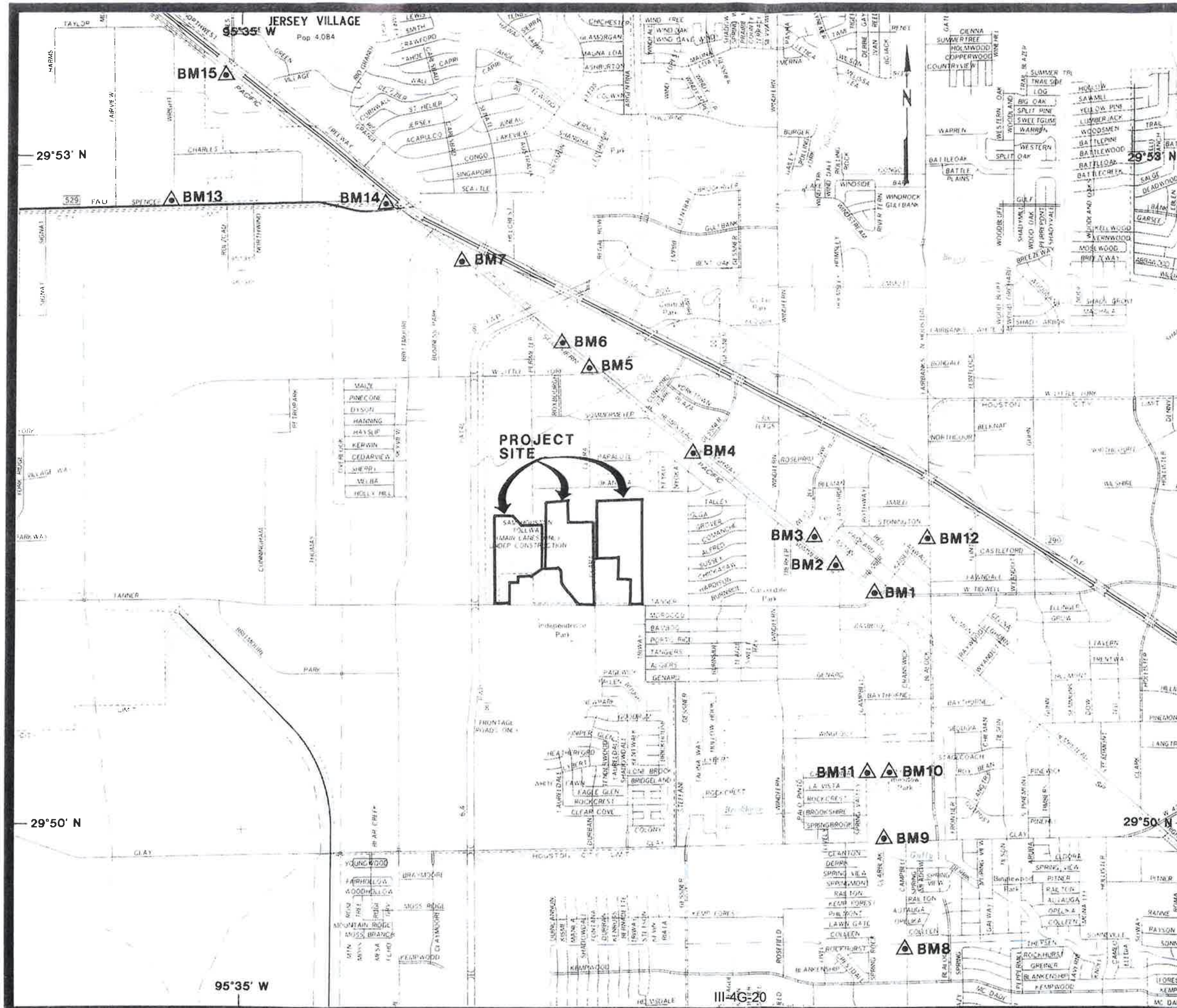
NOTED	LLD/SMH / LAL	10-11-93 / 10-11-93	90-0638

1980 VAN SICLEN STUDY — FIGURE D-3



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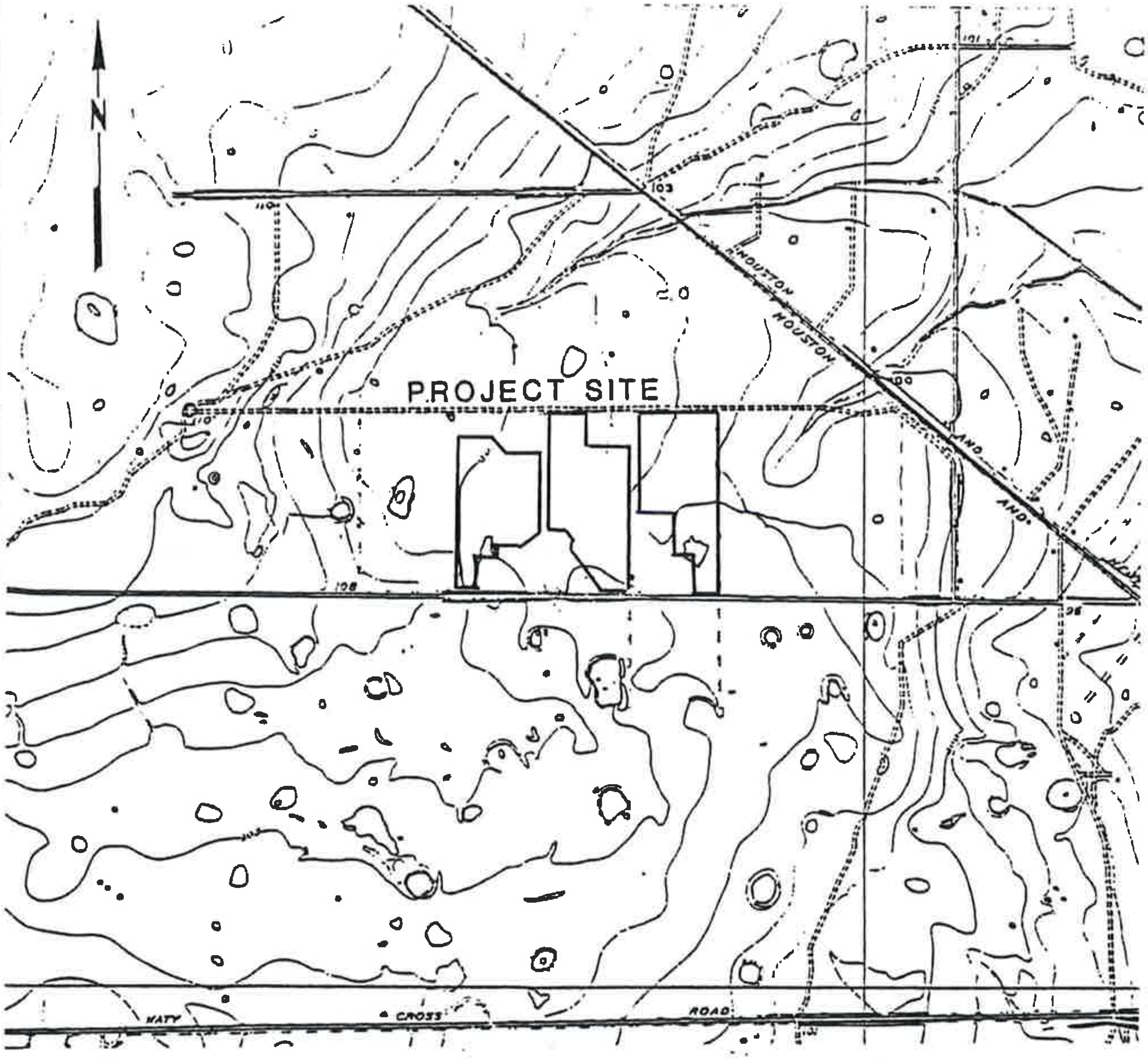
NOTED	CHECK	JS	DATE	9-15-93	90-063[illegible]

BENCHMARK MAP FIGURE D-4



SCALE

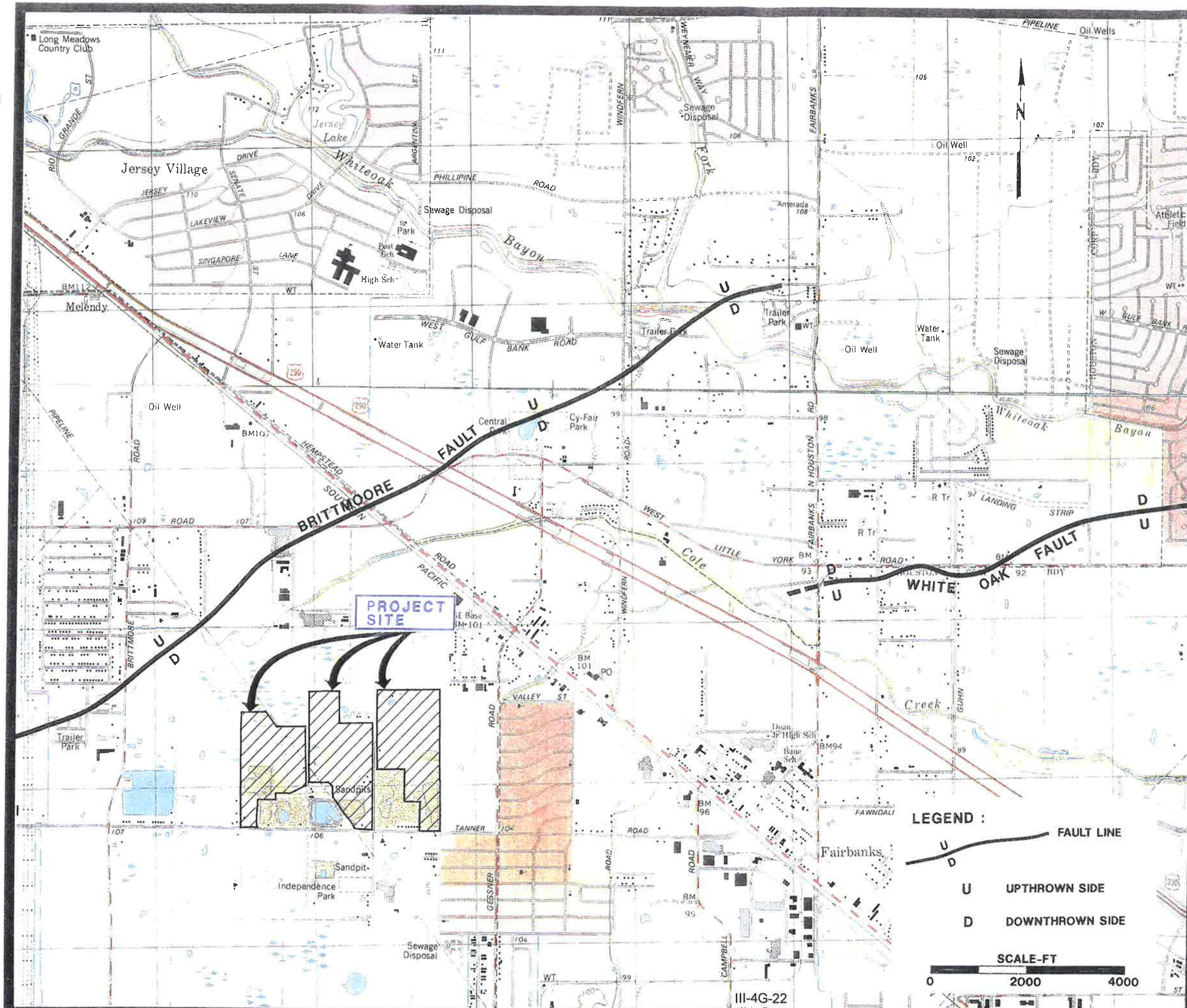
0 1/4 1/2
MILES

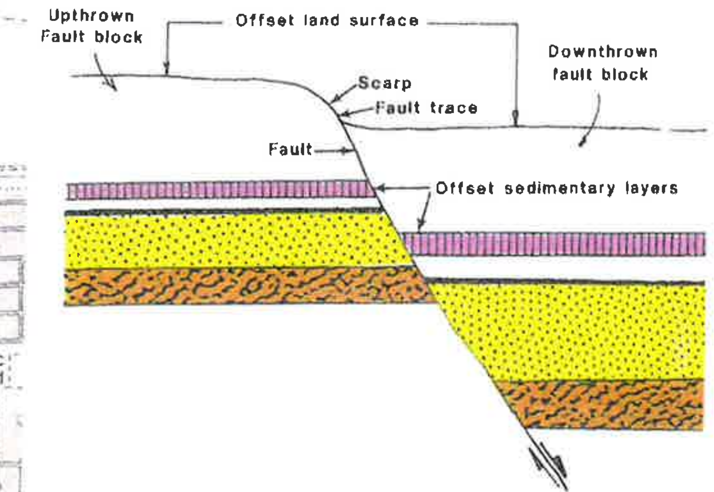
SITE VICINITY MAP

FROM U.S. GEOLOGICAL SURVEY 1918 HILLENDAHL QUADRANGLE

(1-FT CONTOUR INTERVAL)

PROJECT NO. 90-0638
FIGURE D-5
McBride-Ratcliff and Associates, Inc.





Vertical section through a hypothetical fault in the Houston area. Land surface was originally level, but has since been displaced by movement along the fault. Note thickening of sedimentary layers on the downthrown side. This indicates that faulting occurred repeatedly over a long period of time, while the sediments were being deposited. Such faults are common in the Texas Gulf Coast.

According to E.R. Verbeek, K.W. Ratzlaff and U.S. Clanton, rigid structures such as highways, runways, and building foundations, where built astride active faults, commonly display the consequences of differential vertical movement and horizontal extension. Breakage occurs as the sinking ground surface on the downthrown side no longer supports the structural load. Maximum damage normally occurs on and immediately adjacent to the fault scarp, within a zone that is typically 2-3 m wide, but which may vary in width from less than 1 m to more than 10 m. To either side of this zone, some limited fault-related failure may be seen in brittle material, but the most visible effect of fault movement here is tilting. The amount of tilt progressively decreases away from the fault scarp and is, for most faults, minor at distances of 20-30 m from the scarp. Surveying data, however, suggest that detectable amounts of tilt may be found as much as 70 m away from some faults.

Based on our observation of structural distress along the Brittmoore Fault northwest of the proposed site, the zone of surface deformation of this fault conforms to the description by Verbeek, Ratzlaff, and Clanton. It is confined to an area less than 200 ft on the downthrown block of the fault.

TEXT FROM "FAULTS IN PARTS OF NORTH-CENTRAL AND WESTERN HOUSTON METROPOLITAN AREA, TEXAS" BY E.R. VERBEEK, K.W. RATZLAFF ADN U.S. CLANTON, 1979.

TOPOGRAPHIC MAP FROM U.S. GEOLOGICAL SURVEY, HEDWIG VILLAGE, TEXAS, 1982.

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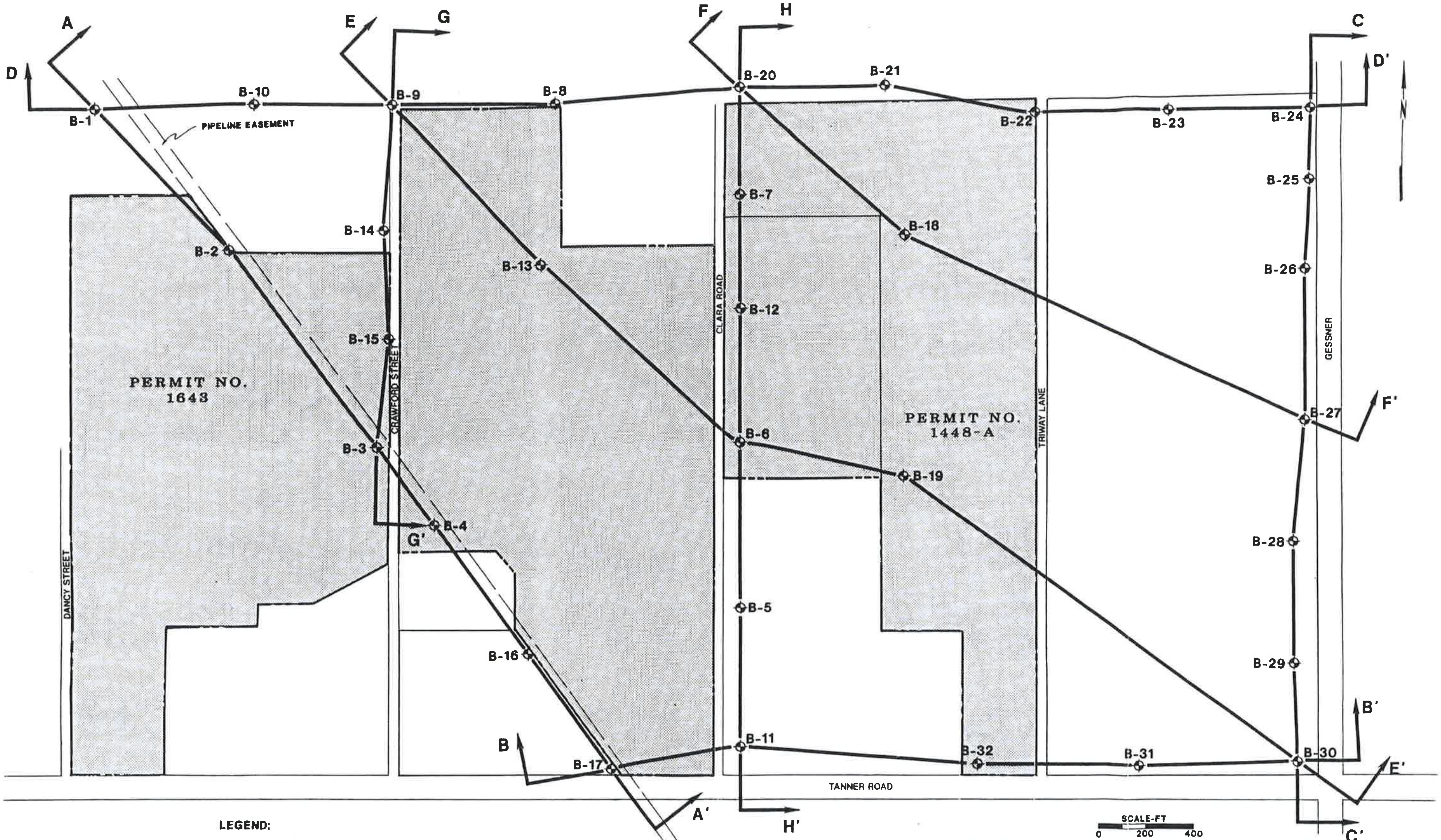
	CHECK	LAL	DATE	10-11-93	

FAULT MAP — FIGURE D-6



LEGEND:

TEST HOLE LOCATION

A —— A' CROSS-SECTION ALIGNMENT

— -- — PROPOSED PERMIT BOUNDARY

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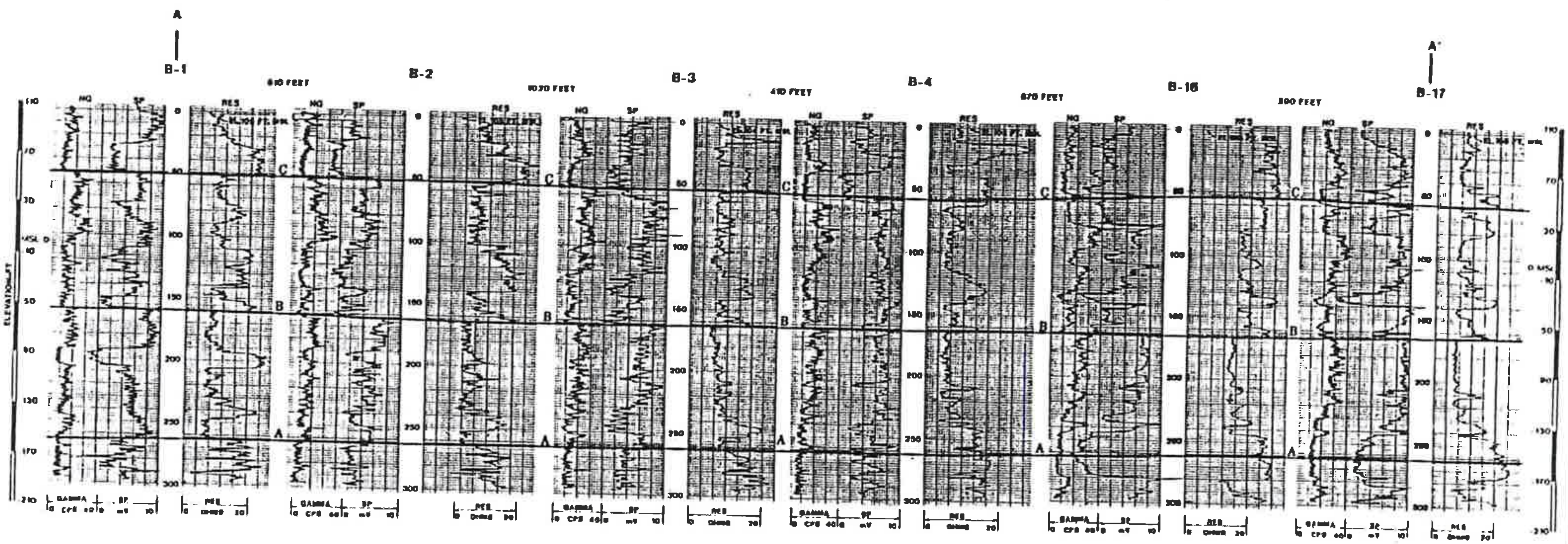
TESTHOLE LOCATIONS FIGURE D-7



LEGEND:

NG = NATURAL GAMMA RAY

SP = SPONTANEOUS POTENTIAL

RES = SINGLE POINT RESISTANCE

A—A' = DESIGNATES CROSS-SECTION

—— = DESIGNATES INTERPRETED MARKER BEDS

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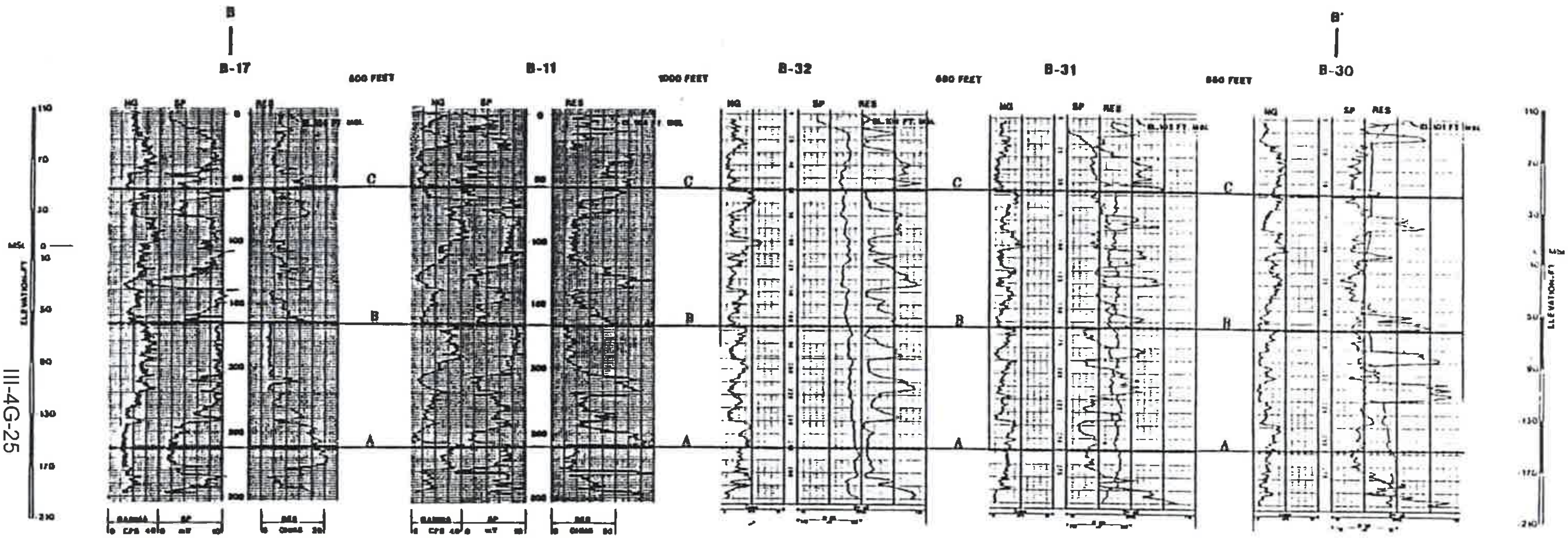
CROSS-SECTION A-A'			FIGURE D-8



LEGEND:

NG	=	NATURAL GAMMA RAY
SP	=	SPONTANEOUS POTENTIAL
RES	=	SINGLE POINT RESISTANCE
A---A'	=	DESIGNATES CROSS-SECTION
———	=	DESIGNATES INTERPRETED MARKER BEDS

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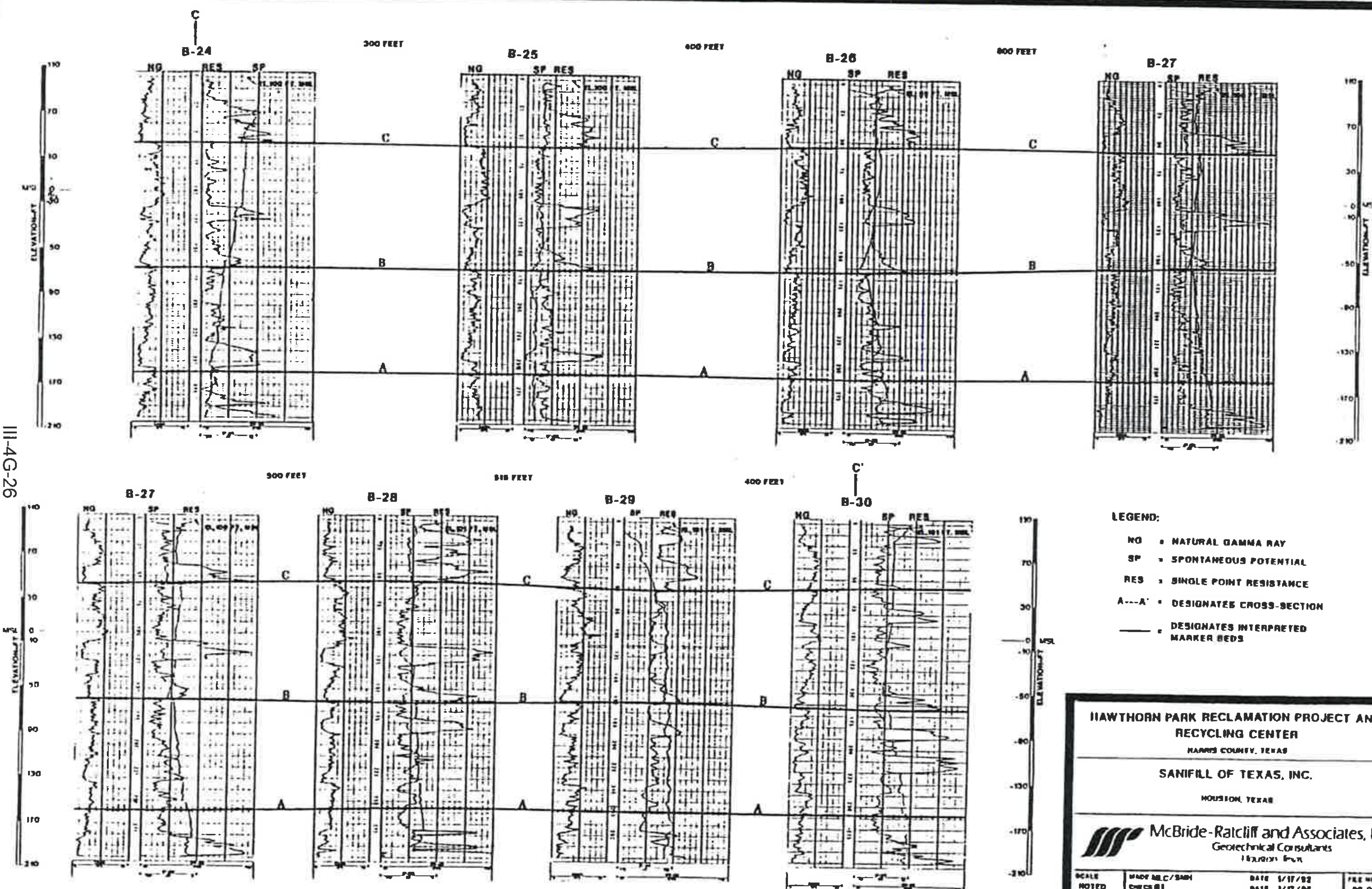
NOTED	CHKD	DATE	

CROSS-SECTION B-B'

FIGURE D-9



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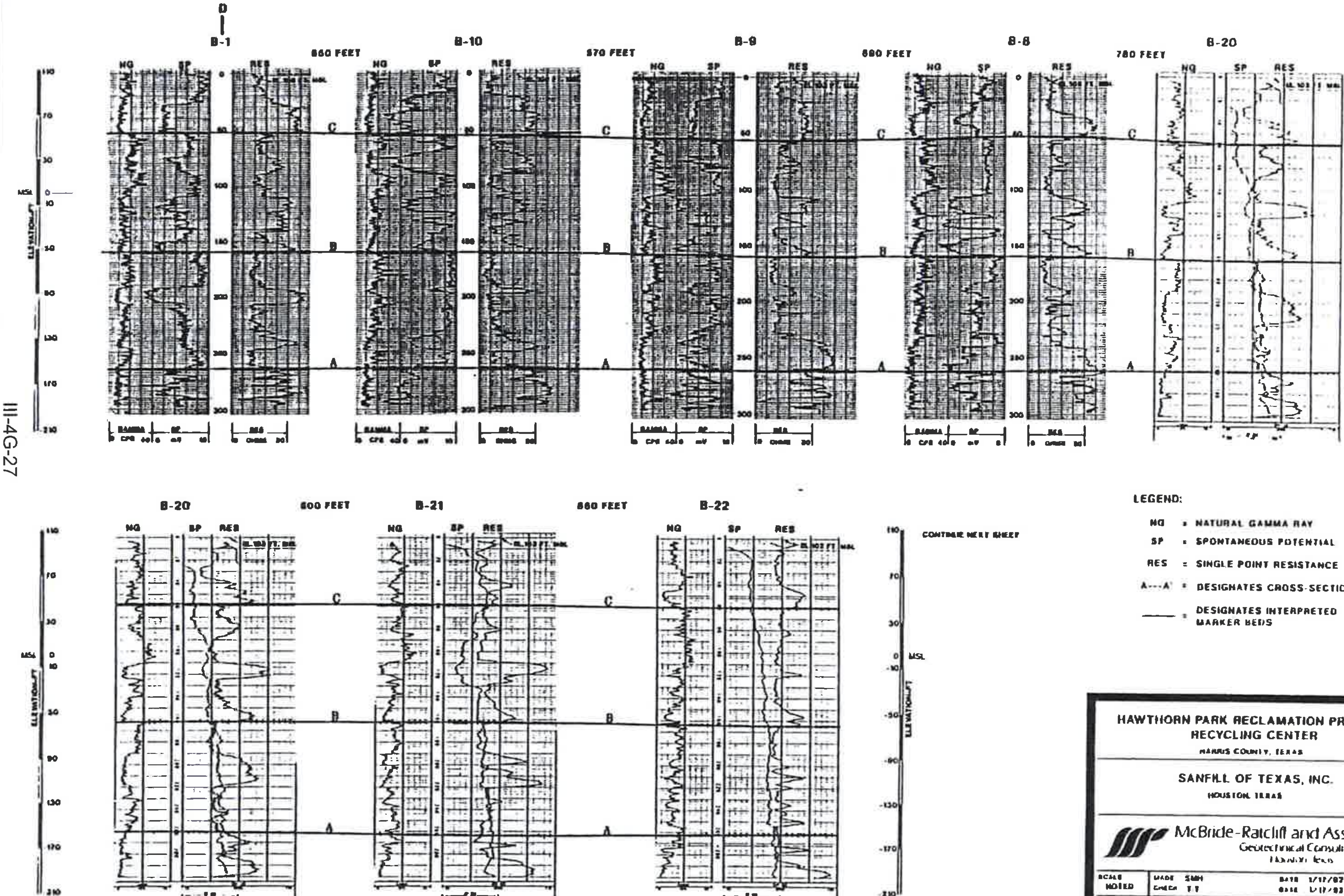
CROSS-SECTION C-C'			FIGURE D-10



LEGEND:

- NG = NATURAL GAMMA RAY
- SP = SPONTANEOUS POTENTIAL
- RES = SINGLE POINT RESISTANCE
- A---A' = DESIGNATES CROSS-SECTION
- ——— = DESIGNATES INTERPRETED MARKER BEDS

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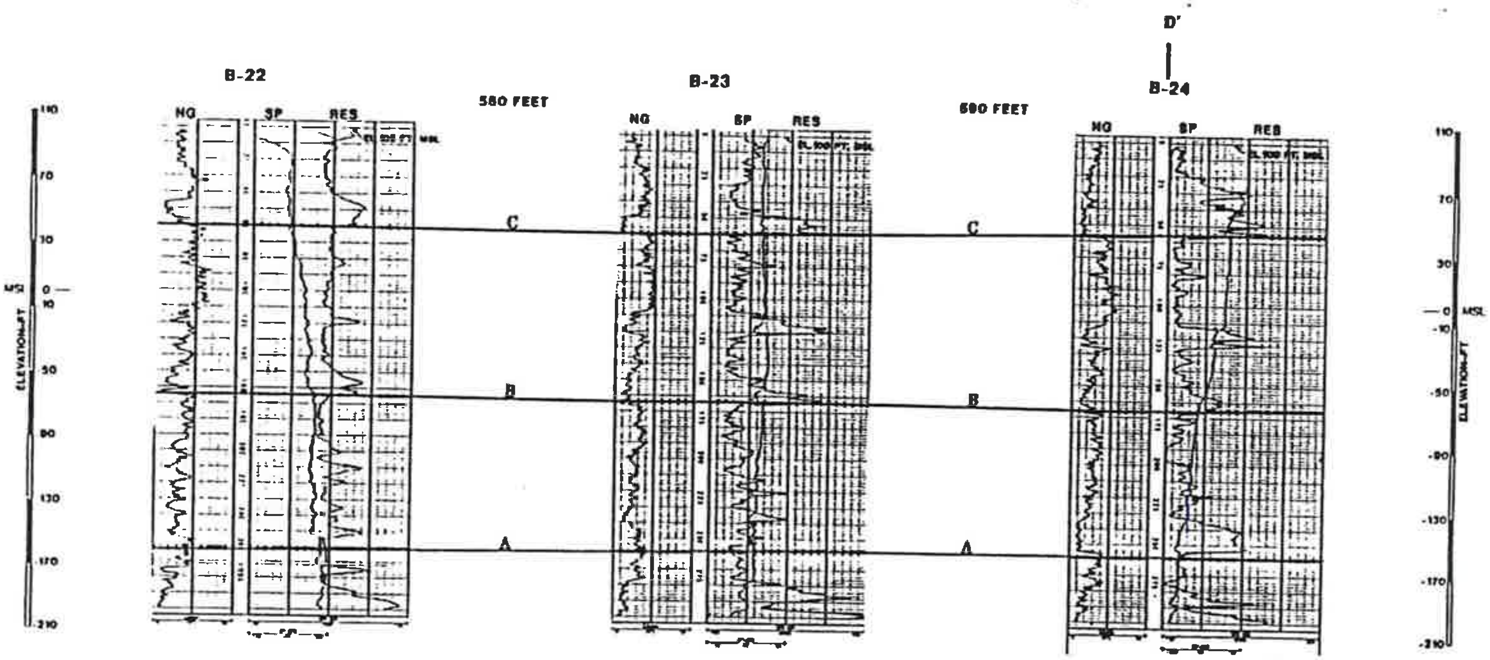
CROSS-SECTION D-D'

FIGURE D-11

CONTINUE FROM PREVIOUS SHEET



LEGEND:

- NG = NATURAL GAMMA RAY
- SP = SPONTANEOUS POTENTIAL
- RES = SINGLE POINT RESISTANCE
- A—A' = DESIGNATES CROSS-SECTION
- —— = DESIGNATES INTERPRETED MARKER BEDS

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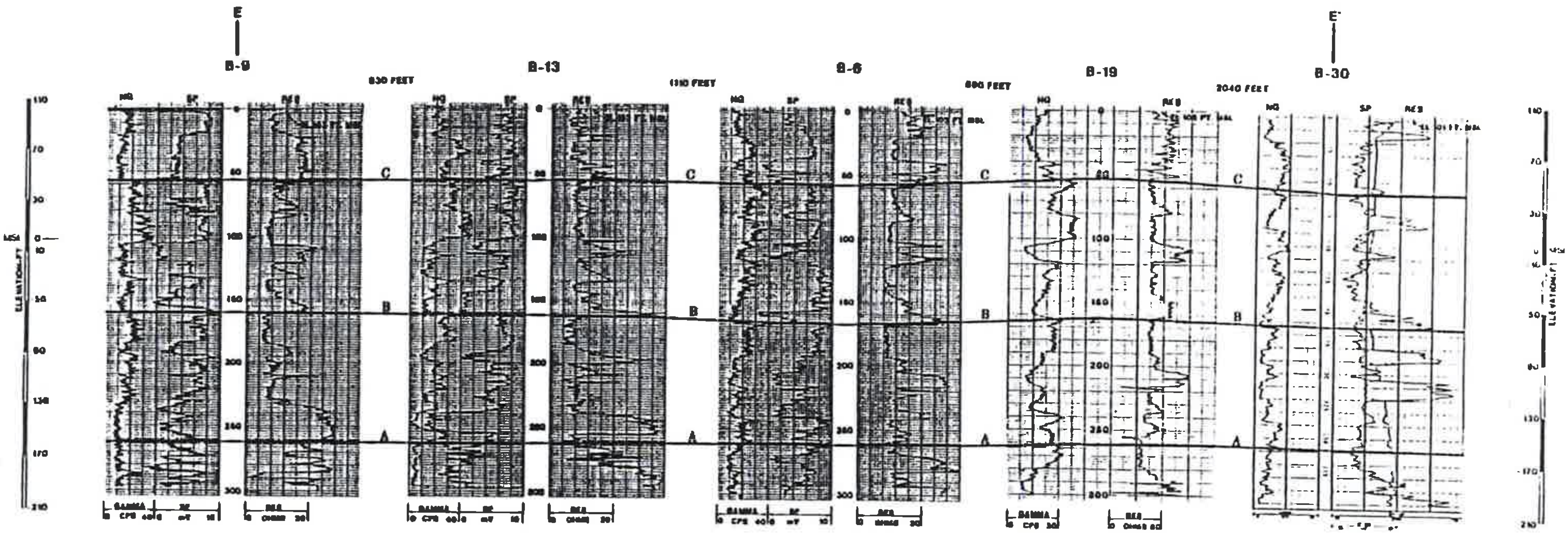
CROSS-SECTION D-D'

FIGURE D-12



LEGEND:

NG = NATURAL GAMMA RAY

SP = SPONTANEOUS POTENTIAL

RES = SINGLE POINT RESISTANCE

A---A' = DESIGNATES CROSS-SECTION

—— = DESIGNATES INTERPRETED MARKER BEDS

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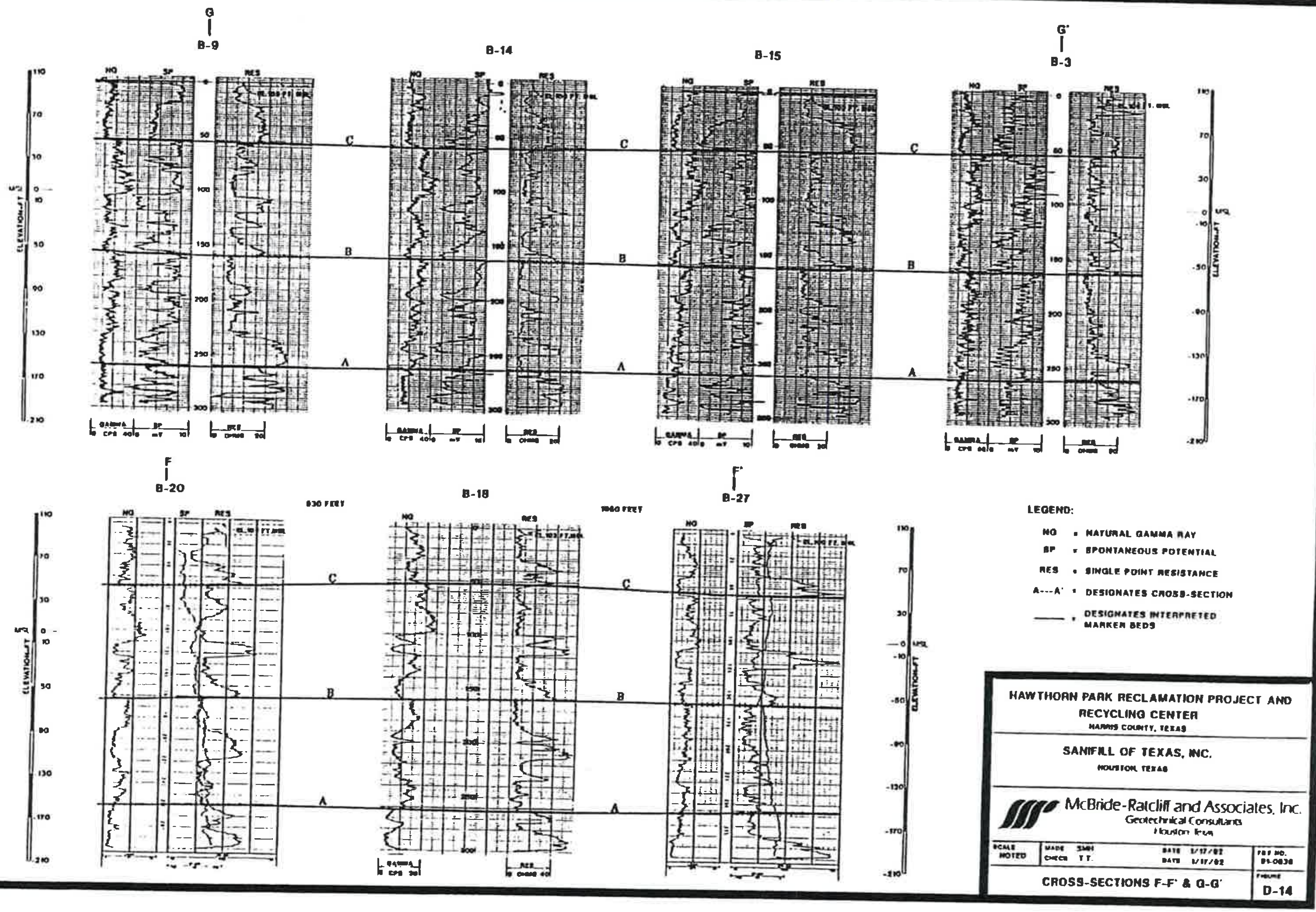
CROSS-SECTION E E'

FIGURE D-13



G
B-9
B-14
B-15
G'
B-3
F
B-20
B-18
F'
B-27
930 FEET
1060 FEET
ELEVATION-FT
MSL
LEGEND:
NG = NATURAL GAMMA RAY
SP = SPONTANEOUS POTENTIAL
RES = SINGLE POINT RESISTANCE
A---A' = DESIGNATES CROSS-SECTION
— = DESIGNATES INTERPRETED MARKER BEDS
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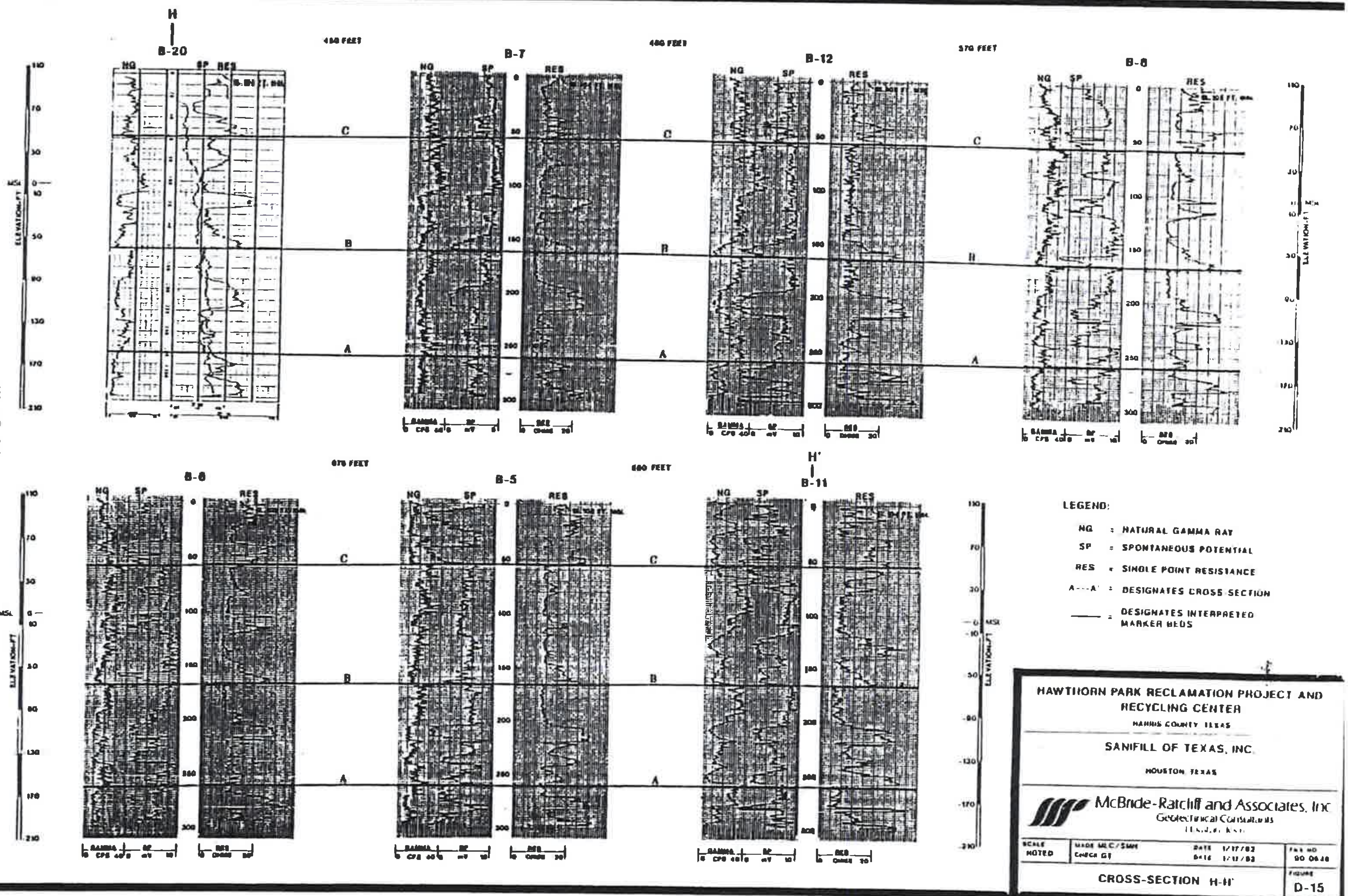
MADE SMH
CHECK T.T.
DATE 3/17/92
DATE 3/17/92
CROSS-SECTIONS F-F' & G-G'
FIGURE
D-14


H
B-20
B-7
B-12
B-8
B-6
B-5
H'
B-11
NG
SP
RES
C
B
A
ELEVATION-FT
MSL
LEGEND:
NG : NATURAL GAMMA RAY
SP : SPONTANEOUS POTENTIAL
RES : SINGLE POINT RESISTANCE
A---A' : DESIGNATES CROSS SECTION
—— : DESIGNATES INTERPRETED MARKER BEDS
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CROSS-SECTION H-H'
FIGURE D-15