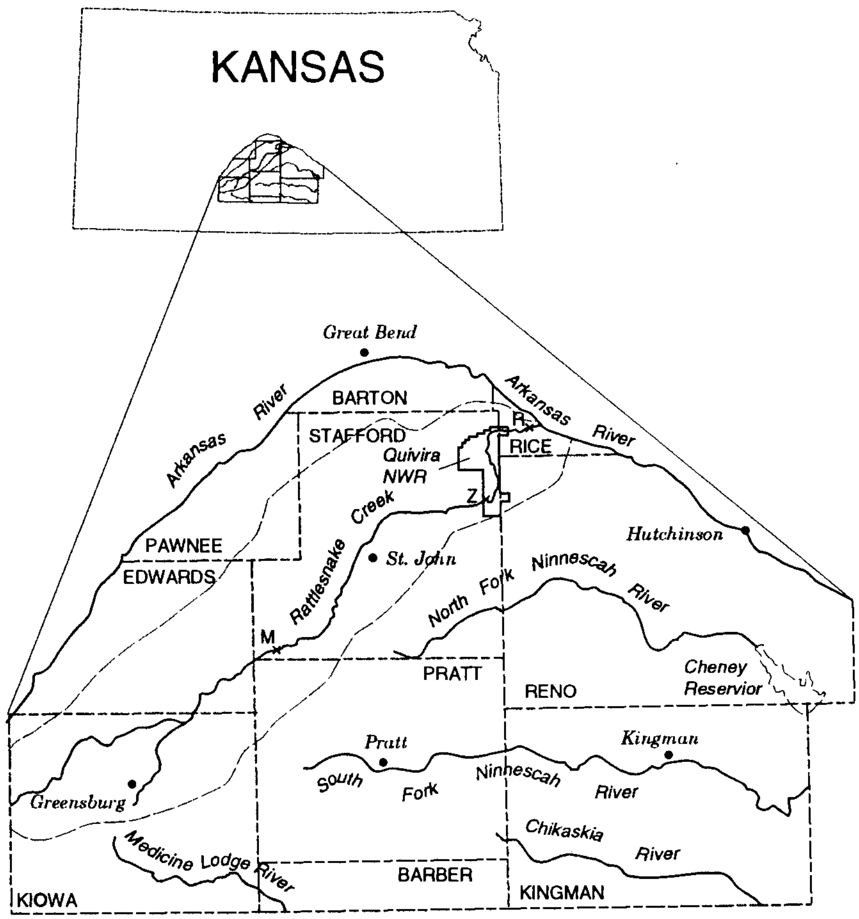
Kansas Geological Survey

Stream-aquifer and mineral intrusion modeling of the lower Rattlesnake Creek basin with emphasis on the Quivira National Wildlife Refuge



Marios Sophocleous
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GEOHYDROLOGY

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I. Statement of the problem

Many regions of western and central Kansas have experienced significant ground-water and streamflow declines, especially during the last two decades (Sophocleous, 1981; Sophocleous and McAllister, 1987, 1990; among others). According to the Kansas Water Office (KWO), extensive ground-water appropriations in the Big Bend Prairie have contributed to extreme low flows in the Arkansas River and Rattlesnake Creek (Water Research Needs Conference, Wichita, Nov. 14, 1984). Also, according to the Kansas Department of Wildlife and Parks, fish and wildlife resources in and along the Arkansas River, the Smoky Hill River, the Pawnee River, Rattlesnake Creek, and other streams in western and south-central Kansas have been significantly affected because of losses of baseflows (Water Research Needs Conference, Wichita, Kansas, Nov. 14, 1984).

In 1983 the Kansas legislature passed the minimum instream flow law, which requires that minimum desirable streamflows be maintained in different streams in Kansas, including the Rattlesnake Creek. According to the Kansas Water Plan document (Kansas Water Plan, sub-section: Minimum Desirable Streamflows, FY1990; KWO, July 1988): "The safe yield policy of Groundwater Management District No. 5 has not protected low flows in the [Rattlesnake] Creek." Implementation of this law certainly requires a better understanding of the stream-aquifer system. According to the Division of Water Resources (Water Research Needs Conference, Wichita, Kansas, Nov. 14, 1984), a more thorough understanding of this stream-aquifer relationship would allow quantitative determination of the effect of ground-water withdrawals on streamflows and would be valuable in the administration of the minimum desirable streamflow program.

The two major central Kansas wetlands—the Cheyenne Bottoms Wildlife Area and the Quivira National Wildlife Refuge, both of which are classified as "outstanding natural resource areas of unique significance" [KAR 28-16c(3)]—are being threatened because of decreasing water supplies and deteriorating water quality. The quality of ground and surface waters is deteriorating mainly because of increased natural nonpoint mineral intrusion from underlying geologic formations; this increased mineral intrusion is considered to be a consequence of freshwater declines in the Quaternary alluvial aquifers of central Kansas. Natural conditions, such as low streamflows and mineral intrusion, result in violations of the dissolved oxygen, chloride, fluoride, and metals criteria for streams during the summer months in several parts of Kansas. According to Fromm and Wilk (1988), streams in central Kansas overlying the Permian red beds and Wellington formation have elevated levels of metals and selenium. In addition to natural conditions, past and current oil and gas production activities have increased the mineral content of some streams. According to the same report (Fromm and Wilk, 1988), the monitoring station on Rattlesnake Creek at Raymond indicates that the 35.4 river miles of the creek governed by that monitoring station are threatened because of the high concentrations of fecal coliform and salt, which are due to agricultural non-point-source pollution and natural saltwater intrusion.

The Quivira National Wildlife Refuge, which covers approximately 21,280 acres in northeast Stafford County, is a major stopover point for migratory birds in the Central Flyway. The refuge was established in 1955 and obtained a permit to divert 22,000 acre-ft of water per year from Rattlesnake Creek. A review of existing water rights in the Rattlesnake Creek basin as of December 31, 1966 (Stramel, 1967), indicated that more water rights had already been filed in the basin than there was water in the stream, and the applications for irrigation rights were increasing. According to Stramel (1967):

> "Development of groundwater in Rattlesnake Creek basin will theoretically, in time, reduce the Creek to a wet weather stream. This results because ground water that

> normally flows to Rattlesnake Creek will be intercepted by pumping and the base flow of the stream will be intercepted.... Irrigators have already decided to develop the groundwater, and much additional irrigation is expected.... It will be impossible to fully develop the groundwater resources of Rattlesnake Creek basin and not dry up the baseflow of the Creek.... Thus, the drying of Rattlesnake Creek is inevitable. You simply cannot have one without the other."

However, the Rattlesnake Creek is the lifeblood of the Quivira National Wildlife Refuge, a critical habitat for several endangered species of birds and, as mentioned, a major stopover point for thousands of migratory birds. Any major changes in the quantity or quality of river flow can upset the delicate balance necessary for the survival of the Quivira ecological system. Furthermore, a Rattlesnake Creek fish investigation by the Kansas Department of Wildlife and Parks (Ray and Coslett, 1972) concluded that

> "... inadequate flow appears to be the most important limiting factor in establishing and maintaining a sport fishery in Rattlesnake Creek.... If the Rattlesnake Creek sport fishery is to survive, effective legislation restricting present use and limiting further exploitation of ground-water supplies within the basin must be enacted. A detailed ground-water and hydrologic study is needed to provide information upon which the design of a balanced water-use schedule can be developed so that adequate stream flow is insured."

This study was undertaken to address some of these water issues affecting the Quivira National Wildlife Refuge. The study area encompasses an approximately 560 square mile area of the lower Rattlesnake Creek watershed predominantly in Stafford County but also includes portions of other counties, such as Pawnee, Barton, Rice, and Reno (fig. 1). The study area encompasses all three existing stream-gaging stations on the Rattlesnake Creek, namely, the Macksville, Zenith, and Raymond stations.

This report is organized into six parts: (1) purpose and objectives, (2) brief hydrogeology of the study region, (3) methodology employed and basic data analysis, (4) model implementation

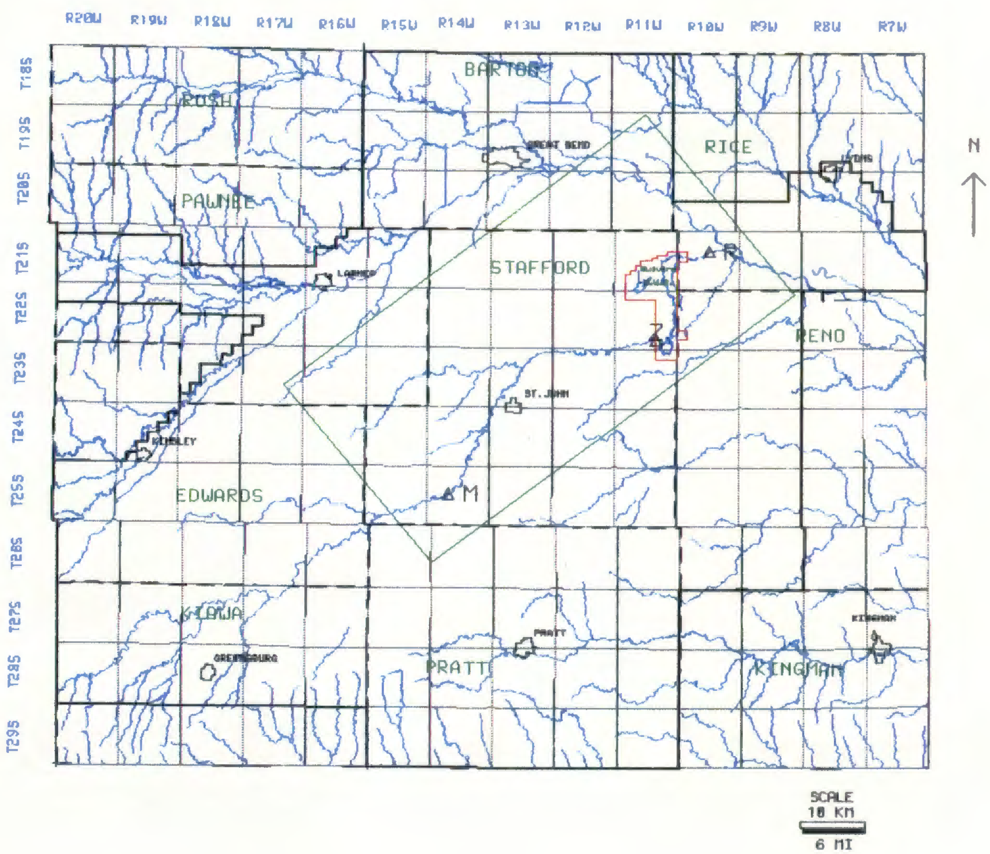

Figure 1. Study area.

and calibration, (5) numerical modeling results and related analyses, and (6) management alternatives to be tested and other work ahead. The more technical, mathematical parts of section IV can be skipped without a loss of continuity.

II. Purpose and objectives

The availability of adequate amounts of water of suitable quality directly affects the future of the Quivira National Wildlife Refuge and the economic development of the Rattlesnake Creek Basin and hence the welfare of the people living in the region. It should be noted that most of the developable water in Kansas has already been developed, and the future water management in Kansas will depend heavily on obtaining more mileage from existing supplies. Sustaining solutions must be based on fundamentally sound hydrologic endeavors and related technology. Therefore the broad goals of this proposed research are to provide information and analysis (1) make better use of scarce water resources and (2) to preserve or improve existing water quality. These two goals can be accomplished only through a basic understanding of the long-term behavior of the stream-aquifer system and development of an effective management policy. Specific objectives of this research include:

1. Analysis of the effects of overall regional appropriations and various pumping patterns on stream baseflows and aquifer water levels and analysis of the effects of mineral intrusion from underlying geologic formations. This will involve development and application of a stream-aquifer saltwater intrusion numerical model for predicting baseflows and water-quality degradation resulting from mineral intrusion, given various pumping and drought scenarios; it will also involve field monitoring of the saltwater-freshwater interface.

2. Evaluation of the outlook for available surface-water and ground-water supplies to the Quivira National Wildlife Refuge and development of strategies to maintain or enhance these supplies. The impacts on the Quivira refuge of recently established minimum streamflows in Rattlesnake Creek and continued water rights appropriations will be analyzed, especially if the Rattlesnake streamflows are less than the current or projected water requirements for properly managing the wetland.

3. Evaluation of the hydrologic effectiveness of management alternatives, including the determination of protective corridors around Rattlesnake Creek for possible water rights restrictions if streamflows fall below established minima or if drought conditions develop. We will test the hydrologic effectiveness of the protective corridor idea to see whether it will appreciably enhance the available water supplies for the refuge.

III. Hydrogeology and Pleistocene history of the Great Bend Prairie with emphasis on the study area

Knowing the geologic history and the geologic composition and structure of the study area is a prerequisite to understanding the water-bearing and water-yielding properties of the modeled stream-aquifer system.

The Great Bend Prairie is covered with a veneer of loess deposits and sand dunes, with underlying Pleistocene alluvium forming the major aquifer of the area (Latta, 1950; Fader and Stullken, 1978). This alluvium was deposited by the ancestral Arkansas River and a small number of local streams and is composed of undifferentiated early Pleistocene sediments (the Meade formation, which consists of interbedded lenses of unconsolidated gravel, sand, and silt; caliche is common throughout the formation) and late Pleistocene sediments (the Sanborn formation, which consists of silt, sandy silt, and fine sand that locally contains lenses of coarse sand and gravel; Latta, 1950). The Pleistocene alluvium overlies Cretaceous and Permian bedrock. A generalized columnar section of the geologic units and their water-bearing properties is given in table 1 from Fader and Stullken (1978), and a bedrock geology map of the region is shown in fig. 2. The lower reaches of the Rattlesnake Creek and the Quivira Refuge represent a natural groundwater discharge area of both the unconsolidated Great Bend Prairie aquifer and the underlying bedrock aquifers.

Most of the Tertiary deposits that make up the Ogallala Formation were removed by erosion before Pleistocene material was deposited. The stratigraphy of the Quaternary alluvium in descending order is generally (1) sand dunes; (2) a relatively continuous near-surface silt-clay bed,

Table 1 Generalized columnar section of geologic units and their water-bearing properties, (from Fader and Stullken, 1978)

System	Geologic unit	Maximum thickness, in feet	Physical character	Remarks
Quaternary	Undifferentiated Pleistocene deposits	360	Unconsolidated deposits of sand and gravel with interbedded lenses of clay, silt, and caliche. Windblown silt (loess) and dune sand occur at the surface over most of the area. Stream-laid deposits (alluvium) of late Quaternary age ranging from clay to gravel occur along the principal stream valleys	Comprises principal aquifer. Water generally is of good chemical quality,* but may be of poor chemical quality in the northeastern part of the area and in deep buried valleys in the south-eastern part. Yields as much as 2,000 gal/min to wells.
Tertiary	Ogallala Formation (Pliocene deposits)	65	Unconsolidated deposits of silt and fine sand with interbedded caliche. Some interbedded sand and gravel.	
Cretaceous	Undifferentiated Lower Cretaceous rocks	380	Upper unit (Dakota Formation) brown to gray fine- to medium-grained sandstone interbedded with gray sandy shale and varicolored shale. Middle unit (Kiowa Formation) dark-gray to black shale interbedded with tan and gray sandstone. Lower unit (Cheyenne Sandstone) gray and brown fine to medium grained sandstone interbedded with dark-gray shale.	Water probably of poor chemical quality. Yields 10 to 100 gal/min to wells locally in the western part of the area.
Permian	Undifferentiated Permian rocks	350	Interbedded reddish shale, siltstone, and sandstone with some beds of dolomite and anhydrite. Includes in descending order, Whitehorse Formation, Dog Creek Formation, Blaine Formation, and Flower-pot Shale.	Water generally of poor chemical quality. May yield as much as 10 gal/min to wells
	Cedar Hills Sandstone	200	Reddish shale, siltstone, silty shale and sandstone.	Sandstone may contribute highly mineral-ized water to the principal aquifer where the two units are in contact.
	Salt Plain Formation	300	Reddish-brown sandy siltstone and fine grained sandstone.	May contribute highly mineralized water to the principal aquifer where the two units are in contact.
	Harper Sandstone	250	Brownish-red siltstone and silty shale with a few thin beds of silty sandstone. Kingman Sandstone Member is near the top of the formation.	Water may be of poor chemical quality. May yield no water or as much as 100 gal/min to wells in the eastern part of area
	Stone Corral Formation	20	White and light-gray anhydrite and dolomite	Not known to yield significant amounts of water to wells in the area.
	Ninnescah Shale	400	Red and grayish-green shale, siltstone and very fine grained silty sandstone.	May yield water of fair to poor chemical quality to wells in the outcrop areas.
	Wellington Formation	550	Calcerous gray and blue shale containing several thin beds of limestone, gypsum, and anhydrite. The Hutchinson Salt Member, when present, is near the middle of the formation.	Not known to yield significant amounts of water to wells in the area.

* Chemical quality of water is classed as good if the concentrations of dissolved solids is less that 500 mg/l (milligrams per liter) or the concentrations of chloride and sulfate are less than 250 mg/L, fair if dissolved solids are 500 to 1,000 mg/L or chloride and sulfate are 250 to 500 mg/L, and poor if dissolved solids are greater than 1,000 mg/L or chloride and sulfate are greater than 500mg/L.

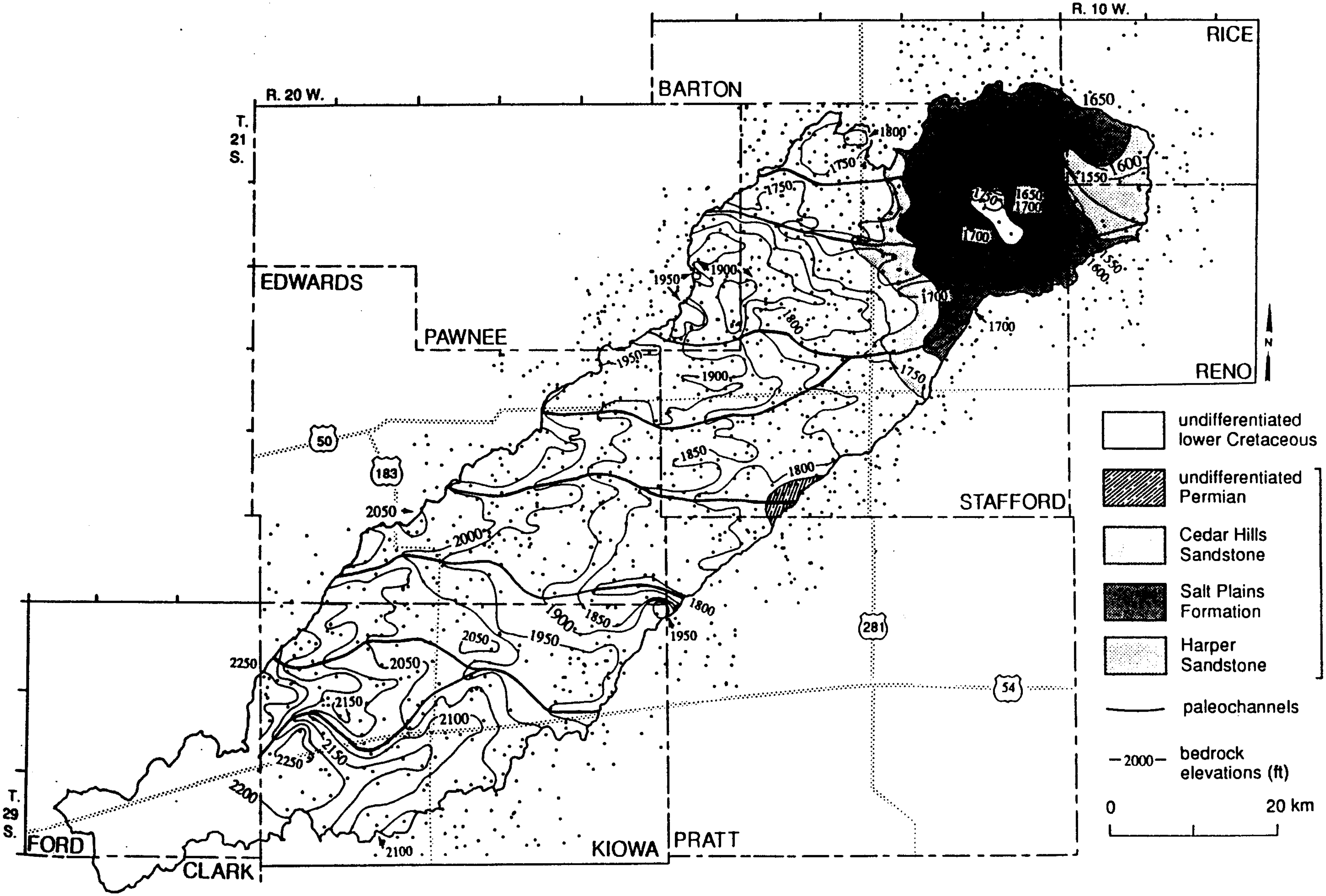

Figure 2. Bedrock geology and elevation contours.

probably a loess deposit; (3) alternating sequences of fining-upward sandy silt-clay, and sand and gravel lenses (not always present); (4) a basal sand and gravel bed of fluvial origin; and (5) bedrock (Rosner, 1988).

The alluvium in the Rattlesnake Creek valley is relatively thin, probably less than 20 ft thick everywhere. It is composed chiefly of poorly sorted sand and gravel that was derived from the Meade formation. The alluvium is underlain by thick deposits of the Meade formation.

The flat areas of the Big and Little salt marshes in northeastern Stafford County are underlain by unconsolidated marsh deposits consisting of clay, silt, sand, and fine to medium gravel that were derived mostly from dune sand but also from the Meade formation and the Kiowa shale. The maximum thickness of these deposits probably does not exceed 15 ft. The upper 1–2 ft consists of fossiliferous sand, silt, and clay, below which are layers of poorly sorted, silty and clayey, fine to coarse sand containing only minor amounts of fine to medium gravel (Latta, 1950).

A ridge of beach sand having a maximum thickness of 15 ft occurs along the eastern and southeastern sides of the intermittent lake that occupies the central part of the Big Salt Marsh. The beach sands are composed of fine to medium sand and are lithologically similar to the dune sand from which they were derived. They are not as well sorted as the dune sand and contain a larger amount of silt, clay, and coarse sand. Some medium to fine gravel is also found locally in the beach sands. The surface of the Big Salt Marsh, although seemingly flat, slopes gently toward an intermittent lake near the center of the marsh. The size of this lake depends entirely on the elevation of the water table. A geologic cross section passing through the Big Salt Marsh in an east to west direction is shown in fig. 3 from Latta (1950). A bedrock ridge trending roughly north-south beneath the Big Salt Marsh and the resulting thinning of the permeable water-bearing material is a major factor in the discharge of ground water there, according to Latta (1950).

The Permian bedrock subcrops along an approximately north-south trend near US–281 and constitutes a source of poor-quality (saline) water east of US–281 in northeast Stafford County (fig. 2). The Permian formations in the area, known as red beds, consist of reddish-brown sandstone, siltstone, shale, salt, gypsum, anhydrite, and limestone. The Permian deposits and

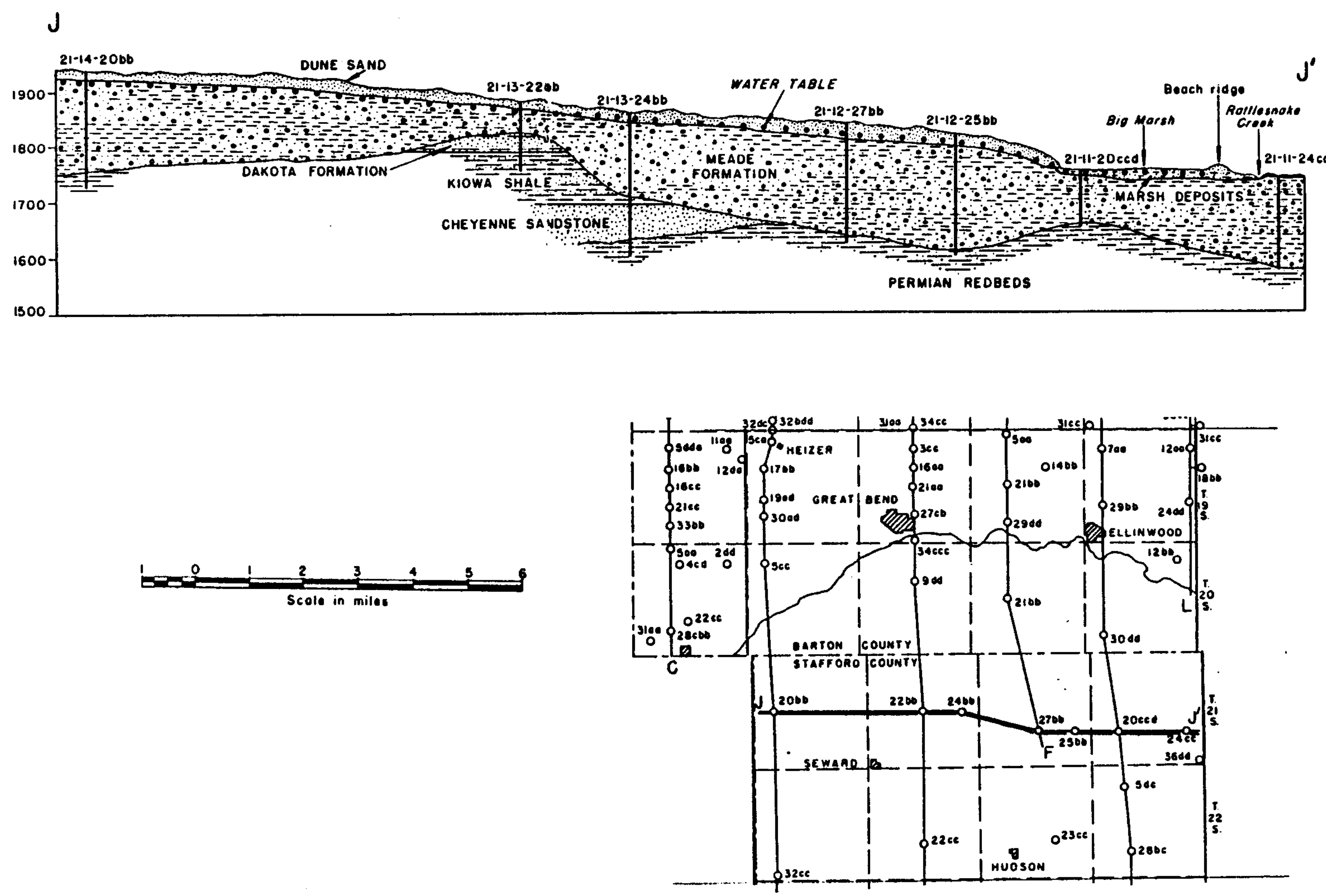

Figure 3. Geologic cross section passing through the Big Salt Marsh (from Latta, 1950).

especially the Late Permian red beds are a source of poor-quality water, which rises upward and increases the water salinity of the unconsolidated aquifer in the lower reaches of Rattlesnake Creek, in particular, the Quivira refuge area.

The mechanical details of the subsurface hydraulic relationships of the consolidated and unconsolidated deposits are not clearly understood. The average chloride load of flow in Rattlesnake Creek at its mouth is about 130 ton/d (U.S. Army Corps of Engineers, 1966). The water near the salt marshes is believed to be a natural occurrence of artesian saltwaters encountered deeper to the west. The saltwater flows from the edges of the bedrock formation into the overlying sediments and rises to the surface in the low areas, primarily along Rattlesnake Creek. The upper reaches of Rattlesnake Creek yield fairly good quality water with little chloride pollution from natural sources. A 1983 electrical-conductivity survey of Rattlesnake Creek (Bindleman, 1983, fig. 4) indicates that conductivity from eastern Edwards County to just northeast of St. John ranged from 350 μS/cm to approximately 625 μS/cm. An abrupt rise in conductivity was observed within a 3-mi distance 1 mi east of where Rattlesnake Creek crosses US-281, with values leveling off at 3,000–4,000 μS/cm. Where the creek enters the Quivira National Wildlife Refuge, another rise in conductivity occurs, with an abrupt increase to values exceeding 20,000 μS/cm within a 2-mi stretch (fig. 4). Before discharging into the Arkansas River, however, the creek's conductivity drops to 3,141 μS/cm. Most of the pollution is from small seeps or marshes in and near the streambed.

Rocks of Cretaceous age form the bedrock surface in the western part of the Great Bend Prairie. These rocks consist of interbedded shales, sandy shales, and fine- to coarse-grained sandstones (Fader and Stullken, 1978). Of the three Cretaceous units (see table 3), only the lower unit (Cheyenne Sandstone) is a potential source of water to large-capacity wells, but the water is believed to be highly mineralized (Fader and Stullken, 1978). The Kiowa Shale is the oldest formation exposed in the Rattlesnake Creek watershed (in the northwestern part of T. 22 S., R. 11 W., northeastern Stafford County), where it consists of dark fossiliferous shale and rusty sandstone. The overlying Dakota Formation is not exposed in the study area.

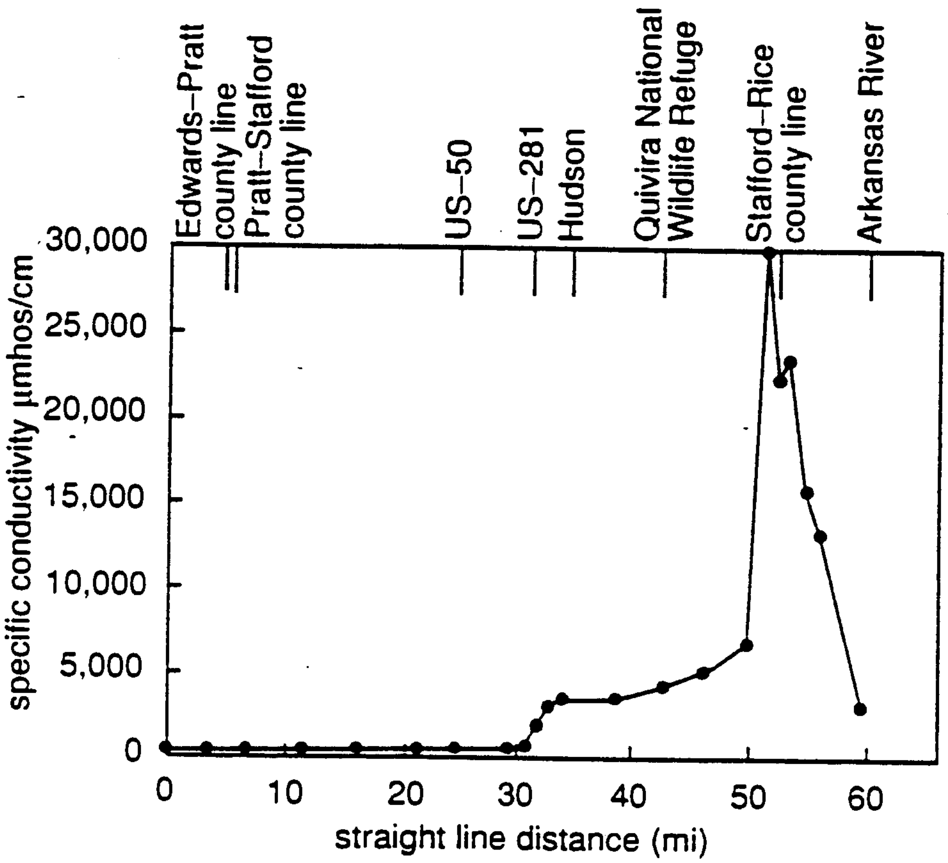

Figure 4. Specific conductance survey along Rattlesnake Creek (adapted from Bindleman, 1983).

In general, the present drainage system of central Kansas is the result of events that took place during the Pleistocene Epoch. The Pleistocene history of the area is complex and is marked by the cutting and filling of deep valleys and by major changes in drainage (Fent, 1950; Frye and Leonard, 1952). During early Pleistocene time, the ancestral Arkansas River, instead of following its present course around the great bend, probably flowed eastward or southeastward across south-central Kansas. This can be seen on the bedrock map of the area (Sophocleous et al., 1990), in which a number of west-east paleodrainage channels progress from south to north throughout the basin (fig. 2).

The Pleistocene drainage patterns of central Kansas record the history of the northeastward migration of through-flowing streams from the Rocky Mountain area. According to Fent (1950), this migration was caused by successive captures of the southern trunk of the ancestral stream by its own northern tributaries. The captures seem to have resulted from the difference in the debris load available in the headwater areas of the streams. Throughout the Pleistocene, through-flowing streams originating from the Rocky Mountains, such as the Arkansas River, filled their channels with coarse gravel and sandy alluvium derived from igneous rocks. This material built up the surface over which the streams flowed, causing stream avulsions and the consequent spreading of alluvial material over wide areas. In contrast, the northern tributaries to the southern trunk stream carried only the finer grained, less permeable sediment load obtained by downcutting in their immediate headwater areas. The silt and fine-grained sand of local origin in the northern Great Bend Prairie, with its low permeability, favored runoff and consequently more erosion and downcutting to below the level of the through-flowing streams; this downcutting led to the eventual capture of the through-flowing streams. This is evident in the relative abundance of northern tributaries to the Arkansas River in central Kansas (Fent, 1950).

IV. Methodology and data analysis results

The methodology we employed in this study consists of three approaches: (1) compilation and analysis of existing information; (2) limited field data collection, and (3) numerical modeling.

A brief summary of the main components of each approach together with some basic data analysis follows.

Compilation and analysis of existing information

Bedrock and predevelopment water-table maps

A comprehensive bedrock and predevelopment water-table map for the Great Bend Prairie region (in which the study area belongs) based on all data accessible or known to us has been prepared and documented separately (Sophocleous et al., 1990). A predevelopment water-table map and a bedrock map of the study area are shown in figs. 5 and 6.

Soils

A soils map of the lower Rattlesnake Creek watershed from near the Macksville stream-gaging station to the confluence with the Arkansas River has been constructed (fig. 7) based on Soil Conservation Service digitized GIS soil coverages (STATSGO). The soils of the watershed formed in several different kinds and ages of parent material, such as sand, loess, and Pleistocene and Holocene sediments.

In early Pleistocene time, alluvium (Meade formation) was deposited over most of the watershed. Soils formed in this old wind-modified alluvium include the Farnum, Blanket, and Lubbock soils (Roth, 1973). Carwile soils also formed in old alluvium.

The loess deposits consist of relatively sand-free silty material that was deposited by wind in late Pleistocene time. The dominant soils formed in this parent material are the Harney, Holdrege, and Uly soils.

Eolian material with a high sand content is the major parent material of the soils in the sand hills. Most of this material was deposited during the Holocene, after the Pleistocene loess was deposited (Roth, 1973). Tivoli soils formed in fine sand, Attica and Pratt soils in loamy fine sand, and Naron soils in fine sandy loam. Tivoli and Pratt soils occur in areas of undulating to dunelike

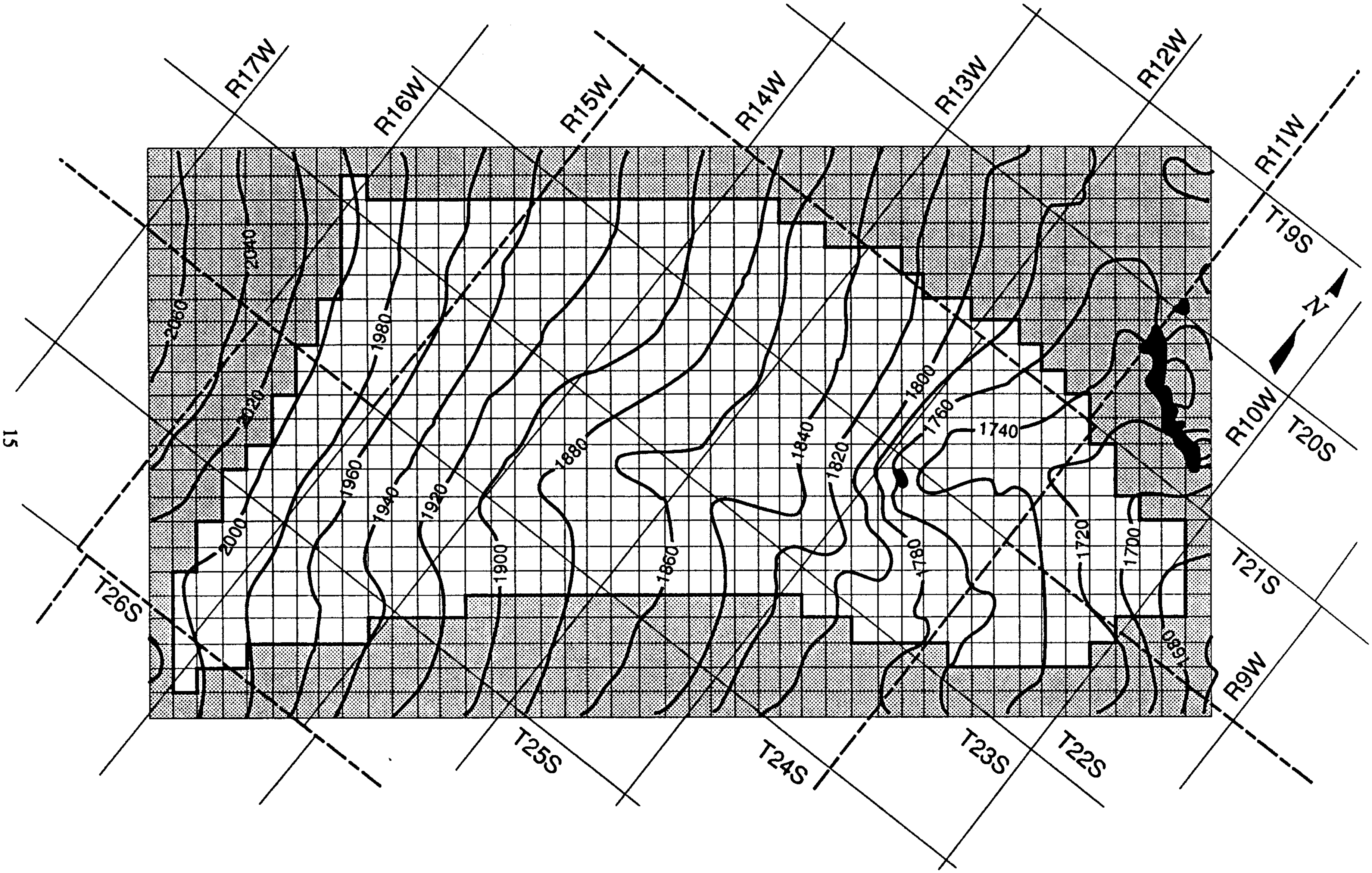

Figure 5. Predevelopment water table map of the study area. Contour interval 20 ft.

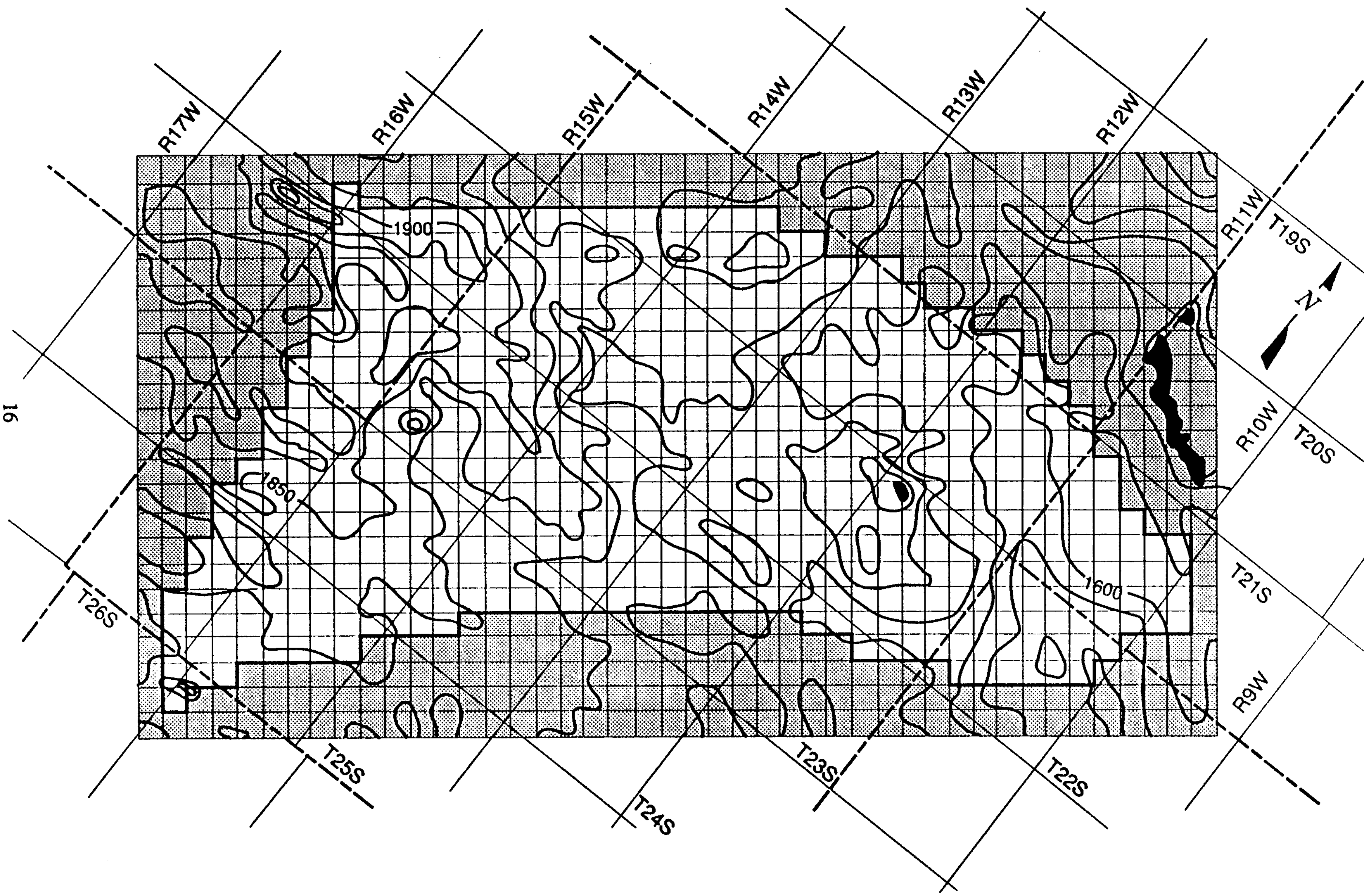

Figure 6. Bedrock contour map of the study area. Contour interval 50 ft.

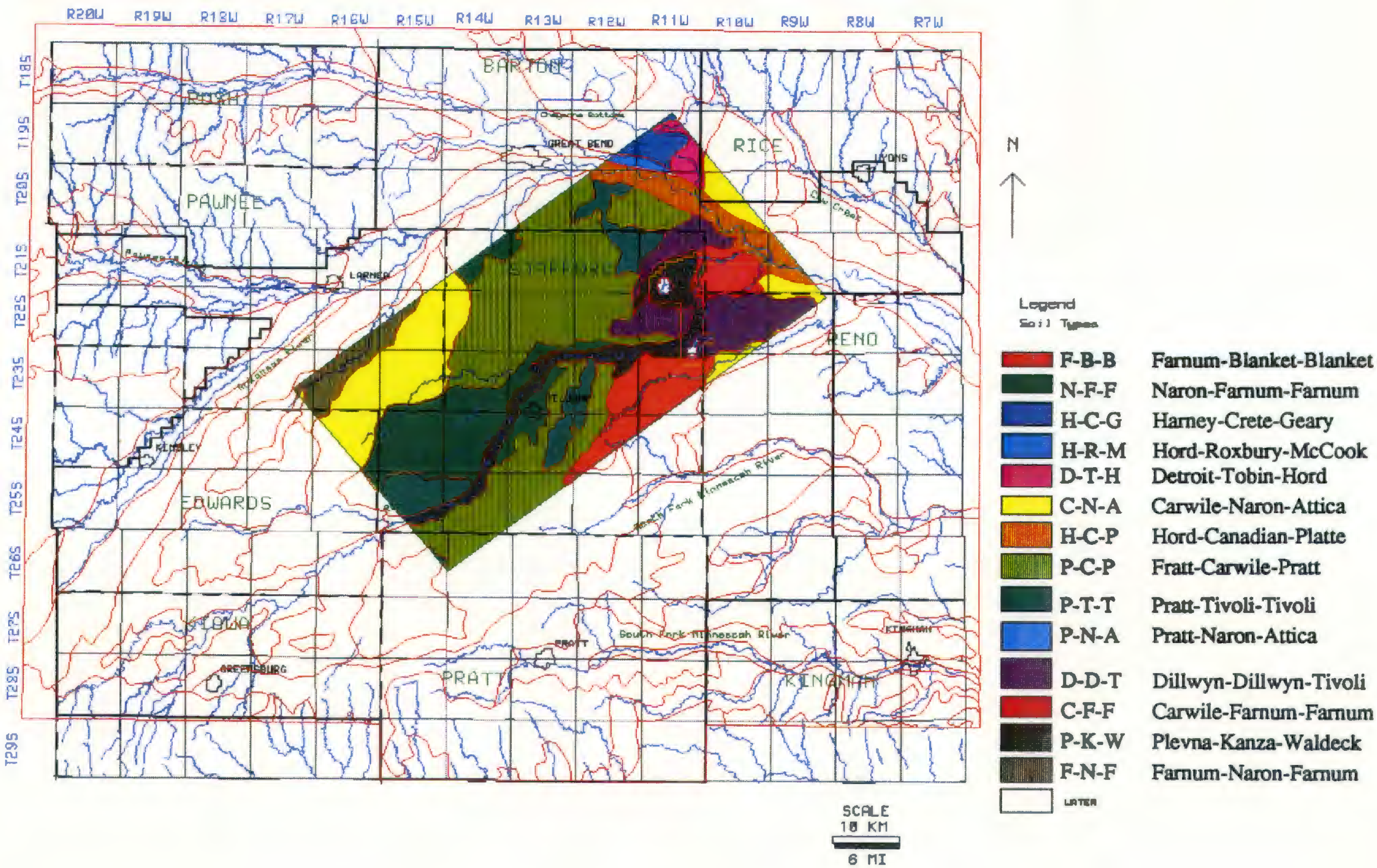

Figure 7. Soil Association map of the study area.

topography. Attica, Naron, and Pratt soils occur in areas of nearly level to undulating topography next to sand-dune areas.

The alluvium that was deposited during the Holocene ranges from sand to clay loam. The dominant soils in this parent material are the Hord and Zenda soils and soils of the Plevna-Kanza-Waldeck association. The latter soils were formed on floodplains and stream terraces along Rattlesnake Creek and in the Big and Little Salt Marsh areas.

Water rights

All current water rights (as of 1990) for the Great Bend Prairie region were obtained on tape from the Division of Water Resources, and the ground-water rights have been processed and displayed on a 1:250,000 map (Sophocleous, 1990, unpublished map). Figure 8 displays the ground-water rights in the study area, and fig. 9 depicts the number of groundwater rights issued in the study area versus time. A listing of the water rights is included in Appendix 1.

Rattlesnake Creek streamflows

Current and historical streamflow data for the area streams have been compiled and analyzed. Average annual streamflows of the Rattlesnake Creek at the Macksville, Zenith, and Raymond stream-gaging stations are shown in figs. 10, 11, and 12, respectively. As can be seen in these figures, the streamflows at all gaging stations have been declining since the flood of 1973. Other stream-related data, such as stream widths and stream slopes, were obtained from area visits and from topographic and other maps.

Climate

Climatic data were obtained from existing National Oceanic and Atmospheric Administration (NOAA) climatic stations in Kansas, and from an ongoing Groundwater Management District 5–Kansas Geological Survey (GMD5-KGS) cooperative study on recharge assessment in GMD5, which encompasses most of the Great Bend Prairie region, including the

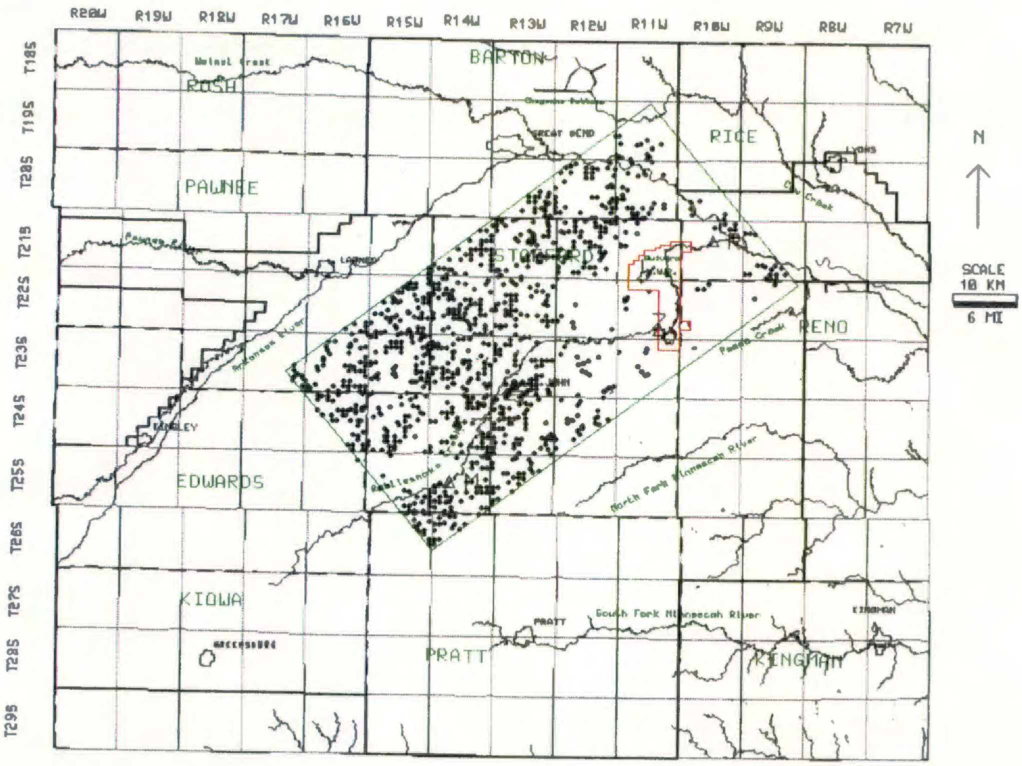

Figure 8. Ground-water rights map of the study area and vicinity.

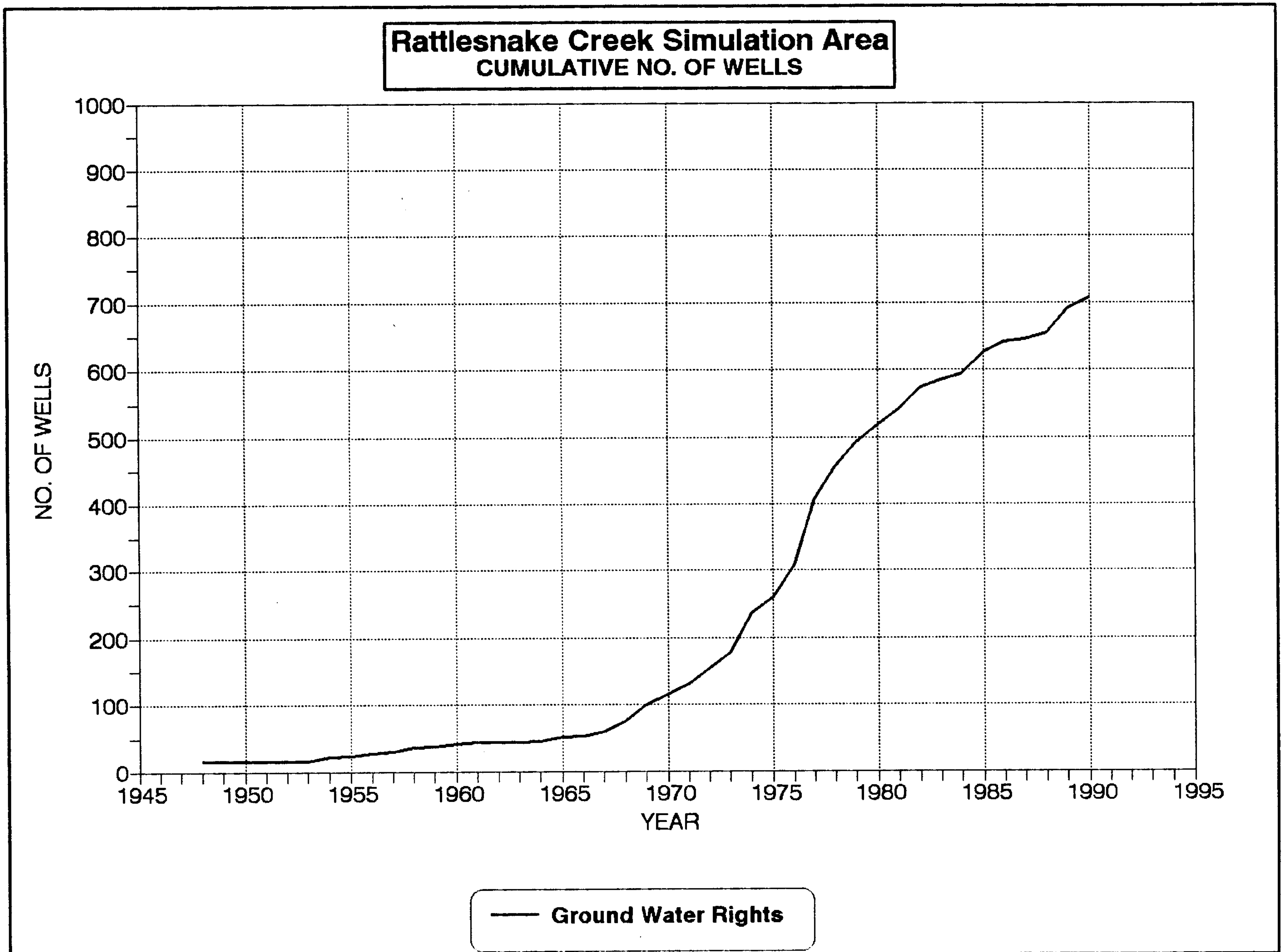

Figure 9. Number of ground-water rights issued in the study area versus time.

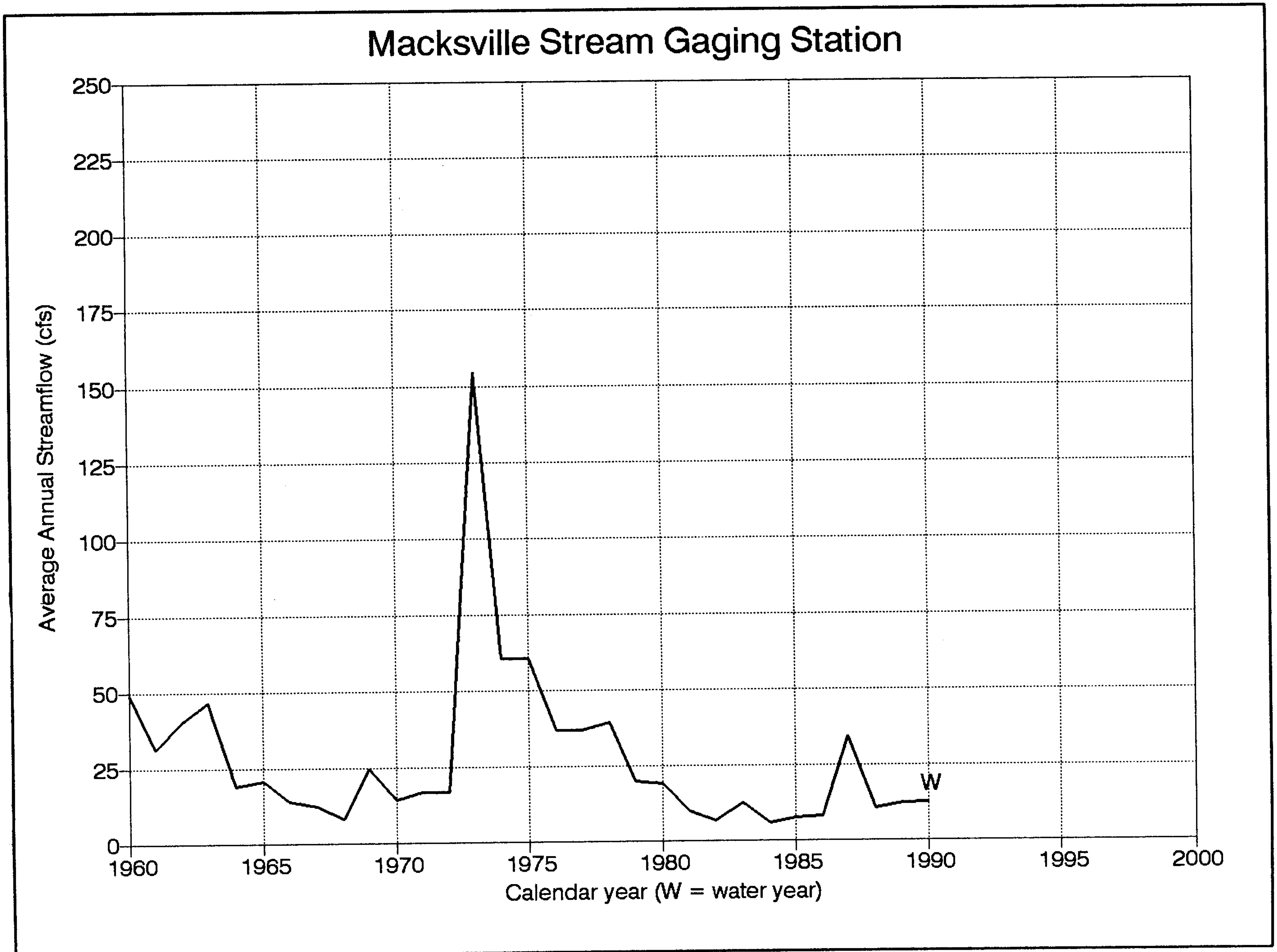

Figure 10. Average annual streamflows of Rattlesnake Creek at the Macksville gaging station.

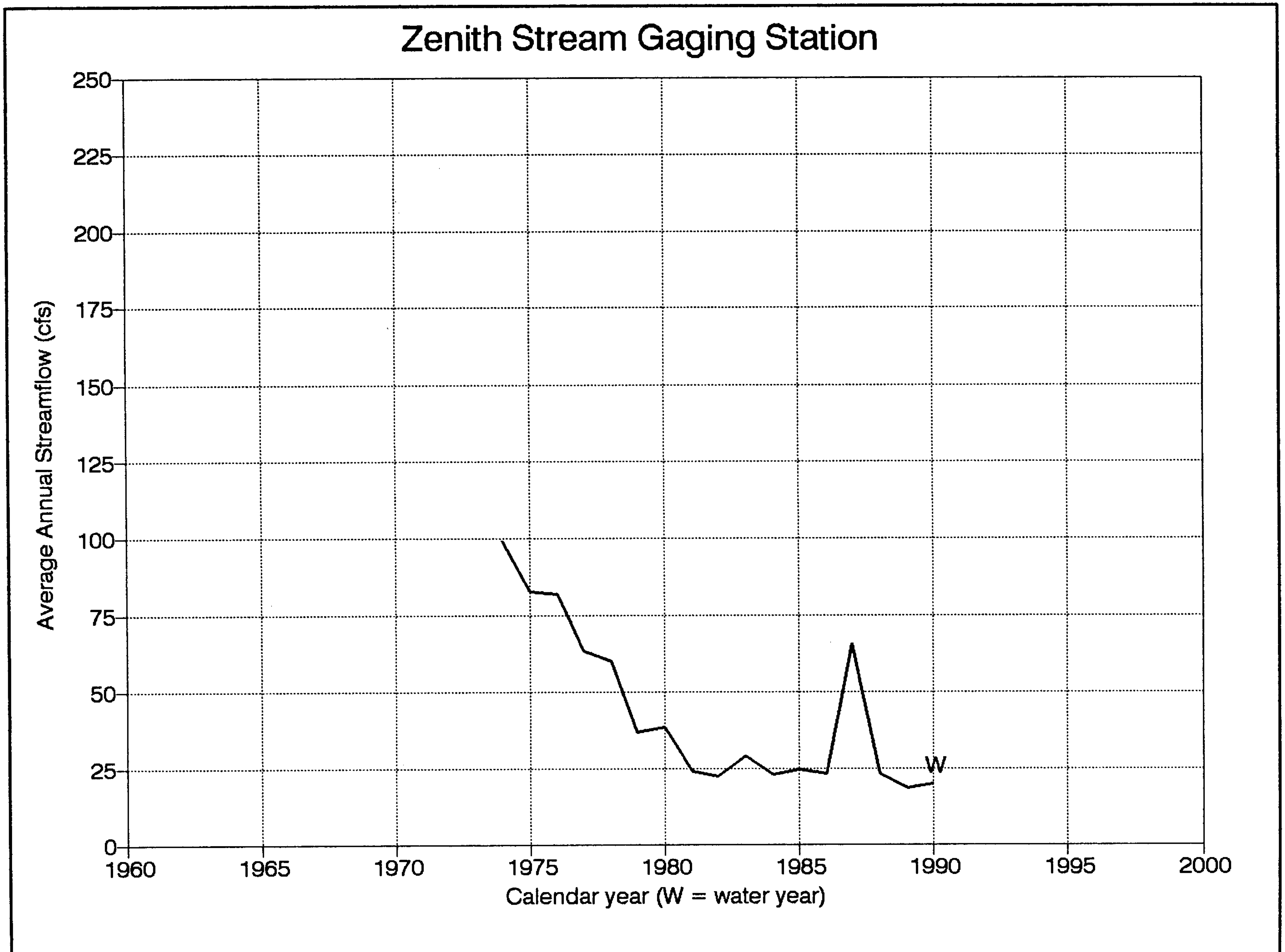

Figure 11. Average annual streamflows of Rattlesnake Creek at the Zenith gaging station.

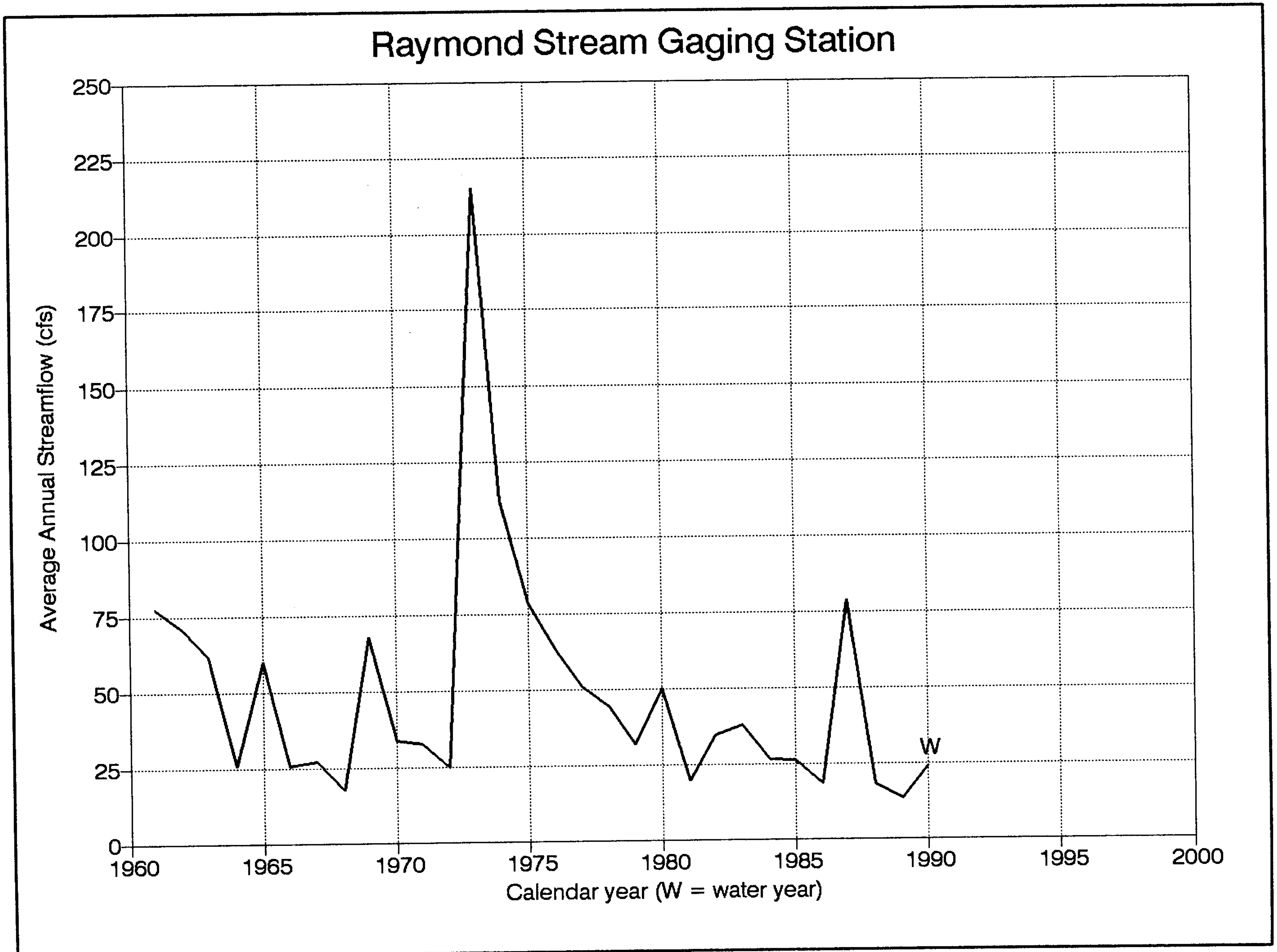

Figure 12. Average annual streamflows of Rattlesnake Creek at the Raymond gaging station.

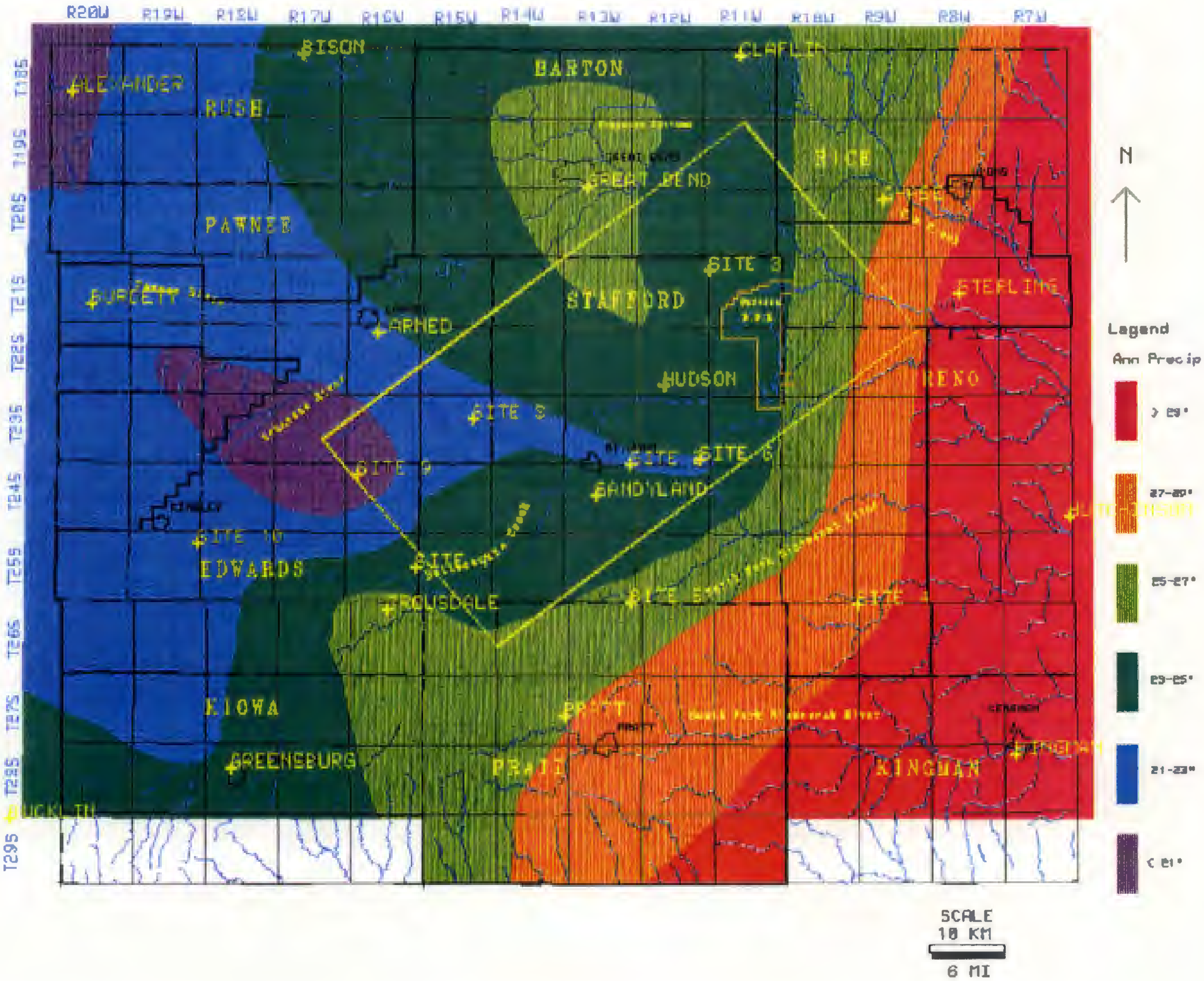

Figure 13. Average (1980–1990) annual precipitation contour map of the study area and vicinity.

study area. The available 1980–1990 average annual precipitation data for all the stations have been compiled and a precipitation contour map of the Great Bend Prairie has been prepared (fig. 13). As can be seen from fig. 13, the Quivira refuge falls in the 23–25 in. average annual precipitation category.

The Great Bend Prairie has a typical continental climate: dry and relatively cold winters, warm to hot summers, a late spring–early summer precipitation maximum, moderate surface winds, and large daily and annual variations in temperature. Two climate controls contribute to the precipitation pattern in the Great Bend Prairie. The Rocky Mountains are effective in producing a rain shadow over western Kansas. The Gulf of Mexico is the principal source of moisture for precipitation in the area. From west to east the average annual amount of precipitation increases by approximately 1 in. for each 17 mi of distance (Bark, 1961). Average annual precipitation in the Great Bend Prairie ranges from 20 in. at the western border to 29 in. near the eastern border. Approximately 75% of the annual precipitation occurs in the growing season of April through September. May and June have the highest average number of rainy days per month and the highest average amounts of precipitation. Most of the total annual precipitation comes from convective shower activity, usually in the evening or at night (Bark, 1978).

Water-table maps

Water-level data from the Great Bend aquifer for predevelopment conditions and for various years since the 1970's have been examined and analyzed to delineate ground-water flow lines that can be used to select boundary flow lines separating the lower Rattlesnake Creek watershed study area from the rest of the Great Bend aquifer.

Field data collection

Water-level survey

During January and February 1991 a ground-water-level survey in the GMD5 encompassing the study area was conducted by GMD5 personnel. These data, combined with the

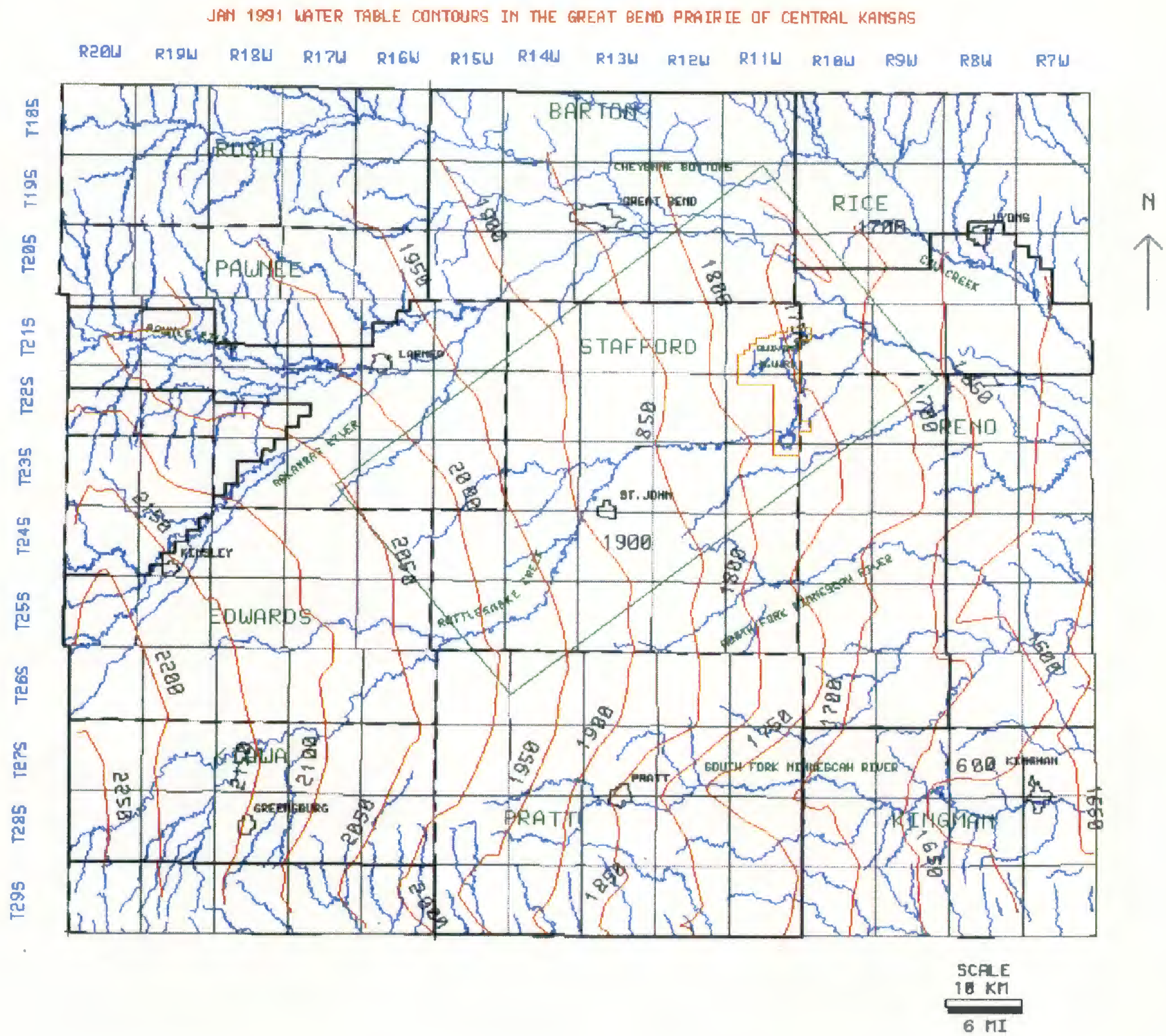

Figure 14. January 1991 water table contour map of the study area and vicinity.

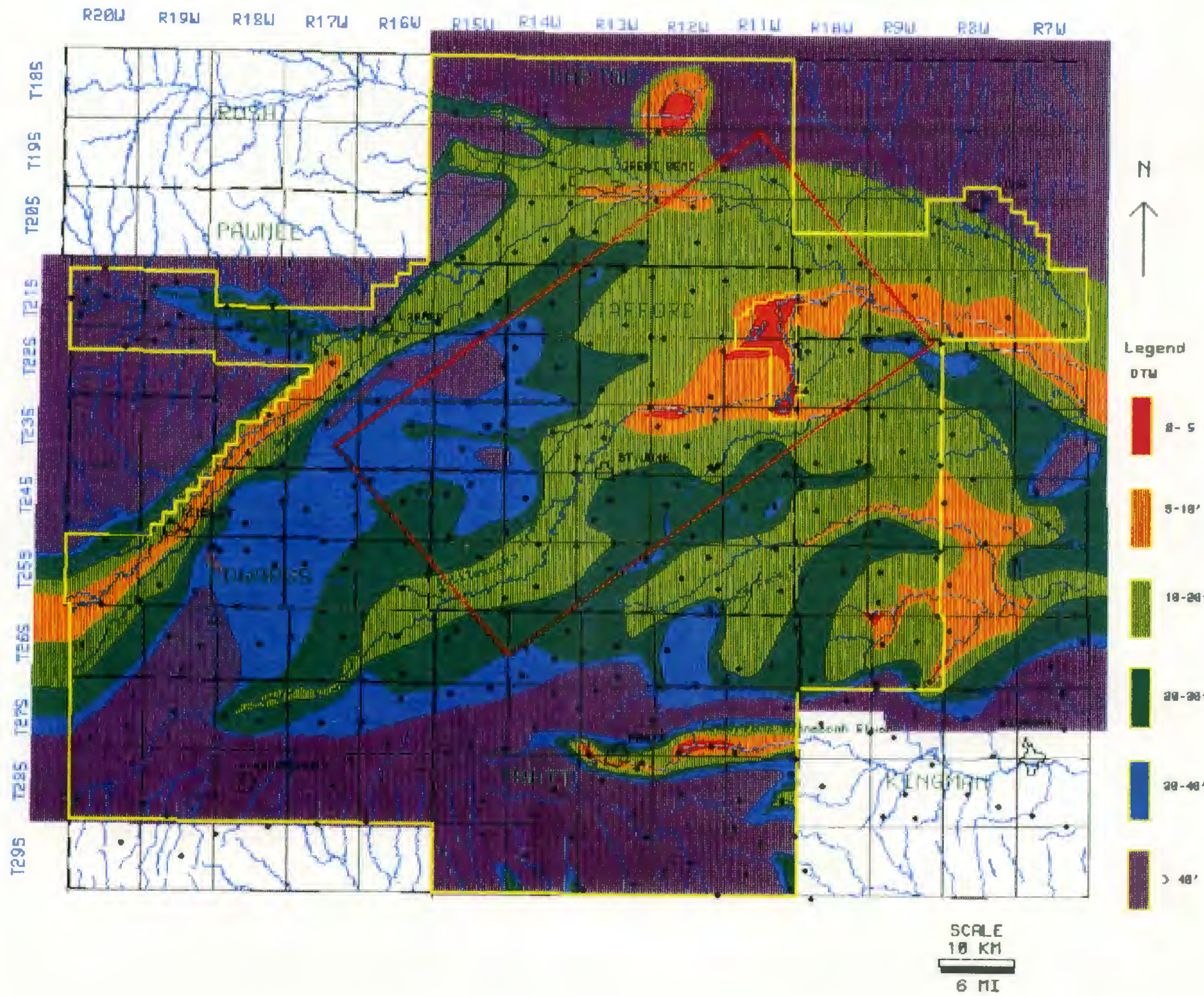

Figure 15. January 1991 depth to water table contour map of the study area and vicinity.

annual water-level measurements taken by the Division of Water Resources in cooperation with the U.S. Geological Survey, were used to produce the January 1991 water-level and depth to water table maps of the study area (figs. 14 and 15).

Geophysical logging

A geophysical logging survey of a limited (because of financial and personnel constraints) number of existing wells in the region was conducted in April and May 1990 using a rented US Geological Survey logging vehicle. The purpose of this survey was to locate the saltwater-freshwater interface below the Great Bend aquifer and to pinpoint locations for detailed study. Despite equipment deficiencies, which resulted in only a qualitative logging survey, the results were helpful in locating the approximate extent of the saltwater interface in specific areas and in siting appropriate locations for drilling saltwater-freshwater interface monitoring wells. The inferred depths to the saltwater-freshwater interface ranged from approximately 130 ft below ground surface east of St. John to approximately 40–45 ft west of the Big Salt Marsh and near the Stafford-Barton County line.

Drilling

Two locations near the Quivira marsh, known as the Sittner and Figger sites, were selected for drilling monitoring wells to track the location and temporal variations of the saltwater-freshwater interface. The locations of these monitoring wells are shown in fig. 16. After landowner permission and other clearances were obtained, two 5-in. fully screened wells down to bedrock were drilled, installed, developed, and logged (lithology and gamma) by the Kansas Geological Survey in May and June 1990. The lithology and gamma logs are shown in figs. 17 and 18; the well record forms are included in Appendix 2. Note that the coarse sand and gravel deposits of the aquifer directly overlie the Permian red siltstone bedrock in both boreholes without any major intervening clay layers.

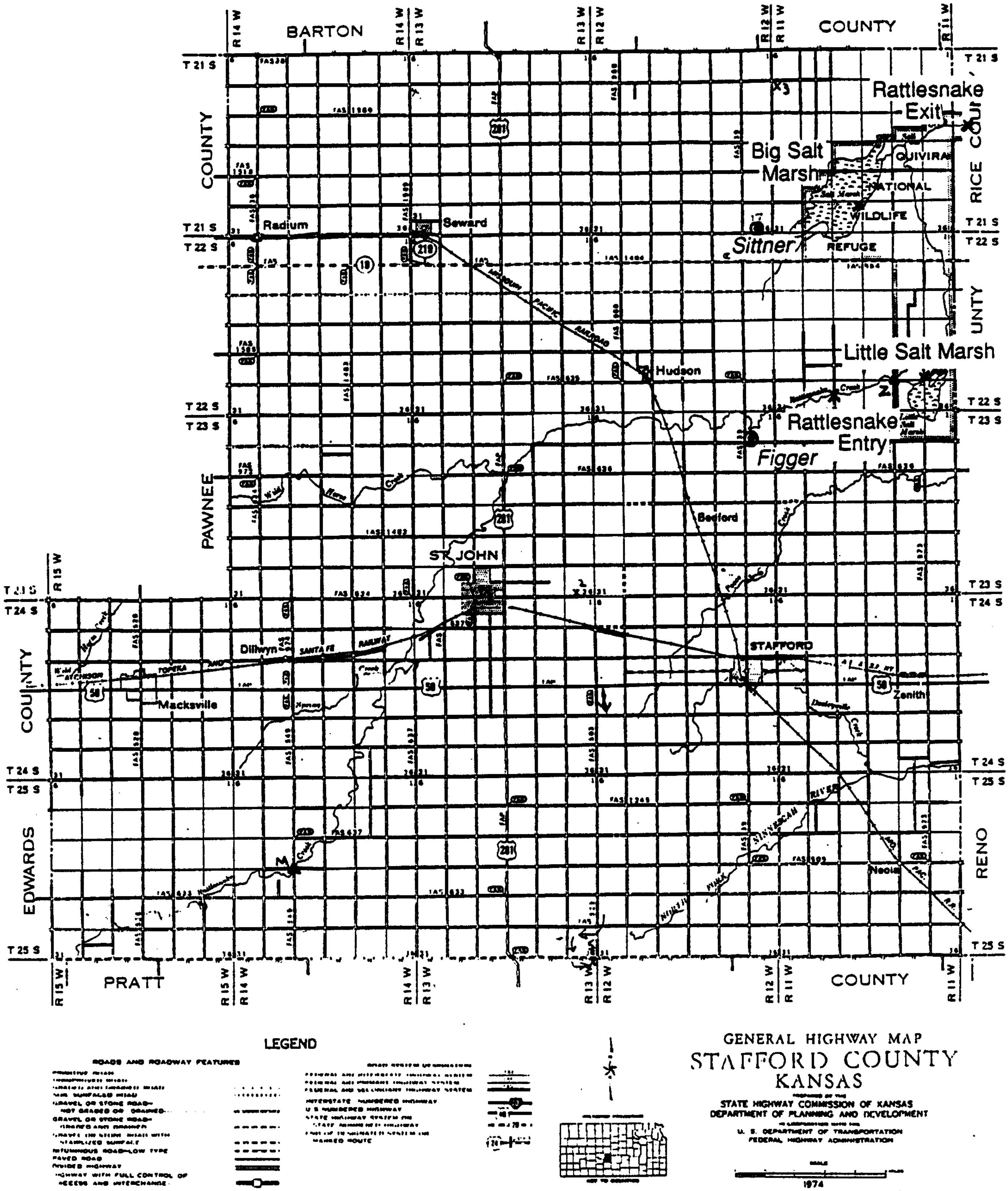

Figure 16. Location of saltwater-freshwater interface monitoring wells and water quality sampling stations.

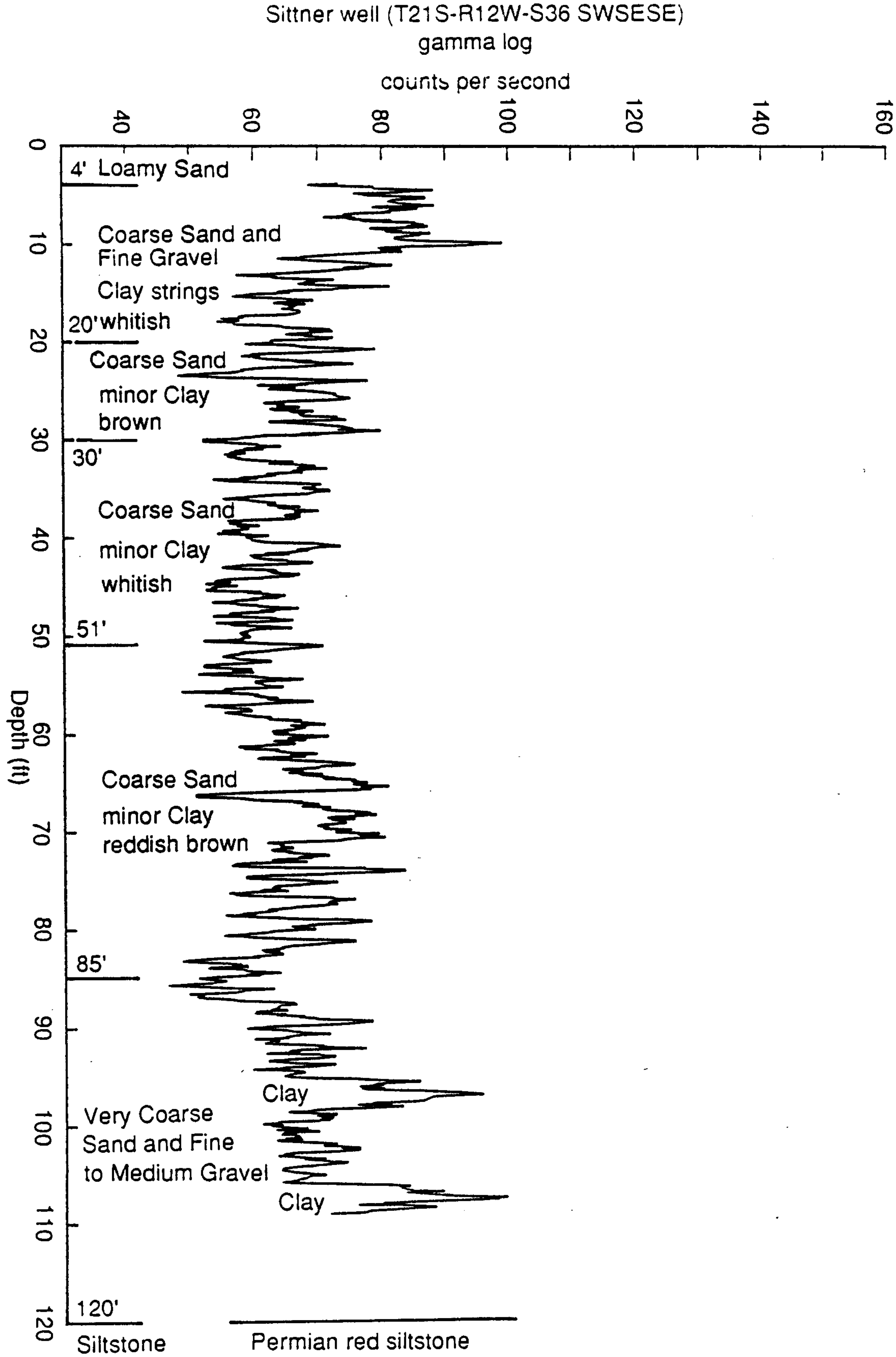

Figure 17. Lithology and gamma log of the Sittner observation well.

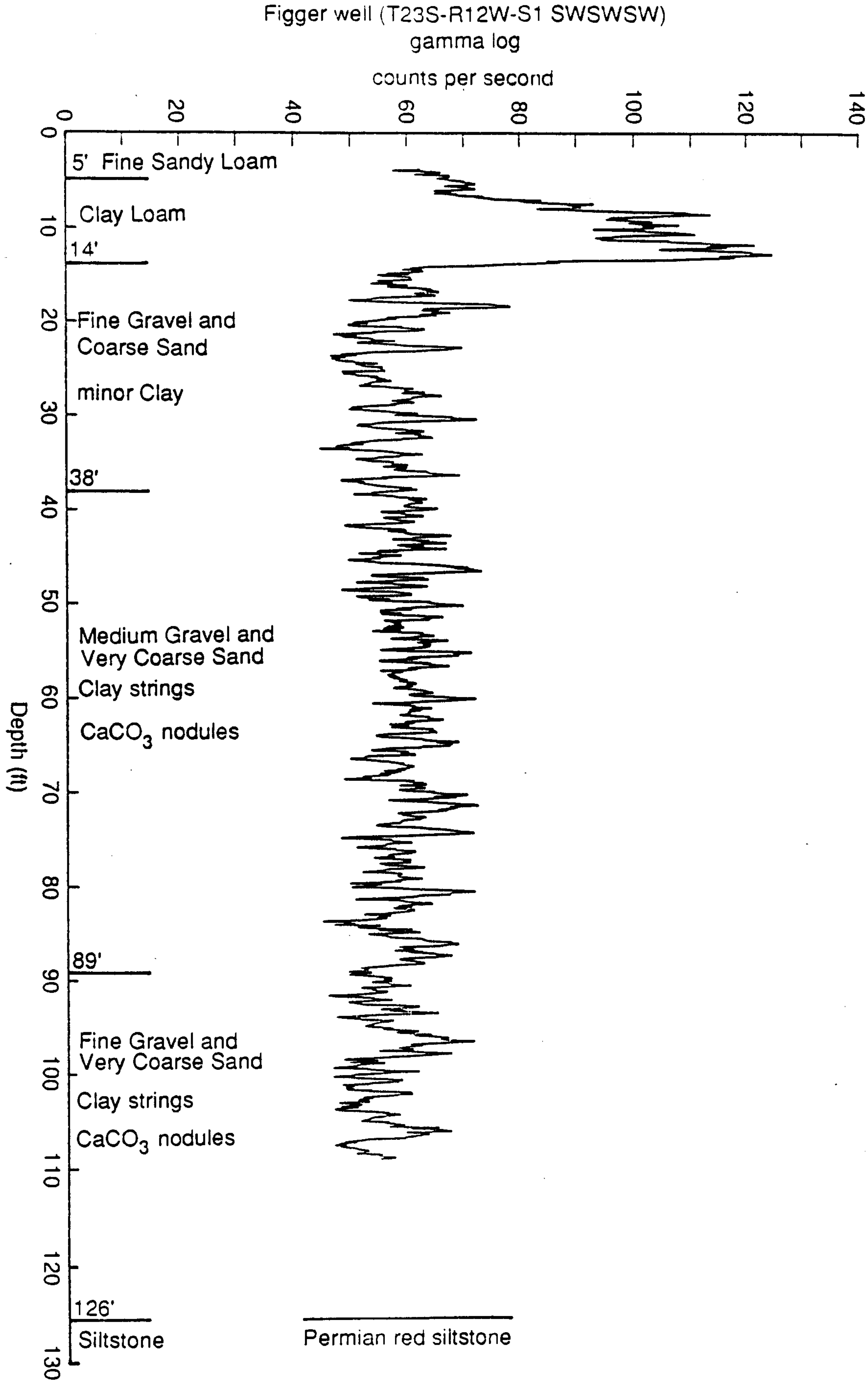

Figure 18. Lithology and gamma log of the Figger observation well.

Saltwater-freshwater interface monitoring

Two conductivity recording probes, one with an electronic data acquisition system (Hydrolab's Datasonde III) and the other with a recording chart, were selected and purchased by the KGS. These probes were checked, adapted to our field situation by rewiring some circuits for extended battery operation, calibrated, and installed in the field in August 1990. Periodic field maintenance and instrumentation adjustment are still being conducted in cooperation with Quivira National Wildlife Reserve personnel.

Results from the saltwater-freshwater interface monitoring sites indicate that the interface is extremely sharp at the Sittner site west of the Big Salt Marsh (within 1 ft the specific conductance increases from 700 µS/cm to 24,000 µS/cm; fig. 19) and fluctuates appreciably (with a range from 55 ft to 90 ft below ground surface; fig. 20) with very small changes in water table levels (less than 0.5 ft in most cases; fig. 21). The saltwater-freshwater interface at the Figger monitoring site west of the Little Salt Marsh and near Rattlesnake Creek is more diffuse (fig. 22) and does not fluctuate as much as at the Sittner site (fig. 23). Appendix 3 contains all the collected data in graphical form. These results indicate that the behavior of the saltwater-freshwater interface in the study area is complex and poorly understood; thus concentrated study of saltwater behavior in the region is needed.

Water quality of the Quivira marsh

Several water-quality surveys of the waters entering and leaving the Quivira marsh and of the Little and Big salt marshes were conducted in late 1990 and in 1991, including surveys specifically conducted for trace element analyses. The location of the regular sampling sites are indicated in fig. 16.

The waters of the Quivira National Wildlife Reserve are typical sodium chloride waters, the detailed chemical analyses of which are included in Appendix 4. One significant aspect of these chemical analysis results is the high concentrations of selenium in the Big Salt Marsh and in Rattlesnake (or Salt) Creek exiting the refuge. Selenium is an essential trace nutrient for terrestrial

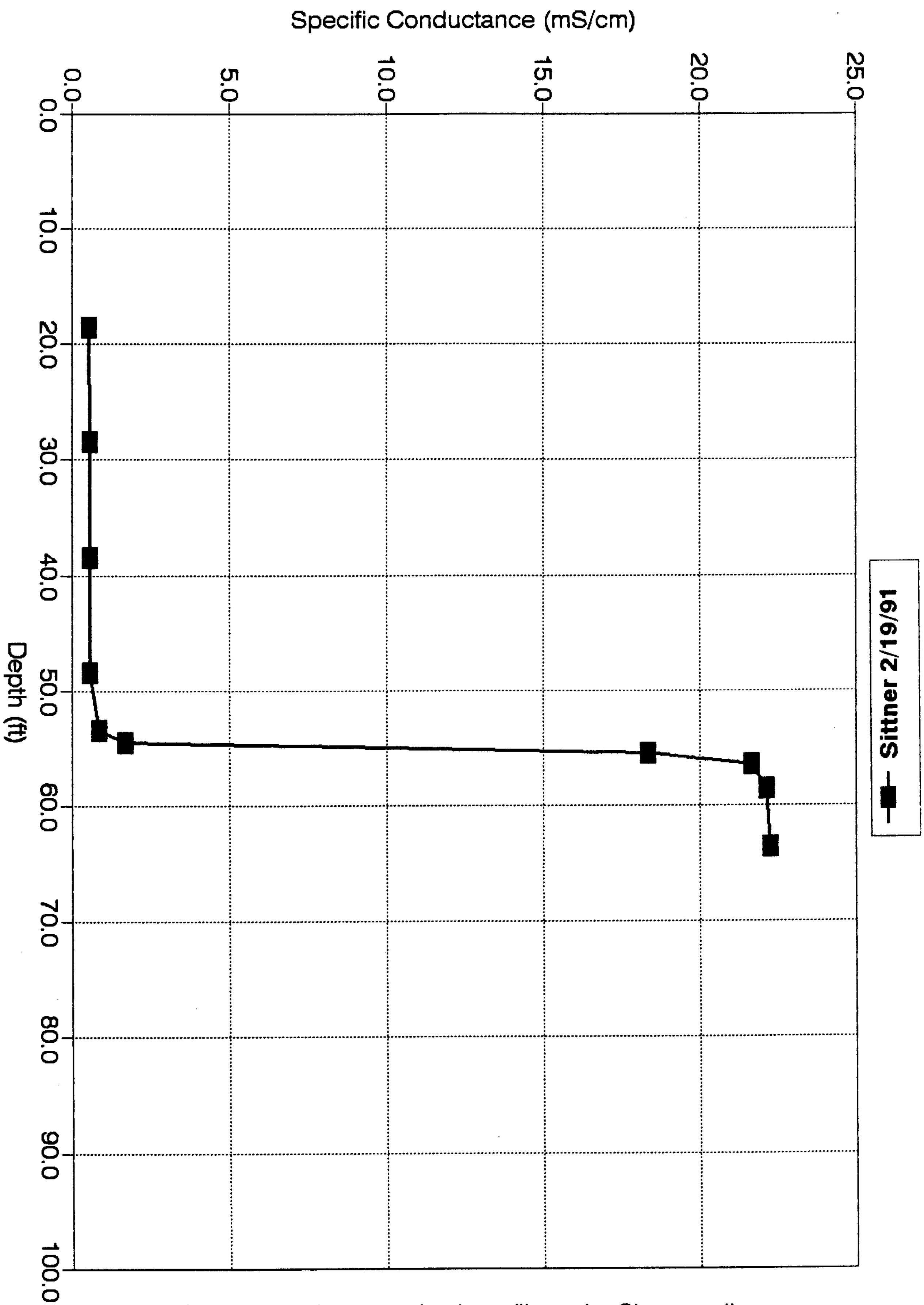

Figure 19. Specific conductance depth profile at the Sittner well.

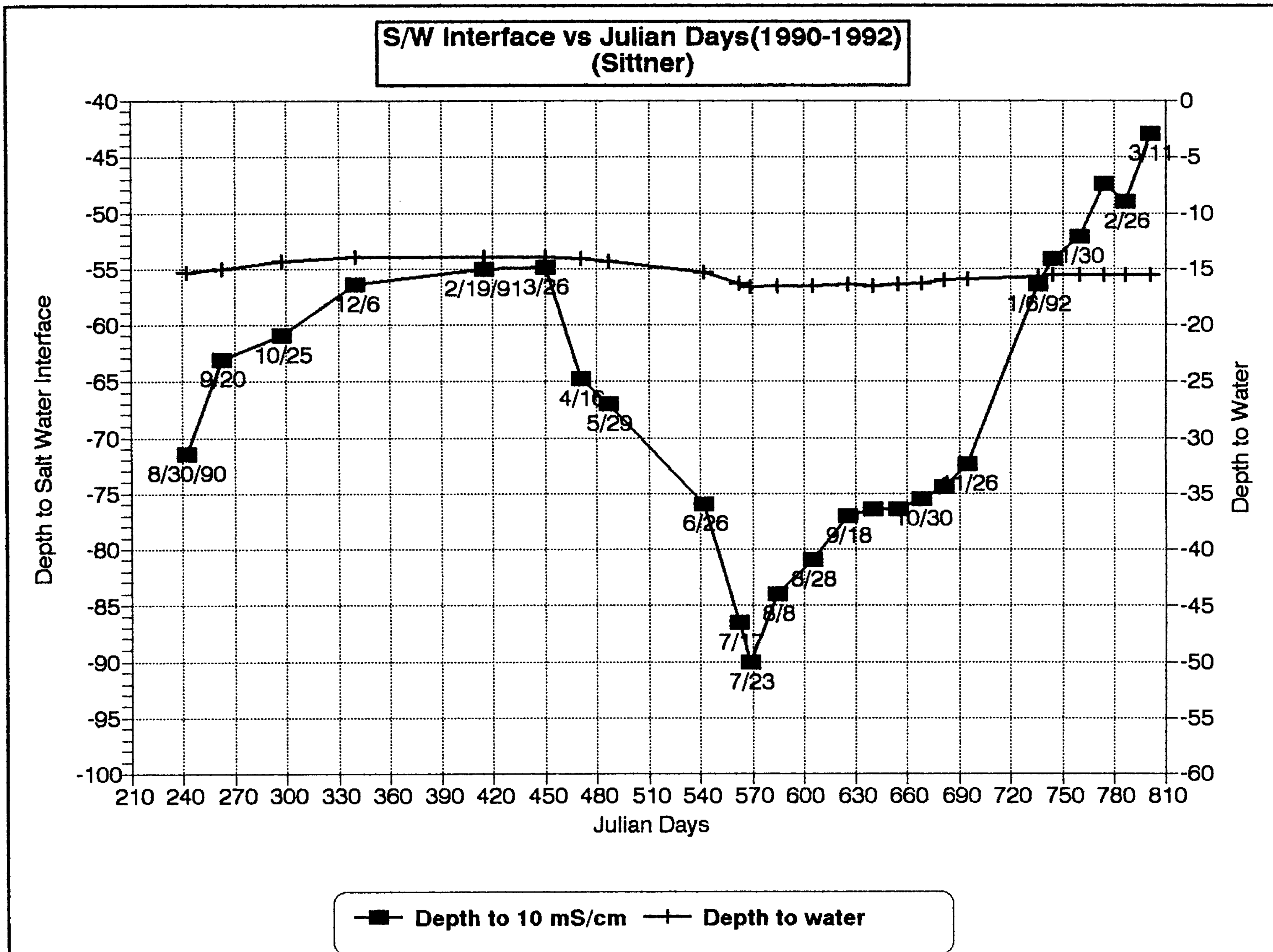

Figure 20. Depth of the saltwater-freshwater interface versus time at the Sittner well.

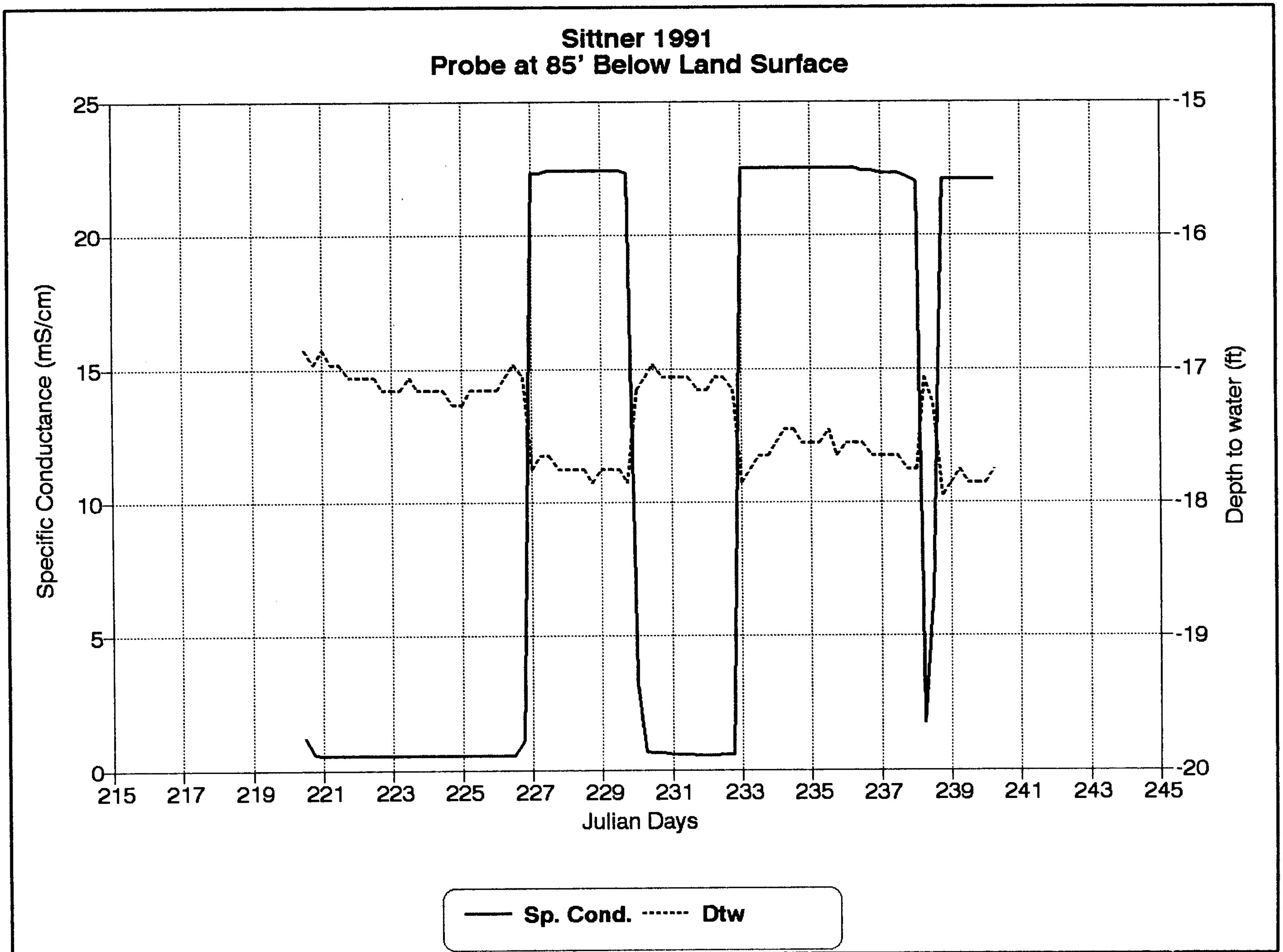

Figure 21. Depth to water table and specific conductance time series near the saltwater-freshwater interface in the Sittner well.

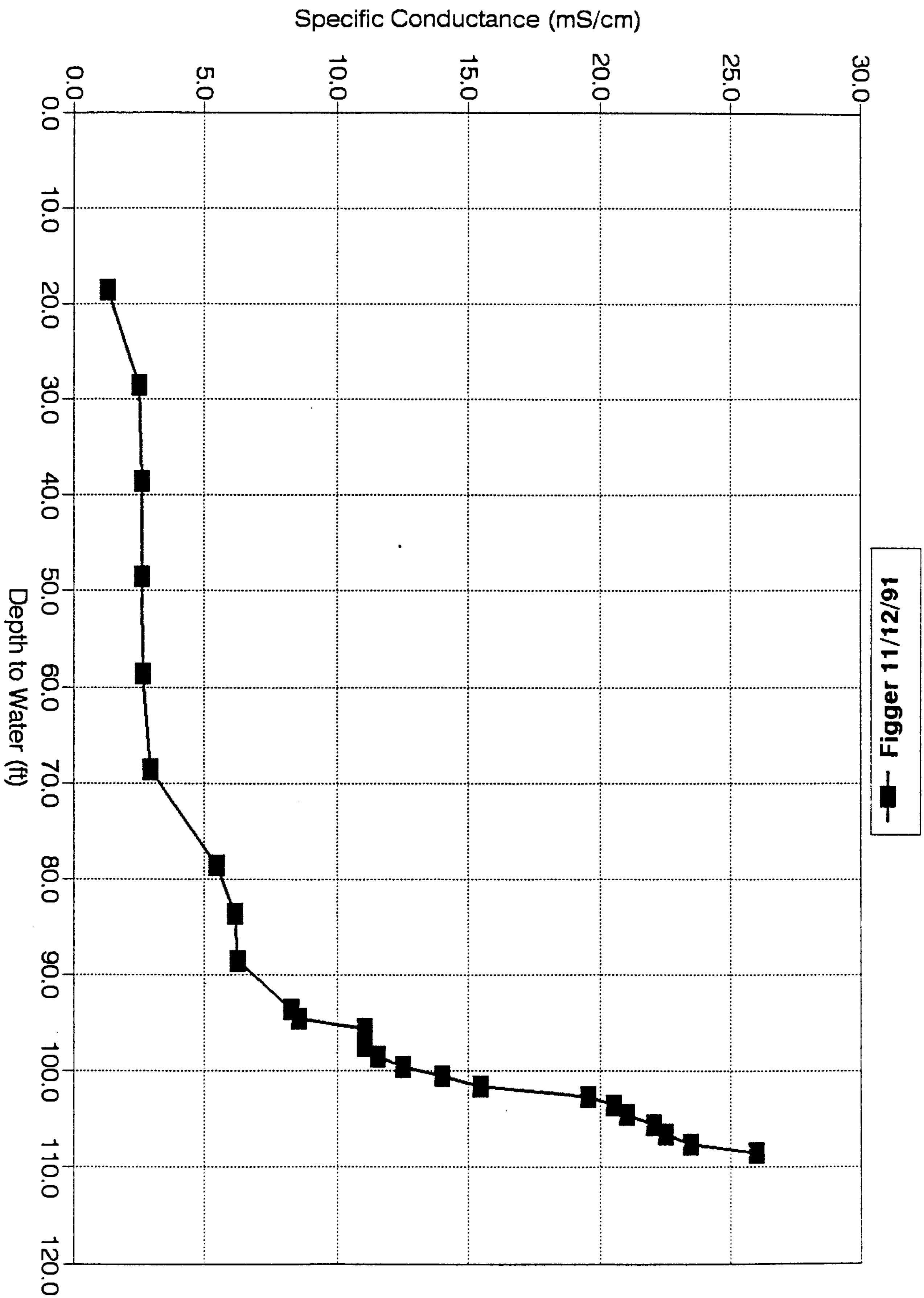

Figure 22. Specific conductance depth profile at the Figger well.

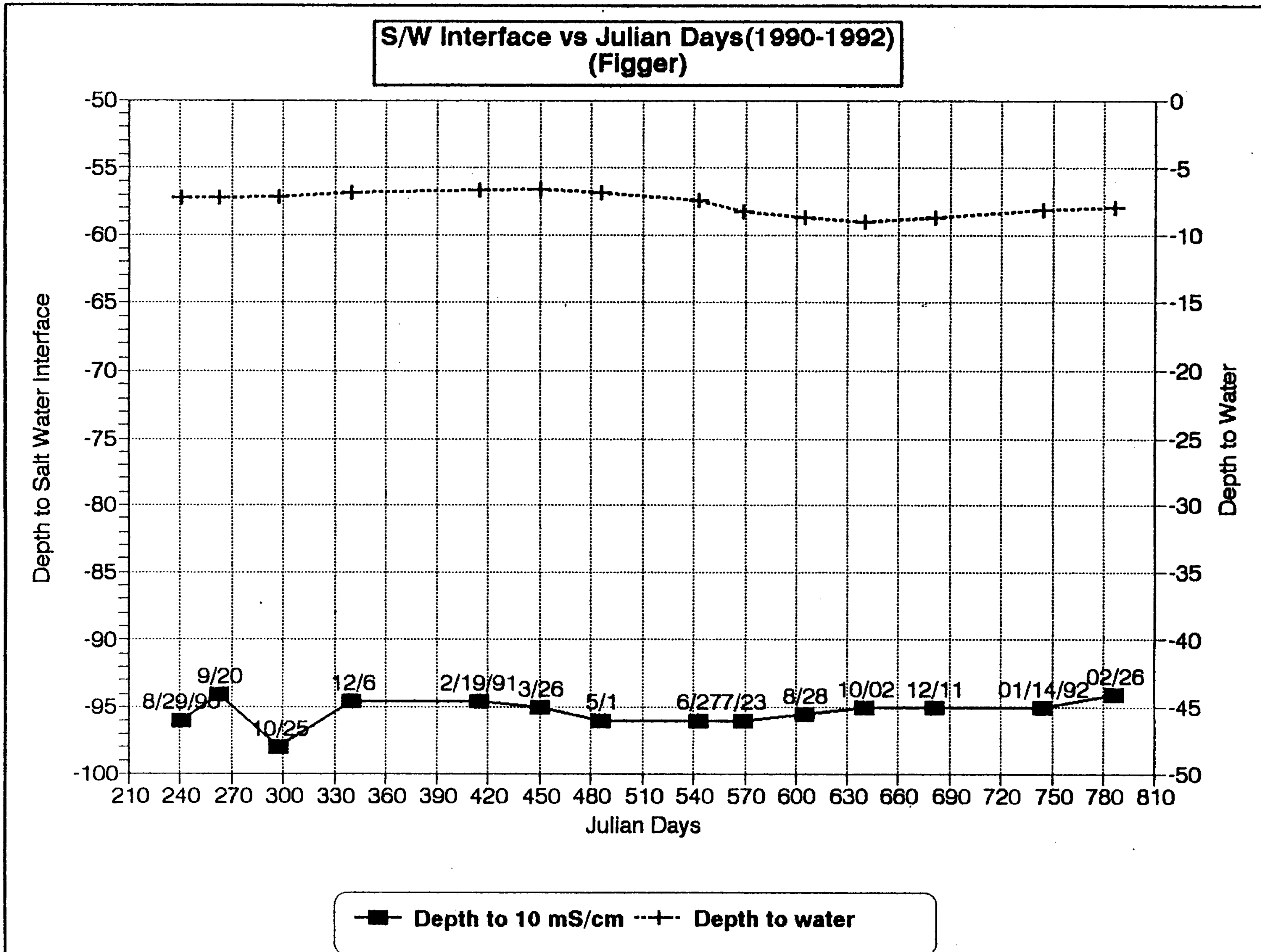

Figure 23. Depth of the saltwater-freshwater interface versus time at the Figger well.

and aquatic organisms; however, proper selenium levels in biota fall within narrow ranges (U. S. EPA, 1987). Selenium has received attention because high levels of selenium borne by irrigation return flows have caused serious problems for fish and wildlife (Ohlendorf, 1989; Saiki and Lowe, 1987). Table 2 summarizes the specific conductance, pH, and chloride and selenium concentrations of the major sampling stations at different times. The EPA limits for chronic and acute selenium concentrations for aquatic life are 8.4 and 11.2 μg/l, respectively. The measured selenium concentrations of the Big Salt Marsh and the Rattlesnake Creek exit usually exceed the acute exposure limits.

It is reported in the literature (Anderson et al., 1961) that Cretaceous shales in the midcontinent and elsewhere contain appreciable amounts of selenium. Therefore the Cretaceous bedrock outcrop southwest of the Big Salt Marsh, which consists predominantly of Kiowa Shale was suspected of being the source of the excess selenium. However, x-ray analysis of 6 rock and sediment samples from the Big Salt Marsh and the bedrock outcrop (see Appendix 5) indicated that the selenium level was below detection (10 ppm).

Table 2. Selected chemical characteristics of the Quivira National Wildlife Refuge waters.

	Specific conductance (μS/cm)				pH				Chloride (mg/l)			Selenium (μg/l)			
Sampling time	Aug 90	Mar 91	Aug 91	Sept 91	Aug 90	Mar 91	Aug 91	Sept 91	Mar 91	Aug 91	Sept 91	Aug 90	Mar 91	Jun 91	Sept 91
Rattlesnake entry to refuge	9,570	7,580	7,130	14,700[a]	7.95	8.15	8.55	8.20	2,220	2,110	4,820	1	3	5	5
Little Salt Marsh	9,020	9,020	8,420	dry	8.45	8.00	8.30	—	2,980	2,470	—	14	4	5	—
Big Salt Marsh	14,460	16,500	18,400	49,900[b]	8.90	8.05	9.65	8.40	5,250	6,020	19,700	21	4	11	19
Rattlesnake exit from refuge	22,300	22,600	24,200	18,700[a]	7.50	7.95	8.00	8.75	7,480	7,920	6,170	51	28	8	15

a. Standing water (stream not flowing).
b. Big Salt Marsh significantly shrunk.

Numerical modeling

A two-dimensional areal model combining stream-pond-aquifer interaction modeling and saltwater-freshwater sharp interface modeling has been developed and tested against analytical and other numerical solutions; this work is documented elsewhere (Sophocleous and Birdie, 1990). However, because of data deficiencies related to the saltwater aspects, the model has not been fully implemented. Instead, the well known MODFLOW model, which is equivalent to our freshwater stream-aquifer model module and a parameter estimation model (MODINV; Doherty, 1990) have been implemented for the Rattlesnake Creek watershed. Because MODFLOW deals only with freshwater aspects and has associated pre- and postprocessors, it was preferred in this phase of the analysis to expedite processing and analysis.

The major thrust of this study is to implement and analyze an appropriate stream-aquifer numerical model for the study area. The simulation model chosen to evaluate the lower Rattlesnake Creek stream-aquifer system is a modified two-dimensional version of the popular modular three-dimensional finite-difference ground-water model (MODFLOW) of McDonald and Harbaugh (1988) with the streamflow routing capabilities of Prudic (1989). MODFLOW solves the three-dimensional ground-water flow equation using finite-difference approximations and includes the effects of such processes as areal recharge, rivers, drains, evapotranspiration, and pumpage. The finite-difference procedure requires that the aquifer be divided into cells. The aquifer properties in each cell are assumed to be uniform. The unknown head in each cell is calculated at a point or node at the center of the cell. The head is calculated by iterating through the finite-difference equations for all nodes until the maximum head change in any cell between the previous iteration and the current iteration is less than a specified small value. Once this criterion is met, the program advances to a new time step, and the process of computing heads at each node is repeated.

Streams superimposed on the aquifer are divided into *reaches* and *segments*. A segment consists of one or more *reaches*. Each reach corresponds to an individual cell in the finite-difference equation used to simulate ground-water flow. Streamflow is specified for the first reach in each segment that enters the model area; streamflow to adjacent downstream reaches in each segment is calculated as equal to inflow in the upstream reach plus or minus leakage from or to the aquifer in the reach. Leakage is calculated for each reach on the basis of the head difference between the stream and aquifer and a conductance term:

$$Q_\ell = C_{str}(H - h), \tag{1}$$

where Q_ℓ is the leakage to or from the aquifer through the streambed, H is the head in the stream, h is the head in the aquifer side of the streambed, and C_{str} is the conductance of the streambed, which is the hydraulic conductivity of the streambed times the product of the width of the stream reach and its length divided by the thickness of the streambed.

The stage in each reach can be computed by using the Manning formula under the assumption of a rectangular stream channel:

$$Q = \frac{c}{n}\left(AR^{2/3}S_0^{1/2}\right), \tag{2}$$

where Q is the stream discharge, n is Manning's roughness coefficient, A is the cross-sectional area of the stream, R is the hydraulic radius, S_0 is the slope of the stream channel, and c is a constant, which is 1.486 for units of cubic feet per second (cfs). The cross-sectional area A and the hydraulic radius R for a rectangular channel are

$$A = wd, \tag{3}$$

$$R = wd/(w + 2d), \tag{4}$$

where d is the depth of the water in the stream and w is the width of the channel.

The amount of leakage in each reach either into or out of the aquifer is incorporated into the ground-water flow model by adding appropriate terms to the finite-difference equation. Recharge to the aquifer in a reach ceases when all the streamflow in the upstream reaches has leaked into the aquifer and the stream is dry. A stream is permitted to flow again in the downstream reaches when the head in the aquifer is above the elevation of the streambed.

For simulation of stream-aquifer interaction, the ground-water flow model with the streamflow-routing package has an advantage over the analytical solution because it can be used to simulate complex systems that cannot be readily solved analytically.

Required input data for the stream-aquifer model include (1) the areal distribution of aquifer-related parameters, such as transmissivity or hydraulic conductivity, storativity, and natural recharge; (2) water levels in the aquifer and the stream(s); (3) bedrock and land surface elevations; (4) the input stream and tributary hydrograph; (5) stream width, slope, streambed elevations, and Manning's roughness coefficients; (6) streambed conductance (i.e., hydraulic conductivity of streambed or canal and ditch sediments divided by their thickness); (7) location and pumping rate of wells; and (8) initial and boundary conditions.

Calibration

One of the most important steps in setting up a ground-water model is calibration. Development of the computer model as a predictive tool is based on the premise that, if historic hydrologic phenomena can be satisfactorily approximated by the model, then so should future conditions. Calibration involves adjusting model input parameters, based on field data, to accurately predict real-world cause-and-effect relationships. The task of manually adjusting parameter and past recharge values over different parts of the aquifer until the model nearly replicates previously measured water-level measurements in a set of observation wells is an arduous one requiring many model runs. Adjustments are often made in a hit-or-miss fashion until the fit between the model and the observed water levels is acceptable. This process is often time-consuming and expensive and sometimes can result in no answer. Also, questions about whether or not the derived solution is the optimum one and how many other solutions are equally good are difficult to answer when trial-and-error methods are used. To avoid problems related to manual calibration, one can use a parameter estimation computer program that uses the MODFLOW program as its forward processor to obtain an optimum set of parameter or input values. The process by which solutions are found for one or more of the model parameters or inputs is known as *inverse modeling* (or the *inverse problem*). Once the parameters or inputs to the model are known (e.g., hydraulic conductivity, storativity, recharge), it is a relatively simple matter to obtain model outputs (such as heads or water levels in the aquifer). This modeling process is known as the *forward problem* or *forward modeling*. In this study we used a parameter optimization method for MODFLOW known as MODINV (for *mod*flow *inv*erse). Using MODINV, we can optimize the specific values taken by any parameter type that MODFLOW can read as a two-dimensional data array such that model-generated heads are as well matched as possible to those observed in the field. Steady-state and transient-state, single-layer and multilayer, and confined and unconfined models can all be calibrated in this manner. MODINV adjusts the parameter and/or recharge values pertaining to a set of constant-value zones chosen by the modeler (based on field data) for each parameter type until the optimum fit between the observed and the model heads is obtained. MODINV then provides the covariance matrix, which indicates the reliability or uncertainty levels of the parameter estimates. Model and observed heads are matched according to the weighted least-squares criterion, and optimization is achieved using the Gauss-Newton-Marquardt method (Draper and Smith, 1981).

Regression problem

The calibration or parameter estimation problem can be viewed as a classical nonlinear regression problem with a solution of the appropriate flow equation forming the regression equation and all unknown quantities (e.g., hydrogeologic parameters, sources, sinks, and boundary fluxes) serving as parameters (Sophocleous, 1984). The measured hydraulic heads are observations of the dependent variable for which a set of least-squares estimates is to be obtained. This regression problem finds the parameters of a given model that produce the best fit of the calculated hydraulic head (dependent) variable to the observed dependent variable and allows implementation of other methods and tests that analyze on a probabilistic basis the propagation of data errors in the estimates of parameters and the predictive capability of the model (Draper and Smith, 1981).

The basic equation to be fitted to the observed hydraulic head data is the general form of the two-dimensional ground-water flow equation (which the MODFLOW program is designed to solve):

$$\frac{\partial}{\partial x}\left(T_{xx}\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(T_{yy}\frac{\partial h}{\partial y}\right)+R(H-h)+W+\sum_{\ell=1}^{N}\delta(x-a_\ell)\delta(y-b_\ell)Q_\ell=S\frac{\partial h}{\partial t}, \qquad (5)$$

where T_{xx} (= $K_{xx}b$) and T_{yy} (= $K_{yy}b$) are the transmissivities in the x and y directions, respectively; K_{xx} and K_{yy} are the hydraulic conductivities of the aquifer in the x and y directions, respectively; $b(x, y)$ is the saturated thickness of the aquifer; $R(x, y)$ is the hydraulic conductance of the streambed, which is the hydraulic conductivity of the streambed times the product of the width of the stream and its length divided by the thickness of the streambed; $H(x, y, t)$ is the head in the stream; $h(x, y, t)$ is the hydraulic head in the aquifer; and $W(x, y, t)$ is a source-sink term (positive for a source, such as recharge) distributed areally. The expression $\sum_{\ell=1}^{N}\delta(x-a_\ell)(y-b_\ell)Q_\ell$ is the Dirac delta designation for N wells, each one pumping at rate Q_ℓ(t) (positive for injection) and located at coordinates (a_ℓ, b_ℓ). S is the storativity (storage coefficient or specific yield); x and y are the Cartesian coordinates; and, finally, t is time.

To approximate the variability of a given parameter, the region of interest is subdivided into zones; the parameter is assumed to be constant within each zone. Zones of one type of parameter, such as hydraulic conductivity, do not necessarily correspond to zones for another type of parameter, such as recharge.

Boundary conditions, such as lateral model inflow rate or constant head levels, are often considered part of the model itself, being neither an input nor a parameter. Along internal discontinuities in hydraulic conductivity the hydraulic head and flux normal to the boundary remain unchanged as the boundary is crossed.

The classical problem of ground-water hydrology is to solve Eq. (5) and its associated boundary conditions (including the initial head at $t = 0$) for the hydraulic head $h = h(x, y, t)$ in the aquifer, whereas an inverse solution involves solving Eq. (5) and its boundary conditions for one or more of the parameters, such as T, K, S, or W.

Sources of error in ground-water data

Numerous problems involving ground-water flow modeling of real field systems exist because the data necessary for the direct or inverse solutions are usually lacking. Head distribution is never known exactly because measurements do not exist at all points and because, where the measurements do exist, they are not exact. Estimates of the parameters either are completely unknown or have been obtained by spot measurements, few of which are directly useful for constructing appropriate effective values for use in Eq. (5). It should be clear that modeling problems in ground-water hydrology involve an incomplete combination of several types of data in which error and error propagation are important considerations.

Some major potential sources of random error in head data with respect to the model [Eq. (5)] have been enumerated by Cooley (1979):

1. Areal groundwater models assume that the head used is the average over the vertical, but wells may not be open over the entire interval modeled, and, if they are, they may not measure the average.

2. Hydraulic conductivity varies from point to point, which causes water levels to vary from values they would have if hydraulic conductivity were uniform. However, models usually do not take this detailed variation into account.

3. Water levels measured in wells in use may contain unknown amounts of residual drawdown. In addition, unused wells may be near wells that are in use, with resulting unknown drawdown in the unused well.

4. Measurement of well-head elevation may be in error.

5. Measurement of water levels may be in error [although usually of the order of 0.1–0.2 ft (0.03–0.06 m)].

Actual total error from the listed sources is highly problem dependent, but it is easy to imagine errors of several feet. In addition, interpolation errors are also of the order of several feet (Sophocleous, 1983). Major model errors in Eq. (5) and its associated boundary conditions can be detected relatively easily and can be eliminated by analysis of model results.

Because there are several different parameters to be considered and because each parameter can be estimated or measured in several different ways, numerous sources of error exist in the parameter data. Some examples of errors in parameter data have been given by Cooley and Naff (1985):

1. Too few estimates of parameters are available to compute stable estimates of statistics such as mean and variance.

2. Results of point sampling are often biased because a large amount of data does not necessarily allow computation of nearly true or effective values of a parameter and its variance. For example, permeability values from core analyses often are not representative of regional values because flow through large fractures is not reproduced by core analyses.

3. Transmissivities estimated from specific capacity data collected by drillers are subject to numerous sources of error. Common sources include mismeasured water levels or pumping rates, recovery of water level after bailing, clogging the slots or screen, and inaccurate reporting. A persistent source of bias results because drillers drill wells in favorable locations and screen only the most productive zones.

4. Transmissivities and storativities estimated from pumping-test analyses are subject to many of the same errors in item 3, but the more carefully controlled tests should reduce their frequency and magnitude. In addition, a single test may not be representative of an entire hydrostratigraphic unit.

5. Transmissivities and storativities estimated from lithologic data are usually biased to an unknown extent.

The necessary elements of $\underline{e}$ and their derivatives are obtained by applying a Gauss-Marquardt linearization scheme to Eq. (6). The technique yields a regression equation, which can be written

$$\Delta \underline{b}_i = -\underline{N}^{-1} \underline{f}_i \tag{9}$$

where $\Delta \underline{b}_i = \underline{b}_{i+1} - \underline{b}_i$, i is the iteration number, $\underline{N}$ is the normal matrix ($\underline{J}^T \underline{wJ}$) consisting of the derivatives of the elements of h with respect to each of the elements of b, and $\underline{f}_i$ is the gradient of the objective function (i.e., the weighted sum of squared head differences between the model and the observed heads).

The sensitivity coefficients J_{ij}, or simply sensitivities, indicate the change in the value of head h_i for a unit change in parameter b_j. The regression algorithm uses only observed values of head in the criterion SS for the best fitting solutions.

Assumptions for the regression analysis

The nonlinear model—assumed to be the true model—represented by the solution of Eq. (6) for h, which is the subset of h_m that applies at nodes that are observation nodes, can be written for observation ℓ as

$$h_\ell^{obs} = f(\xi_\ell, \beta) + \varepsilon_\ell \tag{10}$$

where f indicates a function that is the solution of Eq. (6); ξ_ℓ is a vector of independent variables that is an undetermined but observable function of coordinates x, y, the problem geometry and boundary conditions; β is the vector of true parameters; and ε_ℓ is an error in observation.

To analyze statistically the results of and the predictions made by the regression model, we assume (Draper and Smith, 1981) that

$$E(\varepsilon_\ell) = 0, \tag{11}$$

$$Var\,(\varepsilon_\ell) = \sigma^2, \tag{12}$$

$$Cov\,(\varepsilon_\ell, \varepsilon_m) = 0, \qquad \ell \neq m, \tag{13}$$

where *E*, *Var*, and *Cov* are the expected value, variance, and covariance operators, respectively. These assumptions indicate that ε_ℓ is a random variable with zero mean and constant variance σ^2 and that ε_ℓ and ε_m ($\ell \neq m$) are uncorrelated. In addition, it is often assumed that ε_ℓ is normally distributed with mean 0 and variance σ^2 (I is an identity matrix, and $I\sigma^2$ is a scalar diagonal matrix–covariance matrix) such that

$$\varepsilon \sim N\,(\underline{0}, \underline{I}\sigma^2). \tag{14}$$

This means that the elements of ε are independent and uncorrelated and allow the use of statistical tests and measures involving the *F* and *t* distributions (Draper and Smith, 1981).

Because β is unknown, ε is not observable and the assumptions cannot be checked directly. However, they can often be checked indirectly, after the regression and model analysis have been performed, as demonstrated later.

V. Model implementation and calibration

Grid selection

The study area consists of a 44 × 23 mi rectangle oriented in a southwest to northeast direction; it includes Rattlesnake Creek from west of the Macksville stream-gaging station to the confluence with the Arkansas River (fig. 24). This rectangle is divided into 1,012 squares or cells, each being 1 square mile in area, thus forming a rectangular cell-centered finite-difference grid used by MODFLOW. A total of 562 grid cells form the active area within the boundaries of the model region.

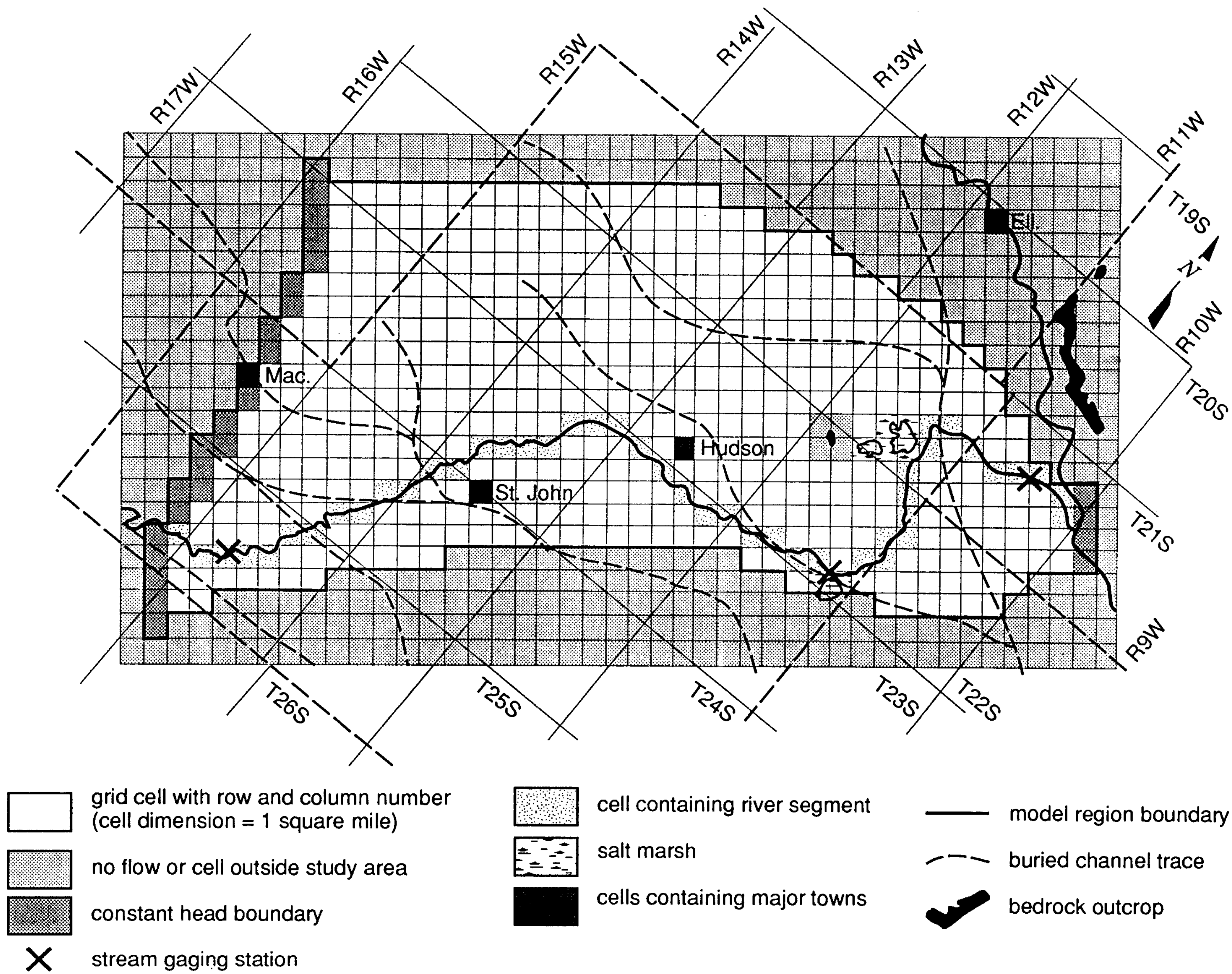

Figure 24. Finite-difference grid of the model area.

Boundary conditions

The model boundaries for the study area, as shown in fig. 24, were arrived at by drawing bounding flow lines on water table maps, as mentioned previously, and using them as no-flow boundaries (because no-flow lines can cross each other) along the northwest and southeast sides. These bounding flow lines coincide approximately with the Rattlesnake Creek watershed boundaries. The southwest boundary was cut along the 2,000-ft iso-water-level contour passing through Macksville, whereas the northeast boundary was taken along the Arkansas River by the confluence with Rattlesnake Creek, thus forming assumed constant-head end boundaries. Examination of the 2,000-ft contour over time from water-table maps of the GMD5 over different years (KGS unpublished maps) since predevelopment time indicates that this contour did not change appreciably over time.

Model stresses

The period of simulation is divided into a series of stress periods within which specified stress parameters are constant. Each stress period, in turn, is divided into a series of yearly time steps. A system of finite-difference equations of the form of Eq. (6) is formulated and solved to yield the head at each node at the end of each time step.

Groundwater pumpage

A computer program was written to read and reformat the water rights tape obtained from the Division of Water Resources and to sort water rights according to year, application number, or legal location. Figure 8 is a plot of all ground-water rights versus year of issue in the model area. The 1990 ground-water appropriation for the model area totaled 96,457 acre-ft. To simplify matters and to avoid excessive input files to the model, we decided to approximate this curve by dividing it into 3-year segments of uniform number and distribution of wells starting in 1955, which is considered an indicator year of predevelopment conditions. Thus the time period from 1955 to 1957 is represented by the 1956 ground-water rights distribution, the 1958–1960 period

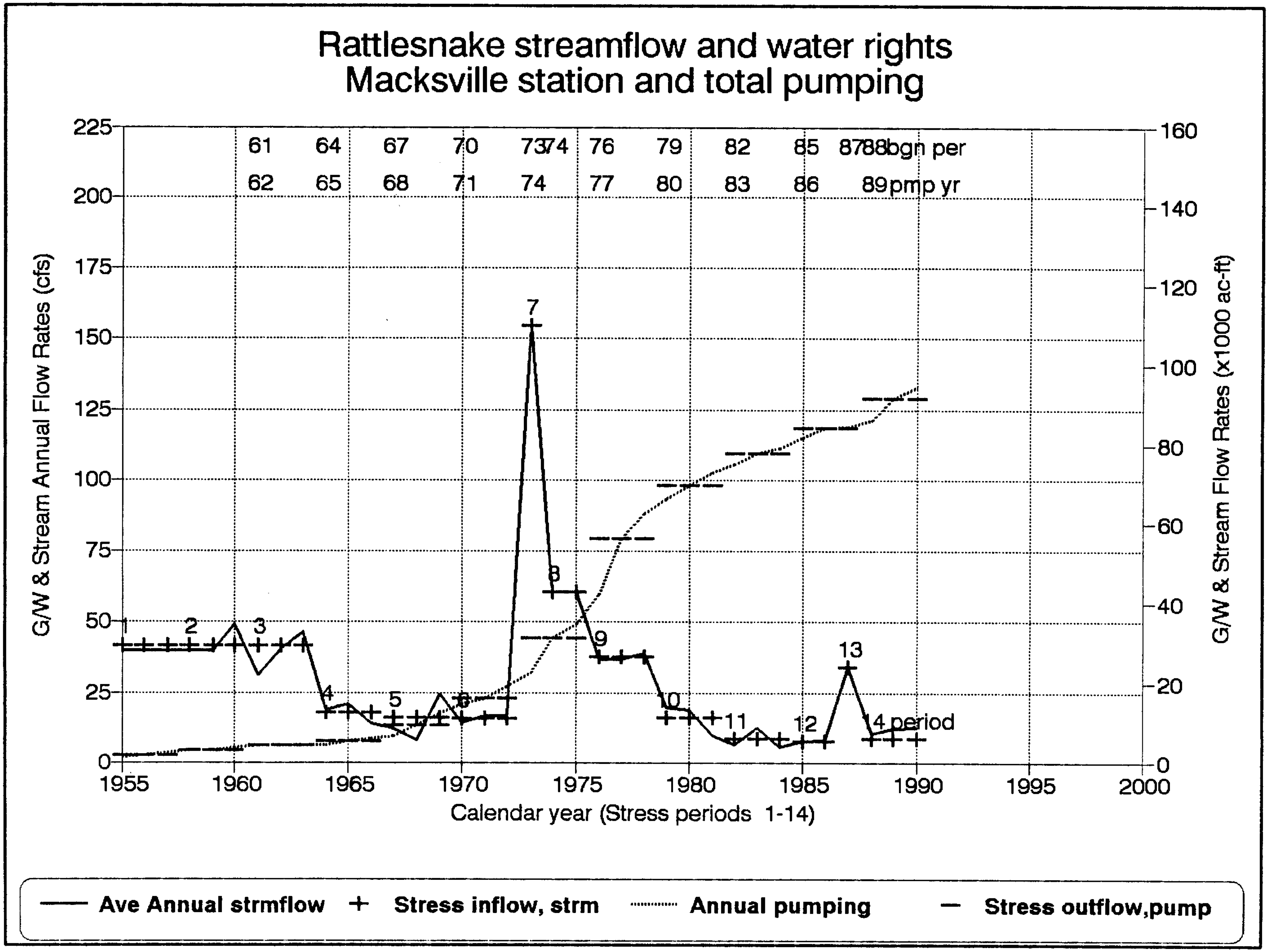

Figure 25. Model stresses (incoming streamflows and ground-water pumping) versus time.

by the 1959 ground-water rights distribution, and so on, as shown by the dash lines in fig. 25. Pumping-well matrices for the different pumping stress periods, as indicated by the chosen index years 1956, 1959, 1962, 1965, 1968, 1971, 1974, 1977, 1980, 1983, 1986, and 1989 were prepared as input to the model (table 3).

Incoming streamflows

Another stress to the model system is the fluctuating amount of streamflow coming into the model area from Rattlesnake Creek, as monitored at the Macksville station. To simplify matters in a way similar to that done for the pumping stresses, we divided the average annual incoming streamflows at Macksville into variable year periods of relatively uniform incoming streamflows (fig. 25). These periods and the average Rattlesnake Creek streamflows are shown in table 3. The progressive decline in incoming streamflow is clearly evident from these data and in fig. 25. Because the Macksville stream-gaging station has been operational only since 1960, all previous streamflows were assumed to be equal to the average streamflow during the 1960–1963 period.

Therefore, by combining the pumping and incoming streamflow stress periods, we obtained 14 pumping and stream stress periods and therefore 14 corresponding input data matrices for the model in simulating stream-aquifer conditions from 1955 to 1990. Table 3 details these 14 stress periods.

Aquifer-related data

Aquifer base

The aquifer base was extracted from the compiled bedrock map by superimposing the model grid on that map and reading (or interpolating) a bedrock elevation value at the center of each cell block (fig. 6).

Table 3. Stress periods employed in the model.

Pumping period	Mid-interval appropriated ground-water pumpage in model area (acre-ft/yr)	Incoming streamflow averaging period	Average annual streamflow (cfs)	Stress period
1955–1957	1829	1960–1963	41.72[a]	1
1958–1960	3252	1960–1963	41.72[a]	2
1961–1963	4345	1960–1963	41.72	3
1964–1966	5505	1964–1966	17.80	4
1967–1969	9627	1967–1969	16.25	5
1970–1972	16693	1970–1972	15.89	6
1973–1975	32250	1973	154.58	7
1973–1975		1974–1975	60.31	8
1976–1978	57483	1976–1978	37.47	9
1979–1981	71051	1979–1981	16.06	10
1982–1984	79273	1982–1984	8.23	11
1985–1987	85889	1985–1986	7.63	12
1985–1987		1987	33.98	13
1988–1990	93628	1988–1990	8.21	14

a. Average streamflows assumed equal to the ones in the 1960–1963 period.

Predevelopment and other water levels

The same procedure as that used to define the aquifer base was followed for the predevelopment water-level map (fig. 5). Water levels from the 1991 survey (fig. 14) were used to create an observed water-level matrix for comparison with corresponding simulated results.

Hydrogeologic properties

Several existing values of hydrogeologic properties from previous reports, such as Fader and Stullken's (1978), were considered for initial parameter values. For example, analysis of specific capacities of 235 irrigation wells in the Great Bend Prairie by Fader and Stullken (1978) indicated an aquifer transmissivity range of 2,500–35,000 ft^2/d, which, assuming a saturated thickness of 125 ft, translates to a range of hydraulic conductivities of 20–280 ft/d.

We know that the study area is characterized by a number of high-transmissivity buried channels (Sophocleous et al., 1990; Sophocleous, 1991b; figs. 2 and 24). We also know that a Cretaceous bedrock outcrop (Kiowa Shale) occurs west of the Big Salt Marsh, implying low aquifer transmissivity in the area surrounding the outcrop. Thus the study area was initially zoned into (1) different hydraulic conductivity regions based on the existence of buried channels, (2) a low hydraulic conductivity region near the bedrock outcrop and (3) the remaining aquifer region.

Values of aquifer storativity are more difficult to come by. However, typical values of storativity for sand range from 0.01 to 0.46 and for gravel from 0.13 to 0.44 (Morris and Johnson, 1967). Because of the limited number of storativity values in the study region, the area was zoned as a single storativity region.

Recharge data

Recharge data from an ongoing study on ground-water recharge assessment of the GMD5 (Sophocleous, 1991a; 1992), a previous study of the Rattlesnake watershed (Sophocleous and McAllister, 1987, 1990) and a recent U.S. Geological Survey study (Hansen, 1991) have been used as initial estimates of the recharge in the study area. Based on those studies, recharge in the study area ranges from approximately 0 to less than 6 in. per year and it averages 1 to 2 inches per year. Because the Big Salt Marsh is a discharge zone for the area and because the region around the bedrock outcrop is characterized by low transmissivities, that combined region is zoned as a very low (minimal) recharge zone for the model. A second recharge zone was established based on the bulging water table contours in the region (fig. 5) between Rattlesnake Creek and the bedrock outcrop, implying relatively high recharge. The rest of the study area was considered a mixed zone containing low, high, and intermediate recharge values.

Groundwater evapotranspiration

As indicated in the January 1991 depth to water table map (fig. 15), the area around the Quivira National Wildlife Refuge is generally characterized by very shallow depths to the water table (less than 10 ft) from which ground water can easily be lost from the aquifer by evapotranspiration. Thus that region was considered a ground-water evapotranspiration zone, and the evaporation modules of the MODFLOW program were activated.

Stream-related data

Stream widths and slopes for the model area were estimated, as mentioned previously, from site visits and topographic and other maps. Streambed hydraulic conductance was approximated based on the knowledge of the area's geology. Manning's coefficients were obtained from tables (Chow, 1959; White, 1979) based on our knowledge of the area streams.

Calibration

Calibration involves adjustment of model input using alternative combinations of parameter values and zones to obtain reasonable agreement with measured data. The model was calibrated for both steady-state and transient-state conditions. For this study we adhered to the *principle of parsimony*, according to which in a choice among competing hypotheses, other things being equal, the simplest hypothesis (i.e., the one with the smallest possible number of parameters for adequate representation) is preferable.

Steady-state calibration

Because of the relatively large number of data points used in the construction of the predevelopment water-level map (Sophocleous et al., 1990) and the minimal amount of external stresses (e.g., pumpage) imposed on the aquifer, the interpolated predevelopment water levels for each active cell of the model grid were considered of similar accuracy to the actually measured ones. Thus all active model grid cells are considered as cells with observed (measured) values that are identical with the initial (starting) water-level cell entries in the model.

Initially, the model area was divided into several hydraulic conductivity zones, as mentioned previously. Using this K zonation and the recharge and evapotranspiration zonation mentioned previously, we ran the MODINV model to optimize the hydraulic conductivity values using the predevelopment (steady-state) conditions, as exemplified by the predevelopment water levels and the 1955 irrigation well distribution. However, when we reran the simulation using fewer buried-channel hydraulic conductivity zones, the results and the sum of squares of the

Hydraulic Conductivity Zonation

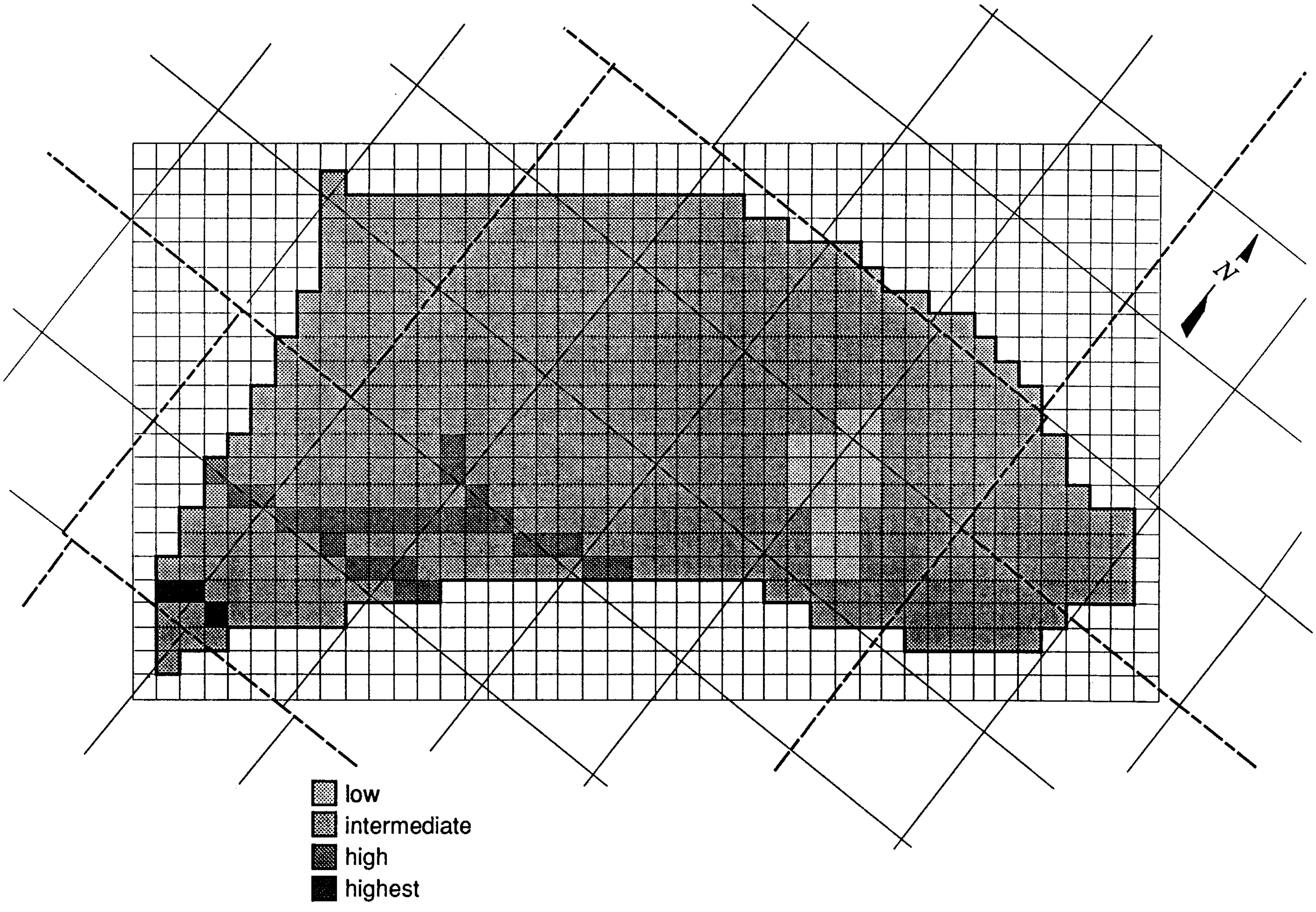

Figure 26. Hydraulic conductivity zonation of the model area.

deviations between simulated and observed heads progressively improved until only two buried channel zones remained (zones 3 and 4 in fig. 25). Therefore only two *K* buried-channel zonations (indicated in fig. 26) were adopted. Using no buried-channel *K* zones increased the sum of squares of the deviations significantly, and thus this option was not adopted. (The parameter zonations for recharge and evapotranspiration are shown in the next section.) The final result of these parameter optimization iterations are shown in section VI.

Transient-state calibration

To ensure that the transient-state model will simulate future conditions in the real system, we found it necessary to first simulate with reasonable accuracy as much hydrologic history as practical. Therefore the transient-state calibration was run from 1955 to 1990 using yearly time steps and the stress history outlined in table 3. When the model is thus calibrated, it can be used to project stream-aquifer responses to hydrologic conditions.

Starting with the optimized parameter estimates from the steady-state calibration and employing the stress periods indicated in the "Model Stresses" section, we ran the MODINV parameter estimation program to optimize, in sequence or simultaneously, storativity, recharge and evapotranspiration, keeping the already optimized hydraulic conductivity values constant. Employing two or more zones of storativity, based on geologic reasoning, versus one zone did not result in any significant difference in the sum of squares of deviations between simulated and observed values of hydraulic head, and thus a single storativity zone was used. The final recharge and evapotranspiration parameter zonations are shown in figs. 27 and 28, respectively. In the transient runs the ground-water pumpage was held at 80% of the appropriated amounts. We judged that 80% of the appropriated water rights was closer to the one actually used, and therefore all transient-state runs were performed under this assumption.

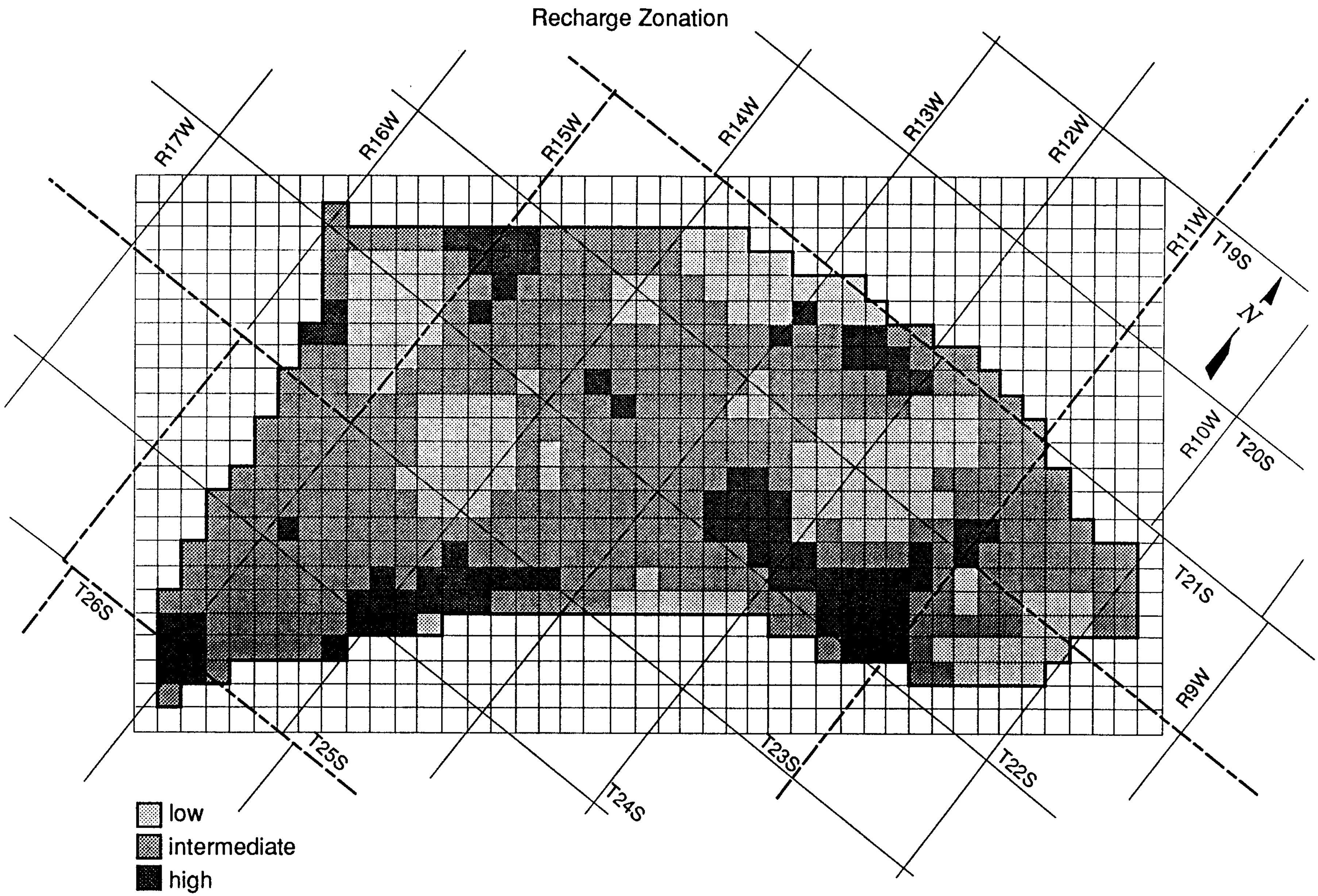

Figure 27. Ground-water recharge zonation of the model area.

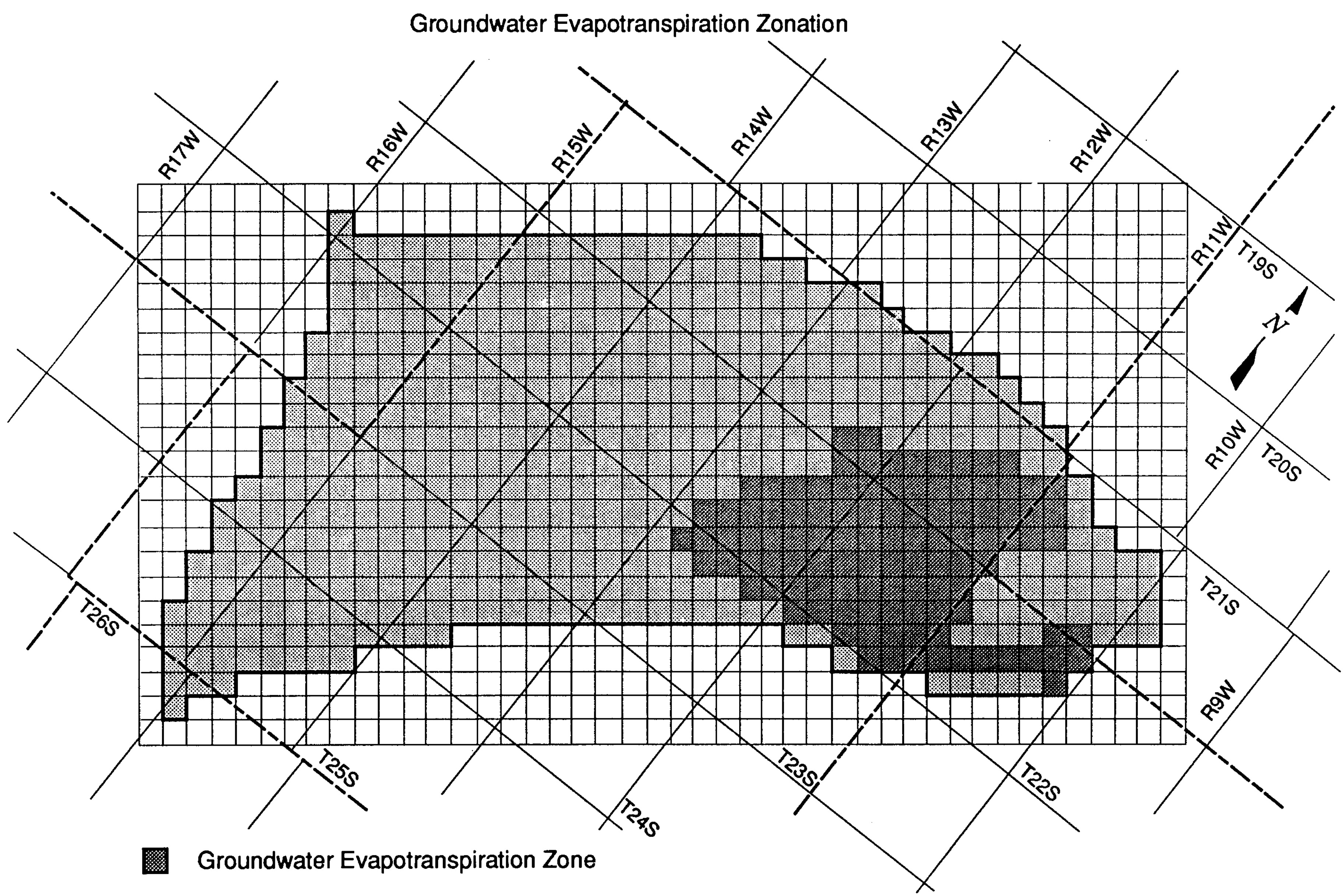

Figure 28. Ground- water evapotranspiration zonation of the model area.

VI. Simulation results and model analysis

As mentioned previously, the calibration or parameter estimation problem is in essence a regression problem, and the various methods and tests that have been developed to analyze regression problems also can be applied to ground-water flow models. Many of these procedures are used in the following steady-state and transient-state model analyses.

Predevelopment (steady-state) conditions

The results of the steady-state analysis are shown in table 4, in which the fit of simulated and observed values of head is very good, as indicated by the high value of the correlation coefficient ($R = 0.9994$). The standard error of the estimate for the *i*th parameter [given by the square root of the *i*th diagonal component of the parameter variance-covariance (or simply covariance) matrix] is a measure of the range over which the parameter can be varied to produce a solution for the dependent variable (i.e., hydraulic head) that is similar to the solution obtained using the estimated parameter. Standard errors are indications of the precision of the determined parameters. Converting such standard errors into a confidence interval requires assuming of some probability distribution for these errors. For example, if the central limit theorem holds, a 95% confidence interval for the parameter values will be given by $\hat{b} \pm 1.96\sigma_E$, where $\hat{b}$ is the estimated value of the parameter and σ_E is the standard error. The final hydraulic conductivity, recharge, and evapotranspiration zonations of the model area are shown in figs. 26, 27, and 28, respectively.

The error variance s^2 of the hydraulic head values is another measure of overall goodness of fit of the model. [It is calculated as the ratio of the weighted sum of squares of the deviations between simulated and observed values of head (*SS*) over the number of observation points minus the number of estimated parameters.] A good overall fit between modeled and measured heads indicates that the head measurement standard deviations (i.e., the square root of the error variance) are small. The value of the ratio of the square root of the error variance over the difference between the highest and the lowest value of head in the model region ($s/\Delta h$) is 0.0085 (table 4), a relatively small value; thus errors in the model are considerably less than the model response, as

Table 4. Steady-state analysis results.

Zone	K(ft/d)	Std. error	Zone	R (in./yr)	Std. error	Zone	ET (in./yr)	Std. error
1	21	2.2	i	0.001	0.038	(1)	2.86	0.304
2	10	12.9	ii	0.54	0.052			
3[a]	50	9.5	iii	5.33	0.646			
4[a]	78	71.7						

s = square root of the error variance = 2.85 ft.
R = correlation between simulated and observed water levels = 0.9994.
N = number of observations = 492.
SS = weighted sum of squares of the deviations between simulated and observed values of head = 3,904 ft^2.

$s/\Delta h = 0.0085$ (Δh = 335 ft).

Std. error = $s/\sqrt{N}$.

a. Paleochannel zones.

indicated by the maximum head loss (Δh) of 335 ft in the model area. A comparison of observed and model simulated water table contours, shown in fig. 29, indicates a satisfactory match.

The main reasons for analyzing residuals are to examine the validity of the various assumptions concerning their distribution [Eqs. (11)–(14)] and to investigate the correctness of the model. Aspects that could be investigated include evidence of spatial nonrandomness and evidence that the residuals are not approximately normally distributed (Sophocleous, 1984). Draper and Smith (1981) give a number of methods for examining residuals, and they emphasize that graphical procedures are valuable tools for detecting nonrandomness because violations of assumptions serious enough to require corrective action generally are apparent on the various plots. In fig. 30 residuals are plotted against values of estimated head. Under the given assumptions the plot should display a roughly horizontal band of residuals having no apparent trend, and this is exactly how the plotted residuals in fig. 30 behave. The residuals were also plotted in Cartesian coordinates and contoured (fig. 31). The residuals show no obvious systematic variation of significant degree over the map area, indicating that this model is probably adequate for these data.

To check whether the residuals are normally distributed, we plotted them on normal probability paper (fig. 32). A relatively good-fitting straight line can be drawn through the bulk of

Observed and predicted predevelopment water levels

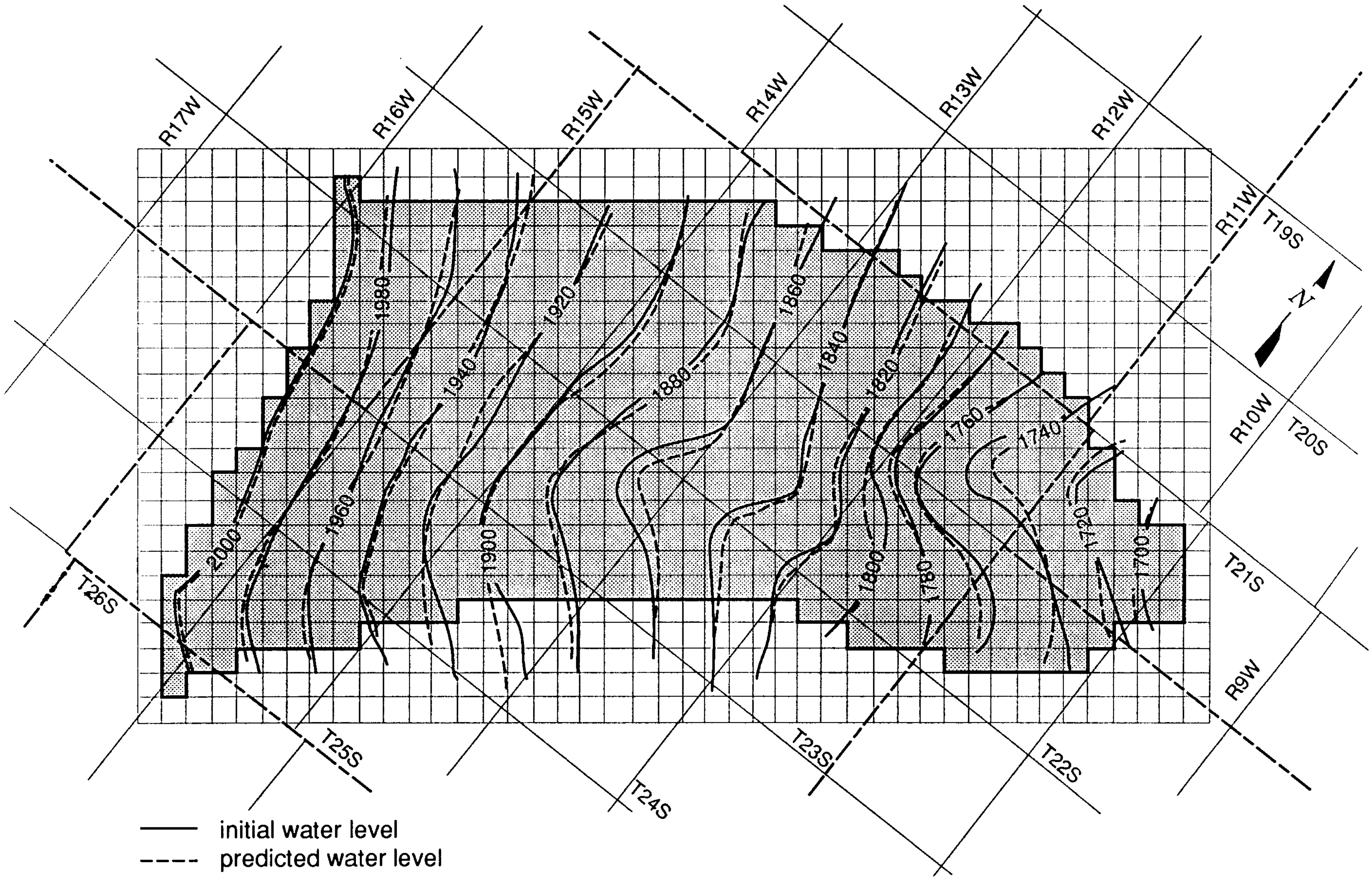

Figure 29. Comparison of observed and simulated steady-state water table contours.

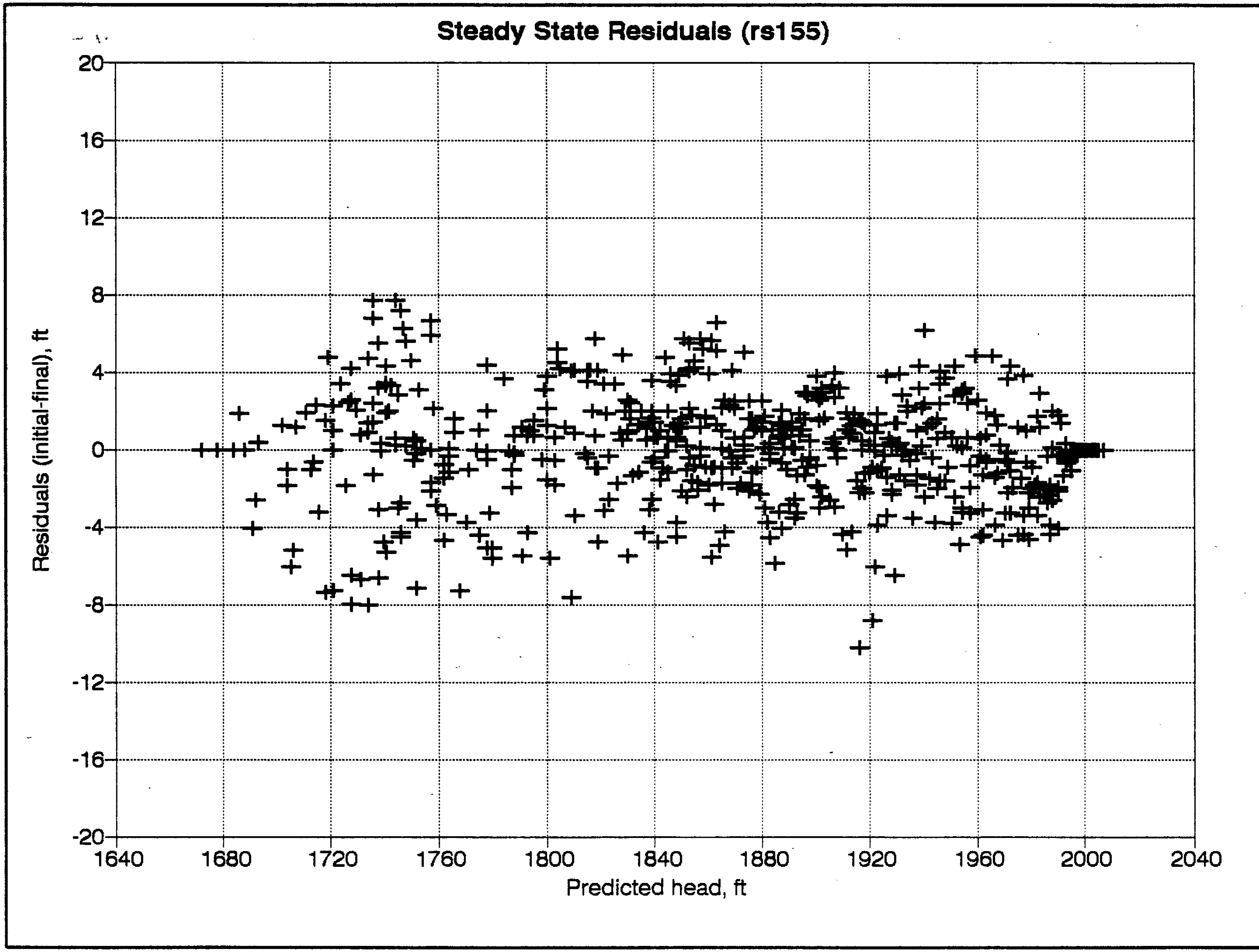

Figure 30. Steady-state residuals (differences between observed and simulated water table values) versus predicted hydraulic head.

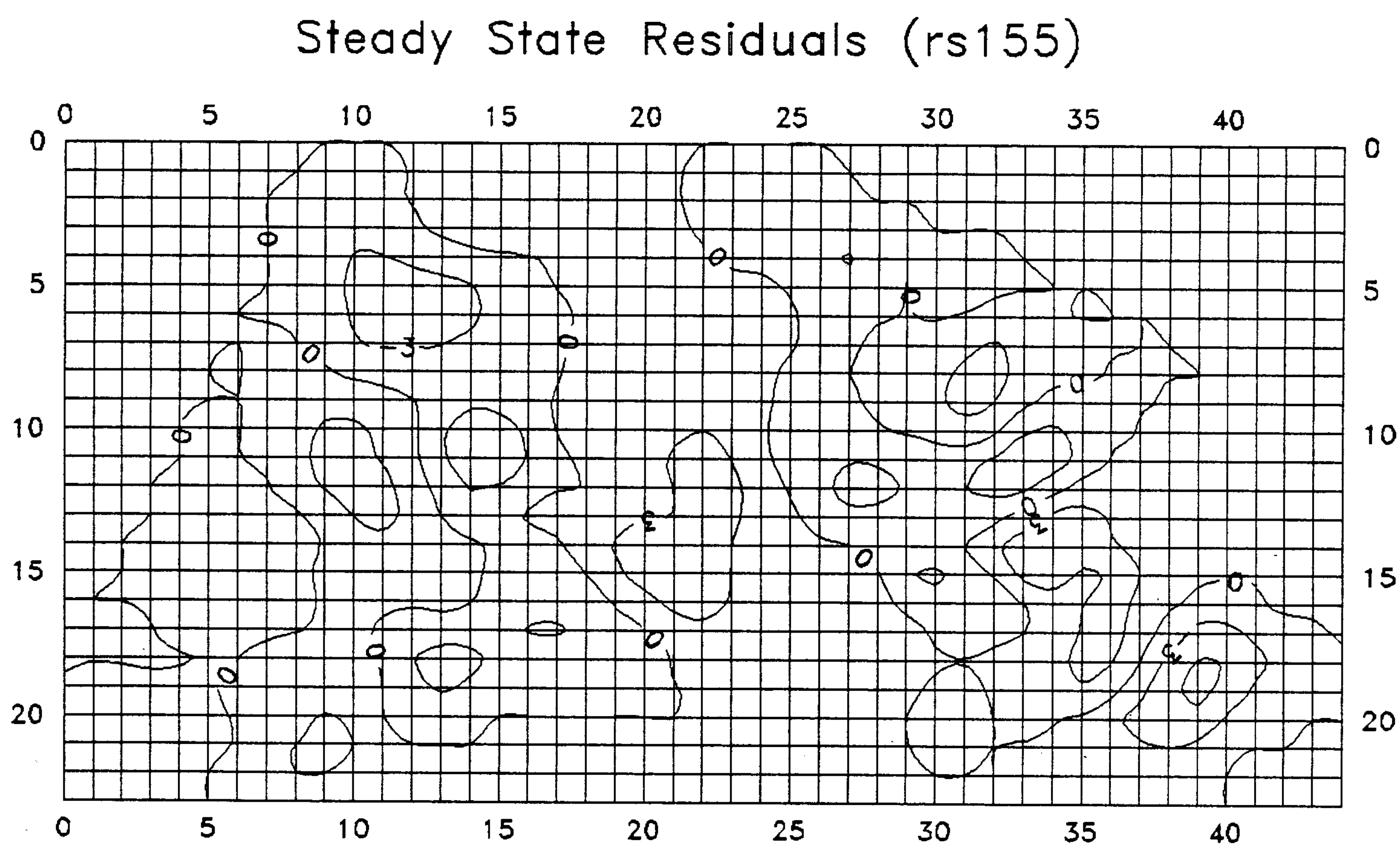

Figure 31. Contours of steady state residuals. Contour interval 3 ft.

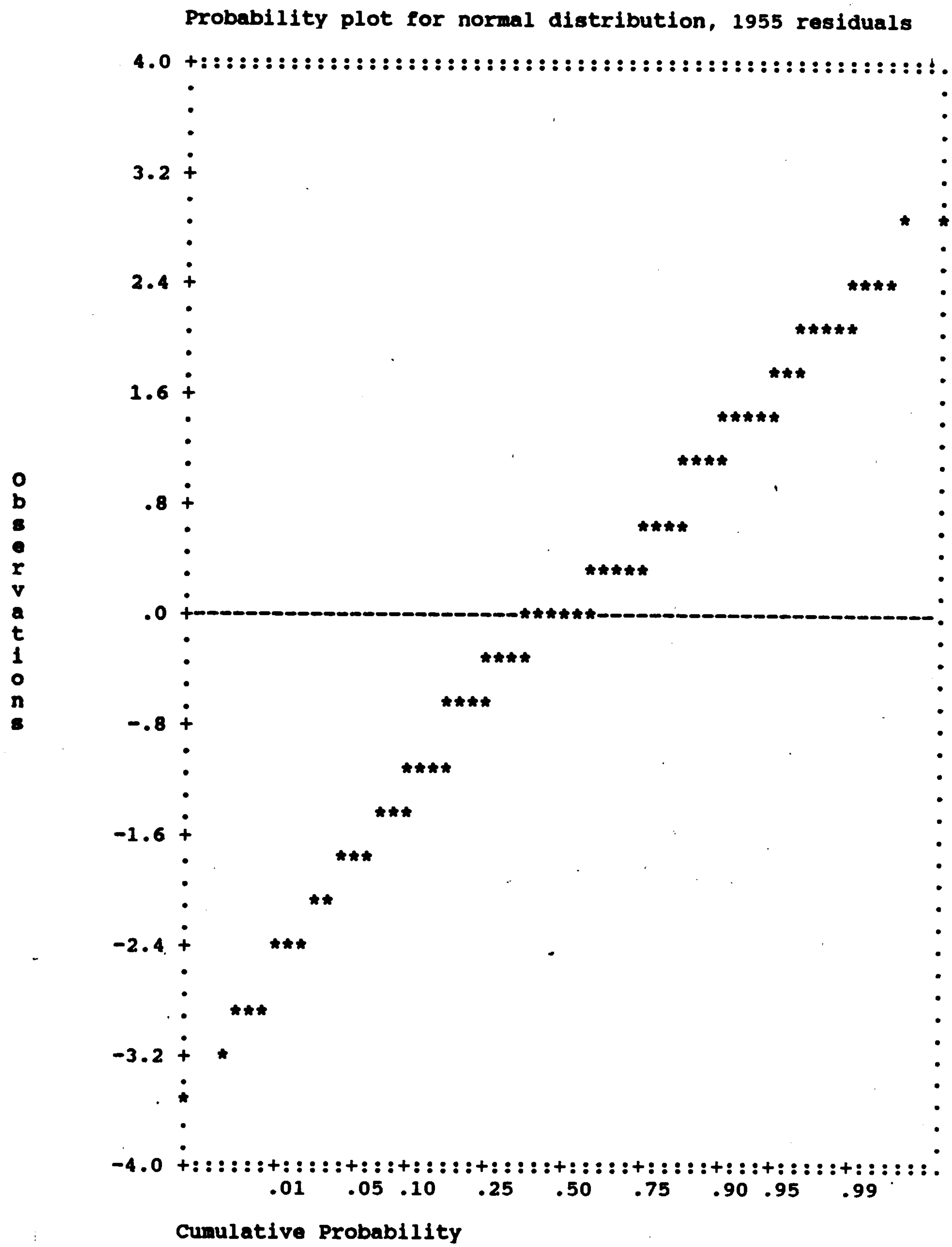

Figure 32. Probability plot of steady state residuals.

the points, indicating that the calculated residuals are approximately normally distributed. For the parameters derived from the least-squares analysis as maximum-likelihood estimates of the true parameters (i.e., parameter estimates that give the greatest probability of obtaining the observed data), residuals must be normally distributed.

Water budget

A summary of all inflows and outflows to a region is generally called a water budget. Because in the model program the water budget is calculated independently of the equation solution process, it provides independent evidence of a valid solution. The difference between total inflow and outflow is given as a percent error, calculated using the formula

$$D = \frac{100(\mathrm{In} - \mathrm{Out})}{(\mathrm{In} + \mathrm{Out})/2}, \qquad (15)$$

where In is the total inflow to the system, Out is the total outflow, and D is the percent error term. If the model equations are solved correctly, the percent error should be small. The overall model water budget is presented to check the acceptability of the solution and to provide summarized information on the flow system. The volumetric water budget for the model area under predevelopment conditions is presented in table 5. It is evident from the table that the bulk input to the stream-aquifer system is ground-water recharge and that the largest outflows from the system are evapotranspiration losses and baseflow contributions to streamflows. Note that the irrigation pumpage is a minor element of total system outflow for the considered period.

Transient-state simulations for the stream-aquifer system

The results of the transient-state simulations from 1955 to 1990 are shown in table 6. The final recharge and evapotranspiration zonations are shown in figs. 27, and 28, respectively. (Storativity was considered uniform throughout the aquifer.) The value of the ratio $s/\Delta h$ (0.0127) is still relatively small, indicating that errors in the model are considerably less than the model

Table 5. Volumetric budget for entire model area under predevelopment conditions (c. 1955).

Water-balance component	Volumetric rate (acre-ft/yr)
Inflows	
Constant head (underflow into study area)	4,800
Recharge	22,603
Stream leakage	998
Total Inflows	28,401
Outflows	
Constant head (underflow out of study area)	760
Pumping wells	1,820
Evapotranspiration	13,695
Stream leakage (net groundwater discharge to stream)	12,133
Total Outflows	28,408
Discrepancy = 0.00%	

response, as indicated by the maximum head loss. Comparisons of predicted versus observed values of hydraulic head, depicted in fig. 33 (for 1990 and Jan. 1991) are satisfactory. A plot of the residuals versus predicted values of hydraulic head for the 1955–1990 period (fig. 34) and a contouring of residual values (fig. 35) reveal that no relationship of significant concern is obvious, indicating that this model is probably adequate for these data. A normal probability plot of the residuals for the 1955–1990 period (fig. 36) reveals a well-fitting straight line through most of the plotted points, indicating that the residuals are approximately normally distributed.

Comparison of predicted groundwater discharge and observed average annual streamflow for the 1955–1990 simulation period near the Zenith stream-gaging station shows a satisfactory match, as indicated in fig. 37. As can be seen from that figure, the model under predicts groundwater discharge during periods of high streamflow because the model does not simulate overland runoff. During periods of low flow, however, most streamflow is derived from groundwater discharge.

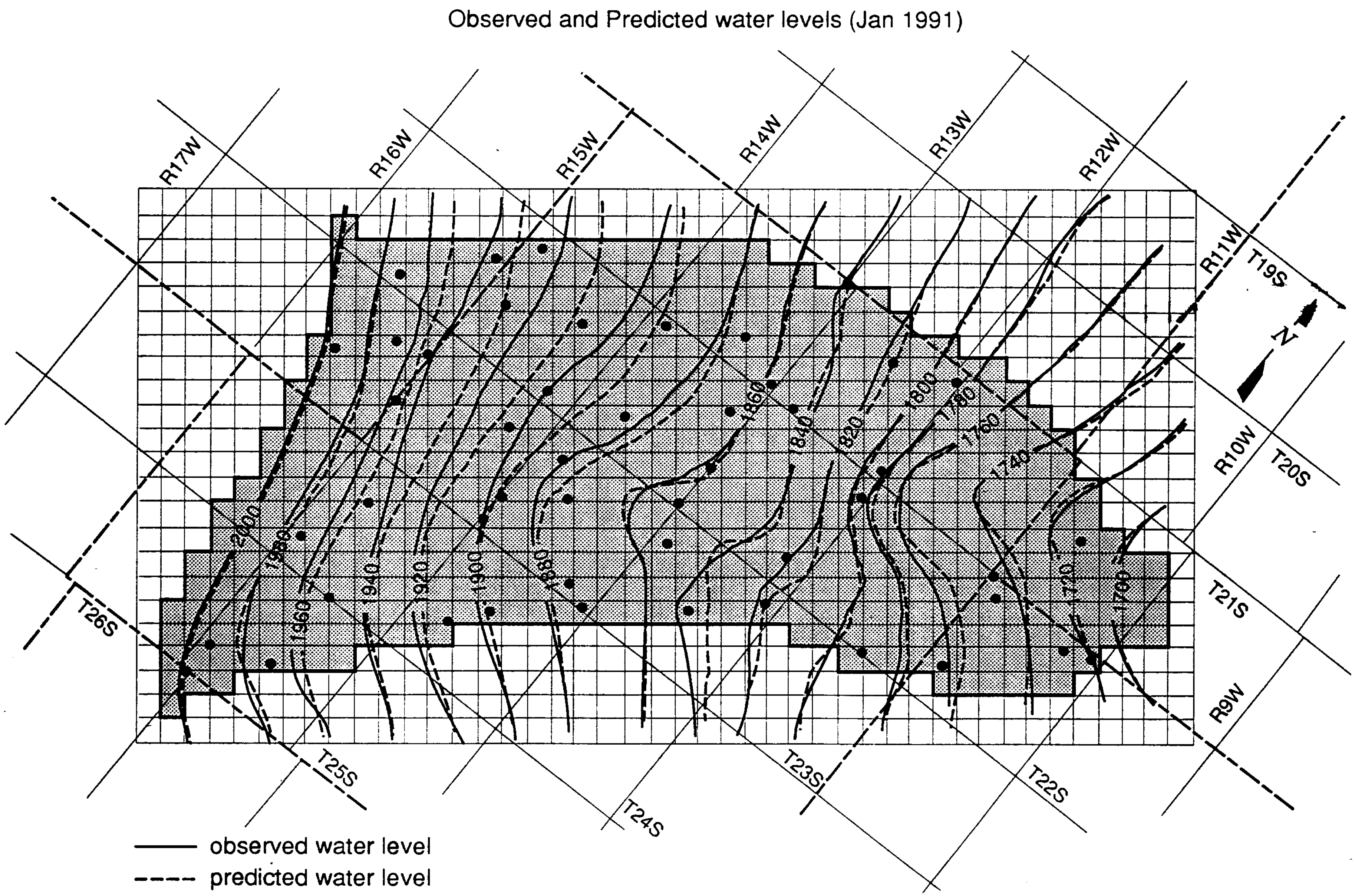

Figure 33. Comparison of observed and model-predicted January 1991 water table contours.

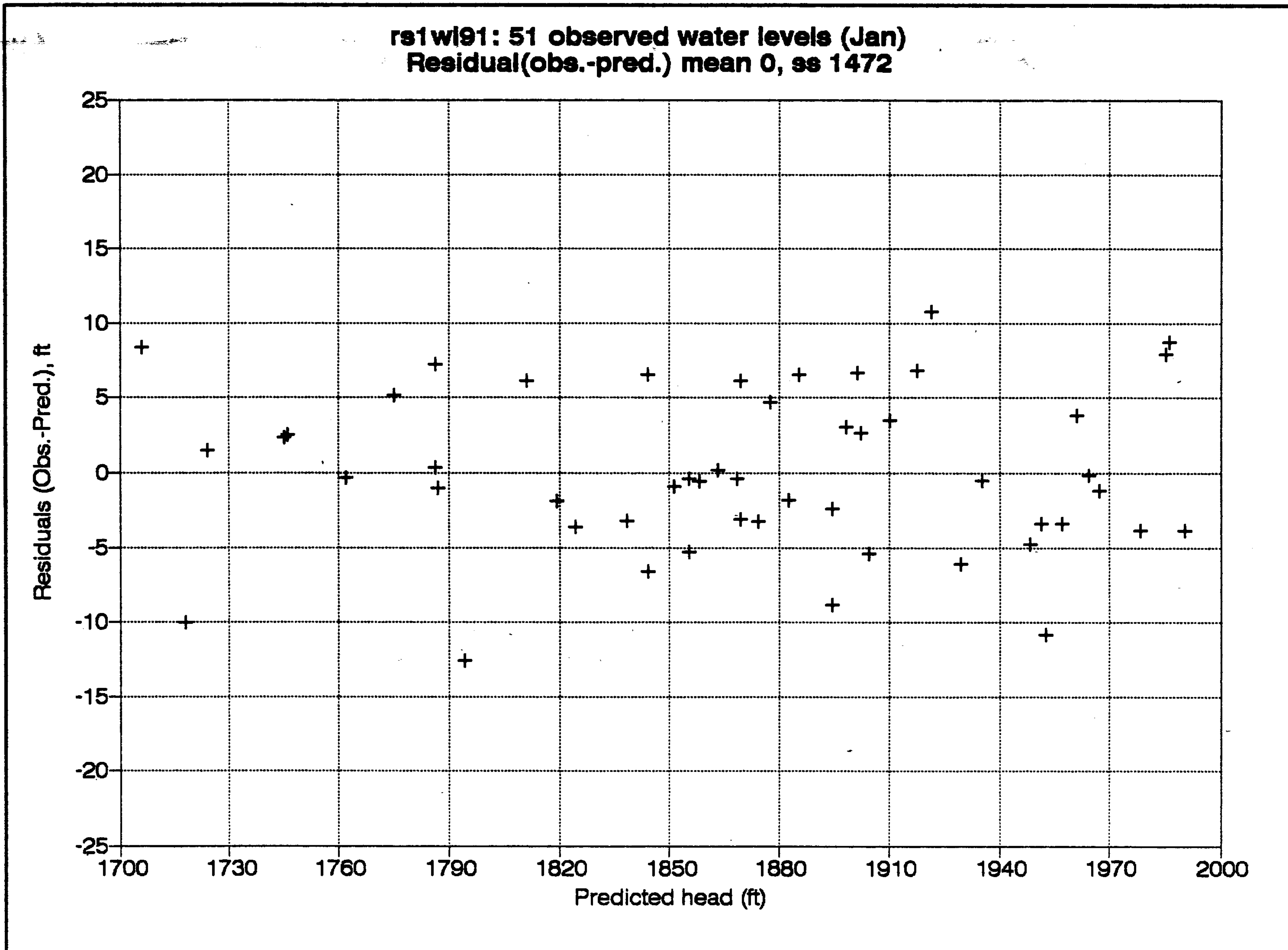

Figure 34. 1990 residuals versus predicted hydraulic head.

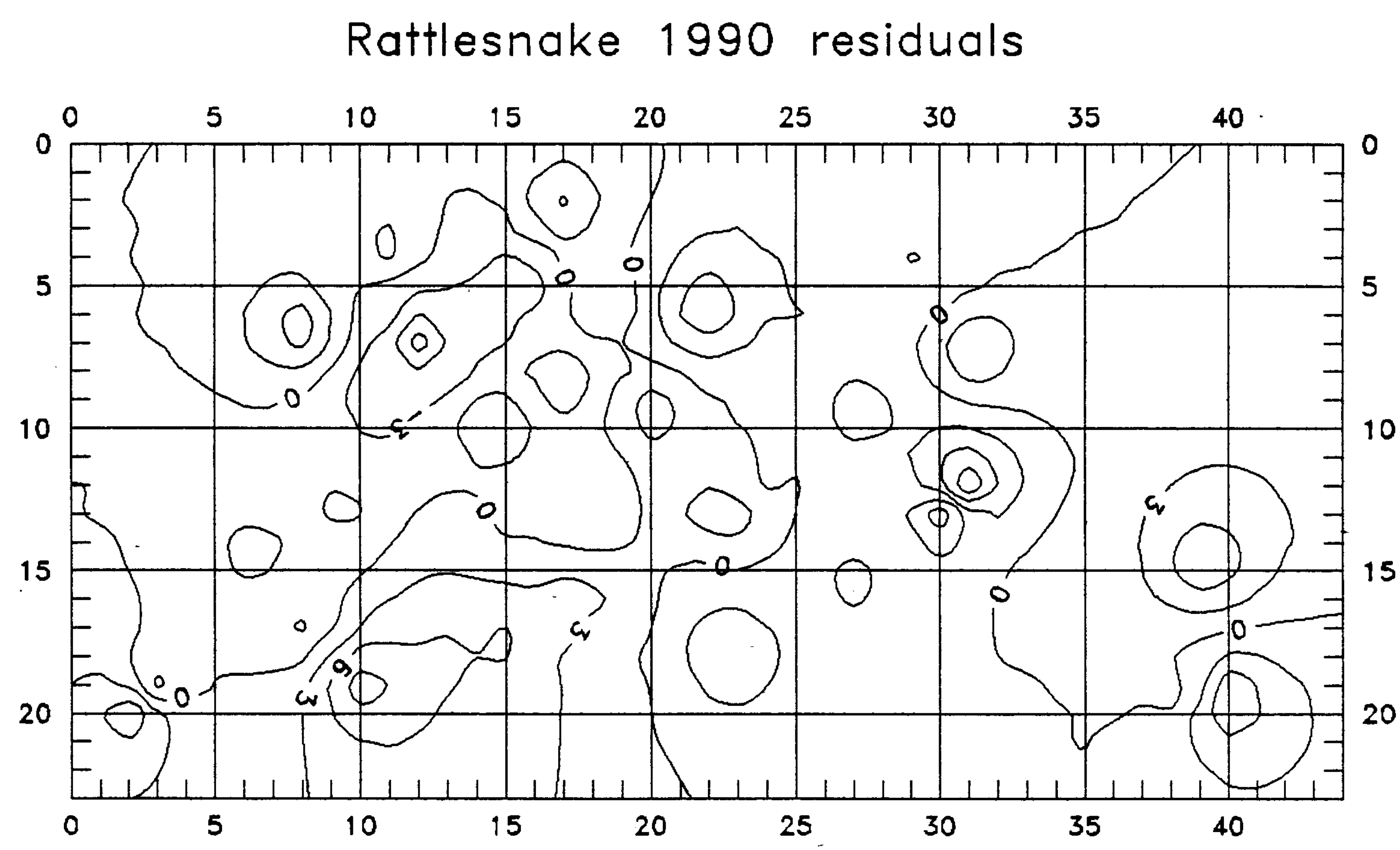

Figure 35. Contours of 1990 residuals. Contour interval 3 ft.

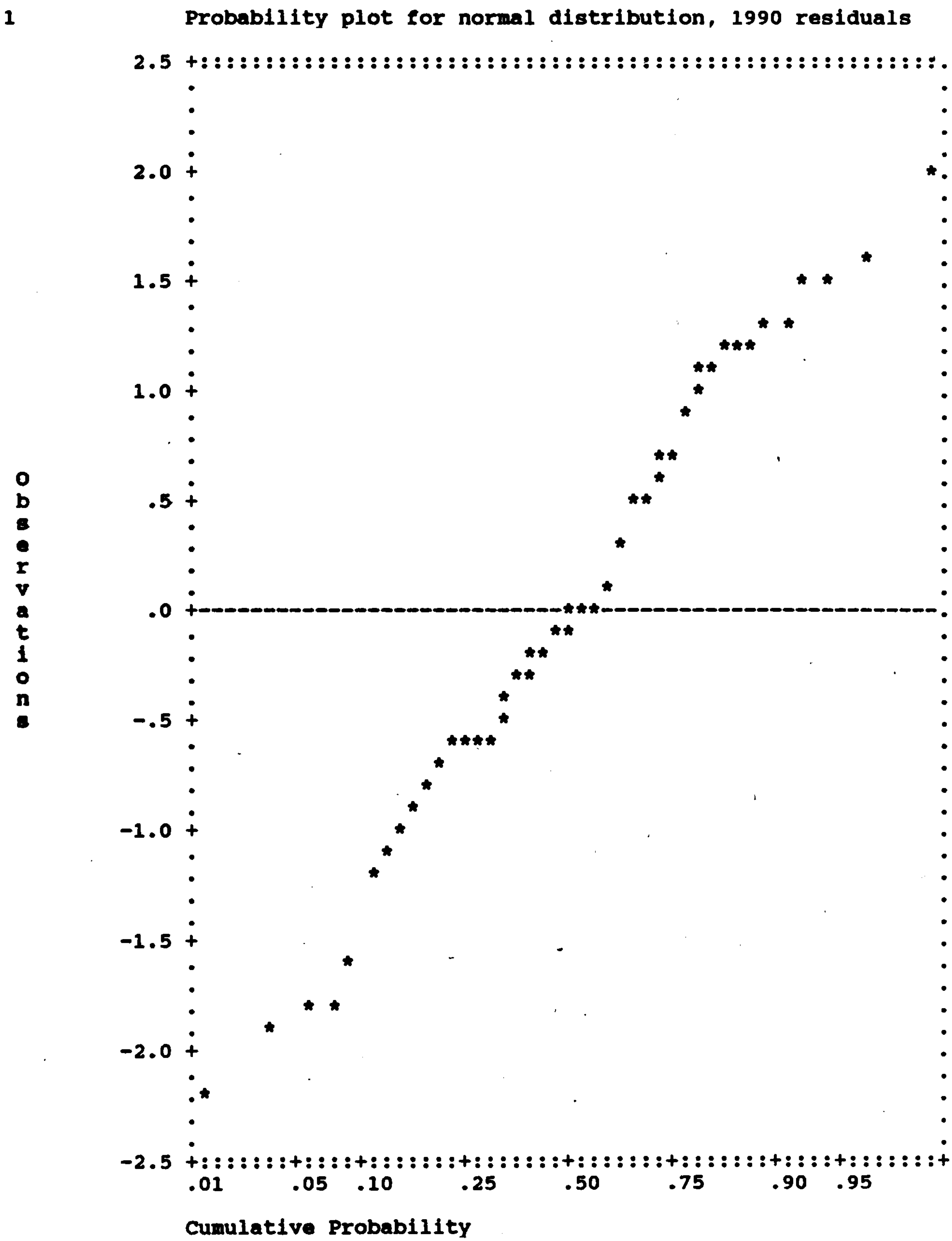

Figure 36. Probability plot of 1990 residuals.

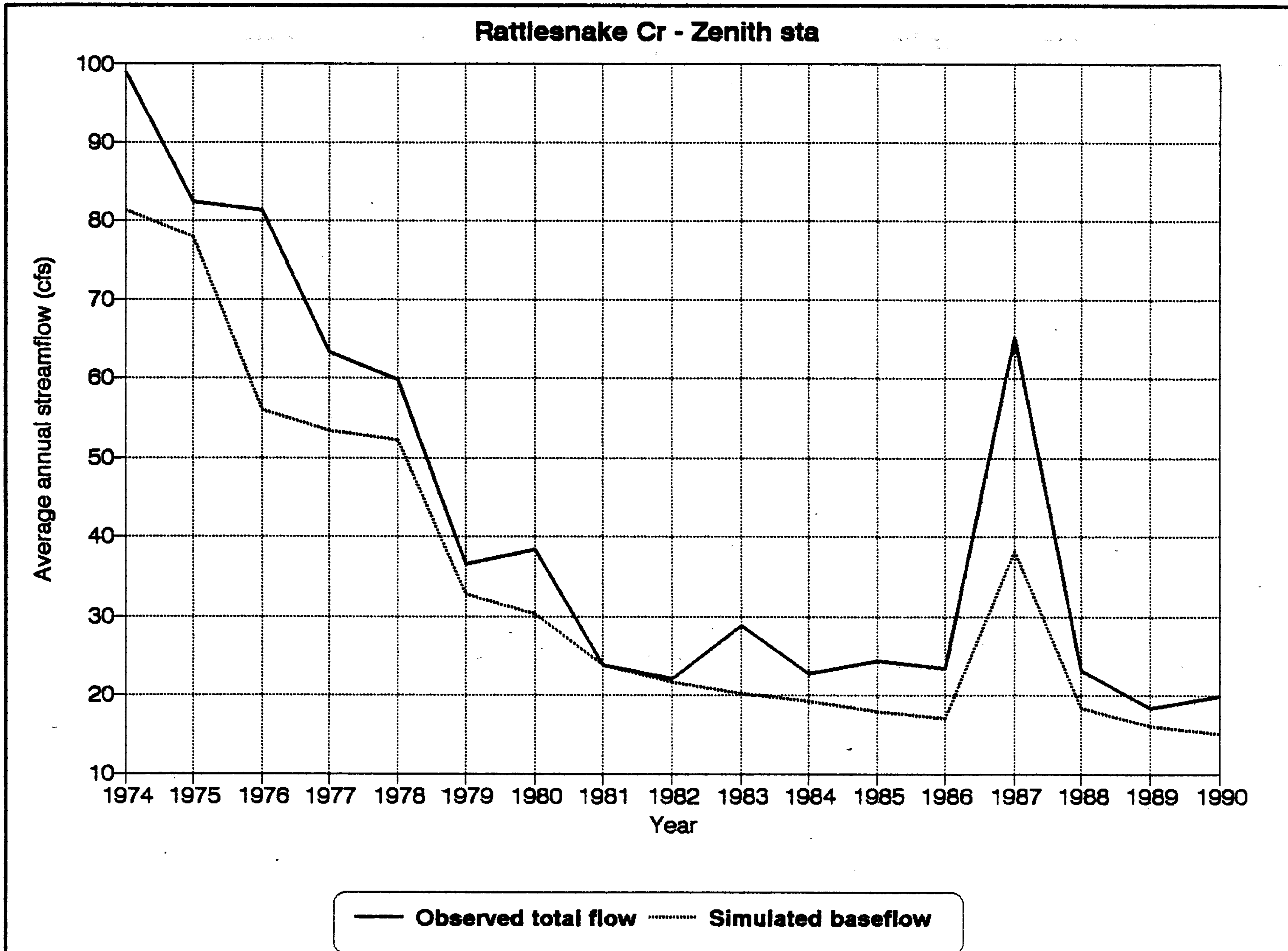

Figure 37. Comparison of predicted Rattlesnake Creek baseflow and streamflow at the Zenith gaging station versus time.

Table 6. Transient 1955–1990 analysis results.

Zone	R(in./yr)	Std. error	Zone	ET (in./yr)	Std. error	Zone	Storage
i	0.001	0.273	a	2.167	0.437	a	0.25
ii	1.681	0.155					
iii	3.001	0.435					

s = square root of the error variance = 4.27 ft.
R = correlation between simulated and observed water levels = 0.9974.
N = number of observations = 42.
SS = weighted sum of squares of the deviations between simulated and observed values of head = 710.9 ft^2.
$s/\Delta h = 0.0127$. (Δh = 335 ft).
Std. error = $\sigma/\sqrt{N}$.

Under natural conditions the water table gradient slopes toward the river, and ground water discharges from the aquifer into the river. This can be seen by the curvature of the iso-water-level contours pointing upstream (fig. 5). However, under drought or pumping conditions the water table gradient decreases, and ground-water discharge to the stream is reduced. If pumping is of sufficient volume and duration, the gradient may be reversed and water from the stream will move by induced infiltration through the streambed into the alluvial aquifer. During predevelopment times (circa 1955), the part of Rattlesnake Creek within the study area was entirely a gaining stream. At present, however, the model results indicate that the stream has both gaining and losing stretches (fig. 38). The major losing stretches are (1) between the Little Salt Marsh and the RCA structure, that is, in T. 22 S., R. 11 W.; and (2) from south of US–50 to northwest of St. John. The major gaining stretches of Rattlesnake Creek, according to our model results, are (1) after the juncture with Salt Creek exiting the Big Salt Marsh and (2) from the confluence with Wild Horse Creek up to southeast of Hudson.

The overall volumetric water budget for the model area during the last stress period (1988–1990) of the 1955–1990 transient-state simulation is presented in table 7. The convention followed in MODFLOW is that flow into or out of storage is considered part of the overall budget inasmuch as accumulation in storage effectively removes water from the flow system and storage release

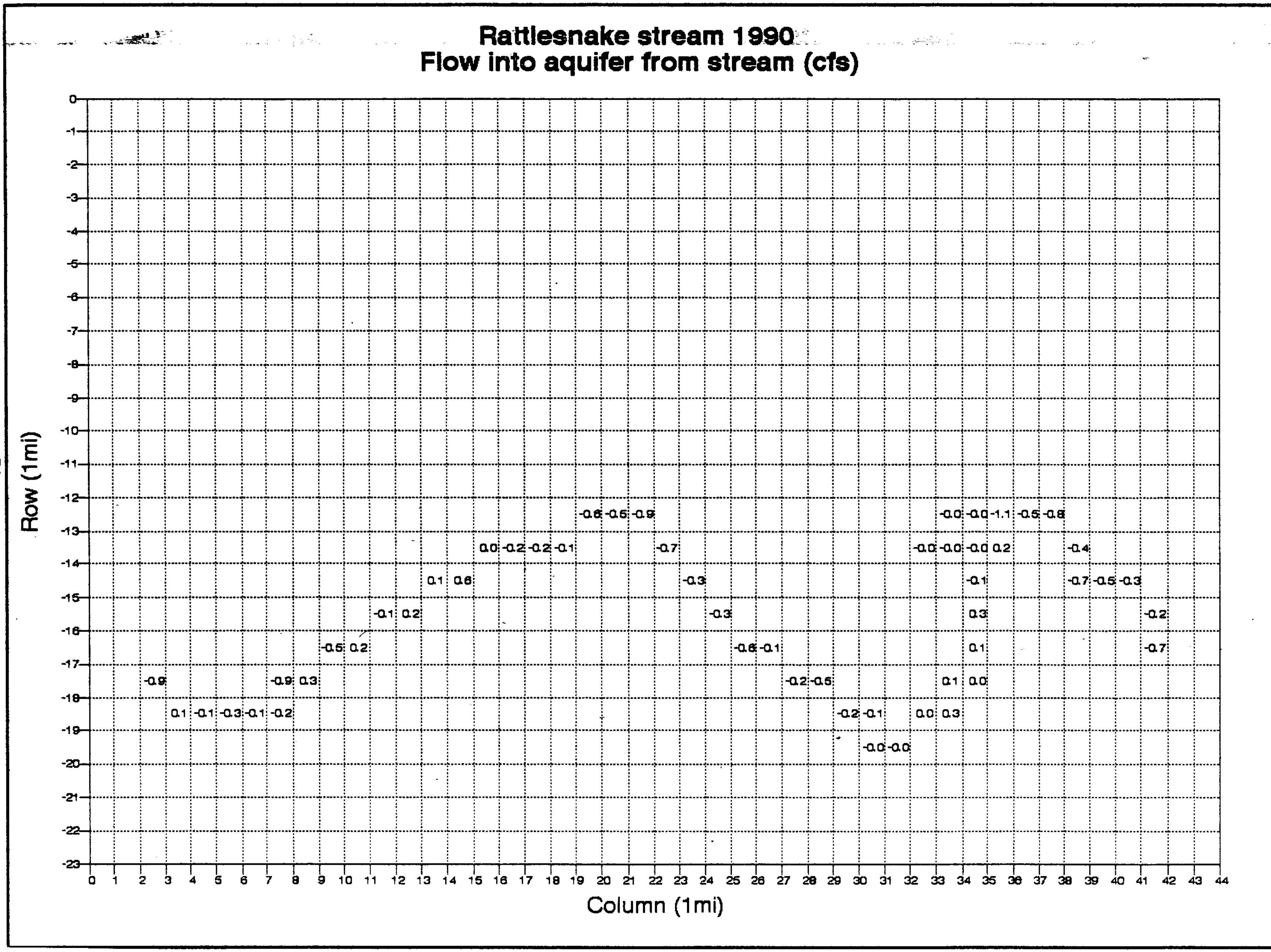

Figure 38. Model-predicted 1990 gaining (negative water fluxes) and losing (positive water fluxes) stretches of Rattlesnake Creek.

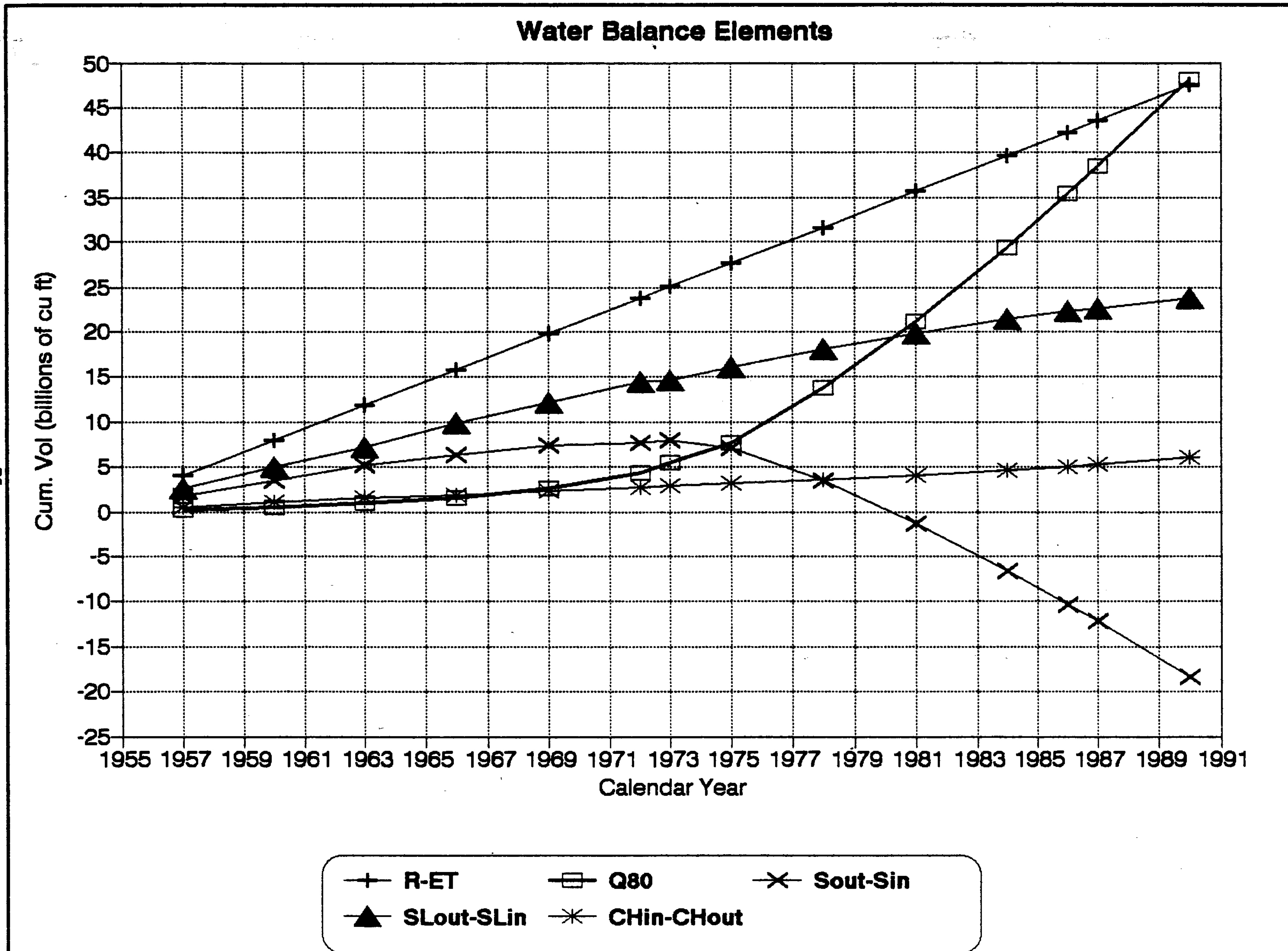

Figure 39. Time distribution of the water balance components during the 1955–1990 simulation period.

effectively adds water to the flow, even though neither process in itself involves the transfer of water into or out of the ground-water regime (McDonald and Harbaugh, 1988).

The time distribution of the water balance components during the 1955–1990 period is shown in fig. 39, in which it is evident that since the mid-1970's aquifer storage depletion (S_{out}–S_{in} curve) has been taking place. This storage depletion coincides with an accelerated irrigation pumping period (Q_{80} curve). Baseflow contributions to streamflow are also decreasing (SL_{out}–SL_{in} curve). (CH_{in} – CH_{out}) denotes the net subsurface inflow in the model area through the constant head boundaries; (R – ET) denotes the net recharge (recharge minus evapotranspiration) in the model area. The water balance for the last stress period (1988–1990) of the 1955–1990 transient-state simulation is shown in table 7. The major inflow and outflow for the transient period is ground-water recharge and pumping, respectively.

In contrast to what was the case during the 1950's and early 1960's, the present-day dominant outflow component from the aquifer is ground-water pumpage for irrigation, which is a new discharge superimposed on the predevelopment (steady-state) system. This irrigation pumpage must be balanced by (1) an increase in the aquifer recharge (by increased induced leakage from streams, drainage of the dewatered aquifer sediments, irrigation return flows, capture of previously "rejected" recharge as surface runoff by increased hydraulic gradients between recharge areas and areas with significant irrigation well development, and increased recharge from below, i.e., from saltwater intrusion from the Permian formations), (2) a decrease in the old natural discharge (by decreased baseflow contributions to streams, decreased outflows to seeps and springs, decreased ground-water evapotranspiration), (3) loss of water storage in the aquifer as manifested by long-term ground-water-level declines, or (4) a combination of these changes. Indeed, a combination of all three types of change is indicated in the water budget of the model area, which shows an increase in recharge, a loss of water in storage, and a decrease in baseflow contributions to streamflows and decreased evapotranspiration losses compared to the predevelopment water budget (table 5).

Table 7. Volumetric water budgets for the last stress period (1988–1990) of the transient 1955–1990 simulation.

Water-balance component	Volumetric rate (acre-ft/yr)
<u>1988–1990 Inflows</u>	
Release from storage	48,347
Constant head (underflow into study area)	6,264
Recharge	42,041
Stream leakage	1,574
Total Inflows	98,226
<u>1988–1990 Outflows</u>	
Uptake to storage	38
Constant head (underflow out of study area)	743
Pumping	74,893
Evapotranspiration	11,731
Stream leakage (net groundwater discharge to stream)	10,820
Total Outflows	98,225
Discrepancy = 0.00%	

A 35-mi-long southwest to northeast water table profile along a model cell row (row 13, fig. 24) passing through or near the towns of Macksville and Hudson and also through the Big Salt Marsh is shown in fig. 40. The thickness of the profile line is proportional to the simulated change in the water table over the 1955–1990 period. It is clear from the figure that (1) the water table elevation declines from the southwest to the northeast, (2) the water table declines the most in the area between Macksville and northeast of St. John, along this chosen row, (3) the water table slope flattens out near the Rattlesnake Creek and Hudson areas, (4) the water table steepens abruptly and declines the least from northeast of Hudson to near the Big Salt Marsh, and (5) the water table flattens out again at the Big Salt Marsh and Rattlesnake Creek northeast of the marsh. Another similar profile (40 mi long) along model cell row 17 passing through southeast St. John and midway between the Little Salt Marsh and the Big Salt Marsh is shown in fig. 41; the largest water table declines are in the area around St. John. The predevelopment groundwater fluxes (fig. 42a) are much more pronounced and contributed to Rattlesnake streamflows and the Quivira marsh more water than the presentday conditions indicate (fig. 42b).

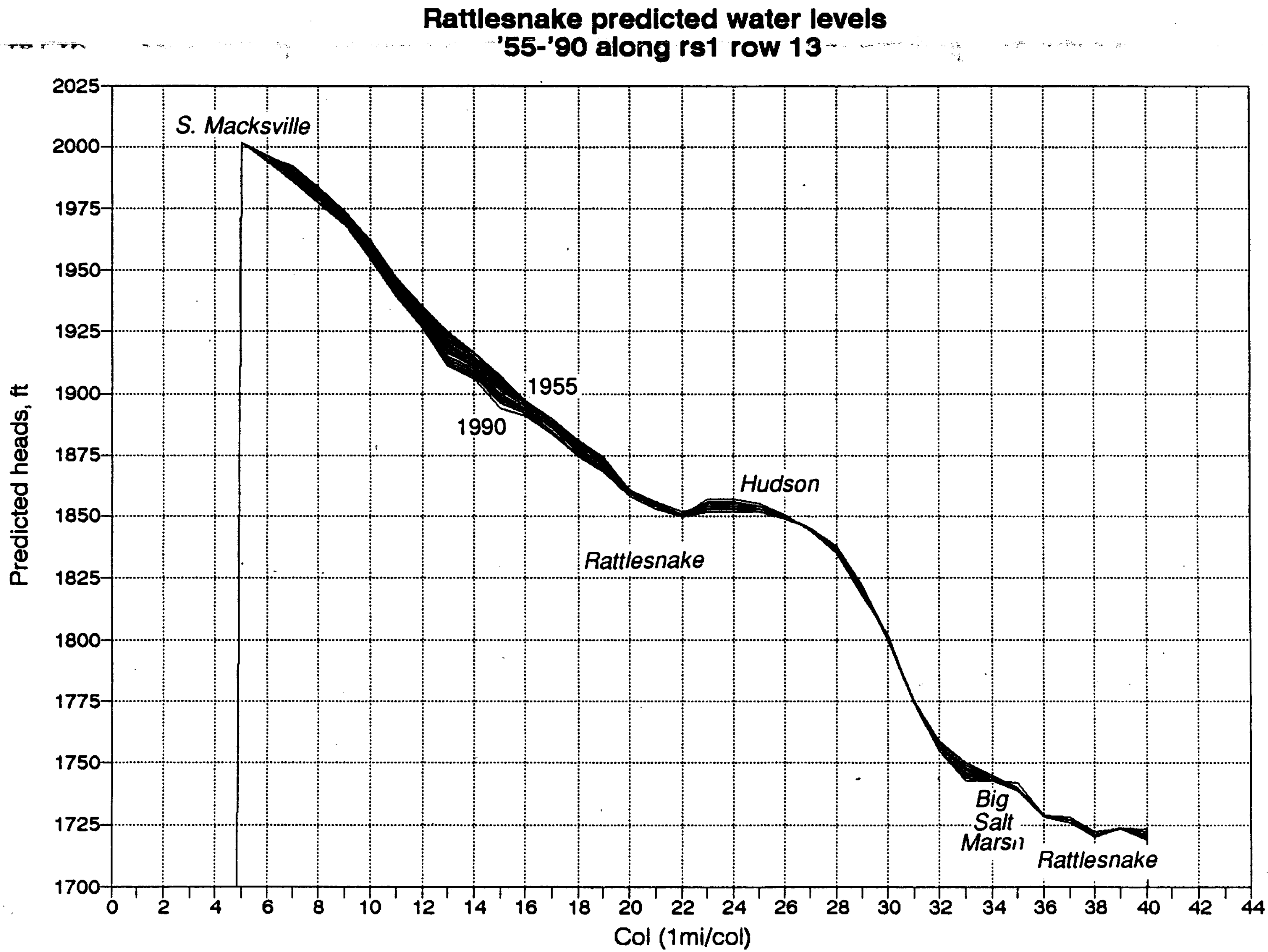

Figure 40. Water table profiles along row 13 passing near Macksville, Hudson, and Big Salt Marsh.

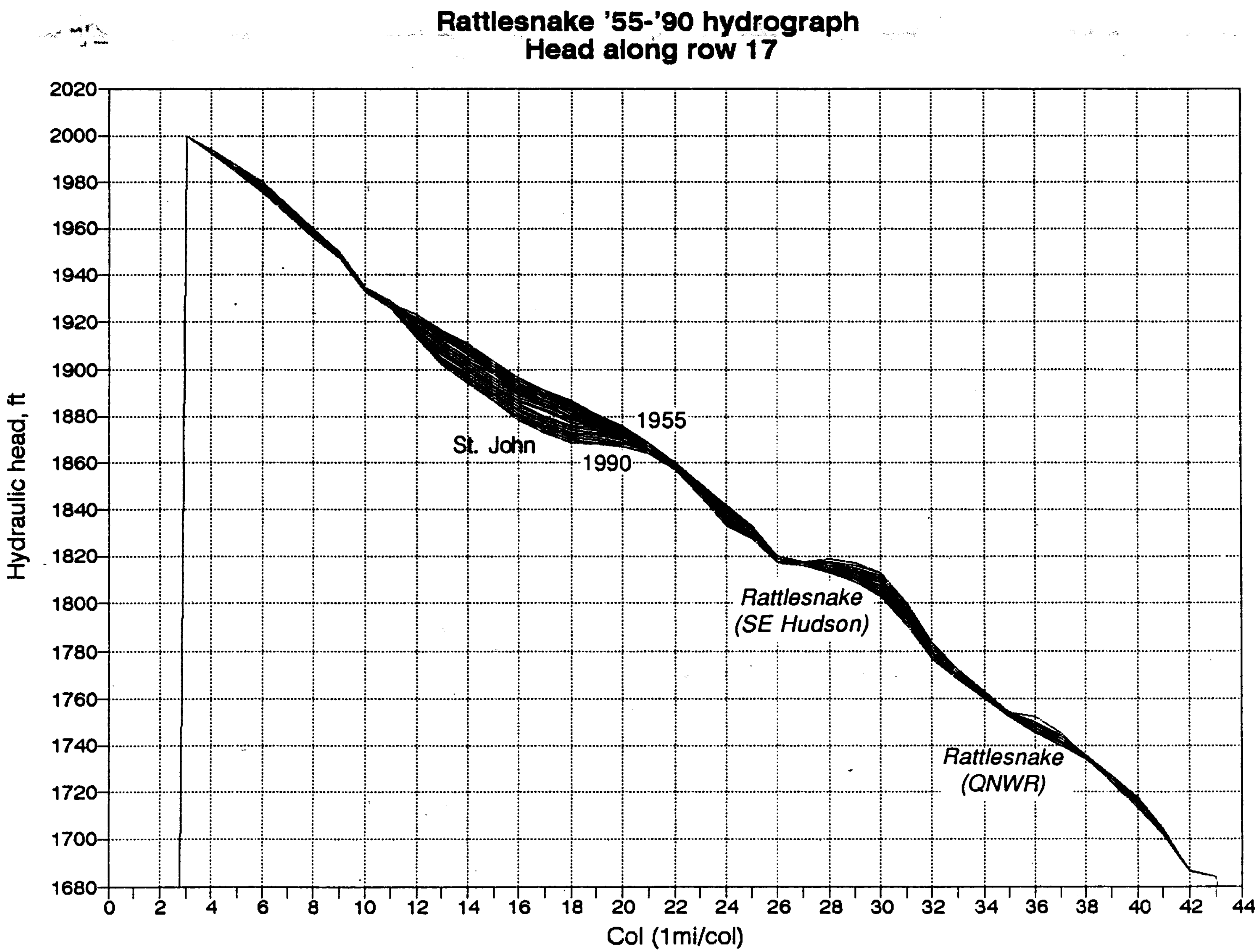

Figure 41. Water table profiles along row 17 passing near St. John and in-between the Little and Big Salt Marshes.

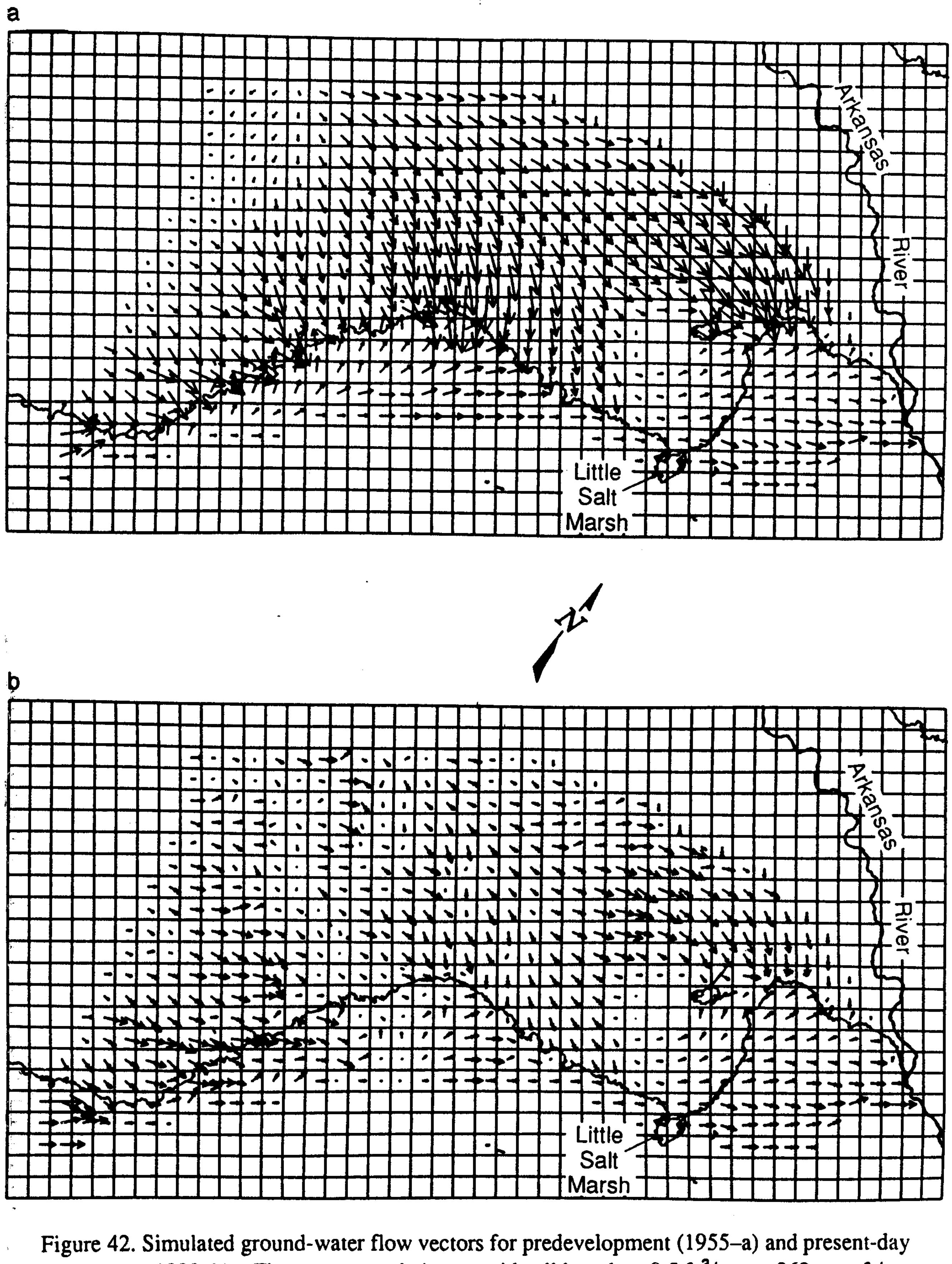

Figure 42. Simulated ground-water flow vectors for predevelopment (1955–a) and present-day conditions (1990–b). Flow vector scale is one grid cell length to 0.5 ft^3/sec or 362 acre-ft/yr.

A plot of the simulated ground-water flow vectors (fig. 42) indicates that ground water flows to the Quivira marsh from the northwest, west, and southwest and that it flows around the Cretaceous bedrock outcrop. The largest ground-water fluxes to the marsh are from the west-northwest feeding into the Big Salt Marsh area. A strong ground-water flow component toward Rattlesnake Creek is also evident, especially after the confluence with Wild Horse Creek and at the Rattlesnake stream course southwest of St. John. Predevelopment groundwater fluxes (fig. 42a) were much more pronounced and contributed more water to Rattlesnake streamflows and the Quivira marsh than present fluxes contribute (fig. 42b).

Sensitivity analysis and predictive runs

Sensitivity analysis, which quantifies the model's response to input parameter changes, gives insight into mechanisms and dependencies. Therefore an analysis was made to determine the sensitivity of the model to variations in the values of selected parameters on both the aquifer and the stream. The input and aquifer parameters considered were pumpage, recharge, hydraulic conductivity, and storativity. The stream parameters considered were conductance of the streambed, Manning's roughness coefficient, stream slope, and stream width. Sensitivity to each parameter was determined by running the model with the optimized parameters for 1990 in a predictive mode from 1990 to 2010 and by varying (increasing and decreasing) each parameter by 50%. Corresponding changes in ground-water hydraulic heads or drawdown were observed, tabulated, and graphed at typical nodes near Hudson [node at row 12, column 24, (12, 24)], near St. John [node (16, 14)], and approximately 3 mi north of the Zenith gaging station [node (17, 31)] (figs. 43–45); the corresponding changes in streamflow (ground-water runoff or baseflow) were displayed for Rattlesnake Creek near the Zenith stream-gaging station [node (19, 31)], and southwest of St. John [node (17,11)] (figs 46–47).

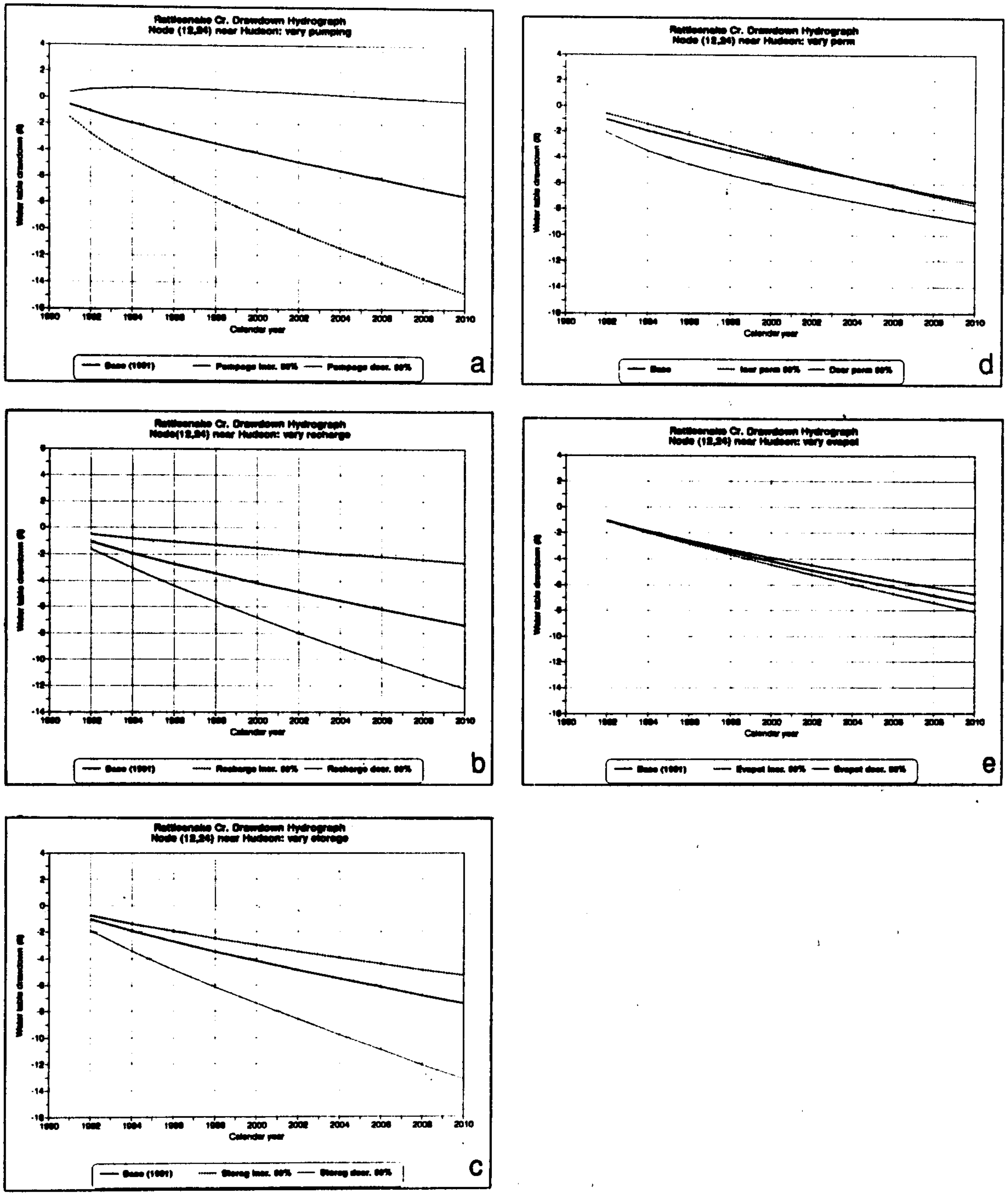

Figure 43. Sensitivity plots of drawdown with changing pumpage, recharge, storativity, hydraulic conductivity and ground-water evapotranspiration at cell 12, 24 (row, col.) near Hudson.

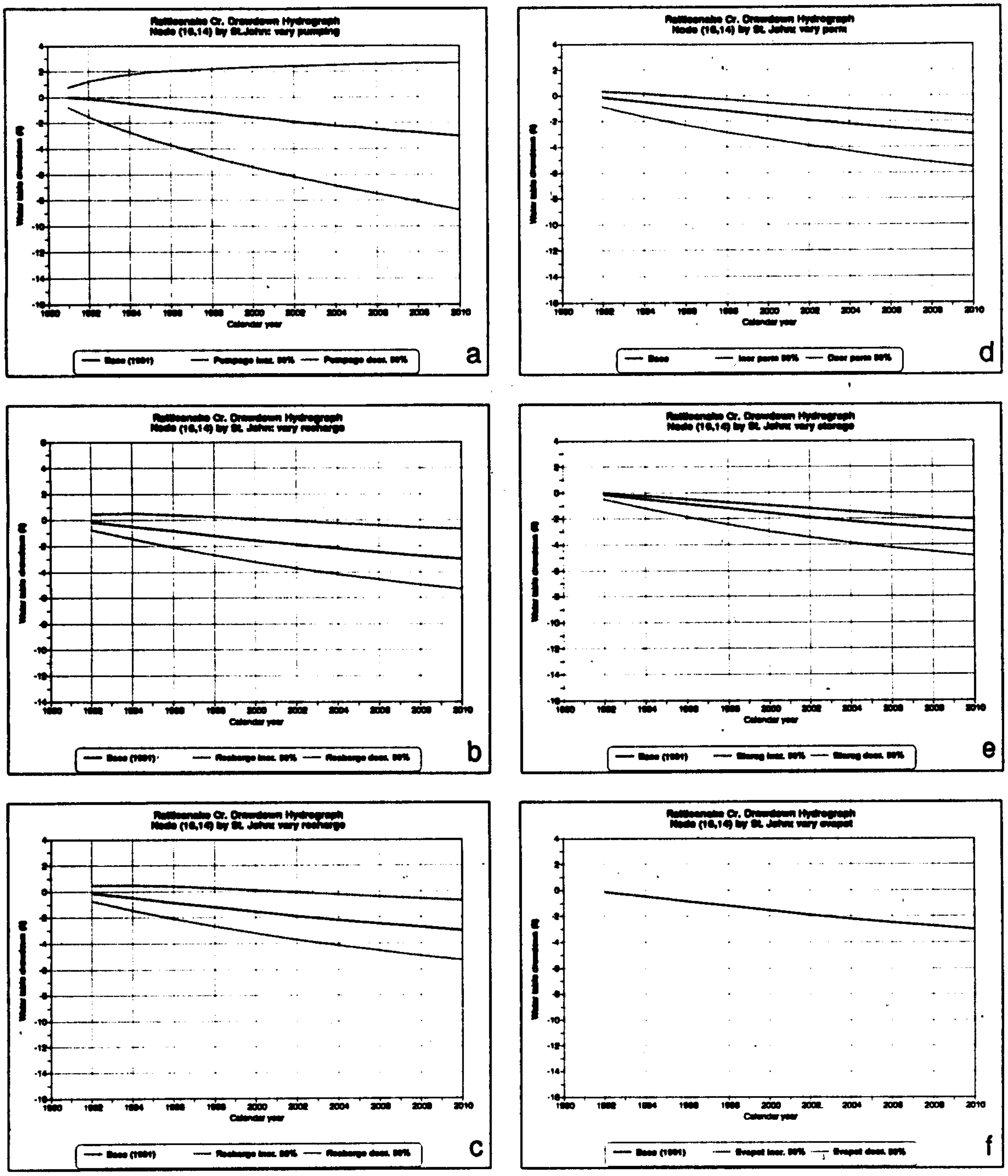

Figure 44. Sensitivity plots of drawdown with changing pumpage, recharge, storativity, hydraulic conductivity and ground-water evapotranspiration at cell 16, 14 (row, col.) near St. John.

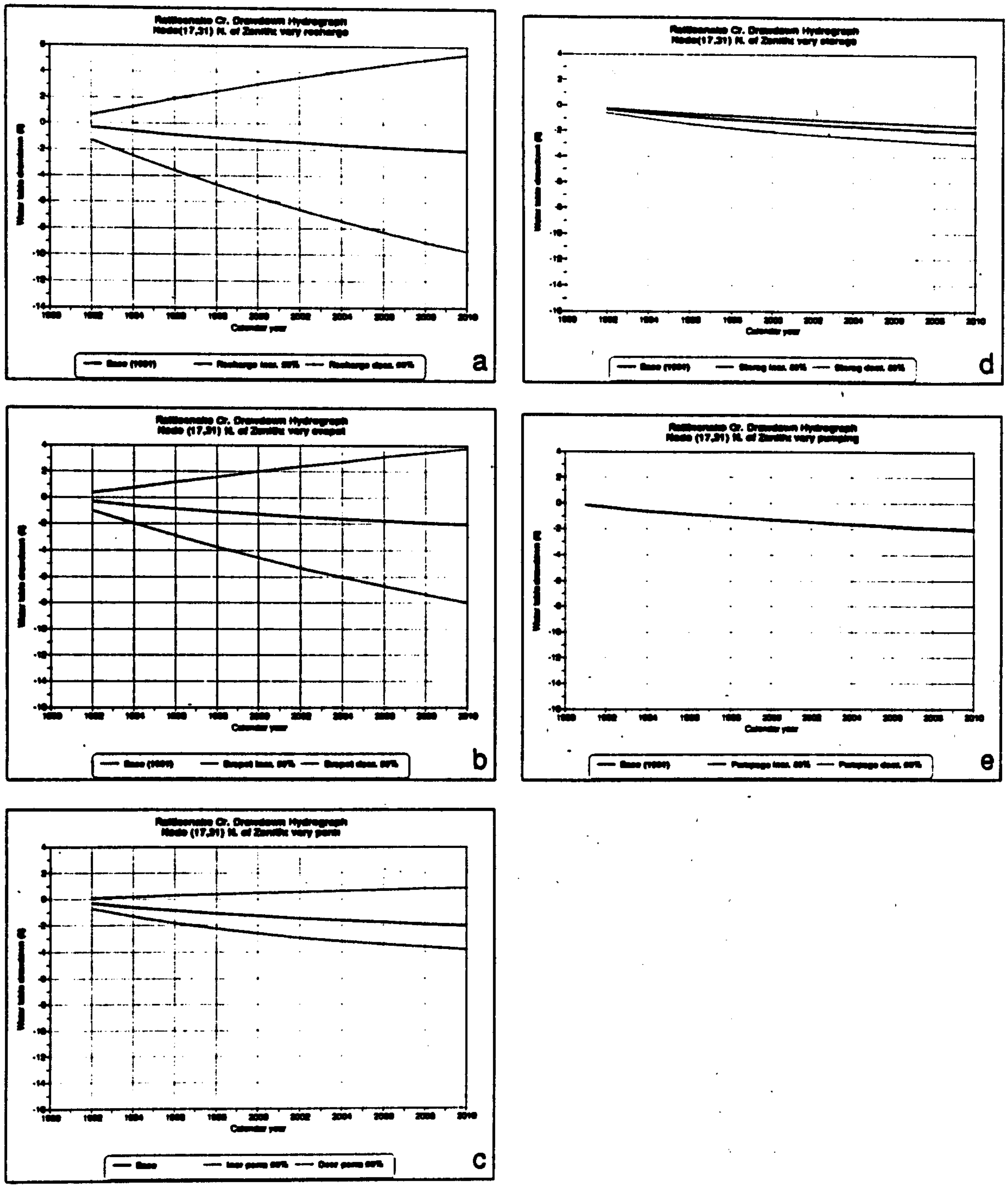

Figure 45. Sensitivity plots of drawdown with changing pumpage, recharge, storativity, hydraulic conductivity and ground-water evapotranspiration at cell 17, 31 (row, col.) north of Zenith.

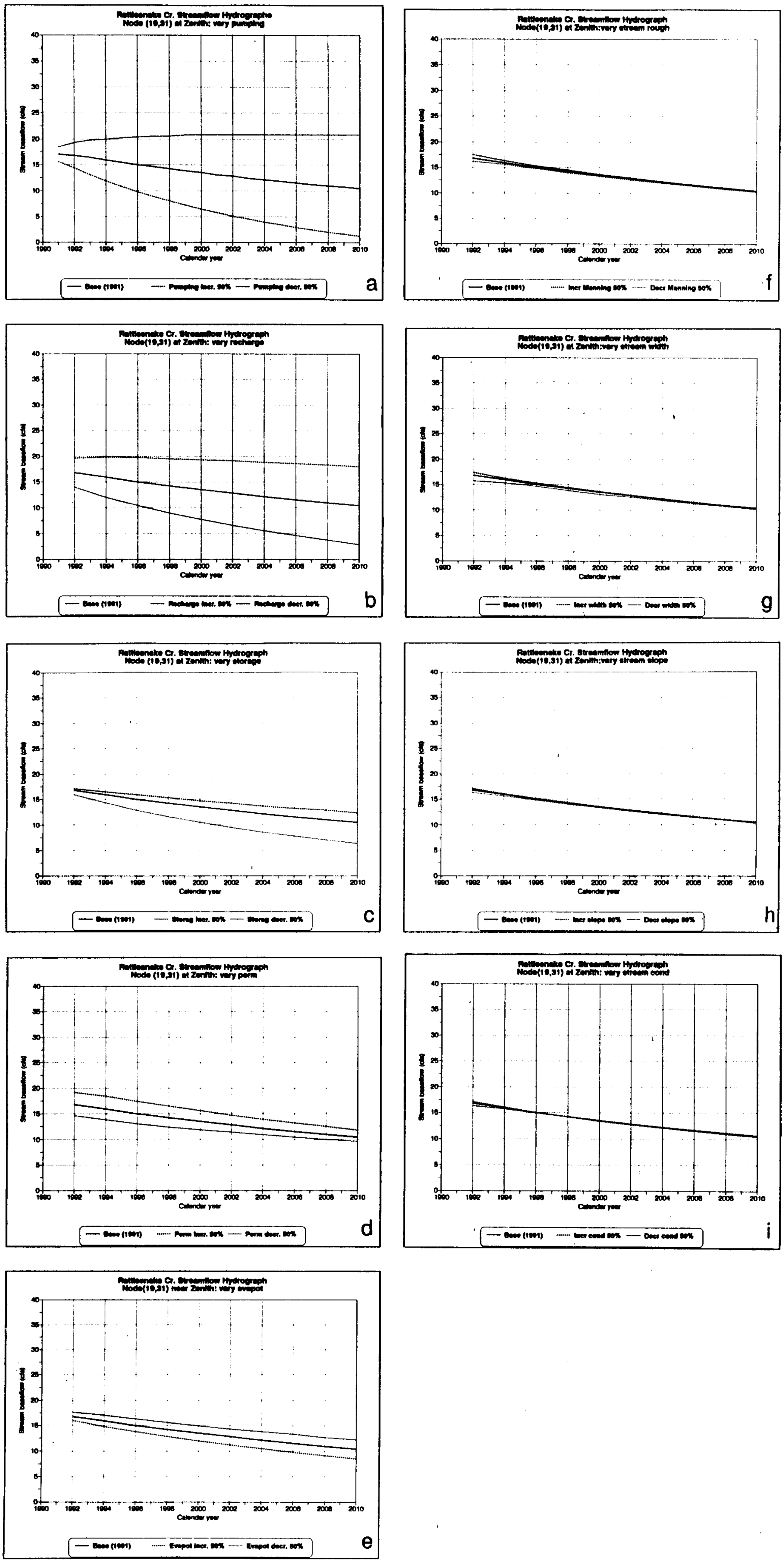

Figure 46. Sensitivity plots of stream baseflow with changing input, aquifer and stream-related parameters at cell 19, 31 (row, col.) near Zenith stream-gaging station.

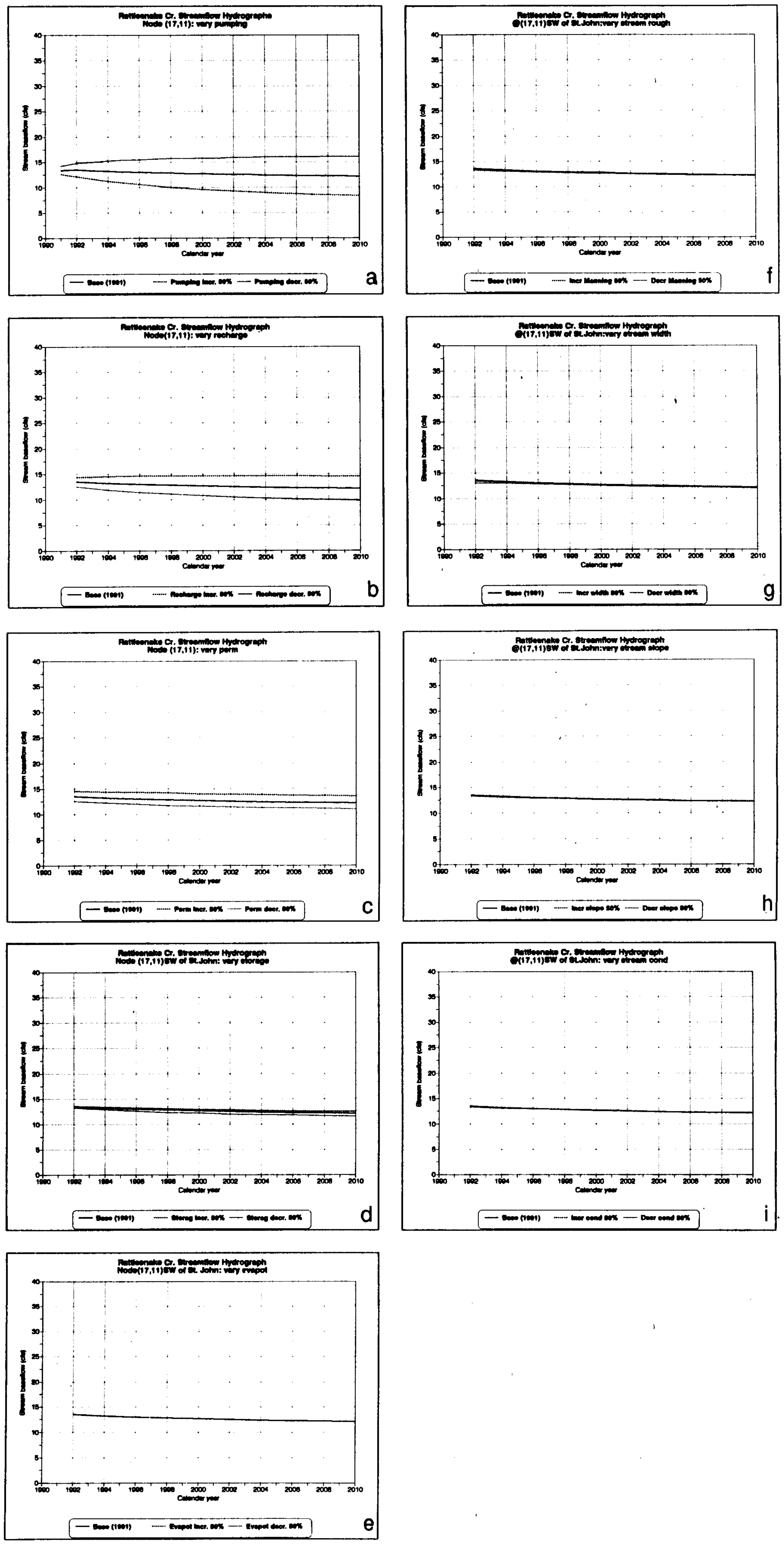

Figure 47. Sensitivity plots of stream baseflow with changing input, aquifer and stream-related parameters at cell 17, 11 (row, col.) southwest of St. John.

Sensitivity of ground-water levels to changing aquifer and input parameters

Examination of figs. 43 and 44 indicates that ground-water pumpage has the largest effect on aquifer water levels (note that the 50% change in pumpage is taken over the assumed 80% water appropriation use). For example, a sustained 50% change in the considered pumpage would cause approximately 7 feet change in the water table drawdown by the year 2010. The water levels are also highly sensitive to the amount of ground-water recharge, followed by aquifer storativity or aquifer hydraulic conductivity. However, different parts of the aquifer respond differently in absolute amount to changing parameters, with the relative significance of some parameters altered in some instances. For example, in the area north of the Zenith gaging station and southeast of the bedrock outcrop (node 17, 31), where irrigation pumping is nonexistent and the depth to the water table is shallow, water levels are most sensitive to recharge and evapotranspiration followed by hydraulic conductivity and storativity with no sensitivity to pumpage (fig. 45).

Sensitivity of streamflows to changing aquifer, input, and stream parameters

Examination of figs. 46 and 47 indicates that, similar to what was observed with regard to water levels, streamflows respond differently to various parameters. The aquifer and aquifer input-related parameters in this case have a much more pronounced effect on streamflows than do stream-related parameters. For example, ground-water pumpage and recharge are more sensitive parameters than aquifer storativity, hydraulic conductivity, or aquifer evapotranspiration, but all these aquifer variables are much more sensitive parameters than streambed conductance, Manning's roughness coefficient, stream slope, or stream width.

A model prediction of baseflows, assuming that present conditions (pumpage, recharge, evapotranspiration, incoming streamflows at the Macksville gaging station) persist throughout the 1990–2010 period, is shown in fig. 48 for three Rattlesnake Creek locations near Macksville, St. John, and the Zenith gaging station. In all three areas future baseflows will be declining, with the steepest decline of approximately 40% by the year 2010 occurring at the Zenith gaging station near the entrance to the Quivira National Wildlife Refuge.

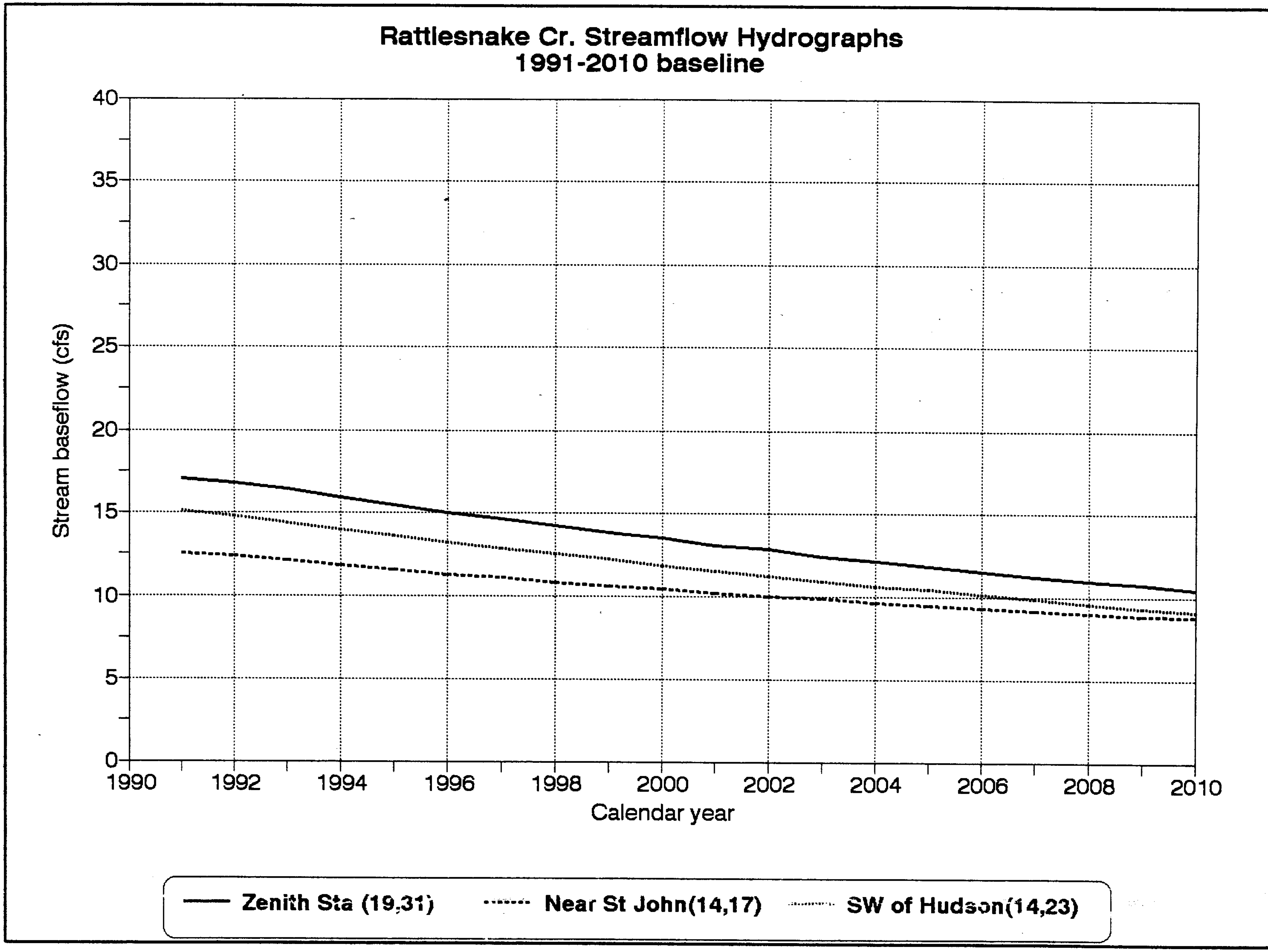

Figure 48. Model-predicted stream baseflow declines during the 1991–2010 period.

VII. Management alternatives to be tested and further work

The predictive capabilities of the calibrated model permit hypothetical conditions to be explored by simply changing the data input to emulate the desired situations. After further checks on model sensitivity and reliability analyses, the following initial set of scenarios are proposed for testing:

1. How would ground-water levels and streamflows respond to increased incoming streamflows from Rattlesnake Creek?

2. What effect do climatic fluctuations (i.e., sequence of flooding and drought years) have on the stream-aquifer system?

3. What effect do changing pumping patterns, including water conservation and improved irrigation efficiency, have on the stream-aquifer system?

4. How can specified minimum desirable streamflows be maintained throughout the Rattlesnake Creek basin?

5. What effect would protective stream corridors of different sizes have on streamflows?

6. In case of drought, what is the most vulnerable subregion of the study area, and what ameliorating options are available?

A finer grid (1/2 mi × 1/2 mi) submodel of the Quivira marsh has been initiated, and several required data inputs have been prepared. Two hydrologic balance models (VB and ERHYM) are being evaluated for possible inclusion into the stream-aquifer program for the more detailed submodel simulations. Separation of climatic from anthropogenic influences on the water balance of this area is an important question which needs to be addressed.

Additional fieldwork is required to characterize the spatial and temporal distribution of the saltwater-freshwater interface so that saltwater intrusion processes can be adequately modeled and predicted.

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Appendix 1. Ground-Water Rights in the Study Area

Appendix 1. Ground-Water Rights in the Rattlesnake Creek Study Area (1990).

Key to Table Columns:

(a) Location of each well (or grid corner) using the Public Land Survey System. Well identification number is listed first, followed by township number (all south of the 40th parallel), range, section number, and quarter-section identifier.

(b) Pumpage rate in gallons per minute.

(c) Water right appropriation amount in acre-feet per year.

(d, e) Well-use codes: (1) domestic, (2) industrial, (3) irrigation, (4) municipal, (5) recreation, (6) stockwatering. G = groundwater right, V = vested right, A . . = appropriated right and year established (e.g., A54 = appropriated 1954).

(f, g) Conversion to longitude, latitude (deg) from legal coordinates (a) automated by LEO I-PC written by C. G. Ross, KGS Open-File Report 91-37, September 1991.

(h, i) Albers projection (x, y) coordinates are with respect to origin (0, 0) located at 36.8750° N latitude, 98.3125° W longitude. Albers projection is based on meridian at 98.3215° W, parallels at 34.0° N and 44.0° N, and earth radius 6,371,007 m (weighted average based on the geodetic reference spheroid WGS-72).

(j, k) Wells are located on a 23 mi × 44 mi rectangle with a regular 1-mile grid of rows and columns. The study-area rectangle's corners are listed at the beginning of the table.

(l, m) Integer values for row and column denote the cell in which the well lies.

(n) Cell activity: 0 = outside model area; –1 = constant head cell; 1 = active model cell.

Study-area grid corners:

Township, range, section, quarter-section	Longitude (deg)	Latitude (deg)	Albers x (m)	Albers:y (m)	Grid row	Grid column
SW corners:						
23 17W 23 CCC	-99.1672	38.0299	-74591.	129201.	0	0
26 14W 19 BCC	-98.9021	37.7704	-51645.	100055.	23	0
NE corners:						
19 11W 3 BDB	-98.5299	38.4302	-18863.	173546	0	44
22 9W 1 BDC	-98.2645	38.1672	4183.	144172.	23	44

Appendix 1. Well data

(a) Well id, township, range, section, quarter-section					(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code	(e) Year		(f, g) Longitude (deg)	Latitude (deg)	(h, i) Albers x (m)	Albers y (m)	(j, k) Grid row/col. (mi)		(l, m) Grid index row/col		(n) cell activ.
BT0002-00	19	11W	31	CAAB	177.00	82.86	4	G	V	-98.5826	38.3545	-23465.	165107.	2.24	38.63	3	39	0
RC0012-00	20	10W	21	CDCC	2.00	3.22	2	G	V	-98.4376	38.2897	-10880.	157857.	10.59	41.94	11	42	0
038126-IR	20	12W	10	BDBB	900.00	147.00	3	G	V	-98.6403	38.3295	-28487.	162336.	1.66	35.13	2	36	0
038126-IN	20	12W	10	BDBB	900.00	65.00	2	G	V	-98.6403	38.3295	-28487.	162336.	1.66	35.13	2	36	0
030718-RE	21	12W	9	BADC	0.00	96.00	5	G	V	-98.6483	38.2431	-29215.	152703.	6.04	31.08	7	32	1
030718-IR	21	12W	9	BADC	1000.00	20.00	3	G	V	-98.6483	38.2431	-29215.	152703.	6.04	31.08	7	32	1
033973-B	22	15W	33	AACB	300.00	72.00	3	G	V	-98.9713	38.0997	-57437.	136845.	2.89	11.32	3	12	1
036564-RE	23	13W	29	CDAA	450.00	5.00	5	G	V	-98.7755	38.0173	-40416.	127551.	13.92	16.00	14	16	1
036563-RE	23	13W	29	CDAD	450.00	5.00	5	G	V	-98.7755	38.0164	-40416.	127450.	13.97	15.96	14	16	1
PN0071-00	23	15W	26	DCBB	350.00	10.00	3	G	V	-98.9396	38.0181	-54737.	127726.	8.34	9.13	9	10	1
PN0072-00	23	16W	12	BDC	1000.00	210.00	3	G	V	-99.0342	38.0664	-62954.	133170.	2.55	7.24	3	8	0
SF0001-00	24	12W	11	CDC	850.00	214.82	4	G	V	-98.6127	37.9702	-26218.	122233.	21.95	20.83	22	21	0
036203-IR	24	12W	14	CADA	50.00	10.50	3	G	V	-98.6098	37.9598	-25967.	121072.	22.61	20.51	23	21	0
SF0002-00	24	13W	4	ABAD	1340.00	245.51	4	G	V	-98.7521	37.9980	-38380.	125388.	15.75	16.15	16	17	1
SF0010-00	24	13W	7	BDC	2050.00	210.00	3	G	V	-98.7966	37.9789	-42277.	123273.	15.28	13.45	16	14	1
SF0004-00	24	14W	9	BDBB	1000.00	265.00	3	G	V	-98.8708	37.9813	-48754.	123578.	12.64	10.43	13	11	1
019757-IR	24	15W	8	CDCD	1025.00	120.00	3	G	V	-98.9979	37.9715	-59861.	122558.	8.87	4.66	9	5	0
SF0003-00	24	15W	15	CCCA	350.00	18.41	4	G	V	-98.9658	37.9580	-57069.	121029.	10.69	5.43	11	6	-1
009364-IR	26	14W	9	BBB	228.00	20.00	3	G	V	-98.8663	37.8052	-48480.	103924.	22.27	3.02	23	4	0
001586-00	20	10W	35	ABD	700.00	140.00	3	G	A54	-98.3935	38.2722	-7042.	155892.	13.01	43.04	14	44	0
001790-00	21	9W	27	BCDA	550.00	104.00	3	G	A54	-98.3031	38.1966	814.	147452.	20.12	43.61	21	44	0
001180-00	23	14W	23	DDBB	450.00	89.00	3	G	A54	-98.8248	38.0322	-44711.	129228.	11.46	14.56	12	15	1
001592-00	23	15W	12	ABA	180.00	18.00	2	G	A54	-98.9184	38.0719	-52842.	133717.	6.16	12.35	7	13	1
002065-00	23	16W	31	DBBB	510.00	71.00	3	G	A54	-99.1221	38.0067	-70680.	126574.	2.77	0.97	3	1	0
001978-00	24	16W	13	CBDD	360.00	126.00	3	G	A54	-99.0363	37.9606	-63224.	121368.	8.16	2.58	9	3	0
001600-00	25	14W	30	CDBB	715.00	266.00	3	G	A54	-98.9069	37.8430	-52012.	108164.	18.86	2.94	19	3	1
001228-00	26	15W	2	BABB	480.00	150.00	3	G	A54	-98.9347	37.8248	-54451.	106145.	18.90	0.98	19	1	0
002149-00	23	13W	7	CACC	750.00	128.00	3	G	A55	-98.7972	38.0618	-42283.	132527.	10.80	17.00	11	18	1
003399-00	19	11W	26	BDAB	400.00	90.00	3	G	A56	-98.5095	38.3723	-17112.	167078.	3.73	42.46	4	43	0
004119-00	22	14W	27	ACC	685.00	34.00	3	G	A56	-98.8470	38.1098	-46594.	137901.	6.54	16.98	7	17	1
003426-00	22	15W	11	ABC	920.00	222.00	3	G	A56	-98.9385	38.1573	-54536.	143252.	0.90	15.19	1	16	0
003425-00	22	15W	11	BDB	1000.00	83.00	3	G	A56	-98.9431	38.1555	-54935.	143055.	0.84	14.92	1	15	0
004654-00	23	13W	15	ADB	1500.00	180.00	3	G	A56	-98.7322	38.0530	-36616.	131511.	13.46	19.36	14	20	1
003664-00	23	16W	16	BAB	85.00	12.00	3	G	A56	-99.0895	38.0571	-67785.	132179.	1.17	4.52	2	5	0
003500-00	24	12W	13	BAC	410.00	30.00	3	G	A56	-98.5944	37.9666	-24625.	121824.	22.76	21.45	23	22	0

Appendix 1. Well data (cont)

(a) Well id, township, range, section, quarter-section					(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code	(e)	Year	(f, g) Longitude (deg)	Latitude (deg)	(h, i) Albers x (m)	Albers y (m)	(j, k) Grid row/col. (mi)		(l, m) Grid index row/col		(n) cell activ.
004570-00	24	14W	3	DDA	700.00	185.00	3	G	A56	-98.8402	37.9880	-46083.	124312.	13.31	12.01	14	13	1
003633-00	24	15W	6	BABB	955.00	207.00	3	G	A56	-99.0169	37.9998	-61502.	125730.	6.71	5.09	7	6	0
004191-00	25	13W	11	ACDD	1230.00	480.00	3	G	A56	-98.7149	37.8907	-35189.	113396.	22.78	13.09	23	14	0
004623-00	25	13W	21	CBA	1400.00	257.00	3	G	A56	-98.7618	37.8606	-39302.	110050.	22.83	9.82	23	10	0
004752-00	25	13W	30	CAB	1500.00	480.00	3	G	A56	-98.7962	37.8462	-42324.	108466.	22.43	7.74	23	8	0
005345-00	19	11W	31	CAAB	0.00	33.68	4	G	A57	-98.5826	38.3545	-23465.	165107.	2.24	38.63	3	39	0
006460-00	21	13W	23	DBBB	2500.00	240.00	3	G	A57	-98.7196	38.2092	-35435.	148945.	5.48	26.63	6	27	1
005905-00	22	15W	19	DCDC	1090.00	135.00	3	G	A57	-99.0100	38.1170	-60796.	138797.	0.65	10.45	1	11	0
005809-00	23	13W	5	AACC	1000.00	190.00	3	G	A57	-98.7696	38.0836	-39859.	134938.	10.56	19.10	11	20	1
005168-00	23	14W	19	ACAA	755.00	104.00	3	G	A57	-98.8995	38.0398	-51224.	130120.	8.53	11.75	9	12	1
005936-00	24	12W	9	CDBB	755.00	230.00	3	G	A57	-98.6496	37.9729	-29446.	122548.	20.56	19.39	21	20	0
005573-00	24	12W	21	DCBB	690.00	171.00	3	G	A57	-98.6451	37.9438	-29057.	119293.	22.28	18.33	23	19	0
005999-00	24	14W	1	CCB	850.00	210.00	3	G	A57	-98.8195	37.9879	-44277.	124291.	14.02	12.88	15	13	1
007165-00	19	11W	30	ACB	1000.00	294.00	3	G	A58	-98.5800	38.3720	-23233.	167068.	1.38	39.50	2	40	0
007324-00	19	11W	34	BBCC	300.00	63.00	3	G	A58	-98.5344	38.3586	-19280.	165553.	3.64	40.83	4	41	0
007322-00	21	13W	5	CBDC	570.00	117.00	3	G	A58	-98.7816	38.2507	-40815.	153600.	1.15	25.81	2	26	0
007286-00	22	15W	25	ADBB	1180.00	213.00	3	G	A58	-98.9164	38.1124	-52638.	138228.	4.06	14.18	5	15	1
007009-00	23	14W	3	ADBC	700.00	240.00	3	G	A58	-98.8430	38.0820	-46267.	134802.	8.16	15.95	9	16	1
007564-00	23	16W	2	DACB	800.00	240.00	3	G	A58	-99.0440	38.0778	-63795.	134447.	1.61	7.32	2	8	0
006649-00	24	13W	25	CDBB	1100.00	192.00	3	G	A58	-98.7044	37.9297	-34251.	117745.	21.04	15.22	22	16	0
006774-00	24	16W	12	DBCC	900.00	120.00	3	G	A58	-99.0305	37.9752	-62711.	122987.	7.57	3.45	8	4	0
007822-00	19	11W	19	BCC	428.00	136.00	3	G	A59	-98.5890	38.3849	-24009.	168508.	0.39	39.67	1	40	0
007705-00	22	14W	35	DDBB	770.00	226.00	3	G	A59	-98.8246	38.0902	-44657.	135702.	8.35	17.07	9	18	1
007965-00	25	14W	13	ACC	1700.00	40.00	5	G	A59	-98.8101	37.8771	-43518.	111919.	20.30	8.49	21	9	0
008032-00	21	13W	9	DBC	615.00	111.00	3	G	A60	-98.7558	38.2365	-38573.	152001.	2.79	26.28	3	27	0
008256-00	22	13W	17	CBA	1400.00	351.00	5	G	A60	-98.7810	38.1369	-40822.	140891.	7.31	20.92	8	21	1
008113-00	23	13W	14	ADBB	910.00	138.00	3	G	A60	-98.7144	38.0534	-35063.	131546.	14.04	20.12	15	21	1
008303-00	22	13W	4	CBD	367.00	80.00	5	G	A61	-98.7627	38.1639	-39220.	143898.	6.47	22.86	7	23	1
008328-00	22	15W	22	DABC	275.00	119.00	3	G	A61	-98.9529	38.1224	-55813.	139369.	2.29	13.08	3	14	1
008348-00	24	13W	10	BDAB	1200.00	405.00	3	G	A61	-98.7392	37.9807	-37263.	123448.	17.12	15.95	18	16	1
008634-00	23	12W	35	ADBB	1000.00	247.00	3	G	A62	-98.6042	38.0088	-25461.	126534.	20.16	22.85	21	23	0
009596-00	22	13W	9	CDBB	1090.00	195.00	3	G	A64	-98.7609	38.1480	-39064.	142124.	7.38	22.25	8	23	1
009416-00	23	12W	25	DCCB	575.00	135.00	3	G	A64	-98.5905	38.0141	-24267.	127128.	20.33	23.66	21	24	0
010470-00	21	13W	31	DCCB	655.00	31.00	3	G	A65	-98.7930	38.1755	-41845.	145210.	4.82	22.09	5	23	1
009737-00	22	14W	16	BDBB	2500.00	378.00	3	G	A65	-98.8708	38.1412	-48645.	141416.	4.05	17.34	5	18	1
010269-00	22	14W	36	CDBB	869.00	160.00	3	G	A65	-98.8154	38.0901	-43855.	135693.	8.66	17.46	9	18	1

Appendix 1. Well data (cont)

(a) Well id, township, range, section, quarter-section					(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code	(e) Year		(f, g) Longitude (deg)	Latitude (deg)	(h, i) Albers x (m)	Albers y (m)	(j, k) Grid row/col. (mi)		(l, m) Grid index row/col		(n) cell activ.
009781-00	23	13W	27	DDBB	800.00	196.00	3	G	A65	-98.7326	38.0170	-36670.	127499.	15.39	17.79	16	18	1
009816-00	25	13W	3	ACDA	265.00	118.00	3	G	A65	-98.7334	37.9063	-36792.	115142.	21.32	12.99	22	13	0
010458-00	25	14W	19	ACA	1187.00	200.00	3	G	A65	-98.8996	37.8644	-51355.	110546.	17.96	4.17	18	5	1
011303-00	21	9W	33	CACB	905.00	211.00	3	G	A66	-98.3203	38.1786	-678.	145441.	20.52	42.11	21	43	0
011492-00	21	13W	14	CBD	2500.00	237.00	3	G	A66	-98.7258	38.2216	-35976.	150330.	4.60	26.90	5	27	1
010931-00	23	13W	28	CABB	790.00	177.00	3	G	A66	-98.7604	38.0209	-39097.	127939.	14.24	16.79	15	17	1
010754-00	24	12W	11	BDBB	1600.00	240.00	3	G	A66	-98.6133	37.9797	-26268.	123294.	21.42	21.21	22	22	0
011363-00	24	14W	11	BDBB	735.00	195.00	3	G	A66	-98.8339	37.9811	-45533.	123539.	13.90	11.98	14	12	1
011266-00	25	15W	23	CDBB	885.00	192.00	3	G	A66	-98.9437	37.8575	-55222.	109806.	16.83	2.01	17	3	-1
011903-00	19	11W	31	DBDC	0.00	107.80	4	G	A67	-98.5780	38.3516	-23069.	164791.	2.55	38.70	3	39	0
011866-00	21	13W	1	BCB	390.00	86.00	3	G	A67	-98.7094	38.2563	-34528.	154189.	3.28	29.08	4	30	0
012106-00	22	12W	30	BDBB	740.00	129.00	3	G	A67	-98.6872	38.1114	-32660.	138009.	11.84	23.77	12	24	1
012313-00	22	15W	26	ADAB	450.00	119.00	3	G	A67	-98.9322	38.1124	-54022.	138239.	3.52	13.51	4	14	1
011559-00	23	12W	7	DBA	1365.00	120.00	3	G	A67	-98.6795	38.0636	-32011.	132680.	14.67	22.04	15	23	1
012479-00	23	15W	23	DBA	680.00	90.00	3	G	A67	-98.9368	38.0357	-54474.	129682.	7.49	10.01	8	11	1
012143-00	23	16W	23	ACA	1000.00	227.00	3	G	A67	-99.0458	38.0392	-63983.	130145.	3.62	5.58	4	6	0
012042-00	24	12W	17	CAB	1500.00	438.00	3	G	A67	-98.6672	37.9617	-30982.	121301.	20.57	18.17	21	19	0
012023-00	24	14W	29	CDBB	700.00	233.00	3	G	A67	-98.8890	37.9304	-50384.	117911.	14.76	7.47	15	8	1
013062-00	20	11W	6	CCCB	1270.00	166.00	3	G	A68	-98.5894	38.3349	-24064.	162928.	3.07	37.50	4	38	0
013032-00	21	9W	31	ADBB	795.00	223.00	3	G	A68	-98.3478	38.1842	-3071.	146072.	19.29	41.20	20	42	0
013557-00	21	13W	26	ACBB	3000.00	396.00	3	G	A68	-98.7196	38.1983	-35443.	147726.	6.06	26.15	7	27	1
012998-00	21	13W	33	DCAD	400.00	85.00	3	G	A68	-98.7530	38.1760	-38367.	145244.	6.14	23.78	7	24	1
013246-00	21	14W	32	ADBB	1215.00	180.00	3	G	A68	-98.8800	38.1848	-49420.	146292.	1.39	18.83	2	19	0
013518-00	22	13W	5	CBC	400.00	40.00	5	G	A68	-98.7834	38.1641	-41015.	143937.	5.76	22.00	6	23	1
012967-00	22	13W	21	BBDD	810.00	165.00	3	G	A68	-98.7619	38.1271	-39164.	139791.	8.48	21.31	9	22	1
013238-00	22	13W	22	CACC	1690.00	240.00	3	G	A68	-98.7423	38.1198	-37459.	138970.	9.53	21.82	10	22	1
013554-00	22	14W	6	DCAA	975.00	221.00	3	G	A68	-98.8993	38.1631	-51116.	143880.	1.91	17.09	2	18	0
013553-00	22	14W	7	ADBB	905.00	214.00	3	G	A68	-98.8982	38.1558	-51024.	143066.	2.34	16.82	3	17	1
013260-00	22	14W	15	DDBC	610.00	150.00	3	G	A68	-98.8432	38.1328	-46246.	140472.	5.43	18.14	6	19	1
013084-00	22	15W	17	DCBB	1700.00	176.00	3	G	A68	-98.9942	38.1342	-59409.	140714.	0.25	11.85	1	12	0
012526-00	23	13W	4	ABDD	1225.00	234.00	3	G	A68	-98.7524	38.0835	-38364.	134927.	11.14	19.82	12	20	1
012922-00	23	13W	32	CDBB	1200.00	237.00	3	G	A68	-98.7788	38.0028	-40707.	125930.	14.60	15.23	15	16	1
012524-00	23	14W	15	CDBB	950.00	162.00	3	G	A68	-98.8524	38.0468	-47105.	130878.	9.74	14.04	10	15	1
014010-00	24	13W	16	ABB	1215.00	215.00	3	G	A68	-98.7548	37.9694	-38630.	122194.	17.20	14.81	18	15	1
013336-00	24	14W	17	ADBB	680.00	158.00	3	G	A68	-98.8800	37.9668	-49573.	121966.	13.11	9.42	14	10	1
013861-00	24	14W	24	CDBB	330.00	120.00	3	G	A68	-98.8155	37.9448	-43949.	119474.	16.48	11.19	17	12	1

Appendix 1. Well data (cont)

(a) Well id, township, range, section, quarter-section					(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code	(e) Year		(f, g) Longitude (deg)	Latitude (deg)	(h, i) Albers x (m)	Albers y (m)	(j, k) Grid row/col. (mi)		(l, m) Grid index row/col		(n) cell activ.
013812-00	24	14W	24	DDBB	960.00	190.00	3	G	A68	-98.8063	37.9449	-43144.	119476.	16.78	11.58	17	12	1
012812-00	24	15W	32	DBCA	1030.00	95.00	3	G	A68	-98.9928	37.9177	-59465.	116550.	11.93	2.55	12	3	0
013092-00	25	13W	9	DDBB	985.00	240.00	3	G	A68	-98.7508	37.8865	-38327.	112937.	21.80	11.40	22	12	0
013432-00	25	14W	20	DDBB	920.00	216.00	3	G	A68	-98.8795	37.8576	-49602.	109776.	19.00	4.72	20	5	1
014314-00	20	11W	9	CABB	1765.00	231.00	3	G	A69	-98.5481	38.3258	-20475.	161901.	4.95	38.85	5	39	0
014678-00	20	13W	24	DCBB	4000.00	240.00	3	G	A69	-98.7090	38.2931	-34478.	158304.	1.31	30.68	2	31	0
014619-00	21	13W	27	CDBC	800.00	120.00	3	G	A69	-98.7427	38.1904	-37457.	146854.	5.71	24.84	6	25	1
015780-00	22	13W	18	DBCC	2000.00	236.00	3	G	A69	-98.7928	38.1346	-41854.	140649.	7.03	20.33	8	21	1
014620-00	22	13W	28	BBDD	965.00	195.00	3	G	A69	-98.7617	38.1125	-39155.	138170.	9.26	20.69	10	21	1
014442-00	22	14W	29	BABB	1195.00	117.00	3	G	A69	-98.8891	38.1159	-50262.	138609.	4.79	15.48	5	16	1
014633-00	22	15W	20	CDCC	1895.00	240.00	3	G	A69	-98.9988	38.1170	-59817.	138794.	1.03	10.92	2	11	0
015053-00	22	15W	27	CBBB	200.00	66.00	3	G	A69	-98.9666	38.1088	-57022.	137861.	2.55	11.91	3	12	1
014674-00	22	15W	29	ACA	1665.00	240.00	3	G	A69	-98.9913	38.1120	-59169.	138232.	1.55	11.02	2	12	0
015459-00	23	11W	4	DDAD	305.00	50.00	3	G	A69	-98.5279	38.0731	-18787.	133697.	19.25	28.83	20	29	0
015976-00	23	11W	22	BCCB	0.00	90.00	3	G	A69	-98.5266	38.0359	-18684.	129547.	21.30	27.29	22	28	0
015975-00	23	11W	22	BCCB	975.00	60.00	3	G	A69	-98.5266	38.0359	-18684.	129547.	21.30	27.29	22	28	0
015010-00	23	12W	21	ACAB	1250.00	180.00	3	G	A69	-98.6432	38.0383	-28859.	129836.	17.25	22.47	18	23	1
014774-00	23	12W	25	CDC	670.00	114.00	3	G	A69	-98.5945	38.0137	-24615.	127081.	20.22	23.47	21	24	0
015174-00	23	12W	36	BBCC	2500.00	266.00	3	G	A69	-98.5996	38.0096	-25062.	126629.	20.26	23.08	21	24	0
015562-00	23	13W	16	CCAA	790.00	221.00	3	G	A69	-98.7616	38.0463	-39187.	130773.	12.83	17.83	13	18	1
014602-00	23	13W	35	BDBB	1760.00	234.00	3	G	A69	-98.7234	38.0097	-35869.	126681.	16.09	17.87	17	18	1
014966-00	23	13W	35	CDBB	780.00	240.00	3	G	A69	-98.7233	38.0025	-35868.	125870.	16.48	17.56	17	18	1
015945-00	23	14W	26	ADBB	730.00	73.00	3	G	A69	-98.8249	38.0249	-44720.	128418.	11.85	14.25	12	15	1
015685-00	23	16W	35	ADBB	2500.00	473.00	3	G	A69	-99.0441	38.0106	-63865.	126951.	5.21	4.41	6	5	0
014329-00	24	12W	17	ADBB	1025.00	224.00	3	G	A69	-98.6587	37.9657	-30238.	121747.	20.64	18.70	21	19	0
015138-00	24	13W	5	BACD	880.00	221.00	3	G	A69	-98.7775	37.9964	-40604.	125217.	14.98	15.01	15	16	1
015682-00	24	13W	20	BCAA	975.00	204.00	3	G	A69	-98.7799	37.9519	-40833.	120249.	17.30	12.99	18	13	1
015312-00	24	14W	10	ADBB	690.00	90.00	3	G	A69	-98.8431	37.9812	-46335.	123549.	13.59	11.59	14	12	1
014773-00	24	14W	22	BBCB	750.00	131.00	3	G	A69	-98.8570	37.9541	-47571.	120530.	14.57	9.84	15	10	1
015762-00	24	14W	25	ADBB	840.00	221.00	3	G	A69	-98.8063	37.9376	-43149.	118665.	17.18	11.26	18	12	1
015761-00	24	14W	25	BDBB	815.00	221.00	3	G	A69	-98.8155	37.9375	-43953.	118664.	16.87	10.87	17	11	1
015611-00	24	15W	10	BABA	1225.00	203.00	3	G	A69	-98.9612	37.9853	-56651.	124074.	9.37	6.80	10	7	-1
015648-00	24	15W	27	ADBB	1080.00	120.00	3	G	A69	-98.9530	37.9378	-55969.	118765.	12.20	5.09	13	6	1
015952-00	24	16W	12	CCBB	1220.00	150.00	3	G	A69	-99.0396	37.9742	-63505.	122887.	7.31	3.02	8	4	0
014931-00	24	16W	15	ADBB	745.00	162.00	3	G	A69	-99.0626	37.9668	-65519.	122077.	6.93	1.74	7	2	0
015781-00	25	14W	17	CDBC	820.00	149.00	3	G	A69	-98.8887	37.8712	-50394.	111305.	17.96	4.93	18	5	1

Appendix 1. Well data (cont)

(a) Well id, township, range, section, quarter-section					(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code	(e) Year		(f, g) Longitude (deg)	Latitude (deg)	(h, i) Albers x (m)	Albers y (m)	(j, k) Grid row/col. (mi)		(l, m) Grid index row/col		(n) cell activ.
016540-00	20	10W	32	ACB	450.00	71.00	3	G	A70	-98.4523	38.2705	-12163.	155707.	11.14	40.49	12	41	0
016686-00	20	12W	5	DACB	855.00	192.00	3	G	A70	-98.6678	38.3383	-30876.	163327.	0.26	34.36	1	35	0
016747-00	20	12W	30	BCAA	780.00	182.00	3	G	A70	-98.6963	38.2858	-33372.	157485.	2.13	30.90	3	31	0
016169-00	22	13W	12	CACB	610.00	113.00	3	G	A70	-98.7057	38.1494	-34255.	142262.	9.16	24.63	10	25	1
016032-00	22	14W	9	BCAC	1200.00	222.00	3	G	A70	-98.8731	38.1548	-48838.	142938.	3.24	17.83	4	18	1
016594-00	22	14W	22	BAD	44.00	47.20	2	G	A70	-98.8495	38.1279	-46796.	139924.	5.48	17.66	6	18	1
016276-00	22	15W	13	ADBB	900.00	240.00	3	G	A70	-98.9163	38.1414	-52608.	141468.	2.50	15.44	3	16	1
016600-00	22	15W	13	DDBB	900.00	240.00	3	G	A70	-98.9163	38.1341	-52619.	140658.	2.89	15.12	3	16	1
016238-00	22	15W	32	CDB	1200.00	236.00	3	G	A70	-98.9982	38.0901	-59793.	135794.	2.49	9.78	3	10	1
016237-00	22	15W	32	DBD	1200.00	240.00	3	G	A70	-98.9913	38.0919	-59191.	135995.	2.62	10.15	3	11	1
016762-05	23	13W	27	CBBB	14.48	6.79	6	G	A70	-98.7465	38.0208	-37877.	127921.	14.72	17.37	15	18	1
016669-00	23	13W	32	ADCC	1765.00	225.50	3	G	A70	-98.7696	38.0073	-39903.	126428.	14.66	15.82	15	16	1
016623-00	23	13W	34	ADBB	1105.00	221.00	3	G	A70	-98.7326	38.0098	-36670.	126688.	15.78	17.48	16	18	1
016624-00	23	14W	15	ADDC	900.00	104.00	3	G	A70	-98.8409	38.0513	-46100.	131367.	9.89	14.71	10	15	1
016137-00	23	14W	36	ABCB	1300.00	126.00	3	G	A70	-98.8112	38.0121	-43530.	126981.	13.00	14.27	14	15	1
016578-00	23	15W	26	DCBB	0.00	101.00	3	G	A70	-98.9396	38.0181	-54737.	127726.	8.34	9.13	9	10	1
016844-00	23	16W	24	CDBB	1200.00	240.00	3	G	A70	-99.0348	38.0324	-63035.	129376.	4.35	5.74	5	6	0
016355-00	23	16W	25	ADBB	4800.00	960.00	3	G	A70	-99.0256	38.0251	-62238.	128562.	5.05	5.82	6	6	0
016335-00	23	16W	35	BDBB	1100.00	233.00	3	G	A70	-99.0533	38.0106	-64668.	126958.	4.90	4.02	5	5	0
016334-00	23	16W	35	CDBB	1100.00	240.00	3	G	A70	-99.0533	38.0033	-64675.	126149.	5.29	3.71	6	4	0
016750-00	24	12W	14	BBBB	400.00	153.44	4	G	A70	-98.6178	37.9688	-26662.	122080.	21.85	20.56	22	21	0
016678-00	24	13W	17	BDBB	870.00	204.00	3	G	A70	-98.7787	37.9664	-40725.	121872.	16.55	13.67	17	14	1
016200-00	24	13W	27	BCBB	44.00	70.89	2	G	A70	-98.7460	37.9371	-37880.	118586.	19.24	13.78	20	14	0
016775-00	25	13W	11	CBCB	475.00	106.00	3	G	A70	-98.7275	37.8881	-36293.	113110.	22.50	12.45	23	13	0
017344-00	19	11W	28	ABCC	1225.00	234.00	3	G	A71	-98.5439	38.3731	-20101.	167183.	2.53	41.06	3	42	0
017313-00	19	11W	28	BCBD	1000.00	228.00	3	G	A71	-98.5520	38.3713	-20798.	166984.	2.36	40.64	3	41	0
017672-00	20	11W	32	AACC	900.00	203.00	3	G	A71	-98.5572	38.2726	-21285.	155961.	7.51	36.17	8	37	0
017670-00	20	11W	33	CDBB	855.00	188.00	3	G	A71	-98.5481	38.2644	-20493.	155052.	8.26	36.21	9	37	1
017046-00	21	9W	28	DDBB	775.00	198.00	3	G	A71	-98.3112	38.1912	116.	146854.	20.14	43.04	21	44	0
017047-00	21	9W	33	ACAB	1000.00	207.00	3	G	A71	-98.3134	38.1840	-80.	146047.	20.45	42.64	21	43	0
017048-00	21	9W	33	DDBB	1000.00	210.00	3	G	A71	-98.3111	38.1767	123.	145236.	20.93	42.42	21	43	0
017704-00	22	13W	17	DDBB	625.00	221.00	3	G	A71	-98.7700	38.1335	-39869.	140515.	7.85	21.24	8	22	1
017705-00	22	13W	20	ACAA	640.00	216.00	3	G	A71	-98.7711	38.1263	-39967.	139704.	8.21	20.88	9	21	1
017153-00	22	14W	24	ADBD	825.00	82.00	3	G	A71	-98.8051	38.1255	-42932.	139641.	7.10	19.42	8	20	1
017030-00	22	14W	34	ADBB	820.00	224.00	3	G	A71	-98.8430	38.0975	-46253.	136526.	7.33	16.62	8	17	1
017129-00	22	15W	10	ADBB	2000.00	233.00	3	G	A71	-98.9528	38.1560	-55782.	143116.	0.48	14.53	1	15	0

Appendix 1. Well data (cont)

(a) Well id, township, range, section, quarter-section				(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code	(e) Year		(f, g) Longitude (deg)	Latitude (deg)	(h, i) Albers x (m)	Albers y (m)	(j, k) Grid row/col. (mi)		(l, m) Grid index row/col		(n) cell activ.
017017-00	22	15W 36	BDBB	1600.00	240.00	3	G	A71	-98.9256	38.0979	-53452.	136617.	4.53	13.17	5	14	1
017085-00	22	16W 25	DDBB	2000.00	414.00	3	G	A71	-99.0256	38.1051	-62164.	137481.	0.76	9.28	1	10	0
016953-00	23	13W 27	CDBB	1000.00	203.00	3	G	A71	-98.7418	38.0171	-37475.	127510.	15.07	17.41	16	18	1
017154-00	23	14W 11	DDDB	280.00	49.00	3	G	A71	-98.8224	38.0593	-44483.	132260.	10.08	15.84	11	16	1
017140-00	23	15W 6	BDBB	800.00	140.00	3	G	A71	-99.0167	38.0832	-61408.	135039.	2.24	8.71	3	9	-1
016892-00	23	16W 36	ADBB	1000.00	240.00	3	G	A71	-99.0257	38.0107	-62253.	126948.	5.83	5.19	6	6	0
017560-00	23	16W 36	CDBB	1500.00	240.00	3	G	A71	-99.0349	38.0034	-63070.	126141.	5.91	4.49	6	5	0
017516-00	24	12W 14	CBBA	305.00	36.00	3	G	A71	-98.6166	37.9617	-26564.	121279.	22.28	20.30	23	21	0
017473-00	24	13W 26	AAD	100.00	28.00	3	G	A71	-98.7108	37.9384	-34807.	118714.	20.36	15.32	21	16	0
017194-00	24	15W 17	BADA	1400.00	119.00	3	G	A71	-98.9956	37.9688	-59662.	122254.	9.10	4.64	10	5	0
016975-00	24	15W 18	ADCB	1075.00	74.00	3	G	A71	-99.0081	37.9652	-60760.	121864.	8.86	3.96	9	4	0
017443-00	25	13W 17	DACC	1245.00	240.00	3	G	A71	-98.7693	37.8728	-39950.	111423.	21.91	10.03	22	11	0
017146-00	25	14W 14	CACC	1340.00	170.00	3	G	A71	-98.8335	37.8731	-45571.	111477.	19.73	7.33	20	8	1
017577-00	25	15W 25	BCBA	1000.00	108.00	3	G	A71	-98.9288	37.8503	-53920.	108985.	17.73	2.33	18	3	1
017252-00	25	15W 34	ADBB	990.00	221.00	3	G	A71	-98.9528	37.8358	-56033.	107381.	17.69	0.69	18	1	0
018105-00	20	11W 26	ADBB	1000.00	221.00	3	G	A72	-98.5019	38.2858	-16470.	157425.	8.65	39.07	9	40	0
018106-00	20	11W 26	DACC	900.00	195.00	3	G	A72	-98.5019	38.2794	-16473.	156716.	8.99	38.79	9	39	0
018675-00	21	10W 2	DDBB	730.00	195.00	3	G	A72	-98.3841	38.2496	-6232.	153371.	14.55	42.47	15	43	0
018004-00	21	11W 5	ADBB	620.00	149.00	3	G	A72	-98.5494	38.2571	-20613.	154229.	8.61	35.83	9	36	1
018421-00	21	13W 13	ADBC	890.00	101.00	3	G	A72	-98.6964	38.2265	-33413.	150866.	5.32	28.34	6	29	1
018388-00	21	14W 32	BACC	1350.00	180.00	3	G	A72	-98.8892	38.1857	-50219.	146401.	1.03	18.49	2	19	0
018039-00	22	13W 21	DBDD	800.00	221.00	3	G	A72	-98.7526	38.1198	-38361.	138976.	9.18	21.38	10	22	1
018129-00	22	14W 14	CACC	900.00	195.00	3	G	A72	-98.8340	38.1346	-45444.	140666.	5.64	18.60	6	19	1
018003-00	22	15W 13	CDBB	680.00	178.00	3	G	A72	-98.9255	38.1342	-53418.	140665.	2.58	14.74	3	15	1
018611-00	22	15W 16	BDBB	1420.00	225.00	3	G	A72	-98.9805	38.1415	-58204.	141513.	0.33	12.75	1	13	0
017839-00	22	15W 26	BAD	1500.00	240.00	3	G	A72	-98.9408	38.1138	-54766.	138397.	3.16	13.21	4	14	1
018209-00	23	12W 25	DBDD	865.00	75.00	3	G	A72	-98.5871	38.0168	-23968.	127430.	20.30	23.92	21	24	0
018270-00	23	12W 35	DDCD	440.00	53.00	3	G	A72	-98.6030	37.9988	-25360.	125418.	20.74	22.47	21	23	0
018058-00	23	14W 3	AACB	700.00	120.00	3	G	A72	-98.8430	38.0848	-46264.	135107.	8.02	16.07	9	17	1
018040-00	23	14W 15	CABB	605.00	58.00	3	G	A72	-98.8524	38.0504	-47103.	131280.	9.55	14.19	10	15	1
018669-00	23	15W 1	ABBB	780.00	221.00	3	G	A72	-98.9211	38.0870	-53071.	135397.	5.26	12.88	6	13	1
018670-00	23	15W 1	BBDD	1000.00	214.00	3	G	A72	-98.9268	38.0842	-53572.	135095.	5.22	12.52	6	13	1
017917-00	23	15W 8	DDBB	785.00	221.00	3	G	A72	-98.9898	38.0615	-59078.	132594.	4.31	8.90	5	9	-1
017901-00	23	15W 9	ADBB	1015.00	221.00	3	G	A72	-98.9715	38.0687	-57481.	133392.	4.54	9.98	5	10	1
018304-00	23	15W 18	DDBB	1045.00	221.00	3	G	A72	-99.0077	38.0470	-60657.	130985.	4.49	7.51	5	8	0
018671-00	23	15W 19	BABC	750.00	172.00	3	G	A72	-99.0166	38.0424	-61436.	130482.	4.43	6.94	5	7	0

Appendix 1. Well data (cont)

(a) Well id, township, range, section, quarter-section					(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code	(e) Year		(f, g) Longitude (deg)	Latitude (deg)	(h, i) Albers x (m)	Albers y (m)	(j, k) Grid row/col. (mi)		(l, m) Grid index row/col		(n) cell activ.
018119-00	23	16W	11	CCDC	350.00	82.00	3	G	A72	-99.0555	38.0587	-64815.	132325.	2.24	6.01	3	7	0
018321-00	23	16W	26	CDBB	1000.00	240.00	3	G	A72	-99.0533	38.0178	-64660.	127768.	4.51	4.34	5	5	0
018322-00	23	16W	36	BDBB	1200.00	240.00	3	G	A72	-99.0349	38.0106	-63059.	126947.	5.52	4.80	6	5	0
018267-00	24	13W	6	ACB	1200.00	240.00	3	G	A72	-98.7920	37.9952	-41865.	125084.	14.56	14.35	15	15	1
017828-00	24	13W	25	ADBB	560.00	173.00	3	G	A72	-98.6951	37.9370	-33434.	118548.	20.96	15.92	21	16	0
017829-00	24	13W	25	BDBB	925.00	224.00	3	G	A72	-98.7044	37.9370	-34249.	118556.	20.65	15.53	21	16	0
018060-00	24	13W	30	CDAB	925.00	195.00	3	G	A72	-98.7949	37.9303	-42155.	117845.	17.95	11.43	18	12	1
018059-00	24	13W	31	BDBB	845.00	195.00	3	G	A72	-98.7971	37.9230	-42357.	117036.	18.27	11.02	19	12	1
017909-00	24	14W	2	DDBB	730.00	165.00	3	G	A72	-98.8247	37.9884	-44729.	124348.	13.82	12.68	14	13	1
018183-00	24	16W	12	ACCC	1000.00	120.00	3	G	A72	-99.0305	37.9788	-62706.	123395.	7.38	3.61	8	4	0
018278-00	24	16W	12	CCBB	0.00	120.00	3	G	A72	-99.0396	37.9742	-63505.	122887.	7.31	3.02	8	4	0
018080-00	25	14W	29	BDBB	825.00	152.00	3	G	A72	-98.8887	37.8503	-50411.	108966.	19.08	4.02	20	5	1
017830-00	26	14W	2	ABBA	1190.00	267.00	3	G	A72	-98.8198	37.8247	-44402.	106080.	22.79	5.82	23	6	0
017827-00	26	15W	2	CABB	1000.00	240.00	3	G	A72	-98.9347	37.8149	-54460.	105048.	19.43	0.55	20	1	0
019518-00	19	11W	34	CCBA	650.00	122.00	3	G	A73	-98.5332	38.3504	-19173.	164645.	4.12	40.53	5	41	0
018886-05	20	11W	32	DAAB	20.00	10.03	6	G	A73	-98.5549	38.2681	-21087.	155458.	7.83	36.08	8	37	0
019615-00	21	12W	5	DDBB	920.00	195.00	3	G	A73	-98.6598	38.2495	-30217.	153414.	5.31	30.87	6	31	1
019482-00	21	14W	21	ABCC	1295.00	192.00	3	G	A73	-98.8662	38.2148	-48198.	149633.	0.24	20.71	1	21	0
019576-00	22	13W	23	CDBB	840.00	176.00	3	G	A73	-98.7238	38.1188	-35849.	138856.	10.20	22.55	11	23	1
019115-00	22	15W	3	DCDB	935.00	166.00	3	G	A73	-98.9551	38.1614	-55975.	143725.	0.12	14.67	1	15	0
019427-00	22	15W	10	BACC	1140.00	206.00	3	G	A73	-98.9620	38.1569	-56582.	143223.	0.13	14.19	1	15	0
019906-00	22	15W	28	BDBB	920.00	195.00	3	G	A73	-98.9804	38.1125	-58217.	138278.	1.89	11.50	2	12	0
019443-00	22	15W	34	ADDD	715.00	175.00	3	G	A73	-98.9496	38.0952	-55547.	136327.	3.86	12.04	4	13	1
019024-00	23	12W	22	BCCB	910.00	99.00	3	G	A73	-98.6364	38.0364	-28260.	129622.	17.59	22.68	18	23	1
019898-00	23	13W	28	DDBB	965.00	156.00	3	G	A73	-98.7511	38.0172	-38284.	127522.	14.76	17.02	15	18	1
019431-00	23	14W	29	ADBB	1200.00	229.50	3	G	A73	-98.8800	38.0253	-49532.	128488.	9.97	11.94	10	12	1
019430-00	23	14W	29	BDBB	1200.00	240.00	3	G	A73	-98.8892	38.0253	-50333.	128497.	9.66	11.56	10	12	1
019377-00	23	16W	2	BAAB	645.00	170.00	3	G	A73	-99.0509	38.0868	-64390.	135466.	0.88	7.43	1	8	0
019168-00	23	16W	31	CBBB	975.00	184.00	3	G	A73	-99.1313	38.0066	-71483.	126575.	2.47	0.58	3	1	0
019351-00	23	17W	25	DABB	965.00	185.00	3	G	A73	-99.1358	38.0212	-71857.	128206.	1.53	1.02	2	2	0
019029-00	24	13W	7	AAAD	860.00	209.00	3	G	A73	-98.7845	37.9837	-41222.	123804.	15.43	14.17	16	15	1
019028-00	24	13W	18	ADBD	1800.00	240.00	3	G	A73	-98.7869	37.9656	-41435.	121785.	16.32	13.29	17	14	1
019438-00	24	13W	24	CDDD	865.00	224.00	3	G	A73	-98.7009	37.9415	-33942.	119060.	20.52	15.87	21	16	0
019694-00	24	13W	30	BDBB	905.00	221.00	3	G	A73	-98.7971	37.9376	-42350.	118659.	17.49	11.65	18	12	1
018696-00	24	13W	31	CDBB	1090.00	189.00	3	G	A73	-98.7971	37.9158	-42358.	116226.	18.66	10.71	19	11	1
019405-00	24	13W	36	ACBB	810.00	221.00	3	G	A73	-98.6998	37.9224	-33848.	116927.	21.59	15.10	22	16	0

Appendix 1. Well data (cont)

(a) Well id, township, range, section, quarter-section					(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code	(e) Year		(f, g) Longitude (deg)	Latitude (deg)	(h, i) Albers x (m)	Albers y (m)	(j, k) Grid row/col. (mi)		(l, m) Grid index row/col		(n) cell activ.
019429-00	24	14W	3	ADBB	785.00	220.00	3	G	A73	-98.8432	37.9959	-46341.	125195.	12.79	12.22	13	13	1
018848-00	24	14W	3	DDA	800.00	289.00	3	G	A73	-98.8402	37.9880	-46083.	124312.	13.31	12.01	14	13	1
018925-00	24	14W	5	DACC	830.00	195.00	3	G	A73	-98.8800	37.9896	-49552.	124510.	11.89	10.41	12	11	1
018924-00	24	14W	9	CACC	865.00	189.00	3	G	A73	-98.8708	37.9750	-48761.	122868.	12.99	10.16	13	11	1
019025-00	24	14W	32	CDBB	860.00	187.00	3	G	A73	-98.8889	37.9159	-50380.	116283.	15.55	6.84	16	7	1
019151-00	24	16W	14	BCBB	1600.00	240.00	3	G	A73	-99.0580	37.9668	-65118.	122076.	7.09	1.93	8	2	0
019923-00	25	14W	30	DACC	945.00	209.00	3	G	A73	-98.8978	37.8439	-51211.	108261.	19.12	3.36	20	4	1
019925-00	25	15W	25	ADBB	955.00	221.00	3	G	A73	-98.9162	37.8503	-52818.	108980.	18.15	2.86	19	3	1
019924-00	26	14W	6	ADBB	965.00	195.00	3	G	A73	-98.8894	37.8198	-50494.	105565.	20.70	2.67	21	3	1
019922-00	26	15W	1	BABB	965.00	195.00	3	G	A73	-98.9164	37.8247	-52850.	106129.	19.52	1.75	20	2	-1
020511-00	20	11W	27	DBCC	935.00	200.00	3	G	A74	-98.5249	38.2797	-18476.	156749.	8.21	37.84	9	38	0
021240-00	20	11W	32	DDBB	730.00	162.00	3	G	A74	-98.5572	38.2644	-21286.	155052.	7.95	35.82	8	36	1
019985-00	20	11W	33	DCAA	715.00	178.00	3	G	A74	-98.5401	38.2644	-19798.	155050.	8.52	36.54	9	37	1
020182-00	20	12W	18	CCAA	800.00	234.00	3	G	A74	-98.6963	38.3076	-33363.	159912.	0.96	31.84	1	32	0
021679-00	21	9W	7	ABDD	885.00	192.00	3	G	A74	-98.3489	38.2432	-3168.	152657.	16.07	43.68	17	44	0
021135-00	21	9W	34	BDBB	900.00	240.00	3	G	A74	-98.3019	38.1839	919.	146041.	20.84	43.12	21	44	0
021134-00	21	9W	34	CDBB	900.00	240.00	3	G	A74	-98.3019	38.1767	924.	145232.	21.23	42.81	22	43	0
021033-00	21	12W	15	CDBB	1200.00	240.00	3	G	A74	-98.6321	38.2204	-27816.	150154.	7.82	30.78	8	31	1
021139-00	21	13W	6	BDBB	835.00	184.50	3	G	A74	-98.7974	38.2570	-42185.	154312.	0.28	25.42	1	26	0
021140-00	21	13W	6	CDBB	665.00	167.00	3	G	A74	-98.7975	38.2500	-42193.	153524.	0.66	25.11	1	26	0
019938-00	21	14W	25	ADBB	785.00	195.00	3	G	A74	-98.8064	38.1992	-43005.	147861.	3.09	22.54	4	23	1
019939-00	21	14W	25	DDBB	1000.00	240.00	3	G	A74	-98.8064	38.1919	-43009.	147049.	3.48	22.23	4	23	1
020841-00	21	15W	36	DCAA	805.00	195.00	3	G	A74	-98.9171	38.1777	-52659.	145518.	0.52	16.97	1	17	0
020566-00	22	9W	3	BCAA	730.00	201.00	3	G	A74	-98.3030	38.1694	827.	144420.	21.59	42.45	22	43	0
020181-00	22	13W	8	CDBB	925.00	221.00	3	G	A74	-98.7792	38.1482	-40664.	142158.	6.75	21.49	7	22	1
020180-00	22	13W	8	DACC	1110.00	193.00	3	G	A74	-98.7701	38.1490	-39864.	142243.	7.02	21.91	8	22	1
021159-00	22	14W	1	CDBB	1000.00	240.00	3	G	A74	-98.8156	38.1628	-43826.	143802.	4.74	20.59	5	21	1
021303-00	22	14W	5	BDA	3000.00	474.00	3	G	A74	-98.8863	38.1699	-49979.	144628.	1.98	17.92	2	18	0
020211-00	22	14W	24	CDBB	810.00	195.00	3	G	A74	-98.8154	38.1192	-43834.	138933.	7.10	18.71	8	19	1
021172-00	22	14W	26	CDBB	765.00	195.00	3	G	A74	-98.8338	38.1047	-45446.	137329.	7.26	17.32	8	18	1
019930-00	22	14W	30	BDBB	1000.00	240.00	3	G	A74	-98.9073	38.1124	-51850.	138221.	4.36	14.56	5	15	1
020839-00	22	15W	1	ACAA	740.00	195.00	3	G	A74	-98.9172	38.1704	-52668.	144708.	0.91	16.65	1	17	0
020840-00	22	15W	1	DCAA	795.00	195.00	3	G	A74	-98.9173	38.1631	-52681.	143893.	1.30	16.33	2	17	0
020816-00	22	15W	24	CCAA	605.00	195.00	3	G	A74	-98.9265	38.1196	-53521.	139045.	3.32	14.07	4	15	1
021651-00	22	15W	35	AACC	550.00	138.00	3	G	A74	-98.9347	38.0988	-54245.	136723.	4.17	12.82	5	13	1
019942-00	22	15W	36	CDBB	660.00	177.00	3	G	A74	-98.9256	38.0906	-53463.	135805.	4.92	12.85	5	13	1

Appendix 1. Well data (cont)

(a) Well id, township, range, section, quarter-section				(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code	(e) Year		(f, g) Longitude (deg)	Latitude (deg)	(h, i) Albers x (m)	Albers y (m)	(j, k) Grid row/col. (mi)		(l, m) Grid index row/col		(n) cell activ.
020221-00	22	16W	26 DCDC	705.00	116.00	3	G	A74	-99.0462	38.1023	-63968.	137185.	0.21	8.29	1	9	0
021198-00	23	12W	16 DABB	1200.00	351.00	3	G	A74	-98.6410	38.0491	-28663.	131047.	16.74	23.03	17	24	1
020744-00	23	13W	23 DDBB	1000.00	195.00	3	G	A74	-98.7143	38.0315	-35069.	129109.	15.22	19.19	16	20	1
021154-00	23	13W	26 CDBB	835.00	221.00	3	G	A74	-98.7234	38.0170	-35870.	127492.	15.70	18.18	16	19	1
019961-00	23	13W	33 BBB	500.00	79.97	2	G	A74	-98.7645	38.0132	-39453.	127084.	14.52	16.28	15	17	1
019937-00	23	14W	20 CDBB	800.00	195.00	3	G	A74	-98.8892	38.0326	-50328.	129306.	9.27	11.87	10	12	1
020309-00	23	14W	21 ADCC	810.00	221.00	3	G	A74	-98.8616	38.0369	-47917.	129777.	9.96	13.22	10	14	1
020308-00	23	14W	21 DDBB	800.00	221.00	3	G	A74	-98.8616	38.0324	-47922.	129272.	10.21	13.02	11	14	1
020605-00	23	14W	27 ADAA	605.00	189.00	3	G	A74	-98.8398	38.0250	-46023.	128433.	11.34	13.62	12	14	1
021309-00	23	14W	36 DCC	1300.00	150.00	3	G	A74	-98.8105	38.0007	-43475.	125716.	13.64	13.81	14	14	1
019935-00	23	15W	1 DDDA	740.00	195.00	3	G	A74	-98.9132	38.0742	-52392.	133968.	6.22	12.66	7	13	1
020980-00	23	15W	2 BCAA	710.00	182.00	3	G	A74	-98.9452	38.0834	-55173.	135010.	4.64	11.72	5	12	1
020571-00	23	15W	2 CDBB	1040.00	158.00	3	G	A74	-98.9441	38.0761	-55082.	134197.	5.07	11.45	6	12	1
020979-00	23	15W	10 CCAA	695.00	160.00	3	G	A74	-98.9636	38.0615	-56797.	132580.	5.20	10.00	6	10	1
021021-00	23	15W	12 CDDD	280.00	80.00	3	G	A74	-98.9224	38.0588	-53206.	132248.	6.74	11.61	7	12	1
021117-00	23	15W	24 CACB	475.00	132.00	3	G	A74	-98.9259	38.0343	-53527.	129524.	7.93	10.41	8	11	1
021310-00	23	16W	4 DDBB	550.00	147.00	3	G	A74	-99.0808	38.0759	-67006.	134260.	0.46	5.70	1	6	0
020568-00	23	16W	17 ADC	550.00	53.00	3	G	A74	-99.0987	38.0517	-68594.	131580.	1.15	3.90	2	4	0
020608-00	24	13W	3 CACC	1145.00	312.00	3	G	A74	-98.7416	37.9889	-37466.	124360.	16.60	16.20	17	17	1
021324-00	24	13W	4 DCAA	840.00	225.00	3	G	A74	-98.7520	37.9880	-38375.	124266.	16.30	15.72	17	16	1
020787-00	24	13W	8 BCAA	940.00	191.00	3	G	A74	-98.7799	37.9810	-40818.	123494.	15.73	14.25	16	15	1
021333-00	24	13W	10 CBDD	915.00	195.00	3	G	A74	-98.7426	37.9744	-37566.	122742.	17.35	15.53	18	16	1
020745-00	24	13W	15 BDBB	895.00	195.00	3	G	A74	-98.7414	37.9662	-37468.	121832.	17.82	15.23	18	16	1
020746-00	24	13W	15 CDBB	980.00	182.00	3	G	A74	-98.7414	37.9590	-37471.	121021.	18.22	14.92	19	15	0
021672-00	24	13W	17 ADBB	700.00	195.00	3	G	A74	-98.7693	37.9663	-39904.	121856.	16.88	14.06	17	15	1
020424-00	24	13W	17 DDBB	745.00	190.00	3	G	A74	-98.7693	37.9591	-39904.	121048.	17.27	13.75	18	14	1
021673-00	24	13W	18 CDBB	1500.00	240.00	3	G	A74	-98.7971	37.9594	-42332.	121091.	16.31	12.59	17	13	1
020861-00	24	13W	19 ADBB	1500.00	240.00	3	G	A74	-98.7880	37.9520	-41541.	120261.	17.02	12.65	18	13	1
020121-00	24	13W	19 BDBB	865.00	183.00	3	G	A74	-98.7971	37.9521	-42336.	120278.	16.71	12.27	17	13	1
020122-00	24	13W	29 CDBB	900.00	195.00	3	G	A74	-98.7787	37.9302	-40745.	117828.	18.50	12.10	19	13	1
020227-00	24	14W	11 ADBB	735.00	195.00	3	G	A74	-98.8247	37.9811	-44730.	123531.	14.21	12.36	15	13	1
020792-00	24	14W	35 ADBB	2000.00	480.00	3	G	A74	-98.8246	37.9230	-44759.	117048.	17.34	9.86	18	10	1
020346-00	24	14W	36 BDBB	800.00	195.00	3	G	A74	-98.8155	37.9230	-43959.	117043.	17.65	10.25	18	11	1
021203-00	24	15W	21 CCBB	1800.00	240.00	3	G	A74	-98.9850	37.9452	-58762.	119610.	10.72	4.06	11	5	0
020845-00	24	16W	3 BBDD	600.00	145.00	3	G	A74	-99.0728	37.9969	-66381.	125443.	4.97	2.61	5	3	0
021006-00	24	16W	26 AACC	1145.00	210.00	3	G	A74	-99.0442	37.9387	-63941.	118925.	9.07	1.29	10	2	0

Appendix 1. Well data (cont)

(a) Well id, township, range, section, quarter-section				(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code	(e)	Year	(f, g) Longitude (deg)	Latitude (deg)	(h, i) Albers x (m)	Albers y (m)	(j, k) Grid row/col. (mi)		(l, m) Grid index row/col		(n) cell activ.
021162-00	24	16W	35	DBDD	845.00	195.00	3	G	A74	-99.0454	37.9168	-64064.	116488.	10.20	0.30	11	1	0
020798-00	25	13W	4	BDAA	900.00	195.00	3	G	A74	-98.7566	37.9083	-38820.	115371.	20.43	12.09	21	13	0
020348-00	25	13W	8	DCAA	800.00	221.00	3	G	A74	-98.7705	37.8866	-40047.	112956.	21.13	10.57	22	11	0
020334-00	25	13W	16	BBDD	925.00	195.00	3	G	A74	-98.7612	37.8801	-39242.	112234.	21.79	10.68	22	11	0
020667-00	25	13W	16	DDBB	995.00	240.00	3	G	A74	-98.7508	37.8719	-38339.	111313.	22.58	10.77	23	11	0
020517-00	25	13W	31	BDBB	835.00	221.00	3	G	A74	-98.7968	37.8358	-42381.	107302.	22.97	7.27	23	8	0
020347-00	25	14W	4	ADBB	380.00	88.00	3	G	A74	-98.8612	37.9086	-47967.	115456.	16.88	7.70	17	8	1
020791-00	25	14W	12	ADBB	1000.00	195.00	3	G	A74	-98.8062	37.8939	-43167.	113795.	19.53	9.38	20	10	0
020977-00	25	14W	24	ADBB	790.00	195.00	3	G	A74	-98.8060	37.8648	-43170.	110548.	21.10	8.13	22	9	0
020547-00	25	14W	24	CDBB	780.00	220.00	3	G	A74	-98.8151	37.8576	-43968.	109742.	21.18	7.44	22	8	0
020451-00	25	14W	27	CACC	815.00	195.00	3	G	A74	-98.8518	37.8439	-47191.	108237.	20.67	5.30	21	6	0
020161-00	25	14W	36	ADBB	800.00	240.00	3	G	A74	-98.8060	37.8358	-43183.	107307.	22.66	6.88	23	7	0
020160-00	25	14W	36	BDBB	955.00	195.00	3	G	A74	-98.8151	37.8358	-43983.	107307.	22.36	6.50	23	7	0
019982-00	26	14W	3	DACC	730.00	214.00	3	G	A74	-98.8347	37.8117	-45713.	104635.	22.99	4.63	23	5	0
020507-00	26	15W	1	DABB	1200.00	195.00	3	G	A74	-98.9072	37.8149	-52054.	105031.	20.36	1.71	21	2	-1
022728-00	20	10W	35	DCBB	825.00	156.00	3	G	A75	-98.3965	38.2639	-7307.	154965.	13.36	42.56	14	43	0
021924-00	20	11W	9	AACC	1200.00	240.00	3	G	A75	-98.5388	38.3303	-19669.	162400.	5.01	39.43	6	40	0
021998-00	20	11W	33	BCAA	915.00	195.00	3	G	A75	-98.5492	38.2717	-20587.	155861.	7.83	36.47	8	37	0
023276-00	20	12W	1	CDBB	830.00	195.00	3	G	A75	-98.6033	38.3367	-25272.	163126.	2.51	36.99	3	37	0
021931-00	21	10W	2	BDBB	745.00	195.00	3	G	A75	-98.3934	38.2568	-7039.	154173.	13.85	42.39	14	43	0
021915-00	21	10W	2	DDBB	0.00	37.00	3	G	A75	-98.3841	38.2496	-6232.	153371.	14.55	42.47	15	43	0
022449-00	21	12W	2	CDBB	1000.00	246.00	3	G	A75	-98.6137	38.2496	-26203.	153414.	6.86	32.81	7	33	1
022407-00	21	12W	28	ADBB	900.00	240.00	3	G	A75	-98.6417	38.1983	-28666.	147701.	8.68	29.43	9	30	1
021775-00	21	14W	31	ADBB	3000.00	480.00	3	G	A75	-98.8982	38.1849	-51004.	146308.	0.77	18.07	1	19	0
022304-00	21	14W	34	CDBB	1600.00	465.00	3	G	A75	-98.8524	38.1775	-47018.	145463.	2.71	19.68	3	20	1
021791-00	22	13W	34	DCCC	815.00	195.00	3	G	A75	-98.7375	38.0871	-37059.	135323.	11.45	20.61	12	21	1
021777-00	22	14W	7	CDBB	785.00	195.00	3	G	A75	-98.9072	38.1486	-51810.	142267.	2.42	16.13	3	17	1
022367-00	22	14W	8	DDBB	1300.00	240.00	3	G	A75	-98.8800	38.1485	-49442.	142236.	3.34	17.27	4	18	1
021778-00	22	14W	18	AACC	725.00	195.00	3	G	A75	-98.8982	38.1422	-51038.	141547.	3.07	16.23	4	17	1
021884-00	22	14W	22	CACC	900.00	195.00	3	G	A75	-98.8522	38.1202	-47042.	139072.	5.80	17.21	6	18	1
022256-00	22	14W	36	BDBB	885.00	187.00	3	G	A75	-98.8154	38.0974	-43848.	136504.	8.27	17.77	9	18	1
022097-00	22	15W	10	CBDD	850.00	197.00	3	G	A75	-98.9632	38.1496	-56693.	142414.	0.47	13.82	1	14	0
022031-00	22	15W	22	DDBB	275.00	72.00	3	G	A75	-98.9528	38.1197	-55811.	139066.	2.43	12.96	3	13	1
021776-00	23	15W	24	DDBB	735.00	195.00	3	G	A75	-98.9167	38.0325	-52730.	129319.	8.34	10.71	9	11	1
022489-00	23	16W	13	CDBB	670.00	195.00	3	G	A75	-99.0348	38.0469	-63021.	131000.	3.57	6.38	4	7	0
021898-00	23	16W	22	ADBB	810.00	192.00	3	G	A75	-99.0625	38.0396	-65440.	130200.	3.03	4.90	4	5	0

Appendix 1. Well data (cont)

(a) Well id, township, range, section, quarter-section				(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code	(e) Year		(f, g) Longitude (deg)	Latitude (deg)	(h, i) Albers x (m)	Albers y (m)	(j, k) Grid row/col. (mi)		(l, m) Grid index row/col		(n) cell activ.
022390-00	23	16W 27	DDBB	800.00	192.00	3	G	A75	-99.0625	38.0178	-65462.	127772.	4.20	3.95	5	4	0
022611-00	24	12W 21	DCBB	1010.00	183.00	3	G	A75	-98.6451	37.9438	-29057.	119293.	22.28	18.33	23	19	0
022934-00	24	13W 7	DDAA	1000.00	240.00	3	G	A75	-98.7846	37.9738	-41231.	122696.	15.96	13.74	16	14	1
021905-00	24	13W 24	DDBB	1200.00	236.00	3	G	A75	-98.6951	37.9442	-33432.	119359.	20.57	16.23	21	17	0
022590-00	24	13W 35	CCAA	695.00	181.00	3	G	A75	-98.7241	37.9153	-35979.	116143.	21.15	13.77	22	14	0
022007-00	24	14W 21	ABB	2500.00	386.00	3	G	A75	-98.8657	37.9554	-48328.	120687.	14.21	9.53	15	10	1
023303-00	24	16W 12	BCBB	1220.00	141.00	3	G	A75	-99.0396	37.9815	-63495.	123703.	6.92	3.34	7	4	0
021843-00	24	16W 25	BDBB	750.00	195.00	3	G	A75	-99.0351	37.9378	-63144.	118820.	9.42	1.64	10	2	0
023096-00	24	16W 25	CDBB	1000.00	240.00	3	G	A75	-99.0351	37.9305	-63148.	118011.	9.81	1.33	10	2	0
023097-00	24	16W 35	ADBB	1000.00	240.00	3	G	A75	-99.0443	37.9232	-63956.	117204.	9.89	0.62	10	1	0
023250-00	24	16W 36	ACAA	685.00	195.00	3	G	A75	-99.0271	37.9232	-62455.	117188.	10.48	1.34	11	2	0
023249-00	24	16W 36	DDBB	1000.00	240.00	3	G	A75	-99.0260	37.9159	-62363.	116372.	10.91	1.08	11	2	0
022654-00	25	13W 15	BDBB	1000.00	240.00	3	G	A75	-98.7415	37.8791	-37522.	112115.	22.51	11.47	23	12	0
023055-00	25	14W 31	BDBB	1000.00	221.00	3	G	A75	-98.9069	37.8358	-52012.	107354.	19.25	2.63	20	3	1
022136-00	25	15W 35	CDBB	1000.00	204.00	3	G	A75	-98.9436	37.8285	-55228.	106570.	18.39	0.77	19	1	0
023138-00	26	15W 12	BDBB	800.00	240.00	3	G	A75	-98.9164	37.8016	-52868.	103554.	20.76	0.75	21	1	0
024009-00	20	11W 3	ABBB	525.00	88.00	3	G	A76	-98.5251	38.3468	-18476.	164237.	4.58	40.71	5	41	0
025175-00	20	11W 19	CCAA	895.00	234.00	3	G	A76	-98.5860	38.2932	-23779.	158266.	5.44	35.85	6	36	0
023884-00	20	12W 3	DACC	850.00	197.00	3	G	A76	-98.6310	38.3374	-27680.	163217.	1.54	35.86	2	36	0
023883-00	20	12W 10	ADBB	785.00	167.00	3	G	A76	-98.6310	38.3294	-27679.	162322.	1.98	35.52	2	36	0
023882-00	20	12W 10	CCAA	755.00	198.00	3	G	A76	-98.6413	38.3223	-28582.	161536.	2.01	34.78	3	35	0
023885-00	20	12W 10	DDBB	740.00	198.00	3	G	A76	-98.6309	38.3222	-27677.	161525.	2.36	35.21	3	36	0
024035-00	20	12W 13	ACDC	805.00	179.00	3	G	A76	-98.5963	38.3123	-24673.	160402.	4.06	36.24	5	37	0
023927-00	20	12W 35	CCAA	935.00	203.00	3	G	A76	-98.6228	38.2642	-26988.	155047.	5.76	33.06	6	34	0
023952-00	20	13W 36	BACC	880.00	195.00	3	G	A76	-98.7136	38.2723	-34884.	155975.	2.28	29.59	3	30	0
024129-00	21	9W 28	CBAA	650.00	181.00	3	G	A76	-98.3215	38.1949	-783.	147266.	19.59	42.76	20	43	0
024128-00	21	9W 29	ADDB	670.00	155.00	3	G	A76	-98.3272	38.1968	-1283.	147472.	19.30	42.60	20	43	0
023778-00	21	12W 15	BDBB	900.00	240.00	3	G	A76	-98.6320	38.2277	-27809.	150971.	7.42	31.10	8	32	1
023716-00	21	12W 27	CDBB	1000.00	240.00	3	G	A76	-98.6327	38.1910	-27881.	146875.	9.38	29.49	10	30	1
024910-00	21	13W 31	BDBB	865.00	195.00	3	G	A76	-98.7974	38.1846	-42229.	146231.	4.18	22.29	5	23	1
024860-00	21	14W 24	DDBB	795.00	195.00	3	G	A76	-98.8064	38.2065	-43000.	148673.	2.70	22.86	3	23	1
025105-00	21	14W 32	DCBC	1620.00	240.00	3	G	A76	-98.8846	38.1767	-49825.	145387.	1.67	18.29	2	19	0
024995-00	21	14W 33	CDBB	1820.00	240.00	3	G	A76	-98.8708	38.1775	-48623.	145475.	2.09	18.91	3	19	1
024927-00	22	14W 1	ACBB	925.00	198.00	3	G	A76	-98.8110	38.1701	-43423.	144614.	4.50	21.09	5	22	1
024877-00	22	14W 4	DBC	1200.00	228.00	3	G	A76	-98.8656	38.1643	-48179.	143997.	2.98	18.55	3	19	1
023612-00	22	14W 9	CCCB	1000.00	216.00	3	G	A76	-98.8754	38.1466	-49043.	142030.	3.60	17.38	4	18	1

Appendix 1. Well data (cont)

(a) Well id, township, range, section, quarter-section					(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code	(e)	Year	(f, g) Longitude (deg)	Latitude (deg)	(h, i) Albers x (m)	Albers y (m)	(j, k) Grid row/col. (mi)		(l, m) Grid index row/col		(n) cell activ.
025079-00	22	14W	20	DDBB	1200.00	240.00	3	G	A76	-98.8799	38.1195	-49459.	139001.	4.91	16.02	5	17	1
025292-00	22	14W	21	ADBB	800.00	240.00	3	G	A76	-98.8615	38.1266	-47848.	139787.	5.14	17.10	6	18	1
025078-00	22	14W	21	CDBB	1200.00	240.00	3	G	A76	-98.8707	38.1194	-48654.	138991.	5.22	16.40	6	17	1
025194-00	22	14W	25	CDCB	525.00	63.00	3	G	A76	-98.8154	38.1028	-43844.	137112.	7.98	18.01	8	19	1
025002-00	22	15W	33	DDDC	630.00	192.00	3	G	A76	-98.9691	38.0879	-57256.	135526.	3.59	10.90	4	11	1
024998-00	22	16W	36	DCAA	665.00	173.00	3	G	A76	-99.0268	38.0905	-62284.	135858.	1.50	8.60	2	9	-1
024554-00	23	12W	7	DBA	500.00	225.00	3	G	A76	-98.6795	38.0636	-32011.	132680.	14.67	22.04	15	23	1
025176-00	23	13W	5	CDBB	1000.00	240.00	3	G	A76	-98.7789	38.0754	-40674.	134033.	10.68	18.36	11	19	1
024455-00	23	13W	36	DBC	850.00	240.00	3	G	A76	-98.6997	38.0038	-33805.	126006.	17.21	18.61	18	19	1
024274-00	23	14W	7	ADBB	1000.00	228.00	3	G	A76	-98.8984	38.0687	-51104.	133348.	7.01	13.05	8	14	1
024321-00	23	14W	8	BCAA	960.00	195.00	3	G	A76	-98.8904	38.0687	-50405.	133340.	7.28	13.38	8	14	1
024757-00	23	14W	16	BDBB	865.00	221.00	3	G	A76	-98.8708	38.0541	-48711.	131703.	8.73	13.58	9	14	1
024452-00	23	14W	19	BDBB	850.00	240.00	3	G	A76	-98.9076	38.0398	-51926.	130121.	8.26	11.41	9	12	1
024675-00	23	14W	20	BDBB	1200.00	240.00	3	G	A76	-98.8892	38.0398	-50322.	130112.	8.88	12.18	9	13	1
023734-00	23	15W	4	CCAA	625.00	181.00	3	G	A76	-98.9816	38.0760	-58353.	134212.	3.81	9.87	4	10	1
024954-00	23	15W	12	BDBB	65.00	17.00	3	G	A76	-98.9258	38.0688	-53492.	133366.	6.09	11.90	7	12	1
024705-00	23	16W	9	CBDC	480.00	180.00	3	G	A76	-99.0924	38.0621	-68033.	132739.	0.81	4.62	1	5	0
025342-00	23	16W	17	DACC	640.00	192.00	3	G	A76	-99.0993	38.0476	-68645.	131126.	1.35	3.70	2	4	0
024586-00	23	17W	23	ADAA	620.00	195.00	3	G	A76	-99.1506	38.0395	-73133.	130254.	0.05	1.19	1	2	0
024710-00	24	12W	6	ADBB	745.00	195.00	3	G	A76	-98.6772	37.9950	-31843.	125022.	18.44	19.18	19	20	0
024668-00	24	13W	16	BDBB	950.00	198.00	3	G	A76	-98.7600	37.9663	-39088.	121845.	17.20	14.45	18	15	1
024669-00	24	13W	16	CBCC	915.00	198.00	3	G	A76	-98.7646	37.9600	-39494.	121143.	17.38	13.98	18	14	1
024711-00	24	13W	33	DDBB	965.00	195.00	3	G	A76	-98.7507	37.9154	-38306.	116170.	20.24	12.65	21	13	0
024126-00	24	14W	8	DDBB	900.00	222.00	3	G	A76	-98.8800	37.9741	-49564.	122778.	12.72	9.73	13	10	1
024513-00	24	14W	12	BABB	1200.00	212.00	3	G	A76	-98.8155	37.9848	-43925.	123934.	14.33	12.91	15	13	1
024278-00	24	14W	28	BDBB	900.00	240.00	3	G	A76	-98.8707	37.9377	-48778.	118710.	14.99	8.55	15	9	1
023520-00	24	14W	34	BBAA	925.00	221.00	3	G	A76	-98.8533	37.9267	-47261.	117478.	16.17	8.81	17	9	1
025094-00	24	14W	36	ADBB	820.00	195.00	3	G	A76	-98.8063	37.9230	-43157.	117042.	17.96	10.63	18	11	1
023666-00	24	15W	12	BCBB	840.00	195.00	3	G	A76	-98.9303	37.9817	-53953.	123652.	10.61	7.94	11	8	1
024933-00	24	15W	20	DABB	1000.00	240.00	3	G	A76	-98.9897	37.9488	-59165.	120021.	10.37	4.03	11	5	0
023860-00	24	15W	23	BDBB	1000.00	240.00	3	G	A76	-98.9439	37.9524	-55164.	120397.	11.72	6.11	12	7	1
023411-00	24	15W	31	BDBB	2400.00	480.00	3	G	A76	-99.0168	37.9232	-61559.	117180.	10.83	1.78	11	2	0
024272-00	24	15W	36	DCAA	745.00	195.00	3	G	A76	-98.9173	37.9159	-52868.	116308.	14.59	5.65	15	6	1
024442-00	24	16W	1	ABBD	750.00	150.00	3	G	A76	-99.0292	37.9989	-62577.	125635.	6.34	4.53	7	5	0
023617-00	24	16W	3	BBDD	120.00	31.00	3	G	A76	-99.0728	37.9969	-66381.	125443.	4.97	2.61	5	3	0
023811-00	24	16W	4	CACC	735.00	173.00	3	G	A76	-99.0901	37.9895	-67898.	124635.	4.78	1.57	5	2	0

Appendix 1. Well data (cont)

(a) Well id, township, range, section, quarter-section	(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code	(e) Year	(f, g) Longitude (deg)	Latitude (deg)	(h, i) Albers x (m)	Albers y (m)	(j, k) Grid row/col. (mi)		(l, m) Grid index row/col		(n) cell activ.
025037-00 25 13W 3 DADD	905.00	233.00	3	G A76	-98.7287	37.9017	-36386.	114632.	21.73	12.99	22	13	0
023390-00 25 13W 6 CCAA	955.00	221.00	3	G A76	-98.7982	37.9012	-42464.	114602.	19.41	10.03	20	11	0
024650-00 25 14W 2 DDBB	1000.00	240.00	3	G A76	-98.8245	37.9012	-44763.	114618.	18.52	8.93	19	9	1
023924-00 25 14W 28 BDBB	860.00	159.00	3	G A76	-98.8703	37.8503	-48799.	108959.	19.71	4.80	20	5	1
023925-00 25 14W 28 CBDD	660.00	104.00	3	G A76	-98.8714	37.8439	-48900.	108247.	20.01	4.48	21	5	0
023500-00 25 14W 31 ADBB	1000.00	221.00	3	G A76	-98.8977	37.8358	-51209.	107349.	19.56	3.01	20	4	1
024774-00 26 14W 18 CDBB	775.00	180.00	3	G A76	-98.8982	37.7799	-51296.	101115.	22.55	0.58	23	1	0
023468-00 26 15W 11 DABB	1000.00	195.00	3	G A76	-98.9255	37.7980	-53672.	103152.	20.65	0.21	21	1	0
027763-00 20 11W 27 ADBB	890.00	151.00	3	G A77	-98.5203	38.2860	-18070.	157451.	8.02	38.30	9	39	0
026149-00 20 11W 29 DDBB	900.00	180.00	3	G A77	-98.5573	38.2789	-21285.	156663.	7.17	36.44	8	37	0
025868-00 20 11W 30 BCAA	725.00	189.00	3	G A77	-98.5860	38.2859	-23782.	157459.	5.83	35.54	6	36	0
027511-00 20 11W 30 CCAA	890.00	186.00	3	G A77	-98.5860	38.2787	-23783.	156656.	6.22	35.23	7	36	0
025961-00 20 12W 2 CDBC	510.00	23.00	3	G A77	-98.6218	38.3356	-26876.	163016.	1.95	36.18	2	37	0
026301-00 20 12W 3 CACC	690.00	140.00	3	G A77	-98.6404	38.3375	-28489.	163227.	1.23	35.48	2	36	0
027731-00 20 12W 25 ACBA	900.00	183.00	3	G A77	-98.5975	38.2860	-24779.	157467.	5.44	35.06	6	36	0
027801-00 20 12W 25 CCAA	845.00	185.00	3	G A77	-98.6043	38.2788	-25379.	156666.	5.60	34.46	6	35	0
026051-00 20 12W 25 DDBB	770.00	192.00	3	G A77	-98.5940	38.2787	-24481.	156659.	5.95	34.89	6	35	0
027802-00 20 12W 26 DABB	815.00	186.00	3	G A77	-98.6124	38.2824	-26080.	157074.	5.13	34.28	6	35	0
026162-00 20 12W 30 CDBB	585.00	160.00	3	G A77	-98.6951	38.2786	-33276.	156675.	2.56	30.64	3	31	0
025989-00 20 12W 34 DDBB	985.00	186.00	3	G A77	-98.6309	38.2642	-27692.	155046.	5.49	32.72	6	33	0
027866-00 20 12W 36 ACAA	830.00	192.00	3	G A77	-98.5951	38.2715	-24581.	155853.	6.30	34.54	7	35	0
026163-00 20 13W 22 DCAA	875.00	180.00	3	G A77	-98.7425	38.2931	-37390.	158318.	0.19	29.28	1	30	0
028067-00 20 13W 23 ADBB	960.00	198.00	3	G A77	-98.7229	38.3004	-35682.	159118.	0.45	30.41	1	31	0
026161-00 20 13W 23 CDBB	700.00	192.00	3	G A77	-98.7322	38.2932	-36490.	158314.	0.53	29.71	1	30	0
027931-00 20 13W 26 BACC	710.00	149.00	3	G A77	-98.7322	38.2868	-36494.	157605.	0.87	29.44	1	30	0
025873-00 20 13W 34 BBDC	915.00	143.00	3	G A77	-98.7528	38.2722	-38294.	155987.	0.97	27.95	1	28	0
026321-00 20 13W 36 CACC	725.00	195.00	3	G A77	-98.7135	38.2649	-34883.	155159.	2.68	29.28	3	30	0
027982-00 21 9W 29 ACCC	995.00	278.00	3	G A77	-98.3341	38.1959	-1883.	147374.	19.12	42.27	20	43	0
027525-00 21 10W 1 CCAA	710.00	98.00	3	G A77	-98.3760	38.2496	-5529.	153368.	14.82	42.81	15	43	0
028267-00 21 12W 1 BDBB	2400.00	476.00	3	G A77	-98.5952	38.2569	-24591.	154226.	7.08	33.91	8	34	1
026621-00 21 12W 2 AACC	950.00	192.00	3	G A77	-98.6044	38.2579	-25395.	154332.	6.72	33.56	7	34	1
026746-00 21 12W 3 ADBB	1000.00	240.00	3	G A77	-98.6228	38.2569	-26998.	154235.	6.15	32.74	7	33	1
026747-00 21 12W 3 DDBB	1000.00	240.00	3	G A77	-98.6229	38.2496	-27003.	153416.	6.55	32.43	7	33	1
026717-00 21 12W 8 BBDD	810.00	195.00	3	G A77	-98.6703	38.2431	-31130.	152700.	5.31	30.15	6	31	1
027306-00 21 12W 11 ADBB	1000.00	240.00	3	G A77	-98.6045	38.2422	-25406.	152590.	7.56	32.88	8	33	1
026562-00 21 12W 11 CDBB	1000.00	240.00	3	G A77	-98.6137	38.2350	-26212.	151779.	7.64	32.18	8	33	1

Appendix 1. Well data (cont)

(a) Well id, township, range, section, quarter-section				(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code	(e) Year		(f, g) Longitude (deg)	Latitude (deg)	(h, i) Albers x (m)	Albers y (m)	(j, k) Grid row/col. (mi)		(l, m) Grid index row/col		(n) cell activ.
027800-00	21	12W 12	DDBB	1100.00	240.00	3	G	A77	-98.5860	38.2348	-23801.	151755.	8.58	33.34	9	34	1
026476-00	21	12W 15	DACB	1000.00	240.00	3	G	A77	-98.6230	38.2222	-27024.	150356.	8.02	31.24	9	32	1
027693-00	21	12W 27	DDBB	1100.00	240.00	3	G	A77	-98.6235	38.1910	-27082.	146872.	9.69	29.88	10	30	1
027075-00	21	13W 5	AACC	715.00	131.00	3	G	A77	-98.7700	38.2578	-39803.	154381.	1.17	26.60	2	27	0
025645-00	21	13W 7	BDBB	880.00	185.00	3	G	A77	-98.7975	38.2428	-42196.	152722.	1.05	24.80	2	25	0
027509-00	21	13W 27	BDBB	605.00	106.00	3	G	A77	-98.7427	38.1986	-37452.	147766.	5.27	25.20	6	26	1
025603-00	21	13W 28	CDBB	720.00	189.00	3	G	A77	-98.7610	38.1916	-39056.	146987.	5.03	24.12	6	25	1
026320-00	21	14W 11	ACA	1000.00	240.00	3	G	A77	-98.8267	38.2423	-44738.	152685.	0.09	23.56	1	24	0
026516-00	21	14W 12	BDBB	900.00	240.00	3	G	A77	-98.8158	38.2428	-43788.	152732.	0.43	24.04	1	25	0
026258-00	21	14W 13	BDBB	800.00	240.00	3	G	A77	-98.8157	38.2283	-43794.	151111.	1.22	23.41	2	24	0
026259-00	21	14W 14	ADBB	800.00	231.00	3	G	A77	-98.8250	38.2283	-44598.	151115.	0.91	23.02	1	24	0
026318-00	21	14W 23	ACAA	820.00	195.00	3	G	A77	-98.8261	38.2137	-44703.	149494.	1.65	22.35	2	23	0
025758-00	21	14W 24	ADBB	775.00	188.00	3	G	A77	-98.8064	38.2138	-42994.	149487.	2.31	23.17	3	24	1
025656-00	21	14W 36	ADBB	1000.00	240.00	3	G	A77	-98.8064	38.1847	-43013.	146238.	3.88	21.92	4	22	1
026257-00	22	10W 4	ADBB	600.00	90.00	3	G	A77	-98.4214	38.1691	-9481.	144393.	17.65	37.45	18	38	1
027399-00	22	13W 18	CDBB	800.00	195.00	3	G	A77	-98.7973	38.1337	-42244.	140550.	6.93	20.10	7	21	1
025627-00	22	13W 19	BDBB	675.00	165.00	3	G	A77	-98.7972	38.1265	-42243.	139739.	7.32	19.79	8	20	1
025714-00	22	13W 20	CDBB	830.00	195.00	3	G	A77	-98.7790	38.1191	-40664.	138909.	8.33	20.24	9	21	1
027905-00	22	13W 20	DBB	300.00	202.00	6	G	A77	-98.7739	38.1222	-40214.	139253.	8.33	20.59	9	21	1
027904-00	22	13W 20	DDBB	800.00	158.00	3	G	A77	-98.7698	38.1190	-39858.	138889.	8.65	20.62	9	21	1
025985-00	22	13W 25	CDBB	1000.00	195.00	3	G	A77	-98.7053	38.1042	-34248.	137221.	11.61	22.70	12	23	1
026084-00	22	13W 29	CDBB	815.00	195.00	3	G	A77	-98.7788	38.1045	-40655.	137282.	9.12	19.62	10	20	1
026893-00	22	13W 30	CDBB	780.00	193.00	3	G	A77	-98.7970	38.1046	-42240.	137301.	8.50	18.86	9	19	1
026105-00	22	13W 31	AACB	495.00	87.00	3	G	A77	-98.7879	38.0991	-41453.	136683.	9.10	19.00	10	20	1
027616-00	22	14W 14	ADBB	1000.00	240.00	3	G	A77	-98.8248	38.1409	-44638.	141368.	5.61	19.26	6	20	1
027617-00	22	14W 14	DDBB	1000.00	240.00	3	G	A77	-98.8248	38.1337	-44643.	140556.	6.00	18.95	7	19	1
027588-00	22	14W 15	BDBB	900.00	240.00	3	G	A77	-98.8523	38.1410	-47040.	141393.	4.68	18.11	5	19	1
026104-00	22	14W 20	ADBB	750.00	188.00	3	G	A77	-98.8800	38.1267	-49455.	139808.	4.52	16.33	5	17	1
026151-00	22	14W 21	BCAA	870.00	189.00	3	G	A77	-98.8719	38.1267	-48753.	139799.	4.79	16.66	5	17	1
026373-00	22	14W 23	ADBB	930.00	195.00	3	G	A77	-98.8247	38.1264	-44643.	139746.	6.39	18.63	7	19	1
027023-00	22	14W 23	DDBB	750.00	181.00	3	G	A77	-98.8246	38.1192	-44639.	138939.	6.79	18.33	7	19	1
026083-00	22	14W 26	BDBB	1000.00	240.00	3	G	A77	-98.8338	38.1120	-45441.	138141.	6.86	17.63	7	18	1
026900-00	22	14W 27	BBD	960.00	203.00	3	G	A77	-98.8539	38.1135	-47191.	138316.	6.11	16.85	7	17	1
026901-00	22	14W 27	DDB	2600.00	690.00	3	G	A77	-98.8424	38.1043	-46197.	137286.	6.99	16.94	7	17	1
027824-00	22	14W 28	ADBB	1000.00	240.00	3	G	A77	-98.8614	38.1121	-47847.	138171.	5.93	16.48	6	17	1
027825-00	22	14W 28	BDBB	1000.00	240.00	3	G	A77	-98.8707	38.1122	-48658.	138182.	5.61	16.09	6	17	1

Appendix 1. Well data (cont)

(a) Well id, township, range, section, quarter-section					(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code	(e) Year		(f, g) Longitude (deg)	Latitude (deg)	(h, i) Albers x (m)	Albers y (m)	(j, k) Grid row/col. (mi)		(l, m) Grid index row/col		(n) cell activ.
026528-00	22	15W	2	CCBB	1800.00	237.00	3	G	A77	-98.9482	38.1632	-55373.	143923.	0.25	15.04	1	16	0
026529-00	22	15W	2	DCBB	1800.00	237.00	3	G	A77	-98.9391	38.1632	-54578.	143911.	0.56	15.42	1	16	0
027957-00	22	15W	9	DDBB	805.00	179.00	3	G	A77	-98.9713	38.1487	-57395.	142317.	0.25	13.45	1	14	0
025979-00	22	15W	13	BACC	855.00	195.00	3	G	A77	-98.9254	38.1423	-53407.	141575.	2.14	15.09	3	16	1
027844-00	22	15W	20	ADCD	875.00	144.00	3	G	A77	-98.9885	38.1243	-58914.	139599.	0.99	11.67	1	12	0
026291-00	22	15W	25	BCAA	800.00	147.00	3	G	A77	-98.9266	38.1124	-53527.	138235.	3.71	13.75	4	14	1
026682-00	22	15W	33	ADBB	165.00	55.00	3	G	A77	-98.9713	38.0979	-57440.	136642.	2.98	11.24	3	12	1
026448-00	23	11W	7	BDBB	850.00	240.00	3	G	A77	-98.5771	38.0667	-23082.	132996.	17.94	26.48	18	27	1
026507-00	23	11W	9	ADBB	900.00	240.00	3	G	A77	-98.5313	38.0668	-19085.	132989.	19.48	28.42	20	29	0
025801-00	23	11W	16	CBDC	1000.00	240.00	3	G	A77	-98.5427	38.0458	-20087.	130654.	20.23	27.03	21	28	0
026789-00	23	13W	13	BDBB	745.00	195.00	3	G	A77	-98.7052	38.0533	-34260.	131539.	14.35	20.51	15	21	1
026462-00	23	14W	3	BDBB	745.00	169.00	3	G	A77	-98.8523	38.0830	-47071.	134914.	7.80	15.60	8	16	1
027988-00	23	14W	4	CDBB	1100.00	240.00	3	G	A77	-98.8708	38.0758	-48690.	134124.	7.56	14.52	8	15	1
026079-00	23	14W	7	BDBB	1250.00	240.00	3	G	A77	-98.9075	38.0688	-51901.	133355.	6.70	12.66	7	13	1
027072-00	23	14W	13	CDBB	850.00	212.00	3	G	A77	-98.8156	38.0466	-43896.	130833.	11.00	15.57	11	16	1
026966-00	23	14W	19	CDBB	900.00	240.00	3	G	A77	-98.9076	38.0326	-51931.	129316.	8.65	11.10	9	12	1
027419-00	23	14W	20	DABC	820.00	188.00	3	G	A77	-98.8800	38.0352	-49524.	129598.	9.43	12.37	10	13	1
027418-00	23	14W	21	CDBB	900.00	212.00	3	G	A77	-98.8708	38.0325	-48724.	129285.	9.89	12.64	10	13	1
026582-00	23	14W	24	BDBB	885.00	195.00	3	G	A77	-98.8156	38.0393	-43903.	130025.	11.39	15.26	12	16	1
026500-00	23	14W	24	CDB	700.00	56.00	3	G	A77	-98.8151	38.0316	-43861.	129165.	11.82	14.95	12	15	1
027987-00	23	14W	25	CDBB	1100.00	240.00	3	G	A77	-98.8158	38.0176	-43928.	127597.	12.55	14.31	13	15	1
026106-00	23	14W	34	CDDC	750.00	88.00	3	G	A77	-98.8502	38.0006	-46942.	125718.	12.30	12.13	13	13	1
027456-00	23	15W	1	CBBB	690.00	195.00	3	G	A77	-98.9303	38.0797	-53876.	134588.	5.35	12.18	6	13	1
026147-00	23	15W	4	DCAA	825.00	182.00	3	G	A77	-98.9726	38.0760	-57568.	134204.	4.11	10.25	5	11	1
025453-00	23	15W	18	CDBB	920.00	180.00	3	G	A77	-99.0166	38.0469	-61432.	130988.	4.19	7.14	5	8	0
025845-00	23	15W	25	ADBB	625.00	183.00	3	G	A77	-98.9168	38.0253	-52737.	128515.	8.72	10.40	9	11	1
025846-00	23	15W	25	DDBB	720.00	195.00	3	G	A77	-98.9168	38.0181	-52743.	127711.	9.11	10.09	10	11	1
028185-00	23	15W	31	DCCC	675.00	195.00	3	G	A77	-99.0126	38.0007	-61121.	125826.	6.81	5.31	7	6	0
026598-00	23	16W	12	ABDD	570.00	162.00	3	G	A77	-99.0268	38.0696	-62304.	133522.	2.63	7.69	3	8	0
025866-00	23	16W	20	BCDB	1095.00	227.00	3	G	A77	-99.1106	38.0376	-69647.	130018.	1.50	2.79	2	3	0
025406-00	23	16W	36	DDBB	800.00	125.00	3	G	A77	-99.0258	38.0034	-62269.	126140.	6.21	4.87	7	5	0
026018-00	23	17W	26	ADDD	785.00	177.00	3	G	A77	-99.1507	38.0222	-73154.	128323.	0.98	0.44	1	1	0
028046-00	23	17W	36	ADBB	690.00	152.00	3	G	A77	-99.1359	38.0103	-71877.	126985.	2.12	0.54	3	1	0
025788-00	24	12W	17	BAC	0.00	198.00	3	G	A77	-98.6672	37.9672	-30983.	121911.	20.28	18.40	21	19	0
026187-00	24	12W	21	BDBB	1000.00	240.00	3	G	A77	-98.6496	37.9511	-29449.	120111.	21.74	18.45	22	19	0
026688-00	24	13W	2	ACB	2000.00	388.00	3	G	A77	-98.7180	37.9947	-35409.	125006.	17.08	17.45	18	18	1

Appendix 1. Well data (cont)

(a) Well id, township, range, section, quarter-section					(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code	(e) Year		(f, g) Longitude (deg)	Latitude (deg)	(h, i) Albers x (m)	Albers y (m)	(j, k) Grid row/col. (mi)		(l, m) Grid index row/col		(n) cell activ.
025596-00	24	13W	8	ADBB	1105.00	195.00	3	G	A77	-98.7694	37.9808	-39899.	123476.	16.09	14.68	17	15	1
026810-00	24	13W	20	CDD	900.00	228.00	3	G	A77	-98.7758	37.9424	-40482.	119190.	17.95	12.76	18	13	1
027146-00	24	14W	1	CDCB	500.00	18.00	3	G	A77	-98.8155	37.9866	-43924.	124138.	14.23	12.99	15	13	1
025859-00	24	14W	8	CDBB	760.00	106.00	3	G	A77	-98.8891	37.9742	-50358.	122789.	12.41	9.35	13	10	1
026049-00	24	14W	14	CDBB	1000.00	240.00	3	G	A77	-98.8339	37.9593	-45547.	121100.	15.08	11.04	16	12	1
026153-00	24	14W	25	CDBB	880.00	195.00	3	G	A77	-98.8155	37.9303	-43957.	117853.	17.26	10.56	18	11	1
026756-00	24	15W	27	CDBB	900.00	216.00	3	G	A77	-98.9620	37.9305	-56764.	117957.	12.29	4.40	13	5	-1
025809-00	24	15W	28	BCBB	1500.00	240.00	3	G	A77	-98.9850	37.9378	-58762.	118792.	11.12	3.75	12	4	0
025811-00	24	15W	28	CCBB	1500.00	218.00	3	G	A77	-98.9849	37.9305	-58763.	117969.	11.52	3.43	12	4	0
025810-00	24	15W	29	ADBB	1000.00	240.00	3	G	A77	-98.9896	37.9378	-59165.	118794.	10.96	3.55	11	4	0
027396-00	24	16W	4	BDBB	1000.00	195.00	3	G	A77	-99.0901	37.9959	-67898.	125346.	4.44	1.84	5	2	0
027397-00	24	16W	5	ACAA	1000.00	195.00	3	G	A77	-99.1005	37.9959	-68800.	125349.	4.09	1.41	5	2	0
025910-00	24	16W	5	CACC	795.00	195.00	3	G	A77	-99.1084	37.9894	-69495.	124638.	4.17	0.80	5	1	0
027398-00	24	16W	8	CACC	980.00	195.00	3	G	A77	-99.1083	37.9749	-69506.	123015.	4.95	0.17	5	1	0
025971-00	24	16W	11	CBDD	865.00	195.00	3	G	A77	-99.0545	37.9750	-64807.	122992.	6.76	2.43	7	3	0
025514-00	24	16W	12	ADBB	850.00	233.00	3	G	A77	-99.0260	37.9816	-62307.	123701.	7.38	3.92	8	4	0
025621-00	24	16W	16	ACAA	930.00	195.00	3	G	A77	-99.0821	37.9667	-67220.	122086.	6.28	0.92	7	1	0
025637-00	25	13W	7	BDBB	1035.00	195.00	3	G	A77	-98.7970	37.8939	-42366.	113788.	19.84	9.77	20	10	0
025473-00	25	13W	8	CDBB	1000.00	240.00	3	G	A77	-98.7786	37.8866	-40755.	112964.	20.86	10.23	21	11	0
026015-00	25	13W	10	ADBB	1200.00	231.00	3	G	A77	-98.7322	37.8936	-36695.	113726.	22.05	12.49	23	13	0
025638-00	25	13W	16	ABDD	1050.00	195.00	3	G	A77	-98.7520	37.8801	-38433.	112227.	22.10	11.07	23	12	0
025692-00	25	13W	19	ADBB	1000.00	231.00	3	G	A77	-98.7877	37.8648	-41565.	110533.	21.72	8.91	22	9	0
025693-00	25	13W	19	BDBB	785.00	195.00	3	G	A77	-98.7969	37.8648	-42369.	110542.	21.41	8.52	22	9	0
026225-00	25	13W	19	CACC	1100.00	195.00	3	G	A77	-98.7968	37.8585	-42368.	109832.	21.75	8.25	22	9	0
027032-00	25	14W	2	CDBB	1000.00	240.00	3	G	A77	-98.8337	37.9013	-45567.	114625.	18.20	8.54	19	9	1
026344-00	25	14W	15	DDBB	995.00	195.00	3	G	A77	-98.8427	37.8722	-46375.	111383.	19.46	6.90	20	7	1
025694-00	25	14W	24	DDBB	900.00	195.00	3	G	A77	-98.8060	37.8576	-43171.	109737.	21.49	7.82	22	8	0
025520-00	25	14W	30	BDBB	980.00	180.00	3	G	A77	-98.9070	37.8503	-52016.	108975.	18.46	3.25	19	4	1
025519-00	25	14W	32	DDBB	915.00	195.00	3	G	A77	-98.8793	37.8284	-49608.	106522.	20.58	3.47	21	4	1
026894-00	25	15W	17	ADBB	3200.00	960.00	3	G	A77	-98.9896	37.8795	-59215.	112281.	14.10	1.03	15	2	0
026398-00	25	15W	21	BDBB	1800.00	480.00	3	G	A77	-98.9804	37.8648	-58425.	110638.	15.20	0.78	16	1	0
026152-00	25	15W	25	DCBB	915.00	195.00	3	G	A77	-98.9207	37.8430	-53214.	108170.	18.39	2.36	19	3	1
028044-00	25	16W	1	CDBB	1000.00	240.00	3	G	A77	-99.0352	37.9013	-63182.	114748.	11.38	0.06	12	1	0
026094-00	26	14W	4	BACC	1175.00	198.00	3	G	A77	-98.8623	37.8211	-48117.	105697.	21.55	3.88	22	4	0
026853-00	26	14W	5	AACC	1000.00	276.00	3	G	A77	-98.8714	37.8211	-48915.	105698.	21.24	3.49	22	4	0
025521-00	26	14W	5	BABB	1000.00	201.00	3	G	A77	-98.8804	37.8247	-49706.	106102.	20.74	3.26	21	4	1

Appendix 1. Well data (cont)

(a) Well id, township, range, section, quarter-section					(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code	(e) Year		(f, g) Longitude (deg)	Latitude (deg)	(h, i) Albers x (m)	Albers y (m)	(j, k) Grid row/col. (mi)		(l, m) Grid index row/col		(n) cell activ.
027245-00	26	14W	7	BDBB	900.00	180.00	3	G	A77	-98.8983	37.8017	-51282.	103550.	21.37	1.52	22	2	-1
026095-00	26	15W	1	AABB	1125.00	201.00	3	G	A77	-98.9072	37.8247	-52044.	106123.	19.83	2.14	20	3	1
028493-00	19	11W	19	BDD	1000.00	94.90	3	G	A78	-98.5824	38.3848	-23433.	168495.	0.62	39.95	1	40	0
030299-00	20	10W	29	CAC	1300.00	248.00	3	G	A78	-98.4555	38.2796	-12432.	156726.	10.54	40.76	11	41	0
028364-00	20	11W	5	ABDC	1800.00	234.00	3	G	A78	-98.5595	38.3443	-21463.	163969.	3.56	39.16	4	40	0
028944-00	20	11W	11	ACAA	690.00	195.00	3	G	A78	-98.5030	38.3288	-16559.	162221.	6.29	40.87	7	41	0
028436-00	20	11W	19	ACDD	705.00	189.00	3	G	A78	-98.5768	38.2977	-22980.	158766.	5.50	36.43	6	37	0
029384-00	20	11W	33	DDAA	785.00	155.00	3	G	A78	-98.5355	38.2644	-19401.	155048.	8.68	36.74	9	37	1
030874-00	20	12W	1	ACBA	720.00	158.00	3	G	A78	-98.5975	38.3439	-24764.	163929.	2.32	37.55	3	38	0
028437-00	20	12W	24	DDBB	715.00	189.00	3	G	A78	-98.5940	38.2932	-24478.	158271.	5.17	35.51	6	36	0
030962-00	20	13W	24	ACAA	845.00	195.00	3	G	A78	-98.7055	38.3004	-34171.	159109.	1.04	31.14	2	32	0
028359-00	20	13W	25	ACAD	895.00	201.00	3	G	A78	-98.7055	38.2850	-34178.	157391.	1.87	30.48	2	31	0
030303-00	21	9W	27	DACB	815.00	203.00	3	G	A78	-98.2928	38.1929	1718.	147043.	20.66	43.89	21	44	0
029463-00	21	9W	35	BCAB	690.00	113.00	3	G	A78	-98.2859	38.1839	2321.	146036.	21.38	43.79	22	44	0
028807-00	21	10W	1	BDBB	850.00	233.00	3	G	A78	-98.3750	38.2567	-5435.	154160.	14.47	43.16	15	44	0
031015-00	21	10W	3	CACD	925.00	247.50	3	G	A78	-98.4108	38.2505	-8552.	153474.	13.60	41.39	14	42	0
030355-00	21	12W	5	AACC	1000.00	97.50	3	G	A78	-98.6597	38.2577	-30204.	154332.	4.88	31.23	5	32	0
029385-00	21	12W	11	BDBB	900.00	240.00	3	G	A78	-98.6137	38.2423	-26207.	152596.	7.25	32.50	8	33	1
028820-00	21	12W	14	CACC	875.00	198.00	3	G	A78	-98.6139	38.2213	-26230.	150251.	8.38	31.59	9	32	1
028819-00	21	12W	23	ABDD	810.00	195.00	3	G	A78	-98.6059	38.2139	-25537.	149429.	9.04	31.61	10	32	1
028818-00	21	12W	23	BDBA	900.00	195.00	3	G	A78	-98.6128	38.2130	-26140.	149330.	8.86	31.28	9	32	1
028822-00	21	12W	23	DBCC	900.00	201.00	3	G	A78	-98.6094	38.2066	-25846.	148608.	9.32	31.14	10	32	1
030697-00	21	14W	13	ADBB	1000.00	240.00	3	G	A78	-98.8064	38.2283	-42987.	151106.	1.53	23.80	2	24	0
029947-00	21	14W	22	DACC	765.00	195.00	3	G	A78	-98.8432	38.2074	-46202.	148795.	1.41	21.35	2	22	0
030458-00	21	14W	23	DDBB	1200.00	240.00	3	G	A78	-98.8249	38.2065	-44607.	148681.	2.08	22.08	3	23	1
029269-00	21	14W	28	ADBB	900.00	227.00	3	G	A78	-98.8616	38.1993	-47804.	147904.	1.23	20.24	2	21	0
029270-00	21	14W	33	BCBB	1200.00	120.00	3	G	A78	-98.8754	38.1848	-49019.	146288.	1.55	19.03	2	20	0
030431-00	22	10W	4	CDBB	575.00	86.00	3	G	A78	-98.4305	38.1617	-10279.	143566.	17.74	36.74	18	37	1
030415-00	22	10W	5	DDBB	1000.00	240.00	3	G	A78	-98.4398	38.1616	-11089.	143559.	17.43	36.35	18	37	1
030763-00	22	12W	25	DCC	350.00	23.00	3	G	A78	-98.5904	38.1011	-24224.	136836.	15.64	27.41	16	28	1
028867-00	22	13W	2	CAC	1200.00	200.00	3	G	A78	-98.7236	38.1635	-35807.	143844.	7.80	24.49	8	25	1
029067-00	22	13W	3	DCCC	810.00	132.00	3	G	A78	-98.7380	38.1596	-37066.	143406.	7.53	23.71	8	24	1
029788-00	22	13W	4	AACB	1000.00	156.00	3	G	A78	-98.7519	38.1714	-38268.	144735.	6.43	23.64	7	24	1
031102-00	22	13W	10	DCAA	1500.00	240.00	3	G	A78	-98.7344	38.1478	-36757.	142091.	8.29	23.35	9	24	1
029417-00	22	13W	20	BDBB	790.00	195.00	3	G	A78	-98.7792	38.1264	-40672.	139720.	7.93	20.55	8	21	1
028869-00	22	13W	24	CCA	1200.00	200.00	3	G	A78	-98.7071	38.1183	-34398.	138794.	10.79	23.23	11	24	1

Appendix 1. Well data (cont)

(a) Well id, township, range, section, quarter-section					(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code	(e) Year		(f, g) Longitude (deg)	Latitude (deg)	(h, i) Albers x (m)	Albers y (m)	(j, k) Grid row/col. (mi)		(l, m) Grid index row/col		(n) cell activ.
030652-00	22	14W	7	BDBB	1000.00	225.00	3	G	A78	-98.9071	38.1558	-51802.	143075.	2.03	16.45	3	17	1
028592-00	22	14W	8	ACBB	1600.00	240.00	3	G	A78	-98.8846	38.1558	-49837.	143052.	2.80	17.39	3	18	1
029811-00	22	14W	11	BCAA	775.00	180.00	3	G	A78	-98.8351	38.1555	-45531.	143002.	4.48	19.45	5	20	1
029455-00	22	15W	14	ACDA	700.00	117.00	3	G	A78	-98.9358	38.1396	-54309.	141279.	1.94	14.54	2	15	0
029271-00	22	15W	16	CDBB	620.00	103.00	3	G	A78	-98.9805	38.1342	-58213.	140705.	0.72	12.43	1	13	0
030086-00	22	15W	28	CBC	800.00	198.00	3	G	A78	-98.9844	38.1065	-58575.	137618.	2.07	11.07	3	12	1
029334-00	23	13W	13	ADBB	1100.00	240.00	3	G	A78	-98.6960	38.0533	-33456.	131533.	14.67	20.90	15	21	1
029825-00	23	13W	26	BACC	800.00	195.00	3	G	A78	-98.7235	38.0252	-35872.	128403.	15.25	18.53	16	19	1
030385-00	23	13W	27	ADBB	800.00	192.00	3	G	A78	-98.7327	38.0243	-36672.	128309.	14.99	18.10	15	19	1
028568-00	23	13W	29	DDDD	1205.00	180.00	3	G	A78	-98.7662	38.0146	-39606.	127238.	14.38	16.27	15	17	1
028679-00	23	14W	6	DDBB	1000.00	240.00	3	G	A78	-98.8984	38.0760	-51099.	134157.	6.62	13.36	7	14	1
028508-00	23	14W	8	ACAA	860.00	195.00	3	G	A78	-98.8812	38.0686	-49602.	133328.	7.60	13.77	8	14	1
029631-00	23	15W	3	CCAA	775.00	195.00	3	G	A78	-98.9635	38.0760	-56778.	134201.	4.42	10.63	5	11	1
028625-00	23	15W	8	ADBB	710.00	178.00	3	G	A78	-98.9896	38.0687	-59059.	133404.	3.93	9.22	4	10	1
029633-00	23	15W	9	BDBB	1200.00	240.00	3	G	A78	-98.9805	38.0687	-58269.	133399.	4.23	9.60	5	10	1
029186-00	23	15W	23	ABAA	535.00	90.00	3	G	A78	-98.9362	38.0434	-54419.	130538.	7.10	10.36	8	11	1
029185-00	23	15W	23	DCAA	675.00	173.00	3	G	A78	-98.9362	38.0325	-54426.	129330.	7.68	9.90	8	10	1
029135-00	23	15W	26	CDBB	580.00	195.00	3	G	A78	-98.9442	38.0181	-55138.	127729.	8.18	8.94	9	9	1
029632-00	23	16W	24	ADBB	1200.00	240.00	3	G	A78	-99.0256	38.0397	-62224.	130184.	4.27	6.45	5	7	0
030172-00	23	16W	30	CCBC	770.00	239.00	3	G	A78	-99.1313	38.0167	-71467.	127694.	1.93	1.02	2	2	0
030407-00	23	16W	34	CCAA	735.00	183.00	3	G	A78	-99.0728	38.0032	-66375.	126152.	4.63	2.89	5	3	0
028388-00	24	13W	36	DDBB	750.00	165.00	3	G	A78	-98.6951	37.9151	-33445.	116105.	22.14	14.98	23	15	0
028768-00	24	14W	31	BDBB	1000.00	240.00	3	G	A78	-98.9071	37.9232	-51972.	117109.	14.54	6.39	15	7	1
028312-00	24	15W	31	DDBB	900.00	240.00	3	G	A78	-99.0077	37.9160	-60770.	116366.	11.52	1.84	12	2	0
029937-00	24	16W	4	DDBB	850.00	126.00	3	G	A78	-99.0809	37.9887	-67095.	124532.	5.14	1.92	6	2	0
030171-00	24	16W	5	BDBB	915.00	195.00	3	G	A78	-99.1084	37.9958	-69493.	125351.	3.82	1.07	4	2	0
028495-00	24	16W	13	DBCC	1200.00	195.00	3	G	A78	-99.0306	37.9606	-62726.	121367.	8.35	2.82	9	3	0
030453-00	24	16W	24	BDBB	1000.00	240.00	3	G	A78	-99.0351	37.9524	-63133.	120452.	8.64	2.27	9	3	0
031021-00	24	16W	35	BDBB	0.00	120.00	3	G	A78	-99.0534	37.9232	-64759.	117207.	9.58	0.24	10	1	0
031020-00	24	16W	35	BDBB	1200.00	120.00	3	G	A78	-99.0534	37.9232	-64759.	117207.	9.58	0.24	10	1	0
030194-00	25	15W	20	DBBB	865.00	204.00	3	G	A78	-98.9943	37.8611	-59641.	110241.	14.92	0.04	15	1	0
029953-00	25	15W	26	DDCC	1500.00	240.00	3	G	A78	-98.9344	37.8402	-54418.	107871.	18.08	1.66	19	2	-1
029954-00	25	15W	36	CCB	800.00	120.00	3	G	A78	-98.9292	37.8281	-53968.	106509.	18.91	1.35	19	2	-1
029306-00	26	14W	19	BDBB	1000.00	240.00	3	G	A78	-98.8982	37.7726	-51300.	100308.	22.94	0.26	23	1	0
031251-00	20	12W	13	CACC	645.00	145.00	3	G	A79	-98.6032	38.3086	-25274.	159999.	4.02	35.79	5	36	0
031418-00	20	12W	31	BDBB	700.00	178.00	3	G	A79	-98.6951	38.2713	-33279.	155863.	2.95	30.33	3	31	0

Appendix 1. Well data (cont)

(a) Well id, township, range, section, quarter-section					(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code	(e) Year		(f, g) Longitude (deg)	Latitude (deg)	(h, i) Albers x (m)	Albers y (m)	(j, k) Grid row/col. (mi)		(l, m) Grid index row/col		(n) cell activ.
032253-00	21	12W	1	ACAA	990.00	201.00	3	G	A79	-98.5871	38.2569	-23885.	154223.	7.35	34.25	8	35	1
031196-00	21	14W	1	DDB	2200.00	480.00	3	G	A79	-98.8060	38.2496	-42934.	153483.	0.40	24.74	1	25	0
032179-00	21	14W	12	DDBB	1000.00	240.00	3	G	A79	-98.8065	38.2355	-42986.	151916.	1.14	24.11	2	25	0
032463-00	21	14W	15	ACAA	720.00	169.00	3	G	A79	-98.8444	38.2283	-46293.	151131.	0.25	22.21	1	23	0
031303-00	21	14W	22	CDBB	1000.00	240.00	3	G	A79	-98.8524	38.2066	-46999.	148707.	1.15	20.93	2	21	0
032122-00	22	13W	25	BDBB	915.00	195.00	3	G	A79	-98.7054	38.1115	-34249.	138033.	11.21	23.01	12	24	1
031294-00	22	13W	26	ADBB	1000.00	240.00	3	G	A79	-98.7146	38.1116	-35049.	138042.	10.90	22.63	11	23	1
031344-00	22	13W	28	CDBB	865.00	195.00	3	G	A79	-98.7605	38.1044	-39056.	137258.	9.74	20.38	10	21	1
032365-00	22	14W	16	DDBB	1100.00	240.00	3	G	A79	-98.8616	38.1338	-47847.	140594.	4.75	17.41	5	18	1
031946-00	22	15W	15	CBCB	535.00	120.00	3	G	A79	-98.9667	38.1360	-57011.	140898.	1.09	13.09	2	14	0
031216-00	22	15W	16	DDBB	1200.00	120.00	3	G	A79	-98.9713	38.1342	-57414.	140699.	1.03	12.82	2	13	0
031217-00	22	15W	16	DDBB	0.00	120.00	3	G	A79	-98.9713	38.1342	-57414.	140699.	1.03	12.82	2	13	0
032016-00	22	15W	34	CCAA	710.00	138.00	3	G	A79	-98.9634	38.0906	-56754.	135828.	3.64	11.26	4	12	1
032015-00	22	15W	35	CCAA	850.00	171.00	3	G	A79	-98.9451	38.0906	-55159.	135820.	4.26	12.03	5	13	1
031830-00	22	15W	35	DACC	0.00	63.00	3	G	A79	-98.9348	38.0915	-54259.	135913.	4.56	12.51	5	13	1
031622-00	22	15W	35	DACC	720.00	65.00	3	G	A79	-98.9348	38.0915	-54259.	135913.	4.56	12.51	5	13	1
031436-00	23	12W	22	CAD	1300.00	212.00	3	G	A79	-98.6289	38.0322	-27611.	129155.	18.06	22.82	19	23	0
032151-00	23	13W	32	ACCC	655.00	132.00	3	G	A79	-98.7742	38.0073	-40308.	126433.	14.51	15.62	15	16	1
031733-00	23	13W	34	CACA	600.00	30.00	3	G	A79	-98.7406	38.0044	-37375.	126088.	15.80	16.91	16	17	1
032087-00	23	14W	6	CDBB	600.00	144.00	3	G	A79	-98.9075	38.0760	-51894.	134166.	6.31	12.98	7	13	1
032316-00	23	14W	17	DDBB	1200.00	233.00	3	G	A79	-98.8800	38.0469	-49517.	130906.	8.80	12.88	9	13	1
031681-00	23	14W	28	BACB	250.00	69.00	3	G	A79	-98.8708	38.0270	-48727.	128679.	10.18	12.41	11	13	1
031454-00	23	15W	21	ABDD	400.00	89.00	3	G	A79	-98.9729	38.0406	-57621.	130255.	6.01	8.70	7	9	1
031458-00	23	15W	21	DCAA	400.00	97.50	3	G	A79	-98.9729	38.0325	-57629.	129348.	6.44	8.35	7	9	1
031749-00	23	15W	25	BDBC	495.00	136.00	3	G	A79	-98.9259	38.0244	-53533.	128419.	8.47	9.98	9	10	1
032106-00	23	15W	26	DDBB	780.00	120.00	3	G	A79	-98.9350	38.0181	-54337.	127724.	8.49	9.32	9	10	1
032028-00	23	15W	36	BDAA	550.00	121.00	3	G	A79	-98.9225	38.0109	-53245.	126909.	9.31	9.54	10	10	1
031425-00	23	16W	8	ADAA	655.00	167.00	3	G	A79	-99.0958	38.0685	-68325.	133449.	0.35	4.75	1	5	0
031623-00	23	16W	11	BCAB	1000.00	240.00	3	G	A79	-99.0555	38.0686	-64804.	133438.	1.71	6.45	2	7	0
031430-00	23	16W	23	BDBB	725.00	198.00	3	G	A79	-99.0533	38.0396	-64637.	130199.	3.34	5.28	4	6	0
031428-00	23	16W	23	CCAA	725.00	198.00	3	G	A79	-99.0544	38.0324	-64743.	129389.	3.69	4.92	4	5	0
031429-00	23	16W	23	DACC	645.00	198.00	3	G	A79	-99.0440	38.0333	-63837.	129483.	3.99	5.40	4	6	0
031972-00	23	16W	36	DDBB	100.00	70.00	3	G	A79	-99.0258	38.0034	-62269.	126140.	6.21	4.87	7	5	0
032393-00	23	17W	23	DDAA	410.00	121.00	3	G	A79	-99.1506	38.0322	-73142.	129444.	0.44	0.88	1	1	0
031556-00	24	12W	19	CCC	950.00	234.00	3	G	A79	-98.6899	37.9419	-32978.	119100.	20.87	16.35	21	17	0
031318-00	24	13W	26	AAD	500.00	26.00	3	G	A79	-98.7108	37.9384	-34807.	118714.	20.36	15.32	21	16	0

Appendix 1. Well data (cont)

(a) Well id, township, range, section, quarter-section					(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code	(e) Year		(f, g) Longitude (deg)	Latitude (deg)	(h, i) Albers x (m)	Albers y (m)	(j, k) Grid row/col. (mi)		(l, m) Grid index row/col		(n) cell activ.
032348-00	24	13W	28	ACBB	1380.00	150.00	3	G	A79	-98.7553	37.9372	-38692.	118602.	18.92	13.40	19	14	1
032530-00	24	13W	28	DDBB	1200.00	240.00	3	G	A79	-98.7506	37.9300	-38291.	117789.	19.47	13.28	20	14	0
031157-00	24	14W	2	BDBB	1065.00	195.00	3	G	A79	-98.8341	37.9959	-45538.	125183.	13.10	12.61	14	13	1
032415-00	24	15W	2	ADBB	920.00	195.00	3	G	A79	-98.9350	37.9964	-54350.	125292.	9.67	8.38	10	9	1
031392-00	24	15W	30	CDBB	1000.00	234.00	3	G	A79	-99.0169	37.9305	-61555.	117992.	10.43	2.09	11	3	0
031201-00	25	13W	10	CCAA	835.00	195.00	3	G	A79	-98.7427	37.8864	-37616.	112928.	22.08	11.74	23	12	0
031535-00	25	14W	1	ADBB	1000.00	240.00	3	G	A79	-98.8063	37.9085	-43163.	115420.	18.74	10.01	19	11	1
031200-00	25	14W	1	BBD	1200.00	240.00	3	G	A79	-98.8171	37.9099	-44111.	115578.	18.30	9.61	19	10	1
032505-00	25	14W	19	CDBB	865.00	155.00	3	G	A79	-98.9071	37.8576	-52015.	109787.	18.07	3.56	19	4	1
032772-00	20	10W	35	DDDC	600.00	119.00	3	G	A80	-98.3894	38.2612	-6688.	154665.	13.74	42.75	14	43	0
032972-00	20	11W	19	DDAB	28.00	7.70	6	G	A80	-98.5734	38.2931	-22681.	158261.	5.86	36.38	6	37	0
033696-00	20	11W	31	CCAA	1010.00	170.00	3	G	A80	-98.5859	38.2643	-23780.	155041.	7.00	34.61	7	35	0
033655-00	20	12W	5	CCAA	825.00	195.00	3	G	A80	-98.6782	38.3365	-31777.	163133.	0.01	33.85	1	34	0
033447-00	21	11W	6	ABBD	335.00	24.00	5	G	A80	-98.5710	38.2598	-22488.	154538.	7.74	35.04	8	36	1
033726-00	21	12W	2	DDBB	1000.00	6.00	3	G	A80	-98.6044	38.2496	-25400.	153408.	7.17	33.20	8	34	1
033725-00	21	12W	5	AACC	0.00	97.50	3	G	A80	-98.6597	38.2577	-30204.	154332.	4.88	31.23	5	32	0
033520-00	21	13W	4	BBB	1000.00	240.00	3	G	A80	-98.7648	38.2600	-39348.	154626.	1.22	26.91	2	27	0
033375-00	21	13W	32	BDBB	980.00	198.00	3	G	A80	-98.7795	38.1845	-40667.	146212.	4.79	23.04	5	24	1
033195-00	21	14W	26	DDBB	765.00	195.00	3	G	A80	-98.8249	38.1920	-44612.	147061.	2.86	21.46	3	22	1
033348-00	21	14W	30	CDBB	1200.00	222.00	3	G	A80	-98.9070	38.1921	-51768.	147122.	0.09	18.02	1	19	0
032764-00	22	13W	16	BDBB	1200.00	240.00	3	G	A80	-98.7608	38.1407	-39064.	141312.	7.78	21.94	8	22	1
033044-00	22	14W	6	CDBB	1000.00	240.00	3	G	A80	-98.9071	38.1631	-51794.	143885.	1.64	16.76	2	17	0
032732-00	22	14W	8	CDBB	1200.00	240.00	3	G	A80	-98.8892	38.1485	-50242.	142246.	3.03	16.88	4	17	1
032643-00	22	14W	35	CACC	800.00	195.00	3	G	A80	-98.8338	38.0911	-45457.	135808.	7.99	16.73	8	17	1
033350-00	22	15W	34	DCAA	840.00	194.00	3	G	A80	-98.9542	38.0906	-55957.	135824.	3.95	11.65	4	12	1
033066-00	23	13W	16	BDBB	1130.00	180.00	3	G	A80	-98.7604	38.0535	-39079.	131584.	12.48	18.19	13	19	1
032997-00	23	13W	20	ACC	1200.00	191.00	3	G	A80	-98.7738	38.0368	-40257.	129722.	12.93	16.91	13	17	1
033456-00	23	14W	4	ADBB	1000.00	240.00	3	G	A80	-98.8615	38.0830	-47878.	134925.	7.49	15.22	8	16	1
033266-00	23	14W	18	BDBB	1000.00	225.00	3	G	A80	-98.9076	38.0543	-51916.	131737.	7.48	12.04	8	13	1
032642-00	23	14W	23	DDBB	365.00	128.00	3	G	A80	-98.8248	38.0322	-44711.	129228.	11.46	14.56	12	15	1
033440-00	23	14W	30	DCBB	1000.00	240.00	3	G	A80	-98.9030	38.0181	-51542.	127700.	9.58	10.67	10	11	1
032992-00	23	15W	12	DAA	1200.00	240.00	3	G	A80	-98.9138	38.0647	-52454.	132904.	6.71	12.22	7	13	1
033064-00	23	15W	25	CABB	270.00	35.00	3	G	A80	-98.9259	38.0217	-53535.	128118.	8.61	9.86	9	10	1
033483-00	24	12W	4	CDBB	900.00	198.00	3	G	A80	-98.6497	37.9875	-29448.	124174.	19.77	20.01	20	21	0
033014-00	24	13W	13	CBDA	1000.00	65.00	3	G	A80	-98.7056	37.9606	-34342.	121192.	19.33	16.50	20	17	0
033513-00	24	14W	1	BDBB	1000.00	240.00	3	G	A80	-98.8156	37.9958	-43927.	125161.	13.73	13.38	14	14	1

Appendix 1. Well data (cont)

(a) Well id, township, range, section, quarter-section					(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code	(e) Year		(f, g) Longitude (deg)	Latitude (deg)	(h, i) Albers x (m)	Albers y (m)	(j, k) Grid row/col. (mi)		(l, m) Grid index row/col		(n) cell activ.
032934-00	24	15W	28	DDBB	1100.00	198.00	3	G	A80	-98.9712	37.9305	-57564.	117962.	11.98	4.01	12	5	0
032561-00	24	16W	10	DDBB	865.00	181.00	3	G	A80	-99.0626	37.9741	-65510.	122890.	6.54	2.05	7	3	0
033244-00	25	13W	30	ADCC	705.00	135.00	3	G	A80	-98.7876	37.8475	-41568.	108609.	22.65	8.17	23	9	0
033494-00	25	14W	19	DDBB	1000.00	240.00	3	G	A80	-98.8979	37.8576	-51213.	109782.	18.38	3.94	19	4	1
033011-00	25	14W	23	DDBB	1200.00	237.00	3	G	A80	-98.8243	37.8576	-44769.	109747.	20.87	7.05	21	8	0
034303-00	19	11W	27	DBCA	365.00	47.00	3	G	A81	-98.5243	38.3667	-18400.	166465.	3.53	41.60	4	42	0
034302-00	19	11W	27	DBCC	455.00	58.00	3	G	A81	-98.5255	38.3658	-18498.	166363.	3.54	41.52	4	42	0
034014-00	20	10W	26	CCB	90.00	19.95	4	G	A81	-98.4051	38.2775	-8055.	156482.	12.34	42.78	13	43	0
034094-00	20	11W	9	ADDB	1000.00	240.00	3	G	A81	-98.5365	38.3276	-19471.	162098.	5.24	39.41	6	40	0
034368-00	20	12W	4	BDBB	1000.00	228.00	3	G	A81	-98.6586	38.3436	-30075.	163916.	0.28	34.97	1	35	0
034785-00	20	12W	22	DDBB	1000.00	237.00	3	G	A81	-98.6309	38.2933	-27686.	158293.	3.92	33.97	4	34	0
033857-00	20	12W	31	ADBB	1000.00	240.00	3	G	A81	-98.6860	38.2713	-32481.	155858.	3.26	30.71	4	31	0
034747-00	20	13W	23	DCAA	345.00	99.00	3	G	A81	-98.7241	38.2932	-35788.	158312.	0.80	30.05	1	31	0
034128-00	20	13W	35	BDBB	1000.00	240.00	3	G	A81	-98.7320	38.2713	-36490.	155877.	1.71	28.78	2	29	0
034192-00	20	13W	36	DACC	920.00	209.00	3	G	A81	-98.7043	38.2649	-34078.	155156.	2.99	29.67	3	30	0
034008-00	21	12W	9	CDBB	1100.00	240.00	3	G	A81	-98.6506	38.2350	-29425.	151793.	6.40	30.63	7	31	1
033885-00	21	12W	28	DDBB	1000.00	120.00	3	G	A81	-98.6419	38.1910	-28681.	146879.	9.07	29.10	10	30	1
034459-00	21	12W	34	ADC	1100.00	240.00	3	G	A81	-98.6231	38.1813	-27046.	145795.	10.22	29.48	11	30	1
033849-00	21	14W	14	DDBB	900.00	240.00	3	G	A81	-98.8249	38.2210	-44600.	150305.	1.30	22.71	2	23	0
034468-00	22	13W	30	DDBB	1000.00	135.00	3	G	A81	-98.7880	38.1046	-41451.	137294.	8.81	19.24	9	20	1
033895-00	22	14W	19	CDBB	1000.00	240.00	3	G	A81	-98.9073	38.1196	-51844.	139030.	3.98	14.87	4	15	1
034607-00	22	14W	21	DDBC	1000.00	240.00	3	G	A81	-98.8614	38.1185	-47844.	138880.	5.58	16.75	6	17	1
034028-00	22	15W	30	CDBB	605.00	169.00	3	G	A81	-99.0166	38.1051	-61382.	137478.	1.06	9.66	2	10	0
034029-00	22	16W	36	CDBB	620.00	164.00	3	G	A81	-99.0348	38.0905	-62984.	135864.	1.23	8.26	2	9	-1
034676-00	23	11W	21	BDAA	750.00	75.00	3	G	A81	-98.5370	38.0377	-19588.	129747.	20.86	26.93	21	27	0
034661-00	23	11W	21	DABB	1000.00	240.00	3	G	A81	-98.5312	38.0341	-19085.	129346.	21.24	27.02	22	28	0
033825-00	23	11W	22	BCCB	0.00	120.00	3	G	A81	-98.5266	38.0359	-18684.	129547.	21.30	27.29	22	28	0
033744-00	23	12W	15	BDBB	1000.00	236.00	3	G	A81	-98.6319	38.0527	-27868.	131438.	16.86	23.57	17	24	1
034463-00	23	13W	14	ADBB	290.00	102.00	3	G	A81	-98.7144	38.0534	-35063.	131546.	14.04	20.12	15	21	1
034469-00	23	13W	14	BCAA	995.00	195.00	3	G	A81	-98.7247	38.0534	-35964.	131556.	13.69	19.69	14	20	1
034657-00	23	13W	23	CDBB	1000.00	203.00	3	G	A81	-98.7235	38.0315	-35870.	129113.	14.91	18.80	15	19	1
034472-00	23	13W	28	CDBA	1000.00	44.00	3	G	A81	-98.7593	38.0172	-38995.	127533.	14.48	16.68	15	17	1
034713-00	23	13W	34	BDDB	1000.00	90.00	3	G	A81	-98.7395	38.0080	-37274.	126492.	15.64	17.11	16	18	1
034664-00	23	13W	34	CBD	1000.00	158.00	3	G	A81	-98.7435	38.0039	-37626.	126039.	15.73	16.77	16	17	1
033803-00	23	13W	36	BDA	1000.00	192.00	3	G	A81	-98.7021	38.0092	-34012.	126618.	16.83	18.74	17	19	1
034684-00	23	14W	9	CDBB	1200.00	218.00	3	G	A81	-98.8708	38.0614	-48706.	132509.	8.34	13.89	9	14	1

Appendix 1. Well data (cont)

(a) Well id, township, range, section, quarter-section					(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code	(e) Year		(f, g) Longitude (deg)	Latitude (deg)	(h, i) Albers x (m)	Albers y (m)	(j, k) Grid row/col. (mi)		(l, m) Grid index row/col		(n) cell activ.
034115-00	23	14W	34	DBAB	595.00	165.00	3	G	A81	-98.8456	38.0069	-46537.	126418.	12.12	12.60	13	13	1
034752-00	23	15W	30	ADBB	910.00	175.00	3	G	A81	-99.0082	38.0251	-60715.	128550.	5.64	6.55	6	7	0
034844-00	23	15W	34	DDCD	765.00	152.00	3	G	A81	-98.9521	38.0009	-55845.	125811.	8.84	7.86	9	8	1
034678-00	23	16W	4	CDBB	635.00	109.00	3	G	A81	-99.0900	38.0758	-67811.	134259.	0.15	5.31	1	6	0
034065-00	23	16W	11	BDB	0.00	48.00	3	G	A81	-99.0526	38.0682	-64554.	133385.	1.83	6.55	2	7	0
034281-00	23	16W	31	BDBB	740.00	195.00	3	G	A81	-99.1267	38.0103	-71076.	126981.	2.42	0.93	3	1	0
034417-00	23	16W	31	DBBB	625.00	159.00	3	G	A81	-99.1221	38.0067	-70680.	126574.	2.77	0.97	3	1	0
033899-00	23	16W	34	ADBB	1000.00	240.00	3	G	A81	-99.0625	38.0106	-65470.	126962.	4.59	3.64	5	4	0
034556-00	23	17W	26	DDBB	640.00	189.00	3	G	A81	-99.1541	38.0176	-73458.	127814.	1.11	0.10	2	1	0
034221-00	24	12W	14	BBBB	200.00	55.23	4	G	A81	-98.6178	37.9688	-26662.	122080.	21.85	20.56	22	21	0
034702-00	25	14W	31	CDBC	1000.00	195.00	3	G	A81	-98.9069	37.8276	-52016.	106444.	19.69	2.27	20	3	1
033896-00	25	14W	33	BDBB	715.00	132.00	3	G	A81	-98.8702	37.8357	-48802.	107330.	20.49	4.17	21	5	0
033756-00	26	14W	5	CACB	1145.00	204.00	3	G	A81	-98.8805	37.8126	-49717.	104753.	21.39	2.74	22	3	0
034576-00	26	15W	2	DDBB	1000.00	195.00	3	G	A81	-98.9255	37.8100	-53663.	104493.	20.00	0.73	21	1	0
034444-00	26	15W	13	ADBB	1030.00	198.00	3	G	A81	-98.9072	37.7871	-52079.	101927.	21.85	0.51	22	1	0
034443-00	26	15W	13	DDBB	1200.00	240.00	3	G	A81	-98.9072	37.7798	-52086.	101115.	22.24	0.19	23	1	0
035364-00	19	11W	31	BCDB	200.00	13.50	3	G	A82	-98.5871	38.3564	-23859.	165321.	1.99	38.52	2	39	0
035363-00	19	11W	31	CBBD	200.00	16.00	3	G	A82	-98.5883	38.3537	-23958.	165026.	2.10	38.36	3	39	0
035595-00	19	11W	32	DCBB	350.00	6.75	2	G	A82	-98.5619	38.3505	-21667.	164663.	3.15	39.33	4	40	0
035076-00	20	12W	17	BBDB	500.00	60.00	3	G	A82	-98.6792	38.3167	-31876.	160919.	1.04	32.95	2	33	0
035033-00	20	12W	19	CDBB	1200.00	238.00	3	G	A82	-98.6951	38.2931	-33268.	158293.	1.78	31.27	2	32	0
035191-00	20	13W	25	BDBB	1000.00	240.00	3	G	A82	-98.7137	38.2859	-34884.	157498.	1.54	30.18	2	31	0
035193-00	20	13W	25	CDBB	1000.00	240.00	3	G	A82	-98.7136	38.2786	-34884.	156688.	1.94	29.87	2	30	0
035196-00	20	13W	26	CDCB	805.00	201.00	3	G	A82	-98.7321	38.2768	-36491.	156487.	1.42	29.01	2	30	0
035199-00	20	13W	26	DDDD	815.00	203.00	3	G	A82	-98.7194	38.2759	-35387.	156387.	1.89	29.51	2	30	0
035192-00	20	13W	27	ADBB	1000.00	240.00	3	G	A82	-98.7414	38.2859	-37295.	157505.	0.62	29.01	1	30	0
035624-00	21	14W	27	ADBB	1000.00	180.00	3	G	A82	-98.8432	38.1992	-46207.	147883.	1.85	21.00	2	22	0
034975-00	22	13W	5	ADBB	870.00	189.00	3	G	A82	-98.7702	38.1698	-39868.	144567.	5.89	22.80	6	23	1
035043-00	22	13W	10	DCAA	0.00	51.00	3	G	A82	-98.7344	38.1478	-36757.	142091.	8.29	23.35	9	24	1
035128-00	22	13W	11	BCA	1500.00	233.00	3	G	A82	-98.7258	38.1545	-36007.	142838.	8.21	24.00	9	25	1
034867-00	22	13W	13	BBD	1000.00	200.00	3	G	A82	-98.7073	38.1418	-34402.	141411.	9.52	24.23	10	25	1
035849-00	22	13W	13	CACC	1000.00	200.00	3	G	A82	-98.7055	38.1341	-34248.	140553.	9.99	23.98	10	24	1
035140-00	22	13W	25	ADBB	1500.00	240.00	3	G	A82	-98.6962	38.1114	-33451.	138020.	11.53	23.39	12	24	1
035111-00	22	15W	11	CDDD	1000.00	240.00	3	G	A82	-98.9403	38.1460	-54699.	141992.	1.44	14.63	2	15	0
034920-00	22	15W	28	ABAB	500.00	120.00	3	G	A82	-98.9734	38.1161	-57610.	138682.	1.93	11.95	2	12	0
034921-00	22	15W	28	ABCB	500.00	120.00	3	G	A82	-98.9757	38.1143	-57813.	138479.	1.95	11.77	2	12	0

Appendix 1. Well data (cont)

(a) Well id, township, range, section, quarter-section				(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code	(e) Year		(f, g) Longitude (deg)	Latitude (deg)	(h, i) Albers x (m)	Albers y (m)	(j, k) Grid row/col. (mi)		(l, m) Grid index row/col		(n) cell activ.
035168-00	22	15W 31	DDBB	1200.00	198.00	3	G	A82	-99.0078	38.0905	-60630.	135848.	2.14	9.39	3	10	1
034918-00	22	16W 34	DABB	755.00	195.00	3	G	A82	-99.0624	38.0941	-65383.	136279.	0.11	7.26	1	8	0
035112-00	22	16W 36	ADBB	1100.00	240.00	3	G	A82	-99.0256	38.0978	-62172.	136669.	1.15	8.96	2	9	-1
035332-00	23	13W 25	DDBB	800.00	153.00	3	G	A82	-98.6958	38.0169	-33457.	127475.	16.63	19.34	17	20	1
035677-00	23	14W 32	AACC	300.00	80.00	3	G	A82	-98.8800	38.0117	-49542.	126968.	10.70	11.35	11	12	1
035675-00	23	14W 32	ADBB	300.00	80.00	3	G	A82	-98.8800	38.0107	-49543.	126867.	10.75	11.32	11	12	1
035676-00	23	14W 32	ADBB	300.00	80.00	3	G	A82	-98.8800	38.0107	-49543.	126867.	10.75	11.32	11	12	1
035806-00	23	15W 29	BBBB	845.00	195.00	3	G	A82	-99.0039	38.0288	-60336.	128951.	5.60	6.89	6	7	0
035807-00	23	15W 29	CBBB	900.00	195.00	3	G	A82	-99.0038	38.0215	-60338.	128144.	5.99	6.58	6	7	0
035226-00	23	16W 1	AADA	1000.00	240.00	3	G	A82	-99.0222	38.0850	-61890.	135245.	1.95	8.55	2	9	-1
035103-00	24	13W 28	CDBB	1500.00	230.00	3	G	A82	-98.7600	37.9300	-39105.	117803.	19.15	12.89	20	13	0
035101-00	24	15W 2	CABB	1200.00	240.00	3	G	A82	-98.9441	37.9927	-55150.	124886.	9.55	7.84	10	8	1
035085-00	24	15W 9	BDBB	1200.00	240.00	3	G	A82	-98.9807	37.9816	-58351.	123669.	8.91	5.82	9	6	0
035102-00	24	15W 12	DCCC	1200.00	240.00	3	G	A82	-98.9211	37.9716	-53158.	122519.	11.47	7.89	12	8	1
035100-00	24	15W 14	BBD	1000.00	177.00	3	G	A82	-98.9457	37.9684	-55307.	122179.	10.81	6.72	11	7	1
035003-00	24	15W 28	ADBB	1800.00	240.00	3	G	A82	-98.9713	37.9378	-57565.	118782.	11.58	4.32	12	5	0
035098-00	24	15W 33	ADBB	1200.00	240.00	3	G	A82	-98.9711	37.9231	-57562.	117144.	12.38	3.70	13	4	0
035099-00	24	15W 33	BDBB	1200.00	240.00	3	G	A82	-98.9803	37.9231	-58362.	117148.	12.07	3.31	13	4	0
035097-00	24	15W 33	DAB	1200.00	240.00	3	G	A82	-98.9705	37.9190	-57511.	116683.	12.62	3.54	13	4	0
035689-00	24	16W 14	DCBB	530.00	27.00	3	G	A82	-99.0489	37.9596	-64325.	121268.	7.78	2.01	8	3	0
034915-00	25	15W 35	DDBB	1100.00	240.00	3	G	A82	-98.9343	37.8285	-54421.	106563.	18.71	1.16	19	2	-1
035252-00	25	15W 36	DCAB	1055.00	195.00	3	G	A82	-98.9183	37.8285	-53017.	106553.	19.25	1.83	20	2	-1
035540-00	26	14W 3	CDBB	1000.00	240.00	3	G	A82	-98.8439	37.8105	-46516.	104501.	22.74	4.19	23	5	0
035281-00	26	14W 9	ADBB	1200.00	240.00	3	G	A82	-98.8530	37.8022	-47322.	103576.	22.88	3.45	23	4	0
035266-00	26	15W 2	BABB	720.00	129.00	3	G	A82	-98.9347	37.8248	-54451.	106145.	18.90	0.98	19	1	0
035237-00	26	15W 2	CDCC	900.00	112.00	3	G	A82	-98.9347	37.8063	-54467.	104087.	19.89	0.18	20	1	0
035989-00	20	10W 29	BACB	500.00	81.00	3	G	A83	-98.4561	38.2873	-12484.	157589.	10.10	41.06	11	42	0
035908-00	21	12W 6	ADBB	1000.00	240.00	3	G	A83	-98.6781	38.2568	-31801.	154231.	4.31	30.42	5	31	1
036169-00	21	13W 13	ADBC	0.00	100.00	3	G	A83	-98.6964	38.2265	-33413.	150866.	5.32	28.34	6	29	1
036382-00	21	14W 22	ADBB	1200.00	230.00	3	G	A83	-98.8432	38.2138	-46198.	149504.	1.07	21.63	2	22	0
036266-00	21	14W 29	ACAD	1000.00	246.00	3	G	A83	-98.8812	38.1984	-49513.	147814.	0.62	19.37	1	20	0
035953-00	22	14W 3	CDBB	1000.00	240.00	3	G	A83	-98.8523	38.1629	-47025.	143833.	3.50	19.05	4	20	1
036010-00	22	14W 17	ADBB	1000.00	240.00	3	G	A83	-98.8800	38.1412	-49447.	141427.	3.73	16.95	4	17	1
036086-00	22	14W 32	AACC	1200.00	240.00	3	G	A83	-98.8800	38.0986	-49477.	136674.	6.02	15.11	7	16	1
035903-00	22	14W 32	BDCB	1000.00	240.00	3	G	A83	-98.8892	38.0959	-50284.	136380.	5.86	14.61	6	15	1
036077-00	23	13W 36	DBBB	0.00	120.00	3	G	A83	-98.7003	38.0061	-33857.	126261.	17.07	18.68	18	19	1

Appendix 1. Well data (cont)

(a) Well id, township, range, section, quarter-section					(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code	(e) Year		(f, g) Longitude (deg)	Latitude (deg)	(h, i) Albers x (m)	Albers y (m)	(j, k) Grid row/col. (mi)		(l, m) Grid index row/col		(n) cell activ.
036147-00	23	14W	15	ADDC	0.00	94.00	3	G	A83	-98.8409	38.0513	-46100.	131367.	9.89	14.71	10	15	1
036202-00	23	15W	6	ADBB	800.00	240.00	3	G	A83	-99.0078	38.0832	-60634.	135034.	2.53	9.08	3	10	1
036201-00	23	15W	6	BDBB	0.00	82.00	3	G	A83	-99.0167	38.0832	-61408.	135039.	2.24	8.71	3	9	-1
036036-00	23	15W	10	BDBB	1100.00	240.00	3	G	A83	-98.9624	38.0688	-56688.	133389.	4.85	10.36	5	11	1
035896-00	23	16W	32	BBCC	1000.00	237.00	3	G	A83	-99.1129	38.0113	-69871.	127079.	2.84	1.55	3	2	0
035893-00	24	13W	3	DDBB	1200.00	222.00	3	G	A83	-98.7323	37.9880	-36662.	124258.	16.96	16.55	17	17	1
036231-00	25	13W	9	DDBB	0.00	57.00	3	G	A83	-98.7508	37.8865	-38327.	112937.	21.80	11.40	22	12	0
036167-00	25	14W	29	CDBB	1000.00	240.00	3	G	A83	-98.8886	37.8430	-50406.	108155.	19.48	3.71	20	4	1
036274-00	25	14W	29	DDBB	1000.00	240.00	3	G	A83	-98.8794	37.8430	-49603.	108149.	19.79	4.10	20	5	1
036287-00	25	15W	22	DACC	1200.00	155.00	3	G	A83	-98.9529	37.8584	-56022.	109911.	16.47	1.67	17	2	0
036405-00	26	14W	4	CDBB	1200.00	240.00	3	G	A83	-98.8623	37.8103	-48124.	104495.	22.13	3.41	23	4	0
036589-00	19	11W	22	CCAB	1500.00	240.00	3	G	A84	-98.5325	38.3795	-19108.	167890.	2.57	41.81	3	42	0
036574-00	20	11W	28	DDBB	1000.00	240.00	3	G	A84	-98.5388	38.2789	-19684.	156659.	7.79	37.22	8	38	0
036926-00	20	12W	29	CDBB	710.00	189.00	3	G	A84	-98.6767	38.2785	-31676.	156664.	3.18	31.41	4	32	0
036925-00	20	12W	33	ADBB	790.00	198.00	3	G	A84	-98.6492	38.2714	-29286.	155856.	4.49	32.26	5	33	0
036865-00	21	13W	28	ADBB	1000.00	240.00	3	G	A84	-98.7519	38.1987	-38254.	147783.	4.96	24.82	5	25	1
036505-00	22	14W	15	ADBB	1000.00	240.00	3	G	A84	-98.8432	38.1410	-46241.	141384.	4.99	18.49	5	19	1
036521-00	22	15W	22	DDAA	350.00	92.00	3	G	A84	-98.9494	38.1197	-55510.	139062.	2.55	13.11	3	14	1
036557-00	22	15W	23	ADBB	800.00	240.00	3	G	A84	-98.9346	38.1269	-54219.	139861.	2.66	14.04	3	15	1
036452-00	23	15W	7	DDBB	1000.00	240.00	3	G	A84	-99.0077	38.0615	-60643.	132604.	3.71	8.14	4	9	-1
036940-00	23	16W	13	ADBB	900.00	240.00	3	G	A84	-99.0256	38.0541	-62215.	131800.	3.49	7.07	4	8	0
036939-00	23	16W	13	DDBB	900.00	240.00	3	G	A84	-99.0256	38.0469	-62219.	130994.	3.88	6.76	4	7	0
036836-00	24	15W	22	BBAC	350.00	55.23	4	G	A84	-98.9646	37.9552	-56969.	120721.	10.87	5.36	11	6	-1
036793-00	25	14W	21	DDBB	1200.00	240.00	3	G	A84	-98.8611	37.8576	-47989.	109764.	19.63	5.50	20	6	1
036785-00	25	14W	29	AACC	900.00	40.00	3	G	A84	-98.8795	37.8512	-49604.	109066.	19.35	4.45	20	5	1
036682-00	25	14W	33	CDBB	1200.00	240.00	3	G	A84	-98.8702	37.8284	-48807.	106517.	20.89	3.86	21	4	1
036945-00	26	14W	6	CDBB	1200.00	222.00	3	G	A84	-98.8982	37.8101	-51275.	104482.	20.92	1.88	21	2	-1
037458-00	20	11W	17	CCDD	800.00	240.00	3	G	A85	-98.5676	38.3049	-22180.	159568.	5.42	37.13	6	38	0
037146-00	20	11W	29	CDBB	1100.00	240.00	3	G	A85	-98.5664	38.2788	-22085.	156657.	6.87	36.05	7	37	0
037500-00	20	12W	7	ADBB	1000.00	240.00	3	G	A85	-98.6861	38.3293	-32469.	162334.	0.13	33.21	1	34	0
037419-00	20	12W	8	ADBB	1000.00	240.00	3	G	A85	-98.6678	38.3294	-30881.	162333.	0.74	33.97	1	34	0
037261-00	20	12W	13	DACC	0.00	120.00	3	G	A85	-98.5940	38.3086	-24472.	159996.	4.33	36.18	5	37	0
037293-00	21	10W	12	BDBB	1200.00	273.00	3	G	A85	-98.3748	38.2424	-5425.	152567.	15.25	42.55	16	43	-1
037049-00	21	11W	7	ABDA	1000.00	240.00	3	G	A85	-98.5689	38.2441	-22309.	152792.	8.65	34.46	9	35	1
037507-00	21	12W	8	ADBB	1000.00	240.00	3	G	A85	-98.6599	38.2422	-30227.	152602.	5.70	30.55	6	31	1
037471-00	21	12W	16	ADBB	1100.00	240.00	3	G	A85	-98.6413	38.2277	-28612.	150973.	7.11	30.71	8	31	1

Appendix 1. Well data (cont)

(a) Well id, township, range, section, quarter-section				(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code	(e) Year		(f, g) Longitude (deg)	Latitude (deg)	(h, i) Albers x (m)	Albers y (m)	(j, k) Grid row/col. (mi)		(l, m) Grid index row/col		(n) cell activ.
037069-00	21	13W 3	ADBB	1100.00	240.00	3	G	A85	-98.7331	38.2568	-36586.	154254.	2.46	28.11	3	29	0
037113-00	21	14W 23	BACC	1200.00	240.00	3	G	A85	-98.8341	38.2146	-45401.	149597.	1.33	22.05	2	23	0
037029-00	21	15W 36	ADBB	1200.00	240.00	3	G	A85	-98.9160	38.1849	-52554.	146322.	0.17	17.33	1	18	0
037155-00	22	12W 29	DDBD	120.00	19.88	2	G	A85	-98.6586	38.1029	-30174.	137054.	13.25	24.61	14	25	1
037152-00	22	14W 33	CDBB	1200.00	473.00	3	G	A85	-98.8708	38.0904	-48681.	135752.	6.78	15.14	7	16	1
037156-00	22	15W 12	DDBB	970.00	195.00	3	G	A85	-98.9162	38.1486	-52598.	142276.	2.11	15.75	3	16	1
037555-00	23	13W 5	AACC	600.00	50.00	3	G	A85	-98.7696	38.0836	-39859.	134938.	10.56	19.10	11	20	1
037028-00	23	13W 5	DDBB	1000.00	240.00	3	G	A85	-98.7696	38.0754	-39867.	134024.	11.00	18.75	11	19	1
037547-00	23	13W 6	CDBB	1200.00	235.00	3	G	A85	-98.7971	38.0755	-42269.	134052.	10.06	17.60	11	18	1
037124-00	23	13W 14	DDBB	1200.00	240.00	3	G	A85	-98.7143	38.0461	-35062.	130733.	14.44	19.81	15	20	1
037407-00	23	13W 32	ACCC	0.00	132.00	3	G	A85	-98.7742	38.0073	-40308.	126433.	14.51	15.62	15	16	1
037110-00	23	13W 32	DCAD	130.00	34.06	4	G	A85	-98.7706	38.0018	-39998.	125818.	14.92	15.53	15	16	1
037109-00	23	13W 33	BDBC	200.00	29.00	4	G	A85	-98.7603	38.0091	-39095.	126620.	14.88	16.28	15	17	1
037477-00	23	14W 28	CDAA	400.00	107.00	3	G	A85	-98.8674	38.0179	-48433.	127659.	10.79	12.16	11	13	1
037251-00	23	14W 28	CDBB	500.00	133.00	3	G	A85	-98.8708	38.0179	-48734.	127664.	10.67	12.01	11	13	1
036971-00	23	15W 28	ADBB	500.00	120.00	3	G	A85	-98.9717	38.0252	-57537.	128539.	6.87	8.09	7	9	1
036970-00	23	15W 28	ADBB	500.00	120.00	3	G	A85	-98.9717	38.0252	-57537.	128539.	6.87	8.09	7	9	1
036972-00	23	16W 33	ADBB	1000.00	240.00	3	G	A85	-99.0809	38.0105	-67073.	126963.	3.97	2.86	4	3	0
037102-00	23	17W 25	ACAA	895.00	176.00	3	G	A85	-99.1369	38.0249	-71950.	128614.	1.30	1.13	2	2	0
037516-00	24	12W 31	BBDA	1200.00	237.00	3	G	A85	-98.6871	37.9241	-32736.	117115.	21.93	15.71	22	16	0
037526-00	24	14W 18	CDBB	1000.00	237.00	3	G	A85	-98.9074	37.9597	-51965.	121182.	12.57	7.96	13	8	1
037531-00	24	15W 33	CDBB	1000.00	240.00	3	G	A85	-98.9802	37.9158	-58360.	116331.	12.47	3.00	13	3	0
037103-00	24	16W 10	CDBB	1000.00	240.00	3	G	A85	-99.0718	37.9740	-66313.	122890.	6.23	1.67	7	2	0
037499-00	24	16W 13	CBDD	300.00	105.00	3	G	A85	-99.0363	37.9606	-63224.	121368.	8.16	2.58	9	3	0
037361-00	25	13W 4	BCDB	600.00	60.00	3	G	A85	-98.7623	37.9065	-39326.	115176.	20.33	11.77	21	12	0
037521-00	25	14W 23	ADBB	1000.00	240.00	3	G	A85	-98.8243	37.8648	-44765.	110556.	20.48	7.36	21	8	0
037515-00	25	14W 24	BCAB	1000.00	240.00	3	G	A85	-98.8174	37.8648	-44165.	110552.	20.71	7.65	21	8	0
037349-00	25	15W 35	BDBB	1200.00	240.00	3	G	A85	-98.9436	37.8357	-55228.	107375.	18.00	1.08	19	2	-1
037496-00	26	14W 18	ADBB	1000.00	240.00	3	G	A85	-98.8894	37.7872	-50513.	101928.	22.45	1.27	23	2	0
037490-00	26	14W 18	BDBB	1000.00	228.00	3	G	A85	-98.8982	37.7872	-51291.	101926.	22.15	0.89	23	1	0
037437-00	26	15W 12	CACC	1100.00	180.00	3	G	A85	-98.9164	37.7953	-52873.	102844.	21.10	0.48	22	1	0
037610-00	20	11W 18	DBDA	800.00	240.00	3	G	A86	-98.5768	38.3094	-22977.	160081.	4.87	36.94	5	37	0
037834-00	21	9W 17	BBAA	1200.00	120.00	3	G	A86	-98.3400	38.2314	-2394.	151338.	17.00	43.55	18	44	0
038073-00	21	9W 18	AAAB	1200.00	240.00	3	G	A86	-98.3457	38.2315	-2890.	151345.	16.81	43.31	17	44	0
037609-00	21	12W 7	ACDA	1000.00	120.00	3	G	A86	-98.6794	38.2403	-31925.	152394.	5.15	29.65	6	30	1
037613-00	21	12W 7	BDAA	1200.00	115.50	3	G	A86	-98.6839	38.2421	-32316.	152598.	4.90	29.54	5	30	1

Appendix 1. Well data (cont)

(a) Well id	township	range	section	quarter-section	(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code		(e) Year	(f) Longitude (deg)	(g) Latitude (deg)	(h) Albers x (m)	(i) Albers y (m)	(j) Grid row (mi)	(k) Grid col (mi)	(l) Grid index row	(m) Grid index col	(n) cell activ.
037899-00	22	13W	14	DADB	400.00	23.93	5	G	A86	-98.7124	38.1351	-34846.	140662.	9.71	23.73	10	24	1
037960-00	22	13W	33	CDBB	1200.00	240.00	3	G	A86	-98.7604	38.0899	-39057.	135641.	10.53	19.76	11	20	1
037710-00	23	12W	5	CCBC	850.00	55.50	3	G	A86	-98.6733	38.0740	-31468.	133840.	14.31	22.75	15	23	1
037703-00	23	12W	9	CDBB	1000.00	240.00	3	G	A86	-98.6503	38.0602	-29466.	132281.	15.84	23.12	16	24	1
037758-00	23	12W	11	CDBB	1000.00	240.00	3	G	A86	-98.6137	38.0597	-26275.	132222.	17.09	24.64	18	25	1
037961-00	23	13W	7	DDBB	1200.00	240.00	3	G	A86	-98.7881	38.0609	-41487.	132419.	11.15	17.35	12	18	1
037716-00	23	14W	22	AABA	550.00	118.00	3	G	A86	-98.8420	38.0431	-46203.	130463.	10.29	14.31	11	15	1
037685-00	23	14W	22	ADBB	550.00	119.00	3	G	A86	-98.8432	38.0395	-46308.	130058.	10.45	14.11	11	15	1
037624-00	23	15W	21	ACCD	400.00	97.50	3	G	A86	-98.9752	38.0370	-57825.	129853.	6.12	8.45	7	9	1
037625-00	23	15W	21	DCCD	400.00	97.50	3	G	A86	-98.9752	38.0298	-57833.	129046.	6.51	8.14	7	9	1
037595-00	24	13W	33	BDBB	1200.00	240.00	3	G	A86	-98.7600	37.9228	-39111.	116994.	19.54	12.58	20	13	0
037894-00	24	15W	1	AACC	200.00	203.00	3	G	A86	-98.9167	37.9972	-52756.	125381.	10.23	9.19	11	10	1
037642-00	24	15W	11	BADA	900.00	240.00	3	G	A86	-98.9406	37.9835	-54854.	123861.	10.17	7.59	11	8	1
037574-00	24	16W	15	CCAB	1200.00	240.00	3	G	A86	-99.0741	37.9595	-66530.	121277.	6.93	0.94	7	1	0
037657-00	25	14W	17	CDBC	0.00	49.00	3	G	A86	-98.8887	37.8712	-50394.	111305.	17.96	4.93	18	5	1
037594-00	25	14W	26	BDBB	1200.00	240.00	3	G	A86	-98.8334	37.8503	-45577.	108939.	20.95	6.35	21	7	0
037963-00	25	15W	4	BDAA	1400.00	480.00	3	G	A86	-98.9767	37.9085	-58061.	115514.	12.98	2.83	13	3	0
038145-00	21	9W	17	BBAA	800.00	120.00	3	G	A87	-98.3400	38.2314	-2394.	151338.	17.00	43.55	18	44	0
038396-00	22	13W	1	DBDD	1000.00	210.00	3	G	A87	-98.6977	38.1629	-33557.	143763.	8.71	25.55	9	26	1
038150-00	22	14W	36	DABD	1000.00	198.00	3	G	A87	-98.8051	38.0928	-42948.	135986.	8.87	18.01	9	19	1
038193-00	24	16W	24	DDCB	1000.00	300.00	3	G	A87	-99.0260	37.9432	-62344.	119420.	9.44	2.26	10	3	0
038481-00	21	12W	17	ADBB	1200.00	240.00	3	G	A88	-98.6600	38.2276	-30243.	150976.	6.49	29.92	7	30	1
038552-00	21	12W	17	DDBB	1200.00	240.00	3	G	A88	-98.6600	38.2203	-30250.	150153.	6.88	29.60	7	30	1
038451-00	21	13W	24	DDBB	1200.00	240.00	3	G	A88	-98.6966	38.2055	-33439.	148517.	6.45	27.43	7	28	1
038512-00	22	12W	19	DBCD	600.00	26.00	2	G	A88	-98.6816	38.1195	-32170.	138915.	11.59	24.36	12	25	1
038646-00	22	14W	12	DABB	1100.00	240.00	3	G	A88	-98.8064	38.1519	-43026.	142579.	5.64	20.51	6	21	1
038494-00	23	13W	2	CABB	800.00	87.36	5	G	A88	-98.7237	38.0789	-35857.	134397.	12.36	20.83	13	21	1
038722-00	24	14W	16	ADBB	1100.00	110.00	3	G	A88	-98.8616	37.9667	-47962.	121946.	13.74	10.19	14	11	1
038657-00	24	15W	13	CBBC	11.67	18.81	2	G	A88	-98.9302	37.9625	-53961.	121509.	11.65	7.12	12	8	1
038612-00	24	16W	16	DDBB	1200.00	240.00	3	G	A88	-99.0809	37.9595	-67129.	121281.	6.70	0.65	7	1	0
038503-00	25	14W	11	BDBB	1200.00	240.00	3	G	A88	-98.8337	37.8940	-45569.	113813.	18.60	8.23	19	9	1
038943-00	21	9W	7	BACC	1000.00	220.50	3	G	A89	-98.3566	38.2432	-3839.	152661.	15.81	43.36	16	44	0
039056-00	21	13W	1	CDBB	1200.00	240.00	3	G	A89	-98.7055	38.2494	-34191.	153420.	3.79	28.95	4	29	0
038743-00	21	13W	10	DABB	800.00	120.00	3	G	A89	-98.7332	38.2386	-36610.	152226.	3.43	27.32	4	28	1
038833-00	21	13W	10	DDBB	800.00	120.00	3	G	A89	-98.7333	38.2349	-36615.	151816.	3.63	27.16	4	28	1
039066-00	21	13W	11	DDBB	1200.00	240.00	3	G	A89	-98.7148	38.2348	-35012.	151797.	4.26	27.93	5	28	1

Appendix 1. Well data (cont)

(a) Well id, township, range, section, quarter-section					(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code	(e) Year		(f, g) Longitude (deg)	Latitude (deg)	(h, i) Albers x (m)	Albers y (m)	(j, k) Grid row/col. (mi)		(l, m) Grid index row/col		(n) cell activ.
039070-00	21	13W	12	BDBB	1200.00	240.00	3	G	A89	-98.7056	38.2421	-34201.	152604.	4.18	28.63	5	29	1
039080-00	21	13W	12	CDBB	1200.00	240.00	3	G	A89	-98.7056	38.2348	-34210.	151790.	4.57	28.31	5	29	1
038740-00	21	13W	15	ACCC	800.00	120.00	3	G	A89	-98.7379	38.2249	-37028.	150705.	4.01	26.53	5	27	1
038840-00	21	13W	15	ADBB	800.00	120.00	3	G	A89	-98.7333	38.2276	-36623.	151002.	4.02	26.84	5	27	1
038834-00	21	13W	15	BDBB	800.00	120.00	3	G	A89	-98.7426	38.2277	-37427.	151017.	3.71	26.46	4	27	1
038742-00	21	13W	15	BDCC	800.00	120.00	3	G	A89	-98.7426	38.2250	-37430.	150712.	3.85	26.34	4	27	1
038831-00	21	13W	16	BDBB	800.00	120.00	3	G	A89	-98.7610	38.2279	-39031.	151047.	3.08	25.69	4	26	1
039132-00	22	12W	19	DBCD	0.00	127.20	2	G	A89	-98.6816	38.1195	-32170.	138915.	11.59	24.36	12	25	1
038921-00	22	13W	34	CCCC	1200.00	229.50	3	G	A89	-98.7467	38.0872	-37867.	135330.	11.13	20.22	12	21	1
039131-00	23	12W	33	CDBB	1100.00	240.00	3	G	A89	-98.6498	38.0021	-29447.	125804.	18.98	20.64	19	21	0
039092-00	23	13W	7	ADBB	1000.00	240.00	3	G	A89	-98.7881	38.0682	-41482.	133231.	10.76	17.66	11	18	1
039077-00	23	13W	7	BDBB	1000.00	195.00	3	G	A89	-98.7972	38.0682	-42277.	133239.	10.45	17.28	11	18	1
039061-00	23	13W	18	BDBB	1000.00	236.00	3	G	A89	-98.7973	38.0537	-42294.	131615.	11.23	16.65	12	17	1
039114-00	23	14W	1	CBDD	1000.00	240.00	3	G	A89	-98.8166	38.0765	-43966.	134172.	9.35	16.82	10	17	1
039093-00	23	14W	1	DBDD	1000.00	205.00	3	G	A89	-98.8074	38.0765	-43165.	134163.	9.66	17.21	10	18	1
039142-00	23	14W	10	ADCB	800.00	120.00	3	G	A89	-98.8431	38.0666	-46285.	133082.	8.99	15.28	9	16	1
039062-00	23	14W	13	DDBB	1000.00	240.00	3	G	A89	-98.8065	38.0465	-43100.	130820.	11.31	15.95	12	16	1
038843-00	23	14W	15	ACCC	1000.00	100.00	3	G	A89	-98.8478	38.0513	-46701.	131375.	9.66	14.42	10	15	1
039067-00	23	14W	25	DDBB	1200.00	240.00	3	G	A89	-98.8066	38.0175	-43126.	127582.	12.87	14.70	13	15	1
039005-00	23	14W	27	DACC	1200.00	240.00	3	G	A89	-98.8433	38.0186	-46327.	127728.	11.57	13.20	12	14	1
039163-00	23	14W	34	B	1000.00	195.00	3	G	A89	-98.8530	38.0110	-47182.	126880.	11.65	12.46	12	13	1
039096-00	23	15W	13	CDBB	1000.00	171.00	3	G	A89	-98.9259	38.0470	-53517.	130935.	7.25	10.95	8	11	1
039126-00	24	12W	4	ACBC	1200.00	343.50	3	G	A89	-98.6452	37.9939	-29047.	124882.	19.58	20.48	20	21	0
038914-00	24	12W	16	DDBB	1200.00	240.00	3	G	A89	-98.6406	37.9584	-28662.	120921.	21.65	19.14	22	20	0
039123-00	24	12W	21	AABC	1200.00	228.75	3	G	A89	-98.6406	37.9538	-28664.	120414.	21.89	18.95	22	19	0
038925-00	24	12W	29	ADAB	1000.00	222.00	3	G	A89	-98.6562	37.9366	-30036.	118492.	22.30	17.55	23	18	0
038727-00	24	14W	16	DCAA	550.00	120.00	3	G	A89	-98.8628	37.9595	-48073.	121141.	14.09	9.83	15	10	1
038771-00	24	14W	16	DDAA	550.00	120.00	3	G	A89	-98.8582	37.9595	-47669.	121138.	14.24	10.02	15	11	1
039049-00	24	14W	18	DDBB	1000.00	240.00	3	G	A89	-98.8983	37.9596	-51177.	121172.	12.88	8.34	13	9	1
039045-00	24	14W	29	DDBB	1000.00	120.00	3	G	A89	-98.8799	37.9305	-49583.	117906.	15.07	7.85	16	8	1
038975-00	24	15W	8	BCDC	1100.00	225.00	3	G	A89	-99.0013	37.9788	-60154.	123380.	8.36	4.84	9	5	0
039168-00	24	15W	12	CCAA	1000.00	240.00	3	G	A89	-98.9269	37.9743	-53657.	122830.	11.12	7.77	12	8	1
039057-00	24	15W	15	ADBB	1000.00	212.00	3	G	A89	-98.9531	37.9671	-55959.	122034.	10.63	6.35	11	7	1
039053-00	24	15W	15	DDBB	1000.00	258.00	3	G	A89	-98.9531	37.9598	-55961.	121221.	11.02	6.04	12	7	1
039047-00	24	15W	22	ADCB	1000.00	240.00	3	G	A89	-98.9531	37.9506	-55966.	120199.	11.51	5.64	12	6	-1
039046-00	24	15W	22	DDBB	1000.00	240.00	3	G	A89	-98.9531	37.9451	-55969.	119583.	11.81	5.41	12	6	-1

Appendix 1. Well data (cont)

(a) Well id, township, range, section, quarter-section					(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code	(e) Year		(f, g) Longitude (deg)	Latitude (deg)	(h, i) Albers x (m)	Albers y (m)	(j, k) Grid row/col. (mi)		(l, m) Grid index row/col		(n) cell activ.
038971-00	24	15W	26	ADBB	1100.00	240.00	3	G	A89	-98.9346	37.9378	-54365.	118754.	12.83	5.86	13	6	1
039118-00	25	14W	22	DDBB	1000.00	240.00	3	G	A89	-98.8427	37.8576	-46378.	109755.	20.25	6.28	21	7	0
039541-00	20	12W	3	CACC	310.00	55.00	3	G	A90	-98.6404	38.3375	-28489.	163227.	1.23	35.48	2	36	0
039288-00	20	12W	17	BBDB	250.00	97.50	3	G	A90	-98.6792	38.3167	-31876.	160919.	1.04	32.95	2	33	0
039248-00	20	12W	23	CDBB	900.00	172.50	3	G	A90	-98.6217	38.2933	-26881.	158288.	4.24	34.36	5	35	0
039421-00	21	9W	31	BDBB	900.00	195.00	3	G	A90	-98.3568	38.1842	-3859.	146072.	18.99	40.82	19	41	1
039545-00	21	11W	8	ADBB	1000.00	203.00	3	G	A90	-98.5496	38.2420	-20630.	152549.	9.41	35.18	10	36	1
039446-00	21	12W	4	AACC	1000.00	179.00	3	G	A90	-98.6413	38.2578	-28599.	154332.	5.49	32.01	6	33	0
039587-00	21	12W	19	DDAB	1200.00	216.00	3	G	A90	-98.6763	38.2056	-31671.	148526.	7.12	28.29	8	29	1
039585-00	21	12W	31	BDBB	1200.00	201.00	3	G	A90	-98.6876	38.1838	-32662.	146094.	7.92	26.87	8	27	1
039480-00	21	12W	32	ADBB	950.00	195.00	3	G	A90	-98.6603	38.1838	-30291.	146080.	8.84	28.02	9	29	1
039753-00	21	12W	33	BDBB	1000.00	190.00	3	G	A90	-98.6512	38.1837	-29492.	146071.	9.15	28.40	10	29	1
039426-00	21	13W	10	BDAB	600.00	120.00	3	G	A90	-98.7401	38.2423	-37210.	152643.	3.00	27.19	4	28	1
039586-00	21	13W	26	BDBB	1200.00	216.00	3	G	A90	-98.7242	38.1984	-35843.	147733.	5.90	25.96	6	26	1
039435-00	21	13W	31	ACBB	1600.00	222.00	3	G	A90	-98.7930	38.1846	-41843.	146228.	4.33	22.48	5	23	1
039434-00	21	13W	31	DDBB	1000.00	120.00	3	G	A90	-98.7885	38.1773	-41456.	145409.	4.88	22.35	5	23	1
039476-00	22	9W	8	CDBB	900.00	195.00	3	G	A90	-98.3387	38.1476	-2280.	141984.	21.58	40.01	22	41	0
039602-00	22	13W	5	ADDB	400.00	13.16	3	G	A90	-98.7679	38.1680	-39669.	144361.	6.07	22.82	7	23	1
039393-00	23	13W	16	BDBB	0.00	15.00	3	G	A90	-98.7604	38.0535	-39079.	131584.	12.48	18.19	13	19	1
039710-00	23	14W	6	CDBC	715.00	181.00	3	G	A90	-98.9075	38.0751	-51895.	134065.	6.36	12.94	7	13	1
039218-00	23	15W	14	A	800.00	180.00	3	G	A90	-98.9356	38.0547	-54355.	131800.	6.51	10.88	7	11	1
039793-00	23	16W	20	CDBB	1000.00	98.00	3	G	A90	-99.1084	38.0322	-69454.	129411.	1.87	2.65	2	3	0
039790-00	23	16W	33	CDBB	1000.00	195.00	3	G	A90	-99.0902	38.0032	-67892.	126158.	4.05	2.16	5	3	0
039353-00	23	17W	25	BACC	1000.00	240.00	3	G	A90	-99.1449	38.0258	-72649.	128726.	0.98	0.84	1	1	0
039419-00	24	13W	22	BDBB	1000.00	195.00	3	G	A90	-98.7414	37.9517	-37474.	120208.	18.61	14.60	19	15	0
039192-00	24	14W	31	CDBB	1200.00	201.00	3	G	A90	-98.9071	37.9159	-51973.	116303.	14.93	6.08	15	7	1
039321-00	24	15W	3	BDBB	800.00	195.00	3	G	A90	-98.9625	37.9963	-56755.	125300.	8.74	7.22	9	8	1
039495-00	24	16W	17	ADBB	900.00	198.00	3	G	A90	-99.0992	37.9668	-68713.	122101.	5.70	0.20	6	1	0
039751-00	25	14W	12	BDBB	1000.00	166.00	3	G	A90	-98.8153	37.8939	-43964.	113799.	19.22	9.00	20	9	1
900076-00	21	10W	12	CBBB	60.00	1.07	2	G	A91	-98.3794	38.2388	-5826.	152161.	15.29	42.20	16	43	-1
900119-00	21	11W	18	BCDD	60.00	0.92	2	G	A91	-98.5780	38.2248	-23108.	150630.	9.39	33.24	10	34	1
900075-00	21	11W	18	CACB	60.00	1.07	2	G	A91	-98.5769	38.2220	-23011.	150325.	9.58	33.17	10	34	1
900157-00	21	11W	18	DABC	60.00	1.07	2	G	A91	-98.5679	38.2230	-22227.	150434.	9.83	33.60	10	34	1
039914-00	21	12W	18	CDDD	1000.00	195.00	3	G	A91	-98.6840	38.2174	-32337.	149844.	6.23	28.47	7	29	1
039894-00	21	12W	19	BACC	1000.00	166.00	3	G	A91	-98.6874	38.2137	-32636.	149435.	6.31	28.17	7	29	1
039890-00	21	12W	19	CDBB	1200.00	195.00	3	G	A91	-98.6875	38.2055	-32650.	148518.	6.75	27.81	7	28	1

Appendix 1. Well data (cont)

(a) Well id, township, range, section, quarter-section					(b) Rate (gpm)	(c) Approp (ac-ft)	(d) Use code	(e) Year		(f, g) Longitude (deg)	Latitude (deg)	(h, i) Albers x (m)	Albers y (m)	(j, k) Grid row/col. (mi)		(l, m) Grid index row/col		(n) cell activ.
039898-00	21	12W	20	BDBB	1000.00	195.00	3	G	A91	-98.6693	38.2129	-31061.	149337.	6.96	28.90	7	29	1
039906-00	21	12W	20	CDBB	1000.00	98.00	3	G	A91	-98.6694	38.2056	-31072.	148524.	7.35	28.58	8	29	1
039889-00	21	12W	30	ADBB	1200.00	195.00	3	G	A91	-98.6786	38.1983	-31875.	147713.	7.44	27.88	8	28	1
039907-00	21	12W	30	CDBB	1000.00	98.00	3	G	A91	-98.6876	38.1910	-32659.	146900.	7.53	27.19	8	28	1
900006-00	21	13W	6	ADCB	100.00	0.30	2	G	A91	-98.7884	38.2552	-41402.	154104.	0.69	25.72	1	26	0
039912-00	21	13W	15	AADA	800.00	120.00	3	G	A91	-98.7298	38.2294	-36318.	151199.	4.04	27.06	5	28	1
039913-00	21	13W	15	BAAD	800.00	120.00	3	G	A91	-98.7391	38.2304	-37122.	151316.	3.68	26.72	4	27	1
039892-00	21	13W	23	CCAA	1000.00	195.00	3	G	A91	-98.7253	38.2057	-35938.	148547.	5.47	26.23	6	27	1
039893-00	21	13W	23	DDBB	1000.00	195.00	3	G	A91	-98.7150	38.2055	-35037.	148529.	5.83	26.66	6	27	1
039915-00	21	13W	24	CDBB	1000.00	195.00	3	G	A91	-98.7058	38.2055	-34238.	148520.	6.14	27.04	7	28	1
900106-00	22	12W	17	DAAD	100.00	0.30	2	G	A91	-98.6564	38.1357	-29968.	140712.	11.56	26.11	12	27	1
900146-00	22	12W	29	ACAD	60.00	0.92	2	G	A91	-98.6609	38.1102	-30375.	137872.	12.78	24.82	13	25	1
039879-00	22	13W	11	A	1200.00	186.00	3	G	A91	-98.7155	38.1553	-35107.	142928.	8.51	24.47	9	25	1
900150-00	22	14W	27	BBCD	100.00	0.30	2	G	A91	-98.8556	38.1130	-47342.	138267.	6.07	16.76	7	17	1
039867-00	23	12W	16	CACB	1000.00	210.00	3	G	A91	-98.6502	38.0474	-29460.	130860.	16.53	22.57	17	23	1
039865-00	23	13W	9	C	1250.00	126.00	3	G	A91	-98.7610	38.0613	-39123.	132446.	12.05	18.50	13	19	1
900165-00	23	13W	14	CDCD	100.00	1.53	2	G	A91	-98.7224	38.0434	-35765.	130434.	14.31	19.36	15	20	1
900123-00	23	13W	28	BCCD	50.00	0.76	2	G	A91	-98.7639	38.0218	-39401.	128045.	14.07	16.68	15	17	1
900077-00	23	14W	9	CABD	100.00	0.30	2	G	A91	-98.8697	38.0640	-48602.	132810.	8.23	14.05	9	15	1
900178-00	23	14W	9	CBAD	60.00	0.92	2	G	A91	-98.8720	38.0641	-48803.	132813.	8.15	13.96	9	14	1
900002-00	23	14W	13	CACA	100.00	1.53	2	G	A91	-98.8145	38.0484	-43794.	131034.	10.94	15.70	11	16	1
899028-00	23	15W	30	CAAA	300.00	17.31	2	G	A91	-99.0135	38.0215	-61184.	128152.	5.66	6.17	6	7	0
900113-00	24	14W	15	DBCC	100.00	0.85	2	G	A91	-98.8477	37.9603	-46757.	121221.	14.55	10.50	15	11	1
039881-00	24	14W	34	C	1000.00	195.00	3	G	A91	-98.8526	37.9163	-47210.	116313.	16.76	8.39	17	9	1
039888-00	25	14W	12	BDBB	1000.00	29.00	3	G	A91	-98.8153	37.8939	-43964.	113799.	19.22	9.00	20	9	1

Appendix 2. Well Records for the Sittner and Figger Sites.

WATER WELL RECORD Form WWC-5 KSA 82a-1212

1 LOCATION OF WATER WELL:
County: STAFFORD
Fraction: SW ¼ SW ¼ SW ¼
Section Number: 1
Township Number: T 23 S
Range Number: R 12 E [✓ W]

Distance and direction from nearest town or city street address of well if located within city? 7 miles North of Stafford, KS

2 WATER WELL OWNER: LEE FIGGER/KANSAS GEOLOGICAL SURVEY
RR#, St. Address, Box # : (STAFFORD, KS) 1930 CONSTANT AVE
City, State, ZIP Code : LAWRENCE, KS 66047
Board of Agriculture, Division of Water Resources
Application Number:

3 LOCATE WELL'S LOCATION WITH AN "X" IN SECTION BOX:
N
NW NE
W E 1 Mile
SW SE
X
S

4 DEPTH OF COMPLETED WELL 125 ft. ELEVATION: 1825 ft
Depth(s) Groundwater Encountered 1. ft. 2. ft. 3. ft.
WELL'S STATIC WATER LEVEL 5.2 ft. below land surface measured on mo/day/yr 07/03/90
Pump test data: Well water was ft. after hours pumping gpm
Est. Yield gpm: Well water was ft. after hours pumping gpm
Bore Hole Diameter 10 in. to ft., and in. to ft.
WELL WATER TO BE USED AS: 1 Domestic 2 Irrigation 3 Feedlot 4 Industrial 5 Public water supply 6 Oil field water supply 7 Lawn and garden only 8 Air conditioning 9 Dewatering [✓ 10 Observation well] 11 Injection well 12 Other (Specify below)
Was a chemical/bacteriological sample submitted to Department? Yes No ✓; If yes, mo/day/yr sample was submitted
Water Well Disinfected? Yes [✓ No]

5 TYPE OF BLANK CASING USED: 1 Steel [✓ 2 PVC] 3 RMP (SR) 4 ABS 5 Wrought iron 6 Asbestos-Cement 7 Fiberglass 8 Concrete tile 9 Other (specify below)
CASING JOINTS: Glued ✓ Clamped Welded Threaded
Blank casing diameter 5 in. to ft., Dia in. to ft., Dia in. to ft.
Casing height above land surface 36 in., weight lbs./ft. Wall thickness or gauge No. schedule 40
TYPE OF SCREEN OR PERFORATION MATERIAL: 1 Steel 2 Brass 3 Stainless steel 4 Galvanized steel 5 Fiberglass 6 Concrete tile 7 PVC 8 RMP (SR) 9 ABS 10 Asbestos-cement [✓ 11 Other (specify)] PVC screen 12 None used (open hole)
SCREEN OR PERFORATION OPENINGS ARE: 1 Continuous slot 2 Louvered shutter [✓ 3 Mill slot] 4 Key punched 5 Gauzed wrapped 6 Wire wrapped 7 Torch cut 8 Saw cut 9 Drilled holes 10 Other (specify) 11 None (open hole)
SCREEN-PERFORATED INTERVALS: From 15 ft. to 125 ft., From ft. to ft.
From ft. to ft., From ft. to ft.
GRAVEL PACK INTERVALS: From 14 ft. to 125 ft., From ft. to ft.
From ft. to ft., From ft. to ft.

6 GROUT MATERIAL: 1 Neat cement 2 Cement grout 3 Bentonite 4 Other bentonite pellets and baroid holeplug
Grout Intervals: From 0 ft. to 14 ft., From 125 ft. to 138.5 ft., From ft. to ft.
What is the nearest source of possible contamination: 1 Septic tank 2 Sewer lines 3 Watertight sewer lines 4 Lateral lines 5 Cess pool 6 Seepage pit 7 Pit privy 8 Sewage lagoon 9 Feedyard 10 Livestock pens 11 Fuel storage 12 Fertilizer storage 13 Insecticide storage 14 Abandoned water well [✓ 15 Oil well/Gas well] 16 Other (specify below)
Direction from well?
How many feet?

FROM	TO	LITHOLOGIC LOG	FROM	TO	LITHOLOGIC LOG
0	5	Fine Sandy Loam			
5	14	Clay loam			
14	38	subrounded Fine Gravel and Coarse sand with minor clay			
38	89	arkosic Medium Gravel and V. coarse sand with yellowish-brown clay stringers and carbonate nodules			
89	126	Fine Gravel and V. Coarse sand with yellow clay stringers and carbonate nodules			
126	138.5	Permian red siltstone mixed (especially in upper depths) with F. Gravel and C. Sand probably cavings from above.			

7 CONTRACTOR'S OR LANDOWNER'S CERTIFICATION: This water well was [✓ (1) constructed], (2) reconstructed, or (3) plugged under my jurisdiction and was completed on (mo/day/year) 05/26/90 and this record is true to the best of my knowledge and belief. Kansas Water Well Contractor's License No. This Water Well Record was completed on (mo/day/yr) 07/11/90
under the business name of KANSAS GEOL. SURVEY by (signature) [illegible]

INSTRUCTIONS: Use typewriter or ball point pen. PLEASE PRESS FIRMLY and PRINT clearly. Please fill in blanks, underline or circle the correct answers. Send top three copies to Kansas Department of Health and Environment, Office of Oil Field and Environmental Geology, Regulation and Permitting Section, Topeka, Kansas 66620-7500, Telephone: 913-862-9360. Send one to WATER WELL OWNER and retain one for your records.

WATER WELL RECORD Form WWC-5 KSA 82a-1212

1 LOCATION OF WATER WELL: County: STAFFORD	Fraction SW ¼ SE ¼ SE ¼	Section Number 36	Township Number T 21 S	Range Number R 12 E(W)

Distance and direction from nearest town or city street address of well if located within city? 14 mi North of Stafford, Ks

2 WATER WELL OWNER: MARVIN SITTNER/KANSAS GEOLOGICAL SURVEY
RR#, St. Address, Box # : (HUDSON, KS) 1930 CONSTANT AVE
City, State, ZIP Code : LAWRENCE, KS 66047
Board of Agriculture, Division of Water Resources
Application Number:

3 LOCATE WELL'S LOCATION WITH AN "X" IN SECTION BOX: N, S, E, W; 1 Mile; NW, NE, SW, SE — X in SE quarter

4 DEPTH OF COMPLETED WELL 111 ft. ELEVATION: 1806 ft
Depth(s) Groundwater Encountered 1. .... ft. 2. .... ft. 3. .... ft.
WELL'S STATIC WATER LEVEL 15.4 ft. below land surface measured on mo/day/yr 07/03/90
Pump test data: Well water was .... ft. after .... hours pumping .... gpm
Est. Yield .... gpm: Well water was .... ft. after .... hours pumping .... gpm
Bore Hole Diameter 10 in. to .... ft., and .... in. to .... ft.
WELL WATER TO BE USED AS: 1 Domestic 2 Irrigation 3 Feedlot 4 Industrial 5 Public water supply 6 Oil field water supply 7 Lawn and garden only 8 Air conditioning 9 Dewatering (10) Observation well 11 Injection well 12 Other (Specify below)
Was a chemical/bacteriological sample submitted to Department? Yes........ No ✓; If yes, mo/day/yr sample was submitted
Water Well Disinfected? Yes (No)

5 TYPE OF BLANK CASING USED: 1 Steel (2) PVC 3 RMP (SR) 4 ABS 5 Wrought iron 6 Asbestos-Cement 7 Fiberglass 8 Concrete tile 9 Other (specify below)
CASING JOINTS: Glued ✓ Clamped .... Welded .... Threaded ....
Blank casing diameter 5 in. to .... ft., Dia .... in. to .... ft., Dia .... in. to .... ft.
Casing height above land surface 36 in., weight .... lbs./ft. Wall thickness or gauge No. schedule 40
TYPE OF SCREEN OR PERFORATION MATERIAL: 1 Steel 2 Brass 3 Stainless steel 4 Galvanized steel 5 Fiberglass 6 Concrete tile 7 PVC 8 RMP (SR) 9 ABS 10 Asbestos-cement (11) Other (specify) PVC screen 12 None used (open hole)
SCREEN OR PERFORATION OPENINGS ARE: 1 Continuous slot 2 Louvered shutter (3) Mill slot 4 Key punched 5 Gauzed wrapped 6 Wire wrapped 7 Torch cut 8 Saw cut 9 Drilled holes 10 Other (specify) .... 11 None (open hole)
SCREEN-PERFORATED INTERVALS: From 11 ft. to 111 ft., From .... ft. to .... ft.
From .... ft. to .... ft., From .... ft. to .... ft.
GRAVEL PACK INTERVALS: From 10 ft. to 111 ft., From .... ft. to .... ft.
From .... ft. to .... ft., From .... ft. to .... ft.

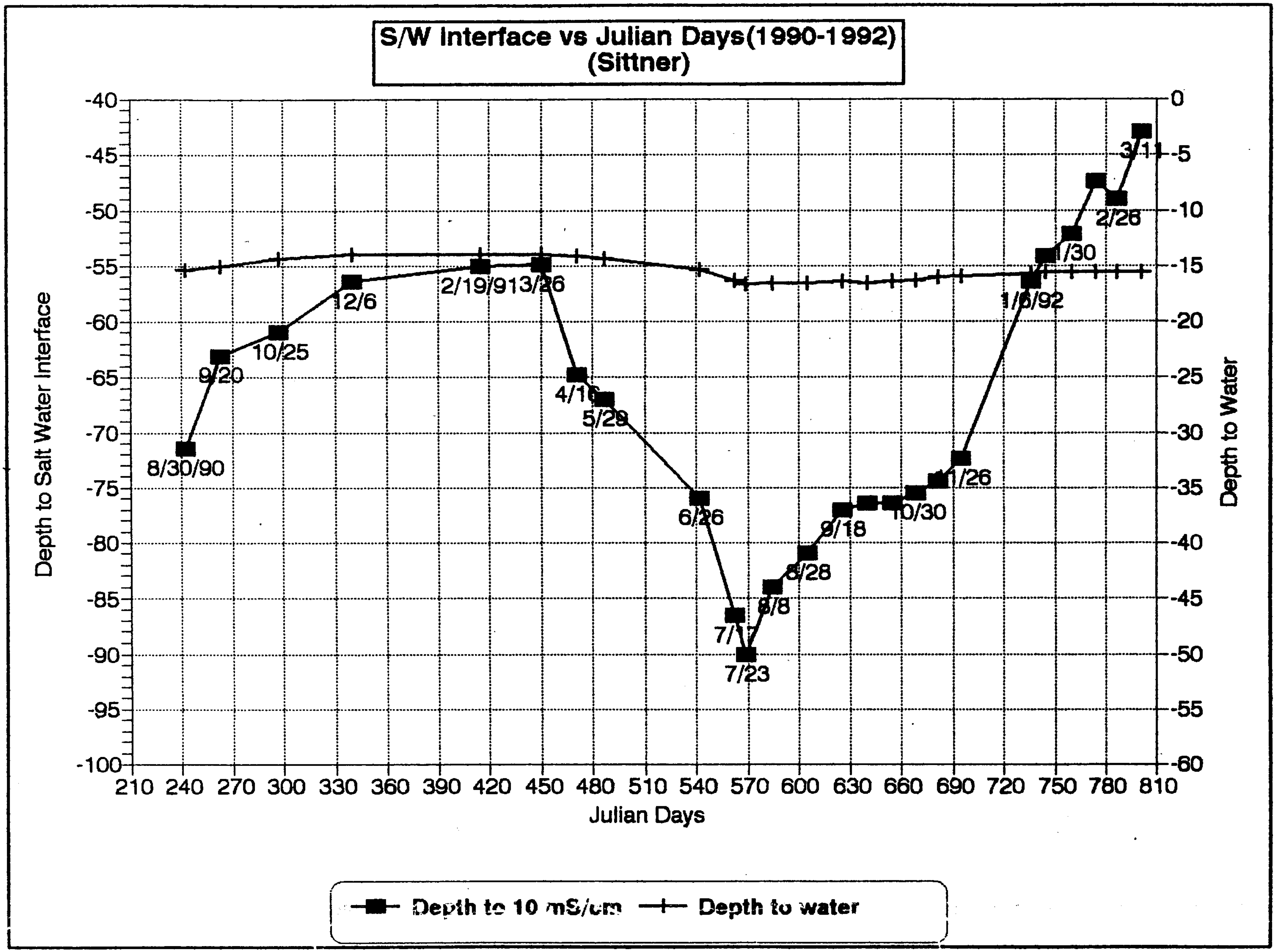
6 GROUT MATERIAL: 1 Neat cement 2 Cement grout 3 Bentonite 4 Other bentonite pellets and baroid holeplug
Grout Intervals: From 0 ft. to 10 ft., From 111 ft. to 120.6 ft., From .... ft. to .... ft.
What is the nearest source of possible contamination: 1 Septic tank 2 Sewer lines 3 Watertight sewer lines 4 Lateral lines 5 Cess pool 6 Seepage pit 7 Pit privy 8 Sewage lagoon 9 Feedyard 10 Livestock pens 11 Fuel storage 12 Fertilizer storage 13 Insecticide storage 14 Abandoned water well (15) Oil well/Gas well 16 Other (specify below)
Direction from well? How many feet?

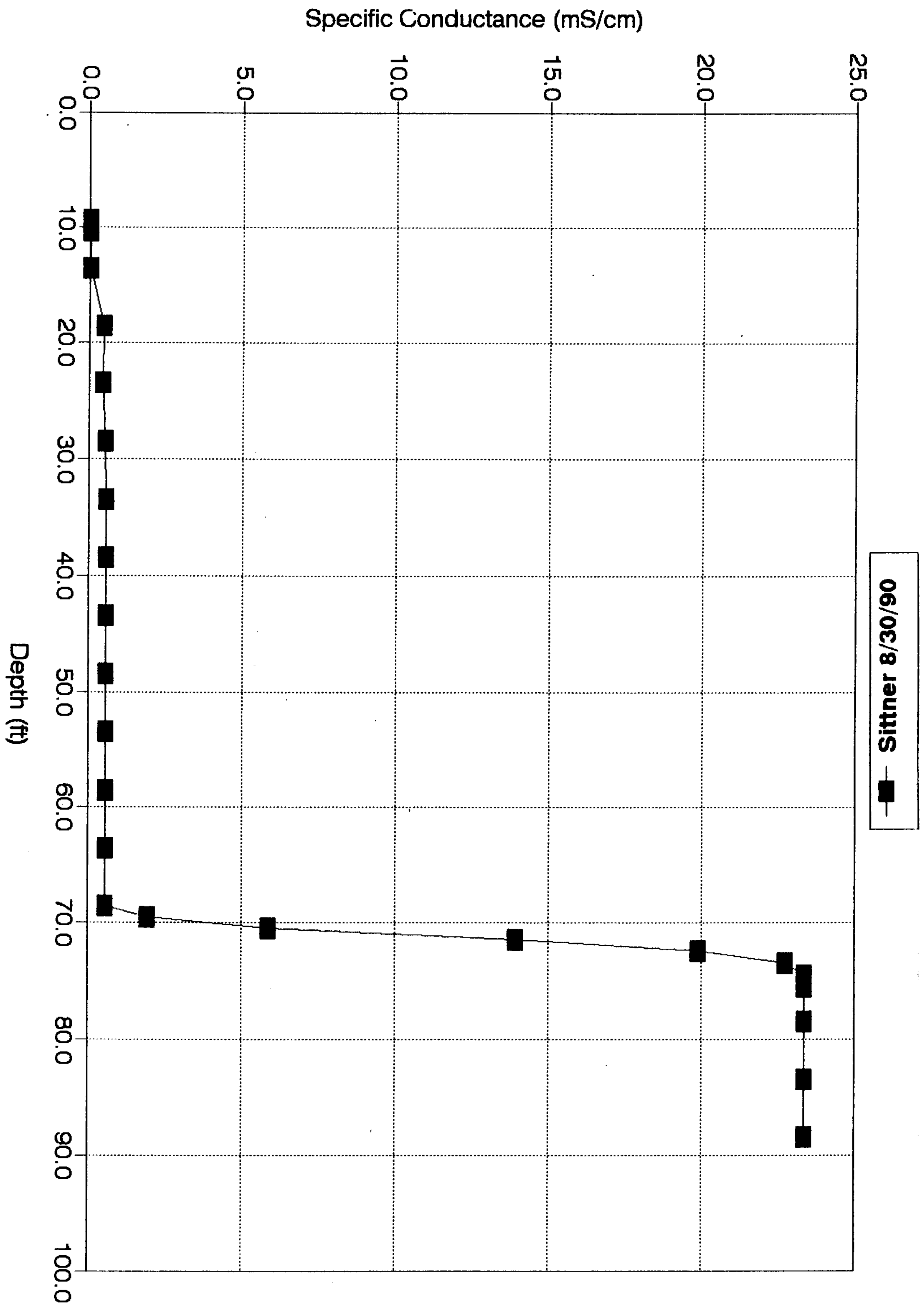
FROM	TO	LITHOLOGIC LOG	FROM	TO	LITHOLOGIC LOG
0	4	Loamy sand			
4	20	Coarse sand and fine gravel, light brown to whitish, calcareous, with clay stringers			
20	30	Coarse sand, brown, calcareous, carbonaceous, granular with minor clay			
30	51	Coarse sand, whitish to light brown, granular, calcareous with minor clay			
51	85	Coarse sand, reddish brown, granular, not as calcareous with minor clay			
85	120	V. Coarse sand and F.&M. gravel coarsening with depth with minor clays becoming prominent at 96-99' and 108-110', rounded, carbonaceous			
120	120.6	Permian red siltstone			

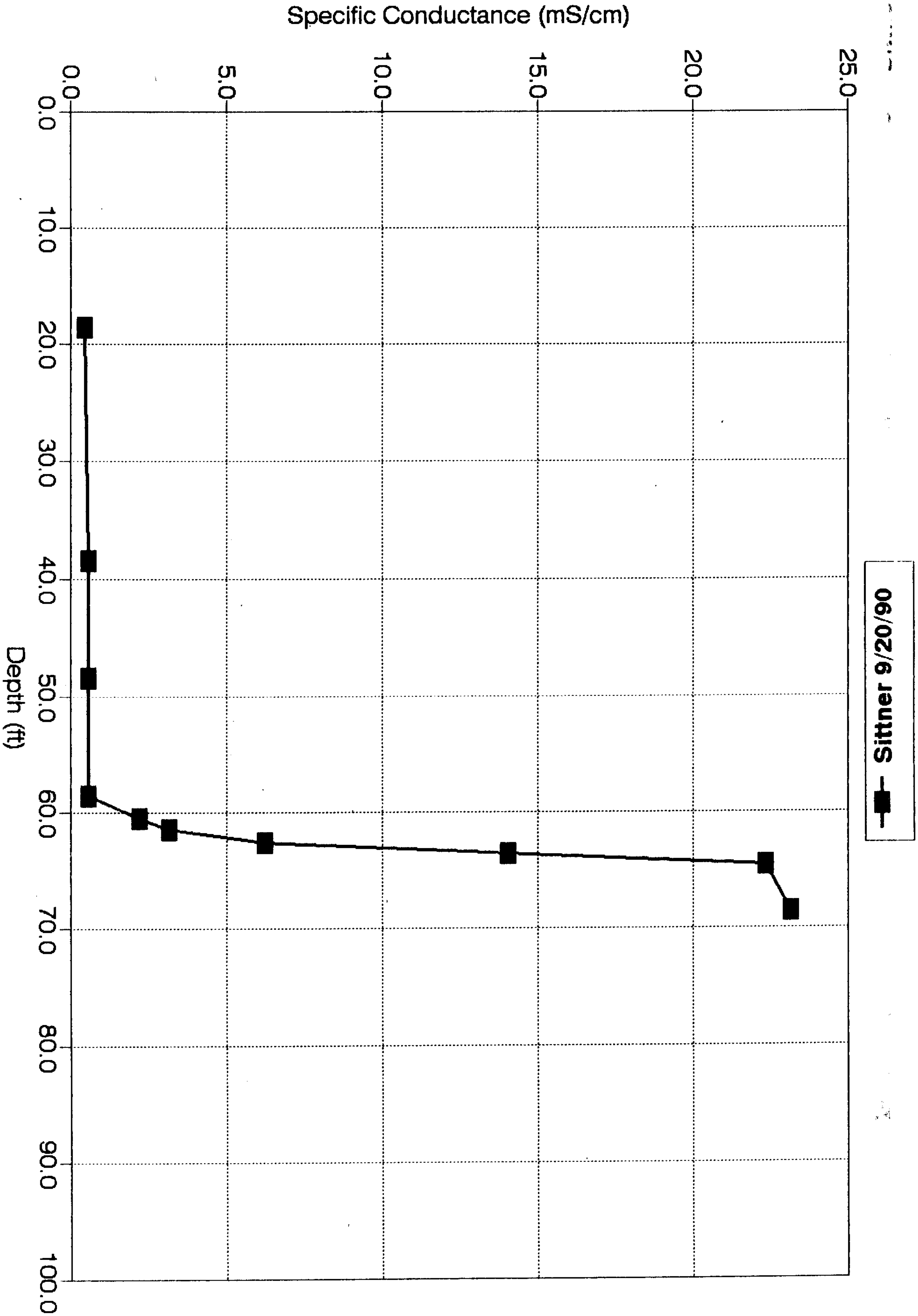
7 CONTRACTOR'S OR LANDOWNER'S CERTIFICATION: This water well was (1) constructed, (2) reconstructed, or (3) plugged under my jurisdiction and was completed on (mo/day/year) 06/06/90 and this record is true to the best of my knowledge and belief. Kansas Water Well Contractor's License No. .... This Water Well Record was completed on (mo/day/yr) 07/10/90 under the business name of KANSAS GEOL. SURVEY by (signature) [signature]

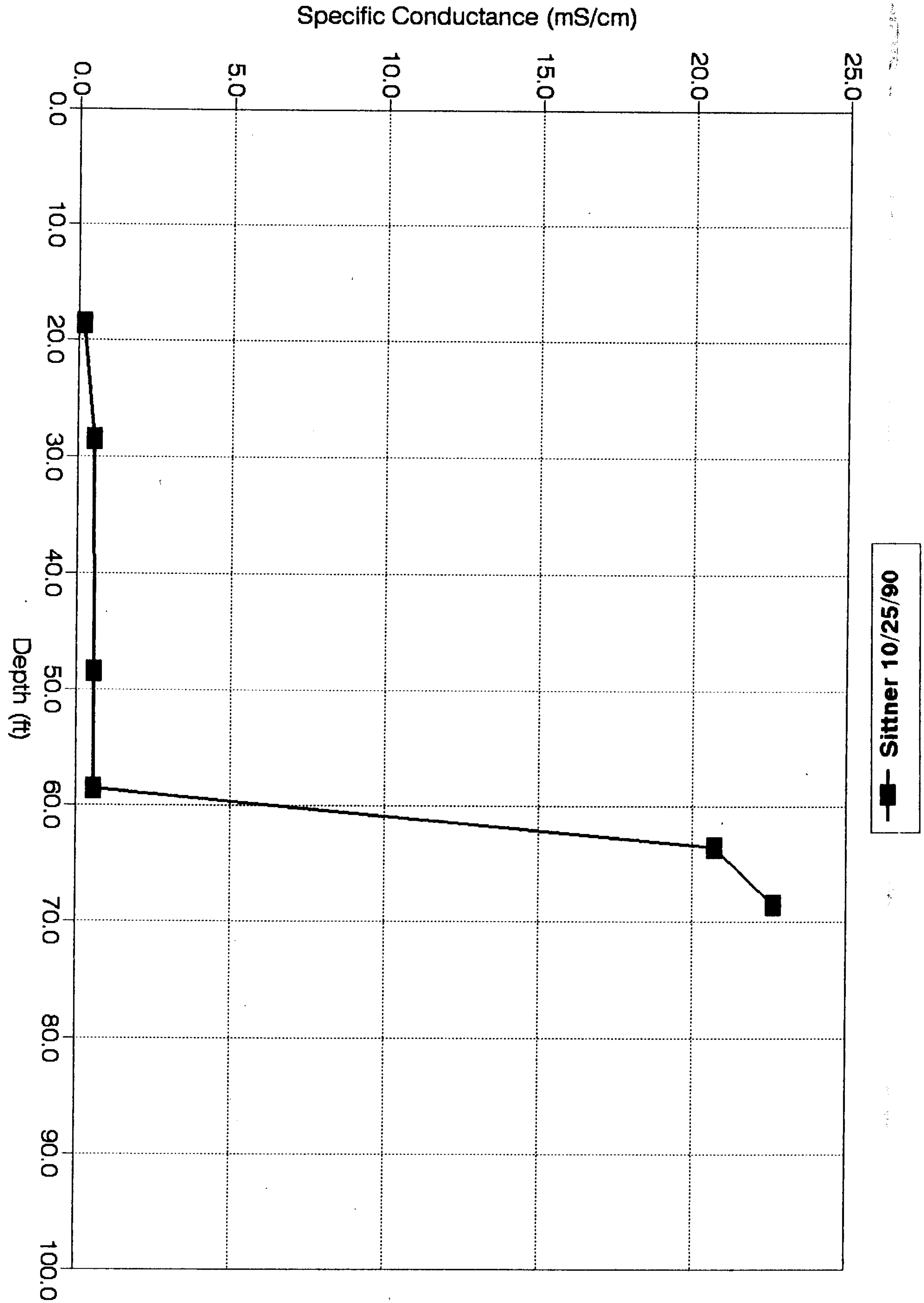
INSTRUCTIONS: Use typewriter or ball point pen. PLEASE PRESS FIRMLY and PRINT clearly. Please fill in blanks, underline or circle the correct answers. Send top three copies to Kansas Department of Health and Environment, Office of Oil Field and Environmental Geology, Regulation and Permitting Section, Topeka, Kansas 66620-7500, Telephone: 913-862-9360. Send one to WATER WELL OWNER and retain one for your records.

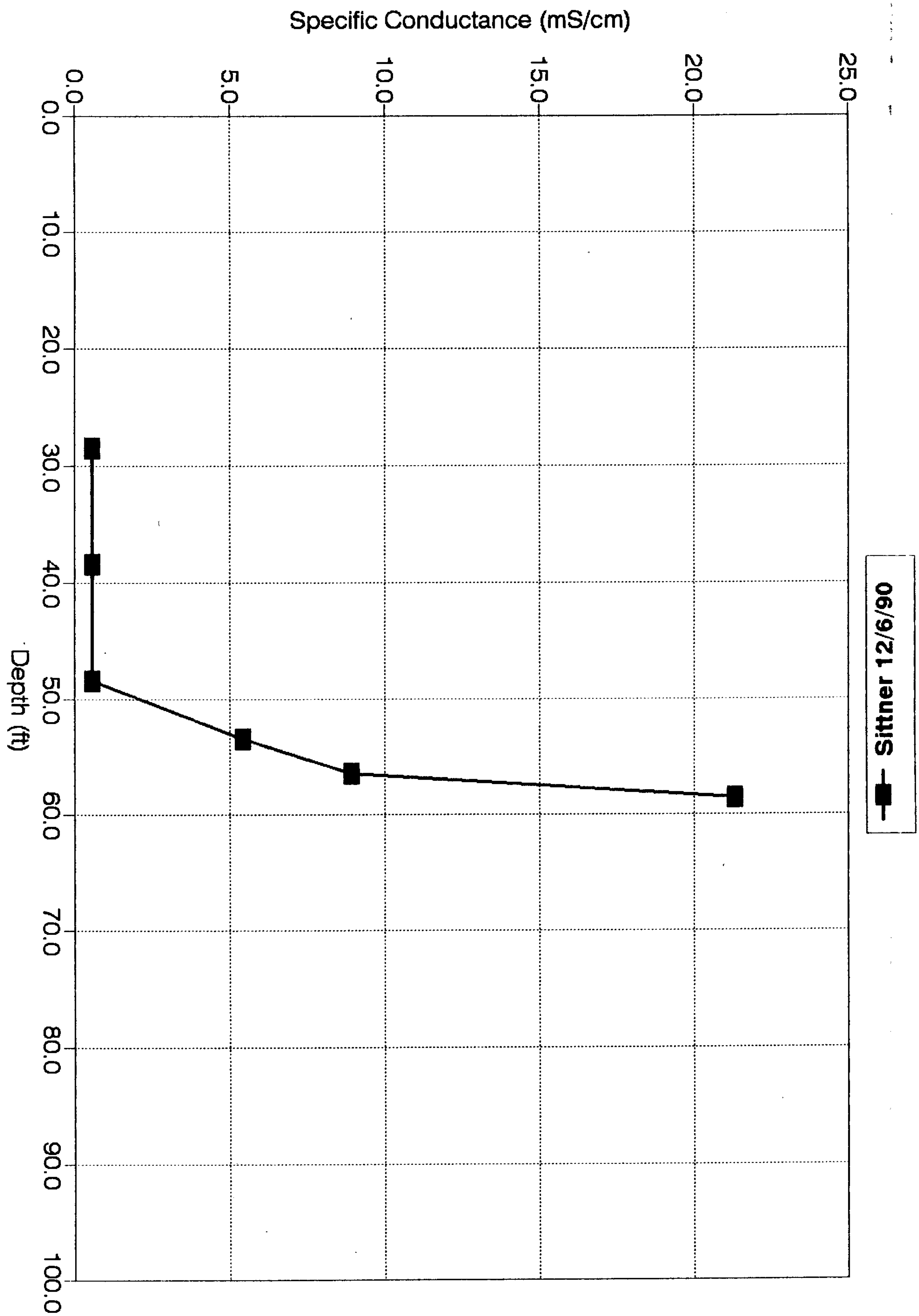
Appendix 3. Graphical Displays of Saltwater-Freshwater Interface Monitoring at the Sittner and Figger Sites.

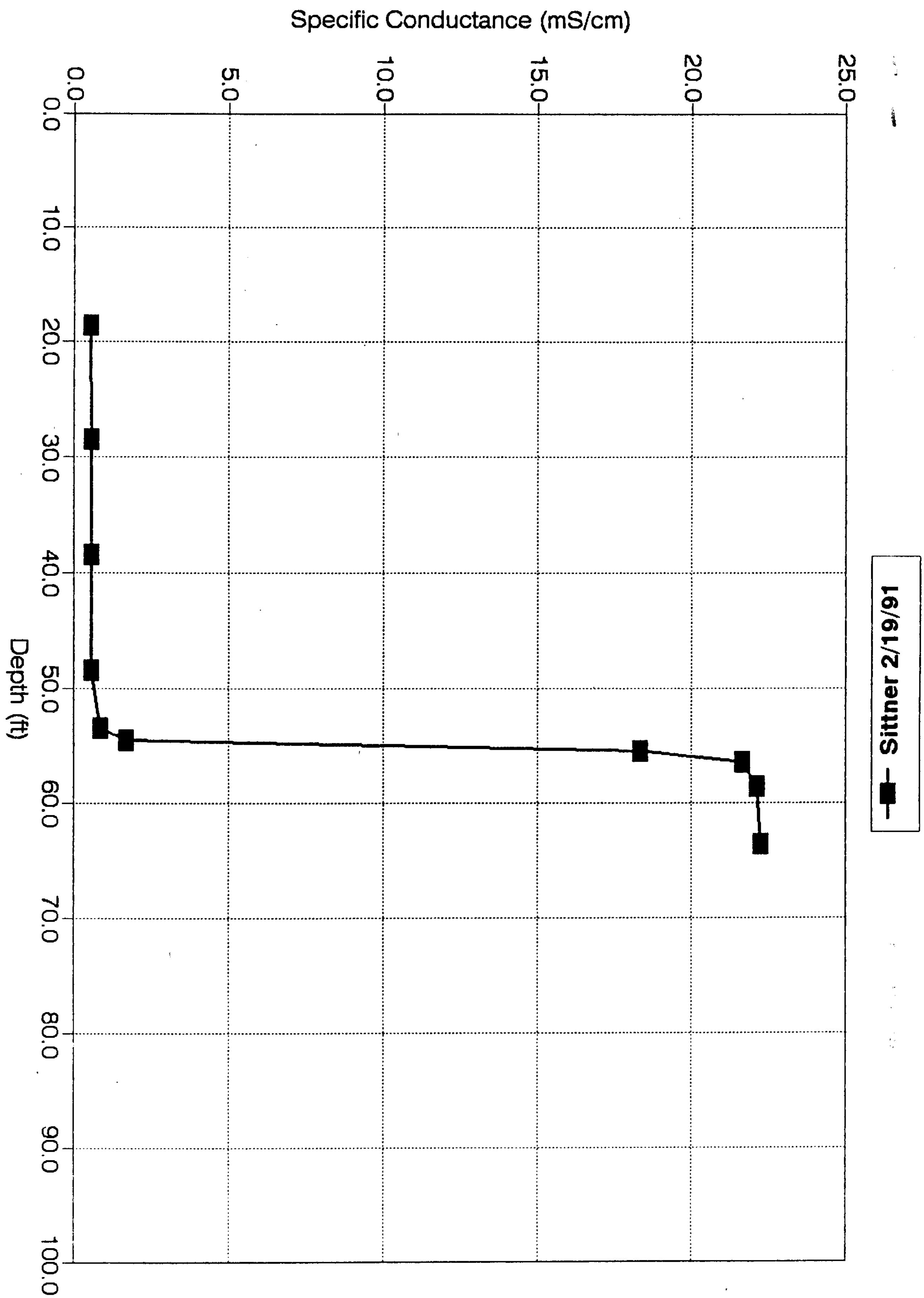

S/W Interface vs Julian Days(1990-1992)
(Sittner)
Depth to Salt Water Interface
Depth to Water
Julian Days
8/30/90
9/20
10/25
12/6
2/19/91
3/26
4/16
5/29
6/26
7/23
8/8
8/28
9/18
10/30
11/26
1/6/92
1/30
2/26
3/11
Depth to 10 mS/cm
Depth to water

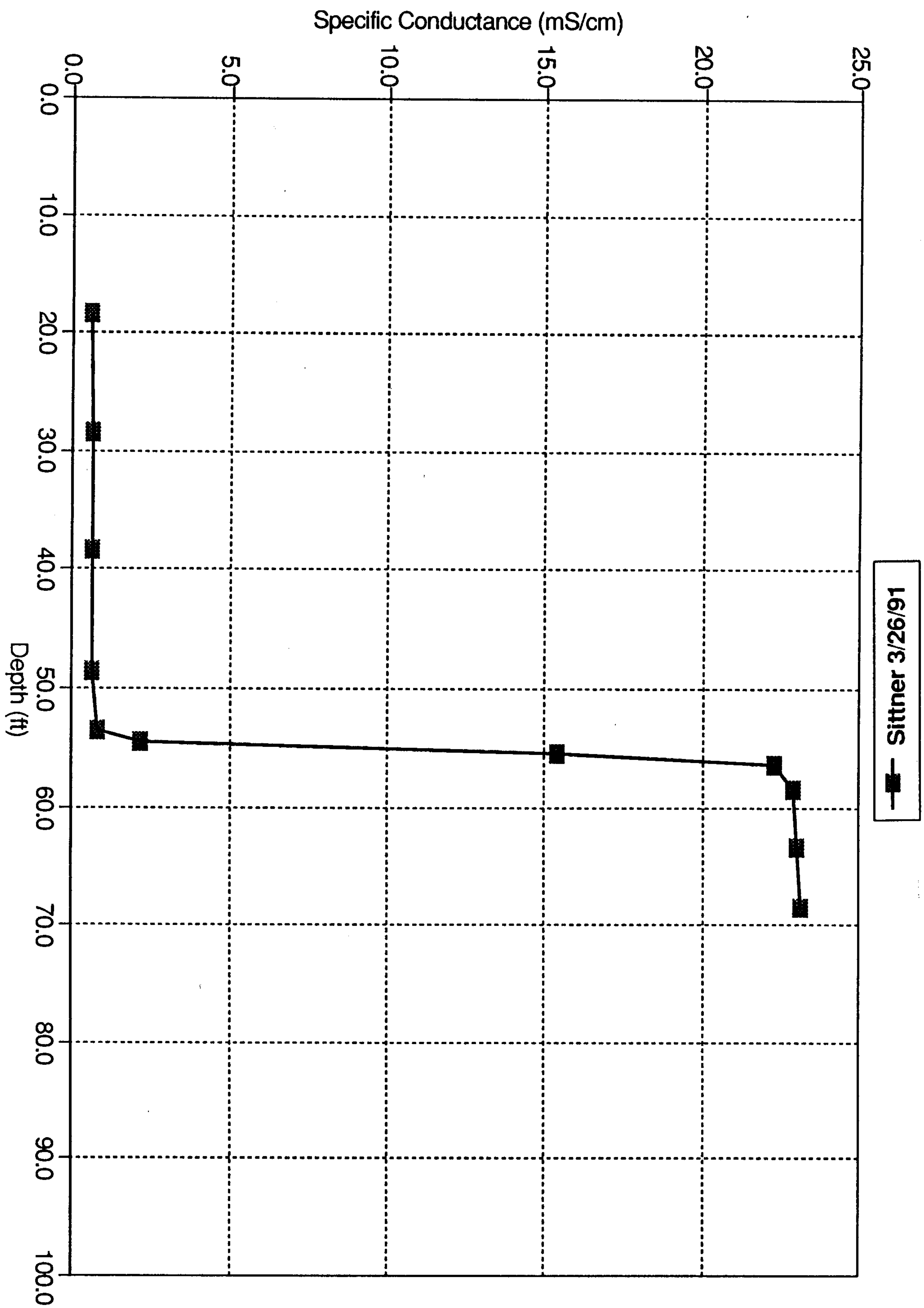

Specific Conductance (mS/cm)
0.0
5.0
10.0
15.0
20.0
25.0
Sittner 8/30/90
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
Depth (ft)

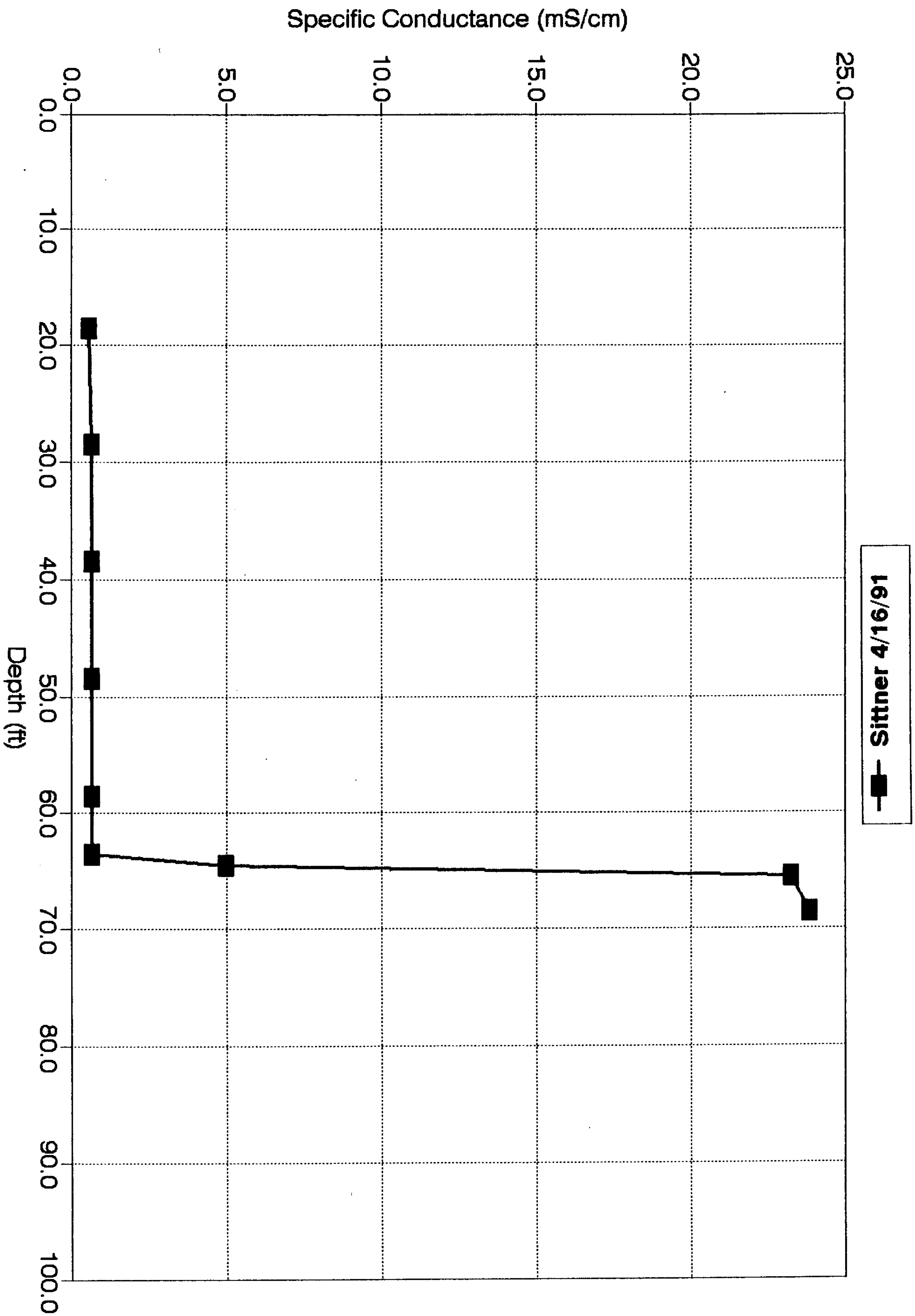

Specific Conductance (mS/cm)
0.0
5.0
10.0
15.0
20.0
25.0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
Depth (ft)
Sittner 9/20/90


Specific Conductance (mS/cm)
0.0
5.0
10.0
15.0
20.0
25.0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
Depth (ft)
Sittner 10/25/90

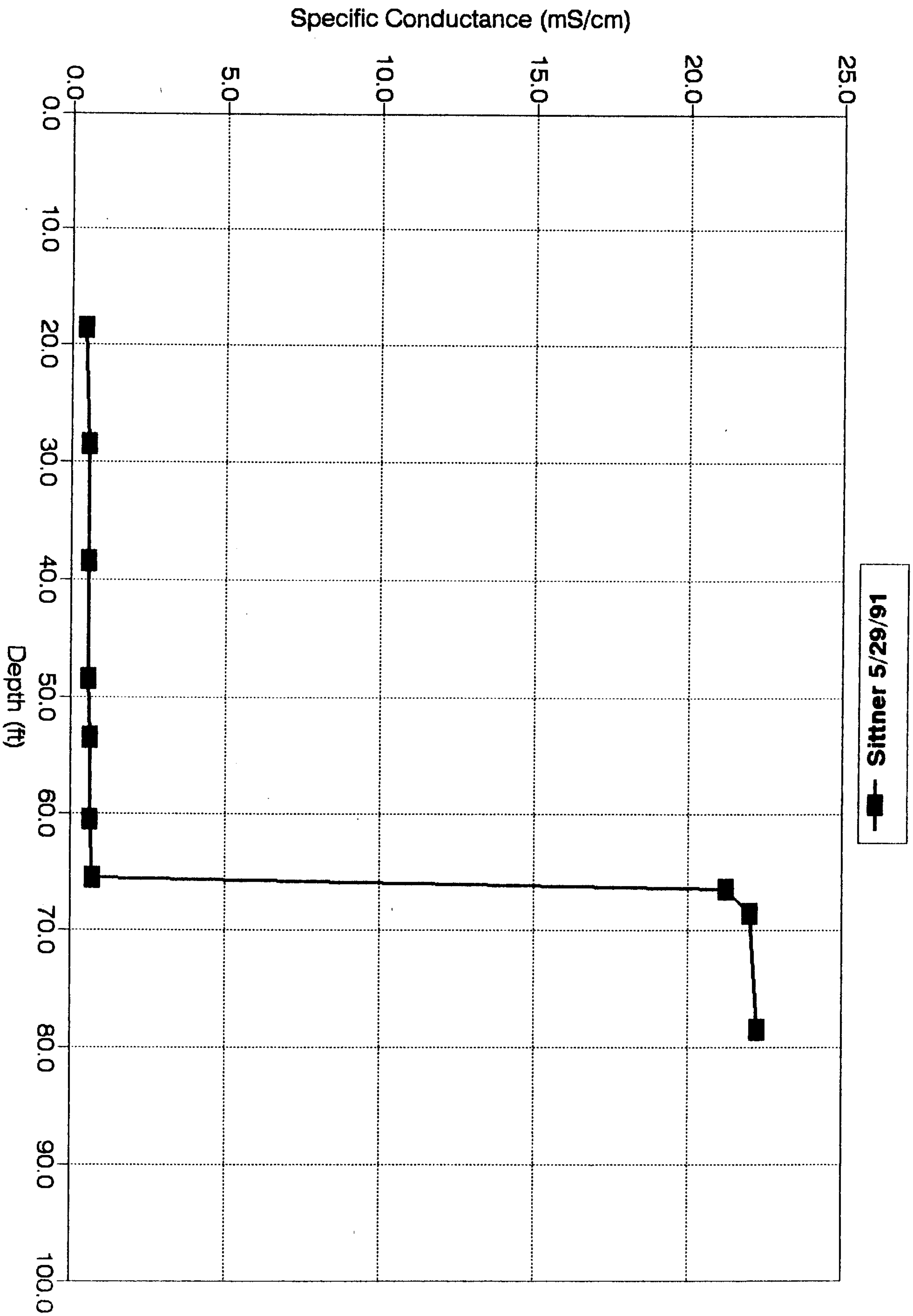

Specific Conductance (mS/cm)
0.0
5.0
10.0
15.0
20.0
25.0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
Depth (ft)
Sittner 12/6/90


Specific Conductance (mS/cm)
Depth (ft)
Sittner 2/19/91
0.0
5.0
10.0
15.0
20.0
25.0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0

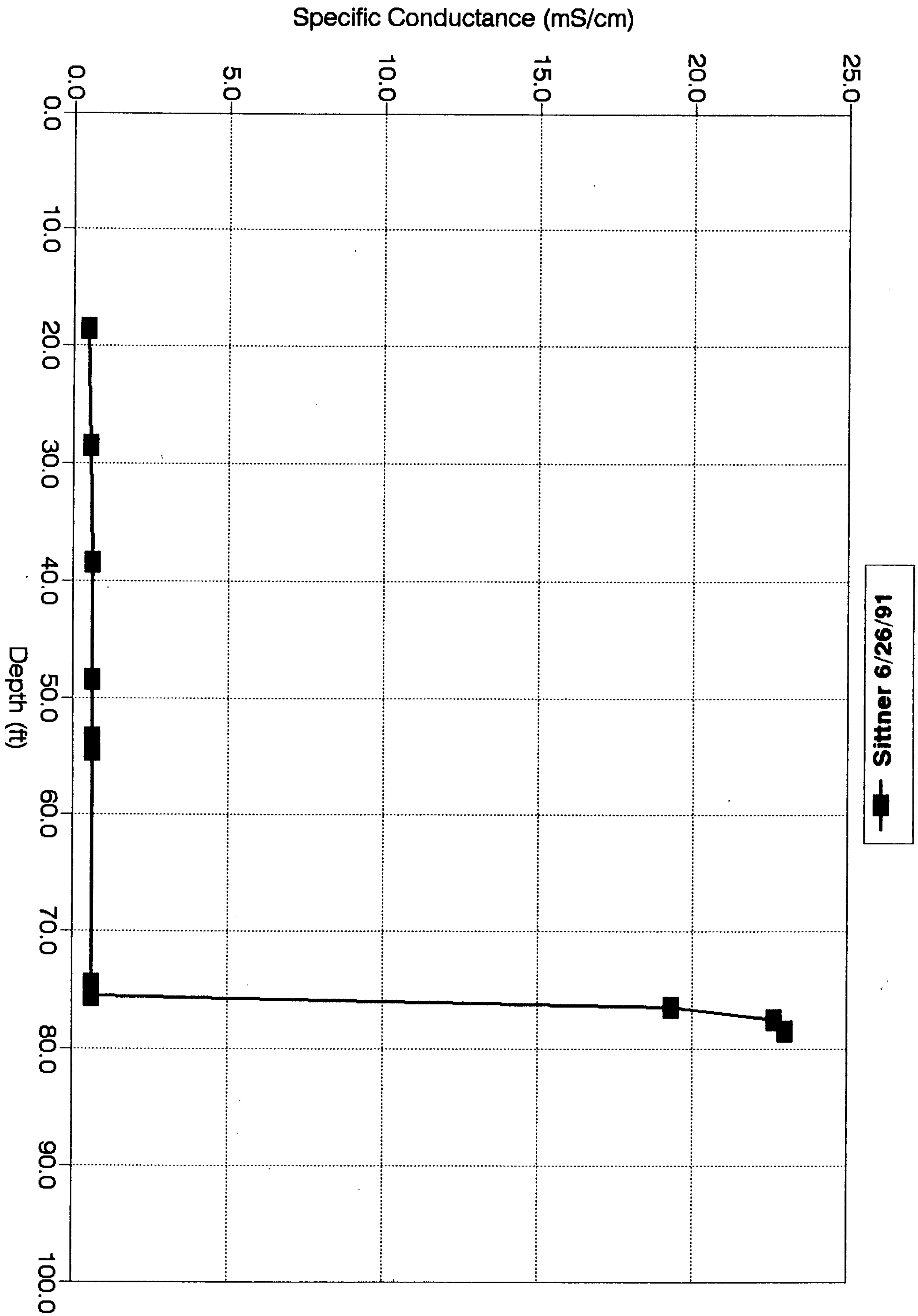

Specific Conductance (mS/cm)
0.0
5.0
10.0
15.0
20.0
25.0
Depth (ft)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
Sittner 3/26/91

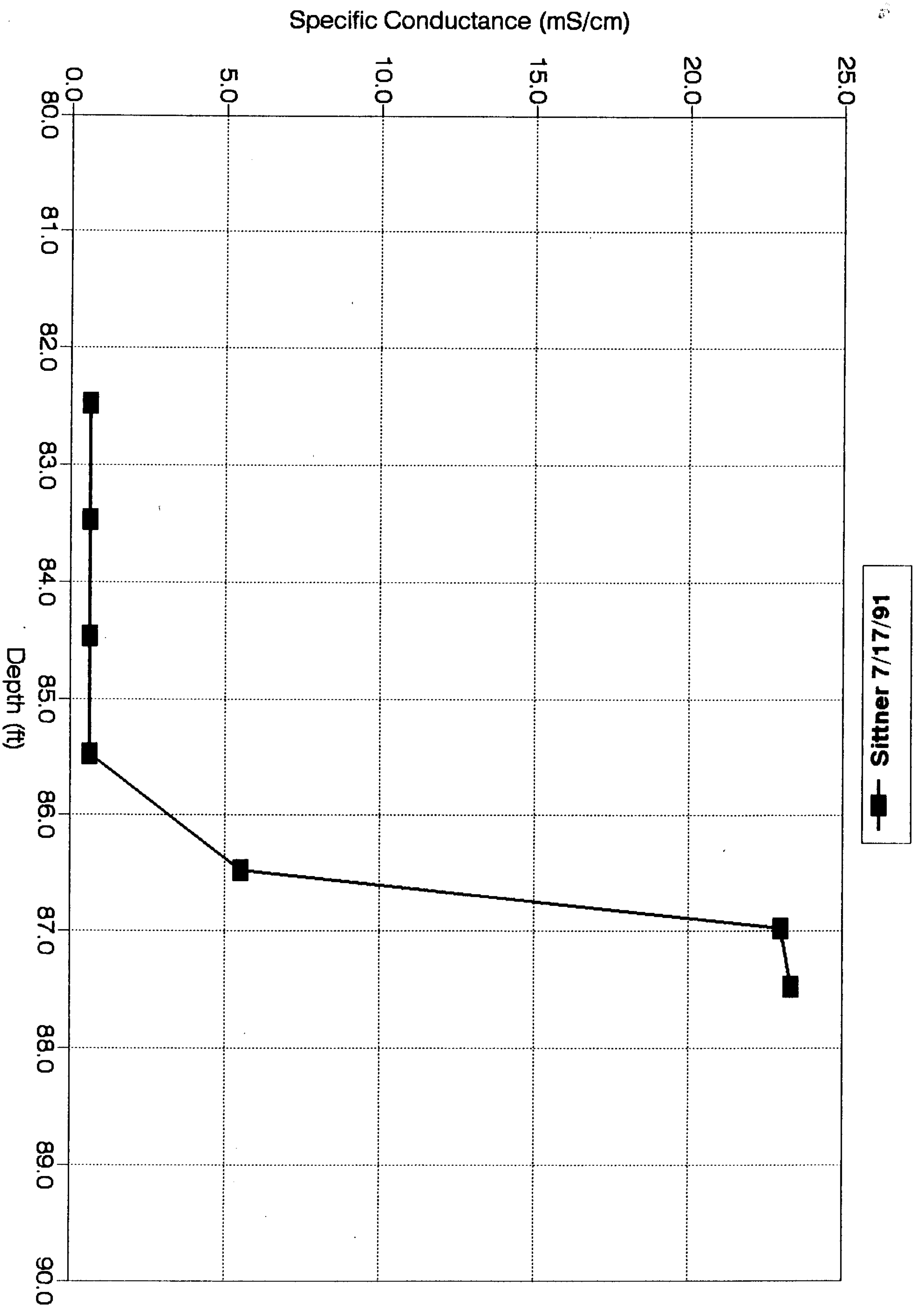


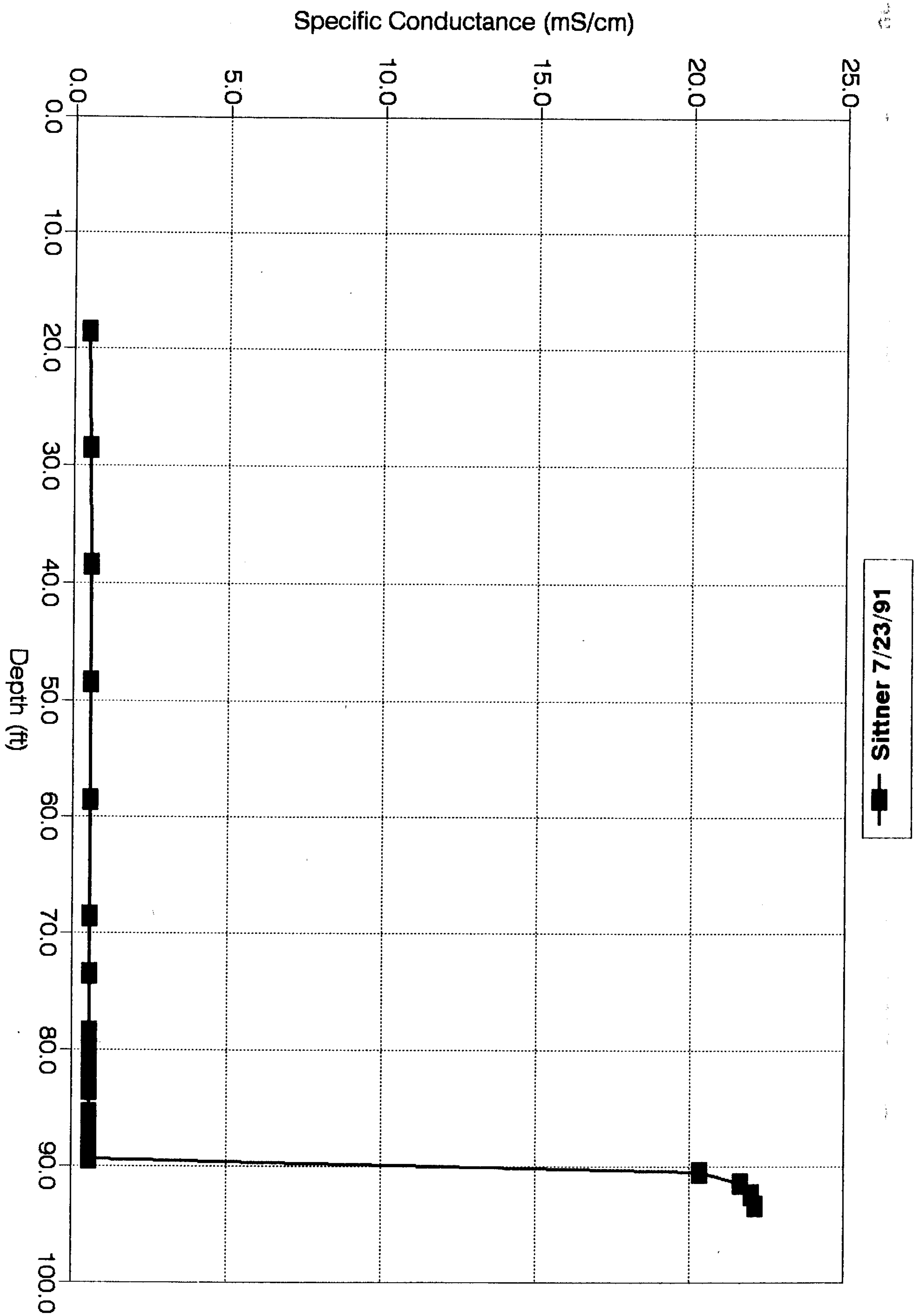
Specific Conductance (mS/cm)
0.0
5.0
10.0
15.0
20.0
25.0
Depth (ft)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
Sittner 4/16/91

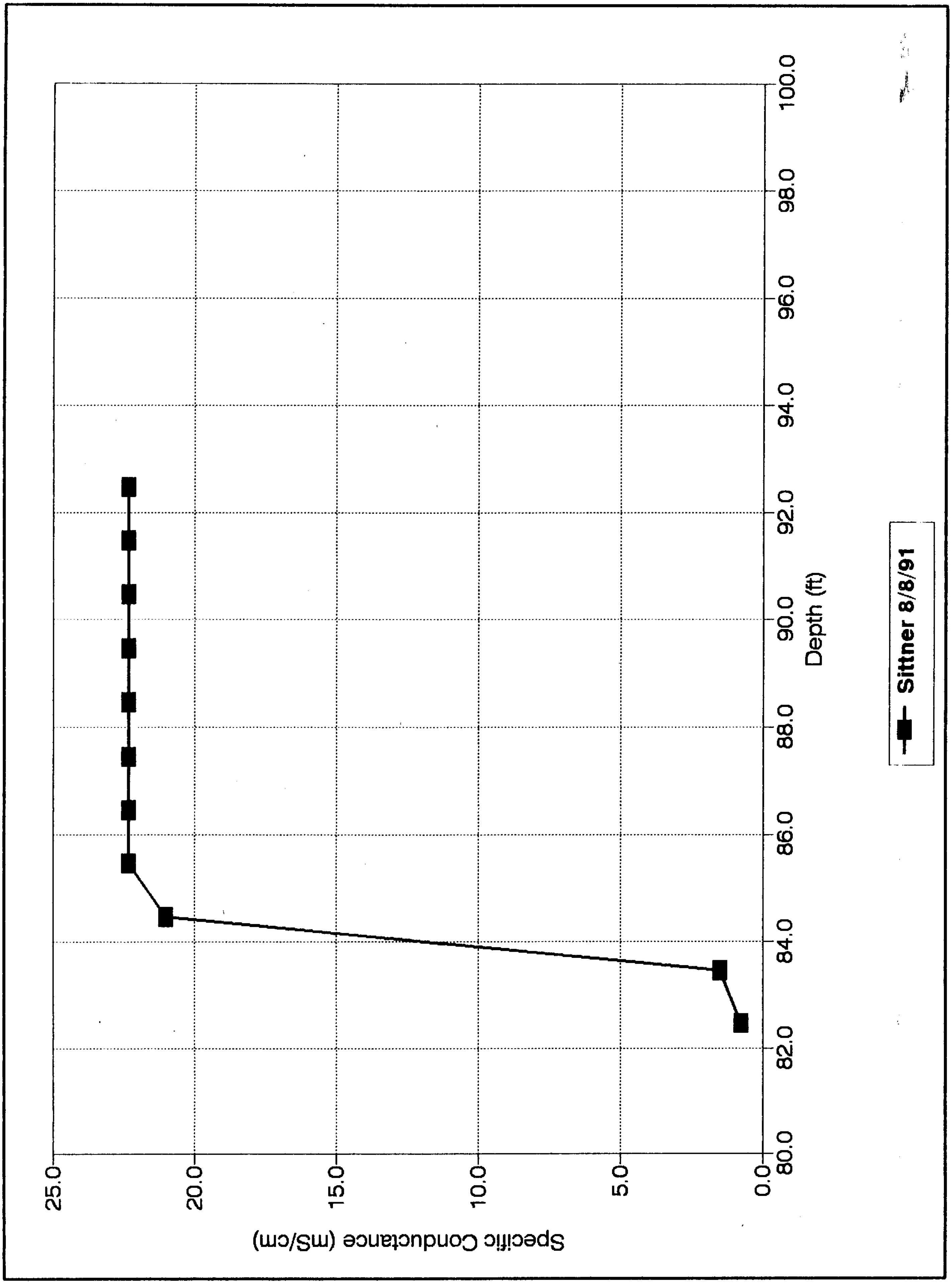


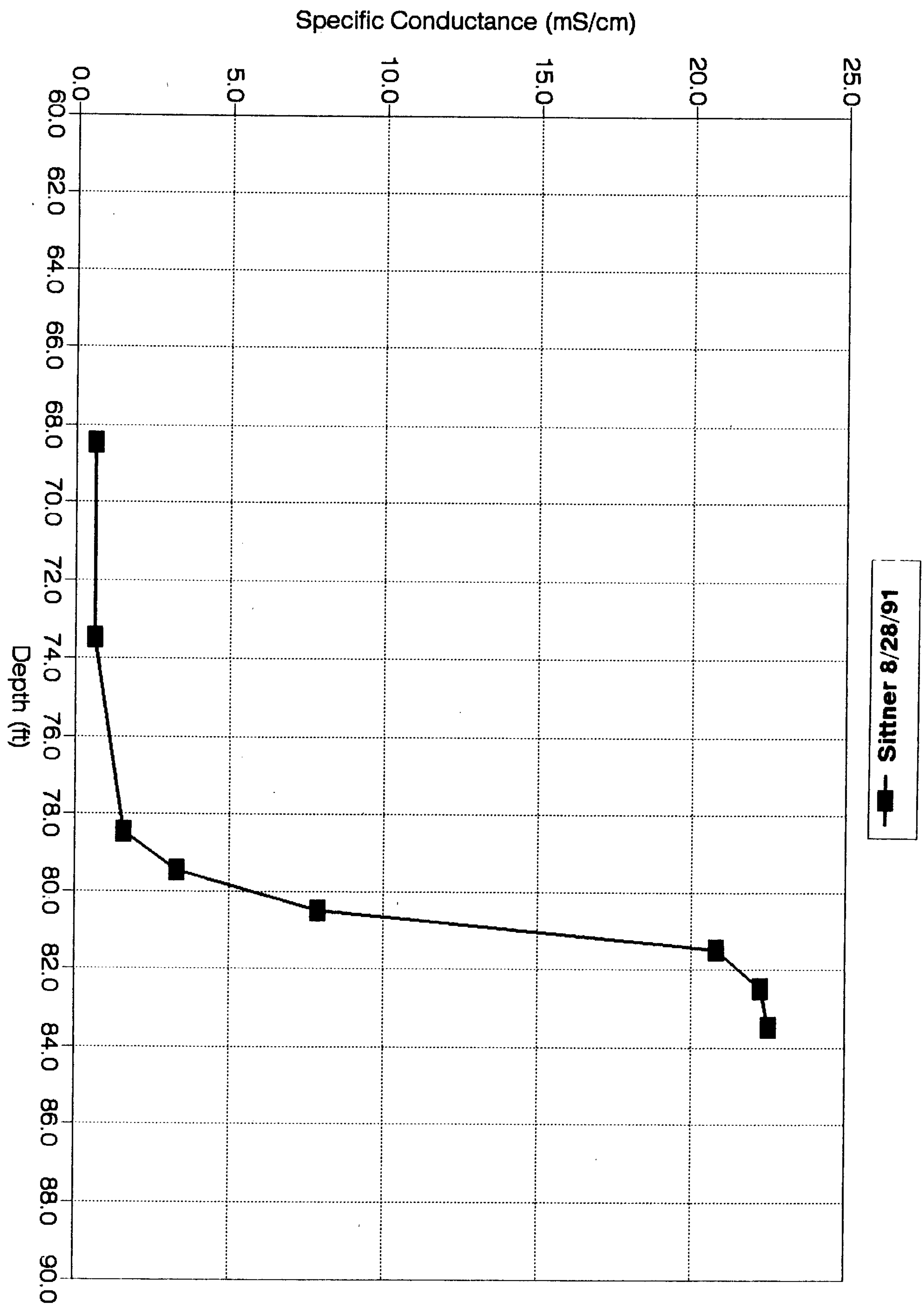
Specific Conductance (mS/cm)
0.0
5.0
10.0
15.0
20.0
25.0
Depth (ft)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
Sittner 5/29/91

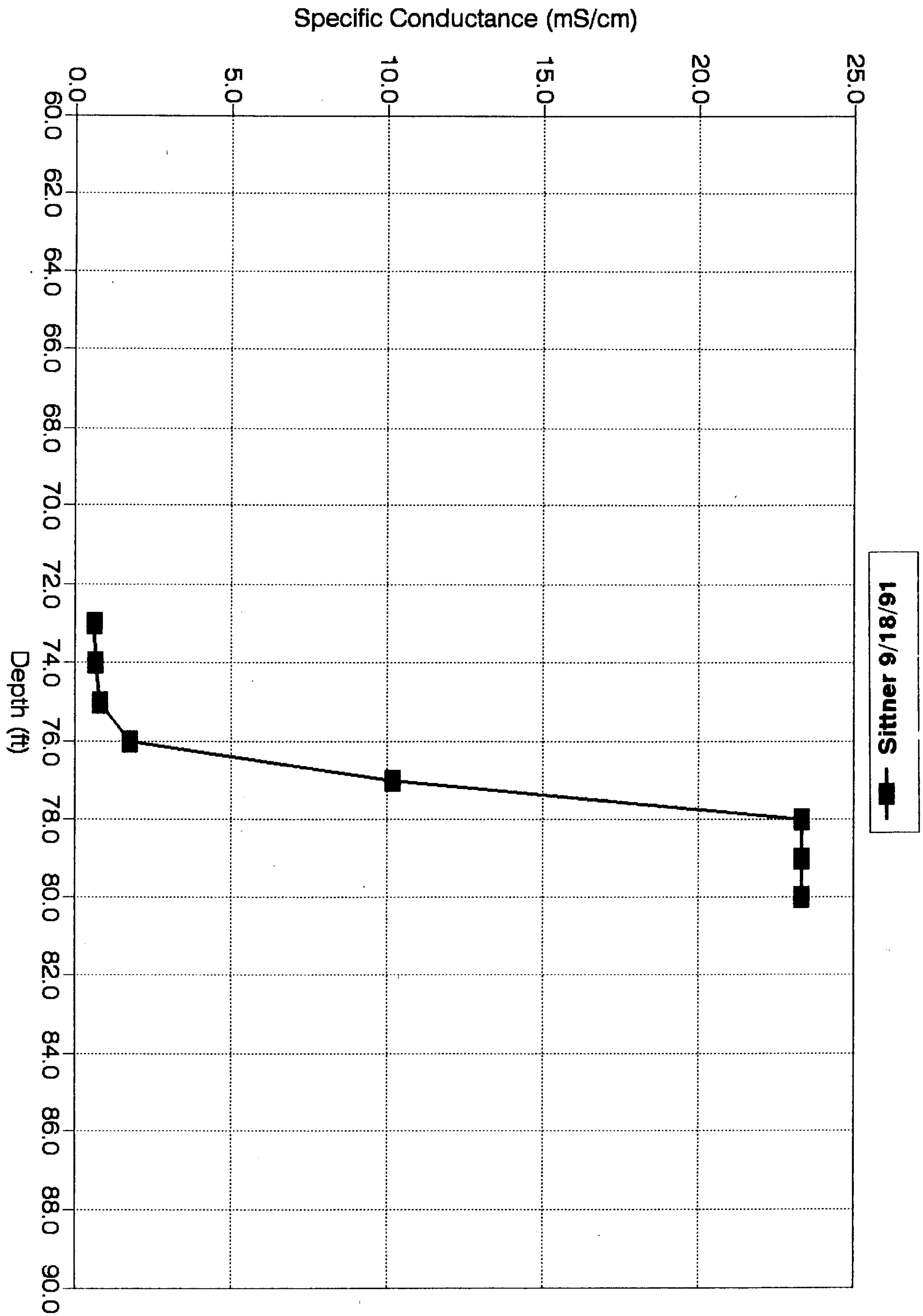

Specific Conductance (mS/cm)
0.0
5.0
10.0
15.0
20.0
25.0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
Depth (ft)
Sittner 6/26/91

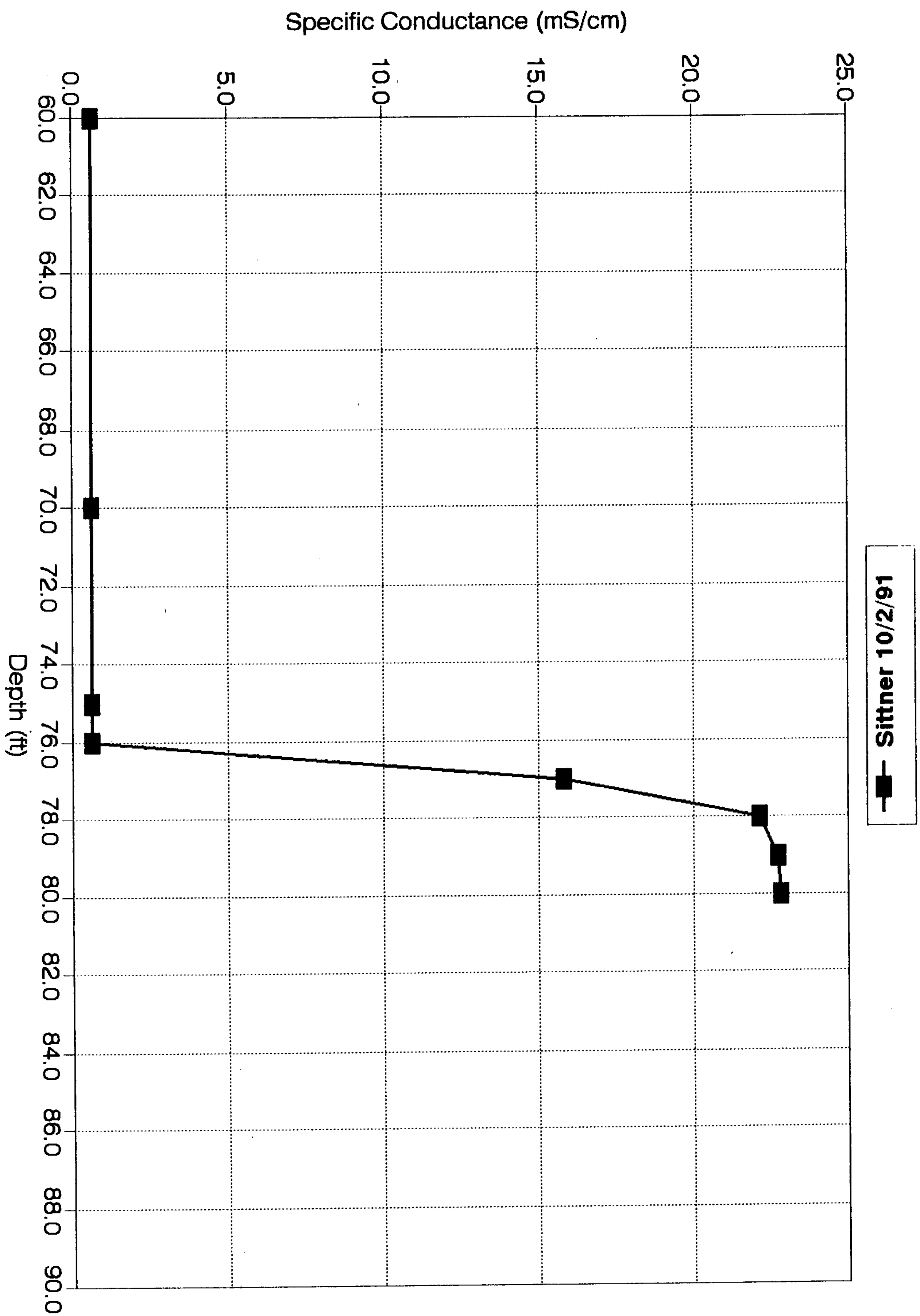

Specific Conductance (mS/cm)
0.0
5.0
10.0
15.0
20.0
25.0
80.0
81.0
82.0
83.0
84.0
85.0
86.0
87.0
88.0
89.0
90.0
Depth (ft)
Sittner 7/17/91


Specific Conductance (mS/cm)
0.0
5.0
10.0
15.0
20.0
25.0
Depth (ft)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
Sittner 7/23/91

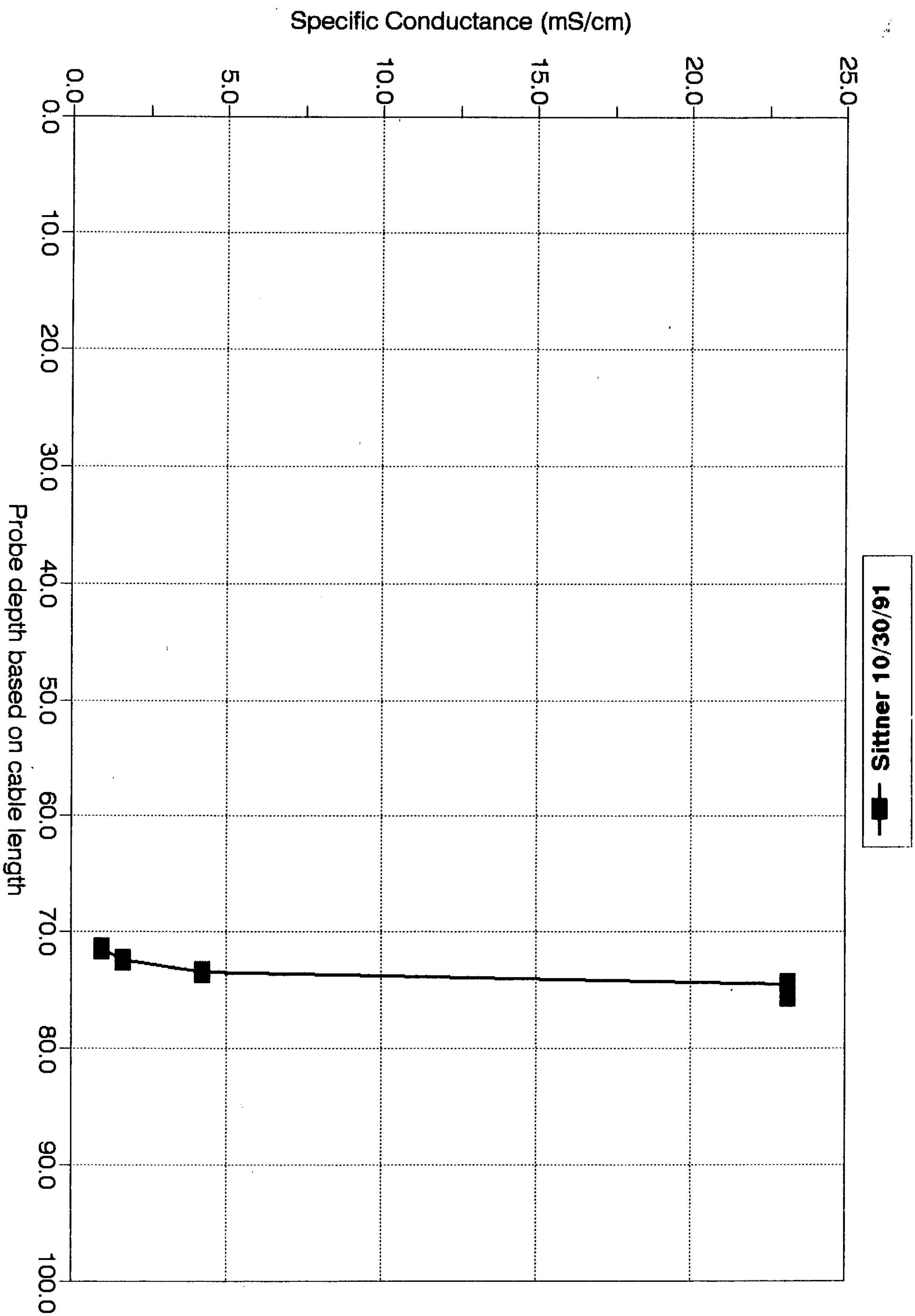

Specific Conductance (mS/cm)
25.0
20.0
15.0
10.0
5.0
0.0
80.0
82.0
84.0
86.0
88.0
90.0
92.0
94.0
96.0
98.0
100.0
Depth (ft)
Sittner 8/8/91

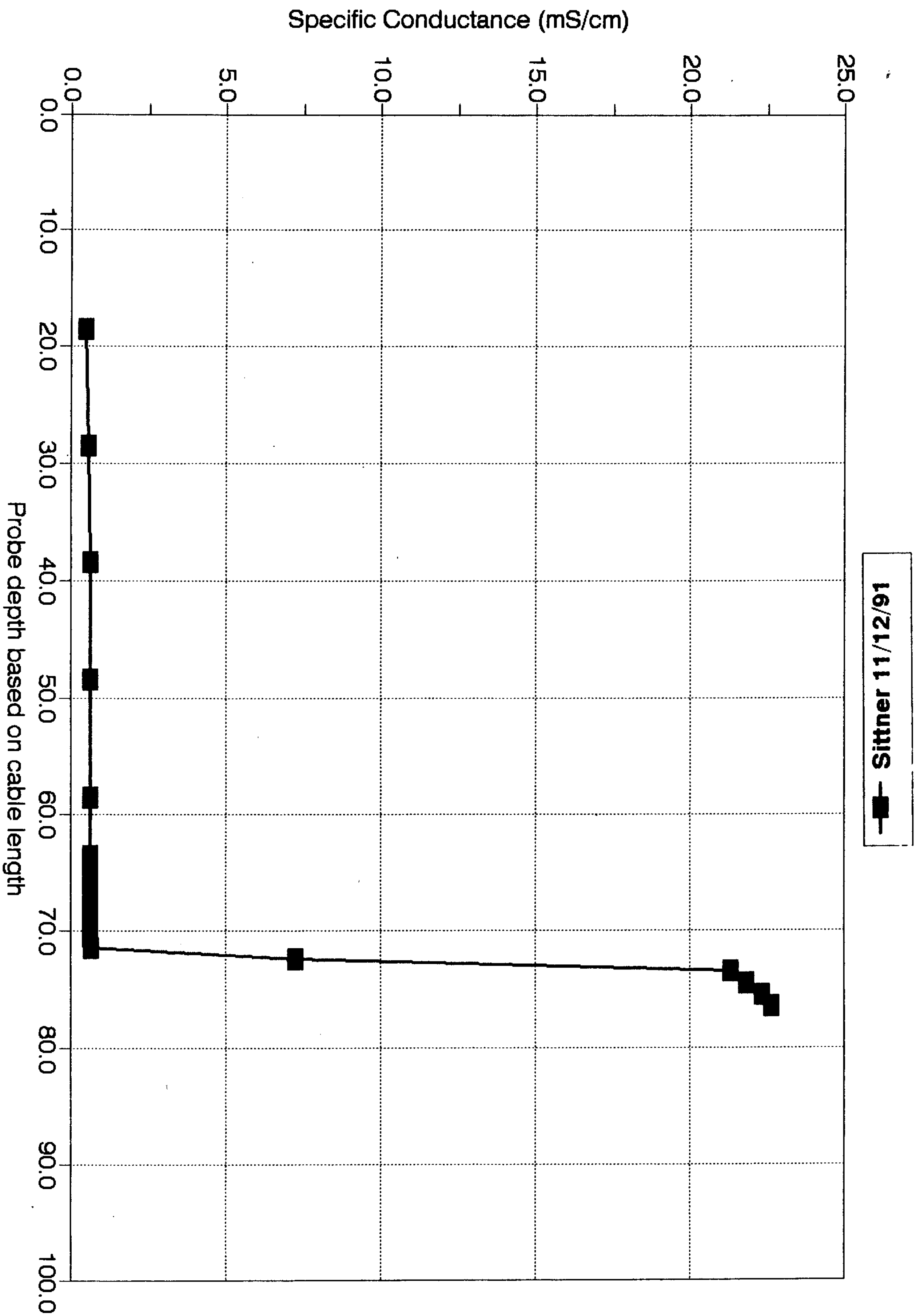

Specific Conductance (mS/cm)
0.0
5.0
10.0
15.0
20.0
25.0
60.0
62.0
64.0
66.0
68.0
70.0
72.0
74.0
76.0
78.0
80.0
82.0
84.0
86.0
88.0
90.0
Depth (ft)
Sittner 8/28/91

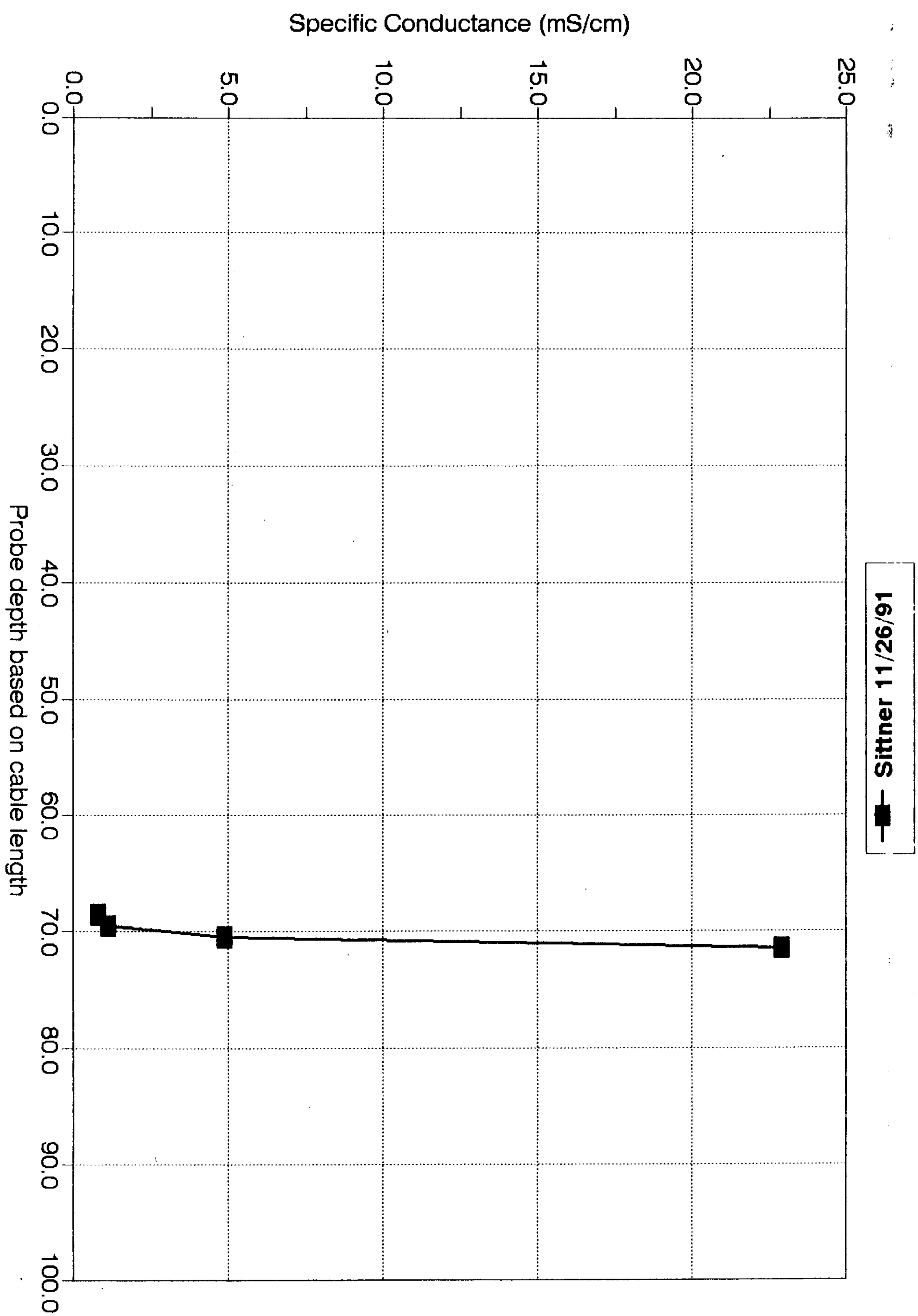

Specific Conductance (mS/cm)
0.0
5.0
10.0
15.0
20.0
25.0
60.0
62.0
64.0
66.0
68.0
70.0
72.0
74.0
76.0
78.0
80.0
82.0
84.0
86.0
88.0
90.0
Depth (ft)
Sittner 9/18/91

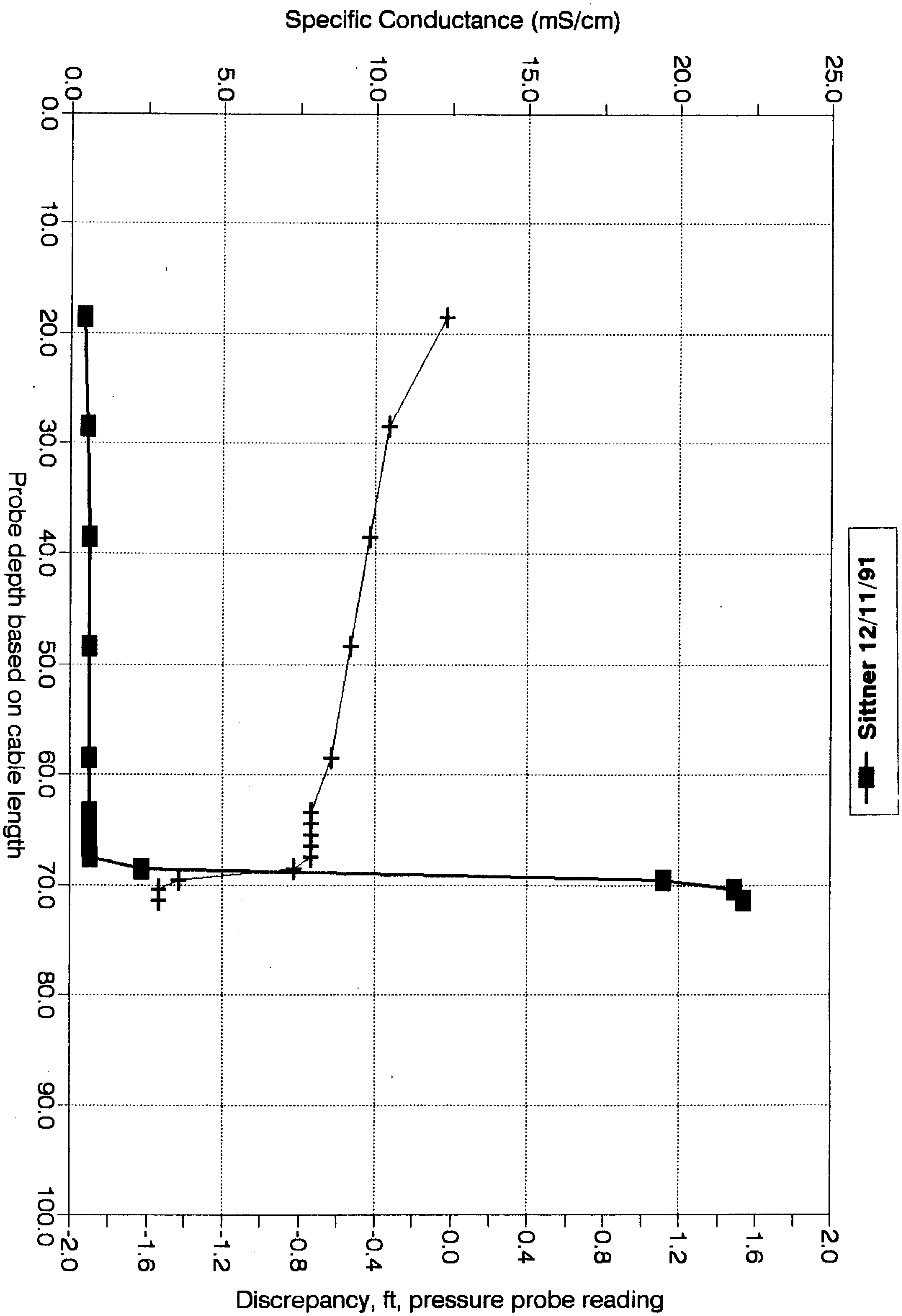


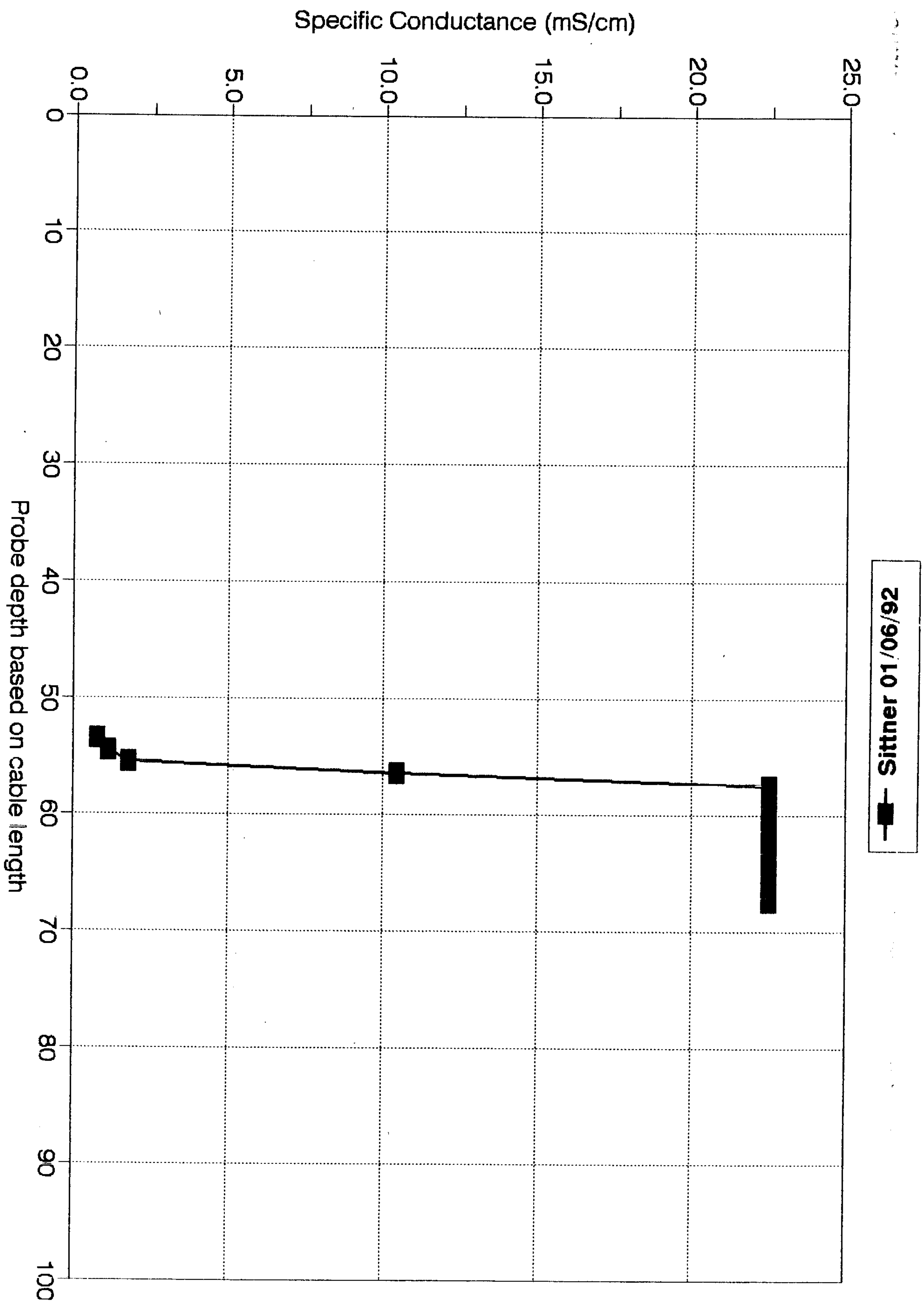
Specific Conductance (mS/cm)
0.0
5.0
10.0
15.0
20.0
25.0
60.0
62.0
64.0
66.0
68.0
70.0
72.0
74.0
76.0
78.0
80.0
82.0
84.0
86.0
88.0
90.0
Depth (ft)
Sittner 10/2/91

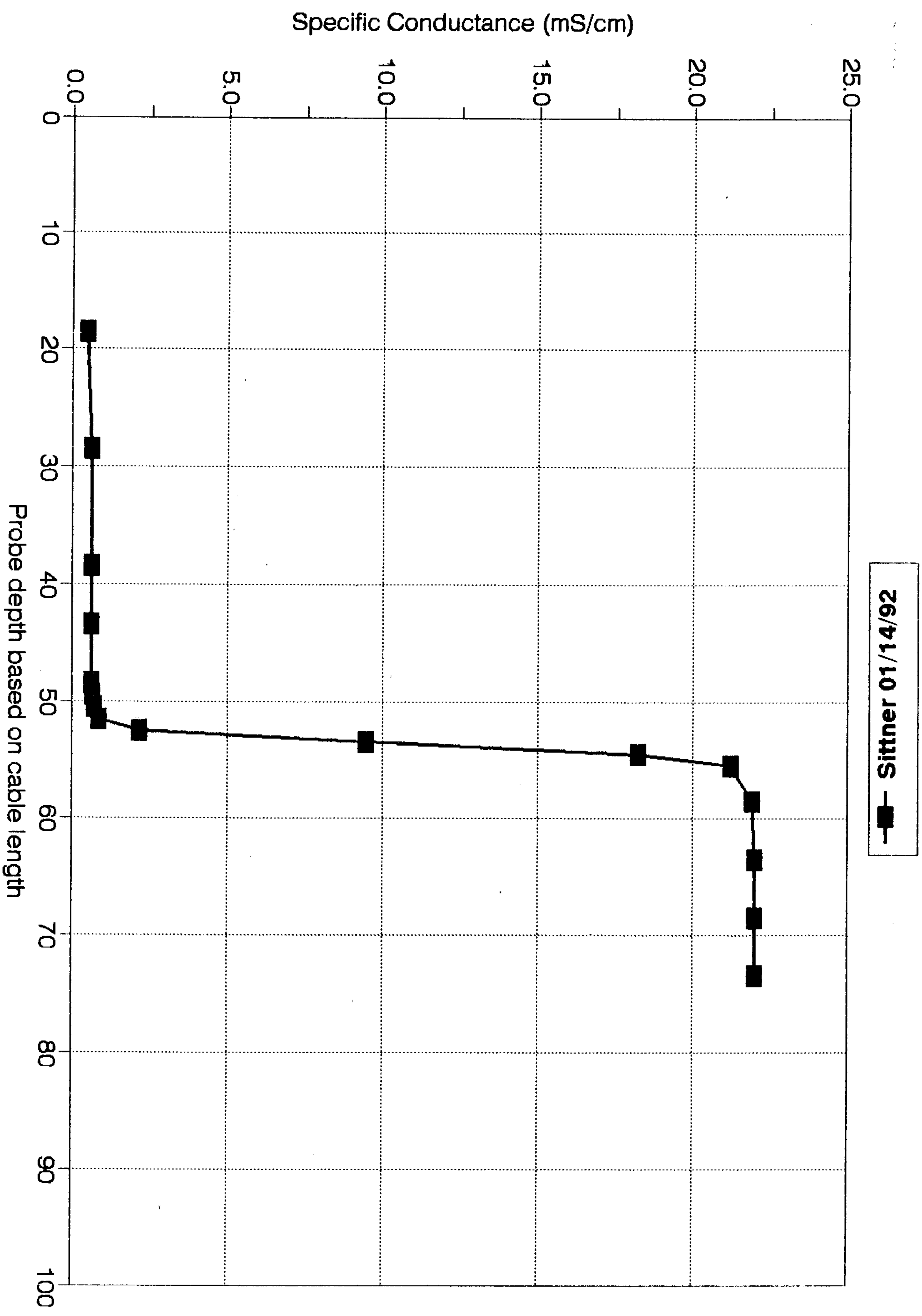

Specific Conductance (mS/cm)
0.0
5.0
10.0
15.0
20.0
25.0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
Probe depth based on cable length
Sittner 10/30/91


Specific Conductance (mS/cm)
0.0
5.0
10.0
15.0
20.0
25.0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
Probe depth based on cable length
Sittner 11/12/91

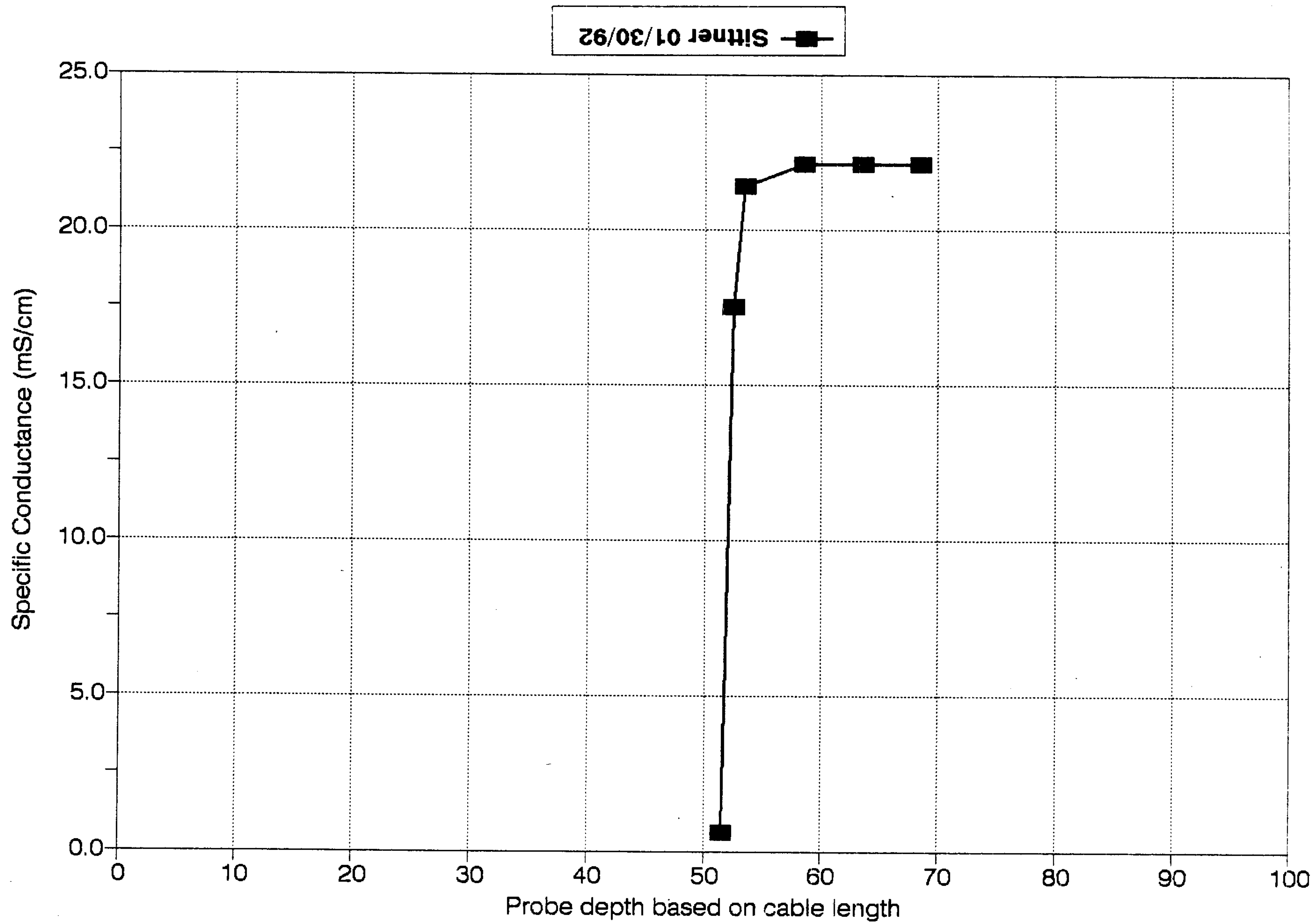

Specific Conductance (mS/cm)
0.0
5.0
10.0
15.0
20.0
25.0
Probe depth based on cable length
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
Sittner 11/26/91

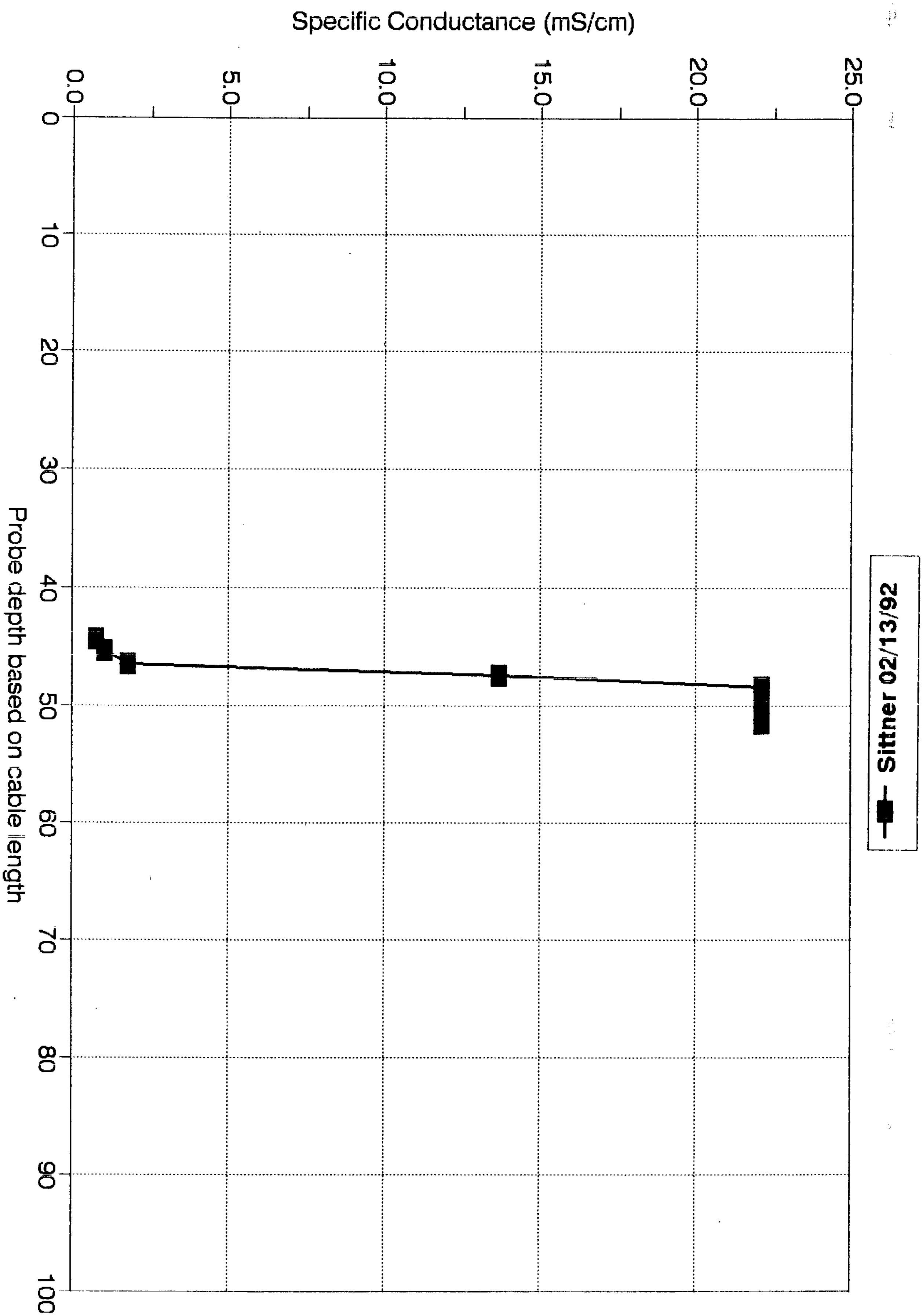

Specific Conductance (mS/cm)
0.0
5.0
10.0
15.0
20.0
25.0
Probe depth based on cable length
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
Sittner 12/11/91
-2.0
-1.6
-1.2
-0.8
-0.4
0.0
0.4
0.8
1.2
1.6
2.0
Discrepancy, ft, pressure probe reading

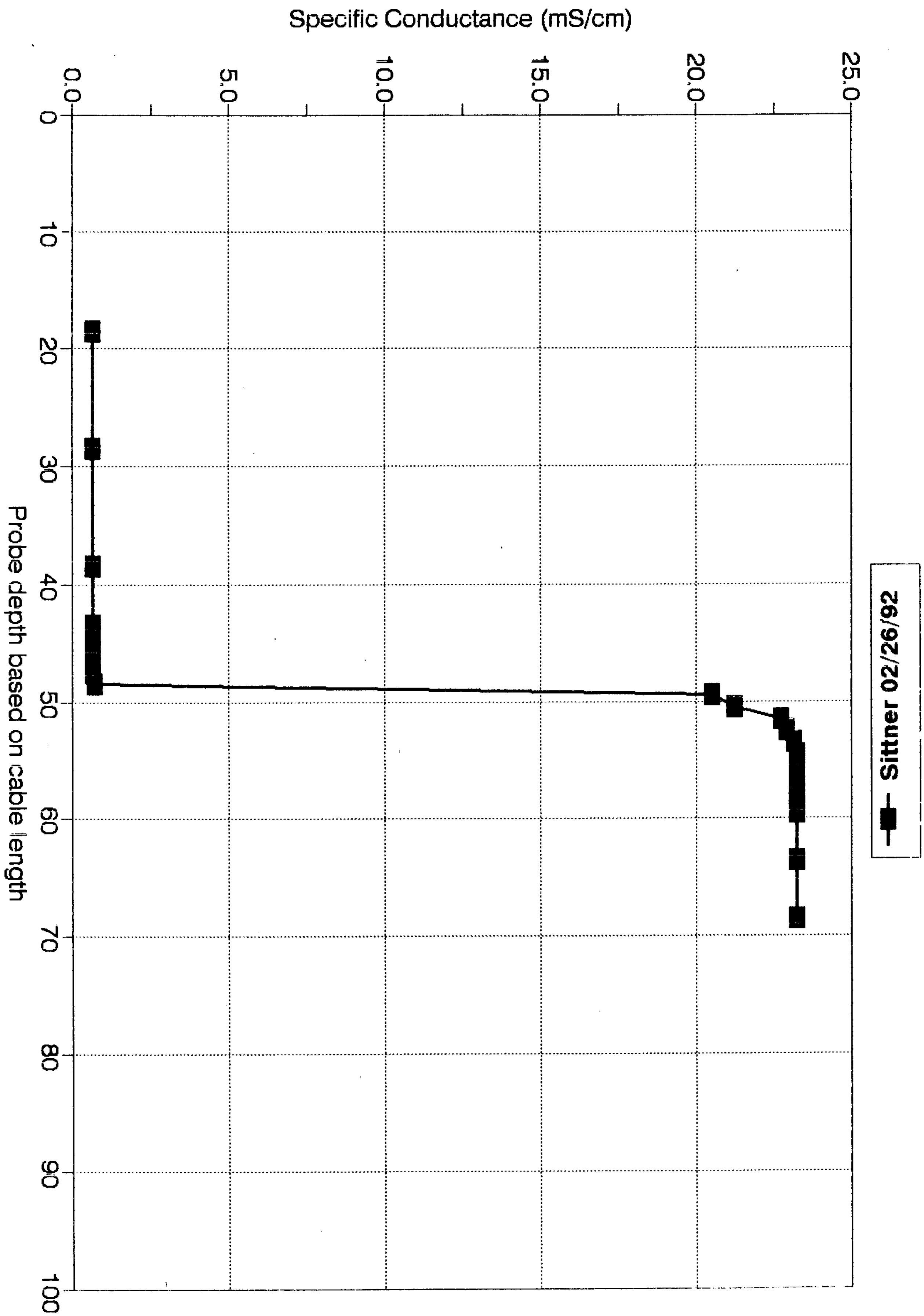

Specific Conductance (mS/cm)
0.0
5.0
10.0
15.0
20.0
25.0
0
10
20
30
40
50
60
70
80
90
100
Probe depth based on cable length
Sittner 01/06/92

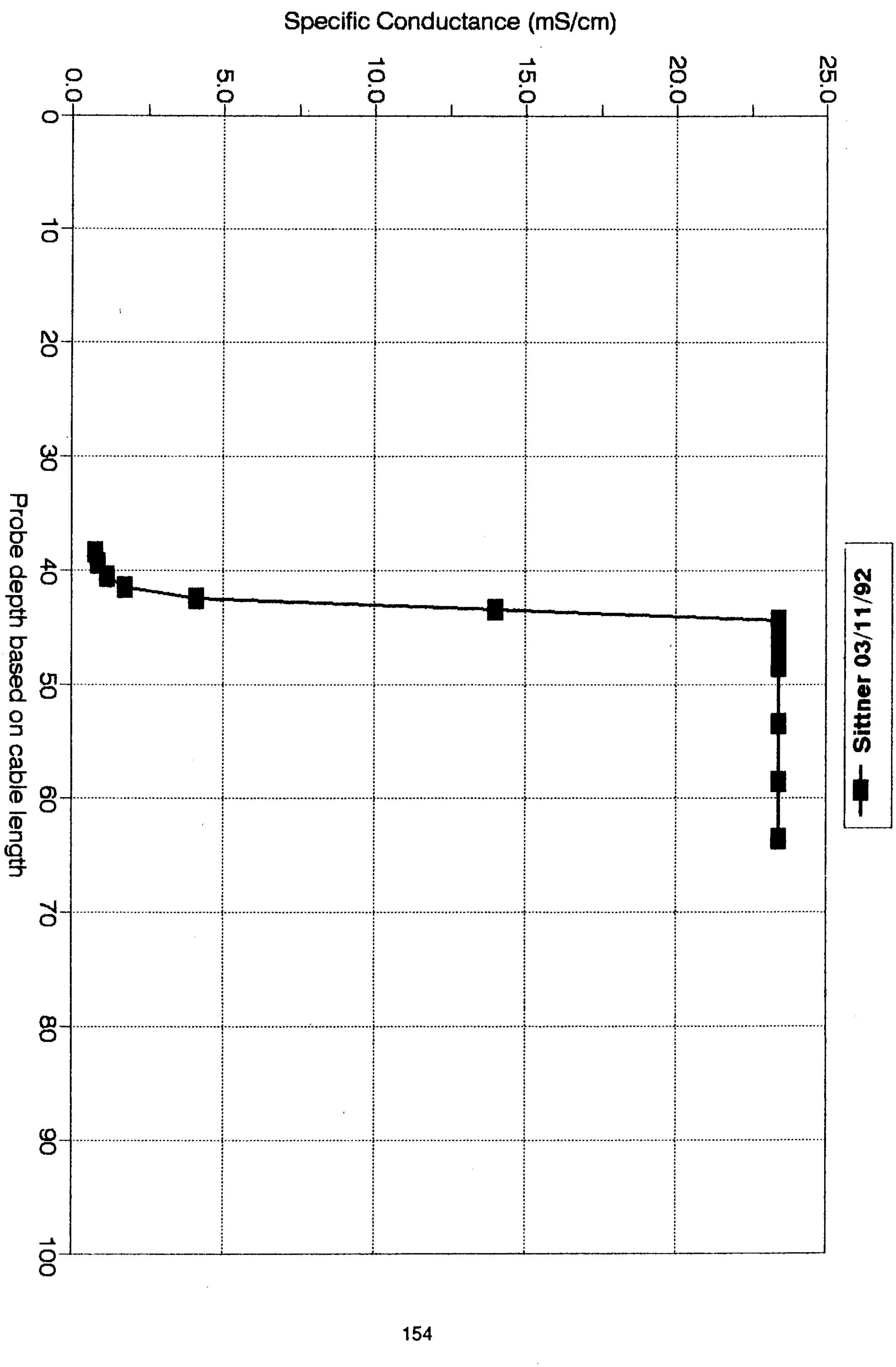


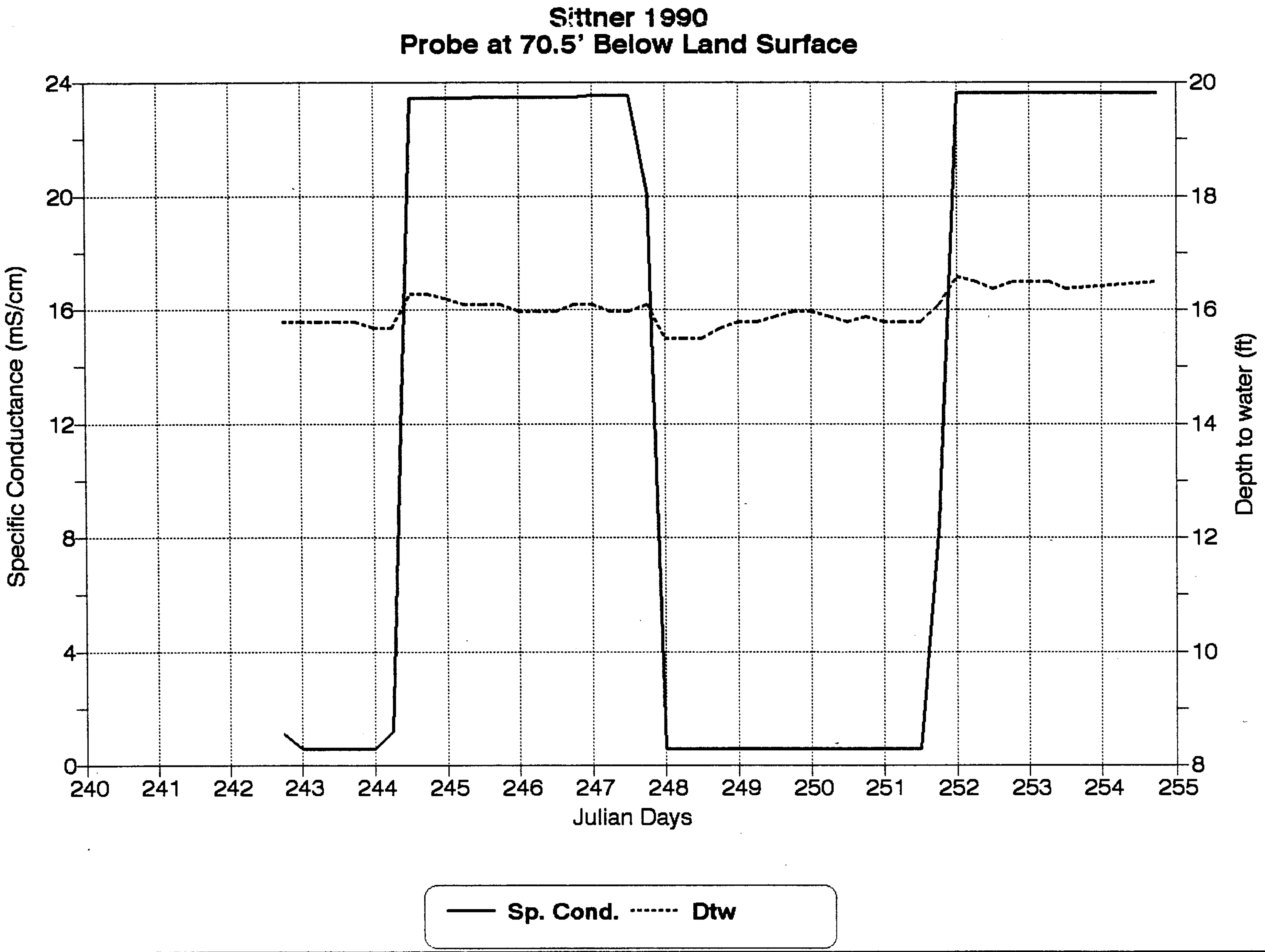
Specific Conductance (mS/cm)
0.0
5.0
10.0
15.0
20.0
25.0
0
10
20
30
40
50
60
70
80
90
100
Probe depth based on cable length
Sittner 01/14/92


Sittner 01/30/92
Specific Conductance (mS/cm)
25.0
20.0
15.0
10.0
5.0
0.0
0
10
20
30
40
50
60
70
80
90
100
Probe depth based on cable length

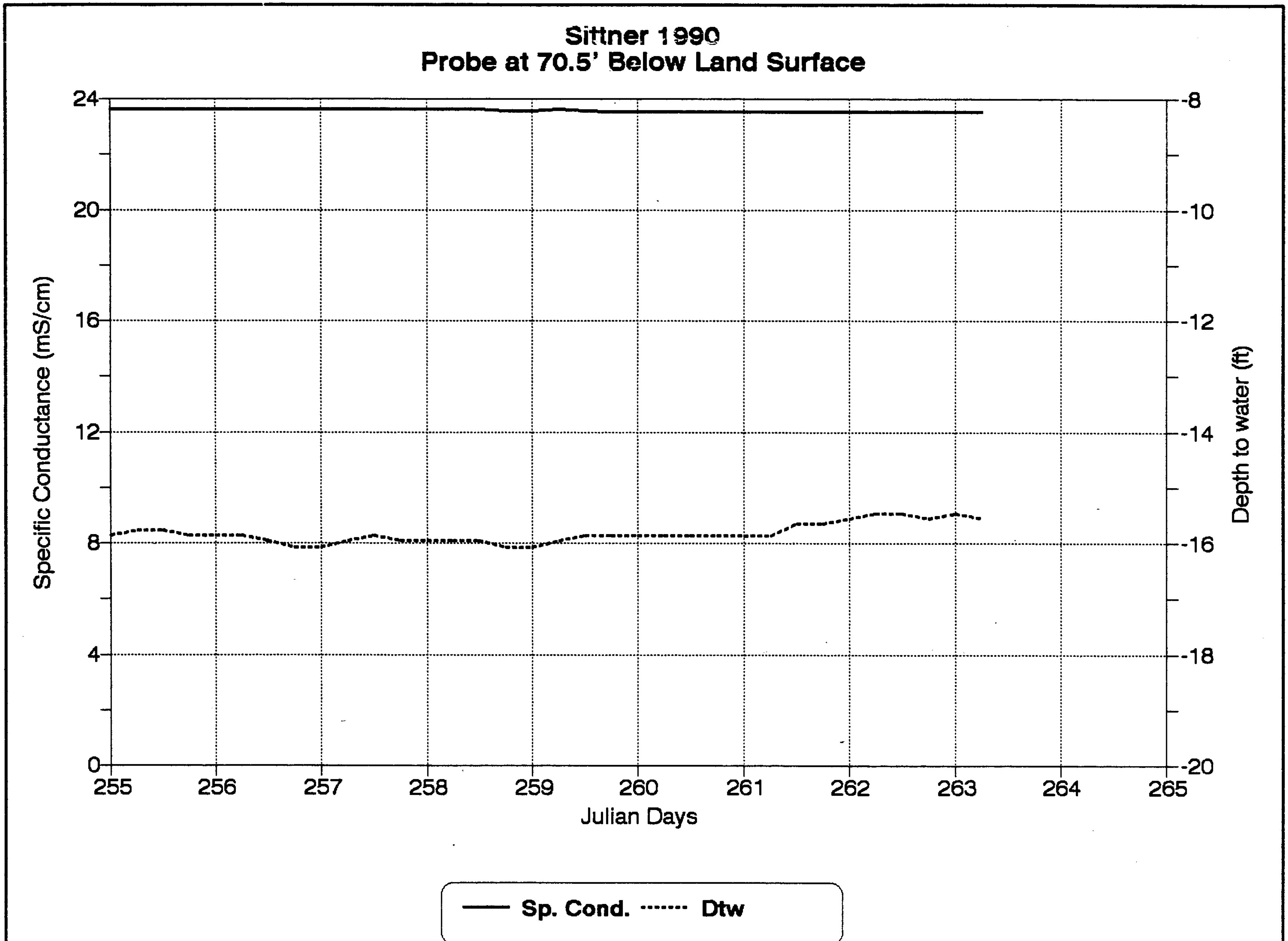

Specific Conductance (mS/cm)
0.0
5.0
10.0
15.0
20.0
25.0
0
10
20
30
40
50
60
70
80
90
100
Probe depth based on cable length
Sittner 02/13/92

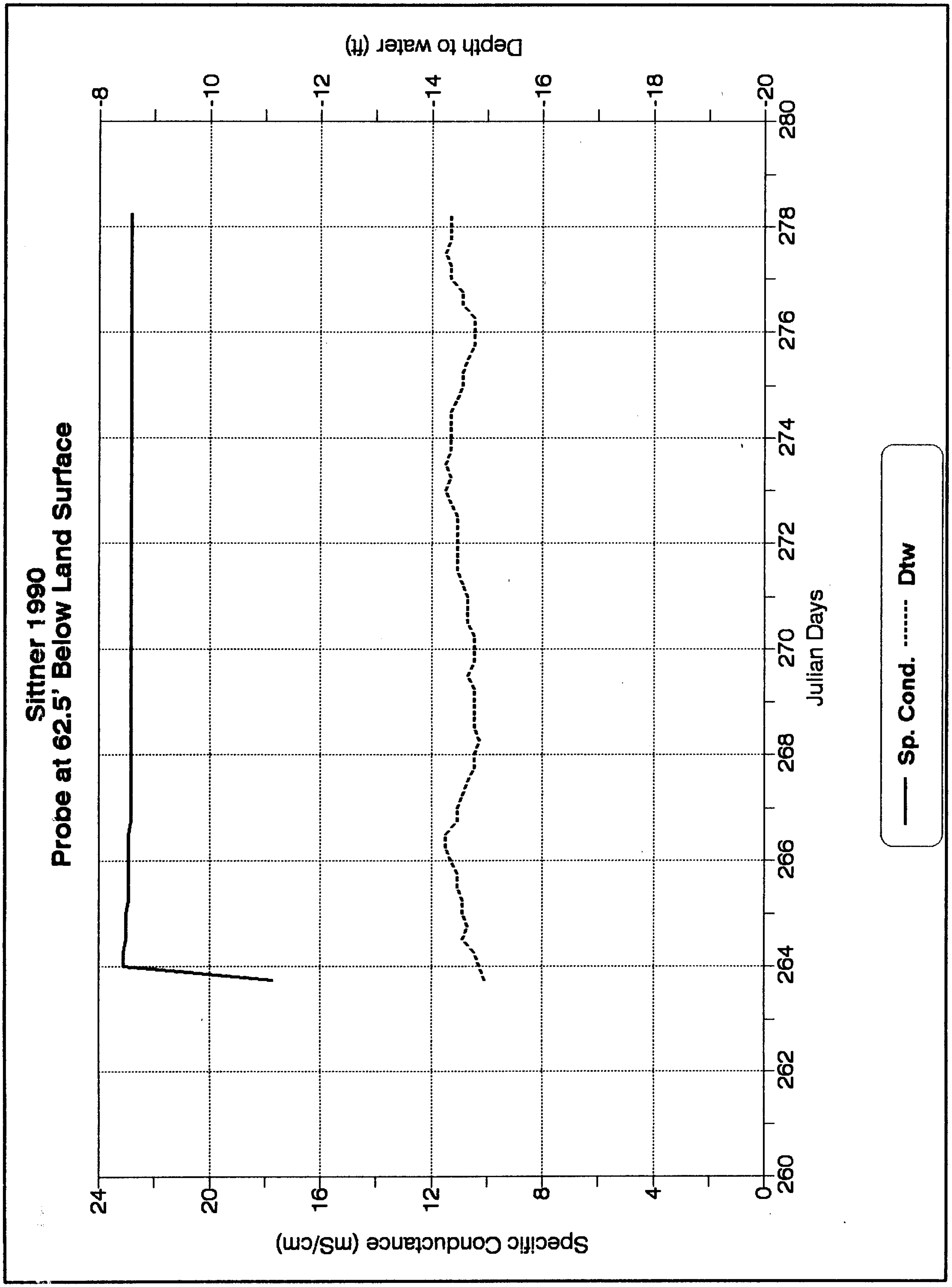

Specific Conductance (mS/cm)
0.0
5.0
10.0
15.0
20.0
25.0
0
10
20
30
40
50
60
70
80
90
100
Probe depth based on cable length
Sittner 02/26/92

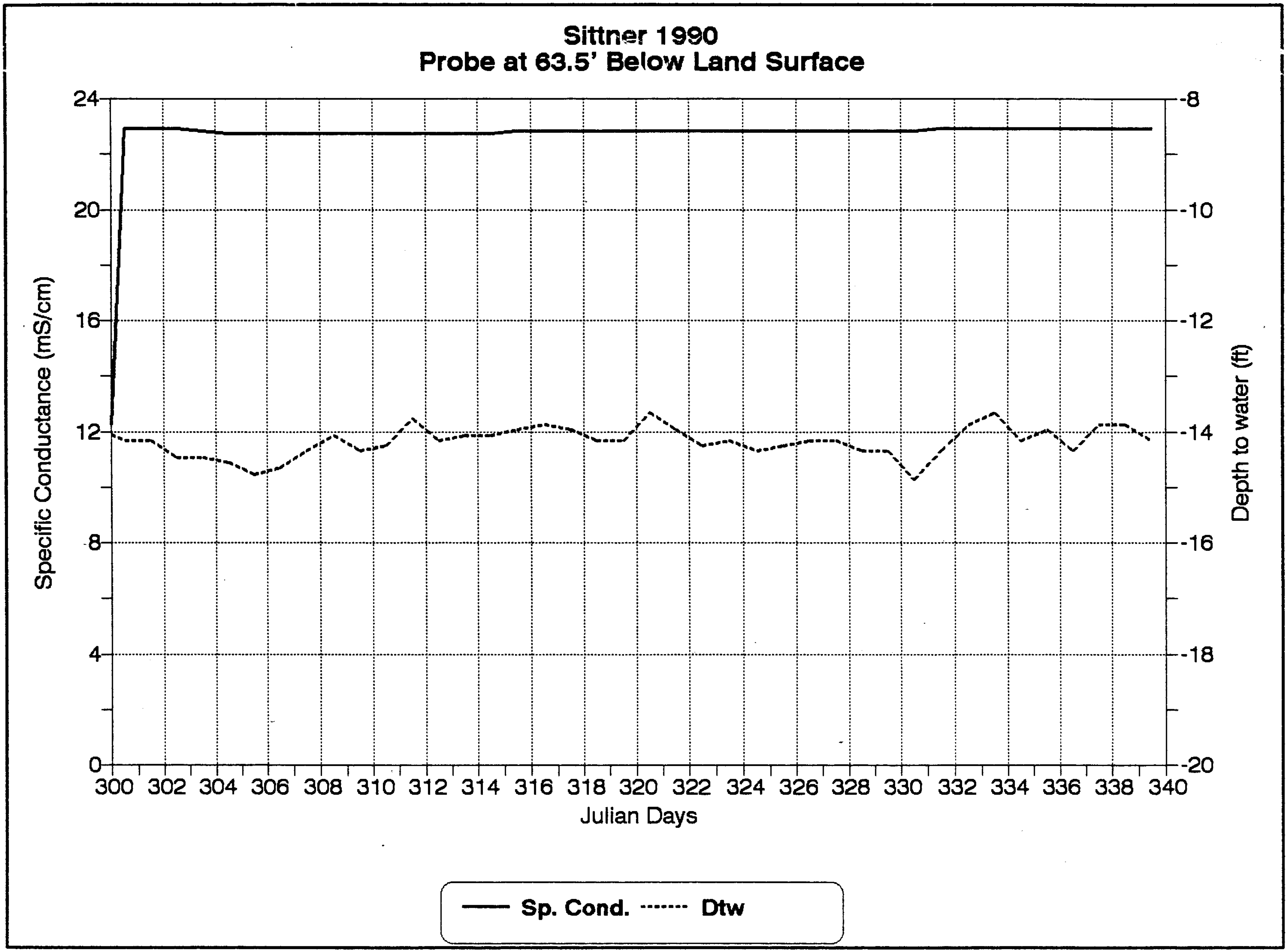

Specific Conductance (mS/cm)
0.0
5.0
10.0
15.0
20.0
25.0
0
10
20
30
40
50
60
70
80
90
100
Probe depth based on cable length
Sittner 03/11/92



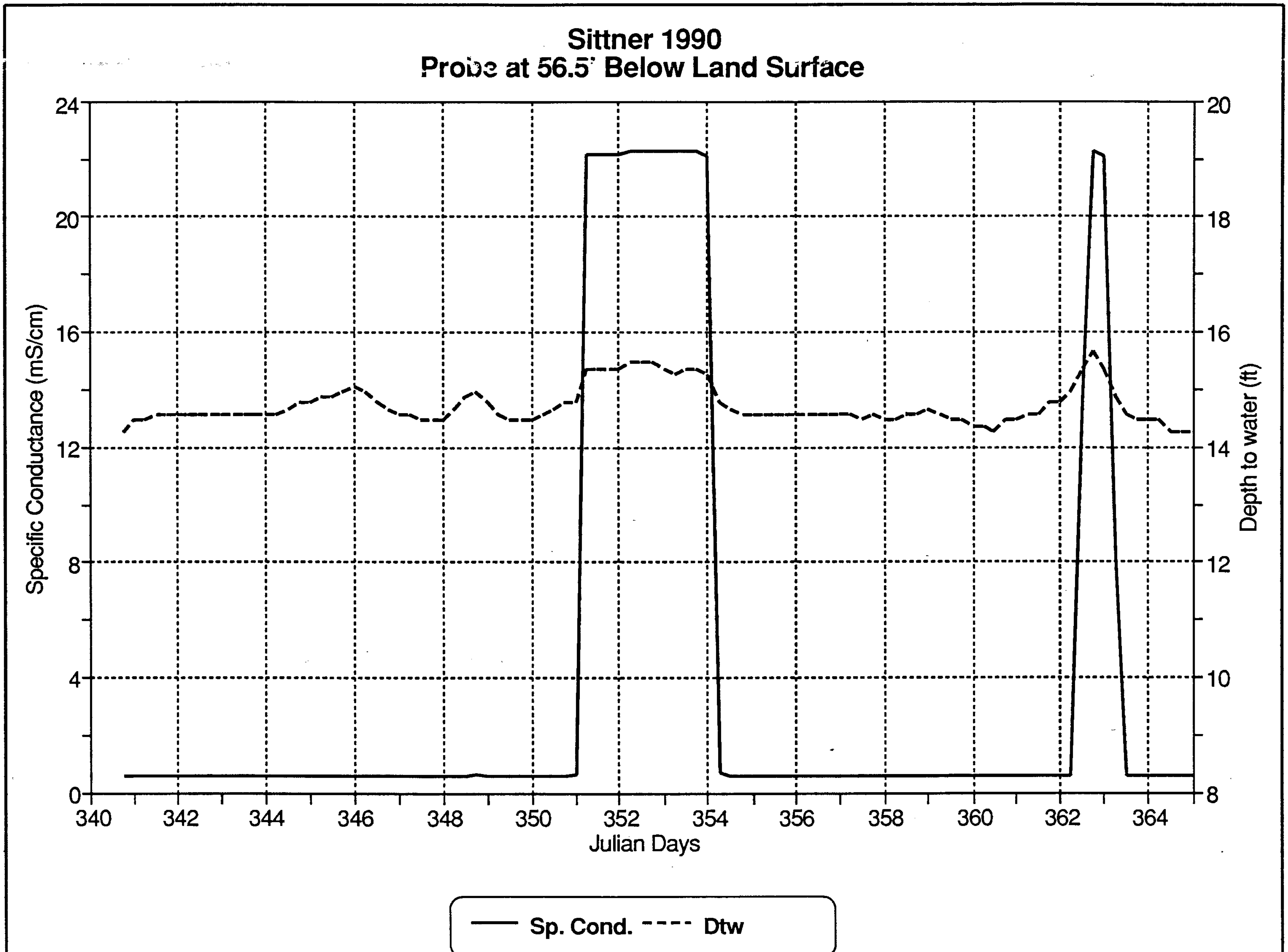
Sittner 1990
Probe at 70.5' Below Land Surface
Specific Conductance (mS/cm)
Depth to water (ft)
Julian Days
24
20
16
12
8
4
0
18
14
10
240
241
242
243
244
245
246
247
248
249
250
251
252
253
254
255
Sp. Cond.
Dtw


Sittner 1990
Probe at 70.5' Below Land Surface
Specific Conductance (mS/cm)
Depth to water (ft)
24
20
16
12
8
4
0
-8
-10
-12
-14
-16
-18
-20
255
256
257
258
259
260
261
262
263
264
265
Julian Days
Sp. Cond.
Dtw

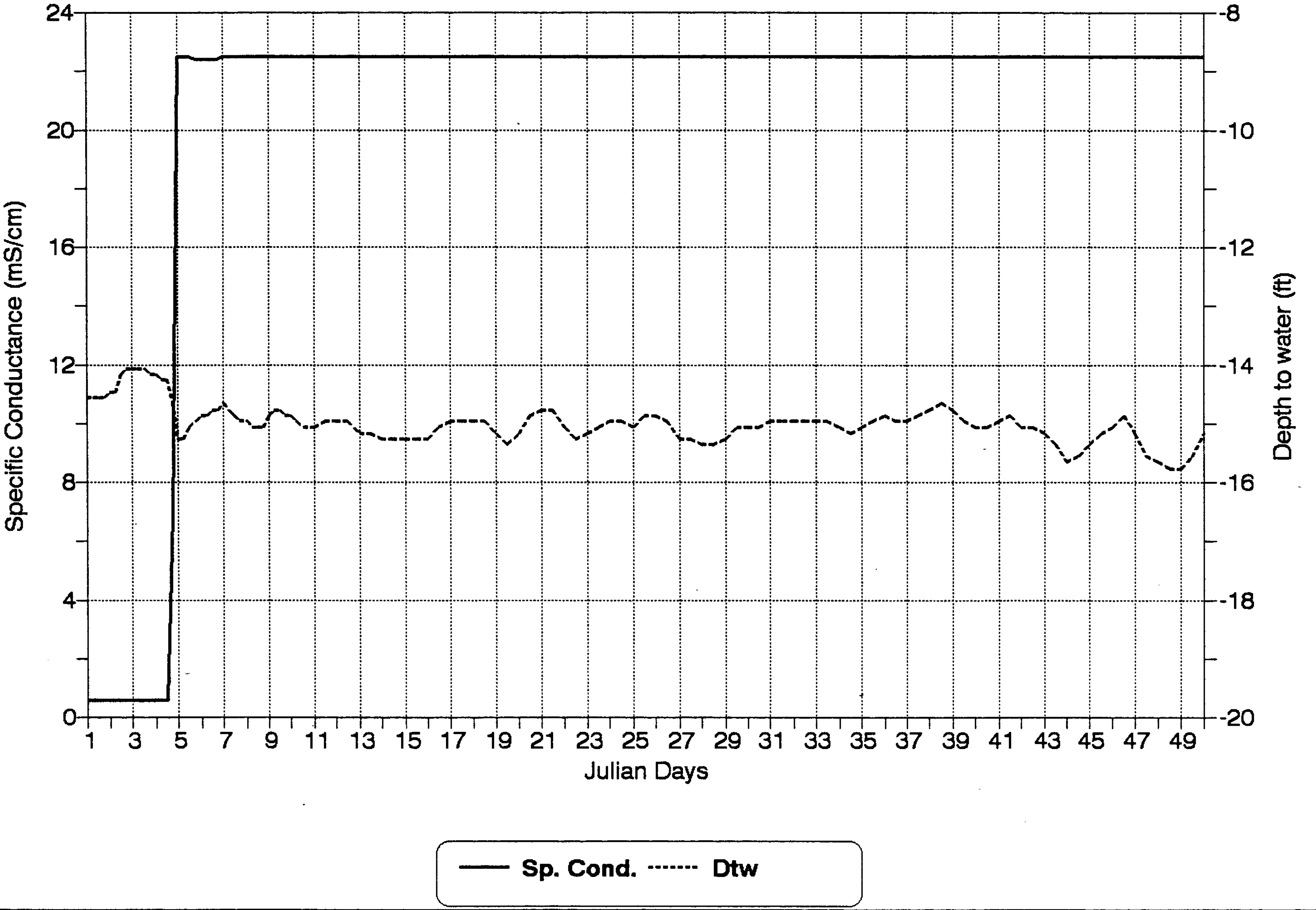

Sittner 1990
Probe at 62.5' Below Land Surface
Specific Conductance (mS/cm)
Depth to water (ft)
Julian Days
0
4
8
12
16
20
24
-8
-10
-12
-14
-16
-18
-20
260
262
264
266
268
270
272
274
276
278
280
— Sp. Cond. ------- Dtw

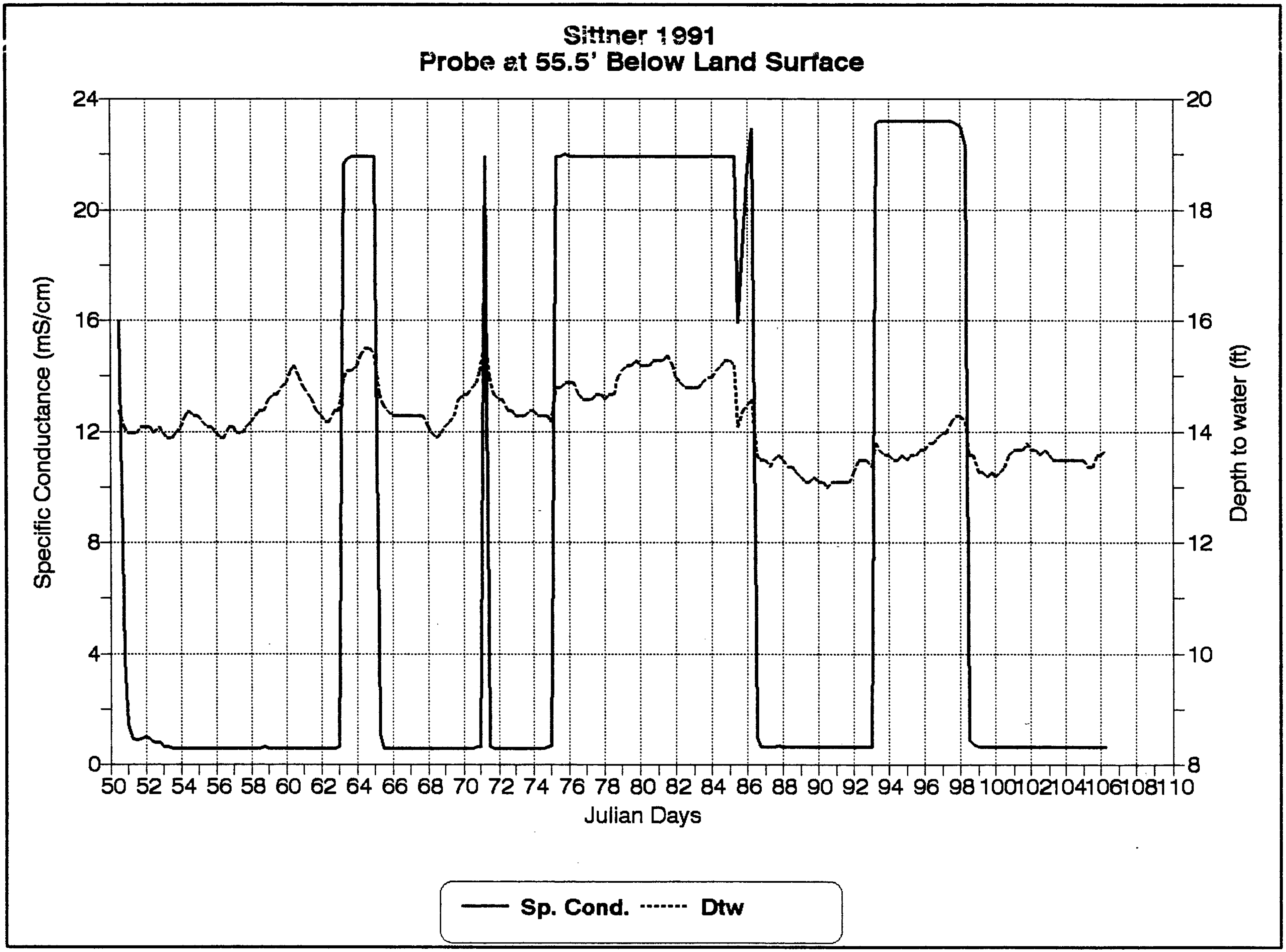


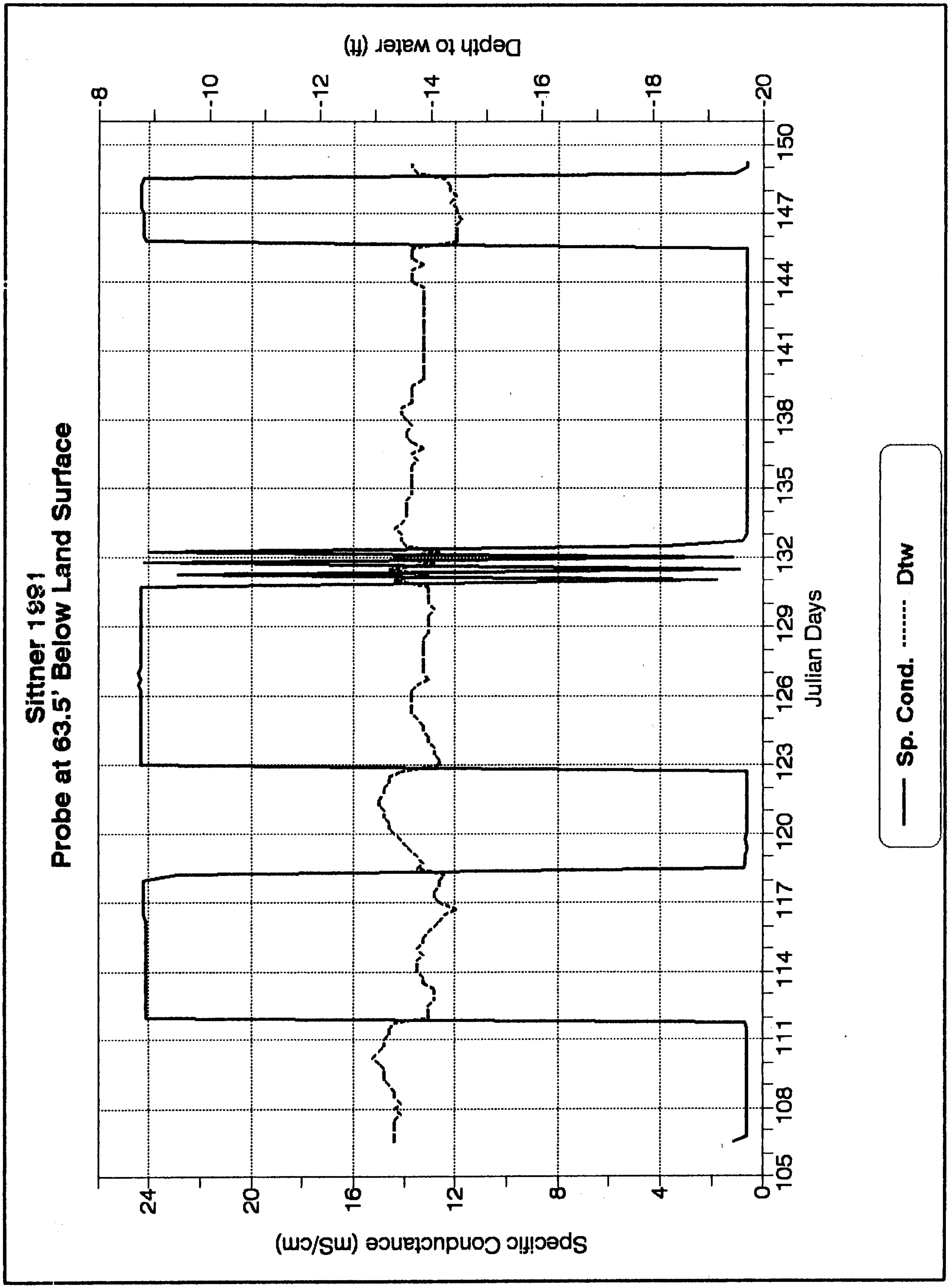
Sittner 1990
Probe at 63.5' Below Land Surface
24
20
16
12
8
4
0
-8
-10
-12
-14
-16
-18
-20
300 302 304 306 308 310 312 314 316 318 320 322 324 326 328 330 332 334 336 338 340
Julian Days
Specific Conductance (mS/cm)
Depth to water (ft)
Sp. Cond.
Dtw

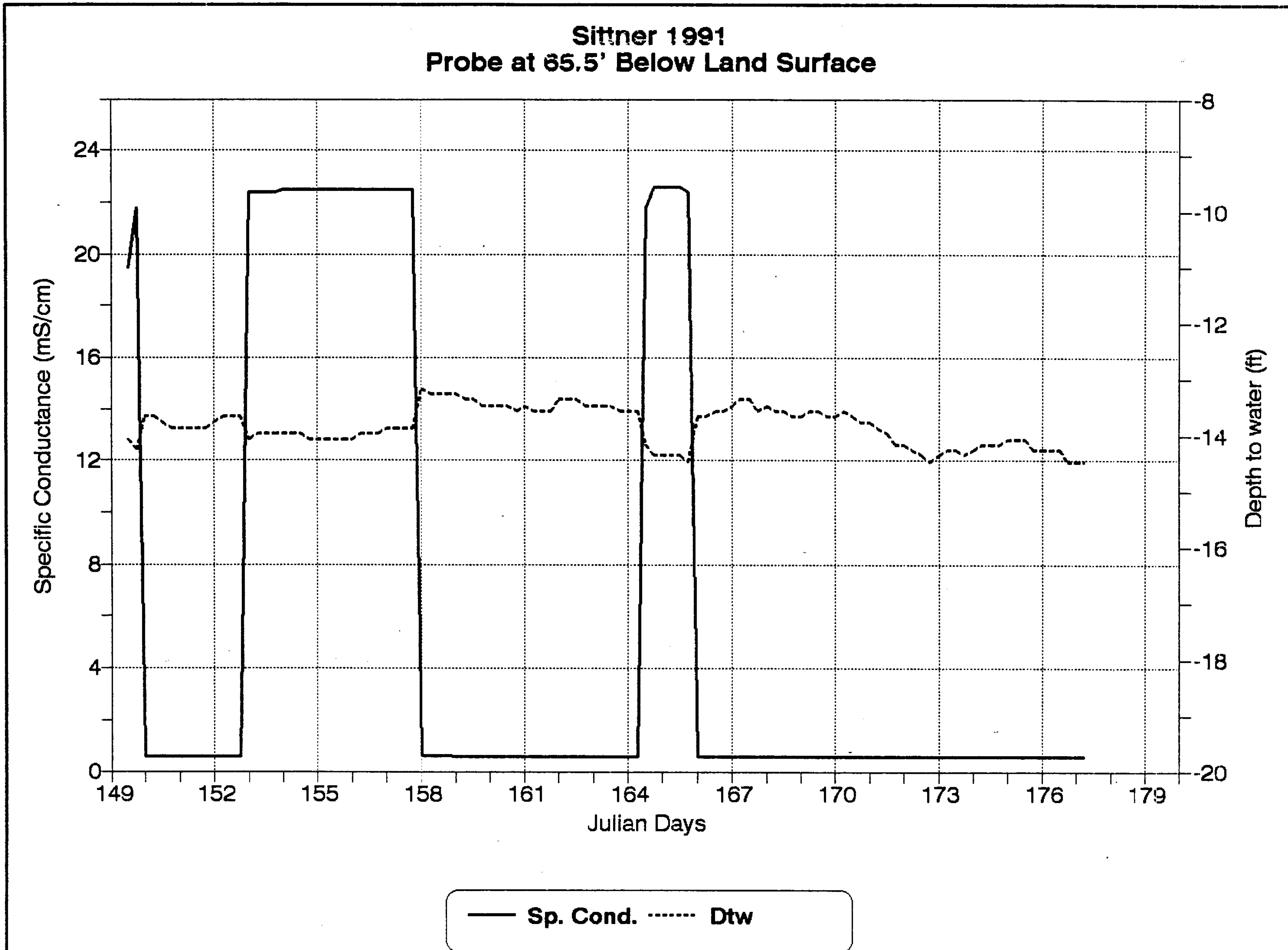

Sittner 1990
Probe at 56.5' Below Land Surface
Specific Conductance (mS/cm)
Depth to water (ft)
Julian Days
24
20
16
12
8
4
0
18
14
10
340
342
344
346
348
350
352
354
356
358
360
362
364
Sp. Cond.
Dtw

Sittner 1991
Probe at 56.5' Below Land Surface



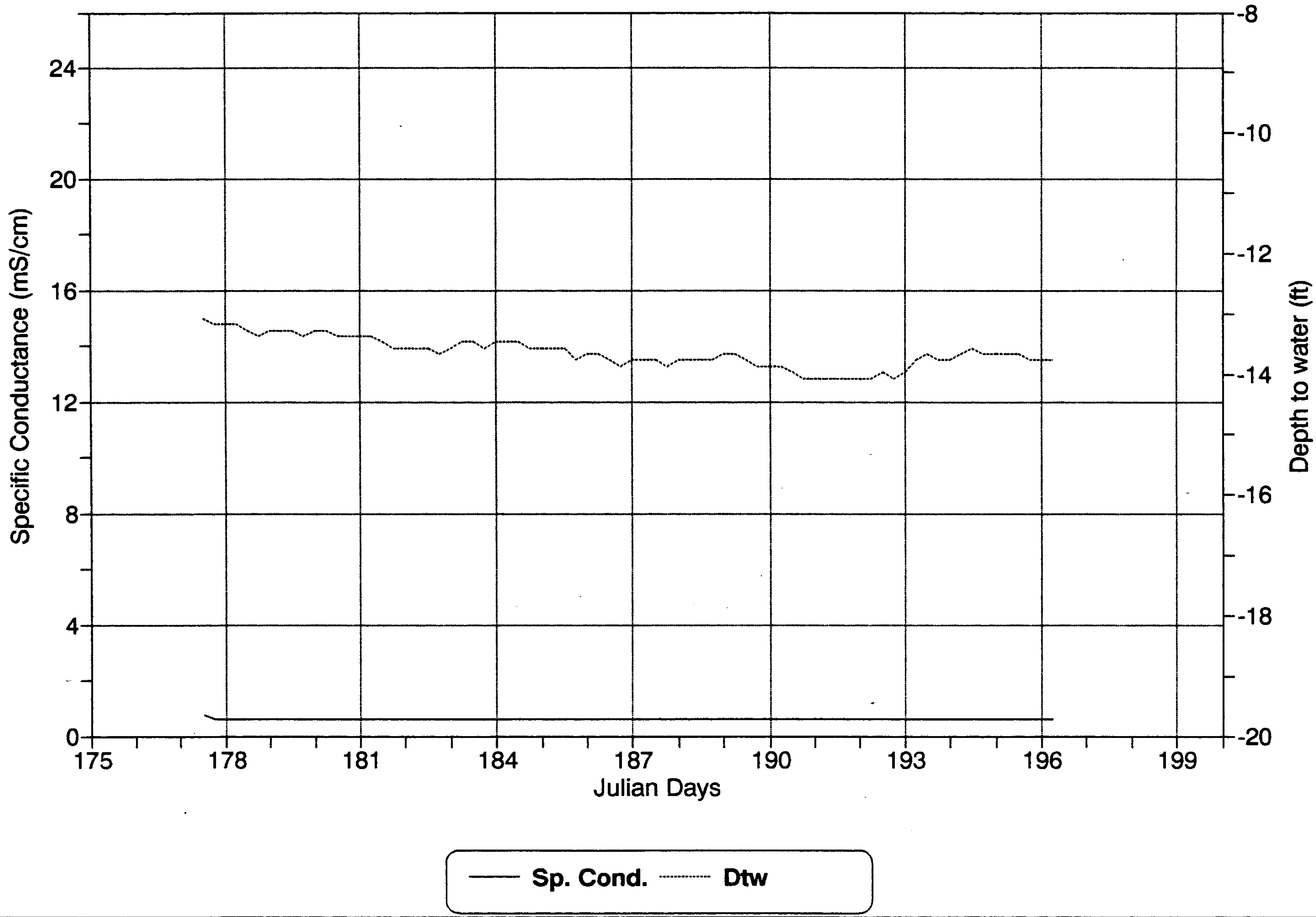

Sittner 1991
Probe at 55.5' Below Land Surface
Specific Conductance (mS/cm)
Depth to water (ft)
Julian Days
0
4
8
12
16
20
24
8
10
12
14
16
18
20
50 52 54 56 58 60 62 64 66 68 70 72 74 76 78 80 82 84 86 88 90 92 94 96 98 100 102 104 106 108 110
Sp. Cond.
Dtw

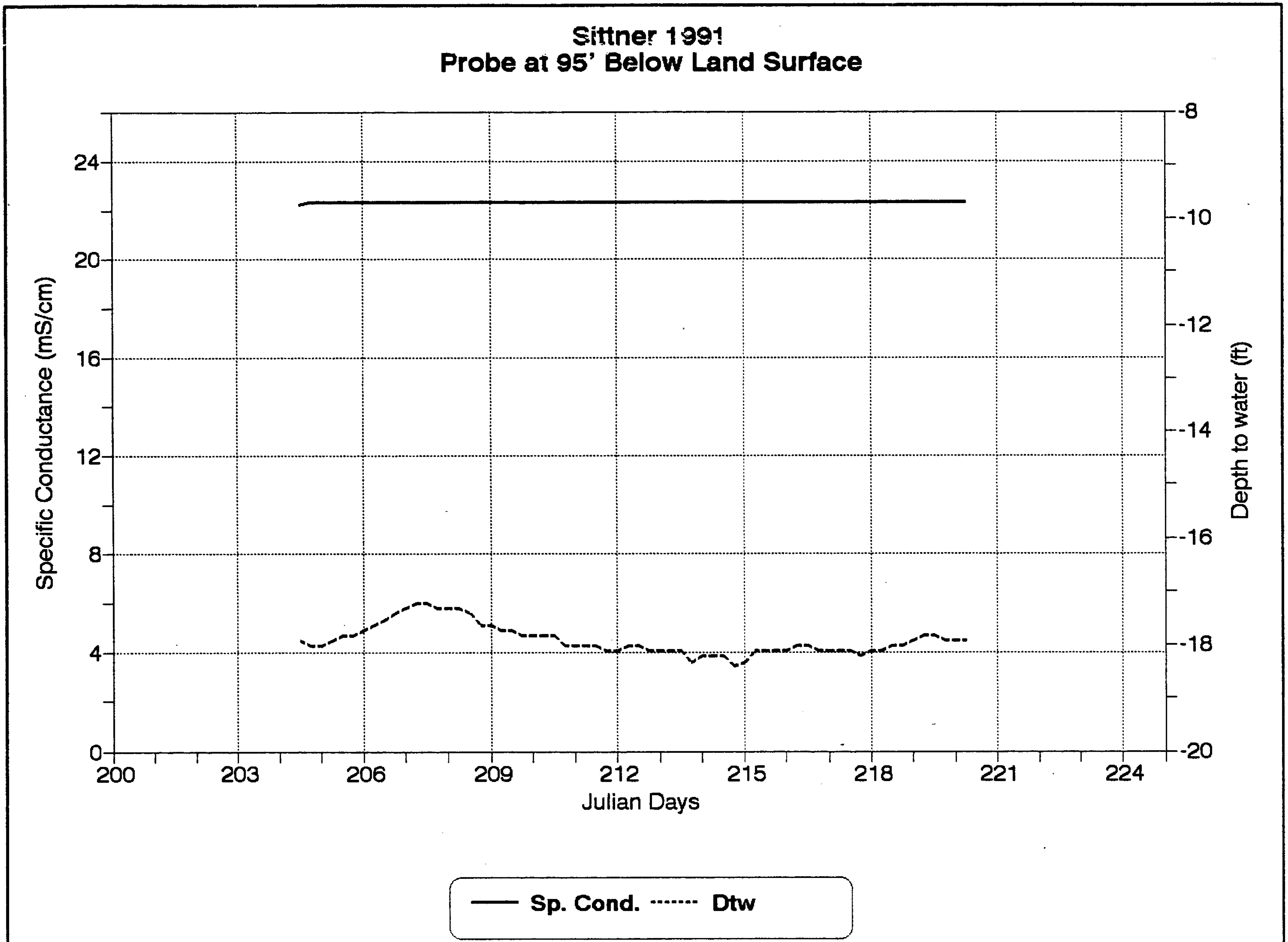

Sittner 1991
Probe at 63.5' Below Land Surface
Specific Conductance (mS/cm)
0
4
8
12
16
20
24
Depth to water (ft)
-8
-10
-12
-14
-16
-18
-20
105
108
111
114
117
120
123
126
129
132
135
138
141
144
147
150
Julian Days
Sp. Cond.
Dtw



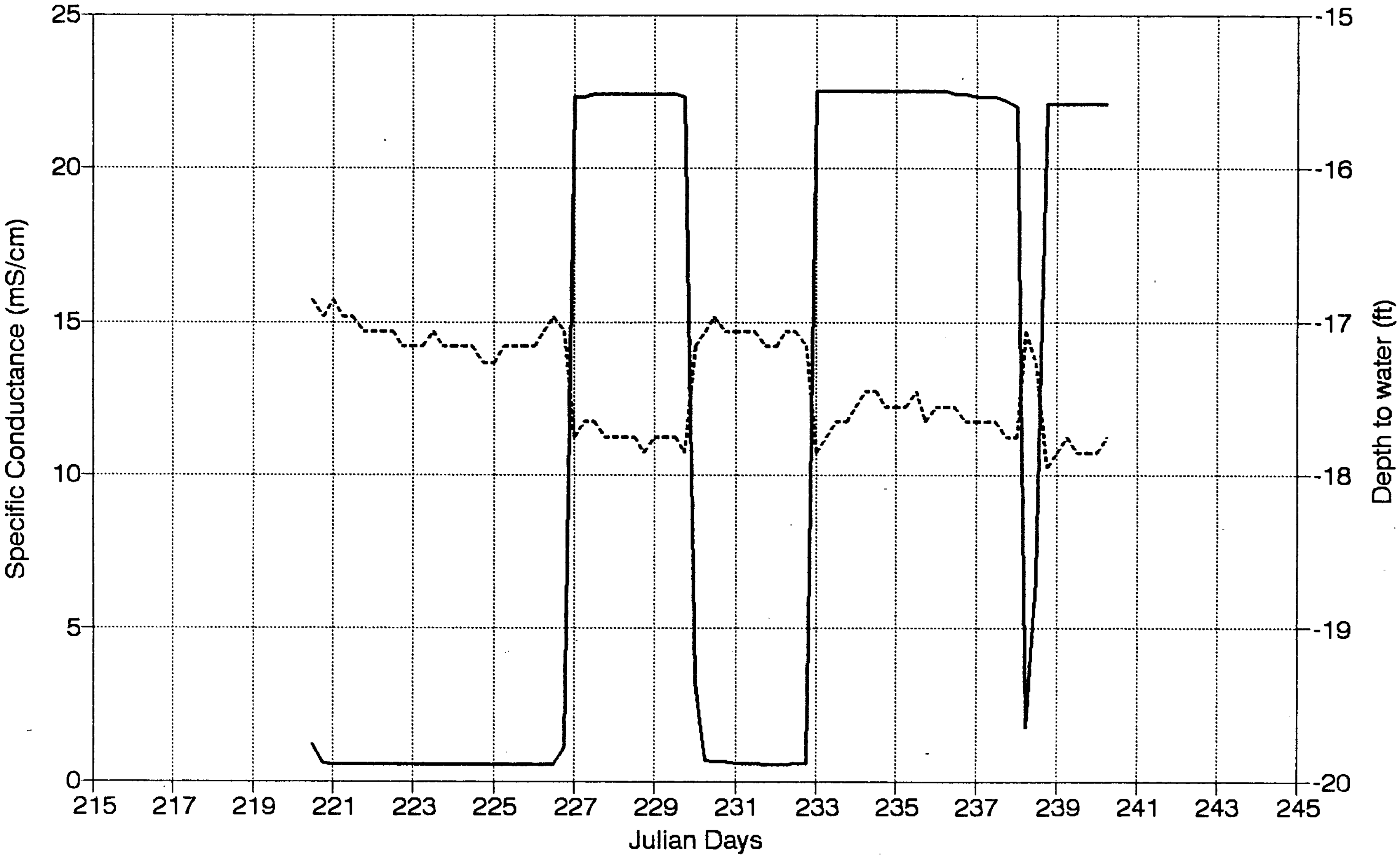
Sittner 1991
Probe at 65.5' Below Land Surface
Specific Conductance (mS/cm)
0
4
8
12
16
20
24
Depth to water (ft)
-8
-10
-12
-14
-16
-18
-20
149
152
155
158
161
164
167
170
173
176
179
Julian Days
Sp. Cond.
Dtw

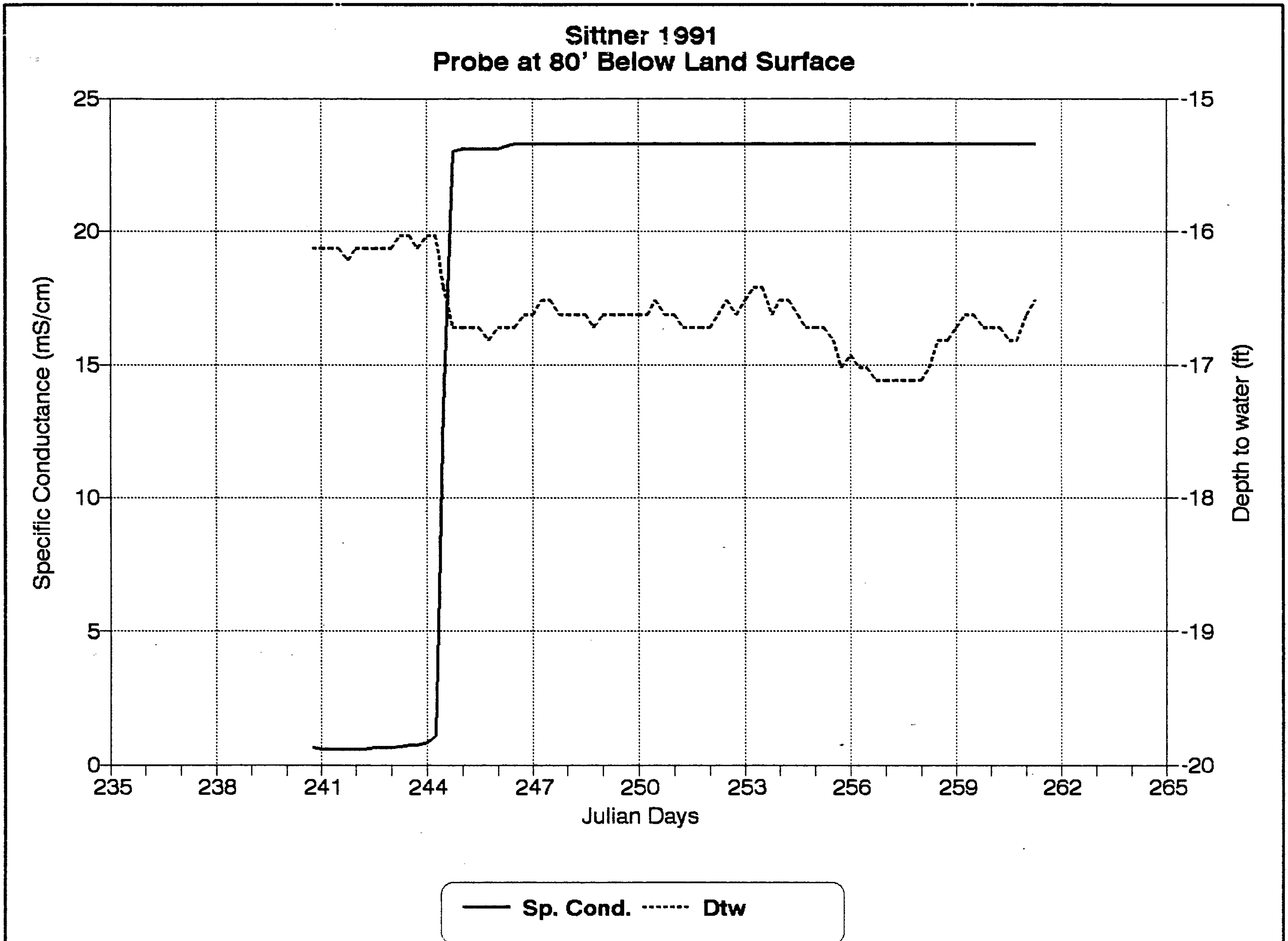
Sittner 1991
Probe at 77' Below Land Surface

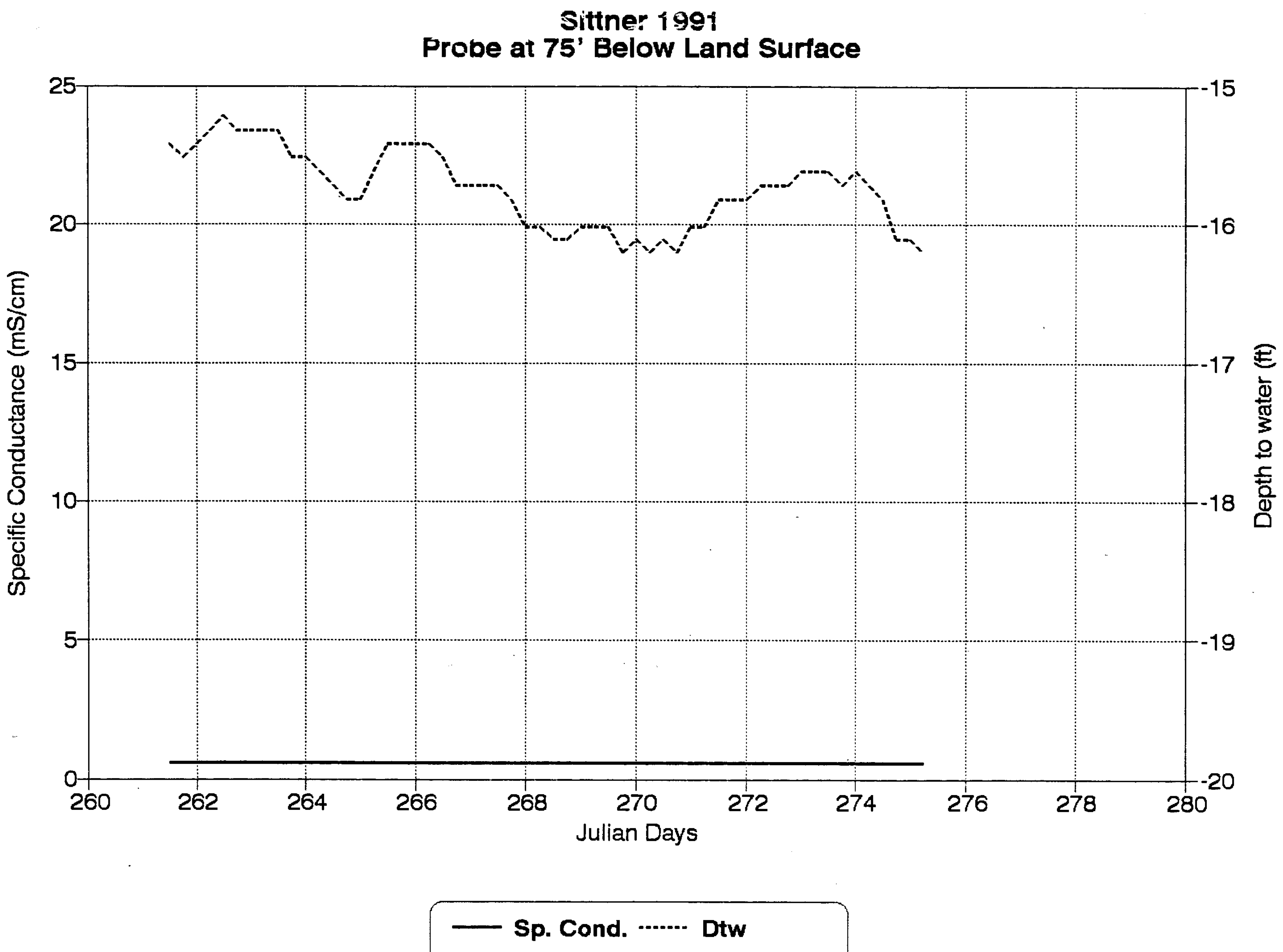



Sittner 1991
Probe at 95' Below Land Surface
Specific Conductance (mS/cm)
0
4
8
12
16
20
24
Depth to water (ft)
-8
-10
-12
-14
-16
-18
-20
200
203
206
209
212
215
218
221
224
Julian Days
Sp. Cond.
Dtw

Sittner 1991
Probe at 85' Below Land Surface

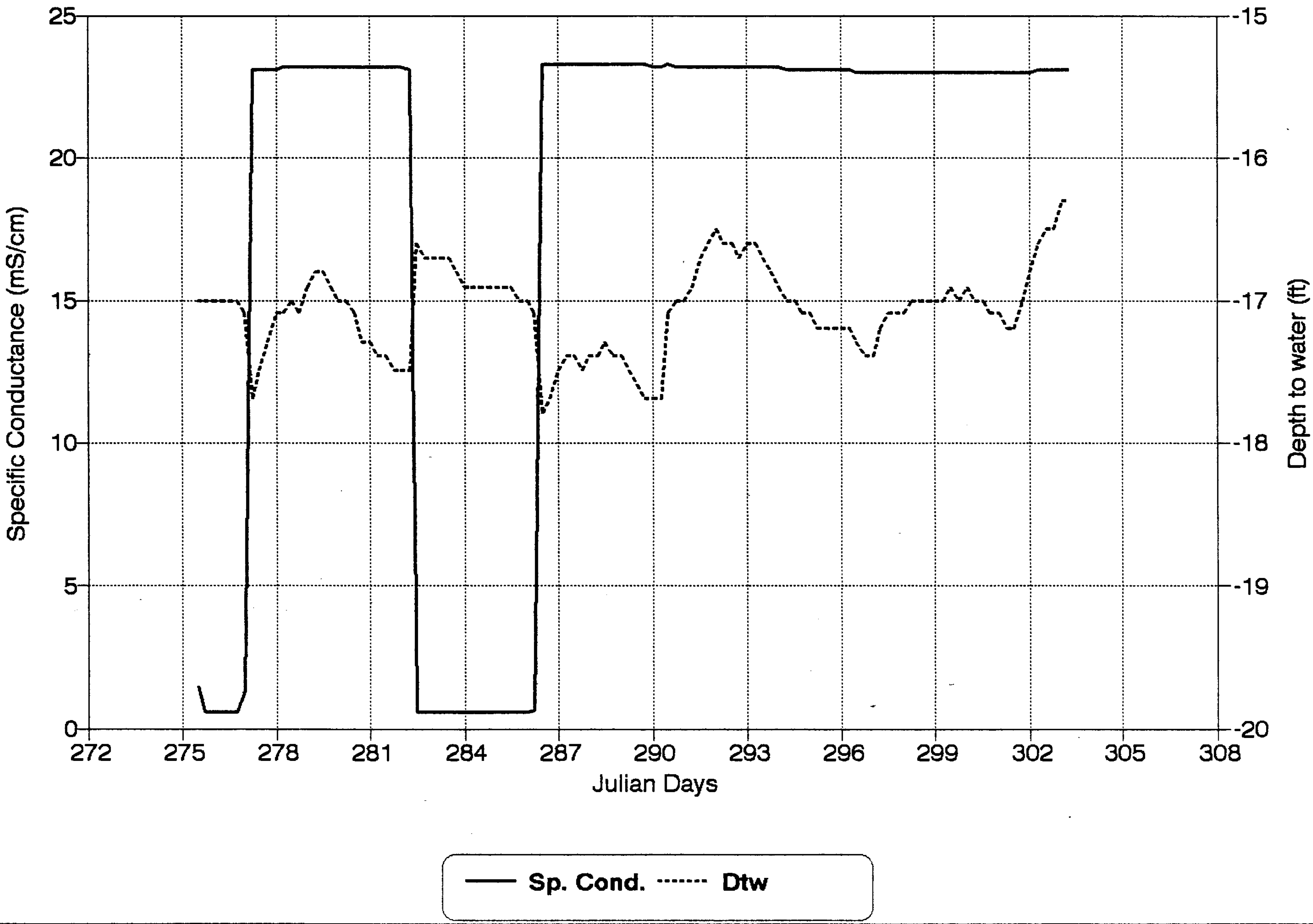


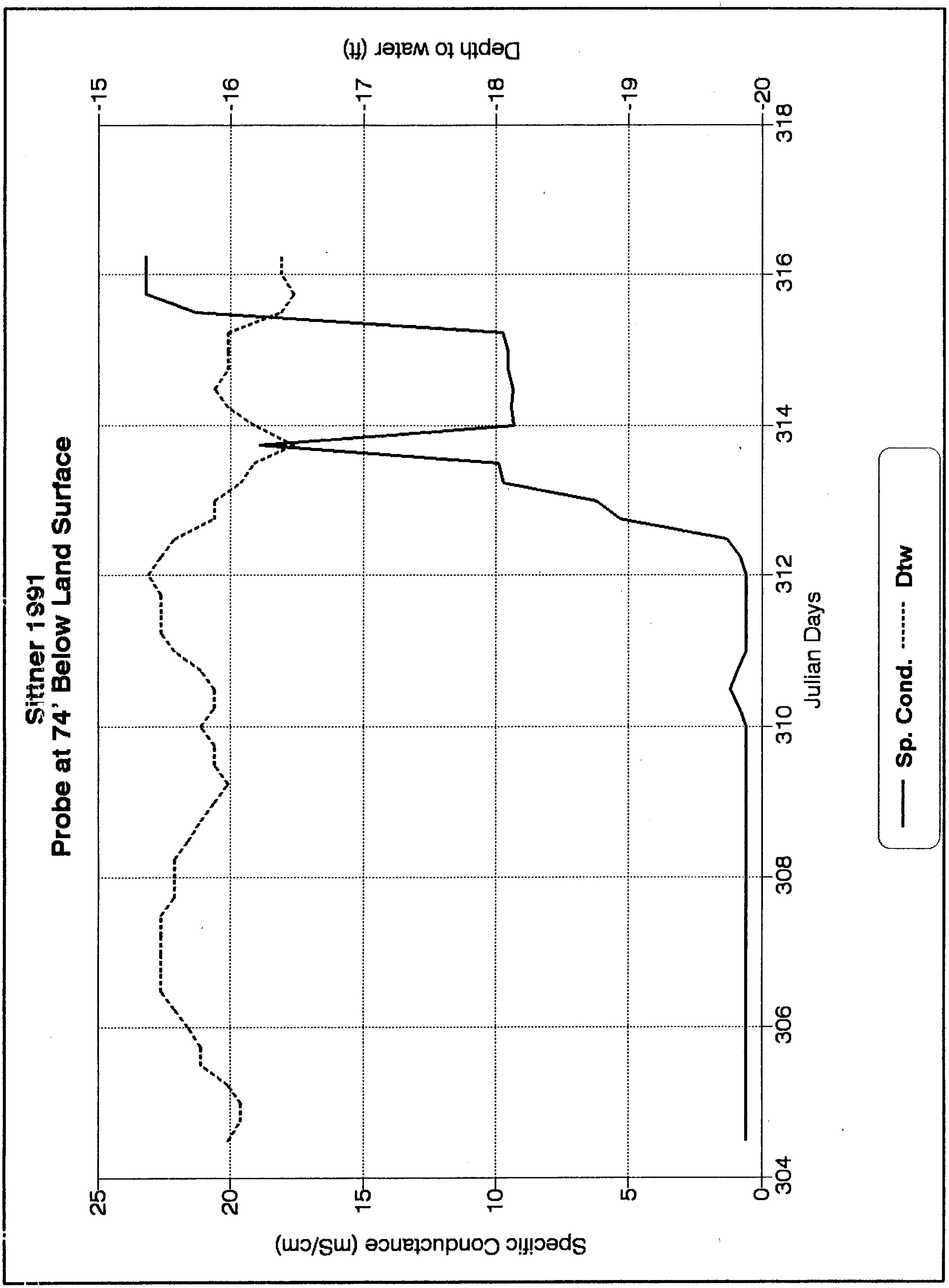

Sittner 1991
Probe at 80' Below Land Surface
Specific Conductance (mS/cm)
25
20
15
10
5
0
Depth to water (ft)
-15
-16
-17
-18
-19
-20
235
238
241
244
247
250
253
256
259
262
265
Julian Days
Sp. Cond.
Dtw

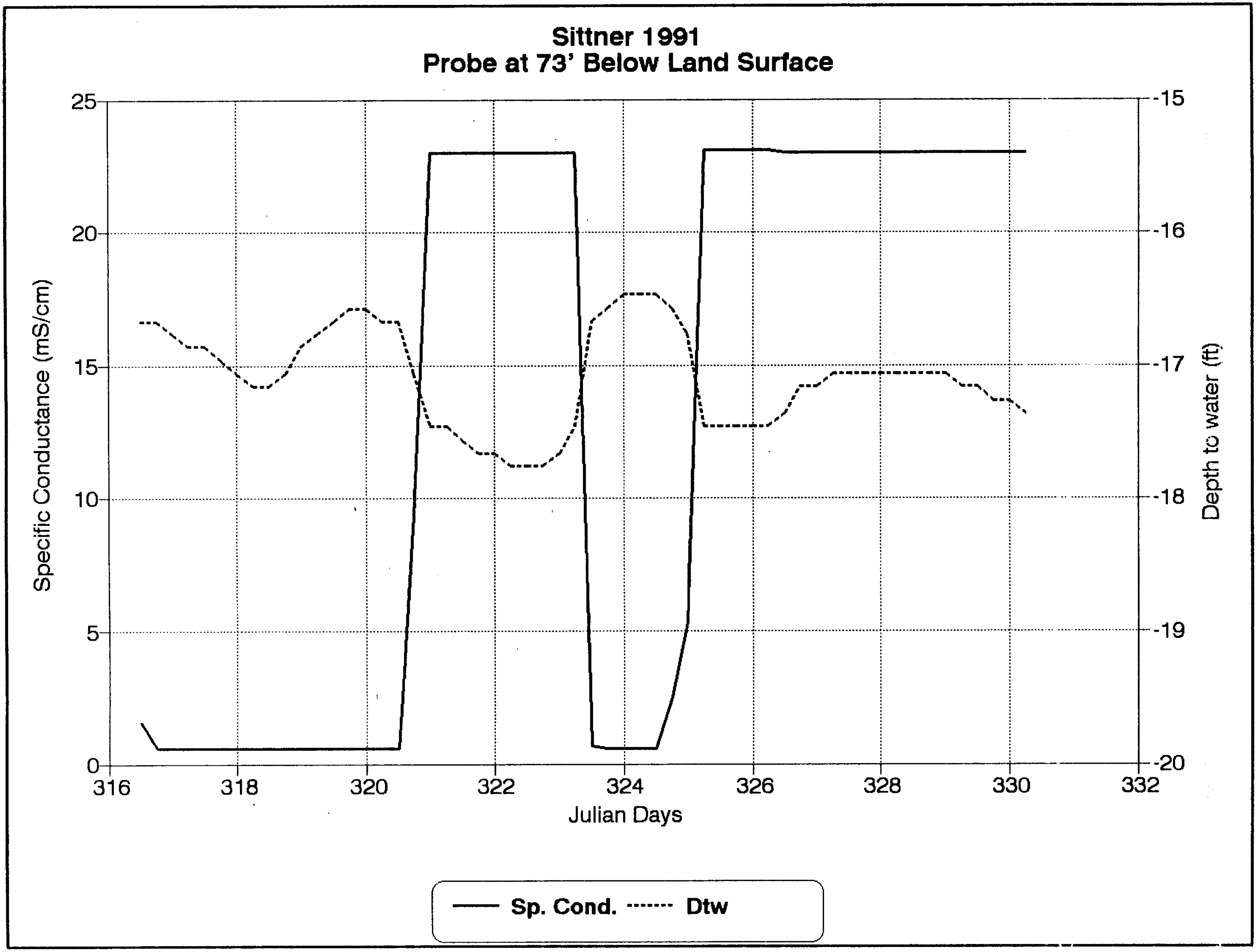


Sittner 1991
Probe at 75' Below Land Surface
Specific Conductance (mS/cm)
Depth to water (ft)
Julian Days
25
20
15
10
5
0
-15
-16
-17
-18
-19
-20
260
262
264
266
268
270
272
274
276
278
280
Sp. Cond.
Dtw

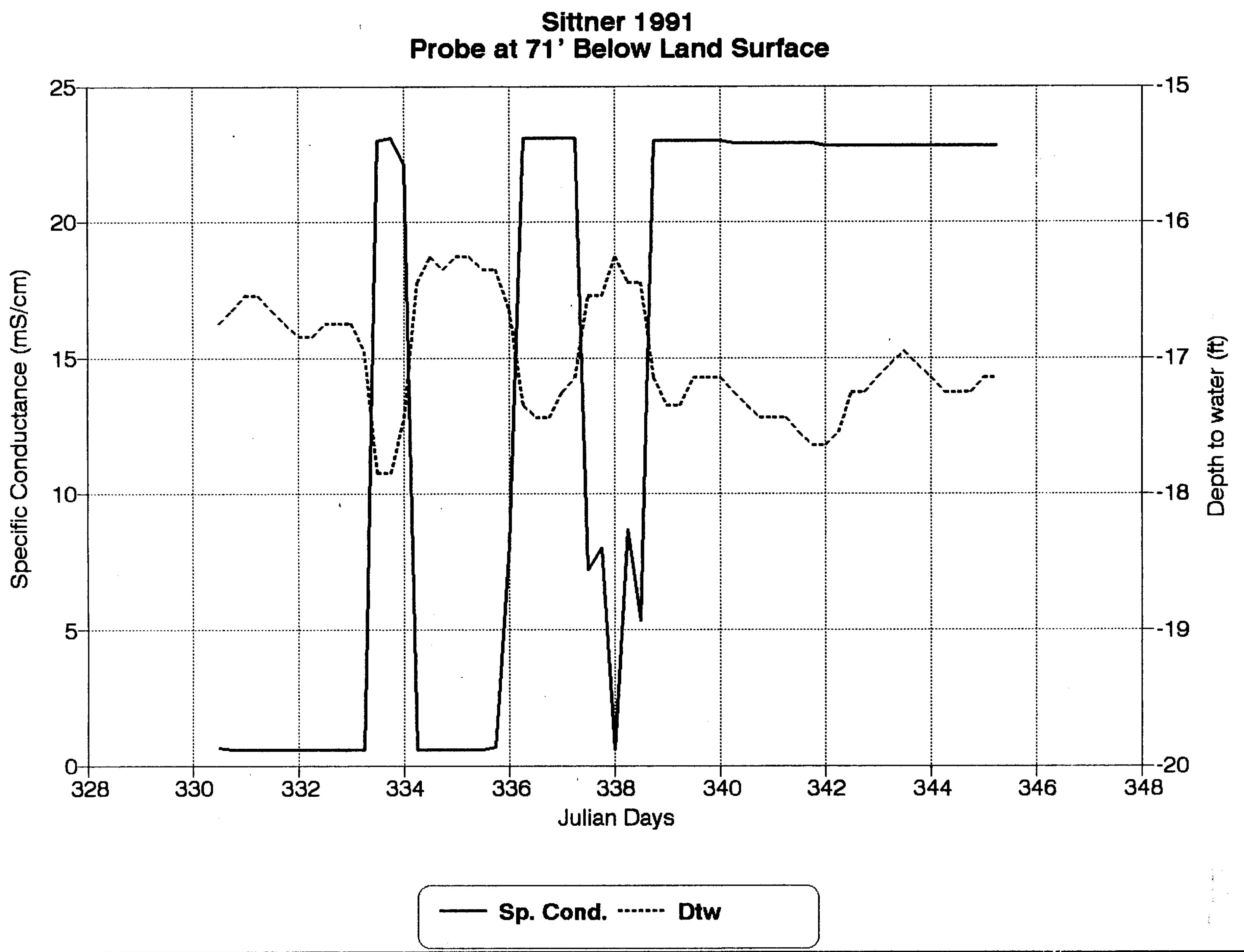
Sittner 1991
Probe at 77' Below Land Surface

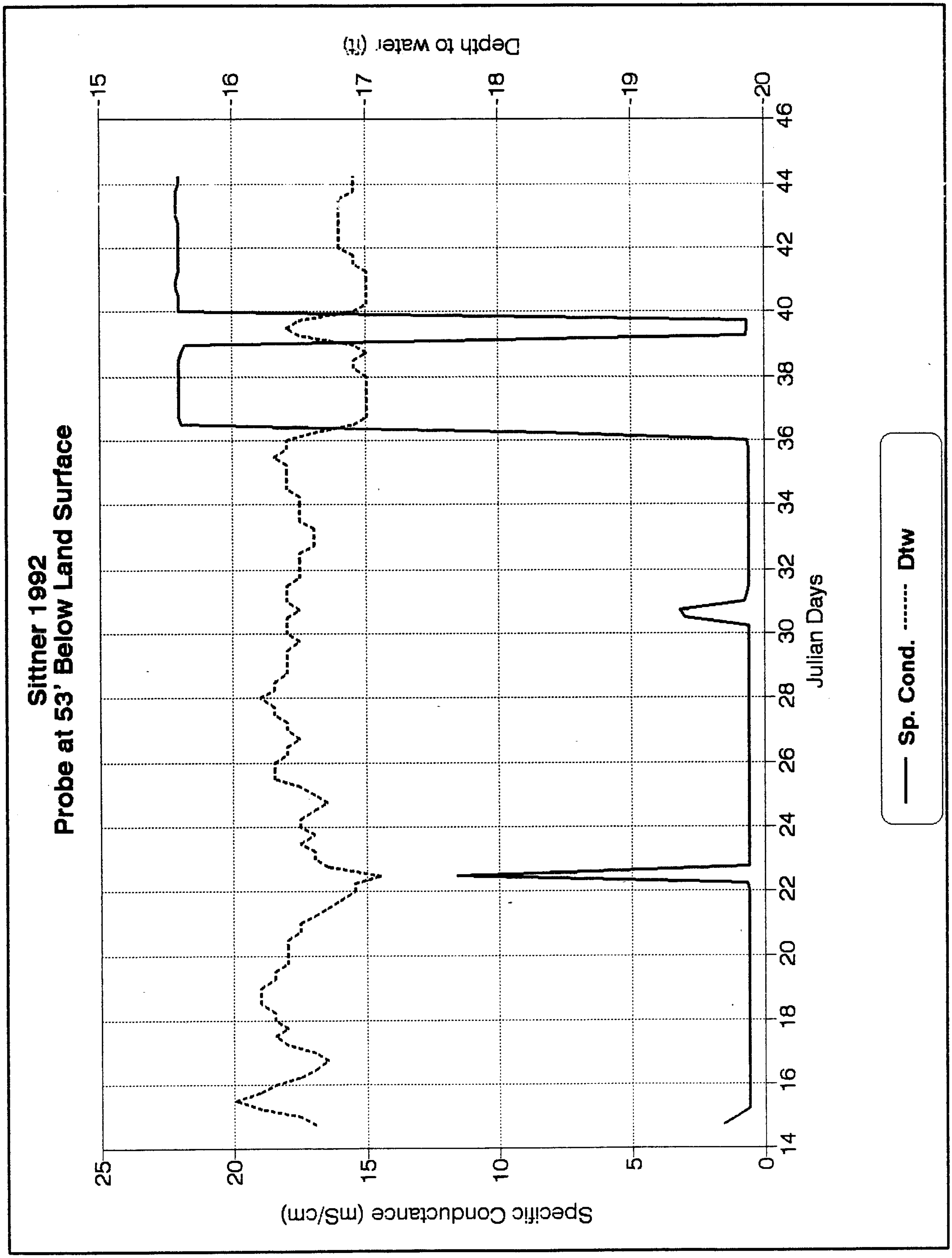



Sittner 1991
Probe at 74' Below Land Surface
Specific Conductance (mS/cm)
Depth to water (ft)
Julian Days
25
20
15
10
5
0
-15
-16
-17
-18
-19
-20
304
306
308
310
312
314
316
318
Sp. Cond.
Dtw

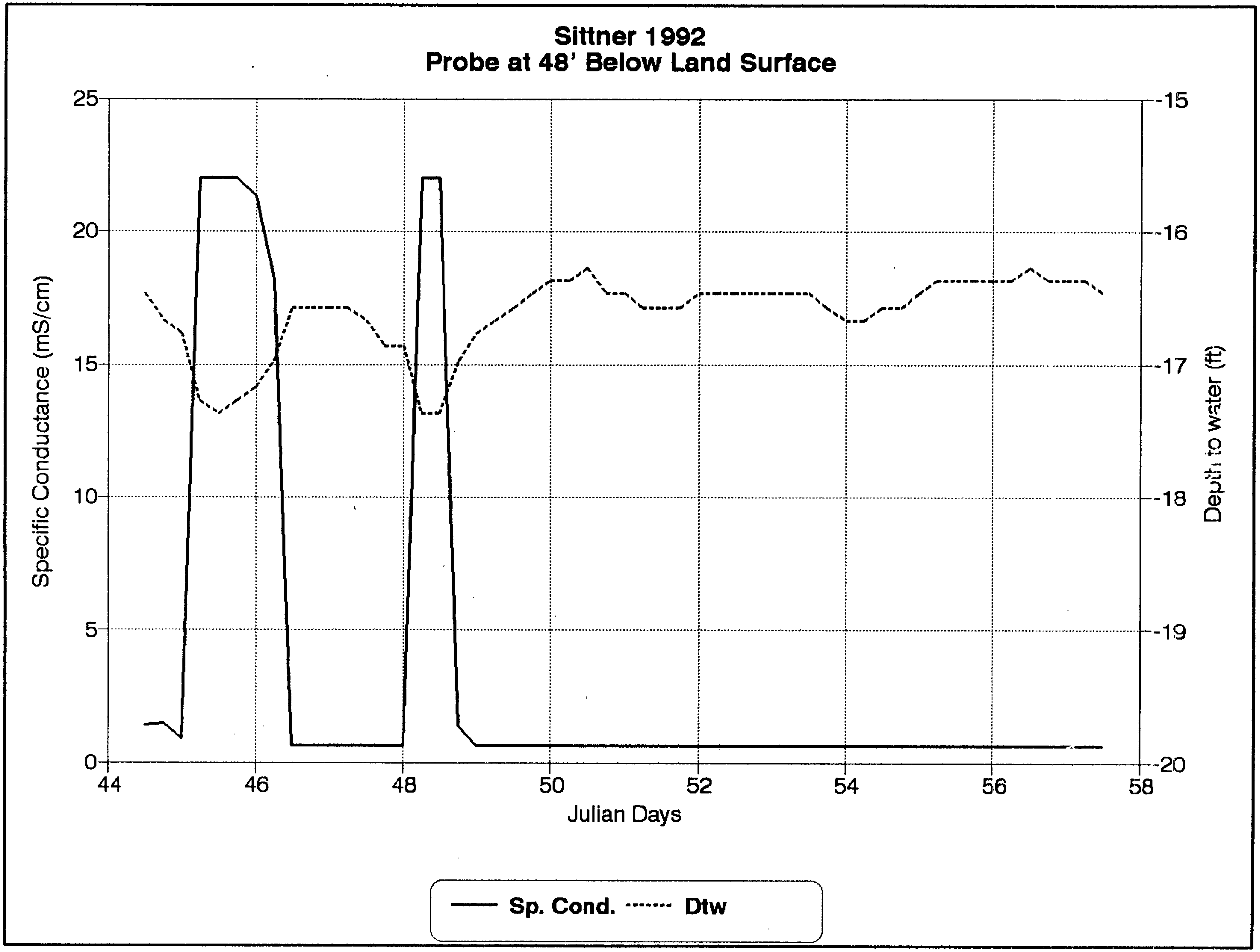


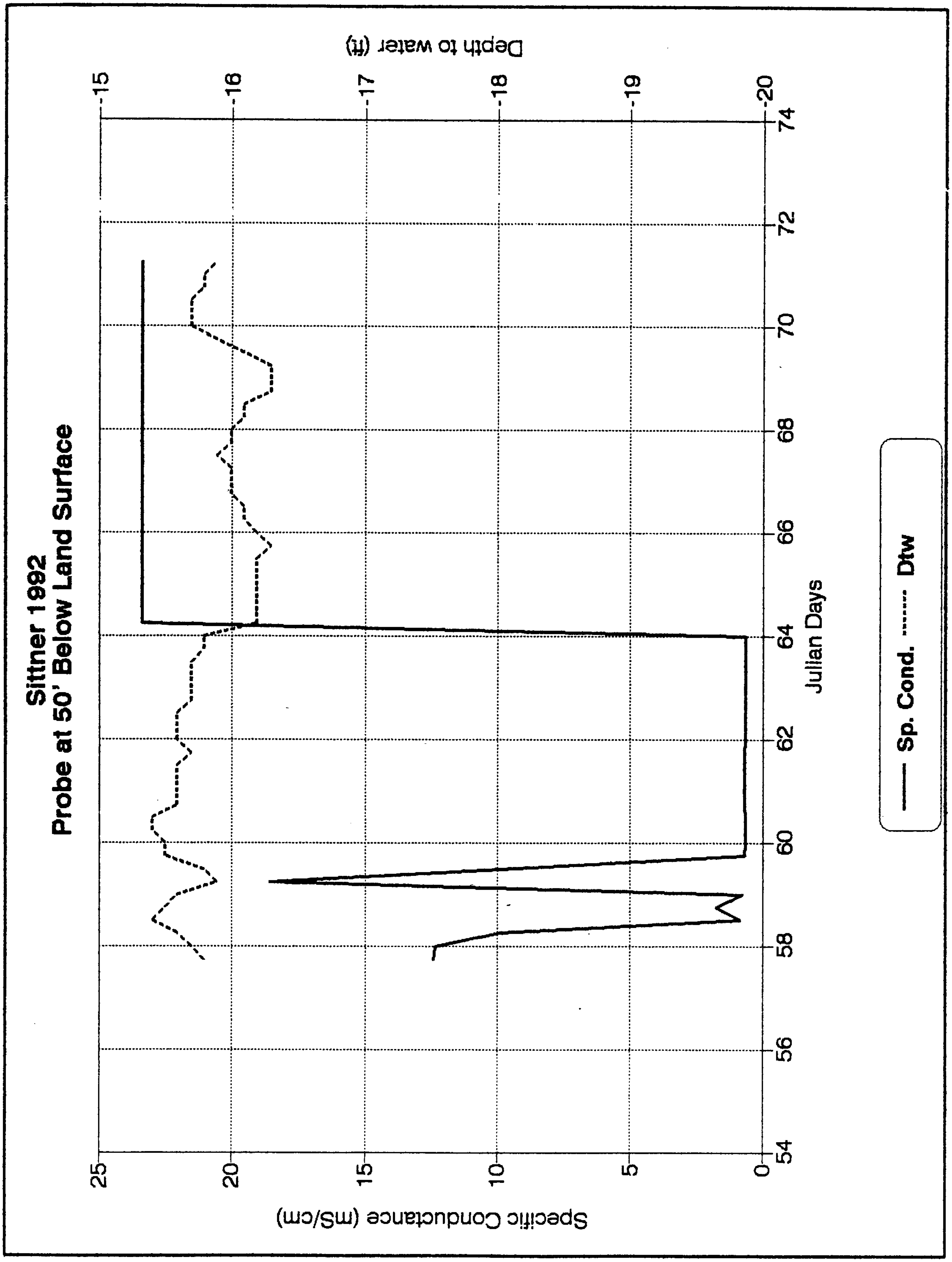
Sittner 1991
Probe at 73' Below Land Surface
25
20
15
10
5
0
Specific Conductance (mS/cm)
-15
-16
-17
-18
-19
-20
Depth to water (ft)
316
318
320
322
324
326
328
330
332
Julian Days
Sp. Cond.
Dtw


Sittner 1991
Probe at 71' Below Land Surface
Specific Conductance (mS/cm)
Depth to water (ft)
Julian Days
25
20
15
10
5
0
-15
-16
-17
-18
-19
-20
328
330
332
334
336
338
340
342
344
346
348
Sp. Cond.
Dtw

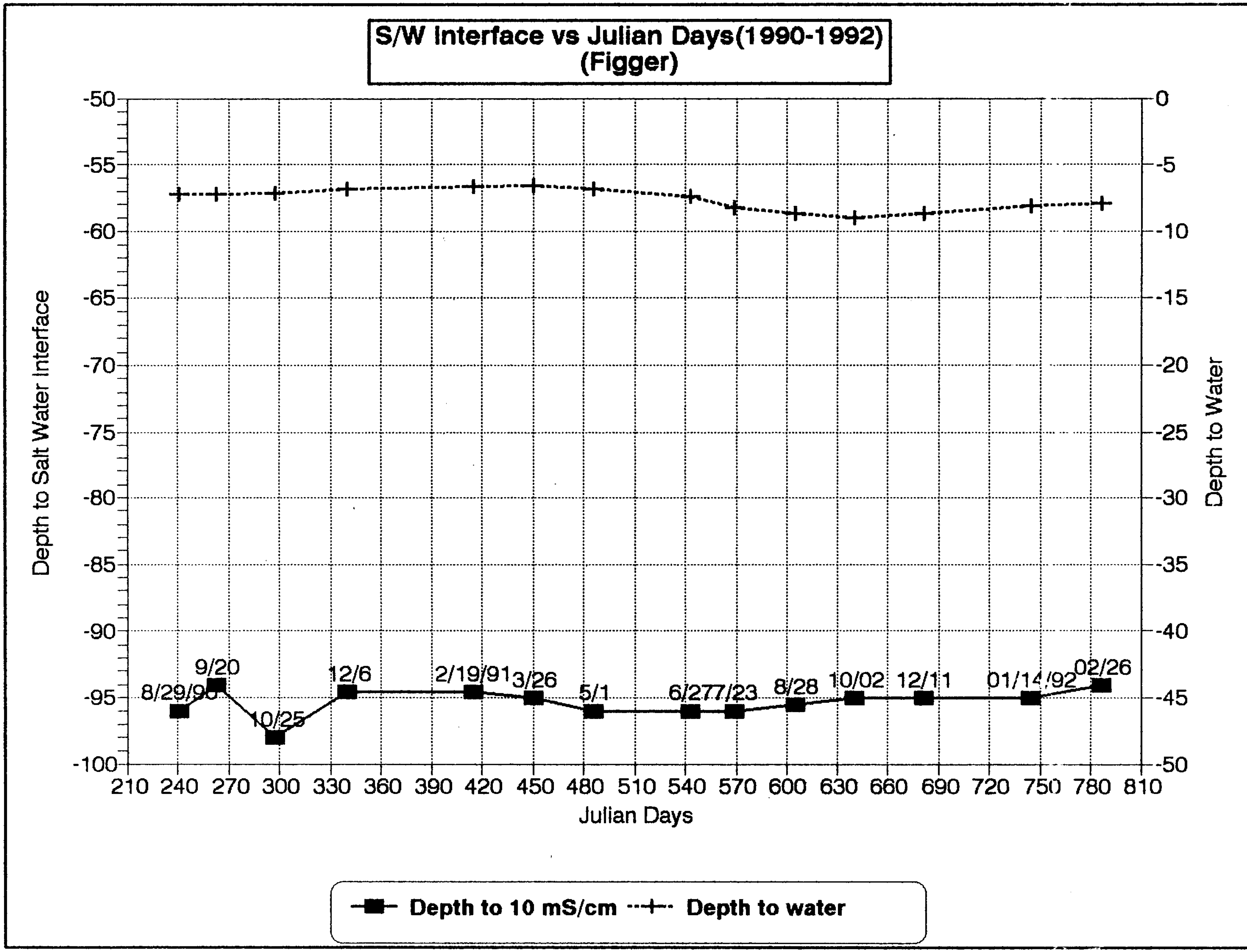


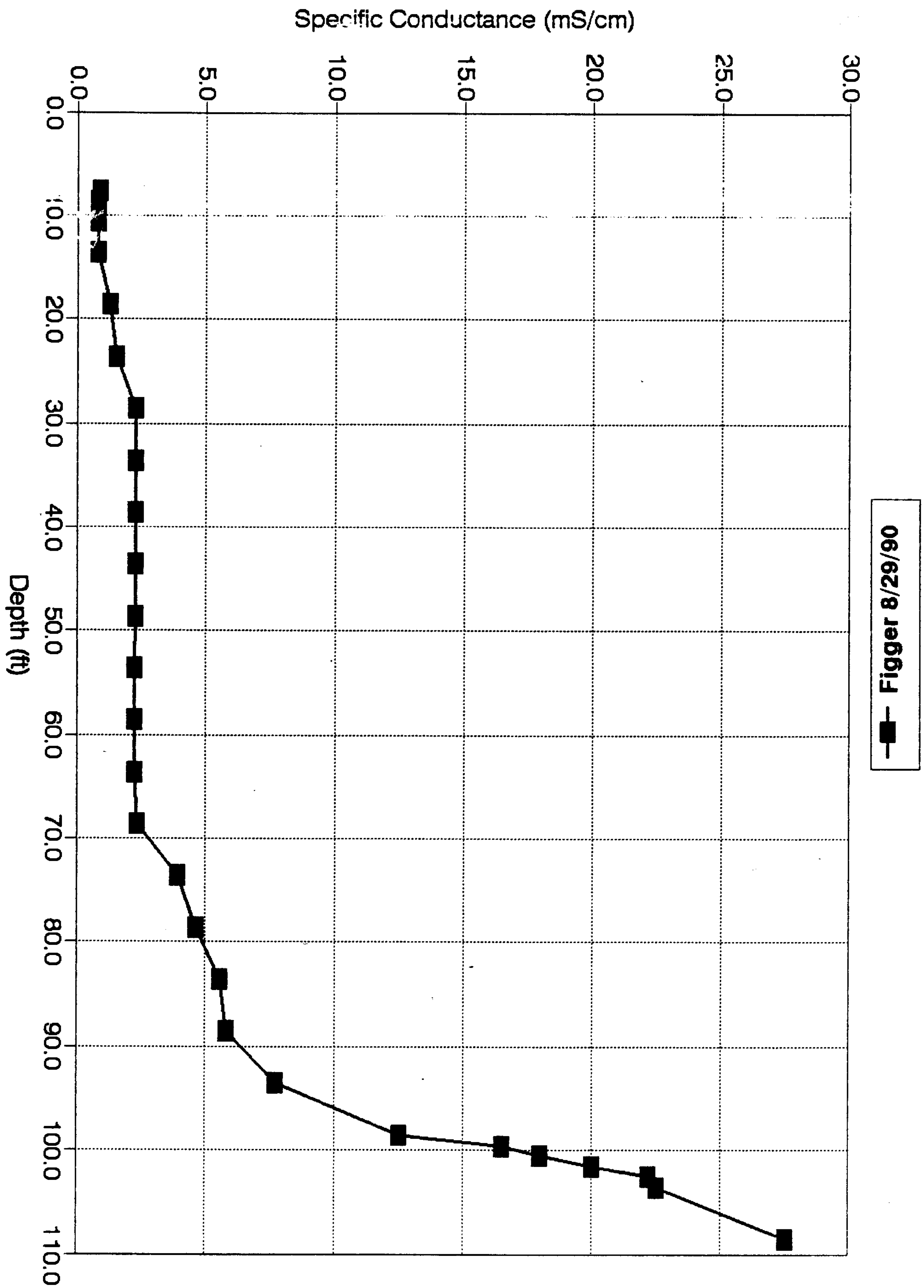
Sittner 1992
Probe at 53' Below Land Surface
Depth to water (ft)
-15
-16
-17
-18
-19
-20
Specific Conductance (mS/cm)
25
20
15
10
5
0
Julian Days
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
Sp. Cond. ------- Dtw

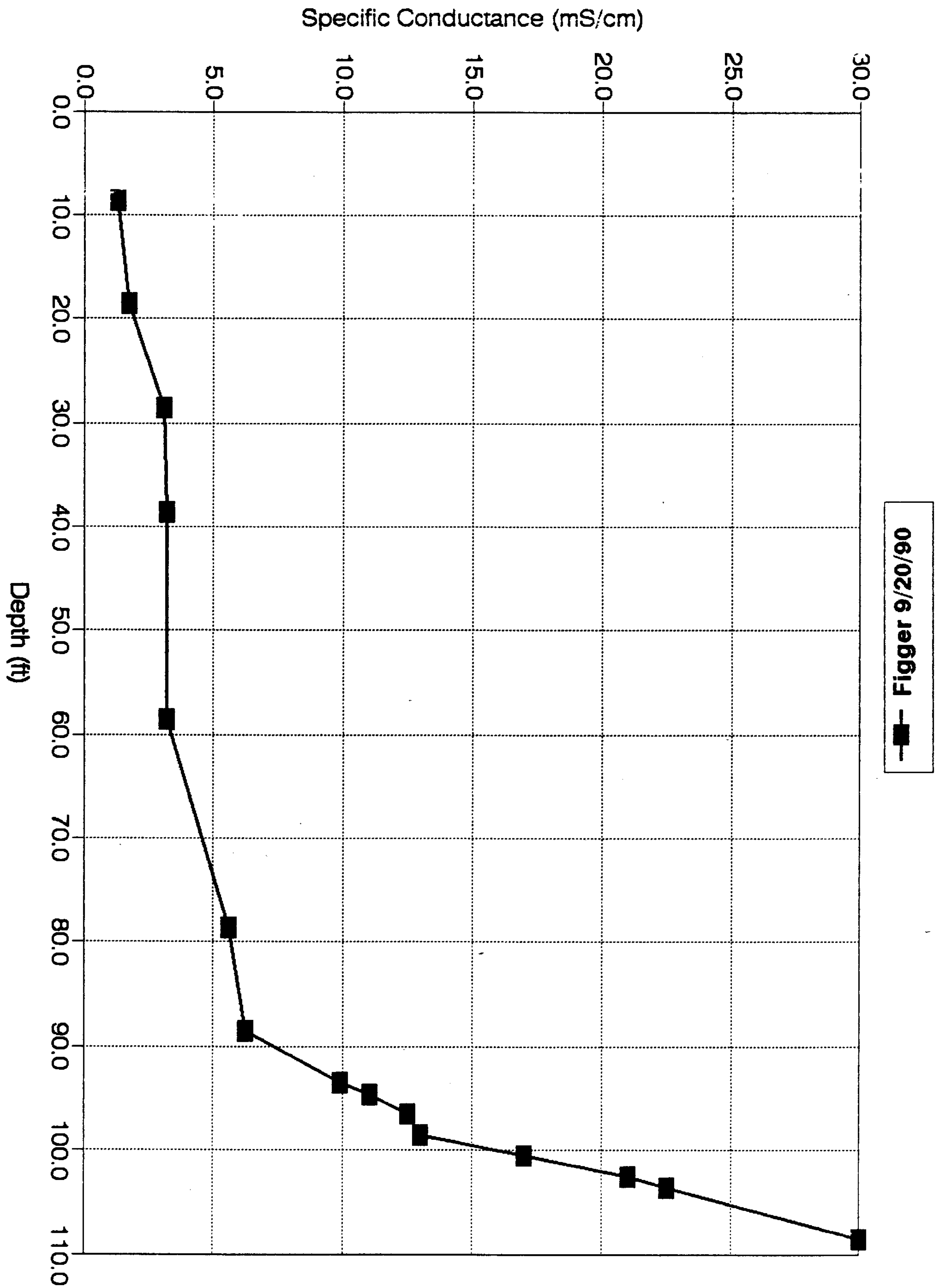

Sittner 1992
Probe at 48' Below Land Surface
Specific Conductance (mS/cm)
Depth to water (ft)
Julian Days
25
20
15
10
5
0
44
46
48
50
52
54
56
58
-15
-16
-17
-18
-19
-20
Sp. Cond.
Dtw

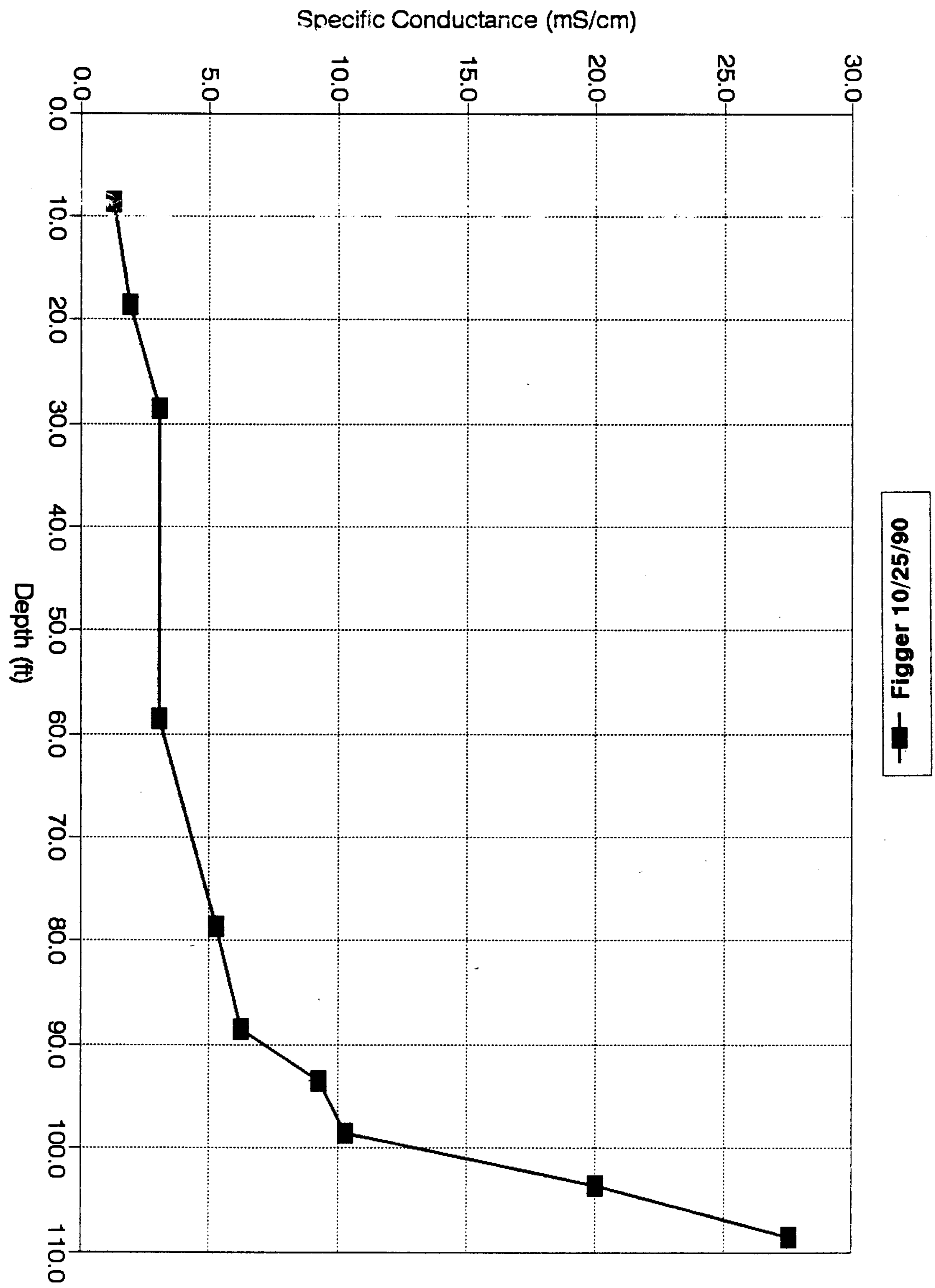


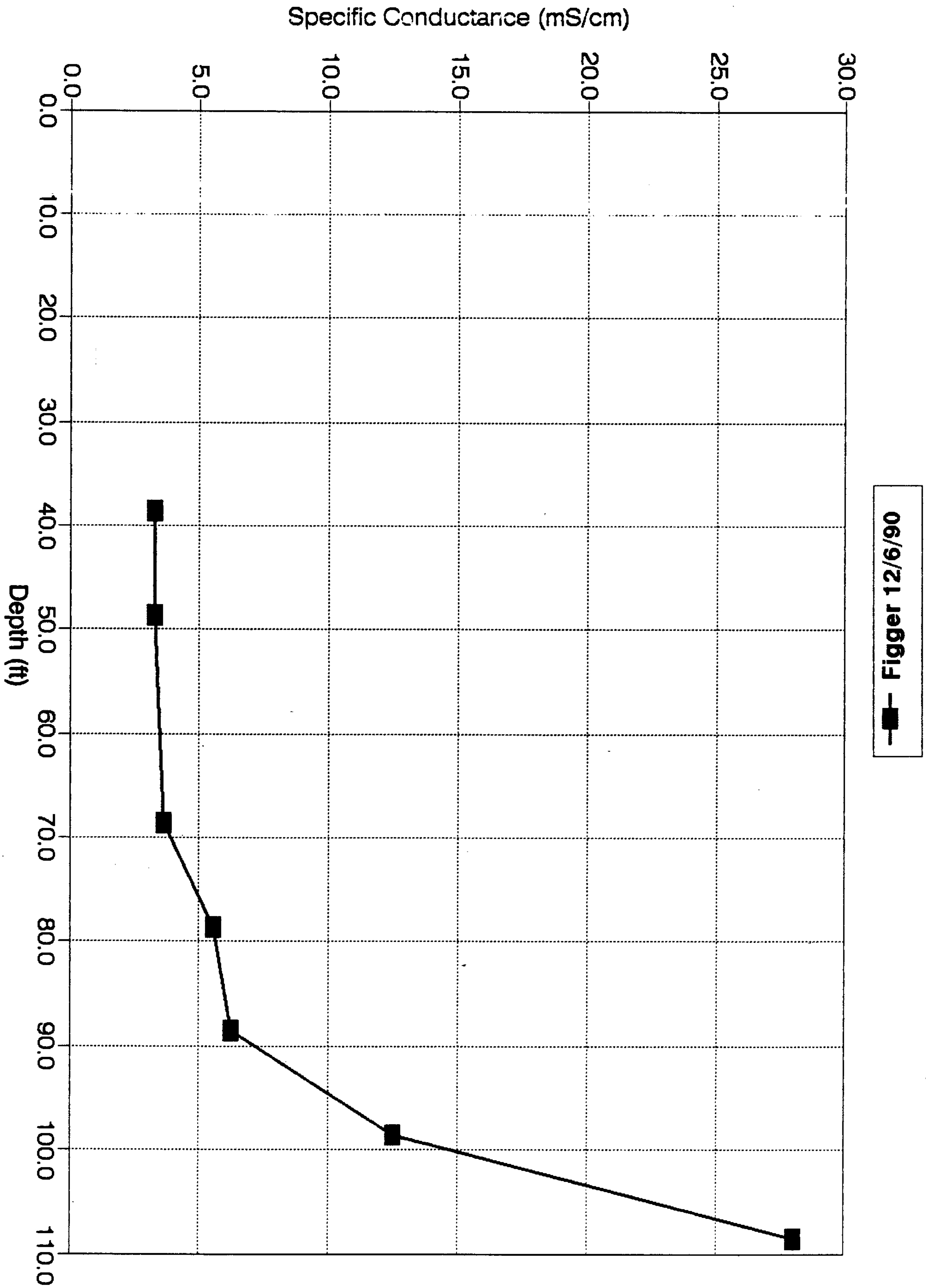
Sittner 1992
Probe at 50' Below Land Surface
Specific Conductance (mS/cm)
0
5
10
15
20
25
Depth to water (ft)
-15
-16
-17
-18
-19
-20
Julian Days
54
56
58
60
62
64
66
68
70
72
74
Sp. Cond. ------- Dtw

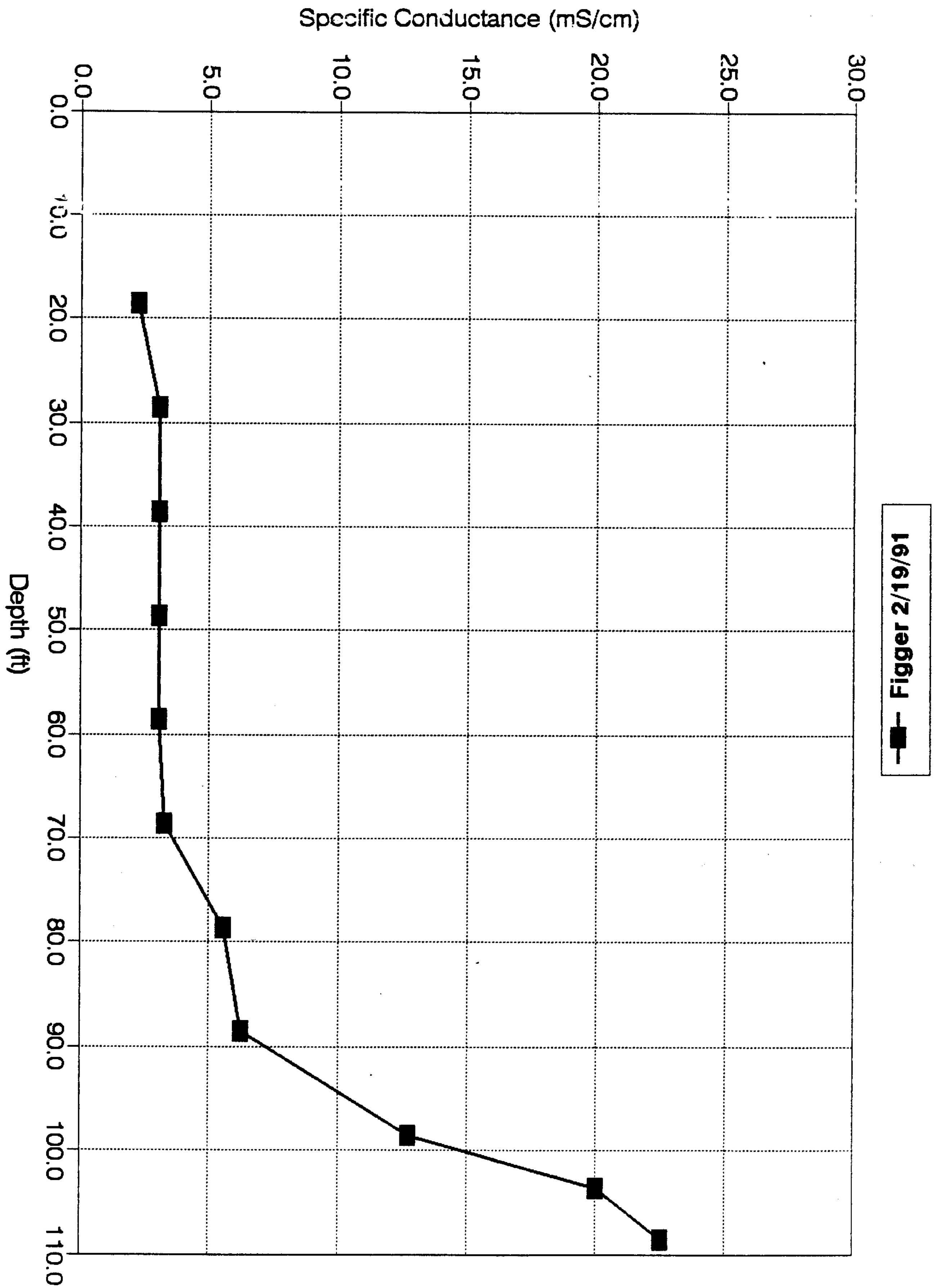

S/W Interface vs Julian Days(1990-1992)
(Figger)
Depth to Salt Water Interface
Depth to Water
Julian Days
-50
-55
-60
-65
-70
-75
-80
-85
-90
-95
-100
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
210 240 270 300 330 360 390 420 450 480 510 540 570 600 630 660 690 720 750 780 810
8/29/90
9/20
10/25
12/6
2/19/91
3/26
5/1
6/27
7/23
8/28
10/02
12/11
01/14/92
02/26
Depth to 10 mS/cm
Depth to water

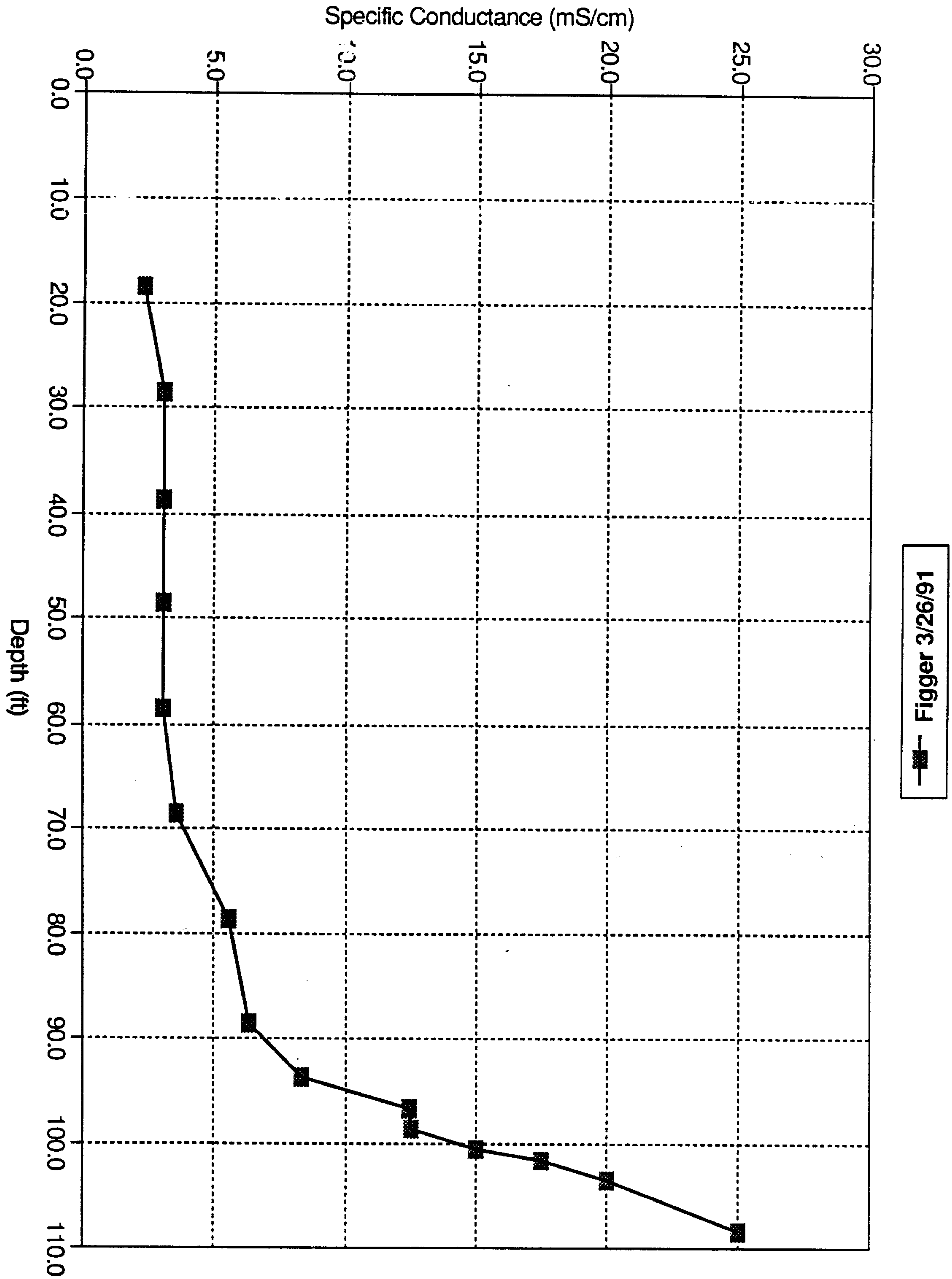

Specific Conductance (mS/cm)
0.0
5.0
10.0
15.0
20.0
25.0
30.0
Depth (ft)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
110.0
Figger 8/29/90

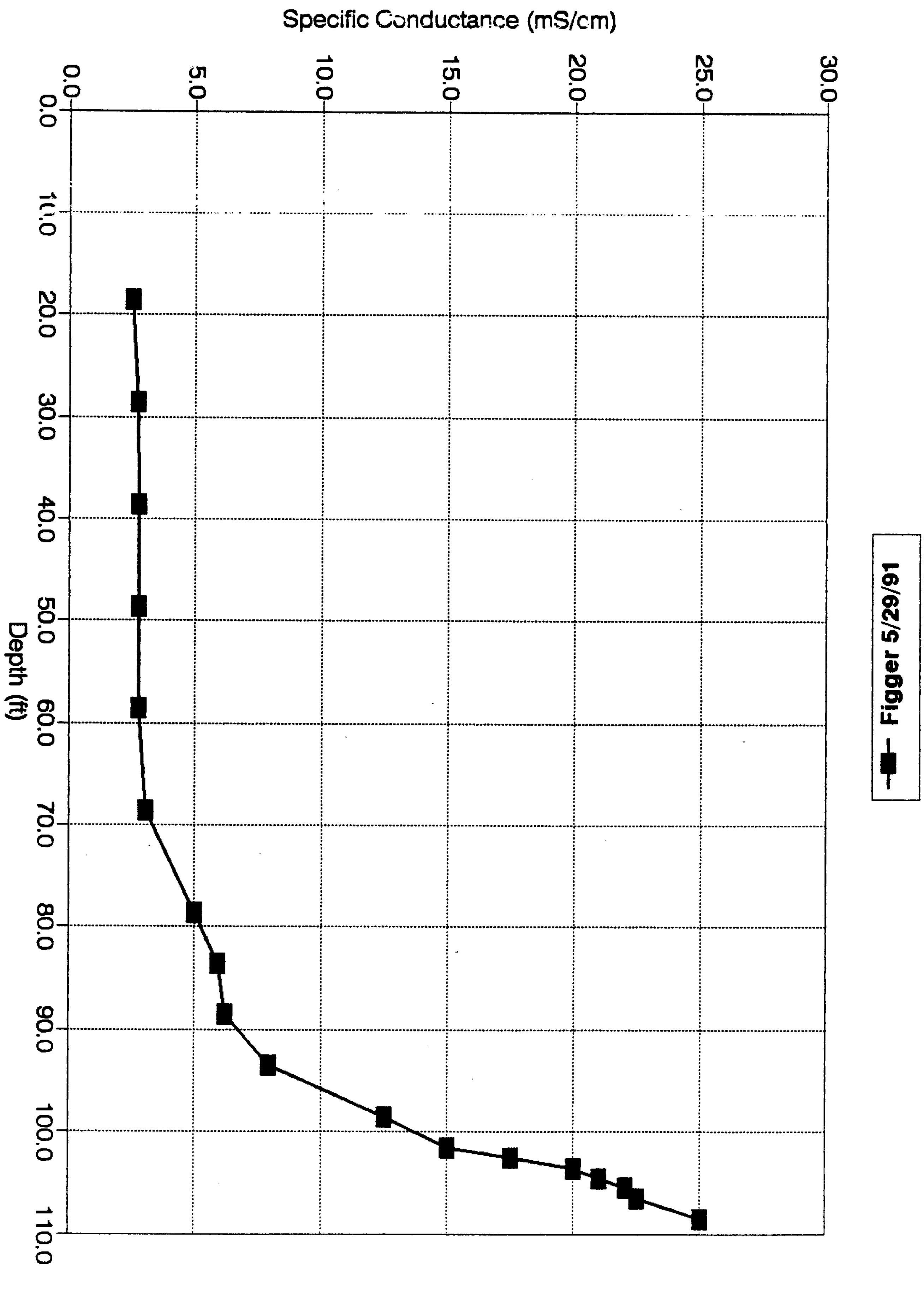

Specific Conductance (mS/cm)
0.0
5.0
10.0
15.0
20.0
25.0
30.0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
110.0
Depth (ft)
Figger 9/20/90

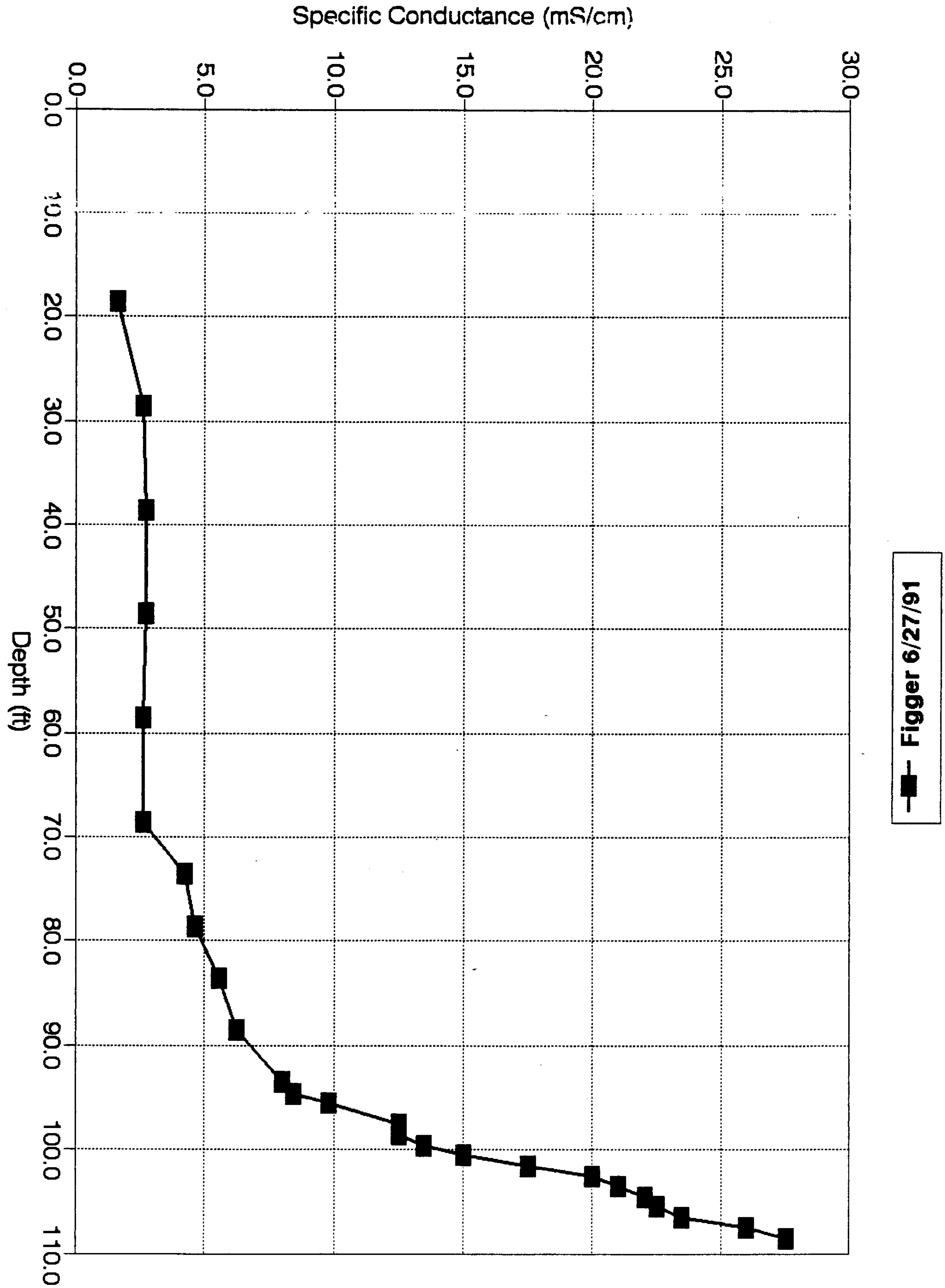

Specific Conductance (mS/cm)
0.0
5.0
10.0
15.0
20.0
25.0
30.0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
110.0
Depth (ft)
Figger 10/25/90

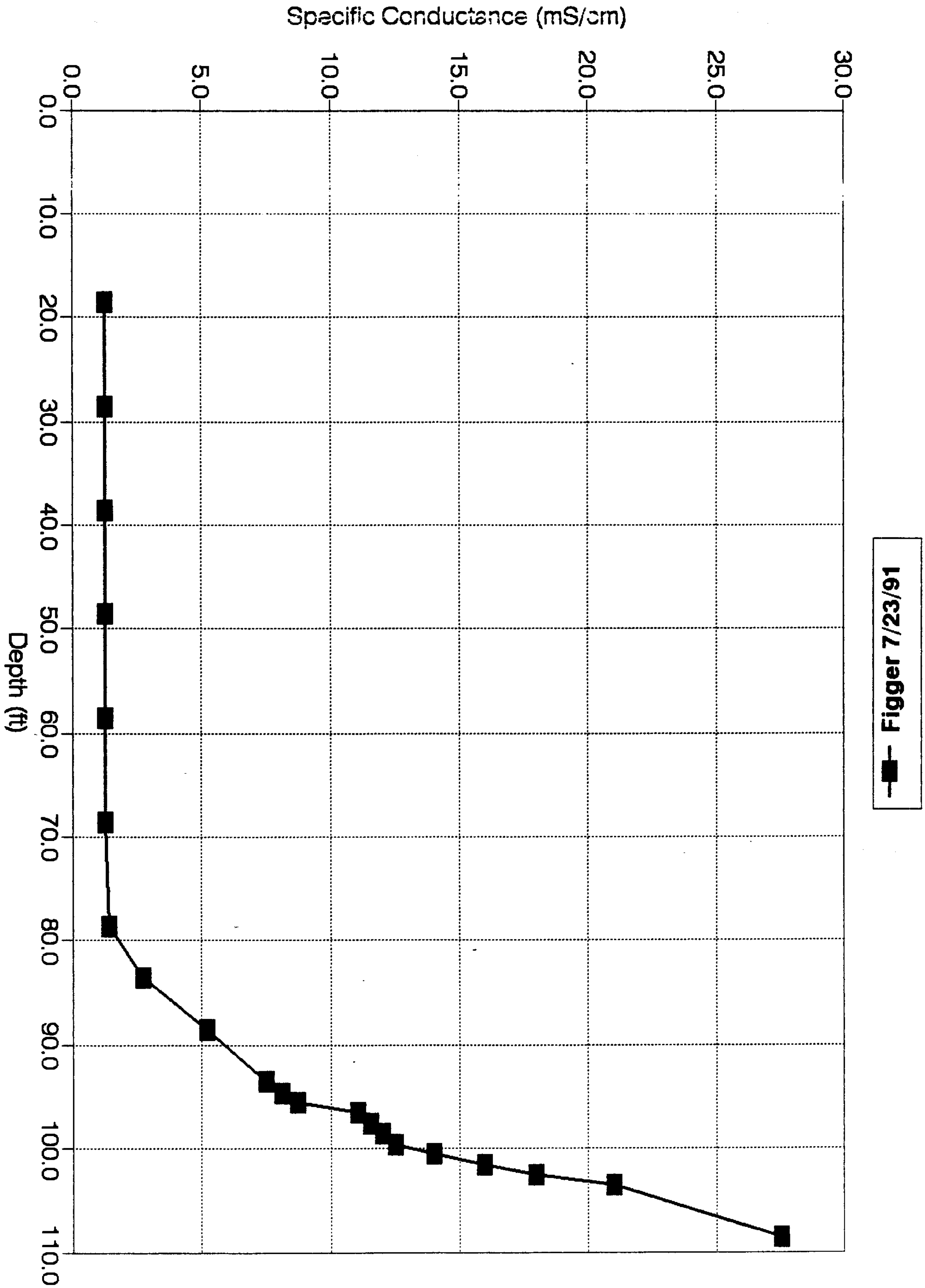

Specific Conductance (mS/cm)
0.0
5.0
10.0
15.0
20.0
25.0
30.0
Depth (ft)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
110.0
Figger 12/6/90


Spccific Conductance (mS/cm)
0.0
5.0
10.0
15.0
20.0
25.0
30.0
Depth (ft)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
110.0
Figger 2/19/91

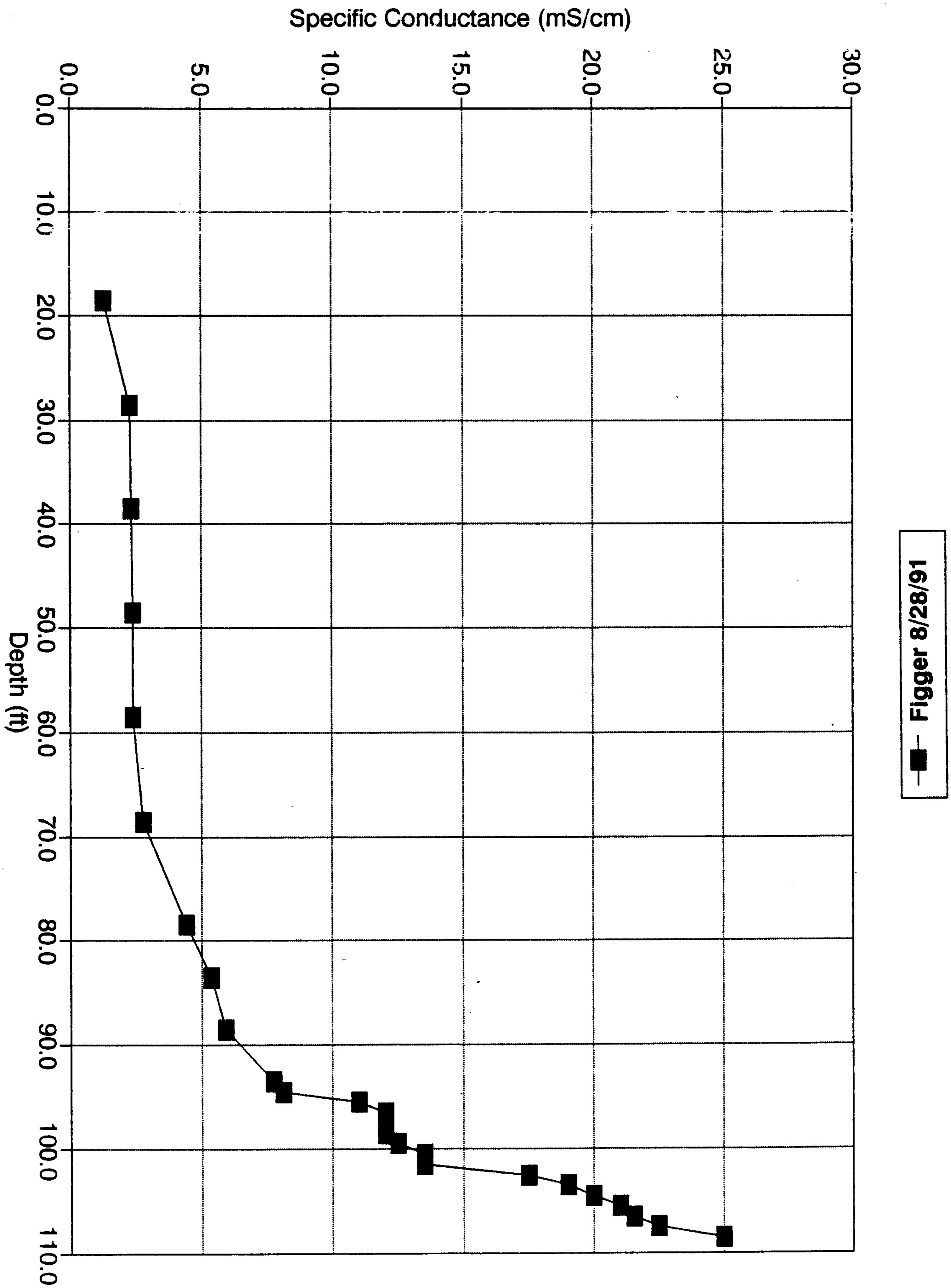

Specific Conductance (mS/cm)
0.0
5.0
10.0
15.0
20.0
25.0
30.0
Depth (ft)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
110.0
Figger 3/26/91

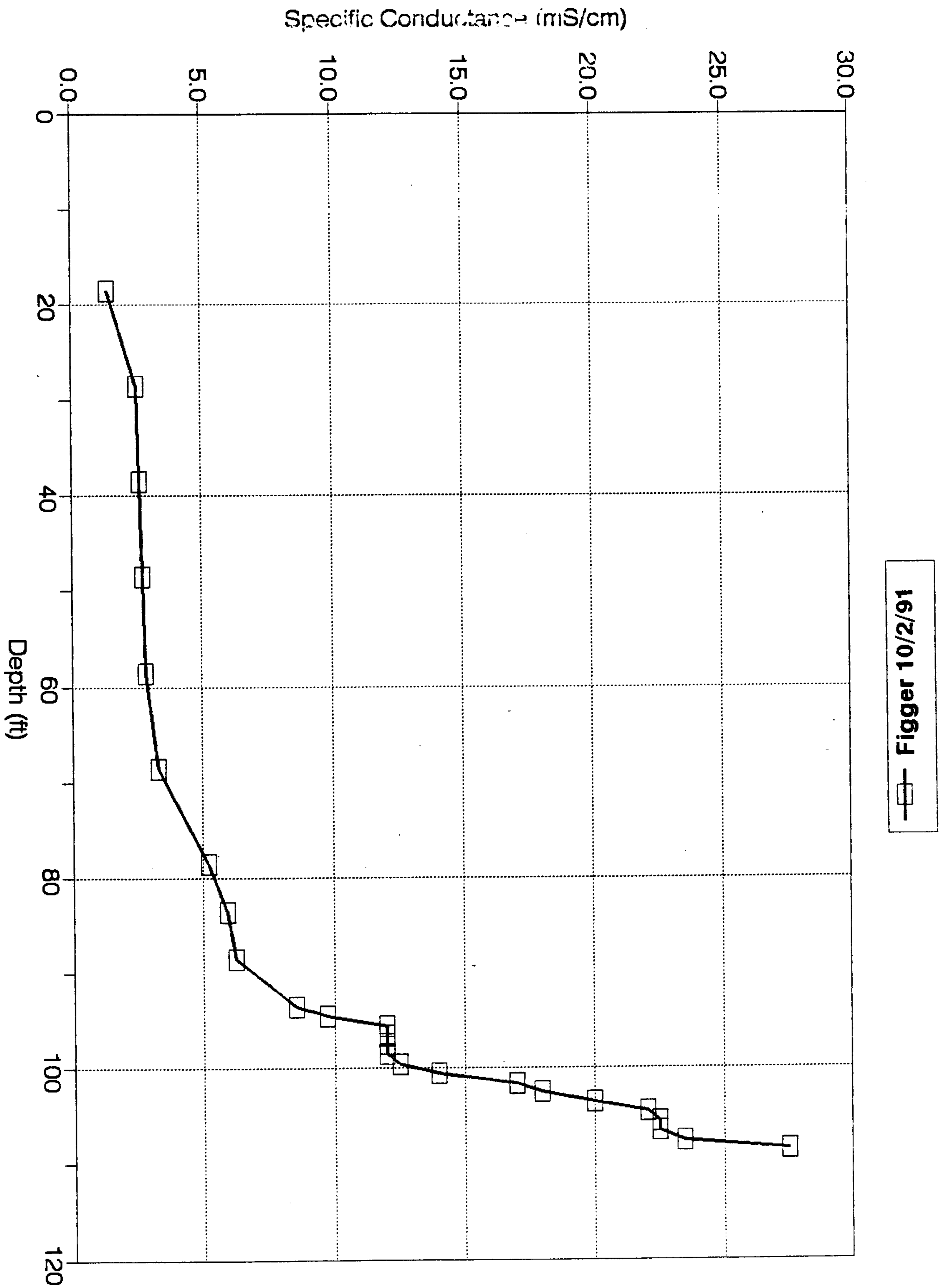

Specific Conductance (mS/cm)
0.0
5.0
10.0
15.0
20.0
25.0
30.0
Depth (ft)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
110.0
Figger 5/29/91


Specific Conductance (mS/cm)
0.0
5.0
10.0
15.0
20.0
25.0
30.0
Depth (ft)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
110.0
Figger 6/27/91

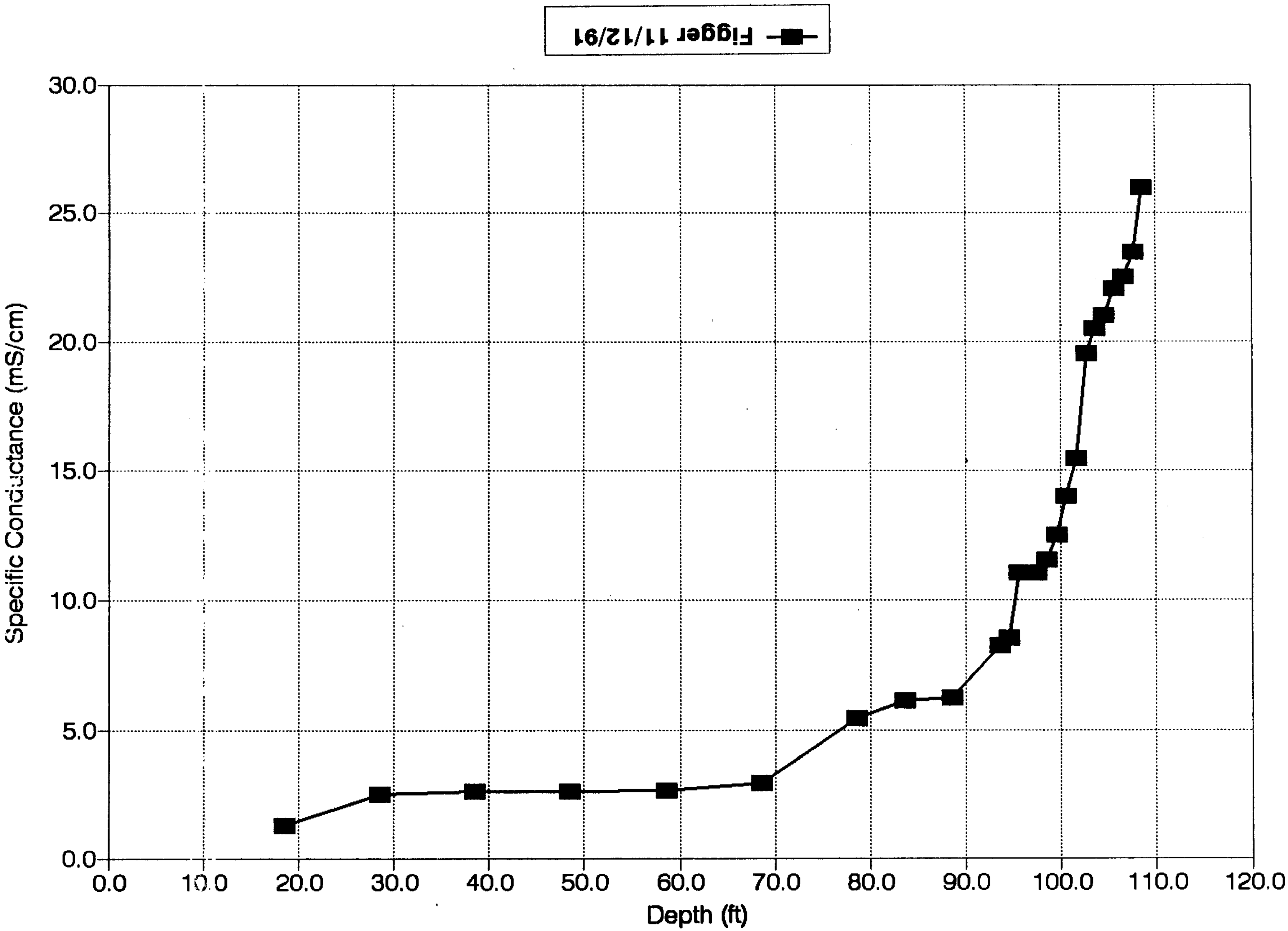


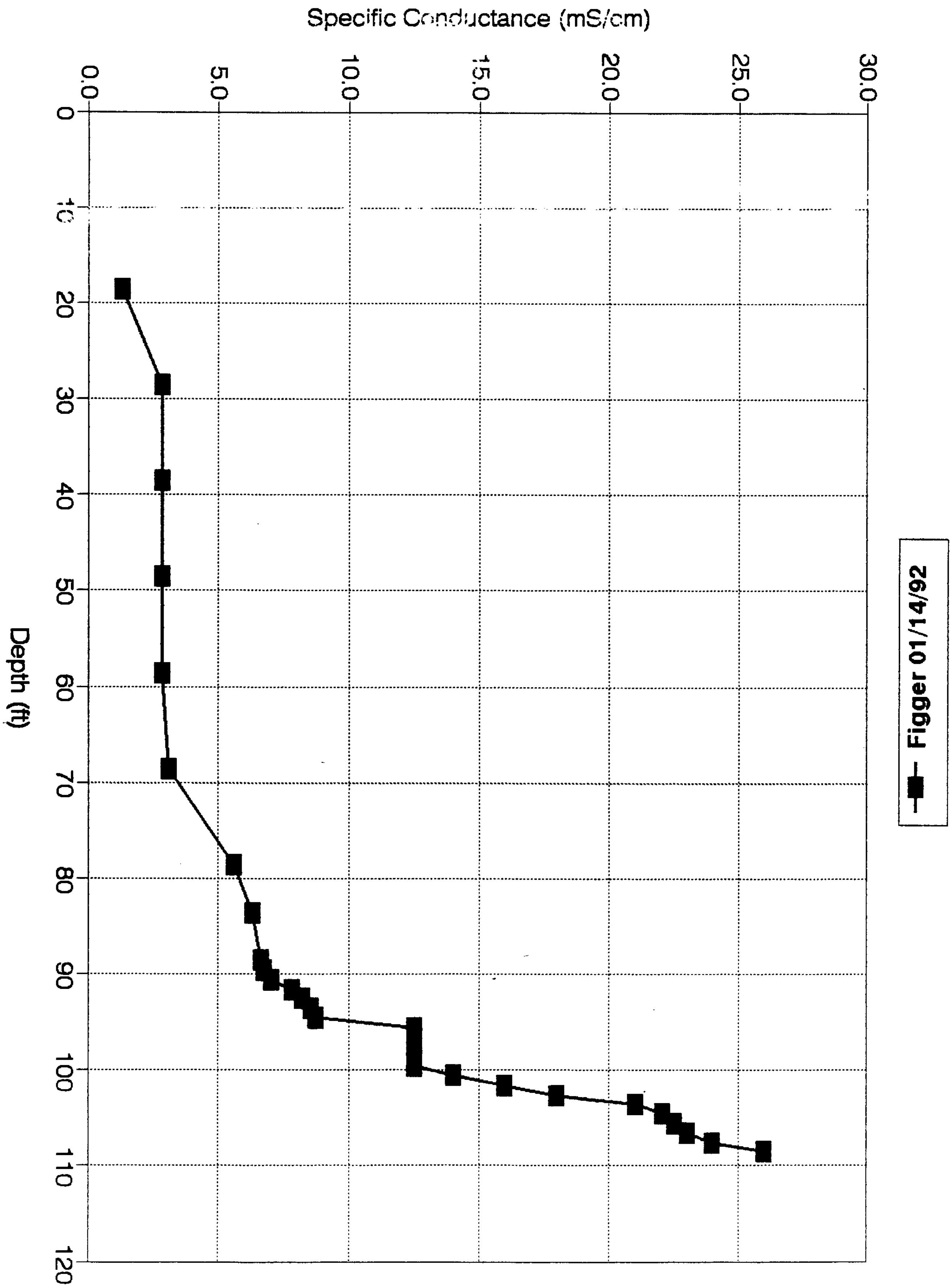
Specific Conductance (mS/cm)
0.0
5.0
10.0
15.0
20.0
25.0
30.0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
110.0
Depth (ft)
Figger 7/23/91

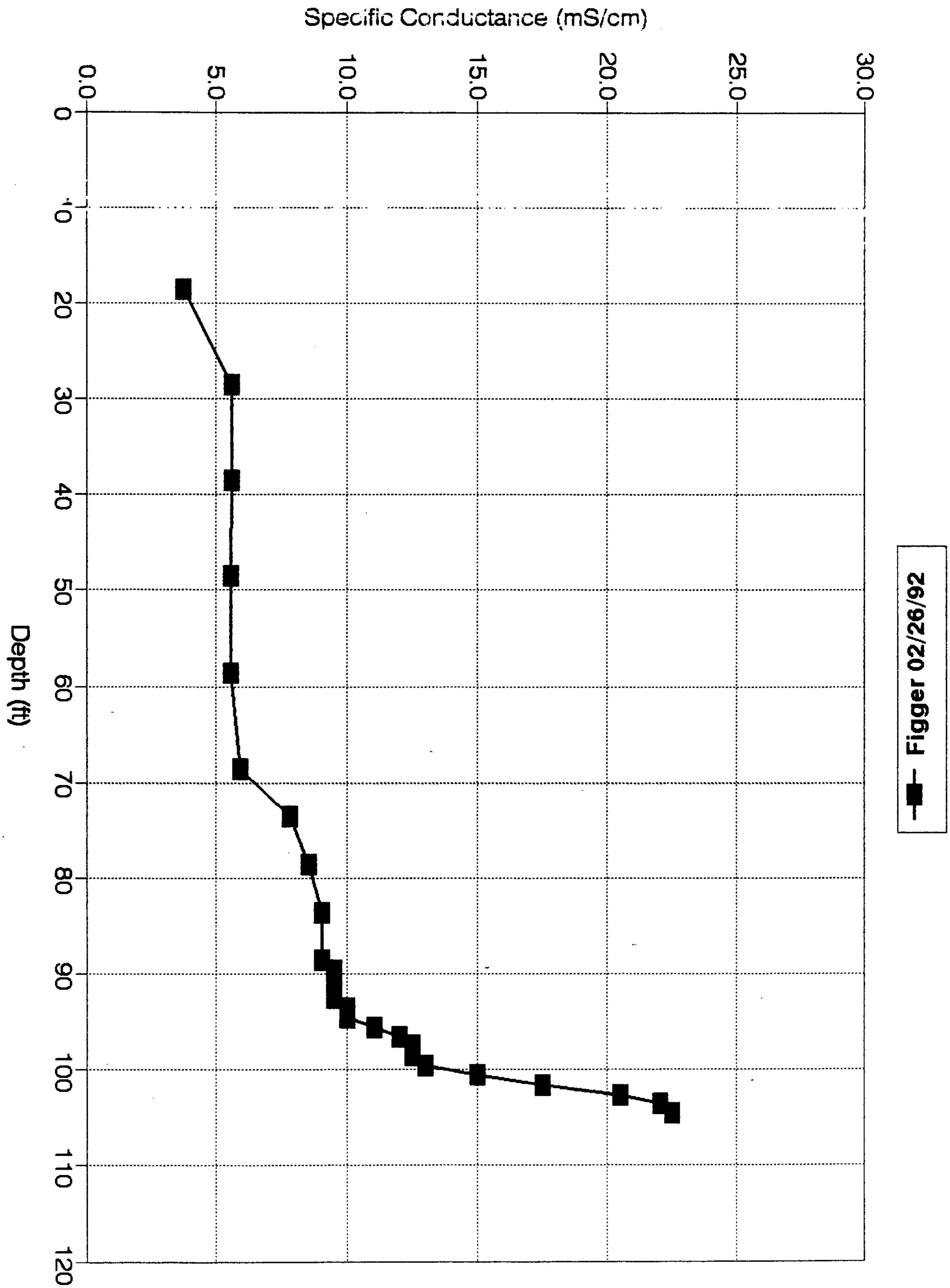

Specific Conductance (mS/cm)
0.0
5.0
10.0
15.0
20.0
25.0
30.0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
110.0
Depth (ft)
Figger 8/28/91

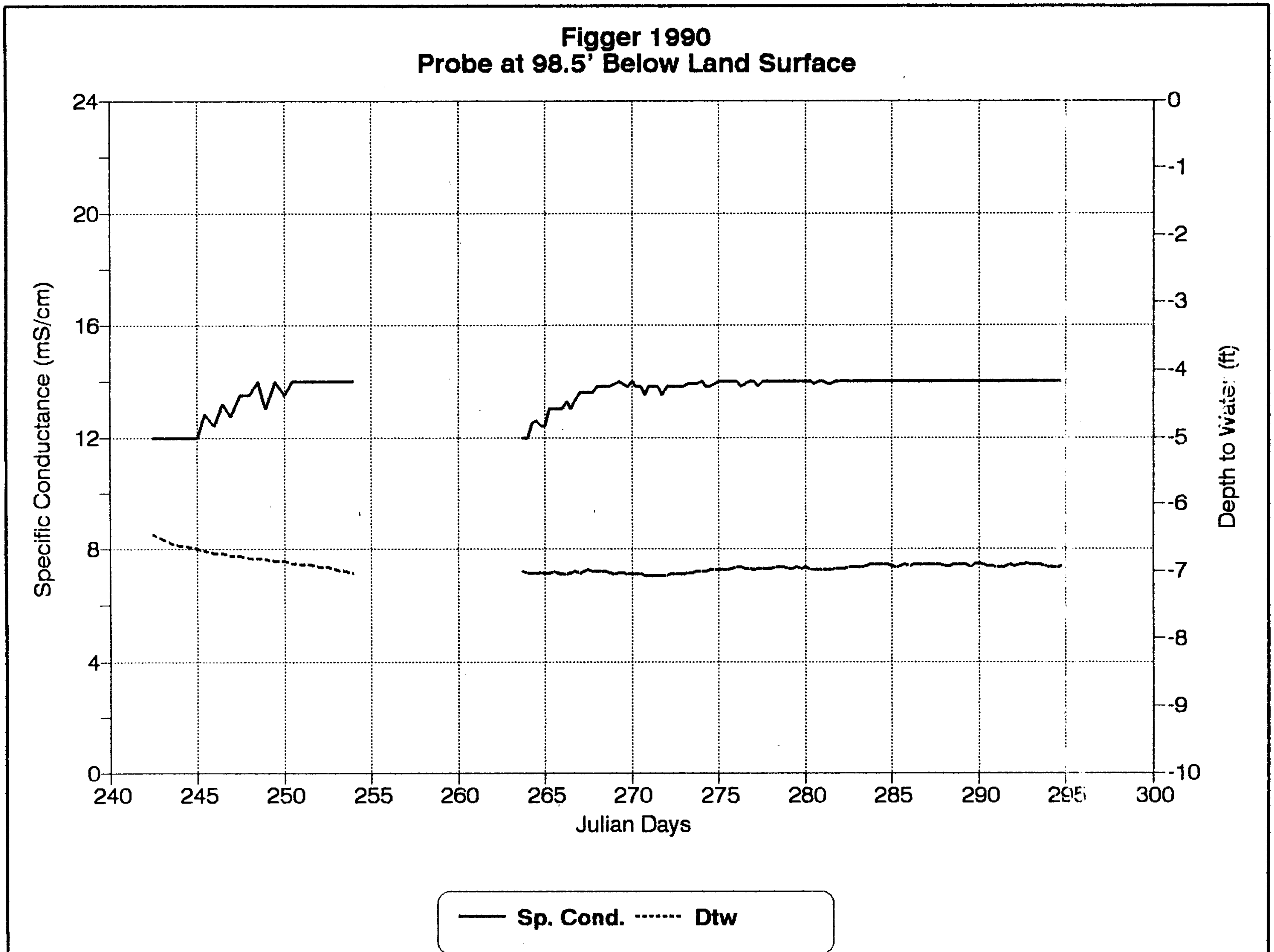


Specific Conductance (mS/cm)
0.0
5.0
10.0
15.0
20.0
25.0
30.0
0
20
40
60
80
100
120
Depth (ft)
Figger 10/2/91

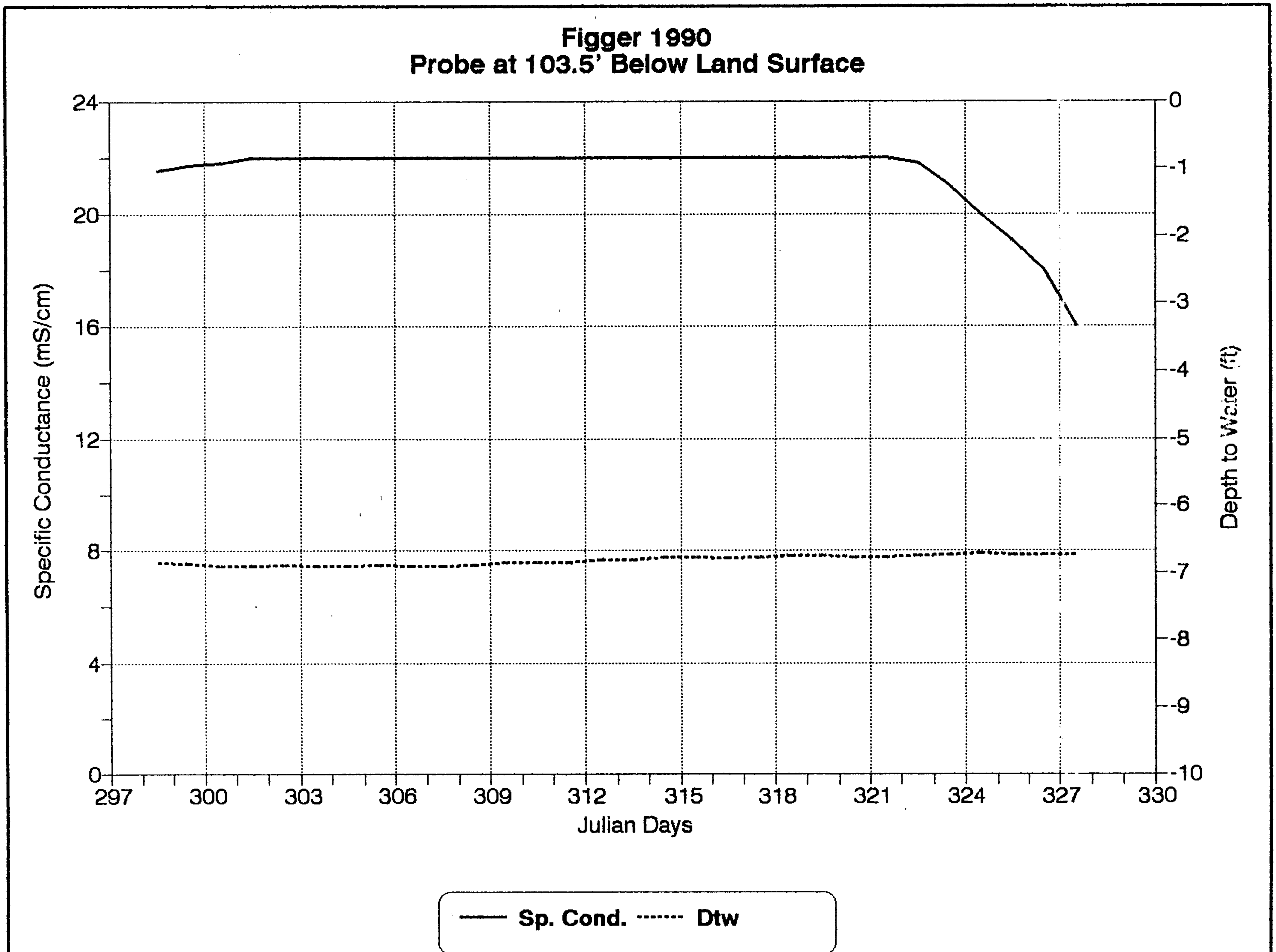

Figger 11/12/91
Specific Conductance (mS/cm)
0.0
5.0
10.0
15.0
20.0
25.0
30.0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
110.0
120.0
Depth (ft)


Specific Conductance (mS/cm)
0.0
5.0
10.0
15.0
20.0
25.0
30.0
0
10
20
30
40
50
60
70
80
90
100
110
120
Depth (ft)
Figger 01/14/92

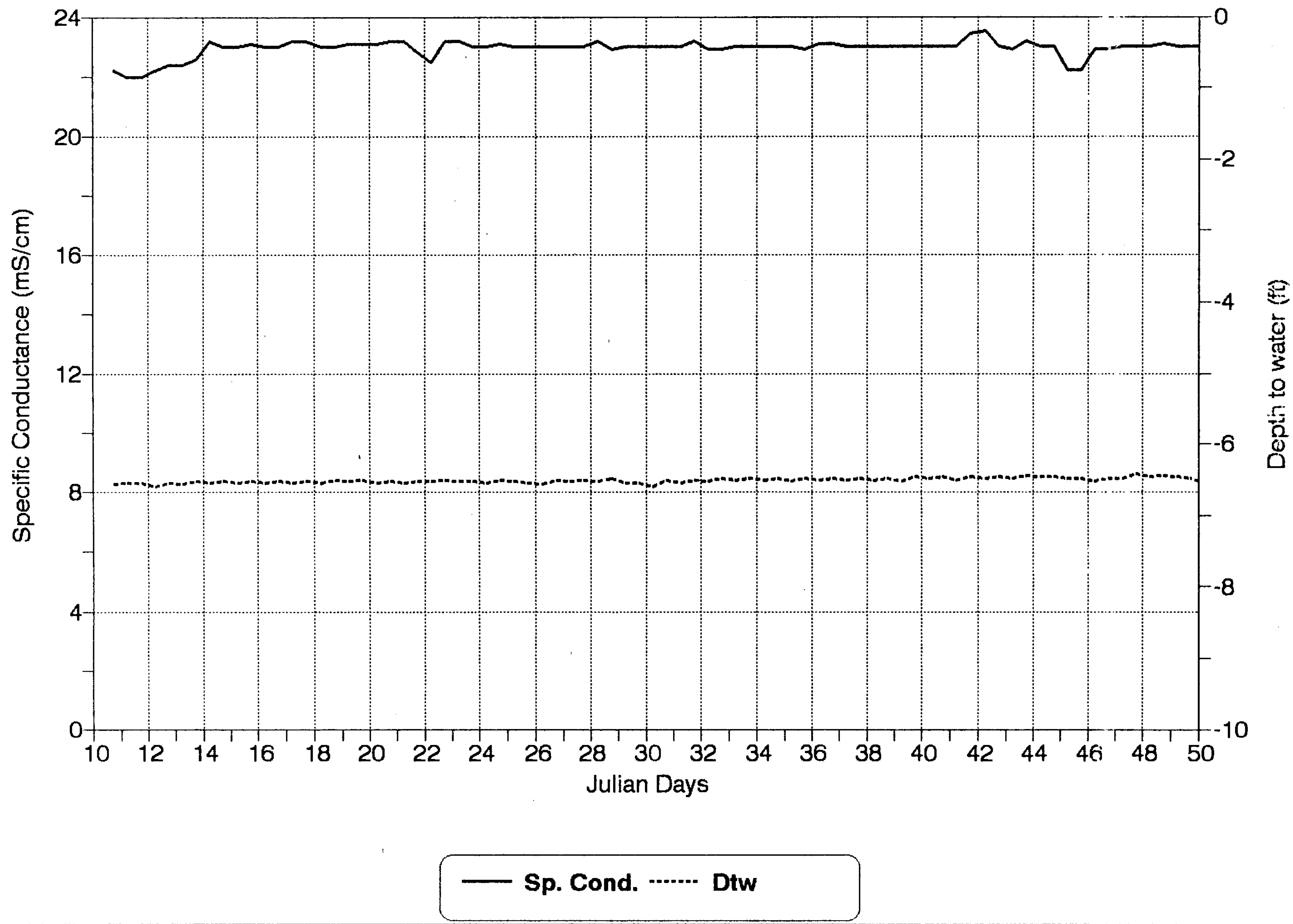

Specific Conductance (mS/cm)
0.0
5.0
10.0
15.0
20.0
25.0
30.0
Depth (ft)
0
10
20
30
40
50
60
70
80
90
100
110
120
Figger 02/26/92

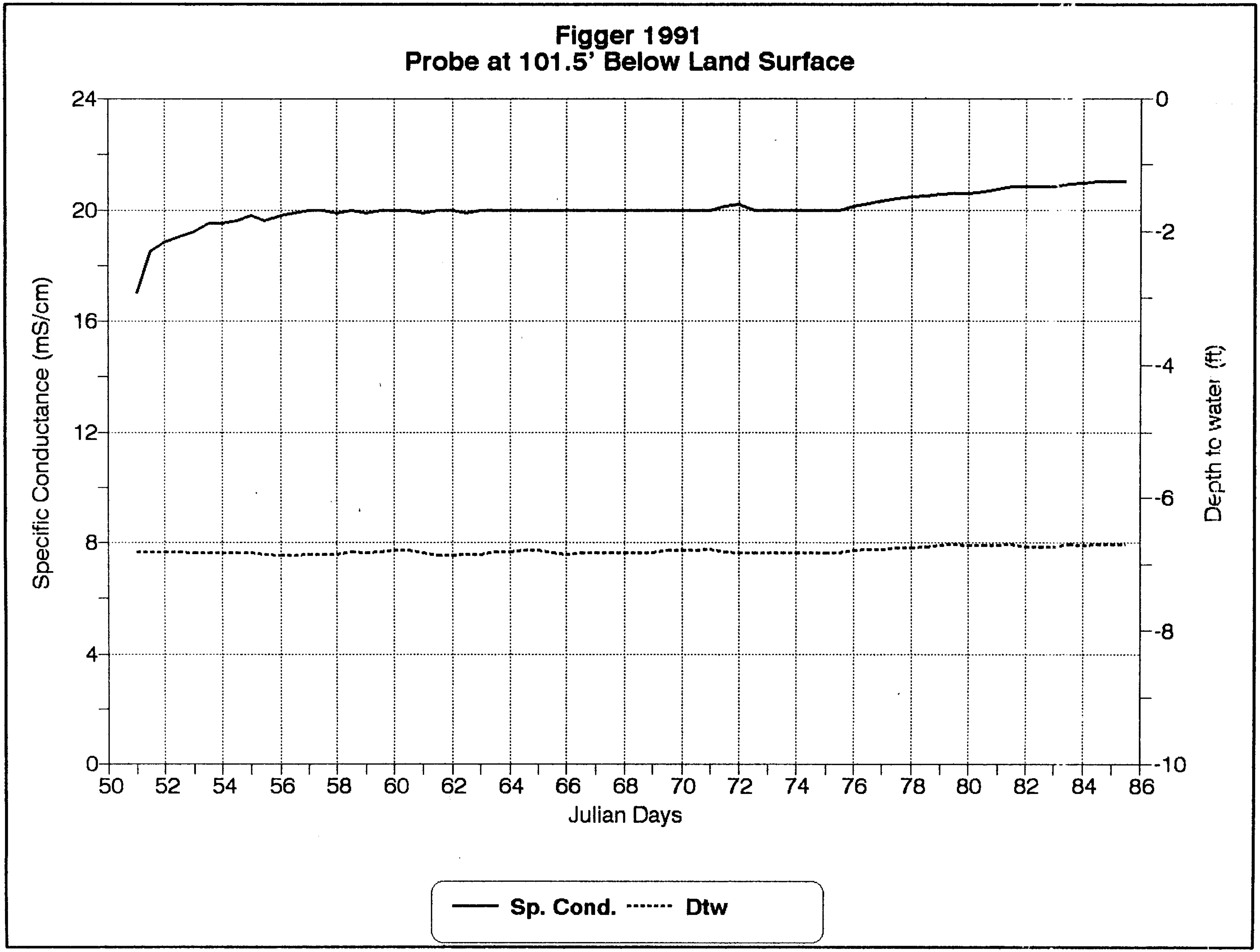


Figger 1990
Probe at 98.5' Below Land Surface
Specific Conductance (mS/cm)
24
20
16
12
8
4
0
Depth to Water (ft)
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
240
245
250
255
260
265
270
275
280
285
290
295
300
Julian Days
Sp. Cond.
Dtw


Figger 1990
Probe at 103.5' Below Land Surface
Specific Conductance (mS/cm)
24
20
16
12
8
4
0
Depth to Water (ft)
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
297
300
303
306
309
312
315
318
321
324
327
330
Julian Days
Sp. Cond.
Dtw

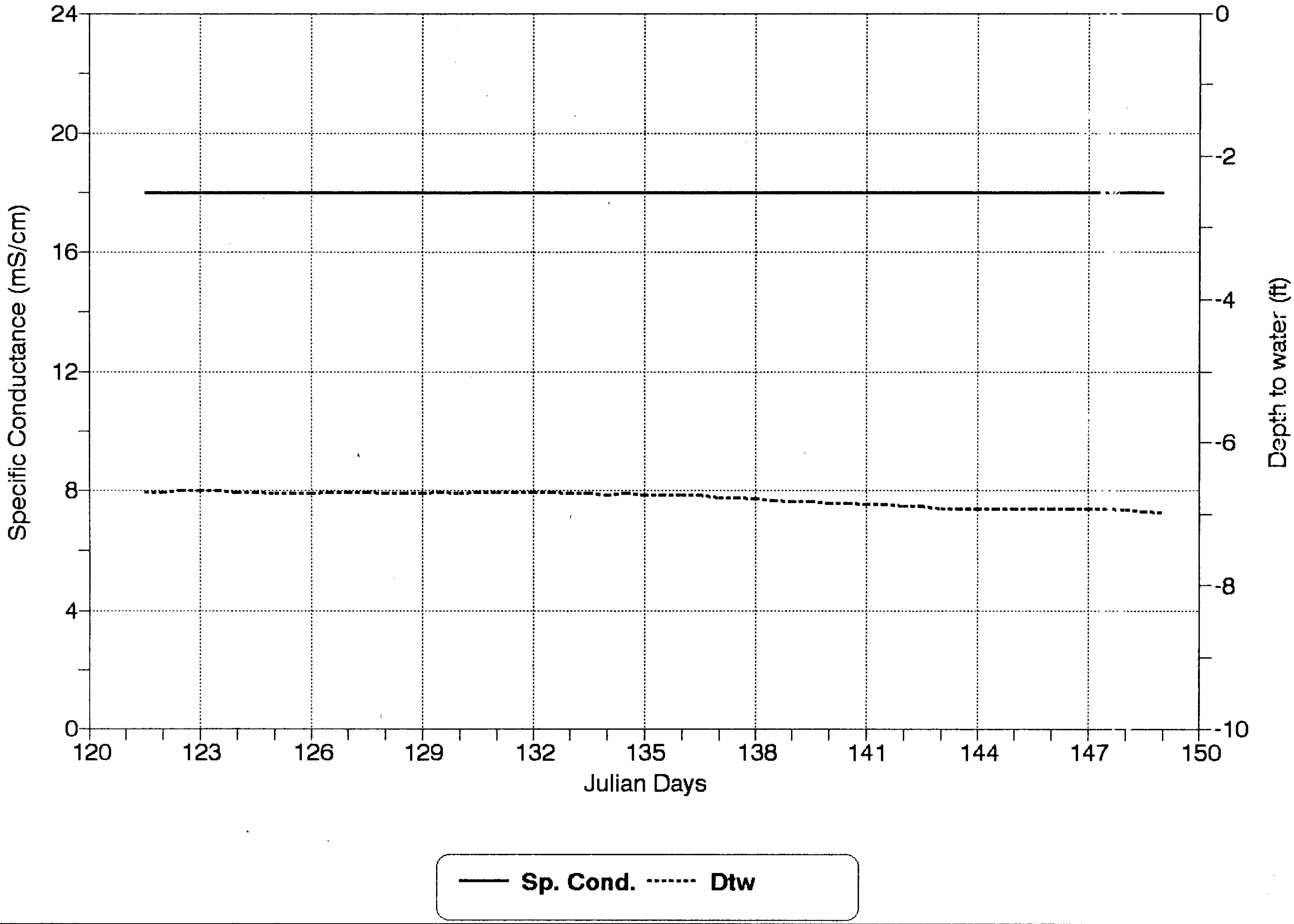
Figger 1991
Probe at 103.5' Below Land Surface

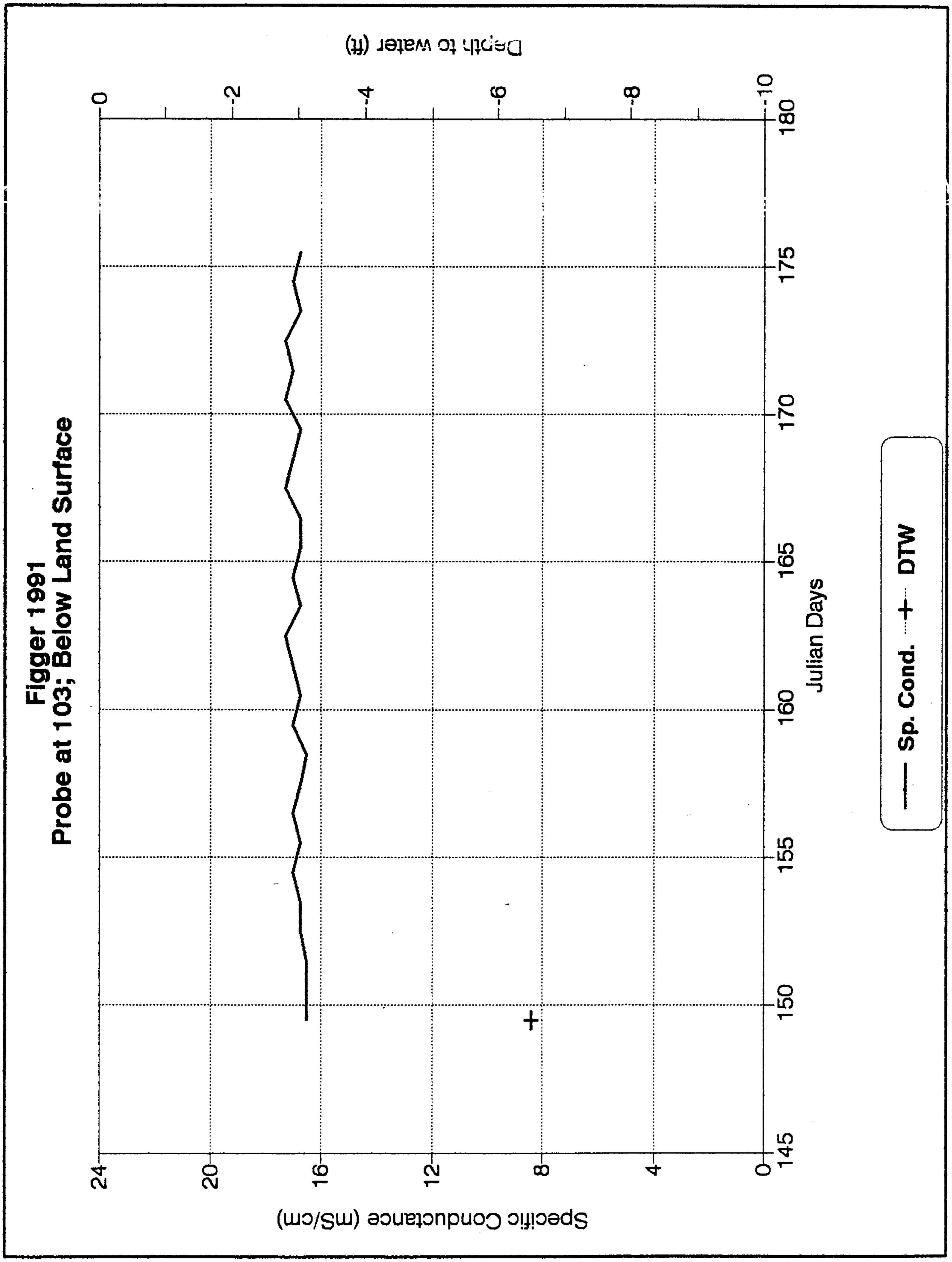


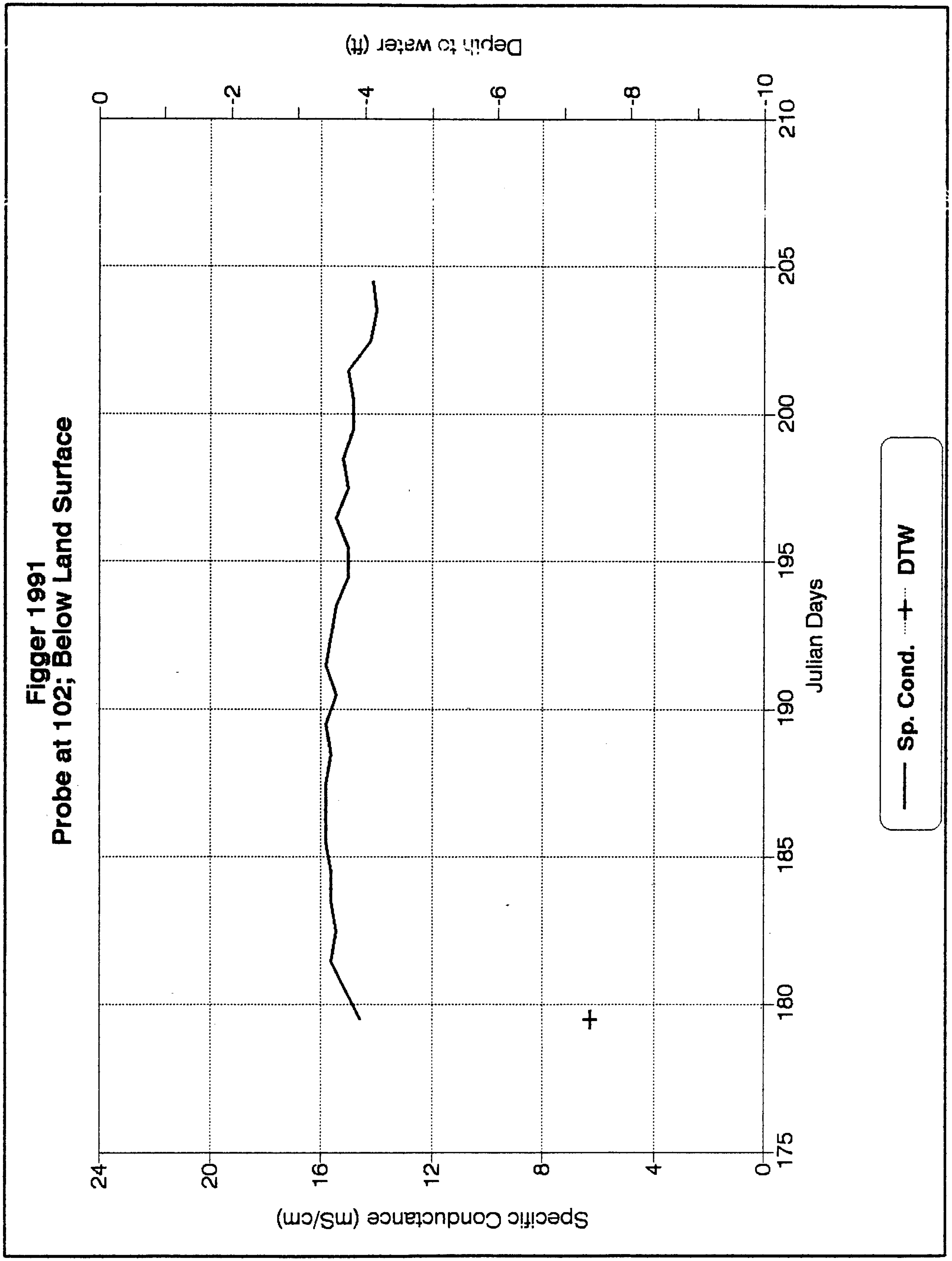


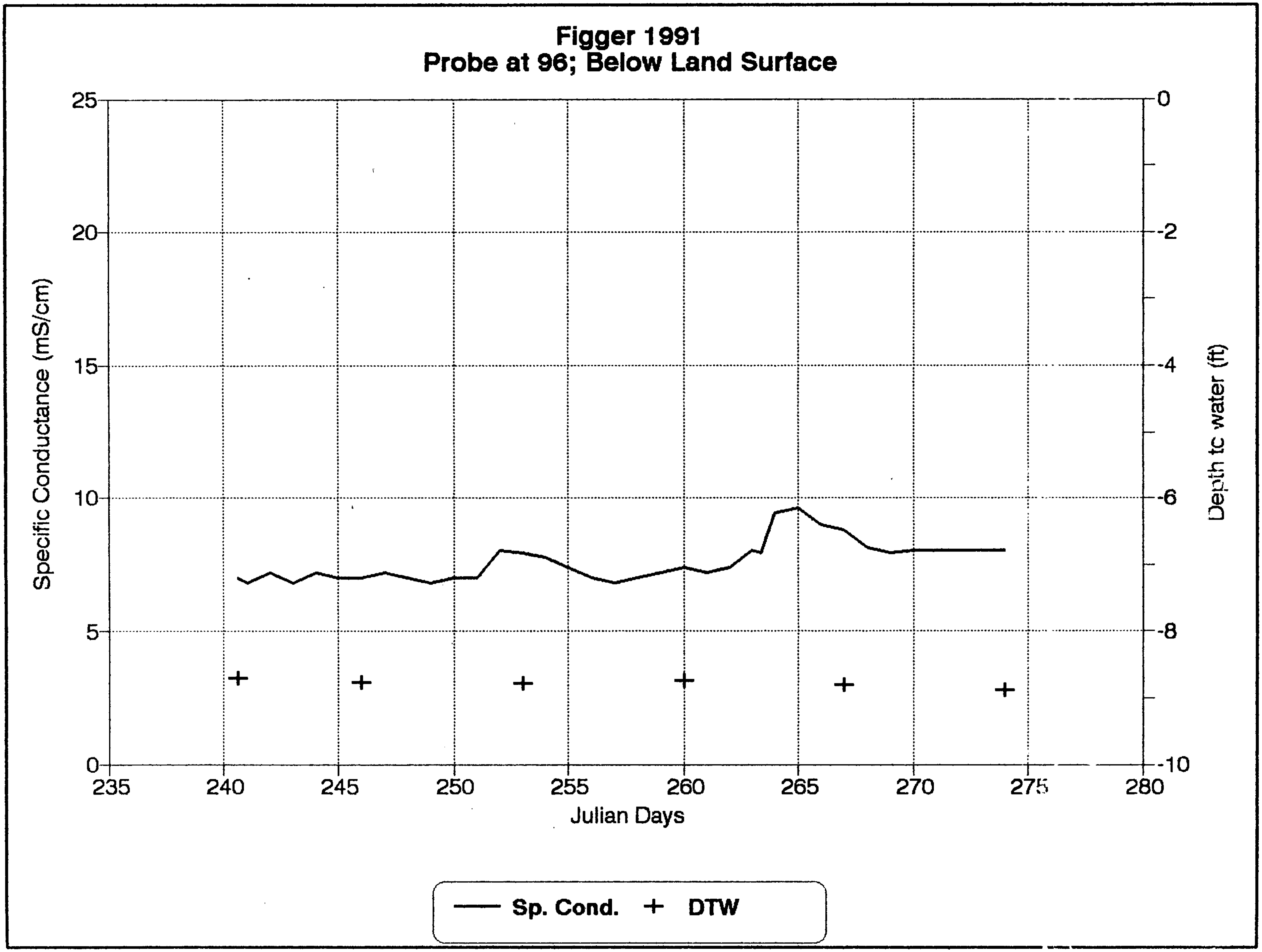
Figger 1991
Probe at 101.5' Below Land Surface
Specific Conductance (mS/cm)
24
20
16
12
8
4
0
Depth to water (ft)
0
-2
-4
-6
-8
-10
50
52
54
56
58
60
62
64
66
68
70
72
74
76
78
80
82
84
86
Julian Days
Sp. Cond.
Dtw

Figger 1991
Probe at 102.5' Below Land Surface

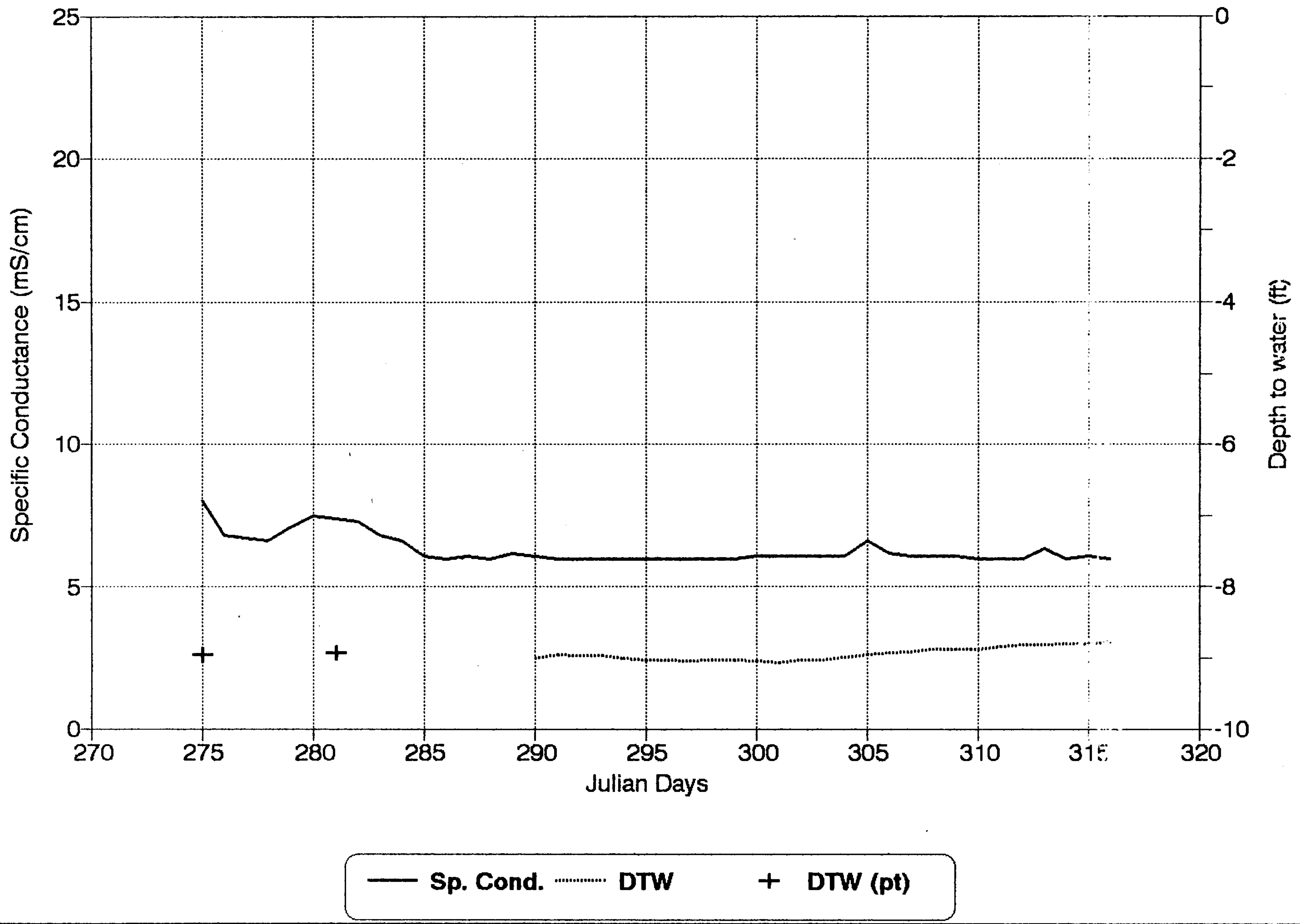


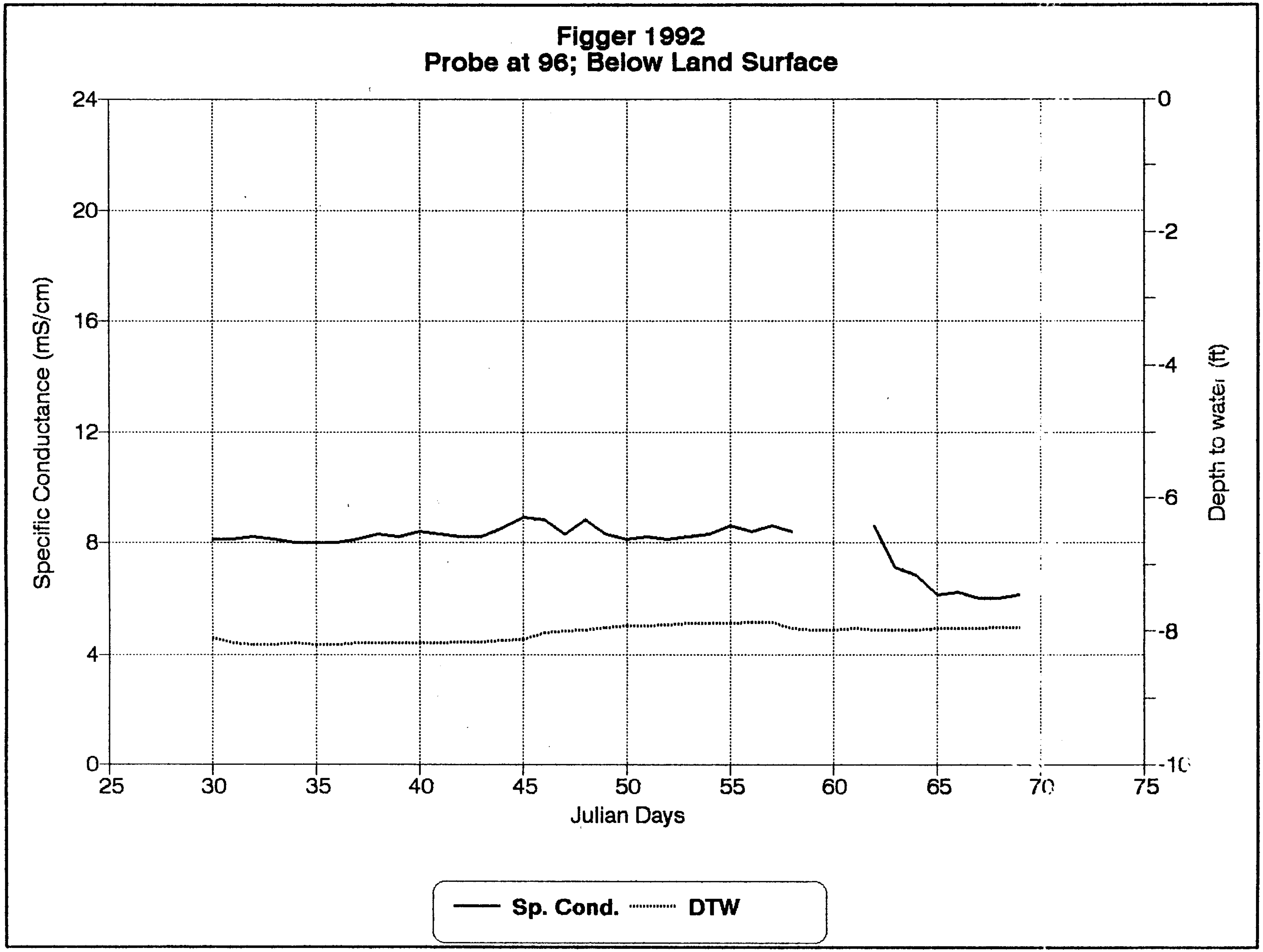

Figger 1991
Probe at 103; Below Land Surface
Specific Conductance (mS/cm)
0
4
8
12
16
20
24
Depth to water (ft)
0
-2
-4
-6
-8
-10
Julian Days
145
150
155
160
165
170
175
180
Sp. Cond.
DTW


Figger 1991
Probe at 102; Below Land Surface
Specific Conductance (mS/cm)
Depth to water (ft)
Julian Days
0
4
8
12
16
20
24
175
180
185
190
195
200
205
210
0
-2
-4
-6
-8
-10
Sp. Cond.
DTW


Figger 1991
Probe at 96; Below Land Surface
Specific Conductance (mS/cm)
Depth to water (ft)
Julian Days
0
5
10
15
20
25
-10
-8
-6
-4
-2
235
240
245
250
255
260
265
270
275
280
Sp. Cond.
DTW

Figger 1991
Probe at 95; Below Land Surface





Figger 1992
Probe at 96; Below Land Surface
Specific Conductance (mS/cm)
Depth to water (ft)
Julian Days
24
20
16
12
8
4
0
0
-2
-4
-6
-8
-10
25
30
35
40
45
50
55
60
65
70
75
Sp. Cond.
DTW

Appendix 4. Chemical Analyses of the Waters of the Quivira National Wildlife Refuge.

QUIVIRA REFUGE STUDY

Location	Date	Fld SpC uS/cm	Lab SpC uS/cm	Fld pH	Lab pH	SiO2 ppm	Ca ppm	Mg ppm	Na ppm	K ppm	Sr ppm	CO3 ppm	HCO3 ppm	SO4 ppm	Cl ppm	F ppm	NO3 ppm	NH4 ppm	PO4 ppb	Al ppb	As ppb	B ppb	Cr ppb	Cu ppb	Fe ppb	Mn ppb	Ni ppb	Pb ppb	Se ppb	Zn ppb	Ba ppb
Rattl Entry	08/31/90	9570	·	7.95																194	18	258	1.3	1.7	<29	62	2.4	14.0	1	<4	185
L S Marsh	08/31/90	9020		8.45																274	5	249	4.7	1.9	60	<4	2.9	5.9	14	31	277
B S Marsh	08/31/90	14460		8.90																425	9	265	1.4	0.8	<29	19	0.8	8.2	21	<4	193
Rattl Exit	08/31/90	22300		7.50																350	28	655	0.1	1.4	<29	247	0.7	6.3	51	21	119
Rattl Entry	03/12/91	6950	7580	8.15	8.15	9.0	100	27	1463	3.2	1.28		249	236	2220	0.48	0.5	<0.1	80	47	0	187	0.2	0.5	<29	127	2.7	2.0	3	11	128
L S Marsh	03/12/91	9140	9820	8.20	8.00	0.6	97	37	1970	7.1	1.55		156	322	2980	0.53	<0.1	0.1	70	54	2	215	0.3	0.4	<29	<4	1.2	1.0	4	27	199
B S Marsh	03/12/91	15100	16500	8.25	8.05	10.0	103	79	3455	14.0	2.26		278	571	5250	1.00	<0.1	0.2	100	78	2	330	0.2	0.5	30	46	0.4	1.8	4	13	193
Rattl Exit	03/12/91	20600	22600	7.25	7.95	12.0	223	122	4840	10.0	4.32		327	927	7480	0.60	<0.1	<0.1	20	59	15	552	0.2	0.1	<29	832	0.6	0.0	28	11	75
Rattl Entry	06/21/91	7020	7130	8.70	8.55	6.1	79	25	1362	8.8	1.08	5.9	173	217	2110	0.54	0.5*	<0.1	50	<79	7	215	0.9	5.6	<21	14	12.0	2.4	5	<4	162
L S Marsh	06/21/91	8480	8420	8.65	8.30	13.0	82	33	1621	14.0	1.26		173	262	2470	0.62	0.9*	0.1	80	<79	7	252	1.1	6.7	<21	4	8.4	4.1	5	14	208
B S Marsh	06/21/91	20000	18400	9.95	9.65	9.2	52	79	3903	22.0	1.85	53.0	46	578	6020	0.96	3.2*	0.2	40	102	6	468	1.3	4.8	<21	4	5.8	4.0	11	5	158
Rattl Exit	06/21/91	26000	24200	7.70	8.00	6.3	193	134	5167	25.0	4.26		203	986	7920	0.58	0.6*	<0.1	10	81	9	665	1.7	5.8	<21	93	12.0	4.0	8	6	93
Rattl Entry	09/20/91	14200	14700	8.25	8.20	10.0	184	58	3105	7.6	2.34		205	426	4820	0.39	0.5*		30	75	4	314	0.7	8.0	<21	62	12.0	5.4	5	9	164
L S Marsh	09/20/91																														
B S Marsh	09/20/91	54400	49900	8.70	8.40	25.0	212	228	13100	37.0	6.28	8.1	253	1830	19700	1.05	11.0*		100	112	13	598	0.6	20.0	<21	7	5.1	4.0	19	6	873
Rattl Exit	09/20/91	21000	18700	8.95	8.75	3.4	128	109	4088	6.8	3.01	14.0	124	770	6170	0.65	0.4*		30	130	10	523	0.9	19.0	34	15	11.0	4.6	15	<4	100

* UV screening value

Appendix 5. X-ray Analyses of Rock and Sediment Samples from the Big Salt Marsh and the Bedrock Outcrops.

ANALYTICAL REPORT
KANSAS GEOLOGICAL SURVEY X-RAY LABORATORY

KSG X-Ray Laboratory Sample Identification Numbers: 910538-910543

Samples Submitted by: Marios Sophocleous

Date collected (if not known, received): 6/20-6/21/91

Description of Samples:

#1 Bedrock outcrop - Kiowa shale
black-gray with white nodules ASL910538

#2 Bedrock outcrop - Pressure structures above Kiowa Sh.
ASL910539

#3 Bedrock outcrop - Capping rusty sandstone ASL910540

#4 Stream bed of Salt Creek outlet from Big Salt Marsh
black gooey stuff with sulfide smell ASL910541

#5 Intermittent Big Salt Marsh by Marsh Road
Salt crust ASL910542

#6 Kiowa Shale - black fissile shale ASL910543

Remarks:

abbr.: dom. - dominate, most or all of sample
maj. - major, more than 10%, usually more than 25%
min. - minor, 5% to 25%, usually 10%-20%
tr. - trace, less than 10%, usually less than 5%

XRF detection limit for Se is approximately 10ppm

Results

#1 XRF: Se below detection
XRD: White nodules - Calcite dom., Quartz tr., clay tr.
matrix - clay maj., Quartz maj.

#2 XRF: Se below detection
XRD: Calcite dom., Quartz tr.

#3 XRF: Se below detection
XRD: Goethite maj., Quartz maj.

#4 XRF: Se below detection
XRD: Quartz maj., Feldspar maj.

#5 XRF: Se below detection
XRD: white crust - Halite dom., Quartz tr.
bulk sample - Halite maj., Quartz maj.
water insoluble - Quartz maj., feldspar min.,
calcite min., clay min.

#6 XRF: Se below detection
XRD: clay maj., Quartz maj.