RICHARD C. SLADE & ASSOCIATES LLC
CONSULTING GROUNDWATER GEOLOGISTS

HYDROGEOLOGIC EVALUATION

PROPOSED R^3 PROJECT
MOJAVE RIVER CHANNEL AREA

VICINITY HESPERIA
SAN BERNARDINO COUNTY
CALIFORNIA

PREPARED FOR:
MOJAVE WATER AGENCY
APPLE VALLEY, CALIFORNIA

PREPARED BY:
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JOB NO. 195-01

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RCS Job No. 195-01
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INTRODUCTION

General Statement

Provided in this report are the findings and conclusions of our hydrogeologic evaluation of the proposed Regional Recharge and Recovery Project (known herein as the R^3 Project) that is to be located along/near the channel of the Mojave River in the vicinity of Hesperia, San Bernardino County, California. The R^3 Project is to ultimately involve the construction of a put-and-take series of wells and transmission pipelines and the use of existing and proposed artificial spreading basins (mainly along the upper reach of the Mojave River). Figure 1, "Location Map," provides a generalized map, on a topographic base, to illustrate the location and alignment of the Mojave River and the general study area for this hydrogeologic evaluation.

The basic R^3 Project plan includes storing and artificially recharging surface water in new/proposed spreading basins in/along the Upper reach of the Mojave River, extracting it at several new water wells to be located just west and east of the river near Hesperia, and then discharging the extracted water via a series of new and/or existing transmission lines and booster pumps; these latter facilities will then convey the water to Victorville, Adelanto and the Southern California Logistics Airport to the west and to the Apple Valley region to the east. The proposed sources of water for this artificial recharge and conveyance project are: State Water Project (SWP) water discharged directly into the Mojave River using MWA's existing Rock Springs Turnout facility located immediately adjacent to the Mojave River near the edge of the mountain front; and/or another river discharge facility that could be constructed for the R^3 Project along the east side of the active river channel about 1½ miles south of the Rock Springs Turnout.; and/or controlled releases from the Department of Water Resources-operated Silverwood Reservoir located in the San Bernardino Mountains south of the study area; and/or

MWA has conceived that the R^3 project could include the construction of as many as 22 new water wells in a new "extraction zone"; it is generally desired that each of these wells should each have a pumping capacity in the order of 1000 to 1500 gallons per minute (gpm). When completed, the R^3 project is reportedly scheduled to deliver approximately 40,000 acre feet (AF) of water over an approximate 9-month period each year to the areas of need located west and northwest of the river.

Purpose and Scope of Services

The basic purpose of this evaluation was to provide MWA with our interpretation of the hydrogeologic details of the subsurface earth materials in the study area. RCS-data interpretations in this report are to be used by MWA and Schlumberger Water Services (SWS) to create a sophisticated computer model of the Upper Mojave River region. Additional work by RCS to support the aforementioned model has been conducted under a separate agreement. That work is also to be included in the model.

As identified in our proposal for hydrogeologic services dated August 24, 2005 to Mr. Lance Eckhart, Principal Hydrogeologist for MWA, our scope of work for this project included the following five tasks:

Task 1 – Collect & Review Basic Data
Task 2 – Field Region Visits
Task 3 – Hydrogeologic Analyses
Task 4 – Prepare Report
Task 5 – Meetings

FINDINGS

Definition of Study Area

The main study area for this hydrogeologic evaluation included a roughly rectangular-shaped, generally north-south oriented area that lies along and on both sides of the current active channel of the Mojave River. As noted on all other figures and plates provided in this report, a much larger area was included in the data research and data analyses for this evaluation.

Key features in the study area include: the location and alignment of the active river channel; the local highways and roads like Interstate 15 (I-15) and Bear Valley Road; the local communities like Hesperia and Victorville; and the numerous municipal-supply water wells in the region, as owned by the various water purveyors. Key purveyors within or near the study area from whom the water well data were collected and analyzed for this project, included:

- Apple Valley Ranchos (AVR)
- Baldy Mesa Water District (BMWD), although now a part of the City of Victorville Water Department.
- Rancho Las Flores (RLF)
- San Bernardino County, Community Services District 70, Zone J and L (CSD-70J and -70L)
- City of Hesperia
- The City of Victorville Water Department, formerly known as the Victor Valley Water District (VVWD), although now also a part of the City of Victorville

Rainfall and Stream Flow Data

To assess overall rainfall conditions in the study area and to look for possible trends, RCS obtained annual rainfall data from a rain gage located in Victorville, California (rain gage No. 049325). These data are available online at the website of the Western Regional Climate Center (WRCC; http://www.wrcc.dri.edu). A period of record ranging from 1949 to 2004 was used for the purposes of this study. Figure 2.1, "Yearly Rainfall, Victorville, CA," provides a bar graph of these annual rainfall data for the period of record; the long-term average annual rainfall at this site is calculated to be 5.57 inches.

In addition to rainfall, stream flow data were obtained from MWA for three stream gages: the Deep Creek Gage, the West Fork Gage, and the Lower Narrows Gage. A portion of these data are also available from the USGS, and are categorized by USGS gage number (10260500), (10260950), and (10261500) respectively. The Lowers Narrows Gage is actually located approximately four miles north of the study area. Both the Deep Creek and West Fork gages lie in the south end of the study area, at and near the headwaters of the Mojave River. Because the confluence of Deep Creek and the West Fork represent the tributaries of the Mojave River, the stream flows measured by these two gages have been summed for the purposes of this study. Figure 2.2, "Annual Streamflow Graph of Lower Narrows Gage," shows the annual streamflow data for the Lower Narrows Gage for the period of available record between the years of 1931 to 2004. Figure 2.3, "Annual Streamflow Graph of Deep Creek/West Fork Gage," shows the combined sum of the streamflows for both the West Fork gage and the Deep Creek gage for a period of record between 1931 and 2004.

For each of the three data sets (annual rainfall at the Victorville gage, annual streamflow at the Lower Narrows gage, and the annual streamflow for the combined Deep Creek/West Fork gage, RCS also calculated the accumulated departure from the average (rainfall or streamflow). Figure 2.4, "Accumulative Departure Curves for Rainfall/Streamflow Gages," illustrates the results of calculating the accumulated departure of each year of rainfall or streamflow relative to the long-term average annual rainfall or streamflow at the respective gage. Review of the graph on Figure 2.4 reveals:

- Whenever the graph ascends upward to the right (such as the period of 1976 through 1981 on the rainfall curve), a period of above-average rainfall (i.e., an overall "wet" period) has occurred. That is, on average, most individual years of annual rainfall in this period were at or above the long-term average for rainfall.

  The same is true for the accumulative departure of streamflow. When the curve ascends to the right, such as between 1978 to 1981, a period of above average stream flow occurred.
- Whenever the graph descends downward to the right (e.g., 1960-1965 on all of the curves), an overall period of below average (deficient) rainfall and stream flow has occurred That is, on average, most individual years of annual rainfall and stream flow during this period were at or below the long-term average rainfall and stream flow.
- The three accumulated departure curves shown on Figure 2.4 are very similar. In general, the curves increase and decrease during similar time periods, albeit at different magnitudes. Because of this similarity, distinguishing the specific correlation of each individual departure curve with water level data for each well proved challenging, as discussed below.

Geologic Conditions

Geologic History of the Composite Victorville Fan

The Mojave Desert Province of California is isolated from the adjoining Peninsular Range and the Colorado Desert provinces by the Transverse Ranges. The Transverse Ranges are comprised by the San Bernardino and San Gabriel mountains. Uplift of these mountains to their current ±11,000-foot maximum elevations dates to about 1.5 million years ago (Mya). Subsequent erosion of these uplifted mountains constitutes the source of the deposits that form what is known as the Composite Victorville Fan. The Composite Victorville Fan complex radiates north from the vicinity of Cajon Summit for a distance of approximately 15 miles toward Victorville (Reynolds and Reynolds, 1994). Further, this fan is also reported to extend as far west as Valyermo (Meisling and Weldon, 1989). Deposition of the fan materials from the San Gabriel Mountains commenced about 1.5 Mya, continued with the deposition of the Shoemaker gravel unit (1.4 to 0.9 Mya), and eventually culminated with the deposition of the final, coarse-grained, upper unit which dates from 0.9 to about 0.5 Mya. Deposition of the fan complex is reported to have ceased around 0.5 Mya. According to the geologic time scale, the base of the Quaternary/top of the Tertiary (base Pleistocene/top Pliocene) is dated at 1.0 Mya. Therefore, the Composite Victorville Fan is considered to be Quaternary to Tertiary ("QT") in age and is designated on our figures map plates herein as "QTof" (Quaternary to Tertiary older fan deposits).

As stated above, the sediment source for the Composite Victorville Fan is the mountains that border the southern edge of the study area. Hence, the Composite Victorville Fan builds out (progrades) to the north of the mountain front, and the fan sediments become progressively younger in the direction of progradation.

Deposition by the ancestral Mojave River began prior to the cessation of deposition of the Composite Victorville Fan, however, no estimated time period for commencement of river deposition was encountered during our review of the published literature. By 0.5 Mya, the Mojave River had become a cohesive drainage which flowed to form the ancestral, Manix Lake of Pleistocene age; this lake was located east of the current City of Barstow. Based on the dates of deposition listed above, the oldest sediments of the Victorville fan complex underlie deposits formed by the ancestral Mojave River. Although Stamos, et al., (USGS 2001) designate the ancestral Mojave River alluvium as "QToa," other researchers limit their age assignment of these deposits as to "Qoa" (Quaternary older alluvium). Due to a lack of data, it is uncertain if the alluvial deposits of the ancestral Mojave River commenced prior to 1.0 Mya. Therefore, for the present study, these deposits are not considered to cross the "QT" boundary. Referenced literature indicates that the Qoa/QTof contact is erosional (i.e., the contact occurs along an unconformity) in some areas, but is gradational (i.e., the contact is one of the interfingering sediments) in other areas. Because the modern Mojave River is interpreted to be eroded into the ancestral older alluvial sediments, the contact between the modern Mojave River sediments and the ancestral alluvial sediments is considered to be unconformable.

<u>Geologic Units Underlying Composite Victorville Fan</u>

The Composite Victorville Fan is underlain by the Harold Formation (QTh), which is exposed at ground surface north and south of Horse thief Canyon Road as shown on the geologic map which accompanies DWR Bulletin No. 84 (1967). This same outcrop, however, is designated by

Dibblee (1967) as the Crowder Formation. At the top of this unit are greenish-gray silty beds which Dibblee indicates are correlative with the "Harold Formation of Noble" (the original reference for this formation). More recently, Stamos, et al (USGS 2001), designates part of this outcrop area as "Pleistocene to Pliocene older alluvium of the ancestral Mojave River" (QToa) and part as "Holocene to Pliocene unconsolidated and undifferentiated alluvium" (QTu).

Later, Morton and Miller (USGS 2003) provided a surface geology map along Horsethief Canyon Road that suggests these sediments are Crowder Formation to the north and "very old fan deposits" ("Qvof") flanked by Crowder Formation ("Tcr") to the south. Crowder Formation reportedly dates from 17 to 9.5 Mya, which is considered to be during approximately late-Miocene time (Morton and Miller, USGS 2003). Pliocene-aged strata originally thought to be the western and eastern facies equivalents of the upper Crowder Formation have been shown to be younger than Crowder Formation (4.5 to 1.5 Mya) by Meisling and Weldon (1989), and have been informally designated "Phelan Peak deposits" (map units QTpp and Tpp; Weldon 1984, 1989). Underlying the Crowder Formation, and reportedly in fault contact with it, is the Cajon Valley Formation ("Tcv"; Morton and Miller, USGS 2003). Previous work in the area by others has suggested that the Cajon Valley Formation was correlative with the younger Punchbowl Formation ("Tpb"). Therefore, there clearly is some confusion and/or disagreement when comparing geologic maps prepared over time by different researchers as to which specific designations or geologic formations actually occur at which location.

Simplification of Geologic Units

Due to obvious differences in the definition of geologic units and the sometimes contradictory terminology in the surficial geologic mapping work published by others, our assessment of the Mojave River area uses the most recent and most detailed geologic mapping available (Morton and Miller, USGS 2003), supplemented by Dibblee (1960a, 1960b, 1960c, 1960d, 1967), where necessary. A vast number of geologic units were mapped in the area by Morton and Miller in that USGS 2003 work. Specifically, map units such as young alluvium and old fan deposits were subdivided into as many as 5 separate, similarly-aged units. For example, map unit Qyf, is shown as units Qyf_1, Qyf_2, Qyf_3, Qyf_4, and Qyf_5 by Morton and Miller (USGS 2003). As a consequence, RCS has produced a simplified revised geologic map for this project in order to consolidate geologically-related and age-related units (see Plate 1, "Basic Geology of Project Area").

In the Mojave River area, alluvium deposited by the Mojave River is divided for this project into only three map units; Qc, Qoc and Qca. Numerous "very young wash deposits" defined by others to be "active" or "intermittently active" are designated herein as Qc (channel deposits). "Wash deposits" defined to be "abandoned" are designated herein as Qoc (older channel deposits). Various "young wash deposits" defined to be "marginal parts of active" channels are designated herein as Qca (channel alluvium).

In the remainder of the study area (i.e., earth materials not within the Mojave River channel), very young, shallow colluvium and wash deposits are shown as the underlying units on the map figure. All USGS 2003 subdivisions of "young fan deposits," "young alluvial valley deposits," and "older alluvial fan deposits" are simplified herein as Qyf, Qya, Qof, respectively.

Based on age-dating research conducted by Reynolds and Reynolds (1994), the "very old fan deposits" (Qvof) which form the upper portion of the Victorville fan, and also the "Shoemaker gravel" which is also a part of the lower Victorville fan), have been simplified for this project as map unit QTof. Morton and Miller (2003) also provided multiple subdivided units of Qvof, such as $QVof_1$, $Qvof_2$, and $Qvof_3$. West of the Mojave River in the southern portion of the study area, these subdivided units are interpreted herein as part of the upper portion of the Victorville fan, and are included within map unit QTof. In the northern portion of the study area, RCS geologists have interpreted that the areas mapped as Qoa are not part of the Composite Victorville fan and therefore, are shown on Plate 1 herein as unit Qoa.

Morton and Miller (USGS 2003) indicate that rocks mapped as Crowder Formation east of the Mojave River probably include Phelan Peak deposits of Weldon (1984) and may include Harold Formation. Also, the geologic contact between the Shoemaker gravel and the underlying Harold Formation is gradational and, in some areas (particularly in the southeast portion of the Composite Victorville fan), the Harold Formation was mapped together with Shoemaker gravel. Hence, on the Simplified Geologic Map, all outcrops designated as "Harold," "Crowder," or "Phelan Peak" have been consolidated as QThcu (Harold and Crowder formations, undifferentiated).

Basement rocks within the study area consist primarily of crystalline quartz diorite, quartz monzonite or gneiss, and the Oro Grande Formation (marble, schist, quartzite). All such units are designated herein as a single unit, “bc” (basement complex), as shown on Plate 1.

Selection of Geologic Cross Section Alignments

This study of the project area required a detailed evaluation of subsurface conditions across the region. Thus, RCS geologists needed to define and assess possible geologic-contact relationships between basement complex rocks, older sedimentary units, the Composite Victorville Fan (which dominates the Pleistocene- to late-Pliocene sediments in the Mojave subbasin), and an extensive veneer of young fan deposits, Hence, five detailed cross sections (four oriented east/west, A-A’, B-B’, C-C’, D-D’; and one oriented north/south along the Mojave River, E-E’) have been prepared (see locations of cross sections on Plate 1). The east/west sections (shown herein as Plates 2.1 through 2.4, respectively) helped to define the eastern edge of the Composite Victorville Fan (QTof) where the fan extends under the Mojave River and onlaps onto surface exposures of the Crowder Formation as defined by USGS 2003; these exposures are located subparallel to the east side of the river as seen on Plate 1. The north-south section (Plate 2.5), was constructed to help determine the thickness of river alluvium along the Mojave River.

Drillers’ logs and electric logs were collected from several sources, including the Mojave Water Agency, the California Department of Oil and Gas, the various water purveyors that exist within the study area, and prior RCS job files. The available data were then reviewed and correlated to help provide reasonable interpretations of subsurface conditions beneath the study area. The very limited oil well data were used to provide lithologic detail and possible depths to the subsurface contacts of geologic formations and/or basement complex. Such geologic contacts tend to be deep and are only rarely encountered during the drilling of boreholes for new water wells because such water well boreholes tend to be relatively shallow in depth. For our interpretation, the locations of wells for which RCS received electric log (elog) and/or lithologic log data were plotted on our base map. Selection of potential cross section alignments was conducted once the wells were plotted were then selected; the final selection of each alignment was based on the availability and quality of the elog data, the location of outcrops of basement complex rocks (bc), and the location of outcrops of geologic units underlying Victorville Fan deposits (QThcu).

Arid-Region Alluvial Fan Processes

Geologic materials comprising the Victorville Fan have primarily granitic, metamorphic, and conglomeratic source areas. Typically, for these types of source areas, fan material is deposited by debris flow, water-laid sheets of sediment, and minor channel deposition. Fans consist of the apex, upper fan, middle fan, lower (distal) fan, and perimeter areas that coalesce with adjoining fans. In arid regions, the main channel is usually incised into the fanhead and it emerges onto the ground surface at a point in midfan called the “intersection point.” Above this point, deposition is primarily by debris flow; below this intersection point, deposition is by water-laid fluvial processes.

Earth materials that are characteristic of deposition by debris flows include cobbles, boulders, and a matrix, poor sorting, and massive beds; another characteristic of debris flows is a uniform bed thickness with radial (apex to toe) beds that may extend for long distances. Viscous debris flow produces clayey or silty gravel. Deposition by water-laid (flood) events includes layers and lenses of well-sorted gravel, sand, and silt, with little clay; often these strata display uniform bed thicknesses. Smaller, braided channels become filled, usually by coarser-grained, and more poorly-sorted, gravel and clayey sand deposits. Thin clay beds are produced by the waning phase of ephemeral flooding.

Progradation and Migration of Fans

Fan deposition will show cyclic sequences. In an individual flood, the coarsest grained material will be carried by the initial flood-water energy. As the flood wanes, material carried will become finer-grained in a downstream (downgradient) direction. In any given location, this will result in a “fining-up” sequence of beds. As flood sequences build upon each other, the fan will build outward (prograde) into a lobe with the general fan shape from apex to toe. In any given location, this will result in an overall “coarsening-up” sequence in the sediments (as a composite of stacked expanding individual cycles). Such “fining-up” and/or “coarsening-up” deposits are often encountered on elog signatures.

As the progradation process continues, the fan will oversteepen and migrate sideways to the downslope side of the fan. The original fan will be abandoned and the locus of deposition will shift downslope, to build another fan lobe. If the shift is minor, part of the new fan will overlap the abandoned fan. If the downslope direction stays relatively the same, the fan will continue to shift sideways, building a series of overlapping lobes toward the same downslope side.

Selection of Key Marker Beds

Selection of key marker beds for our cross sections was made using individual elogs and the correlation of signatures tend to be from one well to another. Hence, these marker bed signatures appear to be distinctive on each log and also tend to be persistent from one correlated well to another along the line of section. In clastic sequences (gravel/sand/silt/clay) such as the Composite Victorville Fan, typically good candidates for marker beds will be the laterally extensive, relatively coarse-grained zones. Occasionally, a widespread relatively thick clay zone can also provide a good marker bed, particularly if it displays a distinctive color that is recorded by a driller on his log and if that distinctive layer has been denoted on drillers' logs of successive wells along the line of section. As a practical matter, such marker beds usually need to be at least 10 to 20 feet thick to be observed and recognized in on elogs.

For our cross sections, marker beds W, X, and Y represent identifiable coarser-grained zones that occur within the Composite Victorville Fan (QTof); each marker bed is 10 to 30 ft thick, and, in our opinion, can be recognized on most elogs throughout the Victorville/Adelanto/Baldy Mesa/Hesperia area. Because outcrops of Shoemaker gravel are shown to extend west to Valyermo (west of the study area), and the Composite Victorville Fan is also reported to extend to Valyermo (Meisling and Weldon, 1989), then it is reasonable to assume that these marker beds within the Composite Victorville Fan may even extend as far west the Valyermo area.

Trends Identified Using Marker Beds

Marker beds W and X appear to be at the tops of different overall, composite coarsening-up sequences and also in the upper portion of the Composite Victorville Fan. It is likely that both marker beds reflect: maximum progradation of a fan lobe with time; then a downslope migration above the marker bed; and finally the building up of another fan lobe. Marker bed Y is at the top of a thicker (200 ft to 300 ft), stable, megasequence of sediments which is comprised by numerous coarsening-up and fining-up zones. The base of this sequence is defined as the base of the Composite Victorville Fan; the fan base overlies the undifferentiated Harold/Crowder Formation (QThcu). In areas of high (shallow) basement complex (such as the area in the north/northeastern portion of Victorville), the fan is deposited directly onto basement complex rocks. Along the Mojave River, marker beds W and X generally have been eroded away by deposition associated with the ancestral and recent Mojave River(s). At the periphery of the fan, the intervals between the marker beds tend to rise, thin, and become finer-grained; hence, the marker beds become indistinct.

HYDROGEOLOGIC CONDITIONS

General Statement

Geologic materials depicted on Plate 1 have been divided according to their relative water-bearing characteristics, that is, to their relative ability to contain, transmit, and yield groundwater to water-supply wells. As such, two divisions are recognized: a potentially water-bearing sediment group and a nonwater-bearing rock group. Plate 1 provides the locations of the ground surface exposures and the areal extents of all of these materials, together with local geologic structure, and the alignment of major faults.

Depending on water levels, the potentially water-bearing sediments can become saturated, thereby permitting them to provide water to wells. Thus, they constitute the groundwater reservoir of the study area. In effect, these sediments should be wholly included within the lateral and vertical boundaries of the local groundwater basin along the Mojave River.

Underlying the water-bearing sediments in the valley areas, and exposed on all adjoining hill and mountain areas, is the relatively impermeable, nonwater-bearing earth materials and rocks.

Potentially Water-Bearing Sediments

This group comprises the following:

- Undifferentiated, unconsolidated alluvial channel and alluvial fan deposits which occur along the active channel of the Mojave River and overlie older fan deposits in the study area. On Plate 1, these sediments include map symbols Qc, Qoc, Qca, Qyf, Qya.
- Undifferentiated, poorly to moderately consolidated older alluvial fan and very old alluvial fan deposits which flank and/or underlie the younger, alluvial-type deposits and

are not a part of the composite Victorville fan (QTof). On Plate 1, these materials include map symbols Qof and Qoa.

- Underlying the younger, alluvial-type deposits beneath the Mojave River and also known to occur at and beneath ground surface in most of the region west of the river channel are the composite Victorville alluvial fan deposits (map unit QTof). These older alluvial fan deposits have a maximum thickness of the order of 700 to 800 feet in the region, as determined by the results of detailed geologic logging of numerous pilot holes for new wells and upon our interpretation and correlation of a large number of electric logs within the study area and its environs.

The undifferentiated alluvial-type deposits are Pleistocene to Holocene (Recent) in geologic age. For the most part, these potentially water-bearing strata are geologically younger, more permeable, less consolidated, and less structurally deformed than the nonwater-bearing, underlying earth materials and rocks.

The potentially water-bearing sediments, as a group, have been penetrated to various depths by the large number of wells in the region and historically have provided virtually all the groundwater extracted by these wells. These sediments constitute the local groundwater reservoir and represent the main focus of this study.

Analysis of available drillers' logs clearly reveals that these sediments are composed of extensively interlayered and interfingered mixtures of gravel, sand, silt, and clay, with variable concentrations of cobbles and boulders. In general, alluvium in the main river valley ranges from medium-to-coarse-grained sand on the south to fine- to medium-grained sand on the north.

The maximum thickness of this undifferentiated alluvium varies along the river, but generally is considered to be on the order of 200 feet. Typically, the alluvium tends to be thickest near the central portion of the river channel and thins or pinches out as the flanks of the adjoining channel are approached.

Nonwater-Bearing Earth Materials and Rocks

Underlying the potentially water-bearing sediments in the study area and exposed in the hillsides on the east, north and south sides of the study area are a series of consolidated, cemented sedimentary strata of Tertiary geologic age, and/or an assemblage of crystalline rocks of the pre-Tertiary age. For the most part, the sedimentary earth materials (map unit QThcu) are exposed along the flanks of the hills which border the east side of the Mojave River.

The geologically older, crystalline, metamorphic and igneous rocks (map unit bc) crop out in the hills north and south of the study area. Exposures of these various bedrock units are depicted on Plate 1.

In certain parts of the study area (such as the deep creek area of the Mojave River, and the AVR area east of the River), the QThcu deposits may locally yield water at useable rates and quantities. However, in the western portion of the study area (such as in the Hesperia area), the QThcu deposits display a very low permeability and are considered to be non-water bearing.

Due to their fine-grained and/or crystalline nature, the above earth materials and rocks are of low permeability and tend to possess only secondary porosity. In general they may contain groundwater only along bedding planes, joints, shears or fractures. As a result, these rocks are not considered capable of yielding groundwater readily to wells. Moreover, they have a very limited storage capacity, and their ability to provide long-term sustained yields to wells is unpredictable. These cemented and/or crystalline rocks are not considered part of the groundwater reservoir in the study area.

Faults

Two faults, known as the Narrows fault and the Apple Valley fault, occur in the general study area and are described in the Stamos et al USGS 2001 report. According to that report, these faults are essentially “model faults.” That is, these faults were postulated by Stamos et al to account for anomalies in water level elevation contour maps discovered during their groundwater modeling work (USGS 2001).

Of these two “model faults,” RCS geologists have reviewed data that may justify the existence of only one of these faults within the study area: the Narrows fault. Nearby electric log and geologic log data used in the RCS interpretation of the subsurface geology in the area tends to help corroborate the possible existence of the Narrows fault. This fault may have some affect on groundwater flow in the area, as originally suggested in the Stamos et al USGS 2001 report.

The Apple Valley fault, as shown by Stamos et al USGS (2001) to be located on the eastern side of the Mojave River, has not been included on Plate 1 for this project. As mentioned above, it is a “model fault.” During our work to review driller’s logs, geologic logs, and available electric logs for the area, RCS geologists have encountered no definitive evidence that would corroborate the existence of this fault. Further, geologic mapping presented in the Morton and Miller USGS "Preliminary Geologic Map of the 30' X 60' San Bernardino Quadrangle" (2003) does not show the Apple Valley fault. That map only shows a fault on the southeastern edge of the Mojave River, and this structure was not extended as far north as Apple Valley by those authors (discussed below).

Geologic mapping of the materials exposed at ground surface in the area of the Apple Valley fault also differs between the USGS 2001 and the USGS 2003 reports. USGS 2001 shows the geologic materials east of the Mojave River as map unit QToa, or Older alluvium of the ancestral Mojave River; in contrast, the USGS 2003 map denotes this area as map unit Tcr, (i.e., the Crowder Formation). This outcrop of the Crowder Formation and the interpreted location of the Apple Valley fault by Stamos, et al (2001) may be the cause of the anomalous water level data in wells in the area in the area immediately east of the Mojave River. Therefore, as shown on Plate 1 herein, the area directly east of the Mojave River is shown as map unit QThcu (a simplified unit containing the USGS 2003 Tcr Crowder map unit). Therefore, the Apple Valley fault is not included on Plate 1.

A fault exists in the southern Apple Valley/Fifteen Mile Valley area according to Meisling and Weldon (1989). It is a north-south trending fault located just east of the southern portion of the Mojave River and it appears to extend northward paralleling the Mojave River until it reaches the Apple Valley area. This fault is labeled as the Deep Creek fault in the Meisling and Weldon 1989 reference. This fault, which is also shown in the 2003 USGS report, is included herein on the Plate 1 geologic map.

Water Well and Test Hole Locations

Many wells exist throughout the study area. Municipal-supply wells, private domestic wells, private agricultural wells, and MWA-owned multiport groundwater monitoring wells are all located within the study area. In addition, a few test holes, or pilot boreholes, that were drilled but not constructed into functioning water wells, exist in the study area. Finally, a few wildcat oil wells, or pilot boreholes drilled for the purpose of oil exploration, are also located within the study area. Plate 3, "Well and Test Hole Location Map," shows the locations of these numerous wells, test holes and wildcat oil wells within the study area.

These location data were compiled form many different sources. MWA and RCS worked cooperatively to refine the previously-existing well database for the area. Well locations for the monitoring wells within the study area were provided by MWA. In addition, RCS has sited and monitored the construction and testing of a number of the newer municipal-supply water wells in the area, and was thus able to provide accurate location data to MWA for these newer wells. Further, RCS has performed a number of studies in the area for the various purveyors, such as the Victorville Valley Water District (now Victorville Water), Hesperia Water District, and Baldy Mesa Water District (also now a part of Victorville Water), and the privately-owned Rancho Las Flores which is located in the hills on the south side of the study area. Hence, well location data and test hole data were available from RCS files. Locations for the Apple Valley Ranchos (AVR) wells were provided by MWA and AVR. Please note that at the specific request of AVR, well numbers for individual AVR wells have been omitted from this text and related figures and plates. The locations of privately-owned domestic- and irrigation-supply water wells were provided by MWA from drillers' logs compiled over time. The locations of these private wells are approximate only; specific location information provided on a driller's log is often non-existent and/or inaccurate. Hence, the locations of the private wells shown on Plate 3 are only for those wells with relatively good location information so that they could be used for the construction of the cross sections on Plates 2.1 through 2.5.

Aquifer Parameters

As stated above, RCS has performed a number of hydrogeologic studies for other agencies within the study area. These studies included the design, construction, and aquifer testing of a few of the wells within the study area. Hence, RCS was able to calculate aquifer parameters for a few of the wells within the study area using the pumping test data for those wells. These aquifer parameters include: transmissivity (T), which is a measure of the ability of an aquifer to transmit water to a pumping well, and is expressed in units of gallons per day per foot of aquifer width (gpd/ft); and storativity (S), which is a measure of the volume of water released to a pumping well for a given volume of aquifer materials. Storativity is dimensionless and has no units. A storativity value cannot be determined solely from water level data acquired in a pumping well during an aquifer test; drawdown data recorded in a nearby observation well must be available to permit calculation of aquifer storativity from a pumping test. Unfortunately, water level data from a nearby observation well were available for only one of the new wells within the study area for which RCS had previously conducted a pumping test.

Table 1, "Aquifer Parameters,", lists the wells for which RCS was able to calculate aquifer parameters using pumping test data. Tabulated data for each well include: well owner; well number; test date; average pumping rate during the subject aquifer test; the final pumping water level resulting from that pumping rate; the calculated aquifer T value; and the lone S value that could be calculated from the available data.

Table 1 – Aquifer Parameters

Owner	Well No.	Date of Constant Rate Pumping Test	Average Pumping Rate (Q, gpm)	Drawdown (s, ft)	Transmissivity (gpd/ft)	Storativity (dimensionless)
VVWD	42	10/1/2005	992	58	45,000	---
VVWD	43	9/29/2005	2146	113	113,200	0.001
VVWD	45	5/2/2007	1994	106	45,000	---
VVWD	47	2/1/2007	786	127	10,000	---
Hesperia	19	4/4/2005	819	64	98,000	---
Hesperia	31	5/1/2005	1575	49	154,000	---
Hesperia	32	9/1/2005	1723	40	98,000	---

Percent Clay Maps

Percolation of groundwater into the alluvial sediments of the Mojave River and through these alluvial sediments into the underlying regional aquifer is essential to the success of the R^3 project. Therefore, in order to preliminarily assess the ability of water to percolate within and through the river sediments, a percent clay analysis was performed. MWA provided RCS with numerous drillers' logs for wells that have been drilled in the past within the study area. These logs contain descriptions by each driller of the cuttings as observed at the time the drilling of the borehole for the particular well was being performed. RCS reviewed these drilled-reported lithologic descriptions to help interpret the relative percentage of clay within the formation; approximately 130 driller's logs were used for this analysis.

To create percent clay maps, it was necessary to estimate the percentage of clay reported on each log by the driller in each 20-foot thick depth zone between ground surface and a depth of 200 ft. A maximum depth of 200 ft was used because this is the approximate thickness of alluvial-type sediments within and along the Mojave River. The resulting percent clay estimations at the location of each well for which a driller's log exists were plotted on a basemap of the area, and then contour lines of the equal percentage of clay were drawn. Then, maps of the approximate thickness of percent clay were produced from these data sets and are presented as Plates 4.1 though 4.10, "Percent Clay Map," for the depth zones of 0 to 20 ft, 20 to 40 ft, 40 to 60 ft, 60 to 80 ft, 80 to 100 ft, 100 to 120 ft, 120 to 140 ft, 140 ft to 160 ft, 160 to 180 ft, and 180 to 200 ft, respectively. These maps depict the various equal contours of clay percentage, and specially denote those areas where the clay percentage is interpreted to be equal to or greater than 60 percent. The higher clay percentage zones are interpreted to be areas in which deep percolation of runoff along in the Mojave River may be somewhat inhibited and/or diminished, and thus, perhaps not ideal for a groundwater recharge zone. Also shown on Plates 4.1 through 4.10 is the approximate active channel of the Mojave River, based on the geologic mapping by others of the Quaternary-aged wash deposits along the river.

Originally, RCS prepared computer-generated contours of the equal percentage of clay. Because some of these contours did not quite fit the data, as can sometimes be the case for computer-derived contours, MWA provided contours of the data using an alternate software package. It was decided by RCS and MWA to use the contours generated by MWA's software package (ESRI ArcScene 9.0) for this project.

Review of Plates 4.1 through 4.10 reveals the following:

- Within the active channel of the Mojave River, almost no clay percentage contours greater than 50% are shown.
- In only limited areas near the river are clay percentages higher than 60%; these areas are around Arrowhead Lake Road, and also to the northeast of the river.
- The northeastern portion of the study area, northeast of the Mojave River, displays the highest overall percentages of clay between ground surface and a depth of 200 ft bgs.

Groundwater Elevations and Regional Flow Directions

Water level data for a number of wells within the study area were provided by MWA, and these were supplemented with data from prior RCS projects where available. MWA also provided RCS with the wellhead elevations for each well within the study area. From the available data, the most recent and extensive water level data set was available for October 2005. Therefore, using these available water level depth data, in conjunction with the wellhead elevations for each respective well, the resulting water level elevations for each well with October 2005 water level data were calculated. Contours of the equal groundwater elevation for October 2005 were then generated using computer methods. It must be noted that these groundwater contours are derived from water level data for wells of various depths and with different perforation intervals, therefore, some of the data appear to be anomalous. Hence, RCS geologists then hand-contoured the water level elevation data. These hand contours are important in that when a geologist is actively involved in contour creation, interpretive decisions can be made during the contouring process, concerning anomalous data points, geologic constraints, etc. Following this manual process, the contours were digitized by RCS geologists using a GIS system. Plates 5.1 and 5.2, "Groundwater Elevation Contour Map, October 2005," provide the resulting, manually-created contours on a topographic base map and a geologic base map, respectively.

In addition to the groundwater elevation contours on Plates 5.1 and 5.2, arrows are also provided to depict the regional direction of groundwater flow. These flow arrows, by definition, are perpendicular to the contour lines they intersect. After reviewing these two plates, the following observations are noted:

- The regional direction of groundwater flow within the study area is generally to the north – northwest.
- The gradient expressed by the elevation contours within the Mojave River generally follows the gradient (slope) of the ground surface contours along the active channel of the river.
- In the southern portion of the study area, near the headwaters of the river and the Deep Creek groundwater monitoring well, there is a component of flow to the west and/or northwest, toward the City of Hesperia.
- Water level data from the AVR wells on the east side of the river suggests that groundwater flows from the Apple Valley area, northwest, toward the Upper Narrows.

- A few “pumping holes” are observed on Plates 5.1 and 5.2, in the areas of the AVR wells. A pumping hole is a depression of water levels that is centered around a few or more, closely-spaced production wells. These pumping holes suggest that either the data used in the contouring process were not truly static water levels (i.e., the well was pumped and turned off just before the measurement was collected), or that water levels in the area of the “pumping hole” have been artificially decreased to excessive pumping.
- North of the Jess Ranch monitoring well, a mound of groundwater is depicted by the groundwater elevation contours. This mound of groundwater coincides with the State-owned Fish Hatchery ponds at that location (see Plate 5.1). Hence, the Fish Hatchery ponds are likely acting as a source of groundwater “recharge” to this portion of the Mojave River.
- Water level contours in the northeasternmost AVR area may not be correlative with water levels nearer the Mojave River, based on the outcrop of the QThu materials located east of the River. Hence, the water level elevation contours are queried in this area.

Hydrographs

Long-term water level data were available for a number of the municipal-supply wells and nested groundwater monitoring wells within the study area. These water level data were received from MWA, and then augmented with water level data from in-house RCS data collected from other projects in the area. In general, water level data were available from the early-1990s through 2005 or 2006; a few wells have water level data available from the mid-1980s. Using these long-term water level data, RCS created numerous hydrographs that are presented on Figures 3.1 though 3.26, “Hydrographs with Accumulated Departure Curves.” Figures 3.1 through 3.7 represent hydrographs for the nested groundwater monitoring wells, and hence, these figures show multiple sets of water level data that correspond with discrete zones within each monitoring well; depths of each monitored zone are also shown on these figures. Figures 3.8 through 3.36 are hydrographs for the municipal-supply wells within the study area; water levels on these figures represent a composite of the various heads created by the entire perforated zone in each well. Depths of the perforation zones within the production wells are also included on Figures 3.8 through 3.36.

Also shown on each graphs are: the accumulated rainfall departure for the rainfall data from the Victorville rain gage; the accumulated stream flow departure from the Lower Narrows gage; and the accumulated stream flow departure from the combined Deep Creek and West Fork stream gages. These accumulated departure curves were plotted so that those accumulated departure trends could be compared to the water level trends in each of the wells, and possible correlations, if any, between water levels and rainfall and/or stream flow might be discernible. Each of the hydrographs has the same vertical scale for water level depths (in ft) to facilitate review. The horizontal time scale varies based on the period of record available for each group of wells. Hence, graphs for the nested monitoring wells and the AVR wells begin in 1985, whereas Hesperia hydrographs begin in 1980, and VVWD hydrographs begin in 1955. A great effort was made to include only static water levels (not pumping water levels) in these data sets However, in a few instances, some of the points that plot anomalously low on the graphs may be due to the inadvertent inclusion of pumping water level data.

Hydrographs for each of the wells with available water level data (shown on Figures 3.1 through 3.36) were plotted on a topographic basemap of the study area, as shown on Plate 6, “Map of Hydrographs.” Using this map, it may be possible to spatially evaluate water level trends, that is, it may be possible to identify trends that may occur in wells from north to south, or from east to west across the study area.

Noteworthy on the individual hydrographs and from Plate 6 are the following:

a. Water level declines in the western portion of the study area (west of the Mojave River) appear to be declining at a higher rate than wells in the northeastern portion of the study area. This suggests that the wells in the northeast are influenced by different factors than the west, as was observed in the groundwater contour data. Wells to the northeast of the river (i.e., the AVR wells) may be more influenced by recharge from the Fifteen Mile Valley area than from direct Mojave River recharge.

b. Water levels in each of the wells are declining in the last 5 years or so (with the exception of VVWD Well No. 10, Figure 3.30, and the two shallowest zones of the Upper Narrows nested monitoring well, Figure 3.7), and seem to correlate with trends in the cumulative departure curves. As discussed above, because of the similarity of the departure cures for rainfall and stream flow, differentiation of trends (or specific relationships) between water levels versus rainfall and/or water levels versus runoff at either of the two gaging areas is very difficult.

c. In general, most of the water level graphs display a cyclic trend of increasing and decreasing water levels during the course of each year, despite the overall downward trend. This is typical of most groundwater reservoirs, in which water levels tend to rise in the spring months of each year due to recharge from antecedent rainfall and a simultaneous decrease in groundwater extractions; water levels tend to display their lowest levels in the fall months of each year due to a lack of antecedent rainfall and a simultaneous increase in groundwater extractions.

d. In the Deep Creek monitoring well, the RS-1 monitoring well, and the Jess Ranch monitoring well (Figures 3.1, 3.2, and 3.3, respectively), the amplitude of the seasonal water level change is generally greater in the shallower nested monitoring zones that are perforated within the older alluvium of the Mojave River (Qoc), than in the deeper zones that are perforated within the QTof (Victorville Fan) or the QThcu geologic units.

e. Water level data for some of the AVR wells are anomalous, and may include pumping water level data (see Figures 3.31 through 3.34, for example).

f. In Figures 3.1 through 3.4, an important trend is observed from north to south within the study area, as listed below; refer to Cross Section E-E' on Plate 2.5 for the references to earth materials into which the nested monitoring zones are constructed:

   1. Beginning at the Deep Creek monitoring well (Figure 3.2), water levels within most of the zones of this nested monitoring well exhibit the same water level depths, with the exception of the deepest zone, which shows slightly higher (shallower) water levels. Note that the shallowest monitoring zone in this well lies within Qoc deposits whereas the three deepest zones in this monitoring well are constructed within the QThcu geologic unit.

   2. Moving north along the river to the RS-1 monitoring well (Figure 3.3), water levels in each of the zones tend to display similar depths during the periods of low water levels (i.e., times of low recharge from rainfall or streamflow). However, during recharge events, water levels in the shallower zones increase more quickly and to a greater degree than do the water levels in the deeper zones. As noted above, only the deepest monitoring zone within this well is constructed into the QThcu deposits.

   3. To the north of RS-1 is the Jess Ranch monitoring well. Water levels in the Jess Ranch monitoring well (Figure 3.3) show a striking difference to those in the Deep Creek and RS-1 monitoring wells. Water levels for the deepest monitored zone in the Jess Ranch well are consistently higher than the water levels in all of the other zones that are monitored in those other monitoring wells. This deep zone is the only zone in the well perforated within the QThcu unit. Hence, as a result of this difference in water levels, there seems to be a separation between the QThcu aquifer and the QTof aquifer at this point along the Mojave River. Note that water levels in the QTof deposits and the Qoc fluvial deposits are very similar.

   4. Just as in the Jess Ranch monitoring well, the water levels in the deepest zone in the SF-1 monitoring well are much higher than they are in the three shallower zones in this well (See Figure 3.4). As with the Jess Ranch well, this deepest zone is constructed within the QThcu deposits; the other three shallower zones are constructed within Victorville Fan (QTof) deposits.

      In addition, water levels from the zone perforated within the QTof fan deposits (the second deepest monitoring zone) are deeper than those in the shallower monitoring zones which are perforated within the Qoc (river deposits). Based on the trends observed above, it appears that the subsurface geologic units in the area of the Jess Ranch and SF-1 monitoring wells are somewhat isolated hydrogeologically.

5. Water levels in the Rincon Road (Figure 3.6) monitoring well appear to be very similar in each of its perforated zones. This well is considered to be constructed completely within the QThcu geologic unit (see cross section D-D' on Plate 2.4).
6. In the AV Ranchos monitoring well (Figure 3.5), water levels in the zones vary slightly; deeper monitoring zones show slightly deeper water levels.

Groundwater Quality

Groundwater quality, and, in particular, the character of the groundwater in and along the Mojave River and its environs, has been evaluated with the use of Stiff water quality pattern diagrams. These diagrams, developed in 1951 by H. Stiff, identify the character of groundwater in wells in a ground surface basin by defining the relative portions of the major dissolved anions and cations within a water sample. In most groundwater, these major ions include the common cations (calcium, magnesium and sodium), and the common anions (bicarbonate, sulfate and chloride). Plate 7, "Stiff Water Quality Pattern Diagram Map," presents the results of creating a Stiff diagram for each well with recent available data, and plotting that pattern diagram adjacent to the well it represents.

For these diagrams, ionic concentrations are plotted for calcium, magnesium, sodium bicarbonate, sulfate, and chloride. The anions (negative ions) are potted to the right of the centerline of the diagram, while the cations (positive ions) are potted to the left. The size or area of a Stiff diagram is an indication of the total dissolved solids concentration and of the overall groundwater character from the well; the larger the area (i.e., the wider the diagram), the greater is the total dissolved solids concentration of the groundwater. Changes in the shape of the diagram reflect changes in the chemical character of the groundwater.

The wells on Plate 7 display somewhat different groundwater character depending on such factors as well location, well depth, and perforation intervals. Stiff diagrams are shown on Plate 7 for:

- Various municipal-supply wells owned by the City of Hesperia, the VVWD (now Victorville Water), the County CSD Zone 64J, and Apple Valley Ranchos (AVR); MWA and/or USGS groundwater monitoring wells (Deep Creek-1-MW on the south, Jess Ranch-1-MW on the north and Santa Fe-1 on the northwest; Rincon Rd-MW-1 and AV Ranchos-MW on the northeast; and Upper Narrows-NW on the north.

- Two privately-owned wells on Rancho Las Flores property in the mountains to the south.

Noticeable trends in water quality from the review of Plate 7.1 and 7.2 include:

1. Stiff water quality patterns for wells can be grouped into three major categories. In the southern portion of the study area, (roughly south of the RS-1 monitoring well), a majority of the wells exhibit a calcium-bicarbonate (Ca-HCO_3) water character. North of the RS-1 well, the water generally displays more of a sodium-bicarbonate ($NaHCO_3$) water character. Sodium (Na) concentrations increase while calcium (Ca) concentrations tend to generally decrease from north to south across the study area (this may represent ion exchange).
2. AVR wells in the northeasternmost part of the study area exhibit a very different, sodium-chloride (Na-Cl) to sodium-sulfate (Na-SO_4) water character. This character is dissimilar to the character shown by any well to the west of the river; this very likely indicates differences in the types and ages of sediments perforated in the AV wells from those perforated in wells to the west.
3. Concentrations of TDS in the study area are generally low, on the order of 100 to 200 mg/L, with the exception of the northeasternmost AVR wells, which display a TDS of concentration on the order of 900 mg/L
4. Recent water quality testing (August 2007) in the nested monitoring wells within the study area revealed very high arsenic concentrations of 58 μg/L and 46 μg/L in the deepest perforated zones in the Jess Ranch and SF-1 monitoring wells, respectively. These values are substantially above the current Federal EPA MCL for arsenic of 10 μg/L for domestic use. These deep zones are perforated within the QThcu geologic unit.
5. Within the Jess Ranch and SF-1 monitoring wells, arsenic concentrations in the zones perforated just below the "y" marker bed of the QTof deposits and simultaneously above the QThcu deposits (see cross section C-C', Plate 2.3) contain arsenic concentrations on the order of 2 to 4 μg /L. However, the deepest monitored zones in both of these monitoring wells are within the QThcu materials and display arsenic concentrations over the state Maximum Contamination Level (MCL) of 10 μg/L at 58 μg/L and 46 μg/L, respectively. This implies that these deeper earth materials contain natural occurrences of elevated arsenic. The reason for the low-level detections of arsenic in the immediately overlying screens in the QTof deposits in both monitoring wells is unclear at this time but may relate to either upward leakage (migration) of arsenic-laden groundwater from below or even to the depositional history of the source of the QTof deposits.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Our review of the data presented above yields the following conclusions:

1. It is our opinion that the R^3 program of recharge and recovery within and along the Mojave River is a hydrogeologically feasible concept. Water that is recharged in the southern part of the river could potentially be recovered from the river alluvium and alluvial fan deposits located in downgradient areas within and along the river. Further, recharge in the southern part of the river may provide additional recharge to the Victorville fan geologic unit (QTof) in addition to the fluvial river-type deposits (Qoc) along the river itself.
2. Water levels in wells for which water level data are available suggest that there is a clear correlation between rainfall/stream flow trends and water level trends within the wells. However, distinguishing between water level changes caused solely by rainfall or solely by stream flow changes is difficult due to the similarity between the rainfall and stream flow accumulated departure curves (see Figure 2.4). This similarity between the rainfall and runoff curves is not unexpected, due to the fact that rainfall events would increase stream flow in and along the Mojave River and because more water is available for release from Lake Silverwood during wet periods.
3. Based on the groundwater elevation contour map (Plate 5), on the water level data presented in the hydrographs (Figure 3 and Plate 6), and on the water quality data presented on Plates 7.1 and 7.2, it appears that the QTof (fan deposits) and the underlying QThcu may be hydraulically connected in the area of the Mojave River south of the RS-1 monitoring well, toward the Deep Creek Monitoring well. This is illustrated by the direction of groundwater flow in the south part of the river, where groundwater appears to regionally be flowing toward the north and the northwest, toward the Hesperia area.
4. North of RS-1, a separation in the aquifer systems appears to occur. Water levels in that area suggest that the QThcu deposits may be confined, and the hydraulic connection between the QThcu and the overlying QTof fan deposits is diminished.
5. A south to north trend in water quality data in which calcium ions appear to be substituted for (exchanged for) sodium ions suggests currently, that surface water runoff and/or rainfall that deep percolates from the Mojave River and into the underlying Qoc and QTof deposits can be detected as far north as the Jess Ranch monitoring well.
6. In the northeastern portion of the study area, water quality in the northeasternmost AVR wells displays a much different water character than that in the rest of the wells in the study area. TDS values in these wells are also much higher than the other wells within the study area. Further, as shown on the groundwater elevation contour map,

there is some question whether or not the water levels in the northeastern portion of the area are correlatable with the water level contours within and west of the Mojave River (see Plate 5). Hence, the northeast AVR area must receive recharge from a source other than Mojave River; this source is likely the Fifteen Mile Valley area to the east. Differences in the groundwater character and in water level data seen on groundwater elevation maps suggest that groundwater moves from the Fifteen Mile Valley area toward the Mojave River. This difference in source water is also illustrated in the water quality data on Plates 7.1 and 7.2.

Recommendations

Key recommendations for the areas of recharge and well construction for the R^3 project include:

1. Based on the groundwater elevation contour map, groundwater in-between the areas of the Deep Creek monitoring well and the RS-1 monitoring well generally flows toward the north along the river, and the northwest, toward Hesperia. Recharge in this area could possibly recharge both the river alluvium (Qoc) and the underlying Victorville Fan deposits (QTof). The in-progress modeling work by Schlumberger, with whom RCS previously provided geologic data, should be used to verify this assertion.
2. In general, new extraction wells should be located within the historic channel of the Mojave River (Qoc deposits) or west of the river (for wells that are to be perforated within the QTof (fan) deposits.
3. We recommend extraction wells for the project be constructed within and along the Mojave River. Actual drilling depths and perforation will be determined by the project geologist at the time of well construction, based on geologic logging of the drill cuttings and on geological interpretation and correlation of the new electric logs.
4. Where possible, new extraction well should be located distant from existing municipal-supply production wells owned by others to help reduce possible water level drawdown interference impacts. Hence, extraction wells should be constructed in the southern portion of the Mojave River, but north of the base of the foothills.
5. Water level monitoring programs should be instituted around the recharge and extraction areas. As shown on the groundwater elevation contour map, a portion of the recharge water in the southern portion of the Mojave River may flow to the northwest.
6. New well construction should be phased over time, so that the depths, locations and perforation intervals in the next phase of well construction can be evaluated and changes can be made to the design where necessary.
7. Wells constructed on the eastern side of the Mojave River should be completed in the Qoc and QTof geologic units. Based on the geology of the area and the groundwater flow data, wells constructed on the east side of the river in the QThcu geologic unit may not have access to the water recharged upstream and therefore any wells constructed on the eastern side of the river should be completed only in the river sediments.

8. Groundwater in the QThcu sediments in the area of the SF-1 and Jess Ranch monitoring wells has arsenic concentrations that are above the MCL for this constituent, and therefore, it is not recommended that extraction wells be completed into this formation. Hence, as stated above, extraction wells in that area should only be completed as deep as the Victorville fan deposits (QTof).
9. Additional sampling of the groundwater within the QThcu and QTof units is necessary in and around the area of the Mojave River and the RS-1 monitoring well to determine the current arsenic concentration in the specific perforated zones that monitor these geologic units. MWA is currently moving forward with the construction of additional monitoring wells in this area.
10. Currently, MWA is planning the construction of three monitoring wells in the area of the Mojave River between the Jess Ranch and Deep Creek monitoring wells. Data collected during these well construction projects will be crucial to helping to better locate and design the final recharge areas and extraction zones. Hence we recommend these data be collected and reviewed before any extraction wells are sited and constructed.

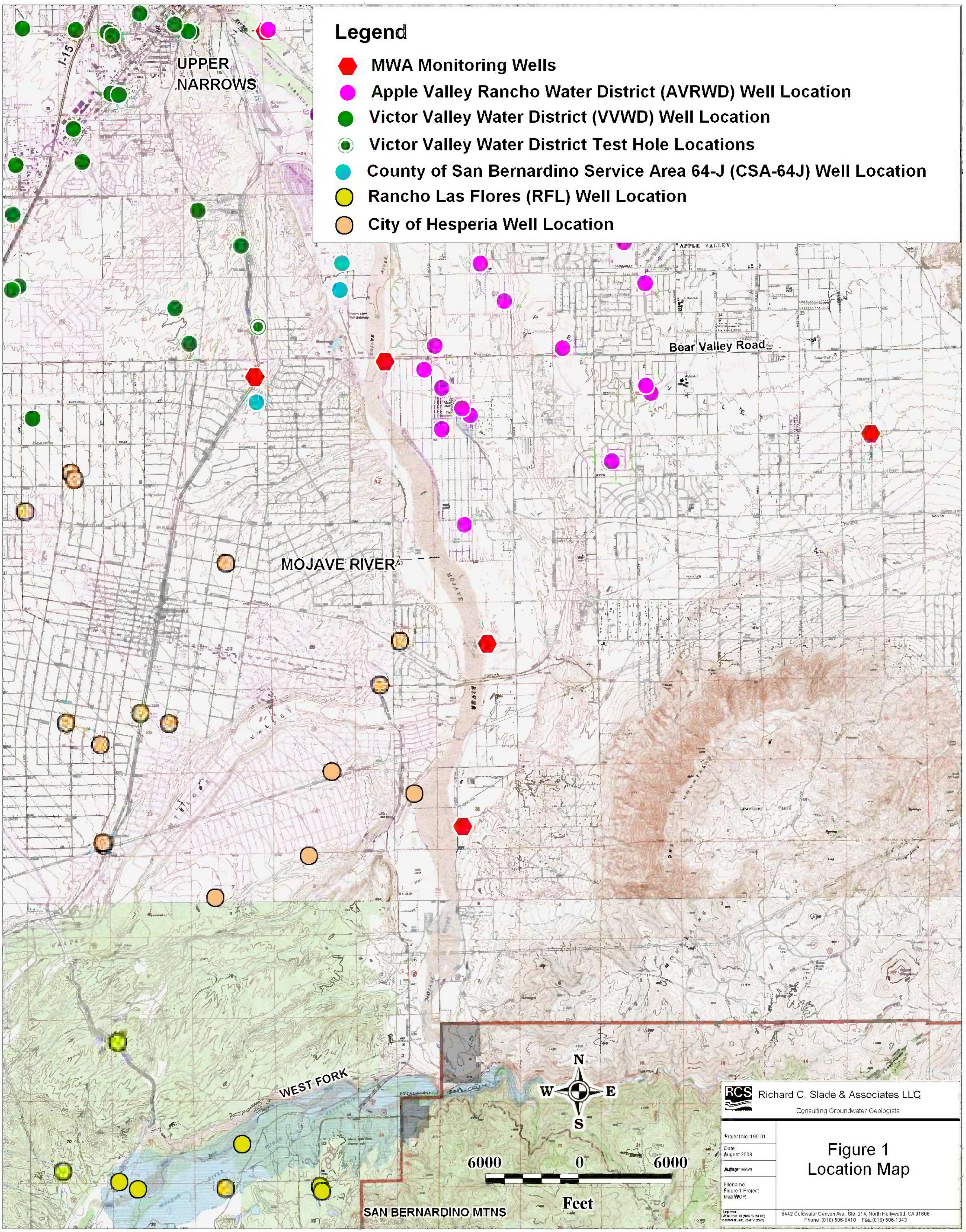

Figure 1
Location Map

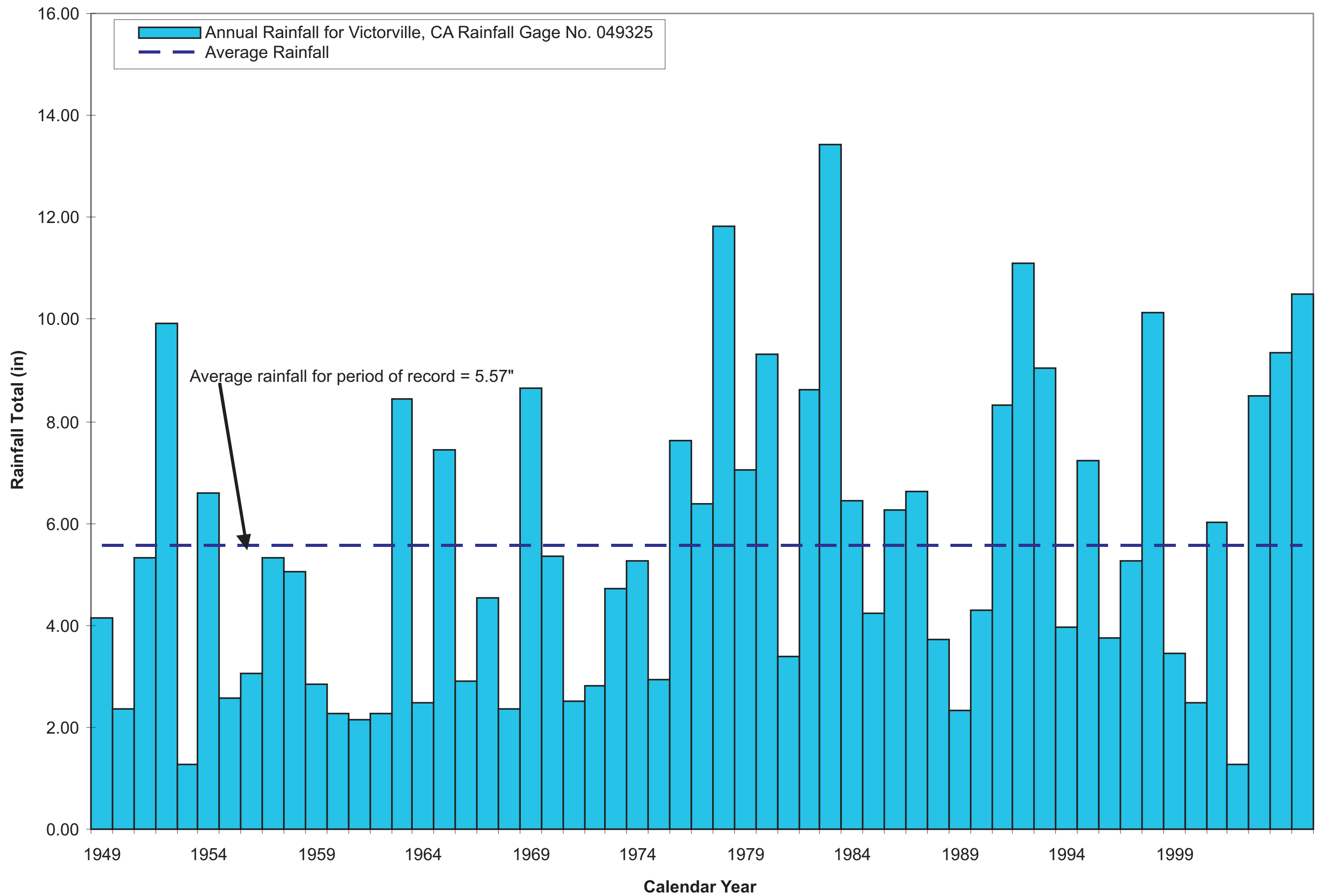

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FIGURE 2.1
Yearly Rainfall
Victorville, CA

Job No. 195-01 **August 2008**

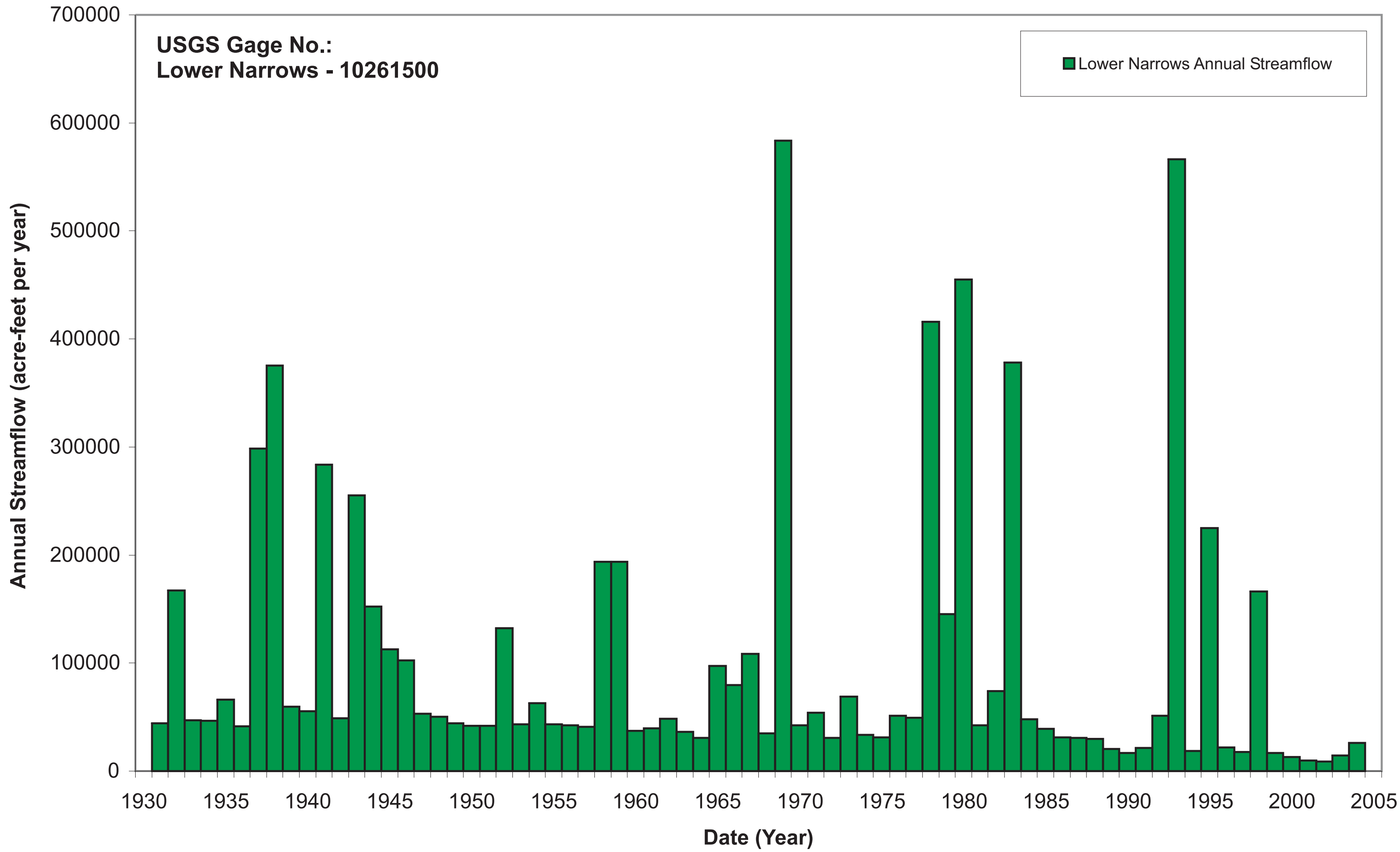

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FIGURE 2.2
Annual Streamflow Graph of Lower Narrows Gage

Job No. 195-01 **August 2008**

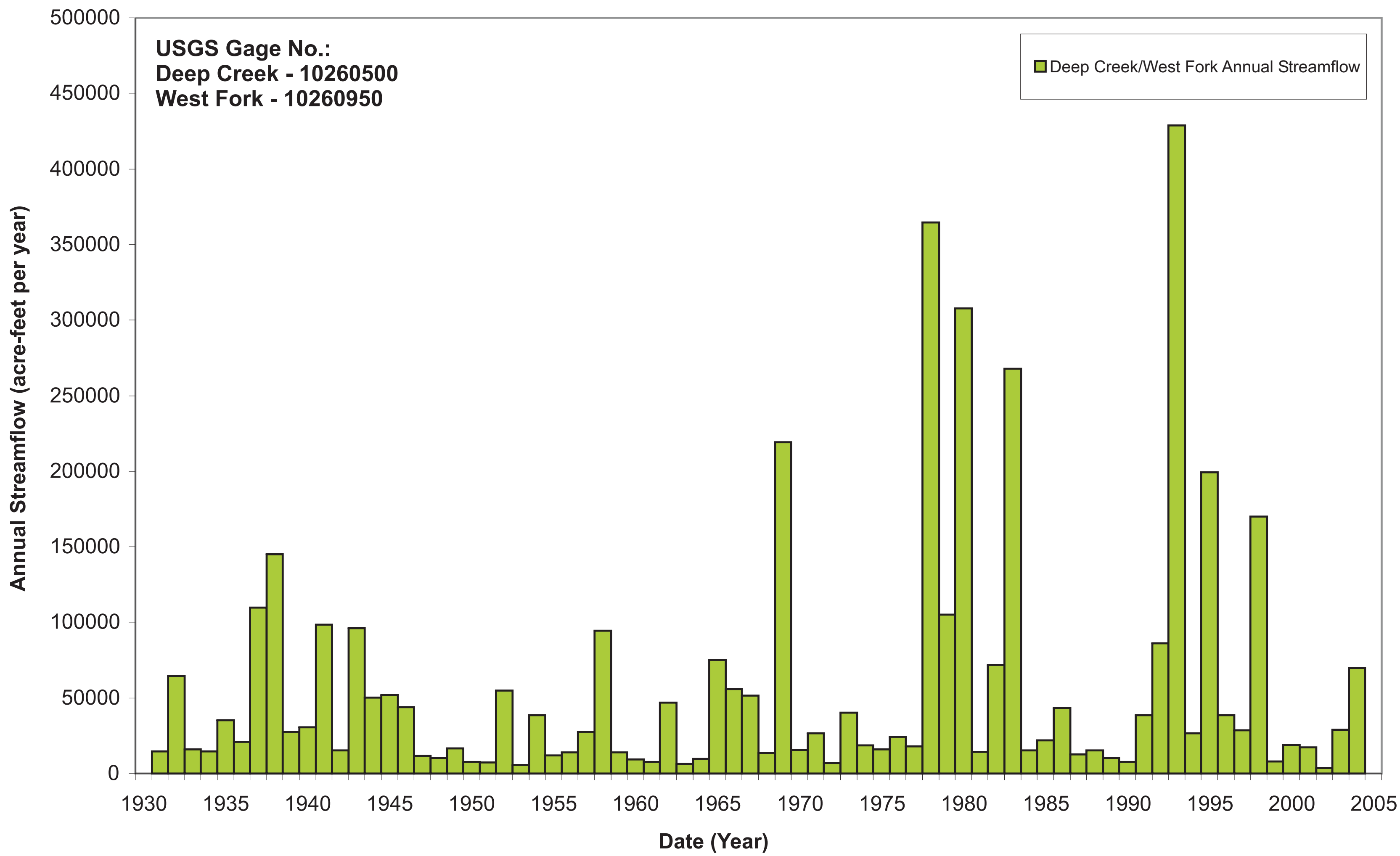

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FIGURE 2.3
Annual Streamflow Graph of Deep Creek/West Fork Gage

Job No. 195-01 **August 2008**

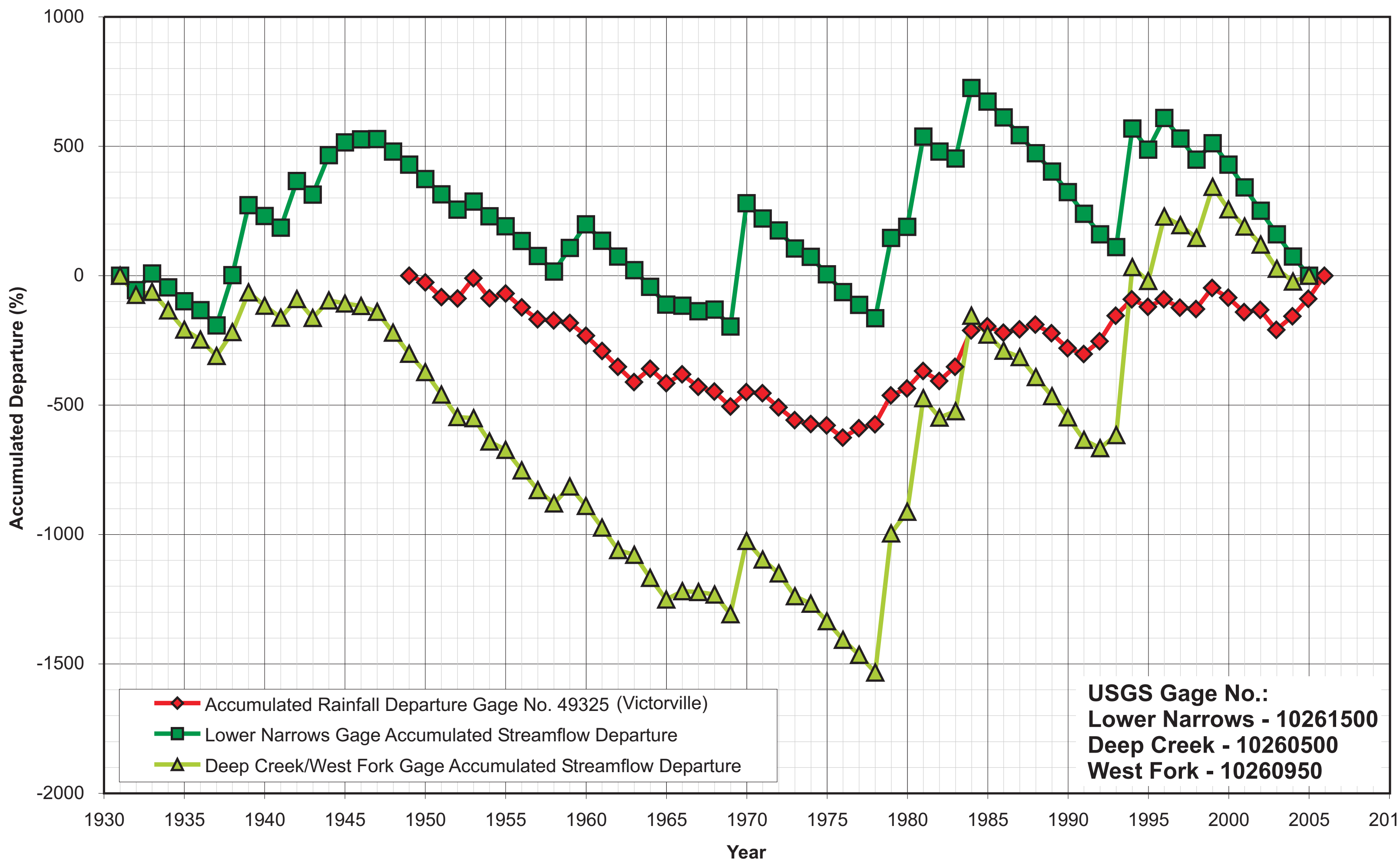

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FIGURE 2.4
Accumulated Departure Curves for Rainfall/Streamflow Gages

Job No. 195-01 **August 2008**

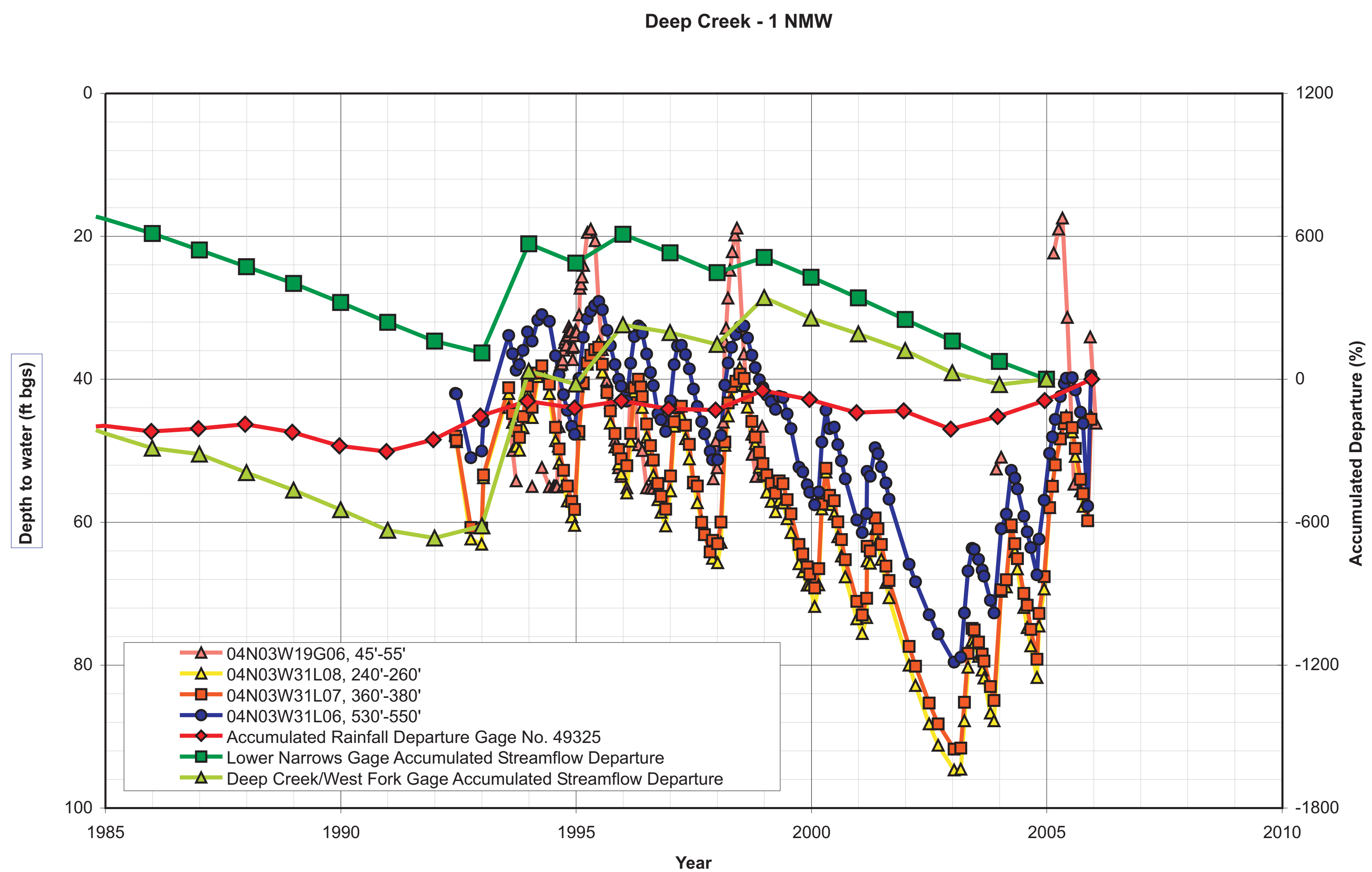

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FIGURE 3.1
DEEP CREEK- 1 NESTED MONITORING WELL
HYDROGRAPH WITH ACCUMULATED DEPARTURE CURVES

Job No. 195-01 **August 2008**

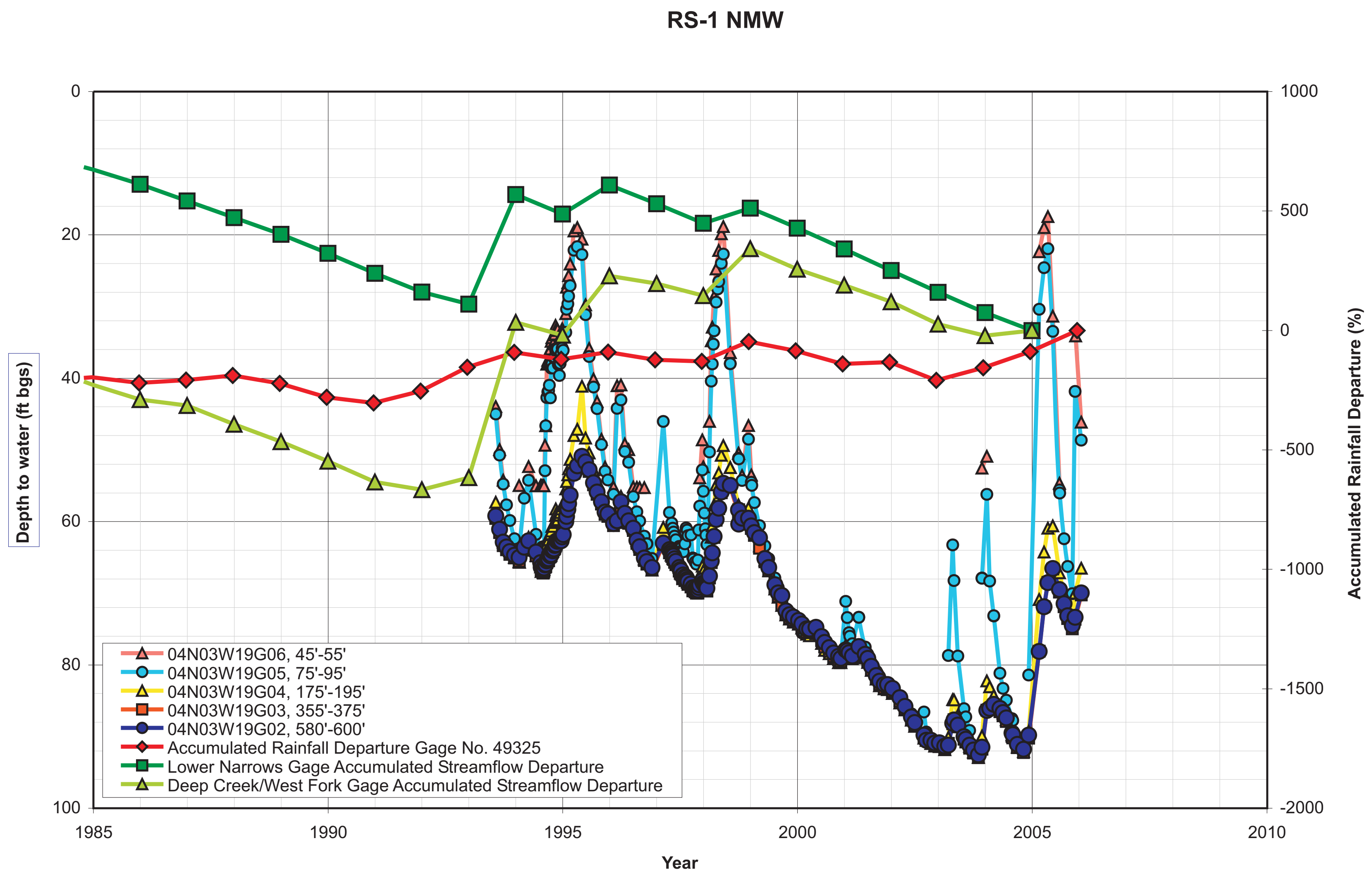

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FIGURE 3.2
RS-1 NESTED MONITORING WELL
HYDROGRAPH WITH ACCUMULATED DEPARTURE CURVES

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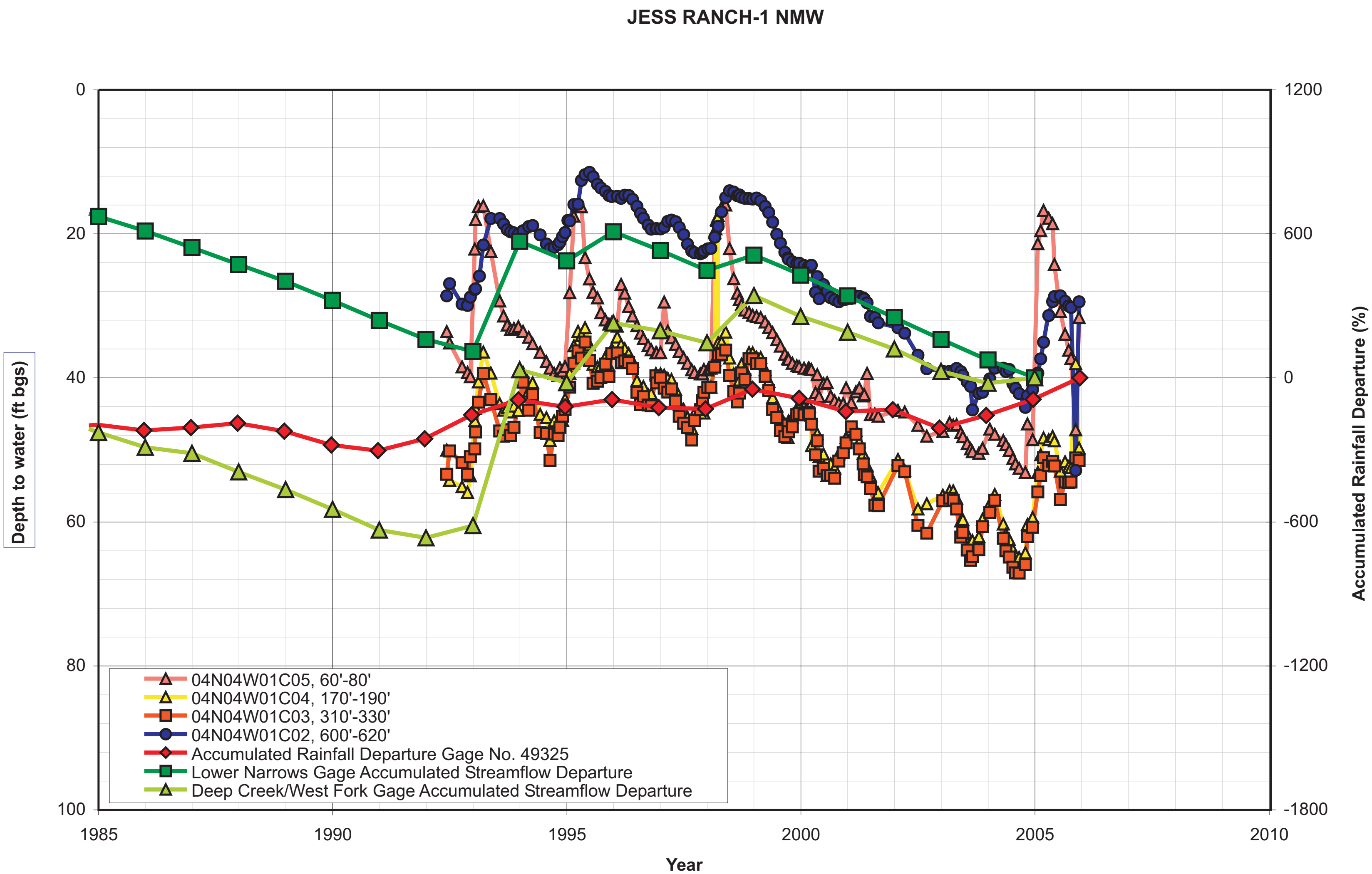

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FIGURE 3.3
JESS RANCH - 1 NESTED MONITORING WELL HYDROGRAPH WITH ACCUMULATED DEPARTURE CURVES

Job No. 195-01 **August 2008**

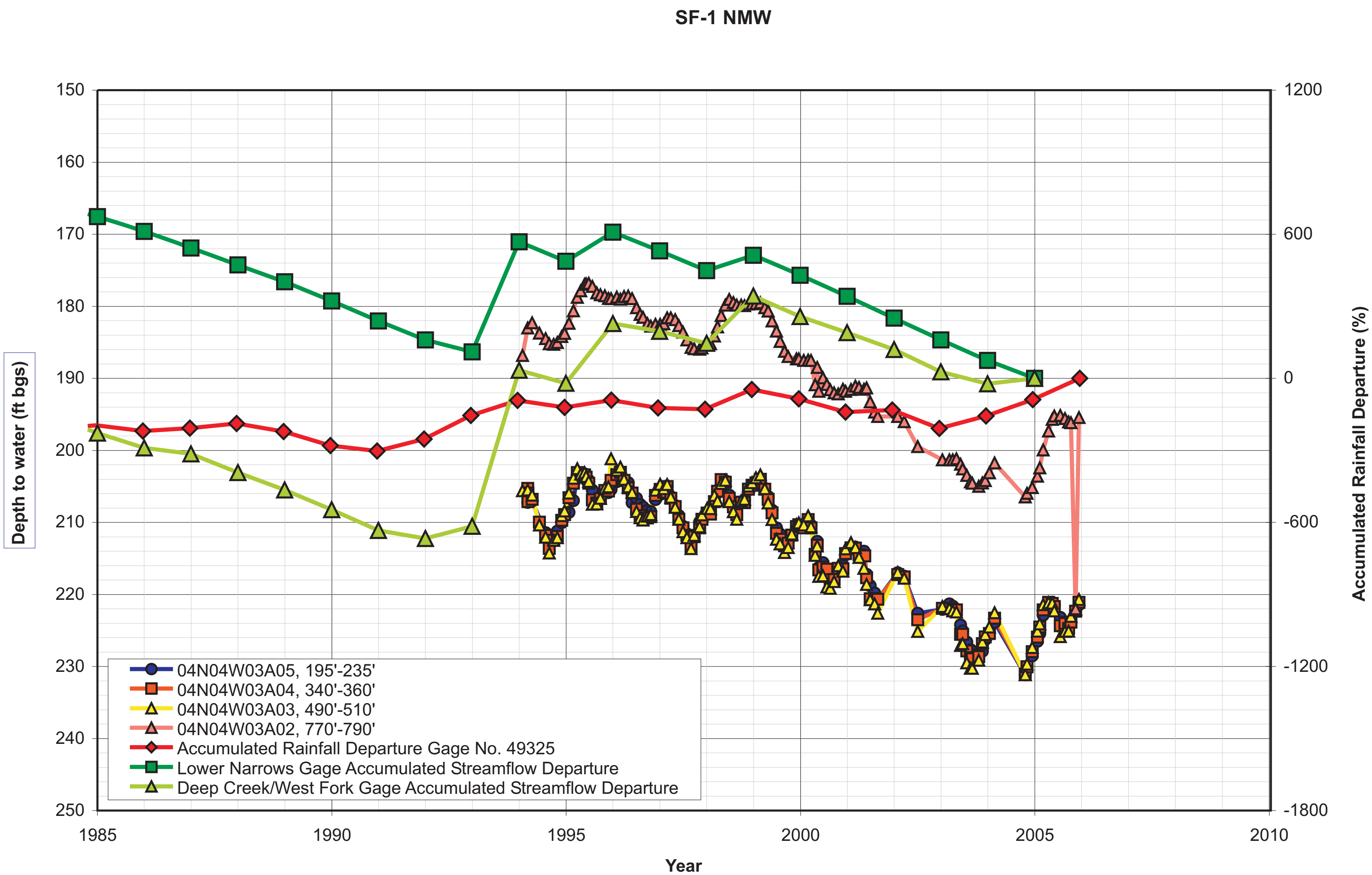

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FIGURE 3.4
SF - 1 NESTED MONITORING WELL
HYDROGRAPH WITH ACCUMULATED DEPARTURE CURVES

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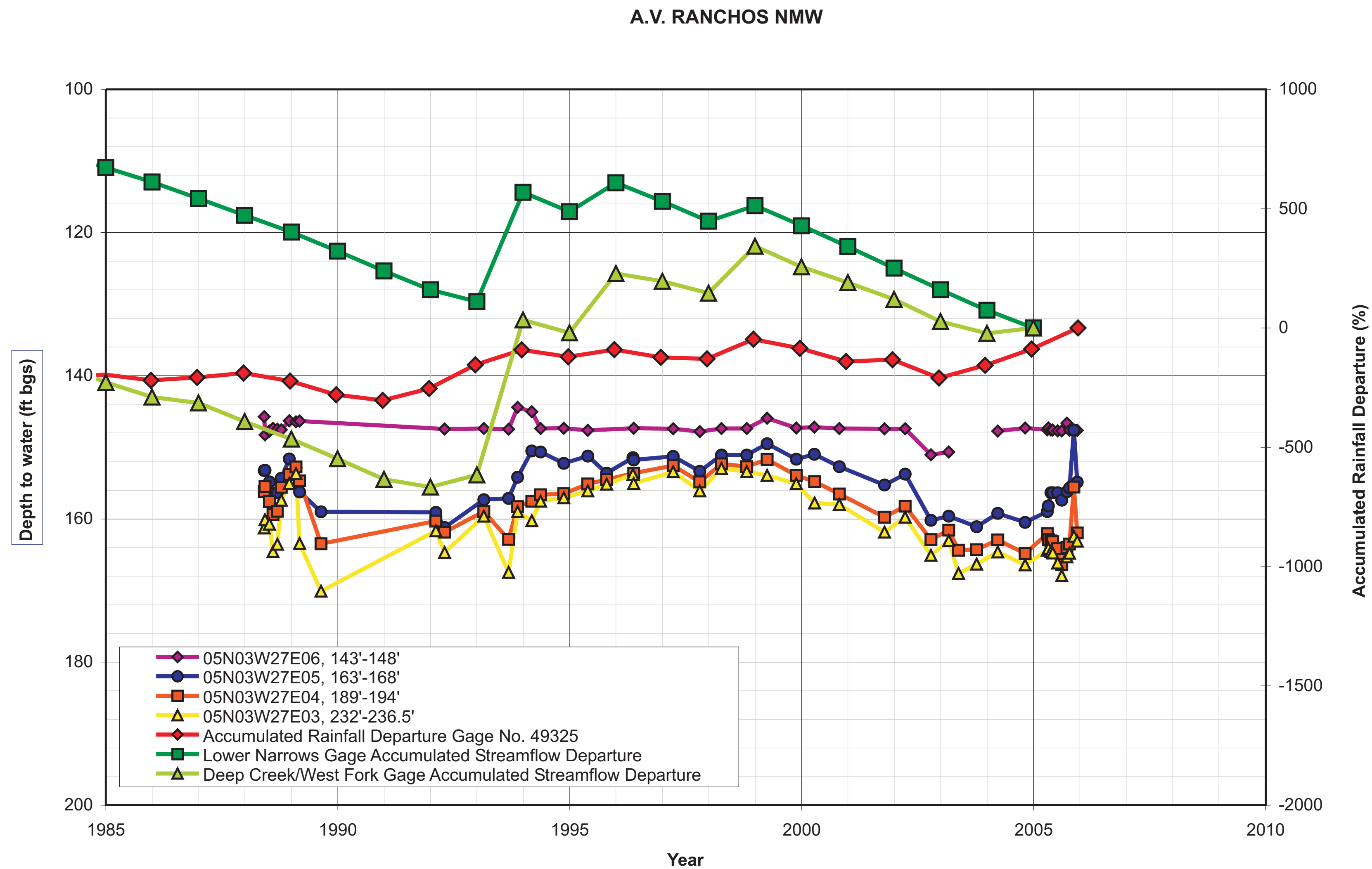

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FIGURE 3.5
A.V. RANCHOS NESTED MONITORING WELL HYDROGRAPH WITH ACCUMULATED DEPARTURE CURVES

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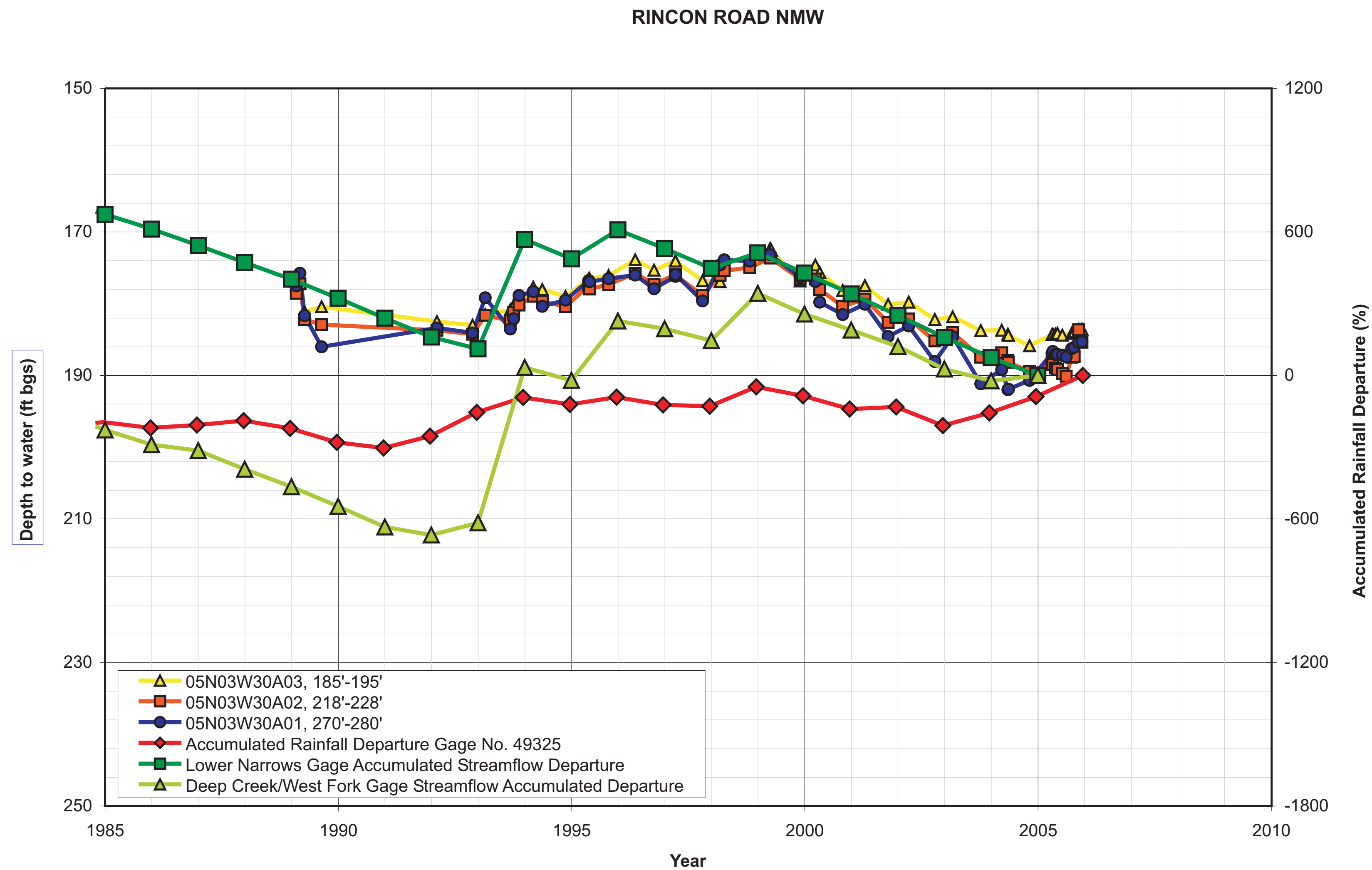

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FIGURE 3.6
RINCON ROAD NESTED MONITORING WELL HYDROGRAPH WITH ACCUMULATED DEPARTURE CURVES

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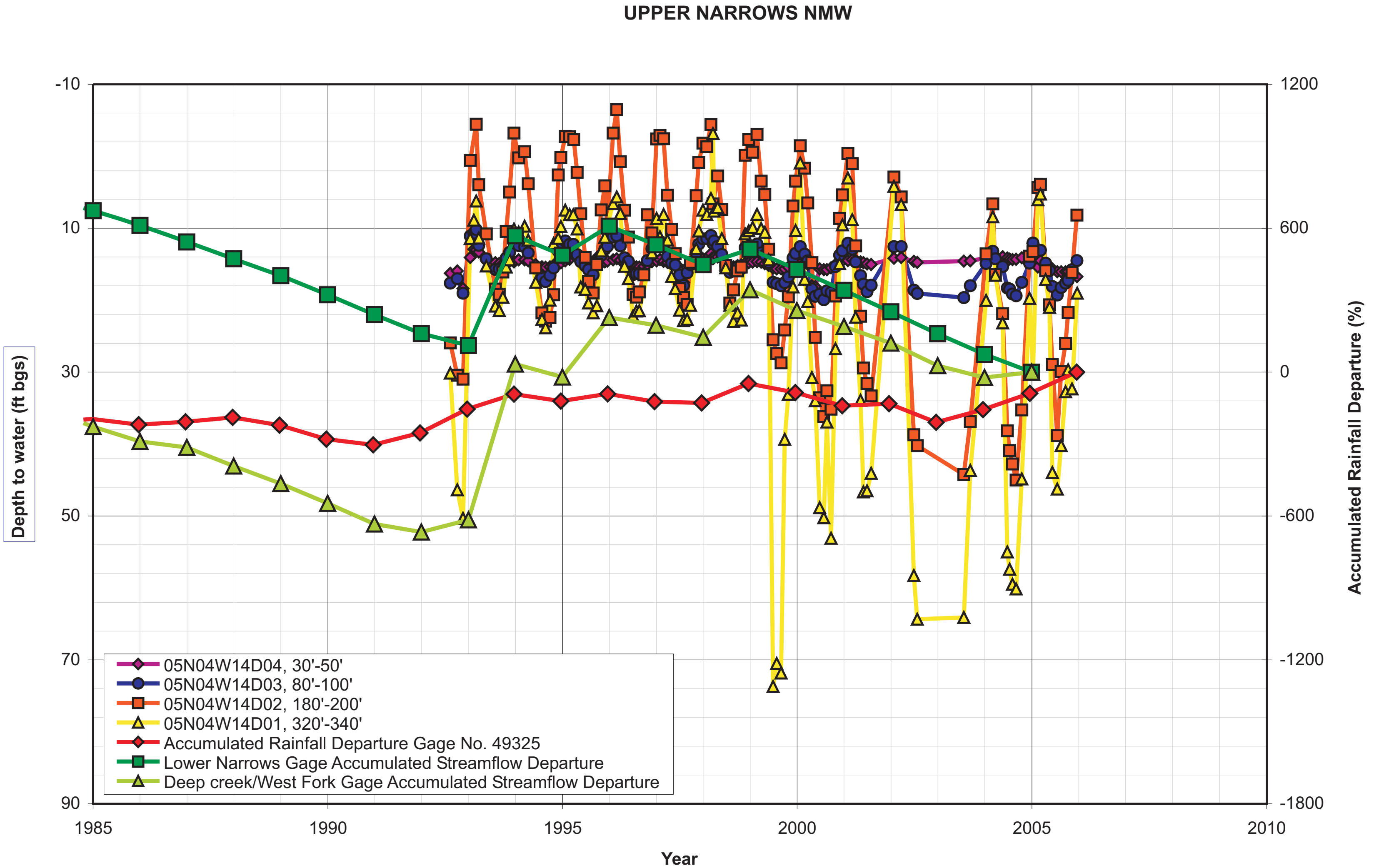

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FIGURE 3.7
UPPER NARROW NESTED MONITORING WELL HYDROGRAPH WITH ACCUMULATED DEPARTURE CURVES

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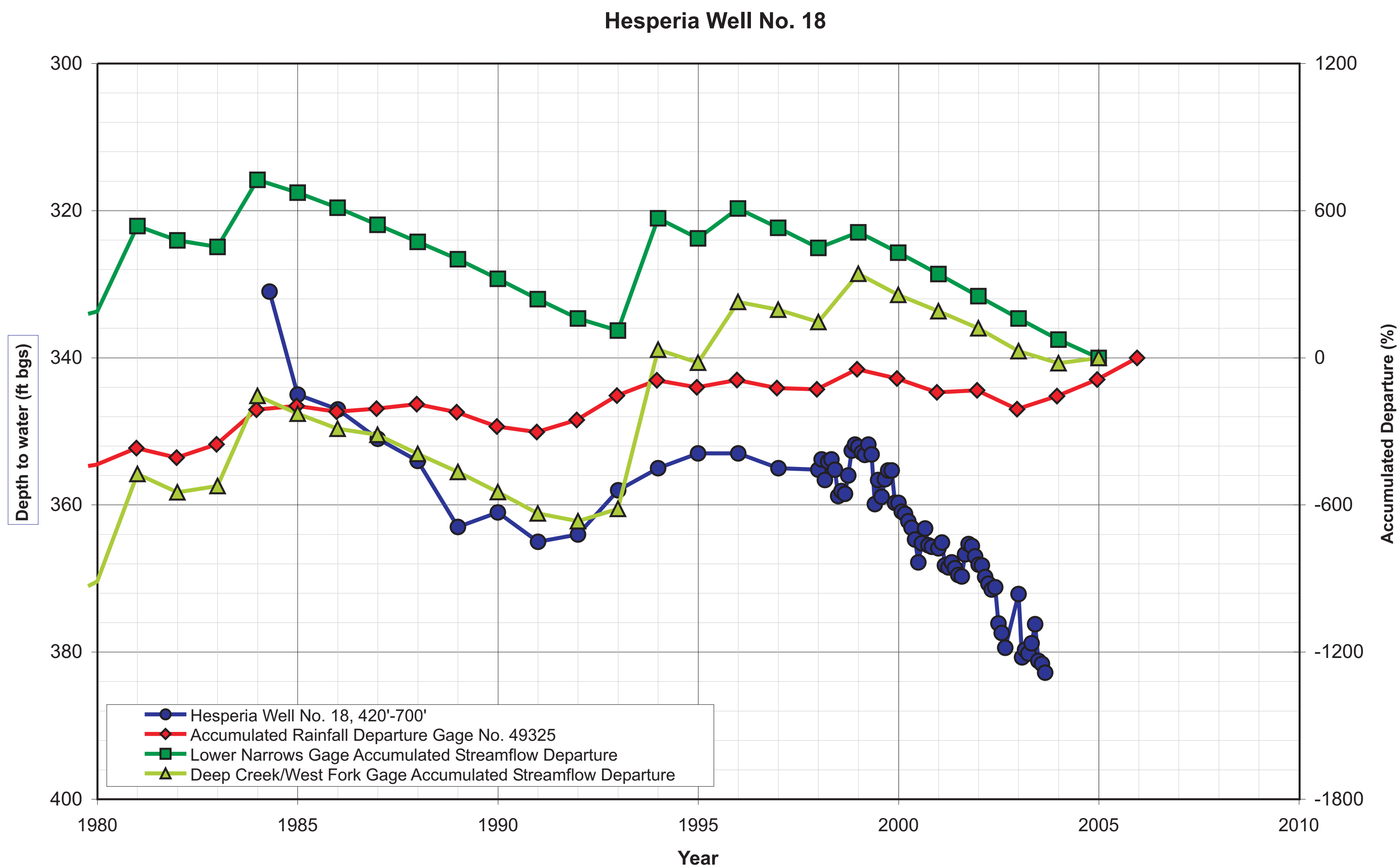

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FIGURE 3.8
HESPERIA WELL NO. 18
HYDROGRAPH WITH ACCUMULATED DEPARTURE CURVES

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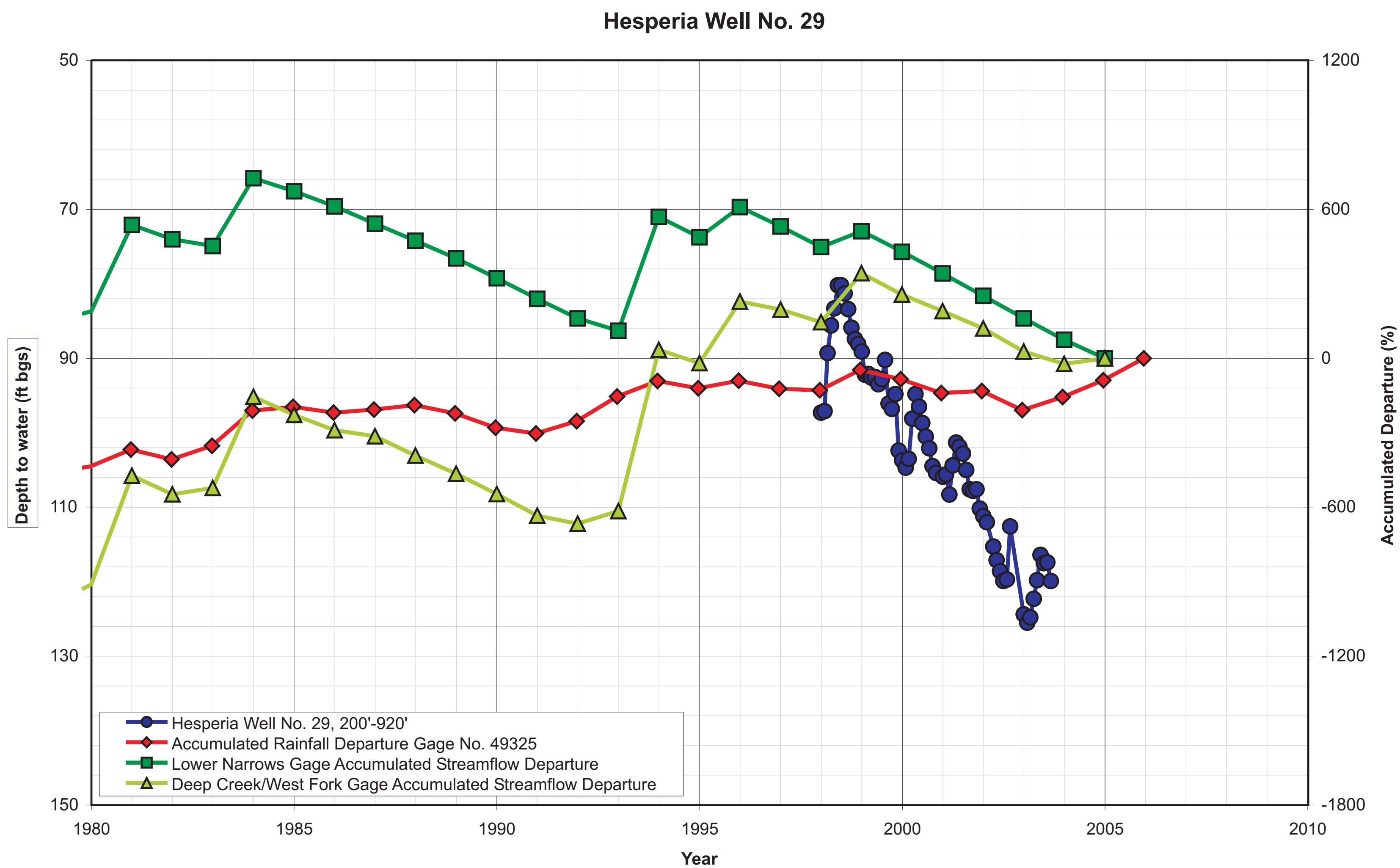

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FIGURE 3.9
HESPERIA WELL NO. 29
HYDROGRAPH WITH ACCUMULATED DEPARTURE CURVES

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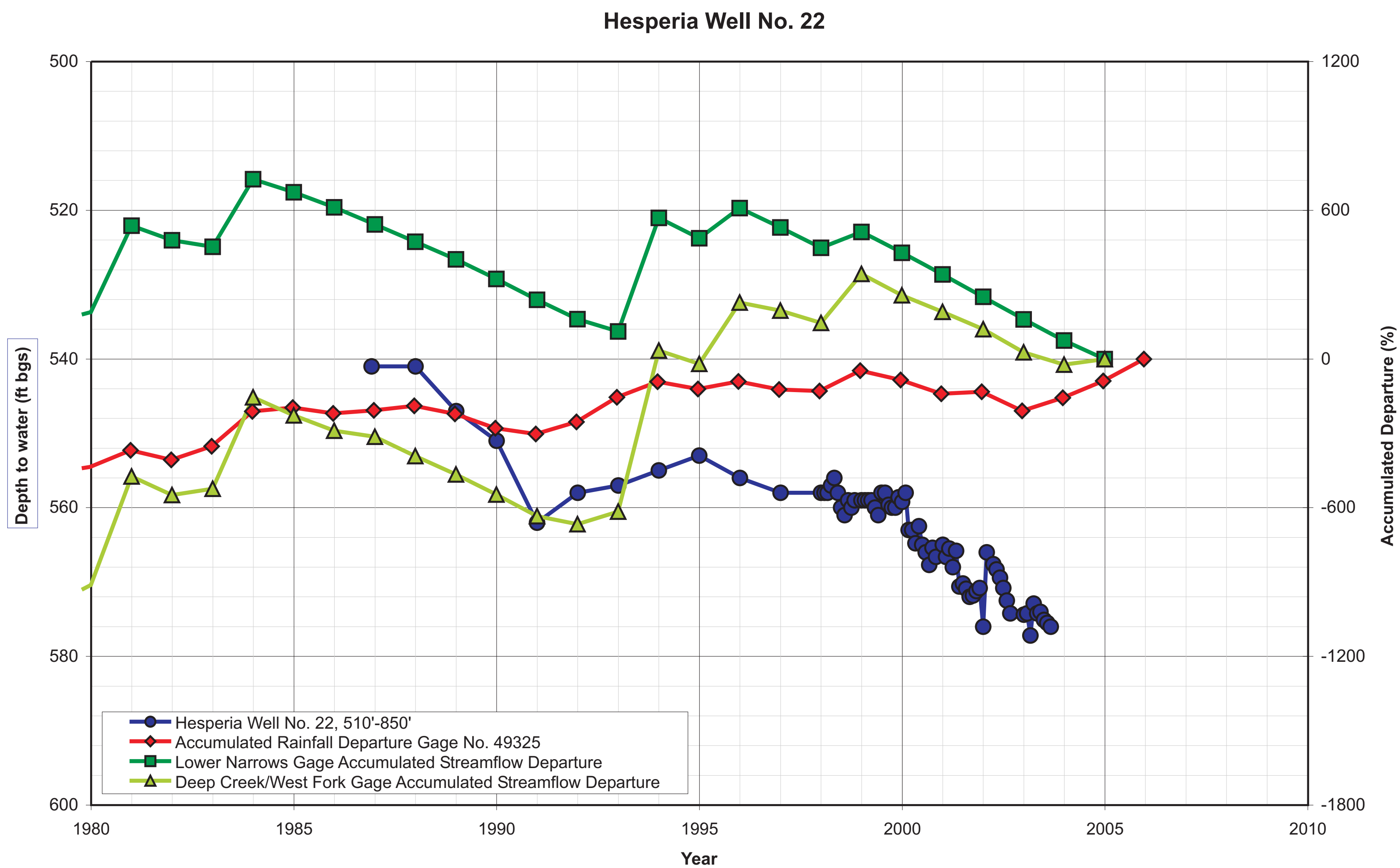

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FIGURE 3.10
HESPERIA WELL NO. 22
HYDROGRAPH WITH ACCUMULATED DEPARTURE CURVES

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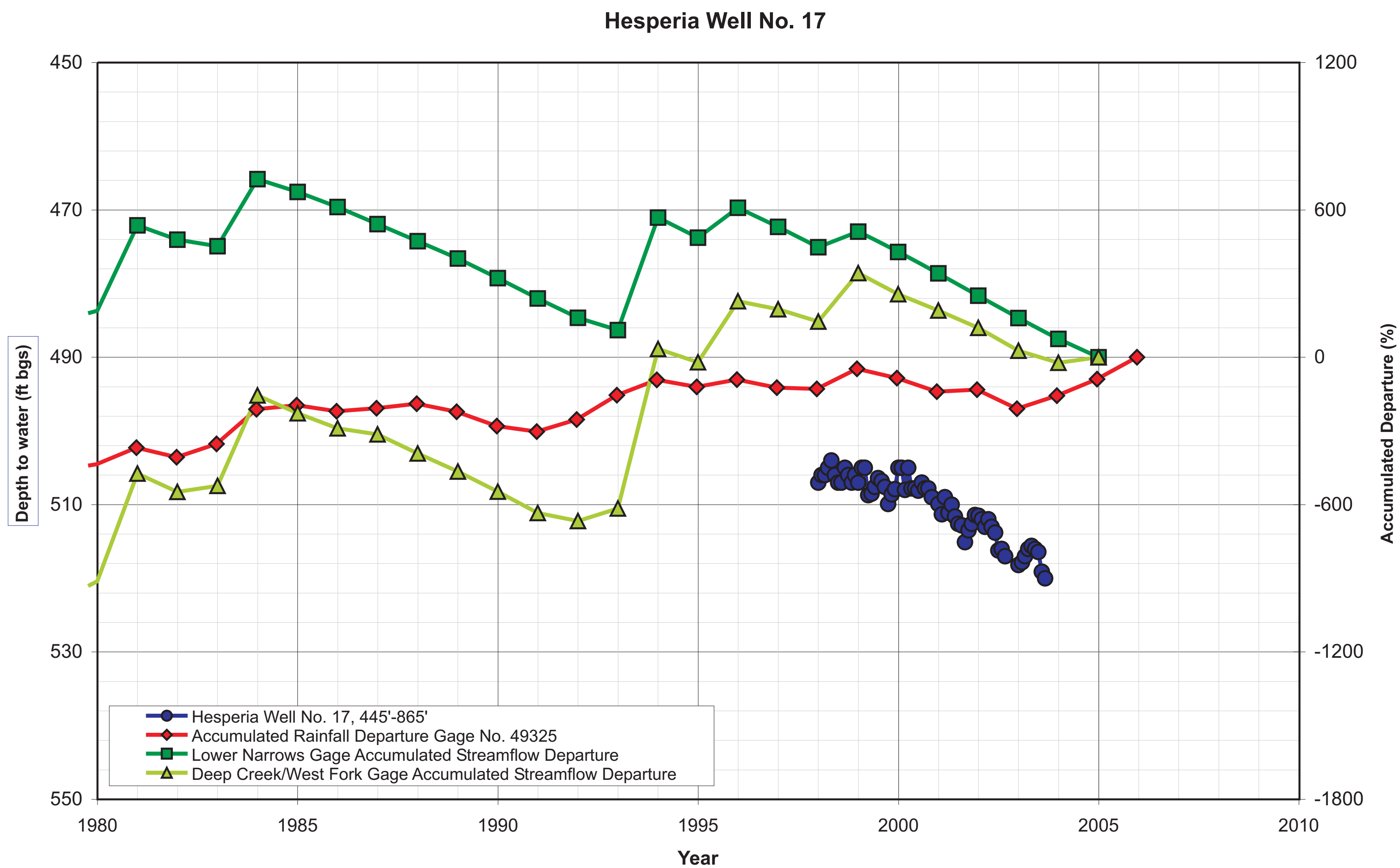

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FIGURE 3.11
HESPERIA WELL NO. 17
HYDROGRAPH WITH ACCUMULATED DEPARTURE CURVES

Job No. 195-01 **August 2008**

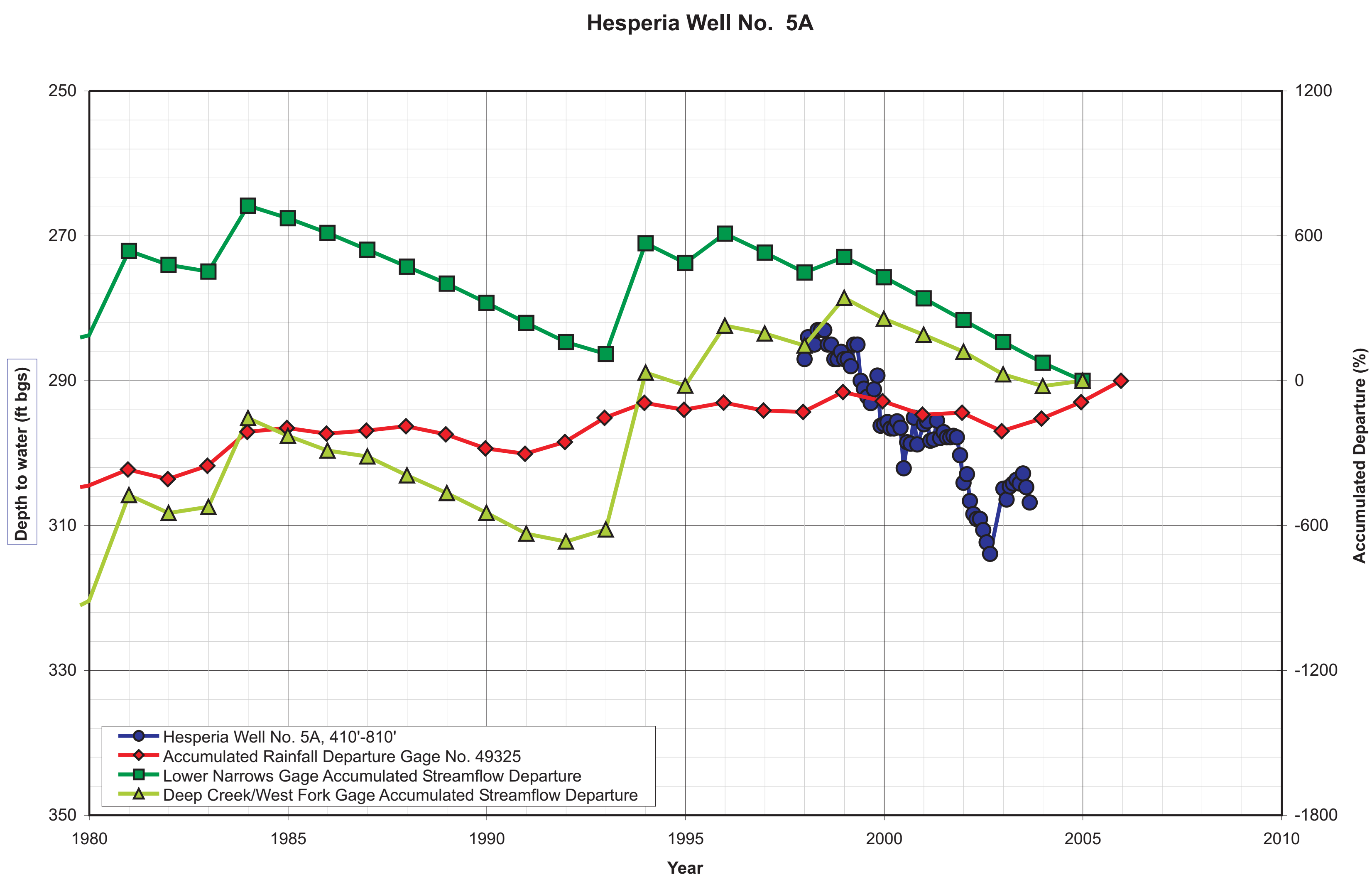

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FIGURE 3.12
HESPERIA WELL NO. 5A
HYDROGRAPH WITH ACCUMULATED DEPARTURE CURVES

Job No. 195-01 **August 2008**

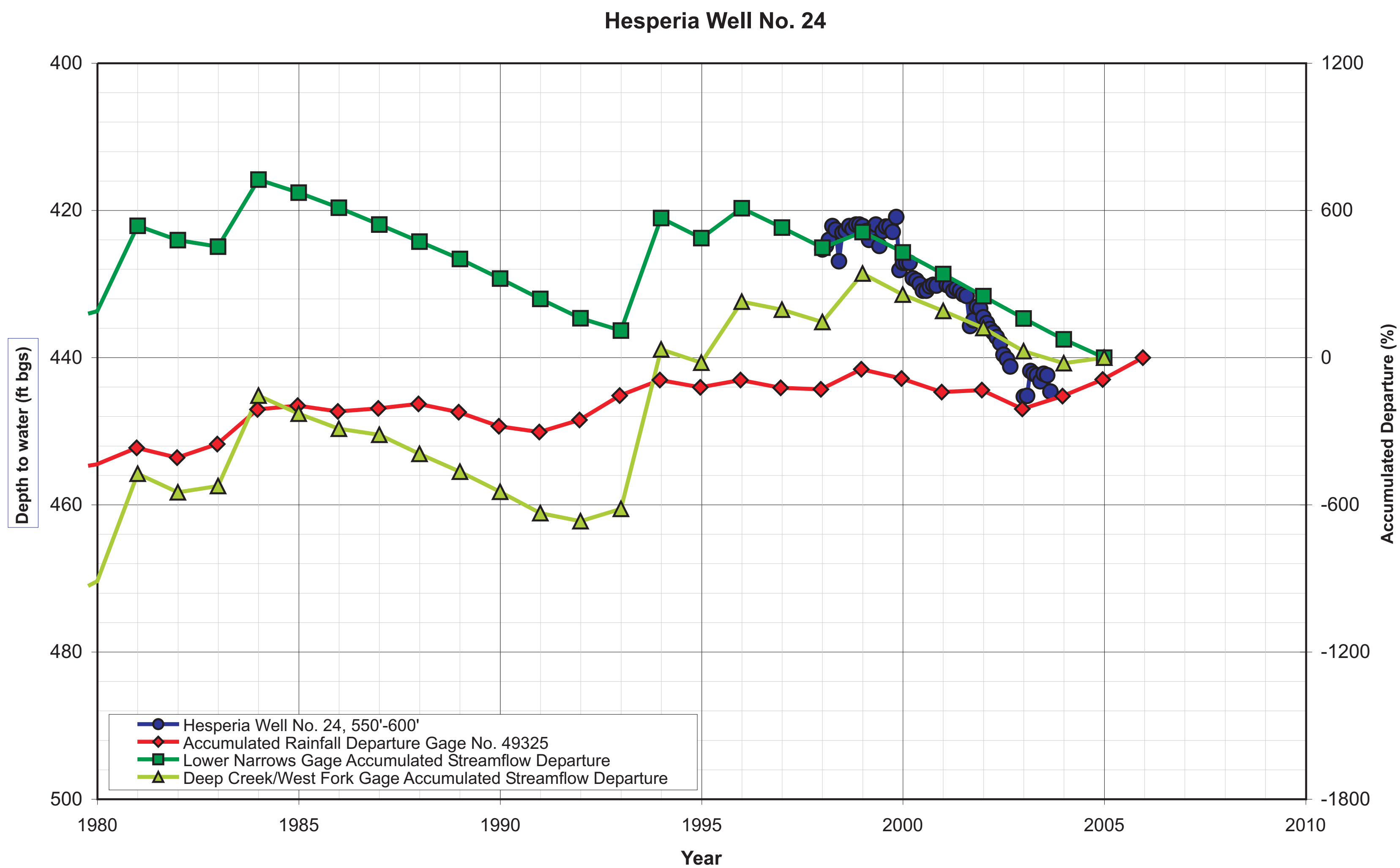

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FIGURE 3.13
HESPERIA WELL NO. 24
HYDROGRAPH WITH ACCUMULATED DEPARTURE CURVES

Job No. 195-01 **August 2008**

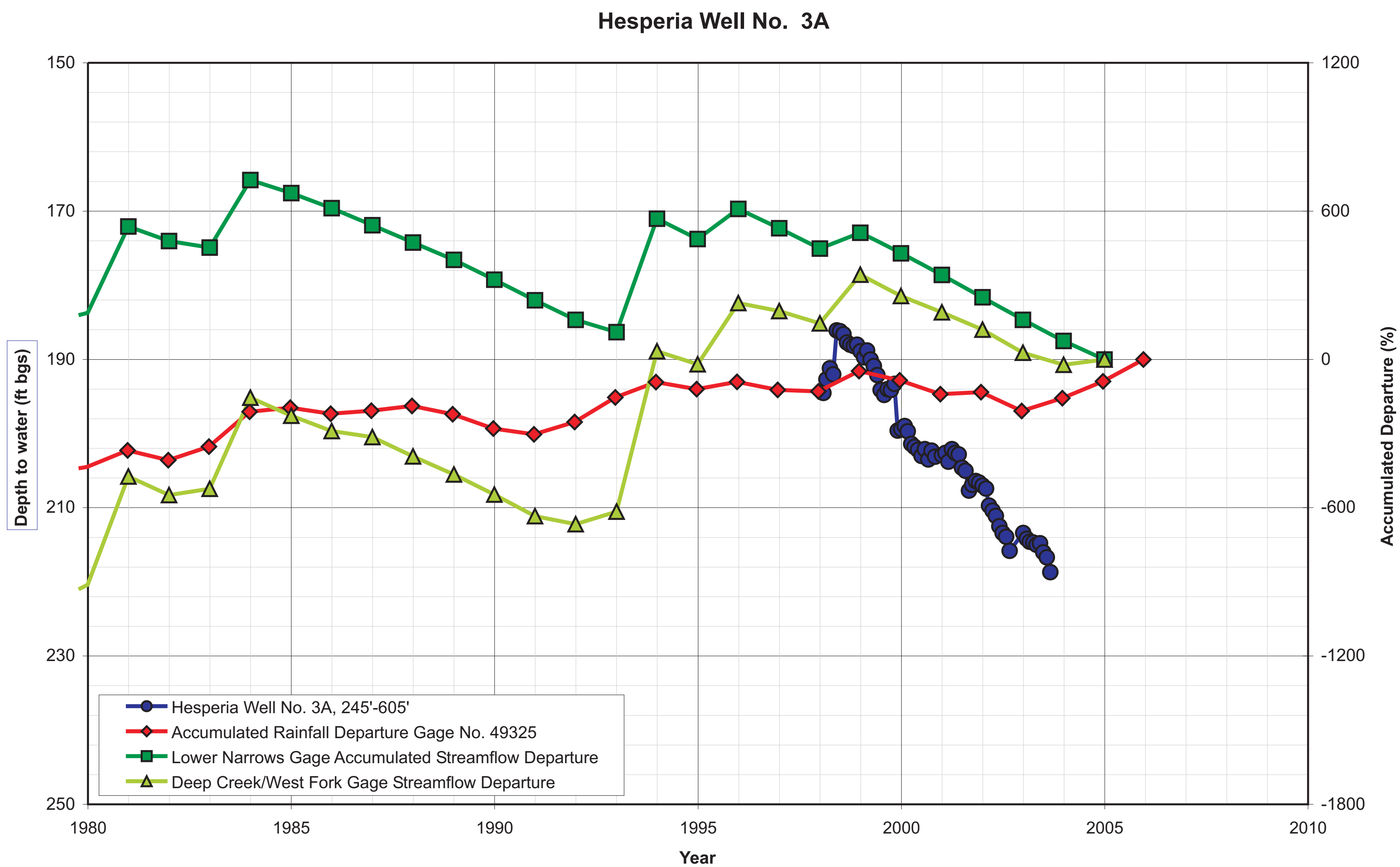

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FIGURE 3.14
HESPERIA WELL NO. 3A
HYDROGRAPH WITH ACCUMULATED DEPARTURE CURVES

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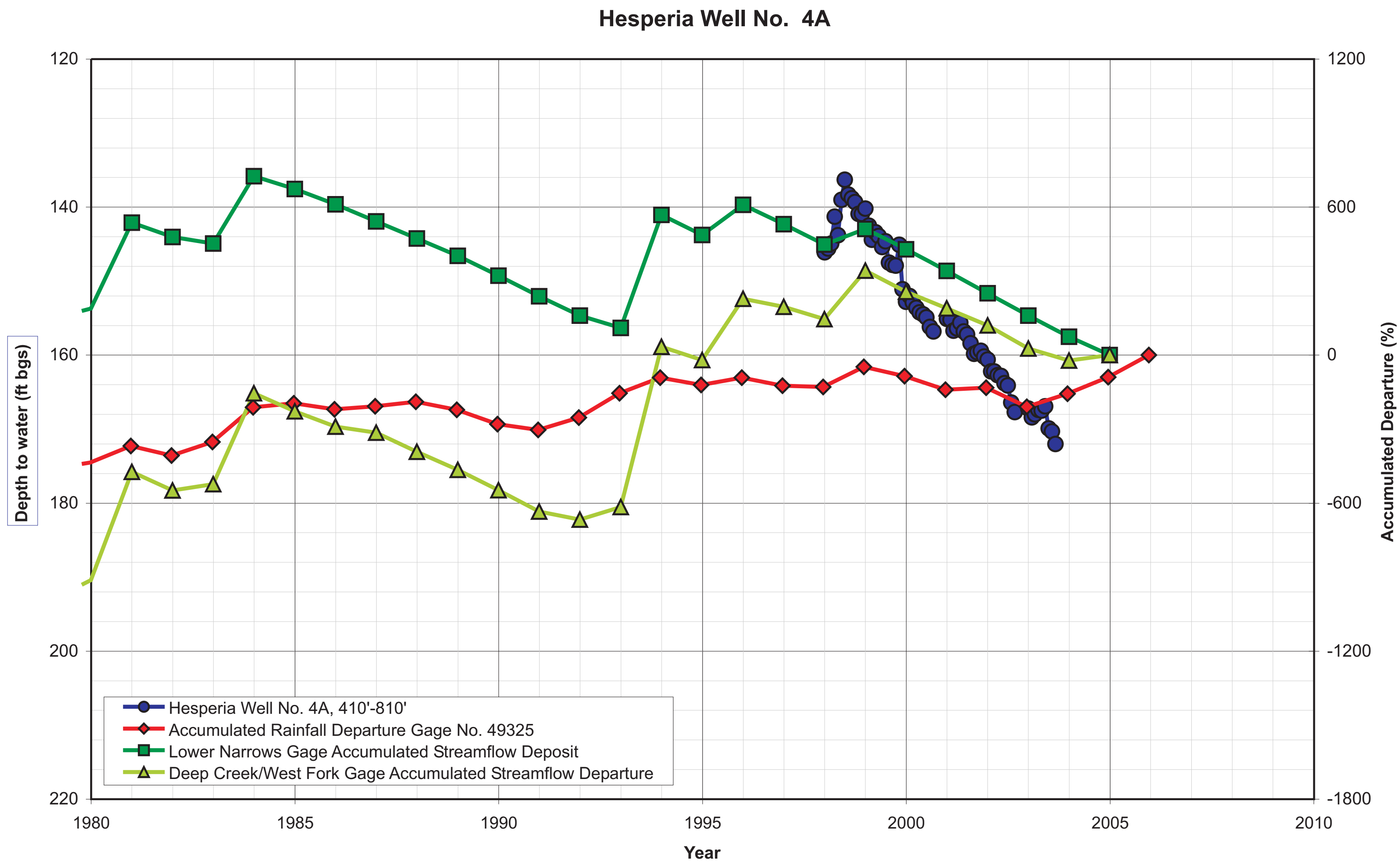

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FIGURE 3.15
HESPERIA WELL NO. 4A
HYDROGRAPH WITH ACCUMULATED DEPARTURE CURVES

Job No. 195-01 **August 2008**

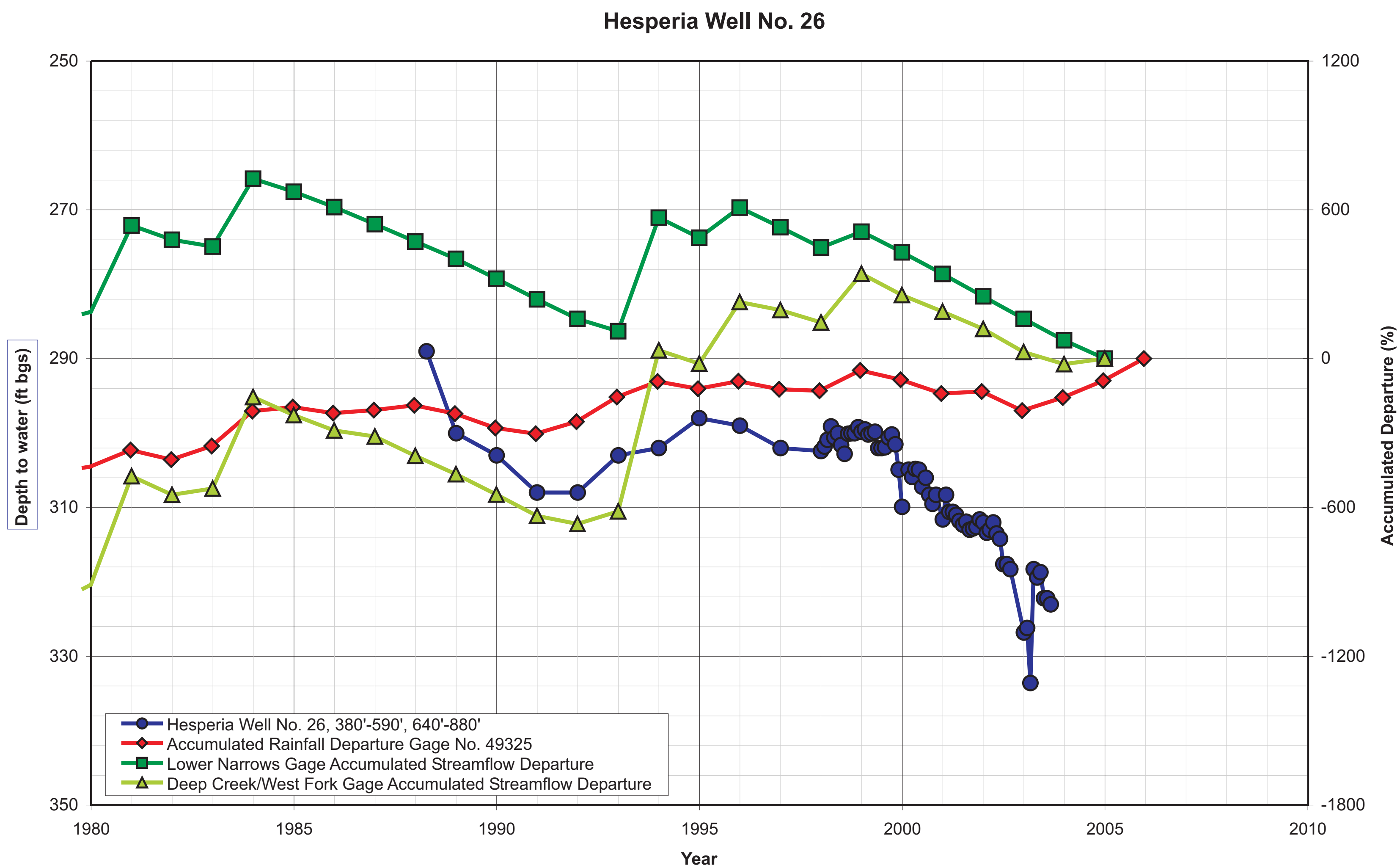

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FIGURE 3.16
HESPERIA WELL NO. 26
HYDROGRAPH WITH ACCUMULATED DEPARTURE CURVES

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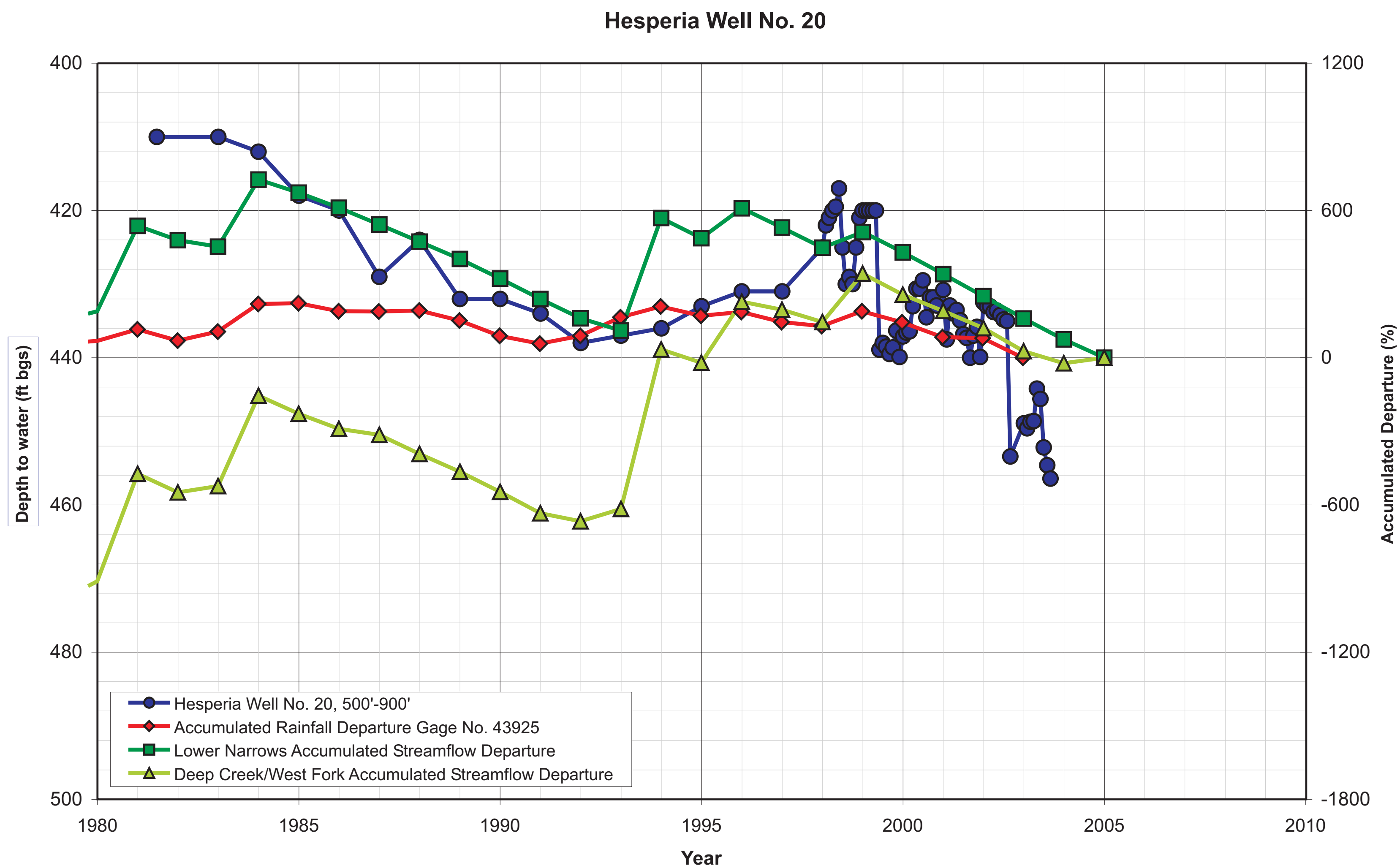

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FIGURE 3.17
HESPERIA WELL NO. 20
HYDROGRAPH WITH ACCUMULATED DEPARTURE CURVES

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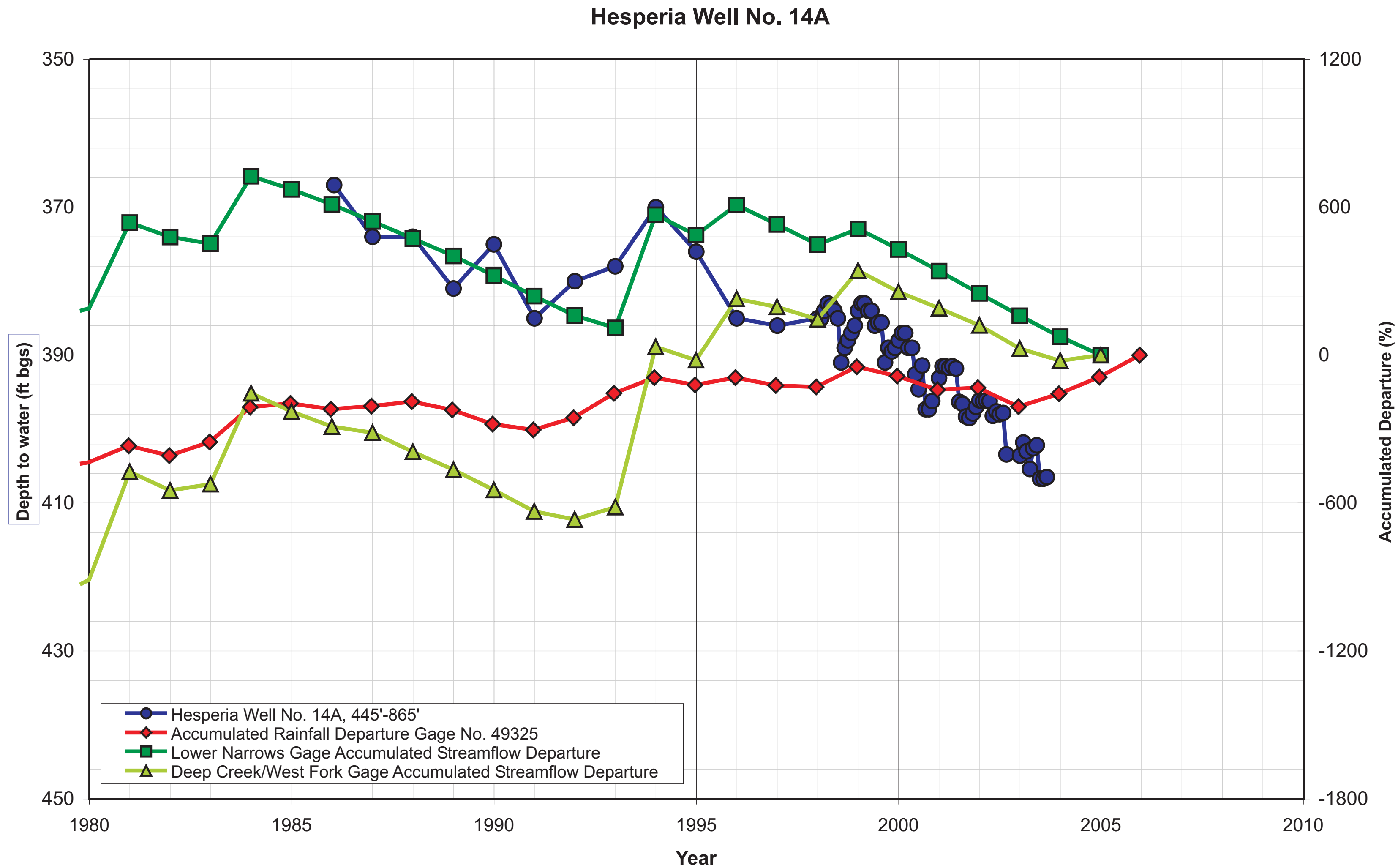

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FIGURE 3.18
HESPERIA WELL NO. 14A
HYDROGRAPH WITH ACCUMULATED DEPARTURE CURVES

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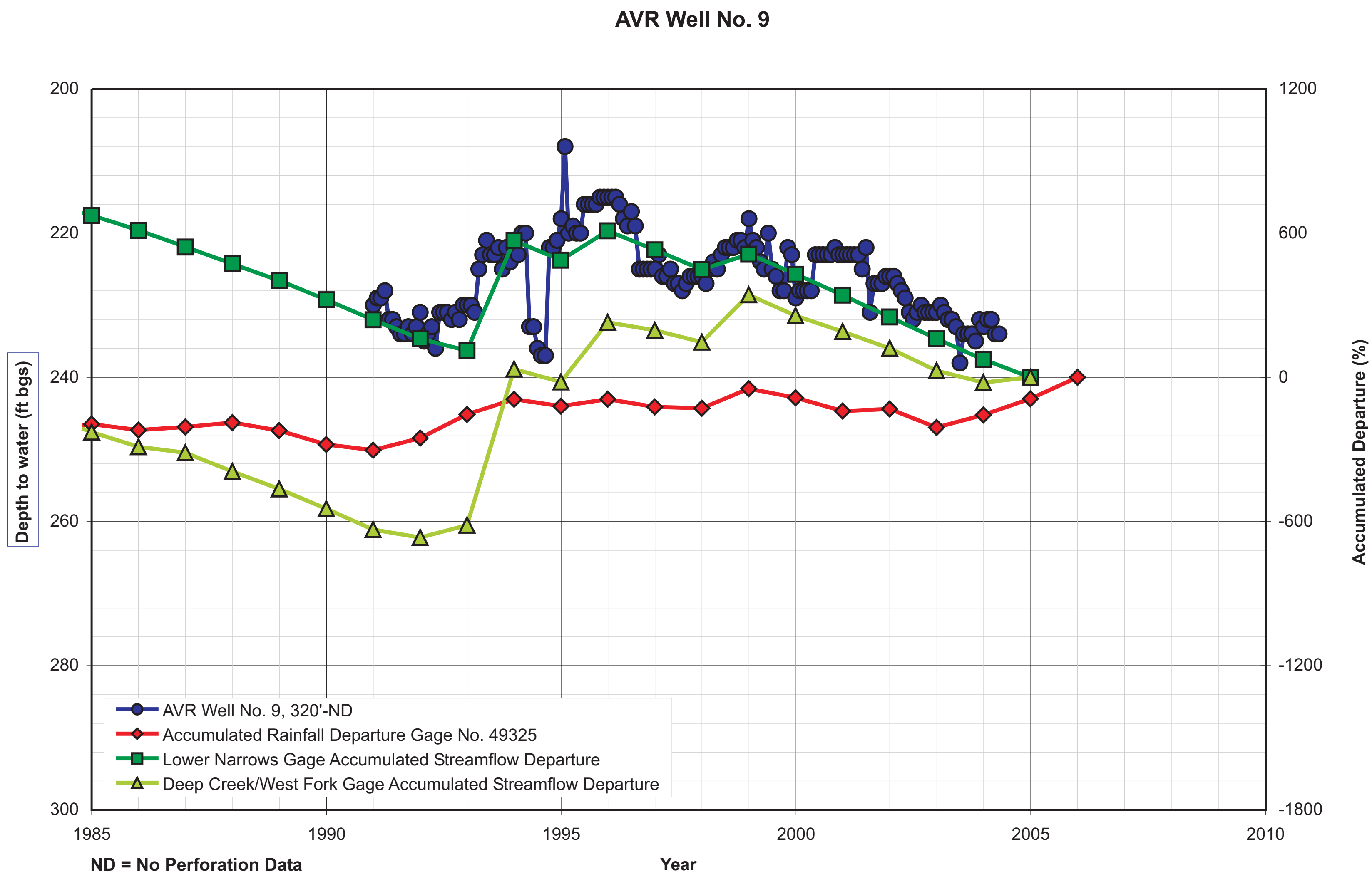

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FIGURE 3.19
AVR WELL NO. 9
HYDROGRAPH WITH ACCUMULATED DEPARTURE CURVES

Job No. 195-01 **August 2008**

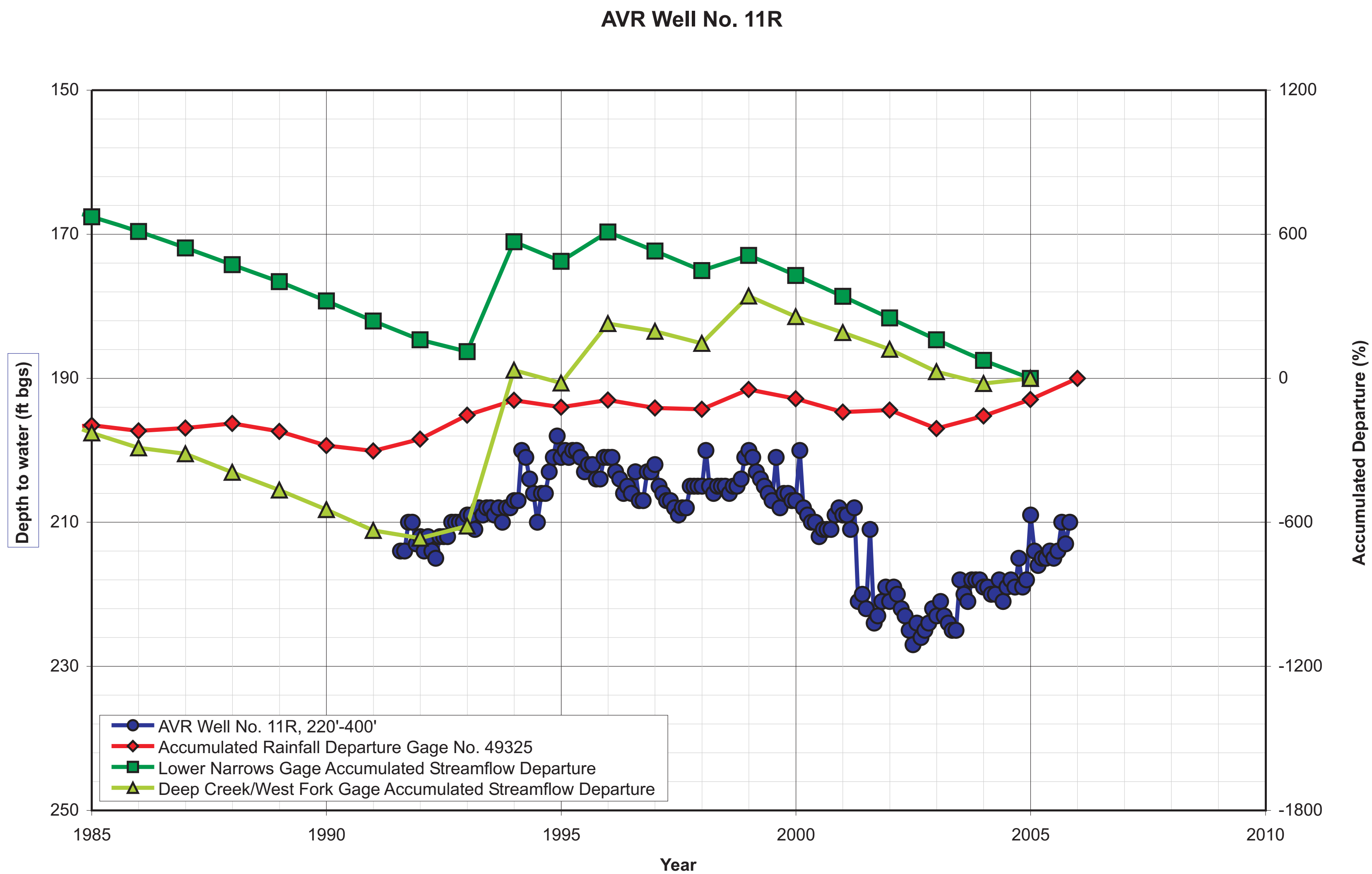

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FIGURE 3.20
AVR WELL NO. 11R
HYDROGRAPH WITH ACCUMULATED DEPARTURE CURVES

Job No. 195-01 **August 2008**

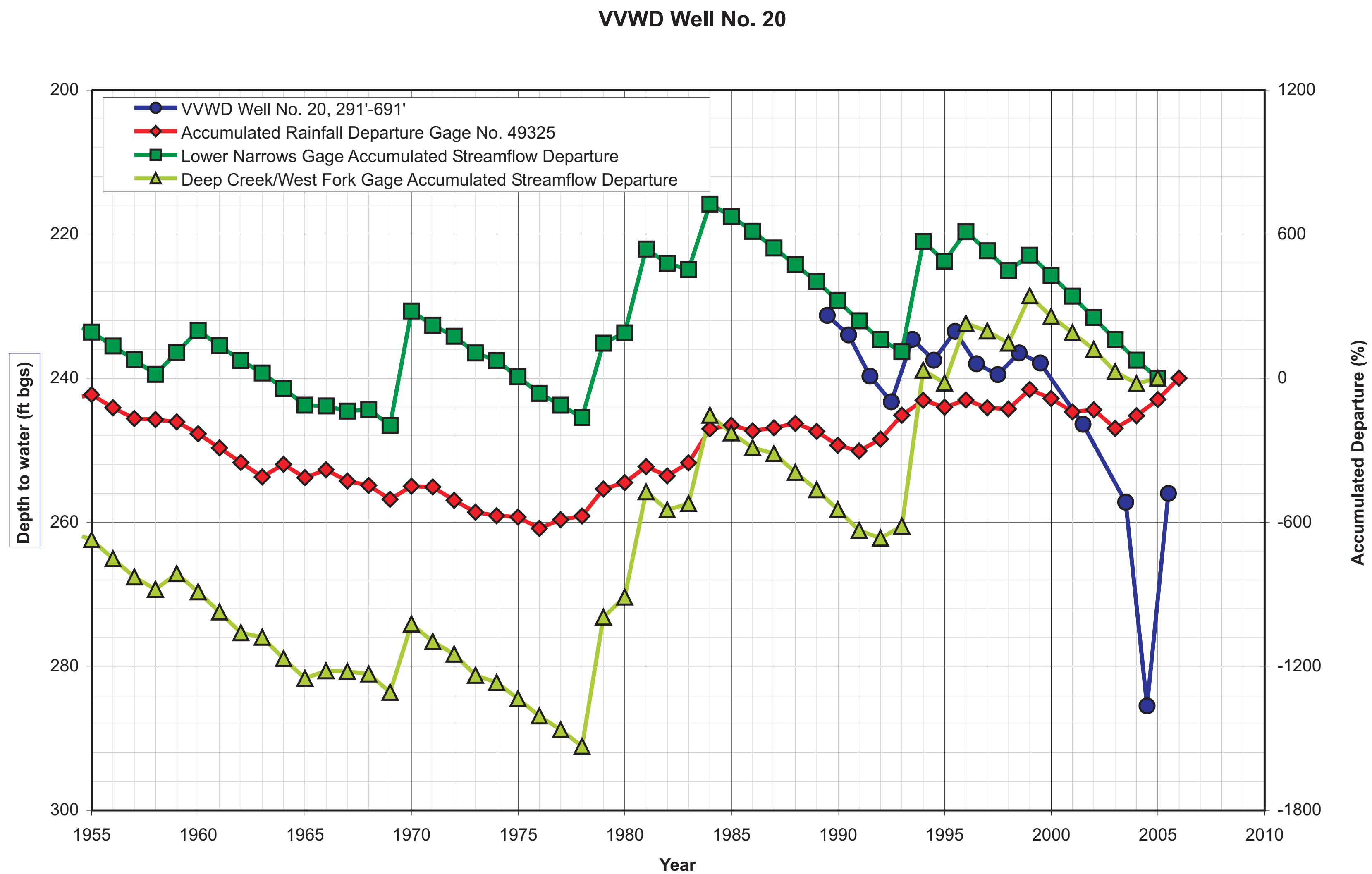

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FIGURE 3.21
VVWD WELL NO. 20
HYDROGRAPH WITH ACCUMULATED DEPARTURE CURVES

Job No. 195-01 **August 2008**

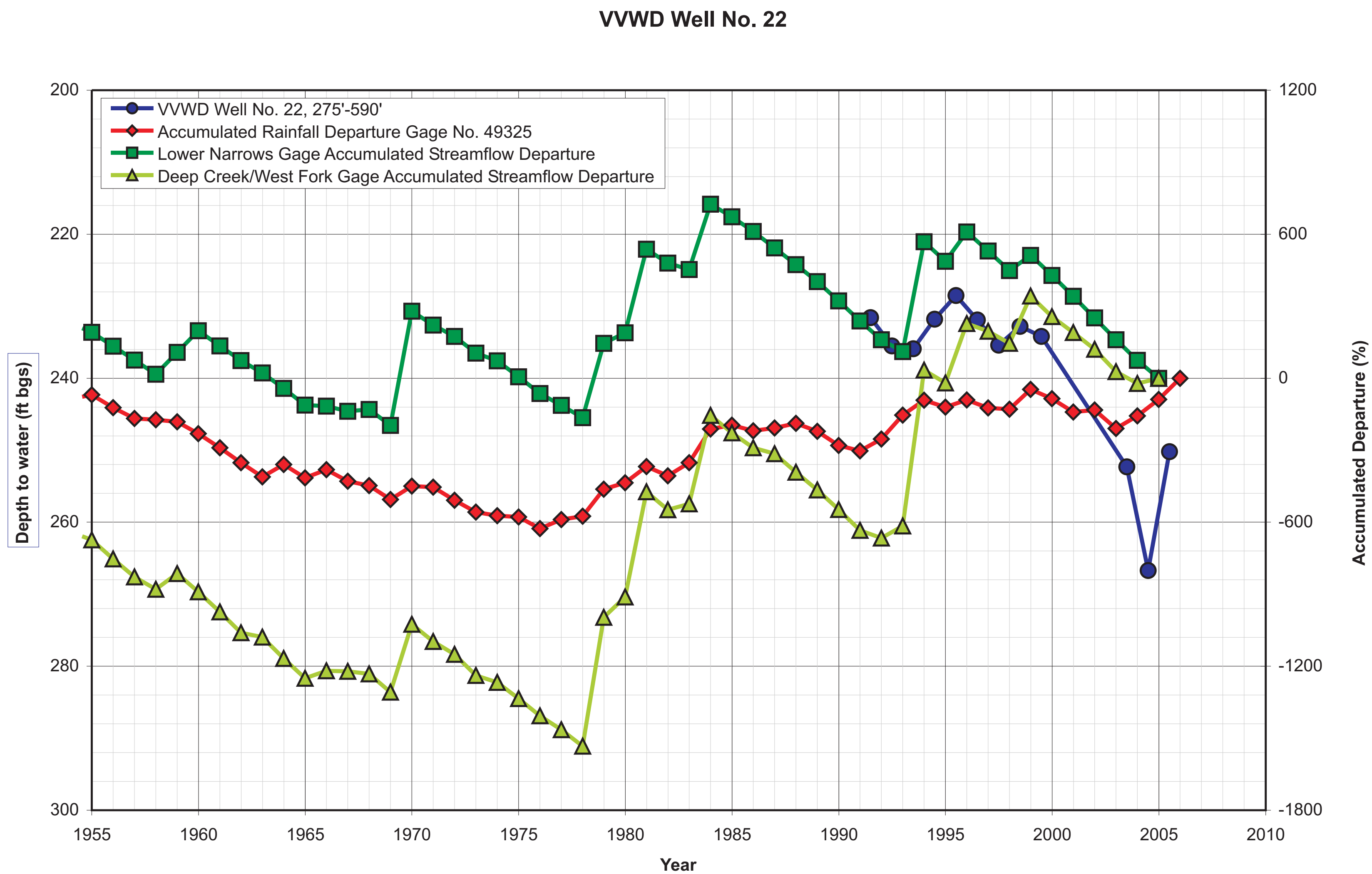

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FIGURE 3.22
VVWD WELL NO. 22
HYDROGRAPH WITH ACCUMULATED DEPARTURE CURVES

Job No. 195-01 **August 2008**

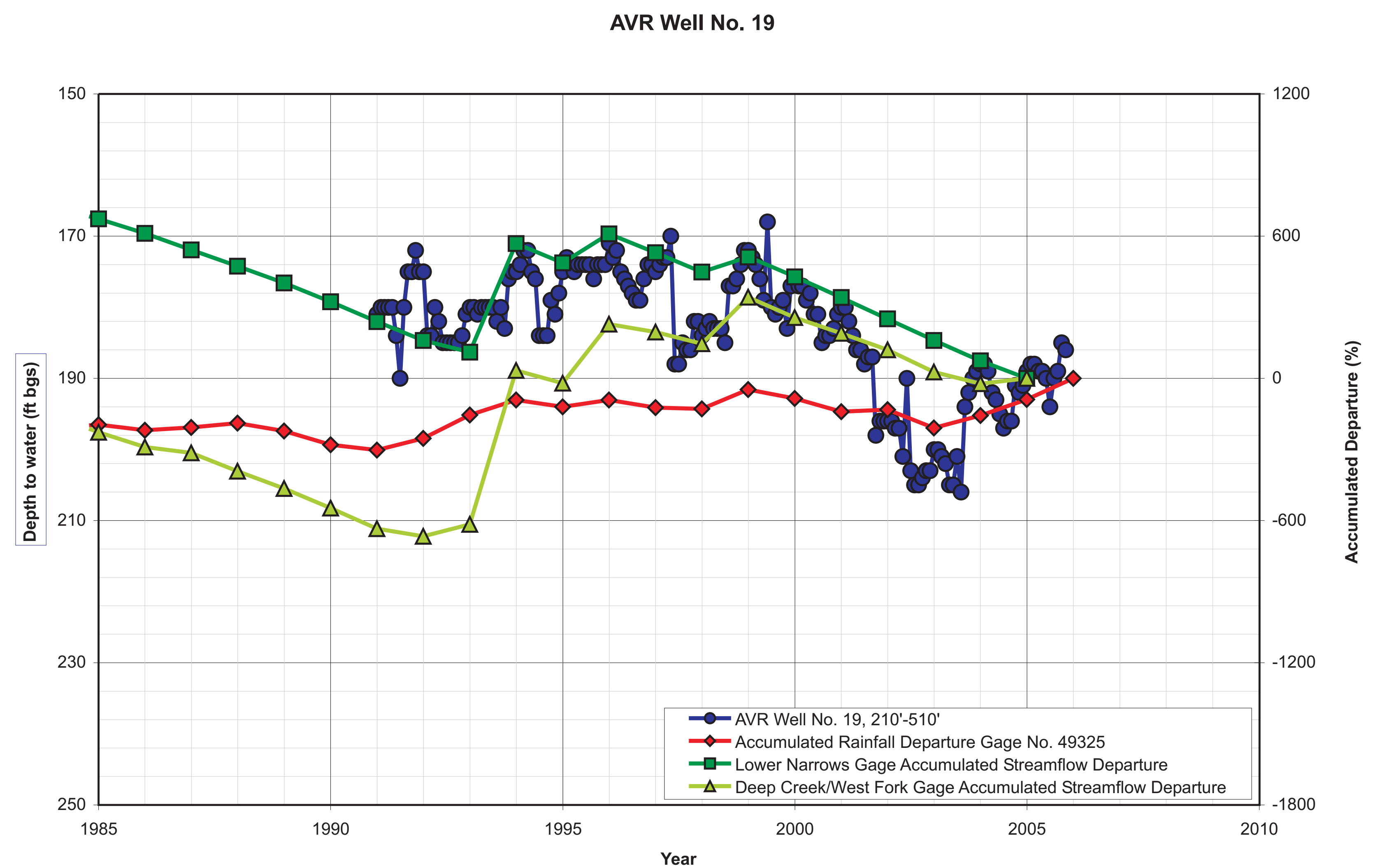

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FIGURE 3.23
AVR WELL NO. 19
HYDROGRAPH WITH ACCUMULATED DEPARTURE CURVES

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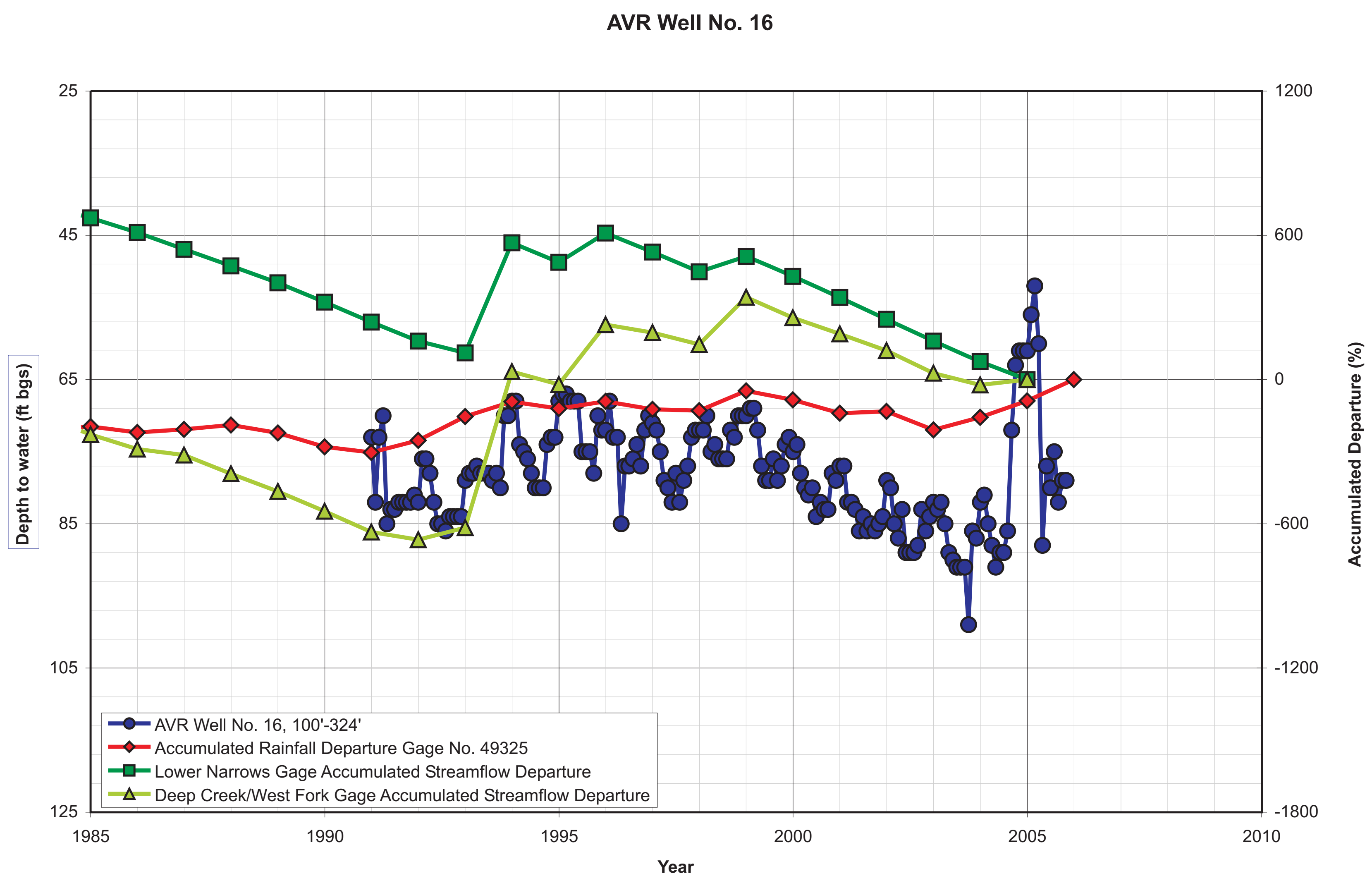

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FIGURE 3.24
AVR WELL NO. 16
HYDROGRAPH WITH ACCUMULATED DEPARTURE CURVES

Job No. 195-01 **August 2008**

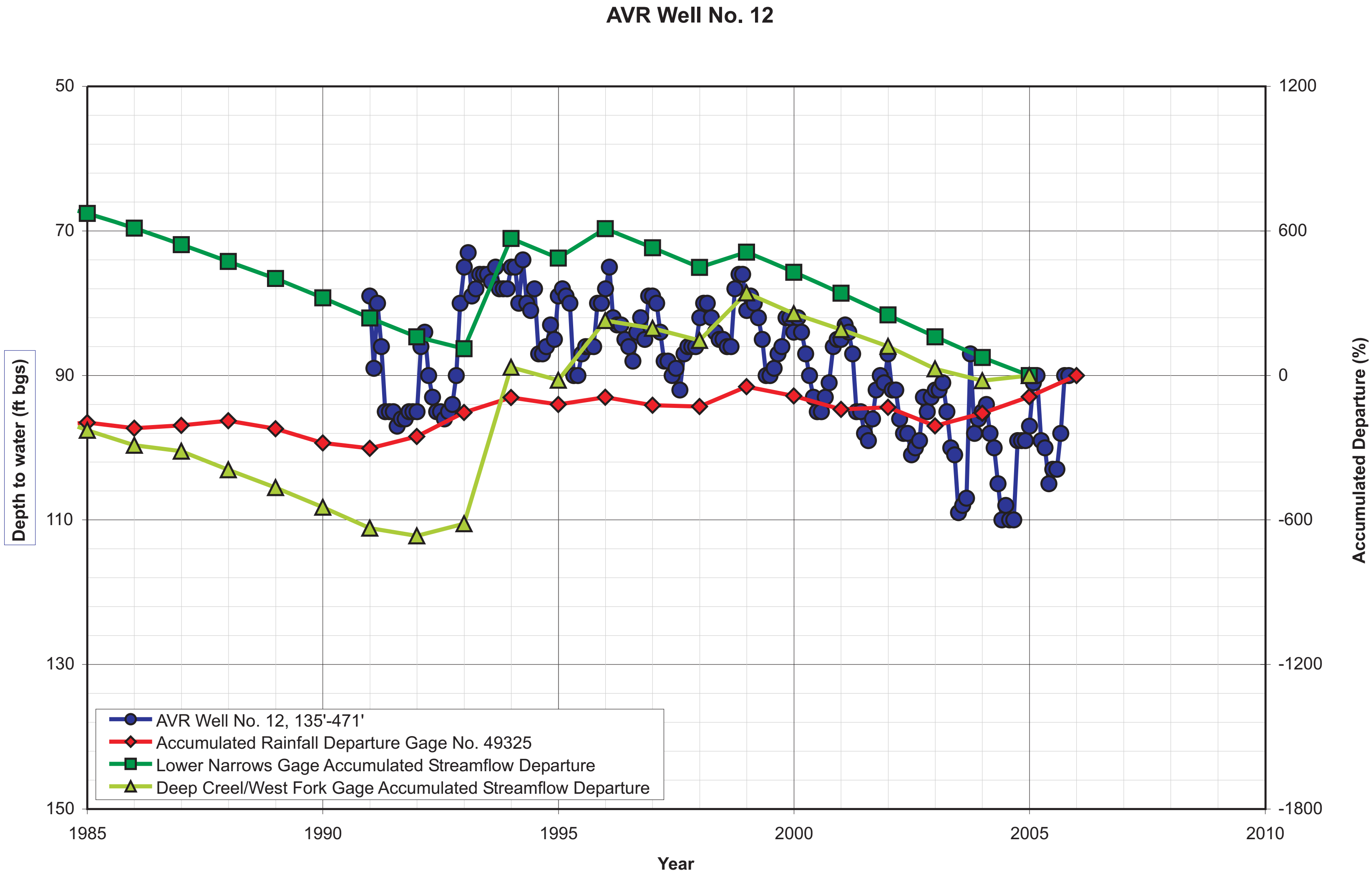

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FIGURE 3.25
AVR WELL NO. 12
HYDROGRAPH WITH ACCUMULATED DEPARTURE CURVES

Job No. 195-01 **August 2008**

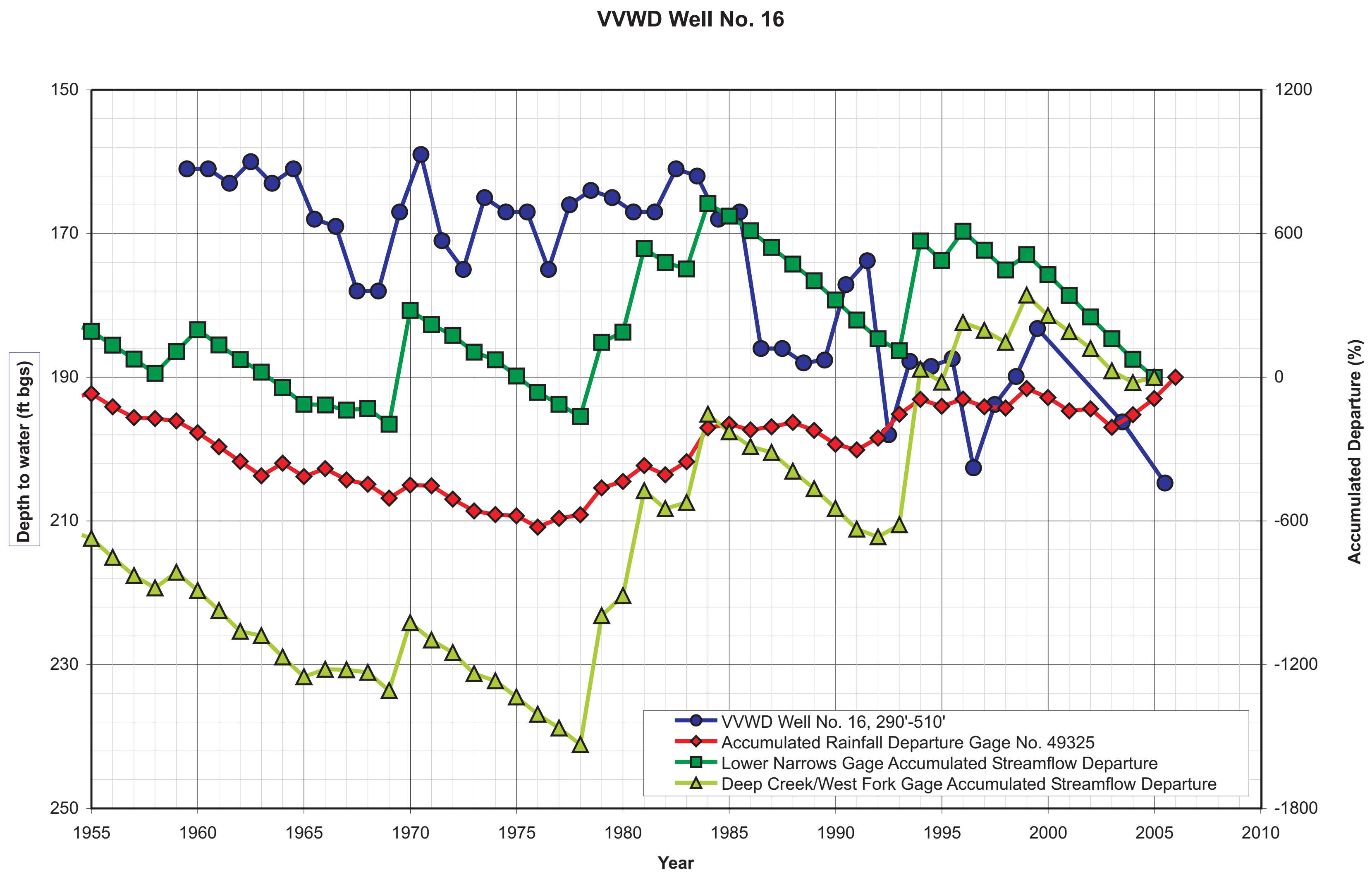

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FIGURE 3.26
VVWD WELL NO. 16
HYDROGRAPH WITH ACCUMULATED DEPARTURE CURVES

Job No. 195-01 **August 2008**

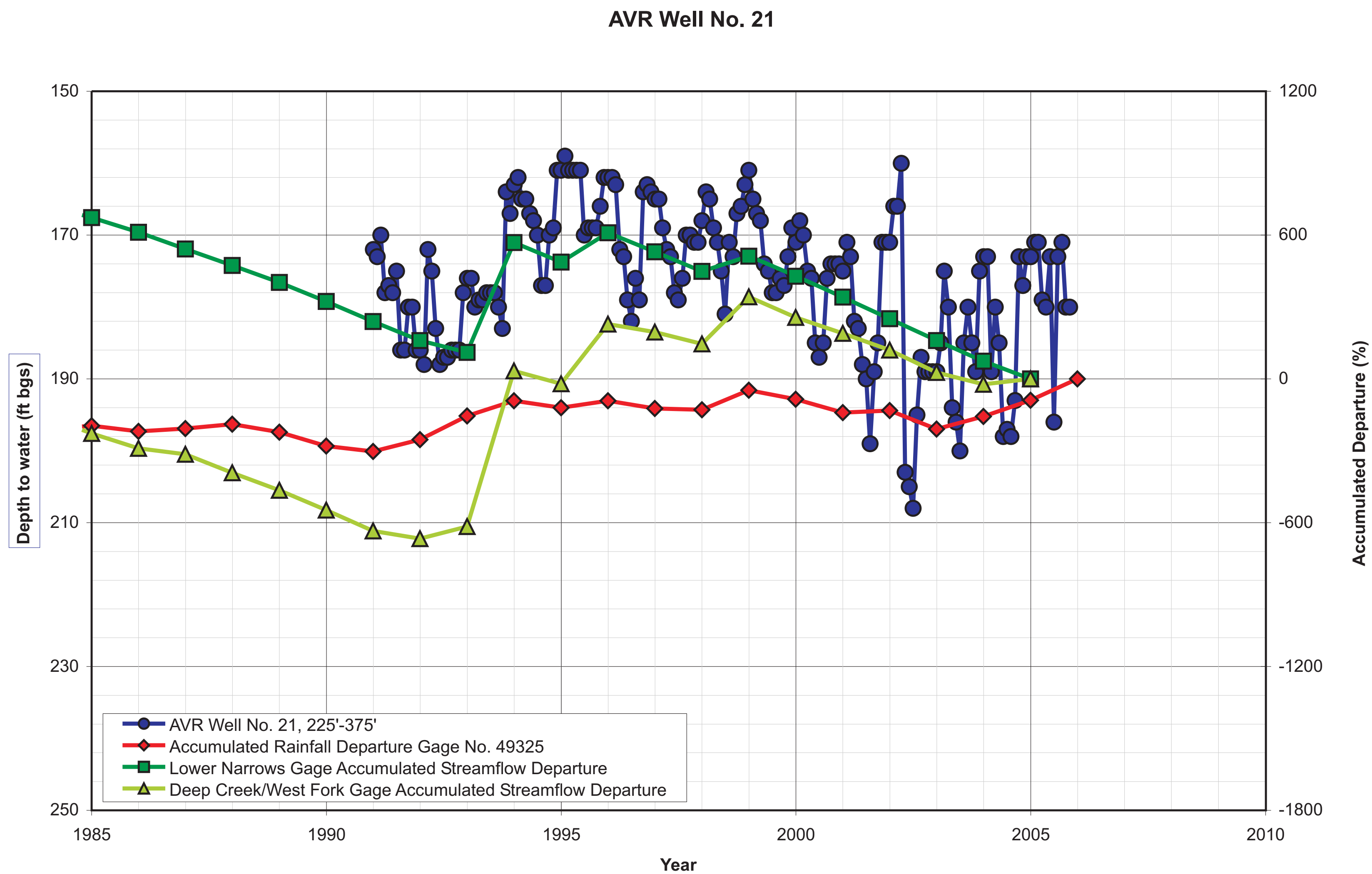

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FIGURE 3.27
AVR WELL NO. 21
HYDROGRAPH WITH ACCUMULATED DEPARTURE CURVES

Job No. 195-01 **August 2008**

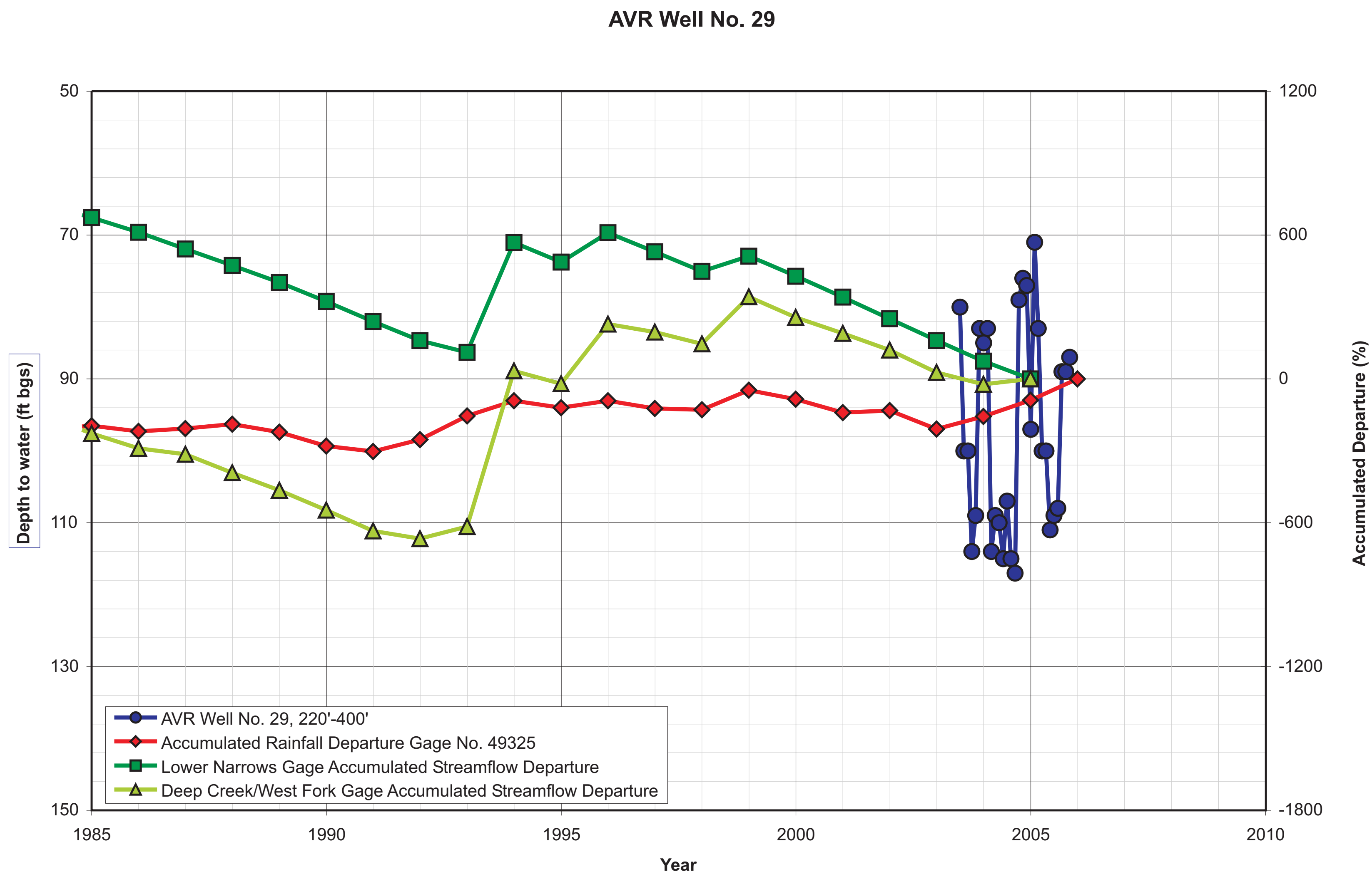

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FIGURE 3.28
AVR WELL NO. 29
HYDROGRAPH WITH ACCUMULATED DEPARTURE CURVES

Job No. 195-01 **August 2008**

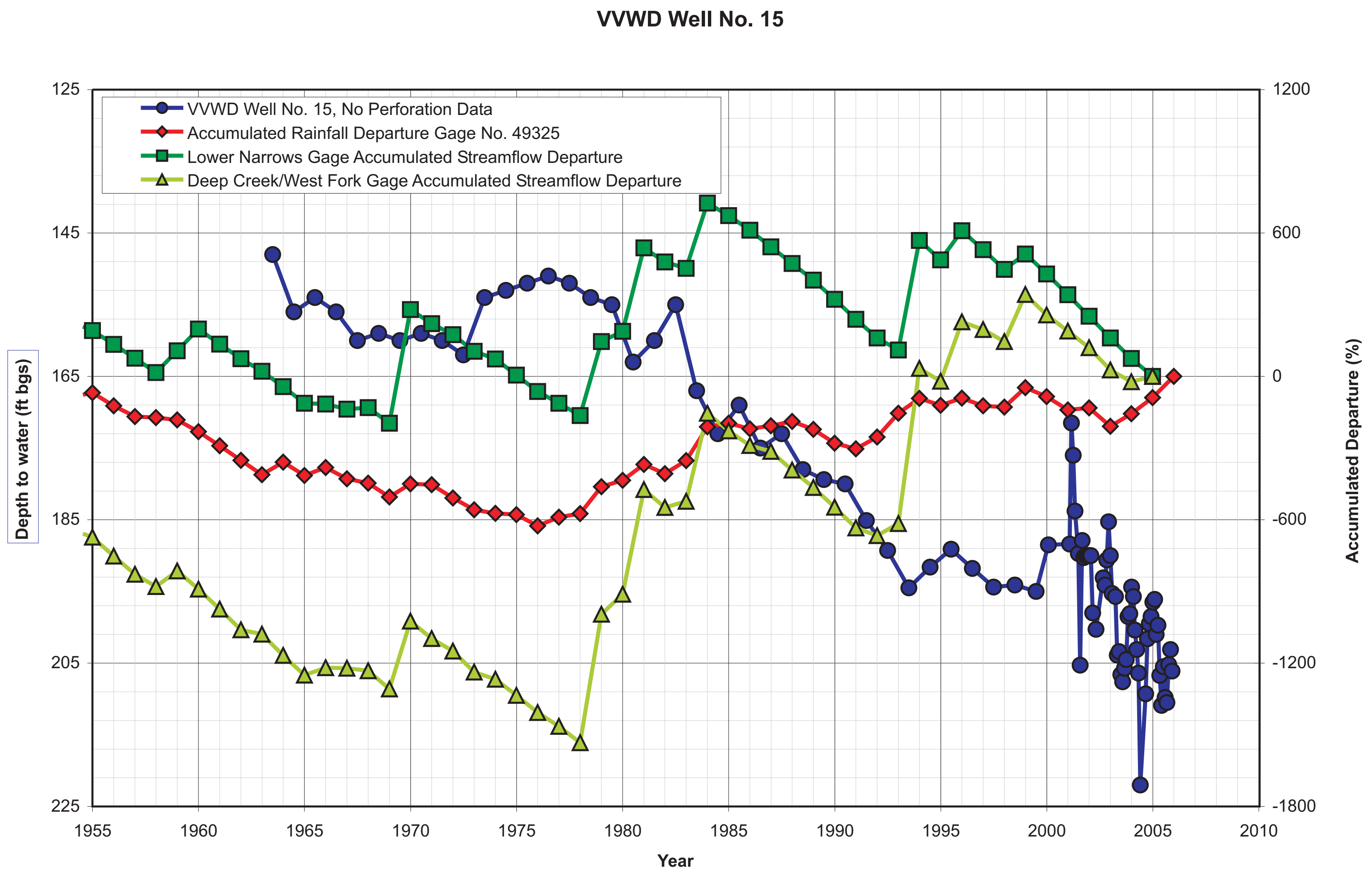

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FIGURE 3.29
VVWD WELL NO. 15
HYDROGRAPH WITH ACCUMULATED DEPARTURE CURVES

Job No. 195-01 **August 2008**

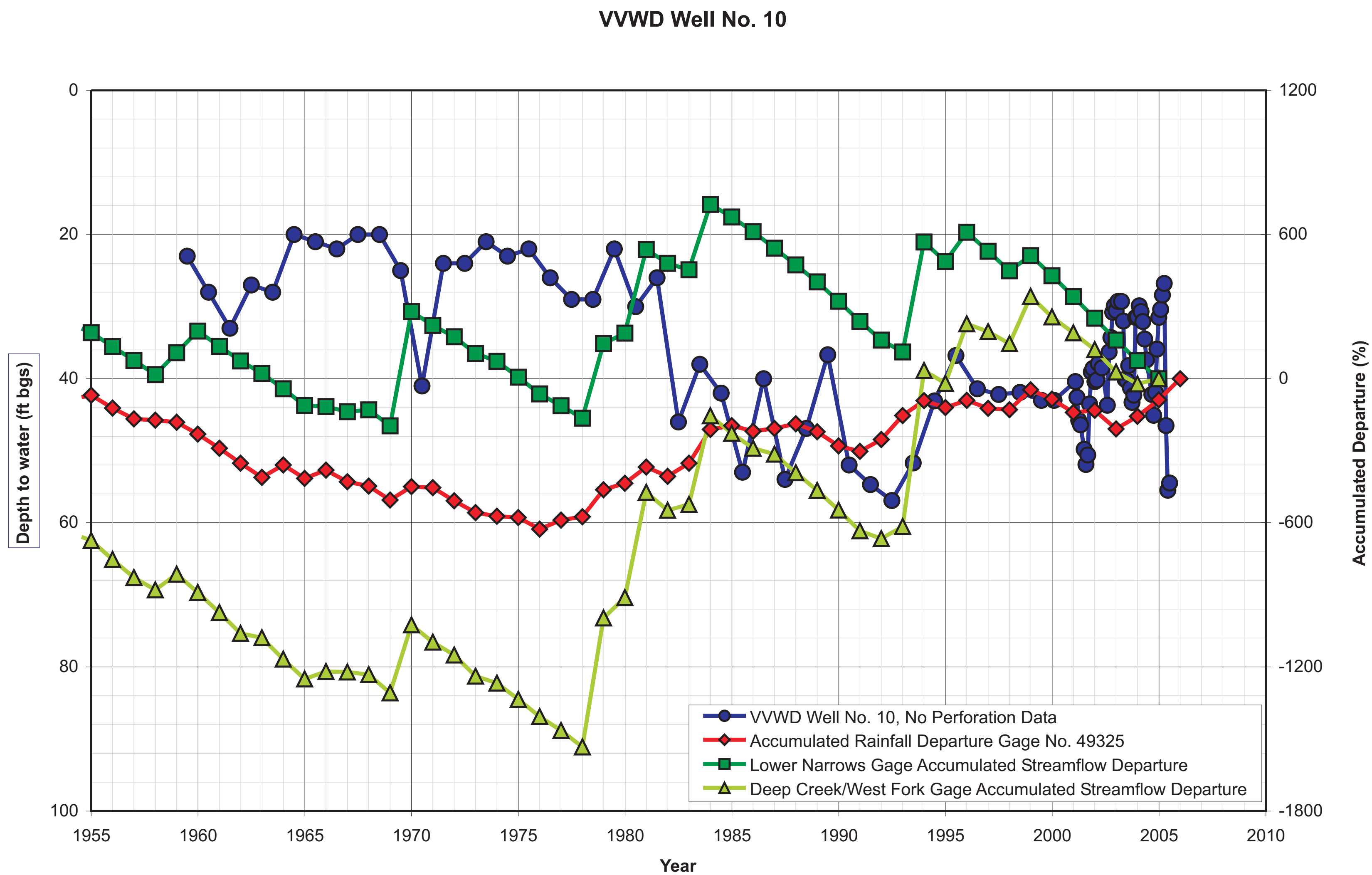

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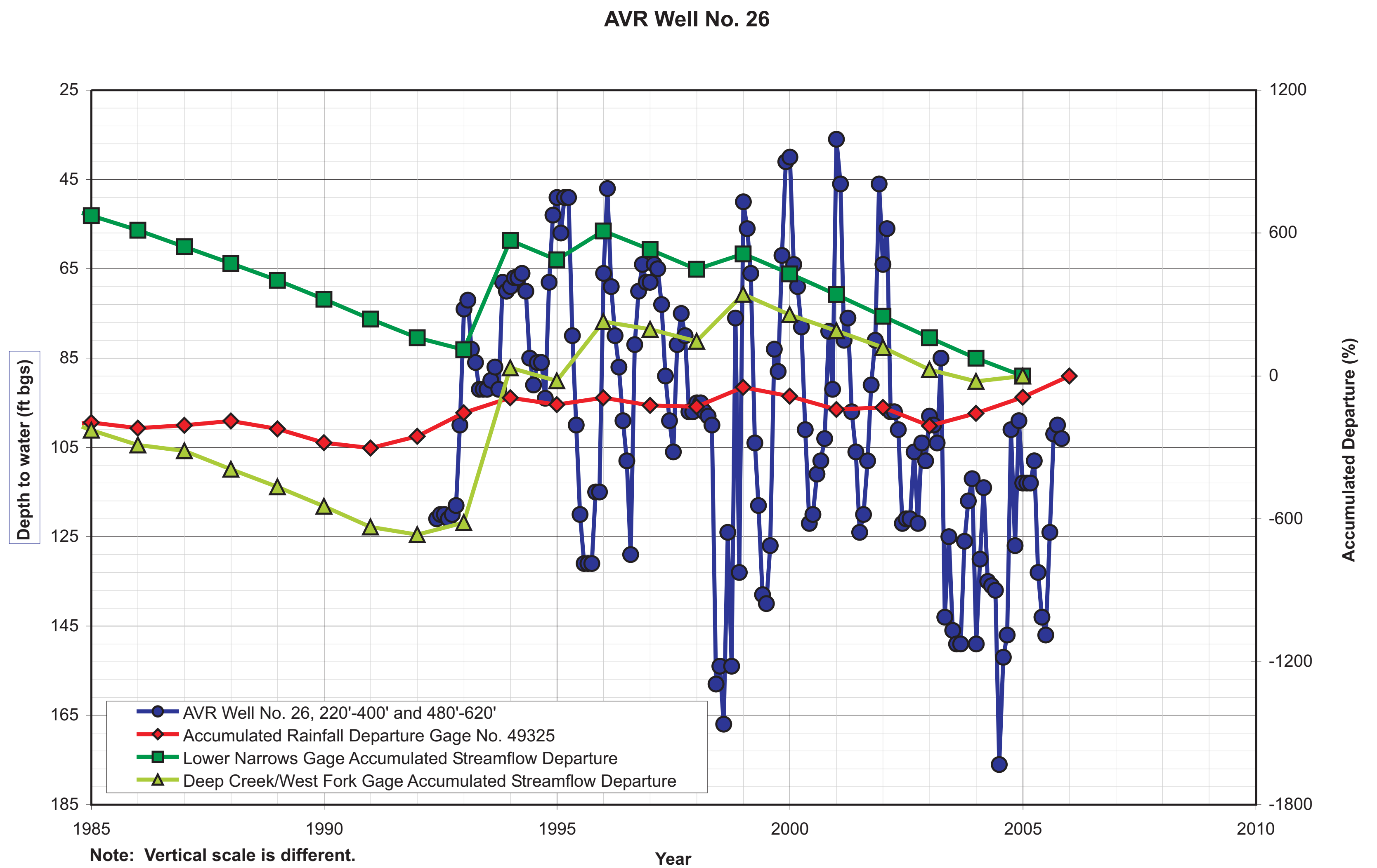
FIGURE 3.30
VVWD WELL NO. 10
HYDROGRAPH WITH ACCUMULATED DEPARTURE CURVES

Job No. 195-01 **August 2008**



Note: Vertical scale is different.

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FIGURE 3.31
AVR WELL NO. 26
HYDROGRAPH WITH ACCUMULATED DEPARTURE CURVES

Job No. 195-01 **August 2008**

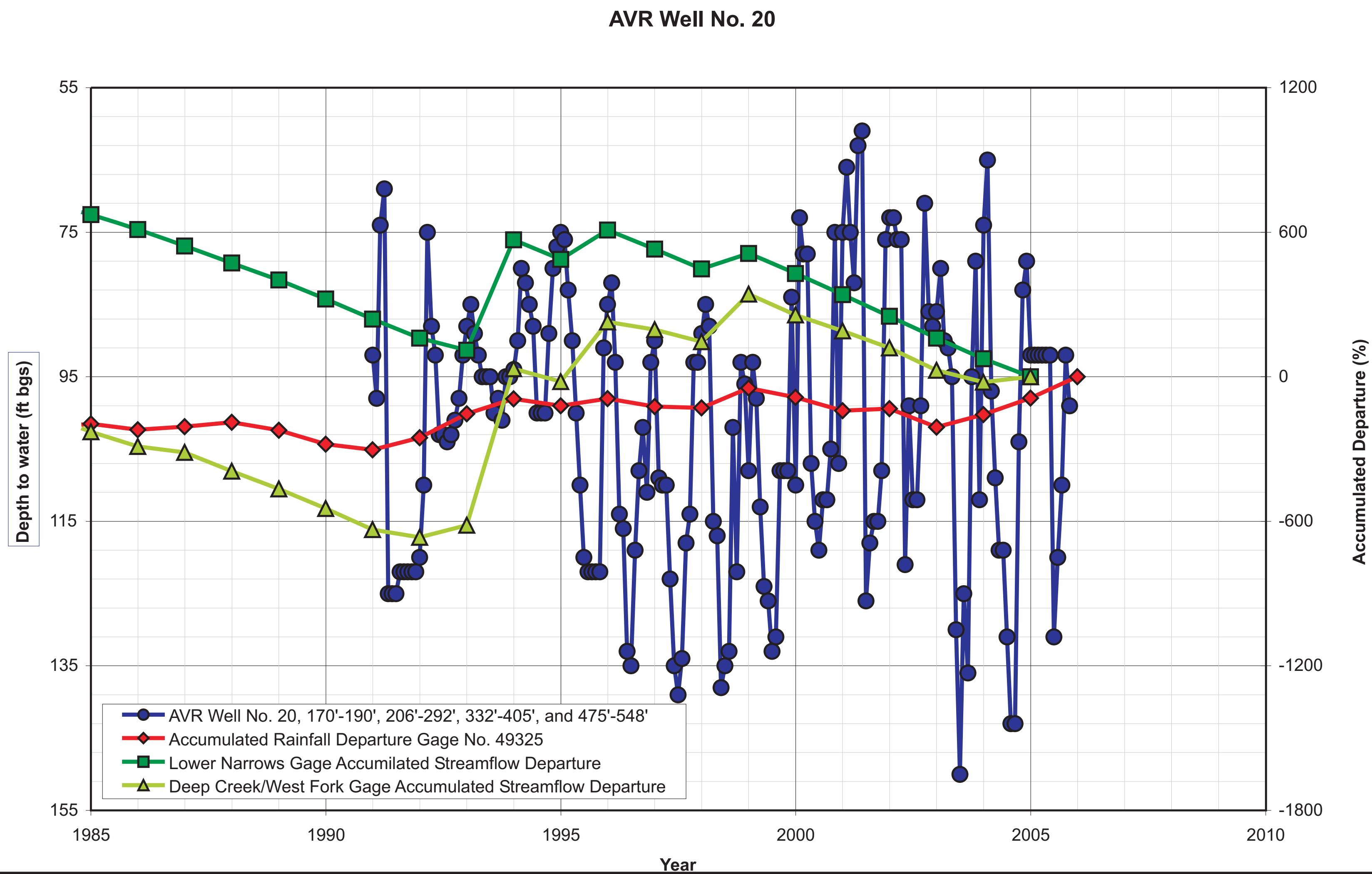

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FIGURE 3.32
AVR WELL NO. 20
HYDROGRAPH WITH ACCUMULATED DEPARTURE CURVES

Job No. 195-01 **August 2008**

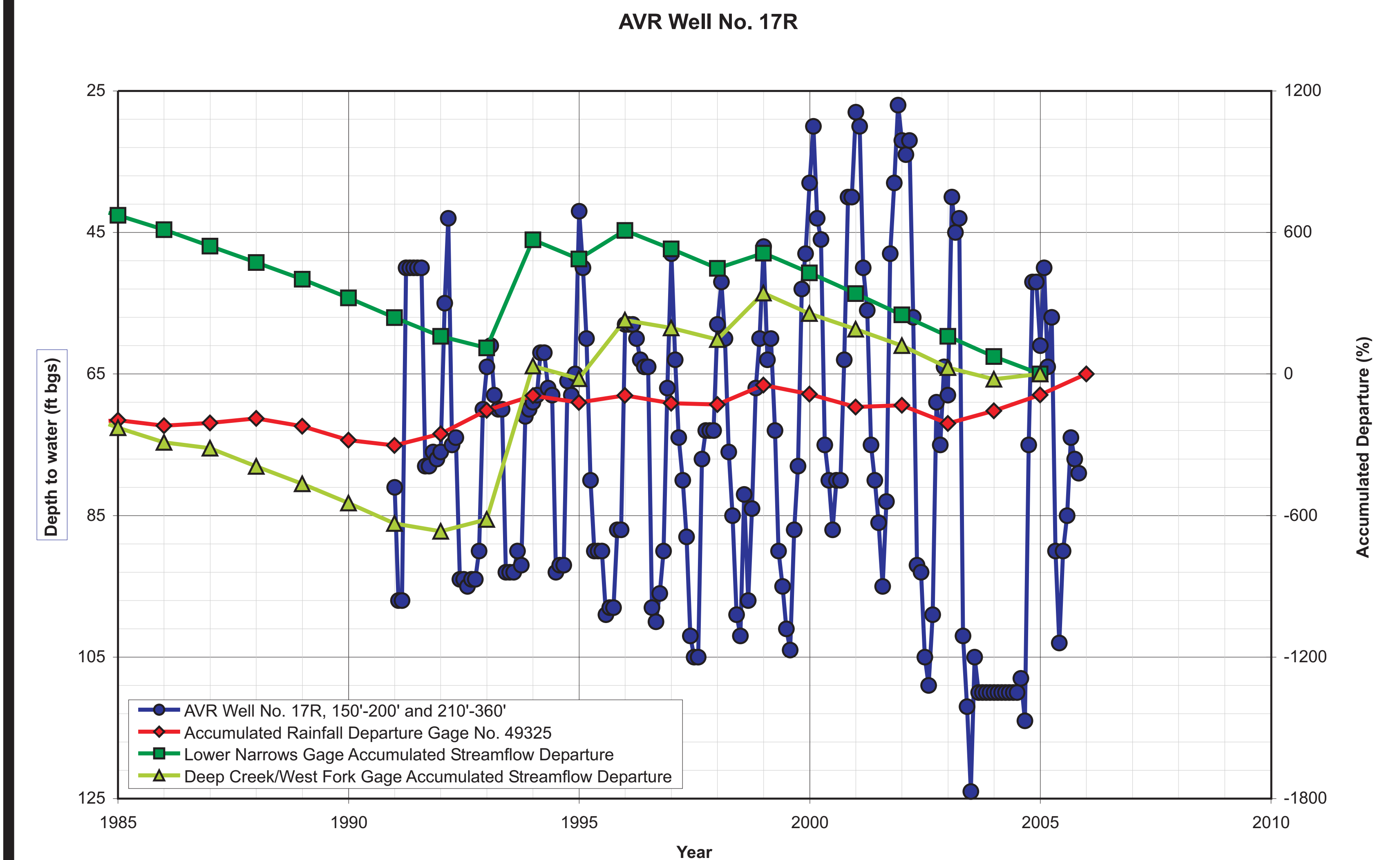

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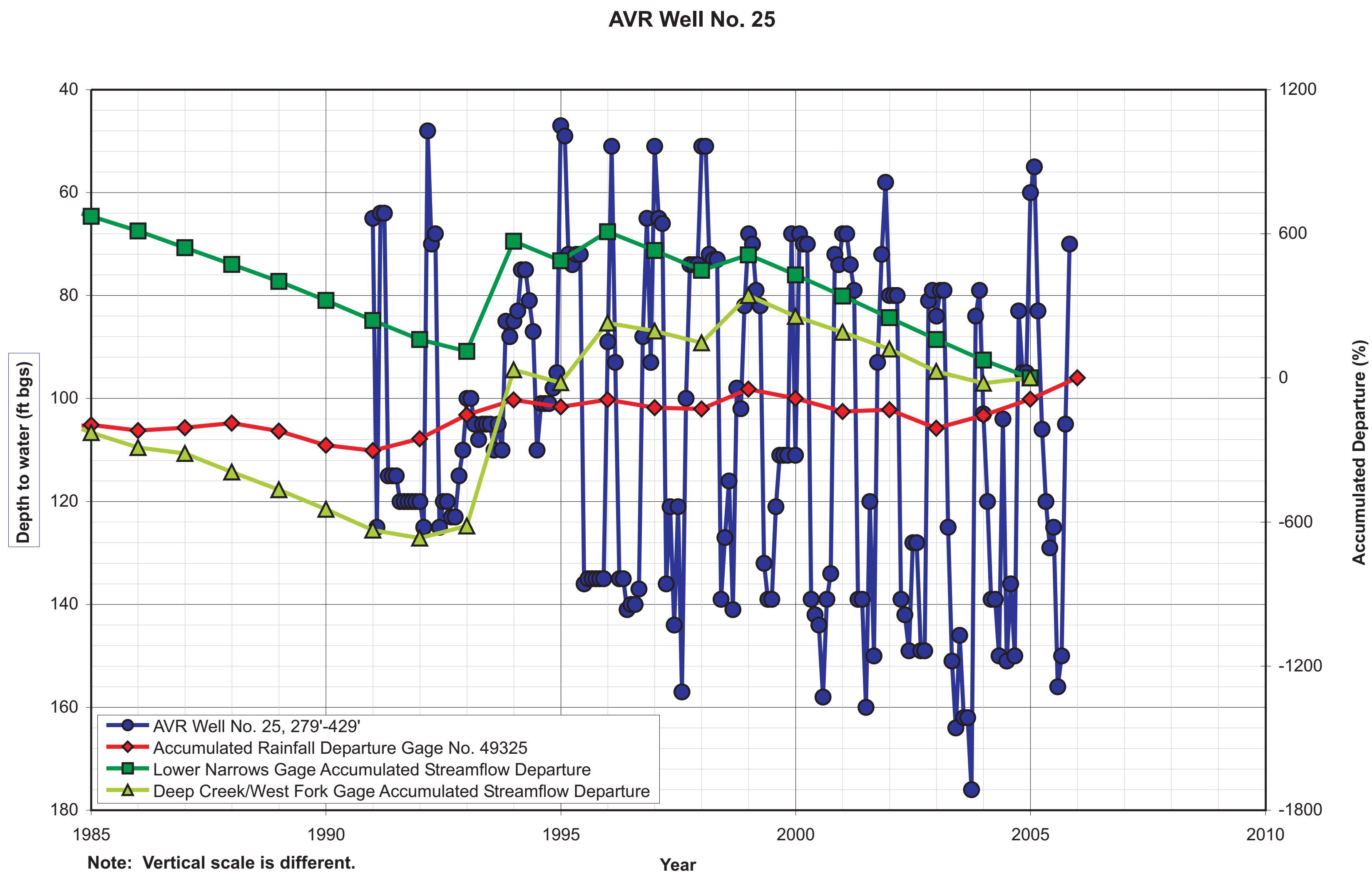
FIGURE 3.33
AVR WELL NO. 17R
HYDROGRAPH WITH ACCUMULATED DEPARTURE CURVES

Job No. 195-01 **August 2008**



Note: Vertical scale is different.

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FIGURE 3.34
AVR WELL NO. 25
HYDROGRAPH WITH ACCUMULATED DEPARTURE CURVES

Job No. 195-01 **August 2008**

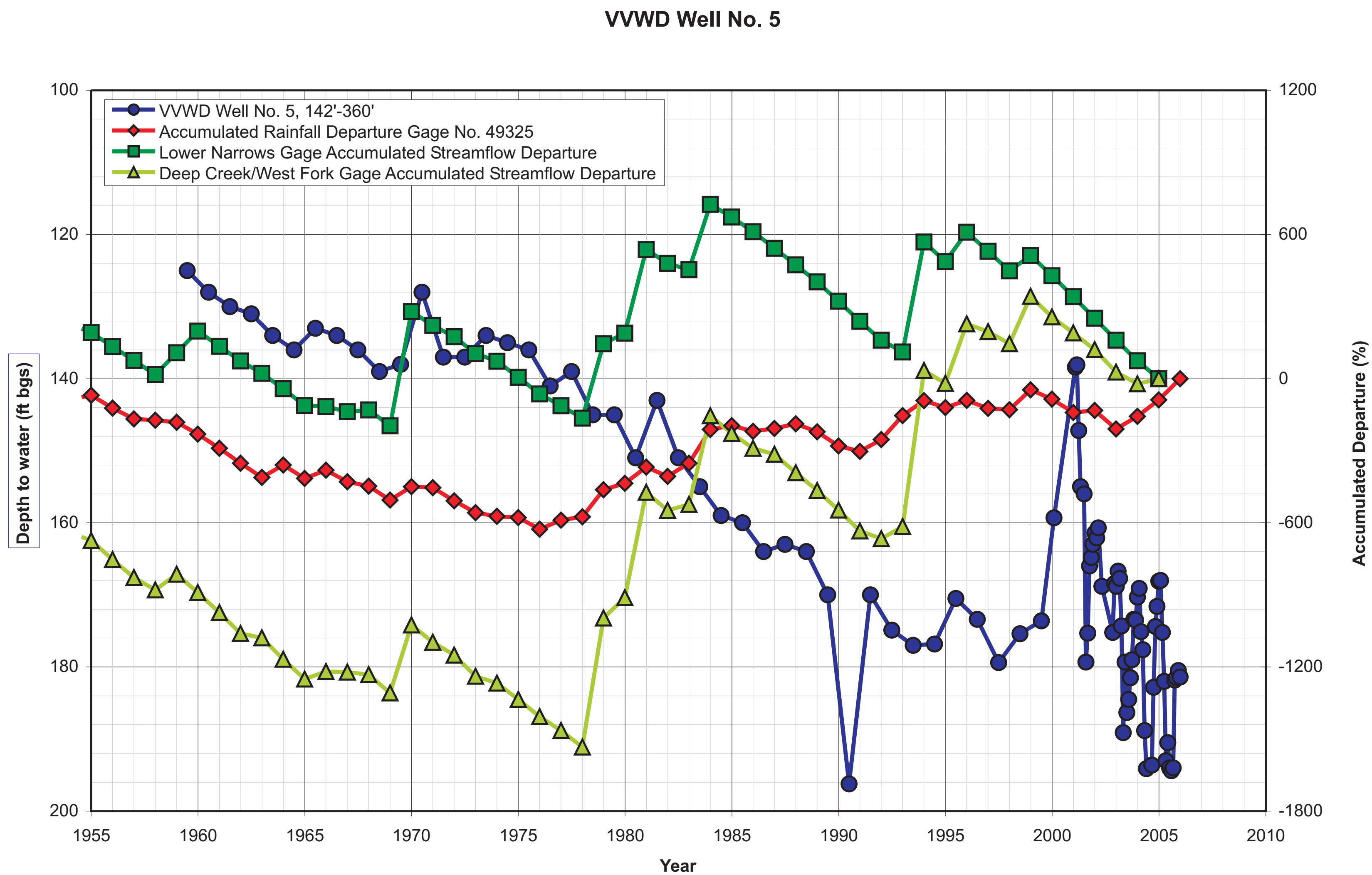

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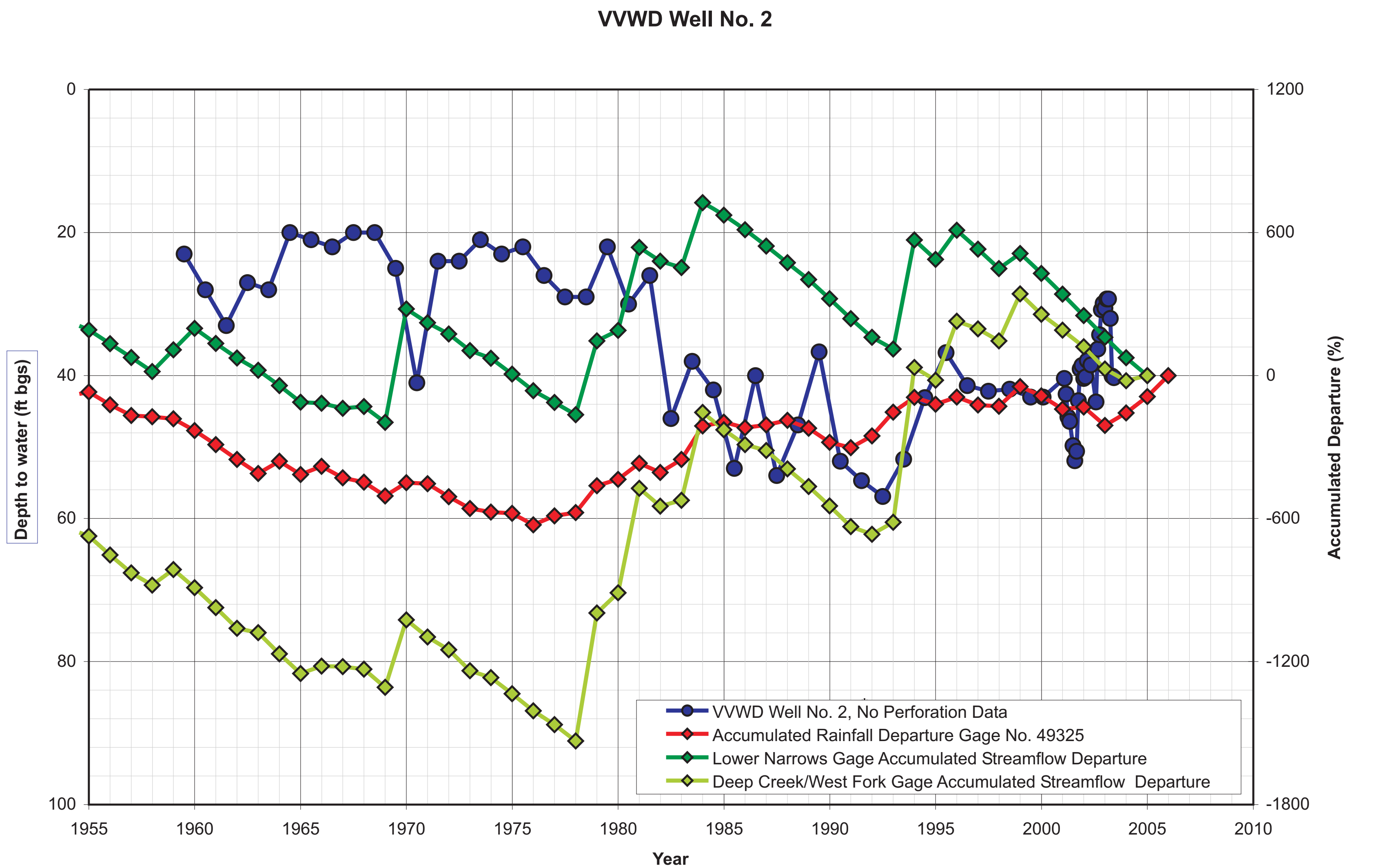
FIGURE 3.35
VVWD WELL NO. 5
HYDROGRAPH WITH ACCUMULATED DEPARTURE CURVES

Job No. 195-01 **August 2008**



RCS

RICHARD C. SLADE & ASSOCIATES LLC
CONSULTING GROUNDWATER GEOLOGISTS
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Studio City Phone (818) 506-0418
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FIGURE 3.36
VVWD WELL NO. 2
HYDROGRAPH WITH ACCUMULATED DEPARTURE CURVES

Job No. 195-01 **August 2008**


Legend
MWA Monitoring Wells
Apple Valley Rancho Water District (AVRWD) Well Location
Victor Valley Water District (VVWD) Well Location
Victor Valley Water District Test Hole Location
County of San Bernardino Service Area 64-J (CSA-64J) Well Location
Rancho Las Flores (RFL) Well Location
City of Hesperia Well Location
Wells with Driller's Log
Oil Well Location
Simplified Fault Line, Approximately Located
Major Road
A A'
Cross Section Line
Qc - Active or Intermittently Active Channel
Qoc - Abandoned (Older) Channel
Qca - Channel Alluvium
Qyf - Young Alluvial-Fan Deposits
Qya - Young Alluvial-Valley Deposits
Qof - Older Alluvial-Fan Deposits
QTof - Very Old Alluvial-Fan Deposits
QThcu - Harold and Crowder Formations, Undifferentiated
bc - Basement Complex
Upper Narrows - MW
Rincon Rd. - MW
A.V. Ranchos - MW
Jess Ranch-1 - MW
SF-1 - MW
RS-1 - MW
Deep Creek-1 - MW
APPLE VALLEY RD
RANCHERIAS RD
SENECA RD
YATES RD
SPRING VALLEY PKWY
RIDGECREST RD
GREEN TREE BLVD
3RD AV
NISQUALLI RD
BALSAM RD
7TH AV
HESPERIA RD
PEACH AV
I AV
EUCALYPTUS ST
LEMON ST
C AV
MAIN ST
CHOICEANA AV
ROCK SPRINGS RD
DANBURY AV
MESQUITE ST
ARROWHEAD LAKE RD
DEEP CREEK RD
KIOWA RD
BEAR VALLEY RD
TUSSING RANCH RD
CENTRAL RD
MOJAVE DR
ROY ROGERS DR
CIVIC DR
6TH ST
7TH ST
VVWD 1
VVWD 47
VVWD 13
VVWD 33
VVWD 27
VVWD 5
VVWD 36
VVWD 4
VVWD 2
VVWD 6
VVWD 11
VVWD 35
VVWD 7
VVWD 8
VVWD 41
VVWD 10
VVWD 9
VVWD 15
VVWD 16
VVWD 31
VVWD 45
VVWD 39
VVWD 43
VVWD 22
VVWD TH-32
VVWD 20
VVWD 40
CSA-64J No. 4
CSA-64J No. 1
CSA-64J No. 6
AVR
05N03W031N
04N03W06E04
Albert Crooks Inland 1
4N3W4
The Ord Oil Co. Ord 1
4N3W9
Hesperia Well 14B
Hesperia Well 14A
Hesperia Well 20
Hesperia Well 26
Hesperia Well 4A
Hesperia Well 3A
Hesperia Oil & Gas Co. of Calif. 1
4N4W29
Hesperia Oil & Gas Co. of Calif. 1-A
4N4W29
Hesperia Well 25
Hesperia Well 15A
Hesperia Well 24
Hesperia Well 17
Hesperia Well 5A
Hesperia Well 23
Hesperia Well 22R
Hesperia Well 22
Hesperia Well 18
Hesperia Well 32
RLF TH-1 at Aqueduct Crossing
RLF 22K1
RLF 20P1
RLF 21N1
RLF Mesa Well (No. 2)
RLF 27C1
RLF 26B1
RLF 26B2
04N04W12G3
04N04W12Q02
04N03W17H01
04N04W13J01
04N03W19B07
04N03W21D01
04N03W19M01
04N03W19J06
04N03W20Q04
04N03W20R01
04N03W19Q06
04N03W30B01
04N03W30C01
04N03W29B03
04N03W28E03
04N03W28E05
04N03W30K03
04N03W31J09
04N03W31R06
03N03W06C12
03N03W06H02
03N04W01K04
03N04W01K09
03N04W12K02
03N03W07M04
03N04W13B03
Qyf
Qoa
Qya
Qc
Qca
QTof
Qoc
QThcu
QThcu?
Qof
QTof?
bc
T5N
T4N
T3N
R4W
R3W
N
W
E
S
2000 0 2000 4000 6000
Feet
RCS
Richard C. Slade & Associates LLC
Consulting Groundwater Geologists
Project No: 195-01
Date: August 2008
Author: MAW/ASH
Filename: Plate 1 Basic Geology Of Project Area.WOR
Plate 1
Basic Geology of
Project Area
12750 Ventura Blvd., Ste. 202, Studio City, CA 91604
Phone: (818) 506-0418 Fax: (818) 506-1343

NW
SE
A
A'
ELEVATION ABOVE SEA LEVEL (IN FEET)
3600
3400
3200
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
4N-4W/26Q2
HESPERIA #5A
Sand, Gravel and Cobbles
Sand, Gravel, Some Cobbles
est.
Marker Bed W
Sand, Gravel, Some Silt
Marker Bed X
Marker Bed Y
Sand, Gravel, Silt
F-C Sand and Silt
TD 1015' (E-LOG)
TD 1115' (DRILLERS LOG)
HESPERIA WELL 5A
QTof
VERY OLD FAN DEPOSITS
QThcu
4N-4W/36G1
HESPERIA #29
CHANNEL ALLUVIUM
Qca
Sand and Cobbles
F-C Sand, Some Cobbles
Sand and Few Cobbles
TD 940'
MOJAVE RIVER
Qc
ACTIVE CHANNEL DEPOSITS
F-M Sand, Gravel, Cobbles
Boulders and F-M Sand
Qoc
Sand and Gravel
QTof
QThcu
HAROLD AND CROWDER FORMATIONS UNDIFFERENTIATED
4N-3W/31L6-9
USGS DEEP CREEK #1
NESTED MONITORING WELL
INTERSECTION WITH E-E'
ABANDONED CHANNEL DEPOSITS
Qoc
Yellow-Brown
F-VC Sand
Clayey F-VC Sand
Yellow-Brown F-VC Sand
Dark Yellow-Brown F-M Sand, Some Clay
VF-F Sand, Some Clay
TD 600'
Deep Creek 120-140 (A)
Deep Creek 240-260 (B)
Deep Creek 360-380 (C)
Deep Creek 530-550 (D)
QThcu
4N-3W/31R6
Qof
M-C Sand with Cobbles
C Sand and Rock
M-F Sand with Gravel
C Sand and Clay
Sandy and Silty Clay
TD 402'
Qof
OLDER FAN DEPOSITS
QThcu
bc
bc
BASEMENT COMPLEX
LEGEND
APPROXIMATE UNCONFORMABLE GEOLOGIC CONTACT
APPROXIMATE GRADATIONAL GEOLOGIC CONTACT
PERFORATION INTERVAL IN WELLS
PERFORATION INTERVAL IN NESTED MONITORING WELLS
TD = TOTAL DEPTH OF WELL CASING
REPORTED ELEVATION OF WATER, OCTOBER 2005
WATER ELEVATION, OCTOBER 2005, INTERPOLATED FROM RCS GROUNDWATER ELEVATION CONTOUR MAP
WATER LEVEL ELEVATION, OCTOBER 2005 FOR NESTED GROUNDWATER MONITORING WELLS; LETTERS A, B, C, AND D REPRESENT EACH RESPECTIVE PERFORATION DEPTH INTERVAL
STIFF WATER QUALITY PATTERN DIAGRAM SHOWING SAMPLING DATE
STIFF WATER QUALITY PATTERN DIAGRAM, SHOWING PERFORATION ZONE AND SAMPLING DATE
Geology Adapted From:
MORTON and MILLER (USGS, 2003, OFR 03-293)
STAMOS, et al. (USGS, 2001)
DWR (1967) BULLETIN No. 84
DIBBLEE (USGS, 1960a, 1960b, 1967)
BADER, PAGE, AND DUTCHER (1959)
Following L.F. NOBLE (1953, 1954)
SCALE
1 INCH = 500 FEET HORIZONTAL
1 INCH = 100 FEET VERTICAL
VERTICAL EXAGGERATION = 5X
NOTE:
Words written next to each well were abstracted from driller's log
F = fine-grained; VF = very fine-grained
C = coarse-grained; VC = very Coarse-grained
RCS
Richard C. Slade & Associates LLC
Consulting Groundwater Geologists
Project No: 195-01
Date: August 2008
Author: LVS/RCS
PLATE 2.1
GEOLOGIC CROSS SECTION A-A'
12750 Ventura Blvd., Ste. 202, Studio City, CA 91604
Phone: (818) 506-0418 Fax: (818) 506-1343

W
SE
B
B'
ELEVATION ABOVE SEA LEVEL (IN FEET)
MOJAVE RIVER
4N-3W/19G2
USGS RS-1
NESTED MONITORING WELL
INTERSECTION WITH E-E'
4N-4W/24G1
HESPERIA #4A
4N-3W/29B3
4N-3W/28E3
ACTIVE CHANNEL DEPOSITS
Qc
Qca
CHANNEL ALLUVIUM
Qoc
ABANDONED CHANNEL DEPOSITS
QTof
VERY OLD FAN DEPOSITS
QTcu
HAROLD AND CROWDER FORMATIONS UNDIFFERENTIATED
bc
BASEMENT COMPLEX
Marker Bed W
Marker Bed X
Marker Bed Y
Sand, Gravel, Cobbles
Sand and Gravel
Sand and Smaller Gravel
Sand, Gravel, 20% Silty Clay
Sand, Gravel, 30% Silty Clay
Dark Yellow Orange F-C Gravelly Sand with Pebbles
Gravelly Clayey F-C Sand
Dark Yellow Orange Gravelly F-C Sand with Pebbles
F-C Sand, Some Gravel
Gravelly M-C Sand
Dark Yellow Orange Clayey Gravelly F-C Sand with Pebbles
Sand and Big Gravel
F Sand and Small Gravel
F Sand and Very Small Gravel, Hard Drilling
Very Hard Drilling, Looks Like Bedrock
Rocks, Sand, "Decomposed Granite"
Sand, "DG" and Clay Layers
Sandy "DG"
Sandy "DG" and Clay Layers
Sand and "DG"
TD 1022'
TD 620'
TD 411'
TD 450'
RS-1 75-95 (A)
RS-1 175-195 (B)
RS-1 355-375 (C)
RS-1 580-600 (D)
Geology Adapted From :
MORTON and MILLER (USGS, 2003, OFR 03-293)
STAMOS, et al. (USGS, 2001)
DWR (1967) BULLETIN No. 84
DIBBLEE (USGS, 1960a, 1960b, 1967)
BADER, PAGE, AND DUTCHER (1959)
Following L.F. NOBLE (1953, 1954)
LEGEND
APPROXIMATE UNCONFORMABLE GEOLOGIC CONTACT
APPROXIMATE GRADATIONAL GEOLOGIC CONTACT
PERFORATION INTERVAL IN WELLS
PERFORATION INTERVAL IN NESTED MONITORING WELLS
TD = TOTAL DEPTH OF WELL CASING
REPORTED ELEVATION OF WATER, OCTOBER 2005
WATER ELEVATION, OCTOBER 2005, INTERPOLATED FROM RCS GROUNDWATER ELEVATION CONTOUR MAP
WATER LEVEL ELEVATION, OCTOBER 2005, FOR NESTED GROUNDWATER MONITORING WELLS; LETTERS A, B, C, AND D REPRESENT EACH RESPECTIVE PERFORATION DEPTH INTERVAL
STIFF WATER QUALITY PATTERN DIAGRAM, SHOWING PERFORATION ZONE 1994 SAMPLE YEAR
NOTE:
Words written next to each well were abstracted from driller's log
F = fine-grained; VF = very fine-grained
C = coarse-grained; VC = very Coarse-grained
SCALE
1 INCH = 500 FEET HORIZONTAL
1 INCH = 100 FEET VERTICAL
VERTICAL EXAGGERATION = 5X
Richard C. Slade & Associates LLC
Consulting Groundwater Geologists
Project No: 195-01
Date: August 2008
Author: LVS/RCS
PLATE 2.2
GEOLOGIC
CROSS SECTION B-B'
12750 Ventura Blvd., Ste. 202, Studio City, CA 91604
Phone: (818) 506-0418 Fax: (818) 506-1343

W
C
NE
C'
ELEVATION ABOVE SEA LEVEL (IN FEET)
4N-4W/3A2-A4
USGS SANTA FE #1
NESTED MONITORING WELL
4N-4W/1C2-C5
USGS JESS RANCH #1
NESTED MONITORING WELL
MOJAVE RIVER
INTERSECTION WITH E-E'
5N-3W/31N
PROJECTED 500''
AVR
Marker Bed W
Marker Bed X
Marker Bed Y
QTof
VERY OLD FAN DEPOSITS
Qca
CHANNEL ALLUVIUM
Qc
ACTIVE CHANNEL DEPOSITS
Qoc
ABANDONED CHANNEL DEPOSITS
Qya
YOUNG ALLUVIAL-VALLEY DEPOSITS
QTof
QTHcu
HAROLD AND CROWDER FORMATIONS UNDIFFERENTIATED
QThcu
TD 798'
TD 620'
TD 450'
TD 490'
TD 400'
Santa Fe 340-360 (B)
Santa Fe 490-510 (C)
Santa Fe 770-790 (D)
Jess Ranch 60-80 (A)
Jess Ranch 170-190 (B)
Jess Ranch 310-330 (C)
Jess Ranch 590-610 (D)
bc
LEGEND
APPROXIMATE UNCONFORMABLE GEOLOGIC CONTACT
APPROXIMATE GRADATIONAL GEOLOGIC CONTACT
PERFORATION INTERVAL IN WELLS
PERFORATION INTERVALS IN NESTED MONITORING WELLS
TD = TOTAL DEPTH OF WELL CASING
REPORTED ELEVATION OF WATER, OCTOBER 2005
WATER ELEVATION, OCTOBER 2005, INTERPOLATED FROM RCS GROUNDWATER ELEVATION CONTOUR MAP
WATER LEVEL ELEVATION, OCTOBER 2005, FOR NESTED GROUNDWATER MONITORING WELLS; LETTERS A, B, C, AND D REPRESENT EACH RESPECTIVE PERFORATION DEPTH INTERVAL
STIFF WATER QUALITY PATTERN DIAGRAM] SHOWING SAMPLE DATE
STIFF WATER QUALITY PATTERN DIAGRAM, SHOWING PERFORATION ZONE AND SAMPLE DATE
BASEMENT COMPLEX
NOTE:
Words written next to each well were abstracted from driller's log
F = fine-grained; VF = very fine-grained
C = coarse-grained; VC = very Coarse-grained
SCALE
1 INCH = 500 FEET HORIZONTAL
1 INCH = 100 FEET VERTICAL
VERTICAL EXAGGERATION = 5X
Geology Adapted From:
MORTON and MILLER (USGS, 2003, OFR 03-293)
STAMOS, et al. (USGS, 2001)
DWR (1967) BULLETIN No. 84
DIBBLEE (USGS, 1960a, 1960b, 1967)
BADER, PAGE, AND DUTCHER (1959)
Following L.F. NOBLE (1953, 1954)
Richard C. Slade & Associates LLC
Consulting Groundwater Geologists
Project No: 195-01
Date: August 2008
Author: LVS/RCS
PLATE 2.3
GEOLOGIC CROSS SECTION C-C'
12750 Ventura Blvd., Ste. 202, Studio City, CA 91604
Phone: (818) 506-0418 Fax: (818) 506-1343

SW
E
D
D'
ELEVATION ABOVE SEA LEVEL (IN FEET)
5N-4W/34J
VVWD TH-32
5N-4W/28R
COUNTY OF SAN BERNARDINO
WELL #4
MOJAVE RIVER
AVR
INTERSECTION WITH E-E'
5N-3W/30A1-A3
USGS RINCON ROAD
(YUCCA LOMA)
NESTED MONITORING WELL
YOUNG FAN DEPOSITS
Qyf
Qya
YOUNG ALLUVIAL-VALLEY DEPOSITS
Qca
CHANNEL ALLUVIUM
Qc
ACTIVE CHANNEL DEPOSITS
Qoc
ABANDONED CHANNEL DEPOSITS
QTof
VERY OLD FAN DEPOSITS
Marker Bed W
Marker Bed X
Marker Bed Y
QThcu
HAROLD AND CROWDER FORMATIONS UNDIFFERENTIATED
QTh
HAROLD FORMATION
Tc
CROWDER FORMATION
bc
BASEMENT COMPLEX
TD 1510'
TD 403'
TD 550'
TD 300'
Gray-Brown Sandy Clay
Sand and Gravel
Brown Clay
F-C Sand, F Gravel
Brown-Gray Clay
Sand
Brown-Maroon Clay
Thin Lenses of C Sand and Gravel, Gray-Brown Clay
Gray Silty Clay with White, Brown, Maroon Lenses
F-C Sand, Gray Clay
Gray Clay, Slightly Sandy
Gray Clay
F-C Sand, F-M Gravel, Weathered Granitic Fragments
Brown Sandy Clay
C Sand, Gravel
Sand and Fractured Quartzite Gravel
Massive C Sand
Gray-Green Clay
Red-Brown-Orange Sand, Mineral Fragments, Very Slow Drilling
Sand and Boulders
Sand and Brown Clay
Sand and Clay
Gravelly C Sand
Silty F Sand
Sandy Clay and Clay
Clayey Sand
C Sand
Interbedded C Sand and Clay
Gravelly C Sand
Sandy Clay
M-C Sand and Gravel
M-C Sand and Cobble Fragments
C Sand and Gravel
C Sand and Clay
F-M Sand
Clay, Some Sand
F-C Sand and Clay
F Sand and Sandstone Fragments
Yellow-Brown F-C Sand
C Sand, Gravel, Light Olive-Gray Clay "Blebs"
Gravel, Rock Fragments, Light Olive-Gray Clay "Clumps"
"Top Soil"
Rincon Road 185-195 (A)
Rincon Road 218-228 (B)
Rincon Road 270-280 (C)
Geology Adapted From:
MORTON and MILLER (USGS, 2003, OFR 03-293)
STAMOS, et al. (USGS, 2001)
DWR (1967) BULLETIN No. 84
DIBBLEE (USGS, 1960a, 1960b, 1967)
BADER, PAGE, AND DUTCHER (1959)
Following L.F. NOBLE (1953, 1954)
LEGEND
APPROXIMATE UNCONFORMABLE GEOLOGIC CONTACT
APPROXIMATE GRADATIONAL GEOLOGIC CONTACT
PERFORATION INTERVAL IN WELLS
TD = TOTAL DEPTH OF WELL CASING
REPORTED ELEVATION OF WATER, OCTOBER 2005
WATER ELEVATION, OCTOBER 2005, INTERPOLATED FROM RCS GROUNDWATER ELEVATION CONTOUR MAP
WATER LEVEL ELEVATION FOR NESTED GROUNDWATER MONITORING WELLS; LETTERS A, B, AND C REPRESENT EACH RESPECTIVE PERFORATION DEPTH INTERVAL
STIFF WATER QUALITY PATTERN DIAGRAM
PERFORATION INTERVAL IN NESTED MONITORING WELLS
NOTE:
Words written next to each well were abstracted from driller's log
F = fine-grained; VF = very fine-grained
C = coarse-grained; VC = very Coarse-grained
SCALE
1 INCH = 500 FEET HORIZONTAL
1 INCH = 100 FEET VERTICAL
VERTICAL EXAGGERATION = 5X
Richard C. Slade & Associates LLC
Consulting Groundwater Geologists
Project No: 195-01
Date: August 2008
Author: LVS/RCS
PLATE 2.4
GEOLOGIC
CROSS SECTION D-D'
6442 Coldwater Canyon Ave., Ste. 214, North Hollywood, CA 91606
Phone: (818) 506-0418 Fax: (818) 506-1343

LEGEND

APPROXIMATE UNCONFORMABLE GEOLOGIC CONTACT

APPROXIMATE GRADATIONAL GEOLOGIC CONTACT

PERFORATION INTERVAL IN WELLS

A B C D PERFORATION INTERVAL IN NESTED MONITORING WELLS

TD = TOTAL DEPTH OF WELL CASING

REPORTED ELEVATION OF WATER, OCTOBER 2005

est. WATER ELEVATION, OCTOBER 2005, INTERPOLATED FROM RCS GROUNDWATER ELEVATION CONTOUR MAP

A WATER LEVEL ELEVATION, OCTOBER 2005, FOR NESTED GROUNDWATER MONITORING WELLS; LETTERS A, B, C, AND D REPRESENT EACH RESPECTIVE PERFORATION DEPTH INTERVAL

STIFF WATER QUALITY PATTERN DIAGRAM SHOWING SAMPLE DATE

STIFF WATER QUALITY PATTERN DIAGRAM, SHOWING PERFORATION ZONE AND SAMPLE DATE

STIFF WATER QUALITY PATTERN DIAGRAM, SHOWING PERFORATION ZONE 1994 SAMPLE YEAR

Geology Adapted From

MORTON and MILLER (USGS, 2003, OFR 03-293)

STAMOS, et al. (USGS, 2001)

DWR (1967) BULLETIN No. 84

DIBBLEE (USGS, 1960a, 1960b, 1967)

BADER, PAGE, AND DUTCHER (1959)

Following L.F. NOBLE (1953, 1954)

NOTE:
Words written next to each well were abstracted from driller's log
F = fine-grained; VF = very fine-grained
C = coarse-grained; VC = very Coarse-grained

SCALE

1 INCH = 1000 FEET HORIZONTAL

1 INCH = 100 FEET VERTICAL

VERTICAL EXAGGERATION = 10X

Richard C. Slade & Associates LLC
Consulting Groundwater Geologists

Project No: 195-01

Date: August 2008

Author: LVS/RCS

PLATE 2.5 GEOLOGIC CROSS SECTION E - E'

Projection: Custom Projection

12750 Ventura Blvd., Ste. 202, Studio City, CA 91604
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Legend
MWA Monitoring Wells
Apple Valley Rancho Water District (AVRWD) Well Location
Victor Valley Water District (VVWD) Well Location
Victor Valley Water District Test Hole Location
County of San Bernardino Service Area 64-J (CSA-64J) Well Location
Rancho Las Flores (RFL) Well Location
City of Hesperia Well Location
Approximate Stream Gage Location
Private Wells with Driller's Log Used for Cross Section Correlation
Oil Well Location
Lower Narrows Stream Gage
Approximately 4 Miles North
Upper Narrows - MW
Rincon Rd. - MW
A.V. Ranchos - MW
Jess Ranch-1 - MW
SF-1 - MW
RS-1 - MW
Deep Creek-1 - MW
Deep Creek Gage
West Fork Gage
T5N
T4N
T3N
R4W
R3W
APPLE VALLEY RD
THUNDERBIRD RD
RANCHERIAS RD
SENECA RD
YATES RD
GREEN TREE BLVD
NISQUALLI RD
BEAR VALLEY RD
MOJAVE DR
CIVIC DR
3RD AV
RIDGECREST RD
SPRING VALLEY PKWY
HESPERIA RD
PEACH AV
BALSAM RD
BALSAM AV
7TH AV
EUCALYPTUS ST
LEMON ST
MAIN ST
ROCK SPRINGS RD
DANBURY AV
MESQUITE ST
CHOICEANA AV
ARROWHEAD LAKE RD
DEEP CREEK RD
KIOWA RD
NAVAJO RD
CENTRAL RD
TUSSING RANCH RD
MOJAVE RIVER
APPLE VALLEY
Hesperia
VVWD 13
VVWD 33
VVWD 5
VVWD 36
VVWD 27
VVWD 2
VVWD 6
VVWD 35
VVWD 11
VVWD 41
VVWD 10
VVWD 9
VVWD 18
VVWD 31
VVWD 16
VVWD 45
VVWD 39
VVWD 43
VVWD 22
VVWD TH-32
VVWD 20
VVWD 40
CSA-64J No. 4
CSA-64J No. 1
CSA-64J No. 6
05N03W031N
04N03W06E04
Albert Crooks Inland 1
The Orl Oil Co. Orl 1
04N04W12G3
04N04W12Q02
04N03W17H01
04N04W13J01
04N03W19B07
04N03W21D01
04N03W19M01
04N03W19J06
04N03W20G04
04N03W19Q06
04N03W20R01
04N03W30B01
04N03W30C01
04N03W29B03
04N03W28E03
04N03W28E05
04N03W30K03
04N03W31J09
04N03W31R06
03N03W06C12
03N03W06H02
03N04W01K04
03N04W01K09
03N04W12K02
03N03W07M04
03N04W13B03
Hesperia Well 14B
Hesperia Well 14A
Hesperia Well 20
Hesperia Well 25
Hesperia Well 4A
Hesperia Well 3A
Hesperia Oil & Gas Co. of Calif. 1
Hesperia Oil & Gas Co. of Calif. 1-A
Hesperia Well 15A
Hesperia Well 24
Hesperia Well 17
Hesperia Well 5A
Hesperia Well 21
Hesperia Well 22B
Hesperia Well 7A
Hesperia Well 22
RLF TH-1 at Aqueduct Crossing
RLF 22K1
RLF 20P1
RLF 20N3
RLF 27G1
RLF 26D1
RLF 26B2
RLF Mesa Well (No. 2)
2000 0 2000 4000 6000
Richard C. Slade & Associates LLC
Consulting Groundwater Geologists
Project No: 195-01
Date: August 2008
Author: CGW
Filename: Plate_3_Well_Location_Map.WOR
Plate 3
Well Location Map
12750 Ventura Blvd., Ste. 202, Studio City, CA 91604
Phone: (818) 506-0418 Fax: (818) 506-1343

RCS Richard C. Slade & Associates LLC
Consulting Groundwater Geologists

Project No: 195-01
Date: August 2008
Author: CGW
Filename: PctClay_00to20Ft.WOR
Projection California 0405, Zone V (1927)

Plate 4.1
Percent Clay Map
00 to 20 ft bgs

12750 Ventura Blvd., Ste. 202, Studio City, CA 91604
Phone: (818) 506-0418 Fax: (818) 506-1343


% Clay Map:
20 to 40 ft bgs
Legend
Well with RCS Selected Driller's Log (Showing Clay Percent)
MWA Nested Monitoring Well with Driller's Log (Showing Clay Percent)
Percent Clay Contour Interval, in feet, Generated by Computer
General Area Where Clay Percentage is Generally Greater than or Equal to 60 Percent
Roads
Approximate Active Trace of the Mojave River (Based on Geologic Mapping by Others)
Service Area Boundaries
Apple Valley Heights Co.Water District
Mariana Ranchos Co. Water District
Southern California Water Comapny
Apple Valley Ranchos Water District
Apple Valley Foothill Co. Water District
Rancheritos Mutual Water Company
Navajo Mutual Water Company
Hesperia Water District
San Bernardino County Service Area
Victor Valley Water District
City Boundaries
City of Apple Valley
City of Victorville
City of Hesperia
T6N
T5N
T4N
T3N
R4W
R3W
WAALEW RD
CORWIN RD
STODDARD WELLS RD
VILLAGE DR
6TH ST
HESPERIA RD
MOJAVE DR
7TH ST
ROY ROGERS DR
APPLE VALLEY RD
RANCHERIAS RD
THUNDERBIRD RD
NAVAJO RD
SENECA RD
YATES RD
SPRING VALLEY PKWY
GREEN TREE BLVD
RIDGECREST RD
3RD AV
NISQUALLI RD
KIOWA RD
BEAR VALLEY RD
7TH AV
EUCALYPTUS ST
PEACH AV
DEEP CREEK RD
CENTRAL RD
TUSSING RANCH RD
LEMON ST
C AV
CHOCEANA AV
MAIN ST
ROCK SPRINGS RD
DANBURY AV
ARROWHEAD LAKE RD
Feet
Richard C. Slade & Associates LLC
Consulting Groundwater Geologists
Project No: 195-01
Date: August 2008
Author: CGW
Filename: PctClay_20to 40Ft.WOR
Projection California 0405, Zone V (1927)
Plate 4.2
Percent Clay Map
20 to 40 ft bgs
12750 Ventura Blvd., Ste. 202, Studio City, CA 91604
Phone: (818) 506-0418 Fax: (818) 506-1343

Plate 4.3
Percent Clay Map
40 to 60 ft bgs


% Clay Map:
60 to 80 ft bgs
Legend
Well with RCS Selected Driller's Log (Showing Clay Percent)
MWA Nested Monitoring Well with Driller's Log (Showing Clay Percent)
Percent Clay Contour Interval, in feet, Generated by Computer
General Area Where Clay Percentage is Generally Greater than or Equal to 60 Percent
Roads
Approximate Active Trace of the Mojave River (Based on Geologic Mapping by Others)
Service Area Boundaries
Apple Valley Heights Co.Water District
Mariana Ranchos Co. Water District
Southern California Water Comapny
Apple Valley Ranchos Water District
Apple Valley Foothill Co. Water District
Rancheritos Mutual Water Company
Navajo Mutual Water Company
Hesperia Water District
San Bernardino County Service Area
Victor Valley Water District
City Boundaries
City of Apple Valley
City of Victorville
City of Hesperia
T6N
T5N
T4N
T3N
R4W
R3W
WAALEW RD
CORWIN RD
STODDARD WELLS RD
VILLAGE DR
6TH ST
HESPERIA RD
MOJAVE DR
7TH ST
ROY ROGERS DR
APPLE VALLEY RD
RANCHERIAS RD
THUNDERBIRD RD
NAVAJO RD
SENECA RD
YATES RD
SPRING VALLEY PKWY
GREEN TREE BLVD
RIDGECREST RD
3RD AV
NISQUALLI RD
KIOWA RD
BEAR VALLEY RD
7TH AV
I AV
PEACH AV
DEEP CREEK RD
EUCALYPTUS ST
CENTRAL RD
TUSSING RANCH RD
LEMON ST
CHOICEANA AV
C AV
MAIN ST
ROCK SPRINGS RD
DANBURY AV
ARROWHEAD LAKE RD
2000 0 2000 4000 6000
Feet
RCS
Richard C. Slade & Associates LLC
Consulting Groundwater Geologists
Project No: 195-01
Date: August 2008
Author: CGW
Filename: PctClay_60to80Ft.WOR
Projection: California 0405, Zone V (1927)
Plate 4.4
Percent Clay Map
60 to 80 ft bgs
12750 Ventura Blvd., Ste. 202, Studio City, CA 91604
Phone: (818) 506-0418 Fax: (818) 506-1343

% Clay Map:
80 to 100 ft bgs
Legend
Well with RCS Selected Driller's Log (Showing Clay Percent)
MWA Nested Monitoring Well with Driller's Log (Showing Clay Percent)
Percent Clay Contour Interval, in feet, Generated by Computer
General Area Where Clay Percentage is Generally Greater than or Equal to 60 Percent
Roads
Approximate Active Trace of the Mojave River (Based on Geologic Mapping by Others)
Service Area Boundaries
Apple Valley Heights Co.Water District
Mariana Ranchos Co. Water District
Southern California Water Comapny
Apple Valley Ranchos Water District
Apple Valley Foothill Co. Water District
Rancheritos Mutual Water Company
Navajo Mutual Water Company
Hesperia Water District
San Bernardino County Service Area
Victor Valley Water District
City Boundaries
City of Apple Valley
City of Victorville
City of Hesperia
T6N
T5N
T4N
T3N
R4W
R3W
WAALEW RD
CORWIN RD
STODDARD WELLS RD
VILLAGE DR
6TH ST
HESPERIA RD
MOJAVE DR
7TH ST
ROY ROGERS DR
APPLE VALLEY RD
RANCHERIAS RD
THUNDERBIRD RD
NAVAJO RD
SENECA RD
YATES RD
SPRING VALLEY PKWY
GREEN TREE BLVD
RIDGECREST RD
3RD AV
NISQUALLI RD
KIOWA RD
BEAR VALLEY RD
7TH AV
I AV
PEACH AV
EUCALYPTUS ST
DEEP CREEK RD
CENTRAL RD
TUSSING RANCH RD
LEMON ST
C AV
CHOICEANA AV
MAIN ST
ROCK SPRINGS RD
DANBURY AV
ARROWHEAD LAKE RD
Feet
2000
0
2000
4000
6000
N
E
S
W
Richard C. Slade & Associates LLC
Consulting Groundwater Geologists
Project No: 195-01
Date: August 2008
Author: CGW
Filename: PctClay_80to100Ft.WOR
Projection California 0405, Zone V (1927)
Plate 4.5
Percent Clay Map
80 to 100 ft bgs
12750 Ventura Blvd., Ste. 202, Studio City, CA 91604
Phone: (818) 506-0418 Fax: (818) 506-1343

% Clay Map:
100 to 120 ft bgs
Legend
Well with RCS Selected Driller's Log (Showing Clay Percent)
MWA Nested Monitoring Well with Driller's Log (Showing Clay Percent)
Percent Clay Contour Interval, in feet, Generated by Computer
General Area Where Clay Percentage is Generally Greater than or Equal to 60 Percent
Roads
Approximate Active Trace of the Mojave River (Based on Geologic Mapping by Others)
Service Area Boundaries
Apple Valley Heights Co.Water District
Mariana Ranchos Co. Water District
Southern California Water Comapny
Apple Valley Ranchos Water District
Apple Valley Foothill Co. Water District
Rancheritos Mutual Water Company
Navajo Mutual Water Company
Hesperia Water District
San Bernardino County Service Area
Victor Valley Water District
City Boundaries
City of Apple Valley
City of Victorville
City of Hesperia
T6N
T5N
T4N
T3N
R4W
R3W
WAALEW RD
CORWIN RD
STODDARD WELLS RD
VILLAGE DR
6TH ST
HESPERIA RD
MOJAVE DR
7TH ST
APPLE VALLEY RD
RANCHERIAS RD
THUNDERBIRD RD
NAVAJO RD
ROY ROGERS DR
SENECA RD
YATES RD
GREEN TREE BLVD
SPRING VALLEY PKWY
RIDGECREST RD
3RD AV
NISQUALLI RD
KIOWA RD
BEAR VALLEY RD
7TH AV
PEACH AV
DEEP CREEK RD
EUCALYPTUS ST
CENTRAL RD
LEMON ST
TUSSING RANCH RD
C AV
CHOICEANA AV
MAIN ST
ROCK SPRINGS RD
DANBURY AV
ARROWHEAD LAKE RD
Feet
RCS
Richard C. Slade & Associates LLC
Consulting Groundwater Geologists
Project No: 195-01
Date: August 2008
Author: CGW
Filename: PctClay_100to120Ft.WOR
Plate 4.6
Percent Clay Map
100 to 120 ft bgs
12750 Ventura Blvd., Ste. 202, Studio City, CA 91604
Phone: (818) 506-0418 Fax: (818) 506-1343

Richard C. Slade & Associates LLC
Consulting Groundwater Geologists

Project No: 195-01
Date: August 2008
Author: CGW
Filename: PctClay_120to140Ft.WOR
Projection: California 0405, Zone V (1927)

Plate 4.7
Percent Clay Map
120 to 140 ft bgs

12750 Ventura Blvd., Ste. 202, Studio City, CA 91604
Phone: (818) 506-0418 Fax: (818) 506-1343

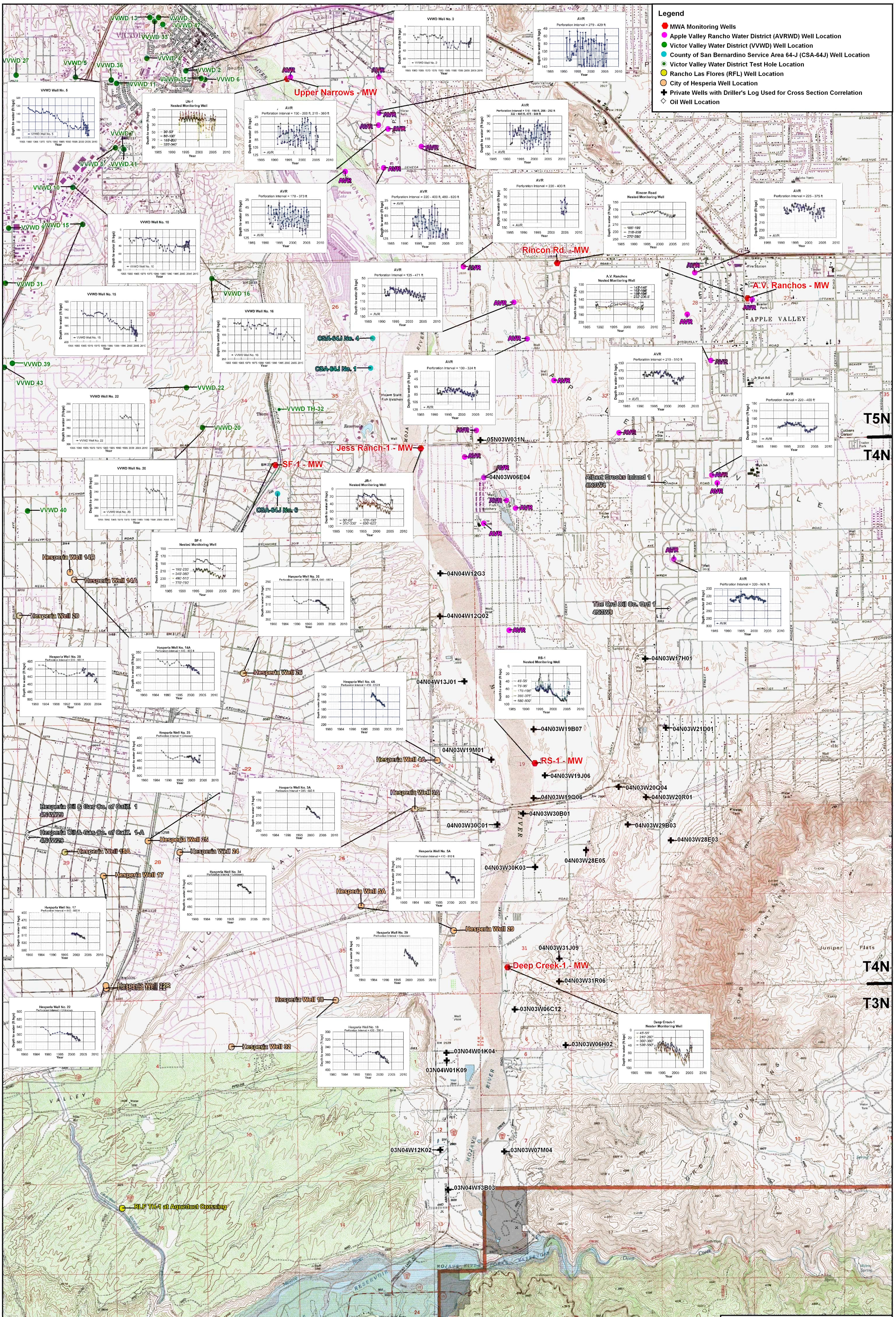
Plate 4.8
Percent Clay Map
140 to 160 ft bgs


% Clay Map
160 to 180 ft bgs
Legend
Well with RCS Selected Driller's Log (Showing Clay Percent)
MWA Nested Monitoring Well with Driller's Log (Showing Clay Percent)
Percent Clay Contour Interval, in feet, Generated by Computer
General Area Where Clay Percentage is Generally Greater than or Equal to 60 Percent
Roads
Approximate Active Trace of the Mojave River (Based on Geologic Mapping by Others)
Service Area Boundaries
Apple Valley Heights Co.Water District
Mariana Ranchos Co. Water District
Southern California Water Comapny
Apple Valley Ranchos Water District
Apple Valley Foothill Co. Water District
Rancheritos Mutual Water Company
Navajo Mutual Water Company
Hesperia Water District
San Bernardino County Service Area
Victor Valley Water District
City Boundaries
City of Apple Valley
City of Victorville
City of Hesperia
T6N
T5N
T4N
T3N
R4W
R3W
WAALEW RD
CORWIN RD
APPLE VALLEY RD
RANCHERIAS RD
THUNDERBIRD RD
NAVAJO RD
SENECA RD
YATES RD
SPRING VALLEY PKWY
RIDGECREST RD
KIOWA RD
BEAR VALLEY RD
DEEP CREEK RD
CENTRAL RD
TUSSING RANCH RD
STODDARD WELLS RD
HESPERIA RD
6TH ST
7TH ST
MOJAVE DR
VILLAGE DR
ROY ROGERS DR
GREEN TREE BLVD
3RD AV
NISQUALLI RD
7TH AV
PEACH AV
EUCALYPTUS ST
LEMON ST
CHOICEANA AV
C AV
MAIN ST
ROCK SPRINGS RD
DANBURY AV
ARROWHEAD LAKE RD
Feet
2000 0 2000 4000 6000
Richard C. Slade & Associates LLC
Consulting Groundwater Geologists
Project No: 195-01
Date: August 2008
Author: CGW
Filename: PctClay_160to180Ft.WOR
Projection: California 0405, Zone V (1927)
Plate 4.9
Percent Clay Map
160 to 180 ft bgs
12750 Ventura Blvd., Ste. 202, Studio City, CA 91604
Phone: (818) 506-0418 Fax: (818) 506-1343


% Clay Map:
180 to 200 ft bgs
Legend
Well with RCS Selected Driller's Log (Showing Clay Percent)
MWA Nested Monitoring Well with Driller's Log (Showing Clay Percent)
Percent Clay Contour Interval, in feet, Generated by Computer
General Area Where Clay Percentage is Generally Greater than or Equal to 60 Percent
Roads
Approximate Active Trace of the Mojave River (Based on Geologic Mapping by Others)
Service Area Boundaries
Apple Valley Heights Co.Water District
Mariana Ranchos Co. Water District
Southern California Water Comapny
Apple Valley Ranchos Water District
Apple Valley Foothill Co. Water District
Rancheritos Mutual Water Company
Navajo Mutual Water Company
Hesperia Water District
San Bernardino County Service Area
Victor Valley Water District
City Boundaries
City of Apple Valley
City of Victorville
City of Hesperia
T6N
T5N
T5N
T4N
T4N
T3N
R4W
R3W
WAALEW RD
CORWIN RD
STODDARD WELLS RD
VILLAGE DR
6TH ST
HESPERIA RD
MOJAVE DR
7TH ST
ROY ROGERS DR
APPLE VALLEY RD
RANCHERIAS RD
THUNDERBIRD RD
NAVAJO RD
SENECA RD
YATES RD
SPRING VALLEY PKWY
GREEN TREE BLVD
RIDGECREST RD
3RD AV
NISQUALLI RD
KIOWA RD
BEAR VALLEY RD
7TH AV
HESPERIA RD
I AV
PEACH AV
DEEP CREEK RD
EUCALYPTUS ST
CENTRAL RD
TUSSING RANCH RD
LEMON ST
CHOICEANA AV
C AV
MAIN ST
MAIN ST
DEEP CREEK RD
ROCK SPRINGS RD
DANBURY AV
ARROWHEAD LAKE RD
2000
0
2000
4000
6000
Feet
Richard C. Slade & Associates LLC
Consulting Groundwater Geologists
Project No: 195-01
Date: August 2008
Author: CGW
Filename: PctClay_180to 200Ft.WOR
Projection California 0405, Zone V (1927)
Plate 4.10
Percent Clay Map
180 to 200 ft bgs
12750 Ventura Blvd., Ste. 202, Studio City, CA 91604
Phone: (818) 506-0418 Fax: (818) 506-1343

Legend
MWA Monitoring Wells
Apple Valley Rancho Water District (AVRWD) Well Location
Victor Valley Water District (VVWD) Well Location
Victor Valley Water District Test Hole Location
County of San Bernardino Service Area 64-J (CSA-64J) Well Location
Rancho Las Flores (RFL) Well Location
City of Hesperia Well Location
Wells with Driller's Log
Oil Well Location
Simplified Fault Line, Approximate Location
Well With Static Water Level Data for October 2005 Showing Water Level Elevation (ft asl)
Groundwater Elevation Contour for October 2005 (ft asl) Contour Interval = 10 ft
Arrows Show Direction of Groundwater Flow
Upper Narrows - MW
Rincon Rd. - MW
A.V. Ranchos - MW
Jess Ranch-1 - MW
SF-1 - MW
Fish Hatchery
Fish Hatchery Recharge
RS-1 - MW
Deep Creek-1 - MW
MOJAVE DR
ROY ROGERS DR
APPLE VALLEY RD
SENECA RD
RANCHERIAS RD
YATES RD
SPRING VALLEY PKWY
GREEN TREE BLVD
NISQUALLI RD
BEAR VALLEY RD
EUCALYPTUS ST
HESPERIA RD
PEACH AV
7TH AV
3RD AV
LEMON ST
TUSSING RANCH RD
DEEP CREEK RD
KIOWA RD
CENTRAL RD
MAIN ST
ROCK SPRINGS RD
DANBURY AV
MESQUITE ST
ARROWHEAD LAKE RD
CHOICEANA AV
BALSAM RD
CIVIC DR
T5N
T4N
T3N
R4W
R3W
Richard C. Slade & Associates LLC
Consulting Groundwater Geologists
Project No: 195-01
Date: August 2008
Author: MAW/ASH
Filename: Plate 5.1 Groundwater Contour.WOR
Projection California 0405, Zone V (1927)
Plate 5.1
Groundwater Elevation
Contour Map
May 2008
Topographic Base Map
12750 Ventura Blvd., Ste. 202, Studio City, CA 91604
Phone: (818) 506-0418 Fax: (818) 506-1343

Legend
MWA Monitoring Wells
Apple Valley Rancho Water District (AVRWD) Well Location
Victor Valley Water District (VVWD) Well Location
Victor Valley Water District Test Hole Location
County of San Bernardino Service Area 64-J (CSA-64J) Well Location
Rancho Las Flores (RFL) Well Location
City of Hesperia Well Location
Wells with Driller's Log
Oil Well Location
Simpified Fault Line, Approximate Location
Well With Static Water Level Data for October 2005 Showing Water Level Elevation (ft asl)
Groundwater Elevation Contour for October 2005 (ft asl) Contour Interval = 10 ft
Arrows Show Direction of Groundwater Flow
Upper Narrows - MW
Rincon Rd. - MW
A.V. Ranchos - MW
SF-1 - MW
Jess Ranch-1 - MW
RS-1 - MW
Deep Creek-1 - MW
Fish Hatchery
Fish Hatchery Recharge
APPLE VALLEY RD
RANCHERIAS RD
SENECA RD
MOJAVE DR
ROY ROGERS DR
GREEN TREE BLVD
NISQUALLI RD
BEAR VALLEY RD
EUCALYPTUS ST
LEMON ST
MAIN ST
ROCK SPRINGS RD
DANBURY AV
MESQUITE ST
TUSSING RANCH RD
DEEP CREEK RD
ARROWHEAD LAKE RD
T5N
T4N
T3N
R4W
R3W
Qyf
Qoa
Qya
Qc
Qca
Qoc
QTof
QThcu
Qof
bc
2000 0 2000 4000 6000
Feet
Richard C. Slade & Associates LLC
Consulting Groundwater Geologists
Project No: 195-01
Date: August 2008
Author: MAW/ASH
Filename: Plate 5.2_GW Elevation_ Contour.WOR
Projection California 0405, Zone V (1927)
Plate 5.2
Groundwater Elevation
Contour Map
May 2008
Geologic Base Map
12750 Ventura Blvd., Ste. 202, Studio City, CA 91604
Phone: (818) 506-0418 Fax: (818) 506-1343



Richard C. Slade & Associates LLC

Consulting Groundwater Geologists

Project No: 195-01

Date: August 2008

Author: MAW

Filename: Plate_6.WOR

Plate 6
Map of Hydrographs

Projection California 0405, Zone V (1927)

12750 Ventura Blvd., Ste. 202, Studio City, CA 91604
Phone: (818) 506-0418 Fax: (818) 506-1343

Legend
MWA Monitoring Wells
Apple Valley Rancho Water District (AVRWD) Well Location
Victor Valley Water District (VVWD) Well Location
County of San Bernardino Service Area 64-J (CSA-64J) Well Location
Victor Valley Water District Test Hole Location
Rancho Las Flores (RFL) Well Location
City of Hesperia Well Location
Private Wells with Driller's Log Used for Cross Section Correlation
Oil Well Location
Upper Narrows - MW
Rincon Rd. - MW
A.V. Ranchos - MW
Jess Ranch-1 - MW
SF-1 - MW
RS-1 - MW
Deep Creek-1 - MW
NOTE: THESE WATER QUALITY DATA ARE PRE-2000 WITH THE EXCEPTION OF ARSENIC
T5N
T4N
T3N
R4W
R3W
Richard C. Slade & Associates LLC
Consulting Groundwater Geologists
Project No: 195-01
Date: August 2008
Author: MAW
Plate 7.1
Stiff Water Quality Pattern Diagram Map
12750 Ventura Blvd., Ste. 202, Studio City, CA 91604
Phone: (818) 506-0418 Fax: (818) 506-1343

RCS Richard C. Slade & Associates LLC
Consulting Groundwater Geologists

Project No: 195-01

Date: August 2008

Author: MAW

Filename: Plate 7.1 Stiff Water Quality Map.WOR

Projection California 0405, Zone V (1927)

Plate 7.2
Stiff Water Quality Pattern Diagram Map

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Phone: (818) 506-0418 Fax: (818) 506-1343