El Paso County, Colorado
Denver Basin Aquifer Resources

Evaluation of Extent and Reliability

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Moore Project No. 24632

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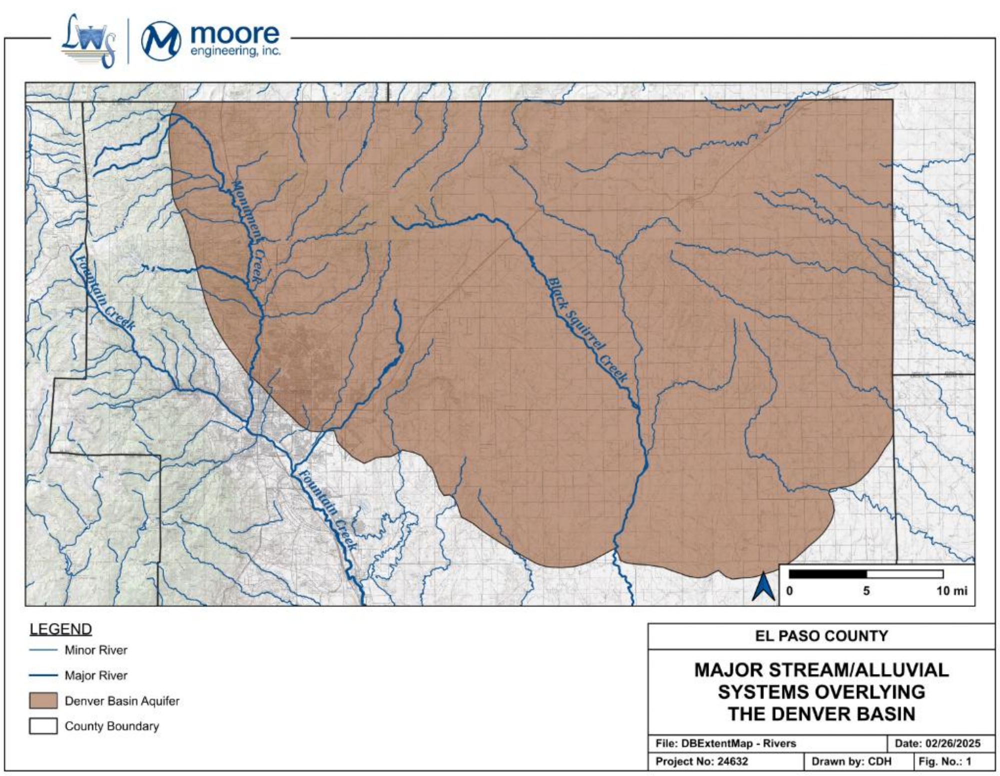
Executive Summary

The Colorado statutory methodology of assessing the annual allocation that can be extracted from the Denver Basin aquifers is based on an estimated aquifer life of 100 years. El Paso County implemented a 300-year rule in the 1980s related to the use of Denver Basin aquifer water in evaluating land use applications and the 300-year rule has been, and is currently, applied equally across the County as the available water supply to support land use applications.

Whether a 100-yr rule or a 300-yr rule is implemented related to land use development, the formula for calculating allocations is a very simplistic means, not accounting for the complex geology and hydrogeology, to estimate available water.. Accepting these simplifying assumptions leads to a misinterpretation of water supply availability in the Denver Basin aquifers as most, if not all, of these layers are fully saturated plus have confined pressure head on the water-bearing strata

Given the many factors that make the Denver Basin a very complex groundwater system, analysis of site-specific data is necessary to better assess water supply availability and reliability, although there will always be a measure of uncertainty in any analysis due to the complexity of the system and the lack of a comprehensive database across the County.

On the western edge of the Denver Basin the principal aquifers are bounded by the Precambrian granites of the Front Range so all four major formations and aquifers are present. To the east the Dawson aquifer outcrops, likely due to erosion of material over time and lack of depositional energy, while the other three principal aquifers generally are present to the eastern boundary of the County. To the south all of the Denver Basin aquifers outcrop within the County, i.e., the termination of the Denver Basin aquifer system (**Figure 1**).



Since there is a large geologic and hydrogeologic variability within the Denver Basin in the County, there can be significant differences between water that is legally available and water that can be physically produced on a reliable, long-term basis. Sustaining the available water supply while adapting to increased development and climatic concerns is of utmost importance to the County. Therefore, the analyses, results, and conclusions of our studies provide additional site-specific data to the County to make informed decisions on future water use policies.

Given our extensive understanding of the Denver Basin aquifer system, in this study we evaluated several factors, including:

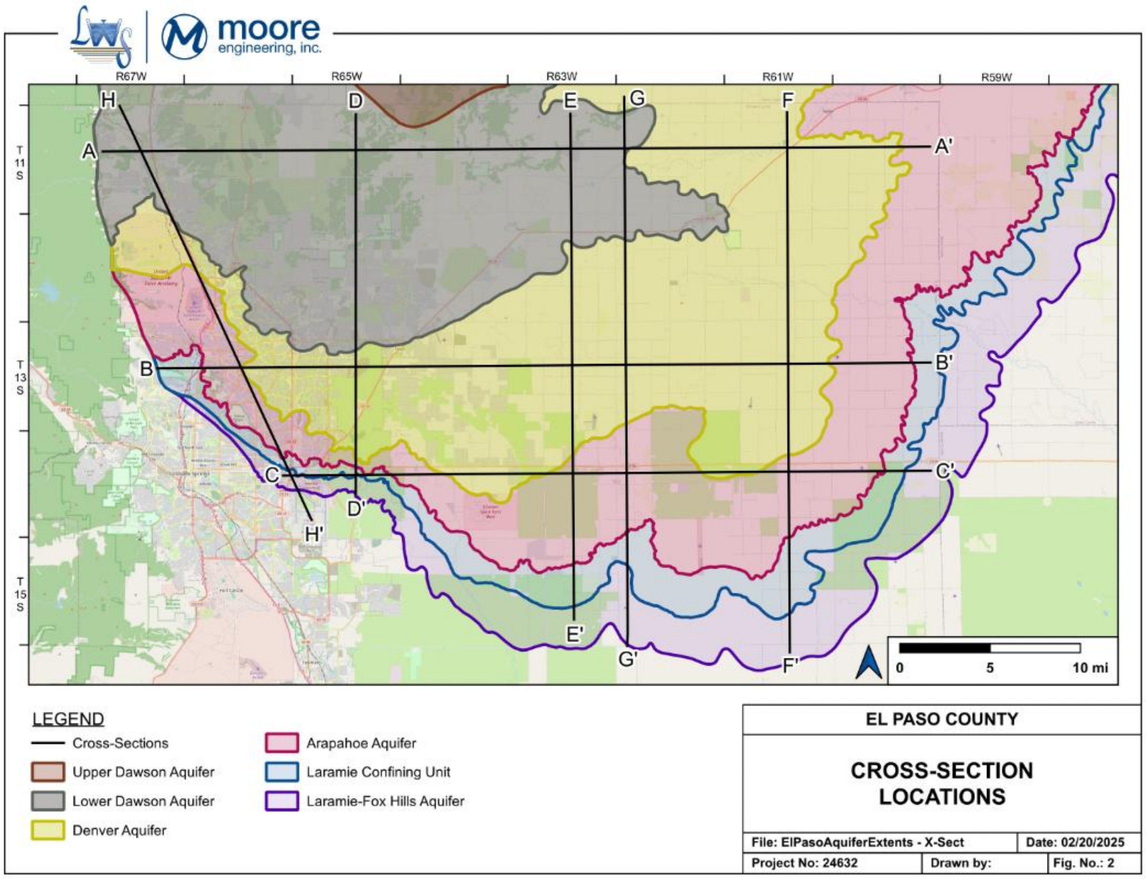
- an analysis of the structure of each of the Denver Basin aquifers within the County;
- an evaluation of the tops and bottoms of each aquifer along multiple north-south and west-east cross sections;
- development of time series hydrographs of water level changes within the aquifers over time, based on publicly-available sources and data provided by some water suppliers within the County;
- assessment of the condition of each aquifer across the County, i.e., fully confined or partially confined, and how those aquifer conditions have changed over time;
- assessment of areas that are potentially impacted by aquifer boundary conditions; and
- assessment of the physical reliability of the Denver Basin aquifers water supply across the County based on the above-described factors.

The analyses presented herein utilized the available geologic and hydrogeologic information to delineate the relative thicknesses of each Denver Basin formation across the County, including the aquifer outcrop/subcrop areas.

To obtain the most site-specific data on water level changes over time at existing Denver Basin aquifer wells, both the County and LWS requested water level hydrographs from all major municipal and quasi-municipal entities that are located within the Denver Basin in the County. The data obtained from these entities were supplemented with water level data from the Colorado Division of Water Resources ("CDWR"), which maintains a database of water levels for the four principal Denver Basin aquifers.

Water level data were collected going back to 1955 for some wells and in some aquifers; however, more emphasis was placed on recent water level data due to the changes occurring since that time. In addition, due to the lack of systematic water level readings over time, some of the data were difficult to interpret relative to whether the reading was a "static" water level versus a water level influenced by pumping of that well or a nearby well. For the long-term water level data, the trend in water levels over time was considered, in addition to fluctuations in water levels that were assumed to reflect pumping of the well.

Three west-east, four north-south, and one northwest to southeast hydrogeologic cross section locations were selected to represent the Denver Basin in El Paso County (**Figure 2**). The cross sections were used as a reference for interpreting water levels from the long-term hydrographs which could reasonably be projected onto the cross sections.



The primary objective in the interpretation of historical water levels on the hydrographs in each of the Denver Basin aquifers was to assess what is the current condition in each aquifer throughout the area underlain by the Denver Basin in the County, and how water levels may have changed over time relative to the tops of the aquifers. Significant water level declines into the aquifer, small aquifer saturated thicknesses, and/or aquifer boundary conditions are indicative of less reliable long term water supplies. Therefore, the hydrographs contain significant information for assessing (1) whether the water levels are above or below the tops of the aquifer, (2) how aquifer conditions may have changed over time, and (3) how reliable water supplies likely vary by location across the County.

While it is well established that water levels are declining in the Denver Basin aquifers to some degree in some areas of the basin, not all areas or all aquifers have the same level of susceptibility to a diminished ability to provide a reliable water supply over time. The level of susceptibility to a diminished reliable water supply over time can be related to (a) declining water levels below the tops of the aquifers, (b) heavily developed areas of the basin, (c) truncation of aquifers due to erosion, (d) no-flow boundaries or outcrops, (e) lack of recharge, or (f) a combination of these factors.

Our analysis considered each of these factors. The following are the key conclusions drawn from this study for each of the Denver Basin aquifers.

Dawson Aquifer

Given the limited extent of the Dawson aquifer in the County there is a significant portion of the aquifer where boundary conditions may affect well production. This, in turn, potentially limits well yields and, in addition, saturated thicknesses are relatively low in the Dawson aquifer which may limit well production capabilities. It is our opinion the Dawson aquifer is well suited to small diameter, low production wells for residential or small commercial uses. These uses will, in our opinion, result in long-term reliability and sustainability. Larger non-exempt uses such as municipal, industrial, or commercial could provide reliable supplies if the density of wells and/or level of use is minimized to be commensurate with the yields which provide full, or near full, recovery between pumping cycles. In this way water levels can be managed to minimize dewatering of the aquifer. Quantification of these parameters is beyond the scope of this study.

Denver Aquifer

With the available data for this study, the Denver aquifer has both substantial saturated thickness and water levels that are near, or above, the top of the formation. There are some areas in the northwestern quadrant of the County where Denver aquifer water levels have been shown to be below the top of the aquifer. To the east and the south the formation thins considerably over the large subcrop area of the formation, although the data indicate the aquifer generally remains fully saturated. There is no evidence of significant dewatering, even in areas of concentrated pumping in the northwestern quadrant of the County, based on the data available to us for this study.

Given the available data, it is our opinion that the Denver aquifer is a viable, reliable source of water for both residential and larger municipal and commercial uses over much of the aquifer extent in the County, although in areas on the eastern portion of the County the thickness of the formation thins considerably and likely is only a reliable water supply source for small residential wells. This is also likely true on the southern edge of the Denver Formation when wells are located within a few miles of the subcrop/outcrop.

Arapahoe Aquifer

The Arapahoe aquifer is generally the most heavily used aquifer in the County. This is because the Arapahoe aquifer in most parts of the basin is both the most productive aquifer and has the best water quality. The Arapahoe Formation is areally extensive across the County, reaching east beyond the eastern boundary of the County, but outcrops to the south along with all of the Denver Basin aquifers (pink in **Figure 2**).

In most areas of the basin in the County, the Arapahoe aquifer is still fully saturated, even in the southern area of the basin. This is likely due to the limited use of the Arapahoe aquifer in the thinner sections of the aquifer and where there is limited development. However, in the eastern portion of the County, there is some dewatering observed and it is known well production rates in this area is quite limited.

Given the available data, it is our opinion that the Arapahoe aquifer is a viable, reliable source of water for both residential and larger municipal and commercial uses over most of the area in the County covered by the Arapahoe Formation. However, in areas on the eastern and southern portions of the County the thickness of the formation thins considerably, and production rates are known to be low, this area may only be suited as a reliable water supply source for small residential wells or limited non-exempt uses.

Laramie-Fox Hills Aquifer

Because of the generally undeveloped nature of the LFH aquifer, this aquifer may have the best longevity of any of the Denver Basin aquifers. The lack of development is not related to the reliability of the LFH aquifer but is generally related to the depth of the aquifer and associated cost to develop LFH aquifer wells, as well as issues with water quality.

Given the available data, it is our opinion that the LFH aquifer is a viable, reliable source of water for both residential and larger municipal and commercial uses throughout most of the County, with the possible exception of the southern area near the outcrop where water-bearing strata have thinned considerably. Having significant head above the top of the aquifer provides the ability for increased pumping rates as long as the head is maintained on the aquifer. It is our opinion the LFH aquifer water supply is reliable on a long-term basis.

It is apparent from the condition of each of the Denver Basin aquifers that the 300-yr rule, based on long-term water level data available to us, has been effective in protecting the longevity of the aquifers. In fact, in each of the aquifers over a relatively large area of the County the aquifers are still fully confined, which means that none of the 100-yr or 300-yr life of the aquifers has been produced to date. However, it should be noted that does not mean there is still a 100 or 300-yr supply remaining from a legal perspective. This is due to the recent Supreme Court decision on the TAW.

Under the ruling, after the 100-yr allocation has been produced all pumping has to cease regardless if there is still economically-viable water that can be produced from the Denver Basin aquifer where the TAW has been reached. Since the TAW is calculated based on fully unconfined aquifer conditions, but actual pumping is under fully or partially confined aquifer conditions, much if not all of the water being pumped is not related to the TAW volume but is being debited as though it is part of the TAW.

In our opinion, in evaluating the current aquifer hydraulic conditions, the effect of the TAW should be considered. However, in all analyses of Denver Basin aquifer water, it needs to be kept in mind that these supplies are non-renewable as there is only minor recharge to these aquifers. Therefore, while we have concluded that these water supplies can be reliable, it is within the context that the aquifer water supplies can be managed commensurate with the local ability of the aquifers to yield water to wells without undue dewatering. Such extensive dewatering is not currently being observed based on the data that are available to us. Therefore, it is our opinion that spatially-varying terms and conditions on the use of the Denver Basin aquifers in the County is not warranted at this time. However, it is likely that the lack of dewatering in the far eastern and southern portions of the Denver Basin in the County is more related to the minimal use in these areas than the ability of the aquifers to produce large, long-term well production.

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1. INTRODUCTION

Moore Engineering, Inc., dba Lytle Water Solutions, LLC ("LWS"), has completed our work related to assisting El Paso County ("County") with an analysis of the available, reliable resources of the Denver Basin aquifers. This work has been completed pursuant to our approved July 2, 2024 proposed scope of work. Our work was designed to provide the County with an analysis that will be useful in reviewing the current County water supply regulations to assess if revisions to these regulations are warranted related to allocations of Denver Basin aquifer water for development within the County.

The Colorado statutory methodology of assessing the annual allocation that can be extracted from the Denver Basin aquifers is based on overlying land ownership using the following formula:

$$V = (A)(b)(S_y)/100$$

where,
- V = annual allocation (acre-feet)
- A = surface area (acres)
- b = saturated thickness (feet)
- S_y = aquifer specific yield (dimensionless)

The multiplication in the numerator yields an estimate of the total water beneath a property in an aquifer (which will vary from aquifer to aquifer due to variable saturated thickness and specific yield), while the annual allocation that can be extracted is calculated by taking the total water availability and dividing it by 100 years ("yrs"). While the statutory method divides by 100, the allowable annual allocation in El Paso County modifies the statutory allocation formula by changing the denominator in the above equation to 300 yrs.

We understand that the County implemented a 300-yr rule in the 1980s related to the use of Denver Basin aquifer water in evaluating land use applications and the 300-yr rule has been, and is currently, applied equally across the County as the available water supply to support land use applications.

Whether a 100-yr rule or a 300-yr rule is implemented related to land use development, in either case the above formula is a very simplistic means to estimate available water that doesn't account for the complex geology and hydrogeology of the Denver Basin aquifers. The formula inherently makes three very simplified assumptions, i.e., (1) there is one continuous water-bearing sandstone in the aquifer ("b"), (2) that water-bearing unit is homogeneous throughout the basin and will yield the same amount of water based on the saturated thickness, and (3) that one continuous water-bearing sandstone is in a completely unconfined aquifer condition ("S_y").

None of these assumptions is correct in the Denver Basin aquifers. Accepting these simplifying assumptions leads to a misinterpretation of water supply availability in the Denver Basin aquifers, as all Denver Basin aquifers are multi-layered with interbedded sandstones, siltstones, and shales and most, if not all, of these layers are fully saturated plus have confined pressure head on the water-bearing strata. Within these multi-layered aquifers, the water-bearing units can be distinctly different hydraulically due to the geologic nature of the strata, e.g., coarse-grained clean sands to fine-grained silty or clayey sands. Therefore, yields can be quite variable spatially even if the saturated thickness is the same at different locations.

The specific yield estimation in the formula assumes fully unconfined conditions, which is not the case to our knowledge in any part of the Denver Basin, expect the very margins near outcrops, due to the interbedded nature of the formations. While the specific yield of the Denver Basin aquifers presumptively ranges from 0.15 to 0.20, the actual "specific yield", or more correctly the storage coefficient in the Denver Basin aquifers under current conditions is in the range of 0.0001, or 1,500 times smaller than the formula value. What this means is that when water level declines are interpreted under current conditions with water levels above the top of the aquifers, it is representative solely of pressure being reduced in the aquifer rather than the aquifer being dewatered. This is a common misconception that is used related to Denver Basin aquifer water level declines over time.

As generally described above, while specific water-bearing units have been classified as aquifers for legal purposes, forgetting the complex nature of the geology in favor of only a simplistic schematic for analysis will lead to incorrect conclusions. Due to the insufficiency of these three simplifying assumptions of the statutory methodology, analysis of site-specific data is necessary to better assess water supply availability and reliability, although there will always be a measure of uncertainty in any analysis due to the complexity of the system and the lack of a comprehensive database across the County. As described below, it is important to understand that, as long as a static water level is above the top elevation of the aquifer, no depletion of the statutory estimate of water availability has occurred.

While some of the aquifers remain fully saturated and under pressure at some locations (i.e., the 300-yr supply has not been diminished at all) this condition is not uniform over the entire County. Some areas, and some aquifers, are not currently fully saturated, i.e., static water levels have dropped below the top of the aquifer (i.e., some portion of the 300-yr supply is being diminished).

While the Denver Basin aquifer system is complex, a generalized outline is helpful to understand it as a whole. The Denver Basin is a large synclinal structure that contains (a) some of the deepest portions of the basin, (b) considerable thinning of the formations to the eastern side of the County, and (c) outcrops in the southern portion of the County. The lowest strata that forms the basement rock for the Denver Basin is the Pierre Shale, the top of which defines the base of the aquifer sequence. Overlying the Pierre Shale, the stratigraphic sequence to ground surface are the Laramie-Fox Hills Sandstone ("LFH aquifer"), Laramie, Arapahoe, Denver, and Dawson Formations. A stratigraphic column of the Denver Basin formations is presented in **Appendix A**.

Along the western margin of the basin in the County there is local faulting so the aquifer units remain at significant depth. Locally, the Denver Basin sediments are overlain by multiple Quaternary alluvial sediments within stream channel areas, the major streams being Monument and Fountain Creeks (**Figure 1**), and unconsolidated colluvial sediments over much of the rest of the County. The geologic sequence of deposition of the Denver Basin formations is very important from a hydrogeologic perspective and the ability to extract water from the aquifers contained within these formations. The LFH aquifer and overlying Laramie Formation formed as depositions from an inland sea and is the oldest formation of the Denver Basin. The remainer of the Denver Basin filled with sediments due to the uplift of the Rocky Mountains, which caused a deeper basin to form to the east of the uplift. Then, sediments shedding into the basin from the uplift formed what are now the upper formations of the Denver Basin.

The LFH aquifer was formed more as a lacustrine deposit, i.e., lake deposits, while the remaining formations formed based on fluvial deposition, i.e., from sediments contained in flowing water. With any fluvial deposition, the highest energy areas of deposition put down layers of coarse, heavier sediments while finer grained sediments were carried further in the depositional environment. As such, thicker formation and aquifer thicknesses are observed nearer the Front Range, while generally finer and thinner depositions are observed at distances from the Front Range.

In geologic time, there have also been many depositional episodes where the energy of deposition have varied, resulting in significant layering of the aquifers across the basin. These variable depositional episodes have resulted in water being deposited in the coarser grained sediment layers but then being bounded in those layers by depositional episodes that resulted in saturated silt/clay layers being formed between the coarser sediment layers which, while saturated, are generally low to non-water bearing sediments.

As a result, in many areas of the Denver Basin the coarse-grained aquifers are bounded above and below by low permeability sediments to form each of the formations. This has occurred *both within* each Denver Basin aquifer *and between* the formations, effectively creating many sub-aquifer water-bearing strata. When an aquifer is confined between low permeability sediments and the water is contained under pressure greater than atmospheric (i.e., the water level rises above the top of the water-bearing strata) it is known as a ***confined aquifer***.

However, because each Denver Basin formation consists of multiple aquifer layers there can be variable confined aquifer conditions. These aquifers may be in a ***fully confined*** condition, i.e., the aquifer water-bearing sediments are fully saturated and under pressure greater than atmospheric. These aquifers can also be converted from fully confined conditions over time based on both localized and regional pumping effects. In some areas of the basin, pumping has reduced water levels below the top of the aquifer resulting in ***partially confined*** conditions, as the upper strata may not be under pressure but the lower strata remain under pressure.

Because of the variable depositional environments over geologic time, the Denver Basin aquifers are hydraulically complex because the series of interbedded water-bearing sandstones/siltstones and low-permeability claystones in the Denver Basin formations produces generally hydraulically separate aquifer units, both vertically within the aquifer and between each aquifer. Therefore, these aquifers do not fully convert from fully confined conditions to ***unconfined*** conditions with declining water levels over time. Rather, with gradual water level declines the top water-bearing strata of an aquifer may become partially unconfined or fully unconfined, with the lower water-bearing strata remaining fully confined. As such, not only are water level changes important to understand but also whether those changes are occurring under fully confined or partially confined aquifer conditions. This is an important consideration related to the Denver Basin aquifers study that has been completed by LWS for El Paso County.

In addition to the hydraulic condition of the aquifer there is also another factor that can constrain the production capability and reliability of a well water supply. Along the southern boundary of the Denver Basin, as well as in some interior areas of the basin in the County, there can be physical and/or hydraulic barriers to flow. These barriers may be related to the interbedded water-bearing strata, variable hydraulic conditions spatially (hydraulic barriers), and the subcropping and outcropping of aquifers (physical barriers). When there are either hydraulic or physical boundaries to flow, this creates ***boundary conditions*** on pumping. Boundary conditions are when water can't be drawn from all directions to a well due to changing aquifer hydraulic conditions and/or physical boundaries in the aquifer. When boundary conditions are encountered well production rates and the sustained production capability can be constrained. As such, boundary conditions can limit the reliability of a well water supply.

Since there is a large geologic and hydrogeologic variability of the Denver Basin in the County, there can be significant differences between legally available water and reliable, long-term physically produced water, which is typically referred to as "paper water". Sustaining the water supply available underneath both limitations of legal and physical frameworks, while adapting to increased development and climatic concerns, is of utmost importance to the County. Therefore, the analyses, results, and conclusions of our studies provide additional site-specific data to the County to make informed decisions on future water use policies.

2. BASIS OF ANALYSIS

Given our extensive understanding of the Denver Basin aquifer system, in this study we have evaluated several factors, including:

- an analysis of the structure of each of the Denver Basin aquifers within the County;
- an evaluation of the tops and bottoms of each aquifer along multiple north-south and west-east cross sections;
- development of time series hydrographs of water level changes within the aquifers over time, based on publicly-available sources and data provided by some water suppliers within the County;
- assessment of the condition of each aquifer across the County, i.e., fully confined or partially confined, and how those aquifer conditions have changed over time; and
- assessment of the physical reliability of the Denver Basin aquifers water supply across the County based on the above-described factors.

Because this assessment evaluated both the geographic and vertical definition of the Denver Basin aquifers, and their associated estimated reliable water supply use by location and by aquifer, it was necessary to develop a well completion and water level database in each of the Denver Basin aquifers. These data were also useful in evaluating the differences in water level changes vertically in each of the Denver Basin aquifers. The following sections describe the databases developed and the analyses of these data.

3. ANALYSIS METHODOLOGY

The LWS analysis utilized the available geologic and hydrogeologic information to delineate the relative thicknesses of each Denver Basin formation across the County, including the aquifer outcrop/subcrop areas. These data are important to consider relative to measured water levels in all of the Denver Basin aquifers, i.e., the location of well water levels relative to the top of the aquifer and the saturated thickness of the aquifer. This is because this can be used as a measure of the reliability of the water supply. Because the vertical component of aquifer conditions was also incorporated into this study, the aquifer boundaries were evaluated in each aquifer separately, based on current or most recent water level conditions.

3.1. Water Levels

To obtain the most site-specific data on water level changes over time at existing Denver Basin aquifer wells, both the County and LWS requested water level hydrographs from the major municipal and quasi-municipal entities that are located within the Denver Basin in the County. However, the responses to these requests was mostly unsuccessful, as site-specific water level data were only obtained from the following entities and then most of the data received were very limited.

- Woodmoor Water and Sanitation District
- Triview Metropolitan District (limited)
- Town of Monument (limited)
- Paint Brush Hills Metropolitan District

To supplement water level data since the response to our request for water level data was limited, the Colorado Division of Water Resources ("CDWR") maintains a database of water levels for the four principal Denver Basin aquifers. Documentation of permitted wells in the state is maintained in a separate database, entitled "CDWR Well Application Database" including USGS well data. This database is not exclusive to wells reporting water level data as it also includes well permit applications for wells that have not been drilled. Therefore, we filtered this database for wells constructed and obtained a static water level from the well construction reports. Based on the available data, hydrographs of time-dependent water levels for wells in each aquifer were constructed. **Appendices B, C, D,** and **E** contain the hydrographs used in our analysis for the Dawson, Denver, Arapahoe, and Laramie Fox-Hills aquifers, respectively.

The distribution of select water levels represents, as much as possible with available data, each aquifer across the County. Water level data were collected going back to 1955; however, more emphasis was placed on recent water level data due to the changes occurring since that time. In addition, due to the lack of systematic water level readings over time, some of the data were difficult to interpret relative to whether the reading was a “static” water level versus a water level influenced by pumping of that well or a nearby well. For the long-term water level data, the trend in water levels over time was considered, in addition to fluctuations in water levels that were assumed to reflect pumping of the well.

Because an important factor is the depth of the water level relative to the top of the aquifer, the long-term water level elevations were compared with the top elevation of the relevant formation at that location to identify where the water levels were in relation to either being above or below the top of the formation. The location of the water level within a well helped to inform us of the past and current condition of the aquifer, i.e., fully confined or partially confined conditions.

The top elevation of each formation was interpreted using a combination of the CDWR aquifer determination tool (“ADT”) (CDWR, 2023), the USGS Digital Elevation Model (“DEM”), the geologic structural top elevations, and professional judgment in geologic interpretations as described below and in **Section 3.2**. The reason all of these tools were necessary for our analyses was because the data sources are inconsistent both spatially and temporally. The interpreted top and bottom elevations of the formation for each well are presented in the hydrographs in **Appendices B** through **E**.

The classification of wells different from the CDWR interpretation was conducted to understand each aquifer unit and conditions therein. Since the administrative terminology and classification of aquifer tops and bottoms has changed over time, this was judged to be a reasonable methodology.

3.2. Hydrogeologic Cross Sections

Three west-east, four north-south, and one northwest to southeast hydrogeologic cross section locations were selected to represent the Denver Basin in El Paso County (**Figure 2**). The west-east cross sections extend from the western edge of the Denver Basin to its eastern edge (Sections A-A’, B-B’, and C-C’), the north-south cross sections extend from the northern boundary of the County to the outcrop of the basin to the south (Sections D-D’, E-E’, F-F’, and G-G’), and the northwest to southeast cross section extends a short section of the County generally following the populated corridor around Interstate 25 (Section H-H’) (**Figure 2**).

The cross sections were constructed from geologic interpretations based on data collected from the ADT. Each cross section shows the general structural outline of the formations along the cross-section line, as well as the confining layers between the formations. The Laramie Formation is generally considered a confining, non-water bearing formation between the Arapahoe Formation and underlying LFH aquifer. **Figures 3** through **5** present the west-east cross sections, **Figures 6** through **9** present the north-south cross sections, and **Figure 10** presents the northwest to southeast cross section. On the western edge of the Denver Basin the principal aquifers are bounded by the Precambrian granites of the Front Range so all four major formations and aquifers are present.

The Dawson Formation contains the uppermost aquifer in the Denver Basin and is generally not overlain by confining units but does contain multiple confining strata between water-bearing units within the aquifer. The extent of the Dawson Formation in the County is limited, with a thick sequence in the northwestern portion of the County, but then moving east the Dawson Formation outcrops, likely due to erosion of material over time and lack of depositional energy. The Dawson Formation outcrops both to the east and south very quickly in the County, as it is only present in Cross-Section A-A' but is absent in B-B' and C-C' (**Figures 3** through **5**). Similarly, the aquifer outcrops to the south along Cross-Section D-D', is barely present in E-E' and G-G', and also outcrops to the south along Cross-Section H-H' (**Figures 6, 7, 9** and **10**).

The Denver aquifer is generally the thickest sequence of the Denver Basin formations. As shown in the cross-sections, the Denver Formation generally has an overlying and underlying confining unit (light brown on **Figures 3** through **10**) that hydraulically separates the Denver Formation from the Dawson and Arapahoe Formations. The Denver Formation maintains a relatively thick sequence through the County from west to east in the northern part of the County. While relatively areally extensive in the northern and western portions of the County, the formation generally extends to within 10 miles of the eastern edge of the County (**Figures 3** and **4**) except in the southern part of the basin where it outcrops (Section C-C', **Figure 5)**. The outcrops along the southern part of the basin are shown in Cross Sections D-D', E-E', F-F', and G-G' (**Figures 6** through **9**).

The Arapahoe Formation is generally the most productive of all the Denver Basin aquifers. The Arapahoe aquifer is generally the thickest sequence of the Denver Basin formations. As shown in the cross-sections, the Arapahoe Formation generally has an overlying confining unit (light brown on **Figures 3** through **10**) and the Laramie Formation underlying the Arapahoe Formation (darker brown on **Figures 3** through **10**), both of which hydraulically separates the Arapahoe Formation from the Denver Formation and the much deeper LFH aquifer. The Arapahoe Formation is areally extensive from west to east and is the exposed formation in the southern part of the basin (Cross-Section C-C', **Figure 5**). The Arapahoe Formation generally extends east of the County line in the northern area of the County (Cross-Sections A-A' and B-B', **Figures 3** and **4),** but thins and eventually outcrops to the southeastern part of the basin (Cross-Section C-C', **Figure 5**). The Arapahoe Formation maintains a relatively thick sequence until very close to its outcrop on the southern end of the basin (Cross-Sections, D-D', E-E', F-F', G-G', and H-H', **Figures 6** through **10**).

The LFH aquifer is the lowermost aquifer in the Denver Basin and is separated from the other Denver Basin formations by the Laramie Formation. The Laramie Formation is a thick sequence of mostly low-permeability shales which provides hydraulic separation from the overlying Arapahoe Formation. Similar to the Arapahoe Formation, the LFH aquifer extends east of the County line (Cross-Sections A-A', B-B', and C-C' (**Figures 3** through **5**), and maintains a relatively thick sequence from west to east. However, the LFH aquifer maintains a relatively thick sequence until very close to its outcrop on the southern end of the basin (Cross-Sections, D-D', E-E', F-F', G-G', and H-H', **Figures 6** through **10**).

The cross sections were used as a reference for interpreting water levels from the long-term hydrographs which could reasonably be projected onto the cross sections. However, all of the hydrographs shown in **Appendices B** through **E** were used in our analyses. The hydrographs contain significant information for use in interpreting (1) whether the water levels are above or below the tops of the aquifer, (2) how aquifer conditions may have changed over time, and (3) how reliable water supplies likely vary by location across the County.

4. INTERPRETATION OF WATER LEVELS

Production capacity trends over time are typically linked to the geologic structure in the basin, proximity to the edges of the basin, and the decline of water levels below the tops of the aquifers in many areas. This study investigated these factors using available water level data from wells in the County, in conjunction with their location in the basin. The primary objective in the interpretation of historical water levels in each of the Denver Basin aquifers was to assess what is the current condition in each aquifer throughout the area underlain by the Denver Basin, and how water levels may have changed over time relative to the tops of the aquifers. Significant water level declines into the aquifer and/or small aquifer saturated thicknesses are indicative of less reliable long term water supplies. The primary objectives in the interpretation of location in the basin was evaluating the thinning of the formation, reduction in saturated thickness, and proximity to the subcrop/outcrop of the formation.

In addition, because geologic structure and water level changes can be variable between aquifers in the same location, our analysis also examined these conditions aquifer by aquifer so that the recommended water use criteria for individual aquifers can be interpreted separately by the County.

4.1. Dawson Aquifer Water Levels

The Dawson Formation has the smallest extent of the Denver Basin sediments in the County, is exposed at the surface where Quaternary alluvium and/or colluvial sediments are absent and is the highest stratigraphic unit in the Denver Basin (gray in **Figure 2** and *see* stratigraphic column shown in **Appendix A**). In a small area in the northwestern portion of the County, the SEO has differentiated the Dawson Formation into an Upper Dawson and Lower Dawson (brown in **Figure 2**). However, this area is very limited and does not affect the interpretation of the Dawson Formation across the County, which is considered in this analysis to be the undifferentiated Dawson Formation.

In the northwestern quadrant of the County the Dawson Formation has significant saturated thickness and total formation thickness as estimated in the ADT, with as much 400 ft of saturated thickness and 800 to 900 ft of total thickness. However, in approximately the Black Forest area, there is a dramatic thinning of the aquifer and saturated thickness (**Figures 3** and **6**). In a distance of less than 10 miles the Dawson Formation transitions from a thick sequence to its outcrop to the east and south. The abrupt reduction in thickness likely will result in significant boundary conditions in the aquifer.

The extent of Dawson Formation wells with significant historical water level databases available to LWS, depicted on **Figure B-1** in **Appendix B**, generally is limited to the northwestern area of the County, as the formation has outcropped over most of the County. There were 20 long-term Dawson Formation hydrographs that we identified either from data provided to us or available in the public domain, which are presented in **Appendix B**. On each of the hydrographs, the top and bottom of the formation, as estimated from the ADT, are shown so trends in water levels could be evaluated.

Several of the Dawson Formation hydrographs indicate that water levels have historically, and continue to be, at or above the top of the aquifer (8 of 20 hydrographs, **Appendix B**). However, in the area of the most intense use of the Dawson aquifer near the western side of Cross-Section A-A’ and the northern portion of Cross-Section H-H’ the hydrographs indicate some significant dewatering of the formation, (e.g., Wells 12278-F, 11349-R-R, 4949-F, 3826-F, 9259-R-F, and 9260-F, **Figure B-1**). This dewatering is likely due to the concentrated area of pumping near the Palmer Divide along I-25 where it is most developed.

Dawson Formation wells more removed from the concentrated area of pumping indicate generally steady water levels over time, mostly at or near the top of the formation. For example, as you move to the south and east of the concentrated area of Dawson aquifer wells but still in the thickest part of the formation, to the south Wells SCO1106728BAD, 43596, and SCO1206605BBD have shown very little water level change in the Dawson Formation over the last 40 years (**Figure B-1** and **Appendix B** hydrographs). Similarly, to the east wells with permit numbers 66461-P, SCO1106611DBD, SCO1106517CCA, SCO1106424ADB, SCO1206511CBA, and SCO1206605BBD all have very consistent water levels over time at, or near, the top of the aquifer. However, it should be noted that as you move south from the concentrated areas of pumping in the Dawson aquifer in the northwestern area of the County, the Dawson aquifer thins considerably to the south, to a total thickness of approximately 200 feet at 31263 and 3750-F. Thinning of the formation to the east is evident from the geologic structure maps (**Appendix A**) to the ultimate outcrop of the formation east of Peyton; however, we do not have any long-term well hydrographs available to us in this area.

The available long-term Dawson aquifer hydrographs (**Appendix B**) indicate that water levels in the Dawson aquifer are variable based on location and the density of use. Where use is heaviest, there are indications of significant dewatering of the aquifer of approximately 20-25 percent, with up to 40 percent (Well 4949-F) dewatering, so the aquifer is in partially confined conditions. In lesser developed areas of Dawson aquifer use, the available data indicate very stable water levels at, or near, the top of the aquifer, which indicates fully confined aquifer conditions. There are no long-term hydrograph data available to us in the extreme southern or eastern areas of the Dawson Formation. Given the data that indicate the Dawson aquifer is dewatering when pumped in a concentrated area, these data suggest low levels of use, e.g., residential wells, will maintain reliable water supplies in the Dawson aquifer. Approval of concentrated use of Dawson aquifer wells as the primary source of supply for larger non-exempt uses, e.g., municipal, commercial, industrial, and irrigation, will likely provide less reliable water supplies.

4.2. Denver Aquifer Water Levels

The Denver aquifer is stratigraphically below the Dawson aquifer and is exposed at the surface where the Dawson aquifer has been removed by erosion (yellow in **Figure 2** and stratigraphic column shown in **Appendix A**). The Denver Formation, which contains the interbedded water-producing Denver aquifer, generally has an upper and a lower confining unit as shown in **Figures 3**, **6**, **7**, and **10**. Where the Denver Formation is at the surface (**Figures 4, 5, 8, and 9**), the Denver aquifer is not uniformly unconfined due to the interbedded nature of the sediments within the formation, i.e., the upper water-bearing strata may be partially dewatered while the remaining lower strata remain fully saturated and under pressure.

The Denver Formation is more areally extensive than the overlying Dawson Formation. The formation has significant saturated thickness and total formation thickness over much of the Denver Formation area as estimated in the ADT, with as much as 560 ft of saturated thickness in the northwestern quadrant of the County, but generally ranging from 200 to 400 ft of saturated thickness in other areas of the County. The total formation thickness generally ranges from 500 to 800 ft. Where the Denver Formation begins to thin to the east and south, the transition is more gradual than in the Dawson Formation. The Denver Formation outcrops just west of the eastern boundary of the County, southeast of Ramah. In this area the Denver Formation somewhat uniformly decreases from approximately 800 ft thick to the outcrop approximately 13 mi to the east. The transition along Cross Section B-B', which goes through the Falcon area, indicates an even more gradual thinning over a distance of approximately 25 mi. On the west side of the County (Cross-Section D-D') there is a much steeper decline in the total thickness of the formation, going from approximately 900 ft thick to an outcrop in approximately 7 mi.

In the thinner areas of the Denver Formation, generally east of Peyton and south of the Black Forest, saturated thicknesses tend to decrease to an average of approximately 100 ft on the east side of the County and a range of 200 to 75 ft until the southern outcrop of the formation east of Colorado Springs. However, in the western portion of the County, while the formation outcrops east of Colorado Springs, saturated thicknesses remain in an approximate range of 300 to 200 ft until within a few miles of the outcrop.
The extent of Denver Formation wells with significant historical water level databases available to LWS, depicted on **Figure C-1** in **Appendix C**, are generally more expansive areally than the Dawson Formation wells, as the Denver Formation covers a much larger area than the Dawson Formation in the County (yellow in **Figure 2**). There were 17 long-term Denver Formation hydrographs, which are presented in **Appendix C**. On each of the hydrographs, the top and bottom of the formation, as estimated from the ADT, are shown so trends in water levels could be evaluated.

Similar to the Dawson Formation, the most concentrated area of pumping in the Denver aquifer is in the northwestern portion of the County. However, for the wells with long-term hydrographs in this area (11350-R, 31264-F, SCO1106721ADD, SCO1106727BDC, and SCO1106728BBC, **Figure C-1**) water levels have been above the top of the aquifer, both historically and currently, based on 40 years of data for many of the wells. The available water level data for one other well in this area (21126-F-R) indicates water levels generally at the top of the aquifer with potentially some pumping water levels below the top of the aquifer but recovering to above the top of the aquifer at times. These data indicate the Denver aquifer in the northwestern area of the County is generally still fully confined.

Wells to the south and east of the Dawson Formation outcrop (31383-M, 62585, 11635, and SCO1206302BCC1, **Figure C-1**) also generally indicate water levels historically at, or above, the top of the aquifer. Well SCO1306304BCD1 is the one exception, as some minor dewatering was apparent with limited water level data from 1985-1990. The current water level conditions at this well are unknown. However, it should be noted that the Denver Formation thins to the east and south, with the Denver Formation being approximately 500 feet thick at 62585 near Peyton, 300 feet thick at 31383-M southeast of Peyton, and 250 feet thick at 11635 northeast of Calhan (**Appendix C** hydrographs). These thicknesses compare to the Denver Formation being generally 800 to 900 feet thick in the northwestern portion of the County.

The available long-term Denver aquifer hydrographs (**Appendix C**) indicate that water levels in the aquifer are quite similar relative to the top of the aquifer, regardless of the density of use. The available data indicate generally fully confined aquifer conditions, both historically and currently (or at least through the water level monitoring period). Given the available data, it is our opinion that the Denver aquifer is a viable source of water for both residential and larger municipal and commercial uses. The one caveat is that in areas on the eastern and southern portions of the County near the subcrop/outcrop areas the thickness of the formation, and associated saturated thickness, thins considerably. This likely limits the production capability of wells in this area and likely is only a reliable water supply source for small residential wells.

4.3. Arapahoe Aquifer Water Levels

The Arapahoe aquifer is stratigraphically below the Denver aquifer (pink in **Figure 2** and stratigraphic column shown in **Appendix A**) and is exposed at the surface where the Dawson and Denver Formations have been removed by erosion. The Arapahoe Formation, which contains the interbedded water-producing Arapahoe aquifer, generally has an upper and a lower confining unit, as shown in **Figures 3** through **10**, with the exception of **Figure 9**. Where the Arapahoe Formation is exposed at the surface (**Figure 9**), the Arapahoe aquifer is not unconfined due to the interbedded nature of the sediments within the formation.

The Arapahoe Formation has significant saturated thickness and total formation thickness over much of the Denver Basin area in the County as estimated in the ADT, with 200 to 250 ft of saturated thickness and approximately 500 ft of total thickness in areas where there is no thinning of the aquifer. Where the Arapahoe Formation begins to thin to the east and south, the transition is relatively steep, although the Arapahoe Formation doesn't outcrop in the northeastern corner of the County (near Ramah), but does outcrop further to the south (near Yoder). There are also areas in the eastern part of the County where the Arapahoe subcrops unconsolidated sediments.

In the eastern area of the County the Arapahoe Formation thickness drops significantly from approximately 500 ft to 250 ft. The transition along Cross Section B-B', which goes through the Falcon area, indicates a relative steep thinning to the outcrop over a distance of approximately 7 mi. On the west side of the County (Cross-Section D-D') there is a very steeper decline in the total thickness of the formation to the south, going from approximately 500 ft thick to an outcrop in approximately 3 mi.

In the thinner areas of the Arapahoe Formation on the east side of the County, generally south of Ramah saturated thicknesses tend to decrease to an average of approximately 100 ft, while further south near Yoder saturated thickness may be 50 ft or less. However, in the western portion of the County, while the formation outcrops east of Colorado Springs, saturated thicknesses remain over 200 ft until within a few miles of the outcrop.

The extent of Arapahoe Formation wells with significant historical water level databases available to LWS, depicted on **Figure D-1** in **Appendix D**, are generally more expansive than either the Dawson or Denver Formation wells. The Arapahoe aquifer is generally the most heavily used aquifer in the Denver Basin in general, and also specifically to the County. This is because the Arapahoe aquifer in most parts of the basin is both the most productive aquifer and has the best water quality. Because of the more extensive use of the Arapahoe aquifer, we were able to obtain 37 long-term Arapahoe Formation hydrographs, which are presented in **Appendix D**. On each of the hydrographs, the top and bottom of the formation, as estimated from the ADT, are shown so trends in water levels could be evaluated.

While the most concentrated area of pumping in the Arapahoe aquifer is in the northwestern portion of the County along the I-25 corridor, there is extensive development of the Arapahoe aquifer across the County, as shown in **Figure D-1**. For many of the Arapahoe aquifer wells where the hydrographs indicate fully confined aquifer conditions, i.e., water levels above the top of the aquifer, there are many wells with trending downward water levels (Wells 16248-F, 17483-F, 24030-F, 34671-F, 27229-F, and DB-120 (Woodmoor 11A), **Figure D-1** and **Appendix D** hydrographs), with some wells exhibiting these trends for a considerable time historically (from the early 2000s). With wells where the period of record doesn't include the current time, it is difficult to extrapolate the known data. When water levels start to drop below the top of the aquifer, time-dependent water level declines can decrease with the combined confined storage coefficient and unconfined storage coefficient in the upper water-bearing interval(s), as water releases per unit volume can increase by a factor of approximately 1,500 times in water-bearing strata that have become unconfined (at the top of the aquifer).

For other Arapahoe aquifer well hydrographs that indicate fully confined aquifer conditions, these wells are not exhibiting a downward water level trend (Wells 34671-F, 15568-F, 16112-F, 55359-F, 60969-F, and 62584-F, **Figure D-1** and **Appendix D** hydrographs). There is no clear pattern of the changing aquifer hydraulic conditions in the fully confined aquifer wells, except they are all located along the western portion of the basin, generally in the I-25 corridor (on Cross Section H-H', **Figure 10**). In concentrated well clusters, there are hydrographs of wells with no apparent trend in the water levels while other wells have clear downward trending water levels. In addition, there are also wells indicating some dewatering is occurring, based on the water level data available to us.

While many Arapahoe aquifer wells have historically been fully confined, and remain fully confined, there are also many wells where water levels are very stable over time and generally are at, or near, the top of the aquifer (Wells 31380-M, 31381-M, 31384-M, 29896-M, SCO1406412CCD1, SCO1406308CCC1, and 47303-F, **Figure D-1** and **Appendix D** hydrographs). All but one of these wells is a monitoring well that doesn't pump water. The data from these wells are very instructive as they are not influenced by pumping cycles in the wells and also don't appear to be regionally influenced by pumping. These wells are all located in the southern part of the basin (**Figure D-1**), which would indicate there is minimal regional water level decline in this area, which is likely related to there not being any large production wells and/or that this area is not well connected hydraulically to the other, more intensively developed areas of the Arapahoe aquifer in the County.

It is unsurprising that there is some dewatering occurring in wells in the eastern portion of the Arapahoe aquifer in the County (Wells 27745-F and 49192-F, **Figure D-1** and **Appendix D** hydrographs) since the

Arapahoe aquifer is less prolific in these areas and the aquifer is thinning. However, there are several wells where water levels are also below the top of the aquifer in the western portion of the basin in the County (Wells 11504-F, 4133-F, 4134-F, 10354-F, and 56816-F, **Figure D-1** and **Appendix D** hydrographs). Most of these wells are in the southwestern portion of the basin in the County.

The available long-term Arapahoe aquifer hydrographs (**Appendix D**) indicate that, for many wells, water levels in the aquifer are either well above or near the top of the aquifer, with some of the wells exhibiting downward trends in water levels while other wells are maintaining steady levels over time, i.e., confined aquifer water level conditions. Most of the Arapahoe aquifer wells that are exhibiting some dewatering are in the southwestern, southern and eastern portions of the basin in the County.

While there is no clear pattern geographically, if more pumping and water level data were available it is our opinion that the difference in trends would be shown to be related to regional effects of pumping, with downward trends observed in the heavier areas of pumping. One other potential for the variable conditions within short distances could be related to the hydraulic characteristics of the Arapahoe aquifer strata, e.g., the hydraulic conductivity of the water-bearing strata. Just because there is a high concentration of Arapahoe aquifer wells does not mean that the area is also a high concentration of pumping. Overall, the condition of the Arapahoe aquifer is still very good, with only indications of minor dewatering of the uppermost water-bearing strata. This means that the majority of the aquifer remains in fully saturated conditions with additional head on these water-bearing strata.

One advantage of the Arapahoe aquifer is that it typically contains a thick sequence, providing head to pump against in fully saturated conditions. Given the available data, it is our opinion that the Arapahoe aquifer is a viable source of water for both residential and larger municipal and commercial uses in virtually all of the area within the County. No significant dewatering of the aquifer was identified with the available long-term hydrographs. However, that doesn't mean there couldn't be areas of dewatering that aren't represented by the hydrographs in **Appendix D**. By experience, we do know that production in the Arapahoe aquifer in the eastern area of the County can be quite limited due to the low hydraulic conductivity of the sediments. This isn't related to dewatering of the aquifer, rather it is related to low hydraulic conductivity of the water-bearing strata that limits well production.

The available data related to the hydraulic conditions in the Arapahoe aquifer across the County indicate a mostly fully saturated state, even after decades of extensive use. While the production capability of wells in the Arapahoe aquifer vary considerably from the western to eastern portion of the basin in the County, the hydraulic conditions related to the reliability of the water supply are relatively consistent, with little to no observed significant dewatering of the Arapahoe aquifer strata. However, reliability for specific uses is also tied to the yields of wells and whether required yields can be met reliably. Our analysis for the Arapahoe aquifer indicates that the water supply is reliable on a long-term basis.

4.4. Laramie-Fox Hills Aquifer Water Levels

The LFH aquifer is stratigraphically below the Laramie Formation confining layer (stratigraphic column in **Appendix A**). The Laramie Formation overlies the LFH aquifer throughout the Denver Basin in the County (**Figures 3** through **10**) and forms the overlying confining unit. Since the LFH aquifer is lowermost aquifer in the Denver Basin, the underlying Pierre Shale forms the underlying low-permeability strata that confines the geographic location of the LFH aquifer. In limited areas where the LFH aquifer is exposed at the surface (**Figures 6** through **9**), the LFH aquifer may be unconfined, as this aquifer does not have the degree of interbedding of low-permeability sediments as the other overlying Denver Basin formations.

The LFH aquifer is the most consistent across the County of all the Denver Basin formations due to the different depositional environment than the other stratigraphically-higher formations. However, it is also the thinnest formation with the lowest saturated thickness of the Denver Basin aquifers. Generally, in most parts of the County the formation thickness is 250 to 300 ft, although there are some limited areas where the thickness can be as much as 400 ft. The LFH aquifer extends east of the eastern boundary of the County and, in the northern portion of the County near Ramah the aquifer is still over 300 ft thick. Even in the southeastern part of the County near Yoder the aquifer is also still approximately 150 ft thick. Where the LFH aquifer does outcrop on the southern portion of the County east of Fountain, the thinning is quite abrupt, thinning from approximately 300 ft to the outcrop in 2 to 5 mi.

Similar to the consistency of the total thickness of the LFH aquifer, the saturated thickness is also relatively consistent over the Denver Basin area in the County. In the area near Ramah on the eastern side of the County the saturated thickness is approximately 225 ft, while near Yoder the saturated thickness is approximately 200 ft. To the south, where the LFH aquifer ultimately outcrops due to erosion of the sediments, the saturated thickness remains at approximately 200 ft east of Colorado Springs, near Ellicott, and also at Yoder.

Because the LFH aquifer is both the deepest Denver Basin aquifer and has water quality issues in many parts of the basin due to the presence of coal seams in the overlying Laramie Formation, there are fewer LFH aquifer wells than in any of the other Denver Basin aquifers. There were 17 LFH aquifer hydrographs available for our review in this study, which are presented in **Appendix E**. On each of the hydrographs, the top and bottom of the formation, as estimated from the ADT, are shown so trends in water levels could be evaluated.

As shown in **Figure E-1**, the density of LFH aquifer wells is quite sparse and is generally limited to the southern portion of the basin in the County. This is likely due to the shallower nature of the LFH aquifer in this area as you get closer to the subcrop/outcrop of the aquifer. Because of the sparse nature of the wells completed in the LFH aquifer, and limited production, the available long-term LFH aquifer hydrographs (**Appendix E**) indicate that water levels in the aquifer are well above the top of the aquifer and are also quite stable, with little to no downward trends in water levels. As such, the available data indicate generally fully confined aquifer conditions, both historically and currently. (or at least through the water level monitoring period).

The LFH aquifer is generally less stratified than the other Denver Basin aquifer, therefore, the full aquifer thickness is principally composed of water-bearing strata. Given the available data, it is our opinion that the LFH aquifer is a viable source of water for both residential and larger municipal and commercial uses throughout the County. Having significant head above the top of the aquifer provides the ability for increased pumping rates as long as the head is maintained on the aquifer. The analysis for the LFH aquifer indicates that the water supply is reliable on a long-term basis.

5. DISCUSSION OF AQUIFER CONDITIONS ACROSS THE COUNTY

While it is well established that water levels are declining in the Denver Basin aquifers to some degree in some areas of the basin, not all areas or aquifers have the same level of susceptibility to a diminished ability to provide a reliable water supply over time. The level of susceptibility to a diminished reliable water supply over time can be related to (a) declining water levels below the tops of the aquifers, (b) heavily developed areas of the basin, (c) truncation of aquifers due to erosion, (d) no-flow boundaries or outcrops, (e) lack of recharge, or (f) a combination of these factors.

In this evaluation we have included:

- an evaluation of the tops and bottoms of each aquifer along multiple north-south and west-east cross sections;
- development of time series hydrographs of water level changes within the aquifers over time, based on publicly-available sources and data provided by some water suppliers within the County;
- assessment of the condition of each aquifer across the County, i.e., fully confined or partially confined, and how those aquifer conditions have changed over time; and
- assessment of the physical reliability of the Denver Basin aquifers water supply across the County based on the above-described factors.

The County currently uses a 300-yr rule as the water supply criterion for assessing the adequacy of the water supply for new land development applications. As such, this criterion is conservative based on the statutory criterion of a 100-yr water supply assessment. Under the recent Supreme Court decision, the Total Allowable Withdrawal ("TAW") limit for any Denver Basin water decreed under the 100-yr rule is that the maximum water that can be extracted under a Denver Basin right is the annual allocation times 100. Therefore, with a 300-yr rule and the TAW limit, the theoretical water supply should be spread out over 300 years. Once the TAW is reached, no further withdrawals will be allowed under the current Supreme Court decision, even if there is economically-viable water that can be produced from one or more of the Denver Basin aquifers.

Taking into account all of the factors described above and the analyses completed as part of this study, we have evaluated the current conditions in each of the Denver Basin aquifers related to reliability and sustainability.

5.1. Dawson Aquifer

The Dawson aquifer only has a limited extent in the County and water level data indicate aquifer conditions can be significantly influenced by regional pumping. While several of the Dawson Formation hydrographs indicate that water levels have historically, and continue to be, at or above the top of the aquifer, in the areas of concentrated use water levels have significantly declined into the aquifer. Of note, there is a significant saturated thickness over much of the limited extent of the Dawson aquifer, which indicates the Dawson aquifer can still provide a reliable water resource as long as the water use intensity is managed.

We recommend management of the use of this resource because, in areas where concentrated pumping has occurred, there isn't an indication of recovery during non-pumping times to a level commensurate with the top, or near the top, of the aquifer. As such, even with significant saturated thicknesses (ranging to over 400 ft), we conclude that the reliable yields in the Dawson aquifer within the northwestern quadrant of the County may be limited. As such, water levels are only at, or above, the top of the aquifer in areas of less extensive use.

Given the limited extent of the Dawson aquifer in the County and potentially limited well yields, it is our opinion the Dawson aquifer is well suited to small diameter, low production wells for residential or small commercial uses. These uses will, in our opinion, result in long-term reliability and sustainability. Larger non-exempt uses such as municipal, commercial, industrial, or irrigation could provide reliable supplies if the density of wells and/or level of use is minimized to be commensurate with the yields that will provide full, or near full, recovery between pumping cycles. In this way water levels can be managed to minimize dewatering of the aquifer. Quantification of these parameters is beyond the scope of this study.

Because the Dawson Formation is quite limited spatially in the County, occurring only in the northwestern quadrant of the County (**Figure 2**), it is also our opinion that the limited production potential of the Dawson aquifer covers the full extent of the formation in the County and there is no quantifiable difference in the

Dawson aquifer's production capability across the limited spatial extent of the aquifer in the County, based on the data available to us for this study.

5.2. Denver Aquifer

While not the most prolific of the Denver Basin aquifers, the Denver Formation typically has the thickest geologic sequence of all the formations (**Figures 3** through **10**). The Denver Formation is areally extensive across the County, reaching to close to the eastern boundary of the County, but outcrops in the far eastern area of the County and also to the south along with all of the Denver Basin aquifers (**Figure 2**).

Based on our review of the long-term hydrographs, water levels have been mostly above the top of the aquifer, both historically and currently. However, there are some Denver aquifer wells in the northwestern quadrant of the County with water levels below the top of the aquifer, likely related to regional pumping effects. Similarly, Denver aquifer wells to the south and east of the concentrated area of wells also generally indicate water levels that historically have been at, or above, the top of the aquifer. We have also observed data from some wells that indicate water levels declining below the top of the aquifer, but recovering to above the top of the aquifer during non-pumping periods, which indicates the aquifer at that location remains fully confined. Given these data, none or very little of the statutory availability of the water supply has been developed at this time. These data indicate there is still significant head that can be produced, which is water availability beyond what has statutorily been allocated.

While water levels indicate good hydraulic conditions over much of the County, it is known that there are areas with limited well production capabilities, mostly to the east and south in the County. This condition is likely related to the water-bearing strata being of a finer grain size and, near the outcrop areas, this also results in physical boundary conditions on pumping, where water can't be drawn from all directions from the well.

Given the available data, it is our opinion that the Denver aquifer is currently a viable source of water for both residential and larger municipal and commercial uses over most of the County, but there are areas in the eastern and southern portion of the Denver Basin in the County where the thickness of the formation thins considerably and likely is only a reliable water supply source for small residential wells.

5.3. Arapahoe Aquifer

The Arapahoe aquifer is generally the most heavily used aquifer in the Denver Basin, and also specifically to the County. This is because the Arapahoe aquifer in most parts of the basin is both the most productive aquifer and has the best water quality. The Arapahoe Formation is areally extensive across the County, reaching east beyond the eastern boundary of the County, but outcrops to the south along with all of the Denver Basin aquifers (**Figure 2**).

Similar to the other Denver Basin aquifers, the most concentrated area of pumping in the Denver aquifer is in the northwestern portion of the County. However, because of the reliability and production capability of the Arapahoe aquifer, there is also extensive development of the aquifer across the County where the aquifer is present.

Since the Arapahoe aquifer is the most heavily developed aquifer in the Denver Basin in the County, the available long-term hydrograph data indicate variable water level conditions across the basin, including variable data within short distances between wells. These variable effects on wells are likely related to well-to-well interference caused by hydraulic conditions that interconnect wells and/or physical boundary conditions. Boundary conditions can limit the reliability of a water supply and these conditions can be the most constraining in areas near the outcrop of the aquifer.

Given the available data, it is our opinion that the Arapahoe aquifer is a viable, reliable source of water for both residential and larger municipal and commercial uses and is viable and reliable across most of the aquifer, although the yields of the wells will be variable spatially, which may indicate less intensive use is better suited in the southern and far eastern portions of the basin.

5.4. Laramie-Fox Hills Aquifer

The LFH aquifer is distinctly different than the overlying Denver Basin aquifer because (a) it is significantly hydraulically distinct due to the thick overlying Laramie Formation, (b) the sediments were deposited as marine sediments, unlike the upper Denver Basin aquifers, so the sandstones are finer grained but more homogeneous, (c) it has not been extensively developed due to its depth over much of the basin, and (d) it is characterized by relatively high heads on the sandstones that have been relatively undiminished over time.

The available hydrograph data support the lack of extensive use of the LFH aquifer, based on the stable water levels over time that are significantly higher than the top of the LFH aquifer. There also isn't a significant thinning of the LFH aquifer from west to east because of the different depositional environment than in the other Denver Basin aquifers.

Because of the generally undeveloped nature of the LFH aquifer, this aquifer may have the best longevity of any of the Denver Basin aquifers. The lack of development is not related to the reliability of the LFH aquifer but is generally related to the depth of the aquifer and associated cost to develop LFH aquifer wells.

Given the available data, it is our opinion that the LFH aquifer is a viable source of water for both residential and larger municipal and commercial uses throughout most of the County, with the possible exception of the southern area near the outcrop where water-bearing strata have thinned considerably. Having significant head above the top of the aquifer provides the ability for increased pumping rates as long as the head is maintained on the aquifer. It is our opinion the LFH aquifer water supply represents a reliable water supply on a long-term basis.

5.5. Conclusions

It is apparent from the condition of each of the Denver Basin aquifers that the 300-yr rule, based on long-term water level data available to us, has been effective in protecting the longevity of the aquifers. In fact, in each of the aquifers over a relatively large area of the County the aquifers are still fully confined, which means that none of the 100-yr or 300-yr life of the aquifers has been produced to date. However, it should be noted that does not mean there is still a 100 or 300-yr supply remaining from a legal perspective. This is due to the recent Supreme Court decision on the TAW.

Under the ruling, after the 100-yr allocation has been produced all pumping has to cease regardless if there is still economically-viable water that can be produced from the Denver Basin aquifer where the TAW has been reached. Since the TAW is calculated based on fully unconfined aquifer conditions, but actual pumping is under fully or partially confined aquifer conditions, much if not all of the water being pumped is not related to the TAW volume but is being debited as though it is part of the TAW.

In our opinion, in evaluating the current aquifer hydraulic conditions, the effect of the TAW should be considered. However, in all analyses of Denver Basin aquifer water, it needs to be kept in mind that these supplies are non-renewable as there is only minor recharge to these aquifers. Therefore, while we have concluded that these water supplies can be reliable, it is within the context that the aquifer water supplies can be managed commensurate with the local ability of the aquifers to yield water to wells without undue dewatering. Such extensive dewatering is not currently being observed based on the data that are available to us. Because of this fact, it is our opinion that spatially-varying terms and conditions on the use of the Denver Basin aquifers in the County is not warranted at this time. However, it is likely that the lack of dewatering in the far eastern and southern portions of the Denver Basin in the County is more related to the minimal use in these areas than the ability of the aquifers to produce large, long-term well production.

6. SUMMARY

This study has been performed by LWS pursuant to our July 2, 2024 proposed scope of work. It should be noted that, while Denver Basin aquifer water level data with time were requested from all major water suppliers in the County, only minimal input was received. Therefore, the analyses and opinions drawn in this report are based on the available geologic and hydrogeologic information of the Denver Basin aquifers within the County, as well as the available water level databases in each of the principal aquifers, and our professional experience working in the County for the past 40 years.

If you have any questions regarding this evaluation of current conditions in the Denver Basin aquifers and the opinions related to the long-term reliability of Denver Basin water by aquifer and by location, please do not hesitate to give us a call.

Ben H. Bader
Project Hydrogeologist

Bruce A. Lytle, P.E.
Senior Project Manager

COLORADO LICENSED
BRUCE A. LYTLE
18575
PROFESSIONAL ENGINEER

7. REFERENCES

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2 Colorado Division of Water Resources (CDWR), 2023. Denver Basin Aquifers - Specific Location Determination Tool. Available at https://dwr.state.co.us/Tools/DenverLocation (Accessed September 2023).

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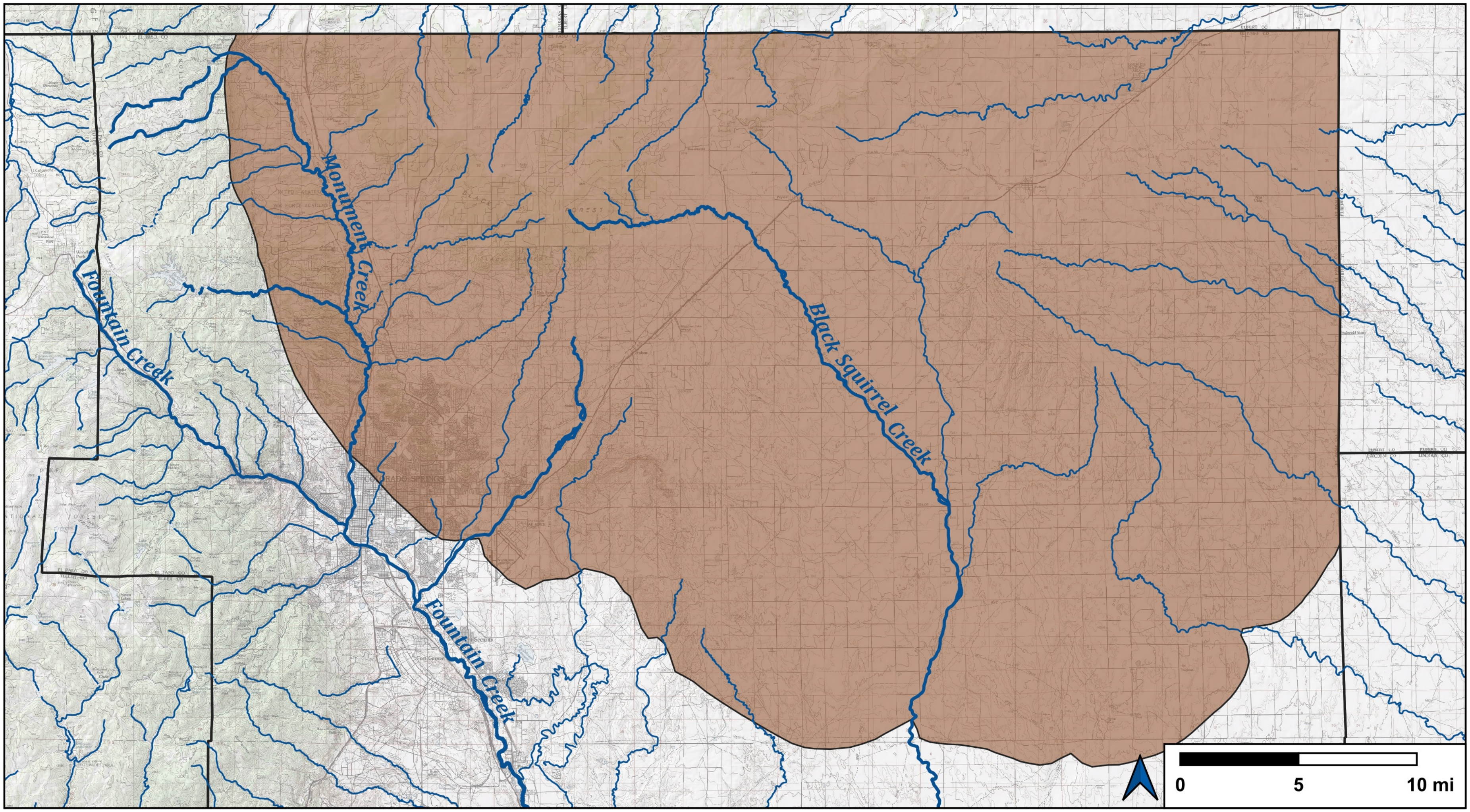
4 Paschke, S.S. (editor) 2011. Groundwater availability of the Denver Basin Aquifer System: U.S. Geological Survey Professional Paper 1770, Chapters A-C, 274 p.

5 Trimble, D.E., and Machette, M.N., 1979b. Map of the Colorado Springs - Castle Rock Area, Front Range Urban Corridor, Colorado, U.S. Geological Survey Miscellaneous Investigation Series Map 1-857-F.



LEGEND

- Minor River
- Major River
- Denver Basin Aquifer
- County Boundary

EL PASO COUNTY

MAJOR STREAM/ALLUVIAL SYSTEMS OVERLYING THE DENVER BASIN

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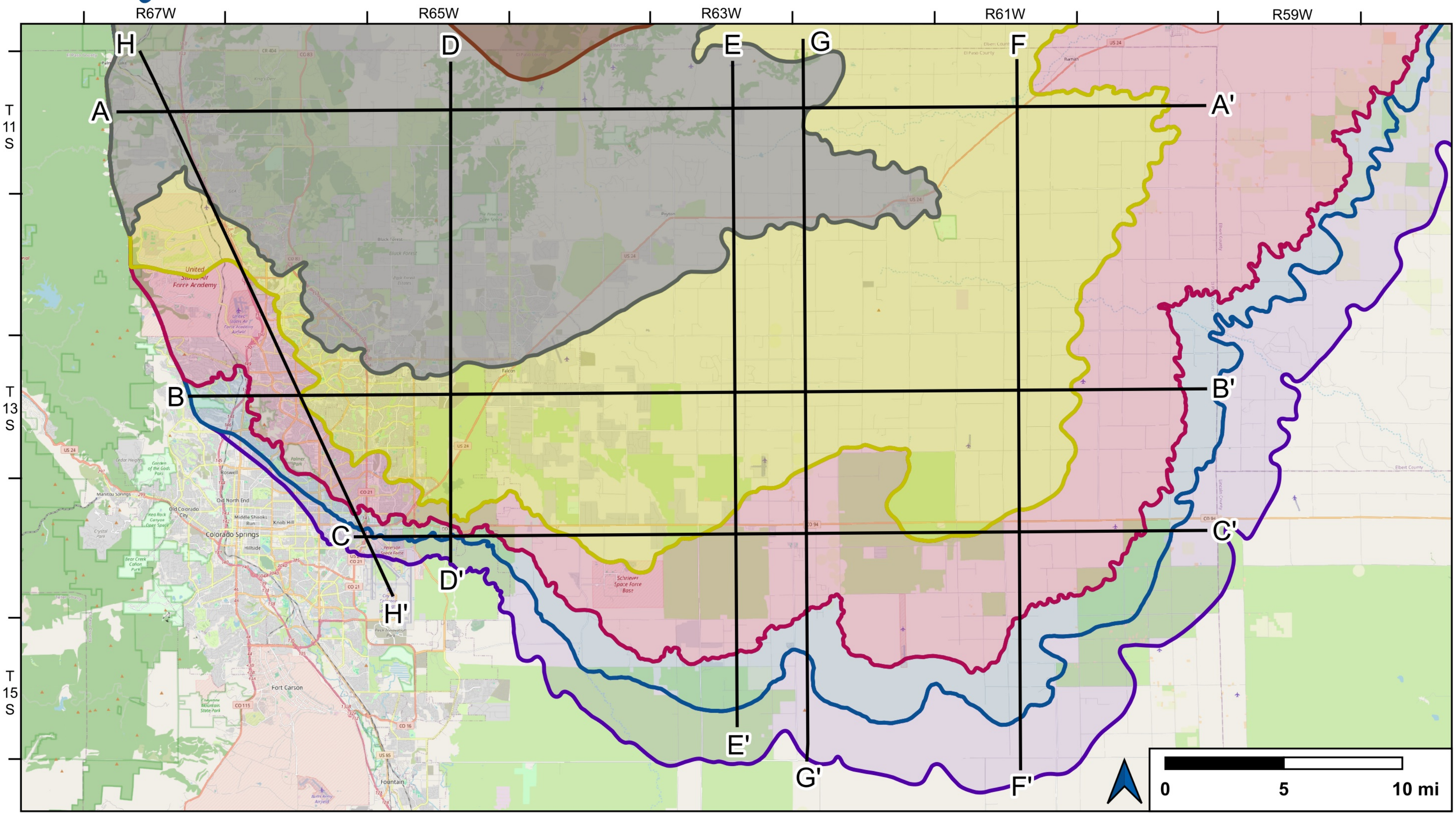
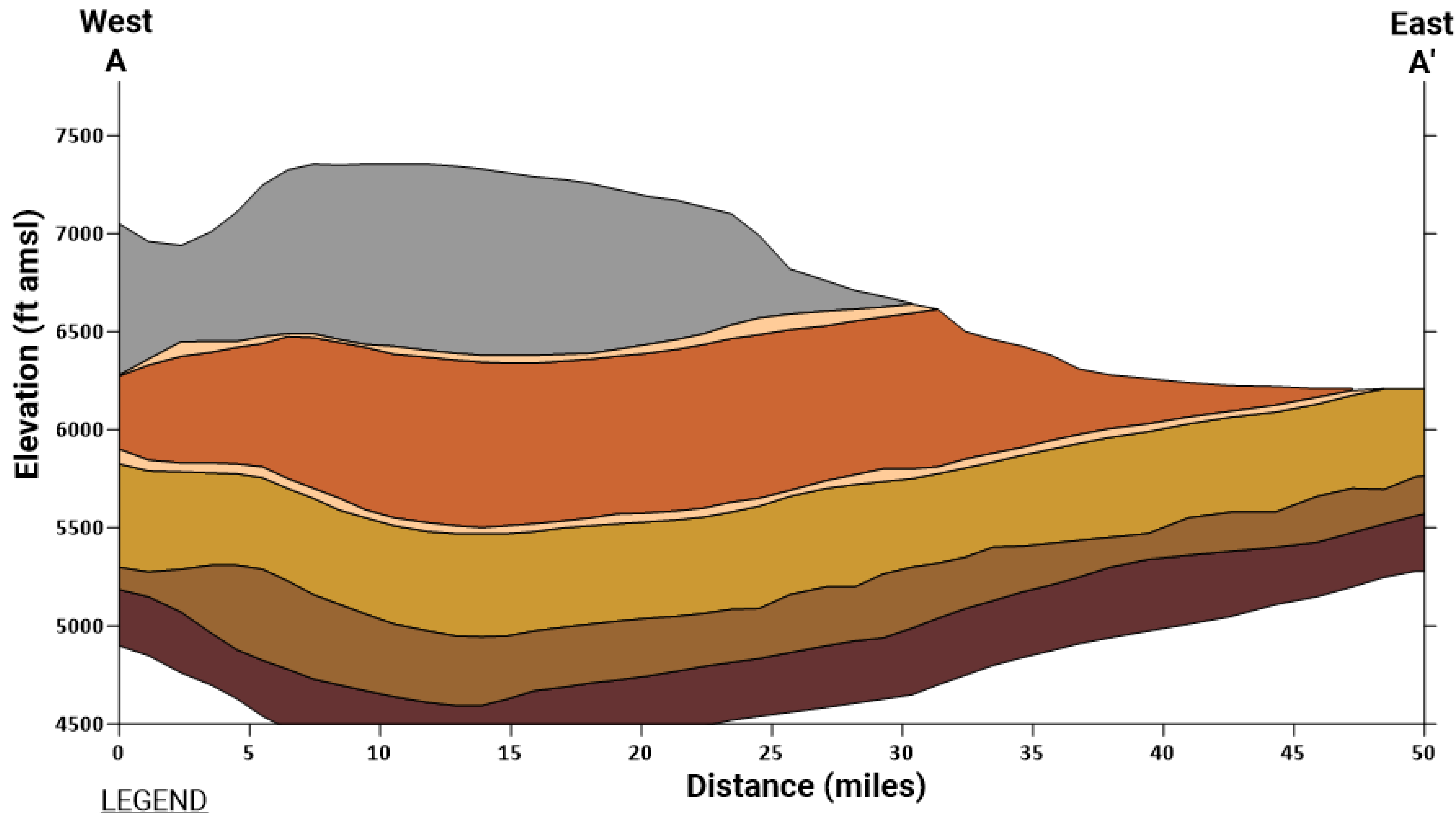
Project No: 24632	Drawn by: CDH	Fig. No.: 1



LEGEND

- Cross-Sections
- Upper Dawson Aquifer
- Lower Dawson Aquifer
- Denver Aquifer
- Arapahoe Aquifer
- Laramie Confining Unit
- Laramie-Fox Hills Aquifer

EL PASO COUNTY		
CROSS-SECTION LOCATIONS		
File: ElPasoAquiferExtents - X-Sect		Date: 02/20/2025
Project No: 24632	Drawn by:	Fig. No.: 2



LEGEND

- Dawson Formation
- Denver Formation
- Arapahoe Formation
- Laramie Formation
- LFH Aquifer
- Confining Layers

Notes:
1. Vertical exaggeration x40.
2. Cross section location on Figure 2.

EL PASO COUNTY		
CROSS SECTION A-A'		
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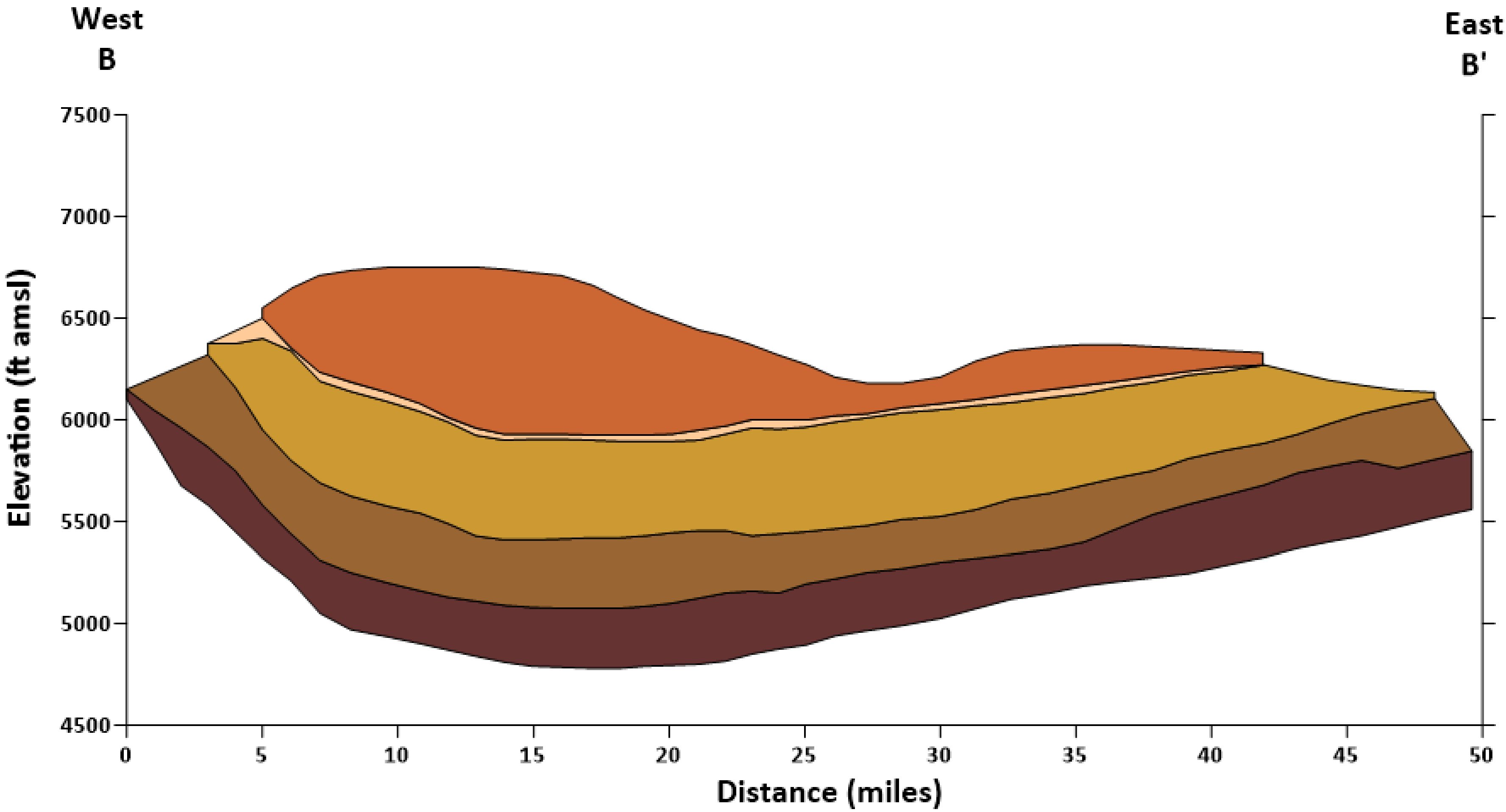

LEGEND

- Denver Formation
- Arapahoe Formation
- Laramie Formation
- LFH Aquifer
- Confining Layers

Notes:
1. Vertical exaggeration x40.
2. Cross section location on Figure 2.

EL PASO COUNTY		
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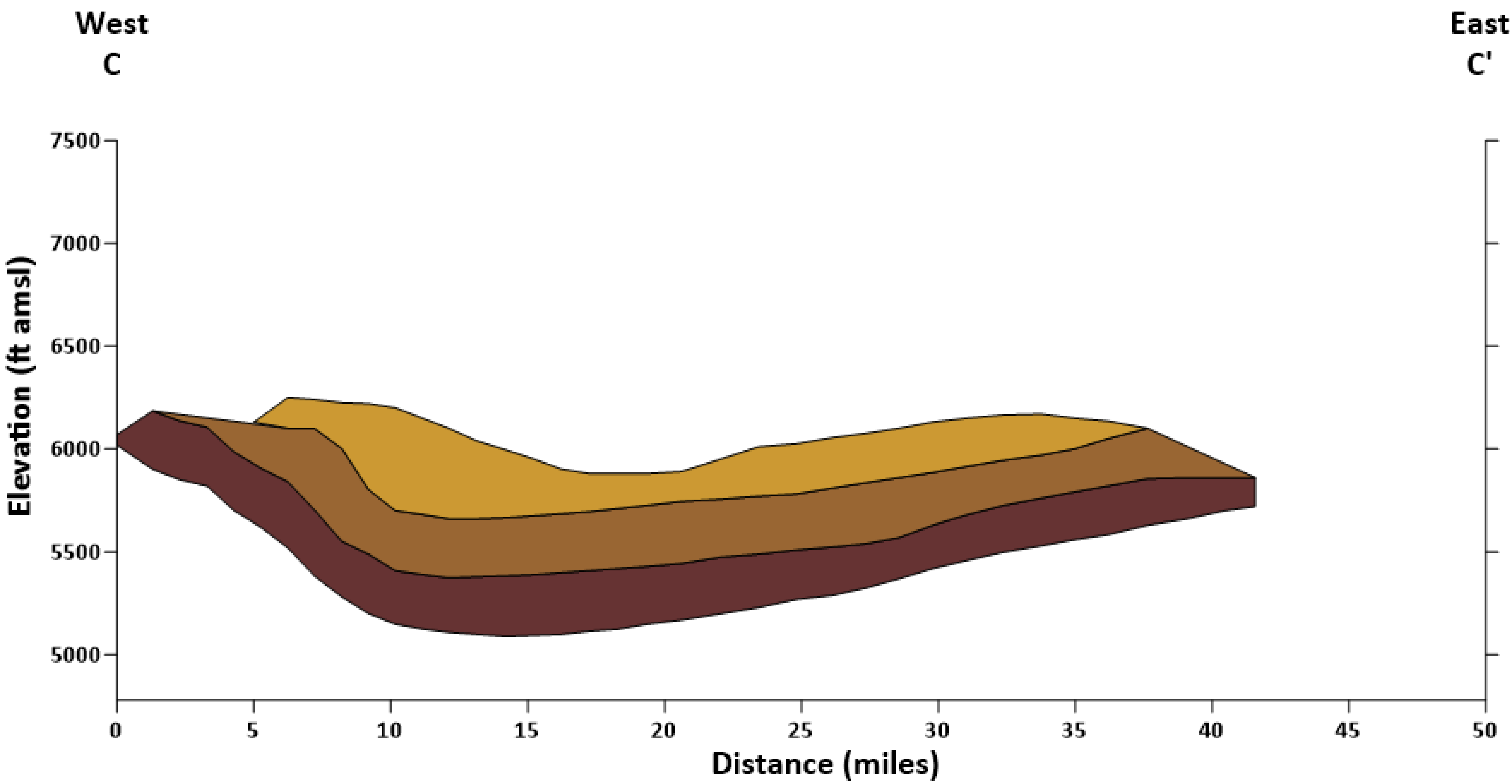

LEGEND

- Arapahoe Formation
- Laramie Formation
- LFH Aquifer
- Confining Layers

Notes:
1. Vertical exaggeration x40.
2. Cross section location on Figure 2.

EL PASO COUNTY

CROSS SECTION C-C'

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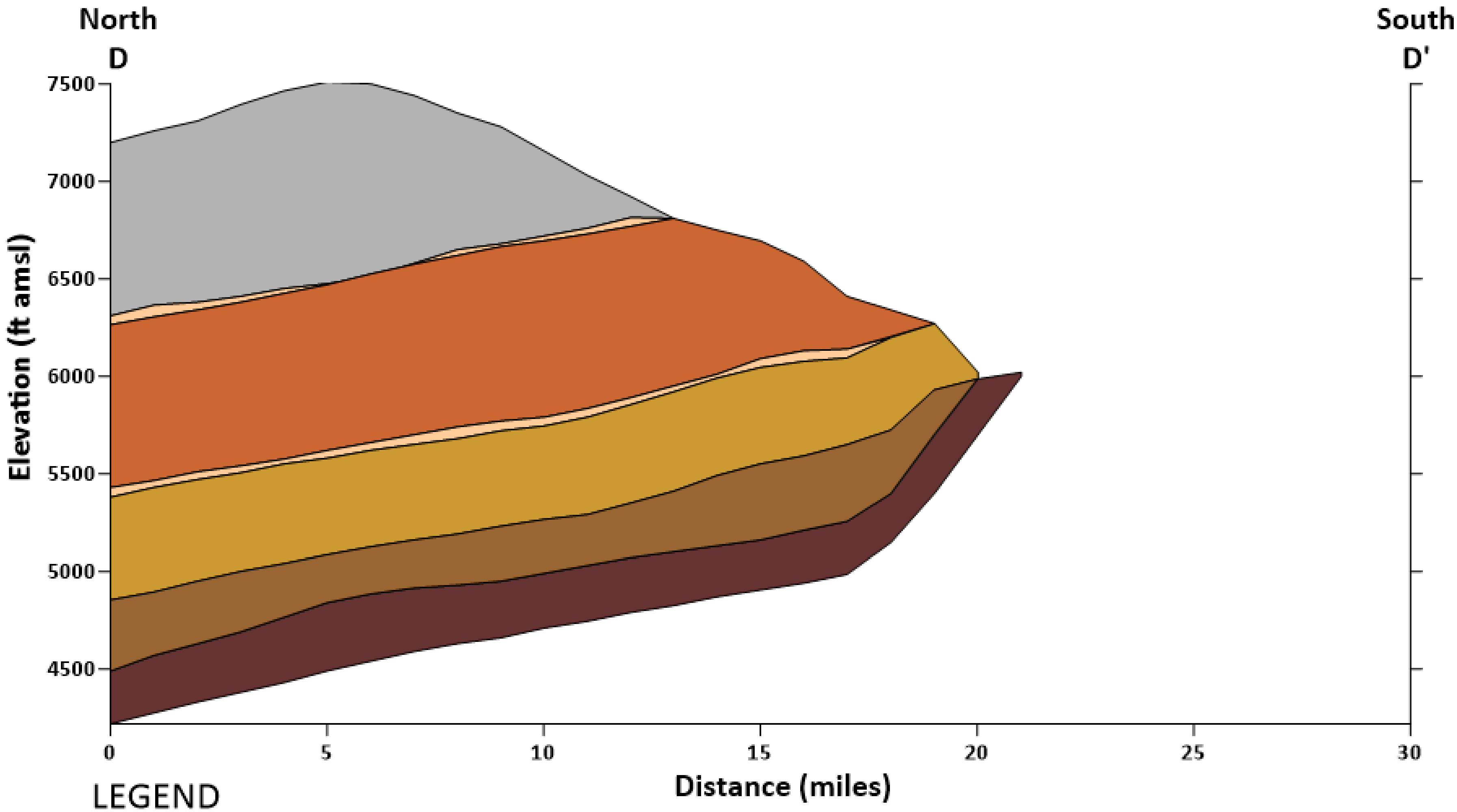

LEGEND

- Dawson Formation
- Denver Formation
- Arapahoe Formation
- Laramie Formation
- LFH Aquifer
- Confining Layers

Notes:
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2. Cross section location on Figure 2.

EL PASO COUNTY		
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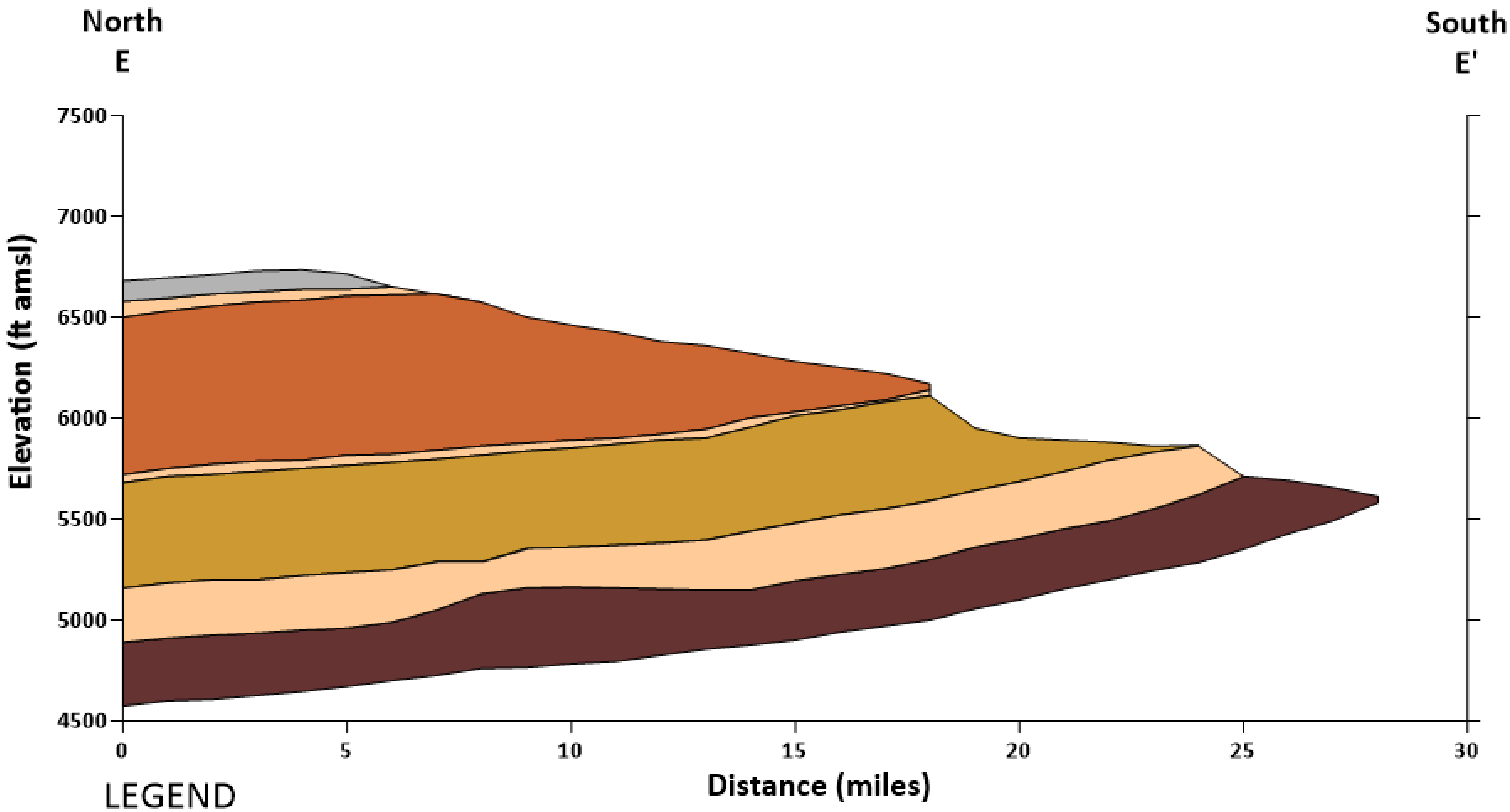

LEGEND

- Dawson Formation
- Denver Formation
- Arapahoe Formation
- Laramie Formation
- LFH Aquifer
- Confining Layers

Notes:

1. Vertical exaggeration x24.
2. Cross section location on Figure 2.

EL PASO COUNTY		
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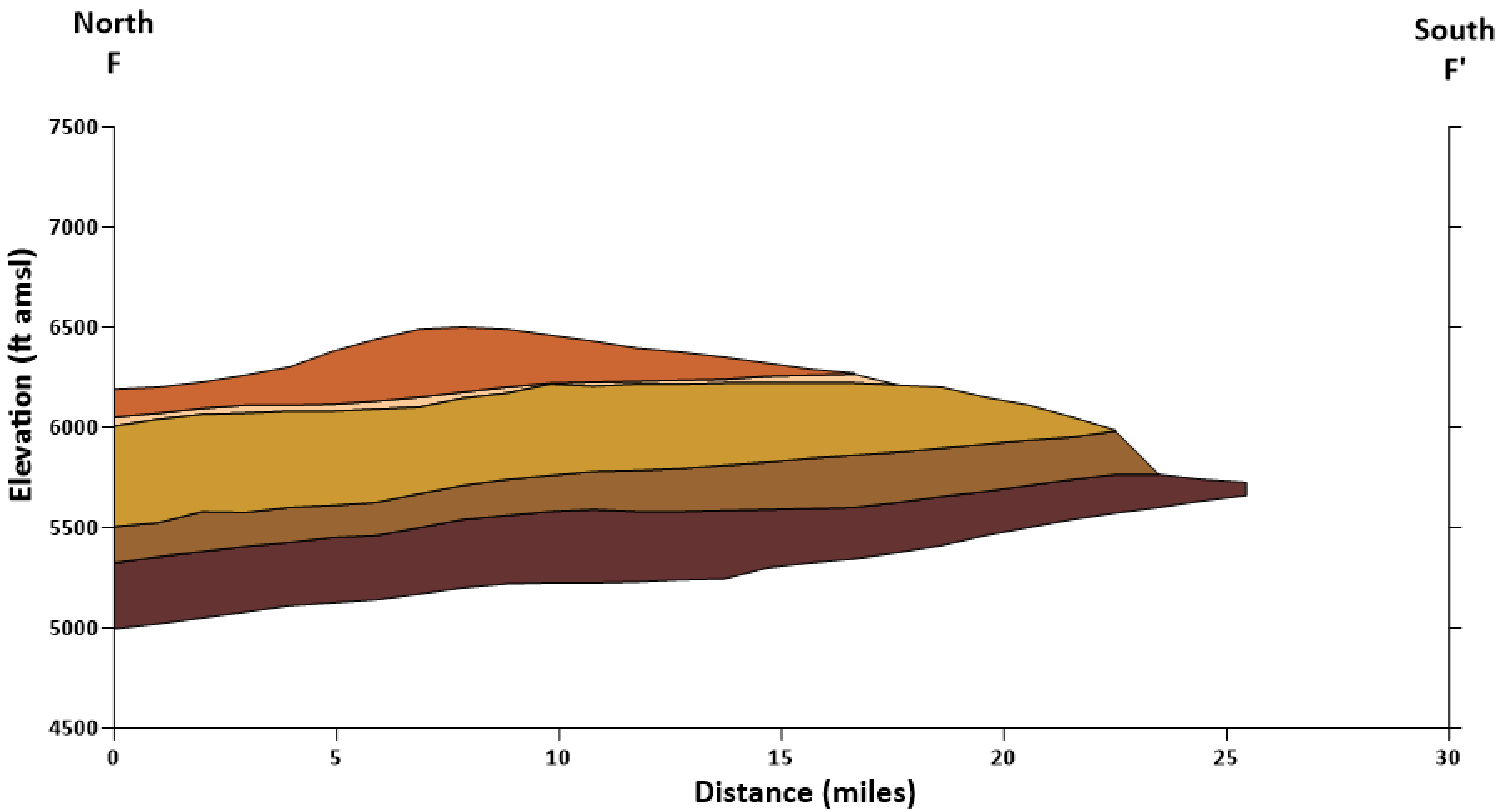

LEGEND

- Denver Formation
- Arapahoe Formation
- Laramie Formation
- LFH Aquifer
- Confining Layers

Notes:
1. Vertical exaggeration x24.
2. Cross section location on Figure 2.

EL PASO COUNTY		
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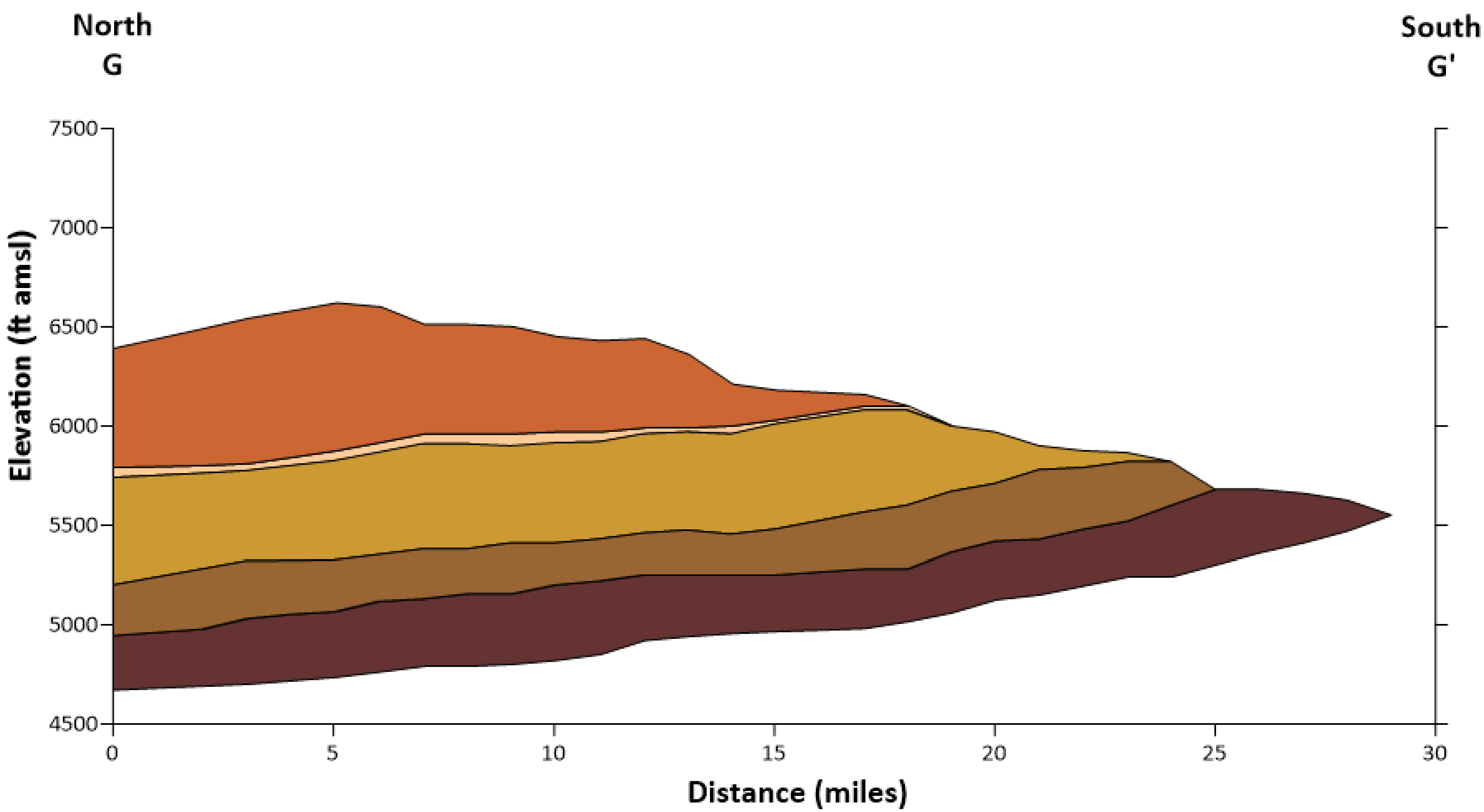

LEGEND

- Denver Formation
- Arapahoe Formation
- Laramie Formation
- LFH Aquifer
- Confining Layers

Notes:
1. Vertical exaggeration x24.
2. Cross section location on Figure 2.

EL PASO COUNTY		
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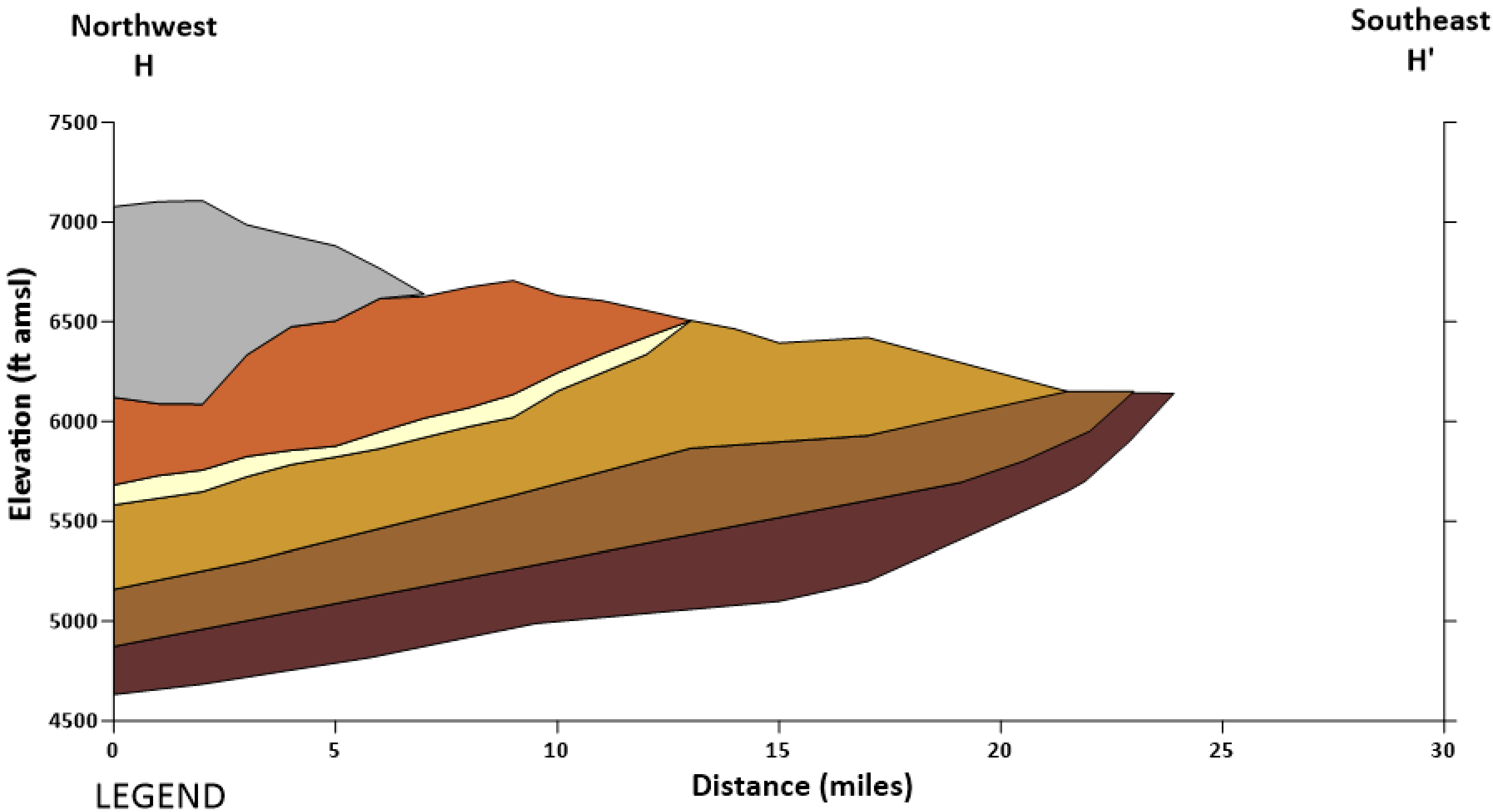

LEGEND

- Dawson Formation
- Denver Formation
- Arapahoe Formation
- Laramie Formation
- LFH Aquifer
- Confining Layers

Notes:
1. Vertical exaggeration x24.
2. Cross section location on Figure 2.

EL PASO COUNTY		
CROSS SECTION H-H'		
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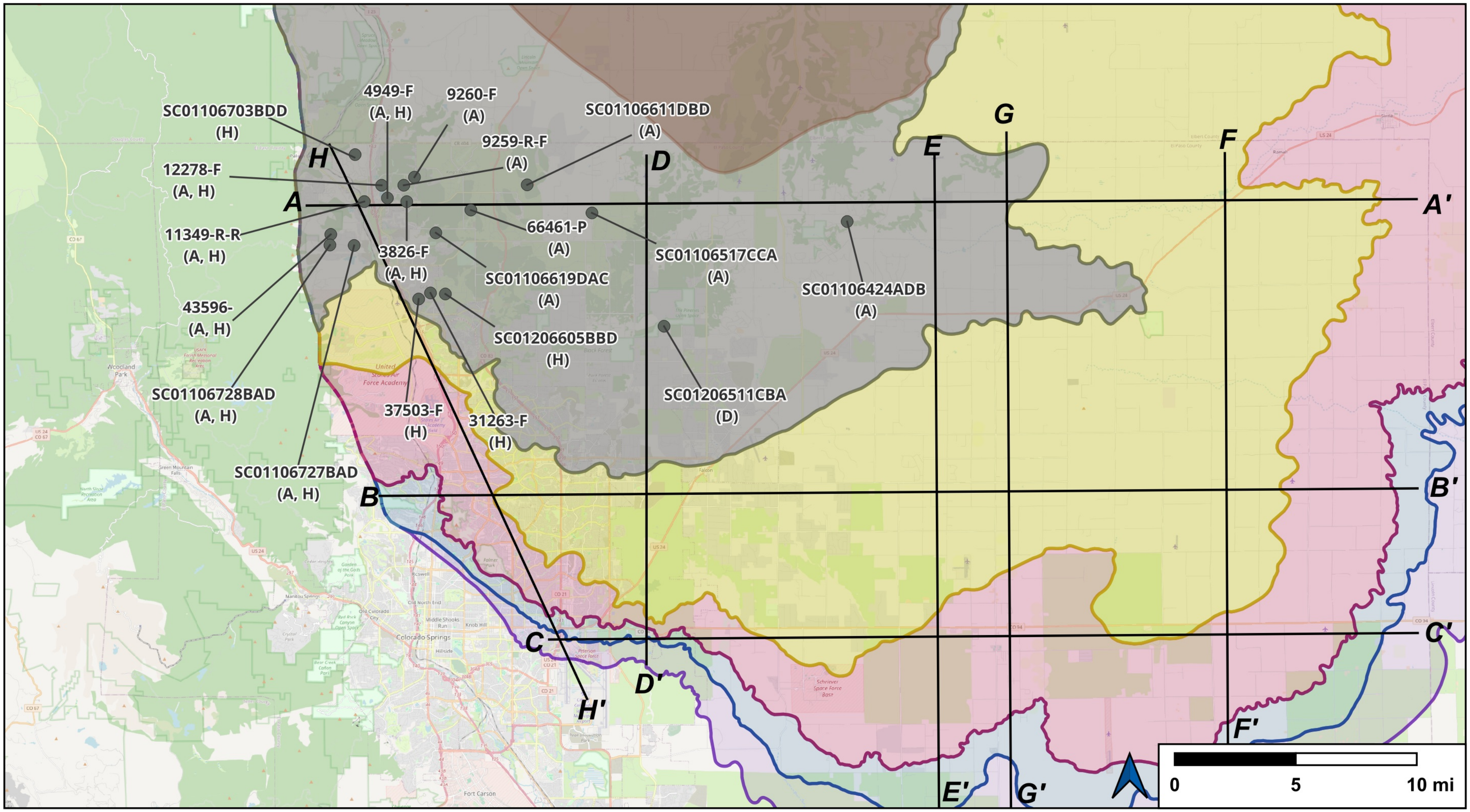
Project No.: 24632	Drawn By: MAM	Fig No.: 10

Appendix A - Stratigraphic Column of the Denver Basin

Geologic unit		Lithology	Geohydrologic unit	Thickness (ft)
Dawson Formation		Sandstone and conglomeratic sandstone with interbedded siltstone and shale.	Dawson aquifer	0–400
Denver Formation		Shale, silty claystone, and interbedded sandstone and shale.	Denver aquifer	0–500
Arapahoe Formation		Sandstone and conglomeratic sandstone with interbedded siltstone and shale.	Arapahoe aquifer	0–600
Laramie Formation	Upper	Shale with interbedded siltstone and very fine grained sandstone.	Laramie confining layer	0–400
Laramie Formation	Lower	Sandstone and siltstone with interbedded shale.	Laramie–Fox Hills aquifer	0–400
Fox Hills Sandstone		Sandstone with some thin shale beds.		
Pierre Shale	Transition zone member	Sandstone, shale, and siltstone.		
Pierre Shale		Shale with interbedded fine-grained sandstone.	Pierre confining layer	0–8,000

Source: USGS Circular 1219 (Knepper 2002)

Appendix B - Dawson Aquifer Hydrographs



LEGEND

- Well Permit # or Name (Cross-Section)
- Cross-Sections
- Upper Dawson Aquifer
- Lower Dawson Aquifer
- Denver Aquifer
- Arapahoe Aquifer
- Laramie Confining Unit
- Laramie-Fox Hills Aquifer

EL PASO COUNTY		
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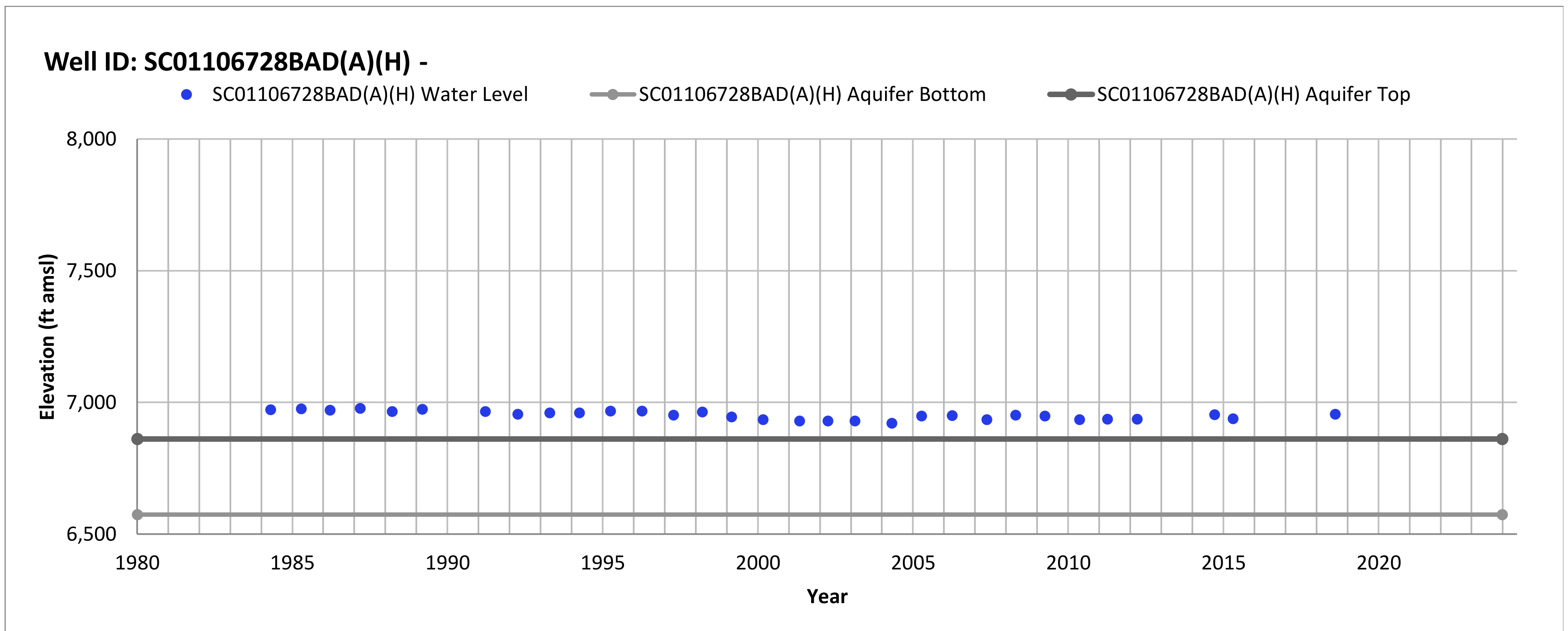
Project No: 24632	Drawn by: CDH	Fig. No.: B-1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7,000
6,500
Elevation (ft amsl)
1980
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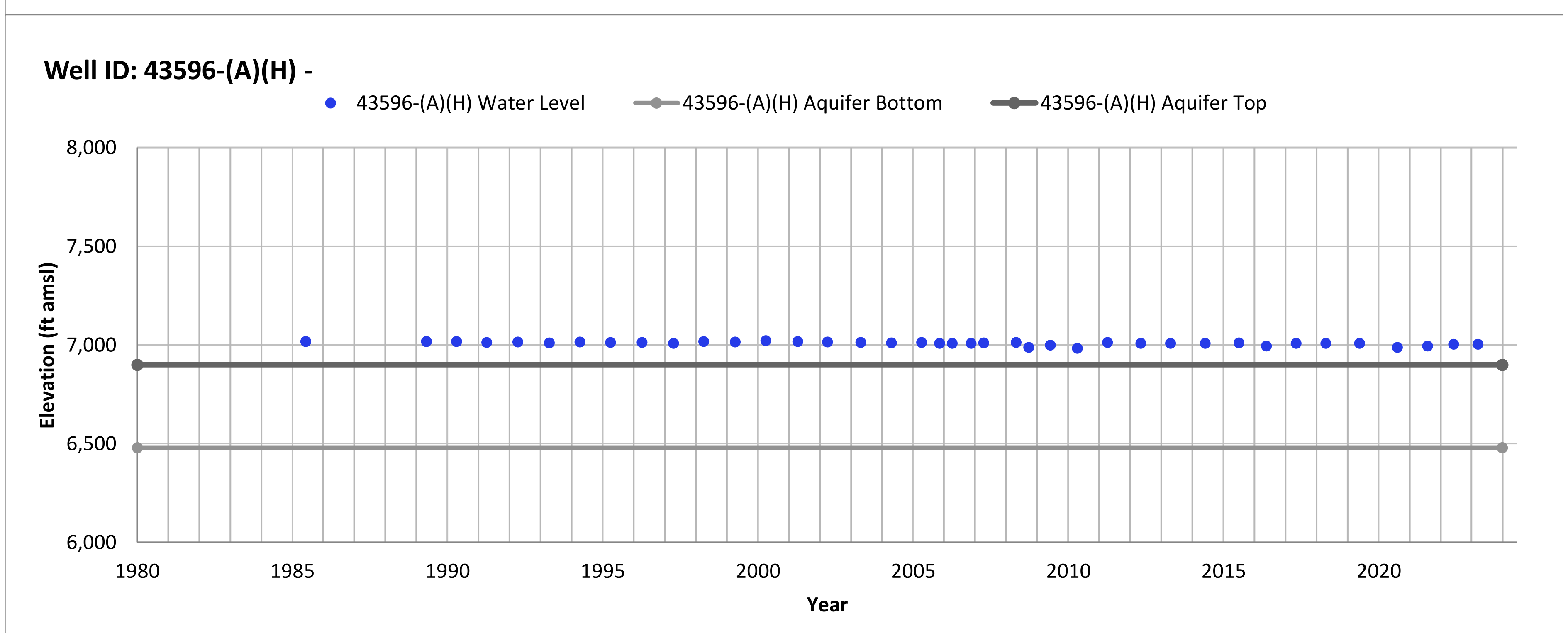
2015
2020
Year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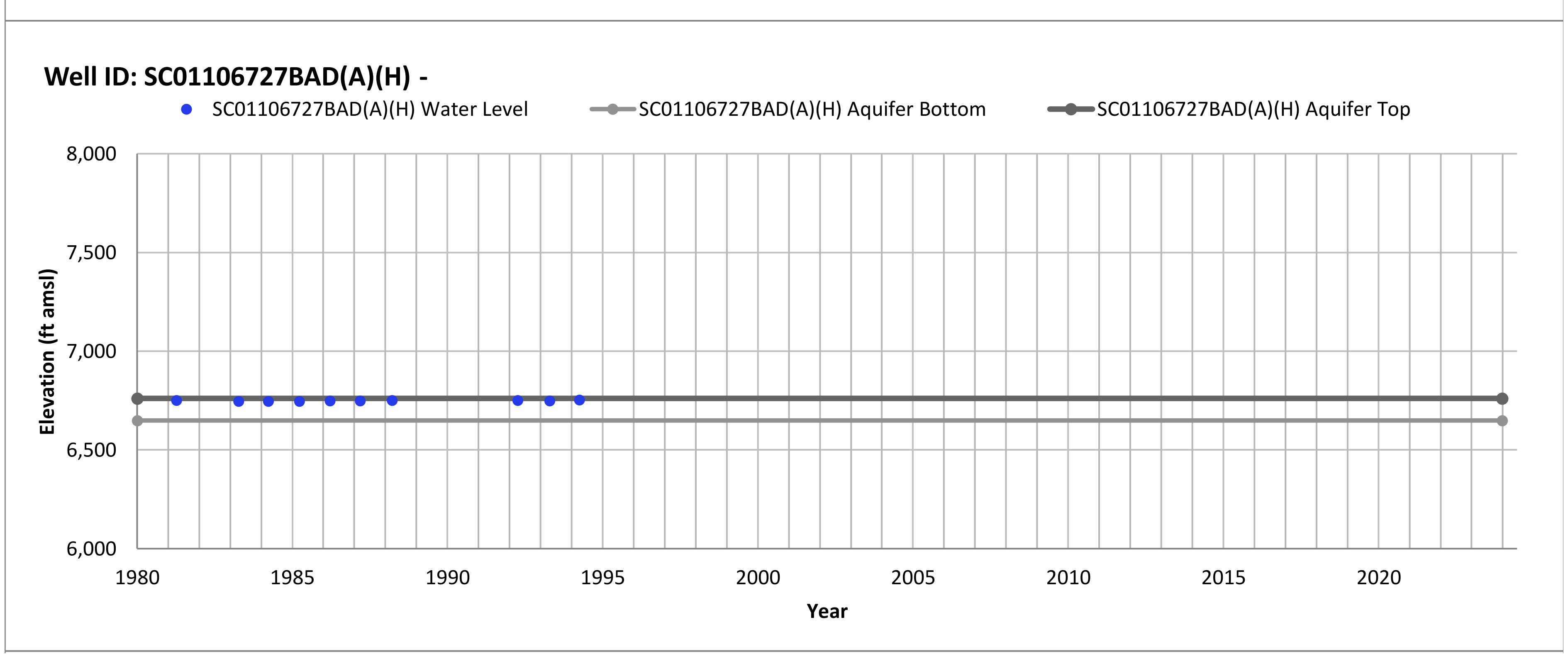
Year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Elevation (ft amsl)
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Year

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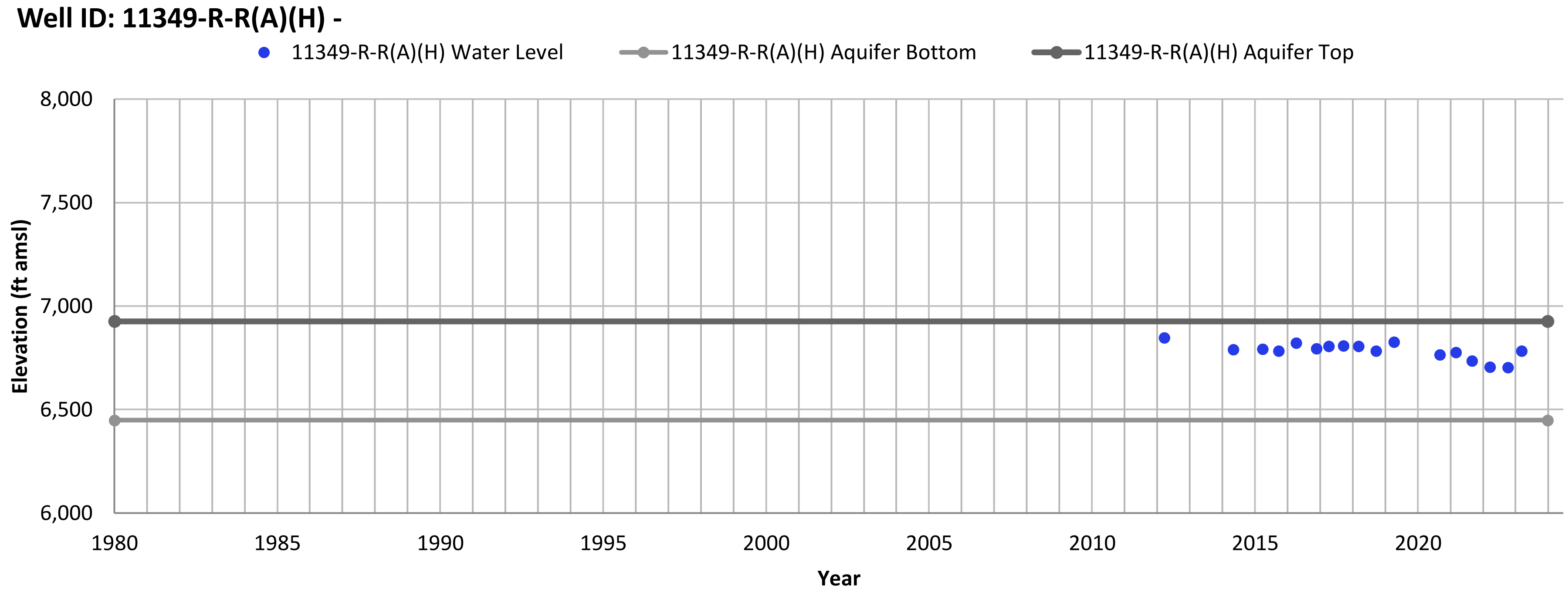

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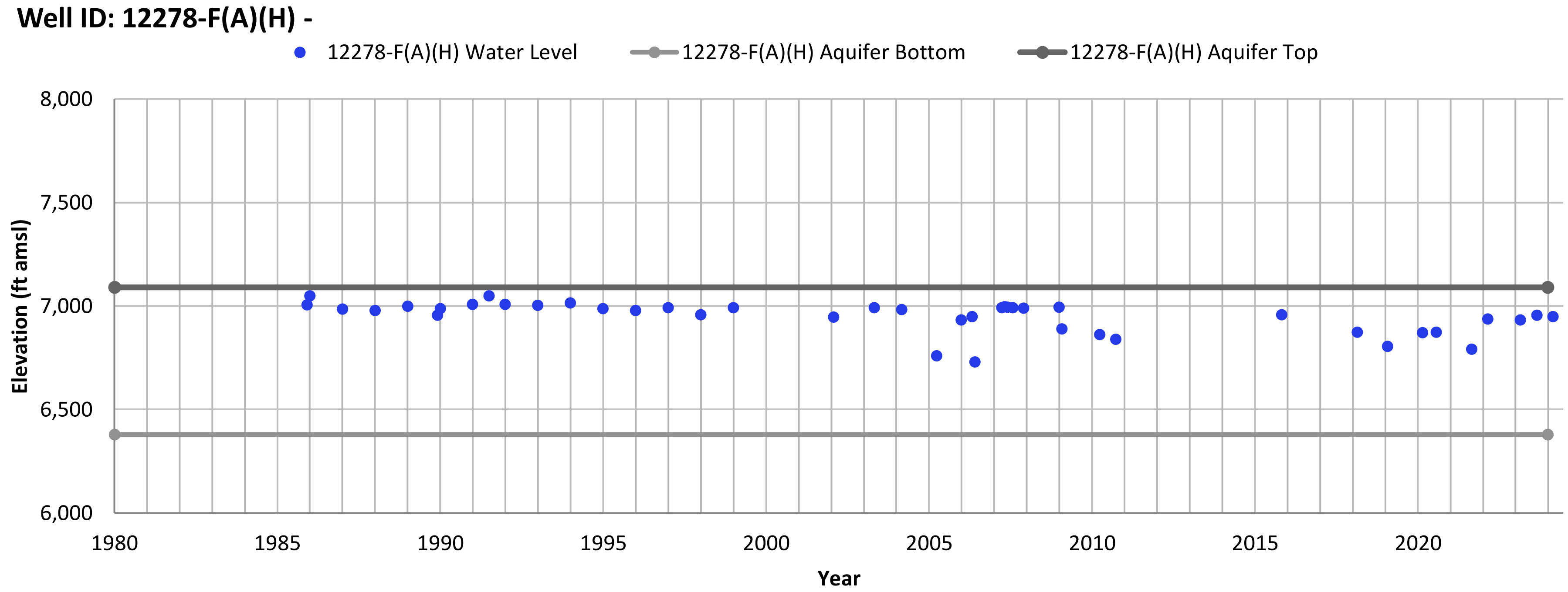

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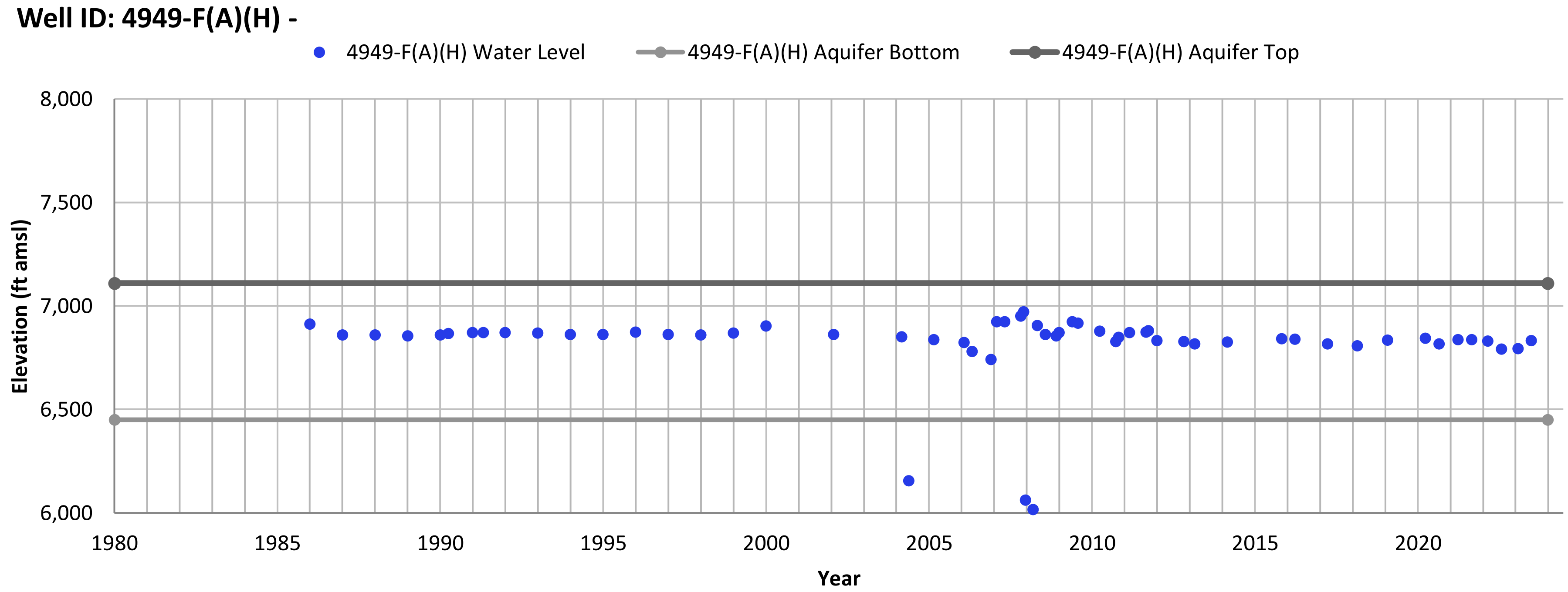

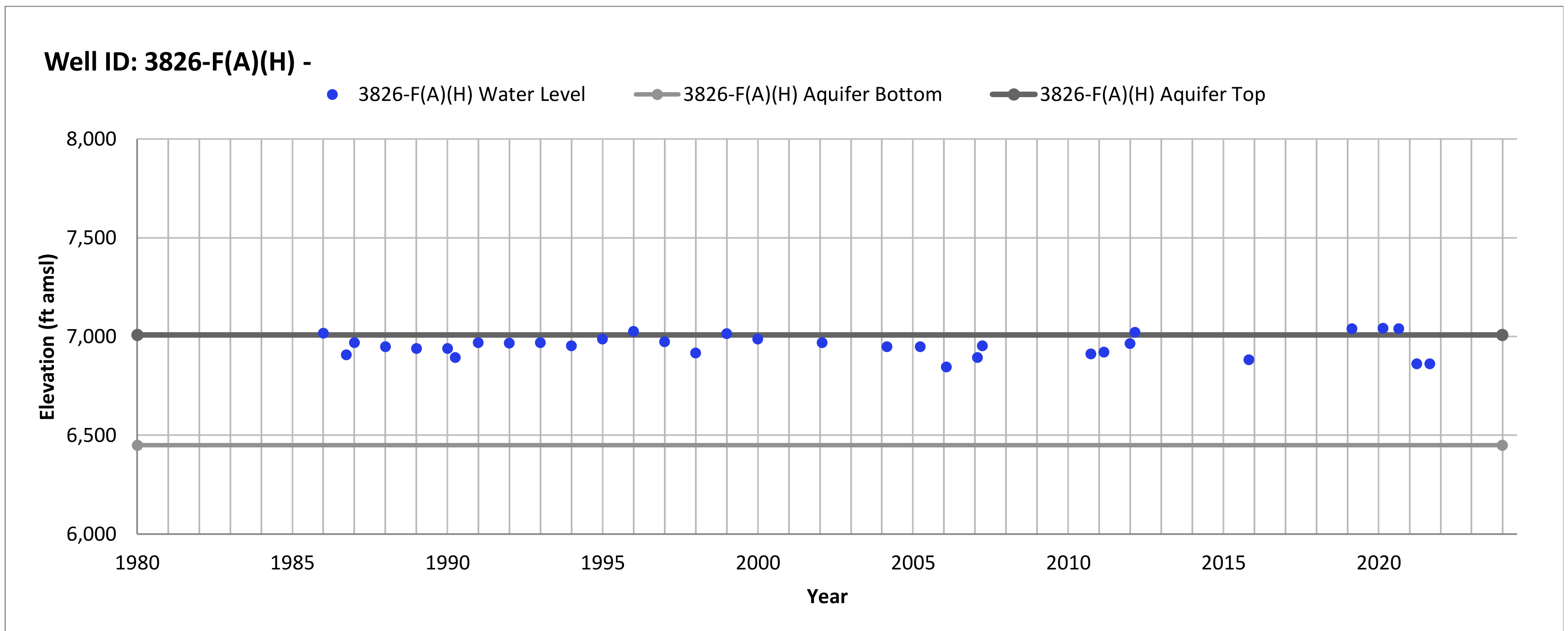

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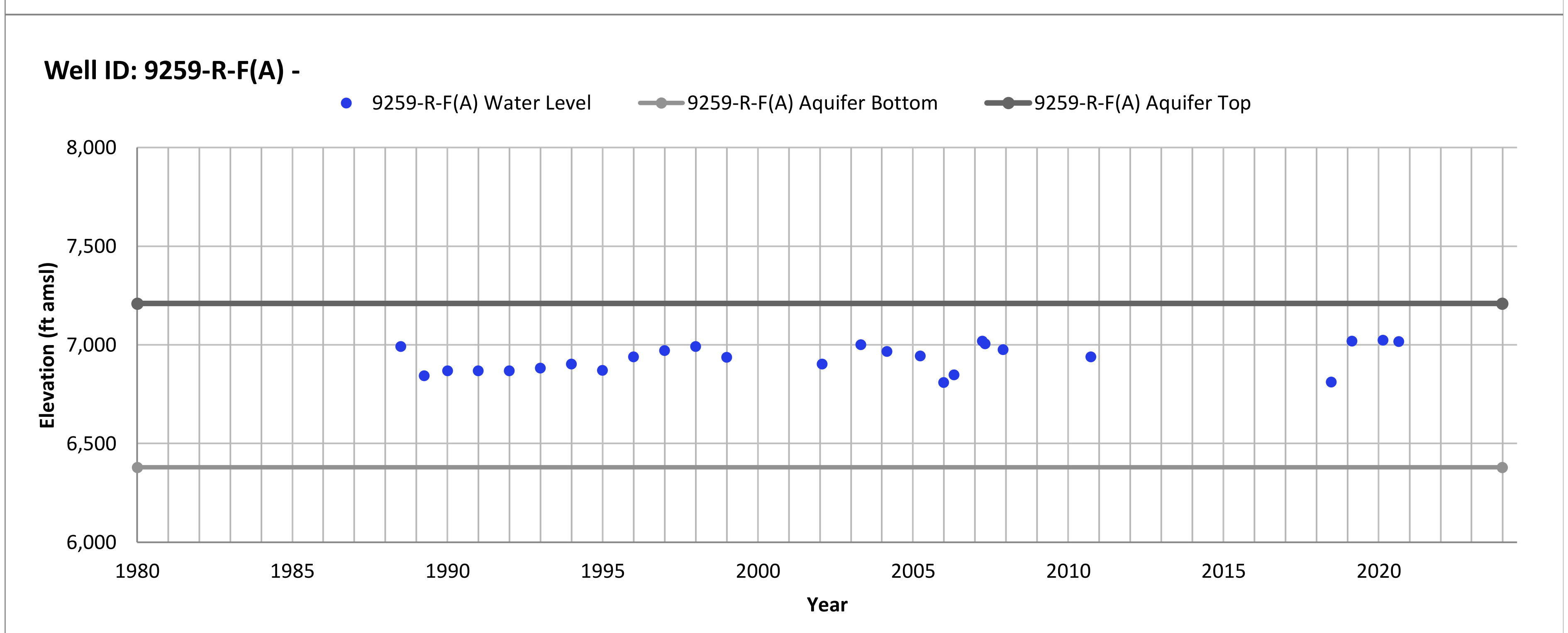
Year



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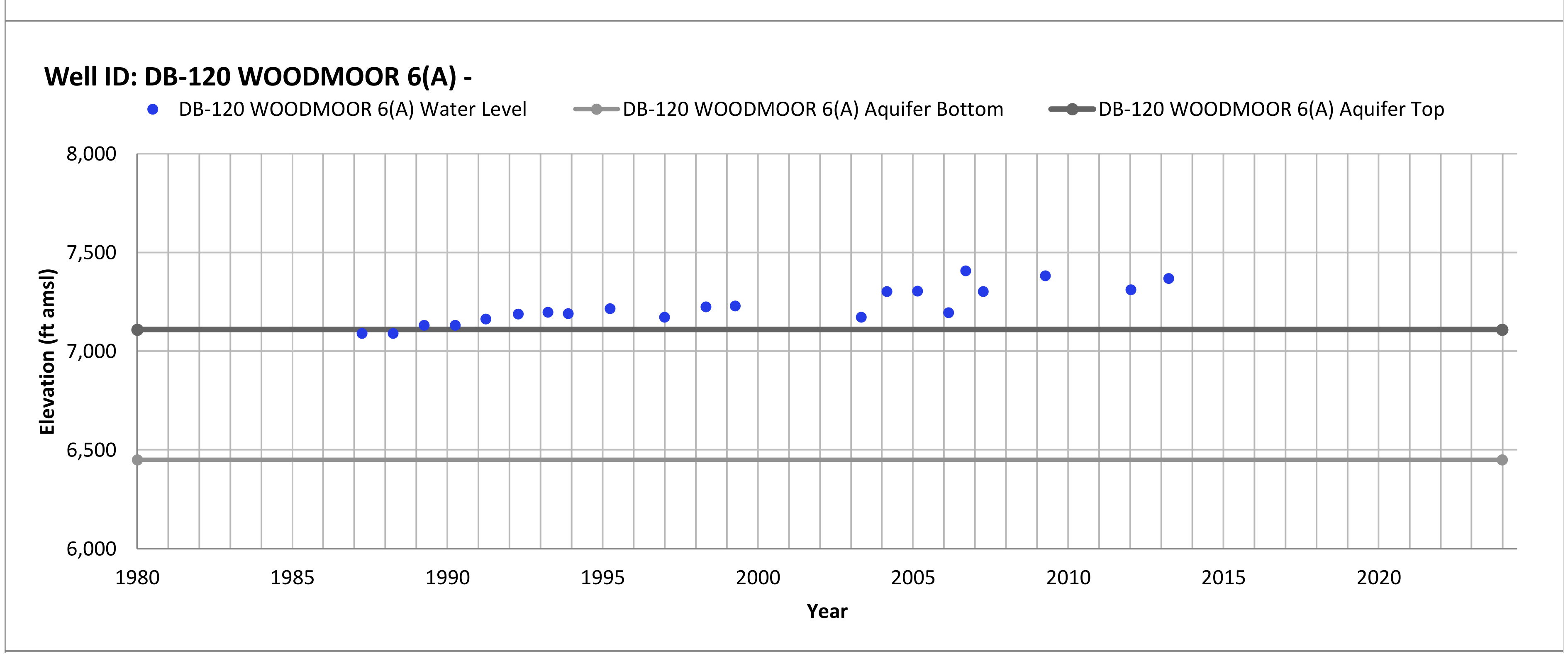

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Elevation (ft amsl)
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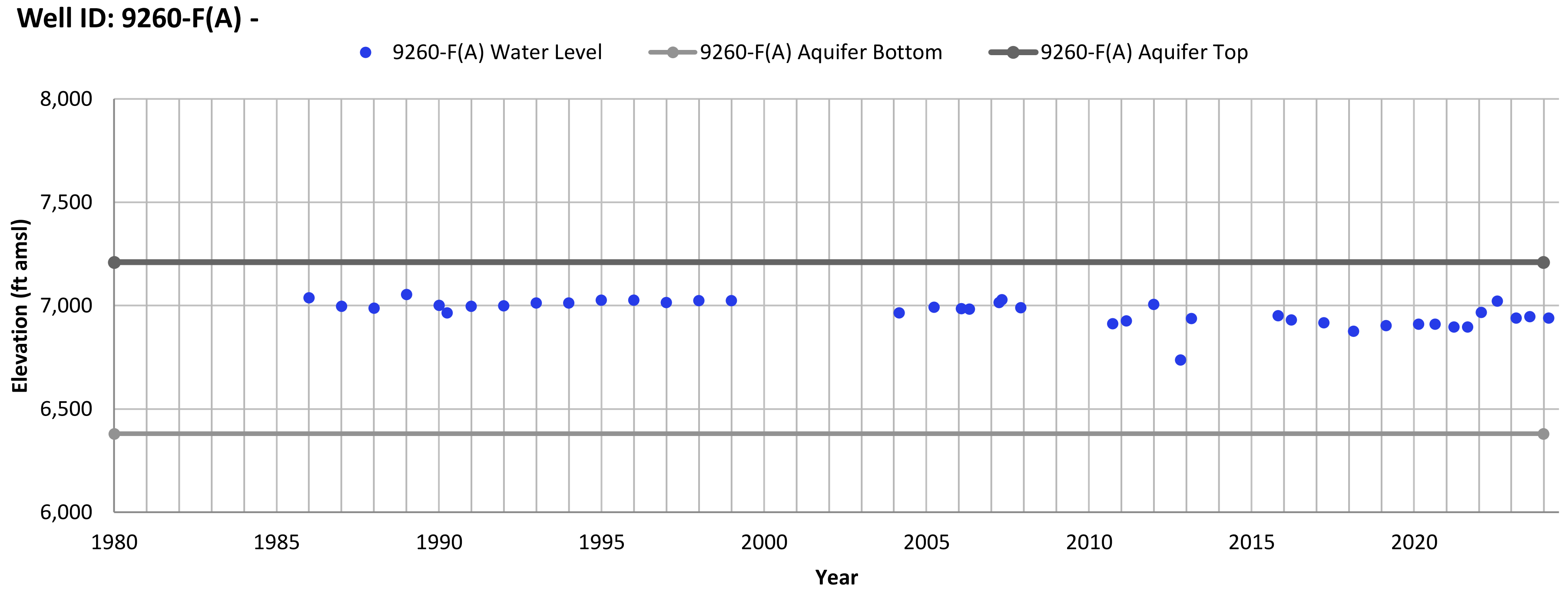

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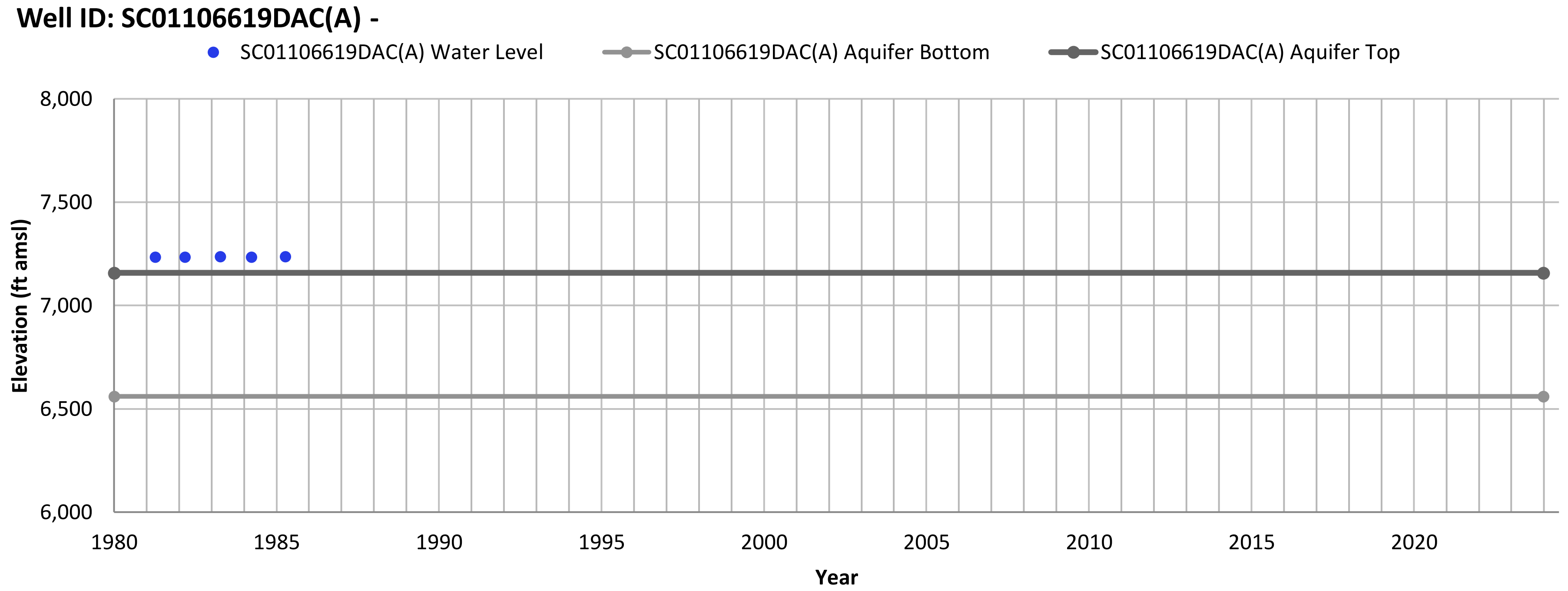

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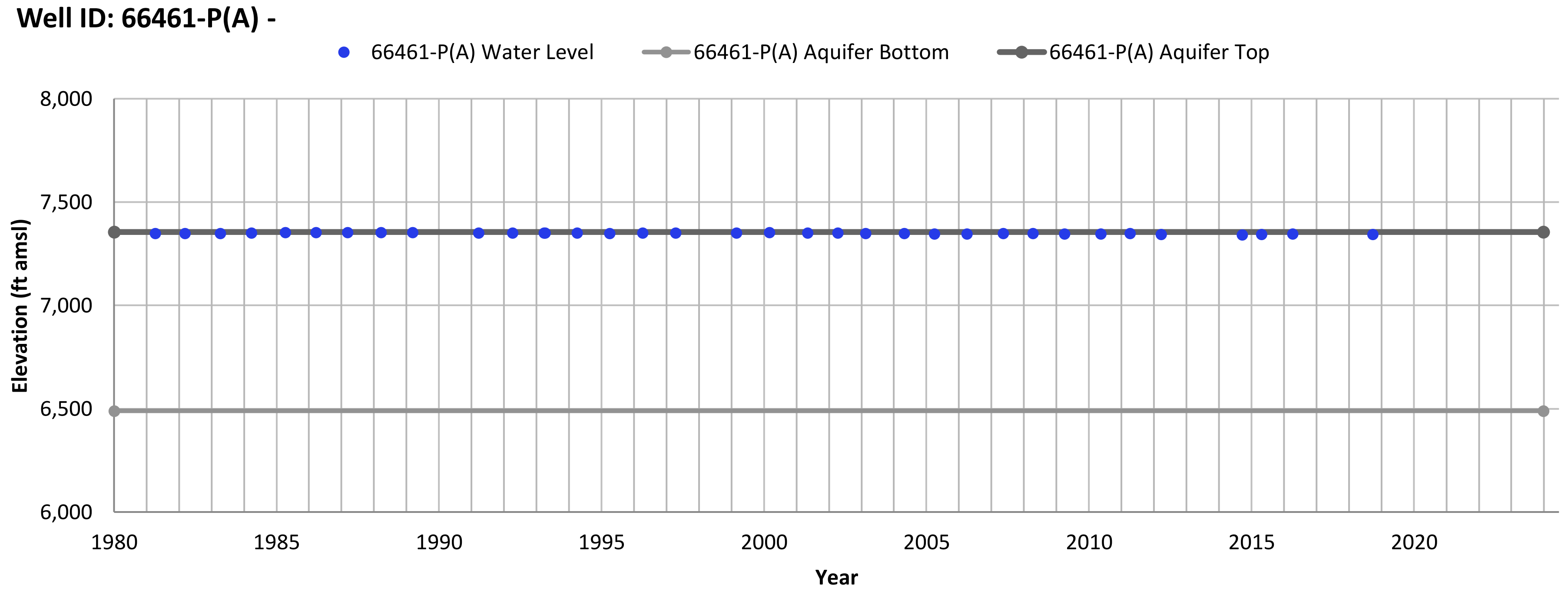

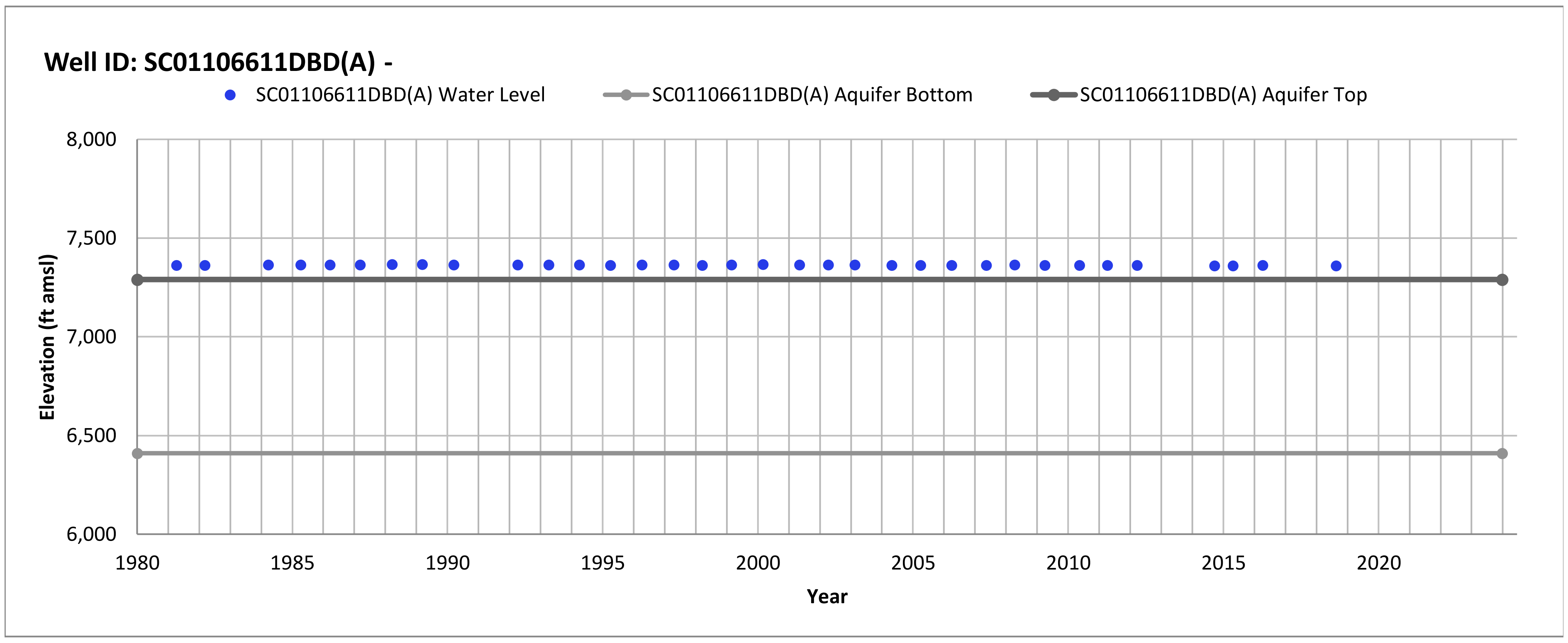
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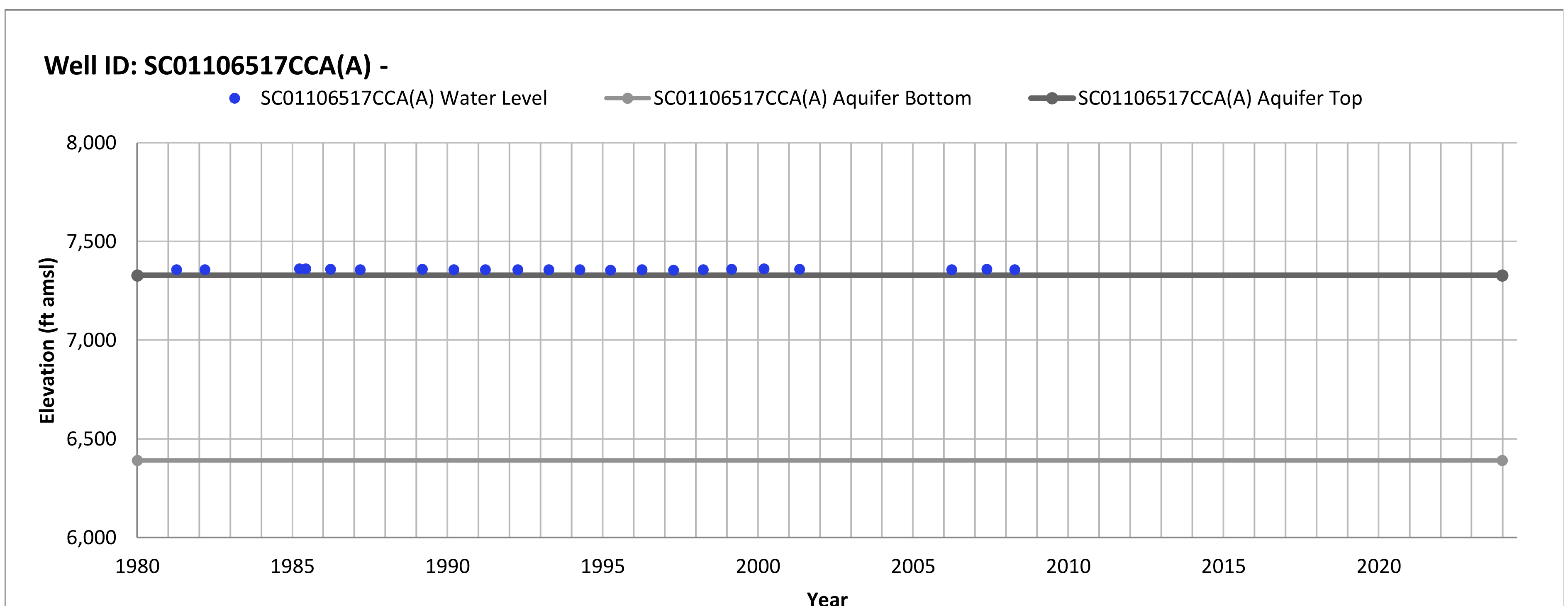
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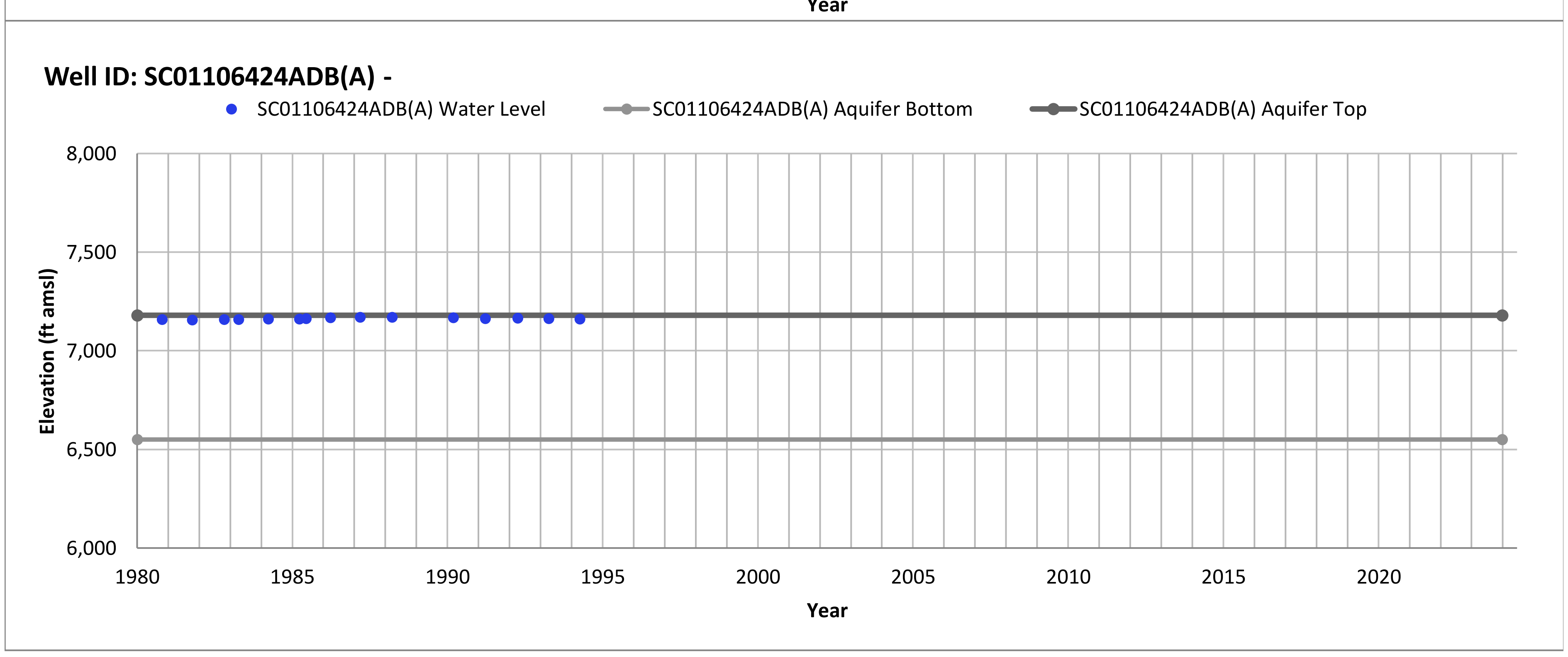
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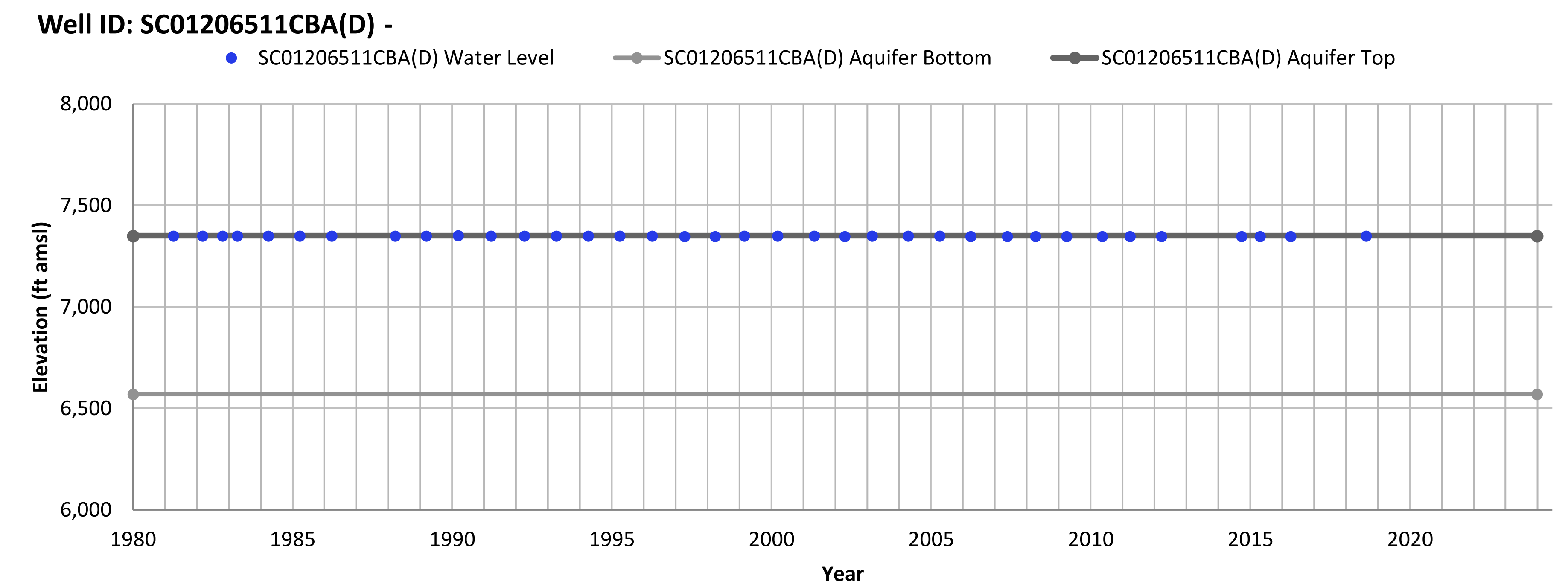
Year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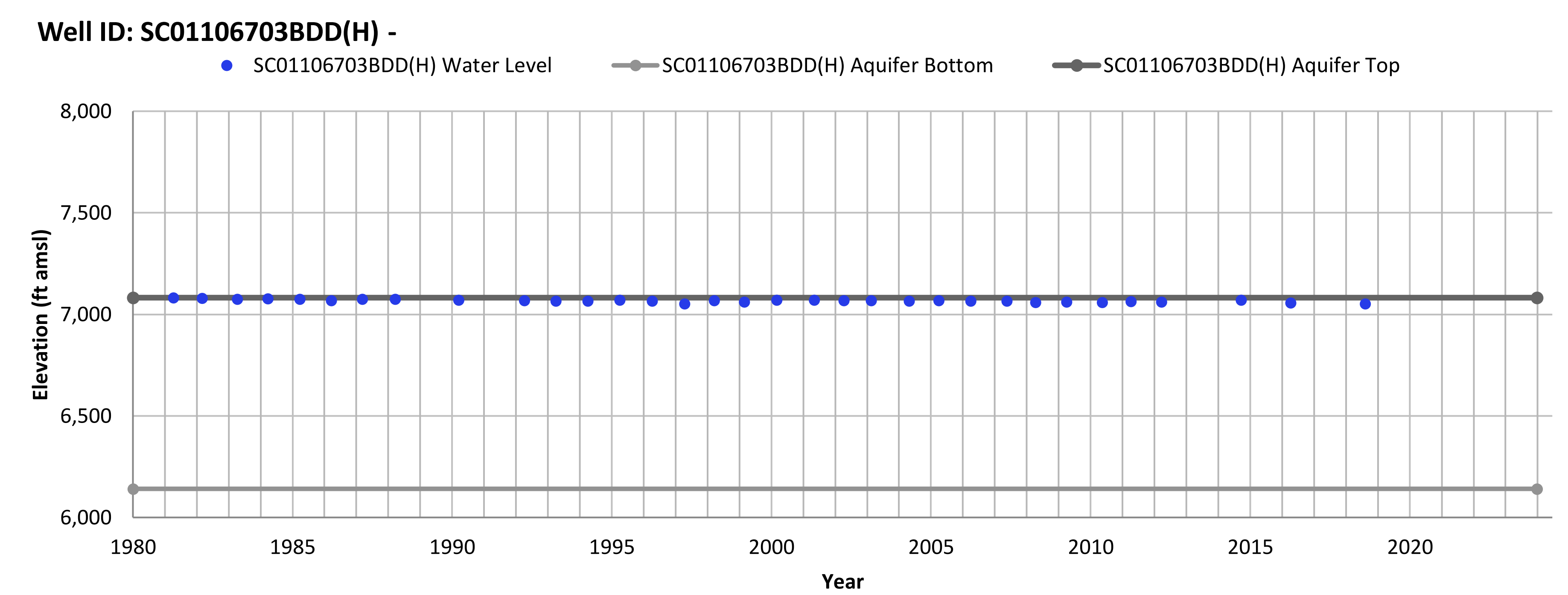
2020
Year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Elevation (ft amsl)
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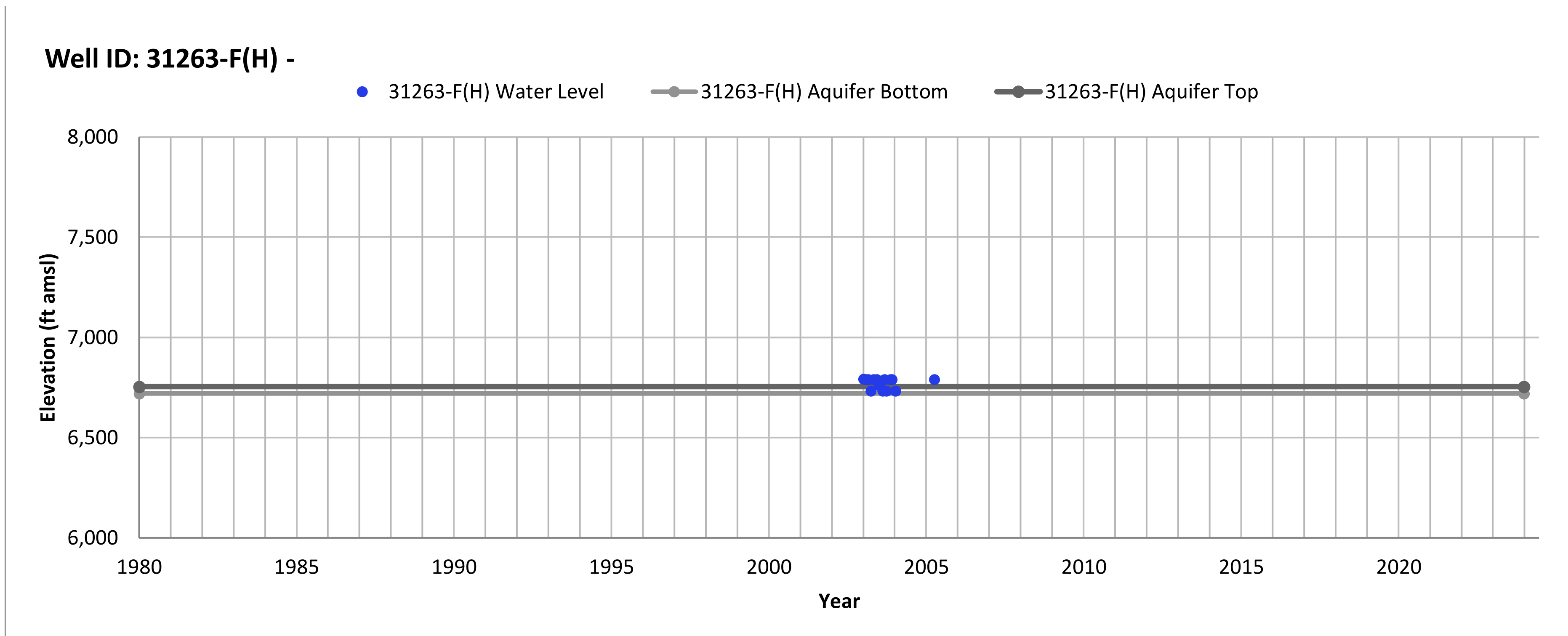
Year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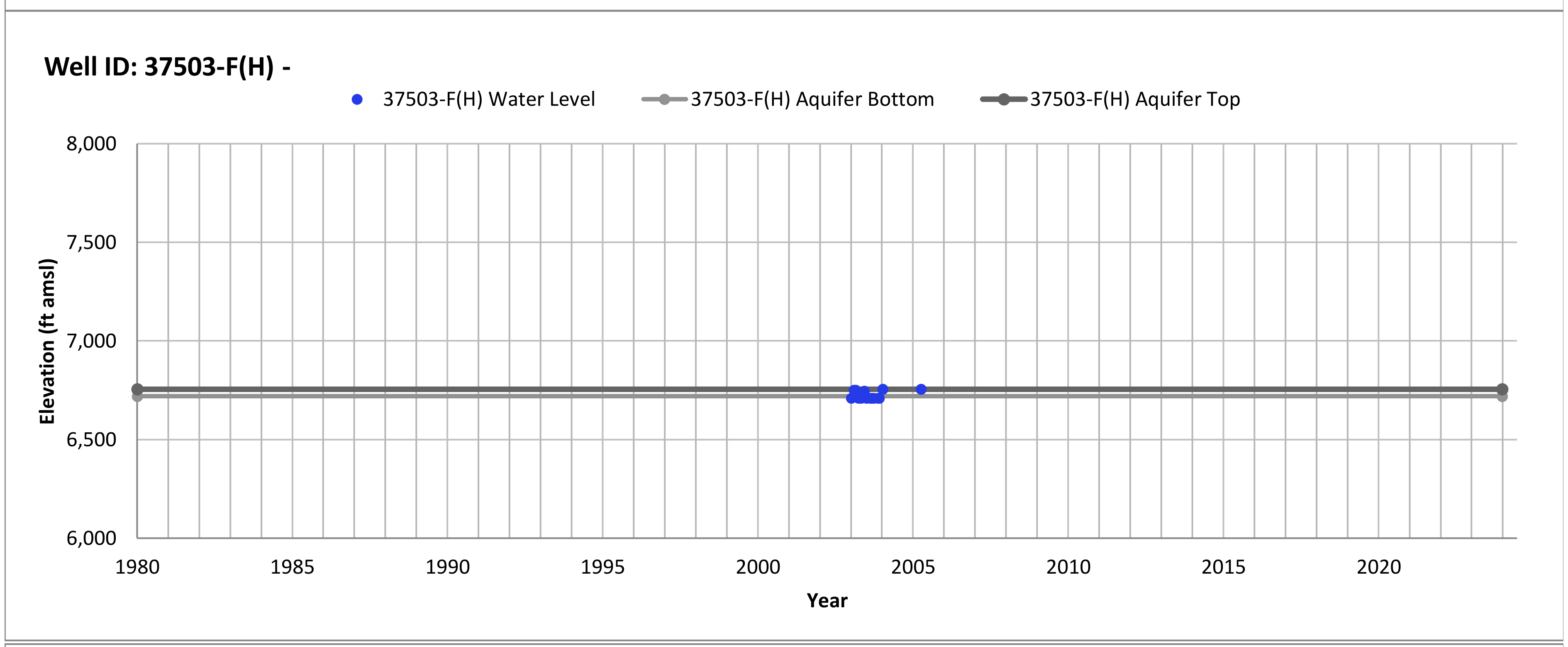
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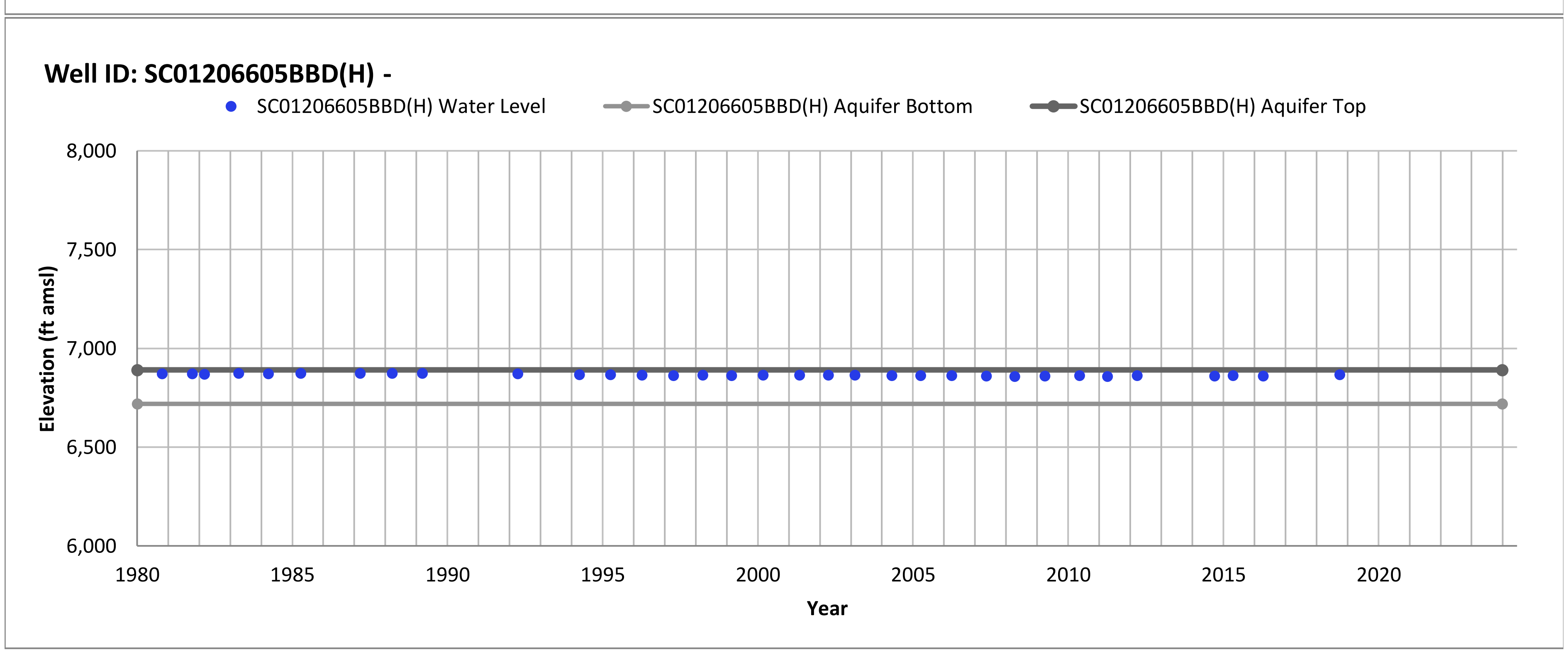
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Elevation (ft amsl)
1980
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2000
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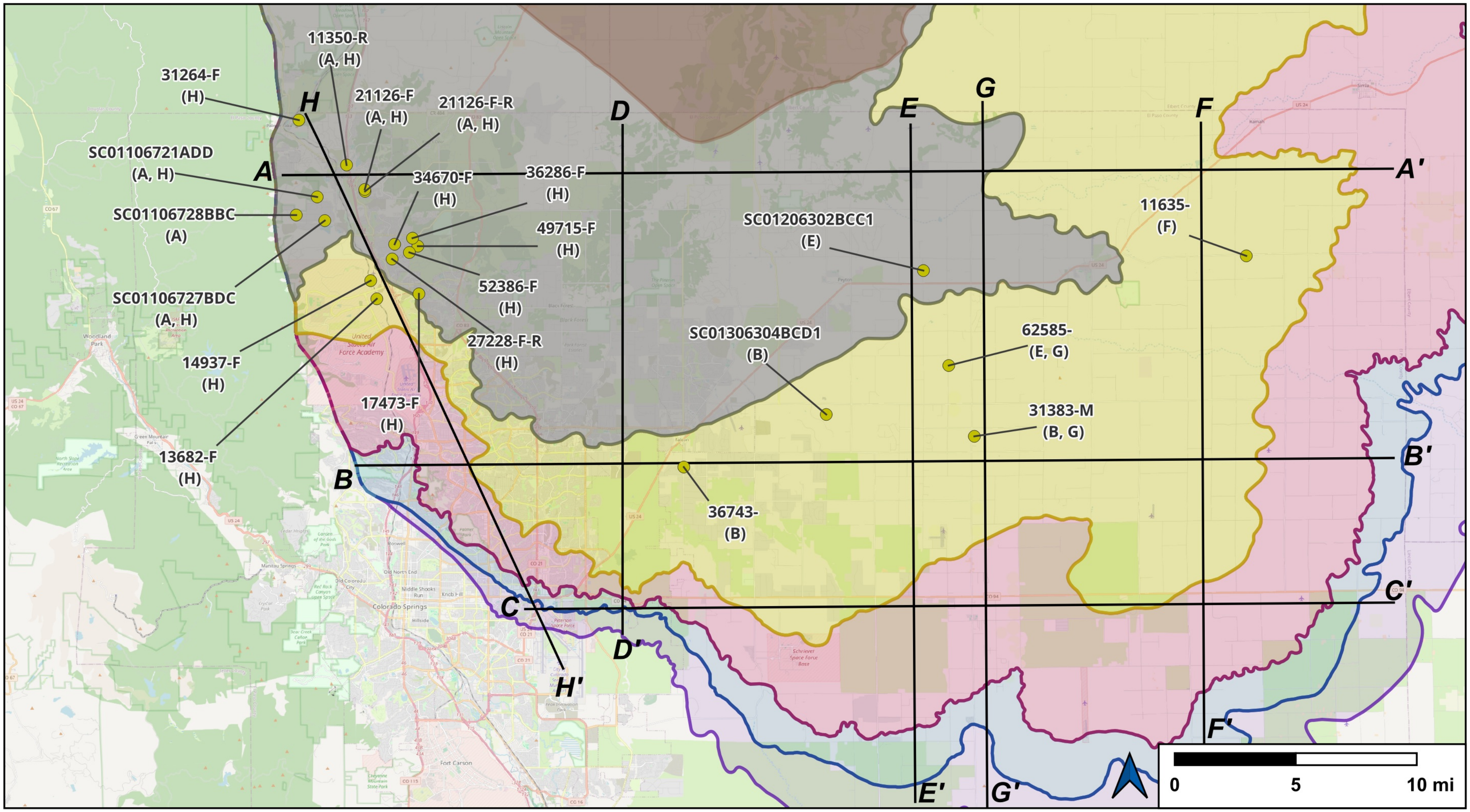
2010
2015
2020
Year

Appendix C - Denver Aquifer Hydrographs



LEGEND

Well Permit # or Name (Cross-Section)

Cross-Sections

Upper Dawson Aquifer

Lower Dawson Aquifer

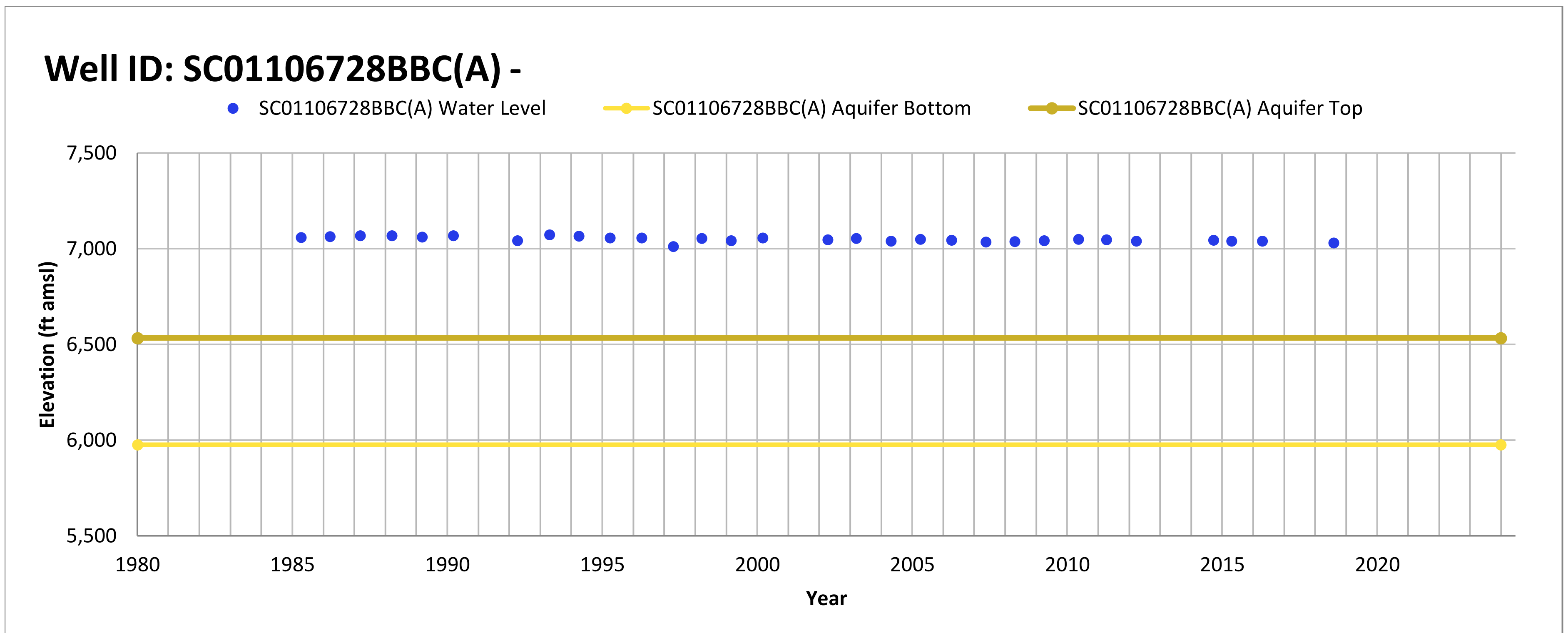
Denver Aquifer

Arapahoe Aquifer

Laramie Confining Unit

Laramie-Fox Hills Aquifer

EL PASO COUNTY		
DENVER WELLS		
File: Wells - Denver		Date: 03/12/2025
Project No: 24632	Drawn by: CDH	Fig. No.: C-1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Elevation (ft amsl)
1980
1985
1990
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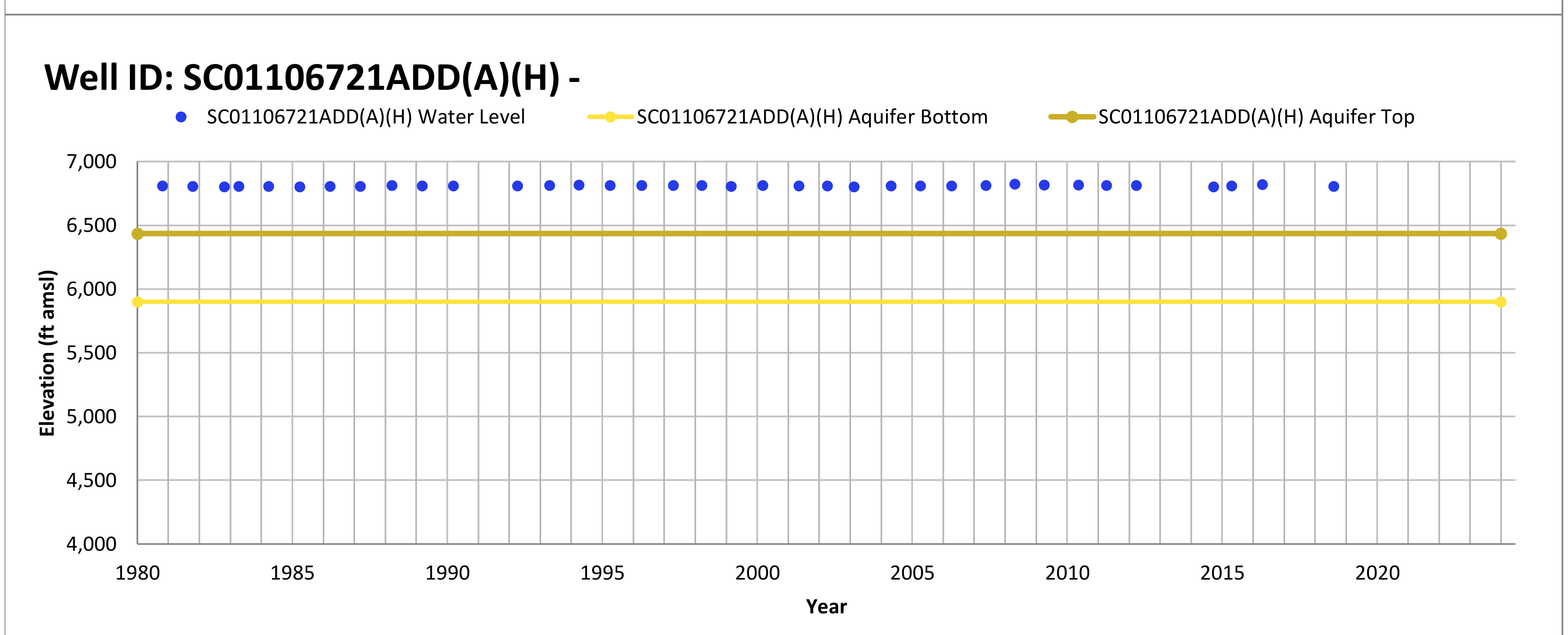
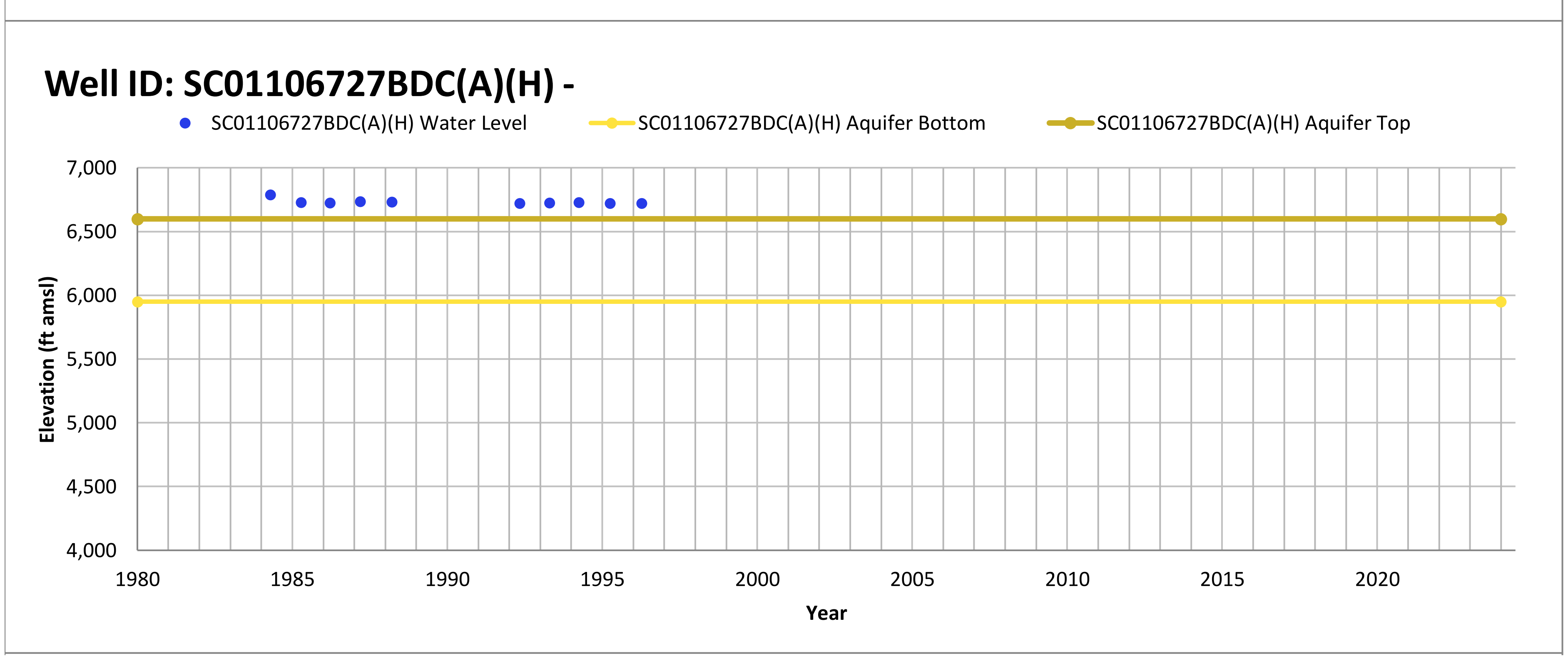
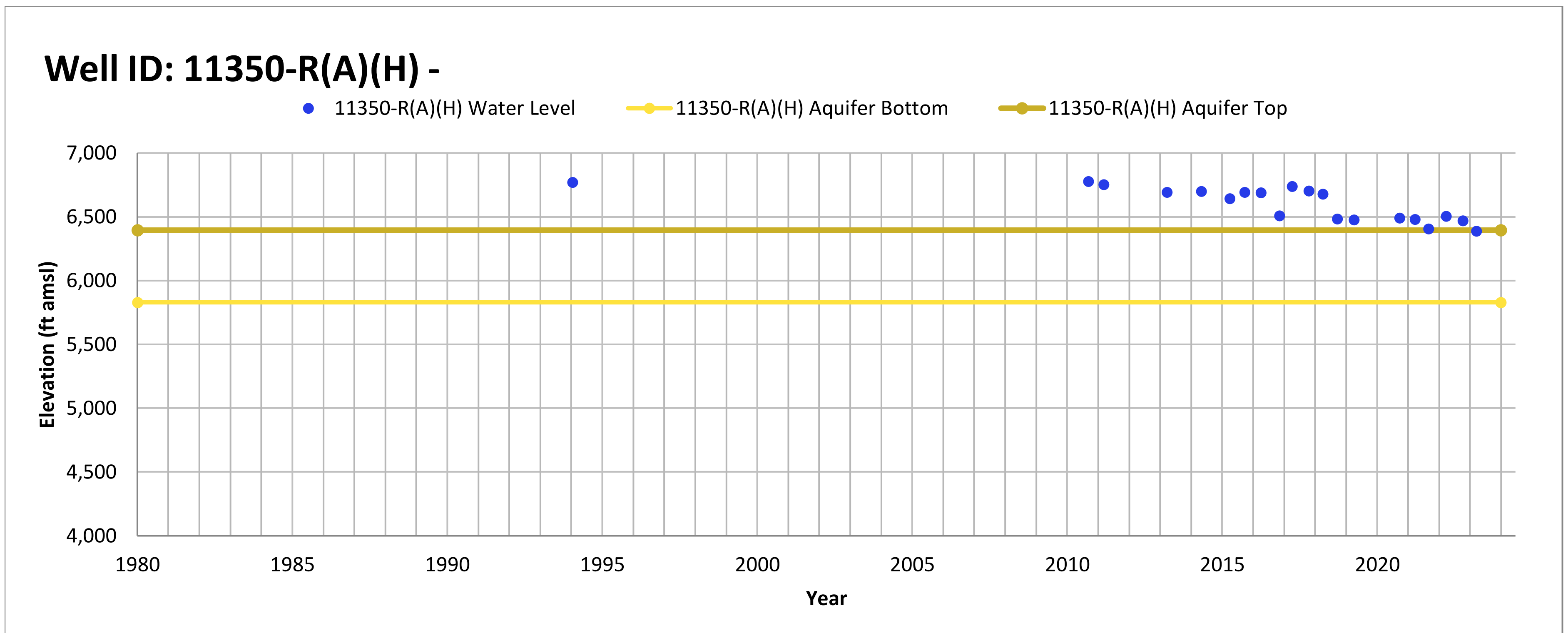
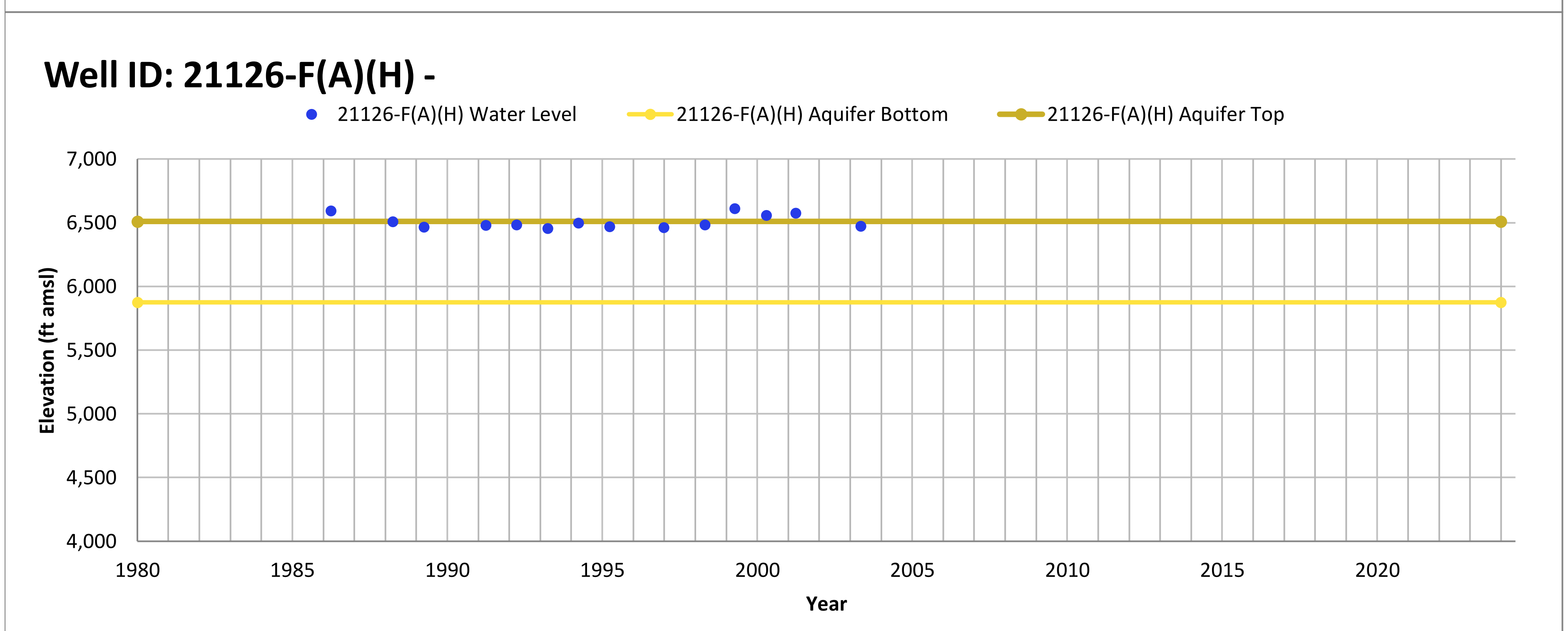
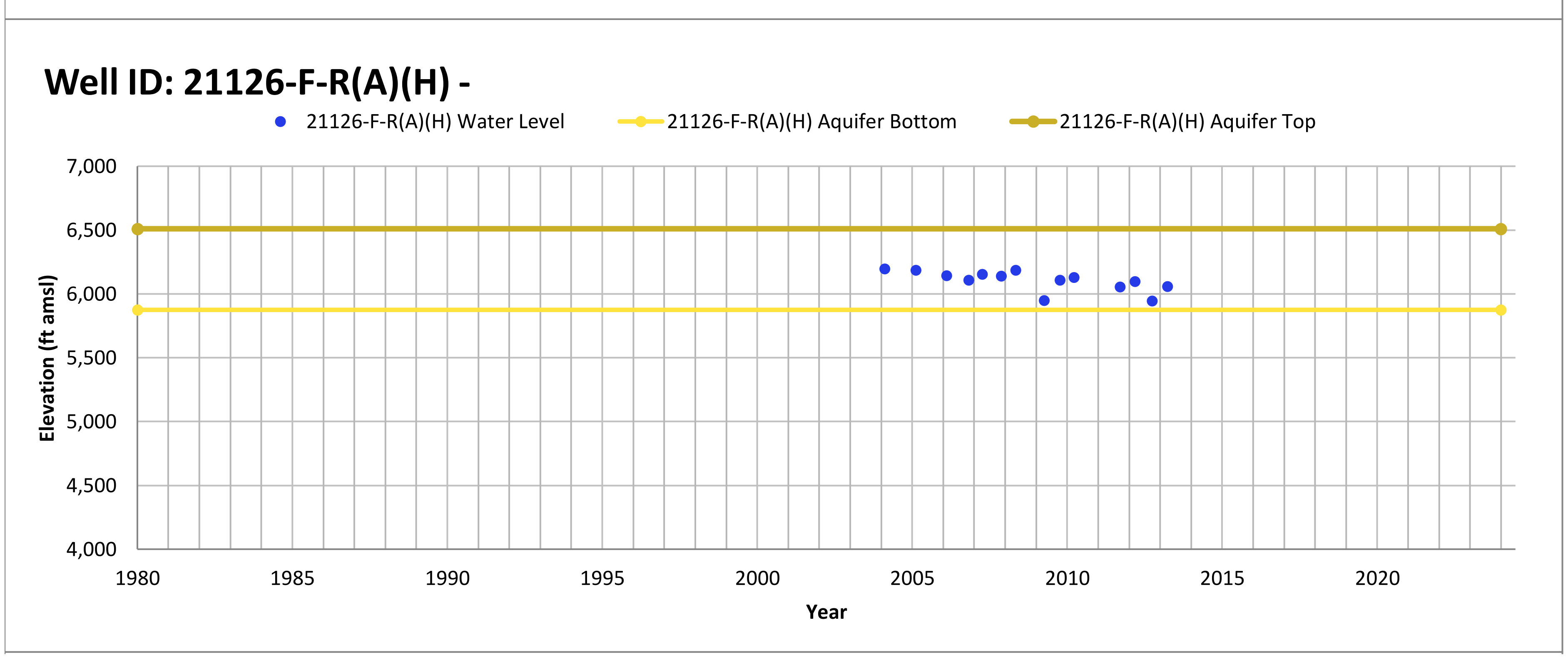
2015
2020
Year

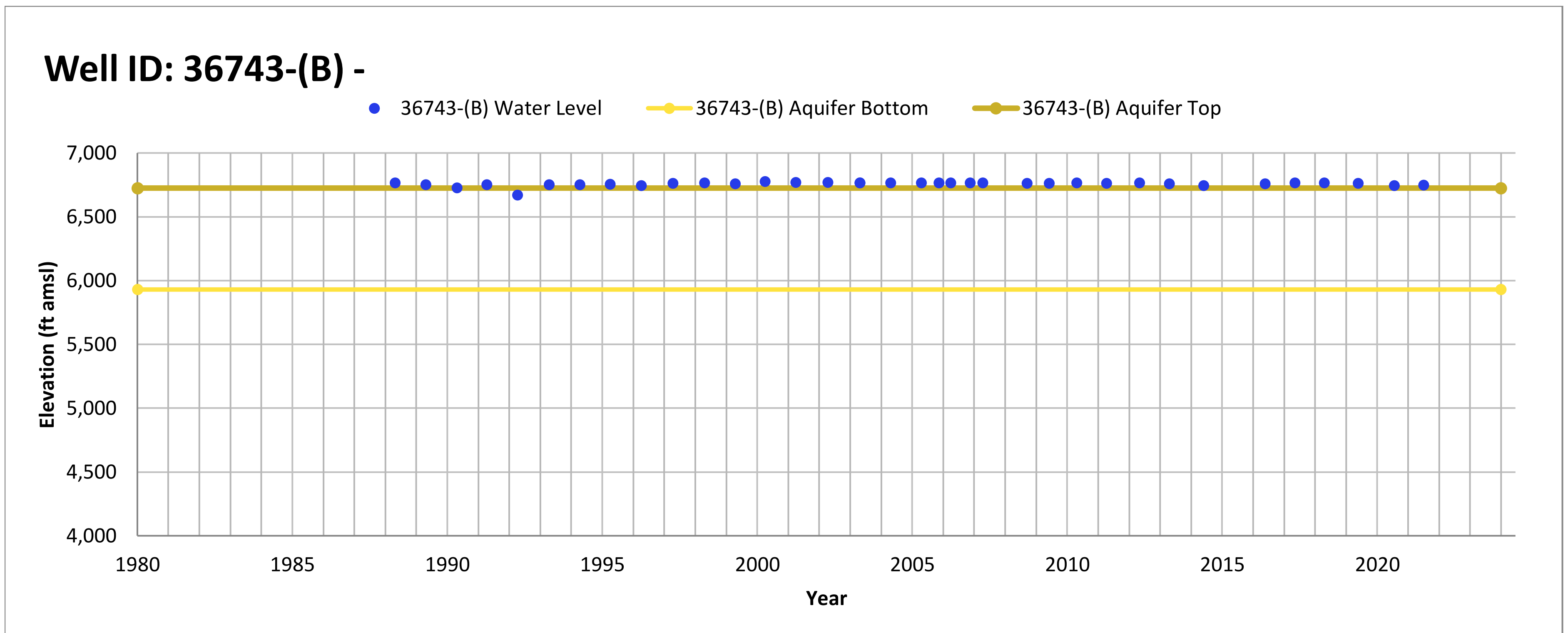

Well ID: SC01106721ADD(A)(H) -
SC01106721ADD(A)(H) Water Level
SC01106721ADD(A)(H) Aquifer Bottom
SC01106721ADD(A)(H) Aquifer Top
7,000
6,500
6,000
5,500
5,000
4,500
4,000
Elevation (ft amsl)
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year

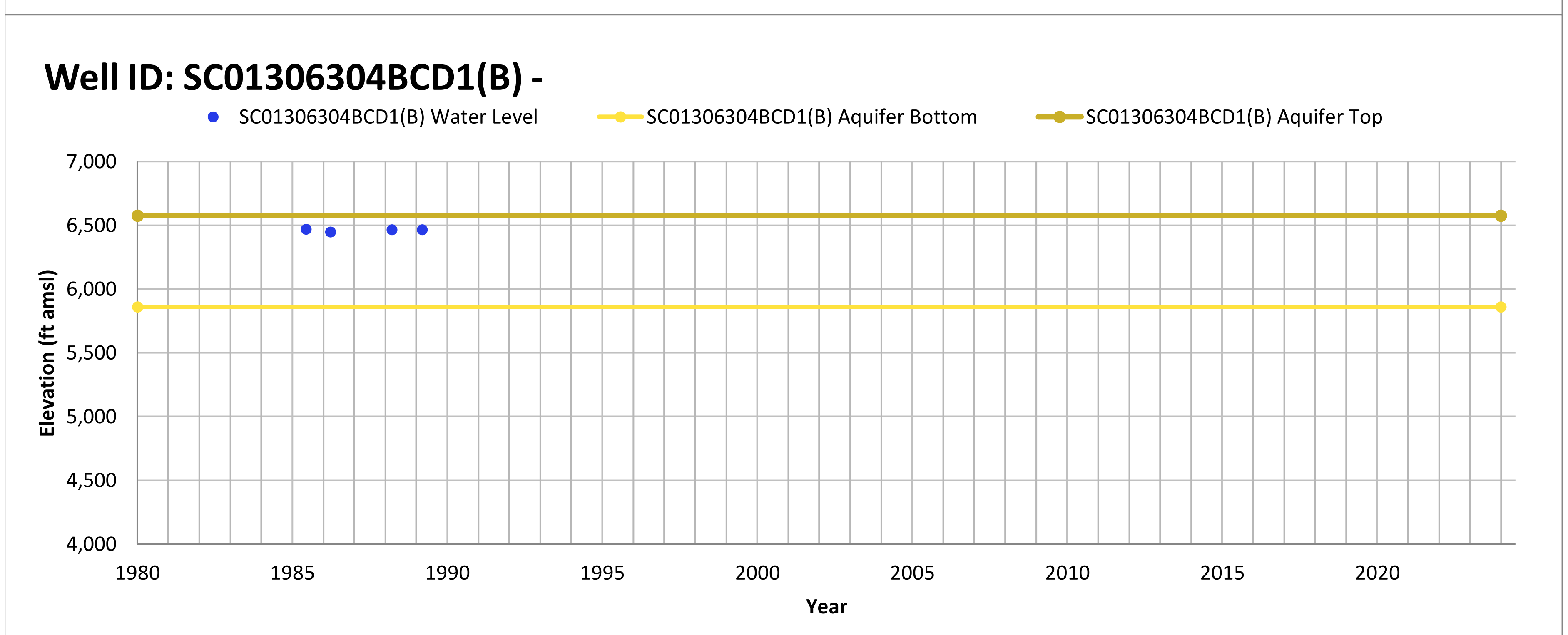

Well ID: SC01106727BDC(A)(H) -
SC01106727BDC(A)(H) Water Level
SC01106727BDC(A)(H) Aquifer Bottom
SC01106727BDC(A)(H) Aquifer Top
7,000
6,500
6,000
5,500
5,000
4,500
4,000
Elevation (ft amsl)
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year

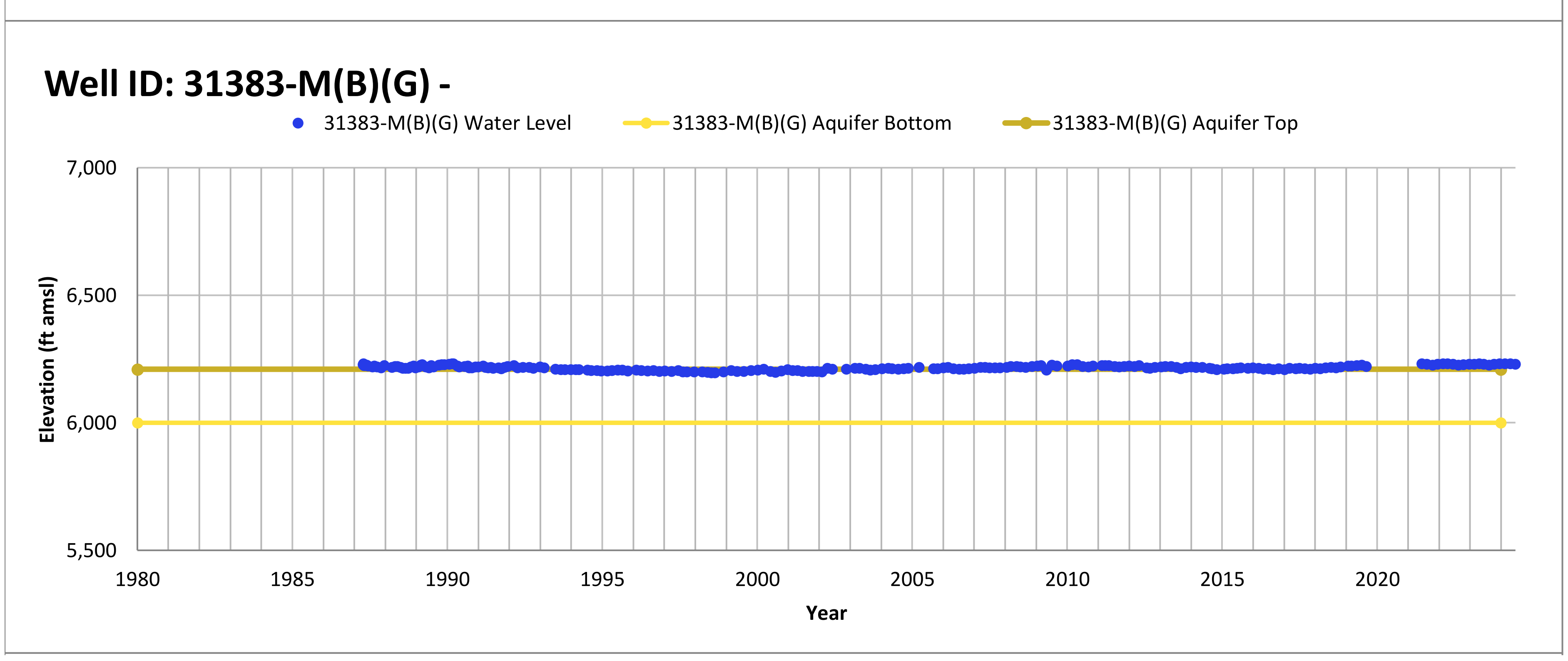

Well ID: 11350-R(A)(H) -
11350-R(A)(H) Water Level
11350-R(A)(H) Aquifer Bottom
11350-R(A)(H) Aquifer Top
Elevation (ft amsl)
7,000
6,500
6,000
5,500
5,000
4,500
4,000
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year

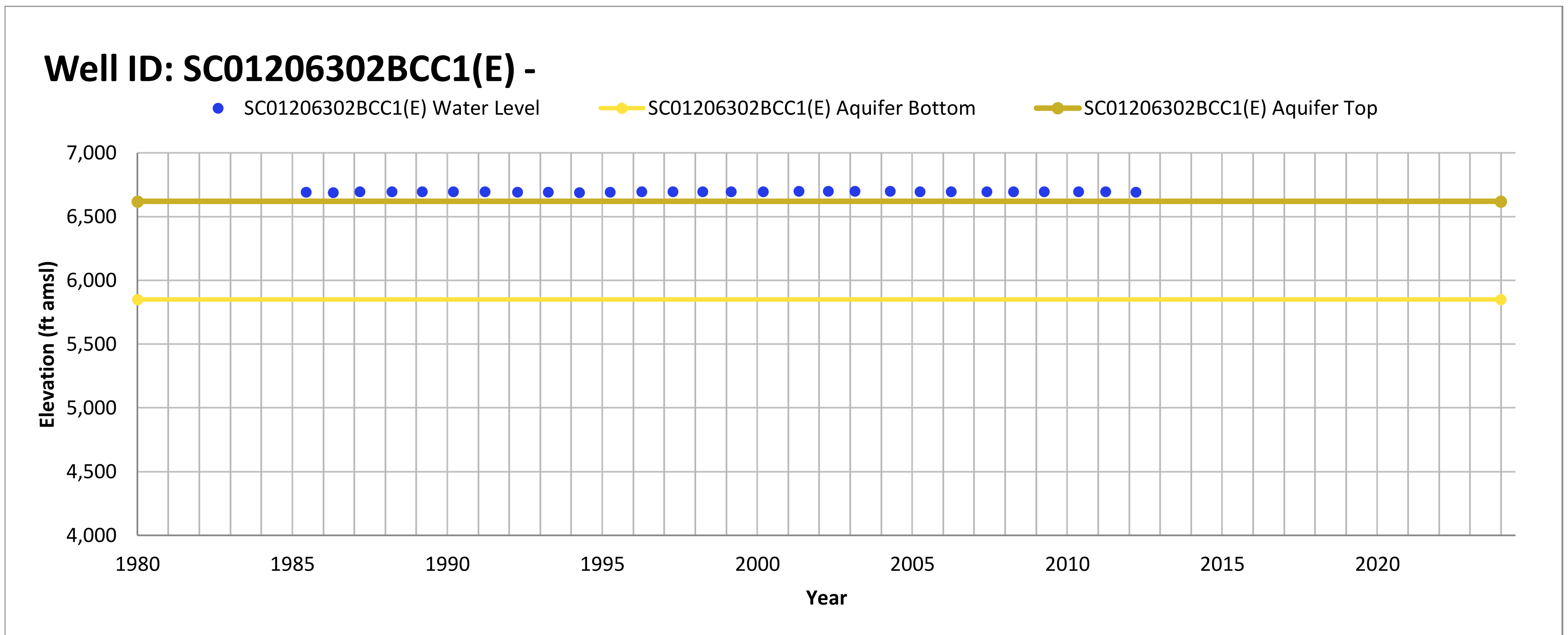

Well ID: 21126-F(A)(H) -
21126-F(A)(H) Water Level
21126-F(A)(H) Aquifer Bottom
21126-F(A)(H) Aquifer Top
Elevation (ft amsl)
7,000
6,500
6,000
5,500
5,000
4,500
4,000
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year

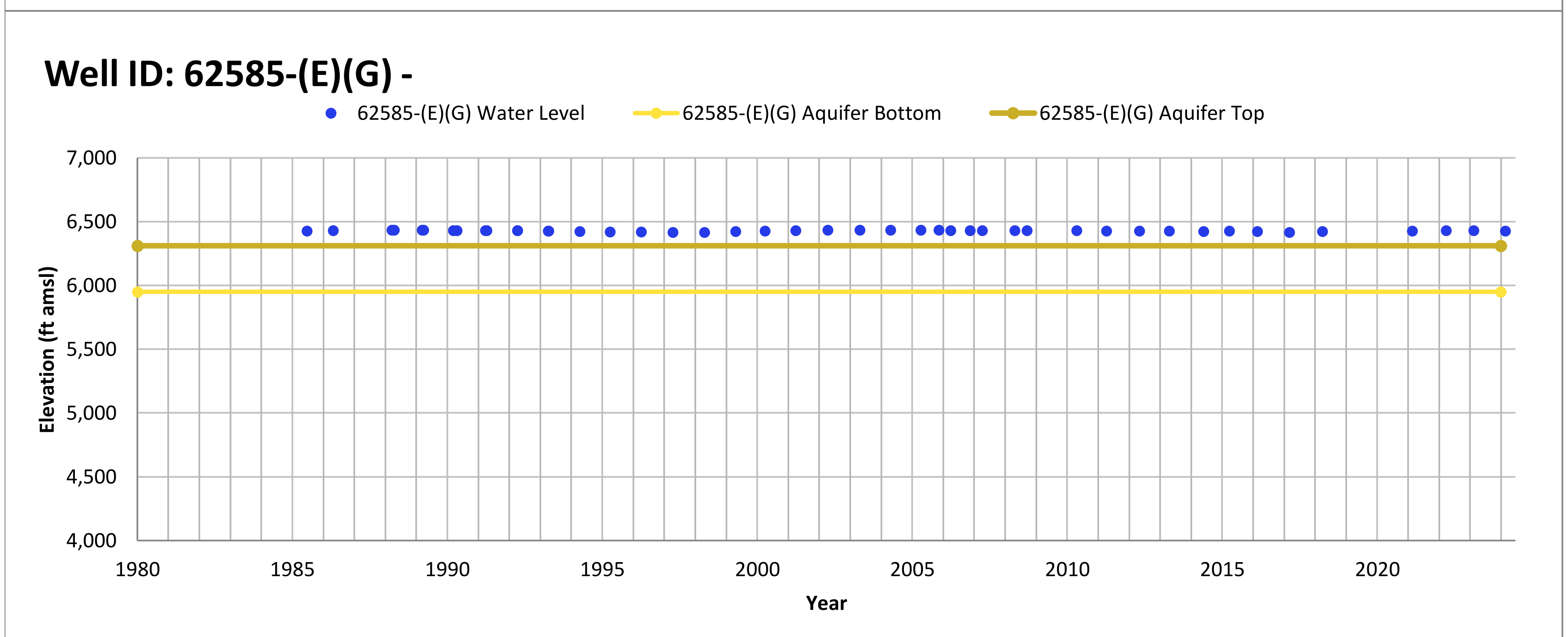

Well ID: 21126-F-R(A)(H) -
21126-F-R(A)(H) Water Level
21126-F-R(A)(H) Aquifer Bottom
21126-F-R(A)(H) Aquifer Top
Elevation (ft amsl)
7,000
6,500
6,000
5,500
5,000
4,500
4,000
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year

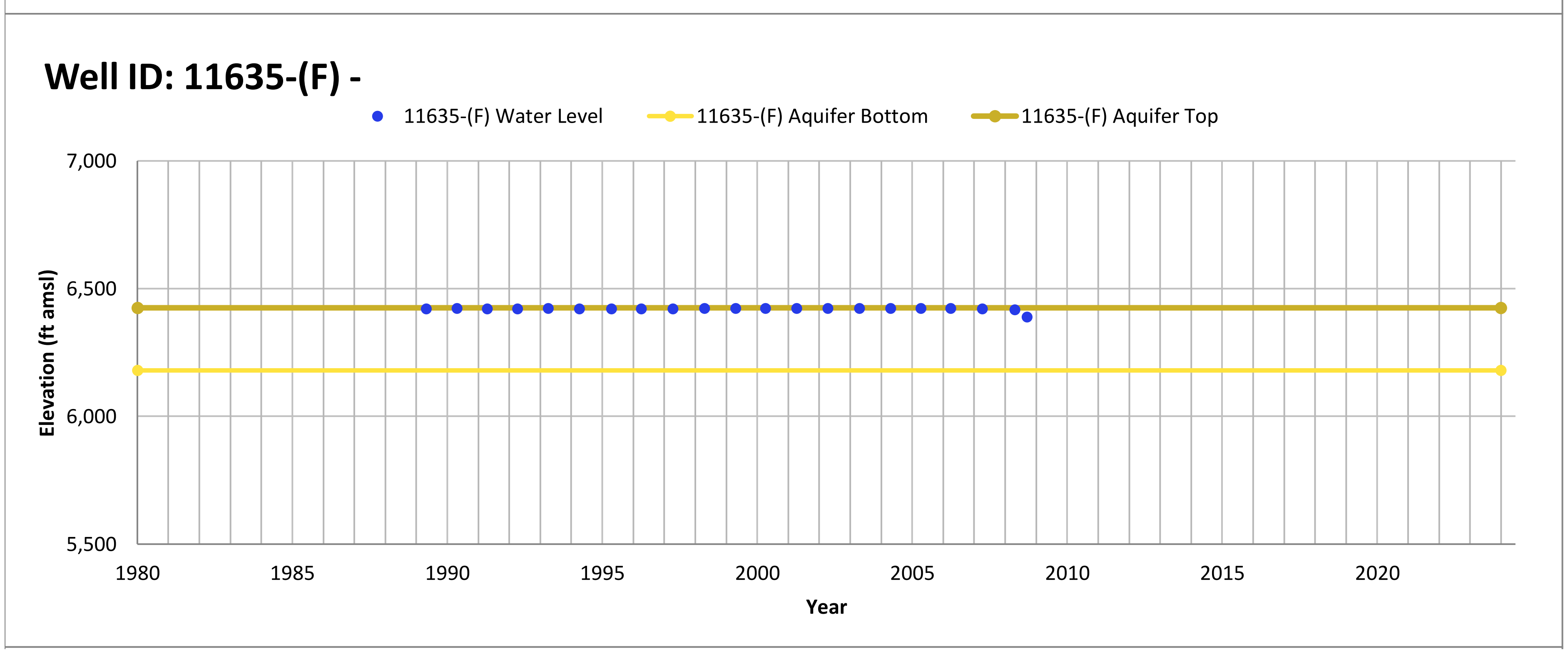

Well ID: 36743-(B) -
36743-(B) Water Level
36743-(B) Aquifer Bottom
36743-(B) Aquifer Top
7,000
6,500
6,000
5,500
5,000
4,500
4,000
Elevation (ft amsl)
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year

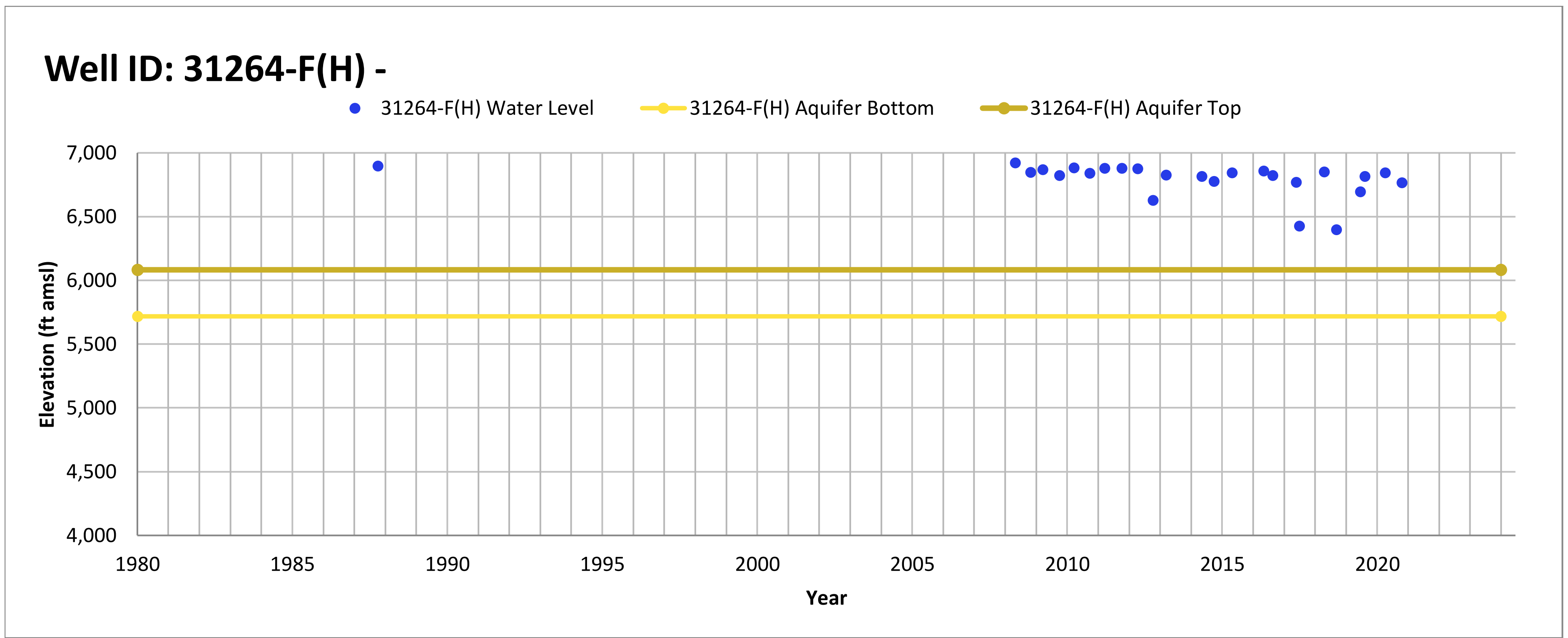

Well ID: SC01306304BCD1(B) -
SC01306304BCD1(B) Water Level
SC01306304BCD1(B) Aquifer Bottom
SC01306304BCD1(B) Aquifer Top
7,000
6,500
6,000
5,500
5,000
4,500
4,000
Elevation (ft amsl)
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year

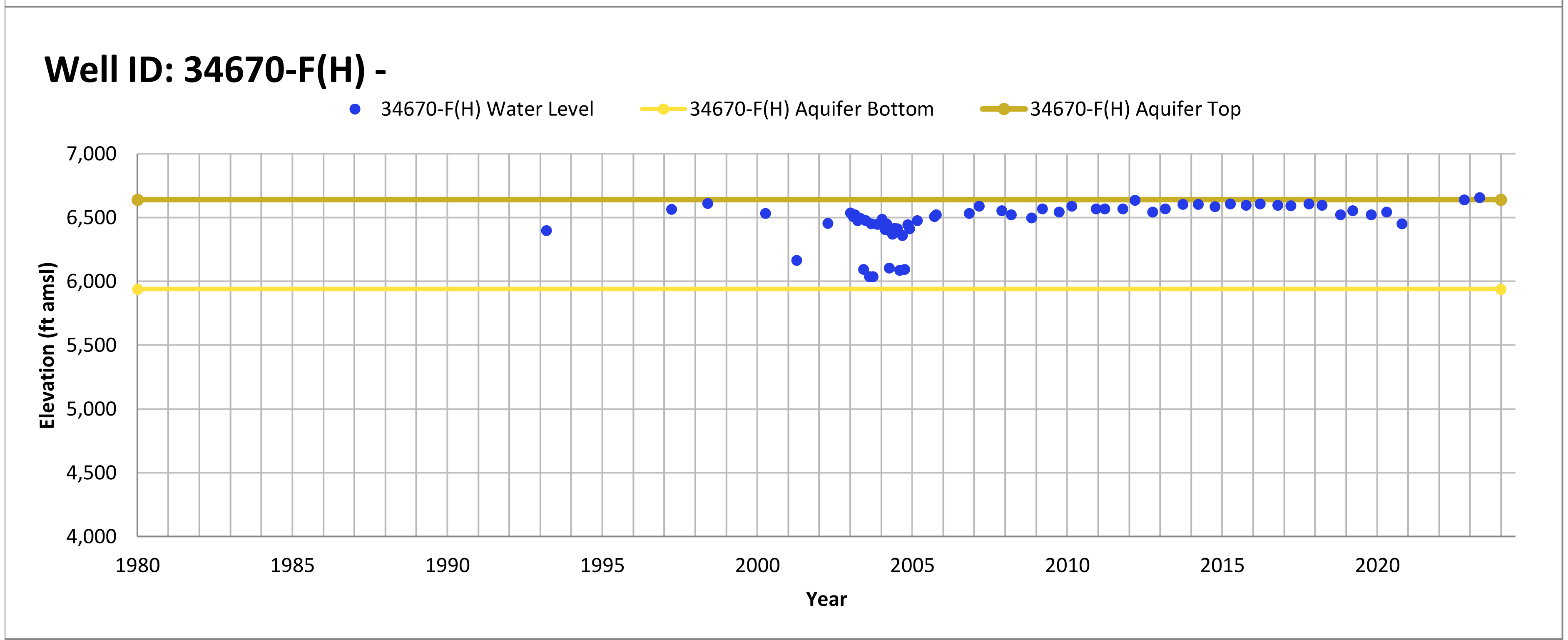

Well ID: 31383-M(B)(G) -
31383-M(B)(G) Water Level
31383-M(B)(G) Aquifer Bottom
31383-M(B)(G) Aquifer Top
7,000
6,500
6,000
5,500
Elevation (ft amsl)
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year

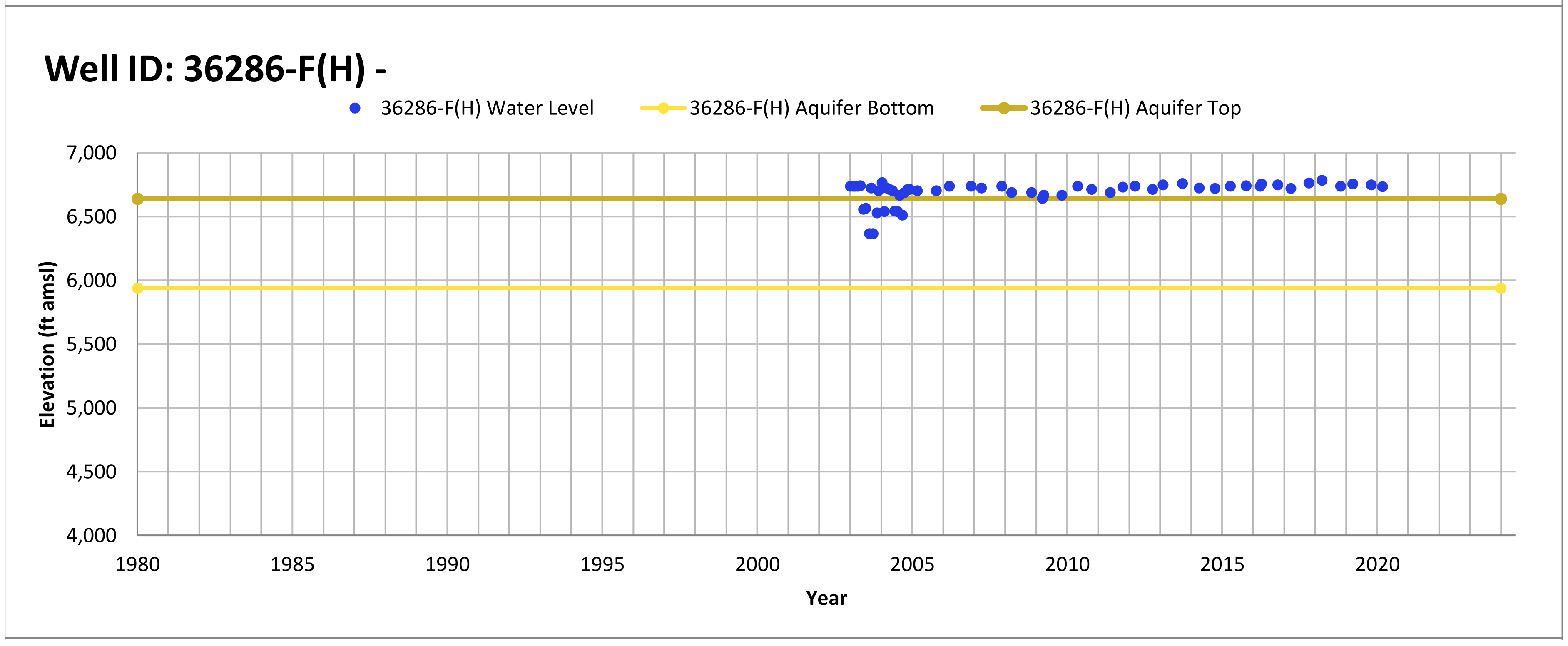

Well ID: SC01206302BCC1(E) -
SC01206302BCC1(E) Water Level
SC01206302BCC1(E) Aquifer Bottom
SC01206302BCC1(E) Aquifer Top
Elevation (ft amsl)
7,000
6,500
6,000
5,500
5,000
4,500
4,000
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year


Well ID: 62585-(E)(G) -
62585-(E)(G) Water Level
62585-(E)(G) Aquifer Bottom
62585-(E)(G) Aquifer Top
Elevation (ft amsl)
7,000
6,500
6,000
5,500
5,000
4,500
4,000
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year

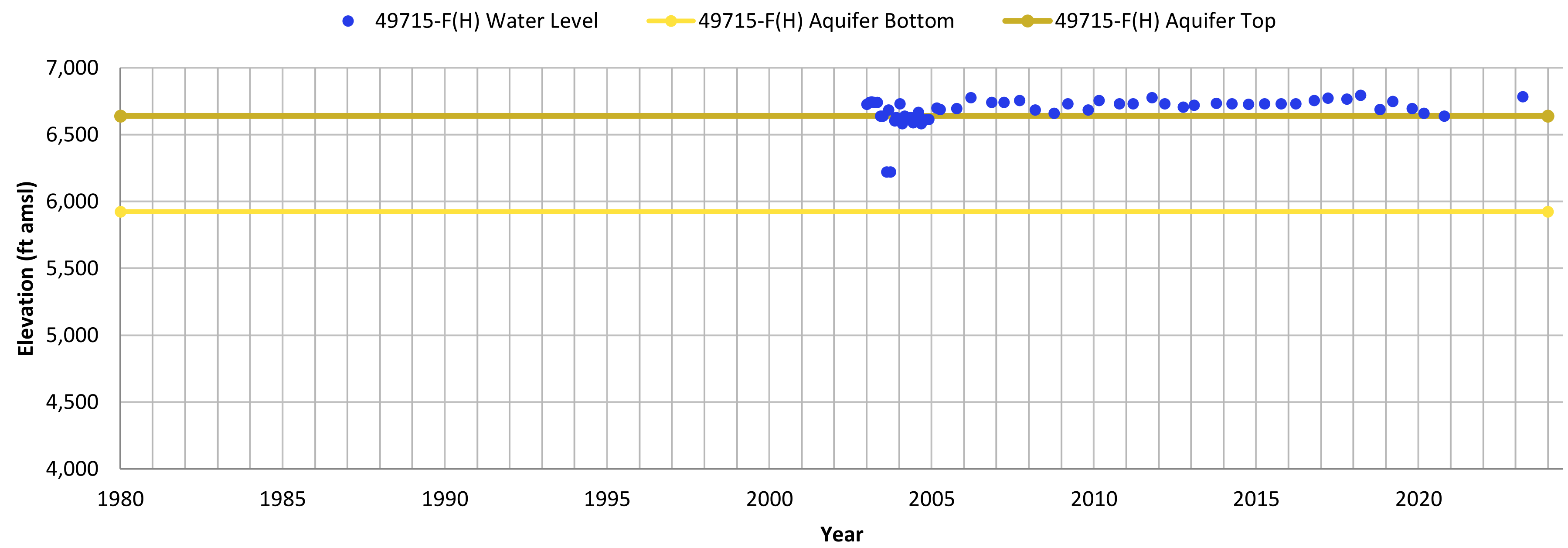

Well ID: 11635-(F) -
11635-(F) Water Level
11635-(F) Aquifer Bottom
11635-(F) Aquifer Top
Elevation (ft amsl)
7,000
6,500
6,000
5,500
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year


Well ID: 31264-F(H) -
31264-F(H) Water Level
31264-F(H) Aquifer Bottom
31264-F(H) Aquifer Top
7,000
6,500
6,000
5,500
5,000
4,500
4,000
Elevation (ft amsl)
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year

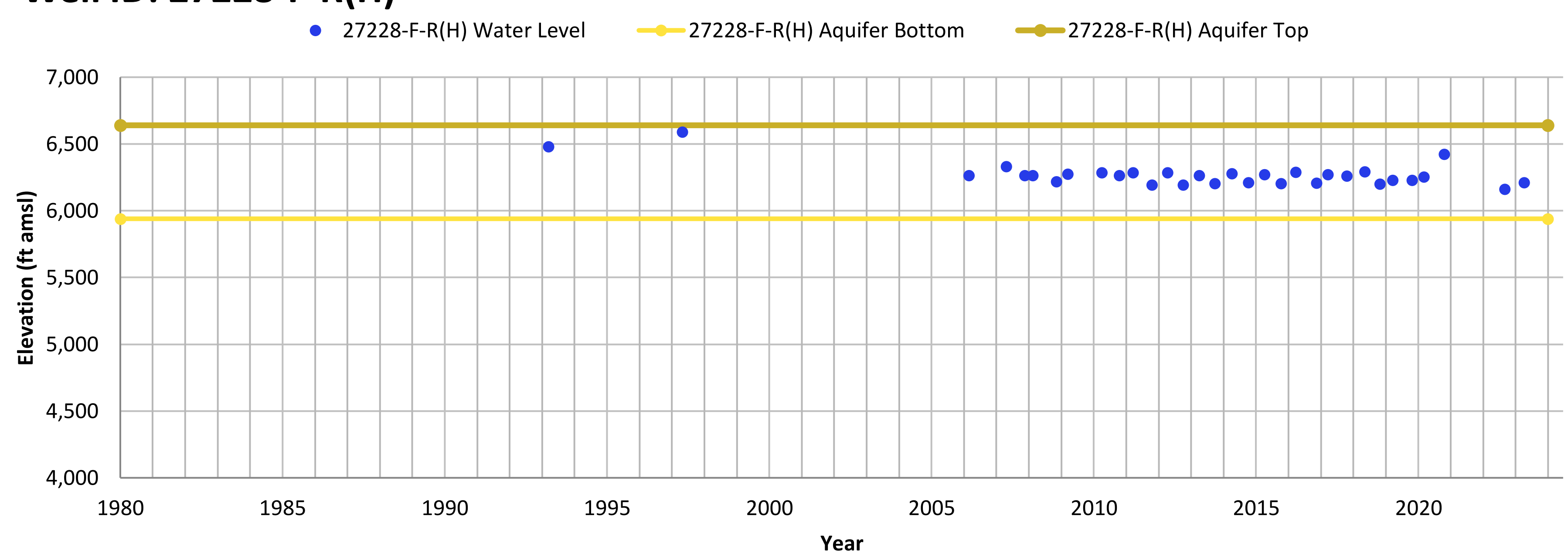

Well ID: 34670-F(H) -
34670-F(H) Water Level
34670-F(H) Aquifer Bottom
34670-F(H) Aquifer Top
7,000
6,500
6,000
5,500
5,000
4,500
4,000
Elevation (ft amsl)
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year


Well ID: 36286-F(H) -
36286-F(H) Water Level
36286-F(H) Aquifer Bottom
36286-F(H) Aquifer Top
7,000
6,500
6,000
5,500
5,000
4,500
4,000
Elevation (ft amsl)
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year

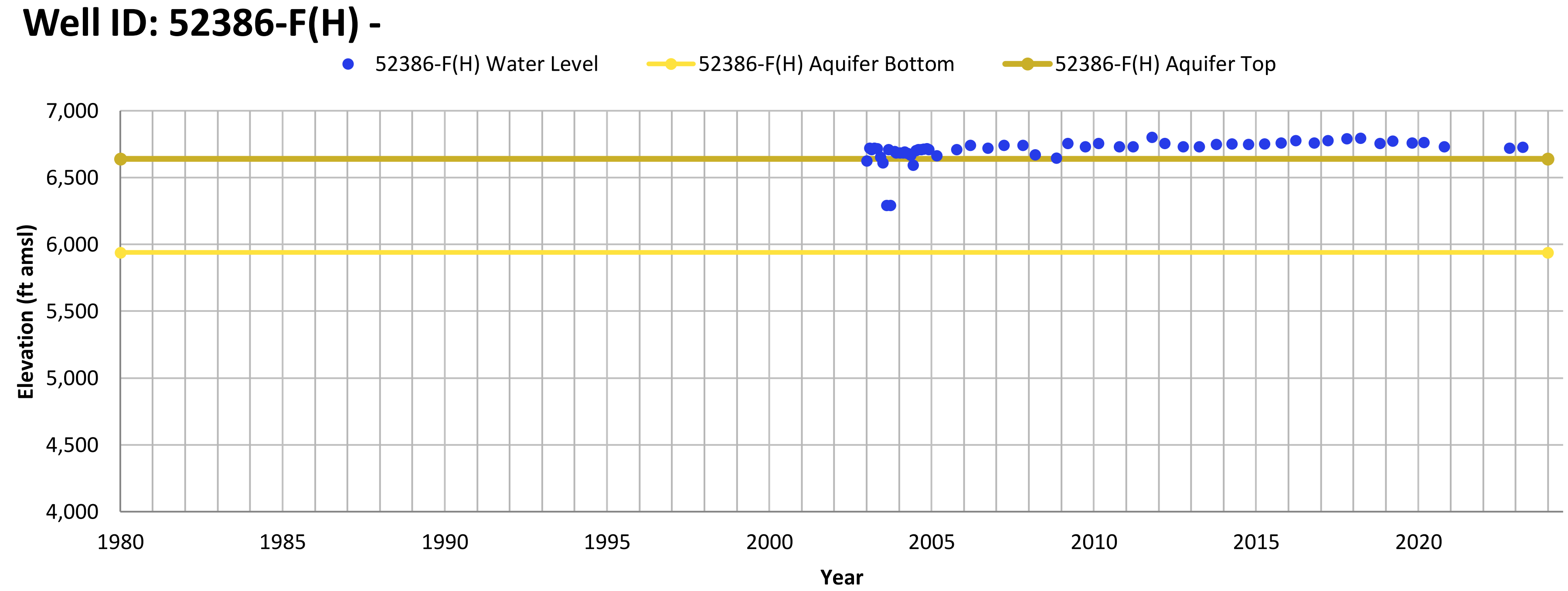
Well ID: 49715-F(H) -

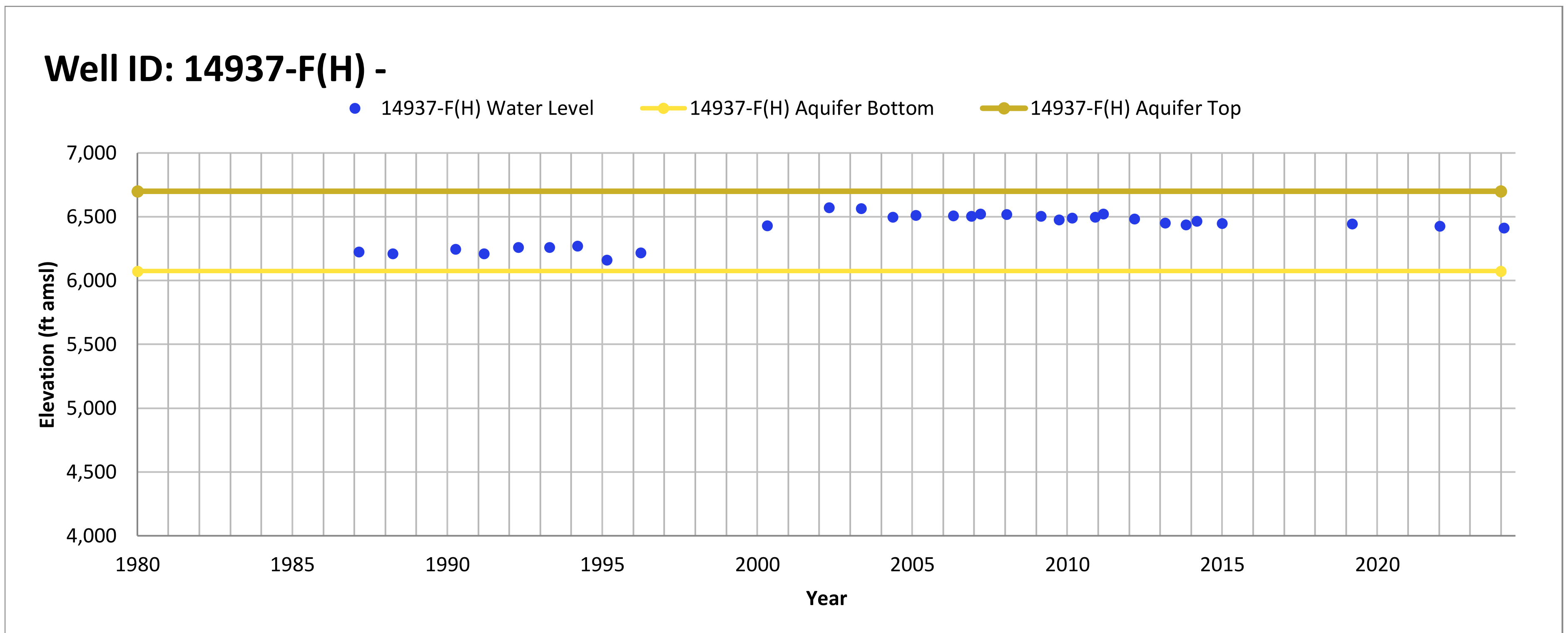


Well ID: 27228-F-R(H) -

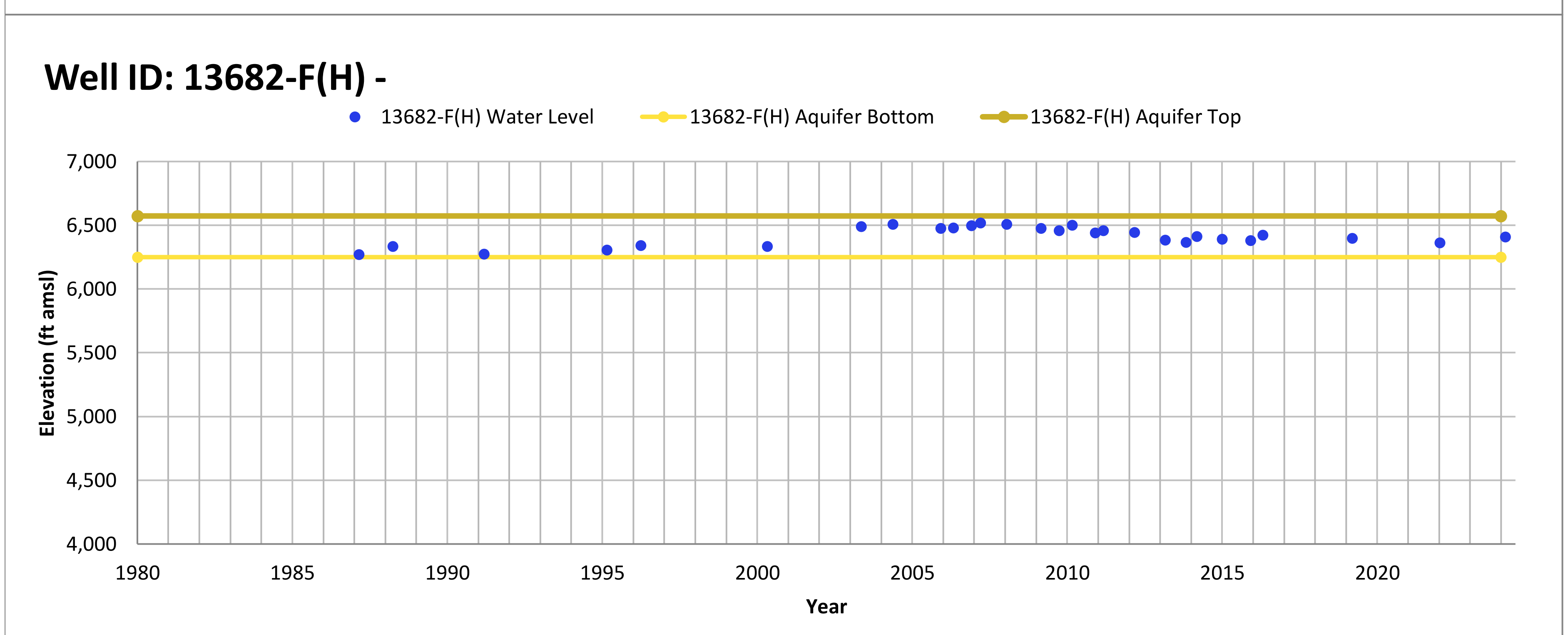


Well ID: 52386-F(H) -

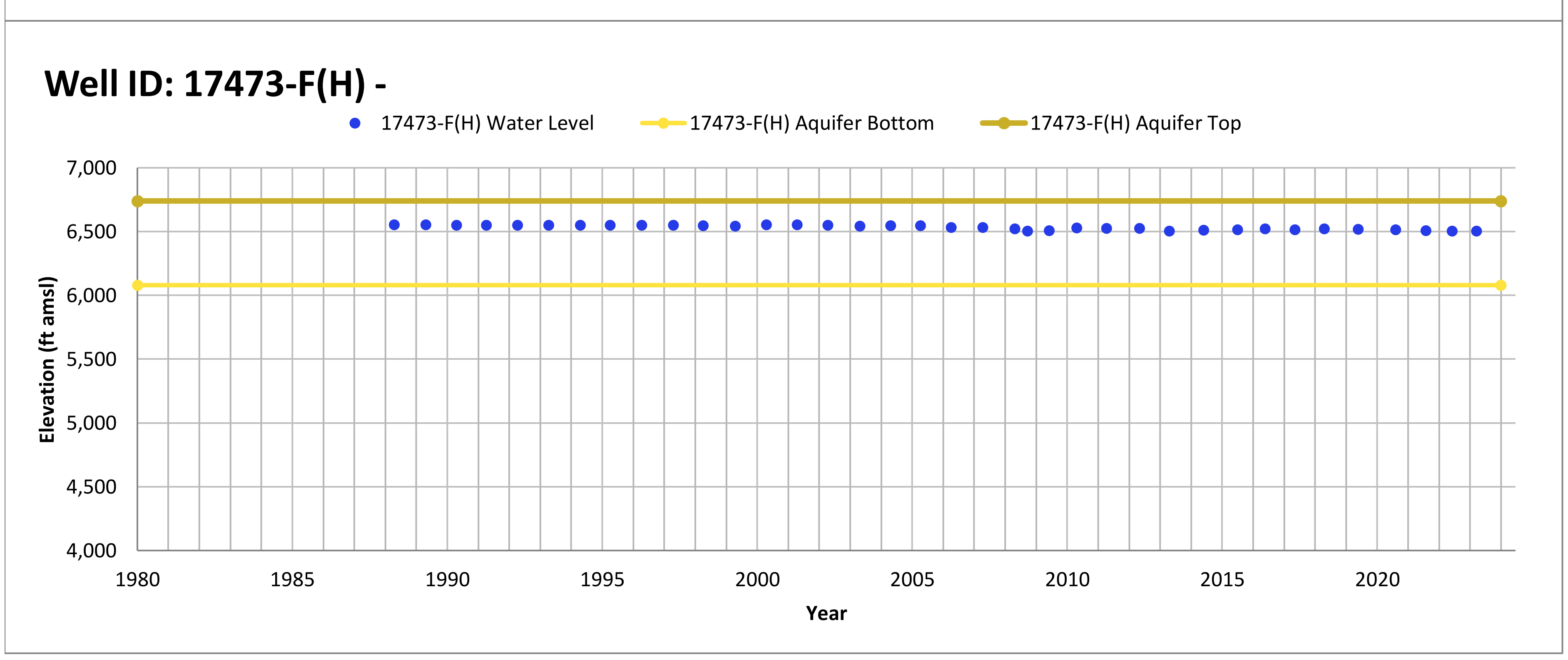




Well ID: 14937-F(H) -
14937-F(H) Water Level
14937-F(H) Aquifer Bottom
14937-F(H) Aquifer Top
7,000
6,500
6,000
5,500
5,000
4,500
4,000
Elevation (ft amsl)
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year

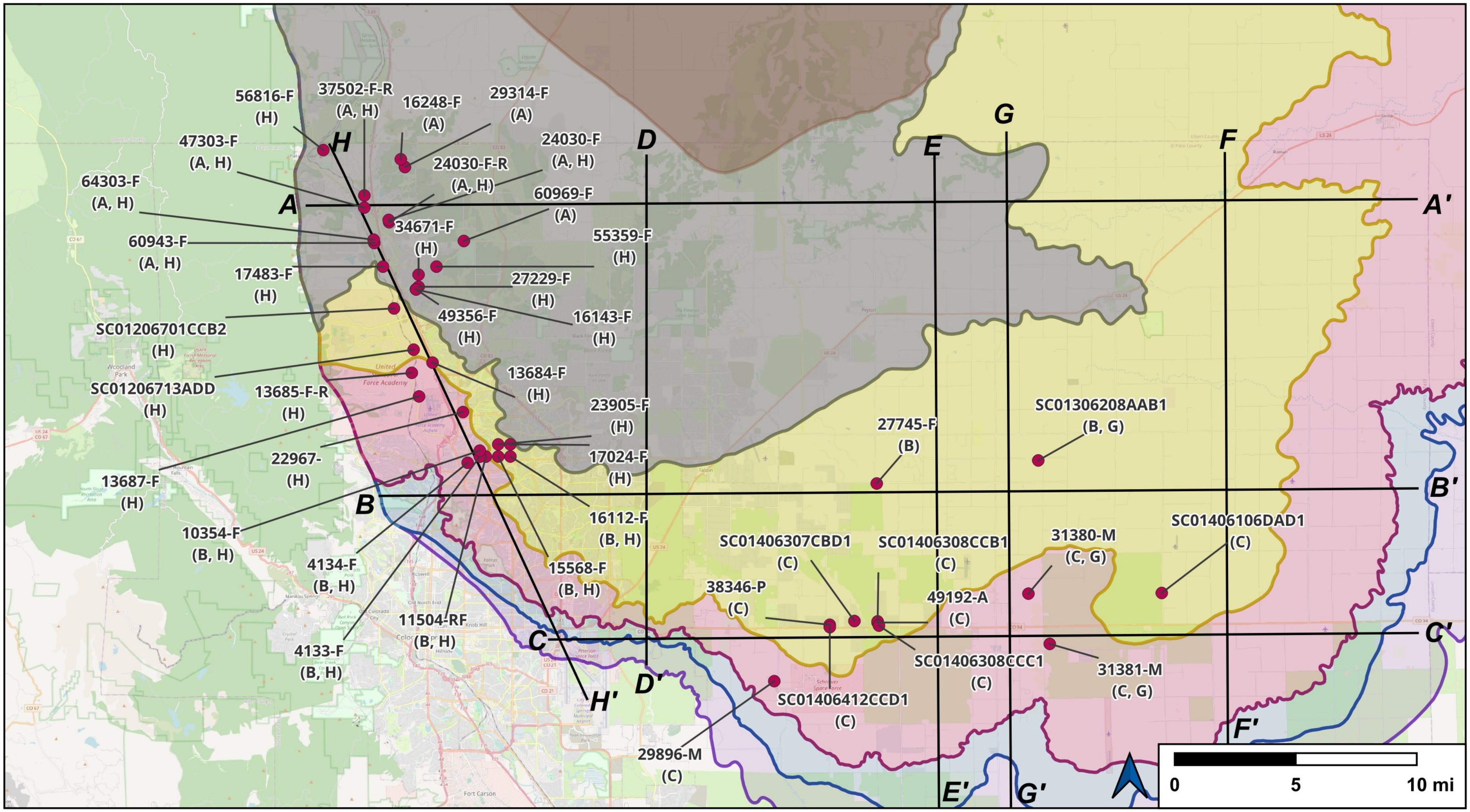


Well ID: 13682-F(H) -
13682-F(H) Water Level
13682-F(H) Aquifer Bottom
13682-F(H) Aquifer Top
7,000
6,500
6,000
5,500
5,000
4,500
4,000
Elevation (ft amsl)
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year



Well ID: 17473-F(H) -
17473-F(H) Water Level
17473-F(H) Aquifer Bottom
17473-F(H) Aquifer Top
7,000
6,500
6,000
5,500
5,000
4,500
4,000
Elevation (ft amsl)
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year

Appendix D - Arapahoe Aquifer Hydrographs

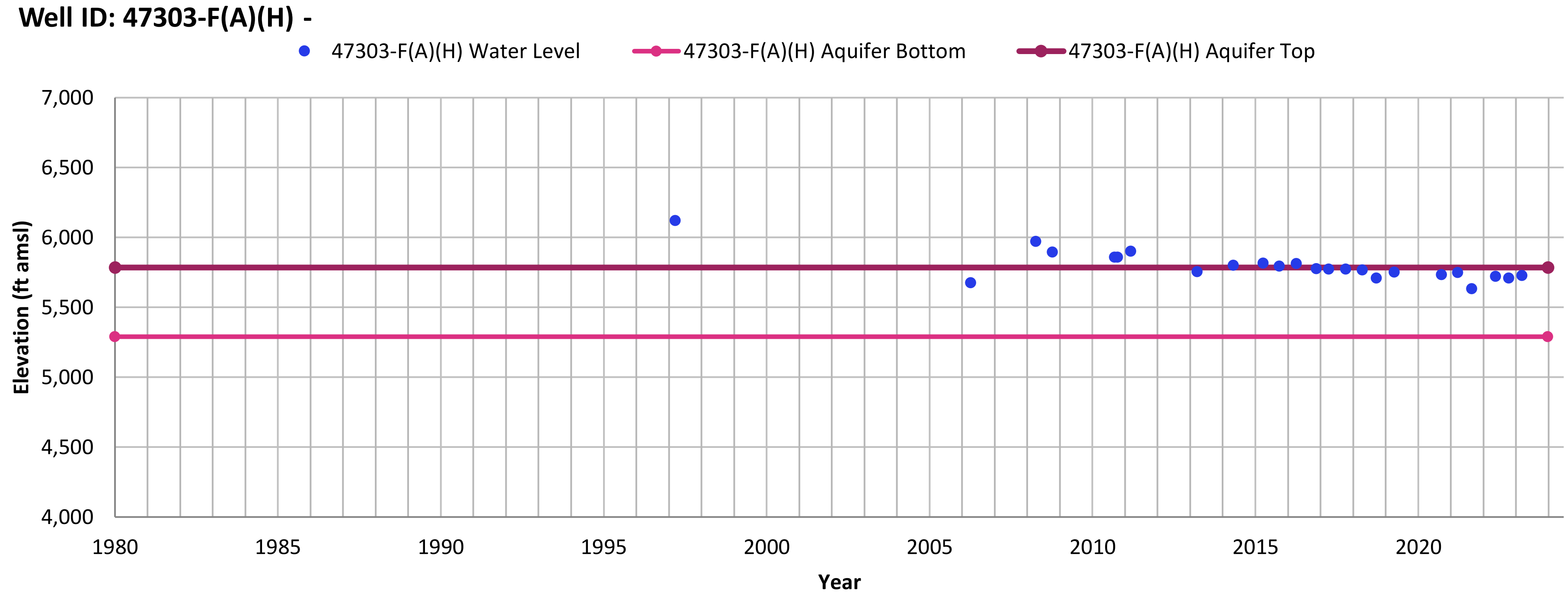


LEGEND

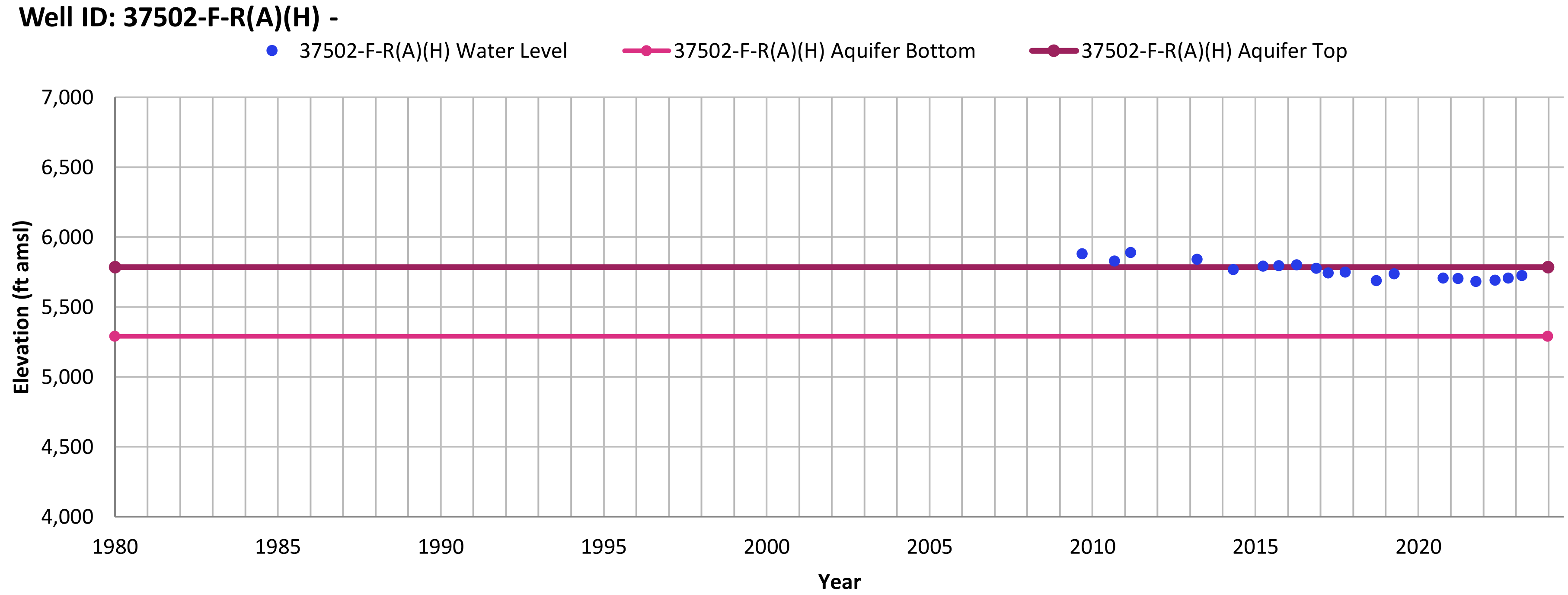
- Well Permit # or Name (Cross-Section)
- Cross-Sections
- Upper Dawson Aquifer
- Lower Dawson Aquifer
- Denver Aquifer
- Arapahoe Aquifer
- Laramie Confining Unit
- Laramie-Fox Hills Aquifer

EL PASO COUNTY		
ARAPAHOE WELLS		
File: Wells - Arapahoe		Date: 03/12/2025
Project No: 24632	Drawn by: CDH	Fig. No.: D-1

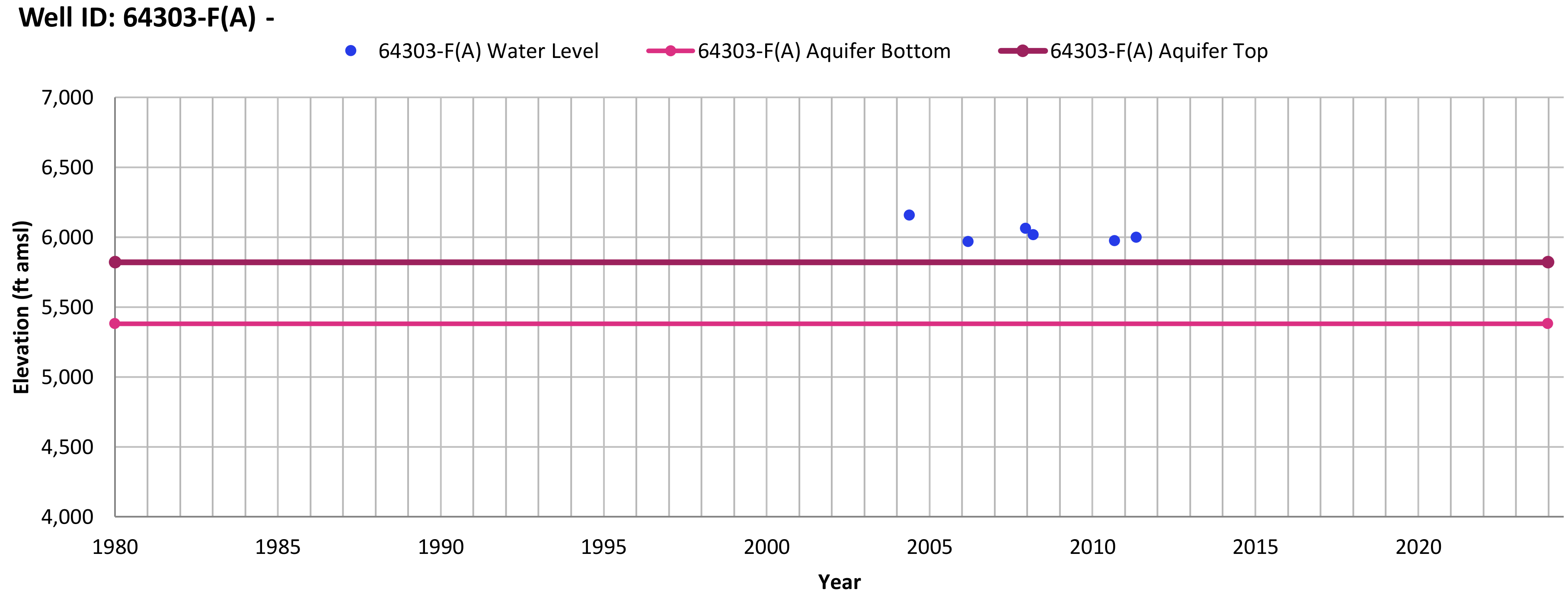
Well ID: 47303-F(A)(H) -

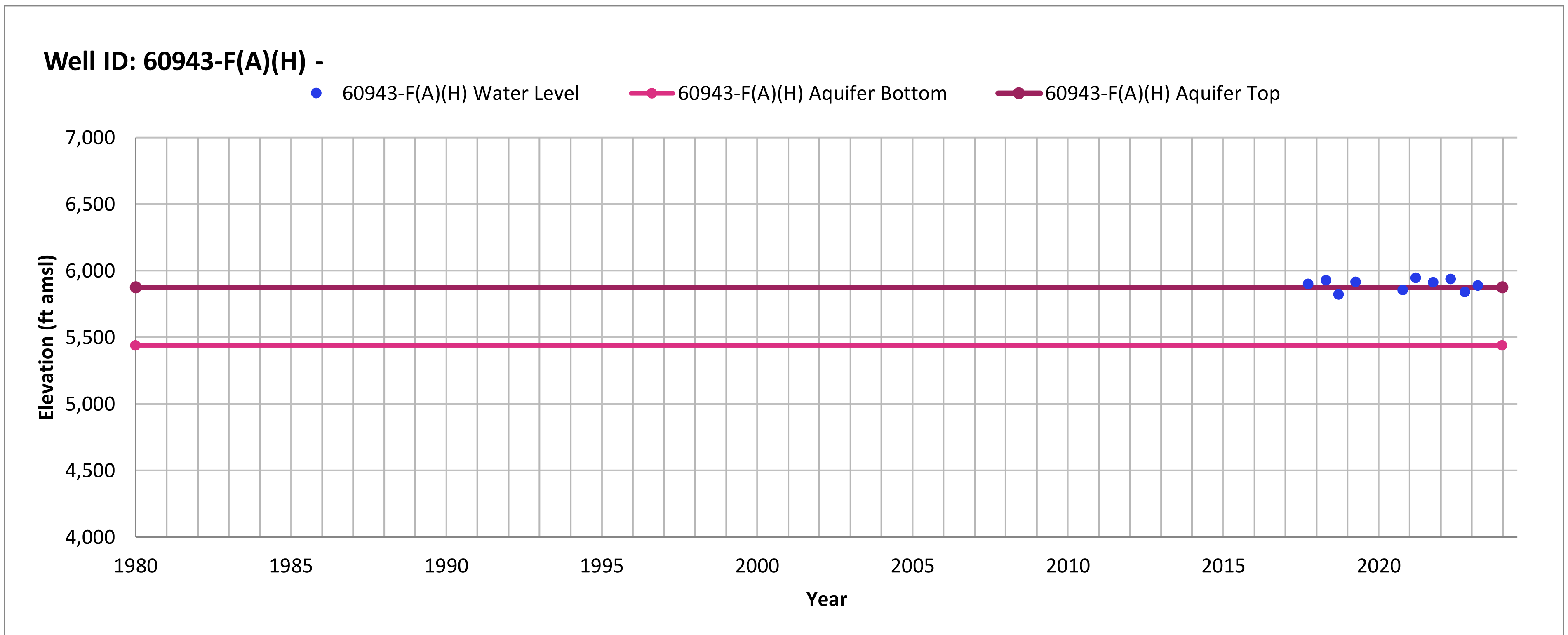


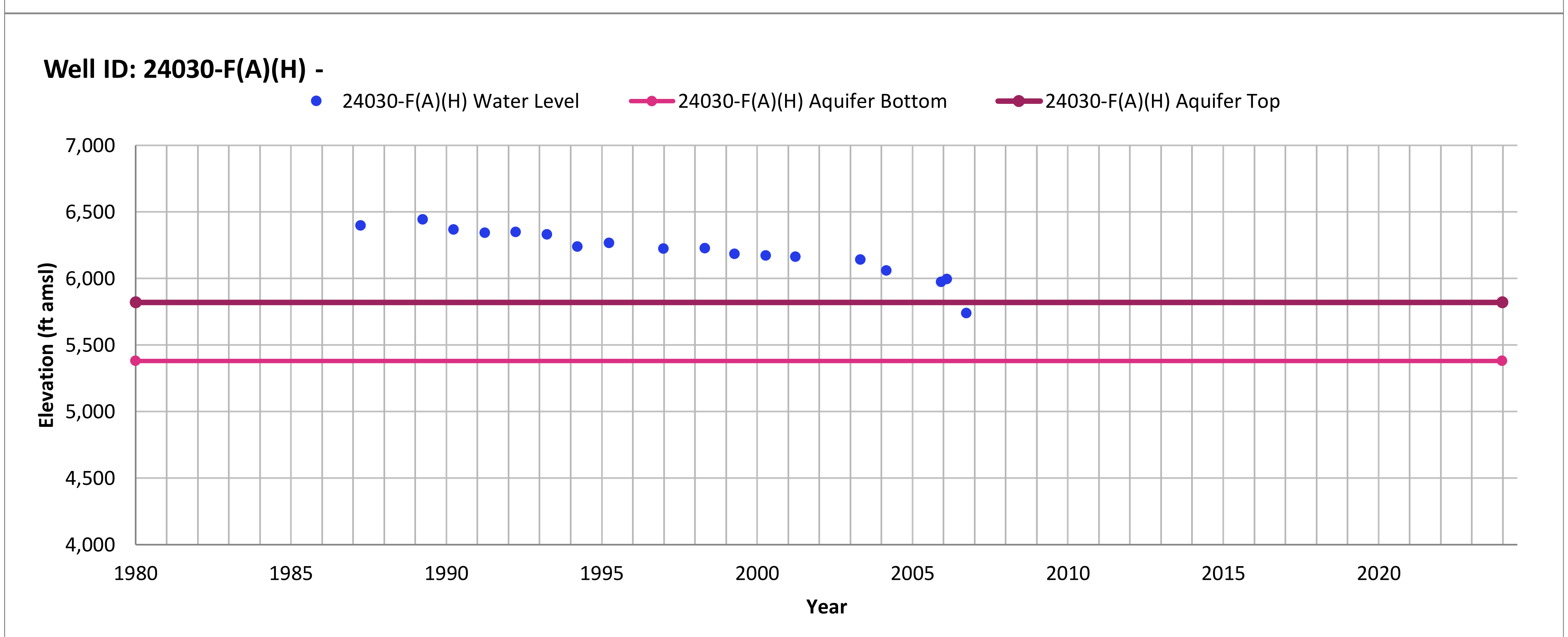
Well ID: 37502-F-R(A)(H) -

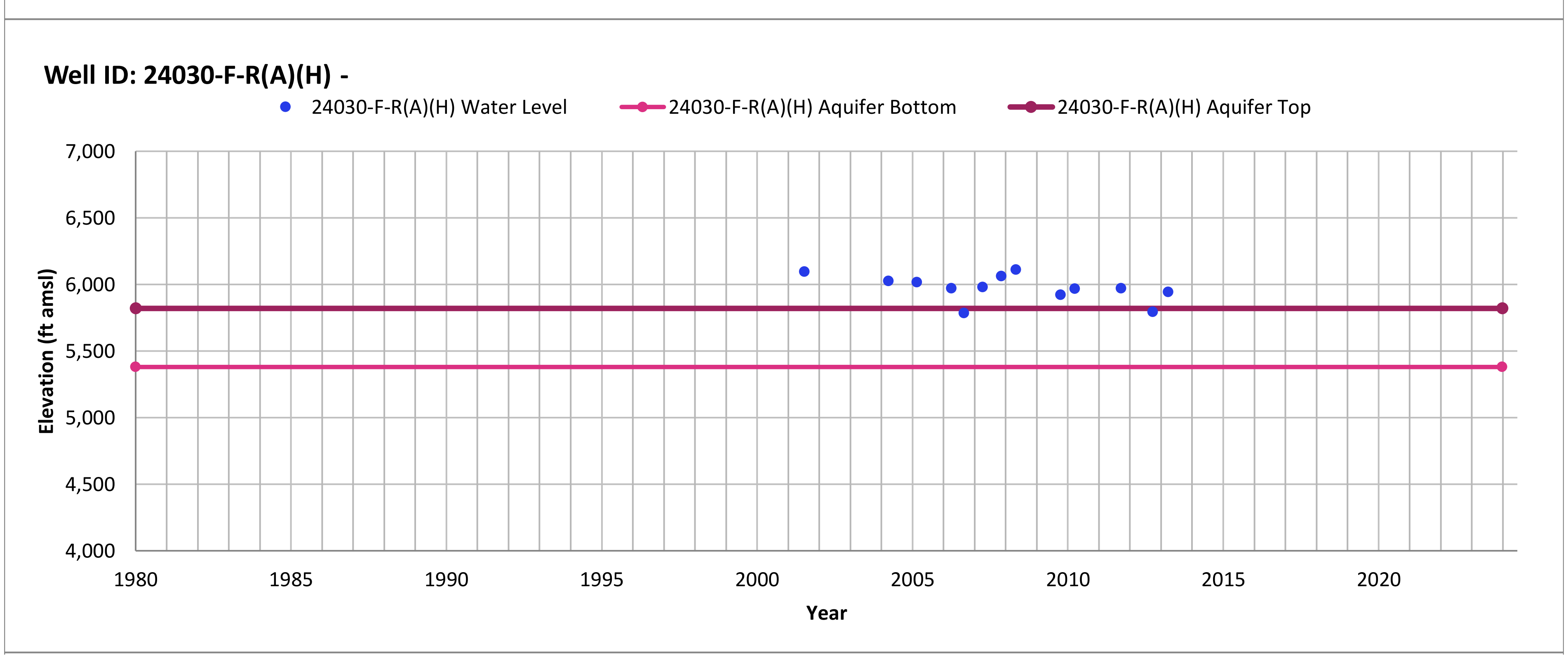


Well ID: 64303-F(A) -

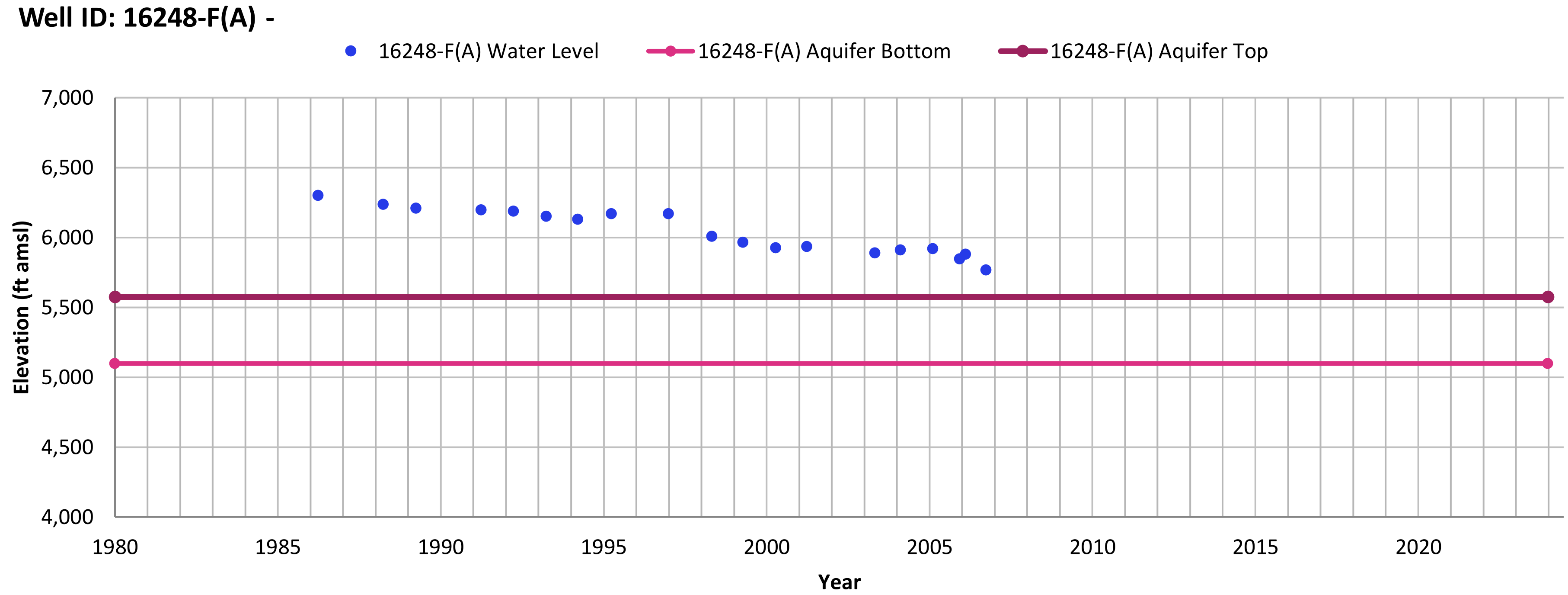



Well ID: 60943-F(A)(H) -
60943-F(A)(H) Water Level
60943-F(A)(H) Aquifer Bottom
60943-F(A)(H) Aquifer Top
Elevation (ft amsl)
7,000
6,500
6,000
5,500
5,000
4,500
4,000
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year

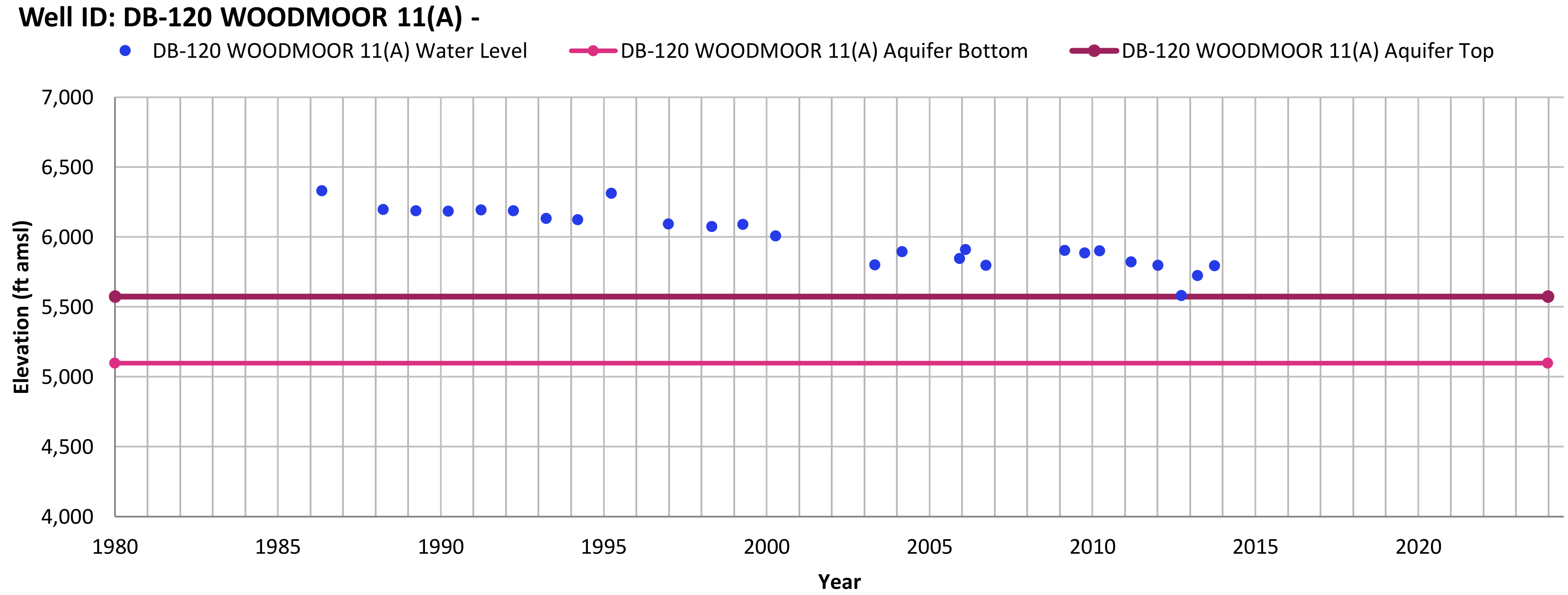

Well ID: 24030-F(A)(H) -
24030-F(A)(H) Water Level
24030-F(A)(H) Aquifer Bottom
24030-F(A)(H) Aquifer Top
Elevation (ft amsl)
7,000
6,500
6,000
5,500
5,000
4,500
4,000
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year


Well ID: 24030-F-R(A)(H) -
24030-F-R(A)(H) Water Level
24030-F-R(A)(H) Aquifer Bottom
24030-F-R(A)(H) Aquifer Top
Elevation (ft amsl)
7,000
6,500
6,000
5,500
5,000
4,500
4,000
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year

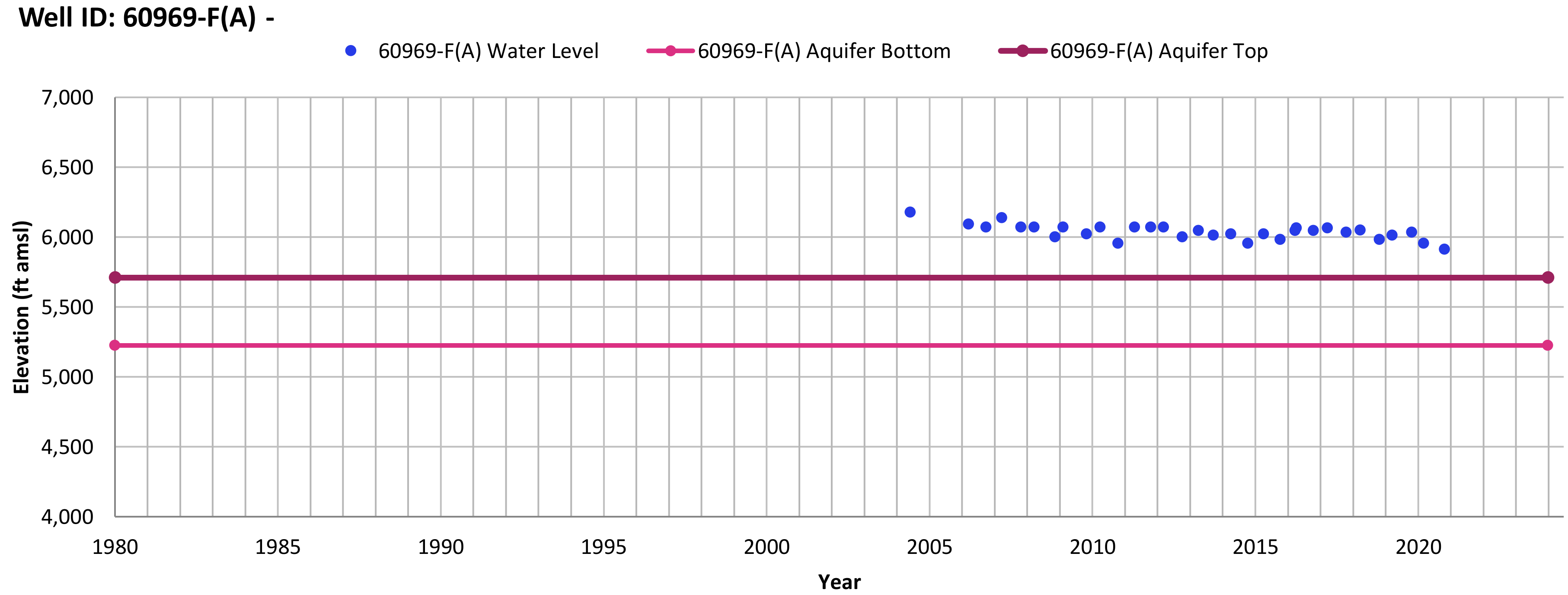
Well ID: 16248-F(A) -

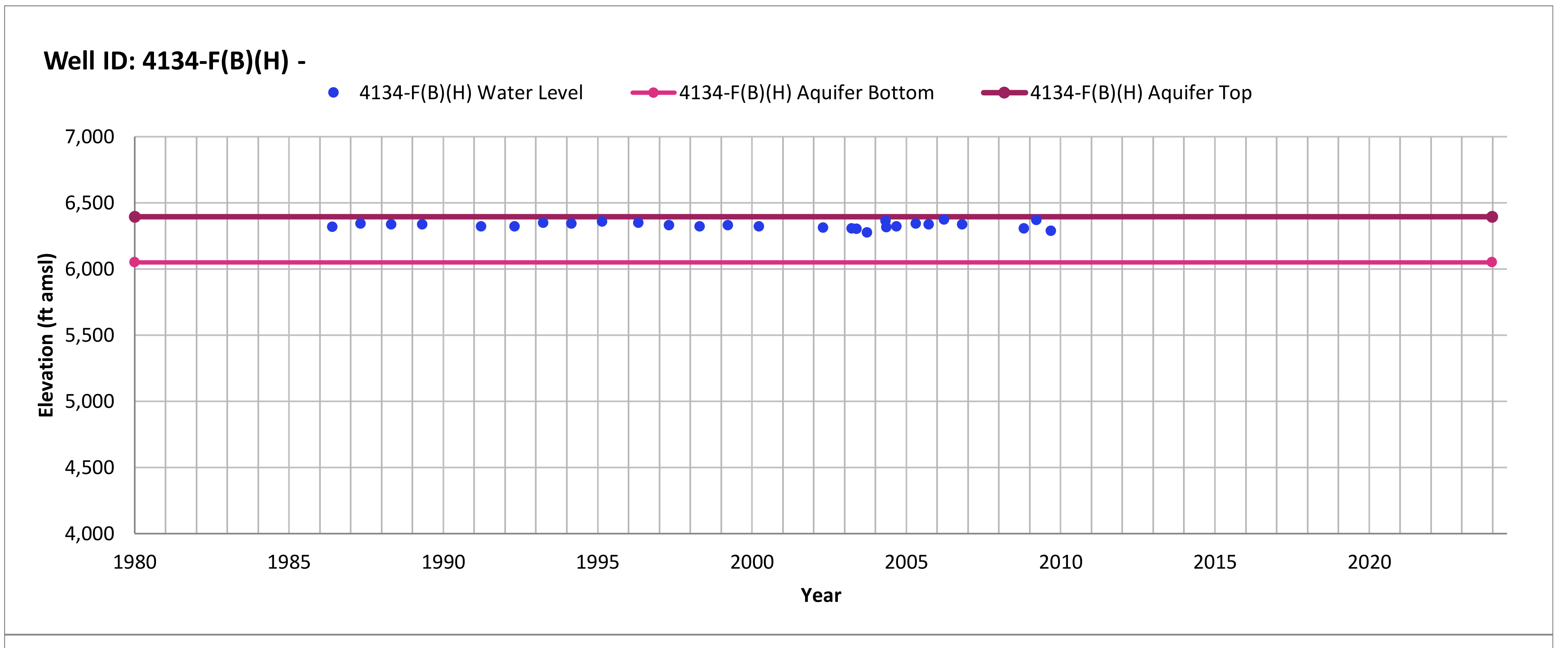


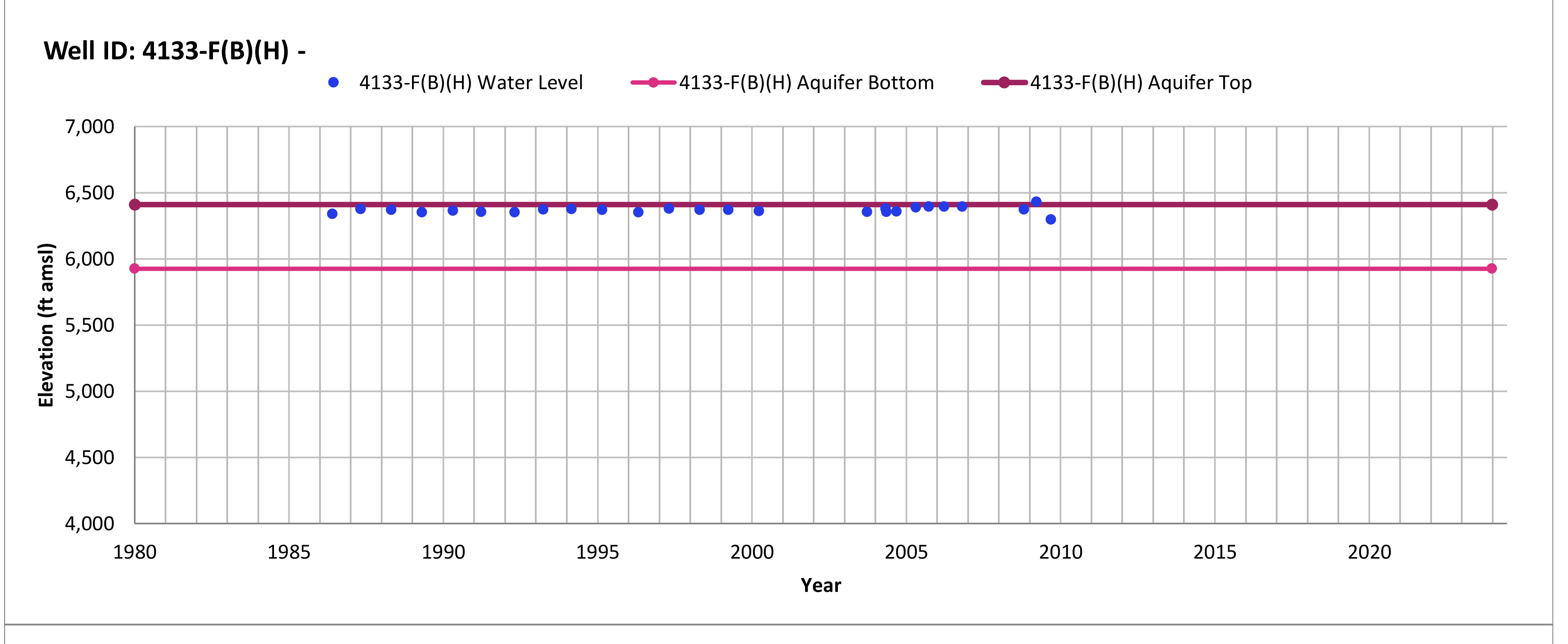
Well ID: DB-120 WOODMOOR 11(A) -

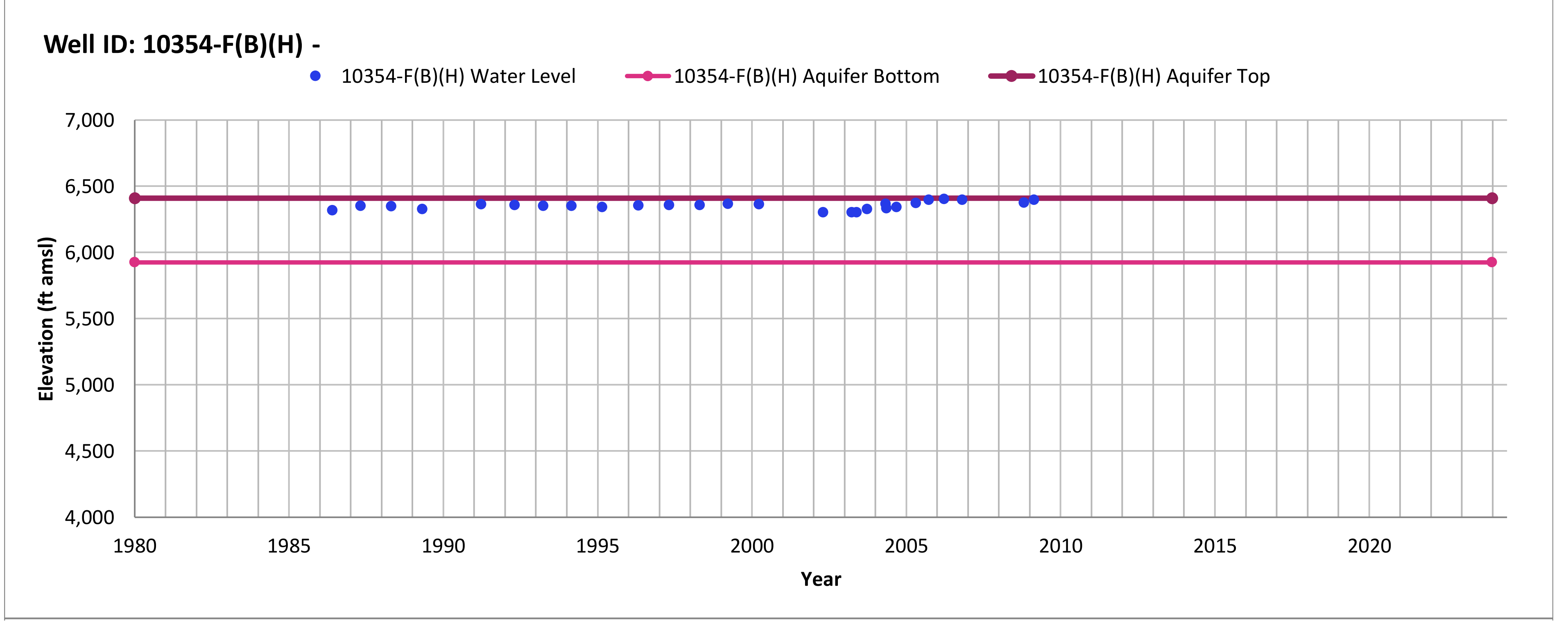


Well ID: 60969-F(A) -

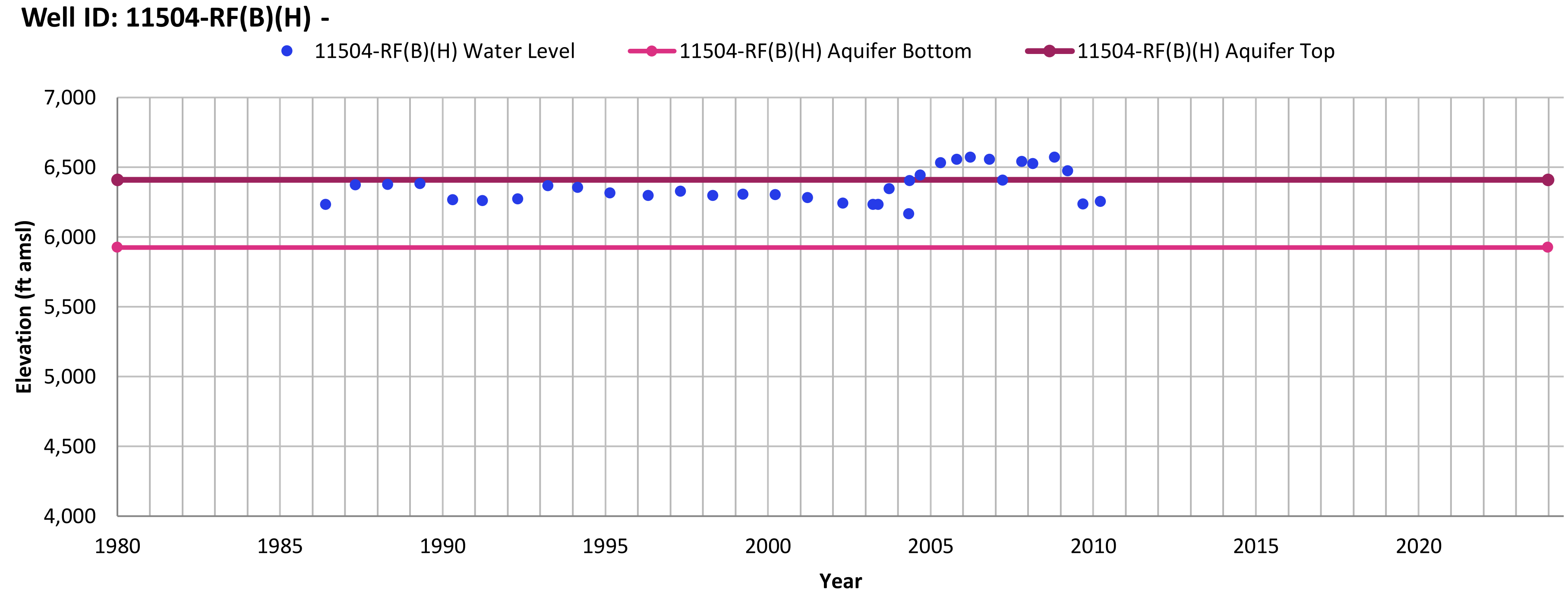



Well ID: 4134-F(B)(H) -
4134-F(B)(H) Water Level
4134-F(B)(H) Aquifer Bottom
4134-F(B)(H) Aquifer Top
Elevation (ft amsl)
7,000
6,500
6,000
5,500
5,000
4,500
4,000
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year

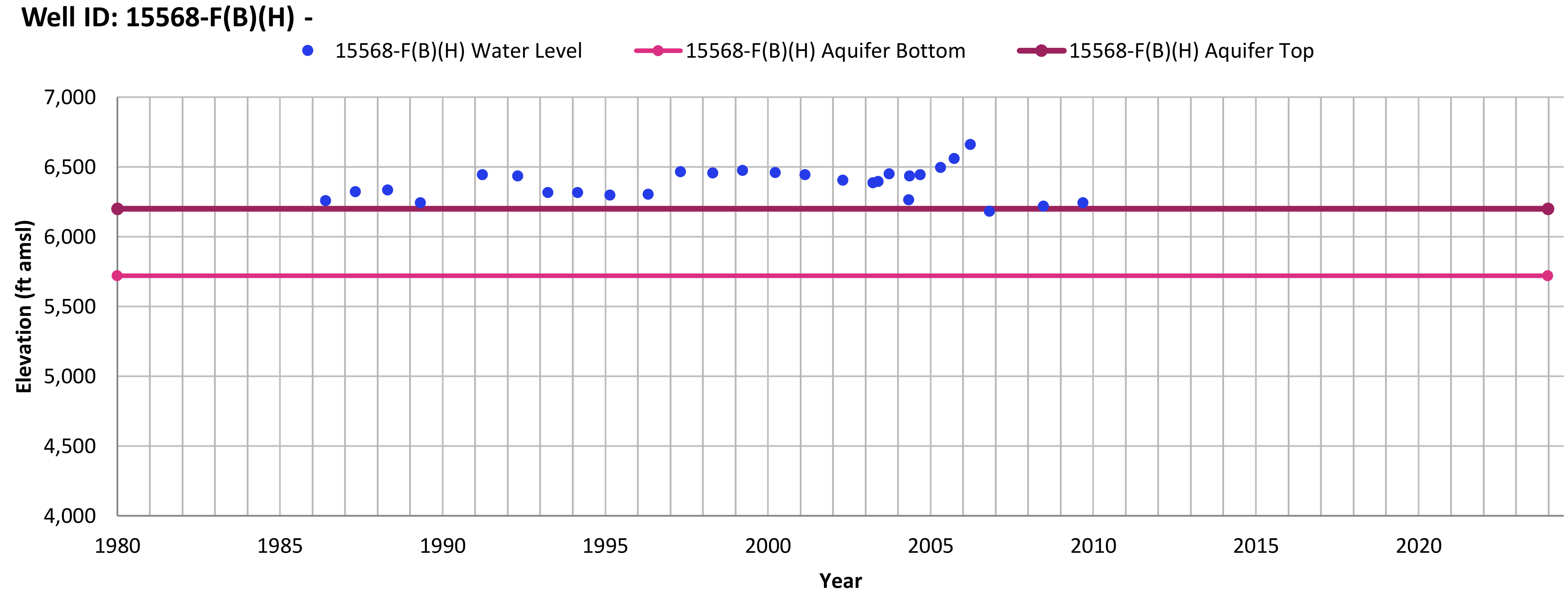

Well ID: 4133-F(B)(H) -
4133-F(B)(H) Water Level
4133-F(B)(H) Aquifer Bottom
4133-F(B)(H) Aquifer Top
Elevation (ft amsl)
7,000
6,500
6,000
5,500
5,000
4,500
4,000
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year


Well ID: 10354-F(B)(H) -
10354-F(B)(H) Water Level
10354-F(B)(H) Aquifer Bottom
10354-F(B)(H) Aquifer Top
Elevation (ft amsl)
7,000
6,500
6,000
5,500
5,000
4,500
4,000
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year

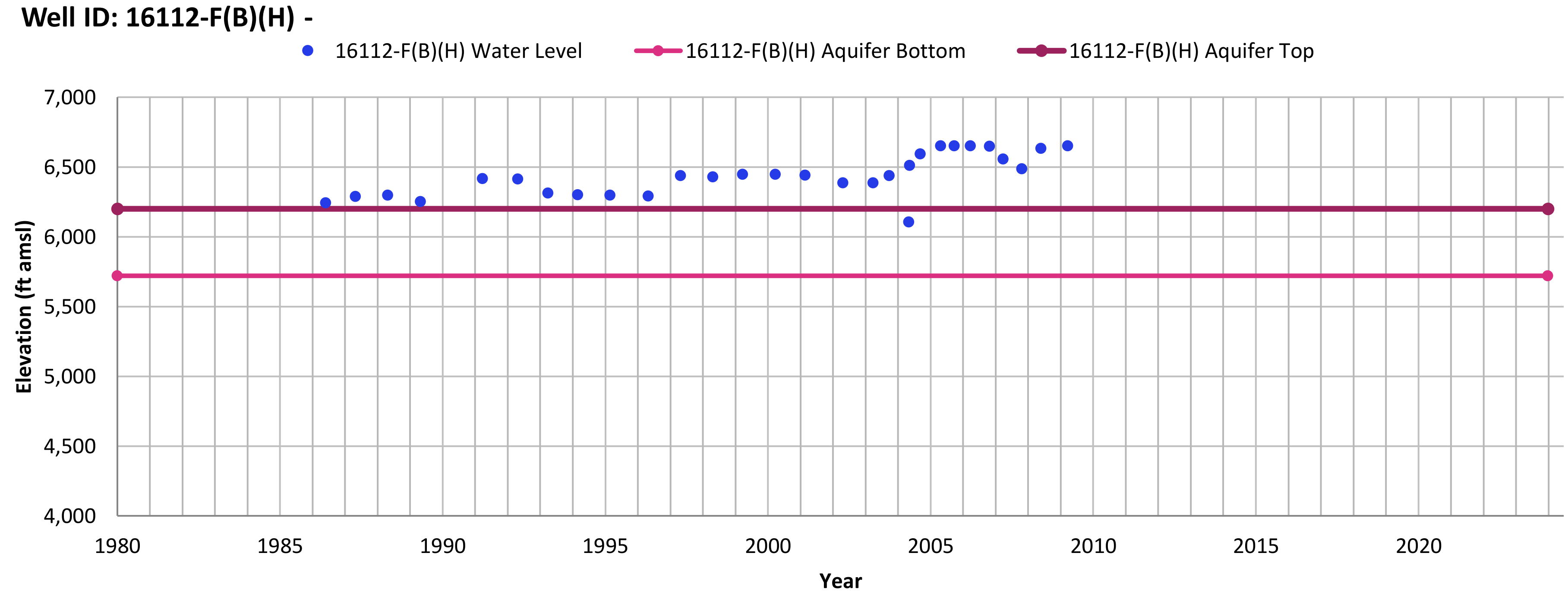
Well ID: 11504-RF(B)(H) -

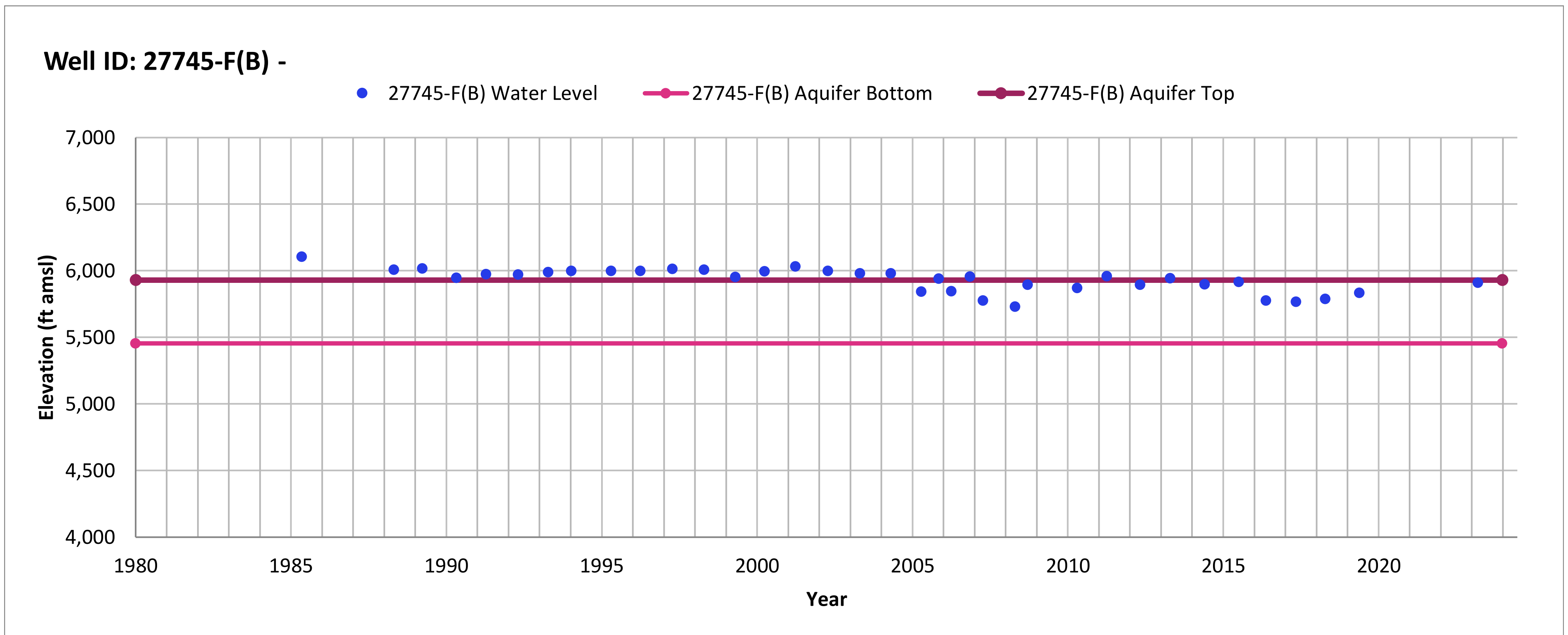


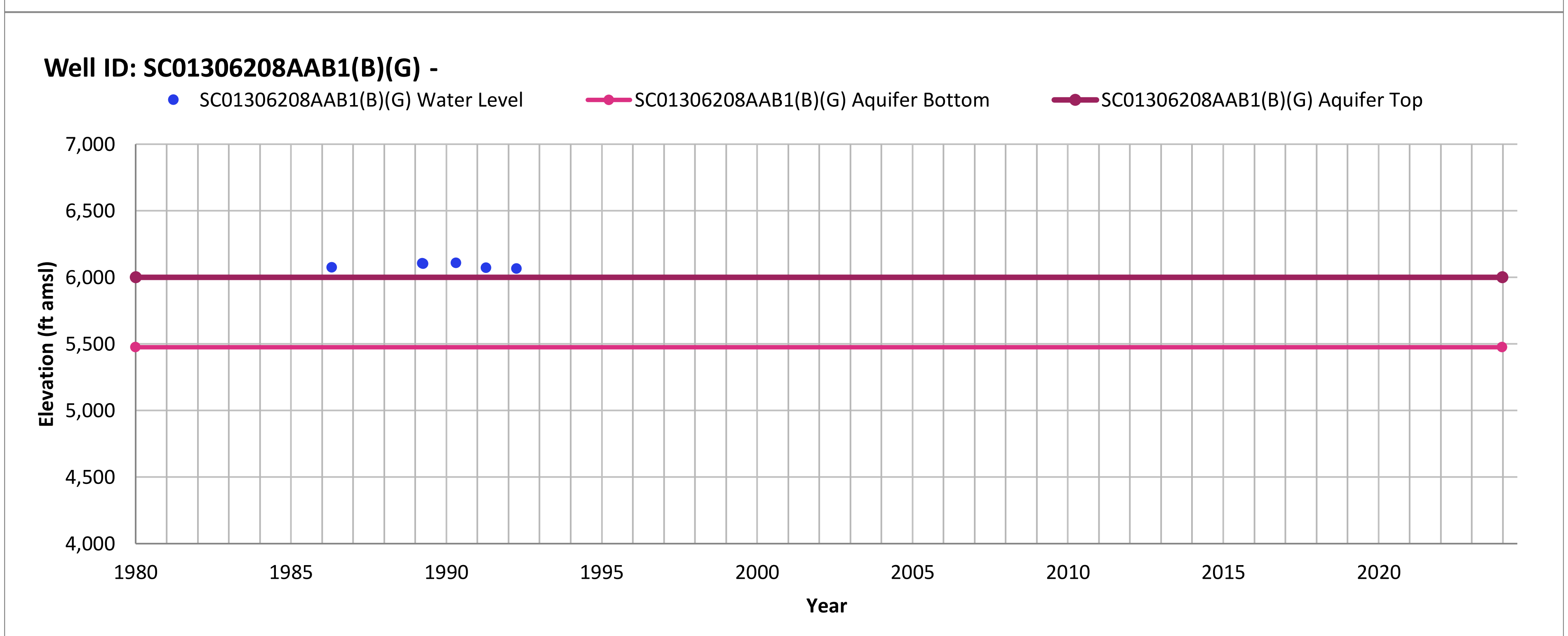
Well ID: 15568-F(B)(H) -

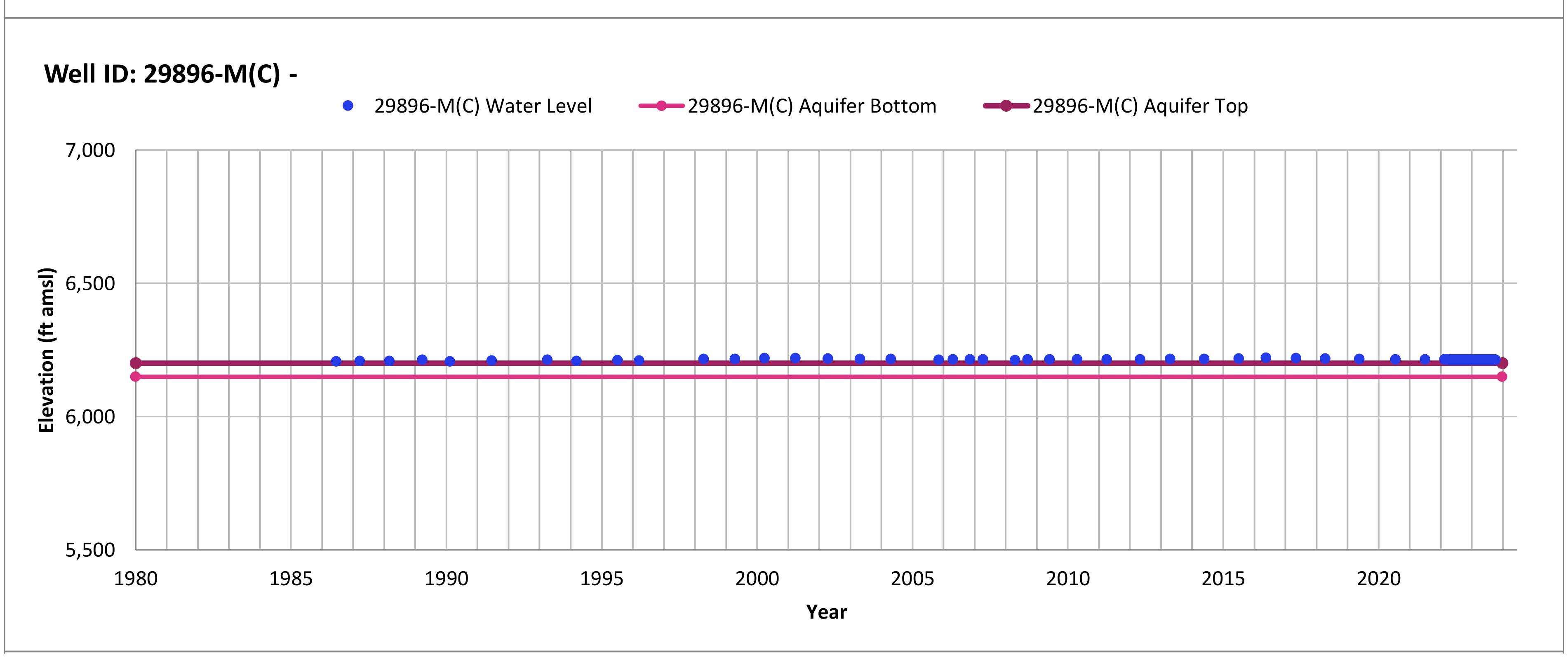


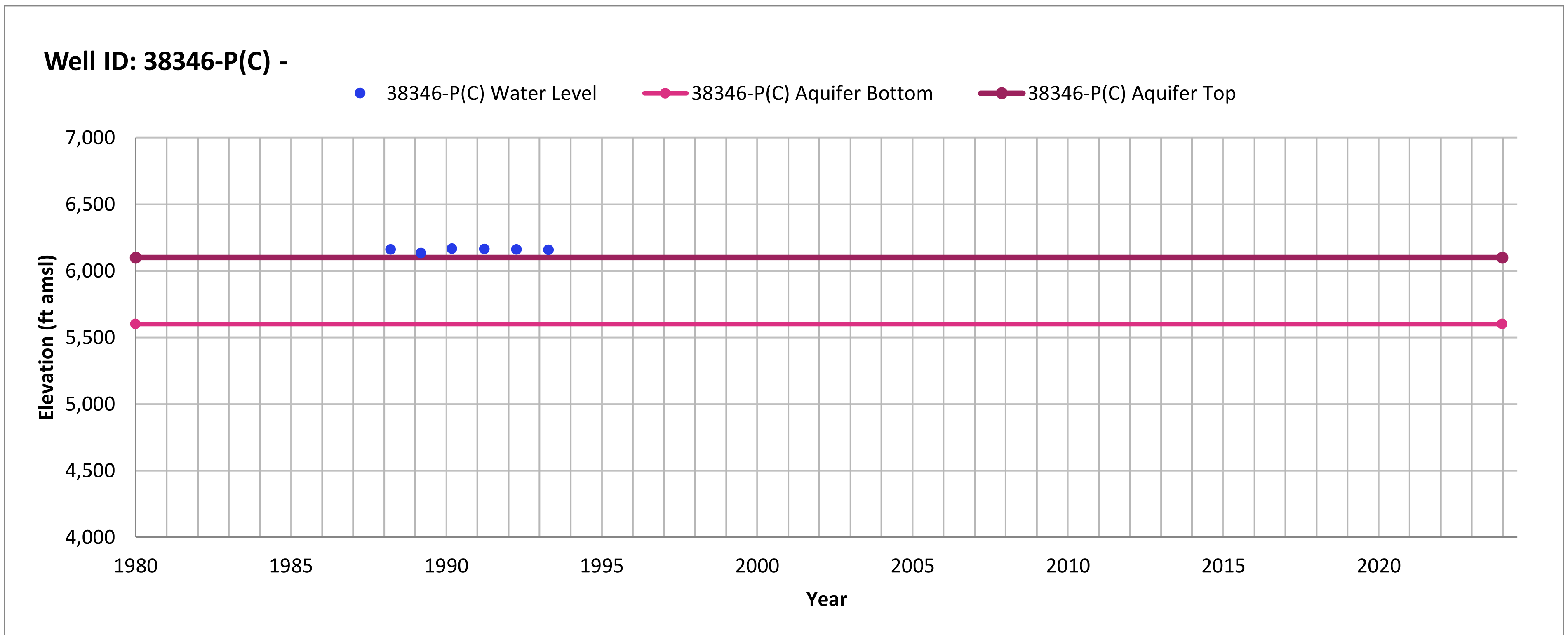
Well ID: 16112-F(B)(H) -

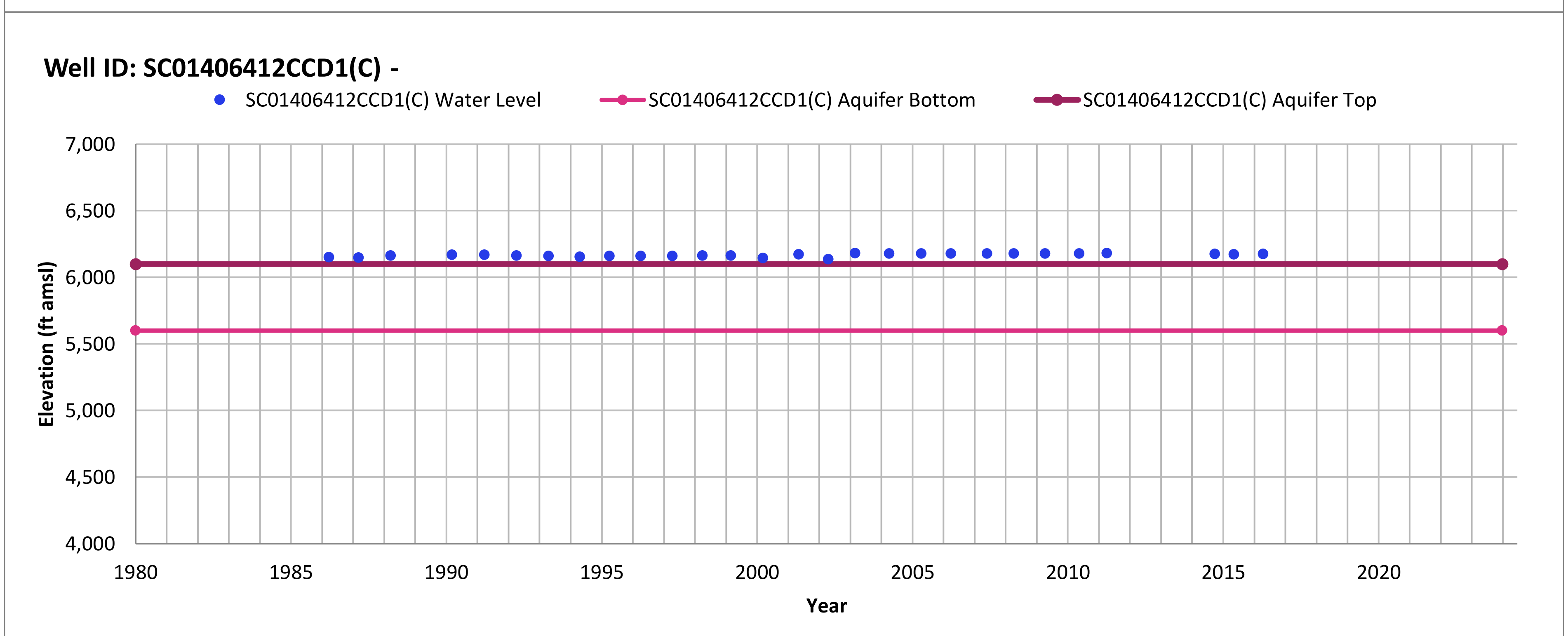


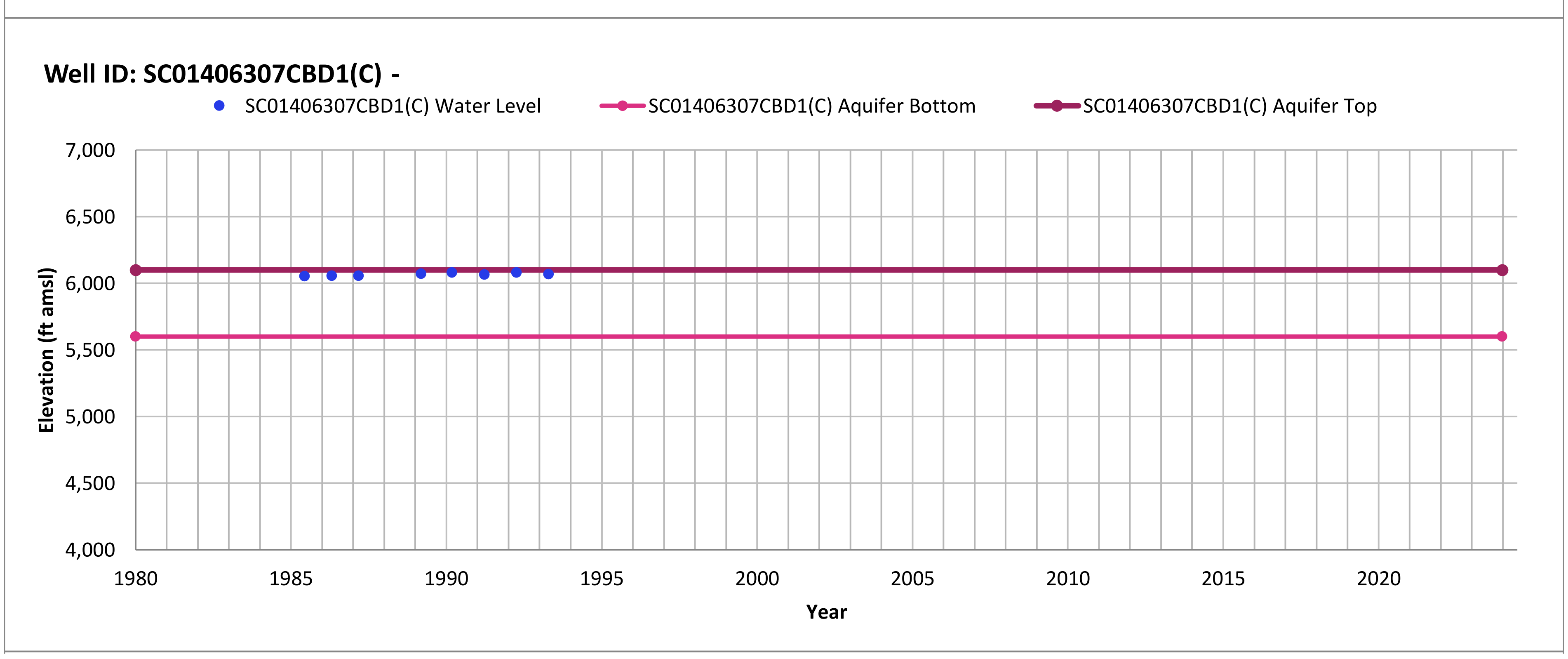

Well ID: 27745-F(B) -
27745-F(B) Water Level
27745-F(B) Aquifer Bottom
27745-F(B) Aquifer Top
7,000
6,500
6,000
5,500
5,000
4,500
4,000
Elevation (ft amsl)
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year


Well ID: SC01306208AAB1(B)(G) -
SC01306208AAB1(B)(G) Water Level
SC01306208AAB1(B)(G) Aquifer Bottom
SC01306208AAB1(B)(G) Aquifer Top
7,000
6,500
6,000
5,500
5,000
4,500
4,000
Elevation (ft amsl)
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year


Well ID: 29896-M(C) -
29896-M(C) Water Level
29896-M(C) Aquifer Bottom
29896-M(C) Aquifer Top
7,000
6,500
6,000
5,500
Elevation (ft amsl)
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year


Well ID: 38346-P(C) -
38346-P(C) Water Level
38346-P(C) Aquifer Bottom
38346-P(C) Aquifer Top
7,000
6,500
6,000
5,500
5,000
4,500
4,000
Elevation (ft amsl)
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year


Well ID: SC01406412CCD1(C) -
SC01406412CCD1(C) Water Level
SC01406412CCD1(C) Aquifer Bottom
SC01406412CCD1(C) Aquifer Top
7,000
6,500
6,000
5,500
5,000
4,500
4,000
Elevation (ft amsl)
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year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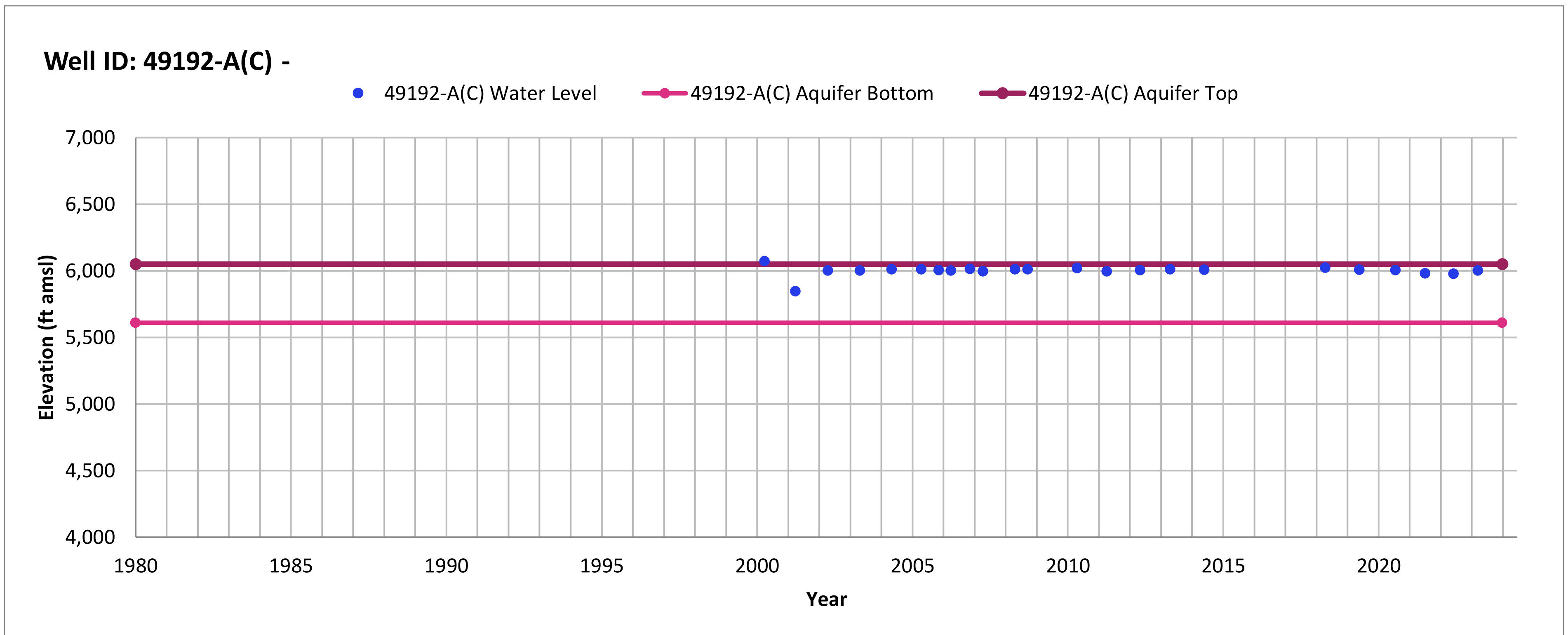
SC01406307CBD1(C) Aquifer Bottom
SC01406307CBD1(C) Aquifer Top
7,000
6,500
6,000
5,500
5,000
4,500
4,000
Elevation (ft amsl)
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year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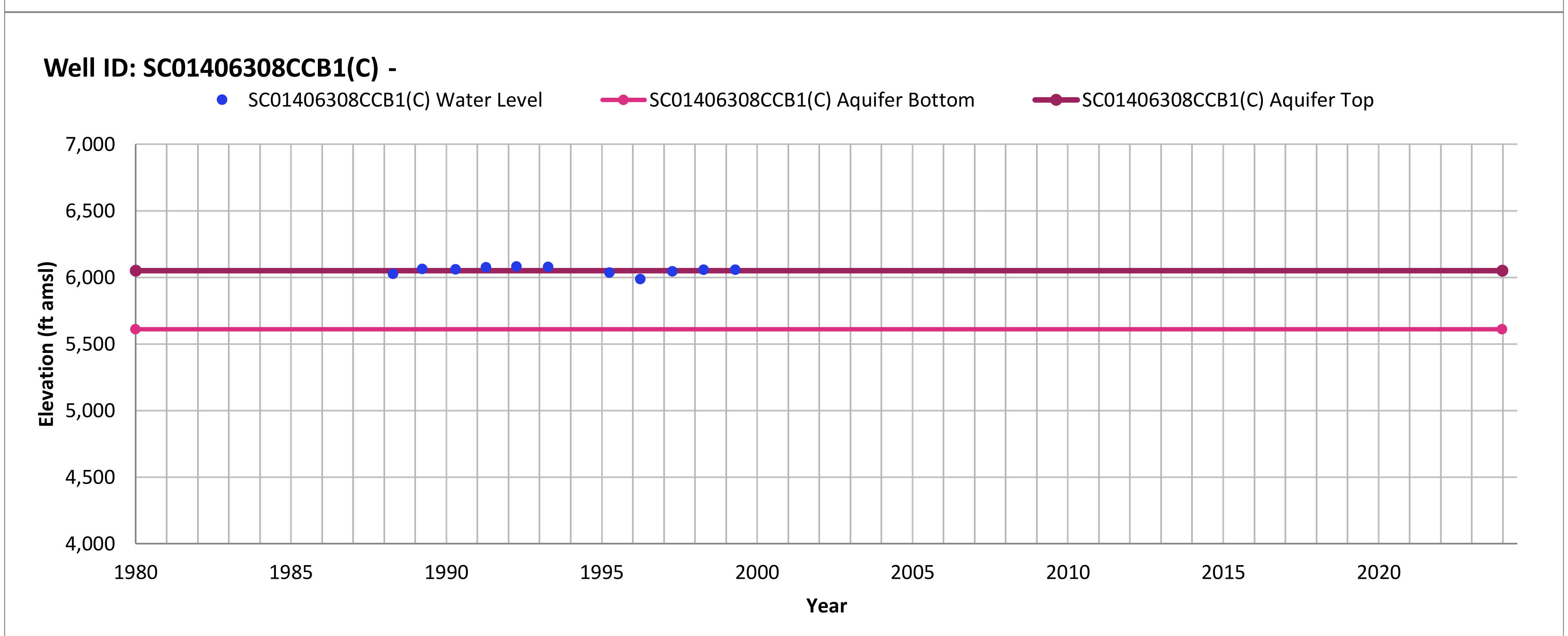
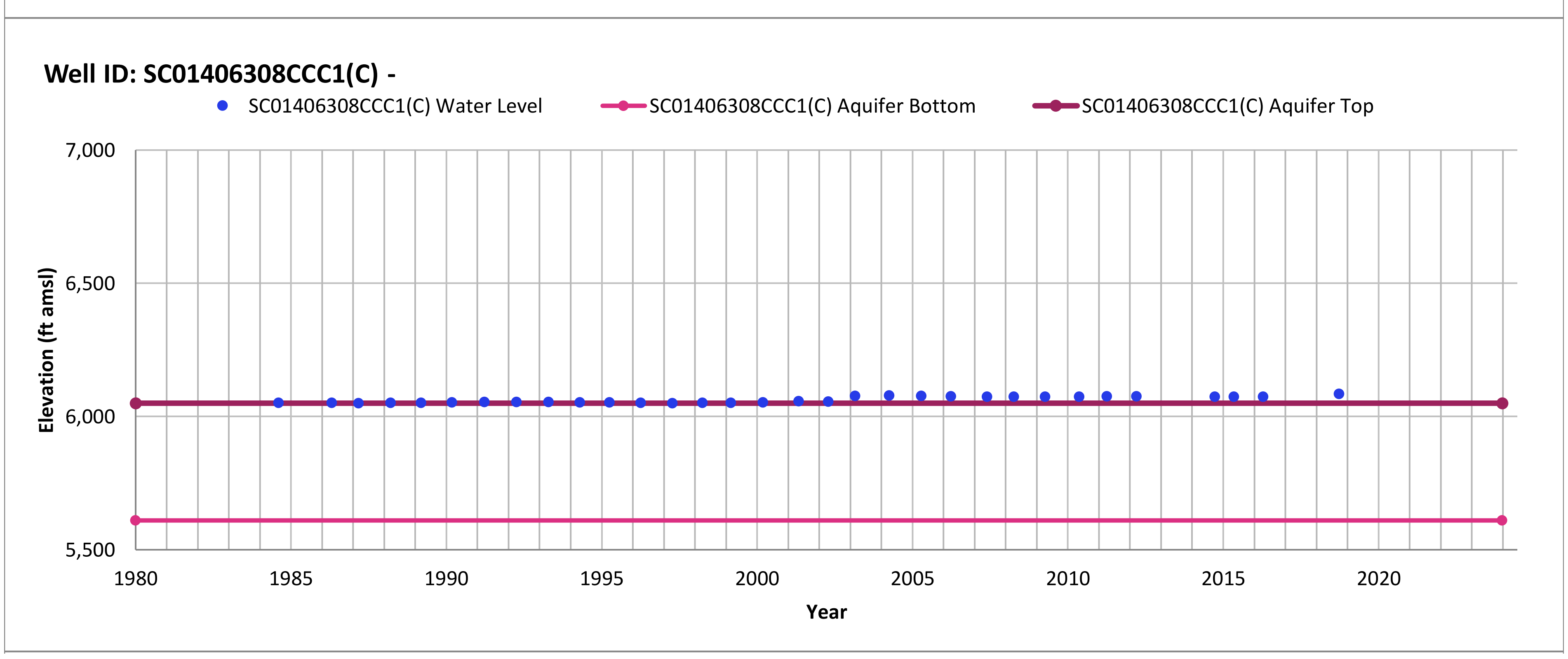
49192-A(C) Water Level
49192-A(C) Aquifer Bottom
49192-A(C) Aquifer Top
7,000
6,500
6,000
5,500
5,000
4,500
4,000
Elevation (ft amsl)
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year


Well ID: SC01406308CCB1(C) -
SC01406308CCB1(C) Water Level
SC01406308CCB1(C) Aquifer Bottom
SC01406308CCB1(C) Aquifer Top
7,000
6,500
6,000
5,500
5,000
4,500
4,000
Elevation (ft amsl)
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year


Well ID: SC01406308CCC1(C) -
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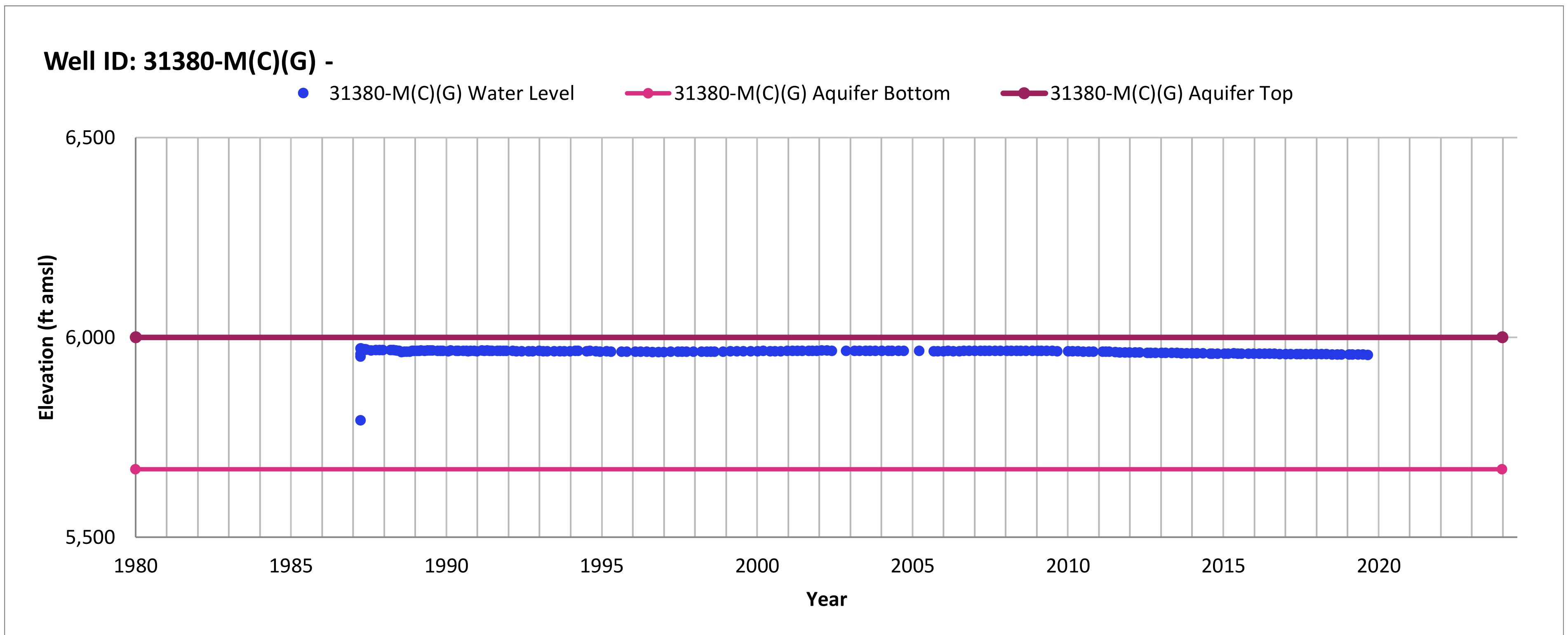
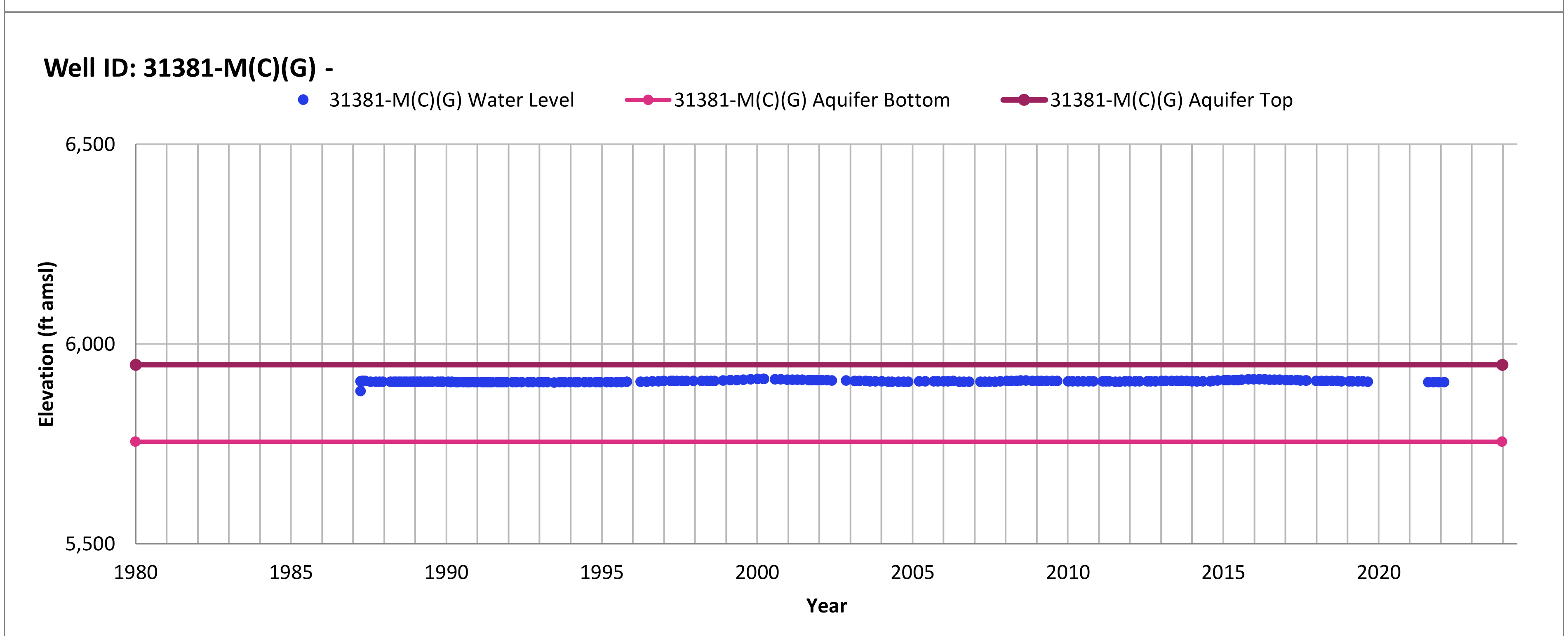
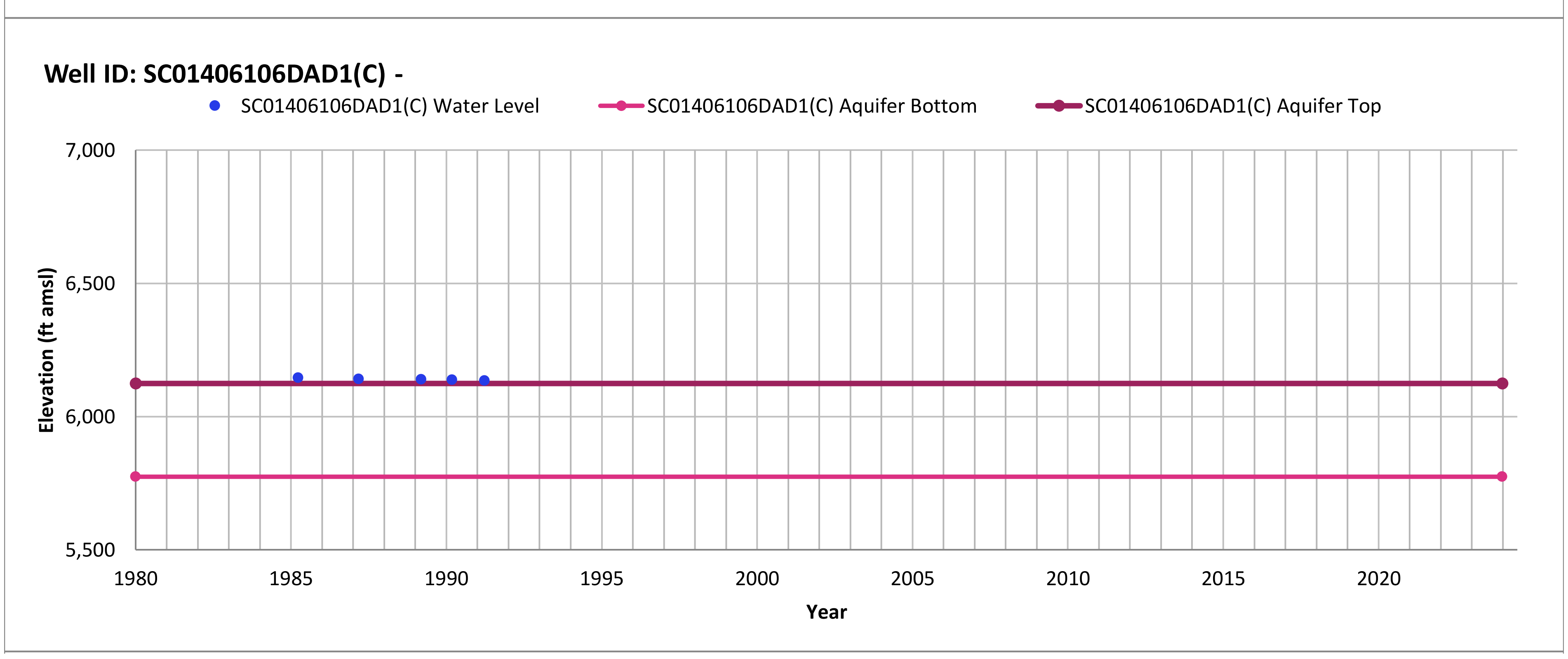
SC01406308CCC1(C) Aquifer Bottom
SC01406308CCC1(C) Aquifer Top
7,000
6,500
6,000
5,500
Elevation (ft amsl)
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year


Well ID: 31380-M(C)(G) -
31380-M(C)(G) Water Level
31380-M(C)(G) Aquifer Bottom
31380-M(C)(G) Aquifer Top
6,500
6,000
5,500
Elevation (ft amsl)
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year


Well ID: 31381-M(C)(G) -
31381-M(C)(G) Water Level
31381-M(C)(G) Aquifer Bottom
31381-M(C)(G) Aquifer Top
6,500
6,000
5,500
Elevation (ft amsl)
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year


Well ID: SC01406106DAD1(C) -
SC01406106DAD1(C) Water Level
SC01406106DAD1(C) Aquifer Bottom
SC01406106DAD1(C) Aquifer Top
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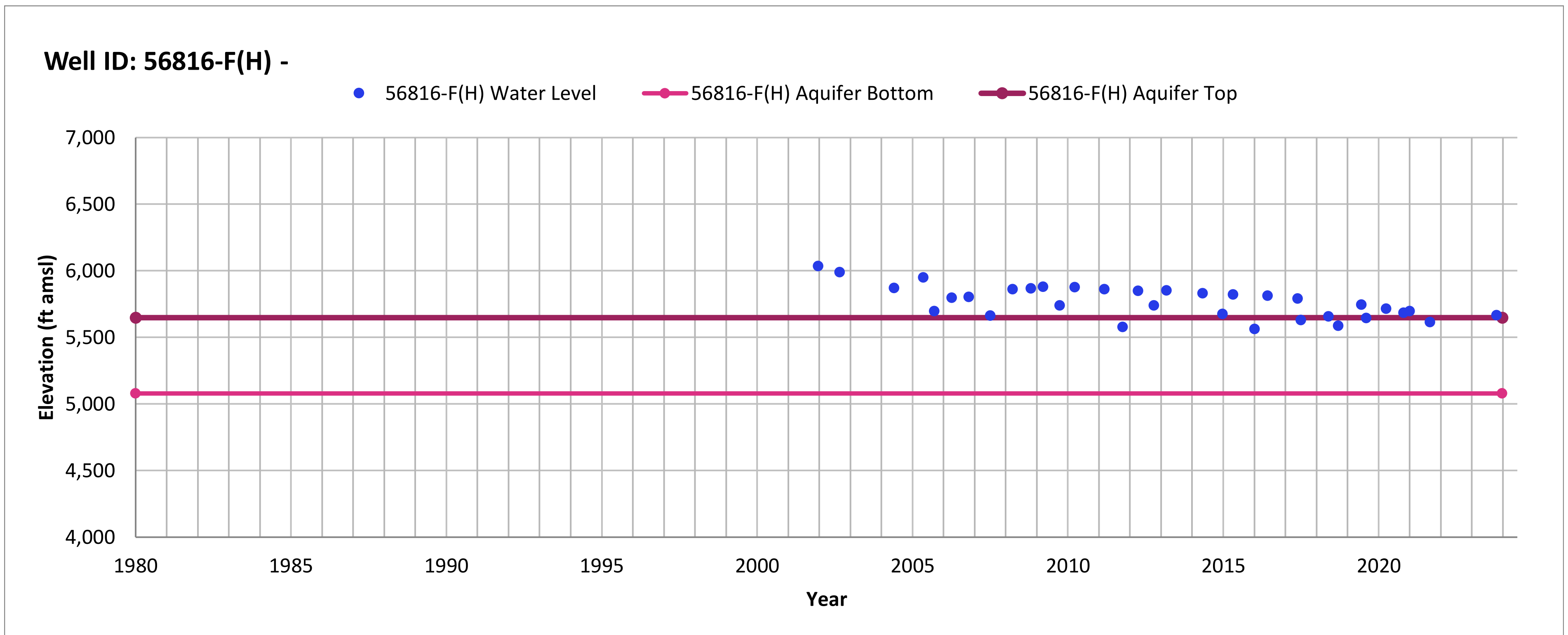
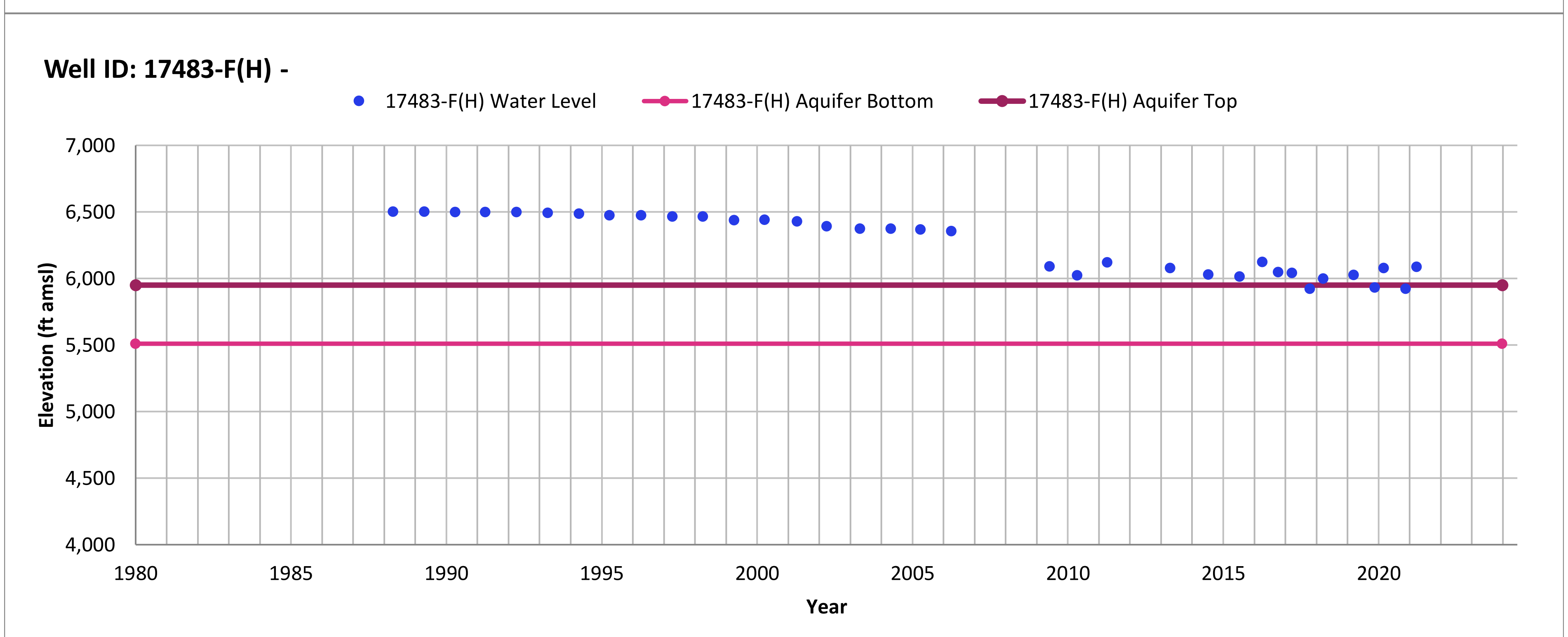
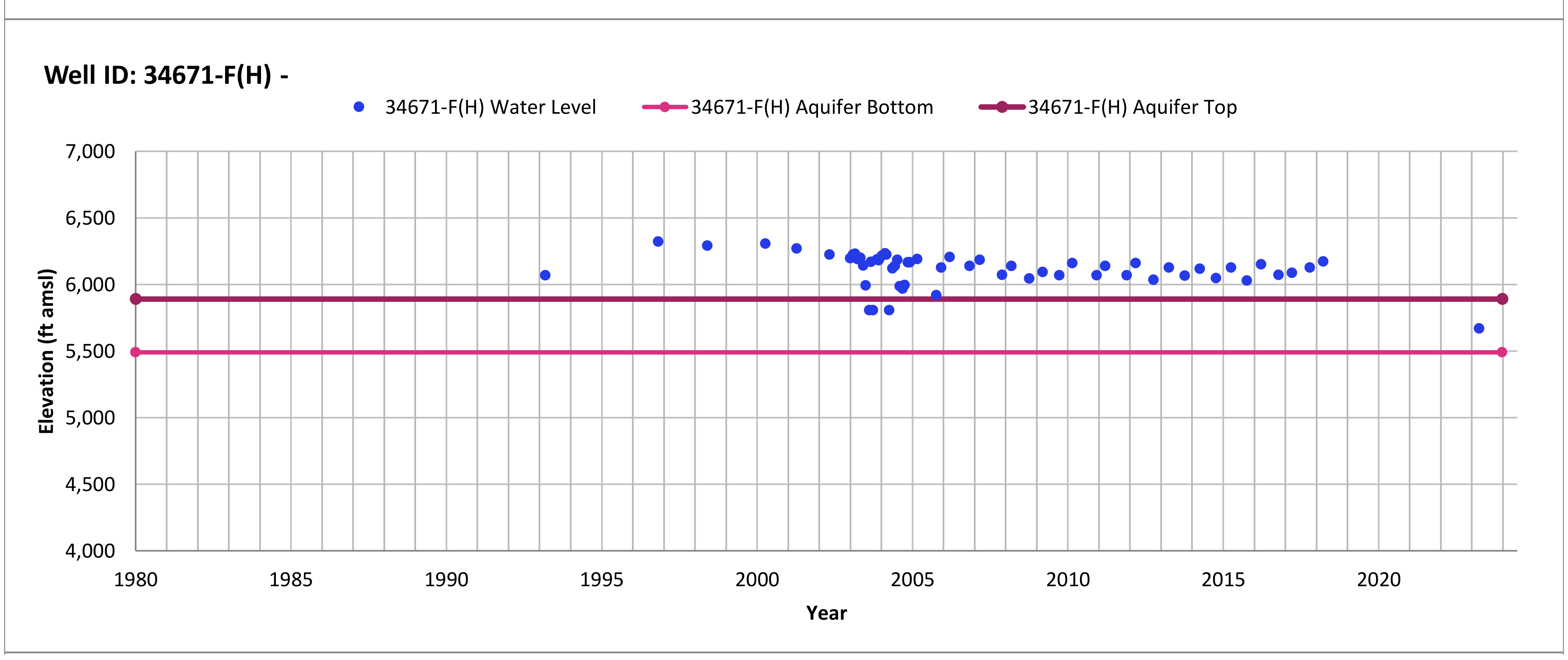
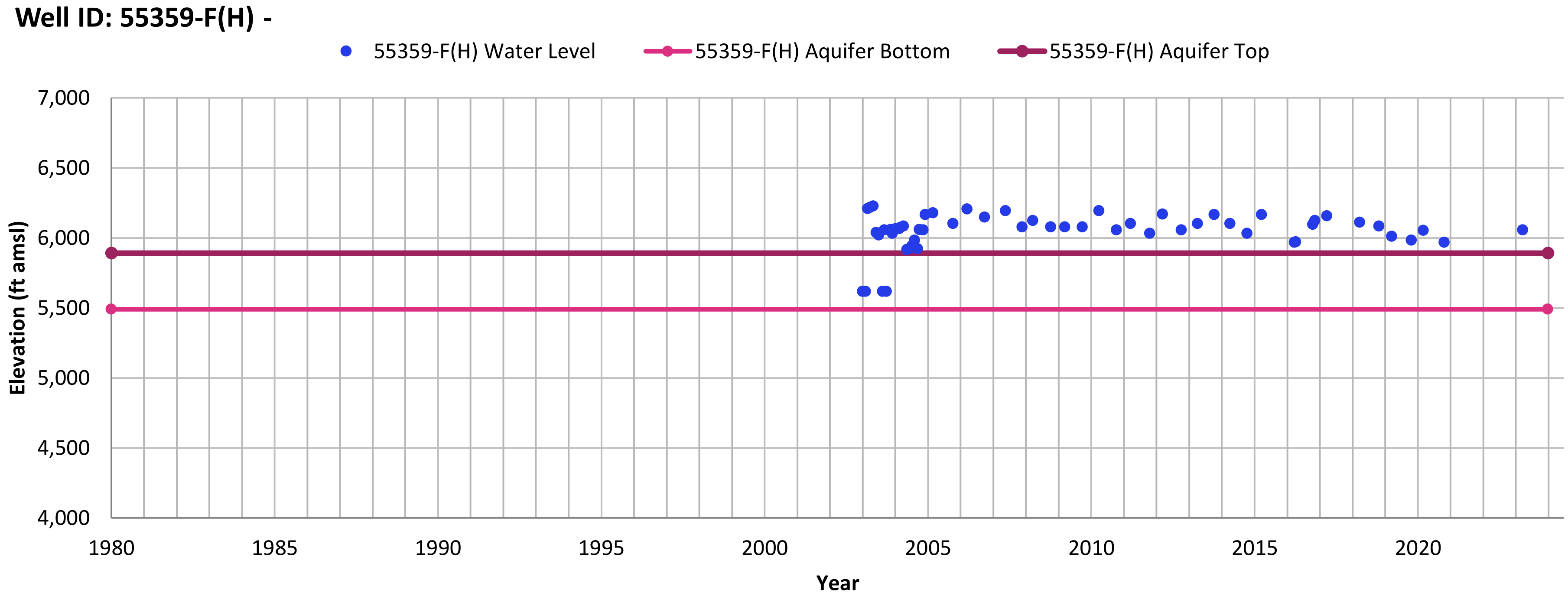
6,000
5,500
Elevation (ft amsl)
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year


Well ID: 56816-F(H) -
56816-F(H) Water Level
56816-F(H) Aquifer Bottom
56816-F(H) Aquifer Top
Elevation (ft amsl)
7,000
6,500
6,000
5,500
5,000
4,500
4,000
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year

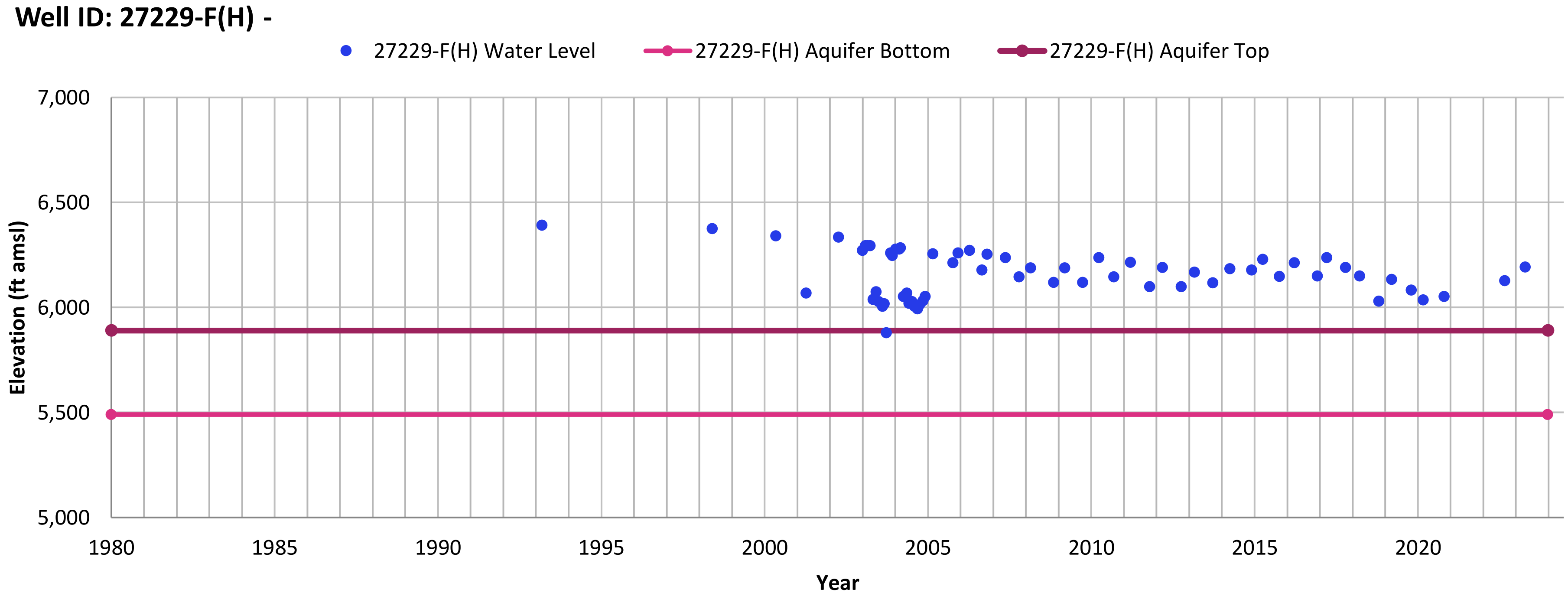

Well ID: 17483-F(H) -
17483-F(H) Water Level
17483-F(H) Aquifer Bottom
17483-F(H) Aquifer Top
Elevation (ft amsl)
7,000
6,500
6,000
5,500
5,000
4,500
4,000
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year


Well ID: 34671-F(H) -
34671-F(H) Water Level
34671-F(H) Aquifer Bottom
34671-F(H) Aquifer Top
Elevation (ft amsl)
7,000
6,500
6,000
5,500
5,000
4,500
4,000
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year

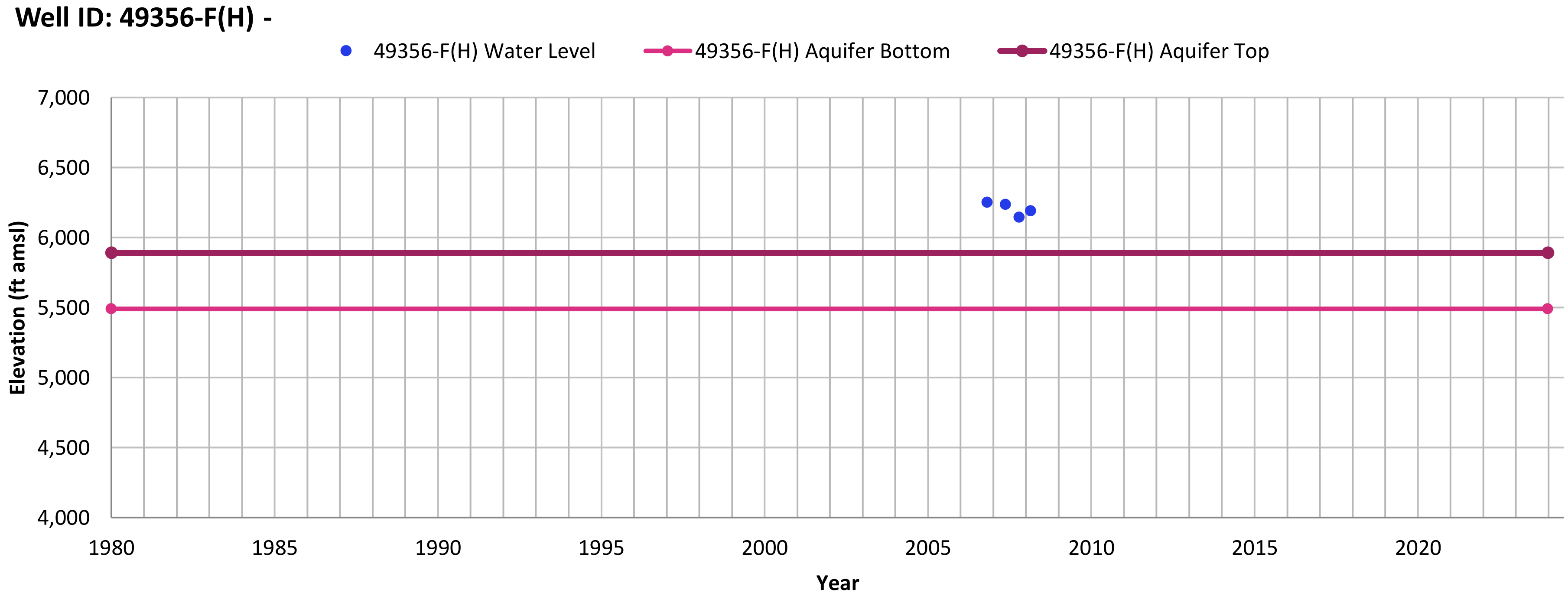
Well ID: 55359-F(H) -

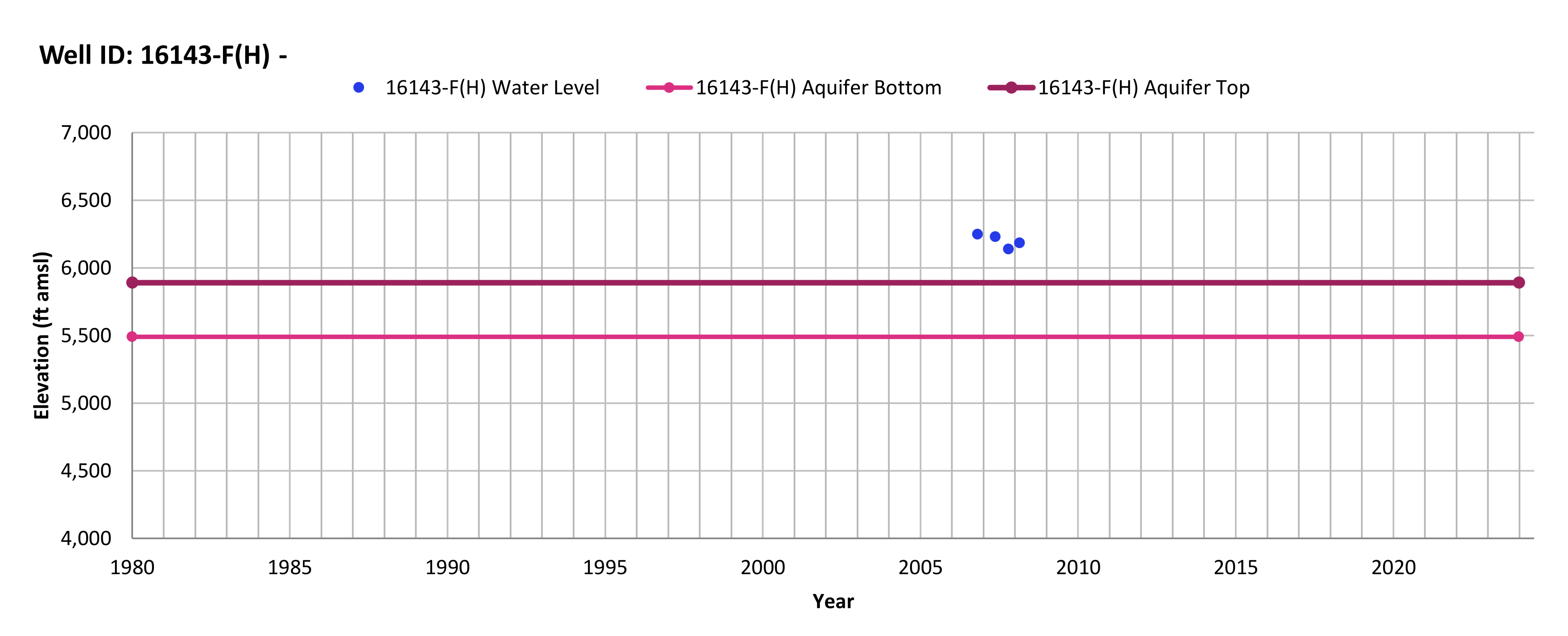


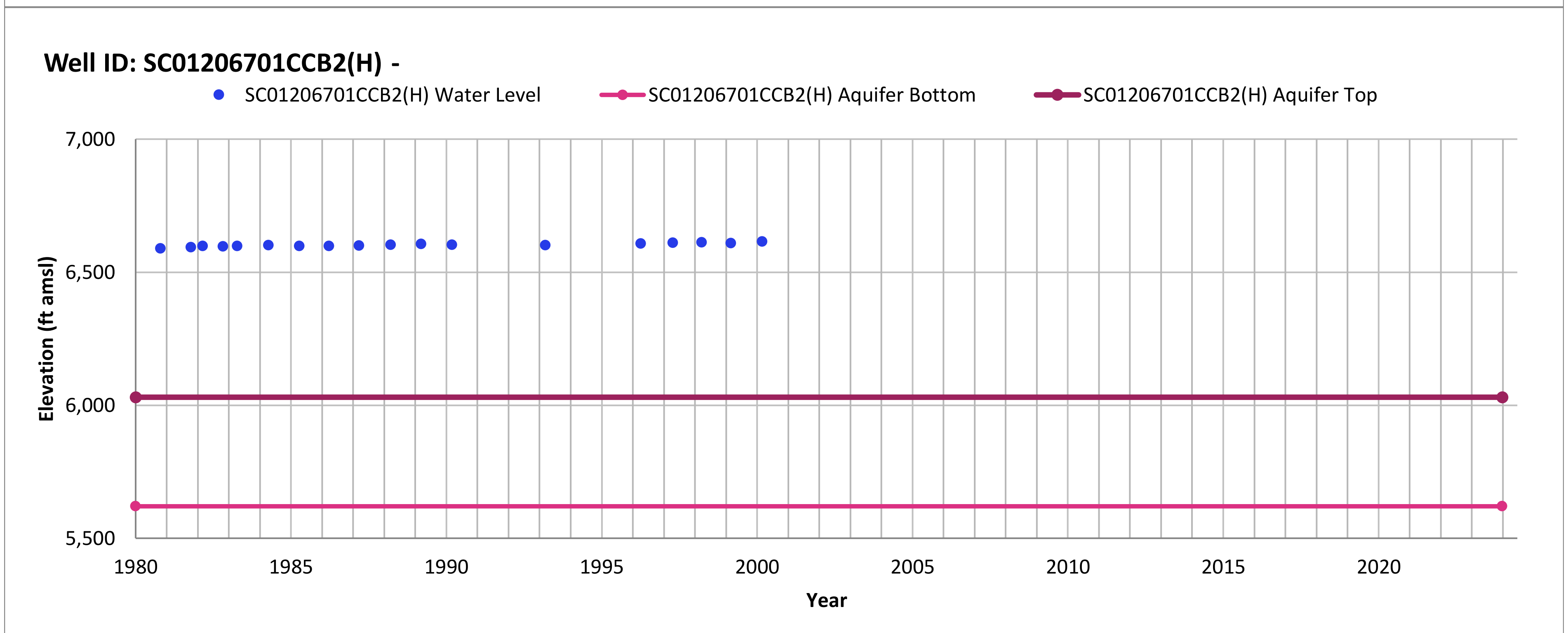
Well ID: 27229-F(H) -

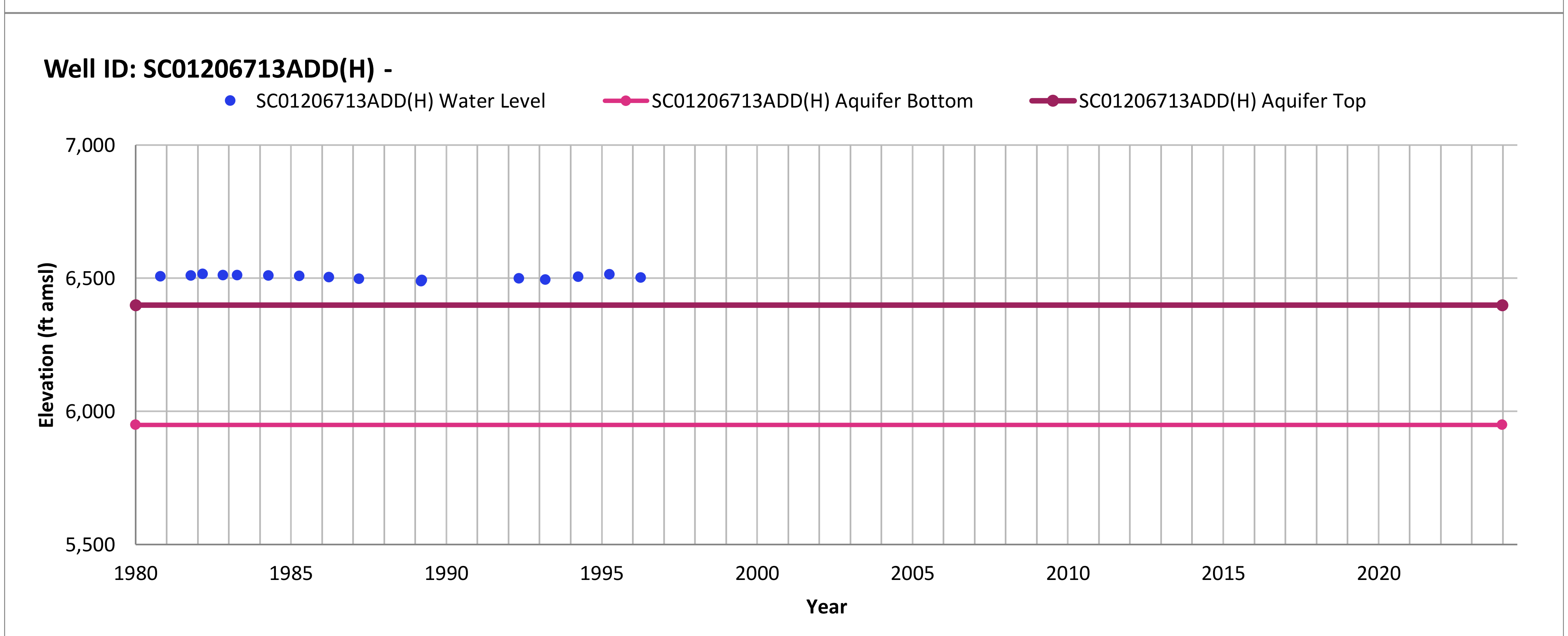


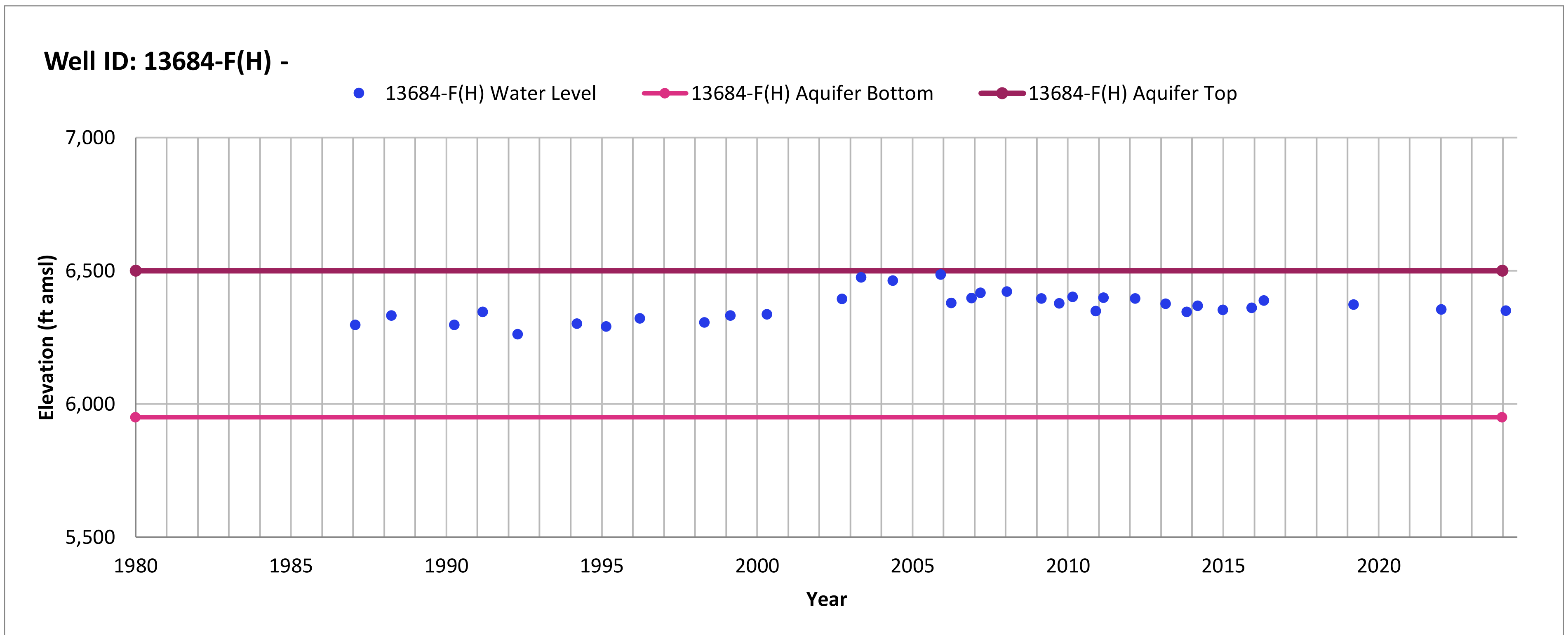
Well ID: 49356-F(H) -

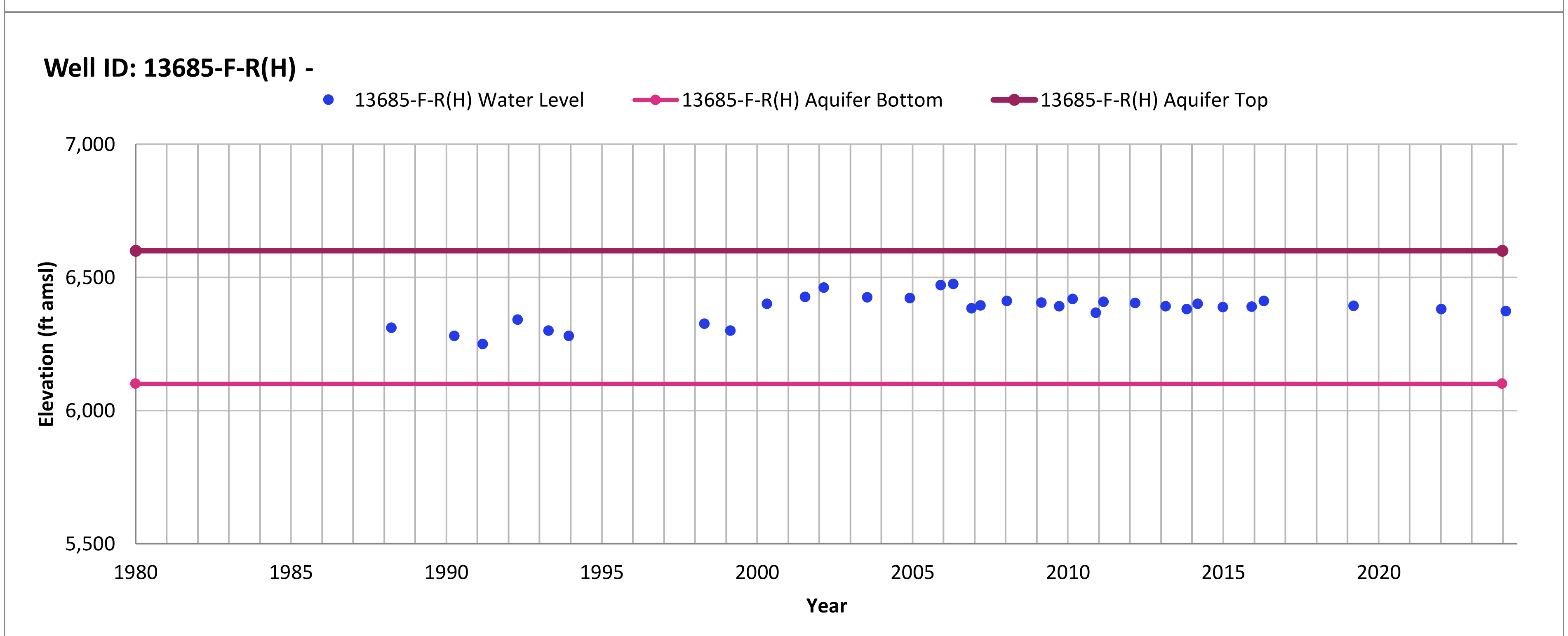


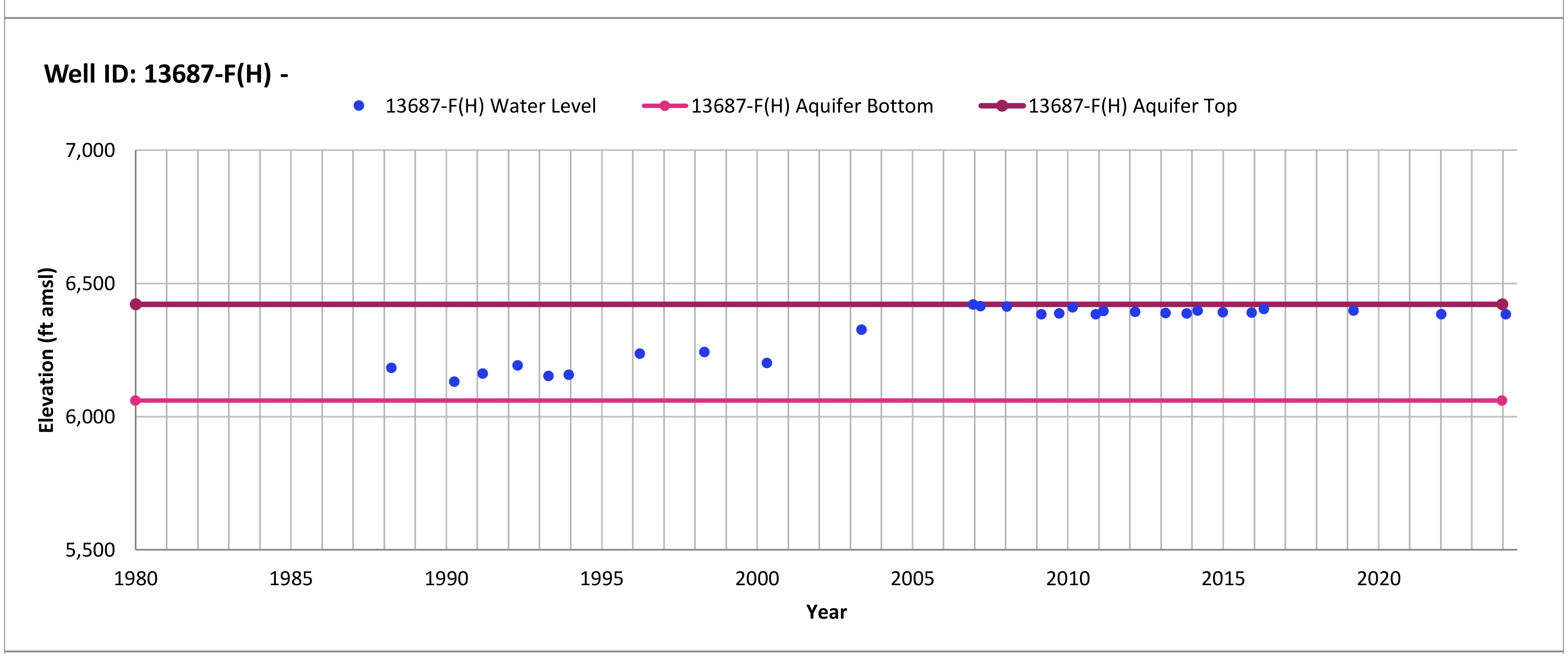

Well ID: 16143-F(H) -
16143-F(H) Water Level
16143-F(H) Aquifer Bottom
16143-F(H) Aquifer Top
Elevation (ft amsl)
7,000
6,500
6,000
5,500
5,000
4,500
4,000
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year

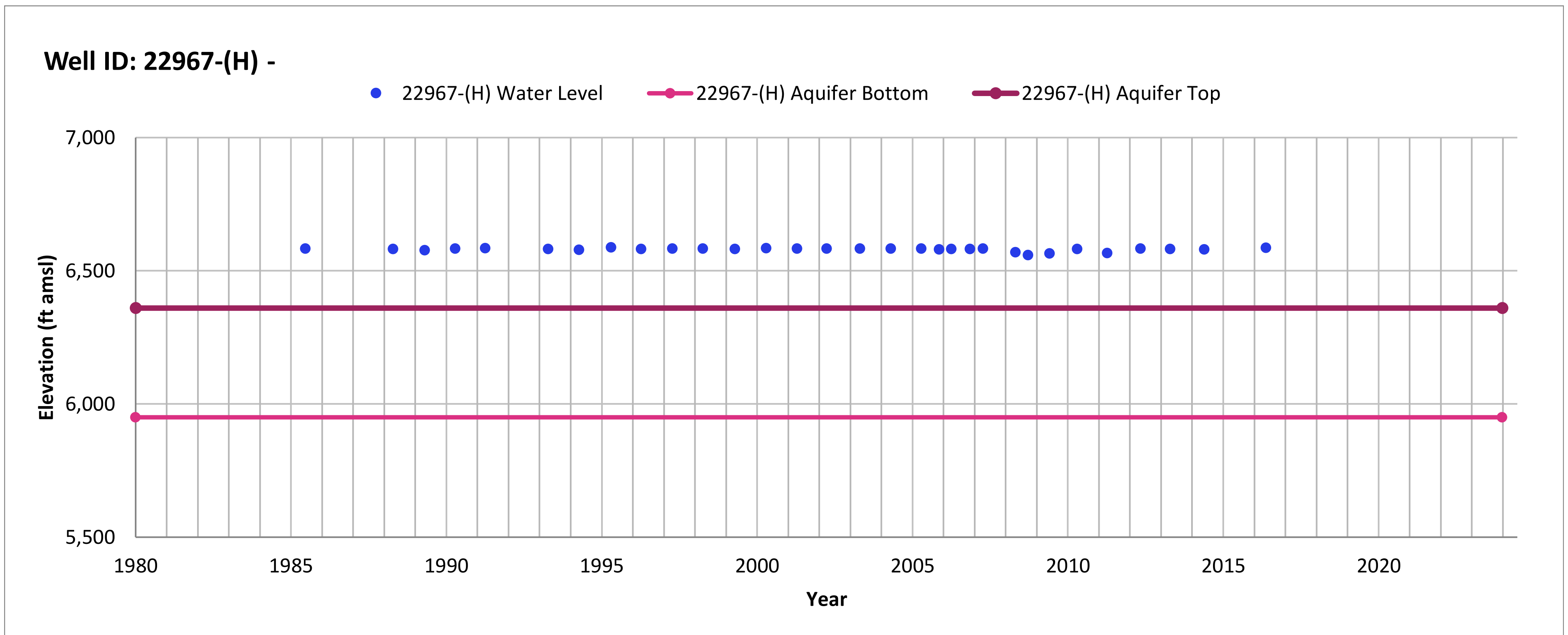

Well ID: SC01206701CCB2(H) -
SC01206701CCB2(H) Water Level
SC01206701CCB2(H) Aquifer Bottom
SC01206701CCB2(H) Aquifer Top
Elevation (ft amsl)
7,000
6,500
6,000
5,500
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year

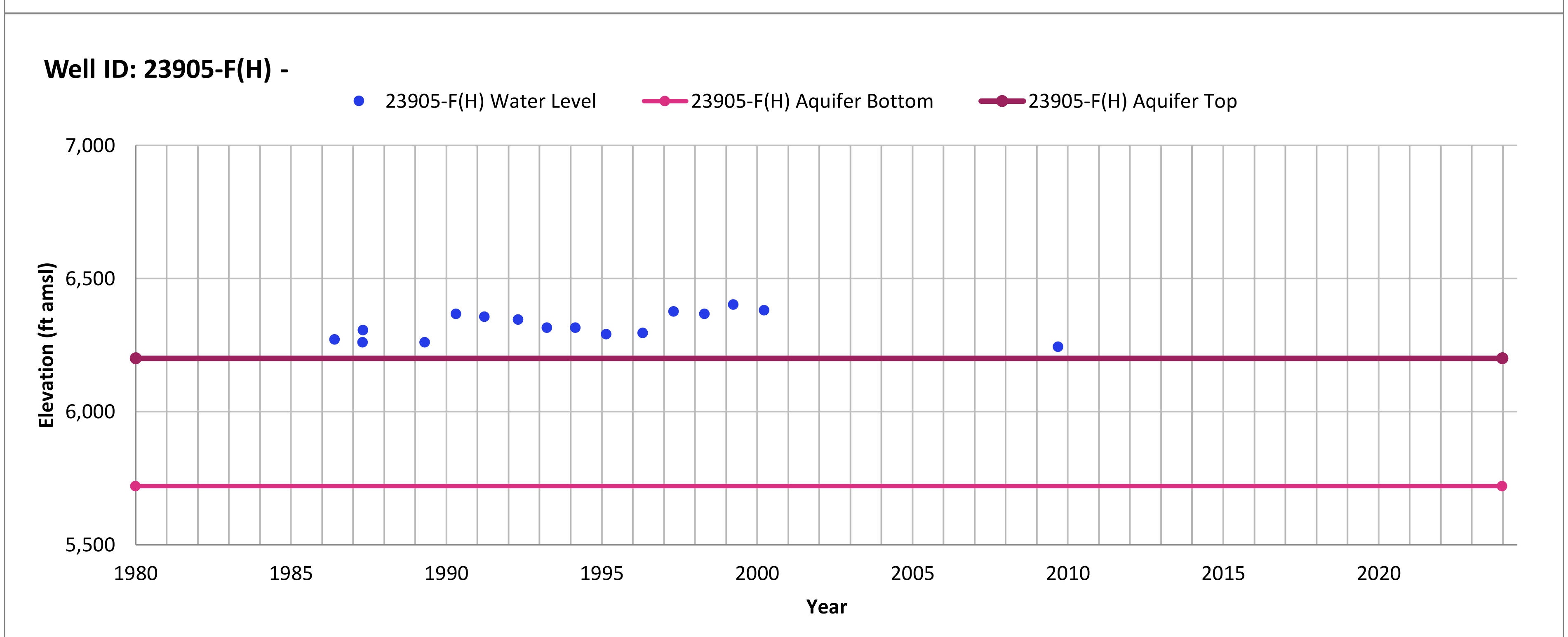

Well ID: SC01206713ADD(H) -
SC01206713ADD(H) Water Level
SC01206713ADD(H) Aquifer Bottom
SC01206713ADD(H) Aquifer Top
Elevation (ft amsl)
7,000
6,500
6,000
5,500
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year

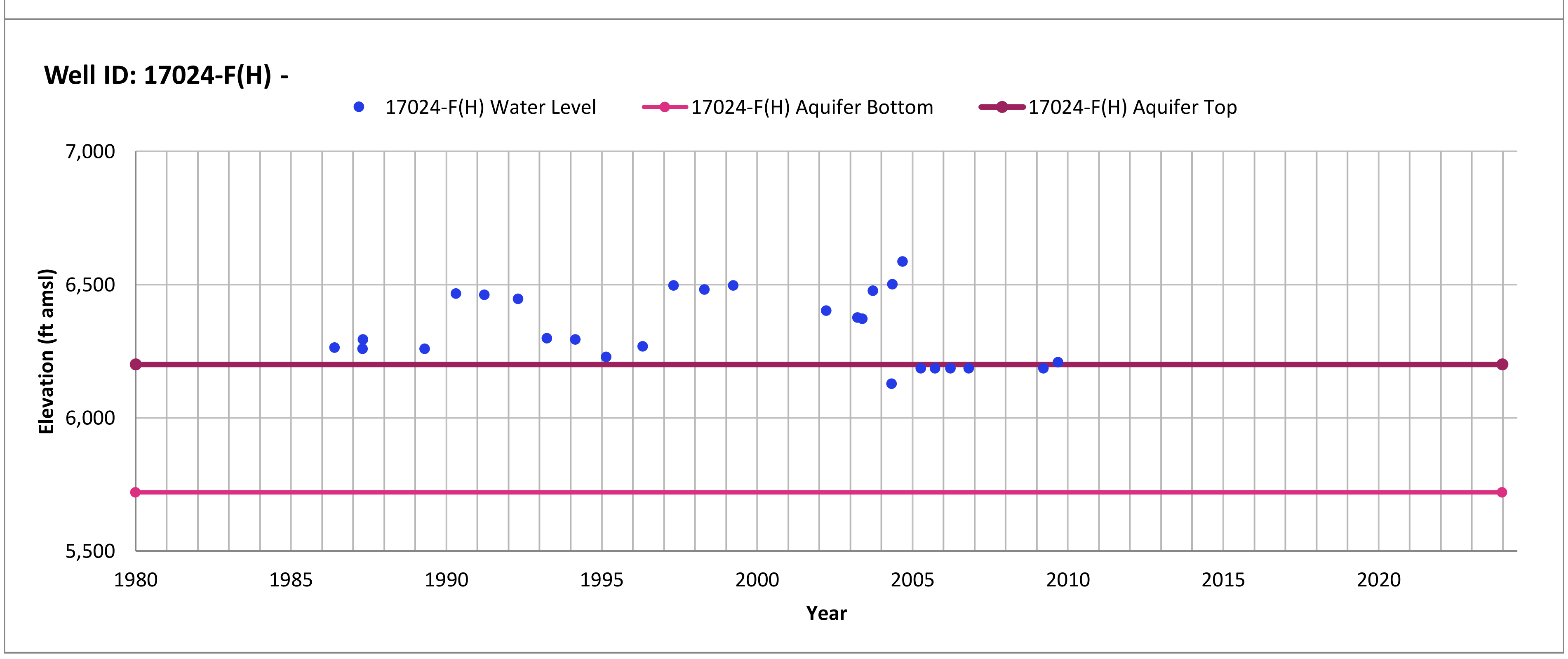

Well ID: 13684-F(H) -
13684-F(H) Water Level
13684-F(H) Aquifer Bottom
13684-F(H) Aquifer Top
7,000
6,500
6,000
5,500
Elevation (ft amsl)
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year


Well ID: 13685-F-R(H) -
13685-F-R(H) Water Level
13685-F-R(H) Aquifer Bottom
13685-F-R(H) Aquifer Top
7,000
6,500
6,000
5,500
Elevation (ft amsl)
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year


Well ID: 13687-F(H) -
13687-F(H) Water Level
13687-F(H) Aquifer Bottom
13687-F(H) Aquifer Top
7,000
6,500
6,000
5,500
Elevation (ft amsl)
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year

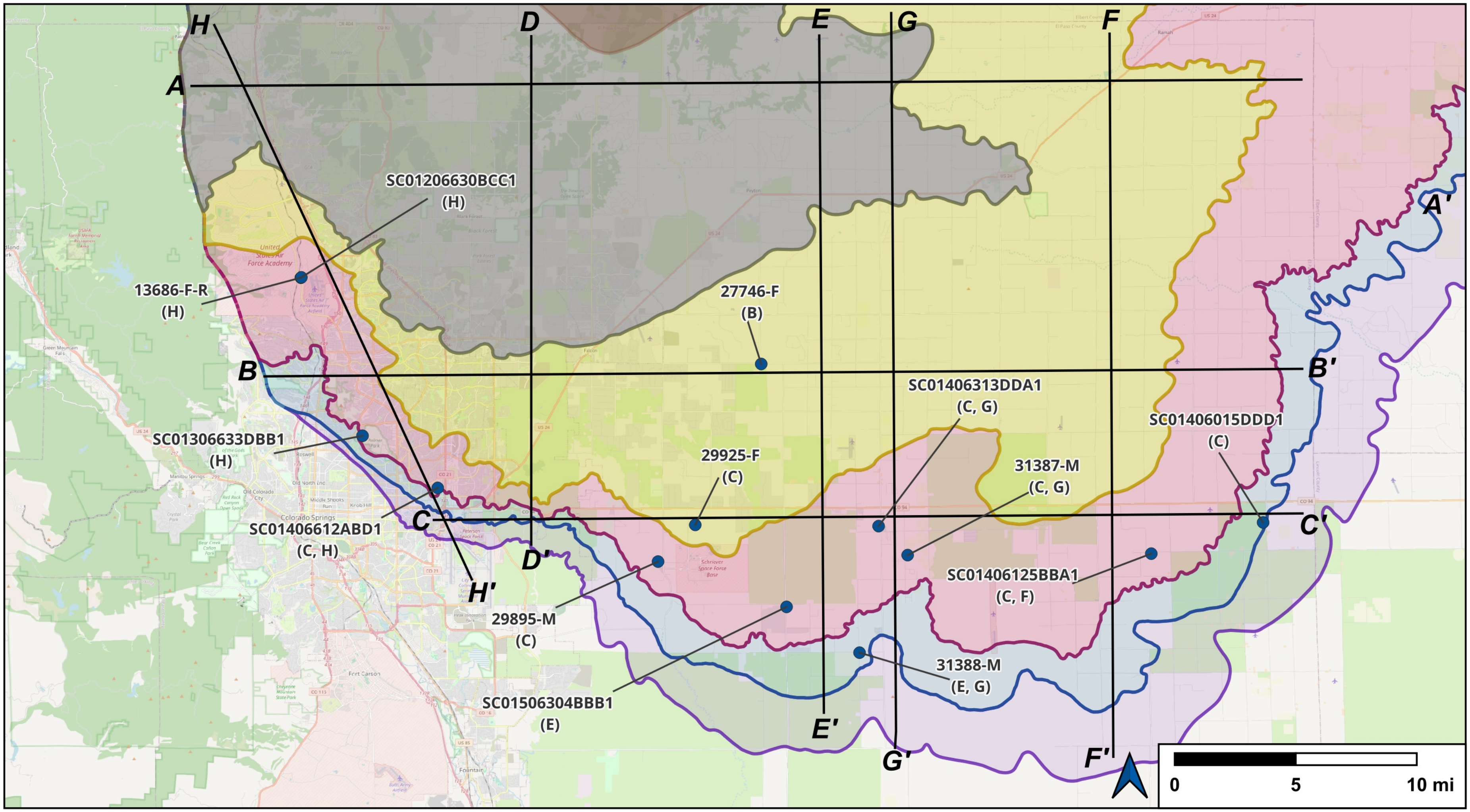

Well ID: 22967-(H) -
22967-(H) Water Level
22967-(H) Aquifer Bottom
22967-(H) Aquifer Top
7,000
6,500
6,000
5,500
Elevation (ft amsl)
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year


Well ID: 23905-F(H) -
23905-F(H) Water Level
23905-F(H) Aquifer Bottom
23905-F(H) Aquifer Top
7,000
6,500
6,000
5,500
Elevation (ft amsl)
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year


Well ID: 17024-F(H) -
17024-F(H) Water Level
17024-F(H) Aquifer Bottom
17024-F(H) Aquifer Top
7,000
6,500
6,000
5,500
Elevation (ft amsl)
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year

Appendix E - Laramie-Fox Hills Aquifer Hydrographs

moore engineering, inc.

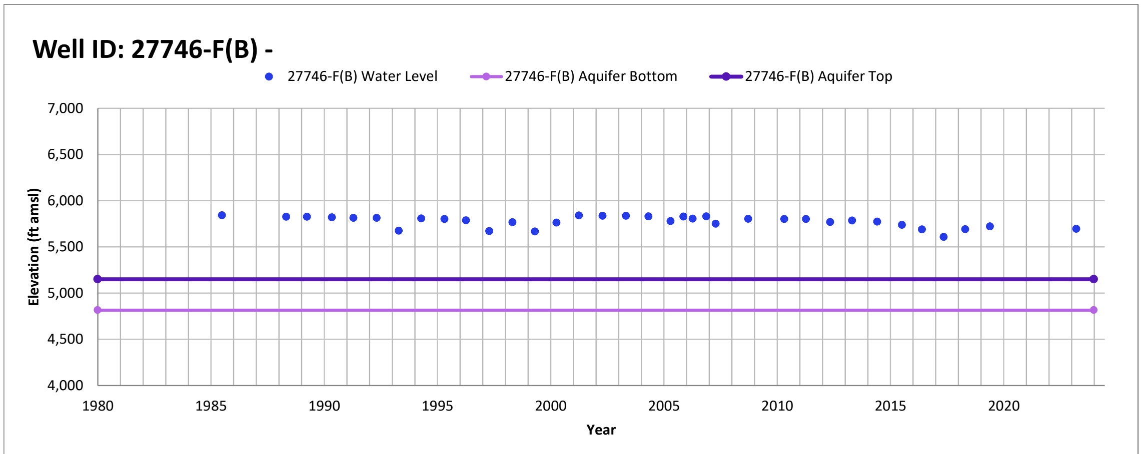


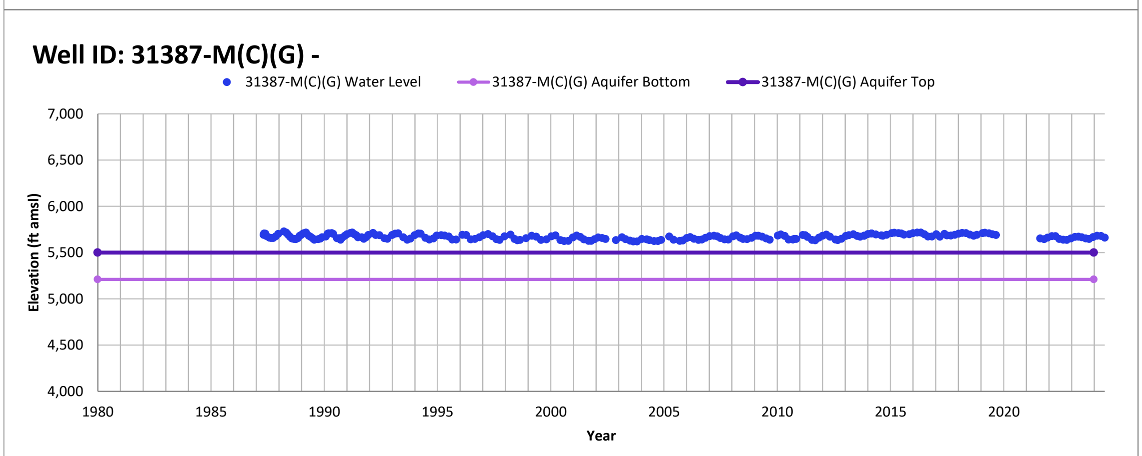
LEGEND

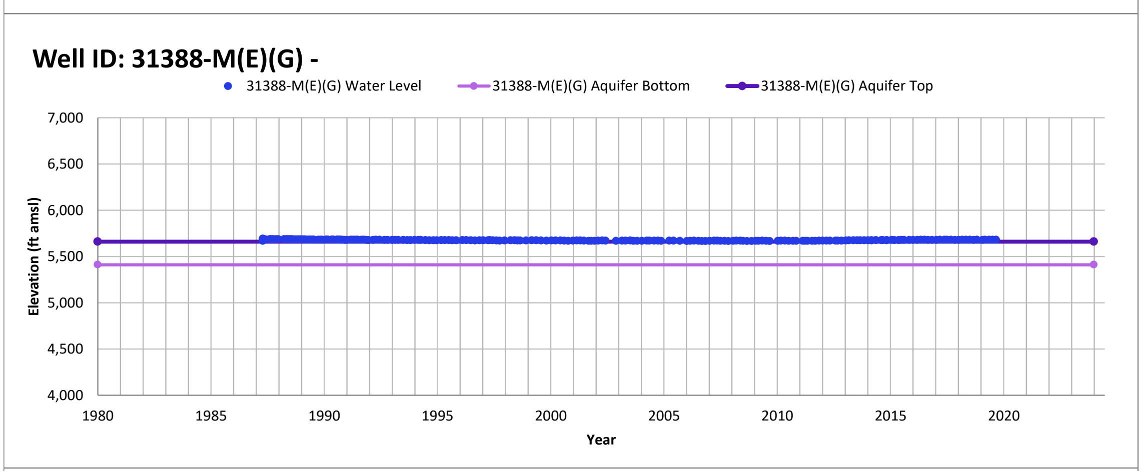
- Well Permit # or Name (Cross-Section Letter)
- Cross-Sections

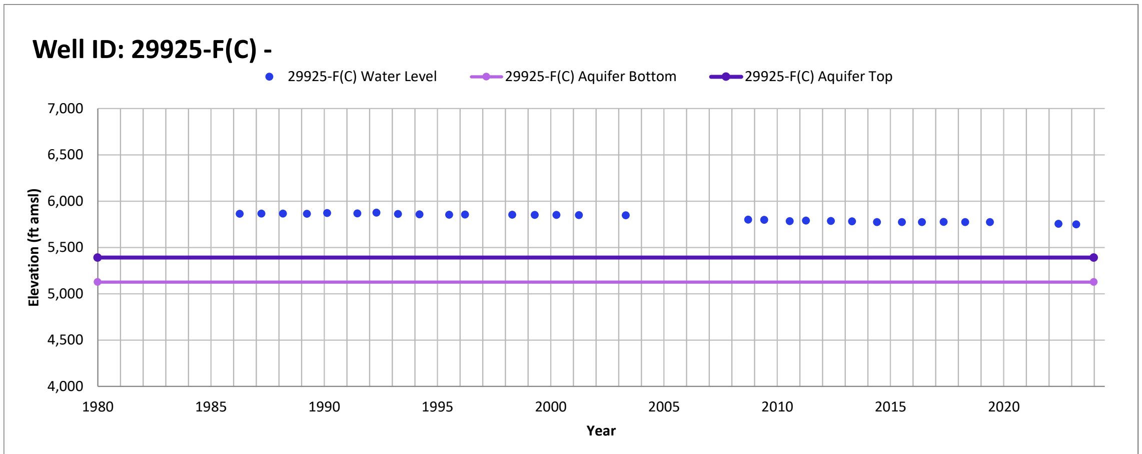
- Upper Dawson Aquifer
- Lower Dawson Aquifer
- Denver Aquifer
- Arapahoe Aquifer
- Laramie Confining Unit
- Laramie-Fox Hills Aquifer

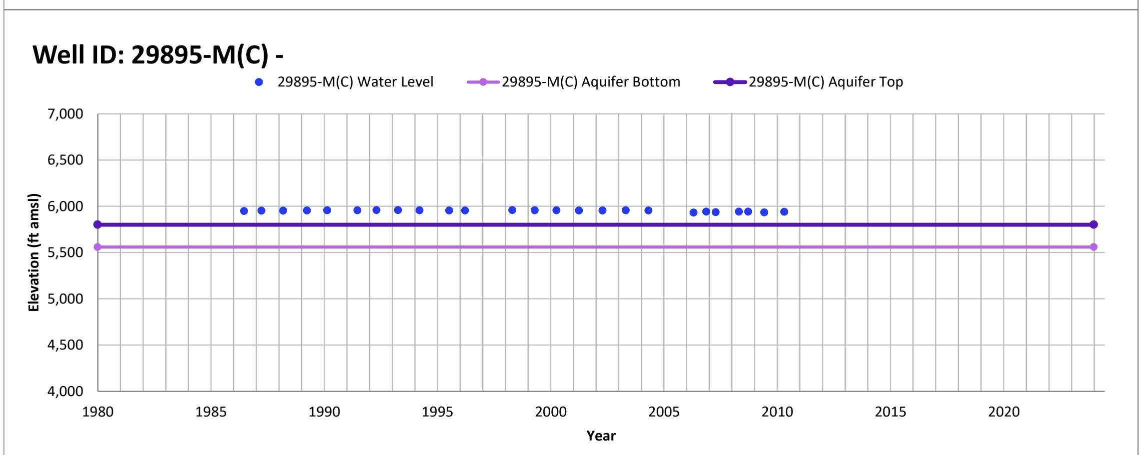
EL PASO COUNTY		
LARAMIE-FOX HILLS WELLS		
File: Wells - LFH		Date: 03/12/2025
Project No: 24632	Drawn by: CDH	Fig. No.: E-1

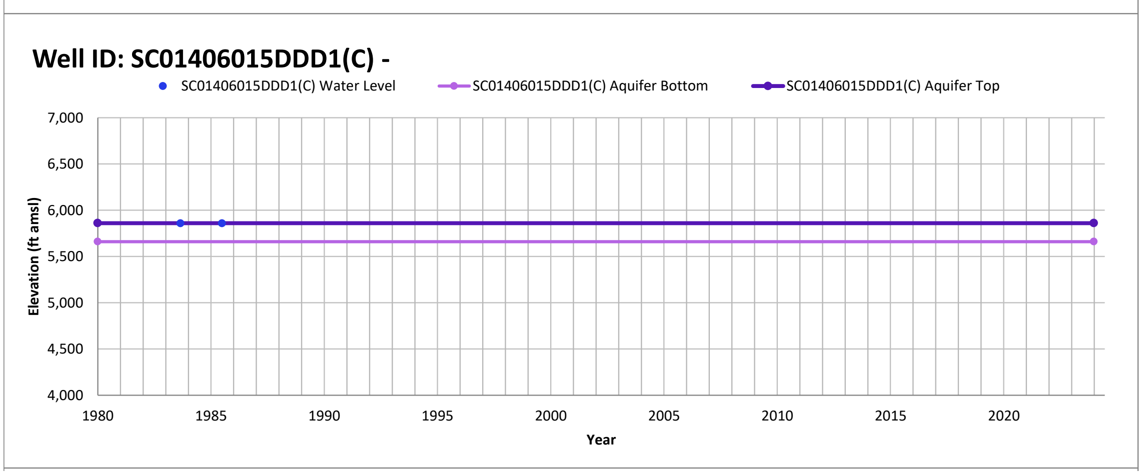

Well ID: 27746-F(B) -
27746-F(B) Water Level
27746-F(B) Aquifer Bottom
27746-F(B) Aquifer Top
7,000
6,500
6,000
5,500
5,000
4,500
4,000
Elevation (ft amsl)
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year


Well ID: 31387-M(C)(G) -
31387-M(C)(G) Water Level
31387-M(C)(G) Aquifer Bottom
31387-M(C)(G) Aquifer Top
7,000
6,500
6,000
5,500
5,000
4,500
4,000
Elevation (ft amsl)
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year

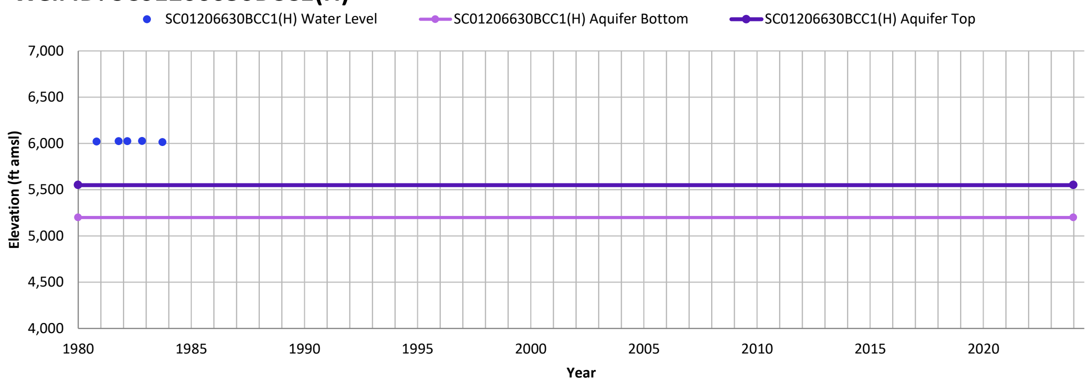

Well ID: 31388-M(E)(G) -
31388-M(E)(G) Water Level
31388-M(E)(G) Aquifer Bottom
31388-M(E)(G) Aquifer Top
7,000
6,500
6,000
5,500
5,000
4,500
4,000
Elevation (ft amsl)
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year


Well ID: 29925-F(C) -
29925-F(C) Water Level
29925-F(C) Aquifer Bottom
29925-F(C) Aquifer Top
Elevation (ft amsl)
7,000
6,500
6,000
5,500
5,000
4,500
4,000
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year

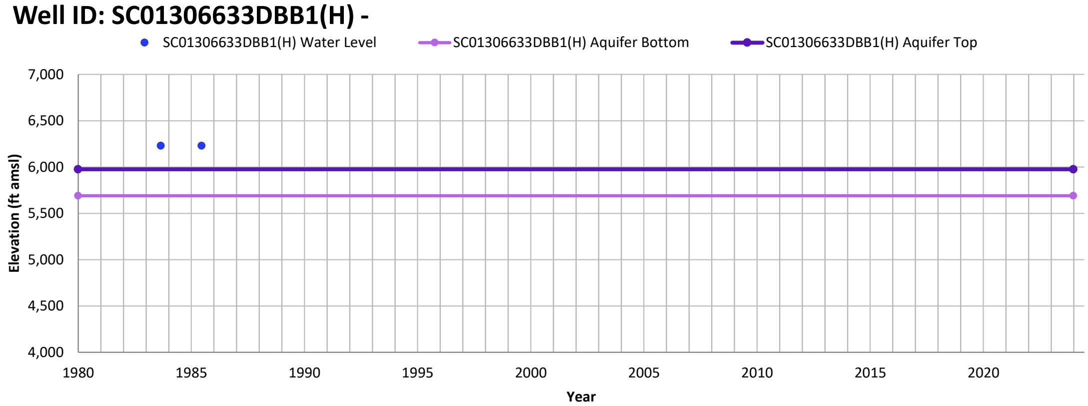

Well ID: 29895-M(C) -
29895-M(C) Water Level
29895-M(C) Aquifer Bottom
29895-M(C) Aquifer Top
Elevation (ft amsl)
7,000
6,500
6,000
5,500
5,000
4,500
4,000
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year


Well ID: SC01406015DDD1(C) -
SC01406015DDD1(C) Water Level
SC01406015DDD1(C) Aquifer Bottom
SC01406015DDD1(C) Aquifer Top
Elevation (ft amsl)
7,000
6,500
6,000
5,500
5,000
4,500
4,000
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year

Well ID: SC01206630BCC1(H) -



Well ID: SC01306633DBB1(H) -



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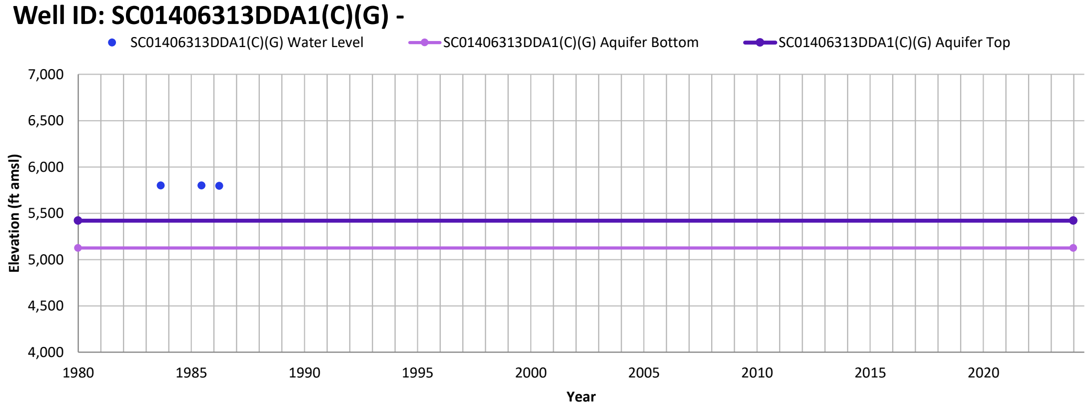

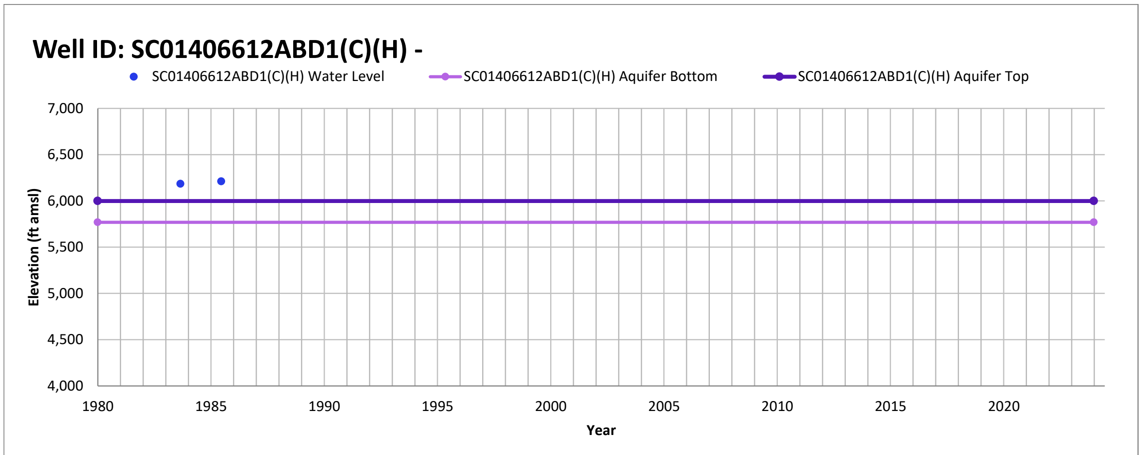
Well ID: SC01406612ABD1(C)(H) -
SC01406612ABD1(C)(H) Water Level
SC01406612ABD1(C)(H) Aquifer Bottom
SC01406612ABD1(C)(H) Aquifer Top
Elevation (ft amsl)
7,000
6,500
6,000
5,500
5,000
4,500
4,000
1980
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1990
1995
2000
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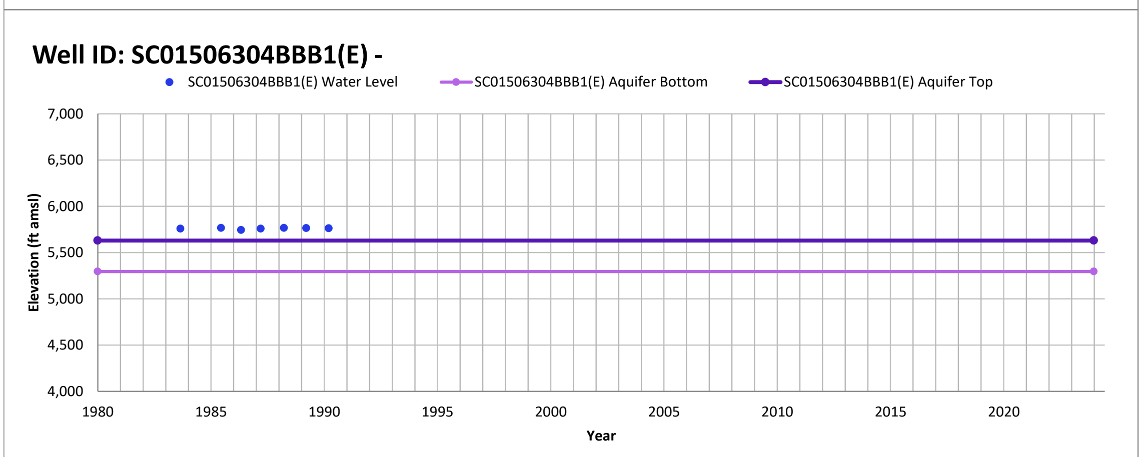
2010
2015
2020
Year


Well ID: SC01506304BBB1(E) -
SC01506304BBB1(E) Water Level
SC01506304BBB1(E) Aquifer Bottom
SC01506304BBB1(E) Aquifer Top
Elevation (ft amsl)
7,000
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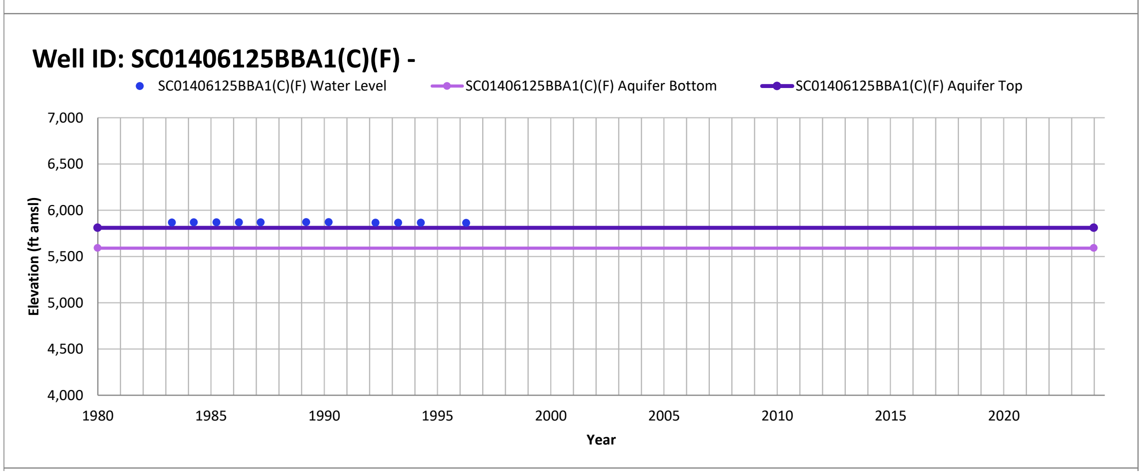
6,000
5,500
5,000
4,500
4,000
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year


Well ID: SC01406125BBA1(C)(F) -
SC01406125BBA1(C)(F) Water Level
SC01406125BBA1(C)(F) Aquifer Bottom
SC01406125BBA1(C)(F) Aquifer Top
Elevation (ft amsl)
7,000
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6,000
5,500
5,000
4,500
4,000
1980
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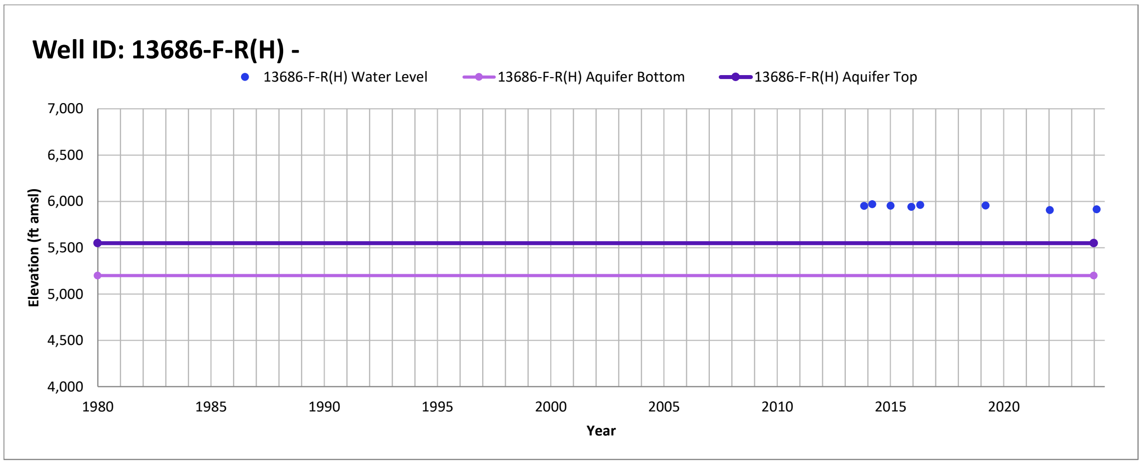
2000
2005
2010
2015
2020
Year



Well ID: 13686-F-R(H) -
13686-F-R(H) Water Level
13686-F-R(H) Aquifer Bottom
13686-F-R(H) Aquifer Top
Elevation (ft amsl)
7,000
6,500
6,000
5,500
5,000
4,500
4,000
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year