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Date: September 25, 2015

Subject: Draft Report

Attached is a draft report for your review:

GROUNDWATER OVERDRAFT IN THE DELTA-MENDOTA SUBBASIN

Please provide comments and direct questions to Ken Schmidt.

Ken Schmidt's schedule for the next week is:

Sept. 28-30 and Oct. 1-2 in Fresno @ 559-224-4412.

GROUNDWATER OVERDRAFT IN THE DELTA-MENDOTA SUBBASIN

Draft Report-For Review Purposes Only

prepared for
San Luis & Delta-Mendota
Water Authority
Los Banos, California

by
Kenneth D. Schmidt & Associates
Groundwater Quality Consultants
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September 2015

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GROUNDWATER OVERDRAFT IN THE DELTA-MENDOTA SUBBASIN

INTRODUCTION

The Delta-Mendota Groundwater sub-basin extends from the San Joaquin County-Stanislaus County line on the northwest to the southeast to an area south of Tranquillity (Figure 1). Water from the Delta-Mendota Canal (DMC) has supplied most of the water used for irrigation in the sub-basin. Groundwater is used for municipal use, except in Dos Palos, and to supplement the irrigation demand. The California Department of Water Resources (DWR) has recently listed the sub-basin as "critically overdrafted". The purpose of this report is to present technical information to support the removal of the sub-basin from this list.

SUBSURFACE GEOLOGIC CONDITIONS

Hotchkiss and Balding (1971) discussed regional groundwater conditions in the part of the sub-basin north of Dos Palos. Davis and Poland (1757) discuss regional groundwater conditions in the area near and south of Mendota. Two primary aquifers have been delineated in the sub-basin. Alluvial deposits comprise these aquifers, which are separated by a widespread laterally continuous clay layer termed the Corcoran Clay. The base of the aquifer generally decreases to the north, from about 1,100 to

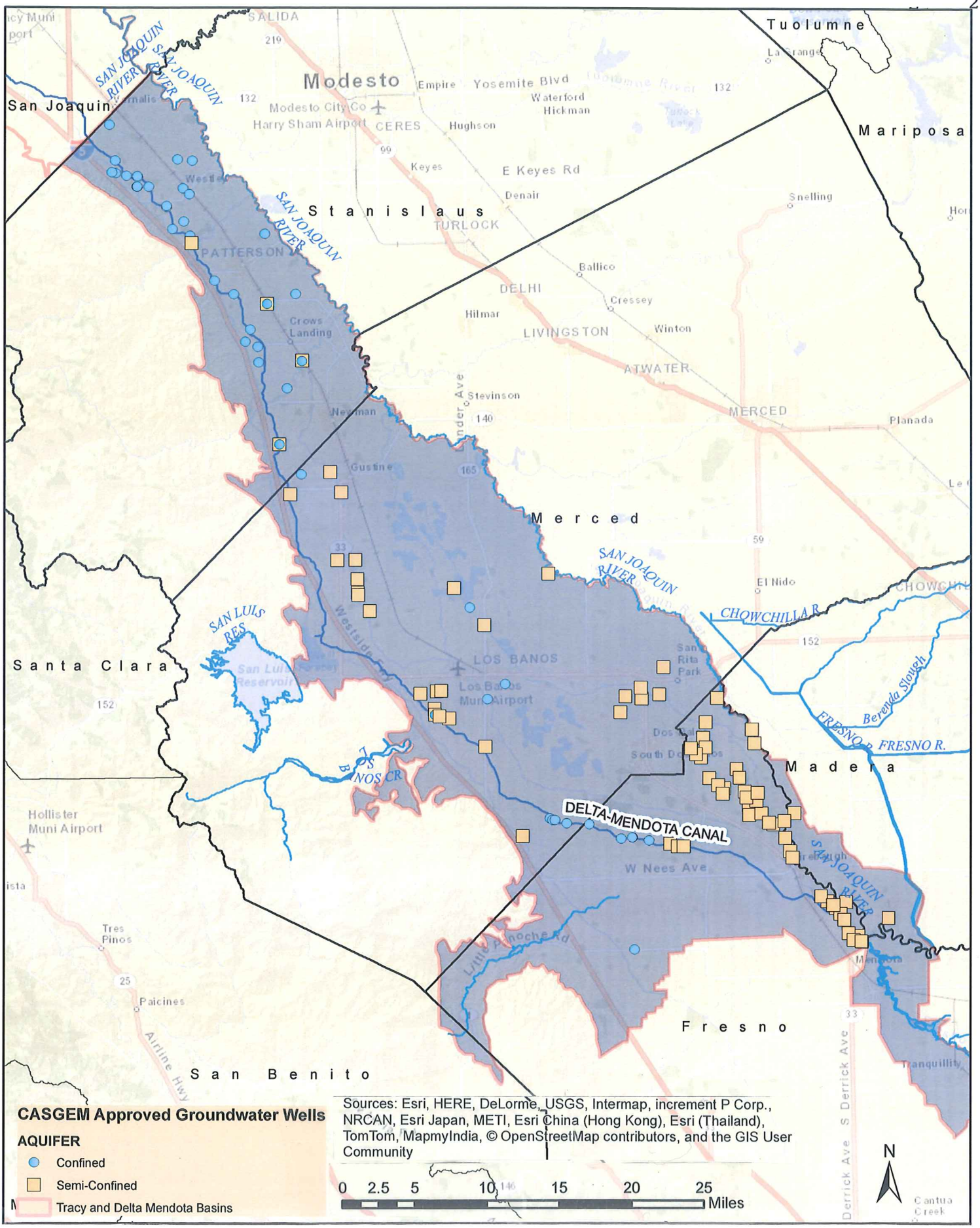


FIGURE 1-DELTA-MENDOTA GROUNDWATER BASIN AND GSAS

1,200 feet deep to the south to about 600 feet to the north. Depth to the top of the clay ranges from less than 100 feet to the west near I-5 to more than 500 feet in the area near Tranquillity. The clay pinches out or is above the water level near the California Aqueduct in the western part of the sub-basin. The Corcoran Clay acts as a confining bed for the under-lying groundwater. Water levels in the upper aquifer (above the clay) are normally significantly shallower than those in the confined lower aquifer. In parts of the sub-basin (i.e. Tranquility and Patterson), higher salinity groundwater is present above the Corcoran Clay, whereas in other parts, (such as at and near Mendota) higher salinity groundwater is present beneath the clay.

Pumpage for irrigation in the sub-basin is primarily from the upper aquifer, particularly in the San Joaquin River Exchange Contractors (SJREC) service area and in the Cities of Mendota, Firebaugh, and Los Banos. Pumpage from the lower aquifer in the sub-basin is primarily in the Panoche Water District, from Warren Act wells near the Delta Mendota Canal (DMC) and Russell Avenue, in part of the Tranquility I.D., and in the City of Patterson. Composite wells tapping both aquifers are present in the area west of Newman.

Lastly, pumpage from the lower aquifer has been associated with land subsidence in some parts of the San Joaquin Valley and this is discussed further in a subsequent section of this report.

GROUNDWATER FLOW DIRECTIONS

Detailed water-level maps for both aquifers have been prepared for the SJREC service area and in the Red Top-El Nido area. Detailed water-level maps for the lower aquifer have been prepared in the Westlands W.D. and in the Red Top-El Nido area. There are too few wells tapping the lower aquifer in part of the sub-basin to allow detailed water-level maps to be prepared. All of the maps prepared in recent years indicate groundwater outflow from the Delta-Mendota sub-basin, except along the western margin, where there is some recharge from local streams and canal seepage.

Upper Aquifer

Water-level elevation maps for the upper aquifer have been prepared for the SJREC water service area and adjoining areas for Fall 1981, Spring 1986, Spring 1997, and February 2013. These were provided in two technical reports by Kenneth D. Schmidt & Associates (KDSA, 1997a and 2014). Detailed maps for the upper aquifer have also been prepared by KDSA for the Red Top-El Nido area for January-February, 2010 and February 2013. Detailed water-level maps for the upper aquifer have been prepared in the Mendota area each year for the past 15 years, as part of the Mendota Pool Pumping Program (Luhdorff & Scalmanini and KDSA, annual reports).

Two of the more extensive upper aquifer water level maps are presented herein. Figure 2 is for Spring 1986 and is considered representative of wet conditions. Figure 3 is for February 2013 and is considered representative of dry conditions. Both maps show similar groundwater flow directions in most of the sub-basin, except for the Orestimba Creek area west of Newman. In that area, groundwater flows to the west during drought conditions, and to the east during wet periods. There was groundwater outflow to the northeast, or towards the San Joaquin River, in much of the sub-basin during both wet and dry periods. A major difference between the two maps is the water-level slopes to the northeast, which are steeper during drought periods, indicative of more groundwater outflow. Calculations based on aquifer transmissivity indicate the net groundwater outflow in the upper aquifer has been about three times greater during drought periods than during normal periods (KDSA 1997).

Lower Aquifer

Two representative water-level maps are provided for the lower aquifer. Figure 4 is for Fall 1981 and is representative of normal conditions. Figure 5 is for Spring 1997 and is representative of drought conditions. Both maps indicate a groundwater divide in the area between Mendota and a point near the San Joaquin River in the Turner Island area (northeast of Los

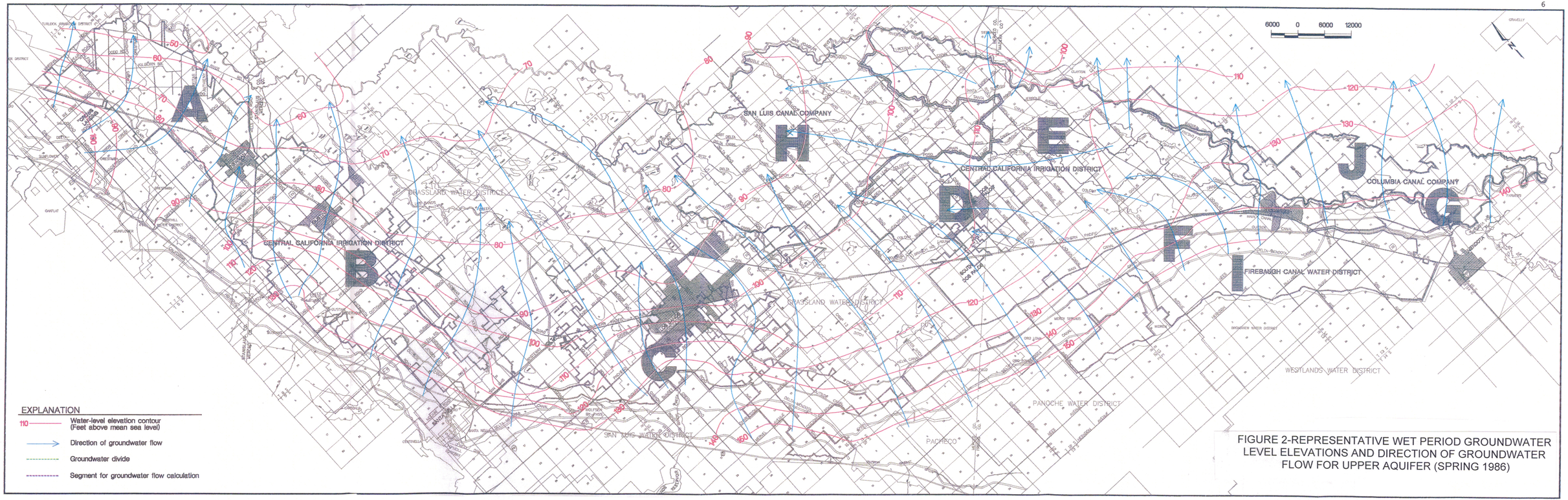


FIGURE 2-REPRESENTATIVE WET PERIOD GROUNDWATER LEVEL ELEVATIONS AND DIRECTION OF GROUNDWATER FLOW FOR UPPER AQUIFER (SPRING 1986)

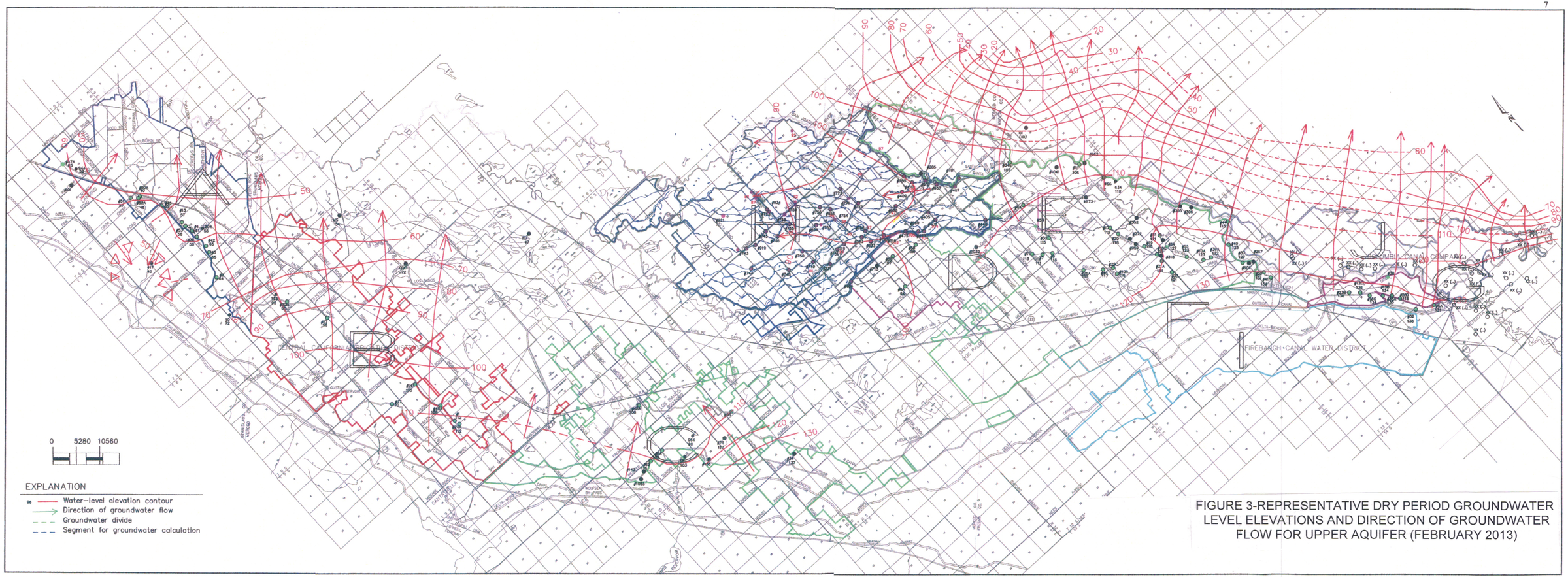


FIGURE 3-REPRESENTATIVE DRY PERIOD GROUNDWATER LEVEL ELEVATIONS AND DIRECTION OF GROUNDWATER FLOW FOR UPPER AQUIFER (FEBRUARY 2013)

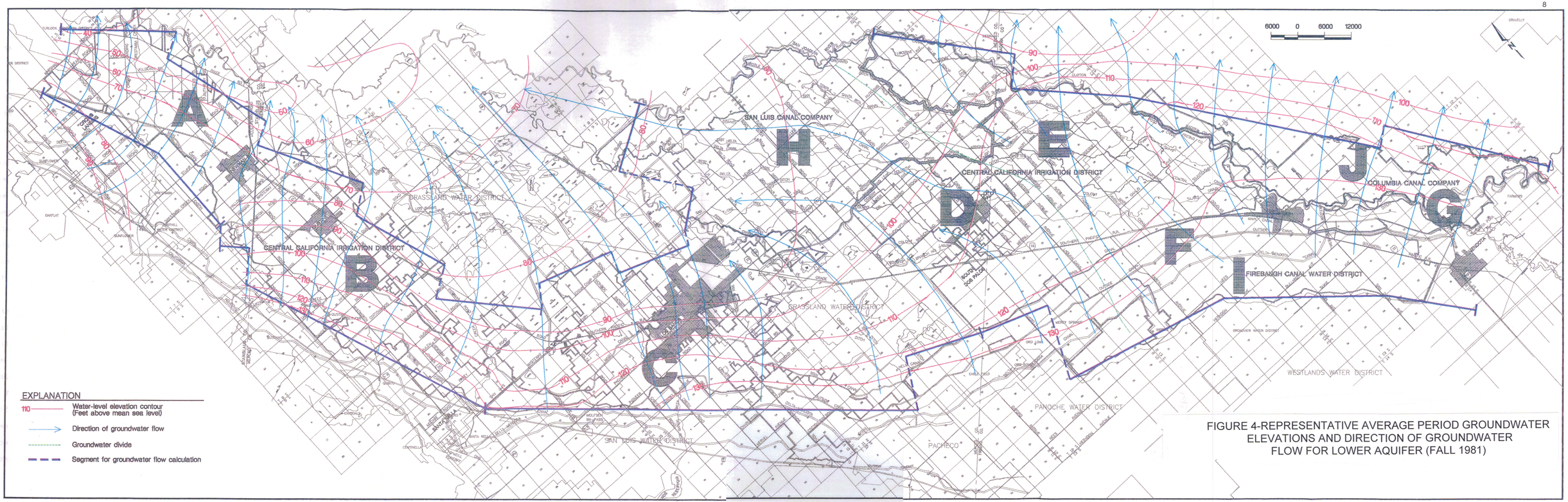


FIGURE 4-REPRESENTATIVE AVERAGE PERIOD GROUNDWATER ELEVATIONS AND DIRECTION OF GROUNDWATER FLOW FOR LOWER AQUIFER (FALL 1981)

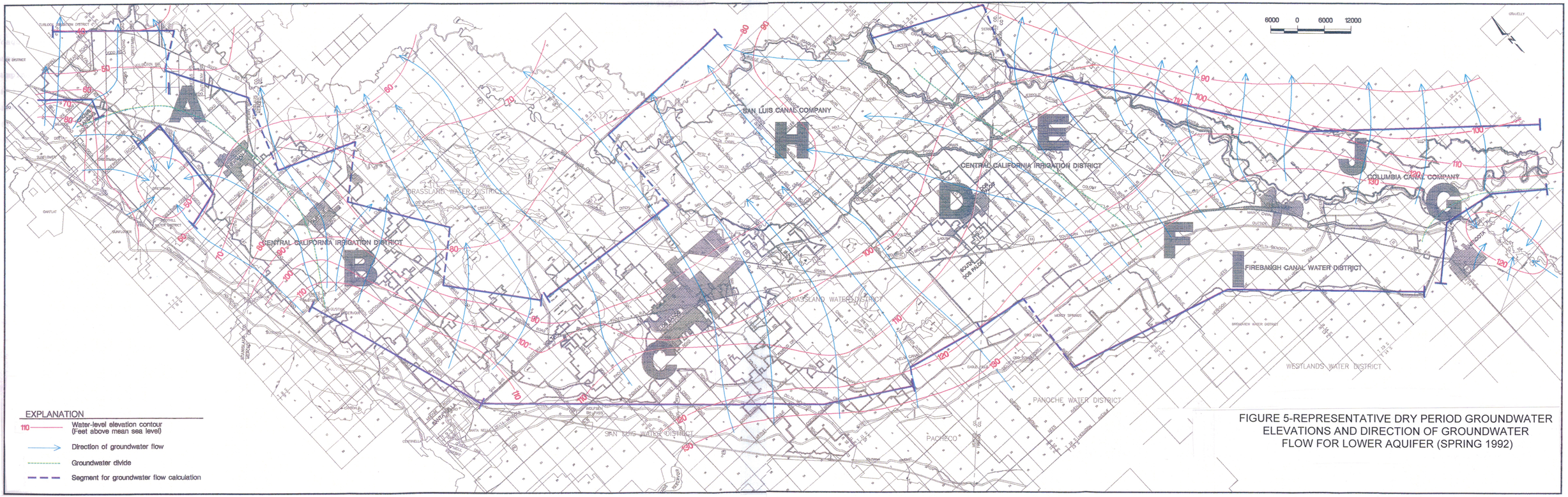


FIGURE 5-REPRESENTATIVE DRY PERIOD GROUNDWATER ELEVATIONS AND DIRECTION OF GROUNDWATER FLOW FOR LOWER AQUIFER (SPRING 1992)

Banos). Groundwater southwest of this divide generally flows to the southwest toward the Panoche and Westlands Water Districts. Groundwater northeast of this divide flows to the northeast into Madera and Merced Counties. The groundwater flow directions in the lower aquifer were essentially the same for both maps, but there were significantly greater water-level slopes during the drought. This trend is thus similar to that for the upper aquifer. The net groundwater outflow in the lower aquifer for the drought conditions has been about two and a half times greater than for the normal conditions (KDSA, 1997).

In summary, there has been net outflow of groundwater from the SJREC service area in both aquifers. Considering projected outflows in the rest of the sub-basin, this indicates that there is no overdraft beneath this sub-basin. Despite the fact that there has been more pumping from wells in the SJREC service area during drought periods, the net groundwater outflow has been about two and a half to three times greater during drought periods. This has been due to greater pumping of groundwater from both aquifers in adjoining areas during drought periods, when surface water supplies have been curtailed. An important point is that pumping in adjoining parts of the sub-basin has largely controlled the groundwater outflow from the sub-basin.

WATER-LEVEL HYDROGRAPHS

Water-level hydrographs for specific wells are the best indication of water-level changes in an area. Water-level hydrographs were provided for most of the SJREC service area by KDSA in two 1997 reports. These hydrographs were identified by well, whether they exclusively tapped the upper aquifer or the lower aquifer, or both aquifers (composite wells). Experience in this area has indicated that water levels in composite wells are more representative of the lower aquifer that the upper aquifer. Water levels evaluated were particularly selected to not represent shallow groundwater (within about 10 to 20 feet of the land surface) which is present in part of the sub-basin, but is not tapped by supply wells. In order to evaluate long-term water-level changes, a period of average hydrologic conditions is normally used. Based on surface water supplies, the period from 1962-89 was considered such a period. The hydrograph evaluations were divided into CCID and nearby management subareas that had been previously delineated and are shown on the previously presented water-level maps. The following section covers most of the management sub-areas, except for H & J, which are discussed later.

1962-1989

Sub-Area A

This subarea comprises the Crows Landing-Newman area. Hydrographs for 40 wells indicated either no long-term change in water level or rising water levels. No hydrograph indicated a long-term water-level decline.

Sub-Area B

This subarea comprises the Gustine vicinity and lands farther south. Hydrographs for 36 wells indicated no long-term water-level changes or rising water levels. Hydrographs for only two wells indicated long-term declines. These declines were more than balanced by the 11 wells that had long-term water-level rises.

Sub-Area C

This sub-area includes the Volta-Los Banos area and lands to the south. Water-level hydrographs for 26 wells indicated either no long-term change or rising water levels. Only one well had a declining water level and this was indicated to be atypical.

Sub-Areas D & E

These subareas include the Dos Palos area and land extending easterly to near the San Joaquin River. Hydrographs for 18 wells indicated either no long-term change or rising water levels. Only one well had a long-term declines, and this was indicated to be atypical of these subareas.

Sub-Areas F & I

These subareas comprise the Firebaugh CWD and the CCID Drainage Area Camp 13. Both of these subareas have subsurface drainage problems and tile drains are extensive. Water-level hydrographs for all six wells evaluated indicated rising water levels during the base period.

Sub-Area G

This subarea includes the Headgate area of the CCID, and northwest of the terminus of the DMC, north and northeast of Mendota. Water-level hydrographs for all of the wells in this subarea showed either no long-term water-level changes or water-level rises during the base period.

KDSA (2008) provided updated water-level hydrographs through 2006, and a base period from 1982 to 2005 was used for the evaluation. Results were similar to those for the previous base period.

1963-2013

KDSA (2014) provided updated hydrographs through early 2013. Measurements for some wells were discontinued, and replacement hydrographs were prepared where necessary. The period evaluated was 1962-2013. Although this base period is somewhat biased because of the dry years near the end of it, the period was include to provide updated information. All of the SJREC manage-

ment sub-areas were evaluated. Representative updated hydrographs are provided in this section.

Sub-Area A

Water-level hydrographs for all 40 wells indicated either long-term stable water levels or rising levels. Figure 6 is a representative updated hydrograph for Sub-Area A.

Sub-Area B

Hydrographs for 26 wells indicated long-term either stable water levels or water-level rises. Hydrographs for two wells had long-term declines, and both of these well tapped strata below the Corcoran Clay. Figure 7 is a representative updated hydrograph for Sub-Area B.

Sub-Area C

Hydrographs for all 24 wells indicated either long-term stable water levels or rising water levels. Figure 8 is a representative updated hydrograph for Subarea C.

Sub-Areas D & E

Hydrographs for 28 wells indicated an overall trend of constant water levels in both aquifers. Water-levels rises that were apparent in earlier evaluations were no longer appear. Figure 9 is a representative updated hydrograph for Subareas D & E.

Sub-Area F & I

The updated six hydrographs indicate that three have been

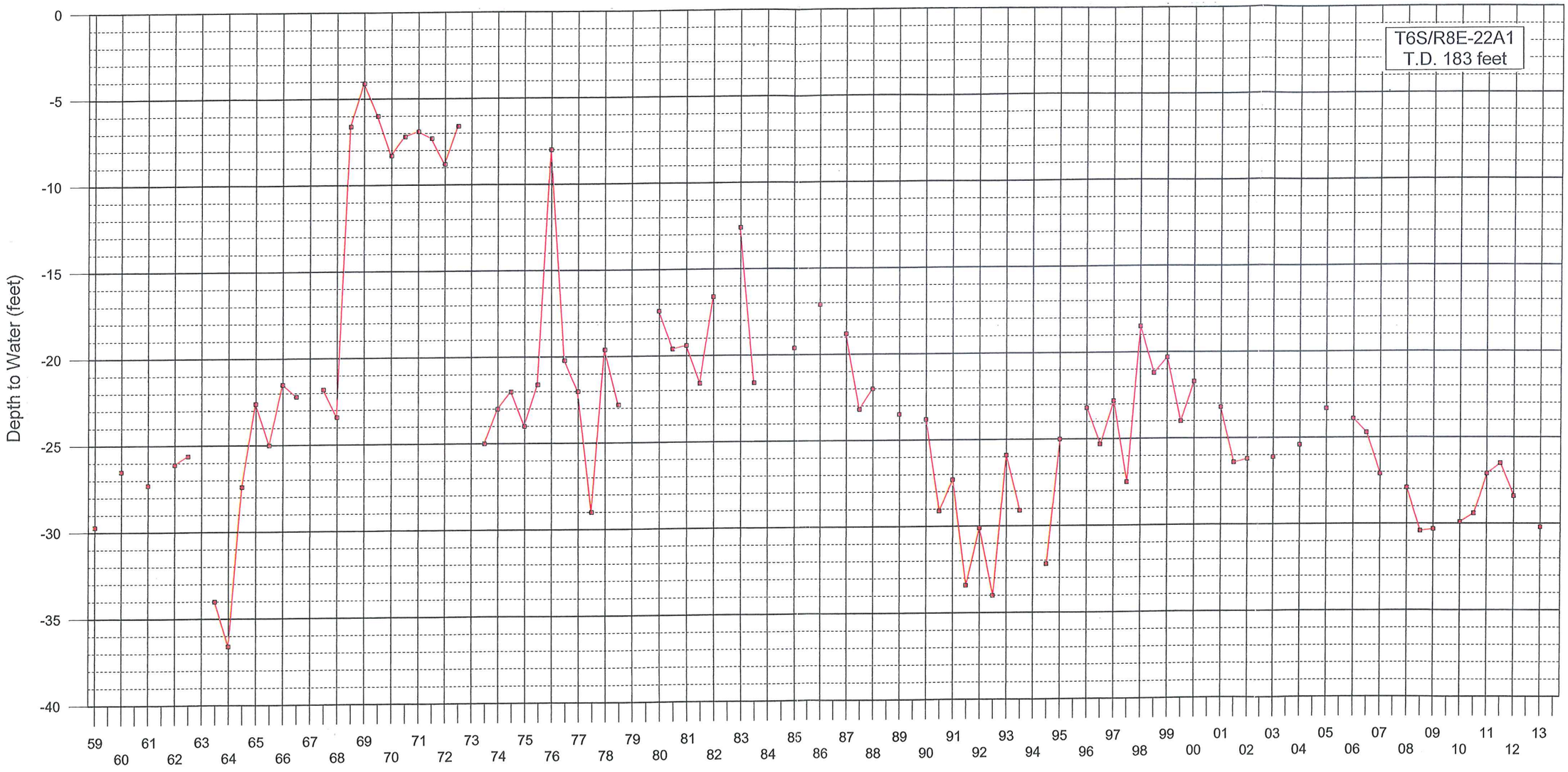


FIGURE 6-REPRESENTATIVE WATER-LEVEL HYDROGRAPH FOR SJREC SUB-AREA A

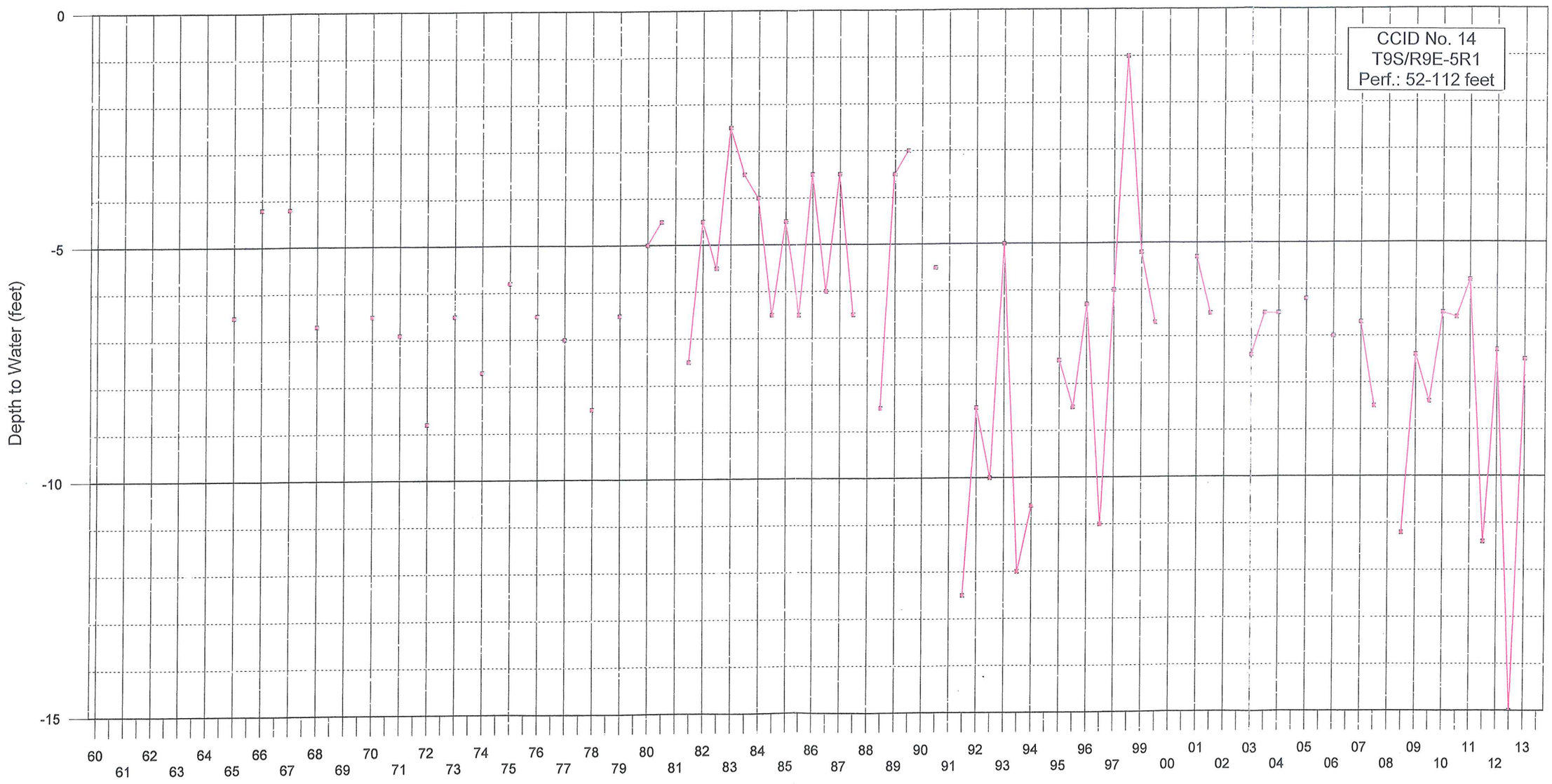


FIGURE 7-REPRESENTATIVE WATER-LEVEL HYDROGRAPH FOR SJREC SUB-AREA B

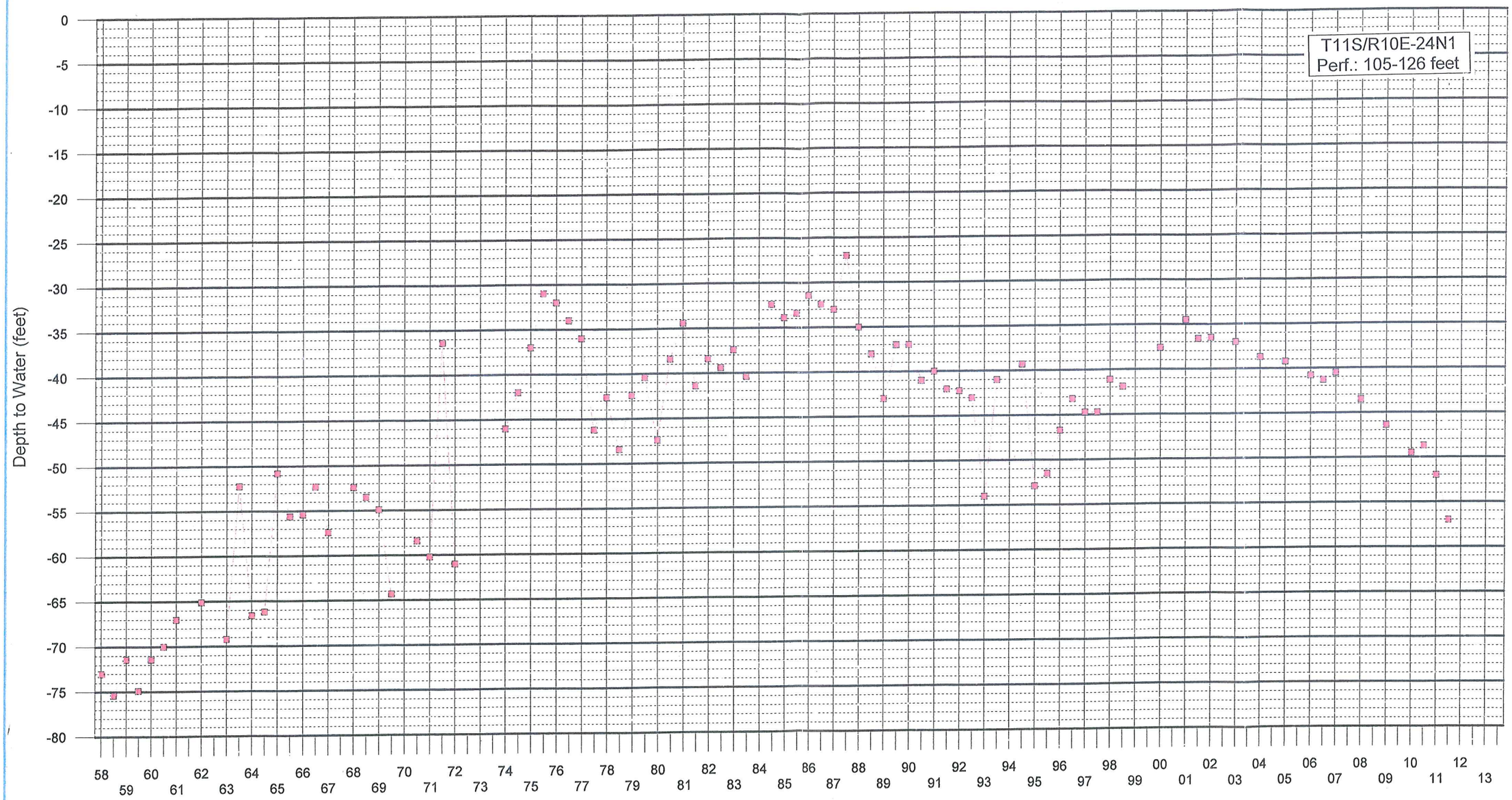


FIGURE 8-REPRESENTATIVE WATER-LEVEL HYDROGRAPH FOR SJREC SUB-AREA C

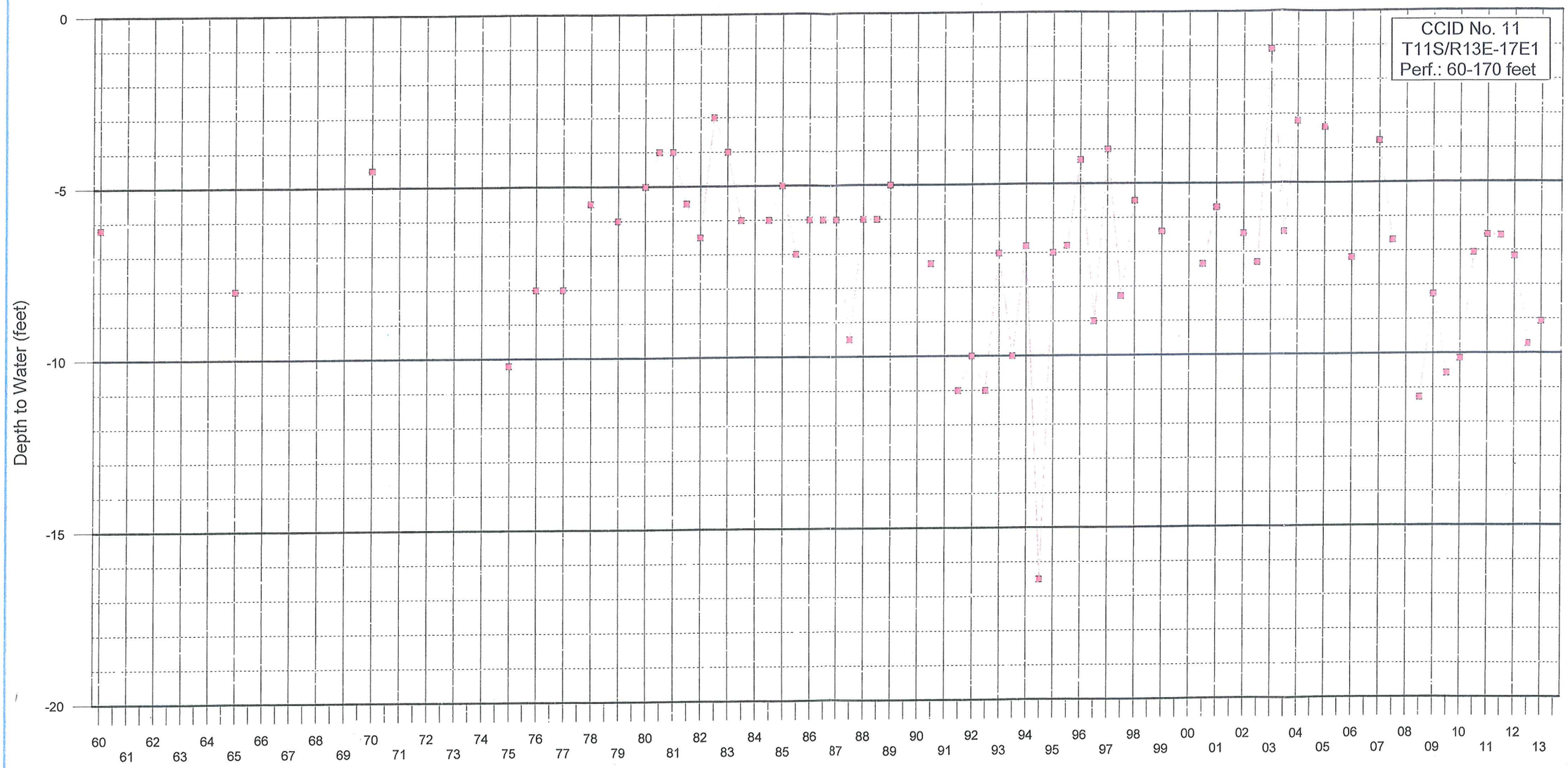


FIGURE 9-REPRESENTATIVE WATER-LEVEL HYDROGRAPH FOR SJREC SUB-AREAS D & E

rising over stable water levels on the long-term in these sub-
rising over stable water levels on the long-term in these sub-
areas. Figure 10 is a representative updated hydrograph for subareas F & I.

Sub-Area G

The updated 10 hydrographs indicated long-term stability of water levels through early 2013. Water-level rises were not apparently after 1989. Figure 11 is a representative updated hydrograph for this sub-area.

Sub-Area H

Updated hydrographs for 17 wells indicated relatively stable over the long term thorough 2013. Figure 12 is a representative updated hydrograph for this sub-area.

Sub-Area J

This sub-area comprises the Columbia Canal Co. service area. Water-level trends in the subarea were evaluated by KDSA (2208). Water-level hydrographs for 1962-2005 were provided for 29 wells. Water levels in a number of these wells declined over the long term. Water levels didn't fully recover after the 1987-94 drought. Updated hydrographs (through early 2013) indicated that many of these wells had slight water levels declines (averaging about 0.5 foot per year) after 1989. This is indicated to be primarily due to increased pumping in areas with no surface water supplies, both north and east of the Columbia Canal

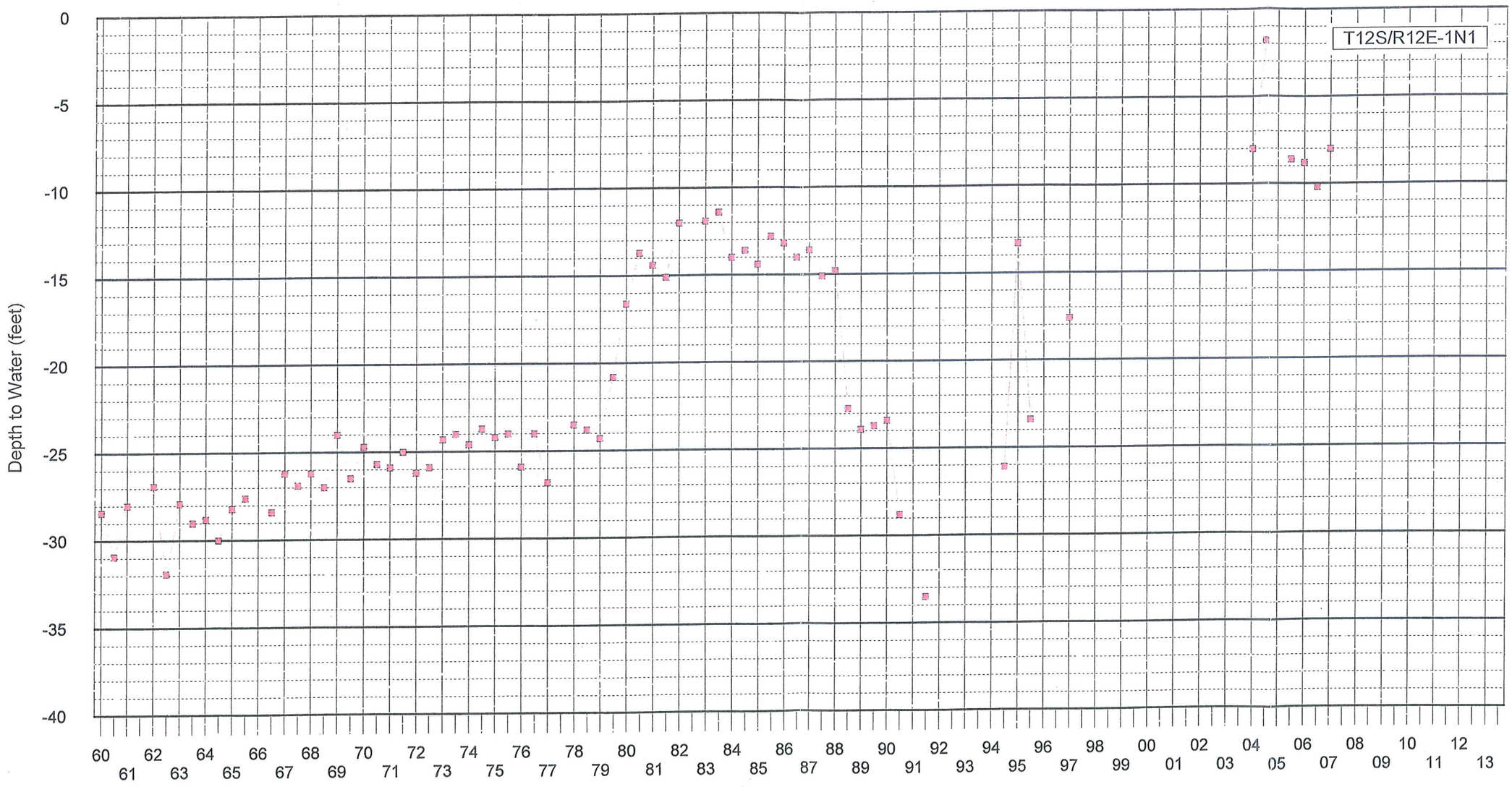


FIGURE 10-REPRESENTATIVE WATER-LEVEL HYDROGRAPH FOR SJREC SUB-AREAS F & I

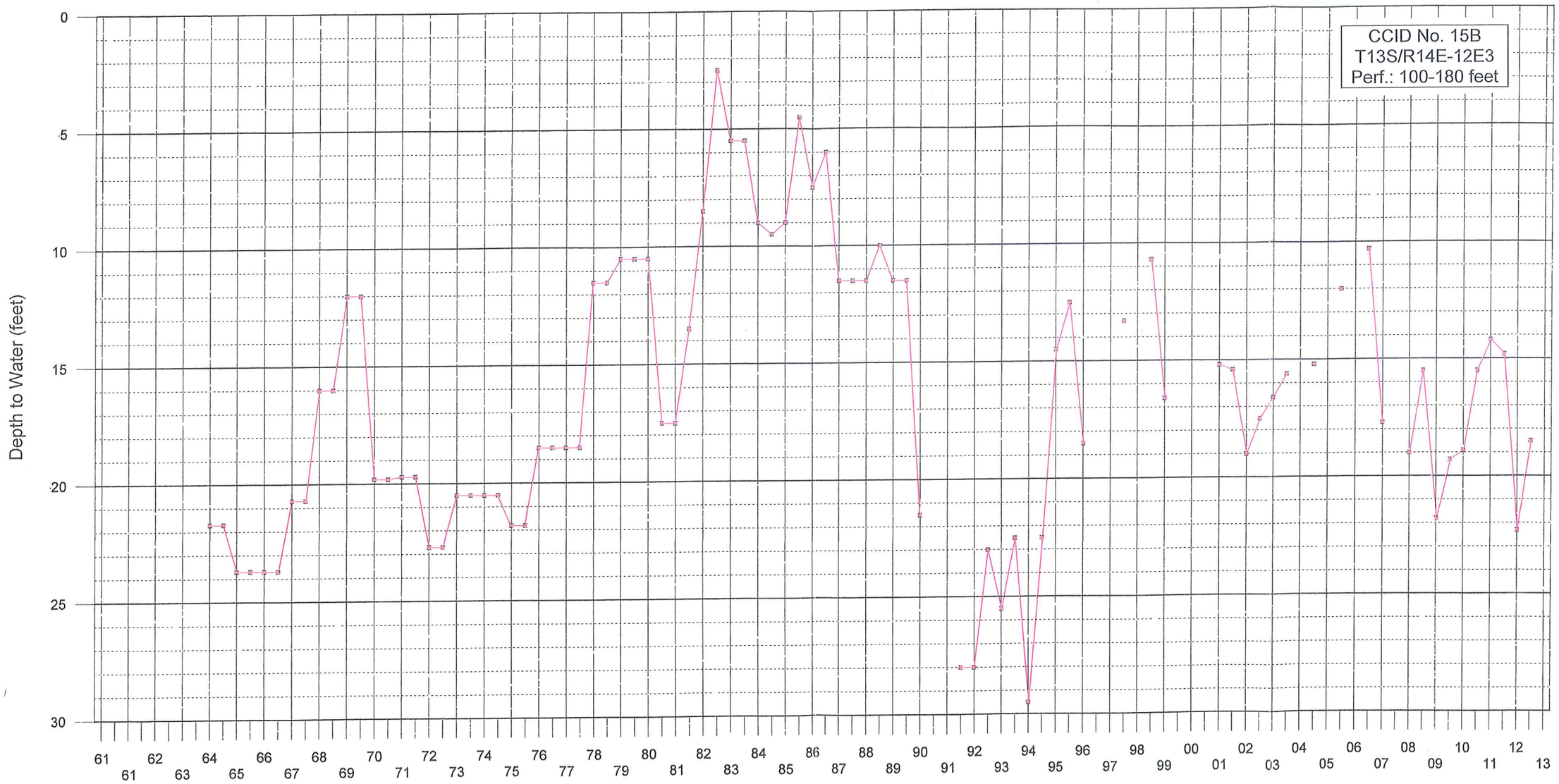


FIGURE 11-REPRESENTATIVE WATER-LEVEL HYDROGRAPH FOR SJREC SUB-AREA G

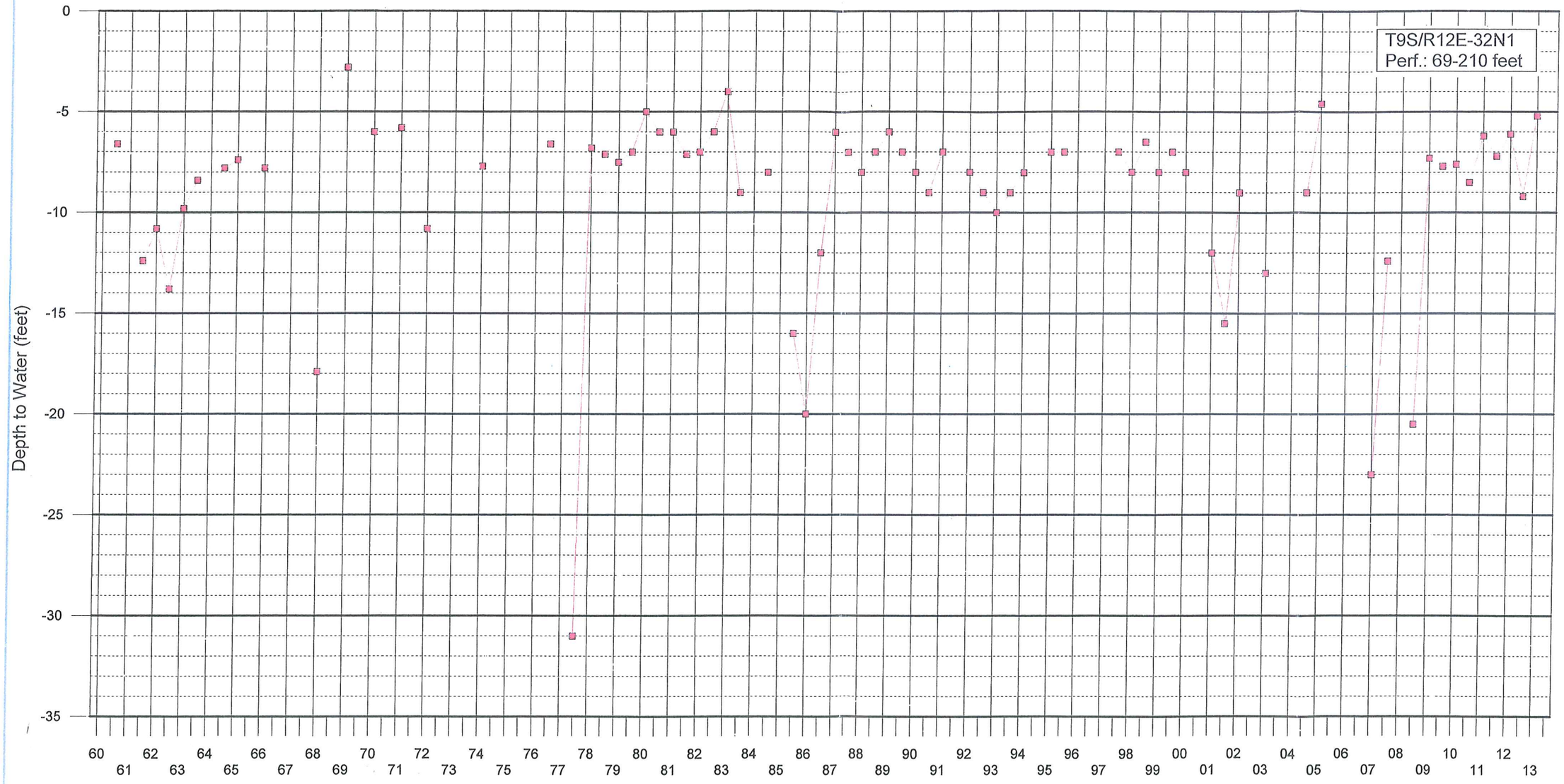


FIGURE 12-REPRESENTATIVE WATER-LEVEL HYDROGRAPH FOR SJREC SUB-AREA H

Co. service area. This is consistent with the fact that the amount of surface water delivered to this service area has exceeded the crop consumptive use. In addition, pumping of wells by the Mendota Pool Group in this area has caused water-level declines. Thus pumpage in the CCC service area was not been responsible for the slight water-level declines. The small water-level declines in Sub-area J were counter-balanced by rising water levels in other parts of the sub-basin.

GROUNDWATER OVERDRAFT

Groundwater overdraft is indicated by water-level declines in unconfined aquifers over normal hydrologic base periods. Changes in storage in confined aquifers are almost insignificant by comparison. In most parts of the San Joaquin Valley, water levels rise during wet periods when pumping is less, and fall during dry periods when pumping is greater. Thus one must evaluate water-level trends over a period that includes both wet years and dry years. In addition, the evaluated period should not start with a wet period and end with a dry period, or start during a dry period and end with a wet period. The previously discussed water-level trends include two hydrologic base periods. These are 1962 to 1989 and 1982 to 2005. Water-level trends updated through early 2013 were also evaluated to provide updated data.

However, the period 1962-2013 is not considered a representative hydrologic base period, because of the predominantly dry years after 2005.

The only part of the Delta-Mendota sub-basin that appears to be in groundwater overdraft is in the Columbia Canal Co, service area. Water levels fell an average of 0.5 foot per year in this area after 1989. The estimated average overdraft in the 16,561-acre area, based on an average specific yield of 0.12, has been about 1,000 acre-feet per year. This small amount of overdraft has been counter-balanced by water-level rises in other parts of the sub-basin. In addition, most of the overdraft in the Columbia Canal Co. is indicated to be due pumping in adjacent areas to the north and east of the Columbia Canal Co. service area, where no surface water supplies are available. The net groundwater flow is indicated to be out from this area, similar to that along the rest of the east side of the SJREC service area.

LAND SUBSIDENCE

Land subsidence in parts of the San Joaquin Valley has been evaluated for many decades. The most important records are from: 1) compaction recorders, and 2) periodic land surface elevation surveys. The DWR (Dane Mathes, June 27, 2015) stated that "DWR is preparing to add the Delta-Mendota Sub-basin (to the critical status) due to the known land subsidence east of

Los Banos". Also, DWR stated that they looked at available information for a non-drought hydrologic base period of 1989-2009. A review of water-level records for the sub-basin indicates that this is a not suitable base period to evaluate overdraft, because it starts following a very wet period and ends in a relatively long dry period.

Compaction Recorders

There are three compaction recorders in the sub-basin that have been monitored for a number of years. First is the Ora Loma or Russell Avenue recorder. Records for this station were described in U.S. Geological Survey Professional Paper 437-G. Updated records are available from the SLDMWA. These records indicate that almost all of the irreversible subsidence has been due to pumping groundwater from the lower aquifer (below the Corcoran Clay). There are two other compaction recorders near Menodota. Records for the Yearout recorder (T13S/R15E-31D) were described in Professional Paper 437-G. This recorder was installed in 1957, and the CCID subsequently took over maintenance of this recorder. The second recorder (Fordel) was installed by the Mendota Pool Group in 1999 at a site near the Mendota Airport. Both the Yearout and Fordel recorders measure compaction above the Corcoran Clay. Results of monitoring of these are presented in annual reports for the MPG program by Luhdroff and

Scalmanini and KDSA. Results from these two recorders have indicated essentially no irreversible land subsidence due to pumping from above the Corcoran Clay.

Recent Land Surveys

The U.S. Geological Survey has been conducting periodic surveys of the land surface in parts of the San Joaquin Valley in recent years. Figure 13 shows land subsidence between December 2011 and December 2014. Of particular importance is the subsidence in the area east of Los Banos (the Red Top-El Nido area). Land subsidence ranged from 0.15 to 0.75 foot in this area during the three-year period. The greatest subsidence (greater than 0.6 foot) was in the area south of Red Top in Madera County. A detailed hydrogeologic evaluation of the Red Top-Sack Dam area was completed by KDSA (2013). Results of the evaluation are presented in the following section.

RED TOP-EL NIDO AREA

KDSA (2013) presented a number of subsurface geologic cross sections and a map showing the depth to the top of the Corcoran Clay in the Red Top-El Nido area. The top of the Corcoran Clay ranges from less than 160 feet deep near El Nido to more than 300 feet to the south near Avenue 10. Little water production

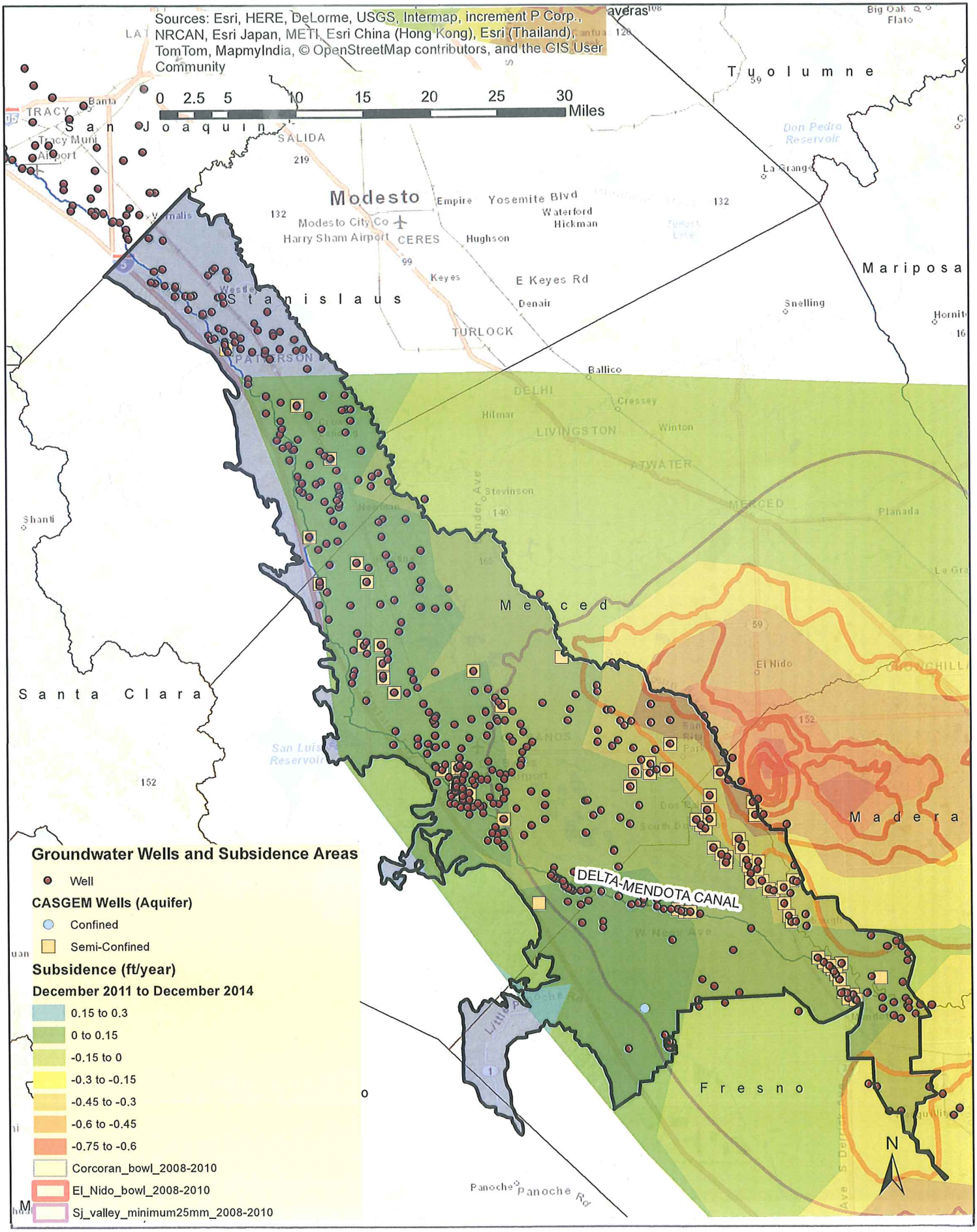
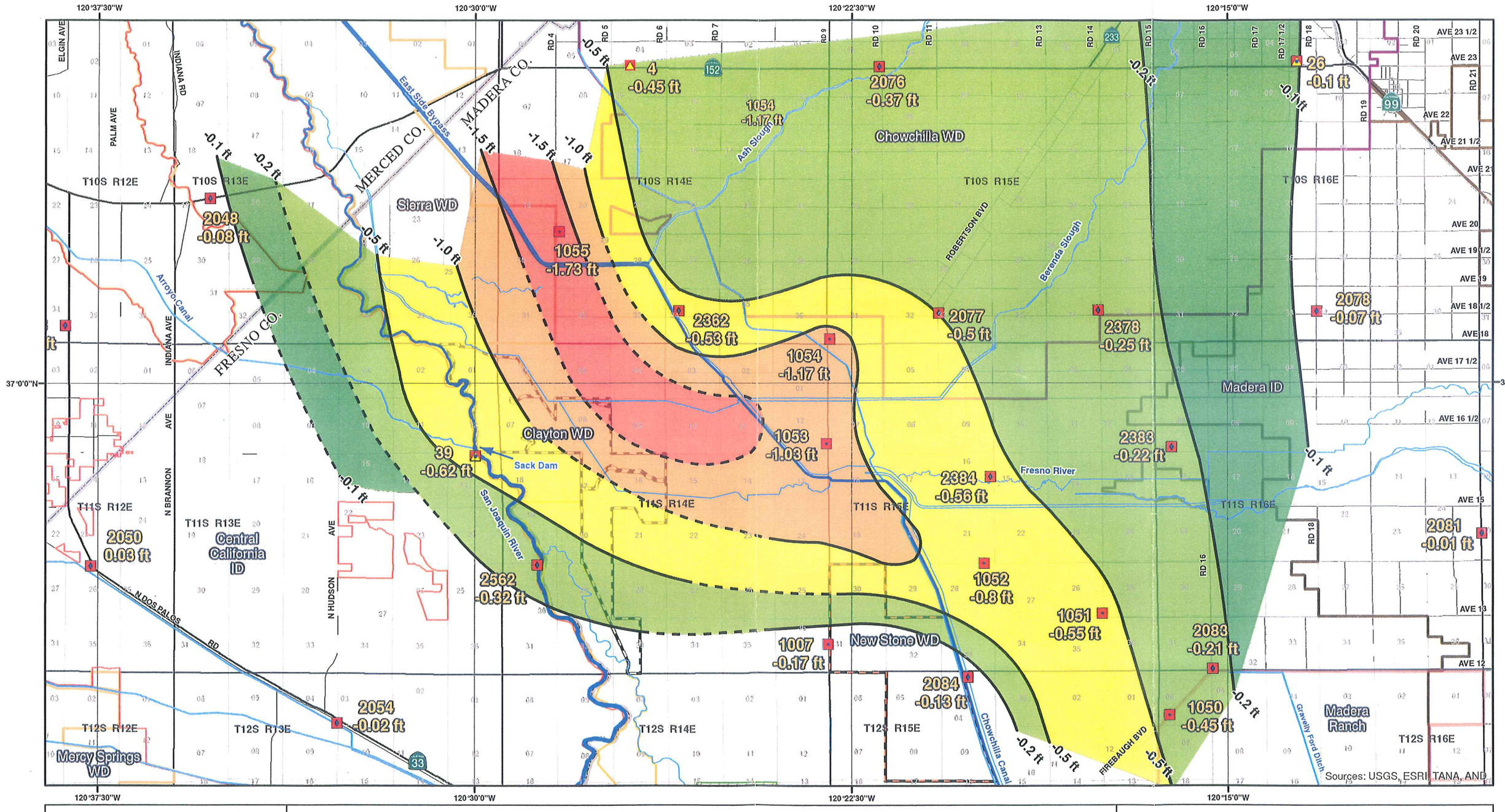


FIGURE 13-LAND SUBSIDENCE (DECEMBER 2011-DECEMBER 2014)

from the upper aquifer is now possible in the area north of Avenue 22.

Water supply wells west of the San Joaquin River and in the sub-basin are indicated to tap only strata in the upper aquifer. These are CCID wells or private land owner wells in the CCID. Prior to about 2006, many water supply wells east of the river (in Madera County) tapped only the upper aquifer. Since then, many dozens of new wells have been drilled in the area east of the river. Most of these wells tap the lower aquifer.

KDSA (2013) prepared water-level elevation maps for both the upper and lower aquifers for both January-February 2010 and January-February 2013. Maps for both aquifers indicated that groundwater flows from west of the river (in the Delta Mendota Sub-basin) to east of the river (in the Madera or Merced Sub-basins). A map of land subsidence was presented for 2008-10 and is reproduced herein as Figure 14. The shape of the contours in the area west of the San Joaquin River clearly indicates that pumping in Madera County (east of the river) caused this land subsidence. Thus there is no evidence of groundwater overdraft in the part of the sub-basin west of the San Joaquin River, and no evidence that pumping in the sub-basin has caused the recent accelerated land subsidence in the Red Top area.



0 4,500 9,000 Feet

Legend

- County
- Township/Range
- Major Canal / Slough / River

Elevation Change (Feet)

- -0.1 to -0.2
- -0.2 to -0.5
- -0.5 to -1.0
- -1.0 to -1.5
- -1.5

*Points Surveyed 06-29-2010
Labeled By Change In Elevation (ft) Since 2008

- AT Point
- Primary Control Pt
- Primary/AT Point
- Secondary Control Pt

From Provost and Pritchard

FIGURE 14-LAND SUBSIDENCE IN THE RED TOP-SACK DAM AREAS FOR 2008-10

SUMMARY AND CONLCUSIONS

Three major issues were evaluated for groundwater in the Delta-Mendota Sub-basin. These were 1) groundwater flows, 2) water-level changes, and 3) locations of wells tapping the lower aquifer in the Red Top-El Nido area. Groundwater flows in both the upper and lower aquifers have greatly exceeded groundwater inflows (which have primarily been from the west). This net outflow of groundwater is indicative of a hydrologically balanced area, not a critically overdrafted area. Second, a thorough examination of long-term water-level trends over several hydrologic base periods indicates no net water-level decline, Generally water-level declines in the Columbia Canal Co. service area have been caused by pumping in adjoining areas to the north and east. The small declines have been more then counterbalanced by rising water levels in other areas, such as SJREC Management Sub-areas F & I. Lastly, although there has been some land subsidence in the sub-basin southwest of Red Top, this is indicated to be from pumping from the lower aquifer in the area east of the San Joaquin River (outside of the Delta-Mendota Sub-basin).

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