Dunnigan Water District
Groundwater Management Plan

Prepared pursuant to the
Groundwater Management Act
AB 3030 and SB 1938

Prepared by

DAVIDS
ENGINEERING, INC

July 2007

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Davis, CA

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I. INTRODUCTION

A. Groundwater Management Act

Groundwater is used extensively to meet water supply requirements in many areas throughout California. For these reasons, the California State Legislature has declared groundwater a valuable natural resource, and has determined that groundwater should be managed to ensure both its safe production and its quality. The Groundwater Management Act (AB 3030) was passed by the State Legislature in 1992 and became law January 1, 1993. Groundwater Management Plan requirements were further refined by SB 1938 in September 2002. The act is codified as Sections 10750 *et seq.* of the California Water Code.

This Groundwater Management Plan (GMP), prepared by Dunnigan Water District (DWD or the District), has been developed pursuant to the provisions of AB 3030 and SB 1938. DWD prepared its first GMP in February 2001. This revised GMP incorporates information obtained during the District's Groundwater Management Investigation performed in 2005 and meets the requirements of SB 1938. Many of the figures presented in this document are from the 2005 investigation report.

The District falls within the Colusa Sub-Basin of the Sacramento Valley Groundwater Basin, as defined by the State Department of Water Resources in Bulletin 118-80, Groundwater Basins in California (DWR 1980).

B. Public Involvement

Groundwater is a public resource, which the landowners and residents of the Dunnigan area depend upon for irrigating crops, watering livestock and supplying domestic water. In preparing this GMP update, DWD has published several notices inviting public participation in the GMP development and implementation process in local newspapers. In accordance with California Water Code 10753.2, a notice of intent to adopt a resolution to prepare a GMP and inviting the public to the March 2006 Board meeting was published. A copy of this notice is included in this report (Appendix A).

An advisory committee was formed to aid in developing this GMP update. The committee, composed of interested residents and landowners, was created to help manage groundwater within the Dunnigan area.

DWD is the first agency in Yolo County to develop Basin Management Objectives (BMOs). Thus, the BMO process used by DWD could serve as a model for other agencies in the county. DWD designed and conducted its BMO process to involve all groundwater users in the area. An advisory committee composed of volunteers from the community was established for this process. This is a standing committee that will review the BMOs annually, or more frequently, if needed.

Public participation in the BMO process was initiated by holding a public meeting. The meeting was advertised by direct mailings and fliers. Letters were sent to District landowners and all Dunnigan post office box holders. Additional letters were sent to neighboring agencies inviting them to the public meeting.

The notification documents provided a description of the purpose, place and time of the meeting. Fliers were placed in locations frequented by Dunnigan residents including the post office, local stores and restaurants, and the District office. Copies of the notification letter and flier are included as Appendix B.

At the public meeting, a presentation was made to introduce the public to the BMO process, objectives, and requirements. Copies of the PowerPoint slides used in the presentation are included as Appendix C. Approximately 30 citizens interested in BMOs attended this meeting. A copy of the sign-in sheet for the meeting is included as Appendix D. Following the presentation, questions from the audience were answered and a sign up sheet for the BMO Advisory Committee was distributed.

C. Advisory Committee

A voluntary advisory committee was formed of community members from among those who attended the initial public meeting. No volunteers were denied participation. Technical understanding and a background in groundwater was not required for participation on the committee. Committee meeting notices were provided to community members who had signed up during the public meeting. Additionally, the District placed fliers at the post office and District office to ensure that community members who were not able to attend the public meeting were invited to the committee meeting.

Advisory committee members came from a variety of backgrounds. Some members were long time members of the community and had extensive experience with groundwater in the Dunnigan area. These members were able to provide the committee with a historical overview of the area's groundwater. All of the committee members were concerned about the possibility of urban development in the area and its potential impact on future groundwater conditions.

The advisory committee met twice during July 2005. During the first meeting, background on the development of BMOs was presented. Sample BMOs from other agencies were distributed and discussed. The differences between quantitative and qualitative BMOs were presented along with potential sources of monitoring data. The agenda and handouts from the first meeting are included as Appendix E.

During the second meeting, draft BMOs for the Dunnigan area were presented and discussed. A significant number of committee members were present who had missed the first meeting. A short review of the discussions from the first meeting was provided to bring committee members up to date. BMOs were discussed in further detail, and draft BMOs were approved for submittal to the DWD board. The agenda from the second meeting is included as Appendix F.

D. Plan Components

According to California Water Code Section 10753.7, a groundwater management plan may include components relating to any or all of the following:

- Control of saline water intrusion
- Identification and management of wellhead protection areas and recharge areas
- Regulation of the migration of contaminated groundwater
- Administration of a well abandonment and well destruction program
- Mitigation of conditions of overdraft
- Replenishment of groundwater extracted by water producers
- Monitoring of groundwater levels and storage

- Facilitating conjunctive use operations
- Identification of well construction policies
- Construction and operation by the local agency of groundwater contamination cleanup, recharge, storage, conservation, water recycling and extraction projects
- Development of relationships with state and federal regulatory agencies
- Review of land use plans and coordination with land use planning agencies to assess activities which create a reasonable risk of groundwater contamination

DWD has selected the following six components for its groundwater management plan. They are to:

1. Monitor groundwater levels and quality
2. Facilitate conjunctive use operations
3. Implement aquifer storage and recovery
4. Construct groundwater management facilities
5. Support county wellhead protection program
6. Promote water conservation

Each of these is described in Section XI.

E. Agency Authorization

California Water Code Section 10753 (a) authorizes any local agency, whose service area includes a groundwater basin, or a portion of a groundwater basin, that is not already subject to groundwater management, to adopt and implement a groundwater management plan. Section 10752 (e) defines a groundwater management plan as "a document that describes the activities intended to be included in a groundwater management program." A groundwater management program is defined by Section 10752 (d) as "a coordinated and ongoing activity undertaken for the benefit of a groundwater basin, or a portion of a groundwater basin, pursuant to a Groundwater Management Plan adopted pursuant to this part.

"Local agency" is defined as any local public agency that provides water service to all or a portion of its service area (Section 10752 (g)). The definition also includes a local public agency that provides flood control, groundwater management, or groundwater replenishment, or a local agency formed pursuant to the Water Code for the principal purpose of providing water service that has not yet provided that service (Section 10753 (b)). These local agencies may exercise the authority of this part, and are authorized by Section 10752 (g) to form Joint Powers Authorities in order to work cooperatively in establishing a groundwater management program.

According to Water Code Section 10754, for purposes of groundwater management, a local agency that adopts a groundwater management plan has the authority of a water replenishment district pursuant to Part 4 (commencing with Section 60220) of Division 18 and may fix and collect fees and assessments for groundwater management in accordance with Part 6 (commencing with Section 60300) of Division 18, subject to the approval of voters within the agency's boundaries.

F. Eligible Groundwater Basins

The act applies to all groundwater basins in the state of California, except those already subject to groundwater management by a local agency or watermaster pursuant to other provisions of law or a court order, judgment or decree, unless the local agency or watermaster agrees to the applications of the act. The Sacramento Valley Groundwater Basin is eligible for groundwater management under AB 3030.

G. Objective of Plan

DWD values the importance of groundwater in the state of California as well as locally. It recognizes that proper management of groundwater basins is necessary to sustain the environmental, social and economic conditions that prevail in today's society. More importantly, the well being of future societies is dependent on the effectiveness of current groundwater resources planning and development. For these reasons, the District elected to prepare a Groundwater Management Plan to protect the groundwater in its area and the Sacramento Valley Groundwater Basin.

The objective of this groundwater management plan is to identify and implement a program of effective groundwater management practices that will maintain the long-term availability and quality of groundwater resources within the District.

H. Relationship to Yolo County

The District intends to work cooperatively with Yolo County toward mutually agreeable groundwater management objectives. However, by development and adoption of this Plan, the District asserts that it holds sole legal authority for management of the District's groundwater resources.

II. DUNNIGAN IRRIGATION DISTRICT

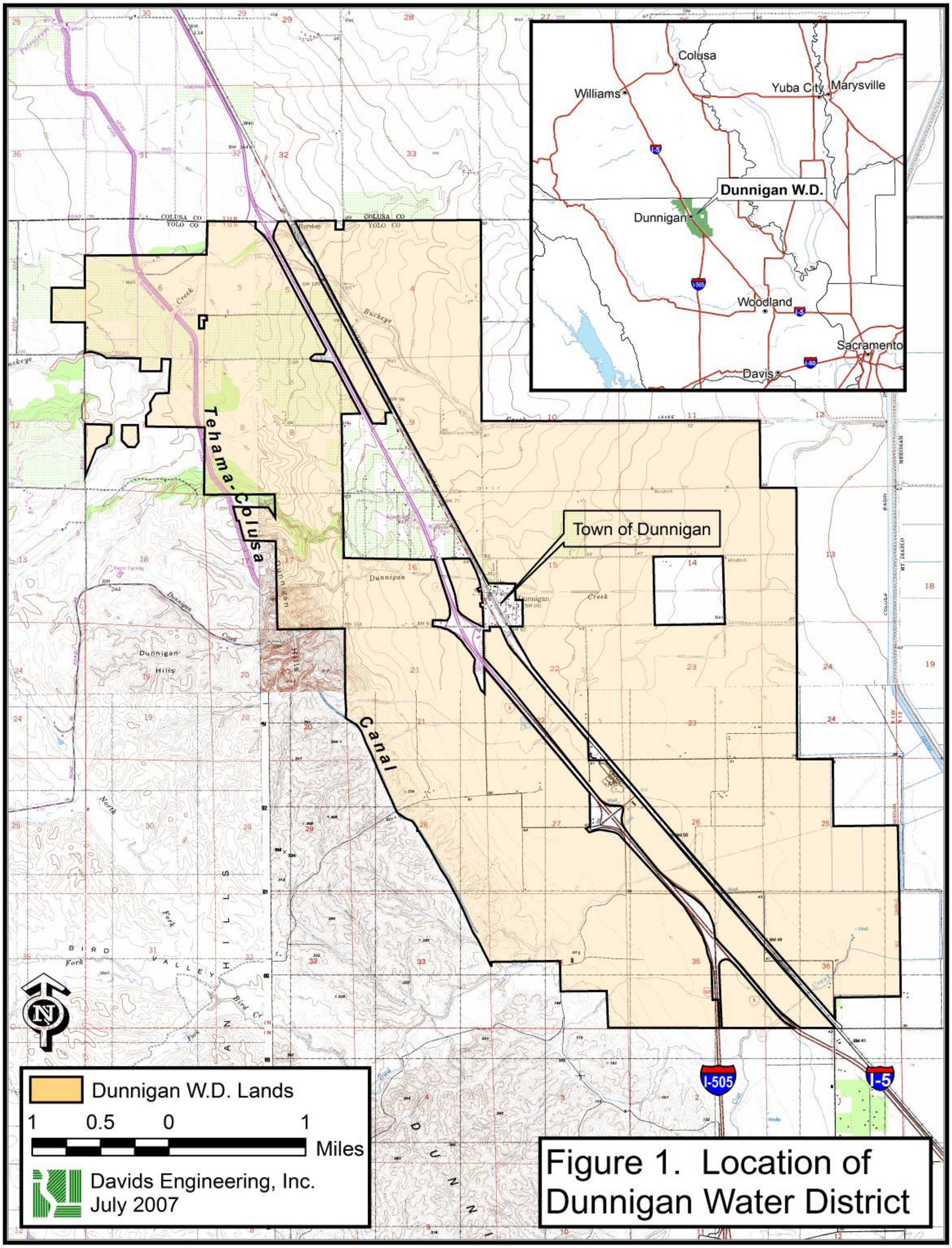
A. District History

DWD is located in the southwestern Sacramento Valley, approximately 20 miles north of Woodland and 40 miles south of Willows. The District is comprised of 10,780 acres, not all of which are presently developed for irrigation but are expected to be developed over time (Figure 1).

The District was formed in 1956 for the purpose of contracting with the Bureau of Reclamation (BOR or Reclamation) for a supplemental surface water supply. Contract 14-06-200-399a was entered into between the District and Reclamation in 1963, and water deliveries began in April 1983. The contract had a 19,000 acre-foot annual contract amount. Since the expiration of that contract in 1995, the District has continued to receive Central Valley Project (CVP) water under a series of interim contracts with Reclamation, each with the same contract amount as the original contract (19,000 acre-feet). Along with other historical CVP water contractors, the District is currently negotiating a new long-term water supply contract.

B. District Facilities

DWD owns and operates a buried pipeline distribution system that conveys CVP water from the Tehama-Colusa Canal to District lands. There is a total of 26 miles of pipeline with diameters ranging from 6 to 48 inches. Water deliveries to farms are measured with totalizing propeller meters


Colusa
Williams
Yuba City
Marysville
Dunnigan W.D.
Dunnigan
Woodland
Sacramento
Davis
Town of Dunnigan
Tehama-Colusa
Canal
Dunnigan Hills
I-505
I-5
Dunnigan W.D. Lands
1 0.5 0 1
Miles
Davids Engineering, Inc.
July 2007
Figure 1. Location of
Dunnigan Water District

and are read daily during the high season. Deliveries to lands lying down gradient (generally east) of the Tehama-Colusa Canal are made by gravity while a canal side pumping plant makes up-gradient deliveries.

C. District Facilities

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D. Cropping Patterns and Irrigation Systems

A depiction of historical land use and cropping for the period 1961 through 2004 has been assembled from a combination of DWR and District records[1] (Figure 2). The total land area within Dunnigan Water District study area is 11,684 acres[2], with most of this used for agriculture. The total cropped area was about 7,800 acres in 1961, rising to a peak of about 9,500 acres in 1981 and moderating to about 7,900 acres in 2004. Urban land use has increased gradually over the period to more than 1,000 acres in 2004. The town of Dunnigan is completely within the study area.

Major crops grown in the District include pasture, grain (wheat) and hay (alfalfa), field crops (tomatoes) and deciduous trees (almonds). There is a recent trend of increasing permanent tree and vineyard crops. Based on District predictions of future cropping patterns, which were used by the BOR in the CVP Water Needs Assessment (2000), this trend will continue. By 2025, out of a projected irrigated area of 9,848 acres, 32% of the land will be cultivated in almonds, 18% in tomatoes and 10% in vineyard.

The types of irrigation systems used in the District in 1983 were predominantly furrow and flood systems (88%). Presently, about two-thirds of the cropped area is surface irrigated and one-third is irrigated with pressurized (drip, micro, or sprinkler) systems. Use of pressurized systems is associated with the expansion of permanent crops and is expected to continue. It is expected that some row crops will also be irrigated with drip systems.

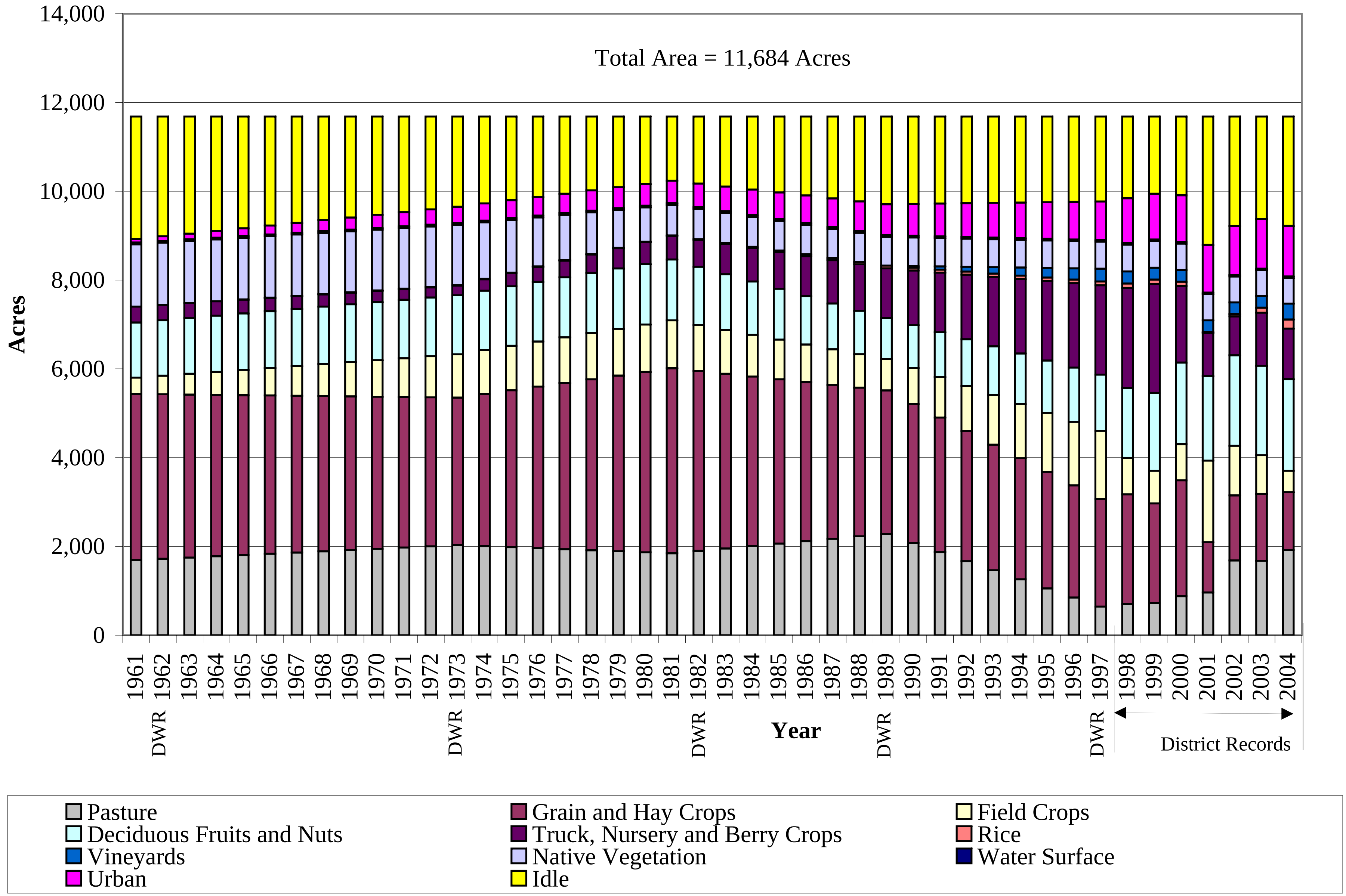
III. DISTRICT WATER DEMANDS AND SUPPLIES

Water demands and supplies are discussed in this section, based on the results of a water balance analysis prepared as part of the District's Groundwater Management Investigation. The water balance was developed for the 44-year period 1961 through 2004. However, because CVP surface water deliveries began in 1983 and have resulted in significant changes in cropping and irrigation practices, only results for 1983 through 2004 are presented here. Projected future water demands and supplies are also discussed.

[1] DWR land use surveys for 1961, 1972, 1981, 1989 and 1997 were used with intervening years determined by straight-line interpolation. District cropping records were used from 1998 through 2004.

[2] This refers to the study area used for the Dunnigan Water District Groundwater Investigation, comprised of a contiguous area encompassing District lands. The study area is larger than the District land area.

Figure 2. Dunnigan Water District Land Use and Cropping (1961 through 2004)



The demand for irrigation water in the District is determined primarily by the crops grown on District lands, weather conditions, and on-farm irrigation systems and management. Historical demand for irrigation water (or Net Irrigation Requirement, NIR) was calculated using the following equation:

$$NIR = (ETc - EP) \div AE$$

where,

ETc = crop evapotranspiration
EP = effective precipitation
AE = irrigation application efficiency

ETc was calculated using the standard "crop coefficient times reference ET" methodology using reference ET from the closest CIMIS weather station and compatible crop coefficients from published sources. Computed ETc was factored downward by 10% to account for the effects of deficit irrigation and other factors that tend to reduce ET from theoretical maximum levels. A monthly rootzone water balance was simulated for each crop grown in the District to estimate the portion of precipitation that is effective in meeting crop ET. The average irrigation application efficiency was estimated to be 78% over the 1983 through 2004 period. The resulting annual irrigation demands are plotted in Figure 3. Total demand has ranged from about 12,000 acre-feet in 1998 (a very wet year) to nearly 20,000 acre-feet in 2004, and has averaged just less than 15,800 acre-feet over the period. Water demand per acre has ranged from a low of 1.4 acre-feet in 1998 to 2.5 acre-feet in 2004, and has averaged 2.0 acre-feet. Both the total volume of demand and demand per acre have increased in recent years, due at least in part to the expansion of permanent crops.

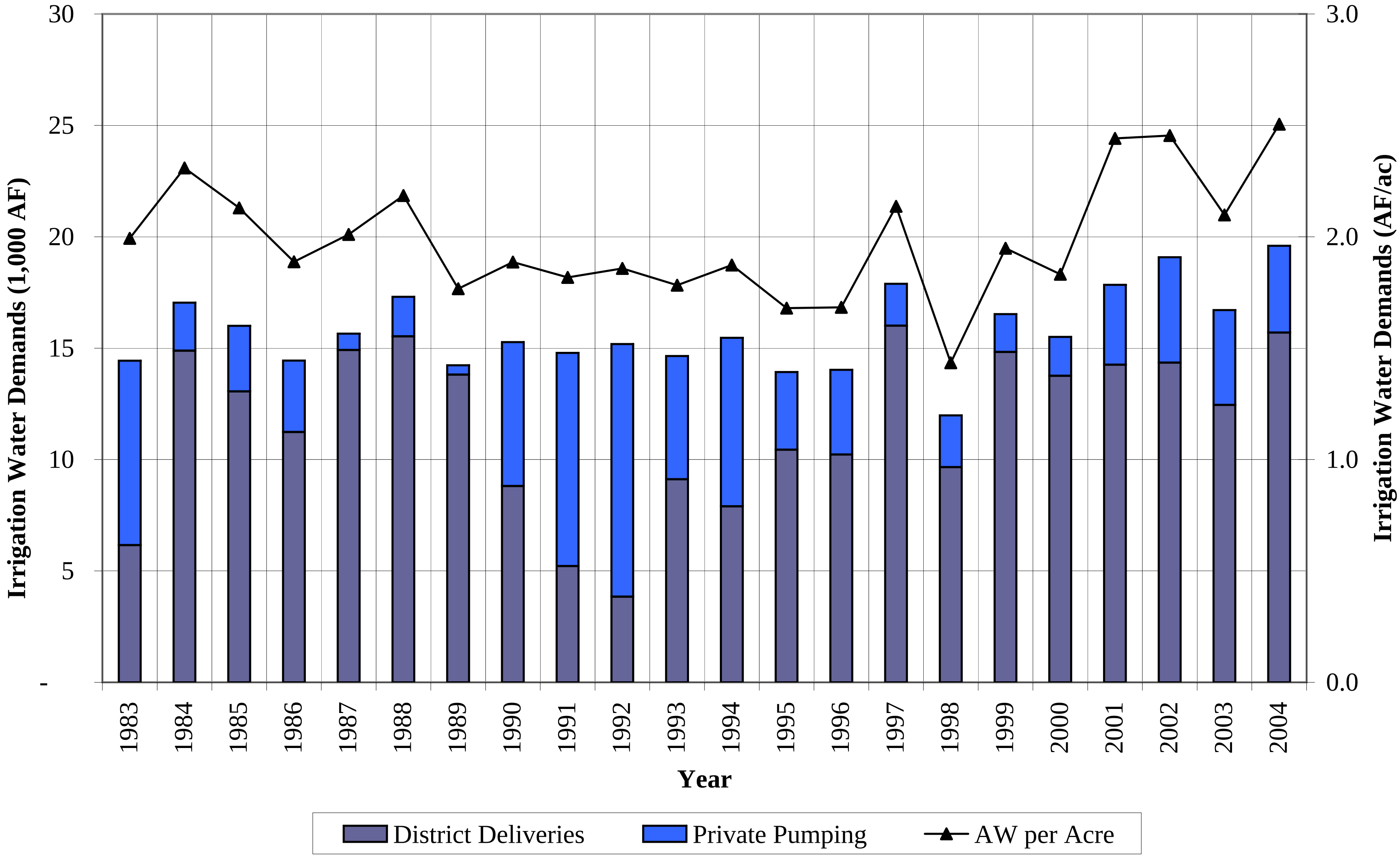
Surface water deliveries to farms have averaged about 11,600 acre-feet, ranging from a low of 3,800 acre-feet in 1992 to a high of 16,000 acre-feet in 2004. This wide variability reflects the uncertain availability of CVP water under the District's contract with Reclamation. Water demands not met by CVP supplies were met with privately pumped groundwater, ranging from a low of just a few hundred acre-feet in 1989 to about 11,300 acre-feet in 1992. The annual blend of surface water and groundwater is plotted in Figure 3.

Reclamation completed a water needs analysis for the District as part of the CVP long-term contract renewal process. For that analysis it was assumed that District irrigated acreage will increase to 9,848 acres by 2025, and the average farm delivery requirement will increase to 3.2 acre-feet per acre. The resulting total irrigation demand is projected to be 31,844 acre-feet annually, based on an aggregate district efficiency of 80 percent. Based on current trends and notwithstanding possible urban land use conversion, District officials suggest that the projected 2025 demand may be realized earlier than 2025. They also note that demand will be less elastic due to increased permanent cropping than it has been historically.

IV. Topography, Watersheds and Precipitation

Figure 4 shows the topography and watersheds in the vicinity of DWD. DWD lies in two watersheds: the 64 square-mile Buckeye Creek watershed and the 21 square-mile Bird Creek watershed. Land surface elevations within DWD range from approximately 25 to 300 feet mean sea level (msl), with the maximum range of land surface elevations occurring in the northern part of the District in the vicinity of Buckeye Creek. Topographic gradients within DWD are typically east-southeasterly, with the

Figure 3. Dunnigan Water District Irrigation Water Demands (1983 through 2004)



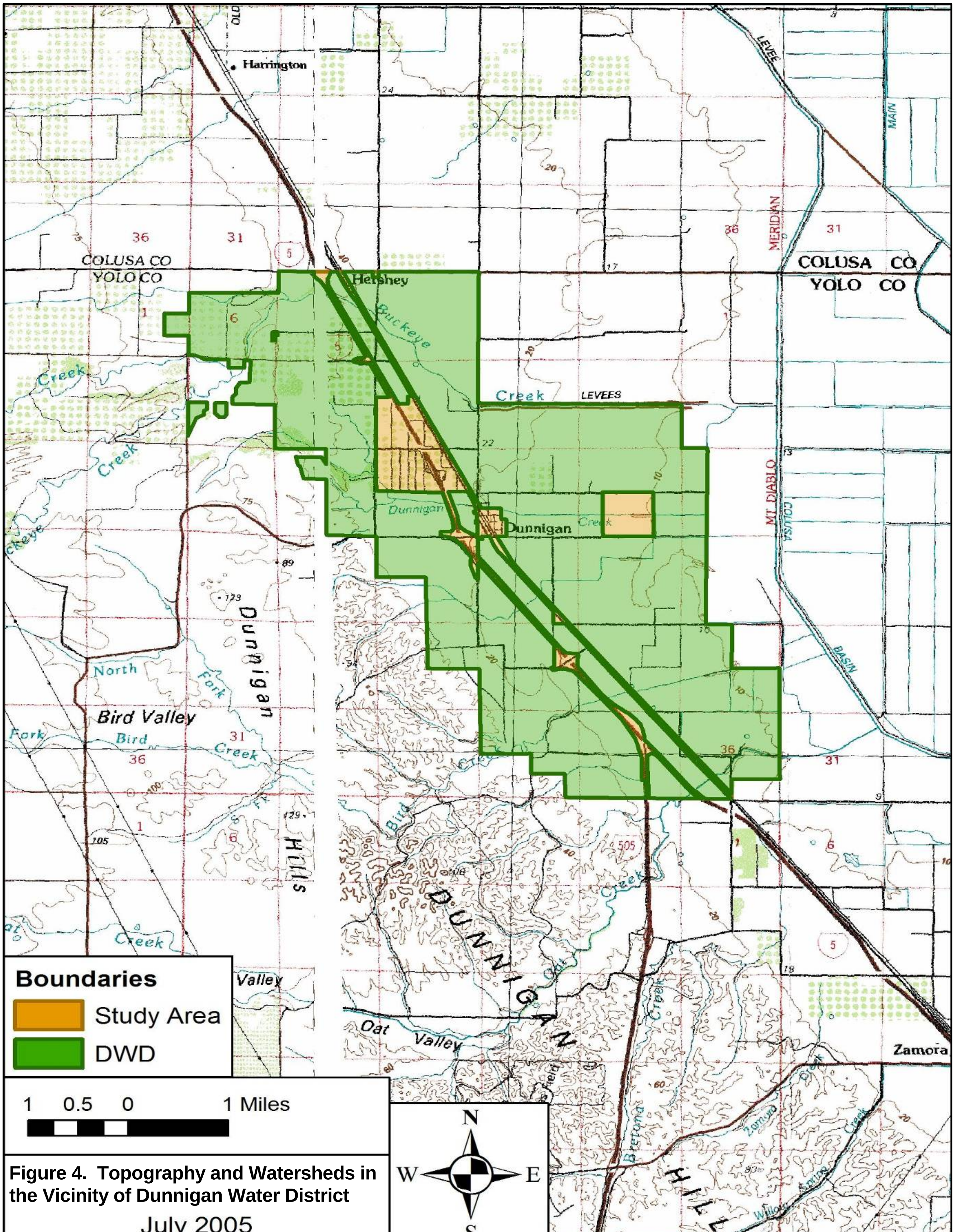


Figure 4. Topography and Watersheds in the Vicinity of Dunnigan Water District
July 2005

steepest gradients also occurring along the Buckeye Creek alluvial fan. West of DWD, the land surface of the Buckeye Creek watershed rises to a maximum elevation of 1,940 feet msl in the Capay Hills.

The land surface in the Bird Creek watershed attains a maximum elevation of approximately 600 feet msl. Land surface elevations in the Dunnigan Hills adjacent to the District reach a maximum elevation of approximately 335 feet msl.

Figure 5 shows the mean annual precipitation within the Buckeye Creek and Bird Creek watersheds, as determined by the Oregon State Climate Center (http://www.ocs.orst.edu/prism). The mean precipitation varies with the land surface elevation, with the lowest mean precipitation (approximately 19 inches per year) occurring on the valley floor. Mean annual precipitation increases westerly with increasing land surface elevations. The upper Buckeye Creek watershed, along the crest of the Capay Hills, receives precipitation of approximately 25 inches per year, the maximum value for the area. The maximum annual precipitation in the lower Bird Creek watershed is approximately 22 inches per year. Based on relative area and precipitation, the Bird Creek watershed likely receives about 30 percent of the precipitation received by the Buckeye Creek watershed.

Figure 6 shows the annual precipitation measured at the National Weather Service Woodland Cooperative Station for the period 1970 though 2003. The January 1997 measurement at the Woodland station was erroneous and was replaced by the measurement at the Zamora station. The annual precipitation ranged from 7 inches in 1976 to 42 inches in 1983. The mean precipitation was 19 inches, consistent with the Oregon State Climate Center results for the Sacramento Valley.

V. Sacramento Valley Groundwater Basin and Colusa Sub-basin

A. Boundaries

The Sacramento Valley Groundwater Basin encompasses approximately 4900 square miles including all of Sutter County, and parts of Yuba, Tehama, Glenn, Butte, Colusa, Yolo, Solano, Placer and Sacramento Counties. Its usable storage capacity has been estimated at approximately 40 million acre-feet (CALFED, 2000), making it one of California's largest groundwater basins.

The Sacramento Valley Groundwater Basin has been partitioned by the California Department of Water Resources (DWR) into groundwater sub-basins based on natural hydrologic boundaries. The largest sub-basin in the Sacramento Valley Groundwater Basin is the Colusa Sub-Basin.

The Colusa Sub-Basin lies on the west side of the Sacramento Valley Groundwater Basin. The northern boundary of the basin runs westerly from Black Butte Reservoir, along Stony Creek. The southern boundary runs along Cache Creek. The Coast Range in the west and the Sacramento River in the east bound the basin. The Dunnigan Water District lies over the southern portion of the Sub-Basin, just north of Cache Creek (Figure 7).

B. Agencies within the Colusa Sub-Basin

In addition to the DWD, there are 5 Irrigation Districts, 11 Water Districts and 6 other Districts that lie completely or partially within the Colusa Sub-Basin (Table 1.) Lands within the boundaries of these districts, as well as unorganized lands within the Sub-Basin, are excluded from this plan.

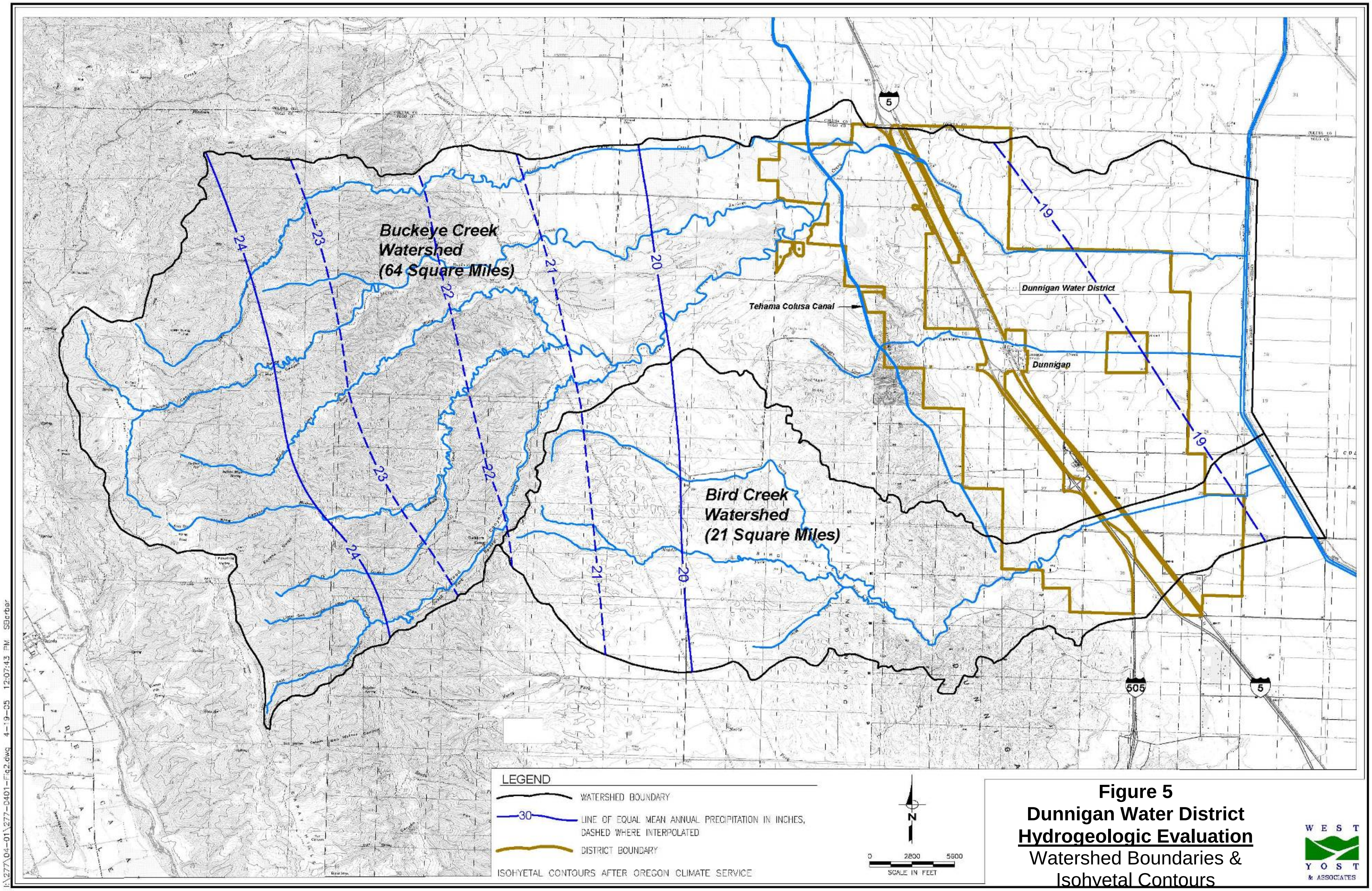
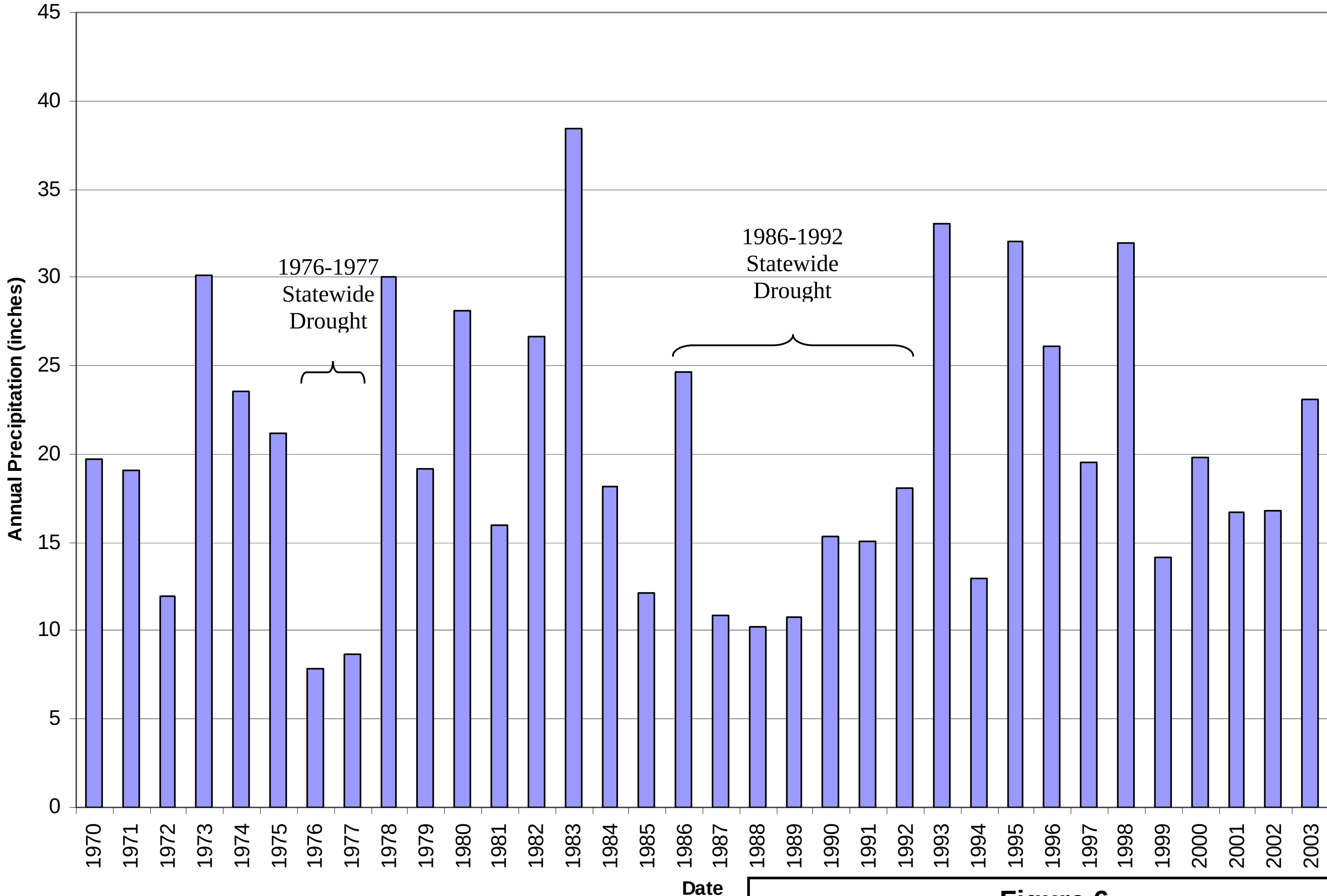


Figure 5
Dunnigan Water District
Hydrogeologic Evaluation
Watershed Boundaries &
Isohyetal Contours



Reference: National Weather Service Woodland Cooperative Station. January 1997 from Zamora CIMIS Station

Figure 6

Dunnigan Water District
Hydrogeological Evaluation

Historical Precipitation by Water Year

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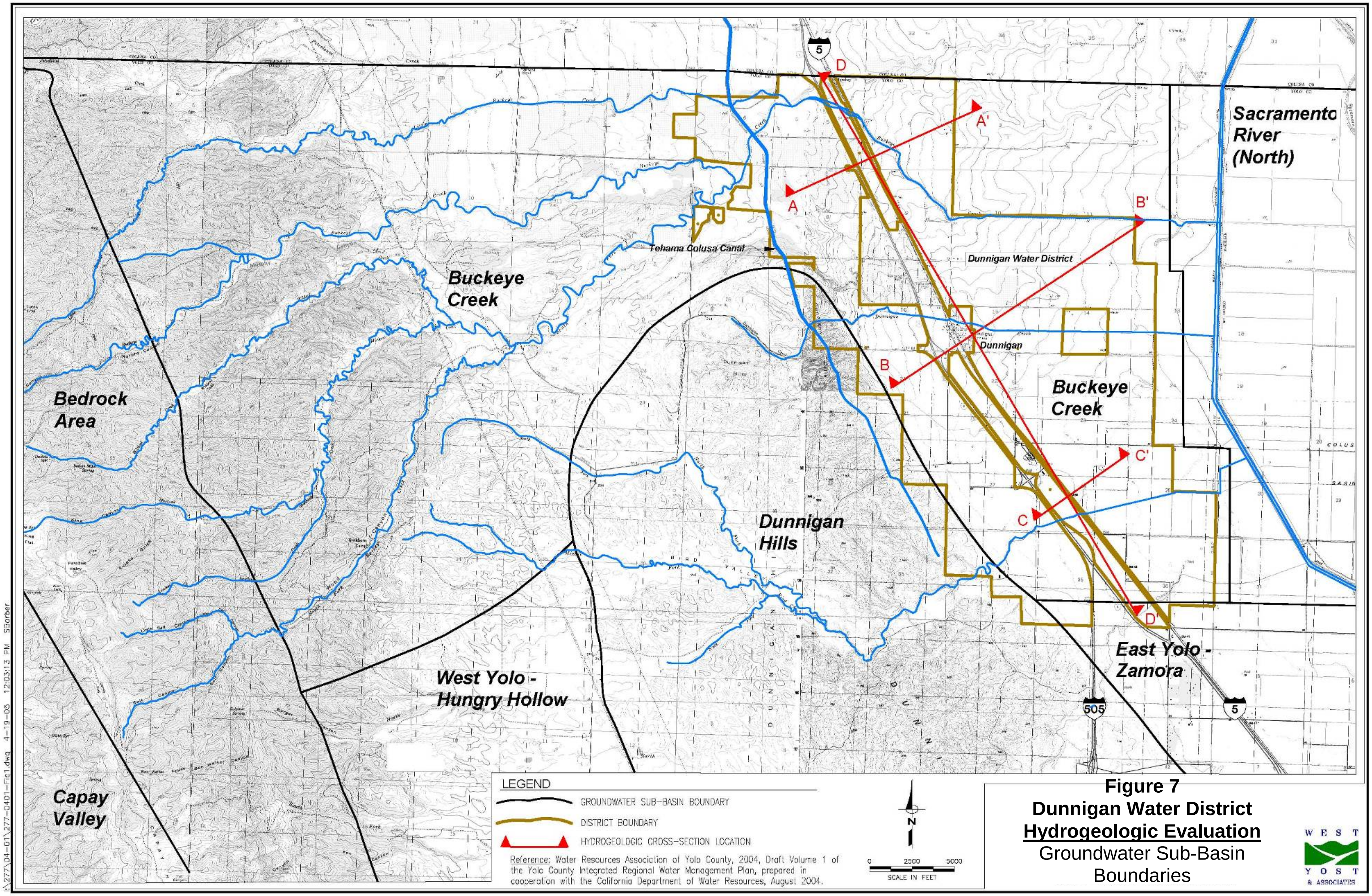


Figure 7
Dunnigan Water District
Hydrogeologic Evaluation
Groundwater Sub-Basin Boundaries

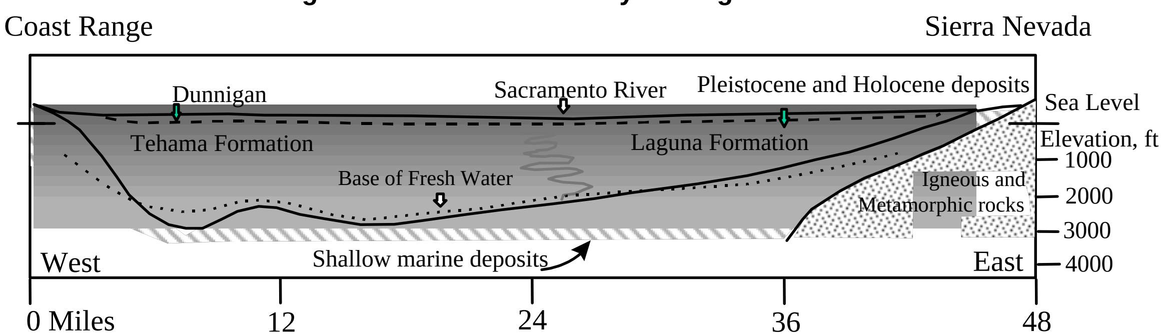
Table 1. Irrigation, Water and Other Districts within the Colusa Sub-Basin

IRRIGATION DISTRICTS	WATER DISTRICTS	OTHER DISTRICTS
Glenn - Colusa	Orland-Artois	Orland Unit W.U.A.
Provident	Glide	Willow Creek M.W.C.
Princeton-Cordora-Glenn	Kanawha	Maxwell P.U.D.
Maxwell	Holthouse	Colusa Drain M.W.C.
	4-M	Myers Marsh M.W.C.
	Glenn Valley	Reclamation District 108
	La Grande	Arbuckle PUD
	Davis	
	Westside	
	Cortina	
	Colusa County	
	Dunnigan	

C. Subsurface Geology

The Sacramento Valley in the vicinity of DWD is filled by a thick sequence of marine sedimentary rock of Late Jurassic (159 million years before present [my]) to Eocene (34 my) age, unconformably overlain by a relatively thin sequence of continental sedimentary deposits of Pliocene (5 my) and younger age (Harwood and Helley, 1987). A generalized geologic cross section through the Sacramento Valley is presented in Figure 8.

Figure 8. Sacramento Valley Geologic Cross Section

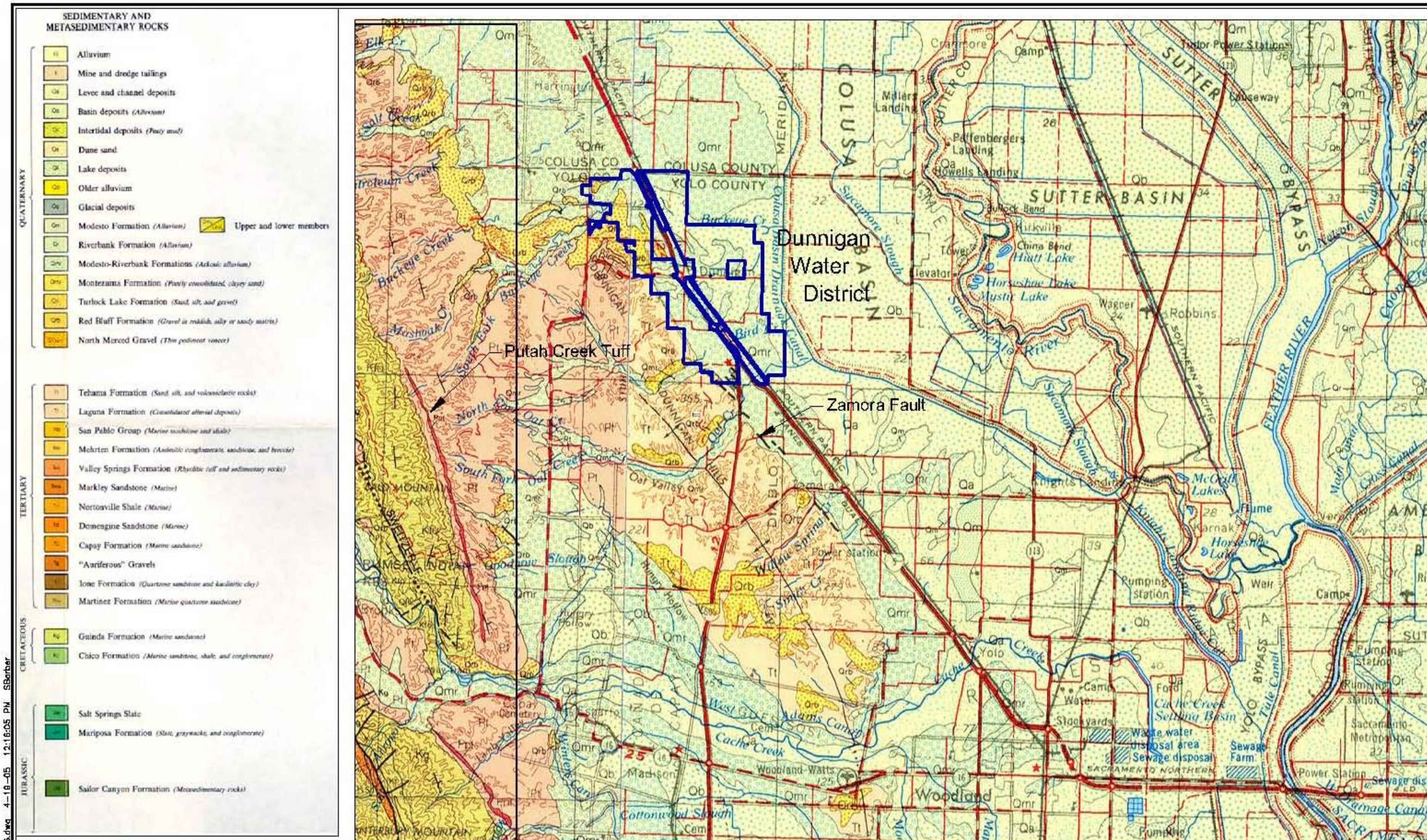


Source: California Department of Water Resources, 1978

The older marine rocks contain saline water. The freshwater aquifers in the vicinity of DWD occur in the overlying continental sedimentary deposits, which are presented from oldest to youngest in the following discussion. Figure 9 is a geologic map encompassing DWD and vicinity. Figure 10 is a geologic column that provides a conceptual overview of the freshwater portion of the aquifer in the vicinity of DWD.

1. Tehama Formation

The Tehama Formation forms the oldest, deepest and thickest part of the freshwater aquifer in the vicinity of DWD. The Tehama Formation consists of up to 2,500 feet of moderately compacted silt, clay, and silty fine sand enclosing thin, discontinuous lenses of sand and gravel, silt and gravel deposited in a fluvial (river-borne) environment. Based on the mineralogy of surface exposures, the



LEGEND

WATER DISTRICT BOUNDARY

References:
California Geological Survey, 1981, Geologic Map of the Sacramento Quadrangle, compiled by D.L. Wagner, C.W. Jennings, T.L. Bedrossian and E.J. Bortugno, 1:250,000, second printing 1987.

California Geological Survey, 1982, Geologic Map of the Santa Rosa Quadrangle, compiled by D.L. Wagner and E.J. Bortugno, 1:250,000, second printing 1999.

0 1.5 3 SCALE IN MILES

Figure 9
Dunnigan Water District
Hydrogeologic Evaluation
Geologic Map

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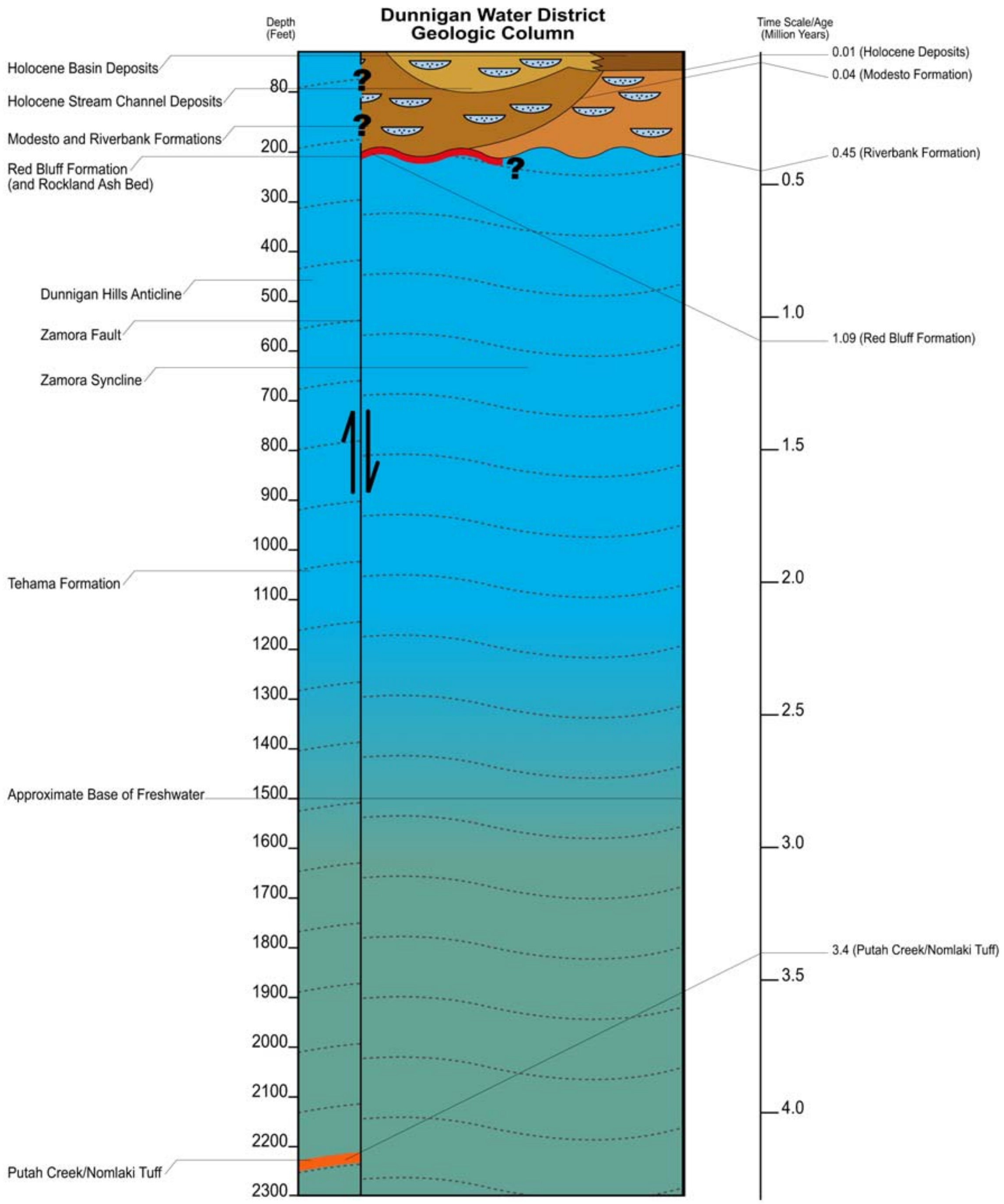

Figure 10

Dunnigan Water District
Hydrogeological Evaluation

DWD Geologic Column

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sediments were derived from erosion of the Coast Ranges and Klamath Mountains (Russell, 1931; DWR, 1978, 2004).

The Tehama Formation is exposed at the land surface over extensive areas to the west of DWD, including in the Dunnigan Hills and the eastern flank of the Capay Hills (Figure 9). The Tehama Formation is buried beneath younger sediments to the east and north of the Dunnigan Hills.

The age of the Tehama Formation is constrained by volcanic rock units, which can be time-correlated with rock units deposited near the base and slightly above the top of the Tehama Formation. The Putah Creek/Nomlaki Tuff, which is located at or near the base of the Tehama Formation, has a radiometrically determined age of 3.4 my (Evernden et. al, 1964; Harwood and Helley, 1987). The Putah Creek Tuff is exposed at the land surface in the Capay Hills west of DWD (Figure 9). Figure 10 shows the estimated stratigraphic position of the Putah Creek/ Nomlaki Tuff in the subsurface, based on the total thickness of the Tehama Formation.

The Tehama Formation is unconformably overlain by a thin gravel pediment known as the Red Bluff Formation (Figures 9 and 10). The age of the Red Bluff Formation is constrained to be 0.45 to 1.09 my by the radiometrically determined ages of the Rockland ash bed and the Deer Creek basalt, respectively (Harwood, et. al., 1981; Harwood and Helley, 1987).

Based on these constraints, deposition of the Tehama Formation began about 3.4 my and ended earlier than 1.09 my, which is equivalent to a Pliocene to Pleistocene age (Figure 10). The permeability of the Tehama Formation varies but is generally less than in the overlying unconsolidated alluvial deposits. Because of the thickness of the producing zones, production from the Tehama Formation can be up to several thousand gallons per minute (gpm) per well (DWR, 2004). The majority of irrigation wells in DWD are completed in the Tehama Formation (Figures 9, 11 and 12).

2. Modesto and Riverbank Formations

The Tehama and Red Bluff Formations are unconformably overlain by the Pleistocene age Riverbank and Modesto Formations. These formations consist of up to 200 feet of loose to moderately compacted silt, silty clay, sand and gravel deposited in alluvial depositional environments during periods of world-wide glaciation (Lettis, 1988; Weissmann, et. al., 2002; DWR, 2004). In the vicinity of DWD, the Modesto and Riverbank Formation are not directly related to glacial activity, because glaciers were generally not present in the Coast Ranges. Instead, the formations were deposited in response to changes in base level and increased precipitation during the glacial periods. The increased precipitation and increased gradients resulted in greater stream discharge and competency than at the present time. The greater competency of the streams led to scouring of stream channels in pre-existing geologic deposits, followed by transport, deposition and burial of sands and gravels in the channels as the glacial cycles progressed.

Figure 9 shows the distribution of the Modesto and Riverbank Formation in the vicinity of DWD. The formations are exposed at the land surface along the channels of Buckeye Creek and Bird Creek, and along the fringes of the Dunnigan Hills and Capay Hills, where they form a series of coalescing alluvial fans, emanating from the mouths of the creeks. The Modesto and Riverbank Formations form an extensive alluvial fan at the mouth of Buckeye Creek, based on the topographic

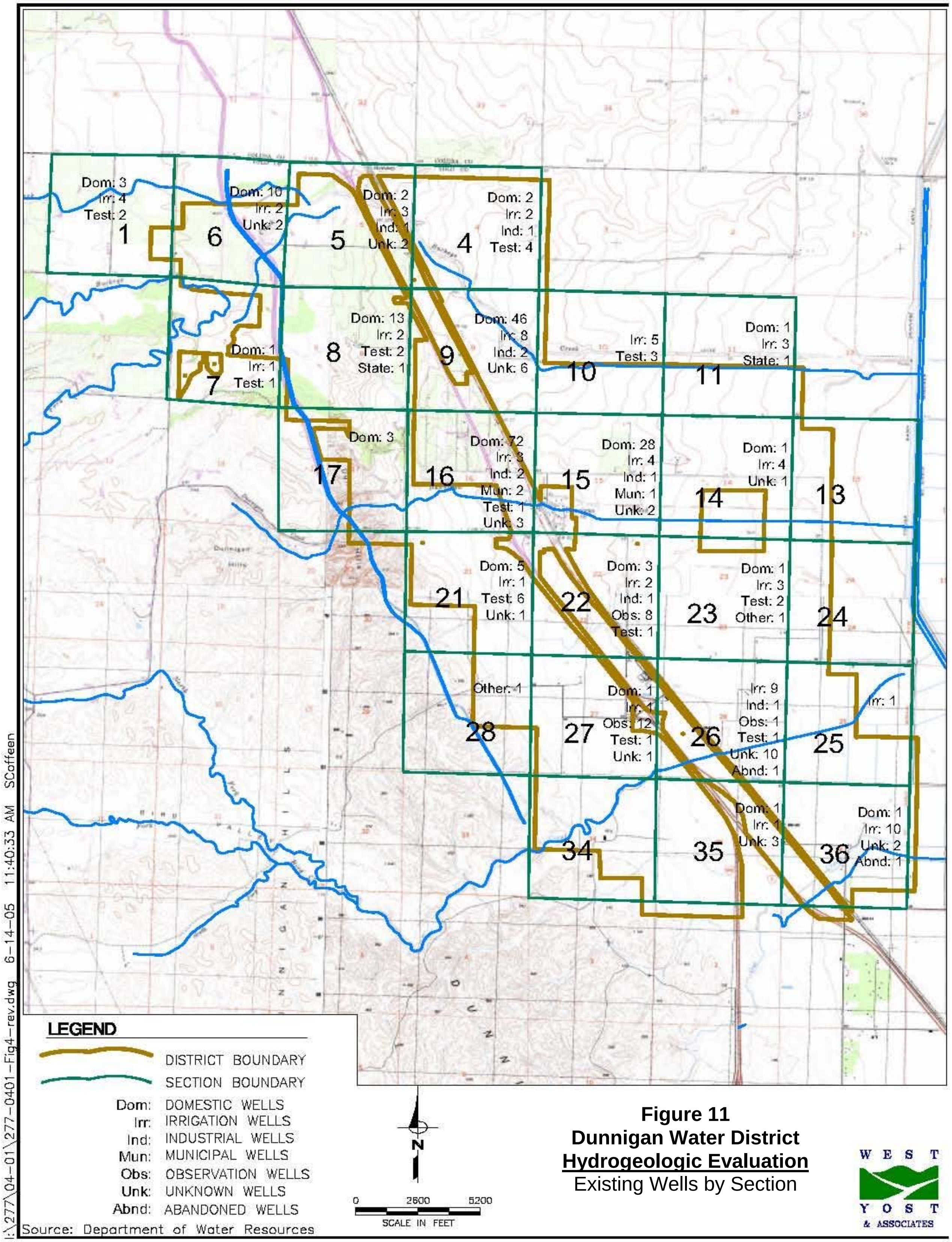


Figure 11
Dunnigan Water District
Hydrogeologic Evaluation
Existing Wells by Section

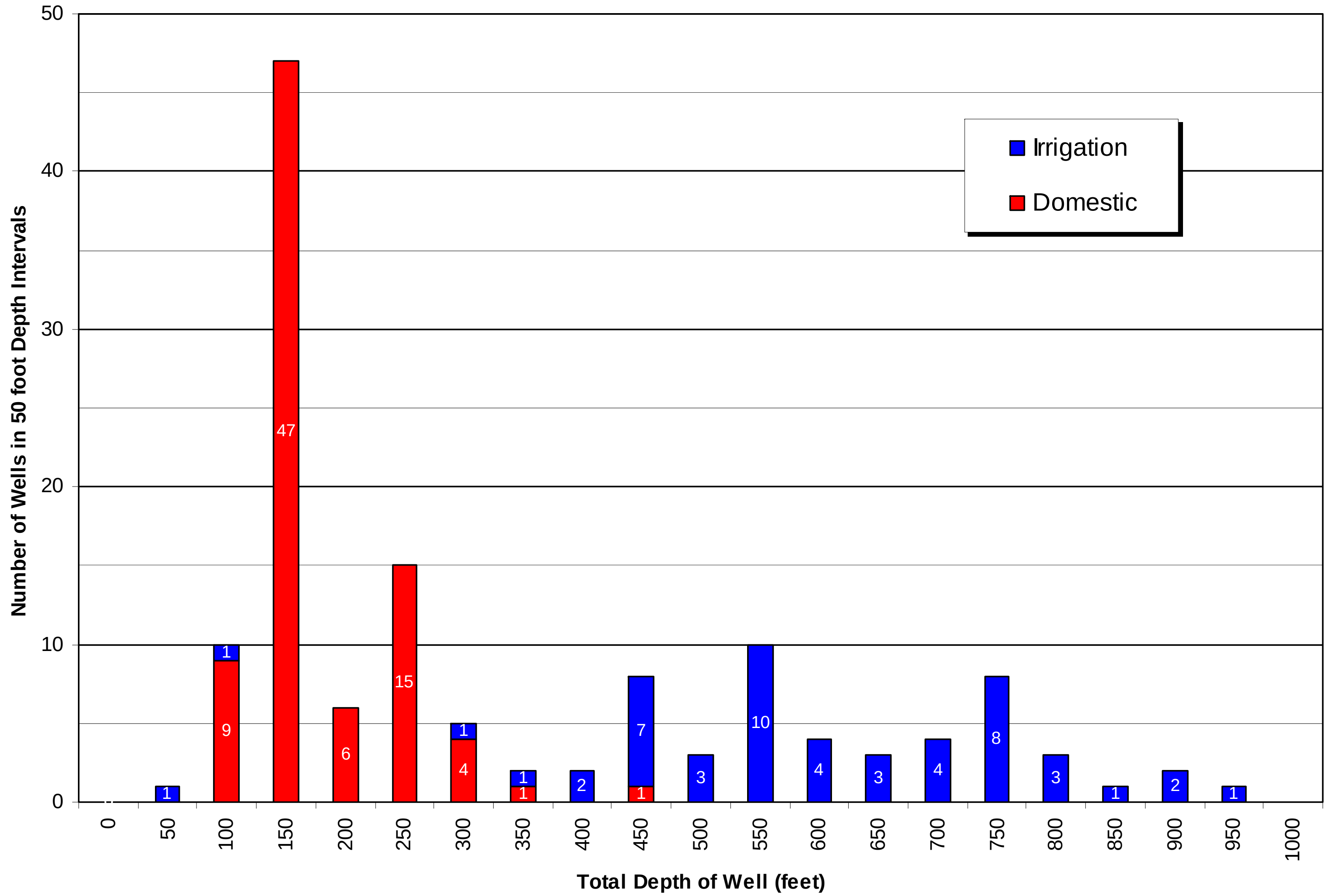


Figure 12

Dunnigan Water District
Hydrogeological Evaluation

Summary of Well Depths and Use

character of the area (Figure 5) and the mapped extent of the Modesto and Riverbank Formations (Figure 9).

The Modesto and Riverbank Formations are not differentiated in most areas shown on Figure 11. However, the formations typically form terraces along stream channels. The oldest terraces occur furthest from the channel and at the highest elevations. Successively younger terraces are incised into the next oldest deposit and, therefore, occur closer to the stream channel and at lower elevations (Figure 10).

The age of the Modesto Formation ranges from approximately 0.01 to 0.042 my and correlates to the Wisconsin glacial stage. The age of the Riverbank Formation ranges from 0.13 to 0.45 my and corresponds to the Illinoisan and older glacial stages. Both formations are Pleistocene age.

Wells penetrating the sand and gravel units of the Modesto and Riverbank Formations produce up to about 1,000 gpm (DWR, 2004). The majority of the domestic wells in the vicinity of DWD are completed in the Modesto and Riverbank Formations (Figures 9, 11 and 12).

3. Holocene Stream Channel and Basin Deposits

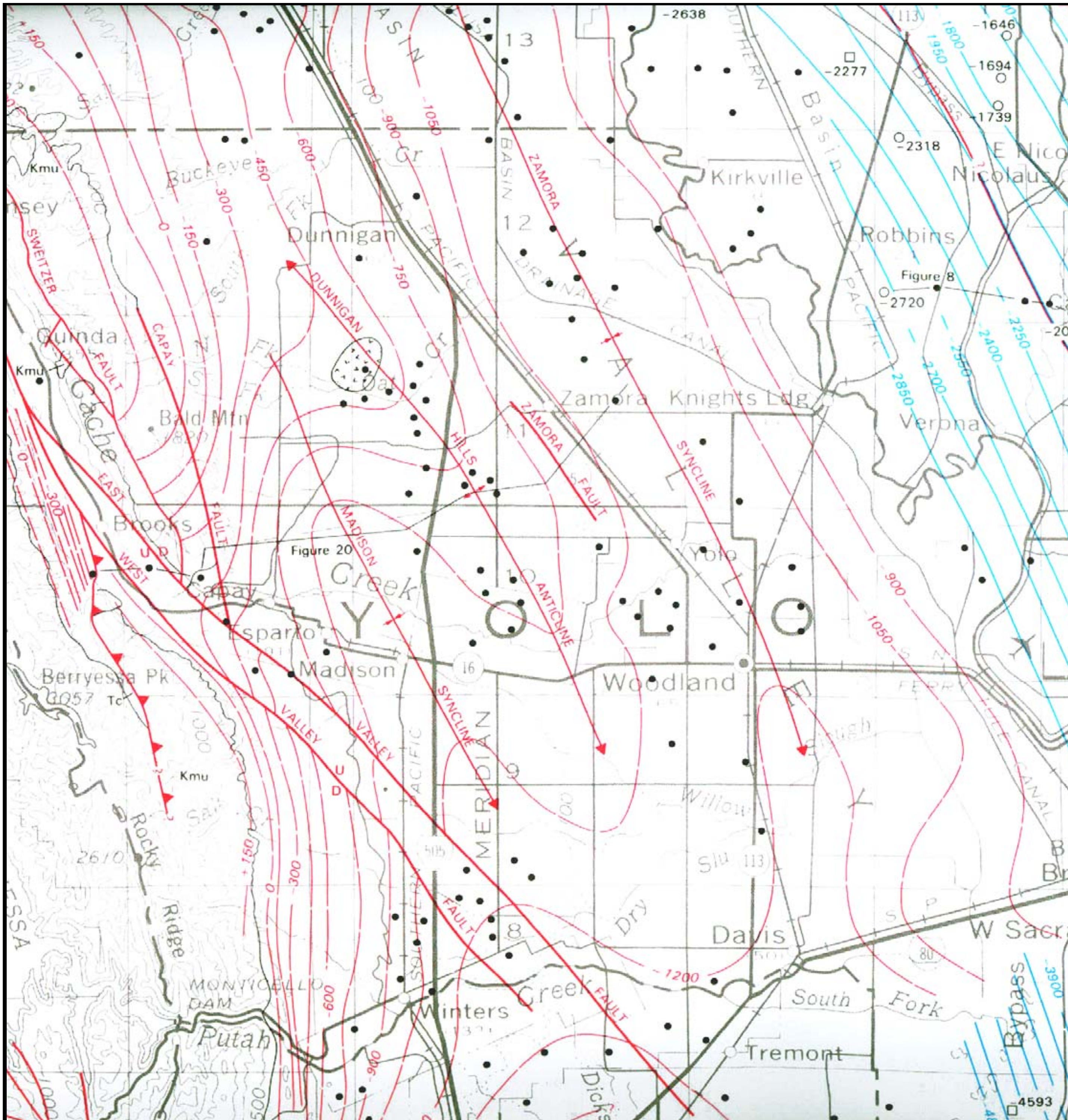
Holocene stream channel and basin deposits are the youngest sediments in DWD, with ages of 10,000 years or less. The stream channel deposits consist of up to 80-foot sections of unconsolidated clay, silt, sand and gravel reworked from older formations by streams. According to DWR (2004), these deposits form a shallow unconfined aquifer of moderate to high permeability, but with limited capacity due to the relatively restricted lateral and vertical extents of the deposits. Some of the shallower domestic wells near Dunnigan and to the northwest may be screened in Holocene stream channel deposits (Figure 9, 11 and 12).

Holocene basin deposits are very young surficial deposits formed during flood events when streams overtopped their natural levees flooding the surrounding area. As the flood water spread, the current velocity and stream competency decreased, resulting in deposition of silts, clays and fine sands. Flood basin deposits reach thicknesses up to 150 feet and may be interbedded with stream channel deposits (DWR, 2004). Because of their low permeability, limited extent, and generally poor water quality, flood basin deposits are typically not used for groundwater production (DWR, 2004).

Figure 9 shows the distribution of flood basin deposits in the vicinity of DWD. The flood basin deposits are generally located along the eastern edge of the District, but are also shown along the lower reaches of Buckeye Creek and Dunnigan Creek. Although mapped as flood basin deposits, sediments along the lower channels of Buckeye Creek and Dunnigan Creek may be Holocene stream channel deposits, since they occur in alluviated areas rather than in the flood basin (Figures 5, 9 and 10).

VI. Geologic Structure

Figure 13, from Harwood and Helley (1987), shows the structural contours in meters delineating the top of the Cretaceous marine sedimentary rocks in the vicinity of DWD. The structural contours were based on the Cretaceous rocks because the resulting surface produces a single structural datum throughout the southwestern Sacramento Valley. This datum reveals the geologic structures – folds and faults – that affect the groundwater basin. The significant structural features in the vicinity of



Reference: Harwood, D.S., and E.J. Helley, 1987, U.S. Geological Survey Professional Paper 1359, Late Cenozoic Tectonism of the Sacramento Valley, California

Figure 13

Dunnigan Water District
Hydrogeological Evaluation

Structural Contour Map

DWD are the Zamora fault, the Dunnigan Hills anticline, and the Zamora syncline. These structural features affect rock units at least as young as the Red Bluff Formation, which indicates that the structural deformation was occurring as recently as 0.45 my – the youngest age of the Red Bluff Formation – and may be continuing at present (Harwood and Helley, 1987).

The Zamora fault is mapped at the land surface along the northeastern flank of the Dunnigan Hills (Figure 9, 10 and 13). The fault has a down to the east vertical displacement that is reported to offset the Red Bluff Formation by at least 200 feet to more than 720 feet (Bryan, 1923; Harwood and Helley, 1987). The fault may affect groundwater flow by bringing geologic materials with different hydraulic properties into contact across the fault plane or by fracturing the materials, which could either increase or decrease permeability, depending on the degree of fracturing and other geologic processes, such as mineralization, active within the fault zone. The fault might, therefore, act as a boundary or barrier affecting the lateral flow of groundwater between adjacent areas, and might act as a conduit allowing vertical or lateral flow within the fault zone. At present the effect of the fault on groundwater flow is unknown, but easterly flow of groundwater beneath the Dunnigan Hills appears to be impeded (DWR, 1978).

The Dunnigan Hills are the topographic expression of a doubly plunging anticline, a fold in which the central axis is raised relative to the limbs. The axis of the Dunnigan Hills anticline is oriented northwest and plunges beneath the land surface on both ends of the structure. The Zamora syncline is a similar structural feature, except that the fold axis is lowered relative to the limbs of the fold and is not doubly plunging. The Zamora syncline is located in the subsurface east of the Dunnigan Hills and Zamora fault (Figure 13). The Zamora syncline has no topographic expression, which means that the thickness of post-Cretaceous sediments, including the Tehama Formation, is greater along the axis of the syncline than on the limbs (Figure 13). This means that the aquifer thickness is greatest along the axis of the syncline.

Folds may also affect groundwater conditions because the folds cause the elevation of geologic units to vary from place to place. This has two effects. First, since the Dunnigan Hills anticline is expressed at the land surface, erosion of the Tehama Formation has exposed older, lower sections of the formation along axis of the fold. The equivalent age units dip to the east towards the axis of the Zamora syncline and occur at successively greater depths until the axis of the syncline is reached. Thus, the folds may affect recharge characteristics where the Tehama Formation is exposed at the land surface or is in contact with overlying formations that transmit recharging water. Second, the permeability and other material properties of sedimentary rocks, such as the Tehama Formation, are typically anisotropic due to the alignment of mineral grains along bedding planes during deposition of the sediments. This alignment of the mineral grains results in greater permeability along than across bedding plans. Typically, this results in a maximum permeability horizontally and a minimum permeability vertically. Subsequent folding of the bedding planes causes a reorientation of the direction of maximum and minimum permeability, which could tend to affect groundwater directions and rates of flow.

Although limited groundwater data are available in the Dunnigan Hills area, easterly groundwater flow appears to be impeded by the Dunnigan Hills anticline (DWR, 1978).

VII. Regional Groundwater Conditions

Shallow groundwater in the DWD region occurs under unconfined conditions in the Holocene stream channel deposits, except where these units are overlain by Holocene Basin Deposits, creating confined conditions (DWR, 1978). At greater depths, groundwater occurs under mostly confined conditions in a single heterogeneous aquifer system, composed of predominantly fine-grained sediments enclosing discontinuous lenses of sand and gravel. The aquifer properties, including hydraulic conductivity, vertical leakance and degree of confinement are dependant on the properties of the fine grained units (Williamson, et. al., 1989; Bertoldi, et. al., 1991).

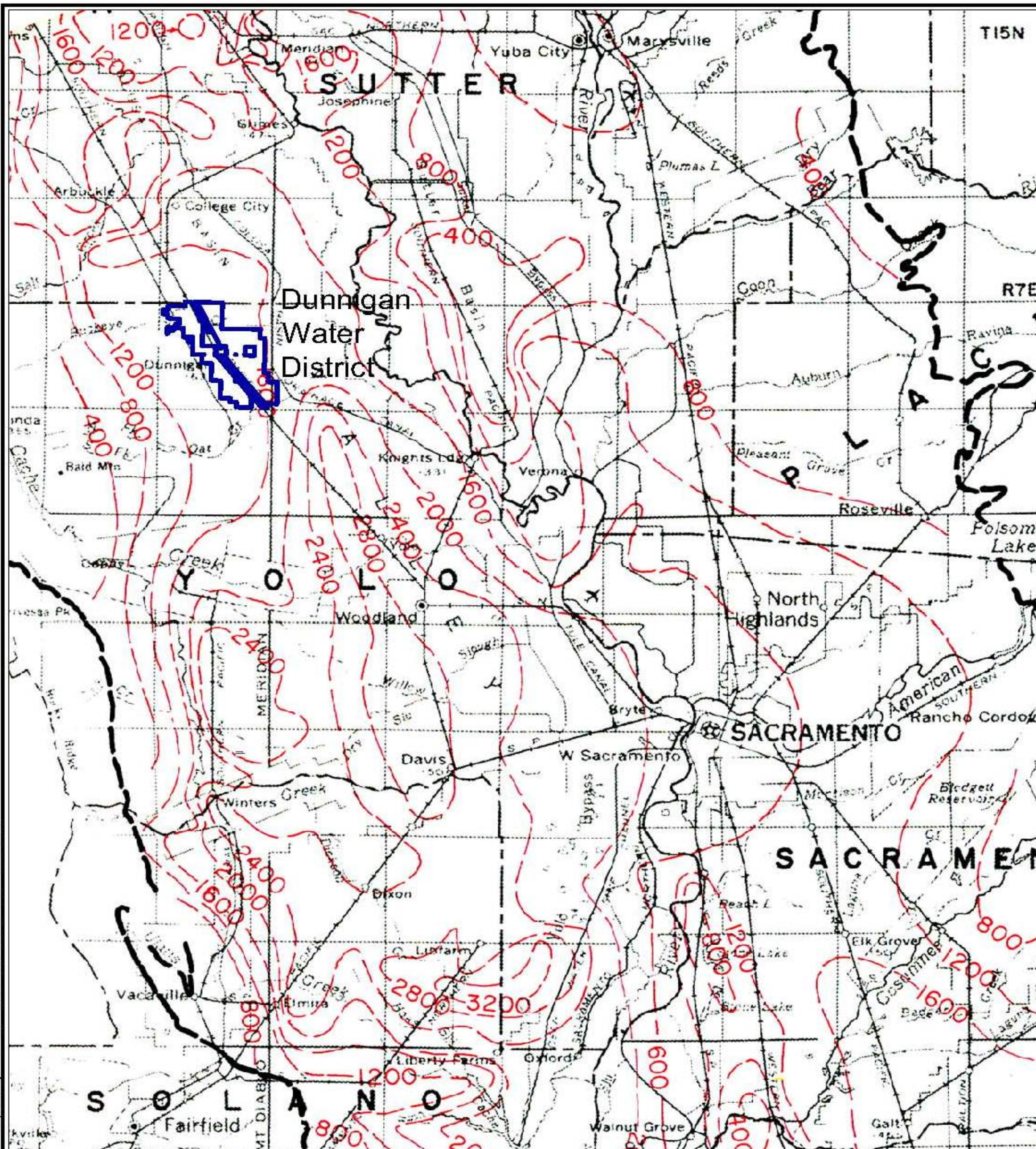
Generally, groundwater flow is from the margins of the Sacramento Valley toward the Sacramento River and thence southward towards the Sacramento-San Joaquin Delta. Groundwater pumping in several areas has created cones of depression that disrupt this pattern. Historically groundwater elevations in the region have ranged from roughly -10 feet to 60 feet msl. Figure 14 shows contours of the base of fresh groundwater from DWR (1978). In the vicinity of DWD, the base of fresh groundwater occurs at a depth of approximately -1,500 feet below sea level, implying that the fresh water aquifer is about 1,500 feet thick near DWD.

VIII. District Hydrogeologic Conditions

Approximately 260 confidential drillers reports on water well construction were obtained from DWR and reviewed to assess hydrogeologic conditions within DWD. Figure 15 shows the locations of four cross sections through DWD. The cross sections are shown on Figures 16 through 19b. Geophysical logs were not available for any of the wells evaluated. Geophysical logs from oil and gas wells in the area were not reviewed because these logs typically begin at depths of 600 feet or greater, and, therefore, would not provide information on the zones from which groundwater is produced.

The geologic information recorded on drillers' reports is rarely detailed, and the descriptive terms used to describe the geologic materials encountered during drilling vary depending on the driller preparing each report. In some instances even basic information, such as sediment color, is not recorded. Also, the typical methods used to drill water wells produce disturbed formation samples that tend to be mixed to a greater or lesser degree as cuttings are removed from the drill hole. Several guidelines were developed to constrain interpretation of the drillers' reports during preparation of the cross sections.

1. The drillers' reports were used to distinguish between coarse and fine grained units. Coarse grained units were delineated on the cross sections where the drillers reports described greater than about 10-foot thicknesses of sand, gravel or sand and gravel mixtures, without silt or clay. All other sediments, including clays, silts and intermixed fine and coarse grained sediments, were classified as fine grained, based on the rationale that the most permeable and productive sections of the aquifer are sands and gravels free of intermixed fine grained sediments.



LEGEND

WATER DISTRICT BOUNDARY

Reference: California Department of Water Resources, 1978, Evaluation of Groundwater Resources: Sacramento Valley, Bulletin 118–6, prepared in cooperation with the U.S. Geological Survey, August.

N

NOT TO SCALE

Figure 14
Dunnigan Water District
Hydrogeologic Evaluation
Base of Fresh Water Contour Map

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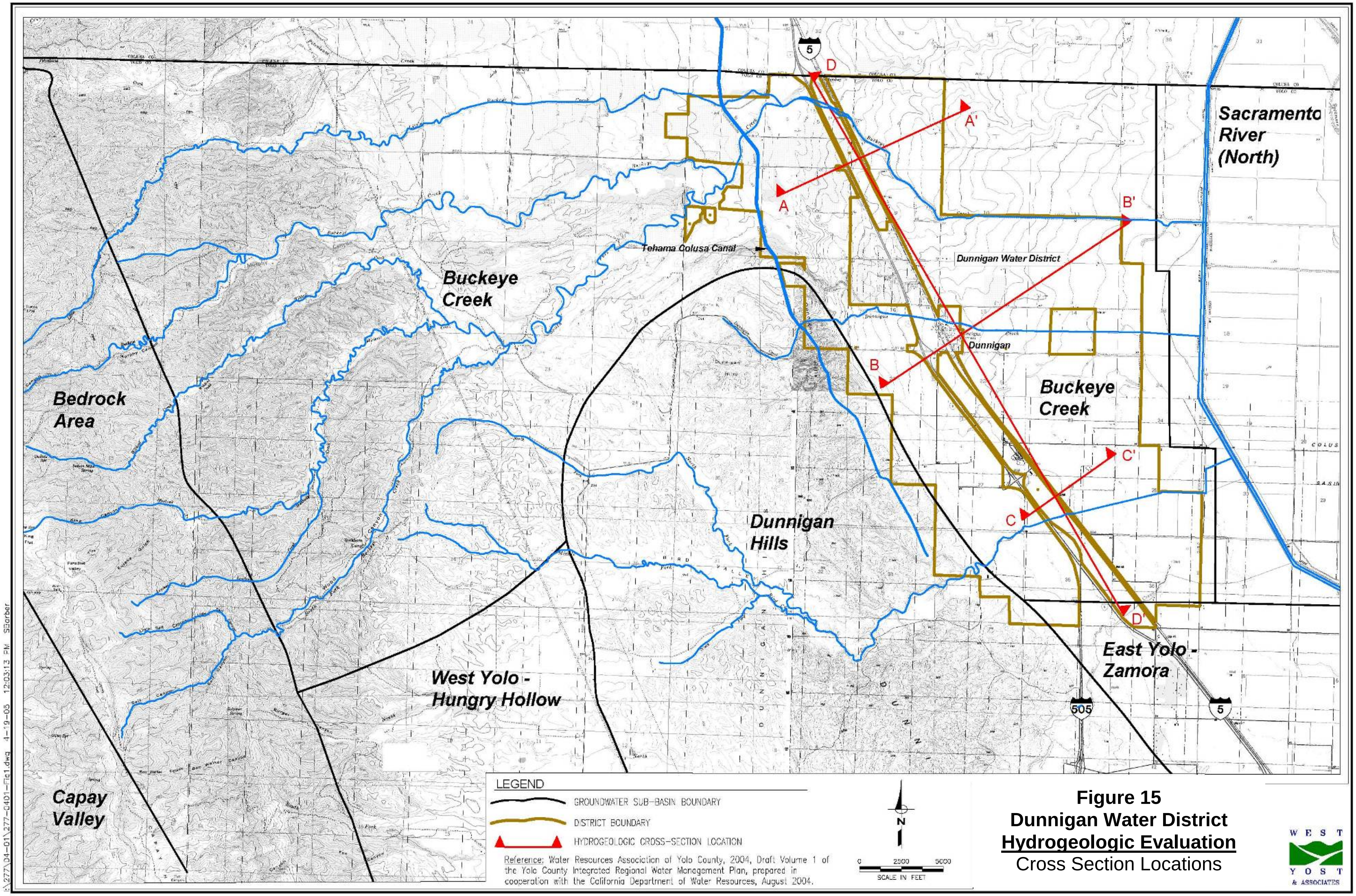

Figure 15
Dunnigan Water District
Hydrogeologic Evaluation
Cross Section Locations

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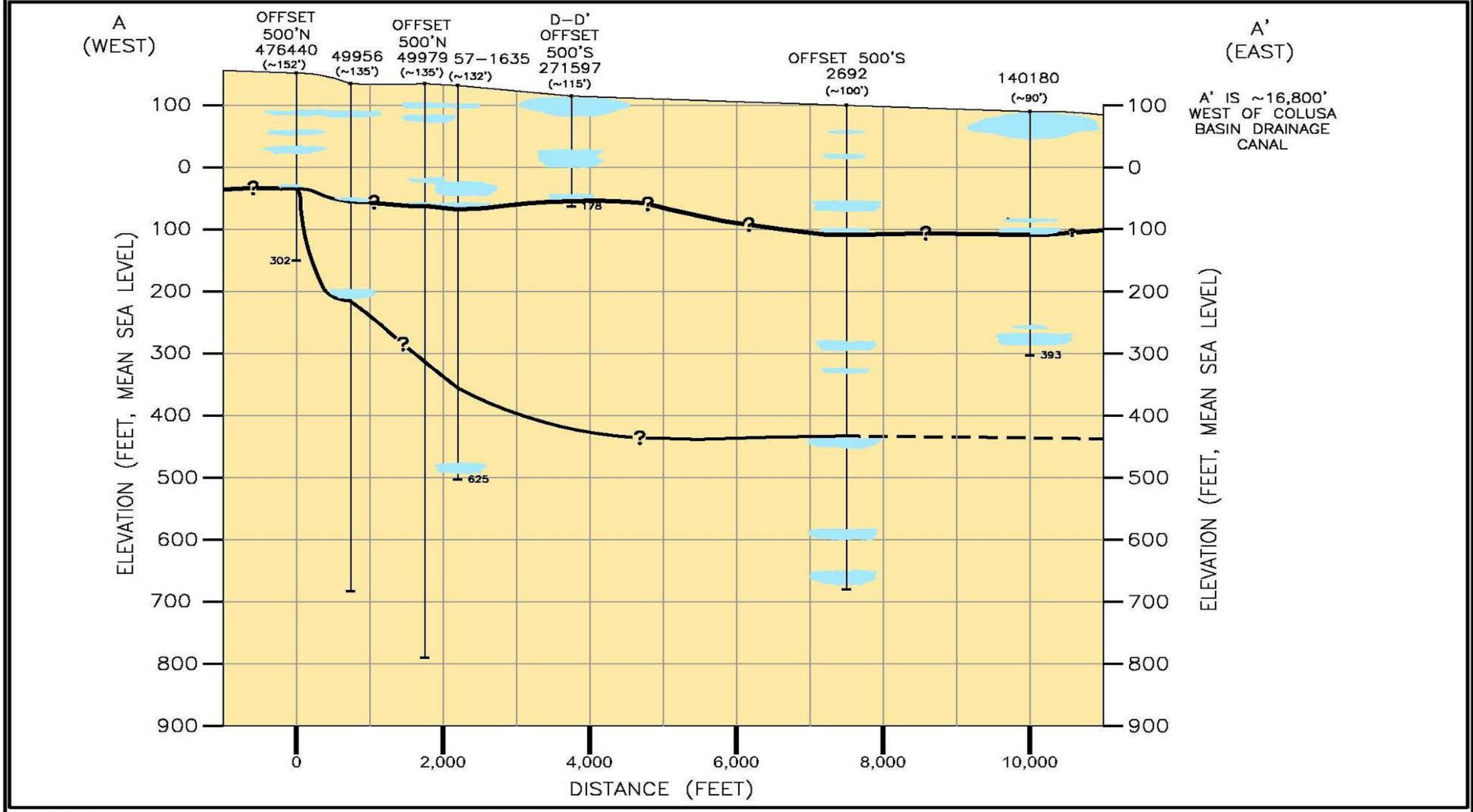


LEGEND

AREAS OF COARSE-GRAINED SEDIMENTS

—?— POSSIBLE POSITION OF MODESTO/RIVERBANK AND RED BLUFF/TEHAMA FORMATION BOUNDARY

—?— APPROXIMATE POSITION OF TRANSITION FROM YELLOW & BROWN TO BLUE & GRAY TONED SEDIMENTS, DASHED WHERE INFERRED.

HORIZ. SCALE 1" = 2,000'
VERT. SCALE: 1" = 200'

Figure 16
Dunnigan Water District
Hydrogeologic Evaluation
Cross Section A_A'

WEST YOST & ASSOCIATES

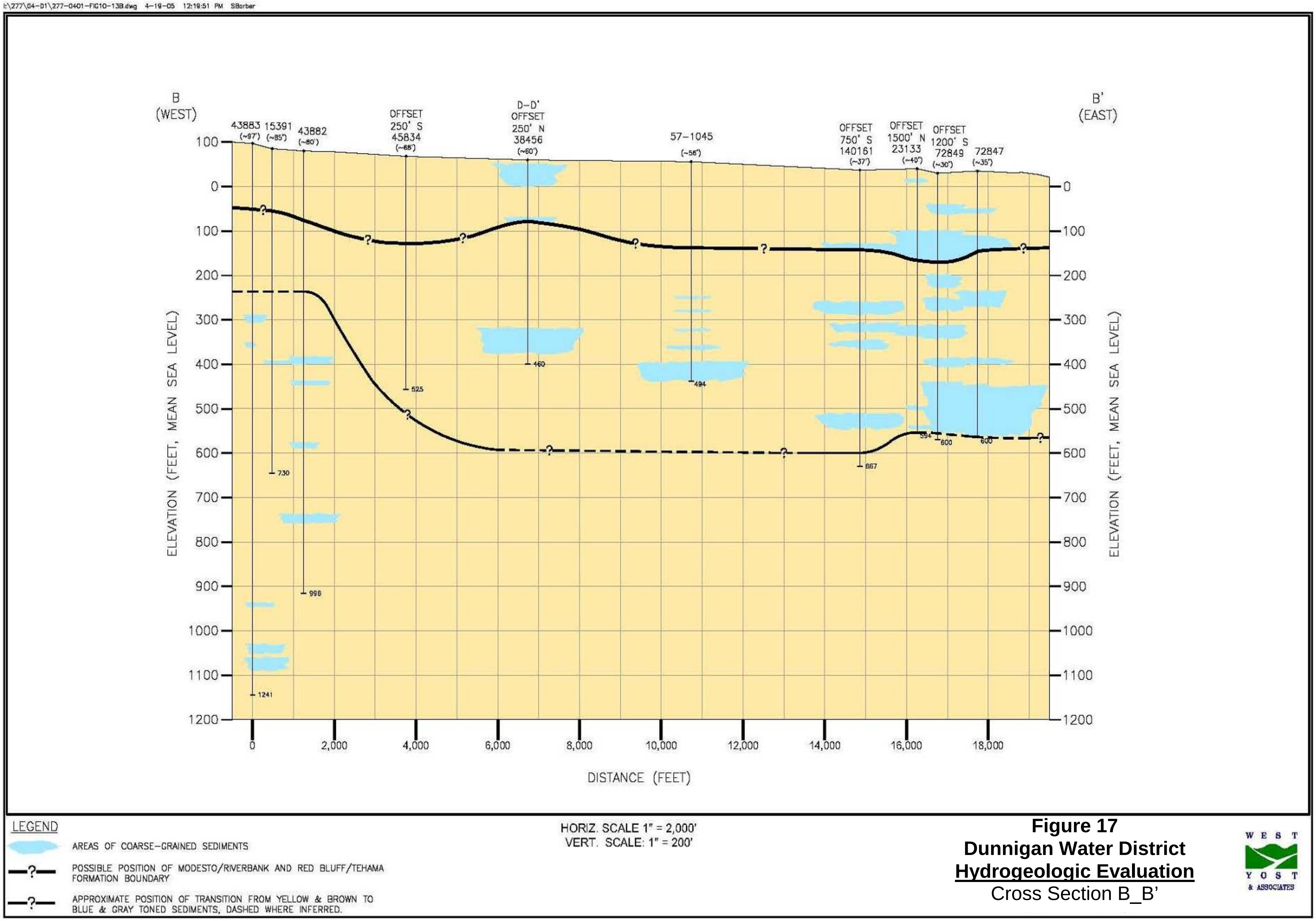
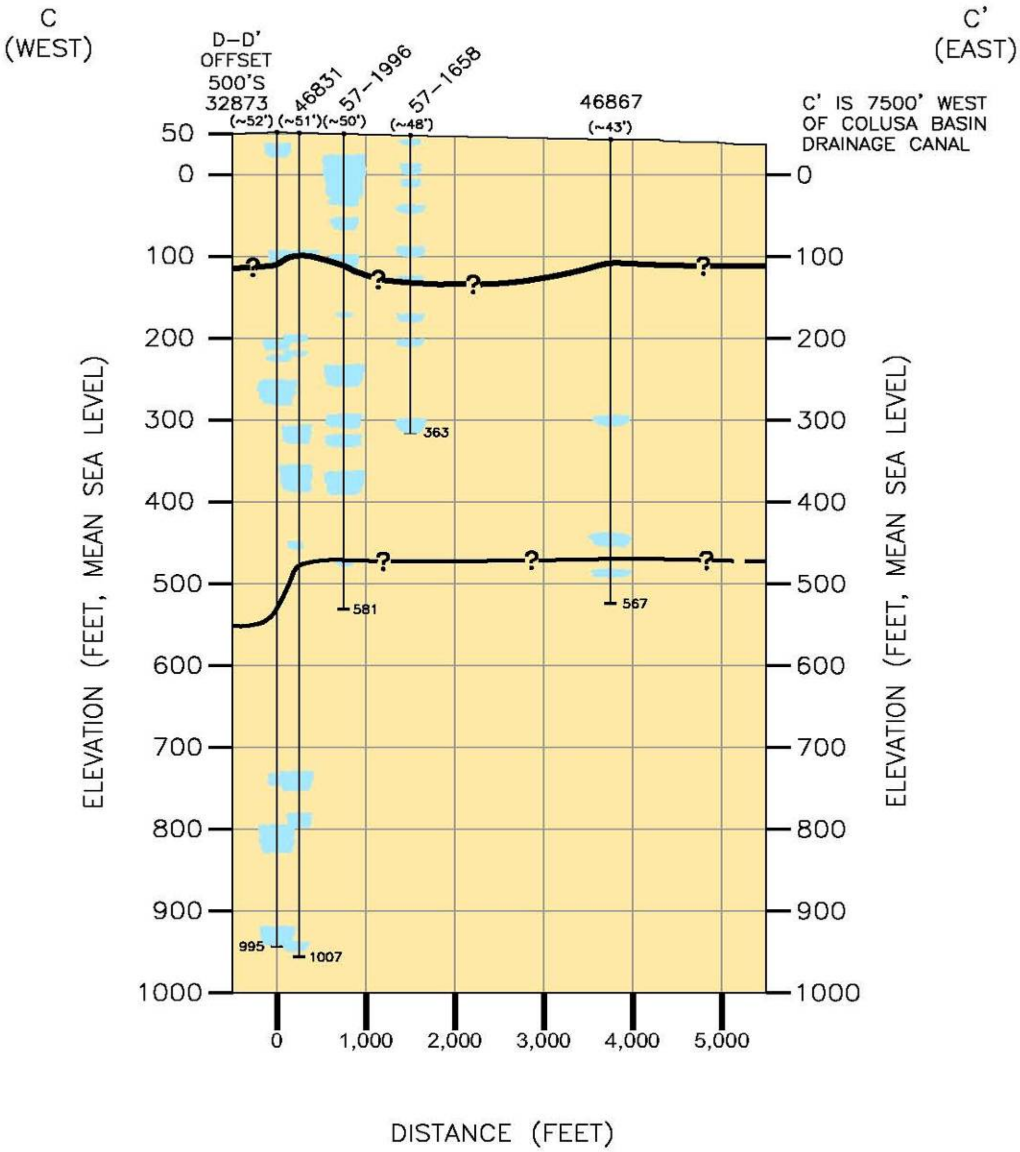


Figure 17
Dunnigan Water District
Hydrogeologic Evaluation
Cross Section B_B'



HORIZ. SCALE: 1" = 2,000'
VERT. SCALE: 1" = 200'

LEGEND

AREAS OF COARSE-GRAINED SEDIMENTS

POSSIBLE POSITION OF MODESTO/RIVERBANK AND RED BLUFF/TEHAMA FORMATION BOUNDARY

APPROXIMATE POSITION OF TRANSITION FROM YELLOW & BROWN TO BLUE & GRAY TONED SEDIMENTS, DASHED WHERE INFERRED.

Figure 18
Dunnigan Water District
Hydrogeologic Evaluation
Cross Section C_C'

WEST YOST & ASSOCIATES

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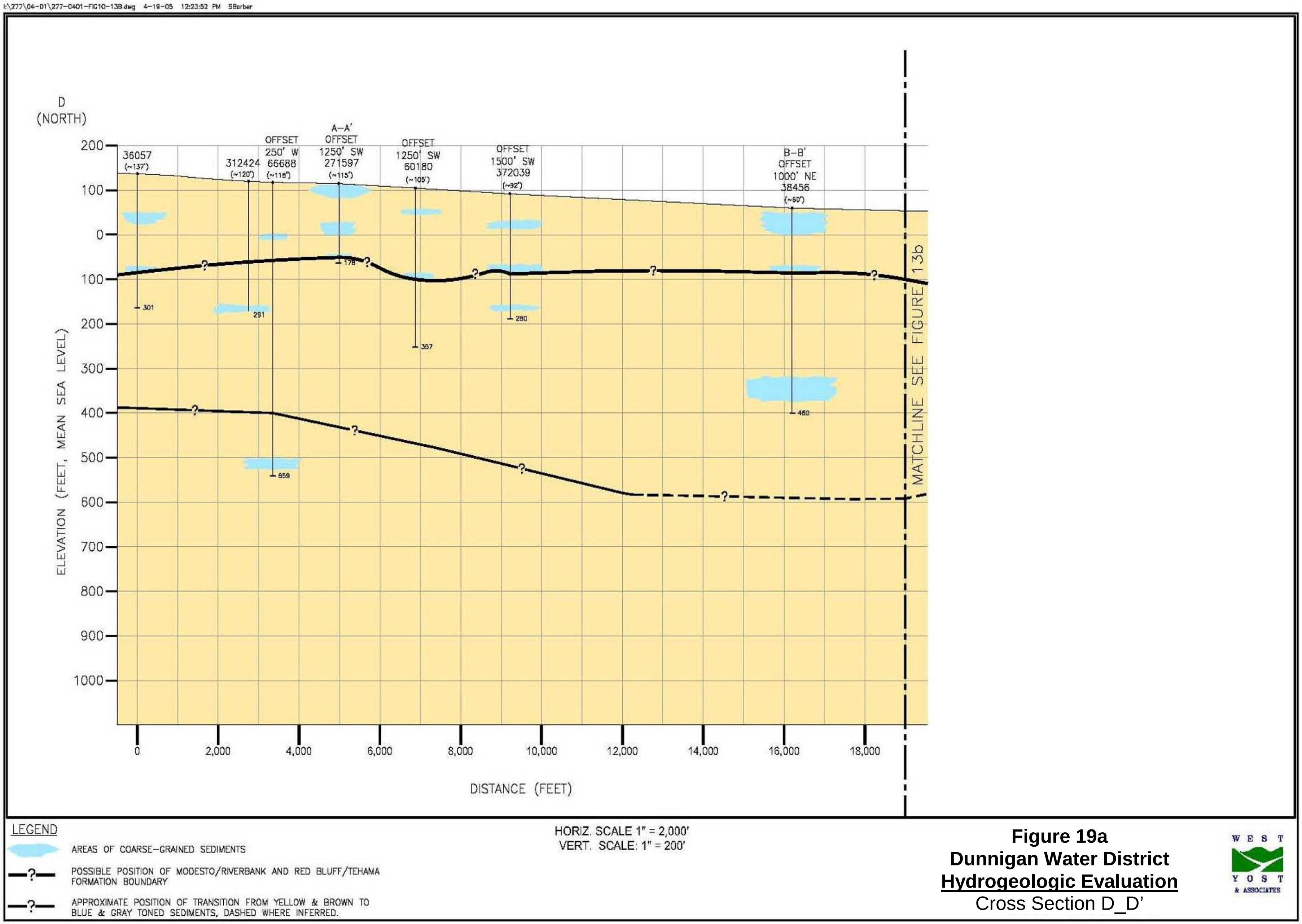


Figure 19a
Dunnigan Water District
Hydrogeologic Evaluation
Cross Section D_D'

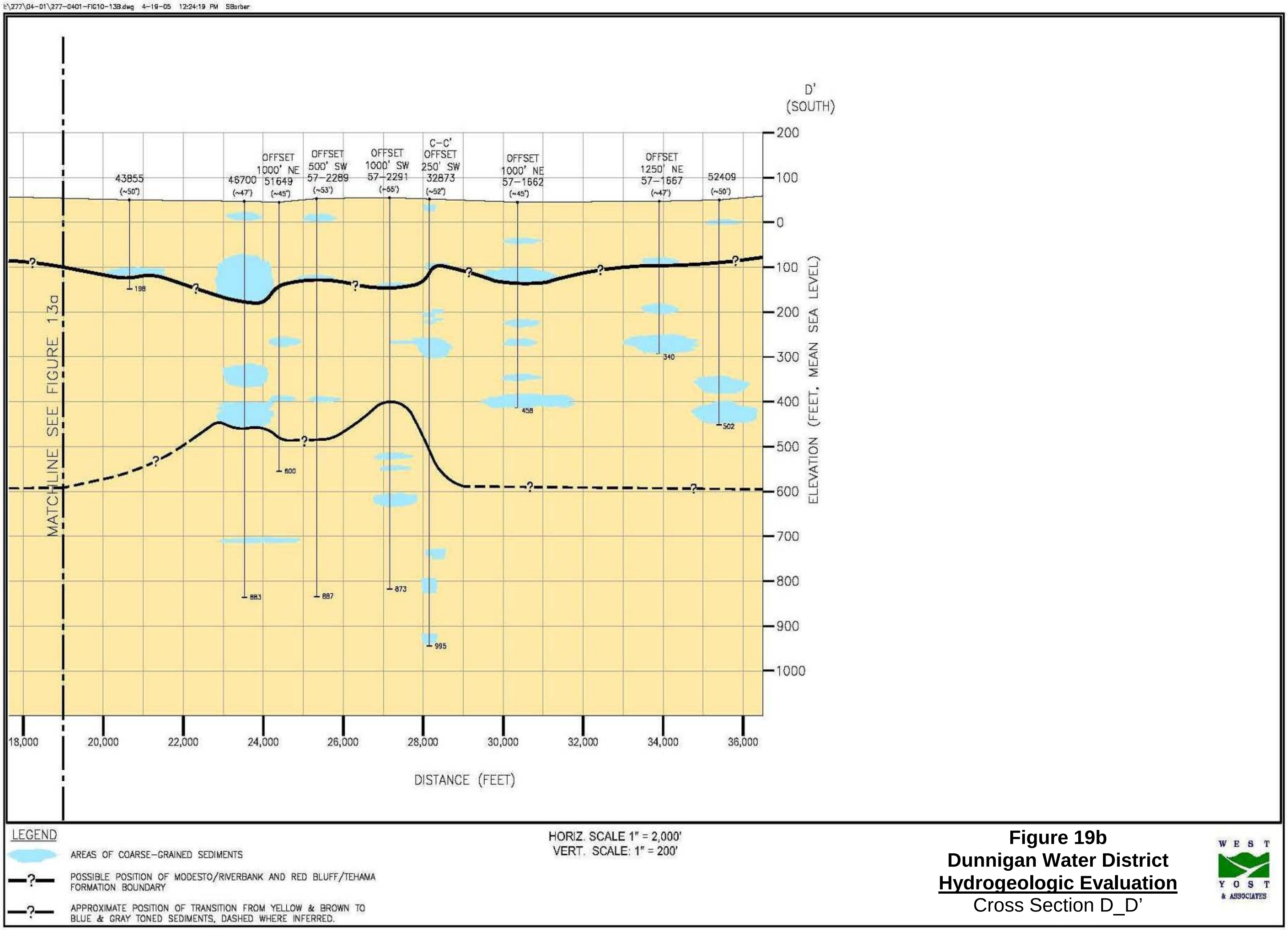


Figure 19b
Dunnigan Water District
Hydrogeologic Evaluation
Cross Section D_D'

2. other areas of Yolo County, including the Cities of Davis and Woodland, where it appears to be associated with a significant change in water quality with depth. During drilling of City of Woodland Well 24 in September 2004, it was noted that brown rinds formed on blue or gray sediments within about 24 hours of sample collection, presumably on exposure to air. This is an indication that the deeper sections of the aquifer are anoxic, or reduced. Oxidation-reduction conditions are a key control on water quality, which is discussed in a following section.

3. The boundary of the Modesto/Riverbank Formations and Tehama Formation was delineated based the following guidelines:

    - Consistency with published reports that indicate that the maximum thickness of the Modesto/Riverbank Formations is about 200 feet
    - Presence of a gravel or cemented gravel in the 100- to 200-foot depth range, overlying a fine grained unit, especially when this fine grained unit was described as heavy, brittle, broken or shale.

As shown on the cross sections, the coarse grained units exist as discrete bodies enveloped by finer grained sediments. The number and thickness of the coarse grained units varies with location and depth throughout the District. In the northern part of the District, in the vicinity of the Buckeye Creek alluvial fan, coarse grained units are relatively prevalent in the upper 200 feet of the aquifer, where they are interpreted to be a combination of Holocene stream channel deposits and the Modesto/Riverbank Formations. Coarse grained units occur only occasionally at greater depths in this area. Sediments at depths below roughly 200 feet are interpreted to be Tehama Formation (Figure 15, 16 and 19a). Further southeast, in the vicinity of Dunnigan, coarse grained deposits are not prevalent at any depth except in the vicinity of lower Buckeye Creek, where a relatively high concentration of coarse grained deposits exists from near land surface to a depth of at least 600 feet (Figures 15 and 17). A relatively high concentration of coarse grained deposits also exists from near land surface to a depth of about 600 feet near lower Bird Creek (Figures 15, 18 and 19b).

The depth to blue or gray sediments ranged from roughly 500 to 650 feet below land surface throughout most of DWD, but several exceptions were noted. Cross section A-A' (Figure 16), which crosses the Buckeye Creek alluvial fan perpendicular to the dominant structural trends in the Tehama Formation, shows that the depth to blue or gray sediments decreases to about 200 feet and coincides with what is interpreted to be the top of the Tehama Formation in the southwestern part of the cross section. Similarly, the depth to the top of the blue or gray sediments decreased to about 300 feet on the southwestern end of cross section B-B' (Figure 17). In both cases the depth to the blue or gray sediments decreases with decreasing distance from the Dunnigan Hills anticline and Zamora fault, or their northeasterly projections in the subsurface.

IX. Hydraulic Parameters

DWR, Central District performed a pump test to determine aquifer hydraulic properties during May and June of 2002 (DWR, 2004). Drawdown was measured during pumping of well 12N01W22A during normal operation for irrigation uses (Figure 20). The pumping well was 554 feet deep with screened intervals at various depths between 182 and 554 feet below land surface. With reference to the cross sections shown on Figures 15, 17 and 19a, the well is very likely screened in the Tehama Formation in an area with a relatively moderate number of coarse grained deposits. Results of the pump test were analyzed using the Theis (1935) method for confined aquifers. Transmissivity estimates

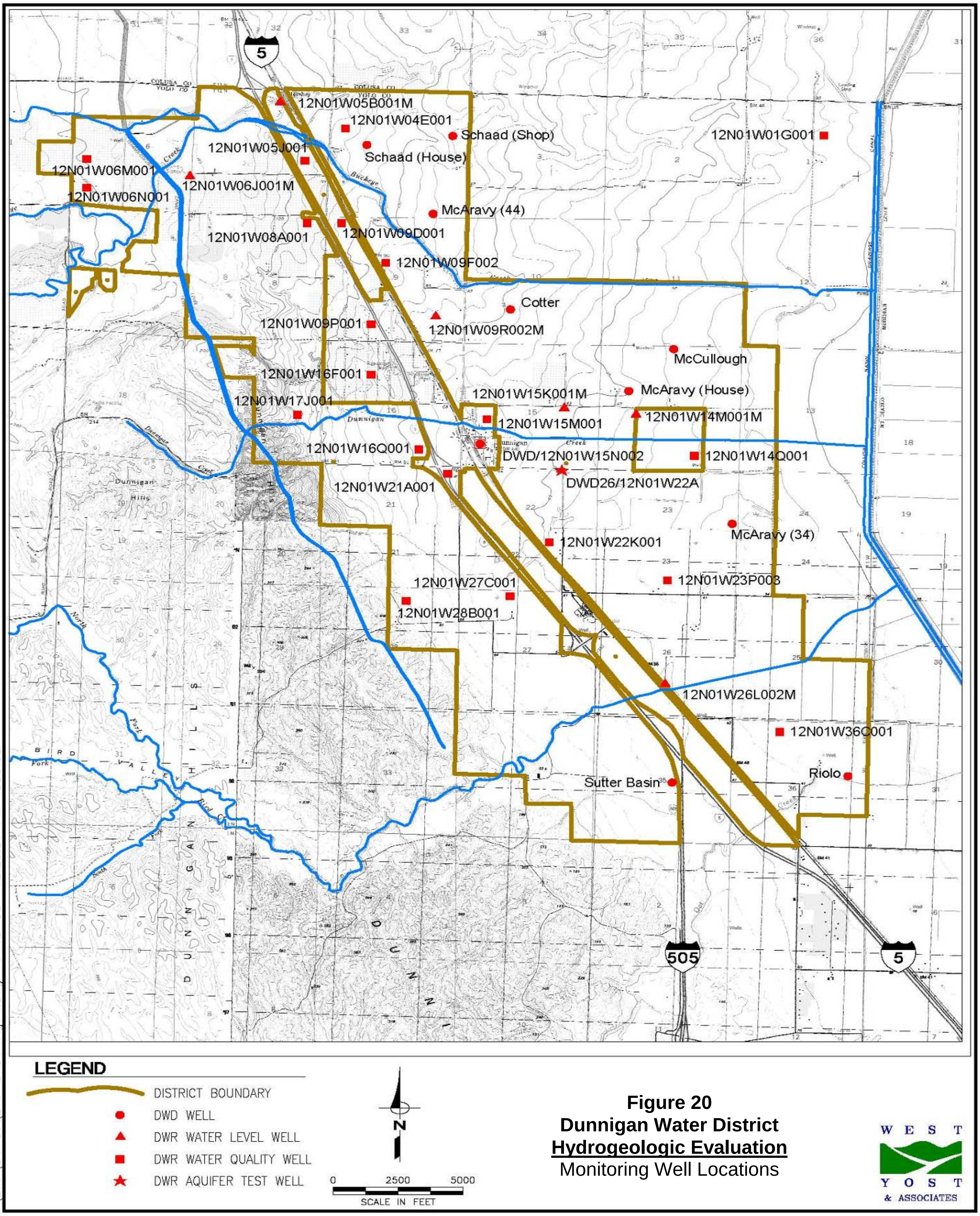


Figure 20
Dunnigan Water District
Hydrogeologic Evaluation
Monitoring Well Locations

I:\277\04-01\277-0401-Fig14.dwg 4-19-05 12:25:34 PM SBarber ranged from 5,600 to 12,000 square-feet per day (ft^2/d) and estimated storativity ranged from 0.0010 to 0.0023. In comparison, City of Davis wells completed at similar depths in the Tehama Formation have estimated transmissivities ranging from 4,000 to 10,000 ft^2/d (WYA, 2004).

X. District Groundwater Elevations

A. Hydrograph Analysis

Historical water elevation data were obtained for DWR monitoring wells 12N01W05B001 and 12N01W06J001, both located in the northern part of the District. The well locations are shown in Figure 20 and the hydrographs are shown on Figure 21. Hydrographs for other DWR wells are provided in Appendix G. Water elevations for well 12N01W05B001 date to 1948 and are presently measured on a monthly basis. The well provides the best long-term record of water levels available in the District. Measurements in well 12N01W06J001 began in 1953, and the well has been measured semi-annually since 1962.

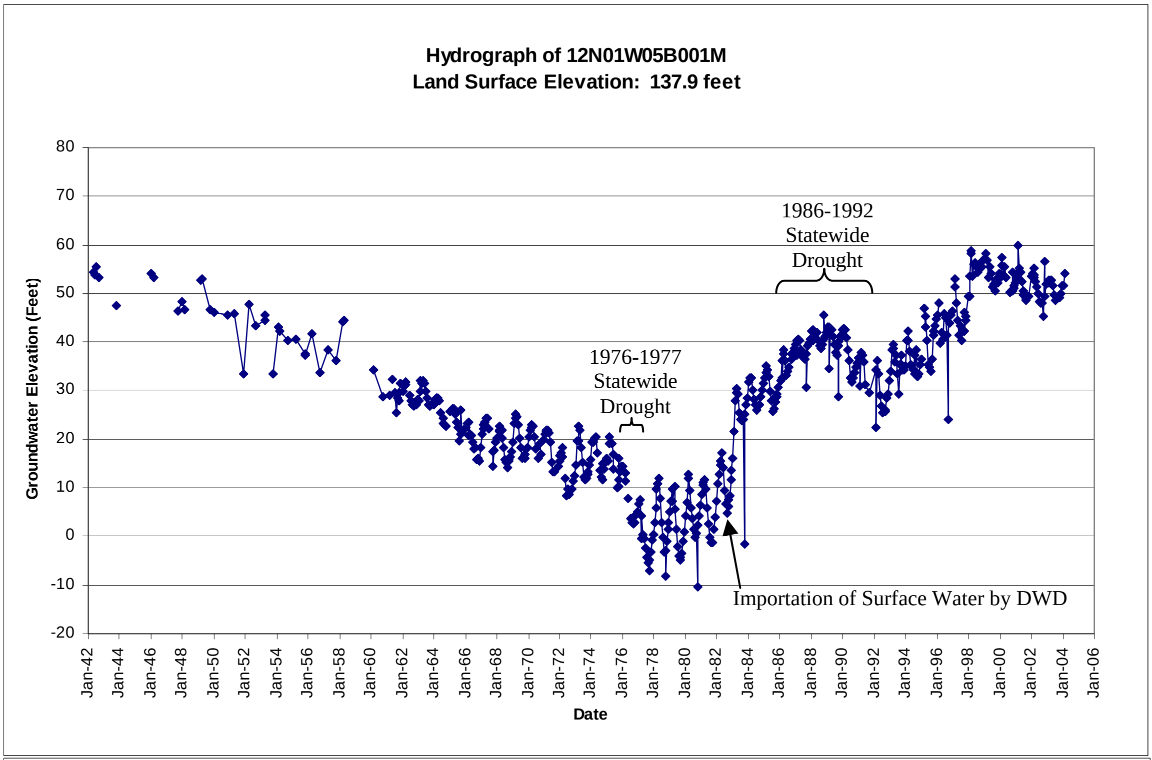
Three time scales of water level variation are evident in the record for well 12N01W05B001. Water levels changed on an annual basis with decreasing water levels during the summer and fall months, and increasing levels during the winter and spring. Second, aquifer response to periods of drought or heavy precipitation is visible over periods of approximately 2 to 5 years. Finally, over periods of decades, there is a general decline in water levels from near the beginning of the data record in the 1940's and 1950's to a historical low in 1976 and 1977. The decline was followed by generally increasing levels through 1999. Since 1999, levels have declined slightly.

Annual variations in water levels in well 12N01W05B001 ranged from 4 to 7 feet in the late 1980's to as much as 17 feet during the 1976–1977 drought. Annual changes were more pronounced in well 12N01W06J001. These annual variations ranged from approximately 6 to 30 feet. The annual variations were largest during the 1966 to 1986 period.

In order to assess the effect of hydrologic conditions on water levels, monthly total precipitation data were obtained for the National Weather Service (NWS) cooperative weather station in Woodland. The data cover the period from 1949 to 2003. A plot of total annual precipitation on a water year basis from 1970 to 2003 is presented in Figure 6. A water year runs from the previous October through September of the year under consideration. The Woodland precipitation values generally follow regional rainfall patterns, with some local variation.

Water level fluctuations over periods of several years appear to be correlated with changing hydrologic conditions. The 1976–1977 drought was the most severe in California history, though it was relatively short. The historical low water elevation of –7.1 feet in well 12N01W05B001 was recorded in October 1977. Similarly, 1986 to 1992 was an extended period of low precipitation statewide and in Dunnigan. Maximum annual water levels in well 12N01W05B001 were approximately stable from 1988 to 1990 before falling approximately 8 feet over the last two years of the period.

The most dramatic changes in water levels came in 1983. In the previous 5-year period, following the 1976-1977 drought, average annual water levels in 12N01W05B001 rose at an average of 1.7 feet per year during a period when annual rainfall was substantial. In the heavy precipitation year of 1983,



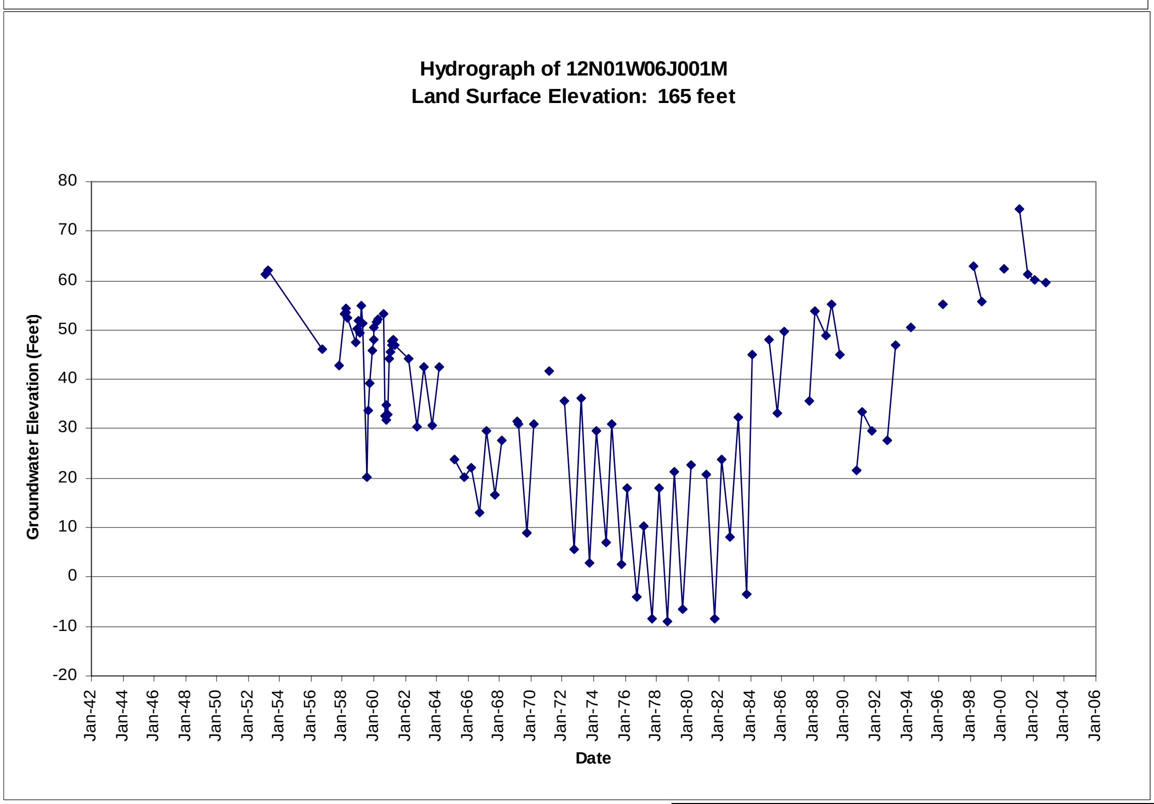


Figure 21

Dunnigan Water District
Hydrogeological Evaluation

Historical Trends in Groundwater Elevation average levels rose 21 feet. The precipitation in 1983 was not enough higher than the previous years to account for such a change.

DWD began deliveries of surface water in 1983. The surface water supply replaced some of the historic groundwater pumping, and a generalized increase in groundwater levels resulted in subsequent years. The imported surface water has also increased the direct recharge to groundwater, further aiding recovery of groundwater levels.

B. Groundwater Elevation Contour Analysis

Groundwater elevation contours are presented in Figures 22 to 25. Figures 22 and 23 are elevations in the fall of 1990 and the spring of 1991, respectively, and represent levels under drought conditions. Figures 24 and 25 show elevations measured in the fall of 1999 and the spring of 2000, respectively, and represent wet period conditions.

In general, groundwater flow in the District is from the northwest to the east and southeast, which roughly corresponds to the trend of the Buckeye Creek alluvial fan. Groundwater movement in the fall of 1990 was to the east and southeast, with an overall gradient of 0.0009 ft/ft between DWR monitoring well 12N01W06J001 in the northwest part of the District and the Riolo well to the southeast. Elevations in the spring of 1991 were up to 20 feet higher than in the fall, and flow was primarily to the southeast, under a gradient of 0.0007 ft/ft. Based on the elevation contours, groundwater was flowing from the Buckeye Creek watershed through the Buckeye Creek alluvial fan into the District.

Water elevations in the fall of 1999 were substantially higher than in fall 1990, with a gradient of 0.001 ft/ft. Well 12N01W05B001 was used for the gradient calculation, as it is a similar distance from the Riolo well, and data from well12N01W06J001 were not available. Even though the levels were measured in the fall, there was clear evidence of recharge from the vicinity of Buckeye Creek. The coarse material composing the alluvial fan provides a likely path of groundwater recharge in that area.

Water levels in the spring of 2000 were generally similar to those measured the previous fall, except for higher levels in the northwestern and southeastern extremities of the District. The contour patterns again evidenced recharge along Buckeye Creek, and the groundwater elevation contours near Bird Creek indicated there may have been recharge in that area as well. The gradient between the Riolo well and well 12N01W06J001 was 0.0014 ft/ft, or twice the spring 1991 gradient.

In both fall 1999 and spring 2000, there was a substantial component of groundwater flow to the east and northeast in the northeastern corner of the District, possibly due to pumping. In all of the periods assessed, pumping is evident in the vicinity of Dunnigan.

XI. GROUNDWATER MANAGEMENT PROGRAM

The District's Groundwater Management Program is presented in this section, comprised of policies and actions that will protect groundwater supplies and groundwater quality for sustainable use in the Dunnigan area.

The District's Groundwater Management Plan is shaped substantially by the prospect that appreciable new urban growth will occur in the Dunnigan area and within Dunnigan Water District

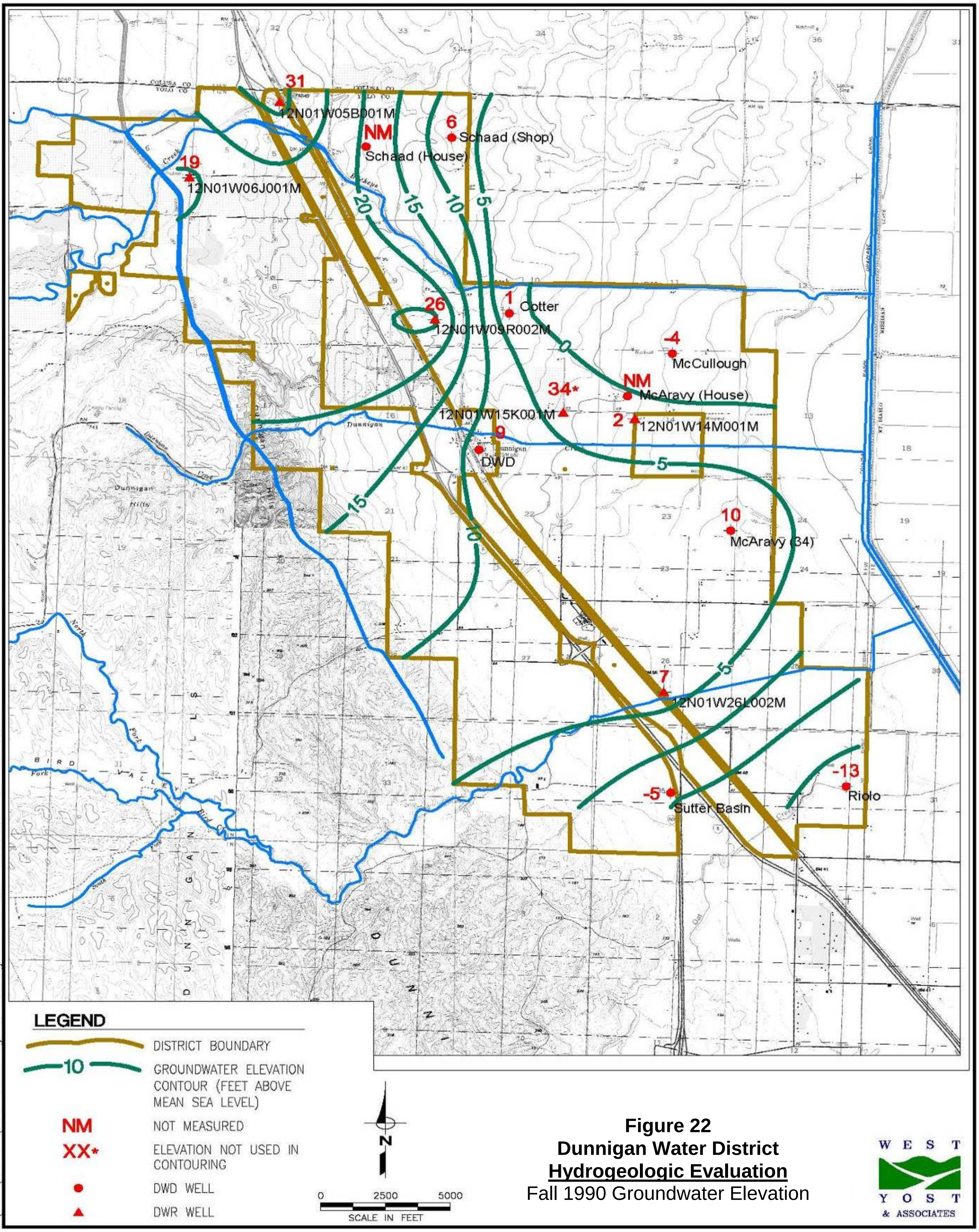


Figure 22
Dunnigan Water District
Hydrogeologic Evaluation
Fall 1990 Groundwater Elevation

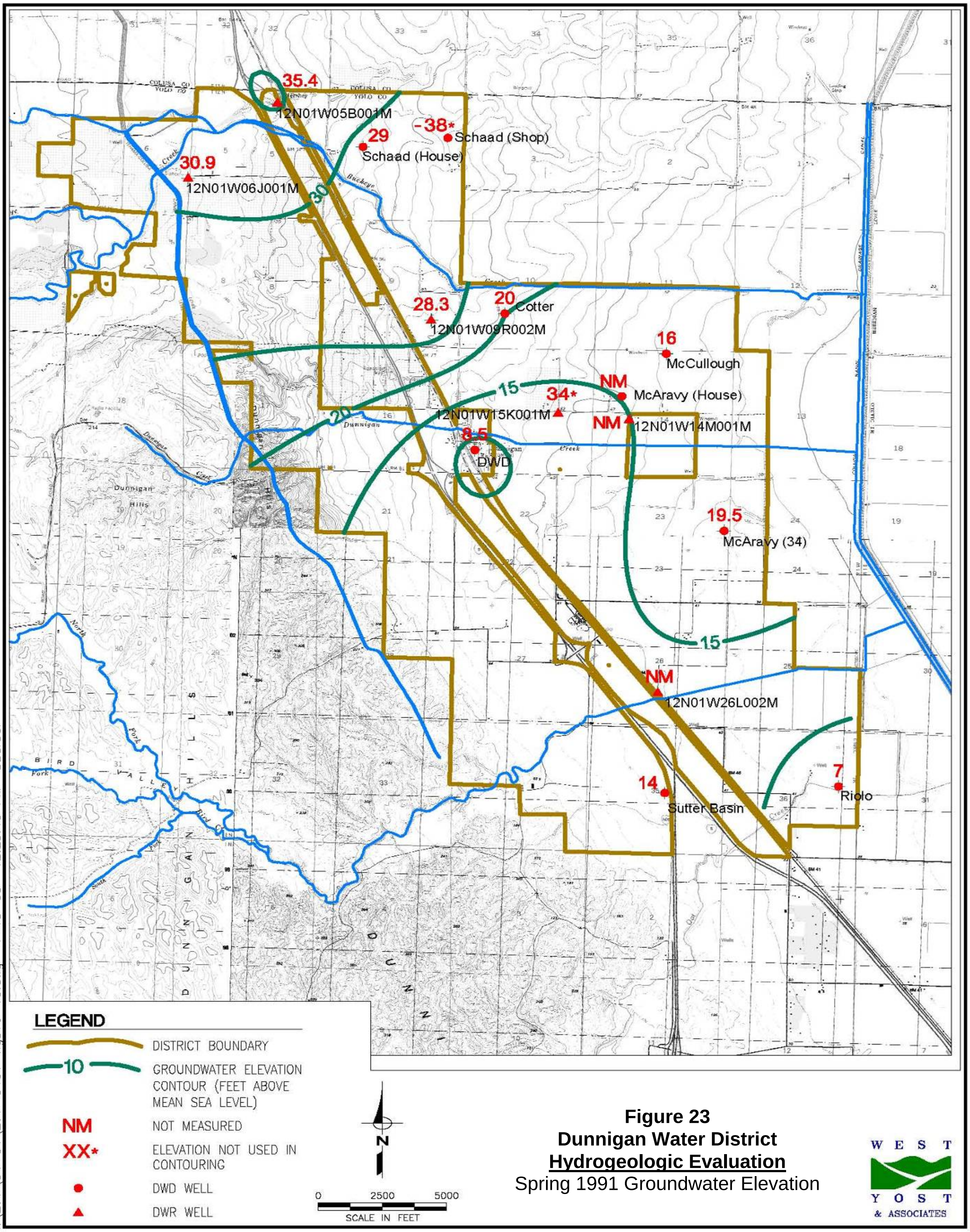


Figure 23
Dunnigan Water District
Hydrogeologic Evaluation
Spring 1991 Groundwater Elevation

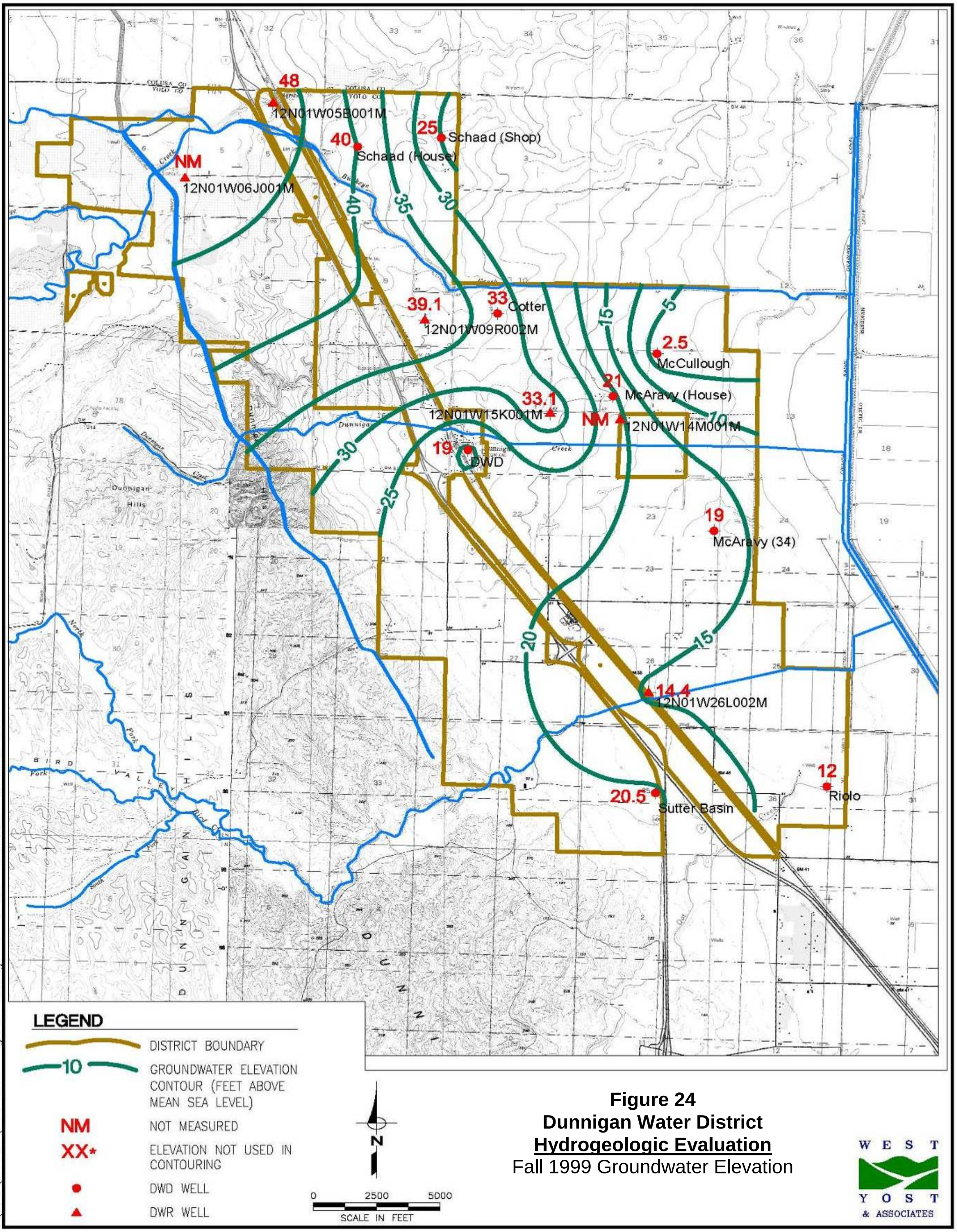


Figure 24
Dunnigan Water District
Hydrogeologic Evaluation
Fall 1999 Groundwater Elevation

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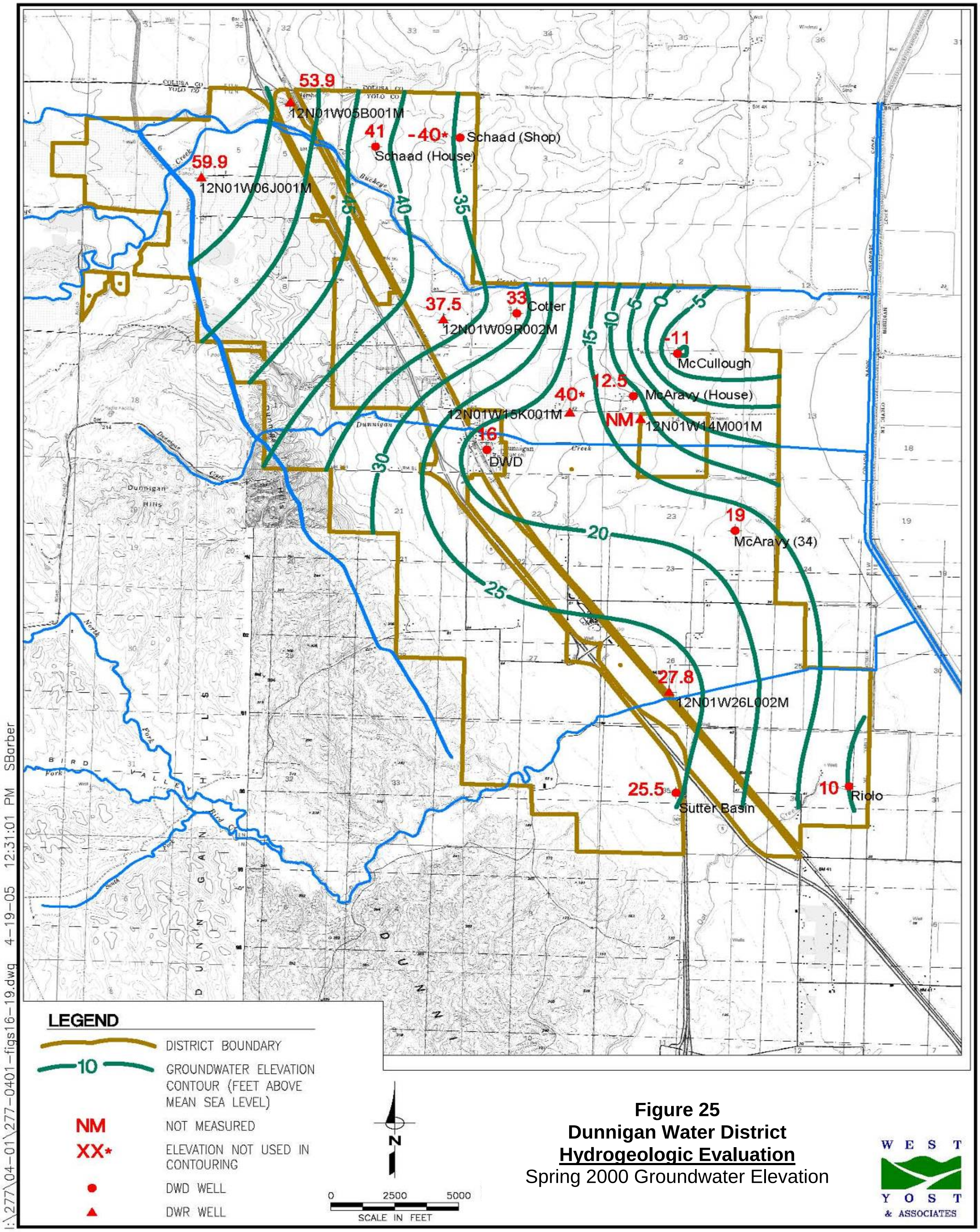

Figure 25
Dunnigan Water District
Hydrogeologic Evaluation
Spring 2000 Groundwater Elevation

in the future. The extent and exact location of urban growth depends in part on the Yolo County General Plan, which is presently being updated.

The potential effects of urban growth were evaluated as part of the District's Groundwater Management Investigation completed in 2005. Based on analyses of historical water balance and groundwater levels, it was concluded that urban development in the Dunnigan area could have adverse effects on groundwater conditions unless specific water management strategies are employed. The following excerpt from the Groundwater Management Investigation final report (October 2005) frames the main findings in this regard.

"Urban growth alternatives that are currently being considered for the Dunnigan area under the Yolo County General Plan Update could have significant adverse effects on the groundwater conditions, unless appropriate water management strategies are adopted. If substantial urban development does occur in and around Dunnigan as planned, overdraft conditions are predicted to result if urban water demands are satisfied by groundwater only and urban wastewater is discharged from the area However, water balance projections indicate that favorable groundwater conditions can be sustained by employing one or some combination of the following water management practices:

1. *Use surface water available through DWD to meet all or a substantial portion of the urban water demands. DWD's CVP contract allows for municipal and industrial use, and the District is favorably inclined to provide water for urban uses, potentially including taking on water treatment and distribution functions.*

2. *Recycle treated urban wastewater for irrigation within DWD. From a water balance perspective, using treated wastewater that would be discharged from the area is equivalent to using imported surface water because it results in a one-to-one reduction in groundwater pumping. However, use of wastewater for irrigation must be conducted by permit consistent with regulations that constrain farmers' crop choices and irrigation practices. Therefore, appropriate incentives would have to be offered to attract farmers willingly into reuse agreements.*

3. *Provide incentives for farmers to use more surface water. In the future, it is likely that DWD farmers will not use all of the surface water the DWD has available, due to high costs resulting from tiered pricing provisions that are expected in renewed CVP contracts. However, if urban users were to offer incentives to growers to use the water that for cost reasons they otherwise would not, this would have the effect to relaxing pumping on a one-to-one basis."*

Each element of the District's Groundwater Management Plan is described below.

A. Identification and Management of Wellhead Protection Areas and Recharge Areas

Deep percolation of rainfall and water applied for irrigation are important components of groundwater recharge in the Dunnigan area. Conversion from agricultural to urban land use has the potential to reduce groundwater recharge, and to increase storm runoff, due to increased land areas covered by roofs and pavement. Effects on recharge and storm runoff can be mitigated by capturing and recharging runoff from urban areas and by other means. Reuse of treated municipal wastewater offers certain water supply advantages but also poses potential risks to soil and water quality. As urban development plans emerge, throughout the processes of environmental, regulatory and statutory compliance, and during implementation, the District will engage to ensure that appropriate consideration is given to effects of urban land use conversion, with the view of preserving groundwater supplies and protecting groundwater quality in the Dunnigan area.

B. Regulation of the Migration of Contaminated Groundwater

Elevated concentrations of nitrates have been detected in groundwater in the Dunnigan area and are of concern to the District and groundwater users. Possible existing nitrate sources include: a) agricultural fertilizers leached by deep percolation of precipitation and applied irrigation water and b) private residential septic systems and small community or private sewage treatment systems that discharge wastewater to ponds or land. Potential future nitrate contamination could result from residential and commercial development.

With respect to agricultural sources, the District supports voluntary adoption by its landowners of agricultural best management practices (BMPs) that could reduce deep percolation. BMP adoption could provide other benefits also.

With respect to existing residential septic systems and small sewage treatment systems, the District: a) supports efforts to provide municipal sewer service to existing residences and businesses to replace use of septic and small sewer systems and ponds, and b) intends to monitor permitting requirements and compliance therewith.

With respect to possible future residential and commercial development, the District intends to ensure that all development will be served by adequately designed, constructed and operated wastewater collection and treatment facilities. The District's long-term goal is to ensure that all wastewater streams generated in the District are collected, treated and disposed in a manner that protects groundwater quality in the Dunnigan area.

C. Administration of a Well Abandonment and Well Destruction Program

Serious groundwater quality problems can result if wellhead areas are contaminated or if groundwater wells are not properly constructed and abandoned. Wells can become conduits for contaminants, pollutants, and degraded waters to flow into otherwise usable groundwater aquifers. All matters pertaining to well construction and abandonment, wellhead protection and contamination are currently administered by Yolo County. The District acknowledges the County's jurisdiction in this regard and will cooperate with the County through provision of any relevant, available information to which the District may have access.

D. Mitigation of Conditions of Overdraft and Promotion of Water Conservation

The District recognizes that good management of available surface and groundwater supplies begins with water conservation, defined here as seeking to minimize the amount of water extracted to accomplish the intended beneficial use. Toward this objective, the District will continue to promote voluntary adoption of on-farm water management practices that are appropriate and cost effective.

E. Monitor Groundwater Levels and Quality

Dunnigan Water District began monitoring groundwater levels in selected production wells in 1990. As part of a groundwater management investigation completed in 2005, this monitoring well network was reviewed based on the increased knowledge of the aquifer system developed through the investigation. The monitoring network was found to provide adequate spatial representation for monitoring the groundwater elevations in DWD; however, reliance on production wells for groundwater levels is problematic due to the influence of well operation on water levels. Therefore, pursuant to the recommendations of consultants and DWR, the District intends to construct at least one and possibly more dedicated monitoring wells. State and possibly other funding sources will be pursued for this purpose.

A groundwater quality monitoring program was also developed as part of the Groundwater Management Investigation with input from consultants and DWR staff. A baseline round of water quality sampling was performed in early October, 2005 with supervision by DWR staff.

Data collected from groundwater monitoring activities (both water levels and water quality) will be stored at the DWD office in a Water Resources Information Database (WRID). The information will also be sent to Yolo County Flood Control and Water Conservation District (YCFC&WCD) for incorporation into the Yolo County WRID. The DWD WRID has been developed using data protocols and guidelines provided by YCFC&WCD to ensure compatibility between the two systems. The DWD WRID stores data in a Microsoft Excel spreadsheet. This program enables easy transfer of data to the Microsoft Access database used in the Yolo County WRID.

Of particular concern to the District is the accumulation of salts in shallow groundwater and agricultural soils because the agricultural crops grown in the District are sensitive to salinity. Cropping choices and crop yields can be reduced significantly when salt concentrations become elevated. The eastern portions of the District, where groundwater levels are shallow, are most vulnerable to salt accumulation. The District will track spoil and shallow groundwater salinity conditions informally through information exchanges with District landowners. If conditions warrant, soil and water chemical tests may be conducted. The District will continue its program of measuring depths to shallow groundwater in the spring and fall of each year.

F. Facilitate Conjunctive Use Operations

Water demands in Dunnigan Water District are satisfied through conjunctive use of surface water supplies delivered by the District and groundwater supplies produced from private wells. The historical balance of surface water and groundwater use since surface water delivery began in 1983 has resulted in reversal of long-term groundwater overdraft and substantial recovery of groundwater levels in most locations in the District. However, potential future land use changes, particularly urbanization of existing agricultural lands and related impacts to the local water balance, could result in a return to overdraft conditions.

As part of this Plan, the District intends to monitor groundwater levels to stay abreast of changes and trends in groundwater conditions. The District will periodically review groundwater monitoring information and evaluate the need to adjust policies to maintain water levels compliant with District BMOs as they may be modified over time. Specifically, the District will: (1) set surface water allocation and pricing policies to ensure maximum practical use of available CVP supplies, (2) work with groundwater producers to maintain or increase the ability to use surface water when its is available and groundwater when it is not (dual supply capability), (3) evaluate proposed land use changes with respect to impact to the local water balance and take action accordingly, (4) cooperate in planning, constructing and operating projects that preserve or enhance the District's conjunctive water management capabilities, and (5) actively seek external sources of funding to enhance the District's ability to plan and implement conjunctive water management initiatives.

G. Identification of Well Construction Policies

The District will rely on Yolo County well construction standards and enforcement thereof so long as those standards and enforcement are, in the opinion of the District, adequate to protect Dunnigan area groundwater supplies and water quality. In the event that the District determines that County standards or enforcement are not adequate, the District may adopt and enforce its own well construction standards.

H. Construct Groundwater Management Facilities

While the District does not presently intend to construct groundwater management facilities, it may elect to do so if long-term overdraft conditions become evident. Facilities that may be considered to address groundwater overdraft conditions include groundwater recharge basins, injection wells, and extraction wells.

I. Development of Relationships with State and Federal Regulatory Agencies

The District will seek out mutually beneficial relationships with state, federal and other agencies for purposes of further developing, updating and implementing this Groundwater Management Plan. In particular, the District will pursue financial assistance, grants and technical services, such as through DWR, to support and advance the elements of this Plan.

J. Review of Land Use Plans and Coordination with Land Use Planning Agencies

The District will review proposed development plans and other documents made available for review through Yolo County, State or other regulatory or statutory processes, such as the Yolo County General Plan Update process. The District will submit comments consistent with its Groundwater Management Plan and other District policy.

XII. Basin Management Objectives

A. Groundwater Level Objectives

Groundwater elevations should be maintained to ensure adequate groundwater supplies to all users. Historical information on groundwater levels combined with hydrologic analyses show that the quantity of groundwater available in the Dunnigan area is limited. As mentioned previously, prior to surface water being available through Dunnigan Water District, groundwater elevations had fallen to a point where many wells were failing and had to be replaced or deepened. Groundwater levels in the area have since recovered, but could decline again due to drought, land use changes and other factors. Urban development in the Dunnigan area is of particular concern.

Decline of groundwater levels could result in increased energy costs for pumping, the need to deepen existing wells and the need to construct new wells. Dunnigan Water District will continue to monitor groundwater levels. Monitoring results will be compared with alert levels established by the BMO advisory committee.

Groundwater level BMOs were developed for selected DWR monitoring wells using a quantitative method. DWR monitoring wells were selected instead of the DWD monitoring wells because their period of record included periods of overdraft, as well as recovery. Because the wells sampled by

DWR can vary, BMOs will eventually be developed for DWD monitoring wells when sufficient data is available. This will ensure uninterrupted monitoring and a sustainable BMO process.

The advisory committee developed a two stage alert system for the BMO indicator wells. The first alert level triggers a warning that groundwater levels have dropped to levels that could cause problems. The second alert level triggers a warning that groundwater levels are precariously low, and corrective actions should be investigated and taken if prudent.

The two alert levels were selected for the BMO indicator wells based on historical spring water levels. Committee members felt that using historical groundwater conditions to set the alert levels was the preferred method of development. The Stage 1 alert levels were selected at groundwater elevations that were at or above the levels observed during the drought of the late 1980's and early 1990's. These levels were selected based on the adverse impacts that occurred to some wells in the area. The Stage 2 alert levels were set to be just above the groundwater elevations experienced during the late 1970's and early 1980's. This period reflects the lowest groundwater elevations ever recorded for the area. Hydrographs for the BMO indicator wells and the Stage 1 and Stage 2 alert levels are provided in Appendix F.

The committee developed the following actions to be taken by DWD in conjunction with the groundwater level objectives:

<u>General Actions:</u>

- Assess the effectiveness of the groundwater level monitoring network on an annual basis.
- Develop relationship between DWR monitored wells and DWD monitored wells.

<u>Stage 1 Alert Actions:</u>

- Resample well(s).
- Evaluate Stage 1 Alert groundwater elevation(s) and determine if the alert is valid. If not, then modify Stage 1 alert level.
- Provide water conservation information to groundwater users.
- Notify Yolo County of Stage 1 Alert.
- Notify Yolo County Water Resources Association of Stage 1 Alert.

<u>Stage 2 Alert Actions:</u>

- Resample well(s).
- Evaluate Stage 2 Alert groundwater elevation and determine if the alert is valid. If not, then modify Stage 2 alert level.
- Evaluate water management strategies that encourage surface water use by Dunnigan Water District farmers.
- Evaluate providing surface water to industrial and residential customers.
- Notify public of Stage 2 Alert.
- Notify Yolo County of Stage 2 Alert.
- Notify Yolo County Water Resources Association of Stage 2 Alert.

B. Groundwater Quality Objectives

DWD wants to prevent degradation of groundwater quality in the Dunnigan area for the benefit of all groundwater users. Groundwater quality in the area is generally well suited for agricultural use. Some shallow domestic wells near the town of Dunnigan produce water with elevated concentrations of nitrates. A baseline round of water quality sampling was performed in 2005. Changes in land use may affect groundwater quality in the area. Baseline and future monitoring results will be compared with historical data and water quality standards for agricultural and drinking water to determine whether potential water quality problems exist. Quantitative groundwater quality BMOs will be developed once a more complete understanding of groundwater quality for the area has been developed.

Dunnigan Water District will monitor groundwater quality in the Dunnigan area and will coordinate with local landowners and appropriate local, state and federal agencies to minimize degradation of groundwater quality. The monitoring network will be reviewed periodically to ensure that changes to the Dunnigan area that could affect groundwater quality are captured in the data. Dunnigan Water District will work with the county to find a solution to the nitrate problem in Dunnigan.

The committee developed the following actions to be taken by DWD in conjunction with the groundwater quality objectives:

General Actions:

- Assess the effectiveness of the groundwater quality monitoring network and water quality tests on an annual basis.
- Work with Yolo County to find a solution to the Dunnigan nitrate problem.
- Coordinate with appropriate state and federal regulatory agencies if water quality problems are found.
- Notify Yolo County when potential problems are discovered.
- Notify public through letters to landowners/households.
- Gather data from other agencies regarding water quality.

C. Subsidence Objectives

DWD wants to protect the area from potential inelastic land surface subsidence. Historically, land subsidence has not been an issue of concern in the Dunnigan area. However, significant land subsidence has occurred south of Dunnigan in the Zamora area. Land subsidence can damage infrastructure and permanently reduce the water storage capacity of the aquifer. There is an on-going land subsidence monitoring network in Yolo County. There are three monitoring stations in the vicinity of the Dunnigan Water District. Dunnigan Water District will review subsidence data and take appropriate actions if land subsidence becomes a concern.

The committee developed the following actions to be taken by DWD in conjunction with the inelastic land subsidence objectives:

General Actions:

- Review results of subsidence monitoring network when reports are published (every three years).
- Evaluate results to determine if a subsidence problem exists.

- Coordinate with local, state and federal agencies to alleviate subsidence problems if subsidence becomes a concern.

XIII. PLAN IMPLEMENTATION

A. Rules and Regulations

According to Water Code Section 10753.8 (a), a local agency shall adopt rules and regulations to implement and enforce an adopted groundwater management plan. The local agency is not authorized to make a binding determination of the water rights of any person or entity (Section 10753.8 (b)). The local agency is also not authorized to limit or suspend extractions unless the local agency has determined through study and investigation that groundwater replenishment programs or other alternative sources of water supply have proved insufficient or infeasible to lessen the demand for groundwater (Section 10753.8 (c)).

In adopting rules and regulations, the local agency shall consider the potential impact of those rules and regulations on business activities, including agricultural operations, and to the extent practicable and consistent with the protection of the groundwater resources, minimize any adverse impacts on those business activities (Section 10753.9).

B. Program Management

This Groundwater Management Program will be implemented and managed according to the policy and guidance of the Board of Directors of Dunnigan Water District. At least annually at one of its regular meetings, the Board will review available information pertaining to groundwater conditions and consider taking appropriate actions consistent with the Program.

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APPENDIX A

Notice of Intent to Adopt a Resolution to Prepare a Groundwater Management Plan

Date

Name
Address
Dunnigan, CA 95937

Dear (Insert Name),

Dunnigan Water District is currently conducting a Groundwater Management Investigation as part of a comprehensive program to ensure long-term water supply reliability and affordability in the Dunnigan area. The investigation is funded by an AB303 grant. Groundwater is an important water supply source in the area and is used for domestic, industrial, commercial and agricultural purposes. The investigation will provide a greater understanding of the capability and limitation of local groundwater aquifers.

As part of this work, Basin Management Objectives (BMOs) are being developed for Dunnigan Water District. BMOs provide a locally controlled, flexible framework for monitoring groundwater levels and quality and responding to unacceptable conditions that could develop. Water agencies are required to adopt BMOs to qualify for future grant funding under the provisions of SB 1938.

As a landowner within Dunnigan Water District, you are invited to participate in the development and adoption of BMOs. This will likely involve two meetings, one to initiate the process and discuss alternative approaches to establishing BMOs, and a second meeting to review specific BMO recommendations. The first meeting is scheduled for June 16th at 6 pm at the Dunnigan Fire Station. Your attendance and participation will be appreciated.

Please call me at 724-3271 should you have any questions.

Sincerely,

Donita Hendrix
Manager, Dunnigan Water District

APPENDIX B

Public Meeting Notification

NOTICE OF PUBLIC HEARING

On Thursday, February 15, 2001, the Directors of the Dunnigan Water District will consider whether to adopt a Groundwater Management Plan, which has been developed according to California Water Code Sections 10750 et. Seq., commonly known as AB3030. The Groundwater Management Plan is part of the District's efforts to protect local groundwater supplies and meet District landowner's irrigation water needs reliably and sustainably. The Plan calls for increased monitoring of groundwater levels and water quality, to better define local groundwater conditions, capabilities and limitations. If undesirable groundwater conditions were to develop in the District, such as declining groundwater levels or worsening water quality, the Plan allows the District to pursue measures and facilities to mitigate those conditions. There are no provisions in the Plan that would restrict the availability of groundwater to District landowners. No special fees will be assessed to implement the Plan, the cost of which is estimated to be $_,___annually. A copy of the draft Plan is available for review at the District office or can be provided for the cost of reproduction. If you are interested in reviewing the draft Plan, please contact District staff at 530/724-3271.

Public Meeting

DUNNIGAN WATER DISTRICT

Help Protect Dunnigan's Groundwater Basin

Please Attend an Informational Meeting Regarding the Adoption of Basin Management Objectives (BMOs) by Dunnigan Water District

June 16th at 6:00 pm at the
Dunnigan Fire Station
29145 Main Street

BMOs will help guide management of the basin for long-term groundwater sustainability

APPENDIX C

PowerPoint Slides used at Initial Public Meeting

Dunnigan Water District

Groundwater Management
Investigation

Basin Management Objectives

Grant Davids, PE
Hilary Reinhard, PE

Purpose of this Meeting

- Provide Overview of DWD
- Review GMI Purpose and Progress
- Provide Information on BMOs
- Describe the BMO Adoption Process
- Form BMO Advisory Committee

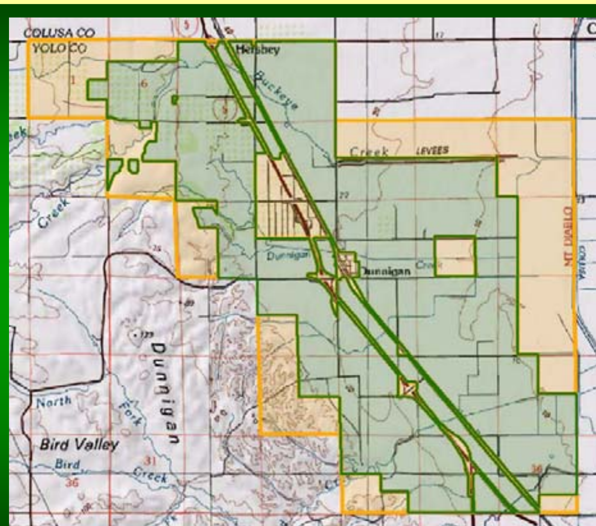
Dunnigan Water District

- Formed in 1956
- Water deliveries began in 1983
- Primarily provides water for agricultural purposes
- 10,780 acres of irrigated farmland
- 19,000 af contract with CVP

DUNNIGAN WATER DISTRICT

DAVIDS ENGINEERING, INC

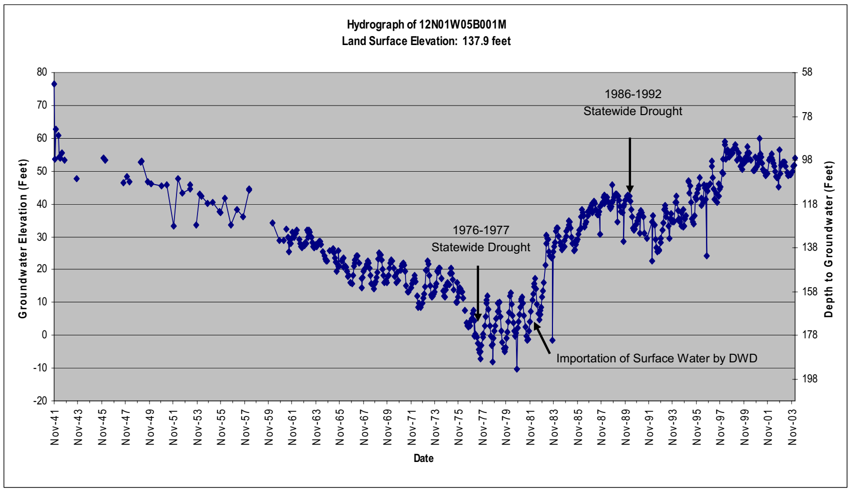
Dunnigan Water District



DUNNIGAN WATER DISTRICT

DAVIDS ENGINEERING, INC

Introduction and Background



Groundwater Management Investigation

Long-term Goals and Objectives:

a. Water supply reliability
b. Water supply affordability
c. Protection of groundwater resources.

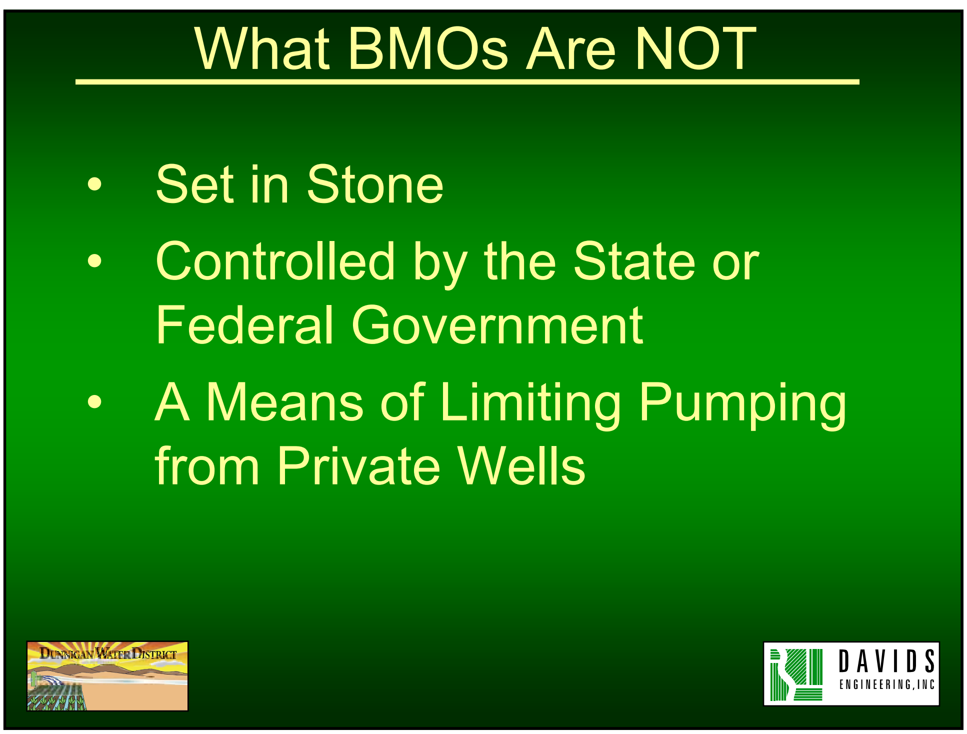
Introduction & Background

- Fall 2002 — Application Submitted
- Spring 2003 — Grant Approved
- Fall 2003 — Original Start Date
- Feb 2004 — Contract Signed
- March 2004 — Start Date
- October 2005 — Project Completion

Task Breakdown

1. Hydrogeologic Characterization
2. Groundwater Monitoring Program
3. Conjunctive Operations Analysis
4. Basin Management Objectives (BMOs)


Basin Management Objectives (BMOs)
• Component of groundwater management
• Protects groundwater conditions
• Review process for groundwater quality and quantity
DUNNIGAN WATER DISTRICT
DAVIDS ENGINEERING, INC


What BMOs Are NOT
• Set in Stone
• Controlled by the State or Federal Government
• A Means of Limiting Pumping from Private Wells
DUNNIGAN WATER DISTRICT
DAVIDS ENGINEERING, INC

What BMOs Are

- Adaptive Management
- Locally Controlled
- Monitoring and Review of Groundwater Conditions

Dunnigan Water District

DAVIDS ENGINEERING, INC

Why Establish BMOs?

- Ensure long-term availability and quality of groundwater
- BMOs are required for future grant funding (SB 1938)

Dunnigan Water District

DAVIDS ENGINEERING, INC

Possible BMO Parameters

- Groundwater Levels
- Groundwater Quality
- Land Subsidence
- Surface Water Flow & Water Quality

BMO Process

Initial Public Meeting

↓

Advisory Committee Formation

↓

Advisory Committee Meetings

↓

Second Public Meeting

↓

BMO Adoption by DWD

Advisory Committee Responsibilities

- Develop BMO objectives
- Select BMO indicator wells
- Select alert levels

Advisory Committee Responsibilities

- Attend 2 or 3 Meetings during the next 2 months


Advisory Committee Volunteers
• Sign up sheet available
• Will contact volunteers to arrange the first meeting
DUNNIGAN WATER DISTRICT
DAVIDS
ENGINEERING, INC


Thank you for your interest.
DUNNIGAN WATER DISTRICT
DAVIDS
ENGINEERING, INC

APPENDIX D

Initial Meeting Sign-in Sheet

Jun 17 05 12:26p DUNNIGAN WATER DISTRICT 530 724 3273 p.1

Dunnigan Water District
BMO Public Meeting #1
Attendance Record

Name	Phone Number	Email Address
Lila J. Ames	530 724-0378	-
Grover J. Cowan	530 724-0379	
Shirley Goach	530-724-3371	
Karl McCullough	530-724-3371	
Secy Hastings	530-724-3239	
Willard Ingalls	724-3243	
Larry & Cathy Cassevah	400-3671	popolarry@hotmail.com
Bill Cotter	530-724-3321	
Vaughnette Lovell	530-724-0113	
Thomas Mazzoni	724-3218	
Donna Bartels WEA	666-2733	wea@dcn.org
Caroline Long	724-3595	
E. Linse	724-3225	
Tommy Gallatt	724-4106	wgallatt@sac.global.net
Neil Busch	724-3373	neilcathy@colusa.net.com
Keith Williams	724-3323	kcwill@inreach.com
Gary Schaad	724-3528	
Dan Miller	724-3582	
Larry Filbert	724 3768	
Gail Fernand	530 724 3730	
Anita Tatum	530 724-0385	
Marlene Garner	724 0556	
Alice Spain	724-3307	sistagirl111042@aol.com
Pat McGreevy		
Amy Terrell	916-721-3770	terrella@rcip.com
Bertha Mondragon	530-724-3026	P.O. Box 358 Dunnigan CA 95937

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APPENDIX E

Agenda and Handout from First Advisory Committee Meeting

Outline
for
DWD First BMO Advisory Committee Meeting

Objectives: **Provide feedback on draft qualitative BMOs**
Select groundwater level indicator wells

1. Review of BMOs
    a. Purpose
    b. Elements Covered
    c. Adaptive Management
    d. BMO Process
        i. Initial public meeting
        ii. Advisory Committee formation
        iii. Advisory Committee meetings
        iv. Public Meeting to discuss BMOs developed by Advisory Committee
        v. BMO adoption

2. BMOs from Other Agencies
    a. Qualitative
    b. Quantitative

3. Resources Available
    a. DWR Groundwater Level Monitoring
    b. DWD Groundwater Monitoring
    c. Yolo County Land Subsidence Study

4. Sample BMOs
    a. Groundwater Concerns

5. Indicator Wells
    a. Location
    b. Period of Record
    c. Alert Levels

Next Meeting: **Present Draft BMOs for Discussion**
Discuss Possible Actions

Jun 17 05 12:26p DUNNIGAN WATER DISTRICT 530 724 3273 p.2

Dunnigan Water District
BMO Advisory Committee
Signup Sheet

Name	Phone Number	Email Address
Vaughnette Farrell	530-724-0113	zimba@accessbee.com
Willard Ingraham	" -724-3243	
Tommy Gullatt	530-724-4106	wgullatt@sbcglobal.net
Alice Spicer	530-724-3307	sistagirl111042@aol.com
Shirley Gooch	530-724-3317	
ERICA LINSE	724.3225	
Anita Tatum	724-0385	
Neil Busch	724-3373	neilcathy@cwnet.com
Sasey Hemmings	724-3239	
Keith G. Williams	724-3323	kcwill@inreach.com
Karl McCullough	724 3371	
LARRY & CATHY CASSEVAH	400-3671	popolarry@hotmail.com
Gary Schaad	724-3528 (If needed)	
DAN MILLER	724-3382	
Bertha Mondragon	724-3026	P.O. Box 388 Dunnigan CA 95937
AMY Terrell	916-721-3770	aterrell@waterboards.ca.gov

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4. **Protect against adverse impacts to surface water flows in the American River and Sacramento River.** Among other important uses, the American and Sacramento rivers provide habitat for a variety of fish and wildlife species. The SGA and its members are committed to the objectives of the WFA, including the objective to protect and enhance the lower American River. Important elements of the WFA include commitments to reduce lower American River diversions during dry years and to not exceed agreed upon groundwater extractions of 131,000 AF/year on average. In addition, the SGA plans to monitor and evaluate the relationship (if any) between groundwater pumping and adjacent river or stream flows.
5. **Protect against adverse impacts to water quality resulting from interaction between groundwater in the basin and surface water flows in the American River and Sacramento River.** In most natural settings, groundwater is higher in TDS and most other constituents than surface water. At the present time, the flow regime is such that groundwater is not discharging to the river systems in the SGA area. It is possible that future actions could temporarily alter that condition. It is the SGA's intent that controllable operations of the groundwater system do not negatively impact the water quality of the area's rivers and streams. The SGA will seek to gain a better understanding of potential impacts of the discharge of local-area groundwater to surface water channels.

3.3 GMP COMPONENTS

The GMP includes a variety of components that are required by CWC § 10753.7, recommended by DWR Bulletin 118 (2003), optional under CWC § 10753.8, and other components that the SGA has already begun. These components can be grouped into five general categories: (1) stakeholder involvement, (2) monitoring program, (3) groundwater resource protection, (4) groundwater replenishment, and (5) planning integration. Each category and its components are presented in this section. Under each component is a discussion, proposed actions, and identification of the objectives toward which the component is directed.

3.4 COMPONENT CATEGORY 1: STAKEHOLDER INVOLVEMENT

The management actions taken by the SGA may have a wide range of impacts on a broad range of individuals and agencies that ultimately have a stake in its successful management of the basin. The local consumer may be most concerned about water rates or assurances that each time the tap is turned a steady, safe stream of water is available. To large state and federal water resource agencies, the degree to which the SGA can achieve local supply reliability and further banking and exchange programs enhances the state and federal programs' opportunity to meet statewide needs, particularly in drier years. To address the needs of all of these stakeholders, the SGA has pursued several means of achieving broader involvement in the management of the North Area Groundwater Basin. These include: (1) involving members of the public, (2) involving other local agencies within and adjacent to the SGA area, (3) using advisory committees for development and implementation of the GMP, (4) developing relationships with state and federal water agencies, and (5) pursuing a variety of partnerships to achieve local supply sustainability. Each of these is discussed further below.

3.4.1 Involving the Public

Groundwater in California is a public resource, and the SGA is committed to involving the public in the development and implementation of its GMP. When the JPA creating the SGA was signed by the cities of Citrus Heights, Folsom, and Sacramento and the County of Sacramento,

Section 4: Objectives and Criteria for Groundwater Management Plan Implementation

The overall objective of the GWMP effort is to maintain and enhance the agricultural and economic productivity of San Benito County in an environmentally responsible manner. The objectives and criteria were initially developed in the 2001 Existing Conditions Report, and were expanded during the process of the preparation of the alternatives analysis presented in the Evaluation of Project Alternatives to Implement Groundwater Management Plan in San Benito County – Draft Report, June 2002 (June 2002 Draft Report). Specific criteria to achieve the overall goal are presented below.

4.1 Water Quantity Objectives and Criteria

- **Water Quantity Objective 1**: Maintain a reliable water supply for present and future users.

  Water Quantity Criterion 1-1: Deliver 100% of agricultural and M&I supply in normal and dry years, and in the first critically dry year of a drought.

  Water Quantity Criterion 1-2: Deliver at least 85% of M&I demands and 75% of agricultural demands in the second and subsequent critically dry years of a drought.

- **Water Quantity Objective 2:** Integrate the management of groundwater, surface water, and imported water, according to the following criteria:

  Water Quantity Criterion 2-1: Maximize efficient use of water supply by implementing water conservation programs for both M&I and agricultural uses. For existing M&I uses, it is assumed that over the next 20 years, water demand will decrease by 1% percent per year for existing residential dwelling units. Conservation will reduce demand from an estimated 420 gpd/du to 344 gpd/du. New development is assumed to have a demand of 312 gpd/du. Based on CVP guidelines, agricultural irrigation is assumed to be at 85% efficiency.

  Water Quantity Criterion 2-2: Provide new M&I water supplies to support planned growth within established urban (service) areas, in accordance with approved growth projections contained in the General Plans for San Benito County and the cities of Hollister and San Juan Bautista.

  Water Quantity Criterion 2-3: Manage groundwater levels to maintain groundwater storage for the protection of the water rights of the overlaying landowners and for emergency storage, limiting drawdown to the historic low levels of about 1977 to preclude and/or minimize the potential for ground settlement.

  Maintain groundwater levels, where practical, no higher than 20-30 feet below ground surface. In portions of the Bolsa, Pacheco, Hollister East and San Juan subbasins it will be impractical to achieve these groundwater levels and subsurface drainage systems and other means of providing improved drainage conditions for the overlying uses will be required. In addition, higher groundwater levels will occur in areas adjacent to streams and where artificial percolation occurs outside of natural streams, such as in the vicinity of the percolation ponds of wastewater treatment plants, septic systems, and off stream groundwater recharge ponds.

Water Quantity Criterion 2-4: Optimize the use of groundwater storage.

4.2 Water Quality Objectives and Criteria

- **Water Quality Objective 1:** Provide water quality to meet both the needs of end users and the established objectives as described in the criteria below .

  Water Quality Criterion 1-1: Manage water resources to minimize imported salts and long-term levels of groundwater salinity to protect beneficial uses as set forth in the applicable revisions of the Regional Water Quality Control Board Basin Plan.

  Water Quality Criterion 1-2: Protect groundwater resources from infiltration of nitrates and salts, as well as other substances that could adversely affect groundwater quality.

  Water Quality Criterion 1-3: Deliver M&I water meeting primary and secondary drinking water quality objectives, with emphasis on achieving the "DHS's Recommended Limit for Consumer Acceptance" of not more than 500 mg/l of TDS and hardness of no greater than 120 mg/l as CaCO3. {It should be noted that there are no secondary standards for hardness; soft waters are typically considered to have 0-60 mg/l of hardness, moderately hard waters have 61-120 mg/l, hard waters have 121 - 180 mg/l, and very hard waters have over 180 mg/l of hardness.}

  Water Quality Criterion 1-4: Deliver agricultural water meeting established quality parameters. In order to optimize crop yield based on the available water sources, salinity (as measured by TDS), sodium hazard (as measured by Sodium Adsorption Ratio, or SAR); and boron have been selected as key indicator parameters. The following water quality objectives for these three water quality parameters have been developed.

  Salinity: <700 mg/L TDS

  SAR: <6.5

  Boron: <0.5 mg/L

  TDS: Levels that range from 480 - 1920 mg/L are considered marginal for irrigation, per Regional Water Quality Control Board Basin Plan.

- **Water Quality Objective 2:** Manage water resources to meet Regional Water Quality Control Board Basin Plan and Department of Health Services water quality objectives.

B-1(e) Groundwater Management

The Yuba County Water Agency (YCWA) draft Groundwater Management Plan (GMP) was developed to address all of the existing CWC mandatory and voluntary components. Additionally, the draft GMP addresses all the DWR suggested components. The draft GMP is included in **Exhibit "A"** of this grant application.

Basin Management Objectives

The YCWA draft GMP states its basin management objectives (BMOs) as (section 3.2 of YCWA draft GMP):

- **Achieve groundwater storage levels** that result in a net benefit to basin groundwater users. YCWA intends to manage groundwater through conjunctive use activities to avoid unreasonable impacts that may occur from changes in groundwater elevations due to external transfers. Groundwater elevation reduction, which may occur as a result of groundwater extraction to meet local and out of county demands in drier years, will be monitored.
- **Maintain or improve groundwater quality** in the basin for the benefit of groundwater users. Generally, the groundwater in the basin is of excellent quality. However, occurrences of both groundwater contamination and increases in total dissolved solids are documented in the basin. In these instances YCWA will coordinate with appropriate local, state and federal agencies to pursue actions that result in the remediation of the problem.
- **Protect against potential inelastic land surface subsidence.** Land subsidence can cause significant damage to essential infrastructure. Historically land surface subsidence within Yuba County area has been minimal, with no known significant impacts to existing infrastructure. Given the historical trends, the potential for land surface subsidence from groundwater extraction in the north and south subbasin areas is remote. However, YCWA intends to coordinate with DWR to monitor for potential land surface subsidence. If inelastic subsidence is documented in conjunction with declining groundwater elevations, YCWA will investigate appropriate actions to avoid adverse impacts.
- **Protect against adverse impacts to surface water flows.** Among other important uses the Yuba River provides habitat for a variety of fish and wildlife species. YCWA is committed to meeting the flow requirements in the Yuba River for protection of habitat. In addition, YCWA plans to coordinate with DWR in monitoring efforts that evaluate the relationship (if any) between groundwater pumping and adjacent river or stream flows.

Use of Hydrogeologic Principles

YCWA intends to make use of hydrogeologic principles in the management of the basin. Specifically the draft GMP states that an annual **Monitoring and Measurement (M&M) Report** will be prepared (as stated in section 4.1 of YCWA draft GMP). This report will summarize groundwater conditions in the subbasins and document groundwater management activities from the previous year. Preparation of this report will allow YCWA to evaluate and revise periodically its management decisions based on hydrogeologic observation and findings from the annual monitoring of the basin. An outline of the Monitoring and Measurement Report is provided in the **Annual Monitoring and Measuring Report Attachment** at the back of Part B-1(c). It will include:

- Summary of monitoring results, including a discussion of historical trends.
- Summary of management actions during the period covered by the report.

COVER REPORT

The Basin Management Objective, or BMO, concept was developed to overcome many of the usual problems of defining safe yield and overdraft in the Sacramento Valley. The California State Department of Water Resources (DWR), Northern District Groundwater Section formulated the concept when they assisted Glenn County in developing their groundwater management ordinance, Ordinance No. 1115. The BMO concept defines acceptable groundwater levels, groundwater quality, and land subsidence conditions required to meet management objectives. For a more detailed explanation see the BMO concept paper prepared by DWR and included here under Appendix A, Supporting Technical Documents.

The objective of these BMOs is to maintain the groundwater surface elevation at a level that will assure an adequate and affordable irrigation water supply. It is the intent of this objective to assure a sustainable agricultural water supply now and into the future. The objective also assures an adequate groundwater supply for all domestic users in Glenn County. Key BMO Wells are comprised of selected wells from water district and municipal independently monitored wells and DWR's groundwater level monitoring network. This summary document describes the BMOs for groundwater surface elevations at these BMO Key Wells.

METHODS FOR DETERMINING BMOs

There are various methods for determining the BMO for groundwater levels. There is no definitive method that should take precedence over the others because of the uncertainty in the data. However, some methods may be preferable based on variability of the data, simplicity, operating procedures, or availability of data. The methods used to calculate BMOs for Glenn County sub-areas are described below.

Method 1 – Regression Method (Used by Sub-areas 9 and 10)

All existing groundwater level monitoring wells within the BMO area were identified. For all wells with a record dating back to at least 1976[1], groundwater levels were obtained using the Department of Water Resources' groundwater level website (wwwdpla.water.ca.gov/nd). The surface water deliveries and annual precipitation data were also obtained from the appropriate websites and water districts. With the built-in correlation function in Microsoft Excel, the correlation between surface water deliveries plus precipitation was calculated. A scatter plot of groundwater elevation vs. surface water deliveries plus precipitation was created. A trendline was then added to create the Stage 1 & 2 alert line that was parallel to the trendline, but lower by half of the average deviation. The Stage 3 alert was determined as the minimum acceptable groundwater elevation, which is based on the level at which pumping efficiency is noticeably reduced.

[1] In 1976 the Tehama-Colusa Canal became operational, changing the relative surface water supply and groundwater supply mix in sub-areas served by the canal. The Glenn County Technical Advisory Committee concluded that groundwater levels from this date forward are representative of recent historical conditions and when possible this historical period of record should be used for developing groundwater level BMOs in these sub-areas.

Method 2 – Standard Deviation (Used by Sub-areas 5, 10, 15, and 17)

All existing groundwater level monitoring wells within the BMO area were identified. For all wells with a record dating back to at least 1976[1], groundwater levels were obtained using the Department of Water Resources' groundwater level website. The Spring data for groundwater surface elevation (WSE) was further analyzed. The average and standard deviation were then calculated for these data. The Stage 1 & 2 alerts were determined to be the average of the Spring data minus one standard deviation. The State 3 alert was the average minus two standard deviations.

Method 3 – (Used by Sub-area 11)

All existing groundwater level monitoring wells within the BMO area were identified. For all wells with a current record, groundwater levels were obtained using the Department of Water Resources' groundwater level website. The average and standard deviation were then calculated for the wells' entire period of record (using Spring and Fall data). The Stage 1 & 2 alerts were determined to be the average of the data minus one standard deviation. The State 3 alert was the lowest Spring record dating back to 1976.

Method 4 – 20% of Range (Used by Sub-area 8)

All existing groundwater level monitoring wells within the BMO area were identified. For all wells with a record dating back to at least 1976[1], groundwater levels were obtained using the Department of Water Resources' groundwater level website. The Spring data for groundwater surface elevation (WSE) was furthered analyzed. The Stage 1 & 2 alerts were determined to be the average of the data minus 20% of the range. The Stage 3 alert was the lowest Spring record dating back to 1976. However, one well had a Stage 3 alert that was not the lowest historical elevation due to data anomalies.

Method 5 – (Used by Sub-areas 12 and 14)

All existing groundwater level monitoring wells within or near the BMO area were identified. For all wells with a record dating back to at least 1976[1], groundwater levels were obtained using the Department of Water Resources' groundwater level website. The Spring data for groundwater surface elevation (WSE) was furthered analyzed. The Stage 1 & 2 alerts were determined to be the average of the Spring data. The State 3 alert was the lowest Spring record dating back to 1976.

Method 6 – (Used by Sub-area 13)

The groundwater surface elevation was obtained for the examined well dating back to 1983. The data are mostly from late summer and early fall. The Stage 1 & 2 alerts were determined to be the average of the data. The State 3 alert was the lowest record dating back to 1983.

1. See previous page.

Groundwater Quality

Prevent degradation of groundwater quality in the Dunnigan area for the benefit of all groundwater users. Groundwater quality in the area is generally well suited for agricultural use. Some shallow domestic wells near the town of Dunnigan produce water with elevated concentrations of nitrates. Dunnigan Water District will monitor groundwater quality in the Dunnigan area and will coordinate with local landowners and appropriate local, state and federal agencies to prevent degradation of groundwater quality.

Groundwater Levels

Maintain groundwater elevations that ensure adequate groundwater supplies to all users. Historical information on groundwater levels combined with hydrologic analyses show that the quantity of groundwater available in the Dunnigan area is finite. Declines in groundwater levels can result in increased energy costs for pumping, the need to deepen existing wells and the need to construct new wells. Dunnigan Water District will continue to monitor groundwater levels and will coordinate with the District landowners to ensure that favorable groundwater elevations are maintained.

Subsidence

Protect against potential inelastic land surface subsidence. Historically, land subsidence has not been an issue of concern in the Dunnigan area. However, significant land subsidence has occurred south of Dunnigan in the Zamora area. Land subsidence can damage infrastructure and permanently reduce the water storage capacity of the aquifer. There is an on-going land subsidence monitoring network in Yolo County. Dunnigan Water District will review subsidence data and take appropriate actions if land subsidence becomes a concern.

APPENDIX F

Agenda from Second Advisory Committee Meeting

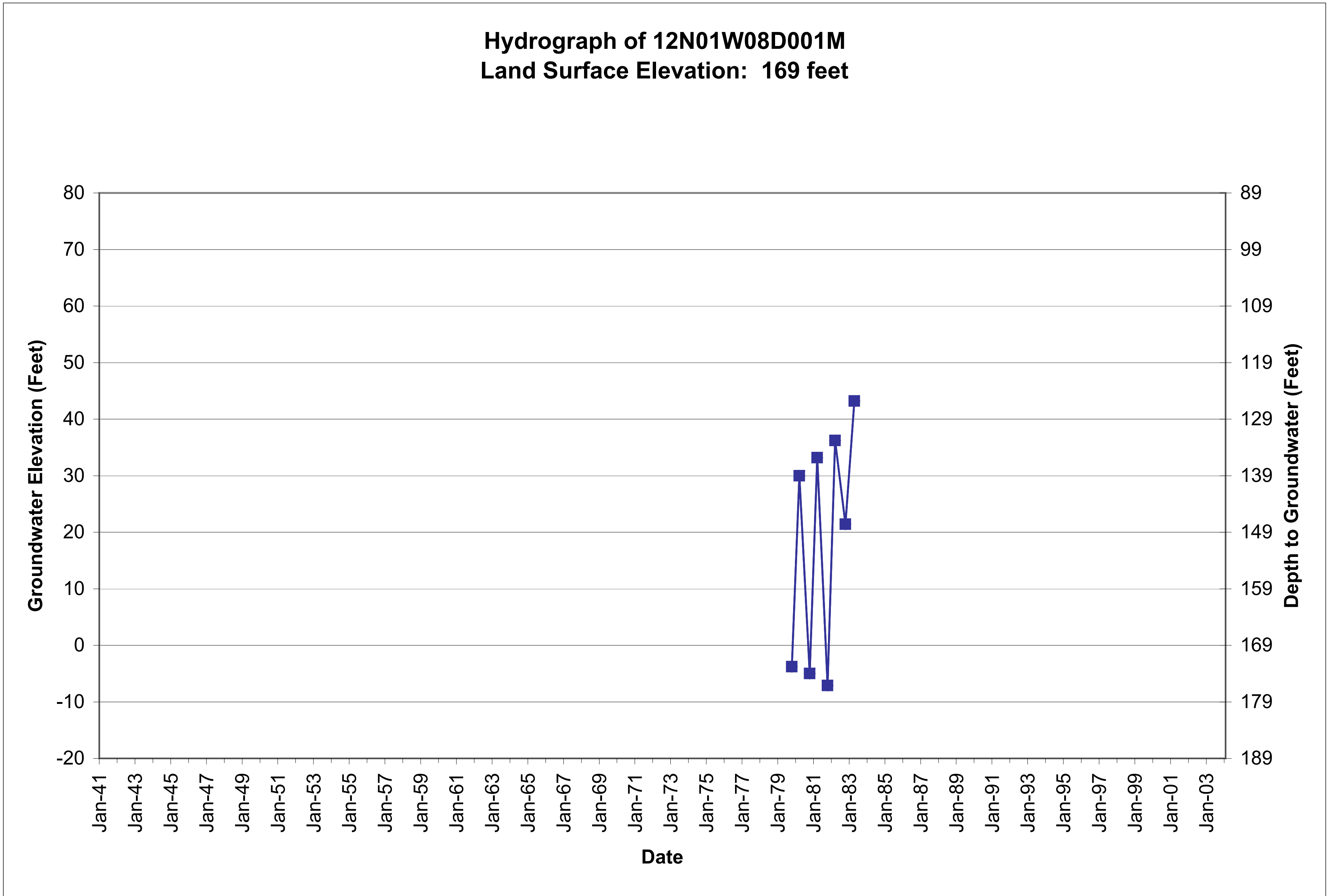
Outline
for
DWD Second BMO Advisory Committee Meeting

Objectives: **Provide feedback on draft quantitative BMO**
Provide feedback on draft qualitative BMOs
Discuss Actions for Alert Levels

1. Review quantitative BMO
2. Review qualitative BMOs
3. Discuss Actions for Alert Levels
4. Discuss Future Advisory Committee Meetings

APPENDIX G

Groundwater Well Hydrographs


Hydrograph of 12N01W08D001M
Land Surface Elevation: 169 feet
Groundwater Elevation (Feet)
Depth to Groundwater (Feet)
Date
80
70
60
50
40
30
20
10
0
-10
-20
89
99
109
119
129
139
149
159
169
179
189
Jan-41
Jan-43
Jan-45
Jan-47
Jan-49
Jan-51
Jan-53
Jan-55
Jan-57
Jan-59
Jan-61
Jan-63
Jan-65
Jan-67
Jan-69
Jan-71
Jan-73
Jan-75
Jan-77
Jan-79
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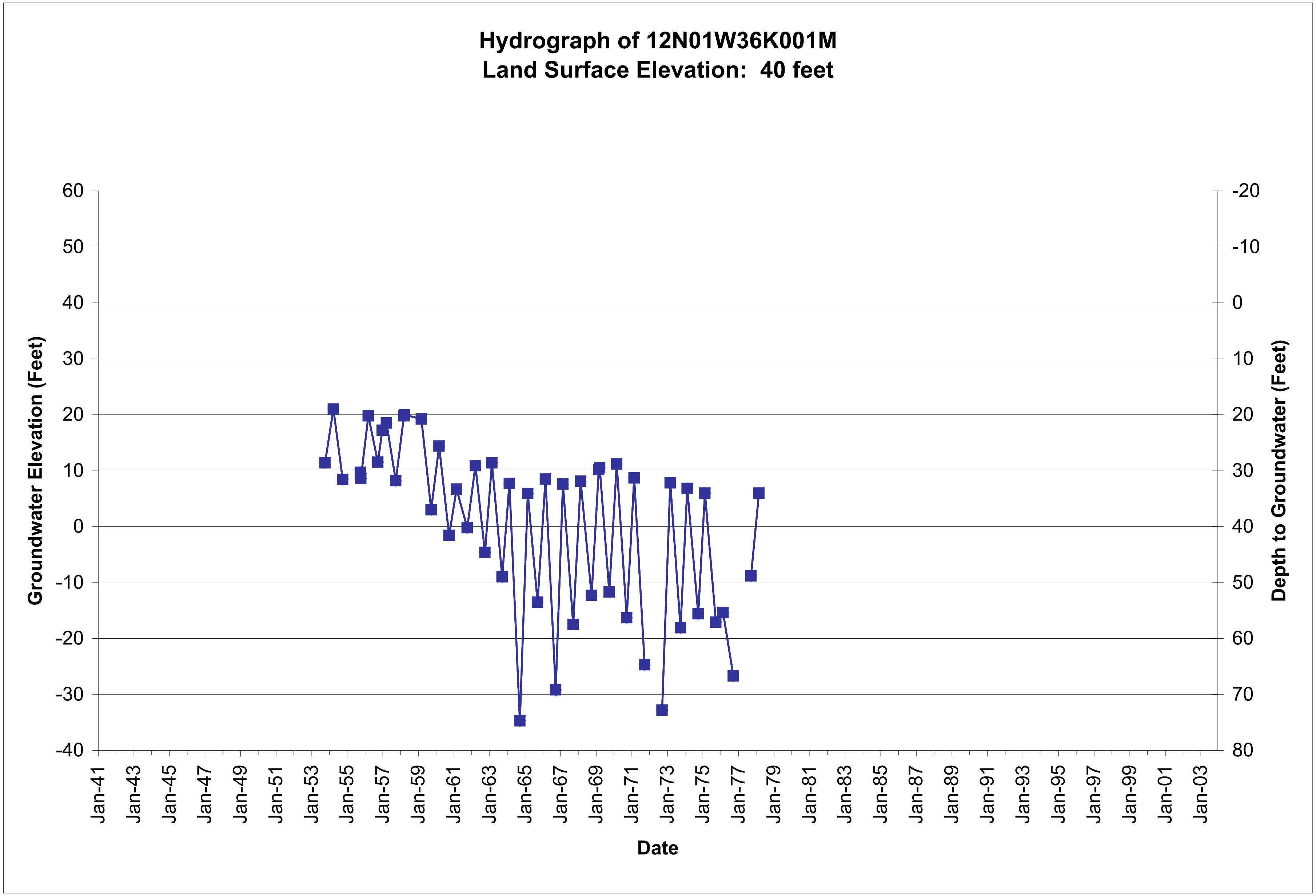
Jan-99
Jan-01
Jan-03


Hydrograph of 12N01W36K001M
Land Surface Elevation: 40 feet
Groundwater Elevation (Feet)
Depth to Groundwater (Feet)
Date
60
50
40
30
20
10
0
-10
-20
-30
-40
-20
-10
0
10
20
30
40
50
60
70
80
Jan-41
Jan-43
Jan-45
Jan-47
Jan-49
Jan-51
Jan-53
Jan-55
Jan-57
Jan-59
Jan-61
Jan-63
Jan-65
Jan-67
Jan-69
Jan-71
Jan-73
Jan-75
Jan-77
Jan-79
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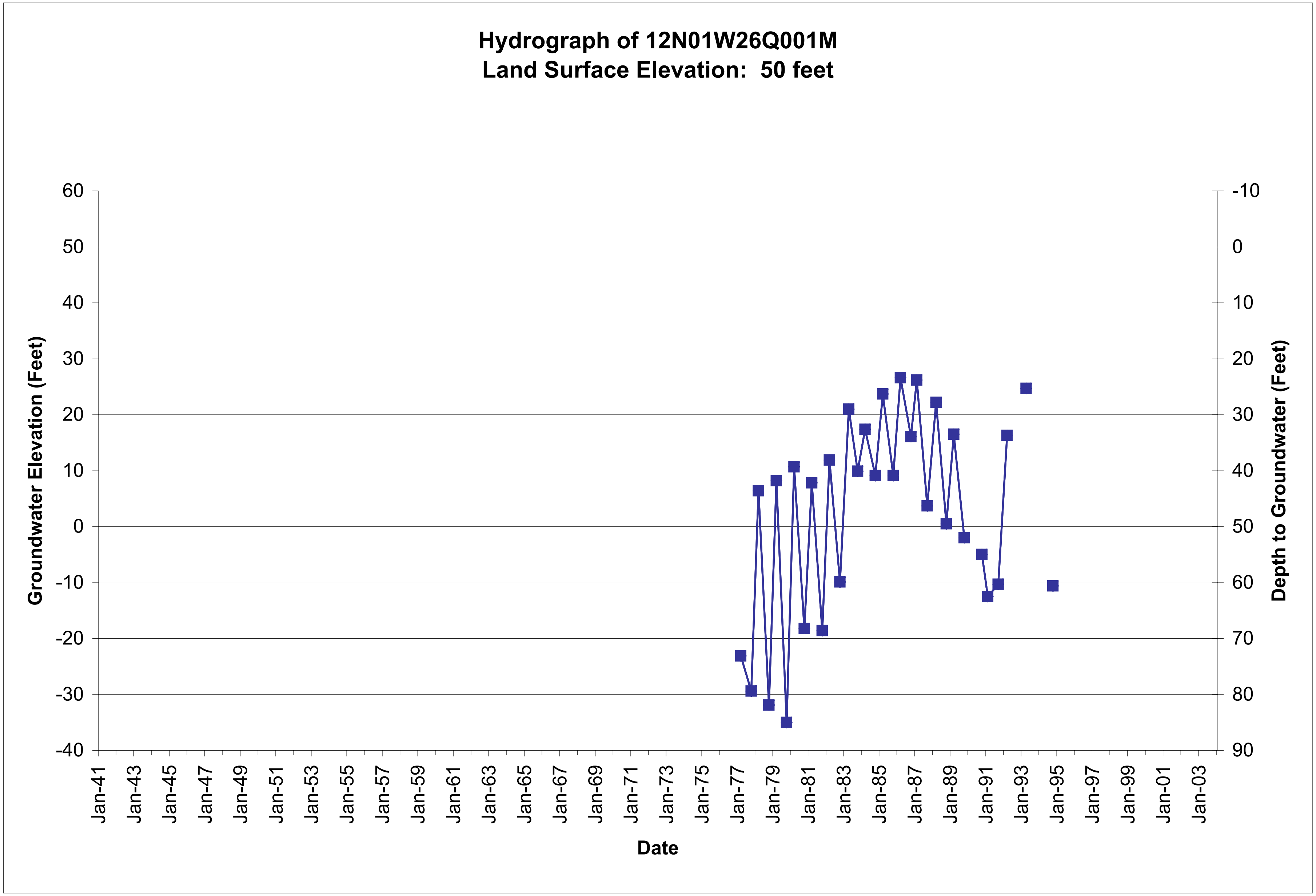
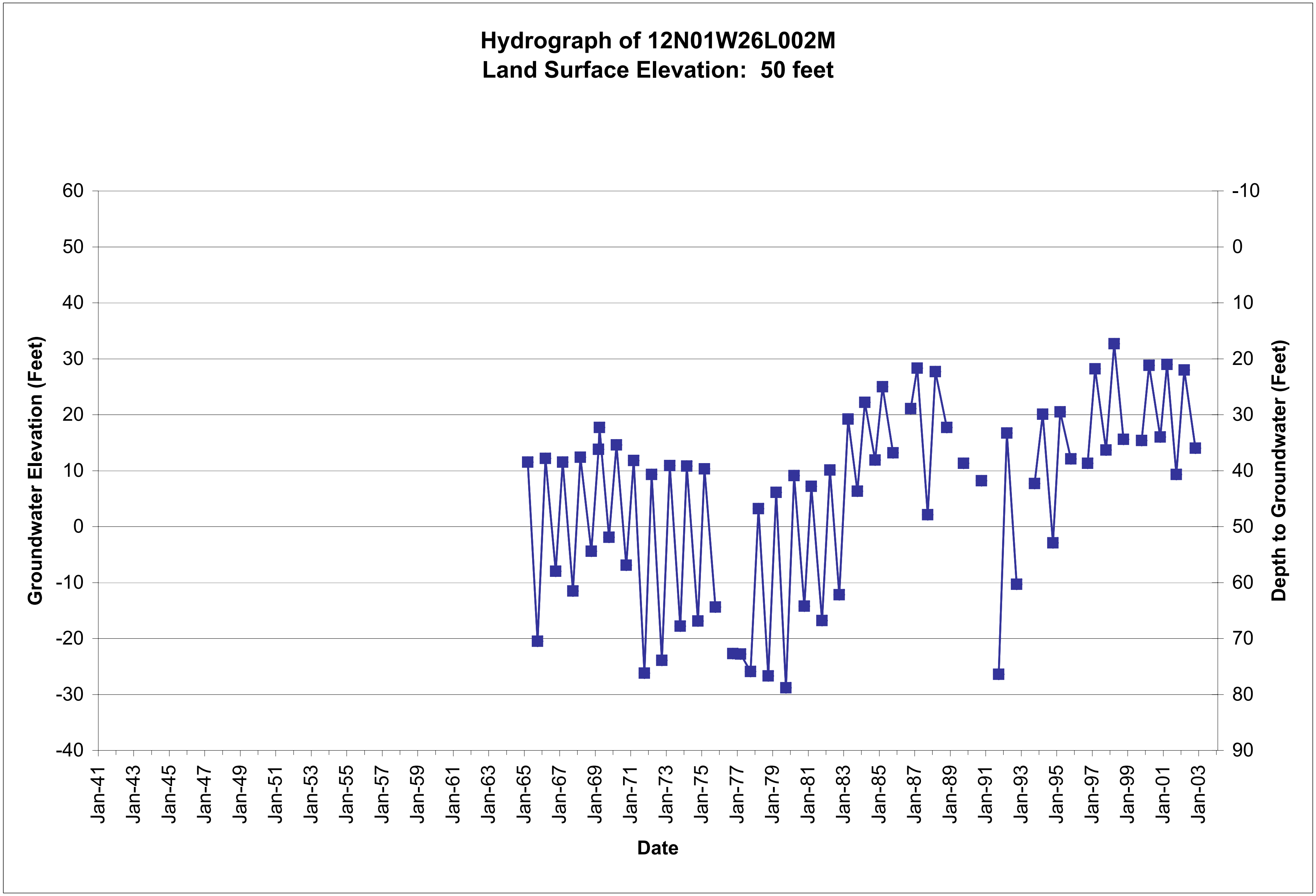
Jan-99
Jan-01
Jan-03


Hydrograph of 12N01W26Q001M
Land Surface Elevation: 50 feet
Groundwater Elevation (Feet)
Depth to Groundwater (Feet)
60
50
40
30
20
10
0
-10
-20
-30
-40
-10
0
10
20
30
40
50
60
70
80
90
Jan-41
Jan-43
Jan-45
Jan-47
Jan-49
Jan-51
Jan-53
Jan-55
Jan-57
Jan-59
Jan-61
Jan-63
Jan-65
Jan-67
Jan-69
Jan-71
Jan-73
Jan-75
Jan-77
Jan-79
Jan-81
Jan-83
Jan-85
Jan-87
Jan-89
Jan-91
Jan-93
Jan-95
Jan-97
Jan-99
Jan-01
Jan-03
Date


Hydrograph of 12N01W26L002M
Land Surface Elevation: 50 feet
Groundwater Elevation (Feet)
Depth to Groundwater (Feet)
Date
60
50
40
30
20
10
0
-10
-20
-30
-40
-10
0
10
20
30
40
50
60
70
80
90
Jan-41
Jan-43
Jan-45
Jan-47
Jan-49
Jan-51
Jan-53
Jan-55
Jan-57
Jan-59
Jan-61
Jan-63
Jan-65
Jan-67
Jan-69
Jan-71
Jan-73
Jan-75
Jan-77
Jan-79
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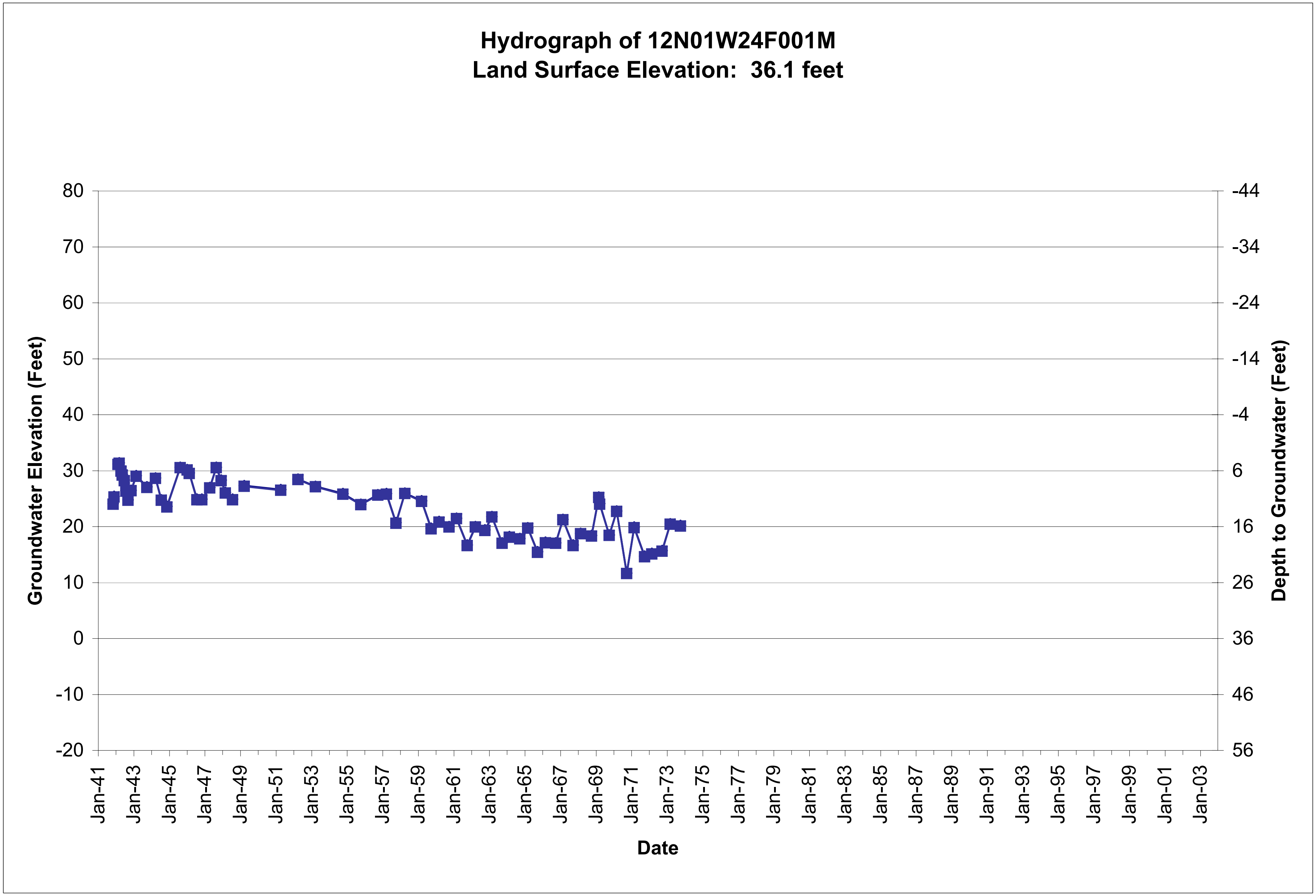
Jan-99
Jan-01
Jan-03


Hydrograph of 12N01W24F001M
Land Surface Elevation: 36.1 feet
Groundwater Elevation (Feet)
Depth to Groundwater (Feet)
Date
80
70
60
50
40
30
20
10
0
-10
-20
-44
-34
-24
-14
-4
6
16
26
36
46
56
Jan-41
Jan-43
Jan-45
Jan-47
Jan-49
Jan-51
Jan-53
Jan-55
Jan-57
Jan-59
Jan-61
Jan-63
Jan-65
Jan-67
Jan-69
Jan-71
Jan-73
Jan-75
Jan-77
Jan-79
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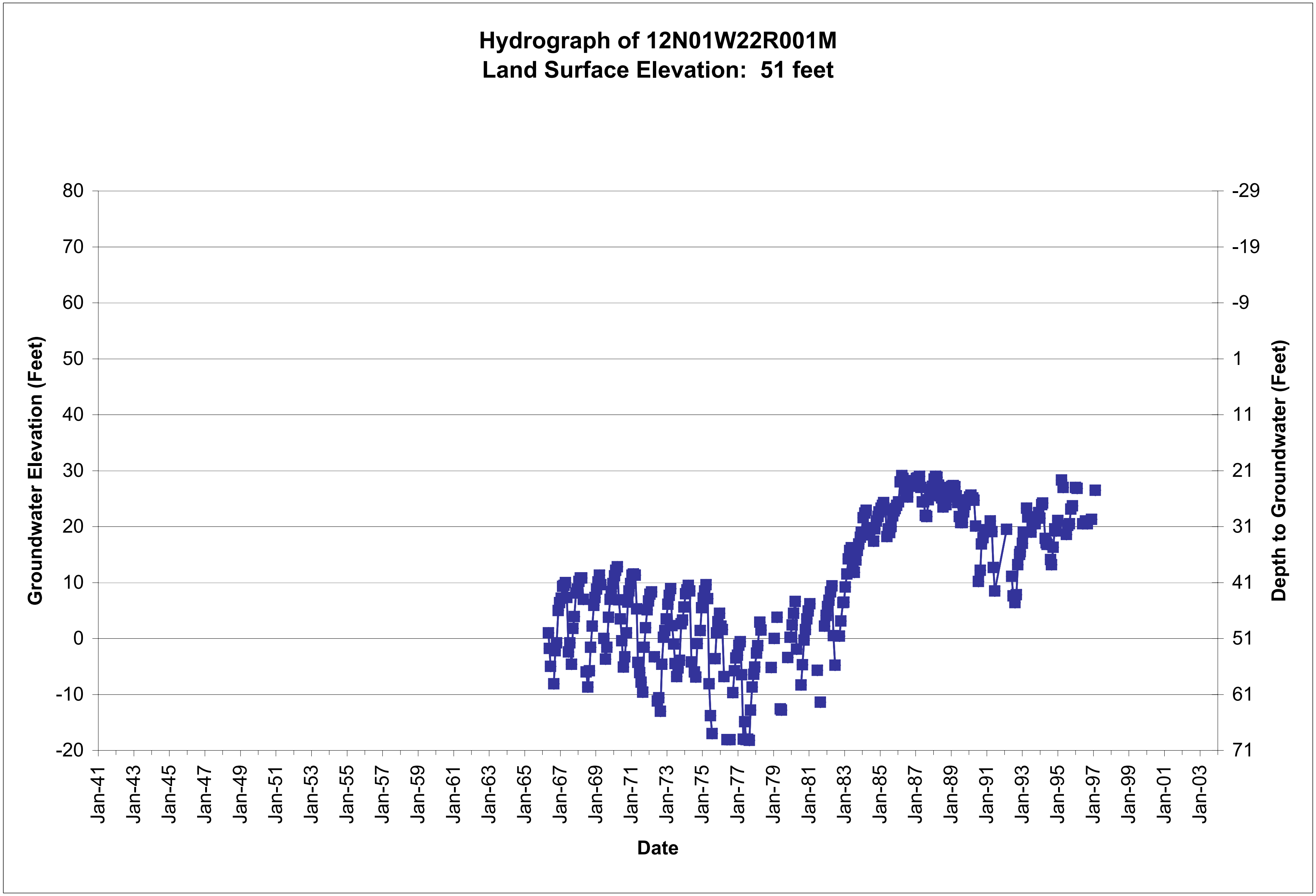
Jan-01
Jan-03


Hydrograph of 12N01W22R001M
Land Surface Elevation: 51 feet
Groundwater Elevation (Feet)
Depth to Groundwater (Feet)
Date
80
70
60
50
40
30
20
10
0
-10
-20
-29
-19
-9
1
11
21
31
41
51
61
71
Jan-41
Jan-43
Jan-45
Jan-47
Jan-49
Jan-51
Jan-53
Jan-55
Jan-57
Jan-59
Jan-61
Jan-63
Jan-65
Jan-67
Jan-69
Jan-71
Jan-73
Jan-75
Jan-77
Jan-79
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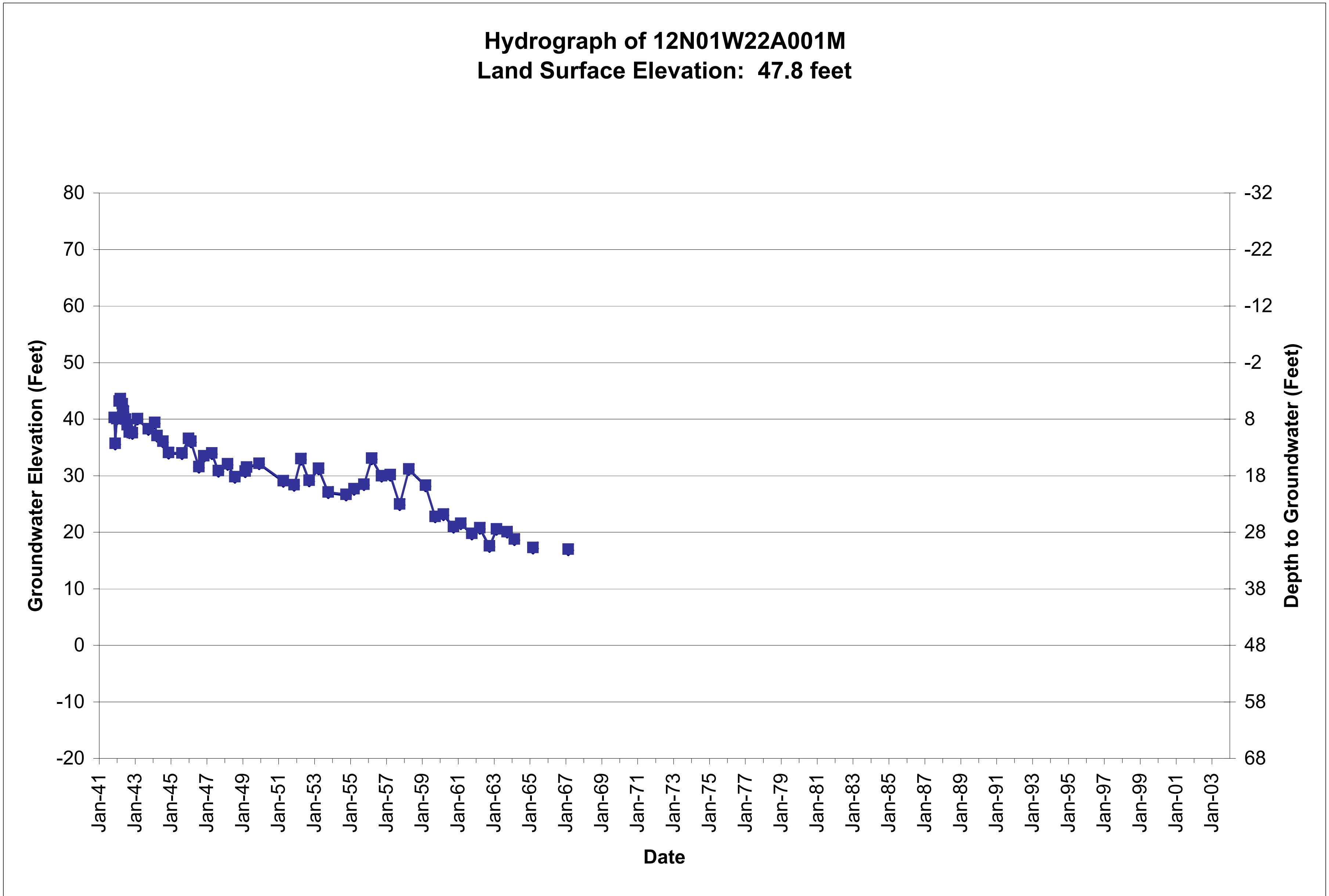
Jan-01
Jan-03


Hydrograph of 12N01W22A001M
Land Surface Elevation: 47.8 feet
Groundwater Elevation (Feet)
Depth to Groundwater (Feet)
Date
80
70
60
50
40
30
20
10
0
-10
-20
-32
-22
-12
-2
8
18
28
38
48
58
68
Jan-41
Jan-43
Jan-45
Jan-47
Jan-49
Jan-51
Jan-53
Jan-55
Jan-57
Jan-59
Jan-61
Jan-63
Jan-65
Jan-67
Jan-69
Jan-71
Jan-73
Jan-75
Jan-77
Jan-79
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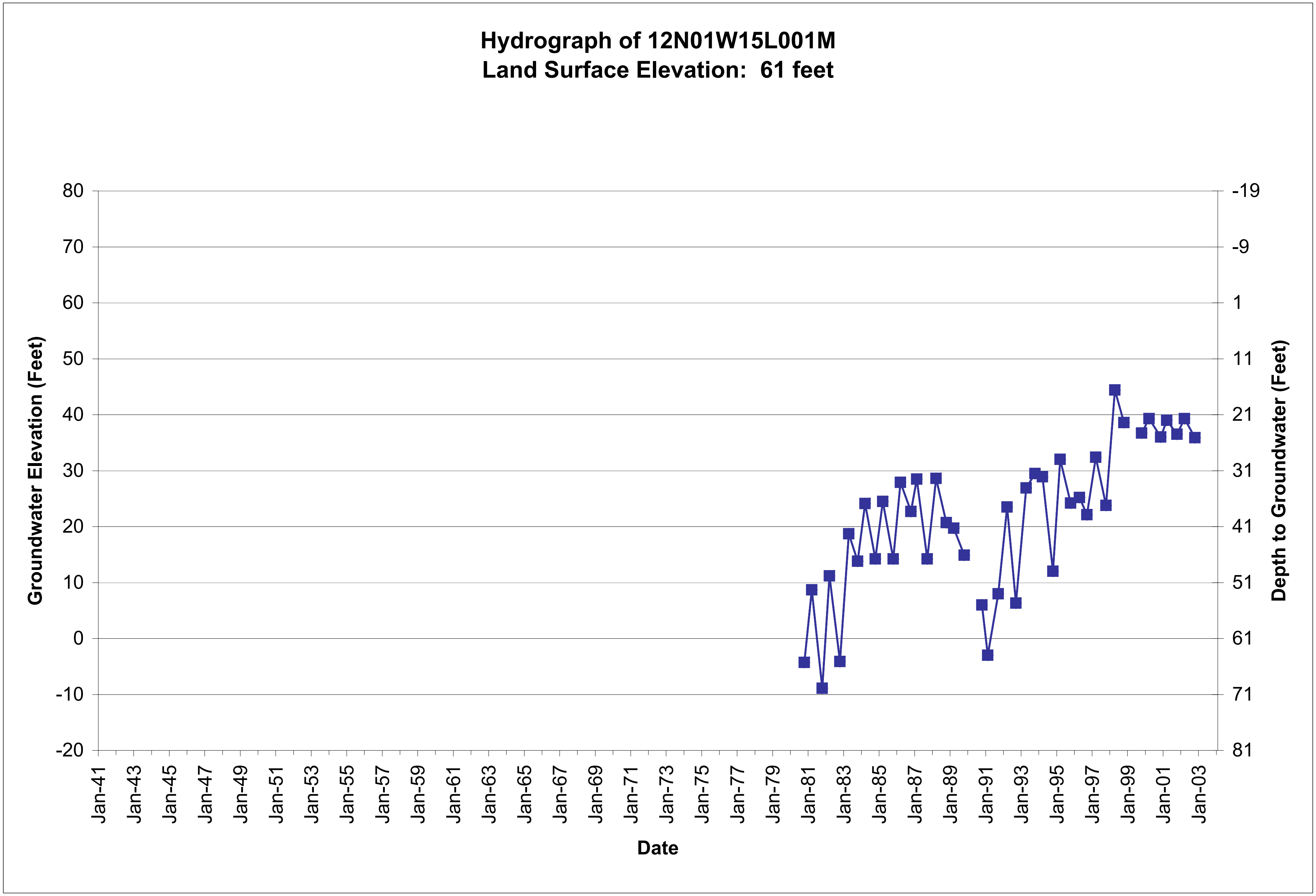
Jan-01
Jan-03


Hydrograph of 12N01W15L001M
Land Surface Elevation: 61 feet
Groundwater Elevation (Feet)
80
70
60
50
40
30
20
10
0
-10
-20
Depth to Groundwater (Feet)
-19
-9
1
11
21
31
41
51
61
71
81
Jan-41
Jan-43
Jan-45
Jan-47
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Jan-71
Jan-73
Jan-75
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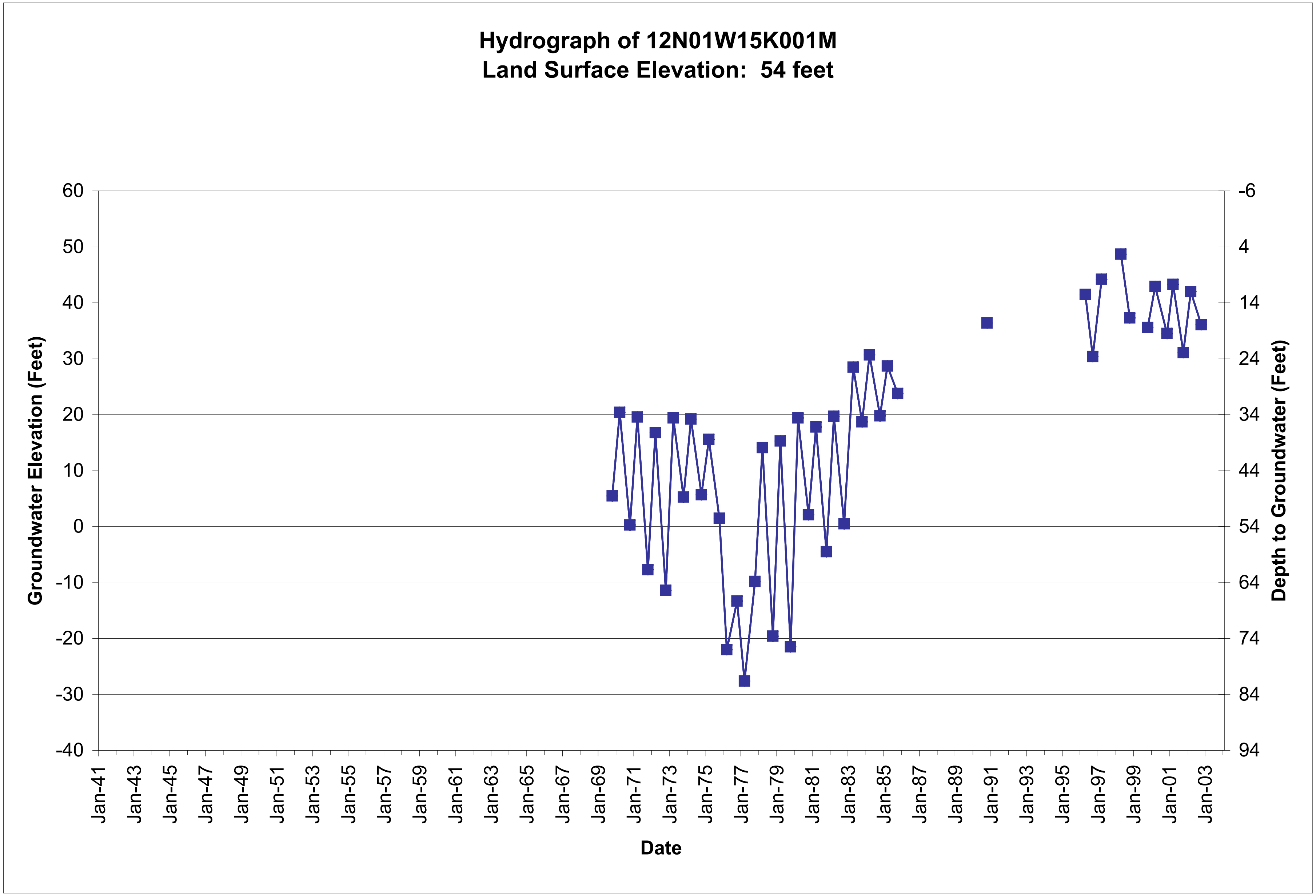
Jan-01
Jan-03
Date


Hydrograph of 12N01W15K001M
Land Surface Elevation: 54 feet
Groundwater Elevation (Feet)
Depth to Groundwater (Feet)
60
50
40
30
20
10
0
-10
-20
-30
-40
-6
4
14
24
34
44
54
64
74
84
94
Jan-41
Jan-43
Jan-45
Jan-47
Jan-49
Jan-51
Jan-53
Jan-55
Jan-57
Jan-59
Jan-61
Jan-63
Jan-65
Jan-67
Jan-69
Jan-71
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Jan-75
Jan-77
Jan-79
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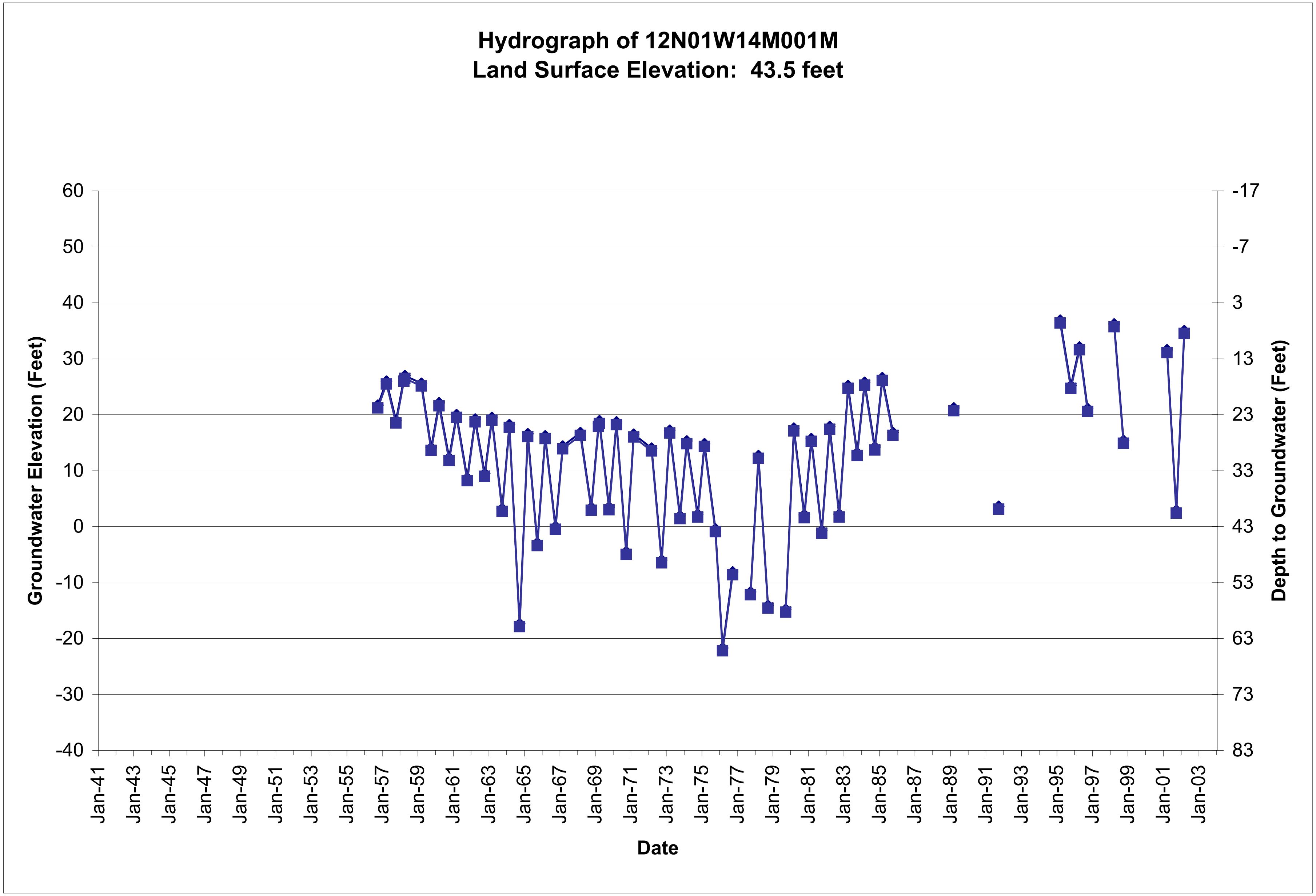
Jan-99
Jan-01
Jan-03
Date


Hydrograph of 12N01W14M001M
Land Surface Elevation: 43.5 feet
Groundwater Elevation (Feet)
Depth to Groundwater (Feet)
Date
60
50
40
30
20
10
0
-10
-20
-30
-40
-17
-7
3
13
23
33
43
53
63
73
83
Jan-41
Jan-43
Jan-45
Jan-47
Jan-49
Jan-51
Jan-53
Jan-55
Jan-57
Jan-59
Jan-61
Jan-63
Jan-65
Jan-67
Jan-69
Jan-71
Jan-73
Jan-75
Jan-77
Jan-79
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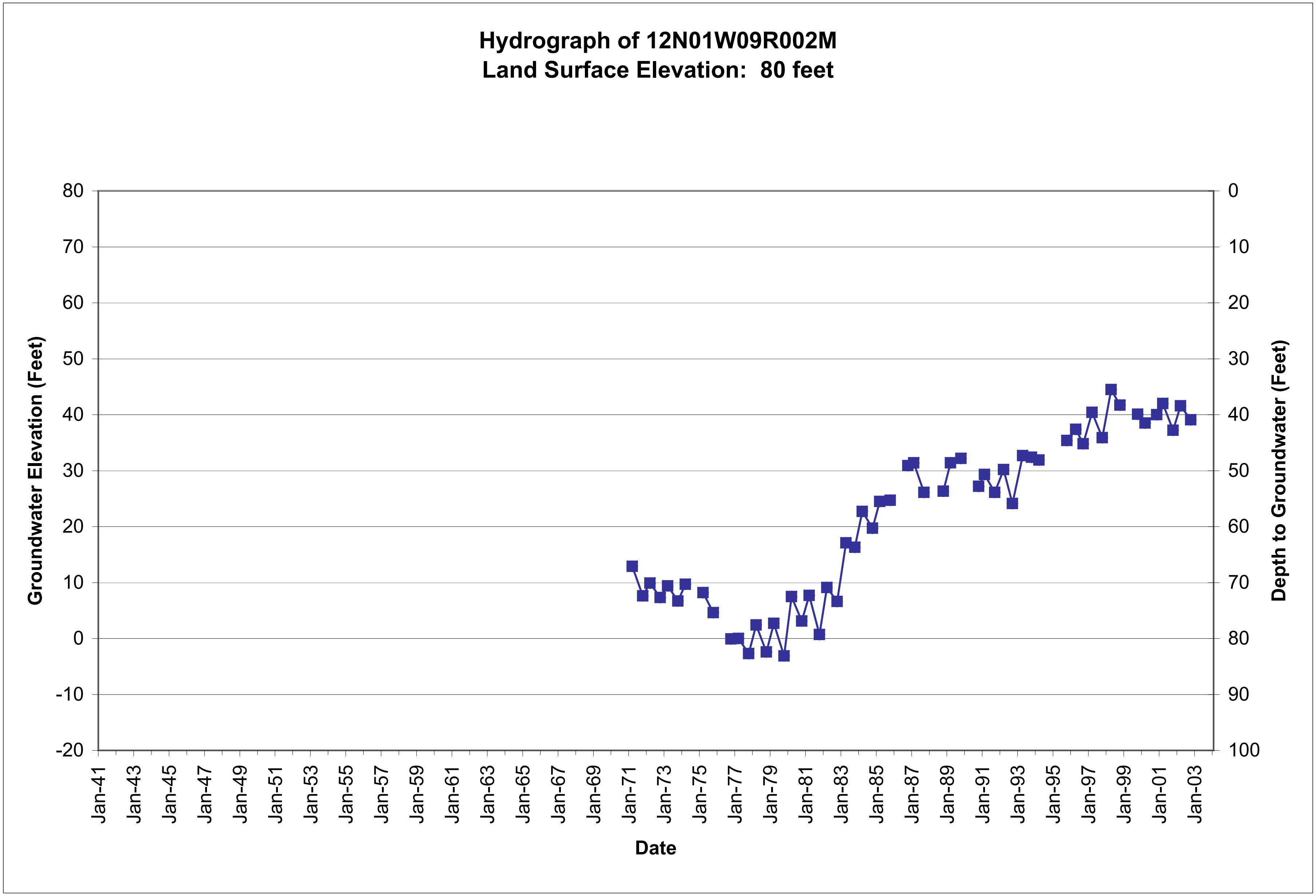
Jan-03


Hydrograph of 12N01W09R002M
Land Surface Elevation: 80 feet
Groundwater Elevation (Feet)
Depth to Groundwater (Feet)
80
70
60
50
40
30
20
10
0
-10
-20
0
10
20
30
40
50
60
70
80
90
100
Jan-41
Jan-43
Jan-45
Jan-47
Jan-49
Jan-51
Jan-53
Jan-55
Jan-57
Jan-59
Jan-61
Jan-63
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Jan-71
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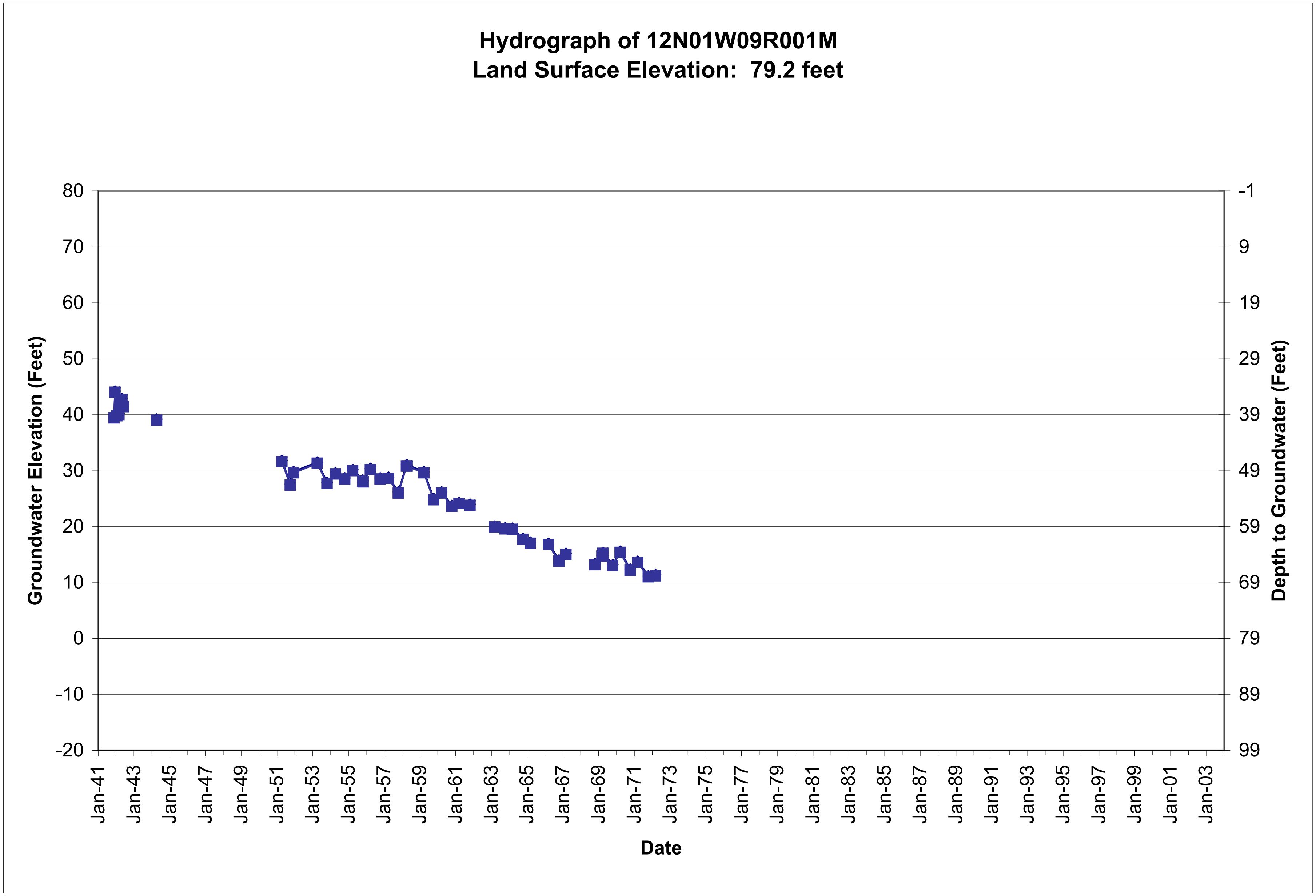
Jan-03
Date


Hydrograph of 12N01W09R001M
Land Surface Elevation: 79.2 feet
Groundwater Elevation (Feet)
Depth to Groundwater (Feet)
80
70
60
50
40
30
20
10
0
-10
-20
-1
9
19
29
39
49
59
69
79
89
99
Jan-41
Jan-43
Jan-45
Jan-47
Jan-49
Jan-51
Jan-53
Jan-55
Jan-57
Jan-59
Jan-61
Jan-63
Jan-65
Jan-67
Jan-69
Jan-71
Jan-73
Jan-75
Jan-77
Jan-79
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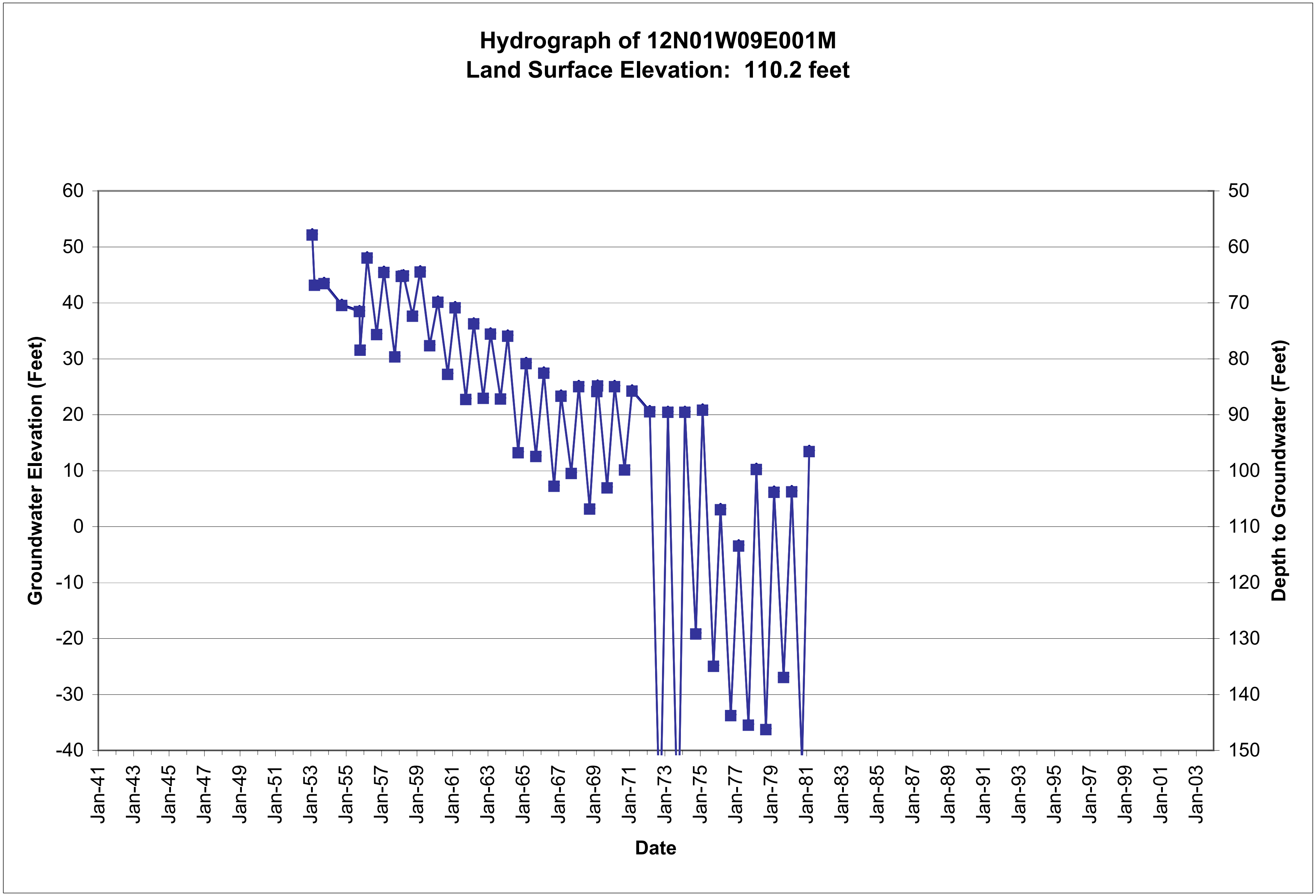
Jan-01
Jan-03
Date


Hydrograph of 12N01W09E001M
Land Surface Elevation: 110.2 feet
Groundwater Elevation (Feet)
Depth to Groundwater (Feet)
Date
60
50
40
30
20
10
0
-10
-20
-30
-40
50
60
70
80
90
100
110
120
130
140
150
Jan-41
Jan-43
Jan-45
Jan-47
Jan-49
Jan-51
Jan-53
Jan-55
Jan-57
Jan-59
Jan-61
Jan-63
Jan-65
Jan-67
Jan-69
Jan-71
Jan-73
Jan-75
Jan-77
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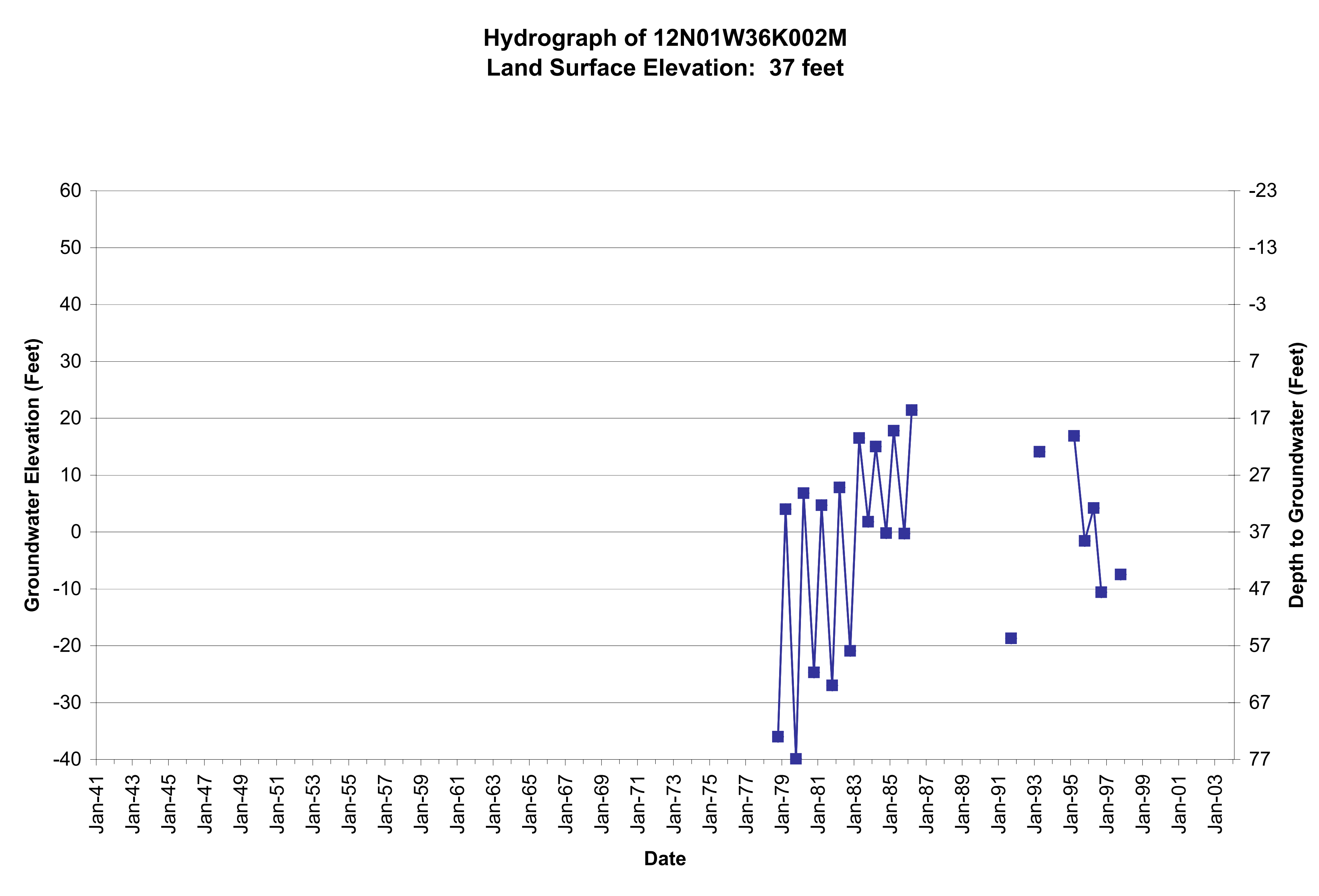
Jan-03


Hydrograph of 12N01W36K002M
Land Surface Elevation: 37 feet
Groundwater Elevation (Feet)
Depth to Groundwater (Feet)
Date
60
50
40
30
20
10
0
-10
-20
-30
-40
-23
-13
-3
7
17
27
37
47
57
67
77
Jan-41
Jan-43
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Jan-59
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Jan-63
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Jan-71
Jan-73
Jan-75
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Jan-79
Jan-81
Jan-83
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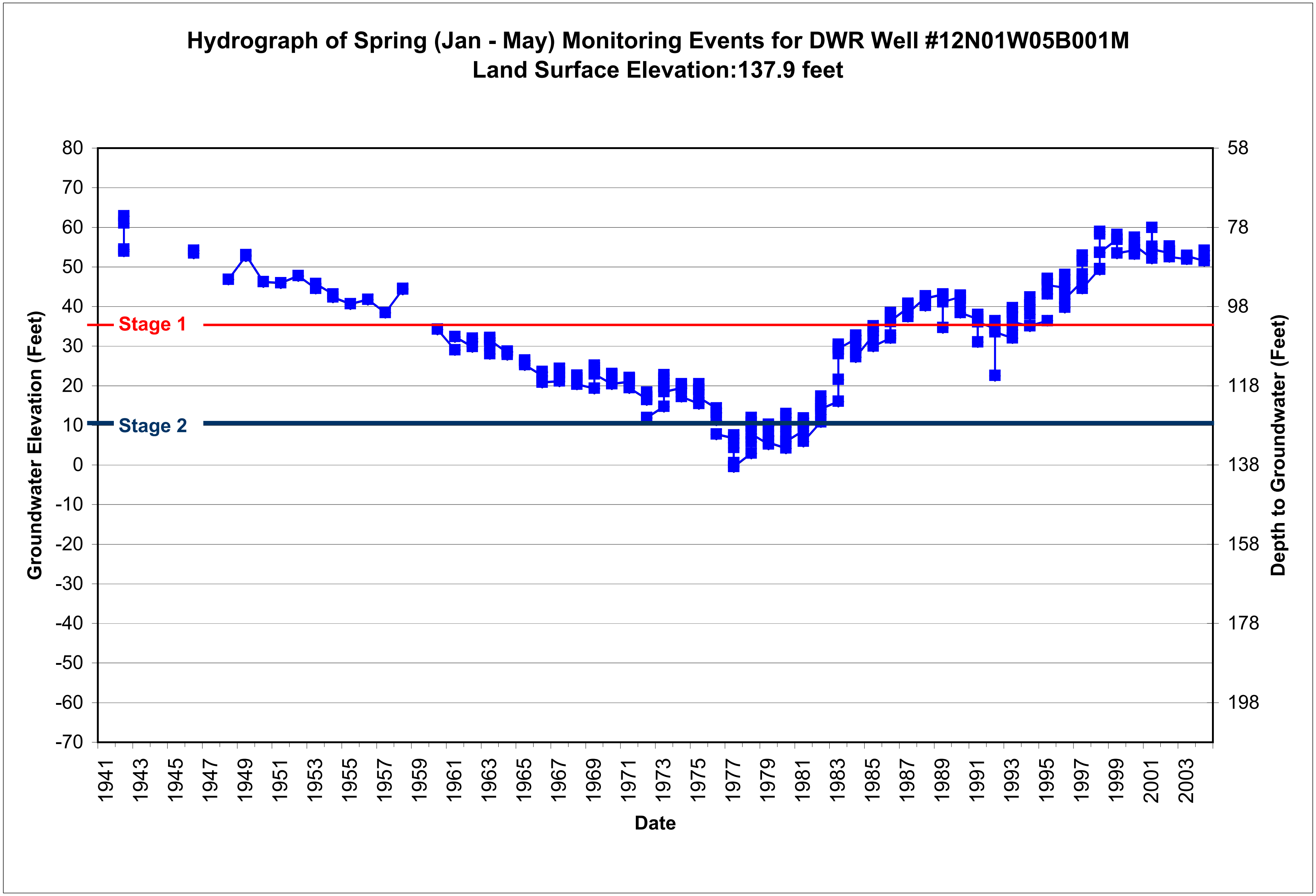
Jan-01
Jan-03

APPENDIX H

Hydrographs for the BMO Indicator Wells Stage 1 and Stage 2 Alert Levels


Hydrograph of Spring (Jan - May) Monitoring Events for DWR Well #12N01W05B001M
Land Surface Elevation:137.9 feet
Groundwater Elevation (Feet)
Depth to Groundwater (Feet)
Date
Stage 1
Stage 2
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
58
78
98
118
138
158
178
198
1941
1943
1945
1947
1949
1951
1953
1955
1957
1959
1961
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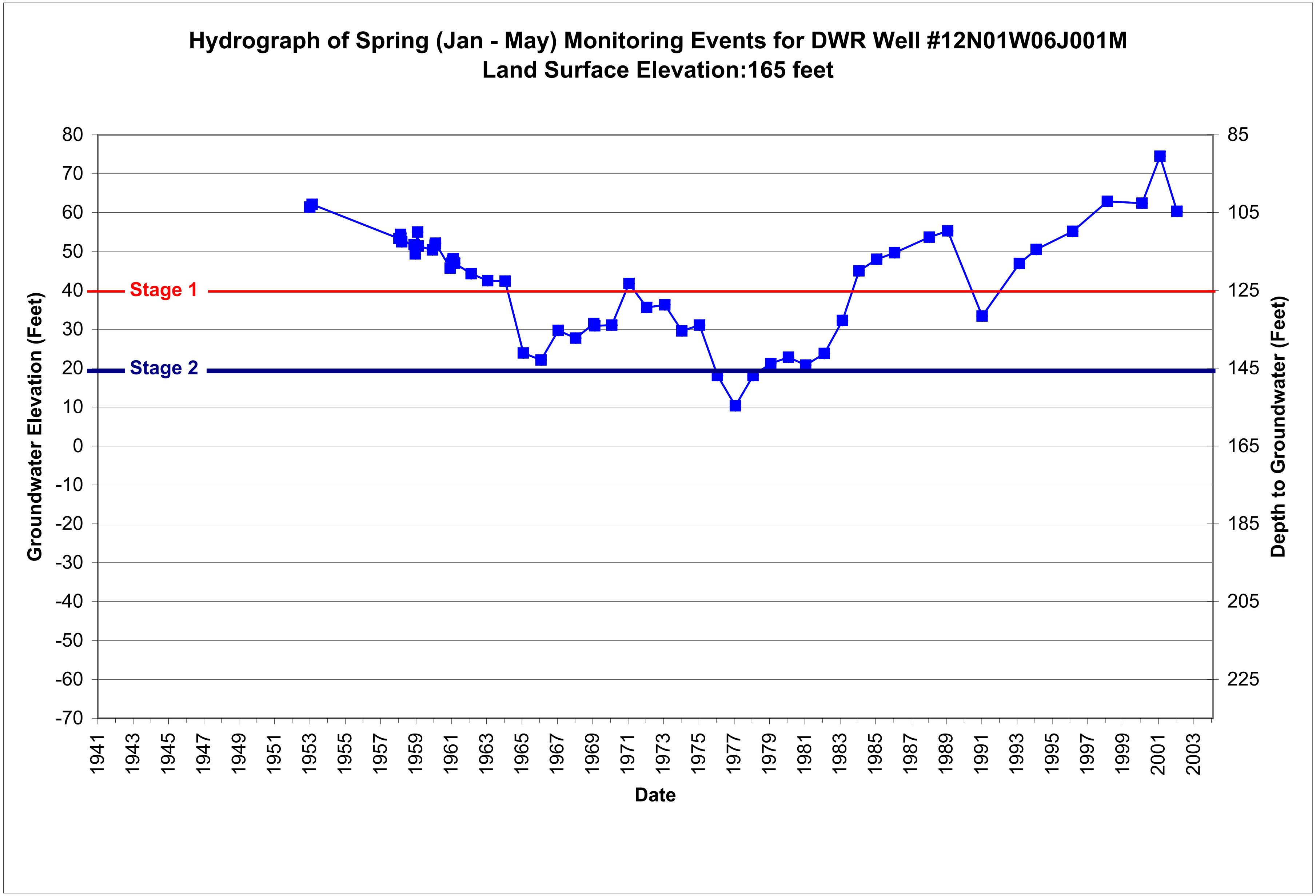
1999
2001
2003


Hydrograph of Spring (Jan - May) Monitoring Events for DWR Well #12N01W06J001M
Land Surface Elevation:165 feet
Groundwater Elevation (Feet)
Depth to Groundwater (Feet)
Date
Stage 1
Stage 2
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
85
105
125
145
165
185
205
225
1941
1943
1945
1947
1949
1951
1953
1955
1957
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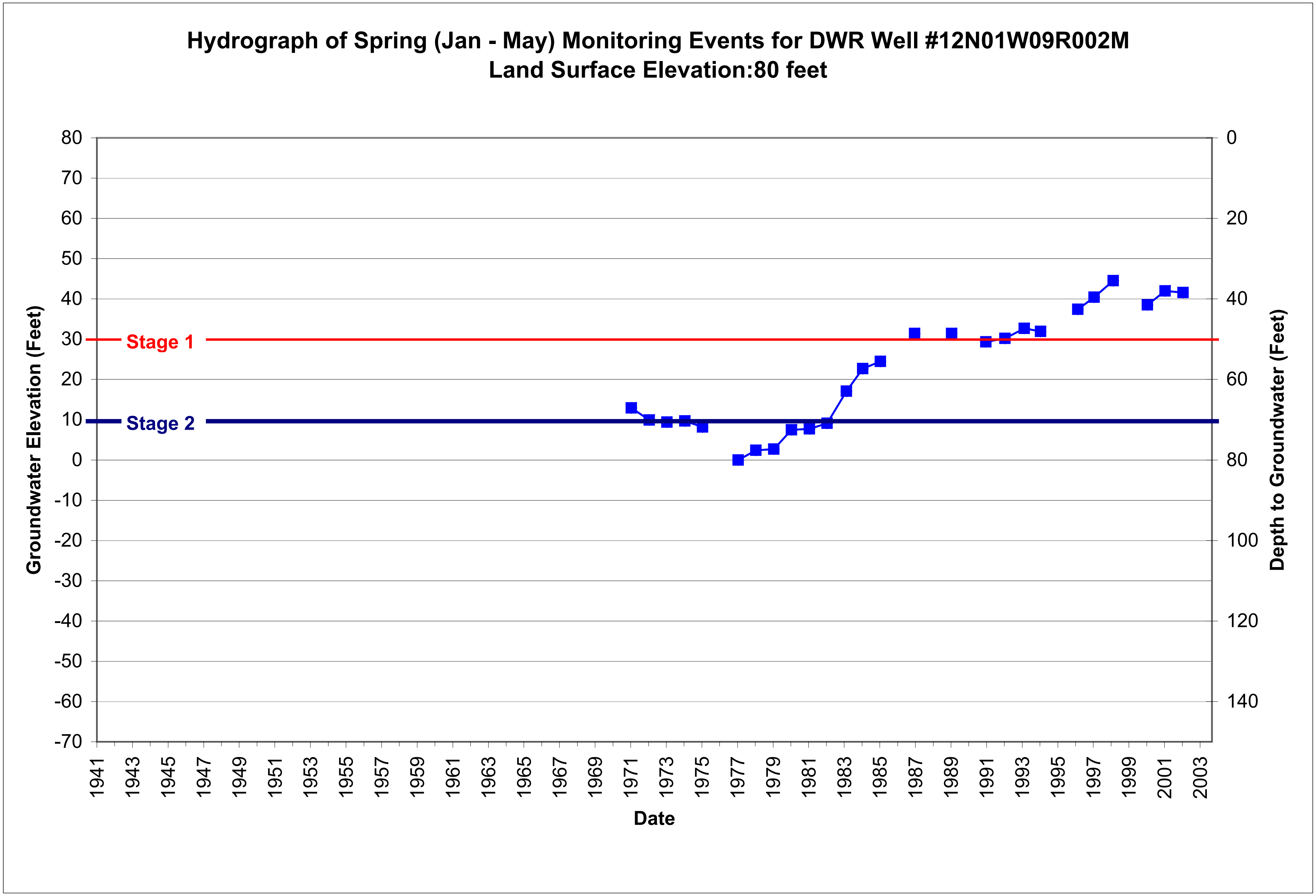
Hydrograph of Spring (Jan - May) Monitoring Events for DWR Well #12N01W09R002M
Land Surface Elevation:80 feet
Groundwater Elevation (Feet)
Depth to Groundwater (Feet)
Stage 1
Stage 2
Date
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
0
20
40
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80
100
120
140
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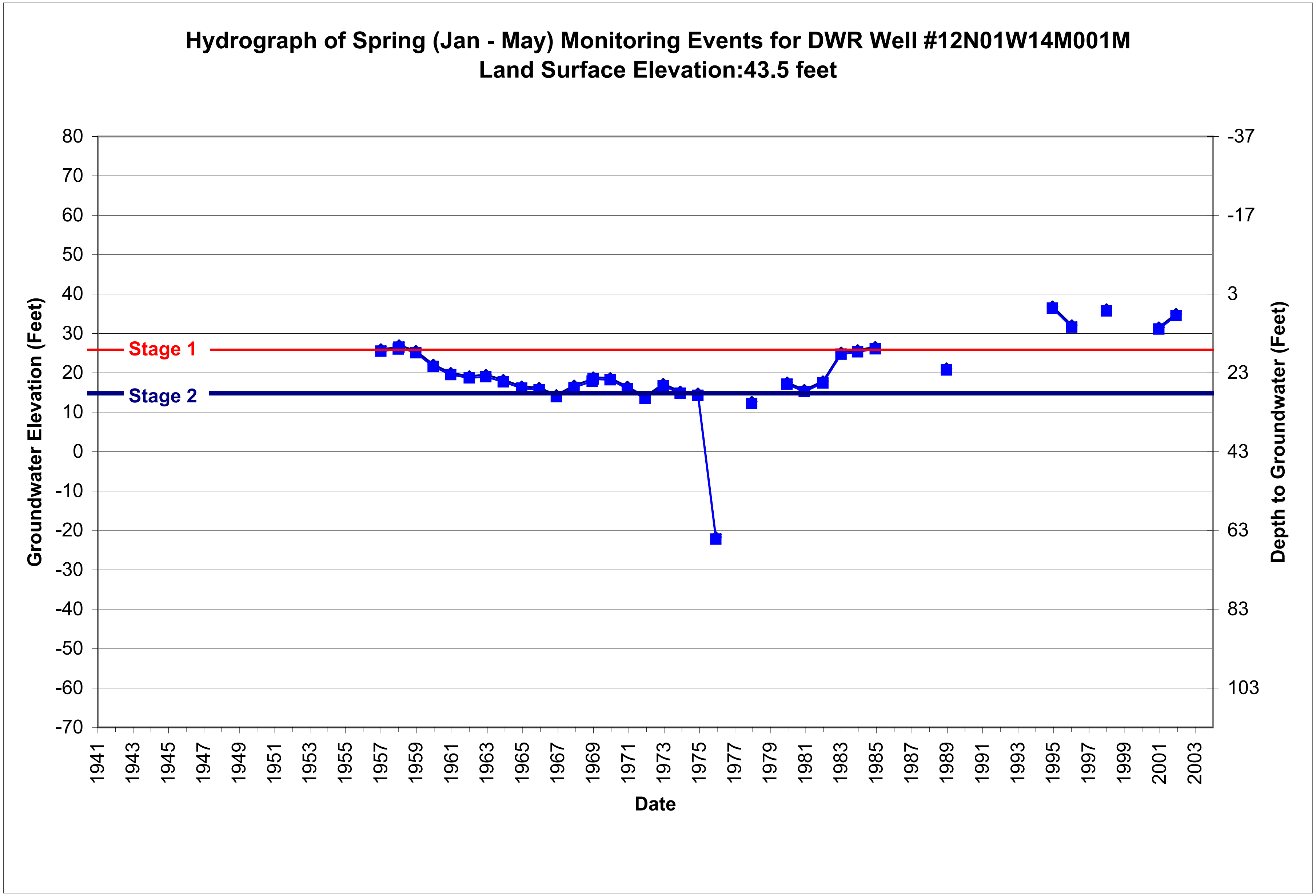
2001
2003


Hydrograph of Spring (Jan - May) Monitoring Events for DWR Well #12N01W14M001M
Land Surface Elevation:43.5 feet
Groundwater Elevation (Feet)
Depth to Groundwater (Feet)
Stage 1
Stage 2
Date
80
70
60
50
40
30
20
10
0
-10
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-30
-40
-50
-60
-70
-37
-17
3
23
43
63
83
103
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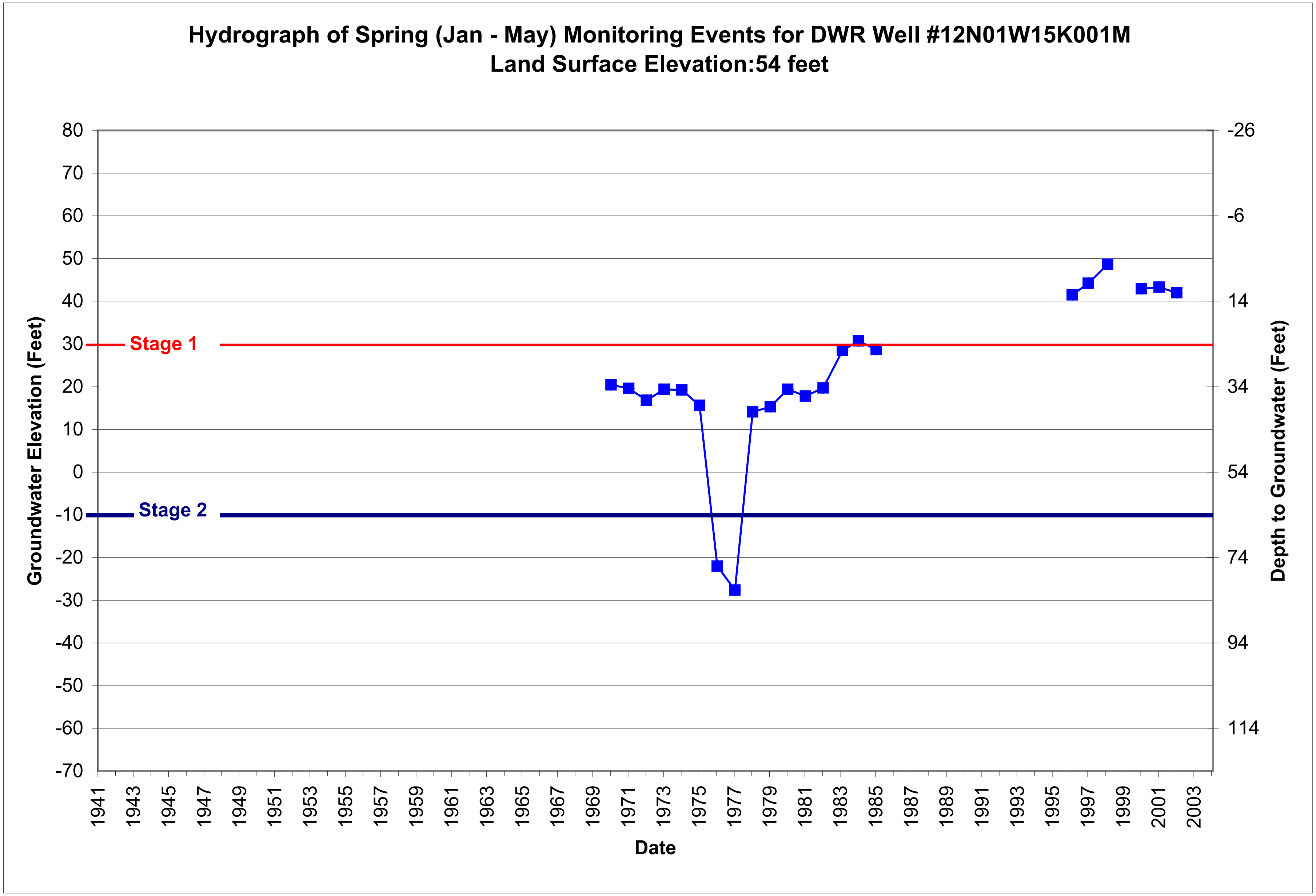
Hydrograph of Spring (Jan - May) Monitoring Events for DWR Well #12N01W15K001M
Land Surface Elevation:54 feet
Groundwater Elevation (Feet)
Depth to Groundwater (Feet)
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
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-70
-26
-6
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34
54
74
94
114
Stage 1
Stage 2
1941
1943
1945
1947
1949
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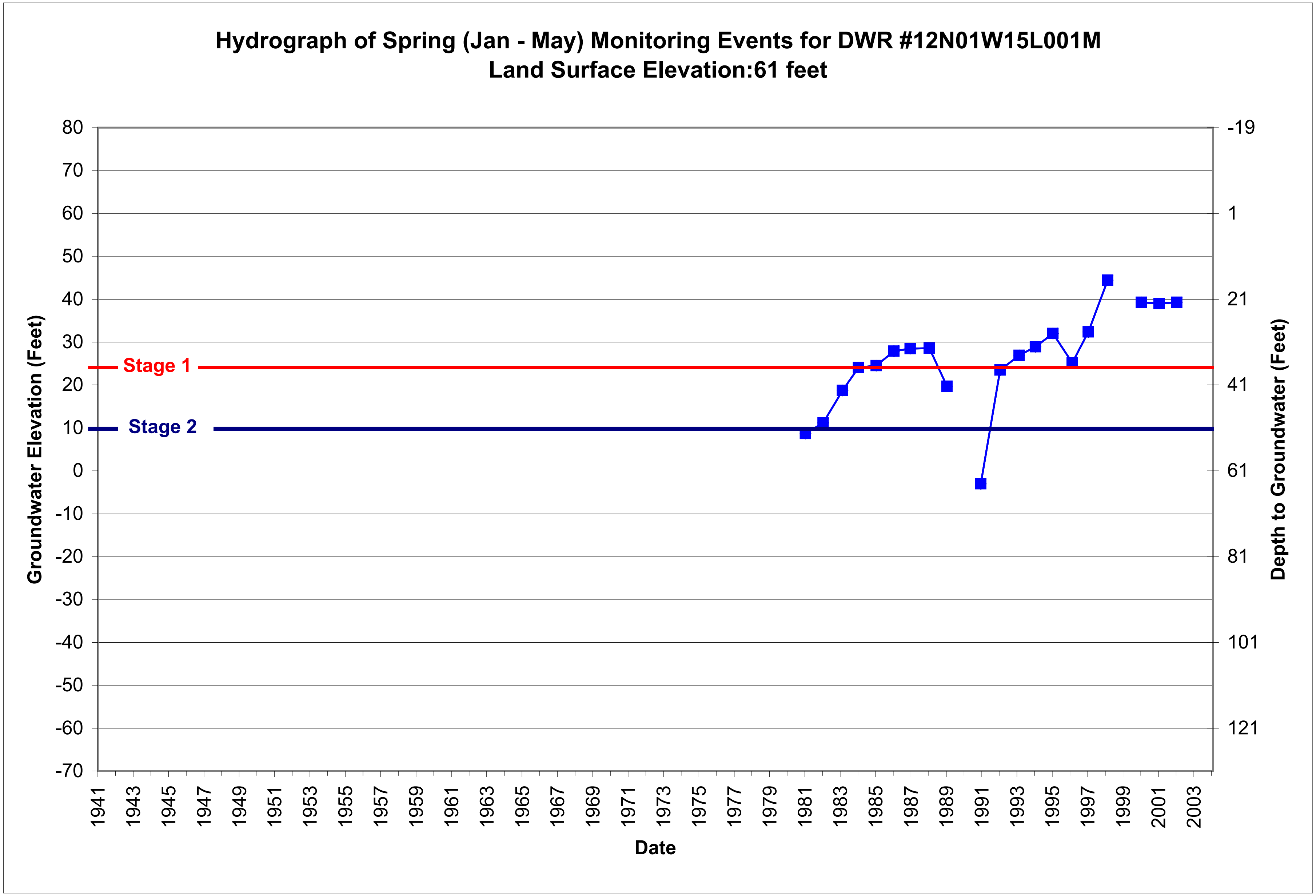
Date


Hydrograph of Spring (Jan - May) Monitoring Events for DWR #12N01W15L001M
Land Surface Elevation:61 feet
Groundwater Elevation (Feet)
Depth to Groundwater (Feet)
Date
Stage 1
Stage 2
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0
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-30
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61
81
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1941
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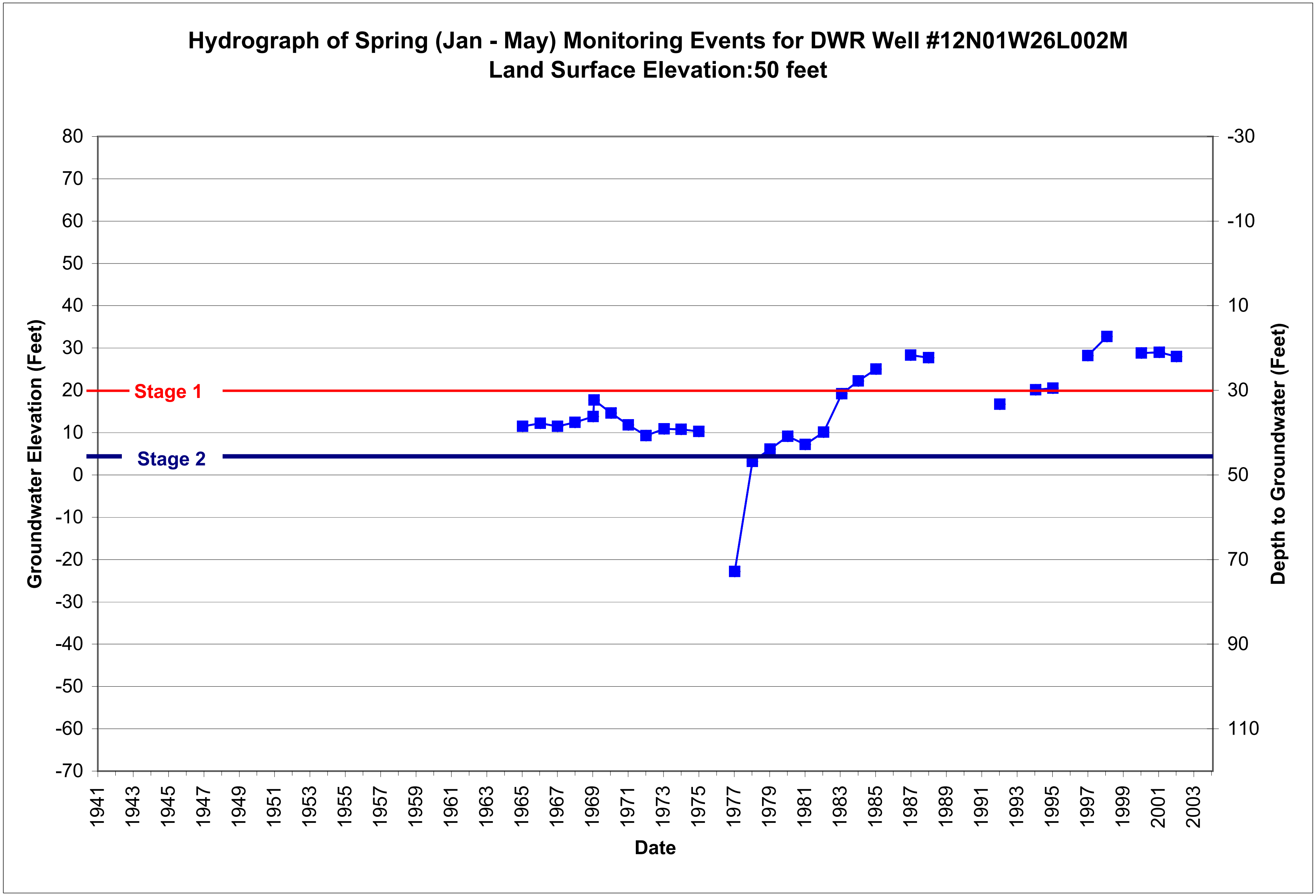
Hydrograph of Spring (Jan - May) Monitoring Events for DWR Well #12N01W26L002M
Land Surface Elevation:50 feet
Groundwater Elevation (Feet)
Depth to Groundwater (Feet)
Stage 1
Stage 2
Date
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