APPENDIX G

Update on Hydrologic Conditions in the Fresno Metropolitan Area by Kenneth D. Schmidt and Associates

UPDATE ON HYDROGEOLOGIC CONDITIONS IN THE FRESNO METROPOLITAN AREA

Draft Report-For Review Purposes Only

prepare for
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Davis, California

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UPDATE ON HYDROGEOLOGIC CONDITIONS IN THE FRESNO METROPOLITAN AREA

INTRODUCTION

The 1992 Fresno Metropolitan Water Resources Management Plan is being updated to include new data and to evaluate significant changes. Kenneth D. Schmidt and Associates (KDSA) provided a detailed hydrogeologic report in January 1992 for the previous plan (Appendix D of CH_2M-Hill (1992). This hydrogeologic update primarily focuses on the following issues:

1. Additional information on deeper subsurface geologic conditions, particularly in the Fresno North Growth Area, east Fresno, and southeast Fresno.
2. City-wide water-level maps are presented for the first time for shallow groundwater (above about 250 feet in depth) and deeper groundwater (below about 450 feet in depth), based on recent water-level measurements for numerous City nested monitor wells and other wells.
3. Numerous water-level hydrographs were updated and long-term (1965-2006) water-level trends were evaluated.
4. Substantial information on aquifer characteristics has been obtained since the last report and this is presented and discussed in terms of the relation to subsurface geologic conditions.

5. Amounts of pumpage and intentional recharge in the Fresno urban area were updated.
6. Updated nitrate, DBCP, and EDB concentration maps and trends in groundwater are discussed.
7. Pumpage of supply wells and treatment for DBCP removal has been practiced for some time in the urban area. The influence of this on DBCP concentrations in groundwater is discussed.
8. City wide trichloropropane (TCP) concentrations are mapped for the first time, and the distribution of this constituent is discussed.

SUBSURFACE GEOLOGIC CONDITIONS

During the past 15 years or so, the City of Fresno has constructed nested monitor wells at about 150 sites. Most of these are located on lots where public supply wells were later developed. From two to four different depth intervals are normally isolated and a separate casing installed in each isolated interval for monitoring. The shallowest perforated casings at each site are usually within the 140 to 230 foot depth range, and tap groundwater above a widespread confining bed that was discussed as part of the City nitrate evaluation (KDSA, 2004). Geologic logs and electric logs are available for all of these nested monitor wells. In addition, other test holes have been done by the direct rotary

method or reverse rotary method for electric logging, and geologic logs are available for most of these. Also, casing hammer test wells have been done at about 30 sites in the FMA, whereby excellent geologic logs are available. Production wells were drilled adjacent to most of these test wells, and electric logs are also avialable.

Figure 2 of Appendix D (KDSA, 1992) showed the locations of test holes and wells with electric logs and geologic logs in the FMA. At that time, most of the deeper drilling had been in the north part of the FMA and in southeast Fresno. KDSA (2004) provided the results of the hydrogeologic evaluation that was done for the City of Fresno on nitrate in groundwater. By this time, more cross sections had been developed by KDSA in the north part of the FMA and near the Cities of Fresno and Clovis Water Reclamation Plant (to the southwest). As part of the nitrate study, numerous new subsurface cross sections were done in the south part of the FMA, much of which is generally underlain by moderate to high nitrate concentrations in the shallow groundwater. Figure 1 of KDSA (2004) showed the locations of subsurface cross sections at that time. During the past several years, substantial deep exploration has been done in the area east of the Fresno Air Terminal and in southeast Fresno. Two more cross sections were developed by KDSA in this area as part of an evaluation of the 501 Zone for the

City in 2005. Figure 1 shows the locations of all of these subsurface geologic cross sections. Appendix A contains copies of these cross sections.

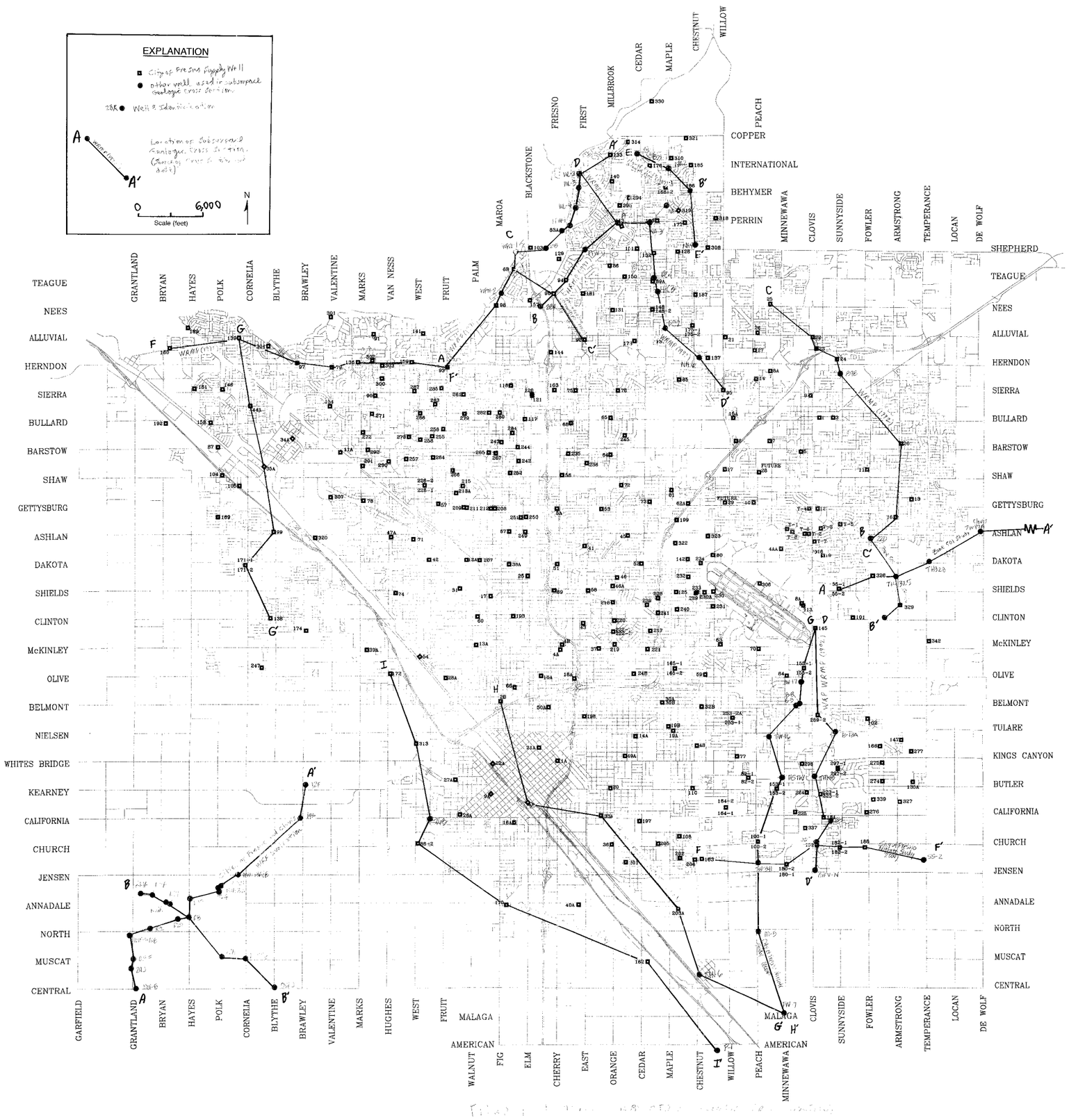
Interpretation

Essentially, these cross sections confirm several long developed concepts about trends in the texture of subsurface deposits in the FMA. In addition, several new concepts have been developed. In general highly permeable deposits are present beneath most of the area within the upper several hundred feet. The upper coarse-grained deposits in the Fresno area were termed the older alluvium by Page and LeBlanc (1969). However, in parts of the area, such as the Fresno North Growth area and parts of Clovis, a substantial thickness of these deposits has been dewatered, and is now above the water level. Coarse-grained stream channel deposits underlie much of northwest Fresno and the south part of the study area. The deposits were first mapped by John Carollo Engineers and Harsh-barger and Associates (1969). These are associated with deposits by the ancestral San Joaquin and Kings Rivers.

Drilling of numerous test holes and wells to depths ranging from about 600 to 1,200 feet during the past 10 to 15 years has better delineated the underlying deposits, which were termed the Tertiary-Quaternary continental deposits by Page and LeBlanc. These deposits are usually finer grained than the overlying depo-

FIGURE 1-LOCATIONS OF SUBSURFACE

GEOLOGIC CROSS SECTIONS


EXPLANATION
City of Fresno Supply Well
other well used in subsurface geologic cross section
Well & Identification
Location of Subsurface Geologic Cross Section (Generally cross section lines)
0
6,000
Scale (feet)
N
A
A'
B
B'
C
C'
D
D'
E
E'
F
F'
G
G'
H
H'
I
I'
SHEPHERD
TEAGUE
NEES
ALLUVIAL
HERNDON
SIERRA
BULLARD
BARSTOW
SHAW
GETTYSBURG
ASHLAN
DAKOTA
SHIELDS
CLINTON
McKINLEY
OLIVE
BELMONT
NIELSEN
WHITES BRIDGE
KEARNEY
CALIFORNIA
CHURCH
JENSEN
ANNADALE
NORTH
MUSCAT
CENTRAL
TULARE
KINGS CANYON
BUTLER
GARFIELD
GRANTLAND
BRYAN
HAYES
POLK
CORNELIA
BLYTHE
BRAWLEY
VALENTINE
MARKS
HUGHES
VAN NESS
WEST
FRUIT
PALM
MAROA
BLACKSTONE
FRESNO
FIRST
MILLBROOK
CEDAR
MAPLE
CHESTNUT
WILLOW
PEACH
COPPER
INTERNATIONAL
BEHYMER
PERRIN
MINNEWAWA
CLOVIS
SUNNYSIDE
FOWLER
ARMSTRONG
TEMPERANCE
LOCAN
DE WOLF
MALAGA
AMERICAN
WALNUT
FIG
ELM
CHERRY
EAST
ORANGE
CEDAR
MAPLE
CHESTNUT
WILLOW
PEACH
MINNEWAWA
CLOVIS
SUNNYSIDE
FOWLER
ARMSTRONG
TEMPERANCE
LOCAN
DE WOLF
WARM WATER
FUTURE

sits and generally lack evidence of stream channel deposits. Substantial water-production has been found at depth in these continental deposits beneath parts of northwest and central Fresno and to the southwest, including at the Cities of Fresno and Clovis WRP. The least productive deeper deposits have been found in the area east of the Fresno Air Terminal, beneath part of the rest of the Zone 501 area (in southeast Fresno) and beneath part of the Fresno North Growth Area. In addition, shallow bedrock (metamorphic rock) is present beneath the northeast part of the City of Clovis. The shallow bedrock and fine-grained nature of the continental deposits pose a constraint to the drilling of deep public supply wells in these areas.

Another important condition that has been shown by the deep drilling is the presence of blue-green or reduced deposits beneath the Fresno North Growth Area, part of the City of Clovis (i.e., near Tarpey Village), and in East Fresno. The nature of these deposits in the Fresno North Growth area was discussed by KDSA (1987). The top of the reduced deposits are shallowest near Woodward Lakes (less than 300 feet deep). The reduced deposits can be associated with high concentrations of iron, manganese, arsenic, and hydrogen sulfide. Methane gas has also been found at some sites. Beneath the remainder of the FMA, these deposits are generally below a depth of 700 or 800 feet, and aren't generally signi-

ficant in terms of development of public supply wells.

In the recently conducted Fresno nitrate study (KDSA, 2004), a laterally extensive fine-grained layer was indicated to be present beneath most of southeast and south Fresno, at an average depth of about 250 feet. This clay is particularly important, as it often separates high nitrate shallow groundwater from lower nitrate deep groundwater. This clay is also important in separating high DBCP shallow groundwater from lower DBCP groundwater in the deeper groundwater.

WATER LEVELS

Supply Wells

Historically, water levels in the FMA have been difficult to contour, because some public supply wells are always in service. Water-level maps for periods of heavy pumping (May-September) are particularly problematic. Another problem is the large differences in well depths and producing intervals for these supply wells. Despite the problems, hydrogeologists have prepared three maps, based on measurements in water supply wells:

1. For 1968, as part of the City of Fresno Water Resources study, by John Carollo Engineers and Harshbarger & Associates.
2. For 1978, as part of the 208 Water Management Plan study, by Ken Schmidt (1979).

3. For 1991, as part of the FMA Water Resources Management Plan study, Appendix D, by Kenneth D. Schmidt and Associates.

Although somewhat composite in nature, these maps proved to be highly useful in evaluating pumping depressions and sources of recharge (such as San Joaquin River seepage and intentional recharge at Leaky Acres). As of 1992, adequate data were not available to prepare City-wide water-level maps for different depth intervals.

Monitor Wells

For this evaluation, the City of Fresno measured water levels in most of the nested monitor wells during April 5-18, 2006. Exact elevations of the measurement points of these wells weren't available, but elevations of the adjacent public supply well pads were. These elevations were used to estimate monitor well elevations to the nearest foot. Besides the nested monitor wells in the City proper, additional measurements were obtained for monitor wells at the Cities of Fresno and Clovis WRP and at several other sites to fill in data gaps.

Shallow Groundwater

Figure 2 is a water-level elevation and direction of groundwater flow map, primarily for the depth interval between about 140

FIGURE 2-WATER-LEVEL ELEVATIONS AND DIRECTION OF FLOW FOR SHALLOW GROUNDWATER (SPRING 2006)

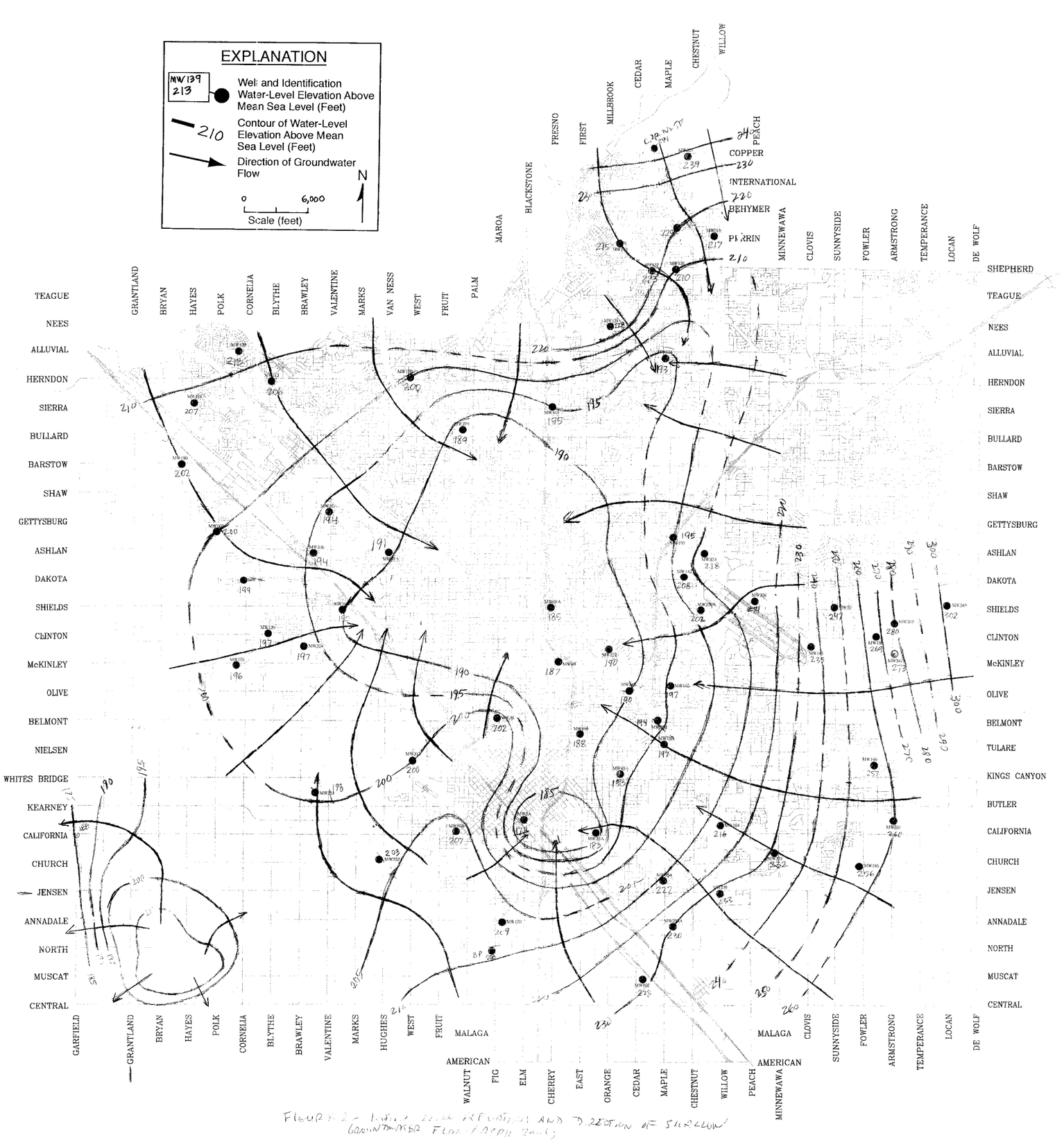


FIGURE 2.- INITIAL WATER-LEVEL ELEVATION AND DIRECTION OF SHALLOW GROUNDWATER FLOW, APRIL 2015

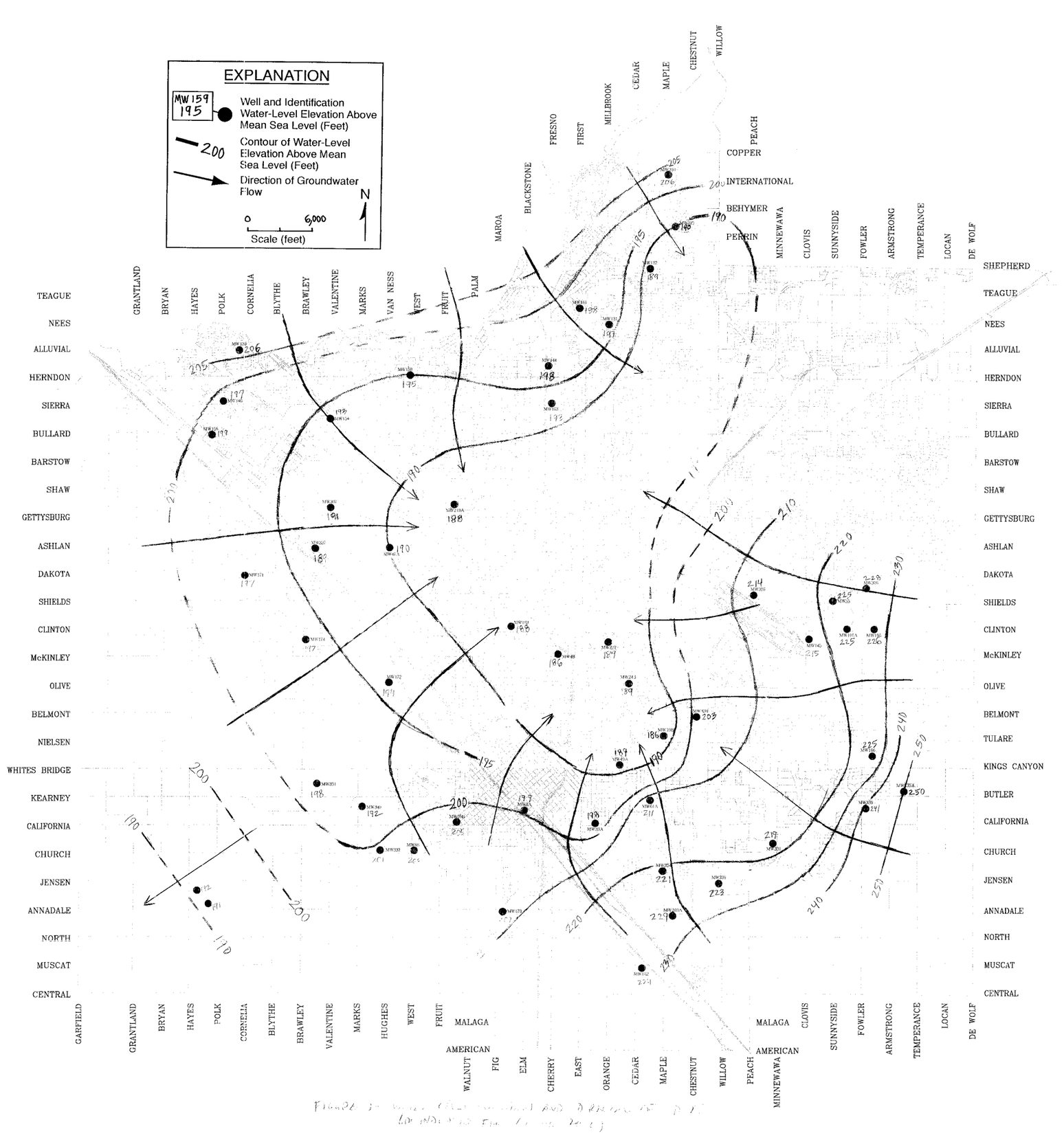
and 250 feet. Water-level elevations ranged from less than 190 feet above mean sea level to more than 300 feet. A large depression cone was indicated by the 195-foot contour. This depression extended from near Herndon Avenue on the north to near Jensen Avenue on the south, and from near Brawley Avenue on the west to Maple Avenue on the east. Beneath northwest Fresno, the direction of groundwater was to the southeast, away from the San Joaquin River. Some of the smallest water-level slopes, less than five feet per mile, were present in this area, associated with highly permeable stream-channel deposits. Beneath the Fresno North Growth Area, the direction of groundwater flow was generally to the south-southeast, also away from the San Joaquin River. Water-level elevations beneath the Fresno North Growth area ranged from about 195 feet near Herndon Avenue to about 240 feet near Copper Avenue. Beneath east Fresno, the direction of groundwater flow was to the west. Water-level elevations ranged from about 220 feet near Minnewawa Avenue to 300 feet near Locan Avenue. Water-level slopes were steeper in this area, averaging about 25 feet per mile, associated with the lower permeability of the shallow deposits in this area, compared to most of the rest of the FMA. The direction of shallow groundwater flow beneath southeast Fresno was to the west or northwest. A smaller cone of depression, where water-level elevations were less than 185 feet, was present beneath the

downtown Fresno area. Water-level slopes were also relatively steep on the west and southeast sides of this depression, probably indicative of lower permeability deposits.

Deep Groundwater

Figure 3 shows water-level elevations and the direction of groundwater flow for the deeper groundwater (generally in the depth interval from about 450 to 600 feet) in April 2006. A large cone of depression was indicated by the 190-foot contour. This depression extended much farther northeast, into the Fresno North Growth Area and the west part of the City of Clovis, than the one for the shallow groundwater. This trend is associated with the development of many new moderately deep wells since the late 1980's in the Fresno North Growth area and in the west part of the Herndon-Shephard Plan area in Clovis. The direction of flow of the deeper groundwater was very similar to that for the shallow groundwater. Water-level elevations ranged from about 190 to 205 feet beneath northwest Fresno. Beneath the Fresno North Growth Area, water-level elevations ranged from about 185 to 190 feet near Herman Avenue to about 220 feet near Copper Avenue. Beneath east Fresno, water-level elevations ranged from about 215 feet near Clovis Avenue to 230 feet near Armstrong Avenue.

FIGURE 3-WATER-LEVEL ELEVATIONS AND DIRECTION OF DEEP GROUNDWATER FLOW (APRIL 2006)


EXPLANATION
MW159
195
Well and Identification
Water-Level Elevation Above
Mean Sea Level (Feet)
200
Contour of Water-Level
Elevation Above Mean
Sea Level (Feet)
Direction of Groundwater
Flow
N
0
6,000
Scale (feet)
TEAGUE
NEES
ALLUVIAL
HERNDON
SIERRA
BULLARD
BARSTOW
SHAW
GETTYSBURG
ASHLAN
DAKOTA
SHIELDS
CLINTON
McKINLEY
OLIVE
BELMONT
NIELSEN
WHITES BRIDGE
KEARNEY
CALIFORNIA
CHURCH
JENSEN
ANNADALE
NORTH
MUSCAT
CENTRAL
SHEPHERD
TULARE
KINGS CANYON
BUTLER
GARFIELD
GRANTLAND
BRYAN
HAYES
POLK
CORNELIA
BLYTHE
BRAWLEY
VALENTINE
MARKS
HUGHES
VAN NESS
WEST
FRUIT
PALM
MAROA
BLACKSTONE
FRESNO
FIRST
MILLBROOK
CEDAR
MAPLE
CHESTNUT
WILLOW
PEACH
COPPER
INTERNATIONAL
BEHYMER
PERRIN
MINNEWAWA
CLOVIS
SUNNYSIDE
FOWLER
ARMSTRONG
TEMPERANCE
LOGAN
DE WOLF
MALAGA
AMERICAN
WALNUT
FIG
ELM
CHERRY
EAST
ORANGE

Time Trends

Water-level hydrographs were originally prepared from 1959-69 for about 50 City of Fresno wells (JCE & JWHA, 1969). Over the years, these hydrographs have been updated (where data are available) and additional hydrographs have been prepared for newer wells, particularly in the City growth areas. In Appendix D (KDSA, 1992), the FMA was divided into six areas, in order to evaluate long-term water-level trends, as follows:

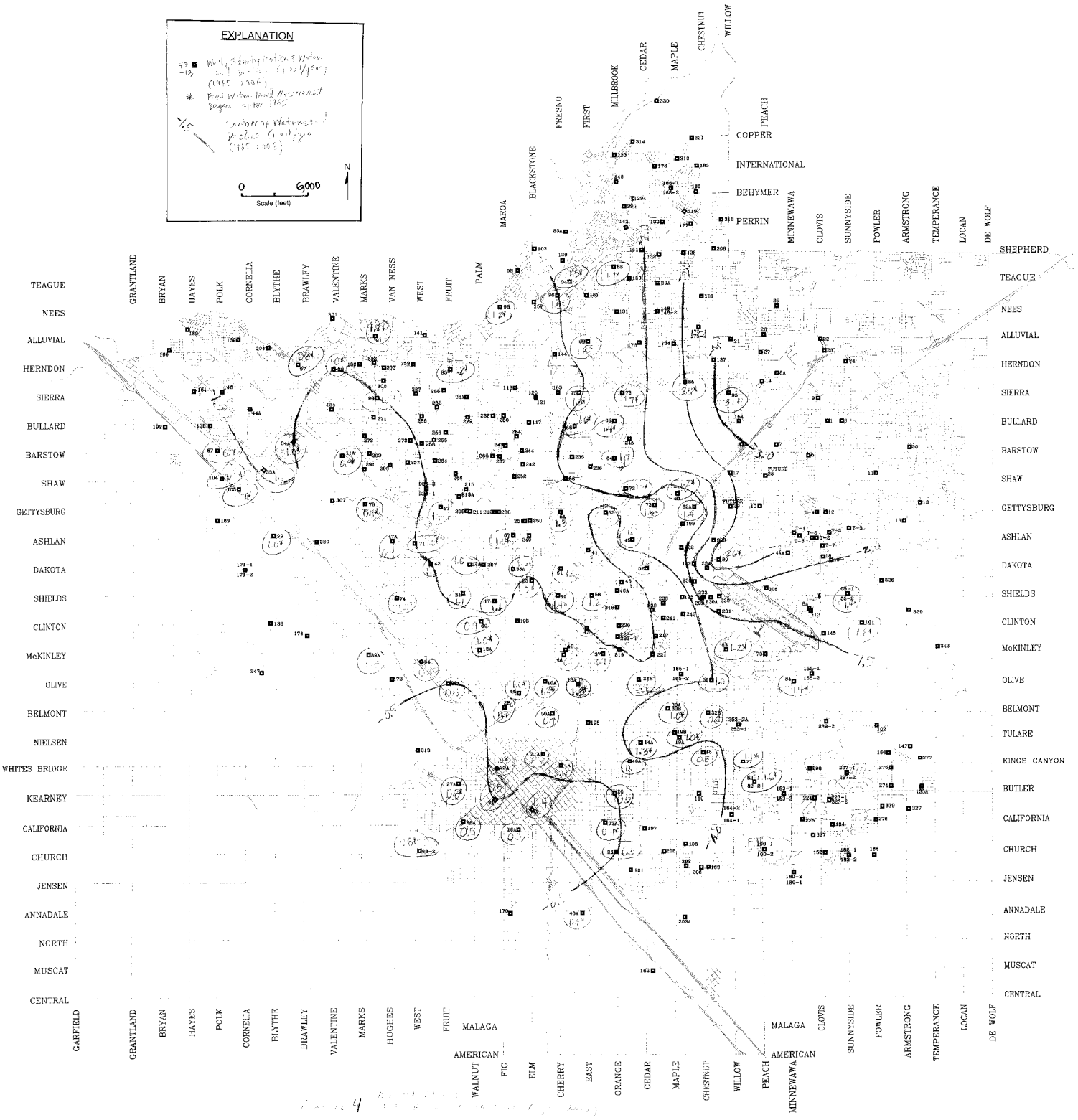
Area	Hydrographs Evaluated
Downtown Fresno	22
Leaky Acres and Downgradient	16
Southeast Fresno	10
Northwest Fresno	30
Fresno North Growth Area	14
East Clovis	3

The period from Spring 1965 to Spring 1990 was used to evaluate water-level trends at that time, because this represented close to average surface water deliveries in the Fresno Irrigation District.

As part of this evaluation, the previously developed water-level hydrographs were updated and evaluated. Figure 4 shows average rates of water-level decline in City of Fresno wells with records extending for at least three decades. For most of these wells, except in the growth areas, records are available since 1965. This year was associated with the commencement of Friant Kern Canal water deliveries to the Fresno Irrigation District. Contours of the average water-level decline during 1965-2006 are

FIGURE 4-AVERAGE RATES OF

WATER-LEVEL DECLINE (1965-2006)


EXPLANATION
0
6,000
Scale (feet)
N
TEAGUE
NEES
ALLUVIAL
HERNDON
SIERRA
BULLARD
BARSTOW
SHAW
GETTYSBURG
ASHLAN
DAKOTA
SHIELDS
CLINTON
McKINLEY
OLIVE
BELMONT
NIELSEN
WHITES BRIDGE
KEARNEY
CALIFORNIA
CHURCH
JENSEN
ANNADALE
NORTH
MUSCAT
CENTRAL
GARFIELD
GRANTLAND
BRYAN
HAYES
POLK
CORNELIA
BLYTHE
BRAWLEY
VALENTINE
MARKS
HUGHES
VAN NESS
WEST
FRUIT
PALM
MALAGA
AMERICAN
WALNUT
FIG
ELM
CHERRY
EAST
ORANGE
CEDAR
MAPLE
CHESTNUT
WILLOW
PEACH
MINNEWAWA
MAROA
BLACKSTONE
FRESNO
FIRST
MILLBROOK
COPPER
INTERNATIONAL
BEHYMER
PERRIN
CLOVIS
SUNNYSIDE
FOWLER
ARMSTRONG
TEMPERANCE
LOGAN
DE WOLF
SHEPHERD
TULARE
KINGS CANYON
BUTLER
FUTURE

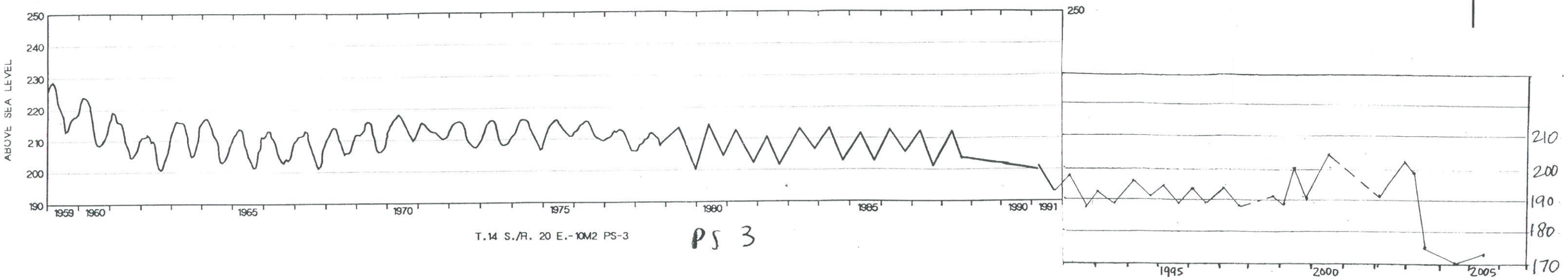
provided. The lowest declines, less than 0.5 foot per year, were generally in the southwest part of the downtown Fresno area. Wells with average water-level declines ranging from about 0.5 to 1.0 foot per year were primarily in the southwest part of the FMA, and in much of the area southwest of Leaky Acres. Wells with average water-level declines ranging from 1.0 to 1.5 feet per year were primarily in two areas. One was in northwest Fresno, and the second was in southeast Fresno, primarily south of the Fresno Air Terminal. Wells with average water-level declines exceeding 1.5 feet per year were primarily in the Fresno North Growth Area, the City of Clovis, and East Fresno (east of the Fresno Air Terminal). Average rates of water-level decline generally increased to the northeast in this part of the FMA, to more than 3.0 feet per year beneath the part of the City of Clovis north of Shaw Avenue. Figures 5 and 6 show updated water-level hydrographs for six City of Fresno wells with long-term records.

These long-term water-level trends don't necessarily reflect trends during the past decade. As intentional recharge in the Fresno urban area has been expanded, water-levels have nearly stabilized in areas where the recharge has been effectively practiced. However, intentional recharge in some areas, such as the Fresno North Growth Area, has been limited due to fine-grained deposits above the water level. Rates of water-level decline since 1990

FIGURE 5

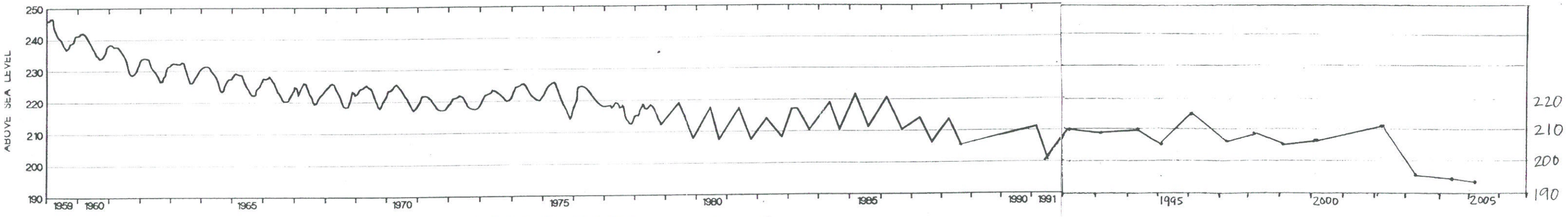
WATER-LEVEL HYDROGRAPHS FOR CITY OF FRESNO

WELLS PS 3, PS 47, AND PS 64



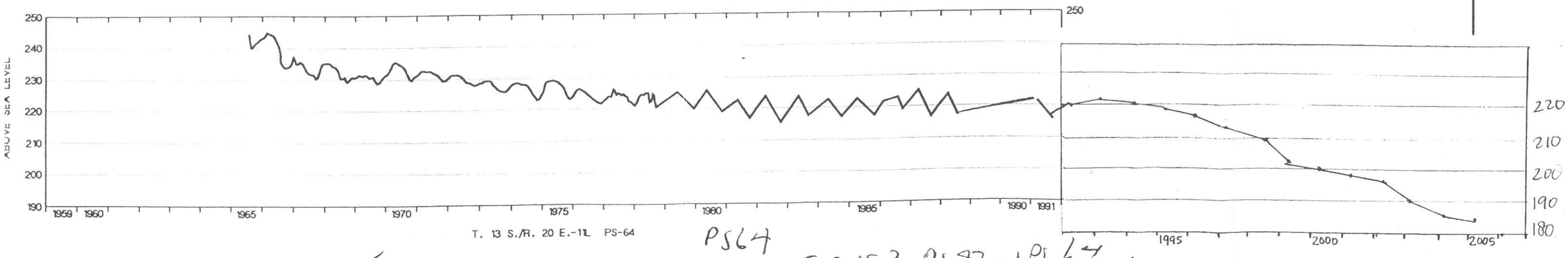
T.14 S./R. 20 E.-10M2 PS-3

PS 3



T. 13 S./R. 20 E.-19C1 PS-47

PS 47



T. 13 S./R. 20 E.-11L PS-64

PS 64

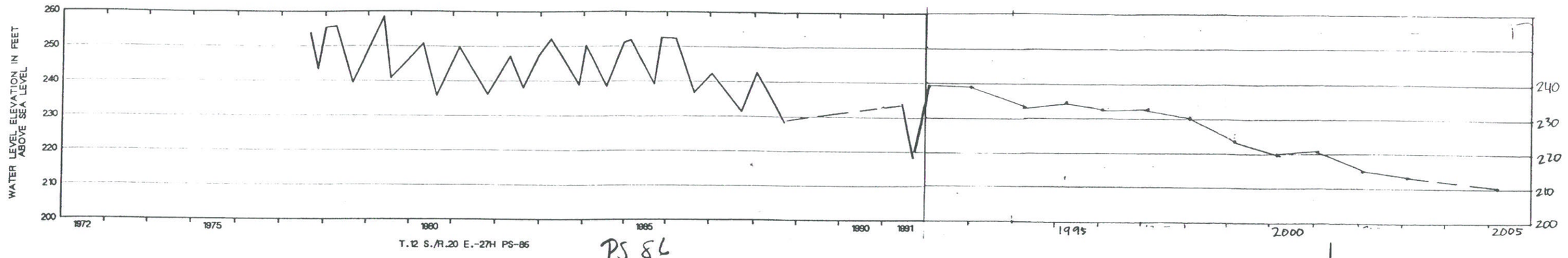
FIGURE 5 WATER-LEVEL HYDROGRAPHS FOR PS 3, PS 47, AND PS 64

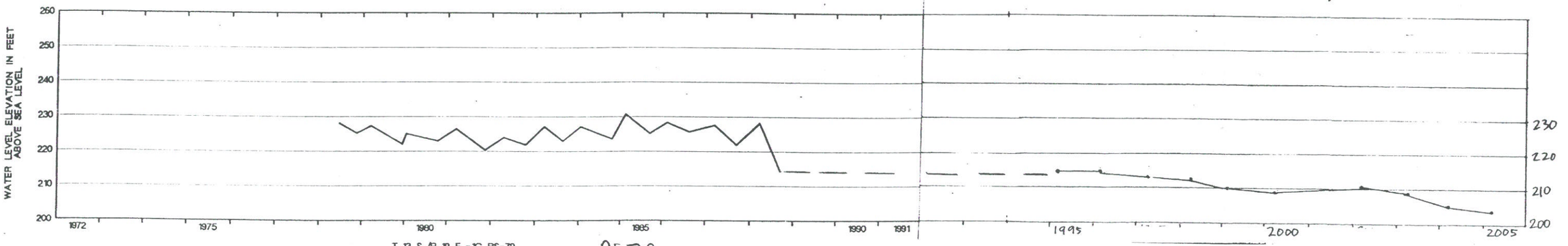
SOURCE: KEN D.SCHMIDT AND ASSOCIATES

FIGURE 6

WATER-LEVEL HYDROGRAPHS FOR CITY OF FRESNO

WELLS PS 77, PS 79, AND PS 86





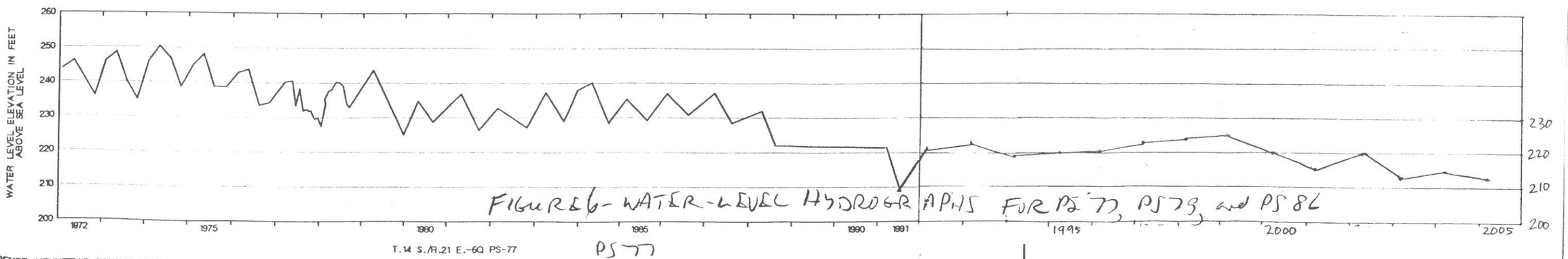


FIGURE 6- WATER-LEVEL HYDROGRAPHS FOR PS 77, PS 79, and PS 8L

RENCE: KENNETH D. SCHMIDT AND ASSOCIATES.

have averaged about 1.5 feet per year in much of the City of Fresno. In addition, as pumping has been reduced in the Fresno North Growth Area once the water treatment plant was online, water level have begun to recover.

The City of Fresno keeps track of annual changes in water levels in 30 City wells. These wells were selected to be representative of the City. Between January 1990 and January 2006, the average water-level decline for these wells was 1.5 feet per year.

AQUIFER CHARACTERISTICS

The results of aquifer tests conducted on large-capacity wells were available for 25 large-capacity wells in the FMA as of 1990. (KDSA, 1990) summarized the results of these in the Appendix D report. As part of this evaluation, results of additional aquifer tests were assembled.

Table 1 shows the results of ten aquifer tests in northwest Fresno. Pumping rates for these tests ranged from 570 to 2,735 gpm, and exceeded 1,700 gpm, except for one well. Specific capacities ranged from 43 to 134 gpm per foot. Transmissivities ranged from 66,000 to 298,000 gpd per foot, and exceeded 112,000 gpd per foot except for one well. As documented previously by CE & JWHA (1969), high transmissivities are characteristic of northwest Fresno, and are primarily associated with the highly permeable stream-channel deposits of the ancestral San Joaquin River.

TABLE 1-SUMMARY OF AQUIFER TESTS FOR WELLS IN NORTHWEST FRESNO (WEST OF FWY 41 & NORTH OF McKINLEY AVENUE)

Well No.	Date	Duration (hours)	Perforated Interval (feet)	Pumping Rate (gpm)	Static Level (feet)	Specific Capacity (gpm/ft)	Transmissivity (gpd/ft)
PS 44A	08/13/69	24	120-520	1,850	84.8	134	250,000
PS 79	08/06/69	24	120-380	1,750	92.7	125	220,000
FCWD 19-3	08/05/88	8	132 O.B.	570	112.6	43	66,000
PS 139	11/13/90	22	190-620	1,915	100.0	69	113,000
PS158	06/11/92	21	200-670	2,049	98.6	54	132,000
PS 160	08/09/91	22	190-760	2,145	85.4	125	253,000
PS 161	04/22/92	24	170-310	1,995	87.9	71	176,000
PS 169	07/10/92	23	200-750	2,735	89.5	64	144,000
PS 189	11/04/93	24	190-690	2,510	108.1	58	194,000
PS 192	09/21/95	22	180-300	2,470	80.6	64	298,000

Table 2 shows the results of 16 aquifer tests in or near the Fresno North Growth Area. Pumping rates ranged from about 500 to 2,450 gpm. Specific capacities ranged from 6 to 57 gpm per foot. Specific capacities for seven of the tested wells were less than 20 gpm per foot. Transmissivities ranged from 10,000 to 179,000 gpd per foot. Except for three wells (PS 96, PS 185, and CRR Irrigation Well 1), transmissivities in this part of the FMA were less than 65,000 gpd per foot. These values are consistent with the location of most of this area in the interfan area. That is, it is between the San Joaquin River stream channel deposits to the northwest and coarse-grained deposits associated with intermittent streams to the southeast. Thus fine-grained strata are predominant in this area.

Table 3 show the results of five aquifer test in east Fresno. Pumping rates ranged from about 450 to 1,740 gpm. Specific capacities ranged from 2 to 38 gpm per foot. Except for one well (PS 63), specific capacities were less than 26 gpm per foot. Transmissivities ranged from 3,500 to 109,000 gpd per foot. Except for two wells (PS 63 and PS 342), transmissivities ranged from 23,000 to 31,000 gpd per foot. This area is also in the interfan area, and because of groundwater quality or other concerns, most of the tested wells don't tap the more permeable, shallower older alluvium. Except for PS 63, these transmissivities are for the fine-

TABLE 2-SUMMARY OF AQUIFER TESTS FOR WELLS IN FRESNO NORTH GROWTH AREA (NORTH OF HERNDON AVENUE & EAST OF FWY 41)

Well No.	Date	Duration (hours)	Perforated Interval (feet)	Pumping Rate (gpm)	Static Level (feet)	Specific Capacity (gpm/ft)	Transmissivity (gpd/ft)
PS 96	10/22/79	24	220-280 440-510	1,250	113.2	26	76,000
PS 132	06/07/90	20	195-510	2,030	126.9	53	100,000
PS 133	02/26/90	24	140-190 265-575	2,100	112.4	43	62,000
PS 134	06/25/90	-	170-260 320-410	1,835	-	64	55,000
PS 140	11/20/90	24	145-300	960	114.5	15	39,000
PS 168-1	07/16/92	23	278-383	590	153.9	6	10,000
PS 168-2	09/28/92	24	198-223	555	137.2	15	56,000
PS 175-1	04/05/93	20	208-248	910	108.2	14	31,000
PS 175-2	04/13/93	21	330-520	1,200	114.9	28	46,000
PS 176	06/07/93	24	200-280	520	144.9	12	41,000
PS 177	11/29/93	24	210-440	1,140	139.6	19	55,000

Continued:

TABLE 2-SUMMARY OF AQUIFER TESTS FOR WELLS IN FRESNO NORTH GROWTH AREA (NORTH OF HERNDON AVENUE & EAST OF FWY 41)
(Continued:)

Well No.	Date	Duration (hours)	Perforated Interval (feet)	Pumping Rate (gpm)	Static Level (feet)	Specific Capacity (gpm/ft)	Transmissivity (gpd/ft)
PS 185	09/27/94	22	150-245	2,445	144.3	57	179,000
PS 187	08/27/94	24	340-370	1,995	158.3	38	59,000
CRR 12 G	09/23/96	240	160-270	495	132.3	14	54,000
CRR Irr No. 1	10/06/95	240	108-305	630	118.6	52	135,000
PS 330	08/02/05	22	385-525	2,025	189.0	34	46,000

TABLE 3-SUMMARY OF AQUIFER TESTS FOR WELLS IN EAST FRESNO
(BETWEEN ASHLAN & OLIVE AVENUES, EAST OF PEACH AVENUE)

Well No.	Date	Duration (hours)	Perforated Interval (feet)	Pumping Rate (gpm)	Static Level (feet)	Specific Capacity (gpm/ft)	Transmissivity (gpd/ft)
PS 63	03/19/87	7	146-287	905	82.1	38	109,000
PS 326	09/15/05	22	260-520	995	135.0	23	23,000
PS 329	05/20/05	22	380-430	1,205	142.1	16	32,000
PS 342	10/18/05	22	315-835	445	132.6	2	3,500
PS 128	03/15/93	25	280-430	1,740	133.3	25	31,000

grained continental deposits below a depth of about 260 feet.

Table 4 shows the results of 13 aquifer tests in southeast Fresno. Pumping rates ranged for about 340 to 1,790 gpm. Specific capacities ranged from 4 to 54 per foot. Except for two shallow wells (PS 225 and 274), specific capacities were less than 25 gpm per foot, characteristic of the fine-grained continental deposits. Transmissivities ranged from 15,000 to 135,000 gpd per foot. Except for four wells (PS 225, PS 274, B-2, and B-14), transmissivities were less than 40,000 gpd per foot, also typical of the finer grained continental deposits.

Table 5 shows the results of six aquifer tests in southwest Fresno. Pumping rates ranged from about 1,510 to 2,515 gpm. Specific capacities ranged from 26 to 92 gpm per foot. Except for one well (Malaga CWD No. 6), specific capacities were 40 gpm per foot or greater. Transmissivities ranged from 57,000 to 369,000 gpd per foot or greater. The highest values (exceeding 275,000 gpd/ft) were for wells tapping the shallow coarse-grained older alluvium. The lowest value was for a relatively deep well in Malaga, that tapped both the older alluvium and continental deposits.

PUMPAGE

Pumpage from public supply FMA from 1980-90 was provided in Table 1 of the Appendix D report (KDSA, 1992). Annual pumpage by the City of Fresno increased from about 119,000 acre-feet in 1990

TABLE 4-SUMMARY OF AQUIFER TESTS FOR WELLS IN SOUTHEAST FRESNO
(EAST OF PEACH AVENUE & SOUTH OF OLIVE AVENUE)

Well No.	Date	Duration (hours)	Perforated Interval (feet)	Pumping Rate (gpm)	Static Level (feet)	Specific Capacity (gpm/ft)	Transmissivity (gpd/ft)
PS 166	10/16/96	22	400-640	350	124.4	10	32,000
PS 182	09/08/94	24	350-570	1,790	74.2	10	15,000
PS 188	11/04/05	22	260-280 350-400	965	70.1	17	36,000
PS 225	03/05/87	7	144 O.B.	995	53.7	48	66,000
PS 274	03/18/87	7	142 O.B.	480	40.8	54	109,000
PS 327	05/12/05	24	270-450	805	75.5	9	21,000
PS 331	03/07/06	22	390-690	745	97.0	13	18,000
PS 341	05/01/06	22	310-835	1,200	78.0	23	33,000
B-2	02/04/05	7	216 O.B.	335	110.3	31	83,000
B-4A	07/24/03	22	260-620	1,414	116.6	15	37,000
B-14	02/02/05	24	202 O.B.	970	113.5	17	135,000
B-15	05/12/03	24	300-750	1,500	102.1	14	30,000
Sunnyside HS	05/05/98	24	255-450	800	90.8	6	18,000

TABLE 5-SUMMARY OF AQUIFER TESTS FOR WELLS IN SOUTHWEST FRESNO
(WEST OF PEACH AVENUE & SOUTH OF McKINLEY AVENUE)

Well No.	Date	Duration (hours)	Perforated Interval (feet)	Pumping Rate (gpm)	Static Level (feet)	Specific Capacity (gpm/ft)	Transmissivity (gpd/ft)
WRF 7	04/28/05	22	500-650	2,040	62.3	40	112,000
WRF 5	06/15/95	24	210-690	1,811	49.9	53	277,000
WRF 6	06/23/95	22	175-480	1,790	49.5	68	278,000
WRF R-5A	02/23/06	22	80-210	2,515	14.1	92	369,000
WRF R-21A	06/09/06		80-250				
Malaga No. 6	07/15/96	24	245-720	1,510	57.0	26	57,000

WRF wells are at Cities of Fresno and Clovis WRP. The R series wells are recovery wells.

to 165,000 acre-feet in 2002 and 2003. The annual pumpage then decreased to about 157,000 acre-feet in 2005, after the City water treatment plant in the Fresno North Growth Area went on line. City of Clovis annual pumpage was about 13,600 acre-feet in 1990 and about 23,000 acre-feet in 2004. After the City of Clovis water treatment plant came on line, pumpage decreased to about 18,200 acre-feet in 2005. Total annual pumpage for public supply in the FMA was about 105,000 acre-feet in 1980, about 139,000 acre-feet in 1990, and about 198,000 acre-feet in 2003. By 2005, annual pumpage in the FMA had been reduced to about 180,000 acre-feet, after the two City's water treatment plants become operative.

INTENTIONAL RECHARGE

Annual intentional recharge by the City of Fresno was about 43,400 acre-feet in 1990 and 60,400 acre-feet in 2000. The greatest annual amount of intentional recharge was about 61,700 acre-feet in 2003. In 2005, the annual City of Fresno intentional recharge was 43,100 acre-feet. However, water delivered to the water treatment plant can be considered in-lieu recharge. The City of Clovis annual intentional recharge was about 5,500 acre-feet in 1990 and 9,100 acre-feet in 2000. In 2005, this recharge was about 10,800 acre-feet per year. Of the 2005 recharge, about 4,700 acre-feet were at the Marion dedicated recharge facility, about 3,600 acre-feet were in Big Dry Creek, and about 2,000 acre-feet were in

FMFCD basins. In 2003, about 69,000 acre-feet of water were intentionally recharged by the Cities of Fresno and Clovis, compared to about 198,000 acre-feet of pumpage for public supply in the FMA. Most of the remainder of this pumpage came from groundwater inflow into the FMA.

GROUNDWATER QUALITY

The constituents that were evaluated as part of this update are TDS, nitrate, DBCP, and TCP.

Total Dissolved Solids

Figure 15 of the Appendix D report (KDSA, 1992) showed TDS concentrations in water from wells in the urban area in 1989-91. TDS concentrations of less than 100 mg/l were present only beneath and downgradient of Leaky Acres and the former City of Clovis recharge facility (near the South City yard). The relatively low salinity of groundwater in these parts of the urban area was due to intentional recharge of low salinity canal water for more than two decades. TDS concentrations in groundwater beneath the northern half of the urban area normally ranged from about 100 to 250 mg/l in 1989-91, except in two formerly unsewered area (Figarden and former FCWD 11 and 14, near Hoover High School). In these two areas, TDS concentrations ranged from about 250 to 400 mg/l. South of McKinley Avenue, TDS concentrations exceeded 250 mg/l in water

from most wells, except in part of downtown Fresno and west and northeast of Sunnyside. The relatively low TDS concentrations in groundwater west and northeast of Sunnyside appeared to be due to seepage from the Fancher Creek, Briggs, and Washington Canals.

There were several known plumes of high salinity groundwater in or near the urban area. One of these extended southwest from the Southern Pacific Railroad Yard (near Shields Avenue and Highway 99). This plume has been extensively evaluated, including during the Fresno County 208 and 205J water quality management programs, based on sampling of small-capacity domestic wells. TDS concentrations in shallow groundwater within this plume have exceeded 650 mg/l. Another plume of high salinity groundwater extended northwest from the former Fresno Meat Company (now Beef Packers), near North and Fig Avenues. A TDS concentration exceeding 2,000 mg/l was found in water from a well in that area in 1972. There was another area of relatively high TDS concentrations near Church and West Avenues (PS 88), where TDS concentrations exceeded 500 mg/l. As part of this evaluation, previously prepared electrical conductivity hydrographs were updated through 2005. A review of electrical conductivity hydrographs for wells in the urban area indicate that constant trends have predominated, except for some increases in the remaining unsewered areas, and decreased due to intentional recharge.

Hydrographs for wells in downtown Fresno generally indicate relatively constant electrical conductivities after the early 1970's. In Tarpey Village, the electrical conductivity of water from most wells has been relatively constant during the past several decades. For most wells in the Sunnyside area, the electrical conductivity has been constant or has slightly decreased since the early 1970's. In the area south of the Fresno Air Terminal, the electrical conductivity of water from several wells (in former FCWD No. 17 and 22) has increased in the recent decade, whereas the electrical conductivity has remained essentially the same in water from other wells. In the south part of the Mayfair District, which has been unaffected from recharge at Leaky Acres, electrical conductivities normally rose through the late 1970's, and have remained relatively constant since that time.

Nitrate

Figure 16 of the Appendix D report (KDSA, 1992) showed nitrate concentrations in water from wells in the urban area in 1989-91. Nitrate concentrations were less than 25 mg/l in most of the urban area, and less than 15 mg/l in the north and northwest parts. The area of lowest nitrate concentrations corresponded to those with low salinity, and this is due to recharge of streamflow and canal water with low nitrate concentrations and salinity.

As of 1990, nitrate concentrations had exceeded the MCL of 45

mg/l in water from only a few public supply wells in the urban area. One of the largest areas of high nitrate concentrations in 1989-91 was west of Clovis Avenue, between Olive and Belmont Avenues. Nitrate concentrations in water from three Bakman Water Company wells in this area ranged from 47 to 55 mg/l in 1990. Nitrate concentrations in water from two other wells (D17-2 and D22-1) had been near the MCL. This area was located immediately downgradient of former waste disposal fields at the Gallo Winery. The area was also downgradient of a large area of nitrate concentrations exceeding 45 mg/l, that extends to the northeast east of Clovis Avenue, along the floodplain of Fancher Creek. The nitrate concentration was 65 mg/l in 1989 in water from a City of Fresno well near West and Church Avenues (PS 88) and this well was closed. This well was located in a northeast trending area of high nitrate that extends southwest from downtown Fresno, through part of the Running Horse project. Both of these high nitrate areas adjacent to the urban area were discussed in detail in the 208 program report (County of Fresno, et al, 1979).

Another area where nitrate concentrations exceeded the MCL in 1989-91 was in the southernmost part of the former unsewered Figarden area. Three wells in former FCWD 1 and 2 had nitrate concentrations ranging from 50 to 57 mg/l in 1989-90, and these wells were closed. A nitrate concentration of 68 mg/l was present in

water from an unused public supply well at Greenfield Village (Jensen and Clovis Avenues) in 1989. Several wells in the unsewered part of the Sunnyside area had relatively high nitrate concentrations. In unsewered urban areas, nitrate concentrations in water from shallow wells frequently increased for a period of about ten years after commencement of septic tank use. Thereafter, nitrate concentrations increased at a more gradual rate. Water from deep wells in or near unsewered areas showed little or no change in nitrate concentration with time.

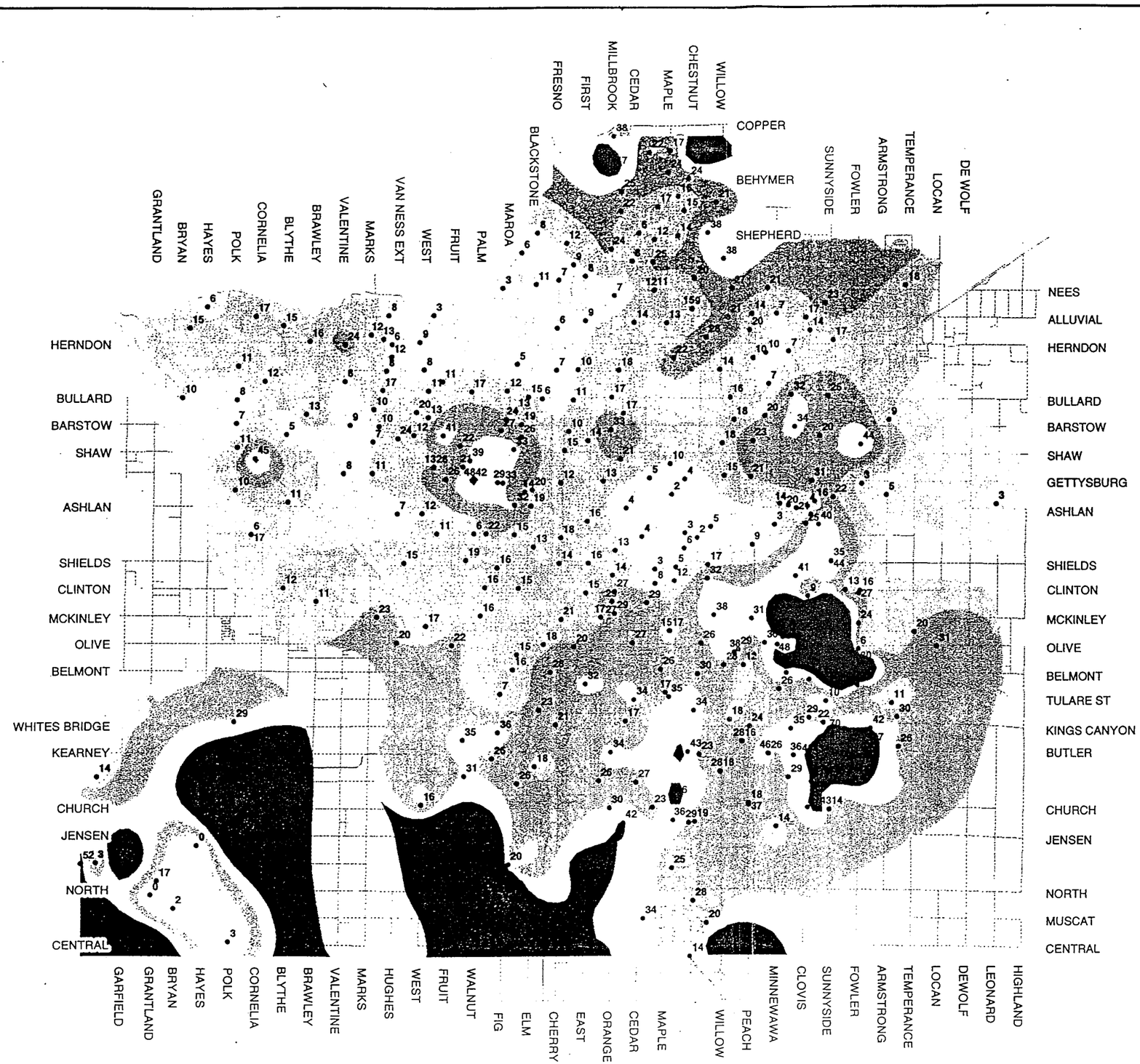
The recent evaluation of nitrate in groundwater in the FMA (KDSA, 2004) provided a detailed update since the Appendix D report. Figure 7 shows nitrate concentrations for 2000-04. Three large areas of high nitrate concentrations were identified:

1. Beneath and downgradient of the Gallo Winery.
2. Beneath and downgradient of the unsewered area in Sunnyside.
3. Beneath large parts of the southwest Fresno area, including at and near the Running Horse project.

Nitrate concentrations in the first two of these areas continued to increase. The City of Fresno is developing a management plan to address high nitrate in groundwater in the FMA.

DBCP

Figure 21 of the Appendix D report (KDSA, 2002) showed the



NITRATE CONCENTRATIONS IN GROUNDWATER (mg/L)

- No data
- less than10 mg/L
- 10 mg/L and greater
- 20 mg/L and greater
- 30 mg/L and greater
- 40 mg/L and greater
- 50 mg/L and greater

●14.5 Well location and NO3 value, in mg/L.

Approximate scale:
0 0.35 0.7 1.4 2.1 Miles

N

Basemap modified from maps supplied by the cities of Fresno and Clovis.
Data provided by the cities of Fresno and Clovis.

FIGURE7

NITRATE CONCENTRATIONS IN WELL WATER (2000 - 2004)

Ken D. Schmidt and Associates

I:\PROJECT\8000s\8958.000-FresnoNitrate\GIS\template_B_NO3.mxd

range in DBCP concentrations found in water from public supply wells in the urban area during 1989-91. The largest areas of DBCP contamination were present in two localities:

1. In the northeast part of the urban area, generally northeast of a line extending from near Cedar and Teague Avenues south to near Cedar and Bullard Avenues, thence southeast to the northeast part of the Fresno Air Terminal.
2. In southeast Fresno, generally southeast of a line extending from Calwa on the west to near Greenfield Village, thence northerly to near Clovis Avenue and Belmont Avenue.

The first of these two areas included the northernmost and southeastern parts of the North Fresno Growth Area, the western part of the Herndon-Shepherd Plan Area, and parts of the City of Clovis, Tarpey Village, and the East Clovis area. In 1990-91 DBCP concentrations exceeding the MCL were present in seven City of Clovis wells in this area, in three City of Fresno wells, and in two additional Fresno Air Terminal wells operated by the City of Fresno. The highest DBCP concentrations were present in a northeast trending zone, extending from City of Fresno PS 85 (near Maple and Palo Alto Avenues) on the southwest to near Shepherd Avenue, between Peach and Minnewawa Avenues, on the northeast. DBCP concentrations exceeded 2.0 ppb in groundwater in this area in 1990-

91. The area of DBCP concentrations exceeding 0.5 ppb was more than four miles long and averaged about one and one-half miles wide. There were two areas in or near the north part of the North Fresno Growth Area where DBCP concentrations also exceeded 2.0 ppb. There were two other local areas where DBCP concentrations exceeded 1.0 ppb (near Herndon and Ninnewawa Avenues and in the north part of Tarpey Village). Another fairly large area of DBCP concentrations exceeding 1.0 ppb extended northeast from the northeast part of the Fresno Air Terminal to near Ashlan and Locan Avenues.

Water from 18 wells in Southeast Fresno at least periodically had water with DBCP concentrations exceeding the MCL in 1989-91. This included four wells in Calwa, two wells in Greenfield Village, three Bakman Water District wells, and nine other City of Fresno wells in the Sunnyside area. DBCP concentrations in groundwater in much of this area exceeded 1.0 ppb in 1990-91.

Elsewhere in the urban area, DBCP contamination was generally at much lower concentrations and more localized than in the two large areas previously discussed. Two wells in the Figarden area (D19-3 and D25-5) had DBCP concentrations ranging from less than 0.02 to 0.09 ppb. Water from four wells west or southwest of CSUF had DBCP concentrations ranging from 0.02 to 0.07 ppb (PS 53, PS 64, PS 65, and D14-2). The northerly three of these wells appeared to be downgradient of PS 85 and the northeast trending lobe of high

DBCP concentration previously described, as of Spring 1991. Seventeen wells in and near the Mayfair area had DBCP contents periodically exceeding 0.02 ppb. DBCP concentrations in water from most of these wells, were less than 0.10 ppb. There were six other wells south of Huntington Boulevard and north of California Avenue where DBCP concentrations were also normally in the range of 0.02 to 0.10 ppb.

As of Summer 1991, there were 15 City of Fresno wells, three City of Clovis wells, and three Bakman Water Company wells closed because of DBCP contamination. In addition, water from one City of Fresno well with DBCP contamination (D24-2) was being treated.

As part of this evaluation, information on DBCP concentrations in public supply wells since 1990 was obtained. Figure 8 shows DBCP concentrations in water from public supply wells in the FMA for 2004-06. Contours are shown for concentrations of 0.01 ppb, 0.1 ppb, and 0.5 ppb. This map indicates that few public supply wells had DBCP concentrations exceeding 0.5 ppb in 2004-06. Two wells in the City of Clovis (No. 21 and 27) and PS 152 in the Sunnyside area had DBCP concentrations exceeding 0.5 ppb. Overall, peak DBCP concentrations were significantly lower than in 1989-91 (when 3 ppb was common).

Areas of DBPC exceeding 0.1 ppb included 1) west Fresno, near Dakota and Cornellia Avenues, 2) the Fresno North Growth Area, east

FIGURE 8 - DBCP CONCENTRATIONS IN WATER FROM SUPPLY WELLS 2004-2006

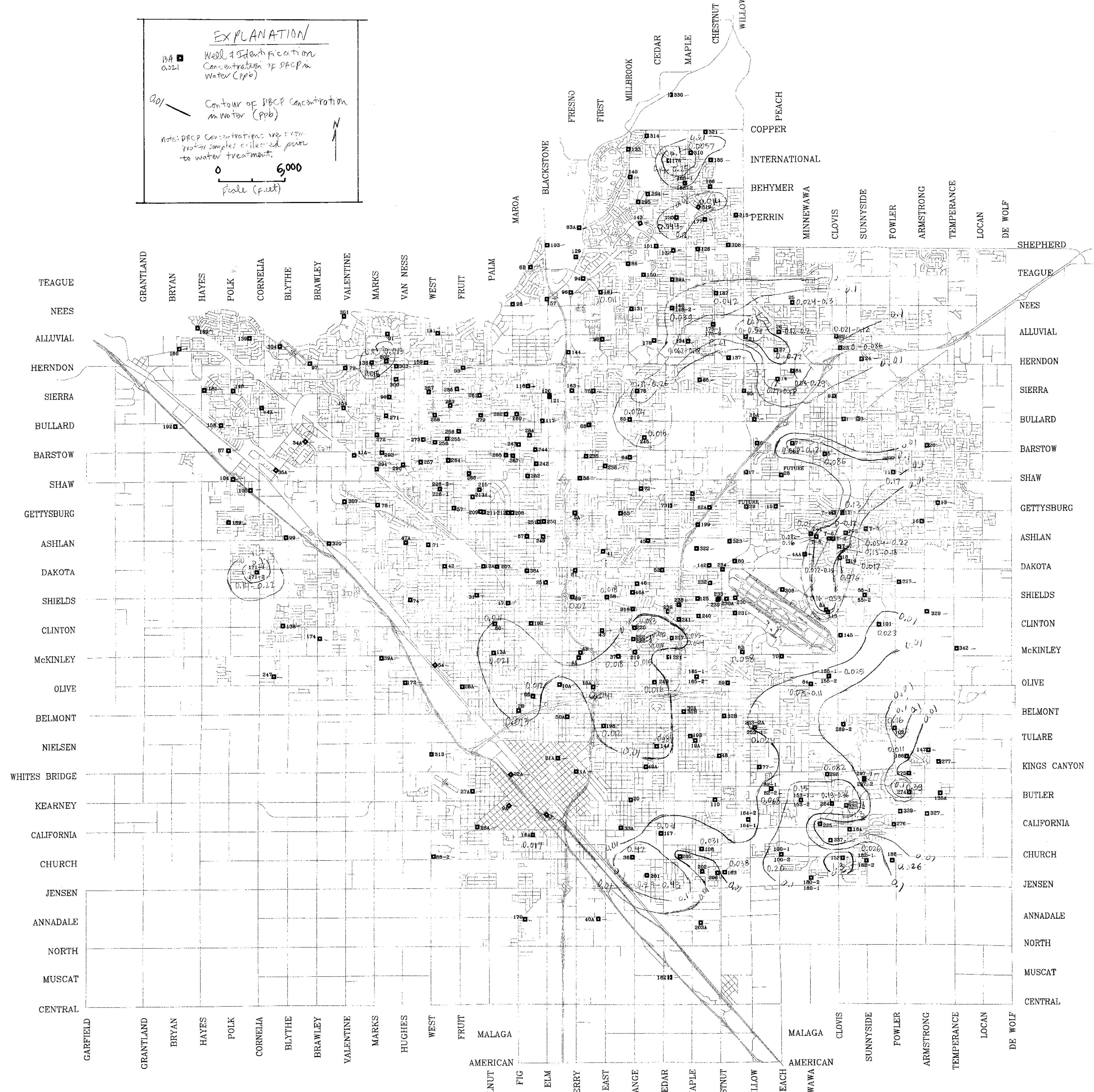


FIGURE 8 - DBCP concentrations in water from public supply wells (2004-2006)

of Cedar Avenue and between Perrin and Copper Avenues (two wells), 3) the City of Clovis and part of the City of Fresno north and west of CSUF (ten wells), 4) the area northeast of the Fresno Air Terminal (about seven wells), and 5) the Sunnyside area, which was the largest area where DBCP concentrations exceeded 0.1 ppb.

As of 1990, DBCP concentrations in southeast Fresno had increased in some former FCWD wells and Bakman Water Company wells since 1979, primarily due to the downgradient movement of high DBCP groundwater from the southeast. This had occurred primarily in Sections 4 and 9 of T14S/R21E, between Tulare and California Avenues, east of Clovis Avenue. On the other hand, DBCP concentrations had either decreased or remained relatively constant in water from wells in the part of the area where DBCP concentrations exceed 1.0 ppb. The decreases were probably due to recharge of low-DBCP water from canal seepage and deep percolation of irrigation return flow since DBCP was banned and degradation of DBCP. In downgradient areas where DBCP concentrations are detectable and less than about 0.1 ppb, slight increases in concentration had generally occurred, due to downgradient migration of contaminated groundwater.

As part of this evaluation, previously prepared DBCP hydrographs were updated. Overall, trends from these hydrographs confirm decreasing DBCP concentrations in the shallow groundwater. In

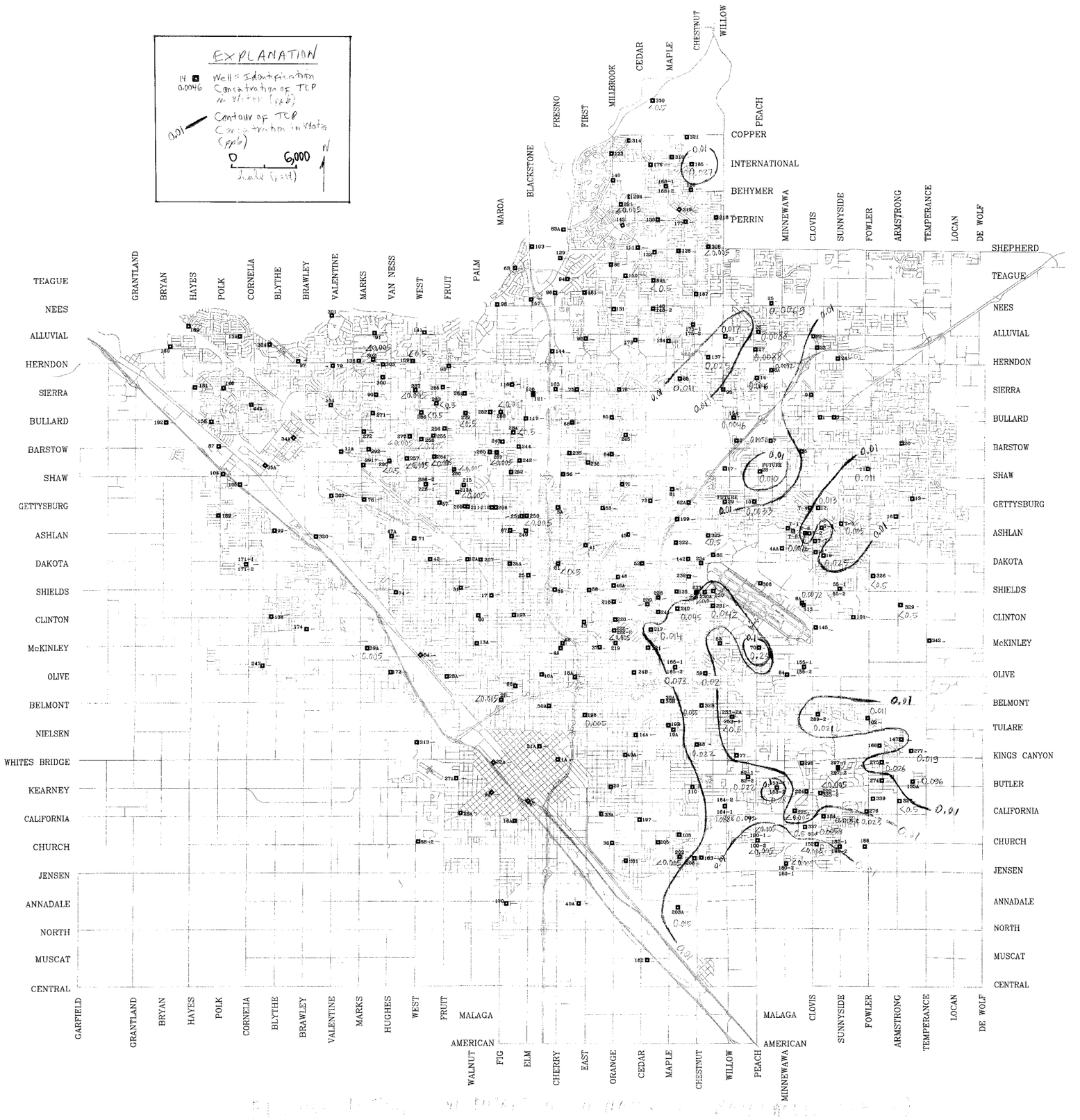
addition to the previously discussed factors, DBCP treatment has been undertaken for _____ City of Fresno wells and _____ City of Clovis wells since the mid-1990's. Pumping of these wells has been a major factor in the decreases in DBCP concentrations that have occurred in City wells during the past decade.

TCP

TCP has been detected at very low concentrations in water from City of Fresno and City of Clovis public supply wells. Figure 9 shows locations of wells where TCP was detected during 2005-06. A detection limit of 0.005 ppb was used for most of these analyses. Contours for TCP concentrations of 0.01 ppb and 0.1 ppb are provided in Figure 9. Most of the higher TCP concentrations are in shallow groundwater beneath parts of the City of Fresno and Clovis where DBCP is also present. No MCL has been developed for TCP.

FIGURE 9-TCP CONCENTRATIONS IN

WATER FROM SUPPLY WELLS(2005-06)


EXPLANATION
Well - Identification
Concentration of TCP in µg/L (1968)
Contour of TCP Concentration in µg/L (1968)
0
6,000
Scale (feet)
N
TEAGUE
NEES
ALLUVIAL
HERNDON
SIERRA
BULLARD
BARSTOW
SHAW
GETTYSBURG
ASHLAN
DAKOTA
SHIELDS
CLINTON
McKINLEY
OLIVE
BELMONT
NIELSEN
WHITES BRIDGE
KEARNEY
CALIFORNIA
CHURCH
JENSEN
ANNADALE
NORTH
MUSCAT
CENTRAL
GARFIELD
GRANTLAND
BRYAN
HAYES
POLK
CORNELIA
BLYTHE
BRAWLEY
VALENTINE
MARKS
HUGHES
VAN NESS
WEST
FRUIT
PALM
MAROA
BLACKSTONE
FRESNO
FIRST
MILLBROOK
CEDAR
MAPLE
CHESTNUT
WILLOW
PEACH
COPPER
INTERNATIONAL
BEHYMER
PERRIN
MINNEWAWA
CLOVIS
SUNNYSIDE
FOWLER
ARMSTRONG
TEMPERANCE
LOCAN
DE WOLF
SHEPHERD
MALAGA
AMERICAN
WALNUT
FIG
ELM
CHERRY
EAST
ORANGE
TULARE
KINGS CANYON
BUTLER

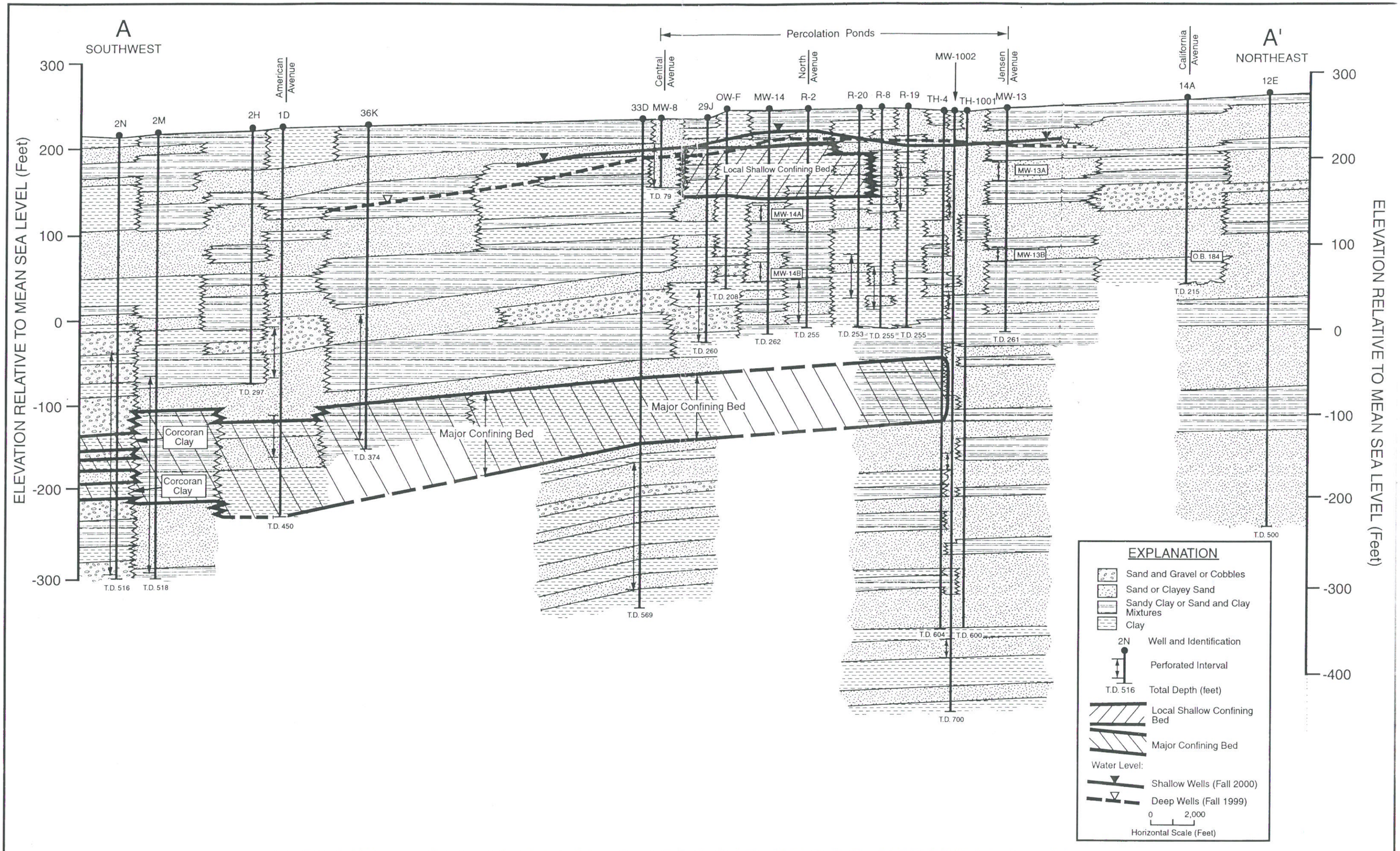


FIGURE 3 - SUBSURFACE GEOLOGIC CROSS SECTION A - A'

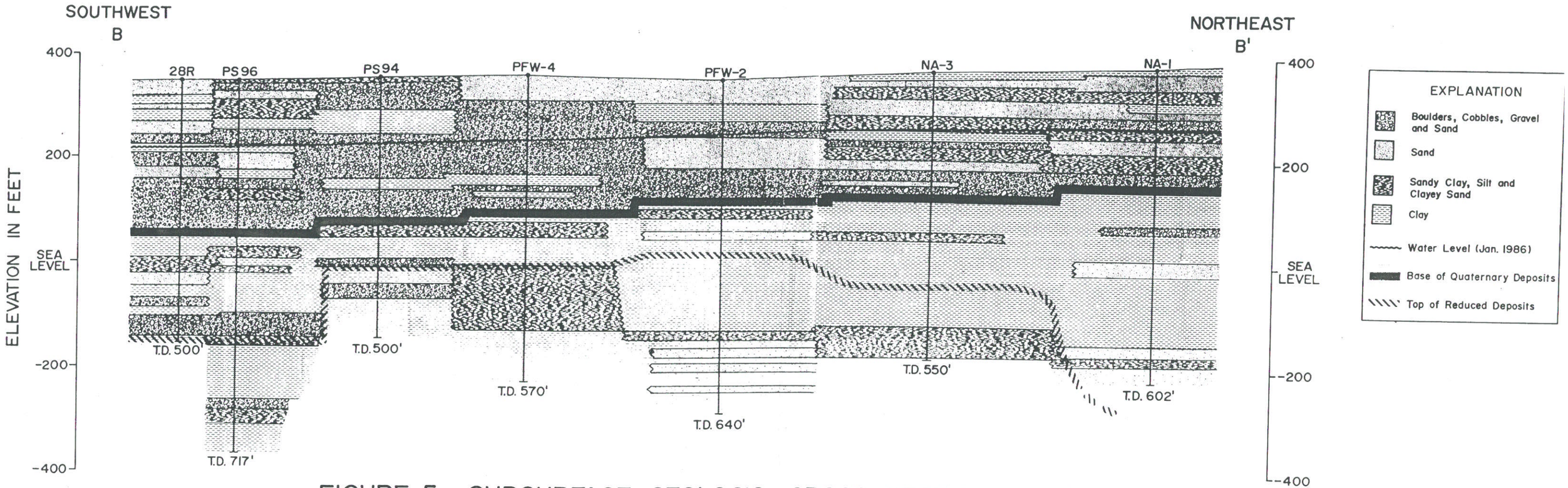


FIGURE 5 - SUBSURFACE GEOLOGIC CROSS-SECTION B-B'

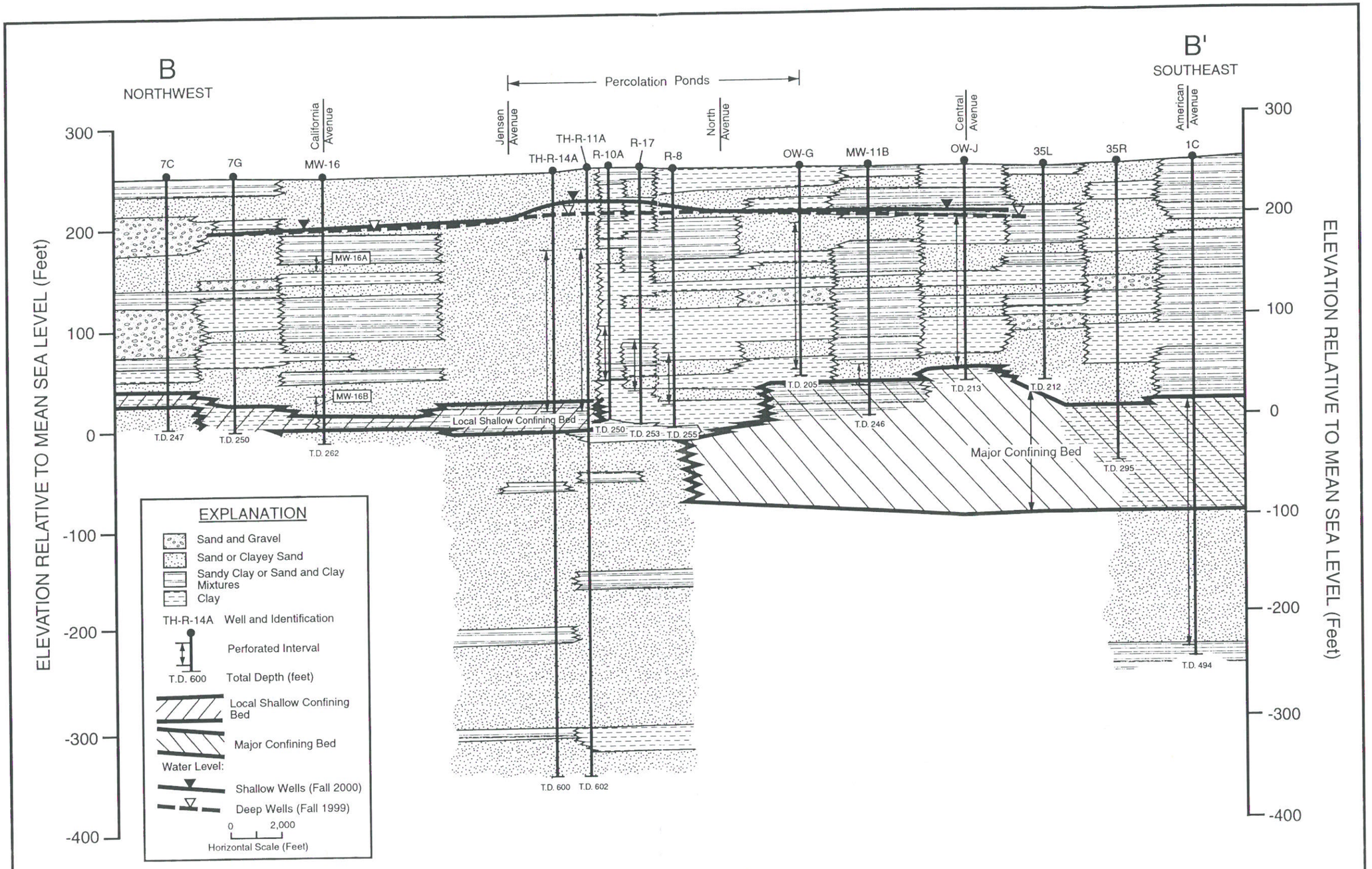


FIGURE 4 - SUBSURFACE GEOLOGIC CROSS SECTION B - B'

NORTH D

SOUTH D'

TH-145B · CLINTON · 33M · 33N · BELMONT · FCWD 26-2 · B-13A · KINGS CANYON · TH-145A · BUTLER · CB-1 · CB-2 · PS-107 · JENSON

TD 205' · TD 361' · TD 520' · TD 600' · TD 820' · TD 498' · TD 678' · TD 950'

ELEVATION (FEET) RELATIVE TO MEAN SEA LEVEL

MEAN SEA LEVEL

350 300 250 200 150 100 50 -50 -100 -150 -200 -250 -300 -350 -400 -450 -500 -550 -600

LEGEND

- BOULDERS, COBBLES, GRAVEL AND/OR SAND
- SANDY CLAY, SILT, AND CLAYEY SAND
- CLAY
- WATER LEVEL (SPRING 1991)
- APPROXIMATE BASE OF DBCP CONTAMINATION
- 33M — IDENTIFICATION OF WELL, BORING, OR TEST HOLE
- WELL
- TD 205' — TOTAL DEPTH (FEET)

0 1000 2000 3000 4000

HORIZONTAL SCALE (FEET)

REFERENCE: KENNETH D. SCHMIDT AND ASSOCIATES

FRESNO / CLOVIS METROPOLITAN Water Resources MANAGEMENT PLAN

FIGURE 6

SUBSURFACE GEOLOGIC CROSS SECTION D-D'

SAC32704.04.55 DECEMBER 1991
FILE: 32704FB3.DWG

CH2M HILL

WEST
E

EAST
E'

PS-30-A
PS-32
FCWD 17-1
5B
FCWD 26-2
B-13A
JN
TH-147
SS-1

TD 396'
TD 324'
TD 297'
TD 205'
TD 351'
TD 520'
TD 315'
TD 991'
TD 600'

MEAN SEA LEVEL

ELEVATION (FEET) RELATIVE TO MEAN SEA LEVEL

LEGEND

- BOULDERS, COBBLES, GRAVEL AND/OR SAND
- SANDY CLAY, SILT, AND CLAYEY SAND
- CLAY
- WATER LEVEL (SPRING 1991)
- 5B — IDENTIFICATION OF WELL, BORING, OR TEST HOLE
- WELL
- TD 205' — TOTAL DEPTH (FEET)

0 1000 2000 3000 4000
HORIZONTAL SCALE (FEET)

REFERENCE: KENNETH D. SCHMIDT AND ASSOCIATES

FRESNO / CLOVIS METROPOLITAN
Water Resources
MANAGEMENT PLAN

FIGURE 7
SUBSURFACE GEOLOGIC
CROSS SECTION E-E'

SAC32704.04.55 DECEMBER 1991
FILE: 32704F54.DWG

CH2M HILL

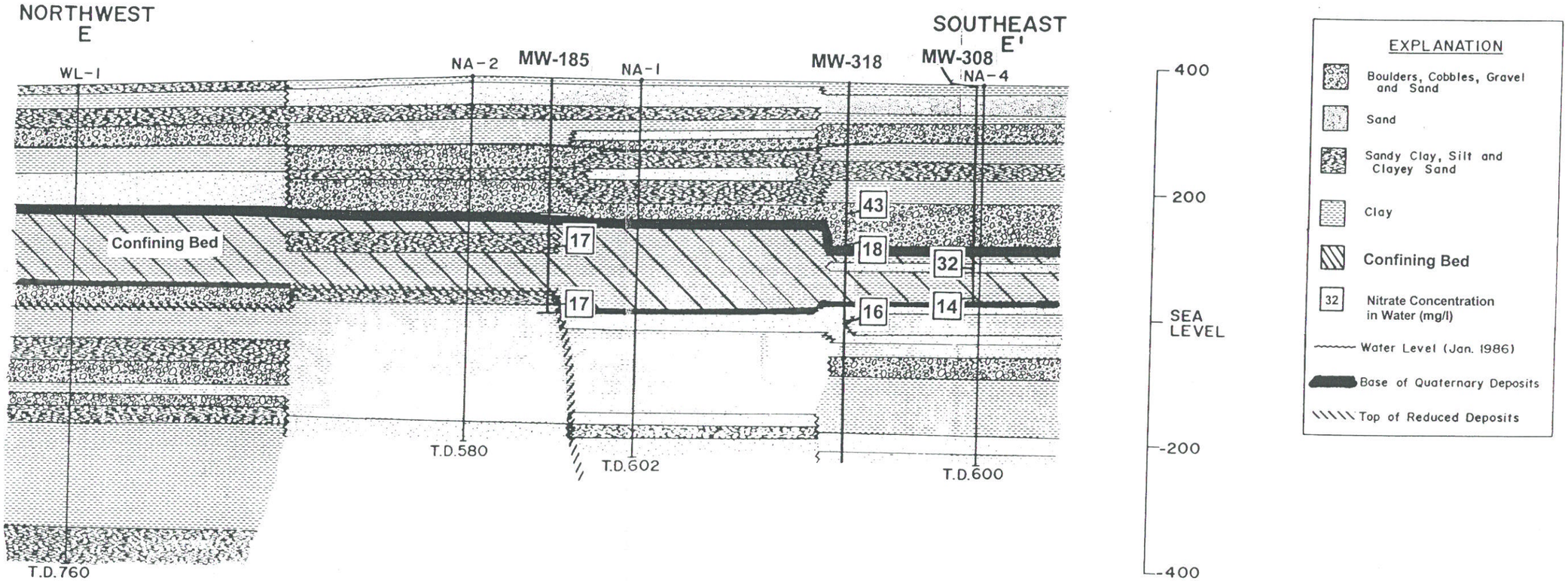
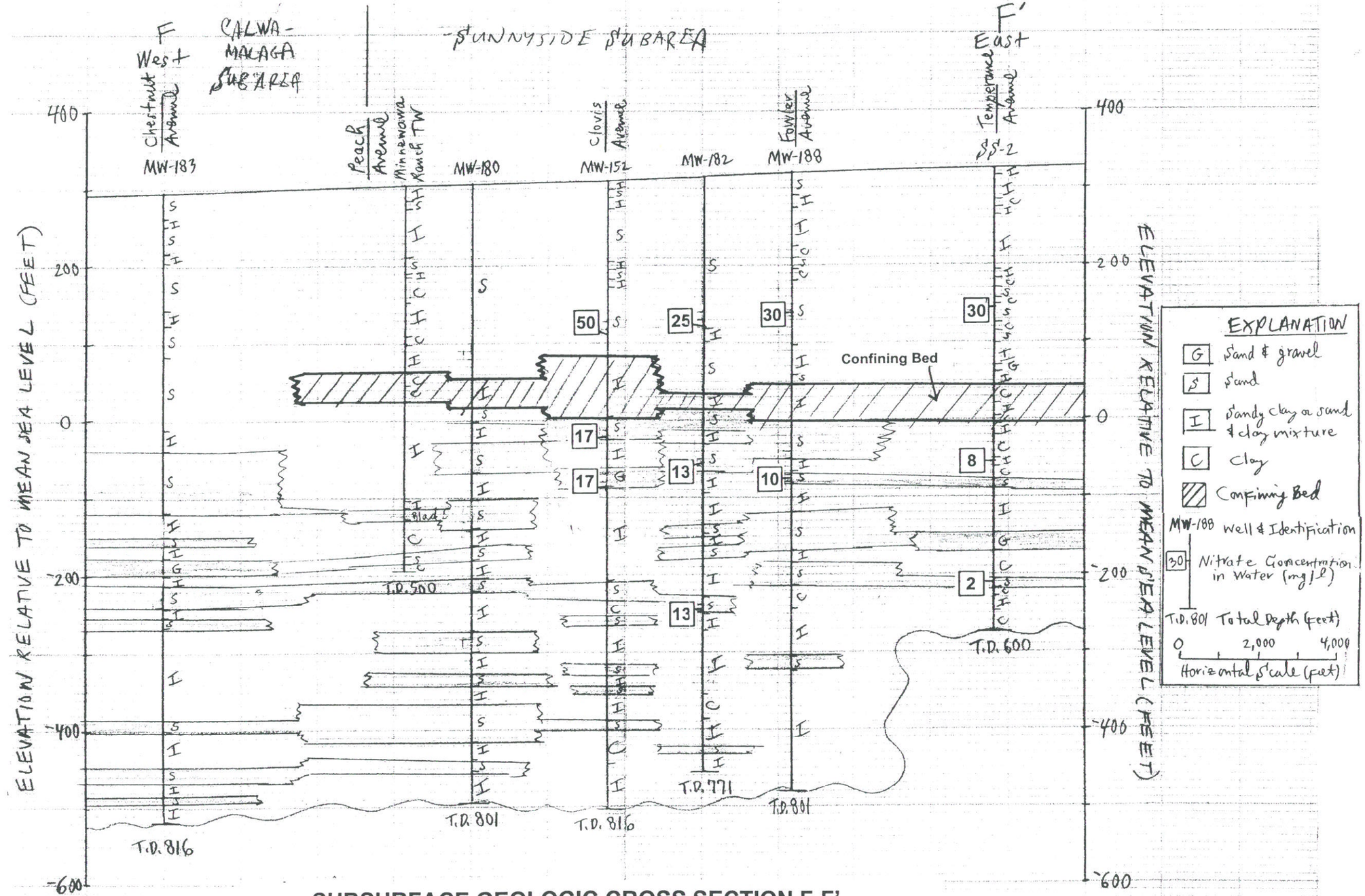


FIGURE 8 - SUBSURFACE GEOLOGIC CROSS-SECTION E-E'



SUBSURFACE GEOLOGIC CROSS SECTION F-F'

NORTH
C

SOUTH
C'

PS-139

PS-44-A

PS-35-A

PS-99

TH-171

PS-138

TD 530'

TD 490'

TD 619'

TD 708'

TD 700'

TD 693'

MEAN SEA LEVEL

ELEVATION (FEET) RELATIVE TO MEAN SEA LEVEL

400
350
300
250
200
150
100
50
MEAN SEA LEVEL
-50
-100
-150
-200
-250
-300
-350
-400
-450
-500
-550
-600

BOULDERS, COBBLES, GRAVEL AND/OR SAND

SAND

SANDY CLAY, SILT, AND CLAYEY SAND

CLAY

REFERENCE: KENNETH D. SCHMIDT AND ASSOCIATES

WATER LEVEL (SPRING 1991)

APPROXIMATE BASE OF QUATERNARY DEPOSITS

TOP OF REDUCED DEPOSITS

PS-139 IDENTIFICATION OF WELL, BORING, OR TEST HOLE

WELL

TD 708' TOTAL DEPTH (FEET)

0 1000 2000 3000 4000

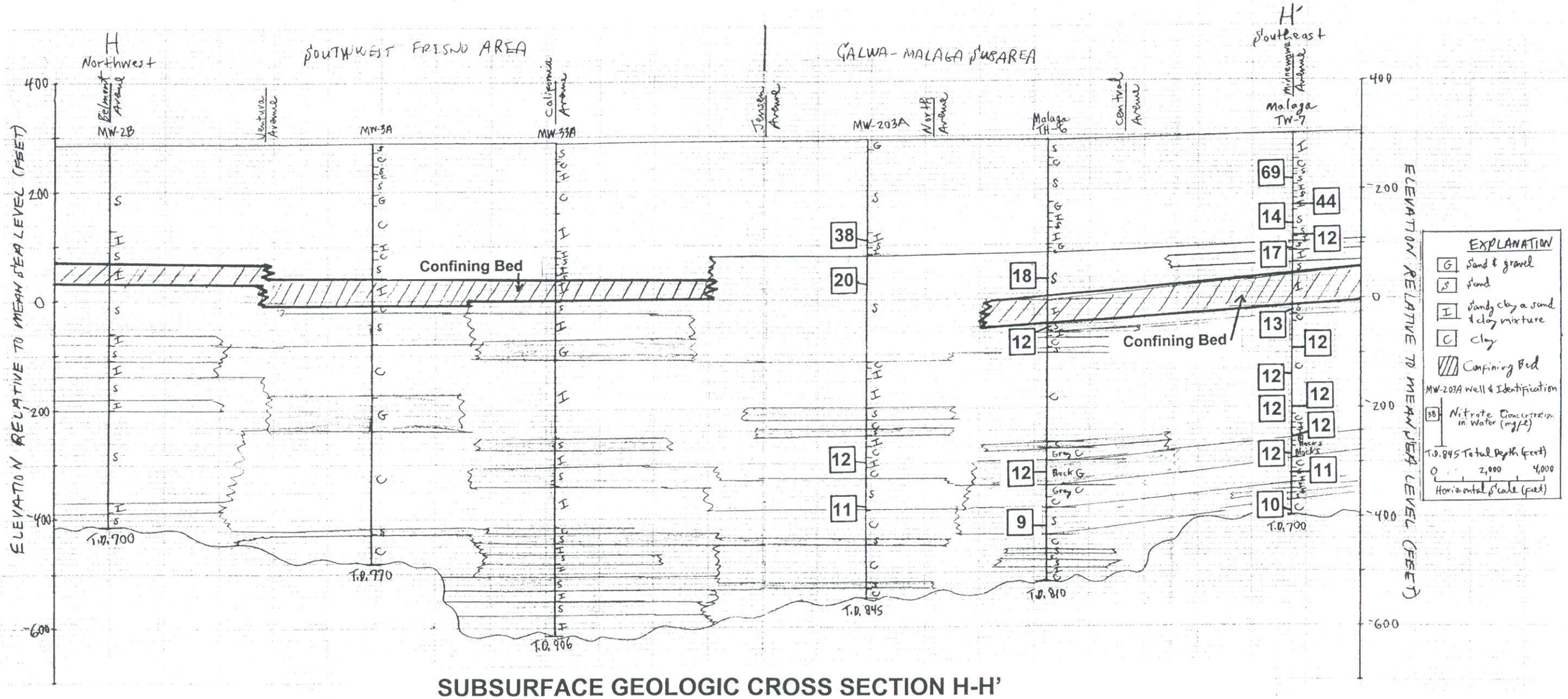
HORIZONTAL SCALE (FEET)

FRESNO / CLOVIS METROPOLITAN
Water Resources
MANAGEMENT PLAN

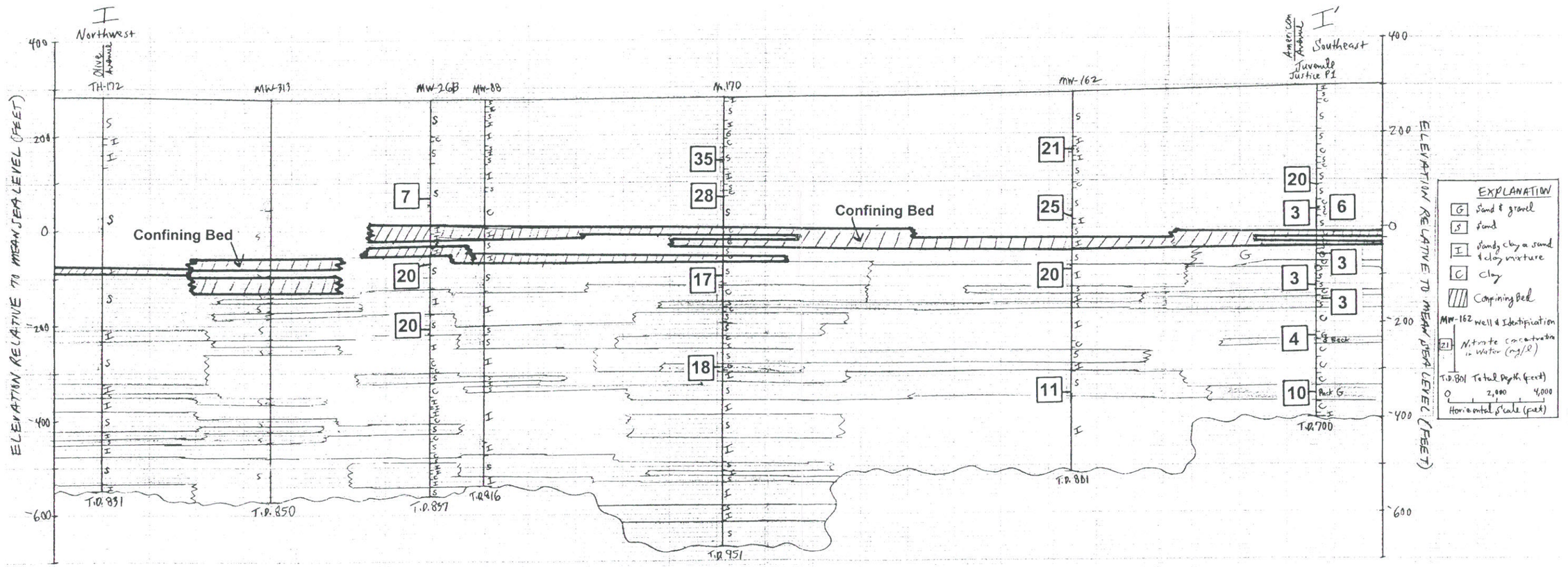
FIGURE 9

SUBSURFACE GEOLOGIC CROSS SECTION C-C'

SAC32704.04.55 DECEMBER 1991
FILE: 32704F51.DWG (REL. 11)



SUBSURFACE GEOLOGIC CROSS SECTION H-H'



SUBSURFACE GEOLOGIC CROSS SECTION I-I'