Investigation of Ground-Water Resources in the East Contra Costa Area

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I. Introduction

Purpose

An investigation was authorized by five east county public agencies in August 1998 to develop a greater understanding about ground-water resources in a portion of eastern Contra Costa County. The participating agencies were the Contra Costa County Water Agency, Contra Costa Sanitation District No. 19 (now Discovery Bay Community Services District), the City of Brentwood, Diablo Water District, and the East Contra Costa Irrigation District. The study area was generally defined as the region encompassing Brentwood and the East Contra Costa Irrigation District, extending to Byron to the south, Oakley to the north, and Discovery Bay to the east. The investigation focused on gathering existing information and organizing it in a manner in which it could be interpreted and analyzed to answer a set of basic questions concerning ground water.

This report documents the results of the subject investigation. Besides the discussion of results contained in the text, the final work product of the investigation includes eight geologic cross sections depicting the distribution of aquifer units throughout the study area, hydrographs showing the fluctuations of ground-water levels over time, water level contour maps, and various graphs and maps of water quality constituents. All of these figures and graphs are included as exhibits to this report.

Scope

The scope of the investigation was posed as a set of basic questions about ground water within the study area:

- What is the areal extent of the ground-water system in the study area? How is the aquifer system vertically divided and distributed?

- Is the ground-water system in the study area hydraulically connected to that in Discovery Bay to the east or Oakley to the north?

- What are the characteristics of the ground-water system in terms of quantity and quality of water?

- How is ground water recharged? How does ground water discharge, or flow out of the area?

- Is the ground-water system overdrafted?

- Can more ground water be developed? How much? Where?

These questions represent significant issues facing public agencies throughout California with respect to managing existing resources and planning for future needs. In the east Contra Costa County study area, ground water has been used for various purposes for decades. However, no previous studies have addressed these questions to the extent that even a conceptual answer to the question concerning overdraft has been documented. In particular, there are no maps, cross sections, or descriptions of aquifer units containing ground water that have been historically targeted for domestic, municipal, or agricultural water supply purposes. In addition, there has been no basis for determining or predicting how incremental increases in ground-water pumping might affect the basin in the future. Finally, with regard to scope, this investigation was intended to address the questions cited above on a regional scale and assumed that, at least to some degree, the ground-water system would be found to be interconnected across boundaries of multiple water entities in the east county area.

Methods

The methods used in the investigation relied on existing information and data. This included material provided by various water entities within the study area, other information found through literature searches, and data obtained through the State Department of Water Resources and Division of Oil and Gas. The information sought for the investigation included anything related to ground water and consisted primarily of well data contained in drillers' reports, i.e., descriptions of aquifer materials encountered while drilling wells. Other useful well data included measurements of ground-water levels over time, results of ground-water quality tests, and well yields or production capacities.

Multiple tools were used to depict ground-water conditions in the study area and included:

Geologic Cross Sections - Cross sections were used to delineate and interpret the distribution and extent of aquifer materials throughout the study area. Aquifer materials were identified from drillers reports, geophysical surveys (electrical logs, or E-logs), as well as surveys conducted in oil and gas exploratory boreholes. Eight cross sections were constructed to correlate the occurrence of aquifer units throughout the study area and provide a depiction of horizontal and vertical distribution of these materials.

Water Level Hydrographs - Hydrographs depicting water levels in wells over time were used to illustrate historical conditions in the ground-water system. Distinguishing trends were noted and used to interpret climatic influences versus possible impacts of pumping activities.

Water Level Contour Maps - Water level contour maps were constructed to show the relative elevation of ground water throughout the study area. The maps illustrate the ground-water flow directions, and can be interpreted to define gradients for ground-water flow. Maps were constructed representing various points in time to interpret flow patterns on a seasonal basis, changes due to extremes in climatic conditions (e.g., drought periods), and changes due to influences of urbanization.

Depth-to-Water Contour Maps - Depth-to-Water contour maps were constructed to show the proximity of ground water to the ground surface and to illustrate depth-to-water changes over time within the study area.

Water Quality Maps and Graphs - Ground-water quality constituents were mapped and plotted in various forms to delineate and interpret distribution and trends in overall water quality.

Findings

In brief, the significant findings of the investigation include:

- There are four ground-water regions within the study area; those regions are distinguished by the manner in which aquifer materials were distributed and deposited.

- Ground-water conditions in the western part of the study area (the vicinity of Brentwood) are distinct from the eastern region (the vicinity of Discovery Bay as well as northward to Oakley) as a result of depositional history.

- For most of the study area, the extent of aquifer materials capable of yielding quantities of water suitable for municipal and/or agricultural purposes is to depths of 400 feet.

- There is no apparent overdraft of the main ground-water system, suggesting that historical extraction patterns have not exceeded the safe yield of the basin with respect to ground-water levels and storage.

- There have been no significant changes in the direction and rate of movement of ground-water within the study area since the late 1950's.

- Data was found to be limiting for the purposes of defining patterns and factors influencing ground-water quality. However, total dissolved solids (TDS) and nitrate concentrations were found to be significant water quality factors throughout much of the study area. Discovery Bay is notable for relatively better water quality in terms of lower TDS and very low nitrate concentration.

With respect to future needs, east county agencies with interests in ground-water resources would benefit from a program aimed at ongoing monitoring of ground-water conditions to avoid adverse impacts to the quantity and quality as a result of any future changes (e.g., increased pumpage) in historical use patterns. Such monitoring can be incrementally implemented with ongoing pumping plus any additions to pumpage which might be undertaken by one ore more of the local agencies.

The following chapters discuss the basis for the findings cited above. In Chapter IV, Conclusions, specific recommendations are provided with regard to instituting a ground-water monitoring program which is considered especially important for management of ground-water resources in the east County area.

II. Geology and Hydrogeology

Introduction

This chapter presents the results of a detailed analysis and interpretation of subsurface conditions throughout the study area based primarily on information contained in well drillers' reports. Three work products were produced in conjunction with this part of the ground-water investigation and are referred to below in the discussions of geologic setting and hydrogeology. The first work product is the project Base Map on which the study area is delineated through annotations of geologic and hydrogeologic features. The second is the project Well Map on which all the wells found and used to interpret the geologic setting are located. The third is a series of eight geologic cross sections which depict subsurface conditions throughout the study area. The location of the cross sections are delineated on the Base Map. The maps and cross sections appear at the end of this report.

The discussion of the geologic setting is presented below to establish the background necessary to develop the subsequent description and interpretation of hydrogeology. Here, hydrogeology refers to how the geology of the study area is related to the occurrence of ground water. Ultimately, the interpretation of geologic setting and the hydrogeology of the study area is used to form distinct depositional models of four regions within the study area which are depicted on the Base Map. These regions are the Alluvial Plain (e.g., the greater Brentwood area), the Fluvial Plain (e.g., the area around Discovery Bay), the Delta Islands, and the Marginal Delta Dunes (e.g,. Oakley and vicinity). These regions have distinguishing subsurface characteristics which are derived from their geologic history.

The depositional models are significant because they provide a basis for describing and predicting the occurrence and characteristics of ground water. Since this investigation is concerned with the beneficial use of ground water, i.e., as a water supply resource, the depositional models may be used to guide ground-water resource development and exploration. The cross sections are particularly suited for defining the horizontal and vertical extent and distribution of aquifer materials which might be targeted as ground-water supply sources. On a small scale, such models may prove useful in explaining such matters of interest as variations in well yields, water quality, and mutual pumping interference. On a larger scale, the models can serve to describe regional patterns of recharge and ground-water flow direction.

References pertaining to the discussion of the geologic setting are listed in Chapter V. It is notable that there were no useful references found regarding hydrogeology and the occurrence of ground water for the East Contra Costa study area. Thus, the material contained in this section and throughout this report is new and represents a basis for future studies and modeling, exploration efforts, water supply development, or any other activities which require some initial description of the hydrogeology of the project area.

Geologic Setting

The East Contra Costa County study area occurs on the western side of the northern San Joaquin Valley portion of the Great Valley province of California. West of the study area lies the lower foothills of the Diablo Mountains of the Coast Range province. At the north in the study area, the Sacramento and San Joaquin Rivers combine in the Delta and drain westward into the San Francisco Bay region.

Surficial geology of the area is shown on the two regional geologic maps for the Sacramento and San Francisco-San Jose quadrangles (Wagner and others, 1981; Wagner and others, 1990). In the Coast Ranges, the geology consists of strongly deformed (faulted and folded) Mesozoic (pre-63 million years ago) marine sedimentary rocks of the Franciscan Complex and Great Valley Sequence. Along the northeastern edge of the Coast Range occur slightly less deformed, Tertiary (Eocene to Miocene, 55 to 5 million years) marine sedimentary rocks. The marine rocks of sandstones, shales, and mudstones trend northwest/southeast and dip, or slope, steeply to the north/northeast. These rocks are exposed in low hills from Deer Valley north to near Antioch, and southeast of Marsh Creek Reservoir. The Tertiary marine rocks extend east beneath the San Joaquin Valley with increasing depths to several thousand feet. These rocks contain saline water from their marine deposition and natural gas accumulations which are exploited in numerous gas fields in the area.

Detailed surface geologic maps of the Coast Range in this area include Davis and Goldman (1958), Brabb and others (1971), and Dibblee (1980 a, b, c). Subsurface characterization of the marine rocks beneath the San Joaquin Valley are contained in oil and gas field summaries produced by the California Division of Oil & Gas (1982), and Theskenand and Adams (1995). General geologic descriptions and histories of these marine rocks are contained in Bartow (1991), and Bertoldi and others (1991). Because of their marine origin, well consolidated nature, and saline water, the Mesozoic and Tertiary marine rocks are not a source of fresh ground water in the study area.

Overlying the Tertiary marine rocks is a sequence of late Tertiary (Pliocene 5.3 to 1.6 million years) and Quaternary (Pleistocene 1.6 to 0.6 million years) non-marine sedimentary deposits. Surface exposures of these Plio-Pleistocene deposits are limited to an area south of Antioch to Oakley, and a small area south of Brentwood. These beds dip moderately to the east to northeast and extend eastward below the San Joaquin Valley. The nature of these Plio-Pleistocene deposits is poorly known in the study area. Subsurface information is limited to a few deep water well boreholes and oil and gas exploratory test holes. It is believed that these deposits occur below about 400 feet to depths of 1,500 to 2,000 feet below the San Joaquin River. Westward, the sequence thins and rises to near the surface overlying the Tertiary marine rocks of the Coast Range. These deposits seem to be dominated by fine-grained clays, silts, and mudstones with few sand beds. Water quality from electrical logs is difficult to interpret, but appears to become brackish with depth in the few sands encountered.

Pleistocene to Holocene (600,000 years to present) alluvium overlies all of the older geologic units. These deposits are largely unconsolidated beds of gravel, sand, silts, and clays becoming weakly consolidated with increasing age and burial depth. These units were deposited by surface stream systems and contain fresh ground water and represent sources for extraction by water wells. Surface geologic mapping of the youngest units have used various names and subdivisions, largely based on soil characteristics (Welch, 1977), topographic position (Helley and others, 1979), and depositional environments (Atwater, 1982).

In the subsurface, separation of the alluvium is difficult because of similar lithologic character and its poorly stratified nature. At best, correlation of sand and gravel beds of the alluvium is locally possible based on relative elevation and lateral extent and the use of water well drillers' reports. The fine-grained silts and clay beds are generally so massive, thick, and homogenous that stratigraphic correlation is not possible. The alluvium thickens from a few tens of feet in the west to about 300 feet beneath Brentwood, and then generally thickens to about 400 feet beneath Old River. Sand and gravel beds tend to be thin and discontinuous in the west, and thin to pinch-out east of Brentwood. Beneath the river floor to the east, is a sequence of thicker more laterally extensive beds of sand and gravel deposited by the river within flood plain silts and clays. Description of the sand and gravel beds and their distribution in the study area are discussed in subsequent sections.

Hydrogeology

Ground water studies or hydrogeologic studies in the area are relatively limited. Regional studies of the thickness of the Tertiary-Quaternary non-marine sedimentary deposits were made by Page (1974), and attempts were also made to evaluate the depth to base of fresh water by California State Water Project Authority (1956), and Berkstresser (1973). Regional studies of the Sacramento-San Joaquin Valley ground water basin include Bertoldi and others (1991), Page (1986), and Williamson and others (1989). The U.S. Geological Survey compiled water quality information which covers the area in a series of reports (Keeter 1980; Sorenson 1981; and Fogelman 1982). However, detailed hydrogeologic studies of east Contra Costa County examining aquifer nature and characteristics are virtually non-existent.

Because of the lack of detailed hydrogeologic study of the subject East County area, a search of water well drillers' reports on file at Department of Water Resources (DWR) was made. The area encompassed eastern Contra Costa County from about two miles west of Oakley, through the Delta Islands to just east of the county line, and extended south through Brentwood to about two miles south of Byron (see Base Map). Between 400 and 500 well logs were collected and the wells were located on topographic base maps based on each report's description. The wells were classified into depth zones of 100 foot intervals and are color coded on the Well Map. The vast majority of wells are less than 300 feet deep, with only a few wells (or boreholes) extending to greater depths. The wells also tend to be clustered in areas of suburban development where municipal water supply systems are not present. These areas are north of Brentwood towards Oakley, east of Oakley, and areas along the edges of the Delta Islands. Outside of these areas, well density is relatively low, generally only a few are located per square mile. The eastern area along the San Joaquin River flood plain has very low well density, with areas of few or no wells present. Outside of Byron, the southern area also has very low well density.

Municipal supply wells are located in Brentwood, Oakley, Discovery Bay, and small service areas in the Delta. Agricultural/irrigation wells are scattered across the area. It is likely that many more domestic and some irrigation wells exist in the area, but do not have water well drillers' reports on file with DWR.

Lithologic descriptions on drillers' reports are subjective, with the quality of the information provided in them dependent upon the experience, attention, and diligence of the multitude of drillers who have drilled in the region over the years. A more quantitative evaluation of subsurface lithologies is possible from geophysical borehole surveys (electrical logs) run by professional well logging services. A search of DWR files, LSCE's in-house files, and water agency files was also made for electrical logs. A few dozen electrical logs were found as a result of this effort, mostly in the Brentwood and Discovery Bay areas. The electrical logs provide the most precise delineation of aquifer units and for that purpose are considered a primary tool.

Because of the lack of deep well control (over 500 feet) over most of the study area, a search of Division of Oil and Gas files was made to review electrical logs from the numerous oil and gas exploratory test holes in the area. About 200 oil and gas test hole files were reviewed. Many of these test holes were associated with the natural gas fields near Brentwood and north to the Delta. Scattered wildcat test holes (outside of the gas fields) were found across the study area with the lowest density in the southern portion of the study area. Most of the oil and gas electrical logs begin at depths of 800 to 1,000 feet, below the surface casing which is installed to protect fresh ground water in accordance with Division of Oil and Gas regulations. A few older test holes, pre-1960, extend to shallower depths, and in a few cases to the surface. The electrical logs were reviewed and notes made of depth of surface casing, lithologic character (clays and sands), and nature of water quality (saline, brackish, fresh). Most of the oil and gas electrical logs showed that the geologic material below 800 feet is dominated by fine-grained (clay and shale) deposits and some sandy zones with indications of saline or brackish water present. The base of fresh water was more difficult to determine, but seemed to correspond with published information. In general, the lack of suitable aquifers (sand and gravels) below 800 feet and their geophysical responses indicate that deep fresh water bearing aquifers do not exist in the area. One exception to this was found in a few oil and gas geophysical logs in the far northeast, outside the study area in San Joaquin County, where some fresh water aquifers in the 1,000 to 2,500 feet horizon were indicated. These may represent Tertiary non-marine deposits which were sourced from the Sierra Nevada. These deposits appear to pinch-out rapidly westward into finer-grained deposits and do not extend beneath the study area. A similar pattern has been seen in southern Sacramento County in the Elk Grove area.

Geologic Cross Sections - In order to evaluate subsurface geologic conditions and relationships, a series of geologic cross sections was constructed as shown on the Base Map. Five cross sections were constructed in an east-west direction extending from the western foothills of the Coast Range out to the east Contra Costa County line (Cross Sections 1-5). Three additional cross sections were drawn in a north-south direction from the Delta to south of Byron (Cross Sections A-C). Because of the few wells extending to depths below 300 feet and areas of low well density, information from electrical logs found at the Division of Oil and Gas was added to the cross sections to show the uppermost extent of deep well control.

Review of these cross sections shows some general patterns in the occurrence and character of sand and gravel aquifers. Four regions having distinguishing characteristics were found and are delineated on the project Base Map. First, from about Lone Tree Road to south of Brentwood, extending about five miles east of the Coast Range foothills, exists the Alluvial Plain region consisting of eastward thickening deposits overlying Tertiary marine rocks. Most of the sand and gravel beds are located in the shallowest portion of these deposits. Near the foothills, the sand and gravel beds are about 100 feet or less in thickness, deepening to about 300 feet below Brentwood. These deposits are believed to be the Quaternary alluvium overlying the finer-grained Plio-Pleistocene non-marine deposits which extend to the base of fresh water or Tertiary marine rocks. The sand and gravel beds in the alluvium are largely thin bedded (less than 10 feet) and discontinuous laterally (Cross Sections 1, 2, 3, A, and B). Locally there are areas where several thin to thick sand beds exist in sequence (Cross Sections 1, 2, 3, and A). East of Brentwood, the number of sand and gravel beds appear to decrease, and bed thickness also decreases (Cross Sections 1, 2, and 3). This decrease in sand bed content can be seen by comparing Cross Sections A and B south of Cross Section 3. About one mile east of Brentwood, Cross Section B shows that most wells encounter mostly silt and clay with only a few thin, fine sand beds south of Cross Section 2. This pattern of low sand bed content extends south through Byron (see Cross Section B).

A second region, Fluvial Plain, occurs to the east below the San Joaquin Valley floor. In this area, the sand and gravel beds appear to be thicker (20 to 30 feet) and more laterally extensive (Cross Sections 1, 2, and 3). These beds seem to correlate well in a north-south direction from Discovery Bay to Rock Slough (Cross Section C; north to about Cross Section 4). Westward, these beds seem to pinch out rapidly and disappear away from the river channels (Cross Sections 1, 2, and 3). The cross sections also show that below depths of 400 feet, a barren zone of few sand and gravel beds exist to at least 800 feet in depth (Cross Sections 1 and C).

North of the Alluvial and Fluvial Plain regions occur two additional regions. The Delta Islands region swings in an arcurate westward direction (Cross Sections 4, 5, A, B, and C). In this area, more numerous thick, fine sand and gravel beds exist and appear to correlate moderately well. Details of the western end of this area beneath Jersey Island is limited by low well density (Cross Section A). Again, at depths below 400 feet, few sand beds are encountered to depths of at least 800 feet (Cross Sections B and C). Evidence of shallow saline or brackish water may be present in the shallow sand beds below the Delta Islands.

The fourth region, Marginal Delta Dune, exists north of Lone Tree Road extending north to the edge of the Delta and westward beneath Oakley towards Antioch. This region has thick, fine sand beds beneath the northeastern and northern areas which correlate moderately well (Cross Sections 5, A, B, and C). In this region, a surficial deposit of Aeolian dune sands occurs, and some of the thicker subsurface fine sands may represent older buried dune fields, which were fed from the Delta Island area sand deposits. Towards the Coast Range, the area has fewer thin sand beds and the western portion, west of Oakley towards Antioch, seems to lack thick sand beds, although well density is very low.

Net Sand Thickness - In conjunction with generalized characteristics derived from the cross sections, sand bed distribution across the entire area was assessed by computing net sand thickness in 100 foot intervals for all wells reviewed. Overlay work maps were generated in 100 foot intervals with well locations color coded to depict net sand thickness. Mapping was performed for the 0-100, 100-200, and 200-300 foot depth ranges. Beneath the Fluvial Plain, the net sand thickness maps show sand thickness of 30 feet or more per hundred feet. The thicknesses are composed of 1 or 2 thick sand beds (20 to 30 feet) which correlate well laterally. To the west, the sand thickness rapidly decreases. In the 0-100 foot interval net sand thickness is low, less than 10 to 20 feet.

In the Delta Islands, net sand thickness appears to thicken northward from about 30 feet to 60 feet and more per hundred feet beneath Bethel Island. This pattern appeared on all of the net sand thickness work maps. The number and thicknesses of the sand beds appear to increase as net thickness increases. To the west below Jersey Island, low well density does not allow accurate evaluation of sand bed thicknesses to be made.

In the Marginal Delta Dune area, net sand thickness appears to be on the order of 30 to 60 feet per hundred feet. The number of sand beds appears to increase, although bed thickness is variable from thin to thick. Local areas of thick net sand thickness appear to occur, possibly related to stream or distributary channels.

In the Alluvial Plain, net sand thickness is generally low, less than 20 feet per hundred, and occurs in several thin beds on all maps. However, local pockets or bands of thicker net sand (30 to 40 feet per hundred feet) occur at various depths. These pockets consist of several thin (10 to 20 foot) beds overlying each other, and may represent stream channel deposits. The work maps also showed the general decrease of sand beds westward towards the Fluvial Plain. Finally, along the western edge of the maps, the bottom of the alluvium is reflected by the increasing depth eastward at which pre-alluvium deposits are encountered.

The net sand evaluation added appreciably to the development of the depositional models described below. The effort to use them as a tool may be useful for other future purposes such as modeling. However, the work maps were not advanced to a final work product and are not included in this report.

Depositional Model of Alluvium

Based on the review of drillers' logs, electrical logs, geologic cross sections, and net sand thickness analysis, a general model of depositional environments responsible for the configuration and character of the sedimentary deposits across the area was developed. The depositional model describes the physical processes which formed the deposits and caused the areal and physical characteristics in different areas. The depositional model is divided into subareas based upon sedimentary characteristics formed by different depositional processes. The model is delineated as four regions on the Base Map.

Fluvial Plain - Along the floor of the San Joaquin Valley, a zone of well-defined, thick-bedded (20 to 30 feet) sands and gravels occurs. These few beds appear to occur at distinct levels or depths separated by intervening clay to silt beds, and extend northward in fairly well defined sequences.

The sand and gravel beds were probably deposited in stream channels which migrated laterally through time, and are confined within and overlain by flood-plain clay and silt deposits. The setting was probably similar to that which occurs today with northward flowing river channels, distributaries, and sloughs across floodplains of overbank areas. The deposits extend to depths of about 350 feet, below which occur largely fine-grained silts and clays.

Delta Islands - North of the Fluvial Plain region is the Delta Islands area (see Base Map). Sand and gravel beds correlate to the Fluvial Plain, but net sand thicknesses and number of beds appear to increase northward. Net sand thickness increases to 60 feet or more per hundred feet beneath much of the Delta Island areas. To the west where well control is limited, the nature of the Delta area is not well documented. The sand beds appear to be somewhat finer-grained than the fluvial plain, with fewer reports of gravel materials. As in other areas, the sand beds exist to depths of about 300 to 350 feet, below which few sands are encountered.

The depositional environment for the Delta Islands is interpreted as multiple stream channels meandering between islands. Channels would be active with through-flowing waters, then abandoned as new channels developed. Possibly slower stream flow and tidal fluctuations allowed thicker, fine-grained sand deposits to form.

Marginal Delta Dunes - Southwest of the Delta Islands region, an area is defined by numerous thin to thick sand beds as the Marginal Delta Dunes region. Net sand thicknesses are generally greater than 30 feet of sand per hundred feet. The sand beds tend to be similar to the Delta Island area, generally finer-grained sands, but thinner individual beds. Locally, areas of thicker sand beds occur.

The depositional environment is envisioned to be a mixture of delta fluvial distributary channels and possibly aeolian dune fields. Between Oakley and northern Brentwood, a surface deposit of rolling gentle hills of relic sand dunes occur. These sand dunes are believed to have been generated by strong winds blowing sand off the delta margins. Some of the deeper sand beds across the Marginal Delta Dunes area are suspected to be similar older dune fields.

Alluvial Plain - South of the Marginal Delta Dune area and west of the Fluvial Plain is the final depositional environment, the Alluvial Plain. This area is characterized by thin sand and gravel beds which correlate poorly between wells. Net sand thicknesses are generally low, less than 20 feet of sand per hundred feet, and generally occurring as several beds. Locally, pockets or bands of thicker sand and gravel beds occur where slightly thicker beds may occur.

The depositional environment for the Alluvial Plain region is one of small streams draining eastward from the Coast Range foothills to the west. Flood flows of these streams spread out from the hills depositing fine-grained deposits, possibly as mud flows with high sediment content. Stream flows deposited thicker sand and gravel beds which tended to stack upon each other causing the thicker bands of sand beds. The Alluvial Plain deposits thin westward to pinch-out against the Coastal Range foothills. These deposits appear to thicken to about 300 to 350 feet eastward. The sand and gravel beds appear to decrease eastward, so the eastern half of the alluvial plain is dominated by silts and clays. These distal alluvial plain deposits probably interbed with floodplain deposits from the adjacent Fluvial Plain region. The thicker stream deposited sand and gravel bands extend eastward until the sands either pinch out or have not been reached by wells. In the north, the stream deposits appear to reach into the Marginal Delta Dunes area and blends into the sand beds that are present there.

Antioch and Byron Areas - These two areas could only be briefly examined due to lack of well control. The Antioch area appears to be a small alluvial plain area with thin sand beds. Possibly, the Plio-Pleistocene non-marine deposits occur at shallow depths and the alluvium is thin in this area. More extensive study towards Antioch would be required to evaluate the area. The Byron area also appears to have few thin sand beds of small alluvial plain area marginal to the greater Fluvial Plain region where fine-grained deposits appear to dominate.

Depositional Model of Plio-Pleistocene Non-Marine Deposits

As reported in the literature and seen on the cross sections, below the alluvium occur poorly defined Plio-Pleistocene deposits. These non-marine deposits appear to thicken eastward from exposure areas to thicknesses of 1,500 to 2,000 feet below the San Joaquin River. Limited borehole data indicates that these deposits are mostly fine-grained silt, clays and mudstones with few sand beds. Electrical logs indicate that fresh to brackish water quality exists in these deposits, although it is difficult to determine because of their fine grained nature.

Regional geologic studies (Bartow, 1991; and Bertoldi and others, 1991) have shown that Miocene marine deposition occurred in the area as shown by the Tertiary marine rocks exposed in the Coast

Ranges. During the following Pliocene, the San Joaquin Valley drained to the south to the ocean via the Salinas Valley. The Sacramento Valley drained westward through the Delta area, and the Coast Range locally apparently had not been uplifted as yet. Deposition may have been confined to distal fluvial plains sourced from the Sierra Nevada area, such that little sand was carried into the area. Similar aged fine grained deposits are seen in southern Sacramento County, near Vacaville, and around Rio Vista reaching thicknesses of 2,000 to 2,500 feet.

In the Quaternary (mid-Pleistocene) period, the San Joaquin Valley south of Tracy was occupied by a large fresh water lake, Corcoran Lake. The study area appears to have remained in low relief, and fine-grained fluvial plain deposition continued. At about 600,000 years ago, northern San Joaquin River drainage and local Coast Range uplift began. It is suspected that this activity marked the beginning of the alluvium deposition where coarse-grained deposits were formed and carried into the area by the San Joaquin River and eroded off of the uplifting Coast Ranges.

III. Ground-Water Conditions

Introduction

This chapter discusses ground-water conditions in terms of ground-water levels, which are a reflection of ground-water storage, and ground-water quality. Throughout the study area, the primary water-bearing units for water supply purposes exist primarily in the upper 300 to 400 feet of geologic material. From the analyses presented in the previous chapter, there is no apparent basis for subdividing the aquifer system into subunits on a regional scale due to a lack of correlation although locally there are apparent variations in aquifer characteristics, water levels, and water quality.

The most extensive collection of historical water level and quality data was provided by the East Contra Costa Irrigation District (ECCID). This data covered the area from Oakley in the north to south of Brentwood, and from west of Highway 4 east toward Discovery Bay. The period of record for the ECCID data began in 1958 and provided an excellent basis to evaluate trends in water levels over time, especially during drought periods. This data was the primary source for the generation of contour maps of equal ground-water elevation and depth-to-water, and water level hydrographs discussed below. Ground-water quality data is also predominantly from this area but is also very limited in scope so that only a few general conclusions could be drawn with respect to questions concerning this topic.

Ground-Water Level Hydrographs

Representative water level elevation hydrographs of wells monitored by ECCID were constructed and evaluated to assess historical trends. A hydrograph, which is a plot of water level versus time, reflects ground-water storage over time. The factors which affect ground-water levels and storage include seasonal and climatic changes, use patterns (e.g., municipal and agricultural pumping), and artificial and natural recharge. A long-term or permanent decline in ground-water elevation is generally interpreted as an overdraft condition where extraction of ground water exceeds the recharge components. Short-term water level declines may result from climatic conditions such as drought. In this case, overdraft would not exist if water levels recover after the drought period. In areas where ground water is extracted for various purposes, seasonal fluctuations can often be correlated to recharge during the winter period (water level rise) and pumping through spring and summer (water levels fall). The hydrographs analyzed for this study and a well location map are included under Exhibits at the end of this report.

Ground-water level data obtained from ECCID spanned from the late 1950's and served as an excellent basis for interpreting ground-water storage over time for a significant portion of the study area. The data indicates that water levels in the east county area have remained fairly stable with no evidence of long term or dramatic declines. Minor shifts in water levels have occurred in two areas of the east county region. Wells located north of Lone Tree Way in Brentwood in the Marginal Delta Dune area have exhibited an upward to relatively flat trend in water levels. The upward trend is exhibited by an increase of approximately two to five feet over the last 25 to 35 years.

Wells located in the Alluvial Plain area south of the Marginal Delta Dune area have generally exhibited either stable or slightly declining trends in water levels. The wells which have shown a slightly decreasing trend have had a decline of two to five feet in the last 25 to 35 years, almost a mirror image of the upward trend in the Marginal Delta Dune area. The amount of decline is not considered significant in terms of impacts to either ground-water quantity or quality in the affected area.

Climatic and seasonal water level changes are most noticeable in wells located in the western portion of ECCID's well network. These wells commonly have seasonal or climatic water level changes of five to twenty feet. Wells located in other areas of ECCID do not have pronounced seasonal or climatic water level changes. These wells may be affected by proximity to the Delta whereas the wells located in the western portion of ECCID are likely influenced more by boundary effects caused by proximity to the edge of the ground-water system, i.e., the Coast Range foothills.

Long-term water level data were not found for other east County areas. This problem could be addressed by extending the monitoring conducted by ECCID to the other regions including south of Brentwood in the Byron area, the Oakley area, the Discovery Bay area, and east beyond the county line. However, considering that the most significant historical ground-water extraction activities have been focused in the greater Brentwood area, it is expected that the outlying areas would not show a significant deviation from the stability reflected in the ECCID data. In Discovery Bay, long-term monitoring of water levels of the confined unit tapped by its municipal wells would be of key importance with regard to ground-water conditions in that area.

Ground-Water Level Contour Maps

Regional water level contours were constructed for spring and fall of 1958, 1975, and 1991, and spring or fall of 1977, 1986, and 1996. The 1991 contour maps were augmented with data from Diablo Water District and Discovery Bay. The contour maps were used to assess historical changes in ground-water flow directions since 1958 during time periods which experienced wide variations in precipitation, e.g., during "wet" years (mid 1980's) and "dry" years (mid 1970's, late 1980's). The plots were also used to determine areas which have experienced increases in ground-water pumpage and which have little or no recorded water level data.

All the ground-water elevation contour plots show ground-water flow directions from west to east in the southern portion of the study area (Brentwood to Discovery Bay) and from southwest to northeast in the central and northern portions of the area (from Brentwood toward Holland Tract). Immediately south and southwest of Brentwood near ECCID's Main Canal, there appears to be a flattening of ground-water elevations, possibly resulting from ground-water pumping in the vicinity (an effort should be made in the future to verify the measuring point elevations in this area as the apparent flattening of contours could be a data quality problem). This is most noticeable from 1975 through 1991, when more water level data is available in this area, and does not appear to be developing into a ground-water depression, even during drought periods (1977 and 1991). There is a lack of data south of Brentwood in 1996 and prior to 1975 to evaluate whether the flattening of ground-water levels persists before or after that time period. This area does not appear to have a dramatic affect on water levels either in the Discovery Bay area or in the Brentwood area.

The hydraulic gradient is approximately 15 feet per mile in the southern portion of the basin to 20 feet per mile in the northern portion of the basin. The hydraulic gradients have not changed significantly since 1958 with the exception of the flattening of the gradient in the area south of Brentwood since 1975.

Depth-to-Water Contour Maps

Depth-to-water contour maps were prepared for the same time periods as the water level elevation contours discussed above. These maps, included in the Exhibits section along with the ground-water elevation maps, can be used to assess how depth-to-water in a particular area has changed over time; they can also, for example, serve as a useful reference when assessing available drawdown for well development purposes. Unfortunately, there is a lack of historical water level data west of Highway 4, in the Oakley area, south of Brentwood to Byron, and in the Dutch Slough, Rock Slough, and Indian Slough areas; this lack of data limits the scope of depth-to-water mapping in the overall study area.

The depth-to-water maps show that ground water occurs at shallower depths from west to east. These maps are consistent with the hydrographs and elevation contour maps in that they indicate no significant changes over time nor any apparent significant impacts by historical extraction within the area for which data is available.

Ground-Water Levels in Newer Brentwood Municipal Wells - Although there is no extensive data on water levels in municipal wells operated by the City of Brentwood, it is known that static levels in the City's two main well fields (Wells 6, 7, and 8 near Marsh Creek and Wells 11, 12, and 13 to the south) are deeper than the shallower levels reflected in the broad ECCID data base. Static water level readings from Brentwood's wells indicate that the water level difference may be 20 to 40 feet in magnitude and is most likely caused by the municipal pumping. The City's pumping, however, has not impacted the larger regional system as reflected in the well hydrographs or water elevation contours discussed previously. At least locally, the City should be concerned with how the water level difference between the deeper completion zones of its newer municipal wells and the shallow zones might cause degradation of water quality by inducing downward movement of water quality constituents of local concern (e.g., nitrate). As development of the deepest portion of the aquifer occurs, it would be advisable to monitor the municipal wells separately to determine if a distinction of the aquifer system into shallow and deep units is appropriate.

Ground-Water Quality

Ground-water quality data was reviewed to assess trends and characteristics of ground water throughout the study area. Data was limited in quantity and distribution, with most concentrated in the greater Brentwood area and within the East Contra Costa Irrigation District. Water quality data is presented in a series of graphs for wells located on the study Base Map under Exhibits at the end of this report.

Ground-water quality data posted on maps include concentrations of total dissolved solids (TDS), chloride, and nitrate. As discussed below, because of the limited amount of data, the most significant finding concerning water quality variations throughout the study area is the notably better water quality in Discovery Bay as compared to other areas where data is available.

A series of graphs was also used to assess water quality characteristics for this investigation. These graphs were constructed by plotting various water quality constituents versus the depth of the well intake structure; that is, the top of the well perforations or screen. Most notably, there is a strong correlation between nitrate concentration and the depth of the intake structure, which is consistent with the generally understood concept that nitrate degradation occurs as a result of surficial influences. Other constituents also showed a relationship that suggests that water quality improves with depth as discussed below.

Total Dissolved Solids - Data on total dissolved solids in ground water in the study area varies widely, although it is characteristically high, up to 1,000 mg/l, in many areas (see TDS map). Discovery Bay is notable for significantly lower TDS in ground water with all measured values between 500 and 600 mg/l. As discussed further below, this information lends support to the theory that the ground-water system in that area may be hydraulically distinct from the depositional areas to the west and perhaps the north. This hydraulic distinction is not apparent from the ground-water elevation maps discussed previously because of a lack of data around Discovery Bay.

Other constituents of ground-water quality, including electrical conductivity, were plotted as a function of the depth of the well intake structure. Each of these indicates a slight trend of better water quality with depth. Considering a very strong relationship with nitrate, which is usually derived from surficial sources, it may be possible that there is some degradation in ground-water quality (besides nitrate) that is a result of the same influences. However, the preponderance of the data suggests that water quality is naturally high in TDS (up to 1,000 mg/l) and other constituents such as chloride, and that local degradation may have occurred possibly due to man-made influences.

Nitrate - Nitrate in ground water is widely distributed in the study area, with some values exceeding the maximum contaminant level (MCL) set by EPA for drinking water (45 mg/l as nitrate). The eastern portion of the study area is notable as having significantly lower values; the wells in Discovery Bay have no detectable nitrate present. While the occurrence of nitrate in ground water in this area has generally been attributed to agricultural influences, its occurrence is clearly limited to the upper sequences of aquifer materials as reflected in the plot of nitrate concentration versus depth of well intake structures. For the available data, nitrate concentrations decline appreciably for wells completed below 200 feet; i.e., for wells where the top of the perforations are 200 feet or more below the surface. This suggests that, in many cases, nitrate contamination may be mitigable through well design, for example, by incorporation of wells seals to 200 feet and limitation of well screens to depths below 200 feet.

Aquifer Confinement

The representative hydrographs and contour maps analyzed for this investigation are included at the back of the report under Exhibits. The wells monitored by ECCID are widely distributed throughout the region and are representative of the main aquifer system which occurs in the upper 300 to 400 feet below ground surface. The water level data reflects primarily conditions in the western portion of the study area, with most of that falling within the Alluvial Plain depositional region but extending into the Marginal Delta Dune region around Oakley. Considering the depositional region as well as the consistencies in data from well to well, the aquifer system appears to act locally confined. That is, there appears to be hydraulic continuity from the shallow aquifer materials to the deeper ones as reflected by the similarities in water levels from all wells.

The hypothesis of local confinement is supported by the apparent discontinuous nature of aquifer materials as reflected in the cross sections discussed in the previous chapter. Under this model, some local confinement would be expected as a result of the presence of clay beds and would affect the drawdown characteristics of wells, for example. However, these beds are not areally extensive and hydraulic equilibrium would likely be reached between shallow and deep zones when wells are inactive (e.g., in the winter). In the Brentwood area, this is consistent with the experience that well sealing can successfully mitigate nitrate degradation by preventing locally induce downward migration of shallow ground water as a result of deeper pumping.

In contrast to the apparent conditions in the Alluvial Plain, municipal wells in Discovery Bay produce from a zone which appears to be confined by an extensive layer of clay material (see Cross Sections 1 and C). The confinement of the main aquifer in the Discovery Bay area is indicated also by the difference in head between the deep zone and a shallow brackish zone which has caused some problems in operation of the municipal well facilities. These problems have been shown to be effectively mitigated by sealing the well through the brackish zone to achieve complete hydraulic isolation of both the deeper aquifer and the well structures from the brackish aquifer.

The apparent confinement of the main aquifer at Discovery Bay appears to be representative of the Fluvial Plain region. The same may not be true immediately north into the Delta Islands where the cross section interpretation seems to make confinement more difficult to correlate and there is no water level data for added support.

Recharge Sources

The study area consists of an aquifer system having a mix of depositional patterns as discussed in Chapter II. From the depositional models, it is not unlikely that there are different sources of recharge of the various aquifer materials which are sources of water supply. From water level data, it is clear that ground water is moving from the Coast Range foothills toward the east through the Alluvial Plain and Marginal Delta Dune regions. As discussed above, there is no clear extensive confinement of aquifer materials in these areas. In contrast, ground water developed in municipal supply wells in Discovery Bay appears to be confined and, when water quality information is considered, it is likely that there is different recharge source as well. One possibility is that the Fluvial Plain region, where Discovery Bay is located, is recharged from the south in a manner that is consistent with the depositional model discussed previously. Again, it should be noted that this is not reflected on the ground-water elevation contour maps primarily because of lack of data around Discovery Bay.

Recharge of the Delta Islands may be a combination of fluvial influences from the south but also the hydraulics of the Delta system. The lack of pronounced seasonal and climatic influences on water levels as cited previously underscores the likely significance of the Delta system with regard to recharge. The latter is especially true considering the lack of the correlatable confinement that is a characteristic of the Fluvial Plain. No other conclusions regarding recharge could be made except for those cited above mainly because of the lack of water level information outside of the ECCID area. It should be noted that in some areas, particularly to the north in the Delta Islands and Marginal Delta Dune regions, significant increases in pumpage may have the potential to induce recharge from poor quality, or brackish, water as a result of proximity to Bay and Delta influences. The inability to assess recharge in parts of the study area underscores the need to develop a broader range of water level monitoring outside the boundaries of ECCID. In Discovery Bay particularly, where ground water is relied on for municipal water supply purposes, it would be desirable to investigate ground-water conditions in more detail to the north, south, and east to delineate flow direction and potential recharge influences.

Basin Yield

Historical conditions as reflected in the hydrographs and contour maps discussed above suggest that, for much of the Alluvial Plain and Marginal Delta Dune regions, where most of the historical data is available, extraction activities have not exceeded the sustainable yield of the ground-water system. Here, sustainable yield, sometimes called "safe" yield, refers to that level at which extraction has not adversely impacted ground-water conditions, e.g. levels, storage, quality, etc. As cited above, stability in ground-water levels and storage reflected in the well hydrographs and the ground-water contour maps.

Although it may be stated that the sustainable yield in much of the east County area has not been adversely impacted as reflected by the ground-water level data, less certainty exists at Discovery Bay and other areas, including Brentwood (deeper zones), because of the lack of data and/or short period of record. It is unlikely, however, that sustainable yield, as defined above, has been exceeded because of the general lack of ground-water development throughout much of these other areas. Furthermore, areas in the vicinity of the river and Delta systems have a large source of potential recharge which could offset potential adverse impacts due to increased extraction.

Sustainable yield also refers to that level at which ground-water extraction does not degrade water quality. On this matter, less is apparent based on available water quality data in the study area. It is likely that pumping on a local level in the Brentwood area, for example, induces some degradation by nitrate. However, it is also likely that some of these local influences are caused by, and can therefore be mitigated through, well design practices. On a regional scale, significant increases in pumpage could cause migration of poor quality water in some areas, particularly the Alluvial Plain region, which could degrade water quality (e.g., nitrate, TDS). In the Delta areas, increased extraction may not affect quantity, but may induce movement of shallow brackish water that would be a hazard to fresh ground-water sources. Again, these considerations further point to the need for expanded monitoring in parts of the study area to better understand local conditions beyond where historical data is concentrated.

IV. Conclusions

Data Quantity and Quality

Initial efforts to collect and organize information resulted in the development of a large data base of well driller's reports and ground-water levels which formed the basis for addressing the investigatio objectives. Ground-water quality data was the most sparse and lacking of the primary categories of information sought for the study. As a result, some firm conclusions could be drawn with respect to the occurrence and distribution of aquifer materials, as well as historical ground-water conditions, but with limited conclusions regarding ground-water quality.

Well data in the form of driller's reports permitted construction of geologic cross sections covering the entire study area. These tools can serve various future water supply development needs including targeting depths for exploratory test holes prior to new well construction. Since there was a limited quantity of electrical logs available, which provide precise delineation of lithologies, the cross sections should be reassessed when new logs become available (from new wells).

The data did not permit quantification of how much additional pumpage might be sustained in the basin without impacting the sustainable yield. As a result, it is recommended below that any significant incremental pumpage be monitored to determine if sustainable yield is exceeded. This can be accomplished by identifying key representative wells for the purposes of tracking water levels in the form of updated hydrographs and water level contour maps. These tools will permit detection of adverse or downward trends in water levels or flow patterns; they will also allow identification of appropriate local or other corrective measures (e.g., relocation or redistribution of pumpage, augmentation of recharge, etc.).

Because of the lack of water quality data, a systematic ground-water quality sampling and testing program is also recommended to more fully assess ground-water quality in the region and to serve as a basis for future ground-water management activities.

Hydrogeologic Regions

Four ground-water regions were delineated in the study area which are distinguished by the manner in which aquifer materials were distributed and deposited. These include the Alluvial Plain, Fluvial Plain, Delta Islands, and the Marginal Delta Dune. For reference, the aquifer system underlying the City of Brentwood is representative of the Alluvial Plain region; the aquifer system in Discovery Bay is representative of the Fluvial Plain; Bethel Island is central to the Delta Islands regions; and Oakley is within the Marginal Delta Dunes. The western extent of the entire hydrogeologic system is at the Coast Range foothills which represent the most distinct hydrogeologic boundary in the study area.

For most of the study area, the extent of aquifer materials capable of yielding quantities of water suitable for municipal and/or agricultural purposes is to depths of 400 feet. Each region has characteristic quantities of aquifer materials (i.e., net sand thickness) that are related to depositional patterns.

The depositional models are useful for a number of purposes. For example, differences in the occurence and patterns of aquifer units, as well as ground-water quality and quantity, between the western part of the study area (represented by Brentwood) and the eastern (represented by Discovery Bay as well as the other regions) can be attributed to the natural history (i.e., geology) of the region. The distinctions between the Alluvial Plain and the Fluvial Plain likely include different recharge sources which explains some significant differences in water quality between Brentwood and Discovery Bay, for example.

Ground-Water Conditions

Water level hydrographs reflect seasonal fluctuations and, in some areas, climatic influences (such as drought periods) on ground water. In general, comparing conditions since the late 1950's to present, the data indicates that there is no apparent overdraft of the ground-water system, suggesting that historical extraction patterns have not exceeded the sustainable yield of the system. However, there may be localized pumping influences around Brentwood that should be investigated further. In that area, newer municipal wells which tap deeper aquifer units (below 300 feet) have apparent lower static water levels than measured in the surrounding ECCID data base.

Ground water contour maps, constructed to depict ground-water levels at various times since the late 1950's, reveal patterns and directions of ground-water flow throughout a large portion of the study area from the western edge toward Discovery Bay. The maps indicate that there have been no significant changes in movement of ground water within the study area since the late 1950's. Furthermore, there have apparently been limited, if any, adverse impacts to ground-water storage in the study area as a result historical use patterns. Impacts appear to be limited to the occurrence of elevated nitrate concentrations in shallow ground water which is likely a result of agriculture and, in some cases, possibly septic systems.

Ground-Water Quality

Ground-water quality data, while sparse, indicates wide variations in TDS and nitrate concentrations. Discovery Bay is notable for relatively better water quality in terms of lower TDS and no detectable nitrate concentrations when compared to areas directly to the west. This is likely attributable to the distinct depositional environments associated with the two areas, as cited previously, as well as differences in historical land use. Nitrate problems in the greater Brentwood area are likely a result of surficial influences by agricultural practices where localized infiltration has caused introduction of nitrogen to shallow ground water. Such problems are most likely best addressed through specific well design features, such as selective well completions and deep annular well seals, to hydraulically isolate the shallow zones from the target completion intervals (i.e., water zones) in supply wells.

In the northern hydrogeologic regions, shallow, poor quality water (i.e., brackish) may exist as a result of influence by the Bay in the Delta over geologic time. The extend of this problem can be identified through exploration tools such as electrical logs and may be mitigated through well design. The known shallow brackish zone at Discovery Bay is considered anomalous in that the fluvial depositional model does not suggest a source of the poor quality water.

Ground-Water Exploration and Development Potential

Based on the geologic evaluation and cross sections, some general conclusions may be drawn regarding future ground-water exploration and development in the study area. In general, exploration should be confined to depths above about 400 feet except within a mile or two of the Coast Range Foothills where depths of exploration would be even shallower. Most alluvium sand and gravels beds occur above about 350 feet depth. Some thin sand or sandstone beds may be found below 400 feet.

In the Fluvial Plain region, wells of relatively high yields (up to 2,200 gpm capacity) have been constructed above 400 feet in the Discovery Bay area. However, shallow and possibly deeper brackish water problems have been found which must be avoided. The better water quality (in terms of lower TDS) developed in the municipal wells in Discovery Bay, as compared to the other regions, is likely due to the existence of a separate recharge source to the south. This source is likely related to the depositional pattern of the river system.

Development of wells in the Fluvial Plain region, with characteristics similar to the Discovery Bay municipal wells, may be possible particularly north of that community. However, this area does not have a population base to warrant such development at present. It is expected that exploration below 400 feet will not encounter suitable aquifers for water supply purposes.

In the eastern Delta Islands, wells of moderate yield appear to have been constructed. From the drillers' reports, depths of 400 feet appear to be the bottom of exploration potential. Brackish or saline water quality problems, especially in shallow aquifers above 200 feet, may be found as discussed previously.

In the Marginal Delta Dunes area, limited exploration has occurred to 400 feet. Potentially moderate yielding wells may be possible, but exploration is needed to evaluate deeper aquifer potential. Potential shallow aquifer problems of brackish water may be present and should be evaluated as part of any exploration effort in that area.

In the Alluvial Plain area, local areas of thick alluvial sand and gravel above 350 feet represent the best potential for development of ground-water sources. Two areas have been identified, one to the north near City of Brentwood Wells 6, 7, and 8, and an area to the south near City Well 13. In the southern area, additional exploration to the northeast may allow mapping of the sand beds of the channel sequence. Exploration between the north and south area is recommended to evaluate the possibility of correlation between the two areas, which may reveal a greater distribution of aquifer units suitable for ground-water extraction.

Some development of deeper aquifers below 300 feet has occurred, but has resulted in low well yields (less than 400 gpm capacity) due to poor aquifer characteristics, although good water quality was encountered (Brentwood Well 13). In general, it is suspected that high yielding wells (1,000 gpm capacity or more) suitable for municipal or irrigation needs will only be found in the alluvium to about 300 to 350 feet in depth. Shallow water quality has been found to be degraded by the presence of nitrate in the upper 100 to 200 feet of the alluvium zone and must be considered in well development programs. Exploration to the east, outside of the trends of the stream channel sand zones, is not likely to be encouraging based on the results of this subsurface investigation.

The area west of Oakley towards Antioch is poorly defined, but is suspected to be a poor ground-water supply region due to lack of alluvium deposits and possible brackish water quality problems. The Byron area shows very low exploration potential due to limited sand beds present and its apparent marginal relationship to the greater Alluvial Plain region in which Brentwood is central as well as representative.

Recommendations

The east County water entities are in a position to manage ground-water resources at a point in time that impacts of future development can readily be assessed for a system which has been relatively stable over several decades. Considering the vertical extent as well as the quality of aquifer materials present in the study area, the entities should prepare to react to any adverse changes in the historical water level and flow patterns caused by changes in extraction patterns. This need is underscored by the fact that water quality is poor in many areas (e.g., high TDS and nitrate) and the aquifer system is limited areally and vertically (i.e., to depths of about 400 feet) as reflected in the geologic cross sections constructed for this investigation.

The east County entities should be concerned with any increment of ground-water extraction that results in downward trends in water levels or shifts in flow direction. The affected entities should consider instituting a program to monitor conditions on a periodic basis. Since the basin extends across multiple boundaries of influence, it would be beneficial to share information in order to completely depict regional ground-water conditions. This program should consist of:

- identification of key wells for water level monitoring and water quality testing.
- updating hydrographs for key wells on a semi-annual (spring and fall) basis.
- updating water level contour maps on a semi-annual (spring and fall) basis.
- production of an annual report which incorporates updated hydrographs, contour maps, and water quality test results; the report should highlight any significant changes in ground-water use patterns.

Such a program is conducted in many major ground-water basins in the State. The various maps and hydrographs created for this investigation can serve as initial products of an ongoing monitoring program. These products can be easily interpreted for ground-water management purposes including protection of water quality and limiting of extraction to the sustainable yield of the basin. They would also be useful with efforts to increase sustainable yield, correspondingly increasing pumpage, by management actions such as augmenting recharge and treatment of high TDS and/or nitrate-contaminated water.

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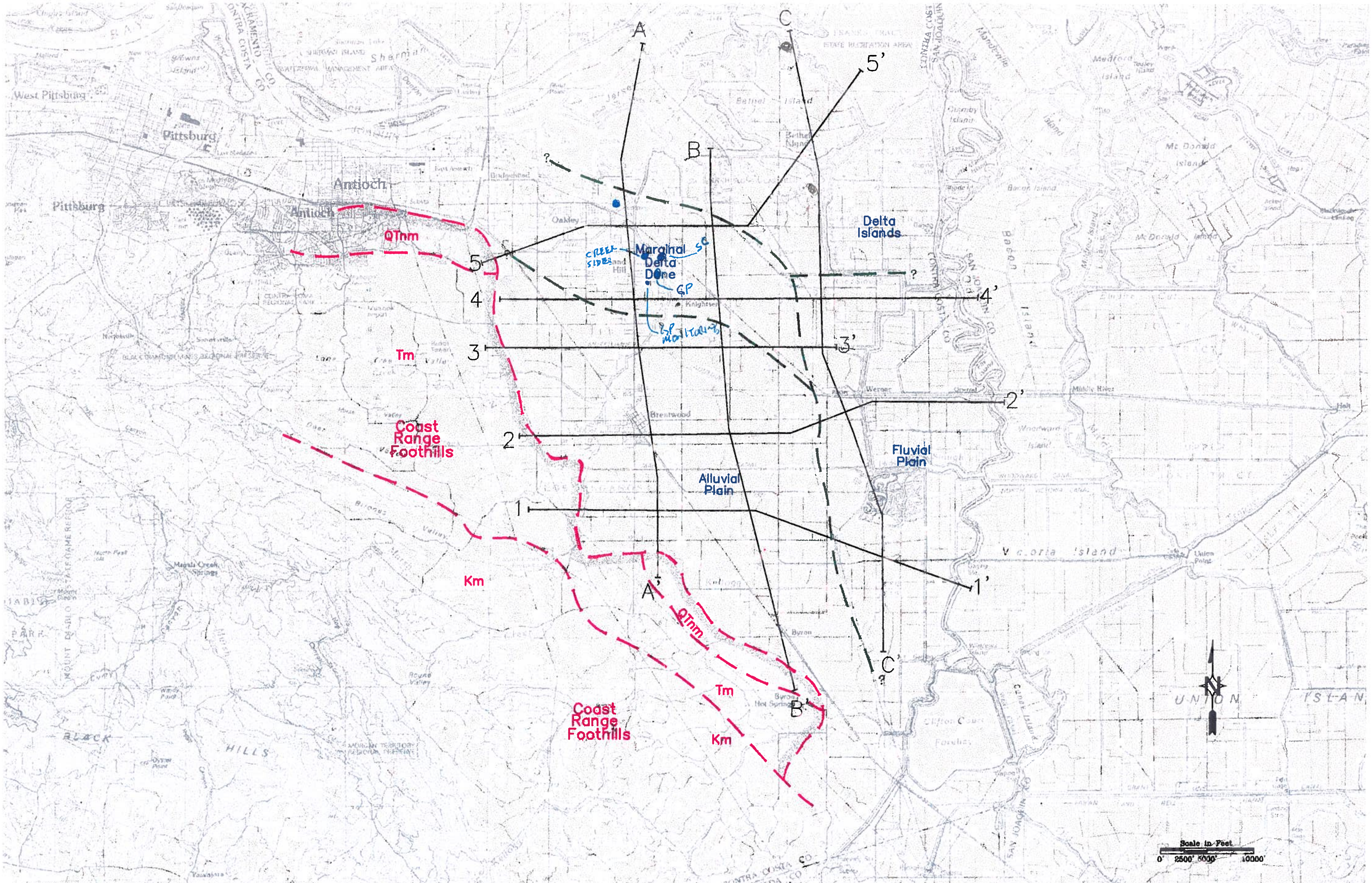
EXHIBITS



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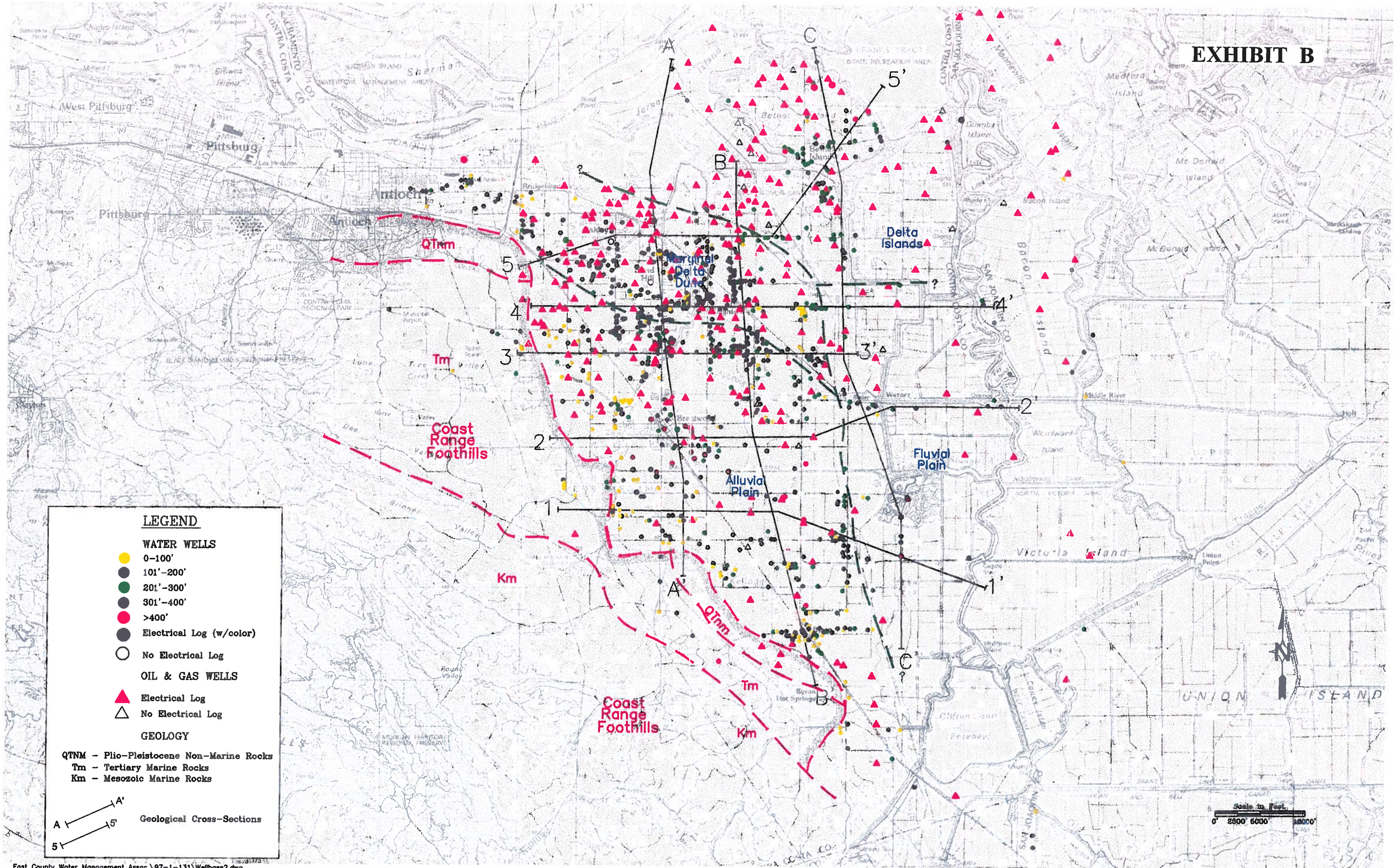
Base Map
East County Water Management Association
Ground-Water Resources Assessment



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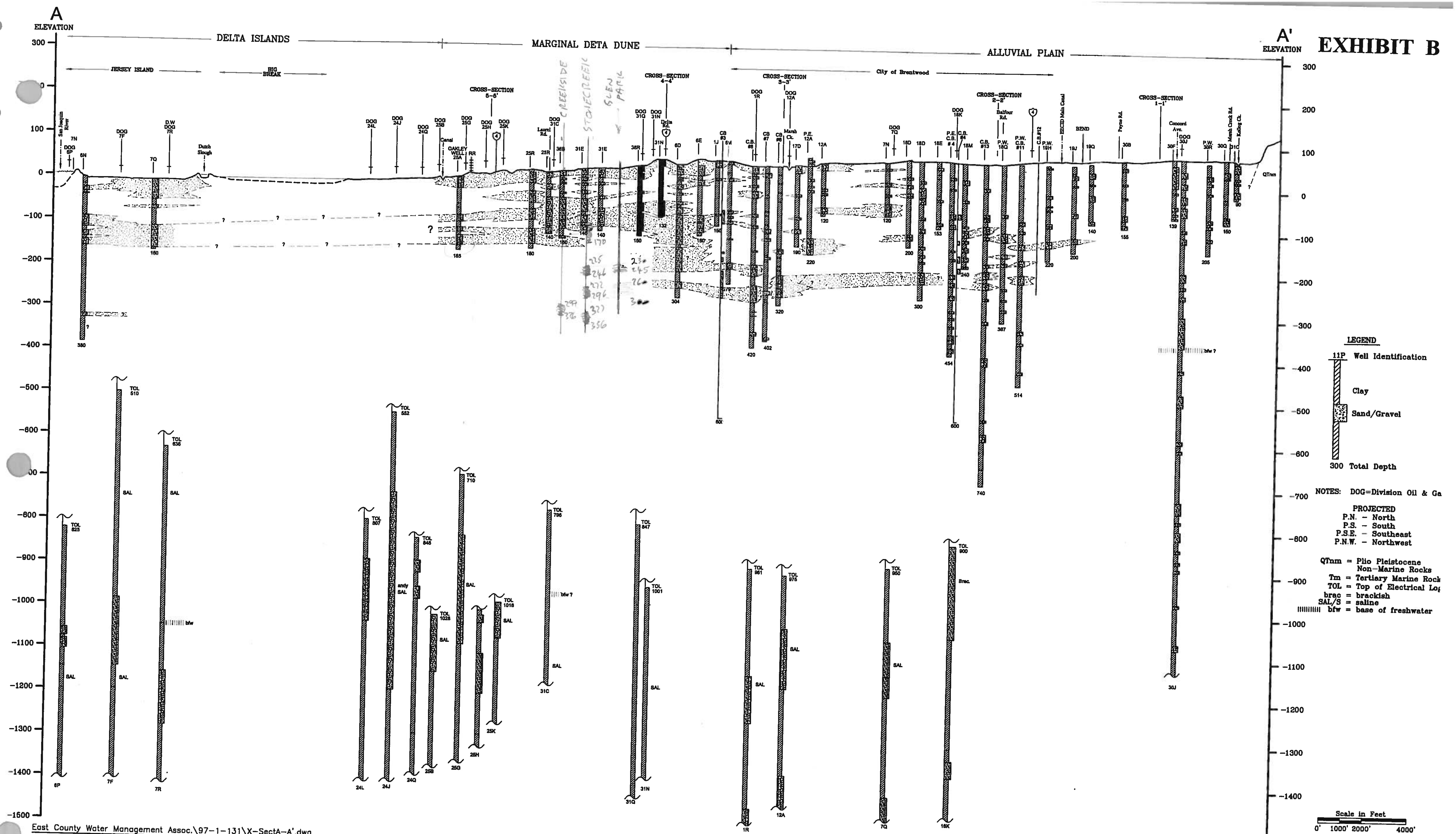
CONSULTING ENGINEERS

Well Map
East County Water Management Association
Ground-Water Resources Assessment

GEOLOGIC CROSS SECTIONS

EXHIBIT B



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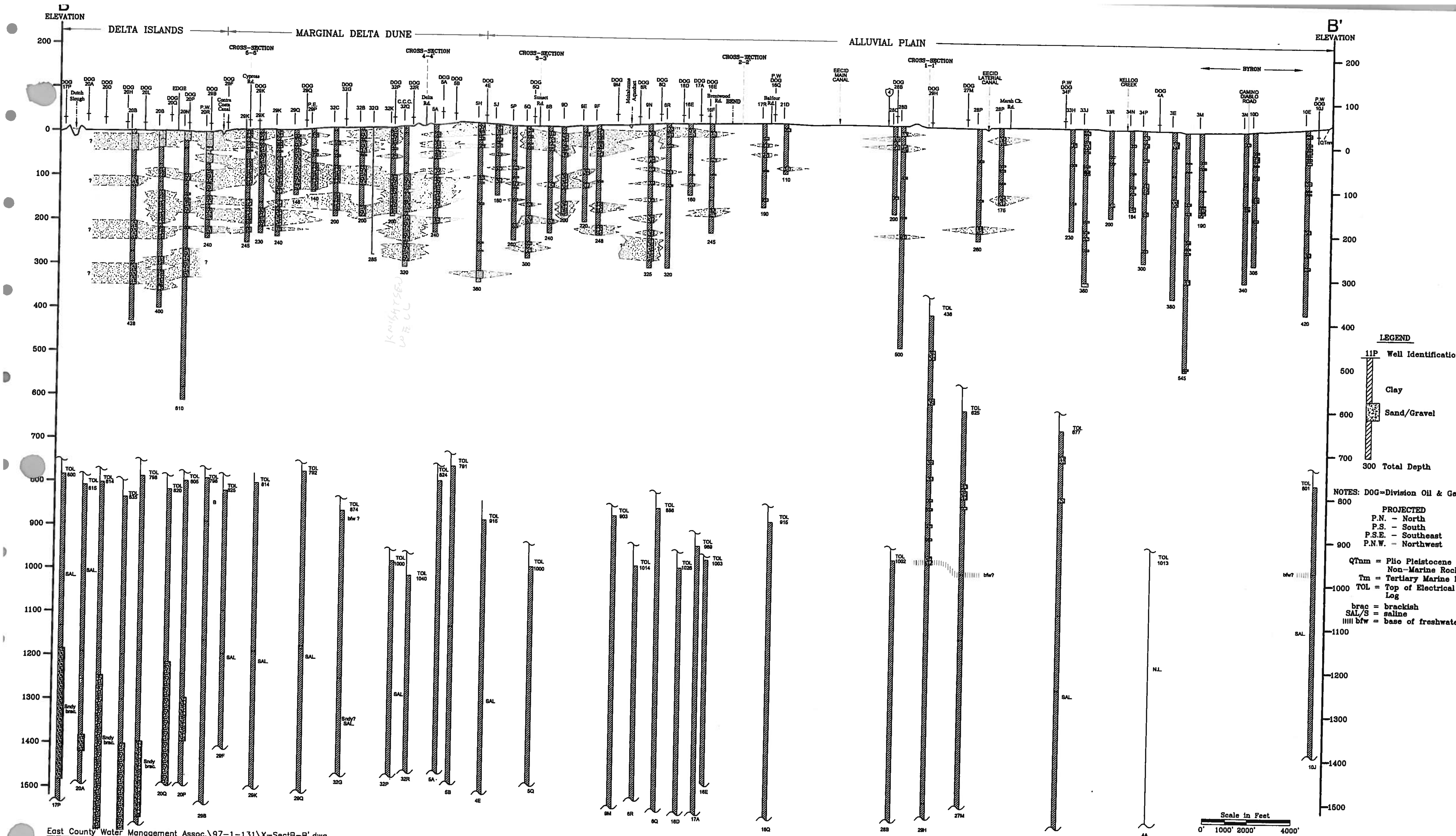
Geologic Cross Section A-A'
East County Water Management Association
Ground-Water Resources Assessment



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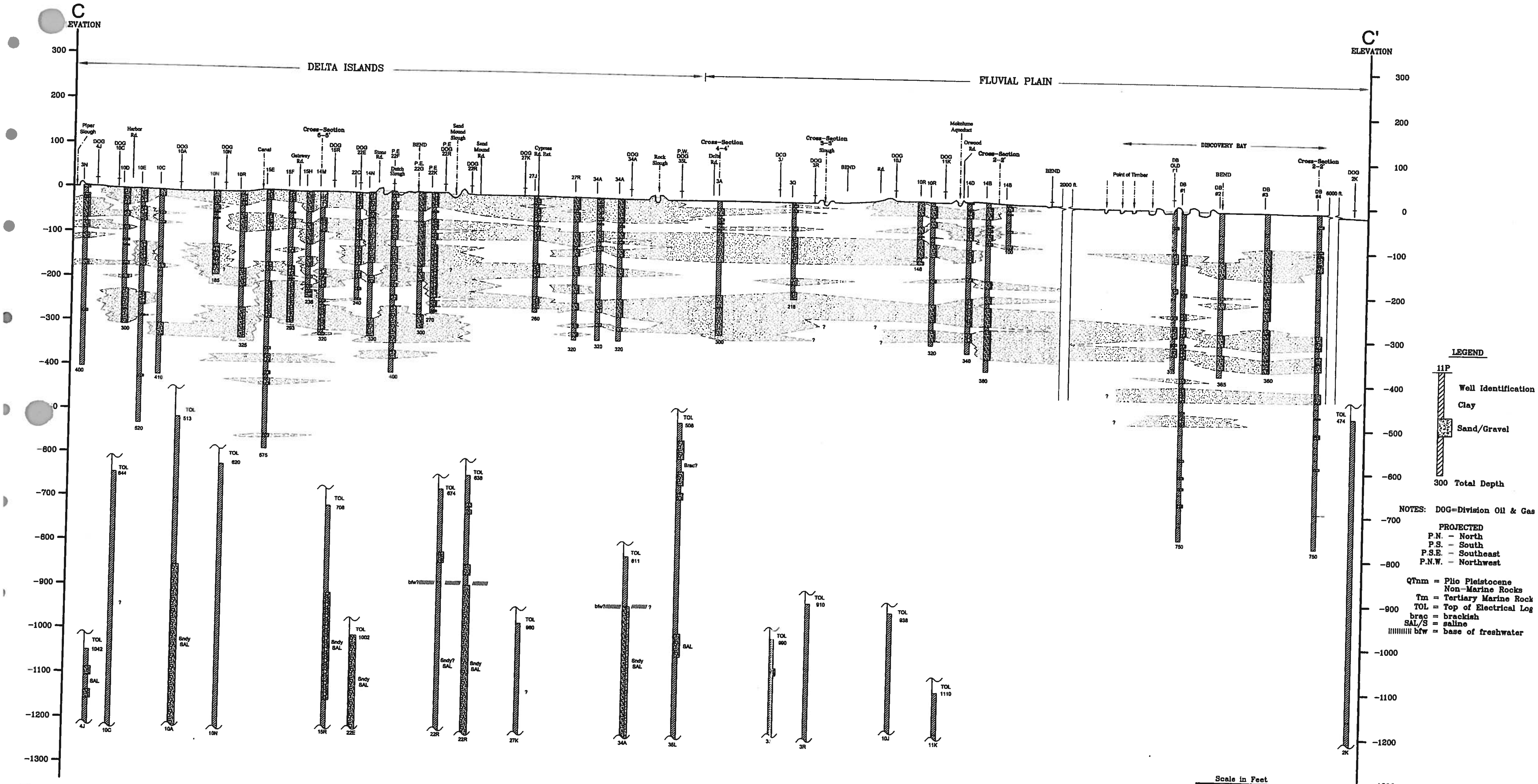

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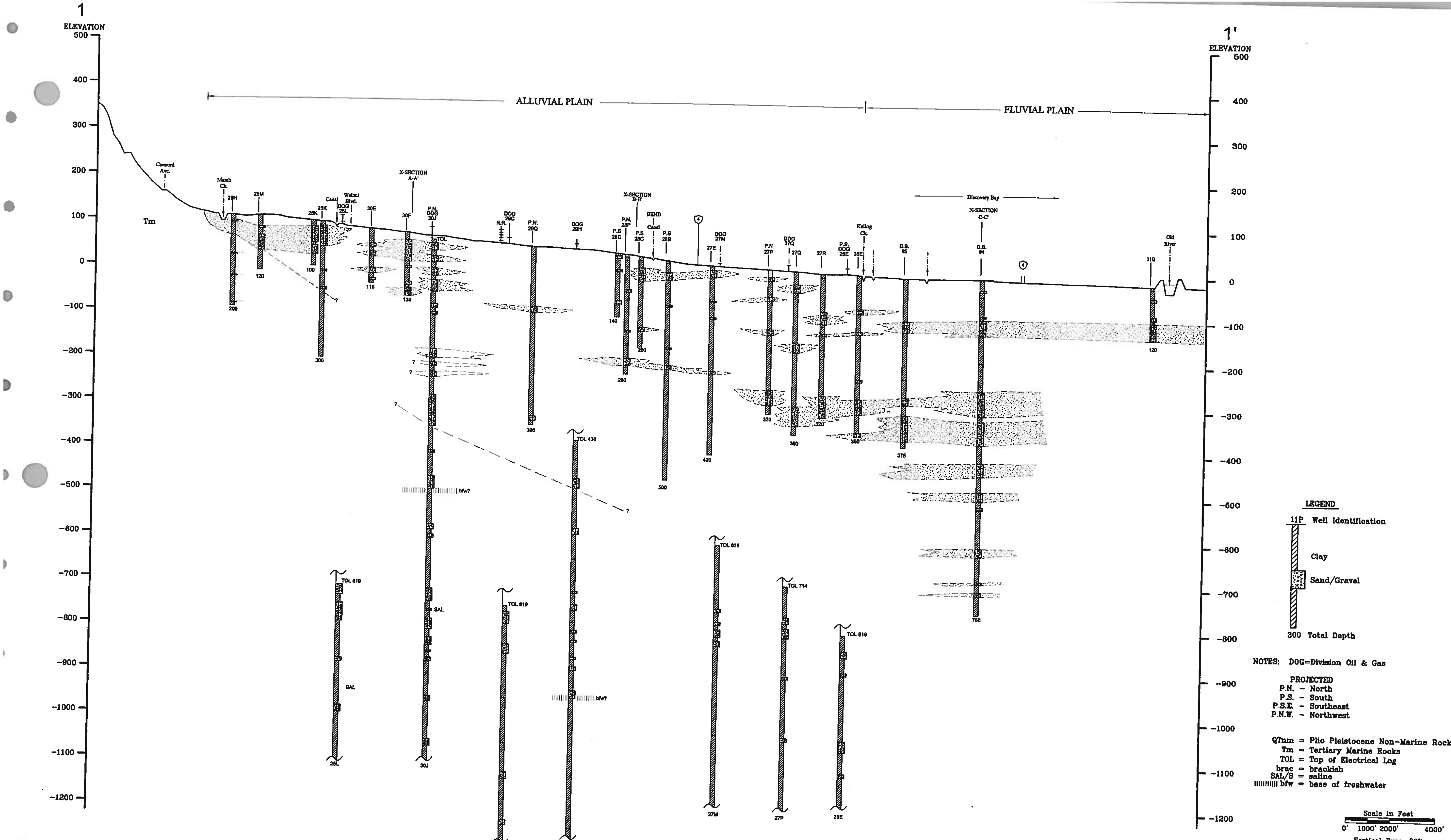
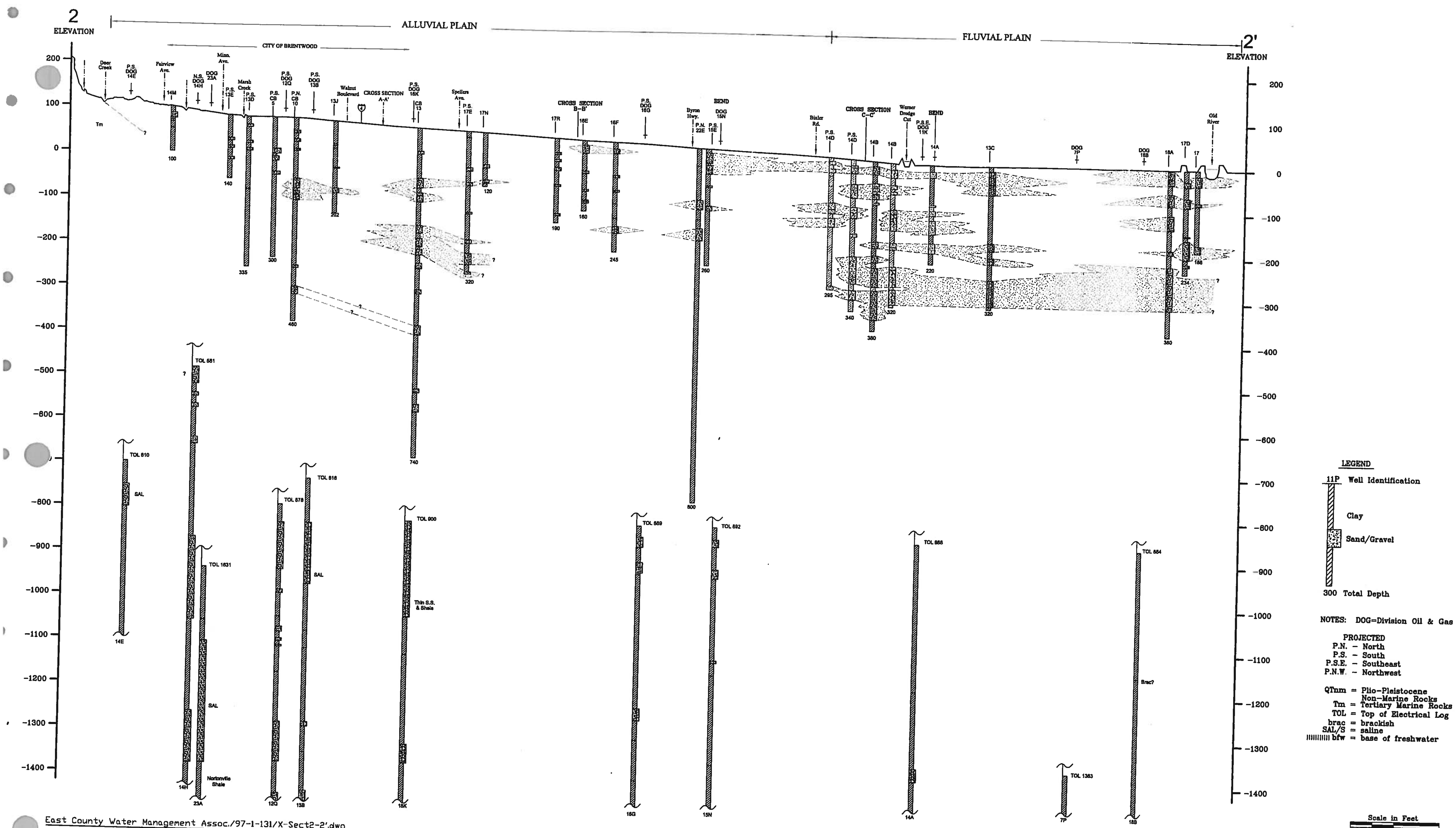
Geologic Cross-Section C-C'
East County Water Management Association
Ground-Water Resources Assessment



East County Water Management Assoc./97-1-131/X-Sect1-1'.dwg

LUHDORFF & SCALMANINI
CONSULTING ENGINEERS

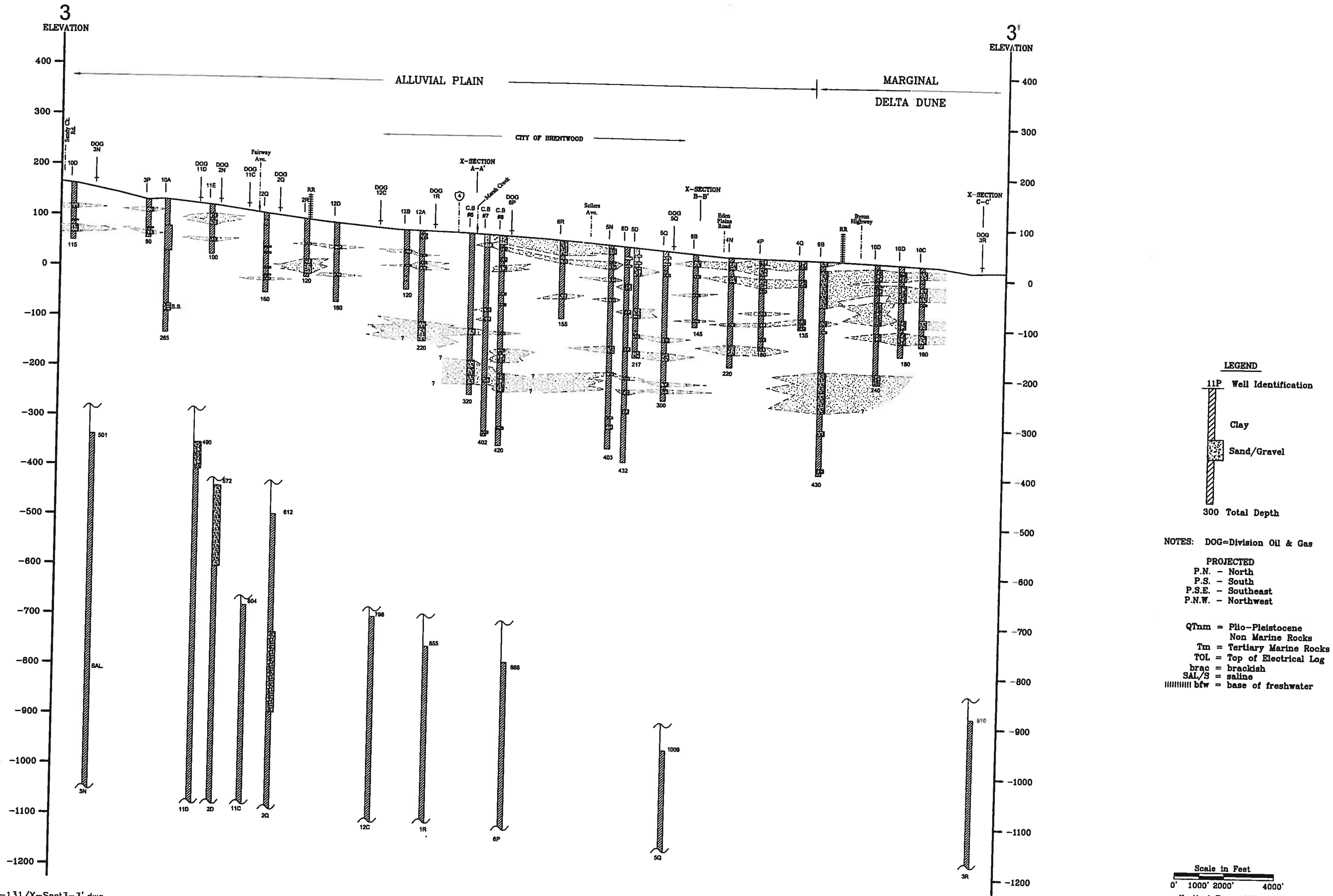
Geologic Cross Section 1-1'
East County Water Management Association
Ground-Water Resources Assessment



East County Water Management Assoc./97-1-131/X-Sect2-2'.dwg

LUHDORFF & SCALMANINI
CONSULTING ENGINEERS

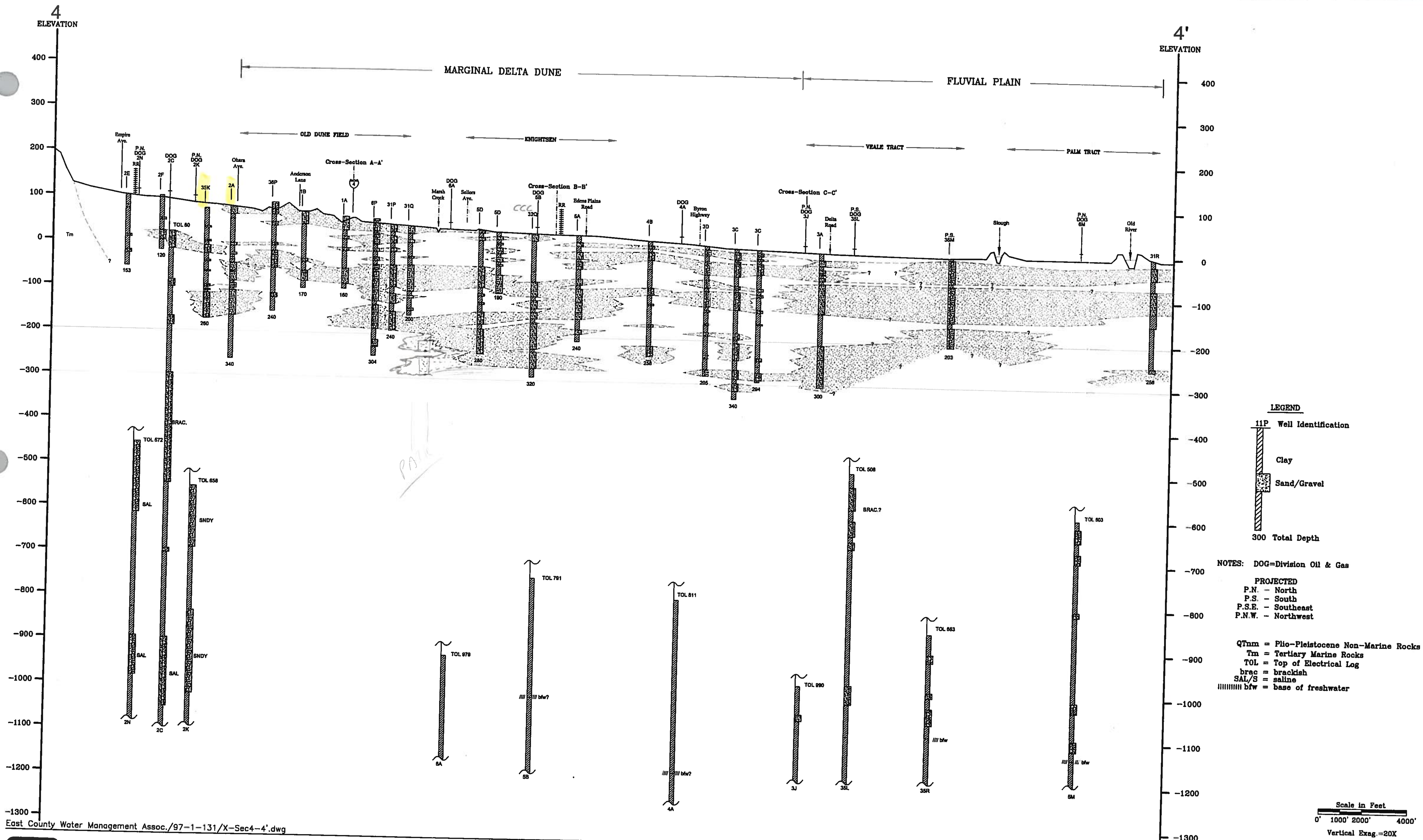
Geologic Cross Section 2-2'
East County Water Management Association
Ground-Water Resources Assessment



East County Water Management Assoc./97-1-131/X-Sect3-3'.dwg

LUHDORFF & SCALMANINI
CONSULTING ENGINEERS

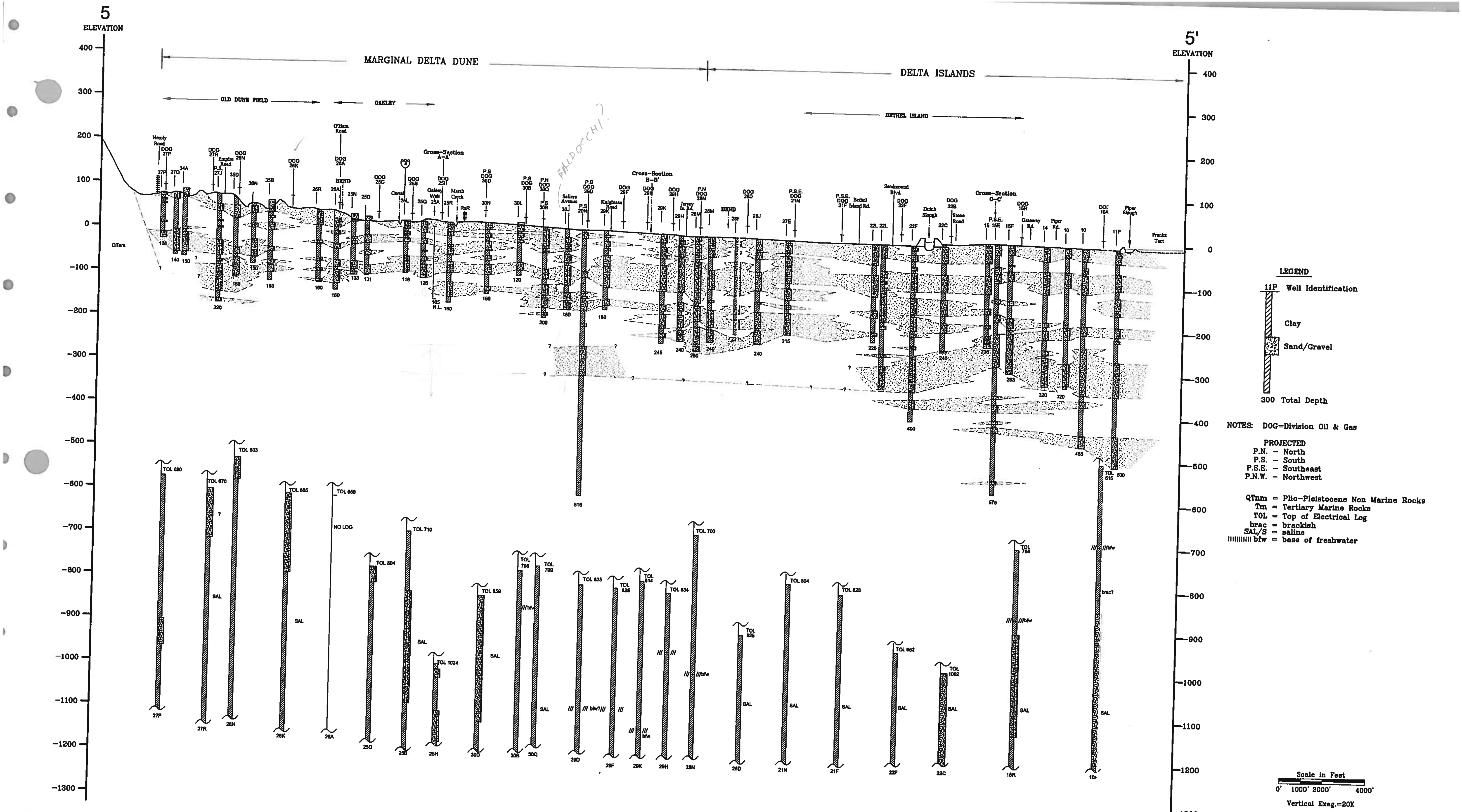
Geologic Cross Section 3-3'
East County Water Management Association
Ground-Water Resources Assessment



East County Water Management Assoc./97-1-131/X-Sec4-4'.dwg

LUHDORFF & SCALMANINI
CONSULTING ENGINEERS

Geologic Cross Section 4-4'
East County Water Management Association
Ground-Water Resources Assessment

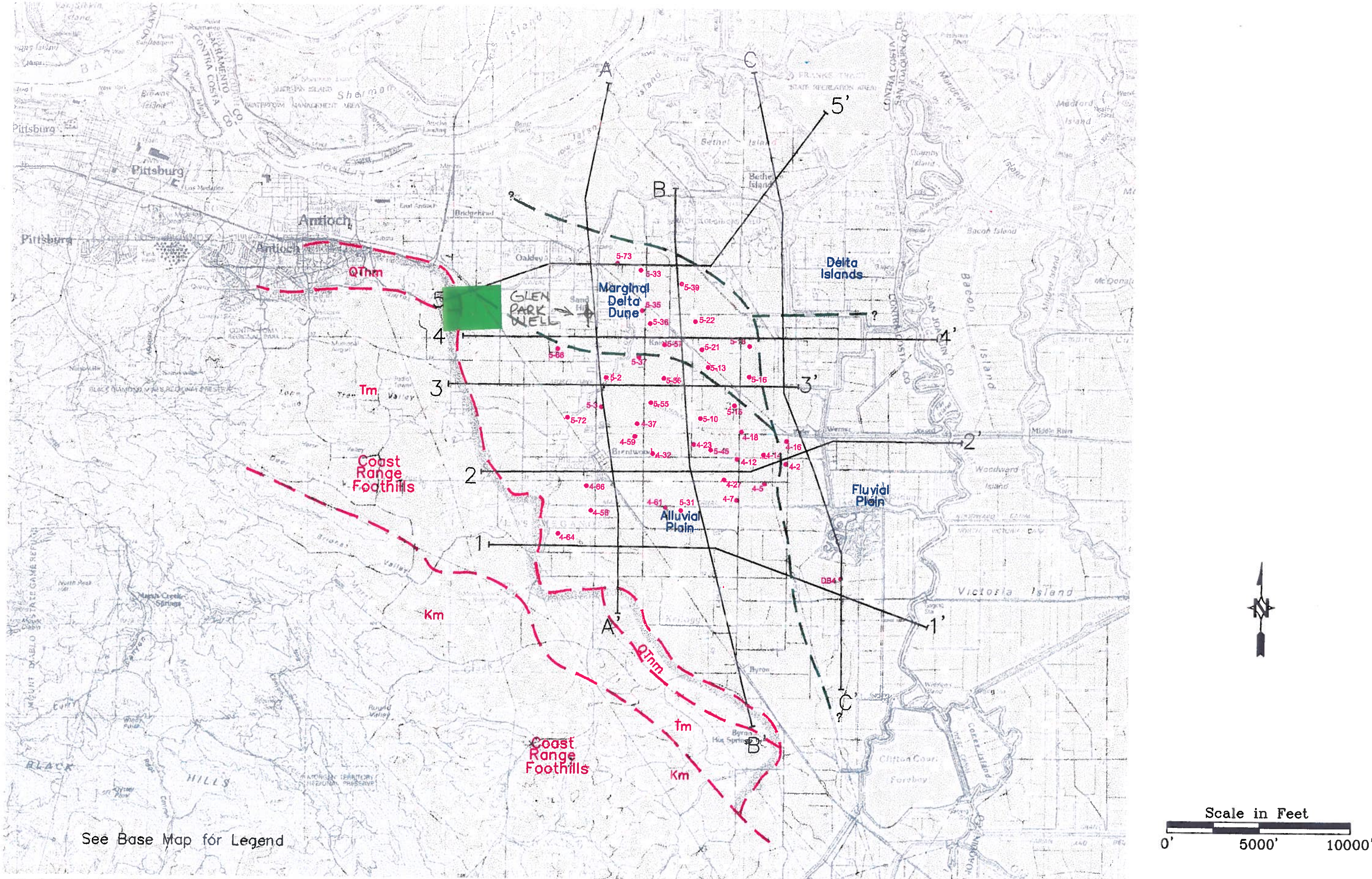


East County Water Management Assoc./97-1-131/X-Sect5-5'.dwg

LUHDORFF & SCALMANINI
CONSULTING ENGINEERS

Geologic Cross Section 5-5'
East County Water Management Association
Ground-Water Resources Assessment

WATER LEVEL INFORMATION

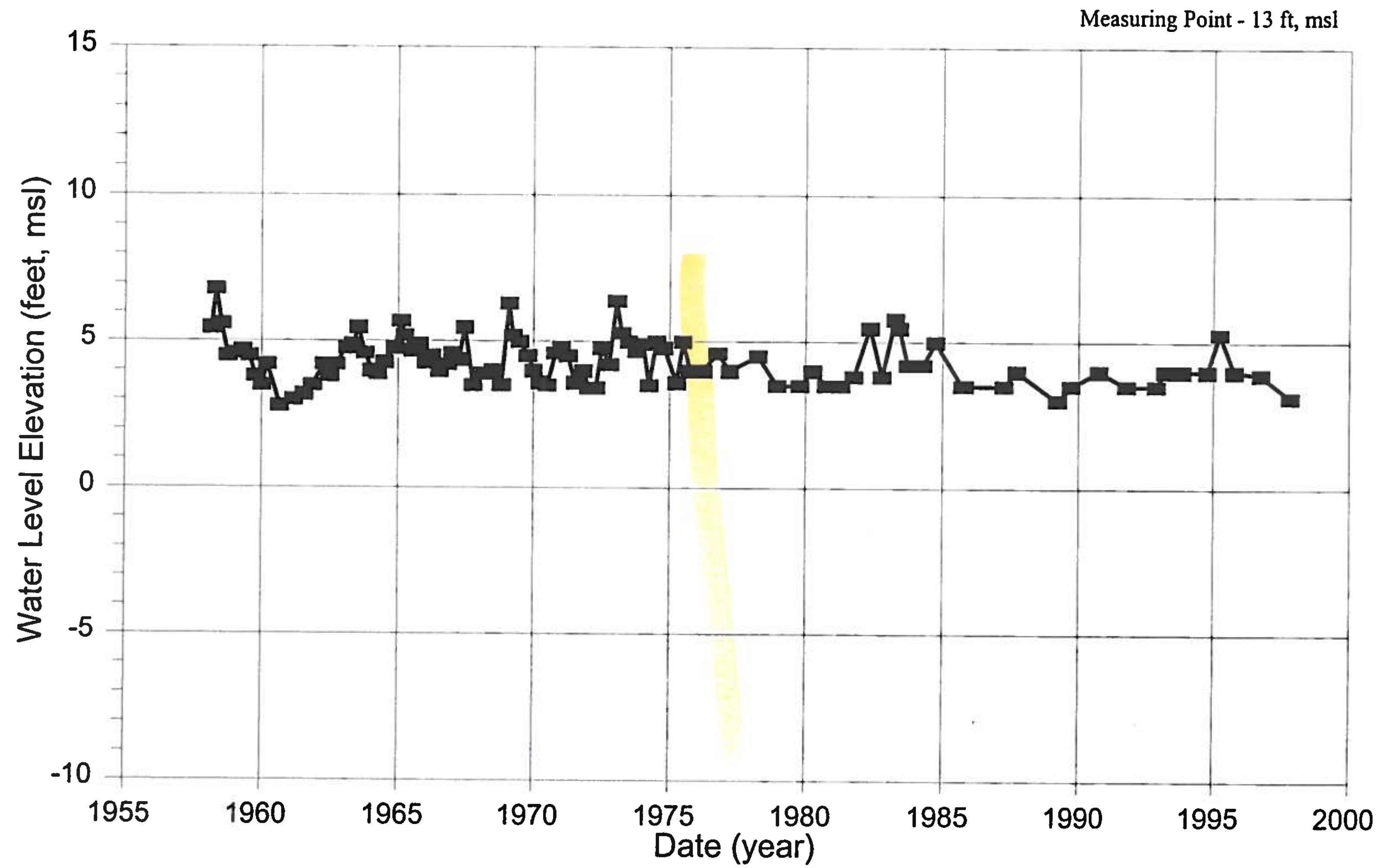


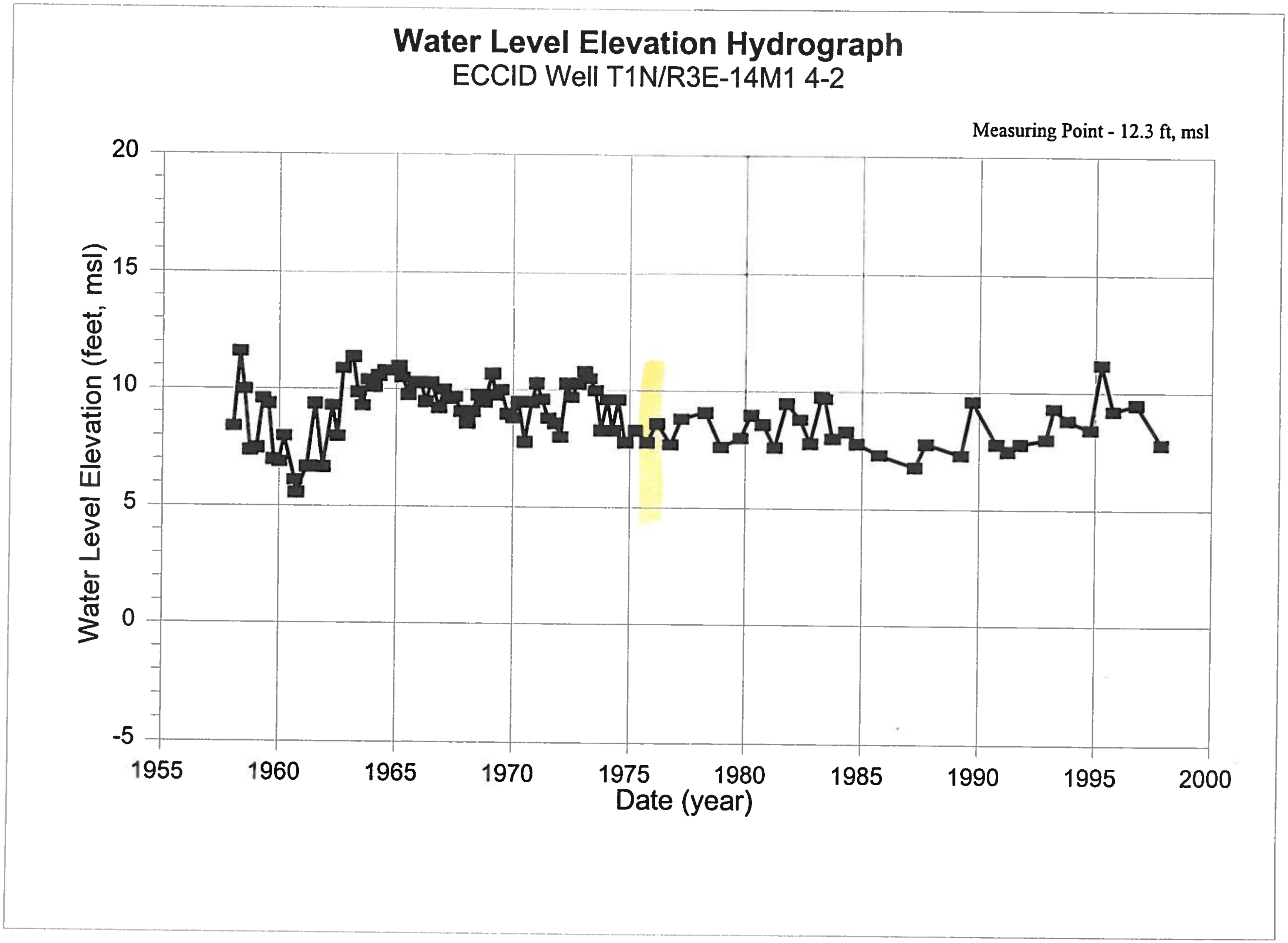
LUHDORFF & SCALMANINI CONSULTING ENGINEERS

Well Hydrograph Location Map
East County Water Management Association
Ground-Water Resources Assessment

Water Level Elevation Hydrograph

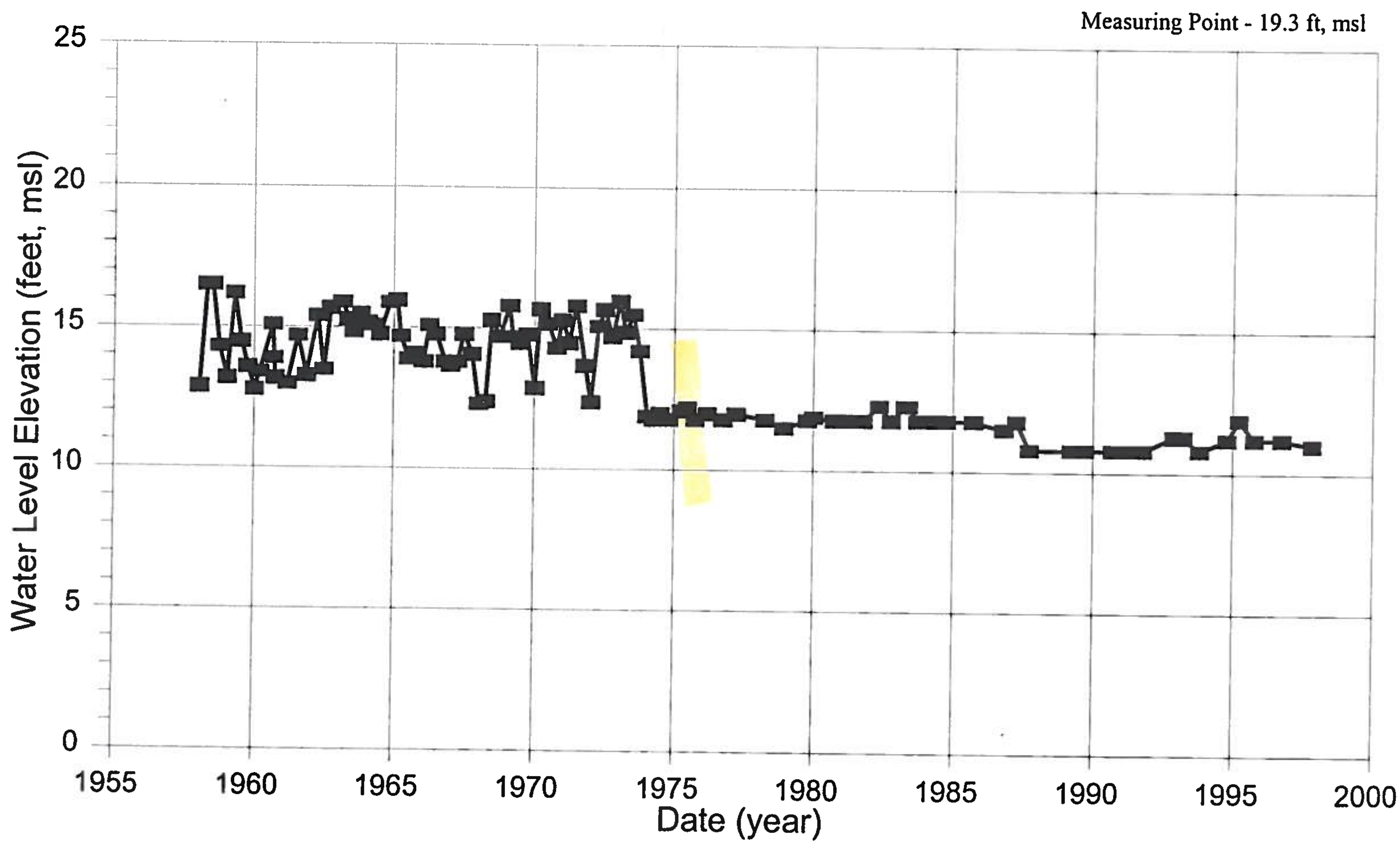
ECCID Well T1N/R3E-22J1 4-1

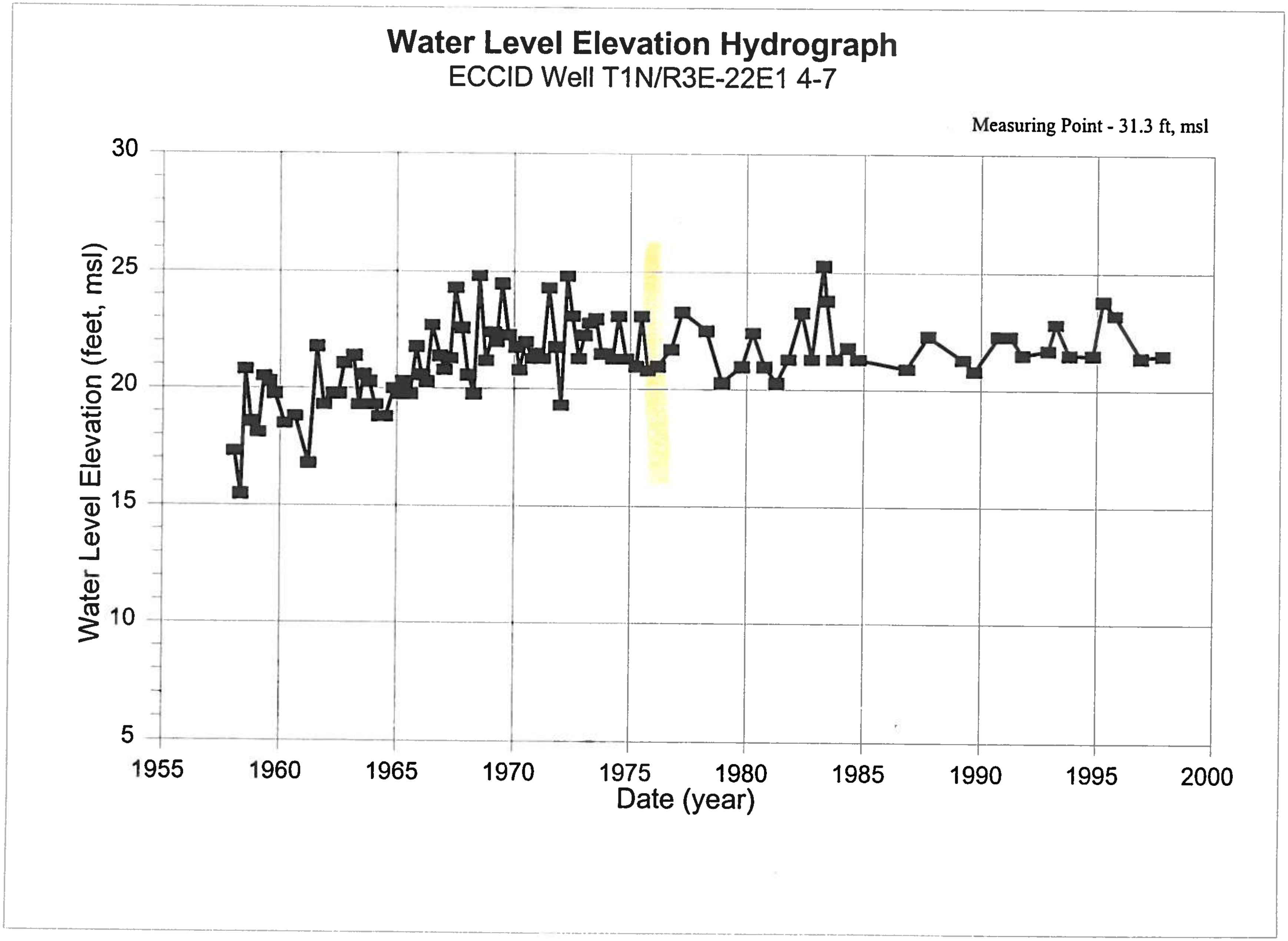


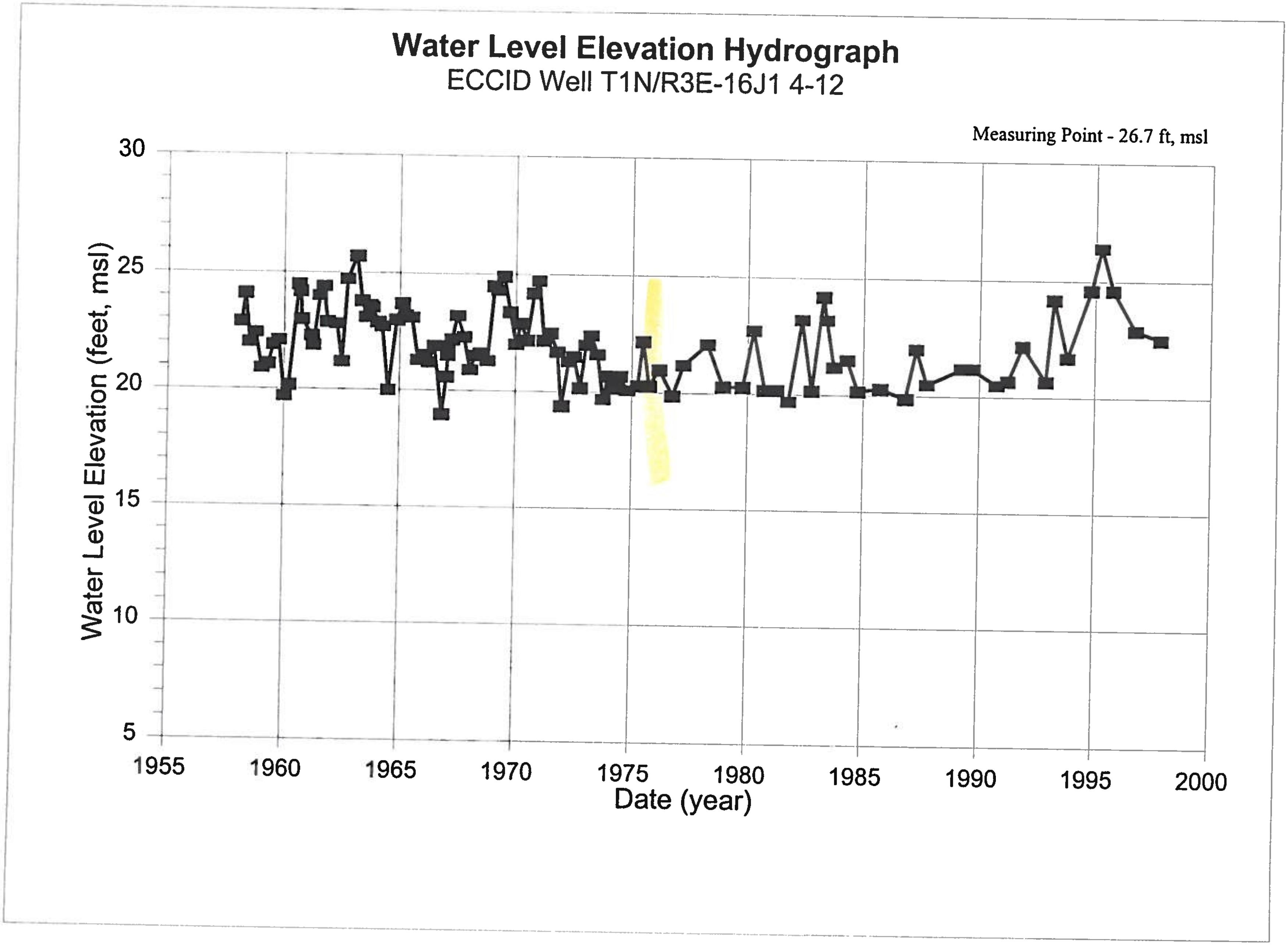

Water Level Elevation Hydrograph
ECCID Well T1N/R3E-14M1 4-2
Measuring Point - 12.3 ft, msl
Water Level Elevation (feet, msl)
20
15
10
5
0
-5
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
Date (year)

Water Level Elevation Hydrograph

ECCID Well T1N/R3E-22B2 4-5

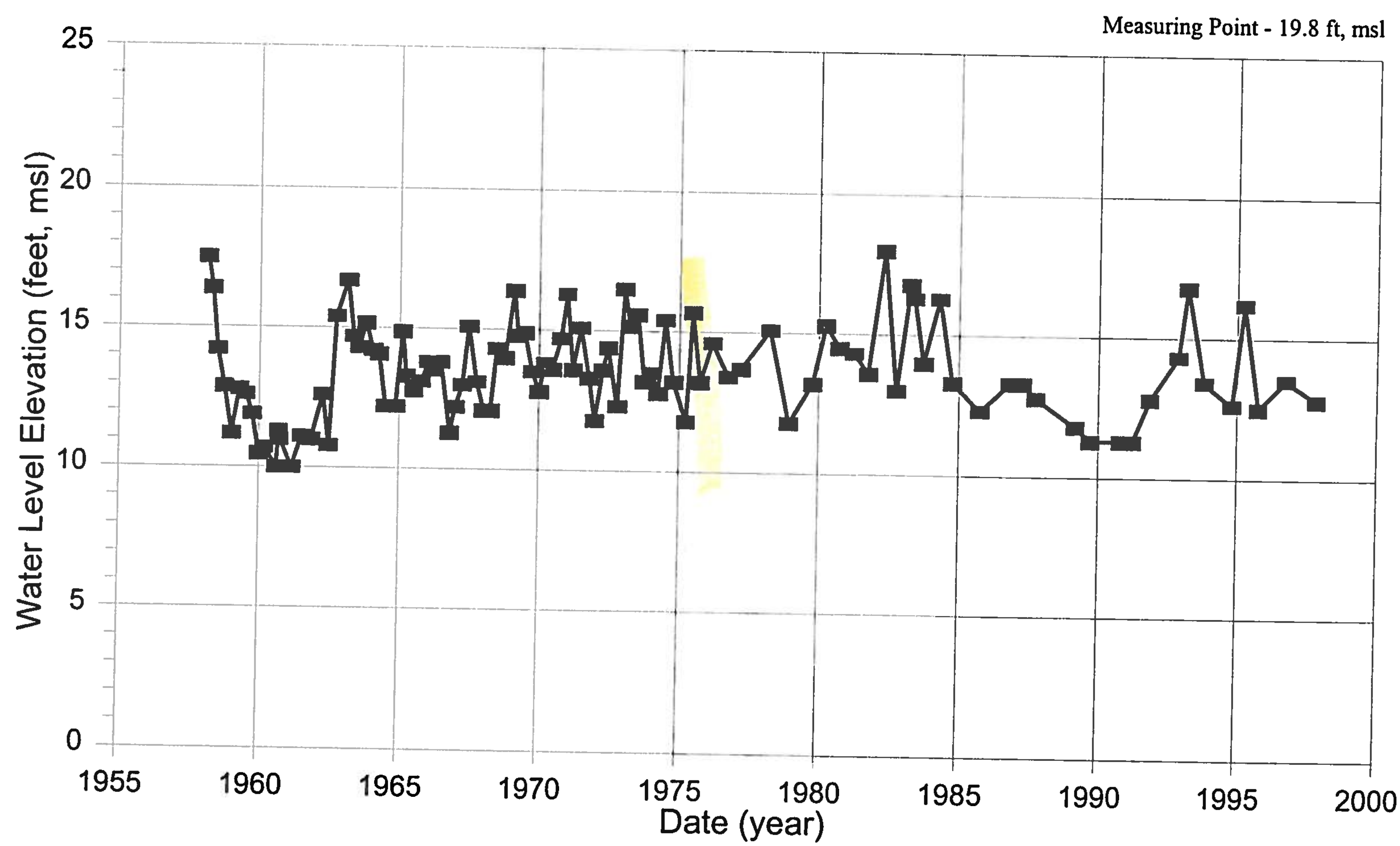


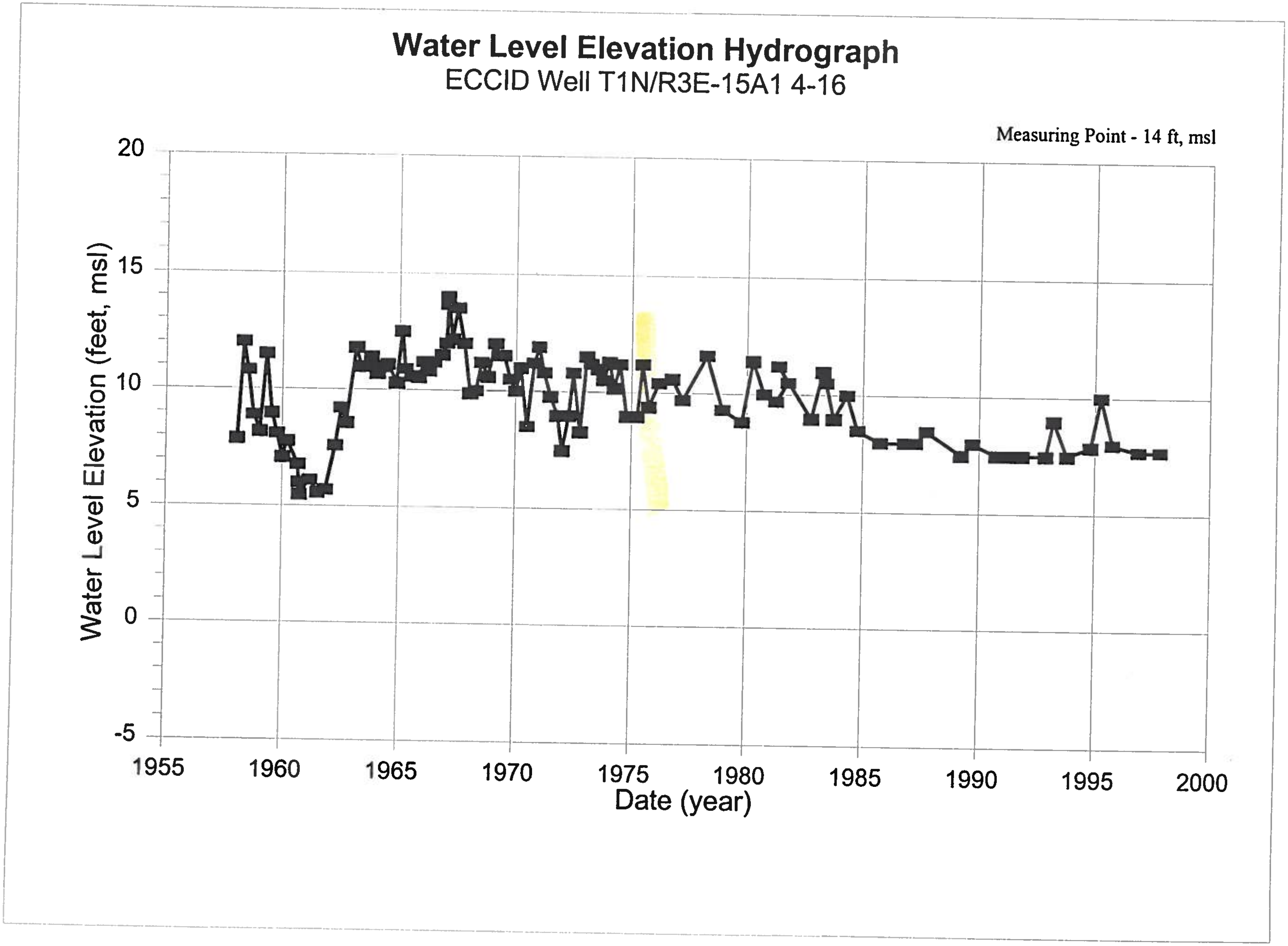

Water Level Elevation Hydrograph
ECCID Well T1N/R3E-22E1 4-7
Measuring Point - 31.3 ft, msl
Water Level Elevation (feet, msl)
30
25
20
15
10
5
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
Date (year)


Water Level Elevation Hydrograph
ECCID Well T1N/R3E-16J1 4-12
Measuring Point - 26.7 ft, msl
30
25
20
15
10
5
Water Level Elevation (feet, msl)
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
Date (year)

Water Level Elevation Hydrograph

ECCID Well T1N/R3E-15G1 4-14

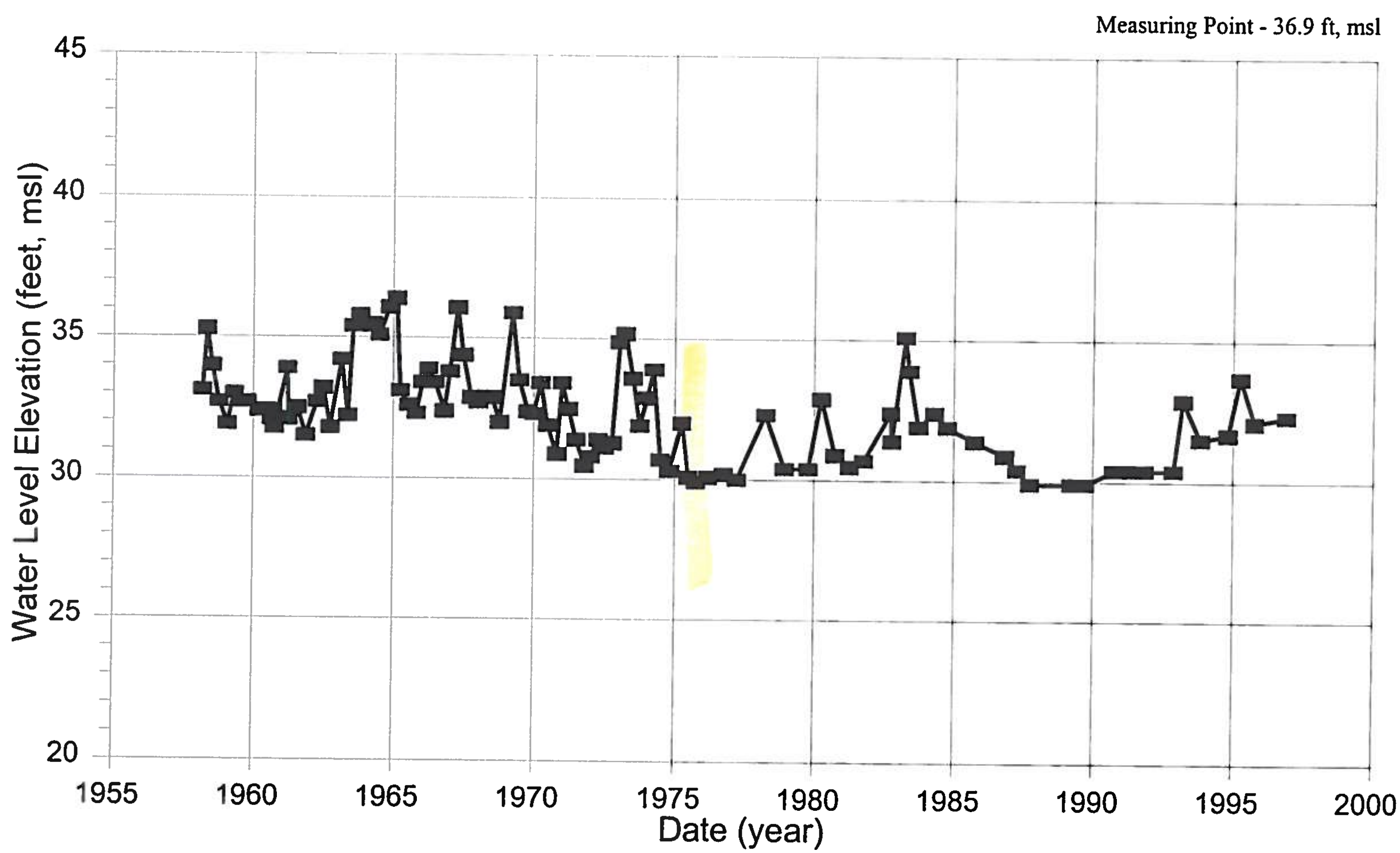


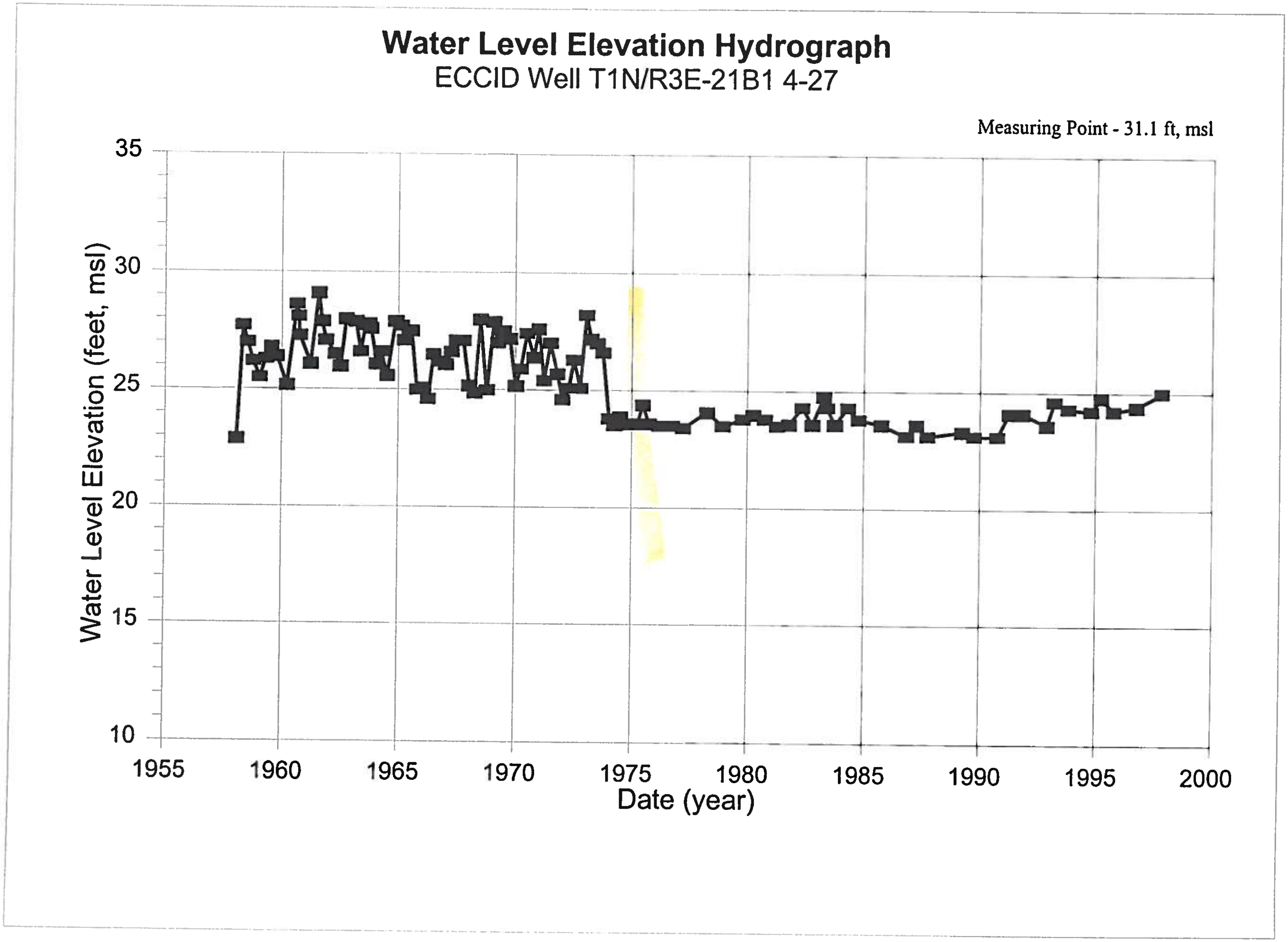


Water Level Elevation Hydrograph
ECCID Well T1N/R3E-15A1 4-16
Measuring Point - 14 ft, msl
Water Level Elevation (feet, msl)
20
15
10
5
0
-5
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
Date (year)

Water Level Elevation Hydrograph

ECCID Well T1N/R3E-16D1 4-23

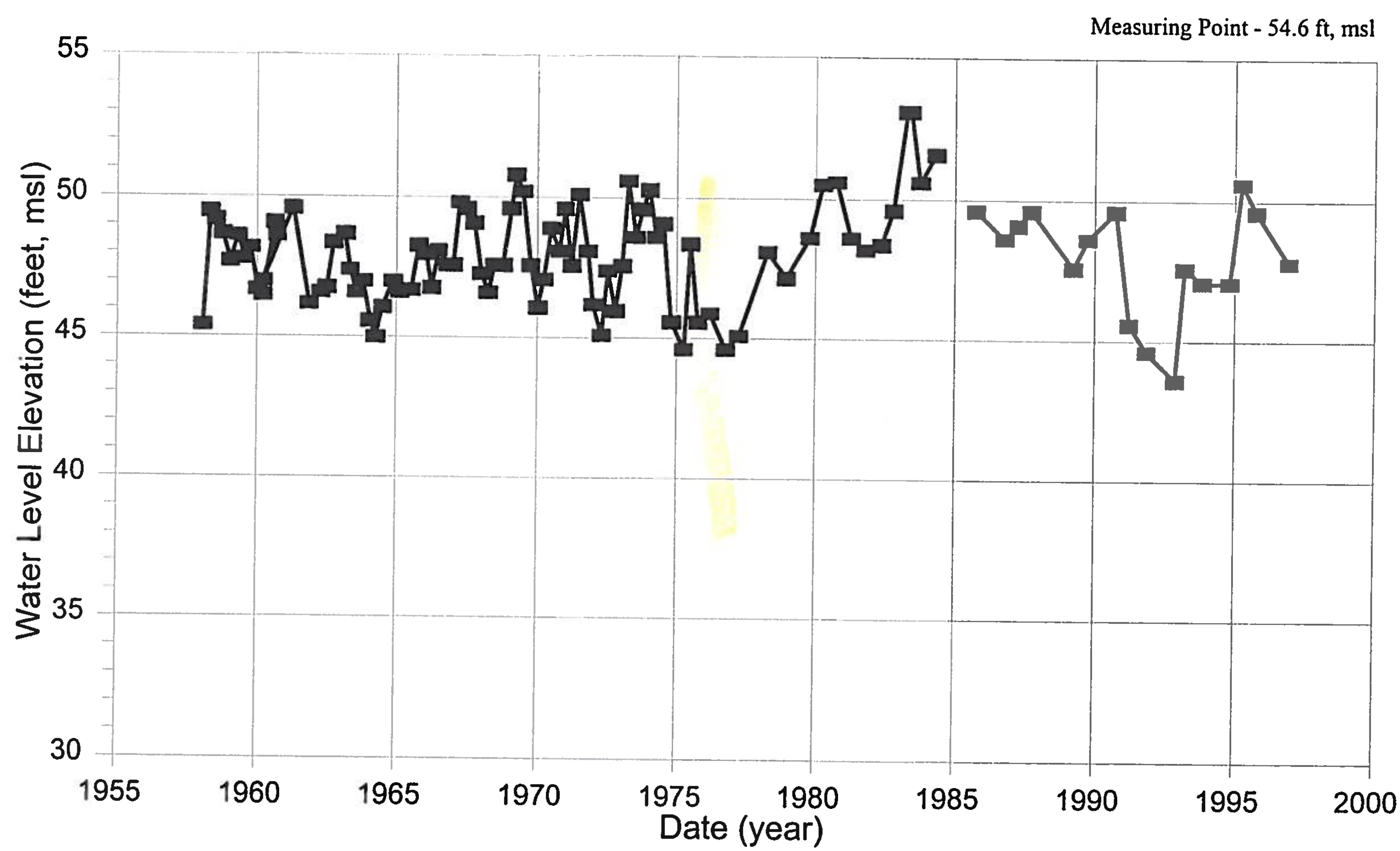


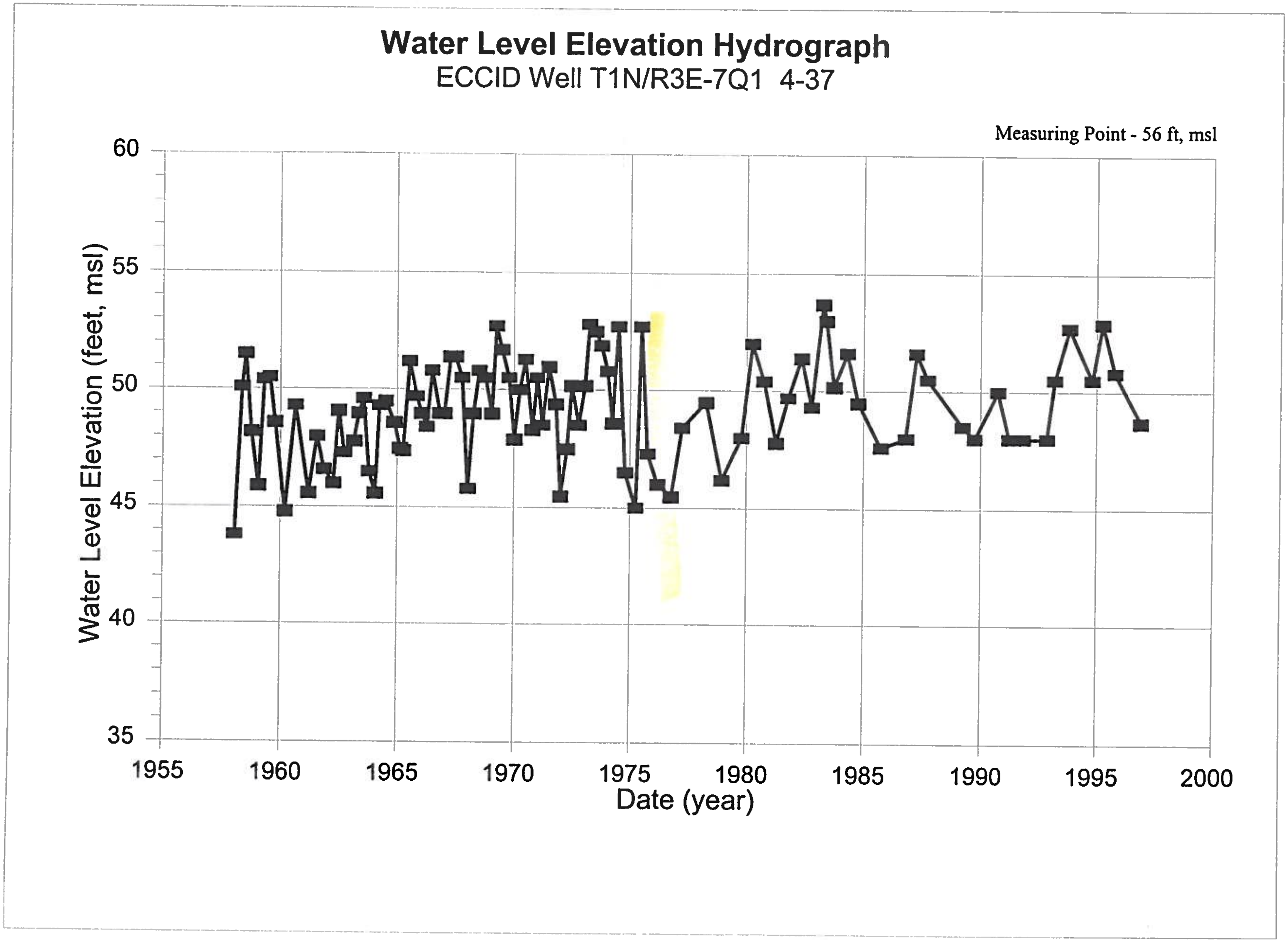


Water Level Elevation Hydrograph
ECCID Well T1N/R3E-21B1 4-27
Measuring Point - 31.1 ft, msl
Water Level Elevation (feet, msl)
35
30
25
20
15
10
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
Date (year)

Water Level Elevation Hydrograph

ECCID Well T1N/R3E-17E1 4-32





Water Level Elevation Hydrograph
ECCID Well T1N/R3E-7Q1 4-37
Measuring Point - 56 ft, msl
Water Level Elevation (feet, msl)
60
55
50
45
40
35
1955
1960
1965
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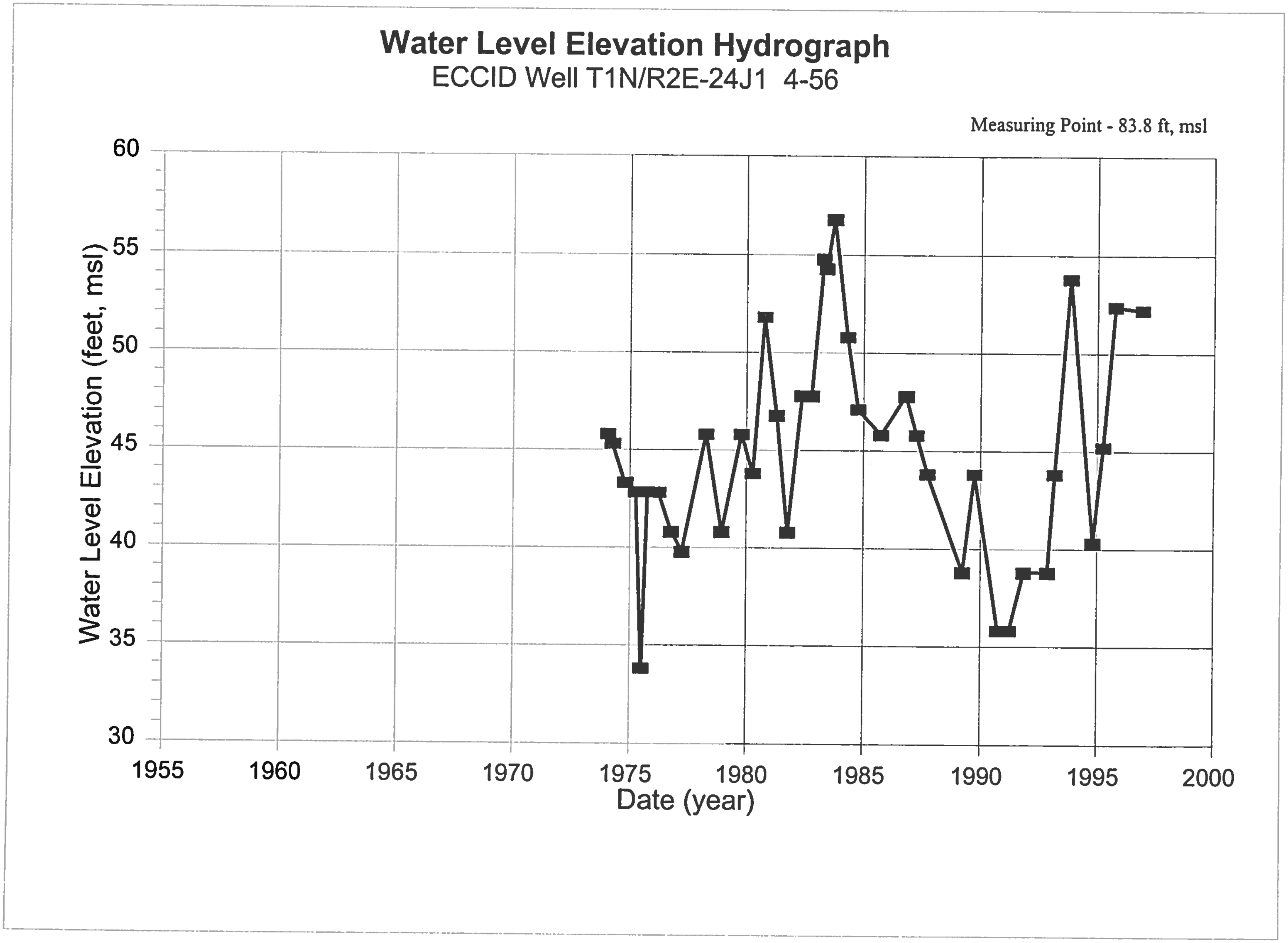
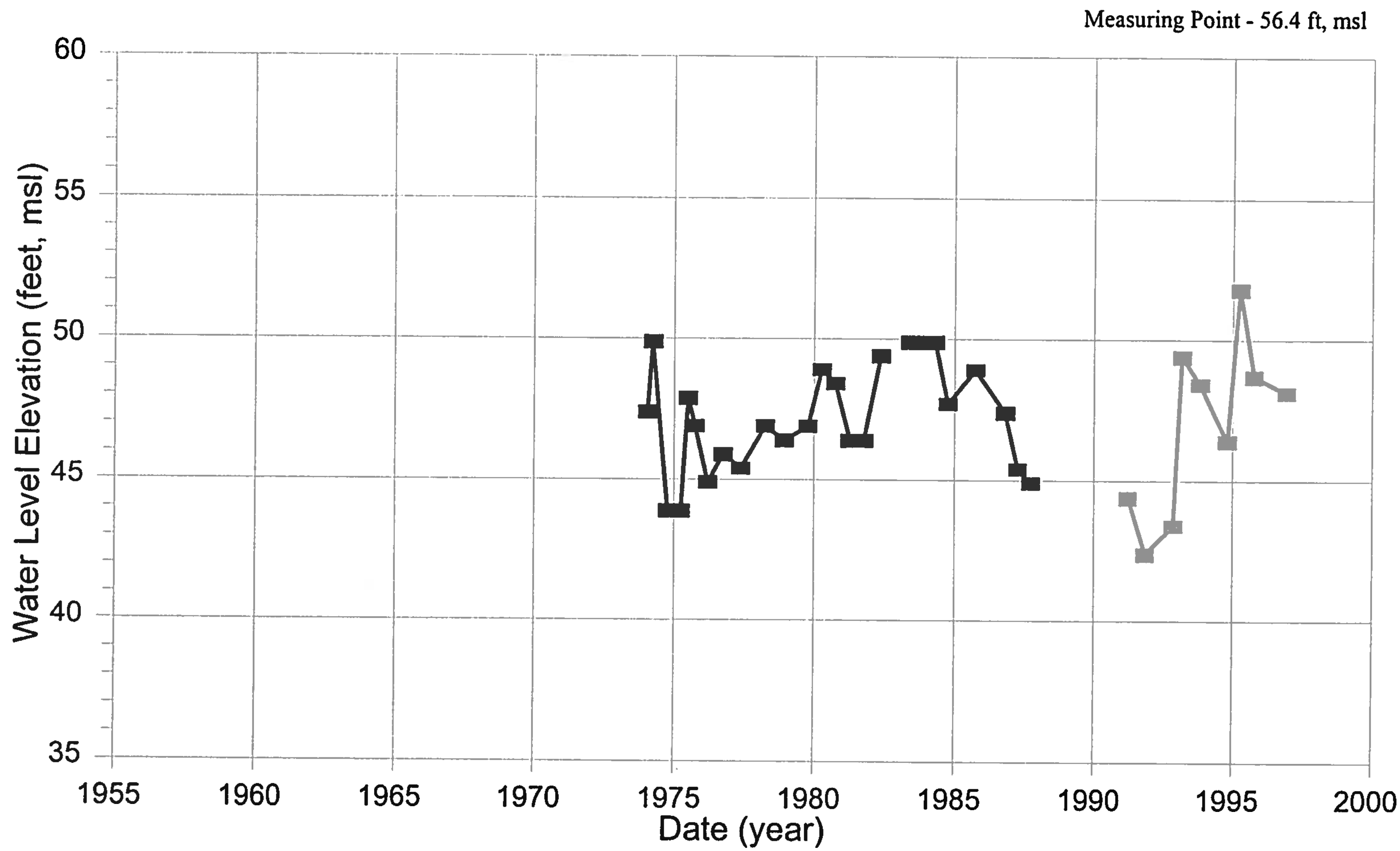
1975
1980
1985
1990
1995
2000
Date (year)

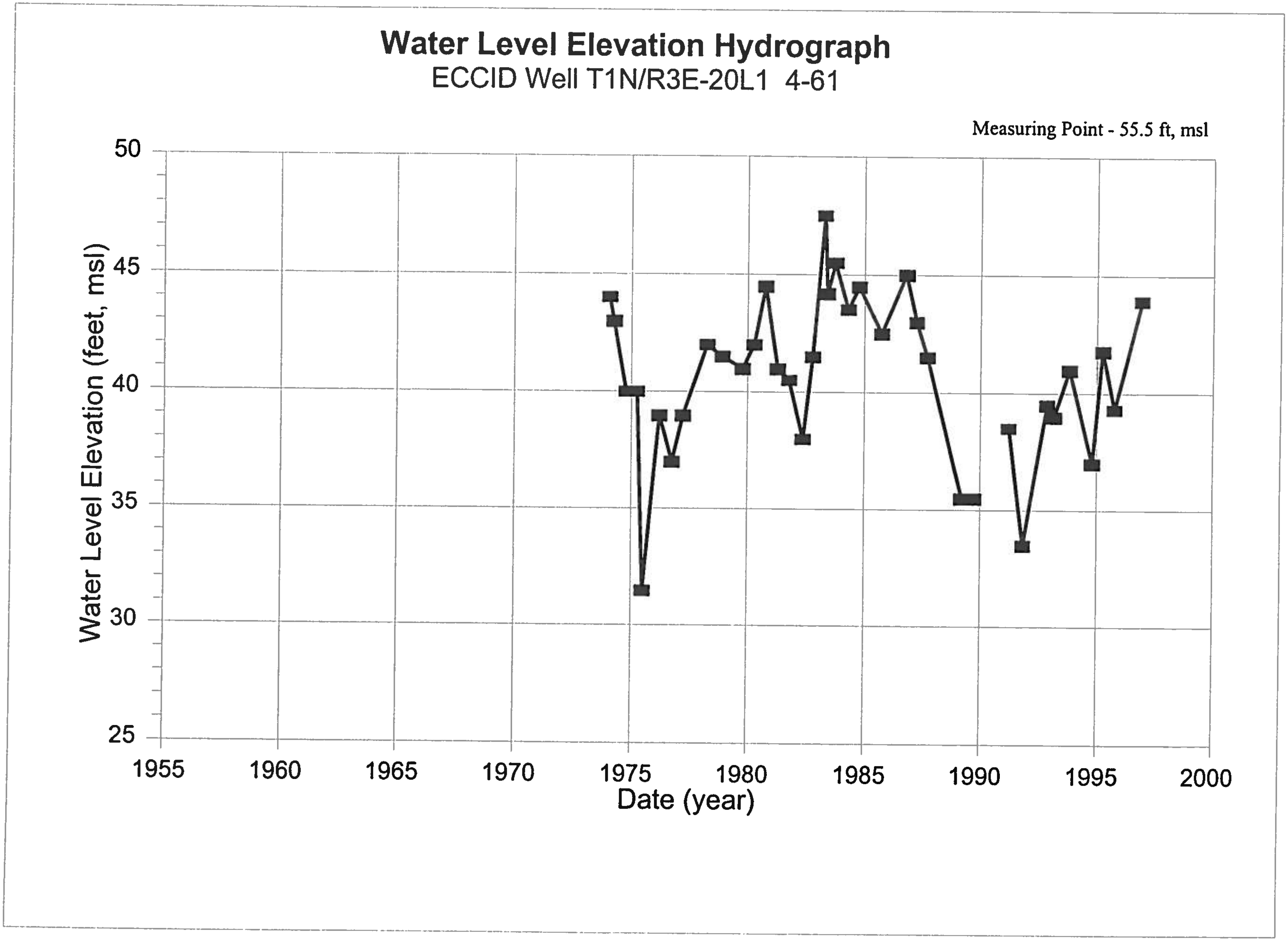


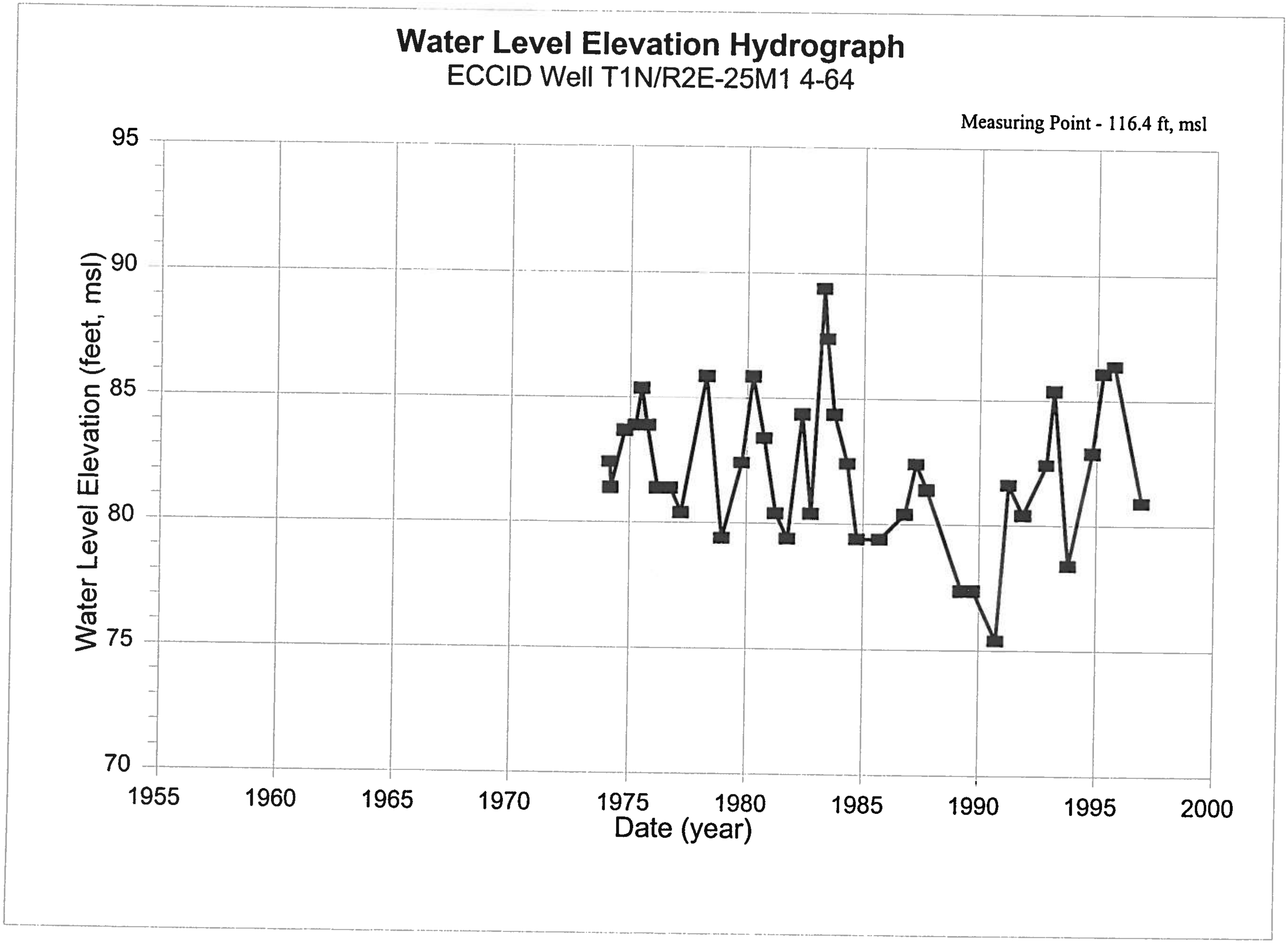
Water Level Elevation Hydrograph
ECCID Well T1N/R2E-24J1 4-56
Measuring Point - 83.8 ft, msl
Water Level Elevation (feet, msl)
60
55
50
45
40
35
30
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
Date (year)

Water Level Elevation Hydrograph

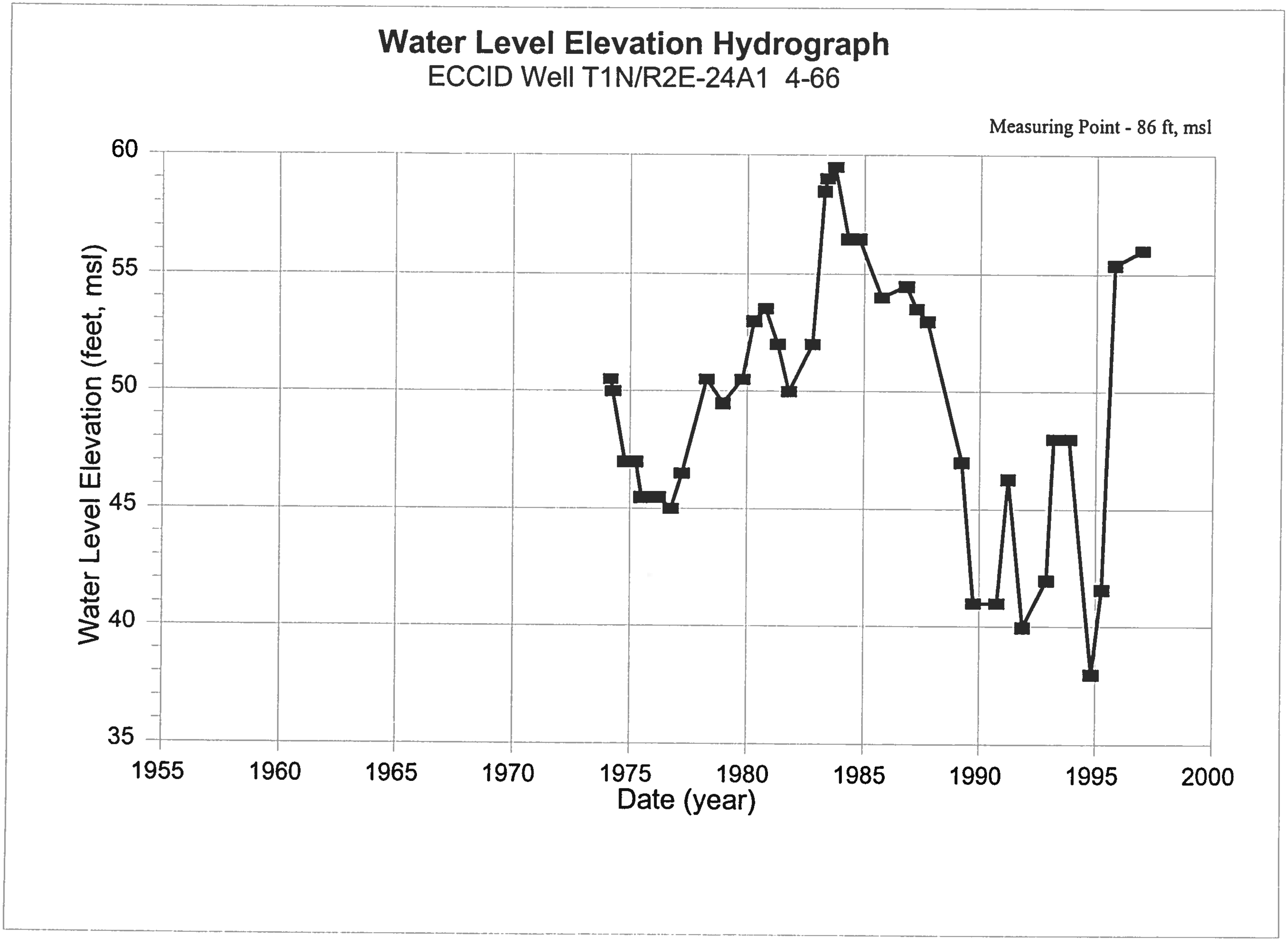
ECCID Well T1N/R2E-18B1 4-59



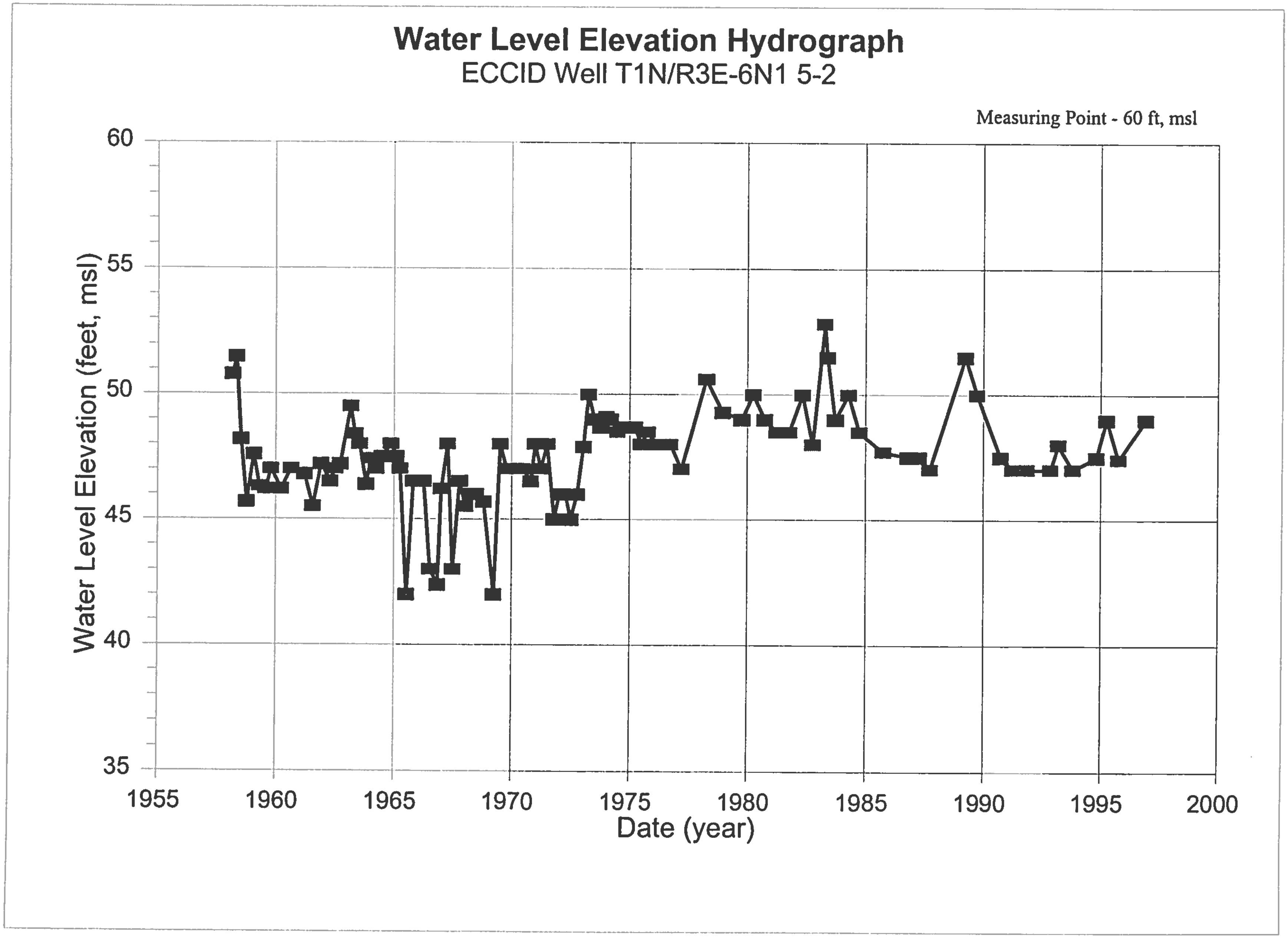

Water Level Elevation Hydrograph
ECCID Well T1N/R3E-20L1 4-61
Measuring Point - 55.5 ft, msl
Water Level Elevation (feet, msl)
50
45
40
35
30
25
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
Date (year)



Water Level Elevation Hydrograph
ECCID Well T1N/R2E-25M1 4-64
Measuring Point - 116.4 ft, msl
Water Level Elevation (feet, msl)
95
90
85
80
75
70
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
Date (year)

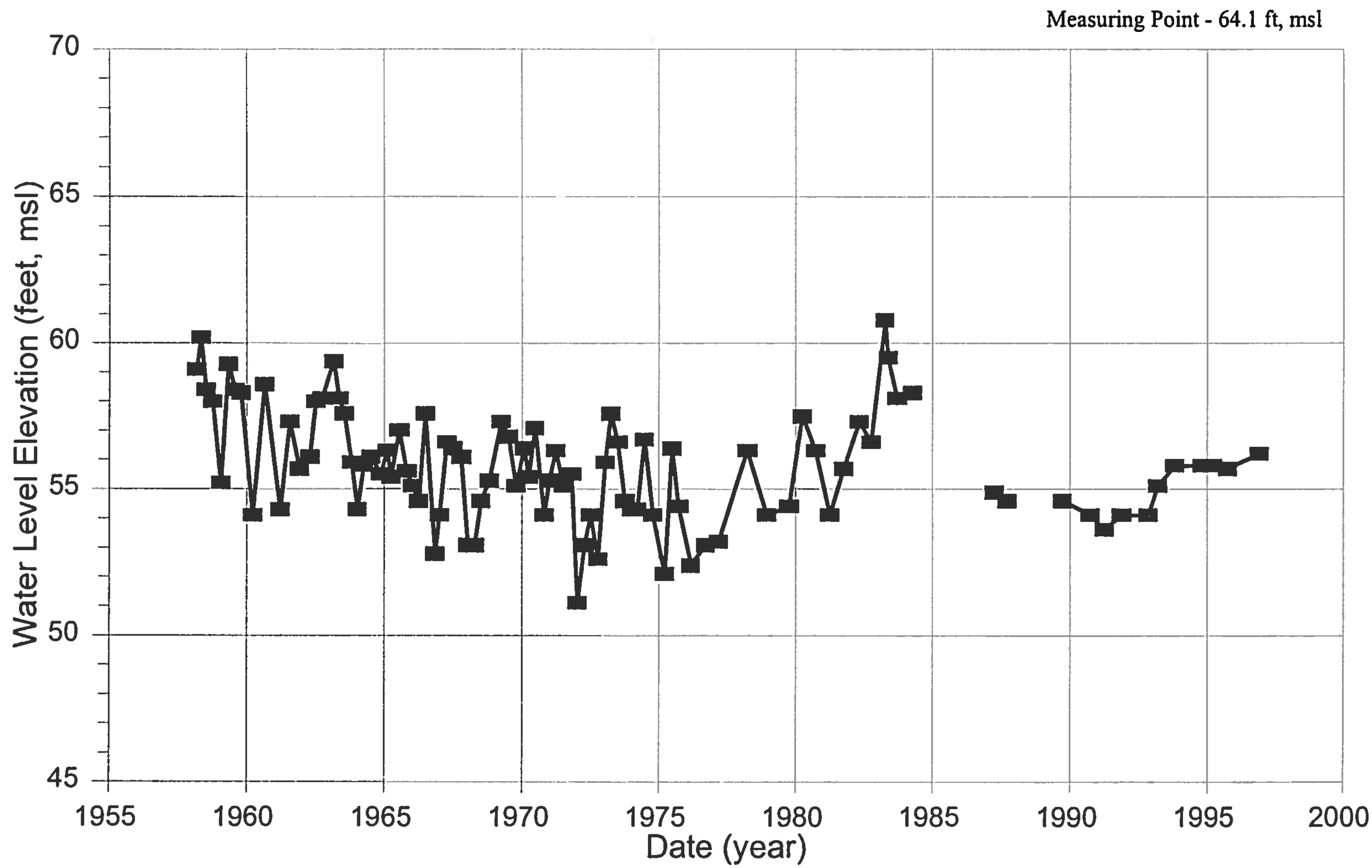


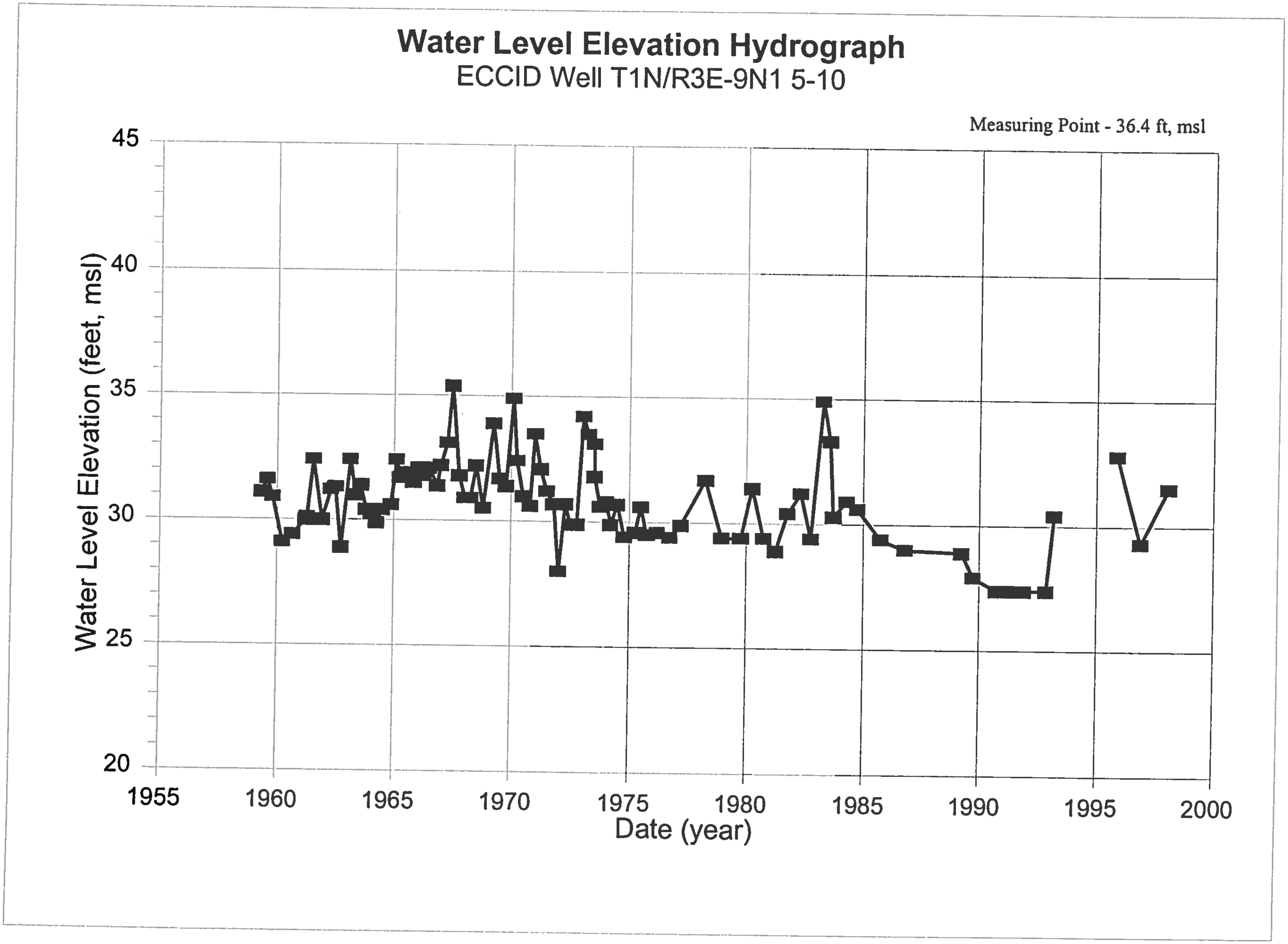
Water Level Elevation Hydrograph
ECCID Well T1N/R2E-24A1 4-66
Measuring Point - 86 ft, msl
60
55
50
45
40
35
Water Level Elevation (feet, msl)
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
Date (year)

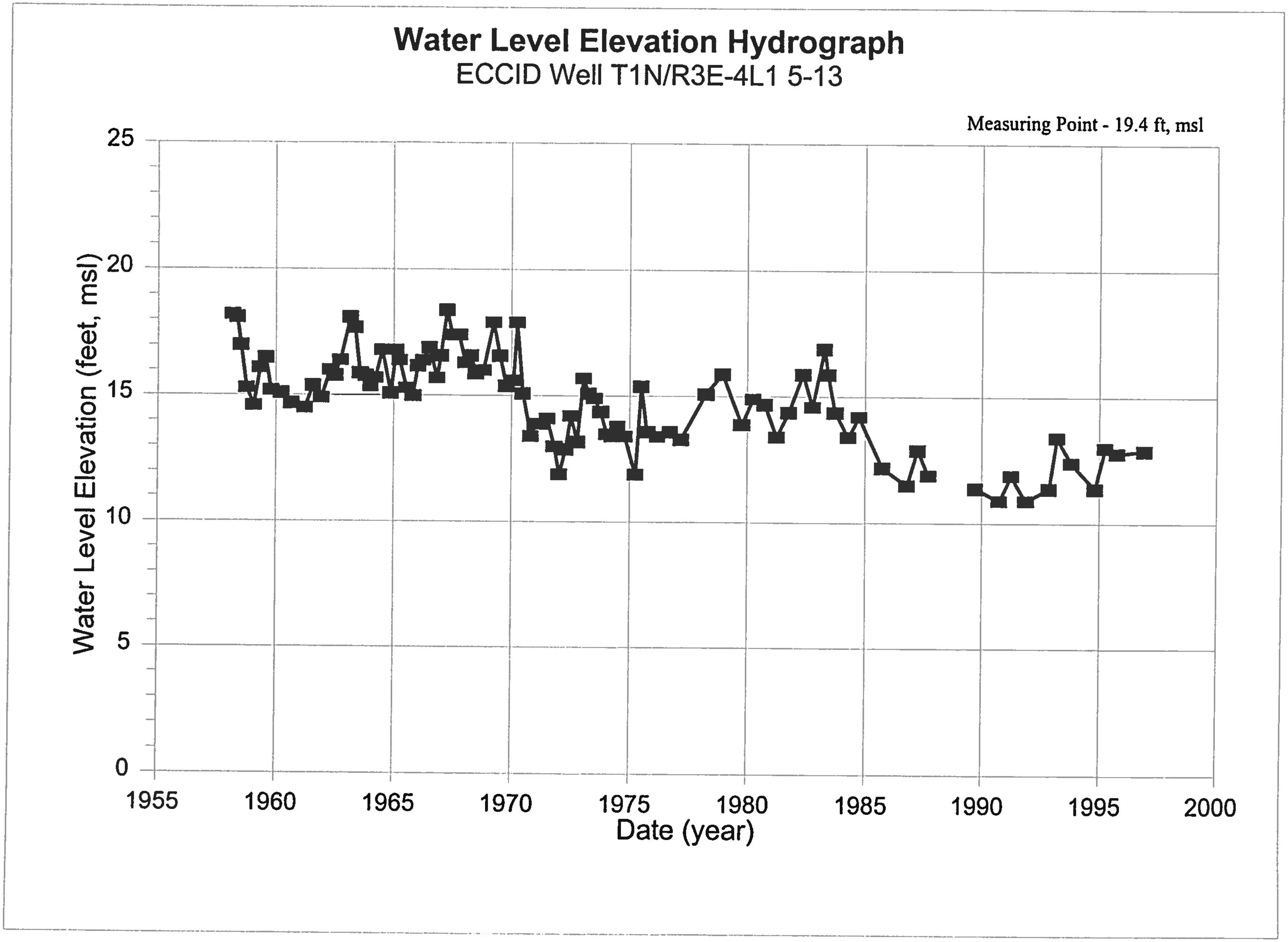

Water Level Elevation Hydrograph
ECCID Well T1N/R3E-6N1 5-2
Measuring Point - 60 ft, msl
Water Level Elevation (feet, msl)
60
55
50
45
40
35
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
Date (year)

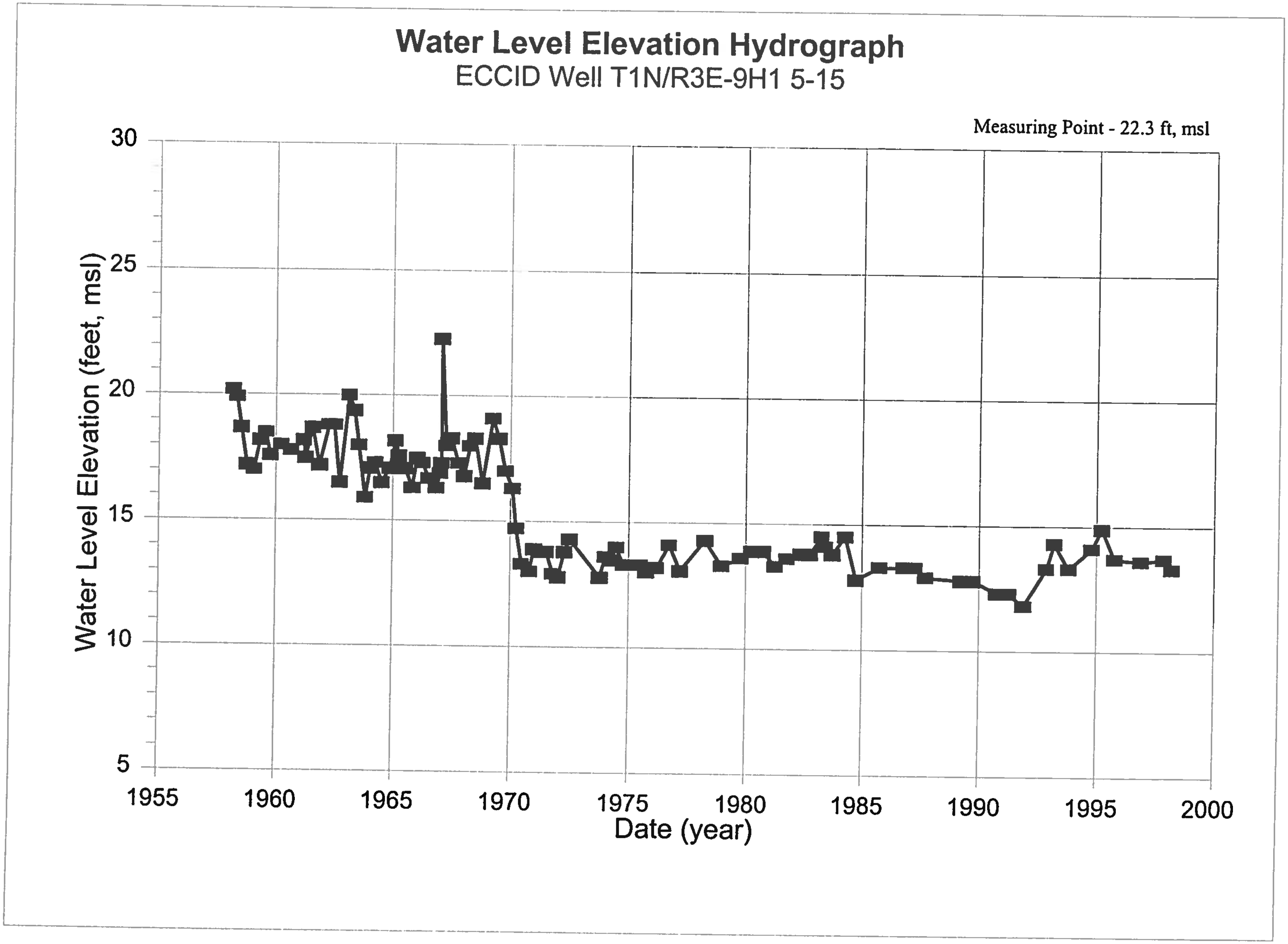
Water Level Elevation Hydrograph

ECCID Well T1N/R3E-7M1 5-3



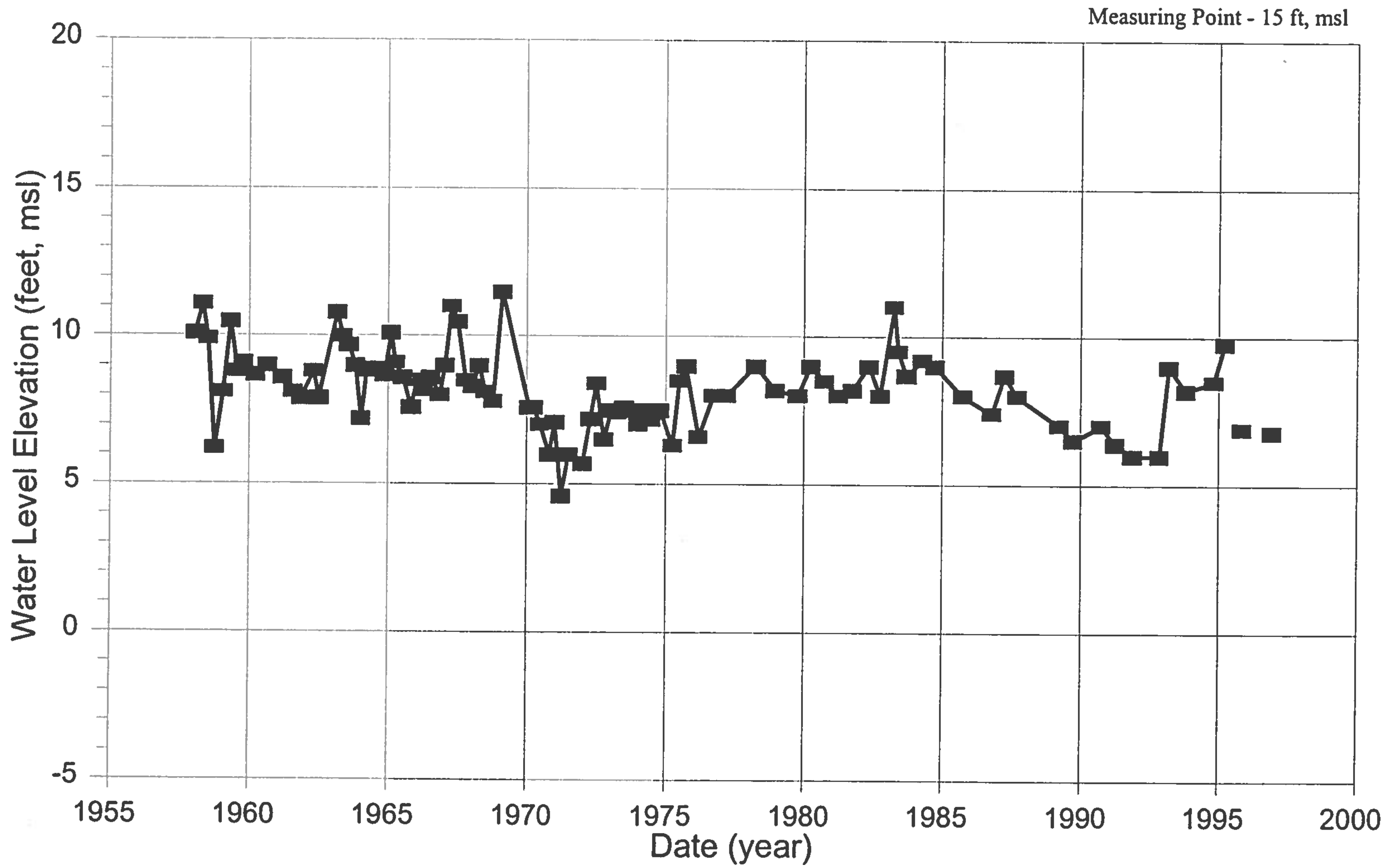

Water Level Elevation Hydrograph
ECCID Well T1N/R3E-9N1 5-10
Measuring Point - 36.4 ft, msl
Water Level Elevation (feet, msl)
45
40
35
30
25
20
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
Date (year)

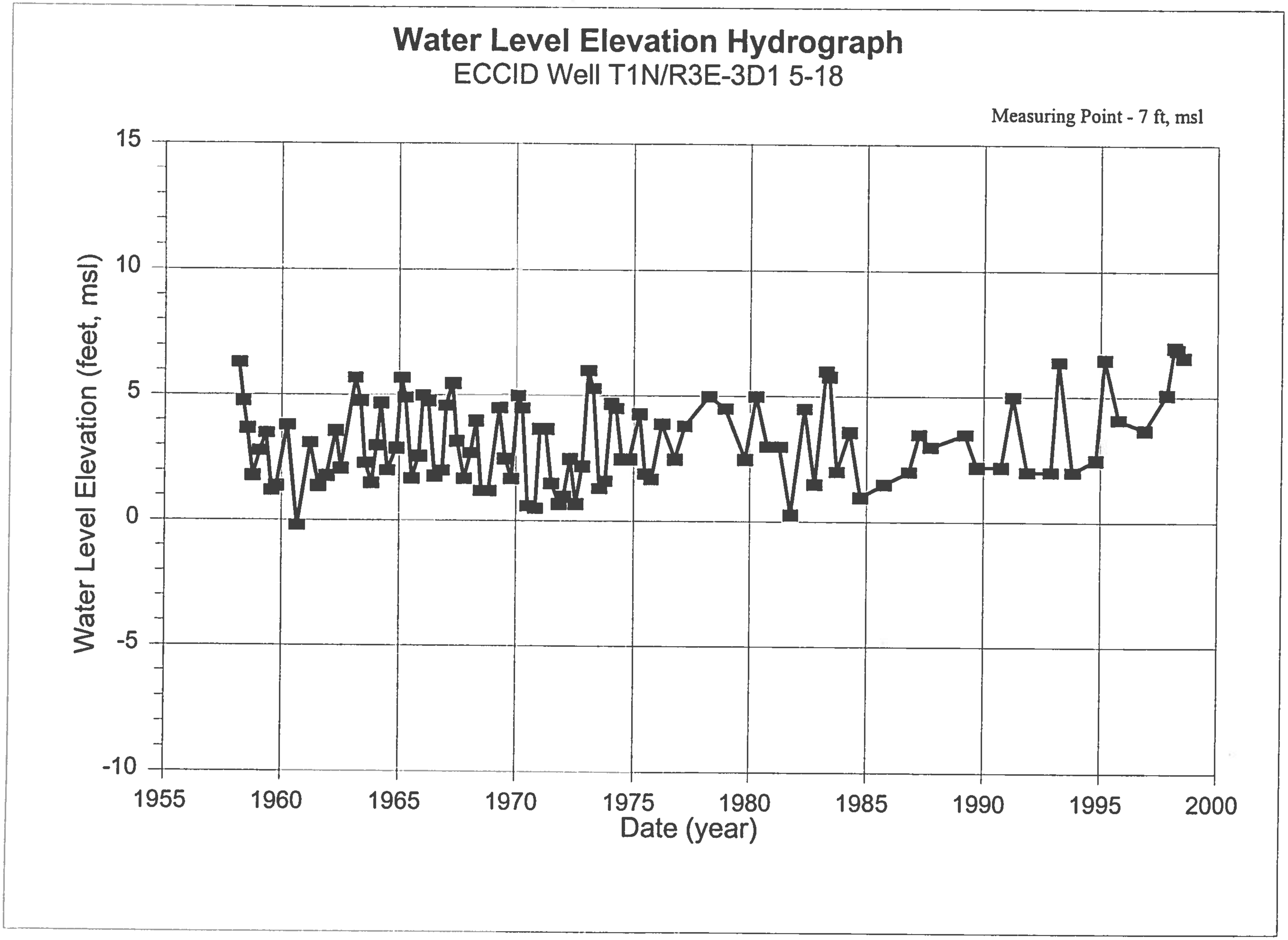

Water Level Elevation Hydrograph
ECCID Well T1N/R3E-4L1 5-13
Measuring Point - 19.4 ft, msl
Water Level Elevation (feet, msl)
25
20
15
10
5
0
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
Date (year)

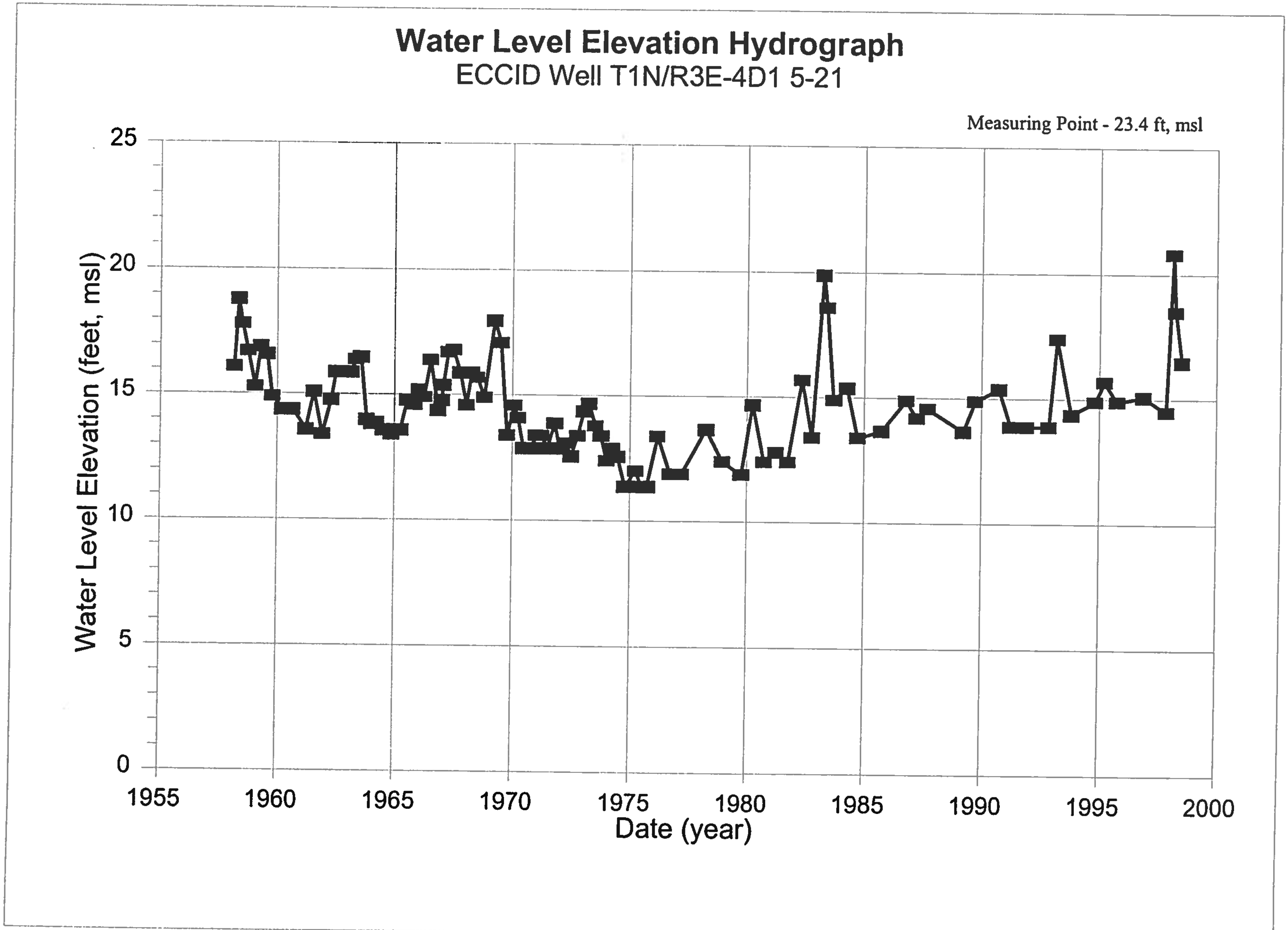

Water Level Elevation Hydrograph
ECCID Well T1N/R3E-9H1 5-15
Measuring Point - 22.3 ft, msl
Water Level Elevation (feet, msl)
30
25
20
15
10
5
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
Date (year)

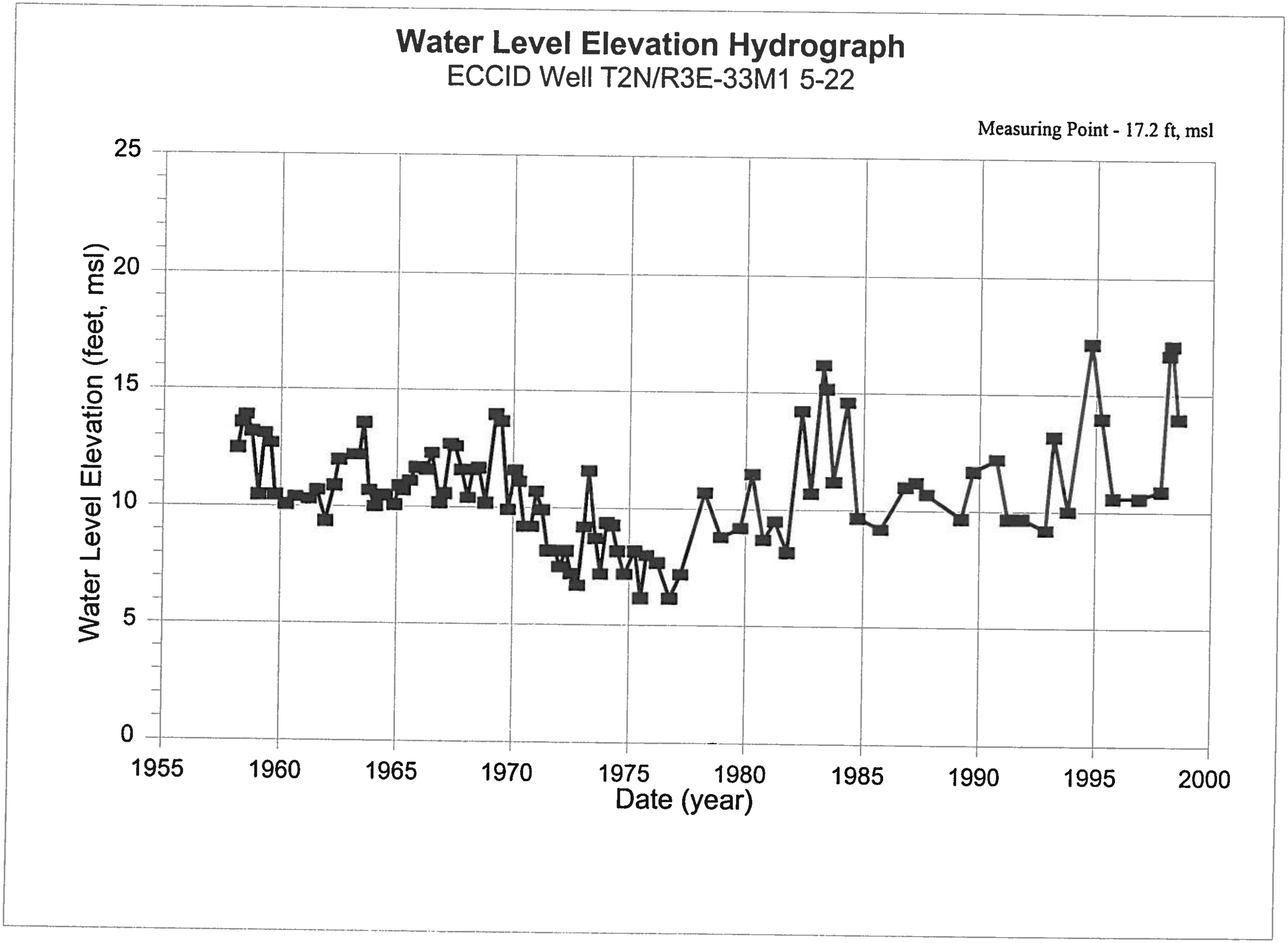
Water Level Elevation Hydrograph

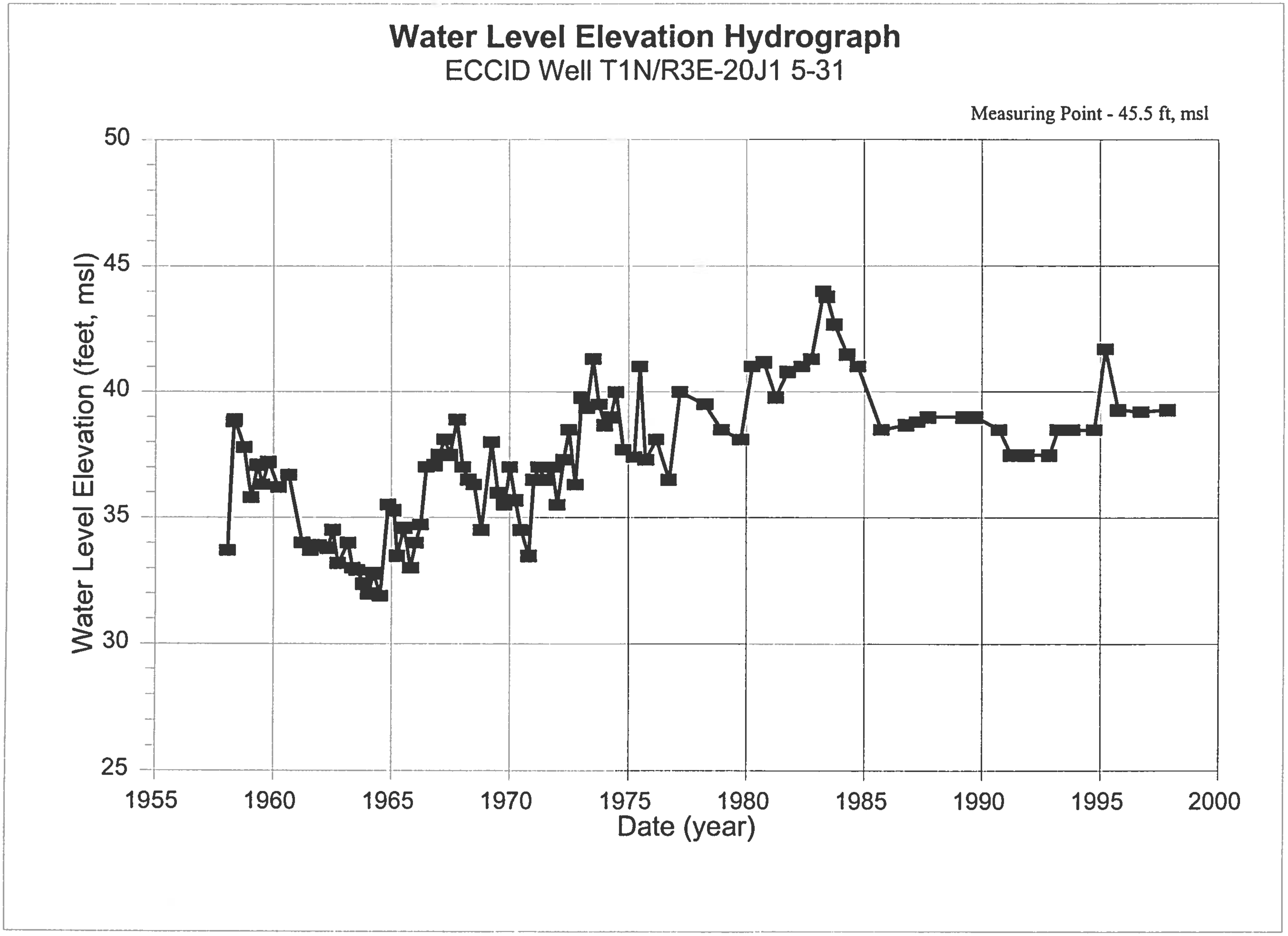
ECCID Well T1N/R3E-3N1 5-16




Water Level Elevation Hydrograph
ECCID Well T1N/R3E-3D1 5-18
Measuring Point - 7 ft, msl
Water Level Elevation (feet, msl)
15
10
5
0
-5
-10
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
Date (year)


Water Level Elevation Hydrograph
ECCID Well T1N/R3E-4D1 5-21
Measuring Point - 23.4 ft, msl
Water Level Elevation (feet, msl)
25
20
15
10
5
0
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
Date (year)


Water Level Elevation Hydrograph
ECCID Well T2N/R3E-33M1 5-22
Measuring Point - 17.2 ft, msl
Water Level Elevation (feet, msl)
25
20
15
10
5
0
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
Date (year)


Water Level Elevation Hydrograph
ECCID Well T1N/R3E-20J1 5-31
Measuring Point - 45.5 ft, msl
Water Level Elevation (feet, msl)
50
45
40
35
30
25
1955
1960
1965
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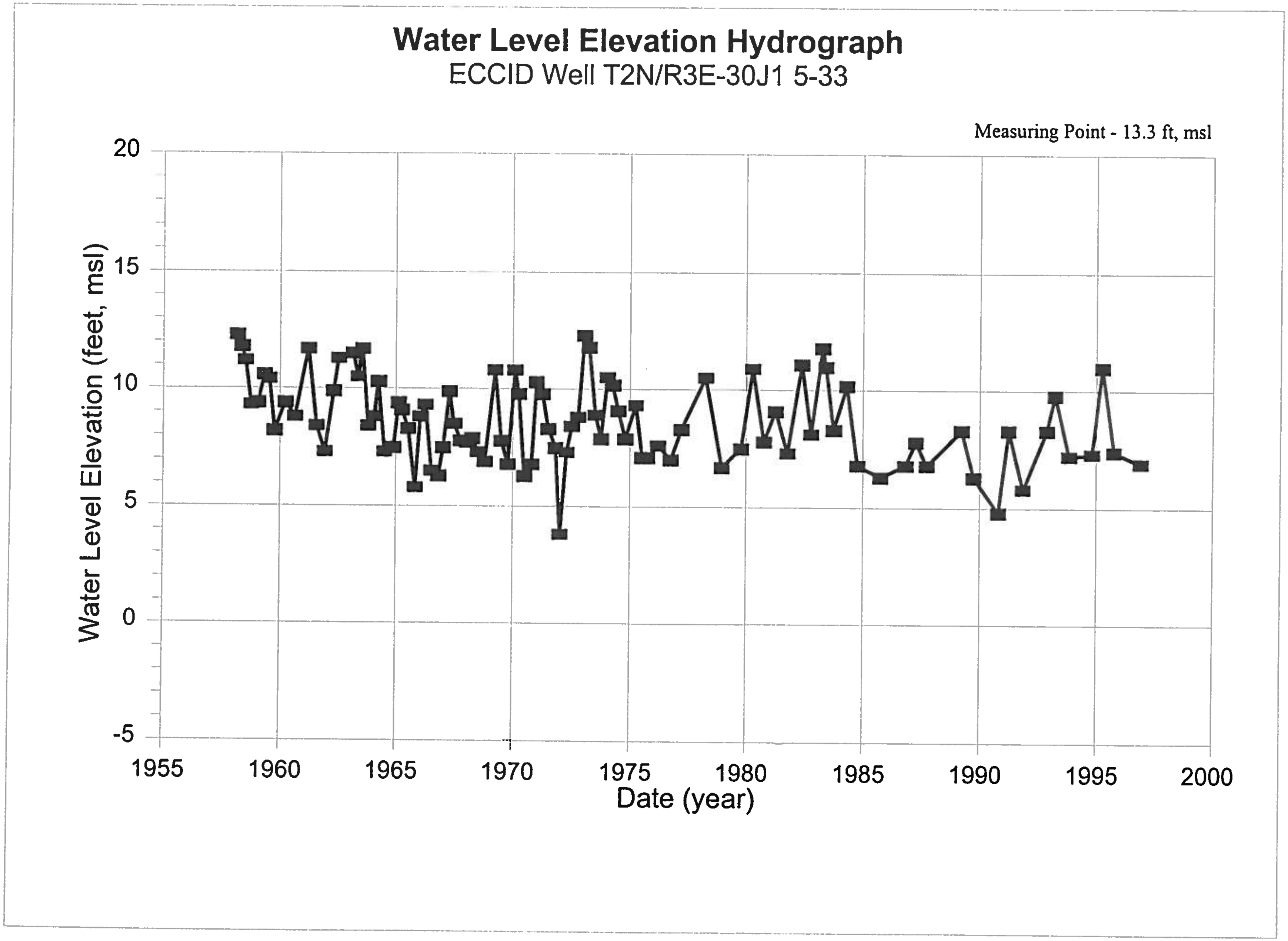
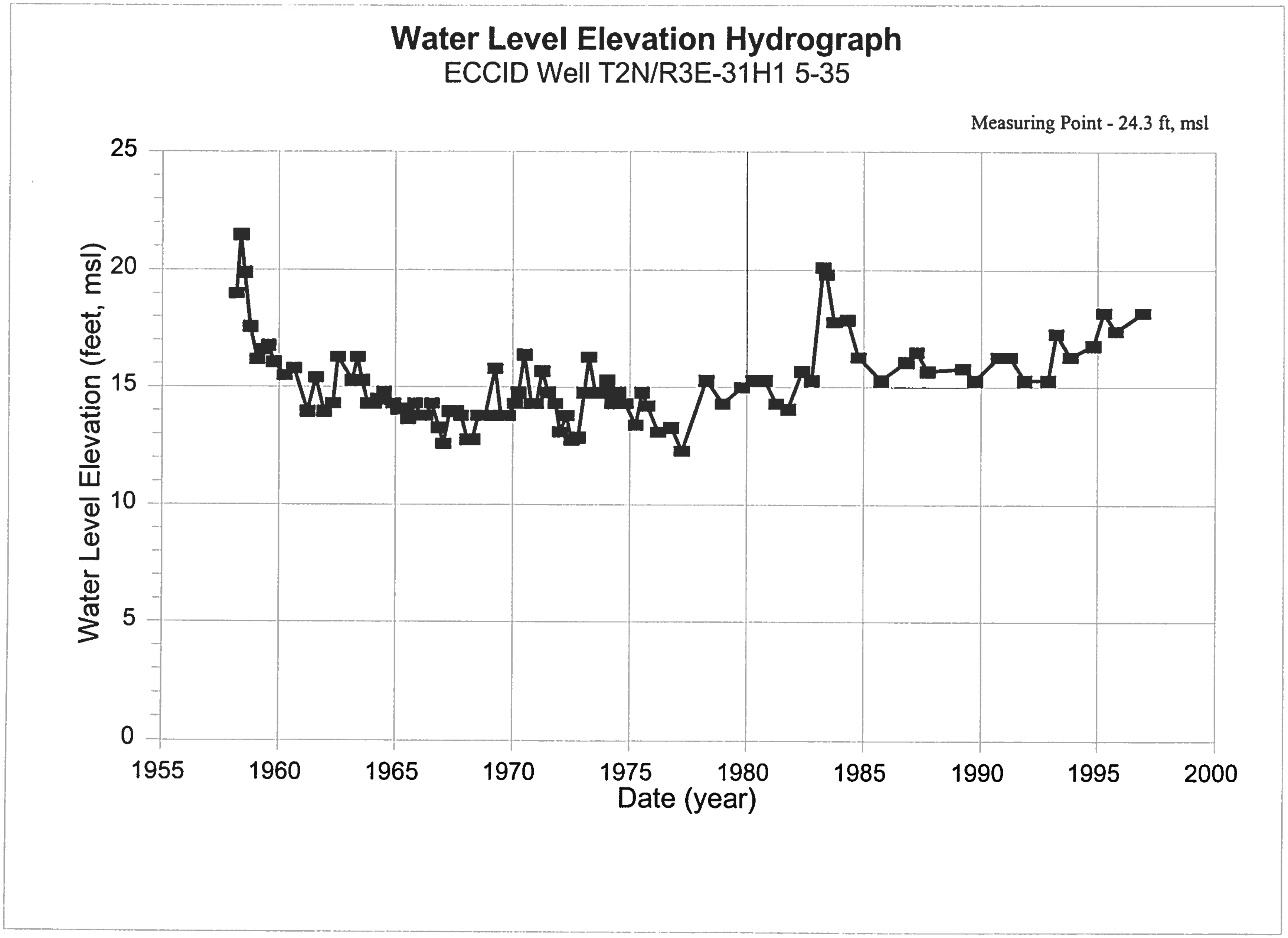
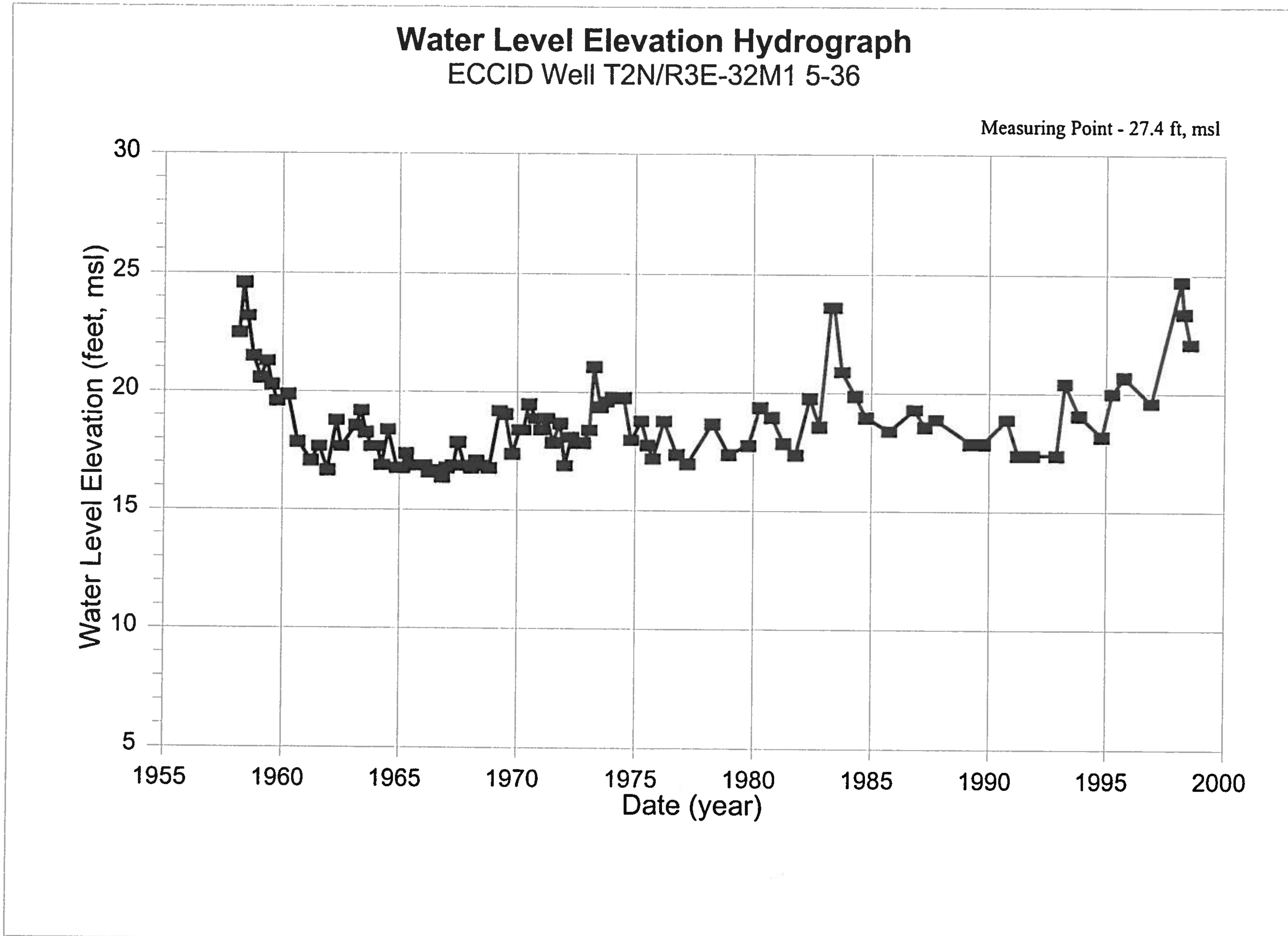
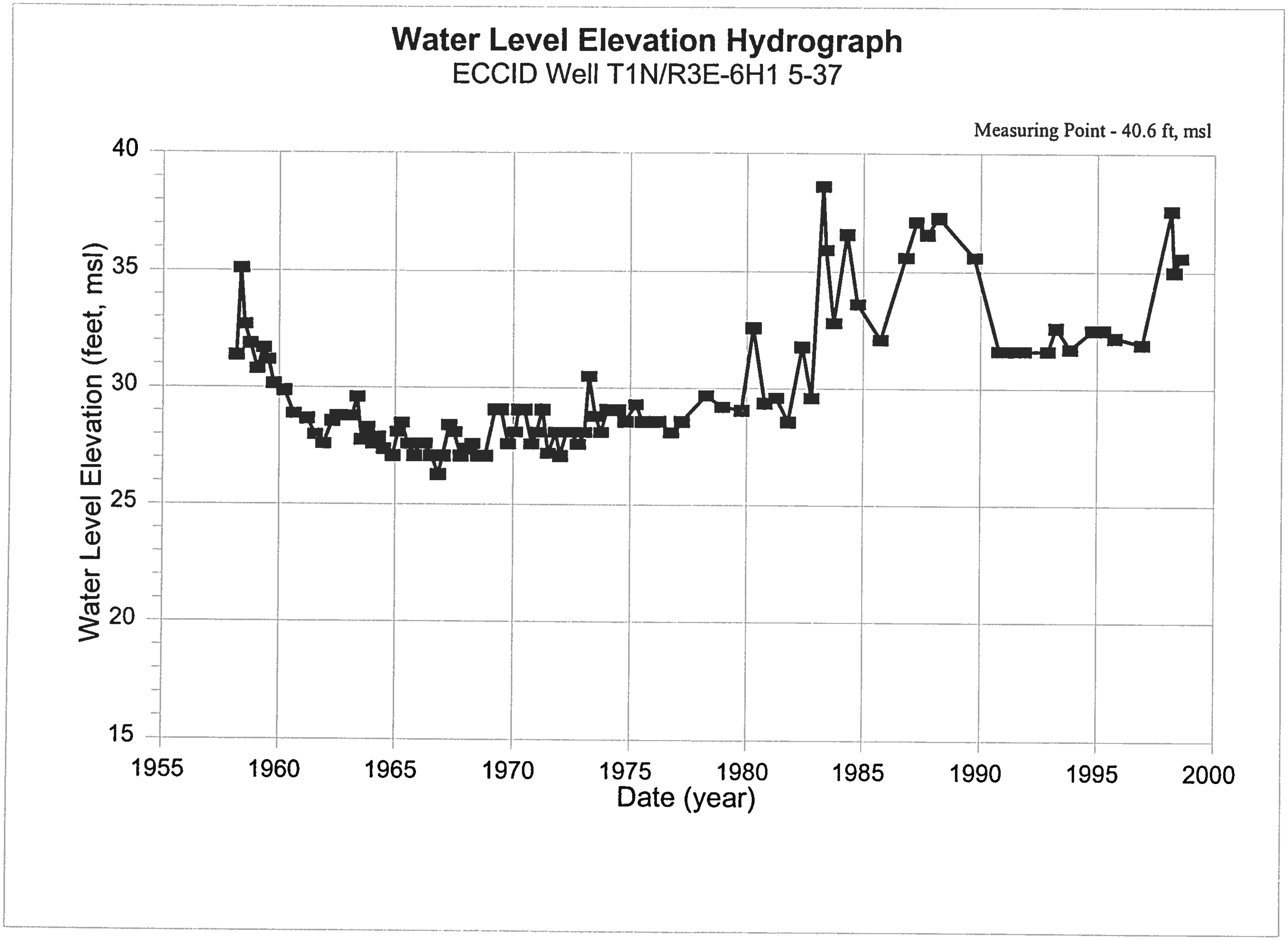
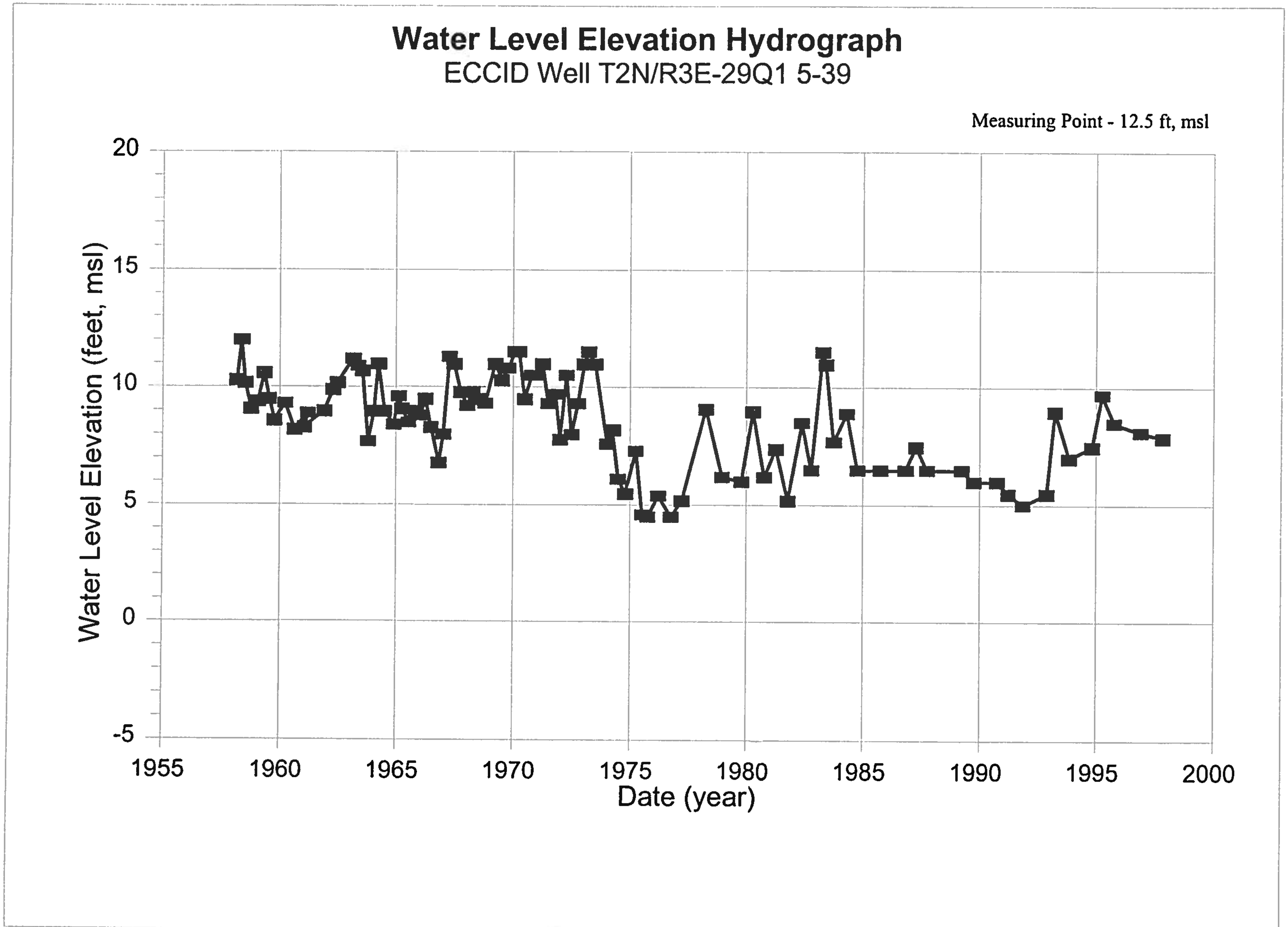
1975
1980
1985
1990
1995
2000
Date (year)

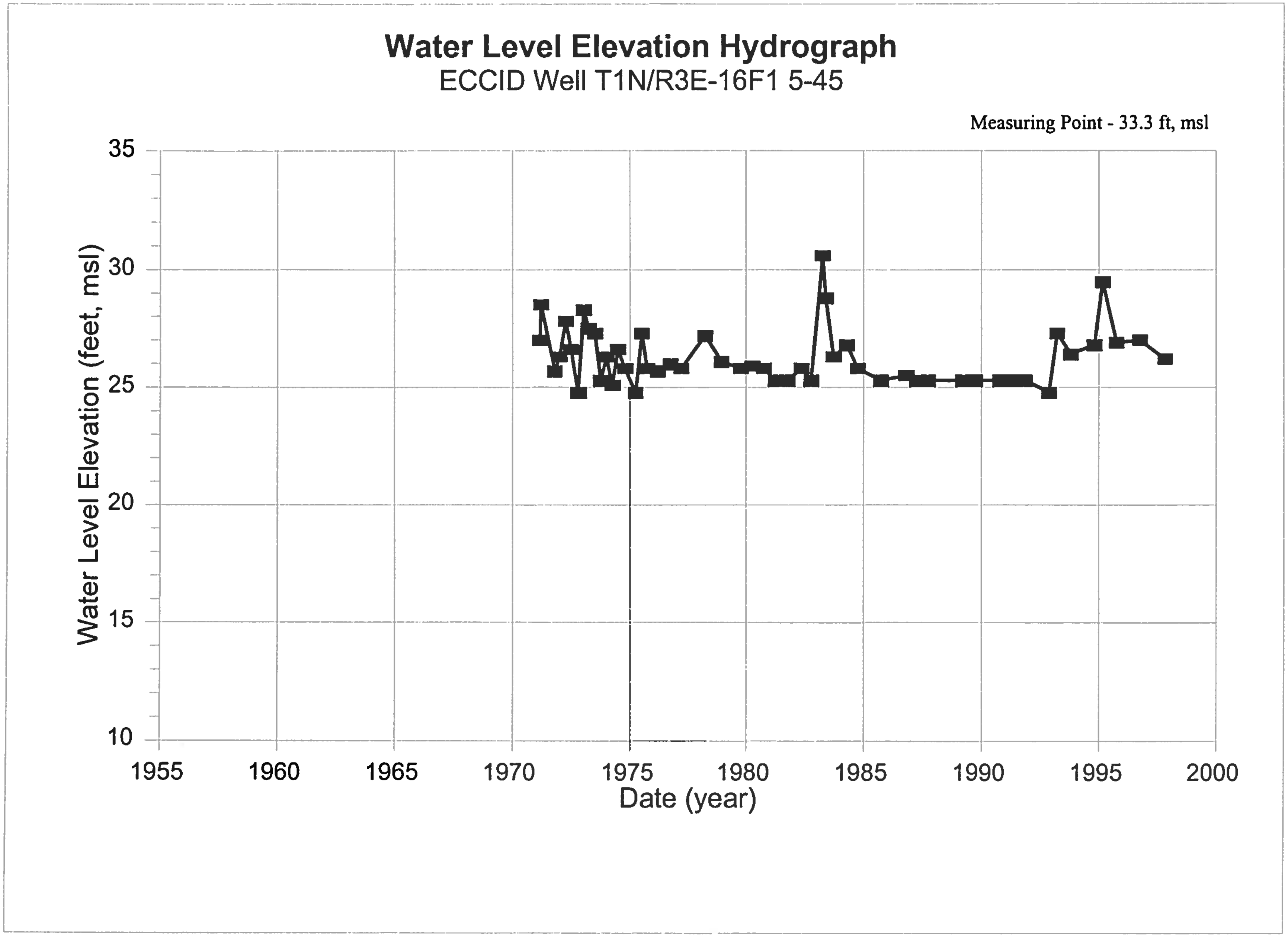

Water Level Elevation Hydrograph
ECCID Well T2N/R3E-30J1 5-33
Measuring Point - 13.3 ft, msl
Water Level Elevation (feet, msl)
20
15
10
5
0
-5
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
Date (year)


Water Level Elevation Hydrograph
ECCID Well T2N/R3E-31H1 5-35
Measuring Point - 24.3 ft, msl
Water Level Elevation (feet, msl)
0
5
10
15
20
25
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
Date (year)


Water Level Elevation Hydrograph
ECCID Well T2N/R3E-32M1 5-36
Measuring Point - 27.4 ft, msl
Water Level Elevation (feet, msl)
30
25
20
15
10
5
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
Date (year)


Water Level Elevation Hydrograph
ECCID Well T1N/R3E-6H1 5-37
Measuring Point - 40.6 ft, msl
Water Level Elevation (feet, msl)
40
35
30
25
20
15
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
Date (year)

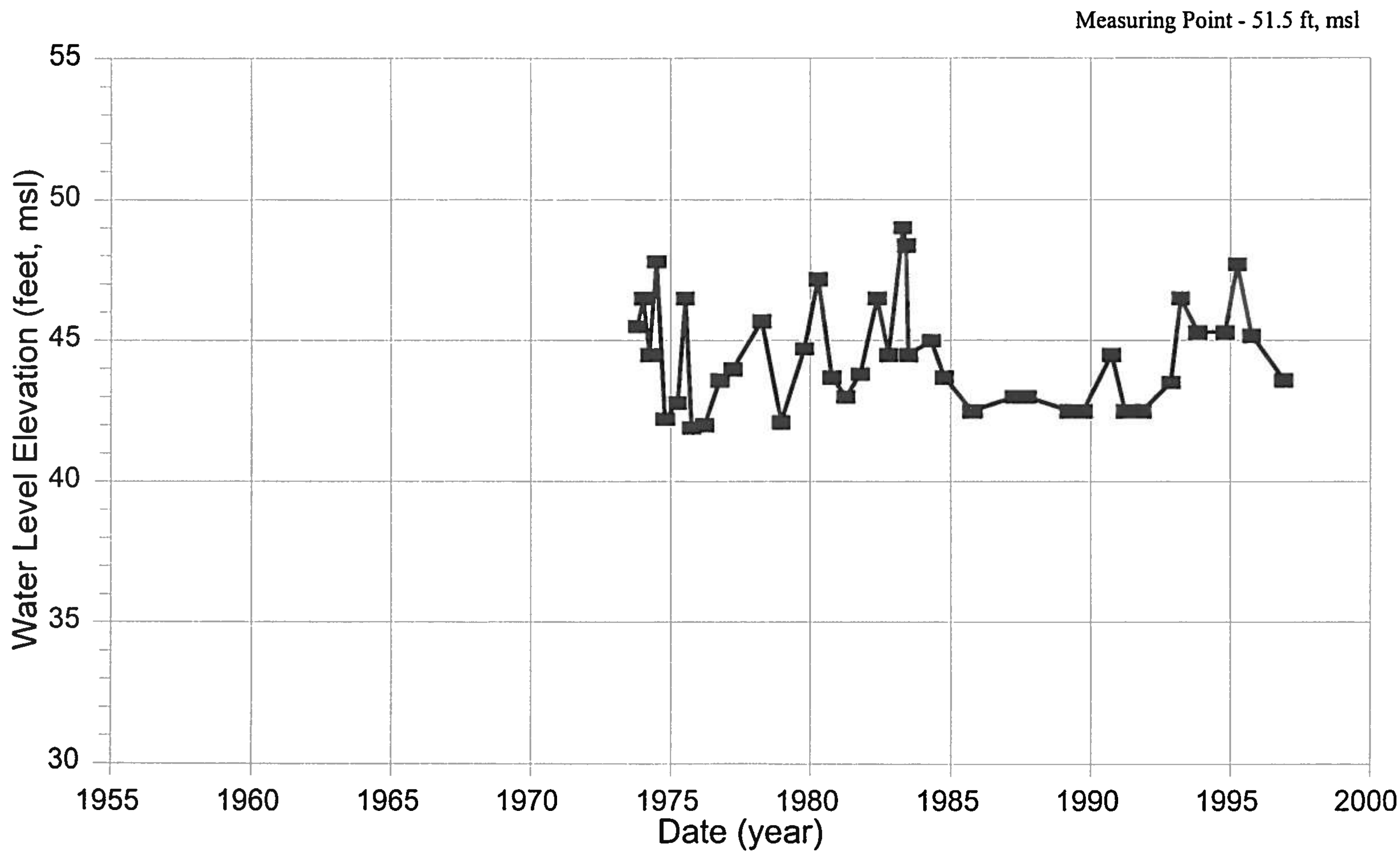

Water Level Elevation Hydrograph
ECCID Well T2N/R3E-29Q1 5-39
Measuring Point - 12.5 ft, msl
Water Level Elevation (feet, msl)
20
15
10
5
0
-5
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
Date (year)



Water Level Elevation Hydrograph
ECCID Well T1N/R3E-16F1 5-45
Measuring Point - 33.3 ft, msl
Water Level Elevation (feet, msl)
35
30
25
20
15
10
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
Date (year)

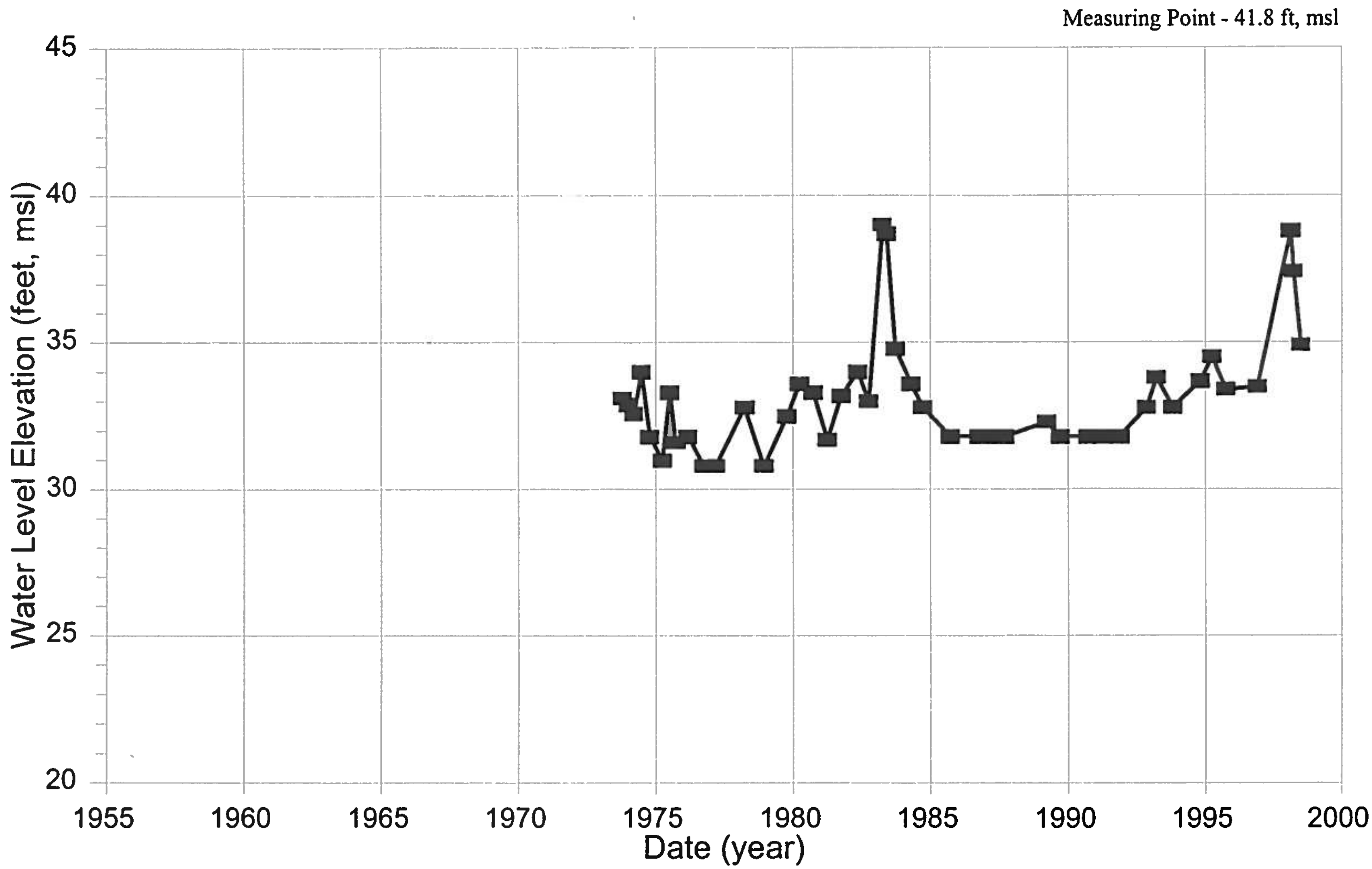
Water Level Elevation Hydrograph

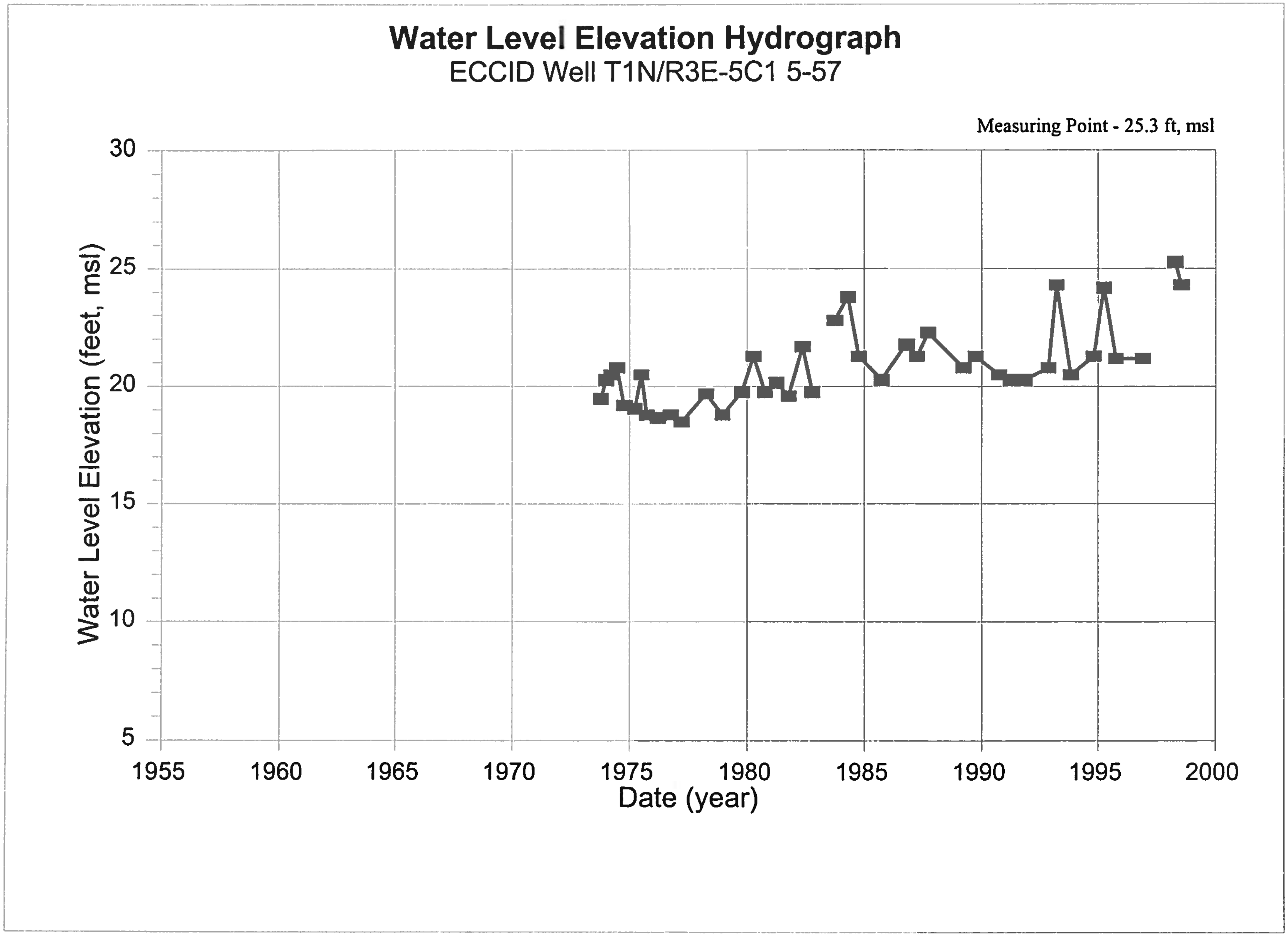
ECCID Well T1N/R3E-8E1 5-55



Water Level Elevation Hydrograph

ECCID Well T1N/R3E-5P1 5-56

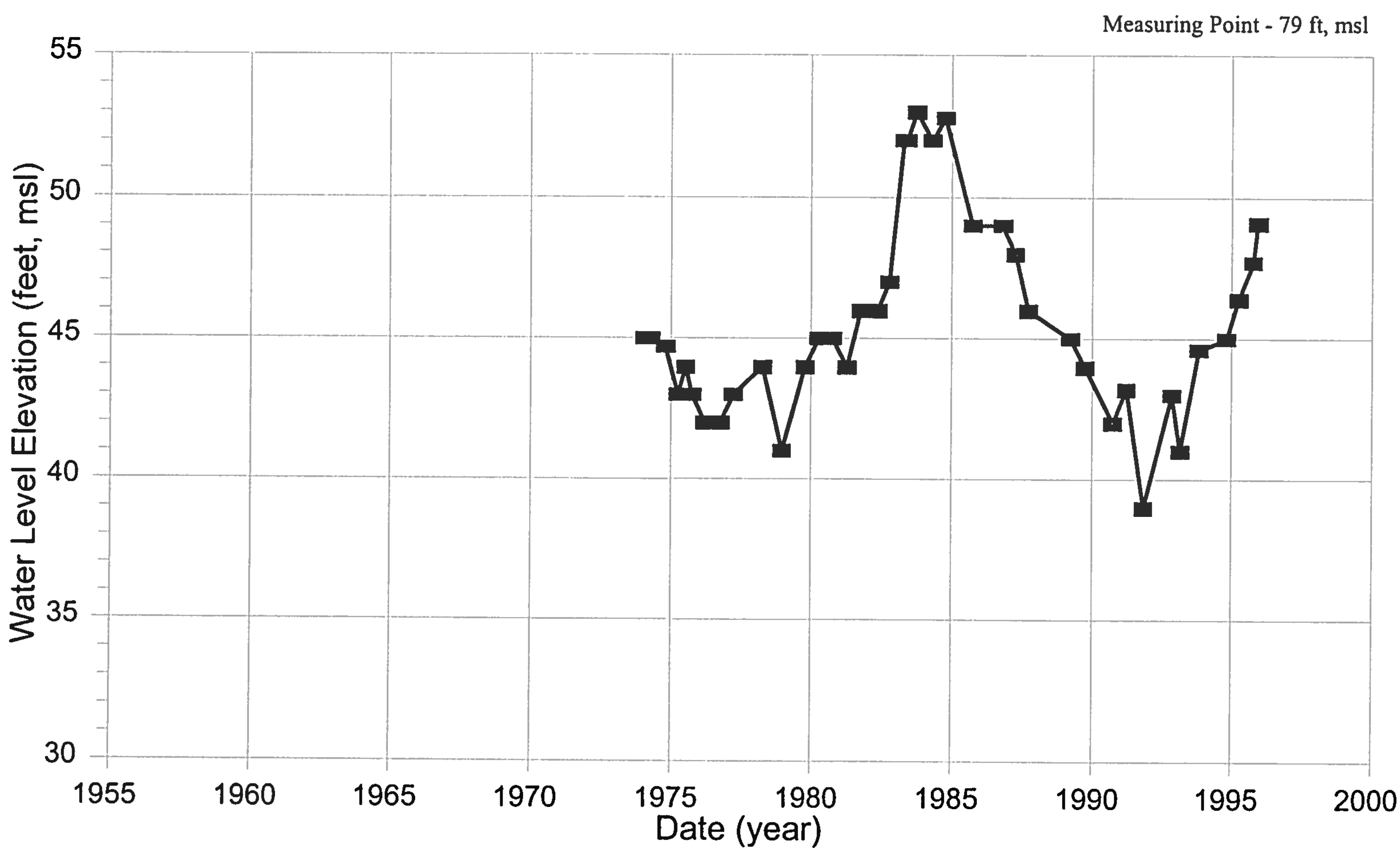




Water Level Elevation Hydrograph
ECCID Well T1N/R3E-5C1 5-57
Measuring Point - 25.3 ft, msl
Water Level Elevation (feet, msl)
30
25
20
15
10
5
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
Date (year)

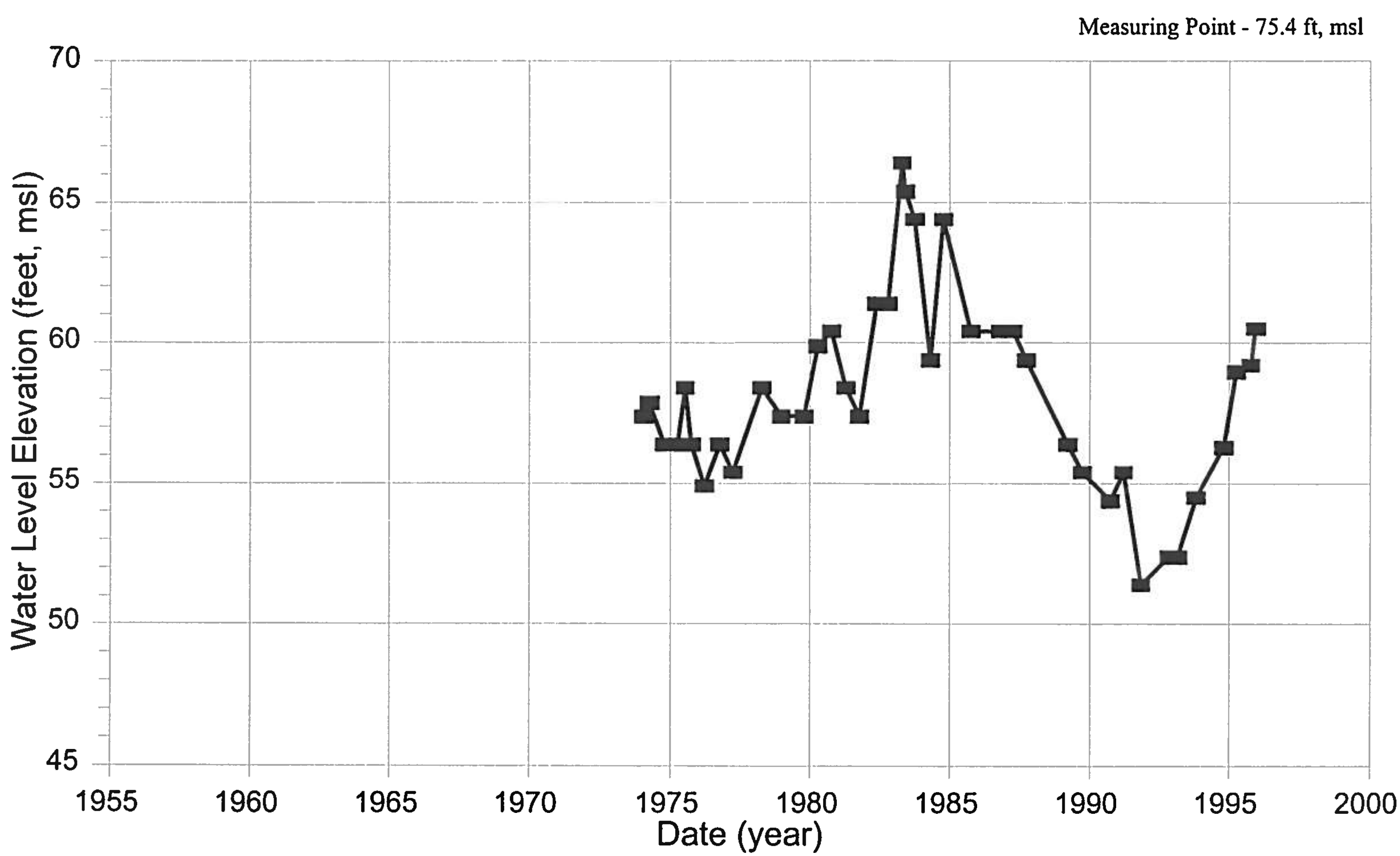
Water Level Elevation Hydrograph

ECCID Well T1N/R2E-1E1 5-66



Water Level Elevation Hydrograph

ECCID Well T1N/R2E-12L1 5-72



EAST COUNTY WATER MANAGEMENT A

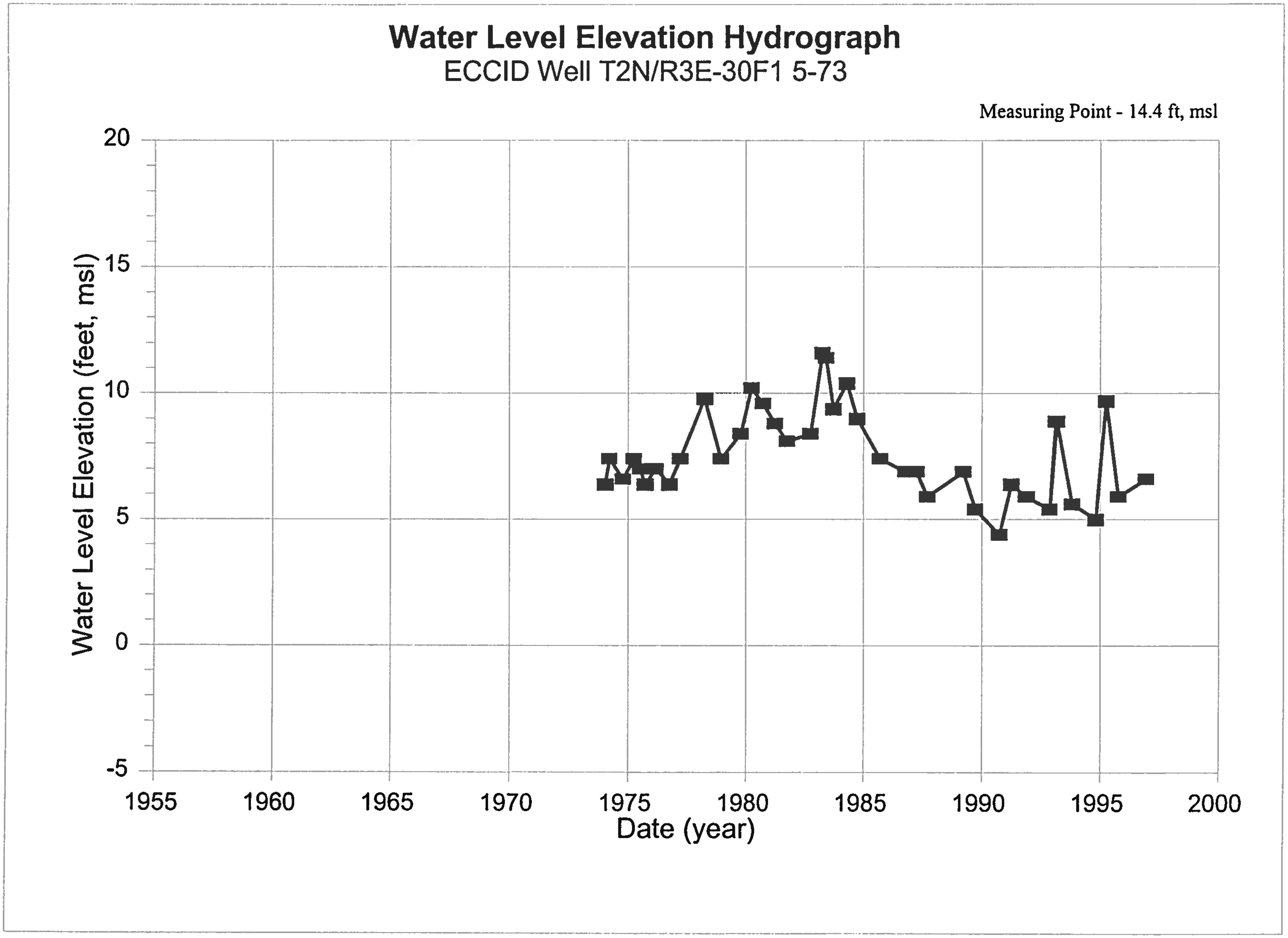
AGENCY: DIABLO WATER DISTRICT

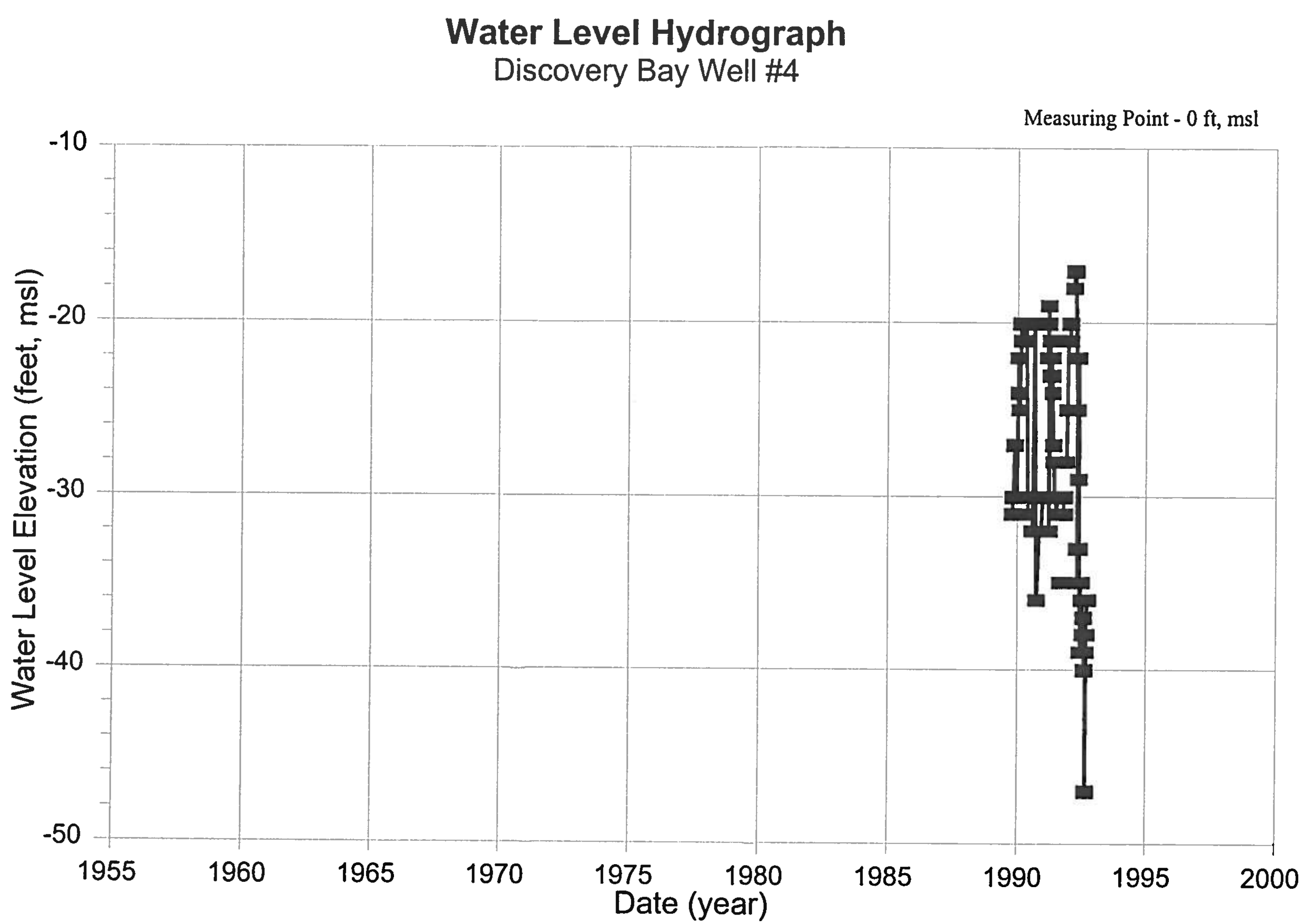
GROUNDWATER LEVEL DATABASE

Well Number	Date	Time	RP	DTW	ELEV	CODE
T1N/R3E 25A	10/04/94	900.0	25.00	65.00	-40.00	
T1N/R3E 25A	04/03/95	900.0	25.00	68.00	-43.00	
T1N/R3E 25A	10/04/96	930.0	25.00	68.00	-43.00	
T1N/R3E 25A	03/17/97	915.0	25.00	73.00	-48.00	

.SSOCIATION

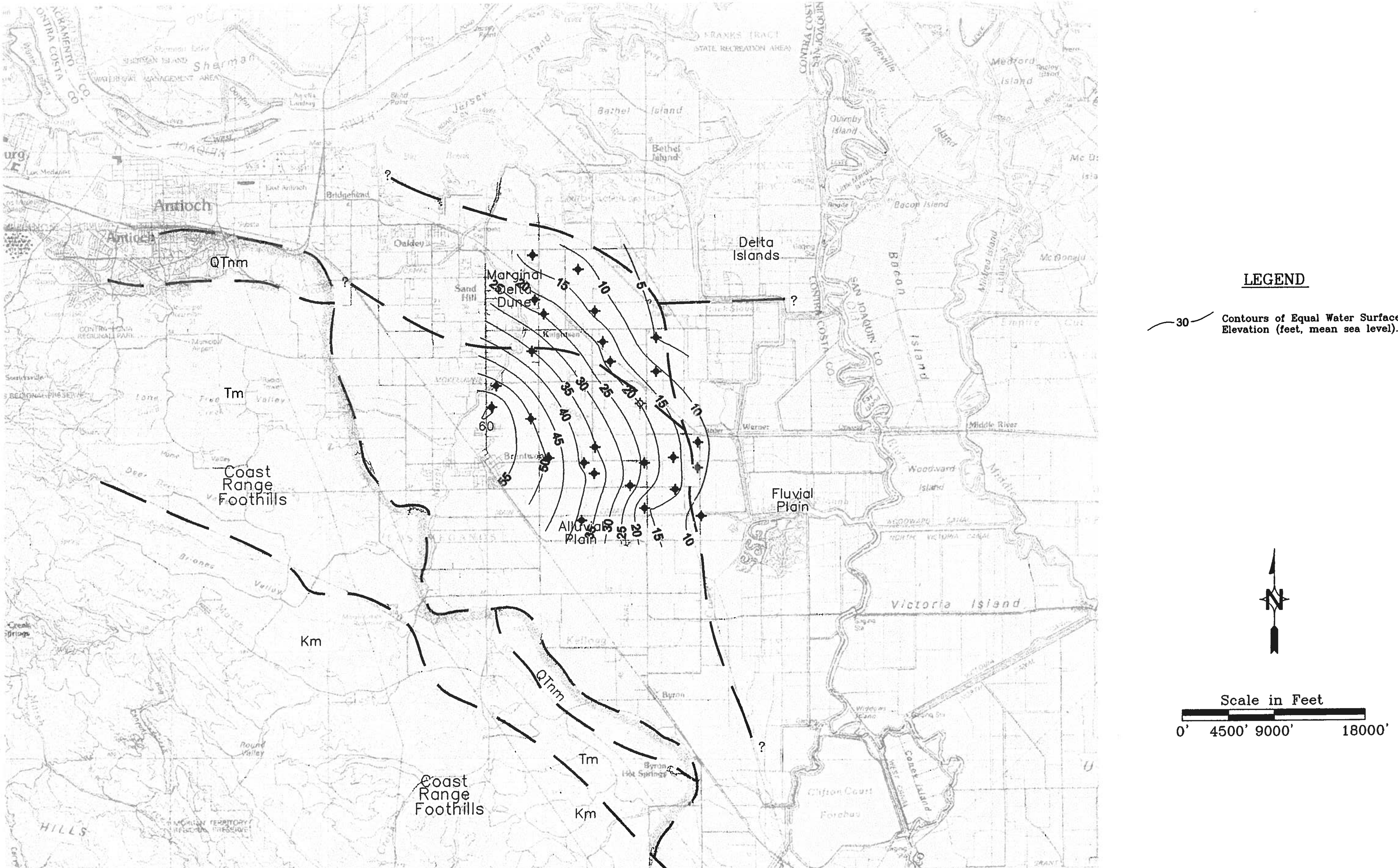
REMARK	FLAG
DRAW DOWN 30 FEET	
DRAW DOWN 34 FEET	


Water Level Elevation Hydrograph
ECCID Well T2N/R3E-30F1 5-73
Measuring Point - 14.4 ft, msl
Water Level Elevation (feet, msl)
20
15
10
5
0
-5
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
Date (year)



Water Level Hydrograph
Discovery Bay Well #4
Measuring Point - 0 ft, msl
-10
-20
-30
-40
-50
Water Level Elevation (feet, msl)
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
Date (year)

GROUNDWATER CONTOUR MAPS



East County Water Management Assoc./97-1-131/Spr1958wl.dwg

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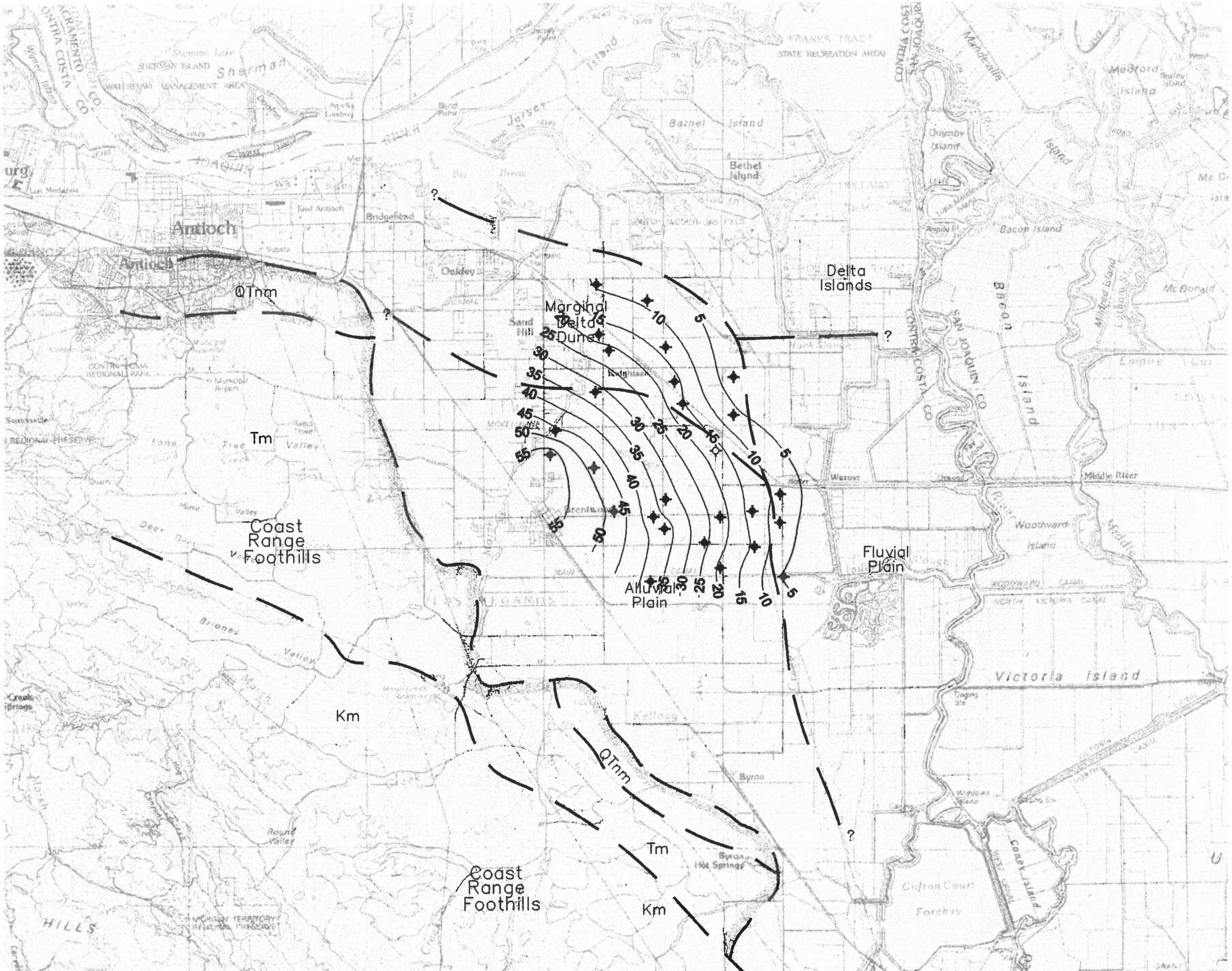
Contours of Equal Ground-Water Elevation - Spring 1958
East County Water Management Association
Ground-Water Resources Assessment



East County Water Management Assoc./97-1-131/Fall1958wl.dwg

LEGEND

30 — Contours of Equal Water Surface Elevation (feet, mean sea level).

Scale in Feet

0' 4500' 9000' 18000'

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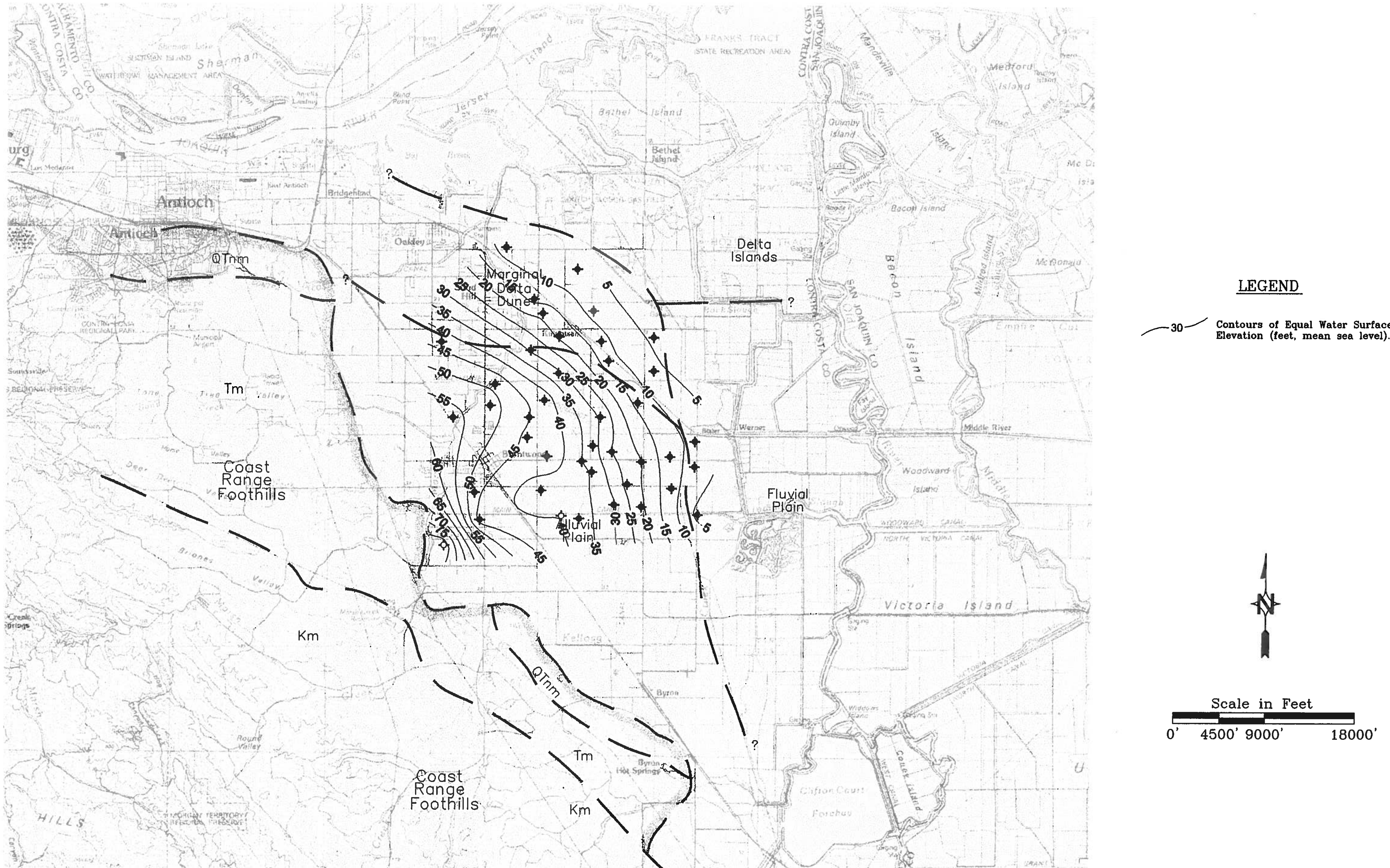
Contours of Equal Ground-Water Elevation - Fall 1958
East County Water Management Association
Ground-Water Resources Assessment



East County Water Management Assoc./97-1-131/Spr1975el.dwg

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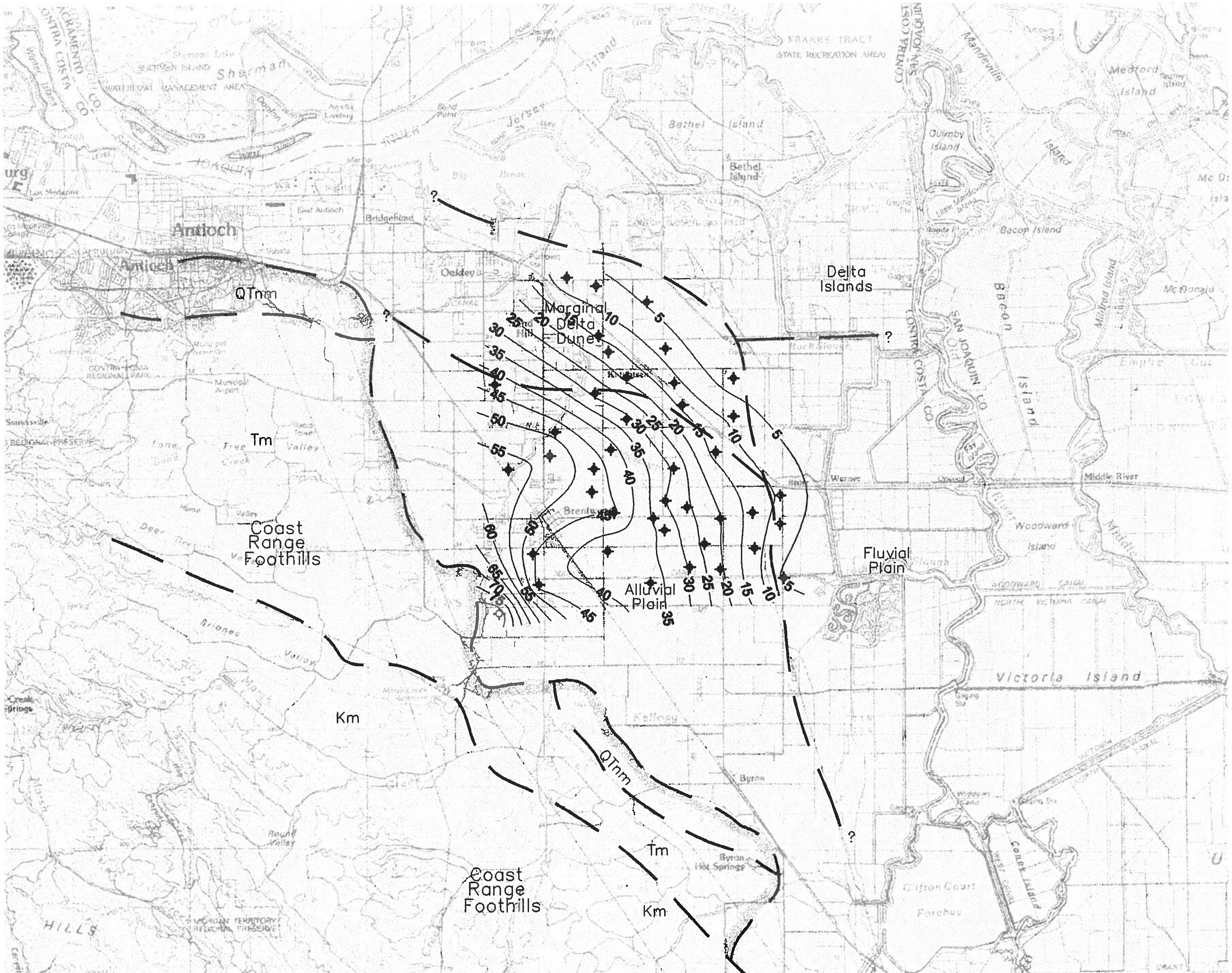
Contours of Equal Ground-Water Elevation - Spring 1975
East County Water Management Association
Ground-Water Resources Assessment



LEGEND

30 — Contours of Equal Water Surface Elevation (feet, mean sea level).

Scale in Feet

0' 4500' 9000' 18000'

N

East County Water Management Assoc./97-1-131/Fall1975wl.dwg

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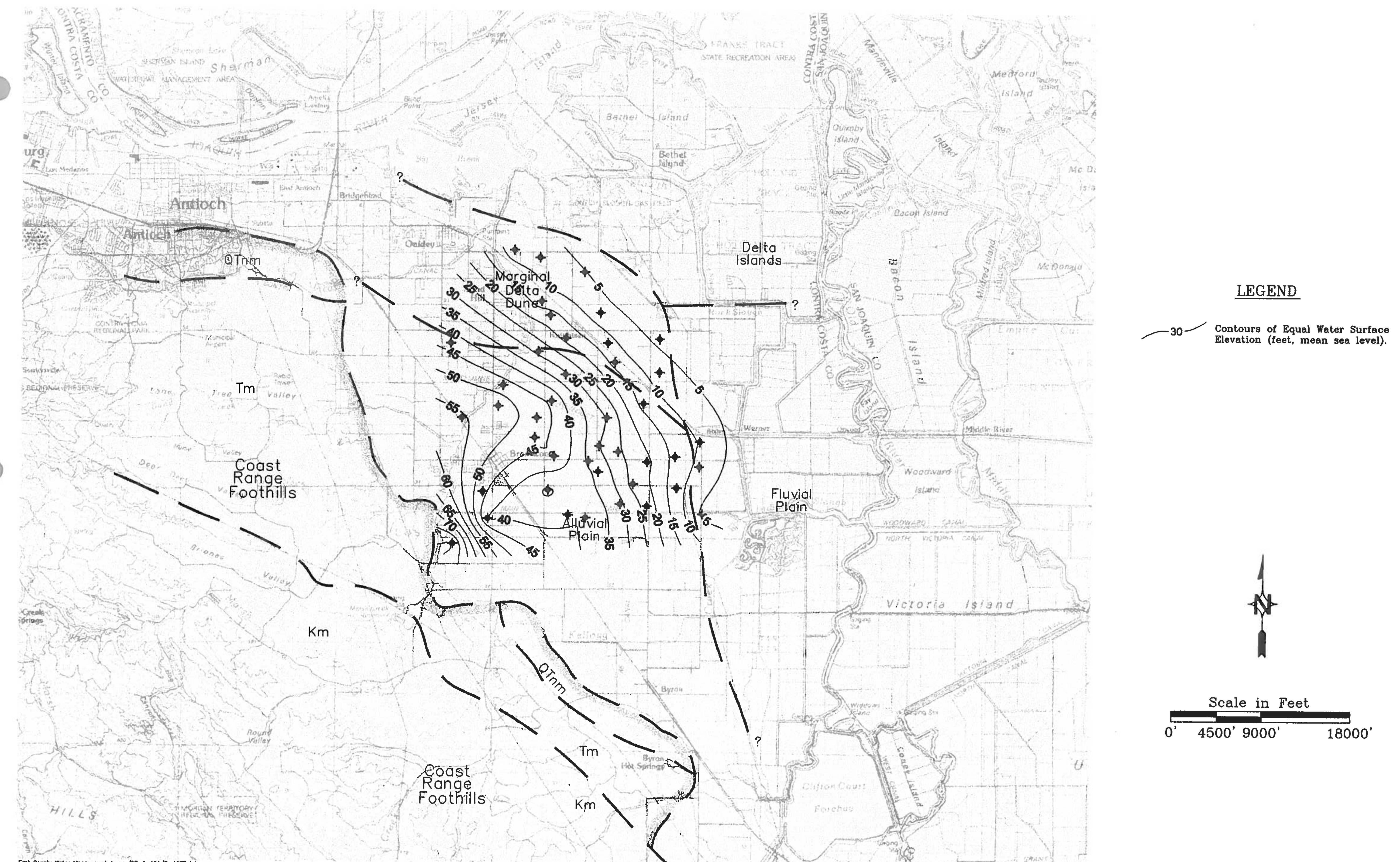
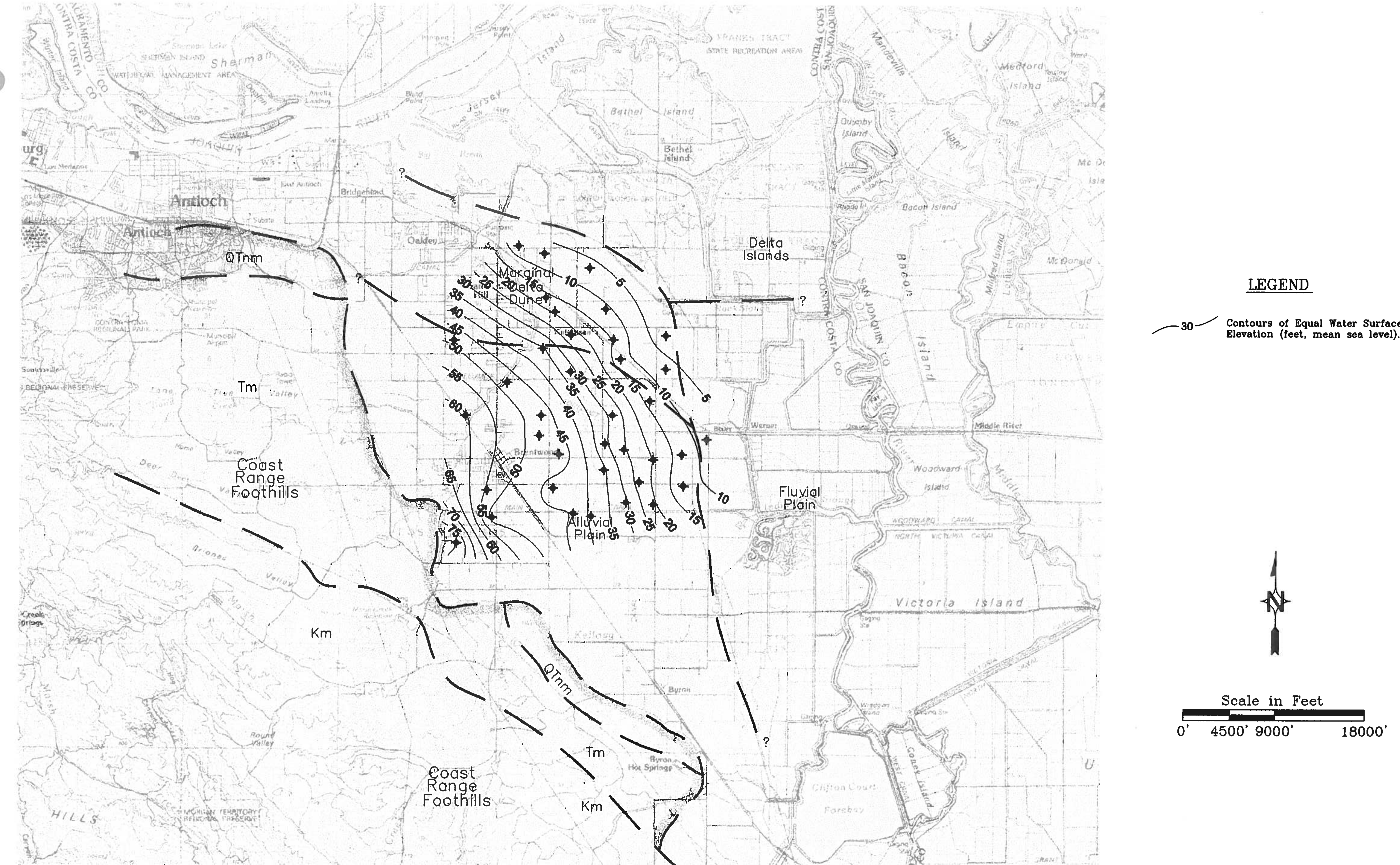
Contours of Equal Ground-Water Elevation - Fall 1975
East County Water Management Association
Ground-Water Resources Assessment



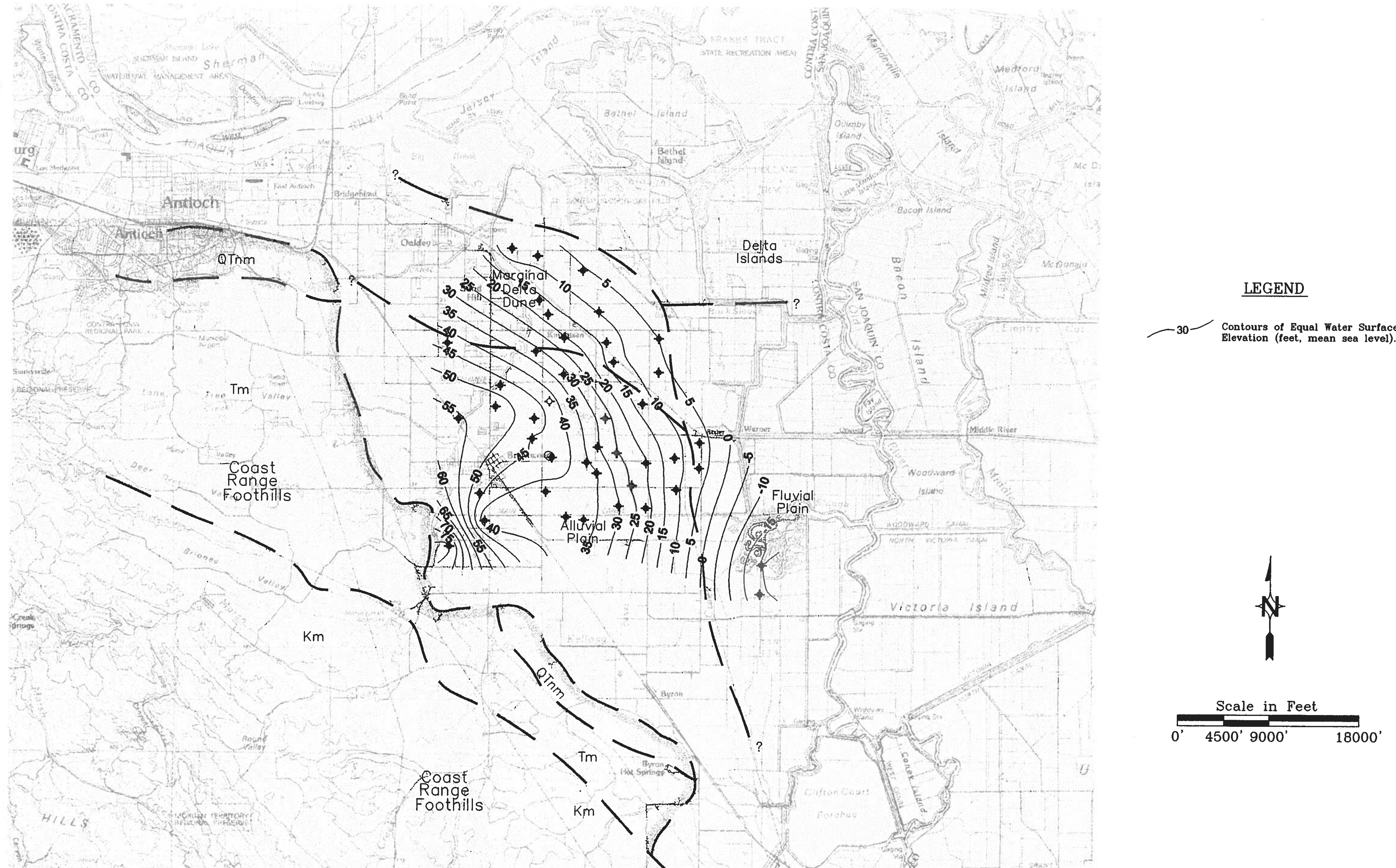
LUHDORFF & SCALMANINI CONSULTING ENGINEERS

Contours of Equal Ground-Water Elevation - Spring 1977
East County Water Management Association
Ground-Water Resources Assessment



LUHDORFF & SCALMANINI
CONSULTING ENGINEERS

Contours of Equal Ground-Water Elevation - Fall 1986
East County Water Management Association
Ground-Water Resources Assessment



East County Water Management Assoc./97-1-131/Spr1991wl.dwg

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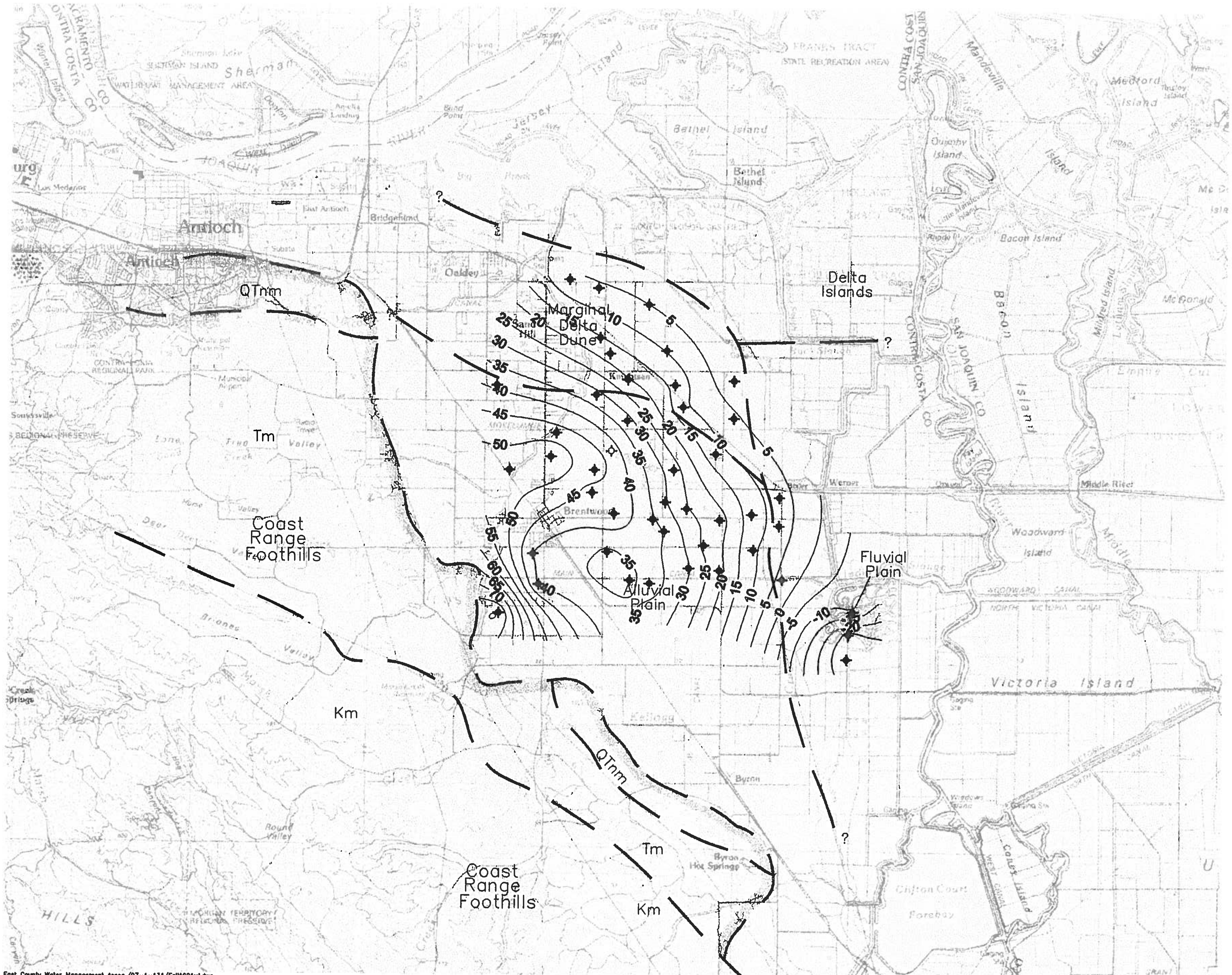
Contours of Equal Ground-Water Elevation - Spring 1991
East County Water Management Association
Ground-Water Resources Assessment



LEGEND

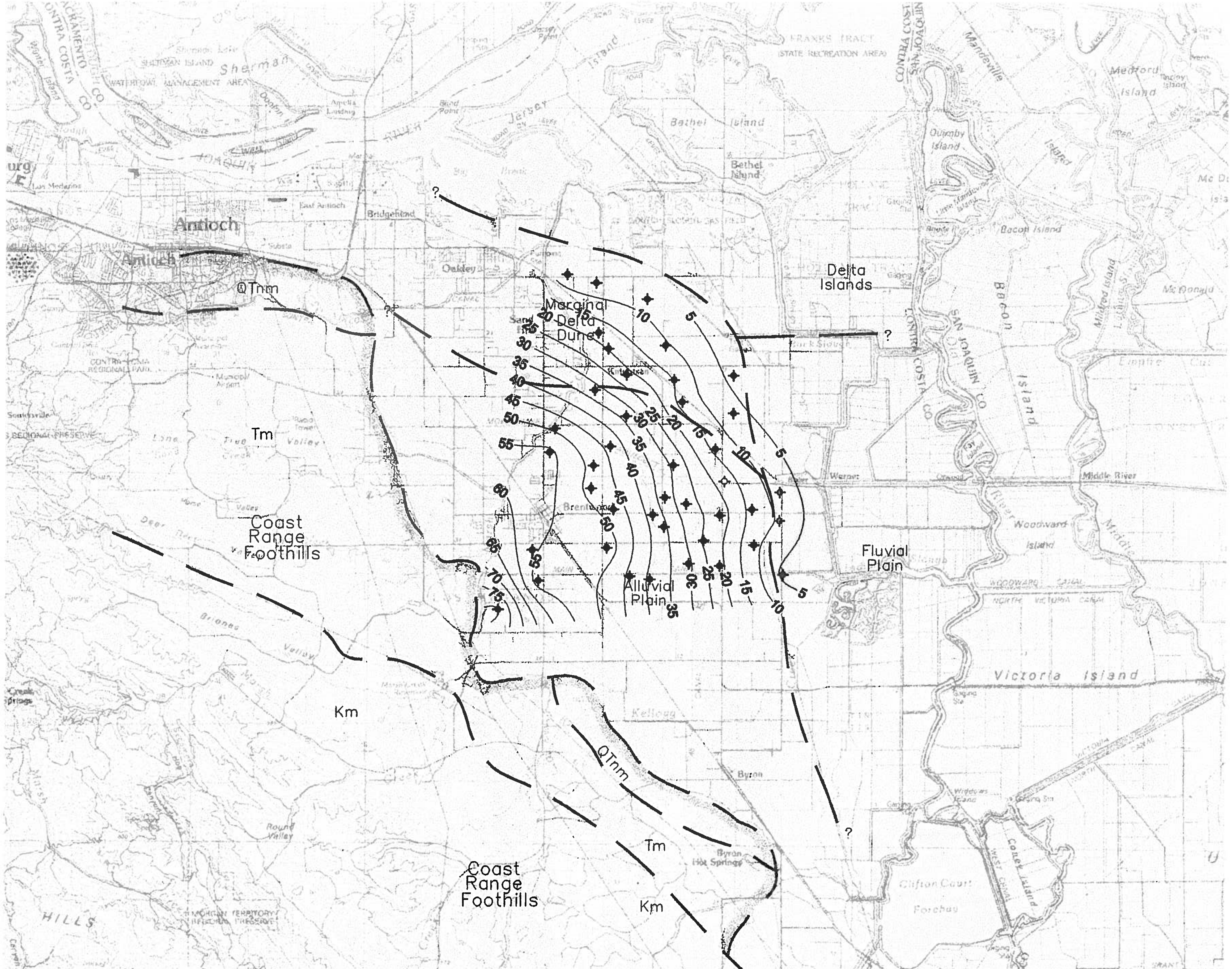
30 — Contours of Equal Water Surface Elevation (feet, mean sea level).

Scale in Feet

0' 4500' 9000' 18000'

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

Contours of Equal Ground-Water Elevation - Fall 1991
East County Water Management Association
Ground-Water Resources Assessment



LEGEND

—30— Contours of Equal Water Surface Elevation (feet, mean sea level).

N

Scale in Feet

0' 4500' 9000' 18000'

East County Water Management Assoc./97-1-131/Fall1996wl.dwg

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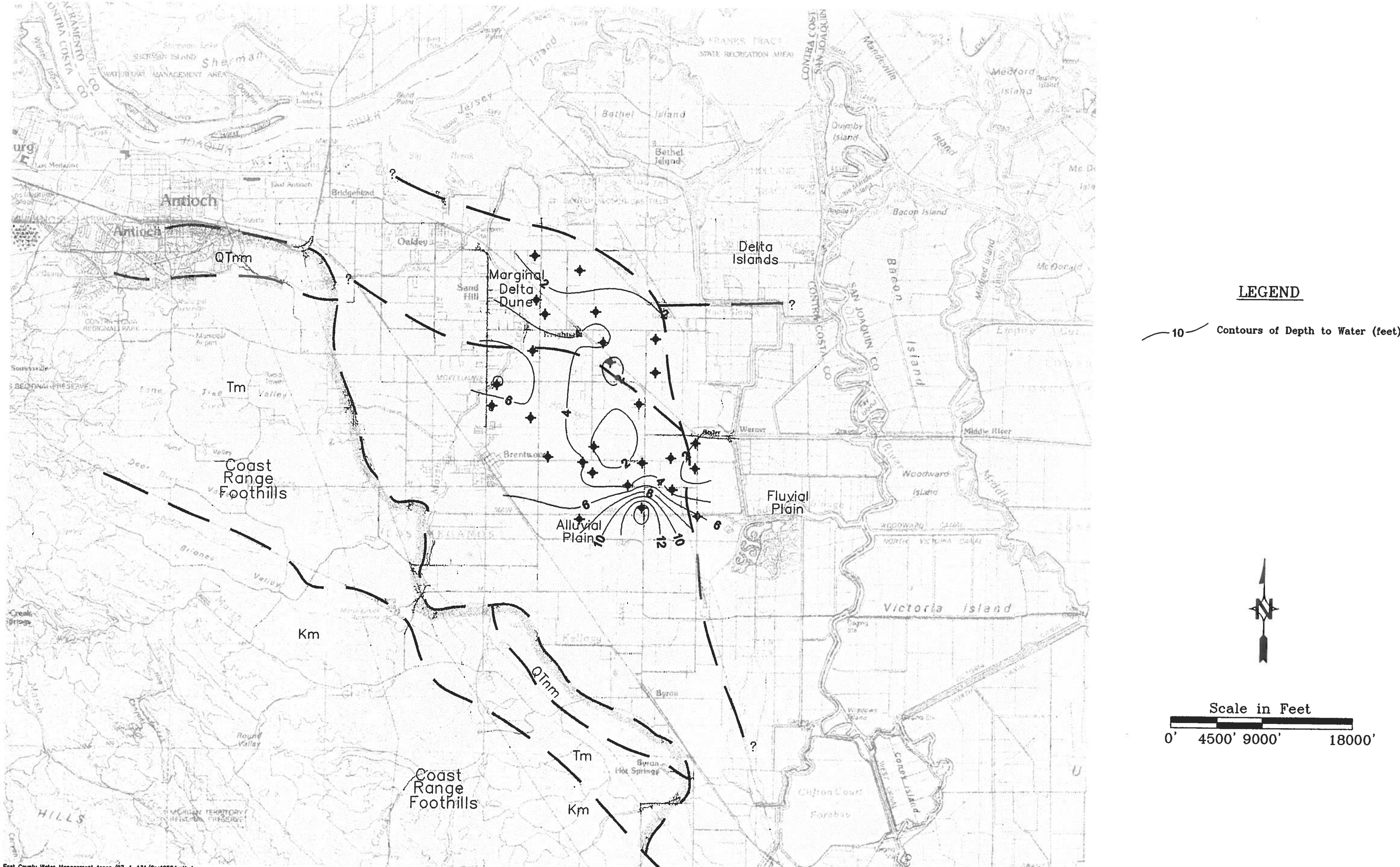
Contours of Equal Ground-Water Elevation - Fall 1996
East County Water Management Association
Ground-Water Resources Assessment

CONTOURS OF DEPTH TO WATER



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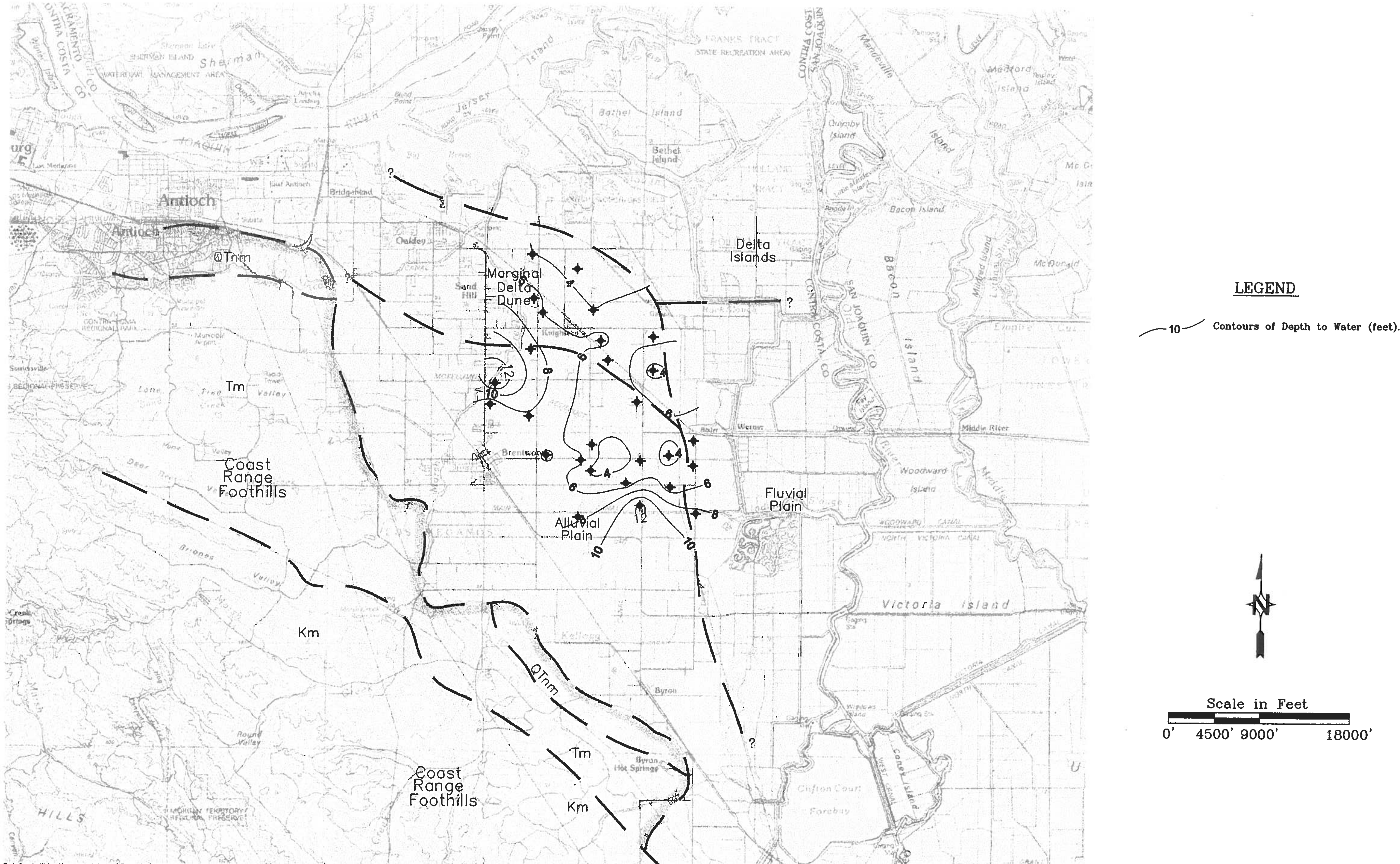
Contours of Depth to Water - Spring 1958
East County Water Management Association
Ground-Water Resources Assessment



East County Water Management Assoc./97-1-131/Fall1958depth.dwg

LUHDORFF & SCALMANINI
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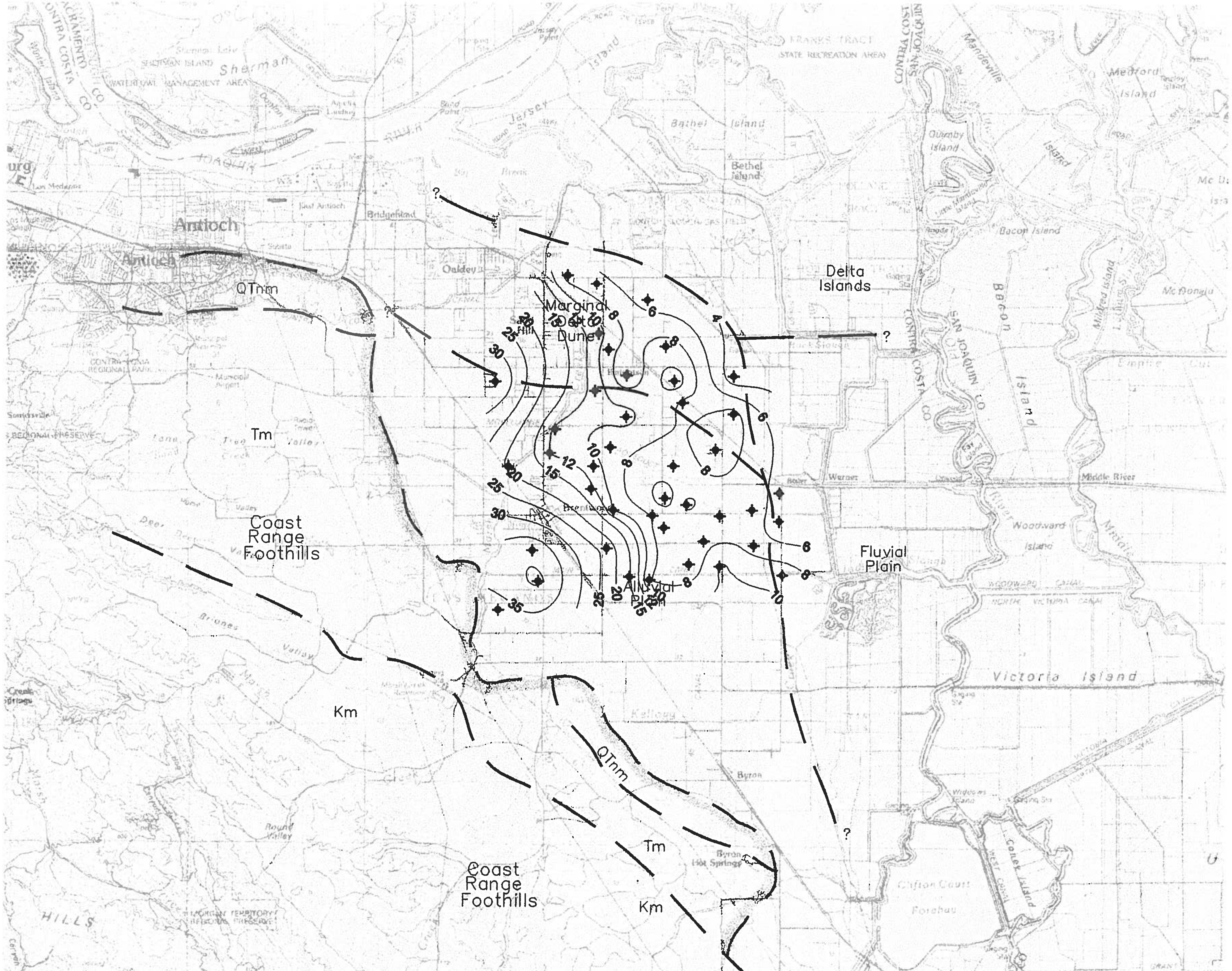
Contours of Depth to Water - Fall 1958
East County Water Management Association
Ground-Water Resources Assessment



LEGEND

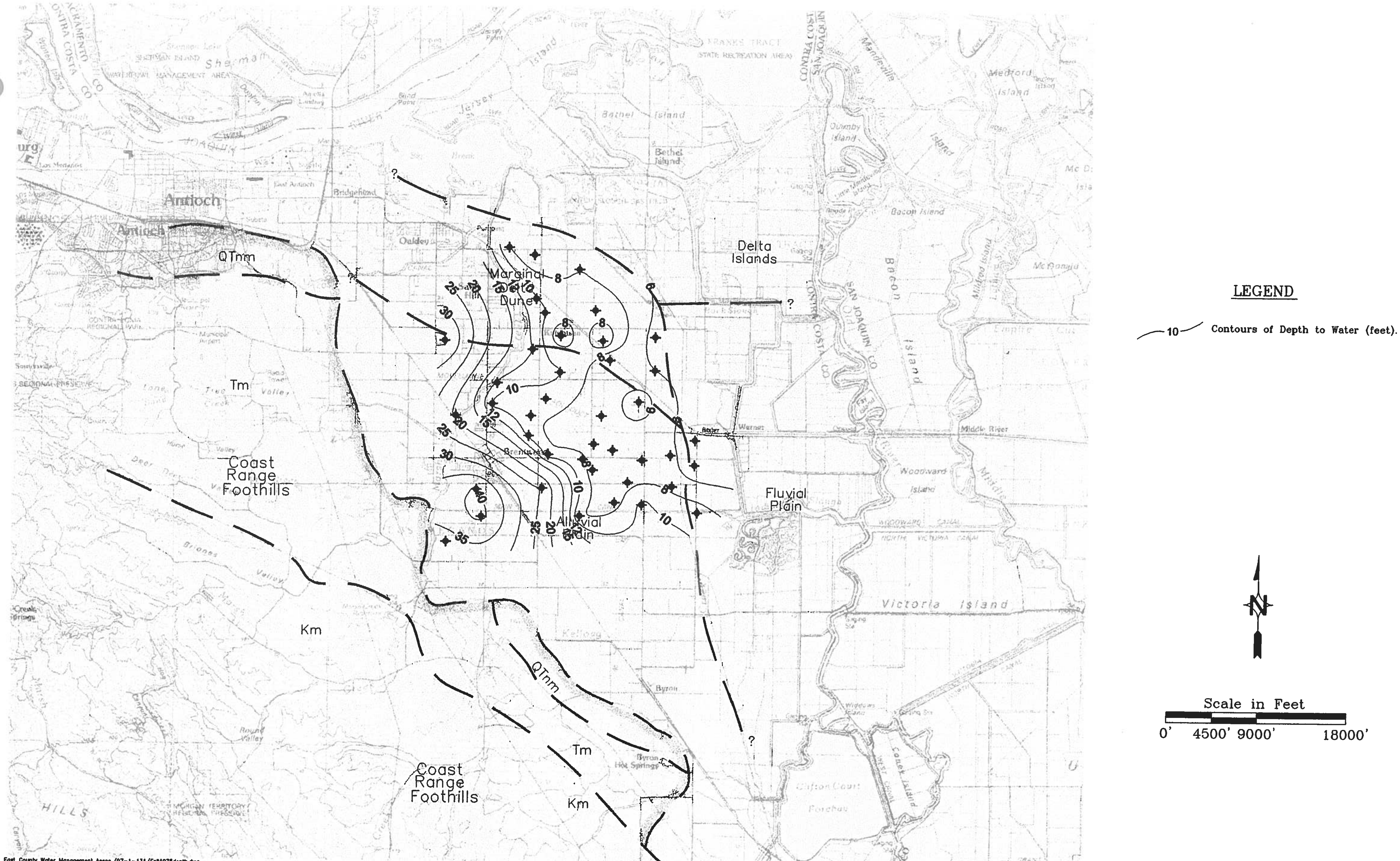
—10— Contours of Depth to Water (feet).

Scale in Feet

0' 4500' 9000' 18000'

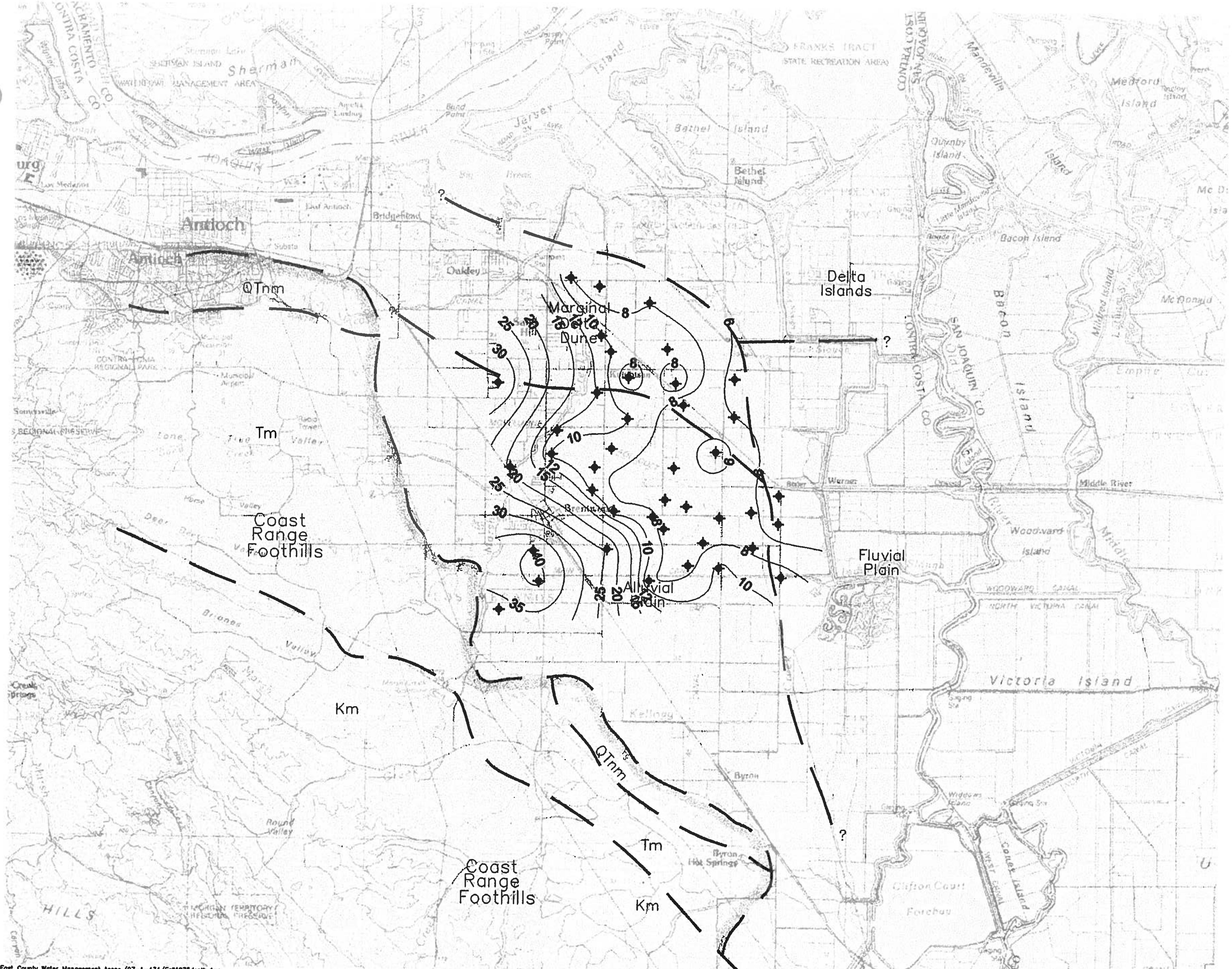
LUHDORFF & SCALMANINI CONSULTING ENGINEERS

Contours of Depth to Water - Spring 1975
East County Water Management Association
Ground-Water Resources Assessment



LUHDORFF & SCALMANINI CONSULTING ENGINEERS

Contours of Depth to Water - Fall 1975
East County Water Management Association
Ground-Water Resources Assessment



LEGEND

—10— Contours of Depth to Water (feet).

Scale in Feet

0' 4500' 9000' 18000'

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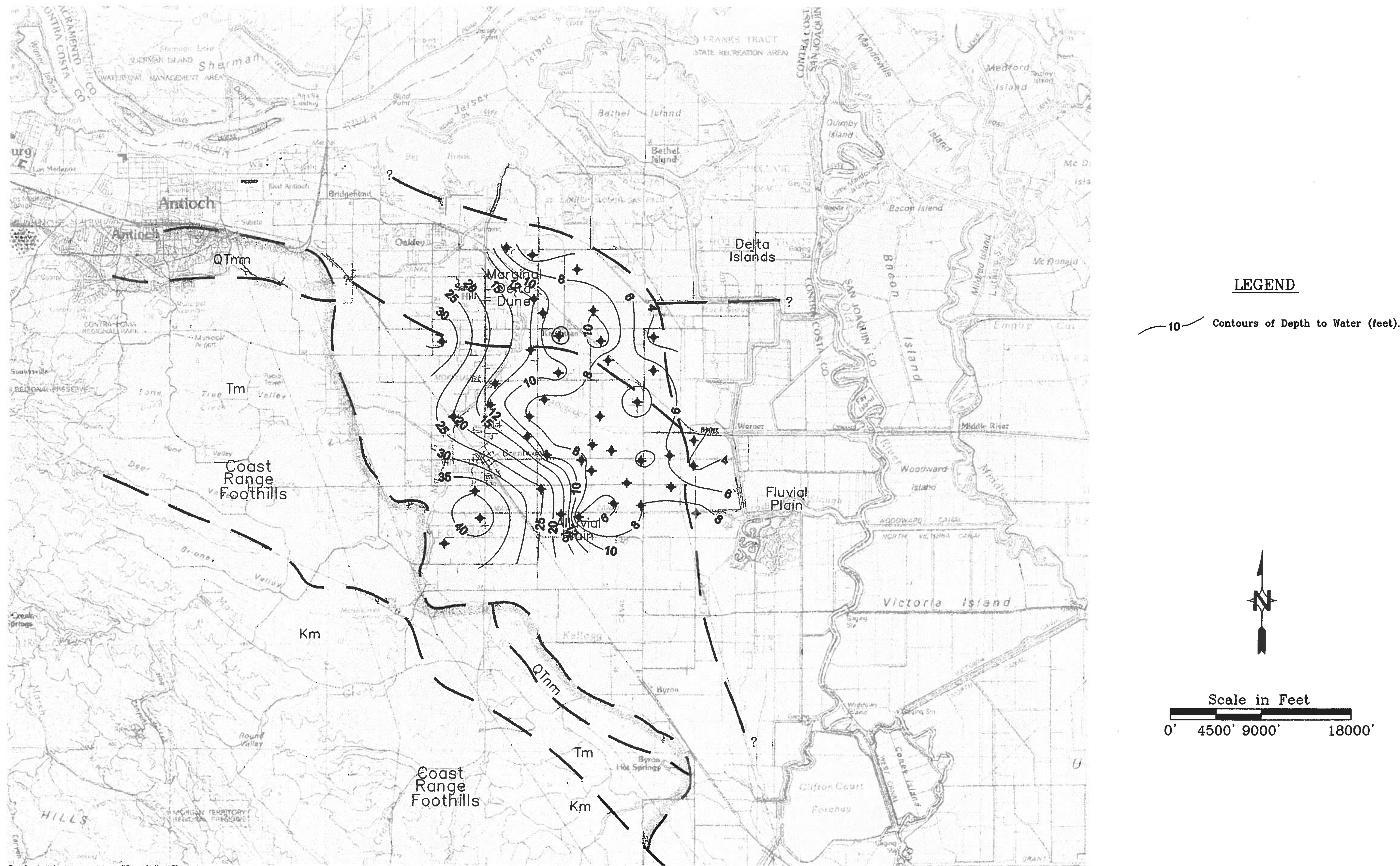
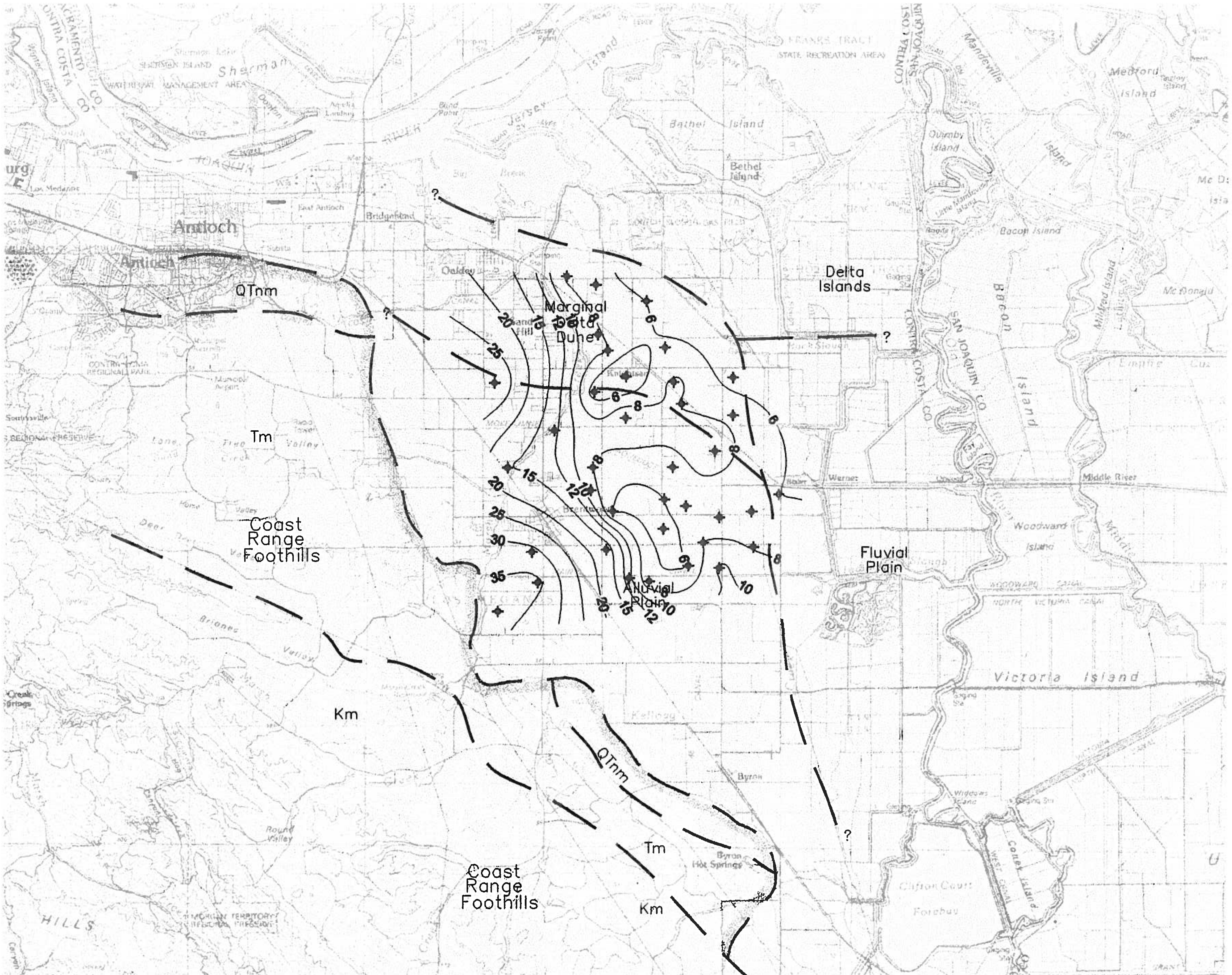
Contours of Depth to Water - Fall 1975
East County Water Management Association
Ground-Water Resources Assessment



LUHDORFF & SCALMANINI CONSULTING ENGINEERS

Contours of Depth to Water - Spring 1977
East County Water Management Association
Ground-Water Resources Assessment



LEGEND

10 — Contours of Depth to Water (feet).

N

Scale in Feet

0' 4500' 9000' 18000'

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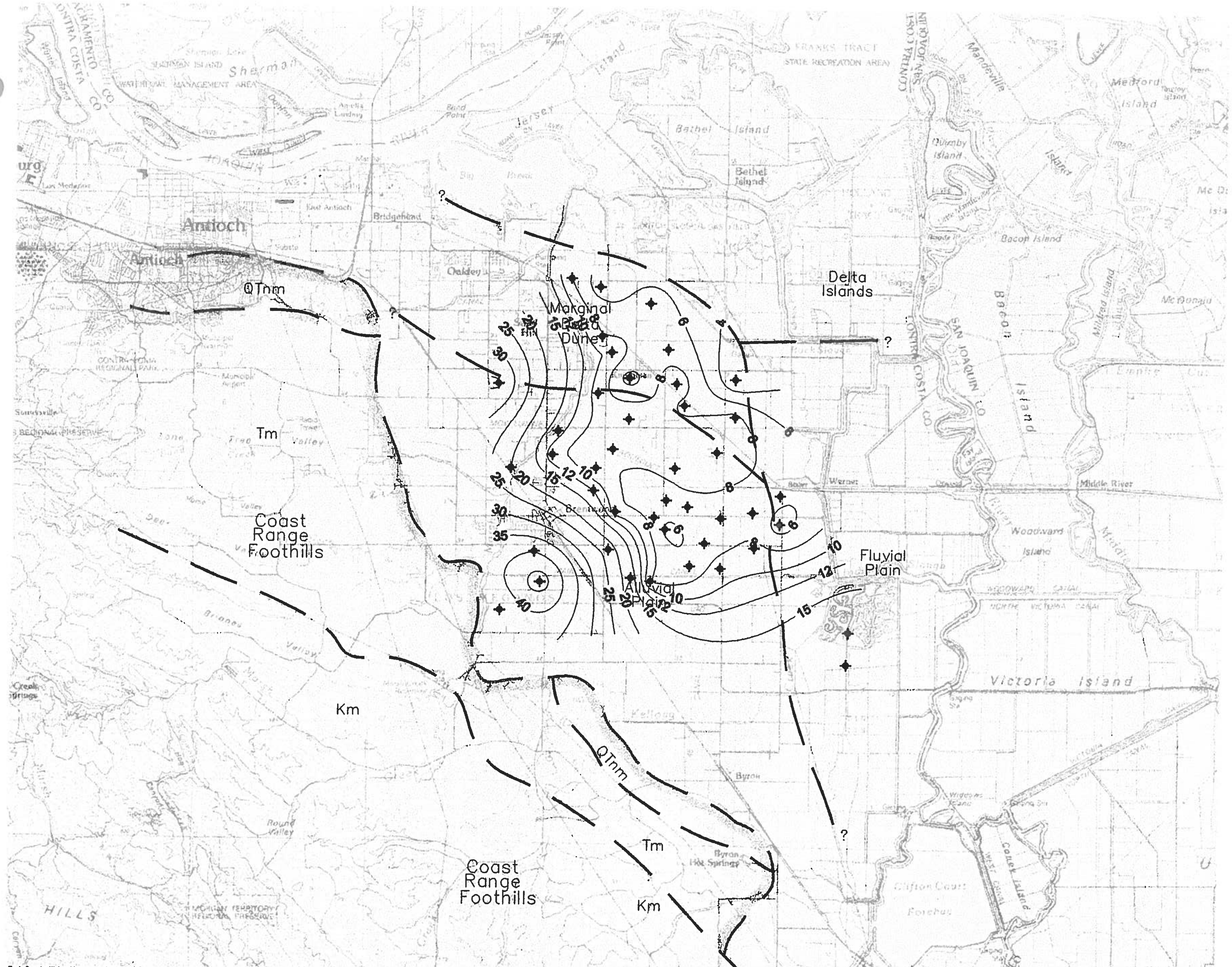
Contours of Depth to Water - Fall 1986
East County Water Management Association
Ground-Water Resources Assessment



LEGEND

10 Contours of Depth to Water (feet).

N

Scale in Feet

0' 4500' 9000' 18000'

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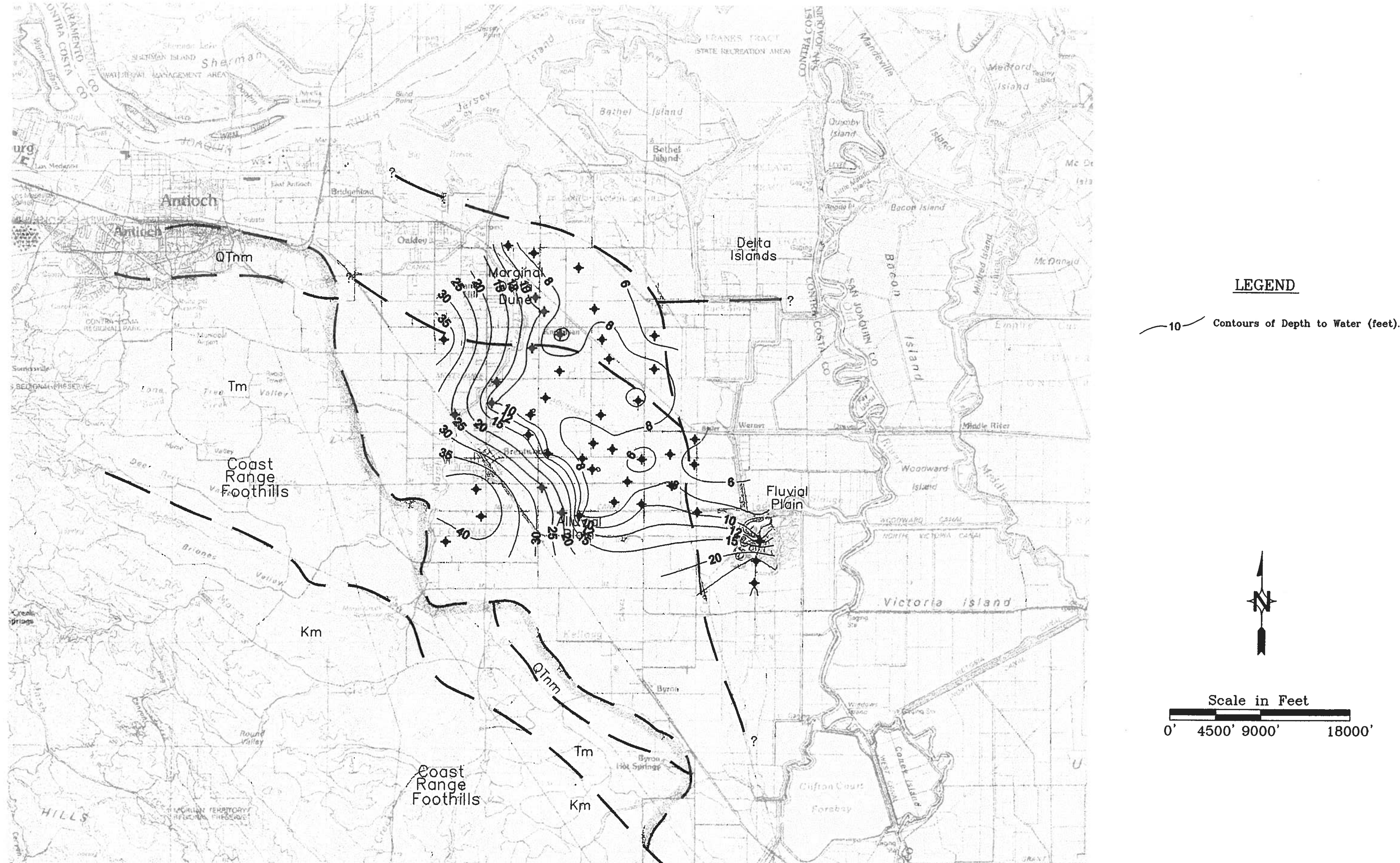
Contours of Depth to Water - Spring 1991
East County Water Management Association
Ground-Water Resources Assessment



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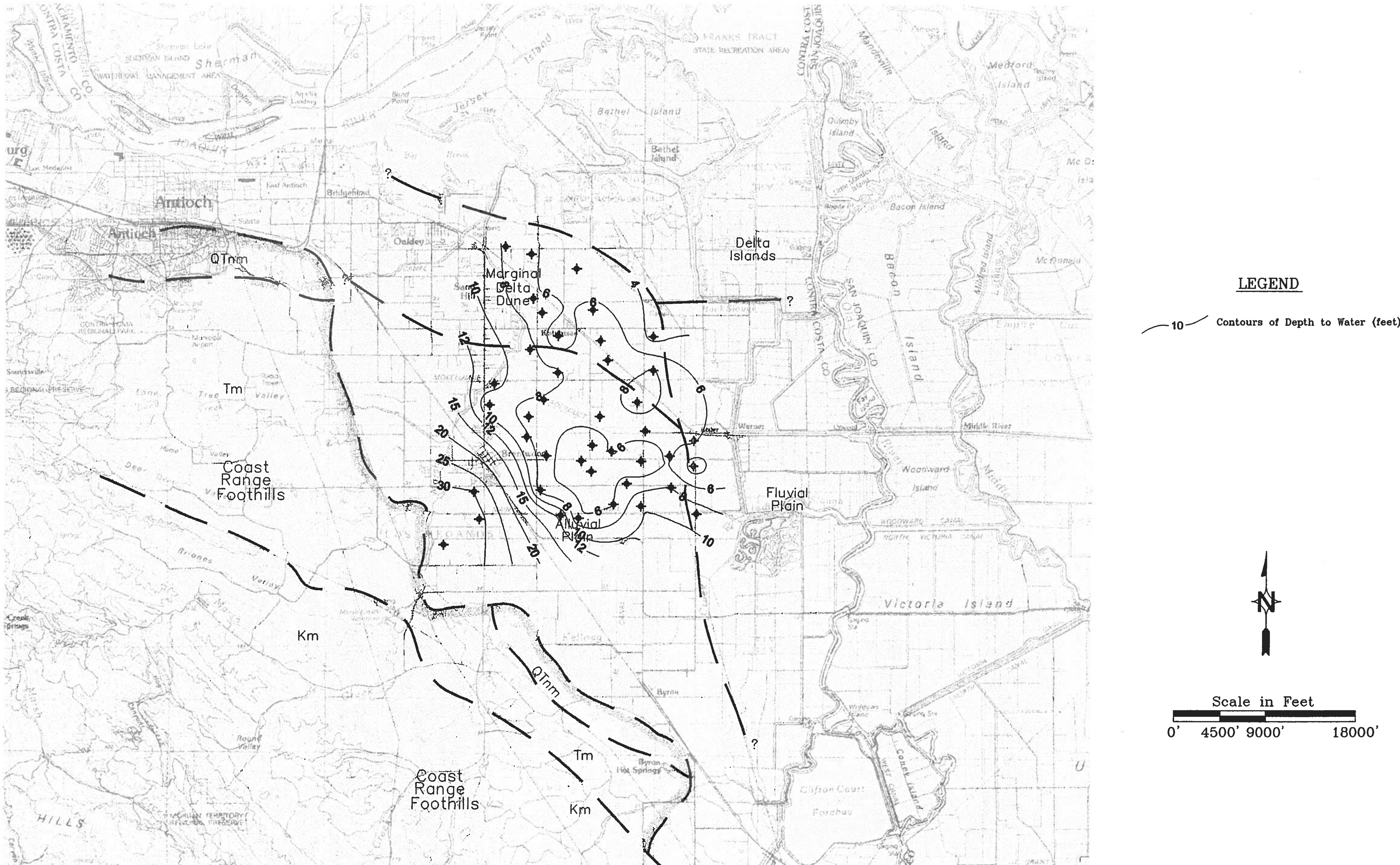
Contours of Depth to Water - Fall 1991
East County Water Management Association
Ground-Water Resources Assessment



East County Water Management Assoc./97-1-131/Fall1996depth.dwg

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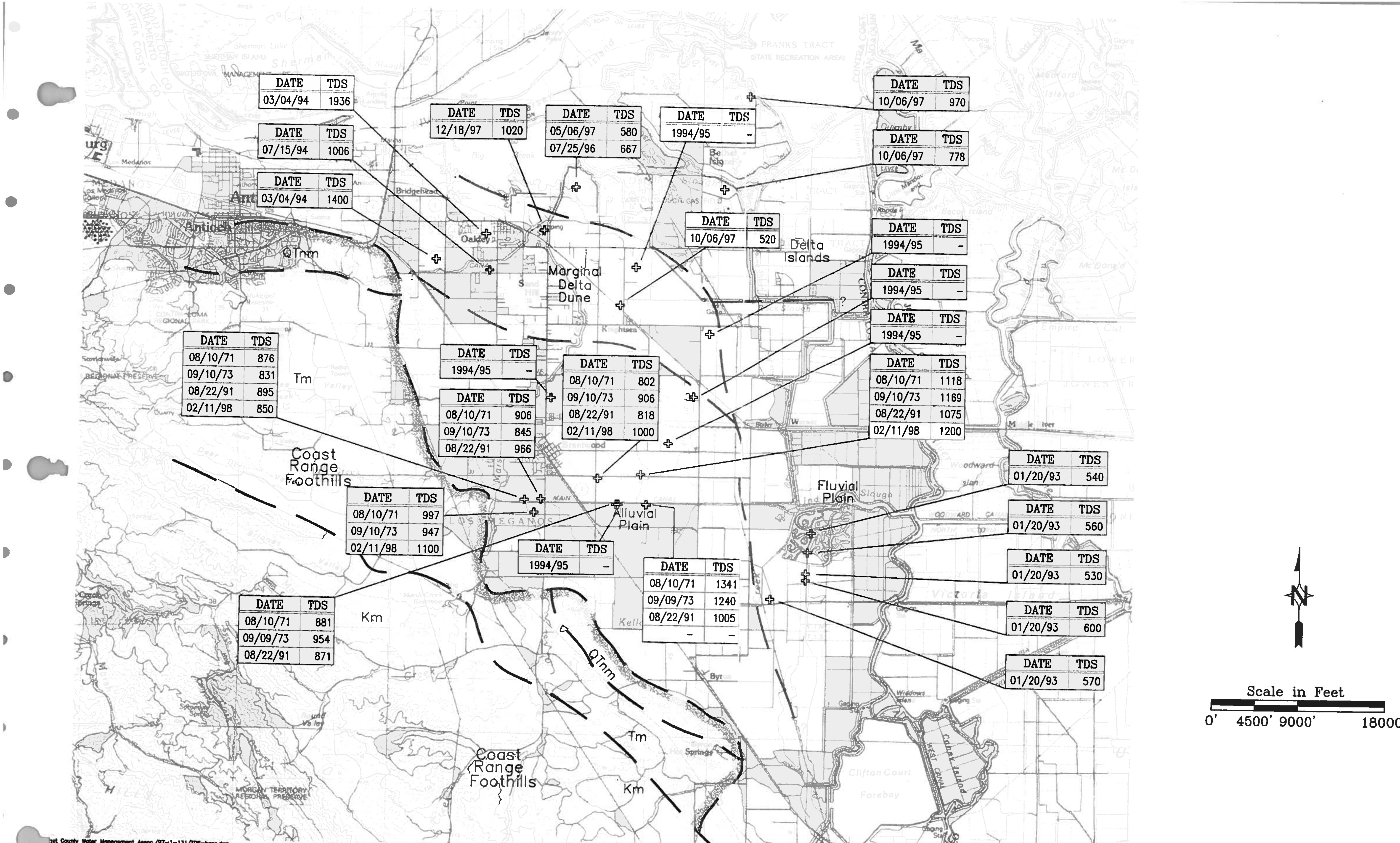
Contours of Depth to Water - Fall 1996
East County Water Management Association
Ground-Water Resources Assessment

WATER QUALITY CONTOURS



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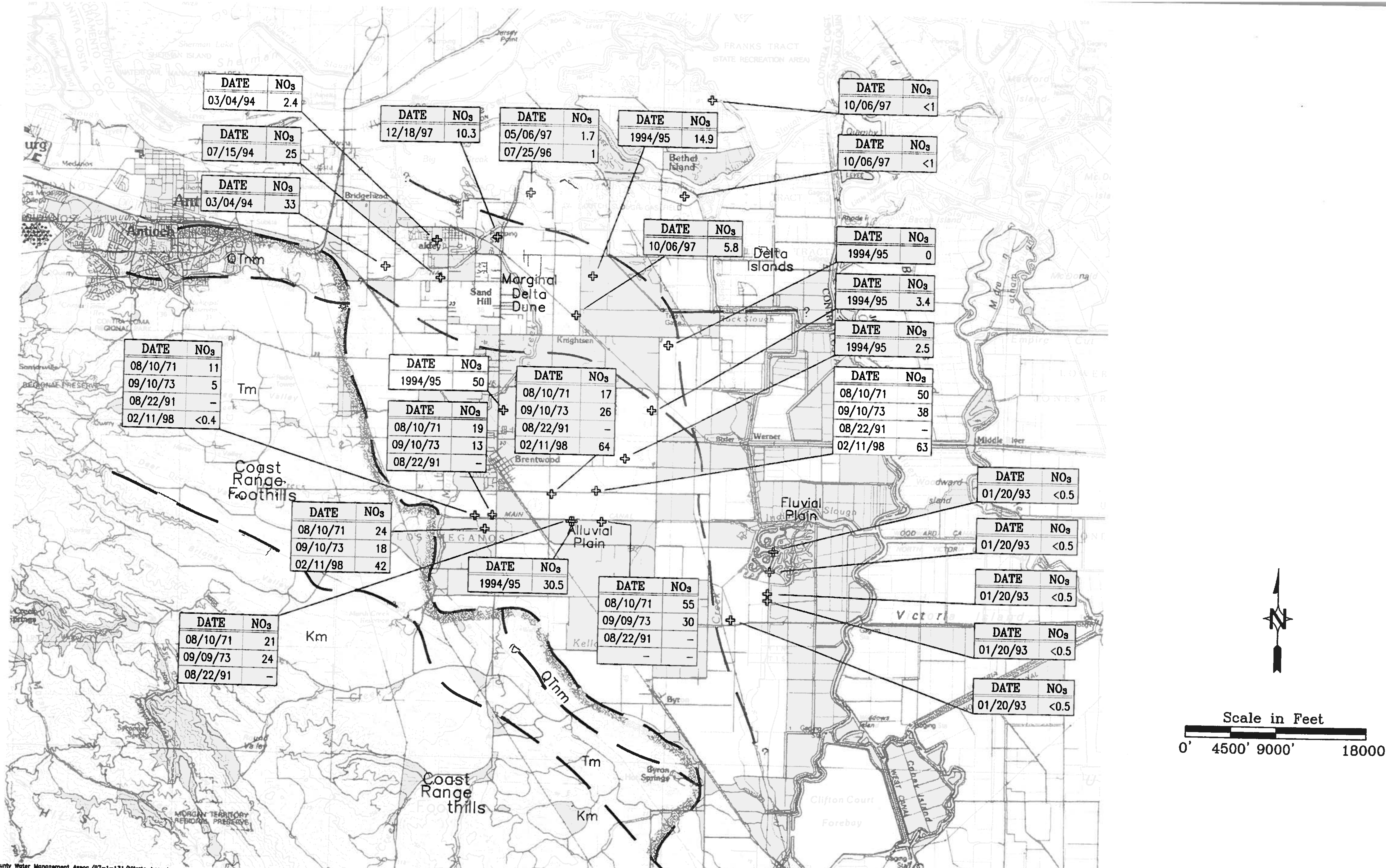
Water Quality Data for TDS
East County Water Management Association
Ground-Water Resources Assessment



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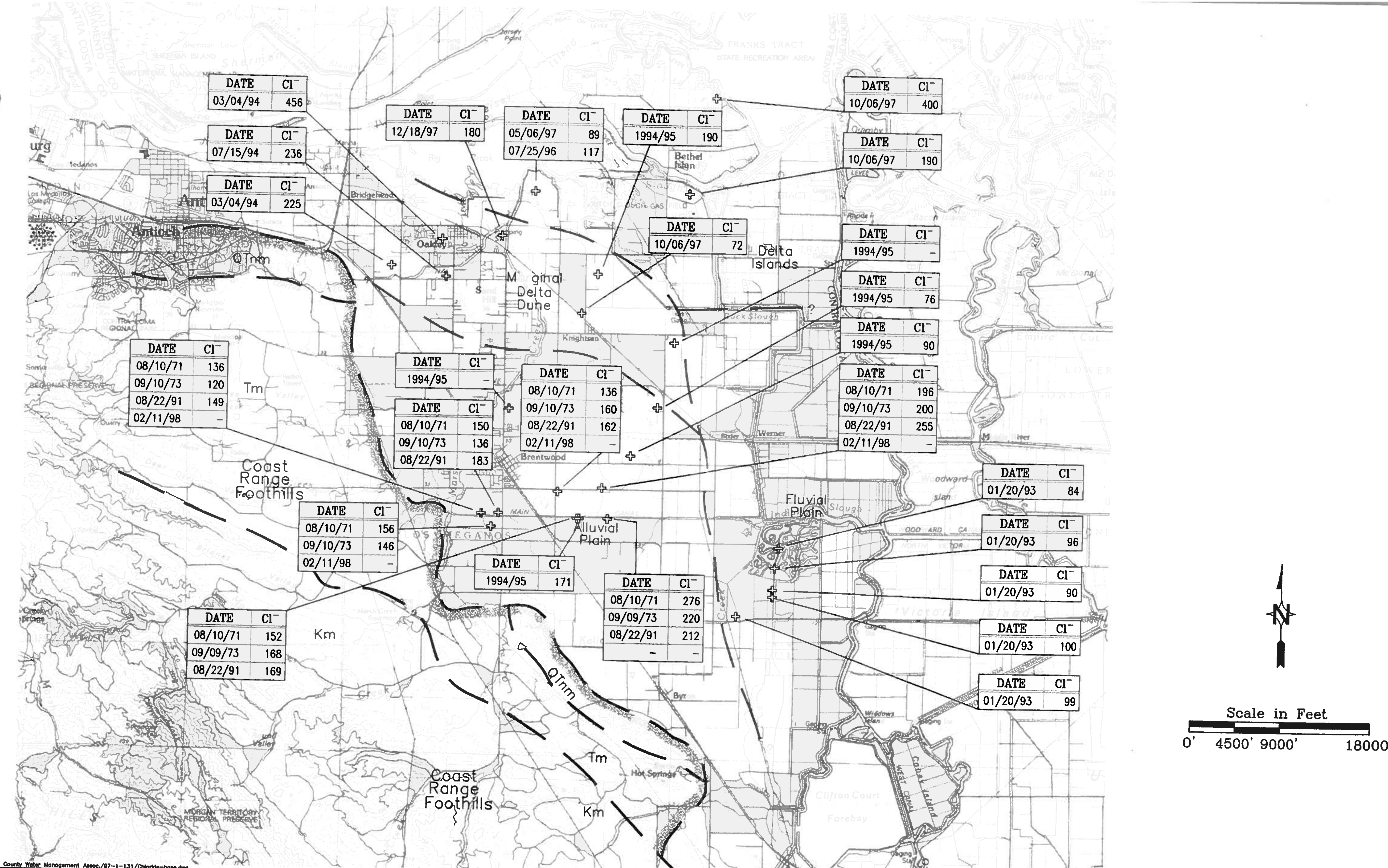
Water Quality Data for Nitrate
East County Water Management Association
Ground-Water Resources Assessment



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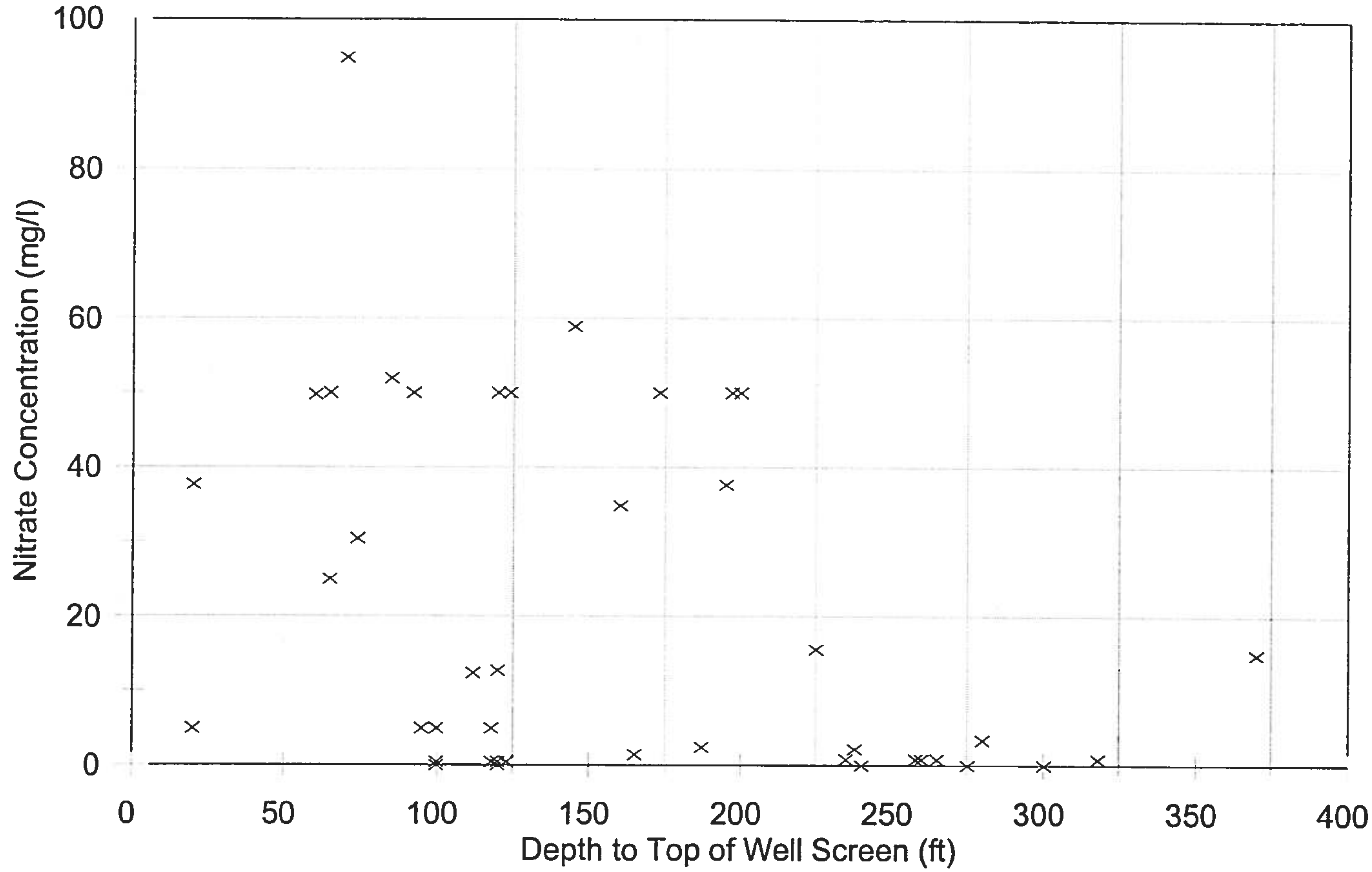
Water Quality Data for Chloride
East County Water Management Association
Ground-Water Resources Assessment

WATER QUALITY GRAPHS

Nitrate Concentration

Relation to Well Completion



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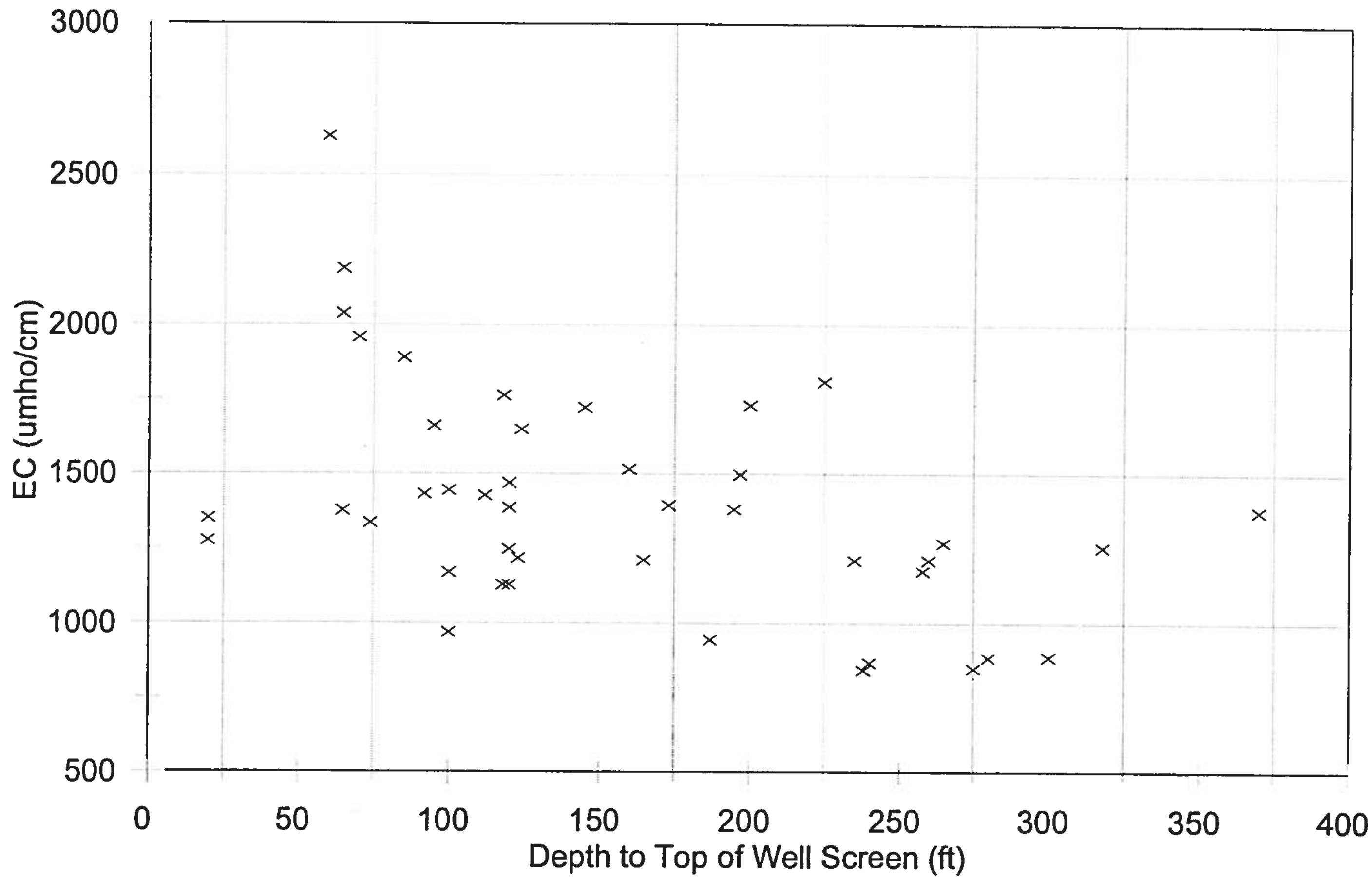
Ground-Water EC

Relation to Well Completion



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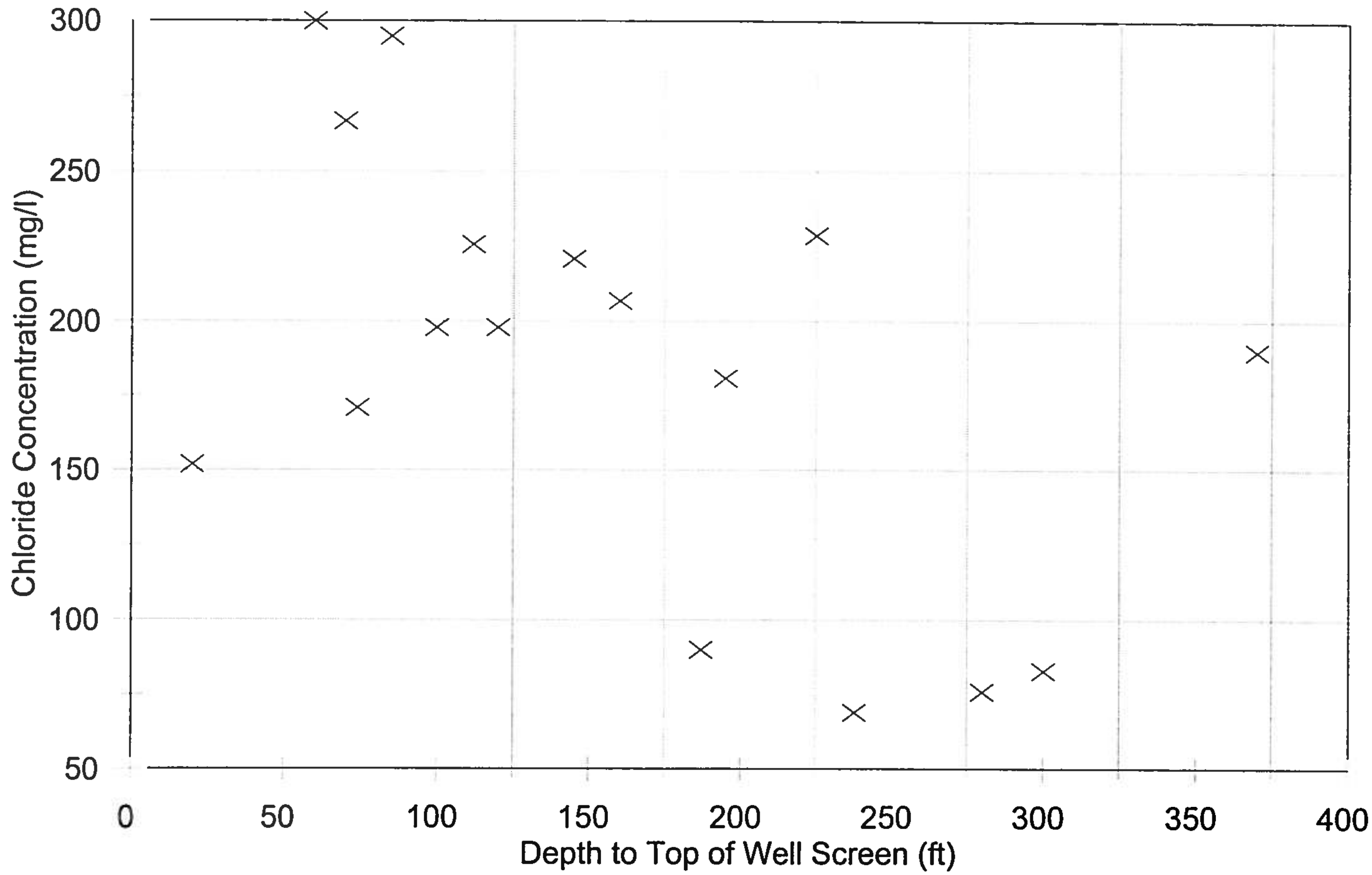
Chloride Ion Concentration

Relation to Well Completion



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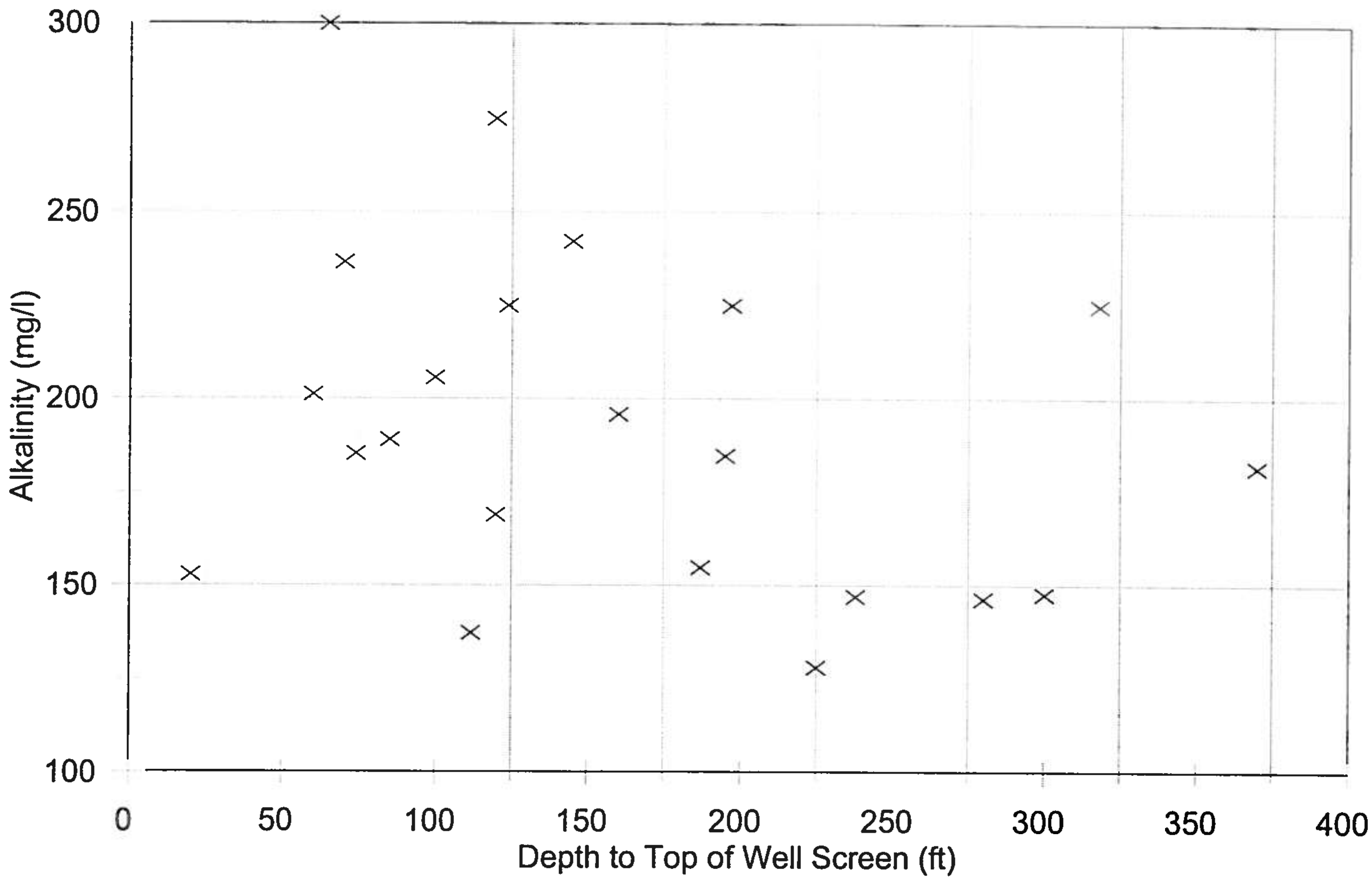
Ground-Water Alkalinity
Relation to Well Completion



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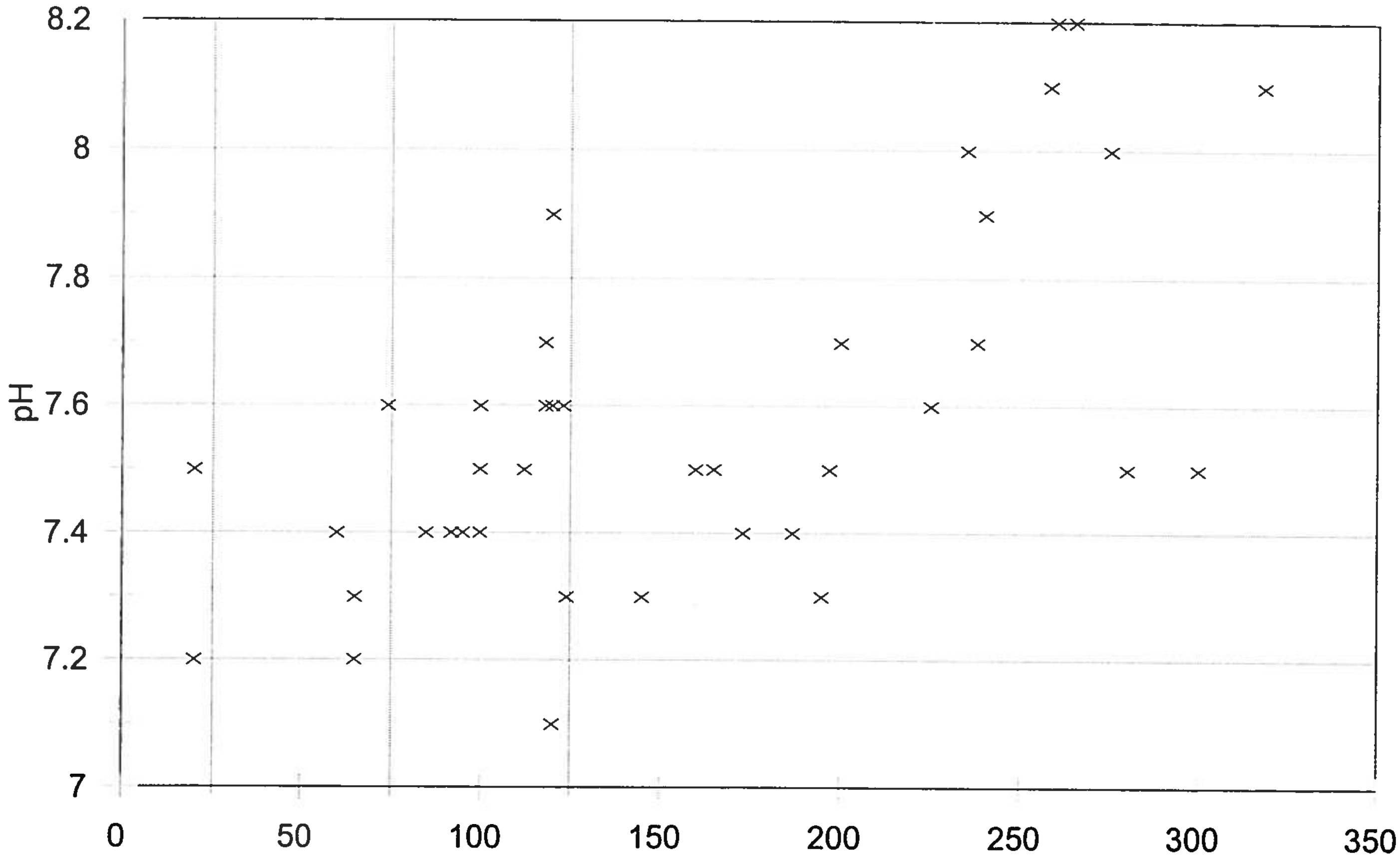
Ground-Water pH
Relation to Well Completion



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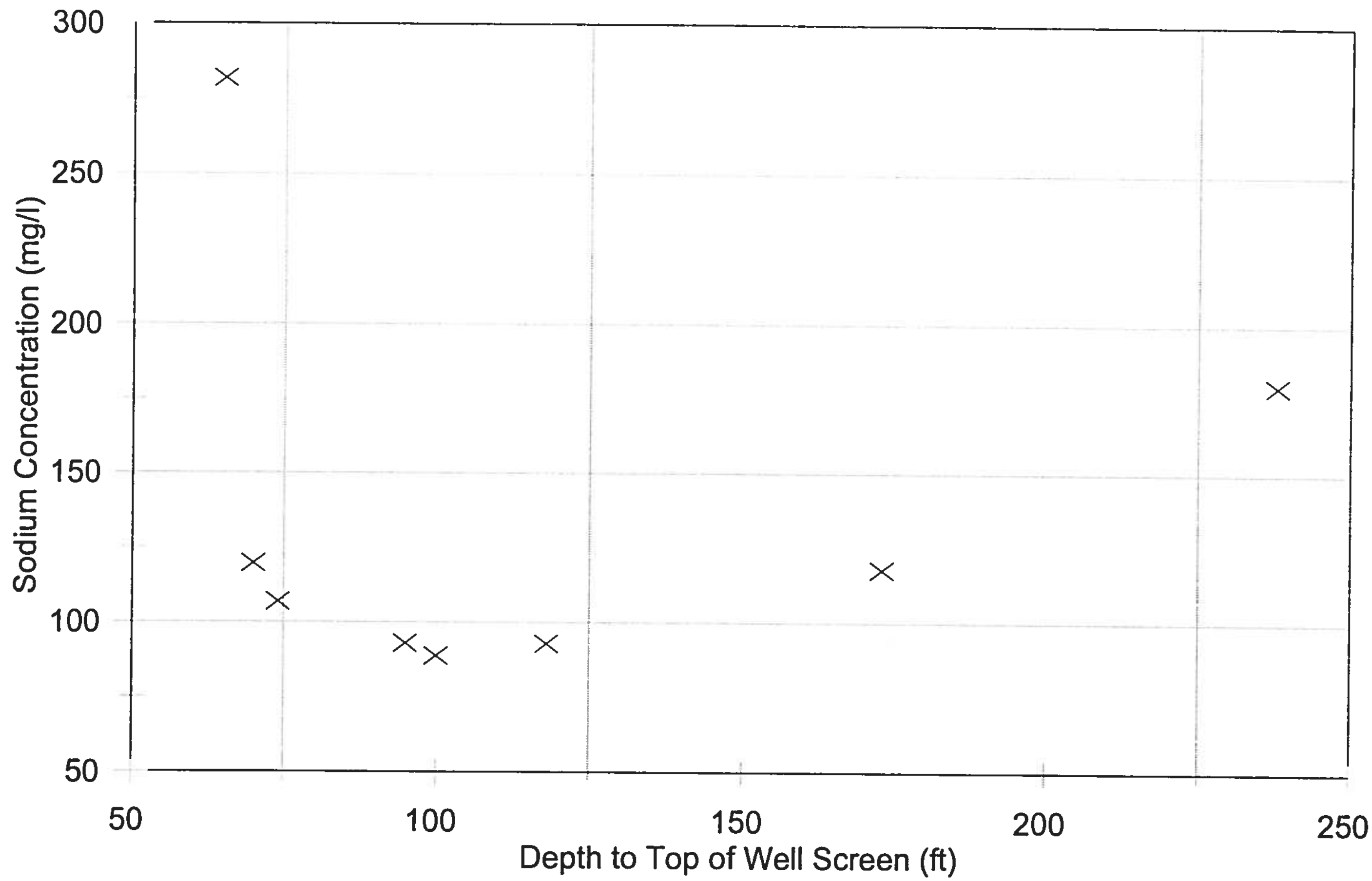
Sodium Ion Concentration

Relation to Well Completion



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GROUND-WATER RESOURCES
HYDROLOGY • DEVELOPMENT • MANAGEMENT