

APPENDIX G

Groundwater Basin Descriptions and
Discussion on Groundwater Operational Yield

San Joaquin Valley Groundwater Basin Modesto Subbasin

- Groundwater Subbasin Number: 5-22.02
- County: Stanislaus
- Surface Area: 247,000 acres (385 square miles)

Basin Boundaries and Hydrology

The San Joaquin Valley is surrounded on the west by the Coast Ranges, on the south by the San Emigdio and Tehachapi Mountains, on the east by the Sierra Nevada and on the north by the Sacramento-San Joaquin Delta and Sacramento Valley. The northern portion of the San Joaquin Valley drains toward the Delta by the San Joaquin River and its tributaries, the Fresno, Merced, Tuolumne, and Stanislaus Rivers. The southern portion of the valley is internally drained by the Kings, Kaweah, Tule, and Kern Rivers that flow into the Tulare drainage basin including the beds of the former Tulare, Buena Vista, and Kern Lakes.

The Modesto subbasin lies between the Stanislaus River to the north and Tuolumne River to the south and between the San Joaquin River on the west and crystalline basement rock of the Sierra Nevada foothills on the east. The northern, western, and southern boundaries are shared with the Eastern San Joaquin Valley, Delta-Mendota, and Turlock Groundwater Subbasins, respectively. The subbasin comprises land primarily in the Modesto Irrigation District (MID) and the southern two-thirds of the Oakdale Irrigation District (OID). The City of Modesto is in the southwestern portion of the subbasin. Average annual precipitation for this subbasin is 11 to 15 inches, increasing eastward.

Hydrogeologic Information

The San Joaquin Valley represents the southern portion of the Great Central Valley of California. The San Joaquin Valley is a structural trough up to 200 miles long and 70 miles wide. It is filled with up to 32,000 feet of marine and continental sediments deposited during periodic inundation by the Pacific Ocean and by erosion of the surrounding mountains, respectively. Continental deposits shed from the surrounding mountains form an alluvial wedge that thickens from the valley margins toward the axis of the structural trough. This depositional axis is below to slightly west of the series of rivers, lakes, sloughs, and marshes, which mark the current and historic axis of surface drainage in the San Joaquin Valley.

Water Bearing Formations

The primary hydrogeologic units in the Modesto Subbasin include both consolidated and unconsolidated sedimentary deposits. The consolidated deposits include the Ione Formation of Miocene age, the Valley Springs Formation of Eocene age, and the Mehrten Formation, which was deposited during the Miocene to Pliocene Epochs. The consolidated deposits lie in the eastern portion of the subbasin and generally yield small quantities of water to wells except for the Mehrten Formation, which is an important aquifer. In the Subbasin, the Mehrten Formation is composed of up to 300 feet of sandstone, breccia, conglomerate, tuff siltstone and claystone (Page 1973).

The unconsolidated deposits were laid down during the Pliocene to present and, from oldest to youngest, include continental deposits lacustrine and marsh deposits, older alluvium, younger alluvium, and flood-subbasin deposits. The continental deposits and older alluvium are the main water-yielding units in the unconsolidated deposits. The lacustrine and marsh deposits (which include the Corcoran, or "E-" Clay), and the flood-subbasin deposits yield little water to wells, and the younger alluvium in most places probably yields only moderate quantities of water to wells (Page 1973).

The continental deposits consist of poorly sorted gravel, sand, silt and clay varying in thickness from 0 to 450 feet occurring at the surface on the eastern side of the subbasin to over 400 feet deep in the western portion. These deposits are the equivalent of the North Merced Gravels and the lower Turlock Lake Formation (Davis and others 1959). The older alluvium consists of intercalated beds of gravel sand, silt and clay with some hardpan. This alluvium is up to 400 feet thick and is generally present near or at the surface of the western one-half of the subbasin. The older alluvium is largely equivalent to the Riverbank and Modesto Formations (Davis and others 1959).

Ground water occurs under unconfined, semi-confined, and confined conditions. The unconfined water body occurs in the unconsolidated deposits above and east of the Corcoran Clay, which underlies the southwestern portion of the subbasin at depths ranging from 150 to 250 feet (DWR 1981). Where clay lenses restrict the downward flow of ground water, semi-confined conditions occur. The confined water body occurs in the unconsolidated deposits below the Corcoran Clay and extends downward to the base of fresh water.

The estimated average specific yield of this subbasin is 8.8 percent (based on DWR San Joaquin District internal data and Davis and others 1959).

Restrictive Structures

Groundwater flow is primarily to the southwest, following the regional dip of basement rock and sedimentary units. The lower to middle reaches of the Stanislaus and Tuolumne Rivers in the Subbasin appear to be gaining streams with groundwater flow into both, especially the Tuolumne River (DWR 2000). No faults have been identified that affect the movement of fresh groundwater (Page and Balding 1973).

Recharge Areas

Groundwater recharge is primarily from deep percolation of applied irrigation water and canal seepage from MID and OID facilities. Seepage from Modesto Reservoir is also significant (STRGBA 1995). Lesser recharge occurs as a result of subsurface flows originating in the mountains and foothills along the east side of the subbasin, losses from minor streams, and from percolation of direct precipitation.

Groundwater Level Trends

Changes in groundwater levels are based on annual water level measurements by DWR and cooperators. Water level changes were

evaluated by quarter township and computed through a custom DWR computer program using geostatistics (kriging). On average, the subbasin water level has declined nearly 15 feet from 1970 through 2000. The period from 1970 through 1978 showed steep declines totaling about 12 feet. The six-year period from 1978 to 1984 saw stabilization and rebound of about 7 feet. 1984 through 1995 again showed steep declines, bottoming out in 1995 at nearly 20 feet below the 1970 level. Water levels then rose about 5 feet from 1996 to 2000. Water level declines have been more severe in the eastern portion of the subbasin, but have risen faster in the eastern subbasin between 1996 and 2000 than in any other portion of the subbasin.

Groundwater Storage

Estimations of the total storage capacity of the subbasin and the amount of water in storage as of 1995 were calculated using an estimated specific yield of 8.8 percent and water levels collected by DWR and cooperators.

According to these calculations, the total storage capacity of this subbasin is estimated to be 6,500,000 af to a depth of 300 feet. According to published literature, the amount of stored groundwater in this subbasin as of 1961 is 14,000,000 af to a depth of ≤ 1000 feet (Williamson 1989).

Groundwater Budget (Type B)

Although a detailed budget was not available for this subbasin, an estimate of groundwater demand was calculated based on the 1990 normalized year and data on land and water use. A subsequent analysis was done by a DWR water budget spreadsheet to estimate overall applied water demands, agricultural groundwater pumpage, urban pumping demand and other extraction data.

Natural recharge into the subbasin is estimated to be 86,000 af. Artificial recharge and subsurface inflow values are not determined. There is approximately 92,000 af of applied water recharge. Annual urban and agricultural extractions are estimated to be 81,000 and 145,000 af, respectively. There are no other extractions, and values for subsurface outflow are not determined.

Groundwater Quality

Characterization. The groundwater in this basin is of a calcium bicarbonate type in the eastern subbasin to a calcium-magnesium bicarbonate or calcium-sodium bicarbonate type in the western portion. TDS values range from 60 to 8,300 mg/L, with a typical range of 200 to 500 mg/L. The Department of Health Services, which monitors Title 22 water quality standards, reports TDS values in 88 wells ranging from 60 to 860 mg/L, with an average value of 295 mg/L.

Impairments. There are areas of hard groundwater and localized areas of high chloride, boron, DBCP, nitrate, iron, and manganese. Some sodium chloride waters of high TDS values are found along the east side of the subbasin. There are also some areas of shallow groundwater in the subbasin that require dewatering wells.

Water Quality in Public Supply Wells

Constituent Group ¹	Number of wells sampled ²	Number of wells with a concentration above an MCL ³
Inorganics – Primary	110	3
Radiological	109	25
Nitrates	114	3
Pesticides	117	14
VOCs and SVOCs	117	8
Inorganics – Secondary	110	8

¹ A description of each member in the constituent groups and a generalized discussion of the relevance of these groups are included in *California's Groundwater – Bulletin 118* by DWR (2003).

² Represents distinct number of wells sampled as required under DHS Title 22 program from 1994 through 2000.

³ Each well reported with a concentration above an MCL was confirmed with a second detection above an MCL. This information is intended as an indicator of the types of activities that cause contamination in a given basin. It represents the water quality at the sample location. It does not indicate the water quality delivered to the consumer. More detailed drinking water quality information can be obtained from the local water purveyor and its annual Consumer Confidence Report.

Well Characteristics

	Well yields (gal/min)	
Municipal/Irrigation	Range: 350 – 4,500	Average: 1,000 - 2,000
	Total depths (ft)	
Domestic		
Municipal/Irrigation	Range: 50 - 500	

Active Monitoring Data

Agency	Parameter	Number of wells /measurement frequency
DWR (incl. Cooperators)	Groundwater levels	230 Semi-annually
Oakdale Irrigation District	Drinking water parameters	15 Monthly to every 3 years
Department of Health Services (including Cooperators)	Title 22 water quality	209 Varies

Basin Management

Groundwater management: The Stanislaus and Tuolumne Rivers' Groundwater Subbasin Association has developed an AB3030 ground water management plan for the individual Association members (City of Modesto, Del Este Water Company, County of Stanislaus, Oakdale I.D., City of Oakdale, City of Riverbank, and Modesto I.D.)

Conjunctive use programs, stormwater recharge subbasins, water conservation programs operated by Oakdale and Modesto I.Ds., Stanislaus County and other public entities.

Water agencies

Public

Oakdale I.D., Modesto I.D.; Stanislaus and Tuolumne Rivers' Groundwater Subbasin Association; City of Oakdale; City of Riverbank

Private

References Cited

California Department of Water Resources (DWR), San Joaquin District. Unpublished Land and Water Use Data.

_____. Well completion report files.

_____. 1981. *Depth to Top of Corcoran Clay*. 1:253,440 scale map.

_____. 1995. Internal computer spreadsheet for 1990 normal computation of net water demand used in preparation of DWR Bulletin 160-93.

_____. 2000. *Spring 1999, Lines of Equal Elevation of Water in Wells, Unconfined Aquifer*. 1:253,440 scale map sheet.

Davis, GH, Green, JH, Olmstead, SH, and Brown, DW. 1959. *Ground Water Conditions and Storage Capacity in the San Joaquin Valley, California*; US Geological Survey Water Supply Paper No. 1469, 287p.

Page, RW, and Balding, GO. 1973. *Geology and Quality of Water in the Modesto-Merced Area, San Joaquin Valley, California, with a Brief Section of Hydrology*. USGS Water-Resources Investigations 6-73, 85p.

Stanislaus and Tuolumne Rivers' Groundwater Subbasin Association (STRGBA). 1995. *Development of a Groundwater Management Plan Phase I*. Technical Memorandum. Prepared by Black & Veatch, Provost & Pritchard, and Kenneth D. Schmidt & Associates Consulting Firms.

Williamson, Alex K, Prudic, David E, and Swain, Lindsay A. 1989. *Groundwater flow in the Central Valley, California*. US Geological Survey Professional Paper 1401-D. 127 p.

Additional References

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California Department of Water Resources (DWR). 1980. Bulletin 118-80, Ground Water Subbasins in California.

_____. 1994. Bulletin 160-93. California Water Plan Update, Vol. 1.

Davis, SN and Hall, FR. 1959. Water Quality of Eastern Stanislaus and North Merced Counties, California; Stanford Univ. Pubs., Geol. Sci., v. 6, no. 1. 112 p.

Errata

Changes made to the basin description will be noted here.

San Joaquin Valley Groundwater Basin Turlock Subbasin

- Groundwater Basin Number: 5-22.03
- County: Stanislaus, Merced
- Surface Area: 347,000 acres (542 square miles)

Basin Boundaries and Hydrology

The San Joaquin Valley is surrounded on the west by the Coast Ranges, on the south by the San Emigdio and Tehachapi Mountains, on the east by the Sierra Nevada and on the north by the Sacramento-San Joaquin Delta and Sacramento Valley. The northern portion of the San Joaquin Valley drains toward the Delta by the San Joaquin River and its tributaries, the Fresno, Merced, Tuolumne, and Stanislaus Rivers. The southern portion of the valley is internally drained by the Kings, Kaweah, Tule, and Kern Rivers that flow into the Tulare drainage basin including the beds of the former Tulare, Buena Vista, and Kern Lakes.

The Turlock Subbasin lies between the Tuolumne and Merced Rivers and is bounded on the west by the San Joaquin River and on the east by crystalline basement rock of the Sierra Nevada foothills. The northern, western, and southern boundaries are shared with the Modesto, Delta-Mendota, and Merced Groundwater Subbasins, respectively. The subbasin includes lands in the Turlock Irrigation District, the Ballico-Cortez Water District, the Eastside Water District, and a small portion of Merced I.D. Average annual precipitation is estimated as 11 to 13 inches, increasing eastward, with 15 inches in the Sierran foothills.

Hydrogeologic Information

The San Joaquin Valley represents the southern portion of the Great Central Valley of California. The San Joaquin Valley is a structural trough up to 200 miles long and 70 miles wide. It is filled with up to 32,000 feet of marine and continental sediments deposited during periodic inundation by the Pacific Ocean and by erosion of the surrounding mountains, respectively. Continental deposits shed from the surrounding mountains form an alluvial wedge that thickens from the valley margins toward the axis of the structural trough. This depositional axis is below to slightly west of the series of rivers, lakes, sloughs, and marshes that mark the current and historic axis of surface drainage in the San Joaquin Valley.

Water Bearing Formations

The primary hydrogeologic units in the Turlock Subbasin include both consolidated and unconsolidated sedimentary deposits. The consolidated deposits include the Ione Formation of Miocene age, the Valley Springs Formation of Eocene age, and the Mehrten Formation, which was deposited during the Miocene to Pliocene Epochs. The consolidated deposits lie in the eastern portion of the subbasin and generally yield small quantities of water to wells except for the Mehrten Formation, which is an important aquifer. The Mehrten Formation is composed of up to 800 feet of sandstone, breccia, conglomerate, tuff siltstone and claystone (Page 1973).

Unconsolidated deposits include continental deposits, older alluvium, younger alluvium, and flood-basin deposits. Lacustrine and marsh deposits, which constitute the Corcoran or E-clay aquitard, underlie the western half of the subbasin at depths ranging between about 50 and 200 feet (DWR 1981). The continental deposits and older alluvium are the main water-yielding units in the unconsolidated deposits. The lacustrine and marsh deposits and the flood-subbasin deposits yield little water to wells. The younger alluvium, in most places, probably yields only moderate quantities of water.

There are three ground water bodies in the Turlock Subbasin: the unconfined water body; the semi-confined and confined water body in the consolidated rocks; and the confined water body beneath the E-clay in the western Subbasin. The estimated average specific yield of the subbasin is 10.1 percent (based on DWR San Joaquin District internal data and Davis 1959).

Restrictive Structures

Groundwater flow is primarily to the southwest, following the regional dip of basement rock and sedimentary units. Based on recent groundwater measurements (DWR 2000), a paired groundwater mound and depression appear beneath the city of Turlock and to its east, respectively. The lower to middle reaches of the Tuolumne River and the reach of the San Joaquin River in the subbasin appear to be gaining streams during this period also. No faults have been identified that affect the movement of fresh groundwater (Page 1973).

Groundwater Level Trends

Changes in groundwater levels are based on annual water level measurements by DWR and cooperators. Water level changes were evaluated by quarter township and computed through a custom DWR computer program using geostatistics (kriging). On average the subbasin water level has declined nearly 7 feet from 1970 through 2000. The period from 1970 through 1992 showed a generally steep decline totaling about 15 feet. Between 1992 and 1994, water levels stayed near this low level. From 1994 to 2000, the water levels rebounded about 8 feet, bringing them to approximately 7 feet below the 1970 levels. Water level declines have been more severe in the eastern portion of the subbasin after 1982. From 1970 to 1982, water level declines were more severe in the western portion of the subbasin.

Groundwater Storage

Estimations of the total storage capacity of the subbasin and the amount of water in storage as of 1995 were calculated using an estimated specific yield of 10.1 percent and water levels collected by DWR and cooperators. According to these calculations, the total storage capacity of this subbasin is estimated to be 15,800,000 af to a depth of 300 feet and 30,000,000 af to the base of fresh groundwater. These same calculations give an estimate of 12,800,000 af of groundwater to a depth of 300 feet stored in this subbasin as of 1995 (DWR 1995). According to published literature, the amount of stored groundwater in this subbasin as of 1961 is 23,000,000 af to a depth of \leq 1000 feet (Williamson 1989).

Groundwater Budget (Type B)

Although a detailed budget was not available for this subbasin, an estimate of groundwater demand was calculated based on the 1990 normalized year and data on land and water use. A subsequent analysis was done by a DWR water budget spreadsheet to estimate overall applied water demands, agricultural groundwater pumpage, urban pumping demand and other extraction data.

Natural recharge of the subbasin was estimated to be 33,000 af. Artificial recharge and subsurface inflow were not determined. Applied water recharge was calculated to be 313,000 af. Annual urban extraction and annual agricultural extraction were calculated at 65,000 and 387,000 af, respectively. Other extractions and subsurface inflow were not determined.

Groundwater Quality

Characterization. The groundwater in this subbasin is predominately of the sodium-calcium bicarbonate type, with sodium bicarbonate and sodium chloride types at the western margin and a small area in the north-central portion. TDS values range from 100 to 8,300 mg/L, with a typical range of 200 to 500 mg/L. The Department of Health Services, which monitors Title 22 water quality standards, reports TDS values in 71 wells ranging from 100 to 930 mg/L, with an average value of 335 mg/L. EC values range from 168 to 1,000 μ mhos/cm, with a typical range of 244 to 707 μ mhos/cm.

Impairments. There are localized areas of hard groundwater, nitrate, chloride, boron, and DBCP. Some sodium chloride type water of high TDS is found along the west side of the subbasin. Two wells in the city of Turlock have been closed, one for nitrate and one for carbon tetrachloride (Dan Wilde 2001).

Water Quality in Public Supply Wells

Constituent Group¹	Number of wells sampled²	Number of wells with a concentration above an MCL³
Inorganics – Primary	84	0
Radiological	80	12
Nitrates	90	8
Pesticides	89	5
VOCs and SVOCs	86	3
Inorganics – Secondary	84	11

¹ A description of each member in the constituent groups and a generalized discussion of the relevance of these groups are included in *California's Groundwater – Bulletin 118* by DWR (2003).

² Represents distinct number of wells sampled as required under DHS Title 22 program from 1994 through 2000.

³ Each well reported with a concentration above an MCL was confirmed with a second detection above an MCL. This information is intended as an indicator of the types of activities that cause contamination in a given basin. It represents the water quality at the sample location. It does not indicate the water quality delivered to the consumer. More detailed drinking water quality information can be obtained from the local water purveyor and its annual Consumer Confidence Report.

Well Characteristics

Well yields (gal/min)	
Municipal/Irrigation	Range: 200 – 4,500 Average: 1,000 - 2,000
Total depths (ft)	
Domestic	
Municipal/Irrigation	Range: 50 - 350

Active Monitoring Data

Agency	Parameter	Number of wells /measurement frequency
DWR (incl. Cooperators)	Groundwater levels	307 Semi-annually
Department of Health Services (including cooperators)	Title 22 water quality	163 Varies

Basin Management

Groundwater management:	Turlock District has an adopted AB 3030 ground water management plan. Eastside WD adopted its plan on September 25, 1997.
Water agencies	
Public	Eastside Water District , Turlock Irrigation District, Ballico-Cortez Water District (inactive), Merced I.D. (portion).
Private	

References Cited

- California Department of Water Resources (DWR), San Joaquin District. Unpublished Land and Water Use Data.
- _____. 1995. Internal computer spreadsheet for 1990 normal computation of net water demand used in preparation of DWR Bulletin 160-93.
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Davis, S.N. and Hall, F.R. 1959. *Water Quality of Eastern Stanislaus and North Merced Counties, California*. Stanford Univ. Pubs., Geol. Sci., v.6, no. 1. 112 p.

Errata

Updated groundwater management information and added hotlinks where applicable.
(1/20/06)

San Joaquin Valley Groundwater Basin Delta-Mendota Subbasin

- Groundwater Subbasin Number: 5-22.07
- County: Stanislaus, Merced, Madera, Fresno
- Surface Area: 747,000 acres (1,170 square miles)

Basin Boundaries and Hydrology

The San Joaquin Valley is surrounded on the west by the Coast Ranges, on the south by the San Emigdio and Tehachapi Mountains, on the east by the Sierra Nevada and on the north by the Sacramento-San Joaquin Delta and Sacramento Valley. The northern portion of the San Joaquin Valley drains toward the Delta by the San Joaquin River and its tributaries, the Fresno, Merced, Tuolumne, and Stanislaus Rivers. The southern portion of the valley is internally drained by the Kings, Kaweah, Tule, and Kern Rivers that flow into the Tulare drainage basin including the beds of the former Tulare, Buena Vista, and Kern Lakes.

The Delta-Mendota subbasin is bounded on the west by the Tertiary and older marine sediments of the Coast Ranges, and on the north by the Stanislaus/San Joaquin county line. The eastern boundary follows the San Joaquin River to Township 11 S, where it jogs eastward and follows the eastern boundary of Columbia Canal company to the San Joaquin River, then follows the Chowchilla Bypass and the eastern border of Farmer's Water District. It then trends southerly through Township 14S Range 15E on the eastern side of Fresno Slough, then follows the Tranquility ID boundary to its southern extremity. Heading northward, it follows the eastern, northern, and northwestern boundary of San Joaquin Valley – Westside Groundwater Subbasin (corresponding with Westlands Water District boundaries). Average annual precipitation is nine to 11 inches, increasing northwards.

Hydrogeologic Information

The San Joaquin Valley represents the southern portion of the Great Central Valley of California. The San Joaquin Valley is a structural trough up to 200 miles long and 70 miles wide filled with up to 32,000 feet of marine and continental sediments deposited during periodic inundation by the Pacific Ocean and by erosion of the surrounding mountains, respectively. Continental deposits shed from the surrounding mountains form an alluvial wedge that thickens from the valley margins toward the axis of the structural trough. This depositional axis is below to slightly west of the series of rivers, lakes, sloughs, and marshes, which mark the current and historic axis of surface drainage in the San Joaquin Valley.

Water Bearing Formations

The geologic units that comprise the ground water reservoir in the Delta-Mendota subbasin consist of the Tulare Formation, terrace deposits, alluvium, and flood-basin deposits. The Tulare Formation is composed of beds, lenses, and tongues of clay, sand, and gravel that have been alternately deposited in oxidizing and reducing environments (Hotchkiss 1971). The Corcoran Clay Member of the formation underlies the basin at depths ranging about 100 to 500 feet and acts as a confining bed (DWR 1981).

Terrace deposits of Pleistocene age lie up to several feet higher than present streambeds. They are composed of yellow, tan, and light-to-dark brown silt, sand, and gravel with a matrix that varies from sand to clay (Hotchkiss 1971). The water table generally lies below the bottom of the terrace deposits. However, the relatively large grain size of the terrace deposits suggests their value as possible recharge sites.

Alluvium is composed of interbedded, poorly to well-sorted clay, silt, sand, and gravel and is divided based on its degree of dissection and soil formation. The flood-basin deposits are generally composed of light-to-dark brown and gray clay, silt, sand, and organic materials with locally high concentrations of salts and alkali. Stream channel deposits of coarse sand and gravel are also included.

Groundwater in the Delta-Mendota subbasin occurs in three water-bearing zones. These include the lower zone, which contains confined fresh water in the lower section of the Tulare Formation, an upper zone which contains confined, semi-confined, and unconfined water in the upper section of the Tulare Formation and younger deposits, and a shallow zone which contains unconfined water within about 25 feet of the land surface (Davis 1959).

The estimated specific yield of this subbasin is 11.8 percent (based on DWR San Joaquin District internal data and Davis 1959). Land subsidence up to about 16 feet has occurred in the southern portion of the basin due to artesian head decline (Ireland 1964).

Restrictive Structures

Groundwater flow was historically northwestward parallel to the San Joaquin River (Hotchkiss 1971). Recent data (DWR 2000) show flow to the north and eastward, toward the San Joaquin River. Based on current and historical groundwater elevation maps, groundwater barriers do not appear to exist in the subbasin.

Groundwater Level Trends

Changes in groundwater levels are based on annual water level measurements by DWR and cooperators. Water level changes were evaluated by quarter township and computed through a custom DWR computer program using geostatistics (kriging). On average, the subbasin water level has increased by 2.2 feet from 1970 through 2000. The period from 1970 through 1985 showed a general increase, topping out in 1985 at 7.5 feet above the 1970 water level. The nine-year period from 1985 to 1994 saw general declines in groundwater levels, reaching back down to the 1970 groundwater level in 1994. Groundwater levels rose in 1995 to about 2.2 feet above the 1970 groundwater level. Water levels fluctuated around this value until 2000.

Groundwater Storage

Estimations of the total storage capacity of the subbasin and the amount of water in storage as of 1995 were calculated using an estimated specific yield of 11.8 percent and water levels collected by DWR and cooperators.

According to these calculations, the total storage capacity of this subbasin is estimated to be 30,400,000 af to a depth of 300 feet and 81,800,000 af to the base of fresh groundwater. These same calculations give an estimate of 26,600,000 af of groundwater to a depth of 300 feet stored in this subbasin as of 1995 (DWR 1995). According to published literature, the amount of stored groundwater in this subbasin as of 1961 is 51,000,000 af to a depth of \leq 1,000 feet (Williamson 1989).

Groundwater Budget (Type B)

Although a detailed budget was not available for this subbasin, an estimate of groundwater demand was calculated based on the 1990 normalized year and data on land and water use. A subsequent analysis was done by a DWR water budget spreadsheet to estimate overall applied water demands, agricultural groundwater pumpage, urban pumping demand and other extraction data.

Natural recharge is estimated to be 8,000 af. Artificial recharge and subsurface inflow are not determined. Applied water recharge is approximately 74,000 af. Annual urban and agricultural extractions estimated to be 17,000 af and 491,000 af, respectively. Other extractions are approximately 3,000 af, and subsurface outflow is not determined.

Groundwater Quality

Characterization. The groundwater in this subbasin is characterized by mixed sulfate to bicarbonate types in the northern and central portion with areas of sodium chloride and sodium sulfate waters in the central and southern portion. TDS values range from 400 to 1,600 mg/L in the northern portion of the subbasin and from 730 to 6,000 mg/L in the southern portion of the subbasin (Hotchkiss 1971). The Department of Health Services (DHS), which monitors Title 22 water quality standards, reports TDS values in 44 public supply wells to range from 210 to 1,750 mg/L, with an average value of 770 mg/L. A typical range of water quality in wells is 700-1,000 mg/L.

Impairments. Shallow, saline groundwater occurs within about 10 feet of the ground surface over a large portion of the subbasin. There are also localized areas of high iron, fluoride, nitrate, and boron in the subbasin (Hotchkiss 1971).

Water Quality in Public Supply Wells

Constituent Group¹	Number of wells sampled²	Number of wells with a concentration above an MCL³
Inorganics – Primary	47	2
Radiological	47	1
Nitrates	51	4
Pesticides	47	1
VOCs and SVOCs	45	0
Inorganics – Secondary	47	18

¹ A description of each member in the constituent groups and a generalized discussion of the relevance of these groups are included in *California's Groundwater – Bulletin 118* by DWR (2003).

² Represents distinct number of wells sampled as required under DHS Title 22 program from 1994 through 2000.

³ Each well reported with a concentration above an MCL was confirmed with a second detection above an MCL. This information is intended as an indicator of the types of activities that cause contamination in a given basin. It represents the water quality at the sample location. It does not indicate the water quality delivered to the consumer. More detailed drinking water quality information can be obtained from the local water purveyor and its annual Consumer Confidence Report.

Well Characteristics

Well yields (gal/min)		
Municipal/Irrigation	Range: 20 – 5,000	Average: 800-2,000
Total depths (ft)		
Domestic		
Municipal/Irrigation	Range: 50 - 800	Average: 400-600

Active Monitoring Data

Agency	Parameter	Number of wells /measurement frequency
DWR (incl. Cooperators)	Groundwater levels	816 Semi-annually
DWR (incl. Cooperators) Department of Health Services (incl. Cooperators)	Mineral, nutrient, & minor element. Title 22 water quality	120 Varies

Basin Management

Groundwater management:	Panoche Water District is approximately 11 months into the AB3030 process and will be doing a joint plan with other districts and the county. San Luis and Delta-Mendota Water Authority North adopted an AB 3030 plan on December 5, 1997.
Water agencies	
Public	Merced County, Fresno County, Broadview WD, Centinella WD, Central California ID, Davis WD, Del Puerto WD, Eagle Field WD, El Solyo WD, Farmers WD, Firebaugh Canal WD, Foothill WD, Fresno Slough WD, Grasslands WD, Hospital WD, Kern Canon WD, Laguna WD, Mercy Springs WD, Mustang WD, Oak Flat WD, Orestimba WD, Oro Loma WD, Pacheco WD, Panoche WD, Patterson WD, Romero WD, Salado WD, San Luis Canal Company, San Luis WD, Santa Nella C.WD, Sunflower WD, Tranquility ID, West Stanislaus ID, Widren WD, Quinto WD
Private	None.

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Errata

Updated groundwater management information and added hotlinks to applicable websites.
(1/20/06)

APPENDIX G GROUNDWATER OPERATIONAL YIELD MEMORANDUM

Preface

The attached memorandum entitled “Discussion on Operational Yield for the 2005 Urban Water Management Plan” was prepared by the City of Modesto and included in the Joint City of Modesto/MID 2005 Urban Water Management Plan (UWMP). The purpose of the memorandum was to describe the basis for estimating the “operational yield”, or annual groundwater pumping quantity, that could be extracted from the aquifer underlying the City’s water service area that includes the Modesto, Turlock and Delta-Mendota sub-basins. As described in the memorandum, the City’s Operational Yield was estimated to be 53,500 acre-feet per year.

The memorandum describes that the City had increased its groundwater pumping in recent years (from 1999 to 2002) to meet growing demands, but that the City’s reliance on groundwater is anticipated to decrease when the Modesto Regional Water Treatment Plant (MRWTP) Phase Two is completed. Although the completion of MRWTP Phase Two has been delayed (currently anticipated to be completed in late 2012), the findings and conclusions described in the memorandum have not changed and are appropriate for inclusion in the Joint City of Modesto/MID 2010 UWMP.

It should be noted that the United States Geological Survey (USGS) is currently in the process of developing a simulation/optimization model of the Modesto Area Groundwater Basin for use in evaluating water resources management alternatives. It is anticipated that this USGS study will be completed by mid-2011. The findings of the USGS study may result in changes to the City’s estimate of the Operational Yield. However, the City’s current estimate of the Operational Yield of 53,500 af/yr will continue to be assumed pending the USGS study findings.

Memo

To: Nick Pinhey – Public Works Director
Rolly Stevens – Assistant City Attorney
Alison Barratt-Green – Senior Deputy City Attorney

From: William Wong – Associate Civil Engineer

CC: Rich Ulm, Jack Bond, Garner Reynolds, Jim Alves, Violet Jakab, Allen Lagarbo

Date:

Re: **FINAL** - Discussion on Operational Yield for the 2005 Urban Water Management Plan (UWMP)

This memorandum establishes an empirical basis for estimating the “operational yield” for the rate of groundwater pumping within the City’s water service area that includes the Modesto, Turlock, and Delta-Mendota sub-basins. Information incorporated into this study includes water well pumping records, groundwater elevation data, and future demands based on land use densities at build-out.

For clarification, and as used in this report, the following terms are defined:

Operational Yield – is an amount (or rate in acre-feet per year) of localized groundwater withdrawn on an annual average basis by a given agency that does not exceed the long-term annual average recharge rate of the localized aquifer(s) from which the groundwater is being pumped.

Sustainable Yield – is similar to operational yield, but applies to an entire groundwater basin and all of the entities pumping from it as a whole, rather than just a localized area and a specific agency.

Safe Yield – is everything defined for sustainable yield, but also includes other considerations beyond just a quantity of water extracted or recharged, such as its quality and potential surface subsidence issues. Safe yield can be defined as the maximum amount of water that can be pumped without creating any long-term undesirable results. However, for the purposes of this report, safe yield is considered to be synonymous with sustainable yield.

Overdraft – is when the long-term annual average rate of extracted groundwater exceeds the annual average rate of recharge, as measured by groundwater levels (as measure of groundwater volume is difficult). Overdraft is also defined as the deficit between the water pumped from a groundwater basin and the long-term basin recharge.

The basis of previous estimates of the combined City’s “safe yield” of 50,000 AFY repeated in various City documents is not clear through researching of available literature. Previous documents reference a historic water budget, using data that was not directly measured, but estimated. The uncertainty of this data and the

determination of the safe yield are currently considered questionable, and recent data suggests that this value may not be correct.

This memorandum attempts to use existing data from various sources to reconcile an estimate of the City's current groundwater operational yield, instead of "safe yield" for the entire City of Modesto's Water Service Area.

Establishing an Operational Yield:

It is envisioned that the City will undertake a more comprehensive, hydro-geological groundwater yield study in the upcoming fiscal year where more resources can be devoted to the task of quantifying the City's groundwater operational yield. Until then, it is believed that the rate of extraction established in this report accurately reflects the best data readily available to staff and will be incorporated into the 2005 Urban Water Management Plan.

Prior to 1995, the City's sole source of domestic water was from groundwater pumping. The effect of long-term groundwater extraction consequently resulted in a decline of groundwater elevation, which led to temporary overdraft conditions, primarily in the downtown Modesto area. However, once the City began to implement conjunctive use by supplementing its water supplies with 33,602 AFY of treated surface water from Phase 1 of the MID Modesto Regional Water Treatment Plant (MRWTP) in 1995, the City has been able to reduce its groundwater extraction. As a result, groundwater levels began to rise correcting the temporary overdraft conditions. **Figure 1** shows that recent groundwater levels have decreased slightly as groundwater pumping increased over the last six years (2000 – 2005); however, until additional hydrogeologic studies are completed, it appears that current groundwater extractions and water levels are, to some extent, in a steady state condition.

The current annual water demands for the entire City of Modesto water system, in the Modesto and Turlock sub-basins, are over 79,000 AFY. The City's current rate of groundwater extractions is about 70% of the historically high pumping levels of 1994, and is not causing an overdraft condition.

Table 1 – Current Annual Groundwater Extractions

Year	Annual GW Extractions from the Modesto Subbasin (AFY) ^a	Annual GW Extractions from the Turlock Subbasin (AFY) ^{a,b}	Average GW Extractions from the Delta-Mendota Subbasin (AFY) ^{a,c}	Totals
2000	37,495	4,958	261	42,714
2001	40,857	4,837	297	45,991
2002	43,535	5,445	324	49,304
2003	41,990	5,053	287	47,330
2004	41,681	4,194	261	46,136
2005	41,090	4,849	237	46,176
Average Annual Groundwater Extractions	41,108	4,889	278	46,275

- a. Based on City of Modesto SCADA records
- b. Includes South Modesto, Hickman, portions of North Ceres and Turlock.
- c. The Community of Grayson is within the Delta-Mendota Subbasin

As shown in **Table 1**, current six-year average (between 2000 and 2005) of groundwater extractions for the entire City of Modesto water system is 46,275 AFY. These water demands also reflect some water conservation due to continuous implementation of Stage I restrictions from the City's Drought Contingency Plan in 2003.

The City maximizes its surface water allocation within the City's contiguous service area, and must rely on groundwater pumping to meet its maximum day and peak hour demands. To meet the demands of future development, the City will currently be working with the MID to double the capacity of the Modesto Regional Water Treatment Plant (MRWTP) to 67,204 AFY. However, the Phase 2 Expansion of the MRWTP is not anticipated to be on-line until mid- to late-2009, and therefore the City will need to increase its groundwater pumping to meet the demands for near-term development. This would be done by drilling new wells, rehabilitating currently out-of-service wells, or increasing the pumping from existing wells.

The movement of groundwater for both sub-basins is generally in a westward direction from the Sierra Nevada foothills. Recent analysis by the USGS and information from California's Groundwater Bulletin 118 has indicated that the geological characteristics of the Modesto and portions of Turlock sub-basins that are served by the City of Modesto appear to be similar. Although the Tuolumne River separates the Modesto and Turlock sub-basins, the USGS has determined that both groundwater and surface water systems are interconnected, and it can be reasonably assumed that groundwater flows between the two sub-basins. This has also been indirectly substantiated by analysis of the City's static well level data; the average groundwater elevations of the City's production wells between the Modesto and Turlock groundwater sub-basins are very comparable. Therefore, in this analysis, it is assumed that the cumulative groundwater extractions by the City apply to the entire City's water service area and no further distinctions are made between the two sub-basins (this does not apply to the Delta-Mendota sub-basin).

Based on California's Groundwater Bulletin 118 for the Modesto Sub-basin, as a result of long-term groundwater pumping, a cone of depression formed when the groundwater elevations reached around 30 feet above sea level (ASL) (see **Figure 2**). In order to extrapolate an operational yield using empirical data, a minimum groundwater elevation of 40 feet ASL was selected as the lowest elevation that the City will allow groundwater to reach. By establishing this minimum groundwater elevation allowable, the City can reasonably establish a conservative operational yield and be certain that the associated amount groundwater pumping should not result in an overdraft condition.

Based on a relative stabilization of groundwater elevations through the City's water service area, the City's current annual average groundwater pumping constitutes a non-overdraft condition, and therefore it can be assumed that the City is within its operational yield range. **Figure 3** plots the City's groundwater pumping and associated well levels between 1993 through 2006. It is apparent that there is not a linear relation between groundwater extractions to groundwater levels. Nevertheless, a linear factor rate was extrapolated from existing well information and can be considered a conservative representation of the effects of groundwater levels due to pumping. An empirical equation was extrapolated from these data points, which estimates that the groundwater levels will decline at a rate of approximately **0.685 feet/1,000 AFY** (or 1 foot per 1,430 AFY) of groundwater extracted over the entire water service area.

It is reasonable that, until hydrogeologic studies are complete, the City can use this estimated rate as the City's "**operational yield factor**". Using 40 ft ASL as the minimum allowable groundwater elevation, the associated **operational groundwater yield** is approximately **53,500 AFY**. This calculated operational yield is a projection of the City's water service area's groundwater pumping capacity (AFY) and is based on the following:

- Groundwater elevation data from 1993 to 2006 obtained from spring and fall field measurements by the City Water Department.
- Groundwater pumping data obtained from Water Department and from the City's SCADA from 2003 to current. Prior pumping records were obtained through Del Este and City of Modesto files.
- Assumes that Ag-to-Urban conversion accounted for in the calculated operational yield estimate.

The calculated operational yield does not account for:

- The City's ability to extract groundwater from the subbasins to meet demands.
- Seasonal peak water demands, and localized water distribution and pressure issues.

- Growth beyond the City's current water service area, either within the contiguous Modesto System or the outlying areas.
- Varying economic factors that could effect the projected growth assumptions.
- More stringent water quality standards would result in potential losses in well production from taking wells out-of-service due to contamination, such as from Arsenic, Nitrates and Uranium.

Additionally, once the City begins necessary groundwater studies to determine an actual operational yield (or specific yield) of the groundwater sub-basins, water budget and quality analyses for the groundwater sub-basins, the City would be able to develop procedures to optimize its groundwater extractions, and determine potential Aquifer Storage and Recovery (ASR) opportunities, where the City could potentially recharge the groundwater basins with surface water during seasonal low demand periods.

Conclusions:

Recent projections from MID anticipate that Phase 2 of the MRWTP expansion will be complete by mid- to late-2009. However, until the additional 33,602 AFY of surface water is available to meet demands, the City will need to increase its groundwater extractions to meet water demands until Phase 2 is on-line.

More extensive studies and modeling will be required to quantify the City's operational yield and water budget for both the Modesto and Turlock sub-basins. However, based on self-imposed groundwater level limits, the City's current Operational Yield is estimated at **53,500 AFY**.

Recent information has indicated that the City has gradually increased its groundwater pumping over the last few years to meet growth demands. It is not anticipated that the City will continue to increase its groundwater extractions for an extended period of time, since Phase 2 is expected to be online by mid- to late- 2009. It is not expected that this short term increase of pumping would cause an overdraft condition in the Modesto Subbasin, which is typically a result from a cumulative effect of long-term over-pumping.

Figure 1 - 1993-2006 Groundwater Elevation and Pumping Data

**ESTIMATED ANNUAL
GROUND WATER ELEVATION vs GROUND WATER
PUMPING
1993 - 2006**

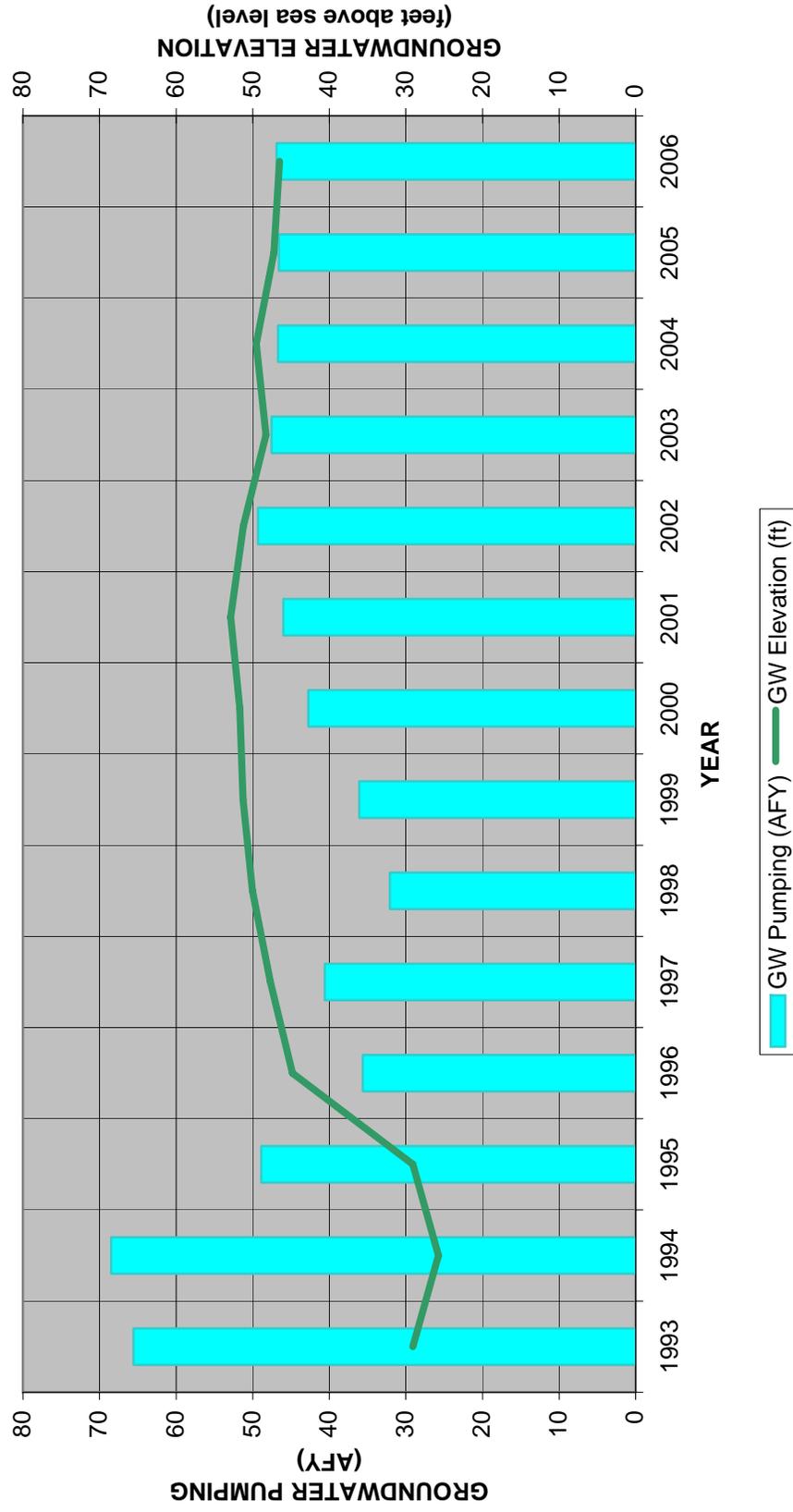
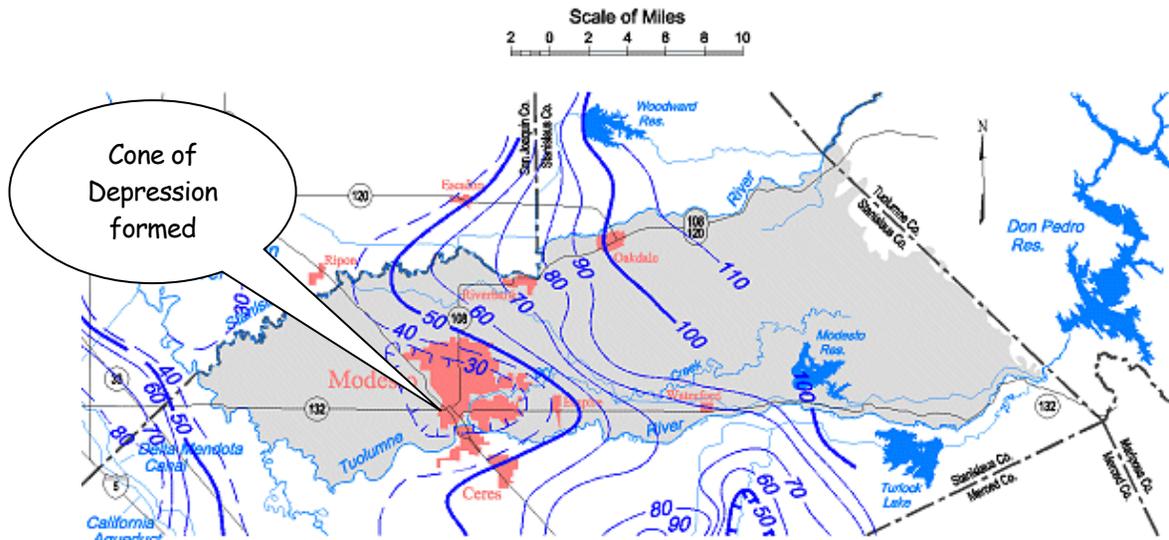


Figure 2 – 1993 and 1998 Groundwater Elevations (above sea level)

Source: Department of Water Resources (DWR) Website - http://www.sjd.water.ca.gov/groundwater/basin_maps/index.cfm

Modesto Groundwater Basin

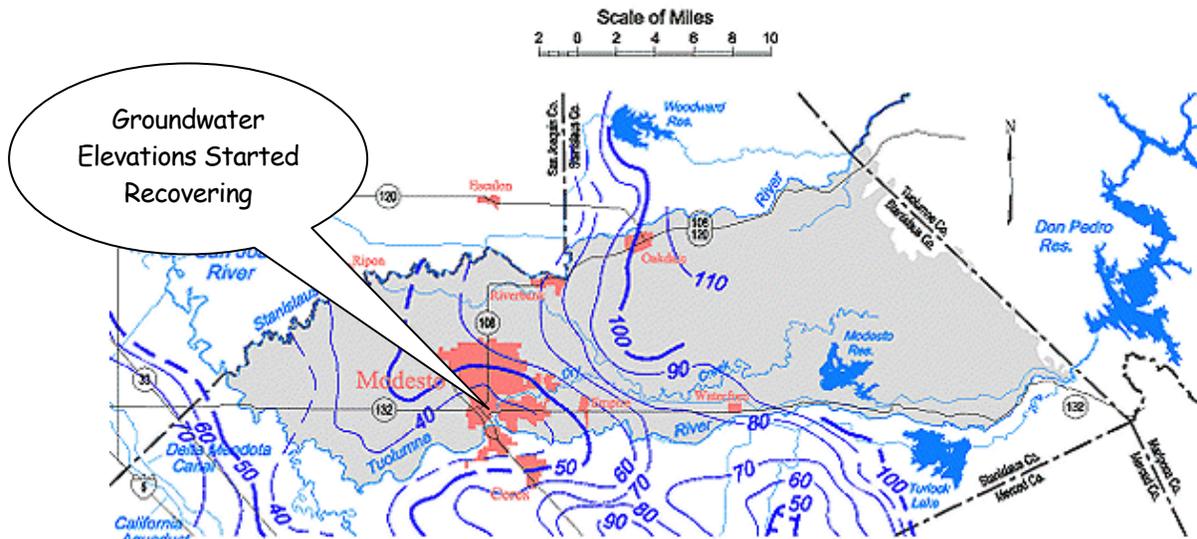
Spring 1993, Lines of Equal Elevation of Water in Wells, Unconfined Aquifer



Contours are dashed where inferred. Contour interval is 10 feet.

Modesto Groundwater Basin

Spring 1998, Lines of Equal Elevation of Water in Wells, Unconfined Aquifer



Contours are dashed where inferred. Contour interval is 10 feet.

Figure 3 - Annual Groundwater Pumping (AFY) vs. Groundwater Elevation (feet, above sea level)

Groundwater Pumping vs Elevation (1993-2006)

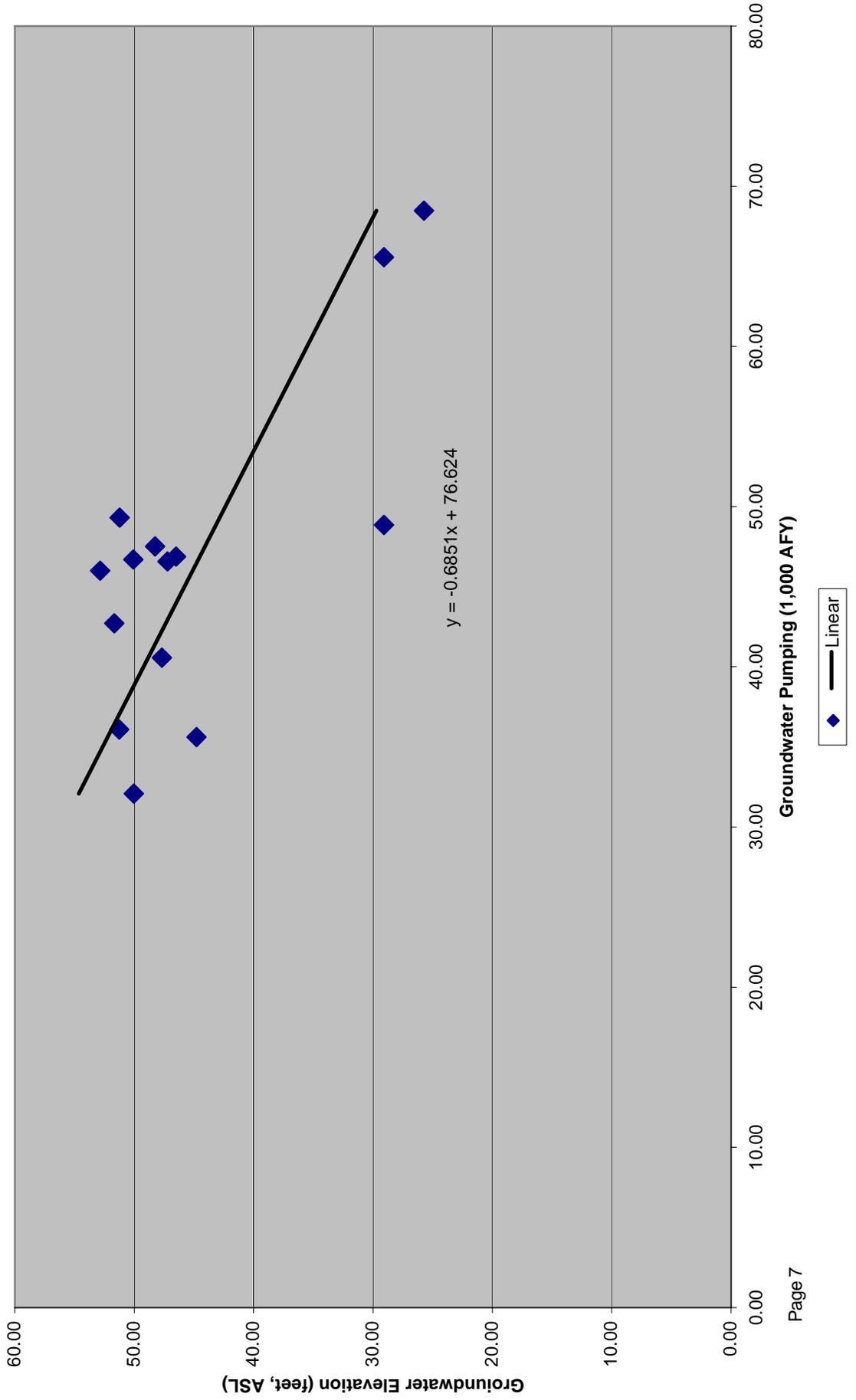


Figure 4 - Projected Near-Term Water Demands (to 2010)

ACTUAL ANNUAL AND PROJECTED GROUND WATER ELEVATION vs GROUND WATER PUMPING

